WQCF SLUDGE THICKENER AND DEWATERING UNIT NO. 3 PROJECT
CIP 24006 & 24007

BID FORM, CONTRACT DOCUMENTS AND TECHNICAL SPECIFICATIONS

January 2025

Digitally signed by Kyle Thomas Leonard
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Kevin Jorgensen II Director of Engineering/City Engineer	Kyle Leonard Engineer of Record

Recommended for Approval

Somporn Boonsalat
Deputy Director of Engineering

WQCF SLUDGE THICKENER AND DEWATERING UNIT NO. 3 PROJECT CIP 24006 & 24007

BID FORM, CONTRACT DOCUMENTS AND TECHNICAL SPECIFICATIONS

January 2025

Prepared for:

City of Manteca
1001 West Center Street
Manteca, CA 95337

Prepared by:

Carollo Engineers, Inc.
2795 Mitchell Drive
Walnut Creek, CA 94598

WQCF SLUDGE THICKENER AND DEWATERING UNIT NO. 3 PROJECT
CIP 24006 & 24007

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SECTION 00020

INVITATION TO BID
WQCF SLUDGE THICKENER AND DEWATERING UNIT NO. 3 PROJECT
CIP 24006 & 24007
(ESTIMATED CONSTRUCTION COST: $ 28,200,000)

SEALED BIDS will be received by the City Clerk of the City of Manteca at 1001 West Center Street, Manteca, California until **2:00 p.m. Pacific Time, Tuesday February 25, 2025,** for the **WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 (Project)**. As soon as practical thereafter, sealed bids for the project will be publicly opened and read for performing work as follows:

Furnishing all labor, materials, and equipment, and performing all work necessary and incidental to the construction of the project known as the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 according to the plans and specifications as prepared by the City of Manteca and according to the Contract Documents. The work includes, but not limited to, conversion of the existing dissolved air flotation (DAF) thickeners into sludge blend tanks, new rotating drum thickener (RDT) facility, co-thickening of primary sludge and waste activated sludge, new thickening odor control facility, installation of Centrifuge No. 3, and associated piping.

Project shall have **Substantial Completion within 900 calendar days** and **Final Completion within 990 calendar days** from the date specified in the Notice to Proceed. Time for commencement and completion of the work is important, and is the essence of the Contract.

This receives funding from:

- **Federal: None**
- **State: None**
- **Local: Sewer Operations & Maintenance Funds**

The required DBE participation is: None

Required Apprentice/Trainee:

- **Federal: None**
- **State: None**
- **Local: None**

A **MANDATORY PRE-BID MEETING AND JOB WALK** will be held as follows:

1. **DATE/TIME**: Thursday, February 6, 2025 at 2:00 p.m.
2. **LOCATION:** WQCF 2450 W Yosemite Ave, Manteca, CA 95337
3. **GENERAL**: No other pre-bid meetings or job site visits will be scheduled.
4. **The deadline to submit questions and/or inquiries is 5:00 p.m. Pacific Time, February 17, 2025**

PROJECT PLANS AND SPECIFICATIONS ARE POSTED ON THE CITY WEBSITE AT:
https://www.manteca.gov/departments/project-bid

BIDDERS MUST SUBMIT BIDS ON A HARD COPY OF THE BID PROPOSAL FORMS PROVIDED IN THE CONTRACT DOCUMENTS.

Project information is available on the Internet at:

https://www.manteca.gov/departments/project-bid

Questions regarding the contract documents shall be submitted in writing to:

Attn: Kyzen Nicolas, Associate Engineer
City of Manteca
Department of Engineering
1001 West Center Street
Manteca, CA 95337
Fax: (209) 923-8956
email: knicolas@manteca.gov

The City will post all bid-related questions and answers on its web site at:

https://www.manteca.gov/departments/project-bid

Refer to this web address periodically as it will be updated with bid-related questions and answers until **5:00 p.m. Pacific Time, Thursday February 20, 2025.** The questions and answers posted at the web address above shall form part of the Contract Documents.

Bidding procedures are prescribed in the contract documents. Bids shall only be executed upon the bound bid forms provided, which are a part of said contract documents. Bid guarantee in an amount not less than ten percent (10%) of the total bid dollar amount and conforming to the prescribed bidding procedures is required to be submitted with each bid, as a guaranty to be forfeited should the bidder, if awarded the contract, fail to enter into the same, or fails to furnish in a timely manner the bonds and/or proof of insurance.

Pursuant to the provisions of California Labor Code Section 6707, each bid submitted in response to this Invitation to Bid shall contain, as a bid item, adequate sheeting, shoring, and bracing, or equivalent method, for the protection of life and limb in trenches and open excavation, which shall conform to applicable safety orders. By listing this sum, the bidder warrants that its actions pursuant to this bid item shall not impose tort liability on the City, the Engineer, the Construction Manager, and their employees, agents, and subconsultants.

Pursuant to Section 1770, et. seq., of the California Labor Code, the successful bidder shall pay not less than the prevailing rate of per diem wages as determined by the Director of the California

Department of Industrial Relations. Copies of such prevailing rate of per diem wages are on file at the City of Manteca Engineering Department, 1001 West Center Street, Manteca, CA, which copies will be made available to any interested party on request.

Pursuant to Public Contract Code Section 22300, for moneys earned by the Contractor and withheld by the City of Manteca to ensure the performance of the Contract, the Contractor may, at its option, choose to substitute securities meeting the requirements of said Public Contract Code Section 22300.

All bidders shall be licensed under the provisions of Chapter 9, Division 3 of the Business and Professions Code of the State of California to do the type of work contemplated in the project. In accordance with provisions of California Public Contract Code Section 3300, the City has determined that the **Contractor shall possess a valid Class A license** at the time that the bid is submitted. Failure to possess the specified license shall render the bid non-responsive.

The successful bidder will be required to furnish a Payment bond in the amount equal to one hundred percent (100%) of the Contract price, as well as a Faithful Performance Bond, in the amount equal to one hundred percent (100%) of the Contract price. All bonds submitted shall be from admitted sureties.

Each bidder shall submit with its bid a statement setting forth its experience on the forms included in the Bid Proposal.

Telephones will not be available to bidders for the preparation of the bids or for calling in bid results. Bid forms received after the designated time will not be accepted. Bidders and their authorized agents are invited to attend the bid opening.

No bidder may withdraw its bid for one hundred twenty (120) calendar days after the date set for the opening of bids.

The successful bidder must insure that employees and applicants for employment are not discriminated against on the basis of age, color, race, national origin, ancestry, religion, sex, sexual preference, marital status, and comply with the Americans With Disabilities Act.

The City reserves the right to reject any or all bids; to make any awards or any rejections in what it alone considers to be in the best interest of the City; and waive any irregularities in the bids. Each bid must be signed by or on behalf of the bidder and must be enclosed in a DOUBLE SEALED ENVELOPES with the following information on the inner envelope and outer envelope:

1. Name and address of bidder
2. Project for which the bid is being submitted
3. Date and time of bid opening

The outer envelope shall include:

- Contractor's bid bond
- Contractor's bid schedule
- Sealed inner envelope

The inner envelope shall include:

- All other bid forms other than Contractor's bid bond and Contractor's bid schedule

The envelope shall be addressed to the City of Manteca, City Clerk, 1001 West Center Street, Manteca, California 95337.

Dated: _____City of Manteca

_____

Cassandra Candini-Tilton, Director of Legislative Services / City Clerk

END OF SECTION

SECTION 00100

INSTRUCTIONS TO BIDDERS

1.00 WORK TO BE DONE

It is the intention of the City to construct improvements as shown and set forth on the plans, and in the particular locations shown on the plans. All of the work is particularly set forth in the plans and specifications, and all of said work, together with all other work incidental thereto, is included. Insurance requirements shall be as specified in the attached EXHIBIT 1, INSURANCE REQUIREMENTS FOR CONSTRUCTION CONTRACTS

The work includes the furnishing of labor, materials, incidentals and equipment necessary for the construction of the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007. The Bidder shall be required to provide, at its own cost and expense, all necessary insurance, as required by law or these specifications, and shall pay the cost and expense of any and all incidental matters herein required.

2.00 EXAMINATION OF CONTRACT DOCUMENTS

Each bidder shall thoroughly examine and be familiar with the contract documents. The submission of a bid shall constitute an acknowledgment, upon which the City may rely, that the bidder has thoroughly examined and is familiar with the contract documents. The failure or neglect of a bidder to receive or examine any of the contract documents shall in no way relieve it from any obligation with respect to its proposal or to the Contract. No claim for additional compensation will be allowed which is based upon a lack of knowledge of any contract documents.

3.00 INSPECTION OF SITE

Bidders are required to inspect the site of the work to satisfy themselves by personal examination or by such other means, as they may prefer, of the location of the proposed work, and of the actual conditions, including subsurface, of and at the site of work. If, during the course of its examination, a bidder finds facts or conditions which appear to be in conflict with the letter or spirit of the bidding documents, the Bidder may apply to the City, in writing, for additional information and explanation before submitting its bid.

Submission of a bid by the bidder shall constitute conclusive evidence that, if awarded the Contract, it has relied and is relying on its own examination of (1) the site of the work, (2) access to the site, (3) all other data and matters requisite to the fulfillment of the work and on its own knowledge of existing facilities on and in the vicinity of the site of the work to be constructed under the Contract, (4) the conditions to be encountered, (5) the character, quality and scope of the proposed work, (6) the quality and quantity of the materials to be furnished, and (7) the requirements of the bid, the plans, the specifications, and the other contract documents.

The information provided by the City is not intended to be a substitute for, or a supplement to the independent verification by the bidder to the extent such independent investigation of site conditions is deemed necessary or desirable by the bidder.

4.00 INTERPRETATION OF CONTRACT DOCUMENTS

No oral representations or interpretations will be made to any bidder as to the meaning of the contract documents. Requests for an interpretation shall be made in writing and received at least ten (10) calendar days before the time announced for opening the bids to:

City of Manteca
Department of Engineering
Attention: Kyzen Nicolas, Associate Engineer
1001 West Center Street Manteca, CA 95336
Fax: (209) 923-8956
Email: knicolas@manteca.gov

Requests to clarify possible ambiguous or incomplete statements or designs require issuance of an addendum by the City for the interpretation to become effective. All requests for clarifications shall be made in writing.

5.00 POSTPONEMENT OF OPENING

The City reserves the right to postpone the date and time for receiving and/or opening of bids at any time prior to the date and time established in the Invitation to Bid. Postponement notices shall be mailed to plan-holders of record in the form of an addendum.

6.00 OPENING OF BIDS

All bids, irrespective of any irregularities or informalities, if received on time, will be opened and publicly read aloud at the time and place set forth in the Invitation to Bid. Bidders, their representatives and other interested persons may be present at the opening and reading of bids.

Any bids received after the scheduled closing time as set forth in the Invitation to Bid or as postponed by addenda will be considered non-responsive and will not be opened. Any such bids will be returned unopened to the Bidder. The public reading of each bid will include at least the following:

A. Name and address of bidder.
B. The total amount of bid.
C. The nature and amount of the security furnished with the bid.

7.00 PREPARATION OF BID FORMS

Bid shall be made on the bid forms provided in the contract documents and must be submitted at the time and place stated in the Invitation to Bid. All blanks in the bid forms must be appropriately filled in either in ink or typed, and all prices must be stated in figures. All bid forms must be submitted in sealed envelopes bearing on the outside the name of the bidder, its address, and the name of the project for which the bid is submitted. It is the sole responsibility of the bidder to see that its bid is received in proper time. Any bid received after the scheduled closing time for receipt of bids will be returned to the bidder unopened. City shall not be responsible for errors or omissions in the bid. Bidders shall write their names on each bid form at the space provided.

Each bid must be signed by or on behalf of the bidder and must be enclosed in a DOUBLE SEALED ENVELOPES with the following information on the inner envelope and outer envelope:

Name and address of bidder
Project and project number for which the bid is being submitted
Date and time of bid opening

The outer envelope shall include:

- Contractor's bid bond
- Contractor's bid schedule
- Sealed inner envelope

The inner envelope shall include:

- All other bid forms other than Contractor's bid bond and Contractor's bid schedule

8.00 BIDDER'S SIGNATURE AND AUTHORITY

If the bid is made by an individual, this person's name, signature, and post office address must be shown; if made by a firm or partnership, the name and post office address of the firm or partnership, a list of the general partners, and the signature of at least one of the general partners must be shown, if made by a corporation, the bid shall show the name of the state under the laws of which the corporation is chartered, the name and post office address of the corporation, and the title of the person who signs on behalf of the corporation. If the bid is made by the corporation, a certified copy of the bylaws or resolution of the Board of Directors of the corporation shall be furnished showing the authority of the officer or agent signing the bid to execute Contracts on behalf of the corporation. If the bid is made by a joint venture, the bid shall be signed by a representative of one of the joint venture firms. Additionally, the bid shall include a copy of the resolution or agreement empowering the representative to execute the bid and bind the joint venture.

9.00 ERASURES AND CORRECTIONS

The bid submitted must not contain any erasure, interlineations, or other corrections unless

each such correction is suitably authenticated by affixing, in the margin immediately opposite the correction, the initials of the person or persons submitting the bid.

10.00 BID IRREGULARITIES

Changes in or additions to the bid form, recapitulations of the work bid upon, alternative bids, omissions, or any other modifications of the bid form which are not specifically called for in the contract documents may result in rejection of the bid by the City, as not being responsive to the Invitation to Bid. No oral or telephonic modification of any bid submitted will be considered.

The City reserves the right to reject any or all bids; to make any awards or any rejections in what it alone considers to be in the best interest of the City; and waive any irregularities in the bids.

11.00 MODIFICATION OF BID

On written request filed with the City, a bid already received may be modified or withdrawn at any time prior to the time established for receiving bids. The request must be executed by the bidder or its authorized representative as described in Paragraph 00100-8.00, BIDDER'S SIGNATURE AND AUTHORITY. Modifications shall be made in writing, executed, and submitted in the same form and manner as the original bid.
Withdrawal of a bid does not prejudice a bidder's right to submit a new bid within the time designated for the submission of bids. No bid may be withdrawn after the scheduled closing time except as provided in Paragraph 00100-12.00, WITHDRAWAL OF BIDS.

12.00 WITHDRAWAL OF BIDS

In accordance with Public Contract Code 5103, within five calendar days after the opening of bids, a bidder may withdraw its bid providing the bidder can establish to the City's satisfaction that a mistake was made in preparing the bid. A bidder desiring to withdraw shall give written notice to the City, specifying, in detail, how the mistake occurred and how the mistake made the bid materially different than it was intended to be. Withdrawal will not be permitted for mistakes resulting from errors in judgment or carelessness in inspecting the site of the work or in reading the contract documents.

13.00 ADDENDA

Addenda issued during the time of bidding shall become a part of the documents furnished bidders for the preparation of bids, shall be covered in the bids, and shall be made a part of the Contract. Each bid shall include specific acknowledgment in the space provided of receipt of all Addenda issued during the bidding period. Failure to so acknowledge may result in the bid being rejected as not responsive. Failure of any bidder to receive such Addenda shall not be grounds for non-compliance with the terms of the instructions.

14.00 BID PRICES

Bid prices shall include everything necessary for the completion of the work including but not limited to providing the materials, equipment, tools, plant and other facilities, and the management, superintendence, labor and services. Bid prices shall include allowance for all federal, state and local taxes

In the event of a difference between a price quoted in words and a price quoted in figures for the same quotation, the words shall be the amount bid. In the event that the product of a unit price and an estimated quantity does not equal the extended amount quoted, the unit price shall govern, and the correct product of the unit price and the estimated quantity shall be deemed to be the amount bid. If the sum of two or more items in a bidding schedule does not equal the total amount quoted, the individual item amounts shall govern and the correct total shall be deemed to be the amount bid.

The award of contract, if it is awarded, will be awarded to the lowest responsive, responsible Bidder whose proposal complies with all the requirements prescribed.

15.00 BID GUARANTY

The bid form shall be accompanied by a bid guaranty bond provided by an admitted surety insurer authorized to carry on business in the State of California with a minimum a Class IV rating with Best's Rating Guide for payment to the City or meeting the following minimum requirements:

If the Best's Rating for any surety company who has furnished a bid guaranty for the bidder is less than A - Class IV and/or not Treasury Rated, bidder may be required to, within 5 calendar days of bid opening, submit to the City an original or certified copy of each of the following documents for each surety company which has furnished a bid guaranty for that bidder:

1. Appropriate authorization of the signatory to execute each bid guaranty.

2. A certificate of authority issued by the State Insurance Commissioner.

3. A certificate from the County Clerk that the above certificate is not ineffective; and

4. The surety company's financial statement for the prior quarter as specified in Section 995.670 of the California Code of Civil Procedure.

Simultaneously with the submission of the documents described in the preceding paragraphs, the bidder shall also submit an affidavit or declaration, under penalty of perjury under the laws of the State of California, demonstrating the following facts for each bid guaranty submitted or to be submitted on the bidder's behalf.

1. That the surety company's assets exceed its liabilities by more than the amount of

the bid guaranty or guaranties submitted on the bidder's behalf, and

2. That in issuing the bid guaranty or guaranties submitted on the bidder's behalf, the surety company shall be in full compliance with California Insurance Code Section 12090, supported by appropriate references to the surety company's most recent financial statement on file in the office of the State Insurance Commissioner.

Any bidder wishing to object to the sufficiency of any surety company used by another bidder shall comply fully with the provisions of Section 995.650 of the California Code of Civil Procedure.

The bid guaranty bond shall be in the sum of at least ten (10) percent of the total amount of the bid price, or, alternatively, by a certified or cashier's check, payable to the City in the sum of at least ten (10) percent of the total amount of the bid price. The bid guaranty bond shall be provided on the form included in Section 00410, BID GUARANTY BOND, of these contract documents.

The amount payable to the City under the bid guaranty bond, or the certified or cashier's check and the amount thereof, as the case may be, shall be forfeited to the City as liquidated damages in case of a failure or neglect of the bidder to furnish, execute, and deliver to the City the required performance and payment bonds, evidences of insurance, and to enter into, execute, and deliver to the City the Agreement on the form provided herewith, within ten (10) calendar days after receiving written notice from the City that the award has been made and the Agreement is ready for execution.

The bid guarantees of the three lowest bidders will be retained until the Agreement is signed, evidence of insurance provided, and satisfactory bonds furnished or other disposition made thereof. The bid guarantees of all bidders except the three lowest responsive bids will be returned within 15 calendar days after the bids are opened.

16.00 QUALIFICATION OF BIDDER

Each bidder shall complete and submit with their bid Section 00420, CERTIFICATION OF BIDDER'S EXPERIENCE AND QUALIFICATIONS.

Upon the request of City, any bidder whose bid is under consideration for the award of the Contract shall promptly submit satisfactory evidence showing the bidder's financial resources, its construction experience, and its organization's availability for the performance of the Contract.

The bidder may be required to establish, to the satisfaction of the City, the reliability and responsibility of the persons or entities proposed to furnish and perform the work described in the contract documents.

17.00 SUBCONTRACTORS

In accordance with California Public Contracting Code Section 4100, et. seq., the bidder shall list, in Section 00430, PROPOSED SUBCONTRACTORS, the name, portion of work to be performed, and location of the place of business for the following.

1) Each subcontractor who will perform work or labor or render service to the bidder in or about the construction of the work or improvement, in an amount in excess of one-half of one percent of the bidder's total bid.

2) Any subcontractor licensed by the State of California who, under subcontract to the bidder, will specially fabricate and install a portion of the work or improvement according to detailed drawings contained in the plans and specifications, in an amount in excess of one-half of one percent of the bidder's total bid.

Failure to list the subcontractors defined in subparts 1) and 2) above will render the bid non-responsive and will be grounds for rejection of the bid. Failure to comply with the provisions of the California "Subletting and Subcontracting Fair Practices Act" shall make the Contractor subject to the sanctions as set forth in the Act.

18.00 SUBSTITUTIONS DURING BIDDING

Manufacturers or suppliers of materials and equipment may offer an alternative product to the Contractor and request that alternatives to specified products be considered equal. Inclusion of such alternatives in the bid is the responsibility of the Contractor. Inclusion should only be considered if the Contractor believes the offered alternative is equal in quality and performance to the specified product. After award of the Contract, such offers of alternative products will be reviewed and processed as a substitution as provided under Section 00700, GENERAL CONDITIONS.

19.00 BIDDERS INTERESTED IN MORE THAN ONE BID

No person, firm, or corporation, under the same or different name, shall make, file, or be interested in more than one bid for the same work unless alternate bids are called for.

Pursuant to Public Contract Code Section 7106, bidders shall execute and furnish with their bids Section 00480, NON-COLLUSION AFFIDAVIT. Reasonable grounds to believe that any individual, partnership, corporation, or combination is interested in more than one bid for the proposed work may cause rejection of all bids for parties involved.

A person, firm, or corporation may, however, submit subproposals or quote prices on materials to more than one bidder.

20.00 SHEETING, SHORING AND BRACING

Pursuant to the provisions of California Labor Code Section 6707, each bid submitted shall contain, in the bid item indicated, the amount included in the bid for adequate

sheeting, shoring, and bracing, or equivalent method, for the protection of life and limb in trenches and open excavation, which shall conform to applicable safety orders. By listing this sum, the bidder warrants that its actions pursuant to this bid item shall not impose tort liability on the City, the Designer, the Construction Manager, or their employees, agents, and subconsultants.

Pursuant to California Labor Code Section 6705, the Contractor shall submit a detailed plan showing the design of shoring, bracing, sloping, or other provisions to be made for worker protection from the hazard of caving ground during the excavation of such trench or trenches. If such plan varies from the shoring system standards, the plan shall be prepared by a registered civil or structural engineer.

21.00 WAGE RATES

Pursuant to provisions of the Labor Code Section 1770, et. seq., of the State of California, the Director of the Department of Industrial Relations has ascertained the prevailing rate of wages of the locality in which the Work is to be performed and applicable to the work to be done. Prevailing wage for each job category shall be as published by Department of Industrial Relations at the time of project work.

This project is subject to compliance monitoring and enforcement by the Department of Industrial Relations. Bidders shall complete the form in SB 96 COMPLIANCE AFFIDAVIT and submit with their Bid.

No Contractor or subcontractor may be listed on a bid proposal for a public works project unless registered with the Department of Industrial Relations pursuant to Labor Code Section 1725.5 [with limited exceptions form this requirement for bid purposes only under Labor code section 1771.1(a)]

No Contractor or subcontractor may be awarded a contract for public work on a public works project unless registered with the Department of Industrial Relations pursuant to Labor Code Section 1725.5.

Contractor shall post job site notices prescribed by regulation.

All Contractors and subcontractors shall furnish electronic certified payroll records directly to the Labor Commissioner (aka Division of Labor Standards Enforcement).

22.00 OFFER OF ASSIGNMENT OF ANTITRUST ACTIONS

As provided by Section 7103.5, of the California Public Contract Code, in entering into a public works contract or subcontract, the Contractor or subcontractor offers and agrees to assign to the City all rights, title and interest in, and all causes of action it may have under Section 4 of the Clayton Act (15 U. S.C. Section 15) or under the Cartwright Act (Chapter 2) commencing with Section 16700 (of Part 2 of Division 7 of the Business and Professions Code), arising from purchases of goods, services or materials pursuant to the public works contract or subcontract. This assignment shall be made and become effective at the time

the City tenders final payment to the Contractor, without further acknowledgment by the parties.

23.00 ASSIGNMENT OF CONTRACT

Any attempted assignment by the Contractor of any contract to be entered into hereunder, or any part thereof, or of funds to be received thereunder by the Contractor, is void unless such assignment has had prior written approval of City and the Surety has been given due notice of such assignment in writing and has consented thereto in writing.

24.00 REJECTION OF BIDS

The City reserves the right to reject any or all bids; to make any awards or any rejections in what it alone considers to be in the best interest of the City; and waive any irregularities in the bids and further reserves the right to reject any bids which are:

a) non-responsive (e.g.: bids which are incomplete, obscure, or irregular-, bids which omit a bid on any one or more items on which the bids are required, bids which are unbalanced-, bids accompanied by insufficient or irregular bid guaranties); or

b) any bids from bidders who have previously failed to perform properly or to complete on time contracts of any nature with the City or other public agencies; or

c) any bids from bidders who have a history of change orders in excess of 5% or failing to meet substantial completion by 5%; or

d) any bid which fails to provide satisfactory documentation of the bidder's qualifications as required by Section 00100-16.00, QUALIFICATION OF BIDDER.

25.00 BONDS AND INSURANCE

The successful bidder, simultaneously with the execution of the Agreement, will be required to furnish a Payment Bond on forms provided by the City in an amount equal to one hundred percent (100%) of the Contract Price, a Faithful Performance Bond in an amount equal to one hundred percent (100%) of the Contract Price, the Workers Compensation Insurance Certificate, and evidences of insurance. Said insurance and bonds shall only use the forms attached and shall be secured from a surety company satisfactory to City with a minimum A -Class IV rating with Best's Rating Guide or meeting the following minimum requirements:

If the Best's Rating for any surety company from which the bidder intends to procure the payment bond, performance bond, or both, is less than A - Class IV and/or not Treasury Rated, bidder may be required to, within 5 working days after bid opening, submit to the City an original or certified copy of each of the following documents for each surety company from which the bidder intends to procure such bond or bonds:

1. Appropriate authorization of the signatory to execute each bond.

2. A certificate of authority issued by the State Insurance Commissioner.

3. A certificate from the County Clerk that the above certificate is not ineffective; and

4. The surety company's financial statement for the prior quarter as specified in Section 995.670 of the California Code of Civil Procedure.

Simultaneously with the submission of the documents described in the preceding paragraphs, the bidder shall also submit an affidavit or declaration, under penalty of perjury under the laws of the State of California, demonstrating the following facts for the bond or bonds submitted or to be submitted on the bidder's behalf.

1. That the surety company's assets exceed its liabilities by more than the amount of the bond or bonds submitted on the bidder's behalf, and

2. That in issuing the bond or bonds submitted on the bidder's behalf, the surety company shall be in full compliance with California Insurance Code Section 12090, supported by appropriate references to the surety company's most recent financial statement on file in the office of the State Insurance Commissioner.

Any bidder wishing to object to the sufficiency of any surety company used by another bidder shall comply fully with the provisions of Section 995.650 of the California Code of Civil Procedure.

The form of Agreement, as provided in Section 00500, AGREEMENT, which the successful bidder as Contractor will be required to execute, and the forms of bonds as provided in Sections 00610, FAITHFUL PERFORMANCE BOND and 00620, PAYMENT BOND, which it will be required to furnish, shall be carefully examined by the bidder. The Faithful Performance Bond is to secure the faithful performance of the Contract, and the Payment Bond is to secure the payment of those to whom the bidder may become legally indebted for labor, materials, tools, equipment, or services of any kind used or employed by the bidder in performing the work.

26.00 AWARD OF CONTRACT

Within one hundred twenty (120) calendar days after the time of opening of the bids, the City will act either to accept a bid, to reject all bids or with the consent of the bidders and their sureties to extend the time in which the City may act. The acceptance of a bid will be evidenced by a Notice of Award of Contract in writing, delivered in person or by certified mail to the bidder whose bid is accepted. No other act of City will constitute acceptance of a bid. The issuance of a Notice of Award of Contract shall obligate the bidder whose bid is accepted to furnish performance and payment bonds and evidences of insurance, and to execute the Agreement in the form set forth in the contract documents. The Agreement will require the completion of the work according to the contract documents.

If award is made, it will be based on the lowest responsive, responsible bid.

27.00 EXECUTION OF CONTRACT

The Agreement shall be executed by the successful bidder and returned, together with the Contract bonds and evidences of insurance, within ten (10) calendar days after receiving written Notice of the Award of the Contract. Time is of the essence in this regard. After execution by City, one copy of the Agreement shall be returned to Contractor.

Failure or refusal to enter into a Contract as herein provided or to conform to any of the stipulated requirements in connection therewith shall be just cause for annulment of the award and the forfeiture of the proposal guaranty. If the successful bidder refuses or fails to execute the agreement, the City may award the contract to the second lowest responsible bidder. If the second lowest responsible bidder refuses or fails to execute the agreement, the City may award the contract to the third lowest responsible bidder. On the failure or refusal of such second or third lowest bidder to execute the agreement, such bidder's guarantees shall be likewise forfeited to the City. The work may then be re-advertised.

28.00 CONSTRUCTION DOCUMENTS

Within five (5) calendar days after the execution of the Agreement by the City, the City will furnish electronic copies (PDF's) of the Plans and Specifications to the Contractor for their use.

29.00 BID PROTEST

An unsuccessful bidder who intends to protest the award of a contract must inform the project contact, specified in section 00020 Invitation to Bid and submit a Notice of Intent to Protest in writing on or before 5:00 p.m. of the fifth business day following the opening of all bids, unless a different time period is specified in the Notice Inviting Bids or other bid solicitation documents. Failure to give written notice by Close of Business on that day shall waive the right to protest.

The protestant shall submit a full and complete statement specifying in detail the grounds of the protest and the facts in support thereof at least two weeks before the scheduled date of City Council award. The protest must be hand delivered or sent via mail or emailed with confirmed response from the City as proof that request was received by the City within the time period set forth above. The protest document must include the following:

1. A complete statement of the factual and legal basis for the protest.
2. The protest must include the name, address and telephone number of the person representing the protesting party.
3. The protesting party must concurrently transmit a copy of the written protest document and any attached documentation to all other bidders who may have a reasonable prospect of receiving the award depending upon the outcome of the protest.

4. Each Protestant not certified as a Small Business shall make a deposit of the estimated arbitration costs, by check or money order made payable to the City of Manteca Engineering Department, in an amount not less than 1% of the advertised Engineers Estimate.

The procedure and time limits set forth herein are mandatory and the bidder's sole and exclusive remedy in the event of protest. No bidder may bring an action or proceeding challenging the bidding process or any award, or intent to award, any contract unless the above procedures are followed. The failure of a party originating a protest to comply with these procedures shall constitute a waiver of any right to further pursue the protest, including filing a government code claim or legal proceeding. The City reserves the right to modify the bid protest procedures in the Notice Inviting Bids or other bid solicitation documents and to require any protesting party to submit additional or clarifying information or documentation in support of any protest.

**END OF SECTION*

SECTION 00200

INFORMATION AVAILABLE TO BIDDERS

1.0 SUBSURFACE CONDITIONS

Subsurface investigation has previously been conducted at the site of the Work. The geotechnical report with the records of borings made at the work site is included in the Project Manual. These records pertain to conditions at the boring locations. Upon review of the Contract Documents, the geotechnical report(s) and personal site inspection, the Bidders may develop reasonable interpretation of subsurface conditions. Contractors, as bidders, are expected to make a personal inspection of the site and otherwise satisfy themselves as to the conditions affecting the work as detailed in these Contract Documents. The subsurface investigation and geotechnical report were developed for design purposes, and as such may not include necessary information for, any or all, construction related activities including, but not limited to, excavations, sheeting, shoring, bracing and dewatering.

The City disclaims responsibility for the Bidder's interpretation of data, such as, projecting or extrapolating from the test holes to other locations on the site of the Work, soil bearing values and profiles, and soil stability, as well as the presence, level, and extent of underground water for subsurface conditions during construction operations.

2.0 RECORD DRAWINGS AND ADDITIONAL INFORMATION

None.

*** END OF SECTION ***

SECTION 00300
(To be submitted with Bid)

BID FORM

1. Enter Into Agreement

The undersigned, as bidder, declares that we have received and examined the Contract Documents entitled WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 (Project), and will contract with the City, on the form of Agreement provided herewith, to do everything required for the fulfillment of the Contract Document for the construction of said Project at the prices and on the terms and conditions herein contained.

2. Bidder Accepts

Bidder accepts all of the terms and conditions of the Invitation to Bid and Instructions to Bidders, including, without limitation, those dealing with the disposition of Bid security. This Bid will remain subject to acceptance for the period specified for Notice of Award after the day of Bid opening. Bidder will sign and deliver the required number of counterparts of the Agreement with the Bonds and other documents as detailed in the Instruction to Bidders.

3. Bidder's Representations

In submitting this Bid, Bidder represents, as more fully set forth in the Agreement, that:

a. Bidder has examined and carefully studied the Bidding Documents and the Addenda.

   We acknowledge that the following addenda numbers have been received and have been examined as part of the Contract Documents.

Addenda No.	Date Received	Initials

b. Bidder has visited the site and become familiar with and is satisfied as to the general, local and site conditions that may affect cost, progress, performance and furnishing of the Work.

c. Bidder is familiar with and is satisfied as to all federal, state and local Laws and Regulations that may affect cost, progress, performance and furnishing of the Work.

d. Bidder has carefully studied all reports of explorations and tests of subsurface conditions at or contiguous to the site and all drawings of physical conditions in or relating to existing surface or subsurface structures at or contiguous to the site (except Underground Facilities) which have been identified in the Supplementary Conditions as provided in Paragraph 4.02.A. of the General Conditions.

Bidder accepts the determination set forth in Paragraph SC-4.02. of the Supplementary Conditions of the extent of the "technical data" contained in such reports and drawings upon which Bidder is entitled to rely as provided in Paragraph 00700-4.02. of the General Conditions.

Bidder acknowledges that such reports and drawings are not Contract Documents and may not be complete for Bidder's purposes.

Bidder acknowledges that Owner and Engineer do not assume responsibility for the accuracy or completeness of information and data shown or indicated in the Bidding Documents with respect to existing Underground Facilities at or contiguous to the site.

e. Bidder has obtained and carefully studied (or assumes responsibility for having done so) all such additional or supplementary examinations, investigations, explorations, tests, studies and data concerning conditions (surface, subsurface and Underground Facilities) at or contiguous to the site or otherwise which may affect cost, progress, performance or furnishing of the Work or which relate to any aspect of the means, methods, techniques, sequences and procedures of construction to be employed by Bidder and safety precautions and programs incident thereto.

   Bidder does not consider that any additional examinations, investigations, explorations, tests, studies or data are necessary for the determination of this Bid for performance and furnishing of the Work in accordance with the times, price and other terms and conditions of the Contract Documents.

f. Bidder is aware of the general nature of Work to be performed by Owner and others at the site that relates to Work for which this Bid is submitted as indicated in the Contract Documents.

g. Bidder has correlated the information known to Bidder, information and observations obtained from visits to the site, reports and drawings identified in the Contract Documents and all additional examinations, investigations, explorations, tests, studies and data with the Contract Documents.

h. Bidder has given City written notice of all conflicts, errors, ambiguities or discrepancies in the Contract Documents and the written resolution thereof by Engineer is acceptable to Bidder, and the Contract Documents are generally sufficient to indicate and convey understanding of all terms and conditions for performing and furnishing the Work for which this Bid is submitted. Where conflicts, errors, ambiguities or discrepancies have been discovered in or between Contract Documents and/or other related documents, and where said conflicts, etc., have not been resolved through the interpretations or clarifications by Engineer as described in the Instructions to Bidders, because of insufficient time or otherwise, Bidder has included in the Bid the greater quantity or better quality of Work, or compliance with the more stringent requirement resulting in a greater cost.

i. This Bid is genuine and not made in the interest of or on behalf of any undisclosed person,

firm or corporation and is not submitted in conformity with any agreement or rules of any group, association, organization or corporation; Bidder has not directly or indirectly induced or solicited any other Bidder to submit a false or sham Bid; Bidder has not solicited or induced any person, firm or corporation to refrain from bidding; and Bidder has not sought by collusion to obtain for itself any advantage over any other Bidder or over Owner.

4. Bid Prices

Bidder will complete the Work in accordance with the Contract Documents for the following prices(s):

BASE BID SCHEDULE

Bid Item	Item Description	Unit[a]	Quantity	Unit Price	Item Total
1	Mobilization, Demobilization, Bonds, Permits, and Insurance on all work.	LS	1		
2	Sheeting, Shoring, Bracing, or Equivalent Method for Protection of Life and Limb in Trenches and Open Excavations	LS	1		
3	Training of City Staff	LS	1		
4	Final O&M Manuals	LS	1		
5	Record Drawings	LS	1		
6	Monument Preservation	LS	1		
7	Demolition Work	LS	1		
8	Civil and Site Improvements	LS	1		
9	Repurpose Existing DAFTs to Sludge Blend Tanks	LS	1		
10	Construction of New RDT Facility	LS	1		
11	Construction of New Thickening Odor Control Facility	LS	1		
12	Dewatering Facility Improvements	LS	1		
13	MCC-E Replacement	LS	1		
14	All Other Work Not Included in Above Bid Items	LS	1		
TOTAL BASE BID (BID ITEMS 1 - 14)					

[a] LS=Lump Sum, LF=Linear Feet, EA=Each, HR=Hour; VF=Vertical Feet

Total Base Bid (Bid Items 1-14) (written out) _____

_____Dollars.

Date Contractor is available to start work: _____

Proposed High-level Baseline Schedule (Section 00800 Project Milestones) Included? ☐ YES ☐ NO

The City reserves the right to select the lowest, responsible, responsive bidder based on the total base bid, and/or the combined total for the total Base Bid and Bid Alternates, and/or based upon the date the Contractor is available to start work, and/or based on reference checks, and/or past experience, and/or based on proposed high-level baseline schedule, and/or selection panel's

professional judgement regardless of the lowest bid amount.

5. Attached Documents

We agree that the following shall be attached hereto and made a part of this bid.

SECTION	TITLE
00301	Authority to Bid
00410	Bid Guaranty Bond
00420	Certification of Bidder's Experience and Qualifications
00425	CA Government Code Section 14310 Questionnaire
00430	Proposed Subcontractors
00431	Equal Employment Opportunity Certification
00432	Public Contract Code Section 10285.1 Certification
00433	Public Contract Code Section 10232 Certification
00434	Debarment and Suspension Certification
00435	Local Business Enterprise
00436	Nonlobbying Certification
00440	Site Visit Affidavit
00450	Schedule of Major Equipment and Material Supplies
00470	Acknowledgement of Insurance Requirements
00480	Non-Collusion Affidavit
00490	DIR Compliance Affidavit
00491	Statement Acknowledging Penal and Civil Penalties Concerning The Contractors' Licensing Laws
N/A	Proposed High-level Baseline Schedule (Showing compliance with Section 00800 Project Milestone, 11"x17")

6. Completion

We agree, if our bid is accepted and a Contract for Performance of the Work is entered into with the City, to so plan work and to prosecute it with such diligence that the work shall be completed within the time stipulated.

If our bid is accepted, we agree to sign the Agreement without qualifications and to furnish the performance and payment bonds and the required evidences of insurance within 10 calendar days after receiving written Notice of Award of the Contract.

Attached is a bid guaranty bond as required.

_____
Name of Bidder

7. Contractor's License and Address for Communications

The undersigned certifies that the undersigned holds California Contractor's License, Class A, number _____, expiration date _____.

_____
Name of Bidder

_____
Signature of Bidder

_____
Title of Signator

_____
Address of Bidder

_____ _____
Witness

_____ _____
Title of Witness State of Incorporation

_____
Phone Number

_____
FAX Number

END OF SECTION

SECTION 00301
(To be submitted with Bid)

AUTHORITY TO BID

I, the bidder, am a (check one below)

☐ An individual, bidder's name, signature, and physical address (not P.O Box) must be shown.

☐ A firm or partnership, a list of the partners, and the signature of at least one of the general partners must be shown.

☐ A corporation, the bid shall show the name of the state under the laws of which the corporation is chartered, the name and post office address of the corporation, and the title of the person who signs on behalf of the corporation. If the bid is made by a corporation, a certified copy of the bylaws or resolution of the Board of Directors of the corporation shall be furnished showing the authority of the officer signing the bid to execute contracts on behalf of the corporation.

☐ If the bid is made by a joint venture, the bid shall be signed by a representative of one of the joint venture firms. Additionally, the bid shall bind the joint venture. The required information shall be attached to the Bid Form and submitted with the bid.

By my signature below I certify under the penalty of perjury that I have the authority to bind myself/firm/partnership/corporation/joint venture to the subject project bid and have attached all required documentation as detailed above.

Bidders Authorized Agent

Signature	Address

Name: _____

Title: _____

*** END OF SECTION ***

SECTION 00 41 00
(To be submitted with Bid)

BID GUARANTY BOND

The attached form shall be turned in with the bid as the Bid Guaranty Bond with the form signed and notarized by the surety. Alternately, the bidder may submit the following forms of bidder's security:

a. Cash.
b. A cashier's check made payable to the City.
c. A certified check made payable to the City.

If a bid guaranty bond is submitted on a form other than that provided herein, then the alternate bid guaranty bond must meet all the requirements of the form provided herein. If the alternate bid guaranty bond is not acceptable to the City, then the bid may be subject to rejection. The City shall be the sole judge as to whether the alternate bid guaranty bond form is acceptable.

KNOW ALL PERSONS BY THESE PRESENTS:

THAT WE, _____AS PRINCIPAL, AND _____AS SURETY, are held and firmly bound unto the City of Manteca in the penal sum of 10 PERCENT OF THE TOTAL AMOUNT OF THE BID of the Principal above named, submitted by said Principal to the City of Manteca for the work described below, for the payment of which sum in lawful money of the United States, well and truly to be made to the City of Manteca to which said bid was submitted, we bind ourselves, our heirs, executors, administrators, and successors, jointly and severally, firmly by these presents, in no case shall the liability of the surety hereunder exceed the sum of $_____.

THE CONDITION OF THIS OBLIGATION IS SUCH

THAT WHEREAS, the Principal has submitted the above-mentioned bid to the City of Manteca, aforesaid, for certain construction specifically described as follows, for which bids are to be opened at _____.

FOR:_____

NOW, THEREFORE, if the aforesaid Principal is awarded the contract and, within the time and manner required under the specifications, after the prescribed forms are presented for signature, the Principal enters into a written contract in the prescribed form, in accordance with the bid, and files two bonds with the City of Manteca, one to guarantee faithful performance, and the other to guarantee payment for labor and materials as required by law, and provide certificate of insurance coverage required by the contract documents, then this obligation shall be null and void; otherwise, it shall be and remain in full force and effect, and the surety shall pay said penal sum of City of Manteca on demand.

IN WITNESS WHEREOF, we have hereunto set our hand on this _____day of _____, 20_____.

Title of Signator (seal)	Title of Signator (seal)
Signature of Principal	Signature of Surety
	Best Rating: _____
Address:	Address:

Note: Signatures of those executing for the surety must be properly acknowledged.

END OF SECTION

SECTION 00420

CERTIFICATION OF BIDDER'S EXPERIENCE AND QUALIFICATIONS

1.00 QUALIFICATIONS

By signing in the area indicated below, the Bidder acknowledges and certifies the following:

A. The Bidder – at the time of bidding, award, and throughout the period of the contract – shall be licensed under the provisions of Chapter 9, Division 3, of the Business and Professions Code of the State of California, to do the type of work contemplated in the contract documents. In accordance with Public Contract Code Section 20103.5, any Bidder not so licensed shall be subject to all legal penalties imposed by law, including, but not limited to, any appropriate disciplinary action by the Contractor's State License Board.

B. The Bidder is skilled and regularly engaged in the general class and type of work called for in the contract documents.

C. The Bidder is competent, knowledgeable, and has special skills required for the nature, extent, and inherent conditions of the work to be performed.

D. The Bidder has the financial ability and experience to perform the work as indicated in the Project Document.

E. The Bidder acknowledges that there may be certain peculiar and inherent conditions existent in the construction of the particular facilities which may create, during the construction program, unusual or peculiar unsafe conditions hazardous to persons and property. Bidder expressly acknowledges that it is aware of such peculiar risks and that it has the skill and experience to foresee and to adopt protective measures to adequately and safely perform the construction work with respect to such hazards.

2.00 EXPERIENCE

To be considered for award, Bidder, as a company, shall have substantially completed within the last five (5) years, at least three (3) projects of similar size.

1. Project Name: _____

   Owner: _____

   Construction Cost: _____

   Owner's Representative: _____

   Owner's Telephone No.: (____)_____

   Date of Substantial Completion: _____

   Percent Change Order: _____

2. Project Name: _____

   Owner: _____

   Construction Cost: _____

   Owner's Representative: _____

   Owner's Telephone No.: (_)_____

   Date of Substantial Completion: _____

   Percent Change Order: _____

3. Project Name: _____

   Owner: _____

   Construction Cost: _____

   Owner's Representative: _____

   Owner's Telephone No.: (____)_____

   Date of Substantial Completion: _____

   Percent Change Order: _____

Signed this _____day of _____, 20____.

_____
Name of Bidder

_____
Contractor's License No.

_____
Expiration Date

_____
Signature of Bidder

_____
Title of Signator

*** END OF SECTION ***

SECTION 00425

CA GOVERNMENTA CODE SECTION 14310 QUESTIONNAIRE

(To be submitted with Bid)

Pursuant to California Government Code 14310, the bidder shall complete, under penalty of perjury, the following questionnaire below.

1. Has the bidder, any officer of the bidder, or any employee of the bidder who has a proprietary interest in the bidder, ever been disqualified, removed, or otherwise prevented from bidding on, or completing a federal, state, or local government project because of a violation of the law or a safety regulation?	YES____ NO____
2. Has a contractor's license held by your firm and/or any owner, officer or partner of your firm been revoked at anytime in the last five years?	YES____ NO____
3. Within the last five years, has a surety firm completed a contract on your firms behalf, or paid for completion of a contract to which your firm was a party, because your firm was considered to be in default or was terminated for cause by the project owner?	YES____ NO____
4. At the time of submitting this questionnaire, is your firm ineligible to bid on or be awarded a public works contract, or perform as a contractor on a public works contract, pursuant to either California Labor Code Section 1777.1 (prevailing wage violations) or Labor Code Section 1777.7 (apprenticeship violations)?	YES____ NO____
5. At any time in the last five years, has your firm, or any of its owners, officers or partners been convicted of a crime involving the awarding of a contract for a government/public construction project, or the bidding or performance of a government/public contract?	YES____ NO____
6. Within the last five years, has your firm been assessed liquidated damages on any public contract?	YES____ NO____
7. Within the last three years has your firm or representatives been debarred from bidding on, or completing any public works construction contract for any reason?	YES____ NO____

8. Has CAL OSHA assessed penalties against your firm for any serious or willful violation occurring on a construction project at anytime in the last three years?	YES____ NO____
9. In the past three years, have civil penalties or Notice of Complaint (letter of warning) been issued or assessed against your firm pursuant to California Labor Code 1777.7 for violation of California public works apprenticeship requirements by the California Division of Apprenticeship Standards (DAS)?	YES____ NO____
10. In the past three years, has a public agency in California withheld contract payments or assessed penalties against your firm for violation of public works prevailing wage requirements?	YES____ NO____
11. Has your firm been assessed penalties for violation of public works prevailing wage requirements by the DLSE (Labor Commissioner)?	YES____ NO____
12. Does your firm have any pending complaints or investigations by a regulatory authority?	YES____ NO____

I, the undersigned, certify and declare that I have read and understood the questionnaire. I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Date _____ Signature _____

END OF SECTION

SECTION 00430

PROPOSED SUBCONTRACTORS
(To be submitted with Bid)

Pursuant to California Public Contracting Code, Section 4100 et. seq., the following list gives the name, business address, and portion of work (description of work to be done) for each subcontractor that will be used in the work if the bidder is awarded the Contract. (Additional supporting data may be attached to this page. Each page shall be sequentially numbered, and headed "Proposed Subcontractors" and shall be signed.)

Name	CLSB License Number	Description of Work	% of Work	[1]Status

_____
Name of Bidder

[1] **Status** **M = Minority Owned Business Enterprise.**
W = Women Owned Business Enterprise.

SECTION 00431

EQUAL EMPLOYMNET OPORTUNITY CERTIFICATION
(To be submitted with Bid)

I the bidder _____, and proposed subcontractor(s) _____, hereby certify under penalty of perjury that the foregoing is true and correct:

I/we has/have ____ , has/have not ____ , participated in a previous contract or subcontract subject to the equal opportunity clauses, as required by Executive Orders 10925, 11114, or 11246, and that, where required, he has filed with the Joint Reporting Committee, the Director of the Office of Federal Contract Compliance, a Federal Government contracting or administering agency, or the former President's Committee on Equal Employment Opportunity, all reports due under the applicable filling requirements.

Note: The above certification is required by the Equal Employment Opportunity Regulations of the Secretary of Labor (41 CFR 60-1.7(b) (1)), and must be submitted by bidders and proposed subcontractors only in connection with contracts and subcontracts which are subject to the equal opportunity clause. Contracts and subcontracts which are exempt from the equal opportunity clause are set forth in 41 CFR 60-1.5. (Generally only contracts or subcontracts of $10,000 or under are exempt.)

Currently, Standard Form 100 (EEO-1) is the only report required by the Executive Orders or their implementing regulations.

Proposed prime contractors and subcontractors who have participated in a previous contract or subcontract subject to the Executive Orders and have not filed the required reports should note that 41 CFR 60-1.7(b) (1) prevents the award of contracts and subcontracts unless such contractor submits a report covering the delinquent period or such other period specified by the Federal Highway Administration or by the Director, Office of Federal Contract Compliance, U.S. Department of Labor.

The bidder must place a checkmark after "has/have" or "has/have not" in one of the blank spaces provided. Bidders are cautioned that making a false certification may subject the certifier to criminal prosecution.

Bidders Name: _____ Date: _____

Bidders Signature: _____
Authorized Agent

*** END OF SECTION ***

SECTION 00432

PUBLIC CONTRACT CODE SECTION 10285.1 CERTIFICATION
(To be submitted with Bid)

I the bidder _____, and proposed subcontractor _____, hereby certify under penalty of perjury that the foregoing is true and correct:

I/we has/have ____ , has/have not ____ , participated in a previous contract or subcontract subject to the equal opportunity clauses, as required by Executive Orders 10925, 11114, or 11246, and that, where required, he has filed with the Joint Reporting Committee, the Director of the Office of Federal Contract Compliance, a Federal Government contracting or administering agency, or the former President's Committee on Equal Employment Opportunity, all reports due under the applicable filling requirements.

> **Note:** The above certification is required by the Equal Employment Opportunity Regulations of the Secretary of Labor (41 CFR 60-1.7(b) (1)), and must be submitted by bidders and proposed subcontractors only in connection with contracts and subcontracts which are subject to the equal opportunity clause. Contracts and subcontracts which are exempt from the equal opportunity clause are set forth in 41 CFR 60-1.5. (Generally only contracts or subcontracts of $10,000 or under are exempt.) Currently, Standard Form 100 (EEO-1) is the only report required by the Executive Orders or their implementing regulations.

Proposed prime contractors and subcontractors who have participated in a previous contract or subcontract subject to the Executive Orders and have not filed the required reports should note that 41 CFR 60-1.7(b) (1) prevents the award of contracts and subcontracts unless such contractor submits a report covering the delinquent period or such other period specified by the Federal Highway Administration or by the Director, Office of Federal Contract Compliance, U.S. Department of Labor.

The bidder must place a checkmark after "has/have" or "has/have not" in one of the blank spaces provided. Bidders are cautioned that making a false certification may subject the certifier to criminal prosecution.

Bidders Authorized Agent	*Bidders' Subcontractor Authorized Agent*
_____	_____
Signature	Signature
Name: _____	Name: _____
Title: _____	Title: _____

*** END OF SECTION ***

SECTION 00433

PUBLIC CONTRACT CODE SECTION 10232 CERTIFICATION
(To be submitted with Bid)

I the bidder _____, In accordance with Public Contract Code Section 10232, the Contractor, hereby state under penalty of perjury, that:

☐ No more than one final unappealable finding of contempt of court by a federal court has been issued against the Contractor within the immediately preceding two year period because of the Contractor's failure to comply with an order of a federal court which orders the Contractor to comply with an order of the National Labor Relations Board.

The bidder must place a checkmark in one of the box above. Bidders are cautioned that making a false certification may subject the certifier to criminal prosecution.

Bidders Authorized Agent

_____
Signature

Name: _____

Title: _____

*** END OF SECTION ***

SECTION 00434

DEBARMENT AND SUSPENSION CERTIFICATION
(To be submitted with Bid)

I the bidder _____, In accordance with Title 49, Code of Federal Regulations, Part 29, hereby state under penalty of perjury, that, except as noted below, he/she or any other person associated therewith in the capacity of owner, partner, director, officer, manager:

- ☐ Is not currently under suspension, debarment, voluntary exclusion, or determination of ineligibility by any Federal agency.
- ☐ Has not been suspended, debarred, voluntarily excluded or determined ineligible by any Federal agency within the past 3 years
- ☐ Does not have a proposed debarment pending.
- ☐ Has not been indicted, convicted, or had a civil judgment rendered against it by a court of competent jurisdiction in any matter involving fraud or official misconduct within the past 3 years.

If there are any exceptions to this certification, insert the exceptions in the following space.

The bidder must place a checkmark in the applicable box(es) above. Bidders are cautioned that making a false certification may subject the certifier to criminal prosecution.

Bidders Authorized Agent

_____
Signature

Name: _____

Title: _____

*** END OF SECTION ***

SECTION 00435

LOCAL BUSINESS ENTERPRISE

1. RECITALS

1. Whereas it is the responsibility of the City to assure that all competitive bids for services, supplies and projects, as well as all professional services, are comprehensively reviewed and evaluated by City staff to ensure the best quality of work is received for the least amount of taxpayer money; and

2. Whereas the City is desirous of providing a preference for local business enterprises (vendors), in an attempt to keep as many local jobs as local as possible, and

3. Whereas the City hopes to balance this preference with assuring the public that the best enterprise/vendor is selected for each and every City contract.

2. POLICY

Definition of "Local Business Enterprise (LBE):" A business enterprise, including but not limited to a sole proprietorship, partnership or corporation, which has a legitimate business presence in the incorporated City limits of the City of Manteca. Evidence of legitimate presence in Manteca shall include:

A. Having a current Manteca business license; and

B. Having either of the following types of offices operating legally within the City of Manteca:
   1. The contractor's principal office; or
   2. The contractor's regional, branch or satellite office with at least one full-time employee located in the corporate boundaries of the City of Manteca. A post office box address alone does not constitute a "Local Business Enterprise."

Public, Competitive Bids:

If two or more bids received from responsible bidders are for the same total amount or unit price – quality and service being equal – preference shall be given to the LBE.
In the event two or more bids are received and they are not for the same total amount or unit price, and a bid submitted by **a qualified LBE is within 5% (total net cost)** of the lowest bid or quote, the LBE may be deemed to be the lowest bidder if the LBE agrees, in writing within one business day, to reduce its bid to match the bid or quote of the lowest bidder, providing that the City determines the LBE to be a responsible bidder.

LOCAL BUSINESS ENTERPRISE

(To be submitted with Bid)

Are you a local business enterprise according to this policy?

Yes _____ No _____

If the answer is yes, complete the following:

City of Manteca Business License Number: _____

Address of local office with at least one full-time employee:

_____

I certify under penalty of perjury that the foregoing is true and correct.

Bidders Name: _____ Date: _____

Bidders Signature: _____
Authorized Agent

SECTION 00436

NON LOBBYING CERTIFICATION
(To be submitted with Bid)

I the bidder _____, in accordance with Section 1352, Title 31 of the US Code, hereby state under penalty of perjury, that, to the best of my knowledge and belief, that:

- ☐ No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any Federal agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreements not currently under suspension, debarment, voluntary exclusion, or determination of ineligibility by any Federal agency.
- ☐ If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any Federal agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in conformance with its instructions.
- ☐ This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.
- ☐ I shall require that the language of this certification be included in the award documents for all subcontractors at all tiers and that all subrecipients shall certify and disclose accordingly.

The bidder must place a checkmark in the applicable box(es) above. Bidders are cautioned that making a false certification may subject the certifier to criminal prosecution.

Bidders Authorized Agent

_____
Signature

Name: _____

Title: _____

*** END OF SECTION ***

SECTION 00437

DISCLOSURE OF LOBBYING ACTIVITY
Not Applicable

*** END OF SECTION ***

SECTION 00438

CALTRANS LOCAL ASSISTANCE PROCEDURES MANUAL DISADVANTAGED BUSINESS ENTERPRISE REQUIREMENT

Not Applicable

*** END OF SECTION ***

SECTION 00439

REQUIRED STATE/FEDERAL CONTRACT LANGUAGE

Not Applicable

*** END OF SECTION ***

SECTION 00440

SITE VISIT AFFIDAVIT
(To be submitted with Bid)

NAME OF PROJECT: WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 (Project)

State of California

County of _____

_____, being first duly sworn, deposes
(Printed Name of Contractor's Authorized Representative)

he or she is

_____of _____,
(Title of Representative) (Bidder's Name)

the party making the bid, has visited the Site of the Work as described in the Contract Documents and has examined and familiarized themselves with the existing conditions, as well as all other conditions relating to the construction which will be performed. The submitting of a bid shall be considered an acknowledgement on the part of the Bidder of familiarity with conditions at the site of Work. The Bidder further acknowledges that the site examination has provided adequate and sufficient information related to existing conditions which may affect cost, progress or performance of the Work.

Signed this _____day of _____, 20____.

_____
Authorized Signature

*** END OF SECTION ***

SECTION 00450

SCHEDULE OF MAJOR EQUIPMENT AND MATERIAL SUPPLIERS

(To Accompany Bid)

Bidders must designate the manufacturer/supplier of each item of equipment, materials or systems listed below. By such designation, Bidder warrants the equipment and material manufactured and/or supplied by the named manufacturer or supplier, with the exception of substitutions which may be proposed.

A substitute may be proposed in accordance with Public Contract Code 3400. Bidder agrees that should it propose a substitute manufacturer/supplier, that prior to award, Bidder shall submit complete information, satisfactory to the City, demonstrating that such manufacturer's or supplier's equipment is in general compliance with the requirements of the Contract Documents. Full submittal information as specified under Specifications Section 01340, Shop Drawings, Products Data and Samples, shall be submitted following award.

If the City should determine that the proposed substitute does not meet the requirements of the Contract Documents, the Bidder's Bid will be rejected unless, prior to award, the Bidder agrees in writing to furnish a listed manufacturer/supplier or submits an acceptable substitute without change in the Bid price.

Equipment substitutions listed in this section are exempt from the cost sharing provisions of Specifications Section 01340, Substitutions. However, the Bidder will be responsible for any additional costs necessary for the incorporation of such substitutions as provided for in Specification Section 01340, Modifications and Costs.

The following named items of major equipment and materials will be supplied by the manufacturers or suppliers as written in by the bidder. By so indicating, the bidder warrants that the equipment and material manufactured and/or supplied by the named manufacturer or supplier will be provided on the project unless review of submittal information or performance under tests reveals that the equipment or material does not meet the Contract requirements. Failure to indicate a manufacturer or supplier listed in the following schedule may render the Bid non-responsive and may be the basis for rejection of the Bid.

If the Bidder fails to identify a manufacturer/supplier for any item shown on this list, the City has the right to waive such omission. In such case it will be assumed that the manufacturer/supplier to be used by the Bidder will be the first listed manufacturer/supplier identified for the given item.

NAME OF BIDDER _____

SCHEDULE OF MAJOR EQUIPMENT AND MATERIAL SUPPLIERS			
Item	Description	Section	Manufacturer/Supplier
1	Fiberglass Metering Manhole	11210	
2	High-Pressure Washers	11215	
3	Large Bubble Mixing System	11227	
4	Polymer Blending and Feed Equipment: Liquid	11246	
5	Heavy-Duty Fabricated Stainless Steel Slide Gates	11294B	
6	Progressing Cavity Pumps	11312I	
7	In-line Grinders	11334	
8	Thickeners	11354	
9	Centrifuge Dewatering Equipment	11358	
10	Rotary Screw Air Compressor System	11372C	
11	Package Odor Control System	11395A	

**** END OF SECTION ***

SECTION 00470

ACKNOWLEDGEMENT OF INSURANCE REQUIREMENTS

(To be submitted with Bid)

At the time the bid proposal is submitted to the City, the Bidder is not required to obtain the required insurance coverage as outlined in the Contract Documents. The objective of this acknowledgement is for the Bidder to verify they have reviewed and understood the insurance requirements and that they are able to obtain the insurance coverage if awarded the Project.

If awarded the Project, the Bidder also acknowledges that the City will not accept contract change orders that are based on insurance costs that were not appropriately considered.

Bidder certifies that full compensation for the requirements set forth in Section 00820 **LIABILITY AND INSURANCE REQUIREMENTS** of the Contract Documents is included in the Bid Price.

Bidder acknowledges that he has reviewed the insurance requirements for the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 and certifies that he can and will acquire the insurance specified coverages and limits if the City awards the Project to the Bidder.

Bidder's Signature _____

Date _____

*** END OF SECTION ***

SECTION 00480

NON-COLLUSION AFFIDAVIT
(To be executed by Bidder and submitted with Bid)

State of California)
) ss.
County of)

_____, being first duly sworn, deposes and say that he or she is of _____the party making the foregoing bid that the bid is not made in the interest of, or on behalf of, any undisclosed person, partnership, company, association, organization, business entity, business combination, or corporation; that the bid is genuine and not collusive or sham; that the bidder has not directly or indirectly induced or solicited any other bidder to put in a false or sham bid, and has not directly or indirectly colluded, conspired, connived, or agreed with any bidder or anyone else to put in a sham bid, or that anyone shall refrain from bidding; that the bidder has not in any manner, directly or indirectly sought by agreement, communication, or conference with anyone to fix the bid price of the bidder or any other bidder, or to fix any overhead, profit, or cost element of the bid price, or of that of any other bidder, or to secure any advantage against the public body awarding the contract of anyone interested in the proposed contract; that all statements contained in the bid are true; and, further, that the bidder has not, directly or indirectly, submitted his or her bid price or any breakdown thereof, or the contents thereof, or divulged information or data relative thereto, or paid, and will not pay, any fee to any corporation, partnership, company association, organization, bid depository, or to any member or agent thereof to effectuate a collusive or sham bid.

_____
Signature

_____

Name of Bidder

_____

Title

_____

Date

Subscribed and sworn to before me this

_____day of _____, 20____.

_____
Signature of Notary Public in and for
the County of _____,
State of California.

*** END OF SECTION ***

SECTION 00490

DEPARTMENT OF INDUSTRIAL RELATIONS COMPLIANCE AFFIDAVIT

In accordance with California Labor Code as amended through Senate Bill (SB) 96, no contractor or subcontractor shall be listed on a bid proposal for a public works project or awarded a contract for public work on a public works project unless registered with the California Department of Industrial Relations (DIR).

This project is subject to compliance monitoring and enforcement by the DIR. For information regarding registration, please go to:

www.dir.ca.gov

I, the Bidder, certify that:

> I am aware of the provisions of SB 96 and subsequent DIR regulations which require Contractors/Vendors to comply with all labor compliance requirements including, but not limited to, prevailing wage requirements, Labor Code Sections 1725.5, 1771.1(a), 1774-1776, 1777.5, 1813, 1815, Public Works Contractor Registration Program, Electronic Certified Payroll Records to Labor Commissioner, and other requirements described in the DIR website. I will comply with such provisions before commencing the performance of the work of this contract and maintain compliance throughout the completion of said contract. Any fees levied by DIR as a result of contractor's non-compliance shall be borne by the contractor.

Signature	Date
Print Name	Business Name
Title	CSLB License Number
	DIR Registration Number

END OF SECTION

SECTION 00491

STATEMENT ACKNOWLEDGING PENAL AND CIVIL PENALTIES CONCERNING THE CONTRACTORS' LICENSING LAWS

[Business & Professions Code § 7028.15]
[Public Contract Code § 20103.5]

I, the undersigned, certify that I am aware of the following provisions of California law and that I, or the entity on whose behalf this certification is given, hold a currently valid California contractor's license as set forth below:

Business & Professions Code § 7028.15:

(a) It is a misdemeanor for any person to submit a bid to a public agency in order to engage in the business or act in the capacity of a contractor within this state without having a license therefor, except in any of the following cases:

(1) The person is particularly exempted from this chapter.
(2) The bid is submitted on a state project governed by Section 10164 of the Public Contract Code or on any local agency project governed by Section 20104 [now § 20103.5] of the Public Contract Code.

(b) If a person has been previously convicted of the offense described in this section, the court shall impose a fine of 20 percent of the price of the contract under which the unlicensed person performed contracting work, or four thousand five hundred dollars ($4,500), whichever is greater, or imprisonment in the county jail for not less than 10 days nor more than six months, or both.

In the event the person performing the contracting work has agreed to furnish materials and labor on an hourly basis, "the price of the contract" for the purposes of this subdivision means the aggregate sum of the cost of materials and labor furnished and the cost of completing the work to be performed.

(c) This section shall not apply to a joint venture license, as required by Section 7029.1. However, at the time of making a bid as a joint venture, each person submitting the bid shall be subject to this section with respect to his or her individual licensure.

(d) This section shall not affect the right or ability of a licensed architect, land surveyor, or registered professional engineer to form joint ventures with licensed contractors to render services within the scope of their respective practices.

(e) Unless one of the foregoing exceptions applies, a bid submitted to a public agency by a contractor who is not licensed in accordance with this chapter shall be considered nonresponsive and shall be rejected by the public agency. Unless one of the foregoing exceptions applies, a local public agency shall, before awarding a contract or issuing a purchase order, verify that the Contractor was properly licensed when the Contractor submitted the bid. Notwithstanding any other provision of law, unless one of the

foregoing exceptions applies, the registrar may issue a citation to any public officer or employee of a public entity who knowingly awards a contract or issues a purchase order to a Contractor who is not licensed pursuant to this chapter. The amount of civil penalties, appeal, and finality of such citations shall be subject to Sections 7028. 7 to 7028.13, inclusive. Any contract awarded to, or any purchase order issued to, a contractor who is not licensed pursuant to this chapter is void.

(f) Any compliance or noncompliance with subdivision (e) of this section, as added by Chapter 863 of the Statues of 1989, shall not invalidate any contract or bid awarded by a public agency during which time that subdivision was in effect.

(g) A public employee or officer shall not be subject to a citation pursuant to this section if the public employee, officer, or employing agency made an inquiry to the board for the purposes of verifying the license status of any person or contractor and the board failed to respond to the inquiry within three business days. For purposes of this section, a telephone response by the board shall be deemed sufficient.

Public Contract Code § 20103 .5:

In all contracts subject to this part where federal funds are involved, no bid submitted shall be invalidated by the failure of the bidder to be licensed in accordance with the laws of this state. However, at the time the contract is awarded, the Contractor shall be properly licensed in accordance with the laws of this state. The first payment for work or material under any contract shall not be made unless and until the Registrar of Contractors verifies to the agency that the records of the Contractors' State License Board indicate that the Contractor was properly licensed at the time the contract was awarded. Any bidder or contractor not so licensed shall be subject to all legal penalties imposed by law, including, but not limited to, any appropriate disciplinary action by the Contractors' State License Board. The agency shall include a statement to that effect in the standard form of pre-qualification questionnaire and financial statement. Failure of the bidder to obtain proper and adequate licensing for an award of a contract shall constitute a failure to execute the contract and shall result in the forfeiture of the security of the bidder.

Signature, Date	Business Name
Print Name	Contractor License Number, Class
Title	Contractor License Expiration

*** END OF SECTION ***

SECTION 00500

AGREEMENT FOR THE CONSTRUCTION OF
WQCF Sludge Thickener and Dewatering Unit No. 3 Project
CIP 24006 & 24007

This AGREEMENT, made this _____day of _____, 20____by and between City of Manteca, hereinafter called the "City," and _____ _____hereinafter called the "Contractor."

W I T N E S S E T H:

Article 1. WORK

WHEREAS, the City has caused the contract documents to be prepared comprised of bidding and contract requirements and technical specifications and plans for the construction of the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 (PROJECT) as described therein, and

WHEREAS, the Contractor has offered to perform the proposed work in accordance with the terms of this AGREEMENT and the contract documents in the sum of $_____.

NOW, THEREFORE, in consideration of the mutual covenants and agreements of the parties herein contained and to be performed, the Contractor hereby agrees to complete the work at the total bid and on the terms and conditions herein contained, and the City agrees to pay the Contractor as provided herein for the fulfillment of the work and the performance of the covenants set forth herein.

The further terms, conditions, and covenants of the Contract are set forth in the contract documents, each of which is by this reference made a part hereof.

Article 2. ENGINEER

The Project has been designed by **Carollo Engineers, Inc.**, who is hereinafter called Engineer and who is to act as Owner's Representative, assume all duties and responsibilities, and have the rights and authority assigned to the Engineer of Record in connection with completion of this PROJECT and in accordance with the contract documents.

Article 3. CONTRACT TIMES

3.1. TIME ALLOWED FOR COMPLETION
The Work shall be completed within **900** calendar days of Notice to Proceed for Substantial Completion and **90** calendar days after Substantial Completion for Final Completion as provided in Paragraph 2.03 of the General Conditions, and ready for final payment in accordance with Paragraph 14.07B of the General Conditions

3.2. LIQUIDATED DAMAGES

Owner and Contractor recognize that time is of the essence of this Agreement and that Owner will suffer financial loss if the Work is not completed within the times specified in Paragraph 3.1. above, plus any extensions thereof allowed in accordance with Article 12 of the General Conditions. They also recognize the delays, expense and difficulties involved in proving the actual loss suffered by Owner if the Work is not completed on time.

Accordingly, instead of requiring any such proof, Owner and Contractor agree that as liquidated damages for delay (but not as a penalty), Contractor shall pay Owner $5,000 for each calendar day that expires after the time specified in Paragraph 3.1 for Substantial Completion until the Work is substantially complete.

After Substantial Completion, if Contractor shall neglect, refuse or fail to complete the remaining Work within the time specified in Paragraph 3.1. for completion and readiness for final payment or any proper extension thereof granted by Owner, Contractor shall pay Owner $1,000 for each calendar day that expires after the time specified in Paragraph 3.1. for completion and readiness for final payment.

Article 4. PAYMENT PROCEDURES

Contractor shall submit Applications for Payment in accordance with Article 14 of the General Conditions. Applications for Payment will be processed by Construction Manager as provided in the General Conditions.

Article 5. INTEREST

Payment of interest shall be as provided in the General Conditions.

Article 6. CONTRACTOR'S REPRESENTATIONS

In order to induce Owner to enter into this Agreement, Contractor makes the following representations:

6.1. Contractor has thoroughly examined and carefully studied the contract documents (including the Addenda listed in Paragraph 8.) and the other related data identified in the Bidding Documents including "technical data."

6.2. Contractor has visited the site and become familiar with and is satisfied as to the general, local and site conditions that may affect cost, progress, performance or furnishing of the Work.

6.3. Contractor is familiar with and is satisfied as to all federal, state and local Laws and Regulations that may affect cost, progress, performance or furnishing of the Work.

6.4. Contractor has carefully studied all reports of explorations and tests of subsurface conditions at or contiguous to the site and all drawings of physical conditions in or relating to existing surface or subsurface structures at or contiguous to the site which have been identified in the

Supplementary Conditions as provided in Paragraph 4.02A. of the General Conditions.

Contractor accepts the determination set forth in Paragraph 4.02. of the Supplementary Conditions of the extent of the "technical data" contained in such reports and drawings upon which Contractor is entitled to rely as provided in Paragraph 4.02. of the General Conditions.

Contractor acknowledges that such reports and drawings are not contract documents and may not be complete for Contractor's purposes.

Contractor acknowledges that Owner and Engineer do not assume responsibility for the accuracy or completeness of information and data shown or indicated in the contract documents with respect to Underground Facilities at or contiguous to the site.

Contractor has obtained and carefully studied (or assumes responsibility for having done so) all such additional supplementary examinations, investigations, explorations, tests, studies and data concerning conditions (surface, subsurface and Underground Facilities) at or contiguous to the site or otherwise which may affect cost, progress, performance or furnishing of the Work or which relate to any aspect of the means, methods, techniques, sequences and procedures of construction to be employed by Contractor and safety precautions and programs incident thereto.

Contractor does not consider that any additional examinations, investigations, explorations, tests, studies or data are necessary for the performance and furnishing of the Work at the Contract Price, within the contract times and in accordance with the other terms and conditions of the contract documents.

6.5. Contractor is aware of the general nature of work to be performed by Owner and others at the site that relates to the Work as indicated in the contract documents.

6.6. Contractor has correlated the information known to Contractor, information and observations obtained from visits to the site, reports and drawings identified in the contract documents and all additional examinations, investigations, explorations, tests, studies and data with the contract documents.

6.7. Contractor has given Owner written notice of all conflicts, errors, ambiguities or discrepancies in the contract documents and the written resolution thereof by Engineer through issued addendum or addenda is acceptable to Contractor, and the contract documents are generally sufficient to indicate and convey understanding of all terms and conditions for performance and furnishing of the Work. When said conflicts, etc., have not been resolved through interpretation or clarification by Owner, because of insufficient time or otherwise, Contractor has included in the Bid the greater quantity or better quality of Work, or compliance with the more stringent requirement resulting in a greater cost; and said greater cost is included in the Contract Price.

Article 7. CONTRACT DOCUMENTS

The contract documents which comprise the entire agreement between Owner and Contractor

concerning the Work consist of the following:

7.1. This Agreement.

7.2. Exhibits to this Agreement.

7.3. Performance, Payment, and other Bonds.

7.4. Notice to Proceed.

7.5. General Conditions.

7.6. Supplementary Conditions.

7.7. Drawings consisting of a cover sheet and sheets numbered 1 through _____.

7.8. Addenda numbers to ____, inclusive.

7.9. Bid Period Questions and Answers (Enclosure A).

7.10. Contractor's Bid (pages ____to ___, inclusive) marked Exhibit _____.

7.11. Documentation submitted by Contractor prior to Notice of Award (pages ____to ____ inclusive).

7.12. The following which may be delivered or issued after the Effective Date of the Agreement and are not attached thereto:

7.13. All written amendments and other documents amending, modifying or supplementing the contract documents pursuant to Paragraph 3.04 of the General Conditions.

There are no contract documents other than those listed above in this Article 7. The contract documents may only be amended, modified or supplemented as provided in Paragraph 3.04 of the General Conditions.

Article 8. MISCELLANEOUS

8.1. Terms used in this Agreement which are defined in Article 1 of the General Conditions will have the meanings indicated in the General Conditions

8.2. No assignment by a party hereto of any rights under or interests in the contract documents will be binding on another party hereto without the written consent of the party sought to be bound; and, specifically but without limitation, moneys that may become due and moneys that are due may not be assigned without such consent (except to the extent that the effect of this restriction may be limited by law), and unless specifically stated to the contrary in any written consent to an assignment, no assignment will release or discharge the assignor from any duty or responsibility under the contract documents.

8.3. Owner and Contractor each binds itself, its partners, successors, assigns and legal representatives to the other party hereto, its partners, successors, assigns and legal representatives in respect to all covenants, agreements and obligations contained in the contract documents.

8.4. Any provision or part of the contract documents held to be void or unenforceable under any Law or Regulation shall be deemed stricken, and all remaining provisions shall continue to be valid and binding upon Owner and Contractor, who agree that the contract documents shall be reformed to replace such stricken provision or part thereof with a valid and enforceable provision that comes as close as possible to expressing the intention of the stricken provision.

IN WITNESS WHEREOF, this agreement has been executed on this _____day of _____, 20_____.

_____
Name of Contractor

_____
Signature of Contractor

_____
Title of Signator

_____
Address

_____
Phone Number

_____
Contractor's License No.

CITY OF MANTECA

_____
Toni Lundgren, City Manager

ATTEST

_____
Cassandra Candini-Tilton, City Clerk

APPROVED AS TO FORM

_____
L. David Nefouse, City Attorney
By: Daniella Green, Assistant City Attorney

END OF SECTION

SECTION 00610

FAITHFUL PERFORMANCE BOND

KNOW ALL PERSONS BY THESE PRESENTS, THAT, WHEREAS, City of Manteca, hereinafter designated the "City," has, on _____, 20___, awarded to _____, hereinafter designated as the "Principal," a Contract for the construction of the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007.

WHEREAS, said Principal is required under the terms of said Contract to furnish a bond for the faithful performance of said Contract:

NOW, THEREFORE, WE, the Principal, and _____, as Surety, are held and firmly bound unto the City the penal sum of _____, dollars ($_____) lawful money of the United States, for the payment of which sum well and truly to be made, we bind ourselves, our heirs, executors, administrators, and successors, jointly and severally, firmly by these presents.

THE CONDITION OF THIS OBLIGATION IS SUCH, that if the above bounden Principal, it or its heirs, executors, administrators, successors, or assigns, shall in all things stand to and abide by, and well and truly keep and faithfully perform the covenants, conditions, and agreements in the said contract and any alterations made as therein provided, on it or their part to be kept and performed, at the time and in the manner therein specified, and in all respects according to their true intent and meaning, and shall indemnify and save harmless, the City, its officers and agents as therein stipulated, then this obligation shall become null and void; otherwise it shall be and remain in full force and effect.

It is acknowledged that the Contract provides for one-year warranty period, during which time this bond remains in full force and effect.

And the said Surety, for value received, hereby stipulates and agrees that no change, extension of time, alteration, or addition to the terms of the Contract or to the work to be performed thereunder or the specifications accompanying the same shall, in any way, affect its obligations on this bond, and it does hereby waive notice of any such change, extension of time, alteration, or addition to the terms of the Contract or to the work or to the specifications. Said Surety hereby waives the provisions of Sections 2819 and 2845 of the Civil Code of the State of California.

IN WITNESS WHEREOF, the above bounden parties have executed this instrument under their seals this _____day of _____, 20___, the name and corporate seal of each corporate party being hereto affixed and these presents duly signed by its undersigned representative, pursuant to authority of its governing body.

Principal

(Seal)

Signature for Principal

Title of Signator

Surety

(Seal)

Signature for Surety

Title of Signator

APPROVED AS TO FORM:

L. David Nefouse, City Attorney
By: Daniella Green, Assistant City Attorney

APPROVED AS TO SUFFICIENCY:

Kevin Jorgensen II
Director of Engineering/City Engineer

Attach Notary Form Here

END OF SECTION

SECTION 00620

PAYMENT BOND

KNOW ALL PERSONS BY THESE PRESENTS, THAT, WHEREAS, City of Manteca, hereinafter designated as the "City," has, on _____, 20___, awarded to _____, hereinafter designated as the "Principal," a Contract for the construction of the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007, and

WHEREAS, said Principal is required to furnish a bond in connection and with said Contract, providing that if said Principal, or any of it or its subcontractors shall fail to pay for any materials, provisions, or other supplies used in, upon, for, or about the performance of the work contracted to be done, or for any work or labor done thereon of any kind, the Surety of this bond will pay the same to the extent hereinafter set forth:

NOW, THEREFORE, we, the Principal, and _____, as Surety, are held and firmly bound unto the City the penal sum of _____Dollars ($ _____) lawful money of the United States, for the payment of which sum well and truly to be made, we bind ourselves, our heirs, executors, administrators, and successors jointly and severally, firmly by these presents.

THE CONDITION OF THIS OBLIGATION IS SUCH, that if said Principal, it or its heirs, executors, administrators, successors, or assigns, shall fail to pay for any materials, provisions, or other supplies used in, upon, for, or about the performance of the work contracted to be done, or for any work or labor thereon of any kind or for amount due under the Unemployment Insurance Act with respect to such work or labor, or for any amounts due, or to be withheld pursuant to Sections 18806 of the Revenue and Taxation Code of the State of California with respect to such work or labor, then said surety will pay the same in or to an amount not exceeding the amount hereinabove set forth, and also will pay in case suit is brought upon this bond, such reasonable attorney's fees to the City as shall be fixed by the court.

This bond shall insure to the benefit of any and all persons, companies, and corporations named in Section 3181 of the Civil Code of the State of California so as to give a right of action to them or their assigns in any suit brought upon this bond.

And the said Surety, for value received, hereby stipulates and agrees that no change, extension of time, alteration, or addition of the terms of the Contract or to the work to be performed thereunder or the specifications accompanying the same shall, in any way, affect its obligations of this bond, and it does hereby waive notice of any change, extension of time, alteration, or addition to the terms of the contract or to the work or to the specifications. Said Surety hereby waives the provisions of Sections 2819 and 2845 of the Civil Code of the State of California.

IN WITNESS WHEREOF, the above bounden parties have executed this instrument under their seals this _____day of _____, 20__, the name and corporate seal of each corporate party being hereto affixed and these presents duly signed by its undersigned representative, pursuant to authority of its governing body.

_____
Principal

(Seal)

_____
Signature for Principal Title

_____
Surety

(Seal)

_____
Signature for Surety Title

APPROVED AS TO FORM:

L. David Nefouse, City Attorney
By: Daniella Green, Assistant City Attorney

APPROVED AS TO SUFFICIENCY:

Kevin Jorgensen II
Director of Engineering/City Engineer

Attach Notary Form Here

*** END OF SECTION ***

SECTION 00630

WARRANTY BOND

Whereas, the City Council of the City of Manteca, State of California, and

_____

(hereinafter designated as "Contractor") have entered into a Contract whereby Contractor agrees to repair any improvements set forth in said Contract identified as the WQCF Sludge Thickener and Dewatering Unit No. 3 Project CIP 24006 & 24007 and awarded by Resolution to Contractor on _____, 20____, is hereby referred to and made a part hereof, and

Whereas, the Contractor is required under the terms of said Contract to furnish a one year bond starting at Final Completion for the Warranty of Improvements of said Contract.

Now, therefore, we, the Contractor and _____ as surety, are held and firmly bound unto the City of Manteca, hereinafter called "City" in the penal sum of _____dollars ($_____) lawful money of the United States, for the payment of which sum well and truly to be made, we bond ourselves, our heirs, successors, executors and administrators, jointly and severally, firmly by these presents.

The condition of this obligation is such that if the above bounded Contractor, his or its heirs, executors, administrators, successors or assigns, shall in all things stand to and abide by, and well and truly keep and perform the covenants, conditions and provisions in the said Contract and any alteration thereof made as therein provided, on his or their part, to be kept and performed at the time and in the manner therein specified, and in all respects according to their true intent and meaning, and shall indemnify and save harmless the City of Manteca, its officers, agents and employees, as therein stipulated, then this obligation shall become null and void; otherwise it shall be and remain in full force and effect.

As a part of the obligation secured hereby and in addition to the face amount specified therefore, there shall be included costs and reasonable expenses and fees, including reasonable attorney's fees, incurred by City in successfully enforcing such obligation, all to be taxed as costs and included in any judgment rendered.

In witness whereof, this instrument has been duly executed by the Contractor and surety above named, on _____, 20____.

Name of Contractor	Name of Surety
Address	Address and Telephone
Signature of Contractor	Signature of Surety

APPROVED AS TO FORM:	**APPROVED AS TO SUFFICIENCY:**
L. David Nefouse, City Attorney By: Daniella Green, Assistant City Attorney	Kevin Jorgensen II Director of Engineering/City Engineer

Attach Notary Form Here

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*** END OF SECTION ***

SECTION 00650

WORKERS' COMPENSATION INSURANCE

In accordance with California Labor Code Section 1861, prior to commencement of work on the Contract, the Contractor shall sign and file with the City the following certification:

> "I am aware of the provisions of Section 3700 of the Labor Code which require every employer to be insured against liability for workers' compensation or to undertake self-insurance in accordance with the provisions of that code, and I will comply with such provisions before commencing the performance of the work of this contract."

_____
Signature

_____
Name of Contractor

_____
Title

_____
Date

END OF SECTION

STANDARD GENERAL CONDITIONS OF THE CONSTRUCTION CONTRACT

CITY OF MANTECA

These General Conditions are based in part on

EJCDC C-700 (2002 Copyrighted Edition)

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GENERAL CONDITIONS

ARTICLE 1. DEFINITIONS AND TERMINOLOGY

Section 1.01 Defined Terms

A. Wherever used in these General Conditions or in other Contract Documents, the terms listed below have the meanings indicated which are applicable to both the singular and plural thereof. Said terms are generally capitalized or written in italics, but not always. When used in a context consistent with the definition of a listed-defined term, the term shall have a meaning as defined below whether capitalized or italicized or otherwise.

1. *Addenda*--Written or graphic instruments issued prior to the opening of Bids, which clarify, correct, or change the Bidding Requirements or the proposed Contract Documents.
2. *Agreement*--The written instrument which is evidence of the agreement between Owner and Contractor covering the Work.
3. *Application for Payment*--The form acceptable to Construction Manager which is to be used by Contractor during the course of the Work in requesting progress or final payments and which is to be accompanied by such supporting documentation as is required by the Contract Documents.
4. *Asbestos*--Any material that contains more than one percent asbestos and is friable or is releasing asbestos fibers into the air above current action levels established by the United States Occupational Safety and Health Administration.
5. *Bid*--The offer or proposal of a Bidder submitted on the prescribed form setting forth the prices for the Work to be performed.
6. *Bidder*--The individual or entity who submits a Bid directly to Owner.
7. *Bidding Documents*--The Bidding Requirements and the proposed Contract Documents (including all Addenda).
8. *Bidding Requirements*--The Advertisement or Invitation to Bid, Instructions to Bidders, bid security of acceptable form, if any, and the Bid Form with any supplements.
9. *Change Order*--A document recommended by Construction Manager which is signed by Contractor and Owner and authorizes an addition, deletion, or revision in the Work or an adjustment in the Contract Price or the Contract Times, issued on or after the Effective Date of the Agreement.
10. *City*--City of Manteca, San Joaquin County, California, including its agencies, departments or divisions whose conduct or action is related to the work.
11. *Claim*--A demand or assertion by Owner or Contractor seeking an adjustment of Contract Price or Contract Times, or both, or other relief with respect to the terms of the Contract. A demand for money or services by a third party is not a Claim.
12. *Construction Manager*--The individual or entity retained by the Owner to perform construction quality assurance and contract administration functions not involving reviews and interpretations with respect to design intent. The Construction Manager is a representative of the City, either an employee or consultant, employed to act as advisor to the City in construction matters related to the Contract.
13. *Contract*--The entire and integrated written agreement between the Owner and Contractor concerning

the Work. The Contract supersedes prior negotiations, representations, or agreements, whether written or oral.

14. *Contract Documents*-- Those items so designated in the Agreement. Only printed or hard copies of the items listed in the Agreement are Contract Documents. Approved Shop Drawings, other Contractor's submittals, and the reports and drawings of subsurface and physical conditions are not Contract Documents.
15. *Contract Price*--The moneys payable by Owner to Contractor for completion of the Work in accordance with the Contract Documents as stated in the Agreement (subject to the provisions of Paragraph 11.03 in the case of Unit Price Work).
16. *Contract Times*--The number of days or the dates stated in the Agreement to: (i) achieve Milestones, if any, (ii) achieve Substantial Completion; and (iii) complete the Work so that it is ready for final payment as evidenced by Construction Manager's written recommendation of final payment.
17. *Contractor*--The individual or entity with whom Owner has entered into the Agreement.
18. *Cost of the Work*--See Paragraph 11.01.A for definition.
19. *Day*-- 24 consecutive hours running from midnight to midnight; calendar day.
    a. *business day*: Day on the calendar except a Saturday and a holiday.
    b. *working day*: Time measure unit for work progress. A working day is any 24-consecutive-hour period except:
        1) Saturday and a holiday.
        2) Day during which Contractor cannot perform work on the controlling activity for at least 50 percent of the scheduled work shift with at least 50 percent of the scheduled labor and equipment due to any of the following:
            i) Adverse weather-related conditions.
            ii) Traffic maintenance under the Contract.
            iii) Suspension of a controlling activity that Contractor and the Owner agree benefits both parties.
            iv) Unanticipated event not caused by either party, such as:
                a) Act of God
                b) Act of a public enemy.
                c) Epidemic.
                d) Fire.
                e) Flood.
                f) Governor-declared state of emergency.
                g) Landslide.
                h) Quarantine restriction.
            v) Issue involving a third party, including:
                i) Industry or area-wide labor strike.
                j) Material shortage.
                k) Freight embargo.

l) Jurisdictional requirement of a law enforcement agency.

m) Workforce labor dispute of a utility or non-City facility owner resulting in a non-City facility rearrangement not described and not solely for the Contractor's convenience. Rearrangement of a non-City facility includes installation, relocation, alteration, or removal of the facility.

3) Day during a concurrent delay.

20. *Drawings*--That part of the Contract Documents prepared or approved by Engineer which graphically shows, on paper, the scope, extent, and character of the Work to be performed by Contractor. Shop Drawings and other Contractor submittals are not Drawings as so defined.

21. *Delay*--Event that extends the completion of an activity.

    a. *excusable delay*: Delay caused by the Department and not reasonably foreseeable when the work began, such as:

        1) Change in the work

        2) Department action that is not part of the Contract

        3) Presence of an underground utility main not described in the Contract or in a location substantially different from that specified

        4) Described facility rearrangement not rearranged as described, by the utility owner by the date specified, unless the rearrangement is solely for the Contractor's convenience

        5) Department's failure to obtain timely access to the right-of-way

        6) Department's failure to review a submittal or provide notification in the time specified

    b. *critical delay*: Excusable delay that extends the scheduled completion date.

    c. *concurrent delay*: Occurrence of at least 2 of the following events in the same period of time, either partially or entirely:

        1) Critical delay

        2) Delay to a controlling activity caused by the Contractor

        3) Non–working day

22. *Department*--Engineering Department, City of Manteca, and its authorized representatives.

23. *Detour*--Temporary route for traffic around a closed road part. A passageway through a job site is not a detour.

24. *Director*--the Director of the Engineering Department, City of Manteca.

25. *Effective Date of the Agreement*--The date indicated in the Agreement on which it becomes effective, but if no such date is indicated, it means the date on which the Agreement is signed and delivered by the last of the two parties to sign and deliver.

26. *Engineer*--The individual or entity named as such in the Agreement.

27. *Field Order*--A written order issued by Engineer which requires minor changes in the Work but which does not involve a change in the Contract Price or the Contract Times.

28. *Force Account Work*--Work ordered on a construction project without an existing agreement on its cost, and performed with the understanding that the contractor will bill the owner according to the cost of labor, materials, and equipment, plus a certain percentage for overhead and profit. (Refer to Section 12.01 of these General Conditions, and the California Department of Transportation

Equipment Rental Rates and Labor Surcharge).

29. *General Requirements*--Sections of Division 1 of the Specifications. The General Requirements pertain to all sections of the Specifications.

30. *Hazardous Environmental Condition*--The presence at the Site of Asbestos, PCBs, Petroleum, Hazardous Waste, or Radioactive Material in such quantities or circumstances that may present a substantial danger to persons or property exposed thereto in connection with the Work.

31. *Hazardous* Waste--The term Hazardous Waste shall have the meaning provided in Section 1004 of the Solid Waste Disposal Act (42 USC Section 6903) as amended from time to time.

32. *Holiday*--Holiday shown in the following table:

Holidays

Holiday	Date observed
Every Sunday	Every Sunday
New Year's Day	January 1st
Birthday of Martin Luther King, Jr.	3rd Monday in January
Lincoln's Birthday	February 12th
Washington's Birthday	3rd Monday in February
Cesar Chavez Day	March 31st
Memorial Day	Last Monday in May
Independence Day	July 4th
Labor Day	1st Monday in September
Columbus Day	2nd Monday in October
Veterans Day	November 11th
Thanksgiving Day	4th Thursday in November
Day after Thanksgiving Day	Day after Thanksgiving Day
Christmas Day	December 25th

If January 1st, February 12th, March 31st, July 4th, November 11th, or December 25th falls on a Sunday, the Monday following is a holiday. If November 11th falls on a Saturday, the preceding Friday is a holiday.

Additionally, the City offices are closed every Friday. Special accommodations must be made by the Contractor for City staff to be available for any work to occur on these Fridays.

If the Contractor plans to work outside of the normal working hours, submit to the City a plan highlighting the proposed times/days outside of normal working hours for City review and approval at a minimum of 72 hours prior. If approved, costs incurred by the City outside of the normal working hours will be charged to the Contractor. (Refer to Section 00700 Subsection 6.02B)

33. *Laws and Regulations; Laws or Regulations*--Any and all applicable laws, rules, regulations, ordinances, codes, and orders of any and all governmental bodies, agencies, authorities, and courts having jurisdiction.

34. *Liens*--Charges, security interests, or encumbrances upon Project funds, real property, or personal property.

35. Material shortage--

a. *Shortage of raw or produced material that is area-wide and caused by an unusual market condition except if any of the following occurs:*

1) Shortage relates to a produced, nonstandard material

2) Supplier's and the Contractor's priority for filling an order differs

3) Event outside the United States for a material produced outside the United States

4) Unavailability of water that delays a controlling activity

36. *Milestone*--A principal event specified in the Contract Documents relating to an intermediate completion date or time prior to Substantial Completion of all the Work.

37. *Notice of Award*--The written notice by Owner to the Successful Bidder stating that upon timely compliance by the Successful Bidder with the conditions precedent listed therein, Owner will sign and deliver the Agreement.

38. *Notice to Proceed*--A written notice given by Owner to Contractor fixing the date on which the Contract Times will commence to run and on which Contractor shall start to perform the Work under the Contract Documents.

39. *Owner*--The individual or entity with whom Contractor has entered into the Agreement and for whom the Work is to be performed.

40. *PCBs*--Polychlorinated biphenyls.

41. *Petroleum*--Petroleum, including crude oil or any fraction thereof which is liquid at standard conditions of temperature and pressure (60 degrees Fahrenheit and 14.7 pounds per square inch absolute), such as oil, petroleum, fuel oil, oil sludge, oil refuse, gasoline, kerosene, and oil mixed with other non-Hazardous Waste and crude oils.

42. *Progress Schedule*--A schedule, prepared and maintained by Contractor, describing the sequence and duration of the activities comprising the Contractor's plan to accomplish the Work within the Contract Times.

43. *Project*--The total construction of which the Work to be performed under the Contract Documents may be the whole, or a part.

44. *Project Manual*--The bound documentary information prepared for bidding and constructing the Work. A listing of the contents of the Project Manual, which may be bound in one or more volumes, is contained in the table(s) of contents.

45. *Quality Control Plan*--Contractor's plan to ensure QC.

46. *Radioactive Material*--Source, special nuclear, or byproduct material as defined by the Atomic Energy Act of 1954 (42 USC Section 2011 et seq.) as amended from time to time.

47. *Related Entity*--An officer, director, partner, employee, agent, consultant, or subcontractor.

48. *Resident Project Representative*--The authorized representative of Construction Manager who may be assigned to the Site or any part thereof.

49. *Samples*--Physical examples of materials, equipment, or workmanship that are representative of some portion of the Work and which establish the standards by which such portion of the Work will be judged.

50. *Schedule of Submittals*--A schedule, prepared and maintained by Contractor, of required submittals and the time requirements to support scheduled performance of related construction activities.

51. *Schedule of Values*--A schedule, prepared and maintained by Contractor, allocating portions of the Contract Price to various portions of the Work and used as the basis for reviewing Contractor's Applications for Payment.

52. *Shop Drawings*--All drawings, diagrams, illustrations, schedules, and other data or information which are specifically prepared or assembled by or for Contractor and submitted by Contractor to illustrate some portion of the Work.

53. *Site*--Lands or areas indicated in the Contract Documents as being furnished by Owner upon which the Work is to be performed, including rights-of-way and easements for access thereto, and such other lands furnished by Owner which are designated for the use of Contractor.

54. *Specifications*--That part of the Contract Documents consisting of written requirements for materials, equipment, systems, standards and workmanship as applied to the Work, and certain administrative requirements and procedural matters applicable thereto.

55. *Subcontractor*--An individual or entity having a direct contract with Contractor or with any other Subcontractor for the performance of a part of the Work at the Site.

56. *Substantial Completion*--The time at which the Work (or a specified part thereof) has progressed to the point where, in the opinion of Construction Manager, the Work (or a specified part thereof) is sufficiently complete, in accordance with the Contract Documents, so that the Work (or a specified part thereof) can be safely and conveniently utilized for the purposes for which it is intended. The terms "substantially complete" and "substantially completed" as applied to all or part of the Work refer to Substantial Completion thereof.

57. *Substantial Defects*--Defects plainly seen as damaged, displaced, or missing parts or improper functioning of materials, parts, equipment, or systems.

58. *Successful Bidder*--The Bidder submitting a responsive Bid to whom Owner makes an award.

59. *Supplementary Conditions*--That part of the Contract Documents which amends or supplements these General Conditions.

60. *Supplier*--A manufacturer, fabricator, supplier, distributor, material man, or vendor having a direct contract with Contractor or with any Subcontractor to furnish materials or equipment to be incorporated in the Work by Contractor or any Subcontractor.

61. *Traffic*--Pedestrians, bicyclists, ridden or herded animals, vehicles, streetcars, and other conveyances either singularly or together while using any street, roadway or sidewalk for purposes of travel.

62. *Traffic lane*--Portion of traveled way used for the movement of a single line of vehicles.

63. *Traveled way*--Portion of the roadway for the movement of vehicles, exclusive of the shoulders, berms, sidewalks, and parking lanes.

64. *Unauthorized Work*: Work performed outside of the scope of the agreement or beyond the lines and grades described in the Contract or established by the Engineer or extra work performed without City authorization.

65. *Underground Facilities*--All underground pipelines, conduits, ducts, cables, wires, manholes, vaults, tanks, tunnels, or other such facilities or attachments, and any encasements containing such facilities, including those that convey electricity, gases, steam, liquid petroleum products, telephone or other communications, cable television, water, wastewater, storm water, other liquids or chemicals, or traffic or other control systems.

66. *Unit Price Work*--Work to be paid for on the basis of unit prices.

67. *Work*--The entire construction or the various separately identifiable parts thereof required to be provided under the Contract Documents. Work includes and is the result of performing or providing all labor, services, and documentation necessary to produce such construction, and furnishing, installing, and incorporating all materials and equipment into such construction, all as required by the Contract Documents.

68. *Work Change Directive*--A written statement to Contractor issued on or after the Effective Date of the Agreement and signed by Owner and recommended by Construction Manager ordering an addition, deletion, or revision in the Work, or responding to differing or unforeseen subsurface or

physical conditions under which the Work is to be performed or to emergencies. A Work Change Directive will not change the Contract Price or the Contract Times but is evidence that the parties expect that the change ordered or documented by a Work Change Directive will be incorporated in a subsequently issued Change Order following negotiations by the parties as to its effect, if any, on the Contract Price or Contract Times. The signatory for the Owner may authorize a Work Change Directive for work on a Not-to-Exceed basis, where the Engineer's estimate for probable cost for said work is within the signatories authority and threshold in conformance of the City's purchasing policies.

69. *Withhold*--Money temporarily or permanently taken from a progress payment.
70. *Work*--Resources and activities required for Contract acceptance, including labor, materials, equipment, and the created product.
71. *Work Plan*--Detailed formulation of a program of action.
72. *Work Zone*--Area of a roadway or street with construction, maintenance, or utility work activities.

Section 1.02 Terminology

A. The following words or terms are not defined but, when used in the Bidding Requirements or Contract Documents, have the following meaning.

B. Intent of Certain Terms or Adjectives

1. The Contract Documents include the terms "as allowed," "as approved," "as ordered", "as directed" or terms of like effect or import to authorize an exercise of professional judgment by Engineer or Construction Manager. In addition, the adjectives "reasonable," "suitable," "acceptable," "proper," "satisfactory," or adjectives of like effect or import are used to describe an action or determination of Engineer or Construction Manager as to the Work. It is intended that such exercise of professional judgment, action or determination will be solely to evaluate, in general, the Work for compliance with the requirements of and information in the Contract Documents and conformance with the design concept of the completed Project as a functioning whole as shown or indicated in the Contract Documents (unless there is a specific statement indicating otherwise). The use of any such term or adjective is not intended to and shall not be effective to assign to Engineer or Construction Manager any duty or authority to supervise or direct the performance of the Work or any duty or authority to undertake responsibility contrary to the provisions of Paragraph 9.09 or any other provision of the Contract Documents.

C. Day

1. The word "day" means a calendar day of twenty-four (24) hours measured from midnight to the next midnight.

D. Defective

1. The word "defective," when modifying the word "Work," refers to Work that is unsatisfactory, faulty, or deficient in that it:

   a. does not conform to the Contract Documents, or

   b. does not meet the requirements of any applicable inspection, reference standard, test, or approval referred to in the Contract Documents, or

   c. has been damaged prior to –Construction Manager's recommendation of final payment (unless responsibility for the protection thereof has been assumed by Owner at Substantial Completion in accordance with Paragraph 14.04 or 14.05).

E. Furnish, Install, Perform, Provide, Supply

1. The word "Furnish" or the word "Install" or the word "Perform" or the word "Provide" or the word "Supply," or any combination or similar directive or usage thereof, shall mean FURNISHING AND INCORPORATING IN THE WORK including all necessary labor, materials, equipment, and everything necessary to perform the Work indicated, unless specifically limited in the context used.

2. Unless stated otherwise in the Contract Documents, words or phrases which have a well-known technical or construction industry or trade meaning are used in the Contract Documents in accordance with such recognized meaning.

ARTICLE 2. PRELIMINARY MATTERS

Section 2.01 Delivery of Bonds and Evidence of Insurance

A. When Contractor delivers the executed counterparts of the Agreement to Owner, Contractor shall also deliver to Owner such bonds as Contractor may be required to furnish.

B. Evidence of Insurance: Before any Work at the Site is started, Contractor and Owner shall each deliver to the other, with copies to each additional insured identified in the Supplementary Conditions, certificates of insurance (and other evidence of insurance which either of them or any additional insured may reasonably request) which Contractor and Owner respectively are required to purchase and maintain in accordance with Article 5.

Section 2.02 Copies of Documents

A. Owner shall furnish to Contractor up to ten printed or hard copies of the Drawings and Project Manual. Additional copies will be furnished upon request at the cost of reproduction.

Section 2.03 Commencement of Contract Times; Notice to Proceed

A. The Contract Times will commence to run on the thirtieth day after the Effective Date of the Agreement or, if a Notice to Proceed is given, on the day indicated in the Notice to Proceed. A Notice to Proceed may be given at any time within 30 days after the Effective Date of the Agreement.

Section 2.04 Starting the Work

A. Contractor shall start to perform the Work on the date when the Contract Times commence to run. No Work shall be done at the Site prior to the date on which the Contract Times commence to run.

Section 2.05 Before Starting Construction

A. Preliminary Schedules: Within ten (10) days after the Effective Date of the Agreement (unless otherwise specified in the General Requirements), Contractor shall submit to Construction Manager for timely review:

1. a preliminary Progress Schedule; indicating the times (numbers of days or dates) for starting and completing the various stages of the Work, including any Milestones specified in the Contract Documents;

2. a preliminary Schedule of Submittals; and

3. a preliminary Schedule of Values for all of the Work which includes quantities and prices of items which when added together equal the Contract Price and subdivides the Work into component parts in sufficient detail to serve as the basis for progress payments during performance of the Work. Such prices will include an appropriate amount of overhead and profit applicable to each item of Work.

Section 2.06 Preconstruction Conference

A. Before any Work at the Site is started, a conference attended by Owner, Contractor, Construction Manager and Engineer, and others as appropriate will be held to establish a working understanding among the parties as to the Work and to discuss the schedules referred to in Paragraph 2.05.A, procedures for handling Shop Drawings and other submittals, processing Applications for Payment, and maintaining required records.

Section 2.07 Initial Acceptance of Schedules

A. At least ten (10) days before submission of the first Application for Payment a conference attended by Contractor, Construction Manager, and others as appropriate will be held to review for acceptability to Construction Manager as provided below the schedules submitted in accordance with Paragraph 2.05.A. Contractor shall have an additional 10 days to make corrections and adjustments and to complete and resubmit the schedules. No progress payment shall be made to Contractor until acceptable schedules are submitted to Engineer.

B. The Progress Schedule will be acceptable to Construction Manager if it provides an orderly progression of the Work to completion within the Contract Times. Such acceptance will not impose on Construction Manager responsibility for the Progress Schedule, for sequencing, scheduling, or progress of the Work nor interfere with or relieve Contractor from Contractor's full responsibility therefor.

C. Contractor's Schedule of Submittals will be acceptable to Construction Manager and Engineer if it provides a workable arrangement for reviewing and processing the required submittals.

D. Contractor's Schedule of Values will be acceptable to Construction Manager as to form and substance if it provides a reasonable allocation of the Contract Price to component parts of the Work for each Bid Item as submitted on the Bid Sheet.

ARTICLE 3. CONTRACT DOCUMENTS: INTENT, AMENDING, REUSE

Section 3.01 Intent

A. The Contract Documents are complementary; what is required by one is as binding as if required by all.

B. It is the intent of the Contract Documents to describe a functionally complete Project (or part thereof) to be constructed in accordance with the Contract Documents. Any labor, documentation, services, materials, or equipment that may reasonably be inferred from the Contract Documents or from prevailing custom or trade usage as being required to produce the intended result will be provided whether or not specifically called for at no additional cost to Owner.

C. Clarifications and interpretations with respect to the design intent of the Contract Documents shall be issued by Engineer through the Construction Manager, and clarifications and interpretations with respect to administrative matters shall be issued by the Construction Manager as provided in Article 9.

D. The Specifications may vary in form, format and style. Some specification sections are written in varying degrees of streamlined or declarative style and some sections may be relatively narrative by comparison. Omissions of such words and phrases as "the Contractor shall," "in conformity with," "as shown," or "as specified" are intentional in streamlined sections. Omitted words and phrases shall be supplied by inference. Similar types of provisions may appear in various parts of a section or articles within a part depending on the format of the section. The Contractor shall not take advantage of any variation of form, format or style in making claims for extra Work.

E. The cross referencing of specification sections under the subparagraph heading "Related Sections include but are not necessarily limited to:" and elsewhere within each specification section is provided as an aid

and convenience to the Contractor. The Contractor shall not rely on the cross referencing provided and shall be responsible to coordinate the entire work under the Contract Documents and provide a complete Project whether or not the cross referencing is provided in each section or whether or not the cross referencing is complete.

Section 3.02 Reference Standards

A. Standards, Specifications, Codes, Laws, and Regulations

1. Reference to standards, specifications, manuals, or codes of any technical society, organization, or association, or to Laws or Regulations, whether such reference be specific or by implication, shall mean the standard, specification, manual, code, or Laws or Regulations in effect at the time of opening of Bids (or on the Effective Date of the Agreement if there were no Bids), except as may be otherwise specifically stated in the Contract Documents.

2. No provision of any such standard, specification, manual or code, or any instruction of a Supplier shall be effective to change the duties or responsibilities of Owner, Contractor, Engineer or Construction Manager, or any of their subcontractors, consultants, agents, or employees from those set forth in the Contract Documents. No such provision or instruction shall be effective to assign to Owner, Engineer or Construction Manager, or any of their Related Entities, any duty or authority to supervise or direct the performance of the Work or any duty or authority to undertake responsibility inconsistent with the provisions of the Contract Documents.

Section 3.03 Reporting and Resolving Discrepancies

A. Reporting Discrepancies

1. Contractor's Review of Contract Documents Before Starting Work: Before undertaking each part of the Work, Contractor shall carefully study and compare the Contract Documents and check and verify pertinent figures therein and all applicable field measurements. Contractor shall promptly report in writing to Construction Manager any conflict, error, ambiguity, or discrepancy which Contractor may discover and shall obtain a written interpretation or clarification from Engineer through Construction Manager before proceeding with any Work affected thereby.

2. Contractor's Review of Contract Documents During Performance of Work: If, during the performance of the Work, Contractor discovers any conflict, error, ambiguity, or discrepancy within the Contract Documents or between the Contract Documents and any provision of any Law or Regulation applicable to the performance of the Work or of any standard, specification, manual or code, or of any instruction of any Supplier, Contractor shall promptly report it to Construction Manager in writing. Contractor shall not proceed with the Work affected thereby (except in an emergency as required by Paragraph 6.16.A) until an amendment or supplement to the Contract Documents has been issued by one of the methods indicated in Paragraph 3.04.

3. Contractor shall not be liable to Owner, Construction Manager or Engineer for failure to report any conflict, error, ambiguity, or discrepancy in the Contract Documents unless Contractor knew or reasonably should have known thereof.

B. Resolving Discrepancies

1. Except as may be otherwise specifically stated in the Contract Documents, the provisions of the Contract Documents shall take precedence in resolving any conflict, error, ambiguity, or discrepancy between the provisions of the Contract Documents and:

   a. the provisions of any standard, specification, manual, code, or instruction (whether or not specifically incorporated by reference in the Contract Documents); or

   b. the provisions of any Laws or Regulations applicable to the performance of the Work (unless such

an interpretation of the provisions of the Contract Documents would result in violation of such Law or Regulation).

Section 3.04 Amending and Supplementing Contract Documents

A. The Contract Documents may be amended to provide for additions, deletions, and revisions in the Work or to modify the terms and conditions thereof by either a Change Order or a Work Change Directive.

B. The requirements of the Contract Documents may be supplemented, and minor variations and deviations in the Work may be authorized, by one or more of the following ways:

1. A Field Order

2. Engineer's approval of a Shop Drawing or Sample; (Subject to the provisions of Paragraph 6.17.D.3); or

3. Engineer's written interpretation or clarification of matters of design intent issued through the Construction Manager, and Construction Managers written interpretation or clarification of administrative matters.

Section 3.05 Reuse of Documents

A. Contractor and any Subcontractor or Supplier or other individual or entity performing or furnishing all of the Work under a direct or indirect contract with Contractor, shall not:

1. have or acquire any title to or ownership rights in any of the Drawings, Specifications, or other documents (or copies of any thereof) prepared by or bearing the seal of Engineer or Engineer's consultants, including electronic media editions; or

2. reuse any of such Drawings, Specifications, other documents, or copies thereof on extensions of the Project or any other project without written consent of Owner and Engineer and specific written verification or adoption by Engineer.

B. The prohibition of this Paragraph 3.05 will survive final payment, or termination of the Contract. Nothing herein shall preclude Contractor from retaining copies of the Contract Documents for record purposes.

Section 3.06 Electronic Data

A. Copies of data furnished by Owner or Engineer to Contractor or Contractor to Owner or Engineer that may be relied upon are limited to the printed copies (also known as hard copies). Files in electronic media format of text, data, graphics, or other types are furnished only for the convenience of the receiving party. Any conclusion or information obtained or derived from such electronic files will be at the user's sole risk. If there is a discrepancy between the electronic files and the hard copies, the hard copies govern.

B. Because data stored in electronic media format can deteriorate or be modified inadvertently or otherwise without authorization of the data's creator, the party receiving electronic files agrees that it will perform acceptance tests or procedures within sixty (60) days, after which the receiving party shall be deemed to have accepted the data thus transferred. Any errors detected within the 60-day acceptance period will be corrected by the transferring party.

C. When transferring documents in electronic media format, the transferring party makes no representations as to long term compatibility, usability, or readability of documents resulting from the use of software application packages, operating systems, or computer hardware differing from those used by the data's creator.

ARTICLE 4. AVAILABILITY OF LANDS; SUBSURFACE AND PHYSICAL CONDITIONS; HAZARDOUS ENVIRONMENTAL CONDITIONS; REFERENCE POINTS

Section 4.01 Availability of Lands

A. Owner shall furnish the Site. Owner shall notify Contractor of any encumbrances or restrictions not of general application but specifically related to use of the Site with which Contractor must comply in performing the Work. Owner will obtain in a timely manner and pay for easements for permanent structures or permanent changes in existing facilities. If Contractor and Owner are unable to agree on entitlement to or on the amount or extent, if any, of any adjustment in the Contract Price or Contract Times, or both, as a result of any delay in Owner's furnishing the Site or a part thereof, Contractor may make a Claim therefor as provided in Paragraph 10.05.

1. Where easement lines are shown on the Contract Drawings they shall be considered as shown in their final location unless stipulated otherwise in the Supplementary Conditions.

B. Upon reasonable written request, Owner shall furnish Contractor with a current statement of record legal title and legal description of the lands upon which the Work is to be performed and Owner's interest therein as necessary for giving notice of or filing a mechanic's or construction lien against such lands in accordance with applicable Laws and Regulations.

C. Contractor shall provide for all additional lands and access thereto that may be required for temporary construction facilities or storage of materials and equipment.

Section 4.02 Subsurface and Physical Conditions

A. *Reports and Drawings:* The Supplementary Conditions identify:

1. those reports of explorations and tests of subsurface conditions at or contiguous to the Site that Engineer has used in preparing the Contract Documents; and

2. those drawings of physical conditions in or relating to existing surface or subsurface structures at or contiguous to the Site (except Underground Facilities) that Engineer has used in preparing the Contract Documents.

B. *Limited Reliance by Contractor on Technical Data Authorized*: Contractor may rely upon the general accuracy of the "technical data" contained in such reports and drawings, but such reports and drawings are not Contract Documents. Such "technical data" is identified in the Supplementary Conditions. Except for such reliance on such "technical data," Contractor may not rely upon or make any claim against Owner or Engineer, or any of their Related Entities with respect to:

1. the completeness of such reports and drawings for Contractor's purposes, including, but not limited to, any aspects of the means, methods, techniques, sequences, and procedures of construction to be employed by Contractor, and safety precautions and programs incident thereto; or

2. other data, interpretations, opinions, and information contained in such reports or shown or indicated in such drawings; or

3. any Contractor interpretation of or conclusion drawn from any "technical data" or any such other data, interpretations, opinions, or information.

Section 4.03 Differing Subsurface or Physical Conditions

A. *Notice*: If Contractor believes that any subsurface or physical condition at or contiguous to the Site that is uncovered or revealed either:

1. is of such a nature as to establish that any "technical data" on which Contractor is entitled to rely as provided in Paragraph 4.02 is materially inaccurate; or

2. is of such a nature as to require a change in the Contract Documents; or

3. differs materially from that shown or indicated in the Contract Documents; or

4. is of an unusual nature, and differs materially from conditions ordinarily encountered and generally recognized as inherent in work of the character provided for in the Contract Documents;

then Contractor shall, promptly after becoming aware thereof and before further disturbing the subsurface or physical conditions or performing any Work in connection therewith (except in an emergency as required by Paragraph 6.16.A), notify Owner and Construction Manager in writing about such condition. Contractor shall not further disturb such condition or perform any Work in connection therewith (except as aforesaid) until receipt of written order to do so.

B. *Construction Manager's and Engineer's Review*: After receipt of written notice as required by Paragraph 4.03.A, Construction Manager will promptly review the pertinent condition with Engineer as appropriate, determine the necessity of Owner's obtaining additional exploration or tests with respect thereto, and advise Owner in writing (with a copy to Contractor and Engineer) of Construction Manager's findings and conclusions.

C. Possible Price and Times Adjustments:

1. The Contract Price or the Contract Times, or both, will be equitably adjusted to the extent that the existence of such differing subsurface or physical condition causes an increase or decrease in Contractor's cost of, or time required for, performance of the Work; subject, however, to the following:

a. such condition must meet any one or more of the categories described in Paragraph 4.03.A; and

b. with respect to Work that is paid for on a Unit Price Basis, any adjustment in Contract Price will be subject to the provisions of Paragraphs 9.07 and 11.03.

2. Contractor shall not be entitled to any adjustment in the Contract Price or Contract Times if:

a. Contractor knew of the existence of such conditions at the time Contractor made a final commitment to Owner with respect to Contract Price and Contract Times by the submission of a Bid or becoming bound under a negotiated contract; or

b. the existence of such condition could reasonably have been discovered or revealed as a result of any examination, investigation, exploration, test, or study of the Site and contiguous areas required by the Bidding Requirements or Contract Documents to be conducted by or for Contractor prior to Contractor's making such final commitment; or

c. Contractor failed to give the written notice as required by Paragraph 4.03.A.

3. If Owner and Contractor are unable to agree on entitlement to or on the amount or extent, if any, of any adjustment in the Contract Price or Contract Times, or both, a Claim may be made therefor as provided in Paragraph 10.05. However, Owner, Engineer and Construction Manager, and any of their Related Entities shall not be liable to Contractor for any claims, costs, losses, or damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) sustained by Contractor on or in connection with any other project or anticipated project.

Section 4.04 Underground Facilities

A. Shown or Indicated: The information and data shown or indicated in the Contract Documents with respect to existing Underground Facilities at or contiguous to the Site is based on information and data furnished to Owner or Engineer by the owners of such Underground Facilities, including Owner, or by others. Unless

it is otherwise expressly provided in the Supplementary Conditions:

1. Owner and Engineer shall not be responsible for the accuracy or completeness of any such information or data; and
2. the cost of all of the following will be included in the Contract Price, and Contractor shall have full responsibility for:
    a. reviewing and checking all such information and data,
    b. contacting and coordinating with underground service alert (USA) and locating all Underground Facilities within the construction area
    c. coordination of the Work with the owners of such Underground Facilities, including Owner, during construction, and
    d. the safety and protection of all such Underground Facilities and repairing any damage thereto resulting from the Work.
3. Pursuant to Government Code Section 4216-4216.9, the Contractor shall notify the appropriate regional notification center of all excavations as required under Government Code sections 4216 to 4216.9. The Contractor shall contact Underground Service Alert at 1-800-642-2444 for the location of subsurface installations. Contractor shall furnish to the Construction Manager written documentation of its contact(s) with Underground Service Alert within two (2) days after such contact(s).
4. At least two (2) days before performing any excavation work, the Contractor shall request the utility owners to mark or otherwise indicate the location of their service. Contractor shall furnish to the Construction Manager written documentation of its contact(s) with utility owners requesting them to mark or otherwise indicate the location of their respective facilities within three (3) days after such contact(s).
5. It shall be the Contractor's responsibility to determine the exact location and depth of all utilities, including service connections, which have been marked by the respective owners and which Contractor believes may affect or be affected by Contractor's operations. If no pay item is provided in the Contract for this work, full compensation for such work shall be considered as included in the prices bid for other items of work.

B. Not Shown or Indicated:

1. If an Underground Facility is uncovered or revealed at or contiguous to the Site which was not shown or indicated, or not shown or indicated with reasonable accuracy in the Contract Documents, Contractor shall, promptly after becoming aware thereof and before further disturbing conditions affected thereby or performing any Work in connection therewith (except in an emergency as required by Paragraph 6.16.A), identify the owner of such Underground Facility and give written notice to that owner and to Owner and Construction Manager. Construction Manager will promptly review the Underground Facility and determine the extent, if any, to which a change is required in the Contract Documents to reflect and document the consequences of the existence or location of the Underground Facility. During such time, Contractor shall be responsible for the safety and protection of such Underground Facility.
2. If Construction Manager concludes that a change in the Contract Documents is required, a Work Change Directive or a Change Order will be issued to reflect and document such consequences. An equitable adjustment shall be made in the Contract Price or Contract Times, or both, to the extent that they are attributable to the existence or location of any Underground Facility that was not shown or indicated or not shown or indicated with reasonable accuracy in the Contract Documents and that Contractor did not know of and could not reasonably have been expected to be aware of or to have

anticipated. If Owner and Contractor are unable to agree on entitlement to or on the amount or extent, if any, of any such adjustment in Contract Price or Contract Times, Owner or Contractor may make a Claim therefor as provided in Paragraph 10.05. In accordance with Government Code Section 4215 the Contractor shall not be assessed liquidated damages for delay in completion of the project, when such delay is caused by the failure of the Owner or utility company to provide for the removal or relocation of facilities for which they are the responsible party.

3. When the General Requirements, Specifications, or Construction Drawings indicate that a utility is to be relocated, altered or constructed by others, the City will conduct all negotiations with the utility company and the work will be done at no cost to the Contractor.

4. Temporary or permanent service, relocation or alteration of utilities desired by the Contractor for its own convenience shall be the Contractor's responsibility and it shall make arrangements and bear all costs.

5. Except where the owner of a damaged utility has advised that it intends to repair the damage through its own forces or forces that it will retain or has retained, Contractor shall, within 24 hours of receipt from the Owner of notice to commence correction of damage, notify the Construction Manager in writing if Contractor intends to repair the damage. During nights and weekends when work is not in progress, Owner may give such notice by telephone or by facsimile transmission to the Contractor's facsimile number and such notice will be immediately effective. The Contractor's failure to provide timely written notification that it intends to repair the damage shall be deemed its agreement that the Owner may repair the damage at Contractor's expense without further notice and without prejudice to any other remedy available to Owner. In such event, the Contractor may observe the Work if this can be done without in any way delaying the progress thereof, but may not contest any element of the expense of repair or the lack of further notice. This provision is in addition to any other remedy, including the remedy provided in 13.09, Owner May Correct Defective Work.

Section 4.05 Reference Points

A. Owner shall provide engineering surveys to establish reference points for construction which in Construction Manager's judgment are necessary to enable Contractor to proceed with the Work. Contractor shall be responsible for laying out the Work, shall protect and preserve the established reference points and property monuments, and shall make no changes or relocations without the prior written approval of Owner. Contractor shall report to Construction Manager whenever any reference point or property monument is lost or destroyed or requires relocation because of necessary changes in grades or locations, and shall be responsible for the accurate replacement or relocation of such reference points or property monuments by licensed land surveyor registered in the state of California.

Section 4.06 Hazardous Environmental Condition at Site

A. *Reports and Drawings*: Reference is made to the Supplementary Conditions for the identification of those reports and drawings relating to a Hazardous Environmental Condition identified at the Site, if any, that have been utilized by the Engineer in the preparation of the Contract Documents.

B. *Limited Reliance by Contractor on Technical Data Authorized:* Contractor may rely upon the general accuracy of the "technical data" contained in such reports and drawings, but such reports and drawings are not Contract Documents. Such "technical data" is identified in the Supplementary Conditions. Except for such reliance on such "technical data," Contractor may not rely upon or make any claim against Owner or Engineer, or any of their Related Entities with respect to:

1. the completeness of such reports and drawings for Contractor's purposes, including, but not limited to, any aspects of the means, methods, techniques, sequences and procedures of construction to be employed by Contractor and safety precautions and programs incident thereto; or

2. other data, interpretations, opinions and information contained in such reports or shown or indicated in such drawings; or

3. any Contractor interpretation of or conclusion drawn from any "technical data" or any such other data, interpretations, opinions or information.

C. Contractor shall not be responsible for any Hazardous Environmental Condition uncovered or revealed at the Site which was not shown or indicated in Drawings or Specifications or identified in the Contract Documents to be within the scope of the Work. Contractor shall be responsible for a Hazardous Environmental Condition created with any materials brought to the Site by Contractor, Subcontractors, Suppliers, or anyone else for whom Contractor is responsible.

D. If Contractor encounters a Hazardous Environmental Condition or if Contractor or anyone for whom Contractor is responsible creates a Hazardous Environmental Condition, Contractor shall immediately: (i) secure or otherwise isolate such condition; (ii) stop all Work in connection with such condition and in any area affected thereby (except in an emergency as required by Paragraph 6.16.A); and (iii) notify Owner and Construction Manager (and promptly thereafter confirm such notice in writing). Owner shall promptly consult with Construction Manager concerning the necessity for Owner to retain a qualified expert to evaluate such condition or take corrective action, if any.

1. Contractor shall not be required to resume Work in connection with such condition or in any affected area until after Owner has obtained any required permits related thereto and delivered to Contractor written notice: (i) specifying that such condition and any affected area is or has been rendered safe for the resumption of Work; or (ii) specifying any special conditions under which such Work may be resumed safely. If Owner and Contractor cannot agree as to entitlement to or on the amount or extent, if any, of any adjustment in Contract Price or Contract Times, or both, as a result of such Work stoppage or such special conditions under which Work is agreed to be resumed by Contractor, either party may make a Claim therefor as provided in Paragraph 10.05.

E. If after receipt of such written notice Contractor does not agree to resume such Work based on a reasonable belief it is unsafe, or does not agree to resume such Work under such special conditions, then Owner may order the portion of the Work that is in the area affected by such condition to be deleted from the Work. If Owner and Contractor cannot agree as to entitlement to or on the amount or extent, if any, of an adjustment in Contract Price or Contract Times as a result of deleting such portion of the Work, then either party may make a Claim therefor as provided in Paragraph 10.05. Owner may have such deleted portion of the Work performed by Owner's own forces or others in accordance with Article 7.

F. To the fullest extent permitted by Laws and Regulations, Owner shall indemnify and hold harmless Contractor, Subcontractors, Engineer and Construction Manager, and the officers, directors, partners, employees, agents, consultants, and subcontractors of each and any of them from and against all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to a Hazardous Environmental Condition, provided that such Hazardous Environmental Condition: (i) was not shown or indicated in the Drawings or Specifications or identified in the Contract Documents to be included within the scope of the Work, and (ii) was not created by Contractor or by anyone for whom Contractor is responsible. Nothing in this Paragraph 4.06.F shall obligate Owner to indemnify any individual or entity from and against the consequences of that individual's or entity's own negligence.

G. To the fullest extent permitted by Laws and Regulations, Contractor shall indemnify and hold harmless Owner, Engineer and Construction Manager, and the officers, directors, partners, employees, agents, consultants, and subcontractors of each and any of them from and against all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to a Hazardous Environmental Condition created by Contractor or by anyone for whom Contractor is

responsible. Nothing in this Paragraph 4.06.G shall obligate Contractor to indemnify any individual or entity from and against the consequences of that individual's or entity's own negligence.

1. The provisions of Paragraphs 4.02, 4.03, and 4.04 do not apply to a Hazardous Environmental Condition uncovered or revealed at the Site.

ARTICLE 5. BONDS AND INSURANCE

Section 5.01 Performance, Payment, and Other Bonds

A. Contractor shall furnish performance and payment bonds, each in an amount at least equal to the Contract Price as security for the faithful performance and payment of all of Contractor's obligations under the Contract Documents. These bonds shall remain in effect until one year after the date when final payment becomes due or until completion of the correction period specified in Paragraph 13.07, whichever is later, except as provided otherwise by Laws or Regulations or by the Contract Documents. Contractor shall also furnish such other bonds as are required by the Contract Documents.

B. All bonds shall be in the form prescribed by the Contract Documents except as provided otherwise by Laws or Regulations, and shall be executed by such sureties as are named in the current list of "Companies Holding Certificates of Authority as Acceptable Sureties on Federal Bonds and as Acceptable Reinsuring Companies" as published in Circular 570 (amended) by the Financial Management Service, Surety Bond Branch, U.S. Department of the Treasury. All bonds signed by an agent must be accompanied by a certified copy of the agent's authority to act.

C. If the surety on any bond furnished by Contractor is declared bankrupt or becomes insolvent or its right to do business is terminated in any state where any part of the Project is located or it ceases to meet the requirements of Paragraph 5.01.B, Contractor shall promptly notify Owner and Engineer and shall, within 20 days after the event giving rise to such notification, provide another bond and surety, both of which shall comply with the requirements of Paragraphs 5.01.B and 5.02.

Section 5.02 Licensed Sureties and Insurers

A. All bonds and insurance required by the Contract Documents to be purchased and maintained by Owner or Contractor shall be obtained from surety or insurance companies that are duly licensed or authorized in the jurisdiction in which the Project is located to issue bonds or insurance policies for the limits and coverages so required. Such surety and insurance companies shall also meet such additional requirements and qualifications as may be provided in the Supplementary Conditions.

Section 5.03 Certificates of Insurance

A. Contractor shall deliver to Owner, with copies to each additional insured identified in the Supplementary Conditions, certificates of insurance (and other evidence of insurance requested by Owner or any other additional insured) which Contractor is required to purchase and maintain.

B. Owner shall deliver to Contractor, with copies to each additional insured identified in the Supplementary Conditions, certificates of insurance (and other evidence of insurance requested by Contractor or any other additional insured) which Owner is required to purchase and maintain.

Section 5.04 Contractor's Liability Insurance

A. Contractor shall purchase and maintain such liability and other insurance as is appropriate for the Work being performed and as will provide protection from claims set forth below which may arise out of or result from Contractor's performance of the Work and Contractor's other obligations under the Contract Documents, whether it is to be performed by Contractor, any Subcontractor or Supplier, or by anyone

directly or indirectly employed by any of them to perform any of the Work, or by anyone for whose acts any of them may be liable:

1. claims under workers' compensation, disability benefits, and other similar employee benefit acts;
2. claims for damages because of bodily injury, occupational sickness or disease, or death of Contractor's employees;
3. claims for damages because of bodily injury, sickness or disease, or death of any person other than Contractor's employees;
4. claims for damages insured by reasonably available personal injury liability coverage which are sustained:
    a. by any person as a result of an offense directly or indirectly related to the employment of such person by Contractor, or
    b. by any other person for any other reason;
5. claims for damages, other than to the Work itself, because of injury to or destruction of tangible property wherever located, including loss of use resulting therefrom; and
6. claims for damages because of bodily injury or death of any person or property damage arising out of the ownership, maintenance or use of any motor vehicle.

B. The policies of insurance required by this Paragraph 5.04 shall:

1. with respect to insurance required by Paragraphs 5.04.A.3 through 5.04.A.6 inclusive, include as additional insured (subject to any customary exclusion regarding professional liability) Owner, Engineer and Construction Manager, and any other individuals or entities identified in the Supplementary Conditions, all of whom shall be listed as additional insureds, and include coverage for the respective officers, directors, partners, employees, agents, consultants and subcontractors of each and any of all such additional insureds, and the insurance afforded to these additional insureds shall provide primary coverage for all claims covered thereby;
2. include at least the specific coverages and be written for not less than the limits of liability provided in the Contract Documents or required by Laws or Regulations, whichever is greater;
3. include completed operations insurance;
4. include contractual liability insurance covering Contractor's indemnity obligations under Paragraphs 6.11 and 6.20;
5. contain a provision or endorsement that the coverage afforded will not be canceled, materially changed or renewal refused until at least 30 days prior written notice has been given to Owner and Contractor and to each other additional insured identified in the Supplementary Conditions (and the certificates of insurance furnished by the Contractor pursuant to Paragraph 5.03 will so provide);
6. remain in effect at least until final payment and at all times thereafter when Contractor may be correcting, removing, or replacing defective Work in accordance with Paragraph 13.07; and
7. with respect to completed operations insurance, and any insurance coverage written on a claims-made basis, remain in effect for at least two years after final payment.
    a. Contractor shall furnish Owner and each other additional insured identified in the Supplementary Conditions evidence satisfactory to Owner and any such additional insured of continuation of such insurance at final payment and one year thereafter.
8. With respect to all insurance required by this paragraph 5.04., Contractor agrees to waive all rights of subrogation against Owner, Engineer and Construction Manager, and each additional insured

identified in the Supplemental Conditions.

Section 5.05 Owner's Liability Insurance

A. In addition to the insurance required to be provided by Contractor under Paragraph 5.04, Owner, at Owner's option, may purchase and maintain at Owner's expense Owner's own liability insurance as will protect Owner against claims which may arise from operations under the Contract Documents.

Section 5.06 Property Insurance

A. Unless otherwise provided in the Supplementary Conditions, Contractor shall purchase and maintain property insurance upon the Work at the Site in the amount of the full replacement cost thereof (subject to such deductible amounts as may be provided in the Supplementary Conditions or required by Laws and Regulations). This insurance shall:

1. include the interests of Owner, Contractor, Subcontractors, Engineer and Construction Manager, and any other individuals or entities identified in the Supplementary Conditions, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them, each of whom is deemed to have an insurable interest and shall be listed as an insured or additional insured;

2. be written on a Builder's Risk "all-risk" or open peril or special causes of loss policy form that shall at least include insurance for physical loss or damage to the Work, temporary buildings, false work, and materials and equipment in transit, and shall insure against at least the following perils or causes of loss: fire, lightning, extended coverage, theft, vandalism and malicious mischief, collapse, explosion, debris removal, demolition occasioned by enforcement of Laws and Regulations, water damage, (other than caused by flood) and such other perils or causes of loss as may be specifically required by the Supplementary Conditions;

3. include expenses incurred in the repair or replacement of any insured property (including but not limited to fees and charges of engineers and architects);

4. cover materials and equipment stored at the Site or at another location that was agreed to in writing by Owner prior to being incorporated in the Work, provided that such materials and equipment have been included in an Application for Payment recommended by Engineer;

5. allow for partial utilization of the Work by Owner;

6. include testing and startup; and

7. be maintained in effect until final payment is made unless otherwise agreed to in writing by Owner, Contractor, Engineer and Construction Manager with thirty (30) days written notice to each other additional insured.

B. Contractor shall purchase and maintain such boiler and machinery insurance or additional property insurance as may be required by the Supplementary Conditions or Laws and Regulations which will include the interests of Owner, Contractor, Subcontractors, Engineer and Construction Manager, and any other individuals or entities identified in the Supplementary Conditions, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them, each of whom is deemed to have an insurable interest and shall be listed as an insured or additional insured.

C. All the policies of insurance (and the certificates or other evidence thereof) required to be purchased and maintained in accordance with Paragraph 5.06 will contain a provision or endorsement that the coverage afforded will not be canceled or materially changed or renewal refused until at least thirty (30) days prior written notice has been given to Owner and Contractor and to each other additional insured and will contain waiver provisions in accordance with Paragraph 5.07.

D. Owner shall not be responsible for purchasing and maintaining any property insurance specified in this

Paragraph 5.06 to protect the interests of Contractor, Subcontractors, or others in the Work to the extent of any deductible amounts that are identified in the Supplementary Conditions. The risk of loss within such identified deductible amount will be borne by Contractor, Subcontractors, or others suffering any such loss, and if any of them wishes property insurance coverage within the limits of such amounts, each may purchase and maintain it at the purchaser's own expense.

E. If Contractor requests in writing that other special insurance be included in the property insurance policies provided under Paragraph 5.06, Owner shall, if possible, include such insurance, and the cost thereof will be charged to Contractor by appropriate Change Order. Prior to commencement of the Work at the Site, Owner shall in writing advise Contractor whether or not such other insurance has been procured by Owner.

Section 5.07 Waiver of Rights

A. Owner and Contractor intend that all policies purchased in accordance with Paragraph 5.06 will protect Owner, Contractor, Subcontractors, Engineer and Construction Manager, and all other individuals or entities identified in the Supplementary Conditions to be listed as insureds or additional insureds (and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them) in such policies and will provide primary coverage for all losses and damages caused by the perils or causes of loss covered thereby. All such policies shall contain provisions to the effect that in the event of payment of any loss or damage the insurers will have no rights of recovery against any of the insureds or additional insureds thereunder. Owner and Contractor waive all rights against each other and their respective officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them for all losses and damages caused by, arising out of or resulting from any of the perils or causes of loss covered by such policies and any other property insurance applicable to the Work; and, in addition, waive all such rights against Subcontractors, Engineer and Construction Manager, and all other individuals or entities identified in the Supplementary Conditions to be listed as insured or additional insured (and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them) under such policies for losses and damages so caused. None of the above waivers shall extend to the rights that any party making such waiver may have to the proceeds of insurance held by Owner as trustee or otherwise payable under any policy so issued.

B. Owner waives all rights against Contractor, Subcontractors, Engineer and Construction Manager, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them for:

1. loss due to business interruption, loss of use, or other consequential loss extending beyond direct physical loss or damage to Owner's property or the Work caused by, arising out of, or resulting from fire or other perils whether or not insured by Owner; and

2. loss or damage to the completed Project or part thereof caused by, arising out of, or resulting from fire or other insured peril or cause of loss covered by any property insurance maintained on the completed Project or part thereof by Owner during partial utilization pursuant to Paragraph 14.05, after Substantial Completion pursuant to Paragraph 14.04, or after final payment pursuant to Paragraph 14.07.

C. Any insurance policy maintained by Owner covering any loss, damage or consequential loss referred to in Paragraph 5.07.B shall contain provisions to the effect that in the event of payment of any such loss, damage, or consequential loss, the insurers will have no rights of recovery against Contractor, Subcontractors, Engineer or Construction Manager, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them.

Section 5.08 Receipt and Application of Insurance Proceeds

A. Any insured loss under the policies of insurance required by Paragraph 5.06 will be adjusted with Owner and made payable to Owner as fiduciary for the insureds, as their interests may appear, subject to the

requirements of any applicable mortgage clause and of Paragraph 5.08.B. Owner shall deposit in a separate account any money so received and shall distribute it in accordance with such agreement as the parties in interest may reach. If no other special agreement is reached, the damaged Work shall be repaired or replaced, the moneys so received applied on account thereof, and the Work and the cost thereof covered by an appropriate Change Order.

B. Owner as fiduciary shall have power to adjust and settle any loss with the insurers unless one of the parties in interest shall object in writing within 15 days after the occurrence of loss to Owner's exercise of this power. If such objection be made, Owner as fiduciary shall make settlement with the insurers in accordance with such agreement as the parties in interest may reach. If no such agreement among the parties in interest is reached, Owner as fiduciary shall adjust and settle the loss with the insurers and, if required in writing by any party in interest, Owner as fiduciary shall give bond for the proper performance of such duties.

Section 5.09 Acceptance of Bonds and Insurance; Option to Replace

A. If either Owner or Contractor has any objection to the coverage afforded by or other provisions of the bonds or insurance required to be purchased and maintained by the other party in accordance with Article 5 on the basis of non-conformance with the Contract Documents, the objecting party shall so notify the other party in writing within 10 days after receipt of the certificates (or other evidence requested) required by Paragraph 2.01.B. Owner and Contractor shall each provide to the other such additional information in respect of insurance provided as the other may reasonably request. If either party does not purchase or maintain all of the bonds and insurance required of such party by the Contract Documents, such party shall notify the other party in writing of such failure to purchase prior to the start of the Work, or of such failure to maintain prior to any change in the required coverage. Without prejudice to any other right or remedy, the other party may elect to obtain equivalent bonds or insurance to protect such other party's interests at the expense of the party who was required to provide such coverage, and a Change Order shall be issued to adjust the Contract Price accordingly.

Section 5.10 Partial Utilization, Acknowledgment of Property Insurer

A. If Owner finds it necessary to occupy or use a portion or portions of the Work prior to Substantial Completion of all the Work as provided in Paragraph 14.05, no such use or occupancy shall commence before the insurers providing the property insurance pursuant to Paragraph 5.06 have acknowledged notice thereof and in writing effected any changes in coverage necessitated thereby. The insurers providing the property insurance shall consent by endorsement on the policy or policies, but the property insurance shall not be canceled or permitted to lapse on account of any such partial use or occupancy.

1. All insurance required by the Contract Documents, or by laws or regulations shall remain in full force and effect on all phases of the Work, whether or not the Work is occupied or utilized by Owner, until all Work included in the agreement has been completed and final payment has been made.

2. Nothing contained in the insurance requirements shall be construed as limiting the extent of Contractor's responsibility for payment of damages resulting from Contractor's, subcontractors' or suppliers' operations under the Contract. Contractor agrees that Contractor alone shall be completely responsible for procuring and maintaining full insurance coverage as provided herein or as may be otherwise required by the Contract Documents. Any approval by Owner or Construction Manager shall not operate to the contrary.

ARTICLE 6. CONTRACTOR'S RESPONSIBILITIES

Section 6.01 Supervision and Superintendence

A. Contractor shall supervise, inspect, and direct the Work competently and efficiently, devoting such

attention thereto and applying such skills and expertise as may be necessary to perform the Work in accordance with the Contract Documents. Contractor shall be solely responsible for the means, methods, techniques, sequences, and procedures of construction. Contractor shall not be responsible for the negligence of Owner or Engineer in the design or specification of a specific means, method, technique, sequence, or procedure of construction which is shown or indicated in and expressly required by the Contract Documents. Means or methods of work suggested by the Owner, the Construction Manager, or the Engineer to the Contractor, but not specified or required, if adopted or followed by the Contractor in whole or in part, shall be used at the risk and responsibility of the Contractor. The Owner, Construction Manager, or the Engineer assume no responsibility therefor, and in no way will be held liable for any defects in the Work which may result from or be caused by use of such plan or method of Work.

B. At all times during the progress of the Work, Contractor shall assign a competent resident superintendent who shall not be replaced without written notice to Owner and Construction Manager except under extraordinary circumstances. The superintendent will be Contractor's representative at the Site and shall have authority to act on behalf of Contractor. All communications given to or received from the superintendent shall be binding on Contractor.

Section 6.02 Labor; Working Hours

A. Contractor shall provide competent, suitably qualified personnel to survey and lay out the Work and perform construction as required by the Contract Documents. Contractor shall at all times maintain good discipline and order at the Site.

B. In the absence of any Federal, state or local laws, regulations or covenants, the Contractor may conduct its performance of the Work at the Contractor's sole discretion, except that the cost of any overtime pay or other expense incurred by the Owner for Resident Project Representative, Owner's Representative and construction observation services, occasioned by the conduct of Work on Saturday, Sunday, any legal holiday, or as overtime on any regular work day, shall be reimbursed to the Owner by the Contractor. Contractor shall provide to Construction Manager 72-hour written notice of intent to work outside of regular working hours.

C. Prevailing Wage:

1. Pursuant to SB 854 and to provisions of the Labor Code Section 1770, et. seq., of the State of California, the Director of the Department of Industrial Relations has ascertained the prevailing rate of wages of the locality in which the Work is to be performed and applicable to the work to be done. Prevailing wage for each job category shall be as published by Department of Industrial Relations at the time of project work.

2. This project is subject to compliance monitoring and enforcement by the Department of Industrial Relations.

3. No Contractor or subcontractor may be awarded a contract for public work on a public works project unless registered with the Department of Industrial Relations pursuant to Labor Code Section 1725.5

4. Contractor shall post job site notices prescribed by regulation.

5. For each worker paid less than the stipulated rate in the execution of the Contract by the Contractor, or any subcontractor under it, in violation of the provisions of the Labor Code, and in particular, Section 1770 to Section 1780, inclusive, the Contractor shall be subject to the provisions and penalties of Section 1775 of the Labor Code. In addition to said penalty, and pursuant to said Section 1775, the difference between such stipulated prevailing wage rates and the amounts paid to each worker for each calendar day, or portion thereof, for which each worker was paid less than the stipulated prevailing rate shall be paid to each worker by the Contractor.

6. The wage rates set forth are the minimum that may be paid by the Contractor. Nothing herein

contained shall be construed as preventing the Contractor from paying more than the minimum set forth.

7. No extra compensation whatever shall be allowed by the City due to the inability of the Contractor to hire labor at the minimum rate nor for any necessity for payment by the Contractor for subsistence, travel time, overtime, or other added compensation, all of which possibilities are elements to be considered and ascertained to the Contractor's own satisfaction in preparing the bid.

8. If it becomes necessary to employ a craft other than those listed in the prevailing rates, the Contractor shall notify the City immediately and the City will obtain the additional prevailing rate from the Director of the Department of Industrial Relations and the rate thus determined shall be applicable as a minimum at the time of initial employment.

9. The Contractor shall pay travel and subsistence payments to workers needed to execute the work as such travel and subsistence payments are defined in the applicable collective bargaining agreement filed with the Department of Industrial Relations pursuant to Labor Code Section 1773.8.

10. City and Contractor stipulate that Labor Code Section 1775 will be complied with.

11. The City will consider the type of work performed by classification traditionally employed to perform said work in San Joaquin County when determining appropriate craft, classification or type of worker under Section 1733.2 of the California Labor Code.

12. Not Used.

13. Certified Payrolls - In accordance with Section 1776 of the Labor Code, each Contractor and subcontractor shall keep an accurate payroll record, showing the name, address, social security number, work classification, straight time, and overtime hours worked each day and week, and the actual per diem wages paid to each journeyman, apprentice, worker, or other employee employed by the Contractor or the subcontractor in connection with the project. Pursuant to SB 854, All Contractors and subcontractors must furnish electronic certified payroll records directly to the Labor Commissioner (aka Division of Labor Standards Enforcement).

14. The payroll records shall be certified and shall be available for inspection at all reasonable hours at the principal office of the Contractor on the following basis:

    a. A certified copy of an employee's payroll record shall be made available for inspection or furnished to the employee or its authorized representative on request.

    b. A certified copy of all payroll records shall be made available for inspection or furnished upon request to a representative of the City, the Division of Labor Standards Enforcement, and the Division of Apprenticeship Standards of the Department of Industrial Relations.

    c. A certified copy of all payroll records shall be made available upon request by the public in accordance with Section 1776 of the Labor Code.

15. The Contractor is responsible for its and its subcontractors' compliance with the provisions of Section 1776 of the Labor Code.

16. Overtime Requirements - The Contractor shall forfeit, as a penalty to the City, the penalty as provided in Section 1813 of the Labor Code for each worker employed in the execution of the Contract by the Contractor, or any subcontractor under the Contractor, for each day during which such worker is required or permitted to work more than eight (8) hours in any one day and forty (40) hours in any one week, in violation of the provisions of the Labor Code, and in particular, Section 1810 to Section 1815 thereof, inclusive, except that work performed by employees of Contractors in excess of eight (8) hours a day and forty (40) hours during one week, shall be permitted upon compensation for all hours worked in excess of eight (8) hours per day, at not less than one and a half (1.5) times the basic rate of pay as provided for in Section 1815 of the Labor Code.

17. Apprentice and Trainee - Attention is directed to the provisions in Section 1777.5 of the Labor Code and in accordance with the regulations of the California Apprenticeship Council concerning the employment of apprentices by the Contractor or any subcontractor under the Contractor.

18. Section 1777.5 requires the Contractor or subcontractors employing tradespersons in any apprenticeable occupation to apply to the joint apprenticeship committee nearest the site of the project that administers the apprenticeship program in that trade for a certificate of approval. The Contractor and subcontractors are required to submit contract award information to the applicable joint apprenticeship committee. As provided for in Section 1777.5 of the Labor Code, the Contractor is required to make contributions to funds established for the administration of apprenticeship programs.

19. It shall be the responsibility of the Contractor to abide by the provisions of Section 1777.5 of the Labor Code and to require all subcontractors employed by or contracting with the Contractor to abide by said provisions. The Contractor shall furnish the City any and all evidence of compliance with this code section when requested by the City.

20. For failure to comply with Section 1777.5 of the Labor Code, the Contractor shall be subject to the penalties in Section 1777.7 of the Labor Code. The provisions of this paragraph apply only to the extent not preempted by Federal law.

21. Workers' Compensation Insurance - The Contractor is required to secure the payment of compensation to its employees in accordance with the provisions of Sections 1860 and 3700 of the Labor Code and Paragraph 00820-2.40, Workers' Compensation Insurance.

Section 6.03 Services, Materials, and Equipment

A. Unless otherwise specified in the Contract Documents, Contractor shall provide and assume full responsibility for all services, materials, equipment, labor, transportation, construction equipment and machinery, tools, appliances, fuel, power, light, heat, telephone, water, sanitary facilities, temporary facilities, and all other facilities and incidentals necessary for the performance, testing, start-up, and completion of the Work.

   1. Where the Work requires equipment be furnished, due to the lack of standardization of equipment as produced by the various manufacturers, it may become necessary to make minor modifications in the structures, buildings, piping, mechanical work, electrical work, accessories, controls, or other work, to accommodate the particular equipment offered. Contractor's bid price for any equipment offered shall include the cost of making any necessary changes subject to the approval of Construction Manager.

B. All materials and equipment incorporated into the Work shall be as specified or, if not specified, shall be of good quality and new, except as otherwise provided in the Contract Documents. All special warranties and guarantees required by the Specifications shall expressly run to the benefit of Owner. If required by Engineer or Construction Manager, Contractor shall furnish satisfactory evidence (including reports of required tests) as to the source, kind, and quality of materials and equipment.

C. All materials and equipment shall be stored, applied, installed, connected, erected, protected, used, cleaned, and conditioned in accordance with instructions of the applicable Supplier, except as otherwise may be provided in the Contract Documents.

   1. Materials and equipment, if furnished by the Owner, will be made available as designated in the General Requirements. The cost of unloading, hauling and handling, and placing Owner-furnished materials and equipment shall be considered as included in the price bid for the Contract item involving such Owner-furnished material.

   2. Contractor shall inspect and assure itself of the amount and soundness of such materials and

equipment.

3. The Contractor will be held responsible for all materials and equipment furnished to it and received by it, and shall pay all demurrage and storage charges. City-furnished materials and equipment lost or damaged from any cause whatsoever shall be replaced by the Contractor. The Contractor will be liable to the Owner for the cost of replacing Owner-furnished material and equipment and such costs may be deducted from any moneys due or to become due the Contractor.

D. All items of standard equipment shall be the latest model at the time of bid, unless otherwise specified.

Section 6.04 Progress Schedule

A. Contractor shall adhere to the Progress Schedule established in accordance with Paragraph 2.07 as it may be adjusted from time to time as provided below.

1. Contractor shall submit to Construction Manager for acceptance (to the extent indicated in Paragraph 2.07) proposed adjustments in the Progress Schedule that will not result in changing the Contract Times. Such adjustments will comply with any provisions of the General Requirements applicable thereto.

2. Proposed adjustments in the Progress Schedule that will change the Contract Times shall be submitted in accordance with the requirements of Article 12. Adjustments in Contract Times may only be made by a Change Order.

Section 6.05 Substitutes and "Or-Equals"

A. Whenever an item of material or equipment is specified or described in the Contract Documents by using the name of a proprietary item or the name of a particular Supplier, the specification or description is intended to establish the type, function, appearance, and quality required. Unless the specification or description contains or is followed by words reading that no like, equivalent, or "or-equal" item or no substitution is permitted, other items of material or equipment or material or equipment of other Suppliers may be submitted to Engineer for review under the circumstances described below.

1. *"Or-Equal" Items*: If in Engineer's sole discretion an item of material or equipment proposed by Contractor is functionally equal to that named and sufficiently similar so that no change in related Work will be required, it may be considered by Engineer as an "or-equal" item, in which case review and approval of the proposed item may, in Engineer's sole discretion, be accomplished without compliance with some or all of the requirements for approval of proposed substitute items. For the purposes of this Paragraph 6.05.A.1, a proposed item of material or equipment will be considered functionally equal to an item so named if:

a. in the exercise of reasonable judgment Engineer determines that:

i) it is at least equal in materials of construction, quality, durability, appearance, strength, and design characteristics;

ii) it will reliably perform at least equally well the function and achieve the results imposed by the design concept of the completed Project as a functioning whole; it has a proven record of performance and availability of responsive service; and

Contractor certifies that, if approved and incorporated into the Work:

iii) there will be no increase in cost to the Owner or increase in Contract Times, and

iv) it will conform substantially to the detailed requirements of the item named in the Contract Documents.

2. Substitute Items

a. If in Engineer's sole discretion an item of material or equipment proposed by Contractor does not qualify as an "or-equal" item under Paragraph 6.05.A.1, it will be considered a proposed substitute item.

b. Contractor shall submit sufficient information as provided below to allow Engineer to determine that the item of material or equipment proposed is essentially equivalent to that named and an acceptable substitute therefor. Requests for review of proposed substitute items of material or equipment will not be accepted by Construction Manager from anyone other than Contractor.

c. The requirements for review by Engineer will be as set forth in Paragraph 6.05.A.2.d, as supplemented in the General Requirements and as Engineer may decide is appropriate under the circumstances.

d. Contractor shall make written application to Construction Manager for review of a proposed substitute item of material or equipment that Contractor seeks to furnish or use. The application:

i) shall certify that the proposed substitute item will:

1) perform adequately the functions and achieve the results called for by the general design,

2) be similar in substance to that specified, and

3) be suited to the same use as that specified;

ii) will state:

1) the extent, if any, to which the use of the proposed substitute item will prejudice Contractor's achievement of Substantial Completion on time;

2) whether or not use of the proposed substitute item in the Work will require a change in any of the Contract Documents (or in the provisions of any other direct contract with Owner for other work on the Project) to adapt the design to the proposed substitute item; and

3) whether or not incorporation or use of the proposed substitute item in connection with the Work is subject to payment of any license fee or royalty;

iii) will identify:

1) all variations of the proposed substitute item from that specified; and

2) available engineering, sales, maintenance, repair, and replacement services.

iv) and shall contain an itemized estimate of all costs or credits that will result directly or indirectly from use of such substitute item, including costs of redesign and claims of other contractors affected by any resulting change.

B. Substitute Construction Methods or Procedures: If a specific means, method, technique, sequence, or procedure of construction is expressly required by the Contract Documents, Contractor may furnish or utilize a substitute means, method, technique, sequence, or procedure of construction approved by Engineer. Contractor shall submit sufficient information to allow Engineer, in Engineer's sole discretion, to determine that the substitute proposed is equivalent to that expressly called for by the Contract Documents. The requirements for review by Engineer will be similar to those provided in Paragraph 6.05.A.2.

C. *Engineer's Evaluation*: Engineer will be allowed a reasonable time within which to evaluate each proposal or submittal made pursuant to Paragraphs 6.05.A and 6.05.B. Engineer may require Contractor to furnish additional data about the proposed substitute item. Engineer will be the sole judge of acceptability. No "or

equal" or substitute will be ordered, installed or utilized until Engineer's review is complete, which will be evidenced by either a Change Order for a substitute or an approved Shop Drawing for an "or equal." Engineer will advise Contractor in writing of any negative determination.

D. *Special Guarantee*: Owner may require Contractor to furnish at Contractor's expense a special performance guarantee or other surety with respect to any substitute.

E. *Engineer's Cost Reimbursement:* Engineer will record Engineer's costs in evaluating a substitute proposed or submitted by Contractor pursuant to Paragraphs 6.05.A.2 and 6.05.B. Whether or not Engineer approves a substitute item so proposed or submitted by Contractor, Contractor shall reimburse Owner for the charges of Engineer for evaluating each such proposed substitute. Contractor shall also reimburse Owner for the charges of Engineer for making changes in the Contract Documents (or in the provisions of any other direct contract with Owner) resulting from the acceptance of each proposed substitute.

F. *Contractor's Expense*: Contractor shall provide all data in support of any proposed substitute or "or-equal" at Contractor's expense.

Section 6.06 Concerning Subcontractors, Suppliers, and Others

A. Contractor shall not employ any Subcontractor, Supplier, or other individual or entity (including those acceptable to Owner as indicated in Paragraph 6.06.B), whether initially or as a replacement, against whom Owner may have reasonable objection. Contractor shall not be required to employ any Subcontractor, Supplier, or other individual or entity to furnish or perform any of the Work against whom Contractor has reasonable objection.

B. If the Supplementary Conditions require the identity of certain Subcontractors, Suppliers, or other individuals or entities to be submitted to Owner in advance for acceptance by Owner by a specified date prior to the Effective Date of the Agreement, and if Contractor has submitted a list thereof in accordance with the Supplementary Conditions, Owner's acceptance (either in writing or by failing to make written objection thereto by the date indicated for acceptance or objection in the Bidding Documents or the Contract Documents) of any such Subcontractor, Supplier, or other individual or entity so identified may be revoked on the basis of reasonable objection after due investigation. Contractor shall submit an acceptable replacement for the rejected Subcontractor, Supplier, or other individual or entity, and the Contract Price will be adjusted by the difference in the cost occasioned by such replacement, and an appropriate Change Order will be issued. No acceptance by Owner of any such Subcontractor, Supplier, or other individual or entity, whether initially or as a replacement, shall constitute a waiver of any right of Owner or Engineer to reject defective Work.

C. Contractor shall be fully responsible to Owner, Engineer, and Construction Manager for all acts and omissions of the Subcontractors, Suppliers, and other individuals or entities performing or furnishing any of the Work just as Contractor is responsible for Contractor's own acts and omissions. Nothing in the Contract Documents:

1. shall create for the benefit of any such Subcontractor, Supplier, or other individual or entity any contractual relationship between Owner, Engineer or Construction Manager and any such Subcontractor, Supplier or other individual or entity, nor

2. shall create any obligation on the part of Owner or Engineer to pay or to see to the payment of any moneys due any such Subcontractor, Supplier, or other individual or entity except as may otherwise be required by Laws and Regulations.

D. Contractor shall be solely responsible for scheduling and coordinating the Work of Subcontractors, Suppliers, and other individuals or entities performing or furnishing any of the Work under a direct or indirect contract with Contractor.

E. Contractor shall require all Subcontractors, Suppliers, and such other individuals or entities performing or

furnishing any of the Work to communicate with Construction Manager and Engineer through Contractor.

F. The divisions and sections of the Specifications and the identifications of any Drawings shall not control Contractor in dividing the Work among Subcontractors or Suppliers or delineating the Work to be performed by any specific trade.

G. All Work performed for Contractor by a Subcontractor or Supplier will be pursuant to an appropriate agreement between Contractor and the Subcontractor or Supplier which specifically binds the Subcontractor or Supplier to the applicable terms and conditions of the Contract Documents for the benefit of Owner, Construction Manager and Engineer. Whenever any such agreement is with a Subcontractor or Supplier who is listed as an additional insured on the property insurance provided in Paragraph 5.06, the agreement between the Contractor and the Subcontractor or Supplier will contain provisions whereby the Subcontractor or Supplier waives all rights against Owner, Contractor, Construction Manager and Engineer, and all other individuals or entities identified in the Supplementary Conditions to be listed as insureds or additional insureds (and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them) for all losses and damages caused by, arising out of, relating to, or resulting from any of the perils or causes of loss covered by such policies and any other property insurance applicable to the Work. If the insurers on any such policies require separate waiver forms to be signed by any Subcontractor or Supplier, Contractor will obtain the same.

Section 6.07 Patent Fees and Royalties

A. Contractor shall pay all license fees and royalties and assume all costs incident to the use in the performance of the Work or the incorporation in the Work of any invention, design, process, product, or device which is the subject of patent rights or copyrights held by others. If a particular invention, design, process, product, or device is specified in the Contract Documents for use in the performance of the Work and if to the actual knowledge of Owner or Engineer its use is subject to patent rights or copyrights calling for the payment of any license fee or royalty to others, the existence of such rights shall be disclosed by Owner in the Contract Documents.

B. To the fullest extent permitted by Laws and Regulations, Contractor shall indemnify and hold harmless Owner, Construction Manager and Engineer, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them from and against all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to any infringement of patent rights or copyrights incident to the use in the performance of the Work or resulting from the incorporation in the Work of any invention, design, process, product, or device not specified in the Contract Documents.

Section 6.08 Permits

A. Unless otherwise provided in the Supplementary Conditions, Contractor shall obtain and pay for all construction permits and licenses. Owner shall assist Contractor, when necessary, in obtaining such permits and licenses. Contractor shall pay all governmental charges and inspection fees necessary for the prosecution of the Work which are applicable at the time of opening of Bids, or, if there are no Bids, on the Effective Date of the Agreement. Owner shall pay all charges of utility owners for connections for providing permanent service to the Work.

Section 6.09 Laws and Regulations

A. Contractor shall give all notices required by and shall comply with all Laws and Regulations applicable to the performance of the Work. Except where otherwise expressly required by applicable Laws and Regulations, neither Owner, Construction Manager nor Engineer shall be responsible for monitoring Contractor’s compliance with any Laws or Regulations.

B. If Contractor performs any Work knowing or having reason to know that it is contrary to Laws or Regulations, Contractor shall bear all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to such Work. However, it shall not be Contractor's primary responsibility to make certain that the Specifications and Drawings are in accordance with Laws and Regulations, but this shall not relieve Contractor of Contractor's obligations under Paragraph 3.03.

C. Changes in Laws or Regulations not known at the time of opening of Bids (or, on the Effective Date of the Agreement if there were no Bids) having an effect on the cost or time of performance of the Work shall be the subject of an adjustment in Contract Price or Contract Times. If Owner and Contractor are unable to agree on entitlement to or on the amount or extent, if any, of any such adjustment, a Claim may be made therefor as provided in Paragraph 10.05.

Section 6.10 Taxes

A. Contractor shall pay all sales, consumer, use, and other similar taxes required to be paid by Contractor in accordance with the Laws and Regulations of the place of the Project which are applicable during the performance of the Work.

Section 6.11 Use of Site and Other Areas

A. Limitation on Use of Site and Other Areas

1. Contractor shall confine construction equipment, the storage of materials and equipment, and the operations of workers to the Site and other areas permitted by Laws and Regulations, and shall not unreasonably encumber the Site and other areas with construction equipment or other materials or equipment. Contractor shall assume full responsibility for any damage to any such land or area, or to the owner or occupant thereof, or of any adjacent land or areas resulting from the performance of the Work.

2. Should any claim be made by any such owner or occupant because of the performance of the Work, Contractor shall promptly settle with such other party by negotiation or otherwise resolve the claim by arbitration or other dispute resolution proceeding or at law.

3. To the fullest extent permitted by Laws and Regulations, Contractor shall indemnify and hold harmless Owner, Construction Manager and Engineer, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them from and against all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to any claim or action, legal or equitable, brought by any such owner or occupant against Owner, Engineer, or any other party indemnified hereunder to the extent caused by or based upon Contractor's performance of the Work.

B. *Removal of Debris During Performance of the Work*: During the progress of the Work Contractor shall keep the Site and other areas free from accumulations of waste materials, rubbish, and other debris. Removal and disposal of such waste materials, rubbish, and other debris shall conform to applicable Laws and Regulations.

C. *Cleaning:* Prior to Substantial Completion of the Work Contractor shall clean the Site and the Work and make it ready for utilization by Owner. At the completion of the Work Contractor shall remove from the Site all tools, appliances, construction equipment and machinery, and surplus materials and shall restore to original condition all property not designated for alteration by the Contract Documents.

D. *Loading Structures*: Contractor shall not load nor permit any part of any structure to be loaded in any manner that will endanger the structure, nor shall Contractor subject any part of the Work or adjacent property to stresses or pressures that will endanger it.

Section 6.12 Record Documents

A. Contractor shall maintain in a safe place at the Site one record copy of all Drawings, Specifications, Addenda, Change Orders, Work Change Directives, Field Orders, and written interpretations and clarifications in good order and annotated to show changes made during construction. These record documents together with all approved Samples and a counterpart of all approved Shop Drawings will be available to Construction Manager for reference, and shall be current at the time of Contractor's submission of Application for Payment as a condition precedent for Construction Manager's recommendation of payment. Upon completion of the Work, these record documents, Samples, and Shop Drawings will be delivered to Construction Manager for Owner. Contractor shall include accurate locations for buried and imbedded items.

Section 6.13 Safety and Protection

A. Contractor shall be solely responsible for initiating, maintaining and supervising all safety precautions and programs in connection with the Work. Contractor shall take all necessary precautions for the safety of, and shall provide the necessary protection to prevent damage, injury or loss to:

1. all persons on the Site or who may be affected by the Work;
2. all the Work and materials and equipment to be incorporated therein, whether in storage on or off the Site; and
3. other property at the Site or adjacent thereto, including trees, shrubs, lawns, walks, pavements, roadways, structures, utilities, and Underground Facilities not designated for removal, relocation, or replacement in the course of construction.

B. Contractor shall comply with all applicable Laws and Regulations relating to the safety of persons or property, or to the protection of persons or property from damage, injury, or loss; and shall erect and maintain all necessary safeguards for such safety and protection. Contractor shall notify owners of adjacent property and of Underground Facilities and other utility owners when prosecution of the Work may affect them, and shall cooperate with them in the protection, removal, relocation, and replacement of their property.

1. At least three (3) business days before performing any excavation work or other work that could damage existing improvements within, or adjacent to, the Work area, the Contractor shall notify the owners of properties adjacent to the Work area of intended commencement of such Work and request that such owners mark or otherwise indicate the location of underground improvements of which they are aware or other improvements not readily apparent from visual inspection of the adjacent property, such as survey points and utility service installations not owned by the appropriate utility. The Contractor shall also give three (3) business days notice to occupants or owners of adjacent property to permit them to salvage or relocate plants, trees, fences, sprinklers, and other improvements within the right-of-way that are designated for removal or would be destroyed because of the Work. Contractor shall furnish to the Construction Manager written documentation of its contact(s) with property owners (1) requesting them to mark or otherwise indicate the location of their respective facilities, and (2) notifying them to salvage or relocate landscaping or improvements within or adjacent to the Work area within two (2) days after such contact(s).
2. It shall be the Contractor's responsibility to determine the exact location (including depth for underground improvements) and to document the existing condition of all existing improvements which are not designated for removal (e.g., curbs, sidewalks, survey points, fences, walls, signs, utility installations, pavements, structures, etc.) which the Contractor believes may affect or be affected by Contractor's operations.
3. In the event that existing improvements are found that have not been identified in the Contract

Documents or indicated by the respective property owner, or are found to exist in a substantially different location than so indicated, the Contractor shall (1) immediately notify the Construction Manager thereof in writing, and (2) take steps to avoid damaging such improvements, including ascertaining their exact location if not yet known.

C. All damage, injury, or loss to any property referred to in Paragraph 6.13.A.2 or 6.13.A.3 caused, directly or indirectly, in whole or in part, by Contractor, any Subcontractor, Supplier, or any other individual or entity directly or indirectly employed by any of them to perform any of the Work, or anyone for whose acts any of them may be liable, shall be remedied by Contractor (except damage or loss attributable to the fault of Drawings or Specifications or to the acts or omissions of Owner, Construction Manager or Engineer, or anyone employed by any of them, or anyone for whose acts any of them may be liable, and not attributable, directly or indirectly, in whole or in part, to the fault or negligence of Contractor or any Subcontractor, Supplier, or other individual or entity directly or indirectly employed by any of them).

1. The Contractor shall immediately notify the Construction Manager and the property owner of any damage to any existing improvements that have not been designated to be removed. The Contractor shall be responsible for the cost of repairing or restoring all existing improvements which are not designated for removal (e.g., curbs, sidewalks, survey points, fences, walls, signs, utility installations, pavements, structures, etc.) and are damaged or removed as a result of its operations. Repairs and replacements shall be at least equal to existing improvements and shall match them in finish and dimension.

2. The Contractor shall protect from damage all landscaping (e.g., trees, lawns, shrubbery, etc.) adjacent to the Work area or within the Work area that have not been designated to be removed. The Contractor shall immediately notify the Construction Manager and the property owner of any damage to any such landscaping which is not designated for removal. The Contractor shall be responsible for the cost of restoring or replacing such landscaping in as nearly the original conditions and location as it is reasonably possible. Lawns shall be re-seeded and covered with suitable mulch.

3. Except where an owner of damaged improvements or landscaping has advised that he or she intends to repair the damage himself or through forces that he or she will retain or has retained, Contractor shall, within 24 hours of receipt from the Owner of notice to commence correction of damage, notify the Construction Manager in writing if Contractor intends to repair the damage. During nights and weekends when work is not in progress, Owner may give such notice by telephone or by facsimile transmission to the Contractor's facsimile number designated and such notice will be immediately effective. The Contractor's failure to provide timely written notification that it intends to repair the damage shall be deemed its agreement that the Owner may repair the damage at Contractor's expense without further notice and without prejudice to any other remedy available to City. In such event, the Contractor may observe the Work if this can be done without in any way delaying the progress thereof, but may not contest any element of the expense of repair or the lack of further notice. This provision is in addition to any other remedy, including the remedy provided in 13.09, Owner May Correct Defective Work.

D. Contractor’s duties and responsibilities for safety and for protection of the Work shall continue until such time as all the Work is completed and Construction Manager has issued a notice to Owner and Contractor in accordance with Paragraph 14.07.B that the Work is acceptable (except as otherwise expressly provided in connection with Substantial Completion).

E. The Contractor shall establish, implement, and maintain a Written injury prevention program as required by Labor Code Section 6401.7. This written program shall be submitted to the Construction Manager within five (5) days of Notice to Proceed. The Contractor's injury prevention program will not be reviewed for approval. Before proceeding with any construction work, the Contractor shall take the necessary action to comply with all provisions for safety and accident prevention. The Contractor shall develop and maintain for the duration of this Contract, a safety program that will effectively incorporate and implement

all required safety provisions. The Contractor shall appoint an employee as safety supervisor who is qualified and authorized to supervise and enforce compliance with the safety program. The Contractor, as a part of its safety program, shall maintain at its office or other well-known place at the Site, safety equipment applicable to the Work as prescribed by the aforementioned authorities, all items necessary for giving first aid to the injured, and shall establish the procedure for the immediate removal to a hospital or a doctor's care of persons who may be injured on the jobsite.

1. In accordance with the provisions of Section 6705 of the Labor Code, the Contractor shall submit, in advance of excavation 5 feet or more in depth, detailed plans showing the design of shoring, bracing, sloping, or other provisions to be made for worker protection from hazard of caving ground during such excavation. If such plans vary from the shoring system standards set forth in the Construction Safety Orders in Title 8, California Code of Regulations, the plans shall be prepared and signed by a registered civil or structural engineer. Shoring, bracing, sloping, or other protective system shall not be less effective than required by the California Construction Safety orders. The Contractor shall designate in writing to the Construction Manager the "competent person" with the authority and responsibilities designated in the Construction Safety Orders.
2. If death or serious injuries or serious damages are caused, the accident shall be reported immediately by telephone or messenger to both the Construction Manager and the City. In addition, the Contractor must promptly report in writing to the Construction Manager all accidents whatsoever arising out of, or in connection with, the performance of the Work whether on, or adjacent to, the Site, giving full details and statements of witnesses. The Contractor shall make all reports as are, or may be, required by any authority having jurisdiction, and permit all safety inspections of the work being performed under this Contract.
3. If a claim is made by anyone against the Contractor or any subcontractor on account of any accident, the Contractor shall promptly report the facts in writing to the Construction Manager, giving full details of the claim.

Section 6.14 Safety Representative

A. Contractor shall designate a qualified and experienced safety representative at the Site whose duties and responsibilities shall be the prevention of accidents and the maintaining and supervising of safety precautions and programs.

Section 6.15 Hazard Communication Programs

A. Contractor shall be responsible for coordinating any exchange of material safety data sheets or other hazard communication information required to be made available to or exchanged between or among employers at the Site in accordance with Laws or Regulations.

Section 6.16 Emergencies

A. In emergencies affecting the safety or protection of persons or the Work or property at the Site or adjacent thereto, Contractor is obligated to act to prevent threatened damage, injury, or loss. Contractor shall give Construction Manager prompt written notice if Contractor believes that any significant changes in the Work or variations from the Contract Documents have been caused thereby or are required as a result thereof. If Engineer determines that a change in the Contract Documents is required because of the action taken by Contractor in response to such an emergency, a Work Change Directive or Change Order will be issued.

B. If Contractor fails to take appropriate action in an emergency, the Owner also reserves the right to perform any portion of the work that threatens the safety or health of the public or Owner, and the safety of the work or any property or equipment. In the event the Owner performs work in an emergency, an appropriate Change Order shall be issued unilaterally deducting from the payments then or thereafter due the

Contractor the cost for performing such Work, including compensation for the Engineer's, the Construction Manager's, and City's additional services made necessary by such emergency.

Section 6.17 Shop Drawings and Samples

A. Contractor shall submit required Shop Drawings and Samples to Engineer for review and approval in accordance with the acceptable Schedule of Submittals (as required by Paragraph 2.07). Each submittal will be identified as Engineer may require.

1. Shop Drawings:

a. Submit number of copies specified in the General Requirements.

i) Data shown on the Shop Drawings will be complete with respect to quantities, dimensions, specified performance and design criteria, materials, and similar data to show Engineer the services, materials, and equipment Contractor proposes to provide and to enable Engineer to review the information for the limited purposes required by Paragraph 6.17.D.

ii) Shop Drawings submitted as herein provided by Contractor and reviewed by Engineer for conformance with the design concept shall be executed in conformity with the Contract Documents unless otherwise required by Owner.

iii) When Shop Drawings are submitted for the purpose of showing the installation in greater detail, their review shall not excuse Contractor from requirements shown on the drawings and Specifications.

iv) For-Information-Only submittals upon which the Engineer is not expected to conduct review or take responsive action may be so identified in the Contract Documents.

2. *Samples*: Contractor shall also submit required Samples to Engineer for review and approval in accordance with the acceptable schedule of Shop Drawings and Sample submittals.

a. Submit number of Samples specified in the Specifications.

b. Clearly identify each Sample as to material, Supplier, pertinent data such as catalog numbers, the use for which intended and other data as Engineer may require to enable Engineer to review the submittal for the limited purposes required by Paragraph 6.17.D.

B. Where a Shop Drawing or Sample is required by the Contract Documents or the Schedule of Submittals, any related Work performed prior to Engineer's review and approval of the pertinent submittal will be at the sole expense and responsibility of Contractor.

C. *Submittal Procedures:*

1. Before submitting each Shop Drawing or Sample, Contractor shall have determined and verified:

a. all field measurements, quantities, dimensions, specified performance and design criteria, installation requirements, materials, catalog numbers, and similar information with respect thereto;

b. the suitability of all materials with respect to intended use, fabrication, shipping, handling, storage, assembly, and installation pertaining to the performance of the Work;

c. all information relative to Contractor's responsibilities for means, methods, techniques, sequences, and procedures of construction, and safety precautions and programs incident thereto; and

d. shall also have reviewed and coordinated each Shop Drawing or Sample with other Shop Drawings and Samples and with the requirements of the Work and the Contract Documents.

2. Each submittal shall bear a stamp or specific written certification that Contractor has satisfied Contractor's obligations under the Contract Documents with respect to Contractor's review and approval of that submittal.

3. With each submittal, Contractor shall give Engineer specific written notice of any variations, that the Shop Drawing or Sample may have from the requirements of the Contract Documents. This notice shall be both a written communication separate from the Shop Drawing's or Sample Submittal; and, in addition, by a specific notation made on each Shop Drawing or Sample submitted to Engineer for review and approval of each such variation; otherwise Contractor will not be relieved of the responsibility of executing the Work in accordance with the Contract Documents, even though such Shop Drawings or Samples have been otherwise reviewed.

   a. If a Shop Drawing or Sample, as submitted, indicates a variation from the Contract Requirements as set forth in the Contract Documents and Engineer finds same to be in the interest of Owner and to be so minor as not to involve a change in the Contract Price or time for performance, Engineer may approve the Shop Drawings or Samples; provided however, such departure is slight in nature and does not affect the design concept of the Work.

4. Contractor shall submit all Shop Drawings and Samples sufficiently in advance of construction requirements to allow ample time for checking, correcting, resubmitting and rechecking and to avoid any delay in progress of the Work.

5. Shop Drawings and Sample submittals not conforming to requirements of this paragraph 6.17D and Section 01340 will be returned to Contractor without action for resubmittal and the resulting delay shall be entirely the responsibility of Contractor.

D. Engineer's Review

1. Engineer will provide timely review of required Shop Drawings and Samples in accordance with the Schedule of Submittals acceptable to Engineer. Engineer's review and approval will be only to determine if the items covered by the submittals will, after installation or incorporation in the Work, conform to the information given in the Contract Documents and be compatible with the design concept of the completed Project as a functioning whole as indicated by the Contract Documents.

2. Engineer's review and approval will not extend to means, methods, techniques, sequences, or procedures of construction (except where a particular means, method, technique, sequence, or procedure of construction is specifically and expressly called for by the Contract Documents) or to safety precautions or programs incident thereto. The review and approval of a separate item as such will not indicate approval of the assembly in which the item functions.

3. Engineer's review and approval shall not relieve Contractor from responsibility for any variation from the requirements of the Contract Documents unless Contractor has complied with the requirements of Paragraph 6.17.C.3 and Engineer has given written approval of each such variation by specific written notation thereof incorporated in or accompanying the Shop Drawing or Sample. Engineer's review and approval shall not relieve Contractor from responsibility for complying with the requirements of Paragraph 6.17.C.1.

4. Engineer's check and review of Shop Drawings and Samples, Standard Specifications and descriptive literature submitted by Contractor will be only for general conformance with design concept, except as otherwise provided, and shall not be construed as:

   a. permitting any departure from the Contract Requirements;

   b. relieving Contractor of the responsibility for any error in details, dimensions or otherwise that may exist in such submittals;

   c. constituting a blanket approval of dimensions, quantities, or details of the material or equipment

shown; or

d. approving departures from additional details or instructions previously furnished by Engineer. Such check or review shall not relieve Contractor of the full responsibility of meeting all of the requirements of the Contract Documents.

E. Resubmittal Procedures

1. Contractor shall make corrections required by Engineer and shall return the required number of corrected copies of Shop Drawings and submit, as required, new Samples for review and approval. Contractor shall direct specific attention in writing to revisions other than the corrections called for by Engineer on previous submittals.

Section 6.18 Continuing the Work

A. Contractor shall carry on the Work and adhere to the Progress Schedule during all disputes or disagreements with Owner. No Work shall be delayed or postponed pending resolution of any disputes or disagreements, except as permitted by Paragraph 15.04 or as Owner and Contractor may otherwise agree in writing.

Section 6.19 Contractor's General Warranty and Guarantee

A. Contractor warrants and guarantees to Owner that all Work will be in accordance with the Contract Documents and will not be defective. Construction Manager and Engineer, and their Related Entities, shall be entitled to rely on representation of Contractor's warranty and guarantee.

B. Contractor's warranty and guarantee hereunder excludes defects or damage caused by:

1. abuse, modification, or improper maintenance or operation by persons other than Contractor, Subcontractors, Suppliers, or any other individual or entity for whom Contractor is responsible; or

2. normal wear and tear under normal usage.

C. Contractor's obligation to perform and complete the Work in accordance with the Contract Documents shall be absolute. None of the following will constitute an acceptance of Work that is not in accordance with the Contract Documents or a release of Contractor's obligation to perform the Work in accordance with the Contract Documents:

1. observations by Construction Manager and Engineer;

2. recommendation by Construction Manager or payment by Owner of any progress or final payment;

3. the issuance of a certificate of Substantial Completion by Construction Manager or any payment related thereto by Owner;

4. use or occupancy of the Work or any part thereof by Owner;

5. any review and approval of a Shop Drawing or Sample submittal or the issuance of a notice of acceptability by Engineer;

6. any inspection, test, or approval by the Construction Manager, Engineer or others; or

7. any correction of defective Work by Owner.

Section 6.20 Indemnification

A. To the fullest extent permitted by Laws and Regulations, Contractor shall indemnify and hold harmless Owner, Construction Manager and Engineer, and the officers, directors, partners, employees, agents, consultants and subcontractors of each and any of them from and against all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other

professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to the performance of the Work, provided that any such claim, cost, loss, or damage is attributable to bodily injury, sickness, disease, or death, or to injury to or destruction of tangible property (other than the Work itself), including the loss of use resulting therefrom but only to the extent caused by any act or omission of Contractor, any Subcontractor, any Supplier, or any individual or entity directly or indirectly employed by any of them to perform any of the Work or anyone for whose acts any of them may be liable.

B. In any and all claims against Owner or Engineer or any of their respective consultants, agents, officers, directors, partners, or employees by any employee (or the survivor or personal representative of such employee) of Contractor, any Subcontractor, any Supplier, or any individual or entity directly or indirectly employed by any of them to perform any of the Work, or anyone for whose acts any of them may be liable, the indemnification obligation under Paragraph 6.20.A shall not be limited in any way by any limitation on the amount or type of damages, compensation, or benefits payable by or for Contractor or any such Subcontractor, Supplier, or other individual or entity under workers' compensation acts, disability benefit acts, or other employee benefit acts.

C. The indemnification obligations of Contractor under Paragraph 6.20.A shall not extend to the liability of Construction Manager and Engineer and their respective officers, directors, partners, employees, agents, consultants and subcontractors arising out of:

1. the preparation or approval of, or the failure to prepare or approve, maps, Drawings, opinions, reports, surveys, Change Orders, designs, or Specifications; or

2. giving directions or instructions, or failing to give them, if that is the primary cause of the injury or damage.

Section 6.21 Delegation of Professional Design Services

A. Contractor will not be required to provide professional design services unless such services are specifically required by the Contract Documents for a portion of the permanent Work or unless such services are required to carry out Contractor's responsibilities for construction means, methods, techniques, sequences and procedures. Contractor shall not be required to provide professional services in violation of applicable law.

B. If professional design services or certifications by a design professional related to permanent systems, materials or equipment incorporated into the Work are specifically required of Contractor by the Contract Documents, Owner and Engineer will specify all performance and design criteria that such services must satisfy. Contractor shall cause such services or certifications to be provided by a properly licensed professional, whose signature and seal shall appear on all drawings, calculations, specifications, certifications, Shop Drawings and other submittals prepared by such professional. Shop Drawings and other submittals related to the Work designed or certified by such professional, if prepared by others, shall bear such professional's written approval when submitted to Engineer.

C. Owner and Engineer shall be entitled to rely upon the adequacy, accuracy and completeness of the services, certifications or approvals performed by such design professionals, provided Owner and Engineer have specified to Contractor all performance and design criteria that such services must satisfy.

D. Pursuant to this Paragraph 6.21, Engineer's review and approval of design calculations and design drawings will be only for the limited purpose of checking for conformance with performance and design criteria given and the design concept expressed in the Contract Documents. Engineer's review and approval of Shop Drawings and other submittals (except design calculations and design drawings) will be only for the purpose stated in Paragraph 6.17.D.1.

E. Contractor shall not be responsible for the adequacy of the performance or design criteria required by the Contract Documents.

Section 6.22 Waste Disposal Services

A. Contractor shall pay for and use City garbage services for the disposal of construction waste. Contractor shall recycle waste as appropriate. Contractor shall provide a monthly update to the City of the quantity of waste recycled and general waste.

ARTICLE 7. OTHER WORK AT THE SITE

Section 7.01 Related Work at Site

A. Owner may perform other work related to the Project at the Site with Owner's employees, or via other direct contracts therefor, or have other work performed by utility owners. If such other work is not noted in the Contract Documents, then:

1. written notice thereof will be given to Contractor prior to starting any such other work; and

2. if Owner and Contractor are unable to agree on entitlement to or on the amount or extent, if any, of any adjustment in the Contract Price or Contract Times that should be allowed as a result of such other work, a Claim may be made therefor as provided in Paragraph 10.05.

B. Contractor shall afford each other contractor who is a party to such a direct contract, each utility owner and Owner, if Owner is performing other work with Owner's employees, proper and safe access to the Site, a reasonable opportunity for the introduction and storage of materials and equipment and the execution of such other work, and shall properly coordinate the Work with theirs. Contractor shall do all cutting, fitting, and patching of the Work that may be required to properly connect or otherwise make its several parts come together and properly integrate with such other work. Contractor shall not endanger any work of others by cutting, excavating, or otherwise altering their work and will only cut or alter their work with the written consent of Construction Manager and the others whose work will be affected. The duties and responsibilities of Contractor under this Paragraph are for the benefit of such utility owners and other contractors to the extent that there are comparable provisions for the benefit of Contractor in said direct contracts between Owner and such utility owners and other contractors.

C. If the proper execution or results of any part of Contractor's Work depends upon work performed by others under this Article 7, Contractor shall inspect such other work and promptly report to Construction Manager in writing any delays, defects, or deficiencies in such other work that render it unavailable or unsuitable for the proper execution and results of Contractor's Work. Contractor's failure to so report will constitute an acceptance of such other work as fit and proper for integration with Contractor's Work except for latent defects and deficiencies in such other work.

Section 7.02 Coordination

A. If Owner intends to contract with others for the performance of other work on the Project at the Site, the following will be set forth in Supplementary Conditions:

1. the individual or entity who will have authority and responsibility for coordination of the activities among the various contractors will be identified;

2. the specific matters to be covered by such authority and responsibility will be itemized; and

3. the extent of such authority and responsibilities will be provided.

B. Unless otherwise provided in the Supplementary Conditions, Owner shall have sole authority and responsibility for such coordination.

Section 7.03 Legal Relationships

A. Paragraphs 7.01.A and 7.02 are not applicable for utilities not under the control of Owner.

B. Each other direct contract of Owner under Paragraph 7.01.A shall provide that the other contractor is liable to Owner and Contractor for the reasonable direct delay and disruption costs incurred by Contractor as a result of the other contractor's actions or inactions.

C. Contractor shall be liable to Owner and any other contractor for the reasonable direct delay and disruption costs incurred by such other contractor as a result of Contractor's action or inactions.

ARTICLE 8. OWNER'S RESPONSIBILITIES

Section 8.01 Communications to Contractor

A. Except as otherwise provided in these General Conditions, Owner shall issue all communications to Contractor through Construction Manager.

Section 8.02 Replacement of Construction Manager or Engineer

A. In case of termination of the employment of either Construction Manager or Engineer, Owner shall appoint a Construction Manager or engineer to whom Contractor makes no reasonable objection, whose status under the Contract Documents shall be that of the former Construction Manager or Engineer.

Section 8.03 Furnish Data

A. Owner shall promptly furnish the data required of Owner under the Contract Documents.

Section 8.04 Pay When Due

A. Owner shall make payments to Contractor when they are due as provided in Paragraphs 14.02.C and 14.07.C.

Section 8.05 Lands and Easements; Reports and Tests

A. Owner's duties in respect of providing lands and easements and providing engineering surveys to establish reference points are set forth in Paragraphs 4.01 and 4.05. Paragraph 4.02 refers to Owner's identifying and making available to Contractor copies of reports of explorations and tests of subsurface conditions and drawings of physical conditions in or relating to existing surface or subsurface structures at or contiguous to the Site that have been utilized by Engineer in preparing the Contract Documents.

Section 8.06 Insurance

A. Owner's responsibilities, if any, in respect to purchasing and maintaining liability and property insurance are set forth in Article 5.

Section 8.07 Change Orders

A. Owner is obligated to execute Change Orders as indicated in Paragraph 10.03.

Section 8.08 Inspections, Tests, and Approvals

A. Owner's responsibility in respect to certain inspections, tests, and approvals is set forth in Paragraph 13.03.B.

Section 8.09 Limitations on Owner's Responsibilities

A. The Owner shall not supervise, direct, or have control or authority over, nor be responsible for, Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work. Owner will not be responsible for Contractor's failure to perform the Work in accordance with the Contract Documents.

Section 8.10 Undisclosed Hazardous Environmental Condition

A. Owner's responsibility in respect to an undisclosed Hazardous Environmental Condition is set forth in Paragraph 4.06.

Section 8.11 Evidence of Financial Arrangements

A. If and to the extent Owner has agreed to furnish Contractor reasonable evidence that financial arrangements have been made to satisfy Owner's obligations under the Contract Documents, Owner's responsibility in respect thereof will be as set forth in the Supplementary Conditions.

ARTICLE 9. CONSTRUCTION MANAGER'S AND ENGINEER'S STATUS DURING CONSTRUCTION

Section 9.01 Owner's Representative

A. Construction Manager and Engineer will be Owner's representatives during the construction period. The duties and responsibilities and the limitations of authority of Construction Manager and Engineer as Owner's representatives during construction are set forth in the Contract Documents and will not be changed without written consent of Owner, Construction Manager and Engineer.

Section 9.02 Visits to Site

A. Engineer may make visits to the Site at intervals appropriate to the various stages of construction as Engineer deems necessary in order to observe as an experienced and qualified design professional the progress that has been made and the quality of the various aspects of Contractor's executed Work. Based on information obtained during such visits and observations, Engineer, for the benefit of Owner, will determine, in general, if the Work is proceeding in accordance with the Contract Documents. Engineer will not be required to make exhaustive or continuous inspections on the Site to check the quality or quantity of the Work. Engineer's efforts will be directed toward providing for Owner a greater degree of confidence that the completed Work will conform generally to the Contract Documents. On the basis of such visits and observations, Engineer will endeavor to guard Owner against defective Work.

B. Construction Manager will make visits to the Site at intervals appropriate to the various stages of construction as Construction Manager deems necessary in order to observe the progress that has been made and the quality of the various aspects of Contractor's executed Work. Based on information obtained during such visits and observations, Construction Manager, for the benefit of Owner, will determine, in general, if the Work is proceeding in accordance with the Contract Documents. Construction Manager will not be required to make exhaustive or continuous inspections on the Site to check the quality or quantity of the Work. Construction Manager's efforts will be directed toward providing for Owner a greater degree of confidence that the completed Work will conform generally to the Contract Documents. On the basis of such visits and observations, Construction Manager will keep Owner informed of the progress of the Work, and will endeavor to guard Owner against defective Work.

C. Engineer's and Construction Manager's visits and observations are subject to all the limitations on

Engineer's authority and responsibility set forth in Paragraph 9.09. Particularly, but without limitation, during or as a result of Engineer's visits or observations of Contractor's Work Engineer will not supervise, direct, control, or have authority over or be responsible for Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work.

Section 9.03 Construction Manager's Project Representative

A. If Owner and Construction Manager agree, Construction Manager will furnish a Resident Project Representative to assist Construction Manager in providing more extensive observation of the Work. The authority and responsibilities of any such Resident Project Representative and assistants will be as provided in the Supplementary Conditions, and limitations on the responsibilities thereof will be as provided in Paragraph 9.09. If Owner designates another representative or agent to represent Owner at the Site who is not Construction Manager's consultant, agent or employee, the responsibilities and authority and limitations thereon of such other individual or entity will be as provided in the Supplementary Conditions.

B. Construction Manager's Resident Project Representative shall not authorize any deviation from the Contract Documents or substitutions of materials or equipment.

Section 9.04 Authorized Variations in Work

A. Construction Manager or Engineer may authorize minor variations in the Work from the requirements of the Contract Documents which do not involve an adjustment in the Contract Price or the Contract Times and are compatible with the design concept of the completed Project as a functioning whole as indicated by the Contract Documents. These may be accomplished by a Field Order and will be binding on Owner and also on Contractor, who shall perform the Work involved promptly. If Owner or Contractor believes that a Field Order justifies an adjustment in the Contract Price or Contract Times, or both, and the parties are unable to agree on entitlement to or on the amount or extent, if any, of any such adjustment, a Claim may be made therefor as provided in Paragraph 10.05.

Section 9.05 Rejecting Defective Work

A. Construction Manager will have authority to reject Work which Construction Manager or Engineer believes to be defective, or that Construction Manager or Engineer believes will not produce a completed Project that conforms to the Contract Documents or that will prejudice the integrity of the design concept of the completed Project as a functioning whole as indicated by the Contract Documents. Construction Manager will also have authority to require special inspection or testing of the Work as provided in Paragraph 13.04, whether or not the Work is fabricated, installed, or completed.

B. The acceptance at any time of materials or equipment by or on behalf of Owner shall not be a bar to future rejection if they are subsequently found to be defective, inferior in quality, or not equal to the material or equipment specified, or are not as represented to Construction Manager, Engineer or Owner.

Section 9.06 Shop Drawings, Change Orders and Payments

A. In connection with Engineer's authority, and limitations thereof, as to Shop Drawings and Samples, see Paragraph 6.17.

B. In connection with Engineer's authority, and limitations thereof, as to design calculations and design drawings submitted in response to a delegation of professional design services, if any, see Paragraph 6.21.

C. In connection with Engineer's authority as to Change Orders, see Articles 10, 11, and 12.

D. In connection with Construction Manager's authority as to Applications for Payment, see Article 14.

Section 9.07 Determinations for Unit Price Work

A. Construction Manager will determine the actual quantities and classifications of Unit Price Work performed by Contractor. Construction Manager will review with Contractor the Engineer's preliminary determinations on such matters before rendering a written decision thereon (by recommendation of an Application for Payment or otherwise). Construction Manager's written decision thereon will be final and binding (except as modified by Construction Manager to reflect changed factual conditions or more accurate data) upon Owner and Contractor, subject to the provisions of Paragraph 10.05.

Section 9.08 Decisions on Requirements of Contract Documents and Acceptability of Work

A. Engineer will be the initial interpreter of the requirements of the Contract Documents with respect to matters of design intent. Construction Manager will be the initial interpreter of the requirements of the Contract Documents with respect to administrative matters and judge of the acceptability of the Work thereunder. All matters in question and other matters between Owner and Contractor arising prior to the date final payment is due relating to the acceptability of the Work, and the interpretation of the requirements of the Contract Documents pertaining to the performance of the Work, will be referred initially to Construction Manager in writing within 30 days of the event giving rise to the question.

B. Construction Manager or Engineer through Construction Manager will, with reasonable promptness, render a written decision on the issue referred. If Owner or Contractor believe that any such decision entitles them to an adjustment in the Contract Price or Contract Times or both, a Claim may be made under Paragraph 10.05. The date of Construction Manager's or Engineer's decision shall be the date of the event giving rise to the issues referenced for the purposes of Paragraph 10.05.B.

C. Construction Manager's or Engineer's written decision on the issue referred will be final and binding on Owner and Contractor, subject to the provisions of Paragraph 10.05.

D. When functioning as interpreter and judge under this Paragraph 9.08, Construction Manager and Engineer will not show partiality to Owner or Contractor and will not be liable in connection with any interpretation or decision rendered in good faith in such capacity.

Section 9.09 Limitations on Construction Manager's and Engineer's Authority and Responsibilities

A. Neither Construction Manager's and Engineer's authority or responsibility under this Article 9 or under any other provision of the Contract Documents nor any decision made by Construction Manager or Engineer in good faith either to exercise or not exercise such authority or responsibility or the undertaking, exercise, or performance of any authority or responsibility by Construction Manager or Engineer shall create, impose, or give rise to any duty in contract, tort, or otherwise owed by Construction Manager or Engineer to Contractor, any Subcontractor, any Supplier, any other individual or entity, or to any surety for or employee or agent of any of them.

B. Construction Manager and Engineer will not supervise, direct, control, or have authority over or be responsible for Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work. Construction Manager and Engineer will not be responsible for Contractor's failure to perform the Work in accordance with the Contract Documents.

C. Construction Manager and Engineer will not be responsible for the acts or omissions of Contractor or of any Subcontractor, any Supplier, or of any other individual or entity performing any of the Work.

D. Construction Manager's review of the final Application for Payment and accompanying documentation and all maintenance and operating instructions, schedules, guarantees, bonds, certificates of inspection, tests and approvals, and other documentation required to be delivered by Paragraph 14.07.A will only be to determine generally that their content complies with the requirements of, and in the case of certificates

of inspections, tests, and approvals that the results certified indicate compliance with the Contract Documents.

E. The limitations upon authority and responsibility set forth in this Paragraph 9.09 shall also apply to, the Resident Project Representative, if any, and assistants, if any.

ARTICLE 10. CHANGES IN THE WORK; CLAIMS

Section 10.01 Authorized Changes in the Work

A. Without invalidating the Contract and without notice to any surety, Owner may, at any time or from time to time, order additions, deletions, or revisions in the Work by a Change Order or a Work Change Directive. Upon receipt of any such document, Contractor shall promptly proceed with the Work involved which will be performed under the applicable conditions of the Contract Documents (except as otherwise specifically provided).

1. Change Proposal Request:

a. When Owner requests Contractor to present a proposal to accomplish a change in the Work, the request will be made in the form of a Change Proposal Request (CPR) prepared by Construction Manager. The CPR will describe the change and request Contractor to propose a cost and Contract Price and/or Contract Time change. Contractor will propose cost and/or time changes, if any, sign the CPR and return it to Construction Manager. If requested by Owner or Construction Manager, Contractor shall provide an itemized breakdown of the cost of the change. Construction Manager will make recommendations to Owner concerning acceptance. If the CPR is approved by Owner, the CPR will be included in a Change Order. Contractor is not authorized to proceed with a change contained in a CPR until the Change Order is properly signed and issued in conformance with the Owner’s purchasing policies.

b. When the Contractor desires to propose changes to the Work, it may initiate a CPR in the same form as provided in Paragraph 10.01A.1.a. and submit the CPR to the Construction Manager for the Engineer's review and recommendation.

2. Work Change Directive:

a. The Owner may issue a work change directive as an order to perform additional work that is deemed necessary if the Owner and Contractor cannot agree upon a cost or schedule for proposed additional work or when they agree that delays could cause damage such that work must proceed immediately. Work change directives are valid if signed by a signatory approved by Owner. The Owner’s signatory may authorize a work change directive for work on a Not-to-Exceed basis, where the Engineer’s estimate for probable cost for said work is within the signatory’s authority and threshold in conformance of the City’s purchasing policies. Upon issuance of a valid Work Change Directive, Contractor shall proceed with work. A work change directive shall be followed by a valid change order for an agreed upon or force account adjustment to Contract payment or schedule for the additional work, as provided in Section 12.01.

3. Force Account:

a. Work paid for by force account may be authorized by Owner under a valid work change directive. For work paid by force account, the Construction Manager compares the Owner’s records to Contractor’s daily force-account work report. When the Contractor and the Owner agree on the contents of the daily force-account work reports, the Owner accepts the report and the Owner pays for the work. If the records differ, the Owner pays for the work based only on the information shown on the Owner's records. If a subcontractor performs work at force account, the markups specified for labor, materials, and equipment include compensation for all delay costs, overhead

costs, and profit. If an item's unit price is adjusted for work-character changes, the Owner excludes Contractor's cost of determining the adjustment. Payment for owner-operated labor and equipment is made at the market-priced invoice submitted.

B. If the Owner chooses to pay for change order work based on an agreed price, but Contractor and the Owner cannot agree on the price, the Owner may choose to pay by force account. If a portion of extra work is covered by bid items, the Owner pays for this work as changed quantities in those items. The Owner pays for the remaining portion of the extra work by force account or agreed price.

C. Force account work shall conform to this Agreement, including the articles of these general conditions. In cases where this Agreement does not specify applicable requirements, terms or conditions, force account work shall conform to those applicable requirements as set forth in the most current version of Section 9-1.04 of the California Department of Transportation Standard Specifications.

D. If Owner and Contractor are unable to agree on entitlement to, or on the amount or extent, if any, of an adjustment in the Contract Price or Contract Times, or both, that should be allowed as a result of a Work Change Directive, a Claim may be made therefor as provided in Paragraph 10.05.

Section 10.02 Unauthorized Changes in the Work

A. Contractor shall not be entitled to an increase in the Contract Price or an extension of the Contract Times with respect to any work performed that is not required by the Contract Documents as amended, modified, or supplemented as provided in Paragraph 3.04, except in the case of an emergency as provided in Paragraph 6.16 or in the case of uncovering Work as provided in Paragraph 13.04.B.

Section 10.03 Execution of Change Orders

A. It is at the sole discretion of the City Council, or a delegate explicitly authorized by City Council, to execute Change Orders. The City and the Construction Manager will review all change orders, and, if the changes are deemed reasonable and appropriate by the City, the City will proceed to execute the appropriate change orders accordingly. Change orders recommended by the Construction Manager to the City shall consist of:

1. changes in the Work which are: (i) ordered by Owner pursuant to Paragraph 10.01.A, (ii) required because of acceptance of defective Work under Paragraph 13.08.A or Owner's correction of defective Work under Paragraph 13.09, or (iii) agreed to by the parties;

2. changes in the Contract Price or Contract Times which are agreed to by the parties, including any undisputed sum or amount of time for Work actually performed in accordance with a Work Change Directive; and

3. changes in the Contract Price or Contract Times which embody the substance of any written decision rendered by Construction Manager or by Engineer through Construction Manager pursuant to Paragraph 10.05; provided that, in lieu of executing any such Change Order, an appeal may be taken from any such decision in accordance with the provisions of the Contract Documents and applicable Laws and Regulations, but during any such appeal, Contractor shall carry on the Work and adhere to the Progress Schedule as provided in Paragraph 6.18.A.

Section 10.04 Notification to Surety

A. If notice of any change affecting the general scope of the Work or the provisions of the Contract Documents (including, but not limited to, Contract Price or Contract Times) is required by the provisions of any bond to be given to a surety, the giving of any such notice will be Contractor's responsibility. The amount of each applicable bond will be adjusted to reflect the effect of any such change.

Section 10.05 Claims

A. *Construction Manager's Decision Required:* All Claims, except those waived pursuant to Paragraph 14.09, shall be referred to the Construction Manager for decision. A decision by Construction Manager shall be required as a condition precedent to any exercise by Owner or Contractor of any rights or remedies either may otherwise have under the Contract Documents or by Laws and Regulations in respect of such Claims.

B. *Notice*: Written notice stating the general nature of each Claim shall be delivered by the claimant to Construction Manager and the other party to the Contract promptly (but in no event later than 30 days) after the start of the event giving rise thereto. The responsibility to substantiate a Claim shall rest with the party making the Claim. Notice of the amount or extent of the Claim, with supporting data shall be delivered to the Construction Manager and the other party to the Contract within 60 days after the start of such event (unless Construction Manager allows additional time for claimant to submit additional or more accurate data in support of such Claim). A Claim for an adjustment in Contract Price shall be prepared in accordance with the provisions of Paragraph 12.01.B. A Claim for an adjustment in Contract Time shall be prepared in accordance with the provisions of Paragraph 12.02.B. Each Claim shall be accompanied by claimant's written statement that the adjustment claimed is the entire adjustment to which the claimant believes it is entitled as a result of said event. The opposing party shall submit any response to Construction Manager and the claimant within thirty (30) days after receipt of the claimant's last submittal (unless Construction Manager allows additional time).

C. *Construction Manager's Action:* Construction Manager will review each Claim and, within thirty (30) days after receipt of the last submittal of the claimant or the last submittal of the opposing party, if any, take one of the following actions in writing:

   1. deny the Claim in whole or in part,
   2. recommend approval of the Claim to the City, or
   3. notify the parties that the Construction Manager is unable to resolve the Claim if, in the Construction Manager's sole discretion, it would be inappropriate for the Construction Manager to do so. For purposes of further resolution of the Claim, such notice shall be deemed a denial.

D. In the event that Construction Manager does not take action on a Claim within said thirty (30) days, the Claim shall be deemed denied.

E. Construction Manager's written action under Paragraph 10.05.C or denial pursuant to Paragraphs 10.05.C.3 or 10.05.D will be final and binding upon Owner and Contractor, unless Owner or Contractor invoke the dispute resolution procedure set forth in Article 16 within thirty (30) days of such action or denial.

F. No Claim for an adjustment in Contract Price or Contract Times will be valid if not submitted in accordance with this Paragraph 10.05.

ARTICLE 11. COST OF THE WORK; ALLOWANCES; UNIT PRICE WORK

Section 11.01 Cost of the Work

A. *Costs Included*: The term Cost of the Work means the sum of all costs, except those excluded in Paragraph 11.01.B, necessarily incurred and paid by Contractor in the proper performance of the Work, or the reasonable cost that would have been incurred in the case of deleted Work. When the value of any Work covered by a Change Order or when a Claim for an adjustment in Contract Price is determined on the basis of Cost of the Work, the costs to be reimbursed to Contractor will be only those additional or incremental costs required because of the change in the Work or because of the event giving rise to the Claim. Except

as otherwise may be agreed to in writing by Owner, such costs shall be in amounts no higher than those prevailing in the locality of the Project, shall include only the following items, and shall not include any of the costs itemized in Paragraph 11.01.B.

1. Payroll costs for employees in the direct employ of Contractor in the performance of the Work under schedules of job classifications agreed upon by Owner and Contractor. Such employees shall include, without limitation, superintendents, foremen, and other personnel employed full time at the Site. Payroll costs for employees not employed full time on the Work shall be apportioned on the basis of their time spent on the Work. Payroll costs shall include, but not be limited to, salaries and wages plus the cost of fringe benefits, which shall include social security contributions, unemployment, excise, and payroll taxes, workers' compensation, training, health and retirement benefits, bonuses, sick leave, vacation and holiday pay applicable thereto. The expenses of performing Work outside of regular working hours, on Saturday, Sunday, or legal holidays, shall be included in the above. For Change Order pricing, the Labor Surcharge (social security contributions, unemployment excise, and payroll taxes) shall be twenty-seven (27) percent of the sum of the wages, vacation, and fringe benefits (workers' compensation, training, health and retirement benefits, sick leave, bonuses, and holiday pay).
2. Cost of all materials and equipment furnished and incorporated in the Work, including costs of transportation and storage thereof, and Suppliers' field services required in connection therewith. All cash discounts shall accrue to Contractor unless Owner deposits funds with Contractor with which to make payments, in which case the cash discounts shall accrue to Owner. All trade discounts, rebates and refunds and returns from sale of surplus materials and equipment shall accrue to Owner, and Contractor shall make provisions so that they may be obtained.
3. Payments made by Contractor to Subcontractors for Work performed by Subcontractors. If required by Owner, Contractor shall obtain competitive bids from subcontractors acceptable to Owner and Contractor and shall deliver such bids to Owner, who will then determine, with the advice of Construction Manager, which bids, if any, will be acceptable. If any subcontract provides that the Subcontractor is to be paid on the basis of Cost of the Work plus a fee, the Subcontractor's Cost of the Work and fee shall be determined in the same manner as Contractor's Cost of the Work and fee as provided in this Paragraph 11.01.
4. Costs of special consultants (including but not limited to engineers, architects, testing laboratories, surveyors, attorneys, and accountants) employed for services specifically related to the Work.
5. Supplemental costs including the following:
    a. The proportion of necessary transportation, travel, and subsistence expenses of Contractor's employees incurred in discharge of duties connected with the Work.
    b. Cost, including transportation and maintenance, of all materials, supplies, equipment, machinery, appliances, office, and temporary facilities at the Site, and hand tools not owned by the workers, which are consumed in the performance of the Work, and cost, less market value, of such items used but not consumed which remain the property of Contractor.
    c. Rentals of all construction equipment and machinery, and the parts thereof whether rented from Contractor or others in accordance with rental agreements approved by Owner with the advice of Construction Manager, and the costs of transportation, loading, unloading, assembly, dismantling, and removal thereof. All such costs shall be in accordance with the terms of said rental agreements. The rental of any such equipment, machinery, or parts shall cease when the use thereof is no longer necessary for the Work.
    d. Sales, consumer, use, and other similar taxes related to the Work, and for which Contractor is liable, imposed by Laws and Regulations.

e. Deposits lost for causes other than negligence of Contractor, any Subcontractor, or anyone directly or indirectly employed by any of them or for whose acts any of them may be liable, and royalty payments and fees for permits and licenses.

f. Losses and damages (and related expenses) caused by damage to the Work, not compensated by insurance or otherwise, sustained by Contractor in connection with the performance of the Work (except losses and damages within the deductible amounts of property insurance established in accordance with Paragraph 5.06.D), provided such losses and damages have resulted from causes other than the negligence of Contractor, any Subcontractor, or anyone directly or indirectly employed by any of them or for whose acts any of them may be liable. Such losses shall include settlements made with the written consent and approval of Owner. No such losses, damages, and expenses shall be included in the Cost of the Work for the purpose of determining Contractor's fee.

g. The cost of utilities, fuel, and sanitary facilities at the Site.

h. Minor expenses such as telegrams, long distance telephone calls, telephone service at the Site, expresses, and similar petty cash items in connection with the Work.

i. The costs of premiums for all bonds and insurance Contractor is required by the Contract Documents to purchase and maintain. For Change Order pricing, bonds and insurance shall be 1 percent of the Change Order value for both additive and credit changes that are above the original Contract value and 0 percent of the Change Order value for both additive and credit changes that are below the original Contract value.

B. *Costs Excluded:* The term Cost of the Work shall not include any of the following items:

1. Payroll costs and other compensation of Contractor's officers, executives, principals (of partnerships and sole proprietorships), general managers, safety managers, engineers, architects, estimators, attorneys, auditors, accountants, purchasing and contracting agents, expediters, timekeepers, clerks, and other personnel employed by Contractor, whether at the Site or in Contractor's principal or branch office for general administration of the Work and not specifically included in the agreed upon schedule of job classifications referred to in Paragraph 11.01.A.1 or specifically covered by Paragraph 11.01.A.4, all of which are to be considered administrative costs covered by the Contractor's fee.

2. Expenses of Contractor's principal and branch offices other than Contractor's office at the Site.

3. Any part of Contractor's capital expenses, including interest on Contractor's capital employed for the Work and charges against Contractor for delinquent payments.

4. Costs due to the negligence of Contractor, any Subcontractor, or anyone directly or indirectly employed by any of them or for whose acts any of them may be liable, including but not limited to, the correction of defective Work, disposal of materials or equipment wrongly supplied, and making good any damage to property.

5. Other overhead or general expense costs of any kind and the costs of any item not specifically and expressly included in Paragraphs 11.01.A and 11.01.B.

C. *Contractor's Fee*: When all the Work is performed on the basis of cost-plus, Contractor's fee shall be determined as set forth in the Agreement. When the value of any Work covered by a Change Order or when a Claim for an adjustment in Contract Price is determined on the basis of Cost of the Work, Contractor's fee shall be determined as set forth in Paragraph 12.01.C.

D. *Documentation:* Whenever the Cost of the Work for any purpose is to be determined pursuant to Paragraphs 11.01.A and 11.01.B, Contractor will establish and maintain records thereof in accordance with generally accepted accounting practices and submit in a form acceptable to Construction Manager an

itemized cost breakdown together with supporting data.

Section 11.02 Allowances

A. It is understood that Contractor has included in the Contract Price all allowances so named in the Contract Documents and shall cause the Work so covered to be performed for such sums and by such persons or entities as may be acceptable to Owner and Construction Manager.

B. Cash Allowances

1. Contractor agrees that:

a. the cash allowances include the cost to Contractor (less any applicable trade discounts) of materials and equipment required by the allowances to be delivered at the Site, and all applicable taxes; and

b. Contractor's costs for unloading and handling on the Site, labor, installation , overhead, profit, and other expenses contemplated for the cash allowances have been included in the Contract Price and not in the allowances, and no demand for additional payment on account of any of the foregoing will be valid.

C. Contingency Allowance

1. Contractor agrees that a contingency allowance, if any, is for the sole use of Owner to cover unanticipated costs.

D. Prior to final payment, an appropriate Change Order will be issued as recommended by Construction Manger to reflect actual amounts due Contractor on account of Work covered by allowances, and the Contract Price shall be correspondingly adjusted.

Section 11.03 Unit Price Work

A. Where the Contract Documents provide that all or part of the Work is to be Unit Price Work, initially the Contract Price will be deemed to include for all Unit Price Work an amount equal to the sum of the unit price for each separately identified item of Unit Price Work times the estimated quantity of each item as indicated in the Agreement.

B. The estimated quantities of items of Unit Price Work are not guaranteed and are solely for the purpose of comparison of Bids and determining an initial Contract Price. Determinations of the actual quantities and classifications of Unit Price Work performed by Contractor will be made by Construction Manager subject to the provisions of Paragraph 9.07.

C. Each unit price will be deemed to include an amount considered by Contractor to be adequate to cover Contractor's overhead and profit for each separately identified item. Work described in the Contract Documents, or reasonably inferred as required for a functionally complete installation, but not identified in the listing of unit price items shall be considered incidental to unit price work listed and the cost of incidental work included as a part of the unit price.

D. Owner or Contractor may make a Claim for an adjustment in the Contract Price in accordance with Paragraph 10.05 if:

1. the total cost of a particular item of Unit Price Work amounts to ten percent (10%) or more of the Contract Price at time of Notice of Award and the variation in the quantity of that particular item of Unit Price Work performed by Contractor differs by more than twenty-five percent (25%) from the estimated quantity of such item indicated in the Agreement; and if there is no corresponding adjustment with respect to any other item of Work; and if Contractor believes that Contractor has incurred additional expense as a result thereof; or if Owner believes that the quantity variation entitles Owner to an adjustment in the unit price, either Owner or Contractor may make a claim for an

adjustment in the Contract Price in accordance with Article 11 if the parties are unable to agree as to the effect of any such variations in the quantity of Unit Price Work performed.; and

2. there is no corresponding adjustment with respect any other item of Work; and

3. Contractor believes that Contractor is entitled to an increase in Contract Price as a result of having incurred additional expense or Owner believes that Owner is entitled to a decrease in Contract Price and the parties are unable to agree as to the amount of any such increase or decrease.

ARTICLE 12. CHANGE OF CONTRACT PRICE; CHANGE OF CONTRACT TIMES

Section 12.01 Change of Contract Price

A. The Contract Price may only be changed by a Change Order. Any Claim for an adjustment in the Contract Price shall be based on written notice submitted by the party making the Claim to the Construction Manager and the other party to the Contract in accordance with the provisions of Paragraph 10.05.

B. The value of any Work covered by a Change Order or of any Claim for an adjustment in the Contract Price will be determined as follows:

1. where the Work involved is covered by unit prices contained in the Contract Documents, by application of such unit prices to the quantities of the items involved (subject to the provisions of Paragraph 11.03); or

2. where the Work involved is not covered by unit prices contained in the Contract Documents, by a mutually agreed lump sum including overhead and profit not necessarily in accordance with Paragraph 12.01.C.2, and shall include the cost of any secondary impacts that are foreseeable at the time of pricing the cost of extra Work; or

3. where the Work involved is not covered by unit prices contained in the Contract Documents and agreement to a lump sum is not reached under Paragraph 12.01.B.2, on the basis of the Cost of the Work (either by estimate before the work is performed or force account) plus a Contractor's fee for overhead and profit (determined as provided in Paragraph 12.01.C).

C. Contractor's Fee: The Contractor's fee for overhead and profit shall be determined as follows:

1. a mutually acceptable fixed fee; or

2. if a fixed fee is not agreed upon, then a fee based on the following percentages of the various portions of the Cost of the Work:

a. for costs incurred under Paragraphs 11.01.A.1 and 11.01.A.2, the Contractor's fee shall be fifteen percent (15%);

b. for costs incurred under Paragraph 11.01.A.3, the Contractor's fee shall be five percent (15%);

c. where one or more tiers of subcontracts are on the basis of Cost of the Work plus a fee and no fixed fee is agreed upon, the intent of Paragraph 12.01.C.2.a is that the Subcontractor who actually performs the Work, at whatever tier, will be paid a fee of fifteen percent (15%) of the costs incurred by such Subcontractor under Paragraphs 11.01.A.1 and 11.01.A.2 and that any higher tier Subcontractor and Contractor will each be paid a fee of five percent (5%) of the amount paid to the next lower tier Subcontractor;

d. no fee shall be payable on the basis of costs itemized under Paragraphs 11.01.A.4, 11.01.A.5, and 11.01.B;

e. the amount of credit to be allowed by Contractor to Owner for any change which results in a net decrease in cost will be the amount of the reasonable cost that would have been incurred to perform

the Work plus a deduction in Contractor's fee by an amount equal to five percent (5%) of such net decrease; and

f. when both additions and credits are involved in any one change, the adjustment in Contractor's fee shall be computed on the basis of the net change in accordance with Paragraphs 12.01.C.2.a through 12.01.C.2.e, inclusive.

g. costs and mark up percentages for force account work shall conform to this Agreement, including the articles of these general conditions. In cases where this Agreement does not specify applicable requirements, terms or conditions, force account work shall conform to those applicable requirements as set forth in the most current version of Section 9-1.04 of the California Department of Transportation Standard Specifications and the California Department of Transportation Labor Surcharge and Equipment Rental Rates.

Section 12.02 Change of Contract Times

A. The Contract Times may only be changed by a Change Order. Any Claim for an adjustment in the Contract Times shall be based on written notice submitted by the party making the Claim to the Construction Manager and the other party to the Contract in accordance with the provisions of Paragraph 10.05.

B. Any adjustment of the Contract Times covered by a Change Order or any Claim for an adjustment in the Contract Times will be determined in accordance with the provisions of this Article 12.

C. No extension of the Contract Time will be allowed for additional Work or for claimed delay unless the additional Work contemplated or claimed delay is shown to be on the critical path of the Project's schedule of construction or Contractor can show by Critical Path Method analysis how the additional Work or claimed delay adversely affects the critical path.

Section 12.03 Delays

A. Where Contractor is prevented from completing any part of the Work within the Contract Times due to delay beyond the control of Contractor, the Contract Times will be extended in an amount equal to the time lost due to such delay if a Claim is made therefor as provided in Paragraph 12.02.A. Delays beyond the control of Contractor shall include, but not be limited to, acts or neglect by Owner, acts or neglect of utility owners or other contractors performing other work as contemplated by Article 7, fires, floods, epidemics, abnormal weather conditions, or acts of God.

B. If Owner, Construction Manager, Engineer, or other contractors or utility owners performing other work for Owner as contemplated by Article 7, or anyone for whom Owner is responsible, delays, disrupts, or interferes with the performance or progress of the Work, then Contractor shall be entitled to an equitable adjustment in the Contract Price or the Contract Times, or both. Contractor's entitlement to an adjustment of the Contract Times is conditioned on such adjustment being essential to Contractor's ability to complete the Work within the Contract Times.

C. If Contractor is delayed in the performance or progress of the Work by fire, flood, epidemic, abnormal weather conditions, acts of God, acts or failures to act of utility owners not under the control of Owner, or other causes not the fault of and beyond control of Owner and Contractor, then Contractor shall be entitled to an equitable adjustment in Contract Times, if such adjustment is essential to Contractor's ability to complete the Work within the Contract Times. Such an adjustment shall be in accordance with Paragraph 12.02 C, and shall be Contractor's sole and exclusive remedy for the delays described in this Paragraph 12.03.C.

D. Owner, Construction Manager, Engineer and the Related Entities of each of them shall not be liable to Contractor for any claims, costs, losses, or damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) sustained by Contractor on or in connection with any other project or anticipated project.

E. Contractor shall not be entitled to an adjustment in Contract Price or Contract Times for delays within the control of Contractor, or for concurrent delays. Delays attributable to and within the control of a Subcontractor or Supplier shall be deemed to be delays within the control of Contractor.

ARTICLE 13. TESTS AND INSPECTIONS; CORRECTION, REMOVAL OR ACCEPTANCE OF DEFECTIVE WORK

Section 13.01 Notice of Defects

A. Prompt notice of all defective Work of which Owner or Engineer has actual knowledge will be given to Contractor. All defective Work may be rejected, corrected, or accepted as provided in this Article 13.

Section 13.02 Access to Work

A. Owner, Construction Manager, Engineer, their consultants and other representatives and personnel of Owner, independent testing laboratories, and governmental agencies with jurisdictional interests will have access to the Site and the Work at reasonable times for their observation, inspecting, and testing. Contractor shall provide them proper and safe conditions for such access and advise them of Contractor's Site safety procedures and programs so that they may comply therewith as applicable.

Section 13.03 Tests and Inspections

A. Contractor shall give Construction Manager timely notice of readiness of the Work in accordance with the Contract Documents for all required inspections, tests, or approvals and shall cooperate with inspection and testing personnel to facilitate required inspections or tests.

B. Owner shall employ and pay for the services of an independent testing laboratory to perform Quality Assurance inspections, tests, or approvals on behalf of the Owner as specified under the Contract Documents except:

1. for inspections, tests, or approvals covered by Paragraphs 13.03.C and 13.03.D below;
2. that costs incurred in connection with tests or inspections conducted pursuant to Paragraph 13.04.B shall be paid as provided in said Paragraph 13.04.C; and
3. as otherwise specifically provided in the Contract Documents.

C. All inspection and testing required to maintain the contractor's quality control and execute the construction in conformance with the Contract Documents are the contractors responsibility. Where the contractor fails to meet quality assurance requirements, and additional inspection, testing or approvals are necessary to provide the required quality assurance as specified in the Contract Documents, the contractor shall bear the cost for said additional inspection, testing or approvals.

D. If Laws or Regulations of any public body having jurisdiction require any Work (or part thereof) specifically to be inspected, tested, or approved by an employee or other representative of such public body, Contractor shall assume full responsibility for arranging and obtaining such inspections, tests, or approvals, pay all costs in connection therewith, and furnish Engineer the required certificates of inspection or approval.

E. Contractor shall be responsible for arranging and obtaining and shall pay all costs in connection with any inspections, tests, or approvals required for Owner's and Construction Manager's acceptance of materials or equipment to be incorporated in the Work; or acceptance of materials, mix designs, or equipment submitted for approval prior to Contractor's purchase thereof for incorporation in the Work. Such inspections, tests, or approvals shall be performed by organizations acceptable to Owner and Construction Manager.

F. If any Work (or the work of others) that is to be inspected, tested, or approved is covered by Contractor without written concurrence of Construction Manager, it must, if requested by Construction Manager, be uncovered for observation.

G. Uncovering Work as provided in Paragraph 13.03.E shall be at Contractor's expense unless Contractor has given Construction Manager timely notice of Contractor's intention to cover the same and Construction Manager has not acted with reasonable promptness in response to such notice.

Section 13.04 Uncovering Work

A. If any Work is covered prior to the specified inspection, testing or approvals required in the Contract Documents or contrary to the written request of Construction Manager, it must, if requested by Construction Manager, be uncovered for Construction Manager's observation and replaced at Contractor's expense.

B. If Construction Manager considers it necessary or advisable that covered Work be observed by Construction Manager or inspected or tested by others, Contractor, at Construction Manager's request, shall uncover, expose, or otherwise make available for observation, inspection, or testing as Construction Manager may require, that portion of the Work in question, furnishing all necessary labor, material, and equipment.

C. If it is found that the uncovered Work is defective, Contractor shall pay all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to such uncovering, exposure, observation, inspection, and testing, and of satisfactory replacement or reconstruction (including but not limited to all costs of repair or replacement of work of others); or Owner shall be entitled to accept defective Work in accordance paragraph 13.08 in which case Contractor shall still be responsible for all costs associated with exposing, observing, and testing the defective Work. If the parties are unable to agree as to the amount thereof, Owner may make a Claim therefor as provided in Paragraph 10.05.

D. If the uncovered Work, which had previously been inspected, tested or approved by the as specified and was deemed by the Engineer and Construction Manager to conform with the requirements set forth in the Contract Documents, is not found to be defective, Contractor shall be allowed an increase in the Contract Price or an extension of the Contract Times, or both, directly attributable to such uncovering, exposure, observation, inspection, testing, replacement, and reconstruction. If the parties are unable to agree as to the amount or extent thereof, Contractor may make a Claim therefor as provided in Paragraph 10.05.

Section 13.05 Owner May Stop the Work

A. If the Work is defective, or Contractor fails to supply sufficient skilled workers or suitable materials or equipment, or fails to perform the Work in such a way that the completed Work will conform to the Contract Documents, Owner may order Contractor to stop the Work, or any portion thereof, until the cause for such order has been eliminated; however, this right of Owner to stop the Work shall not give rise to any duty on the part of Owner to exercise this right for the benefit of Contractor, any Subcontractor, any Supplier, any other individual or entity, or any surety for, or employee or agent of any of them.

Section 13.06 Correction or Removal of Defective Work

A. Promptly after receipt of notice, Contractor shall correct all defective Work, whether or not fabricated, installed, or completed, or, if the Work has been rejected by Construction Manager or Engineer, remove it from the Project and replace it with Work that is not defective. Contractor shall pay all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to such correction or removal (including but not limited to all costs of repair or replacement of

work of others).

B. When correcting defective Work under the terms of this Paragraph 13.06 or Paragraph 13.07, Contractor shall take no action that would void or otherwise impair Owner's special warranty and guarantee, if any, on said Work.

Section 13.07 Correction Period

A. If within one year after the date of Final Acceptance of the Work by Owner (or such longer period of time as may be prescribed by the terms of any applicable special guarantee required by the Contract Documents) or by any specific provision of the Contract Documents, any Work is found to be defective, or if the repair of any damages to the land or areas made available for Contractor's use by Owner or permitted by Laws and Regulations as contemplated in Paragraph 6.11.A is found to be defective, Contractor shall promptly, without cost to Owner and in accordance with Owner's written instructions:

1. repair such defective land or areas; or
2. correct such defective Work; or
3. if the defective Work has been rejected by Owner, remove it from the Project and replace it with Work that is not defective,
4. satisfactorily correct or repair or remove and replace any damage to other Work, to the work of others or other land or areas resulting therefrom, and
5. Contractor shall provide a Warranty Form to the Owner with all appropriate Contractor contact information for the Owners Staff to contact the Contractor in relation to warranty items.

B. If Contractor does not promptly comply with the terms of Owner's written instructions, or in an emergency where delay would cause serious risk of loss or damage, Owner may have the defective Work corrected or repaired or may have the rejected Work removed and replaced. All claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) arising out of or relating to such correction or repair or such removal and replacement (including but not limited to all costs of repair or replacement of work of others) will be paid by Contractor.

C. In special circumstances where a particular item of equipment is placed in continuous service before Substantial Completion of all the Work, the correction period for that item may start to run from an earlier date if so provided in the Specifications.

D. Where defective Work (and damage to other Work resulting therefrom) has been corrected or removed and replaced under this Paragraph 13.07, the correction period hereunder with respect to such Work will be extended for an additional period of one year after such correction or removal and replacement has been satisfactorily completed.

E. Contractor's obligations under this Paragraph 13.07 are in addition to any other obligation or warranty. The provisions of this Paragraph 13.07 shall not be construed as a substitute for or a waiver of the provisions of any applicable statute of limitation or repose.

Section 13.08 Acceptance of Defective Work

A. If (prior to Construction Manager's recommendation of final payment), instead of requiring correction or removal and replacement of defective Work, Owner prefers to accept it, Owner may do so. Contractor shall pay all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) attributable to Owner's evaluation of and determination to accept such defective Work (such costs to be approved by Construction Manager as to reasonableness) and the diminished value of the

Work to the extent not otherwise paid by Contractor pursuant to this sentence. If any such acceptance occurs prior to Construction Manager's recommendation of final payment, a Change Order will be issued incorporating the necessary revisions in the Contract Documents with respect to the Work, and Owner shall be entitled to an appropriate decrease in the Contract Price, reflecting the diminished value of Work so accepted. If the parties are unable to agree as to the amount thereof, Owner may make a Claim therefor as provided in Paragraph 10.05. If the acceptance occurs after such recommendation, an appropriate amount will be paid by Contractor to Owner.

Section 13.09 Owner May Correct Defective Work

A. If Contractor fails within a reasonable time after written notice from Construction Manager to correct defective Work or to remove and replace rejected Work as required by Engineer in accordance with Paragraph 13.06.A, or if Contractor fails to perform the Work in accordance with the Contract Documents, or if Contractor fails to comply with any other provision of the Contract Documents, Owner may, after seven days written notice to Contractor, correct or remedy any such deficiency.

B. In exercising the rights and remedies under this Paragraph 13.09, Owner shall proceed expeditiously. In connection with such corrective or remedial action, Owner may exclude Contractor from all or part of the Site, take possession of all or part of the Work and suspend Contractor's services related thereto, take possession of Contractor's tools, appliances, construction equipment and machinery at the Site, and incorporate in the Work all materials and equipment stored at the Site or for which Owner has paid Contractor but which are stored elsewhere. Contractor shall allow Owner, Owner's representatives, agents and employees, Owner's other contractors, Construction Manager and Engineer and Engineer's consultants access to the Site to enable Owner to exercise the rights and remedies under this Paragraph.

C. All claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) incurred or sustained by Owner in exercising the rights and remedies under this Paragraph 13.09 will be charged against Contractor, and a Change Order will be issued incorporating the necessary revisions in the Contract Documents with respect to the Work; and Owner shall be entitled to an appropriate decrease in the Contract Price. If the parties are unable to agree as to the amount of the adjustment, Owner may make a Claim therefor as provided in Paragraph 10.05. Such claims, costs, losses and damages will include but not be limited to all costs of repair, or replacement of work of others destroyed or damaged by correction, removal, or replacement of Contractor's defective Work.

D. Contractor shall not be allowed an extension of the Contract Times because of any delay in the performance of the Work attributable to the exercise by Owner of Owner's rights and remedies under this Paragraph 13.09.

ARTICLE 14. PAYMENTS TO CONTRACTOR AND COMPLETION

Section 14.01 Schedule of Values

A. The Schedule of Values established as provided in Paragraph 2.07.A will serve as the basis for progress payments and will be incorporated into a form of Application for Payment acceptable to Construction Manager. Progress payments on account of Unit Price Work will be based on the number of units completed.

Section 14.02 Progress Payments

A. Applications for Payments

1. At least twenty (20) days before the date established in the Agreement for each progress payment (but not more often than once a month), Contractor shall submit to Construction Manager for review

an Application for Payment filled out and signed by Contractor covering the Work completed as of the date of the Application and accompanied by such supporting documentation as is required by the Contract Documents. If payment is requested on the basis of materials and equipment not incorporated in the Work but delivered and suitably stored at the Site or at another location agreed to in writing, the Application for Payment shall also be accompanied by a bill of sale, invoice, or other documentation warranting that Owner has received the materials and equipment free and clear of all Liens and evidence that the materials and equipment are covered by appropriate property insurance or other arrangements to protect Owner's interest therein, all of which must be satisfactory to Owner.

2. Beginning with the second Application for Payment, each Application shall include an affidavit of Contractor stating that all previous progress payments received on account of the Work have been applied on account to discharge Contractor's legitimate obligations associated with prior Applications for Payment.

3. *Retention* - The Owner will deduct from each progress payment and retain as part security, five percent (5%) of the amount earned until the final payment.

4. Pursuant to Public Contract Code Section 22300, for moneys earned by the Contractor and withheld by the Owner to ensure the performance of the Contract, the Contractor, may, at their option, choose to substitute securities meeting the requirements of said Section 22300. In the event the Contractor wishes to choose this option, the Contractor shall enter into an escrow agreement with the Owner and the escrow agent, a qualified bank to be acceptable to the Owner, in the form of the agreement included in the project specifications. The costs of such escrow shall be paid by the Contractor. The securities to be deposited in said escrow account shall be equivalent, in fair market value, to the amount to be withheld as performance retention. The securities shall be held in accordance with the provisions of Public Contract Code Section 22300, and the implementing agreement.

5. Contractor shall have the obligation of ensuring that such securities deposited are sufficient so as to maintain, in total fair market value, an amount equal to the cash amount of the sums to be withheld under the Contract. If, upon written notice from the Owner, or from the appropriate escrow agent, indicating that the fair market value of the securities has dropped below the dollar amount of moneys to be withheld by the Owner to ensure performance, Contractor shall, within five (5) days of the date of such notice, post additional securities as necessary to ensure that the total fair market value of all such securities held by the Owner, or in escrow, is equivalent to the amount of money to be withheld by the Owner under the Contract.

6. Any Contractor wishing to exercise this option shall give notice in writing to Owner, and shall thereafter execute an escrow agreement in the form of the form included with these Contract Documents.

7. Materials, as used herein, shall be considered to be those items that are fabricated and manufactured goods and equipment. Only those materials for which the Contractor can demonstrate are properly stored and secured in conformance with the Contract documents, and can transfer clear title to the City will be qualified for partial payment. The Contractor may request payment of seventy-five percent (75%) of the actual net cost of these materials, not to exceed fifty percent (50%) of the total adjusted line item extension as found in the bid schedule.

8. To receive partial payment for materials and equipment delivered to the Site, but not incorporated in the Work, it shall be necessary for the Contractor to submit to the Construction Manager a list of such materials, at least seven (7) business days prior to submitting the monthly estimate of amount earned for work completed. At the Construction Manager's sole discretion, the Construction Manager will approve items for which partial payment is to be made subject to the following:

   a. Only equipment or materials that have received favorable review of shop drawings will qualify.

   b. Eligible equipment or materials must be delivered and properly stored, protected, and maintained

in a manner favorably reviewed by the Construction Manager, at the job site or at a bonded warehouse.

c. The Contractor's actual net cost for the materials must be supported by invoices of suppliers, or other documentation requested by the Construction Manager.

d. Materials or equipment delivered to the Site less than thirty (30) days prior to their scheduled incorporation in the Work shall not qualify.

e. Final payment shall be made only for materials actually incorporated in the Work. Upon acceptance of the Work, all materials remaining for which advance payments had been made shall revert to the Contractor, unless otherwise agreed, and partial payments made for these items shall be deducted from the final payment for the Work.

f. Partial payments for materials and equipment on hand shall not be deemed to be final payment for the material nor relieve the Contractor of its obligations under the Contract.

g. Partial payments for materials and equipment on hand shall be subject to retention in accordance with the Contract Documents.

9. After receipt of the last progress payment, but prior to acceptance of the Work by the City, the Contractor shall send a letter to the Construction Manager. The letter, pursuant to California Public Contract Code Section 7100, shall state that acceptance of the final payment described below shall operate as and shall be, a release to the City, the Construction Manager, the Designer, and their duly authorized agents, from all claim of and/or liability to the Contract arising by virtue of the Contract related to those amounts. Disputed Contract claims in stated amounts previously filed as provided in Paragraph 00700-7.03b, Claims, may be specifically excluded by the Contractor from the operation of the release.

B. Review of Applications

1. Construction Manager will, within ten (10) business days after receipt of each Application for Payment, either indicate in writing a recommendation of payment and present the Application to Owner or return the Application to Contractor indicating in writing City’s reasons for refusing to recommend payment. In the latter case, Contractor may make the necessary corrections and resubmit the Application.

2. Construction Manager’s recommendation of any payment requested in an Application for Payment will constitute a representation by Construction Manager to Owner, based on Construction Manager’s observations on the Site of the executed Work as an experienced and qualified design professional and on Construction Manager’s review of the Application for Payment and the accompanying data and schedules, that to the best of Construction Manager’s knowledge, information and belief:

a. the Work has progressed to the point indicated;

b. the quality of the Work is generally in accordance with the Contract Documents (subject to an evaluation of the Work as a functioning whole prior to or upon Substantial Completion, to the results of any subsequent tests called for in the Contract Documents, to a final determination of quantities and classifications for Unit Price Work under Paragraph 9.07, and to any other qualifications stated in the recommendation); and

c. the conditions precedent to Contractor’s being entitled to such payment appear to have been fulfilled in so far as it is Construction Manager’s responsibility to observe the Work.

3. By recommending any such payment Construction Manager will not thereby be deemed to have represented that:

a. inspections made to check the quality or the quantity of the Work as it has been performed have

been exhaustive, extended to every aspect of the Work in progress, or involved detailed inspections of the Work beyond the responsibilities specifically assigned to Construction Manager in the Contract Documents; or

b. there may not be other matters or issues between the parties that might entitle Contractor to be paid additionally by Owner or entitle Owner to withhold payment to Contractor.

4. Neither Construction Manager's review of Contractor's Work for the purposes of recommending payments nor Construction Manager's recommendation of any payment, including final payment, will impose responsibility on Construction Manager:

   a. to supervise, direct, or control the Work, or

   b. for the means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or

   c. for Contractor's failure to comply with Laws and Regulations applicable to Contractor's performance of the Work, or

   d. to make any examination to ascertain how or for what purposes Contractor has used the moneys paid on account of the Contract Price, or

   e. to determine that title to any of the Work, materials, or equipment has passed to Owner free and clear of any Liens.

5. Construction Manager may refuse to recommend the whole or any part of any payment if, in Construction Manager's opinion, it would be incorrect to make the representations to Owner stated in Paragraph 14.02.B.2. Construction Manager may also refuse to recommend any such payment or, because of subsequently discovered evidence or the results of subsequent inspections or tests, revise or revoke any such payment recommendation previously made, to such extent as may be necessary in Construction Manager's opinion to protect Owner from loss because:

   a. the Work is defective, or completed Work has been damaged, requiring correction or replacement;

   b. the Contract Price has been reduced by Change Orders;

   c. Owner has been required to correct defective Work or complete Work in accordance with Paragraph 13.09; or

   d. Construction Manager has actual knowledge of the occurrence of any of the events enumerated in Paragraph 15.02.A.

C. Payment Becomes Due

1. Forty-five (45) days after presentation of the Application for Payment to Owner with Construction Manager's recommendation, the amount recommended will (subject to the provisions of Paragraph 14.02.D) become due, and when due will be paid by Owner to Contractor. Payment will be made by the Owner to the Contractor in accordance with Owner's normal accounts payable procedure.

D. Reduction in Payment

1. Owner may refuse to make payment of the full amount recommended by Construction Manager because:

   a. claims have been made against Owner on account of Contractor's performance or furnishing of the Work;

   b. Liens have been filed in connection with the Work, except where Contractor has delivered a specific bond satisfactory to Owner to secure the satisfaction and discharge of such Liens;

   c. there are other items entitling Owner to a set-off against the amount recommended; or

d. Owner has actual knowledge of the occurrence of any of the events enumerated in Paragraphs 14.02.B.5.a through 14.02.B.5.c or Paragraph 15.02.A.

2. If Owner refuses to make payment of the full amount recommended by Construction Manager, Owner will give Contractor written notice (with a copy to Construction Manager) within (10) days after receipt of each Application for Payment stating the reasons for such action and promptly pay Contractor any amount remaining after deduction of the amount so withheld. Owner shall promptly pay Contractor the amount so withheld, or any adjustment thereto agreed to by Owner and Contractor, when Contractor corrects to Owner's satisfaction the reasons for such action.

3. If it is subsequently determined that Owner's refusal of payment was not justified, the amount wrongfully withheld shall be treated as an amount due as determined by Paragraph 14.02.C.1.

Section 14.03 Contractor's Warranty of Title

A. Contractor warrants and guarantees that title to all Work, materials, and equipment covered by any Application for Payment, whether incorporated in the Project or not, will pass to Owner no later than the time of payment free and clear of all Liens.

Section 14.04 Substantial Completion

A. When Contractor considers the entire Work ready for its intended use Contractor shall notify Owner and Construction Manager in writing that the entire Work is substantially complete (except for items specifically listed by Contractor as incomplete) and request that Construction Manager issue a certificate of Substantial Completion.

B. Promptly after Contractor's notification, Owner, Contractor, and Construction Manager shall make an inspection of the Work to determine the status of completion. If Construction Manager does not consider the Work substantially complete, Construction Manager will notify Contractor in writing giving the reasons therefor.

C. If Construction Manager considers the Work substantially complete, Construction Manager will deliver to Owner a tentative certificate of Substantial Completion which shall fix the date of Substantial Completion. There shall be attached to the certificate a tentative list of items to be completed or corrected before final payment. Owner shall have seven (7) days after receipt of the tentative certificate during which to make written objection to Construction Manager as to any provisions of the certificate or attached list. If, after considering such objections, Construction Manager concludes that the Work is not substantially complete, Construction Manager will within fourteen (14) days after submission of the tentative certificate to Owner notify Contractor in writing, stating the reasons therefor. If, after consideration of Owner's objections, Construction Manager considers the Work substantially complete, Construction Manager will within said fourteen (14) days execute and deliver to Owner and Contractor a definitive certificate of Substantial Completion (with a revised tentative list of items to be completed or corrected) reflecting such changes from the tentative certificate as Construction Manager believes justified after consideration of any objections from Owner.

D. At the time of delivery of the tentative certificate of Substantial Completion, Construction Manager will deliver to Owner and Contractor a written recommendation as to division of responsibilities pending final payment between Owner and Contractor with respect to security, operation, safety, and protection of the Work, maintenance, heat, utilities, insurance, and warranties and guarantees. Unless Owner and Contractor agree otherwise in writing and so inform Construction Manager in writing prior to Construction Manager's issuing the definitive certificate of Substantial Completion, Construction Manager's aforesaid recommendation will be binding on Owner and Contractor until final payment.

E. Owner shall have the right to exclude Contractor from the Site after the date of Substantial Completion subject to allowing Contractor reasonable access to complete or correct items on the tentative list.

Section 14.05 Partial Utilization

A. Prior to Substantial Completion of all the Work, Owner may use or occupy any substantially completed part of the Work which has specifically been identified in the Contract Documents, or which Owner, Engineer, and Contractor agree constitutes a separately functioning and usable part of the Work that can be used by Owner for its intended purpose without significant interference with Contractor's performance of the remainder of the Work, subject to the following conditions.

1. Owner at any time may request Contractor in writing to permit Owner to use or occupy any such part of the Work which Owner believes to be ready for its intended use and substantially complete. If and when Contractor agrees that such part of the Work is substantially complete, Contractor will certify to Owner and Engineer that such part of the Work is substantially complete and request Construction Manager to issue a certificate of Substantial Completion for that part of the Work.

2. Contractor at any time may notify Owner and Construction Manager in writing that Contractor considers any such part of the Work ready for its intended use and substantially complete and request Construction Manager to issue a certificate of Substantial Completion for that part of the Work.

3. Within a reasonable time after either such request, Owner, Contractor, and Construction Manager shall make an inspection of that part of the Work to determine its status of completion. If Construction Manager does not consider that part of the Work to be substantially complete, Construction Manager will notify Owner and Contractor in writing giving the reasons therefor. If Construction Manager considers that part of the Work to be substantially complete, the provisions of Paragraph 14.04 will apply with respect to certification of Substantial Completion of that part of the Work and the division of responsibility in respect thereof and access thereto.

4. No use or occupancy or separate operation of part of the Work may occur prior to compliance with the requirements of Paragraph 5.10 regarding property insurance.

Section 14.06 Final Inspection

A. Upon written notice from Contractor that the entire Work or an agreed portion thereof is complete, Construction Manager will promptly make a final inspection with Owner and Contractor and will notify Contractor in writing of all particulars in which this inspection reveals that the Work is incomplete or defective. Contractor shall immediately take such measures as are necessary to complete such Work or remedy such deficiencies.

Section 14.07 Final Payment

A. Application for Final Payment

1. After Contractor has, in the opinion of Construction Manager, satisfactorily completed all corrections identified during the final inspection and has delivered, in accordance with the Contract Documents, all maintenance and operating instructions, schedules, guarantees, bonds, certificates or other evidence of insurance certificates of inspection, marked-up record documents (as provided in Paragraph 6.12), and other documents, Contractor may make application for final payment following the procedure for progress payments.

2. The final Application for Payment shall be accompanied (except as previously delivered) by:

   a. all documentation called for in the Contract Documents, including but not limited to the evidence of insurance required by Paragraph 5.04.B.7;

   b. consent of the surety, if any, to final payment;

   c. a list of all Claims against Owner that Contractor believes are unsettled; and

d. complete and legally effective releases or waivers (satisfactory to Owner) of all Lien rights arising out of or Liens filed in connection with the Work.

3. In lieu of the releases or waivers of Liens specified in Paragraph 14.07.A.2 and as approved by Owner, Contractor may furnish receipts or releases in full and an affidavit of Contractor that: (i) the releases and receipts include all labor, services, material, and equipment for which a Lien could be filed; and (ii) all payrolls, material and equipment bills, and other indebtedness connected with the Work for which Owner or Owner's property might in any way be responsible have been paid or otherwise satisfied. If any Subcontractor or Supplier fails to furnish such a release or receipt in full, Contractor may furnish a bond or other collateral satisfactory to Owner to indemnify Owner against any Lien.

B. Construction Manager's Review of Application and Acceptance

1. If, on the basis of Construction Manager's observation of the Work during construction and final inspection, and Construction Manager's review of the final Application for Payment and accompanying documentation as required by the Contract Documents, Construction Manager is satisfied that the Work has been completed and Contractor's other obligations under the Contract Documents have been fulfilled, Construction Manager will, within ten (10) days after receipt of the final Application for Payment, indicate in writing Construction Manager's recommendation of payment and present the Application for Payment to Owner for payment. At the same time Construction Manager will also give written notice to Owner and Contractor that the Work is acceptable subject to the provisions of Paragraph 14.09. Otherwise, Construction Manager will return the Application for Payment to Contractor, indicating in writing the reasons for refusing to recommend final payment, in which case Contractor shall make the necessary corrections and resubmit the Application for Payment.

C. Payment Becomes Due

1. Forty-five (45) days after final project acceptance by City Council and within sixty (60) days after the presentation to Owner of the Application for Payment and accompanying documentation, the amount recommended by Construction Manager, less any sum Owner is entitled to set off against Construction Manager's recommendation, including but not limited to liquidated damages, will become due and will be paid by Owner to Contractor. In the case of a disputed claim, the City may withhold a portion of final payment in an amount not to exceed 150 percent of any amount disputed in accordance with California Public Contracts Code Section 7107 (c).

Section 14.08 Final Completion Delayed

A. If, through no fault of Contractor, final completion of the Work is significantly delayed, and if Construction Manager so confirms, Owner shall, upon receipt of Contractor's final Application for Payment (for Work fully completed and accepted) and recommendation of Construction Manager, and without terminating the Contract, make payment of the balance due for that portion of the Work fully completed and accepted. If the remaining balance to be held by Owner for Work not fully completed or corrected is less than the retainage stipulated in the Agreement, and if bonds have been furnished as required in Paragraph 5.01, the written consent of the surety to the payment of the balance due for that portion of the Work fully completed and accepted shall be submitted by Contractor to Construction Manager with the Application for such payment. Such payment shall be made under the terms and conditions governing final payment, except that it shall not constitute a waiver of Claims.

Section 14.09 Waiver of Claims

A. The making and acceptance of final payment will constitute:

1. a waiver of all Claims by Owner against Contractor, except Claims arising from unsettled Liens, from

defective Work appearing after final inspection pursuant to Paragraph 14.06, from failure to comply with the Contract Documents or the terms of any special guarantees specified therein, or from Contractor's continuing obligations under the Contract Documents; and

2. a waiver of all Claims by Contractor against Owner other than those previously made in accordance with the requirements herein and expressly acknowledged by Owner in writing as still unsettled.

ARTICLE 15. SUSPENSION OF WORK AND TERMINATION

Section 15.01 Owner May Suspend Work

A. At any time and without cause, Owner may suspend the Work or any portion thereof for a period of not more than 90 consecutive days by notice in writing to Contractor and Engineer which will fix the date on which Work will be resumed. Contractor shall resume the Work on the date so fixed. Contractor shall be granted an adjustment in the Contract Price or an extension of the Contract Times, or both, directly attributable to any such suspension if Contractor makes a Claim therefor as provided in Paragraph 10.05.

Section 15.02 Owner May Terminate for Cause

A. The occurrence of any one or more of the following events will justify termination for cause:

1. Contractor's persistent failure to perform the Work in accordance with the Contract Documents (including, but not limited to, failure to supply sufficient skilled workers or suitable materials or equipment or failure to adhere to the Progress Schedule established under Paragraph 2.07 as adjusted from time to time pursuant to Paragraph 6.04);

2. Contractor's disregard of Laws or Regulations of any public body having jurisdiction;

3. Contractor's disregard of the authority of Construction Manager or Engineer; or

4. Contractor's violation in any substantial way of any provisions of the Contract Documents.

B. If one or more of the events identified in Paragraph 15.02A. occur, Owner will provide written notice to Contractor and Surety to arrange a conference with Contractor and Surety to address Contractor's failure to perform the Work. Conference shall be held not later than fifteen (15) days, after receipt of notice.

1. If the Owner, the Contractor, and the Surety do not agree to allow the Contractor to proceed to perform the Construction Contract, the Owner may, to the extent permitted by Laws and Regulations, declare a Contractor Default and formally terminate the Contractor's right to complete the Contract. Contractor Default shall not be declared earlier than twenty (20) days after the Contractor and Surety have received notice of conference to address Contractor's failure to perform the Work.

2. If Contractor's services are terminated, Surety shall be obligated to take over and perform the Work. If Surety does not commence performance thereof within fifteen (15) consecutive calendar days after date of an additional written notice demanding Surety's performance of its obligations, then Owner, without process or action at law, may take over any portion of the Work and complete it as described below.

3. If Owner completes the Work, Owner may exclude Contractor and Surety from the site and take possession of the Work and of all tools, appliances, construction equipment and machinery at the site and use the same to the full extent they could be used by Contractor and Surety (without liability to Contractor and Surety for trespass or conversion), incorporate in the Work all materials and equipment stored at the site or for which Owner has paid Contractor or Surety but which are stored elsewhere, and finish the Work as Owner may deem expedient.

4. Whether Owner or Surety completes the Work, Contractor shall not be entitled to receive any further payment until the Work is finished. If the unpaid balance of the Contract Price exceeds all claims,

costs, losses and damages sustained by Owner arising out of or resulting from completing the Work, such excess will be paid to Contractor. If such claims, costs, losses and damages exceed such unpaid balance, Contractor shall pay the difference to Owner. Such claims, costs, losses and damages incurred by Owner will be reviewed by Engineer as to their reasonableness and when so approved by Engineer incorporated in a Change Order, provided that when exercising any rights or remedies under this Paragraph, Owner shall not be required to obtain the lowest price for the Work performed.

5. Neither Owner, Engineer, nor any of their respective consultants, agents, officers, directors or employees shall be in any way liable or accountable to Contractor or Surety for the method by which the completion of the said Work, or any portion thereof, may be accomplished or for the price paid therefor.

6. Owner, notwithstanding the method used in completing the Contract, shall not forfeit the right to recover damages from Contractor or Surety for Contractor's failure to timely complete the entire Contract. Contractor shall not be entitled to any claim for damages on account of the method used by Owner in completing the Contract.

7. Maintenance of the Work shall continue to be Contractor's and Surety's responsibilities as provided for in the bond requirements of the Contract Documents or any special guarantees provided for under the Contract Documents or any other obligations otherwise prescribed by law.

C. If Owner proceeds as provided in Paragraph 15.02.B, Contractor shall not be entitled to receive any further payment until the Work is completed. If the unpaid balance of the Contract Price exceeds all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) sustained by Owner arising out of or relating to completing the Work, such excess will be paid to Contractor. If such claims, costs, losses, and damages exceed such unpaid balance, Contractor shall pay the difference to Owner. Such claims, costs, losses, and damages incurred by Owner will be reviewed by Engineer as to their reasonableness and, when so approved by Engineer, incorporated in a Change Order. When exercising any rights or remedies under this Paragraph Owner shall not be required to obtain the lowest price for the Work performed.

D. Notwithstanding Paragraphs 15.02.B and 15.02.C, Contractor's services will not be terminated if Contractor begins within seven (7) days of receipt of notice of intent to terminate to correct its failure to perform and proceeds diligently to cure such failure within no more than thirty (30) days of receipt of said notice.

E. Where Contractor's services have been so terminated by Owner, the termination will not affect any rights or remedies of Owner against Contractor then existing or which may thereafter accrue. Any retention or payment of moneys due Contractor by Owner will not release Contractor from liability.

F. If and to the extent that Contractor has provided a performance bond under the provisions of Paragraph 5.01.A, the termination procedures of that bond shall supersede the provisions of Paragraphs 15.02.B, and 15.02.C.

Section 15.03 Owner May Terminate For Convenience

A. Upon seven (7) days written notice to Contractor, Construction Manager and Engineer, Owner may, without cause and without prejudice to any other right or remedy of Owner, terminate the Contract. In such case, Contractor shall be paid for (without duplication of any items):

1. completed and acceptable Work executed in accordance with the Contract Documents prior to the effective date of termination, including fair and reasonable sums for overhead and profit on such Work;

2. expenses sustained prior to the effective date of termination in performing services and furnishing

labor, materials, or equipment as required by the Contract Documents in connection with uncompleted Work, plus fair and reasonable sums for overhead and profit on such expenses;

3. all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals and all court or arbitration or other dispute resolution costs) incurred in settlement of terminated contracts with Subcontractors, Suppliers, and others; and

4. reasonable expenses directly attributable to termination.

B. Contractor shall not be paid on account of loss of anticipated profits or revenue or other economic loss arising out of or resulting from such termination.

Section 15.04 Contractor May Stop Work or Terminate

A. If, through no act or fault of Contractor, (i) the Work is suspended for more than ninety (90) consecutive days by Owner or under an order of court or other public authority, or (ii) Construction Manager fails to act on any Application for Payment within thirty (30) days after it is submitted, or (iii) Owner fails for thirty (30) days to pay Contractor any sum finally determined to be due, then Contractor may, upon seven (7) days written notice to Owner and Construction Manager, and provided Owner or Construction Manager do not remedy such suspension or failure within that time, terminate the Contract and recover from Owner payment on the same terms as provided in Paragraph 15.03.

B. In lieu of terminating the Contract and without prejudice to any other right or remedy, if Construction Manager has failed to act on an Application for Payment within thirty (30) days after it is submitted, or Owner has failed for thirty (30) days to pay Contractor any sum finally determined to be due, Contractor may, seven (7) days after written notice to Owner and Construction Manager, stop the Work until payment is made of all such amounts due Contractor, including interest thereon. The provisions of this Paragraph 15.04 are not intended to preclude Contractor from making a Claim under Paragraph 10.05 for an adjustment in Contract Price or Contract Times or otherwise for expenses or damage directly attributable to Contractor's stopping the Work as permitted by this Paragraph.

ARTICLE 16. DISPUTE RESOLUTION

Section 16.01 Methods and Procedures

A. The process for resolving claims shall comply with the California Public Contracts Code as amended by Section 9204 et. seq.. The Contractor shall furnish sufficient documentation, as determined by the Construction Manager, to support any claim.

B. Either Owner or Contractor may request mediation of any Claim submitted to Construction Manager for a decision under Paragraph 10.05 before such decision becomes final and binding. The mediation will be governed by the Construction Industry Mediation Rules of the American Arbitration Association in effect as of the Effective Date of the Agreement. The request for mediation shall be submitted in writing to the American Arbitration Association and the other party to the Contract. Timely submission of the request shall stay the effect of Paragraph 10.05.E.

C. Upon receipt of a claim pursuant, the Owner shall conduct a reasonable review of the claim and, within a period not to exceed forty-five (45) days, shall provide the Contractor a written statement identifying what portion of the claim is disputed and what portion is undisputed. Upon receipt of a claim, the Owner and Contractor may, by mutual agreement, extend the time period provided in this subdivision.

D. If the Owner needs approval from its governing body to provide the claimant a written statement identifying the disputed portion and the undisputed portion of the claim, and the governing body does not meet within the forty-five (45) days or within the mutually agreed to extension of time following receipt of a claim sent by registered mail or certified mail, return receipt requested, the Owner shall have up to

three (3) days following the next duly publicly noticed meeting of the governing body after the 45-day period, or extension, expires to provide the claimant a written statement identifying the disputed portion and the undisputed portion.

E. The Owner shall pay any undisputed portion of the claim. Payment shall be processed and made within sixty (60) days after the Owner issues its written statement.

F. If the Owner fails to issue a written statement, the claim shall be deemed rejected in its entirety. A claim that is denied by reason of the Owner's failure to have responded to a claim, or its failure to otherwise meet the time requirements of this section, shall not constitute an adverse finding with regard to the merits of the claim or the responsibility or qualifications of the claimant.

G. If the Contractor disputes the Owner's written response, or if the Owner fails to respond to a claim issued within the time prescribed, the Contractor may demand in writing an informal conference to meet and confer for settlement of the issues in dispute. Upon receipt of a demand in writing sent by registered mail or certified mail, return receipt requested, the Owner shall schedule a meet and confer conference within thirty (30) days for settlement of the dispute.

H. Within ten (10) business days following the conclusion of the meet and confer conference, if the claim or any portion of the claim remains in dispute, the Owner shall provide the Contractor a written statement identifying the portion of the claim that remains in dispute and the portion that is undisputed. Any payment due on an undisputed portion of the claim shall be processed and made within sixty (60) days after the Owner issues its written statement. Any disputed portion of the claim, as identified by the Contractor in writing, shall be submitted to nonbinding mediation, with the Owner and Contractor sharing the associated costs equally. The Owner and Contractor shall mutually agree to a mediator within ten (10) business days after the disputed portion of the claim has been identified in writing. If the parties cannot agree upon a mediator, each party shall select a mediator and those mediators shall select a qualified neutral third party to mediate with regard to the disputed portion of the claim. Each party shall bear the fees and costs charged by its respective mediator in connection with the selection of the neutral mediator. If mediation is unsuccessful, the parts of the claim remaining in dispute shall be subject to applicable procedures outside this section.

I. Amounts not paid in a timely manner as required by this section shall bear interest at 2 percent per annum.

J. If a subcontractor or a lower tier subcontractor lacks legal standing to assert a claim against a public entity because privity of contract does not exist, Contractor may present to the Owner a claim on behalf of a subcontractor or lower tier subcontractor. A subcontractor may request in writing, either on his or her own behalf or on behalf of a lower tier subcontractor, that Contractor present a claim for work which was performed by the subcontractor or by a lower tier subcontractor on behalf of the subcontractor. The subcontractor requesting that the claim be presented to the Owner shall furnish reasonable documentation to support the claim. Within forty-five (45) days of receipt of this written request, Contractor shall notify the subcontractor in writing as to whether the Contractor presented the claim to the Owner and, if Contractor did not present the claim, provide the subcontractor with a statement of the reasons for not having done so.

K. Owner and Contractor shall participate in the mediation process in good faith. The process shall be concluded within the timeline as stipulated under the California Public Contracts Code. The date of termination of the mediation shall be determined by application of the mediation rules referenced above.

L. If the Claim is not resolved by mediation, Owner's action under Paragraph 10.05.C or a denial pursuant to Paragraphs 10.05.C.3 or 10.05.D shall become final and binding thirty (30) days after termination of the mediation unless, within that time period, Owner or Contractor:

1. elects in writing to invoke any dispute resolution process provided for in the Supplementary Conditions, or

2. agrees with the other party to submit the Claim to another dispute resolution process, or
3. gives written notice to the other party of their intent to submit the Claim to a court of competent jurisdiction.

ARTICLE 17. MISCELLANEOUS

Section 17.01 Giving Notice

A. Whenever any provision of the Contract Documents requires the giving of written notice, it will be deemed to have been validly given if:

1. delivered in person to the individual or to a member of the firm or to an officer of the corporation for whom it is intended, or
2. delivered at or sent by registered or certified mail, postage prepaid, to the last business address known to the giver of the notice.

Section 17.02 Computation of Times

A. When any period of time is referred to in the Contract Documents by days, it will be computed to exclude the first and include the last day of such period. If the last day of any such period falls on a Saturday or Sunday or on a day made a legal holiday by the law of the applicable jurisdiction, such day will be omitted from the computation.

Section 17.03 Cumulative Remedies

A. The duties and obligations imposed by these General Conditions and the rights and remedies available hereunder to the parties hereto are in addition to, and are not to be construed in any way as a limitation of, any rights and remedies available to any or all of them which are otherwise imposed or available by Laws or Regulations, by special warranty or guarantee, or by other provisions of the Contract Documents. The provisions of this Paragraph will be as effective as if repeated specifically in the Contract Documents in connection with each particular duty, obligation, right, and remedy to which they apply.

B. No action or failure to act by the Owner, the Engineer, or the Construction Manager shall constitute a waiver of any right or duty afforded any of them under the Contract, nor shall any such action or failure to act constitute an approval of or acquiescence in any breach thereunder, except as may be specifically agreed in writing.

Section 17.04 Survival of Obligations

A. All representations, indemnifications, warranties, and guarantees made in, required by, or given in accordance with the Contract Documents, as well as all continuing obligations indicated in the Contract Documents, will survive final payment, completion, and acceptance of the Work or termination or completion of the Contract or termination of the services of Contractor.

Section 17.05 Controlling Law

A. This Contract is to be governed by the law of the state of California, the county of San Joaquin, and city of Manteca.

Section 17.06 Headings

A. Article and paragraph headings are inserted for convenience only and do not constitute parts of these General Conditions.

Section 17.07 Penalty for Collusion

A. If, at any time, it is found that the person, firm, or corporation to whom the Contract has been awarded has, in presenting any bid or bids, colluded with any other party or parties, then the Contract shall be null and void, and the Contractor and its sureties shall be liable for loss or damage which the City may suffer thereby, and the City may advertise for new bids for said Work.

END OF SECTION

SECTION 00800

SUPPLEMENTARY GENERAL CONDITIONS

1.0 MODIFICATIONS TO THE GENERAL CONDITIONS

These Supplementary General Conditions amend and supplement Section 00700, GENERAL CONDITIONS, and other provisions of the contract documents as indicated below. All provisions of the General Conditions that are amended or supplemented remain in full force and effect as so amended or supplemented. All provisions of the General Conditions which are not so amended or supplemented remain in full force and effect.

1.1 **Time Allowed for Completion**

In accordance with the provisions of Section 00700, **Contract Time**, substantial completion of this project shall be completed within nine hundred (900) consecutive days from the date established in the Notice to Proceed for the commencement of Contract Time. In addition, the following milestone item(s) shall be substantially completed within the time period defined below.

Milestone	Milestone Substantial Completion Time Period
Milestone A – Approval of all critical submittals	180 calendar days from NTP
Milestone B – Dewatering Facility Improvements	540 calendar days from NTP
Milestone C – MCC-E Improvements	540 calendar days from NTP
Milestone D – RDT Facility and Thickening Odor Control Facility	650 calendar days from NTP
Milestone E – Substantial Completion	900 calendar days from NTP
Milestone F – Final Completion	990 calendar days from NTP

Milestone A – Approval of all critical submittals: Secure Engineer's approval of all critical submittals. Allow time in the schedule for Engineer's review of each submittal and resubmittal. Critical submittals are defined as products or equipment that have a lead time over 180 days or any submittal related to Work on the Contractor's critical path schedule.

Milestone B – Dewatering Facility Improvements: Substantial Completion of all work associated with the Dewatering Facility.

Milestone C – MCC-E Improvements: Substantial Completion of all work associated with replacing MCC-E.

Milestone D – RDT Facility and Thickening Odor Control Facility: Substantial Completion of all work associated with the new RDT Facility and Thickening Odor Control Facility.

1.2 **Damages for Delays**

In accordance with the provisions of Section 00700, **Liquidated Damages**, for the period of time that any portion of the work remains unfinished after the time fixed for an interim milestone and/or Substantial Completion in Section 00800-1.1, **Time Allowed for Completion**, as modified by extensions of time granted by the City, it is understood and agreed that the Contractor shall pay the City the damages listed below.

Milestone	Liquidated Damages Amount
Milestone A – Approval of all critical submittals	$1,000 per calendar day
Milestone B – Dewatering Facility Improvements	$1,000 per calendar day
Milestone C – MCC-E Improvements	$1,000 per calendar day
Milestone D – RDT Facility and Thickening Odor Control Facility	$1,000 per calendar day
Milestone E – Substantial Completion	$5,000 per calendar day
Milestone F – Final Completion	$1,000 per calendar day
SHUTDOWN REQUEST DELAYS – All City approved shutdown requests that are delayed/rescheduled by Contractor. **No shutdowns allowed on Thursdays and Fridays.**	$1,000 per calendar day

1.3 **Weather Days**

In accordance with the provisions of Paragraph 00700-6.4.2.C, Weather Delays, the following allowance(s) for weather caused delay have been included in the time allowed for completion. For the Construction Schedule defined in Section 01310-4.0, **WEATHER CONDITIONS AND WEATHER DAY ALLOWANCE**, the weather days shall be allocated as listed below:

Milestone	Weather Day Allowance (Calendar Days)
Milestone A – Approval of all critical submittals	Zero (0)
Milestone B – Dewatering Improvements	Zero (0)
Milestone C – MCC-E improvements	Zero (0)
Milestone D – RDT Facility and Thickening Odor Control Facility	Zero (0)
Milestone E – Substantial completion	Zero (0)
Milestone F – Final Completion	Zero (0)

This allowance represents the Owner's assessment of potential lost working days. This allowance includes both weather days due to inclement weather conditions and the conditions resulting from weather in accordance with Paragraph 00700, Weather Delays. These weather days shall be included in the Contractor's schedule as specified in Section 01310, WEATHER CONDITIONS. This allowance is not a warranty as to the extent that weather may or may not impact the Work. The Contractor shall make its own independent assessment of potential impacts to the Work due to weather based on the Project location, the Work required, the Contract Period, the schedule, and the Contractor's planned means, methods and appliances, and the Contractor shall take such factors into

consideration in its Bid and planning of the Work. The Contractor is responsible for determining the means, methods and appliances for prosecuting the Work as defined in Section 00700, Means, Methods and Appliances.

5.0 SUBSTANTIAL COMPLETION

Substantial completion of the Project as required by Section 00700, **Substantial Completion**, requires that the following portions of the Work must be operational and ready for the City's continuous use as intended:

The following items of work must be fully tested and functional for Project Substantial Completion to be attained:

A. Completion of the Corrective Work Item(s).

B. All health and safety systems are complete, fully tested and operational.

C. All mechanical (including HVAC), electrical (including lighting), control, and instrumentation equipment is installed, fully tested and operational in normal and automatic modes.

D. All civil, structural, demolition, and architectural elements identified in the Contract Documents are completed.

E. All alarms are fully functional, tested and demonstrated to properly associate locally, remotely and of the SCADA system.

F. Training has been completed for all electrical, mechanical and instrumentation systems.

G. Approved final copies of the Project's Operation and Maintenance Manuals as specified in the Contract Documents and as required in Sections 01010 and 01670.

H. All instruments, local and remote, are fully tested and functional. All interlocked functions between equipment items are tested and documented.

Portions of the Work not essential to the system operation, which can be completed without interruption of system operations, may be completed after the Work is accepted as substantially complete, and may include the following items:

A. Final Site Clean-Up.

B. Final Building Clean-Up.

C. Completion of the Final Punch List prepared by the Construction Manager.

A. **Paragraph 00700-3.03.B.2:**

Add the following paragraph:

Where conflicts exist among the Contract Documents and/or any reference specifications, such conflicts shall be clarified according to the following order, the first ranked taking precedence over the lower ranked:

1. Amendments, Change Orders or other modifications to the Contract Documents, as executed by the City in accordance with the requirements of the Contract Documents.
2. Agreement.
3. Supplementary Conditions.
4. General Conditions.
5. Division 01 Documents.
6. Technical Specifications.
7. Drawings.
8. Notice Inviting Bids and Information to Bidders.
9. Contract Payment Bond.
10. Performance Bond.
11. Warranty Bond (if required).
12. Any provisions required by law or valid regulations to be inserted in this contract, whether actually inserted or not.
13. Appendices (photographs, data contained in reports, and other information).

Additional rules of interpretation:

1. Written numbers over figures, unless obviously incorrect.
2. Figured dimensions over scaled dimensions.
3. Large-scale drawings over small-scale drawings.
4. Any conflict between a bill or list of materials shown in the Contract Documents and the actual quantities required to complete the Work required by Contract Documents, will be resolved in favor of the actual quantities, date (i.e., the most recent document), and if the dates are the same or not determinable, then in favor of Specifications.

B. **Paragraph 00700-5.04B:**

The entities listed below are "additional insureds as their interest may appear" including their respective officers, directors, agents and employees.

Construction Manager: To Be Determined

The insured and the additional insured shall be listed in the insurance coverage by specific name and not by genre.

C. **Paragraph 00700-6.11.A.4:**

Add the following paragraph:

All Contractor activities including site ingress/egress shall be coordinated with the City of Manteca. Site access shall be secured by Contractor personnel after typical hours of City operation, **6:30 a.m. to 4:00 p.m., Monday through Friday**, unless scheduled Two weeks in advance with the Construction Manager.

D. **Paragraph 00700-12.01.D:**

Add the following paragraphs:

The Contractor shall be responsible to reimburse the City for any unforeseen costs incurred, including labor and materials, relating to any disruption of City operations or services due to Contractor's activities or negligence. Unforeseen City costs may include, but are not limited to:

1. Labor, materials, and administrative civil liabilities associated with sanitary sewer overflows/regulatory violations due to Contractor activities or negligence.

2. Labor, including overtime hours, and materials associated with City forces preparing for a scheduled outage that is canceled subsequently by the Contractor.

3. Labor, including overtime hours, and materials associated with City activities necessitated by outages extending beyond the scheduled duration caused by the Contractor.

Reimbursement to the City shall be accomplished through a 'back-charge" and a resultant reduction in contract price. Documentation of City costs will be furnished to the Contractor.

E. **Paragraph 00700-12.03F:**

Time extensions will not be granted for rain, wind, flood, or other natural phenomena of normal intensity for the locality where Work is performed. For purpose of determining extent of delay attributable to unusual weather phenomena, a determination shall be made by comparing the weather for the month involved with the average of the preceding 10-year climatic range during the same month based on U.S. Weather Bureau statistics for the locality where the Work is performed.

END OF SECTION

SECTION 00810

ENVIRONMENTAL REQUIREMENTS

1.0 GENERAL

The City prepared and filed a Notice of Exemption for the project per the requirements of the California Environmental Quality Act. A copy of this document in included in the Appendix.

2.0 MITIGATION MEASURES

None.

END OF SECTION

SECTION 00820

LIABILITY AND INSURANCE REQUIREMENTS

1. INDEMNIFICATION

The Contractor shall indemnify, hold harmless and assume the defense of the City, the Engineer, the Construction Manager and their elected officials, officers, agents, employees and representatives from all damages, costs, or expenses in law or equity, including attorney's fees, that may at any time arise to cause damages to property, or of personal injury received by reason of or in the course of performing work, which may be occasioned by any willful or negligent act or omission of the Contractor, any of the Contractor's employees, or any of its subcontractors arising out of work under this Contract.

Approval of any insurance contracts by the City does not relieve the Contractor or subcontractors from liability under Section 00820, Indemnification, and the Contractor shall be responsible for payment of all amounts it is obligated to pay under Section 00820, Indemnification, which have not been paid by such insurance contracts. The City shall not be liable for any accident, loss, or damage to the work prior to its completion and acceptance.

2. INSURANCE REQUIREMENTS

After award of Contract, the Contractor shall promptly obtain, at its own expense, all the insurance required under Appendix 1 – Exhibit 1 Insurance Requirements for Construction Contracts, and shall submit coverage verification for review and approval by the City prior to execution of the Contract.

The Notice to Proceed with the Work under this Contract will not be issued, and the Contractor shall not commence work, until such insurance has been approved by the City. The Contractor shall not allow any subcontractors to commence work on its subcontract until all similar insurance required of the subcontractor has been obtained and verified by the Contractor. Such insurance shall remain in full force and effect at all times during the prosecution of the Work and until the final completion and acceptance thereof.

The Notice to Proceed does not relieve the Contractor of the duty to maintain such insurance as required by the project documents.

END OF SECTION

SECTION 01010

LOCATION AND SUMMARY OF WORK

PART 1 – GENERAL

1.01 GENERAL

A. The work to be performed under this Contract shall consist of furnishing all tools, equipment, materials, supplies, and manufactured articles, and for furnishing all transportation and services, including fuel, power, water and essential communications, and for the performance of all labor, work, or other operations required for the fulfillment of the Contract in strict accordance with the Contract Documents. Quality Assurance and referenced standards are detailed in each specification. The Contractor certifies that the Contractor is experienced and qualified to anticipate and meet the requirements of this Project.

B. The work shall be complete and include all labor, materials, and services not expressly shown or called for in the Contract Documents which may be necessary for the complete and proper construction. Work in good faith shall be completed and performed, furnished, and installed by the Contractor as though originally so specified or shown, at no increase in cost to the City.

1.02 SUMMARY OF WORK

A. The work consists of construction of sludge thickening and dewatering improvements to the Manteca Wastewater Quality Control Facility including, but not be limited to, the following items:

1. Modifications to the existing dissolved air flotation thickeners to convert them into sludge blend tanks.
2. A new co-thickening RDT facility.
3. A new thickening odor control facility.
4. Modifications to the existing dewatering facility, including the installation of a third centrifuge.
5. Modifications to the site paving and grading.
6. Additions and modifications to the yard piping systems.
7. Demolition required for new construction.
8. Electrical system improvements.
9. Instrumentation and control system improvements.
10. Commissioning of the Work.
11. Repair and reconstruction of existing facilities affected by the Work and all Work necessary to render the facility complete and operational.

1.03 PRECONSTRUCTION MEETING

The Contractor shall submit the following at or before the preconstruction meeting, in accordance with Section 01300, SUBMITTALS.

A. Construction schedule consistent with the contract time of completion and anticipated sequence of work.

B. Methods of access to the construction site.

C. Noise abatement procedure; estimated decibel measurements to surrounding residences.

D. Temporary facilities to be established.

E. Permits

F. A work schedule and hours of operation.

G. Plan for storm water and non-storm water Best Management Practices (BMPs) for erosion and run-off control.

1.04 PERMITS

A. The Contractor shall obtain and pay for all permits in accordance to the laws and regulations governing the work. At a minimum the following permit must be secured:

1. City Encroachment Permit to work on City right of way

2. City Fire Hydrant Water Meter Permit, available from the Public Works Dept. https://www.manteca.gov/home/showpublisheddocument/6571/638587055674070000

3. Air Permit from the San Joaquin Valley Air Pollution Control District

1.05 CONSTRUCTION WATER DISPOSAL AND DRAINAGE

A. Applicable Local, County, and State guidelines related to proper disposal of construction water shall be followed by the Contractor.

1.06 SITE RESTORATION

A. Contractor shall restore site to preconstruction conditions.

B. Remove rubbish, unused materials, and other unlike materials belonging to Contractor or used under Contractor's direction during construction.

1.07 PROJECT LOCATION

A. Work associated with this project will take place at the Manteca Wastewater Quality Control Facility, 2450 W Yosemite Ave, Manteca, CA 95337.

1.08 BID ITEMS DESCRIPTION

Bid Item 1 - Mobilization, Demobilization, Bonds, Permits, and Insurance on all work (Maximum 3% of Total Base Bid)

Includes preparatory work and operations, including but not limited to, those necessary for the movement of personnel, equipment, supplies and incidentals to the project site; for the establishment of all offices, buildings and other facilities necessary for work on the project; for the marshaling of equipment; and for all other work and operations which must be performed or costs incurred prior to beginning work on the various contract items on the project site, including obtaining the bonds, insurance policies, permits required by the Contract Documents for this Project, and final site clean-up.

Includes project closeout work and operations, including but not limited to, those necessary for the movement of personnel, equipment, supplies and incidentals off the project site; removal of all offices, buildings and other facilities necessary for work on the project; and final site clean-up.

Payment will be in the amount shown in the Bid Schedule and will be made on a lump sum basis at one hundred percent (100%) of the indicated amount contingent upon the Contractor furnishing, and the Construction Manager's acceptance of, the Construction Schedule, the Contractor's Cost Breakdown, and proof of acquisition of all required bonds, insurance, and permits.

Bid Item 2 - Sheeting, Shoring, Bracing, or Equivalent Method for Protection of Life and Limb in Trenches and Open Excavations

Includes cost for providing all shoring and bracing on all Bid Items as required per Sections 6705 and 6707 of the California Labor Code as applicable.

Payment will be in the amount shown in the Bid Schedule and will be made on a lump sum basis at one hundred percent (100%) of the indicated amount contingent upon the Contractor furnishing, and the Construction Manager's acceptance of, the Construction Schedule, the Contractor's Cost Breakdown.

Bid Item 3 - Training of City Staff

Includes cost for providing all required training of City staff.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 4 - Final O&M Manuals

Includes cost for providing all final, approved operations and maintenance manuals.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 5 - Record Drawings

Includes cost for providing approved record drawings.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 6 - Monument Preservation

Includes cost for all work related to monument preservation.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 7 - Demolition Work

Includes performing the work and the payment of all related expenses necessary for demolition of the following facilities, or select portions thereof, as shown and specified, including but not limited to:

- Site demolition.
- Yard piping demolition.
- Flow meter vault.
- Biotower effluent channel and pump station.
- Dissolved air flotation thickeners.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 8 - Civil and Site Improvements

Includes performing the work and the payment of all related expenses necessary for providing civil and site improvements, as shown and specified, including but not limited to:

- Site preparation.
- Yard piping.
- Paving and grading.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 9 - Repurpose Existing DAFTs to Sludge Blend Tanks

Includes performing the work and the payment of all related expenses necessary for repurposing the existing dissolved air flotation thickeners to sludge blend tanks including but not limited to verification, relocation, protection, and/or support of utilities, earthwork, dewatering, quality control testing, structural, architectural, mechanical, all equipment, appurtenances, piping, valve, signage, electrical, and instrumentation work in place complete, as shown and specified. Includes testing, startup, and commissioning.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 10 - Construction of New RDT Facility

Includes performing the work and the payment of all related expenses necessary for constructing the new RDT Facility including but not limited to verification, relocation, protection, and/or support of utilities, earthwork, dewatering, quality control testing, structural, architectural, mechanical, all equipment, appurtenances, piping, valve, signage, electrical, and instrumentation work in place complete, as shown and specified. Includes testing, startup, and commissioning.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 11 - Construction of New Thickening Odor Control Facility

Includes performing the work and the payment of all related expenses necessary for constructing the new Thickening Odor Control Facility including but not limited to verification, relocation, protection, and/or support of utilities, earthwork, dewatering, quality control testing, structural, architectural, mechanical, all equipment, appurtenances, piping, valve, signage, electrical, and instrumentation work in place complete, as shown and specified. Includes testing, startup, and commissioning.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 12 - Dewatering Facility Improvements

Includes performing the work and the payment of all related expenses necessary for constructing the improvements to the Dewatering Facility including but not limited to verification, relocation, protection, and/or support of utilities, earthwork, dewatering, quality control testing, structural, architectural, mechanical, all equipment, appurtenances, piping, valve, signage, electrical, and instrumentation work in place complete, as shown and specified. Includes testing, startup, and commissioning.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 13 - MCC-E Replacement

Includes performing the work and the payment of all related expenses necessary for replacement of MCC-E including but not limited to verification, relocation, protection, and/or support of utilities, earthwork, dewatering, quality control testing, structural, architectural, mechanical, all equipment, appurtenances, piping, valve, signage, electrical, and instrumentation work in place complete, as shown and specified. Includes testing, startup, and commissioning.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

Bid Item 14 - All Other Work Not Included in Above Bid Items

Includes costs for all work required under the Contract except for work specifically being provided under Bid Items 1 through 13. This item shall constitute full compensation for all such work as required per the Contract Documents.

Payment will be made at the lump sum fixed price given in the Bid Schedule, in accordance with the accepted Contractor's Cost Breakdown.

END OF SECTION

SECTION 01025

MEASUREMENT AND PAYMENT

PART 1 – GENERAL

1.01 SUMMARY

A. Section includes description of requirements and procedures for determining amount of Work performed and for obtaining payment for Work performed.

1.02 SCOPE OF WORK

A. Work under Contract Documents, or under any Bid Item, allowance, or alternate, shall include all labor, materials, taxes, transport, handling, storage, supervision, administration, and all other items necessary for the satisfactory completion of Work, whether or not expressly specified or indicated.

1.03 DETERMINATION OF QUANTITIES

A. Quantity of work to be paid for under any item for which a unit price is fixed in Contract Documents shall be number, as determined by Construction Manager, of units of work satisfactorily completed in accordance with Contract Documents or as directed by Construction Manager. Unless otherwise provided, determination of number of units of work so completed will be based, so far as practicable, on actual measurement or count within prescribed or ordered limits, and no payment will be made for work done outside of limits. Measurements and computations will be made by methods set forth in Contract Documents, including without limitation this section. If methods are not so set forth, measurements shall be made in any manner which Construction Manager considers appropriate for class of Work measured (e.g., pre-assigned values, percentage completion, units completed or incremental milestones). Contractor must immediately inform Construction Manager of any disputes regarding quantity measurements and shall immediately supply Construction Manager with any documentation supporting the disputed measurements.

1.04 SCOPE OF PAYMENT

A. Except as otherwise expressly stated in Section 01010, LOCATION AND SUMMARY OF WORK, payment to Contractor at the unit price or other price fixed in Contract Documents for performing Work required under any item, or (if the Contract is on a single lump sum price basis) at the lump sum price fixed in the Contract Documents for performing all Work required under Contract Documents, and as either may be adjusted pursuant to any approved Change Order or Construction Change Directive, shall be full compensation for completing, in accordance with Contract Documents, all Work required under the item or under Contract Documents, and for all expense incurred by Contractor for any purpose in connection with the performance and completion of said Work, including all incidental work necessary for completion of the Work.

B. The Contract Sum, whether lump sum, unit price or otherwise, shall be deemed to include all costs necessary to complete required Work, all costs (if any) for loss or damage arising from nature of Work or prosecution of the Work, and from action of elements. Unless Contract Documents expressly provide otherwise, the Contract Sum shall be deemed to include:

1. Any and all costs arising from any unforeseen difficulties which may be encountered during, and all risks of any description connected with, prosecution of Work or prosecution of Bid Item (whether lump sum or unit price) until acceptance by the Owner;

2. All expenses incurred due to suspension, or discontinuance of Work or discontinuance of Bid Item (whether lump sum or unit price) as provided in Contract Documents;

3. Escalation to allow for cost increases between time of Contract Award and completion of Work or completion of Bid Item (whether lump sum or unit price).

C. Whenever it is specified herein that Contractor is to do work or furnish materials of any class for which no price is fixed in Contract Documents, it shall be understood that Contractor is to do such work or furnish such materials without extra charge or allowance or direct payment of any sort, and that cost of doing work or furnishing materials is to be included in price Bid, unless it is expressly specified herein, in particular cases, that work or material is to be paid for as extra work.

D. Unit Prices shall apply to work covered by unit prices so long as actual quantities performed on the Project are not less than 75 percent or greater than 125 percent of the estimated quantities contained in the BID PROPOSAL FORM, or otherwise referenced in Section 01010, LOCATION AND SUMMARY OF WORK. If actual quantities exceed these parameters, then the unit price shall be adjusted by an amount to reflect the Contractor's incremental cost differential resulting from increased or decreased economies of scale.

E. The Construction Manager may, in its discretion, where Contractor requests payment on the basis of materials and equipment not incorporated in the Work, require the Contractor to satisfy the following conditions:

1. The materials and/or equipment shall be delivered and suitably stored at the site or at another local location agreed to in writing, for example, a mutually acceptable warehouse;

2. Full title to the materials and/or equipment shall vest in the Owner at the time of delivery to the site, warehouse or other storage location;

3. Obtain a negotiable warehouse receipt, endorsed over to the Owner for materials and/or equipment stored in an off-site warehouse. No payment will be made until such endorsed receipts are delivered to the Owner;

4. Stockpiled materials and/or equipment shall be available for the Owner inspection, but the Owner shall have no obligation to inspect them and its inspection or failure to inspect shall not relieve Contractor of any obligations under the Contract Documents. Materials and/or equipment shall be segregated and labeled or tagged to identify these specific Contract Documents;

5. After delivery of materials and/or equipment, if any inherent or acquired defects are discovered, defective materials and/or equipment shall be removed and replaced with suitable materials and/or equipment at Contractor's expense;

6. At Contractor's expense, insure the materials and/or equipment against theft, fire, flood, vandalism, and malicious mischief, as well as any other coverages required under the Contract Documents;

7. Contractor's Application for Payment shall be accompanied by a bill of sale, invoice or other documentation warranting that the Owner has received the materials and equipment free and clear of all liens and evidence that the materials and equipment are covered by appropriate property insurance and other arrangements to protect the Owner's interest therein, all of which must be satisfactory to the Owner. This documentation shall include, but not be limited to, conditional releases of mechanics' liens and stop notices from all those providing materials and equipment as to which the Application for Payment relates, as well as unconditional releases of the same from the same as to the previous Application for Payment for which they have not already been provided.

F. Amounts previously paid for materials and equipment prior to incorporation into the Work shall be deducted from amounts otherwise due Contractor as they are incorporated.

1.05 BASIS OF PAYMENT

A. Unit Price Quantities: When estimated quantity for specific portions of Work is listed in Bid Form, quantity of Work to be paid for shall be actual number of units satisfactorily completed, as determined by Construction Manager and certified by Contractor, in accordance with Contract Documents.

B. Lump Sum: When estimated quantity for specific portion of Work is not indicated and unit is designated as lump sum, payment will be on a lump sum basis for Work satisfactorily completed in accordance with Contract Documents.

C. Allowances: Allowance items (if any) will be paid for as provided in Section 01010, LOCATION AND SUMMARY OF WORK. Funds authorized for allowance work will not be released for contract payments unless Construction Manager has authorized Allowance work in writing.

D. The Owner does not expressly, or by implication, agree, warrant, or represent in any manner, that actual amount of Work will correspond with amount shown or estimated and reserves right to increase or decrease amount of any class or portion of Work, to leave out entire Bid Item or Items, or to add work not originally included in Bid or Contract Documents, when in its judgment such change is in best interest of the Owner. No change in Work shall be considered a waiver of any other condition of Contract Documents. No claim shall be made for anticipated profit, for loss of profit, for damages, or for extra payment whatever, except as otherwise expressly provided for in Contract Documents, because of any differences between amount of work actually done and estimated amount as set forth herein, or for elimination of Bid Items.

1.06 PROGRESS PAYMENTS

A. If requested by Contractor, progress payments will be made monthly.

B. **Schedule of Values:**

1. Within twenty-eight (28) days from issuance of Notice of Award and prior to the Contractor's first Application for Payment, submit a detailed breakdown of its Bid by scheduled Work items and/or activities, including coordination responsibilities and Project Record Documents responsibilities. Where more than one Subcontractor comprises the work of a Work item or activity, the Schedule of Values shall show a separate line item for each subcontract. Furnish such breakdown of the total Contract Sum by assigning dollar values (cost estimates) to each applicable Progress Schedule network activity, which cumulative sum equals the total Contract Sum. The format and detail of the breakdown shall be as directed by the Construction Manager to facilitate and clarify future progress payments to Contractor for direct Work under Contract Documents. This breakdown shall be referred to as the Schedule of Values.

2. Contractor's overhead, profit, insurance, cost of bonds (except to the extent expressly identified in a Bid Item) and/or other financing, as well as "general conditions costs," (e.g., site cleanup and maintenance, temporary roads and access, off-site access roads, temporary power and lighting, security, and the like), shall be prorated through all activities so that the sum of all the Schedule of Values line items equals Contractor's total Contract Sum, less any allowances designated by the Construction Manager. Scheduling, record documents and quality assurance control shall be separate line items.

3. The Construction Manager will review the breakdown in conjunction with the Progress Schedule to ensure that the dollar amounts of this Schedule of Values are, in fact, fair market cost allocations for the Work items listed. Upon favorable review by the Construction Manager, the Owner will accept this Schedule of Values for use. The Construction Manager shall be the sole judge of fair market cost allocations.

4. The Owner will reject any attempt to increase the cost of early activities, i.e., "front loading," resulting in a complete reallocation of moneys until such "front loading" is corrected. Repeated attempts at "front loading" may result in suspension or termination of the Work for default, or refusal to process progress payments until such time as the Schedule of Values is acceptable to the Owner.

C. Applications for Payment: Contractor shall establish and maintain records of cost of the Work in accordance with generally accepted accounting practices. In addition:

1. On or before the 20th Day of each month but after receipt of the Owner's approval of the updated schedule as required by Section 01310, CONTRACTOR'S CONSTRUCTION SCHEDULE, Contractor shall submit to the Construction Manager five copies of an Application for Payment for the cost of the Work put in place during the period from the 15th Day of the previous month to the 15th Day of the current month. Such Applications for Payment shall be for the total value of activities completed or partially completed, including approved activity costs, based upon Schedule of Values prices (or Bid item prices if unit

price) of all labor and materials incorporated in the Work up until midnight of the last Day of that one month period, less the aggregate of previous payments. Accumulated retainage shall be shown as separate item in payment summary. Contractor shall submit in a form acceptable to the Construction Manager an itemized cost breakdown of Contractor's record of Cost of the Work together with supporting data and any certification required by the Owner. If Contractor is late submitting its Application for Payment, that Application may be processed at any time during the succeeding one-month period, resulting in processing of Contractor's Application for Payment being delayed for more than a day for day basis.

2. Applications for Payment may include, but are not necessarily limited to the following:

   a. Material, equipment, and labor incorporated into the Work, less any previous payments for the same;

   b. Up to 75 percent of the cost of equipment identified in Paragraph 1.04E of this section (if any), if purchased and delivered to the site or stored off site, as may be approved by the Construction Manager.

   c. Up to 50 percent of the cost of materials identified in Paragraph 1.04E of this section (if any), specifically fabricated for the Project that are not yet incorporated into the Work.

3. At the time any Application for Payment is submitted, certify in writing the accuracy of the Application and that Contractor has fulfilled all scheduling requirements of Section 01310, CONTRACTOR'S CONSTRUCTION SCHEDULE, including updates and revisions. A responsible officer of Contractor shall execute the certification.

4. No progress payment will be processed prior to Construction Manager receiving all requested, acceptable schedule update information. Failure to submit a schedule update complying with Section 01310, CONTRACTOR'S CONSTRUCTION SCHEDULE justifies denying the entire Application for Payment.

5. Each Application for Payment shall list each Change Order and Construction Change Directive ("CCD") executed prior to date of submission, including the Change Order/CCD Number, and a description of the work activities, consistent with thedescriptions of original work activities. Submit a monthly Change Order/CCD status log to the Construction Manager.

6. If Construction Manager requires substantiating data, submit information requested by Construction Manager, with cover letter identifying Project, Application for Payment number and date, and detailed list of enclosures. Submit one copy of substantiating data and cover letter for each copy of Application for Payment submitted.

7. If Contractor fails or refuses to participate in work reconciliations or other construction progress evaluation with Construction Manager, Contractor shall not receive current payment until Contractor has participated fully in providing construction progress information and schedule update information to the Construction Manager.

D. **Progress Payments**

1. The Construction Manager will review Contractor's Application for Payment following

receipt. If adjustments need to be made to percent of completion of each activity, Construction Manager will make appropriate notations and return to Contractor. Contractor shall revise and resubmit. All parties shall update percentage of completion values in the same manner, i.e., express value of an accumulated percentage of completion to date.

2. Each Application for Payment may be reviewed by Construction Manager and/or inspectors to determine whether the Application for Payment is proper, and shall be rejected, revised, or approved by Construction Manager pursuant to the Schedule of Values prepared in accordance with Paragraph 1.06B of this section.

3. If it is determined that the Application for Payment is not proper and suitable for payment, Construction Manager will return it to the Contractor as soon as practicable, but no later than seven Days after receipt, together with a document setting forth in writing the reasons why the Application for Payment is not proper. If Construction Manager determines that portions of the Application for Payment are not proper or not due under the Contract Documents, then Construction Manager may approve the other portions of the Application for Payment, and in the case of disputed items or defective Work not remedied, may withhold up to 150 percent of the disputed amount from the progress payment.

4. Pursuant to Public Contract Code Section 20104.50, if the Owner fails to make any progress payment within 30 Days after receipt of funds from the State of California, the Owner shall pay interest to the Contractor equivalent to the legal rates set forth in subdivision (a) of Section 685.010 of the Code of Civil Procedure. The 30-Day period shall be reduced by the number of days by which the Owner exceeds the seven-day return requirement set forth herein.

5. As soon as practicable after approval of each Application for Payment for progress payments, the Owner will pay to Contractor in manner provided by law, an amount equal to 90 percent of the amounts otherwise due as provided in the Contract Documents, or a lesser amount if so provided in Contract Documents, provided that payments may at any time be withheld if, in judgment of the Construction Manager, Work is not proceeding in accordance with Contract, or Contractor is not complying with requirements of Contract, or to comply with stop notices or to offset liquidated damages accruing or expected.

6. Before any progress payment or final payment is due or made, Contractor shall submit satisfactory evidence that Contractor is not delinquent in payments to employees, Subcontractors, suppliers, or creditors for labor and materials incorporated into Work. This specifically includes, without limitation, conditional lien release forms for the current progress payment and unconditional release forms for past progress payments. The Owner also may elect in its sole discretion to pay progress payments by joint check to Contractor and each Subcontractor having an interest in that progress payment in such amount.

7. The Owner reserves and shall have the right to withhold payment for any equipment and/or specifically fabricated materials that, in the sole judgment of the Owner, are not adequately and properly protected against weather and/or damage prior to or following incorporation into the Work.

8. Granting of progress payment or payments by the Owner, or receipt thereof by Contractor, shall not be understood as constituting in any sense acceptance of Work or of any portion thereof, and shall in no way lessen liability of Contractor to replace unsatisfactory work or material, though unsatisfactory character of work or material may have been apparent or detected at time payment was made.

9. When the Owner shall charge sum of money against Contractor under any provision of Contract Documents, amount of charge shall be deducted and retained by the Owner from amount of next succeeding progress payment or from any other moneys due or that may become due Contractor under Contract. If, on completion or termination of Contract, such moneys due Contractor are found insufficient to cover the Owner's charges against it, the Owner shall have right to recover balance from Contractor or Sureties.

1.07 SUBSTITUTION OF SECURITIES IN LIEU OF RETENTION

In accordance with the provisions of Public Contract Code Section 22300, substitution of securities for any moneys withheld under Contract Documents to ensure performance is permitted under following conditions:

A. At request and expense of Contractor, securities listed in Section 16430 of the Government Code, bank or savings and loan certificates of deposit, interest bearing demand deposit accounts, standby letters of credit, or any other security mutually agreed to by Contractor and the Owner which are equivalent to the amount withheld under retention provisions of Contract shall be deposited with Controller or with a state or federally chartered bank in California, as the escrow agent, who shall then pay such moneys to Contractor. Upon satisfactory completion of Contract, securities shall be returned to Contractor.

B. Alternatively, Contractor may request and the Owner shall make payment of retentions earned directly to the escrow agent at the expense of Contractor. At the expense of Contractor, Contractor may direct the investment of the payments into securities and receive the interest earned on the investments upon the same terms provided for in this section for securities deposited by Contractor. Upon satisfactory completion of Contract Documents, Contractor shall receive from escrow agent all securities, interest, and payments received by the escrow agent from the Owner, pursuant to the terms of this section. Pay to each Subcontractor, not later than 20 Days after receipt of the payment, the respective amount of interest earned, net of costs attributed to retention withheld from each Subcontractor, on the amount of retention withheld to insure the performance of Contractor.

C. Contractor shall be beneficial owner of securities substituted for moneys withheld and shall receive any interest thereon.

D. Enter into escrow agreement with Controller according to Document 00680 (Escrow Agreement for Security Deposits in Lieu of Retention), as authorized under Public Contract Code Section 22300, specifying amount of securities to be deposited, terms and conditions of conversion to cash in case of default of Contractor, and termination of escrow upon completion of Contract Documents.

E. Public Contract Code Section 22300 is hereby incorporated in full by this reference.

1.08 FINAL PAYMENT

A. As soon as practicable after all required Work is completed in accordance with Contract Documents, including punchlist, testing, record documents and Contractor maintenance after Final Acceptance, the Owner will pay to Contractor, in manner provided by law, unpaid balance of Contract Sum of Work (including without limitation retentions), or whole Contract Sum of Work if no progress payment has been made, determined in accordance with terms of Contract Documents, less sums as may be lawfully retained under any provisions of Contract Documents or by law.

B. Prior progress payments shall be subject to correction in the final payment. The Owner's determination of amount due as final payment shall be final and conclusive evidence of amount of Work performed by Contractor under Contract Documents and shall be full measure of compensation to be received by Contractor.

C. Contractor and each assignee under an assignment in effect at time of final payment shall execute and deliver at time of final payment, and as a condition precedent to the Owner's obligation to make final payment, a final release discharging the Owner, its officers, agents, employees, and consultants of and from liabilities, obligations, and claims arising under Contract Documents.

1.09 EFFECT OF PAYMENT

Payment will be made by the Owner, based on Construction Manager's observations at the site and the data comprising the Application for Payment. Payment will not be a representation that Construction Manager has:

A. Made exhaustive or continuous on-site inspections to check the quality or quantity of Work;

B. Reviewed construction means, methods, techniques, sequences, or procedures;

C. Reviewed copies of requisitions received from Subcontractors and material suppliers and other data requested by Construction Manager to substantiate Contractor's right to payment; or

D. Made examination to ascertain how or for what purpose Contractor has used money previously paid on account of the Contract Sum.

END OF SECTION

SECTION 01060

SAFETY AND HEALTH

1.01 GENERAL

A. The Contractor certifies that he is experienced and qualified to anticipate and meet the safety and health requirements of this project. The Contractor shall require his personnel to observe proper hygienic and safety precautions.

B. The Contractor shall take measures to assure his personnel observe proper safety precautions when working in these areas.

1.02 SAFETY AND HEALTH REGULATIONS

A. The Contractor shall comply with Safety and Health Regulations for Construction, promulgated by the Secretary of Labor under Section 107 of the Contract Work Hours and Safety Standards Acts, as set forth in Title 29, Code of Federal Regulations (CFR). Copies of these regulations may be obtained from Labor Building, 14th and Constitution Avenue NW, Washington, DC 20013.

B. The Contractor shall also comply with the provisions of the Federal and State of California Occupational Safety and Health Act (OSHA), as amended.

END OF SECTION

SECTION 01065

WATER POLLUTION CONTROL

PART 1 - GENERAL

1.03 SCOPE

A. This section includes general specifications for preventing, controlling, and abating water pollution in streams, waterways, and other bodies of water.

1.04 QUALITY ASSURANCE

A. The editions of the specifications and standards referenced herein, published by the following organizations, apply to the work only to the extent specified by the reference. The latest version in effect at the time of bid shall apply.

1. State of California, Department of Transportation (CALTRANS) Publications CALTRANS

2. Standard Specifications, State of California Business and Transportation Agency, Department of Transportation, 2024.

B. State Standard Specifications: Whenever this specification is referenced, the following is understood.

1. All references to statistical testing are deleted.
2. Whenever a discrepancy occurs between the Standard Specifications and this specification, it is understood that this specification governs.
3. All references to measurement and payment are deleted.

C. Information on forms, reports, and other documents can be found in the following manuals:

1. CalTrans Storm Water Handbooks available at: http://www.dot.ca.gov/hq/construc/stormwater/manuals.htm

2. California Stormwater Quality Association (CASQA) Stormwater Best Management Practice (BMP) Handbooks available at: http://www.cabmphandbooks.com/

1.05 Regulatory Requirements

A. The Water Pollution Control (WPC) quality control and assurance (QA/QC) shall conform to the requirements set forth in Section 13-1.01D Quality Control and Assurance of the Standard

Specifications, except as modified herein, City of Manteca Stormwater Pollution Program and the SWRCB NPDES Permit CA0081558 ORDER R5-2021-0003. The Contractor shall be responsible for all costs associated with the implementation of the QA/QC of WPC submittals to comply these Provisions, the Standard Specifications, and with all applicable storm water requirements of the City, San Joaquin County, the State of California, and United States.

B. The contractor shall comply the State Water Resources Control Board under General permit 2022-0057-DWQ. The City's general permit governs stormwater and nonstormwater discharges from the City's properties, facilities, and activities.

C. A Water Pollution Control Plan (WCPC) can be either a SWPPP or an erosion and sediment control plan (ESCP). In general projects that are larger than 5 acers or projects between 1 acre and 5 acres that are not exempt, the contractor must apply for a NOI under the CGP and a SWPPP is required. Projects that are between 1 and 5 acres that are exempt or projects that are less than one acre, the contractor shall prepare an ESCP.

D. Projects that disturb one acre or more of soil or disturb less than one acre but are part of a larger common plan or development or sale are subject to the Construction General Permit (CGP) in addition to the construction site storm water runoff control ordinance.

E. The project disturbs less than one acre therefore the Contractor will not need to submit a Water Pollution Control Plan (WCPC) for the City's review and written approval.

F. A WCPC will not be approved unless it contains appropriate site-specific construction site BMPs that meet the minimum requirements of the City. Any revisions to the erosion and sediment control plan shall review and approved by the city prior to implementation by the Contractor.

G. If the project requires a SWPPP, the contractor shall apply for a permit under the CGP. The contractor shall submit all necessary documents and complete the required form on the State water Resources Control Board, Storm Water Multiple Application and Report Tracking System (SMARTS): https://smarts.waterboards.ca.gov/smarts/faces/SwSmartsLogin.jsp

H. After completing the application on SMARTS, the contractor shall notify the Engineer to certify the application.

I. Note, the application requires the QSD to enter their name and QSD number. The City shall not responsible for delays resulting from incomplete application process.

J. The ESCP shall list all applicable permits directly associated with the grading activity, including, but not limited to the State Water Board's CGP, State Water Board 401 Water Quality Certification, U.S. Army Corps 404 permit, and California Department of Fish and Game 1600 Agreement. The erosion and sediment control plan include the rationale used for selecting BMPs including supporting soil loss calculations, if necessary.

K. The SWPPP developed pursuant to the CGP may substitute for the ESCP for projects where a SWPPP is developed. SWPPP or ESCP shall be prepared by a California certified QSD. Implementation shall occur under the supervision of a California-certified QSP. Any modification of the SWPPP or ESCP prior to or during construction shall be reviewed and approved by the QSD in responsible charge The WPC manager must be a California certified Qualified SWPPP Practitioner (QSP) certified through the California State Water Resources Control Board (SWRCB). The Contractor shall assign one WPC manager to implement the WPCP for the project.

L. Do not start job site activities until:

1. The Water Pollution Control Plan (WPCP) is approved.

2. WPCP review requirements have been fulfilled. If the RWQCB requires time for review, allow 21 business days for the review.

M. If the contractor operate a Contractor-support facility, protect stormwater systems or receiving waters from the discharge of potential pollutants by using water pollution control practices.

N. Contractor-support facilities include:

1. Staging areas

2. Storage yards for equipment and materials

3. Mobile operations

4. Batch plants for PCC and HMA

5. Crushing plants for rock and aggregate

6. Other facilities installed for the Contractor’s convenience, such as haul roads

O. Discharges from manufacturing facilities, such as batch plants and crushing plants, must comply with the general waste discharge requirements for Order 2014-0057-DWQ, issued by the State Water Resources Control Board for "Discharge of Storm Water Associated with Industrial Activities Excluding Construction Activities" and referred to herein as "General Industrial Permit." For the General Industrial Permit, go to the Web site for the State Water Resources Control Board.

P. If the contractor operate a batch plant to manufacture PCC, HMA, or other material or a crushing plant to produce rock or aggregate, obtain coverage under the General Industrial

Permit. The contractor must be covered under the General Industrial Permit for batch plants and crushing plants located:

1. Outside of the job site

2. Within the job site that serve 1 or more contracts

Q. If the contractor obtain or dispose of material at a non-commercially operated borrow or disposal site, prevent water pollution due to erosion at the site during and after completion of the Contractor's activities. Upon completion of the Contractor's work, leave the site in a condition such that water will not collect or stand therein.

R. The City does not pay for water pollution control practices at Contractor-support facilities and non-commercially operated borrow or disposal sites.

S. The Contractor shall be responsible for all costs associated with Water Pollution Control (WPC), and the proper use and applications of the facilities to comply with the applicable storm water requirements of the City, San Joaquin County, the State of California, and the United States. This item shall be included in the bid under water pollution control. The City does not pay for equipment, labor, permit fees or any other costs associated with WPC beyond those included in the associated bid item. The Engineer may correct the deficiency and deduct the cost of correcting the deficiency from payment if the contractor fails to correct the deficiency by the agreed date or before the onset of precipitation.

1.02 SUBMITTALS

A. If the project meetings the requirements in Section 1.02 above, then the Contractor shall submit a WPCP, otherwise a WPCP is not required. Best Management Practices and all other methods associated with ORDER R5-2021-0003, NPDES General Permit No. CA0081558 shall be employed to prevent anything other than rain from entering the storm drain facility.

B. The WPC program shall conform to the requirements set forth in Section 13-2 Water Pollution Control Program of the Standard Specifications.

C. The WPC submittals shall conform to the requirements set forth in Section 13-1.01C Submittals of the Standard Specifications. The Contractor shall be responsible for all costs associated with the preparation and delivery of WPC submittals to comply these Provisions, the Standard Specifications, and with all applicable storm water requirements of the City, San Joaquin County, the State of California, and United States.

PART 2 - PRODUCTS

2.01 MATERIALS

A. The WPC materials shall conform to the requirements set forth in Section 13-1.02 Materials of the Standard Specifications, , except as modified herein, City of Manteca Stormwater Pollution Program and, the SWRCB NPDES Permit CA0081558 ORDER R5-2021-0003.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. The WPC construction shall conform to the requirements set forth in Section 13-1.03 Construction of the Standard Specifications. The Contractor shall:

1. Install facilities and devices used for water pollution control practices before performing work activities.

2. Install soil stabilization materials for water pollution control practices in all work areas that are inactive or before storm events.

3. Repair or replace water pollution control practices within 24 hours of discovering any damage, unless a longer period is approved.

B. The Engineer does not pay for the cleanup, repair, removal, disposal, or replacement of water pollution control practices due to improper installation or the Contractor’s negligence.

C. The Contractor may request changes to the water pollution control work or the Engineer may order changes to water pollution control work. Changes may include additional or new water pollution control practices. Additional water pollution control work may be paid for as extra work.

D. The Contractor shall retain a printed copy of the approved WPCP at the job site and make available during site visits at the request of the City, County or State.

E. Monitor the National Weather Service's forecast on a daily basis. For the National Weather Service's forecast, go to the Web site for the National Weather Service. Monitoring and inspection shall be conducted in conformance with Section 13-1.03B and 13-1.03C of the Standard Specifications, except as modified herein, City of Manteca Stormwater Pollution Program and the SWRCB NPDES Permit CA0081558 ORDER R5-2021-0003. All inspection documentation shall be maintained at the site and made available by the contractor at the request of the City, County or State.

F. Whenever the contractor or the Engineer identifies a deficiency in the implementation of the approved WPCP, correct the deficiency:

1. Immediately, unless a later date is approved

2. Before precipitation occurs

G. The Engineer may correct the deficiency and deduct the cost of correcting the deficiency from payment if the contractor fails to correct the deficiency by the agreed date or before the onset of precipitation.

3.02 JOB SITE MANAGEMENT

A. The contractor shall perform appropriate job site management, including spill prevention and control, material management, waste management, nonstormwater management, and dewatering activities. The contractor shall implement effective handling, storage, usage, and disposal practices to control material pollution and manage waste and non-stormwater at the job site before they come in contact with storm drain systems and receiving waters.

B. Job site management shall conform to the requirements set forth in Section 13-4 Job Site Management of the Standard Specifications. Linear sediment barriers must comply with Section 13-10.

C. The Contractor shall be maintain and provide all submittals in accordance with Section 13-4.01B Submittals of the Standard Specifications. The contractor shall maintain all records on site, and provide a copy at the request of the City, County or State.

D. Stockpiling materials; storing pile-driving equipment and liquid waste containers; washing vehicles and equipment in outside areas; and fueling and maintaining vehicles and equipment activities must be performed at safe distance, such that no illicit discharge may occur, from concentrated flows of stormwater, drainage courses, and inlets, unless otherwise authorized by the Engineer.

3.03 TEMPORARY SOIL STABILIZATION

A. The use, submittals, materials and construction of temporary soil stabilization shall conform to the requirements set forth in Section 13-5 Temporary Soil Stabilization of the Standard Specifications. The Contractor shall be responsible for all costs associated with performing job site management to comply these Provisions, the Standard Specifications, and with all applicable storm water requirements of the City, San Joaquin County, the State of California, and United States.

B. The Engineer designates the areas to receive soil stabilization materials by directing the placement of stakes or other suitable markers in increments of 1 acre or less.

3.04 TEMPORARY SEDIMENT CONTROL

A. The use, submittals, materials and construction of temporary sediment controls, excluding temporary linear sediment barriers, shall conform to the requirements set forth in Section 13-6 of the Standard Specifications. Install, relocate and remove control measures as needed to comply with all applicable regulations.

3.05 TEMPORARY TRACKING CONTROL

A. The use, submittals, materials and construction of temporary linear sediment barriers shall conform to the requirements set forth in Section 13-7 of the Standard Specifications. Install, relocate and remove facilities as needed to comply with all applicable regulations.

B. The Contractor shall retain and submit records of street sweeping activities, including sweeping times, sweeping locations, and the quantity of disposed sweeping waste. Records shall be maintained on-site and made available to the City, County or State upon request.

3.06 TEMPORARY CONCRETE WASHOUTS

A. The use, submittals, materials and construction of temporary linear sediment barriers shall conform to the requirements set forth in Section 13-9 of the Standard Specifications.

B. Install, relocate or remove portable temporary concrete washout or bins as needed for concrete work. Remove and dispose of concrete waste within 2 business days after a concrete washout becomes filled. Dispose of concrete waste material from a concrete washout at a plant licensed to receive solid concrete waste, liquid concrete waste, or both. Secure portable temporary concrete washout or bin to prevent spilling of concrete waste material whenever it is being relocated or transported within the job site. Whenever any spilled material is observed, clean up the spilled material and place it back into the concrete washout unit. The City does not pay for installing, relocating or removing a portable temporary concrete washout or bin.

3.07 TEMPORARY LINEAR SEDIMENT BARRIERS

A. The use, submittals, materials and construction of temporary linear sediment barriers shall conform to the requirements set forth in Section 13-10 of the Standard Specifications.

B. Install, relocate and remove facilities as needed to comply with all applicable regulations.

END OF SECTION

SECTION 01070

ENVIRONMENTAL STEWARDSHIP

PART 1 - GENERAL

1.01 SCOPE

A. This section includes general specifications for environmental compliance and environmental resource management.

1.02 QUALITY ASSURANCE

A. References

1. The editions of the specifications and standards referenced herein, published by the following organizations, apply to the work only to the extent specified by the reference. The latest version in effect at the time of bid shall apply.

2. State of California, Department of Transportation (CALTRANS) Publications:
   a. *Standard Specifications, State of California Business and Transportation Agency, Department of Transportation, 2024.*

3. State Standard Specifications: Whenever this specification is referenced, the following is understood.
   a. Whenever a discrepancy occurs between the Standard Specifications and this specification, it is understood that this specification governs.

   b. All references to measurement and payment are deleted.

B. Regulatory Requirements

1. Air Quality: Section 14-9 includes specifications relating to air quality.

2. Air Pollution Control: Comply with air pollution control rules, regulations, ordinances, and statutes that apply to work performed under the Contract, including air pollution control rules, regulations, ordinances, and statutes provided in Govt Code § 11017 (Pub Cont Code § 10231). Do not burn material to be disposed of.

1.01 DEFINITIONS

A. Listed Fish

1. Fish that is listed or proposed as a Threatened Species or as an Endangered Species under

the Federal Endangered Species Act (FESA), or listed or proposed as a Threatened Species or as an Endangered Species under the California Endangered Species Act (CESA).

B. **Listed Salmonid**

1. Salmon, steelhead, or trout that are listed as a Threatened Species or as an Endangered Species under FESA, or listed or proposed as a Threatened Species or as an Endangered Species under CESA.

C. **Regulated Fish**

1. Listed fish species that are protected by law or regulation.

1.02 ENVIRONMENTALLY SENSITIVE AREAS

A. No ESAs have been identified within the boundaries of the project sites. Care must be taken that the Contractor avoid any disturbance or adverse impacts to ESAs. Should any disturbance or other impacts by the Contractor occur, notify the City immediately.

PART 2 - PRODUCTS

NOT USED

PART 3 - EXECUTION

3.01 NOISE AND VIBRATION

B. Do not operate construction equipment or run the equipment engines from 6:00 p.m. to 7:00 a.m., or on Saturdays or Sundays, except where authorized by the Engineer or to operate equipment within the project limits during these hours to:

1. Service traffic control facilities
2. Service construction equipment

B. If authorized to work during these times, Contractor shall take steps to comply with the local noise ordinance.

C. Equip an internal combustion engine with the manufacturer-recommended muffler. Do not operate an internal combustion engine on the job site without the appropriate muffler.

3.02 DUST CONTROL

A. Prevent and alleviate dust by applying water, dust palliative, or both and by covering active and inactive stockpiles. Apply water in conformance with Section 17 of these Provisions. Apply dust palliative under Section 18 of these Provisions. If ordered, apply water, dust palliative, or both to control dust caused by public traffic.

B. The Contractor shall be responsible for all costs associated with the implementing appropriate dust control measures, and the proper use and applications of those measures to comply with the applicable storm water requirements of the City, San Joaquin County, the State of California, and the United States. This item shall be included in the bid under water pollution control. The City does not pay for equipment, labor or any other costs associated with implementation of dust control measures beyond those included in the associated bid item. The Engineer may correct the deficiency and deduct the cost of correcting the deficiency from payment if the contractor fails to correct the deficiency by the agreed date or before the onset of precipitation.

C. In accordance with City of Manteca City Council Resolution R1999-138, Contractor shall begin application of water, for dust control purposes, upon their property under construction when the average sustained wind speed is six (6) miles per hour (MPH) or higher. Water shall be continuously applied until the wind speed drops below six (6) MPH or notification to cease is received from the Director of Engineering/City Engineer.

Engineering will issue a six (6) MPH wind advisory warning via email to Contractors that have provided an email address to the City. The National Weather Service forecast data will be used.

Contractor shall begin application of water within one hour after the wind advisory warning is issued. If water application does not begin within the allotted time, the City may enlist the services of private water trucks to provide necessary services for which Contractors shall pay to the City the actual cost of the water truck services plus a 15% administrative fee. Said amount shall be paid prior to acceptance of the public improvements by the City. As a minimum, to control dust in a proactive manner, Contractors are advised to use one (1) 4,000 gallon water truck per ten (10) acres of land being developed, including building pads.

3.03 SOLID WASTE DISPOSAL AND RECYCLING

A. Do not allow litter, trash, or debris to accumulate anywhere on the job site, including storm drain grates, trash racks, and ditch lines. Pick up and remove litter, trash, and debris from the job site at least once a week. WPC manager must monitor solid waste storage and disposal procedures on the job site.

B. If practicable, recycle nonhazardous job site waste and excess material. If recycling is not practicable, dispose of it.

C. Furnish enough closed-lid dumpsters of sufficient size to contain the solid waste generated by work activities. When refuse reaches the fill line, empty the dumpsters. Dumpsters must be watertight. Do not wash out dumpsters at the job site. Furnish additional containers and more frequent pickup during the demolition phase of construction.

D. Solid waste includes:

1. Brick

2. Mortar
3. Timber
4. Metal scraps
5. Sawdust
6. Pipe
7. Electrical cuttings
8. Nonhazardous equipment parts
9. Styrofoam and other packaging materials
10. Vegetative material and plant containers from highway planting
11. Litter and smoking material, including litter generated randomly by the public
12. Other trash and debris

E. Furnish and use trash receptacles in the job site yard, field trailers, and locations where workers gather for lunch and breaks.

F. Submit to the Engineer a final annual Solid Waste Recycling Report in conformance with Section 14-10.02 Solid Waste Disposal and Recycling Report of the Standard Specification within 5 business days after Contract acceptance. For each failure to submit a completed report, the Engineer withholds $10,000.

3.04 HAZARDOUS WASTE AND CONTAMINATION

A. No hazardous waste or contamination has been identified at the project sites. If potentially hazardous waste or contamination is encountered, stop work within 100 feet of that area and contact the City immediately. The handing, storage, transport, disposal, documentation and reporting related to hazardous waste and contamination that may be encountered at a project site shall conform to the requirements set forth in Section 14-11 Hazardous Waste and Contamination of the Standard Specifications, except as modified herein, and all local, State and Federal requirements. The handing, storage, transport, disposal, documentation and reporting related to regulated hazardous waste or contamination encountered at a project site under the authorization of the Director would represent a change in work character and is eligible for a change order in accordance with Section 4-1.05 of these Provisions.

B. Unauthorized work is not eligible for reimbursement under a change order.

3.05 ARCHAEOLOGICAL RESOURCES

A. If archaeological resources are discovered at the job site, do not disturb the resources and immediately:

1. Stop all work within a 60-foot radius of the discovery
2. Protect the discovery area
3. Notify the Engineer

B. The Engineer investigates. Do not move archaeological resources or take them from the job site. Do not resume work within the discovery area until approved.

C. If ordered, furnish resources to assist in the investigation or recovery of archaeological resources. This work will be paid for as extra work (with or without a reference to a section).

3.06 BIRD PROTECTION

A. Protect migratory and nongame birds, their occupied nests, and their eggs.

B. The City anticipates breeding and nesting or attempted nesting by migratory and nongame birds in the area of the project site from February 1 to August 31 of each year. As described in the environmental documents, of particular concern in this area is potential disturbance of the Clapper Rail breeding and nesting.

C. The federal Migratory Bird Treaty Act, 16 USC § 703–711, and 50 CFR Pt 10 and Fish & Game Code §§ 3503, 3513, and 3800 protect migratory and nongame birds, their occupied nests, and their eggs.

D. The federal Endangered Species Act of 1973, 16 USC § 1531 and § 1543, and the California Endangered Species Act, Fish & Game Code §§ 2050–2115.5, prohibit the take of listed species and protect occupied and unoccupied nests of threatened and endangered bird species.

E. The Bald and Golden Eagle Protection Act, 16 USC § 668, prohibits the destruction of bald and golden eagles and their occupied and unoccupied nests.

F. If migratory or nongame bird nests are discovered that may be adversely affected by construction activities or an injured or killed bird is found, immediately:

1. Stop all work within a 100-foot radius of the discovery
2. Notify the Engineer

G. Do not resume work within the specified radius of the discovery until authorized.

H. If ordered, use exclusion devices, take nesting prevention measures, remove and dispose of partially constructed and unoccupied nests of migratory or nongame birds on a regular basis to prevent their occupation, or perform any combination of these. This work will be paid for as extra work .

I. Prevent nest materials from falling into waterways.

3.07 FISH PROTECTION

A. Protect all life stages of anadromous fish in streams, conduct work activities to allow free passage of anadromous migratory fish or as allowed by PLAC terms and conditions. Assure

that construction work does not produce sound in water that results in unauthorized take of listed species.

3.08 PALEONTOLOGICAL RESOURCES

A. If paleontological resources are discovered at the job site, do not disturb the material and immediately:

1. Stop all work within a 60-foot radius of the discovery
2. Protect the area
3. Notify the Engineer

B. The Engineer investigates and modifies the dimensions of the protected area if necessary. Do not move paleontological resources or take them from the job site. Do not resume work within the specified radius of the discovery until approved.

END OF SECTION

SECTION 01080

SITE PROTECTION

PART 1 – GENERAL

1.01 SUMMARY

A. All initial work at the site relating to implementation of Storm Water Best Management Practices, and also work throughout the project to maintain ongoing implementation of the BMPs.

B. Preparation of the well site to allow safe access to the site for work, to protect existing improvements, for public safety, and to allow for all weather site access.

C. All work in the Section is subject to the review and approval of the Owner.

1.02 STORMWATER BEST MANAGEMENT PRACTICES

A. Erosion, Sediment and Water Pollution Control shall comply with the provisions set forth in Section 01065 of these specifications.

B. The Contractor shall implement, at a minimum, Best Management Practices (BMPs); depending on field conditions, additional measures may be necessary to minimize erosion and the transport of sediments.

1.03 FENCES

A. Fences, Barricades, Warning Signs, and Lights.

1. When used, shall conform to CAL-OSHA regulations, other State of California and local codes, rules, regulations, and ordinances for protection of workers, public and private property, and provide, install and maintain barricades, warning devices and other protection required therefore.

2. Contractor shall provide temporary fencing as required to protect materials, equipment, livestock, and miscellaneous items from theft, vandalism, unauthorized access and/or harm.

B. All open excavations shall have temporary fencing around their perimeter, as stated in 1.03 A of this section, if site is to be unmanned.

1.04 ALL WEATHER ACCESS

A. The Contractor shall prepare site as necessary to ensure that the site will remain accessible

during wet weather conditions. Should the Contractor insufficiently prepare the site for such conditions, no standby time will be paid for time lost, or time required to remedy the site conditions.

B. Suggested preparation for all weather access includes the installation of a gravel blanket of Class 2 aggregate over the entire site. All traffic at the site should be restricted to the gravel blanket. The gravel blanket should be of adequate thickness to accommodate wet weather conditions and to allow for all construction activities at the site.

1.05 SITE INGRESS/EGRESS

A. The Contractor shall provide a tire beat-down area that will sufficiently clean vehicle tires of accumulated dirt and mud, and shall route all traffic exiting the site through this area.

B. The Contractor shall regularly sweep and maintain the adjacent roadway free and clear of sediment and debris.

1.06 TRAFFIC CONTROL

A. A traffic control program shall be implemented to protect the entrance to the site and any equipment, vehicles, or the public on the adjacent roadways. Construction area signs and traffic cones shall be furnished, installed, maintained, and removed when no longer required.

B. The Contractor shall submit a written traffic control plan for approval to the City, and shall notify local authorities of its intent to begin work at least five (5) days before work is begun. The Contractor shall cooperate with local authorities relative to handling traffic through the area and shall make its own arrangements relative to keeping the working area clear of parked vehicles. The Contractor shall coordinate as necessary with other construction activities in the area.

C. When the Contractor's operations create a condition hazardous to traffic or to the public, he shall furnish, erect and maintain, at his expense and without cost to the Owner, such fences, barricades, lights, signs and other devices as are necessary to prevent accidents or damage or injury to the public. The Contractor shall also furnish such flagmen, provided with the necessary equipment kept clean and in good condition by the Contractor at his expense, as may be necessary to give adequate warning to traffic or to the public that the roadway is under construction or of any dangerous conditions to be encountered.

D. The Contractor shall not block access to any private driveways. Any damage created to private driveways as a result of vehicles or equipment during construction activities, shall be borne to the Contractor. The damage will be repaired by the Contractor at no expense to the Owner.

PART 2 - PRODUCTS

NOT USED

PART 3 - EXECUTION

NOT USED

END OF SECTION

SECTION 01116

CONTRACT DOCUMENT LANGUAGE

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Explanation of arrangement, language, reference standards, and format.

1.02 REFERENCES

A. Construction Specifications Institute (CSI):
   1. MasterFormat™.
   2. SectionFormat™.
   3. PageFormat™.

1.03 PROJECT MANUAL ARRANGEMENT

A. Document and Section numbers used in Project Manual, and Project Manual arrangement are in accordance with CSI MasterFormat™, except where departures have been deemed necessary.

B. Sections are written in CSI SectionFormat™, Three-Part Section Format, except where departures have been deemed necessary.

C. Page format for Sections in the Project Manual is in PageFormat™, except where departures have been deemed necessary.

1.04 CONTRACT DOCUMENT LANGUAGE

A. Specification Section Paragraphs entitled "Section Includes" summarize briefly what is generally included in the section.
   1. Requirements of Contract Documents are not limited by "Section Includes" paragraphs.

B. Specifications have been partially streamlined by intentionally omitting words and phrases, such as "the Contractor shall," "in conformity therewith," "shall be" following "as indicated," "a," "an," "the" and "all."
   1. Assume missing portions by inference.

C. Phrase "by Engineer" modifies words such as "accepted," "directed," "selected," "inspected," and "permitted," when they are unmodified.

D. Phrase "to Engineer" modifies words such as "submit," "report," and "satisfactory," when they are unmodified.

E. Colons (:) are used to introduce a list of particulars, an appositive, an amplification, or an illustrative quotation:
   1. When used as an appositive after designation of product, colons are used in place of words "shall be."

F. Word "provide" means to manufacture, fabricate, deliver, furnish, install, complete, assemble, erect in place, test, or render ready for use or operation, including necessary related material, labor, appurtenances, services, and incidentals.

G. Words "Contractor shall" are implied when direction is stated in imperative mood.

H. Term "products" includes materials and equipment as specified in Section 01600 - Product Requirements.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01140

WORK RESTRICTIONS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Requirements for sequencing and scheduling the Work affected by existing site and facility, work restrictions, and coordination between construction operations and plant operations.

1.02 SUBMITTALS

A. Baseline Schedule with MOP tasks.

B. Method of Procedure (MOP) Form.

C. Method of Procedure (MOP) Log.

D. Progress Schedule with MOP tasks.

1.03 METHOD OF PROCEDURE (MOP)

A. Comply with MOP Instructions as specified in Attachment A - Method of Procedure (MOP).

B. Prepare MOP for the following conditions:
   1. Shutdowns, diversions, and tie-ins to the existing facility.
   2. Process start-up activities.
   3. Power interruption and tie-ins.
   4. Switch over between temporary and permanent facilities, equipment, piping, and electrical and instrumentation systems.
   5. Process constraints requiring interruption of operating processes or utilities.

C. Other Work not specifically listed may require MOPs as determined necessary by the Contractor, Owner, or Engineer.

D. Submit Baseline Schedule, as specified in Section 01310 - Contractor's Construction Schedule with proposed MOPs.

E. Submit MOP Log at construction progress meetings.

F. No consideration will be given to claims of additional time and cost associated to preparing MOPs required by the Owner and Engineer to complete this work in a manner that facilitates proper operation of the facility and compliance with effluent discharge criteria.

G. Where required to minimize treatment process interruptions while complying with specified constraints, provide temporary pumping, power, lighting, controls, instrumentation, and safety devices.

1.04 GENERAL CONSTRAINTS ON WORK AND SCHEDULING OF WORK

A. Plant access for Contractor will be provided at the main gate.

B. Perform abandoned pipe Work as specified in Section 01738 - Selective Alterations and Demolition.

C. Wastewater projects:
   1. The Manteca Wastewater Quality Control Facility is the City of Manteca's only means of treating domestic and industrial wastewater prior to discharging to the San Joaquin River or land application. Impairing the operational capabilities of this treatment plant will result in serious environmental damage and monetary fines.
   2. Conduct Work in a manner that will not impair the operational capabilities of essential elements of the treatment process or reduce the capacity of the entire treatment plant below levels sufficient to treat the quality of raw wastewater to the water quality limitations specified in the discharge permit.
   3. Contractor shall note that all work will be performed in an active facility that treats raw sewage and sewage sludges. As such, the Contractor should expect to encounter pathogens, sewer gas, odors, and other conditions associated with raw sewage. In addition, due to the nature and the physical condition of the existing facility, the Contractor should expect to be working in or around OSHA defined confined spaces and areas of the plant that are in disrepair and represent safety hazards.
   4. Several construction activities require the draining of existing tanks, channels, and pipes for work to be completed. Contractor shall assist plant staff in taking process units in and out of service for construction activities by providing personnel and equipment to completely drain and clean tanks, channels, and pipes. No extra compensation shall be allowed for this work, and it shall be included in the Contractor's bid price.
   5. Contractor shall note that a portion of the Work is in close proximity to digesters and related processes that produce, compress, or consume digester gas and/or natural gas. Classification envelopes around the digesters, digester gas utilization equipment, natural gas lines, and digester gas lines are defined by the National Electrical Code and National Fire Protection Association, Publication NFPA 820 (2020 or latest edition). All appropriate equipment, including sparkless equipment, shall be used within these classified areas. Contractor shall use caution and appropriate safety measures to address the presence of natural and digester gas in the area of Work.
   6. The existing digesters and surrounding areas contain digester gases which include, but are not limited to, methane, carbon dioxide, and hydrogen sulfide. Piping systems including digester gas and natural gas are also present in and around the area of Work.
      a. Work shall be conducted in conformance with all OSHA requirements.
         1) Work within the digesters shall be performed in conformance with OSHA requirements for confined space entry.

b. The Contractor shall coordinate all operations with the plant practices recommended by OSHA and the Owner's gas safety practices must be enforced at all times.
c. Contractor shall monitor the air in the work area with suitable gas monitoring equipment. Contractor shall suspend all work activities and immediately notify the Owner whenever monitored gases are present in sufficient quantities to present a hazard to workers.
d. Contractor shall provide safety equipment including high volume ventilation blowers, portable ladder, crane, etc., and procedures and shall enforce such procedures while working on or near the digesters to prevent fire and explosion of methane gas.

7. Conduct commissioning activities as specified in Section 01660 - Equipment and System Performance and Operational Testing in a manner that will not impair the operational capabilities of essential elements of the treatment process or reduce the capacity of the entire treatment plant below levels sufficient to treat the quality of raw wastewater to the water quality limitations specified in the discharge permit.
   a. Conduct PCIS Optimization and Fine-Tuning as specified in Section 01660 - Equipment and System Performance and Operational Testing.
8. The status of the treatment plant shall be defined as “operational” when it is capable of treating the entire quantity of wastewater received to the water quality limits specified in the discharge permit.

1.05 COMPLIANCE WITH NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM PERMIT

A. The existing facility is operating under the terms of a National Pollutant Discharge Elimination System permit issued by the California Regional Water Quality Control Board.
   1. This permit specifies the water quality limits that the plant must meet prior to discharge of effluent.
   2. A copy of the existing permit is on file for review at the Manteca Wastewater Quality Control Facility.

B. Perform work in a manner that will not prevent the existing facility from achieving the finished water quality requirements established by regulations.

C. Bear the cost of penalties imposed on the Owner for discharge violations caused by actions of the Contractor.

D. Conduct the Work and provide temporary facilities required to keep the existing plant continuously operational.

E. Do not remove or demolish existing facilities required to keep the existing plant operational at the capacities specified until the existing facilities are replaced by temporary, new, or upgraded facilities or equipment.
   1. Test replacement facilities to demonstrate operational success prior to removing or demolishing existing facilities.

1.06 USE OF SITE

A. The Drawings designate the areas of the site Contractor may use or occupy.

B. Operations and Maintenance Access:
   1. Provide safe, continuous access to process control equipment for plant operations and maintenance personnel.

C. Use and maintenance of onsite roadways:
   1. Contractor shall limit its use of roadways to those areas necessary to service its work and to those designated on the Drawings as approved for use.
   2. Roads shall be kept clean and undamaged by Contractor's activities. Damage shall immediately be repaired as approved by Owner.
   3. Contractor's use of roads shall not impair Owner's free passage or access to operating parts of the plant.
   4. Paved road shall be washed and/or swept clean each day.

D. Speed limit on all onsite roads is 10 miles per hour.

E. Parking:
   1. Contractor and its personnel, subcontractors, suppliers, and visitors shall park only in areas designated on the Drawings or otherwise directed by Owner.

F. Concurrent construction projects:
   1. Other construction projects will be taking place concurrently on the project site. Refer to Drawing 00G006 Contractor Staging Plan for locations of other construction on site and staging areas reserved for other contractors.
   2. Contractor shall cooperate with the Owner in facilitating work by other Contractors, coordinating shutdowns with other projects, and sharing Contractor's site access gate and plant roads.

G. Contractor shall be responsible for providing necessary labor and appropriate equipment to complete work at locations with restricted access on site (such as under power lines). Owner shall not be responsible for Contractor's limited site access vertically or horizontally.

1.07 UTILITIES

A. Provide advance notice to and utilize services of Underground Services Alert (U.S.A.) for location and marking of underground utilities operated by utility agencies other than the Owner.

B. Maintain electrical, telephone, water, gas, sanitary facilities, and other utilities within existing facilities in service. Provide temporary utilities when necessary.

C. New yard utilities were designed using existing facility drawings.
   1. Field verification of utilities locations was not performed during design.
   2. Services crossed or located nearby by new yard utilities may require relocation and possible shutdowns.
   3. Pipe alignments as indicated on the Drawings.

1.08 WORK BY OTHERS

A. Where proper execution of the Work depends upon work by others, inspect and promptly report discrepancies and defects.

1.09 TEMPORARY SERVICES, MATERIALS, AND EQUIPMENT

A. Contractor may elect to temporarily reroute some existing plant process piping, utility piping, electrical conduits or electrical duct banks as required in order to perform the Work. These proposed temporary relocated process piping, utility piping, electrical conduit or electrical duct banks and associated shutdowns are subject to approval by the Owner. Any relocated pipes, utilities, or electrical duct banks shall be replaced to match existing at no additional cost to the Owner.

1.10 SHUTDOWN CONSTRAINTS

A. General shutdown constraints:
   1. Execute the Work while the existing facility is in operation.
   2. Some activities may be accomplished without a shutdown.
   3. Apply to activities of construction regardless of process or work area.
   4. Activities that disrupt plant or utilities operations must comply with these shutdown constraints.
   5. Organize work to be completed in a minimum number of shutdowns.
   6. Provide thorough advanced planning, including having required equipment, materials, and labor on hand at time of shutdown.
   7. Shutdown MOPs:
      a. Advise the Engineer a minimum of 4 weeks prior to need for any complete or partial plant shutdown for tie-ins.
      b. Prepare and submit MOP to Engineer for any complete or partial plant shutdown required a minimum of 4 weeks prior to the shutdown.
      c. Owner’s written approval of MOP is required 2 weeks prior to beginning Work.
   8. Where required to minimize treatment process interruptions while complying with specified constraints, provide temporary pumping, power, lighting, controls, instrumentation, and safety devices.
   9. Final determination of the permitting of shutdowns will be the sole judgment of the Owner.
   10. Owner maintains the ability to abort on the day of the scheduled shutdown.
   11. Unplanned shutdowns due to emergencies are not specified in this Section.

B. Unit process availability work limitations:
   1. Shutdowns and tie-ins or other activities that disrupt plant operations are prohibited unless the following unit process availability conditions exist and unless otherwise approved in writing by the Owner and Engineer.
   2. At a minimum, the following facilities must be in service in order to proceed with a scheduled shutdown.
      a. WAS thickening (1 existing DAFT or 2 RDTs) and all associated systems.
      b. Solids dewatering (one centrifuge) and hauling, and all associated systems, including temporary polymer blending unit system.

C. Process, electrical and instrumentation - tie-in shutdowns:
   1. Maximum shutdown duration: 4 hours.
   2. Schedule no more than 1 tie-in shutdown per day.
   3. Shutdowns shall be permitted between the hours of 4 a.m. and 8 a.m. on working days unless otherwise approved by the Owner.
   4. No shutdowns allowed on Thursdays and Fridays.

1.11 WORK SEQUENCE AND CONSTRAINTS

A. General:
   1. The Possible Work Sequence and Constraints presented herein do not necessarily include all items affecting the completion of the Work but are intended to describe in general the critical events necessary to minimize disruptions of existing facilities and to ensure compliance with the NPDES permit requirements. Utilize the description of critical events in the Work Sequence and Constraints in this Section as a guideline for scheduling and completing the Work. Additional Constraints may be imposed during the Work depending on Contractor's sequence of work.
   2. Unless indicated otherwise, Owner will be responsible for taking existing tanks or structures out of service, draining the tanks, and rinsing each tank with plant water, and generally removing liquid, sludge, sand, grit, and other debris to within 2 feet from the side wall of the tank or structure. Contractor shall be responsible for removing remaining liquid, sludge, sand, and other debris and cleaning surfaces as needed to complete the Work.
   3. Unless indicated otherwise, Contractor will be responsible for isolating and draining of liquid containing pipes. While reasonable efforts will be made by Owner to positively shut-off tanks, valves, gates, weirs, and other isolation devices, Contractor shall plan for and provide additional means in his work to drain and dispose of remaining pipe contents, and remove any liquid leakage, dripping, and spills from the shut-off device or the isolated pipe in a manner without impacting his work. Contents removed from structures and pipes shall be disposed of at the plant by the Contractor with exact location to be coordinated with Owner.

B. The General Construction and Tie-In Sequences described below can proceed in parallel and independently, except as noted.

C. Constraints and Possible Work Sequence for Key Project Elements:
   1. MCC-E Improvements:
      a. Constraints:
         1) Electrical loads served by the existing MCC-E shall remain in service at all times, except for brief individual shutdowns to transfer loads from the MCC to the temporary MCC.
      b. Possible Work Sequence:
         1) Procure all equipment and materials required for the MCC-E improvements.
         2) Install and commission the temporary MCC-E.
         3) Use individual brief (less than 4 hours) shutdowns to move existing loads from MCC-E to the temporary MCC-E.

4) Perform demolition work as indicated on the Drawings, including but not limited to:
    a) Demolish MCC-E and housekeeping pad.
    b) Demolish concrete stairs and handrail.
5) Perform new construction and modifications as indicated on the Drawings, including but not limited to:
    a) Construct new concrete elevated slab, housekeeping pad, and support walls.
    b) Install new stairs and handrail.
    c) Install and test new permanent MCC-E.
    d) Install new electrical and control equipment and appurtenances.
6) Use individual brief (less than 4 hours) shutdowns to move loads from temporary MCC-E to the new permanent MCC-E.
7) Perform testing, start-up, and commissioning.

2. RDT Facility:
    a. Constraints:
        1) MCC-E shall be fully commissioned and placed into service prior to start-up of the RDT Facility.
        2) Testing, start-up, and commissioning of the RDT Facility shall occur at the same time as the Thickening Odor Control Facility.
        3) Both existing DAFTs shall remain in operation until the RDT Facility has been fully commissioned and placed into service.
        4) The RDT Facility shall be fully commissioned twice:
            a) WAS only: prior to conversion of DAFTs into Sludge Blend Tanks.
            b) Primary sludge and WAS: after conversion of DAFTs into Sludge Blend Tanks.
    b. Possible Work Sequence:
        1) Procure all equipment and materials required for the RDT Facility.
        2) Perform demolition work as indicated on the Drawings.
        3) Perform site work as indicated on the Drawings, including ground improvement system.
        4) Perform new construction and modifications as indicated on the Drawings, including but not limited to:
            a) Install all below grade piping and pipe encasement.
            b) Construct new concrete foundation, elevated platform, and prefabricated canopy.
            c) Install new polymer blend units and associated piping, valves, and appurtenances.
            d) Install new thickeners and appurtenances.
            e) Install new thickened sludge pumps and associated piping, valves, and appurtenances.
            f) Install new foul air ducting and appurtenances.
            g) Install new electrical and control equipment and appurtenances.
        5) Perform testing, start-up, and commissioning with WAS only prior to conversion of DAFTs into Sludge Blend Tanks.
        6) Perform testing, start-up, and commissioning with primary sludge and WAS after conversion of the DAFTs into Sludge Blend Tanks.

3. Thickening Odor Control Facility:
    a. Constraints:
        1) MCC-E shall be fully commissioned and placed into service prior to start-up of the Thickening Odor Control Facility.
        2) Testing, start-up, and commissioning of the Thickening Odor Control Facility shall occur at the same time as the RDT Facility.
    b. Possible Work Sequence:
        1) Procure all equipment and materials required for the Thickening Odor Control Facility.
        2) Perform demolition work as indicated on the Drawings.
        3) Perform site work as indicated on the Drawings, including ground improvement system.
        4) Perform new construction and modifications as indicated on the Drawings, including but not limited to:
            a) Construct new concrete slab.
            b) Install new odor control equipment, ducting, and appurtenances.
            c) Install new electrical and control equipment and appurtenances.
        5) Perform testing, start-up, and commissioning.
4. Dewatering Facility Improvements:
    a. Constraints:
        1) Two centrifuges and associated feed pumps, polymer feed systems, and all appurtenances shall be available for operation at all times.
    b. Possible Work Sequence:
        1) Procure all equipment and materials required for the Dewatering Facility improvements.
        2) Install the temporary polymer feed system.
        3) Perform demolition work as indicated on the Drawings, including but not limited to:
            a) Demolish existing polymer blend units and associated piping, valves, and appurtenances.
            b) Demolish existing polymer blend units concrete pad, platform, and patch floor.
            c) Demolish existing pump pad and patch floor.
        4) Perform new construction and modifications as indicated on the Drawings, including but not limited to:
            a) Install new polymer blend units and associated piping, valves, and appurtenances.
            b) Install new centrifuge pump and associated piping, valves, and appurtenances.
            c) Install new centrifuge and appurtenances.
            d) Install new electrical and control equipment and appurtenances.
        5) Perform testing, start-up, and commissioning.
5. Sludge Blend Tanks:
    a. Constraints:
        1) Both existing DAFTs shall remain in operation until the RDT Facility has been fully commissioned and placed into service.
    b. Possible Work Sequence:
        1) Procure all equipment and materials required for the Sludge Blend Tanks.

2) Perform demolition work as indicated on the Drawings, including but not limited to:
    a) Demolish all DAFT equipment and appurtenances.
    b) Demolish pressure recycle pumps, air retention tanks, and associated piping, valves, and appurtenances.
    c) Demolish thickened sludge pumps and associated piping, valves, and appurtenances.
    d) Demolish DAFT Polymer Facility.
    e) Demolish concrete slabs.
    f) Demolish below grade piping.
3) Perform site work as indicated on the Drawings.
4) Perform new construction and modifications as indicated on the Drawings, including but not limited to:
    a) Install all below grade piping and pipe encasement.
    b) Construct new concrete slabs.
    c) Construct new concrete walkway on blend tanks.
    d) Install all PS, WAS, and PS/WAS piping, valves, and appurtenances.
    e) Install new RDT feed pumps, blended sludge grinders, and associated piping, valves, and appurtenances.
    f) Install new large bubble mixing system and appurtenances.
    g) Install new electrical and control equipment and appurtenances.
5) Perform testing, start-up, and commissioning.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

ATTACHMENT A - METHOD OF PROCEDURE (MOP)

"METHOD OF PROCEDURE" (MOP)
Instructions and Forms

Definition and Purpose

"Method of Procedure" (MOP) is a detailed document submitted by the Contractor to request process shutdown(s), utility tie-in(s), work in areas that may risk unanticipated outages, or flow diversions to accommodate site construction activities during a project. Such activities may include (but are not limited to) new tie-ins to utilities or structures, mechanical modifications to process piping or equipment, demolition, bulkhead installation, and cleaning processes.

The MOP provides a detailed plan to the Owner and Engineer that describes specific aspects of the work including purpose, time of execution, and anticipated impacts on treatment processes. The MOP also includes contingency measures and provisions for rapid closure in the event that shutdown or work progress difficulties are encountered. Information from relevant trades associated with the requested shutdown, diversion, or tie-in is also included.

The Owner should use the information within the MOP to define operational procedures and methods to safely and successfully assist the Contractor.

MOP Process Summary

WHO	STEP	TIMING
Contractor	1. Identify MOPs needed on MOP Log and Baseline Schedule.	No later than 7 days prior to Preconstruction Scheduling Meeting
Contractor, Owner, Engineer	2. Pre-MOP Meeting.	More than 35 days (5 weeks) prior to work
Contractor	3. Submits MOP.	No later than 28 (4 weeks) days prior to work
Owner	4. Reviews MOP.	
Owner	5. MOP finalized.	Approval no later than 14 days (2 weeks) prior to work
Contractor	6. Complete Readiness Checklist.	No later than 7 days (1 week) prior to work
Contractor	7. Complete Safety Checklist.	Immediately prior to commencing work
Contractor	8. Complete Work.	
Contractor	9. Update MOP Log and Progress Schedules.	Monthly

MOP Process Detail

STEP 1. Identifies MOPs needed on MOP Log and Baseline Schedule.

Contractor submits a preliminary list of anticipated project MOPs on MOP Log. MOPs identified but not limited to those shutdowns, diversions, or tie-ins described in the Contract Documents. Incorporate MOPs as tasks in Baseline Schedule. Date scheduled MOPs to coincide with the appropriate construction activities.

STEP 2. Pre-MOP Meeting.

Contractor requests a Pre-MOP Meeting with the Owner and Engineer to discuss the nature of the shutdown, diversion, or tie-in, and to gather the information necessary to complete the MOP Form. The pre-MOP meeting may be waived by the Owner or Engineer if the work is deemed to be minor.

STEP 3. Submits MOP.

Contractor completes the MOP Form and submits 3 copies for approval to the Owner's Project Manager (OPM).

STEP 4. Reviews MOP.

OPM distributes MOP Form for review by the Owner's Construction Coordinator, O&M Representative, and Engineer's Project Representative. Review MOP Form for completeness, accuracy, compliance with both the construction schedule, constraints defined in Contract Documents, and to ensure that the requested work does not negatively impact plant operations or other concurrent project activities. Additional information may be requested to better understand the nature of and method for completing the Work.

STEP 5. MOP finalized.

Once the MOP is agreed to by all parties, the MOP will be finalized by signature. Copies are distributed to the Owner, Engineer, and Contractor.

STEP 6. Complete Readiness Checklist.

Contractor verifies everything is ready for the Work.

STEP 7. Complete Safety Checklist.

Contractor ensures safety.

STEP 8. Complete Work.

Contractor completes Work.

STEP 9. Update MOP Log and Progress Schedules.

Contractor updates MOP Log weekly and distributes at the regularly scheduled construction progress meetings.

ATTACHMENT B - METHOD OF PROCEDURE (MOP) FORM

METHOD OF PROCEDURE (MOP) FORM

Owner: _____ **Date:** _____

Contractor: _____ **Carollo Project No.:** _____

Project Name: _____ **Submittal No.:** _____

Submittal Title: _____ **Spec/Drawing. Ref.:** _____

MOP #:	TASK TITLE: *(Provide <10 word title)*	SUBMITTAL DATE: *(No later than 28 days prior to work)*

SCHEDULE OF WORK ACTIVITY:

START: *(Date/Time)* END: *(Date/Time)*

REQUESTOR:

PRIMARY POINT OF CONTACT:	PHONE/PAGER:
SECONDARY POINT OF CONTACT:	PHONE/PAGER:

NOTIFY: ☐	Control Room, Phone:	☐	Security, Phone:

BUILDING:	LOCATION OF WORK FLOOR/LEVEL:

DESCRIPTION OF WORK: *(Provide sufficient details on process isolation, work sequencing, and safety (i.e. control of significant hazards unique to the work) to demonstrate an understanding of the work and how it will be completed within the constraints, and its impact on the processes and facility.)*

Task Summary: _____

Processes Affected: _____

Trades Affected: _____

WORK PLAN:

Work Sequencing: _____

Process Isolation: _____

Spill Prevention Plan: _____

Contingency Plans: _____

CRITICAL EQUIPMENT / TOOLS: *(Pumps and discharge hoses with correct fittings, blind flanges and pipe plugs, no-hub fittings, properly sized electrical service components, generators, portable lighting, chlorine for potable water pipe breaks, etc.)*

☐	Acoustic Ceiling/or Walls Access	☐	Excavation Permit	☐	Lock Out/Tag Out
☐	Chemical Use Approval	☐	Fire Sprinkler Impairment	☐	Life Safety Systems
☐	Confined Space Permit	☐	Flammable Materials	☐	Roof Protocol
☐	Critical Lift Plan	☐	Flush / Discharge	☐	Work After Dark
☐	Energized Electrical Work	☐	High Pressure Test	☐	
☐	Elect. Panel Schedules	☐	Hot Work/Open Flame	☐	

EXISTING SERVICE(S) AT RISK:							
☐	Breathing Air	☐	Elect Normal	☐	Process Access	☐	Telephones
☐	Chemical Distribution	☐	Fire Protection	☐	Safety Showers	☐	UPS
☐	City Water	☐	HVAC	☐	SCADA	☐	VAX/DATA
☐	Communication	☐	Inert Gas	☐	Security	☐	
☐	Domestic Drain	☐	Instrument - Air	☐	Solvent Drain	☐	
☐	Elect-Bus Duct	☐	Life Safety System	☐	Specialty Gases	☐	
☐	Elect. Emergency	☐	Natural Gas	☐	Storm Drain	☐	
REVIEWER'S INSTRUCTIONS/COMMENTS:							
☐	PREJOB BRIEFING MUST BE COMPLETED PRIOR TO COMMENCING WORK:						

	Full Name (printed)	**Signature**	**Phone**	**Date**
Submitted By				
System Owner				
Reviewer (if needed)				
Reviewer (if needed)				
Reviewer (if needed)				
Reviewer (if needed)				

Work Plan:

1. Provide a) Pre-shutdown Activities, b) Shutdown Activities, and c) Post-shutdown Activities.
2. Provide in great detail what is proposed for the Work. Include relevant project drawings that are annotated neatly to call out the proposed Work Activity. Shutdown requests will be rejected without annotated drawings of the proposed Work.
3. Provide Work details in hourly breakdowns.

Contingency Plan:

1. Provide sufficient detail of what Contractor will do in the event the Work Plan does not go accordingly to plan.

ATTACHMENT C - READINESS CHECKLIST

READINESS CHECKLIST

(7 days prior to work)

Checklist provided as a guide but is not all inclusive.

1. Confirm all parts and materials are on site: _____

2. Review work plan: _____

3. Review contingency plan: _____

ATTACHMENT D - SAFETY CHECKLIST

SAFETY CHECKLIST

(Just prior to commencing work)

Checklist provided as a guide but is not all inclusive.

1. Location awareness:
   a. Emergency exits: _____
   b. Emergency shower and eyewash: _____
   c. Telephones and phone numbers: _____
   d. Shut-off valve: _____
   e. Electrical disconnects: _____
2. Inspect work area:
   a. Take time to survey the area you are working in. Ensure that what you want to do will work. Do you have enough clearance? Is your footing secure? Do you have adequate lighting and ventilation? Are surrounding utilities out of the way for you to perform your work?
3. SDS (Safety Data Sheets):
   a. Understand the chemicals and substances in the area you are working in by reading the SDS.
4. Lockout/Tagout Procedure:
   a. Lockout/tagout energy sources before beginning work.
   b. Make sure all valves associated with the work are locked out and tagged out on each side of the penetration.
   c. Make sure the lines are depressurized.
5. Overhead work:
   a. Use appropriate personal protective equipment; i.e., safety harness, lifeline, etc.
   b. Select appropriate tie-off points; i.e., structurally adequate, not a pipe or conduit, etc.
   c. Spotter assigned and in position.
   d. Pipe rack access; i.e., check design capacity, protective decking or scaffolding in place, exposed valves or electrical switches identified and protected.
6. Safety equipment:
   a. Shepherd's hook.
   b. ARC flash protection.
   c. Fire extinguisher.
   d. Other: _____
7. Accidents:
   a. Should accidents occur, do not shut off and do not attempt to correct the situation unless you are absolutely positive that your action will correct the problem and not adversely affect other people or equipment.
8. Review process start-up documents:
   a. In the event the system is shutdown, the Control Center should have a working knowledge of the process start-up procedures in order to deal effectively with unforeseen events.
9. Evacuation procedures:
   a. Do not obstruct evacuation routes.
   b. Take time to survey the area for evacuation routes.

ATTACHMENT E - METHOD OF PROCEDURE (MOP) LOG

METHOD OF PROCEDURE (MOP) LOG
Sample

MOP Number	Task Title	Date Requested	Date Approved	Date Work Planned	Work Completed (Yes/No)
001					
002					
003					

SECTION 01200

INSPECTION AND PROJECT MEETINGS

PART 1 – GENERAL

1.01 Preconstruction Meeting

A. A mandatory preconstruction meeting will be held within ten working days of Award of the Contract. The purpose of the meeting will be to discuss the various requirements of the specifications and the Contractor's responsibilities with regard to process control, schedule, submittals, traffic control, and safety. The Contractor shall not commence construction work until after the preconstruction meeting and issuance of a Notice to Proceed. Attendance of a representative from City of Manteca at the preconstruction meeting is mandatory and the Contractor shall notify the City when the meeting is scheduled.

1.02 Monthly Status Meetings

A. Regular monthly construction progress meetings shall be held throughout the construction period from the time the Contractor begins work until the acceptance of the work by the Owner. The Construction Manager and representatives of the Owner will attend the meeting. The Contractor shall be represented by his designated construction manager and superintendent and representatives of any major subcontractor whose work will be discussed at the meeting.

B. The purpose of the meeting shall be as follows:

1. Review of progress of the work during the preceding month and the job to date for compliance with the approved construction schedule as described in Section 01310, CONTRACTOR'S CONSTRUCTION SCHEDULE.

2. Discuss work and coordination of activities that will be required for the completion of all work scheduled for the following month.

3. Discuss additional measures required to bring the progress of the work into compliance with the approved schedule if required to satisfy the provisions of the contract.

4. Review status of submittals, change orders, directives, and equipment delivery dates.

5. Any additional items of concern to the Owner or Construction Manager.

1.03 Weekly Meetings

A. The Contractor's superintendent shall meet with the Construction Manager at the beginning of each week to discuss the activities scheduled for the following week and the compliance of the work with the schedule established at the previous monthly status meeting.

1.04 Additional Meetings

A. Additional meetings with the Construction Manager, the Owner, Engineer, and Contractor will be called by the Construction Manager to resolve disputes on various items of work on the project, including, but not limited to, progress payments, design omissions or conflicts, and changes in work and/or schedule.

1.05 Inspection Purpose and General Requirements

A. The primary purpose of the Engineer's inspections is to confirm that the work is being performed in accordance with the Contract requirements.

B. The secondary purpose of the Engineer's inspections is to evaluate conditions throughout construction, so the Engineer can provide the Contractor with interpretation and clarification of the Contract requirements as they apply to specific work items and conditions.

C. The Engineer's observations and comments during inspections are intended to provide the Contractor with suggestions and guidance for completing the work in accordance with the Contract requirements. The Contractor is solely responsible for determining the appropriate course of action, for directing the work, and for fulfilling the Contract requirements. The Engineer's observations and comments shall not be considered to be direction of the work.

D. The Contractor shall make a good faith effort to make the work available for inspection by the Engineer, to collect and provide samples for inspection by the Engineer, and to honestly represent the work to the Engineer.

E. The Engineer shall make a good faith effort to accommodate the Contractor's construction schedule, to be available throughout construction to make inspections on short notice at the Contractor's request, and to provide interpretation and clarification of the Contract requirements.

1.06 Mobilization

A. Contractor shall notify the Engineer a minimum of 24 hours in advance of the anticipated time of mobilization, and shall update the Engineer with any changes in the schedule for mobilization.

B. Contractor shall make drilling equipment and accessories, and sanitary facilities, available for inspection by the Engineer.

C. Contractor shall delineate with marking paint the proposed location of mud pits (if used) and any other excavations, for inspection by the Engineer.

1.07 **Site Preparation**

A. Contractor shall provide Engineer with access for inspection and approval of any site preparation to be performed as part of this Contract.

1.08 **Surface Completion**

A. Contractor shall notify Engineer a minimum of 24 hours in advance of the anticipated time of surface completion, and shall update the Engineer with any changes in schedule, so the Engineer may be on site to witness the surface completion.

B. Contractor shall make surface completion materials and methods available for inspection by the Engineer.

1.09 **Site Clean-up and Records**

A. Contractor shall notify Engineer a minimum of 24 hours in advance of the anticipated time of the video inspection, and shall update the Engineer with any changes in schedule, so the Engineer may be on site to witness the video inspection.

B. Contractor shall make wellhead security, backfilling and compaction, and site cleanup available for inspection by the Engineer.

C. Backfilling and compaction must be witnessed by the Engineer. Backfilling and compaction not witnessed by the Engineer, or improperly performed, shall not be considered valid for final acceptance unless otherwise approved by the Engineer in writing.

END OF SECTION

SECTION 01260

CONTRACT MODIFICATION PROCEDURES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Administrative and procedural requirements for executing a change in the Work.

1.02 PRELIMINARY REQUIREMENTS

A. Change Order Cost Basis Summary Form:
   1. Submit a sample to Engineer for review within 15 calendar days following Notice to Proceed.
      a. Items will be reviewed and their value, percentage, or calculation method mutually agreed to by the Contractor and Owner prior to executing a Change Order on the Project.
   2. Used by the Contractor for pricing each Change Order required for additions, deletions, or revisions in the Work.
   3. Include the following information:
      a. Agreed upon markups, percentages, and procedures for calculating all surcharges, etc. associated with the Cost of the Change Order Work.
      b. References for unit price information and special unit price information.
      c. Attachments with the following information:
         1) Certified labor rates breakdown.
         2) Equipment rates.
         3) Bond and insurance rates (PI&I).

1.03 REQUEST FOR INFORMATION OR INTERPRETATION (RFI)

A. Contractor may issue RFIs to request interpretation of the documents or to request for information that may be missing.

B. General Instructions:
   1. Number RFIs consecutively.
      a. Add a consecutive letter to the RFI number on modified submittals of the same RFI (i.e., RFI 4B).
   2. Provide RFI for 1 item.
      a. There may be exceptions when multiple items are so functionally related that expediency indicates review of the group of items as a whole.
      b. RFIs with multiple items will be rejected without review.
   3. Contractor sign and date RFIs indicating review and approval.
      a. Contractor’s signature indicates that they have satisfied RFI review responsibilities and constitutes Contractor's written approval of RFI.

b. RFIs without Contractor's signature will be returned to the Contractor unreviewed. Subsequent submittal of this information will be counted as the first resubmittal.

C. Engineer will render a written clarification, interpretation, or decision on the issue submitted or initiate an amendment or supplement to the Contract within 21 days.
   1. In the event the Contractor identifies an RFI as critical to the progress of the project, Engineer will make every effort to reduce the RFI response time.

1.04 PRELIMINARY PROCEDURES

A. Owner or Engineer may initiate changes by submitting a Request for Proposal (RFP) to Contractor including the following information:
   1. Detailed description of the Change, Products, and location of the change in the Project.
   2. Supplementary or revised drawings or specifications.
   3. Projected time span for making the change, and a specific statement if overtime work is authorized.
   4. A specific period of time during which the requested price will be considered valid.
   5. Such request is for information only, and is not an instruction to execute the changes, or to stop work in progress.

B. Contractor may initiate changes by submitting a Change Proposal to Engineer containing the following:
   1. Description of proposed changes.
   2. Reason for making changes.
   3. Specific period of time during which requested price will be considered valid.
   4. Effect on Total Contract Cost and/or Contract Time.
   5. Documentation supporting any change in Total Contract Cost and/or Contract Time, as appropriate.

1.05 WORK CHANGE DIRECTIVE AUTHORIZATION

A. In lieu of a Request for Proposal (RFP), Engineer may issue a Work Change Directive Authorization for Contractor to proceed with a change for subsequent inclusion in a Change Order.

B. Authorization will describe changes in the Work, both additions and deletions, with attachments of revised Contract Documents to define details of the change and will designate method of determining any change in the Contract Sum and/or the Contract Time, as appropriate.

C. Owner and Engineer will sign and date the Work Change Directive Authorization as authorization for the Contractor to proceed with the changes.

D. Contractor may sign and date the Work Change Directive Authorization to indicate agreement with the terms.

1.06 DOCUMENTATION OF CHANGE PROPOSALS

A. Change proposal:
   1. Support with sufficient substantiating data to allow Engineer to evaluate the quotation.
      a. Lump sum.
      b. Unit prices: Use previously established unit prices.
      c. Time-and-material/force account basis:
         1) Name of the Owner's authorized agent who ordered the work, and date of the order.
         2) Dates and times work was performed, and by whom.
         3) Time record, summary of hours worked, and hourly rates paid.
         4) Receipts and invoices for:
            a) Equipment used, listing dates and times of use.
            b) Products used, listing of quantities.
            c) Subcontracts.
   2. Provide additional data to support time and cost computations:
      a. Labor required.
      b. Equipment required.
      c. Products required:
         1) Recommended source of purchase and unit cost.
         2) Quantities required.
      d. Taxes, insurance, and bonds.
      e. Credit for work deleted from Contract, similarly documented.
      f. Overhead and profit.
      g. Justification for change to Contract Time.

1.07 PREPARATION OF CHANGE ORDERS AND FIELD ORDERS

A. Engineer will prepare each Change Order and Field Order.

B. Change Orders:
   1. Will describe changes in the Work, both additions and deletions, with attachments of revised Contract Documents to define details of the change.
   2. Will provide an accounting of the adjustment in the Contract Sum and in the Contract Time.
   3. Recommendation of Change Proposal is indicated by Engineer's signature.
   4. Upon signature and execution by Owner, the Change Proposal becomes a Change Order altering the Contract Time and Total Contract Cost, as indicated.
      a. Owner's Representative will transmit one signed copy each to Contractor and Engineer.
   5. Contractor may only request payment for changes in the Work against an approved Change Order.
   6. If either Engineer or Owner's Representative disapproves the Change Proposal, the reason for disapproval will be stated.
      a. A request for a revised proposal or cancellation of the proposal will be shown.

C. Field Orders:
   1. Order minor changes in the Work without changes in Contract Price or Contract Times.

1.08 LUMP-SUM/FIXED PRICE CHANGE ORDER

A. Content of Change Orders will be based on, either:
   1. Engineer's Proposal Request and Contractor's responsive Change Proposal as mutually agreed between Owner and Contractor.
   2. Contractor's Change Proposal for a change, as recommended by Engineer.

B. Owner and Engineer will sign and date the Change Order to establish the change in Contract Sum and in Contract Time and serve as authorization for the Contractor to proceed with the changes.

C. Contractor will sign and date the Change Order to indicate agreement with the terms.

1.09 UNIT PRICE CHANGE ORDER

A. Content of Change Orders will be based on, either:
   1. Engineer's definition of the scope of the required changes.
   2. Contractor's Change Proposal for a change, recommended by Engineer.
   3. Survey of completed work.

B. The amounts of the unit prices to be:
   1. Those stated in the Contract.
   2. Those mutually agreed upon between Owner and Contractor.

C. When quantities of each of the items affected by the Change Order can be determined prior to start of the work:
   1. Owner and Engineer will sign and date the Change Order as authorization for Contractor to proceed with the changes.
   2. Contractor will sign and date the Change Order to indicate agreement with the terms.

D. When quantities of the items cannot be determined prior to start of the work:
   1. Engineer or Owner will issue a Work Change Directive authorization directing Contractor to proceed with the change on the basis of unit prices, and will cite the applicable unit prices.
   2. At completion of the change, Engineer will determine the cost of such work based on the unit prices and quantities used.
   3. Contractor shall submit documentation to establish the number of units of each item and any claims for a change in Contract Time.

E. Owner and Engineer will sign and date the Change Order to establish the change in Contract Sum and in Contract Time and serve as authorization for the Contractor to proceed with the changes.

F. Contractor will sign and date the Change Order to indicate their agreement with the terms.

1.10 TIME AND MATERIAL/FORCE ACCOUNT CHANGE ORDER/WORK CHANGE DIRECTIVE AUTHORIZATION

A. Engineer will issue a Work Change Directive for the Owner's signature authorizing Contractor to proceed with the changes.

B. At completion of the change, Contractor shall submit itemized accounting and supporting data as specified in this Section.

C. Engineer will determine the allowable cost of such work, as provided in the Contract Documents.

D. Owner and Engineer will sign and date the Change Order to establish the change in Contract Sum and in Contract Time and serve as authorization for the Contractor to proceed with the changes.

E. Contractor will sign and date the Change Order to indicate their agreement.

1.11 CORRELATION WITH CONTRACTOR'S SUBMITTALS

A. Periodically revise Schedule of Values and Applications for Payment forms to record each Change Order as a separate item of Work, and to record the adjusted Contract Sum.

B. Periodically revise the Construction Schedule to reflect each change in Contract Time. Revise subschedules to show changes for other items of work affected by the changes.

C. Upon completion of work under a Change Order, enter pertinent changes in Record Documents.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01300

SUBMITTALS

PART 1 – GENERAL

1.01 GENERAL

A. Where required by the specifications, the Contractor shall submit descriptive information that will enable determination of whether the Contractor's proposed materials, equipment, or methods of work are in general conformance to the design concept and in compliance with the plans and specifications. The information to be submitted shall consist of drawings, specifications, descriptive data, certificates, samples, test results and such other information, all as specifically required in the specifications. In some instances, specified submittal information describes some, but not all, features of the material equipment, or method of work. Features not requiring submittals shall be as specified.

B. Submittal review shall be only for general conformance with the design concept and general compliance with the information given in the contract documents. It shall not include review of quantities, dimensions, weights or gages, fabrication processes, construction safety precautions, all of which are the sole responsibility of the Contractor. Review of a specific item shall not indicate acceptance of an assembly of which the item is a component. The Construction Manager shall not be required to review and shall not be responsible for any deviations from the contract documents not clearly noted by the Contractor, nor shall the Construction Manager be required to review partial submissions or those for which submissions for correlated items have not been received.

C. The Contractor may authorize material or equipment suppliers to deal directly with the Construction Manager with regard to such submittals; however, ultimate responsibility for the accuracy and completeness of the information contained in the submittal shall remain with the Contractor.

1.02 CONTRACTOR'S RESPONSIBILITIES

A. The Contractor shall be responsible for the accuracy and completeness of the information contained in each submittal and shall assure that the material, equipment, or method of work shall be described in the submittal. The Contractor shall verify that all features of all products conform to the requirements of the specifications and plans. The Contractor shall insure that there is no conflict with other submittals and shall notify the Construction Manager in each case where his submittal may affect the work of the Owner or others. The Contractor shall insure coordination of submittals among the related crafts and subcontractors.

B. Immediately following Award of the Contract, the Contractor shall review the plans and specifications and shall prepare a list of all submittals anticipated on the project and shall

submit this list to the Construction Manager. Items not on the list but requiring review shall be added to the list as requested by the Construction Manager at any time during the construction.

1.03 TRANSMITTAL PROCEDURE

A. General

- Submittals regarding material and equipment shall be accompanied by a transmittal form. A separate form shall be used for each specific item, class of material, equipment, and for items specified in separate, discrete sections. Submittals for various items shall be made with a single form when the items taken together constitute a manufacturer's package or are so functionally related that expediency indicates checking or review of the group or package as a whole.

- A unique number, sequentially assigned, shall be noted on the transmittal form accompanying each item submitted. Submittal numbers shall have the following format: "XXX-YYYYY-ZZ"; where "XXX" is the sequential number assigned by the Contractor, "YYYYY" is the specification section number covered by the submittal, and "ZZ" is the sequential number of the submittal ("01" for the first submittal, "02" for the second submittal, etc.). Resubmittals shall have the same submittal number format; where "XXX" is the originally assigned submittal number.

- Submittal 25-11350-02, for example, would be the second submittal (first re-submittal) of submittal 25 covering Section 11350.

B. Deviation from Contract

- If the Contractor proposes to provide material, equipment, or method of work that deviates from the contract documents, he shall indicate so on the transmittal form accompanying the submittal copies.

C. Submittal Completeness

- Submittals that do not contain all the information required to be submitted, including deviations, are not acceptable and will be returned without review.

D. Requests for Substitution

- The Contractor may offer material or equipment of equal or better quality and performance in substitution for those specified. The Owner will consider offers for substitution only from the Contractor and will not acknowledge or consider such offers from suppliers, distributors, manufacturers, or subcontractors. The Contractor's offers of substitution shall be made in writing to the Construction Manager and shall include sufficient data to enable the Construction Manager to assess the acceptability of the material or equipment for the particular application and requirements.

- If the offered substitution necessitates changes to or coordination with other portions of the work, the data submitted shall include drawings and details showing such changes.

- Contractor agrees to perform these changes as part of the substitution of material or equipment at no additional cost to the Owner. Within 28 calendar days after receipt of the offer of substitution, the Construction Manager will review the material submitted by the Contractor and advise the Contractor of objections, if any, to the proposed substitution or if further information is required. Upon notification by the Construction Manager, the Contractor shall either provide material or equipment that complies with project specifications or furnish requested additional information. While the Construction Manager might not take any objections to the proposed substitution, such action shall not relieve the Contractor from responsibility for the efficiency, sufficiency, quality and performance of the substitute material or equipment, in the same manner and degree as the material and equipment specified by name. Any cost differential associated with a substitution shall be reflected in the offer and the contract documents shall be modified by a change order.

1.04 REVIEW PROCEDURE

A. When the contract documents require a submittal, the Contractor shall submit copies of the specified information as follows unless otherwise specified:

- One reproducible original (electronic is appropriate) of all the submitted information. When individual sheets in the submittal exceed 8½-inch x 11-inch, a sepia shall be submitted.

- Submittals shall be delivered electronically to:

  City of Manteca
  Department of Engineering, Associate Engineer
  Attention: Kyzen Nicolas
  1001 West Center Street Manteca, CA 95336
  Email: knicolas@manteca.gov
  With a Copy to: Construction Manager

B. Unless otherwise specified, within **28 calendar days** after receipt of the submittal, the submittal shall be reviewed and returned to the Contractor. The original shall be retained by the Construction Manager. The returned submittal shall indicate one of the following actions:

- If the review indicates that the material, equipment, or work method is in general conformance with the design concept and complies with the drawings and specifications, submittal copies will be marked "NO EXCEPTIONS TAKEN." In this event, the Contractor may begin to implement the work method or incorporate the material or equipment covered by the submittal.

- If the review indicates limited corrections are required, copies will be marked "MAKE CORRECTIONS NOTED." The Contractor may begin implementing the work method or incorporating the material and equipment covered by the submittal in accordance with the

noted corrections. Where submittal information will be incorporated in operation and maintenance information, a corrected copy shall be provided.

- If the review reveals that the submittal is insufficient or contains incorrect data, copies will be marked "REVISE AND RESUBMIT." Except at his own risk, the Contractor shall not undertake work covered by this submittal until it has been revised, resubmitted and returned marked either "NO EXCEPTIONS TAKEN" or "MAKE CORRECTIONS NOTED."

- If the review indicates that the material, equipment, or work method is not in general conformance with the design concept or in compliance with the drawings and specifications, copies of the submittal will be marked "REJECTED". Submittals with deviations that have not been identified clearly may be rejected. Except at his own risk, the Contractor shall not undertake the work covered by such submittals until a new submittal is made and returned marked either "NO EXCEPTIONS TAKEN" or "MAKE CORRECTIONS NOTED".

C. Following the initial review, two (2) "resubmittals" will be allowed by the Construction Manager prior to a "back charge" for engineering review and administration costs being incurred by the Contractor. The "back charge" will be deducted from any amounts due the Contractor.

1.05 EFFECT OF REVIEW OF CONTRACTOR'S SUBMITTALS

A. Review of drawings, methods of work, or information regarding materials or equipment the Contractor proposes to provide shall not relieve the Contractor of his responsibility for errors therein and shall not be regarded as an assumption of risks or liability by the Owner, or by any officer or employee thereof, or by any engineering firm conducting such review on behalf of the Owner, and the Contractor shall have no claim under the contract on account of the failure, or partial failure, of the method of work, material, or equipment so reviewed. A mark of "NO EXCEPTIONS TAKEN" or "MAKE CORRECTIONS NOTED" shall mean that the Owner has no objection to the Contractor, upon his own responsibility, using the plan or method of work proposed, or providing the materials or equipment proposed.

END OF SECTION

SECTION 01310

CONTRACTOR'S CONSTRUCTION SCHEDULE

PART 1 – GENERAL

1.01 SCOPE

A. This section specifies the procedures for preparing the construction schedule used for planning and managing construction activities. The schedule provides a basis for determining the progress status of the project relative to the completion time and specific dates. The Contractor shall present the construction schedule at a public meeting prior to beginning work as specified in Section 01200, INSPECTIONS AND PROJECT MEETINGS.

1.02 DESCRIPTION

A. A schedule shall be provided to depict all significant construction activities and all items of work listed in the breakdown of contract prices submitted by the Contractor in accordance with the BID SCHEDULE section of these specifications. The dependencies between activities shall be indicated so that it may be established what effect the progress of any one activity has on the schedule.

B. Detailed network activities shall include, in addition to construction activities, the submittal and approval of samples of material and shop drawings, the procurement of critical materials and equipment, and their installation and testing. All submittals of equipment and materials shall be shown on the schedule together with appropriate allowances for review and delivery times, installation, testing and training as appropriate. All activities of the Owner and Construction Manager that affect the progress of the work shall be shown. Any omission of work from the schedule required for contract compliance shall not excuse the Contractor from completing such work within any applicable completion date.

C. Completion time and all specific contract dates given in Section 01015, CONTRACT TIME shall be shown on the schedule. Activities making up the critical path shall be identified.

D. No activity on the schedule shall have a duration longer than 21 calendar days except activities comprising only fabrication and delivery, which may extend for more than 21 calendar days. Activities which exceed these limits shall be divided into more detailed components. The scheduled duration of each activity shall be based on the work being performed during the normal 40-hour work week with allowances made for legal holidays and normal weather conditions.

E. The Contractor shall not work on legal holidays except by permission of the Construction Manager. Legal holidays are defined as the holidays observed by the Owner. The Contractor shall notify the Construction Manager by Friday of their intent to work on any immediately

following Saturday or Sunday. Delays to project completion experienced during holidays or weekends without proper permission or notice will not be considered to be the responsibility of the Owner or Construction Manager.

F. Schedules shall be realistic. Contractors shall be required to show use of all calendar days allowed for completion in their schedule or accept a no cost change order reducing the number of days allowed for the completion of the work to the amount shown on the proposed and approved schedule.

1.03 SUBMITTAL PROCEDURES

A. Within 10 calendar days after the date of the Notice of Proceed, the Contractor shall complete a construction schedule conforming to Paragraph 1.02, Description, and representing in detail all planned procurement and onsite construction activities. The schedule shall be prepared on reproducible paper and may be in draft form with legible freehand lines and lettering. The Contractor shall submit the original and six copies to the Construction Manager in accordance with Section 01300, SUBMITTALS.

B. No progress payments shall be made prior to the acceptance of the schedule. Failure to resubmit updated schedules as required herein shall result in an increase in the retentions of the amounts due the Contractor.

C. Within 10 calendar days after receipt of the submittal, the Construction Manager shall review the submitted schedule and return two copies of the marked up original to the Contractor. If the Construction Manager finds that the submitted schedule does not comply with specified requirements, the corrective revisions will be noted on the submittal copy returned to the Contractor for corrections and resubmittal as specified in Section 01300, SUBMITTALS.

1.04 SCHEDULE REVISIONS

Revisions to the accepted construction schedule may be made only with written approval of the Contractor and the Owner. Changes in timing for activities which are not on the critical path may be modified with written agreement of the Contractor and Construction Manager.

1.05 CONTRACT EXTENSIONS

A. If, at any time during the project, the Contractor believes that the work cannot be completed within the Contract time, the Contractor shall notify the Engineer in writing. The Contractor shall provide a full explanation of the reasons for the delay, and shall state the amount of additional time the Contractor requests to complete the work.

B. No Contract extensions will be granted for delays caused by any of the following:

1. Contractor's failure to provide, mobilize to the project site, set up, operate, maintain in good working condition, and demobilize from the project site, all equipment necessary

for the successful completion of the project in a timely manner.

2. Contractor's failure to provide the required submittals in a timely manner.
3. Contractor's failure to devote the necessary resources and labor to make equipment repairs in a timely manner.
4. In the event that the equipment repairs cannot be made in a timely manner, or repairs are not successful, Contractor's failure to replace the broken equipment.
5. Contractor's failure to comply with the provisions of this Contract.
6. Contractor's failure to make a good faith effort to complete the work within the Contract time.

   All other causes for delays will be evaluated by the Engineer on a case-by-case basis and Contract extensions, if any, will be granted only if the Engineer determines that the Contractor was not responsible for the delay.

1.06 PROJECT STATUS UPDATE

A jobsite meeting will be held each month at a time mutually agreed upon by the Contractor, Construction Manager, and the Owner to review the construction progress for compliance with the approved schedule. Weekly meetings will also be held between the Contractor and Construction Manager to review the progress of the work of the previous week and to coordinate the work of the subsequent week. The schedule shall be revised whenever: the schedule does not represent the progress of the work; equipment submittals, approvals or deliveries make rescheduling of activities necessary; any change to the sequence of activities occurs or any change occurs to activities on the critical path; or when a contract modification necessitates a revision to the schedule. Updates to the schedule shall, at a minimum, be required on a monthly basis.

END OF SECTION

SECTION 01340

SHOP DRAWINGS, PRODUCT DATA AND SAMPLES

1.0 SUBMITTALS

1.1 General

Where the Contractor is required by these Specifications to make submittals, they shall be made to the Construction Manager with a letter of transmittal and in accordance with the requirements of this section.

The Contractor shall submit to the Construction Manager. Seven (7) copies of the following items listed immediately below unless other provisions of the Contract Document stipulate a different quantity. Two (2) copies of submittals which require review will be returned to the Contractor with review comments, if any, noted. Reviewed copies of the construction schedule and the Final Operation and Maintenance Manuals will not be returned to the Contractor. It shall be the Contractor's responsibility to copy and/or to conform reviewed submittals in sufficient numbers for its files, subcontractors, and vendors. Alternatively, the Contractor can submit electronic copies of these items but shall provide one hard copy of the submittal that matches the electronic version.

Contractor’s Representative
Safety Program
Safety Supervisor
Designated “Competent Person(s)”
Cost Breakdown
Construction Schedules
Substitutions
Shop Drawings
Material Safety Data Sheets
Operation and Maintenance Manuals
Working Drawings
Warranty Data
Others as Specified in the Technical Specifications

1.2 Contractor’s Responsibilities

The Contractor shall submit, at its own expense, submittals and details of structural and reinforcing steel, equipment, material, electrical controls, architectural fabrications, pipe, pipe joints, special pipe sections, and any other appurtenances as required in technical specifications.

All submittals and supporting data, catalogs, schedules, etc., shall be submitted as the instruments of the Contractor, who shall be responsible for their accuracy and completeness and coordination. Such responsibility shall not be delegated in whole or part to subcontractors or suppliers. These submittals may be prepared by the Contractor, subcontractors, or suppliers, but the Contractor shall ascertain that submittals meet all of the requirements of the Contract Documents, while conforming to structural, space, and access conditions at the point of installation. Designation of work "by others," if shown in submittals, shall mean that the work will be the responsibility of the Contractor rather than the subcontractor or supplier who prepared the submittals. The Contractor shall insure that there is no conflict with other submittals and notify the Construction Manager in each

case where its submittal may affect the work of another contractor or the City. The Contractor shall insure coordination of submittals among the related crafts and subcontractors. The Contractor accepts the responsibility and expense for additional costs and delays which may result from Work performed without favorably reviewed submittals.

Submittals shall be prepared in such form that data can be identified with the applicable Specification paragraph. The data shall clearly demonstrate compliance with the Contract Plans and Specifications and shall relate to the specific equipment to be furnished. Where manufacturer's standard drawings are employed, they shall be marked clearly to show what portion of the data is applicable to this project.

2.0 MATERIAL AND EQUIPMENT SUBSTITUTIONS

2.1 General

In preparing these Specifications, the Design Consultant has named those products, which to its knowledge meet the Specifications and are equivalent in construction, functional efficiency, and durability.

Wherever catalog numbers and specific brands or trade names preceded by "similar and equal" or followed by the designation "or equal" are used in conjunction with a designated material, product, thing, installation, or service mentioned in these Specifications, they are used to establish the standards of quality and utility required.

The first-named manufacturer is the basis for the project design and the use of alternative-named or unnamed manufacturer's products proposed by the Contractor may require modifications in the project design and construction. Where only one product has been named by brand, it is the only brand, trade name, or manufactured product known to the Design Consultant that meets these Specifications.

The City has made a determination that no substitution will be considered and that the following listed materials and/or equipment must be furnished as designated below in order to match others in use by the City or because it is a unique or novel product application required to be used by the City:

The City has made a determination that no substitution will be considered and that the following listed materials and/or equipment must be furnished as designated below in order to match others in use by the City or because it is a unique or novel product application required to be used by the City.

1. Schneider Altivar Process 660 variable frequency drives.
2. Scheider X80 PLC and RIO hardware.

2.2 Substitutions

Substitutions which are equal in quality and utility to those specified will be permitted, subject to the following provisions. For this purpose, the Contractor shall submit to the Construction Manager within forty (40) days of the Notice of Award, a typewritten list containing a description of each proposed substitute item or material. Sufficient data, drawings, samples, literature, calculations, or other detailed information as will demonstrate to the Design Consultant that the proposed substitute is equal in quality and utility to the material specified shall be appended to this list. The Design Consultant will favorably review in writing such proposed substitutions as are, in its opinion, equal in quality to the items or materials specified. In the event that a substitute is favorably reviewed, fifty percent (50%) of all savings shall be credited to the City.

Insufficient product data and other related information which does not permit an informed evaluation is an adequate basis for rejection of the proposed substitution.

Failure of the Contractor to submit proposed substitutions for review in the manner described above and within the time prescribed shall be sufficient cause for rejection by the Construction Manager of any substitutions otherwise proposed.

2.3 **Modifications and Costs**

If alternative named or substitutions are proposed by the Contractor and favorably reviewed by the Design Consultant, the Contractor is responsible for providing, at no additional cost to the City, any electrical, mechanical, structural, or other related changes or testing that may be required to accommodate or provide the particular material or equipment the Contractor desires to use. Any deviation from the Specifications or the Drawings resulting from the type of material or equipment to be used shall not be the basis for any "extra charges" above and in excess of the original bid price of the work.

In addition the Contractor is responsible for all additional costs to the City, and its agents and representatives, for evaluation of data submitted by the Contractor for alternative named or substitutions and any redesign necessary. The City shall deduct said costs from the Contract monies due the Contractor.

3.0 SUBMITTAL AND MATERIAL LIST

Within ten (10) days of the Notice of Award the City will provide the Contractor with a Preliminary List of anticipated submittals. This list is intended as a reference to assist the Contractor in the submittal process and may not include all submittals required by the Contract. Accordingly, the Contract requirements shall govern over the City provided Preliminary List.
Within five (5) days after the Notice to Proceed and prior to the submission of the initial shop drawings, the Contractor shall submit a complete list of all required submittals to the Construction Manager for favorable review. The Submittal and Material List shall include a description of each item, Specification reference and the anticipated submittal date. The List shall include all items of equipment and materials for architectural, structural, mechanical, piping, electrical, heating and ventilating, equipment piping, and plumbing work; and the names of manufacturers with whom purchase orders have been placed. Items on the List shall be arranged in the same order as in these Specifications, and shall contain sufficient data to identify precisely the items of material and equipment the Contractor proposes to furnish. The List shall reference the applicable Specification section or Drawing. After the submission is favorably reviewed and returned to the Contractor by the Construction Manager, it shall become the basis for the submission of detailed manufacturer's drawings, catalog cuts, curves, diagrams, schematics, data, and information on each separate item for review. No work shall proceed on any item until it has been submitted and favorably reviewed. An incomplete submittal list is not a basis for avoiding a submittal required by the specifications.

4.0 TRANSMITTAL PROCEDURES

4.1 **Transmittal Form**

A separate transmittal form shall be used for each specific item, class of material, equipment, and items specified in separate, discrete sections, for which the submittal is required. Submittal documents common to more than one piece of equipment shall be identified with all the appropriate equipment numbers. Submittals for various

items shall be made with a single form when the items taken together constitute a manufacturer's package or are so functionally related that expediency indicates checking or review of the group or package as a whole. The specification section and subsection or paragraph to which the submittal is related shall be indicated on the transmittal form.

A unique number, sequentially assigned, shall be noted on the transmittal form accompanying each item submitted. Original submittal numbers shall have the following format: "XXX"; where "XXX" is the sequential number assigned by the Contractor. Resubmittals shall have the following format: "XXX-Y"; where "XXX" is the originally assigned submittal number and "Y" is a sequential letter assigned for resubmittals, i.e., A, B, or C being the 1st, 2nd, and 3rd resubmittals, respectively. Submittal 25B, for example, is the second resubmittal of submittal 25.

4.2 **Deviations From The Contract**

If the submittals show any deviations from the Contract requirements, the Contractor shall submit with the submittal submission a separate written description of such deviations and the reasons therefor. If the Owner accepts such deviation, the City shall issue an appropriate Contract Change Order, except that, if the deviation is minor, or does not involve a change in price or in time of performance, a Change Order need not be issued. If any deviations from the Contract requirements are not noted on the submittal, the review of the shop drawing shall not constitute acceptance of such deviations.

4.3 **Submittal Completeness**

The Contractor shall review and check all submittals before submitting them to the Construction Manager. The Contractor shall stamp and certify on the transmittal letter and on each shop drawing that they have been checked, are in compliance with the Plans and Specifications, and all deviations from the Contract requirements are noted.

If the Contractor submits an incomplete submittal, the submittal will be returned to the Contractor without review. A complete submittal shall contain sufficient data to demonstrate that the items comply with the Specifications, shall meet the minimum requirements for submissions cited in the technical specifications, shall include materials and equipment data and seismic anchorage certifications where required, and shall include any necessary revisions required for equipment other than first named.

It is considered reasonable that the Contractor shall make a complete and acceptable submittal to the Construction Manager at least by the second submission of data. The City reserves the right to deduct monies from payments due the Contractor to cover additional costs of review beyond the second submission.

4.4 **Submittal Period**

Contractor shall be responsible for submitting each submittal to meet their project schedule, factoring in Engineer’s review time, resubmittals preparation time, and resubmittals review time.

4.5 **Alternate Submittals**

If a submittal is approved and the Contractor elects to submit an alternate item for review for the same application, the Contractor shall be responsible for the review costs for the alternate submittal.

5.0 REVIEW PROCEDURE

Submittals shall be submitted to the Construction Manager for review and returned to the Contractor within 28 days after receipt. Review of submittals by the Design Consultant has as its primary objective the completion for the City of a project in full conformance with the Contract Documents, unmarred by field corrections, and within the time provided

After review by the Design Consultant of each of the Contractor's submissions, the material will be returned to the Contractor with actions defined as follows:

A. **NO EXCEPTIONS NOTED (RESUBMITTAL NOT REQUIRED) -** Accepted subject to its compatibility with future submissions and additional partial submissions for portions of the work not covered in this submission. Does not constitute approval or deletion of specified or required items not shown in the partial submission.

B. **MAKE CORRECTIONS NOTED (RESUBMITTAL NOT REQUIRED)** - Same as A, except that minor corrections as noted shall be made by the Contractor.

C. **MAKE CORRECTIONS NOTED (RESUBMIT)** - Rejected because of major inconsistencies or errors which shall be resolved or corrected by the Contractor prior to subsequent review by the Design Consultant.

D. **NOT ACCEPTABLE (RESUBMIT) -** Submitted material does not conform to Plans and Specifications in major respect., i.e.: wrong size, model, capacity, or material.

Items A and B above (no resubmittal required) are considered "favorable review." Items C and D above (correction and resubmittal required) are considered "unfavorable review."

6.0 EFFECT OF REVIEW OF CONTRACTOR'S SUBMITTALS

The Design Consultant's favorable review of submittals shall be obtained prior to the fabrication, delivery and construction of items requiring submittal review.

The favorable review of all submittals by the Design Consultant shall apply in general design only and shall in no way relieve the Contractor from responsibility for errors or omissions contained therein. Favorable review by the Design Consultant shall not relieve the Contractor of its obligation to meet contractual requirements, safety requirements and all other requirements of laws, nor constitute a Contract Change Order. Favorable review will not constitute acceptance of any responsibility for the accuracy, coordination, and completeness of the submittals or the items of equipment represented on the submittals.

END OF SECTION

SECTION 01342

PHOTOGRAPHIC AND VIDEOGRAPHIC DOCUMENTATION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Requirements for photographs and videos.

B. The purpose of the photographs and videos is to document the condition of the facilities prior to the Contractor beginning work at the Project site, the progress of the Work, and the Project site after Substantial Completion of the Work.

C. The scope of the photographic and videographic documentation shall be the sole responsibility of the Contractor but shall be acceptable to the Engineer.

1.02 SUBMITTALS

A. Photographer qualifications.

B. Pre-construction photographs and videos: Submit prior to beginning work at the Project site or prior to the Preconstruction Conference specified in Section 01200 - Project Meetings, whichever occurs earlier.

C. Construction photographs and videos: Submit with each application for payment.

D. Post-construction photographs and videos: Submit with project closeout documents as specified in Section 01700 - Contract Closeout.

1.03 PHOTOGRAPHER

A. Photographer qualified and equipped to photograph either interior or exterior exposures, with lenses ranging from wide angle to telephoto.

B. Submit example work of previous photographs and video recording meeting the requirements of this Section.
   1. Provide to Engineer no later than the pre-construction conference.
   2. Provide photographs used for site examination.
   3. Provide video of site examination.
   4. Provide samples that used same camera and lighting equipment proposed for the Work.
   5. Engineer will review work examples to determine if the quality of the images is acceptable.
   6. Contractor is responsible for modifications to equipment and/or inspection procedures to achieve report material of acceptable quality.
   7. Do not commence Work prior to approval of the material by the Engineer.
   8. Once accepted, the standard report material shall serve as a standard for the remaining work.

1.04 KEY PLAN

A. Submit key plan of Project site with notation of vantage points marked for location and direction of each photograph.

B. Include the same label information as the corresponding set of photographs.

1.05 PHOTOGRAPHS

A. Provide prints of each photograph for each area of Work.

B. Provide a digital copy of each photograph for each area of Work.
   1. Monthly: Indexed digital flash drive.
   2. Project record documents:
      a. Catalog and index prints in chronological sequence.
      b. Include typed table of contents.

1.06 PRE-CONSTRUCTION PHOTOGRAPHS AND VIDEOS

A. Provide photographs and video of the condition entire site including each area of Work prior to the start of Work.
   1. Areas to be photographed and videoed shall include the site of the Work and all existing facilities, either on or adjoining the Project site, including the interior of existing structures that could be damaged as a result of the Contractor's Work.
   2. Include general condition, structures, vegetation, staging, storing, working, parking areas and excavation areas.

1.07 CONSTRUCTION PHOTOGRAPHS AND VIDEOS

A. Provide photographs and videos of construction in each area of Work throughout progress of Work including a key plan designating where each photograph was taken.

B. Take site and interior photographs and videos from differing directions of building demolition, pre-excavation, footing excavation, soil testing, utility crossings, installation of bypass piping, excavation of access pits, installation of lining system in pipes, rehabilitation of manholes, building modifications, utilities, electrical and instrumentation modifications, and other applicable activities indicating relative progress of the work.

C. Take photos a maximum of 7 calendar days prior to Submittal.

1.08 POST-CONSTRUCTION PHOTOGRAPHS AND VIDEOS

A. Provide photographs of the entire site including each area of Work at the completion of Work.
   1. Include general condition, structures, vegetation, staging, storing, working, parking areas and excavation areas.
   2. Take photos and video from same points in same direction as pre-construction examination.

B. Submittal of photos and videos is a condition of final payment.

PART 2 PRODUCTS

2.01 MEDIA

A. Digital media:
   1. Flash drive compatible with current Microsoft Windows.
   2. Provide photos as individual, indexed JPG files with the following characteristics:
      a. Compression shall be set to preserve quality over file size.
      b. Highest resolution JPG images shall be submitted. Resizing to a smaller size when high resolution JPGs are available shall not be permitted.
      c. JPG image resolution shall be 5 megapixels at 2,400 by 1,800 or higher.
      d. Images shall have rectangular, clean images. Artistic borders, beveling, drop shadows, etc., are not permitted.
   3. Identification: On photograph, provide the following information:
      a. Name of project.
      b. Date stamp: Unless otherwise indicated, date and time stamp each photograph as it is being taken so stamp is integral to photograph.
      c. Description of vantage point, indicating location and direction by compass point.

B. Videos:
   1. Video quality shall be 720p HD or greater in MPG, AVCHD, AVI, or MP4 format.
   2. Digital color video format.
   3. Provide audio portion of the composite video sufficiently free from electrical interference and background noise to provide complete intelligibility of oral report.
   4. Identification: On each copy provide a label with the following information:
      a. Name of project.
      b. Date video was recorded.
   5. Submit 1 copy of each video within 7 days of recording.
   6. Display continuous running time.
   7. At start of each video recording, record weather conditions from local newspaper or television and the actual temperature reading at Project site.

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01354

HAZARDOUS MATERIAL PROCEDURES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Procedures required when encountering hazardous materials at the Work site.

1.02 REFERENCES

A. California Code of Regulations (CCR):
   1. Title 8: Industrial Relations.
   2. Title 22 Division 4.5: Environmental Health Standards for the Management of Hazardous Waste.

B. California Occupational Safety and Health Administration (Cal-OSHA).

C. United States Code of Federal Regulation (CFR):
   1. Title 29 - Labor:
      a. 1926.62 - Lead.
   2. Title 40 - Protection of Environment:
      a. 261 - Identification and Listing of Hazardous Waste.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Adequately wet: Penetration of the pipe wall with liquid to prevent release of particulates.
   2. Asbestos cement pipe: Also commonly referred to as AC transite pipe, AC pipe or ACP. Pipe that is generally composed of cement and asbestos fibers.
   3. Competent person: A trained worker who is capable of identifying existing and predictable asbestos hazards, perform exposure assessment and monitoring, is qualified to train other workers, and has the authority to take immediate corrective action to eliminate a hazardous exposure.
   4. Non-friable asbestos-containing material (NACM): Material containing more than 1 percent asbestos, that when dry, cannot be crumbled, pulverized, or reduced to powder by hand pressure.
   5. Regulated asbestos-containing material (RACM): Category II non-friable ACM that has a high probability of becoming or has become crumbled, pulverized, or reduced to powder in the course of work.

1.04 SUBMITTALS

A. Submit laboratory reports, hazardous material removal plans, and certifications.

B. Submit the following work plan:
    1. Removal and Legal Disposal of Asbestos Cement Pipe Plan.
        a. Work plan shall include, but not be limited, to the following:
            1) Schedule of work.
            2) Security measures for work and disposal area.
            3) Staff training: Provide at least one competent person who is capable of identifying asbestos hazards at the job site for the entire duration of the AC pipe removal and disposal operation.
            4) Trenching and removal of pipe procedure.

1.05 OPERATING DIGESTERS

A. Observe safety precautions in vicinity of operating digesters which contain digester gases, including methane, hydrogen sulfide, and carbon dioxide.

1.06 HAZARDOUS MATERIALS PROCEDURES

A. Hazardous materials are those defined by 40 CFR and State specific codes.

B. Forward to Engineer, copies of reports, permits, receipts, and other documentation related to remedial work.

C. Contractor is responsible for the cost of any hazardous material testing required for obtaining permits.

D. Assume responsibility for worker health and safety, including health and safety of Subcontractors and their workers.
    1. Instruct workers on recognition and reporting of materials that may be hazardous.

E. File requests for adjustments to Contract Times and Contract Price due to the finding of Hazardous Materials in the Work site in accordance with Contract Documents.
    1. Minimize delays by continuing performance of the Work in areas not affected by hazardous materials operations.

F. When hazardous materials have been found:
    1. Prepare and initiate implementation of plan of action.
    2. Notify immediately Owner, Engineer, and other affected persons.
    3. Notify such agencies as are required to be notified by laws and regulations with the times stipulated by such laws and regulations.
    4. Designate a Certified Industrial Hygienist to issue pertinent instructions and recommendations for protection of workers and other affected persons' health and safety.
    5. Identify and contact Subcontractors and licensed personnel qualified to undertake storage, removal, transportation, disposal, and other remedial work required by, and in accordance with, laws and regulations.

1.07 LEAD PAINT REMOVAL AND DISPOSAL

A. Existing paint on the interior or exterior surfaces that may contain lead in concentrations which will require implementation of hazardous material compliance procedures as legislated by the following:
   1. CFR, Title 29 and Title 40.
   2. CCR, Title 8 and Title 22 Division 4.5.

B. Remove samples of paint from the structures identified in this Section and have samples tested by a certified testing laboratory to determine lead content in samples.
   1. Ensure that sufficient numbers of paint samples are removed and tested to provide adequate information regarding lead content in paint.
   2. Ensure that samples contain the total thickness of the paint to the substrate where removed.
   3. Ensure that each sample contains a sufficient quantity of paint to facilitate proper and adequate analyses by testing laboratory.
   4. Ensure that samples are adequately identified with location from which they were removed.

C. Laboratory testing of paint samples: In accordance with 40 CFR 261,
   1. Submit 10 copies of complete laboratory analyses of paint samples.

D. Submit a plan for the removal, containment, and disposal of lead-based paint and associated debris.
   1. Submit 10 copies of plan.

E. Prior to beginning work associated with the removal, containment, and disposal of lead-based paints, prepare and submit to the Engineer for his review 6 copies of the following:
   1. Listing of lead paint removal equipment to be used.
   2. Outline of procedures to be used to remove lead paint.
   3. Data and specifications describing chemical stripping materials to be used.
   4. Data and specifications describing abrasive blast materials and grit size to be used.
   5. Plan describing lead paint removal, hazardous waste debris containment, and hazardous waste disposal methods.
   6. Safety plan, consisting of a written plan of action covering operational requirements for safe removal of lead paint, safe handling and containment of waste and debris generated by the operation, and safe disposal of hazardous waste and non-hazardous waste materials, complying with the most stringent requirements of the following:
      a. Equipment and material manufacturer’s safety sheets.
      b. 29 CFR 1926.62.

F. Carry out lead paint removal, containment, and disposal work in accordance with the following SSPC guidelines:
   1. SSPC-Guide 6.
      a. Open Abrasive Blast Cleaning with Expendable Abrasive.
      b. Open Abrasive Blast Cleaning with Recyclable Abrasive.
      c. Closed Abrasive Blast Cleaning with Recyclable Abrasive.
      d. Chemical Stripping.

2. SSPC-Guide 7.

G. Assume responsibility for the proper utilization of the paint removal method selected.
   1. When abrasive blast cleaning is selected to remove lead-based paint, comply with all applicable federal, state, and local air quality, pollution, and environmental control regulations for blast cleaning.
   2. When chemical stripping is selected to remove the lead based paint, adhere to the chemical manufacturer's recommendations for the application of the product, the removal of the paint, and the containment of the debris.

H. Lead paint removal work shall be performed by a Contractor having prior experience in the removal method selected and shall provide at least 5 references of similar projects completed, 3 of which must have been completed within the past 12 months, documenting his experience.

I. Utilize a minimum of Class 3 containment and ventilation system as described in SSPC-Guide 6 during lead paint removal and containment procedures as required for the conditions.

J. Do not leave spent abrasive blast material, chemical stripping material, or lead paint debris uncontained on the project site overnight.

K. Test each container of paint debris, spent blast cleaning abrasive, chemical stripping debris, and other waste material generated by the operation to determine the waste material hazardous waste classification.

L. Assume responsibility for the disposal of lead paint waste and associated waste generated by the removal of the lead paint and the preparation of the surfaces for recoating. Dispose in accordance with applicable federal, state, and local requirements and regulations.

M. Accurately complete the Uniform Hazardous Waste Manifest included at the end of SSPC-Guide 7. Indicate on the Manifest that the Owner is the hazardous waste generator, and obtain the Owner's Environmental Protection Agency identification number for use in completing the Manifest.

1.08 ASBESTOS MATERIALS

A. It is the specific intent of these Contract Documents to exclude from the Work any and all products or materials containing asbestos. No products containing asbestos shall be incorporated in the Work.

B. Removal of existing ACM shall be performed by a firm that is registered by Cal-OSHA and certified by the State Contractors Licensing Board and shall be a licensed abatement contractor in the state where the Project is located.

C. Submit 10 copies of plan for the removal, containment, and disposal of ACM.

D. Submit 6 copies of abatement license of ACM removal contractor.

PART 2 PRODUCTS

2.01 ASBESTOS CEMENT PIPE (ACP)

A. Pipe to be removed from the ground has been in service for approximately 45 years.
   1. Manufacturer and exact composition of the pipe to be removed is unknown.
   2. ACP is generally manufactured using Portland cement or pozzolan cement and asbestos fiber.
   3. Common pipe lengths: 3 feet 3 inches, 6 feet 6 inches, 9 feet 9 inches, and 13 feet 0 inches.

B. Pipe fittings. Separate from pipe brass, galvanized pipe, copper, cast iron, galvanized pipe or steel fittings and dispose of separately.

PART 3 EXECUTION

3.01 ASBESTOS MATERIALS

A. Notifications:
   1. Notify Cal-OSHA 24 hours prior to performing asbestos material removal operations.
   2. Notify Owner 3 working days in advance of commencing asbestos material removal operations.

B. Work area:
   1. Establish a regulated work area, using at a minimum, construction warning tape to establish limits of work area for the asbestos material removal.
   2. On site stockpiling or storage of asbestos material designated for disposal shall not be allowed.

C. Safety:
   1. Conduct an Initial Exposure Assessment (IEA).
   2. Provide a hand/face wash station.

D. Worker qualifications:
   1. Asbestos removal shall be performed by employees trained in wet methods, vacuum cleaners with HEPA filters to collect debris and prompt cleanup in accordance with CCR, Title 8, § 1529, Section (g) Methods of Compliance, of “Asbestos,”.

E. Legal disposal:
   1. Legal disposal of asbestos material is the Owner’s responsibility.
   2. Transport the asbestos material to the location designated by the Owner and place into the location designated for this project.

3.02 EXCAVATION OF AC PIPE

A. Machine excavates to expose asbestos cement pipe.

B. Hand excavates areas under pipe where breaks are planned.

C. Pipe shall be pre-wetted prior to any breaks being made.

D. Pipe shall be snapped using mechanical snapping methods.

3.03 AC PIPE REMOVAL

A. All required pipe breaking operations shall require adequate pre-wetting with potable water.

B. Make every effort to minimize the number of pipe breaks. Wherever possible, the pipe should be removed by pulling the pipe out of the pipe joint collars.

C. Remove sections of AC pipe intact at joint collars by mechanical snapping methods between collars.

D. Wet and containerize waste materials as removed from the trench. Use lifting straps and methods that do not further damage the pipe.

E. Sections of AC pipe that become cut, have broken edges or have any friable surface shall be wet at exposed fractures and immediately wrapped.
   1. Pipe ends shall be sealed completely using a minimum 6-mil poly film wrap, which is securely fastened, taped to completely enclose the pipe and ACP appurtenances and shall have conspicuous, legible labeling that has the following or equivalent labeling: CAUTION: CONTAINS ASBESTOS FIBERS. BREATHING ASBESTOS DUST MAY CAUSE SERIOUS BODILY HARM.

F. AC pipe sections shall not be left exposed in public view, either in trench or in disposal area.

G. All connecting parts of pipe, rubber gaskets, and pipe couplings shall be discarded with pipe.

H. AC pipe from this project only shall be placed in the bin designated.

END OF SECTION

SECTION 01357

DELEGATED DESIGN PROCEDURES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Delegated Design procedures.

1.02 GENERAL

A. Delegated Design - Professional design services assigned to the Contractor by express delegation in the Contract Documents. Work is “Delegated Design” where the Technical Sections require the Contractor to provide professional design services and to submit signed and sealed documents from a registered Professional Engineer.

B. Contractor’s Professional Engineer - The design professional retained by the Contractor to perform Delegated Design.

C. Owner may require Contractor to provide professional design services for a portion of the Work by express delegation in the Contract Documents.
   1. Requirements of Delegated Design component as specified in the Technical Section and as indicated on the Drawings.
   2. Such delegation will specify the performance and design criteria that such services must satisfy, and the Submittals that the Contractor must furnish to the Engineer with respect to the Delegated Design.

D. Contractor shall cause such Delegated Design services to be provided pursuant to the professional standard of care by a properly licensed design professional, whose signature and seal shall appear on Drawings, calculations, Specifications, certifications, and Submittals prepared by such design professional.
   1. Contractor shall not be responsible for the adequacy of performance or design criteria specified by the Owner or Engineer.
   2. Contractor is not required to provide professional services in violation of applicable Laws and Regulations.
   3. Such design professional shall issue certifications of design required by Laws and Regulations.
   4. If a Shop Drawing or other Submittal related to the Owner-delegated design is prepared by the Contractor, a Subcontractor, or others for submittal to the Engineer, then such Shop Drawing or other Submittal shall bear the written approval of Contractor’s design professional when submitted by the Contractor to the Engineer.

E. Owner and Engineer shall be entitled to rely upon the adequacy, accuracy, and completeness of the services, certifications, and approvals performed or provided by the design professionals retained or employed by Contractor under Delegated

Design, subject to the professional standard of care and the performance and design criteria stated in the Contract Documents.

F. Engineer's review, approval, and other determinations regarding design drawings, calculations, Specifications, certifications, and other Submittals furnished by Contractor pursuant to a Delegated Design will be only for the following limited purposes:
   1. Confirming that Submittal is in conformance with the performance and design criteria specified in the Contract Documents.

1.03 CONTRACTOR'S PROFESSIONAL ENGINEER

A. Contractor or Subcontractor shall retain a licensed Professional Engineer to perform Delegated Design.

B. Qualifications:
   1. Holding a current license to perform the specified design in the same jurisdiction as the Project Site.
   2. Experienced in designing similar systems of similar complexity.

C. Insurance:
   1. Provide Contractor's Professional Engineer's Professional Liability Insurance appropriate to the Contractor's Professional Engineer's profession, with limit no less than $1,000,000 per occurrence or claim, $2,000,000 aggregate.

D. Responsibilities:
   1. Review and design in accordance with system performance and design criteria stated in the Contract Documents.
      a. Prepare written requests for clarifications or interpretations of performance or design criteria for submittal to the Engineer by the Contractor.
   2. Sign and seal design reports, calculations, design drawings and specifications, and other design Submittals for the Delegated Design Work.
   3. Review and submit written approval of Submittals related to the Delegated Design Work.
   4. Design modifications to the Delegated Design Work as required.
   5. Visit the Site, as required, to verify that installation of the Delegated Design Work is in conformance with the Delegated Design Drawings and Specifications.
   6. Submit through Contractor to Engineer written, signed, and sealed certification that the installed Delegated Design Work complies with Contractor's Professional Engineer's design.

1.04 SUBMITTALS

A. Prior to the start of Delegated Design:
   1. Contractor's Professional Engineer's qualifications:
      a. Experience for the Delegated Design.
      b. Evidence of Professional Engineering license.
   2. Contractor's Professional Engineer Professional Liability Insurance certificate.

B. Delegated Design:
   1. Product data:
      a. Details related to the Delegated Design as specified in Technical Sections to completely describe the system.
   2. Design documents with signature and seal from the Contractor's Professional Engineer.
      a. Design documents include, but are not limited to, Drawings, calculations, Specifications, inspection reports, and certifications.
   3. Lists and schedules:
      a. Prepare and submit lists or schedules of items where Delegated Design is required by the Contract Documents.
      b. Group items by location in the Work.
         1) When "Area Numbers" are indicated on the Contract Drawings, group lists in accordance with those "areas."
         2) For work without area numbers, group using logical divisions acceptable to the Engineer.
         3) Group items within each "area" as follows:
            a) Systems.
            b) Components.
            c) Supports.
            d) Anchorage.
            e) Bracing.

C. Construction services:
   1. Contractor's Professional Engineer's comments on Submittals.
   2. Other construction documents, as required.

1.05 ENGINEER RESPONSE TO DELEGATED DESIGN SUBMITTALS

A. Engineer response will be either of the following:
   1. Approved. Make Corrections Noted - See Comments:
      a. Contractor may proceed with the Work; however, all notations and comments must be incorporated into the final product.
      b. Review was for the limited purpose of determining that the document was stamped by a Professional Engineer and that such design is generally consistent with and will not negatively affect the design concept presented in the Contract Documents.
   2. Rejected - See Remarks:
      a. Contractor may not proceed with the Work described in the Submittal.
      b. Submittal does not meet the intent of the Contract Documents.
      c. Resubmittal of complete Submittal package is required with materials, equipment, methods, etc., that meet the requirements of the Contract Documents.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01400

REJECTION OF WORK

PART 1 - GENERAL

1.01 Rejection of Work

A. Any work that is not in compliance with the contract documents, or does not meet the performance requirements, or is not suitable for the intended use, may be rejected by the Owner.

B. Contractor may salvage materials from any rejected work. Salvaged materials shall not be used in corrections or replacement of work unless approved by the Owner in writing.

1.02 Correction of Work

A. The Contractor will be given two (2) opportunities to correct rejected work, unless otherwise approved by the Owner in writing.

B. The Contractor must submit to the Owner a plan for correcting the work. The Owner must approve this plan before the Contractor proceeds with any corrections.

C. If, in two (2) attempts, the Contractor does not correct the work so that it is as specified, meets the performance requirements, and is suitable for the intended use, the work will be rejected and the Contractor will be required to provide a replacement.

1.03 Replacement of Work

A. All replacement work shall be performed in accordance with this Contract and as specified.

1.04 Acceptance of Incomplete or Inadequate Work

A. At the Owner’s sole discretion, the Owner may choose to accept incomplete or inadequate work.

B. The Owner shall negotiate a reduced price, subject to the concurrence of the Contractor, for any incomplete or inadequate work that the Owner chooses to accept.

C. If an agreement about a reduced price for incomplete or inadequate work cannot be reached, the work shall be considered rejected.

1.05 Payment for Corrections, Replacement Work, and Rejected Work

A. No payment will be made for rejected work.

B. The Contractor will only be paid for bid items that are completed as specified, meet the performance requirements, and are suitable for the intended use.

C. No additional payment will be made for corrections or replacement work.

D. No payment will be made for salvaged materials that are not accepted for reuse in corrections or replacement of work.

END OF SECTION

SECTION 01410

REGULATORY REQUIREMENTS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Regulatory authorities and codes.

1.02 AUTHORITIES HAVING JURISDICTION (AHJ)

A. Also referred to as the permitting agency.

B. Building Department: City of Manteca Development Services Department, Building Safety Division.

C. Fire Department: City of Manteca Fire Department.

1.03 APPLICABLE CODES

A. Products in contact with drinking water
   1. Materials in contact with drinking waters: In accordance with NSF 61 and NSF 372.
      a. Certification by an independent ANSI accredited third party, including, but not limited to, NSF International, as being lead free.
   2. Materials in contact with drinking waters: In accordance with California Health and Safety Code, Section 116875.

B. California Code of Regulations (CCR), California Building Standards Code, CCR Title 24:
   1. Building code:
      a. California Building Code (CBC), Title 24, Part 2 - 2022.
   2. Electrical code:
      a. California Electrical Code (CEC), Title 24, Part 3 - 2022.
   3. Mechanical code:
      a. California Mechanical Code (CMC), Title 24, Part 4 - 2022.
   4. Plumbing code:
      a. California Plumbing Code (CPC), Title 24, Part 5 - 2022.
   5. Energy code:
      a. California Energy Code (CEC), Title 24, Part 6 - 2022.
   6. Historical building code:
      a. California Historical Building Code (CHBC), Title 24, Part 8 - 2022.
   7. Fire code:
      a. California Fire Code (CFC), Title 24, Part 9 - 2022.
   8. Existing building code:
      a. California Existing Building Code (CEBC), Title 24, Part 10 - 2022.

9. Green building standards code:
    a. California Green Building Standards Code (CALGreen), Title 24, Part 11 - 2022.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01450

QUALITY CONTROL

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Quality control and control of installation.
   2. Tolerances.
   3. References.
   4. Mock-up requirements.
   5. Authority and duties of the Owner's representative or inspector.
   6. Sampling and testing.
   7. Testing and inspection services.
   8. Contractor's responsibilities.

1.02 QUALITY CONTROL AND CONTROL OF INSTALLATION

A. Monitor quality control over suppliers, manufacturers, products, services, Site conditions, and workmanship, to produce Work of specified quality.

B. Comply with manufacturers' instructions, including each step in sequence.

C. When manufacturers' instructions conflict with the Contract Documents, request clarification from the Engineer before proceeding.

D. Comply with specified standards as minimum quality for the Work, except where more stringent tolerances, codes, or specified requirements indicate higher standards or more precise workmanship.

E. Perform Work by persons qualified to produce required and specified quality.

F. Verify field measurements are as indicated on Shop Drawings or as instructed by the manufacturer.

G. Secure products in place with positive anchorage devices designed and sized to withstand stresses, vibration, physical distortion, or disfigurement.

H. When specified, products will be tested and inspected either at point of origin or at Work site:
   1. Notify the Engineer in writing well in advance of when products will be ready for testing and inspection at point of origin.
   2. Do not construe that satisfactory tests and inspections at point of origin is final acceptance of products. Satisfactory tests or inspections at point of origin do not preclude retesting or re-inspection at the Work site.

I. Do not ship products which require testing and inspection at point of origin prior to testing and inspection.

1.03 TOLERANCES

A. Monitor fabrication and installation tolerance control of products to produce acceptable Work. Do not permit tolerances to accumulate.

B. Comply with manufacturers' tolerances. When manufacturers' tolerances conflict with the Contract Documents, request clarification from the Engineer before proceeding.

C. Adjust products to appropriate dimensions; position before securing products in place.

1.04 REFERENCES

A. ASTM International (ASTM):
   1. E329 - Standard for Agencies Engaged in Construction Inspection, Testing or Special Inspection.

B. National Institute of Standards and Technology (NIST).

1.05 MOCK-UP REQUIREMENTS

A. Tests will be performed under provisions identified in this Section and identified in respective product specification sections.

B. Assemble and erect specified items with specified attachment and anchorage devices, flashings, seals, and finishes.

C. Accepted mock-ups shall be comparison standard for remaining Work.

D. Where mock-up has been accepted by the Engineer and is specified in product specification sections to be removed; remove mock-up and clear area when directed to do so by the Engineer.

1.06 AUTHORITY AND DUTIES OF OWNER'S REPRESENTATIVE OR INSPECTOR

A. Owner's Project Representative employed or retained by the Owner is authorized to inspect the Work.

B. Inspections may extend to entire or part of the Work and to preparation, fabrication, and manufacture of products for the Work.

C. Deficiencies or defects in the Work which have been observed will be called to the Contractor's attention.

D. Inspector will not:
   1. Alter or waive provisions of the Contract Documents.
   2. Inspect the Contractor's means, methods, techniques, sequences, or procedures for construction.
   3. Accept portions of the Work, issue instructions contrary to intent of the Contract Documents, or act as foreman for the Contractor. Supervise, control, or direct the Contractor's safety precautions or programs; or inspect for safety

conditions on Work site, or of persons thereon, whether the Contractor's employees or others.

E. Inspector will:
   1. Conduct on-site observations of the Work in progress to assist the Engineer in determining when the Work is, in general, proceeding in accordance with the Contract Documents.
   2. Report to the Engineer whenever the inspector believes that Work is faulty, defective, does not conform to the Contract Documents, or has been damaged; or whenever there is defective material or equipment; or whenever the inspector believes the Work should be uncovered for observation or requires special procedures.

1.07 SAMPLING AND TESTING

A. General:
   1. Prior to delivery and incorporation in the Work, submit listing of sources of materials, when specified in sections where materials are specified.
   2. When specified in sections where products are specified:
      a. Submit sufficient quantities of representative samples of character and quality required of materials to be used in the Work for testing or examination.
      b. Test materials in accordance with standards of national technical organizations.

B. Sampling:
   1. Furnish specimens of materials when requested.
   2. Do not use materials which are required to be tested until testing indicates satisfactory compliance with specified requirements.
   3. Specimens of materials will be taken for testing whenever necessary to determine quality of material.
   4. Assist the Engineer in preparation of test specimens at site of work, such as soil samples and concrete test cylinders.

1.08 TESTING AND INSPECTION SERVICES

A. Contractor will employ and pay for specified services of an independent firm to perform the Contractor quality control testing as required in the technical specifications for various work and materials.

B. Owner will employ and pay for specified services of an "Owner's independent testing firm" certified to perform testing and inspection as required in the technical specifications for various work and materials or stipulated in Section 01455 - Regulatory Quality Assurance to confirm the Contractor's compliance with the Contract Documents.

C. Owner's independent testing firm will perform tests, inspections, and other services specified in individual specification sections and as required by the Owner and requested by the Engineer.

D. The qualifications of laboratory that will perform the testing, contracted by the Owner or by the Contractor, shall be as follows:
   1. Has authorization to operate in the state where the Project is located.
   2. Meets “Recommended Requirements for Independent Laboratory Qualification,” published by American Council of Independent Laboratories.
   3. Meets requirements of ASTM E329.
   4. Laboratory Staff: Maintain full time specialist on staff to review services.
   5. Testing Equipment: Calibrated at reasonable intervals with devices of accuracy traceable to NIST or accepted values of natural physical constants.
   6. Will submit copy of report of inspection of facilities made by Materials Reference Laboratory of NIST during most recent tour of inspection, with memorandum of remedies of deficiencies reported by inspection.

E. Testing, inspections, and source quality control may occur on or off the Project Site. Perform off-site testing inspections and source quality control as required by the Engineer or Owner.

F. Contractor shall cooperate with the Owner’s independent testing firm, furnish samples of materials, design mix, equipment, tools, storage, safe access, and assistance by incidental labor as requested.
   1. Notify the Engineer and Owner’s independent testing firm 48 hours prior to expected time for operations requiring testing.
   2. Make arrangements with the Owner’s independent testing firm and pay for additional samples and tests required for the Contractor’s use.

G. Limitations of authority of testing laboratory: Owner’s independent testing firm or laboratory is not authorized to:
   1. Agency or laboratory may not release, revoke, alter, or enlarge on requirements of the Contract Documents.
   2. Agency or laboratory may not approve or accept any portion of the Work.
   3. Agency or laboratory may not assume duties of the Contractor.
   4. Agency or laboratory has no authority to stop the Work.

H. Testing and employment of an Owner’s independent testing firm or laboratory shall not relieve the Contractor of obligation to perform Work in accordance with requirements of the Contract Documents.

I. Re-testing or re-inspection required because of non-conformance to specified requirements shall be performed by the same Owner’s independent testing firm on instructions by the Engineer. Payment for re-testing or re-inspection will be charged to the Contractor by deducting testing charges from the Contract Sum/Price.

J. Owner’s independent testing firm responsibilities will include:
   1. Test samples of mixes submitted by the Contractor.
   2. Provide qualified personnel at Site. Cooperate with the Engineer and Contractor in performance of services.
   3. Perform specified sampling and testing of products in accordance with specified standards.
   4. Ascertain compliance of materials and mixes with requirements of the Contract Documents.

5. Promptly notify the Engineer and Contractor of observed irregularities or non-conformance of Work or products.
6. Perform additional tests required by the Engineer.
7. Attend preconstruction meetings and progress meetings when requested.

K. Owner's independent testing firm individual test reports:
1. After each test, the Owner's independent testing firm will promptly submit electronically report to the Engineer and Contractor.
2. Test reports shall include at least the following information:
a. Date issued.
b. Project title and number.
c. Name of inspector.
d. Date and time of sampling or inspection.
e. Identification of product and specifications section.
f. Location in Project.
g. Type of inspection or test.
h. Date of test.
i. Certified test results stamped and signed by a registered Engineer in the state where the Project is located.
j. Summary of conformance with the Contract Documents.
k. When requested by the Engineer, the Owner's independent testing firm will provide interpretation of test results.

1.09 CONTRACTOR'S RESPONSIBILITIES

A. Cooperate with the Owner's independent testing firm or laboratory personnel and provide access to construction and manufacturing operations.

B. Secure and deliver to the Owner's independent testing firm or laboratory adequate quantities of representative samples of materials proposed to be used and which require testing.

C. Provide to the Owner's independent testing firm or laboratory and the Engineer preliminary mix design proposed to be used for concrete, and other materials mixes which require control by testing laboratory.

D. Submit product test reports electronically.

E. Furnish incidental labor and facilities:
1. To provide access to construction to be tested.
2. To obtain and handle samples at Work site or at source of product to be tested.
3. To facilitate inspections and tests.
4. For storage and curing of test samples.

F. Notify the Owner's independent testing firm or laboratory 48 hours in advance of when observations, inspections and testing is needed for laboratory to schedule and perform in accordance with their notice of response time.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01455

REGULATORY QUALITY ASSURANCE

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Project regulatory requirements for quality assurance that includes Special Inspections, Special Certification, and Structural Observation.

B. Special Certification and Special Inspections in this Section are in addition to the requirements specified in Section 01450 - Quality Control, and in the individual Sections.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 318 - Building Code Requirements for Structural Concrete.
   2. 530 - Building Code Requirements for Masonry Structures.
   3. 530.1 - Specification for Masonry Structures.

B. American Institute of Steel Construction (AISC):
   1. 360 - Specification for Structural Steel Buildings.

C. American Society of Civil Engineers (ASCE):
   1. 7 - Minimum Design Loads for Buildings and Other Structures.

D. American Welding Society (AWS):
   1. D1.3 - Structural Welding Code - Sheet Steel.
   2. D1.4 - Structural Welding Code - Reinforcing Steel.

E. ASTM International (ASTM):
   1. A706 - Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement.
   2. C31 - Standard Practice for Making and Curing Concrete Test Specimens in the Field.
   3. C172 - Standard Practice for Sampling Freshly Mixed Concrete.
   4. C1611 - Standard Test Method for Slump Flow of Self-Consolidating Concrete.

F. Building Code:
   1. As specified in Section 01410 - Regulatory Requirements.

G. The Masonry Society (TMS):
   1. 402 - Building Code for Masonry Structures.
   2. 602 - Specifications for Masonry Structures.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Special Certification: Certification for designated seismic systems that demonstrates compliance with performance requirements.
   2. Special Inspection: Inspection of the materials, installation, fabrication, erection, or placement of components and connections requiring special expertise to ensure compliance with approved construction documents and referenced standards.
   3. Special Inspection, Continuous: The full-time observation of work requiring Special Inspection by an approved special inspector who is present in the area where the work is being performed.
   4. Special Inspection, Periodic: The part-time, or intermittent observation of work requiring Special Inspection by an approved special inspector who is present in the area where the work is being performed and at the completion of the work.
   5. Structural Observation: The visual observation of the structural system by a registered design professional for general conformance to the approved construction documents at significant construction stages and at completion of the structural system.

1.04 SUBMITTALS

A. Submit Special Certifications for designated seismic systems.

B. Schedule and coordinate the submittal of Special Inspection reports and test results prepared by others.

1.05 SPECIAL INSPECTION

A. Owner will employ one or more special inspectors who will provide Special Inspections during construction.

B. Special inspector(s) shall be qualified for inspection of the particular type of materials or operations requiring Special Inspection.

C. Duties of special inspector:
   1. General: Required duties of the special inspector(s) shall be as described in the Building Code.
   2. Reporting: Special inspector(s) shall provide reports of each inspection to the Owner and shall distribute copies of inspection reports to the Engineer and Contractor as required.
      a. Reports shall, at a minimum, include the following items:
         1) Date and time of inspection, and name(s) of individual(s) performing the inspection.
         2) Structures and areas of the structure where work or testing was observed.
         3) Discrepancies between the requirements of the Contract Documents and the work or testing observed.
         4) Other areas of deficiency in the Work.

D. Special Inspections shall not be construed as fulfilling the requirements for Structural Observation.

E. Owner or special inspector will select materials for Special Inspection.
   1. Contractor shall not select materials for Special Inspection.

1.06 SPECIAL CERTIFICATION

A. Provide equipment that meets the special certification requirements of the Building Code.

B. Designated seismic systems shall be subject to the testing and qualification requirements of the regulatory Building Code, and shall require Special Certification as set forth in ASCE 7:
   1. Mechanical equipment that is assigned an importance factor of 1.50 as specified in Section 01850 - Design Criteria.
   2. All electrical equipment.

C. Special certification requirements for designated seismic systems:
   1. Submittals shall include certification that the equipment is seismically qualified. Certifications are subject to review and acceptance by Owner.
   2. Certifications may be at least one of the following in accordance with ASCE 7:
      a. Analysis.
      b. Testing.
      c. Experience data.

1.07 STRUCTURAL OBSERVATION

A. Owner will employ one or more registered design professionals to provide Structural Observation(s) during construction.
   1. Registered design professional will be a civil or structural engineer currently licensed as such in the state where the project is located and regularly engaged in structural design equivalent to or similar to that indicated on the Drawings.

B. Structural Observations shall not be construed as fulfilling the requirements for Special Inspections.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 SPECIAL INSPECTIONS

A. Owner will provide Special Inspection of the following types of work as described in the Building Code wherever such work occurs, unless otherwise specified.
   1. Attachment A - Concrete - Special Inspection Schedule.
   2. Attachment B - Mechanical, and Electrical Components - Special Inspection Schedule.

3. Attachment C - Soils - Special Inspection Schedule.
4. Attachment D - Structural Steel Welding - Special Inspection Schedule.
5. Attachment E - Structural Steel Bolting - Special Inspection Schedule.
6. Attachment F - Steel Construction - Steel Deck, Open Web Steel Joists and Joist Girders, and Cold Formed Steel Trusses - Special Inspection Schedule.
7. Attachment G - Ground Improvements, Cast-in-Place - Special Inspection Schedule.

3.02 SPECIAL CERTIFICATION

A. Special inspector shall examine the designated seismic system(s) and determine whether the designated system components, including anchorage, are consistent with the evidence of compliance submitted for Special Certification.

3.03 STRUCTURAL OBSERVATION

A. The following work requires Structural Observation in accordance with the Building Code.
   1. All structures in all areas:
      a. RDT Platform, Canopy and Slab
      b. Ground Improvements
      c. MCC and Dewatering Building Improvements

3.04 SCHEDULE

A. Allow time necessary for Special Inspections and Structural Observation specified in this Section.

B. Sufficient notice shall be given so that the Special Inspections and Structural Observations can be performed. Allow time for individuals performing to travel to the Site.

3.05 PROCEDURE

A. Special inspector will immediately notify the Engineer of any corrections required and follow notification with appropriate documentation.

B. Contractor shall not proceed until the Work is satisfactory to the Engineer.

END OF SECTION

ATTACHMENT A - CONCRETE - SPECIAL INSPECTION SCHEDULE

CONCRETE - SPECIAL INSPECTION SCHEDULE
(Includes: Cast-in-place, precast, prestressed, precast-prestressed, and shotcrete.)

Verification and Inspection	Reference Standard	Frequency of Inspection[(1)] (During Task Listed)	
		Continuous	Periodic
1. Inspect reinforcement, including prestressing tendons, and verify placement.	ACI 318 Building Code		●
2. Inspect anchors cast in concrete.	ACI 318		●
3. Inspect anchors post-installed in hardened concrete members:			
a. Adhesive anchors installed in horizontally or upwardly inclined orientations to resist sustained tension loads.	ACI 318	●	
b. Mechanical anchors and adhesive anchors not defined in 4.a.	ACI 318		●
4. Verify use of required design mix.	ACI 318 Building Code		●
5. Prior to concrete placement, fabricate specimens for strength tests, perform slump and air content tests, and determine the temperature of the concrete.	ASTM C172 ASTM C31 ACI 318 Building Code	●	
6. Inspect concrete and shotcrete placement for proper application techniques.	ACI 318 Building Code	●	
7. Verify maintenance of specified curing temperature and techniques.	ACI 318 Building Code		●
8. Verify in-situ concrete strength, prior to stressing of tendons in post-tensioned concrete and prior to removal of shores and forms from beams and structural slabs.	ACI 318		●
9. Inspect formwork for shape, location and dimensions of the concrete member being formed.	ACI 318		●

Notes:

(1) "●" represents a required inspection activity for the project where it occurs.

ATTACHMENT B - ARCHITECTURAL, MECHANICAL, AND ELECTRICAL COMPONENTS - SPECIAL INSPECTION SCHEDULE

MECHANICAL AND ELECTRICAL COMPONENTS - SPECIAL INSPECTION SCHEDULE

Verification and Inspection	Reference Standard	Frequency of Inspection[1] (During Task Listed)	
		Continuous	Periodic
1. Plumbing, mechanical, and electrical components:			
a. Anchorage of electrical equipment for emergency and standby power systems.	Building Code		●
b. Anchorage of other electrical and mechanical equipment over 400 lb. on floors or roofs.	Building Code		●
c. Installation and anchorage of pipelines carrying hazardous chemicals and their associated mechanical units.	Building Code		●
d. Installation and anchorage of pipelines greater than 6 inches in diameter.	Building Code		●
e. Installation and anchorage of ductwork designed to carry hazardous materials.	Building Code		●
f. Installation and anchorage of ductwork greater than 6 sf in cross section.	Building Code		●
g. Installation and anchorage of vibration isolation systems where Contract Documents require nominal clearance of 1/4 inch or less between the equipment support frame and its support/restraint.	Building Code		●
h. Installation of mechanical and electrical equipment, including ductwork, piping systems and their structural supports, where automatic fire sprinkler systems are installed.	Building Code		●

Notes:

(1) "●" represents a required inspection activity for the project where it occurs.

ATTACHMENT C - SOILS - SPECIAL INSPECTION SCHEDULE

SOILS - SPECIAL INSPECTION SCHEDULE

Verification and Inspection	Reference Standard	Frequency of Inspection[1] (During Task Listed)	
		Continuous	Periodic
1. Verify materials below shallow foundations are adequate to achieve the design bearing capacity.	Building Code		●
2. Verify excavations are extended to proper depth and have reached proper material.	Building Code		●
3. Perform classification and testing of fill and backfill materials.	Building Code		●
4. Verify use of proper materials, densities, and lift thicknesses during placement and compaction of fill and backfill.	Building Code	●	
5. Prior to placement of fill, observe subgrade and verify that Site has been prepared properly.	Building Code		●

Notes:

(1) "●" represents a required inspection activity for the project where it occurs.

ATTACHMENT D - STRUCTURAL STEEL WELDING - SPECIAL INSPECTION SCHEDULE

STRUCTURAL STEEL WELDING - SPECIAL INSPECTION SCHEDULE

Verification and Inspection	Reference Standard	Frequency of Inspection[(1)] (During Task Listed)	
		Continuous	Periodic
Inspection Tasks Prior to Welding	AISC 360		
1. Welding procedure specifications (WPSs) available.		●	
2. Manufacturer certifications for welding consumables available.		●	
3. Material identification (type/grade).			●
4. Welder identification system.			●
5. Fit-up groove welds (including joint geometry): • Joint preparation. • Dimensions (alignment, root opening, root face, bevel). • Cleanliness (condition of steel surfaces). • Tacking (tack weld quality and location). • Backing type and fit (if applicable).			●
6. Configuration and finish of access holes.			●
7. Fit-up of fillet welds: • Dimensions (alignment, gaps at root). • Cleanliness (condition of steel surfaces). • Tacking (tack weld quality and location).			●
8. Check welding equipment.			●
Inspection Tasks During Welding	AISC 360		
9. Use of qualified welders.			●
10. Control and handling of welding consumables: • Packaging. • Exposure control.			●
11. No welding over cracked tack welds.			●
12. Environmental conditions: • Wind speed within limits. • Precipitation and temperature.			●
13. WPS followed: • Settings on welding equipment. • Travel speed. • Selected welding materials. • Shielding gas type/flow rate. • Preheat applied. • Interpass temperature maintained (min/max). • Proper position (F, V, H, OH).			●

Verification and Inspection	Reference Standard	Frequency of Inspection[1] (During Task Listed)	
		Continuous	Periodic
14. Welding techniques: • Interpass and final cleaning. • Each pass within profile limitations. • Each pass meets quality requirements.			●
Inspection Tasks After Welding	AISC 360		
15. Welds cleaned.			●
16. Size, length, and location of welds.		●	
17. Welds meet visual acceptance criteria: • Crack prohibition. • Weld/base-metal fusion. • Crater cross section. • Weld profiles. • Weld size. • Undercut. • Porosity.		●	
18. Arc strikes.		●	
19. k-area.		●	
20. Backing removed and weld tabs removed (if required).		●	
21. Repair activities.		●	
22. Document acceptance or rejection of welded joint or member.		●	
Notes: (1) "●" represents a required inspection activity for the project where it occurs.			

ATTACHMENT E - STRUCTURAL STEEL BOLTING - SPECIAL INSPECTION SCHEDULE

STRUCTURAL STEEL BOLTING - SPECIAL INSPECTION SCHEDULE

Verification and Inspection	Reference Standard	Frequency of Inspection[1] (During Task Listed)	
		Continuous	Periodic
Inspection Tasks Prior to Bolting	AISC 360		
1. Manufacturer's certifications available for fastener materials.		●	
2. Fasteners marked in accordance with ASTM requirements.			●
3. Proper fasteners selected for the joint detail (grade, type, bolt length if threads are to be excluded from shear plane).			●
4. Proper bolting procedure selected for joint detail.			●
5. Connecting elements, including the appropriate faying surface condition and hole preparation, if specified, meet applicable requirements.			●
6. Pre-installation verification testing by installation personnel observed and documented for fastener assemblies and methods used.			●
7. Proper storage provided for bolts, nuts, washers and other fastener components.			●
Inspection Tasks During Bolting	AISC 360		
8. Fastener assemblies, of suitable condition, placed in all holes and washers (if required) are positioned as required.			●
9. Joint brought to the snug-tight condition prior to the pretensioning operation.			●
10. Fastener component not turned by the wrench prevented from rotating.			●
11. Fasteners are pretensioned in accordance with the RCSC Specification, progressing systematically from the most rigid point toward the free edges.			●
Inspection Tasks After Bolting	AISC 360		
12. Document acceptance or rejection of bolted connections.		●	

Notes:

(1) "●" represents a required inspection activity for the project where it occurs.

ATTACHMENT F - DEEP FOUNDATIONS, CAST-IN-PLACE - SPECIAL INSPECTION SCHEDULE

GROUND IMPROVEMENTS, CAST-IN-PLACE - SPECIAL INSPECTION SCHEDULE

Verification and Inspection	Reference Standard	Frequency of Inspection[(1)] (During Task Listed)	
		Continuous	Periodic
1. Observe drilling operations and maintain complete and accurate records for each element.	Building Code	●	
2. Verify placement locations and plumbness, confirm element diameters, bell diameters (if applicable), lengths, embedment into bedrock or specified stratum (if applicable), and adequate end-bearing strata capacity. Record concrete or grout volumes.	Building Code	●	

Notes:

(1) "●" represents a required inspection activity for the project where it occurs.

SECTION 01460

CONTRACTOR QUALITY CONTROL PLAN

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Contractor Quality Control Plan.

1.02 SUBMITTALS

A. Qualifications of the Contractor's Quality Control (CQC) Plan Manager.

B. Contractor's Daily Quality Control Report:
   1. Submit to Engineer within 1 day of completion of each inspection using the approved form.

C. Daily Inspection Report:
   1. Submit to Engineer at the end of each working day or no later than prior to the beginning of the next working day using the approved form.

1.03 CONTRACTOR'S INSPECTION OF THE WORK

A. Work performed by Contractor shall be inspected by the Contractor's CQC Plan Manager. Non-conforming Work and any safety hazards in the Work area shall be noted and promptly corrected.

B. No materials or equipment shall be used in Work without inspection and acceptance by Contractor's CQC Plan Manager.

1.04 QUALIFICATIONS

A. Contractor's CQC Plan Manager: Demonstrate having performed similar CQC functions on similar type projects. Submit records of personnel experience, training, and qualifying registrations.

B. Minimum qualifications: Candidate must have a minimum of 10 years of experience on projects of similar type and size.

1.05 COVERING WORK

A. Whenever Contractor intends to backfill, bury, cast in concrete, or otherwise cover any Work, notify Engineer not less than 24 hours in advance to request inspection before beginning any such Work of covering. Failure of Contractor to notify Engineer in accordance with this requirement shall be resolved according to Section 13 of the General Conditions.

1.06 CONTRACTOR'S QUALITY CONTROL PROGRAM

A. General: Establish and execute a Quality Control (CQC) Plan for Work. The plan shall establish adequate measures for verification and conformance to defined requirements by Contractor personnel and lower-tier Subcontractors (including Fabricators, Suppliers, and Subcontractors). This program shall be described in a Plan responsive to this Section.

B. CQC personnel:
   1. Contractor's CQC Plan Manager shall report to a Senior Project Manager of the Contractor and shall have no supervisory or managerial responsibility over the workforce.
   2. The Contractor CQC Plan Manager shall be on-site as often as necessary, but not less than the daily working hours specified in the Contract Documents to remedy and demonstrate that Work is being performed properly and to make multiple observations of Work in progress.
   3. The Contractor is to furnish personnel with assigned CQC functions reporting to the CQC Manager. Persons performing CQC functions shall have sufficient qualifications, authority, and organizational freedom to identify quality problems and to initiate and recommend solutions.

C. CQC Plan:
   1. Contractor's CQC Plan shall include a statement by the Senior Project Manager designating the CQC Plan Manager and specifying the authority delegated to the CQC Plan Manager to direct cessation or removal and replacement of defective Work.
   2. Describe the CQC program and include procedures, work instructions, and records. Describe methods relating to areas that require special testing and procedures as required by the specifications.
   3. Include specific instructions defining procedures for observing Work in process and comparing this Work with the Contract requirements (organized by specifications section).
   4. Describe procedures to ensure that equipment or materials that have been accepted at the Site are properly stored, identified, installed and tested.
   5. Include procedures to verify that procured products and services conform to the requirements of the Specifications. Requirements of these procedures shall be applied, as appropriate, to lower-tier Suppliers and/or Subcontractors.
   6. Commissioning quality control: Include procedures to verify that the commissioning requirements of the Contract Documents are integrated into the Contractor's CQC Plan and conform to the requirements of the Specifications. Requirements of these procedures shall be applied, as appropriate, to the Contractor and the lower-tier Suppliers and/or Subcontractors.
   7. Include instructions for recording inspections and requirements for demonstrating through the Daily Inspection Reports that Work inspected was in compliance or a deficiency was noted and action to be taken.
   8. Procedures to preclude the covering of deficient or rejected Work.
   9. Procedures for halting or rejecting Work.
   10. Procedures for resolution of differences between the CQC Plan Manager and the production personnel.

11. Identify contractual hold/inspection points as well as any Contractor-imposed hold/inspection points.

D. Daily Inspection Report: Include, at a minimum:
   1. Inspection of specific work.
   2. Quality characteristics in compliance.
   3. Quality characteristics not in compliance.
   4. Corrective/remedial actions taken.
   5. Statement of certification.
   6. CQC Manager's signature, electronic signature is acceptable.
   7. Information provided on the daily report shall not constitute notice of delay or any other notice required by the Contract Documents.

E. Deficient and Non-conforming Work and Corrective Action: Include procedures for handling deficiencies and non-conforming Work. Deficiencies and non-conforming Work are defined as documentation, drawings, material, equipment, or Work not conforming to the indicated requirements or procedures. The procedure shall prevent non-conformances by identification, documentation, evaluation, separation, disposition, and corrective action to prevent reoccurrence. Conditions having adverse effects on quality shall be promptly identified and reported to the senior level management. The cause of conditions adverse to quality shall be determined and documents and measures implemented to prevent recurrence. In addition, at a minimum, this procedure shall address:
   1. Personnel responsible for identifying deficient and non-complying items within Work.
   2. How and by whom deficient and non-compliant items are documented "in the field."
   3. The personnel and process utilized for logging deficient and non-compliant Work at the end of each day onto a deficiency log.
   4. Tracking processes and tracking documentation for deficient and non-conforming Work.
   5. Personnel responsible for achieving resolution of outstanding deficiencies.
   6. Include detailed procedures for the performance and control of special process (e.g., welding, soldering, heat treating, cleaning, plating, nondestructive examination, etc.).

F. Audits: The CQC program shall provide for regularly scheduled documented audits to verify that CQC procedures are being fully implemented by Contractor and its Subcontractors. Audit records shall be made available to Engineer upon request.

G. Documented control/quality records:
   1. Establish methods for control of Contract Documents that describe how Drawings and Specifications are received and distributed to ensure the correct issue of the document being used. Describe how record document/drawing data are documented and furnished to Engineer.
   2. Maintain evidence of activities affecting quality. Including operating logs, records of inspection, audit reports, personnel qualification and certification records, procedures, and document review records.
   3. Maintain quality records in a manner that provides for timely retrieval and traceability. Protect quality records from deterioration, damage and destruction.

4. Develop a list of specific records as required by the Contract Documents that will be furnished to Engineer at the completion of activities.

H. Acceptance of CQC Plan: Engineer's acceptance of the CQC Plan shall not relieve Contractor from any of its obligations for performance of Work. Contractor's CQC staffing is subject to Engineer's review and continued acceptance. Owner, at its sole discretion, and without cause, may direct Contractor to remove and replace the CQC Plan Manager.
   1. Acceptance of the CQC Plan by the Engineer is required prior to the start of construction. Acceptance is conditional and will be predicated on satisfactory performance during the construction.
   2. After acceptance of the CQC Plan, notify the Engineer in writing of any proposed change. Proposed changes are subject to acceptance by the Engineer.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01500

TEMPORARY FACILITIES AND CONTROLS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Furnishing, maintaining, and removing construction facilities and temporary controls, including temporary utilities, construction aids, barriers and enclosures, security, access roads, temporary controls, project sign, field offices and sheds, and removal after construction.

1.02 REFERENCE

A. American National Standards Institute (ANSI).

B. Occupational Safety and Health Administration (OSHA).

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

1.04 TEMPORARY UTILITIES

A. Temporary electrical power:
   1. Arrange with local utility to provide adequate temporary electrical service.
   2. Provide and maintain adequate jobsite power distribution facilities conforming to applicable Laws and Regulations.
   3. Provide, maintain, and pay for electric power for performance of the Work.
   4. Pay for and construct electrical power facilities to serve Construction Manager's field office.
   5. Contractor may use electrical power from the WQCF's electrical system without cost, but the Contractor is responsible for all costs associated with constructing and removing temporary hookups to the system. When combined demand of the Work and plant exceeds plant supply capacity, provide additional temporary supply capacity.

B. Temporary electrical lighting:
   1. In work areas, provide temporary lighting sufficient to maintain lighting levels during working hours not less than lighting levels required by OSHA and state agency which administers OSHA regulations where Project is located.
   2. When available, permanent lighting facilities may be used in lieu of temporary facilities:
      a. Prior to final completion of the Work, replace bulbs, lamps, or tubes used by Contractor for lighting.

C. Temporary heating, cooling, and ventilating:
   1. Heat and ventilate work areas to protect the Work from damage by freezing, high temperatures, weather, and to provide safe environment for workers.
   2. Permanent heating system may be utilized when sufficiently completed to allow safe operation.

D. Temporary water:
   1. Pay for and construct facilities necessary to furnish potable water for human consumption and non-potable water for use during construction.
   2. Remove temporary piping and connections and restore affected portions of the facility to original condition before final acceptance.
   3. Pay for potable water used for construction prior to final acceptance.
   4. The City has Water Reduction Act ordinance in place requiring the Contractor to use recycled water for construction purposes, or obtain an exception and submit the form to the Water Division.
   5. Development of non-potable water supply:
      a. Post ample signs throughout the work area warning that plant water is not potable.
      b. Non-potable water is available from hydrants or hose valves within plant without cost. When combined demand of the Work and plant exceeds plant supply capacity, provide additional temporary supply capacity.

E. Temporary sanitary facilities:
   1. Provide suitable and adequate sanitary facilities that are in compliance with applicable Laws and Regulations.
   2. Existing facility use is not allowed.
   3. At completion of the Work, remove sanitary facilities and leave site in neat and sanitary condition.

F. Temporary fire protection:
   1. Provide fire protection required to protect the Work and ancillary facilities.

G. First aid: Post first aid facilities and information posters conforming to requirements of OSHA and other applicable Laws and Regulations in readily accessible locations.

H. Utilities in existing facilities: As specified in Section 01140 - Work Restrictions.

I. Temporary piping systems:
   1. Submit layout drawings showing proposed routing of piping, including proposed pipe support and pipe restraint locations.
   2. Submit product data for piping, fittings, appurtenances, restraints, supports, and other components of the temporary piping system.
   3. Submit information at least 28 days prior to when each temporary piping system is scheduled to be installed and allow 14 days for review and comment.

J. Temporary pumping systems:
   1. Submit pump data, performance curves, and other operating information as specified in Section 15050 - Common Work Results for Mechanical Equipment.

2. Submit sketches showing layout of temporary pumping system, including pump quantity, configuration in wet well, and proposed piping layout specified in this Section.
3. Submit piping headloss calculations based on proposed temporary piping system layout.
4. Submit information at least 28 days prior to when the temporary pumping system is scheduled to be installed and allow 14 days for review and comment.

1.05 CONSTRUCTION AIDS

A. Provide railings, kick plates, enclosures, safety devices, and controls required by Laws and Regulations and as required for adequate protection of life and property.

B. Use construction hoists, elevators, scaffolds, stages, shoring, and similar temporary facilities of ample size and capacity to adequately support and move loads.

C. Design temporary supports with adequate safety factor to ensure adequate load bearing capability:
   1. When requested, submit design calculations by professional registered engineer prior to application of loads.
   2. Submitted design calculations are for information and record purposes only.

D. Accident prevention:
   1. Exercise precautions throughout construction for protection of persons and property.
   2. Observe safety provisions of applicable Laws and Regulations.
   3. Guard machinery and equipment and eliminate other hazards.
   4. Make reports required by authorities having jurisdiction, and permit safety inspections of the Work.
   5. Before commencing construction work, take necessary action to comply with provisions for safety and accident prevention.

E. Barricades:
   1. Place barriers at ends of excavations and along excavations to warn pedestrian and vehicular traffic of excavations.
   2. Provide barriers with flashing lights after dark.
   3. Keep barriers in place until excavations are entirely backfilled and compacted.
   4. Barricade excavations to prevent persons from entering excavated areas in streets, roadways, parking lots, treatment plants, or other public or private areas.

F. Warning devices and barricades: Adequately identify and guard hazardous areas and conditions by visual warning devices and, where necessary, physical barriers:
   1. Provide devices in accordance with minimum requirements of OSHA and State agency which administers OSHA regulations where Project is located.

G. Hazards in public right-of-way:
   1. Comply with local jurisdiction standards and requirements for right-of-way barricades and other safety devices.

2. Mark at reasonable intervals, trenches, and other continuous excavations in public right-of-way, running parallel to general flow of traffic, with traffic cones, barricades, or other suitable visual markers during daylight hours:
    a. During hours of darkness, provide markers with torches, flashers, or other adequate lights.
3. At intersections or for pits and similar excavations, where traffic may reasonably be expected to approach head on, protect excavations by continuous barricades:
    a. During hours of darkness, provide warning lights at close intervals.

H. Hazards in protected areas: Mark or guard excavations in areas from which public is excluded, in manner appropriate for hazard.

I. Above grade protection: On multi-level structures, provide safety protection that meets requirements of OSHA and State agency which administers OSHA regulations where Project is located.

J. Protect existing structures, trees, shrubs, and other items to be preserved on Project site from injury, damage, or destruction by vehicles, equipment, worker or other agents with substantial barricades or other devices commensurate with hazards.

K. Fences:
1. Enclose site of the Work with fence adequate to protect the Work against acts of theft, violence, and vandalism.

1.06 SECURITY

A. Make adequate provision for protection of the work area against fire, theft, and vandalism, and for protection of public against exposure to injury.

B. The Owner shall not be responsible for any theft or damage to Project material or equipment stored on site or Contractor’s equipment or property.

1.07 ACCESS ROADS

A. General:
1. Build and maintain access roads to and on site of the Work to provide for delivery of material and for access to existing and operating plant facilities on site.
2. Build and maintain dust free roads which are suitable for travel at 20 miles per hour.

B. On-site access roads:
1. Maintain access roads to storage areas and other areas to which frequent access is required.
2. Maintain similar roads to existing facilities on site of the Work to provide access for maintenance and operation.
3. Protect buried vulnerable utilities under temporary roads with steel plates, wood planking, or bridges.
4. Maintain on-site access roads free of mud.

5. Provide controls to prevent vehicles leaving the site from tracking mud off the site onto the public right-of-way.
6. Speed limit for onsite roads is 10 miles per hour.
7. Where Contractor's routing is shown on the Drawings, confine construction traffic to those routes.

1.08 TEMPORARY CONTROLS

A. Dust control:
   1. Prevent dust nuisance caused by operations, unpaved roads, excavation, backfilling, demolition, or other activities.
   2. Control dust by sprinkling with water, use of dust palliatives, modification of operations, or other means acceptable to agencies having jurisdiction.

B. Noise control:
   1. Comply with noise and work hours regulations by local jurisdiction.
   2. In or near inhabited areas, particularly residential, perform operations in manner to minimize noise.
   3. In residential areas, take special measures to suppress noise during night hours.

C. Mud control:
   1. Prevent mud nuisance caused by construction operations, unpaved roads, excavation, backfilling, demolition, or other activities.

1.09 PROJECT SIGN

A. Provide and maintain Project identification sign consisting of painted 8-foot wide by 4-foot high exterior grade plywood and minimum 10-foot long, 4 by 4 lumber posts, set in ground at least 3 feet, with exhibit lettering by professional sign painter using no more than 5 sign colors:
   1. List at least the title of the Project, and names of the Owner, Engineer, Construction Manager, and Contractor.
   2. Identify Contractor's, Engineer's, and Construction Manager's names in upper right-hand corner underneath the bid number.

B. Erect Project identification sign where directed by Engineer within 14 days after the issuance of the Notice to Proceed.

C. Replace or repair the project sign if it is damaged or covered with graffiti within 2 working days of observation or notification of damage or graffiti.

1.10 CONTRACTOR FIELD OFFICES AND SHEDS

A. Maintain on Project Site weather tight space in which to keep copies of Contract Documents, progress schedule, shop drawings, and other relevant documents.

B. Provide field office with adequate space to examine documents and provide lighting and internet service in that space.

C. Secure and pay for all permits associated with Contractor field offices and sheds.

1.11 CONSTRUCTION MANAGER/ENGINEER'S FIELD OFFICES AND SHEDS

A. Construction Manager field office:
   1. Provide separate field office on project site for the exclusive use of the Construction Manager, as follows:
      a. Size: Approximately 12 feet by 50 feet with 8-foot minimum ceiling height.
      b. Construction: Weather tight building constructed at the site, pre-manufactured building, or trailer.
      c. Layout approved by Construction Manager.
         1) Private offices: 2, each approximately 7-feet wide with interior doors.
         2) Conference area: 1.
         3) Washroom: 1.
            a) Room partitioned off from the working area.
            b) Single water discharge to nearest approved sanitary facility.
            c) Flush toilet.
            d) Vented exhaust fan.
            e) Sink with hot and cold water.
            f) Mirror.
            g) Water heater: 10-gallon minimum capacity.
            h) Toilet tissue holder.
            i) Paper towel holder.
         4) Closet with shelving: 1.
      d. Exterior materials:
         1) Weather-resistant and finished in one color acceptable to Construction Manager.
         2) Skirting for under pinning of field office.
      e. Provide wood stairs with handrails for each entry.
         1) Porch landing 5 feet by 5 feet for each entry.
      f. Interior materials in offices:
         1) Sheet-type materials for walls and ceilings, prefinished or painted; resilient floors and bases.
         2) Insulate interior walls for noise attenuation.
      g. Openings:
         1) At least 8 lockable windows (with operable sash, insect screens, and blinds).
         2) Entrance doors: Provide 2, each with cylinder lock and 4 keys.
      h. Exterior lighting over entrance doors.
      i. Fire extinguishers:
         1) Appropriate type fire extinguisher(s) for field office.
      j. Twenty 110 volts AC duplex receptacles with at least 4 in each office, 1 on each wall.
   2. Arrange and pay for:
      a. Daily janitorial service, including dusting, floor cleaning (sweeping, vacuuming or mopping), and trash removal, and monthly comprehensive cleaning, including windows.
      b. Heating, ventilating, and air conditioning equipment in operating condition, capable of maintaining all spaces by cooling to 68 degrees Fahrenheit and heating to 72 degrees Fahrenheit.
         1) Furnish maintenance and consumables.
      c. Electric wiring, power, and lighting fixtures capable of providing at least 75-foot candles of light on work surfaces.

d. A continuous supply of toilet paper, paper hand towels, and hand soap for each washroom.
e. Private telephone line(s).
f. Bottled drinking water service with hot and cold dispenser including water cups.
g. Provide and maintain First Aid Kit and Cabinet in accordance with ANSI Z 308.1, and OSHA requirements.
h. Provide boot scraper and brush at each entrance.
i. Maintain approach walks, decking, porches, and parking lot free of mud, water, and snow.
j. Secure and pay for all permits associated with Construction Manager's field office.

3. Provide following furnishings and equipment:
   a. For each private office:
      1) Office desk: One 30- by 72-inch surface with 6 drawers (at least 2 lockable).
      2) One ergonomic, swivel arm, multifunction office chair.
      3) Two padded metal stackable chairs.
      4) One 4-drawer, 18- by 30- by 52-inch metal filing cabinet with lockable drawers.
      5) One bookcase with not less than 12 linear feet of shelves.
   b. Additional furnishings for each field office:
      1) One conference table (not less than 48 by 144 inches).
         a) Conference table may be multiple metal folding tables with heat-resistant, stain- resistant, and damage-resistant tops.
      2) Padded metal stackable chairs: 10.
      3) Padded folding chairs: 10.
      4) Drafting table: 1 (not less than 36 by 72 inches).
      5) Metal drafting stools with backs: 2.
      6) One magnetic dry erase board (not less than 96 by 48 inches).
      7) Plan-hold, rolling stand for 12 binders, with binders: 2.
      8) Waste baskets: 8.
      9) Refrigerator: 15 cubic feet capacity with ice maker.
      10) 1,200-watt microwave oven, at least 1 cubic foot.
      11) K-cup coffee maker with direct water hookup and coffee cups.
      12) Provide kitchen sink with hot and cold running water.
      13) Provide and mount in field office, a high-quality, wall-mounted OLED smart TV monitor with a minimum of 2 USB and at least 2 HDMI inputs. Size: minimum 75-inch.
4. Locate field office where directed.
5. Have field office ready for occupancy within 2 weeks after start of the Work.
6. Parking: 5 hard surfaced parking spaces for use by Engineer or Construction Manager connected to office by a hard surfaced walkway.

1.12 FIELD OFFICE DATA SERVICE AND EQUIPMENT

A. Provide the following data services for the duration of the project.

B. Contractor is responsible for maintenance of service and hardware.

C. Data service will be dedicated to the Construction Manager and not shared with any other party.

D. Contractor provide a durable and weather tight system for connecting the Construction Manager trailer to the service provider's facilities at the jobsite boundary.

E. Data service:
   1. Broadband Internet.
      a. Minimum Internet bandwidth speed:
         1) Download: 500 Million bits per second (Mbps).
         2) Upload: 100 Million bits per second (Mbps).
      b. Modem, if applicable: Disable the wireless radio.

F. Printer/Scanner:
   1. Manufacturers: The following or equal:
      a. Canon Color Digital Multifunction printer (ImageRUNNER Advance C3330i).
   2. Functions:
      a. Print, scan, and sort 11 inch by 17 inch and smaller paper size.
      b. Send and receive Fax.
   3. Maintenance contract: Onsite maintenance for duration of project.
   4. Supplies: Paper (8 1/2 inch by 11 inch, 8 1/2 inch by 14 inch, and 11 inch by 17 inch) trays, toner, and other supplies for duration of project.

1.13 REMOVAL

A. Remove temporary facilities and controls before inspection for final Completion or when directed.

B. Clean and repair damage caused by installation or use of temporary facilities.

C. Remove underground installations to minimum depth of 24 inches and grade to match surrounding conditions.

D. Restore existing facilities used during construction to specified or original condition.

1.14 TEMPORARY PROCESS PIPING SYSTEMS

A. Provide piping, appurtenances, and other materials as required to provide temporary piping systems as specified in this Section, as indicated on the Drawings, and as needed to perform the Work.

B. Provide field route piping as needed and as field conditions dictate, unless otherwise indicated on the Drawings, and determine appropriate lengths of piping and quantity/type of pipe fittings needed to construct temporary piping system. Do not block access points such as stairs, doors, and walkways to existing facilities unless approved in writing by the Owner.

C. Restrain piping at valves and at fittings where piping changes direction, changes sizes, and at ends:
   1. When piping is buried, use concrete thrust block or mechanical restraints.
   2. When piping is exposed or under water, use mechanical or structural restraints.
   3. Determine thrust forces by multiplying the nominal cross sectional area of the piping by the operating pressure of the piping.

D. Install temporary piping systems in a manner that will not damage existing or new facilities.

E. Piping material, including gaskets: Suitable for the process fluid requiring temporary piping, unless indicated otherwise.

F. Temporary piping includes, but is not limited to, the following piping services:
   1. WAS piping from WAS pump stations to temporary RDT feed pumps and RDT Facility.

G. After temporary piping system is no longer required:
   1. Remove temporary piping system.
   2. Clean and repair damage caused by installation or use of temporary piping system.
   3. Restore existing facilities to original condition.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01600

PRODUCT REQUIREMENTS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Requirements for products.

1.02 TERMINOLOGY

A. The words and terms listed below, are not defined terms that require initial capital letters, but, when this Section is referenced in other Specifications, have the indicated meaning.
   1. Manufacturer's instructions:
      a. Stipulations, directions, and/or recommendations issued by the manufacturer of the product addressing handling, storage, installation, protection, erection, and/or application of the product.
   2. Product data:
      a. Information about the product, typically found in the manufacturer's catalogs specifications or other resources, including data sheets, bulletins, and brochures.

1.03 SHIPMENT

A. Transport products by methods that avoid product damage.

B. Deliver products in undamaged condition in the manufacturer's unopened packaging.

1.04 DELIVERY AND HANDLING

A. Handle products in accordance with the manufacturer's instructions.

B. Deliver products in undamaged condition in the manufacturer's unopened packaging.

C. Provide construction equipment and personnel to handle products by methods in accordance with the manufacturer's instructions.

D. Upon delivery, promptly inspect shipments:
   1. Verify compliance with the Contract Documents, correct quantities, and undamaged condition of products.
   2. Acceptance of shipment does not constitute final acceptance of products.

1.05 STORAGE

A. Immediately store and protect products until installed in the Work.

B. Store products with seals and legible labels intact.

C. Protect painted or coated surfaces against impact, abrasion, discoloration, and damage.

D. Storage of spare parts, maintenance products, special tools.
   1. Immediately store in accordance with the manufacturer's instructions.
   2. Store spare parts, maintenance products, and special tools in an enclosed, weather-proof, and lighted facility during the construction period.
   3. Protect parts subject to deterioration, such as ferrous metal items and electrical components with appropriate lubricants, desiccants, or hermetic sealing.
   4. Store large items individually:
      a. Weight: Greater than 50 pounds.
      b. Size: Greater than 24 inches wide by 18 inches high by 36 inches long.
      c. Clearly labeled:
         1) Equipment tag number.
         2) Equipment manufacturer.
         3) Subassembly component, if appropriate.
   5. Store smaller items in spare parts boxes:
      a. Weight: Less than 50 pounds.
      b. Size: Less than 24 inches wide by 18 inches high by 36 inches long.
      c. Clearly labeled:
         1) Equipment tag number.
         2) Equipment manufacturer.
         3) Subassembly component, if appropriate.
   6. Spare parts and special tools box:
      a. Box material: Waterproof, corrosion resistant.
      b. Hinged cover with locking hasp:
         1) Inventory list taped to underside of cover.
         2) Clearly labeled:
            a) "Spare Parts and/or Special Tools".
            b) Equipment tag number.
            c) Equipment manufacturer.
            d) Subassembly component, if appropriate.

E. Exterior storage of fabricated products:
   1. Place on aboveground supports that allow for drainage.
   2. Cover products subject to deterioration with impervious sheet covering.
   3. Provide ventilation to prevent condensation under covering.

F. Store moisture sensitive products in watertight enclosures.

G. Store loose granular materials on solid surfaces in well-drained area.
   1. Prevent materials mixing with foreign matter.
   2. Provide access for inspection.

H. When needed and approved by the Engineer, offsite storage location shall be within 20 miles of the Project Site.
   1. Provide proof of insurance coverage for products stored offsite.

I. Payment will not be made for products improperly stored or stored without providing the Engineer with the manufacturer's instructions for storage.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Provide products by the same manufacturer when units are of similar nature, unless otherwise specified.

B. Provide like parts of duplicate units that are interchangeable.

C. Provide equipment or products that have not been in service prior to delivery, except as required by tests.

D. For products or workmanship specified by association, trade, or other consensus standards, comply with requirements of the standard, except when more rigid requirements are specified or are required by applicable codes.
   1. Conform to reference standard by date of issue current on date of Contract Documents, except where specific date is established by code.

E. Provide products produced by manufacturers regularly engaged in the production of these products.

F. Provide products that bear approvals and labels as specified such as Factory Mutual (FM), Underwriters Laboratory (UL), or National Sanitation Foundation (NSF International) that are acceptable to the Authority Having Jurisdiction.

2.02 MATERIAL

A. Dissimilar metals:
   1. Separate contacting surfaces with dielectric material.
   2. Neoprene, bituminous impregnated felt, heavy bituminous coatings, nonmetallic separators, washers, petrolatum tape, or other materials as specified.
   3. Dielectric coatings can be used to separate dissimilar metal couples from surrounding environment if isolation of metals is not possible, with approval of the Engineer.

B. Edge grinding:
   1. Sharp projections of cut or sheared edges of ferrous metals which are not to be welded shall be ground to a radius required to ensure satisfactory paint adherence and mitigate any safety hazard.
   2. A surface profile will need to be re-established for coating adherence based on coating manufacturer’s profile requirements.

C. Use anti-galling compound on threads of stainless steel fasteners during factory assembly.

D. Provide anti-galling compound with stainless steel fasteners shipped for field assembly.

E. Aluminum in contact with concrete or masonry: Apply epoxy mastic as specified in Section 09960 - High-Performance Coatings, coating system EPX-M-5.

2.03 PRODUCT SELECTION

A. When products are specified without named manufacturers, provide products that meet or exceed the Specifications.

B. When products are specified with names of manufacturers but no model numbers or catalog designations, provide products by one of the named manufacturers that meet or exceed specifications.

C. When products are specified with names of manufacturers and model numbers or catalog designations, provide products with model numbers or catalog designations by one of the named manufacturers.

D. When products are specified with names of manufacturers, but with brand or trade names, model numbers, or catalog designations by one manufacturer only, provide:
   1. Products specified by brand or trade name, model number, or catalog designation.
   2. Products by another named manufacturer proven, in accordance with requirements for an “or equal”, including the Engineer’s approval, to meet or exceed quality, appearance and performance of specified brand or trade name, model number, or catalog designation.

E. When products are specified with only one manufacturer followed by “or equal,” provide:
   1. Products meeting or exceeding specifications by specified manufacturer.
   2. Engineer deemed “or equal” evidenced by an approved Shop Drawing or other written communication.

F. When products are specified by naming 2 or more manufacturers with 1 manufacturer as a “Basis of Design”:
   1. Any of the named manufacturers can be submitted.
   2. If the product submitted is not by the named “Basis of Design” product and requires a change in the scope (dimensions, configuration, physical properties, etc.), schedule (longer lead time), or budget, the Contractor must submit a substitution request.

PART 3 EXECUTION

3.01 INSTALLATION

A. Inspect equipment or products prior to installation.

B. Repaint or recoat damaged painted or coated surfaces after installation.

C. Use anti-galling compound on stainless steel threads used for field assembly.

3.02 PROTECTION AFTER INSTALLATION

A. Provide coverings as necessary to protect installed products from damage due to traffic and subsequent construction operations.
   1. Remove covering when no longer needed.
   2. Replace corroded, damaged, or deteriorated products before acceptance of the Project.

END OF SECTION

SECTION 01620

PROTECTION OF MATERIALS AND EQUIPMENT

PART 1 - GENERAL

1.01 GENERAL

A. Materials and equipment including spare parts shall be shipped, handled, stored, and installed by methods which will prevent damage to the items. Damaged items will not be permitted as part of the work except in cases of minor damage that have been satisfactorily repaired and are acceptable to the Construction Manager. Acceptance of spare parts shall be at such times as determined by the Construction Manager.

1.02 MATERIALS

A. Handle products in accordance with the manufacturer's written recommendations, and in a manner to prevent damage.

B. Store products prior to installation as recommended by the manufacturer:

- Store products such as pipe off the ground in approved storage yards.
- Store items subject to damage by the elements, vandalism, or theft in secure buildings.

C. Provide manufacturer's recommended maintenance during storage, installation, and until products are accepted for use by Owner’s Representative.

D. Store products to provide access for inspection and inventory control. Contractor shall document products in storage to facilitate inspection and to estimate progress payments for products delivered but not installed in the work.

END OF SECTION

SECTION 01660

EQUIPMENT AND SYSTEM PERFORMANCE AND OPERATIONAL TESTING

1.0 GENERAL

The requirements for the Contractor's performance in documenting testing work required under this Contract are provided for in this Section. The requirements for the Contractor's performance during installed performance testing of all mechanical, electrical, instrumentation, and HVAC equipment and systems, including structures for watertight construction, required under this Contract are provided for in this Section. The requirements of this Section apply to all equipment required to be installed and tested by the Contractor. This Section supplements but does not supersede specific testing requirements, constraints, and sequence of work found elsewhere in the Project Documents, specifically those in Section 01010 and the equipment's technical specification sections and/or operation and maintenance manuals.

In general, the Contractor shall conduct testing requirements in the following chronological order:

- Conduct witness and/or non-witness factory testing and submit testing reports to the Construction Manager for review and approval prior to shipping. Any witness testing requirements shall be stated in the individual equipment technical specification section(s).
- Provide updated factory drawings (i.e., fabrication, wiring, termination, etc.) of the equipment, if applicable, prior to shipping.
- Conduct initial start-up of equipment in the presence of the Construction Manager and submit start-up reports from the Contractor's Quality Assurance Manager and/or the equipment manufacturer's authorized start-up representative.
- If any devices need to be connected to the SCADA network, the Contractor shall plan and coordinate with City staff, who shall be responsible for conducting an internal Information technology security audit of the new PLC system(s) and/or changes to the existing PLC and/or SCADA system(s) and/or SCADA device(s) prior to "going live." The Contractor shall provide a written notification to the City at least two weeks prior to field testing of the PLC and/or SCADA system(s) and allow for two weeks for the City's Information Technology staff to conduct the security audit.
- After the Contractor completes factory testing, start-up, functional testing of all equipment, the Contractor shall proceed with the overall system Operational testing of the entire facility or system. This may require using clean water prior to using actual process fluid and/or solids.
- The overall system Operational testing shall proceed continuously for the specified period of time without interruption (defined as any activity that is controllable by the Contractor, including equipment, material, and workmanship provided by the Contractor). After successful Operational testing the Contractor may request that the City start the process commissioning testing.

2.0 TESTING

2.1 Contract Requirements

A. The testing on the Project shall encompass at a minimum the following and shall be performed in the following sequence:
   (1) Performance/Factory Testing: As specified in this section and individual equipment technical sections.
   (2) Installation Testing: As specified in this section and individual equipment technical sections.
   (3) Functional equipment Testing: As specified in this section and individual equipment technical sections.
   (4) Operational Testing: As specified in this section and individual equipment technical sections.
   (5) Process Commission Testing: As specified in this section and individual equipment technical sections.

B. Contractor shall coordinate with City for start-up and testing of the instrumentation and controls.

C. The Contractor shall appoint a qualified person as Testing Coordinator to manage, coordinate, and supervise the Contractor's testing program. The Testing Coordinator shall have at least five (5) years of total experience, or experience on at least five separate projects, in managing the testing and start-up of mechanical, electrical, instrumentation, HVAC and piping systems for a wastewater or water treatment plant.

D. Complete testing, training, and start-up, along with full and complete documentation of these activities, within the Contract Times. The Project's training requirements are specified in more detail in Section 01670, **Operations, Maintenance, and Training Requirements** and the individual technical specification sections.

E. Testing, training, and start-up shall be integrated across equipment and systems. The Contractor shall coordinate and integrate the documentation and efforts of manufacturers and subcontractors to achieve unified tests and test plans.

F. Allow realistic duration in the Progress Schedule for testing, training, start-up, and documentation activities.

G. The Contractor shall be responsible for system setup and installation of bypasses, bulkheads, temporary piping or other controls as necessary to allow the testing to be performed. Furnish labor, power, tools, equipment, instruments, and services required for and incidental to completing testing.

H. Provide competent, experienced technical representatives of equipment manufacturers for assembly, installation and testing guidance, and operator training.

I. The Contractor shall allow adequate time in the project schedule and provide adequate labor, equipment, overhead and other costs in the project bid to allow for the Programmer to correct software problems with Programmer-provided software during start-up and testing.

2.2 **Submittals – Start-up Plan**

A. Submit start-up plan for each piece of equipment and each system not less than 70 days prior to planned initial start-up of equipment or system.

B. Include overall testing, training, and start-up activities on the project progress schedule specified in Section 01310, **CONTRACTOR'S CONSTRUCTION SCHEDULE**. Testing, training, and start-up shall be detailed in a sub-network of the overall project progress schedule with the following activities identified:

(1) Manufacturer's services.
(2) Installation certifications.
(3) Operator training.
(4) Submission of Operation and Maintenance Manual.
(5) Electrical testing
(6) Instrumentation testing
(7) Installation Testing
(8) Functional testing.
(9) Operational testing.
(10) Process Commission Testing

C. Provide testing plan with test logs for each item of equipment and each system. Include testing of alarms, control circuits, capacities, speeds, flows, pressures, vibrations, sound levels, and other parameters.

D. Contractor shall prepare functional testing plans and procedures for all project equipment and systems and for all modes of operation. Functional testing procedures shall be in the cause and effect format. The person conducting the operating test shall initiate an action (cause) and, upon the systems or subsystems producing the required result (effect), the specific test requirement will have been satisfied. A sample form illustrating this concept and which shows the level of detail required in the Contractor-developed functional testing form is appended to the end of this Section. Only computer-generated functional testing forms shall be submitted; handwritten forms are unacceptable.

E. Submittal requirements for field calibration, loop acceptance, and end-to-end acceptance testing are specified in Division 17.

F. Submittal requirements for mechanical equipment testing are specified in individual equipment sections and Division 15.

G. Submittal requirements for electrical testing are specified in Division 16.

H. Provide summary of shutdown requirements for existing systems which are necessary to complete start-up of new equipment and systems.

I. Revise and update start-up plan based upon review comments, actual progress, or to accommodate changes in the sequence of activities.

J. Contractor is responsible for regulatory non-compliance and local area complaints for noise, odors, and other nuisance conditions resulting from start-up plan actions and activities.

K. The Functional and Operational Testing Plans required for this section shall list the personnel who will be present to assist with and witness the tests. This list shall include the Testing Coordinator, any Contractor personnel, the Instrumentation and Control Systems Installation Supervisor, subcontractors, manufacturer's representatives, City staff, Construction Manager, Design Consultant, and any other required personnel.

L. Vendor/Manufacturer's Representatives shall, at a minimum provide for a properly trained technician to be on site as follows:
   1. Installation Testing: Minimum of two (2) days prior to electrical energization of equipment to confirm, verify and certify in writing that the equipment has been properly installed and is ready for energizing. Once energized, perform the necessary calibration of the equipment and certify in writing that this has been completed.
   2. Functional Testing: Minimum of one (1) day to evaluate that the equipment is functioning as expected and required. The representative shall be responsible for making any adjustments to the equipment to meet the Contract requirements.
   3. Operational Testing: Minimum of two (2) days at the start of Operational Testing to provide on site troubleshooting assistance. After two (2) days of continuous operation the Construction Manager will provide notification that the services of the technician familiar with the project shall remain available by phone through the remainder of the Operational Test period to provide technical assistance.

The Start-up Team shall jointly develop the start-up plans for the Functional, Operational, and Process Testing specified in this sections at least 90 days before testing is scheduled at each area. The Construction Manager will provide the individual to lead the Start-up Team. The City will provide and designate other members of the Start-up Team from the Design Consultant, Programmer, and Operations Staff. The Contractor's Testing Coordinator and the Instrumentation and Control Systems Installation Supervisor shall each be members of this Start-up.

2.3 **Performance Testing**

A. Test equipment for proper performance at point of manufacture or assembly when specified.

When source quality control testing is specified:

(1) Demonstrate equipment meets specified performance requirements.
(2) Provide certified copies of test results.
(3) Do not ship equipment until certified copies have received written acceptance from Construction Manager. Written acceptance does not constitute final acceptance.
(4) Perform testing as specified in the equipment specification sections.

2.4 **Installation Testing**

A. Mechanical Systems: As specified in the individual equipment specification sections in Division 15:

(1) Remove rust preventatives and oils applied to protect equipment during construction.
(2) Flush lubrication systems and dispose of flushing oils. Recharge lubrication system with lubricant recommended by manufacturer.
(3) Flush fuel system and provide fuel for testing and start-up.
(4) Install and adjust packing, mechanical seals, O-rings, and other seals. Replace defective seals.
(5) Remove temporary supports, bracing, or other foreign objects installed to prevent damage during shipment, storage, and erection.
(6) Check rotating machinery for correct direction of rotation and for freedom of moving parts before connecting driver.
(7) Perform cold alignment and hot alignment to manufacturer's tolerances.
(8) Adjust V-belt tension and variable pitch sheaves.
(9) Inspect hand and motorized valves for proper adjustment. Tighten packing glands to insure no leakage, but permit valve stems to rotate without galling. Verify valve seats are positioned for proper flow direction.
(10) Tighten leaking flanges or replace flange gasket. Inspect screwed joints for leakage.
(11) Install gratings, safety chains, handrails, shaft guards, and sidewalks prior to operational testing.
(12) Implement lockout/tagout procedures.
(13) Demonstrate alignment, speed, flow, pressure, vibration, sound level, adjustments, and calibration over the full operating range of equipment and systems. Perform initial checks in the presence of and with the assistance of the manufacturer's representative.
(14) Other requirements as defined in the equipment Operation and Maintenance Manuals.

Electrical Systems: As specified in Divisions 16 and 17, and the individual equipment specification sections.

(15) Electrical testing shall be performed in two stages. The first stage shall consist of electrical equipment testing prior to energization and operation of electrical equipment. The following shall be submitted to Construction Manager for review prior to equipment startup and energization:
   a. Completed field calibration testing data forms as specified in Division 13.
   b. The following completed electrical equipment testing data forms required by Division 16:
      (i) Low-Voltage Cables.
      (ii) Medium-Voltage Cables.
      (iii) Grounding Systems.
      (iv) Rotating Machinery: AC Motors.

      Unsatisfactory equipment test results shall require that the equipment be repaired and re-tested until acceptable results are obtained at no additional cost to the City.

(16) The second stage of electrical testing shall occur after energization and start-up of equipment and shall consist of performing the complete testing of all other equipment as specified in Division16.

Instrumentation Systems: As specified in Division 17 and the individual equipment specification sections:

(17) Requirements for field calibration, loop acceptance, and end-to-end acceptance testing are specified in Division 17.
(18) Field calibration, loop acceptance, and end-to-end acceptance testing shall not begin until design submittals and Contractor-prepared drawings required by Divisions 16 and 17 have been reviewed by the Design Consultant and returned marked as "No Exceptions Noted".
(19) General:
   a. Bench or field calibrate instruments and make required adjustments and control point settings and document these changes as required in Divisions 16, and 17.
   b. Energize transmitting and control signal systems, verify proper operation, ranges, and settings; update documentation if changes were made.

2.5 **Functional Testing (8-Hour Test)**

A. Functional testing and initial equipment operation test shall not begin until after the Installation Testing including the Electrical Testing specified in this section have been completed for individual systems or pieces of equipment.

B. The functional stage of testing shall involve the completion of functional testing forms which include all possible operating scenarios, alarm conditions, prohibitive interlocks, and indication functions. Contractor shall perform a "dry run" for all functional tests to ensure that systems are working properly prior to witnessing by the Construction Manager. After the "dry run" is successfully completed, Contractor shall provide minimum 48 hours notice to the Construction Manager that systems are ready for witnessed functional testing. The Construction Manager will witness functional testing and will initial all functional testing forms upon successful operation of systems.

C. Functional testing of all process equipment shall take place with plant 3W. The Contractor is responsible for the installation and removal of any additional piping, valves, pumps, etc to deliver the test water to the process area and to discharge the water to intended location. Where due to process reasons equipment cannot be operated without sewage the Functional Testing shall be performed to the extent possible.

D. The Contractor is responsible for all costs of the functional testing, including the supply of materials and chemicals necessary for the performance of the tests.

E. The Contractor is responsible for functional testing for all project equipment and systems in all modes of operation, including remote SCADA modes of operation. Verifying the required functional testing results for the SCADA modes of operation will be a joint effort between the Contractor and the City/Programmer as specified in Division 17 where the City provides the software programming and configuration.

F. Demonstrate proper operation of each instrument loop function including alarms, local and remote controls, instrumentation and other equipment functions. Generate signals with test equipment to simulate operating conditions in each control mode as required in Division 17.

G. Conduct continuous 8 hour test under normal operating conditions. If any equipment or system does not meet all of the parameters defined in the Functional Test Plan, the Contractor shall correct the problem and shall repeat the test until it is successful. Software problems with Programmer-provided software shall be corrected by the Programmer. The City reserves the right to waive portions of functional test which fail due to problems with Programmer-provided software.

H. Functional test of mechanical and electrical equipment required for operation of a process area shall be completed prior to performing the operational test for the process area.

I. Certificate of Proper Installation:

1. At completion of Functional Testing and prior to Operational Testing, furnish written report prepared and signed by manufacturer's authorized representative, certifying equipment:
    c. Has been properly installed, adjusted, aligned, and lubricated.
    d. Is free of any stresses imposed by connecting piping or anchor bolts.
    e. Is suitable for satisfactory full-time operation under full load conditions.
    f. Operates within the allowable limits for vibration.
    g. Controls, protective devices, instrumentation, and control panels furnished as part of the equipment package are properly installed, calibrated, and functioning.
    h. Control logic for start-up, shutdown, sequencing, interlocks, and emergency shutdown have been tested and are properly functioning.

2. Furnish written report prepared and signed by the electrical and/or instrumentation subcontractor certifying:
    a. Control logic that resides in motor control centers, control panels, and circuit boards furnished by the electrical and/or instrumentation subcontractor has been calibrated and tested and is properly operating.
    b. Control logic for equipment start-up, shutdown, sequencing, interlocks and emergency shutdown has been tested and is properly operating.

3. Co-sign the reports along with the manufacturer's representative and subcontractors.

2.6 **Operational Testing (7-Day Test)**

A. The Operational Test shall demonstrate satisfactory operation of equipment and systems in actual operation. Refer to Section 01010 for additional operational acceptance testing requirements.

B. Conduct operational acceptance test for 5 sequential workdays for eight hours per day under the supervision and control of the Contractor. The test shall simulate actual operating conditions to the greatest extent possible.

C. The Contractor is responsible for all costs of the functional testing, including the supply of materials and chemicals necessary for the performance of the tests.

D. Operational testing of all process equipment shall take place with process wastewater or sludge

E. Immediately correct defects in material, workmanship, or equipment which become evident during operational test.

F. Repeat operational test when malfunctions or deficiencies cause shutdown or partial operation of the facility or results in performance that is less than specified in the Contract Documents.

G. Failure of any major process unit during the five (5)-day test will result in the abandonment of the test and the test procedures shall be restarted from the beginning.

2.7 **Process/Commission Testing (30-Day Minimum)**

A. Cleanup: Following completion of an area Operational Test, the Contractor shall remove, clean and replace all permanent and temporary filters and strainers in all pipeline systems; replace all HVAC filters, dewater and clean sumps; and dewater, where directed by the Construction Manager, all process units for final inspection as a condition precedent to proceeding with Process Testing.

B. Commissioning Team: The Contractor shall assemble under the direction of the Testing Coordinator a commissioning team. The commissioning team shall consist of representatives of the Contractor's mechanical, electrical, and instrumentation subcontractors, and others as appropriate. The commissioning team shall be available at the site of the work during normal working hours (8 hours a day, 5 days a week, Saturdays, Sunday and legal holidays excepted) and shall be available within 2 hours notice at all other times upon notice by telephone. The commissioning team shall at all times be equipped and ready to provide for emergency repairs, adjustments, and corrections to the equipment and systems installed and modified as a part of this Contract.

C. Process testing of equipment and systems shall take place following Functional and Operational Testing at each process area and after the City's staff has acknowledged in writing that they have received the necessary training for the applicable equipment and systems. The Contractor shall remove all temporary piping, bulkheads, controls and other alterations to the permanent systems that may have been needed during the Functional and Operational Testing and shall perform the tasks necessary to make the improvements constructed under this Contract fully operational. Process Testing will be performed utilizing the intended process flows.

D. The City will provide operations personnel, power, fuel, chemicals and other consumables for the Process Testing.

E. All processes and systems shall be Process Tested during the performance of the Process Test for one of the areas defined below. Substantial Completion of an area will not be issued until after successful completion of the associated Process Test.
   1. Sludge Blend Tanks.
   2. RDT Facility and Thickening Odor Control.
   3. Dewatering Facility.
   4. MCC-E Replacement.

F. Process testing shall be coordinated with City occupancy requirements as defined in Section 01010, **SUMMARY OF WORK**.

G. Contractor shall document modifications to process equipment made during Process and start-up testing.

2.8 **Record Keeping**

H. Maintain and submit following records generated during start-up and testing phase of Project:

(1) Daily logs of equipment testing identifying all tests conducted and outcome.

(2) Logs of time spent by manufacturer's representatives performing services on the job site.

(3) Equipment lubrication records.

(4) Electrical phase, voltage, and amperage measurements.

(5) Insulate resistance measurements.

(6) Data sheets of control loop testing including testing and calibration of instrumentation devices and set points.

END OF SECTION

SECTION 01670

OPERATIONS, MAINTEANCE, AND TRAINING REQUIREMENTS

1.0 OPERATION AND MAINTENANCE

After all equipment shop drawings and submittals are favorably reviewed, but prior to the delivery, installation, and operation by City staff of any item of machinery or equipment the Contractor shall submit a preliminary Operation and Maintenance Manual and Equipment Summary Form(s). The manual will be reviewed by the Construction Manager for general content, and the Construction Manager will advise the Contractor within five days of receipt if the manual is acceptable in general content for the delivery and installation of the equipment or machinery. The preliminary manuals must at a minimum include the completed equipment summary form(s) for each piece of equipment, the detailed manufacturer's requirements for storage and installation of the equipment, and a recommended preventative maintenance schedule. Delivery and installation of any item of machinery or equipment will not be permitted until the preliminary Operation and Maintenance Manual and Equipment Summary Form(s) have been approved.

After all startup and operational testing of any item of machinery or equipment has been successfully completed, the Contractor shall submit a final Operation and Maintenance Manual. The Contractor shall submit the final Operation and Maintenance Manuals for all equipment provided in the Project before the City takes beneficial occupancy of said equipment. The City will not grant Project Substantial Completion until the final Manuals are submitted.

Final Operation and Maintenance Manuals shall be bound in 3.5" wide 3 ring binders with rigid covers marked to indicate: job name, job number, volume number, contractor name, design engineer, and date of completion both on the front cover and on the binding. As the binders are filled a new volume (binder) should be started until all of the completed and approved O&M manuals have been packaged into binders making a complete set. Four (4) identical complete sets shall be submitted for approval. Retention will not be released until all three sets have been submitted and favorably reviewed by the City. Each volume of each set of Operation and Maintenance Manuals shall include:

1. Laminated Table of Contents which includes volume number, a description of the tabbed section, specification section, and a general description of the information provided within each tabbed section.
2. A typed completed Equipment Summary Form in the format attached below. Insert the completed and favorably reviewed Equipment Summary Form immediately after tab sheet of each equipment section. The manufacturer's standard form will not be accepted. Manuals submitted without Equipment Summary Forms including equipment identification numbers will be rejected and returned. Any reference to the O&M manual in lieu of information required on the form will be rejected and returned. If a piece of equipment is packaged equipment each component of the packaged equipment needs its own Equipment Summary Form (e.g. Pump/motor, blower/motor, or fan/motor).
3. The manufacturer warrantee certificate.
4. Lubrication Information: Required lubricants and lubrication schedules.
5. Control Diagrams: Internal and connection wiring, including logic diagrams, wiring diagrams for control panels, ladder logic for computer based systems, and connections between existing systems and new additions, and adjustments such as calibrations and set points for relays, and control or alarm contact settings.

6. Start-up Procedures: Recommendations for installation, adjustment, calibration, and troubleshooting.
7. Operating Procedures:
   a. Step-by-step procedures for starting, operating, and stopping equipment under specified modes of operation.
   b. Include safety precautions and emergency operating shutdown instructions.
8. Preventative Maintenance Procedures: Recommended steps and schedules for maintaining equipment.
9. Overhaul Instructions: Directions for disassembly, inspection, repair and reassemble of the equipment; safety precautions; and recommended tolerances, critical bolt torque's, and special tools that are required.
10. Parts List: Generic title and identification number of each component part of equipment; include bearing manufacturer, model and ball or roller pass frequencies for every bearing.
11. Spare Parts List: Recommended number of parts to be stored at the site and special storage precautions.
12. Drawings: Exploded view or plan and section views with detailed callouts.
13. Provide electrical and instrumentation schematic record drawings. Contractor shall also provide a CD with any and all CAD files created for electrical or instrumentation schematic drawings for the project.
14. Source (Factory) Quality Control Test Results: Provide copies of factory test reports as specified in the Technical Specifications.

15. Field Quality Control Test Results: After field testing is completed, insert field test reports as specified in the Technical Specifications.

All final Operation and Maintenance manuals and materials shall be provided in electronic data format on CD or DVD disks (AutoCAD 2012 or higher drawing files; Microsoft Word 2010 or higher text files; and scanned filed for manual text and manual drawings). Scanned (raiser-based) drawings shall be provided as PDF files, and shall have a minimum 400 bpi resolution, black and white or color as necessary. An electronic (html format) index of all electronic files shall also be submitted. Where available, the electronic files shall be in their native PDF form (e.g., equipment catalog cutsheets, drawings converted to PDF within their native programs) with the objective of providing clean and legible copies.

2.0 TRAINING OF CITY STAFF

2.1 General

a. Operation and maintenance training of City's personnel shall be provided for equipment listed in the approved Operation and Maintenance Manuals submitted by the Contractor. Training content is to be tailored to the needs of each group. These training services shall be conducted at the City's wastewater treatment facility by the manufacturer's representative and shall ensure that City's personnel are trained to perform equipment task requirements, including essential knowledge and skills. The City may conduct objective evaluations of its employees receiving this training to verify compliance with this requirement.

b. Training shall be conducted by competent representatives who are certified by the manufacturer to be thoroughly familiar with the subject matter as well as instructional methods.

c. Training materials shall be submitted to the City for review. Training materials shall include a list of task statements which the City's employees may perform with the equipment, the learning objectives (derived from the task list and by which the training will be evaluated) and the training plan (or lesson plan) top demonstrates how the learning objectives will be achieved. Acceptance of training materials

is required prior to start of training. The Contractor shall provide an adequate number of printed trainee materials for all persons being trained.

d. The Contractor shall submit, within 60 days of Notice to Proceed, a list of all equipment items or systems for which training will be provided in accordance with the specifications. The list shall include item number, specification section, description and required training in hours.

e. The City shall have the right to videotape all training sessions, or may designate separate sessions or portions thereof for the sole purpose of videotaping.

2.2 Training Coordinator

a. The Contractor shall designate and provide one or more persons to be responsible for coordinating and expediting his training duties. The person or persons so designated shall be present at all training coordination meetings with the City.

2.3 Training Schedule

a. The Contractor's coordinate shall coordinate the training periods with the Construction Manager and shall submit a training schedule and the training material for each piece of equipment or system for which training is to be provided. Said training schedule and materials shall be submitted not less than 60 calendar days prior to the time that the associated training is to be provided, and the training materials shall be approved at least 20 days before the associated training is provided.

b. Equipment and/or systems shall be deemed suitable for use in training upon satisfactory completion of functional testing. Training for equipment in a process system must be completed prior to commencement of the Process/Commissioning Test for that area.

c. Training sessions for each piece of equipment shall be 4 hours total except as otherwise noted. Training sessions shall be scheduled on Tuesdays through Thursdays. Training sessions shall be provided during the day between the hours of 8:00 am and 4:00 pm.

d. The Contractor shall schedule separate training sessions for both operations and maintenance personnel and meet the following criteria:

1. Maintenance training shall be provided for each piece of equipment listed in the approved Operation and Maintenance manual submitted by the Contractor. Training shall emphasize theory of operations, troubleshooting, preventive maintenance and repair procedures. The training shall encourage issues relating to instrumentation, electrical, and mechanical systems.

2. Operations training shall be provided for each piece of equipment listed in the approved Operation and Maintenance manual submitted by the Contractor. Training shall emphasize theory of operations, startup and shutdown instructions, normal operation, abnormal and emergency operations (where applicable), lockout procedures, troubleshooting, preventive maintenance and alarm and control logic.

e. The Contractor shall confirm each training period a minimum of three (3) working days prior to the

scheduled time.

f. The Contractor shall have the following listed equipment suppliers conduct follow-up training and "troubleshooting" consultation sessions(s) after the equipment has been installed and continually operated by the City for at least three (3) months but prior to expiration of the one year warranty period. The City shall contact the equipment supplier directly to coordinate the scheduling for this training. The suppliers shall include a minimum of eight (8) hours for this training.

Contractor shall record in color using DVD format, every session of the instruction program for each respective equipment item or system. Recording shall be performed by a person experienced in the operation of video recording equipment. Care shall be taken to properly place the camera, and provide adequate lighting and sound systems to ensure good video and audio quality. The final submitted DVD shall be subject to City approval and acceptance.

2.4 Recording of Training Sessions

For video recording of "hands-on" training at the equipment, ambient noise shall be considered too loud to obtain satisfactory sound quality. For "hands-on" training sessions at the equipment, the recording shall be done without sound and the instructor shall dub a detailed narrative onto the recording by a means that will provide sound quality satisfactory to the City. Contractor shall propose a dubbing methodology to the City for approval prior to the first "hands-on" training session. Contractor is not required to video record factory certification training that occurs at the manufacturer's facilities, but shall record any such training that occurs at City facilities.

Label each DVD identifying the session and respective equipment item or system. Multiple sessions of the same instruction program may be contained on the same DVD, but only one equipment item or system shall be recorded on the same DVD. The original and one copy of each DVD shall be submitted to the City within seven days following completion of each respective instruction program and any post-session dubbing. Responsibility for coordinating and providing all equipment, including video recorder and microphones, necessary to satisfactorily record each session, including all associated costs, shall be borne by the Contractor at no additional cost to the City.

Equipment Summary Form – _____

1. **Equipment Description***: _____
2. **Cost*:** _____
3. **Manufacturer*:** _____

   Address: _____

   Phone #: _____ Fax: _____

   Email: _____ Website: _____
4. Equipment Identification Numbers:

   Serial Number*: _____

   Model*: _____

   Part #: _____

   Tag/Drawing #(s): _____

   Hansen Equip ID No. _____
5. Location of Equipment: _____
6. Weight (Over 100 Pounds): _____
7. Nameplate Data:

   Horsepower: _____ Other: _____

   Size: _____

   Capacity(cfm): _____

   RPM: _____
8. Manufacturer's Local Representative:

   Name: _____

   Address: _____

   Telephone Number: _____

   Email: _____ Website: _____
9. Maintenance Requirements (including schedules):

TASK	SCHEDULE

10. Lubricant List (mfg recommended):

11. Spare Parts (mfr suggested spare part):

Description	Part #	Description	Part #

12. Comments:

13. General Info:

Accepted Date*:

Expected Life*:

Project Name & Number:

Design Engineer:

14. Warranty:

Start Date:

Expiration Date:

Prorated:

SECTION 01700

CONTRACT CLOSEOUT

PART 1 – GENERAL

1.01 CLEANING OF SITE

A. The Contractor shall not allow the site of the work to become littered with trash and waste material but shall maintain the site in its normal neat and orderly condition throughout the construction period.

B. On or before the completion of the work, the Contractor shall remove rubbish of all kinds from the jobsite and any of the grounds which he has occupied and leave them in first-class condition to the satisfaction of the Construction Manager. Pavement shall be swept daily and/or flushed to remove any spilled soil or aggregate base material after placement of both temporary and final pavement. Pipes, drainage inlets, streets and sewers used by the Contractor or contaminated by his operations shall be cleaned thoroughly to the satisfaction of the Construction Manager.

C. Acceptance by the City of Manteca must be obtained for completed work.

PART 2 – RECORD DRAWINGS

2.01 GENERAL

A. The Contractor shall maintain one set of record drawings at the site at all times as a true, complete and accurate record of the work. The drawings shall consist of one set of the contract drawings marked up to reflect all changes that have been made during the course of the work and other supplementary information. The record drawings shall be updated weekly and be available for inspection by the Construction Manager at all times.

B. Progress payments may be withheld if the drawings are not kept current.

C. Record drawings shall be stored during the contract period in the Contractor's field office apart from the documents used for construction in suitable files or racks. The record drawings shall be maintained in a clean, dry legible condition and in good order until delivered to the Construction Manager at the completion of the work. Record drawings shall not be used for construction purposes.

END OF SECTION

SECTION 01722

FIELD ENGINEERING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Field engineering to establish lines and grades for the Work.

1.02 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Qualifications of the professional land surveyor or licensed civil engineer with the authority to provide land surveying in California that will be performing the field engineering.

C. Pre-Excavation Report.

1.03 PRE-EXCAVATION REPORT

A. Prior to the start of the Work, create a report confirming the verification of the following data:
   1. Site elevation.
   2. Existing structures, including, but not limited to, buildings, manholes (sanitary, storm, electrical, and other), drainage inlets:
      a. Location coordinates.
      b. Top of wall elevation and coordinates.
      c. Floor elevations.
      d. Invert elevations.
   3. Existing utilities as specified in Section 02280 - Subsurface Utility Engineering.
   4. Proposed building corners, tank, and equipment locations.
   5. Verify existing electrical, instrumentation, and phone utilities.

B. Incorporate information from Pre-Excavation Report into the Record Drawings.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 SURVEY REFERENCE POINTS

A. Basic reference line, a beginning point on basic reference line, points with referenced coordinates, and a benchmark will be provided by the Owner.

B. From these reference points, establish other control and reference points as required to properly lay out the Work.

C. Locate and protect control points prior to starting site work, and preserve permanent reference points during construction:
   1. Make no changes or relocations without prior written notice.
   2. Replace Project control point, when lost or destroyed, in accordance with original survey control.

D. Set monuments for principal control points and protect them from being disturbed and displaced:
   1. Re-establish disturbed monuments.
   2. When disturbed, postpone parts of the Work that are governed by disturbed monuments until such monuments are re-established.

3.02 PROJECT SITE SURVEY REQUIREMENTS

A. Establish minimum of 2 permanent benchmarks on site referenced to data established by survey control points.

B. Record permanent benchmark locations with horizontal and vertical data on Project Record Documents.

C. Perform verifications and checking in accordance with industry standard surveying practice.

D. Maintain complete, accurate log of control points and survey.

E. Affix civil engineer's or professional land surveyor's signature and license number to Record Drawings to certify accuracy of information shown.

3.03 CONSTRUCTION STAKES, LINES, AND GRADES

A. Execute the Work in accordance with the lines and grades indicated.

B. Make distances and measurements on horizontal planes, except elevations and structural dimensions.

3.04 QUALITY CONTROL

A. Accuracy of stakes, alignments, and grades may be checked randomly by the Engineer:
   1. Notice of when checking will be conducted will be given.
   2. When notice of checking is given, postpone parts of the Work affected by stakes, alignments, or grades to be checked until checked.
   3. Engineer's check does not substitute or complement required field quality control procedures.

3.05 RECORD DOCUMENTS

A. Prepare and submit Record Documents as specified in Section 01700 - Contract Closeout.

B. Submit both pre-construction and post-construction Record of Survey to San Joaquin County and obtain their acceptance.

END OF SECTION

SECTION 01738

SELECTIVE ALTERATIONS AND DEMOLITION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Cutting or modifying of existing and new work.
   2. Partial demolition of structures.
   3. In-place abandonment of pipe.

1.02 REFERENCES

A. American National Standards Institute (ANSI):
   1. A10.6 - Safety and Health Program Requirements for Demolition Operations.

B. International Concrete Repair Institute (ICRI):
   1. Guideline No. 310.2R - Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair.
   2. Guideline No. 310.3R - Guide for the Preparation of Concrete Surfaces for Repair Using Hydrodemolition Methods.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Chipping hammer: A hand-operated electrical or pneumatic demolition device for removal of hardened concrete or masonry materials having a weight of less than 15 pounds and an impact frequency of greater than 2,000 blows/minute.
   2. Concrete breaker: A hand-operated electrical or pneumatic demolition device for removal of hardened concrete or masonry materials having a weight greater or impact frequency less than the limits defined for a chipping hammer.
   3. Coring equipment: Non-impact rotary drill with diamond cutting edges.
   4. Heavy abrasive blast: Cleaning procedure by which various abrasives materials, or steel shot, are forcibly propelled by high pressure against a surface to remove loose material and produce a concrete surface roughened to ICRI Surface Profile CSP-7, or higher, as specified in ICRI 301.3R.
   5. Salvage material: Materials removed from existing facilities and stored for the Owner’s future reuse.

1.04 DESCRIPTION OF WORK

A. The Work includes partial demolition, cutting, and modifying of existing facilities, utilities, and/or structures.

B. These facilities may be occupied and/or operational. Satisfactory completion of the Work will require:
   1. Planning activities carefully to work around unavoidable obstacles and to maintain overall stability of structures and structural elements.
   2. Restoration of existing facilities, utilities, and structures that are to remain in place and that are damaged by demolition or removal operations.

1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Shop Drawings:
   1. Show the location of all embedded items using diagrams and/or other media that clearly show dimensions and locations of existing structural elements, existing embedded items and any new embedded items and their relationship to each other.
   2. Drawings and/or other media documenting locations of service lines and capped utilities.

C. Pipe abandonment plan:
   1. Prepare a comprehensive pipe abandonment plan for the Work.
      a. Include provisions to demonstrate and verify with camera inspection that all solids have been removed and that the pipe is free of residuals.
   2. At a minimum, define the following elements:
      a. Proposed sequence, methods, cleaning procedures, or demolition, removal, and disposal of contents of the piping.
      b. Method of verification of final pipe condition.
      c. Detailed drawings showing treatment of pipe ends.
   3. Submit plan a minimum of 4 weeks before abandonment is scheduled to begin.

D. Selective demolition plan:
   1. Prepare a comprehensive selective demolition plan for the Work, including the following elements, at a minimum:
      a. Proposed sequence, methods, temporary support, and equipment for demolition, removal, and disposal of portions of structure(s).
      b. Provisions and procedures for salvage and delivery to the Owner of salvaged items, if required.
      c. Method(s) of removing embedded relics and antiques.
      d. Detailed drawings showing proposed weatherproof closures and dustproof partitions.
   2. Submit plan a minimum of 4 weeks before demolition is scheduled to begin.

E. Submittals for record only:
   1. Permits and notices authorizing demolition.
   2. Certificates of severance of utility services.
   3. Permit for transport and disposal of debris.
   4. Selective demolition plan.
   5. Pipe abandonment plan.

F. Quality Assurance Submittals:
   1. Qualifications of non-destructive testing agency/agencies.

G. Project Record Documents:
   1. As specified in Section 01700 - Contract Closeout.

1.06 QUALITY ASSURANCE

A. Qualifications:
   1. Assign relocation, removal, cutting, coring, and patching to trades and workers qualified to perform the Work in manner that causes the least damage and that provides means of returning surfaces to an appearance at least equal to that of the surrounding areas unaffected by the Work.
   2. Non-destructive testing agencies:
      a. Minimum of 5 years' experience performing non-destructive testing for location of steel reinforcement in existing concrete under conditions similar to that required for this Work.

1.07 SEQUENCING

A. Perform Work in sequences and within times specified in Section 01140 - Work Restrictions.

B. Owner will cooperate to assist in expediting the Work.

C. Coordinate the Work with operation of the facility:
   1. If the facility or utility to be modified cannot be removed from service, perform the Work while the facility is in operation using procedures and equipment that do not jeopardize operation or materially reduce the efficiency the facility.
   2. Do not begin alterations of designated portions of the Work until specific permission for activities in each area has been granted by the Owner in writing.
   3. Operational functions of the facility that are required to be performed to facilitate the Work will be performed by facility personnel only.
   4. Complete Work as quickly and with as little delay as possible.
      a. When necessary for the proper operation or maintenance of portions of the facility, reschedule operations so the Work will not conflict with required operations or maintenance.

1.08 REGULATORY REQUIREMENTS

A. Dispose of debris in accordance with governing regulatory agencies.

B. Comply with applicable air pollution control regulations.

C. Obtain permits for building demolition, transportation of debris to disposal site, and dust control.

1.09 PROJECT CONDITIONS

A. Do not interfere with use of adjacent structures and elements of the facility not subject to the Work described in this Section. Maintain free and safe passage to and from such facilities.

B. Provide, erect, and maintain barricades, lighting, guardrails, and protective devices as required to protect building occupants, general public, workers, and adjoining property:
   1. Do not close or obstruct roadways without permits.
   2. Conduct operations with minimum interference to public or private roadways.

C. Prevent movement, settlement, or collapse of structures, adjacent services, sidewalks, driveways and trees:
   1. Provide and place bracing or shoring.
   2. Cease operations and notify the Engineer immediately when the safety of structures appears to be endangered.
      a. Take precautions to properly support structure.
      b. Do not resume operations until safety is restored.
   3. Assume liability for movement, settlement, or collapse. Promptly repair damage.

D. Arrange and pay for capping and plugging utility services. Disconnect and stub off.
   1. Notify affected utility company in advance and obtain approval before starting demolition.
   2. Place markers to indicate location of disconnected services.

E. Unknown conditions:
   1. Drawings may not represent all conditions at the Site and adjoining areas. Compare actual conditions with Drawings before commencement of Work.
   2. Existing utilities and drainage systems below grade are located from existing documents and from surface facilities such as manholes, valve boxes, area drains, and other surface fixtures.
   3. If existing active services encountered are not indicated or otherwise made known to the Contractor and interfere with the permanent facilities under construction, notify the Engineer in writing, requesting instructions on their disposition.
      a. Take immediate steps to ensure that the service provided is not interrupted, and do not proceed with the Work until written instructions are received from the Engineer.

PART 2 PRODUCTS

2.01 SALVAGE MATERIALS

A. Materials designated for salvage:
   1. Air compressors.

B. Handling and storage:
   1. Prevent damage to salvaged materials during removal, handling, and transportation.
   2. Prepare salvaged materials for storage:
      a. Build crate for storing each piece of equipment or item.
      b. Tag or mark items including a complete list of components.
   3. Store salvaged materials in the following locations:
      a. Coordinate with City 14 days prior to salvage of materials for appropriate location.

C. Pay costs associated with salvaging materials, including handling, transporting, and storage.

PART 3 EXECUTION

3.01 EXAMINATION

A. Prior to beginning selective demolition operations, perform a thorough inspection of the facility and Site.
   1. Report to the Engineer defects, structural damage, and deterioration of existing construction to remain in place.

B. Examine areas affected by the Work and verify the following conditions prior to commencing demolition:
   1. Disconnection of utilities as required.
   2. Verify that utilities serving occupied or active portions of surrounding facilities will not be disturbed, except as otherwise indicated.

C. If unsatisfactory conditions exist, notify the Engineer, and do not begin demolition operations until such conditions have been corrected.

3.02 PREPARATION

A. Plan and organize Work to minimize inconvenience to adjacent buildings and to plant operations.

B. Non-destructive evaluation of existing concrete and masonry:
   1. Prior to cutting, drilling, coring, and/or any other procedure that penetrates existing concrete or masonry, retain and pay for the services of a qualified non-destructive testing agency to perform investigations to determine the location of existing steel reinforcement, plumbing, conduit, and/or other embedments in the concrete.
   2. Submit documentation of the investigations to the Engineer for review and approval as specified in Section 01300 - Submittals, before any work involving penetration of existing concrete is initiated.

C. Protection:
   1. Erect weatherproof closures to protect the interior of facilities and elements or equipment that are not designed for exposure to the weather.
   2. Provide temporary heat, cooling, and humidity control as necessary to prevent damage to existing and new equipment and construction.
   3. Maintain existing exiting paths and/or provide new paths in accordance with Building Code requirements.
   4. Erect and maintain dustproof partitions as required to prevent spread of dust to other parts of building. Maintain negative pressure in the area where the Work is being performed to prevent the accidental spread of dust and to minimize the spread of fumes related to the Work.
   5. Upon completion of the Work, remove weatherproof closures and dustproof partitions.
   6. Repair damaged surfaces to match adjacent surfaces.

7. Provide and maintain protective devices to prevent injury from falling objects.
8. Locate guardrails in stairwells and around open shafts to protect workers. Post clearly visible warning signs.
9. Protect the following from damage or displacement during the Work.
    a. Benchmarks and survey points.
    b. Existing construction that will remain in place.
    c. Trees and landscaping designated to remain in place.
10. Carefully remove designated materials and equipment to be salvaged by the Owner or reinstalled.
11. Store and protect materials and equipment to be reinstalled.

D. Layout:
1. The limits of selective demolition are indicated on the Drawings. Confine demolition operations within the limits indicated on the Drawings.
2. Lay out demolition and removal work at the Site and coordinate with related work for which demolition and removal is required.
3. Clearly mark the extent of structural elements to be removed on the actual surfaces that will be removed.
4. Arrange for the Engineer's inspection of the layout extents.
5. Do not begin demolition/removal operations until the layout markings have been reviewed by the Engineer.

3.03 DEMOLITION

A. General:
1. Perform demolition work in accordance with ANSI A10.6.
2. Demolish designated portions of structures and appurtenances in orderly and careful manner in accordance with the selective demolition plan.
3. Conduct demolition and removal work in a manner that will minimize dust and flying particles.
    a. Use water or dust palliative when necessary to prevent airborne dust.
    b. Provide and maintain hoses and connections to water main or hydrant.
4. Remove materials carefully, to the extent indicated and as required.
    a. Provide neat and orderly junctions between existing and new materials.
    b. Use methods that terminate surfaces in straight lines at natural points of division.
5. Do not remove anything beyond the limits of the Work indicated without prior written authorization from the Engineer.
    a. If in doubt about whether to remove an item, obtain written authorization from the Engineer prior to proceeding.
6. Perform Work so as to provide the least interference and most protection to existing facilities to remain.
7. Demolished materials:
    a. Assume possession of materials unless otherwise indicated on the Drawings or specified.
    b. Remove demolished materials from the Site at least weekly and dispose of them in accordance with laws and regulations.
    c. Do not burn or bury materials on site.

B. Demolition of concrete and masonry:
   1. Demolish in small sections.
      a. Perform demolition with small tools as much as possible.
      b. Blasting with explosive charges is not permitted.
   2. Saw cut concrete to establish the edges of demolition, wherever possible.
      a. Do not use a concrete breaker within 6 inches of reinforcing or structural metals that are designated to remain in place.
      b. At edges that are not saw cut, remove the final 6 inches of material with a chipping hammer as specified in this Section. At surfaces where material is removed with a chipping hammer, follow with a heavy abrasive blast to remove loose material and microcracking.
      c. Alternate techniques to remove concrete may be used if acceptable to the Engineer, however, techniques other than those deemed by ICRI Guideline No. 310.2R to provide a low risk of introducing microcracking will require a subsequent procedure to remove loose material and microcracked.
      d. Provide final surface preparation for repairs as specified.
   3. At locations indicated on the Drawings where the existing reinforcing is to be preserved, remove concrete using methods that do not damage the reinforcing. Use one of the following techniques:
      a. Hydrodemolition techniques as outlined in ICRI Guideline No. 310.3R.
      b. Chipping hammer, as specified in this Section, followed by heavy abrasive blast to remove loose material and microcracking at remaining surfaces impacted by the chipping hammer.
      c. Alternate methods may be used, only when accepted in advance by the Engineer.
      d. For all methods, provide a small, completed area for the Engineer's review and acceptance. If the proposed method, in the opinion of the Engineer, damages the reinforcing, revise the removal method to remove the concrete with a less aggressive technique to protect the reinforcing.
   4. Removal of concrete bases for equipment:
      a. Saw-cut perimeter of removal in a regular shape, along straight lines, without overcutting corners at intersections.
         1) Cut to a depth below the finished surface equal to the concrete cover over the reinforcement, minus 1/2 inch.
         2) Do not cut existing reinforcement in slab.
      b. Chip concrete within scored lines and to the cut depth within the full area of the saw cut.
      c. Cut reinforcing steel and anchor bolts that will project above the surrounding concrete at the bottom of the chipped excavation.

C. Sizing of openings in existing concrete or masonry:
   1. Make openings large enough to permit final alignment of pipe and fittings without deflections, but without oversizing.
   2. Allow adequate space for packing around pipes and conduit to ensure watertightness.
   3. If the Engineer deems the opening to be insufficient in size to accomplish this criteria, remove additional material using the procedures outlined in this Section.

D. Cutting openings in existing concrete or masonry:
   1. Do not allow saw cuts to extend beyond limits of openings.
   2. Create openings by the following method or other means acceptable to the Engineer that prevents over-cutting of member at corners:
      a. Core-drill through slab or wall at corners, being careful not to damage materials beyond the area to be removed.
      b. Saw cut completely through the member, between the core holes at the corners.
      c. As an alternate to saw cutting through the member, score the edges of the opening with a saw to a 1-inch depth.
         1) Provide score on both surfaces (when accessible).
         2) Remove concrete or masonry to within 6 inches of material to remain with a concrete breaker.
         3) Remove the remaining material with a chipping hammer.
      d. Remove the remaining material at the corners left by the core-drilling with a chipping hammer.
   3. Prevent debris from falling into adjacent tanks or channels in service or from damaging existing equipment and other facilities.

E. In-place abandonment of pipe:
   1. As indicated on the Drawings.
   2. Clean buried or exposed solids service piping to a condition free of residual.
      a. Solids service piping includes: centrate (CEN), digested sludge (DSL), primary sludge (PS), primary scum (PSC), sludge overflow (SOF), thickened waste activated sludge (TWAS), waste active sludge (WAS), or other similar solids service subject to biological degradation, etc.
   3. Provide closure of abandoned pipe cut ends as indicated on the Drawings using one of the following methods:
      a. Leave one end open.
      b. Install cap.
      c. Install plug.
      d. Install drain valves, pressure relief valves, vents, etc.
      e. Fill abandoned pipe as specified in Section 02312 - Controlled Low Strength Material (CLSM).

F. Buried structures:
   1. Pump out buried tanks.
   2. Remove tanks and service piping from the Site.

G. Immediately upon discovery, remove and dispose of contaminated, vermin-infested, or dangerous materials using safe means that will not endanger the health of workers and the public.

H. Backfill open pits and holes caused by demolition as specified in Section 02300 - Earthwork.

I. Rough grade areas affected by demolition.

J. Remove demolished materials, tools, and equipment upon completion of demolition.

3.04 RESTORATION

A. General:
   1. Repair damage caused by demolition to conditions equal to those that existed prior to beginning of demolition.
      a. Patch and replace portions of existing finished surfaces that are damaged, lifted, and discolored.
         1) Refinish patched portion surfaces in a manner which produces uniform color and texture to entire surface, and that matches color and texture of adjacent surfaces.
      b. When existing finish cannot be matched, refinish entire surface to nearest change of plane where the angle of change exceeds 45 degrees.
   2. Cost of repairs shall be at the Contractor's expense at no increase in the Contract Price.
   3. When new construction abuts or finishes flush with existing construction, make smooth transitions. Match finish of existing construction.
   4. Where partitions are removed, patch floors, walls, and ceilings with finish materials that match existing materials.
   5. Where removal of partitions results in adjacent spaces becoming one, rework floors, walls, and ceilings to provide smooth planes without breaks, steps, or bulkheads.
      a. Where change of plane between adjacent surfaces exceeds 2 inches, request and obtain instructions for making transition from the Engineer.
         1) Refinish door surfaces and edges as necessary.
   6. Trim existing doors as necessary to clear new floors.
   7. Match patched construction with adjacent construction in texture and appearance so that patch or transition is invisible at 5-foot distance.
   8. When finished surfaces are cut so that smooth transition is impossible, terminate existing surface in neat manner along straight line at natural line of division and provide appropriate trim.

B. At areas where existing concrete reinforcement is exposed:
   1. Where existing reinforcement is to be incorporated into the new Work:
      a. Protect, clean, and extend existing reinforcement into new concrete as indicated on the Drawings.
   2. Where existing reinforcement is not to be incorporated into the new Work, cut off as follows:
      a. Where new concrete joins existing concrete at the removal line:
         1) Cut reinforcement flush with concrete surface at the removal line.
         2) Bond new concrete as indicated on the Drawings.
      b. Where concrete surface at the removal line will become the finished surface in the new Work:
         1) Cut reinforcement at least 1-1/2 inches below the surface,
         2) Pressure wash cut ends of reinforcement and the surrounding concrete depression.
         3) Paint concrete surfaces within the depression and cut ends of bars with epoxy bonding agent as specified in Section 03071 - Epoxies.
         4) Fill depressions with dry-pack mortar as specified in Section 03366 - Concrete Finishes. Finish exposed surfaces to match the surrounding concrete.

C. Restore areas affected by removal of existing equipment, equipment pads and bases, piping, supports, electrical panels, electric devices, conduits, and fasteners so little or no evidence of the previous installation remains:
   1. After removal of piping, conduit, fasteners, and other construction, fill areas in existing concrete and masonry as indicated on the Drawings.
   2. Finish surfaces exposed in the finished Work to match the surrounding surfaces.

D. Terminate abandoned piping and conduits with blind flanges, caps, or plugs.
   1. Secure closures in place.

E. Where existing fasteners projecting from concrete and masonry are not to be retained, cut off and repair as specified in the preceding paragraphs for reinforcement.

3.05 FIELD QUALITY CONTROL

A. Do not proceed with demolition without the Engineer's inspection of the layout.

B. Do not deviate from the submitted demolition plan without notifying the Engineer prior to the Work.

END OF SECTION

SECTION 01757

DISINFECTION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Cleaning and disinfection requirements for new and existing facilities affected by the Work.

1.02 REFERENCES

A. American Water Works Association (AWWA):
   1. C651 - Disinfecting Water Mains.
   2. C652 - Disinfection of Water Storage Facilities.
   3. C653 - Disinfection of Water Treatment Plants.
   4. C655 - Field Dechlorination.

B. U.S. Environmental Protection Agency (EPA):
   1. Safe Drinking Water Act (SDWA).

1.03 SUBMITTALS

A. Disinfection test plan, detailing the procedure to be utilized to disinfect the facilities, including:
   1. Method and locations of disinfectant application.
   2. Locations of sampling points.
   3. Method of flushing and location of flushing ports (as appropriate for method of chlorination).
   4. Method of dechlorination (as appropriate for method of chlorination).
   5. Disposal location for chlorinated water (as appropriate for method of chlorination).

B. Disinfection reports, including the following:
   1. Date issued.
   2. Project name and location.
   3. Treatment subcontractor’s name, address, and phone number.
   4. Type and form of disinfectant used.
   5. Time and date of disinfectant injection start.
   6. Time and date of disinfectant injection completion.
   7. Test locations.
   8. Initial and 24-hour disinfectant residuals in milligrams per liter for each outlet tested.
   9. Time and date of flushing start.
   10. Time and date of flushing completion.
   11. Disinfectant residual after flushing in milligrams per liter for each outlet tested.

C. Bacteriological reports, including the following:
   1. Date issued.
   2. Project name and location.
   3. Laboratory name, certification number, address, and phone number.
   4. Time and date of water sample collection.
   5. Name of person collecting samples.
   6. Test locations.
   7. Time and date of laboratory test start.
   8. Coliform bacteria test results for each outlet tested.
   9. Certification that water conforms or fails to conform to bacterial standards of the SDWA.
   10. Bacteriologist's signature and bacteriological laboratory's evidence of certification.

D. Required permits, including, but not limited to, permit clearance.
   1. Coordinate with the Owner and Engineer to obtain any necessary signatures.

1.04 QUALITY ASSURANCE

A. Bacteriological and physical chemistry laboratory: Certified by the state in which the Project is located.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Protect chlorine and bacteriological samples against damage and contamination.

B. Maintain caution labels on hazardous materials.

C. Maintain storage room dry and with temperatures as uniform as possible between 60 degrees Fahrenheit and 80 degrees Fahrenheit.

1.06 PROTECTION

A. Provide necessary signs, barricades, and notices to prevent persons from accidentally consuming water or disturbing system being treated.

PART 2 PRODUCTS

2.01 MATERIALS

A. Disinfectant: Free chlorine in liquid, powder, tablet, or gas form in accordance with AWWA C653.

B. Dechlorination agent: Sulfur dioxide, sodium bisulfate, sodium sulfite, or sodium thiosulfate, in accordance with AWWA C655.

PART 3 EXECUTION

3.01 SURFACES TO BE DISINFECTED

A. Disinfect the following:
   1. Piping systems that are used to convey potable water.

3.02 DISINFECTION OF WATER LINES

A. Complete hydrostatic/leakage tests prior to disinfection.

B. Provide necessary blind flanges, hoses, sample taps, or any other appurtenances that may be required to clean and disinfect the piping and wetted surfaces.

C. Cleaning:
   1. Remove by flushing or other means, soil and debris from water pipes in accordance with AWWA C651 prior to chlorination.
   2. Protect surfaces from adverse environmental exposure between the cleaning and the disinfection stages.

D. Inspection:
   1. Verify that water system is completed and cleaned of soil and debris prior to chlorination.
   2. Start disinfection when conditions are satisfactory.

E. System treatment:
   1. Perform disinfection of water lines in accordance with AWWA C651, C652, and C653, and as specified in this Section.
   2. Starting at outlet closest to water source, bleed water from each outlet until water produces odor of disinfectant. Repeat process at each outlet throughout system.
   3. Test for disinfectant residual at each of following locations and other locations in accordance with submitted disinfection test plan:
      a. Ends of piping runs.
      b. Any outlets.
   4. Maintain disinfectant in system for appropriate 6-hour or 24-hour interval in accordance with AWWA C652.
   5. When disinfectant residual is less than 10 milligrams per liter after 24 hours, repeat system treatment.

3.03 REPAIRS OR CONNECTIONS TO EXISTING LINES

A. Perform disinfection in accordance with AWWA C651 and as specified in this Section.

B. Clean and sterilize the interior surfaces of new piping, fittings, equipment, and appurtenances to be installed in an existing potable water system or connected to an existing system.

C. Clean and sterilize the existing pipe or facilities for a minimum distance of 3 pipe diameters back from the ends of the pipe. Plug the ends of the line when work is not being performed on the pipe.

D. Perform sterilization by swabbing each item with a concentrated chlorine solution.
   1. Each piece is to be disinfected prior to being assembled for installation in the existing pipe.
   2. Disinfect each piece just prior to assembly to help prevent recontamination.
   3. Plug the ends of the assembly until a new item is to be added to the assembly.
   4. Store disinfected materials on blocks to prevent contact with the ground.

3.04 FLUSHING

A. Remove disinfection water from the facilities as appropriate for the type of disinfectant and method used for disinfection.

B. Flush facilities with potable water containing no more disinfectant residual than the active distribution system or 1 milligram per liter, whichever is greater, as appropriate for method of chlorination.

C. Continue flushing until water at designated flushing ports contains disinfectant residual equal to concentration specified above.

3.05 DISPOSAL OF CHLORINATED WATER

A. Dispose in accordance with AWWA C655 and as specified in this Section.

B. Dispose of chlorinated water in accordance with the submitted disinfection test plan and applicable requirements of federal, state, county, and city having jurisdiction over disposal of hazardous wastes in the location of the Project and disposal site.

C. Chlorinated water may only be disposed of in a sanitary sewer system with the written permission of the Owner. If allowed, discharge the chlorinated water at a low rate so it does not surcharge the sewer line.

3.06 BACTERIOLOGICAL TEST

A. Instruct bacteriological laboratory to collect water samples no sooner than 24 hours after start of disinfection of each facility.

B. A minimum of 24 hours after flushing system and within 24 hours before the water line is placed into service, collect bacteriological quality samples at each of the following locations and other locations in accordance with the submitted disinfection test plan and Standard Methods for the Examination of Water and Wastewater:
   1. Where water enters system.
   2. Inlet piping.
   3. Ends of piping runs.
   4. Any outlets.

C. Analyze water samples in accordance with Standard Methods for Examination of Water and Wastewater.

D. When bacteriological test proves water quality to be unacceptable, repeat disinfection treatment process until water meets quality standards for disinfection.

E. Bacteriology testing shall also include Heterotrophic Plate Counts (HPC). The presence of HPC must be at concentrations less than or equal to 500 colony forming units per milliliter (cfu/mL).

F. Two consecutive samples shall be tested to produce satisfactory bacteriological samples and negative for coliform organisms. The water main shall be reflushed and resampled daily from the same sampling point(s) until 2 consecutive samples produce satisfactory bacteriological samples and negative for coliform organisms.

END OF SECTION

SECTION 01783

WARRANTIES AND BONDS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Warranty and bonds requirements.

1.02 SUBMITTALS

A. For each item of material or equipment furnished under the Contract:
   1. Submit manufacturer's warranty prior to fabrication and shipment of the item from the manufacturer's facility.
   2. Submit manufacturer's special warranty when specified.

B. Provide consolidated warranties and bonds within 15 calendar days of Substantial Completion.
   1. Contents:
      a. Organize warranty and bond documents:
         1) Include Table of Contents organized by Specification Section number and the name of the product or work item.
      b. Include each required warranty and bond in proper form, with full information, certified by manufacturer as required, and properly executed by Contractor, or subcontractor, supplier, or manufacturer.
      c. Provide name, address, phone number, and point of contact of manufacturer, supplier, and installer, as applicable.
   2. Hardcopy format:
      a. Submit 2 copies.
      b. Assemble in 3 D-side ring binders with durable cover.
      c. Identify each binder on the front and spine with typed or printed title "Warranties and Bonds"; Project Name or Title, and the Name Address and Telephone Number of the Contractor.
   3. Electronic copy in PDF format:
      a. Submit 1 copy.

1.03 OWNER'S RIGHTS

A. Owner reserves the right to reject warranties.

B. Owner reserves the right to refuse to accept Work for the project if the required warranties have not been provided.

1.04 RELATIONSHIP TO GENERAL WARRANTY AND CORRECTION PERIOD

A. Warranties specified for materials and equipment shall be in addition to, and run concurrent with, both Contractor's general warranty and the correction period requirements.

B. Disclaimers and limitations in specific materials and equipment warranties do not limit Contractor’s general warranty, nor does such affect or limit Contractor’s performance obligations under the correction period.

1.05 MANUFACTURER’S 1 YEAR WARRANTY MINIMUM REQUIREMENTS

A. Written warranty issued by item’s manufacturer.

B. Project-specific information, properly executed by product manufacturer, and expressly states that its provisions are for the benefit of the Contractor.

C. Covers all costs associated with the correction of the defect, including, but not limited to, removal of defective parts, new parts, labor, and shipping.

D. Provides a timely response to correct the defect.
   1. Manufacturer shall provide, in a timely fashion, temporary equipment as necessary to replace warranted items requiring repair or replacement, when warranted items are in use and are critical to the treatment process, as defined by Owner.

E. Warranty commence running on the date of substantial completion.
   1. For items of Work for which acceptance is delayed beyond Date of Substantial Completion, submit warranty within 10 calendar days after acceptance, listing date of acceptance as beginning of warranty period.

F. Duration of warranty: 1 year from City of Manteca’s acceptance of Project (Notice of Completion).

1.06 MANUFACTURER’S SPECIAL WARRANTY

A. Manufacturer’s special warranty is a written warranty published by the manufacturer which includes the requirements as specified in the Technical Section.
   1. Project-specific information and requirements.
   2. Properly executed by product manufacturer.
   3. Expressly states that its provisions are for the benefit of the Contractor or Owner.
   4. Manufacturer’s special warranties commence on the date that the associated item is certified by Engineer as substantially complete.

1.07 WARRANTY WORK

A. Contractor’s responsibilities:
   1. Manufacturer’s disclaimers and limitations on product warranties do not relieve the Contractor of the warranty on the work that incorporates the product, nor

does it relieve suppliers, manufacturers, and subcontractors required to countersign special warranties with Contractor.

B. Replacement cost:
   1. Upon determination that work covered by warranty has failed, replace or rebuild the work to an acceptable condition complying with requirement of the Contract Documents.
      a. Contractor is responsible for the cost of replacing or rebuilding defective work regardless of whether Owner has benefited from the use of the work through a portion of its anticipated useful service life.

C. Related damages and losses:
   1. When correcting warranted work that has failed, remove and replace other work that has been damaged as a result of such failure or that must be removed and replaced to provide access for correction of warranted work.

D. Owner's recourse:
   1. Written warranties are in addition to implied warranties, and shall not limit the duties, obligations, rights, and remedies otherwise available under the law, nor shall warranty periods be interpreted as limitation on time in which Owner can enforce such other duties, obligations, rights, or remedies.

E. Reinstatement of warranty:
   1. When work covered by a warranty has failed and has been corrected by replacement or rebuilding, reinstate the warranty by written endorsement.
      a. The reinstated warranty shall be equal to the original warranty with an equitable adjustment for depreciation.

1.08 IMPLIED WARRANTIES

A. Warranty of title and intellectual rights:
   1. Except as may be otherwise indicated in the Contract Documents, implied warranty of title required by Laws and Regulations is applicable to the Work and to materials and equipment incorporated therein.
   2. Provisions on intellectual rights, including patent fees and royalties, are in the General Conditions, as may be modified by the Supplementary Conditions.

B. Implied warranties: Duration in accordance with Laws and Regulations.

1.09 BONDS

A. Equipment bond and other bond requirements as specified in the Technical Sections.

B. Bonds commence running on the date of substantial completion.
   1. For items of Work for which acceptance is delayed beyond Date of Substantial Completion, submit warranty within 10 calendar days after acceptance, listing date of acceptance as beginning of bond period.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 01850

DESIGN CRITERIA

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Design criteria for use in the selection of equipment and appurtenances specified in Technical Sections of these Specifications and indicated on the Drawings.
   2. Criteria for design of systems, components and equipment fabricated off site and shipped to the Work for installation.
   3. Criteria for design of anchors to connect equipment and appurtenances to supports and structures.

B. The criteria in this Section apply throughout the Work, unless additional criteria, or more restrictive criteria, are indicated.
   1. Additional criteria and requirements relevant to specific locations, specific materials, and specific equipment are indicated on the Drawings, and in the Technical Sections.

1.02 REFERENCES

A. American Society of Civil Engineers (ASCE):
   1. 7-16 - Minimum Design Loads and Associated Criteria for Buildings and Other Structures. (ASCE 7).

B. American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE):
   1. ASHRAE Fundamentals Handbook.

C. International Code Council (ICC):
   1. International Energy Conservation Code (IECC).
   2. International Plumbing Code (IPC).

D. Sheet Metal and Air Conditioning Contractor's National Association (SMACNA):
   1. Seismic Restraint Manual: Guidelines for Mechanical Systems, 3rd edition 2008.

PART 2 PRODUCTS

2.01 DESIGN CRITERIA - SITE INFORMATION

A. Site name: Wastewater Quality Control Facility (WQCF).
   1. Street address: As specified in Section 01010 - Location and Summary of Work.
   2. Site elevation (approximate):
      a. 25 feet above mean sea level.

3. Groundwater elevation:
    a. See Project geotechnical reports, listed in Document 00800 - Supplementary General Conditions, for information.

2.02 DESIGN CRITERIA - REGULATORY REQUIREMENTS

A. Requirements of authorities having jurisdiction over the Project are included in Section 01410 - Regulatory Requirements.

2.03 DESIGN CRITERIA - OPERATING ENVIRONMENT

A. Drawings and Technical Sections include additional criteria and requirements relevant to specific locations, materials, and equipment.

B. Outdoor conditions:
    1. IECC: Climate Zone 3B.
    2. ASHRAE site climatic data location: Stockton Metropolitan Airport, WMO 724920.
    3. Temperature criteria: As specified in the following Table: Design Temperatures - Outdoor Criteria in Accordance with ASHRAE Fundamentals Handbook.

Table: Design Temperatures - Outdoor Criteria in Accordance with ASHRAE Fundamentals Handbook

Condition	Criteria
Hottest Month DB Range:	61 - 95 degrees Fahrenheit.
Winter:	At or above this temperature 99.6 percent of the time: 30 degrees Fahrenheit dry-bulb.
Summer:	At or above this temperature 0.4 percent of the time: 103 degrees Fahrenheit dry-bulb.

4. Rainfall intensity:
    a. Reference: International Plumbing Code (IPC):
        1) 1.5 inches per hour (100-year, 1-hour rainfall).

2.04 DESIGN CRITERIA - STRUCTURAL

A. General:
    1. Criteria for structural design of:
        a. Equipment at locations subject to seismic events.
        b. Equipment exposed to outdoor environments.
        c. Equipment supports and bracing, and anchorage of such items to building and non-building structures.
        d. Structures provided for the Work through Delegated Design.
        e. Manufactured and prefabricated structures, and anchorage of such structures to foundations or other supporting elements.
    2. Structural design criteria used by the Engineer of record and required by the building code to be indicated on the Drawings are included on the Contract Drawing titled “General Structural Notes.”

B. Delegated Design:
   1. As specified in Section 01357 - Delegated Design Procedures.
   2. Structural engineering design shall be performed by a Civil or Structural Engineer licensed in the State of California.

C. Structure risk category:
   1. Develop design loads and provide detailing in accordance with the provisions of ASCE 7 and the building code specified in Section 01410 - Regulatory Requirements, based on the Structure Risk Category indicated in Table: Project Structures - Risk Category and Seismic Design Information.

D. Seismic loads:
   1. Seismic design parameters: Basic parameters - ASCE 7:
      a. Ground motion MCE_R, 5 percent damped:
         1) Short periods, Ss = 0.825 g.
         2) 1 second period, S_1 = 0.309 g.
      b. Peak ground acceleration, MCE_G:
         1) Peak ground acceleration, PGA = 0.343 g.
      c. Mapped long-period transition period:
         1) TL = 8 seconds.
   2. Structures - General:
      a. Seismic Design Category (SDC): As indicated in the following Table: Project Structures - Risk Category and Seismic Design Information.

Table: Project Structures - Risk Category and Seismic Design Information

Description: Wastewater Treatment Facility

Area	Description	Risk Category	Site Class	S_{DS}	S_{D1}	Seismic Design Category(1)
All	All Structures	III	D	0.660	0.615	D

Notes:

(1) Seismic Design Category for Delegated Design, and for seismic certification of electrical and mechanical equipment as required by ASCE 7.

      b. Structure response modification coefficient, R:
         1) In accordance with ASCE 7 and the requirements of the Technical Sections.
   3. Structures - Tanks and vessels.
      a. Includes: Tank structures, tank supports, and anchorage to structures or foundations.
      b. Liquid storage structures (e.g., basins and tanks).
         1) Include impulsive and convective (“sloshing”) effects.
         2) Component response modification factor - impulsive effects, Ri: In accordance with ASCE 7, Table 15.4-2.
         3) Component response modification factor - convective effects, Rc = 1.0.
      c. Dry material storage structures (e.g., silos, hoppers):
         1) Include effects of stored materials.
         2) Component response modification factor - impulsive effects, Ri: In accordance with ASCE 7, Table 15.4-2.

4. Non-structural components - General:
   a. Includes:
      1) Mechanical and electrical equipment; anchorage of equipment to structures or supports; design of supports; and anchorage of supports to structures or foundations.
      2) Distribution systems associated with mechanical and electrical equipment such as piping, ductwork, conduits, cable trays, raceways, bus ducts, and similar items; anchorage of such systems to supports and structures; and bracing or such systems.
   b. Seismic design requirements for non-structural components are based on the Seismic Design Category (SDC) of the structure or facility where the equipment is installed.
   c. Design components, component anchorage, and component connections to piping and utilities in accordance with the requirements of ASCE 7, Table 13.2-1.
   d. Component amplification factor (ap), response factor (Rp), and overstrength factor for anchorage to concrete (Ωo):
      1) Mechanical and electrical components and systems: In accordance with ASCE 7, Table 13.6-1, unless otherwise indicated in the Technical Sections for these items.
      2) Architectural components and systems: In accordance with ASCE 7, Table 13.6-1, unless otherwise indicated in the Technical Sections for these items.
   e. Component importance factor, I_p:
      1) In accordance with the following Table: Component Importance Factor for Seismic Design, I_p.
      2) For items not listed in Table: Component Importance Factor for Seismic Design, I_p, designate importance factor in accordance with the provisions of ASCE 7, Chapter 13, and submit to the Engineer for review prior to developing calculations and details related to that component.

Table: Component Importance Factor for Seismic Design, I_p

Structure Seismic Design Category	Components	I_p
All	Electrical: Items and distribution system components specified in Division 16 - Electrical.	1.5
All	Process Control and Instrumentation Systems: Components and distribution systems specified in Division 17 - Instrumentation and Controls.	1.5
All	Equipment and components specified in Divisions 11 through 15, except HVAC and plumbing components listed below.	1.5
All	Other equipment not listed above.	1.0

5. Non-structural components: HVAC ductwork.
   a. Component importance factor, I_p: Determine in accordance with ASCE 7, Section 15.4.1.1.

b. Seismic design category:
1) See Table: Component Importance Factor for Seismic Design, I_p (preceding).
c. SMACNA seismic hazard level.
1) Seismic hazard level for design of heating, ventilating, and air conditioning ductwork in accordance with SMACNA Seismic Restraint Manual:
a) SMACNA Seismic hazard level = A.

E. Wind loads:
1. Design structures and non-structural components that are exposed to wind to withstand design wind loads.
a. Reduction of wind loads based on shielding effects of surrounding structures or components is not allowed.
b. Design for wind loading is not required for non-structural components and for non-building structures located inside enclosed buildings.
2. Design parameters:
a. Basic wind speed:
1) 100 miles per hour (33 feet, 3 second gust).
b. Exposure category: C.
c. Topographic factor, Kzt: 1.0.

F. Rainfall loads:
1. Determine rainfall loads using rainfall intensity specified in this Section and including effects of exposed surface slope, height above surface to discharge elevation, and deflection of ponded surfaces.

G. Operational loads:
1. Loads may include equipment vibration, torque, thermal effects, effects of internal contents (weight and sloshing), surge or “water hammer,” and other load conditions.
2. Design for loads indicated by the equipment manufacturer.
3. Design for loads indicated in the Technical Sections for equipment and appurtenances.

H. Serviceability considerations:
1. Deflection, unless otherwise indicated on the Drawings, or specified:
a. Beam deflection as fraction of span:
1) Walkways and platforms: Total load = L/240; live load = L/360.
2) Equipment supports: L/450.

PART 3 EXECUTION

3.01 GENERAL

A. Design approach and criteria in accordance with:
1. Regulatory requirements, including, but not limited to, the building code specified in Section 01410 - Regulatory Requirements.
2. Reference standards and project-specific design criteria listed in this Section.

3. Specific requirements for individual elements and components of the Work as specified in subsequent Technical Sections.

B. In the event of conflicts between design criteria, contact Engineer for interpretation.

C. Where Owner-Delegated Design is required by the Specifications, prepare and submit designs as specified in Section 01357 - Delegated Design Procedures.

3.02 DELEGATED DESIGN

A. Where Delegated Design is required by the Technical Sections, prepare and submit designs as specified in Section 01357 - Delegated Design Procedures.

B. Calculations:
   1. Where submittal of calculations is required:
      a. Provide complete calculations, including sketches to illustrate the design concepts being evaluated, and details to fully describe proposed construction.
   2. Requirements for seismic design calculations will be waived for the following:
      a. Furniture and storage racks 6 feet in height or less.
      b. Moveable equipment.
      c. Mechanical and electrical equipment and components located in structures designated as Seismic Design Category A or B.
      d. Mechanical and electrical equipment and components located in structures designated as Seismic Design Category C and where the component importance factor, I_p, is equal to 1.0.
   3. Requirements for wind design calculations will be waived for the following:
      a. Equipment and components located inside structures, and away from the effects of wind loads.

C. Shop Drawings:
   1. Describing components and manufacturer's requirements for connections.
      a. Include details for connections of components to structures and supports.
      b. Include details for anchoring bracing to structures where required.

3.03 DESIGN - ANCHORS FOR EQUIPMENT, COMPONENTS, AND BRACING

A. General:
   1. Engineer's approval of anchor designs is required before placement of construction that supports or provides bracing for anchored equipment and components.
      a. Prepare anchor designs after the Engineer's approval of the products and layout, and before placement of concrete or masonry that supports them.
   2. Adjust equipment pad sizes and add additional anchor confinement reinforcing to provide required strength at anchorage points between equipment and pad, and between pad and structure.
   3. Supports and bracing:
      a. Design and install braces and anchors to transfer forces from equipment and components to the lateral force resisting system of the surrounding structure.

b. Anchor and brace piping, ductwork, and electrical distribution components so that lateral or vertical displacement does not result in damage to or failure of essential architectural, mechanical, or electrical equipment.
    1) Provide supplementary framing where required to transfer forces.
    2) Detail and locate braces and anchors to minimize differential movements between components and structure.

B. Preparation:
1. Obtain manufacturer's information:
    a. Weight and dimensions of components.
    b. Layout and location of anchors that connect to equipment base plates, sole plates, skids, or pads.
    c. Sizes of holes for anchors that will be provided in equipment bases or support frames.

C. Analysis and design:
1. Perform and submit calculations to determine anchor designs at locations where equipment and equipment supports are connected to the supporting structure.
    a. Indicate number, size, type, and material for anchors.
2. In determining forces at locations where equipment is anchored to structures, include effects of:
    a. Equipment self-weight and operating weight.
    b. Location of equipment center of mass.
    c. Forces from equipment operation, including, but not limited to:
        1) Effects of internal contents, including weight and sloshing.
        2) Effects of thrust, surge, and water hammer where specified.
        3) Equipment reactions and operating torque.
        4) Equipment vibration.
        5) Thermal effects from equipment and from distribution systems connected to the equipment (piping, ducts, and electrical).
        6) Other load or displacement inducing conditions.
    d. Forces on equipment from loads specified in this Section.
        1) Include effects of wind, snow, and icing loads where applicable.
        2) Design for load combinations indicated in ASCE 7, unless otherwise specified or indicated on the Drawings.
        3) Seismic and wind loads: For equipment and tanks with weight that varies based on the volume of contained material, determine anchor forces to accommodate the full range of filled, partially filled, and empty conditions.
3. Determine forces and overturning moments at equipment supports and at locations where supports are anchored to structures.
    a. Indicate shear force and associated axial force at each anchor.
4. Do not use friction to resist sliding resulting from seismic or wind forces.
    a. Resist sliding only by direct application of sliding loads to fasteners as bearing, shear, tension, or compression forces.
5. Using combined shears and axial forces at each anchor, design anchors and anchor groups for ductile failure.
    a. Ductile failure: Anchor yield before failure of base material, typically concrete or masonry, at the anchor.

6. Anchor selection:
    a. Provide anchors type indicated on the Drawings.
    b. Where anchors are not specifically indicated on the Drawings, select in accordance with the following:
        1) Anchors that resist seismic and wind forces:
            a) Cast-in-place forged hex-head anchor bolt.
        2) Anchors loaded in sustained tension:
            a) Cast-in-place forged hex-head anchor bolt.
        3) Anchors for reciprocating, vibrating, and rotating equipment:
            a) Cast-in-place forged hex-head anchor bolt.
    c. Do not use post-installed anchors, mechanical or adhesive, unless:
        1) Post-installed anchors are indicated on the Drawings, or
        2) Post-installed are approved by the Engineer prior to placement of the surrounding concrete or masonry.
    d. Anchor diameter:
        1) Select diameter so that hole in base plate is not greater than 125 percent of the nominal diameter of the anchor, nor greater than the diameter of the anchor plus 1/4 inch.
7. Determine number, size, layout, and minimum effective embedment for anchors.
    a. Layout includes anchor spacing and required distance(s) from anchor to edge(s) of supporting concrete or masonry.
    b. Anchors in concrete: Design based on minimum specified 28-day compressive strength, f'c, as follows, unless otherwise indicated on the Drawings for the Work area:
        1) Concrete placed for this Work: f'c = 4,000 pounds per square inch.
        2) Existing concrete in place prior to this Work: f'c = 4,000 pounds per square inch.
    c. Anchors in masonry: Design based on minimum specified compressive strength, f'm, as follows, unless otherwise indicated on the Drawings for the Work area:
        1) Concrete masonry placed for this Work: f'm = 4,000 pounds per square inch.
8. Prepare Drawings showing construction details of anchor designs.
9. Submit design calculations and Drawings prior to placement of anchors, and of the structural elements to which they will connect.

END OF SECTION

SECTION 02050

SOILS AND AGGREGATES FOR EARTHWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Material requirements for soils and aggregates.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C117 - Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing.
   2. C131 - Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
   3. C136 - Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
   4. C535 - Standard Test Method for Resistance to Degradation of Larger-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
   5. D2419 - Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate.
   6. D2844 - Standard Test Method for Resistance R-Value and Expansion Pressure of Compacted Soils.
   7. D4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
   8. D4829 - Standard Test Method for Expansion Index of Soils.
   9. D5821 - Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate.

B. California State Transportation Agency, Department of Transportation (CALTRANS):
   1. (Standard Specifications).
   2. California Test Methods (CTM):
      a. California Test 205 - Method of Test for Determining Crushed Particles.
      b. California Test 211 - Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Abrasion Testing Machine.
      c. California Test 217 - Method of Test for Sand Equivalent.
      d. California Test 229 - Method of Test for Durability Index.
      e. California Test 301 - Method of Test for Determining the Resistance “R” Value of Treated and Untreated Bases, Subbases, and Basement Soils by the Stabilometer.

1.03 SUBMITTALS

A. Product data:
   1. Material source.

2. Gradation.
3. Testing data.

B. Quality control for aggregate base course:
1. Test reports: As required by Sections of Standard Specifications.
2. Certificates of compliance: As required by Sections of Standard Specifications.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Storage and protection: Protect from segregation and excessive moisture during delivery, storage, and handling.

B. Comply with Standard Specifications storage requirements, if applicable.

PART 2 PRODUCTS

2.01 MATERIALS - GENERAL

A. Provide material having maximum particle size not exceeding 4 inches and that is free of trash, lumber, debris, leaves, grass, roots, stumps, and other organic matter.

B. Materials derived from processing demolished or removed asphalt concrete are not acceptable.

C. Comply with soil and aggregate material requirements in the Standard Specifications unless specified otherwise.

2.02 NATIVE MATERIAL

A. Native soil-select:
1. Sound earthen material.
2. Sum of plasticity index when tested in accordance with ASTM D4318 and the percent of material by weight passing a No. 200 sieve shall not exceed 23 when tested in accordance with ASTM C136.
3. Organic content not be greater than 3 percent by volume.
4. Corrosion resistance requirements:
a. Resistivity minimum (wet aggregates): 5,000 ohm-cm.
b. pH: 5.0 to 12.0.
c. Chlorides maximum: 100 parts per million.
d. Sulfates maximum: 200 parts per million.

2.03 AGGREGATE BASE COURSE

A. Material requirements:
1. Class 2, 3/4-inch maximum aggregate size, free from organic matter and other deleterious substances, and of such nature that aggregate can be compacted readily under watering and rolling to form a firm, stable base.
2. Aggregate base course for structures:
a. Consist of crushed or fragmented particles.

b. Coarse aggregate material retained in No. 4 sieve shall consist of material of which at least 25 percent by weight shall be crushed particles when tested in accordance with California Test 205.

3. Aggregate shall not be treated with lime, cement, or other chemical material.
4. Durability index: Not less than 35 when tested in accordance with California Test 229.
5. Aggregate grading and sand equivalent tests shall be performed to represent not more than 500 cubic yards or 1 day's production of material, whichever is smaller.
6. Sand equivalent: Not less than 25 when tested in accordance with California Test 217.
7. Resistance (R-value): Not less than 78 when tested in accordance with California Test 301.
8. Conforms to size and grade within the following limits when tested in accordance with ASTM C117 and ASTM C136:

Sieve Sizes (Square Openings)	Percent by Weight Passing Sieve
1 inch	100
3/4 inch	90 - 100
No. 4	35 - 60
No. 30	10 - 30
No. 200	2 - 9

2.04 GRAVEL

A. Material requirements:
1. The existing imported gravel may be reused if it does not become contaminated with other materials.
2. Consists of hard, durable particles of stone or gravel; or crushed to the specified sizes and gradations; and free from organic matter, lumps or balls of clay, and other deleterious matter.
3. Crush or waste coarse material and add or waste fine material in order to meet the specified gradations.
4. Fraction of material passing No. 40 sieve: Material having plasticity index not greater than 5 when tested in accordance with ASTM D4318.
5. Durability: Percentage of wear not greater than 40 percent when tested in accordance with ASTM C131.
6. Conforms to sizes and grade within the following limits when tested in accordance with ASTM C117 and ASTM C136:

Sieve Size (Square Openings)	Percent by Weight Passing Sieve		
	Type A	Type B	Type C
2 inch	100	--	--
1-1/2 inch	95 - 100	100	--
3/4 inch	35 - 60	55 - 85	100
3/8 inch	15 - 40	35 - 65	50 - 100

Sieve Size (Square Openings)	Percent by Weight Passing Sieve		
	Type A	Type B	Type C
No. 4	0 - 25	20 - 35	30 - 45
No. 30	--	5 - 15	10 - 20
No. 200	0 - 5	2 - 9	2 - 9

2.05 DRAIN ROCK

A. Material requirements:
   1. Durability: Percentage of wear not greater than 40 percent when tested in accordance with ASTM C131.
   2. Consists of hard, durable particles of stone or gravel; screened or crushed to specified size and gradation; and free from organic matter, lumps or balls of clay, or other deleterious matter.
   3. Crush or waste coarse material and waste fine material as required to meet gradation requirements.
   4. Conforms to size and grade within the following limits when tested in accordance with ASTM C117 and ASTM C136:

Sieve Size (Square Openings)	Percent by Weight Passing Sieve
2 inch	100
1-1/2 inch	95 - 100
3/4 inch	50 - 100
3/8 inch	15 - 55
No. 200	0 - 2

2.06 CLASS 2 PERMEABLE FILL

A. Material requirements:
   1. Durability: Percentage of wear not greater than 40 percent when tested in accordance with ASTM C131.

2.07 IMPORTED FILL

A. Material requirements: Any imported fill materials to be used for engineered fill should be sampled and tested by a representative of the project Geotechnical Engineer prior to being transported to the site. The following table provides general criteria for imported fill.

Fill Requirement		**Test Procedures**
Gradation		*ASTM*
Sieve Size	Percent Passing	
3 inch	100	D6913
3/4-inch	70-100	D6913

Fill Requirement		Test Procedures
No. 200	15-70	D6913
Plasticity		
Liquid Limit	Plasticity Index	
<35	<12	D4318
R-Value		_
30 or more		---
Organic Content		
No visible organics		---
Expansion Potential		
20 or less		D4829
Soluble Sulfates		
Less than 2,000 ppm		---
Soluble Chloride		
Less than 300 ppm		---
Resistivity		
Greater than 2,000 ohm-cm		---

B. Lightweight material:
   1. Manufacturers: One of the following or equal:
      a. Glass Mountain Pumice, Inc.
      b. Witelite Pumice, Witelite.
   2. Shall have a dry density of 48 to 65 pounds per cubic foot, absorption of 12 to 16 percent, and sand equivalent of 68.
   3. Conforms to size and grade within the following limits when tested in accordance with ASTM C117 and ASTM C136:

Sieve Size (Square Openings)	Percent by Weight Passing Sieve
3/4 inch	100
No. 4	40 - 50
No. 30	10 - 20
No. 200	0 - 5

2.08 SAND

A. Clean, coarse, natural sand.

B. Non-plastic when tested in accordance with ASTM D4318.

C. Conforms to size and grade within the following limits when tested in accordance with ASTM C117 and ASTM C136:

Sieve Size (Square Openings)	Percent by Weight Passing Sieve
1/2 inch	100
No. 200	0 - 20

2.09 STABILIZATION MATERIAL

A. Durability: Percentage of wear not greater than 40 percent when tested in accordance with ASTM C131.

B. Consists of clean, hard, durable particles of crushed rock or gravel; screened or crushed to the specified sizes and gradations; and free of any detrimental quantity of soft, friable, thin, elongated, or laminated pieces, disintegrated material, organic matter, oil, alkali, or other deleterious substance.

C. Shall be free of slaking or decomposition under the action of alternate wetting and drying.

D. The portion of material retained on the 3/8-inch sieve shall contain at least 50 percent of particles having 3 or more fractured faces.
   1. Not over 5 percent shall be pieces that show no such faces resulting from crushing. Of that portion which passes the 3/8-inch sieve but is retained on the No. 4 sieve, not more than 10 percent shall be pieces that show no faces resulting from crushing.

E. Conforms to size and grade within the following limits when tested in accordance with ASTM C117 and ASTM C136:

Sieve Size (Square Openings)	Percent by Weight Passing Sieve
1 inch	100
3/4 inch	90 - 100
No. 4	0 - 10
No. 200	0 - 2

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 02078A SURVEY MONUMENTS

PART 1 – GENERAL

1.01 SCOPE

The work covered by this section consists of furnishing all labor, equipment and material necessary for survey monument work as specified herein and/or as indicated on the plans.

1.02 SPECIAL PROVISIONS

Survey Monuments shall conform to the requirements set forth in Section 78-2 (Survey Monuments) under Section 78 "Incidental Construction" of the 2023 Caltrans Standard Specifications (and other sections referenced, if any) and as modified herein.

Adjust Utility Frames, Covers, and Manholes shall conform to the requirements set forth in Section 78-23 (Adjust Utility Frames, Covers, and Manholes) under Section 78 "Incidental Construction" of the 2023 Caltrans Standard Specifications (and other sections referenced, if any) and as modified herein.

1.03 MODIFICATIONS TO 2023 CALTRANS STANDARD SPECIFICATIONS

Section 78-2.01 GENERAL
Add to the end of the section:

1. Contractor shall comply with the Professional Land Surveyors' Act – Business & Professions Code, Section 8771(b) regarding referencing, preserving, and reconstructing monuments, whether or not the monuments are shown on the plans.

2. Before beginning any construction on the Project, the following tasks shall be accomplished by or under the direction of a licensed land surveyor licensed in the State of California:
    a. Conduct records research to identify horizontal and vertical control monuments, prepare and submit a map to the City of the monuments within the Project site. The map will identify if a monument is in a well, covered, or obliterated.
    b. Locate and reference monuments. A pre-construction record of survey of the references shall be filed with the County Surveyor. The City shall receive a copy of the submitted record of survey documents.

3. Before the certificate of completion for the Project is issued by the City, the following tasks shall be accomplished by or under the direction of a licensed land surveyor licensed in the State of California:
    a. Monuments shall be reset in the surface of the new construction in a monument box and lid listed below:

i. Box: Bingham & Taylor, Mark V 10-in Rim Heavy with Flange, part number CUL10RHVYF, or approved equal.
ii. Lid: Bingham & Taylor, Mark V 10-in Lid Standard, with the word "MONUMENT" stamped on lid, part number CUL10LHVYCPT, or approved equal.

b. Monuments wells shall be raised to the new surface elevation.

c. For section corners, quarter section corners, or center quarter section corners located in unimproved areas, the monuments shall be reset by placing heavily galvanized iron pipe or galvanized iron stake not less than 2-inches in diameter, minimum 3 ft long and 1 ft below the surface.

d. File a post-construction record of survey with the County Surveyor for the reset monuments. The City shall receive a copy of the submitted and the final recorded record of survey documents.

The Contractor shall not disturb any monuments not installed by the Contractor without permission of the Department. The Contractor shall bear the expense of locating, surveying and resetting any monuments which may be disturbed without permission. If the monuments not installed by the Contractor are destroyed, and the Department replaces, The Department may deduct the cost from the Contract. In cases of accidental damage or displacement of the monuments where, in the opinion of the Department, new concrete monuments are required, reset or replace and reference monuments. A corner record or record of survey shall be filed with the County Surveyor. The City shall receive a copy of the submitted and recorded corner record or record of survey documents. New monuments shall be of a type and quality in accordance with San Joaquin County Standard Drawings and shall be placed in a manner consistent with good and recognized engineering and surveying practices in accordance with State of California regulations. Replacement of monuments shall be paid for at the Contractor's sole expense.

If you cause damage, you are responsible.

Install suitable safeguards to preserve and protect facilities from damage.

Section 78-2.02 MATERIALS
Delete the second paragraph:
The Department furnishes the survey marker disks.

Replace with:
Furnish the survey marker disks.

END OF SECTION

SECTION 02101 WATER REDUCTION ACT REQUIREMENTS

PART 1 – GENERAL

1.01 SCOPE

Potable water use for construction purposes is prohibited, except on projects of less than twenty acres in total project acreage and physically located further than one mile from the water quality control facility's (WQCF) recycled water fill station at 2450 W Yosemite Avenue, Manteca, California. Persons authorized to use potable water for construction purposes shall obtain a "Fire Hydrant Water Meter Permit" from the city or at the following City website: https://www.manteca.gov/home/showpublisheddocument/2116/638052450793430000 The City will provide the contractor a water meter. All potable water used for construction purposes shall be metered by said city provided assembly.

1. The Contractor shall obtain and pay for any municipal potable water use necessary to implement the Contract, including any special connections or devices necessary to obtain said potable water (including water meter and reduced pressure (RP) backflow preventer). The Contractor shall coordinate with the City of Manteca Finance Department for payment, and the City of Manteca Water Division to obtain a water meter.

2. When obtaining water from a hydrant to a water truck, the Contractor shall only use trucks equipped to prevent backflow by means of an air gap of at least two times the diameter of the fill pipe, from the bottom of the fill pipe to the top of the receiving vessel. If an air gap is not present then a RP backflow preventer shall be attached to the vessel or the hydrant.

3. The Contractor shall coordinate potable water access with Engineer's Representative and the City of Manteca Water Division.

Temporary Service Fee:

Meter Size	**Deposit***	**Monthly Rental Charge**	**Water Consumption Charge per Hundred Cubic Feet Used**
	Sept 1, 2018 and thereafter	**Sept 1, 2018 and thereafter**	**Sept 1, 2018 and thereafter**
1″	$1,500	$26.50	$3.76
3″	$5,000	$142.70	$3.76

* The deposit shall be refunded to the applicant upon return of the water meter provided it is returned in the same condition as furnished.

Potable water for use by the Contractor's personnel or other purposes shall be coordinated by the Contractor at the Contractor's expense. No provisions in this Section are intended to prevent the Contractor from making arrangements for water from other than Owner sources. All costs involved shall be the responsibility of the Contractor.

Projects in excess of twenty acres or closer than one mile to the WQCF's recycled water fill station shall use city supplied recycled water, except where approved by the Director of Engineering or the Director of Public Works. In order to receive recycled water, the water truck operator must obtain a certification card from the Public Works Department for recycled water handling by attending a mandatory workshop on recycled water. Recycled water is available at no cost to the Contractor at the Water Quality Control Facility (WQCF) 2450 W. Yosemite Avenue, Manteca, California.

Recycled water is available at the WQCF during regular working hours, or may be made available after-hours upon special request for limited periods through WQCF.

Recycled water will only be available to water truck drivers who attend the mandatory recycled water handling workshop and have the City issued Certification Card. The mandatory workshops are held two times per month.

Please call 209-456-8470 or e-mail jfirmalo@manteca.gov to reserve your space. When calling or e-mailing please provide the following information: company name, names of employees attending the class, and desired class dates.

The compensation for implementing City of Manteca Water Reduction Act Requirements shall be paid for under bid item of Mobilization"Manteca Water Reduction Act Coordination" and shall include full compensation for training requirements, furnishing all labor, materials, tools, equipment, incidentals, and disposal of waste for work involved.

END OF SECTION

SECTION 02200

SITE CLEARING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Clearing, grubbing, and stripping project site.

1.02 REFERENCES (NOT USED)

1.03 DEFINITIONS

A. Clearing: Consists of removal of natural obstructions and existing foundations, buildings, fences, lumber, walls, stumps, brush, weeds, rubbish, trees, boulders, utility lines, and any other items which interferes with construction operations or are designated for removal.

B. Grubbing: Consists of the removal and disposal of wood or root matter below the ground surface remaining after clearing and includes stumps, trunks, roots, or root systems greater than 1 inch in diameter or thickness to a depth of 6 inches below the ground surface.

C. Stripping: Includes the removal and disposal of all organic sod, topsoil, grass and grass roots, and other objectionable material remaining after clearing and grubbing from the areas designated to be stripped. The depth of stripping is estimated to be 8 inches, but the required depth of stripping will be determined by the Engineer.

1.04 QUALITY ASSURANCE

A. Regulatory requirements: Verify and comply with applicable regulations regarding those governing noise, dust, nuisance, drainage and runoff, fire protection, and disposal.

B. Pre-construction conference: Meet with Engineer to discuss order and method of work.

1.05 PROJECT CONDITIONS

A. Environmental requirements:
   1. For suspected hazardous materials found: As specified in Section 01354 - Hazardous Material Procedures.

1.06 SEQUENCING AND SCHEDULING

A. Clearing and grubbing: Perform clearing and grubbing in advance of grading operations.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions: Examine site and verify existing conditions for beginning work.

3.02 PREPARATION

A. Protect existing improvements from damage by site preparation work.

3.03 INSTALLATION

A. Clearing:
   1. Clear areas where construction is to be performed and other areas as indicated on the Drawings, or specified in this Section, of fences, lumber, walls, stumps, brush, roots, weeds, trees, shrubs, rubbish, and other objectionable material of any kind which, if left in place, would interfere with proper performance or completion of the work, would impair its subsequent use, or form obstructions.
   2. Do not incorporate organic material from clearing and grubbing operations in fills and backfills.
   3. Contractor's temporary construction facilities: Fill or remove pits, fill, and other earthwork required for erection of facilities, upon completion of the work, and level to meet existing contours of adjacent ground.

B. Grubbing:
   1. From excavated areas: Grub stumps, roots, and other obstructions 3 inches or over in diameter to depth of not less than 18 inches below finish grade.

Height of Embankment over Stump	Depth of Clearing and Grubbing
0 feet to 2 feet	Grub stumps or roots 3 inches or over in diameter to 18 inches below original grade. Cut others flush with ground.
2 feet to 3 feet	Grub stumps 1 foot and over in diameter to 18 inches below original grade. Cut others flush with ground.
Over 3 feet	Leave no stumps higher than stump top diameter, and in no case more than 18 inches.

   2. Backfill and compact cavities left below subgrade elevation by removal of stumps or roots to density of adjacent undisturbed soil.

C. Stripping:
   1. The depth of stripping will be dependent upon the thickness of the loose

gravels at the site. Remove soil material containing sod, grass, or other vegetation to depth of 8 inches from areas to receive fill or pavement and from area within 5 feet beyond of the proposed structure.

2. Deposit stripped material in accordance with following requirements:
   a. At locations acceptable to Engineer.
   b. Use accepted material in top 8 inches of areas to be used for future planting.

D. Material reuse and recycling:
   1. 100 percent of trees, stumps, rocks and associated vegetation and soils resulting primarily from land clearing shall be reused or recycled. For a phased project, such material may be stockpiled on site until project completion.
   2. Contractor shall provide Engineer with list of local markets and salvage sites for reuse of clearing debris.

END OF SECTION

SECTION 02240

DEWATERING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Installation and maintenance of dewatering systems.
   2. Disposal of water entering excavation or other parts of the work.

1.02 REFERENCES

A. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

1.03 SUBMITTALS

A. Dewatering plan:
   1. Dewatering design analysis.
   2. Required permits.
   3. Arrangement, location, and depths of dewatering system components.
   4. Type and sizes of filters.
   5. Identify proposed alignment, support, and protection for discharge pipe. Identify location of discharge and provide details for that location. For pipes discharging to manholes, provide details of pipe entry at manhole.

B. Well construction logs. Include:
   1. Descriptions of actual materials encountered, categorized in accordance with Unified Soil Classification System.
   2. Construction details.
   3. Well development procedures and results.
   4. Deviations from original design.

C. Flowmeter:
   1. Product information on flowmeter and chart recorder.
   2. Recent flowmeter calibration documentation.
   3. Chart(s) from flowmeter chart recorder**.**

D. Qualifications:
   1. Dewatering contractor.
   2. Dewatering design engineer.
   3. Testing laboratory.

E. Control points and schedule of measurements:
   1. Location and details of control points and method and schedule of measurements.

2. All structures or facilities located within the radius of influence of the dewatering operation shall have control points established to detect any settlement which may develop.
3. Within 24 hours of constructing control points, survey and submit measurements at each control point. Submit copy of field notes with measurements.
4. Survey and submit measurements of control points every 7 days. Submit measurements within 24 hours. For each control point:
    a. Show current measurement and the change in measurement from first measurement taken.
    b. Show graphical plot of movements.

1.04 QUALITY ASSURANCE

A. Dewatering plan and dewatering system analysis:
1. Prepared by a qualified Civil Engineer, licensed in the state where the Project is located.
    a. The dewatering design engineer shall have at least 8 years of experience in designing similar systems.

B. Dewatering Contractor shall have at least 8 years of experience in installing similar systems.

C. Testing laboratory shall meet discharge permit testing laboratory qualifications.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Flowmeter and chart recorder: The following or equal:
1. Badger Turbo Series Meter with totalizer.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:
1. Keep excavations reasonably free from water. Draw down static groundwater level to minimum of 2 to 3 feet below anticipated bottom of excavations before the excavation reaches bottom elevation. Dewatering design analysis. Include the following:
    a. Evaluation of anticipated subsurface conditions.
    b. Required well spacing.
    c. Diameter of wells.
    d. Depth to screen, screen height, and mesh size.
    e. Backfill and filter pack.
    f. Pump size.
    g. Drawdown duration.
    h. Drawdown and steady state flow rates.
    i. Anticipated area influenced by dewatering system and potential impacts to adjacent structures, existing and proposed. Mitigation measures needed to prevent any expected settlements. Contingency plan for restoring

nearby structures if settlement is observed as result of dewatering operations.

j. Expected settlements.

2. Include water drawdown curves in dewatering calculations.
3. Coordinate dewatering design with excavation and shoring design. Excavation and shoring design shall consider changes in groundwater conditions and associated earth pressures.
4. Do not place concrete or masonry foundations or concrete slabs in water. Do not allow water to rise over these elements until concrete or mortar has set for at least 24 hours.
5. Maintain operation of dewatering system until complete structure including walls, slabs, beams, struts, and other structural elements has been constructed; concrete has attained its specified compressive strength; and backfill has been completed to 3 feet above normal static groundwater level at the site.
6. Provide standby power to ensure continuous dewatering in case of power failure.

B. Dewatering shored excavations:
   1. Dewater from within shoring.
   2. Use impermeable shoring system to minimize lowering of groundwater outside shoring.
   3. Extend impermeable shoring below bottom of excavation sufficient amount to:
      a. Minimize lowering of groundwater outside shoring.
      b. Prevent unstable excavation due to piping and heave.
   4. To minimize settlement outside shoring due to dewatering, do not lower groundwater outside shoring more than 1 foot. Provide groundwater recharge if required to maintain this groundwater elevation outside of shoring.
   5. Provide monitoring wells located outside shoring for monitoring groundwater elevation.

C. Obtain written permission from Engineer before locating wells, well points, or drain lines for dewatering within the limits of a structure's foundation.

D. Locate dewatering facilities where they will not interfere with utilities and construction work to be performed by others.

E. To facilitate construction, the contractor may need to cover the bottom of the excavation(s) with a 6- to 12-inch-thick stabilizing layer of clean, crushed gravel that is firmly tamped into place. The crushed gravel can also serve as a collection medium for rainwater or seepage that can be removed by pumping from shallow sumps. Consult with the geotechnical engineer prior to implementing any remedial measure to observe the subgrade condition and provide site-specific recommendations.

F. Discharge:
   1. Discharge water to nearest plant drain manhole. Coordinate with plant staff prior to discharging.
   2. Discharge to storm drain inlets will not be permitted.

PART 3 EXECUTION

3.01 INSTALLATION

A. The responsibility for conducting the dewatering operation in a manner which will protect adjacent structures and facilities rests solely with Contractor.

B. During construction, provide and maintain ample means and devices to promptly remove and properly dispose of water entering excavation or other parts of the work, whether water is surface water or underground water.

C. Keep excavations reasonably free of water.

D. Make provisions to maintain continuous dewatering:
   1. Provide standby power to maintain dewatering during power outages and interruptions.
   2. Provide 24-hour monitoring by personnel skilled in operation and maintenance of the system, and capable of providing or obtaining work required to maintain system operation.

E. Intercept and divert precipitation and surface water away from excavations. Use dikes, curb walls, ditches, pipes, sumps, or other means acceptable to Engineer.

F. Disposal of water:
   1. Dispose of water from the work in suitable manner without damage to adjacent property.
   2. Do not drain water into work built or under construction.
   3. Properly dispose of discharge water in accordance with Federal, State, and local requirements and permits and in such manner that it will not be a menace to public health or safety.
   4. For discharge of water into holding tanks or infiltration ponds, include a means of overflow protection that is acceptable to Engineer.

G. Wells, well points, and drain lines for dewatering:
   1. Provide after receiving Engineer's written acceptance.

3.02 CONSTRUCTION

A. Prior to release of groundwater to its static level: Confirm that:
   1. All groundwater pressure relief devices for structure are fully operational.
   2. Construction of structure is complete and concrete has reached its specified compressive strength.
   3. Backfill of structure is complete.

B. Control release of groundwater to its static level to prevent disturbance of natural foundation soils or compacted backfills and fills and to prevent flotation or movement of structures, pipelines, or other facilities.

3.03 FIELD QUALITY CONTROL

A. Flowmeter and chart recorder:
   1. Provide flowmeter and continuous 24-hour chart recorder for recording dewatering flow.
   1. Maintain meter recorder and provide continuous reading charts with minimum capacity of 24 hours each.
   2. Calibrate flowmeter and recorder device to provide accuracy within 5 percent.
   3. Submit written evidence of calibration of meter and recorder signed by a Professional Engineer registered in the state where Project is located.
   4. Portable recorder (bench mount), dual scale, and mounted in NEMA Type 4X enclosure with transparent plastic door and latch. Operate unit off 115-volts, 60-Hertz power supply.
   5. Submit readings to the Engineer on a weekly basis.

END OF SECTION

SECTION 02260

EXCAVATION SUPPORT AND PROTECTION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Designing, providing, maintaining, and removing excavation support and protection.

1.02 REFERENCES

A. American Society of Civil Engineers (ASCE):
   1. Guidelines of Engineering Practice for Braced and Tied-Back Excavations.

B. California Code of Regulations (CCR):
   1. Title 8 - Industrial Relations:
      a. Division 1. Department of Industrial Relations.
         1) Chapter 4. Division of Industrial Safety.
            a) Subchapter 4. Construction Safety Orders.
               (1) Article 6. Excavations.

C. Department of the Navy Naval Facilities Engineering Command (NAVFAC):
   1. Design Manual 7.2 - Foundations and Earth Structures.
   2. Design Manual 7.3 - Soil Dynamics and Special Design Aspects.

D. State of California Department of Transportation (Caltrans):
   1. Caltrans California Trenching and Shoring Manual.

E. United States Steel Corporation (USS):
   1. Steel Sheet Piling Design Manual.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. General engineering design practice: In area of the Project, performed in accordance with recent engineering literature on subject of shoring and stability of excavations.
   2. Shoring: A temporary structural system designed to support vertical faces, or nearly vertical faces, of soil or rock for purposes of excavation. Shoring includes internally braced sheet piling, slurry walls, and other similar shoring systems. Sloping of the soil is not shoring.
   3. Support levels: Level of tiebacks, wales, rakers, bottom of excavation, and other types of support.

1.04 SUBMITTALS

A. Shop Drawings and calculations:
   1. Calculations for different load, support, and other conditions that occur during the sequence of installation of shoring, construction of facilities protected by shoring, and sequence of removal of shoring.
   2. Sketches showing the condition at various stages of installation and removal of shoring.
   3. Show on plan shoring, structures, pipelines, and other improvements located near shoring.
   4. When utilities penetrate shoring, show location of penetrations on elevation of sides of shoring.
   5. Show details for ground support and sealing around utility penetrations.
   6. Indicate method used for installing driven shoring.

B. Control points and schedule of measurements:
   1. Submit location and details of control points and method and schedule of measurements.
   2. Survey data.

C. Furnish Submittals for excavation support and protection as complete package and include items required in this Section:
   1. Incomplete Submittals will not be reviewed and will be returned for resubmittal as a complete package.

D. Furnish dewatering Submittals as specified in Section 02240 - Dewatering with Submittals for excavation support and protection.

1.05 SEQUENCING

A. Do not begin construction of any shoring or excavation operations until:
   1. Submittals for shoring and dewatering have been accepted.
   2. Control points as specified in this Section and on existing structures and other improvements as indicated on the Drawings have been established and surveyed to document initial elevations and locations.
   3. Materials necessary for installation are on site.

B. Furnish Submittals a minimum of 60 days prior to scheduled date to begin excavation work.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Where general engineering design practice is specified, provide Drawings and calculations that are performed and signed by civil or structural engineer registered in the state where the Project is located:
   1. Clearly disclose assumptions made, criteria followed, and stress values used for materials being used in design calculations.

2. Submit list of references acceptable to the Engineer that substantiate appropriateness of design assumptions, criteria, and stress values.

B. Design requirements:
   1. General:
      a. In accordance with requirements in CCR, Title 8, Chapter 4, Subchapter 4, Article 6 for trench excavations 5 feet or more in depth and for trenches less than 5 feet in depth when there is potential for cave-in.
         1) Where such designs vary from excavation support standards set forth in CCR, Title 8, Chapter 4, Subchapter 4, Article 6, submit design calculations pursuant to general engineering design practice.
         2) Provide means for safe and stable excavations that are not less effective than required in CCR, Title 8, Chapter 4, Subchapter 4, Article 6.
         3) The preceding requirements do not apply to trench excavation support in accordance with standards set forth CCR, Title 8, Chapter 4, Subchapter 4, Article 6.
      b. Dewatering:
         1) Dewater soil inside shoring as specified in Section 02240 - Dewatering.
         2) Do not lower groundwater outside of shoring more than 1 foot.
         3) Recharge groundwater outside shoring to limit groundwater draw down outside of shoring to amount specified above.
      c. When electing to design with material stresses for temporary construction higher than allowable stresses prescribed in building code as specified in Section 01410 - Regulatory Requirements, increase in such stresses shall not exceed 10 percent of value of prescribed stresses.
      d. Minimum safety factor used for design shall not be less than 1.5.
      e. Calculated minimum depth of penetration of shoring below bottom of excavation shall be increased not less than 30 percent if full value of allowable passive pressure is used in design.
      f. Maximum height of cantilever shoring above bottom of excavation shall not exceed 15 feet. Use braced shoring when height of shoring above bottom of excavation exceeds 15 feet.
      g. Location of point of fixity for shoring shall not be less than half calculated minimum embedment depth below bottom of excavation.
      h. Generally acceptable references for design of shoring and excavations are as follows:
         1) ASCE Guidelines of Engineering Practice for Braced and Tied-Back Excavations.
         2) Caltrans California Trenching and Shoring Manual.
         3) NAVFAC Design Manual 7.2.
         4) NAVFAC Design Manual 7.3.
         5) USS Steel Sheet Piling Design Manual.
      i. Maximum total deflection of shoring at any point on shoring shall not be more than 1/2inch.

   2. Soil anchors, rock anchors, and deadman anchors:
      a. Design tieback anchors for a safety factor of not less than 2 times calculated load from shoring.

b. Proof load production anchors to 125 percent of calculated load from shoring.
c. Lock off production anchors at calculated load from shoring.
d. Length of soil anchors used to calculate resistance to load from shoring shall not include any length within potential active pressure soil failure zone behind face of shoring.
e. Design tie rods for tieback anchors for 130 percent of calculated load from shoring.
f. Design tie rods for tieback anchors for 150 percent of the calculated load from shoring when tie rod couplers are used and for other conditions where stress concentrations can develop.

3. Set inside face of shoring back from structure not less than greater of following:
   a. 5 feet from face of wall.
   b. 2 foot-6 inches from edge of foundation.
   c. Depth of excavation below bottom of foundation.

C. Performance requirements:
1. General:
   a. Support faces of excavations and protect structures and improvements in vicinity of excavations from damage and loss of function due to settlement or movement of soils, alterations in ground water level caused by such excavations, and related operations.
   b. Specified provisions:
      1) Complement, but do not substitute or diminish, obligations of the Contractor for furnishing of safe place of work pursuant to provisions of the Occupational Safety and Health Act of 1970 and its subsequent amendments and regulations and for protection of work, structures, and other improvements.
      2) Represent minimum requirement for:
         a) Number and types of means needed to maintain soil stability.
         b) Strength of such required means.
         c) Methods and frequency of maintenance and observation of means used for maintaining soil stability.
2. Provide safe and stable excavations by means of sheeting, shoring, bracing, sloping, and other means and procedures, such as draining and recharging groundwater and routing and disposing of surface runoff, required to maintain stability of soils and rock.
3. Provide support for trench excavations for protection of workers from hazard of caving ground.
4. Provide shoring:
   a. Where, as result of excavation work and analysis performed pursuant to general engineering design practice, as defined in this Section:
      1) Excavated face or surrounding soil mass may be subject to slides, caving, or other types of failures.
      2) Stability and integrity of structures and other improvements may be compromised by settlement or movement of soils, or changes in soil load on structures and other improvements.
   b. For trenches 5 feet and deeper.
   c. For trenches less than 5 feet in depth, when there is potential for cave-in.

5. For safe and stable excavations, use appropriate design, construction, and maintenance procedures to minimize settlement of supported ground and to prevent damage to structures and other improvements, including:
    a. Using stiff shoring systems.
    b. Following appropriate construction sequence.
    c. Using shoring system that is tight enough to prevent soil loss through the shoring.
    d. Using shoring system that extends far enough below bottom of excavation to prevent piping, heave, or flow of soil under shoring.
    e. Design for safety factor of not less than 1.50.
    f. Providing surface runoff routing and discharge away from excavations.
    g. Where dewatering inside shoring is necessary, recharge groundwater outside shoring as necessary to prevent settlement in area surrounding shored excavation.
    h. Where sheet piling is used, use interlocking type sheets:
        1) Sheet piles shall be continuous and driven in interlock.
        2) If bottom of the excavation is located below the water table, use “ball and socket” or “thumb and finger” type interlock.
    i. Not applying shoring loads to existing structures and other improvements.
    j. Not changing existing soil loading on existing structures and other improvements.
    k. Provide welded steel packing between soil retaining members such as sheet piles and wales and similar members when gap exceeds 1/2 inch before wales are loaded.

PART 3 EXECUTION

3.01 CONSTRUCTION

A. Installation of shoring:
    1. Install means for providing safe and stable excavations as indicated in Submittals.

B. Removal of shoring:
    1. Except for concrete encased soldier piles, slurry walls, and similar shoring systems, remove shoring by completion of the Work.
    2. Select shoring system and method of removal, which will minimize soil that sticks to shoring from creating voids and causing settlement.
    3. To prevent settlement caused by pulling shoring, fill voids with pressure injected grout:
        a. Inject grout starting at bottom of void and progressively fill void to grade.
        b. Minimize length of shoring removed ahead of grouting operation and limit time void is left ungrouted to prevent void from closing up before being grouted.
    4. Pressure preservative treated wood lagging may be left in place if acceptable to the Engineer.

C. Control points:
   1. Establish control points on shoring and on structures and other improvements in vicinity of excavation for measurement of horizontal and vertical movement:
      a. Set control points on shoring support system:
         1) Set points at distances not exceeding 25 feet at each support level.
   2. Promptly upon completion of construction of control points survey control points. Submit copy of field notes with measurement.
   3. Perform horizontal and vertical survey and measurement of control points at least once every week.
      a. Field notes shall show current measurement and change in measurement from first measurement taken.
   4. Set control points on corners of existing structures and on curbs, manholes., and other improvements at the locations indicated on the Drawings.
   5. Provide plumb bobs with horizontal targets indicating original position of plumb bobs in relation to shoring at control points.

D. Maintenance:
   1. Where loss of soil occurs, plug gap in shoring and replace lost soil with fill material acceptable to the Engineer.
   2. Where measurements and observations indicate possibility of failure or excessive movement of excavation support, determined in accordance with general engineering design practice, take appropriate action immediately.

END OF SECTION

SECTION 02280

SUBSURFACE UTILITY ENGINEERING

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Requirements for subsurface utility engineering (SUE) as part of the Work for new pipelines.

1.02 REFERENCES

A. American Society of Civil Engineers (ASCE):
   1. 38-02 Standard Guideline for the Collection and Depiction of Existing and Subsurface Utility Data.

1.03 DEFINITIONS

A. General: Definitions used in this Section are in accordance with ASCE 38-02.

1.04 REQUIREMENTS

A. Existing utilities indicated on the Drawings are approximate only and are provided based on the best information available.

B. Existing utilities are shown for the convenience of Contractor only.
   1. It is the Contractor's responsibility to field verify the vertical and horizontal location of all utilities including those not indicated or incorrectly indicated on the Drawings.

C. Contractor is responsible to review all geotechnical reports, record drawings, and Contract Documents.

D. Coordinate with utility locator, such as CALL BEFORE YOU DIG, and other affected entities when they have jurisdiction over the project site.

E. Contractor is responsible for protecting all utilities encountered.
   1. Before any excavation, follow requirements of Section 01140 - Work Restrictions.
   2. If a conflict exists between what is indicated on the Drawings and what exists in the field, Contractor shall notify Engineer immediately.

F. Where scheduled, provide subsurface utility engineering services by a Civil Engineer registered in the state of Californiain accordance with ASCE 38-02.

G. Requirements: The SUE shall entail the following at a minimum:
   1. Review of existing record drawings.
   2. Geophysical methods such as ground-penetrating radar.
   3. Soft excavation to locate known utilities along the proposed pipeline alignment.

4. Open trench excavation to locate unknown utilities along the proposed pipeline alignment.
5. Utilization of field survey by a Professional Land Survey licensed in the state of California for determination of vertical and horizontal locations.

1.05 QUALIFICATIONS

A. General: Contractor shall utilize the services of a qualified subconsultant for SUE services with minimum qualifications that include but are not limited to:
   1. Minimum of 5 years of SUE experience in the state of California where providing vertical and horizontal locations of utilities in accordance with ASCE 38-02 utility quality level A was required.
   2. Completion of 5 SUE projects of equal or greater magnitude within the past 5 years.

1.06 SUBMITTALS

A. Shop drawings:
   1. Contractor shall submit all SUE information as follows:
      a. Plan drawings that clearly illustrate vertical and horizontal location of known and unknown utilities.
         1) Horizontal location shall include northing and easting coordinates.
      b. Identifies size and material and service for known utilities.
      c. Identify size and material for unknown utilities.
   2. Review of shop drawings and calculations by Engineer and Owner are for record only.
   3. Drawings shall be performed, stamped, and endorsed by a Civil Engineer registered in the state of California.
   4. Field survey information shall be performed, stamped, and endorsed by a Surveyor registered in the state of California.

B. Detailed sequence of SUE:
   1. Submit a schedule for all SUE events that shows start, end, and intermediate milestones.
   2. Provide sketches showing the conditions at various stages in the sequence of SUE.

C. Submit submittals for stability of excavations as a complete package and include all items required in this Section.
   1. Incomplete submittals will not be reviewed and will be returned for resubmittal as a complete package.

1.07 SEQUENCING AND SCHEDULING

A. Coordinate all Work with restrictions provided in Section 01140 - Work Restrictions.

B. Do not begin Work until submittals have been accepted by Engineer and until equipment and materials necessary for installation are on site.

C. Submit submittals a minimum of 30 days prior to the scheduled date to begin excavation work.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 SUE SCHEDULE

A. Provide SUE services to identify all crossing utilities and connection points for the following pipelines.

Description	Reference Drawings
16-inch Plant Drain (PD)	00C002, 00C003, 00C005
12- inch Plant Drain (PD)	00C002, 00C005
12-inch Reclaimed Water (3W)	00C003, 00C006
8-inch Storm Drain (SD)	00C002, 00C007
6-inch Primary Sludge (PS)	00C002, 00C003, 00C004

END OF SECTION

SECTION 02300

EARTHWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Loosening, excavating, filling, grading, borrow, hauling, preparing subgrade, compacting in final location, wetting and drying, and operations pertaining to grading for proposed site work..
   2. Backfilling and compacting under and around structures.

1.02 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):
   1. Standard Specifications for Highway Bridges.

B. ASTM International (ASTM):
   1. D1557 - Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3).
   2. D6938 - Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Backfill adjacent to structure: Backfill within volume bounded by the exterior surfaces of structure, the surface of undisturbed soil in the excavation around structure, and finish grade around structure.
   2. Embankments: Dikes, levees, berms, and similar facilities.
   3. Excavation: Consists of loosening, removing, loading, transporting, depositing, and compacting in final location, wet and dry materials, necessary to be removed for purposes of construction of structures, ditches, grading, roads, and such other purposes as are indicated on the Drawings.

1.04 SUBMITTALS

A. Copy of Property Owner’s Agreement allowing placement of surplus soil material on their property.

B. Excavation plan:
   1. All excavations should comply with applicable local, state, and federal safety regulations including the current Occupational Safety & Health Administration (OSHA) Excavation and Trench Safety Standards. Construction site safety generally is the responsibility of the Contractor, who is responsible for the means, methods, and sequencing of construction operations.

2. To reduce potential for settlement of existing foundations, the contractor should consider structural shoring/ or underpinning if the projected footing geometries fall within an imaginary 1-1/2 to 1 (1.5:1) projection between the existing bottom of foundation and the proposed bottom of foundation. It is the contractor's responsibility through means and methods to prevent settlement of existing facilities during construction.
3. Excavated slope height, slope inclination, or excavation depths (including utility trench and wet well excavations) should in no case exceed those specified in local, state, and/or federal safety regulations (e.g., OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926, or successor regulations). Such regulations are strictly enforced and, if they are not followed, the Owner, Contractor, and/or earthwork and utility subcontractors could be liable for substantial penalties.
4. Should construction be performed during or subsequent to wet weather, near-surface site soils may be significantly above the optimum moisture content. These conditions could hamper equipment maneuverability and efforts to compact site soils to the recommended compaction criteria. Disking to aerate, chemical treatment, replacement with drier material, stabilization with a geotextile fabric or geogrid, or other methods may be required to mitigate the effects of excessive soil moisture and facilitate earthwork and construction operations.

C. Testing lab: Submit the Contractor's proposed testing laboratory capabilities and equipment.

D. Test reports:
1. Submit certified test reports of tests specified to be performed by the Contractor.
2. Sign and seal test reports by a registered civil engineer who practices geotechnical engineering registered in the state of California.

1.05 QUALITY ASSURANCE

A. Initial compaction demonstration:
1. Adequacy of compaction equipment and procedures: Demonstrate adequacy of compaction equipment and procedures before exceeding any of following amounts of earthwork quantities:
   a. 50 cubic yards of backfill adjacent to structures.
   b. 100 cubic yards of embankment work.
   c. 100 cubic yards of fill.
   d. 50 cubic yards of roadway base material.
   e. 100 cubic yards of road fill.
2. Compaction sequence requirements: Until specified degree of compaction on previously specified amounts of earthwork is achieved, do not perform additional earthwork of the same kind.
3. After satisfactory conclusion of initial compaction demonstration and at any time during construction, provide confirmation tests as specified under the Field Quality Control article.

B. Perform Work related to this Section in accordance with the approved Stormwater Pollution Prevention Plan (SWPPP).

1.06 SEQUENCING AND SCHEDULING

A. Schedule earthwork operations to meet requirements specified in this Section for excavation and uses of excavated material.

B. If necessary, stockpile excavated material in order to use it at specified locations.

C. Excavation, backfilling, and filling: Perform excavation, backfilling, and filling during construction in manner and sequence that provides drainage at all times.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Performance requirements:
   1. Where mud or other soft or unstable material is encountered, remove such material and refill space with stabilization material. Wrap stabilization material with stabilization fabric.
   2. Obtain acceptable import material from other sources if surplus obtained within the Project Site does not conform to specified requirements or are not sufficient in quantity.
   3. No extra compensation will be made for hauling of fill materials nor for water required for compaction.

2.02 MATERIALS

A. Water for compacting: Use water from source acceptable to the Engineer.

B. Soil and rock materials:
   1. General:
      a. Provide aggregate base course, Class 2 permeable, controlled low-strength material, drain rock, gravel, lightweight material, native material, sand, select material, and stabilization material where specified or indicated on the Drawings.
      b. If suitable surplus materials are available, obtain native material and select material from cut sections or excavations or imported materials.
   2. Aggregate base course materials: As specified in Section 02050 - Soils and Aggregates for Earthwork.
   3. Gravel: As specified in Section 02050 - Soils and Aggregates for Earthwork.
   4. Native material: As specified in Section 02050 - Soils and Aggregates for Earthwork.
   5. Sand: As specified in Section 02050 - Soils and Aggregates for Earthwork.
   6. Select material: As specified in Section 02050 - Soils and Aggregates for Earthwork.
   7. Stabilization material: As specified in Section 02050 - Soils and Aggregates for Earthwork.

C. Controlled low-strength material: As specified in Section 02312 - Controlled Low Strength Materials (CLSM).

D. Geotextile fabrics:
    1. Stabilization: As specified in Section 02621 - Stabilization Fabric.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions:
    1. Character and quantity of material:
        a. Verify character and quantity of rock, gravel, sand, silt, water, and other inorganic or organic materials to be encountered in Work to be performed.
        b. Determine gradation, shrinkage, and swelling of soil, and suitability of material for use intended in Work to be performed.
        c. Determine quantity of material, and cost thereof, required for construction of backfills, cuts, embankments, excavations, fills, and roadway fills, whether from on-site excavations or imported materials. Include in cost of Work to be performed.
        d. Include wasting of excess material, if required, in the cost of Work to be performed.

3.02 PREPARATION

A. Backfills:
    1. After clearing and excavation are completed, scarify entire areas that underlie backfills or structures to a depth of 8 inches and until surface is free of ruts, hummocks, and other features that would prevent uniform compaction by equipment to be used.
    2. Recompact scarified areas to density specified before placing backfill material or concrete. The exposed subgrades (existing or over-excavated) to receive engineered fills should be proof-rolled with a fully-loaded tandem-axle dump truck or water truck.
    3. If foundation areas have soft soils, do not scarify the top 8 inches prior to compaction.
        a. Remove loose material using hand equipment or with a flat-edged backhoe bucket. Over-excavate to firm, native soil, or to depths determined by the geotechnical engineer during construction.
        b. Do not remold and weaken the remaining soil by operating heavy equipment on final bottom elevation of excavation**.**
    4. If foundation areas have cemented rock, cobbles, or boulders, do not scarify the top 8 inches prior to compaction. Moisten the native soil and compact the coarse fill as specified in this Section.
    5. Do not place backfill against walls until:
        a. Walls have been cast full height of structure and concrete has reached the specified strength.
        b. Connecting slabs and beams have been cast, and concrete has reached the specified strength.
    6. Prior to backfilling:
        a. Remove forms.
        b. Clean trash and debris from the excavation site.

7. After inspection of foundation, walls, and pipes, place backfill symmetrically around structures to prevent eccentric loading of structures.

B. Fills:
   1. After clearing is completed, scarify entire areas that underlie fill sections or structures to a depth of 8 inches and until surface is free of ruts, hummocks, and other features that would prevent uniform compaction by equipment to be used.
   2. Recompact scarified areas to density specified for compacted fills before placing of fill material or concrete.
   3. If fill areas have cemented rock, cobbles, or boulders, do not scarify the top 8 inches prior to compaction. Moisten the native soil and compact the coarse fill as specified in this Section.

C. Roadway fills:
   1. After clearing is completed, scarify entire areas that underlie roadway fills to a depth of 8 inches and until surface is free of ruts, hummocks, and other features that would prevent uniform compaction by equipment to be used.
   2. Recompact scarified areas to density specified for roadway fills before placing of roadway fill material.
   3. If roadway fill areas have cemented rock, cobbles, or boulders, do not scarify the top 8 inches prior to compaction. Moisten the native soil and compact the coarse fill as specified in this Section.

D. Sloped surfaces for fill or foundations:
   1. Foundations for fill having slopes in excess of 1 vertical to 4 horizontal:
      a. Bench or terrace to adequately key existing ground and fill built thereon.
   2. Slopes of original hillsides and old fills: Bench minimum of 10 feet horizontally as fill is placed.
   3. Provision of new benches:
      a. Start new bench wherever vertical cut of next lower bench intersects existing grade.
      b. Recompact material thus cut out along with new embankment material at no additional cost to the Owner.

3.03 INSTALLATION

A. General:
   1. Dispose of excavated materials that are not required or are unsuitable for fill and backfill in lawful manner.
   2. Dispose of surplus material on private property only when written permission agreement is furnished by the owner of the property. Submit copies of such agreements.
   3. Rocks, broken concrete, or other solid materials larger than 4 inches in greatest dimension: Remove from the Project Site at no additional cost to the Owner.
   4. Stabilization of subgrade: Provide materials used, or perform Work required, to stabilize subgrade so it can withstand loads that may be placed upon it by the Contractor’s equipment.

B. Borrow area: There is no borrow area on the Project Site.
   1. Where material is required, import material from source located off Project Site selected by the Contractor and subject to acceptance by the Engineer.

C. Compaction:
   1. Provide specified compaction for backfills, cuts, fills, roadway fills, and other earthwork.
   2. Perform confirmation tests to verify and confirm that Work has complied, and is complying at all times, with compaction requirements specified in this Section for initial compaction demonstration and field quality control testing.
   3. In-place density of compacted backfills, cuts, embankments, fills, and roadway fills determined in accordance with ASTM D6938.
   4. Maximum density, laboratory compaction: Soil maximum density and optimum water content when tested in accordance with ASTM D1557.
   5. To prevent damage to structures due to backfilling operations, place backfill with equipment that does not exceed AASHTO Standard Specifications for Highway Bridges, H-20 vehicle loading, within a distance from the face of the structure of not less than 1/2 the depth of backfill.
      a. Depth of backfill is the distance between the level being compacted and the bottom of the excavation. Outside this distance, heavier compaction equipment may be used.
   6. Compact to percentage of maximum density as follows:
      a. Backfill adjacent to structures: At least 95 percent.
      b. Backfilling voids: At least 95 percent.
      c. Demolition areas: At least 95 percent.
      d. Other areas: At least 95 percent.
      e. Under present and future structures: At least 95 percent.
      f. Under roadways, parking and storage areas, curbs, and sidewalks: Combination of 90 percent and 95 percent per City of Manteca standard detail U-5.
      g. Upper 6 inches of cuts: At least 95 percent.
      h. Fills: At least 95 percent.

D. Dewatering: As specified in Section 02240 - Dewatering.

E. Excavation:
   1. Blasting: Not permitted.
   2. Excavations for trenching: As specified in Section 02318 - Trenching.
   3. Excavations for structures:
      a. Provide excavations conforming to the dimensions and elevations indicated on the Drawings for each structure.
      b. After clearing is complete, excavate for the structure, down to the elevation indicated on the Drawings. Unless directed by the Engineer, do not carry excavations below elevation indicated on the Drawings.
      c. Where soil is encountered having unsuitable bearing value, the Engineer may direct in writing that excavation be carried to elevations below those indicated on the Drawings.
      d. Where excavations are made below elevations indicated on the Drawings, adjust elevations of excavations in accordance with the following requirements:
         1) Under slabs: Restore to proper elevation in accordance with procedure specified for backfill in this Section.
         2) Under footings: Restore to the proper elevation using one of the following:
            a) Aggregate base course.

b) Controlled low-strength material.

e. Excavation width:
1) Extend excavations at least 2 feet clear from walls and foundations of structures to allow for placing and removal of forms, installation of services, and inspection.
2) Do not undercut slopes.

f. Difficulty of excavation: No extra compensation will be made for removal of rock or any other material due to difficulty of excavation.

4. Excavation of ditches and gutters:
a. Cut ditches and gutters accurately to cross sections and grades indicated on the Drawings.
b. Take care not to excavate ditches and gutters below grades indicated on the Drawings.
c. Backfill excessive ditch and gutter excavations to grade with suitable material acceptable to the Engineer.
d. Do not deposit any material within 3 feet of edge of ditch unless otherwise indicated on the Drawings.

5. Necessary over excavation:
a. Where it becomes necessary to excavate beyond normal lines of excavation in order to remove boulders or other interfering objects, backfill voids remaining after removal as specified in backfilling of voids below, or as acceptable to the Engineer.
b. Backfill voids with material acceptable to the Engineer:
1) With acceptance of the Engineer, backfill with one of the following:
a) Aggregate base course.
b) Controlled low-strength material.

F. Materials for backfills, embankments, fills, and roadway fills:
1. General:
a. Obtain import material from other sources if surplus materials from cuts and excavations obtained from within the Project Site do not conform to specified requirements or are not sufficient in quantity for construction of Project.

2. Backfills:
a. Backfill adjacent to structures, slabs, or walls: Native material or imported material meeting the requirements of select material, unless otherwise specified or indicated on the Drawings.
b. Backfill material under concrete structures: Aggregate base course material, except in areas where controlled low-strength material or concrete encasement are indicated on the Drawings.
c. Extend backfill in any area under concrete structures from undisturbed soil or rock to the bottom aggregate base course material layer.

3. Fills:
a. Native material or imported material meeting the requirements of select material, unless otherwise specified or indicated on the Drawings.
b. Extend fill in any area under concrete structures from undisturbed soil or rock to the bottom aggregate base course material layer.

4. Roadway fills: One of the following, unless otherwise specified or indicated on the Drawings:
a. Aggregate base course material.

b. Native material or imported material meeting the requirements select material.

G. Placement:
1. General:
a. Lines and grades:
1) Construct backfills, embankments, fills, and road fills, at locations and to lines and grades indicated on the Drawings.
2) Overbuild permanent fill slopes by at least 1 foot and then cut to final grade to provide adequate compaction of the remaining fill.
2. Backfills:
a. Place loose material in successive layers that do not exceed 8 inches in depth after compaction.
b. Bring each layer to a moisture content between optimum moisture content and 1 to 4 percent above optimum moisture content before compacting.
c. Defective compacted backfills: Remove and recompact.
3. Fills:
a. Place loose material in successive layers that do not exceed 8 inches in depth after compaction.
b. Bring each layer to a moisture content between optimum moisture content and 1 to 4 percent above optimum moisture content before compacting.
c. Defective compacted fills: Remove and recompact.
4. Roadway fills:
a. Place loose material in successive layers that do not exceed 8 inches in depth after compaction.
b. Bring each layer to a moisture content between optimum moisture content and 1 to 4 percent above optimum moisture content before compacting.
c. Defective compacted roadway fills: Remove and recompact.

3.04 FIELD QUALITY CONTROL

A. Confirmation tests:
1. Contractor's responsibilities:
a. Adequacy of compaction equipment and procedures:
1) Demonstrate adequacy of compaction equipment and procedures.
2) At each test location include tests for each type or class of backfill from bedding to finish grade.
b. Compaction sequence requirements:
1) Do not perform additional earthwork of the same kind until specified degree of compaction has been demonstrated.
c. Cost of confirmation tests: Paid for by the Contractor.
d. Qualifications of the Contractor's testing laboratory: Acceptable to the Engineer.
e. Copies of confirmation test reports: Submit promptly to the Engineer.
2. Frequency of confirmation testing:
a. Maximum dry density versus moisture:
1) Backfill: Once per 500 cubic yards.
2) Cuts: Once per 1,000 cubic yards.
3) Fills: Once per 500 cubic yards.
4) Roadway fills: Once per 500 cubic yards.

b. Cost of confirmation tests:
    1) Paid for by the Contractor.
c. Qualifications of the Contractor's testing laboratory:
    1) Perform confirmation testing by soils testing laboratory acceptable to the Engineer. Copies of confirmation test reports: Submit promptly to the Engineer.

B. Tolerances:
1. Finish grading of backfills, cuts, embankments, fills, and roadway fills:
    a. Perform fine grading under concrete structures such that finish surfaces are never above the grade or cross section indicated on the Drawings and are never more than 0.10 feet below.
    b. Provide finish surface for areas outside of structures that are within 0.10 feet of grade or cross section indicated on the Drawings.
2. Areas which are not under structures, concrete, asphalt, roads, pavements, sidewalks, dikes, and similar facilities:
    a. Provide finish graded surfaces of either undisturbed soil, or cohesive material not less than 6-inches deep.
    b. Intent of proceeding is to avoid sandy or gravelly areas.
3. Finish grading of surfaces:
    a. Reasonably smooth, compacted, and free from irregular surface changes.
    b. Provide degree of finish that is ordinarily obtainable from blade grader operations, except as otherwise specified.
    c. Uniformly grade areas that are not under concrete.
    d. Finish ditches and gutters so that they drain readily.

C. Compliance tests:
1. Frequency of testing: Periodic compliance tests will be made by the Engineer to verify that compaction is meeting requirements previously specified.

3.05 ADJUSTING

A. Finish grades of excavations, backfills, and fills:
1. Repair and reestablish grades to required elevations and slopes due to any settlement or erosion that may occur from action of the elements or any other cause prior to final acceptance.

3.06 PROTECTION

A. Finish grades of backfills, cuts, excavations, and fills:
1. Protect newly graded areas from erosion and deterioration by action of the elements.

B. Ditches and gutters:
1. Maintain ditches and gutters free from detrimental quantities of debris that might inhibit drainage until final acceptance.

END OF SECTION

SECTION 02312

CONTROLLED LOW STRENGTH MATERIAL (CLSM)

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Controlled low strength material (CLSM), also known as flowable fill.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 229R - Report on Controlled Low-Strength Materials.
   2. 301 - Specifications for Structural Concrete.

B. ASTM International (ASTM):
   1. C33 - Standard Specification for Concrete Aggregates.
   2. C94 - Standard Specification for Ready Mix Concrete.
   3. C143 - Standard Test Method for Slump of Hydraulic Cement Concrete.
   4. C150 - Standard Specification for Portland Cement.
   5. C260 - Standard Specification for Air-Entraining Admixtures for Concrete.
   6. C403 - Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance**.**
   7. C494 - Standard Specification for Chemical Admixtures for Concrete.
   8. C618 - Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
   9. D698 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3(600 kN-m/m^3)).
   10. D1557 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)).
   11. D4832 - Standard Test Method of Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders.
   12. D5971 - Standard Practice for Sampling Freshly Mixed Controlled Low Strength Material.
   13. D6023 - Standard Test Method for Density (Unit Weight), Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low-Strength Material.

1.03 SUBMITTALS

A. Product data: Submit data completely describing materials in the mix and demonstrating compliance with the requirements of this Section.
   1. Cement: Mill tests. Indicate alkali content representative of each shipment.
   2. Fly ash: Identify source and type of fly ash.
   3. Water: Identify source and quality if not from a municipal treatment source.
   4. Admixtures: Manufacturer's product data indicating suitability for use in CLSM mixes and recommended dosage rates.

5. Aggregate:
    a. Submit source, type, and sieve analyses. Include testing to demonstrate that materials in accordance with ASTM C33 requirements.
    b. Resubmit at any time there is a significant change in grading of materials.

B. Mix design:
    1. Submit full details, including mix design calculations for mix proposed for use.
    2. Trial batch test data:
        a. Submit data for each test cylinder.
        b. Submit data that identifies mix and slump for each test cylinder.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Store or stockpile cement, fly ash, and aggregate in accordance with ACI 301.

B. Store admixtures in accordance with the manufacturer's recommendations.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Mixture of portland cement, water, pozzolan, fine aggregate and admixtures, proportioned in accordance with the recommendations of ACI 229 to produce a homogeneous mixture that is flowable, that will readily work into corners and angles; that will not segregate in the plastic state; and that is self-compacting at the time of placement without the use of mechanical vibration.

B. Performance requirements:
    1. Air content, total calculated in accordance with ASTM D6023: Not less than 8.0 percent, nor greater than 12.0 percent.
    2. Compressive strength, measured in accordance with ASTM D4832 at 28 days: Not less than 50 pounds per square inch, nor greater than 150 pounds per square inch.
    3. Wet density: Not greater than 132 pounds per cubic foot.
    4. Slump, measured in accordance with ASTM C143 at the point of placement: Greater than 9 inches and that allows CLSM to flow freely and to be self-compacting during placement.

2.02 MATERIALS

A. Cement:
    1. Portland cement in accordance with ASTM C150, Type I or Type II.
    2. Having total alkali content not more than 0.60 percent.

B. Fly ash: Class C or Class F fly ash in accordance with ASTM C618.

C. Water:
    1. Potable water: Clean and free from oil and deleterious amounts of alkali, acid, organic matter, or other substances.

D. Admixtures: Products of a single manufacturer, specifically manufactured or recommended by that manufacturer for use in CLSM.
   1. Air-entraining admixture: In accordance with ASTM C260.
   2. Water-reducing admixture: In accordance with ASTM C494, Type A.

E. Aggregate:
   1. Non-expansive, non-reactive, inert natural sand conforming to the following requirements:
      a. Not more than 12 percent passing a No. 200 sieve.
      b. No plastic fines present.
      c. Including pea gravel no larger than 3/8 inch.
   2. Non-expansive, non-reactive, inert natural sand in accordance with ASTM C33 for fine aggregate.

2.03 MIXES

A. See the Design and Performance Criteria article in this Section for performance requirements of the plastic and hardened mix.

2.04 SOURCE QUALITY CONTROL

A. Trial batch:
   1. After mix design has been accepted by the Engineer, have trial batch of the accepted mix design prepared by testing laboratory acceptable to the Engineer.
   2. Prepare trial batches using the specific cement, fly ash, admixtures, aggregates, and water proposed for the Work.
   3. Prepare trial batch with quantity sufficient to determine slump, workability, and consistency; and to provide test cylinders as indicated in this Section.

B. Trial batch testing:
   1. Determine slump in accordance with ASTM C143, with the following modifications:
      a. Do not rod the concrete material.
      b. Place material in slump cone in one semi-continuous filling operation, slightly overfill, tap lightly, strike off, and then measure and record slump.
   2. Prepare and test trial batch specimens in accordance with ASTM D4832, with the following modifications:
      a. Provide cylindrical test specimens, each 6 inches in diameter by 12 inches high.
      b. Provide a minimum of 8 cylinders for testing of each trial batch.
      c. Fill the molds to overflowing and tap sides lightly to settle the mix.
      d. Do not rod the mix for consolidation in the cylinder.
      e. Strike off the excess material.
   3. Place test cylinders in a moist curing room. Exercise caution in moving and transporting the cylinders since they are fragile and will withstand only minimal bumping, banging, or jolting without damage.
   4. Do not remove the test cylinder from mold until that cylinder is to be capped and tested.
      a. Perform the capping carefully to prevent premature fractures.
      b. Do not perform initial compression test until the cylinders reach a minimum age of 3 days.

5. Provide compressive strength tests:
    a. Test 4 test cylinders at 7 days after casting, and another 4 cylinders at 28 days after casting.
    b. Compression strength of the 4 test cylinders tested at 28 days shall be equal to or greater than the minimum required compression strength, but shall not exceed maximum compression strength.

C. If the trial batch tests do not meet the Specifications for strength or density, revise and re-submit the mix design, prepare additional trial batch(es), and complete additional trial batch tests. Repeat until an acceptable trial batch that conforms to the specifications is produced.
    1. All trial batches and acceptability of materials shall be paid by the Contractor.
    2. After acceptance, do not change the mix design without submitting a new mix design, trail batches, and test information.

PART 3 EXECUTION

3.01 PREPARATION

A. Do not place CLSM until preparation and condition of surfaces receiving the fill have been observed and accepted by the Engineer.

B. Remove debris foreign matter, and standing or running water from excavations and areas receiving CLSM before placement.

3.02 INSTALLATION

A. Pipes and trenches.
    1. Install CLSM as indicated on the Drawings and specified.
    2. Where CLSM is placed around and over pipes, secure pipes in place, or place CLSM in lifts to prevent pipe flotation.
    3. Where CLSM is placed in long, open trenches, confine material using bulkheads of sandbags, earth dams, or stiffer concrete at open ends of placement.
    4. Place CLSM at specified access points in the abandoned in-place pipe**.**

B. Soil preparation:
    1. Prior to placement of CLSM, prepare underlying soils as follows:
        a. Scarify surface to a depth of 8 inches.
        b. Adjust moisture content to or slightly above the optimum in accordance with ASTM D1557.
        c. Re-compact scarified surface to a minimum of 90 percent relative density in accordance with ASTM D1557.

3.03 MEASURING, BATCHING, MIXING, AND TRANSPORTING

A. Measure, batch, mix, and transport CLSM in accordance with the requirements of ASTM C94 and as specified in this Section.

B. Mix until there is uniform distribution of materials.

C. Discharge mixer completely prior to recharging.

D. After trial batch testing and mix acceptance, maintain slump during construction within 1 inch of the design slump.

3.04 PLACING

A. Place controlled low strength material by method that preserves the quality of the material in terms of compressive strength and density.

B. Maintain fluid properties of the mix during placement.
   1. At point of placement, provide material that flows easily around, beneath, or through walls, pipes, conduits, or other structures.
   2. Do not place CLSM that has partially hardened or that has been contaminated by foreign materials.
   3. Handle and place CLSM using methods that minimize segregation of the mix.
   4. Deposit mix as near its final position as possible to avoid segregation due to rehandling or flowing.
   5. Contain and confine mix while it is fluid. Design containment structures and bracing at walls and forms to withstand lateral pressures of wet mix.

C. Lifts:
   1. Limit lift heights of CLSM placed against structures and other facilities that could be damaged due to the pressure from the CLSM, to the lesser of 3 feet or the lift height indicated on the Drawings.
   2. Do not place another lift of CLSM until the last lift of CLSM has set and gained sufficient strength to prevent additional lateral load against the forms or structure due to the weight of the next lift of CLSM.

D. Water conditions:
   1. Do not place CLSM in standing or flowing water.
   2. Do not permit water to flow over the surface of freshly placed or un-hardened CLSM.
   3. Do not submerge CLSM in water within 24 hours after placement.

E. Manage CLSM bleed water.
   1. Grade top surface of CLSM to drain away from the fill.
   2. Provide side containment that permits bleed water to drain to a contained management area away from the fill.

3.05 CURING AND PROTECTION

A. Curing:
   1. Prior to and during curing, install barriers to prevent equipment or personnel from falling into or becoming entrapped in CLSM.

B. Protect CLSM from:
   1. Damage from the elements.
   2. Damage of any nature during surrounding construction operations.
   3. Freezing: Do not use salt, manure, or other chemicals to provide protection from cold temperatures.

3.06 FIELD QUALITY CONTROL

A. Provide quality control over the Work of this Section as specified in Section 01450 - Quality Control and Section 01460 - Contractor Quality Control Plan, and as specified in this Section.

B. General:
   1. Engineer inspection and acceptance required prior to placement.
   2. Make provisions for and furnish all material for the test specimens, and provide manual assistance to assist the Owner's testing laboratory in preparing said specimens.

3.07 FIELD QUALITY ASSURANCE

A. Provide quality control over the Work of this Section as specified in Section 01450 - Quality Control and Section 01460 - Contractor Quality Control Plan.

B. Field inspections:
   1. Engineer shall provide on-site inspection for the Work of this Section.
   2. Advise the Engineer of readiness to proceed at least 24 hours prior to each placement of CLSM.
   3. Required inspections:
      a. Engineer will observe the prepared areas. Do not place CLSM until the Engineer has observed and accepted preparations.
   4. Record of inspections.

C. Special tests and inspections:
   1. As specified in Section 01455 - Regulatory Quality Assurance.

D. Field sampling and testing:
   1. During construction, the Contractor shall provide sampling and testing to determine whether the CLSM, as produced and placed, complies with the requirements specified.
      a. Make provisions for and furnish material for test specimens.
         1) Cooperate by allowing free access for the Owner's independent testing firm to sample and test materials.
         2) Provide assistance in obtaining and preparing said specimens.
   2. Sample CLSM for testing in accordance with ASTM D5971.
   3. Required tests:
      a. Air content: Prepare sample and test in accordance with ASTM D6023.
      b. Compressive strength: Prepare and test cylinder specimens in accordance with ASTM D4832.
         1) Prepare 6-inch diameter by 12-inch high specimens for testing.
            a) Provide 1 set of specimens for each 150 cubic yards of CLSM placed, but not less than 1 set for each half day's placement.
            b) Prepare and test not less than 3 cylinders for each set.
            c) Place CLSM in the molds in accordance with ASTM D4832. Do not rod or otherwise consolidate the material in the mold.
            d) In accordance with ASTM D4832 recommendations for displacing bleed water at the top of the molds and refilling the molds before covering with a lid. Do not use air-tight lids.

2) Place the cylinders in a safe location away from construction activities.
    a) Protect cylinders from bumping and impact.
    b) Maintain temperature surrounding cylinders between 60 and 80 degrees Fahrenheit until delivery to the laboratory for testing.
    c) After the first day, surround molds with a high humidity environment by covering with wet burlap or equivalent highly absorptive material.
        (1) Maintain saturation of the cover.
        (2) Do not sprinkle water directly on the cylinders.
3) After 4 days, place the cylinders in a protective container for transport to the laboratory for testing.
    a) Exercise caution in moving and transporting the cylinders since they are fragile and will withstand only minimal bumping, banging, or jolting without damage.
    b) Transport container may be a box with a Styrofoam or similar lining that will limit jarring and bumping of the cylinders.
4) Upon receipt at the testing laboratory, place test cylinders in a moist curing room until dates for testing.
5) Do not remove test cylinders from molds until the day that cylinders is to be capped and tested.
6) Cap and test for compressive strength in accordance with ASTM D4832.
    a) Do not perform initial compression test until the cylinders reach an age of at least 4 days.
    b) Test 1 cylinder at 7 days and 2 cylinders at 28 days.
7) Compressive strength of the cylinders tested at 28 days shall be equal to or greater than the minimum required compression strength, but shall not exceed maximum compression strength specified.

3.08 NON-CONFORMING WORK

A. When testing or observation indicates CLSM with properties outside the specified and accepted range, the Engineer will issue instructions regarding disposition of non-conforming materials.

B. Engineer may:
    1. Reject CLSM represented by those test specimens and require its removal and replacement.
    2. Require modification of the mix design to provide CLSM with the properties specified.

C. Make such modifications at no additional expense to the Owner and with no adjustment to the schedule.

END OF SECTION

SECTION 02318

TRENCHING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Trench excavation and trench backfill for pipelines, manholes, vaults, and appurtenances.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. D1557 - Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3).
   2. D6938 - Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).
   3. D2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Backfill: Material placed in trench above the pipe embedment zone.
   2. Bedding: Material placed under, around, and over pipes or ducts in trenches.
   3. Fine grading: Bedding material placed directly below pipes or ducts to provide support at the bottom of the trench and to bring those elements to required grades and elevations.
   4. Flexible pipe: Includes steel, ductile iron, thermoplastics such as polyvinyl chloride (PVC) and high-density polyethylene (HDPE), thermosetting plastics such as fiberglass-reinforced polymer (FRP), bar-wrapped concrete cylinder pipe, and corrugated steel pipes.
   5. Haunch zone: Material placed below and beside the pipe up to the pipe springline.
   6. Lift: A layer of soil or aggregate material, measured before compaction.
   7. Maximum density, Field Compaction: Soil density and water content when tested in accordance with ASTM D6938.
   8. Maximum density, Laboratory Compaction: Soil maximum density and optimum water content when tested in accordance with ASTM D1557**.**
   9. Pavement section: Includes pavement plus underlying courses such as base course and subgrade.
   10. Pipe embedment zone: Includes bedding, fine grading, and haunch zone.
   11. Pipe foundation: Material placed at the bottom of trench to provide support.
   12. Pipe springline: A horizontal reference line located at mid-height, or halfway point, of a circular conduit, pipe, or tunnel. It is the maximum horizontal dimension or diameter of a circular conduit, pipe, or tunnel.

13. Rigid pipe: Includes reinforced non-cylinder concrete, reinforced concrete cylinder, prestressed concrete cylinder, vitrified clay, polymer concrete, cast iron, asbestos cement and cast-in-place pipes.

1.04 SUBMITTALS

A. As specified in Section 01300 - Submittals.

B. Product data on soils and aggregates.
   1. Material source.
   2. Gradation.
   3. Test data to demonstrate compliance with requirements as specified in this Section.

C. Samples:
   1. Provide 50-pound sample of materials when requested by the Engineer.

D. Confirmation testing:
   1. Certification of Contractor's testing laboratory.
   2. Record copy report for tests performed by the Contractor's testing laboratory.

PART 2 PRODUCTS

2.01 MATERIALS

A. As specified in Section 02050 - Soils and Aggregates for Earthwork.

B. Controlled low-strength material: As specified in Section 02312 - Controlled Low Strength Material (CLSM).

PART 3 EXECUTION

3.01 PREPARATION

A. Stabilize excavations as specified in Section 02260 - Excavation Support and Protection.

B. Perform subsurface utility engineering (SUE) for utility locating and verification prior to any excavation work and as specified in Section 02280 - Subsurface Utility Engineering.

3.02 DEWATERING

A. As specified in Section 02240 - Dewatering.

3.03 TRENCH EXCAVATION

A. Excavate bottom of trench to depth indicated on the Drawings.

B. Areas of new fill or embankment:
   1. Prior to laying pipes or electrical service, place fill and compact as specified to not less than 2 feet above top of pipe, conduit, or duct bank.
   2. Excavate through fill for pipe trench.

C. Trench widths as specified in the following table:

Buried Pipe or Accessory	Minimum Trench Width	Maximum Trench Width
Nominal Pipe Diameter: 4-inch to 24-inch	OD + 18 inches	OD + 24 inches
Nominal Pipe Diameter: Greater than 24-inch	OD + 24 inches	OD + 36 inches
Manholes, vaults, valves, or other accessories	12 inches between outer surface and trench side or shoring	Not applicable

D. At access roads:
   1. Provide temporary asphalt or plating for traffic or access unless approved in writing by the Owner.
   2. When trench width at top of pipe is increased beyond width specified in this Section because of soil conditions, safety requirements, or other reasons, Engineer approval for remedy is required without additional cost to the Owner.
      a. Remedy may include upgrade laying conditions or install stronger pipe designed in accordance with Specifications.

3.04 TRENCH BACKFILL - GENERAL

A. Trench area terminology and locations as indicated on the Drawings.

B. Place material, except CLSM and concrete, in maximum 8-inch lifts, measured before compaction.

C. Backfilling of manhole excavation: In accordance with backfilling requirements for trenches as specified in this Section.

3.05 PIPE FOUNDATION

A. Provide trench bottom with firm, dry, uniform bearing surface at the grade indicated on the Drawings.

B. Excess excavation below elevation indicated on the Drawings will require installation of pipe foundation material to bring the trench bottom back to the elevation indicated on the Drawings at no additional cost to the Owner.
   1. Materials and placement:
      a. Stabilization material:
         1) Wrap stabilization material as specified in Section 02621 - Stabilization Fabric.

C. If bottom of trench excavation consists of soil:
   1. Scarify bottom of trench to a depth of 8 inches below the grade indicated on the Drawings.
   2. Materials and placement:
      a. Recompact scarified material per City of Manteca standard details U-5, U-6, or U-7.

D. If bottom of trench excavation consists of rock or any material that, because of its hardness, cannot be excavated to provide uniform bearing surface:
   1. Remove such rock or other material to a depth of not less than 4 inches below pipe embedment zone.
   2. Materials:
      a. CLSM.

E. If bottom of trench excavation consists of mud or other soft unstable material:
   1. Remove such unacceptable material to a depth of not less than 18 inches below pipe embedment zone.
   2. Material and placement:
      a. Stabilization material:
         1) Wrap stabilization material as specified in Section 02621 - Stabilization Fabric.

3.06 PIPE EMBEDMENT ZONE

A. Pipe displacement:
   1. Take necessary precautions in placement and compaction of bedding material to prevent displacement of piping.
   2. In event there is movement or floating of the piping, re-excavate, re-lay, and backfill the pipe.

B. Fine grading:
   1. Place 6 inches of approved haunch zone bedding material from the trench bottom to the bottom of the pipe or duct to provide support at the bottom of the trench and to bring those elements to required line and grade.

C. Depressions for joints or couplings:
   1. Excavate holes in the fine grading material at the bottom of the trench.
   2. Provide holes of sufficient width to provide ample room for grouting, banding, or welding as necessary for making joints and to ensure that pipe rests upon prepared trench bottom and not supported by any portion of the joint.

D. Rigid pipe:
   1. Pipe embedment zone: Below pipe springline:
      a. Materials and placement:
         1) Class III aggregate base compacted per City of Manteca standard details U-5, U-6, or U-7.
   2. Pipe embedment zone: Above pipe springline:
      a. Compacted to a depth above pipe: 12 inches minimum.
      b. Materials and placement:
         1) Native material compacted per City of Manteca standard details U-5 or U-6.

E. Flexible pipe:
    1. Pipe embedment zone:
        a. Compacted to a depth above pipe: 12 inches minimum.
        b. Materials and placement:
            1) Class III aggregate base compacted per City of Manteca standard details U-5, U-6, or U-7.
            2) CLSM. Place gravel bags to support and set pipe to line and grade prior to CLSM placement. Place CLSM in lifts as necessary to prevent floatation.
            3) Sand.

3.07 BACKFILL

A. Trenches:
    1. Materials and placement:
        a. Native soil or Native soil - select compacted per City of Manteca standard details U-5, U-6, or U-7.
        b. Imported fill compacted to 90 percent maximum dry density.
        c. Aggregate base course compacted per City of Manteca standard details U-5, U-6, or U-7.
        d. CLSM.

B. Trenches below or within 10 feet of the outside perimeter of structures:
    1. Backfill to underside of structural fill below structure, as specified in Section 02300 - Earthwork.
    2. Materials and placement:
        a. Aggregate base course compacted per City of Manteca standard detail U-5.
        b. CLSM.

C. Trenches in roadways and paved areas:
    1. Backfill trench to underside of pavement.
    2. Materials and placement:
        a. Aggregate base course compacted per City of Manteca standard detail U-5.
        b. CLSM.

D. Trenches in areas outside the improved section of roadways or in open country:
    1. Backfill to finished grade
    2. Materials and placement:
        a. Native soil, native soil - select, imported material, or aggregate base course compacted per City of Manteca standard detail U-6.

E. Trenches under existing intersecting pipes, duct banks, or conduits larger than 3 inches in diameter:
    1. Backfill from above top of new pipe embedment zone to springline of intersecting pipe or conduit.
        a. Extend backfill at least 2 feet on either side of intersecting pipe or conduit to ensure backfill material remains in place while other backfill is being placed.

b. Materials and placement:
1) CLSM, unless otherwise indicated on the Drawings.
2. Backfill remainder of trench:
a. Materials and placement:
1) CLSM.

3.08 EXCESS MATERIAL

A. Remove excess excavated material from the Project Site as specified in Section 02300 - Earthwork.

3.09 FIELD QUALITY CONTROL

A. Provide field quality control for the Work as specified in Section 01450 - Quality Control.

B. Confirmation tests: As specified in Section 02300 - Earthwork.
1. Minimum frequency of confirmation testing:
a. At each test location include tests for each type or class of backfill from bedding to finished grade.
b. For trenches: 1 location every 200 linear feet.
c. In open fields: 2 locations every 1,000 linear feet or 1 location every 200 cubic yards.
d. Along dirt or gravel road or off traveled right-of-way: 1 location at every 500 linear feet.
e. Crossing paved roads: 1 location at each crossing.
f. Under pavement cuts or within 2 feet of pavement edges: 1 location every 400 linear feet.

C. Compliance tests:
1. Make periodic compliance tests to verify that compaction is meeting requirements as specified in this Section.
2. Perform remedial work if compaction test fails to meet specified requirements using one of the following methods:
a. Remove and replace backfill at the proper density.
b. Other means acceptable to the Engineer.
3. Retesting:
a. Costs of retesting: Contractor is responsible for the costs of retesting required to confirm and verify that remedial work has brought compaction within specified requirements.
b. Contractor’s confirmation tests during performance of remedial work:
1) Performance: Perform tests in manner acceptable to the Engineer.
2) Frequency: Double amount specified for initial confirmation tests.

D. Piping system testing:
1. As specified in Section 15956 - Piping Systems Testing.

END OF SECTION

SECTION 02344

RAMMED AGGREGATE PIERS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Rammed aggregate pier ground improvement system.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. A36 - Standard Specification for Carbon Structural Steel.
   2. A108 - Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished.
   3. A153 - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   4. A615 - Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
   5. D1143 - Standard Test Methods for Deep Foundations Under Static Axial Compressive Load.
   6. D1557 - Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft(2,700 kN-m/m)).
   7. D3689 - Standard Test Methods for Deep Foundations Under Static Axial Tensile Load.
   8. F436 - Standard Specification for Hardened Steel Washers.
   9. STP399 - Dynamic Penetrometer Testing.

B. International Conference of Building Officials (ICBO):
   1. Legacy ER 5916, September 2002.

C. Where specifications and reference documents conflict, the more stringent shall govern.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Testing agency: Engineering testing firm hired by Owner to provide quality assurance services for rammed aggregate piers.
   2. Zone of influence: An envelope defined by a horizontal distance of 5 feet from the pier edge then extending down 5 feet to a point that intersects an imaginary 1 to 1 sloping plane from the top of the rammed aggregate pier element. The zone of influence continues along the 1 to 1 slope to a point that corresponds to the bottom of the pier element elevation.

1.04 SUBMITTALS

A. Rammed aggregate pier design Submittal:
   1. Submit design calculations, Ground Improvement Drawings, and Shop Drawings at least 4 weeks prior to the beginning of rammed aggregate pier installation, unless otherwise accepted in writing by the Engineer.
   2. Submit detailed explanation of the design properties for settlement calculations with the design calculations.
   3. Design calculations and Ground Improvement Drawings shall be prepared, signed, and stamped by a geotechnical Engineer licensed in the state where the Project is located.
   4. When hold-down anchors are used in the design, a structural Engineer licensed in the state where the Project is located shall also stamp and sign the Ground Improvement Drawings.
   5. Submit quality control test program for rammed aggregate pier elements.

B. Modulus test:
   1. Submit description of the installation equipment, installation records, complete test data, analysis of the test data, and recommended allowable design bearing pressure based on modulus test results. Report shall be prepared by or under the supervision of a geotechnical Engineer licensed in the state where the Project is located.

C. Aggregate:
   1. Submit letter stating that the quarry has the required rating for Caltrans Class 3 aggregate base. Gradation or sieve analysis test results from a certified testing laboratory shall verify the requirements for 3/4 inch, 1 inch, 1-1/2 inch, and larger crushed open-graded rock (up to 6 inch).

D. Daily rammed aggregate pier progress reports:
   1. Installer shall submit a complete and accurate record of rammed aggregate pier installation:
      a. Indicate the pier location, length, average lift thickness, and final elevations of the base and top of piers.
      b. Indicate type and size of the ramming equipment used.
      c. Immediately report any unusual conditions encountered during installation to the Contractor, Engineer, and Testing Agency.

E. Report on footing excavation and preparation by the Testing Agency.

1.05 QUALITY ASSURANCE

A. Testing Agency:
   1. Owner will retain Testing Agency, preferably the geotechnical engineer, to provide quality assurance services.
   2. Monitor the modulus test and hold-down tests. Rammed aggregate installer shall provide and install dial indicators and other measuring devices.
   3. Monitor the installation of rammed aggregate pier elements to verify that the production installation practices are similar to those used during the installation of rammed aggregate pier elements used for the modulus tests.

4. Perform bottom stabilization test and dynamic cone penetrometer tests as described.
5. Report any discrepancies to installer, Contractor, and Engineer immediately.

B. Qualifications:
1. Installers of rammed aggregate pier foundation system shall have a minimum of 5 years of experience with the installation of rammed aggregate pier ground improvement systems and shall have completed at least 25 projects.
2. A licensed rammed aggregate pier installer that has specialized in installing rammed aggregate piers similar to those required for Project shall perform rammed aggregate pier installations.
   a. Installer shall adhere to methods and standards described in this Section.
   b. Installers currently licensed for these works are:
      1) Farrell Design-Build Inc.
      2) GeoConstructors, Inc.
      3) Geopier Foundation Co.
      4) Helical Drilling, Inc.
      5) Peterson Contractors, Inc.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:
1. Design shall consider the bearing capacity and settlement of footings supported by rammed aggregate pier ground improvement elements.
2. Design shall be in accordance with acceptable engineering practice and these Specifications.
3. Consider total and differential settlement in the design.
4. Design life of the structure shall be 50 years, unless otherwise specified.
5. Rammed aggregate pier element design:
   a. Ground improvement elements shall be designed in accordance with generally accepted engineering practice and the methods and standards described in this Section. Design shall meet the following criteria:

Description	Amount
Design Bearing Pressure for Rammed Aggregate Pier Improved Soil (ASD)	2,500 pounds per square foot (D+L Load)*
Minimum Rammed Aggregate Pier Element Area Coverage (for spread footings)	30 percent
Maximum Total Long-Term Settlement	Less than or equal to 1 inch
Maximum Long-Term Differential Settlement	Less than or equal to 1/2 inch
Minimum Rammed Aggregate Pier Bearing Stiffness (verified by modulus test)	200 pounds per square inch per inch
Minimum Rammed Aggregate Pier Hold-Down Stiffness (verified by Hold-Down Load Test)	To be determined by the Geotechnical Engineer prior to construction.
Note: *1/3 increase permissible for short term loading.	

6. Capacity and size of the rammed aggregate pier elements:
    a. Size and spacing of the rammed aggregate pier elements shall be determined by the Contractor and approved by the geotechnical engineer.
    b. Installer shall be responsible for delivering a system that will support the loading conditions and control settlement in accordance with these specifications.
    c. Modifications in size and spacing of the rammed aggregate pier elements must be acceptable to the Engineer.
7. Rammed aggregate pier elements shall be designed to preclude plastic bulging deformations at the top-of-pier design stress and to preclude significant tip stresses as determined from the shape of the telltale test curve from telltales installed in modulus test, test pier(s). Results of the modulus test shall be used to verify the design assumptions.
8. Installer shall demonstrate that the rammed aggregate pier ground improvement system has been ICBO certified in accordance with Legacy ICBO ER 5916, Sept. 2002.
9. Rammed aggregate piers shall be designed and constructed to meet the loading and load combinations in accordance with building code as specified in Section 01410 - Regulatory Requirements. Column loads are listed in the schedule below:

Grid	**DL**		**LL**		**EQ (Service)**		**ρ*EQ (Service)**		**Ω*EQ (Strength)**	
--	Axial (k)	Moment (k-ft)	Axial (k)	Moment (k-ft)	Axial (k)	Moment (k-ft)	Axial (k)	Moment (k-ft)	Axial (k)	Moment (k-ft)

B. Construct rammed aggregate pier system by ramming (compacting) aggregate in an excavated or drilled shaft using special high-energy impact ramming equipment.
    1. Elements shall be in a columnar-type or prismatic-type configuration and shall be used to reinforce soils for the support of slabs and high bearing pressure footings.

C. Use special high-energy impact ramming apparatus to construct the rammed aggregate pier ground improvement system.
    1. Ramming assembly shall include a 3,500-pound class hydraulic break hammer, equivalent or greater, with a patented beveled rammer.
    2. Construction of the rammed aggregate pier ground improvement elements shall be as determined by the Contractor and approved by the geotechnical engineer.

D. Rammed aggregate pier ground improvement system shall include the installation of a structurally designed hold-down anchors where required by structural load conditions and Ground Improvement Drawings.
    1. This includes the pattern, spacing, type, size, and lengths of the hold-down anchor, as well as, the required drill shaft diameter, and embedment depths.
    2. Ground Improvement Drawings shall also indicate other details including the bottom anchor plate size and any additional required corrosion protection for the hold-down anchor and its components.

2.02 MATERIALS

A. Aggregate installed above and below water level:
   1. Type 1 aggregate: Aggregate above the water table for rammed aggregate pier elements shall be aggregate base course material, recycled aggregate, recycled Portland cement concrete, or shall be other well-graded aggregate selected by the pier installation firm and successfully used in the modulus test.
      a. Recycled AC paving shall not be used.
      b. Grading shall conform to Caltrans Class 3 specifications for 3/4-inch or 1-1/2-inch aggregate base.
   2. Type 2 aggregate: Aggregate used at the bottom of the drilled shaft (bottom bulb) and below the water table shall be crushed open graded rock with particle sizes of 3/4 inch, 1 inch, 1-1/2 inch, or larger up to 6 inch, and must be the same or larger as used in the modulus test.

B. Water for aggregate:
   1. Use potable water to increase aggregate moisture content when applicable unless non-potable water has been used successfully within the graded aggregate for the modulus test and the use of non-potable water is acceptable to the Engineer.

2.03 MANUFACTURED UNITS

A. Rammed aggregate pier hold-down anchors:
   1. Corrosion protection system:
      a. Constructed by the installer and shall include as a minimum, specially coated hold-down anchors with bolted connection to the bottom bearing plate as indicated on the Ground Improvement Drawings.
      b. Rammed aggregate pier element hold-down anchor assembly shall be isolated from footing reinforcement.
         1) If necessary, the hold-down anchorage in the footing shall be covered with plastic tape or other method for isolating the hold-down anchor system steel from the footing reinforcement.
      c. Minimum corrosion protection of thread bars shall include oversizing the thread bars by an additional 1/8-inch diameter, hot-dip galvanizing in accordance with ASTM A153, and polyethylene coating:
         1) Coating manufacturers: The following or equal:
            a) ENTEC, Shawcor Pipe Protection, MP130-002 Specification.
      d. Minimum corrosion protection of bottom anchor plate shall include hot-dip galvanizing in accordance with ASTM A153 and 1 coat spray-on polyurethane coating:
         1) Coating manufacturers: The following or equal:
            a) SEM Products, Inc., Pro Tex 4064.
   2. Hold-down anchor thread bars, bearing plates, hex nuts, washers, and couplers:
      a. Thread bars:
         1) In accordance with ASTM A615.
         2) Continuous concentric rolled thread deformation pattern that ensures a consistent cross sectional area and strength at points along the bar.

3) Diameter, lengths, and required strengths shall be as noted on the Ground Improvement Drawings.
4) Manufacturers: The following or equal:
a) Williams Form Engineering Co., Grade 75 All-Thread Rebars.

b. Bearing (hold-down anchor) plates:
1) Steel in accordance with ASTM A36.
2) Size and thickness shall be as indicated on the Ground Improvement Drawings.

c. Hex nuts:
1) Manufacturer's standard, heavy duty, hexagonal pattern, machined from steel in accordance with ASTM A108 and designed for use with the thread bars.
2) Tapped oversize when additional corrosion protection of epoxy coating or hot-dip galvanizing is specified.
3) Develop in excess of 125 percent of the yield strength of the thread bar and an ultimate strength of not less of than 100 percent of the guaranteed ultimate tensile strength of the thread bar.

d. Washers:
1) Hardened steel washer in accordance with ASTM F436.
2) Used between the hex nut and the bottom and top bearing plates.

e. Mechanical couplings:
1) May be used to splice the thread bars and shall be capable of developing 100 percent of the guaranteed ultimate tensile strength of the thread bar.
2) Provide a positive internal threaded connection to the thread bar and shall be machined from steel in accordance with ASTM A108.
3) Tapped oversize when additional corrosion protection of hot-dip galvanizing is specified.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:
1. Perform rammed aggregate pier ground improvement after rough grading of the Project site or building pad.
2. Predrill rammed aggregate piers 30 inches for bearing elements and 33 inches for elements with hold-down piers as determined by the Contractor and approved by the geotechnical engineer. Do not install rammed aggregate piers without pre-drilling.
3. If cave-ins occur during excavation such that the sidewalls of the shaft are deemed to be unstable, use a temporary steel casing to stabilize the excavation.
4. If cave-ins occur on top of a lift of aggregate such that the volume of the caved soils is greater than 25 percent of the volume of the aggregate in the lift, then the aggregate shall be considered contaminated.
a. Remove contaminated aggregate and replaced with uncontaminated aggregate.

B. Ramming and densification of aggregate:
   1. Employ special high-energy impact ramming apparatus to install the rammed aggregate pier elements used for support of foundations and slabs.
      a. Ramming assembly shall include a 3,500-pound class hydraulic hammer that imparts vertical ramming energy.
      b. Apparatus shall apply direct downward impact ramming energy to each lift of aggregate.
   2. Perform ramming and densification using a patented beveled rammer foot. Beveled rammer foot is required to improve the matrix soil and to adequately increase the lateral earth pressure in the matrix soil during installation.
   3. Energy source shall apply minimum hydraulic hammer CIMA energy level of 3,000 foot-pounds of impact energy. Downward pressure shall be applied to the rammer apparatus during ramming of aggregate using a 22-ton minimum hydraulic excavator.
   4. After drilling the shaft, apply rammer energy on the first lift of Type 2 aggregate to form the bottom bulb.
      a. After construction of the bottom bulb, ram Type 1 or Type 2 aggregate in thin lifts in the shaft to the planned top elevation as determined by the Contractor and approved by the geotechnical engineer..
   5. Ram well-graded Type 1 aggregate to a density that provides resistance to the dynamic penetration test in accordance with ASTM STP 399 of a minimum average of 15 blows per 1.75 inches of vertical movement.
   6. Ram each lift of aggregate for a minimum of 10 seconds.
   7. Aggregate lift thickness shall not exceed 18 inches in loose thickness.
   8. Place Type 1 aggregate above the water table at or below optimum moisture content in accordance with ASTM D1557.

C. Location of rammed aggregate pier elements:
   1. Locate each rammed aggregate pier element in accordance with accepted Ground Improvement Drawings.
      a. Mark location of individual rammed aggregate pier elements using a 60-penny spike with poly stranded feather.
      b. Place spike at the center of each rammed aggregate pier.
      c. Use fluorescent pink for bearing elements and fluorescent green for hold-down elements.
   2. Installed center location of each pier element shall be within 6 inches of the plan locations indicated on the Ground Improvement Drawings.
      a. Final measurement of the top of rammed aggregate piers shall be the lowest point on the aggregate in the last rammed lift.
   3. Rammed aggregate pier elements installed outside of the above tolerances and deemed not acceptable shall be rebuilt at no additional expense to the Owner.

D. Hold-down anchor assembly:
   1. The contractor determines the number of thread bars attached to the bottom bearing plate with specified hex nuts for each anchor.
      a. Hex nuts shall be hand-wrench tightened to the top and bottom of the plate.
      b. Anchor shall be pre-assembled prior to placing in the rammed aggregate pier drilled shaft.

2. Bottom anchor plate shall be clean and free of dirt and grease prior to polyurethane application.
    a. Polyurethane coating shall be field applied to the entire bottom anchor plate, bolted connections, and up 4 inches of thread bars above bolted connection in accordance with SEM Products Inc., Pro-Tex 4064 procedures or equivalent.

E. Hold-down anchor installation:
1. After construction of the bottom bulb or ramming of soil at bottom of the drilled shaft, lower the hold-down anchor assembly into the rammed aggregate pier drilled shaft.
2. Install hold-down anchor assembly to the depth as determined by the Contractor and approved by the geotechnical engineer.
    a. Align hold-down anchor assembly parallel to the closest footing wall, unless otherwise indicated on the Ground Improvement Drawings.
3. Bottom bearing plate may be pressed down with the ramming apparatus to the depth indicated on the Ground Improvement Drawings.
4. Then install rammed aggregate pier as described above.

F. Hold-down anchor connection to foundation:
1. Use hex nuts and bearing plates, supplied by the rammed aggregate pier installer, for connection in the foundation concrete and reinforcement as determined by the Contractor and approved by the geotechnical engineer..
    a. Any changes in the hold-down anchor connection to the foundation must be acceptable to the Engineer.
2. Cut the thread bars to the elevation determined by the Contractor and approved by the geotechnical engineer. Construct and install the top bearing plates in the foundation as determined by the Contractor and approved by the geotechnical engineer..
3. Hold-down element hold-down anchor assembly shall be electrically isolated from foundation reinforcement.
    a. If necessary, the hold-down anchorage in the foundation shall be covered with plastic tape.
4. Do not weld to either thread bars or to the internal threaded components.
5. Do not use the thread bars as grounding for electric welding apparatus.
6. Thread bars that have been bent must be cut 2 inches below the bend and coupled using Mechanical Couplings and a thread bar extension.

G. Obstructions:
1. Remove obstructions encountered during drilling or excavation for rammed aggregate piers, or the pier shall be relocated or abandoned as accepted by the Engineer.
    a. Obstructions include, but are not limited to, boulders, timbers, concrete, bricks, debris, utility lines that prevent installing the aggregate piers to the required depth or cause the aggregate pier to drift from the required locations.
    b. Dense natural rock layers shall not be deemed obstructions.
2. Rammed aggregate pier elements may be terminated short of design depths on top of rock or partially weathered rock, or very dense gravel layers as accepted by the Engineer.

3. If acceptable to the Engineer, install an additional, adjacent pier when required by presence of obstacles.
4. Relocated, abandoned, and shortened rammed aggregate pier elements as a result of obstruction shall be paid as full length rammed aggregate pier elements.

H. Footing excavations:
1. Foundation excavations that expose the tops of rammed aggregate pier elements shall be made in a workmanlike manner, and shall be protected until concrete has been placed using procedures and equipment best suited to:
   a. Prevent softening of the matrix soil between and around the rammed aggregate pier elements before placing structural concrete.
   b. Achieving direct and firm contact between the dense, undisturbed rammed aggregate pier elements and the concrete footing.
2. Perform the following procedures to achieve the above conditions:
   a. Limit over-excavation below the bottom of the footing to 15 inches, including disturbance from the teeth of the excavation equipment.
   b. Bottom of footing excavation and top of rammed aggregate pier elements shall be compacted with at least 3 passes of an impact type compactor ("Wacker Packer," "Jumping Jack," or similar).
      1) Compaction shall be performed over the entire footing bottom to compact any loose soil, aggregate base course material, and loose pier aggregate.
      2) No debris, loose soil, or loose aggregate shall exist in the footing bottom prior to the placement of footing reinforcement and concrete.
      3) Sled-type vibratory compaction devices are not acceptable and shall not be used.
   c. Footing bearing on expansive or sensitive soils: Place footing concrete immediately after footing excavation is made and approved, preferably the same day as the excavation.
   d. Slabs supported by rammed aggregate pier elements: Compact subgrade over entire slab area with a smooth drum roller to compact loose soil and loose pier aggregate disturbed by heavy equipment tracks or tires.
   e. If rain is possible before placing footing concrete, then a minimum 3-inch thick lean concrete seal ("mud mat") or a 6-inch minimum layer of aggregate base course material shall be installed immediately after the footing is excavated, compacted, and approved by the Testing Agency.

I. Utility excavations:
1. Protect completed rammed aggregate pier elements. Coordinate excavations made subsequent to rammed aggregate pier installations that are within the rammed aggregate pier Zone of Influence indicated on the Ground Improvement Drawings.
2. In the event that utility excavations are required within the Zone of Influence, contact the rammed aggregate pier designer to develop construction solutions to minimize impacts on the installed rammed aggregate piers. Recommended procedures include:
   a. Using cement-treated base to construct portions of the rammed aggregate piers subject to future excavations.
   b. Replacing excavated soil with compacted aggregate base course material in the portions of excavations where the rammed aggregate piers have

been disturbed. Placement and compaction of the aggregate base course material shall meet the following requirements:

1) Place aggregate base course material in a controlled manner using motorized impact compaction equipment.
2) Compact aggregate base course material to 95 percent of the maximum dry density in accordance with ASTM D1557.
3) Testing Agency will be on site to observe placement, compaction, and provide density testing.
    a) Test results shall be submitted to the Engineer and Contractor. Notify the Testing Agency and the Engineer when excavation, placement, and compaction will occur and arrange for construction observation and testing.
4) Replacing excavated soil with control low strength material as specified in Section 02312 - Controlled Low Strength Material (CLSM).

3.02 FIELD QUALITY CONTROL

A. Installer shall have a full-time quality control representative on site to verify and report installation procedures. Quality control representative may be a member of the installation crew.
    1. Quality control representative shall immediately report any unusual conditions encountered during installation to the Engineer, Contractor, and Testing Agency.
    2. Quality control procedures shall include the preparation of rammed aggregate pier progress reports completed during each day of installation that contains the following:
        a. Foundation and rammed aggregate pier location.
        b. Rammed aggregate pier length and drilled diameter.
        c. Planned and actual rammed aggregate pier elevations at the top and bottom of the element.
        d. Average lift thickness for each rammed aggregate pier.
        e. Depth to groundwater, if encountered.
        f. Documentation of any unusual conditions encountered.
        g. Type and size of ramming equipment used.

B. Modulus test:
    1. Perform to verify the parameter values selected for design.
        a. Shall be of the type and installed in a manner specified in this Section.
        b. Perform in accordance with the requirements outlined in the rammed aggregate pier design Submittal.
    2. Coordinate location of the test with the Engineer.
    3. Install telltale at the bottom of the test pier so that bottom of pier deflections can be measured. Acceptable performance is indicated when the bottom of the pier deflection is no more than 20 percent of the top of pier deflection at the design stress level.
    4. Use general test procedures in accordance with ASTM D1143 as a guide to establishing load increments, load increment duration, and load decrements.
    5. Perform modulus test in and on the neat, drilled diameter of the rammed aggregate pier element only, with no exceptions.
        a. Use of a foundation area is not acceptable.

6. With the exception of the load increment representing approximately 115 percent of the design maximum top of rammed aggregate pier stress, load increments shall be held for a minimum of 15 minutes, a maximum of 1 hour, and until the rate of deflection reduces to 0.01 inches per hour or a deflection of less than 0.0025 inches in 15 minutes.
7. Load increment that represents approximately 115 percent of the design maximum stress on the rammed aggregate pier shall be held for a minimum of 15 minutes, a maximum of 4 hours, and until the rate of deflection reduces to 0.01 inches per hour or 2 consecutive deflections of less than 0.0025 inches in 15 minutes.
8. Apply seating load equal to 5 percent of the total load prior to application of load increments and prior to measurement of deflections.

C. Hold-down load test:
1. Conduct hold-down load test procedures in general accordance with ASTM D3689 quick/continuous loading method, as appropriate and except as modified with the requirements outlined in the rammed aggregate pier design Submittal.
2. Coordinate location of the hold-down load test with the Engineer.
3. Hold-down load test information shall be used to verify that the aggregate-pier system design is consistent with the behavior exhibited during the hold-down load test.

D. Bottom stabilization test:
1. After completion of the bottom bulb, or at any time during the process of constructing the pier, the energy source may be turned off, and bottom stabilization test may be performed.
2. One bottom stabilization test shall be performed and recorded for every 5 pier elements installed.
3. A baseline bottom stabilization test value shall be measured and recorded on the modulus test aggregate pier for reference during the project.
4. Perform bottom stabilization tests by placing a reference bar over the drilled shaft, marking the rammer apparatus, applying energy to the rammer for an additional 15 seconds, and observing the downward deflection of the rammer apparatus by observing the downward deflection of the mark.
5. Acceptable performance is indicated if the vertical movement of the shaft is less than 150 percent of the vertical movement measured for the baseline bottom stabilization test.
6. If the measured vertical movement exceeds 150 percent of the baseline bottom stabilization test, apply added energy to re-ram the bulb.
    a. Procedure for measure is then repeated.
    b. If there is still movement greater than 150 percent of the baseline bottom stabilization test, a lift of loose aggregate may be placed on top of the rammed aggregate, and the bottom stabilization test may be performed on this next lift after it is rammed.
    c. If there is excessive movement on this lift, another lift may be placed and tested.
7. Movement must be limited to less than 150 percent of the baseline bottom stabilization test before completion of 2/3 of the pier depth.

E. Dynamic cone penetrometer test:
   1. Test rammed aggregate pier elements by the dynamic cone penetrometer method in accordance with ASTM STP 399 at locations within the upper 1/3 of the pier shaft length and in Type 1 aggregate only.
   2. Minimum acceptable criteria for acceptable ramming improvement shall be not less than 15 blows for 1.75 inches penetration.
   3. Perform dynamic cone penetrometer testing in each pier until such time as 5 consecutive tests indicate that the minimum criterion is met. Thereafter, such tests need not be performed on every pier, provided that the aggregate used in the elements is representative of that previously tested.
   4. If the average penetration resistance measured exceeds 15 blows, and less than 10 percent of tests fall below 15 blows, then testing may be reduced to spot checks.
   5. One dynamic cone penetrometer test shall be performed and recorded for every 10 pier elements installed. If the maximum deflection outlined above is exceeded, then a minimum of 5 more dynamic cone penetrometer tests shall be performed.
   6. Observation of questionable aggregate moisture content or questionable aggregate gradation appearance may determine the need for additional dynamic cone penetrometer testing to verify that the proper ramming improvement is being achieved.
   7. Use of dynamic cone penetrometer test is not appropriate for use on Type 2 open graded aggregate.

3.03 ADJUSTING

A. Rejected rammed aggregate pier elements:
   1. Pier elements improperly located or installed beyond the maximum allowable tolerance shall be abandoned and replaced with new rammed aggregate pier elements unless other remedial measures are accepted by the Engineer.
   2. All material and labor required to replace rejected rammed aggregate pier elements shall be provided at no additional cost to the Owner.

END OF SECTION

SECTION 02552

TEMPORARY BYPASS PUMPING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Temporary bypass pumping of wastewater flows.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. B241 - Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube.
   2. D3350 - Standard Specification for Polyethylene Plastic Pipe and Fittings Material.

B. National Fire Protection Association (NFPA):
   1. 820 - Standard for Fire Protection in Wastewater Treatment and Collection Facilities.

1.03 REQUIREMENTS

A. Provide services related to, but not limited to, mobilization, setup, around-the-clock operations and maintenance, demobilization, traffic control, permits, and all other materials, labor, and equipment to install, maintain, and operate a complete continuous pumping and transport system for sludge overflow and process fluids 24 hours per day, 7 days per week, until the portion(s) of the Work have been completed to the satisfaction of the Engineer.

B. Means and methods of accomplishing and maintaining the temporary bypass pumping and associated facilities is the sole responsibility of the Contractor.

C. Installed as a complete standalone system.
   1. Provide power, fuel, and backup power supply and/or backup pumps for operation of the system.

D. Operation shall be limited to the months or seasons indicated in the Work, unless approved in writing by the City of Manteca.

E. Pumping shall be continuously monitored.

F. Contractor shall be responsible for bypassing the 12-inch SOF line in a way that ensures that no sludge overflow or process fluids is allowed to leak outside of the bypass pipelines.

G. No bypassing to the ground surface, receiving waters, storm drains, or bypassing that results in soil or groundwater contamination or any potential health hazards shall be permitted.
   1. Adhere to agency restrictions regarding the transport and conveyance of wastewater.

H. Contractor shall be liable for cleanup, damages, and resultant fines in the event of spills, leaks, or backups associated with bypass pumping activities, which includes Commissioning, operation, and decommissioning of bypass pumping facilities.

I. No interruption of flow shall be permitted throughout the duration of the Project. Contractor is responsible for overflows during construction of this Work and bypass operations.

J. Coordinate the placement of the bypass piping and pumping equipment with the Engineer and City of Manteca.

K. Where bypass pipelines are required to cross traffic lanes and will be in place for more than 3 days, the piping and fittings shall be buried a minimum of 4 inches below the pavement surface and backfilled with temporary asphalt concrete surfacing or use an approved flow-through drivable apparatus approved by the Engineer.
   1. At no time shall traffic lanes be blocked or closed, unless specifically allowed in writing by the Owner.
   2. Temporary ramps may be constructed over pipelines 6 inches in diameter, or less, to allow access to driveways. Where pipelines larger than 6 inches in diameter cross driveways, they shall be buried a minimum of 4 inches below the existing ground or pavement surface and backfilled with temporary asphalt concrete surfacing. No driveway access shall be blocked without the written authorization of the affected property owner.

L. Identify additional connections not indicated on the Drawings that may require bypass pumping.

M. After the Work is completed, flow shall be returned to the installed 16-inch PD line and temporary equipment removed.

1.04 SUBMITTALS

A. Submit a temporary bypass pumping plan as required to complete the Work to the Engineer and the Owner 30 days prior to bypass pipe installation, for review as specified in Section 01300 - Submittals.
   1. Plan Submittal shall be satisfactory to the Engineer and the Owner prior to commencing the bypass pumping operation.
      a. Notify the Engineer and Owner 24 hours prior to commencing the bypass pumping operation.
   2. Plan must provide for accessibility to pedestrians and vehicular traffic in accordance with Owner requirements.
   3. Plan shall include the following at a minimum:
      a. Number, type, capacity, and size of pumps, standby equipment, pipe material, pipe layout with pressure relief, and air/vacuum valve locations, and power requirements, if applicable.

b. Design calculations of the system and selected equipment; including flow, TDH with static head, including all friction and minor losses; and pump curves showing operating range of flow and TDH.
c. Standby power generator size and location for electrically driven bypass pumps.
d. Downstream discharge plan.
e. Pipe thrust and restraint block sizes and locations.
f. Temporary pipe supports and anchoring required.
g. Schedule that shows duration of temporary bypass pumping, including milestones for installation, maintenance, and removal of equipment and accessories.
h. Means and methods of installing, operating, monitoring, and maintaining the temporary bypass pumping shall be provided.
i. Plan indicating bypass pumping line locations.
    1) Include details showing methods used to protect and identify the bypass pumping lines through the length of the bypass corridor.
j. Plans for access to bypass pumping locations.
k. Detailed plans of a redundant backup system.
l. Address access vehicular traffic.
m. Mechanical plan showing equipment, valves, pipe sizes and locations, pipe materials, dimensions, vehicle access (where applicable), pedestrian access (where applicable).
n. Proposed type, catalog cutsheets, and location of piping plugs.
o. Emergency response plan.
p. Staffing plan.
q. Spill prevention and cleanup plan.
r. Health and safety plan.
s. Catalog cutsheets for pumping equipment, including pump performance curves, pipe and fittings, valves, and health and safety plan.

1.05 QUALITY ASSURANCE

A. Contractor's qualifications:
    1. Minimum 5 years of experience in performing substantially similar temporary bypass pumping operations.
    2. Submit a list of at least 5 separate construction projects completed within the last 10 years that include the satisfactory setup, operation, and maintenance of a pumping and piping system used to bypass wastewater during construction similar to the specified Work.

B. Fulfillment of the specified experience requirements shall be a condition of acceptance.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Collect flow data or request flow data from the Owner to determine the appropriate range of design flows and design total dynamic head (TDH). The following criteria shall be determined at a minimum:
   1. Minimum flow and TDH.
   2. Average daily flow and TDH.
   3. Peak flow and TDH.

B. The following is known based on existing conditions:
   1. Minimum flow: 115,000 gallons per day
   2. Average daily flow: 700,000 gallons per day
   3. Peak flow: 1,400,000 gallons per day

C. Contact the City of Manteca Plant staff to confirm proposed flow values prior to the Work.

2.02 CAPACITY

A. Pumps, piping, and accessories shall be of adequate capacity and size to handle the range of wastewater flows from minimum flow to peak flow.

B. Piping, fittings, and accessories shall withstand 1.5 times the maximum pressure.

C. Maintain onsite sufficient equipment and materials to ensure continuous and successful operation of the bypass system.
   1. Have standby pump(s) incorporated into the system that provide 100 percent redundancy of the bypass system design peak flow.
      a. Redundant pump(s) shall be plumbed, fueled, and available for operation in 10 minutes upon emergency backup.
   2. Maintain onsite a sufficient number of valves, tees, elbows, connections, tools, pipe plugs, piping, and other parts or system hardware to ensure immediate repair or modification of any part of the bypass system as necessary.

2.03 BYPASS PUMPS

A. A minimum of 2 pumps shall be provided, each capable of transporting 100 percent of the peak flow.

B. Capacity shall be sufficient to pump the anticipated peak hour flow with the largest pump out of service.

C. Packaged unit with a skid base or 2-wheel trailer.

D. Fully automatic, self-priming, close-coupled centrifugal units that do not require use of foot valves or vacuum pumps for priming.

E. Utilize oil-lubricated mechanical seal.

F. Materials:
   1. Volute: Cast iron.
   2. Impeller: Cast iron.
   3. Pump shaft: Type 431 stainless steel.
   4. Mechanical seal faces: Silicon carbide.

G. Capable of passing 4-inch diameter solids, rags, rocks, hair, and other debris encountered in municipal wastewater.

H. Operated by diesel engine and include the following:
   1. Minimum 24-hour capacity diesel fuel tank as defined by fuel consumption during peak pumping rate.
   2. Fuel gauge with red warning light when tank approaches empty.

I. Capable of dry operation for up to 5 hours to accommodate large fluctuations in flow.

J. Maximum pump speed shall not exceed 2,200 revolutions per minute.

K. System shall include the following features:
   1. START/STOP operation.
   2. Instrumentation and controls for operation and monitoring for each pump.
   3. Autodialer to alert Contractor when pump alarms are activated.

L. Electrical equipment, instrumentation, and accessories shall be suitable for Class I, Division 1service in accordance with NFPA 820.

2.04 BYPASS PIPING

A. Use HDPE or aluminum piping.

B. HDPE:
   1. In accordance with ASTM D3350.
   2. Joints shall be butt-fusion welded.

C. Aluminum:
   1. In accordance with ASTM B241 or approved by the Engineer.
   2. Standard pipe fittings made of aluminum alloy suitable for 30 percent above maximum shutoff pressure.
   3. Joints shall be EPDM.

2.05 PIPE PLUGS

A. Contractor is responsible for providing means of isolating pipeline for bypass pumping.

2.06 ODOR CONTROL (NOT USED)

2.07 NOISE CONTROL (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Notify the Owner a minimum of 30 days prior to the Work requiring temporary bypass pumping and notify the Engineer at least 72 hours prior to bypassing or diverting flow in any of the pipelines or laterals or structures.

B. Pumps, generators, and other equipment shall be placed on a plastic tarp to protect against spills of petroleum products used by the equipment.

C. Before taking interceptor out of service, verify that the bypass system is fully operational and acceptable to the Engineer.

D. Flow in the existing lines shall not be restricted or dammed for any period of time without the approval of the Engineer.

E. Wastewater facilities, shall remain in continuous and full operation during construction.

3.02 PROTECTION

A. Pumps and piping shall be sized to adequately convey the flows anticipated at each bypass application.
   1. Bypass system shall be watertight; no leakage will be allowed.

B. Bypass flows.
   1. Inspect the entire bypass pumping and piping system for leaks or spills at a frequency of not less than 2 times per shift.
   2. Temporary bypass system shall not be shut down between shifts, on holidays or weekends, or during work stoppages without written permission from the Engineer.

C. System will have trained and qualified attendants available 24 hours per day, 7 days per week, whose only duty is to maintain the bypass system until the bypassing of the system is no longer required. Attendants shall:
   1. Be capable of performing pump and piping maintenance required.
   2. Have a cellular phone for communication with the Contractor and Engineer in the event of emergencies.

D. In the event of any wastewater spill, Contractor shall be responsible for the prompt cleanup and disinfecting of the spill as called for in the temporary bypass pumping plan.
   1. Compensate the Owner for the cost of any fines levied as the result of a spill or unauthorized discharge.

E. Implement measures to prevent interference between the public and the bypass pumping equipment, pipelines, and wastewater.

F. Take precautions to protect bypass lines from damage.
   1. Any aboveground portions of the bypass lines shall be clearly identified by flashers, fencing, or other means to warn the public of their presence.

3.03 FIELD QUALITY CONTROL

A. Hydrostatic pressure test:
   1. Prior to operation, test each section of discharge piping with maximum pressure equal to 1.5 times the maximum operating pressure.
   2. Test shall run for a duration of 2 hours.
   3. Fill the line with water.
   4. Line shall be sealed on the discharge end.
   5. Line may be put in service if, after the specified test duration, the pressure has been maintained and there are no observable leaks.
   6. Notify the Engineer at least 24 hours prior to testing.

B. Inspection:
   1. An attendant/operator shall inspect the temporary bypass piping system at a minimum of every hour 24 hours per day.
   2. Inspection log: Keep at each pumping location.

3.04 CLEAN-UP

A. System shall be cleaned and drained prior to being dismantled.

B. Alternate pigging and purging of the system to remove loose material.
   1. After the pipe has been cleaned, and prior to dismantling of the piping for removal from the Project Site, disinfect with 10 percent chlorine solution.

C. Disturbed areas:
   1. Upon completion of bypass pumping operation, clean disturbed areas, restoring to original condition, including pavement restoration, at least equal to that which existed prior to the start of the Work.
   2. As specified in Section 02952 - Pavement Restoration and Rehabilitation.

3.05 SCHEDULING

A. System shall not be shut down between shifts, on holidays or weekends, or during work stoppages.

B. System shall have trained and qualified attendants 24 hours per day, 7 days per week, whose only duty is to maintain the bypass system from the start of bypass until the bypassing of the system is no longer required.

END OF SECTION

SECTION 02621

STABILIZATION FABRIC

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Woven and geogrid stabilization fabric used for subgrade enhancement.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. D4355 - Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.
   2. D4491 - Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
   3. D4533 - Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
   4. D4632 - Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
   5. D4751 - Standard Test Method for Determining Apparent Opening Size of a Geotextile.
   6. D6241 - Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe.

1.03 DEFINITIONS

A. Stabilization Fabric: Woven geotextile fabric manufactured from polypropylene yarns.

1.04 SUBMITTALS

A. Product data.

B. Samples.

C. Quality control submittals:
   1. Certificates of Compliance.
   2. Manufacturer's Installation Instructions.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Storage and protection:
   1. Furnish stabilization fabric in protective covers capable of protecting the fabric from ultraviolet rays, abrasion, and water.

1.06 PROJECT CONDITIONS

A. Field measurements:
   1. Take field measurements to determine the exact lengths and dimensions of the surfaces to receive the fabric.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or equal:
   1. Tensar HX145
   2. Propex, Geotex 315ST.
   3. Ten Cate Geosynthetics, Mirafi 600X.

2.02 MATERIAL REQUIREMENTS

A. Physical properties: Meet the following minimum requirements:

Property (1)	Test Method	Unit	Requirements (1)
Grab Tensile Strength	ASTM D4632	lbs	315
Grab Elongation	ASTM D4632	%	15
Trapezoid Tear Strength	ASTM D4533	lbs	120
CBR Puncture Resistance	ASTM D6241	lbs	900
UV Resistance (strength retained at 500 hours)	ASTM D4355	%	70
Apparent Opening Size (AOS)	ASTM D4751	US sieve	40
Permittivity	ASTM D4491	sec^{-1}	0.05
Flow Rate	ASTM D4491	gpm/ft^2	4
(1) Minimum average roll values.			

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions: Verify that conditions are satisfactory for the installation of stabilization fabric.

3.02 PREPARATION

A. Surface preparation: During grading operations, take care not to disturb the subgrade. This may require use of lightweight dozers for low strength soils such as saturated, cohesionless, or low cohesion soils.

B. Prior to placement of fabric: Prepare surface to smooth condition free of debris, depressions, or obstructions that may damage the fabric.

3.03 INSTALLATION

A. Follow manufacturer's installation instructions and as complimented in this Section.

B. Place the stabilization fabric smoothly without folds or wrinkles.

C. Use special care when placing the stabilization fabric in contact with the soil so that no void spaces occur between the stabilization fabric and the prepared surface.

D. Overlap the parallel rolls and ends of rolls a minimum of 24 inches and not less than recommended by manufacturer.

E. Do not drag stabilization fabric across subgrade.

F. Make overlaps at ends of rolls in the direction of the aggregate placement with the previous roll on top.

G. Use lightweight dozers, if necessary. Do not allow equipment directly on stabilization fabric.

3.04 FIELD QUALITY CONTROL

A. Inspection: Before covering, the condition of the fabric will be observed by the Engineer to determine that no holes or rips exist in the fabric. Repair all holes or rips by placing a new layer of fabric extending beyond the defect in all directions, a distance equal to the minimum overlap required for adjacent rolls.

END OF SECTION

SECTION 02705

POLYVINYL CHLORIDE (PVC) PIPE: GRAVITY

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Gravity sewer pipe and fittings in accordance with ASTM D3034 and ASTM F679 standards.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C923 - Standard Specification for Resilient Connectors Between Reinforced Concrete Manhole Structures, Pipes, and Laterals.
   2. D1784 - Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
   3. D2321 - Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.
   4. D3034 - Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings.
   5. D3212 - Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals.
   6. F477 - Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.
   7. F679 - Standard Specification for Poly(Vinyl Chloride) (PVC) Large-Diameter Plastic Gravity Sewer Pipe and Fittings.

1.03 ABBREVIATIONS

A. PVC: Polyvinyl chloride.

B. SDR: Standard dimension ratio; the outside diameter divided by the pipe wall thickness.

1.04 SUBMITTALS

A. Product data: As specified in Section 15052 - Common Work Results for General Piping.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Protect from sunlight, scoring, and distortion.

B. Do not allow surface temperatures to exceed 120 degrees Fahrenheit.

C. Store and handle as recommended by manufacturer in published instructions.

PART 2 PRODUCTS

2.01 PIPE

A. Extruding and molding material: Virgin material containing no scrap, regrind, or rework material except where permitted in the referenced standards.

B. PVC compound: Cell classification 12454-C in accordance with ASTM D1784.

C. Stabilizers, antioxidants, lubricants, colorants, and other additives and fillers not to exceed 10 parts by weight per 100 of PVC resin in the compound.

D. Pipe less than or equal to 15-inch diameter:
   1. In accordance with ASTM D3034.
   2. Wall thickness SDR 26 as specified in the Piping Schedule in Section 15052 - Common Work Results for General Piping.
   3. Joints: Push-on in accordance with ASTM D3212.
      a. Integral bell.
      b. Factory installed gaskets meeting the requirements in accordance with ASTM F477.

E. Pipe greater than or equal to 18-inch diameter:
   1. In accordance with ASTM F679.
   2. Minimum pipe stiffness: PS 46in accordance with Table 1 in ASTM F679.
   3. Joints: Push-on in accordance with ASTM D3212.
      a. Integral bell.
      b. Factory installed gaskets meeting the requirements in accordance with ASTM F477.
   4. Bell:
      a. Fabricated from pipe sections.
      b. Bell wall thickness equivalent to pipe wall thickness.
   5. Gasket ring: Locked into the bell.
   6. Spigot end of the pipe: Marked by the manufacturer to identify the final in place position of the spigot in the bell.

2.02 FITTINGS

A. Same material as the pipe.

B. Minimum wall thickness: Same as the minimum wall thickness of the equivalent size pipe as specified in Table 1 of ASTM F679.

C. Supplied by the pipe manufacturer.

D. Factory molded with joints and gaskets equal to those of the pipe.

E. Gasket:
   1. In accordance with ASTM F477.
   2. Manhole adapter gasket: Stainless steel clamp with gasket or similar device to seal the penetration.

F. Flexible gaskets for precast bases with a flexible pipe connection: In accordance with ASTM C923:
   1. Manufacturer: One of the following or approved equal:
      a. Press-Seal Gasket Corp.: PSX.
      b. A-Lok Premium.

G. Waterstop grouting rings:
   1. Manufacturer: One of the following or approved equal:
      a. NPC.
      b. Press-Seal Gasket Corp.

2.03 SOURCE QUALITY CONTROL

A. Mark pipe and fittings in accordance with ASTM D3034 and ASTM F679 as appropriate.

B. Mark the production control code on pipe and fittings.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:
   1. Install piping in accordance with ASTM D2321 and manufacturer's published installation instructions.
   2. Provide plugs or caps for stubs and branch pipes left unconnected to laterals.
   3. Lubricate and assemble joints in accordance with the pipe manufacturer's published instructions.
   4. Trenching and backfill as specified in Section 02318 - Trenching.
   5. For open cut installations, install underground warning tape as specified in Section 15076 - Pipe Identification.

B. Connections to manholes:
   1. Make connections to manholes with a manhole gasket that prevents infiltration and exfiltration through the penetrations using 1 of the following methods:
      a. Precast bases with a flexible pipe connection:
         1) Pipe connectors shall be cast into the base.
            a) Pipe openings shall contain flexible gaskets.
         2) Follow manufacturer's recommendation for lubrication to prevent damage to the gasket during pipe insertion.
         3) When PSX gaskets are used, the take-up screws for the gasket clamps shall be positioned a minimum of 90 degrees apart.
         4) Install and grout in place per manufacturer's instructions.
      b. Cast in place or precast bases using grouting rings:
         1) Provide opening for connection large enough to allow subsequent grouting around the grouting ring.
         2) Grout around the pipe penetration manhole gasket and seal the opening.

3.02 FIELD QUALITY CONTROL

A. Test pipe as specified in Section 15956 - Piping Systems Testing.

B. Mandrel tests:
   1. Perform initial mandrel test:
      a. After cleaning and completion of other tests.
      b. After placement and compaction of backfill.
      c. Before construction of pavement or surfacing.
      d. Not sooner than 30 days after pipe installation.
      e. Not later than 60 days after installation.
   2. Perform final verification mandrel test:
      a. Not sooner than 30 days before the end of the warranty period.
      b. Not later than 10 days before the end of the warranty period.
      c. Consider the final verification mandrel test a warranty service, and include the costs related to final verification mandrel test in the Contract Price.
   3. Utilize a 9 rod mandrel with minimum length equal to NPS and diameter as follows:

Nominal Pipe Size (NPS)	Mandrel Dia (in) (SDR 35/PS46)	Mandrel Dia (in) (SDR 26/PS 115)
6	5.45	5.33
8	7.28	7.11
10	9.08	8.87
12	10.79	10.55
15	13.20	12.90
18	16.13	15.76
21	19.00	18.57
24	21.36	20.87
27	24.06	23.51
30	27.68	27.04

   4. Test procedure: Pull the mandrel through the line under test by 1 person, by hand, with reasonable effort, without the aid of mechanical equipment.
   5. Failing test: Where the mandrel test is not successful, remove and replace the section of piping with the obstruction; test the piping again, including visible leaks test, pressure test with maximum leakage allowance, mandrel tests, and other specified tests:
      a. Correction of excessive deflection or obstructions by methods other than removal of the affected piping and replacement of the removed piping with new piping will not be accepted.

END OF SECTION

SECTION 02742A

ASPHALTIC CONCRETE PAVING (CA)

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Asphalt pavement on prepared subgrade or aggregate base course to lines, grades, and compacted thickness as indicated on the Drawings.

1.02 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):
   1. T 209 - Standard Method of Test for Theoretical Maximum Specific Gravity and Density of Asphalt Mixtures.

B. Caltrans Standard Test Methods:
   1. California Test 304 - Preparation of Bituminous Mixtures for Testing.
   2. California Test 362 - Determining Asphalt Content in Bituminous Mixtures by Vacuum Extraction.
   3. California Test 375 - Determining the In-Place Density and Relative Compaction of AC Pavement.
   4. California Test 382 - Determining Asphalt Content in Bituminous Mixtures (Ignition Oven Method).

C. State of California Department of Transportation Standard Specifications, latest edition (Caltrans Standard Specifications):
   1. Section 37 - Bituminous Seals.
   2. Section 39 - Asphalt Concrete.
   3. Section 92 - Asphalt Binders.
   4. Section 94 - Asphaltic Emulsions.

1.03 SUBMITTALS

A. Job mix formula.

B. Shop Drawings.

C. Product data:
   1. Asphalt binder.
   2. Asphalt aggregate.
   3. Pavement reinforcing fabric.
   4. Tack coat application rate calculations.

D. Quality control Submittals:
   1. Test results.
   2. Certificate of Compliance.

3. Certificate of Competence.

E. Equipment list.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Asphalt pavement delivery:
   1. Transport the mixture from the mixing plant to the point of use in vehicles having tight bodies previously cleaned of foreign materials.
   2. Treat bodies as necessary to prevent material from sticking to the bodies.
   3. Cover each load with canvas or other suitable material of sufficient size and thickness to protect the asphalt mixture from the weather.

1.05 PROJECT CONDITIONS

A. Environmental requirements:
   1. Asphalt concrete:
      a. Place asphalt concrete only when surface is dry, and when atmospheric temperature in the shade is 40 degrees Fahrenheit and rising, or above 50 degrees Fahrenheit if falling.
      b. Do not place asphalt concrete when weather is foggy or rainy, when base on which material is to be placed is in wet or frozen conditions, or when, in the opinion of the Engineer, weather conditions will prevent proper handling, finishing, or compaction of the mixtures.
   2. Prime coat:
      a. Do not apply prime coat when atmospheric temperature is below 60 degrees Fahrenheit.
      b. Apply prime coat only when base course is dry or contains moisture not in excess of that which will permit uniform distribution and desired penetration.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. This Work shall consist of furnishing and mixing aggregate and asphalt binder at a central mixing plant, spreading and compaction of the mixture as specified and as indicated on the Drawings.

B. In general, asphalt concrete and asphalt concrete base shall be in accordance with to Section 39 “Asphalt Concrete,” and applicable referenced sections of the Caltrans Standard Specifications:
   1. Where conflicts exist, this Specification shall govern.

2.02 ASPHALT PAVEMENT MATERIALS

A. Asphalts:
   1. Asphalt binder: Steam-refined paving asphalt, PG 64-10 in accordance with Section 92-1.02B “Performance Grades Asphalt Binders” of the Caltrans Standard Specifications.

2. Tack coat: Asphaltic emulsion, Grade SSA1in accordance with Section 94 of the Caltrans Standard Specifications.

B. Asphalt aggregate:
   1. Aggregate shall be in accordance with Section 39-2.02B(4)(b) of the Caltrans Standard Specifications for Type A HMA grading:
      a. For pavement placed in multiple lifts:
         1) Aggregate for the final lift (surface layer) shall be 1/2-inch maximum, medium.
         2) Aggregate for other lifts/layers shall be 3/4-inch maximum, medium.
      b. For pavements placed in a single lift:
         1) Aggregate shall be 1/2-inch maximum, medium.
   2. Use of reclaimed asphalt pavement (RAP) in asphalt concrete and asphalt concrete base is prohibited.

C. Asphalt pavement shall be produced in a batch mixing plant, a continuous pugmill mixing plant, or dryer-drum mixing plant:
   1. Proportioning shall be in accordance with Section 39-2.01B(8)(a) of the Caltrans Standard Specifications.
   2. Mixing shall be in accordance with Section 39-2.01B(8)(a) of the Caltrans Standard Specifications.

2.03 AGGREGATE BASE COURSE

A. As specified in Section 02050 - Soils and Aggregates for Earthwork.

B. Placed at the following locations:
   1. At locations indicated on the Drawings.
   2. Asphalt pavement.

C. Compacted thickness shall be as indicated on the Drawings**.**

2.04 EQUIPMENT

A. Spreading and compacting equipment:
   1. Spreading equipment shall be in accordance with Section 39-2.01C(2) and applicable referenced sections of the Caltrans Standard Specifications:
      a. Only in areas inaccessible to the machine, by approval of the Engineer, will hand spreading be permitted.
   2. Compaction equipment shall be in accordance with Section 39-2.01C(2) and applicable referenced sections of the Caltrans Standard Specifications.

2.05 SOURCE QUALITY CONTROL

A. Engineer will perform sampling and tests of materials in accordance with California Test Method Number 304 and California Test Method Number 362 or 382, as applicable. Samples will be taken from materials as delivered to the site.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions: Verify surfaces and site conditions are ready to receive work. If unsatisfactory conditions exist, do not commence installation until such conditions have been corrected. Beginning application means acceptance of existing conditions.

3.02 PREPARATION

A. Protection:
   1. Protect concrete pavements and walks, curbs and bases, and other improvements adjacent to the operations with suitable materials.
   2. Building and other surfaces shall be covered with paper or other protection, when required.
   3. Repair any damage caused by the Contractor's employees or operations to the satisfaction of the Engineer at no additional cost to the Owner.

B. Subgrade preparation:
   1. Immediately prior to applying prime coat or tack coat, or immediately prior to placing the asphalt pavement when prime coat or tack coat is not required, the subgrade to receive asphalt pavement shall be in accordance with the compaction requirement and elevation tolerances specified for the material involved and shall be cleaned to remove any loose or extraneous material.
   2. If the asphalt pavement is to be placed on an existing base or pavement that was not constructed as part of the contract, clean the surface by sweeping, flushing, or other means to remove loose particles of paving, dirt, and other extraneous material immediately before applying the prime coat or tack coat.

3.03 TACK COAT

A. Tack coat:
   1. A tack coat of asphaltic emulsion shall be applied to vertical surfaces of existing pavement, curbs, gutters, and construction joints in the surfacing against which additional material is to be placed, or as otherwise specified in this Section.
   2. Applied in 1 application at a rate according to Section 39-2.01A(3)(j) and residual rate requirements according to the mix design and application.

3.04 ASPHALT PAVEMENT

A. Placing materials in a windrow, then picking it up and placing it in the asphalt paver with loading equipment, will be permitted provided that:
   1. Asphalt paver is of such design that the material will fall into a hopper that has a movable bottom conveyor to feed and screed.
   2. Loader is constructed and operated so that substantially of the material deposited into windrows is picked up and deposited into the paving machine.
   3. Windrow is deposited only so far in advance of the paver to provide for continuous operation of the paver and not so far as to allow the temperature of the asphalt pavement in the windrow to fall below 260 degrees Fahrenheit.

B. Unless lower temperatures are directed by the Engineer, asphalt concrete shall be spread, and the first coverage of initial or breakdown compaction shall be complete before the surface temperature of the mixture drops below 250 degrees Fahrenheit.
   1. Breakdown and intermediate compaction shall be completed before the surface temperature drops below 190 degrees Fahrenheit.
   2. Compaction shall be completed before the surface temperature drops below 150 degrees Fahrenheit.

C. Spread and compacted in the number of layers and of the thicknesses indicated in the following table:
   1. Thickness tolerance of within 0.1 inch is allowed for asphalt concrete.
   2. Total thickness tolerance of within 0.2 inches is allowed for asphalt concrete base.

Total Thickness Indicated on Drawings(1)	**Number of Lifts**	**Top Layer Thickness (inches)**		**Next Lower Layer Thickness (inches)**		**Other Lower Layer Thicknesses (inches)**	
		Min.	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
<2-3/4 inches	1	-----	-----	-----	-----	-----	-----
3 inches(2)	2	1-1/4	1-1/2	1-1/4	1-1/2	-----	-----
3-1/4 to 4-3/4 inches	2	1-3/4	2-1/4	1-3/4	3	-----	-----
>5 inches	(3)	1-3/4	2-1/4	1-3/4	3	1-3/4	4-3/4

Notes:

(1) When pavement-reinforcing fabric is shown to be placed between layers of asphalt pavement, the thickness of asphalt pavement above the pavement-reinforcing fabric shall be considered to be the "Total Thickness Indicated on the Drawings" for the purpose of spreading and compacting the asphalt pavement above the pavement-reinforcing fabric.

(2) If approved by the Engineer, 1 lift of 3 inches may be placed.

(3) At least 2 layers shall be placed if the total thickness is less than 5 inches. At least 3 layers shall be placed if the total thickness is more than 5 inches, and less than 10-1/2 inches. At least 4 layers shall be placed if the total thickness is greater than 10-1/2 inches.

D. A layer shall not be placed over another layer which exceeds 3 inches in compacted thickness until the temperature of the layer which exceeds 3 inches in compacted thickness is less than 160 degrees Fahrenheit at mid depth.

E. If the temperature of any layer drops below 140 degrees Fahrenheit, or if directed by the Engineer, apply tack coat before placing next layer.

F. Unless otherwise indicated on the Drawings, asphalt mixtures shall not be handled, spread, or windrowed in a manner that will stain the finished surface of any pavement or other improvements.

G. Completed mixture shall be deposited on the prepared subgrade at a uniform quantity per linear foot, as necessary to provide the required compacted thickness without resorting to spotting, picking up, or otherwise shifting the mixture.

H. Spreading:
   1. All layers of asphalt pavement shall be spread with an asphalt paver and shall be in accordance with Section 39-2.01C and applicable referenced sections of the Caltrans Standard Specifications.
   2. At locations where the asphalt pavement is to be placed over areas inaccessible to spreading and rolling equipment, layers of asphalt pavement shall be distributed directly out of the back of the dump truck and spread by hand:
      a. Asphalt pavement spread by hand shall be compacted thoroughly to the required lines, grades, and cross-sections by means of pneumatic tampers, or by other methods that will produce the same degree of compaction as pneumatic tampers.

I. Compaction:
   1. Compaction of asphalt pavement shall be in accordance with Section 39-2.01C, and applicable referenced sections of the Caltrans Standard Specifications.
   2. Percent of maximum theoretical density for each layer of asphalt pavement shall be 91 to 97 percent. Theoretical maximum density to be determined using AASHTO T 209 and Caltrans Standard Specifications Section 39.

J. Segregation shall be avoided, and the surfacing shall be free of pockets of coarse or fine material. Asphalt pavement containing hardened lumps shall not be used:
   1. In areas inaccessible to paving and compacting equipment where spreading is done by hand, minimize the amount of segregation.

K. Location of longitudinal joints in the top layer will be determined by the Engineer and shall not adversely affect the quality of the finished product.

L. At locations, or as directed by the Engineer, the asphalt concrete shall be square and at least 1-inch thick when conforming to existing surfacing. Tapering or feathering is not allowed.

3.05 FIELD QUALITY CONTROL

A. Control the quality of Work and shall provide adequate testing to ensure compliance with these Specifications:
   1. Type and size of the samples shall be suitable to determine conformance with stability, density, thickness, and other specified requirements.
      a. Use an approved power saw or core drill for cutting samples.
      b. Furnish tools, labor, and materials for cutting samples, testing, and replacing the pavement where samples were removed.
      c. Take a minimum of 1 sample for every 4,000 square feet of asphalt pavement placed.
   2. Where open graded friction course is to be placed, core samples shall be taken prior to friction course placement.

B. Asphalt pavement shall match the grades indicated on the Drawings and shall be completely free from unintended hollows and high spots:
   1. After completion of paving work, paving shall be flooded with water.
      a. Any ponding that results in standing water greater than 3/4 inch in depth shall be ringed with chalk.

b. Such hollows shall be corrected by removing and replacing the asphalt concrete.
c. Asphalt concrete patch shall be square and at least 1-inch thick when conforming to existing surfacing.
d. Tapering or feathering is not allowed.

C. Perform in-place density and compaction tests of the completed pavement in accordance with California Test Method Number 375, to determine compliance with the specified requirements. Submit test results to Engineer for approval.

D. Cracks, settling of surface, improper drainage, improper compaction, and sloppy connection to previously laid surfaces will be construed as improper workmanship and will not be accepted.

3.06 MAINTENANCE OF PAVEMENT

A. Upon completion of final rolling, traffic shall not be permitted on the finished pavement for at least 6 hours, or until the asphalt pavement has cooled sufficiently to withstand traffic without being deformed.

3.07 WORKMANSHIP AND WARRANTY

A. Provide written warranty against defects in materials or workmanship for a period of not less than 1 year upon completion of Work.

END OF SECTION

SECTION 02952

PAVEMENT RESTORATION AND REHABILITATION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Resurfacing roads and paved surfaces in which surface is removed or damaged by installation of new work.

1.02 SUBMITTALS

A. Mix designs:
   1. Prior to placement of asphalt concrete, submit full details, including design and calculations for the asphalt concrete mix proposed.
   2. Submit gradation of aggregate base.
   3. Submit proposed mix design of portland cement concrete.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Performance requirements:
   1. Limiting dimensions:
      a. Determine the exact lengths and dimensions of such roads, pavements, parking areas, and walks that will require removal and replacement for new work.
      b. Join existing surfaces to terminals of new surfacing in smooth juncture.

2.02 MATERIALS

A. Aggregate base course: As specified in Section 02050 - Soil and for Earthwork.

B. Asphalt pavement: As specified in Section 02742A - Asphaltic Concrete Paving.

C. Portland cement concrete replacement material: Class A concrete as specified in Section 03300 - Cast-in-Place Concrete.

2.03 EQUIPMENT

A. Roads, pavements, parking areas, and walks:
   1. Equipment requirements: Good condition, capable of performing work intended in satisfactory manner.

2.04 ACCESSORIES

A. Material for painting asphalt concrete pavement: Tack coat as specified in Section 02742A - Asphaltic Concrete Paving.

PART 3 EXECUTION

3.01 INSTALLATION

A. Aggregate surface removal replacement:
   1. When trench cut is in aggregate surfaced areas, replace aggregate base course material with material matching existing material compacted to 95 percent of its maximum density.

B. Pavement removal and temporary asphalt replacement:
   1. Install temporary asphalt pavement or first course of permanent pavement replacement immediately following backfilling and compaction of trenches that have been cut through existing pavement.
   2. Except as otherwise provided, maintain this temporary pavement in safe and reasonably smooth condition until required permanent pavement is installed.
   3. Remove and dispose of temporary paving from project site.
   4. Where longitudinal trench is partly in pavement, replace pavement to original pavement edge, on a straight line, parallel to centerline of roadway.
   5. Where no part of longitudinal trench is in pavement, surfacing replacement shall only be required where existing surfacing materials have been removed.

C. Asphalt pavement replacement:
   1. Replace asphalt pavement to same thickness as adjacent pavement and match as nearly as possible adjacent pavement in texture, unless otherwise indicated on the Drawings.
   2. Cut existing asphalt pavements to be removed for trenches or other underground construction by wheel cutter, clay spade, or other device capable of making neat, reasonably straight and smooth cut without damaging adjacent pavement. Cutting device operation shall be subject to acceptance of Engineer.
   3. Cut and trim existing pavement after placement of required aggregate base course and just prior to placement of asphalt concrete for pavement replacement, and paint trimmed edges with material for painting asphalt concrete pavement immediately prior to constructing new abutting asphalt pavements. No extra payment will be made for these items, and costs incurred in performing this work shall be incidental to pipe laying or pavement replacement.
   4. Conform replacement of asphalt pavement to contour of original pavement.

D. Portland cement concrete pavement replacement:
   1. Where trenches lie within portland cement concrete section of streets, alleys, sidewalks, and similar concrete construction, saw cut such concrete (to a depth of not less than 1-1/2 inches) to neat, vertical, true lines in such manner adjoining surfaces are not damaged.

2. Place portland cement concrete replacement material to dimension as indicated on the Drawings.
3. Provide expansion joints that match existing.
4. Before placing replacement concrete, thoroughly clean edges of existing pavement and wash with neat cement and water.
5. Surface finish: Wood float finish.

E. Curb, gutter, and sidewalk replacement:
1. Where any concrete curb, gutter, or sidewalk has been removed or displaced, replace to nearest construction joints with new Class A curb, gutter, or sidewalk to same dimensions and finish as original construction that was removed:
a. Provide expansion joints of same spacing and thickness as original construction.

F. Asphalt pavements:
1. Trim existing asphalt pavements which are to be matched by pavement widening or pavement extension to neat true line with straight vertical edges free from irregularities with saw specifically designed for this purpose. Minimum allowable depth of cut shall be 1-1/2 inches.
2. Cut and trim existing pavement after placement of required aggregate base course and just prior to placement of asphalt concrete for pavement widening or extension, and paint trimmed edges with material for painting asphalt concrete pavement immediately prior to constructing new abutting asphalt concrete pavements.
3. No extra payment will be made for these items and costs incurred in performing this work shall be incidental to widening or pavement extension.

3.02 FIELD QUALITY CONTROL

A. Tests:
1. Asphalt concrete as specified in Section 02742A - Asphaltic Concrete Paving.
2. Concrete as specified in Section 03300 - Cast-in-Place Concrete.

B. Inspection:
1. Asphalt concrete:
a. Lay 10-foot straightedge parallel to centerline of trench when the trenches run parallel to street, and across pavement replacement when trench crosses street at angle.
b. Remove and correct any deviation in cut pavement replacement greater than 1/4 inch in 10 feet.
2. Portland cement concrete replacement pavement:
a. Lay 10-foot straightedge either across pavement replacement or longitudinal with centerline of gutter or ditch.
b. Remove and correct any deviation in cut pavement replacement greater than 1/4 inch in 10 feet.

END OF SECTION

SECTION 03055

ADHESIVE-BONDED REINFORCING BARS AND ALL THREAD RODS IN CONCRETE

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Bonding reinforcing bars and all thread rods in concrete using adhesives.

1.02 REFERENCES

A. American Concrete Institute (ACI).
   1. 355.4 - Qualification of Post-Installed Adhesive Anchors in Concrete and Commentary.

B. American National Standards Institute (ANSI):
   1. Standard B212.15 - Carbide Tipped Masonry Drills and Blanks for Carbide Tipped Masonry Drills.

C. ASTM international (ASTM):
   1. C881 - Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.
   2. E488 - Standard Test Method for Strength of Anchors in Concrete Elements.

D. Concrete Reinforcing Steel Institute (CRSI).

E. ICC Evaluation Service, Inc. (ICC-ES):
   1. AC308 - Acceptance Criteria for Post-Installed Adhesive Anchors in Concrete Elements.

F. Society for Protective Coatings (SSPC):
   1. SP 1 - Solvent Cleaning.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Evaluation Service Report (ESR): Report prepared by ICC-ES or other testing agency acceptable to the Engineer and to the building official that documents testing and review of a product to confirm that it complies with the requirements of designated ICC-ES acceptance criteria, and to document its acceptance for use under the building code specified in Section 01410 - Regulatory Requirements.

1.04 SUBMITTALS

A. Product data: Technical data for adhesives, including:
   1. Manufacturer’s printed installation instructions (MPII).

2. Independent laboratory test results indicating allowable loads in tension and shear for concrete of the types included in this Work, with load modification factors for temperature, spacing, edge distance, and other installation variables.
3. Handling and storage instructions.

B. Quality Control Submittals:
1. Special inspection: Detailed step-by-step instructions for the special inspection procedures required by the building code specified in Section 01410 - Regulatory Requirements.
2. For each adhesive to be used, Evaluation Report confirming that the product complies with the requirements of ICC-ES AC308 for both un-cracked and cracked concrete and for use in Seismic Design Categories A through F.
3. Installer qualifications:
   a. Submit evidence of successful completion of the adhesive manufacturer's installation training program.
   b. Submit evidence of current certification for installation of inclined and overhead anchors under sustained tension loading.
4. Inspection and testing reports:
   a. Field quality control: Reports of inspections and tests.
   b. Field quality assurance: Reports of special inspections and tests.

1.05 QUALITY ASSURANCE

A. Qualifications:
1. Installation requirements:
   a. Have available at the Site and install anchors in accordance with the adhesive MPII.
2. Installer qualifications:
   a. Demonstrating successful completion of the adhesive manufacturer's on-site training program for installation of adhesive-bonded anchors.
   b. Holding current certification for installation of adhesive-bonded anchors by a qualified organization acceptable to the Engineer and to the building official.
      1) Organizations/certification programs deemed to be qualified are:
         a) ACI-CRSI Adhesive Anchor Installer Certification Program.
         b) Adhesive anchor manufacturer's certification program, subject to acceptance by the Engineer and the building official.

1.06 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements.

B. Store and protect products as follows, unless more restrictive requirements are recommended by the manufacturer:
1. Store adhesives and adhesive components on pallets or shelving in a covered storage area protected from weather.
2. Control temperature to maintain storage within the manufacturer's recommended temperature range.
   a. If products have been stored at temperatures outside the manufacturer's recommended range, test by methods acceptable to the Engineer to confirm acceptability before installing in the Work.

3. Dispose of products that have passed their expiration date.

1.07 PROJECT CONDITIONS

A. As specified in Section 01850 - Design Criteria.

B. Seismic Design Category (SDC) for structures: As specified in Section 01850 - Design Criteria.

PART 2 PRODUCTS

2.01 GENERAL

A. Like items of materials: Use end products of one manufacturer in order to achieve structural compatibility and singular responsibility.

B. Adhesives shall have a current Evaluation Report documenting testing and compliance in accordance with ACI 355.4 and ICC-ES AC308 for use with un-cracked concrete and with cracked concrete in the seismic design category specified.

C. Bond reinforcing bars and all thread rods in concrete using epoxy adhesive unless other adhesives specified are specifically indicated on the Drawings or approved in writing by the Engineer.

2.02 EPOXY ADHESIVE

A. Materials:
   1. In accordance with the physical requirements of ASTM C881, Type IV, Grade 3, Class B or C, depending on Site conditions.
   2. Two-component, 100 percent solids, insensitive to moisture.
   3. Cure temperature, pot life, and workability: Compatible with intended use and environmental conditions.

B. Packaging:
   1. Disposable, self-contained cartridge system furnished in side-by-side cartridges designed to fit into a manually or pneumatically operated caulking gun, and with resin and hardener components isolated until mixing through the manufacturer's static mixing nozzle.
      a. Nozzle designed to dispense components in the proper ratio and to thoroughly blend the components for injection from the nozzle directly into the prepared hole.
      b. Provide nozzle extensions as required to allow full-depth insertion and filing from the bottom of the hole.
   2. Container markings: Include the manufacturer's name, product name, batch number, mix ratio by volume, product expiration date, ANSI hazard classification, and appropriate ANSI handling precautions.

C. Manufacturers: One of the following or equal:
   1. Hilti, Inc., HIT-RE 500-V3.
   2. Simpson Strong-Tie Co., Inc., SET-3G.

2.03 ALL THREAD RODS

A. Materials: As specified in Section 05120 - Structural Steel Framing for rods, nuts, and washers.

2.04 REINFORCING BARS

A. As specified in Section 03200 - Concrete Reinforcing.

2.05 REPAIR MATERIALS

A. Dry-pack mortar: As specified in Section 03366 - Concrete Finishes.

B. Epoxy grout: As specified in Section 03600 - Grouting.

PART 3 EXECUTION

3.01 GENERAL

A. Execution of this Work is restricted to installers who have personally completed the adhesive manufacturer's on-site training for the products to be installed, and who are personally certified through a qualified certification program described under the Quality Assurance article and accepted by the Engineer and the building official.
   1. Do not install holes or adhesive until training is complete.

B. Perform Work in compliance with the accepted MPII and the following instructions. Where the accepted MPII and the instructions conflict, the MPII shall prevail.

C. Install reinforcing bars and all thread rods to embedment depth and at spacing and locations indicated on the Drawings.
   1. If embedment depth is not indicated, contact the Engineer for requirements.

3.02 PREPARATION

A. Do not begin installation of adhesive bonded anchors until:
   1. Concrete has achieved an age of at least 21 days after placement.
   2. On-site training in installation of adhesive bonded anchors by the manufacturer's technical representative is complete. Do not drill holes in concrete or install adhesive and embeds in holes.

B. Review the MPII and "Conditions of Use" stipulated in the Evaluation Report before beginning work.
   1. Bring to the attention of the adhesive manufacturer's technical representative any discrepancies between these documents and resolve before proceeding with installation.

C. Install adhesive bonded anchors in full compliance with the MPII using personnel who have successfully completed the manufacturer's on-site training for products to be used and who hold certifications specified in this Section.

D. Confirm that adhesive and substrate receiving adhesive are within the manufacturer's recommended range for temperature and moisture conditions and will remain so during the curing time for the product.

3.03 HOLE SIZING AND INSTALLATION

A. Drilling holes:
   1. Determine location of reinforcing bars or other obstructions with a nondestructive indicator device and mark locations with construction crayon on the surface of the concrete.
   2. Do not damage or cut existing reinforcing bars, electrical conduits, or other items embedded in the existing concrete without prior acceptance by the Engineer.

B. Hole-drilling equipment:
   1. Electric or pneumatic rotary impact type with medium or light impact.
      a. Installation of anchors in cored holes is not permitted.
      b. Set drill to "rotation only" mode, or to "rotation plus hammer" mode in accordance with the manufacturer's installation instructions and the requirements of the Evaluation Report.
      c. Where edge distances are less than 2 inches and "rotation plus hammer" mode is permitted, use lighter impact equipment to prevent micro-cracking and concrete spalling during the drilling process.
   2. Drill bits: Carbide-tipped in accordance with ANSI B212-15, unless otherwise recommended by the manufacturer or required as a condition of use in the Evaluation Report.
      a. Hollow drill bits with flushing air systems are preferred. Air supplied to drill bits shall be free of oil, water, or other contaminants that will reduce bond.

C. Hole diameter: As recommended in the manufacturer's installation instructions and the Evaluation Report.

D. Hole depth: As recommended in the manufacturer's installation instructions to provide minimum effective embedment indicated on the Drawings.

E. Obstructions in drill path:
   1. If an existing reinforcing bar or other obstruction is hit while drilling a hole, unless otherwise accepted by the Engineer, stop drilling. Prepare and fill the hole with dry-pack mortar. Relocate the hole to miss the obstruction and drill another hole to the required depth.
      a. Obtain the Engineer's acceptance of distance between abandoned and relocated holes before proceeding with the relocation.
      b. Allow dry-pack mortar to cure to a strength equal to that of the surrounding concrete before resuming drilling in the area.
      c. Epoxy grout may be substituted for dry-pack mortar when accepted by the Engineer.
   2. Avoid drilling an excessive number of holes in an area of a structural member, which would excessively weaken the member and endanger the stability of the structure.
   3. When existing reinforcing steel is encountered during drilling and when specifically accepted by the Engineer, enlarge the hole by 1/8 inch, core

through the existing reinforcing steel at the larger diameter, and resume drilling at original hole diameter using pneumatic rotary impact drill.

4. Bent bar reinforcing bars: Where edge distances are critical and interference with existing reinforcing steel is likely, if acceptable to the Engineer, drill hole at 10 degree (or less) angle from axis of reinforcing bar or all thread rod being installed.

F. Cleaning holes:
   1. Insert air nozzle to bottom of hole and blow out loose dust.
      a. Use compressed air that is free of oil, water, or other contaminants that will reduce bond.
      b. Provide minimum air pressure of 90 pounds per square inch for not less than 4 seconds.
   2. Using a stiff bristle brush with diameter that provides contact around the full perimeter of the hole, vigorously brush hole to dislodge compacted drilling dust.
      a. Insert brush to the bottom of the hole and withdraw using a simultaneous twisting motion.
      b. Repeat at least 4 times.
   3. Repeat the preceding steps as required to remove drilling dust or other material that will reduce bond, and in the number of cycles required by the MPII and the Evaluation Report.
   4. Leave prepared holes clean and dry.
   5. Protect prepared and cleaned holes from contamination and moisture until adhesive is installed.
   6. Re-clean and dry previously prepared holes if, in the opinion of the Engineer, the hole has become contaminated after initial cleaning.

3.04 INSTALLATION OF ADHESIVE AND INSERTS

A. Clean and prepare inserts reinforcing bars and all thread rods:
   1. Prepare embedded length of reinforcing bars and all thread rods by cleaning to bare metal. Inserts shall be free of oil, grease, paint, dirt, mill scale, rust, or other coatings that will reduce bond.
   2. Solvent clean prepared reinforcing bars and all thread rods over the embedment length in accordance with SSPC-SP 1. Provide an oil and grease free surface for bonding of adhesive to steel.

B. Fill holes with adhesive:
   1. Fill hole with adhesive only when dry. Do not fill when the hole is filled with water or damp, except with written authorization by the Engineer.
   2. Starting at the bottom of the hole, fill hole with adhesive inserting the reinforcing bar or all thread rod.
   3. Fill hole as nozzle is withdrawn without creating air voids.
   4. Unless otherwise indicated on the Drawings, fill hole with sufficient adhesive so that excess adhesive is extruded out of the hole when the reinforcing bar or all thread rod is inserted.
   5. Where necessary, seal hole at surface of concrete to prevent loss of adhesive during curing.

C. Installing reinforcing bars and all thread rods.
   1. Unless otherwise indicated on the Drawings, install bars and rods perpendicular to the concrete surface.
   2. Insert reinforcing bars and all thread rods into adhesive in accordance with the manufacturer's recommended procedures.
   3. Confirm that insert has reached the designated embedment in the concrete and that adhesive completely surrounds the embedded portion.
   4. Securely brace bars and all thread rods in place to prevent displacement while the adhesive cures. Bars and rods displaced during curing will be considered damaged and replacement will be required.
   5. Clean excess adhesive from the mouth of the hole.

D. Curing and loading.
   1. Provide and maintain curing conditions recommended by the adhesive manufacturer for the period required to fully cure the adhesive at the temperature of the concrete.
   2. Do not disturb or load bonded embeds until the manufacturer's recommended cure time, based on temperature of the concrete, has elapsed.

3.05 POST-INSTALLATION ACTIVITIES

A. Do not bend bars or all thread rods after bonding to the concrete, unless accepted in advance by the Engineer.

B. Attachments to all thread rods:
   1. After assemblies to be connected are placed, install nuts and washers for threaded rods as indicated on the Drawings.

3.06 FIELD QUALITY CONTROL

A. Provide field quality control over the Work of this Section as specified in Section 01450 - Quality Control.

B. Do not allow Work described in this Section to be performed by individuals who do not hold the specified certifications and who have not completed the specified jobsite training.

C. Manufacturer's services:
   1. Before beginning installation, adhesive manufacturer's technical representative to conduct on-site training in proper storage and handling of adhesive, drilling and cleaning of holes, and preparation and installation of reinforcing bars and all thread rods.
      a. Provide notice of scheduled training to the Engineer and to special inspector(s) not less than 10 working days before training occurs. Engineer and special inspector may attend training sessions.
   2. Submit record, signed by the manufacturer's technical representative, listing the Contractor's personnel who completed the training. Only qualified personnel who have completed the manufacturer's on-site training shall perform installations.

D. Field inspections and testing:
   1. Hole drilling and preparation.
   2. Results: Submit records of inspections and testing to the Engineer by electronic copies within 24 hours after completion.

3.07 FIELD QUALITY ASSURANCE

A. Provide field quality assurance over the Work of this Section as specified in Section 01450 - Quality Control.

B. Special inspections, special tests, and structural observation:
   1. Provide as specified in Section 01455 - Regulatory Quality Assurance.
   2. Frequency of inspections:
      a. Unless otherwise indicated on the Drawings or in this Section, provide periodic special inspection as required by the Evaluation Report for the product installed.
      b. Provide continuous inspection for the initial installation of each type and size of adhesive bonded reinforcing bar and all thread rod. Subsequent installations of the same anchor may be installed with periodic inspection as defined in subsequent paragraphs.
   3. Preparation:
      a. Review Drawings and Specifications for the Work to be observed.
      b. Review the adhesive manufacturer's MPII and recommended installation procedures.
      c. Review Evaluation Report "Conditions of Use" and "Special Inspection" requirements.
   4. Inspection: Periodic:
      a. Initial inspection. Provide an initial inspection for each combination of concrete and reinforcing bar strength or concrete strength and all thread rod material being installed. During initial inspection, observe the following for compliance with the installation requirements.
         1) Concrete: Class (minimum specified compressive strength) and thickness.
         2) Environment: Temperature conditions at the work area and moisture conditions of concrete and drilled hole.
         3) Holes: Locations, spacing, and edge distances; verification of drill bit compliance with requirements; cleaning equipment and procedures; cleanliness of hole. Before adhesive is placed, confirm that depth and preparation of holes conforms to the requirements of the Contract Documents, the MPII, and the "Conditions of Use" listed in the Evaluation Report.
         4) Adhesive: Product manufacturer and name, lot number and expiration date, temperature of product at installation, installation procedure. Note initial set times observed during installation.
         5) Reinforcing bars and all thread rods: Material diameter and length; steel grade and/or strength; cleaning and preparation; cleanliness at insertion; minimum effective embedment provided.

b. Subsequent inspections: Subsequent installations of the same reinforcing bars or all thread rods may be performed without the presence of the special inspector, provided that:
    1) There is no change in personnel performing the installation, the general strength and characteristics of the concrete receiving the inserts, or the reinforcing bars and all thread rods being used.
    2) For ongoing installations, the special inspector visits the Site at least once per day during each day of installation to observe the Work for compliance with material requirements and installation procedures.

5. Inspection: Continuous.
    a. Make observations as described under “Inspection - Periodic, Initial Inspection” during drilling, cleaning, and bonding activities for all bars and rods installed.
6. Records of inspections:
    a. Provide a written record of each inspection using forms acceptable to the Engineer and to the building official.
    b. Submit electronic copies of inspection reports to the Engineer within 24 hours after completion of inspection.

END OF SECTION

SECTION 03071

EPOXIES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Epoxy.
   2. Epoxy gel.
   3. Epoxy bonding agent.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C881 - Standard Specification for Epoxy-Resin-Base Systems for Concrete.
   2. C882 - Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear.
   3. D638 - Standard Test Method for Tensile Properties of Plastics.
   4. D695 - Standard Test Method for Compressive Properties of Rigid Plastics.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data:
   1. Manufacturer's data completely describing epoxy materials:
   2. Evidence of conformance to ASTM C881. Include manufacturer's designations of type, grade, class, and color.
   3. Documentation that materials meet or exceed the specified strength and performance characteristics. Indicate test methods and test results.

C. Installation instructions:
   1. Provide manufacturer's installation instructions.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Performance requirements:
   1. Provide epoxy materials that are new.
   2. Store and use products within limitations in accordance with the manufacturer.
   3. Perform and conduct Work of this Section in a neat, orderly manner.

2.02 MATERIALS

A. General:
   1. Moisture tolerant, water-insensitive, two-component epoxy resin adhesive material containing 100 percent solids, and meeting or exceeding the performance properties specified when tested in accordance with the standards specified.

B. Epoxy: Low viscosity product in accordance with ASTM C881; Types I, II, and IV; Grade 1; Class C, except as modified in this Section.
   1. Manufacturers: One of the following, or equal:
      a. Dayton Superior, Unitex Pro-Poxy 100.
      b. Sika Corporation, Sikadur 35 Hi-Mod LV.
   2. Required properties:

Table 1. Material Properties - Epoxy

Property	Test Method	Required Results ("neat")
Tensile Strength (7-day)	ASTM D638	7,000 pounds per square inch, minimum.
Compressive Yield Strength (7-day)	ASTM D695	10,000 pounds per square inch, minimum.
Bond Strength (harded concrete to harded concrete after 2-day cure)	ASTM C882	1,000 pounds per square inch, minimum. Concrete failure before failure of epoxy.
Viscosity (mixed)		250 to 550 centipoise

Notes:

(1) Testing results are for materials installed and cured at a temperature between 72 and 78 degrees Fahrenheit for 7 days, unless otherwise noted.

C. Epoxy gel: Non-sagging product in accordance with ASTM C881, Types I and IV, Grade 3, Class C.
   1. Manufacturers: One of the following, or equal:
      a. Sika Corp., Sikadur 31, Hi-Mod Gel.
   2. Required properties:

Table 2. Material Properties - Epoxy Gel

Property	Test Method	Required Results ("neat")
Tensile Strength (7-day)	ASTM D638	2,000 pounds per square inch, minimum.
Compressive Yield Strength (7-day)	ASTM D695	8,000 pounds per square inch, minimum.
Bond Strength (14-day)	ASTM C882	1,500 pounds per square inch, minimum.

Notes:

(1) Testing results are for materials installed and cured at a temperature between 72 and 78 degrees Fahrenheit for 7 days, unless otherwise noted.

D. Epoxy bonding agent: Non-sagging product in accordance with ASTM C881, Type II, Grade 2, Class C.
   1. Manufacturers: One of the following, or equal:
      a. Sika Chemical Corp., Sikadur 32 Hi-Mod LPL.

2. Required properties:

Table 3. Material Properties - Epoxy Bonding Agent		
Property	**Test Method**	**Required Results**
Tensile Strength (7-day)	ASTM D638	3,300 pounds per square inch, minimum.
Compressive Yield Strength (7-day)	ASTM D695	8,300 pounds per square inch, minimum.
Bond Strength (14-days)	ASTM C882	1,800 pounds per square inch, minimum. Concrete failure before failure of epoxy bonding agent.
Pot Life	-	Minimum 90 minutes at 73 degrees Fahrenheit. Minimum 60 minutes at 100 degrees Fahrenheit.
Notes: (1) Testing results are for materials installed and cured at a temperature between 72 and 78 degrees Fahrenheit for 7 days, unless otherwise noted.		

PART 3 EXECUTION

3.01 INSTALLATION

A. Install and cure epoxy materials in accordance with the manufacturer's installation instructions.

B. Epoxy:
   1. Apply in accordance with the manufacturer's installation instructions.

C. Epoxy gel:
   1. Apply in accordance with the manufacturer's installation instructions.
   2. Use for vertical or overhead work, or where high viscosity epoxy is required.
   3. Epoxy gel used for vertical or overhead work may be used for horizontal work.

D. Epoxy bonding agent:
   1. Apply in accordance with the manufacturer's installation instructions.
   2. Will not be required for filling form tie holes or for normal finishing and patching of similar sized small defects.

END OF SECTION

SECTION 03072

EPOXY RESIN/PORTLAND CEMENT BONDING AGENT

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Epoxy resin/portland cement bonding agent.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C109 - Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. Cube Specimens).
   2. C348 - Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars.
   3. C496 - Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.
   4. C882 - Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear.

B. Federal Highway Administration (FHWA):
   1. FHWA-RD-86-193 - Highway Concrete Pavement Technology Development and Testing Volume V: Field Evaluation of SHRP C9206 Test Sites (Bridge Deck Overlays).

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Sika Corp., Sika Armatec 110.

B. Substitutions: The use of other than the specified product will be considered, providing the Contractor requests its use in writing to the Engineer. This request shall be accompanied by:
   1. A certificate of compliance from an approved independent testing laboratory that the proposed substitute product meets or exceeds specified performance criteria, tested in accordance with the specified test standards.
   2. Documented proof that the proposed substitute product has a 1-year proven record of performance of bonding portland cement mortar/concrete to hardened portland cement mortar/concrete, confirmed by actual field tests and 5 successful installations that the Engineer can investigate.

2.02 MATERIALS

A. Epoxy resin/portland cement adhesive:
   1. Component "A" shall be an epoxy resin/water emulsion containing suitable viscosity control agents. It shall not contain butyl glycidyl ether.

2. Component "B" shall be primarily a water solution of a polyamine.
3. Component "C" shall be a blend of selected portland cements and sands.
4. The material shall not contain asbestos.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. Properties of the mixed epoxy resin/portland cement adhesive:
   1. Pot life: 75 to 105 minutes.
   2. Contact time: 24 hours.
   3. Color: Dark gray.

B. Properties of the cured epoxy resin/portland cement adhesive:
   1. Compressive strength in accordance with ASTM C109:
      a. 3 day: 4,500 pounds per square-inch minimum.
      b. 7 days: 6,500 pounds per square-inch minimum.
      c. 28 days: 8,500 pounds per square-inch minimum.
   2. Splitting tensile strength in accordance with ASTM C496:
      a. 28 days: 600 pounds per square-inch minimum.
   3. Flexural strength:
      a. 1,100 pounds per square-inch minimum in accordance with ASTM C348.
   4. Bond strength in accordance with ASTM C882 modified at 14 days:
      a. 0 hours open time: 2,800 pounds per square-inch minimum.
      b. 24 hours open time: 2,600 pounds per square-inch minimum.
   5. The epoxy resin/portland cement adhesive shall not produce a vapor barrier.
   6. Material must be proven to prevent corrosion of reinforcing steel when tested under the procedures as set forth by the FHWA Program Report Number FHWA-RD-86-193. Proof shall be in the form of an independent testing laboratory corrosion report showing prevention of corrosion of the reinforcing steel.

PART 3 EXECUTION

3.01 INSTALLATION

A. Mixing the epoxy resin: Shake contents of Component "A" and Component "B." Empty all of both components into a clean, dry mixing pail. Mix thoroughly for 30 seconds with a jiffy paddle on a low speed with 400 to 600 revolutions per minute drill. Slowly add the entire contents of Component "C" while continuing to mix for a minimum of 3 minutes and until uniform with no lumps. Mix only the quantity that can be applied within its pot life.

B. Placement procedure:
   1. Apply to prepared surface with stiff-bristle brush, broom, or "hopper-type" spray equipment:
      a. For hand applications: Place fresh plastic concrete/mortar while the bonding bridge adhesive is wet or dry, up to 24 hours.
      b. For machine applications: Allow the bonding bridge adhesive to dry for 12 hours minimum.

C. Adhere to all limitations and cautions for the epoxy resin/portland cement adhesive in the manufacturer's current printed literature.

3.02 CLEANING

A. Leave finished work and work area in a neat, clean condition without evidence of spillovers onto adjacent areas.

END OF SECTION

SECTION 03102

CONCRETE FORMWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Concrete formwork.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 117 - Specifications for Tolerances for Concrete Construction and Materials and Commentary.

B. NSF International (NSF):
   1. 61 - Drinking Water System Components - Health Effects.

C. Underwriters Laboratories (UL).

1.03 SUBMITTALS

A. Information on proposed forming system:
   1. Submit in such detail as the Engineer may require to assure themselves that intent of the Specifications can be complied with by use of proposed system.
   2. Alternate combinations of plywood thickness and stud spacing may be submitted.

B. Form release agent: NSF 61 certification prepared by NSF, UL, or other similar nationally recognized testing laboratory acceptable to the Engineer.

1.04 QUALITY ASSURANCE

A. Qualifications of formwork manufacturers: Use only forming systems by manufacturers having a minimum of 5 years of experience, except as otherwise specified, or accepted in writing by the Engineer.

B. Regulatory requirements: Install Work of this Section in accordance with local, state, and federal regulations.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:
   1. Concrete forms, falsework, and shoring in accordance with local, state, and federal regulations.

2. Forms and ties to withstand concrete pressures without bulging, spreading, or lifting of forms.

B. Performance requirements:
   1. Construct forms so that finished concrete conforms to shapes, lines, grades, and dimensions indicated on the Drawings.
   2. It is intended that surface of concrete after stripping presents smooth, hard, and dense finish that requires minimum amount of finishing.
   3. Provide sufficient number of forms so that the Work may be performed rapidly and present uniform appearance in form patterns and finish.
   4. Use forms that are clean and free from dirt, concrete, and other debris.
      a. Coat with form release agent if required, prior to use or reuse.

2.02 MANUFACTURED UNITS

A. Forms:
   1. Built-up plywood:
      a. May be substituted for prefabricated forming system, subject to the following minimum requirements:
         1) Size and material:
            a) Use full size 4-foot by 8-foot plywood sheets, except where smaller pieces are able to cover entire area.
            b) Sheet construction: 5-ply plywood sheets, 3/4-inch nominal, made with 100 percent waterproof adhesive, and having finish surface that is coated or overlaid with surface which is impervious to water and alkaline calcium and sodium hydroxide of cement.
         2) Wales: Minimum 2-inch by 4-inch lumber.
         3) Studding and wales: No loose knots and free of warps, cups, and bows.
   2. Steel:
      a. Rigidly constructed and capable of being braced for minimum deflection of finish surface.
      b. Capable of providing finish surfaces that are flat without bows, cups, or dents.
   3. Steel-framed plywood:
      a. Provide forms that are rigidly constructed and capable of being braced.
      b. Plywood paneling: 5-ply, 5/8-inch nominal or 3/4-inch nominal, made with 100 percent waterproof adhesive, and having finish surface that is coated or overlaid with surface which is impervious to water and alkaline calcium and sodium hydroxide of cement.

B. Form release agent.
   1. Effective, non-staining, bond-breaking coating compatible with form surfaces and concrete mixes used.

C. Form ties:
   1. General:
      a. Provide form ties for forming system selected that are manufactured by a recognized manufacturer of concrete forming equipment.
      b. Do not use wire ties or wood spreaders.
      c. Provide ties of type that accurately tie, lock, and spread forms.

d. Provide form ties of such design that when forms are removed, they locate no metal or other material within 1-1/2 inches of the surface of the concrete.
e. Do not allow holes in forms for ties to allow leakage during placement of concrete.

2. Cone-snap ties:
   a. Shall form a cone shaped depression in the concrete with minimum diameter of 1 inch at the surface of the concrete and minimum depth of 1-1/2 inches.
   b. Provide neoprene waterseal washer that is located near the center of the concrete.
3. Taper ties:
   a. Neoprene plugs for taper tie holes: Size so that after they are driven, plugs are located in center third of wall thickness.

D. Incidentals:
1. External angles:
   a. Where not otherwise indicated on the Drawings, provide with 3/4-inch bevel, formed by utilizing true dimensioned wood or solid plastic chamfer strip on walkways, slabs, walls, beams, columns, and openings.
   b. Provide 1/4-inch bevel formed by utilizing true dimensioned wood or solid plastic chamfer strip on walkways, walls, and slabs at expansion, and construction joints.
2. Keyways: Steel, plastic, or lumber treated with form release agent.

PART 3 EXECUTION

3.01 EXAMINATION

A. Site verification of conditions:
1. Do not place concrete until forms have been checked for alignment, level, and strength, and mechanical and electrical inserts or other embedded items for correct location.

3.02 INSTALLATION

A. Forms:
1. Built-up plywood:
   a. Studding:
      1) Spaced at 16 inches or 24 inches on center.
      2) Closer spacing may be required depending upon strength requirements of the forms, in order to prevent any bulging surfaces on faces of finished concrete work.
      3) Install studs perpendicular to grain of exterior plys of plywood sheets.
   b. Wales: Double lumber material with minimum size as specified in this Section.
   c. Number of form reuses: Depends upon durability of surface coating or overlay used, and ability to maintain forms in condition such that they are capable of producing flat, smooth, hard, dense finish on concrete when stripped.

2. Steel:
    a. Adequately brace forms for minimum deflection of finish surface.
3. Steel-framed plywood:
    a. Rigidly construct and brace with joints fitting closely and smoothly.
    b. Number of form reuses: Depends upon durability of surface coating or overlay used.
4. As specified in this Section, built-up plywood forms may be used in conjunction with steel forms or steel-framed plywood forms for special forming conditions such as corbels and forming around items which will project through forms.

B. Form bracing and alignment:
1. Line and grade: Limit deviations to tolerances which will permit proper installation of structural embedded items or mechanical and electrical equipment and piping.
2. Formwork:
    a. Securely brace, support, tie down, or otherwise hold in place to prevent movement.
    b. Make adequate provisions for uplift pressure, lateral pressure, and deflection of forms.
3. When second lift is placed on hardened concrete, take special precautions in formwork at top of old lift and bottom of new lift to prevent:
    a. Spreading and vertical or horizontal displacement of forms.
    b. Grout “bleeding” on finish concrete surfaces.
4. Pipe stubs, anchor bolts, conduits, and other embedded items:
    a. Set in forms, position, and secure prior to placement of concrete to maintain a minimum 1-1/2-inch clearance between the item and any concrete reinforcement.
    b. Securing embedded items in position by wiring or welding to the reinforcement is not permitted.
5. Cracks, openings, or offsets at joints in formwork: Close those that are 1/16 inch or larger by tightening forms or by filling with acceptable crack filler acceptable to the Engineer.

C. Forming incidentals:
1. Keyways: Construct as indicated on the Drawings.
2. Reentrant angles: May be left square.
3. Level strips: Install at top of wall concrete placements to maintain true line at horizontal construction joints.
4. Inserts:
    a. Encase pipes, anchor bolts, steps, reglets, castings, and other inserts, as indicated on the Drawings or as required, in concrete.

D. Form release agent:
1. Apply in accordance with the manufacturer’s instructions.

E. Form ties:
1. Cone-snap ties: Tie forms together at not more than 2-foot centers vertically and horizontally.

3.03 FORM REMOVAL

A. General:
   1. Keep forms in place, as specified in the following paragraphs, to provide curing and to protect concrete surfaces and edges from damage.
   2. Immediately after forms are removed, carefully examine concrete surfaces, and repair any irregularities in surfaces and finishes as specified.

B. Form removal:
   1. Do not remove forms from concrete which has been placed when outside ambient air temperature is below 50 degrees Fahrenheit until the following conditions are satisfied:
      a. Concrete has sufficient strength to allow form removal without damage to surfaces.
      b. At least 48 hours have elapsed since the end of concrete placement.
      c. Provisions are in place to maintain moisture for curing concrete, and temperature at or above the required minimum curing temperature specified.
   2. Vertical forms:
      a. Retain in place for a minimum of 24 hours after concrete is placed.
      b. If concrete has sufficient strength and hardness to resist surface or other damage after 24 hours, forms may be removed.
   3. Other forms supporting concrete, and shoring: Retain in place as follows:
      a. Formed sides of footings: 24 hours minimum.
      b. Formed vertical sides of beams, girders, and similar members: 48 hours minimum.
      c. Forms below slabs, beams, and girders: Until concrete strength reaches specified strength f'c or until shoring is installed.
         1) Shoring for slabs, beams, and girders: Shore until concrete strength reaches minimum specified 28-day compressive strength.

3.04 SURFACE REPAIRS AND FINISHING

A. Immediately after forms are removed, carefully examine concrete surfaces, and repair any irregularities in surfaces and finishes as specified in Section 03300 - Cast-in-Place Concrete.

B. Form ties:
   1. Snap ties:
      a. Break off ties and remove from concrete.
      b. Roughen cone shaped tie holes by heavy sandblasting before repair.
      c. Dry pack cone shaped tie holes with dry-pack mortar as specified in Section 03600 - Grouting.
   2. Taper ties:
      a. Rubber plugs in tie holes:
         1) After forms and taper ties are removed from wall, plug tie holes with neoprene plug as follows:
            a) Heavy sandblast and then clean tie holes.

b) After cleaning, drive neoprene plug into each of taper tie holes with steel rod.
(1) Final location of neoprene plug shall be in center third of wall thickness.
(2) Bond neoprene plug to concrete with epoxy.
c) Locate steel rod in cylindrical recess and against middle of plug during driving.
(1) Do not drive on flat area outside cylindrical recess.

b. Dry-pack of tie holes:
1) After installing plugs in tie holes, coat tie hole surface with epoxy bonding agent and fill with dry-pack mortar as specified in Section 03600 - Grouting.
a) Place dry-pack mortar in holes in layers with thickness not exceeding tie hole diameter and heavily compact each layer.
b) Dry-pack hole on the outside of the face of the wall no sooner than 7 days after hole on the inside of the face of the wall has been dry packed.
c) Wall surfaces in area of dry-packed tie holes: On the water side of water containing structures and the outside of below grade walls:
(1) Cover with minimum of 10 mils of epoxy gel.
(2) Provide epoxy gel coating on wall surfaces that extends a minimum of 2 inches past dry-pack mortar-filled tie holes.
(3) Provide finish surfaces that are free from sand streaks or other voids.

3.05 CONCRETE TOLERANCES

A. Finish concrete shall conform to shapes, lines, grades, and dimensions indicated on the Drawings.

B. Construct Work within the tolerances in accordance with ACI 117, except as modified in the following paragraphs or as indicated on the Drawings.
1. General:
a. At certain locations, tolerances required for equipment placement and operation may be more restrictive than the general tolerance requirements in this Section.
b. Confirm equipment manufacturers' required tolerances for location and operation of equipment that will be installed, and construct concrete to satisfy those requirements.
2. Slabs:
a. Slope: Uniformly sloped to drain when slope is indicated on the Drawings.
b. Slabs indicated to be level: Maximum vertical deviation of 1/8 inch in 10-foot horizontal length without any apparent changes in grade.
3. Circular tank walls:
a. May deviate from finish line indicated on the Drawings by use of forms with chord lengths not to exceed 2 feet.
4. Inserts and embedments:
a. Set to tolerances required for proper installation and operation of equipment or systems to which insert pertains.

b. Maximum tolerances as follows:

Item	Tolerance
Sleeves and inserts	Plus 1/8 inch; minus 1/8 inch.
Anchor bolts:	
Projected ends	Plus 1/4 inch; minus 0.0 inch.
Axial alignment	Not more than 2 degrees off the axis indicated on the Drawings.
Setting location	Plus 1/16 inch; minus 1/16 inch.
All embedments	Minimum 1 inch clearance from reinforcing steel.

c. Securing embedded items in formwork by wiring or welding to reinforcement is not permitted.

C. Remove and replace Work that does not conform to the required tolerances.

END OF SECTION

SECTION 03150

CONCRETE ACCESSORIES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Waterstops.
   2. Joint fillers.

1.02 REFERENCES

A. ASTM International (ASTM):
   1.
   2. D570 - Standard Test Method for Water Absorption of Plastics.
   3. D624 - Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers.
   4. D638 - Standard Test Method for Tensile Properties of Plastics.
   5. D746 - Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact.
   6. D747 - Standard Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam.
   7. D792 - Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
   8. D1751 - Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types).
   9. D1752 - Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction.
   10. D2240 - Standard Test Method for Rubber Property - Durometer Hardness.

B. American National Standards Institute (ANSI):
   1. A135.4 - Basic Hardboard.

C. U. S. Army Corps of Engineers (USACE):
   1. CRD-C-572, Specification for Polyvinyl Chloride Waterstop.

1.03 SUBMITTALS

A. Product data:
   1. Polyvinyl chloride waterstops: Complete physical characteristics.
   2. Preformed expansion joint material: Sufficient information on each type of material for review to determine conformance of material to requirements specified.

B. Samples:
   1. Polyvinyl chloride waterstop.

C. Laboratory test reports: Indicating that average properties of polyvinyl chloride waterstops material and finish conform to requirements specified in this Section.

D. Quality control submittals:
   1. Certificates of Compliance:
      a. Written certificates that polyvinyl chloride waterstops supplied on this Project meet or exceed physical property in accordance with USACE CRD-C-572 and the requirements of this Section.
   2. Manufacturer's instructions: For materials specified in this Section that are specified to be installed with such instructions.

1.04 QUALITY ASSURANCE

A. Mock-ups:
   1. Welding demonstration:
      a. Demonstrate ability to weld acceptable joints in polyvinyl chloride waterstops before installing waterstop in forms.

B. Field joints:
   1. Polyvinyl chloride waterstops field joints: Free of misalignment, bubbles, inadequate bond, porosity, cracks, offsets, and other defects which would reduce the potential resistance of material to water pressure at any point. Replace defective joints. Remove faulty material from site and disposed of by Contractor at its own expense.

C. Inspections:
   1. Quality of welded joints will be subject to acceptance of Engineer.
   2. Polyvinyl chloride waterstop: Following defects represent partial list that will be grounds for rejection:
      a. Offsets at joints greater than 1/16 inch or 15 percent of the material thickness, at any point, whichever is less.
      b. Exterior crack at joint due to incomplete bond, which is deeper than 1/16 inch or 15 percent of material thickness, at any point, whichever is less.
      c. Any combination of offset or crack that will result in net reduction in cross section of waterstop in excess of 1/16 inch or 15 percent of material thickness, at any point, whichever is less.
      d. Misalignment of joint that will result in misalignment of waterstop in excess of 1/2 inch in 10 feet.
      e. Porosity in welded joint as evidenced by visual inspection.
      f. Bubbles or inadequate bonding.

PART 2 PRODUCTS

2.01 JOINT FILLERS

A. General:
   1. Use specific type in applications as indicated on the Drawings.
   2. Do not use scrap or recycled materials to manufacture joint fillers.

B. Preformed expansion joint materials:
   1. Bituminous fiber expansion joint material:
      a. Properties:
         1) Thickness: To match joint width indicated on the Drawings.
         2) Asphalt-impregnated fiber in accordance with ASTM D1751.
      b. Manufacturers: One of the following or equal:
         1) Durajoint.
         2) W.R. Meadows, SealTight Fibre Expansion Joint.
   2. Synthetic sponge rubber expansion joint material:
      a. Properties:
         1) Thickness: As recommended for width indicated on the Drawings.
         2) Material in accordance with ASTM D1752, Type I.
      b. Manufacturers: One of the following or equal:
         1) Williams Products Inc., Everlastic 1300.
         2) W.R. Meadows, SealTight Sponge Rubber.

2.02 WATERSTOPS

A. Waterstops - polyvinyl chloride (PVC):
   1. Manufactured from prime virgin polyvinyl chloride plastic compound containing the plasticizers, resins, stabilizers, and other materials necessary to meet the requirements as specified in this Section.
   2. Manufacturers: One of the following or equal:
      a. Vinylex Corp.
      b. Sika Corp., Greenstreak PVC Waterstop.
   3. Type: Ribbed waterstop:
      a. Construction joints: 6-inch wide ribbed type.
      b. Expansion joint for wall penetrations for concrete encased electrical duct banks: 6-inch ribbed type with hollow center bulb.
      c. Expansion joints: 9-inch wide ribbed type with hollow center bulb.
      d. Dumbbell-type waterstop will not be allowed unless otherwise specified or indicated on the Drawings.
      e. No scrap or reclaimed material shall be used.
   4. Properties as indicated in the following table:

Physical Characteristics	Test Method	Required Results
Specific Gravity	ASTM D792	Not less than 1.3.
Hardness	ASTM D2240	70 to 90 Type A15 Shore durometer.
Tensile Strength	ASTM D638	Not less than 2,000 pounds per square inch.
Ultimate Elongation	ASTM D638	Not less than 300 percent.

Physical Characteristics	Test Method	Required Results
Alkali Extraction	CRD-C-572	Change in weight after 7 days: Between minus 0.1 percent and plus 0.25 percent. Change in hardness after 7 days: Not more than plus 5 points.
Low Temperature Brittle Point	ASTM D746	No sign of cracking or chipping at -35 degrees Fahrenheit.
Water Absorption	ASTM D570	Not more than 0.15 percent after 24 hours.
Accelerated Extraction Test	CRD-C-572	Tensile strength: Not less than 1,600 pounds per square inch. Elongation: Not less than 280 percent.
Stiffness in Flexure	ASTM D747	Not less than 600 pounds per square inch.
Tear Resistance	ASTM D624	Not less than 225 pounds per inch.
Thickness	-	3/8 inch.
Center Bulb		
6-inch Waterstops	-	7/8 inch or 1-inch nominal outside diameter.
9-inch Waterstops	-	For expansion joints 1 inch and narrower: 1-inch nominal outside diameter. For expansion joints wider than 1 inch: 2-inch nominal outside diameter.
Allowable Tolerances		
Width	-	Plus or minus 3/16 inch.
Thickness	-	Plus or minus 1/32 inch.

PART 3 EXECUTION

3.01 INSTALLATION

A. Waterstops:
   1. General:
      a. Store waterstops so as to permit free circulation of air around waterstop material and prevent direct exposure to sunlight.
      b. Install waterstops in concrete joints where indicated on the Drawings.
      c. Carry waterstops in walls into lower slabs and join to waterstops in slabs with appropriate types of fittings.
      d. In waterbearing structures: Provide all joints with waterstops, whether indicated on the Drawings or not.

e. Provide waterstops that are continuous.
f. Set waterstops accurately to position and line as indicated on the Drawings.
g. Hold and securely fix edges in position at intervals of not more than 24 inches so that they do not move during placing of concrete.
h. Position the waterstop so that symmetrical halves of waterstop are equally divided between concrete pours. Center axis of waterstop shall be coincident with centerline of the joint.
i. Do not drive nails, screws, or other fasteners through waterstops in vicinity of construction joints.
j. Use wires at not more than 24 inches on centers near outer edge of waterstop to tie waterstops into position.
k. Special clips may be used in lieu of wires, at Contractor's option.
l. Terminate waterstops 3 inches from top of finish surfaces of walls and slabs unless otherwise specified or indicated on the Drawings.
m. When any waterstop is installed in concrete on one side of joint, while the other half or portion of the waterstop remains exposed to the atmosphere for more than 2 days, take suitable precautions to shade and protect exposed waterstop from direct rays of sunlight during entire exposure and until exposed portion is embedded in concrete.
n. When placing concrete at waterstops in slabs, lift edge of waterstop while placing concrete below the waterstop. Manually force waterstop against and into concrete, and then cover waterstop with fresh concrete.

2. Polyvinyl chloride waterstop:
   a. Install waterstops so that joints are watertight.
   b. Weld joints such as unions, crosses, ells, and tees, with thermostatically controlled equipment recommended by waterstop manufacturer:
      1) Do not damage material by heat sealing.
      2) Make joints by overlapping, then simultaneously cut ends of sections to be spliced so they will form smooth even joint. Heat cut ends with splicing tool until the plastic melts. Press 2 ends together until plastic cools.
      3) Maintain continuity of waterstop ribs and tubular center axis.
      4) The splices shall have tensile strength of not less than 60 percent of unspliced materials tensile strength.
   c. Butt joints of ends of 2 identical waterstop sections may be made while material is in forms.
   d. Manufacturer shall factory prefabricate joints for crosses and tees.
   e. Split-type waterstops will not be permitted except where specifically indicated on the Drawings.

B. Joints:
   1. Construct construction and expansion joints as indicated on the Drawings.
   2. Preformed expansion joint material: Fasten expansion joint strips to concrete, masonry, or forms with adhesive. No nailing will be permitted, nor shall expansion joint strips be placed without fastening.

END OF SECTION

SECTION 03200

CONCRETE REINFORCING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Reinforcing bars.
      a. Carbon steel.
   2. Thread bars.
   3. Bar supports.
   4. Tie wires.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 318 - Building Code Requirements for Structural Concrete and Commentary.
   2. SP-66 - ACI Detailing Manual.

B. American Iron and Steel Institute (AISI).

C. American Welding Society (AWS):
   1. D1.4 - Structural Welding Code - Reinforcing Steel.

D. ASTM International (ASTM):
   1. A493 - Standard Specification for Stainless Steel Wire and Wire Rods for Cold Heading and Cold Forging.
   2. A615 - Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement.
   3. A706 - Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement.
   4. A1064 - Standard Specification of Carbon-Steel wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete.

E. Concrete Reinforcing Steel Institute (CRSI):
   1. Manual of Standard Practice.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Architectural concrete: Concrete surfaces that will be exposed to view in the finished work.
      a. Additionally, for purposes of this Section, includes:
         1) Concrete surfaces that are designated to receive paints or coatings.
         2) Exposed concrete in open basins, channels, and similar liquid containing structures: Surfaces shall be considered exposed to view

if located above a line 2 feet below the normal operating water surface elevation in that structure.

2. Bars: Reinforcement or reinforcing bars as specified in this Section.
3. Evaluation Report: Report prepared by ICC-ES, or by other testing agency acceptable to the Engineer and to the Building Official, that documents testing and review of a product to confirm that it complies with the requirements of designated ICC-ES Acceptance Criteria, and its acceptance for use under the Building Code specified in Section 01410 - Regulatory Requirements.
4. Give away bars: Reinforcing bars that are not required by the Contract Documents but are installed by the Contractor to provide support for the required reinforcing bars.
5. Wire supports: Metal reinforcing supports constructed of steel wire as specified. Includes individual high chairs, continuous high chairs, bolsters and other similar configurations and shapes.

1.04 SUBMITTALS

A. General:
   1. Submit in accordance with Section 01300 - Submittals.
   2. Changes to reinforcement in Contract Documents:
      a. Indicate in a separate letter submitted with Shop Drawings any changes to reinforcement indicated on the Drawings or specified.
      b. Such changes will not be acceptable unless the Engineer has accepted them in writing.

B. Product data:
   1. Bar supports:
      a. Wire bar supports:
         1) Schedule of support materials to be provided and locations of use.
      b. Precast concrete bar supports (“dobies”):
         1) Manufacturer's data indicating compression strength of concrete and confirming dimensions and thickness(es).height(s) to be provided for each location where used.

C. Shop Drawings:
   1. Reinforcement Shop Drawings:
      a. Submit Drawings showing bending and placement of reinforcement required by the Contract Documents.
      b. Provide CAD generated Shop Drawings.
      c. Clearly indicate structures or portions of structures covered by each Submittal.
         1) Submit reinforcement Shop Drawings for each structure as a complete package. Submittals addressing only a portion of a structure will be rejected and returned without review, unless such presentation is accepted by the Engineer in advance.
      d. Shop Drawings shall conform to the recommendations of the CRSI Manual of Standard Practice and be in accordance with ACI SP-66.
      e. Use the same bar identification marks on bending detail Drawings, placement Drawings, and shipping tags.

f. Submittals consisting solely of reinforcing bar schedules, without accompanying placement Drawings, will not be accepted unless accepted under prior written agreement with the Engineer.

2. Reinforcement placement Drawings:
   a. Clearly show placement of each bar listed in the bill of materials, including additional reinforcement at corners and openings, and other reinforcement required by details in the Contract Documents.
   b. Clearly identify locations of reinforcement with coatings (e.g., galvanized or epoxy) and with yield strength other than ASTM A615, Grade 60.
   c. Show anchor bolt locations based on anchor bolt templates for approved equipment.
   d. Show splice locations.
3. Reinforcement fabrication Drawings:
   a. If bend types or nomenclature differs from that recommended in the CRSI Manual of Standard Practice, provide details showing bend types and dimensional designations.
   b. Clearly identify reinforcement with coatings and with yield strength other than ASTM A615, Grade 60.

D. Samples (when requested by the Engineer):
1. Bar supports/wire reinforcement supports: Samples of each type of chair and bolster proposed for use. Submit with letter stating where each type will be used.
2. Precast concrete bar supports: Samples of each type of precast support proposed for use. Submit with letter stating where each will be used.

E. Test reports:
1. Certified copy of mill test for each steel used. Show physical properties and chemical analysis.
   a. Mill test reports may be submitted as record documents at the time the reinforcement from that heat of steel is shipped to the site.
   b. In such cases, submit certificates under the Shop Drawing Submittal number with the letter “R” (for record date) appended to the end (e.g., if the reinforcement was submitted as 03200-002-1, deliver the associated mill certificate as Submittal 03200-002-1R).

F. Manufacturer's instructions:

G. Special procedures:
1. Welding procedures in accordance with AWS D1.4 for reinforcement to be field welded.
   a. Procedures qualification record.

H. Qualifications statements:
1. Welder qualifications.

I. Closeout documents:
1. Field quality control and inspection reports.
2. Field quality assurance special inspection and testing reports.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and shipping:
   1. Deliver bars bundled and tagged with identifying tags.

B. Acceptance at site:
   1. Reinforcing bars: Deliver reinforcing bars lacking grade identification marks with letter containing manufacturer's guarantee of grade.

1.06 SEQUENCING AND SCHEDULING

A. Bar supports:
   1. Do not place concrete until samples and product data for bar supports have been accepted by the Engineer.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Drawings contain notes describing the size and spacing of reinforcement and its placement, details of reinforcement at wall corners and intersections, and details of extra reinforcement around openings in concrete, and other related information.

2.02 MATERIALS

A. Reinforcing bars:
   1. Provide reinforcement of the grades and quality specified, fabricated from new stock, free from excessive rust or scale, and free from unintended bends or other defects affecting its usefulness.
   2. ASTM A615 Grade 60 deformed bars, including the following requirements:
      a. Actual yield strength based on mil tests of reinforcement provided shall not exceed the minimum yield strength specified in this Section by more than 18,000 pounds per square inch.
      b. Ratio of actual ultimate tensile strength to actual tensile yield strength shall not be less than 1.25.
   3. Reinforcing bars designated or required to be welded:
      a. Low-alloy, ASTM A706 Grade 60, deformed bars.
   4. Reinforcing bars that are required to resist earthquake-induced flexural and axial forces in concrete frame members and in concrete shear wall boundary members where indicated on the Drawings:
      a. Low-alloy, ASTM A706 Grade 60, deformed bars.

B. Thread bars:
   1. Reinforcing bars in accordance with ASTM A615, Grade 60, unless otherwise indicated on the Drawings, and having a continuous rolled-in pattern of thread-like deformations along entire length.
      a. Substitution of shop-cut threads on regular ASTM A615 or ASTM A706 reinforcing bars is not permitted.

2. Thread bar hardware, including nuts (hex and jamb), couplers, and washers (flat, spherical, and beveled):
    a. Provided by same manufacturer as the threaded bars.
    b. Capable of developing a load equal to at least 125 percent of the yield strength of the threaded bar.
3. Manufacturers: One of the following, or equal:
    a. DYWIDAG-Systems International (DSI), DYWIDAG Threadbar®:
    b. Williams Form Engineering Corp., Grade 75 all-thread rebar:

C. Bar supports:
1. Wire supports:
    a. All stainless steel bar supports:
        1) Conforming to CRSI Manual of Standard Practice recommendations for types and details, but custom fabricated entirely from stainless steel wire in accordance with ASTM A493, AISI Type 316.
    b. Stainless steel protected bar supports:
        1) Conforming to CRSI Manual of Standard Practice Class 2, Type B, and consisting of bright basic wire support fabricated from cold-drawn carbon steel wire with stainless steel ends attached at the bottom of each leg.
        2) Stainless steel wire ends shall be in accordance with ASTM A493, AISI Type 316 and shall extend at least 3/4 inch inward from the formed surface of the concrete.
    c. Bright basic wire bar supports.
        1) Conforming to CRSI Manual if Standard Practice, Class 3.
2. Plastic supports:
    a. Manufacturers: The following or equal:
        1) Aztec Concrete Accessories.
3. Deformed steel reinforcing bar supports:
    a. Fabricated of materials and to CRSI details recommended for typical reinforcement embedded in concrete and bent to dimensions required to provide specified clearances and concrete cover.
4. Precast concrete bar supports (“dobies”):
    a. Pre-manufactured, precast concrete blocks with cast-in annealed steel wires, 16-gauge or heavier.
    b. Compression strength of concrete: Equal to or exceeding the compression strength of the surrounding concrete.
    c. Block dimensions:
        1) Height to provide specified concrete cover.
        2) Footprint not less than 3 inches by 3 inches, and adequate to support the weight of the reinforcement and maintain specified concrete cover without settling into the underlying surface.

D. Tie wires:
1. General use: Black annealed steel wire, 16-gauge or heavier.

E. Welded wire fabric reinforcement:
1. Material:
    a. Carbon steel in accordance with ASTM A1064.
2. Provide welded wire reinforcement in flat sheet form. Rolled wire fabric is not permitted.

3. Fabric may be used in place of reinforcing bars if accepted by the Engineer:
    a. Provide welded wire fabric having cross-sectional area per linear foot not less than the cross-sectional area per linear foot of reinforcing bars indicated on the Drawings.

2.03 FABRICATION

A. Shop fabrication and assembly:
    1. Cut and bend bars in accordance with provisions of ACI 318 and the CRSI Manual of Standard Practice.
    2. Bend bars cold. Use bending collars to develop the recommended bend radius.
    3. Provide bars free from defects and kinks and from bends not indicated on the Drawings.
    4. Circumferential and radiused reinforcement: Roll to the radius required for its location in the structure before installation.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions:
    1. Reinforcing bars and welded wire reinforcement:
        a. Verify that reinforcement is new stock, free from rust scale, loose mill scale, excessive rust, dirt, oil, and other coatings that will adversely affect bonding capacity when placed in the Work.
    2. Welded wire fabric:
        a. Verify that sheets are not curled or kinked before or after installation.

3.02 PREPARATION

A. Surface preparation:
    1. Reinforcing bars - uncoated:
        a. Clean reinforcement of concrete, dirt, oil and other coatings that will adversely affect bond before embedding bars in subsequent concrete placements.
        b. Thin coating of red rust resulting from short exposure will not be considered objectionable. Thoroughly clean bars having rust scale, loose mill scale, or thick rust coat.
        c. Partially embedded reinforcement: Remove concrete or other deleterious coatings from dowels and other projecting bars by wire brushing or sandblasting before bars are embedded in subsequent concrete placements.

3.03 INSTALLATION

A. Reinforcing bars: General:
    1. Field-cutting of reinforcing bars is not permitted.

Table 1. Reinforcement Placing Tolerances		
Member	**Tolerance on Reinforcement Location (1)**	**Tolerance on Minimum Concrete Cover (1,2)**
Slabs, beams, walls and columns except as noted below:		
10 inches thick and less	± 3/8 inch	- 3/8 inch
More than 10 inches thick	± 1/2 inch	- 1/2 inch
Formed soffits	As noted above	- 1/4 inch
Longitudinal location of bends and ends of reinforcement:		
Conditions not listed below	± 2 inches	- 1/2 inch
At discontinuous ends of brackets and corbels	± 1/2 inch	- 1/4 inch
At discontinuous ends of other members	± 1 inch	- 1/2 inch

Notes:

(1) ± indicates "plus or minus;" - indicates "minus;" + indicates "plus."
(2) Tolerance on cover is limited as noted but decrease in cover shall not exceed one third of the minimum cover indicated on the Drawings.

2. Field-bending of reinforcing bars, including straightening and rebending, is not permitted.

B. Placing reinforcing bars:
   1. Accurately place bars to meet position and cover requirements indicated on the Drawings and specified. Secure bars in position.
   2. Tolerances for placement and minimum concrete cover: As listed in Table 1.
   3. Spacing between bars:
      a. Minimum clear spacing between bars in a layer:
         1) As indicated on the Drawings, but not less than the larger of 1.5 times the bar diameter or 1-1/2 inches.
      b. Minimum clear spacing between bars in 2 or more parallel layers:
         1) Place bars in upper layers directly above bars in lower layers.
         2) Minimum spacing between layers: As indicated on the Drawings, but not less than the larger of 1.5 times the bar diameter or 1-1/2 inches.
      c. Limits on minimum clear spacing between bars also applies to the clear spacing between a lap splice and the adjacent bars and/or lap splices.
   4. Lap splices for bars:
      a. Lap splice locations and lap splice lengths: As indicated on the Drawings. Where lap lengths are not indicated, provide in accordance with ACI 318.
      b. Unless otherwise specifically indicated on the Drawings (and noted as "non-contact lap splice"), install bars at lap splices in contact with each other and fasten together with tie wire.
      c. Where bars are to be lap spliced at concrete joints, ensure that bars project from the first concrete placement a length equal to or greater than minimum lap splice length indicated on the Drawings.
      d. Stagger lap splices where indicated on the Drawings.

e. Where lap splice lengths are not indicated on the Drawings, provide lap splice lengths in accordance with ACI 318.

C. Reinforcing supports:
   1. Provide supports of sufficient numbers, sizes, and locations to maintain concrete cover, to prevent sagging and shifting, and to support loads during construction without displacement and without gouging or indentation into forming surfaces.
      a. Quantities and locations of supports shall not be less than those indicated in ACI SP-66 and the CRSI Manual of Standard Practice.
   2. Do not use brick, concrete masonry units, concrete spalls, rocks, wood, or similar materials for supporting reinforcement.
   3. Do not use “give away bars” that have less cover than that required by the Contract Documents. Do not adjust the location of reinforcement required by the Contract Documents to provide cover for giveaway bars.
   4. Provide bar supports of height required to maintain the clear concrete cover indicated on the Drawings.
   5. Provide bar supports at formed vertical faces to maintain the clear concrete cover indicated on the Drawings.
   6. Schedule of reinforcement support materials: Provide bar supports as indicated in Table 2.

Table 2. Reinforcement Support Materials

Case	Location	Material
a.	Concrete placed over earth and concrete seal slabs (“mud mats”)	Precast concrete bar supports.
b.	Concrete placed against forms and exposed to water or wastewater process liquids (whether or not such concrete received additional linings or coatings)	All stainless steel bar supports.
c.	Concrete placed against forms and exposed to earth, weather, frequent washdown, or groundwater in the finished work	All stainless steel bar supports.
d.	Concrete placed against forms and exposed to interior equipment/piping areas in the finished work	All stainless steel bar supports.
e.	Between mats of reinforcement, and fully embedded within a concrete member	Bright basic wire bars supports, or deformed steel reinforcing bars.

D. Tying of reinforcing:
   1. Fasten reinforcement securely in place with wire ties.
   2. Tie reinforcement at spacings sufficient to prevent shifting.
      a. Provide at least 3 ties in each bar length. (Does not apply to dowel lap splices or to bars shorter than 4 feet, unless necessary for rigidity).
   3. Tie slab bars at every intersection around perimeter of slab.

4. Tie wall bars and slab bar intersections other than around perimeter at not less than every fourth intersection, but at not more than the spacing indicated in Table 3:

Table 3. Maximum Spacing of Tie Wires for Reinforcement		
Bar Size	**Slab Bar Spacing (inches)**	**Wall Bar Spacing (inches)**
Bars Number 5 and Smaller	60	48
Bars Number 6 through Number 9	96	60
Bars Number 10 and Number 11	120	96

5. After tying:
    a. Bend ends of wires inward towards the center of the concrete section. Minimum concrete cover for tie wires shall be the same as cover requirements for reinforcement.
    b. Remove tie wire clippings from inside forms before placing concrete.

E. Welded wire fabric reinforcement:
1. Install only where indicated on the Drawings or accepted in advance by the Engineer.
2. Install necessary tie wires, spacing chairs, and supports to keep welded wire fabric at its designated position in the concrete section while concrete is being placed.
3. Straighten welded wire fabric to make sheets flat in the Work.
4. Do not allow wire fabric to drape between supports unless such a configuration is specifically indicated on the Drawings.
    a. If fabric is displaced during placement of concrete, make provisions to restore it to the designated location using methods acceptable to the Engineer.
5. Bend welded wire fabric as indicated on the Drawings or required to fit Work.
6. Lap splice welded wire fabric as indicated on the Drawings.
    a. If lap splice length is not indicated, splice in accordance with ACI 318, but not less than 1 1/2 courses of fabric or 8 inches minimum. Tie laps at ends and at not more than 12 inches on center.

F. Welding reinforcing bars:
1. Weld only where indicated on the Drawings or where acceptance is received from the Engineer prior to welding.
2. Perform welding in accordance with AWS D1.4 and welding procedures accepted by the Engineer.
    a. Conform to requirements for minimum preheat and interpass temperatures.
3. Submit:
    a. Welding procedures specification.
    b. Procedures qualification record.
    c. Welder qualification test record.
4. Do not tack weld reinforcing bars except where specifically indicated on the Drawings.

3.04 FIELD QUALITY CONTROL

A. Provide quality control for the Work of this Section as specified in Section 01450 - Quality Control.

B. Field inspections and testing:
   1. Submit records of inspections and testing to the Engineer in electronic format within 24 hours after completion.

3.05 FIELD QUALITY ASSURANCE

A. Provide quality assurance as specified in Section 01450 - Quality Control.

B. Special inspections and tests:
   1. Provide as specified in Section 01455 - Regulatory Quality Assurance.
   2. Frequency of inspections:
      a. Unless otherwise indicated on the Drawings or in this Section, provide periodic special inspection as required by the Building Code specified in Section 01410 - Regulatory Requirements.
   3. Preparation:
      a. Review Drawings and Specification for the Work to be observed.
      b. Review approved Submittals and Shop Drawings.
   4. Inspections: Special inspection shall include, but is not limited to, the following items:
      a. Reinforcement: General:
         1) Type (material) and location of reinforcement supports.
         2) Bar material/steel grade and bar size.
         3) Location, placement, and spacing of bars.
         4) Clear concrete cover over reinforcement.
         5) Lap splice: Location and lap length. Bars within tolerances for contact (unless non-contact splice is indicated on the Drawings.)
         6) Bar hooks and development lengths embedded within concrete sections as indicated on the Drawings.
         7) Reinforcement tired in position and tie wire legs turned inward toward the center of the concrete section.
      b. Reinforcement: Welding:
         1) Inspector qualification and inspections shall be in accordance with the requirements of AWS D1.4.
         2) Provide periodic inspection for:
            a) Weldability of reinforcement other than ASTM A706.
            b) Single pass fillet welds with thickness less than or equal to 5/16 inch.
         3) Provide continuous inspection for:
            a) Other welds.
            b) Welds at mechanical reinforcing bar couplers and end anchors.
         4) In addition to visual inspection, Owner may inspect reinforcing bar welds by other methods, including radiographic inspection.

5. Records of inspections:
    a. Provide a written record of each inspection using forms acceptable to the Engineer and to the Building Official.
    b. Submit electronic copies of inspection reports to the Engineer within 24 hours after completion of inspections.

3.06 NON-CONFORMING WORK

A. Before placing concrete, adjust or remove and re-install reinforcement to conform to the requirements of the Contract Documents.

END OF SECTION

SECTION 03300

CAST-IN-PLACE CONCRETE

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PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Cast-in-place concrete.

B. The requirements of this Section require advance planning for preparation and testing of trial batches. Review the mix design and testing requirements carefully, and schedule preparations and testing with sufficient time to complete tests, to obtain the Engineer's review of mixes and testing results, and to complete revisions and re-testing if required.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. CODE-318 - Building Code Requirements for Structural Concrete and Commentary.
   2. CODE-350 - Code Requirements for Environmental Engineering Concrete Structures and Commentary.
   3. PRC-212.3 - Report on Chemical Admixtures for Concrete.
   4. PRC-302.1 - Guide to Concrete Floor and Slab Construction.
   5. PRC-305 - Guide to Hot Weather Concreting.
   6. PRC-306 - Guide to Cold Weather Concreting.

B. ASTM International (ASTM):
   1. C29 - Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate.
   2. C31 - Standard Practice for Making and Curing Concrete Test Specimens in the Field.
   3. C33 - Standard Specification for Concrete Aggregates.
   4. C39 - Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.
   5. C40 - Standard Test Method for Organic Impurities in Fine Aggregates for Concrete.
   6. C42 - Standard Test Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.
   7. C88 - Standard Test Method of Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.
   8. C94 - Standard Specification for Ready-Mixed Concrete.
   9. C114 - Standard Test Methods for Chemical Analysis of Hydraulic Cement.
   10. C117 - Standard Test Method for Materials Finer that 75-m (No. 200) Sieve in Mineral Aggregates by Washing.
   11. C123 - Standard Test Method for Lightweight Particles in Aggregate.
   12. C131 - Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.
   13. C136 - Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
   14. C138 - Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete.

15. C142 - Standard Test Method for Clay Lumps and Friable Particles in Aggregate.
16. C143 - Standard Test Method for Slump of Hydraulic-Cement Concrete.
17. C150 - Standard Specification for Portland Cement.
18. C156 - Standard Test Method for Water Loss from a Mortar Specimen Through Liquid Membrane-Forming Curing Compounds for Concrete.
19. C157 - Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete.
20. C171 - Standard Specifications for Sheet Materials for Curing Concrete.
21. C172 - Standard Practice for Sampling Freshly Mixed Concrete.
22. C173 - Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.
23. C260 - Standard Specification for Air-Entraining Admixtures for Concrete.
24. C293 - Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading).
25. C295 - Standard Guide to Petrographic Examination of Aggregates for Concrete.
26. C309 - Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.
27. C311 - Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete.
28. C494 - Standard Specification for Chemical Admixtures for Concrete.
29. C595 - Standard Specification for Blended Hydraulic Cements.
30. C618 - Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.
31. C702 - Standard Practice for Reducing Samples of Aggregate to Testing Size.
32. C856 - Standard Practice for Petrographic Examination of Hardened Concrete.
33. C989 - Standard Specification for Slag Cement for Use in Concrete and Mortars.
34. C1064 - Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete.
35. C1218 - Standard Test Method for Water-Soluble Chloride in Mortar and Concrete.
36. C1260 - Standard Test Method of Potential Alkali Reactivity of Aggregates (Mortar Bar Method).
37. C1293 - Standard Test Method for Determination of Length Change of Concrete due to Alkali-Silica Reaction.
38. C1602 - Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete.
39. C1778 - Standard Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete.
40. D75 - Standard Practice for Sampling Aggregates.
41. D2103 - Standard Specification for Polyethylene Film and Sheeting.
42. D3665 - Standard Practice for Random Sampling of Construction Materials.
43. D4791 - Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate.

C. National Ready-Mixed Concrete Association (NRMCA).

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Alkali: The sum of sodium oxide and potassium oxide calculated as sodium oxide.
   2. Alkali load: Amount of alkalis contributed by the Portland cement in a concrete mixture, expressed in pounds per cubic yard (lb/yd^3) and calculated by multiplying the Portland cement content of the concrete in lb/yd^3 by the alkali content of the Portland cement, or the Portland cement portion of a blended cement, divided by 100.
   3. Architectural concrete: Concrete surfaces that will be exposed to view in the finished Work.
      a. For purposes of this Section, includes only those surfaces that receive paint or coatings.
      b. Exposed concrete surfaces in open basins, channels, and similar liquid containing structures: Surfaces will be considered exposed to view if located above the water line as defined in Section 03366 - Concrete Finishes.
      c. Exterior concrete surfaces with portions above and below grade: Surface will be considered exposed to view of located above the grade line as defined in Section 03366 - Concrete Finishes.
   4. Average daily temperature: Calculated by summing hourly measurements of air temperature in the shade at the face of the concrete and dividing that sum by 24. In calculating the sum of the temperatures recorded, any measurement less than 50 degrees Fahrenheit shall be recorded as 0 degrees Fahrenheit and included in the sum.
   5. Cementitious materials: Portland cement or blended cement and supplementary cementitious materials.
   6. Class of concrete: Refers to a mix with characteristics, proportions, and constituents (including a specific combination of admixtures) as specified in this Section.
      a. Any change in the source or characteristics of constituent materials, in the proportions of materials, or in the admixtures included in a mix shall be considered as creating a new and separate class of concrete.
      b. Any mix to be placed by pumping shall be considered as creating a new and separate class of concrete.
   7. Cold weather: Includes one or more of the following conditions:
      a. Current air temperature is 45 degrees Fahrenheit and falling.
      b. Air temperature during the first 24 hours after placement is expected to fall into the range of 45 degrees Fahrenheit to 40 degrees Fahrenheit.
      c. A period when, for more than 3 consecutive days, the following conditions exist:
         1) The average daily air temperature drops below 40 degrees Fahrenheit.
         2) The air temperature is not greater than 50 degrees Fahrenheit for more than one-half of any consecutive 24-hour period.
   8. Cold weather concreting: Operations for placing, finishing, curing, and protecting concrete during cold weather.
   9. Green concrete: Concrete that has not yet achieved 100 percent of the minimum specified compressive strength, f'c, for that mix.

10. Hairline crack: Crack with a crack width of less than 4 thousandths of an inch (0.004 inches).
11. Hot weather: Any combination of ambient temperature, concrete temperature, relative humidity, wind speed, and solar radiation intensity that creates conditions that will evaporate water from a free concrete surface at a rate equal to or greater than 0.2 pounds per square foot per hour as determined by the Menzel Formula and nomograph published in ACI PRC-305 and in this Section, Attachment A - Menzel Formula and Nomograph.
12. Hot weather concreting: Operations for placing, finishing, curing, and protecting concrete during hot weather.
13. Paste content: The total concrete volume minus the volume of aggregate, expressed as a percentage of total volume. Paste volume includes volume of cementitious materials, water, air, admixtures materials, and any fibers.
14. Supplemental cementitious material: Inorganic material such as fly ash, natural pozzolans, silica fume, or slag cement that reacts pozzolanically or hydraulically.

1.04 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Concrete mix designs.

1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. General:
   1. Data for concrete mixes and mix constituents supplied to the Work shall be coordinated through a single supplier.
   2. A maximum of 2 mix designs will be reviewed by the Engineer for each class of concrete required.
      a. Review of additional mix designs shall be at the expense of the Contractor.

C. Product data:
   1. Submit data completely describing products and demonstrating compliance with the requirements of this Section.
   2. Data for all products in the mix for each class of concrete shall be submitted concurrently with that mix design.
   3. Where products conforming to NSF 61 are required, submit evidence of testing and listing under NSF 61 for use in direct contact with potable water. Testing and listing shall be by a nationally recognized agency acceptable to the Engineer.
   4. Admixtures:
      a. For each admixture included in concrete mixes, submit manufacturer’s product data demonstrating compliance with standards specified.
      b. If air entraining admixture requires test method other than ASTM C173 to accurately determine air content, make special note of requirements in Submittal.
   5. Curing compound: Submit complete data on proposed compound.

D. Delegated Design Submittals:
    1. Concrete mix designs:
        a. Submit full details, including mix design calculations and plots, for concrete mixes proposed for use for each class of concrete.
        b. Include mix design calculations of proportions by both weight and volume.
        c. Determine and include the alkali load of the proposed mix.
        d. Include information on correction of batching for varying moisture contents of fine aggregate.
        e. Submit source quality test records with mix design Submittal.
        f. Provide calculations demonstrating that the mixes proposed provide the required average compression strength of concrete (f'cr) based on source quality test records.
        g. For each Class A mix design submitted, plot the mix design Attachment B - Coarseness Factor Chart and submit.
        h. For each Class A mix design submitted, plot the combined aggregate gradation on the chart Attachment C - Combined Aggregate Gradation Chart and submit.

E. Concrete mixes - Trial batches:
    1. Drying shrinkage test results.
        a. Submit results of testing.
    2. Compression strength test results.
        a. Submit results of testing. Provide data for each cylinder tested.
        b. Submit data indicating trial batch mix designator, slump, and specimen number for each test cylinder.
            1) Using indelible marker, clearly label each cylinder with concrete class, trail batch number, and specimen number.
    3. If there is any change in suppliers or in quality of concrete mix constituents, submit new test data.

F. Test reports:
    1. Dated not more than 24 months prior to the date of Submittal.
    2. Aggregate:
        a. Submit certified copies of commercial laboratory tests proposed for use in concrete.
        b. Sieve analyses:
            1) During construction, submit sieve analyses of coarse, intermediate, fine, and combined aggregates used any time there is a change in supplier, or a significant change in the character and/or grading of materials, and when requested by the Engineer.
        c. Aggregates - coarse:
            1) Physical properties:
                a) Sieve analysis.
                b) Percentage of particles having flat and/or elongated characteristics.
                c) Abrasion loss.
                d) Soundness.
            2) Deleterious substances:
                a) Clay lumps and friable particles content.
                b) Materials finer than No. 200 sieve (percentage).
                c) Shale and chert content.

d) Coal and lignite content.
3) Alkali reactivity.

d. Aggregates - Intermediate:
1) Physical properties:
a) Sieve analysis.
b) Percentage of particles having flat and/or elongated characteristics.
c) Abrasion loss.
d) Soundness.
2) Deleterious substances:
a) Clay lumps and friable particles content.
b) Chert and shale content.
c) Coal and lignite content.
d) Materials finer than No. 200 sieve.
3) Alkali reactivity.

e. Aggregates - Fine:
1) Physical properties:
a) Sieve analysis and fineness modulus.
b) Soundness.
2) Deleterious substances:
a) Clay lumps and friable particles (percentage).
b) Materials finer than No. 200 sieve (percentage).
c) Coal and lignite (percentage).
d) Shale and chert.
e) Organic impurities (“Color” as determined by ASTM C40).
3) Alkali reactivity.

f. Aggregates - Combined:
1) Test combined gradation for the following sieve sizes: 1.5 inches, 1 inch, 3/4 inch, 1/2 inch, 3/8 inch, No. 4, No. 8, No. 16, No. 30, No. 100, No. 200.
2) Bulk density in accordance with ASTM C29.
3) Void content in accordance with ASTM C29.
4) Submit at:
a) Initial mixture design Submittal.
b) Intervals of not more than 4 weeks.
c) Any time there is a change in character or grading of constituent materials.
d) When requested by the Engineer.

3. Cement:
a. Mill tests, including alkali content measured as equivalent alkalis, for each shipment of cement included in the Work.
1) During construction, submit mill certificates for cement being used at intervals of not more than 90 days, any time there is a change in supplier or a significant change in the character of the materials, and when requested by the Engineer.

4. Supplemental cementitious material:
a. Fly ash: Identify source and provide testing results to demonstrate compliance with requirements of ASTM C618 and this Section.
1) Include the Supplier’s report certifying the total alkali content of the material, expressed as equivalent percentage of sodium oxide (Na_2Oe).

b. Slag cement: Identify source and provide testing results to demonstrate compliance with requirements of ASTM C989 and this Section.

G. Certificates:
1. Current NRMCA certification for all plants and trucks that will be used to supply concrete.

H. Source Quality Control Submittals:
1. Truck batch tickets for each load of concrete delivered to the Site, whether accepted or rejected.
2. Concrete supplier's quality control plan. Include the following elements, at a minimum:
a. Names and qualifications of key quality control personnel:
1) Quality control manager.
2) Testing and inspection personnel.
b. Names and qualifications of testing laboratories:
1) Each laboratory shall hold current accreditation from the AASHTO Accreditation Program, or other accreditation program acceptable to the Engineer, for each test performed.
c. Example forms for: Inspection reports, certificates of compliance, and test results.
d. Quality control procedures: Method and frequency of performing each procedure, including inspections and materials testing. At a minimum, the plan shall include:
1) Daily testing of aggregate gradation.
2) Monthly testing of cement quality.
3) Monthly testing of fly ash quality.
e. Procedures to control quality characteristics, including standard procedures to address properties outside the specified operating limits, and example reports to document non-conformances and corrective actions taken. Include procedure for notifying the Contractor and Engineer of non-conformances.
f. Procedures for verifying that:
1) Materials are properly stored during concrete batching operations.
2) Batch plants have the ability to maintain concrete consistency during periods of extreme heat and of low temperatures.
3) Admixtures are dispensed in the correct dosages within the accuracy requirements specified.
4) Delivery trucks have a valid NRMCA certification card.
g. Procedures for verifying that weighmaster certificate for each load of concrete shows:
1) Cement and supplementary materials are from sources designated in the approved Submittals.
2) Concrete as-batched complies with the constituent weights designated in the approved Submittals.
3) Corrections for aggregate moisture are being correctly applied.
4) Any mix water withheld from the batch.
h. Procedures for visually inspecting concrete during discharge.

I. Field Quality Control Submittals:
1. Contractor's notifications of readiness for concrete placement.

2. Contractor's reports of field quality control testing.
    a. Include with each report the concrete batch ticket number and identification numbers for associated cylinders used for compressive strength testing.
    b. Testing results for slump, temperature, unit weight, and air entrainment.
    c. Testing results for compressive strength at 7 and 28 days, and for any compressive strength tests after 28 days.
    d. Note on batch ticket the amount of water that was withheld and the maximum amount that can be added on site as "Max add water." Record on the batch ticket the volume of water actually added at the Site.
    e. Note on the batch ticket the concrete mix classification as defined in Table 3 of this Section.

J. Special procedure Submittals:
    1. Sequence of concrete placing:
        a. Submit proposed sequence of placing concrete showing proposed beginning and ending of individual placements. Submittal shall include plans sections and details to address all pours.
    2. Cold weather concreting plan.
    3. Hot weather concreting plan.
    4. Repair of defective concrete: Submit mix design for repair materials to be used.

1.06 QUALITY ASSURANCE

A. Pre-installation meetings:
    1. Schedule and conduct pre-installation meeting at least 10 days prior to batching and placing of concrete.
        a. Provide additional meetings if necessary, to discuss specific concrete Submittals, mixes, or placing and curing conditions.
        b. Notify the Engineer of location and time of each conference.
    2. Required attendees:
        a. Contractor, including Contractor's superintendent and key personnel.
        b. Concrete supplier.
        c. Technical representative(s) of supplier(s) of concrete admixtures.
        d. Subcontractor(s) providing pumping, placing, finishing, and curing.
        e. Subcontractor(s) providing embedded items (structural embedded plates, electrical conduit).
        f. Sampling and testing personnel.
        g. Engineer.
        h. On-site inspectors representing the Engineer.
        i. Other persons deemed by the Engineer and the Contractor to be critical to the quality and efficiency of the Work.
    3. Agenda:
        a. Review of requirements of Drawings and Specifications.
        b. Project and product safety requirements.
        c. Discussion of points of interface and coordination between various trades or products to be used in the Work.
        d. Contractor's schedule for cast-in-place concrete work.
        e. Mix designs, mix tests, and Submittals.
        f. Admixture types, dosing, performance, requirements for monitoring, and limits on dosing or re-dosing at the Site.

g. Placement and consolidation methods, techniques, and equipment and the effects of those methods on form pressures.
h. Slump and limits on placing time or conditions to maintain placeability.
1) Field adjustment of slump and air content.
i. Procedures for finishing, curing, and retention of moisture during these operations.
j. Procedures and protection for hot and cold weather conditions.
k. Requirements and coordination for inspections.
1) Responsibility for test specimen curing and storage.
2) Distribution of test reports.
l. Other Specification requirements requiring coordination between parties to the Work.

4. Prepare and submit minutes of the pre-installation meeting as specified in Section 01200 - Project Meetings.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Packing and shipping:
1. Deliver, store, and handle concrete materials in a manner that prevents damage and inclusion of foreign substances.
2. Deliver and store packaged materials in original containers until ready for use.
3. Deliver aggregate to mixing site and handle in such manner that variations in moisture content will not interfere with steady production of concrete of specified degree of uniformity and slump.
4. For Class M concrete:
a. Store coarse and fine aggregate in covered area. Shade aggregates to prevent heating by direct sunlight.
b. Store cementitious materials in covered, shaded silos to prevent heating by direct sunlight.

B. Acceptance at Site:
1. Reject material containers or materials showing evidence of water or other damage.
2. Concrete mixes: Do not accept or incorporate into the Work concrete mixes that do not comply with the specified requirements for water content, slump, temperature, and air content.

1.08 PROJECT CONDITIONS

A. Cold weather concreting: During periods of cold weather as defined in this Section, implement cold weather concreting procedures in this Section.

B. Hot weather concreting: During periods of hot weather as defined in this Section, implement hot weather concreting procedures in this Section.

1.09 SEQUENCING AND SCHEDULING

A. Schedule placing of concrete in a manner that completes all placing operations from one construction, contraction, or expansion joint to another construction, contraction, or expansion joint.

B. Joints at each end of the placement shall be as indicated on the Drawings, or as identified and accepted in advance by the Engineer.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Provide concrete with a homogeneous mixture, that, when hardened, will have required strength, watertightness, and durability.

B. Provide a workable, low-shrinkage concrete mix that maximizes aggregate content and minimizes paste content.

C. Performance requirements:
   1. General:
      a. Except as otherwise specified, provide concrete composed of portland cement or blended cement, supplemental cementitious materials, aggregate, admixtures and water, proportioned and mixed to produce a plastic, workable mixture in accordance with requirements of this Section, and suitable to specific conditions of placement.
      b. Proportion aggregates to produce an optimized gradation of aggregate that combines fine , intermediate, and coarse aggregate in well-graded proportions that maximizes the aggregate content and minimizes the paste content of the mix. Gradation should maximize long-term durability and strength of the concrete mixture.
      c. Durability requirements will be deemed to be satisfied when:
         1) Mixture is proportioned with a well-graded combined aggregate.
         2) Specified water-cement ratio is satisfied.
         3) Concrete contains the specified range of air content.
         4) Maximum specified paste content is satisfied.
      d. Proportion materials in a manner that will secure the lowest cement content, water-cementitious materials ratio, and paste volume that is consistent with good workability that provides a plastic and cohesive mixture, and that provides a slump that is within the specified range.
      e. Construction and expansion joints have been positioned in structures as indicated on the Drawings, and curing methods have been specified, for purpose of to reduce the number and size of cracks, resulting from normal expansion and contraction expected from the concrete mixes specified.
      f. Remove and replace, or repair as specified in this Section, non-conforming work and surfaces with cracks, voids and honeycombs, or surface wetness.
   2. Workmanship and methods: Provide concrete work, including detailing of reinforcing, conforming with best standard practices and as set forth in ACI CODE-318, and ACI CODE-350.

2.02 MATERIALS - GENERAL

A. Water and ice:
   1. Water for concrete mixes, for washing aggregate, and for curing concrete: Clean and free from oil and deleterious amounts of alkali, acid, organic matter, or other substances.

2. Water from non-potable sources shall comply with the limits of ACI CODE-350, Table 3.4.3.5.
3. Do not use water from concrete production operations, or combined water from concrete production operations as defined in ASTM C1602.

2.03 MATERIALS - CONCRETE MIX CONSTITUENTS

A. Water and ice:
   1. As specified in the preceding paragraphs.

B. Cementitious materials:
   1. Portland cement:
      a. In accordance with ASTM C150.
         1) Type II , or Type II (MH) as scheduled for each mix.
      b. Single source: To provide uniformity of appearance, for each structure use only one source, type, and brand of Portland cement for walls and slabs that will be exposed in the finished Work.
         1) Confirm adequate supply of cement over duration of the Project before making trial batches or beginning concrete placements.
      c. Cement for finishing: Provide cement from the same source and of the same type as concrete to be finished or repaired.
   2. Blended hydraulic cement:
      a. In accordance with ASTM C595:
         1) Type IP (MS).
         2) Type IL (MS).
      b. Single source: To provide uniformity of appearance and quality, for each structure use only one source, type, and brand of cement.
      c. Confirm adequate supply of cement over duration of the Project before making trial batches or beginning concrete placements.
      d. Cement for finishing: Provide cement from same source and of same type as concrete to be finished or repaired.

C. Supplementary cementitious materials:
   1. Fly ash:
      a. Class C or Class F fly ash in accordance with the requirements of ASTM C618, except as modified in this Section.
         1) Class C may be used in concrete made with Type II Portland cement.
         2) Class F required if used in concrete mixes containing aggregates classified as potentially reactive based on ASTM C1293 or ASTM C1260.
            a) CaO content: Less than 18 percent.
      b. Loss on ignition: Not exceeding 3 percent.
      c. Replace Portland cement at ratio of 1.0 pound fly ash for each pound of cement, up to minimum and maximum replacement as specified in Requirements for mix proportioning.
   2. Slag cement:
      a. Grade 80, 100, or 120 in accordance with ASTM C989, except as modified below:
         1) Fineness: Amount retained on a No. 325 sieve: 20 percent maximum.

2) Total alkalis Na2O + 0.658 K2O:
   a) Minimum: 0.60 percent.
   b) Maximum: 0.90 percent.

D. Admixtures:
   1. General:
      a. Do not include admixtures, other than those specified, unless written acceptance has been obtained from the Engineer during Submittal of mix designs.
      b. Compatible with concrete constituents and with other admixtures.
         1) All admixtures in a given mix shall be products of the same manufacturer to ensure compatibility.
         2) Manufacturers: One of the following or equal.
            a) Euclid Chemical.
            b) GCP Applied Technologies (formerly W.R. Grace).
            c) Master Builders Solutions/Sika.
            d) Sika Corp.
      c. Do not use admixtures containing chlorides, calculated as chloride ion, in excess of 0.5 percent by weight of cement.
      d. Use in accordance with manufacturer's recommendations. Add each admixture to concrete mix separately.
      e. Admixtures used shall be the same products used in concrete trial batches, or the same products used in concrete represented by submitted field test records.
   2. Air entraining admixture (AEA):
      a. In accordance with ASTM C260 and dosed to provide entrained air percentages specified in this Section.
      b. Provides entrained air as bubbles, evenly dispersed at the time of placement and during curing.
   3. Water reducing admixture (WRA):
      a. May be used at the Contractor's option.
      b. In accordance with ASTM C494, Type A (water-reducing).
         1) ASTM C494, Type D (water-reducing and retarding) may be used during periods of hot weather with prior acceptance by the Engineer.
      c. Not containing air-entraining agents.
      d. Liquid form before adding to the concrete mix.
   4. High-range water reducing admixtures (superplasticizers) (HRWR):
      a. Not permitted without acceptance by the Engineer.
   5. Shrinkage reducing admixture (SRA):
      a. May be used at the Contractor's option.
         1) Provide shrinkage reducing admixture in sufficient dosage so as to produce shrinkage within the limits specified.
      b. Not containing expansive agents.
      c. In accordance with ASTM C494, Type S (specific performance).
      d. One of the following or equal:
         1) Euclid Chemical: Eucon SRA Series.
         2) GCP Applied Technologies: Eclipse Series.
         3) Master Builders Solutions/Sika: SRA Series.
   6. Set-controlling admixtures:
      a. Shall not be used without prior acceptance from the Engineer.
      b. Accelerating admixtures: Not permitted.

E. Coloring admixtures:
   1. Conduit encasement coloring agent:
      a. Red color concrete used for encasement of electrical ducts, conduits, and similar type items.
      b. Manufacturers: One of the following or equal:
         1) Davis Co., #100 Utility Red.
         2) Euclid Chemical Co., Increte Division, Colorcrete Brick Red.
         3) I. Reiss Co., Inc., equivalent product.
      c. Conduit encasement concrete: Mix into each cubic yard of concrete 10 pounds of coloring agent.

F. Aggregate:
   1. General:
      a. Provide concrete aggregates that are sound, graded as specified, and free of deleterious material in excess of allowable amounts specified.
      b. Provide aggregates to produce in place concrete with unit weight as follows:
         1) Normal weight concrete: Not less than 140 pounds per cubic foot.
      c. Do not use aggregate made from recycled materials such as crushed and screened hydraulic-cement concrete, brick, and other construction materials.
      d. Do not use aggregate recycled from fresh concrete returned to the batching facility.
   2. Alkali-silica reactivity:
      a. Provide aggregate classified as aggregate-reactivity class of R0 in accordance with ASTM C1778 with expansion not greater than 0.10 percent at 14 days when tested in accordance with ASTM C1260, and not greater than 0.04 percent at 1 year when tested in accordance with ASTM C1293.
   3. Fine aggregate:
      a. Material graded such that 95 to 100 percent of material passes the No. 4 (4.75 mm) sieve, when sampled in accordance with ASTM D75 and ASTM D3665, and tested in accordance with ASTM C136.
      b. Provide fine aggregate consisting of clean, natural sand, or sand prepared from crushed stone or crushed gravel.
      c. In accordance with ASTM C33 requirements for grading, deleterious substances, soundness, and alkali reactivity, except as modified in the following paragraphs:
         1) Grading: For sieve sizes listed in ASTM C33 for fine aggregate, not more than 45 percent passing any sieve and retained on the next consecutive sieve.
         2) Deleterious substances: Not in excess of the percentages by weight specified in Table 1 of this Section.

Table 1. Fine Aggregate, Limits on Deleterious Substances		
Item	**Test Method**	**Percent (maximum)**
Materials finer than No. 200 sieve(2)	ASTM C117	3.00(2)
Clay lumps and friable particles	ASTM C142	1.00
Lightweight particles (SG < 2.40)	ASTM C123	1.00
Chert or shale(1)	ASTM C295	1.00(1)
Coal and lignite	ASTM C123	0.50

Notes:

(1) ASTM C123 tests for particles in the sample having a specific gravity less than 2.40. ASTM C295 is used to identify which of those lightweight particles are chert, shale, or coal and lignite. If testing under ASTM C123 indicates a combined percentage of lightweight particles (sum of shale, chert, coal and lignite) not greater than 1.00, testing under ASTM C295 will not be required.

(2) For manufactured sand, if material finer than the No. 200 sieve consists of crusher dust and the aggregate is essentially free of clay or shale, maximum percentage may be increased to 5.0 percent.

3) Organic impurities: Free of injurious amounts of organic matter and producing a supernatant liquid with color not darker than “standard color” when tested in accordance with ASTM C40.
4) Soundness: In accordance with requirements of ASTM C33 when tested in accordance with ASTM C88 using sodium sulfite solution.

4. Intermediate aggregate:
   a. Material graded such that 90 to 100 percent of material passes the 3/8-inch sieve, and not more than 5 percent of material passes the No. 50 (300 µm) sieve, when sampled in accordance with ASTM D75 and ASTM D3665 and tested in accordance with ASTM C136.
   b. Requirements for maximum percentage of impurities, abrasion loss, and soundness: As specified for coarse aggregate.
5. Coarse aggregate:
   a. Materials graded such that not more than 10 percent of material passes the 3/8-inch sieve, when sampled in accordance with ASTM D75 and ASTM D3665 and tested in accordance with ASTM C136.
   b. Consisting of gravel, crushed gravel, crushed stone, or a combination of these materials having clean, hard, durable particles free from calcareous coatings, organic matter, or other deleterious substances.
   c. Conforming to the requirements of ASTM C33, Class 4S for physical properties, deleterious substances, and alkali reactivity, except as modified in the following paragraphs:
      1) Grading:
         a) Size number as specified in ASTM C33, and as indicated in Table 3 of this Section, except as otherwise specified or accepted by the Engineer.
         b) Weights of flat or elongated particles (particles having a length greater than 3 times average width or thickness) not exceeding 15 percent when tested in accordance with ASTM D4791.
      2) Deleterious substances: Not in excess of the percentages by weight specified in Table 2 of this Section and having total of all deleterious substances exceeding 2 percent.

Table 2. Coarse Aggregate, Limits on Impurities		
Item	**Test Method**	**Percent (maximum)**
Clay lumps and friable particles	ASTM C142	0.50
Lightweight particles (SG < 2.40)	ASTM C123	1.25
Chert or shale(1)	ASTM C295	1.00(1)
Materials finer than No. 200 sieve	ASTM C117	0.50(2)
Coal and lignite	ASTM C123	0.25

Notes:

(1) ASTM C123 tests for particles in the sample having a specific gravity less than 2.40. ASTM C295 is used to identify which of those lightweight particles are chert, shale, or coal and lignite. If testing under ASTM C123 indicates a combined percentage (sum of shale, chert, coal and lignite) not greater than 1.25, testing under ASTM C295 will not be required.

(2) When material finer than No. 200 sieve consists of crusher dust, maximum percentage may be increased to 1.00 percent. When mix design complies with provisions of ASTM C33, Table 4, footnote C, the maximum percentage may be increased in accordance with the equation in footnote C, up to a maximum of 1.5 percent.

3) Abrasion loss: Loss not greater than 45 percent after 500 revolutions when tested in accordance with ASTM C131.
4) Soundness: Loss not greater than 10 percent when tested in accordance with ASTM C88 using sodium sulfate solution.

2.04 MATERIALS FOR PLACING, CURING AND FINISHING

A. General:
   1. Materials shall be compatible with concrete and with other materials.

B. Cement grout:
   1. Use: For spreading over surface of construction and cold joints in concrete before placing additional concrete above those joints.
   2. As specified in Section 03600 - Grouting.

C. Concrete sealer:
   1. As specified in Section 03366 - Concrete Finishes.
   2. Not for use in water-containment structures.

D. Evaporation retardant:
   1. Use: For mitigating surface moisture evaporation from freshly placed concrete during rapid drying conditions. Placed after screeding.
   2. Waterborne, monomolecular, spray-applied compound, with fugitive dye to indicate coverage.
   3. Manufacturers: One of the following or equal:
      a. Euclid Chemical Co., Eucobar.
      b. Master Builders Solutions/Sika, MasterKure ER 50.

E. Nonslip abrasive:
   1. Aluminum oxide abrasive size 8/16, having structure of hard aggregate that is, homogenous, nonglazing, rustproof, and unaffected by freezing, moisture, or cleaning compounds.

2. Manufacturers: One of the following or equal:
    a. Abrasive Materials, Inc.
    b. Exolon Co.

F. Plastic membrane for curing:
1. Polyethylene film: In accordance with ASTM C171.
2. Properties:
    a. Color: White.
    b. Thickness: Nominal thickness of polyethylene film shall not be less than 0.0040 inches when measured in accordance with ASTM D2103. Thickness of polyethylene film at any point shall not be less than 0.0030 inches.
    c. Loss of moisture: Not exceeding 0.055 grams per square centimeter of surface when tested in accordance with ASTM C156.

G. Sprayed membrane curing compound:
1. Combination curing and sealing products (cure and seal) will not be permitted.
2. Properties:
    a. Clear type with fugitive dye conforming with ASTM C309, Type 1D and containing no wax, paraffin, or oils.
    b. For concrete placed or cured during hot weather, curing compound shall be as specified, except that:
        1) It shall include a white, reflective fugitive dye.
        2) Moisture loss during a 72-hour period shall not exceed 0.55 kg/square meter when tested in accordance with ASTM C156.

H. Surface-applied crystalline coating:
1. Manufacturers: One of the following or equal:
    a. Euclid Chemical Co., Vandex Super.
    b. Kryton International, Inc., Krystol T1.
    c. Xypex Chemical Corp., Xypex Concentrate.
2. Where surface-applied crystalline coating is placed over concrete containing permeability reducing admixture for concrete exposed to hydrostatic conditions (PRAH), provide products of same manufacturer providing the admixture.

2.05 EQUIPMENT

A. General:
1. Provide adequate equipment and facilities for accurate measurement and control of materials and for readily changing proportions of material into mixers.

B. Batching equipment, or batch plant.
1. Capable of controlling delivery of all material to mixer within 1 percent by weight of individual material.

C. Mixing equipment:
1. Mixers may be of stationary plant, paver, or truck mixer type, as appropriate to the Work.

2. Capable of combining aggregates, water, and cementitious materials, and admixtures within specified time into a thoroughly mixed and uniform mass, and of discharging the mixture without segregation.
    a. Maintain concrete mixing equipment in good working order, and operate at loads, speeds, and timing recommended by manufacturer or as specified.
    b. Proportion cementitious materials and aggregate by weight.
3. If bulk cementitious materials are used, weigh them on separate visible scale which will accurately register scale load at any stage of weighing operation from zero to full capacity.
4. Prevent cementitious materials from coming into contact with aggregate or with water until materials are in mixer ready for complete mixing with all mixing water.
5. Procedure of mixing cementitious materials with sand or with sand and coarse aggregate for delivery to the Project Site, for final mixing and addition of mixing water will not be permitted.
6. Retempering of concrete will not be permitted.
7. Discharge entire batch before recharging.
8. Volume of mixed material per batch: Not to exceed manufacturer's rated capacity of mixer.
9. Equip each mixer with device for accurately measuring and indicating quantity of water entering concrete, and operating mechanism such that leakage will not occur when valves are closed.
10. Equip each mixer with device for automatically measuring, indicating, and controlling time required for mixing:
    a. Interlock device to prevent discharge of concrete from mixer before expiration of mixing period.
11. Transit-mixed concrete:
    a. Mix and deliver in accordance with ASTM C94.
    b. Total elapsed time between addition of water at batch plant and discharging completed mix.
    c. Not to exceed 90 minutes.
    d. Elapsed time at the Project Site shall not exceed 30 minutes.
    e. Under conditions contributing to quick setting, total elapsed time permitted may be reduced by the Engineer.
    f. Equip each truck mixer with device interlocked to prevent discharge of concrete from drum before required number of turns and furnish device that is capable of counting number of revolutions of drum.
12. Continuously revolve drum after it is once started until it has completely discharged its batch:
    a. Do not add water until drum has started revolving.
    b. Right is reserved to increase required minimum number of revolutions or to decrease designated maximum number of revolutions allowed, if necessary, to obtain satisfactory mixing. Contractor will not be entitled to additional compensation because of such increase or decrease.

D. Other types of mixers: For other types of mixers, mixing shall be as follows:
    1. Mix concrete until there is uniform distribution of materials, and discharge mixer completely before recharging.
    2. Neither speed nor volume loading of mixer shall exceed manufacturer's recommendations.

3. Continue mixing for minimum of 1-1/2 minutes after all materials are in drum, and for batches larger than 1 cubic yard increase minimum mixing time 15 seconds for each additional cubic yard or fraction thereof.

2.06 CONCRETE MIXES

A. General:
   1. Develop and provide mix designs for each concrete class listed in Table 3 of this Section.
   2. Select and proportion mixes and document properties using one of the 2 methods that follow. Procedures and requirements for use of each alternative are specified in subsequent paragraphs of this Section.
      a. Field experience method.
      b. Trial batch method.
   3. Organize and submit mix designs with data on all constituent materials and products for that mix for the Engineer's review.
   4. Do not place concrete until the mix design for that concrete class has been accepted by the Engineer.
   5. After acceptance, do not modify accepted mixes or provide new mixes without the Engineer's prior review and acceptance of the proposed alternative.
      a. Exception: At all times, adjust batching of water to compensate for free moisture content of the fine aggregate used.
      b. For any change to approved mixes, the Engineer may require new trial batching and testing program as specified in this Section before acceptance and use.
      c. For any change to approved mixes, make modifications within limits set forth in this Section.
      d. If there is change in source or quality of any constituent of the concrete class or mix, the revised mix will be considered a new class of concrete and shall require full re-submittal of all data describing mix constituents, design, and testing.
   6. Material sampling, mix designs, trial batch preparation and testing, modifications to mix designs, and any re-testing required to satisfy the requirements of this Section or to obtain satisfactory performance shall be at the Contractor's expense and shall not be considered cause for delay.

B. Measurements of materials:
   1. Measure materials by weighing, except as otherwise specified or where other methods are specifically authorized in writing by the Engineer.
   2. Furnish apparatus for weighing aggregates and cementitious materials that is suitably designed and constructed for this purpose.
   3. Accuracy of weighing devices: Furnish devices that have capability of providing successive quantities of individual material that can be measured to within 1 percent of desired amount of that material.
   4. Measuring or weighing devices: Subject to review by the Engineer. Shall bear valid seal of the Sealer of Weights and Measures having jurisdiction.
   5. Weighing cementitious materials:
      a. Weigh cementitious materials separately.
      b. Cement in unbroken standard packages (sacks): Need not be weighed.
      c. Weigh bulk cementitious materials and fractional packages.
   6. Measure mixing water by volume or by weight.

C. Requirements for mix proportioning:
    1. Develop and provide mixes that:
        a. Can be readily worked into corners and angles of forms and around reinforcement, without excessive vibration, and without permitting materials to segregate or free water to collect on surface.
        b. Prevent unnecessary or haphazard changes in the consistency of the concrete supplied.
    2. Constituent materials:
        a. Provide concrete mixes composed of Portland cement or blended cement, blended aggregates, admixtures and water.
            1) Admixtures required for each concrete class are indicated in Table 3 of this Section. Admixtures not specifically required by that table for a specific concrete class are optional and may be included at the discretion of the Contractor based on the Contractor's planned means and methods of construction.
        b. In no case shall returned fresh concrete or its constituents be incorporated into concrete batched for the Work.
    3. Minimum specified compressive strength:
        a. Minimum specified compressive strength is designated at 28 days, unless otherwise indicated in Table 3 of this Section.
        b. For locations where the placed concrete is adequately protected and is not subjected to loads for an extended period during construction, the Contractor may request that the period for achieving the minimum specified compressive strength be extended to 56 days.
            1) If accepted by the Engineer, provide mixes that achieve at least 75 percent of their minimum specified compressive strength after 28 days.
    4. Proportions and consistency:
        a. Ratio of water to cementitious materials, and cementitious materials content:
            1) Conform to maximum and minimum cementitious material content requirements specified in Table 3 of this Section.
            2) Cementitious materials content: Consisting of Portland cement or blended cement as indicated in Table 3 of this Section, plus supplemental cementitious materials if aggregate testing indicates potentially reactive aggregates:
                a) Fly ash content:
                    (1) Minimum: 15 percent of the total weight of cementitious materials.
                    (2) Maximum: 25 percent of the total weight of cementitious materials.
                    (3) Class M: Provide 20 to 25 percent by weight of the total cementitious content as Class F fly ash.
                b) Slag cement content:
                    (1) Minimum: 20 percent of the total weight of cementitious materials.
                    (2) Maximum: 50 percent of the total weight of cementitious materials.
        b. Aggregate size and content:
            1) Blend aggregates to produce an optimized gradation that combines well-graded coarse, intermediate, and fine aggregates in proportions

that maximize the aggregate content of the mix, and that minimize the cement paste content of the mix.

a) Percentage of individual fractions of the combined aggregate gradation retained on individual sieve sizes: Within the range shown in Attachment C - Combined Aggregate Gradation Chart (Tarantula Curve).
b) Sum of the percentages of individual fractions retained on the No. 8, No. 16, and No. 30 sieves: Greater than 20 percent.
c) Sum of the percentages of individual fractions retained on the No. 30, No. 50, No. 100, and No. 200 sieves: Within the range of 25 percent to 40 percent.

c. Determine bulk density and void content of the combined gradation of aggregates in accordance with ASTM C29. Results for combined aggregates shall not be the summation of results of testing of the individual gradations.
   1) Sample the combined aggregate from a flowing aggregate stream or conveyor in accordance with ASTM D75. Take care to ensure that the sample is representative of the proportions of the combined aggregate of the proposed mix.
   2) Reduce sample of combined aggregate to test sample size in accordance with ASTM C702, Method A - mechanical splitter or Method B - quartering.
   3) Perform bulk density test of combined aggregate in accordance with ASTM C29, Procedure A - rodding.
   4) Determine void content of the combined aggregate in accordance with ASTM C29, Procedure A - rodding. Specific gravity of the combined aggregate shall be determined in accordance with ASTM C136.
d. Paste content: Limited to the following:
   1) Class A mixes without air entrainment: Maximum 28 percent measured by volume.
   2) Class A mixes with air entrainment: Maximum 28 percent measured by volume plus the target air content.
   3) Paste content shall be limited to 175 percent of the void content of the combined aggregate gradation determined by ASTM C29.
e. Total water content:
   1) Not exceeding the water to cementitious material ratio specified in Table 3 of this Section.
f. Coarseness/workability (Shilstone Method):
   1) Proportion mixes to fall into the “Optimal” zone (Zone II) when plotted on the Coarseness Factor Chart (“Coarseness Factor” versus “Workability Factor”) included as Attachment B - Coarseness Factor Chart to this Section. Provide plot for each Class A mix to be used in the Work.
   2) Coarseness factor (CF) for each mix shall be calculated as the percent of the combined aggregate gradation retained on the 3/8-inch sieve, divided by the percent of the combined aggregate gradation retained on the No. 8 sieve, multiplied by 100, or:

$$CF = \frac{(\%\ \text{retained on 3/8-in sieve})}{(\%\ \text{retained on No. 8 sieve})} \times 100$$

3) Workability factor (WF) for each mix shall be the percent of the combined aggregate gradation retained on the No. 8 sieve, adjusted for cement content in the mix.
   a) Determine volume of total cementitious material in the mix.
   b) For each 94 pounds of cement content above 564 pounds per cubic yard, increase workability factor by 2.5 units.
   c) For each 94 pounds of cement below 564 pounds per cubic yard, decrease workability factor by 2.5 units.
   d) Proportion adjustment factor by linear interpolation for each fraction of 94 pounds above or below the 564 pound basis.
   e) Example:
   650 pounds per cubic yard = 564 pounds + 86 pounds.
   Adjustment = (86 lb / 94 lb) x 2.5 = + 2.28.

D. Concrete classes for use in the Work:
   1. Provide concrete classes listed in Table 3 of this Section.
   2. Provide normal weight concrete, having minimum weight of 140 pounds per cubic foot, unless otherwise noted.
   3. Pumped concrete:
      a. Provide pumped concrete that complies with all requirements of this Section.
      b. Mixes placed by pumping shall be considered a sub class of each concrete class listed in Table 3 of this Section. Prepare and submit a separate mix design for each mix to be placed by pumping.
   4. Class PM concrete: In addition to the requirements of Table 3 of this Section, conform to the following:
      a. Minimum 28 day flexural strength: 650 psi when tested in accordance with ASTM C293.
      b. Cementitious materials content: 75 percent Portland cement plus 25 percent Class F fly ash (by weight), blended cement conforming to Type IP(25), or 75 percent Type IL blended cement plus 25 percent Class F fly ash (by weight).
      c. Aggregate:
         1) Minimum 55 percent coarse aggregate conforming to ASTM C33 size number 357 or size number 467.
         2) Substitute ASTM C33 size number 57, or size number 67 if mechanical paving equipment is not used.
   5. Class M concrete: In addition to the requirements of Table 3 of this Section, conform to the requirements for Class A concrete.

Table 3. Concrete Classes									
Concrete Class[1]	**Minimum Specified Compressive Strength at 28 days, f'c [2] (pounds per square inch)**	**Ratio of water to cementitious materials[3] (minimum - maximum)**	**Cementitious Materials Content (pounds per cubic yard of concrete by weight)[4]**	**Cement Type**	**Maximum Chloride Content (percent by weight of cement)**	**Maximum Size of Coarse Aggregate (ASTM C33)**	**Air Entrainment (percent), (n/a: not applicable)**	**Admixtures required[4,5,6]**	**Slump Range (inches)**
A	4,000	0.40 to 0.42	535 to 575	ASTM C150, Type II(MH) or ASTM C595, Type IL(<15)(MS) or IP(20)(MS)	0.30	#57	6±1.5	AEA WRA	2 to 4
A-NA	4,000	0.40 to 0.45	535 to 575	ASTM C150, Type II(MH) or ASTM C595, Type IL(<15)(MS) or IP(20)(MS)	0.30	#57	n/a	WRA	2 to 4
C	2,500	0.62 max.	423 min.	ASTM C150, Type II(MH) or ASTM C595, Type IL(<15)(MS) or IP(20)(MS)	No limit	#57	6±1.5	AEA WRA	3 to 6
CE	3,000	0.62 max.	423 min.	ASTM C150, Type II(MH) or ASTM C595, Type IL(<15)(MS) or IP(20)(MS)	No limit	#8	5±1.5	AEA WRA	3 to 6
PM	5,000	0.40	535 to 575	ASTM C150, Type II(MH) or ASTM C595, Type IL(<15)(MS) or IP(20)(MS)	0.15	#57	5±1.5	AEA WRA	3 to 6
M	4,000 or 4,500 at 56 or 90 days	0.40 to 0.42	535 to 575	ASTM C150, Type II(MH) or ASTM C595, Type IL(<15)(MS) or IP(25)(MS)	0.30	#4	6±1.5	AEA WRA	2 to 4

Notes:

(1) Sub classes within major concrete classes are designated as follows:
NA: Without air entrainment.

Table 3. Concrete Classes									
Concrete Class[1]	Minimum Specified Compressive Strength at 28 days, f'c [2] (pounds per square inch)	Ratio of water to cementitious materials[3] (minimum - maximum)	Cementitious Materials Content (pounds per cubic yard of concrete by weight)[4]	Cement Type	Maximum Chloride Content (percent by weight of cement)	Maximum Size of Coarse Aggregate (ASTM C33)	Air Entrainment (percent), (n/a: not applicable)	Admixtures required[4,5,6]	Slump Range (inches)

(2) At locations where concrete will not be subjected to load from other elements of the structure or from the Contractor's placing and/or backfilling operations, maximum time period for achievement of specified compressive strength may be extended to 56 days when accepted by the Engineer.

(3) W/C Ratio = Ratio of water to cementitious materials by weight. Include weight of admixtures in the water content of the mix when the quantity of the admixtures exceeds 10 ounces per 100 pounds of cement.

(4) Cementitious material includes Portland cement plus supplemental cementitious materials. If trial batch testing demonstrates that the required strength cannot be met at 28 or 56 days with the specified combined aggregate gradation and the paste content limits, cementitious material content may be increased with the Engineer's approval if Class M concrete is provided and Thermal Control Plan and Temperature Monitoring Program in accordance with Section 03703 - Thermal Control of Concrete is provided for cast-in-place concrete elements. Cement content and/or threshold for the thermal control requirement may be adjusted by the Engineer based on the Equivalent Cement Content (ECC) of the approved Class M concrete mix.

(5) Admixtures are designated as follows:
AEA: Air entraining admixture.
HRWR: High-range water-reducing admixture.
WRA: Water-reducing admixture.

E. Install concrete classes in accordance with the following requirements, unless otherwise indicated on the Drawings.
   1. Class A concrete: Structural concrete.
      a. Use at all locations unless other Classes are specified or indicated on the Drawings.
   2. Class A-NA concrete: Structural concrete without air entrainment.
      a. May be used in lieu of Class A at indoor slabs (not subject to freezing and thawing) where inclusion of an air-entraining admixture makes it difficult to achieve the specified concrete finish.
   3. Class C concrete: Miscellaneous concrete fill and encasement.
      a. May be used for fill for unauthorized excavation, for thrust blocks and ground anchors for piping, for bedding of pipe, and where indicated on the Drawings.
   4. Class CE concrete: Use for electrical conduit encasements.

F. Concrete mix design documented by field experience:
    1. Mix design:
        a. Prepare preliminary mix design for each concrete class. Submit mix design with product and testing data for materials to be used in the mix for the Engineer's review.
    2. Historical records for similar mix.
        a. Determinations of similarity of materials and proportions between historical and proposed mixes shall be by the Engineer, and that shall be final.
        b. Historical record - Materials:
            1) Submit with each mix design the following data for a previously supplied concrete mix similar to that proposed for this Work.
            2) Records demonstrating that the previously supplied mix included similar materials and proportions as those of the proposed mix.
                a) Documentation that the same concrete supplier will provide both mixes.
                b) Documentation that the materials used was from the same suppliers and had essentially the same properties, demonstrated by test data, as those proposed.
                c) Documentation that proportions of materials in the record mix are essentially the same as those proposed and that the specified compressive strength of the record mix is within 1,000 pounds per square inch of that required by this Section.
                d) Concrete supplier's statement describing any changes made to production of the record mix during the time period reported.
                e) Concrete supplier's statement that preparation and quality control procedures for the record mix were essentially the same as those to be employed for this Work.
        c. Historical record - Testing:
            1) Submit with each record mix, corresponding test data for slump, compressive strength (with relationships for rate of strength gain between testing ages), and drying shrinkage.
            2) Only records satisfying the following requirements will be accepted.
                a) All tests were conducted within a period of 1 year preceding the date of the Submittal.
                b) All tests were conducted over a period including not less than 45 days.
                c) Record of compressive strength testing includes at least 30 tests for slump and 28-day compressive strength.
                d) Record of compressive strength tests is consecutive. In other words, it includes all tests conducted on the subject mix within the 1-year time period described above (not just selected tests during that period).
                e) Submit concrete supplier's sworn statement confirming that all tests for the record mix have been reported.
                f) Tests for drying shrinkage are described in subsequent paragraphs of this Section for "concrete mix design documented by trial batch preparation and testing".
                g) Provide supplementary testing if requested by the Engineer.

d. For mixes determined to be similar and to have an acceptable test history, acceptance criteria shall be as follows:
    1) Acceptance criteria:
        a) Slump: All tests within limits specified for record mix.
        b) Compressive strength: Average compression strength for tests, as determined by ACI CODE-350 not less than minimum required average strength.
        c) Drying shrinkage: Within limits stated in subsequent paragraphs of this Section for “concrete mix design documented by trial batch preparation and testing”.

G. Concrete mix design documented by trial batch preparation and testing:
1. Mix design and trial batches:
    a. Prepare preliminary mix design for each concrete class. Submit mix design with product and testing data for each combination of materials and proportions to be used for the Engineer’s review.
        1) Determine water content of the mix based on curves showing the relation between water-cementitious materials ratio and the 7- and 28-day compressive strength of the concrete.
        2) Determine each curve using 4 or more points, each representing the average compressive strength value of at least 3 specimens tested at each age.
    b. After materials and proposed mix designs have been accepted by the Engineer, have trial batches for each concrete mix design prepared by the Contractor’s testing laboratory.
        1) Prepare trial batches using the cementitious materials, aggregates, and admixtures proposed to be used for the Work.
        2) Provide batches of sufficient quantity to determine slump, workability, consistency, and finishing characteristics, and to provide sufficient specimens for testing.
    c. For each trial batch, make and test specimens to determine and report slump, compressive strength (with relationships for rate of strength gain between testing ages), and drying shrinkage.
        1) If trial batches do not produce concrete conforming to the specified requirements for slump, strength, workability, consistency, drying shrinkage, restrained shrinkage, and finishing, change mix proportions and, if necessary, sources of materials.
        2) Make additional trial batches and perform additional tests until a batch that conforms to requirements of this Section is produced.
2. Testing - Slump:
    a. Determine slump in accordance with ASTM C143.
    b. Acceptance criterion: Slump within range specified.
3. Testing - Compressive strength:
    a. Prepare 4-inch diameter by 8-inch long cylinders in accordance with ASTM C31 for tests specified in this Section.
    b. Determine average compressive strength:
        1) Test at least 12 cylinders from each trial batch for compressive strength in accordance with ASTM C39.
        2) Test 4 cylinders at 7 days, another 4 at 28 days, and another 3 at 56 days. Calculate average compression strength for 7-day tests, for 28-day tests, and for 56-day tests.

3) Calculate ratios for:
   a) Average 7 day strength to average 28 day strength.
   b) Average 28 day strength to average 56 day strength.

c. Determine the required average compressive strength for each mix, f'cr, as described in the following paragraphs:
   1) Calculate required average compressive strength (f'cr) based on the minimum specified 28-day compressive strength, f'c, plus a standard deviation determined from the test history available for that mix.
   2) Determine f'cr as specified in ACI CODE-350, except as modified in the following paragraphs:
      a) Where 15 or more 28-day compressive strength tests are available, calculate standard deviation as described in the preceding paragraphs for "concrete mix design documented by field experience". Add this standard deviation to the specified minimum compressive strength to determine the required average compressive strength (f'cr) for the mix.
      b) Where fewer than 15 compressive strength tests at 28 days are available, determine minimum required compressive strength, (f'cr) from Table 4 of this Section.

Table 4. Required Average Compressive Strength, Fewer than 15 Tests Available

Minimum Specified Compressive Strength, f'c (pounds per square inch)	Required Average Compressive Strength, f'cr (pounds per square inch)
Less than 3,000	f'c + 1,000
3,000 to 5,000	f'c + 1,200
Over 5,000	f'c + 1,400

d. Acceptance criterion: Average compressive strength of the 4 cylinders tested at 28 days, or of the 4 cylinders tested at 56 days when permitted by the Engineer, shall equal or exceed the required average compression strength, f'cr for that concrete mix design.

4. Testing - Chloride content:
   a. Submit test results showing that the concrete mix contains water-soluble chloride ion content contributed from the constituents, including water, aggregates, cementitious materials, and admixtures is less than the limit specified in Table 3 of this Section. Test shall be performed in accordance with ASTM C1218 at age between 28 and 42 days.
5. Testing - Drying shrinkage - Prism specimens:
   a. Class A (including A, A-NA, A-SP, and A-NA-SP), Class M, and Class PM: From trial batch for each mix, prepare 10 drying shrinkage specimens in accordance with ASTM C157.
      1) Divide specimens into 2 groups of 5 specimens each: 1 group including shrinkage-reducing admixture and 1 group without shrinkage-reducing admixture.

b. Prepare, cure, and test both groups in accordance with ASTM C157, except as modified in the following paragraphs.
    1) Remove drying shrinkage specimens from molds at age of 23 hours, plus or minus 1 hour, after trial batching.
        a) Immediately place them in lime-saturated water maintained at 73 degrees Fahrenheit, plus or minus 3 degrees, for at least 30 minutes.
        b) Remove specimens from the water and wipe with a damp cloth.
        c) Measure to nearest 0.0001 inch to determine original length.
        d) Record measurements and re-submerge specimens in lime-saturated water at 73 degrees Fahrenheit, plus or minus 3 degrees, for moist curing.
    2) Maintain submerged curing conditions at 73 degrees Fahrenheit, plus or minus 3 degrees, for 7 days. 7 days after batching, remove specimens from water and repeat measuring procedures.
    3) Immediately store specimens in a humidity controlled room maintained at 73 degrees Fahrenheit, plus or minus 3 degrees, and at 50 percent relative humidity plus or minus 4 percent for remainder of the test.
    4) At periods of 14, 21, 28, and 56 days after batching, remove specimens from curing room and repeat measurements.
c. Drying shrinkage test report:
    1) Report measurements of all specimens at 1, 7, 14, 21, 28, and 56 days after batching.
    2) Using measured length at 7 days as base length for drying shrinkage, calculate the following for each measuring period:
        a) Drying shrinkage of each specimen. Determine as difference between the 7-day base length and measured length for each period.
        b) Average of these differences. If drying shrinkage of any specimen departs from the average of the measurements for each period by more than 0.0004 inch, disregard results obtained from that specimen.
        c) Percentage of drying shrinkage from batching to date of measurement.
d. Drying shrinkage acceptance criteria:
    1) Average shrinkage of trial batch concrete specimen group at 28 days after batching, when measured and cured as indicated, shall not exceed 0.035 percent.
e. Mixes accepted by the Engineer:
    1) Retain drying shrinkage test specimens. Bag in re-sealable plastic bags and submit to the Engineer.
    2) Indicate trial batch identifier, specimen number, and date of final measurements on each specimen bag.

2.07 SOURCE QUALITY CONTROL

A. Sample and test materials in accordance with the following requirements:
    1. Sampling, testing, and reporting frequency:
        a. In preparation for mix design submittals and trial batch tests.

b. Whenever there is a change in source of the material, or a significant change in the characteristics or quality of materials from the same source.
c. For each 10,000 cubic yards of concrete mix produced.
d. At intervals not exceeding 90 calendar days, unless otherwise specified in the following paragraphs.

2. Supplemental cementitious materials.
   a. Sample and test fly ash in accordance with ASTM C311.
   b. Sample and test slag cement in accordance with ASTM C989.
3. Aggregate:
   a. Sample combined aggregate in accordance with ASTM D75 and ASTM D3665, and test for gradation in accordance with ASTM C136.
   b. At least once every 30 days, and when requested by the Engineer.
   c. Submit test results.
4. Cementitious materials:
   a. Sample and test cementitious materials and provide mill certificates demonstrating compliance with ASTM C150 or ASTM C595, and additional requirements of this Section.
      1) Determine alkali content by method set forth in ASTM C114.
   b. At least once every 90 days, and when requested by the Engineer.
   c. Submit test results.

B. Batch materials in accordance with the following requirements:
1. Concrete batch weights: Control and adjust so as to secure maximum yield, and at all times maintain proportions of concrete mix within specified limits.
2. Aggregates:
   a. Obtain aggregate from a source capable of providing uniform quality, moisture content, and grading during any single day's operation.
   b. Furnish satisfactory means at batching plant for checking moisture content of fine aggregate for each batch.
3. Admixtures:
   a. Batch solutions using mechanical batcher capable of accurate measurement.
   b. Air entraining admixture: Add to batch in portion of the mixing water, unless otherwise recommended by the admixture manufacturer.

PART 3 EXECUTION

3.01 PREPARATION

A. Prepare and submit mix designs for each concrete class indicated in Table 3 of this Section.

B. Submit proposed sequence of concrete placements. After acceptance, adhere to proposed sequence of placing concrete, except when specific changes are requested by the Contractor and accepted by the Engineer.
1. Use construction methods and sequence work to allow concrete placement to reach adequate strength and to be constructed with required support to prevent overstress of the concrete structure during construction.

C. Make provisions for monitoring weather conditions:
   1. Install an outdoor weather station capable of measuring and recording ambient temperature, wind speed, and humidity. Furnish instruments accurate to within 2 degrees Fahrenheit, 5 percent relative humidity, and 1 mile per hour wind speed.
   2. Monitor the weather forecast beginning at least 48 hours prior to any concrete placement and make provisions for cold weather concreting or hot weather concreting if those conditions exist or are forecast to exist during the period of placement, finishing, and curing.
      a. Record temperature, relative humidity, and wind speeds for each placement beginning at least 24 hours before scheduled delivery of concrete.

D. Place no concrete without the Engineer's prior acceptance of conditions.

E. Notify the Engineer in writing that preparations are complete and ready for placement of concrete. Such notification shall indicate readiness - not just intention - to place concrete for the designated portion of the Work.
   1. Submit notification to the Engineer on forms provided by or acceptable to the Engineer and bearing the signature of the Contractor's superintendent.
      a. Sample form is included at the end of this Section, see Attachment B - Coarseness Factor Chart.
   2. Submittal of notification will be the Contractor's certification that preparations are complete and in accordance with the Contract Drawings and Specifications.
   3. Provide notification for the Engineer to make final observations at the locations of concrete placements not less than 24 hours before commencing placement of concrete.

3.02 CONCRETE JOINTS

A. Locations of joints are indicated on the Drawings.
   1. In order to preserve strength and watertightness of structures, make no other joints, except as authorized by the Engineer.
   2. Construct joints where indicated, and as indicated on the Drawings.
   3. Where joint locations are not indicated on the Drawings, submit the Contractor's proposed locations for the Engineer's review and acceptance. Provide construction joints in slabs and walls at intervals not greater than 35 feet.

B. Time between placements of adjacent concrete separated by joints.
   1. Provide not less than 3 days (72 hours) between placement of adjacent sections for the following:
      a. Slabs.
      b. Walls.
   2. Provide not less than 7 days (168 hours) between placement of the lower and upper pours for the following:
      a. Walls over slabs.
      b. Slabs over walls.
      c. Slabs keyed into the sides of walls.

C. Edges of joints:
   1. Provide joints have edges detailed as indicated on the Drawings.

2. Protect wall and slab surfaces at edges from concrete splatter. Thoroughly clean adjacent surfaces after completion of each placement.

D. Keyways in joints:
   1. Provide keyways in joints unless specifically noted otherwise on the Drawings.
   2. Treat lumber keyway material with form release coating, applied in accordance with manufacturer's instructions.

E. Joint construction:
   1. Preparation of forms:
      a. Provide cleanout holes at base of each wall and column for inspection and cleaning.
      b. Wash forms and adjacent joint surfaces of sawdust, chips, and other debris after forms are built, and immediately before concrete or grout placement.
      c. Should formwork confine sawdust, chips, or other loose matter in such manner that it is impossible to remove them by flushing with water, use a vacuum cleaner for their removal and then flush cleaned surfaces with water.
   2. Before placing concrete against previously placed concrete, thoroughly clean the prior placement of laitance, grease, oil, mud, dirt, curing compounds, mortar droppings, or other objectionable matter by means of pressure washing.
   3. Provide and install waterstops, expansion joint material, and other similar materials as indicated on the Drawings and as specified.
      a. Take special care to ensure that waterstops are secured in proper position.
      b. Take special care to ensure that concrete is well consolidated around and against waterstops during placement.
   4. Horizontal joints:
      a. As initial placement over cold joints, thoroughly spread bed of cement grout as specified in Section 03600 - Grouting.
         1) Thickness: Not less than 1/2 inch or more than 1 inch.
      b. For wall placements above planned cold joints, placement of cement grout will not be required for locations where the wall mix includes high-range water-reducing admixture (superplasticizers), and the Contractor can demonstrate dense concrete joints without voids or honeycomb after the forms are removed.

3.03 MEASURING AND BATCHING MATERIALS

A. Measurements of materials:
   1. Proportion and measure cementitious materials and aggregates by weight.
      a. Weigh cementitious materials separately.
      b. If bulk cementitious materials are used, weigh them on separate visible scale that will accurately register scale load at any stage of weighing operation from zero to full capacity.
      c. Cement in unbroken standard packages (sacks) need not be weighed.
   2. Mixing water: Measure by volume or by weight.
   3. Other mix constituents: Measure by weight, except as otherwise specified or accepted by the Engineer.
   4. Weighing and measuring devices:
      a. Use equipment designed and constructed specifically for that purpose.

b. Furnish devices capable of weighing successive quantities of individual material measured to within 1 percent of desired weight of that material.
c. Bearing valid seal of the department of weights and measures for the authority having jurisdiction over the Work.

5. Measurements and measuring devices:
   a. Subject to review by the Engineer.

B. Batching:
1. Admixtures shall be added at the concrete batch plant.
2. Addition of admixtures in the field is permitted only with prior acceptance by the Engineer, and only when the following conditions are satisfied:
   a. Dosage and mixing is personally overseen by the concrete supplier's trained technologist.
   b. Adequate mixing is provided after addition.
   c. Maximum time to placement of concrete remains 90 minutes after water added to mix - not 90 minutes after any field additions/adjustments.
   d. Slump at discharge after additions/modifications conforms to the requirements of Table 3 of this Section.

3.04 MIXING AND TRANSPORTING

A. Machine mixing:
1. Prevent cementitious materials from coming into contact with aggregate or with water until materials are in mixer and ready for complete mixing with all mixing water.
2. Procedure of mixing cementitious materials with sand, or with sand and coarse aggregate, for delivery to the Project Site for final mixing and addition of mixing water is not permitted.
3. Remixing of concrete that has started to take its initial set (retempering) is not permitted.
4. Discharge entire batch before recharging.
5. Volume of mixed material per batch: Not exceeding manufacturer's rated capacity of mixer.

B. Transit-mixed concrete:
1. Mix and deliver in accordance with ASTM C94, except as modified in this Section.
2. Total elapsed time between addition of water at batch plant and discharging completed mix:
   a. Not to exceed 90 minutes or 300 revolutions of the mixing drum.
   b. Under conditions contributing to rapid setting, total elapsed time permitted may be reduced by the Engineer.
3. Temperature - minimum and maximum allowable during mixing and transporting:
   a. Minimum: 50 degrees Fahrenheit.
   b. Maximum: 90 degrees Fahrenheit.
4. Continuously revolve drum after it is started until it has completely discharged its batch.
   a. Do not add water until drum has started revolving.
   b. Engineer reserves the right to increase required minimum number of revolutions or to decrease designated maximum number of revolutions

allowed, if necessary, to obtain satisfactory mixing. Contractor will not be entitled to additional compensation because of such increase or decrease.

C. Concrete delivery:
   1. Furnish to the Engineer a delivery ticket for each batch of ready mixed concrete within 24 hours after delivery. Include the following information on each ticket:
      a. Time of day concrete was batched, and time of day that discharge from the truck is complete.
      b. Printed record of the individual weight of each of the following constituents in the batch: Fine aggregate, coarse aggregate, cement, pozzolan, and water.
      c. Concrete class as defined in Table 3 of this Section.
      d. Type, brand, and quantity of each admixture in the batch.
      e. Total volume of water allowed in the mix, volume of mixing water added at the batch plant, volume of mixing water withheld from the mix during batching, and total volume of any water added to the mix after leaving the batch plant.
         1) In no case shall volume of mixing water withheld result in a water/cementitious materials ratio less than the minimum values specified in Table 3 of this Section.
      f. Number of revolutions of transit truck at arrival on site, and total number of revolutions when discharge is complete.
      g. Volume of concrete delivered in the batch.
      h. Numerical sequence of the batch delivered for that placement.
   2. Additional water may only be added to the mix when the following conditions are fully satisfied:
      a. Batch ticket showing total volume of water already added and maximum volume of water that may be added is available for the Engineer's observation before any additional water is added.
      b. Total volume of water in the mix after the addition will be less than the maximum allowable volume of water indicated on the ticket.
      c. Full concrete load is still within the truck's mixing drum, and truck has not begun to discharge the load. Under no conditions shall water be added in the field to a partial truckload of concrete.
      d. Volume of water added, and time of addition are clearly marked for record on the batch ticket delivered to the Engineer.
   3. Addition of admixtures in the field is permitted only with prior approval by the Engineer, and when the following conditions are satisfied:
      a. Dosage and mixing is personally overseen by the concrete supplier's trained technologist and the admixtures supplier's representative.
      b. Adequate mixing time is provided after addition of admixtures.
      c. Maximum time to placement of concrete remains 90 minutes after water is added to the mix - not 90 minutes after any field additions/adjustments.
      d. Slump at discharge after additions/modifications conforms to the requirements of Table 3 of this Section.

D. Conveying concrete:
   1. Convey concrete from mixer to location of final deposit by methods that prevent separation or loss of materials.

2. Use equipment for chutes, pumps, and conveying of concrete of such size and design as to ensure practically continuous flow of concrete, from delivery to the point of placement, without separation of materials.
3. Design and use chutes and devices for conveying and depositing concrete that direct concrete vertically downward when discharged from chute or conveying device.
4. Keep equipment for conveying concrete thoroughly clean by washing and scraping upon completion of any day's placement.

3.05 PLACING AND CONSOLIDATING

A. Preparation:
   1. Obtain the Engineer's acceptance of completed preparations before placing concrete.
      a. Notify the Engineer in writing that all preparations are complete and ready for placement of concrete. Such indication shall indicate readiness, not just intention, to place concrete for the designated portion of the Work.
      b. Submit completed Attachment D - Contractor's Concrete Placement Checklist Form.
   2. Confirm completeness of the following before notification of readiness is given to the Engineer:
      a. Place forms, reinforcement, screeds, anchors, ties, and inserts in final position.
      b. Reinforcement is secure and properly fastened in its correct position.
      c. Loose form ties at construction joints have been retightened.
      d. Dowels, bucks, sleeves, hangers, pipes, conduits, anchor bolts, and any other fixtures required to be embedded in concrete have been placed and adequately anchored to maintain a minimum 2-inch clearance between the item and any concrete reinforcement.
         1) Securing embedded items in position by wiring or welding to the reinforcement is not permitted.
      e. Forms have been cleaned of debris and form release agents are applied as specified.
   3. Preparation for placement of footings and slabs on grade:
      a. Do not place concrete on ground or compacted fill until subgrade is in moist condition acceptable to the Engineer.
      b. If necessary, sprinkle subgrade with water not less than 6 or more than 20 hours in advance of placing concrete.
      c. If subgrade surface becomes dry prior to actual placing of concrete, sprinkle again, without forming pools of water.
      d. Do not place concrete if subgrade is muddy or soft.
   4. Keep sufficient protective coverings on hand at all times for protection of concrete during and after placement.
      a. Protect concrete placed before rain to prevent water from coming in contact with such concrete.
      b. Protect concrete placed before winds to prevent excessive drying or embedment of debris in the finished surfaces.

B. Concrete placement:
   1. Do not place concrete:
      a. With slump outside the limits specified in Table 3 of this Section.

b. In which initial set has occurred, or that has been retempered.
c. During rainstorms or high velocity winds.

2. Deposit concrete at or near its final position to avoid segregation caused by rehandling or flowing.
   a. Do not deposit concrete in large quantities in one place, and then work material along forms with vibrator or by other methods.
3. Do not drop concrete freely into place from height greater than 5 feet. Use tremies for placing concrete where drop is over 5 feet.
4. Place concrete on slopes starting from bottom of slope and working upward.
5. Place concrete in horizontal lifts not exceeding 24 inches in depth and bring up evenly in all parts of forms.
6. After concrete placement begins, continue in a continuous operation without significant interruption until the end of the placement. Plan and implement precautions to prevent any delay, between layers or adjacent volumes, from exceeding 20 minutes.
7. If concrete is to be placed over previously placed concrete and more than 20 minutes has elapsed, spread layer of cement grout over surface before placing additional concrete. Provide grout layer thickness of not less than 1/2 inch or more than 1 inch.
8. Placement of concrete for slabs, beams, or walkways:
   a. If cast monolithically over walls or columns, do not commence until concrete in walls or columns has been allowed to set and shrink.
   b. Allow set time of not less than 1 hour for shrinkage.
      1) During waiting time, keep top surface of concrete moist, but not wet.
      2) Do not permit water to pond or stand on the surface.
      3) Do not coat surface with evaporation retarders or curing agents.
   c. Start placement above wall or column with layer of cement grout as described in the preceding paragraph.

C. Consolidating concrete:
1. Consolidate concrete with aid of acceptable mechanical vibrators.
2. Thoroughly consolidate concrete around reinforcement, pipes, or other shapes built into the Work.
3. Provide sufficiently intense vibration to cause concrete to flow and settle readily into place and to visibly affect concrete over radius of at least 18 inches.
4. Vibrators:
   a. Keep sufficient vibrators on hand at all times to vibrate concrete as placed.
   b. In addition to vibrators in actual use while concrete is being placed, have on hand a minimum of 1 spare vibrator in operable condition.
   c. Do not place concrete until it has been confirmed that all vibrating equipment, including spares, are in operable condition.
5. Place concrete solidly against forms and concrete surfaces, leaving no voids or honeycomb.
6. Make concrete solid, compact, and smooth. If for any reason surfaces or interiors have voids or are in any way defective, repair such concrete in manner acceptable to the Engineer.
7. Do not over-vibrate so as to produce segregation.

3.06 FINISHING CONCRETE

A. Provide concrete finishes in accordance with Section 03366 - Concrete Finishes, unless otherwise indicated on the Drawings.

B. Liquid evaporation retardant:
   1. Under conditions that result in rapid evaporation of moisture from the surface of the concrete, coat the surface of the concrete with a liquid evaporation retardant immediately after screeding.
   2. Conditions that result in rapid evaporation of moisture are defined as any combination of ambient temperature, concrete temperature, relative humidity, wind speed, and solar radiation intensity that creates conditions that will evaporate water from a free concrete surface at a rate equal to or greater than 0.1 pounds per square foot per hour as determined by the Menzel Formula and nomograph published in ACI PRC-305 and included as Attachment A - Menzel Formula and Nomograph to this Section.
   3. Apply evaporation retardant again after each finishing operation as necessary to prevent drying shrinkage cracks.
   4. Do not work evaporation retardant into the surface of the concrete.
   5. Do not use evaporation retardant as finishing aid (to rehydrate surface a creamy state for finishing).

C. Concrete sealer:
   1. Floors and slabs to receive concrete sealer: See Room Finish Schedule on the Drawings, and Section 03366 - Concrete Finishes.

D. Surface-applied crystalline coating:
   1. Apply surface-applied crystalline coating in strict accordance with the manufacturer's directions.
   2. Spray, squeegee or roll on liquid to clean, dry concrete surface at 225 square feet per gallon.
      a. Scrub liquid into the surface with a mechanical scrubber.
      b. Keep surface wet for a minimum of 30 minutes with the surface-applied crystalline coating during application.
      c. When the product thickens, but not more than 60 minutes after initial application, squeegee or vacuum the surface to remove all excess liquid.
      d. Do not leave any residue on surface.
      e. Do not track material on to untreated surfaces.
   3. Where concrete continues to sweat or leak, apply additional coats of surface-applied crystalline coating until the sweating or leaks stop.

3.07 CURING

A. Cure concrete by methods specified in this Section.

B. For placements of Class M concrete, as specified in Section 03703 - Thermal Control of Concrete for additional requirements.

C. Cure period: Keep concrete continuously moist and at an average daily temperature of at least 50 degrees Fahrenheit for a minimum of 7 days after placement.
   1. If hourly temperatures at any surface of a concrete placement drop below 50 degrees Fahrenheit during the curing period, count the period below 50 degrees Fahrenheit as zero degrees, and extend the curing time to compensate.

D. Schedule of curing methods:
   1. Cure the following concrete surfaces using water curing or plastic membrane curing.
      a. Floor surfaces of water containment structures.
      b. Surfaces where additional concrete will be placed over or against the surface, including concrete joints.
      c. Surfaces where grout or other toppings will be placed over the surface.
      d. Slabs scheduled to receive concrete sealer, or other bonded or adhered architectural finishes.
      e. Formed surfaces scheduled to receive coatings, paint, adhered masonry, cementitious materials, or other similar finishes, and where formwork is removed within the specified cure period after concrete placement.
      f. Horizontal concrete surfaces at tops of walls.
   2. Cure the following concrete surfaces by water curing, plastic membrane curing, or sprayed curing membrane. Selection of methods shall be at the Contractor's option.
      a. Surfaces not listed in the preceding paragraph.

E. Water curing:
   1. Keep surfaces of concrete constantly and visibly wet, day and night, for not less than the specified cure period.
      a. Each day forms remain in place will be counted as 1 day of water curing.
      b. Do not loosen form ties during period when concrete is cured by leaving forms in place. No further curing credit will be allowed for forms remaining in place after contact has been broken between concrete surface and forms.
   2. Begin water curing as soon as concrete attains initial set.
   3. Maintain a wet surface by ponding, continuous sprinkling, covering with saturated burlap, or otherwise saturating the surface by means acceptable to the Engineer.
      a. Flood top of walls with water at least 3 times per day and keep surfaces moist at all times during the curing period.
      b. Provide plastic sheet material over surfaces if required to maintain a wet surface during arid or windy conditions. See plastic membrane curing requirements for additional details.
   4. Use water having a temperature within 20 degrees Fahrenheit of the temperature of concrete, and not lower than the minimum temperature allowed for the concrete surface during curing.

F. Plastic membrane curing:
   1. Install plastic membrane as soon as concrete is finished and can support limited pedestrian traffic without damage.
   2. Cover entire surface of finished concrete with membrane.
   3. Anchor membrane to prevent uplift from wind or air trapped below the sheet.

4. Fully seal joints and edges to provide full seal around perimeter.
5. Keep concrete under plastic membrane moist, regularly monitoring surfaces and adding supplemental moisture if necessary. Add water as specified for water curing.

G. Sprayed membrane curing compound:
   1. Apply curing compound to concrete surface after repairing and patching, and within 1 hour after forms are removed.
      a. If more than 1 hour elapses after removal of forms, do not use membrane curing compound. Instead, provide water curing for not less than the specified cure period.
      b. Do not remove sprayed membrane curing compound from concrete before the end of the specified cure period.
      c. When application of curing compound at concrete joints is accepted by the Engineer, take care to apply curing compound to all surfaces along full profile of joints.
   2. Apply curing compound by mechanical, power operated sprayer with mechanical agitator that will uniformly mix all pigment and compound.
      a. Apply curing compound in at least 2 coats. Each coat shall be applied at the manufacturer's recommended application rate.
      b. Apply each coat in direction turned 90 degrees from application direction of the preceding coat.
      c. Apply curing compound in sufficient quantity so that concrete has uniform appearance and its natural color is effectively and completely concealed immediately after spraying. This requirement may require additional coats and/or application rates than indicated above.
      d. Continue to coat and recoat surfaces until specified coverage is achieved and until coating film remains on concrete surfaces.
   3. Thickness and coverage of curing compound:
      a. Provide curing compound having film thickness that can be scraped from surfaces at any and all points after drying for at least 24 hours.
      b. Contractor is cautioned that method of applying curing compound specified in this Section may require more curing compound than normally suggested by manufacturer of curing compound and is more than is customary in the trade. Apply amounts specified in this Section, regardless of manufacturer's recommendations or customary practice.
   4. If the Contractor desires to use a curing compound other than specified product, coat sample areas of concrete wall with proposed curing compound, and also coat similar adjacent area with the specified compound in the manner specified, for comparison:
      a. If proposed sample is not equal or better, in the opinion of the Engineer, the proposed substitution will not be allowed.
   5. Removal of curing compound.
      a. After curing period is complete, remove curing compound placed on surfaces that will receive additional concrete, including all concrete joint surfaces, by heavy sandblasting or by other means acceptable to the Engineer. Complete removal and cleanup prior to placing any new concrete against the surface.
      b. Where additional finishes will be applied over concrete surfaces, unless otherwise recommended by the manufacturer of the finish to be applied,

remove curing compound by sandblasting. Provide blasting as necessary to fully remove curing compound.

6. Prior to final acceptance of the Work, remove, by sandblasting or by other method acceptable to the Engineer, any curing compound on surfaces exposed to process water or exposed to view, so that only natural color of finished concrete is visible and uniform over the entire surface.

3.08 PROTECTION

A. General:
   1. Keep forms in place, as specified in Section 03102 - Concrete Formwork, to provide curing and to protect concrete surfaces and edges from damage.
   2. Immediately after forms are removed, carefully examine concrete surfaces, and repair any irregularities in surfaces and finishes as specified.

B. Loading of concrete members:
   1. Placement of loads on or against green concrete is not permitted.
   2. Do not place soil against walls, or fill over the top of concrete until conditions designated in the following paragraphs are satisfied:
      a. Walls have been cast to their full height in the structure and have achieved their minimum specified 28-day compressive strength.
      b. Connecting slabs and beams that brace the walls are in place, are complete, and (in the case of concrete) have achieved their minimum specified 28-day compressive strength.

3.09 HOT WEATHER CONCRETING

A. Implement hot weather concrete procedures during periods of hot weather as defined in this Section.
   1. Comply with the recommendations of ACI PRC-305 and this Section.

B. If placements during hot weather are expected, and when requested by the Engineer, prepare a hot weather concreting plan.
   1. Maintain at least 1 copy on site.
   2. Provide plan for review if requested by the Engineer.
      a. Include procedures for batching, delivery, placement, curing, protection, and monitoring and recording the temperature of the concrete and the surrounding environment.
      b. Describe procedures to be implemented in the event of abrupt changes in weather conditions, or in the event of equipment failure.
      c. Review hot weather concreting plan during pre-construction meeting. Make provisions to address any concerns expressed by the Engineer before beginning concrete placements.

C. Preparation:
   1. Do not place concrete against forms, reinforcement, or embedments with a surface temperature greater than 120 degrees Fahrenheit.
      a. If necessary, to maintain maximum concrete temperature during placing, cool forms and reinforcement to temperature below 90 degrees Fahrenheit using water or shades.
      b. Do not allow water to puddle in forms or placement areas.

2. Moisten forms or subgrade to maintain a saturated surface without standing water or soft spots.
3. Provide windbreaks, shades, fog spray, sprinkling, wet cover, or other means required to protect concrete from premature loss of moisture and rapid temperature gain.

D. Batching and delivery:
   1. Retarding admixtures will not be permitted.
   2. Temperature of concrete delivered for placement shall not exceed 90 degrees Fahrenheit.
      a. Maintain uniform temperature in the mix below this level during batching, delivery, placing, and consolidation.
      b. Temperature of mix, even if below the maximum allowable temperature specified, shall be maintained at a level to avoid loss of slump, flash setting, or cold joints in placements.
   3. If necessary:
      a. Mix water may be chilled or replaced with ice to maintain mix temperature. Where mix water is replaced with ice, provide replacement at a 1-to-1 ratio by weight.
      b. Shade transit mixed concrete trucks, or cool mixing outside of container with water to control temperature of concrete.

E. Placing and finishing:
   1. Place and finish concrete promptly. Place so that vertical lift lines will not be visible in exposed concrete surfaces.
   2. Provide plastic sheeting, fog nozzles, shades or other means to reduce concrete temperature and protect from moisture loss.
   3. For placements of Class M concrete, use fog sprayers to reduce ambient air temperature and increase humidity during concrete placement.

F. Protection and curing:
   1. Furnish and locate maximum/minimum temperature recording thermometers in sufficient numbers to confirm concrete temperatures over full area and edges of concrete.
   2. Flatwork: Protect and cure using water curing methods as specified in this Section.
      a. Water curing:
         1) Keep concrete continuously wet and make provisions for runoff.
         2) For sprinkling or soaker hoses, maintain temperature of water as close as possible to the temperature of the concrete to minimize effects of thermal shock.
   3. Formed surfaces: Protect and cure using forms left in place or membrane curing methods as specified in this Section.
      a. Cover forms and keep continuously moist for at least 24 hours after placement.
      b. Loosen forms as soon as this can be accomplished without damaging the concrete.
      c. Maintain continuously moist surfaces by fogging or spraying with water, or by application of curing compound as specified.

3.10 FIELD QUALITY CONTROL BY CONTRACTOR

A. Provide quality control over the Work of this Section as required by Section 01450 - Quality Control.

B. Temperature Monitoring Program:
   1. For placements of Class M concrete, execute temperature monitoring program required in Section 03703 - Thermal Control of Concrete.

C. Field tests:
   1. During progress of construction, provide testing to determine whether the concrete, as being produced, complies with requirements specified.
   2. Sampling and testing shall be performed by the Contractor's testing laboratory. See Section 01455 - Regulatory Quality Assurance - Special Tests and Inspections for requirements.
      a. Cooperate in testing by allowing free access to the Work for testing laboratory to sample and test materials.
      b. Provide full access for the Engineer to observe concrete sampling and testing at any time.
      c. Contractor is responsible for providing care of and curing conditions for test specimens in accordance with ASTM C31 until specimens are collected by testing laboratory.
      d. Provide 4 firmly braced, insulated, heated, closed wooden curing boxes, each sized to hold 10 specimens. Include cold weather temperature and hot weather temperature control thermostat for initial curing and storage from time of fabrication through shipment to the Owner's testing laboratory.
   3. Testing shall include:
      a. Sampling of concrete in accordance with ASTM C172.
      b. Temperature of concrete at delivery in accordance with the requirements of ASTM C1064 and as specified in this Section.
      c. Slump of concrete using slump cone in accordance with requirements of ASTM C143. Test slump at the following intervals:
         1) At the beginning of each placement.
         2) As often as necessary to keep slump within the specified range, but not less than every sixth truck.
         3) When requested to do so by the Engineer.
         4) Observe concrete during slump test for signs of segregation.
            a) Observe concrete to see if mortar or moisture flows from slumped concrete.
            b) Reject concrete if mortar or moisture flows out of mix.
      d. Unit weight of concrete in accordance with ASTM C138.
      e. Air entrainment in accordance with ASTM C173. Test air content at the following intervals:
         1) At beginning of each placement.
         2) As often as necessary to keep entrained air within specified range, but not less than every 6th truck.
         3) When requested to do so by the Engineer.
         4) Test air entrainment in concrete in accordance with ASTM C173. If air entraining admixtures used for the Work require alternate testing procedures, advise the independent testing laboratory well in

advance of the dates of testing, and confirm that appropriate equipment and personnel are provided for the test.

5) Make air test at point of delivery (discharge from mixer). For pumped concrete, make air tests at point of delivery and at point where expelled after pumping for placement.

f. Compressive strength in accordance with ASTM C39. Required number of cylinders is as follows:

1) Not less than 6 cylinder specimens, 4 inches in diameter by 8 inches long, will be tested for each 100 cubic yards of each class of concrete or 5,000 square feet of slab or wall, with minimum of 6 specimens for each class of concrete placed; not less than 6 specimens for each half day's placement; and not less than 2 sets of 6 specimens for each structure.

2) 1 cylinder will be broken at 7 days, 1 at 14 days, and 3 at 28 days. 6th cylinder may be used to evaluate strength after 28 days if requested by the Engineer.

3) Retain and store 6th cylinders (tested and untested) at testing laboratory until 56 days. Break 6th cylinder when directed by the Engineer.

g. Provide full access for the Engineer to observe concrete sampling and testing at any time.

D. Test completed liquid containment structures listed in Section 01759 - Water Leakage Test for Concrete Structures for watertightness.

3.11 FIELD QUALITY CONTROL BY OWNER

A. As specified in Section 01450 - Quality Control.

B. Special tests and inspections: As specified in Section 01455 - Regulatory Quality Assurance.

C. Field inspections:

1. Observe construction for conformance to the Contract Documents and the accepted submittals.
2. Records of inspections:
   a. Provide a record of each inspection.
   b. Submit copies to the Contractor upon request.

D. Field tests:

1. Engineer may request, at any time, additional testing to confirm materials being delivered and placed conform to the requirements of the Contract Documents.
   a. If such additional testing shows that the material do not conform to the specified requirements, the Contractor shall pay the cost of these tests.
   b. If such additional testing shows that the materials do conform to the specified requirements, the Owner will pay the cost of these tests.

3.12 NON-CONFORMING WORK

A. Remove and replace or repair non-conforming and defective work.
   1. Provide repairs having strength equal to or greater than specified concrete for areas involved.
   2. Provide replacement or repair of non-conforming work by means acceptable to the Engineer and at no additional cost to the Owner.
   3. Project schedule will not be extended based on work to address non-conforming concrete.

B. Concrete not conforming to the specified requirements for properties of plastic concrete: Remove from the Site and replace with conforming materials at no additional cost to the Owner.
   1. Temperature: Do not use concrete having a temperature above or below the limits specified in this Section.
   2. Slump: Do not place concrete that does not conform to requirements for slump.
   3. Air entrainment: Do not use concrete that does not conform to requirements for percentage of entrained air.

C. Concrete not conforming to the specified requirements for compressive strength:
   1. Concrete is expected to reach a compressive strength equal to or greater than the minimum specified compressive strength f'c in Table 3 of this Section.
   2. Strength of concrete will be considered acceptable if the following conditions are satisfied.
      a. Averages of all sets of 3 consecutive strength test results is greater than or equal to the specified compressive strength f'c.
      b. No individual strength test (average of 3 cylinders) falls below the strength specified in Table 6 of this Section.
      c. Where relationships between 7-day and 28-day compressive strength, or between 28-day and 56-day compressive strength, have been provided as part of the mix design submittals:
         1) 7-day strength may be considered as an indication of 28-day strength provided effects of temperature and humidity between 7 days and 28 days are taken into account.
         2) 28-day strength may be considered as indication of 56-day strength provided effects of temperature and humidity between 28 days and 56 days are taken into account.

Table 6. Strength Compliance Requirements

Minimum Specified Compressive Strength, f'c (pounds per square inch)	Lower Bound of an Individual Compressive Strength Test (pounds per square inch)
Less than 5,000	f'c - 500
Over 5,000	f'c - (0.10 x f'c)

   3. Non-compliant strength tests.
      a. Mark non-compliant strength test reports to highlight the non-complying results, and immediately forward copies to all parties on the test report distribution list.

b. Initial treatment may consist of additional curing of affected portion(s) followed by not less than 3 cores at each affected area, taken in accordance with ASTM C42 and ACI CODE-318. Obtain the Engineer's acceptance of proposed coring locations before proceeding with that work.
c. Submit report of compressive strength testing for the Engineer's review.
d. If requested by the Engineer, provide additional cores, and obtain petrographic testing in accordance with ASTM C856. Submit results for the Engineer's review.
e. If additional curing does not bring the average strength of 3 cores taken in affected area to at least specified compressive strength f'c, designate such concrete in affected area will be considered defective.
f. Engineer may require the Contractor to strengthen defective concrete by means of additional concrete, additional reinforcing steel, or replacement of defective concrete, all at the Contractor's expense.

D. Concrete sections or surfaces with honeycombing and voids:
1. Provide repairs having surface appearance and finish consistent with that of the surrounding work and acceptable to the Engineer.
2. Do not patch, repair, or cover defective work without prior inspection by the Engineer.
3. Preparation of concrete for repair:
a. Make no repair until the Engineer has accepted methods for preparing surfaces and for making and curing repairs.
b. Chip out and key-in imperfections in the Work to make them ready for repair.
c. Coat bonding surfaces and edges of repair area with one of the following bonding agents as accepted by the Engineer.
1) Epoxy bonding agent as specified in Section 03071 - Epoxies; or,
2) Epoxy resin/Portland cement bonding agent as specified in Section 03072 - Epoxy Resin/Portland Cement Bonding Agent.
4. Methods of repair:
a. Dry pack mortar method:
1) Use for holes having depth nearly equal to or greater than least surface dimension of hole, for cone-bolt holes, and for narrow slots cut for repair.
2) Smooth holes: Clean and roughen by heavy sandblasting before repair.
3) Install dry-pack mortar as specified in Section 03600 - Grouting.
b. Cement mortar method:
1) Use for holes too wide to dry pack and too shallow for concrete replacement; and for comparatively shallow depressions, large or small, that extend no deeper than nearest surface reinforcement.
2) Install cement mortar as specified in Section 03600 - Grouting.
c. Concrete replacement:
1) Use when holes extend entirely through the concrete section or when holes are more than 1 square foot in area and extend halfway or more through the section.
2) Form, place, consolidate, and cure concrete of same mix as the surrounding work.

E. Leaking construction joints and cracks in concrete walls and slabs:
   1. Repair cracks that develop in walls or slabs, and repair cracks that show any signs of leakage until all leakage is stopped.
   2. Pressure inject visible cracks in the following areas, other than hairline cracks and crazing, with repair products and methods acceptable to the Engineer.
      a. Floors and walls of water bearing structures.
      b. Walls and overhead slabs of passageways and occupied spaces where the opposite face of the member is exposed to weather or may be washed down and where the opposite face does not receive a separate waterproofing membrane.
      c. Other items not specified to receive separate waterproofing membrane, including slabs over water channels, wet wells, reservoirs, and other similar surfaces.
   3. Continue pressure injection of cracks as specified until structure is watertight and remains watertight for not less than 1 year after date of Substantial Completion or date of final repair, whichever occurs later in time.

F. Leaking expansion joints in concrete walls or slabs that include waterstops:
   1. Repair any signs of leakage until all leakage is stopped.
   2. Pressure inject visible leaks with hydrophilic polyurethane foam resin as specified in Section 03933 - Hydrophilic and Hydrophobic Foam Polyurethane Resin Injection System.
   3. Continue pressure injection along joints lines as specified until structure is watertight and remains watertight for not less than 1 year after date of Substantial Completion or date of final repair, whichever occurs later in time.

G. Walls and slabs at overhead channels that leak or sweat because of porosity or cracks too small for successful pressure injection with epoxy.
   1. Seal on water or weather side by coating using surface-applied crystalline coating as specified in this Section.
   2. Apply as recommended by manufacturer published instructions. Where concrete continues to sweat or leak, apply additional coats of surface-applied crystalline coating until the sweating or leaks stop.
   3. Continue application of surface-applied crystalline coating until structure is watertight and remains watertight for not less than 1 year after date of Substantial Completion, or date of final repair, whichever occurs later in time.

END OF SECTION

ATTACHMENT A - MENZEL FORMULA AND NOMOGRAPH

MENZEL FORMULA AND NOMOGRAPH

Source: ACI PRC-305

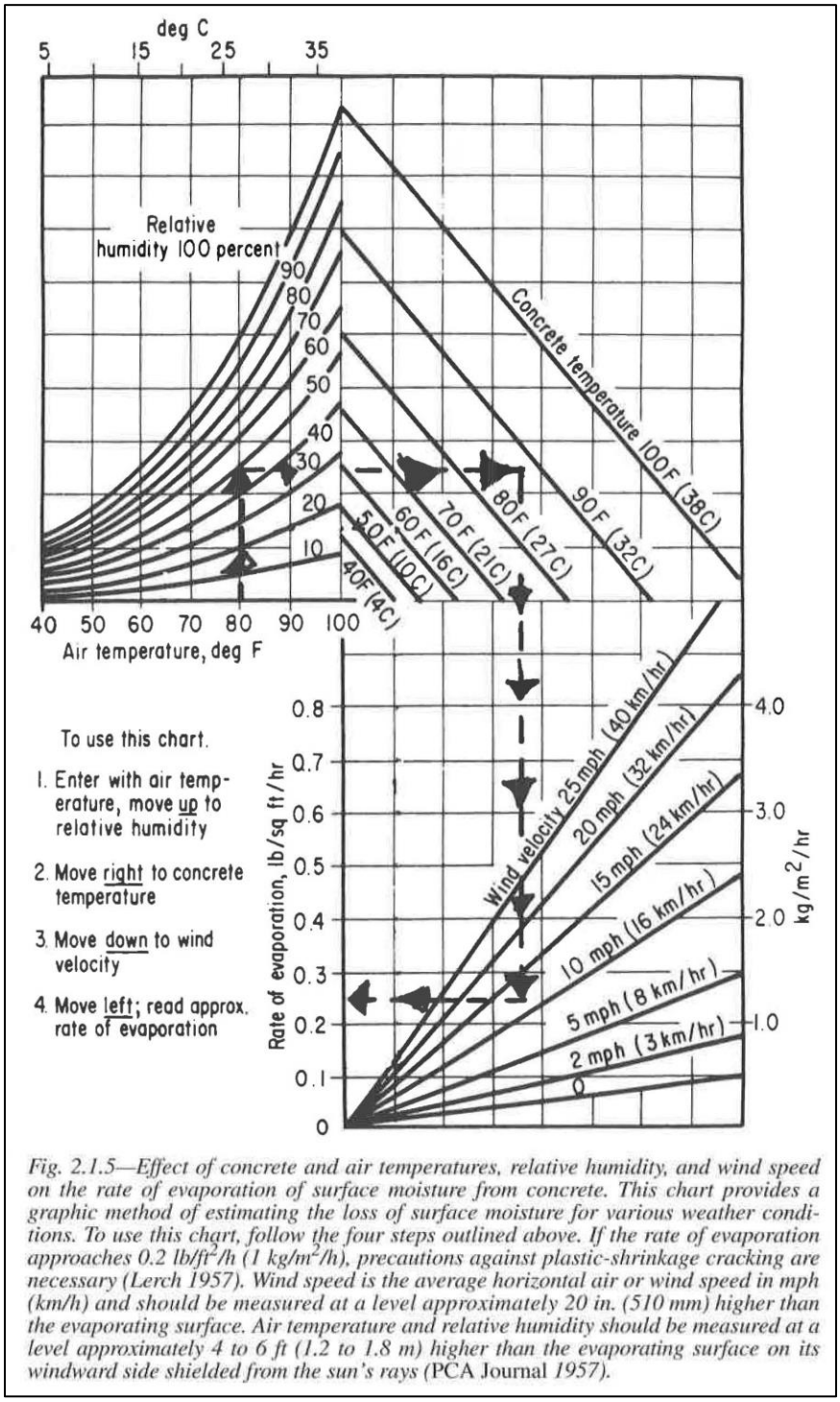


*Fig. 2.1.5—Effect of concrete and air temperatures, relative humidity, and wind speed on the rate of evaporation of surface moisture from concrete. This chart provides a graphic method of estimating the loss of surface moisture for various weather conditions. To use this chart, follow the four steps outlined above. If the rate of evaporation approaches 0.2 lb/ft²/h (1 kg/m²/h), precautions against plastic-shrinkage cracking are necessary (Lerch 1957). Wind speed is the average horizontal air or wind speed in mph (km/h) and should be measured at a level approximately 20 in. (510 mm) higher than the evaporating surface. Air temperature and relative humidity should be measured at a level approximately 4 to 6 ft (1.2 to 1.8 m) higher than the evaporating surface on its windward side shielded from the sun's rays (*PCA Journal *1957).*

ATTACHMENT B - COARSENESS FACTOR CHART

COARSENESS FACTOR CHART

Source: ACI PRC-302.1-15, Figure 8.9.2.2.

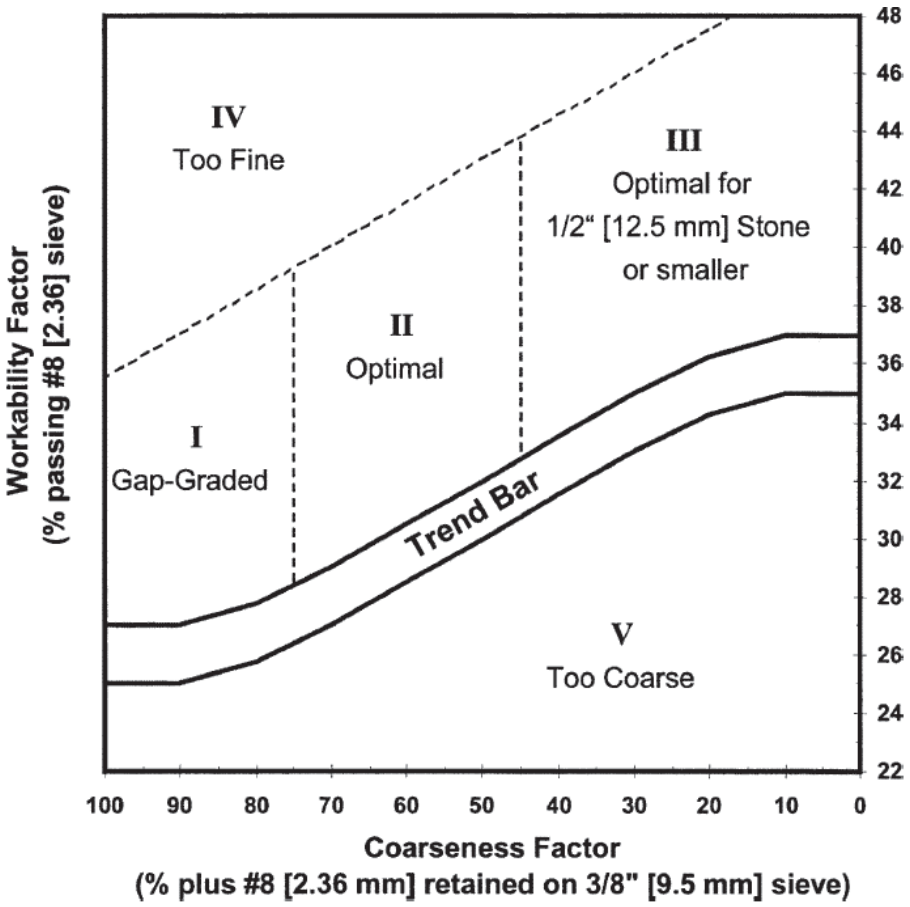
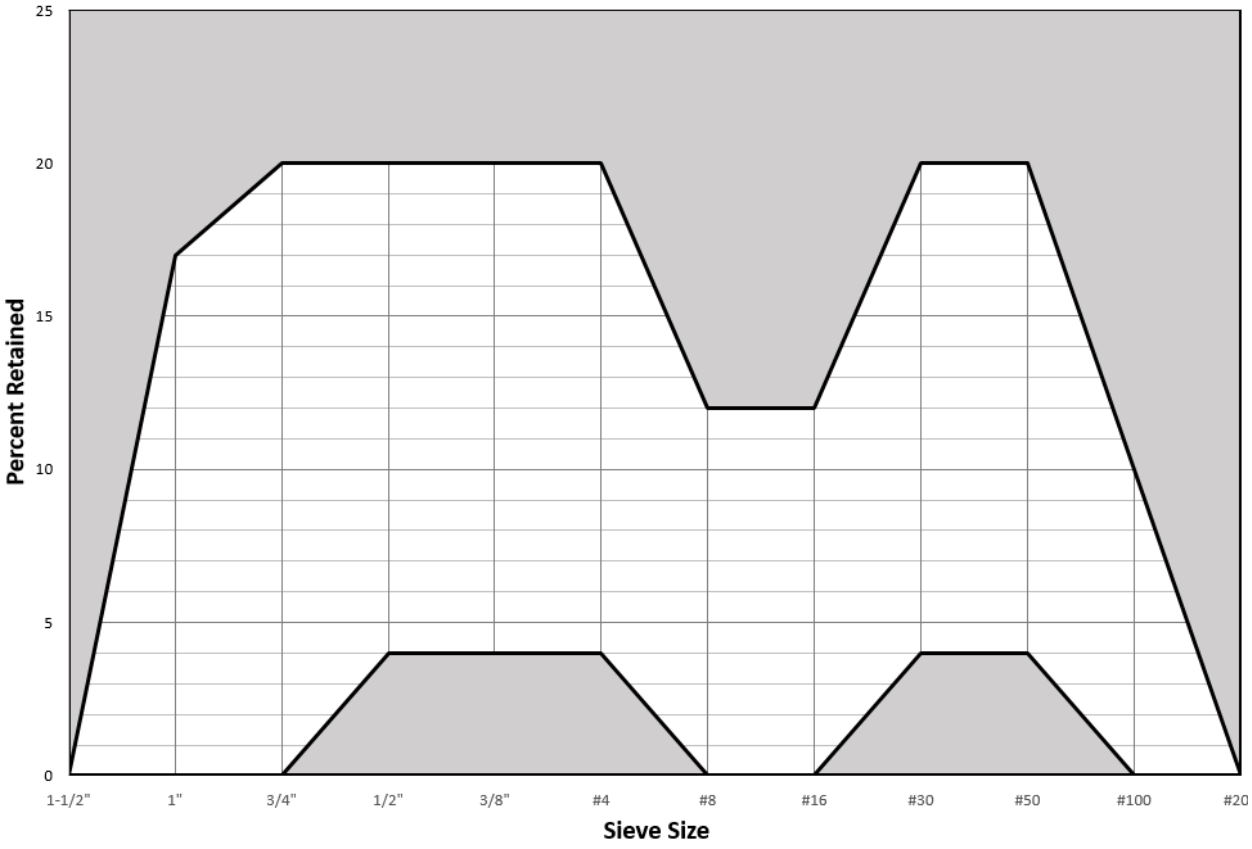


Fig. 8.9.2.2—Coarseness factor chart for evaluating potential performance of mixture.

ATTACHMENT C - COMBINED AGGREGATE GRADATION CHART

COMBINED AGGREGATE GRADATION CHART



ATTACHMENT D - CONCRETE PLACEMENT CHECKLIST

CONCRETE PLACEMENT CHECKLIST

Project: _____ Class of Concrete: _____

Project No: _____ Test Cylinders Taken? Yes: _____ No: _____

Preparation Slab	Contractor	N/A
Compaction Subgrade		
Filter Fabric/Drain Rock-ABC/Separator Fabric		
Drain Rock, Pea Gravel & Void Form		
Starter Wall Forms		
Reinforcing Steel		
Screeds		

Embedded Items	Contractor	N/A
A. Anchor Bolts		
B. Water Stop		
C. Rebar		
D. Electrical		
E. Plumbing Rough-in		
F. Mechanical		
G. HVAC		

Concrete Placement Equip.	Contractor	N/A
A. Crane		
B. Buckets		
C. Hoppers		
D. Vibrators		
E. Elephant trunks		
F. Floodlights		
G. Pump Truck		

Building Department Notification	
Date:	Time:

Prep Wall Concrete	Contractor	N/A
Access To Work		
Ladders Secured		
Clean up and Washed Out		
Reinforcing Steel		

Forms	Contractor	N/A
A. Alignment & Grade		
B. Scaffolding		
C. Sleeves & Wall Castings		
D. Embedded Items		
E. Electrical		
F. Plumbing Rough-in		
G. Piping		

Record of Curing Conditions During Placement	
Start:	Finish:
Date:	
Time:	
Weather:	
Temperature:	
Comments:	

Location of Placement _____

The Contractor certifies the above-proposed concrete placement is prepared as indicated and is in accord with the Contract Drawings and Specifications. The Contractor requests permission to begin placement of concrete on the date of _____ at _____. The estimated number of yards is _____. The estimated duration of the placement is _____.

By: _____
Contractor

Released for placement by: _____
Engineer

SECTION 03366

CONCRETE FINISHES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Concrete finishes.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 117-10 - Specification for Tolerances for Concrete Construction and Materials and Commentary.

B. International Concrete Repair Institute (ICRI):
   1. Guideline No. 301.2: Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Grade line: A reference line that separates surfaces considered to be above grade from those considered to be below grade. Located 12 inches below finished grades at the perimeter of the structure.
   2. Water line: A reference line that separates surfaces considered to be above the water level (and visible in the finished work) from those considered to be below the water level (and not visible in the finished work). For each water-bearing cell of a structure, defined as a line located 2 feet below the normal operating water level in that cell.

1.04 QUALITY ASSURANCE

A. Qualifications:
   1. Finishing personnel:
      a. Use qualified flatwork finishers.
      b. Finishing supervisor must have at least 5 years of experience finishing concrete.

B. Mockups:
   1. Construct mockup panels showing finishing of formed surfaces for review by the Engineer.
      a. Construct mockup panels demonstrating concrete finishes for vertical surfaces:
         1) Construct mockup panels for F4 and F5 finishes and tie-hole repairs for review by the Engineer.

2. Construct mockup slabs showing finishing of unformed surfaces for review by the Engineer.
    a. Construct mockup slabs demonstrating concrete finishes for horizontal surfaces:
        1) Construct mockup slabs for S1, S2, S4, and S5 finishes.
3. Include the following elements in mockup panels and slabs.
    a. Concrete joints:
        1) Horizontal and vertical joints of the types included in the Work.
    b. Concrete repairs:
        1) Repairs using materials and procedures proposed for the Work.
4. Construct mockup panels and slabs at the beginning of the Project for review by the Engineer.
5. Panels and portions thereof accepted by the Engineer will serve as the standard of quality and workmanship for the Work.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and shipping:
    1. Deliver and store packaged materials in original containers until ready for use.

PART 2 PRODUCTS

2.01 MATERIALS

A. Materials for mortar:
    1. As specified in Section 03300 - Cast-in-Place Concrete, unless otherwise noted.
    2. Where finished surfaces will be visible in the finished work, use same cement used for concrete batches in that area. Add white cement if required to obtain color match between base concrete and finishing mortars.

2.02 MIXES

A. Cement mortar:
    1. As specified in Section 03600 - Grouting.

B. Dry-pack mortar:
    1. As specified in Section 03600 - Grouting.

C. Mortar mix for F4 finish (“F4 Mortar”):
    1. Consisting of 1 part cement and 1-1/2 parts of fine sand passing Number 100 screen. Mix with enough water and emulsified bonding agent to have consistency of thick cream.

D. Mortar mix for F5 finish (“F5 Mortar”):
    1. Consisting of 1 part cement to 1-1/2 parts of sand passing Number 16 screen.

2.03 EVAPORATION RETARDANT

A. As specified in Section 03300 - Cast-in-Place Concrete.

2.04 NON-SLIP ABRASIVE

A. Type: Aluminum oxide abrasive of size 8/16, having structure of hard aggregate. Homogeneous, non-glazing, rust-proof, and unaffected by freezing, moisture, and cleaning compounds.

B. Manufacturers: One of the following or equal:
   1. Abrasive Materials Incorporated, Hillsdale, MI.
   2. Exolon Company, Tonawanda, NY.

2.05 CONCRETE SEALERS

A. Floor sealer and dust-proofer:
   1. Non-membrane forming, breathable, non-yellowing, penetrating sealer designed to densify and seal a cured concrete surface.
   2. Low odor, VOC content of 0 grams per liter, and stable when exposed to ultraviolet radiation from sunlight.
   3. Manufacturers: One of the following or equal:
      a. Dayton Superior, Day-Chem Sure Hard Densifier (J-17).
      b. Euclid Chemical Company, Euco Diamond Hard.
      c. L&M Construction Chemicals, Seal Hard.
      d. W.R. Meadows, Liqui-Hard.

PART 3 EXECUTION

3.01 CONCRETE FINISHING - FORMED SURFACES

A. Scope:
   1. Finish formed surfaces with one of the finishes specified in the following paragraphs and as indicated in the Schedule of Concrete Finishes in this Section.
   2. Formed surfaces are those surfaces that the plastic concrete is placed against a temporary containment surface that will be removed after the concrete sets and takes its final form.

B. General:
   1. Provide setting and curing time from casting of concrete to removal of forms as specified in Section 03300 - Cast-in-Place Concrete.
   2. Provide curing after removal of forms as specified in Section 03300 - Cast-in-Place Concrete.
   3. Materials and mixes for finishes.
      a. Cement: Add white cement to mortars and grouts used for finishing if required to match color of repairs to surrounding surfaces.
   4. Grinding:
      a. Where grinding of concrete surfaces is permitted:
         1) Perform grinding using an iron-free wheel, such as an aluminum oxide wheel, to avoid entrapment of particles that produce rust stains.
         2) At locations where plastic-protected reinforcing bar supports are used, limit grinding to a maximum depth of 1/16 inch.

C. F1 finish: “Rough Form Finish”:
   1. Repair defective work.
   2. Remove fins and other projections larger than 1/2 inch.
   3. Fill tie holes using dry-pack mortar.
   4. After removal of any curing compounds, fill depressions larger than 1 inch wide or 1/2 inch deep using dry-pack mortar.
   5. Leave surface with texture imparted by forms.
   6. Surface irregularity: Not exceeding a 1-inch gap when measured over the length of a 5-foot straightedge.

D. F2 finish: “Form Finish”:
   1. Repair defective work.
   2. Remove fins and other projections larger than 1/4 inch.
   3. Fill tie holes using dry-pack mortar.
   4. Fill depressions.
      a. Fill after removal of any curing compounds.
      b. Fill depressions larger than 1/2 inch in width or 1/2 inch in depth using cement mortar.
      c. Fill larger voids and depressions, use dry-pack mortar.
   5. Leave surfaces with texture imparted by forms.
   6. Surface irregularity: Not exceeding a 1/4-inch gap when measured over the length of a 5-foot straightedge.

E. F3 finish: “Smooth Form Finish”:
   1. Repair defective work.
   2. Repair rough or irregular surface finishes resulting from failure of form release agent or other form conditions and provide a smooth, uniform surface appearance.
   3. Remove fins: Grind offsets, projections, and rough spots smooth.
   4. Fill tie holes using dry pack mortar.
   5. Fill depressions:
      a. Fill after removal of any curing compounds.
      b. Fill depressions 1/4 inch and larger in depth or 3/4 inch in width using cement mortar.
      c. For larger depressions, fill using dry pack mortar.
   6. Top coat tie holes and filled depressions with cement mortar to provide uniform appearance.
   7. Leave surfaces with texture that is generally smooth and uniform in appearance.
   8. Surface irregularity: Not exceeding a 1/8-inch gap when measured over the length of a 5-foot straightedge.

F. F4 finish: “Rubbed Finish”:
   1. As specified for F3 finish, except prepare surfaces and fill depressions 1/16 inch or larger in depth or width as follows.
   2. Fill depressions.
      a. “Brush-off” sandblast surfaces to expose depressions and voids near the surface of the concrete.
      b. Thoroughly wet surfaces and begin filling depressions while surfaces are still damp.
      c. Use clean burlap, sponge rubber floats, or trowels to rub plastic F4 mortar over the entire surface to be finished. Fill pits, holes, and depressions.

d. Wipe surfaces clean. Do not leave any mortar on the surface, except that within the depressions.
e. Cure: Moist cure surfaces.

G. F5 finish: “Stoned Finish”:
1. As specified for F3 finish, except add stoned finish as follows:
2. Fill depressions:
a. Wet surfaces thoroughly with brush.
b. Rub wetted surfaces with a hard wood float dipped in water containing 2 pounds of Portland cement per gallon of water.
c. Rub surfaces until form marks and projections are removed.
d. Using a brush, spread plastic grindings from the rubbing operation uniformly over the surface. Work the material in to fill pits and small voids.
e. Cure: Moist cure brushed surfaces for at least 72 hours.
3. Finish surfaces:
a. After curing, obtain final finish by rubbing with a No. 50 grit carborundum stone.
b. Continue rubbing until entire surface has a smooth texture and is uniform in color.
c. Cure: Continue curing for remainder of specified time.
4. If surfaces have become too hard to finish as specified in the preceding paragraphs, the following alternative procedure may be used:
a. Sandblast and wash related surfaces exposed to view, whether finished or not.
b. While surfaces are still damp, rub surface with mortar mix for F5 finish.
c. Finish by rubbing mortared surface with No. 60 grit carborundum stone. Add F5 mortar until surface is evenly filled without excess mortar. Continue stoning until surface is hard.
d. Moist cure surface for 72 hours.
e. After curing, make surface smooth in texture and uniform in color by rubbing with a No. 50 or No. 60 grit carborundum stone.
f. Continue curing until 7-day curing period is complete.

3.02 CONCRETE FINISHING - UNFORMED SURFACES

A. Scope:
1. Finish unformed surfaces with one of the finishes specified in the following paragraphs and as indicated in the Schedule of Concrete Finishes in this Section.
2. Unformed surfaces are those surfaces that are not cast against a temporary containment and the specified finish is achieved by tooling.

B. General:
1. Concrete placement:
a. Place concrete at a rate that allows spreading, straight-edging, and initial floating before bleed water appears.
1) Consider characteristics of concrete mixes used, including potential for accelerating or retarding effects of admixtures, fly ash, and temperatures, on plans for and scheduling of placement and finishing.
b. Place, consolidate, strike-off, and screed concrete level to bring surfaces to required planes and lines. Eliminate high and low spots.

c. Strike tops of walls and similar surfaces smooth and finish as specified to a texture consistent with that of adjacent formed surfaces.
d. After screeding, apply evaporation retardant to concrete surface if weather conditions will result in rapid evaporation of moisture from the surface of the concrete. Do not work evaporation retardant into the surface of the concrete.

2. Floating and re-straightening:
   a. Float concrete to compact and consolidate the surface.
   b. Initial floating:
      1) Provide initial floating immediately after screeding.
      2) Perform by hand using a wide bull float, darby, or highway straightedge.
      3) Complete before excess moisture or bleed water is present on the surface.
   c. Wait for concrete to stiffen and for the bleed water to stop rising and dissipate before proceeding with edging, hand-tooled jointing, and second floating.
   d. After initial floating, apply evaporation retardant to concrete surface if weather conditions will result in rapid evaporation of moisture from the surface of the concrete. Do not work evaporation retardant into the surface of the concrete.
   e. Second floating:
      1) Do not commence until bleed water has dissipated and concrete has stiffened enough to support weight of finishers and finishing equipment.
      2) May be by hand, or, if accepted by the Engineer, may be done using a bladed power float equipped with float shoes, or a power disk float.
      3) Float surfaces to a true, even plane, with no coarse aggregate visible.
      4) Evaporation retardant may not be applied after second floating.
   f. Flatness:
      1) Specified tolerances for flatness may require re-straightening of the surface between first and second floating operations and before steel troweling. Re-straighten concrete as required.
      2) Modify power equipment with alternate float shoes or other equipment if required to achieve specified flatness.

3. Troweling: Where finishes require troweling, conform to the following requirements:
   a. After surface moisture from floating has disappeared, steel trowel to a smooth, hard, dense concrete surface.
   b. Provide at least 2 trowelings.
      1) Avoid excessive troweling.
      2) Use smaller trowels for successive troweling.
      3) Make each successive troweling perpendicular to the previous pass.
   c. Do not add dry cement or additional water to the surface during troweling.
   d. In lieu of hand steel troweling, a power machine for finishing concrete may be used if accepted by the Engineer.
      1) Do not use power machine if concrete has not attained the set necessary to permit finishing without introduction of high and low spots into the concrete surface.
      2) Use equipment in full compliance with the manufacturer’s recommendations.

3) Use smaller blades or higher pressure for each successive troweling.
4) Hand trowel areas of the concrete not accessible to power equipment.
5) Tolerances for flatness specified may require re-straightening of the surface during finishing. Modify power equipment with alternate shoes or other equipment if required to achieve these requirements.

e. Finishing with a fresno trowel or finishing to a “fresno finish” is not allowed.

4. Finishing tolerances:
   a. Slabs sloped to drain: Finish surfaces to adequately drain toward designated points or lines, regardless of tolerances specified.

C. S1 finish: “Scratch Finish”:
1. Place, consolidate, and screed concrete level.
2. Provide initial floating of concrete.
3. Provide surface conforming to the “Conventional” floor flatness tolerance requirements of ACI 117 using the manual straightedge method (maximum 1/2-inch gap in 10 feet at 90 percent of locations; maximum 3/4-inch gap at any location), unless otherwise indicated.
4. Before final set, roughen the surface with rakes.
   a. For sloped surfaces, rake grooves in the direction of drainage.
   b. Provide roughness equivalent to CSP 6 surface as designated by ICRI Guideline 310.2.
5. Pressure wash surface to remove laitance before placing grout or toppings.

D. S2 finish: “Floated Finish”:
1. Place, consolidate, and screed concrete to required elevations and slopes.
2. Provide initial and second floatings of concrete. Float to a uniform texture.
3. Provide surface conforming to the “Flat” floor flatness tolerance requirements of ACI 117 using the manual straightedge method (maximum 1/4-inch gap in 10 feet at 90 percent of locations; maximum 3/8-inch gap at any location), unless otherwise indicated.
4. Remove laitance and leave surface clean.

E. S3 finish: “Steel Trowel Finish”:
1. Place, consolidate, and screed concrete to required elevations and slopes.
2. Provide S2 Floated Finish.
3. Provide 2 trowelings:
4. Provide finish conforming to the “Flat” floor flatness tolerance requirements of ACI 117 (maximum 1/4-inch gap in 10 feet), unless otherwise indicated.

F. S4 finish: “Steel Trowel Finish - Free of Trowel Marks”:
1. Finish as specified for S3 Steel Trowel Finish, except that final troweling shall remove all trowel marks from the slab surface.

G. S5 finish: “Broomed Finish”:
1. Finish as specified for S2 Floated Finish, except modify as follows:
2. Finish surface by drawing a fine-hair broom lightly across the freshly floated surface.
   a. Provide resulting roughness for a non-skid surface. Finishing and roughness is subject to review and acceptance by the Engineer.

b. Direction of brooming:
    1) General:
        a) In same direction of and parallel to expansion joints.
        b) Perpendicular to primary direction of traffic.
    2) For sloped slabs, parallel to the direction of drainage.
    3) For round roof slabs, in the radial direction.

H. S6 finish: “Non-Slip Abrasive Finish”:
1. Place, consolidate, and screed concrete to required elevations and slopes.
2. Provide initial floating of surface.
3. Prepare and apply abrasive as recommended by the manufacturer.
    a. Apply using a shake screen or other accepted method to ensure even coverage without segregation of the abrasive.
    b. Install abrasive at a rate of 25 pounds for each 100 square feet of surface area.
4. After concrete has hardened enough to support the weight of a person and unless otherwise indicated by the abrasive manufacturer, apply approximately 2/3 of the abrasive material required for coverage.
5. Finish as specified for S2 Floated Finish, except that re-floating is not required.
6. Apply remaining abrasive material at right angles to the first application and in locations necessary to provide the minimum specified thickness.
7. Immediately after the second application, re-float the surface to embed abrasive.
8. Finish as specified for S2 Steel Trowel Finish. Trowel abrasive into the surface, properly exposing material to produce a non-slip finish.

3.03 FIELD QUALITY CONTROL

A. Provide field quality control for the Work of this Section as specified in Section 01450 - Quality Control.

B. Field quality control by the Contractor:
1. Field inspections and testing:
    a. Submit records of inspections and testing to the Engineer within 24 hours after completion.
2. Manufacturer’s services.
    a. Non-slip abrasive finish. Before beginning installation, conduct pre-installation meeting with the manufacturer’s technical representative to review product use and installation requirements.

C. Field quality control by the Owner:
1. Special inspections, special tests, and structural observation:
    a. Not required.
2. Field inspections:
    a. Observe construction for conformance to the Contract Documents and the accepted Submittals.
    b. Provide record of each inspection. Submit copies to the Engineer upon request.

3.04 NON-CONFORMING WORK

A. Unsatisfactory finishes that have hardened will require removal, grinding, topping, or other correction acceptable to the Engineer.

B. Re-work or refinish unsatisfactory finishes at no additional cost to the Owner.

C. Requirements as specified in Section 03300 - Cast-In-Place Concrete.

3.05 SCHEDULE OF CONCRETE FINISHES

A. Formed surfaces: As specified in Table 03366-A.

B. Unformed surfaces: As specified in Table 03366-B.

Table 03366-A: Concrete Finishes - Formed Surfaces

Elements	Location	Surface Exposure	Finish	Notes
Exterior Surfaces:				
Walls, columns, slab edges	Wet structure	Above grade or water line		
		Exposed to view	F4	
		Covered	F2	1a
		Below grade or water line		
		No coating	F1	
		Bituminous coating	F2	
		Waterproofing	F3	
	Dry structure	Above grade line		
		Exposed to view	F4	
		Covered	F2	1a
		Below grade line		
		No coating	F1	
		Bituminous coating	F2	
		Waterproofing	F3	
Interior Surfaces:				
Walls, columns, slab edges	Wet structure	Open basin		
		Above water line	F4	
		Below water line	F3	
		Covered basin		
		Above water line	F3	
		Below water line	F3	
	Dry structure	Exposed to view	F4	
		Covered	F2	1b

Table 03366-A: Concrete Finishes - Formed Surfaces				
Elements	**Location**	**Surface Exposure**	**Finish**	**Notes**
Overhead slabs and beams	Wet structure	Open basin	F3	1c, 1d
		Covered basin	F2	1d
	Dry structure	Exposed	F3	1c, 1d
		Covered by ceiling	F1	1d

Notes:
(1a) Coverings include additional surfaces applied over the concrete, such as veneer, stucco, plaster, etc.
(1b) Coverings include additional surfaces applied over the concrete, such as veneer, stucco, plaster, furring strips with drywall, etc.
(1c) Applies to overhead surfaces visible from normal pedestrian travel routes.
(1d) At overhead slabs and beams, patch tie holes on sides of members.

Table 03366-B: Concrete Finishes - Unformed Surfaces				
Element	**Location**	**Exposure**	**Finish**	**Notes**
Exterior Surfaces:				
Footings	Extensions	Exposed	S3	
		Covered by soil	S2	
Slabs and beams - exposed	Walking or possible walking paths	Tops of treatment structures	S5	2a, 2b, 2g, 2h
		Stairs and landings	S5	
	Roofs	Exposed	S5	
		Covered by roofing	S2	
Slabs and beams - submerged	Unless otherwise noted	All	S3	2g
Walls, corbels	Top of wall or corbel	All	S3	One troweling
Sidewalks	All		S5	
Equipment slabs	All		S5	
Interior Surfaces:				
Floor slabs, includes flat and sloping surfaces	Wet structure	Exposed		
		Basins and channels	S3	
		Covered		
		To receive basin bottom grout	S1	2e
		To receive concrete fill	S1	2f
	Dry structure	Exposed		
		Pipe galleries	S4	2c
		Stairs and landings	S4	2d
		Shops and garages	S4	
		Equipment rooms	S4	
		Covered		
		Tile on mortar bed	S2	
		Resilient flooring	S3	
		Carpet	S3	

Notes:
(2a) Includes slabs covering tanks, basins, channels and similar structures.
(2b) Includes tops of walls or beams that serve as walkways.
(2c) In galleries with slabs subject to wetting, provide broom finish (S5) where **indicated on the Drawings**.
(2d) Provide broom finish (S5) where **indicated on the Drawings**.
(2e) Finish for basin bottom grout: As specified in Section 03565 - Basin Bottom Grout.
(2f) Finish for concrete fill: See floor slab, wet structure, exposed basins and channels.
(2g) Slabs include flat and sloping surfaces.
(2h) Includes top of vault slabs exposed to traffic.

C. Finish concrete surfaces in accordance with the Finish Schedule indicated on the Drawings.

END OF SECTION

SECTION 03600

GROUTING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Cement grout.
   2. Cement mortar.
   3. Dry-pack mortar.
   4. Epoxy grout.
   5. Grout.
   6. Non-shrink epoxy grout.
   7. Non-shrink grout.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C109 - Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (using 2-inch cube specimens).
   2. C230 - Standard Specification for Flow Table for Use in Tests of Hydraulic Cement.
   3. C531 - Standard Test Method for Liner Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes.
   4. C579 - Standard Test Method for Compressive Strength of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes.
   5. C939 - Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method).
   6. C942 - Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory.
   7. C1107 - Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Non-shrink).
   8. C1181 - Standard Test Methods for Compressive Creep of Chemical-Resistant Polymer Machinery Grouts.

B. International Concrete Repair Institute (ICRI):
   1. 310.2R - Selecting and specifying Concrete Surface Preparations for Sealers, Coatings, Polymer Overlays, and Concrete Repair.

1.03 SUBMITTALS

A. Cement grout:
   1. Mix design.
   2. Material Submittals.

B. Cement mortar:
   1. Mix design.
   2. Material Submittals.

C. Non-shrink epoxy grout:
   1. Manufacturer's literature.

D. Non-shrink grout:
   1. Manufacturer's literature.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials to jobsite in their original, unopened packages or containers, clearly labeled with manufacturer's product identification and printed instructions.

B. Store materials in cool dry place and in accordance with manufacturer's recommendations.

C. Handle materials in accordance with the manufacturer's instructions.

PART 2 PRODUCTS

2.01 MANUFACTURED UNITS

A. Non-shrink epoxy grout:
   1. Manufacturers: One of the following, or equal:
      a. Five Star Products, Inc., Five Star DP Epoxy Grout.
      b. L&M Construction Chemicals, Inc., EPOGROUT.
      c. Master Builder Solutions/Sika, MasterFlow 648.
   2. Non-shrink epoxy grout shall be 100 percent solid, premeasured, prepackaged system containing 2-component thermosetting epoxy resin and inert aggregate.
   3. Maintain flowable consistency for at least 45 minutes at 70 degrees Fahrenheit.
   4. Shrinkage or expansion: Less than 0.0006 inches per inch when tested in accordance with ASTM C531.
   5. Minimum compressive strength: 10,000 pounds per square inch at 24 hours and 14,000 pounds per square inch at 7 days when tested in accordance with ASTM C579, Method B.
   6. Compressive creep: Not exceed 0.0037 inches/per inch when tested under 400 pounds per square inch constant load at 140 degrees Fahrenheit in accordance with ASTM C1181.
   7. Coefficient of thermal expansion: Not exceed 0.000018 inches per inch per degree Fahrenheit when tested in accordance with ASTM C531, Method B.

B. Non-shrink grout:
   1. Manufacturers: One of the following, or equal:
      a. Five Star Products, Inc., Five Star Grout.
      b. L&M Construction Chemicals, Inc., CRYSTEX.
      c. Master Builder Solutions/Sika, MasterFlow 928.
   2. In accordance with ASTM C1107.
   3. Preportioned and prepackaged cement-based mixture.

4. Contain no metallic particles such as aluminum powder and no metallic aggregate such as iron filings.
5. Require only addition of potable water.
6. Water for pre-soaking, mixing, and curing: Potable water.
7. Free from emergence of mixing water from within or presence of water on its surface.
8. Remain at minimum flowable consistency for at least 45 minutes after mixing at 45 degrees Fahrenheit to 90 degrees Fahrenheit when tested in accordance with ASTM C230.
    a. If at fluid consistency, verify consistency in accordance with ASTM C939.
9. Dimensional stability (height change):
    a. In accordance with ASTM C1107, volume-adjusting Grade B or C at 45 degrees Fahrenheit to 90 degrees Fahrenheit.
    b. Have 90 percent or greater bearing area under bases.
10. Have minimum compressive strengths at 45 degrees Fahrenheit to 90 degrees Fahrenheit in accordance with ASTM C1107 for various periods from time of placement, including 5,000 pounds per square inch at 28 days when tested in accordance with ASTM C109 as modified by ASTM C1107.

2.02 MIXES

A. Cement grout:
    1. Use same sand-to-cementitious materials ratio for cement grout mix that is used for concrete mix.
    2. Use same materials for cement grout that are used for concrete.
    3. Use water-to-cementitious materials ratio that is no more than that specified for concrete.
    4. For spreading over surfaces of construction or cold joints.

B. Cement mortar:
    1. Use same sand-to-cementitious materials ratio for cement mortar mix that is used for concrete mix.
    2. Use same materials for cement mortar that are used for concrete.
    3. Use water-to-cementitious materials ratio that is no more than that specified for concrete being repaired.
    4. At exposed concrete surfaces not to be painted or submerged in water: Use sufficient white cement to make color of finished patch match that of surrounding concrete.

C. Dry-pack mortar:
    1. Proportions by weight: 1 part Portland cement to 2 parts concrete sand.
        a. Portland cement: As specified in Section 03300 - Cast-in-Place Concrete.
        b. Concrete sand: As specified in Section 03300 - Cast-in-Place Concrete.

D. Epoxy grout:
    1. Consist of mixture of epoxy or epoxy gel and sand.
        a. Epoxy: As specified in Section 03071 - Epoxies.
        b. Epoxy gel: As specified in Section 03071 - Epoxies.
        c. Sand: Clean, bagged, graded, and kiln-dried silica sand.

2. Proportioning:
    a. For horizontal work: Consist of mixture of 1 part epoxy with not more than 2 parts sand.
    b. For vertical or overhead work: Consist of 1 part epoxy gel with not more than 2 parts sand.

E. Grout:
1. Mix in proportions by weight: 1 part Portland cement to 4 parts concrete sand.
    a. Portland cement: As specified in Section 03300 - Cast-in-Place Concrete.
    b. Concrete sand: As specified in Section 03300 - Cast-in-Place Concrete.

F. Non-shrink epoxy grout:
1. Mix in accordance with manufacturer's installation instructions.

G. Non-shrink grout:
1. Mix in accordance with manufacturer's installation instructions such that resulting mix has flowable consistency and is suitable for placing by pouring.

PART 3 EXECUTION

3.01 EXAMINATION

A. Inspect concrete surfaces to receive grout or mortar and verify that they are free of ice, frost, dirt, grease, oil, curing compounds, paints, impregnations, and loose material or foreign matter likely to reduce bond or performance of grout or mortar.

3.02 PREPARATION

A. Surface preparation for grouting other baseplates:
1. Remove grease, oil, dirt, dust, curing compounds, laitance, and other deleterious materials that may affect bond to concrete and bottoms of baseplates.
2. Roughen concrete surfaces in contact with grout to ICRI CSP-6 surface profile or rougher.
    a. Remove loose or broken concrete.
3. Metal surfaces in contact with grout: Grit blast to white metal surface.

3.03 INSTALLATION

A. Mixing:
1. Cement grout:
    a. Use mortar mixer with moving paddles.
    b. Pre-wet mixer and empty out excess water before beginning mixing.
2. Cement mortar:
    a. Use mortar mixer with moving paddles.
    b. Pre-wet mixer and empty out excess water before beginning mixing.
3. Dry-patch mortar:
    a. Use only enough water so that resulting mortar will crumble to touch after being formed into ball by hand.

4. Non-shrink epoxy grout:
    a. Keep temperature of non-shrink epoxy grout from exceeding manufacturer's recommendations.
5. Non-shrink grout:
    a. May be drypacked, flowed, or pumped into place. Do not overwork grout.
    b. Do not retemper by adding more water after grout stiffens.

B. Placement:
1. Cement grout:
    a. Exercise care in placing cement grout because it is required to furnish structural strength, impermeable water seal, or both.
    b. Do not use cement grout that has not been placed within 30 minutes after mixing.
2. Cement mortar:
    a. Use mortar mixer with moving paddles.
    b. Pre-wet mixer and empty out excess water before beginning mixing.
3. Epoxy grouts:
    a. Wet surfaces with epoxy for horizontal work or epoxy gel for vertical or overhead work prior to placing epoxy grout.
4. Non-shrink epoxy grout:
    a. Mix in complete units. Do not vary ratio of components or add solvent to change consistency of mix.
    b. Pour hardener into resin and mix for at least 1 minute and until mixture is uniform in color. Pour epoxy into mortar mixer wheelbarrow and add aggregate. Mix until aggregate is uniformly wetted. Over mixing will cause air entrapment in mix.
5. Non-shrink grout:
    a. Add non-shrink cement grout to premeasured amount of water that does not exceed the manufacturer's maximum recommended water content.
    b. Mix in accordance with manufacturer's instructions to uniform consistency.

C. Curing:
1. Cement based grouts and mortars:
    a. Keep continuously wet for minimum of 7 days. Use wet burlap, soaker hose, sun shading, ponding, and in extreme conditions, combination of methods.
    b. Maintain above 40 degrees Fahrenheit until it has attained compressive strength of 3,000 pounds per square inch, or above 70 degrees Fahrenheit for minimum of 24 hours to avoid damage from subsequent freezing.
2. Epoxy based grouts:
    a. Cure grouts in accordance with manufacturers' recommendations.
        1) Do not water cure epoxy grouts.
    b. Do not allow any surface in contact with epoxy grout to fall below 50 degrees Fahrenheit for minimum of 48 hours after placement.

D. Grouting equipment bases, baseplates, soleplates, and skids: As specified in Section 15050 - Common Work Results for Mechanical Equipment.

E. Grouting other baseplates:
   1. General:
      a. Use non-shrink grout as specified in this Section.
      b. Baseplate grouting shall take place from 1 side of baseplate to other in continuous flow of grout to avoid trapping air in grout.
      c. Maintain hydrostatic head pressure by keeping level of grout in headbox above bottom of baseplate. Fill headbox to maximum level and work grout down.
      d. Vibrate, rod, or chain non-shrink grout to facilitate grout flow, consolidate grout, and remove trapped air.
   2. Forms and headboxes:
      a. Build forms using material with adequate strength to withstand placement of grouts.
      b. Use forms that are rigid and liquidtight. Caulk cracks and joints with elastomeric sealant.
      c. Line forms with polyethylene for easy grout release. Coating forms with 2 coats of heavy-duty paste wax is also acceptable.
      d. Headbox shall be 4 to 6 inches higher than baseplate and shall be located on 1 side of baseplate.
      e. After grout sets, remove forms and trim back grout at 45 degree angle from bottom edges of baseplate.

3.04 FIELD QUALITY CONTROL

A. Non-shrink epoxy grout:
   1. Test for 24-hour compressive strength in accordance with ASTM C579, Method B.

B. Non-shrink grout:
   1. Test for 24-hour compressive strength in accordance with ASTM C942.

END OF SECTION

SECTION 03926

STRUCTURAL CONCRETE REPAIR

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Repairing damaged structural concrete.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C109 - Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens).
   2. C293 - Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading).
   3. C348 - Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars).
   4. C666 - Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.
   5. C882 - Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear.

1.03 SUBMITTALS

A. Product data: Submit manufacturer's data completely describing structural repair concrete materials.

B. Certificates of Compliance.

C. Manufacturer's instructions.

1.04 QUALITY ASSURANCE

A. Manufacturer qualifications: The manufacturer of the specified product shall have been in existence for a minimum of 10 years.

B. Allowable tolerances: Deviation from plumb or level shall not exceed 1/8 inch within 10 feet in any direction, as determined with a 10-foot straight edge.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver the specified product in original, unopened containers with the manufacturer's name, labels, product identification, and batch numbers.

B. Store and condition the specified product as recommended by the manufacturer.

C. Deliver, store, and handle packaged materials in the manufacturer's original, sealed containers, each clearly identified with the manufacturer's name, and name and type of product.

D. Store materials subject to damage by dirt and moisture in a clean, dry location, off the ground, and suitably protected.

1.06 PROJECT CONDITIONS

A. Existing conditions:
   1. Hot weather: ACI 305.
   2. Cold weather: ACI 306.
   3. Do not place concrete repair mortar during precipitation, unless adequate protection is provided.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. General: Structural repair concrete composed of cementitious material capable of being placed in formed vertical and overhead applications, and on horizontal surfaces.

B. Design requirements:
   1. Provide material suitable for performing in environments subject to corrosive attack by chlorides and sulfates, freeze/thaw cycles, low permeability, and abrasion resistant.
   2. Provide concrete repair mortar cement that is placeable from 1 inch in depth and extendable in greater depths.
   3. Concrete repair mortar shall be capable of being poured in place or troweled in place to suit the conditions encountered.

2.02 MATERIALS

A. Structural repair concrete:
   1. Manufacturers: One of the following or equal:
      a. Master Builder Solutions/Sika, MasterEmaco S 466CI.
      b. Sika Corp., SikaTop 123 Plus.
   2. Compressive strength: As follows in accordance with ASTM C109:
      a. 1 day: 2,500 pounds per square inch, minimum.
      b. 7 day: 6,000 pounds per square inch, minimum.
      c. 28 day: 7,000 pounds per square inch, minimum.
   3. Bond strength by slant shear: 2,200 pounds per square inch minimum at 28 days, in accordance with ASTM C882 modified.
   4. Flexural strength: 2,000 pounds per square inch minimum at 28 days, when tested in accordance with ASTM C293, or 770 pounds per square inch minimum at 28 days when tested in accordance with ASTM C348.
   5. Rapid freeze/thaw durability: In accordance with ASTM C666; Procedure A.
      a. Relative durability factor at 300 cycles: 95 percent minimum.
   6. Working time: 30 to 40 minutes.

7. Color: Concrete gray.

B. Water: Potable, clean, not detrimental to concrete.

C. Form materials:
   1. Smooth finish.
   2. Brace as required to maintain tolerances.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that concrete surfaces and exposed reinforcing are clean and free of contaminants.

3.02 PREPARATION

A. Prepare existing concrete by cleaning with steel brush and applying bonding agent in accordance with manufacturer's instructions.

B. Thoroughly clean reinforcement and other embedded items to remove loose rust and other objectionable matter.

C. Thoroughly wet wood forms, except coated plywood, and adjacent concrete at least 1 hour in advance of placing concrete; securely close cleanout end inspection ports; repeat wetting as necessary to keep forms damp.

D. Damaged concrete:
   1. Areas to be repaired shall be clean, sound, and free of contaminants.
      a. Remove loose and deteriorated concrete by mechanical means acceptable to the Engineer.
      b. Saw cut perimeter 1/2-inch maximum.
   2. Chip concrete substrate to obtain a surface profile of 1/16 inch to 1/8 inch in depth with a new fractured aggregate surface.
      a. Area to be repaired shall be not less than 1 inch in depth.
   3. Concrete removal shall extend along the reinforcing steel to locations along the bar free of bond inhibiting corrosion, and where the bar is well bonded to surrounding concrete.

E. Use the following procedures where reinforcing steel with active corrosion is encountered:
   1. Sandblast reinforcing steel to remove contaminants and rust.
   2. Determine section loss, splice new reinforcing steel where there is more than 15 percent loss as directed by the Engineer.
      a. If more than half the diameter of the reinforcing steel is exposed, chip out behind the reinforcing steel a minimum of 1/2 inch. Distance chipped behind the reinforcing steel must also equal or exceed the minimum placement depth of the accepted material.

F. Treat cracks in the substrate at the area of patching or overlay work as directed by the Engineer.

G. Extend existing control and expansion joints through any concrete repair.

H. Apply an epoxy-bonding agent to area to be repaired, as specified in Section 03071 - Epoxies, prior to patching concrete with polymer-modified Portland cement mortar.

3.03 MIXING

A. Mix in accordance with manufacturer's mixing instructions.

3.04 INSTALLATION

A. Formed surface finishes:
   1. Smooth finish:
      a. Obtain by the use of plywood, sheet metal, or lined wood forms; no fins, pockmarks, or other irregularities shall be present in the exposed surfaces of concrete.
      b. Place no structural repair concrete without prior authorization of the Engineer.

B. Verify that form materials are in place and ready to receive installation of concrete repair material.

C. Install in accordance with manufacturer's installation instructions.

D. In accordance with ACI recommendations, apply concrete repair material only when ambient conditions of moisture, temperature, humidity, and wind are favorable for curing.

E. Scrub mortar into substrate, filling cracks, voids, and pores.

F. For new construction, finish of repaired area shall match required finish for concrete being repaired.

G. For existing concrete, finish of repair area shall match finish of concrete being repaired.

H. During the curing process, protect concrete repair from rain, wind, or freezing as required:
   1. Keep sufficient covering on hand at all times for protection of repair concrete.

3.05 CLEANING

A. Remove debris and excess material. Leave work site in a neat, clean condition.

END OF SECTION

SECTION 03931

EPOXY INJECTION SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Epoxy injection system.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C881 - Standard Test Method for Epoxy-Resin-Base Bonding Systems for Concrete.
   2. C882 - Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete by Slant Shear.
   3. D638 - Standard Test Method for Tensile Properties of Plastics.
   4. D648 - Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position.
   5. D695 - Standard Test Method for Compressive Properties of Rigid Plastics.
   6. D790 - Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data:
   1. Manufacturer's data completely describing epoxy injection system materials and including test methods and results for strength in tension, flexure, compression and bond; flexural modulus of elasticity; coefficient of thermal expansion; and elongation.

C. Quality control submittals:
   1. Certificates of Compliance.
   2. Manufacturer's Instructions.

D. Special procedure submittals:
   1. Protection plan for surrounding areas and non-cementitious surfaces.

1.04 QUALITY ASSURANCE

A. Products:
   1. Provide materials that are new and use them within shelf life limitations set forth by manufacturer.

B. Qualifications:
   1. Installer:
      a. Minimum 5 years' experience in concrete repair, with focus on application of similar systems and products to projects of similar size and scope.

C. Pre-installation meeting:
   1. At least 1 week prior to commencing work of this Section, convene a meeting at the project site to review and discuss the following:
      a. Surface preparation.
      b. Substrate conditioning and pre-treatment.
      c. Installation procedures.
      d. Environmental conditions (including weather forecast) and curing requirements.
      e. Testing and inspection procedures.
      f. Protection of surrounding surfaces and equipment.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in manufacturer's original, unopened, undamaged containers with identification labels intact. Labels shall include product identification, batch numbers, and shelf life information.

B. Store materials off the ground and away from moisture and direct sunlight, and at temperatures within manufacturer's recommended range.

C. Pre-condition materials to manufacturer's recommended temperatures before mixing and using.

1.06 PROJECT CONDITIONS

A. Take precautions to protect surfaces and equipment in the work area from damage and staining.

PART 2 PRODUCTS

2.01 MATERIALS

A. General:
   1. Repair materials shall be free of chlorides or alkalis (except for those attributed to water).
   2. To ensure compatibility of materials and methods, a single manufacturer shall produce and provide all products used together in a single area of concrete repair.

B. Manufacturers: One of the following, or equal:
   1. Sika Chemical Corp., Sikadur 35 Hi-Mod LV.

C. Epoxy:
   1. In accordance with ASTM C881, Types I, II and IV, Grade 1, Class C.

2. Water-insensitive 2-component low viscosity, epoxy adhesive material containing 100 percent solids and meeting or exceeding following characteristics when tested in accordance with standards specified:

Table 1. Epoxy, Physical Properties		
Characteristic	**Test Method**	**Required Results, minimum(1),(2)**
Viscosity (mixed)	--	250 to 375 centipoise
Tensile Strength	ASTM D638	7,500 pounds per square inch
Tensile Elongation at Break	ASTM D638	1 percent
Compressive Strength	ASTM D695	11,000 pounds per square inch
Compressive Modulus	ASTM D695	2.5×10^5 pounds per square inch
Bond Strength, slant shear, hardened concrete to hardened concrete	ASTM C882	1,500 pounds per square inch at 2 days at minimum 73 degrees Fahrenheit. Concrete shall fail before failure of epoxy.
Heat Deflection Temperature	ASTM D648	124 degrees Fahrenheit
Notes: (1) Properties for mixes with neat epoxy. (2) Results after 7-day cure at temperature between 72 and 78 degrees Fahrenheit, unless otherwise noted.		

2.02 EQUIPMENT

A. Injection pump:
   1. Use positive displacement injection pump with interlock to provide in-line mixing and metering system for 2-component epoxy.
   2. Use pressure hoses and injection nozzle designed to properly mix of 2 components of epoxy.
   3. Standby injection unit may be required.

PART 3 EXECUTION

3.01 PREPARATION

A. Surface preparation:
   1. Confirm that surface temperature and moisture conditions are within manufacturer's recommended limits. Condition surfaces to within those limits before commencing epoxy injection.
   2. Sweep or clean area in vicinity of cracks that will be injected with epoxy. Leave area in generally clean condition after epoxy injection is complete.
   3. Clean cracks so they are free from dirt, laitance, and other loose matter.

3.02 INSTALLATION

A. Install and cure epoxy materials in accordance with manufacturer's installation instructions.

B. Mixing:
   1. Mix epoxy in accordance with manufacturer's installation instructions.
   2. Do not use solvents to thin epoxy system materials introduced into cracks or joints.

C. Injection:
   1. Apply adequate surface seal to crack to prevent leakage of epoxy.
   2. Establish injection points at distance along crack not less than thickness of cracked member.
   3. Crack injection sequence:
      a. Inject epoxy into crack or joint at first port with sufficient pressure to advance epoxy to adjacent port. Start at lowest port along the injection line and work upwards.
      b. Seal original port and shift injection to next adjacent port where epoxy appears.
      c. Continue port-to-port injection until crack has been injected for its entire length.
      d. For small amounts of epoxy, or where excessive pressure developed by injection pump might further damage structure, premixed epoxy and use hand caulking gun to inject epoxy if acceptable to the Engineer.
      e. Seal ports, including adjacent locations where epoxy seepage occurs, as necessary to prevent drips or run out.
      f. After epoxy injection is complete, remove surface seal material, and refinish concrete in area where epoxy was injected to match existing concrete. Leave finished work and work area in a neat, clean condition.

3.03 FIELD QUALITY ASSURANCE

A. Provide Contractor quality control as specified in Section 01450 - Quality Control.

B. Field inspections and testing:
   1. Submit records of inspections and tests to Engineer within 24 hours after completion.

C. Manufacturer's services.
   1. Pre-installation meeting: Provide manufacturer's technical representative to attend pre-installation meeting specified in this Section.

3.04 FIELD QUALITY CONTROL

A. Provide Owner's quality assurance for the Work of this Section as specified in Section 01450 - Quality Control.

B. Special inspections special tests, and structural observation:
   1. Not required.

C. Field inspections:
   1. Preparation.
      a. Review manufacturer's product data and installation instructions.

2. Required inspections.
    a. Observe surfaces to be injected for temperature and moisture conditions and for surface preparation.
    b. Observe conditioning and mixing of epoxy resin components.
    c. Observe injection procedures for filling cracks.
3. Records of inspections:
    a. Provide record of each inspection.
    b. Submit to Engineer upon request.

3.05 NON-CONFORMING WORK

A. Rework surface finishes that do not match surrounding concrete to the satisfaction of the Engineer at no additional cost to the Owner.

END OF SECTION

SECTION 05120

STRUCTURAL STEEL FRAMING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Structural steel shapes and plate.
   2. Fasteners and structural hardware:
      a. All thread rods.
      b. High-strength bolts.
   3. Welding.
   4. Bolting.

1.02 REFERENCES

A. American Institute of Steel Construction (AISC):
   1. 303 - Code of Standard Practice for Steel Buildings and Bridges.
   2. 360 - Specification for Structural Steel Buildings.

B. American Iron and Steel Institute (AISI):
   1. Steel and stainless steel alloys (types) as indicated.

C. American Welding Society (AWS):
   1. A5.1 - Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.
   2. A5.17 - Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding.
   3. A5.20 - Specification for Carbon Steel Electrodes for Flux Cored Arc Welding.
   4. D1.1 - Structural Welding Code - Steel.
   5. D1.6 - Structural Welding Code - Stainless Steel.

D. ASTM International (ASTM):
   1. A6 - Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling.
   2. A36 - Standard Specification for Carbon Structural Steel.
   3. A123 - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   4. A153 - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   5. A194 - Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   6. A240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
   7. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   8. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.

9. A500 - Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
10. A501 - Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
11. A563 - Standard Specification for Carbon and Alloy Steel Nuts.
12. A992 - Standard Specification for Structural Steel Shapes.
13. F436 - Standard Specification for Hardened Steel Washers.
14. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
15. F594 - Standard Specification for Stainless Steel Nuts.
16. F959 - Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners.
17. F2329 - Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners.
18. F3125 - Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength.

E. Research Council on Structural Connections (RCSC):
   1. Specification for Structural Joints Using High-Strength Bolts (RCSC Specification).

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Snugtight: At bolted joints, the tightness attained with a few impacts of an impact wrench, or by the full effort of an ironworker using a spud wrench to bring the connected plies into firm contact.
   2. Stainless steel related terms:
      a. Descaling: Removal of heavy, tightly adherent oxide films resulting from hot-forming, heat-treatment, welding, and other high-temperature operations.
      b. Passivation: Chemical treatment of stainless steel with a mild oxidant for the purpose of enhancing the spontaneous formation of the steel's protective passive film.
      c. Pickling: Chemical descaling of stainless steel using aqueous solutions of nitric and hydrofluoric acid, or various proprietary formulations as specified.

1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Product data:
   1. Welding electrodes for field welds: Electrode manufacturer's data.
   2. Stainless steel: Fabricator name and qualifications, member dimensions and structural section properties, and specifications and procedures used for pickling and passivating members.

C. Shop Drawings:
   1. Fabrication and erection drawings.

D. Quality Control Submittals:
   1. Welding procedure specifications (WPS) in accordance with AWS D1.1 and D1.6.
      a. Submit WPS for each type of welded joint used, whether prequalified or qualified by testing.
         1) State electrode manufacturer and specific electrodes used.
         2) Indicate required AWS qualification for joint.
      b. Submit WPS with Shop Drawings that indicate those welds.
      c. Submit Procedure Qualification Record (PQR) in accordance with AWS D1.1 and D1.6 for welding procedures qualified by testing.
   2. Welder qualifications: For each welding process and position:
      a. Welder's qualification certificates.
      b. Contractor's statement that certificate will be "in effect" at the time(s) welding will be performed based on the "Period of Effectiveness" provisions of AWS D1.1 and D1.6.
   3. Steel fabricator's AISC certification.

E. Test reports:
   1. Certified copies of mill tests and analyses made in accordance with applicable ASTM standards, or reports from a recognized commercial laboratory, including chemical and tensile properties of each shipment of structural steel or part thereof having common properties.

1.05 QUALITY ASSURANCE

A. Certification:
   1. Steel fabricators shall be certified by the AISC or other certification acceptable to the Engineer and the building official having jurisdiction.

B. Welding:
   1. Perform welding of structural metals in accordance with AWS D1.1 and D1.6 using welders who have current AWS qualification certificate for the process, position, and joint configuration to be welded.
   2. Make welding procedure specifications available at the locations where welding is performed.
   3. Notify the Engineer at least 24 hours before starting shop or field welding.
   4. Engineer may check materials, equipment, and qualifications of welders.
   5. Remove welders performing unsatisfactory Work, or require requalification.
   6. Engineer may use gamma ray, magnetic particle, dye penetrant, trepanning, or other aids to visual inspection to examine any part of welds or all welds.
   7. Contractor shall bear costs of retests on defective welds.
   8. Contractor shall also bear costs in connection with qualifying welders.

1.06 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements.

B. Packing and shipping: Deliver structural steel free from mill scale, rust, and pitting.

C. Storage and protection: Until erection and painting, protect from weather items not galvanized or protected by a shop coat of paint.

PART 2 PRODUCTS

2.01 MATERIALS

A. Unless otherwise specified or indicated on the Drawings, materials shall be in accordance with the following:

Item	ASTM Standard	Class, Grade, Type, or Alloy Number
Carbon Steel		
Plate, bars, rolled shapes (except W and WT shapes), and miscellaneous items	A36	--
Rolled W and WT shapes	A992	Grade 50
Hollow structural sections/HSS: Round, square, or rectangular (including "pipe" where indicated for structural members and supports)	A500	Grade C
Stainless Steel		
Plate, sheet, and strip	A240	Type 304(1) or 316(2)
Bars and shapes	A276	Type 304(1) or 316(2)
(1) Use Type 304L (low-carbon stainless steel) if material will be welded. (2) Use Type 316L (low carbon stainless steel) if material will be welded.		

2.02 FASTENERS AND STRUCTURAL HARDWARE

A. General:
   1. Materials: Of domestic manufacture.
   2. Where fasteners and hardware are specified to be galvanized, hot-dip galvanize in accordance with ASTM A153 or ASTM F2329, unless otherwise specified.

B. All thread rods:
   1. Carbon steel:
      a. In accordance with ASTM A36 unless otherwise indicated on the Drawings.
      b. High strength all thread rods: In accordance with ASTM F1554, Grade 55.
      c. Nuts: ASTM A194.
      d. Washers: ASTM F436.
   2. Galvanized carbon steel:
      a. In accordance with ASTM A36 unless otherwise indicated on the Drawings and hot dip galvanized in accordance with ASTM A153.
      b. Nuts: ASTM A194; hot-dip galvanized in accordance with ASTM A153.
      c. Washers: ASTM F436; hot-dip galvanized in accordance with ASTM A153.

3. Stainless steel:
    a. Units descaled, pickled, and passivated as specified in the Fabrication article in this Section.
    b. Threaded rods and nuts shall be the products of a single manufacturer/fabricator to ensure proper fit without galling. Ship all thread rods with properly fitting nuts attached.
    c. Alloy Type 304 or Type 316 as indicated on the Drawings.
    d. Type 304:
        1) Rod: ASTM F593, Group 1, Condition CW, coarse threads.
        2) Nuts: ASTM F594. Match alloy of rod (group and UNS designation).
        3) Washers: Type 304 stainless steel.
    e. Type 316:
        1) Rod: ASTM F593, Group 2, Condition CW, coarse threads.
        2) Nuts: ASTM F594. Match alloy of rod (group and UNS designation).
        3) Washers: Type 316 stainless steel.

C. Anchor bolts, anchor rods, and post-installed steel anchors: As indicated on the Drawings and as specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

D. High-strength bolts:
    1. Provide high-strength bolt assembly with nuts, hardened flat washers, and compressible-washer-type direct tension indicators. Carbon steel: Uncoated:
        a. Bolts: Plain heavy hex structural bolts in accordance with ASTM F3125, Grade A325, Type 1 , or ASTM F3125, Grade A490, Type 1 where Grade A490 bolts are indicated on the Drawings.
        b. Nuts: Heavy hex nuts in accordance with ASTM A563, Grade C.
        c. Washers:
            1) Adjacent to normal, oversized, and short-slotted holes: Circular, square or rectangular beveled, clipped, or extra thick washers in accordance with ASTM F436, Type 1. Flat circular washers unless otherwise indicated on the Drawings.
            2) Adjacent to long slotted holes: Fabricated from 5/16-inch thick plate in accordance with ASTM A36 or 3/8-inch plate where Grade A490 bolts are indicated on the Drawings.
        d. Load indicator devices: At slip critical connections, provide one of the following devices at each bolt:
            1) Compressible-washer-type direct tension indicators (DTI): In accordance with ASTM F959, Type 325-1, or ASTM F959, Type 490-1 where Grade A490 bolts are indicated on the Drawings.
            2) Twist-off type tension-control bolt assemblies: ASTM F3125, Grade F1852 or ASTM F3125, Grade F2280 where Grade A490 bolts are indicated on the Drawings.

E. Stainless steel bolts (for use in stainless steel structures):
    1. General:
        a. Bolts and nuts shall be the products of a single manufacturer/fabricator to ensure proper fit without galling. Units descaled, pickled and passivated as specified in the Fabrication article in this Section.
    2. Alloy: Type 304 or Type 316 to match alloy of structural members being connected.

3. Type 304:
    a. Bolts: ASTM F593, Group 1, Condition CW, coarse threads.
    b. Nuts: ASTM F594. Match alloy (group and UNS designation) and threads of bolts.
    c. Washers: Type 304 stainless steel.
4. Type 316:
    a. Bolts: ASTM F593, Group 2, Condition CW, coarse threads.
    b. Nuts: ASTM F594. Match alloy (group and UNS designation) and threads of bolts.
    c. Washers: Type 316 stainless steel.

2.03 ISOLATING SLEEVES AND WASHERS

A. As indicated on the Drawings and as specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

2.04 SUPPLEMENTARY PARTS

A. Furnish as required for complete structural steel erection, whether or not such parts and Work are specified or indicated on the Drawings.

2.05 FABRICATION

A. Shop assembly:
    1. Fabricate structural steel in accordance with AISC 360 and AISC 303 unless otherwise specified or modified by applicable regulatory requirements.
    2. Where anchors, connections, or other details of structural steel are not specifically indicated on the Drawings or specified, their material, size and form shall be equivalent in quality and workmanship to items specified.
    3. Round off sharp and hazardous projections and grind smooth.
    4. Take measurements necessary to properly fit work in the field. Take responsibility for and be governed by the measurements and proper working out of all the details.
    5. Take responsibility for correct fitting of metalwork.
    6. Welded connections:
        a. In accordance with AWS requirements for the metals to be welded.
        b. Weld only in accordance with approved welding procedure specifications.
        c. Keep welding procedure specifications readily available for welders and inspectors during fabrication processes.

B. Stainless steel shapes and assemblies:
    1. For structural members such as W shapes, S shapes, channels, angles, and similar rolled shapes not available in quantity, size, and type of stainless steel specified or indicated on the Drawings:
        a. Fabricate shapes using laser-fused, full penetration welds between pieces of plate to attain same or higher section modulus and moment of inertia as that of members indicated on the Drawings.
        b. Fabricate shapes from dual grade stainless steel.
        c. Fabricate beams and channels in accordance with ASTM A6 tolerances.
        d. Manufacturers: The following or equal:
            1) Stainless Structural, LLC.

2. Cleaning and passivation:
    a. Following shop fabrication of stainless steel members and bolts, clean and passivate fabrications at point of manufacture.
    b. Finish requirements: Remove free iron, heat tint oxides, weld scale and other impurities, and obtain a bright passive finished surface with no etching, pitting, frosting, or discoloration.
    c. Provide quality control testing to verify effectiveness of cleaning agents and procedures and to confirm that finished surfaces are clean and passivated.
        1) Conduct sample runs using test specimens with proposed cleaning agents and procedures as required to avoid adverse effects on surface finishes and base materials.
    d. Pre-clean, chemically de-scale (pickle), passivate, and final-clean fabrications in accordance with the requirements of ASTM A380.
        1) If degreasing is required before cleaning (pickling) to remove scale or iron oxide, cleaning with citric acid treatments is permissible; however, such treatments shall be followed inorganic cleaners.
        2) Pickle and passivate stainless steel using a nitric acid solution in accordance with ASTM A380, Annex A2, Table A2.1, Part II.
        3) Pickling by citric acid treatment or sulfuric acid treatment is not considered to satisfy the requirements of this Section.
    e. Inspect after cleaning using methods specified for “gross inspection” in ASTM A380.
    f. Improperly or poorly cleaned and passivated materials shall not be shipped and will not be accepted at the Site.

C. Galvanized carbon steel:
    1. Where galvanizing is required, hot-dip structural steel after fabrication in accordance with ASTM A123.
    2. Do not electro-galvanize or mechanically-galvanize unless specified or accepted by the Engineer.
    3. Re-straighten galvanized items that bend or twist during galvanizing.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions: Examine Work in place to verify that it is satisfactory to receive the Work of this Section. If unsatisfactory conditions exist, do not begin this Work until such conditions have been corrected.

3.02 ERECTION

A. General:
    1. Fabricate structural and foundry items to true dimensions without warp or twist.
    2. Form welded closures neatly and grind off smooth where weld material interferes with fit or is unsightly.
    3. Install structural items accurately and securely, true to level, plumb, in correct alignment and grade, with all parts bearing or fitting structure or equipment for which intended.

4. Do not shift out of alignment, re-drill, re-shape, or force fit fabricated items.
5. Place anchor bolts or other anchoring devices accurately and make surfaces that bear against structural items smooth and level.
6. Rigidly support and brace components to preserve straight, level, even, and smooth lines.
    a. Install non-shrink grout as indicated on the Drawings.
    b. Keep items braced until grout has hardened for 48 hours minimum.
7. Erect structural steel in accordance with AISC 303 unless otherwise specified or modified by applicable regulatory requirements.
8. Where anchors, connections, and other details of structural steel erection are not specifically indicated on the Drawings or specified, form, locate, and attach with equivalent in quality and workmanship to items specified.
9. Round off sharp or hazardous projections and grind smooth.
10. Paint or coat steel items as specified in Section 09910 - Painting and Section 09960 - High-Performance Coatings.

B. Stainless steel: Take necessary precautions to avoid iron contamination of stainless steel during delivery, storage, and handling.
    1. Segregate stainless steel from iron.
    2. Tools and handling devices.
        a. Do not use iron tools clamps, chokes, working surfaces, or brushes when fabricating, handling, and erecting stainless steel.
        b. Do not use tools that have been contaminated by contact with iron.
        c. Use stainless steel, polymer coated, or wood tools and handling equipment. Do not use tools that have been contaminated by contact with iron or steel.

C. Welding: General:
    1. Make welds full penetration type, unless otherwise indicated on the Drawings.
    2. Remove backing bars and weld tabs after completion of weld. Repair defective welds observed after removal of backing bars and weld tabs.

D. Welding: Carbon steel:
    1. In accordance with AWS D1.1:
        a. Weld ASTM A36 and ASTM A992 structural steel and ASTM A500 and ASTM A501 structural tubing with electrodes in accordance with AWS A5.1, using E70XX electrodes; AWS A5.17, using F7X-EXXX electrodes; or AWS A5.20, using E7XT-X electrodes.

E. Welding: Stainless steel:
    1. In accordance with AWS D1.6.
    2. Passivation of field-welded surfaces:
        a. Provide cleaning, pickling and passivating as specified in the Fabrication article of this Section. Clean using Derustit stainless steel cleaner, or equal.

F. Interface with other products:
    1. Where steel members and fasteners come in contact with dissimilar metals (aluminum, stainless steel, etc.), separate or isolate the dissimilar metals with isolating sleeves and washers as specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

G. Fasteners: General:
   1. Install bolts to project 2 threads minimum, but 1/2 inch maximum beyond nut.
   2. Anchor bolts and anchor rods: Install as specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.
      a. Unless otherwise specified, tighten nuts on anchor bolts and anchor rods specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry to the “snugtight” condition.
   3. All thread rods in drilled holes bonded to concrete with adhesive: Install as specified in Section 03055 - Adhesive-Bonded Reinforcing Bars and All Thread Rods in Concrete.

H. Fasteners: High-strength carbon steel bolts:
   1. Connections with high-strength bolts shall be in accordance with the RCSC Specification for Structural Joints Using High-Strength Bolts.
   2. Provide slip-critical joints at bolted connections.
   2. Joints: Slip-critical.
      a. Confirm that faying surfaces at connections are free of dirt and other foreign material, have been blast cleaned, and are free of coatings and inadvertent overspray in accordance with the RCSC Specification.
      b. Furnish hardened flat washers in accordance with ASTM F436:
         1) On outer plies with slotted holes.
         2) When one or more plies of the connected material has a yield strength less than 40 ksi.
         3) Under element, nut, or bolt head, turned in tightening.
      c. Install tension indicator washers, placed in accordance with ASTM F959, Figure X1, to confirm adequate tightening of bolts.
      d. Tighten bolts to full pretension.
   5. Joints: Snugtight:
      e. Install bolts with washers where required in accordance with the RCSC Specification.
      f. Tighten bolts to bring the connected plies into firm contact.
         1) Tightening shall progress systematically beginning with the most rigid part of the joint.
         2) More than 1 cycle through the bolt pattern may be required to achieve this condition.
      g. Verify adequate tightening of bolts by visual observation to confirm that washers have been installed at locations required in accordance with the RCSC Specification and that the plies of the connected parts have been brought into firm contact.

I. Fasteners: Stainless steel bolts:
   1. Connections shall be snugtight joints unless otherwise indicated on the Drawings.
   2. Prior to installing nuts, coat threads of stainless steel fasteners with thread coating to prevent galling of threads.
   3. Rotate nuts using a slow, smooth action without interruptions. Avoid over-tightening.

3.03 FIELD QUALITY CONTROL

A. As specified in Section 01450 - Quality Control.

3.04 FIELD QUALITY ASSURANCE

A. As specified in Section 01450 - Quality Control.

B. Special inspections, special tests, and structural observation:
   1. As specified in Section 01455 - Regulatory Quality Assurance.

END OF SECTION

SECTION 05190

MECHANICAL ANCHORING AND FASTENING TO CONCRETE AND MASONRY

PART 1 GENERAL

1.01 SUMMARY

A. Section includes requirements for:
   1. Cast-in anchors and fasteners.
   2. Post-installed steel anchors and fasteners.
   3. Appurtenances for anchoring and fastening.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 355.2 - Qualification of Post-Installed Mechanical Anchors in Concrete & Commentary.

B. American National Standards Institute (ANSI):
   1. B212.15 - Cutting Tools - Carbide-tipped Masonry Drills and Blanks for Carbide-tipped Masonry Drills.

C. American Welding Society (AWS):
   1. D1.1 - Structural Welding Code - Steel.
   2. D1.6 - Structural Welding Code - Stainless Steel.

D. ASTM International (ASTM):
   1. A29 - Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for.
   2. A36 - Standard Specification for Carbon Structural Steel.
   3. A123 - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   4. A240 - Standard Specification for Chromium and Chromium Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
   5. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
   6. B633 - Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel.
   7. F436 - Standard Specification for Hardened Steel Washers.
   8. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws and Studs.
   9. F594 - Standard Specification for Stainless Steel Nuts.
   10. F1554 - Standard Specification for Anchor Bolts, Steel, 36, 55 and 105-ksi Yield Strength.
   11. F2329 - Standard Specification for Zinc Coating, Hot-Dip, Requirements for Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners.

E. International Code Council Evaluation Service, Inc. (ICC-ES):
   1. AC193 - Acceptance Criteria for Mechanical Anchors in Concrete Elements.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Built-in anchor: Headed bolt or assembly installed in position before filling surrounding masonry units with grout.
   2. Cast-in anchor: Headed bolt or assembly installed in position before placing plastic concrete around.
   3. Overhead installations: Fasteners installed on overhead surfaces where the longitudinal axis of the fastener is more than 45 degrees above a horizontal line so the fastener resists sustained tension loads.
   4. Passivation: Chemical treatment of stainless steel with a mild oxidant for the purpose of enhancing the spontaneous formation of the steel's protective passive film.
   5. Post-installed anchor: Fastener or assembly installed in hardened concrete or finished masonry construction, typically by drilling into the structure and inserting a steel anchor assembly.
   6. Terms relating to structures or building environments as used with reference to anchors and fasteners:
      a. Corrosive locations: Describes interior and exterior locations as follows:
         1) Locations used for delivery, storage, transfer, or containment (including spill containment) of chemicals used for plant treatment processes.
         2) Exterior and interior locations at the following treatment structures:
            a) Wastewater treatment facilities: Solids stream:
               (1) Thickening facilities.
      b. Wet and moist locations: Describes locations, other than "corrosive locations," that are submerged, are immediately above liquid containment structures, or are subject to frequent wetting, splashing, or wash down. Includes:
         1) Exterior portions of buildings and structures.
         2) Liquid-containing structures:
            a) Locations at and below the maximum operating liquid surface elevation.
            b) Locations above the maximum operating liquid surface elevation and:
               (1) Below the top of the walls containing the liquid.
               (2) At the inside faces and underside surfaces of a structure enclosing or spanning over the liquid (including walls, roofs, slabs, beams, or walkways enclosing the open top of the structure).
         3) Liquid handling equipment:
            a) Bases of pumps and other equipment that handles liquids.
         4) Indoor locations exposed to moisture, splashing, or routine wash down during normal operations, including floors with slopes toward drains or gutters.
         5) Other locations indicated on the Drawings.

c. Other locations:
1) Interior dry areas where the surfaces are not exposed to moisture or humidity in excess of typical local environmental conditions.

1.04 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Calculations.

1.05 SUBMITTALS

A. General:
1. Submit as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Product data:
1. Cast-in anchors:
a. Manufacturer's data, including catalog cuts showing anchor sizes and configuration, materials, and finishes.
2. Post-installed anchors:
a. For each anchor type, manufacturer's data, including catalog cuts showing anchor sizes and construction, materials and finishes, and load ratings.

C. Delegated Design Submittals:
1. When requesting product substitutions for post installed anchors, submit calculations, indicating the diameter, effective embedment depth and spacing of the proposed anchors, and demonstrating that the substituted product will provide load resistance that is equal to or greater than that provided by the anchors listed in this Section.

D. Samples:
1. Samples of each type of anchor, including representative diameters and lengths, if requested by the Engineer.

E. Certificates:
1. Cast-in anchors:
a. Mill certificates for steel anchors that will be supplied to the Site.
2. Post-installed anchors:
a. Manufacturer's statement or certified test reports demonstrating that anchors that will be supplied to the Site comply with the materials properties specified.

F. Test reports:
1. Post-installed anchors: For each anchor type used for the Work:
a. Current ICC-ES report (ESR) demonstrating:
1) Acceptance of that anchor for use under the building code specified in Section 01410 - Regulatory Requirements.

G. Manufacturer's instructions:
    1. Requirements for storage and handling.
    2. Recommended installation procedures, including details on drilling, hole size (diameter and depth), hole cleaning and preparation procedures, anchor insertion, and anchor tightening.
    3. Requirements for inspection or observation during installation.

H. Qualification statements:
    1. Post-installed anchors: Installer qualifications:
        a. Submit list of personnel performing installations. Include letter of training from manufacturer indicating date of manufacturer's training for each installer.

1.06 QUALITY ASSURANCE

A. Qualifications:
    1. Post installed anchors shall be in accordance with building code specified in Section 01410 - Regulatory Requirements.

B. Special inspection:
    1. Provide special inspection of post-installed anchors as specified in Section 01455 - Regulatory Quality Assurance and this Section.

1.07 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements.

B. Deliver post-installed anchors in manufacturer's standard packaging with labels visible and intact. Include manufacturer's installation instructions.

C. Handle and store anchors and fasteners in accordance with manufacturer's recommendations and as required to prevent damage.

D. Protect anchors from weather and moisture until installation.

1.08 PROJECT OR SITE CONDITIONS

A. As specified in Section 01850 - Design Criteria.

B. Seismic Design Category (SDC) for structures is indicated on the Drawings.

PART 2 PRODUCTS

2.01 MANUFACTURED UNITS

A. General:
    1. Furnish threaded fasteners with flat washers and hex nuts fabricated from materials corresponding to the material used for threaded portion of the anchor.
        a. Cast-in anchors: Provide flat washers and nuts as listed in the ASTM standard for the anchor materials specified.

b. Post-installed anchors: Provide flat washers and nuts supplied for that product by the manufacturer of each anchor.

2. Size of anchors and fasteners, including diameter and length or minimum effective embedment depth: As indicated on the Drawings or as specified in this Section. In the event of conflicts, contact the Engineer for clarification.
3. Where anchors and connections are not specifically indicated on the Drawings or specified, their material, size and form shall be equivalent in quality and workmanship to items specified.

B. Materials:
1. Provide and install anchors of materials as specified in this Section.

2.02 CAST-IN ANCHORS AND FASTENERS

A. Anchor bolts:
1. Straight steel rod having one end with an integrally forged head, and one threaded end. Embedded into concrete with the headed end cast into concrete at the effective embedment depth indicated on the Drawings or specified, and with the threaded end left to project clear of concrete face as required for the connection to be made.
2. Furnish anchor bolts with heavy hex forged head or equivalent acceptable to the Engineer.
a. Rods or bars with angle bend for embedment in concrete (i.e., “L” or “J” shaped anchor bolts) are not permitted in the Work.
3. Materials:
a. Ship anchor bolts with properly fitting nuts attached.
b. Type 316 stainless steel:
1) Surfaces descaled, pickled, and passivated in accordance with ASTM A380.
2) Bolts: ASTM F593, Group 2, Condition CW, coarse threads.
3) Nuts: ASTM F594. Match alloy (group and UNS designation) and threads of bolts.
4) Washers: Type 316 stainless steel.
c. Type 304 stainless steel:
1) Surfaces descaled, pickled, and passivated in accordance with ASTM A380.
2) Bolts: ASTM F593, Group 1, Condition CW, coarse threads.
3) Nuts: ASTM F594. Match alloy (group and UNS designation) and threads of bolts.
4) Washers: Type 304 stainless steel.
d. Galvanized steel:
1) Hot-dip galvanized coating in accordance with ASTM F2329.
2) Bolts: ASTM F1554, Grade 36, heavy hex, coarse thread.
3) Nuts: ASTM A563, Grade A, heavy hex, threads to match bolt.
4) Washers: ASTM F436, Type 1.

B. Steel plates or shapes for fabrications, including assemblies with welded studs or deformed bar anchors:
1. Stainless steel: Type 316L or Type 304L:
a. Plates (embedded): ASTM A240.

2. Galvanized steel:
    a. Hot dip galvanized in accordance with ASTM A123.
    b. Steel: ASTM A36.

2.03 POST-INSTALLED ANCHORS AND FASTENERS - ADHESIVE

A. Epoxy bonding of reinforcing bars, all thread rods, and threaded inserts in concrete: As specified in Section 03055 - Adhesive-Bonded Reinforcing Bars and All Thread Rods in Concrete.

2.04 POST-INSTALLED ANCHORS AND FASTENERS - MECHANICAL

A. General:
    1. Post-installed anchors shall hold a current ICC Evaluation Service report demonstrating acceptance for use under the building code specified in Section 01410 - Regulatory Requirements. Acceptance report shall indicate acceptance of the product for use under the following conditions:
        1) In regions of concrete where cracking has occurred or may occur.
        2) To resist short-term loads due to wind forces.
        3) To resist short-term loading due to seismic forces for the Seismic Design Category of the structure where the product will be used.

B. Concrete anchors:
    1. Post-installed anchor assembly consisting of a threaded stud and a surrounding wedge expansion sleeve that is forced outward by torquing the center stud to transfer loads from the stud to the concrete through bearing, friction, or both. Sometimes referred to as “expansion anchors” or “wedge anchors.”
        a. Do not use slug-in, lead cinch, and similar systems relying on deformation of lead alloy or similar materials to develop holding power.
    2. Concrete expansion bolts for anchorage to concrete:
        a. Shall have a current ICC-ES report demonstrating that the anchors have been tested and qualified for performance in both cracked and un-cracked concrete, and for short-term loading due to wind and seismic forces for Seismic Design Categories A through F in accordance with ACI 355.2 and with ICC-ES AC193 (including all mandatory tests and optional tests for seismic tension and shear in cracked concrete).
        b. Performance in the current ICC-ES report shall be “Category 1” as defined in ACI 355.2.
        c. Manufacturers: One of the following:
            1) Hilti, Kwik Bolt TZ2 Wedge Anchor.
            2) Simpson Strong-Tie, Strong-Bolt 2 Wedge Anchor.
        d. Materials. Integrally threaded stud, wedge, washer, and nut:
            1) Stainless steel: Type 316.
                a) Type 304 stainless steel acceptable for use at wet and moist locations when accepted in writing by the Engineer.
            2) Galvanized: Carbon steel, zinc plated in accordance with ASTM B633, minimum 5 microns (Fe/Zn 5).

C. Flush shells:
    1. Post-installed anchor assembly consisting of an internally threaded mandrel that is forced into a pre-drilled concrete hole with a setting tool until the top of

the anchor is flush with the face of the concrete. Once installed, a removable threaded bolt is installed in the mandrel.

2. Flush shell anchors are not permitted in the Work.

2.05 APPURTENANCES FOR ANCHORING AND FASTENING

A. Anchor bolt sleeves:
   1. Fabricated steel sleeves:
      a. Construct as specified in Section 05500 - Metal Fabrications.
      b. Fabricate to the following dimensions unless otherwise indicated on the Drawings:
         1) Inside diameter: At least 2 inches greater than bolt diameter.
         2) Inside length: Not less than 10-bolt diameters.
         3) Bottom plate:
            a) Square plate with dimensions equal to the outside diameter of the sleeve plus 1/2 inch each side.
            b) Thickness equal to or greater than 1/2 of the anchor bolt diameter.
      c. Carbon steel:
         1) Fabricated from ASTM A36 plate and ASTM A53, Grade B pipe.
         2) Welded connections: Conform to requirements of AWS D1.1.
         3) Hot dip galvanized in accordance with ASTM A153.
      d. Stainless steel:
         1) Fabricated from ASTM A240 plate and pipe. Type 304L or Type 316L to match type of the anchor bolt.
         2) Welded connections: In accordance with AWS D1.6.

B. Isolating sleeves and washers:
   1. Manufacturers: One of the following or equal:
      a. Allied Corrosion Industries.
      b. Central Plastics Co.
   2. Sleeves: Mylar, 1/32-inch thick, 4,000 volts per mil dielectric strength, of proper size to fit bolts and extending halfway into both steel washers.
   3. One sleeve required for each bolt.
   4. Washers: Inside diameter of washers shall fit over the isolating sleeve, and both the steel and isolating washers shall have the same inside diameter and outside diameter.
      a. Proper size to fit bolts.
      b. Two 1/8-inch thick steel washers for each bolt.
      c. G3 Phenolic: 2 insulating washers are required for each bolt:
         1) Thickness: 1/8 inch.
         2) Base material: Glass.
         3) Resin: Phenolic.
         4) Water absorption: 2 percent.
         5) Hardness (Rockwell): 100.
         6) Dielectric strength: 450 volts per mil.
         7) Compression strength: 50,000 pounds per square inch.
         8) Tensile strength: 20,000 pounds per square inch.
         9) Maximum operating temperature: 350 degrees Fahrenheit.

C. Coating for repair of galvanized surfaces:
   1. Manufacturers: The following or equal:
      a. Jelt, Galvinox.

D. Thread coating: For use with threaded stainless steel fasteners:
   1. Manufacturers: One of the following or equal:
      a. Bostik, Never-Seez.
      b. Oil Research, Inc., WLR No. 111.

PART 3 EXECUTION

3.01 EXAMINATION

A. Examine Work in place to verify that it is satisfactory to receive the Work of this Section. If unsatisfactory conditions exist, do not begin this Work until such conditions have been corrected.

3.02 INSTALLATION - GENERAL

A. Where anchors and fasteners are not specifically indicated on the Drawings or specified, make attachments with materials specified in this Section.

B. Substitution of anchor types:
   1. Post-installed anchors may not be used as an alternative to cast-in/built-in anchors at locations where the latter are indicated on the Drawings.
   2. Cast-in/built-in anchors may be used as an alternative to post-installed mechanical anchors at locations where the latter are indicated on the Drawings.

C. Protect products from damage during installation. Protect threads and threaded ends.

D. Accurately locate and position anchors and fasteners:
   1. Unless otherwise indicated on the Drawings, install anchors perpendicular to the surfaces from which they project.
   2. Install anchors so that at least 2 threads, but not more than 1/2 inch of threaded rod, projects past the top nut.

E. Interface with other products:
   1. Where steel anchors come in contact with dissimilar metals (aluminum, stainless steel, etc.), use stainless steel anchors and separate or isolate dissimilar metals using isolating sleeves and washers.
   2. Prior to installing nuts, coat threads of stainless steel fasteners with thread coating to prevent galling of threads.

3.03 INSTALLATION - CAST-IN ANCHORS

A. General:
   1. Accurately locate cast-in and built-in anchors.
      a. Provide anchor setting templates to locate anchor bolts and anchor rods. Secure templates to formwork.

b. Brace or tie off embedments as necessary to prevent displacement during placement of plastic concrete or of surrounding masonry construction.
c. Position and tie cast-in and built-in anchors in place before beginning placement of concrete or grout. Do not “stab” anchors into plastic concrete, mortar, or grout.
d. Do not allow cast-in anchors to touch reinforcing steel. Where cast-in anchors are within 1/4 inch of reinforcing steel, isolate the metals by wrapping the anchors with a minimum of 4 wraps of 10-mil polyvinyl chloride tape in area adjacent to reinforcing steel.

2. For anchoring at machinery bases subject to vibration, use 2 nuts, with 1 serving as a locknut.
3. Where anchor bolts or anchor rods are indicated on the Drawings as being for future use, thoroughly coat exposed surfaces that project from concrete or masonry with non-oxidizing wax. Turn nuts down full length of the threads, and neatly wrap the exposed thread and nut with a minimum of 4 wraps of 10-mil waterproof polyvinyl tape.

B. Anchor bolts:
1. Minimum effective embedment: 10-bolt diameters, unless a longer embedment is indicated on the Drawings.
2. Where indicated on the Drawings, set anchor bolts in galvanized steel or stainless steel sleeves to allow for adjustment.
a. Fill sleeves with grout as indicated on the Drawings and as specified in Section 03600 - Grouting.

3.04 INSTALLATION - POST-INSTALLED ADHESIVE ANCHORS

A. Epoxy and acrylic adhesive bonding of reinforcing bars, all thread rods, and internally threaded inserts in concrete: As specified in Section 03055 - Adhesive-Bonded Reinforcing Bars and All Thread Rods in Concrete.

3.05 INSTALLATION - POST-INSTALLED MECHANICAL ANCHORS

A. General:
1. Install anchors in accordance with the manufacturer’s instructions, ACI 355.2, the anchor’s ICC-ES report. Where conflict exists between the ICC-ES report and the requirements specified in this Section, the requirements of the ICC-ES report shall control.
2. Where anchor manufacturer recommends the use of special tools and/or specific drill bits for installation, provide and use such tools.
3. After anchors have been positioned and inserted into concrete or masonry, do not:
a. Remove and reuse/reinstall anchors.
b. Loosen or remove bolts or studs.

B. Holes drilled into concrete and masonry:
1. Do not drill holes in concrete or masonry until the material has achieved its minimum specified compression strength (f’c or f’m).

2. Accurately locate holes:
    a. Before drilling holes, use a reinforcing bar locator to identify the position of reinforcing steel, conduit, and other embedded items within a 6-inch radius of each proposed hole.
    b. If the hole depth exceeds the range of detection for the rebar locator, the Engineer may require radiographs of the area designated for investigation before drilling commences.
3. Exercise care to avoid damaging existing reinforcement and other items embedded in concrete and masonry.
    a. If embedments are encountered during drilling, immediately stop work and notify the Engineer. Await the Engineer's instructions before proceeding.
4. Unless otherwise indicated on the Drawings, drill holes perpendicular to the concrete surface into which they are placed.
5. Drill using anchor manufacturer's recommended equipment and procedures:
    a. Unless otherwise recommended by the manufacturer, drill in accordance with the following:
        1) Drilling equipment: Electric or pneumatic rotary type with light or medium impact. Where edge distances are less than 2 inches, use lighter impact equipment to prevent micro-cracking and concrete spalling during drilling process.
        2) Drill bits: Carbide-tipped in accordance with ANSI B212.15. Hollow drills with flushing air systems are preferred.
6. Drill holes at manufacturer's recommended diameter and to depth required to provide the effective embedment indicated.
7. Clean and prepare holes as recommended by the manufacturer and as required by the ICC-ES report for that anchor.
    a. Unless otherwise recommended by anchor manufacturer, remove dust and debris using brushes and clean compressed air.
    b. Repeat cleaning process as required by the manufacturer's installation instructions.
    c. When cleaning holes for stainless steel anchors, use only stainless steel or non-metallic brushes.

C. Insert and tighten (or torque) anchors in accordance with the manufacturer's installation instructions.
    1. Once anchor is tightened (torque), do not attempt to loosen or remove its bolt or stud.

D. Concrete anchors: Minimum effective embedment lengths unless otherwise indicated on the Drawings:

Concrete Anchors			
	Minimum Effective Embedment Length		**Minimum Member Thickness**
Nominal Diameter	**In Concrete**	**In Grouted Masonry**	
3/8 inch	2-1/2 inch	2-5/8 inch	8 inch
1/2 inch	3-1/2 inch	3-1/2 inch	8 inch
5/8 inch	4-1/2 inch	4-1/2 inch	10 inch
3/4 inch	5 inch	5-1/4 inch	12 inch

E. Flush shell anchors:
   1. Not permitted in the Work.
   2. If equipment manufacturer's installation instructions recommend the use of flush shell anchors, contact the Engineer for instructions before proceeding.

F. Sleeve anchors:
   1. Minimum effective embedment lengths unless otherwise indicated on the Drawings:

Sleeve Anchors			
	Minimum Effective Embedment Length		Minimum Member Thickness
Nominal Diameter	In Concrete	In Grouted Masonry	
M8 (1/2 inch)	70 mm (2-3/4 inch)	Not accepted	100 mm (8 inch)
M10 (5/8 inch)	76 mm (3 inch)	Not accepted	250 mm (10 inch)
M12 (3/4 inch)	80 mm (3-1/4 inch)	Not accepted	300 mm (12 inch)

   2. Install with the sleeve fully engaged in the base material.

G. Screw anchors:
   1. Minimum effective embedment lengths unless otherwise indicated on the Drawings:

Screw Anchors			
	Minimum Effective Embedment Length		Minimum Member Thickness
Nominal Diameter	In Concrete	In Grouted Masonry	
3/8 inch	2-1/2 inch	3-1/4 inch	8 inch
1/2 inch	3-1/4 inch	4-1/2 inch	8 inch
5/8 inch	4 inch	5 inch	10 inch
3/4 inch	5-1/2 inch	6-1/4 inch	12 inch

   2. Install using equipment and methods recommended by the manufacturer. Continue driving into hole until the washer head is flush against the item being fastened.

H. Undercut concrete anchors:
   1. Minimum effective embedment lengths unless otherwise indicated on the Drawings:

Undercut Anchors			
Nominal Diameter (bolt)	Minimum Effective Embedment Length		Minimum Member Thickness[(1)]
	In Concrete	In Grouted Masonry	
M10 (3/8 inch)	100 mm (4 inch)	Not accepted	200 mm (8 inch)
M12 (1/2 inch)	125 mm (5 inch)	Not accepted	350 mm (14 inch)
M16 (5/8 inch)	190 mm (7-1/2 inch)	Not accepted	460 mm (18 inch)
M20 (7/8 inch)	250 mm (10 inch)	Not accepted	510 mm (20 inch)

Undercut Anchors			
Nominal Diameter (bolt)	Minimum Effective Embedment Length		Minimum Member Thickness[(1)]
	In Concrete	In Grouted Masonry	

Notes:

(1) Thickness indicated is for pre-set units. If through-set units are accepted, obtain minimum member thickness requirements from the Engineer.

2. Installations of undercut anchors shall not be allowed where edge distances are less than 12 times the nominal diameter of the anchor stud.
3. Undercut bottom of hole using cutting tools manufactured for this purpose by the manufacturer of the undercut anchors being placed.

3.06 FIELD QUALITY CONTROL

A. Provide quality control over the Work of this Section as specified in Section 01450 - Quality Control.
   1. Expenses associated with Work described by the following paragraphs shall be paid by the Contractor.

B. Post-installed anchors:
   1. Review anchor manufacturer's installation instructions and requirements of the Evaluation Service report (hereafter referred to as "installation documents") for each anchor type and material.
   2. Observe hole-drilling and cleaning operations for conformance with the installation documents.
   3. Certify in writing that the depth and location of anchor holes, and the torque applied for setting the anchors conforms to the requirements of the installation documents.

3.07 FIELD QUALITY ASSURANCE

A. Owner's representative will provide on-site observation and field quality assurance for the Work of this Section.
   1. Expenses associated with work described by the following paragraphs shall be paid by the Owner.

B. Field inspections and special inspections:
   1. Required inspections: Observe construction for conformance to the approved Contract Documents, the accepted Submittals, and the manufacturer's installation instructions for the products used.
   2. Record of inspections:
      a. Maintain record of each inspection.
      b. Submit copies to the Engineer upon request.
   3. Statement of special inspections: At the end of the Project, prepare and submit to the Engineer and the authority having jurisdiction inspector's statement that the Work was constructed in general conformance with the approved Contract Documents, and that deficiencies observed during construction were resolved.

C. Special inspections: Anchors cast into concrete and built into masonry.
   1. Provide special inspection during positioning of anchors and placement of concrete or masonry (including mortar and grout) around the following anchors:
      a. Anchor bolts.
   2. During placement, provide continuous special inspection at each anchor location to verify that the following elements of the installation conform to the requirements of the Contract Documents.
      a. Anchor:
         1) Type and dimensions.
         2) Material: Galvanized steel, Type 304 stainless steel or Type 316 stainless steel, as specified in this Section or indicated on the Drawings.
         3) Positioning: Spacing, edge distances, effective embedment, and projection beyond the surface of the construction.
         4) Reinforcement at anchor: Presence, positioning, and size of additional reinforcement at anchors indicated on the Drawings.
   3. Following hardening and curing of the concrete or masonry surrounding the anchors, provide periodic special inspection to observe and confirm the following:
      a. Base material (concrete or grouted masonry):
         1) Solid and dense concrete or grouted masonry material within required distances surrounding anchor.
         2) Material encapsulating embedment is dense and well-consolidated.

D. Special inspections: Post-installed mechanical anchors placed in hardened concrete and in grouted masonry.
   1. Provide special inspection during installation of the following anchors:
      a. Concrete anchors.
   2. Unless otherwise noted, provide periodic special inspection during positioning, drilling, placing, and torquing of anchors.
      a. Provide continuous special inspection for post-installed anchors in “overhead installations” as defined in this Section.
   3. Requirements for periodic special inspection:
      a. Verify items listed in the following paragraphs for conformance to the requirements of the Contract Documents and the Evaluation Service report for the anchor being used. Observe the initial installation of each type and size of anchor, and subsequent installation of the same anchor at intervals of not more than 4 hours.
         1) Any change in the anchors used, in the personnel performing the installation, or in procedures used to install a given type of anchor shall require a new “initial inspection.”
      b. Substrate: Concrete or masonry surfaces receiving the anchor are sound and of a condition that will develop the anchor’s rated strength.
      c. Anchor:
         1) Manufacturer, type, and dimensions (diameter and length).
         2) Material (galvanized, Type 304 stainless steel, or Type 316 stainless steel).
      d. Hole:
         1) Positioning: Spacing and edge distances.
         2) Drill bit type and diameter.
         3) Diameter, and depth.

4) Hole cleaned in accordance with the manufacturer's required procedures. Confirm multiple repetitions of cleaning when recommended by the manufacturer.
5) Anchor's minimum effective embedment.
6) Anchor tightening/installation torque.

4. Requirements for continuous special inspection:
   a. Special inspector shall observe all aspects of anchor installation, except that holes may be drilled in their absence provided that they confirm the use of acceptable drill bits before drilling, and later confirms the diameter, depth, and cleaning of drilled holes.

E. Field tests:
1. Owner's Representative may, at any time, request testing to confirm that materials being delivered and installed conform to the requirements of the Specifications.
   a. If such additional testing shows that the materials do not conform to the specified requirements, the Contractor shall pay the costs of these tests.
   b. If such additional testing shows that the materials do conform to the specified requirements, the Owner shall pay the costs of these tests.

3.08 NON-CONFORMING WORK

A. Remove misaligned or non-performing anchors.

B. Fill empty anchor holes and repair failed anchor locations using non-shrink cement grout as specified in Section 03600 - Grouting, unless otherwise directed by the Engineer.

C. If more than 10 percent of all tested anchors of a given diameter and type fail to achieve their specified torque or proof load, the Engineer will provide directions for required modifications. Make such modifications, up to and including replacement of all anchors, at no additional cost to the Owner.

3.09 SCHEDULES

A. Stainless steel: Provide and install stainless steel anchors at the following locations:
1. "Corrosive locations" as defined in this Section: Type 316 stainless steel.
2. "Wet and moist locations" as defined in this Section: Type 316 stainless steel.
3. "Other locations:"
   a. For connecting steel members to concrete or masonry: Type 304 stainless steel.
   b. For connecting aluminum members to concrete or masonry.
4. At locations indicated on the Drawings.

B. Provide and install anchor materials as scheduled in the following table.

Required Anchoring Materials by Location				
Location/Exposure			**Materials**	**Notes**
1.	**Anchors into concrete and grouted masonry for attachment of carbon steel, including structural steel and other steel fabrications:**			
a.	Interior dry areas		Carbon steel - galvanized	
b.	Locations with galvanized steel structures or fabrications		Stainless steel - Type 304 or 316	1
c.	Exterior and interior wet and moist locations		Stainless steel - Type 316	1
d.	Corrosive locations		Stainless steel - Type 316	1
2.	**Anchors into concrete and grouted masonry for attachment of aluminum, stainless steel, or fiber-reinforced plastic (FRP) shapes and fabrications:**			
a.	Interior dry areas		Stainless steel - Type 304 or 316	1
b.	Exterior and interior wet and moist locations		Stainless steel - Type 316	1
c.	Corrosive locations		Stainless steel - Type 316	1
3.	**Anchors for attaching equipment and its appurtenances:**			
a.	All locations		Stainless steel - Type 316 (unless Type 304 is specifically indicated in the specifications for the equipment.)	1

Notes:

(1) Where anchors are in contact with a metal that differs from that of the anchor, provide isolation sleeves and washers.

END OF SECTION

SECTION 05500

METAL FABRICATIONS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Aluminum grating stair tread.
   2. Aluminum stair nosing.
   3. Cast iron stop plank grooves.
   4. Concrete inserts.
   5. Handrails and guardrails.
   6. Ladders.
   7. Manhole frames and covers.
   8. Metal gratings.
   9. Metal tread plate.
   10. Preformed channel pipe supports.
   11. Stairs.
   12. Miscellaneous metals.
   13. Associated accessories to the above items.

1.02 REFERENCES

A. Aluminum Association (AA):
   1. DAF-45: Designations from Start to Finish.
      a. M12-C22-A41.

B. American Association of State Highway and Transportation Officials (AASHTO):
   1. Standard Specifications for Highway Bridges.

C. American Welding Society (AWS):
   1. A2.4 - Standard Symbols for Welding, Brazing, and Nondestructive Examination.

D. ASTM International (ASTM):
   1. A36 - Standard Specification for Carbon Structural Steel.
   2. A48 - Standard Specification for Gray Iron Castings.
   3. A53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded, and Seamless.
   4. A123 - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   5. A240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels for General Applications.
   6. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   7. A307 - Standard Specification for Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength.

8. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
9. A489 - Standard Specification for Carbon Steel Lifting Eyes.
10. A500 - Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
11. A501 - Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.
12. A635 - Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for.
13. A653 - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
14. A992 - Standard Specification for Structural Steel Shapes.
15. B209 - Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.
16. B221 - Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes.
17. B308 - Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles.
18. B429 - Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube.
19. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws and Studs.
20. F3125 - Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength.

E. National Association of Architectural Metal Manufacturers (NAAMM):
1. Metal Finishes Manual.

F. Occupational Safety and Health Administration (OSHA).

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
1. Passivation: Removal of exogenous iron or iron compounds from the surface of a stainless steel by means of chemical dissolution resulting from treatment with an acid solution that removes the surface contamination but does not significantly affect the stainless steel itself.

1.04 SUBMITTALS

A. Product data:
1. Aluminum grating stair tread.
2. Aluminum stair nosing.
3. Cast iron stop plank grooves.
4. Handrails and guardrails.
5. Manhole frames and covers.
6. Metal grating.

B. Shop Drawings:
   1. Handrails and guardrails:
      a. Including details on connection attachments, gates, kick plates, ladders, and angles.
      b. Indicate profiles, sizes, connection attachments, reinforcing, anchorage, size and type of fasteners, and accessories.
      c. Include erection drawings, elevations, and details where applicable.
      d. Indicate welded connections using standard AWS A2.4 welding symbols. Indicate net weld lengths.
   2. Ladders.
   3. Metal grating.
   4. Metal tread plate.
   5. Stairs.
   6. Miscellaneous metals.

C. Samples:
   1. Guardrails with specified finishes.

D. Quality Control Submittals:
   1. Design data.
   2. Test reports:
      a. Guardrails: 3 copies of certified tests performed by an independent testing laboratory certifying that guardrails meet current state and OSHA strength requirements.
      b. Gratings:
         1) Grating manufacturers' calculations showing that gratings will meet specified design load, stress, and deflection requirements for each size grating for each span.
         2) Reports of tests performed.

PART 2 PRODUCTS

2.01 MATERIALS

A. Unless otherwise specified or indicated on the Drawings, structural and miscellaneous metals in accordance with the standards of the ASTM, including the following:

Item	ASTM Standard No.	Class, Grade Type, or Alloy No.
Cast Iron		
Cast iron	A48	Class 40B
Steel		
Galvanized sheet iron or steel	A653	Coating G90
Coil (plate)	A635	--
Structural plate, bars, rolled shapes, and miscellaneous items (except W shapes)	A36	--
Rolled W shapes	A992	Grade 50

Item	ASTM Standard No.	Class, Grade Type, or Alloy No.
Standard bolts, nuts, and washers	A307	--
High strength bolts, nuts, and hardened flat washers	F3125, Grade A325	--
Eyebolts	A489	Type 1
Tubing, cold-formed	A500	--
Tubing, hot-formed	A501	--
Steel pipe	A53	Grade B
Stainless Steel		
Plate, sheet, and strip	A240	Type 304* or 316**
Bars and shapes	A276	Type 304* or 316**
Bolts (Type 304)	F593	Group 1 Condition CW
Bolts (Type 316)	F593	Group 2 Condition CW
Aluminum		
Flashing sheet aluminum	B209	Alloy 5005-H14, 0.032 inches minimum thickness
Structural sheet aluminum	B209	Alloy 6061-T6
Structural aluminum	B209, B308	Alloy 6061-T6
Extruded aluminum	B221	Alloy 6063-T42
Notes: * Use Type 304L if material will be welded. ** Use Type 316L if material will be welded.		

1. Stainless steels are designated by type or series defined by ASTM.
2. Where stainless steel is welded, use low-carbon stainless steel.

2.02 MANUFACTURED UNITS

A. Aluminum grating stair tread:
   1. Manufacturers: One of the following or equal:
      a. Harsco Industrial IKG, Aluminum Grating Stair Tread with Mebac® nosing.
      b. McNichols Co., Type A-Standard with corrugated angle nosing.
   2. Material: Welded aluminum grating tread with non-slip nosing and integral end plates for bolt on attachment to stair stringers.
   3. Size:
      a. Tread width: To equal tread spacing plus 1 inch minimum.
      b. Tread length: Length to suit stringer-to-stringer dimension indicated on the Drawings.
      c. Depth: 1-3/4 inches.
   4. Bolts: Type 316 stainless steel.

B. Aluminum stair nosing:
   1. Manufacturers: One of the following or equal:
      a. American Safety Tread Co., Inc., Style 801 nosing.

b. Wooster Products, Inc., Type 101 nosing.

2. Material: Cast aluminum abrasive nosings with aluminum oxide granules integrally cast into metal, forming permanent, nonslip, long-wearing surface.
3. For installation in cast-in-place stairs.
4. Configuration: 4 inches wide, fabricated with integrally cast stainless steel anchors at approximately 12-inch centers. Length to extend within 3 inches of stair edge on each side.

C. Cast iron stop plank grooves:
1. Manufacturers: One of the following or equal:
   a. McKinley Iron Works, Type L.
   b. Neenah Foundry Co., R-7500 Series, Type A.
2. Size: 2-inch wide groove opening by 1-1/2 inch deep, unless otherwise indicated on the Drawings.
3. Recess groove with the cast iron surface of the groove set flush with the concrete surface.

D. Concrete inserts:
1. For supporting pipe and other applications are specified in Section 15061 - Pipe Supports.

E. Handrails and guardrails:
1. General:
   a. Design and fabricate assemblies shall be in accordance with current local, state, and OSHA standards and requirements.
   b. Coordinate layout of assemblies and post spacings to avoid conflicts with equipment and equipment operators:
      1) Indicate on the Shop Drawings locations of such equipment.
      2) Highlight locations where railings cannot be made continuous, and obtain the Engineer's directions on how to proceed before fabricating or installing railings.
2. Aluminum handrails and guardrails (nonwelded pipe):
   a. Rails, posts, and fitting-assembly spacers:
      1) In accordance with ASTM B429, 6005, 6063 or 6105, minimum Schedule 40, extruded aluminum pipe of minimum 1.89-inch outside diameter and 0.14-inch wall thickness.
   b. Kick plates: 6061 or 6105 aluminum alloy.
   c. Fastenings and fasteners: As recommended or furnished by the manufacturer.
   d. Other parts: 6063 extruded aluminum, or F214 or F514.0 aluminum castings:
      1) Fabrications: In accordance with ASTM B209 or ASTM B221 extruded bars:
         a) Bases: 6061 or 6063 extruded aluminum alloy.
      2) Plug screws or blind rivets: Type 305 stainless steel.
         a) Other parts: Type 300 series stainless steel.

e. Finish of aluminum components:
1) Anodized finish, 0.7 mil thick, applied to exposed surfaces after cutting.
a) AA DAF-25 Specification M12-C22-A41: Mechanical finish non specular as fabricated, chemical finish-medium matte, anodic coating-clear Class I Architectural.
2) Pretreat aluminum for cleaning and removing markings before anodizing.
f. Fabrication and assembly:
1) Fabricate posts in single, unspliced pipe length.
2) Perform without welding.
3) Do not epoxy bond the parts.
4) Maximum clear opening between assembled railing components as indicated on the Drawings.
g. Manufacturers: One of the following or equal:
1) Craneveyor Corp. Enerco Metals, C-V Rail.
2) Golden Railings, Riveted System.
3) Moultrie Manufacturing Co., Wesrail.
3. Guardrail gates:
a. Supplied by the guardrail manufacturer:
1) Of same material, quality, and workmanship as specified for guardrail system in which they will be installed.
2) Of design similar to that of handrail or railing system in which they will be installed.
b. Components: Gate frame, stainless steel self-closing device, hinges, gate stops, and durable self-locking type latch. Fabricate components in accordance with OSHA minimum strength requirements.
4. Fastenings and fasteners: As recommended or furnished by the guardrail manufacturer for use with this system.

F. Ladders:
1. General:
a. Type: Safety type in accordance with local, state, and OSHA standards as minimum. Furnish guards for ladder wells.
b. Size: 18 inches wide between side rails of length, size, shape, detail, and location indicated on the Drawings.
2. Aluminum ladders:
a. Material: 6063-T5 aluminum alloy.
b. Rungs:
1) 1-inch minimum solid square bar with 1/8-inch grooves in top and deeply serrated on all sides.
2) Capable of withstanding 1,000-pound load without failure.
c. Side rails: Minimum 4-inch by 1/2-inch flat bars.
d. Finish of aluminum components:
1) Anodized finish, 0.7 mil thick, applied to exposed surfaces after cutting.
a) AA DAF-45 Specification M12-C22-A41: Mechanical finish non specular as fabricated, chemical finish-medium matte, anodic coating-clear Class I Architectural.
2) Pretreat aluminum for cleaning and removing markings before anodizing.

e. Fabrication:
    1) Welded construction, of size, shape, location, and details indicated on the Drawings.
    2) For fixed ladders over 24 feet high, provide a fall prevention system designed in accordance with state and OSHA requirements.
f. Fall prevention system: Including, but not limited to, railing, brackets, clamps, 2 sleeves, and 2 belts, in accordance with OSHA safe climbing requirements:
    1) Manufacturers: One of the following or equal:
        a) North Consumer Products, Saf-T-Climb.
        b) Swager Communications, Climbers Buddy System.

G. Manhole frames and covers:
1. Material: Gray iron castings, in accordance with ASTM A48, Class 30-B.
2. Type: Heavy-duty traffic type, with combined minimum set weight of 265 pounds.
3. Machine horizontal and vertical bearing surfaces to fit neatly, with easily removable cover bearing firmly in frame without rocking.
4. Frame:
    a. Bottom flange type.
    b. Approximately 4-1/2-inches frame height.
    c. Dimensions as indicated on the Drawings.
        1) Minimum inside clear dimension may not be smaller than nominal diameter minus 2 inches.
5. Cover:
    a. Skid-resistant grid pattern design stamped with name of utility service provided by manhole, such as ELECTRICAL, SEWER, TELEPHONE, or WATER.
    b. Solid type without ventilation holes.
6. Finish: Unpainted.

H. Metal gratings:
1. General:
    a. Fabricate grating to cover areas indicated on the Drawings.
    b. Unless otherwise indicated on the Drawings, grating over an opening shall cover entire opening.
    c. Make cutouts in grating where required for equipment access or protrusion, including valve operators or stems, and gate frames.
    d. Band ends of grating and edges of cutouts in grating:
        1) End banding: 1/4 inch less than height of grating, with top of grating and top edge of banding flush.
        2) Cutout banding: Full height of grating.
        3) Use banding of same material as grating.
        4) Panel layout: Enable installation and subsequent removal of grating around protrusions or piping.
        5) Openings 6 inches and larger: Lay out grating panels with edges of 2 adjacent panels located on centerline of opening.
        6) Openings smaller than 6 inches: Locate opening at edge of single panel.

7) Where an area requires more than 1 grating section to cover area, clamp adjacent grating sections together at 1/4-points with fasteners acceptable to the Engineer.
8) Fabricate steel grating sections in units weighing not more than 50 pounds each.
9) Fabricate aluminum grating sections in units of weighing not more than 50 pounds each.
10) Gaps between adjacent grating sections shall not be more than the clear spacing between bearing bars.

e. When requested by the Engineer, test 1 section of each size grating for each span length involved on the job under full load:
1) Furnish a suitable dial gauge for measuring deflections.

f. Grating shall be aluminum, unless otherwise specified or indicated on the Drawings.

2. Aluminum grating:
a. Material for gratings, shelf angles, and rebates: 6061-T6 or 6063-T6 aluminum alloy, except crossbars may be 6063-T5 aluminum alloy.
b. Shelf angle concrete anchors: Type 304 or Type 316 stainless steel.
c. Grating rebate rod anchors: 6061-T6 or 6063-T6 aluminum alloy.
d. Bar size and spacing: As determined by the manufacturer to enable grating to support design load.
e. Design live load: A minimum of 100 pounds per square foot uniform live load on entire grating area, but not less than the live load indicated on the Drawings for the area where grating is located.
f. Maximum fiber stress for design load: 12,000 pounds per square inch.
g. Maximum deflection due to design load: 1/240 of grating clear span.
h. Maximum spacing of main grating bars: 1-1/8 inches clear between bars.
i. Minimum grating height: 1-1/2 inches.
j. Manufacturers: The following or equal:
1) Harsco Industrial IKG, Swaged Aluminum I-Bar with striated finish.

3. Heavy-duty steel grating:
a. Fabricated from structural steel and designed in accordance with AASHTO Standard Specifications for Highway Bridges, using H-20 loading.
b. Hot-dip galvanized after fabrication in accordance with ASTM A123.
c. Manufacturers: One of the following or equal:
1) Reliance Steel Products Co., Heavy-Duty Steel Grating.
2) Seidelhuber Metal Products, Inc., equivalent product.

I. Metal tread plate:
1. Having a raised figured pattern on one surface to provide improved traction.

J. Preformed channel pipe supports:
1. As specified in Section 15062 - Preformed Channel Pipe Support System.

K. Stairs:
1. Aluminum stairs:
a. Stringers: 6061-T6 aluminum alloy.
b. Stair treads:
1) Aluminum of same type specified under aluminum grating.

2) Of sizes indicated on the Drawings, and 1-3/4 inch minimum depth with cast abrasive type safety nosings.

c. Handrails and guardrails: Aluminum pipe specified under the aluminum handrails and guardrails (nonwelded pipe) article.

d. Fasteners: Type 304 or Type 316 stainless steel.

L. Miscellaneous aluminum:

1. Fabricate aluminum products, not covered separately in this Section, in accordance with the best practices of the trade and field assemble by riveting or bolting.
2. Do not weld or flame cut.

M. Miscellaneous cast iron:

1. Tough, gray iron, free from cracks, holes, swells, and cold shuts.
2. Quality such that hammer blow will produce indentation on rectangular edge of casting without flaking metal.
3. Before leaving the foundry, clean castings and apply 16-mil dry film thickness coating of coal-tar epoxy, unless otherwise specified or indicated on the Drawings.

N. Miscellaneous stainless steel:

1. Provide miscellaneous stainless steel items not specified in this Section as indicated on the Drawings or specified elsewhere.
   a. Fabricate and install in accordance with the best practices of the trade.
2. Cleaning and passivation:
   a. Following shop fabrication of stainless steel members, clean and passivate fabrications.
   b. Finish requirements: Remove free iron, heat tint oxides, weld scale and other impurities, and obtain a passive finished surface.
   c. Provide quality control testing to verify effectiveness of cleaning agents and procedures and to confirm that finished surfaces are clean and passivated.
      1) Conduct sample runs using test specimens with proposed cleaning agents and procedures as required to avoid adverse effects on surface finishes and base materials.
   d. Pre-clean, chemically descale (pickle), and final clean fabrications in accordance with the requirements of ASTM A380 to remove deposited contaminants before shipping.
      1) Passivation by citric acid treatment is not allowed.
         a) If degreasing is required before cleaning to remove scale or iron oxide, cleaning (pickling) treatments with citric acid are permissible; however, these treatments shall be followed by inorganic cleaners such as nitric-hydrofluoric acid.
      2) Provide acid descaling (pickling) in accordance with Table A1.1 of Annex A1 of ASTM A380.
      3) After pickling, final cleaning of stainless steel shall be in accordance with Part II of Table A2.1 of Annex A2 of ASTM A380.
   e. After cleaning, inspect using methods specified for “gross inspection” in ASTM A380.
   f. Improperly or poorly cleaned and passivated materials shall not be shipped and will not be accepted at the job site.

O. Miscellaneous structural steel:
   1. Provide miscellaneous structural steel items not specified in this Section as indicated on the Drawings or specified elsewhere.
      a. Fabricate and install in accordance with the best practices of the trade.

P. Isolating sleeves and washers:
   1. As indicated on the Drawings and as specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions:
   1. Examine work in place to verify that it is satisfactory to receive the Work of this Section.
   2. If unsatisfactory conditions exist, do not begin this work until such conditions have been corrected.

3.02 INSTALLATION

A. General:
   1. Install products as indicated on the Drawings, and in accordance with Shop Drawings and the manufacturer's printed instructions, as applicable, except where specified otherwise.
   2. Interface between materials:
      a. Dissimilar metals: Where steel comes in contact with dissimilar metals (aluminum, stainless steel, etc.), separate or isolate the dissimilar metals.
         1) Make application so that the isolating or protective barrier is not visible in the completed construction.
         2) Isolating sleeves and washers: As specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.
      b. Aluminum in contact with concrete or masonry: Coat aluminum surfaces as specified in Section 09960 - High Performance Coatings.
      c. Aluminum in contact with concrete or masonry.

B. Aluminum stair nosing:
   1. Install on treads of concrete stairs, including top tread on upper concrete slab.
   2. Omit where concrete is submerged.
   3. Cast in fresh concrete, flush with tread and riser faces. Install nosing in center of step.

C. Cast iron stop plank grooves:
   1. Recess stop plank grooves with cast iron surfaces of groove set flush with concrete surface.

D. Handrails and guardrails:
   1. General:
      a. Fasten pipe rails to fittings with Series 300 stainless steel pop rivets or flush set screws.

b. Make pipe cuts clean and straight, free of burrs and nicks, and square and accurate for minimum joint-gap.
c. Drill and countersink holes to proper size, as required for a tight flush fit of screws and other component parts.
d. Space attachment brackets as indicated in the manufacturer's instructions.

2. Aluminum pipe handrails and guardrails:
   a. During construction, keep exterior surfaces of handrails and guardrails covered with minimum 0.4 millimeters of heat shrink polyethylene film.
   b. Do not remove protective film before handrails and guardrails have been accepted by the Engineer or before other work in proximity of handrails and guardrails has been completed.
   c. Discontinue handrails and guardrails at lighting fixtures.
   d. Provide 1/8-inch diameter weep hole at base of each post.
   e. Space posts as indicated on the Drawings.
   f. Anchor posts into concrete by grouting posts into formed holes in concrete, into stainless steel sleeves cast in concrete; or bracket mount to face of concrete surfaces as specified and indicated on the Drawings.
   g. Space rails as indicated on the Drawings.
   h. Make adequate provision for expansion and contraction of kick plates and rails.
      1) Make provisions for removable sections where indicated on the Drawings.
   i. Make lower rails a single, unspliced length between posts, or continuous.
   j. Make top rails continuous whenever possible, and attach single, unspliced lengths to 3 posts minimum.
   k. Draw up fasteners tight with hand wrench or screwdriver.
   l. Space attachment brackets as indicated on the Drawings or in the manufacturer's installation instructions.
   m. Completed installation shall have handrails and railings rigid and free of play at joints and attachments.
   n. Protect handrail and guardrail finish from scratches, gouges, dents, stains, and other damage.
   o. Replace damaged or disfigured handrails and guardrails with new.
   p. Shortly before final acceptance of the Work, and after removal of protective polyethylene film, clean handrails and guardrails with mild detergent or with soap and water.
      1) After cleaning, thoroughly rinse handrails and guardrails and wipe with soft cloth.
   q. Erect guardrail straight, level, plumb, and true to the positions as indicated on the Drawings. Correct deviations from true line of grade, which are visible to the eye.

3. Guardrail gates:
   a. Install gate to be a vertical plane with the guardrail when in the closed position.
   b. Install hinges so that each gate can swing 180 degrees from the closed position to the fully open position.
   c. Install so that the gates swing to the walkway side of the guardrail only.
      1) Install gate stops on the stationary railing posts to prohibit gates from swinging in the wrong direction.
   d. Install gate frames, hinges, stops, and latches in accordance with OSHA minimum strength requirements.

E. Ladders:
   1. Secure to supporting surface with bent plate clips providing minimum 8 inches between supporting surface and center of rungs.
   2. Where exit from ladder is forward over top rung, extend side rails 3 feet and 3 inches minimum above landing, and return the rails with a radius bend to the landing.
   3. Where exit from ladder is to side, extend ladder 5 feet and 6 inches minimum above landing and rigidly secure at top.
   4. Erect rail straight, level, plumb, and true to position indicated on the Drawings:
      a. Correct deviations from true line or grade which are visible to the eye.

F. Manhole frames and covers:
   1. Installation: As recommended by the manufacturer.

G. Metal gratings:
   1. General:
      a. Allow 1/8-inch maximum clearance between ends of grating and inside face of vertical leg of shelf angles.
      b. Horizontal bearing leg of shelf angles shall be 2 inches minimum.
      c. Install aluminum plate or angles where necessary to fill openings at changes in elevation and at openings between equipment and grating.
      d. Install angle stops at ends of grating.
      e. Installed grating shall not slide out of rebate or off support.
      f. Weld stops in place, unless otherwise specified or indicated on the Drawings.
      g. Top surfaces of grating sections adjacent to each other shall lie in same plane.
   2. Aluminum grating:
      a. Support on aluminum shelf angles or rebates.
   3. Heavy-duty steel grating:
      a. Support on hot-dip galvanized structural steel rebates embedded and anchored in concrete.
      b. Use for roadways, traffic areas, and where indicated on the Drawings.

H. Stairs:
   1. Install guard railings around stair wells as indicated on the Drawings or specified.

I. Stainless steel:
   1. Welding:
      a. Passivate field-welded surfaces:
         1) Provide cleaning, pickling and passivating as specified in this Section.
         2) Clean using Derustit stainless steel cleaner, or equal.

END OF SECTION

SECTION 06608

FIBERGLASS REINFORCED PLASTIC

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. General fabrication and design requirements for fiberglass reinforced plastic fabrications.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. RTP-1 - Reinforced Thermoset Plastic Corrosion Resistant Equipment.

B. ASTM International (ASTM):
   1. C582 - Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment.
   2. D883 - Standard Terminology Relating to Plastics.
   3. D2563 - Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts.
   4. D2583 - Standard Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.
   5. D2584 - Standard Test Method for Ignition Loss of Cured Reinforced Resins.
   6. D3299 - Standard Specification for Filament-Wound Glass Fiber Reinforced Thermoset Resin Corrosion-Resistant Tanks.
   7. D4097 - Standard Specification for Contact-Molded Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Chopped glass: Fibrous material consisting of randomly oriented chopped filaments applied directly to a mold surface or laminated under construction by a chopper gun.
   2. Equipment: Fiberglass reinforced plastic equipment, including ancillary equipment, work, and materials as described in this Specification.
   3. Fabrication drawings: Those drawings produced by the fabricator or Contractor with the intention of providing the necessary information to construct or install the equipment.
   4. Fiber prominence (Jackstraw): Distinct visibility of individual glass strands causing a loss of translucency of the laminate.
   5. Fiberglass reinforced plastic: Fiberglass reinforced plastic or glass fiber and resin fabrication consisting of approximately 35 to 55 percent glass fiber reinforcement by weight for hand lay-up structural laminates and 55 to

70 percent glass for filament wound structural laminates, unless otherwise specified.

6. Mat: Fibrous material consisting of randomly oriented chopped or swirled filaments loosely held together with a binder.
7. Terminology of this Specification is in accordance with ASTM D883. Fabricators using this Specification are responsible for correct interpretation.

1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals:

B. Shop Drawings and calculations:
   1. Submit general arrangement and fabrication drawings, calculations, and elements of the design.
   2. Include Submittal information which describes specifically how the equipment is to be built and details necessary to ascertain that products meet specified requirements. Provide in the form of drawings, standards, specifications, or other shop instructions, but may also be partially contained in quality control records. Submittal shall include, but not be limited to:
      a. Fabrication drawings.
      b. General arrangement drawings signed by an Engineer registered in the state where the Project is located, showing complete structural, fasteners, and erection procedures for a complete assembly.
      c. Quality control programs.
      d. Verification that the manufacturer has been engaged in fabrication of similar fiberglass reinforced plastic equipment for a minimum of 5 years.
      e. Statement of compliance with Contract design requirements, codes, and standards.
      f. Recommendation for each resin selection from the resin manufacturer.
      g. Type and amounts of fillers.
      h. Nominal corrosion liner description.
      i. Reinforcement types and glass content range for hand lay-up laminates.
      j. For filament wound laminates:
         1) Helix angle.
         2) Glass content range.
         3) Strand yield.
         4) Strand per inch in the winding band.
         5) Ply thickness.
         6) Amount of chop or unidirectional roving interspersed with winding, if any, and location within laminate.
      k. For other components:
         1) Construction type.
         2) Laminate thicknesses.
         3) Ply sequences.
         4) Glass content range.
      l. For secondary overlays (both interior and exterior):
         1) Laminate thicknesses.
         2) Ply sequences and widths.

m. Construction details: For assembly and other special configurations, including:
    1) Tank bottom/top attachments with knuckle configuration and overlays and thicknesses.
    2) Tank support and anchor lugs, including attachment details.
    3) Tank nozzles and installation, including cutout reinforcement, gusseting, and similar items.
    4) Tank lateral or other support fabrication details, including platform attachment clips and/or shoulders.
    5) Scrubber configuration and fabrication details of internal support system and other specialty items.
    6) Cover panel joints, anchorage detail, and details of doors and inspection ports and their attachment or incorporation within the cover.
n. Miscellaneous equipment required.
o. Test reports and certification of compliance with physical property requirements.
p. Color samples.
q. Manufacturer's installation instructions.
r. ASME RTP-1 certification.

C. Operation and maintenance data.

D. Warranty.

1.05 QUALITY ASSURANCE

A. Manufacturer qualifications: Fiberglass reinforced plastic manufacturer with experienced personnel, physical facilities, and management capacity sufficient to produce custom-made glass fiber and resin products of quality and size specified for a minimum of 5 years with satisfactory performance record.

B. Quality assurance plan: Fabricator shall be responsible for implementation of a comprehensive quality assurance plan. Quality assurance plan describes procedures with the following minimum requirements:
    1. Fabricator shall designate personnel to inspect equipment while in process and after completion to ensure compliance to every aspect of the Section and fabrication drawings.
        a. Inspection shall include, as a minimum, checks for visual defects, laminate thickness and sequence, glass content, Barcol hardness, dimensional tolerances, adherence to construction details, surface preparation, and environmental conditions.
        b. Fabricator's inspector shall complete a report of the findings, including method of measurement for each separate assembly.
    2. Prior to use of resins in fabrication, fabricator shall extract samples of resins and retain them for use by the Engineer. Sample size shall be 100 cubic centimeters minimum:
        a. Take 1 sample for each manufacturer's batch number if resin is received in the form it will be used.
        b. If the fabricator alters the resin after receipt, such as through the addition of styrene, promoters, or other additives, take samples from each drum or portion thereof mixed with additives.

c. Fabricator shall provide documentation for each sample, including resin type, manufacturer, batch and lot number, drum number, complete listing of additives with amounts added, and description and manufacturer of each additive.

3. Fabricator shall inspect glass reinforcement prior to use in fabrication.
   a. Do not use glass that does not meet the manufacturer's acceptance standards.
   b. Do not use glass material that is wet or has been wet.
   c. For each type of glass and lot number used, fabricator shall record the manufacturer, product description, binder type, product code, production date, and lot number.
   d. For mat, woven roving, unidirectional roving, and cloth, also include in records actual measured weight per square yard of material.
4. Fabricator shall retain nozzle cutouts and other excess laminate, clearly marking each piece to identify its original location. These laminate samples become the property of the Owner.
5. For areas where valid laminate samples are not available, take sample plugs at the Engineer's request.
   a. Repair subsequent holes in a manner acceptable to the Engineer.
6. Fabricator shall verify glass content on available samples in accordance with ASTM D2584. Complete this test and submit the results complete for each major component where samples are available.
7. Prior to final shipment of the equipment, fabricator shall submit to the Engineer a complete quality control report, consisting of copies of records maintained for compliance with this Section.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Design fiberglass reinforced plastic tanks, scrubbers, and other vessels following the procedures and methods, utilizing the equations and formulas, and incorporating safety factors and allowable design stresses and strains in accordance with ASME RTP-1.
   1. Base the design of duct and other fiberglass reinforced plastic equipment not covered by ASME RTP-1 on the engineering rationale, applicable formulas, and safety factors in accordance with ASME RTP-1.

B. Perform calculations necessary to ensure long-term, low risk service of the fiberglass reinforced plastic equipment with minimum reasonable maintenance requirements.
   1. Long-term, low risk service is defined as a service life of 20 years without major structural failure or leakage.
   2. Design shall ensure proper functioning of the equipment at the stated operating conditions.
   3. Design shall include as a minimum, engineering calculations, materials selection and documented physical and mechanical properties, and detailed drawings required for fabrication and assembly of the equipment.

C. Design in accordance with applicable national, regional, and local design and building codes.
   1. Wind and seismic forces shall be determined in accordance with the building code as specified in Section 01410 - Regulatory Requirements.

D. Resistance to overturning shall not include the weight of the liquid contained in the equipment.

E. Consider the interaction of the installed system, including, but not limited to, thermal expansion of duct, tanks, and vessels and the effects of external loading from piping, fans, pumps, platforms, and other attached items.

F. Allow for the most severe combination of conditions which may include, but not be limited to, the following:
   1. Internal or external pressure.
   2. Static head of contents (working and test conditions).
   3. Mass of structure and contents.
   4. Design temperature, including upset conditions.
   5. Superimposed loads, such as seismic and wind forces.
   6. Bending moments due to eccentric loads.
   7. Localized loads acting at supports, lugs, and other attachments.
   8. Shock loads.
   9. Loads due to heating or cooling and thermal gradients.
   10. Loads applied during transport or erection.
   11. Loads imposed by personnel during erection and operations.
   12. Fatigue.

G. Use safety factors and allowable strains specified in ASME RTP-1 unless otherwise specified. Do not use safety factors and allowable strains less than the following:
   1. Allowable hoop and axial strain shall be 0.001 inch per inch for filament wound tanks.
   2. A safety factor of 10 for hand lay-up components in tension, flexure, or other loading conditions where elastic stability is not in question.
   3. A safety factor of 5 for external loading (vacuum) or local buckling due to seismic or wind loading.

H. Safety factors for upset conditions or infrequent loading situations may be less than the above values for the specific condition if acceptable to the Engineer.

I. There will typically be other aspects which should be considered. Identify and consider their effects, identify design limitations, and submit this information.

J. Provide test reports or other documentation for laminate properties used in the design.
   1. Laminates shall be similar in construction, layer sequence, resin type, and cure to those used to determine tested properties.
   2. Properties shall be adjusted to reflect reductions at operating temperatures.
   3. Test reports shall be provided for:
      a. Grating: Indicate grating strength and deflection.
      b. Physical properties of test cover panels.
      c. Tanks showing conformance with specified strength requirements.

K. Corrosion liner shall be a minimum of 100 mils in thickness, unless otherwise specified, and documentation shall be provided verifying veil type, liner thickness, and resin cure.
   1. Consider 50 mils of the corrosion liner as sacrificial and do not include it in determining structural wall thickness.
   2. Use structural wall thickness not less than 0.375 inches for tanks and vessels and 0.1875 inches for ductwork.
   3. Submit minimum structural thicknesses of other types of fiberglass reinforced plastic fabrications.

L. Laminate types may include hand layup, helical winding, and hoop/chop construction methods.
   1. In laminates with helix angles greater than 80 degrees and in hoop/chop laminates, orientate approximately 10 percent of the structural wall thickness at 0 degrees (longitudinal direction).
   2. Apply this reinforcement in at least 2 layers of weft unidirectional fabric and equally spaced within the structural wall.

M. For tanks and scrubbers; nozzles, determine manways and shell reinforcements according to the tables and formulas in ASME RTP-1.

N. Anchor tanks and vessels using lugs and a continuous filament wound band or an integral filament wound load ledge with external stainless steel anchor clips.
   1. Anchor clips shall be bolted to the concrete foundation; use non-shrink grout to level anchor clips.
   2. Design shall resolve the sum of the moments and the sum of the force equal to 0.

O. Design internal beams and support attachments using a maximum of 200 pounds per square inch shear stress for secondary bonds. Also apply this to design of external lugs required for ladders, platforms, and other attached items.

2.02 RESIN AND REINFORCEMENT MATERIALS

A. General physical properties: In accordance with ASTM C582, ASTM D3299, ASTM D4097, and ASME RTP-1, with verification of properties.
   1. Physical properties may include tensile, flexural, and compression modulus of elasticity and ultimate strengths, limiting strains, Poisson ratios, coefficients of expansion, and other directional properties as required for the design of the equipment.

B. Resin:
   1. Fabricate equipment using the corrosion-resistant resin(s) specified in the fiberglass reinforced plastic equipment specifications.
      a. Fabricator is required to obtain independent endorsement of each resin selection from the resin manufacturer.
      b. Unless otherwise specified, use the resin throughout laminates.
   2. Type of catalyst recommended varies between resin manufacturers. Submit resin/catalyst before fabrication begins to verify compliance to the resin manufacturer’s recommended procedures.

3. Employ no fillers, additives, or pigments in the resin.
    a. A thixotropic agent for viscosity control may be used in the proportion and type recommended by the resin manufacturer.
    b. Use no thixotropic agent in the corrosion liner or on surfaces to be in contact with the corrosive environment.
4. Make resin putty using the same resin as was used in the original fabrication and shall contain milled glass fibers.
    a. Use of silica flour, grinding dust, or other fillers is not allowed.
5. When specified, add antimony trioxide or antimony pentoxide to the resin in the amount necessary to achieve the required fire retardancy rating in the structural wall only. Follow the resin manufacturer's recommendations.
    a. Unless otherwise specified, the corrosion liner shall not contain this additive.

C. Reinforcement:
1. Show the type and sequence of reinforcements to be used on the fabrication drawings.
2. Use as commercial grade corrosion-resistant borosilicate glass fiber reinforcement, unless otherwise specified.
3. Use glass fiber reinforcing having a surface finish and binder that is specifically recommended by the glass manufacturer for the particular resin system to be used.
4. Use Type C (chemical grade) glass, 10 mils (0.01 inches) thickness, or polyester surfacing veil, such as Nexus surfacing veils.
5. Use Type E (electrical grade) glass, 1-1/2 ounces or 3/4 ounce per square foot, with nominal fiber length of 1.25, within 0.75 inches mat.
6. Continuous glass roving used in chopper guns for spray up shall be Type E chopper roving.
7. Woven roving shall be 24 ounces per square yard Type E glass and have a 5-by-4 plain weave.
8. Continuous roving used in filament wound structures shall be Type E glass winder roving with a yield of 200 yards or more per pound.
9. Use Type E glass unidirectional fabric. Weft unidirectional fabric shall be 15.7 ounces per square yard.
10. When specified, use Type ECR glass reinforcements supplied in similar fabric styles to those specified above.

2.03 FABRICATION

A. Molds:
1. Construct molds of a suitable material to produce a smooth and glossy corrosion liner surface on the fiberglass reinforced plastic equipment.
2. Covering of mandrels with cardboard must be accepted by the Engineer prior to start of fabrication.

B. Laminates:
1. Determine specified glass content in accordance with ASTM D2584.
2. Consider laminate thicknesses shown on the fabrication drawings as construction minimums.
    a. Verify that minimum thicknesses are obtained using the laminate sequences specified.

b. When only total laminate thicknesses are specified or indicated on the Drawings, the minimum allowable structural laminate thickness shall be the total laminate thickness less the specified corrosion liner thickness.

3. Interruptions in laminating sequence shall follow the application of a ply of mat and be succeeded by a ply of mat.
4. Interruption shall not exceed 24 hours, and the in-process surface must retain acetone sensitivity until laminating is resumed. Lack of compliance with these aspects or indication that contamination of the surface has occurred shall require that surface preparation be accomplished before resuming.
5. Chopped strand glass applied by chopper gun is allowed in lieu of mat layers in the structural laminates only.
   a. Chopper gun application of the corrosion liner is not allowed.
6. Coat non-mold surfaces with resin containing wax additive in the amount necessary to allow full cure of the surface. In the case of exterior surfaces, this wax coat shall also contain an ultraviolet stabilizer in the type and amount recommended by the resin manufacturer.
7. Exterior surface of equipment shall be resin-rich and reinforced with 1 layer C glass surfacing veil, unless otherwise specified.
8. When specified, the exterior coat shall be an opaque pigmented surface coat, applied only after the Engineer's inspection. Color shall be selected by the Engineer.

C. Corrosion liner laminates:
1. Inner surface of laminates shall be resin-rich and reinforced with surfacing veil of the type and number of layers as shown on the fabrication drawings.
2. Interior layer of the corrosion liner shall consist of 1-1/2 ounces per square foot mat in the number of layers specified on the fabrication drawings. An exotherm interruption is specifically prohibited within the corrosion liner.
3. Chopped glass applied by chopper gun is not allowed in the corrosion liner.
4. Plies of the inner surface and interior layer are to gel completely before proceeding with the structural laminates.
5. Completed corrosion liner as described above shall contain not less than 20 percent nor more than 30 percent glass by weight.
   a. Use no thixotropic material in the resin for the liner, nor in the fabrication of fiberglass reinforced plastic components intended for internal service.
   b. Completed liner shall be the minimum thickness specified or indicated on the Drawings.
6. Do not use a separately cured unreinforced gel coat.

D. Hand lay-up structural laminates:
1. Corrosion liner laminate shall be followed by hand lay-up structural laminates of varying reinforcement sequences as indicated on the fabrication drawings.
2. For hand lay-up structural laminates, reinforcement shall consist of mat and woven roving in the sequence specified on the fabrication drawings.
3. Woven roving shall have a ply of mat on each side. 2 adjacent plies of woven roving are not permitted.
4. Laminates containing primarily 1-1/2 ounces per square foot mat layers in conjunction with woven roving shall contain not less than 35 percent or more than 45 percent glass (by weight).

5. Laminates containing primarily 3/4 ounce per square foot mat layers in conjunction with woven roving are considered to be high strength laminates and shall contain not less than 45 percent or more than 55 percent glass by weight.

E. Filament wound structural laminates:
   1. Corrosion liner laminate shall be followed by filament wound structural laminates as indicated on the fabrication drawings.
   2. For filament wound structural laminates, reinforcement shall consist of continuous strand fiberglass roving applied with a minimum of interruptions until the specified minimum thickness is attained.
      a. This laminate shall contain 55 to 70 percent glass by weight as indicated on the fabrication drawings.
   3. Each complete cycle of filament winding shall form a closed pattern of winding bands which completely covers the surface with 2 bi-directional layers.
      a. Each layer shall be a maximum of 1 roving in thickness.
      b. Uniformly space the filaments across the winding band without bunching or gaping.
   4. Specify the helix angle of winding on the approved fabrication drawings, as measured from the centerline of revolution of the equipment shell.
   5. Tolerance on helix angle is within 2 degrees, unless otherwise specified.
   6. Fabrication drawings may require that layers of unidirectional roving be interspersed within the continuous filament winding.
   7. Apply the unidirectional roving with the glass strand aligned in the axial direction to within 5 degrees.
   8. If layers of mat or chopped glass are needed to ensure proper bonding of unidirectional roving, or within the filament winding to accommodate the fabricator's manufacturing methods, consider the layers' extra material that will result in a thickness greater than specified.
      a. Amount of filament winding and unidirectional roving specified must still be applied.

F. Joining laminates:
   1. Fiberglass reinforced plastic joining laminates are subject to applicable requirements specified in other sections for laminates.
   2. Reinforce fiberglass reinforced plastic joints with an overlay of glass reinforcement and resin which extends equally within 1/2 inch on each side of the joint. Use minimum thickness, ply sequence, and ply widths of fiberglass reinforced plastic joints as indicated on the fabrication drawings.
   3. Restrain parts to be joined to prevent movement until completion and cure of the joint overlay.
   4. Fit-up parts and verify that tolerances and assembly requirements are satisfied. Completely fill the void between component parts with resin putty, taking care not to extrude an excessive amount of putty into the interior.

G. Environment:
   1. Fabrication process and materials at the point of fabrication are to be maintained within a range of 60 to 95 degrees Fahrenheit. This temperature must also be at least 5 degrees greater than wet bulb temperature, as measured with a sling psychrometer.
   2. Store materials in a dry area and within the temperature and humidity limits recommended by the manufacturers.

H. Flanges:
   1. Make flanges by hand lay-up construction with nozzle neck and flange made integrally in 1 piece and fabricated in accordance with the dimensions indicated on the fabrication drawings. Extend layers of reinforcement in the nozzle neck and hub uninterrupted into the flange.
   2. Build-up additional hub thickness using alternating layers of 1-1/2 ounces per square foot mat and 24 ounces per square yard woven roving.
   3. Build-up additional thickness in the flange using “ring” cutouts of mat, evenly distributed throughout the flange thickness.
   4. Press molded or filament wound flanges are not allowed.
   5. Overall machine facing of the back of flanges is not permitted.
      a. To obtain proper seating, spotface bolt holes for SAE size washers.
      b. Resin coat bolt holes and other cut surfaces so that no fibers are exposed.
      c. Spotfacing shall not produce a flange thickness less than indicated in the fabrication drawings.
   6. Bolt holes in flanges shall straddle principal centerlines of the equipment. Tolerance in bolt hole locations and in diameter of bolt circle shall be within 1/16 inch.
   7. Depressions or projections in flange face shall be no greater than 1/32 inch.

I. Allowable visual defects:
   1. Visual defects in areas of the equipment shall not exceed the maximum allowable levels specified in Table A, unless acceptable to the Engineer.
   2. In accordance with ASTM D2563.
   3. Presence of visual defects in excess of the allowable levels of Table A shall be grounds for rejection of the equipment. Listed quantities apply to small, localized areas and shall not be averaged over larger areas.

Table A - Maximum Allowable Levels Of Visual Defects

Condition/ Defect	Inner Surface(1)	Interior Mat Layers(2)	Structural Wall(3)	Exterior Surface(4)
Chip	None	None	None	
Crack	None	None	None	
Crazing	None	None	None	
Delamination	None	None	See Air Bubble	
Dry Spot	None	See Air Bubble	See Air Bubble	
Foreign Inclusion	None	Maximum Diameter 1/32”	See Air Bubble	
Fracture	None	None	None	None
Air Bubble/ Void	Less than 1/64” Ø unlimited. 1/64” to 1/16” Ø 2/sq. in. Maximum Diameter 1/16”	Less than 1/32” Ø unlimited. 1/32” to 1/8” Ø 5/sq. in. Maximum Diameter 1/8”	Less than 3/16” Ø unlimited. 3/16” to 1/4” Ø 2/sq. in. Maximum Diameter 1/4”	
Blister	See Air Bubble	See Air Bubble	See Air Bubble	
Burned	None	None	None	

Table A - Maximum Allowable Levels Of Visual Defects				
Condition/ Defect	**Inner Surface(1)**	**Interior Mat Layers(2)**	**Structural Wall(3)**	**Exterior Surface(4)**
Pit (Pinhole)	Less than 1/32" Ø 50/square feet. 1/32" to 1/16" Ø 10/square feet. Maximum Diameter 1/16" Maximum Depth 1/32"	N/A	N/A	
Resin Pocket	None	Maximum 1 square inch per occurrence	Maximum 1 square inch per occurrence	
Wrinkle	Allowable if laminate is glass reinforced. No sharp edges allowed.	Allowable if laminate is glass reinforced and full mat layer thickness and total thickness are maintained	Allowable if laminate is glass reinforced and full mat layer thickness and total thickness are maintained	
Scratch	None	N/A	N/A	
Fiber Prominence	None	Maximum 10 fibers visible per square inch	Maximum 20 fibers visible per square inch	

Notes:

Dimensions listed in this table refer to the largest dimension measured for defects.

(1) Inner surface: Interior process surface, thickness of surfacing veil(s), and interface between veils and mat layers. Includes surfacing veils on internal joints.
(2) Interior mat layers: Layers of mat following the inner surface, and interface between liner and structural wall. Includes mat layers on internal joints.
(3) Structural wall: Layers of filament winding or alternating layers of mat and woven roving following the corrosion liner, and layers of mat and woven roving in internal overlays.
(4) Exterior surface of the laminate and the thickness of the surfacing veil.

2.04 SOURCE QUALITY CONTROL

A. Inspection:
   1. Owner's inspection: Permit the Engineer access to the equipment during fabrication and upon completion for the purpose of verifying compliance with the Contract Documents. Inspection is not intended to replace the fabricator's own quality control procedures.
   2. In no respect does inspection of equipment by the Engineer relieve the fabricator of compliance with the Contract Documents.
      a. A final inspection will be performed by the Engineer.
   3. Fabricator shall notify the Engineer at the completion of particular milestones during fabrication. Milestones are as follows:
      a. View tooling prior to fabrication.
      b. Beginning application of corrosion liner for each part, extraction of each part prior to beginning assembly.
      c. Upon completion of each separate assembly, the Engineer reserves the right to include additional milestones.

4. Allow the Engineer to photograph the equipment while in process and/or upon completion.
5. Engineer may use magnification or other special viewing or measurement devices during inspection.
6. Evidence of poor workmanship or lack of compliance with aspects of the Contract Documents will be grounds for rejection of the equipment.
7. Subsequent repair of rejected equipment may, at the Engineer's option, be undertaken in an attempt to bring the equipment to an acceptable state.
    a. Repair procedures must be accepted by the Engineer prior to implementation.

2.05 TESTING

A. Engineer may employ destructive testing, such as ultimate tensile or flexure strength tests or glass content ignition tests, on available samples or use other non-destructive test methods, such as acoustic emission or ultrasonic polygauge thickness measurement, on the completed equipment for verification of compliance with the Contract Documents.

B. Testing performed by the Engineer will be accomplished through use of applicable ASTM test methods when appropriate.

C. Hardness tests will be made for acceptance by the Engineer on the liner surface using the Barcol impressor, Model GYZJ 934 1, calibrated at 2 points in accordance with ASTM D2583.
    1. 10 readings will be taken in a localized area, deleting the 2 highest and 2 lowest, and averaging the remaining 6.
    2. Minimum acceptable Barcol hardness will be a reading of 30, unless otherwise specified.

D. An acetone sensitivity test will also be performed by the Engineer as an acceptance criteria. Evidence of a sticky or tacky surface following rubbing with an acetone-saturated cloth will be grounds for rejection of the equipment.

PART 3 EXECUTION (NOT USED)

END OF SECTION

SECTION 06611

FIBERGLASS REINFORCED PLASTIC FABRICATIONS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Fiberglass reinforced plastic fabrications including:
      a. Weirs.

1.02 REFERENCES

A. American Water Works Association (AWWA):
   1. F 102 - Matched-Die-Molded, Fiberglass-Reinforced Plastic Weir Plates, Scum Baffles, and Mounting Brackets.

B. ASTM International (ASTM):
   1. D635 - Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position.
   2. D638 - Standard Test Method for Tensile Properties of Plastics.
   3. D790 - Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
   4. D2583 - Standard Test Method for Indentation of Hardness of Rigid Plastics by Means of a Barcol Impressor.
   5. E84 - Standard Test Method for Surface Burning Characteristics of Building Materials.

C. United States Department of Agriculture (USDA).

D. United States Department of the Interior:
   1. Bureau of Reclamation (USBR):
      a. ISO 9826 - Water Measurement Manual, Measurement of Liquid Flow in Open Channel.

1.03 SUBMITTALS

A. Submit general arrangement and fabrication drawings, calculations, and elements of the design for grating and stairs.

B. Product Data.

C. Manufacturer's Installation Instructions.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Parshall flume liner: Provide temporary bracing for liner to ensure maintenance of dimensions during shipment. Maintain bracing in place for installation.

PART 2 PRODUCTS

2.01 WEIR PLATES

A. General:
   1. In accordance with AWWA F 102, and as specified in this Section.

B. Materials:
   1. Laminate construction: Glass fiber-reinforced, chemical-resistant polyester resin.
      a. Glass content of laminate: Minimum 20 percent by weight.
      b. Resin fillers: Minimum 40 percent.
   2. Physical properties of laminate: Equal to or exceeding the tensile, flexural, impact, hardness, and water absorption properties specified in AWWA F 102.
   3. Performance criteria:
      a. Chemical resistance: Classification: AWWA F 102 Type II (chemical-resistant resin, filler and fabrications) and suitable for long-term exposure to process wastewater and sludge in municipal wastewater treatment plant.
   4. Color: Manufacturer's standard aqua/turquoise.

C. Fabrications:
   1. Fabricated to the shapes, dimensions, and details indicated on the Drawings and specified**,** and using processes as specified in this Section.
   2. Dimensions:
      a. Conform to tolerances in accordance with AWWA F 102, unless otherwise indicated.
      b. Final laminate thickness: Plus or minus 10 percent of nominal thickness.
   3. Fabricate weir plates with oversize holes to allow vertical adjustment.
   4. Seal cut edges of non-standard lengths, and edges of drilled and countersunk holes in fiberglass reinforced plastic fabrications with resin.
   5. Furnish fiberglass reinforced plastic lapped plate splices at joints.

D. Rectangular "flat crested" weirs:
   1. Fabrication:
      a. Molded to produce uniform, smooth surfaces.
      b. Tolerances: In accordance with AWWA F 102.
   2. Manufacturers: One of the following or equal:
      a. Glass Steel, Inc.
      b. MFG Water Treatment Products.
      c. NEFCO, Inc.
      d. Warminster Fiberglass.

E. Accessories:
   1. Washers: Of same material as weirs, with surfaces smooth, free of voids, and without dry spots and crazes.
   2. Assembly hardware: Concrete anchors as specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that conditions are satisfactory for installation of products as specified in Section 01600 - Product Requirements.

3.02 ERECTION AND INSTALLATION, GENERAL

A. Install products where indicated on the Drawings in accordance with manufacturer's printed instructions.

3.03 WEIRS

A. Carefully install weirs, aligning and leveling to the elevations indicated on the Drawings.

B. Installation tolerances:
   1. In the completed installation:
      a. The variation in elevation between any 2 points of the weir plate in a tank shall not exceed 1/16 inch.

END OF SECTION

SECTION 07900

JOINT SEALANTS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Acrylic-latex sealant.
   2. Silicone sealant.
   3. Synthetic rubber sealing compound.
   4. Synthetic sponge rubber filler.
   5. Related materials.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C920 - Standard Specification for Elastomeric Joint Sealants.
   2. C1330 - Standard Specification for Cylindrical Sealant Backing for Use with Cold Liquid-Applied Sealants.
   3. C1521 - Standard Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints.
   4. D412 - Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension.
   5. D624 - Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomer.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product Submittals:
   1. As specified in Section 01600 - Product Requirements.
   2. Product data.
   3. Shop Drawings.
   4. Samples, include color selections.
   5. Manufacturer’s instructions.
   6. Calculations.
   7. Schedules.

1.04 QUALITY ASSURANCE

A. Manufacturer qualifications: Manufacturer of proposed product for minimum of 5 years with satisfactory performance record.

B. Installer qualifications: Manufacturer approved installer of products similar to specified products on minimum 5 projects of similar scope as the Project with satisfactory performance record.

1.05 PROJECT OR SITE CONDITIONS

A. Do not apply sealant on wet or frosty surfaces or when surface temperature is higher than 100 degrees Fahrenheit or lower than recommended by the manufacturer.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle products in accordance with the manufacturer's recommendations.

B. Code date packages:
   1. Do not use material older than the manufacturer's published shelf life.
   2. Store materials at temperatures lower than 80 degrees Fahrenheit.
   3. Condition materials in accordance with the manufacturer's instructions prior to installation.

1.07 SEQUENCING AND SCHEDULING

A. Caulk joints prior to painting.

1.08 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

B. Warrant to correct defective products for a minimum of 1 year in accordance with the manufacturer's standard warranty.

PART 2 PRODUCTS

2.01 SEALANTS

A. General:
   1. Provide colors matching materials being sealed.
   2. Where compound is not exposed to view in finished work, provide the manufacturer's color which has best performance.
   3. Nonsagging sealant for vertical and overhead horizontal joints.
   4. Sealants for horizontal joints: Self-leveling pedestrian/traffic grade.
   5. Joint cleaner, primer, bond breaker: As recommended by the sealant manufacturer.
   6. Sealant backer rod and/or compressible filler made from closed cell polyethylene, polyethylene jacketed polyurethane foam, or other flexible, nonabsorbent, non-bituminous material recommended by the sealant manufacturer to:
      a. Control joint depth.
      b. Break bond of sealant at bottom of joint.
      c. Provide proper shape of sealant bead.
      d. Serve as expansion joint filler.

2.02 ACRYLIC-LATEX SEALANT

A. Permanently flexible, nonstaining, and nonbleeding latex modified acrylic sealant compound, colors as selected by the Engineer from the manufacturer's standard options.
   1. Manufacturers: One of the following or equal:
      a. Pecora Corp., AC-20.
      b. Sonneborn, Sonolac.
      c. Tremco, Tremflex 834.

2.03 SILICONE SEALANT

A. ASTM C920, Type S, Grade NS, Class 25, single component silicone sealant.
   1. Manufacturers: One of the following or equal:
      a. Dow Corning, 795.
      b. General Electric, 1200 Series.
      c. Pecora Corp., 864.
      d. Tremco, Proglaze.

2.04 SYNTHETIC RUBBER SEALING COMPOUND

A. Manufacturers: One of the following or equal:
   1. Pacific Polymers, Elastothane 227R.
   2. Sika Corporation, Sikaflex 2c NS or SL.

B. Material: In accordance with ASTM C920, Type M, Grade P (pourable), Class 25; and Type M, Grade NS (non-sag), Class 25; multi-part polyurethane; able to cure at room temperature to firm, highly resilient polymer; able to perform satisfactory when continuously submerged in water or sewage and exposed to direct sunlight in dry condition; with the following properties determined at 75 degrees Fahrenheit and 50 percent relative humidity.
   1. Base: Polyurethane rubber.
   2. Application time: Minimum 2 hours.
   3. Cure time: Maximum 3 days.
   4. Tack free time: Maximum 24 hours.
   5. Ultimate hardness: Non-sag 25, pourable/SL 40, within 5 Shore A.
   6. Tensile strength: Non-sag 95 pounds per square inch minimum and self-leveling minimum 170 pounds per square inch when tested in accordance with ASTM D412.
   7. Ultimate elongation: Minimum 340 percent when tested in accordance with ASTM D412.
   8. Tear resistance: Non-sag 45 pounds per inch minimum and self-leveling minimum 85 pounds per inch when tested in accordance with ASTM D624, Die C.
   9. Service temperature range: -25 degrees to 158 degrees Fahrenheit.

C. Color: Gray to match concrete, unless indicated on the Drawings.

2.05 SYNTHETIC SPONGE RUBBER FILLER

A. Closed-cell expanded sponge rubber manufactured from synthetic polymer neoprene base, or resilient polyethylene foam backer rod. In accordance with ASTM C1330, Type C.
   1. Manufacturers: The following or equal:
      a. Presstite, No. 750.3 Ropax Rod Stock.

B. Characteristics:
   1. Suitable for application intended.
   2. Strength: As necessary for supporting sealing compound during application.
   3. Resiliency: Resistance to environmental conditions of installation.
   4. Bonding: No bonding to the sealing compound.
   5. Structure: Cellular, prevents absorption of water.
   6. Compatibility with other materials in joint and acceptance by the manufacturer of the sealing compound.
   7. Size: Minimum 25 percent greater than nominal joint width.

2.06 RELATED MATERIALS

A. Primer: Nonstaining type, recommended by the sealant manufacturer to suit application.

B. Joint cleaner: Noncorrosive, nonstaining, compatible with joint forming materials and as recommended by the sealant manufacturer.

C. Bond breaker tape: Pressure-sensitive tape recommended by the sealant manufacturer to suit application.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify acceptability of joint dimensions, physical, and environmental conditions.

B. Verify that surfaces are dry, clean, and free of dirt, grease, curing compound, and other residue which might interfere with adhesion of sealants.

3.02 PREPARATION

A. Allow concrete to cure thoroughly before caulking.

B. Synthetic sponge rubber filler:
   1. Prepare surfaces designated to receive filler in accordance with the manufacturer’s installation instructions.
   2. Do not stretch filler beyond its normal length during installation.

C. Caulking:
   1. Verify that surfaces are dry, clean, and free of dirt, grease, curing compounds, and other residue that might interfere with adhesion of sealant.

2. Concrete, masonry, wood, and steel surfaces: Clean and prime in accordance with the manufacturer's instructions prior to caulking.

D. Synthetic rubber sealing compound:
   1. Ensure surfaces to which synthetic rubber must bond are dry and free of dust, dirt, and other foreign residue.
   2. Heavy sandblasted caulking groove to sound surface and prime with the manufacturer's recommended primer for particular surface.

E. For sidewalks, pavements, and similar joints sealed with elastomeric sealants and subject to traffic and other abrasion and indentation exposures, fill joints to depth equal to 75 percent of joint width, but neither more than 5/8 inches deep nor less than 3/8 inches deep.

F. For normal moving building joints sealed with elastomeric sealants not subject to traffic, fill joints to depth equal to 50 percent of joint width, but neither more than 1/2 inch deep nor less than 1/4 inch deep.

G. For joints sealed with acrylic-latex sealants, fill joints to depth in range of 75 percent to 125 percent of joint width.

H. Use joint filler to achieve required joint depths, to allow sealants to perform properly.

I. Prepare surfaces and install synthetic sponge rubber filler in accordance with the manufacturer's recommendations.

J. Do not stretch filler beyond normal length during installation.

K. Apply bond breaker when recommended by the joint sealer manufacturer.

3.03 INSTALLATION

A. Synthetic sponge rubber filler: Install in accordance with the manufacturer's installation instructions.

B. Caulking, joints, and sealing:
   1. Construct expansion, contraction, and construction joints as indicated on the Drawings.
   2. Install pipe and conduit in structures as indicated on the Drawings.
   3. Caulk doors, windows, louvers, and other items installed in or over concrete openings inside and out.
   4. Use synthetic rubber sealing compound for caulking where indicated on the Drawings or as specified, except for masonry construction and where specified otherwise.
   5. Complete caulking prior to painting.
   6. Verify that concrete is thoroughly cured prior to caulking.
   7. When filler compressible material is used, use untreated type.
   8. Apply caulking with pneumatic caulking gun.
   9. Use nozzles of proper shape and size for application intended.

10. Maintain continuous bond between caulking and sides of joint to eliminate gaps, bubbles, or voids and fill joint in continuous operation without layering of compound.
11. Employ experienced applicators to caulk joints and seams in neat workmanlike manner.
12. To hasten curing of compound when used on wide joints subject to movement, apply heat with infrared lamps or other convenient means.
13. Apply synthetic rubber sealing compound with pneumatic caulking tool or other acceptable method.

3.04 CLEANING

A. Clean surfaces adjacent to sealant as work progresses.

B. Remove excess uncured sealant by soaking and scrubbing with sealant cleaning solvent.

C. Remove excess cured sealant by sanding with No. 80 grit sandpaper.

D. Leave finished work in neat, clean condition.

3.05 SCHEDULE

A. Acrylic latex:
   1. Use where indicated on the Drawings.
   2. Interior joints with movement less than 7.5 percent and not subject to wet conditions.

B. Silicone:
   1. Use where indicated on the Drawings.
   2. Joints and recesses formed where window, door, louver and vent frames, and sill adjoin masonry, concrete, stucco, or metal surfaces.
   3. Door threshold bedding.
   4. Moist or wet locations, including joints around plumbing fixtures.
   5. Stainless steel doors and frames, including joints between applied stops and frames, and around anchor bolts.
   6. Plenum joints.

C. Synthetic rubber sealing compound, non-sag Type II:
   1. Use where indicated on the Drawings.
   2. Water-bearing and earth-bearing concrete structures.
   3. Joints in masonry, concrete vertical surfaces, and metal-faced panels in vertical surfaces.
   4. Joints between sheet metal flashing and trim.
   5. Joints between sheet metal flashing and trim, and vertical wall surfaces.
   6. Small voids between materials requiring filling for weathertight performance in vertical surfaces.
   7. Perimeters of frames of doors, windows, louvers, and other openings where bonding is critical to airtight performance.
   8. Expansion and control joints in masonry vertical surfaces.

D. Synthetic rubber sealing compound, self-leveling Type I:
   1. Use where indicated on the Drawings.
   2. Expansion and control joints in masonry, concrete horizontal surfaces, and metal panels in horizontal surfaces.
   3. Small voids between materials requiring filling for weathertight performance in horizontal surfaces.
   4. Pavement joints.
   5. Perimeters of frames of doors, windows, louvers, and other openings in horizontal surfaces where bonding is critical to airtight performance.

3.06 FIELD QUALITY CONTROL

A. Adhesion testing:
   1. Perform adhesion tests in accordance with ASTM C1521 and the following criteria:
      a. Water bearing structures: 1 test per every 1,000 linear feet of joint sealed.
      b. Chemical containment areas: 1 test per every 1,000 linear feet of joint sealed.
      c. Building expansion joints: 1 test per every 500 linear feet of joint sealed.
      d. All other type of joints, except butt glazing joints: 1 test per every 3,000 linear feet of joint sealed.
      e. Manufacturer's authorized factory representative provide written recommendations for remedial measures on failing tests.

END OF SECTION

SECTION 09960

HIGH-PERFORMANCE COATINGS

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ATTACHMENT A - SCHEDULE OF SURFACES TO BE COATED

ATTACHMENT B - COATING DETAIL SHEETS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Coatings, including coating systems, surface preparation, application requirements, and quality control requirements.

1.02 REFERENCES

A. Abbreviations:
   1. CMU - Concrete masonry units.
   2. CSA - Coating system applicator. Specialty subcontractor retained by the Contractor to perform surface repairs, surface preparations, and apply coating systems as specified in this Section.
   3. CSM - Coating system manufacturer.
   4. CTR - Coating system manufacturer's technical representative.
   5. DFT - Dry-film thickness. Thickness of cured film, usually expressed in mils (0.001 inch).
   6. VOC - Volatile organic compound. The portion of the coating that is a compound of carbon, is photochemically reactive, and evaporates during drying or curing; expressed in grams per liter (g/l) or pounds per gallon (lb/gal). VOC is determined by EPA Method 24.
   7. WFT - Wet film thickness. Coating thickness as measured immediately after application. Usually expressed in mils (0.001 inch).

B. Standards:
   1. ASTM International (ASTM):
      a. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
      b. A780 - Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
      c. D16 - Standard Terminology for Paint, Related Coatings, Materials, and Applications.
      d. D2200 - Standard Practice for Use of Pictorial Surface Preparation Standards and Guides for Painting Steel Surfaces.
      e. D3359 - Standard Test Methods for Rating Adhesion by Tape Test.
      f. D3960 - Standard Practice for Determining Volatile Organic Compound (VOC) Content of Paints and Related Coatings.
      g. D4262 - Standard Test Method for pH of Chemically Cleaned or Etched Concrete Surfaces.
      h. D4263 - Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method.
      i. D4285 - Standard Test Method for Indicating Oil or Water in Compressed Air.
      j. D4414 - Standard Practice for Measurement of Wet Film Thickness by Notch Gages.
      k. D4417 - Standard Test Methods for Field Measurement of Surface Profile of Blast-Cleaned Steel.
      l. D4787 - Standard Practice for Continuity Verification of Liquid or Sheet Linings Applied to Concrete Substrates.

m. D5162 - Standard Practice for Discontinuity (Holiday) Testing of Nonconductive Protective Coating on Metallic Substrates.
n. D7234 - Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers.
o. E337 - Standard Test Method for Measuring Humidity with a Psychrometer (the Measurement of Wet- and Dry-Bulb Temperatures).
p. F1869 - Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride.
q. F2170 - Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using In-situ Probes.

2. International Concrete Repair Institute (ICRI):
   a. 310.2 - Guideline for Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair.
3. NACE International (NACE):
   a. SP0178 - Design, Fabrication, and Surface Finish Practices for Tanks and Vessels to Be Lined for Immersion Service.
   b. SP0188 - Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.
4. National Association of Pipe Fabricators (NAPF):
   a. 500-03 - Surface Preparation Standard for Ductile Iron Pipe and Fittings in Exposed Locations Receiving Special External Coatings and/or Special Internal Linings.
5. NSF International (NSF):
   a. 61 - Drinking Water System Components - Health Effects.
   b. 600 - Health Effects Evaluation and Criteria For Chemicals In Drinking Water.
6. Occupational Safety and Health Administration (OSHA).
7. Society for Protective Coatings (SSPC):
   a. Glossary - SSPC Protective Coatings Glossary.
   b. Guide 6 - Guide for Containing Surface Preparation Debris Generated during Paint Removal Operations.
   c. PA 1 - Shop, Field, and Maintenance Painting of Steel.
   d. PA 2 - Procedure for Determining Conformance to Dry Coating Thickness Requirements.
   e. PA 9 - Measurement of Dry Coating Thickness Using Ultrasonic Gages.
   f. QP 1 - Field Application of Coatings to Complex Industrial and Marine Structures.
   g. QP 3 - Shop Application of Complex Protective Coating Systems.
   h. SP 1 - Solvent Cleaning.
   i. SP 2 - Hand Tool Cleaning.
   j. SP 3 - Power Tool Cleaning.
   k. SP 5 - White Metal Blast Cleaning.
   l. SP 7 - Brush-Off Blast Cleaning.
   m. SP 10 - Near-White Metal Blast Cleaning.
   n. SP 11 - Power Tools Cleaning to Bare Metal.
   o. SP 13 - Surface Preparation of Concrete.
   p. SP 16 - Brush-Off Blast Cleaning of Coated and Uncoated Galvanized Steel, Stainless Steels, and Non-Ferrous Metals.
   q. SP VIS 1 - Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning.

1.03 TERMINOLOGY

A. Definitions used in this Section are in accordance with definitions referenced in ASTM D16, ASTM D3960, and SSPC Glossary of Definitions.

B. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Abrasive: Material used for blast cleaning, such as sand, grit, or shot.
   2. Abrasive blast cleaning: Cleaning/surface preparation by abrasive propelled at high speed.
   3. Anchor pattern: Profile or texture of prepared surface(s).
   4. Biogenic sulfide corrosion: Corrosion caused by sulfuric acid formed when *Thiobacillus* bacteria metabolizes hydrogen sulfide.
   5. Bug holes: Small cavities resulting when air bubbles are entrapped in the surface of formed concrete during placement and consolidation.
   6. Dew point: Temperature a given air/water vapor mixture starts to condense.
   7. Dry to recoat: Time interval between material application and its ability to receive the next coat.
   8. Dry to touch: Time interval between material application and its ability to tolerate a light touch without coating damage.
   9. Drying time: Time interval between application and material curing.
   10. Exposed surface: Any indoor or outdoor surface not buried or encased.
   11. Feather edging: Reducing coating thickness at its edge to blend with existing surrounding coating.
   12. Ferrous: Cast iron, ductile iron, wrought iron, and all steel alloys, except stainless steel.
   13. Field coat: Application of a surface coating system at the work site.
   14. Finish coat: Final coat in a paint system, including texture, color, smoothness of surface, and other properties affecting appearance.
   15. Hold point: A defined point, specified in this Section, at which Work shall be halted for inspection.
   16. Holiday: A discontinuity, skip, void, or pinhole in coating or coating system film that exposes the substrate.
   17. Honeycomb: Segregated and porous surface of hardened concrete due to insufficient consolidation.
   18. Hydroblast: High or ultra-high-pressure water jet surface preparation.
   19. Immersed/Immersion: A service condition in which substrate is submerged, is immediately above liquids, or is subject to frequent wetting, splashing, or washdown.
   20. Incompatibility: One coating’s inability to overlay another coating or surface as evidenced by bleeding, poor bonding, or lifting of old coating; inability of a coating to bond to a substrate.
   21. Laitance: A thin, weak, brittle layer of cement and aggregate fines on a concrete surface.
   22. Mil: 0.001 inch.
   23. Overspray: Dry spray, particularly paint bonded to an unintended surface.
   24. Pinhole: A small diameter discontinuity in a coating or coating system film, created by off gassing from a void in a concrete or masonry substrate causing a void between coats or exposing the substrate. Usually caused by coating application while temperature is rising.

25. Pot life: Time interval after components are mixed and coating can be satisfactorily applied.
26. Prime coat: First full paint coat applied to a surface when using a multicoat system. Primers adhere to a new substrate, protect the substrate, and promote adhesion of subsequent coats of paint. The prime coat on metal surfaces is the first full coat and does not include solvent wash, grease emulsifiers, or other pretreatment applications.
27. Resurfacer/Resurfacing material: A layer of cementitious and/or resin-based material used to fill or otherwise restore surface continuity to worn or damaged concrete surfaces.
28. Shop coat: One or more coats applied in an off-site shop or plant before shipment to work site where field or finishing coat(s) are applied.
29. Stripe coat: A separate brush coat of paint applied to all weld seams, pits, nuts/bolts/washers, and edges. This coat shall not be applied until the previous coats have cured. Once applied, the coat shall be allowed to cure before subsequent coats are applied.
30. System: Protective film with one or more coats applied in a predetermined order, including surface preparation and quality control requirements.
31. Thick film coating system: A coating system applied with a minimum dry film thickness of 25 mils.
32. Touch-up painting: Application of paint on previously painted surfaces to repair marks, scratches, and deteriorated or damaged areas to restore the appearance and performance of the coating.
33. Water blast: An alternative to air abrasive blast cleaning that can be used with or without abrasive injection. Water cleaning at pressures up to 5,000 pounds per square inch is called low-pressure water cleaning or power washing. High-pressure water cleaning uses water pressures between 5,000 and 10,000 pounds per square inch. Water jetting is water blasting with added abrasive at pressures between 10,000 and 25,000 pounds per square inch. Ultra-high-pressure water jetting is water blasting at pressures above 25,000 pounds per square inch.
34. Weld splatter: Beads of non-structural weld metal that adhere to the surrounding surface, removed as part of surface preparation.

1.04 SUBMITTALS

A. As specified in Section 01300 - Submittals, submit the following:
   1. Schedule of proposed coating materials.
   2. Schedule of surfaces to be coated with each coating material.
   3. Dehumidification and heating plan.
   4. Methods for tenting blasting areas and methods to protect existing equipment from dust and debris.
   5. Abrasives and abrasive blast cleaning disposal.
   6. Product data, application, and safety data sheets.
   7. NSF certification of coatings for potable water supply systems, including NSF 600 and/or NSF 61.
   8. Compliance with regulatory requirements:
      a. VOC limitations.
      b. Hazardous lead compounds and polychlorinated biphenyls (removal and disposal methods).
   9. Manufacturer’s standard color samples.

10. Include 8-inch square drawdowns or brushouts of topcoat finish when requested. Identify each sample as to finish, formula, color name and number, sheen name, and gloss units.
11. Affidavits signed by an officer of the CSM's corporation attesting to full compliance of each coating system component with current federal, state, and local air pollution control regulations and requirements.
12. Thick film coating systems (greater than 25 mils):
    a. CSM's detailed written instructions for coating system treatment and graphic details for coating system terminations in coated structures, including pipe penetrations, metal embedments, gate frames, and other terminations encountered.
    b. Include detailed treatment for coating system at concrete joints.
13. Quality assurance Submittals:
    a. Quality assurance plan.
    b. Qualifications:
        1) Field coating applicator includes:
            a) Provide a minimum of 5 project references where similar coating work has been performed by the company in the past 5 years:
                (1) Name and address of project.
                (2) Year of installation.
                (3) Year placed in operation.
                (4) Point of contact: Name and phone number.
            b) SSPC-QP 1 certified as required.
        2) Shop coating applicator includes:
            a) Provide a minimum of 5 project references where similar coating work has been performed by the company in the past 5 years:
                (1) Name and address of project.
                (2) Year of installation.
                (3) Year placed in operation.
                (4) Point of contact: Name and phone number.
            b) SSPC-QP 3 certified as required.
    c. Field Quality Control:
        1) Provide certification letters from NACE Certified Level 3 Coating Inspector for surface preparation and coating application conformance with these specifications for any field-applied procedures performed as may be applicable to the Project.
        2) Indicate results of applicators furnished tests and inspections, including, but not limited to, ambient environmental conditions, surface cleanliness, surface profile, DFT measurements, holiday testing, etc.
    d. CSA reports:
            a) Written daily quality control inspection reports.
            b) Reports to observe and approve surface preparation of structures to be coated.
            c) Reports to observe and approve coating application procedures.
            d) Reports on visits to plants to observe and approve surface preparation and coating application on shop-coated items.
14. For each substituted coating material "equal" to specified product in the coating tabulation:
    a. List of not less than 5 similar successful material applications:
        1) Project name, location, type of structure, and application dates.

2) Owner's name, address, and telephone number.
b. Certification that material meets or exceeds specified requirements:
1) Manufacturer's certification, including technical representative's signature and date of signature.
2) Independent laboratory's certified test reports.

1.05 QUALITY ASSURANCE

A. Coating inspector:
1. CSA inspector and/or third-party inspector shall be trained and knowledgeable in the specified coating's application.
2. Provide calibrated inspection instruments and demonstrate use as required.
3. Applicator's quality assurance inspector foreman shall oversee all aspects of coating work and shall be NACE Level III certified or an SSPC Protective Coatings Inspector (PCI).
a. Oversees lesser qualified inspectors and provides them training and guidance for testing and report preparations, provides documentation for all inspection equipment showing calibrations, and verifies the equipment is free from damage and is in proper working condition.

B. Regulatory requirements: Comply with governing agencies' regulations by using coatings in accordance with their VOC limits.
1. Lead-based coatings are not permitted.
2. Do not use coal-tar epoxy in contact with drinking water or exposed to ultraviolet radiation.

C. Certification:
1. Certify that applicable pigments resist deterioration when exposed to hydrogen sulfide and other sewage gases.
2. Product data shall designate coating as being suitable for wastewater service.

D. Pre-installation conference: Conduct as specified in Section 01200 - Project Meetings.
1. Coordinate Hold Point schedule.

E. Field samples:
1. Prepare and coat a minimum 100-square-foot area of each system between corners or limits such as control or construction joints.
2. Approved field sample may be part of the Work.

F. Obtain approval before coating other surfaces. Use products by the same manufacturer for prime coats, intermediate coats, and finish coats on same surface, unless specified otherwise. Coatings must be compatible with one another and complete a cohesive coating system.

G. CSM services:
1. CSA shall arrange for CTR to attend pre-installation conferences.
2. Visit the Project Site periodically to consult on and inspect specified surface preparation and application Hold Points.
3. Visit coating plants to observe and approve surface preparation procedures and coating application of items to be shop primed and coated.

4. CTR shall provide written inspection reports.

H. Quality control requirements:
   1. Applicator shall be responsible for the workmanship and quality of the coating system installation.
      a. Inspections by the Owner, Engineer, or CTR will not relieve or limit the CSA's responsibilities.
   2. In accordance with this Specification's requirements and the standards referenced in this Section. Changes in the coating system application requirements will be allowed only with the Engineer's written acceptance.
   3. Specially trained crews with experience applying the specified coating system coating are required for:
      a. Coating application using plural component spray equipment or other specialty equipment.
      b. Coating with specialty linings for severe service conditions, including floor coatings, and with linings for corrosive headspaces or secondary containment areas.
   4. CTR shall specially train personnel for coating systems as specified in Attachment B - Coating Detail Sheets.
      a. CSM shall approve personnel in writing applying the coating system.
   5. Do not use contaminated, outdated, diluted materials, and/or materials from previously opened containers.
   6. Identify inspection access points used by the Owner's or Engineer's personnel.
   7. Provide ventilation, ingress, egress, or other means as necessary for the Owner's or Engineer's personnel to safely access the work areas.
   8. Conduct and continually inspect Work so the coating system is installed as specified. CSM shall provide written directions to correct coating work not in accordance with the specifications or is otherwise unacceptable.
   9. Provide written daily reports summarizing test data, work progress, surfaces covered, ambient conditions, quality control inspection test findings, and other information pertinent to the coating system application.
      a. Determine relative humidity in accordance with ASTM E337. Confirm other conditions, such as proper protective measures for surfaces not to be coated and safety requirements for personnel.
         1) Measure daily at the shift's beginning and end and at intervals not to exceed 4 hours during the shift.
         2) Determine the acceptability of weather and/or environmental conditions within the structure in accordance with the CSM's requirements.
      b. Monitoring surface preparation: Spot check cleanliness, surface profile, and surface pH testing at least 3 times daily. Check each surface at least once. In accordance with:
         1) ASTM D4262.
         2) ASTM D4263.
         3) ASTM D4417.
         4) ICRI 310.2 requirements.
         5) SSPC surface preparation standards.
      c. Confirm that compressed air used for surface preparation or blow-down cleaning is free of oil and moisture.
      d. Monitor surface preparation daily at the shift's beginning and end and at intervals not to exceed 4 hours during the shift.

e. Do not apply coatings when environmental conditions are outside of the CSM's published limits.
f. Monitoring coatings application: Continuously inspect, measure, and record the wet film thickness and general film quality (visual inspection) for runs, sags, pinholes, holidays, etc., during coating.
    1) Perform WFT measurements in accordance with ASTM D4414.
g. Post cure evaluation: Measure and inspect the overall dry film thickness on all surfaces.
    1) Conduct a DFT survey and perform adhesion testing, holiday detection, or cure testing as specified in this Section and/or the CSM's written instructions.
    2) Perform applicable tests in accordance with ASTM D4541, ASTM D4787, ASTM D5162, ASTM D7234, SSPC-PA 1, SSPC-PA 2, SSPC-PA 9, and other pertinent standards and recommended practices.

I. Inspection at Hold Points:
1. Conduct inspections at Hold Points during the coating system application and record the results.
2. Coordinate Hold Points with the Engineer so the Engineer can observe the Contractor's inspections on a scheduled basis.
3. Provide the Engineer with a minimum of 24 hours of notice before conducting Hold Point inspections.
4. Hold Points shall be as follows:
    a. Conditions before surface preparation: Before starting surface preparation, observe, record, and confirm that oil, grease, and/or soluble salts are gone from the surface.
    b. Post surface preparation: After completing surface preparation, measure and inspect for cleanliness and proper surface profile as specified in this Section and in the CSM's written instructions.
    c. Coatings application: At the beginning of any coating system application, measure, record, and confirm acceptability of surface and ambient air temperature and humidity. Inspect applicator's equipment for serviceability and suitability for coatings application.
    d. Post application inspection: Identify defects in application work on all surfaces, including pinholes, holidays, excessive runs, or sags, inadequate or excessive film thickness, and other problems.
    e. Follow-up corrective actions and final inspection: Measure and re-inspect corrective coating work performed to repair defects at prior Hold Points and repeat until the surface condition is acceptable. Conduct final visual inspection with follow-up tests, such as holiday detection, adhesion tests, and DFT surveys.
    f. Coatings application: At the beginning of coating system application, measure, record, and confirm acceptability of surface and ambient air temperature and humidity. Inspect applicator's equipment for serviceability and suitability for coatings application.
        1) Observe conditions during the pre-application meeting.

1.06 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements.

B. Immediately remove unspecified and unapproved coatings from the Project Site.

C. Deliver new, labeled, unopened containers:
   1. Do not deliver materials after the manufacturer's expiration date or over 12 months from manufacturing date, whichever is more stringent. Store materials in well-ventilated enclosed structures and protect from weather and excessive heat or cold in accordance with the CSM's recommendations.
      a. Store flammable materials in accordance with federal, state, and local requirements.
      b. Store rags and cleanup materials appropriately to prevent fire and spontaneous combustion.
   2. Store and dispose of hazardous waste in accordance with federal, state, and local requirements. This requirement specifically applies to waste solvents and coatings.
   3. Container labels shall show the following:
      a. Brand name or product title.
      b. CSM's batch number.
      c. CSM's manufacture date.
      d. CSM's name.
      e. Generic material type.
      f. Application and mixing instructions.
      g. Hazardous material identification label.
      h. Shelf-life expiration date.
      i. Color.
      j. Mixing and reducing instructions.
   4. Clearly mark containers to indicate safety hazards associated with the use of or exposure to materials.

1.07 PROJECT CONDITIONS

A. Apply coatings to dry surfaces.
   1. Surface moisture: In accordance with the manufacturer's requirements or as specified in this Section.
      a. Plaster and gypsum wallboard: 12 percent.
      b. Masonry and concrete blocks: 12 percent.
      c. Interior located wood: 15 percent.
      d. Concrete floors: Moisture vapor transmission rate of no more than 3.0 pounds per 1,000 square feet per 24 hours in accordance with ASTM F1869 or relative humidity no greater than 80 percent if tested in accordance with ASTM F2170, unless the CSM's recommendations are more restrictive.
      e. Concrete structures: Negative results from plastic sheet test in accordance with ASTM D4263, and maximum of 80 percent relative humidity in accordance with ASTM F2170.

B. Do not apply coatings when the following conditions exist. If such conditions exist, provide containment, covers, environmental controls, and other necessary measures.
   1. During rainy, misty, or damp weather, or to surfaces with frost or condensation.
   2. When the surface temperature is below 10 degrees Fahrenheit above the dew point.

3. When ambient or surface temperature:
    a. Is less than 55 degrees Fahrenheit unless the manufacturer allows a lower temperature.
    b. Is less than 65 degrees Fahrenheit for clear finishes unless the manufacturer allows a lower temperature.
    c. Exceeds 90 degrees Fahrenheit unless the manufacturer allows a higher temperature.
    d. Exceeds the manufacturer's recommendation.
4. When relative humidity is higher than 85 percent.
5. Under dusty or adverse environmental conditions.
6. When light on surfaces measures less than 15-foot candles.
7. When wind speed exceeds 15 miles per hour.

C. Apply coating only under evaporation conditions rather than condensation.
    1. Use dehumidification equipment, fans, and/or heaters inside enclosed areas to maintain required atmospheric and surface temperature requirements for proper coating application and cure.
    2. Measure and record relative humidity and air and surface temperatures at the start and end of each shift to confirm proper humidity and temperature levels inside the work area.
        a. Submit test results.

D. Continuously ventilate, dehumidify, and heat enclosed spaces with high humidity during surface preparation, coating application, and curing.
    1. Maintain minimum air temperature of 55 degrees Fahrenheit and 10 degrees Fahrenheit above the dew point.
    2. Maintain dew point of at least 10 degrees Fahrenheit less than the temperature of the coldest part of the structure where work is performed.
    3. Reduce dew point temperature in conditioned space by at least 10 degrees Fahrenheit within 20 minutes.
    4. Seal work areas and maintain positive pressure in accordance with the dehumidification equipment supplier's recommendations.
    5. Maintain these conditions before, during, and after application to ensure proper adhesion and cure of coatings for no less than:
        a. Entire curing period.
        b. 8 hours after coating.

E. Systems:
    1. Site electrical power availability as specified in Section 01500 - Temporary Facilities and Controls.
    2. Internal combustion engine generators may be used.
        a. Obtain required permits and provide air pollution and noise control devices on equipment as required by permitting agencies require.
        b. Comply with state, federal, and local fire and explosion protection measures when locating and operating generators.
        c. Locate engine generator outside hazardous classified areas in accordance with NFPA 820.
        d. Provide daily fuel service for generators for duration of use.
    3. Dehumidification:
        a. Provide desiccant or refrigeration drying.

b. Use only desiccant types with a rotary desiccant wheel capable of continuous operation.
c. Liquid, granular, or loose lithium chloride drying systems are not acceptable.

4. Heating:
   a. Use electric, indirect combustion, or steam coil.
   b. Direct-fired combustion heaters are not acceptable heat sources during abrasive blasting, coating application, or coating cure.
5. Filters:
   a. Use a filtration system for dust removal designed to not interfere with the dehumidification equipment's ability to control dew point and relative humidity inside the reservoir.
   b. Do not allow air from the working area or dust filtration equipment to recirculate through thein dehumidifier during coating application or when solvent vapors are present.
6. Design and Submittals:
   a. Prepare and submit dehumidification and heating plan, including all equipment, and operating procedures.
   b. Suppliers of services and equipment shall have at least 3 years of experience in similar applications.

F. Provide containment and ventilation system components in accordance with SSPC-Guide 6, Level 3, and as required for hazardous materials.

1.08 MAINTENANCE

A. Provide extra materials:
   1. Minimum 1 gallon of each type and color of coating applied or provide additional quantities if specified in the Contract Documents:
      a. Deliver unopened factory-labeled cans when the manufacturer packages material in gallon cans.
      b. Deliver material in new gallon containers, properly sealed and identified with permanently affixed, durable, printed labels indicating brand, type, and color, when the manufacturer does not package material in gallon cans.

1.09 TECHNICAL REPRESENTATIVES' RESPONSIBILITIES

A. General:
   1. Attend pre-installation conference.
   2. Perform on-site application training.

B. Coating system installation training:
   1. Provide a minimum of 8 hours of classroom and off-site training for application personnel and supervisory personnel in one of the following ways:
      a. Train a minimum of 2 supervisory personnel and 2 application personnel.
      b. Submit a letter from the CSM stating that CSM approves the supervisory and application personnel, listed by name and responsibility, and no additional training is required.
   2. CTR can train up to 14 application personnel and 3 supervisory personnel at a time.

3. Minimum training requirements:
    a. Explain in detail the mixing, application, curing, and termination requirements.
    b. Provide hands-on demonstration of coating system mixing.
    c. Explain in detail the ambient condition requirements for temperature and humidity.
    d. Explain in detail the surface preparation requirements.
    e. Explain in detail the re-coat times, cure times, and related ambient condition requirements.
    f. Write a letter stating that training was satisfactorily completed by the personnel, listed by name and responsibility.
4. Provide special training as specified in the coating detail sheets.
5. Visit the Site at the following intervals:
    a. On the first day of application of any coating system.
    b. As necessary during surface preparation and application to ensure installations are made in accordance with the manufacturer's recommendations.
    c. As required to resolve field problems attributed to or associated with the manufacturer's products.
6. Routinely inspect and verify in writing that application personnel have successfully performed surface preparation, filler/surfacer application, coating system application, and quality control inspection in accordance with this Section and to warrantable quality.
    a. Be on site to periodically observe and oversee:
        1) Coating application.
        2) End of surface preparation.
        3) During coating application.
        4) Post-cure inspection.
7. Conduct final review of completed coating system installation and submit detailed report to the Owner.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Coating materials shall be formulated for environments encountered in water and wastewater treatment processes.

B. Coating materials that encounter water distributed as potable water shall be certified in accordance with NSF 61.

2.02 MATERIALS

A. General:
    1. As specified in Section 01600 - Product Requirements.

2.03 COATING SYSTEMS IDENTIFICATION

A. Naming conventions: Coating systems identifications contain the elements defined in Table 1.

Table 1. Coating System Identification Elements						
First Element	**-**	**Second Element**	**-**	**Third Element**	**-**	**Fourth Element (optional)**
3 or 4 alpha characters		1-3 alpha characters		1 number		3 or 4 alpha characters
Coating Type		Substrate		System Number		Additional Substrate or Special Condition
Example: EPX	-	C	-	6	-	BSC

1. First element identifies the coating type using the following abbreviations:
   a. ACR: Acrylic.
   b. CTE: Coal tar epoxy.
   c. ELA: Elastomeric acrylic.
   d. EPU: Epoxy-polyurethane.
   e. EPX: Epoxy.
   f. POL: Polyurethane.
   g. SIL: Silicone.
   h. SILX: Siloxane or silane.
   i. VE: Vinyl ester.
2. Second element identifies the substrate using the following abbreviations:
   a. C: Concrete or masonry.
   b. F: Concrete flooring.
   c. FRP: Fiber-reinforced plastic.
   d. GM: Galvanized metal.
   e. M: Metal.
   f. PVC: Polyvinyl chloride, chlorinated polyvinyl chloride.
3. Third element identifies the sequential system number.
   a. For example, EPX-C-2 is the second standard epoxy coating system for concrete substrates.
4. Fourth element is optional and identifies the additional substrate or special condition with the following abbreviations:
   a. BG: Below grade or buried.
   b. BSC: Biogenic sulfide corrosion-resistant applications in wastewater.
   c. OZ: Organic zinc primer, epoxy polyurethane system.
   d. PWS: Potable water service applications (NSF-61 approved).
   e. SC: Secondary containment.

2.04 PRODUCTS FOR COATING SYSTEMS

A. Products: As specified in Attachment B - Coating Detail Sheets.

B. Cleaning solvents:
   1. Requirements for solvent wash, solvent wipe, or cleaner used, including, but not limited to, those used for surface preparation in accordance with SSPC-SP 1.
   2. Use clean white cloths and clean fluids in solvent cleaning.

PART 3 EXECUTION

3.01 GENERAL PROTECTION REQUIREMENTS

A. Protect adjacent surfaces from coatings and damage associated with coating work and repair any damage that occurs.

B. Place coating waste, cloths, and material that may pose a fire hazard in closed metal containers and remove daily from the Site.

C. Remove electrical plates, surface hardware, fittings, and fasteners before coating application.
   1. Carefully store, clean, and replace items after completing coating in each area.
   2. Do not use solvent or degreasers to clean hardware that may remove permanent lacquer finishes.

D. Erect and maintain protective enclosures in accordance with SSPC-Guide 6.

E. Protect the following surfaces from abrasive blasting by masking or by other means:
   1. Threaded portions of valve and gate stems, grease fittings, and identification plates.
   2. Machined surfaces for sliding contact.
   3. Surfaces to be assembled against gaskets.
   4. Surfaces of shafting where sprockets will be fit.
   5. Surfaces of shafting where bearings will be fit.
   6. Machined bronze surfaces, including slide gates.
   7. Cadmium-plated items, except cadmium-plated, zinc-plated, or sherardized fasteners used to assemble equipment requiring abrasive blasting.
   8. Galvanized items, unless scheduled to be coated.

3.02 GENERAL SURFACE PREPARATION REQUIREMENTS

A. Prepare surfaces in accordance with coating detail sheets in Attachment B - Coating Detail Sheets.
   1. Include coating and surface preparation requirements.
   2. CSM's instructions will also have surface preparation requirements but follow the more stringent if information conflicts.

B. Where required by the Owner's representative, a NACE International certified coatings inspector, provided by the Owner or Engineer, will inspect and approve surfaces to be coated before applying a coating.
   1. Applicator shall coordinate coating inspections.
      a. Identify coating inspection Hold Points during the pre-installation conference.
      b. Provide at least 2 days' notice before inspection.
   2. Correct surface defects identified by the inspector at no additional cost to the Owner.

3.03 MECHANICAL AND ELECTRICAL EQUIPMENT PREPARATION

A. Remove grilles, covers, and access panels for mechanical and electrical system and coat separately.

B. Prepare and finish coat equipment primed by the manufacturer using specified intermediate and topcoats, as applicable, and color selected by the Owner.

C. Prepare, prime, and coat both insulated and bare pipes, conduits, boxes, insulated and bare ducts, hangers, brackets, collars, and supports, except where items are covered with material not requiring coating, or with a prefinished coating.

D. Replace identification markings on mechanical or electrical equipment when coated over or spattered.

E. Prepare and coat interior surfaces of air ducts and convector and baseboard heating cabinets visible through grilles and louvers with 1 coat of flat black paint to limit of sight line.

F. Prepare and coat dampers exposed immediately behind louvers, grilles, and convector and baseboard heating cabinets to match face panels.

G. Prepare and coat exposed conduit and appurtenances occurring in finished areas with color and texture to match adjacent surfaces.

H. Prepare and coat sides, front, back, and edges of plywood backboards for electrical equipment before installing backboards and mounting equipment on them.

I. Color code equipment, piping, conduit, and exposed ductwork and apply color banding and identification, such as flow arrows, naming, and numbering, in accordance with the Contract Documents.

3.04 CLEANING OF NEW AND PREVIOUSLY COATED OR NEW SURFACES

A. Utilize cleaning agent to remove soluble salts, such as chlorides, from concrete and metal surfaces:
   1. Cleaning agent: Biodegradable non-flammable and containing no VOC.
   2. Manufacturers: The following or equal:
      a. CHLOR*RID International, Inc.
         1) Complete soluble salt removal with steam or warm water cleaning.
   3. Steam clean and degrease surfaces to be coated to remove oils and grease.
   4. Clean surfaces with decontamination agent in conjunction with abrasive blast cleaning, steam cleaning, high-pressure washing, or hand washing, as approved by the CTR and the Engineer.
   5. Test cleaned surfaces to ensure removal of soluble salts. Carry out additional cleaning as needed.
   6. Complete final surface preparation before applying the new coating system in accordance with the manufacturers printed instructions.

3.05 BLAST CLEANING

A. Surface preparation requirements:
   1. Do not reuse spent blast abrasive.
   2. Ensure that filter compressed air used for blast cleaning is free of condensed water and oil.
      a. Clean moisture traps at least once every 4 hours or more frequently, as required, to prevent moisture from entering the abrasive blasting equipment air supply.
      b. Check blast air for moisture and oil after each cleaning in accordance with ASTM D4285.
   3. Install oil separators just downstream of compressor discharge valves and at the discharge point of blast pot discharges. Check separators on the same frequency as the moisture traps.
   4. Keep regulators, gauges, filters, and separators on compressor air lines connected always when blasting nozzles operational.
   5. Install an air dryer or desiccant filter drying unit to dry the compressed air before blast pot connections. Use and maintain the dryer throughout surface preparation work.
   6. Use a venturi-type, or other high velocity-type, abrasive blast nozzles supplied with at least 100 pounds per square inch gauge air pressure at the nozzle and enough volume to obtain appropriate blast cleaning production rates and surface cleanliness.
   7. Provide airborne particulate evacuation and filtering that meets OSHA safety standards. Maintain optimal visibility both to clean and provide the specified surface profile and to allow inspection of the substrate during surface preparation work.
   8. Surfaces blasted and prepared and not coated/painted the same day shall be re-prepared prior to coating/painting. Any rust-back occurring before coating shall be removed.
   9. Prepared blasted surfaces may be open longer if dehumidification (DH) is used to reduce moisture vapor and eliminate the potential for rust-back.

3.06 PREPARATION REQUIREMENTS FOR CONCRETE SURFACES

A. Cure for at least 28 days before coating.

B. Remove degraded concrete using abrasive blast cleaning or high or ultra-high-pressure water jetting, chipping, or other abrading tools until achieving a sound, clean substrate. Remove bruised or cracked concrete.

C. Prepare substrate cracks and areas requiring resurfacing; perform detailed treatment, including, but not limited to, terminating edges in accordance with the CSM's recommendations, and as indicated on the Drawings.
   1. Prepare concrete surfaces in accordance with SSPC-SP 13.

D. Prepare concrete surfaces in accordance with SSPC-SP 13.
   1. Inspect concrete surfaces to select appropriate surface preparation method to provide a suitable substrate for the specified coating system.

2. Use blast cleaning or other means to expose the complete perimeter of air voids or bug holes. Do not leave shelled over, hidden air voids beneath the exposed concrete surface.
3. Repair concrete defects and physical damage.
4. Clean concrete surfaces of dust, mortar, formwork, fins, loose concrete particles, form release materials, oil, and grease.
5. Fill voids to provide surface as specified in Section 03366 - Concrete Finishes.

E. Provide clean substrate visually free of calcium sulfate, loose, coarse, or fine aggregate, laitance, loose hydrated cement paste, and otherwise harmful substances.
1. Confirm concrete surface minimum pH of 9.0 with surface pH testing.
2. If after surface preparation the surface pH remains below 9.0, perform additional water blasting, cleaning, or abrasive blast cleaning until additional pH testing indicates an acceptable pH level.

F. Prepare concrete surface for coating in accordance with SSPC-SP 13.
1. Provide ICRI 310.2 minimum No. 3 concrete surface profile (CSP) or as specified on the coating detail sheets.
2. Evaluate profile of the prepared concrete using ICRI 310.2 surface profile replicas.

G. Blast clean cementitious repair mortars or grouts to the same profile and degree of cleanliness requirements required for concrete substrates.

H. Blast clean polymer-based surfacers or waterborne modified cementitious surfaces only if they have exceeded the CSM’s recommended recoat time.

I. Vacuum or blow down concrete surfaces before coating application, leaving a dust free, sound concrete substrate.
1. Thoroughly clean concrete surfaces to be coated to remove loose dirt and spent abrasive.
2. Remove debris produced by blast cleaning from the structures to be coated, and legally dispose of it off site.

J. Test moisture content of concrete to be coated:
1. Conduct ASTM D4263 plastic sheet test at least once for every 500 square feet of surface area to be coated.
   a. Any moisture on plastic sheet after test period constitutes a non-acceptable test, and the concrete must be dried further.
2. Conduct ASTM F1869 test at least once for every 1,000 square feet of concrete floor surface area to be coated.
3. Conduct ASTM F2170 one relative humidity moisture test at least once for each 500 square feet of non-floor concrete surface area where the opposite side is exposed to soil or water.
   a. Waterproof surfaces exposed to soil or water where specified in Section 07110 - Dampproofing.
4. Comply with specified minimum moisture content and the CSM’s written recommendations for moisture vapor transmission rates or relative humidity values.

K. Masonry surfaces:
   1. Cure for at least 28 days before coating.
   2. Prepare masonry surfaces to remove chalk, laitance, loose dirt, dried mortar splatter, dust, peeling, or loose existing coatings, or otherwise deleterious substances to leave a clean, sound substrate.
   3. Wash and scrub masonry surfaces with clear water. Do not use muriatic acid.
   4. Seal or fill masonry surfaces with a sealer or block filler compatible with the specified primer after cleaning.
   5. Confirm that masonry surfaces are dry before coating application.
      a. When using pressure washing or low-pressure water blast cleaning for preparation, allow the masonry to dry for at least 5 days under dry weather conditions or until the minimum ambient temperature is 70 degrees Fahrenheit before coating.

3.07 GENERAL PREPARATION REQUIREMENTS FOR METALLIC SURFACES

A. Remove rust, scale, and welding slag and spatter.
   1. Remove and grind smooth excessive weld material and weld spatter on metal surfaces before blast cleaning in accordance with NACE SP0178.
   2. Grind sharp edges on metal substrate to approximately 1/16-inch radius before abrasive blast cleaning.

B. Prepare metallic surfaces in accordance with applicable portions of surface preparation specifications of the SSPC specified for each coating system.
   1. Remove grease and oil in accordance with SSPC-SP 1.
   2. Measure profile depth of the surface to be coated in accordance with Method C of ASTM D4417. Select blast particle size and gradation to produce the specified surface profile.
   3. Constantly monitor and maintain ambient environmental conditions to ensure cleanliness and that no “rust back” occurs before coating material application.
   4. Surfaces not coated the same day they are prepared shall be re-prepared prior to coating unless approved moisture control equipment is used and approved by the Owners representative.

C. Prepare metallic surfaces by blast cleaning in accordance with SSPC-VIS 1 (ASTM D2200). Prepare abrasive blast representative areas for the Owner’s representative to inspect on the first day of cleaning.

D. Unless otherwise specified, the requirements for blast cleaning steel, ductile iron, and stainless-steel substrates are as follows:
   1. Ferrous metal surfaces not to be submerged: Abrasive blast in accordance with SSPC-SP 10 unless blasting may damage adjacent surfaces, is prohibited, or is specified otherwise. Where abrasive blasting is not possible, clean surfaces to bare metal with power tools in accordance with SSPC-SP 11.
   2. Ferrous metal surfaces to be submerged: Abrasive blast in accordance with SSPC-SP 5, unless specified otherwise, to clean and provide roughened surface profile with a depth between 2 and 4 mils.
   3. Remove traces of grit, dust, dirt, rust scale, friable material, loose corrosion products, or embedded abrasive from substrate before coating application.
   4. When abrasive blasted surfaces rust or discolor before coating, abrasive blast clean surfaces again.

E. Field preparation of shop-primed surfaces:
   1. Smooth welds and prominences with power tools before applying field-applied coatings.
   2. Clean and dry shop-primed ferrous metal surfaces and fabricated assemblies before applying field coats.
   3. Prepare shop epoxy primed surfaces with light abrasive blasting or abrading and then vacuum before applying finish coats.
      a. Follow CSM instructions for surface preparation when the primer recoat limit has been exceeded.
   4. Non-immersion service: Clean in accordance with SSPC-SP 2 or SSPC-SP 3 and uniformly roughen.
   5. Immersion, BSC, and SC service: Remove shop primer in accordance with SSPC-SP 5.

F. Damaged shop primer or rust bleeding:
   1. Ferrous metals: Clean in accordance with SSPC-SP 1 and spot blast in accordance with SSPC-SP 10 to achieve a uniform surface profile between 2.0 and 2.5 mils before recoating.
   2. Reject galvanized steel with rust bleeding.

G. Damaged coating: Repair by abrasive blast cleaning surfaces as specified for the coating system; feather to a smooth transition before touching up.

3.08 PREPARATION REQUIREMENTS BY SURFACE TYPE

A. Steel and ferrous metal surfaces that require coating:
   1. Degrease or solvent clean (SSPC-SP 1).
   2. Abrasive blast surfaces to a SSPC-SP 10 for non-immersion and a SSPC-SP 5 for immersion.
      a. If abrasive blast cannot be performed, abrade in accordance with SSPC-SP 7.

B. Galvanized steel and non-ferrous metal surfaces:
   1. Degrease or solvent clean (SSPC-SP 1) to remove oily residue.
   2. Abrasive blast clean in accordance with SSPC-SP 16.
      a. If abrasive blast cannot be performed, abrade in accordance with SSPC-SP 3.
   3. Apply metal pretreatment within 24 hours before coating galvanized surfaces that cannot be thoroughly abraded, such as bolts, nuts, or preformed channels.
   4. Test surface for contaminants using copper sulfate solution.

C. Stainless-steel surfaces:
   1. Abrasive blast clean in accordance with SSPC-SP 16 to leave a clean, uniform appearance with surface profile between 1.5 and 2.5 mils.

D. Ductile iron pipe and fittings to be lined or coated: Abrasive blast clean in accordance with NAPF 500-03.

E. Sherardized, aluminum, copper, and bronze surfaces:
   1. Abrasive blast clean in accordance with SSPC-SP 16.
   2. Prepare in accordance with the CSM's instructions.

F. Cadmium-plated, zinc-plated, or sherardized fasteners:
   1. Abrasive blast in the same manner as uncoated metal when assembling equipment designated for abrasive blasting.

G. PVC and FRP surfaces:
   1. Lightly sand surfaces to be coated.
      a. Sand to remove gloss and establish uniform surface profile.
   2. Vacuum to remove loose dust, dirt, and other materials.
   3. Solvent clean with clean white rags and allow solvent to evaporate completely before applying coating materials.

3.09 APPLICATION REQUIREMENTS

A. Apply coatings in accordance with the manufacturer's instructions.

B. Empty aboveground piping to be coated of contents when applying coatings.

C. Items to be coated: Commercial or manufactured items with a factory or shop-applied coating system.
   1. Factory or shop-applied permanent coating system:
      a. Commercial components shall be coated with the manufacturer's standard surface preparation and applied permanent coating system:
         1) Pumps and valves: Shop coat with the manufacturer's highest quality coating system in accordance with the Project Specifications.
         2) Non-immersed equipment: Touch up shop primer, and coat in the field with specified coating system after installation.
         3) Immersed equipment with shop primer: Touch up shop primer and coat in the field with specified coating system after installation.
   2. Items subject to sunlight shall be topcoated with ultraviolet (UV) stable materials.
   3. Permanent coating system shall have a 10-year corrosion-free protection without significant defects stored in atmospheric exposure.
   4. Color and gloss: Manufacturer's standard color unless a specific color is otherwise specified in the color schedule or indicated on the Drawings.
   5. Unless otherwise specified, unexposed surfaces that require coatings, such as interior of cabinets, enclosures, and equipment, shall be given the manufacturer's standard permanent coated finish.
   6. Field repair: Repair damaged areas of coated surfaces with compatible materials to equal thickness and color match of undamaged areas.

D. Repair damaged galvanized surfaces in accordance with ASTM A780. Repair materials containing cadmium and lead are not permitted.

E. Stainless steel surfaces to receive uniform passivation. Clean and restore uniform passivation layer on damaged, contaminated, or depassivated stainless steel surfaces in accordance with ASTM A380.

F. Wash coat and prime sherardized, aluminum, copper, and bronze surfaces, or prime with the manufacturer's recommended special primer.

G. Use equipment designed to apply materials specified.
   1. Use compressors with moisture traps and filters that remove water and oils from the air.
      a. Perform a paper blotter test at the Engineer's request to verify air is sufficiently free of oil and moisture. Do not allow the amount of oil and moisture to exceed the CSM-recommended amount.
   2. Equip spray equipment with properly sized mechanical agitators, pressure gauges, pressure regulators, and spray nozzles.

H. Where 2 or more coats are required, tint prime coat intermediate coats as necessary to distinguish each coating and to help indicate coverage.

I. Apply coating by brush, roller, trowel, or spray, unless a specific application method is required by the coating manufacturer's instructions or these Specifications.
   1. With a brush, stripe coat edges, welds, corners, nuts, bolts, and difficult-to-reach areas, as necessary, before spray application to ensure specified coating thickness along edges.
   2. After the prime coat dries, mark, repair, and retest pinholes and holidays before intermediate or topcoats are applied.

J. Spray application:
   1. With a brush, stripe coat edges, welds, corners, nuts, bolts, and difficult-to-reach areas, as necessary, before spray application to ensure specified coating thickness along edges.
   2. When using spray application, apply each coat to a thickness no greater than recommended in the coating manufacturer's instructions.
   3. Use airless spray method unless air spray method is required by the CSM's instruction or these Specifications.
   4. Conduct spray coating under controlled conditions. Protect adjacent construction and property from coating mist, fumes, or overspray.

K. Shop and field coats:
   1. Prime coat: Shop-apply or field-apply prime coats as specified. Use shop-applied primer compatible with the specified field coating system and apply at the minimum dry film thickness recommended by the finish coat CSM.
      a. Provide datasheets identifying the shop primer to on-site coating application personnel.
      b. Perform adhesion tests on the shop primer.
      c. Remove and recoat damaged, deteriorated, and poorly applied shop coatings.
      d. If the shop primer coat meets this Section's requirements, spot prime exposed metal of shop-primed surfaces before spray applying primer over the entire surface.
   2. Field coats: Apply field coats with one or more prime coats and finish coats to build up coating to dry film thickness specified for the coating system.
      a. Do not apply finish coats until other work in the area is complete and previous coats are inspected.
   3. Adhesion confirmation: Perform adhesion tests after proper coating cure in accordance with ASTM D3359. Demonstrate that:
      a. Primer coat adheres to the substrate.

b. Coatings adhere to the primer and intermediate coats.
    1) Coating 5 mils or more DFT: Achieve adhesion test result of 5A on immersed surfaces and 4A or better on other surfaces.
    2) Coating less than 5 mils DFT: Achieve adhesion test results of 5B on immersed surfaces and 4B or better on other surfaces.

L. Brush, roll, trowel, or spray and back roll coats for concrete and masonry.

M. Plural component coating application:
1. Premix contents of component drums if required by the CSM each day.
2. Before starting application:
    a. Verify gauges are working properly.
    b. Complete ratio checks.
    c. Sample the mix on plastic sheeting to ensure set time is appropriate and complete.
    d. Label and retain spray samples. Submit to the Engineer when requested.

N. Drying and recoating:
1. Provide means to prevent condensate or dew on substrate surface or between coats and during curing after applying the last coat.
2. Allow each coat to cure or dry thoroughly, in accordance with, if required, the CSM's printed instructions before recoating.
3. Use the CSM's printed instructions and the requirements specified in this Section to determine the minimum required drying time.
    a. Recoat coatings within time limits recommended by CSM.
    b. If time limits are exceeded, abrasive blast clean and de-gloss clean before applying another coat.
4. Ensure primer and intermediate coats of coating are unscarred and completely integral when applying each succeeding coat.
5. Touch up suction spots between coats and apply additional coats where required to produce finished surface of solid, even color, free of defects.
6. Repair holidays in accordance with the requirements on pertinent Coating Detail Sheets or as recommended by the CSM.
7. Sand and feather to a smooth transition and recoat scratched, contaminated, or otherwise damaged coating surfaces so repairs are invisible to the naked eye.
8. For submerged service or highly corrosive headspace service, provide a letter to the Engineer stating that the lining system is fully cured and ready to be placed into service.

O. Workmanship:
1. Ensure that coated surfaces are free from runs, drips, ridges, waves, laps, dry spray, and brush marks. Coats shall be applied to produce a smooth, even film of uniform thickness completely coating corners and crevices.
2. Evenly apply each coat of material and sharply cut to a line created with masking tape or other suitable materials.
3. When coating complex steel shapes, stripe coat welds, edges of structural steel shapes, metal cut-outs, pits in steel surfaces, or rough surfaces with the primer before overall coating system application.
    a. Brush apply stripe coat to ensure proper coverage.
    b. Do not stripe coat with spray or roller.
4. Ensure that the finish coat, including repairs, has a uniform color and gloss.

P. Coating properties, mixing, and thinning:
    1. If maximum recoat time is exceeded, prepare surface with solvent washing, light abrasive blasting, sanding, or other procedures in accordance with the CSM's instructions.
    2. Allow adequate drying time between coats as instructed by the CSM, adjusted as necessary for the Site conditions.
    3. Ensure that coatings, when applied, provide a satisfactory film and a smooth even surface. Lightly sand glossy undercoats to provide a surface suitable for proper application and adhesion of subsequent coats. Thoroughly stir and strain coating materials during application and maintain uniform consistency.
    4. Mix coatings with 2 or more components in accordance with the CSM's instructions.
    5. Where necessary to suit conditions of the surface, temperature, weather, and method of application, thin the coating in accordance with the CSM's recommendations.
        a. Ensure that volatile organic content (VOC) of the thinned coating complies with prevailing air pollution control regulations.
        b. Thin coatings to only what is necessary to obtain proper application characteristics.
        c. Use a thinner recommended by the CSM.

Q. Film thickness and continuity:
    1. Apply coating to the specified thicknesses.
        a. Apply additional coats when necessary to achieve specified thicknesses, especially at edges and corners.
    2. Verify WFT of the coating system first coat and after applying each subsequent coat.
    3. Do not allow the minimum thickness at any point to deviate more than 20 percent on the low end and 120 percent on the high end from the required average.
    4. Do not allow the surface area covered per gallon of coating for various types of surfaces to exceed those recommended by the CSM.
        a. Provide coating coverage worksheets listing the maximum and minimum coverage for each unit volume of coating for concrete surfaces.
    5. Apply additional coats to achieve the specified dry film thickness if brush or roller application methods cannot achieve the specified film thickness per coat.

R. Protecting coated surfaces:
    1. Do not handle, work on, or otherwise disturb coated items until the coating is completely dry and hard.
    2. After installation, recoat shop-coated surfaces with specified coating system as necessary to match surrounding surfaces, and to coordinate with the specified color identification requirements.

S. Special requirements:
    1. Before erection, apply all but the final finish coat to interior surfaces of roof plates, roof rafters and supports, pipe hangers, piping in contact with hangers, and contact surfaces inaccessible after assembly. Apply final coat after erection.
    2. Coat structural slip-critical connections and high strength bolts and nuts after erection.

3. Areas damaged during erection:
    a. Prepare surface for spot repairs as specified for the coating system.
    b. Recoat with prime coat before applying subsequent coats.
    c. Touch up surfaces after installation.
    d. Clean and dry surfaces to be coated at time of application.
4. Coat underside of equipment bases and supports not galvanized with at least 2 coats of primer specified before setting the equipment in place.
5. Coat aluminum surfaces in contact with concrete.

3.10 APPLICATION REQUIREMENTS FOR CONCRETE COATING SYSTEMS

A. Apply filler/surfacer as recommended by CSM to fill bug holes and air voids in concrete or block texture in CMU, leaving a uniformly filled surface that does not produce blowholes or outgassing causing the coating system to pinhole.
    1. Allow filler/surfacers to cure sufficiently before applying prime coat as required by the CSM. Use the CSM-recommended drying time between coats.

B. Apply surfacer or filler and let dry before coating application.
    1. Use the drying time between filler/surfacer and coating system specified by the CSM for the Site conditions.
        a. Let concrete substrate dry before applying filler/surfacers or coating system materials.
    2. If the maximum recoat time is exceeded, prepare surfaces by solvent washing, light abrasive blasting, and other procedures in accordance with the CSM's instructions.
    3. Apply a complete parge coat of the specified filler/surfacer material over the entire substrate before applying the coating system.
        a. Scrub filler/surfacer into the substrate to completely fill open air voids and bug holes.
        b. Completely cover the substrate, unless otherwise specified, above such filled voids by 1/8 inch of thickness.
        c. Provide relatively flat, uniformly even surface before coating application.
    4. Secondary containment: Place surfacer or filler 1/16 inch thick above concrete plane to create a monolithic surface free of pinholes.
        a. Floor surfaces: Broadcast with aggregate to create a non-slip surface texture.
        b. Remove excess aggregates and apply base coat to encapsulate embedded non-slip aggregate.

C. Concrete substrate temperatures:
    1. Apply filler/surfacers and the coating system when temperatures are falling, typically late afternoon or evening.
        a. Do not coat concrete with rising concrete substrate surface temperatures or substrates in direct sunlight, to minimize outgassing from the substrate and formation of pinholes, and/or blistering.
    2. Should bubbles, pinholes, or other discontinuities form in the applied coating system material, they shall be repaired.
        a. Should discontinuities develop in the filler/surfacer material or in the first coat of the coating material, repair them before the next coat.
        b. When discontinuities occur, open the air void behind or beneath the discontinuities and completely fill with specified coating material. Then,

abrade the coated area around the discontinuities repair reapply coating over that area.

D. Perform application detail work in accordance with these Specifications, the CSM's current written recommendations, and Drawings, whichever is stricter.

E. Concrete coating systems application requirements:
   1. Concrete coating minimum dry film thickness excludes parge coat, block filler, and sealer.

3.11 COATING SYSTEMS

A. Attachment A - Schedule of Surfaces to be Coated specifies surfaces to be coated in the field with the coating systems required.

3.12 SURFACES NOT REQUIRING COATING

A. Stainless steel piping, valves, pipe supports, instrument sunshades.
   1. Clean and restore uniform passivation layer on damaged, contaminated, or de-passivated stainless-steel surfaces in accordance with ASTM A380.

B. Sliding surfaces on expansion joints, motor and pump shafts, machined surfaces at bearings and seals, grease fittings, etc.

C. Galvanized structural steel framing, galvanized roof decking, galvanized pipe supports.

D. Copper and brass pipe, fittings, valves, etc.

E. Bronze valves, bearings, bushings, and fasteners.

F. Corrosion resistant special alloys: Inconel, Alloy 20, Hastelloy, etc.

G. Exterior concrete.

H. Plastic surfaces, except coat PVC, CPVC, and other plastic piping system exposed to sunlight.

I. Exception - Piping that is encased in concrete or cement mortar:
   1. Coat the first 6 inches of pipe to be encased.
   2. Caulk gaps and seams after encasement.

3.13 QUALITY CONTROL

A. CSA to perform, or contract with an inspection agency to perform, quality control inspection and testing of the coating work covered by this Section. These inspections shall include the following:
   1. Prepare reports, after daily coating work ends, summarizing each day's test data, observations, drawings, and photographs.
   2. Perform the following activities to confirm conformance with the specifications:
      a. Inspect ambient conditions during coating system installation at Hold Points for conformance with the specified requirements.

b. Inspect each coated surface type and coating system applied to verify the following:
    1) Inspect materials upon receipt to ensure that the CSM supplied them.
    2) Verify that specified storage conditions for the coating system materials, solvents, and abrasives are provided.
    3) Inspect and record findings for substrate cleanliness.
    4) Inspect and record pH of concrete and metal substrates.
    5) Inspect and record substrate profile (anchor pattern).
    6) Measure and record ambient air and substrate temperature.
    7) Measure and record relative humidity.
    8) Check for substrate moisture in concrete.
    9) Verify that mixing of coating system materials is in accordance with the CSM's instructions.
    10) Inspect, confirm, and record that the coating system materials' "pot life" is not exceeded during installation. Inspect to verify that recoat limitations for coating materials are not exceeded.
    11) Perform adhesion testing.
    12) Measure and record the coating system's thickness.
    13) Verify proper curing of the coating system in accordance with the CSM's instructions.
    14) Holiday or continuity testing in accordance with NACE SP0188 for coatings that will be immersed or exposed to aggressively corrosive conditions.
    15) Prepare and submit written reports directly to the Owner's representative at the shift's end:
        a) Reports shall identify observations and testing relative to the quality of the surface preparation and painting/coatings work.
        b) Reports shall address any conditions observed which have the potential to adversely impact the finished painting/coating system integrity and performance.
        c) Any such findings shall be immediately repaired.

c. Verify surface profile of substrates by completing the following:
    1) Inspect preparation and application of coating detail treatment at terminations, transitions, metal embedment's in concrete, and joints and cracks in substrates.
    2) Inspect application of filler/surfacer materials for concrete and masonry substrates.

B. Damaged factory finishes shall be repaired and, if directed by the Owner's representative, refinished the entire surfaces of the factory-finish equipment at the applicators' expense.

C. Owner-provided inspection or inspection by others does not limit the required Contractor's or CSA's responsibilities for quality workmanship or quality control. Owners' inspection is in addition to any inspection performed by the applicator.

3.14 CORRECTIVE MEASURES

A. Repair pinholes or holidays identified by holiday testing as follows:
    1. Remove coating system at pinholes and holidays at least 2-inches diameter around the defect back to expose substrate.

2. Concrete voids: Chip back to expose entire cavity in all directions.
    a. Completely fill void with approved filler/surfacer material using a putty knife or other suitable tool and strike off. Cure in accordance with the CSM's recommendations.
3. Aggressively abrade or sand the intact coating system surfaces at least 3 inches beyond the removal area in all directions to produce a uniform 6- to 8-mil profile in the intact coating system.
4. Remove dust, dirt, etc., leaving clean, sound surfaces.
5. Tape to mask the periphery of the prepared intact coating area to prevent coating repair application onto the prepared area.
6. Apply the coating system with enough coats to achieve the specified finish coat thickness over the defect and coating removal area. Feather the coating onto the abraded coated surfaces around the removal area to avoid a lip and to achieve a neat repair outline.
7. Follow curing time between coats as specified by the CSM for the Site conditions. Solvent wash and abrasive blast in accordance with the CSM's instructions if the maximum recoat time is exceeded.
8. Apply coating at specified dry film thickness.

3.15 CLEANUP

A. Remove surplus materials, protective coverings, and accumulated rubbish after completing coating. Thoroughly clean surfaces and repair overspray or other coating-related damage.

3.16 FINAL INSPECTION

A. Conduct final inspection of coating system work to determine whether it meets specifications requirements.

B. Conduct subsequent final inspection with the Engineer to ensure Work is in accordance with Contract Documents requirements.

C. Mark any rework required.
    1. Re-clean and repair, as specified, at no additional cost to the Owner.

END OF SECTION

ATTACHMENT A - SCHEDULE OF SURFACES TO BE COATED

ATTACHMENT A
Schedule of Surfaces to be Coated

A. The following schedule is incomplete. Coat unlisted surfaces with same coating system as similar listed surfaces. Contact Engineer for clarification.

EPU-M-1	Metals, exterior and interior, non-immersed
ACR-PVC-1	CPVC, PVC Exterior Surfaces; Galvanized Rigid Conduit (GRC), PVC-coated Rigid Steel Conduit (PCS), flexible conduit, and associated fittings and appurtenances

Notes:

1: Non-immersed ferrous metal surfaces include:
- a. Doors, doorframes, ventilators, louvers, grilles, exposed sheet metal, and flashing.
- b. Pipe, valves, pipe hangers, supports and saddles, conduit, cable tray hangers, and supports.
- c. Motors and motor accessory equipment.
- d. Drive gear, drive housing, coupling housings, and miscellaneous gear drive equipment.
- e. Valve and gate operators and stands.
- f. Structural steel.
- g. Crane and hoist rails.
- h. Exterior of tanks and other containment vessels.
- i. Mechanical equipment supports, drive units, and accessories.
- j. Bare electrical equipment: boxes, exposed conduit, and accessories.
- k. Pumps not submerged.
- l. Other miscellaneous metals.

2: Immersed ferrous metal surfaces include:
- a. Interior surfaces of ferrous metal tanks.
- b. Field priming of ferrous metal surfaces with defective shop-prime coat; including non-submerged service.
- c. Bell rings, underside of manhole covers and frames.
- d. Sump pumps, including underside of base plates and submerged suction and discharge piping.
- e. Exterior of submerged piping and valves other than stainless steel or PVC piping.
- f. Submerged pipe supports and hangers.
- g. Stem guides.
- h. Other submerged iron and steel metal unless specified otherwise.

ATTACHMENT B - COATING DETAIL SHEETS

Attachment B			
Coating Detail Sheet			
Coating System	EPU-M-1		
Coating Material	Two coats epoxy with polyurethane finish coat		
Substrate	Metal		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	Carboguard 890	Carboguard 890	Carbothane 134 VOC
International Paint	Devran 224V	Devran 224V	Devthane 379H
PPG	Amerlock 2VOC	Amerlock 2VOC	Amershield VOC
Sherwin Williams	Macropoxy 646 100	Macropoxy 646 100	Hi Solids Polyurethane 250
Tnemec	Series 69	Series 69	Series 1095
Service Condition	Interior or Exterior, subject to direct sunlight. Non-immersion.		
Surface Preparation			
General	Prepare surfaces as specified in this Section and as follows.		
Ferrous Metal	Bare surfaces: SSPC-SP10, Near-White Blast Cleaning. Shop primed surfaces: SSPC-SP2, Hand Tool Cleaning or SSPC-SP3, Power Tool Cleaning. Damaged primer or rust: SSPC-SP10, Near White Blast Cleaning and spot prime.		
Nonferrous Metal	SSPC-SP16, Brush Blast Cleaning.		
Galvanized Metal	SSPC-SP16, Brush Blast Cleaning. Test for surface contaminants.		
Surface Profile			
Ferrous Metal	2.5 to 3.0 mils		
Nonferrous Metal	1.5 to 2.0 mils		
Galvanized Metal	1.5 to 2.0 mils		
System Thickness (Dry Film)			
Total	10 to 13 mils		
Primer	4 to 5 mils		
Intermediate Coat	4 to 5 mils		
Finish Coat	2 to 3 mils		
Application			
Special CTR Training	Not required.		

Attachment B			
Coating Detail Sheet			
Coating System	EPX-GM-1		
Coating Material	Epoxy		
Substrate	Galvanized Steel		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	Carboguard CM94	None applied	Carboguard CM94
International Paint	Devran 201V	None applied	Devran 224V
PPG	Amerlock 2/400 Series	None applied	Amerlock 2/400 Series
Sherwin Williams	Macropoxy 646	None applied	Macropoxy 646
Tnemec	Series V69	None applied	Series V69
Service Condition	Interior, moderately corrosive.		
Surface Preparation			
General	Prepare surfaces as specified in this Section and as follows.		
Galvanized Metal	SSPC-SP16, Brush Blast Cleaning. Test for surface contaminants.		
Surface Profile			
Galvanized Metal	1.5 to 2.0 mils		
System Thickness (Dry Film)			
Total	5 to 8 mils		
Primer	3 to 4 mils		
Finish Coat	3 to 4 mils		
Application			
Special CTR Training	Not required.		

Attachment B			
Coating Detail Sheet			
Coating System	EPX-M-5		
Coating Material	Epoxy mastic		
Substrate	Metal		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	CSM recommended	None applied	Carbomastic 15
International Paint	CSM recommended	Bar-Rust 231LV	Bar-Rust 231LV
PPG	No product specified	No product specified	No product specified
Sherwin Williams	CSM recommended	No product specified	No product specified
Tnemec	CSM recommended	Series 135	Series 135
Service Condition	Interior, corrosive environment, confined enclosures, where minimal surface preparation is possible.		
Surface Preparation			
General	Prepare surfaces as specified in this Section and as follows.		
Ferrous Metal	Bare surfaces: SSPC-SP11, Power to Cleaning to Bare Metal. Shop primed surfaces: SSPC-SP3, Power Tool Cleaning. Damaged primer or rust: SSPC-SP11, Power to Cleaning to Bare Metal.		
Nonferrous Metal	SSPC-SP16, Brush-Off Blast Cleaning.		
Surface Profile			
Ferrous Metal	2.0 to 2.5 mils		
Nonferrous Metal	1.0 to 1.5 mils		
System Thickness (Dry Film)			
Total	15 to 19 mils		
Primer	2 to 4 mils		
Finish Coat	15 mils		
Application			
Special CTR Training	Not required.		

Attachment B			
Coating Detail Sheet			
Coating System	EPX-M-6-BG		
Coating Material	Epoxy		
Substrate	Metal		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	Carboguard 890	Carboguard 890	Carboguard 890
International Paint	Bar-Rust 236	Bar-Rust 236	Bar-Rust 236
PPG	Amerlock 400	Amerlock 400	Amerlock 400
Sherwin Williams	No product specified	No product specified	No product specified
Tnemec	Series 69	Series 69	Series 69
Service Condition	Below grade in contact with soil.		
Surface Preparation			
General	Prepare surfaces as specified in this Section and as follows.		
Ferrous Metal	SSPC-SP10, Near White Metal Blast Cleaning.		
Nonferrous Metal	SSPC-SP16, Brush-Off Blast Cleaning.		
Galvanized Metal	SSPC-SP16, Brush-Off Blast Cleaning.		
Surface Profile			
Ferrous Metal	2.5 to 3.0 mils		
Nonferrous Metal	1.5 to 2.0 mils		
Galvanized Metal	1.5 to 2.0 mils		
System Thickness (Dry Film)			
Total	16 mils		
Primer	4 to 6 mils		
Intermediate Coat	4 to 6 mils		
Finish Coat	4 to 6 mils		
Application			
General	Fill all bugholes with a filler/surfacer compatible with the coating.		
Special CTR Training	Not required.		

Attachment B			
Coating Detail Sheet			
Coating System	POL-C-1-BSC		
Coating Material	Hybrid Polyurethane		
Substrate	Concrete or dense masonry		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	Reactamine 760	Reactamine 760	Reactamine 760
Global Eco Technologies	Endura-Flex EF 1200P	Endura-Flex EF 1988	Endura-Flex EF 1988
International Paint	Interseal 670HS LTC Buff	Polibrid 705	Polibrid 705
Sherwin Williams	Macropoxy 5500	Polycote 115	Polycote 115
Service Condition	Interior or exterior, Immersed, non-potable; non-immersed, corrosive environment, biogenic sulfide corrosion, new or existing construction. Waterproofing for exterior of buried tanks.		
Surface Preparation			
General	Prepare surfaces as specified in this Section and as follows.		
Concrete	Apply concrete surfacer, as required, after surface is accepted to provide a smooth surface. Completely fill all bugholes with the same material. Brush blast clean after adequate cure per CSM's instructions to produce a uniform anchor pattern. Let concrete substrate cure under warm conditions (minimum of 75 degrees F) for at least 5 days before coating application if using wet abrasive or water jet surface preparation. Sawcut 1/4" minimum deep groove and provide coating termination and transition details as shown on the drawings and in accordance with CSM's standard details including terminations, transitions at corners, cracks, pipe penetrations, terminations at metal embedments, and other details. Vacuum all surfaces to be coated after surface preparation and curing to remove all loose dirt, dust, or other loose materials.		
Existing Coated Concrete	Prepare as for new concrete. Apply a filler material and coat with surfacer to restore the substrate to a smooth surface suitable for coating. Refer to Section 09968(09_96_08)		
Masonry	Prepare as for new concrete. Apply a skim coat of a surfacer or filler material to provide a smooth surface suitable for coating.		
Surface Profile			
Concrete	ICRI CSP 5.		
Existing Coated Concrete	ICRI CSP 5.		
Masonry	ICRI CSP 3.		
System Thickness (Dry Film)			
Total	125 mils in addition to the surfacer.		
Primer	2-4 mils		
Intermediate and Finish Coats	Each coat at CSM's recommended DFT to specified system thickness.		
Application			
Special CTR Training	Required.		

Attachment B			
Coating Detail Sheet			
Coating System	EPU-FRP-1		
Coating Material	Polyurethane		
Substrate	FRP		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	Carboguard 890	None Applied	Carbothane 134 VOC
International Paint	Devran 224V	None Applied	Devthane 378H
PPG	Amercoat 400	None Applied	Amershield VOC
Sherwin Williams	Macropoxy 646-100	None Applied	VOC Hi Solids Polyurethane 100
Tnemec	Series 69	None Applied	Series 1095
Service Condition	Exterior, exposed to direct sunlight, non-immersed.		
Surface Preparation	Prepare surfaces as specified in this Section and as follows.		
General	Clean to remove loose dirt, dust, or other contaminants. Sand surfaces to achieve a uniform, roughened surface profile. Solvent clean and vacuum to remove loose debris.		
Surface Profile	1.5 to 2.0 mils		
System Thickness (Dry Film)			
Total	4 to 7 mils		
Primer	2 to 4 mils		
Finish Coat	2 to 4 mils		
Application			
Special CTR Training	Not required.		

Attachment B			
Coating Detail Sheet			
Coating System	ACR-PVC-1		
Coating Material	Acrylic		
Substrate	PVC and CPVC pipe		
Products: One of the following or equal:	Primer	Intermediate Coat	Finish Coat
Carboline	Sanitile 120	None Applied	Carbocrylic 3359 DTM
International Paint	Devcryl 1440	None Applied	Devcryl 1448
PPG	Pitt Tech Plus Primer	None Applied	Pitt Tech Plus
Sherwin Williams	Sher Cryl HPA	None Applied	Sher Cryl HPA
Tnemec	Series 1028 or 1029	None Applied	Series 1028 or 1029
Service Condition	Exterior, exposed to direct sunlight, non-immersed.		
Surface Preparation	Prepare surfaces as specified in this Section and as follows.		
General	Clean to remove loose dirt, dust, or other contaminants. Sand surfaces to achieve a uniform, roughened surface profile. Solvent clean and vacuum to remove loose debris.		
Surface Profile	1.5 to 2.0 mils		
System Thickness (Dry Film)			
Total	4 to 8 mils		
Primer	2 to 4 mils		
Finish Coat	2 to 4 mils		
Application			
Special CTR Training	Not required.		

SECTION 09968

CONCRETE REPAIR AND COATING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Field repair and coating of existing concrete.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C109 - Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-Inch Cube Specimens).
   2. C882 - Standard Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete By Slant Shear.
   3. C827 - Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures.
   4. C942 - Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory.
   5. D16 - Standard Terminology for Paint, Related Coatings, Materials, and Applications.
   6. D624 - Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers.
   7. D638 - Standard Test Method for Tensile Properties for Plastic.
   8. D1107 - Standard Test Method for Ethanol-Toluene Solubility of Wood.
   9. D1653 - Standard Test Methods for Water Vapor Transmission of Organic Coating Films.
   10. D2240 - Standard Test Method for Rubber Property - Durometer Hardness.
   11. D2794 - Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact).
   12. D4060 - Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser.
   13. D4263 - Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method.

B. NACE International (NACE):
   1. SP0188 - Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.

C. The Society for Protective Coatings (SSPC):
   1. SP-2 - Hand Tool Cleaning.
   2. SP-3 - Power Tool Cleaning.
   3. SP-10 - Near-White Blast Cleaning.

D. United States Department of Agriculture (USDA).

1.03 DESCRIPTION OF WORK

A. Furnish all labor, tools, equipment, materials, and other items required to:
   1. Repair damaged/deteriorated concrete as determined necessary and as required by Engineer; if required.
   2. Repair cracks in concrete by epoxy injection, as specified in Section 03931 - Epoxy Injection System as determined necessary and as required by Engineer; if required, it will be added as change order.
      a. Do not include in Total Bid Amount.
   3. Apply 100 percent solids elastomeric polyurethane coating to all concrete surfaces as specified in this Section.

B. As determined necessary by Engineer, remove piping, fittings, and associated items where work is to be accomplished.
   1. Replace and coat such items upon completion of work.

1.04 AREAS OF WORK

A. Interior surfaces of existing Sludge Blending Tanks as indicated on the Drawings and described in this Section:
   1. Prepare, repair, and coat all interior surfaces.

1.05 SEQUENCE OF WORK

A. Prepare interior surfaces of Sludge Blending Tanks in preparation for viewing by Owner, Engineer, Contractor, and coating manufacturer's technical representative:
   1. Steam clean and degrease all interior surfaces.
   2. Remove any items as required by Engineer, such as piping, brackets, prior to abrasive blast cleaning of concrete surfaces.
   3. Abrasive blast cleaning of concrete surfaces includes cleaning items, such as piping and brackets, in place.
   4. Abrasive blast clean all concrete surfaces to remove loose concrete and provide a "broom" type finish similar to 60-grit sandpaper.
   5. Work shall be completed within 7 days after structure is taken out of service.

B. Complete all modification work in Sludge Blending Tanks as specified in Contract Documents:
   1. Replace all items previously removed and prepare for coating application.

C. Complete all concrete repair work, necessary epoxy injection work, additional abrasive blast cleaning, and coating application as specified and required by Engineer and in this Section.

D. Perform inspection and necessary repairs to coating as specified in this Section.

1.06 SUBMITTALS

A. Shop drawings: Submit prior to start of work.

B. Product data (general): Submit prior to start of work.

C. Product data for 100 percent solids polyurethane coating:
   1. Manufacturer's literature including installation procedure and warranty for coating system.
   2. Manufacturer's letter of declaration to maintain local permanent inventory and field technical services during coating application and Warranty period.
   3. Test results of product from approved material testing laboratory certifying that product meets or exceeds required physical properties.
   4. Certification of manufacturer's technical services representative.

D. Testing procedure in accordance with ASTM D4263.

E. Coating repair procedures.

F. Coating applicator licensing:
   1. Approval and licensing by manufacturer of 100 percent solids elastomeric polyurethane coating for coating applicator to apply this system.
   2. Certification from patent holder of Eco System expansion process for 100 percent solids elastomeric polyurethane coating that coating applicator is certified to utilize this process.

G. Manufacturer's instructions: Submit in accordance with requirements for product data.

H. Manufacturer's technical representative's field reports.

1.07 QUALITY ASSURANCE

A. Qualifications of concrete repair Contractor:
   1. Manufacturer of specified concrete repair products shall have in existence, for a minimum of 10 years, a program of training, certifying, and technically supporting a nationally organized approved Contractor program with annual recertification of its participants.
   2. Provide list of at least 5 job references where Contractor has successfully repaired spalled concrete surfaces.

B. Qualifications of 100 percent solids elastomeric polyurethane coating applicator:
   1. At least 5 years of experience applying type of coating under conditions similar to the Work specified in this Section:
      a. Submit list of 5 references for similar projects completed.

C. Qualifications of 100 percent solids elastomeric polyurethane coating manufacturer's technical services representative:
   1. Minimum 3 years of experience involving applications of 100 percent solids elastomeric polyurethane epoxy.
   2. Shall be available as required to support application of specified product.

D. Regulatory requirements: Include requirements concerning the following:
   1. Abrasives and abrasive blast cleaning techniques and disposal.

E. Pre-installation conference:
   1. Conduct prior to start of work at mutually agreed time by Owner and Contractor.
   2. Coating manufacturer's technical services representative shall attend pre-installation conference.

F. Certification: Certify that coatings to be applied are resistant to discoloration or deterioration when exposed to hydrogen sulfide and other sewage gases and product data fails to designate coating as "fume resistant."

G. Field samples: Prepare and coat a minimum 100 square foot area between corners or limits such as control or construction joints of each system.
   1. Accepted field sample may be part of Work.

H. Compatibility of coatings: Use products by same manufacturer for prime coats, intermediate coats, and finish coats on same surface, unless specified otherwise.

I. Services of coatings manufacturer's technical representative: Arrange for coating manufacturer's technical representative to attend pre-installation conferences and to make periodic visits to the project site to provide consultation and inspection services during surface preparation and application of coatings.

1.08 DELIVERY, STORAGE, AND HANDLING

A. Remove unspecified and unapproved materials from Project site immediately.

B. Deliver containers with labels identifying the manufacturer's name, brand name, product type, batch number, date of manufacturer, expiration date or shelf life, color, and mixing and reducing instructions.

C. Store materials in a well-ventilated facility that provides protection from the sun, weather, and fire hazards.
   1. Maintain ambient storage temperature between 45 and 90 degrees Fahrenheit, unless otherwise recommended by the manufacturer.

D. Take precautions to prevent fire and spontaneous combustion.

1.09 PROJECT CONDITIONS

A. Surface moisture contents: Do not coat surfaces that exceed coating manufacturer specified moisture contents.

B. Do not coat:
   1. Under dusty conditions.
   2. When light on surfaces measures less than 15 foot-candles.
   3. When ambient or surface temperature is less than 45 degrees Fahrenheit.
   4. When relative humidity is higher than 85 percent.
   5. When surface temperature is less than 5 degrees Fahrenheit above dewpoint.
   6. When surface temperature exceeds coating manufacturer's recommendation.
   7. When ambient temperature exceeds 90 degrees Fahrenheit, unless coating manufacturer allows a higher temperature.

C. Provide fans, heating devices, dehumidification equipment, or other means recommended by manufacturer to prevent formation of condensate or dew on surface of substrate, coating between coats, and within curing time following application of last coat.

1.10 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

B. Special warranty:
   1. Duration: 3 years warranty on concrete repair and coating work accomplished under this Contract stating that Contractor will provide all labor and materials to repair any defects that occur after completion and acceptance date of work at no cost to Owner.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Concrete repair material:
   1. Polymer-modified portland cement mortar: The following or equal:
      a. Five-Star Grout.
   2. Epoxy grout: The following or equal:
      a. Five-Star HP Epoxy Grout.

B. 100 percent solids polyurethane coating materials:
   1. The following or equal:
      a. Global Eco-Technologies, Inc. EnduraFlex EF-1988.

2.02 MATERIALS

A. Repair mortar:
   1. Non-shrink cementitious grout shall be flowable, pre-packed, cement-based grout requiring addition of potable water.
   2. Conforming to performance requirements of ASTM C1107 Grades A, B, C for 45 minutes at 40 degrees Fahrenheit to 90 degrees Fahrenheit (4 degrees Celsius to 32 degrees Celsius).
   3. Grout material shall meet the following typical performance criteria when cured at 73 degrees Fahrenheit (23 degrees Celsius):
      a. Grout shall not contain metallic aggregate, expansive cement, or gas generating additives.
      b. Grout shall contain an air release aggregate to generate positive expansion.
      c. Early height change, ASTM C827: 0.0 to 0.4 percent.
      d. Hardened height change, ASTM C190: 0.0 to 0.3 percent.
      e. Effective bearing area: 95 percent.
      f. Compressive strength, ASTM C942:
         1) 1 Day: 2,500 pounds per square inch.
         2) 7 Days: 5,000 pounds per square inch.
         3) 28 Days: 6,500 pounds per square inch.

g. 28 days bond strength, ASTM C882: 2,000 pounds per square inch (13.8 MPa).
h. Working time: 45 minutes.
i. Application temperature: 40 degrees Fahrenheit to 90 degrees Fahrenheit (4 degrees Celsius to 32 degrees Celsius).
j. Material temperature: 40 degrees Fahrenheit to 90 degrees Fahrenheit (4 degrees Celsius to 32 degrees Celsius.

B. Reinforcing steel coating:
1. Solvent-free, moisture-tolerant, epoxy-modified, cementitious, corrosion inhibiting product.

C. Elastomeric polyurethane coating:
1. 2 components, 100 percent solids, ASTM D16 Type V, aromatic, MDI (Methylene Diisocyanate) elastomeric polyurethane which contains no sand or silica fillers.
2. Certified by an approved material testing laboratory to be resistant to hydrogen sulfide and sodium hypochlorite and meet the following requirements:

Physical Properties	Test Method	Results
Durometer Hardness @ 75 Degrees Fahrenheit, Shore D	ASTM D2240	50-70 Shore D
Tensile Strength	ASTM D638	2,800-3,000 pounds per square inch
Percent Elongation	ASTM D638	65 percent
Abrasion Resistance	ASTM D4060	53 milligrams
Impact Resistance	ASTM D2794	35 pounds per square inch
Tear Resistance	ASTM D624	Greater than 200 pounds per square inch
Water Vapor Permeability	ASTM D1653 Test Method A, at 75-80 mils	0.048 grams per 23 hours per foot squared

3. Systems:
a. Endura-Flex EF-1988:
1) For areas without concrete repair applied: Apply total dry film thickness (DFT) of 250 mils, or as required to be pin-hole free, consisting of a minimum 200 mils of expanded Endura-Flex EF 1988 with minimum 50 mils topcoat of solid Endura-Flex 1988.
2) For areas with concrete repair applied: Apply total of 200 mils, or as required to be pinhole free, consisting of a minimum of 150 mils of expanded Endura-Flex EF 1988 with a minimum 50 mils topcoat.
4. Primer:
a. Endura-Flex 1200P Epoxy Primer: One of the following or equal:
1) Primer to be used only as recommended by coating manufacturer's technical representative.

PART 3 EXECUTION

3.01 GENERAL PREPARATION

A. As required, remove all existing piping, pipe hangers, concrete inserts, and other items as necessary from areas where repair and coating of concrete is required to facilitate repair and coating work, and acceptable to Engineer.

B. Steam clean and degrease all surfaces prior to abrasive blasting.

C. Utilize abrasive blast cleaning to remove surface contaminants and loose material for preparation of concrete surfaces.
   1. Remove debris from structure and dispose of material off-site:
      a. Compressed air used for blasting or blow downs must be clean and free of oil particles.
      b. Air compressors must be equipped with efficient oil and water traps.

D. Utilize SSPC SP2 and SSPC SP3 standards to remove damaged and deteriorated concrete for repair and coating:
   1. For areas with less than 1/2-inch concrete deterioration, provide the expanded polyurethane coating as specified in this Section.
   2. For areas of concrete deterioration between 1/2 inch and 3 inches, provide repair mortar with polyurethane topcoat.
   3. For area with concrete deterioration beyond 3 inches, with exposed reinforcing bars, the concrete must be chipped back to 4-1/2 inches and reinforcing bars repaired as required.

E. Remove loose concrete from spalled areas and cracks:
   1. In areas where concrete deterioration dovetails to original concrete surface, make entire cavity to be repaired at least 1/2-inch deep from original concrete surface by means of saw-cutting.
   2. Provide straight edges, a minimum of 1/2-inch deep in sound concrete 2-inches away from deterioration.
   3. Repair with concrete repair mortar so as to provide a minimum of 1/2 inch of concrete repair material at all locations.
   4. Prepare surface edges of cavity by grinding.
   5. Remove dust, dirt, and loosely bonded material resulting from cleaning.
   6. Ensure cavity surfaces are dry.

F. Use following procedures where reinforcing steel with active corrosion is encountered:
   1. Clean exposed reinforcing bars to SSPC SP10 standard.
   2. Determine reinforcement bar section loss, splice new reinforcing bars where there is more than 15 percent loss as determined by Engineer.
      a. If more than half the diameter of reinforcing steel is exposed, chip out behind reinforcing steel a minimum of 1/2 inch.
      b. Cut reinforcing bars, butt weld new reinforcing bars to undamaged existing reinforcing bars and place repair mortar to original surface.
   3. Coat all exposed reinforcing steel with high solids epoxy immersed service, as specified in Section 09960 - High-Performance Coatings, before installation of final concrete repair material.

G. Restore damaged and deteriorated edges with approved concrete repair material and in accordance with manufacturer's recommendations.

H. For all concrete repair areas:
   1. Provide smooth steel towel finish free from trowel marks and depressions greater than 1/4 inch.
   2. Allow concrete repair areas to cure for minimum of 48 hours before application of elastomeric polyurethane coating, or as recommended by manufacturer of elastomeric polyurethane coating.
   3. Sweep blast all concrete repair areas, followed by air blow-down and vacuuming of all areas to remove all dust and debris before the application of coating.
   4. Provide heaters, fans, or dehumidification equipment as required to allow concrete surfaces to cure and be dry, as recommended by manufacturer of elastomeric polyurethane coating, prior to application of coating.

I. Allow repaired areas to cure for minimum of 48 hours before application of elastomeric polyurethane coating, or as recommended by manufacturer of elastomeric polyurethane coating.
   1. Provide necessary heaters, fans, or dehumidification equipment to allow concrete to cure and to be surface dry for coating application.

J. Cleanliness:
   1. At the direction of the coating manufacturer's technical representative or the Owner, all surfaces shall be pressure cleaned with clean, potable water at a minimum pressure of 1,500 pounds per square inch to remove all dust, dirt, and other debris prior to the application of the elastomeric polyurethane coating.

K. Expansion joints:
   1. Seal expansion joints with bond breaker tape.
      a. Polyethylene-backed adhesive tape is acceptable.
   2. Prior to installation of bond breaker tape, round-off sharp edges, remove debris/dust, and inspect to assure that joint compound is reasonably flush with top edge of expansion joint.
   3. Apply a tack coat of elastomeric polyurethane coating material to adjacent areas, followed immediately with installation of the tape.
   4. Install tape centered over the joint and be of sufficient width to extend a minimum of 1 inch onto the concrete on both sides of the joint.
   5. Tape thickness should be no more than 50 percent of the specified coating thickness.
   6. Topcoat bond breaker tape with elastomeric polyurethane coating material to the minimum specified thickness.

L. Inspection:
   1. After completion of surface preparation Owner, Engineer, and coating manufacturer's technical representative, will inspect all surfaces to be coated prior to coating.
   2. Specified cleanliness shall be verified through the use of accepted practice in accordance with SSPC or NACE standards.
   3. Utilize visual comparators to verify the specified level of cleanliness.

M. Abrasive-blast and concrete debris:
    1. Remove debris generated from the preparation operations from the structures.
    2. Haul and dispose of debris in accordance with all federal, State, and local regulations.

3.02 COATING APPLICATION

A. Equipment requirements:
    1. Utilize plural component proportioning equipment capable of pumping 2 separate streams of polyurethane components at the required ratio volumetrically.
    2. Have capability to heat the 2 different liquid components to a process temperature range from 100 to 125 degrees Fahrenheit depending on the set-up.
        a. Do not use of band heaters.
    3. Have capability to maintain process temperature to spray through a gun or pour through the nozzle.
        a. The use of insulated heat-trace fluid lines is mandatory.
    4. Have capability to pump at pressures ranging from 1,200 pounds per square inch to 3,000 pounds per square inch.
    5. Have capability to bring the 2 separately proportioned streams together as 1 stream and mix them together to provide a homogenous mixture for reacting into a solid polymer of known properties.
    6. Provide spray atomization tip sizes matched to the pumping equipment output which provides a fully atomized spray pattern, free of “fingers” without the addition of solvents of any kind.
    7. For applications requiring expanded films, Contractor must be licensed for the use of the ECOSYSTEM expansion technology, to include trained personnel, and have the equipment capabilities to apply the ENDURA-FLEX® 1988 material using the ECOSYSTEM technology.

B. Before start of application and at such times when long breaks are involved or application of equipment malfunctions, the following 4 material quality tests are recommended:
    1. A ratio check to verify required volumetric proportioning.
    2. A mixed material check to verify proper mixing of components.
    3. Curing cycle test to verify the proper reaction is under way.
        a. At least a pint sample is to be utilized.
        b. First Durometer results should be determined within 15 minutes.
    4. A weight check (10 ounces. Container with solid material and 10 ounces. Container with expanded material) to verify proper expansion rate.

C. All surfaces receiving the coating shall be visually dry and at least 5 degrees Fahrenheit (3 degrees Centigrade) above the dew point prior to starting the installation to prevent moisture entrapment:
    1. The relative humidity must be below 85 percent.
    2. Test surfaces to be coated in accordance with ASTM D4263.
        a. Test method for indicating moisture in concrete is by the plastic sheet method.

D. Compressed air used for coating application shall be clean and free of oil and water.

E. Use primer only at direction of, and as recommended by coating manufacturer's technical representative.

F. Mix polyurethane base component thoroughly with a power mixer.
   1. Heat base and activator to 100 to 110 degrees Fahrenheit prior to use.

G. Materials conditioning:
   1. Perform in accordance with manufacturer's latest published data.
   2. Control temperature in order to produce a repeatable finished product on each application.

H. Deposition of materials: Apply coating to be monolithic and cohesive in nature and to minimize hand work repair.

I. Leading edges: Install a mechanical anchor for the leading edge of the applied coating material:
   1. Leading edge mechanical anchor shall consist of a saw cut to a minimum depth of 1/4 inch and width of 1/8 inch.
   2. Sharp edges of the saw cut shall be rounded, dried, and cleaned of debris.
   3. After cleaning, solid base elastomeric polyurethane coating shall be applied into the saw cut, taking care to penetrate to full depth. The use of a trowel or putty knife might be required.
   4. After installation of the leading edge, topcoat the area with composite elastomeric polyurethane coating material.
      a. Tape-off adjacent areas not scheduled for coating and protected from overspray.

J. Curing:
   1. Protect finished coating from damage during curing.
   2. Cure coatings as recommended by coating manufacturer for a minimum of 3 days before coated areas are placed in service.

K. Cleanup: Clean spillage and overspray from adjacent surfaces as recommended by coating system manufacturer.

3.03 INSPECTION AND TESTING

A. The following inspection equipment (or engineer accepted equal) shall be provided and utilized for performing quality control testing:
   1. Sling psychrometer.
   2. Surface temperature thermometer.
   3. Ambient temperature thermometer.
   4. Psychrometric charts for determining relative humidity and dew point.
   5. High range wet and dry film thickness gauges.
   6. Micrometer.
   7. Durometer: A scale.
   8. Sample cans.
   9. Inspection glass: 30 power minimum.
   10. High voltage holiday detector.

B. The following quality control tests shall be performed, with results recorded and made available to Engineer:
    1. Compressed air quality in accordance with blotter test.
    2. Environmental conditions prior to coating application, including substrate temperature, ambient temperature, relative humidity, and dew point.
    3. Observation of surface preparation, including anchor pattern prior to coating application.
    4. Results of ratio check of plural component proportioning equipment.
    5. Wet and dry film thickness measurements.

C. Owner, Engineer, and coating manufacturer's technical representative shall be given sufficient notice so as to be present when the following hold points are reached:
    1. Completion of surface preparation.
    2. Prior to coating application.
    3. During wet and dry film thickness measurements.
    4. During holiday detection testing.
    5. During coating repairs.

D. Surface cleanliness, pH condition:
    1. Use either pH paper or a pH meter to determine the pH of the concrete surface.
    2. A pH range of 5 to 9 is considered acceptable.

E. Enlist the aid of various tests and implement those tests to verify the integrity of the applied coating.
    1. Permit Owner, Engineer, and coating manufacturer's technical representative full access at all times to observe and be satisfied that the specification is being followed.

F. Wet film thickness shall be monitored throughout the coating installation by means of frequent measurements with a high-range wet film thickness gauge.

G. All layers of material (expanded and solid) shall be applied the same day. This procedure is to ensure minimization of contamination of the coating:
    1. If project is not completed, then at the end of the workday, a 3- to 12-inch "returning edge" of material will be left tapered to the substrate for the start of the next working day.
    2. The "returning edge" shall be cleaned with MEK before proceeding to spray on start up to the following workday.

H. Coating shall be 100 percent electronically tested using high voltage in accordance with NACE procedure SP0188 inspected for discontinuities to include pinholes, voids, and mechanically damaged areas.
    1. Any damaged areas, faulty areas, or discontinuities (pinholes) found during holiday detection within a 24-hour (within recoat window) period of application shall be corrected as follows:
        a. Damaged or faulty areas (i.e., impact damage, off-ratio application):
            1) Clean area thoroughly, extending at least 6 inches beyond damaged area with MEK dampened cloth.

2) Do not apply excessive MEK to repair area, the intent is to clean only.
3) Allow MEK to thoroughly dry.
4) When thoroughly dry to touch, spray area with coating to the specified thickness, feathering material into existing coating.
5) In the event that the damaged area exhibits a discolored substrate substandard to the specified requirements, these areas shall receive the same degree of surface preparation required by the original project specifications prior to application of the coating material.

b. Discontinuity (pinhole) repair:
1) Clean the immediate area around the detected discontinuity with MEK dampened cloth (do not apply excessive MEK to pinhole area, the intent is to clean only), allow MEK to thoroughly dry.
2) Hand apply (putty knife, etc.) a small amount of mixed material directly to the pinhole.
3) For pinhole repairs, hand mix and thoroughly blend a small amount (normally 2 or 3 ounces at a time, for each applicator) of Part A and Part B in correct ratios.

2. Any damaged areas, faulty areas, or discontinuities (pinholes) found during holiday detection inspection after 24 hours of coating installation (exceeding recoat window) shall be corrected as follows:
a. Damaged or faulty areas (i.e., impact damage, off-ratio application, etc.):
1) Abrade the surface using a power grinder and/or power steel grinding brush down to and including exposed bare concrete to roughen the surface and to prepare the substrate to the original standard.
2) Abraded areas shall extend at least 6 inches (15 centimeters) beyond damaged or faulty area.
3) After abrading the surface, vacuum or blow down with clean, dry compressed air thoroughly to remove all loose particles.
4) Clean the area thoroughly, extending at least 6 inches (15 centimeters) beyond the damaged area with MEK dampened cloth (do not apply excessive MEK to pinhole area, the intent is to clean only), allow MEK to thoroughly dry.
5) When thoroughly dry to touch, spray area with coating to the specified thickness, feathering the material into the existing prepared coating.

b. Discontinuity (pinhole) repair:
1) Abrade (hand sand or power tool clean) the immediate areas around the detected pinhole (1/2-inch radius from edge of discontinuity) to establish a roughed surface, and to prepare the substrate to the original standard, followed with vacuuming or blow down with clean, dry compressed air to remove loose particles.
2) After dust removal, wipe abraded area with MEK dampened cloth.
3) Do not apply excessive MEK to pinhole area.
4) The intent is to clean only. Allow MEK to thoroughly dry.
5) Hand apply (putty knife, etc.) a small amount of mixed material directly to the pinhole.
6) For pinhole repairs, hand mix and thoroughly blend a small amount (normally 3 ounces at a time for each applicator) or Part A and Part B in correct ratios.

3.04 REPLACEMENT OF REMOVED ITEMS

A. Clean and recoat items removed from work areas prior to commencing work such as piping, pipe hangers, and associated equipment replace in like manner as removed.

3.05 FINAL INSPECTION AND ACCEPTANCE

A. Final inspection:
   1. Following replacement of previously removed items, a final inspection of the repaired and coated structures shall be made by Engineer, Owner, Contractor, and the coating manufacturer's technical representative.
   2. Any damage that has occurred to the coating shall be repaired in accordance with the coating manufacturer's instructions.

B. Final acceptance:
   1. Written final acceptance of the concrete repair and coating work accomplished to the interiors of the Sludge Blending Tanks structures, as specified in the Contract Documents, shall be prepared by the Engineer or Owner and issued to the Contractor, with a copy to the coating manufacturer.

END OF SECTION

SECTION 10400

SIGNAGE

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Plastic and metal signs for building and Site use.

1.02 REFERENCES

A. American National Standards Institute (ANSI):
   1. Z535.1 - Safety Colors.
   2. Z535.2 - Environmental and Facility Safety Signs.

B. National Fire Protection Association (NFPA):
   1. 704 - Standard System for the Identification of the Hazards of Materials for Emergency Response.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product data:
   1. Manufacturer’s data indicating sign type, style, and color.

C. Shop Drawings:
   1. Include lists of sign types, sizes, text, colors, and locations.

D. Samples: Include actual materials.

E. Manufacturer’s installation instructions.

1.04 QUALITY ASSURANCE

A. Regulatory requirements: Provide signage in accordance with Americans with Disabilities Act as published in the Federal Register, Volume 56, No. 144, Friday, July 26, 1991.

PART 2 PRODUCTS

2.01 SAFETY SIGNS

A. General:
   1. Colors: In accordance with ANSI Z535.1.
   2. Design: In accordance with ANSI Z535.2.
   3. 40-mil thick aluminum with baked enamel finish.

4. Fasteners: Round head stainless steel bolts or screws.

B. Manufacturers: One of the following or equal:
   1. Emedco.
   2. Seton Name Plate Co., Special Wording.

C. Danger signs:
   1. Background: White.
   2. Heading: White lettering on red oval with white border in black rectangular panel.
   3. Message: Black lettering on white.
   4. Size: As scheduled.

D. Caution signs:
   1. Background: Yellow.
   2. Heading: Yellow lettering on black rectangular panel.
   3. Message: Black lettering on yellow.
   4. Size: As scheduled.

E. Safety instruction signs:
   1. Background: White.
   2. Heading: White lettering on green rectangular panel.
   3. Message: Black lettering.
   4. Size: As scheduled.

F. Warning signs:
   1. Background: Orange.
   2. Heading: Black lettering on orange diamond in black rectangular panel.
   3. Message: Flack lettering on orange.
   4. Size: As scheduled.

G. Notice information signs:
   1. Background: White.
   2. Heading: White lettering on blue rectangular panel.
   3. Message: Black lettering.
   4. Size: As scheduled.

H. See Attachment A - Safety Signage Schedule for specific sign size, location, text, and quantity.

2.02 HAZARD MATERIAL SIGNS

A. Manufacturers: One of the following or equal:
   1. Emedco.
   2. Seton Name Plate Co.

B. Requirements:
   1. In accordance with NFPA 704.
   2. Vinyl panels, letters, and symbols with pressure sensitive adhesive.
   3. Sizes as required for viewing distances, letters and symbols in accordance with Attachment B - Hazard Material Signage.

PART 3 EXECUTION

3.01 PREPARATION

A. Protect adjacent surfaces which may be damaged by installation of signs.

B. Prepare substrates in accordance with the sign manufacturer’s instructions.

C. Remove scale, dirt, grease, and other contaminates from substrates.

3.02 INSTALLATION

A. Install signs in accordance with the sign manufacturer’s instructions.

B. Fasten signs securely in level, plumb, and true to plane positions.

C. Install signs where indicated on the Drawings or as indicated in the Attachments.

END OF SECTION

ATTACHMENT A - SAFETY SIGNAGE SCHEDULE

SAFETY SIGNAGE SCHEDULE

A. NON-POTABLE WATER:
   1. Location: At non-potable water hose valves.
   2. Height: In accordance with Typical Detail.
   3. Size: 10 inches wide by 7 inches high.
   4. Heading: DANGER
   5. Wording: NON-POTABLE WATER
      DO NOT DRINK

B. PRESSURE WASHER STATION:
   1. Location: At each pressure washer station.
   2. Height: Above station, approximately 60 inches above floor to center of sign.
   3. Size: 10 inches wide by 7 inches high.
   4. Heading: DANGER
   5. Wording: HIGH PRESSURE
      NON-POTABLE WATER
      DO NOT DRINK

C. EMERGENCY EYE/FACE WASH AND SHOWER STATION:
   1. Location: At each emergency eye/face wash and shower station.
   2. Height: 60 inches above floor or grade to center of sign.
   3. Size: 10 inches wide by 7 inches high.
   4. Heading: SAFETY FIRST
   5. Wording: EMERGENCY EYE/FACE WASH AND SHOWER STATION

D. SLIPPERY WHEN WET:
   1. Location: Adjacent to polymer totes, polymer blending units, polymer pumps, polymer containment areas, polymer injection points, sample sinks, sample ports, hose bibbs.
      a. Mount signs on posts at locations directed by Engineer.
   2. Height: 60 inches above floor or grade to center of sign.
   3. Size: 10 inches wide by 7 inches high.
   4. Heading: CAUTION
   5. Wording: FLOOR MAY BE SLIPPERY

E. REMOTELY CONTROLLED AUTOMATIC EQUIPMENT:
   1. Location: On front and back of equipment that starts automatically by remote control.
   2. Height: As directed by Engineer.
   3. Size: 10 inches wide by 7 inches high.
   4. Heading: DANGER
   5. Wording: THIS EQUIPMENT STARTS AUTOMATICALLY
      BY REMOTE CONTROL

F. LOAD LIMIT FOR MONORAIL:
   1. Location: At RDT Facility, as directed by Engineer.
   2. Height: 60 inches above floor to center of sign.
   3. Size: 10 inches wide by 7 inches high.
   4. Wording: MONORAIL CRANE LOAD LIMIT – 4 TONS
   5. Quantity: 2.

ATTACHMENT B - HAZARD MATERIAL SIGNAGE

HAZARD MATERIAL SIGNAGE

A. HAZARD SIGNAL FOR EMULSION POLYMER:
   1. Location: In polymer mixing areas and polymer tote containment areas.
   2. Height: As directed by Engineer.
   3. View Distance: As directed by Engineer.
   4. Health: 1.
   5. Flammability: 1.
   6. Reactivity: 0.
   7. Special: --

SECTION 10401

SAFETY EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Safety equipment.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME).

B. California Occupational Safety and Health Administration (Cal-OSHA).

1.03 SUBMITTALS

A. Product data:
   1. Submit manufacturer's product literature information for products specified.
   2. Manufacturer's installation instructions.

B. Warranty.

1.04 QUALITY ASSURANCE

A. Manufacturer qualifications: Show evidence that the firm has been engaged in producing such materials and products for at least 5 years and that the product submitted has a satisfactory performance record of at least 5 years.

B. Installer qualifications: Installer shall have 3 years experience in installing these materials for similar projects and shall be approved by the manufacturer prior to bidding of the project.

C. Regulatory requirements: As applicable, equipment of this Section shall comply with requirements of public agencies of the state where the project is located, including Cal-OSHA, ASME, and U.S. Coast Guard.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packing and shipping: Deliver to the job site in manufacturer's original containers.

B. Storage and protection: Store materials in original, unopened containers in compliance with manufacturer's printed instructions.

C. Keep materials dry until ready for use.

D. Keep packages of material off the ground, under cover, and away from sweating walls and other damp surfaces.

E. Protect finished surfaces from soiling and damage during handling and installation. Keep covered with a protective covering.

PART 2 PRODUCTS

2.01 LIFE PRESERVER

A. Chacteristics:
   1. Doughnut-shaped.
   2. Diameter: 30 inches.
   3. U.S. Coast Guard approved.

B. Accessories:
   1. Mounting brackets.
   2. U.S. Coast Guard approved poly-dacron rope:
      a. Length: 90 feet.

C. Cabinet:
   1. Construction:
      a. Cabinet material: fiberglass.
      b. Handle: Non-locking T-handle.
   2. Mounting hardware:
      a. Suitable for rail mounting as indicated on the Drawings.
      b. Material: Type 316 stainless steel.

D. Provide weathertight rubber gasket.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install products and fixed equipment in accordance with manufacturers' recommendations.

B. Replace any equipment found defective with new.

END OF SECTION

SECTION 11210

FIBERGLASS METERING MANHOLES

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Metering manholes.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. C 581 - Practice for Determining Chemical Resistance of Chemical Thermosetting Resins Used in Glass-Fiber Reinforced Structures Intended for Liquid Service.
   2. D 638 - Standard Test Method for Tensile Properties of Plastics.
   3. D 695 - Test Methods for Compressive Properties of Rigid Plastics.
   4. D 790 - Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
   5. D 2583 - Test Method for Indentation Hardness of Rigid Plastics by Means of a Barcol Impressor.
   6. D 2584 - Test Method for Ignition Loss of Cured Reinforced Resins.
   7. D 3753 - Standard Specification for Glass-Fiber Reinforced Polyester Manholes.

B. American Association of State Highway and Transportation Officials (AASHTO):
   1. H-20 - Axial Loading.

1.03 SUBMITTALS

A. Product Data: Test results of representative fiberglass reinforced plastic laminate.

B. Shop Drawings:
   1. Show critical dimensions, jointing and connections, fasteners and anchors.
   2. Materials of construction.
   3. Sizes, spacing, and location of structural members, connections, attachments, openings, and fasteners.
   4. Color(s).

C. Manufacturer’s installation instructions.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Store products indoors or in weather protected area until installation. Protect from construction traffic and damage.

B. During the loading, unloading, and storage, care should be taken to ensure that the manhole is not dropped or otherwise damaged.

C. The manhole shall be stored on a smooth surface free of sharp objects.

D. Nylon or fabric slings should be used in conjunction with a spreader bar to lift or move the manhole. Under no circumstances should cables or chains be in contact with the manhole.

E. If the manhole is stored horizontally, the manhole should be placed in such a way as to avoid damage to the flume, cover, and end adapters.

1.05 WARRANTY

A. The aluminum access hatch shall be warranted against defects in materials and workmanship by the hatch manufacturer for 10 years.

PART 2 PRODUCTS

2.01 MANUFACTURER

A. One of the following or equal:
   1. TRACOM, Inc.; 6575-A Industrial Way, Alpharetta, Georgia 30004; Tel. (877) 435-8637, Fax (770) 664-6565, www.tracomfrp.com.
   2. Plasti-Fab, Inc.; P.O. Box 100, Tualatin, Oregon.
   3. Associated Fiberglass Enterprises; 2417 Weaver Street Fort Worth TX 76117; Tel. 800-798-6561, Associated Fiberglass Provides best Metering Manholes.

B. Fiberglass tanks modified for flume installation shall not be allowed.

C. Warranty: Manholes shall be warranted to be free of defects in workmanship and materials for a period of 2 years from shipment.

2.02 METERING MANHOLES

A. The manhole shall be constructed to the dimensions as indicated on the Drawings.

B. Construction:
   1. Fiberglass reinforced plastic, complying with ASTM D 3753-81.
   2. Factory-assembled, ready for installation except for field-installed equipment.
   3. The exterior surface shall be relatively smooth with no sharp projections. The surface shall be free of blisters larger than 0.5 inch in diameter, delamination and fiber show.
   4. The interior surfaces shall be resin rich with no exposed fibers. The interior surface shall be smooth for improved corrosion resistance and reduced sludge build-up. The surface shall be free of crazing, delamination, blisters larger than 0.5 inch in diameter, and wrinkles of 0.125 inch or greater in depth.
   5. Minimum 0.480 inches wall thickness.
   6. Integral fiberglass ladder bolted and glassed to the manhole wall with 2-inch by 2-inch pultruded fiberglass rungs with a photoluminescent high visibility non-slip top surface and reinforced with threaded T-304 5/6 inch diameter stainless steel rods.

7. Integrally molded inlet and outlet PVC or fiberglass pipe stubs laminated to both the interior and exterior surfaces of the manhole. The nominal diameter of the pipe connections shall be as indicated on the Drawings.
8. Flexible transition coupling with stainless steel bands and stainless steel shield shall connect manhole pipe stubs to plant drain piping. Coupling shall be Fernco 5000 Series Strong Back (RC) Coupling, or equal.
9. A 3/4-inch thick expanded polystyrene bead board shall be supplied to place under the manhole on the concrete slab.
10. A 4-inch integral mounting flange shall be molded around the circumference of the manhole for anchoring to concrete.
11. An OSHA approved “Confined Space Entry” sign shall be applied to the interior surface of the manhole above the first ladder rung.
12. One 2-inch NPT coupling to facilitate the installation of sample tubing, electrical power, or other cabling into the manhole.

C. Materials:
1. The resins used shall be unsaturated, supplier certified, and compose of isophthalic polyester resins. Mixing lots of resin from different manufacturers or “odd-lotting” of resins shall not be permitted. Quality assurance records on the resin shall be maintained. Non-pigmented resin is required to allow for light or “sand” color of manhole surface in order to facilitate easy from grade interior inspection. U.V. inhibitors shall be added directly to the resin to prevent photo-degradation.
2. Fifteen mil isophthalic U.V. resistant gel coat on all exterior surfaces.
3. Reinforcing materials shall be commercial grade E-glass with a coupling agent that will provide a suitable bond between the glass reinforcement and the resin.
4. The laminate shall consist of multiple layers of glass matting and resin. The surface exposed to the sewer/chemical environment shall be resin rich and shall have no exposed fibers.

D. Material Properties
1. Manhole Barrel:
   a. Flexural Strength: 15,400 psi (reducer - hoop).
   b. Compressive Strength: 18,900 psi (barrel).
   c. Barrel stiffness (ASTM D2412):

Manhole Length (feet)	PSI
3-6	0.72
7-12	1.26
13-20	2.01
21-25	3.02
26-35	5.24

2. Flume:
   a. Tensile strength (ASTM D 638): 14,000 psi.
   b. Flexural strength (ASTM D 790): 27,000 psi.
   c. Flexural modulus (ASTM D 790): 1,000,000 psi.
   d. Barcol hardness (ASTM D 2583): 50.

E. Manhole Type: Provide metering manhole of the following type:
    1. 48-inch diameter manhole with aluminum access hatch:
        a. Aluminum hatch shall be rated for a 300 PSF pedestrian load. Hatch shall be mounted to a reinforced fiberglass cover and shall be fabricated from reinforced 1/4 inch thick aluminum diamond plate with T-316 stainless steel hardware. The hatch shall be provided with an automatic locking hold open arm, stainless steel recessed lift handle, and a staple for an Owner-supplied padlock.
        b. Aluminum hatch shall include the following features:
            1) Compression spring assist.
            2) Hatch safety net fall protection, meeting OSHA standard 1926.502 (c) (4) (i) drop test.
                a) Removable safety net.
    2. Height: As indicated on Drawings for invert and finished grade elevations.

F. Manhole Options:
    1. Vapor-resistant 100-watt incandescent light with weatherproof switch.
    2. GFI, duplex outlet in die cast aluminum housing.
    3. Stainless steel anchor bolts (1 set).
    4. Foam pad.
    5. An ultrasonic level element per Section 17100 - Control System Requirements shall be provided for remote monitoring of the level in the flume.
        a. The level transmitter shall be located above grade adjacent to the manhole for local level indication without the need to enter the manhole.

G. Flume Type:
    1. Parshall flume type, 9-inch size with integral inlet and outlet end adapters.

H. Flume Options:
        a. Laminated, high visibility staff gauge:
        b. Graduated in GPM increments.
        c. FRP grating over flume.
        d. FRP bench over voids.
        e. Ultrasonic mounting bracket:
            1) Horizontally and vertically adjustable stainless steel.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify that the flume dimensions are correct and project conditions are suitable for installation. Do not proceed with installation until condition deficiencies have been corrected.

3.02 INSTALLATION

A. Install products in accordance with Drawings, local codes, and in a manner consistent with the installation instructions and recommendations of the manufacturer.

B. Ensure that the product is installed plumb and true, free of twist or warp, within the tolerances specified by the manufacturer and as indicated in the contract documents.

C. Nylon or fabric slings should be used in conjunction with a spreader bar to lift or move the manhole. Under no circumstances should cables or chains be in contact with the manhole.

D. Excavate an area large enough to contain the manhole and the concrete pad while allowing for sufficient space to allow for a safe work environment.

E. Follow all OSHA requirements for open trench construction.

F. Pour a concrete pad to the dimensions indicated on the Drawings. The surface of the pad shall be troweled and leveled to 1/8 inch.

G. Clean the concrete slab of all sharp objects and debris before laying the foam pad provided with the manhole.

H. If PVC boots are provided, install them on the manhole pipe stubs before lowering the manhole into the opening.

I. Lower the manhole onto the pad.

J. Drill holes in the foam and concrete pads to accept the stainless steel anchor bolts.

K. Check to ensure that the flume is level from side to side and from front to back, adjust the pad and anchor bolts as necessary.

L. Connect and secure piping. Do not lubricate the PVC boots, if provided.

M. Grout under all sections of the manhole above the slab.

N. Backfill as indicated on the Drawings.

3.03 ADJUST AND CLEAN

A. Clean surfaces in accordance with the manufacturer’s instructions.

B. Remove trash and debris and leave the site in a clean condition.

END OF SECTION

SECTION 11215

HIGH-PRESSURE WASHERS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: RDT Facility Heater/High Pressure Washer and accessories.

1.02 SYSTEM DESCRIPTION

A. System Requirements:
   1. A high-pressure washer shall be provided where indicated on the Drawings.
   2. The unit shall be wired for 460-V, 3-phase electrical service.
   3. The unit shall produce minimum 4.0 gpm at 2,000 psi.
   4. The unit shall heat water to 180 degrees Fahrenheit.
   5. Furnish such parts, pieces, and accessories necessary to provide a complete and operational system.

1.03 SUBMITTALS

A. As specified in Section 01300 - Submittals and Section 15050 - Common Work Results For Mechanical Equipment General.

B. Shop drawings and product data.

C. Manufacturer's installation instructions.

D. Operations and Maintenance Manual.

1.04 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

1.05 QUALITY ASSURANCE

A. As specified in Section 15050 - Common Work Results For Mechanical Equipment General.

B. One manufacturer shall furnish all pressure washers and accessories as a complete and integrated package for proper coordination and compatibility of equipment.

C. Modifications required to accommodate the manufacturer's equipment will be at no cost to the Owner and subject to Engineer's acceptance.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Ship equipment and accessories complete, except where partial disassembly is required by transportation regulations or for protection of components.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. High-Pressure Washer: The following or equal, modified as necessary to meet the Specification requirements:
   1. Karcher: Model HDS 4.0/20 E Ec.
   2. Hotsy: Model HWE-402009C

2.02 HIGH-PRESSURE WASHER

A. Construction: Stainless steel enclosure, 14-gauge stainless steel frame and stainless steel wall mount bracket.

B. Inlet Water Temperature: Suitable for inlet water temperature as low as 50 degrees Fahrenheit.

C. Provide instant On-Off (no time delay) and overtemperature shutdown to keep the pump from overheating.

D. Automatic Shutdown Feature: Unit shall shut itself off in 1 minute if the water is shut off or the machine is no longer being used.

E. Provide relief pressure unloader to eliminate gun recoil and protect system from trapped pressure.

F. Electrical:
   1. Power supply: 460-V/3-phase/60-hertz.
   2. Connected load: 55 amps, 6.2 horsepower.
   3. Plug connection as indicated on the Drawings.

2.03 ACCESSORIES

A. Provide the following accessories at each remote station:
   1. Stainless Steel Hose connection hanging bracket.
   2. Insulated shutoff trigger gun with twist coupler.
   3. 100-foot high-pressure hose:
      a. 3/18-inch internal diameter, 3,000-psi steel wire-braid hose.
      b. Female quick coupler.
   4. Male quick coupler for connection to Stainless Steel.
   5. 36-inch adjustable pressure wand.
   6. Spray nozzles: 0, 15, and 40 degrees.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install unit and accessories in accordance with manufacturer’s printed instructions, as indicated and specified.

3.02 COMMISSIONING AND PROCESS START-UP REQUIREMENTS

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:

Approved Manufacturers Rep On-Site			
Training Requirements		Functional Test	
Maintenance (hours per session)	Operation (hours per session)	Trips	Days (each trip)
0	0	0	0

C. Source Testing:
   1. Pressure Washer:
      a. Verify performance of pressure washer prior to shipment.
      b. Confirm operation of all emergency shut-offs specified.

D. Equipment Performance Testing:
   1. Pressure Washer:
      a. Performance test: Test Demonstrate performance of unit after installation.
      b. Vibration test: None
      c. Noise test: None.

END OF SECTION

SECTION 11227

LARGE BUBBLE MIXING SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Large bubble mixing systems for installation in sludge blend tanks.
      a. Air receiver tank shall be provided by the large bubble mixing system manufacturer.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. A240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Application.
   2. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   3. A312 - Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes.
   4. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment and Systems.

B. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

C. Underwriters Laboratories, Inc. (UL):
   1. 508 - Standard for Industrial Control Equipment.
   2. 508A - Standard for Industrial Control Panels.
   3. 698A - Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations.
   4. 1283 - Standard for Electromagnetic Interference Filters.
   5. 1449 - Surge Protective Devices.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Header supply pipe: Piping between a valve panel and respective nozzle headers.
   2. MLSS: Mixed liquor suspended solids concentration, in milligrams per liter.
   3. Nozzle: Floor-anchored, large bubble-emitting device.
   4. Nozzle header: Continuous horizontal piping with nozzle offsets, with single inlet connection to header supply pipe and outlet offset connections to nozzles.
   5. Nozzle offset: Piping branching off nozzle header trunk piping, which connects to nozzles.

6. Vendor valve control panel (VVCP): Control panel that controls the firing of integral solenoid valves, which intermittently emit compressed air bursts to the respective header supply pipes.

1.04 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Anchoring and bracing.

1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Product data:
   1. Descriptive literature and dimensional drawings for equipment proposed, including views of the nozzle headers and nozzle offset assemblies indicating materials of construction, material product specification for components, and number, location, and spacing of nozzles, and size and layout of air piping.
   2. Pipe support layout describing methods for supporting and preventing uncontrolled movement of the nozzle headers and nozzle offset grid pipes resulting from flotation dynamic forces, fluid forces developed by firing compressed air for mixing, and other external forces. Methods for supporting and preventing uncontrolled movement of the nozzle headers and nozzle offset grid pipes during filling and draining of the sludge blend tanks shall also be provided as indicated on the Drawings.
   3. Methods for draining the air distribution systems.
   4. Nozzle and nozzle assemblies:
      a. Number of large bubble mixing nozzles.
      b. Complete materials list, material specifications, dimensions, and tolerances of parts of the nozzle assemblies.
   5. Nozzle header pipes:
      a. Complete materials list and specifications, dimensions, critical tolerances of piping, fittings, and accessories.
      b. Layout of header piping, nozzle offsets, nozzles, and pipe supports.
      c. Indicate nozzle-free areas required for ladder access.
   6. Pipe supports:
      a. Complete design criteria, material list, material specifications, and dimensions of parts of the pipe supports.
      b. Include drawings showing proposed support design, including anchor locations and details.
   7. VVCPs:
      a. Product data for control panel enclosures and components.
      b. Shop Drawings of wiring schematics and control panel layouts:
         1) Scaled exterior front and side elevations with dimensional information.
         2) Scaled interior panel layout showing components coordinated with the bill of materials.
         3) Bill of materials with detailed description of components.
         4) Wiring schematics, including wire numbers and terminal numbers.
         5) Single-line diagram of power distribution.

6) Control wiring, control logic, and instrumentation.

C. Delegated Design Submittals:
   1. Anchoring and bracing: Provide project-specific calculations based on support conditions and requirements to resist loads specified in Section 01850 - Design Criteria.

D. Calculations:
   1. Verifying uniform mixing under specified conditions.
   2. Verify the minimal oxygen transfer under specified conditions.
   3. Thermal management calculations for each control panel containing a programmable logic controller (PLC).

E. Full-scale test results from a minimum of 5 U.S. installations demonstrating that the large bubble mixing system achieved homogenous mixing as substantiated through statistical analysis of total suspended solids (TSS) samplings yielding a coefficient of variation (CV) of 10 percent or less.

F. Installation reference list, including a minimum of 5 similar installations for which the manufacturer furnished and integrated the complete system.
   1. Include, at a minimum, nozzles, in-basin piping, valve panels, and air compressor(s).
   2. Facility name/location, design average daily flow, contact name/telephone number, and start-up date for each installation are to be provided.

G. Installation instructions:
   1. Detail the complete installation of the equipment, including rigging, moving, and setting into place.
   2. Provide manufacturer's installation instructions.

H. Quality Control Submittals:
   1. Manufacturer's representative qualifications.
   2. Manufacturer's Certificate of Source Testing as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   3. Manufacturer's Certificate of Installation Verification as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   4. Manufacturer's Certificate of Functional Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

I. Owner Training Submittals:
   1. As specified in Section 01660 - Equipment and System Performance and Operational Testing.

J. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

K. Closeout Submittals:
    1. As-built set of large bubble mixing system drawings:
        a. A maximum of 30 days following the successful completion of the field mixing performance test, provide an as-built set of drawings showing the installed nozzle configuration with pertinent details, including:
            1) Installed number and location of nozzles, nozzle offsets.
            2) Installed configuration of the nozzle header piping, including valves and fittings.
            3) Installed VVCP layouts.
            4) Installed process and instrumentation diagram.
    2. PLC programming.
        a. Programming shall be fully documented.

1.06 ADMINISTRATIVE REQUIREMENTS

A. Programming requirements:
    1. As specified in Section 17101A - Specific Control Strategies.

B. Programming coordination:
    1. Coordinate requirements for data transfer with plant control system (PCS):
        a. Include data registers, data types, and engineering units, etc.
    2. Coordinate with the instrumentation and controls subcontractor (ICSC) and programmer for factory testing.
        a. Vendor shall supply PLC and LOI programming file prior to the testing.
    3. Coordinate data transfer to and from the PCS with the ICSC and programmer at programming meetings as specified in Section 17100 - Control System Requirements.

1.07 QUALITY ASSURANCE

A. Large bubble mixing system, and components (vendor control panels (VCPs), air receiver tank, air distribution piping from the valve control panels to the air nozzles and nozzle assemblies, fasteners and hardware, and piping supports) shall be provided by one manufacturer.

B. System shall be furnished by a single manufacturer who is experienced, reputable, and qualified in the manufacture of the equipment to be furnished.

C. Obtain nozzles, nozzle headers, header supply piping and couplings, panels, and appurtenances from the mixing system manufacturer, as a complete and integrated package to ensure proper coordination and compatibility and operation of the system.

1.08 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements and the manufacturer’s instructions.

1.09 PROJECT OR SITE CONDITIONS

A. As specified in Section 01850 - Design Criteria.

1.10 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

1.11 MAINTENANCE

A. As specified in Section 01600 - Product Requirements.

B. Provide spare parts that are identical to and interchangeable with installed parts.
   1. Air control valve rebuild kits: 2.
   2. Pressure regulator rebuild kit: 1.
   3. Pilot air filter assembly: 1.
   4. Solenoid: 1.
   5. Valve plug and cable assembly: 1.
   6. Relay and circuit breaker: 1.
   7. 5-micron pilot air filter: 1.
   8. Any other standard parts recommended by the manufacturer.

C. List of recommended spare parts.

PART 2 PRODUCTS

2.01 GENERAL

A. Large bubble mixing system includes, but is not limited to:
   1. Air distribution piping (from the valve control panels to air nozzles, including droplegs and nozzle headers).
   2. Piping supports.
   3. Air nozzle and nozzle assembly.
   4. Fasteners and hardware.
   5. Vendor valve control panels.
   6. Air receiver tank.
   7. All items noted above shall be provided by the large bubble mixing system manufacturer.

2.02 MANUFACTURERS

A. One of the following or approved equal as determined by the City Engineer:
   1. EnviroMix, Inc.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. System configuration:
   1. Two sludge blend tanks with layouts and dimensions as indicated on the Drawings and specified.
   2. Nominal basin dimensions, including side water depths (SWD) in units of feet of water for each zone at different operating conditions, are indicated below:

	Length (ft' in")	Width (ft' in")	Minimum SWD (ft' in")	Peak SWD(1) (ft' in")
Sludge Blend Tank 1 and 2	46'-0"	12'-0"	0'-0"	9'-9"

Notes:

(1) SWD in tank varies as indicated on the Drawings. Listed peak SWD is measured from tank floor low point at the west end of the tank.

B. Design requirements:
   1. General:
      a. Large bubble mixing system shall intermittently and sequentially inject compressed air through fixed nozzles located on the basin floor to create large bubbles, which effectively mix the basin contents with negligible oxygen transfer to prevent settlement of solids.
         1) MLSS concentrations in the sludge are expected to range between 1,000 and 30,000 milligrams per liter.
      b. Airflow will be supplied by rotary screw compressors as specified in Section 11372C - Rotary Screw Air Compressor System and the airflow varied independently to maintain the desired firing flow rate and duration in each mixing zone.
      c. Header supply pipe, nozzle headers, nozzle offset pipe, and nozzles shall be capable of handling a mixture of primary sludge and waste activated sludge.
      d. Mixing shall be uniform throughout the tank with effective mixing confirmed through Functional Testing as specified.
      e. Air distribution and balancing shall be sufficient to maintain suspended solids in a state of suspension over the depth of the basins.
      f. Firing flow rate shall be manually adjustable via a throttling valve. Air mixing system equipment and piping shall be sized to thoroughly mix the contents of the basin for which the systems are designed.
   2. Process air requirements for operations:
      a. Free-standing air receiver shall be sized such that there is sufficient air volume and pressure to operate the large bubble mixing system as designed.

C. Nozzle layout:
   1. Provide nozzle quantities and necessary appurtenances to meet minimum performance requirements specified. A minimum of 12 nozzles shall be provided in each tank. Designs with less nozzles are not acceptable.
   2. Provide additional pipe supports and anchorage where indicated on the Drawings. Additional pipe supports and anchorage are to be installed on nozzle headers, nozzle offsets, and nozzles to maintain pipe stability during filling and draining operations in the sludge blend tanks.
   3. Layout is subject to the approval of the Engineer. Engineer shall determine compliance with the stated requirements.
   4. Design the nozzle layout to satisfy the following minimum requirements.
      a. Minimum clearance of 18 inches from any wall, wall fillet, or wall support to the edge of the nozzle.

b. Make provisions for ladder placement to allow entry into each basin from the top of the basin.
    1) A minimum of 36 inches between the ladder face and large bubble mixing nozzles, nozzle offsets, nozzle headers, and header supply pipe shall be provided.
    2) A minimum clearance of 12 inches shall also be provided on each side of the ladder.

2.04 AIR PIPING, NOZZLES, AND APPURTENANCES

A. Header supply piping:
1. Threaded pipe shall not be allowed between the VVCP and the nozzles.
2. Schedule 10S, stainless steel press fit joints as specified in Section 15286 - Stainless Steel Pipe and Tubing.
3. Maximum working pressure: 200 pounds per square inch.
4. Couplings and fittings: Press technology products formed of Type 316/316L stainless steel tubing, including a self-contained O-ring seal(s) molded of synthetic FKM rubber.
5. Pipe: ASTM A312, Type 316/316L stainless steel.

B. Nozzle headers:
1. Schedule 10S, Type 316/3016L stainless steel with Schedule 40S stainless steel nozzle offsets.
2. Nozzle couplings: NPT tapered threads, Type 316/316L stainless steel.
3. Delivered from the manufacturer pre-assembled to the extent practicable to minimize field assembly error and installation time.
4. Pipe: ASTM A312, Type 316/316L stainless steel.
5. Provide nozzle headers with removable end caps.

C. Nozzles:
1. Adequate strength to withstand vertical thrust of mixing air.
2. Threaded rod anchors:
    a. As specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.
    b. A minimum of 2 rod anchors shall be installed per nozzle.

D. Appurtenances:
1. Nuts, bolts, washers, threaded rod, and other non-welded parts shall be stainless steel, ASTM A240, Type 316.
2. Threaded assemblies shall be chemically treated or lubricated prior to assembling to prevent galling.

E. Fabrication:
1. Piping used for the air mixing system shall be Type 316/316L stainless steel, unless otherwise noted.
2. Shop fabricated welded metal parts and assemblies from stainless steel, ASTM A240, Type 316/316L, with a 2D finish.
3. Shop fabricate non-welded parts and pieces from sheets and plates of stainless steel, ASTM A240, Type 316, or from bars of stainless steel ASTM A276, Type 316, unless otherwise specified.

F. Welds and welding procedures:
   1. Shop weld with filler wire using MIG, TIG, or shield-arc, or plasma arc welding inert gas processes. Provide a cross-section equal to or greater than parent metal.
   2. Provide full penetration welds to interior surface with gas shielding to interior and exterior of joint.
   3. Provide smooth, evenly distributed interior weld beads with an interior projection not exceeding 1/16 inch beyond inner diameter of nozzle header or fittings.
   4. Clean welded stainless steel surfaces and welds after fabrication to remove weld splatter and finish clean exterior welds, carbon deposits, and contaminants in accordance with ASTM A380, Section 6.2.11.
   5. Field welding is not permitted.

2.05 AIR RECEIVERS

A. Materials: Steel, as permitted by ASME code.

B. Design:
   1. Pressure rating: 200 psig.
   2. Volume: Determined by large bubble mixing manufacturer, minimum 120 gallons.

C. Accessories:
   1. Pressure gauge: As specified in Section 17100 - Control System Requirements.
   2. Pressure relief valve: ASME stamped.
   3. Drain trap: Externally mounted automatic mechanical type.

D. Finishes:
   1. Factory prime, compatible with finish coat.
   2. Finish coat in field. As specified in Section 09960 - High-Performance Coatings.

2.06 VENDOR VALVE CONTROL PANELS

A. General:
   1. VVCP components and construction shall be as specified in Section 17100 - Control System Requirements.
   2. Provide components and equipment with UL 508 listing.
   3. Provide control panels with UL 508A labeled.
   4. Provide intrinsically safe circuits and equipment in accordance with UL 698A.
   5. VCP shall be fully functional, wired, and factory tested prior to shipment.
      a. Provide field wiring terminal strips for external connections.
   6. Provide surge protection on the incoming power feed.
      a. Provide UL 1449 rated SPD and UL 1283 rated EMI filter on 120 VAC panel power source.
   7. Provide necessary control hardware, software, and components as required for a fully functional and operational installation.
   8. Provide heating, cooling, and dehumidifying devices to maintain devices within their rated temperature range.

9. Power supply:
    a. 120 VAC, 1-phase, 60 hertz.

B. Enclosures and panel components:
1. Enclosure:
    a. Manufacturers: One of the following or equal:
        1) Hoffman.
        2) Enclosure Industries, LLC.
    b. Rating: NEMA Type 4X stainless steel.
    c. Material: Type 304 stainless steel.
2. Enclosure support stand:
    a. Designed by manufacturer.
    b. Material: Type 304 stainless steel.
3. Pilot Air Filter:
    a. Manufacturers: One of the following or equal:
        1) Parker 14F15BB.
    b. Each VVCP shall include a 5-micron filter with 1/4-inch NPT inlet/outlet and an automatic pulse drain to remove fine particles, condensate, and oil from the air supply.
    c. The filter shall be rated for 150 psig maximum pressure, 175 degrees Fahrenheit maximum temperature, and 24 scfm.
4. Operator Interface: Each VVCP shall have a Local-Off-Remote (LOR) selector switch, a Frequency dial, and a Duration dial.
    a. In Local control, the ‘Duration’ dial and the ‘Frequency’ dial inside the VVCP shall allow the operator to adjust mixing intensity locally.
    b. In Remote control, the remote position will function the same as Off position since there is not a master control panel.
5. Controller:
    a. Manufacturers: One of the following or equal:
        1) EnviroMix Zombie Controller.
    b. The controller shall be rated for a -40 degrees Fahrenheit to 176 degrees Fahrenheit temperature range.
    c. The controller shall be programmed to operate according to the dial settings for valve open frequency and duration when the LOR is in Local mode.
6. Air control valves: The air control valves shall be mounted to a common manifold.
7. Nameplate: A stainless steel nameplate shall be provided on the VVCP. The nameplate shall be securely fastened in a conspicuous place and clearly inscribed with the Manufacturer’s name, year of manufacture, and serial number.
8. Alarm Light. A red stack light shall be mounted on the top of the VVCP and indicate an alarm condition specific to the VVCP.

2.07 CONTROL STRATEGY

A. General:
1. Control shall allow mixing to be started and stopped, and mixing intensity to be adjusted at any point during operation. Control features shall be initially set according to the Manufacturer’s recommendations.

2. Mixing Parameters: The operator shall be able to enable/disable mixing operation, select the firing duration and the frequency of firing. Minimum control features selected through the local interface shall include the following:
    a. Local-Off-Remote (LOR) Switch.
        1) Local Position: In Local, the controller in the VVCP controls the mixing intensity. The 'Duration' dial and the 'Frequency' dial inside the VVCP shall allow the operator to adjust mixing intensity locally.
        2) Remote Position: The system does not have a master control panel, so this mode will function the same as the Off position.
        3) Off Position. In Off, the VVCP will be disabled locally and remotely.
    b. Duration Dial:
        1) Selection of the length of time an individual ACV is open during a firing event.
        2) The duration shall be operator adjustable from 0.1 to 1 seconds by adjusting the dial.
        3) The duration will be the same for all ACVs in the VVCP.
    c. Frequency Dial:
        1) Section of the length of time to complete the firing sequence.
        2) The frequency shall be operator adjustable from 1 to 100 seconds by adjusting the dial.
    d. Valve Isolation: Individual ACVs may be removed from the firing sequence at any point during operation by unplugging the solenoid from the ACV. Alternatively, the header supply pipe isolation valve can be closed.
    e. Alarms: Each VVCP shall come equipped with a pressure switch plumbed to the valve manifold. The alarm light will illuminate, and a dry contact shall be provided for remote indication of low pressure.
3. Remote Communication with the Plant Control System.
    a. The VVCP shall interface with the Plant Control System with the following I/O through hard-wired conductors.
        1) Inputs - Mix enable signals (entire VVCP or by ACV/zone/tank) via dry contacts from Plant Control System.
        2) Outputs - Low pressure alarm via dry contact.

B. Control system requirements as specified in Section 17101A - Specific Control Strategies.

PART 3 EXECUTION

3.01 PREPARATION

A. Anchoring and bracing to structures:
    1. Prepare equipment anchor setting template(s) and use to position anchors during construction of supporting structure(s).
    2. Install anchors of type and material indicated on approved anchoring designs.
    3. Install anchors with embedment indicated on approved anchoring designs.

3.02 INSTALLATION

A. Install the specified large bubble mixing system in accordance with the accepted installation instructions, anchorage details, and approved Shop Drawings.

B. Inspect piping for proper joints, supports and threaded rod anchors prior to initiating any field-testing.

C. Test for mounting, levelness, air uniformity, and leakage.

D. Manufacturer's representative onsite to monitor the installation, leveling, and testing of the large bubble mixing equipment in each basin.

E. Flood the sludge blend tanks with water to the top of the nozzle headers.
   1. Check the level of the nozzles on each respective nozzle header to verify that they are at the same elevation within 0.25 inch of a common horizontal plane.

F. Complete the following tests as specified in Section 17100 - Control System Requirements:
   1. Loop checks.
   2. Loop validation tests.

G. Furnish Manufacturer's Certificate of Installation Verification.

3.03 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, Section 15958 - Mechanical Equipment Testing, and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Source Testing.
      b. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements: Require manufacturer's representative to perform the following services as described below and as specified in Section 01660 - Equipment and System Performance and Operational Testing. The specified durations are the minimum required time on the job site. Additional services and/or longer durations shall be provided as needed at no cost to the Owner to meet the required quality of work. Work to be done in a minimum of 4 trips:
      a. Installation assistance: As required:
         1) Advise/observe the Contractor on the installation of the equipment.
         2) Provide additional assistance as required.
      a. Installation inspection: 1 trip, 2-day minimum.
      b. Functional Testing: 2 trips, 2-day minimum each trip.
   3. Training: As defined in Section 01660 - Equipment and System Performance and Operational Testing and this Section:
      a. Operations: 2-hour class, 2 sessions.
      b. Mechanical Maintenance: 3-hour class, 1 session.
      c. Combined Electrical and I&C Maintenance: 1-hour class, 1 session.
   2. Final acceptance checkout: 1 workday (trip may be combined with training).

C. Source Testing (Factory Acceptance Tests):
   1. As specified in Section 01660 - Equipment and System Performance and Operational Testing.

2. Not witnessed.
3. Each unit shall be tested, including control functions prior to shipment.
4. VCP testing:
    a. As specified in Section 17100 - Control System Requirements.
    b. Hardware testing.
    c. Platform testing.
5. Furnish test reports and the Manufacturer's Certificate of Source Testing.

D. Functional Testing:
1. Witnessed.
2. Field performance tests:
    a. Test mixer components with the respective basins full to the maximum water surface elevation.
    b. Test exposed air piping for leaks using soapsuds on joints and applying 100 pounds per square inch test pressure.
        1) Air piping in the tanks may be tested by submerging the piping in non-potable water and pressurizing the piping to 175 pounds per square inch, in lieu of using soapsuds on joints.
        2) Pressure testing requirements shall not apply to supply piping downstream from the VCP of pre-manufactured nozzle headers.
    c. Contractor is responsible for filling and emptying sludge blend tanks with water as required for testing activities.
        1) Water used shall be from the Owner's plant effluent water system.
        2) Contractor shall be responsible for conveying water between the plant's non-potable water and the sludge blend tanks.
        3) Provide written notification to the Engineer a minimum of 5 days in advance of any such use of the non-potable water.
    d. Operate each mixing system at the maximum water surface elevation in the basins for a continuous period of not less than 72 hours.
3. Test as specified in Section 15958 - Mechanical Equipment Testing:
    a. Conduct Level 2 General Equipment Performance Test.
    b. Conduct Level 2 Vibration Test.
    c. Conduct Level 2 Noise Test.
        1) Test equipment and installation to verify tightness, operation, and unit vibration is within the manufacturer's submitted maximum.
4. Complete end-to-end testing (CEET) as specified in Section 17100 - Control System Requirements.
5. 7-day test:
    a. Following successful completion of the 72-hour test, coordinate with the plant operations personnel in placing the sludge blend tanks in operation.
    b. Provide a minimum of 1 week for the Owner to establish operational conditions in the sludge blend tanks.
    c. Upon notice that the sludge blend tanks have achieved operational conditions, begin the 7-day test.
    d. Submit a written procedure for approval prior to beginning the 7-day test.
        1) Correct any deficiencies found during the 7-day test and, at the Owner's option, run the 7-day test again at no additional cost.
6. Field mixing performance testing:
    a. Do not begin mixing performance testing until after the 7-day testing is complete.

b. Do not begin mixing performance testing until after the basins which will be tested shall have been in normal operating mode for at least 2 days with TSS concentration in typical operating ranges specified above. No flow shall enter or exit the respective basin for 2 hours prior to or during the test.
c. Mixing performance testing shall be conducted in the following basins:
    1) Sludge Blend Tank 1.
    2) Sludge Blend Tank 2.
d. Large bubble mixing system manufacturer shall conduct TSS testing using a Cerlic TSS probe, or equal, suspended solids analyzer.
e. Testing procedure:
    1) At least 4 horizontal-plane sample sites to be tested shall be selected by the Engineer.
        a) At each sample site, 3 vertical samples shall be collected as follows:
            (1) 24 inches from the surface, tank sidewall mid-point, and 24 inches above the tank sidewall bottom.
            (2) Each sample site must be a minimum of 4 feet away from any structure within the tank.
    2) Coefficient of variation (CV) shall be determined for the sample set, excluding the maximum and minimum samples.
        a) CV shall be calculated by taking the resultant set of 10 samples as follows:
            (1) CV = (100 x Standard Deviation of 10 Samples)/(Mean Value of 10 Samples).
    3) If the CV is less than or equal to 10 percent then the mixer performance shall be acceptable for that location.
    4) If the CV is greater than 10 percent then the mixer performance shall be unacceptable for that location and the Contractor and/or manufacturer shall make necessary improvements at no additional cost to the Owner and repeat the testing procedure at no additional cost to the Owner until the CV is less than or equal to 10 percent for that location.

7. Furnish test reports and the Manufacturer's Certificate of Functional Compliance.

E. Additional testing:
1. After completion of the network testing, assist in the completion of the following as specified in Section 17100 - Control System Requirements:
    a. Complete end-to-end testing.
    b. Control logic operational validation.
    c. Loop tuning.

END OF SECTION

SECTION 11246

POLYMER BLENDING AND FEED EQUIPMENT: LIQUID

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Complete and operational automatic polymer blending and feed system to handle liquid polymer and delivery of activated polymer.

B. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

C. Tag numbers:
   1. Thickening Polymer Blenders:
      a. THI Polymer Blender Unit 1: THK-POL-07-001.
      b. THI Polymer Blender Unit 2: THK-POL-07-002.
      c. THI Polymer Blender Unit 3: THK-POL-07-003.
   2. Dewatering Centrifuge Polymer Blender:
      a. CNT Polymer Blender Unit 3: DEW-POL-07-003.

1.02 REFERENCES

A. CSA International (CSA).

B. National Electrical Code (NEC).

C. National Electrical Manufacturers Association (NEMA).

D. Underwriters Laboratories, Inc. (UL):
   1. 508 - Standard for Industrial Control Equipment.
   2. 508A - Standard for Industrial Control Panels.
   3. 698A - Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations.
   4. 1283 - Standard for Electromagnetic Interference Filters.
   5. 1449 - Surge Protective Devices.

1.03 SUBMITTALS

A. Product data: As specified in Section 15050 - Common Work Results for Mechanical Equipment:
   1. Detailed specifications and shop drawings with both isometric and orthogonal views of the proposed installation, including dimensions, weights, and complete parts list.
      a. Vendor control panel (VCP):
         1) Wiring schematics and control panel layouts:
            a) Scaled interior and exterior front and side elevations with dimensions and bill of materials.
            b) Wiring schematics, including wire numbers and terminal numbers.

c) Single-line diagram of power distribution.

2. Hydraulic characteristics of the mixer.

B. Shop drawings: As specified in Section 15050 - Common Work Results for Mechanical Equipment.

C. Calculations: As specified in Section 15050 - Common Work Results for Mechanical Equipment.

D. Installation instructions:
   1. Detail the complete installation of the equipment, including rigging, moving, and setting into place.
   2. Provide manufacturer’s installation instructions.

E. Vendor operation and maintenance manuals.

F. Commissioning submittals:
   1. Provide Manufacturer's Certificate of Source Testing.
      a. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section.

G. Operation and maintenance manuals.

1.04 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements, Section 15050 - Common Work Results for Mechanical, and the manufacturer’s instructions.

1.05 PROJECT OR SITE CONDITIONS

A. As specified in Section 01850 - Design Criteria.

1.06 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

B. Special warranty:
   1. Provide warranty on polymer blending mixing chamber for the life of the system to be free of defects in workmanship or materials.
      a. This extended warranty shall not apply if the damage is caused by freezing or other weather related damage or over-pressure.
      b. The polymer blending mixing chamber shall be warranted against failure due to mixing chamber plugging for any reason.
      c. If the mixing chamber plugs a replacement mixing chamber will be provided at no cost to Owner.
      d. This additional warranty does not cover the replacement of seals or motors, where applicable.
      e. The warranty shall apply regardless whether potable or non-potable water is used.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or approved equal as determined by the City Engineer:
   1. VeloDyne, VeloBlend VM Series modified as specified in this Section.
   2. CleanWater1/UGSI, Polyblend, M series modified as specified in this Section.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:
   1. Provide integrated equipment packages capable of automatically metering, diluting, blending, activating, and feeding liquid polymer and water.
   2. Activate concentrated emulsion polymer in a multi-zone hydro-mechanical or mechanical mixing vessel with a tapered mixing regime.

B. Pre-assemble and shop-test system to ensure compliance with pressure and operational requirements.

C. Design criteria:
   1. Polymer type: Emulsion.
   2. Polymer activity (percent active): 30 to 50.
   3. Final (neat) percent solution desired: 0.25 to 1.00.

D. Polymer feeder schedule:
   1. Dilution water flow rate range:
      a. Thickening PBUs:
         1) Primary dilution: As determined by manufacturer.
         2) Post dilution (if required): As determined by manufacturer.
         3) Total dilution water flow range: 100 to 500 gallons per hour.
      b. Dewatering PBUs:
         1) Primary dilution: As determined by manufacturer.
         2) Post dilution (if required): As determined by manufacturer.
         3) Total dilution water flow range: 600 to 6,000 gallons per hour.
   2. Metering pump:
      a. Type: Progressive Cavity.
      b. Output range:
         1) Thickening PBUs: 0.25 to 3.0 gallons per hour.
         2) Dewatering PBUs: 1.5 to 30 gallons per hour.
   3. Mixing motor: 1/2 horsepower, wash-down motor.
   4. Dilution water:
      a. Thickening PBU: Maximum water pressure available for dilution water is 80 pounds per square inch.
      b. Dewatering PBU: Maximum water pressure available for dilution water is 75 pounds per square inch.
      c. Anticipated backpressure on the blending unit: 50 pound per square inch.

2.03 MATERIALS

A. General:
   1. System shall be constructed with a Type 304 stainless steel chassis.

2. Hardware shall be Type 304 stainless steel.
3. Any components in contact with polymer or water shall be constructed of electrolysis nickel-plated brass, stainless steel, or an inert plastic.

2.04 EQUIPMENT

A. Mixing requirements:
   1. Mixing energy shall be provided by a mixer with a variable speed stainless steel or bronze mixing impeller. Plastic impellers are not acceptable. Hydraulic mixing is acceptable, but only in addition to a mixing impeller.
      a. The mixer impeller shall be controlled by a SCR or VFD controller and driven by a wash down duty motor.
      b. The mixer drive shaft shall be sealed by a mechanical seal, which shall have an integrally mounted and factory plumbed seal mounted and flushing valve. The seal shall be easily accessible for replacement.
   2. Mixing system shall be specifically designed to invert, disperse, and activate in solution emulsion and dispersion polymers with viscosities from 200 to 6,000 cps.
   3. The mixing system shall be designed to effectively induce high, non-damaging mixing energy over the systems full flow range.

B. Mixing chamber:
   1. Mixing chamber shall be clear Lexan™ to view the mixing action and blending effectiveness.
   2. Mixing chamber shall have a maximum rated pressure of 100 pounds per square inch.
   3. Provide a brass mixing chamber pressure relief valve and drain valve.
   4. All bearings shall be external from the mixing chamber.
   5. Motor: 1/2 horsepower, 480 VAC, 1,750 revolutions per minute, wash-down duty.
   6. Polymer check valve:
      a. Specifically designed to isolate neat polymer from dilution water.
      b. Readily accessible for cleaning without the use of tools.
      c. Installed inside the mixing chamber not allowed.
      d. Mixing chamber disassembly for access not allowed.
      e. Conventional ball type check valves not allowed.

C. Solution discharge system:
   1. Pressure gauge:
      a. Size: 2-1/2-inch.
      b. Materials: Type 304 stainless steel.
      c. Liquid filled with diaphragm seal.
   2. Check valve:
      a. Type: Flapper.
      b. Materials: PVC and Viton™.
      c. Size: Same size as the solution discharge piping.

D. System skid:
   1. Frame:
      a. Material: Type 304 stainless steel.
         1) Mild steel not accepted.

b. Design: Easy access to all components.
2. All piping rigidly supported.
3. Pump suction mounting height not to exceed 5-inches from the bottom of the skid.
4. The overall system dimensions shall not exceed 34 inches wide by 26 inches deep by 70 inches high.

E. Neat polymer metering pump:
1. Quantity: 1 per blending unit.
2. Integrally mounted on system skid.
3. Range: As indicated in Design and Performance Criteria paragraphs.
4. Positive displacement type.
5. Motor: 1/2 horsepower, 480 VAC, 1,750 revolutions per minute, wash-down duty.
6. Gear reducer size: Maximum speed of the metering pump.
7. All wetted parts shall be stainless steel, Teflon™, or Viton™.
8. Pump body shall be stainless steel.
9. Accessories:
a. Polymer flow sensor:
1) Thermal type.
2) All wetted parts Type 304 stainless steel.
3) Mount on system skid with Type 304 stainless steel bracket.
4) Mount with polymer piping is not acceptable.
5) 120 VAC
b. Pressure relief valve:
1) Materials: PVC and Viton™.
2) Location: Discharge line of the pump.
3) Factory plumbed back to suction of the pump.
c. Pressure gauge:
1) Size: 2-1/2-inch.
2) Materials: Type 304 stainless steel.
3) Liquid filled with diaphragm seal.
4) Location: Discharge line of the pump.
10. Capable of pumping polymer with apparent viscosities of up to 6,000 cps.
11. Capable of a 3.5-feet suction lift of polymer to ensure no loss of suction upon low drum storage levels.

2.05 ACCESSORIES

A. Calibration cylinder:
1. Quantity: 1 per pump or 1 per system.
2. Volume: 1,000 milliliter.
3. Graduation:
a. Minimum increments equal to 1 minute of drawdown at the maximum pump rate.
b. Read in gallons per hour and millimeters.
4. Construction: Clear polyvinyl chloride.
5. Configuration:
a. Nipple and plug for system operation without cylinder.
b. Full port PVC ball valves having Viton™ O-rings:
1) Locate 1 ball valve on the discharge of the calibration column.

2) Locate 1 ball valve on the neat polymer inlet pipe up stream of the calibration column discharge valve.

6. Assembly:
   a. Furnished and rigidly installed on polymer system skid.
   b. Use of piping for support is not acceptable.
7. Calibration: Calibrate for a 1 minute drawdown.

B. IBC Tote Spill Containment Pallet as indicated on the drawings:
1. Manufacturer: One of the following or equal.
   a. Ultratech International.
2. Polyethylene spill containment pallet must be capable of holding a 275-gallon IBC Tote. With an accessible sump capable of holding at least 330 gallons. It shall have a sump drain valve to allow complete draining of the sump. Containment pallet shall be compatible with thickening neat polymer tote platform scale.
3. Platform scale:
   a. Provide platform scales with a 150 percent safe overload capacity.
   b. Scales shall have mechanical stops or other means to minimize possible damage to load cells due to impact loading.
   c. Scales, drums, tanks and tote bins shall be properly secured against shifting and tipping due to possible seismic movement. Any hold-down lugs shall be compatible with chemical tanks.
   d. Transmitter:
      1) Microprocessor based with alphanumeric display.
      2) Operator keypad interface.
      3) Capable of monitoring tare weight, gross weight, net remaining, and daily usage of each scale. Capable of calculating total amount used and rate of feed.
      4) Provide a keypad to accept operator entry of tare weights, specific gravity of chemical and low-level alarm points.
   e. Provide stainless steel tags for each instrument. Tags shall be labeled as specified in the Contract Documents.
   f. Provide sunshades for transmitters located outdoors.
   g. Manufactured by one of the following or equal:
      1) Fairbanks Scales, AGIS Series with FB2250 Transmitter.
      2) Force Flow IBC tote scale with Wizard 4000 Transmitter.
      3) Mettler-Toledo, Model PFA584 floor scale with IND360xx Series Terminal.
   h. Factory calibrate each instrument with a minimum 3-point calibration or according to the manufacturer's standard at a facility that is traceable to the NIST.
      1) Submit calibration datasheets to the Engineer at least 30 days before shipment of the instruments to the Project Site.
      2) Furnish test reports and the Manufacturer's Certificate of Source Testing.

2.06 PACKAGE CONTROL SYSTEM

A. General:
   1. This Section summarizes key control system components for vendor control panels (VCP).
      a. Referenced sections can be obtained from the Contractor for complete control system requirements.
   2. VCP shall be completely preprogrammed, prewired, and factory tested for proper operation prior to shipment.
      a. Additional testing requirements as specified in Section 17100 - Control System Requirements.
   3. Provide necessary control hardware, software, and components as required for a fully functional and operational installation.

B. Panels, Enclosures, and Panel Components:
   1. Enclosure: NEMA 4X, Type 316 stainless steel.
   2. Power Option: 480V / 3PH / 60Hz.
   3. Power Disconnect Type: Rotary Style Circuit Breaker Disconnect.
   4. PLC Controller: VeloDyne.
   5. HMI Operator Interface: 6-inch Color TFT.
   6. Motor Controllers:
      a. Neat Polymer Metering Pump.
      b. Mixing Chamber.
   7. Miscellaneous:
      a. Control Circuit Protection.
      b. Control Relays.
      c. Power Supplies.
      d. Grounding Blocks.
      e. Numbers Terminal Blocks.
      f. Wire Labels, Shrink-Tube Type.
      g. Cabling.

2.07 CONTROL REQUIREMENTS

A. Control level:
   1. PLC-based controls:
      a. The control system shall be designed to precisely control water flow in proportion to dilution polymer flow based on an operator input of desired solution concentration. The controller shall have 2 modes of operation:
         1) Manual Mode: Operator sets polymer pump rate and water rate manually by increase and decrease push buttons on controller face.
         2) Proportional Auto Mode: Operator sets desired solution concentration. Metering pump follows 4-20mA pump pacing input signal. Water rate is controlled to maintained desired solution concentration (i.e. for in-line applications where process flow fluctuates).
   2. Operator interface functions:
      a. System On/Off.
      b. Mode (Change Mode, Select Mode):
         1) Manual Mode.
         2) Proportional Auto Mode.

c. Set Percent Solution (Proportional Modes Only).
d. Set Poly Rate (Manual Mode Only).
e. Polymer Pump Calibrated Value Input.

3. Operator Interface Display:
   a. Pump Rate.
   b. Water Rate.
   c. Solution Concentration.
   d. Status / Alarm Indicators:
      1) Low Water Flow Alarm.
      2) Low Polymer Flow Alarm.
   e. Mode Select.
   f. Calibration Mode.
4. Inputs (signals by others):
   a. Remote Start / Stop (Discrete Dry Contact).
   b. Pacing Signal Based on Process Flow (4-20mA).
5. Outputs:
   a. System Running (Discrete Dry Contact).
   b. Remote Mode (Discrete Dry Contact).
   c. Common Alarm (Discrete Dry Contact).
   d. Polymer Pump Rate (4-20mA).
6. Special Functions / Features:
   a. Proportional control of water to polymer flow (ratio control) as outlined above.
   b. Programmable auto flush - keeps water control valve open for programmable amount of time when unit is shut off.
   c. Polymer pump rate input for calibration.

2.08 SPARE PARTS

A. Provide 1 complete set of special tools needed to assemble and disassemble the system.

B. Vendor to provide spare parts that are required to provide uninterrupted operation for a minimum of 2 years.

PART 3 EXECUTION

3.01 INSTALLATION

A. Alignment of piping may vary from that indicated on the Drawings.
   1. Upon acceptance by the Engineer, align piping to suit the equipment furnished, without additional cost to Owner.

B. Contractor to flush out potable water line until water discharged from line is clear and free of debris, before conducting disinfection of the line as specified in Section 01757 - Disinfection.

C. Contractor to avoid exposing neat polymer lines to water at any point of the system.

D. Identification of the health, flammability, and reactivity of hazardous materials shall be affixed to each chemical storage tote, as specified in Section 10400 - Signage.

3.02 COMMISSIONING

A. Manufacturer services:
   1. Provide certificates:
      b. Manufacturer's Certificate of Source Testing.
      c. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements: Require manufacturer's representative to perform the following services as described below. The specified durations are the minimum required time on the job site. Additional services and/or longer durations shall be provided as needed at no cost to the Owner to meet the required quality of work. Work to be done in a minimum of 4 trips:
      a. Installation assistance: As required:
         1) Advise/observe the Contractor on the installation of the equipment.
         2) Provide additional assistance as required.
      a. Installation inspection: 1 trip, 1-day minimum.
      b. Functional Testing: 2 trips, 1-day minimum each trip.
   3. Training:
      a. Operations: 2-hour class, 2 sessions.
      b. Mechanical Maintenance: 3-hour class, 1 session.
      c. Combined Electrical and I&C Maintenance: 1-hour class, 1 session.
   2. Final acceptance checkout: 1 workday (trip may be combined with training).

B. Source testing:
   1. Test as specified in Section 15958 - Mechanical Equipment Testing.
   2. Polymer feed and blend system:
      a. Test witnessing: Not witnessed.
      b. Conduct Level 1 General Equipment Performance Test.
   3. Electrical Instrumentation and Controls:
      a. Test witnessing: Not witnessed.
      b. Conduct testing as specified in Section 17100 - Control System Requirements.

C. Functional testing:
   1. Functional testing of the entire polymer feed system to be conducted following installation and cleaning of the polymer blending units.
   2. Polymer feed and blend system:
      a. Conduct Level 1 General Equipment Performance Test.
   3. Electrical Instrumentation and Controls:
      a. Conduct testing as specified in Section 17100 - Control System Requirements.

3.03 ADDITIONAL SERVICES

A. Manufacturer's services include a 1-day site visit during the first year of operation as coordinated with Owner.

END OF SECTION

SECTION 11294B

HEAVY-DUTY FABRICATED STAINLESS STEEL SLIDE GATES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Heavy-duty fabricated stainless steel slide gates.

1.02 REFERENCES

A. American Water Works Association (AWWA):
   1. C561 - Fabricated Stainless Steel Slide Gates.

B. American Welding Society (AWS):
   1. D1.6 - Structural Welding Code-Stainless Steel.

C. ASTM International (ASTM):
   1. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   2. B584 - Standard Specifications for Copper Alloy Sand Castings for General Application.
   3. D1248 - Standard Specification for Polyurethane Plastics Extrusion Materials for Wire and Cable.
   4. D2000 - Standard Classification for Rubber Products in Automotive Applications.
   5. D4020 - Standard Specification for Ultra-High Molecular-Weight Polyethylene Molding and Extrusion Materials.

D. Society for Protective Coatings (SSPC):
   1. SP 10 - Near White Metal Blast Cleaning.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Design head: Depth from surface of water to centerline of gate. Use value specified in the gate schedule.
   2. Seating head: Pressure applied to gate slide from weight of water column above gate centerline that forces gate slide into seat.
   3. Slenderness ratio (l/r): The largest ratio obtained by dividing the unsupported length of the stem by the radius of gyration of the stem cross section.
   4. Substantially similar:
      a. Similar in size, design head, and service.
      b. Utilizes the proposed design for critical components, including guides and seals.
   5. Unseating head: Pressure applied to gate slide from weight of water column above gate centerline that forces gate slide away from seat.

1.04 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Anchoring and bracing.

C. Calculations.

1.05 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product Submittals:
   1. As specified in Section 01600 - Product Requirements.
   2. Product data.
   3. Shop Drawings.
      a. Layout and installation drawings for each gate size and type.
      b. Wall thimbles design.
   4. Complete bill of materials.
   5. Calculations:
      a. For manually operated gates, coordinate with Section 13446 - Manual Actuators.

C. Delegated Design Submittals:
   1. Anchoring and bracing: Provide project-specific calculations based on support conditions and requirements to resist loads specified in Section 01850 - Design Criteria.
   2. Calculations:
      a. Calculations and design data substantiating conformance with the Drawings and Specifications.
      b. For coordination purposes, gate manufacturer shall supply calculations verifying the suitability of the selected operator for the application.
         1) For all gates:
            a) Maximum torque required for operation of the gate (including breakaway from seat) with a safety factor of 1.4.
            b) Indicate thrust value and stem factor.
      c. Gate opening and closing thrust forces that will be transmitted to the support structure with operator at extreme positions and load.
      d. Guide frame in accordance with AWWA C561 stress threshold compliance for exterior guide leg and fasteners.

D. Installation instructions:
   1. Detail the complete installation of the equipment, including rigging, moving, and setting into place.
   2. Provide manufacturer’s installation instructions.

E. Quality Control Submittals:
   1. Manufacturer’s representative qualifications.
   2. Manufacturer’s Certificate of Source Testing as specified in Section 01660 - Equipment and System Performance and Operational Testing.

3. Manufacturer's Certificate of Installation as specified in Section 01660 - Equipment and System Performance and Operational Testing.
4. Manufacturer's Certificate of Functional Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

F. Operation and maintenance manuals:
1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

1.06 QUALITY ASSURANCE

A. Manufacturer qualifications:
1. Minimum 10 years of experience in production of fabricated stainless steel slide gates substantially similar to the equipment specified.
2. Submit evidence of satisfactory operation in at least 20 different installations in the United States using the proposed guides and seals design.
3. Multiple gates at a plant shall be considered as one installation toward meeting the experience requirements.

B. Manufacturer's shop welds, welding procedures, and welders: Qualified and certified in accordance with the requirements of AWS D1.6.

C. Factory markings:
1. Mark gates according to the scheduled equipment tag numbers when such numbers are used.
2. For thimbles, frames, and other non-interchangeable components, match mark the entire system.

D. Assembled gates: Shop inspected, adjusted, and tested before shipment.

1.07 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements.

2.02 MANUFACTURERS

A. One of the following or equal:
1. Fontaine Aquanox, Series 20.
2. Waterman Industries, SS-250.
3. Whipps, Inc., Series 900.

B. Operator and wall thimbles: Provided by manufacturer of slide gates.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. Maximum allowable leakage shall be 0.10 gallons per minute per foot of sealing perimeter, the allowable limits set forth in AWWA C561. Leakage testing shall be conducted in accordance with AWWA C561.

B. Except as modified or supplemented in this Section, gates and operators shall be in accordance with the requirements of AWWA C561, latest edition.

C. Gate components:
   1. Frames:
      a. Design for the design head scheduled with a minimum safety factor of 5 with regard to ultimate tensile, compressive, and shear strength.
      b. Self-contained gates: Where frames extend above the operating floor, design to be self-supporting so that no further reinforcing or support is required.
   2. Stem: Select diameter, guide quantity and guide spacing based on following criteria:
      a. Slenderness ratio (l/r): Shall not exceed 200.
      b. Maximum diameter: Provide stem guides at a spacing to maintain stem diameter of 2 inches or less.
      c. Tensile strength: Suitable to withstand the force generated by the operator with the application of a 200 pound force applied to the crank or handwheel or a 250 foot-pound torque applied to the wrench nut.
      d. Compressive strength:
         1) Suitable to withstand buckling due to the force generated by the operator with the application of an 80 pound force applied to the crank or handwheel or a 100 foot-pound torque applied to the wrench nut.
         2) Determine buckling load using Euler Column formula in accordance with AWWA C561, where C = 2.
      e. Design force for power actuators:
         1) Hydraulic cylinder operators: 1.25 times the output thrust at maximum hydraulic fluid operating pressure.
         2) Electric motor operators: 1.25 times the output thrust in the stalled-motor condition.
      f. Gates having widths greater than 2 times the height: Provide with 2 lifting mechanisms connected by a tandem shaft.
   3. Thrust nut: Suitable to withstand thrust developed by operator with the application of a 40 pound force on the crank or handwheel with safety factor of 5. Base design on ultimate strength of material used.
   4. Yokes for self-contained gates:
      a. Design yoke using design loading criteria for stem with safety factor of 5 based on the ultimate strength of the material used.
      b. Maximum deflection at design load: Not to exceed 1/360 of the span.
   5. Slide:
      a. Deflection shall be less than or equal to 1/1,000 of the span of the gate or 1/16 inch, whichever is less, under the design head.
      b. Design for the maximum design head specified with a minimum safety factor of 5 with regard to ultimate tensile, compressive, and shear strength.

2.04 MATERIALS

A. Stainless steel: ASTM A276, Type 316:
   1. Components or structural shapes which are welded: ASTM A276, Type 316L.
      a. Manufacturer's shop welds, welding procedures, and welders:
         1) Qualified and certified in accordance with the requirements of AWS D1.6.
   2. Wetted and unwetted parts, including fasteners and hardware, except as specified in this Section, shall be stainless steel.

B. Ultra-high molecular weight polyethylene: ASTM D1248 and ASTM D4020, virgin materials only.

C. Neoprene: ASTM D2000, Grade 2 BC 510.

D. Manganese bronze: ASTM B584, UNS Number C86500 or Alloy 432.

E. Silicon bronze: ASTM B584 UNS Number C87300.

2.05 COMPONENTS

A. Slide:
   1. Type 316L stainless steel.
   2. Rectangular or square.
   3. Fabricated with a flat plate reinforced with formed plates or structural members.

B. Frame:
   1. Construct gate frame of Type 316L stainless steel structural members or formed plate welded to form a rigid one-piece frame.
      a. Capable of providing true dimensions within tolerances and preventing binding and excessive wear of sliding parts.
   2. Mounting: As indicated on the Drawings and the Slide Gate Schedule.
      a. Centerline of anchors shall be located no closer than 4-1/2 inches from the edge of concrete opening for face-mounted gates.
   3. Adjustable ultra-high molecular weight polyethylene pressure pads.
   4. Flush bottom type unless otherwise indicated on the Drawings.
   5. Allow replacement of top, side, and bottom seals without removing the gate frame from concrete or wall thimble.
   6. Machine surfaces matching with thimble. Provide seal between gate frame and thimble that will meet leakage performance requirements.
   7. Embedded gates: Extend frame to provide access to pressure pad adjusting screws (for seal design alternatives A and B only).

C. Yoke for self-contained gates:
   1. Type 316L stainless steel.
   2. Extend guides and frame so that bottom of yoke is at least 12 inches above top of slide at full open position.
   3. Bolt or weld to frame.
   4. Provide mounting plate on top of yoke to mount operator.
   5. Design yoke to allow removal of gate slide.

D. Guides:
   1. Type 316L stainless steel with ultra-high molecular weight polyethylene insert in contact with gate.
   2. Minimum face width of 1 inch.
   3. Length: To support the slide fully in the open position.
   4. Anchor bolts shall not pass through the guides and seals.

E. Seals:
   1. Designed to achieve the specified leakage requirements.
   2. Sealing and sliding surfaces shall provide a low coefficient of friction with the surface of the slide.
   3. Field replaceable without removing gate from concrete or wall thimble.
   4. Anchor bolts shall not pass through the guides and seals.
   5. J-bulb seals are not acceptable.
   6. Minimum seating surface width: 3/4 inch in contact with slide.
   7. Bottom seal:
      a. Resilient neoprene or EPDM, minimum durometer of 45.
      b. Attached to the bottom of the slide or embedded in gate frame invert.
      c. Compressed by closing action of gate slide against plate for standard upward opening gates.
   8. Side and top seals:
      a. UHMWPE self-adjusting type seals: Utilize a continuous compression cord to ensure contact between the seals and the slide.
         1) An O-ring is not acceptable in lieu of compression cord.
      b. Side seals:
         1) Attach to frame using one of the following approaches.
            a) Held in place between the front and back angles of the guide with Type 316 stainless steel bolts passing through the guide and seal along the length of the guide.
            b) Held in place between front and back of a formed, 1-piece, rigid channel guide. Attach seals to frame using Type 316 stainless steel bolts.
         2) Design and installation shall provide access to and removal of the bolt to allow removal of the side seal without removing the gate from the concrete.
      c. Top seal: UHMWPE self-adjusting type seal with double compression cord.
   9. Provide invert seal for downward (weir) gates.
   10. Set seals to be slightly compressed with slide in closed position.

F. Stem:
   1. Type 316 stainless steel.
   2. Machine cut or rolled full depth ACME threads.
   3. Diameter: Capable of withstanding anticipated opening and closing thrusts under head as indicated on the Drawings. Minimum stem diameter: 1-1/2 inch at the threads.
   4. Length: Capable of permitting easy installation and removal.
   5. Stem couplings:
      a. Silicon bronze or Type 316 stainless steel.
      b. Threaded and keyed to stem or threaded and bolted to stem.

6. Stem guides:
    a. Type 316 stainless steel.
    b. Split collar.
    c. Adjustable in 2 directions.
    d. Ultra-high molecular weight polyethylene bushing.
7. Provide manganese bronze stop collar on stem above actuator.
8. Drill and connect stem to slide structural sections with Type 316 stainless steel bolts.
9. Coordinate the selection of the gate stem configuration with the gate operator and operating speed.
    a. Selected gate stem configuration shall provide the most efficient combination of stem diameter/pitch/lead and keep the operating temperature at the stem nut to a minimum during operation.

G. Operating nut:
1. Locate at operator level.
2. Material: Manganese bronze.

H. Gate operators: As scheduled and specified in Section 13446 - Manual Actuators.
1. Provide cranks and gears necessary to bring operator to height specified, or typical operator height of 3 feet-6 inches if not otherwise shown.

I. Bolts, nuts, and fittings: Type 316 stainless steel.

J. Anchor bolts: Type 316 stainless steel.

2.06 FINISHES

A. Stainless steel:
1. Surface preparation of gates and stop plates after fabrication to remove weld splatter and to polish scratches:
    a. In accordance with SSPC-SP 10 near white metal finish or shot blasting.
2. Clean the entire surface to produce an even color and sheen.

B. Operators, stands, and other accessory equipment: Surface preparation, factory prime, field prime, and finish coats as specified in Section 09960 - High-Performance Coatings.

2.07 FABRICATION

A. Shop assembly:
1. Gates shall be factory assembled, adjusted, and tested.
2. Mount accessories and appurtenances, including, but not limited to, motor operators and limit switches so that the complete system may be tested at the factory.

2.08 SOURCE QUALITY CONTROL

A. Source Testing (Factory Acceptance Tests):
1. As specified in Section 01660 - Equipment and System Performance and Operational Testing.

2. Not witnessed.
3. Furnish test reports and Manufacturer's Certificate of Source Testing.

PART 3 EXECUTION

3.01 EXAMINATION

A. Inspect components for shipping damage, conformance to Specifications, and proper torques and tightness of fasteners, as specified in Section 15050 - Common Work Results for Mechanical Equipment.

3.02 PREPARATION

A. Anchoring and bracing to structures:
   1. Prepare equipment anchor setting template(s) and use to position anchors during construction of supporting structure(s).
   2. Install anchors of type and material indicated on approved anchoring designs.
   3. Install anchors with embedment indicated on approved anchoring designs.

3.03 INSTALLATION

A. Install the equipment in accordance with the accepted installation instructions and anchorage details.

B. Mount gates plumb in both vertical planes and level in horizontal plane.

C. Adjust wedges or other parts of the gate to the point where it will not be possible to insert a 0.004-inch feeler gauge between the gate slide and the gate frame at any point.
   1. Securely lock wedges into position after adjustment.

D. Face mounted gates:
   1. Where wall thimbles are not provided, mount gate to wall with anchor bolts. Install over a minimum 1-inch thick grout pad.
   2. Non-shrink cement grout as specified in Section 03600 - Grouting.

E. Furnish Manufacturer's Certificate of Installation Verification.

3.04 FIELD QUALITY CONTROL

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements:
      a. Installation: 1 trip, 1 day minimum.
      b. Functional Testing: 1 trip, 1 day minimum.

3. Training:
    a. Maintenance: 2 hours per session, 2 sessions.
    b. Operation: 2 hours per session, 2 sessions.

C. Functional Testing:
1. As specified in Section 01660 - Equipment and System Performance and Operational Testing.
2. Witnessed.
3. Exercise each gate through at least 2 full cycles from the closed position to full open position and back to the closed position.
4. Leakage tests:
    a. Conduct in accordance with AWWA C561.
    b. In accordance with specified allowable leakage limits.
5. Furnish test reports and the Manufacturer's Certificate of Functional Compliance.

3.05 GATE SCHEDULE

A. Gate Schedule is as specified in Attachment A - Gate Schedule.

B. Gate Schedule is not a take-off list.
1. Provide gates specified and as indicated on the Drawings.

END OF SECTION

ATTACHMENT A - GATE SCHEDULE

GATE SCHEDULE

Gate Tag Number or Mark Number	Drawing Number	Location	Opening Size W x H (inches)	Wall Opening Shape	Gate Opening Direction	Type of Closure[1]	Gate Design Pressure[2]		Gate Mounting[3]	Type of Frame[4]	Stem Type[5]	Type of Operator[6]	Minimum Gate Travel (inches)	Notes
							Seating (feet)	Unseating (feet)						
1	07M101	Sludge Blend Tanks	24 x 24	Square	Upward	FB	15	15	FM	NSC	RS	CO, PS	24	7

Notes:

(1) Closure: DO = Downward Opening; FB = Flush Bottom; STD = Standard.

(2) Gate design pressure applied at centerline of gate.

(3) Mounting: FM = Face Mounted; EC = Inside Existing Channel; EMB = Embedded; SP = Spigot back; FWT = “F” Wall Thimble; EWT = “E” Wall Thimble.

(4) Frame: SC = Self-Contained; NSC = Non-Self Contained; F = Flatback; FL = Flange back.

(5) Stem: RS = Rising Stem; NRS = Non-Rising Stem.

(6) Operator: CO = Hand crank operator with 2-inch AWWA nut for portable operator; HW = Handwheel; HC = Hand crank; MO = Motor Operator; MOD = Modulating Motor Operator; BS = Bench Stand; FS = Floor Stand; IFS = Interconnect Floor Stand; PS = Pedestal Support.

(7) Provide floor mounted pedestal (torque tube) to transfer thrust from operator to the concrete slab.

SECTION 11312I

PROGRESSING CAVITY PUMPS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Rotary, positive displacement, Moineau principal, single screw, progressing cavity type pumps with drivers, and specified components.

B. Tag numbers: As specified in Pump Schedule.

1.02 REFERENCES

A. American Bearing Manufacturers' Association (ABMA):
   1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
   2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

B. American Gear Manufacturers Association (AGMA).

C. American Society of Mechanical Engineers (ASME):
   1. B16.1 - Gray Iron Pipe Flanges and Flanged Fittings, Class 25, 125, and 250.
   2. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through 24.

D. ASTM International (ASTM):
   1. A48 - Standard Specification for Gray Iron Castings.
   2. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   3. A283 - Specification for Low and Intermediate Tensile Strength Carbon Steel Plates.
   4. A681 - Standard Specification for Tool Steels Alloy.
   5. D2240 - Standard Test Method for Rubber Property—Durometer Hardness.

E. Hydraulic Institute (HI):
   1. 3.1-3.5 - Rotary Pumps.
   2. 3.6 - Rotary Pump Tests.
   3. 9.1-9.5 - Pumps - General Guidelines.

F. National Electrical Manufacturers Association (NEMA).

1.03 DEFINITIONS

A. Pump head (total dynamic head, TDH), flow capacity, pump efficiency, net positive suction head available (NPSHa), and net positive suction head required (NPSHr): As defined in HI 3.1-3.5, 3.6, and 9.1-9.5 and as modified in the Specifications.

B. Suction head: Gauge pressure available at pump intake flange or bell in feet of fluid above atmospheric; average when using multiple suction pressure taps, regardless of variation in individual taps.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Vibration analysis: Submit as specified in Section 15050 - Common Work Results for Mechanical Equipment when scheduled.

C. Product data: As specified in Section 15050 - Common Work Results for Mechanical Equipment:
   1. Submit seal water pressure and flow requirements.

D. Shop drawings: As specified in Section 15050 - Common Work Results for Mechanical Equipment.

E. Calculations: As specified in Section 15050 - Common Work Results for Mechanical Equipment:
   1. Torsional analysis: When scheduled submit as specified in Section 15050 - Common Work Results for Mechanical Equipment.

F. Vendor operation and maintenance manuals: As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

G. Commissioning submittals:
   1. Provide Manufacturer's Certificate of Source Testing as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   2. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.05 QUALITY ASSURANCE

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Provide pumps specified in this Section from same manufacturer.

C. Vibration analysis: Provide equipment vibration analysis as specified in this Section.
   1. Vibration analysis level: As scheduled and as specified in Section 15050 - Common Work Results for Mechanical Equipment.
   2. Vibration analysis expert: Provide when scheduled.

D. Manufacture's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.06 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or approved equal:
   1. Netzsch Inc., Nemo Series.
   2. Moyno Industrial Products Division of Robbins & Meyers, Inc., Model Series 2000.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. Pump type and components:
   1. Rotary, positive displacement, Moineau principle, single screw, progressing cavity type pumps with components.
   2. System includes pump, motor or other driver, drive arrangements, seals, couplings, base plates, guards, supports, anchor bolts, necessary valves, gauges, taps, lifting eyes, stands, and other items as required for a complete and operational system.

B. Design requirements:
   1. Pump performance characteristics:
      a. As specified in the Pump Schedule.
      b. Performance tolerances shall be the same as the test tolerances specified in Section 15958 - Mechanical Equipment Testing.
   2. Motor characteristics: As specified in the Pump Schedule.

C. Product requirements as specified in Section 01600 - Product Requirements and Section 15050 - Common Work Results for Mechanical Equipment.

2.03 MATERIALS

A. General: Materials in the Pump Schedule shall be the type and grade as specified in this Section.

B. Cast iron: ASTM A48, Class 30 minimum.

C. Buna-N: Synthetic rubber with a minimum Durometer hardness of 70 in accordance with ASTM D2240 test methods.

D. Tool steel: ASTM A681 with 0.020 inch minimum chrome plating or AISI 4140 with 0.010-inch minimum hard chrome plating thickness oversized and finish to Rockwell hardness of not less than C60.

E. Stainless steel: ASTM A276, Type as scheduled.

F. Structural steel: ASTM A283, Grade D.

2.04 PUMP CASINGS

A. Construction: Material as scheduled of sufficient strength, weight, and thickness to provide accurate alignment, and prevent excessive deflection.

B. Design Working Pressure: Not less than the maximum of 1.25 the Rated Design Point head or 1.1 times the maximum discharge pressure at the maximum revolutions per minute in vendor published information for the specified model.

C. Hydrostatic test: 5-minute hydrostatic test minimum 1.5 times Design Working Pressure.

D. Suction and discharge piping connections: Flanged in accordance with ASME B16.1, Class 125, or ASME B16.5, Class 150; provide higher pressure class as required to meet Design Working Pressure. Configuration of pipe connections as shown on the Drawings.
   1. For pumps located in RDT Facility:
      a. For required configuration, size, and connections, coordinate with rotary drum thickener manufacturer as specified in Section 11354 - Thickeners.

E. Vent and taps: Provide casings with both 3/4 inch National Pipe Thread high point vent and low point drain taps.

2.05 STATOR AND ROTOR

A. Stages: As scheduled.

B. Materials: As scheduled.

C. Stator Removal: Removable for maintenance replacement.

D. Rotation: Clockwise looking from driver, unless otherwise indicated on the Drawings.

E. Balance: As specified in Section 15050 - Common Work Results for Mechanical Equipment to meet the vibration criteria as specified in Section 15958 - Mechanical Equipment Testing.

2.06 DRIVE SHAFTS

A. Shaft: Hollow or solid.

B. Shaft turned and polished.

C. Material: As scheduled.

D. Joint shall be rated for a minimum of 10,000 hours of operation.

E. Strength: Able to withstand minimum 1.5 times maximum operating torque and other loads, and of ample strength and stiffness to operate without distortion or vibration which may reduce pump life at normal speeds as shown in the manufacturer’s literature.

F. Resonant frequency: As specified in Section 15050 - Common Work Results for Mechanical Equipment and Section 15958 - Mechanical Equipment Testing.

G. Shaft connecting rod: Design to limit operating angle to within 1 degree angular deflection.

H. Shaft-rotor connection:
   1. Shaft shall be rigidly connected to the rotor through a connecting rod and grease or oil lubricated, gear type U-joint. Pin joints are not acceptable.

2.07 BEARINGS AND BEARING FRAME

A. Bearing life: Minimum B-10 life of 100,000 hours at rated design point but not less than 24,000 hours in accordance with ABMA 9 or 11 at bearing design load imposed by pump shutoff with maximum sized impeller at rated speed.

2.08 SHAFT STUFFING BOX

A. Size: As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Materials: Same as pump casing.

C. Shaft seal type: As scheduled and as specified in Section 15050 - Common Work Results for Mechanical Equipment.

D. Drain size: Minimum 3/4 inch, with drain line routed to nearest equipment floor drain.

2.09 COUPLINGS

A. Types: When driver or gear coupled to pump, provide flexible coupling as specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Flexible coupling life: Infinite at up to 0.30 degree misalignment angle total or per disk for disk type at maximum operating loads.

C. Design coupling to withstand a minimum of 1.5 times the maximum operating torque and other imposed loads.

2.10 SUPPORTS, PEDESTALS, AND BASEPLATES

A. Type: Single piece base plate with drive arrangement as scheduled and as specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Materials: Same as pump casing and coated as specified in Section 09960 - High-Performance Coatings or ASTM A283 steel, hot-dip galvanized after fabrication.

C. Pump and driver support strength: Able to withstand minimum 1.5 times maximum imposed operating loads or imposed seismic loads, whichever is greater.

D. Configuration: Allow easy access to stuffing boxes, bearing frames, suction housing and couplings; suction flange at least 2 inches above pump foundation; factory mount pump and driver to baseplate.

E. Motor arrangement:
   1. For overhead, piggyback or side motor arrangements: Provide motor base with slide rails to allow for adequate belt and alignment adjustment of pump and motor.
   2. When in-line motor arrangement scheduled:
      a. Motor centerline to coincide with pump centerline.
      b. Provide gearbox as needed to provide specified pump speed.
   3. When piggyback or overhead motor arrangement scheduled:
      a. Support motor directly above pump centerline.
      b. Mount motor minimum of 6 inches above top of pump on structural frame.
   4. When side-mounted motor arrangement scheduled:
      a. Mount side-mounted motors adjacent to pump, secured directly to baseplates.
      b. Provide side-mounted motors “left-handed” or right-handed” as indicated on the Drawings.

F. Anchor bolts: As specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

2.11 SPEED REDUCERS

A. Gear reducers (when scheduled or required for a pump in this Section):
   1. Provide with NEMA C face connection between motor and gearbox.
   2. Provide helical reduction gears, rated for AGMA Class II service with a 1.5 service factor.
   3. Provide oil bath lubricated.
   4. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. V-belt drives (when scheduled or required for a pump in this Section):
   1. Design to transfer torque of installed driver.
   2. Limit speed reduction ratio to 5 to 1.
   3. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

2.12 EQUIPMENT GUARDS

A. Provide equipment safety guards as specified in Section 15050 - Common Work Results for Mechanical Equipment.

2.13 DRIVERS

A. Horsepower:
   1. As scheduled.
   2. Listed driver horsepower is the minimum to be supplied.
      a. Increase driver horsepower if required to prevent driver overload while operating at any point of the supplied pump operating head-flow curve including runout.
      b. When scheduled driver is a motor, increase motor horsepower if required to prevent operation in the service factor.

c. Make all structural, mechanical, and electrical changes required to accommodate increased horsepower.

B. Motors: Provide motors as specified in Section 16100 - Electrical Requirements and as specified in this Section:
   1. Revolutions per minute: As scheduled:
   2. Enclosure: As scheduled.
   3. Electrical characteristics: As scheduled.
   4. Efficiency, service factor, insulation, and other motor characteristics: As specified in Section 16100 - Electrical Requirements.
   5. Motor accessories: As specified in Section 16100 - Electrical Requirements and in this Section and as indicated on the Drawings.
   6. Coordinate motors with the variable frequency drive manufacturer to ensure compatibility between the motor and variable frequency drive.
      a. Coordinate pump starting torque requirements to ensure supplied variable frequency drive provides sufficient starting torque capacity for all operational conditions, including after extended shutdown periods while in service pumping process fluids and sludge.

C. Other drivers: As scheduled and as specified in sections listed in the Schedule.

D. Non-reverse ratchets: When scheduled, provide driver with non-reverse ratchets or pin mechanism to prevent reverse rotation of the pump and driver in the event of discharge valve failure.

2.14 PUMP ACCESSORIES

A. Provide stator run dry protection for all supplied pumps:
   1. Run dry protection shall be provided for the pump stator through the measurement of temperature at the stator/rotor interface. The temperature run dry protection shall shut down the pump upon high temperature before stator damage occurs.
   2. As part of the run dry protection package, provide thermistor, thermowell drilled and tapped into pump stator, explosion proof connection head, and in relay controller type that can be housed in pump controller.
      a. Connection head shall be aluminum or plastic.
      b. Controller shall include a display indicating stator temperature and alarm setpoint.
      c. Controller shall include fault output for remote monitoring.
      d. Controller shall be mounted within NEMA 4X LCP located near pump.
         1) LCP shall be provided by Contractor.
         2) Controller shall be furnished by the vendor for installation by contractor.
   3. Provide relay to allow annunciation of a high stator temperature (fail) alarm if the temperature reaches an adjustable preset temperature. Setpoint for alarm condition shall be set in the field per Manufacturer’s recommendations.
   4. Electrical characteristic: 120 volts, single-phase, 60 hertz.

2.15 SPARE PARTS AND SPECIAL TOOLS

A. Spare parts:
   1. Pump thrust bearing set.
   2. Pump radial bearing set.
   3. Stators: 1 every type.
   4. Shaft coupling, U-joint, or gear joint rebuild kit: 1 every size and type.
   5. Motor bearing set(s): 1 every type.
   6. Pump rotor: 1 every type.
   7. Mechanical seal: 1 every size and type.

B. Special tools: Deliver 1 set for each furnished pump type and size needed to assemble and disassemble pump system.

PART 3 EXECUTION

3.01 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Source Testing.
      b. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements: Require manufacturer's representative to perform the following services as described below and as specified in Section 01660 - Equipment and System Performance and Operational Testing. The specified durations are the minimum required time on the job site. Additional services and/or longer durations shall be provided as needed at no cost to the Owner to meet the required quality of work. Work to be done in a minimum of 4 trips:
      a. Installation assistance: As required:
         1) Advise/observe the Contractor on the installation of the equipment.
         2) Provide additional assistance as required.
      b. Installation inspection: 1 trip, 2-day minimum.
      c. Functional Testing: 1 trip, 2-day minimum.
   3. Training: As defined in Section 01660 - Equipment and System Performance and Operational Testing and this Section:
      a. Operations: 2-hour class, 2 sessions.
      b. Mechanical Maintenance: 3-hour class, 1 session.
      c. Combined Electrical and I&C Maintenance: 1-hour class, 1 session.
   4. Final acceptance checkout: 1 workday (trip may be combined with training).

C. Source testing: As specified in Pump Schedule. Test as specified in Section 15958 - Mechanical Equipment Testing.

D. Functional testing: As specified in Pump Schedule. Test as specified in Section 15958 - Mechanical Equipment Testing.

E. Refer to Section 16100 - Electrical Requirements and Section 17100 - Control System Requirements for additional requirements.

3.02 PUMP SCHEDULE

Tag Numbers	**DEW-PMP-07-003**	**THK-PMP-07-011 THK-PMP-07-012 THK-PMP-07-013**	**SLB-PMP-07-001 SLB-PMP-07-002 SLB-PMP-07-003**
General Characteristics:			
Service	Centrifuge DSL Feed	Thickened Sludge Transfer	RDT Feed
Quantity	1	3	3
First Named Manufacturer's Model Number	NM090SY02S14K	NM063SS02S12K	NM125SY02S14Z
Minimum Pumped Fluid Temperature, degrees Fahrenheit	60	50	50
Normal Pumped Fluid Temperature, degrees Fahrenheit	95	70	70
Maximum Pumped Fluid Temperature, degrees Fahrenheit	105	85	85
Vibration Analysis Level	1	1	1
Vibration Analysis Expert	Not required	Not required	Not required
Fluid Solids Concentration, Maximum	5%	7%	3%
Pump Characteristics:			
Minimum Number of Rotor Sealing Stages	2	2	2
Bearing Lubrication	Grease	Grease	Grease
Shaft Seal Type	Type 3	Type 3	Type 3
Coupling Type	Flexible	Flexible	Flexible
Speed Control	Constant Torque Variable Frequency Drive	Constant Torque Variable Frequency Drive	Constant Torque Variable Frequency Drive
Suction Arrangement	Flanged	Open Throat[1]	Flanged
Maximum Pump revolutions per minute	280	260	260
Minimum Pump revolutions per minute	60	52	52

Tag Numbers	DEW-PMP-07-003	THK-PMP-07-011 THK-PMP-07-012 THK-PMP-07-013	SLB-PMP-07-001 SLB-PMP-07-002 SLB-PMP-07-003
Rated Design Point (at Maximum Revolutions per Minute):			
Flow, gallons per minute	110	60	450
Head, feet	65	125	95
Required Condition 2:			
Flow, gallons per minute	55	38	200
Head, feet	51	94	40
Required Condition 3:			
Flow, gallons per minute	185	21	N/A
Head, feet	87	92	N/A
Other Conditions:			
Minimum NPSHa at Every Specified Flow, feet	19	33	5
Minimum Suction Static Head, feet	-9 (9 feet suction lift)	N/A	-9 (9 feet suction lift)
Maximum Suction Static Head, feet	8	N/A	6
Pump Materials:			
Pump Casing	Cast Iron	Cast Iron	Cast Iron
Stator	Nitrile	Nitrile	Nitrile
Rotor	Hard Chrome Plating	Hard Chrome Plating	Hard Chrome Plating
Shaft	420 Stainless Steel	420 Stainless Steel	420 Stainless Steel
Pump Bearing Frame	Cast Iron	Cast Iron	Cast Iron
Driver Characteristics:			
Driver Type	Motor	Motor	Motor
Drive Arrangement	Direct Coupled	Side Mounted Belt-Driven	Direct Coupled
Non-reverse Ratchets	None Required	None Required	None Required
Minimum Driver Horsepower	20	15	50
Maximum Driver Speed, revolutions per minute	1,800	1,800	1,800

Tag Numbers	DEW-PMP-07-003	THK-PMP-07-011 THK-PMP-07-012 THK-PMP-07-013	SLB-PMP-07-001 SLB-PMP-07-002 SLB-PMP-07-003
Motor Characteristics (when motor is driver type):			
Inverter Duty Rated	Yes	Yes	Yes
Motor Voltage/Phases/Hertz	460/3/60	460/3/60	460/3/60
Enclosure Type	TEFC	TEFC	TEFC
Source Testing:			
Test Witnessing	Not Witnessed	Not Witnessed	Not Witnessed
Performance Test Level	2	2	2
Vibration Test Level	1	1	1
Noise Test Level	1	1	1
Functional Testing:			
Performance Test Level	2	2	2
Vibration Test Level	1	1	1
Noise Test Level	1	1	1

Notes:

1. Proper mating/connection of the hopper, flanged flexible rectangular connection, and thickened sludge pump suction open throat shall be coordinated by the Contractor.

END OF SECTION

SECTION 11334

INLINE GRINDER

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: In-line grinder including main housing, cutter-drive assembly, and vendor control panel.

1.02 REFERENCES

A. American Iron and Steel Institute (AISI):
   1. 4130 - Heat Treated Alloy Steel.
   2. 4140 - Heat Treated Hexagon Steel.

B. ASTM International (ASTM):
   1. A395 - Standard Specification for Ferritic Ductile Iron Pressure Retaining Castings.
   2. A536 - Standard Specification for Ductile Iron Castings.

C. National Electrical Code (NEC).

D. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1000 V Maximum).

E. Underwriters Laboratories, Inc. (UL):
   1. 508 - Standard for Industrial Control Equipment.
   2. 508A - Standard for Industrial Control Panels.
   3. 698A - Standard for Industrial Control Panels Relating to Hazardous (Classified) Locations.
   4. 1283 - Standard for Electromagnetic Interference Filters.
   5. 1449 - Surge Protective Devices.

1.03 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Anchoring and bracing.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals and Section 15050 - Common Work Results for Mechanical Equipment.

B. Delegated Design Submittals:
   1. Anchoring and bracing: Provide project-specific calculations based on support conditions and requirements to resist loads specified in Section 01850 - Design Criteria.

C. Equipment Submittals:
   1. As specified in Section 01600 - Product Requirements.
      a. Product data.
      b. Shop Drawings.
      c. Calculations.

D. Commissioning Submittals:
   As specified in Section 01660 - Equipment and System Performance and Operational Testing, including the following:
      a. Manufacturer's representative qualifications.
      b. Certificates.
         1) Requirements as specified in this Section.
      c. Test Plans.
         1) Test requirements as specified in this Section.
      d. Test Reports.
      e. Manufacturer's representatives field notes and data.
      f. Owner training.

E. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

1.05 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

2.02 MANUFACTURERS

A. One of the following or equal:
   1. JWC Environmental, 30004T Series Muffin Monster.
   2. Franklin Miller.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:

Criteria	Blended Sludge Grinders
Quantity	2
Maximum flow (gpm)	950
Tag Numbers	SLB-GRD-07-001 SLB-GRD-07-002
Minimum flow (gpm)	150
Maximum pressure drop (psi) at maximum flow rate	3
Inlet (inches)	8
Outlet (inches)	8
Motor size (horsepower)	5
Motor and grinder assembly area classification	Class 1 Division 2

2.04 MATERIALS

A. General:
   1. Sewage grinders shall consist of the following 3 main components:
      a. Main housing.
      b. Cutter cartridge and drive assembly.
      c. Vendor control panel.
   2. Cutter cartridge and drive assembly shall be 2-shaft design and be capable of continuous operation, processing wet or dry:
      a. Single shaft devices utilizing a single rotating cutter bar with stationary cutters will not be acceptable.
   3. Two-shaft design shall consist of parallel shafts alternately stacked with intermeshing cutters and spacers positioned on the shaft to form a helical pattern.
      a. The shafts shall counter-rotate with the driven shaft operating at approximately 2/3 the speed of the drive shaft.

B. Main housing:
   1. Main housing shall be a solid cast structure made of ASTM A395 or A536 ductile iron:
      a. One-piece flanged body to be capable of remaining in-line if removal of the cutter cartridge and drive assembly is required for service.
   2. Inside profile of the main housing shall be concave to follow the radial arc of the cutters:
      a. To direct larger particles toward the cutters and ensure fineness of grind, the main housing must maintain a clearance not to exceed 5/16 inch between the major diameter of the cutter and the concave arc of the housing.

3. Main housing to be provided with a covered access port for equipment inspection. Access port covers to be ASTM A395 or A536 ductile iron.
4. Maintenance and service components:
    a. Provide easy access opening at the top of the grinder for tightening the cutter stacks.
    b. Stack compression to be accomplished by torquing the stack nuts on the top of the grinder.
    c. The stack nuts shall be externally accessible.

C. Cutter cartridge and drive assembly:
1. Cutter cartridge and drive assembly to be removable from the housing as a complete segment without further disassembly. The components of that assembly include cutters, spacers, shafts, reducer, motor, bearings, and seals.
2. Cutters and spacers:
    a. Inside configuration of both cutters and spacers shall be hexagonal so as to fit the shafts with a total clearance not to exceed 0.025 inch across the flats to ensure positive drive and increase the compressive strength of the spacers.
    b. Cutters and spacers to be AISI 4130 Heat Treated Alloy Steel, surface ground for uniformity and through-hardened to a minimum 44-52 Rockwell C.
    c. Cutter configuration shall consist of 1 shaft with 11-tooth cutters and 1 shaft with 11-tooth cam cutters:
        1) To maintain particle size, the height of the tooth must not exceed 1/2 inch above the root diameter.
        2) Cutter root diameter overlap to be not less than 1/16 inch or greater than 1/4 inch to maintain the best possible cutting efficiency while incurring the least amount of frictional losses.
    d. The cutter shall exert a minimum force of 450 pounds per horsepower continuously and 1,430 pounds per horsepower at momentary load peaks at the tooth tip.
3. Grinder drive and driven shafts to be made of AISI 4140 Heat Treated Hexagon Steel with a tensile-strength rating of not less than 149,000 pounds per square inch:
    a. Each shaft hex to be a minimum of 2 inches.
4. Reducer:
    a. The gear speed reducer to be a grease-filled planetary type of reducer with "Heavy Shock" load classification:
        1) The reduction ratio to be 29:1.
        2) High-speed shaft of the grinder to be directly coupled with the reducer using a 2-piece coupling.
5. Motor: Provide motors as specified in Section 16100 - Electrical Requirements and as specified in this Section.
    a. At minimum, motor to be TEFC design, horsepower as scheduled in design criteria, 1,725 revolutions per minute, 208/230/460 volt, 60 hertz, 3 phase:
        1) Motor service factor to be 1.15, the efficiency factor not less than 81 percent at full load, and the power factor not less than 75 percent at full load.
    b. Provide motors suitable for classification included in design criteria.

c. Motor accessories: As specified in Section 16100 - Electrical Requirements and in this Section and as indicated on the Drawings.

6. Required running torque per horsepower:
   a. Continuously: 1,000 inch pounds minimum.
   b. At momentary load peaks: 3,300 inch pounds.
7. Cutter cartridge seal housing and cover to be cast of ASTM A395 or A536 ductile iron and designed to protect the seal labyrinth while guiding particles directly into the cutting chamber.
8. Bearings and seals:
   a. Radial and axial loads of the shafts to be borne by 4 sealed oversize deep-groove ball bearings.
   b. Bearings to be protected by a combination of a replaceable and independent tortuous path device and end face mechanical seals.
   c. Face materials must be a minimum of tungsten carbide to tungsten carbide, not requiring an external flush or any type of lubrication.
   d. The mechanical seal to be rated at 90 pounds per square inch continuous duty by the seal manufacturer.
   e. Bearings and seals to be housed in a replaceable cartridge that supports and aligns the bearings and seals, as well as protects the shafts and end housings. O-rings to be made of Buna-N elastomers.
   f. Products requiring continuous or occasional lubrication or flushing will not be accepted.

2.05 CONTROL SYSTEM

A. Vendor control panel(s):
   1. General:
      a. This Section summarizes key control system components for vendor control panels (VCP).
         1) Referenced sections can be obtained from the Contractor for complete control system requirements.
      b. Conform with requirements of Section 17100 - Control System Requirements.
      c. Provide instruments and other components performing similar functions of the same type, model, or class, and from one manufacturer.
         1) Coordinate with Contractor to align make and model with Contractor-furnished equipment.
      d. Provide a separate control panel for each vendor packaged system such that control panels will have fully independent control of the functions and operations for their respective system.
      e. VCP shall be completely preprogrammed, prewired, where possible and factory tested for proper operation prior to shipment.
         1) Additional testing requirements as specified in Section 17100 - Control System Requirements.
      f. Provide necessary control hardware, software, and components as required for a fully functional and operational installation.
      g. Design and size panels.
         1) Design panels to fit in the space if indicated on the Drawings.
            a) Panel Tags:
               (1) SLB-VCP-07-001 - BLENDED SLUDGE GRINDER 1.
               (2) SLB-VCP-01-002 - BLENDED SLUDGE GRINDER 2.

2. Panel enclosure and components:
    a. Enclosure manufacturers: One of the following or equal:
        1) nVent/Hoffman.
        2) Saginaw Control & Engineering.
    b. Provide panels with dimensions as shown on the drawings, not to exceed 27 inches wide without Engineer approval.
    c. Provide components and equipment with UL 508 listing.
    d. Provide control panels with UL 508A labeled.
    e. Provide fuses for equipment that is not UL listed or recognized.
    f. Provide intrinsically safe circuits and equipment in accordance with UL 698A.
    g. Provide control panel power circuits in accordance with the panel power wiring diagram included with the contract documents.
        1) Design devices and instruments to fail in a safe condition.
    h. Accept single 480 VAC, 3-phase power source:
        1) Equipped with a UL 1449 rated SPD.
        2) Terminate incoming power feed on main circuit breaker as specified in Section 16100 - Electrical Requirements.
            a) Properly rated for the available fault current as calculated as specified in Section 16100 - Electrical Requirements.
        3) Control power transformer:
            a) Provide a single power source.
            b) Control power transformers as required:
                (1) Primary voltage: 460 VAC, 3 phase, 60 hertz.
                (2) Secondary voltages:
                    (a) 120 VAC for controls.
                    (b) Derive additional voltages as required by the application.
                    (c) Sized for all panel components plus 10 percent spare capacity.
                    (d) Primary and secondary fuses.
        4) Protective barriers and touch safe components for 480 VAC equipment.
        5) Provide a physical barrier to separate 480 VAC distribution and starters from controls section of cabinet.
    i. Conform panel enclosure rating to the area classifications as specified in Section 16100 - Electrical Requirements.
    j. Panel shall be rated as follows, unless otherwise specified:
        1) Outdoor panels: NEMA 4X/7, Type 316 stainless steel.
    k. Provide each control panel door with a continuous steel hinge, 3-point latching mechanism and locking handle with rollers on the ends of the latch rods.
        1) Connect latch rods to a common door handle, hold doors securely, and form a compressed seal between door and gasket, at the top, side, and bottom.
    l. Perform and submit thermal management calculations for each control panel.
        1) Provide heating, cooling, and dehumidifying devices in order to maintain instrumentation and control devices within their rated operational temperature range.

m. Pad lockable flange mounted disconnect switch to disconnect power from panel.
    1) Interlock with the panel door.
n. Provide nonmetallic ducts for routing and organization of conductors and cables.
    1) Provide separate ducts for signal and low voltage wiring from power and 120 VAC control wiring.
o. Provide 120 VAC to 24 VDC (or other voltages as required) power supply arrangement that is configured with several modules to supply adequate power in the event of a single module failure in either a 1+1 or N+1 configuration as required:
    1) Provide automatic switchover upon module failure.
    2) Alarm contacts monitored by the PLC.
    3) Design power supply systems so either the primary or backup supply can be removed, repaired, and returned to service without disrupting the system operation.
p. Provide NEC Class 2 power to devices requiring NEC Class 2 or SELV supply power.
q. Provide UL 1449 rated SPD and UL 1283 rated EMI filter on 120 VAC panel power source.
r. Provide GFCI duplex 120 VAC convenience receptacle.
s. Factory-assemble and wire the control panel such that field wiring only requires connections to terminals.
t. Panel instruments as shown on the Drawings, as specified in 17100 - Control System Requirements, and as recommended by the equipment manufacturer to provide a fully operational system.

2. Pilot Devices:
    a. Mounted on outside face of panel door: Refer to Section 17100 - Control System Requirements and as indicated on the Drawings.
    b. Control Devices:
        1) HAND-OFF-REMOTE selector switch.
        2) RESET pushbutton to clear permissives that stop equipment.
        3) PANIC STOP pushbutton.
    c. Pilot Lights:
        1) Status:
            a) Power On.
            b) Running.
            c) Jammed: Indicates jam condition/jam clearing sequence.
        2) Alarms:
            a) Motor Fail.
            b) Jam.
    d. Monitoring and control:
        1) Dry contact rating: 120 VAC at 10 A.
        2) VCP Inputs:
            a) Control:
                (1) Start/Stop command.
        3) VCP Outputs:
            a) Status:
                (1) Running.
                (2) REMOTE indication.

b) Alarms:
(1) Failed.

e. Hardwired control functions:
1) Jam Clearing Sequence: Upon the grinder encountering a jam condition, the vendor control panel will stop the grinder and reverse its rotation to clear the obstruction. If the jam is cleared, the controller will return to normal operation. If the jam condition still exists, the controller will go through 2 additional reversing cycles within 30 seconds (3 times total) before signaling a grinder jam fail condition. Upon a grinder jam fail condition, the controller will stop and latch out the grinder and activate a Jam Fail contact.
2) If a power failure occurs while the grinder is running, the grinder will resume running when power is restored. If the grinder is stopped due to an overload condition and a power failure occurs, the overload indicator will reactivate when power is restored.
3) Starter to provide overcurrent protection. The overload relay to be adjustable so that the range selected includes the full load amps rating and service factor.
4) The following will stop and latch out grinder and activate an alarm at the grinder panel.
a) Panic Stop button pressed.
b) Motor High Temperature.
c) Motor Overload.
d) High Current.
5) If VCP HOR selector switch is in HAND, grinder will run. In REMOTE, VCP will accept a single Start/Stop input command from Area PLC/SCADA.

2.06 FINISHES

A. As specified in Section 09960 - High-Performance Coatings.

2.07 SPARE PARTS

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Provide the following spare parts for each size grinder specified:
1. Three fuses.
2. Three replacement long life indicator lamps.
3. One complete gasket and O-rings set.
4. Three cutters.
5. Three spacers.
6. One complete mechanical seal.

PART 3 EXECUTION

3.01 GENERAL

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, Section 15958 - Mechanical Equipment Testing, and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Source Testing.
      b. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements:
      a. Installation: 1 trip, 2-day minimum.
      b. Functional Testing: 1 trip, 2-day minimum each trip.
   3. Training: As defined in Section 01660 - Equipment and System Performance and Operational Testing and this Section:
      a. Maintenance: 4 hours per session, 2 sessions.
      b. Operation: 2 hours per session, 2 sessions.

C. Source testing:
   1. Test as specified in Section 15958 - Mechanical Equipment Testing.
   2. Grinder:
      a. Test witnessing: Not witnessed.
      b. Conduct Level 1 General Equipment Performance Test.
      c. Conduct Level 1 Vibration Test.
      d. Conduct Level 1 Noise Test.
   3. Electrical Instrumentation and Controls:
      a. Test witnessing: Not witnessed.
      b. Conduct testing as specified in Section 17100 - Control System Requirements.

D. Functional testing:
   1. Grinder:
      a. Conduct Level 2 General Equipment Performance Test.
      b. Conduct Level 2 Vibration Test.
      c. Conduct Level 2 Noise Test.
   2. Electrical Instrumentation and Controls:
      a. Conduct testing as specified in Section 17100 - Control System Requirements.

END OF SECTION

SECTION 11354

THICKENERS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Supplier's requirements for providing a thickening system consisting of rotary drum thickeners (referred to as thickeners hereon) complete with auxiliary equipment, control panels complete with PLC, and appurtenances to thicken blended sludge (BSL) as described herein.

B. The thickening system shall be furnished by the Thickening System Supplier (Supplier) and installed by the Contractor.

C. Equipment tag numbers:
1. Thickener 1: THK-RDT-07-001.
2. Thickener Booster Pump 1: THK-PMP-07-021, (if required).
3. Thickener 1 VCP: THK-VCP-07-001.
4. Thickener 2: THK-RDT-07-002.
5. Thickener Booster Pump 2: THK-PMP-07-022, (if required).
6. Thickener 2 VCP: THK-VCP-07-002.
7. Thickener 3: THK-RDT-07-003.
8. Thickener Booster Pump 3: THK-PMP-07-023, (if required).
9. Thickener 3 VCP: THK-VCP-07-003.

D. Inclusion of a specific manufacturer's name in the Specifications does not mean that the specific manufacturer's standard product will be acceptable. Specified manufacturer's or other manufacturer's standard product shall be modified as required to meet the Specifications.

1.02 REFERENCES

A. American Bearing Manufacturers Association (ABMA):
1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

B. American Society for Testing and Materials (ASTM):
1. A 36 - Specification for Structural Steel.
2. A 48 - Specification for Gray Iron Castings.
3. A 240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
4. A 276 - Specification for Stainless Steel Bars and Shapes.
5. A 320 - Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-Temperature Service.
6. A 380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.

7. A 480 - Specification for Flat-Rolled Stainless and Heat Resisting Steel Plate, Sheet and Strip.
8. A 500 - Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
9. A 572 - Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel.
10. A 992 - Standard Specification for Structural Steel Shapes.

C. American National Standards Institute (ANSI):
1. B 15 - Ball Bearings, Local Bearings and Fatigue Life.
2. B 16.1 - ANSI Standard for Cast Iron Pipe Flanges and Flanged Fittings Class 25, 125, 250, and 800.

D. American Welding Society (AWS):
1. D1.1 - Structural Welding Code - Steel.
2. D1.6 - Structural Welding Code - Stainless Steel.

1.03 DEFINITIONS

A. Thickening System Supplier (Supplier): Manufacturer of the thickener units defined in this Section with whom Contractor will enter into a contract to provide the thickening system specified herein.

B. Contractor: An entity or organization experienced with the installation of thickening systems with whom Owner will enter into a contract to deliver, install, test, commission and place into successful operation the thickening system specified herein.

C. Stainless steel related terms:
1. Descaling: Removal of heavy, tightly adherent oxide films resulting from hot forming, heat-treatment, welding, and other high-temperature operations.
2. Pickling: Chemical descaling of stainless steel using aqueous solutions of nitric and hydrofluoric acid, or various proprietary formulations as specified.
3. Passivation: Chemical treatment of stainless steel with a mild oxidant for the purpose of enhancing spontaneous formation of the steel's protective passive film.

D. Thickener E-Stop Panel: Field mounted E-stop panel separate from the Thickener Vendor Control Panel (VCP).

1.04 SYSTEM DESCRIPTION

A. General:
1. Provide three thickeners, complete with: floc development tanks, driven impellers, rotary drums with screens, supporting frames, spray deflection coverings, spray wash headers, return water collection tanks, hoppers/chutes, control panels, PLC, spray water booster pumps (if required), and auxiliary equipment and appurtenances.
2. Provide rotary drum thickening units:
a. Designed for continuous operation.

b. Capable of performing in accordance with the requirements set forth in these Specifications.
c. Modified from standard equipment to meet all requirements in this Specification.

3. Provide equipment in accordance with Section 15050 - Common Work Results for Mechanical Equipment.

B. Scope of supply:
1. The Supplier shall furnish the following major equipment and services including, but not limited to the following:
a. Three thickener systems, each system containing:
1) Equipment skid base or structural frame.
2) Floc development system.
3) Rotary system.
4) Drum wash system including a thickener booster pump (if required), pressure reducing or regulating valve, and strainer.
5) Spray system consisting of a solenoid valve, spray piping and nozzles, pressure gauge, and pressure switch.
6) Dilution water solenoid valve.
7) Shower deflection cover.
8) Return water/filtrate collection.
9) Thickened sludge discharge hopper with chute and flexible connection.
10) Sludge conditioning system consisting of an inline non-clog venturi mixing valve, polymer injection ring, and manifold.
11) Drive units equipped with VFDs where specified.
12) Vendor control panel (VCP).
13) Thickener instrumentation system.
14) Connections for piping, instruments, and foul air ducting.
b. Submittals as specified herein.
c. Spare parts as specified herein.
d. Factory and performance testing, coordination, communication, system operation, system debugging, and final system calibration for equipment, instrumentation, and controls for the complete thickening system.
e. Other services as specified herein including but not limited to testing, owner training and O&M manuals.
2. Contractor to provide all piping upstream and downstream of the thickeners including any ducting necessary to vent foul air.
3. Contractor shall provide and be responsible for anchoring and bracing of the thickening system for all seismic and operating loads. Anchoring and bracing shall be in accordance with Sections 03055 - Adhesive-Bonded Reinforcing Bars and All Thread Rods in Concrete and 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.
4. Contractor shall be responsible for installing and placing in successful operation the thickening system. In addition, Contractor shall be responsible for coordinating the activities of the Supplier during installation, start-up, performance testing, and operator training.

C. System description:
1. Thickening process: The sludge, mixed with an emulsion polymer, will enter the floc development tank where a low-shear, adjustable speed mixer will

promote flocculation. The flocculated solids and liquid will flow into the rotary drum screen through a step-down header or inlet pipes. In the rotary drum screen, the liquid will separate from the flocculated solids through the perforated plate, be collected in the return water tank, and exit through a drain located as indicated on the Drawings. Mounted above the rotary drum screen will be a self-cleaning wash water spray header. This spray header will keep the rotary drum screen openings clear of solids. Additionally, water is also provided to each thickener to dilute thickened sludge (TSL), if it becomes too thick.

2. Sludge characteristics: Sludge characteristics to be fed to the rotary drum thickeners are as follows:
    a. Type of feed sludge: Blended Sludge (BSL) consisting of waste activated sludge (WAS) and primary sludge (PS).
    b. Feed solids, percent total suspended solids: 0.7 to 1 percent.
    c. Feed volatile solids content, percent: 70 to 90.
    d. Feed pH range: 5.0 to 8.0.
    e. Feed maximum solids size, inches: 1.

D. Performance requirements:
1. The following performance requirements shall be met during performance acceptance testing:
    a. Hydraulic Loading: 200-275 gpm (not including polymer).
        1) Note, this hydraulic loading assumes 1.0 percent total solids sludge concentration.
    b. Solids Loading: 1,000-1,376 dry pounds per hour.
    c. Solids Concentration, range: 0.5 to 1.0 percent total solids.
    d. Minimum Percent Solids Capture:
        1) Feed sludge concentration: 95 percent.
    e. Minimum Thickened Sludge Concentration: 5.0 percent total solids, calculated as prescribed by Standard Methods.
    f. Maximum Polymer Dosage: 15 active pounds per ton dry solids fed.

1.05 SUBMITTALS

A. The Supplier shall submit product data and shop drawings including operation and maintenance manuals to the Engineer for review in accordance with Sections 01670 - Operations, Maintenance, and Training Requirements, 15050 - Common Work Results for Mechanical Equipment, and 01300 - Submittals.

B. Shop Drawings: The following shall be submitted in compliance with Section 15050 - Common Work Results for Mechanical Equipment:
1. Make, model, and weight of each equipment assembly.
2. Complete catalog information, descriptive literature, specifications, bill of materials, capacity/sizing, quantity, and control method.
3. Stainless steel:
    a. Fabricator name and qualifications, member dimensions and structural section properties, and specifications and procedures used for pickling and passivating members.
    b. Quality control submittals:
        1) Welding procedure specifications (WPS) in accordance with AWS D1.1 and D1.6.

2) Submit WPS for each type of welded joint used, whether prequalified or qualified by testing.
3) State electrode manufacturer and specific electrodes used.
4) Indicate required AWS qualification for joint.
5) Submit WPS with shop drawings that indicate those welds.
6) Submit Procedure Qualification Record (PQR) in accordance with AWSD1.1 and D1.6 for welding procedures qualified by testing.

c. Welder qualifications: For each welding process and position:
1) Welder's qualification certificates.
2) Supplier's statement that certificate will be "in effect" at the time(s) welding will be performed based on the "Period of Effectiveness" provisions of AWS D1.1 and D1.6.
3) Test reports: Certified copies of mill tests and analyses made in accordance with applicable ASTM standards, or reports from a recognized commercial laboratory, including chemical and tensile properties of each shipment of structural steel or part thereof having common properties.

4. Detailed structural and mechanical drawings showing the equipment dimensions, size, and installation.
5. Detailed structural and mechanical drawings showing motors, thickener drives, schematic wiring diagrams and interconnections wiring diagrams, interconnecting piping, pipe supports, control panel layouts, and size and length of each support frame member.
6. Factory protective coatings.
7. Anchor bolt calculations and mounting details for each equipment assembly as required by Sections 01850 - Design Criteria and 15050 - Common Work Results for Mechanical Equipment. The anchoring design shall be signed and stamped by a Registered Professional Engineer licensed to practice in the state of California.
8. Bearing life calculations.
9. Electrical information including, but not limited to, full load current and locked rotor current.
10. All submittal information as required per Sections in Divisions 16 and 17.
11. Weight and dimensions for vendor-supplied control panels.
12. Details of storage and off-loading requirements.
13. Sample warranty.

C. Quality control submittals:
1. Factory functional test report.
2. Field performance test report.
3. Certified test results for sludge conditioning system.
4. Certificate of Installation Compliance.
5. Certificate of Functionality Compliance.
6. Supplier's installation manuals.

D. Operation and maintenance manual:
1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.
2. Submit the following:
a. Lubrication instructions.
b. Maintenance instructions.

c. Operation instructions.
d. Start-up instructions.
e. Trouble-shooting instructions.
f. Unloading and handling methods.
g. Storage requirements for equipment and all supplied consumables.

E. Supplier's qualifications: Submit all information proving conformance with quality assurance requirements.

F. Warranties.

G. Commissioning submittals:
1. Provide Supplier's Certificate of Source Testing.
2. Provide Supplier's Certificate of Installation and Functionality Compliance.

H. Technician qualifications resume: Submit resume of technician to perform thickener adjustments, inspections, performance testing, and training.

I. Training course outline.

1.06 QUALITY ASSURANCE

A. Supplier qualifications:
1. Supplier must have at least 15 years' experience in the design, application, and supply of thickeners of the type and with the materials of construction described in this Specification for the municipal wastewater sludge thickening market. Supplier shall provide a signed affidavit stating conformance with these requirements.
2. Supplier must provide references for at least 5 installations at municipal wastewater treatment plants in the United States, which have been in operation for at least 5 years, to show the capability to meet the specification and design requirements of the rotary drum thickeners to be provided under this contract. References shall be for rotary drum thickeners of the type and with the materials of construction described in this Section.
a. Reference information shall include treatment plant name and location, general description of application, contact name for personnel at treatment plant, contact telephone number, date of installation, date of start-up, number, models and sizes of units installed, materials of construction for main thickener components, performance data and type of sludge being treated.
3. Welding:
a. Perform welding of structural metals in accordance with AWS D1.1 and D1.6 using welders who have current AWS qualification certificate for the process, position, and joint configuration to be welded.
b. Make Welding Procedure Specifications available at the locations where welding is performed.
c. Engineer may check materials, equipment, and qualifications of welders.
d. Remove welders performing unsatisfactory Work or require requalification.
e. Engineer may use gamma ray, magnetic particle, dye penetrant, trepanning, or other aids to visual inspection to examine any part of welds or all welds.
f. Supplier shall bear costs of retests on defective welds.

g. Supplier shall also bear costs in connection with qualifying welders.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Provide delivery in accordance with Sections 01600 - Product Requirements and 15050 - Common Work Results for Mechanical Equipment.

B. Packing and shipping: Deliver structural steel free from mill scale, rust, and pitting.

C. The thickener system, including all principal system elements, is to be fully assembled and mounted on a single structural steel skid or structural frame for simplified movement and installation. Spray water booster pumps, if provided, and flocculation tanks may be provided as separate components not included on the skid or structural frame.

1.08 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

1.09 MAINTENANCE

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. If special tools are required for the service and maintenance of the unit, provide one complete set of tools.

C. The following spare parts will be provided:
1. One set pillow block bearings, as appropriate for unit supplied, per thickener.
2. One set of all driven sprockets per thickener.
3. One drive sprocket per thickener.
4. One idler sprocket per thickener.
5. One set of drive chains or belts, as appropriate for unit supplied, per thickener.
6. One spare drum drive, including all associated couplings, gear reducers, and other components required for a fully functioning drive.
7. One spare flocculation tank mixer drive, including all associated couplings, gear reducers, and other components required for a fully functioning drive.
8. Other spare parts as recommended by Supplier.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or approved equal as determined by the City Engineer:
1. FKC, Model RST-S775x3600L with 540-gal Floc Tank (basis of design).

B. Basis of Design:
1. Substitution of any Supplier or thickener model not listed in Paragraph 2.01.A will require Engineer and Owner approval during the bid period per the contract documents.
a. Costs for any modifications to the design documents and constructed installation will be borne by Contractor.

b. All modifications to design documents must be provided by Engineer at Contractor's cost.

2. The contract documents are developed based on the installation of the FKC model listed in Paragraph 2.01 A with potential polymer injection elements and spray water booster pumps as required by FKC.
   a. Listed manufacturer's models will fit in the facility, but may require modifications to the installation shown to comply with manufacturer's requirements.
   b. Contractor shall be responsible through coordination with the Supplier for providing all modifications required to comply with the contract documents and the manufacturer's guidelines at no cost to the Owner.

2.02 IDENTIFICATION

A. Identify each unit of equipment with a corrosion-resistant nameplate, securely affixed in a conspicuous place. Nameplate information shall include equipment model number, serial number, Supplier's name and location, and any data required by Supplier for ordering replacements.

B. Provide in accordance with Section 15050 - Common Work Results for Mechanical Equipment.

2.03 MATERIALS

A. Unless otherwise specified, materials shall conform to the following:

Item	ASTM Standard	Class, Grade, Type, or Alloy Number
Stainless Steel		
Plate, sheet, and strip	A240	Type 304(1) or 316(2)
Bars and shapes	A276	Type 304(1) or 316(2)
Notes: 1) Use Type 304L (low-carbon stainless steel) if material will be welded. 2) Use Type 316L (low carbon stainless steel) if material will be welded.		

B. System components:
   1. Skid or structural frame: Fabricated of Type 316/316L stainless steel.
   2. Floc development tank: Type 316/316L stainless steel.
   3. Input connection: Type 316/316L stainless steel.
   4. Return water collection tank/filtrate collection pan: Type 316/316L stainless steel.
   5. Discharge assembly: Type 316/316L stainless steel.
   6. Driven impeller and shaft: Type 316/316L stainless steel.
   7. Rotary element composed of input assembly: Type 316/316L stainless steel.
   8. All internal drum components, including flights, roll bars, split augers, and detention ports, if provided: Type 316/316L stainless steel.
   9. Filtration media: Type 316/316L stainless steel.
   10. Shower deflection covering: Type 316/316L stainless steel.
   11. Spray headers: Type 316 stainless steel.
   12. Spray nozzles: Type 316 stainless steel.

13. Spray header housing: Type 316 stainless steel.
14. Spray header handwheel: Type 316 stainless steel.
15. Pull cord emergency switch: NEMA 4X, corrosion-resistant.
16. Electrical panels: NEMA 4X, Type 316 stainless steel.
17. Internal piping: Schedule 80 polyvinyl chloride.
18. Anchor bolts and miscellaneous hardware, Including Bolts, Nuts, Washers, and Fastener Clips: ASTM A 320, Type 316 stainless steel.
19. Non-listed miscellaneous equipment: Type 316/316L stainless steel unless otherwise specified.
20. Materials in contact with polyelectrolyte or sludge: Type 316/316L stainless steel, unless otherwise specified.
21. Piping and valve connections: Flanged or grooved-end pipe for metallic pipe, and solvent-welded socket type for polyvinyl chloride.

C. Requirements for system stainless steel:
    1. Stainless steel and associated fabrications shall meet the requirements of Section 05120 - Structural Steel.
        a. Fabricate and install in accordance with the best practices of the trade.
    2. Cleaning and passivation:
        a. Following shop fabrication of stainless steel members, clean and passivate fabrications.
        b. Finish requirements: Remove free iron, heat tint oxides, weld scale and other impurities, and obtain a passive finished surface.
        c. Provide quality control testing to verify the effectiveness of cleaning agents and procedures and to confirm that finished surfaces are clean and passivated.
            1) Conduct sample runs using test specimens with proposed cleaning agents and procedures as required to avoid adverse effects on surface finishes and base materials.
        d. Pre-clean, chemically descale (pickle), and final clean fabrications in accordance with the requirements of ASTM A 380 to remove deposited contaminants before shipping.
            1) Passivation by citric acid treatment is not allowed.
                a) If degreasing is required before cleaning to remove scale or iron oxide, cleaning (pickling) treatments with citric acid are permissible; however, these treatments shall be followed by inorganic cleaners such as nitric-hydrofluoric acid.
            2) Provide acid descaling (pickling) in accordance with Table A1.1 of Annex A1 of ASTM A 380.
            3) After pickling, final cleaning of stainless steel shall conform to Part II of Table A2.1 of Annex A2 of ASTM A 380.
        e. After cleaning, inspect using methods specified for "gross inspection" in ASTM A 380.
        f. Improperly or poorly cleaned and passivated materials shall not be shipped and will not be accepted at the job site.

2.04 EQUIPMENT

A. General:
   1. Total equipment dimensions, excluding flocculation tank, including influent pipe connecting it to the equipment and sludge hopper shall not exceed:
      a. Length: 18 feet 1 inches.
      b. Width: 5 feet 0 inches.
      c. Height: 4 feet 5 inches.
   2. Flocculation tank shall not exceed:
      a. Diameter: 3 feet 10 inches.
      b. Height: 10 feet 3 inches.

B. Equipment skid base or structural frame:
   1. At a minimum, drum, drum drive, drum support system, rotary system and covers must all be mounted on a single skid or structural frame designed for even distribution of all loads. Equipment skid or structural frame shall be designed to accommodate all operating and static loads without deflection, deformation, or vibration, which will in any manner degrade performance of the equipment. If the flocculation tank is provided on the skid/frame, the skid/frame shall meet this same requirement. If the flocculation tank is provided separately, it shall be provided with mounting lugs for anchoring to equipment support pads.
   2. Lifting lugs shall be provided, allowing for movement of entire assembled unit on the skid/frame and for any components supplied off the skid/frame.
   3. The skid/frame shall be fabricated of welded and bolted Type 316/316L stainless steel members.
   4. All thickener loads imposed on the building shall be vertical.
   5. All horizontal loads shall be contained within the structural frame.

C. Floc Development System:
   1. The flocculation tank shall be equipped with a flanged pipe stub inlet near the bottom of the tank and an outlet to one inlet pipe feeding the drum.
   2. The driven impeller of the flocculation system shall be composed of a shaft and a double vertical flat blade on either side of the shaft. The shaft shall be directly coupled to a gearbox without contact with tank bottom.
   3. Float or capacitance type level switch for high level condition in tank shall be provided by the manufacturer as specified in Section 17100 - Control System Requirements.
      a. If float type switch is used, Thickener Supplier shall provide a Type 316 stainless steel bracket within the tank, to accommodate switch mounting.
      b. If capacitance type switch is used, Thickener Supplier shall provide flanged connection, PVC flange and sleeve, spool piece and all necessary accessories to accommodate switch mounting.
      c. Location on tank where bracket or flange connection is located shall be reinforced.
      d. Location and size of switch connection is not shown on drawings. Supplier to size and locate as appropriate for their system. Locate such that equipment is accessible, instrument can accurately sense level, and tank cover remains openable.

4. Thickener Supplier shall provide flanged Type 316 stainless steel 6-inch odor control nozzle on tank to allow withdrawal of foul air from the thickener. Location of odor control nozzle shall be reinforced.
5. Flocculation tank shall have a stainless-steel odor-tight cover with a hinged opening that is easily opened for inspection of the flocculation process.
6. The flocculation tank shall be supported off of the elevated stainless steel channel on the plans. Supplier shall provide support brackets on the tank to facilitate mounting to the equipment pad. Under no circumstances shall the weight of the tank and contents be transferred to the piping below or the aluminum grating platform. Locations on flocculation tank where support brackets are located shall be reinforced.
    a. Lateral design shall be in accordance with Seismic Design Criteria specified in Section 01850 - Design Criteria and with the specified load combinations.
    b. Load combinations: Design each structural member for the most critical load combination resulting from the following load combinations:
        1) Dead Load + Live Load (contents under extreme service conditions).
        2) Dead Load + Live Load (contents under normal service conditions) + Seismic Load.
        3) Dead Load + Seismic Load.
        4) Components shall be designed for additional load combinations per ASCE 7-16.
        5) Live load is nominally defined as the dynamic loads produced by the equipment during operation assuming either normal loading conditions or extreme service conditions such as high-high hopper and flocculation tank levels or as determined as most extreme by equipment manufacturer.

D. Rotary System:
1. The rotary system shall be composed of filter screen on the drum support structure that rotates horizontally around a center feed assembly. The filter screen shall consist of stainless-steel woven-wire mesh or stainless-steel perforated plate selected on the basis of porosity or percent openness and the opening size. The perforated plate selections shall be made on the basis of maximizing flow consistent with the requirements for high-quality filtrate.
    a. Filter screen minimum percent open area: 23 percent.
2. The perforated plate filter screen shall be easily changed from the drum support structure with simple tools or simple procedures that will be included in required training sessions for Owner's staff.
3. The rotary system may be equipped with flights and/or roll bars, split augers, ports, closures, and deflectors to influence shear, water release, and drainage rate independent of flow.
4. The rotary system drive shall be fitted with a zero-motion detector. If movement of the rotary system is not sensed, the zero-motion detector shall relay an alarm. The zero-motion detector shall be calibrated to operate between the minimum and maximum recommended speeds for the rotary system.
    a. Rating: NEMA 4X.
    b. Power supply: 120 VAC.
    c. Dry contacts for alarm.
5. Bearings shall be separated from the wetted environment. All bearings shall be greaseable while the unit is in operation. Bearings that are not separated from

the wetted environment or that require taking the unit offline to grease the bearings are not acceptable. All bearings shall have a minimum L10 bearing life of 675,000 hours under maximum loading conditions, calculated by using the latest ANSI/AFBMA standard.

6. Drums shall be supported by and rotated on a set of full-length polyshafts.
    a. Polyshafts:
        1) A minimum of 2 shafts shall be provided for the unit specified. The full-length drum support shafts shall be supported by a pillow block bearing mounted at each end outside the wetted environment.
        2) The shafts shall be Schedule 40 carbon steel fully coated with polyether polyurethane and machined to match the drum support points.
        3) The polyurethane shall have a minimum thickness of 1/2 inch on all drum supporting surfaces.
        4) Shaft shall have stub ends manufactured from stainless steel.
        5) All rollers shall be supported by 3-inch greaseable type roller bearings, equipped with metal cages, in sealed, splash proof, pillow block housings.
        6) All shafts shall be supported by self-aligning spherical roller bearings mounted in fixed pillow block housings.
        7) Bearing lubrication shall be performed through a type 304 stainless steel grease fitting mounted on the bearing housing.
        8) Bearing housing shall be class 30 cast iron with stainless steel fasteners and seal materials shall be rubber suited for the service. Bearing housing shall be coated as specified herein.
7. Rotation shall be transferred from the drum drive to the drum either through a chain and sprocket system or through a driven shaft system.
    a. If a chain and sprocket system is used:
        1) The chain shall engage with the drive sprocket, driven sprocket, and tensioner sprocket.
        2) The chain shall be constructed of NH78 plastic and assembled with stainless steel pins.
        3) The chain shall be wrapped around the driven sprocket, mounted on the inlet cylinder head of the rotary drum.
        4) The drive assembly shall be mounted on a rigid base with provisions for adjustment of the drive, sprocket, and NH78 plastic chain interface.
        5) The chain shall not require greasing or oiling.
        6) The drive and driven sprockets shall be constructed of cast nylon.
        7) The tensioner sprocket shall be constructed of UHMW.
    b. If a driven shaft system is used:
        1) Input power to the drive roller shaft shall be supplied by the main drum drive through a shaft-mounted gearbox.
        2) The gearbox shall connect directly to the drive shaft.
        3) Other drum support shafts shall be connected to the drive shaft with a poly chain and sprockets so that all shafts are driven.

E. Drum Wash System shall be designed to boost (if required), reduce, or regulate water pressure as necessary and provide a continuous flow to the spray header designed to keep the thickening drum orifices clear of solids. Water supply will

normally be plant service reclaimed water (3W).. Wash water system shall be suitable for both 3W.

1. Water Supply System:
    a. Thickener booster pumps:
        1) Design and supply for Contractor-installation, one thickener booster pump for each thickener, if required for spray water pressure.
        2) Booster pumps shall be base mounted turbine pumps and shall be located as indicated on the Drawings. Booster pumps shall be capable of boosting minimum reliable plant service pressure to required pressure.
        3) To avoid over-pressurizing the wash water spray system when plant water pressure exceeds values acceptable for system, provide pressure reducing or pressure regulating valve for each thickener booster pump system.
    b. Pressure reducing or regulating valves:
        1) Design and supply for Contractor-installation, a pressure reducing or regulating valve for each thickener.
        2) Pressure reducing or regulating valve shall be in compliance with Section 15118 - Pressure Control Valve. Pressure reducing or regulating valve shall be capable of reducing or regulating water pressure to required pressure.
    c. Strainers:
        1) Design and supply for Contractor-installation, a wye strainer for each thickener.
        2) Strainers shall be oversized to accommodate the flow equivalent to twice the normally required wash water flow. Strainers shall be easy to remove for inspection and maintenance cleaning. Strainers shall be in compliance with Section 15125 - Strainers. Perforation size to be selected by the manufacturer.
    d. Wash water has the following characteristics:
        1) Wash water: Plant service water is available at a reliable minimum pressure of 50 psig with fluctuations up to 85 psig.
        2) Solids content: Up to 45 milligrams per liter (mg/L) of suspended solids.
        3) Chlorine residual: Up to 5 mg/L of total chlorine residual.
2. Spray header:
    a. A self-cleaning washing header shall be oriented in a horizontal position the length of the rotary system to maintain positive cleaning with each revolution of the rotary system, forcing the washed off solids to return to the mass of solids tumbling inside the rotary element. The washing header shall be mounted with U-bolts permitting the adjustment of the angle of impact of the water, from tangential to square, relative to the rotary system.
    b. Manufacturers: One of the following or equal:
        1) Appleton Manufacturing, Menasha Corp., Menasha, WI.
        2) Heinrich Stamm Co. Worms AMRhein, Germany.
        3) Sprayco, Nashua, NH.
        4) Lechler, US.

c. Design and supply for Contractor-installation, a solenoid valve for each thickener:
    1) One-inch (if booster pump is provided) or 1 1/2-inch (if booster pump is not provided), 2-way solenoid valve to be connected upstream of the wash water connection to the spray water header.
    2) The solenoid valves shall comply with Section 15117 - Specialty Valves and shall be connected to dissimilar piping with dielectric couplings especially designed for the prevention of chemical reactions between dissimilar metals, as specified in Section 15052 - Common Work Results for General Piping. The valve shall be shipped loose to prevent damage.
d. Nozzles: Replaceable, designed with a built-in hand wheel operated stainless steel brush to provide cleaning action without disassembly; handwheel to extend to outside of thickener so brush can be operated without interruption of the thickener operation.
e. Nozzle spacing shall be such that the sprays from adjacent nozzles overlap one another at the drum surface.
f. The spray header shall be equipped with a manually operated handwheel attached to a flush valve and a series of internal brushes which can clean debris accumulated on the inner surface of the nozzle orifice. Handwheel rotation shall open the flush valve to flush dislodged debris. Reverse rotation of the handwheel shall close the valve and return the header to normal operation.
g. Spray header pressure gauge:
    1) As specified in Section 17100 - Control System Requirements.
    2) Wetted materials: Stainless steel.
    3) Dial: 4-1/2-inch, liquid filled.
    4) Connection: 1/2-inch NPT.
    5) Range: 0-160 PSIG, or as recommended by manufacturer.
    6) Manufacturers: Ashcroft, Wika, or equal.
h. Wash system pressure switch:
    1) Provide pressure switch to indicate issue with wash system.
    2) As specified in Section 17100 - Control System Requirements.
    3) Wetted materials: Stainless steel.
    4) Automatic reset.
    5) Setpoint:
        a) As required by manufacturer to ensure satisfactory wash system pressure.
        b) Adjustable setpoint.
    6) Manufacturers: Ashcroft, United Controls, or equal.
i. Spray piping and nozzles: Braced and of sufficient pressure rating to withstand pressure caused by sudden valve closure.

F. Shower deflection cover:
    1. The rotary element shall be covered on the outside with shower deflection covers designed to contain any fugitive spray and minimize mist emissions. The panels shall overlap and shall be fastened to the framing members of the rotary element. The panels shall be limited in dimension and fastened to the framing members by wing nuts to facilitate removal.

G. Return water/filtrate collection:
   1. All elements of the rotary system and supporting frame shall be contained and mounted over the return water or filtrate water collection tank. Delivery of collected filtrate water shall be by gravity through 1 filtrate tank drain. Supplier shall provide a flanged pipe stub sized for the full feed flow, spray water, and dilute polymer solution. The pipe stub shall discharge in the direction indicated on the Drawings.
   2. Flushing connections or similar provisions shall be provided for easy access during cleaning.
   3. Filtrate pan shall be located such that the moving parts do not come into contact with the pan under any conditions.
   4. The unit shall be specially designed to contain fugitive spray and mist emissions.

H. Thickened sludge discharge hopper/chute:
   1. Rotary drum thickener Supplier shall provide one thickened sludge hopper and chute for each thickener.
      a. Provide the thickened sludge hopper and chute to convey thickened sludge from the thickener discharge to the thickened sludge pump suction as indicated on the Drawings.
      b. The structural design of the hopper and chute, its connections to the thickener, and its supports shall be designed in accordance with the requirements for structural steel in Section 05120 - Structural Steel and the load combinations provided herein.
      c. The hopper and chute shall be supported off of the elevated stainless steel channel on the plans. Supplier shall provide support brackets on the hopper or chute to facilitate mounting to the channel support. Under no circumstances shall the weight of the hopper, chute, and contents be transferred to the pump below. Reinforce all support brackets.
      d. Lateral design shall be in accordance with the specified load combinations.
      e. Load combinations: Design each structural member for the most critical load combination resulting from the following load combinations:
         1) Dead Load + Live Load (contents under extreme service conditions).
         2) Dead Load + Live Load (contents under normal service conditions) + Seismic Load.
         3) Dead Load + Seismic Load.
         4) Components shall be designed for additional load combinations per ASCE 7-16.
         5) Live load is nominally defined as the dynamic loads produced by the equipment during operation assuming either normal loading conditions or extreme service conditions such as high-high hopper and flocculation tank levels or as determined as most extreme by the equipment manufacturer.
      f. Construct the hopper and chute of Type 316/316L stainless steel plates welded and braced as required for rigidity. The stainless steel plates shall conform to the requirements of Section 05120 - Structural Steel.
      g. The hopper shall be fitted with doors to allow easy access for thickened sludge inspection and sampling. Hopper shall contain any fugitive spray and minimize mist emissions.

h. Provide the thickened sludge hopper with two 3-inch diameter welded lifting rings or removable lifting eye brackets fabricated from 1/2-inch thick (minimum) stainless steel bars. Hopper lifting rings shall be reinforced.
i. All materials used for fabrication shall conform to the structural and miscellaneous standards of the American Institute of Steel Construction.
j. Provide hopper and chute with both the interior and exterior surfaces of the hopper smooth, free from sharp edges, burrs, and projections, and with all welds ground smooth and all edges and corners rounded.
k. The hopper and chute, in its entirety, shall be provided by the Supplier.

2. Hopper requirements:
   a. The hopper shall extend down as a rectangular chute that transitions at its termination to a flanged rectangular connection that is fitted with a rectangular flexible coupling connected to the thickened sludge pump suction as indicated on the Drawings.
      1) The chute shall be sized to connect with the thickener manufacturer's hopper outlet and taper to connect to the thickened sludge pump. The overall height of the chute is approximately 98 inches, but it must be coordinated with the Contractor prior to fabrication. Thickened sludge pump open throat dimensions shall be as required by the pump manufacturer but are nominally a minimum of 1.36 feet, wide and 1.33 feet long with "wide" dimension corresponding to the width dimension of the thickener.
      2) Rectangular Flexible Coupling: Rotary drum thickener Supplier to provide flanged rectangular flexible coupling with Neoprene rubber and Type 316 stainless steel hardware manufactured by Mercer-Rubber Co. or equal.
         a) Materials of construction for flexible coupling shall be suitable for conditions experienced in this service.
         b) Coupling size is to match the pump opening. Chute to taper as needed to mate with coupling.
      3) Sludge Chute Bottom Flange: Coordinate with flexible coupling manufacturer and thickened sludge pump manufacturer.
   b. The minimum incline angle of any sloped section of the hopper shall be 60 degrees from the horizontal.
   c. Do not allow any part of the hopper to come in contact with the thickener drives or to interfere with the normal operation of the unit.
   d. Provide a 4-inch diameter flanged connection on rectangular chute as indicated on the Drawings for draining the hopper when the thickened sludge pump is not operating. Location on chute where flanged connection is located shall be reinforced.
   e. Proper mating/connection of the hopper, flanged flexible rectangular connection, and thickened sludge pump suction open throat shall be coordinated by the Contractor.
3. Hydrostatic level sensor and transmitter, as specified in Section 17100 - Control System Requirements, shall be provided by the Contractor for installation and level measurement in the sludge hopper.
   a. Thickener Supplier shall provide a 4-inch diameter flanged connection on rectangular chute for mounting of the hydrostatic level sensor. Flanged connection for sensor shall be located 6 inches above the termination of the chute. Location on chute where flanged connection is located shall be reinforced.

4. Float or capacitance type level switch for high-high level condition in sludge hopper shall be provided by the manufacturer as specified in Section 17100 - Control System Requirements.
    a. If float type switch is used, Thickener Supplier shall provide a Type 316 stainless steel bracket within the hopper, to accommodate switch mounting.
    b. If capacitance type switch is used, Thickener Supplier shall provide flanged connection, PVC flange and sleeve, spool piece and all necessary accessories to accommodate switch mounting.
    c. Location on hopper where bracket or flange connection is located shall be reinforced.
    d. Location and size of switch connection is not shown on drawings. Supplier to size and locate as appropriate for their system. Locate such that equipment is accessible, instrument can accurately sense level, and is not interfered with by dilution water.
5. Thickener Supplier shall provide flanged Type 316 stainless steel 6-inch odor control nozzle on hopper to allow withdrawal of foul air from the thickener. Contractor shall provide Type 316 stainless steel support brackets for 6-inch foul air duct along outside of hopper. Locations on hopper where odor control nozzle and support brackets are located shall be reinforced.
6. Dilution water piping is provided to each thickener hopper to dilute thickened sludge. Water supply will be 3W.
    a. Design and supply for Contractor-installation, a solenoid valve for each thickener:
        1) One-inch, 2-way solenoid valve to be connected to the dilution water pipe.
        2) The solenoid valves shall comply with Section 15117 - Specialty Valves and shall be connected to dissimilar piping with dielectric couplings especially designed for the prevention of chemical reactions between dissimilar metals, as specified in Section 15052 - Common Work Results for General Piping. The valve shall be shipped loose to prevent damage.
    b. Provide 1-inch connection for dilution water piping onto the hopper. The exact location of the connection shall be reinforced and determined by the manufacturer. Locate such that equipment is accessible, dilution water piping does not interfere with instruments connected to the hopper/chute, cover remains openable, and hopper (both upper and lower, if applicable) and chute remain dismantlable.

I. Drive units:
    1. All electrical work will be in accordance with Section 16100 - Electrical Requirements.
    2. The following drive units shall be supplied for each thickener:
        a. Main unit drum drive:
            1) Three-horsepower (maximum), 1,800 revolutions per minute, TEFC, 480-volt, 3-phase, 60-Hertz alternating current, premium high-efficiency motor with 1.0 service factor and conforming to Section 16100 - Electrical Requirements.
            2) The controller shall be a variable frequency drive (VFD) mounted in the thickener vendor control panel and shall comply with Section 16100 - Electrical Requirements.

b. Floc tank drive:
    1) Two-horsepower (maximum), 1,800 revolutions per minute, TEFC, 480-volt, 3-phase, 60-Hertz alternating current, premium high-efficiency motor with 1.0 service factor and conforming to Section 16100 - Electrical Requirements.
    2) The controller shall be a VFD mounted in the thickener vendor-control panel and shall comply with Section 16100 - Electrical Requirements.
c. Thickener booster pump drive (if required), floor mounted separately:
    1) Five horsepower (maximum), 3,500 revolutions per minute, TEFC, 480-volt, 3-phase, 60-hertz alternating current, premium high efficiency motor with 1.15 service factor and conforming to Section 16100 - Electrical Requirements.
    2) The FVNR starter shall be mounted in the thickener vendor control panel and shall comply with Section 16100 - Electrical Requirements.

3. All drive units shall communicate to the plant process control system (PCS) via conformant EtherNet/IP protocol. Gateway or protocol converters are not permitted.
4. Wire equipment statuses and alarms to drive units. Configure units to interlock operation when alarm condition occurs. Interlocks shall interrupt operation in Hand and Remote modes.
5. All motors shall be provided with temperature switches and motor winding heaters as specified in Section 16100 - Electrical Requirements.

J. Junction Boxes:
1. Thickener skid shall be equipped with junction box(es) where conduits and wiring for instruments and equipment on the skid are routed. Thickener manufacturers will route the conduit from the thickener equipment to the junction box(es). The contractor will connect the junction box to route signal and power conduits/wiring to other Contractor-provided equipment. The thickener manufacturer shall minimize the number of junction box(es) provided to provide a consolidated connection point(s) for the Contractor.

K. Vendor Control Panel:
1. All electrical work will be in accordance with Section 16100 - Electrical Requirements.
2. Provide one VCP for each thickener. The VCP shall be powered from a 480-volt, 20-amp, 3-phase, 60-hertz power supply.
    a. Rated to withstand the available fault current as indicated in the study provided by the Contractor in accordance with Section 16100 - Electrical Requirements.
3. The VCP shall have the following major components:
    a. Rockwell PLC CompactLogix has dedicated EtherNet/IP communications for the owner's control system.
        1) All ethernet connections internal to the VCP shall be segregated so they aren't visible to the owner's control system.
    b. Operator interface:
        1) Ethernet/IP communications.
        2) Eight-inch touch color display.
    c. Provide the following pilot devices on the VCP door:
        1) Control Power On light.

2) Control Power On/Off selector.
3) E-Stop pushbutton.
4) Reset pushbutton.

4. NEMA Type 4X 316 stainless steel enclosure.
5. Install each thickener with a safety shutoff switch complete with mounting brackets, eye bolts, and pull cord extending along the entire length of the RDT. Install dual systems accessible from both sides.
   a. Mount cord supported by eye bolts on approximately 10 feet centers. The switch shall be provided with 2 single pole double throw micro-switches with external signal light.
   b. The switch shall be provided in a NEMA 4X aluminum housing with an epoxy coating.
   c. The actuating arm shall be a red epoxy-coated steel handle with a stainless steel shaft.
   d. The switch shall be rated for 120 VAC. The switch, once tripped, shall require a manual reset.

L. Thickener E-Stop Panel:
   1. A local control panel must be provided and installed by the Contractor for each thickener. The control panel will include:
      a. E-stop mushroom pushbutton.
      b. NEMA Type 4X enclosure.

2.05 CONTROLS

A. Automatic control of the thickener flocculator, rotary drum, water booster pump is performed by the Vendor PLC.

B. Flocculator control:
   1. There is a Hand-Off-Remote software selector and speed selector at the LOI.
      a. With the selector in Hand, the flocculator starts. Speed is adjusted through the speed selector.
      b. With the selector in Off, the flocculator is stopped and prevented from operating.
      c. With the selector in Remote, the flocculator is controlled by the Thickener PLC.
      d. In any mode, the flocculator will stop when a high temperature or any E-STOP alarm is detected. The alarm must be reset at the VCP before operation can resume.

C. Rotary drum control:
   1. There is a Hand-Off-Remote software selector and speed selector at the LOI.
      a. With the selector in Hand, the rotary drum starts. Speed is adjusted through the speed selector.
      b. With the selector in Off, the rotary drum is stopped and prevented from operating.
      c. With the selector in Remote, the rotary drum is controlled by the Vendor PLC.
      d. In any mode, the rotary drum will stop when a high temperature, zero-speed, or any E-STOP alarm is detected. The alarm must be reset at the VCP before operation can resume.

D. Booster pump:
   1. There is 1 set of controls for the booster pump, located at the local control panel (provided by Contractor). Information is provided here for coordination purposes with Supplier.
   2. Local Control Panel (by Contractor):
      a. As described in Specification Section 17101B - Specific Control Strategies - Thickening:
         1) HAND/OFF/REMOTE selector switch.
         2) RESET Pushbutton.
         3) Common alarm indicator.
   3. In any mode, the pump will stop when a high temperature high discharge pressure, or any E-Stop alarm is detected. The alarm must be reset at the VCP or at the LCP before operation can resume. Any of these signals should initiate the LCP "Common Alarm" indicator.

E. Provide control and time delay relays in the VCP to alarm on high motor temperatures, high discharge pressure, zero speed, and low wash water alarms. These alarms will remain latched until the Reset pushbutton is pressed at the VCP.

F. Inhibit the low wash water pressure switch alarm when the wash water booster pump is not running.

G. Each flocculation tank is equipped with a level switch (by Thickener manufacturer). The level in each flocculation tank is monitored continuously, even if the associated thickener is not running. If the level reaches a high level (F-12), an alarm shall be generated by Thickener PLC and sent to the PCS.

H. Provide an Ethernet switch to connect all ethernet-enabled drives/devices inside the VCP together, and enable the Plant PCS to monitor and control these drives/devices.

I. The vendor shall integrate the E-Stop local control panel and Booster Pump local control panel into VCP's wiring schematics to form one complete and functional control system.

J. At a minimum, VCP functions shall provide for selection of the follow modes of operation for the respective thickener:
   1. Hand/Off/Remote Mode.
   2. Thickener Auto Start, Controlled Shutdown, No Wash Shutdown, and Critical Shutdown.

K. The VCP shall provide the following signals to the owners control system PCS via Ethernet data network:
   1. Thickener Mode: Hand/Off/Remote.
   2. Thickener Status: Ready, Running, Washdown, NoWash Shutdown, Off, Remote Shutdown-Critical.
   3. Flocculator in Remote.
   4. Flocculator Failed.
   5. Flocculator Running.
   6. Flocculator speed.
   7. Rotary Drum in Remote.

8. Rotary Drum Failed.
9. Rotary Drum Running.
10. Rotary Drum Speed.
11. Rotary Drum No/Low Speed.
12. Booster Pump in Remote.
13. Booster Pump Failed.
14. Booster Pump Running.
15. Spray Water Low Pressure.
16. Pullcord Activated.
17. E-Stop pushbutton activated.
18. Network Link status.
19. UPS fault.
20. Thickener Feed Sludge start/stop request.
21. Thickener Polymer start/stop request.
22. Flocculator tank high level.
23. All alarms and other data recommended by the manufacturer for safe operation.

L. The VCP shall accept the following inputs from the PCS via Ethernet data network:
1. Auxiliary equipment ready (Thickened Sludge Pump, Polymer Blender, Inlet and Drain Valves, Booster Pumps).
2. Thickener Feed Flow Rate (gpm and lb/hr).
3. Polymer System: Running.
4. Polymer System: Failure.
5. Polymer Dose Setpoint (lb active/dry ton).
6. Polymer Pump Speed (as percent).
7. Polymer Solution Flow Rate (gpm).
8. Sludge Feed Pump: Running.
9. Inlet Valve position (opened/closed).
10. Drain Valve position (opened/closed).
11. Hopper level float (high high level) triggered.
12. Hopper level (ft).
13. Thickener Feed Low Flow Alarm.
14. Thickener System Start.
15. Thickener System Shutdown.
16. Thickener System E-Stop (shutdown).
17. Thickened Sludge Low Flow Alarm.
18. Thickened Sludge Low Low Flow Alarm.
19. Network time synchronization.

M. At a minimum, the following points shall be displayed at the VCP LOI:
1. Thickener Status: Hand/Off/Remote, Ready, Running, Washdown, NoWash Shutdown, Off, Shutdown-Critical.
2. Flocculator Status: Hand/Off/Remote.
3. Booster Pump Status: Hand/Off/Remote.
4. Drum Motor Speed (%): Setpoint (F-1) and Actual.
5. Drum Drive Jog (Hand operation only).
6. Flocculator Motor Speed (%): Setpoint and Actual.
7. Inlet Valve Position (Opened/Closed).
8. Spray Water Valve Position (Opened/Closed).
9. Drain Valve Position (Opened/Closed).

10. Thickener Feed Flow Setpoint (gpm).
11. Thickener Feed Flow Rate (gpm and lb/hr).
12. Polymer Blending Unit: Running.
13. Polymer Dose Setpoint (lb active/dry ton).
14. Polymer Pump Speed (as percent).
15. Polymer Solution (as Dilution Water Flow) Flow Rate (gpm).
16. Thickened Sludge Pumps: Running.
17. Drum Motor Runtimes (hrs).
18. Flocculator Motor Runtimes (hrs).
19. Booster Pump Motor Runtimes (hrs).
20. Drum Motor Amperage (amps).
21. Flocculator Motor Amperage (amps).
22. All alarms.
23. Specific shutdown conditions causing thickener system to shut down and result in Failed status.
24. All other data recommended by the manufacturer for safe operation.

N. At a minimum, the following points shall be adjustable at the VCP LOI:
1. Thickener Status/Mode: Hand/Off/Remote, Washdown, No Wash Shutdown, Shutdown Critical.
2. Flocculator Status: Hand/Off/Remote.
3. Booster Pump Status: Hand/Off/Remote.
4. Drum Motor Speed (%): Setpoint (F-1).
5. Drum Drive Jog (Hand operation only).
6. Washdown Drum Speed (F-2).
7. Flocculator Motor Speed (%): Setpoint (F-3).
8. All alarm setpoints.
9. Specific shutdown conditions causing thickener system to shut down and result in Failed status.
10. All other data recommended by the manufacturer for safe operation.

O. Control System Operation:
1. Hand/Off/Remote control shall be provided:
    a. Under Hand:
        1) When the thickener Hand/Off/Remote selector is in the Hand position, and all ancillary systems are in remote and ready, the operator shall be able to Auto Start / Controlled Shutdown / No Wash Shutdown / Critical Shutdown the thickener at the LOI.
    b. Under Remote:
        1) When the Hand/Off/Remote selector is in the Remote position, the thickener shall receive Auto Start / Controlled Shutdown / No Wash Shutdown / Critical Shutdown commands from PCS.

P. Thickener Auto Start sequence:
1. A startup sequence will be initiated when the operator presses the "Auto Start" key at the VCP LOI or the PCS workstation. Upon initiation of "Auto Start", the following sequence will occur:
    a. PCS confirms all auxiliary systems are in Remote.
    b. The PCS will select which thickeners will be running.
    c. The PCS will request a Thickener to start.

d. Thickener PLC shall start up the thickener system and change status to "START UP".
e. PCS shall close the associated Drain Valve.
f. PCS shall start and operate the thickened sludge pump as described in Specification Section 17101B - Specific Control Strategies - Thickening.
g. Thickener PLC starts the Spray Water System (including Booster Pumps, if applicable) and energizes the spray water solenoid valve for setpoint time delay (F-5) before stopping.
h. Thickener PLC starts drum unit drive to setpoint speed (F-1).
i. Thickener PLC starts the flocculator to setpoint speed (F-3).
j. Thickener PLC sends "Sludge Feed Request" to PCS.
k. PCS opens associated Inlet Valve.
l. PCS starts thickener feed pump(s) and sends "Sludge Feed Pump Running" signal to Thickener PLC.
m. PCS opens associated thickener flow control valve to 100 percent for set time period (F-4; by others) to allow for flushing.
n. Thickener PLC sends "polymer request" to PCS.
o. PCS starts polymer system and sends "Polymer Running" signal to Thickener PLC.
p. Thickener PLC sends status change of "RUNNING" to PCS.

Q. Thickener Controlled Shutdown sequence:
1. A Controlled Shutdown will be initiated when the operator presses the "Controlled Shutdown" key at the LOI or PCS workstation. This sequence shall also occur at receipt of the following alarms:
a. Flocculator drive fail.
b. Polymer system fail.
c. Thickener Feed Low Flow alarm.
d. All other alarms or statuses as recommended by the thickener manufacturer.
2. Upon initiation of "Controlled Shutdown", the following sequence will occur:
a. Thickener PLC shall send a shutdown signal to PCS and change status to "WASHDOWN".
b. Thickener PLC removes "Polymer Start Request" signal.
c. PCS will stop associated polymer system and remove running signal for polymer.
d. PCS shall operate and eventually shutdown the thickened sludge pump as described in Specification Section 17101B - Specific Control Strategies - Thickening.
e. Sludge will continue to flow to the thickener to flush out the flocculation tank and the drum. Unthickened sludge will flow out of the thickener to the filtrate line.
f. After a time delay (F-8), Thickener PLC removes "Sludge Feed request" signal to PCS.
g. PCS will close the associated Inlet Valve.
h. PCS will stop associated blended sludge pump and remove sludge pump running signal (if applicable).
i. Thickener PLC sends "Tank Drain request" signal to PCS.
j. PCS opens associated drain valve.
k. After a time delay (F-9), Thickener PLC removes "Tank Drain request" signal to PCS.

l. PCS closes associated drain valve.
m. Thickener PLC shall stop the flocculator.
n. Thickener PLC energizes Spray Water System (including Booster Pumps if applicable).
o. Thickener continues running to clear unit of remaining sludge for time delay (F-10).
p. Thickener PLC stops Spray Water System (including Booster Pumps if applicable).
q. Upon completion of shutdown, the Thickener PLC shall send "OFF" status to PCS.

R. Thickener No Wash Shutdown sequence:
1. A No Wash Shutdown will be initiated when the operator presses the "No Wash Shutdown" key at the LOI, or PCS workstation. This sequence shall also occur at receipt of the following alarms:
a. All other alarms or statuses as recommended by the thickener manufacturer.
2. Upon initiation of "NO WASH SHUTDOWN", the following sequence will occur:
a. Thickener PLC shall send a shutdown signal to PCS and change status to "NO WASH STOP".
b. Thickener PLC removes "Polymer Start Request" signal.
c. PCS will stop associated polymer system and remove running signal for polymer.
d. PCS shall operate and eventually shutdown the Thickened Sludge Pump as described in Specification Section 17101B - Specific Control Strategies - Thickening.
e. Thickener PLC removes "Sludge Feed request" signal to PCS.
f. PCS will close the associated Inlet Valve.
g. PCS will stop associated thickener feed pump and remove sludge pump running signal (if applicable).
h. Thickener PLC shall stop the drum.
i. Thickener PLC shall stop the flocculator.
j. Thickener PLC shall stop the Spray Water System (including Booster Pumps if applicable).
k. Thickener PLC sends "Tank Drain request" signal to PCS.
l. PCS opens associated drain valve.
m. After a time delay (F-11), Thickener PLC removes "Tank Drain request" signal to PCS.
n. PCS closes associated drain valve.
o. Upon completion of shutdown, the Thickener PLC shall send "OFF" status to PCS.

S. Thickener Critical Shutdown sequence:
1. A Critical Shutdown will be initiated when the operator presses the "E-Stop Push Button" pushbutton at the remote VCP, at the LOI, or PCS workstation. This sequence shall also occur at receipt of the following alarms:
a. E-Stop activation.
b. Rotary Drum drive fail.
c. Rotary Drum zero speed.
d. Booster pump failure.
e. Spray wash water low pressure (F-18).

f. Spray wash water high pressure (F-19).
g. Hopper high level.
h. Hopper high high level.
i. Thickener feed low flow alarm.
j. UPS fault.
k. 24VDC power supply fault.
l. Thickened sludge pump "Ready" signal removed for the following reasons:
    1) Thickened Sludge Pump high high discharge pressure.
    2) Thickened Sludge Pump low discharge pressure.
    3) Thickened sludge pump failure.
m. Thickened sludge low flow alarm.
n. Thickened Sludge low low flow alarm.
o. Flocculation Tank High Level (Float; F-12).
p. All other alarms or statuses as recommended by the thickener manufacturer.

2. Upon initiation of "Critical Shutdown", the following sequence will occur concurrently:
    a. Thickener PLC shall send a shutdown signal to PCS and change status to "SHUTDOWN CRITICAL"
    b. Thickener PLC removes "Polymer Start Request" signal.
    c. PCS will stop associated polymer system and remove running signal for polymer.
    d. PCS shall stop the Thickened Sludge Pump as described in Specification Section 17101B - Specific Control Strategies - Thickening.
    e. Thickener PLC removes "Sludge Feed request" signal to PCS.
    f. PCS will close the associated Inlet Valve.
    g. PCS will stop associated thickener feed pump and remove sludge pump running signal (if applicable).
    h. Thickener PLC shall stop the drum.
    i. Thickener PLC shall stop the flocculator.
    j. Thickener PLC shall stop the Spray Water System (including Booster Pumps if applicable).
    k. Upon completion of shutdown, the Thickener PLC shall send "OFF" status to PCS.

T. Adjustable Setpoints Table:
1. Abbreviations:
    a. TD = Time Delay.
    b. SP = Setpoint.
    c. PT = Proving Time.
    d. OA = Operator Adjustable from PLC/SCADA screen.
    e. HC = Hardcoded.
    f. HW = Hardwired.
2. Comments:
    a. Common = One common setpoint value for all similar equipment.
    b. Separate = Separate unique setpoint values for each similar equipment.
    c. Unique = Only one.

3. Adjustable Setpoints Table:

No.	Setpoint Description	Range	Unit	Initial Setting	Operator Adjustable or Hard Coded	Comments
Rotary Drum Thickeners						
F-1	SP - Thickening Cycle Drum Speed (S1) (1) (2)	TBD	Rpm	TBD	OA	Common
F-2	SP – Washdown Thickening Cycle Drum Speed (S2) (1) (2)	TBD	Rpm	TBD	OA	Common
F-3	SP - Flocculator Speed (S3) (1) (2)	TBD	Rpm	TBD	OA	Common
F-5	TD – Water Flushing (Thickening Cycle Sequence)	0-600	Sec	300	OA	Common
F-8	TD – Feed Stop (Wash Down Sequence)	10-30	Min	15	OA	Common
F-9	TD – Drain Stop (Wash Down Sequence)	0-20	Min	10	OA	Common
F-10	TD – Spray Water Stop (Wash Down Sequence)	0-60	Min	30	OA	Common
F-11	TD – Drain Stop (Shut Down/Bypass Sequence)	0-60	Min	10	OA	Common
F-12	SP – High Level in Flocc Tank (1) (2)	TBD	FT	TBD	OA	Common
F-18	SP – Low Spray water pressure (1) (2)	TBD	Psi	TBD	OA	Common
F-19	SP – High Spray Water Pressure (1) (2)	0-160	Psi	TBD	OA	Common

Notes:
1) Coordinate/confirm with selected manufacturer.
2) Initial setting to be determined during commissioning.

2.06 FACTORY FINISHES

A. Coating shall comply with requirements for EPU-M-1 coatings in Section 09960 - High-Performance Coatings.

B. Coat metal surfaces, other than stainless steel, with coating system consisting of 2-part epoxy primer, 2 coats of high solids epoxy, and 1 coat of polyurethane top coat with minimum total dry film thickness of 12 mils.

2.07 SOURCE TESTING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, Section 15958 - Mechanical Equipment Testing, and this Section.

B. Test components, devices, and equipment/system for proper performance at point of manufacture or assembly.
   1. Witnessed.
   2. Test results: Prepare and submit test results with collected data attached.

C. Provide Supplier's Certificate of Source Testing.

PART 3 EXECUTION

3.01 INSTALLATION

A. The rotary drum thickeners, associated equipment, and appurtenances shall be installed by the Contractor under the direction of the Supplier in strict conformance with the Supplier's installation instructions and with a favorable review of shop drawings.

3.02 FIELD TESTING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, Section 15958 - Mechanical Equipment Testing, and this Section.

B. Installation testing:
   1. Contractor shall perform subsystem testing according to approved Subsystem Testing Plans.
   2. Contractor shall obtain and submit the Supplier's Certificate of Installation Compliance for all equipment.
   3. Supplier's Certificate of Installation Compliance certifies the equipment meets the following requirements:
      a. Has been properly installed, adjusted, aligned, and lubricated.
      b. Electrical/instrumentation and mechanical connections meet quality and safety standards.
      c. All applicable safety equipment has been properly installed.
      d. Is free of any stresses imposed by connecting piping or anchor bolts.
      e. Is able to be operated as necessary for Functional Testing.

C. Functional tests:
   1. Functional testing of the entire rotary drum thickening system is to be conducted following inspection, installation, and cleaning of the rotary drum thickeners and all equipment within associated subsystems.
   2. Testing to be conducted by the Contractor and the Supplier's representatives in the presence of the Engineer to demonstrate that equipment is capable of performing its specified function in a satisfactory manner without mechanical or electrical defects, binding, or operational difficulties.

3. Contractor shall perform functional testing as specified herein, in Sections 15958 - Mechanical Equipment Testing and 01660 - Equipment and System Performance and Operational Testing.
    a. Prerequisite: Successful completion with Engineer approval of Installation Testing.
    b. Target minimum Functional Test duration: 8 hours.
    c. Perform Functional Testing to demonstrate that the component equipment functions as an entire system in accordance with the design requirements.
    d. Perform Functional Testing to demonstrate that the unit process has operated in a manner necessary to demonstrate equipment/system functions manually in local, manually in remote (or remote manual), and automatically in remote (in remote auto).
    e. Perform testing with Contractor-provided water.
    f. Repair or replace parts that operate improperly and retest.
    g. Make all final adjustments necessary to place equipment in satisfactory working order.
    h. Test and calibrate all controls, switches, automatic valves, and other instrumentation and control equipment associated with the rotary drum thickening system specified herein, in accordance with the Supplier's printed instruction over the full operating range of the equipment.
    i. Excessive vibration or noise shall be corrected, as specified in Section 15050 - Common Work Results for Mechanical Equipment.
    j. Submit testing reports to the Owner and Engineer for approval of Functional Testing reports.
    k. Upon successful completion of functional testing, Contractor shall obtain and submit completed Manufacturer's Certificate of Functionality for all equipment.
        1) Manufacturer's Certificate of Functionality certifies the equipment/system meets the following requirements:
            a) Is suitable for satisfactory full-time operation under full-load conditions and ready for Process Optimization and Performance Testing.
            b) Operates within the allowable limits for vibration and noise.
            c) All connections, including connections for sludge conditioning system, are watertight.
            d) Electrical and instrumentation requirements:
                (1) Electrical equipment, instrumentation, and control panels are properly installed, calibrated, and functioning.
                (2) Electrical Installation Testing is complete, and test results have been approved by the Engineer.
                    (a) Noted deficiencies have been corrected.
                    (b) Relays, circuit breakers, and other protective devices are set.
                (3) Control logic for start-up, shutdown, sequencing, interlocks, control, and emergency shutdown has been tested and is properly functioning.
                (4) Motor control is calibrated and tested.

D. Process optimization:
    1. A sludge evaluation shall be performed by the Supplier. Three weeks prior to optimization process, the Owner will send to the Supplier a feed sludge

sample. The Supplier shall perform optimization tests for the polymer and inform the Contractor of the polymer selected for optimization.
    a. The Contractor shall notify the Owner 2 weeks prior to the required sludge sample shipping date.
2. Supplier to optimize process including, but not limited to, polymer dosage, diluted polymer solution concentration, location of polymer injection, unit drive speed, and floc drive speed.
3. Optimization of process shall be completed prior to performance test.
4. Contractor shall supply two 300-gallon (nominal) polymer totes of the selected polymer required for optimization and performance testing.
5. Contractor shall obtain and submit results of Supplier's process optimization for approval by Owner.

E. Performance test:
1. Upon completion of process optimization and approval of results, conduct performance tests for each thickener comprising the thickener system to verify that each unit meets the minimum performance requirements specified herein.
    a. Performance testing shall be conducted for one rotary drum thickening system train at a time.
    b. A rotary drum thickening system train includes the thickener and its associated feed pump(s), polymer blending unit, wash water pump, spray water valve, thickened sludge pump, control panel, and system instruments.
2. Supplier shall submit for approval written test procedures including sample collection methods and location, sampling frequency, required analyses, all necessary calculations, and data tracking spreadsheet at least 30 days prior to start of testing.
3. Supplier shall coordinate with Contractor to identify a state-certified laboratory to conduct all necessary analyses. The laboratory shall be identified within the written test procedures submitted by the Supplier. Contractor shall be responsible for procuring analytical services from the selected laboratory.
4. Supplier shall recommend optimal polymer and required polymer concentration based on process optimization.
5. The contractor shall provide the recommended polymer from process optimization.
6. Owner will provide 3W, power, and feed sludge.
7. Equipment and systems installed under this project may be used by the Supplier during the performance test.
8. Performance test for each rotary drum thickening system train shall be 2 consecutive days in duration, 8 hours of operation one day and 8 hours of operation the second day. Operating hours shall represent steady-state conditions and shall exclude startup and shutdown periods.
9. The Supplier shall operate the equipment throughout the duration of the test, obtain the samples in the presence of the Owner or Owner's representative, store the samples per Standard Methods, and document the data needed to confirm the performance of the thickener unit.
10. Contractor shall provide sampling containers and coordinate lab analysis on behalf of the thickener manufacturer.
11. Contractor shall be responsible for logistics of sample transport to laboratory and ensuring all testing is conducted and results are provided in a timely manner.

12. One sample of the following flow streams shall be obtained for each 1/2 hour of operation during the performance test:
    a. Feed sludge.
    b. Filtrate.
    c. Thickened sludge.
13. The samples shall be tested for the following parameters per Standard Methods (latest edition) and results shall be included in the test report:
    a. Feed sludge - Total and volatile solids concentration.
    b. Filtrate - Total suspended solids concentration.
    c. Thickened sludge - Total and volatile solids concentration.
14. The following process data shall be recorded, calculated as necessary, and documented each 1/2 hour of the test and included in the test report:
    a. Feed sludge flow rate.
    b. Feed sludge concentration based on inline sensor readings.
    c. Feed sludge mass flow based on feed sludge flow rate and feed sludge concentration from inline sensor readings.
    d. Neat polymer feed rate, dilution water flow rate, dilute polymer solution concentration, and dilute polymer solution feed rate.
    e. Setpoint polymer dosage (in pounds active polymer per dry ton of thickener feed).
    f. Measured polymer dosage (in pounds active polymer per dry ton of thickener feed) based on polymer characteristics, neat polymer feed rate, sludge flow rate and feed sludge concentration from inline sensor readings.
    g. Thickened sludge flow.
    h. Alarm conditions.
    i. Equipment problems.
    j. Drum drive speed.
    k. Floc drive speed.
15. The following parameters shall be calculated and reported in the test report for each 1/2 hour of the test after samples have been analyzed:
    a. Feed sludge mass flow based on feed sludge flow rate and analytical results for feed sludge total solids concentration.
    b. Actual polymer dosage (in pounds active polymer per dry ton of thickener feed) based on based on polymer characteristics, neat polymer feed rate, feed sludge flow rate and analytical results for total solids concentration.
    c. Thickened sludge mass flow based on thickened sludge flow rate and analytical results for thickened sludge total solids concentration.
    d. Percent capture.
16. Performance test results:
    a. Average values for thickened sludge concentration from analytical results, polymer dose, and percent capture over the 16-hour test period shall be determined for each separate thickener.
    b. The performance of each thickener will be deemed acceptable if the average values for each operating parameter meet or exceed the specified minimum value with an upper confidence limit of 95 percent.
    c. In the case of unacceptable performance, the Supplier shall then have 30 days in which to perform, at its sole expense, any supplemental testing, equipment adjustments, changes, or additions and request an additional retest of the unacceptable system. If the modified equipment

then does not meet the minimum performance requirements of this Specification, a payment retention shall be imposed as damages.
   d. Until all rotary drum thickeners supplied successfully complete performance testing, 5-percent of the thickener price will be retained by the Owner for each thickener that has not passed performance testing.
17. Provide certified Performance Test Report for review and approval by Owner, in accordance with Section 01660 - Equipment and System Performance and Operational Testing.

3.03 SUPPLIER'S FIELD SERVICES

A. Contractor shall coordinate field service work with the Supplier, Owner, and Engineer prior to initiating such work.

B. Supplier shall perform the following services as described below and as specified in Section 01660 - Equipment and System Performance and Operational Testing. The specified durations are the minimum required time on the jobsite. Additional services and/or longer durations shall be provided as needed at no cost to Owner to meet the required quality of work.
   1. Installation Assistance: As required.
   2. Installation Inspection: 1 workday (8 hours).
   3. Functional Testing: 2 workdays (16 hours).
   4. Process Optimization: 1 workday (8 hours).
   5. Performance Testing: 20 hours per thickener (60 hours total).
   6. Training per Section 01660 - Equipment and System Performance and Operational Testing and as described below: 16 hours.
      a. Operations Training: 8 hours, 2 sessions.
      b. Mechanical Maintenance Training: 4 hours, 1 session.
      c. Combined Electrical and I&C Maintenance: 4 hours, 1 session.
   7. Final Acceptance and Checkout: 1 workday (8 hours).
   8. Post Start-up Field Visit: 1 workday (8 hours).

C. Additional training requirements:
   1. Instructor qualifications:
      a. Provide instructors completely knowledgeable in the equipment/system for which they are training.
      b. Provide instructors experienced in conducting classes.
      c. Provide instructor's technical preparation and instructional technology skills and experience.
      d. Sales representatives are not qualified instructors unless they possess the detailed operating and maintenance knowledge required for proper class instruction.
      e. If, in the opinion of the Owner, an appropriately knowledgeable person did not provide the scheduled training, such training shall be rescheduled and repeated with a suitable instructor.
   2. The Supplier shall submit a course outline plan 3 months before training starts, with proposed class material and class schedule to the Owner for approval. Training will begin only if the class material and class schedule have been reviewed and approved by the Owner.
   3. Training will begin only after at least 1 thickener has successfully passed all required functional and performance tests.

4. Subjects of instruction shall include the following:
    a. Start-up procedures.
    b. Shutdown procedures.
    c. Troubleshooting.
    d. Selection of proper polymer types and dosages.
    e. Operating adjustments for performance optimization.
    f. Preventative maintenance.
    g. Removal and replacement of thickener components.
    h. Maintenance procedures.
    i. Emergency procedures.
    j. Record keeping.
    k. Mechanical unit function and description.
    l. Variable frequency drives.
    m. System controls.
5. During training, conduct hands-on instruction according to the following descriptions:
    a. Present hands-on demonstrations of at least the following tasks:
        1) Proper start-up, shutdown, and normal and alternative operating strategies.
        2) Common corrective maintenance repairs for each group.
        3) Recommended procedures to check/test equipment/system following a corrective maintenance repair.
        4) Preventative maintenance points.
6. Provide operation and maintenance instruction lesson plans including mechanical, instrumentation, and electrical aspects:
    a. Equipment operation:
        1) Describe equipment's operating (process) function and system theory.
        2) Describe equipment's fundamental operating principles and dynamics.
        3) Identify equipment's mechanical, electrical, and electronic components and features.
        4) Identify support equipment associated with the operation of subject equipment.
        5) Detail the relationship of each piece of equipment or component to the subsystems, systems, and process.
        6) Cite hazards associated with the operations, exposure to chemicals associated with the component, or the waste stream handled by the component.
        7) Specify appropriate safety precautions, equipment, and procedures to eliminate, reduce, or overcome hazards.
    b. Detailed component description:
        1) Define Preventative Maintenance (PM) inspection procedures required on equipment in operation, spot potential trouble symptoms (anticipate breakdowns), and forecast maintenance requirements (predictive maintenance).
        2) Review preventive maintenance frequency and task analysis table.
        3) Identify each component function and describe in detail.
        4) Where applicable, group relative components into subsystems.
        5) Identify and describe in detail equipment safety features, permissive and controls interlocks.

7. Classroom documentation:
    a. Trainees will keep training materials and documentation after the session.
    b. Operations and maintenance manuals, as specified herein:
        1) Provide the quantity final Engineer-approved operations and maintenance manuals as specified in Section 01670 - Operations, Maintenance, and Training Requirements for use during the classroom instruction.
        2) Owner reserves the right to delay training for a particular equipment item if the operations and maintenance manuals for that equipment are incomplete, inaccurate, or otherwise unsuitable for use by the Owner's staff.
        3) No contract extensions or extra costs will be allowed for training delays due to operations and maintenance manual submittal delays.
    c. Provide supplemental documentation handouts to support instruction.

END OF SECTION

SECTION 11358

CENTRIFUGE DEWATERING EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Sludge dewatering centrifuge systems complete with auxiliary equipment, control panels, remote-mounted variable frequency drive(s), hydraulic back drive (as required) and appurtenances.

B. The Contractor shall assign to the Centrifuge Manufacturer full responsibility for the furnishing functional dewatering centrifuge systems as defined herein.
   1. The Centrifuge Manufacturer shall coordinate the design, assembly, and testing of the dewatering centrifuge systems as specified herein.

C. Each Centrifuge system shall consist at minimum of the following:
   1. Centrifuge.
   2. Centrifuge Control Panel.
   3. Centrifuge Starter Panel containing VFD Drive (may also be combined with Centrifuge Control Panel as a NEMA 4X 316 SST rated control panel).
   4. Centrifuge E-Stop Panel.
      a. By Contractor.
   5. Centrifuge Equipment Motor and Hydraulic Backdrive.
   6. Controls and monitoring of Centrifuge to provide independent operation and monitoring.
   7. Diverter gate.
   8. Dewatered sludge and centrate chutes.

D. The Contractor shall provide 1 complete dewatering centrifuge system and all equipment and facilities ancillary to the centrifuge process and required for the dewatering centrifuge systems to be fully functional either independently or with the existing dewatering centrifuge system. 1 or 2 centrifuges will run at a time, with the remaining centrifuges as a standby.

E. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

F. Tag numbers:
   1. Centrifuge No. 3: CENT-07-003.
   2. Diverter Gate No. 3: DEW-DG-07-003.

1.02 REFERENCES

A. American Bearing Manufacturers Association (ABMA):
   1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
   2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

B. American Society for Testing and Materials (ASTM):
   1. A 167 - Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip.
   2. A 276 - Standard Specification for Stainless Steel Bars and Shapes.
   3. A 380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
   4. A 488 - Standard Practice for Steel Casting, Welding, Qualifications of Procedures and Personnel.
   5. A 995 - Specification for Steel Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts.
   6. G 65 - Procedure A - Dry Sand/Rubber Wheel Test.

C. National Electrical Manufacturer's Association (NEMA):
   1. RN-1 - Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Steel Conduit.

D. Underwriters Laboratories (UL):
   1. UL 6 - Standard for Electrical Rigid Metal Conduit - Steel.
   2. UL 360 - Standard for Liquid-Tight Flexible Steel Conduit.

1.03 DEFINITIONS

A. Centrifuge System:
   1. Each centrifuge shall be a complete dewatering centrifuge system that includes the centrifuge bowl, scroll conveyor, main drive motor, backdrive system, gearbox/torque reducer, lubrication system, diverter gate, bearings, seals, feed tube, solids and centrate discharge chutes, auxiliary equipment, control panels, variable frequency drives, control and monitoring instrumentation, and other necessary appurtenances.

B. Substantial completion for each centrifuge will be upon beneficial use by Owner of that centrifuge as requested in writing by Supplier and confirmed by the Owner.

C. Final completion of the centrifuges shall be defined as resolution of all punchlist items.

D. Percent solids capture defined and calculated as follows:

$$R = \frac{C_k(C_s - T_c)}{C_s(C_k - T_c)} \times 100$$

Where:

R = Percent Solids Capture

C_k = Concentration of Dewatered Cake in percent Dry Solids

C_s = Concentration of Feed Sludge in percent Dry Solids

T_c = Concentration of Centrate suspended solids in percent Dry Solids

E. Bowl Diameter: Internal diameter of cylindrical section of centrifuge bowl.

F. G-Volume Defined and Calculated as Follows:

$$G\text{-Volume} = kN^2D_bL(D_b^2 - D_d^2)$$

Where:

k = 4.83 x 10-8

N = 3,600 rpm maximum (see item 2 below)

D_b = bowl diameter, inches

L = bowl cylindrical length, inches

D_d = solids discharge diameter, inches

1. Definitions of G-Volume other than that specified and other methods of calculation will not be accepted.
2. G-Volume shall be calculated with an operating bowl speed of 3,600 rpm or the manufacturer maximum recommended operating speed, whichever is less.

G. Centrifuge Starter Panel (CSP): Consisting of variable frequency drives for main drive and backdrive motors, associated VFD keypads, pilot devices and all control wiring/interfaces for major power components associated with centrifuge system.

H. Centrifuge Control Panel (CCP): Consisting of programmable logic controller, uninterruptible power supply, local operator interface, and all control wiring/interfaces for major control components associated with centrifuge system.

I. LCP Centrifuge E-Stop Panel: Field mounted E-stop panel. Hydraulic backdrive shall also be shut down when the E-stop button is pressed.

J. PCS: Plant (SCADA) control system.

1.04 DESIGN AND PERFORMANCE CRITERIA

A. Centrifuges:
1. High speed, horizontal, cylindrical-conical, solid bowl, counter-current, scroll type designed for continuous operation.
2. Capable of performing in accordance with the requirements set forth in these specifications.
3. Designed, fabricated, and assembled in accordance with the best engineering and shop practices such that the maximum design operating speed is not less than 3,000 multiples of acceleration due to gravity (Gs) at the bowl wall.
4. Modified from standard equipment to meet all requirements in this Section.

B. System Requirements: Provide solid bowl, horizontal, continuous feed, counter-current, scroll-type centrifuge equipment for dewatering anaerobically digested primary and waste activated sludge from a municipal wastewater treatment facility.
1. Centrifuge Manufacturer shall provide main drive motor, backdrive system, gear reducer, scroll conveyor, lubrication system, bearings, seals, feed tube, diverter gate, and appurtenances for each centrifuge.

2. Centrifuge Manufacturer shall provide motor starters, separate starter panels with a hydraulic-controlled scroll drive), and a separate control panel with programmable logic controller and LOI for each centrifuge.
3. Centrifuge Manufacturer shall provide a control system as described herein to monitor and control the operation of each centrifuge system and related equipment.
4. Centrifuge Manufacturer shall provide all motors, and all motors shall comply with Section 16100 - Electrical Requirements.

C. Operating Conditions:
1. Sludge type: Municipal anaerobically digested blend of primary and waste activated sludge.
2. Maximum percentage of digester feed solids from thickened waste activated sludge: 66 percent by mass
3. Operating ranges for anaerobically digested sludge fed to each centrifuge:

Condition(1)	Range of Percent Total Solids by Mass(2)	Range of Hydraulic Loading per Centrifuge, gpm	Range of Solids Loading per Centrifuge, dry lb/hr
Minimum	2.0	55	610
Maximum	3.0	110	1,220

Note:
(1) Conditions listed may not occur concurrently and are meant to represent the overall range of feed characteristics for feed to each centrifuge.
(2) Range is anticipated and shall be verified after RDT is commissioned. If RDT is not yet commissioned, then range will be based on existing conditions.

4. Maximum volatile content of digested sludge solids fed to centrifuges: 71 percent by mass.
   a. Value listed is volatile solids and is not intended to reflect volatile suspended solids.
5. Digested sludge pH: 6 to 8.
6. Dewatering Operation: 2 duty and 1 standby centrifuge.

D. Performance Requirements:
1. The following performance requirements shall be met during guaranteed performance acceptance testing (GPAT):
   a. Hydraulic Loading: 110 gpm (not including polymer)
      1) Note, this hydraulic loading assumes 2.0 percent total solids sludge concentration.
   b. Solids Loading: 1,220 dry pounds per hour.
   c. Solids Concentration, range: 2.0 to 3.0 percent total solids.
   d. Minimum Percent Solids Capture: 95 percent.
   e. Minimum Cake Dryness: 16.9 percent total solids, calculated as prescribed by Standard Methods.
   f. Maximum Polymer Dosage: 46 active pounds per ton dry solids fed.
2. The following noise and vibration performance requirements shall be met during Factory Mechanical Performance Testing:
   a. Maximum Noise: See Paragraph 2.07 A.1.
   b. Maximum Vibration: See Paragraph 2.07 A.2.

1.05 SUBMITTALS

A. All documentation must be provided in English or accompanied with a certified translation.

B. Provide information as required per Section 15050 - Common Work Results for Mechanical Equipment.

C. Include a copy of this Section and referenced related Sections with clear indication of compliance with the requirements of each paragraph.
   1. Inclusion of “checkmarks” next to each paragraph shall signify full compliance with Section requirements.
   2. Any and all deviations from the Sections or exceptions taken to the Sections shall be clearly indicated and each deviation or exception shall be numbered.
      a. A detailed, written explanation shall be provided for each numbered deviation or exception taken.
   3. Failure to include a copy of the Sections with clearly marked compliance, exceptions, and deviations shall be sufficient cause for rejection of the submittal.

D. Centrifuge Manufacturer Qualifications:
   1. Submit data proving compliance with the Centrifuge Manufacturer’s experience, installations, and references requirements specified herein.
   2. To prove compliance with the installations and references requirements, submit the following for each installation and reference:
      a. Treatment plant name and location, including city and state.
      b. General description of sludge being dewatered (e.g., anaerobically digested blend of municipal primary and waste activated sludge).
      c. Models and sizes of the centrifuges installed.
      d. Number of centrifuges installed.
      e. Year of installation.
      f. Name, current telephone number, and current e-mail address for contact person at treatment plant.
   3. Submit resumes and training backgrounds of service technicians who will serve the plant.

E. Product Data:
   1. Complete bill of material, including control panel materials in compliance with Section 17100 - Control System Requirements.
   2. Submit data completely describing product including plan and section views, and listings of all components and materials of construction. This shall include all control panel layouts.
   3. Submit surface preparation and finishes to be applied to all equipment as specified in Section 09960 - High-Performance Coatings.
   4. Refer to requirements of Section 15050 - Common Work Results for Mechanical Equipment.
   5. Refer to Section 16100 - Electrical Requirements and Section 17100 - Control System Requirements for the centrifuge starter panel and centrifuge control panel and associated instrumentation and internal panel components.
   6. Recommendations for both short and long-term storage of each major component.

F. Shop Drawings:
   1. Outline drawings showing dimensions, weights, and locations of all components.
   2. Installation drawings with dimensions and details of construction inclusive of vibration isolators, anchor bolts, and connections.
   3. Drawings shall clearly indicate:
      a. Bowl diameter.
      b. Bowl length (cylindrical section).
      c. Bowl length (conical/beach section).
      d. Clarification or effective length (inside length dimension from liquid hub to midpoint of feed zone).
      e. Discharge diameter.
      f. Pool or pond depth.
      g. Cone/beach angle.
      h. Required clearances for disassembly and maintenance of centrifuge system.
      i. Indication of how centrifuge rotating assembly is removed from system.
      j. Static and dynamic loads, including indication of load distribution on vibration isolators.
      k. Required connection sizes and types (i.e. threaded, flanged, etc.) for feed, liquid discharge, solids discharge, polymer, wash water, venting, and lubrication system.
   4. Centrifuge starter panel and centrifuge control panel internal and external layout drawings correlated to the bill of materials in compliance with Section 17100 - Control System Requirements.
      a. Scaled drawings with dimensioned top, bottom, and front elevations with internal and external component/device layouts for centrifuge starter panel and centrifuge control panel.
   5. Backdrive system data sheets, description, torque capacity, reduction ratio and motor load.
   6. Lubrication system data sheets, layout, and requirements.
   7. Bearing temperature and vibration monitoring system details and instrument data sheets.
   8. Motor data as specified in Specification Section 16100 - Electrical Requirements, including main drive, backdrive, nameplate data, efficiency, and speed torque curves.
   9. Variable frequency drive data as specified in Specification 16100 - Electrical Requirements for main drive and backdrive (as applicable).
   10. Wiring diagrams, control schematics, and control logic diagrams for all electrical, instrumentation, communication, and control components furnished.
   11. Process and instrumentation diagrams (P&IDs).
   12. Complete I/O list.
   13. Complete description of control systems, including sequence of operation and list of functions monitored, controlled, and alarmed.
   14. Refer to requirements of Section 01300 - Submittals, Section 16100 - Electrical Requirements, and Section 17100 - Control System Requirements for LCP, centrifuge starter panel and centrifuge control panel submittal shop drawings.

G. Design Calculations:
    1. G-Volume, as defined in Article 1.04.
    2. Strength requirements for anchor bolts signed and stamped by a Professional Engineer licensed in the state where the project is located.
        a. Contractor to provide anchor bolts acceptable to Centrifuge Manufacturer.
    3. Provide bearing L10 life calculations in accordance with ABMA calculation method for bearings, motors, and other drive line components signed and stamped by a Professional Engineer.
        a. SKF's New Life Theory bearing life calculations meeting the DIN ISO 281 requirements are also allowed.
        b. Alternative calculation methods must be approved by the Engineer.
    4. Operating torque for specified loadings and performance requirements.

H. Test Procedures:
    1. Laboratory testing of the abrasion resistant materials (ASTM G 65).
    2. Shop tests of the centrifuges, including balancing data.
    3. Liquid dye penetrant tests.
    4. Centrifuge vibration tests.
    5. Control panel factory tests.
    6. Field tests.
    7. Performance tests.

I. Test Results:
    1. Results from all required factory tests.
    2. Results from all required field tests.
    3. Results from ASTM G 65 Test Procedure A for abrasion protection components.
    4. Include calibration certificates for instrumentation used for all tests in test results appendix.

J. Software:
    1. Final electronic PDF reports for PLCs and LOI software shall be submitted after successful installation and testing.
    2. Provide electronic data tables or register mapping information to integrate centrifuge system with PCS. This submittal must be finalized 60 days prior to commencement of Field Testing.
    3. As specified in Section 17100 - Control System Requirements to be compatible with Modicon controller.

K. Certificates:
    1. Furnish affidavit from manufacturer stating that the centrifuge system furnished is in compliance with the Contract Documents.
    2. Furnish affidavit from manufacturer stating that the centrifuges have been installed, tested, and are ready for operation.
    3. Furnish affidavit from manufacturer stating that the bowl, scroll, and gearbox for each unit have been independently balanced.
    4. Certification of test results from ASTM G 65 Test Procedure A for abrasion protection components.
    5. Certification of results from Factory Mechanical Performance Testing.
    6. Certification of results from all required Field Testing.

7. Certification that motors and variable frequency drives furnished for centrifuge system are compatible as specified in Section 16100 - Electrical Requirements.

L. Manufacturer's Installation Instructions: Installation and check-out instructions including lubrication and initial start-up procedures.

M. Operation and Maintenance Manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.
   2. Refer to requirements of Section 15050 - Common Work Results for Mechanical Equipment.

N. Location of nearest Service Center and Service Representative and procedure for responding to warranty and non-warranty requests.

O. Operator Training Lesson Plan.
   1. If an electronic training video/DVD has been previously developed, provide electronic training video/DVD for centrifuge system. Lesson plan must be submitted for review 60 days before training commences.

P. Maintenance Service Agreement (MSA): Provide MSA including maintenance service requirements per paragraph 1.09-E.

1.06 DELIVERY, SHIPPING, AND HANDLING

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Provide draft operation and maintenance manuals and final “for construction” documents to Contractor and Engineer 30 days prior to shipment of goods to the site.

1.07 SCHEDULE AND SEQUENING

A. Contractor shall refer to Section 01010 - Location and Summary of Work.

1.08 WARRANTY

A. Provide warranty as specified in Section 00630 - Warranty Bond.

1.09 MAINTENANCE AND SERVICE

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Special Tools: Provide one set of all special tools and accessories required for repair, adjustment, disassembly and reassembly, and proper maintenance of the centrifuge and all appurtenances. As a minimum, include the following:
   1. One set of special tools (any special wrenches, pliers, screw drivers, T-handle screws, jacking screws, dowel pin and sleeve removers, seal holder pullers, spanners, hexagon keys, snap ring removers, sockets, plastic hammers, etc.) required for units supplied.

2. One bowl lifter, including 2 flexible slings attached to horizontal steel beam designed to allow bowl assembly to be lifted by a single hoist.
3. One scroll conveyor removal lifting device, designed to allow easy removal of scroll conveyor from bowl and insertion of scroll conveyor into bowl. Lifting device shall include steel guide tube with spider flange, flange-mounted roller, come-along, and other accessories required for removal of scroll conveyor from bowl.
4. One tension bar nut wrench.
5. One pillow block bearing nut wrench.
6. One torque wrench.
7. Two weir plate/dam removal wrenches.
8. One T-handle wrench for weir plate/dam adjustment.
9. One thrust bearing puller.
10. One socket wrench for lubricating nipple.
11. One bowl dolly/truck with chocks designed to support bowl securely and wheels with swivel casters of size suitable for units supplied.
12. One set of jigs required for proper alignment of replaceable parts.
13. Two manual grease pumps, if necessary for units supplied.

C. Spare Parts: Provide the following spare parts:
1. One feed tube assembly.
2. One set of main bearings.
3. One set of scroll bearings.
4. One set of thrust bearings.
5. One set of all seals and O-rings.
6. One set of matched drive belts.
7. One spare switch for each type used.
8. One set of replaceable feed, cake, and centrate port abrasion protection inserts.
9. Two sets of various sized weir plates (if adjustable weir plates are not provided).
10. One-year supply of filter cartridges for lubrication system, if necessary.
11. One-year supply of all lubricants.
12. One set of all limit switches, if necessary for units supplied.
13. Other control panel spare parts as required in Section 17100 - Control System Requirements.

D. Service Centers:
1. As part of the warranties and guarantees included in this Scope of Services:
    a. The Centrifuge Manufacturer must have at least 1 service technician who has been trained specifically on the centrifuge system required for this project, and who would be available for a field service call at the Manteca Water Quality Control Facility (WQCF) within 120 hours of written notice.
    b. Centrifuge Manufacturer’s service center must be capable of delivering spare parts, excluding bowls and scrolls and gearbox, to the Manteca WQCF within 14 calendar days after written notice.
    c. Failure to provide service within the 120 hours period during the warranty period will be interpreted as a failure to execute the warranty.

1.10 PROGRAM COORDINATION

A. Centrifuge manufacturer shall coordinate PLC tags with Owner and Engineer prior to delivery including providing tag lists and customizing wire labels for field connections but not including tags internal to the PLC.
   1. Centrifuge Manufacturer shall specifically allocate 40 hours of technician time to coordinate data tables and PLC tags with Owner's SCADA registers.
   2. This time shall be included as part of the Manufacturer's Price.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturer qualifications:
   1. Manufacturer must have at least 20 years of experience in the design, application, and supply of centrifuges for municipal wastewater sludge within the U.S. Manufacturer shall submit a reference list of not less than 15 currently operating U.S. municipal installations operating for at least 2 years with units of the same bowl size or greater as evidence of meeting the experience requirement.
      a. Reference list shall include model installed, bowl size, date of installation, type of sludge being dewatered, and contact information (facility name, contact name, phone number, and email address) for each facility. Installations with multiple units shall count only as a single reference.
   2. Manufacturer must have at least 10 municipal wastewater installations in the United States of the same model and size of centrifuges as that proposed for this facility.
      a. These installations must have at least 4 years of operating history and be currently operating for municipal wastewater sludge dewatering.
      b. Manufacturer shall submit a reference list of these facilities.
         1) Reference list shall include model installed, bowl size, date of installation, type of sludge being dewatered, and contact information (facility name, contact name, phone number, and email address) for each facility. Installations with multiple units shall count only as a single reference.

B. The following or approved equal as determined by the City Engineer:
   1. Centrisys., Model CS21-4 2PH.

2.02 IDENTIFICATION

A. Nameplate: Manufacturer's standard.

B. Provide a corrosion resistant nameplate.

2.03 MATERIALS

A. General:
   1. All wetted parts of the centrifuge rotating assembly shall be Type 316/316L, Type 317, or duplex stainless steel, except for the "O" rings, seals, and

abrasion-resistant material. "O" rings shall be Buna-N or Viton; lip-type seals to be Buna-N or Viton.

2. The feed tube shall be constructed of Type 316/316L or duplex stainless steel.
3. Frame shall be fabricated of structural steel in compliance with Section 05120 - Structural Steel and finished as described in Section 09960 - High-Performance Coatings. Frame shall contain no weighted aggregate.
4. Casing shall be fabricated from Type 316/316L stainless steel.
5. Casing cover shall be fabricated from Type 316/316L stainless steel.
6. Construct all guards of Type 316/316L stainless steel or powder coated carbon steel and shall be designed to meet OSHA standards.
7. All bolts, nuts, and washers shall be Type 316 stainless steel.
8. No dissimilar metals shall be in direct contact unless properly electrically insulated.
9. All system components weighing 50 pounds or more shall be provided with lifting lugs.
10. All motors shall comply with Section 16100 - Electrical Requirements.
11. All variable frequency drives shall comply with 16100 - Electrical Requirements.

B. Bowl:
   1. Manufacture bowl from centrifugal castings of Type 316/316L or duplex stainless steel. Rolled and welded or static cast bowls shall not be allowed.
   2. Design to operate at a minimum of 3,000 Gs at the bowl wall for maximum process flexibility and reliability and to withstand all centrifugal forces encountered at design operating speed with adequate safety factors.
      a. Inspect bowl for cracks, shrinkage, porosity, or other defects, by means of a liquid dye penetrant test. Submit test results with factory test results.
      b. Bowl speed shall not be less than 2,500 rpm and shall not exceed 3,600 rpm for maximum specified hydraulic and solids throughput.
   3. Centrifuge bowl shall be a minimum 70 inches cylindrical length, with a minimum inside diameter of 20.5 inches (nominally 21 inches) in the cylindrical section, plus a conical beach extension with a beach angle between 9 and 15 degrees.
   4. Front and rear bowl hubs shall be centrifugally cast or mold cast 316 stainless steel or cast duplex stainless steel. The nominal thickness of the front and rear bowl hubs shall be a minimum of 2 inches.
   5. Centrifuge bowl shall be supported by main bearings mounted in pillow blocks and fitted for convenient external lubrication, as applicable.
   6. Flow through the centrifuge shall be counter current such that there are no centrate tubes to maintain.
      a. Pool depth shall be readily adjustable via weir plates located at the large diameter end of the bowl.
      b. Weir plates shall be easily accessible.
      c. Solids shall be discharged at the small diameter end of the bowl.
   7. The bowl shall be independently balanced at full operational speed prior to shipment. Certification of balancing shall be provided.

C. Scroll conveyor:
   1. Each centrifuge shall include a Type 316 or duplex stainless steel horizontal conical-cylindrical scroll conveyor equipped with helical flights independently mounted concentrically within the bowl.

2. The scroll shall utilize a differential speed to convey solids from the cylindrical section to the conical section and out of the bowl with a minimum disturbance to the pool.
3. Scroll conveyor shall be supported on grease-lubricated anti-friction roller or ball bearings sealed from process contamination.
4. The edge and the face of the conveyor flights shall be protected by a series of welded on sintered tungsten carbide tiles, as described in the abrasion protection section.
5. Scroll conveyor shall be designed such that the feed is evenly discharged 360 degrees into the bowl through feed ports.
6. The scroll shall be independently balanced at full operational speed prior to shipment. Certification of balancing shall be provided.

D. Bearings:
1. Centrifuges shall be designed so that the entire rotating assembly is supported by two anti-friction main bearings.
    a. Each main bearing shall be a spherical roller or cylindrical roller type.
    b. Main bearings shall be housed in one piece pillow blocks.
    c. Equip main bearings with RTD type temperature sensors to monitor bearing race temperature directly.
2. Scroll conveyor shall be supported on grease-lubricated anti-friction cylindrical roller, spherical roller, or ball bearings sealed from process contamination. Provide external grease fittings for scroll bearings as recommended by manufacturer.
3. Bearings shall be conservatively designed to withstand all stresses of the service specified.
    a. Main bearings shall have a minimum L-10 life rating of 100,000 hours at standard operating speeds at 24-hours-per-day service. Alternative calculations shall be approved by the Engineer.
    b. Scroll bearings shall have a minimum L-10 life rating of 100,000 hours at standard operating speeds at 24-hours per day service. Alternative calculations shall be approved by the Engineer.

E. Frame and casing:
1. Rotating assembly and bearings for the centrifuge shall rest on a frame and casing assembly, specifically designed for rigidity and noise reduction.
2. Frame and casing shall be supplied on a modular sub-frame.
    a. Modular sub-frame shall support both the drive motor and backdrive.
    b. Vibration isolators for the drive motor and backdrive shall be supplied as required.
3. Design case to act as a protective guard and to provide a complete enclosure for odor containment and noise reduction.
4. Bottom of the casing shall contain a flanged solids discharge connection for dewatered sludge cake and a flanged liquid discharge connection for centrate. Provide flexible connectors for the solids and liquid discharge connections.
5. Case top shall be bolted in place. Quick release mechanisms are not acceptable due to strength and safety requirements.
6. A conduit box for all centrifuge mounted switches, sensors, and temperature detectors, except those devices specifically related to the main drive motor, shall be mounted on the base.

7. Contractor shall provide 1 1/4-inch Sch. 80 PVC piping to route all frame drains into the centrate chute of the associated centrifuge.

F. Feed Compartment:
   1. Provide feed tube designed to introduce sludge into centrifuge through feed ports with minimal turbulence to pond.
   2. Feed tube shall be independently removable from the rest of the centrifuge without any major disturbance to the unit.
   3. Sludge feed connection to centrifuge shall be flanged.
      a. Feed tube shall also include threaded connection for polymer, non-potable flushing water, and a sample port as indicated on the Drawings. Connections for polymer, flushing water, and sample port shall be provided with isolation valves.
   4. Required sludge feed pressure at maximum specified hydraulic loading rate shall not exceed 10 psi as measured at the inlet flange.
   5. Required polymer feed pressure at maximum specified hydraulic loading rate shall not exceed 15 psi as measured at the inlet flange.

2.04 DRIVE SYSTEM

A. General:
   1. Provide the centrifuge with separate main drive motor, backdrive control system motor for differential adjustment, air-oil lubrication system (as applicable), and all other smaller motors required for a complete system.
      a. Bowl main drive system shall consist of an electric motor and a belt drive system.
      b. Belt drive system shall consist of multiple belts as required to provide full load capacity and also to withstand the full starting torque of the system.
   2. Provide VFDs for main drive within the centrifuge starter panel. VFD construction shall be as specified above.
      a. Centrifuge starter panel VFDs shall be in a dedicated panel which will be located in a conditioned electrical room as indicated on the Drawings.

B. Main drive motor:
   1. Motor nameplate horsepower rating shall be equal to, or greater than, the maximum brake horsepower of the drive system at its maximum hydraulic flow rate.
   2. Provide NEMA premium efficiency motor as specified in Section 16100 - Electrical Requirements.
   3. Main motor shall be maximum 60 horsepower, suitable for 460 volt, 3-phase, 60 hertz power.
   4. Motor shall be inverter duty rated for use with a VFD and shall be provided with standard long shaft for V-belt drive and terminal box rotatable in 90 degree increments.
   5. Fluid couplings or other hydraulic starting systems using water or oil shall not be allowed.
   6. Motor shall be provided with thermal protection using a bi-metal thermal switch.

7. Motor at ambient temperature shall be capable of making two complete starts in succession with coasting to reset between starts.
    a. Motor shall be capable of at least 1 restart within 1 hour after any shutdown.
    b. Motor shall not take longer than 5 minutes (each start) to accelerate to full rated revolutions per minute at 90 percent nameplate voltage.

C. Backdrive system:
1. Hydraulic backdrive system: A hydraulic backdrive system shall provide speed variation between the conveyor and the bowl. The starter for the backdrive shall be a reduced voltage soft start.
    a. Hydraulic backdrive system:
        1) The differential speed between the centrifuge bowl and scroll conveyor shall be produced by a minimum 15-horsepower, 460 volt, 3-phase motor drive, water cooled hydraulic system which shall independently drive the scroll conveyor.
            a) The hydraulic scroll conveyor drive system shall be designed such that no mechanical gear reducer is required on the scroll conveyor drive train.
            b) The hydraulic drive system shall be capable of operating in either a manual or automatic mode.
            c) In the manual mode, it shall provide for operation at a specific, adjustable scroll differential speed with internal torque allowed to vary up to the maximum allowable scroll shaft torque.
    b. The backdrive shall have a minimum torque output rating of 365,000 in-lbs and utilize a Rotodiff for conversion and transmission of hydraulic energy to the scroll. Use of gearbox shall not be allowed.
    c. In the automatic mode, the centrifuge vendor control panel shall continuously monitor changes in internal torque created by variations in influent feed solids and automatically maintain a preset torque input to the scroll by allowing the differential speed to vary.
        1) The hydraulic drive shall operate in a manner such that, as the reactive torque of scroll shaft increases due to an increase in solids inventory in the bowl, the scroll differential speed shall gradually increase and, conversely, as the inventory of solids in the bowl and resultant reactive torque decreases, the scroll differential speed shall decrease.
        2) The net effect of this system, when operated in the automatic mode, shall be to maximize the time that cake solids are under the influence of accelerated gravitational force to ensure that the driest possible dewatered cake product is produced without plugging the centrifuge.
    d. The system shall use a hydraulic pumping group and hydraulic motor.
        1) Torque-based adjustment shall be a function of input to the driven unit.
        2) The maximum torque input and rate of change of scroll differential speed shall be adjustable.
    e. Provide 2 sets of contacts for determination of excessive torque. One set shall be for high torque, and the second set for high-high torque. Backdrive must require manual reset to clear alarms.
    f. Backdrive system shall be able to run the scroll only without input from the maindrive in plugged conditions.

D. Provide all cables and conduits required for prewired equipment as specified herein. Where required, all support hardware shall be stainless steel with stainless steel preformed channel.

2.05 ABRASION PROTECTION

A. In order to minimize wear due to abrasive materials in the feed, replaceable hard surfacing shall be provided at all points where the abrasive action of the sludge will cause wear on the metal parts of the centrifuge. The following shall be considered a minimum degree of hard surfacing required:
   1. Bowl wall: Bowl wall and conical extensions shall be protected with longitudinal grooves, ribs, or replacement wear strips integrally machined into the bowl designed to trap a protective layer of solids between the bowl wall and the conveyor.
   2. Feed compartment walls: Feed compartment shall be protected by a replaceable accelerator and liner, ceramic and Devcon®, or with flame sprayed tungsten carbide hard surfacing.
      a. Replaceable accelerator shall be guaranteed against failure for 15,000 hours of operation.
   3. Conveyor feed ports: Conveyor feed ports shall be protected by field replaceable solid sintered tungsten carbide or chilled cast iron inserts.
   4. Solids discharge ports: Solids discharge ports shall be protected from abrasion by field replaceable tungsten carbide or chilled cast iron inserts.
   5. Solids discharge casing: Solids discharge casing shall be protected by replaceable urethane or stainless steel wear liner.
   6. Scroll conveyor flights:
      a. The edge and face of the conveyor flights shall be protected against abrasion from the solids by a series of welded-on sintered tungsten carbide tile assemblies the entire length of the conveyor, or partial length up to a minimum of 2 wraps beyond the feed zone or as needed to meet a minimum of 15,000 hours of operation without failure.
      b. Flighting not covered with tiles, as allowed per this paragraph, must be protected with duplex stainless steel that has been flame sprayed to meet a minimum of 15,000 hours of operation without failure.
      c. Each tile assembly shall be weight correct, and consist of a sintered tungsten carbide wear part attached to a stainless steel back-up holder. Each assembly shall be individually replaceable, and include the ability to monitor wear by means of visual inspection. The tile assemblies must extend 0.50 inches beyond the radial edge of the conveyor flight.
   7. All sintered tungsten carbide tiles and chilled cast iron inserts shall be able to meet ASTM G 65 Test Procedure A with a volume loss as specified under Source Quality Control.

2.06 NOISE AND VIBRATION

A. General:
   1. Equip centrifuge with noise suppression devices, such that the average noise level measured at 3 feet around the periphery of the complete centrifuge assembly does not exceed 89 decibels when tested in open field conditions at nameplate speed, without feed, and with the inlet and discharge closed.

2. Dry Operation:
    a. The centrifuge, when running at nameplate speed and with water shall be measured for vibration in the manufacturing facility and field. Peak RMS vibration velocity shall be less than 7 mm/s (0.449 in/s) unfiltered overall when measured at the pillow blocks under dry shop test conditions.
3. Wet Operation:
    a. The centrifuge, when running at nameplate speed and with water shall be measured for vibration in the manufacturing facility and field. Peak RMS vibration velocity shall be less than 7 mm/s (0.315 in/s) unfiltered overall when measured at the pillow blocks under wet shop test conditions.
        1) These conditions must also be met with sludge in the field conditions.
4. The centrifuge shall be equipped with accelerometer or velometer type vibration monitors located on each of the main bearing assemblies (pillow blocks), or more as determined by centrifuge manufacturer, to measure vibration in the horizontal and vertical directions and to protect against excessive vibration.
    a. The monitor shall be interlocked with the controls to shut down the centrifuge if excessive vibration is sensed. Vibration shall be displayed and monitored at the Centrifuge Control Panel.

B. Vibration isolators:
1. Mount centrifuge on low natural frequency elastomeric vibration isolators capable of dampening vibration in all directions. Isolators shall have metal springs and viscous dampening fluid.
2. The number, capacity, and vibration constant of the isolator shall be as recommended by the manufacturer for the load and impact resulting from the operation of the centrifuge provided.
3. Vibration of a predetermined displacement or velocity shall automatically shut down the machine.
4. Rigid connections to the centrifuge will not be allowed.
5. Isolators shall be designed to limit dynamic load imparted to foundation to 5 percent of the static load in the horizontal direction and 10 percent of the static load in the vertical direction.
6. Each isolator shall be provided with built-in leveling bolts and built-in resilient shock absorbers to control oscillation and withstand lateral forces in all directions. Isolators shall allow for adjustable snubbing. Provide snubber inserts, if required, of oil resistant synthetic rubber. Alternative shimmed leveling systems must be approved by the Engineer.
7. Housings shall be welded steel and springs shall be oil tempered high carbon chrome vanadium steel.

C. Flexible connectors:
1. To ensure a quiet installation, provide flexible connectors to isolate the centrifuge from the building structure. Flexible connectors include the solids discharge connection, flexible feed connection, flexible centrate connection, flexible polymer connection for the feed tube, flexible lubricating air-oil connection, and flexible water connection.
    a. Flexible connections for solids discharge, centrate discharge, and feed tube shall be flanged for simple connection to associated piping.
    b. Flexible connection for polymer shall be threaded.

c. Flexible connections associated with lubrication system shall be of type required for units supplied.

2. Because of local conditions, flexible electrical connectors for the drive motor, backdrive, centrifuge junction boxes, and conduit shall be furnished by the installing Contractor, such that all local electrical codes are met.
3. All flexible connectors, other than those required for these electrical components, shall be supplied by the Centrifuge Manufacturer.

2.07 ANCHOR BOLTS

A. Anchor bolts shall be Type 316 stainless steel. Anchor bolts shall be sized and supplied by the Centrifuge Manufacturer.

B. Anchor bolts shall be sized and designed in accordance with Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

2.08 FABRICATION

A. Centrifuge Manufacturer shall be ISO 9001: 2015 certified.

B. Identification:
1. Nameplates for Electrical Equipment:
a. As specified in 16100 - Electrical Requirements.
2. Nameplates for All Other Components: Identify each unit of equipment with a corrosion resistant nameplate, securely affixed in a conspicuous place. Nameplates shall be provided in accordance with Section 15050 - Common Work Results for Mechanical Equipment.

2.09 SHOP FINISHING

A. Provide surface preparation, cleaning, and coating for all components not constructed of stainless steel in compliance with Section 09960 - High-Performance Coatings.

2.10 SOLIDS DISCHARGE AND CENTRATE CHUTES AND DIVERTER GATE

A. The Centrifuge Manufacturer shall provide the solids discharge and centrate chutes from the centrifuge to the connections with the diverter gate and centrate discharge piping system below the centrifuge.
1. The solids discharge chute must include a diverter gate, as described below.
2. The centrate discharge pipes shall be furnished by the Contractor.

B. Solids Discharge Chute:
1. All flexible connectors required for connecting the solids chute to the centrifuge solids outlet shall be supplied by the Centrifuge Manufacturer.
2. Centrifuge Manufacturer shall coordinate with Contractor for proper mating of diverter gate system at connection points.
3. The solids chute shall be provided with an air vent, sized as necessary for the equipment supplied. Vent shall be connected by Contractor to the vent piping supplied by Contractor.

4. Chute shall be constructed of 316 stainless steel and supported independently. Chute weight shall not be supported from flexible connectors. Shop drawings shall be provided for review and approval prior to fabrication.
5. Solids Discharge Chute length for each centrifuge shall not exceed eight feet.

C. Diverter Gate:
   1. Solids discharge chutes provided by centrifuge manufacturer shall include automated knife-gate type diverter gates sized by manufacturer for the required solids discharge chute and bolted to the solids discharge chute.
      a. Diverter gates shall be provided with electric actuators to automatically direct dewatered cake to cake conveyors when torque setpoint is reached. Before torque setpoint is reached, gate will automatically divert out-of-spec “sloppy” sludge to centrate lines through a sloped line connecting the centrate and solids discharge chutes as indicated on the Drawings.
         1) Actuators for diverter gates shall be meet requirements of Section 13447 - Electric Actuators. Actuators shall operate on 480V, 3-phase, 60 Hz power. Enclosures shall be NEMA 4X and watertight.
      b. Interconnecting piping for out-of-spec sludge diversion shall be provided by the centrifuge manufacturer with a flushing system, including all necessary automated valving, that automatically flushes residual cake solids from this line as part of the automated centrifuge operating sequence.
         1) The diverter gate shall be provided with a connection for a 1.5-inch non-potable water flushing connection with a Contractor-provided solenoid valve. Contractor to coordinate pipe connection type with centrifuge manufacturer.
      c. Diverter gates shall fully open or close within 30 seconds or sooner as required by Centrifuge Manufacturer to prevent damage to the centrifuge.
      d. Diverter gates shall be connected to the centrifuge solids discharge with a flexible sleeve fabricated of neoprene and designed such that no exterior loads are transferred to other equipment.
      e. Diverter gates shall be constructed of 304 or 316 stainless steel. Diverter gate frame and slide shall be 304 or 316 SST. Gate shall be provided with PTFE packing and metal seat or resilient seat as required to make gate leak-tight.

D. Centrate Discharge Chute:
   1. All flexible connectors required for connecting the centrate chute to the centrifuge liquid outlet shall be supplied by the Centrifuge Manufacturer.
   2. Centrifuge Manufacturer shall coordinate with Contractor for proper mating between centrate chute and centrate piping.
   3. The centrate chute shall be provided with an air vent, sized as necessary for the equipment supplied. Vent shall be connected by Contractor to the vent piping supplied by Contractor.
   4. The centrate spray line to the centrate discharge chute shall be provided with a connection for a 1-inch non-potable water flushing connection with a Contractor-provided solenoid valve, located on the Centrifuge 3W Panel per the Contract Drawings. Contractor to coordinate pipe connection type with centrifuge manufacturer.

5. Chute shall be constructed of 316 stainless steel and supported independently. Chute weight shall not be supported from flexible connectors. Shop drawings shall be provided for review and approval prior to fabrication.
6. Centrate Discharge Chute length for each centrifuge shall not exceed eight feet.

2.11 CONTROL SYSTEM

A. General:
1. Additional requirements for supplier packages including electrical components, electrical systems, control system hardware/software, all associated process instrumentation, all testing, and all other requirements for a completed system.
2. This Section specifies general requirements which are applicable to providing a completed supplier package control system. A completed supplier package control system includes a complete, functional process control, communication, and signal system.
3. This Section specifies general requirements for the coordination between the area PLC supplier control systems and the Centrifuge System supplier PLC.
4. The supplier package control system shall include all electrical system components and control system components required for a complete, fully functional and operable control system including panels, power supplies, programmable logic controllers (PLC), processors, input/output (I/O) systems, interconnect wiring, communication interfaces, networking devices and instruments.
5. The supplier package control system shall include all coordination, configuration, testing, and any other items required for a complete, fully functional, and operable control system interface via EtherNet/IP protocol over fiber communications to a Modicon area PLC.
6. The supplier package control system shall be provided with system operations and maintenance manuals, user guides, troubleshooting guidelines, and system configuration documentation.
7. Supplier shall also supply backup software and software licenses, and provide fully programmed package system control strategies, hardwired and networked I/O, PLC network interface and data communications, and dynamic operator graphics including process graphical representations of the supplier package system, control graphics (if applicable) alarm logs, trends, and reports in accordance with the supplier package system equipment specifications, block diagrams in the Drawings, and all other Drawings.

B. Roles and Responsibilities:
1. Definition:
   a. For the purpose of this Section, "Supplier" refers to the Centrifuge System supplier. Refer to the Contract Documents for additional requirements for Packaged Systems.
   b. For the purpose of this Section, Project Integrator refers to the area PLC control system integrator.
   c. For the purpose of this Section, “Area PLC supplier” refers to the supplier of the area PLC.
2. Supplier’s roles and responsibilities shall include the following:
   a. Procure, assemble, configure, program, and test components of a Packaged System in the factory. Configuration and programming activities

shall include provisions for area PLC remote automatic control and area PLC remote manual control, as allowed by supplier and coordinated with Area PLC supplier.

b. Ship the Package System to the project site and aid the Contractor in the physical installation of the Package. Where required by the Contract Documents, this may include coordination of all external connection points like conduit, wiring, piping, and other services where required.

c. The Supplier shall provide on-site testing, startup, and commissioning services for the purposes of ensuring the Package System performs the functions required in the Contract Documents.

d. The Supplier shall attend integration meetings with the area PLC supplier and Engineer, for the purposes of integrating the control system supplied with the Package into the plant PLC system.

3. Contractor's roles and responsibilities shall include the following:
   a. Where required by the Contract Documents, the Contractor shall install all components of the Package System as recommended by the Supplier and/or Owner's representative.
4. Project Integrator's roles and responsibilities shall include the following:
   a. Participate in application software meetings for integrating the Package System with the area PLC.
5. Owner's representative roles and responsibilities shall include the following:
   a. Validate that all features of the Package System have been successfully integrated and tested with the area PLC.

C. Hardware and Software:
1. Supply all package control system components as well as any ancillary, or incidental equipment or devices, that are required to monitor and control the supplier package system process equipment from the local supplier package control operator interface on the supplier panel and from the area PLC. The hardware and software shall:
   a. Come with fully programmed PLC and HMI that provide the control strategy functions and operations interfaces as specified in the equipment specification standards specified in Section 17100 - Control Strategies, including all display and control strategy programming requirements and standards.
   b. Provide coordination with the Project Integrator and provide the required network configuration as specified for the supplier package system.
   c. Provide the required area PLC interfaces as specified for the supplier package system. Provide programmed network interfaces to the area PLC, which allow monitoring and control of supplier package control system I/O and virtual data points from the area PLC.
   d. Follow the project standards by partitioning the supplier package control system network hardware. Partition the controller processors and I/O, so that redundant process equipment does not share the same network partition or its network communication path to the package control system.
   e. Store all alarms locally, until they are manually reset, through the area PLC operator interface.

D. Supplier Services:
   1. Design, fabricate, program, factory test, area PLC integration test, and deliver a fully functional package control system that is acceptable to the City Representative.
   2. Provide a fully functional package control system capable of exchanging hardwired and software inputs and outputs and equipment sequence and controls interfaces with the area PLC that complies with the equipment specifications, applications programming requirements of Section 17101D - Specific Control Strategies - Dewatering, and includes:
      a. Program all control logic required for the package system.
      b. Program LOI (Local operator interface) screens.
      c. Program all package system networks to interface with area PLC, MCC, and other network(s) to interface with field devices and motorized equipment.
   3. Required Meetings:
      a. In addition to the virtual meetings required by the relevant package system specification, the Supplier shall attend two virtual meetings with the area PLC integrator and Owner's representative.
      b. The primary meeting function shall be to present the Supplier's approach to controlling the package equipment and solicit input/feedback from the Owner's representative and integrator regarding the presented approach and implementation of the package control system and to review requirements for supplier preparation of Package Control System Implementation Plan submittal.
      c. Supplier shall have a representative in attendance at each meeting who is responsible for the preparation of the Package Control System Implementation Plan. The specific dates for each of the meetings shall be scheduled by the Contractor and accepted by the City Representative and the City.
   4. Participate in area PLC Application Software Integration as specified, including formal Workshops to discuss and review work scope, progress, coordination, and programming review meetings.
   5. Provide the entire package control system and provide training to the Owner as specified herein.
   6. Contractor will provide overall management and coordination of the project testing, start up, and commissioning. Supplier shall participate with Contractor to execute the testing, start up, and commissioning of the supplier package control system and control of the supplier package system equipment.
   7. Support the testing, start-up, and commissioning of the area PLC as it relates to the supplier package system.

E. Supplier Package System/Area PLC Application Software Coordination:
   1. The Supplier shall provide detailed logic and controls to operate all major components or equipment supplied by the Supplier automatically. The system shall interface with the area PLC for supervisory control set points, command initiating points, monitoring, and alarming.
   2. The Supplier shall provide controls to area PLC as per:
      a. Refer to Drawings and this Specification for the minimum required data transfer to the area PLC.
   3. Area PLC Application Software Integration Workshops: The Supplier shall attend discussions with the area PLC Integrator and the Owner's

representative. The workshops shall cover the following topics. Workshop objectives shall include the following, as a minimum:

a. Workshop duration shall be a minimum of 4 hours each workshop, but shall allow for an additional 4 each as necessary.
b. Workshop location shall be via online streaming or similar. This will require all parties to have real-time, live access to video information being communicated by the Supplier.
c. Detail information about the Suppliers controls will be formally communicated to the area PLC Integrator for the purpose of programming the area PLC for remote monitoring and control of the package.
d. Customization of controls to accommodate area PLC remote controls, monitoring, and efficient data transfer between the area PLC and Suppliers' control system.
e. Preliminary and Final testing and commissioning plans, including test procedures, shall be approved by the Owner's Representative.

4. Supplier shall provide a comprehensive overview of the package control system for the purpose of informing all of the controls and monitoring capabilities of the packaged equipment. Handouts shall be provided 3 weeks prior to the workshops showing all possible monitoring and control points available from the Supplier's local LOI. The handout shall be grouped by input/output points (I/O) into the following categories:
   a. All controls to be initiated from the area PLC.
   b. All setpoints to be communicated from the area PLC.
   c. All tags available for remote monitoring.
   d. All alarms are available for remote monitoring.
   e. All configuration parameters used for tuning the system.
5. Vendor equipment programming meetings: Attend a meeting with the PLC Programmer to coordinate with the Owner's control system. The meeting discussion point will include the following at a minimum:
   a. Tag Naming Conventions.
   b. PLC to PLC global data mapping.
   c. All PLCs to HMI tags mapping for SCADA.
   d. LOI screen colors and navigation.
   e. Interlock and Permissive definitions.
   f. Communication Methods.
   g. Standard code blocks for common control functionality.
   h. Alarms - clearing, formats, colors, and status.

F. Vendor Control Panel General Requirements:
   1. General:
      a. Provide a control panel for the centrifuge that provides fully independent control.
      b. Conform with requirements of Section 17100 - Control System Requirements.
      c. Control panel shall consist of, but not be limited to the following to provide a complete and operable system:
         1) Preprogrammed PLC to control operation of the centrifuge system that receives commands from the plant control system:
            a) Dedicated PLC manufactured by Allen-Bradley and fiber optic Ethernet switch. All PLC circuit boards shall be conformally

coated. The PLC shall be provided in conformance with Section 17100 - Control System Requirements.

d. Control panel shall carry a UL label certifying the assembled industrial control panel complies with UL 508.
e. Control panel shall be completely prewired, preprogrammed, and factory tested for proper operation prior to shipment. Refer to Section 17100 - Control System Requirements for additional testing requirements.
f. Communicate with the plant control system over Ethernet/IP as shown on the control system block diagram. Communication shall be via fiber cable. Supplier's cabinet shall contain necessary equipment to enable connection of fiber cable.
g. Provide separate alarm and emergency shutdown functions.
h. Provide local operator interface (LOI) unit for adjustment of setpoints, timers, and alarms.
i. Provide barriers and plexiglass covers for all 480 VAC components within the control panel.

2. Panel enclosure and components:
   a. CSP/CCP enclosure type:
      1) Floor mounting to the slab is required for Centrifuge Starter Panel (CSP). Wall or floor mounting is acceptable for Centrifuge Control Panel.
      2) NEMA 4X rated with continuous hinge and lockable door latch as specified in Section 17100 - Control System Requirements:
         a) Type 316 stainless steel.
      3) The CSP/CCP enclosure shall be adequately sized and designed to dissipate the heat generated inside the enclosure. Provide heating/cooling as specified in Section 17100 - Control System Requirements as needed.
      4) Each CSP/CCP enclosure shall not exceed the following dimensions:
         a) Centrifuge Starter Panel: 90 inches high by 72 inches wide by 24 inches deep.
         b) Centrifuge Control Panel: 60 inches high by 36 inches wide by 18 inches deep.
      5) Manufacturer: One of the following:
         a) Rittal.
         b) Pentair (formerly Hoffman Engineering).
         c) Saginaw Control & Engineering.
      6) Latches:
         a) For panels, provide each door with a 3-point latching mechanism and locking handle with rollers on the ends of the latch rods. Latch rods shall be connected to a common door handle, hold doors securely, and form a compressed seal between door and gasket, at the top, side, and bottom:
            (1) Provide padlock for each enclosure with padlock provisions.
   b. Components - General:
      1) Panel instruments as shown on the Drawings, as specified in Section 17100 - Control System Requirements, and as recommended by the equipment manufacturer to provide a fully operational system.
      2) Design controls such that the equipment cannot operate unless controls are energized.

3) Instruments mounted on the face of the panel and components located within the panel shall meet the requirements specified in Section 17100 - Control System Requirements.
4) Controls and instruments shall fail into a safe condition.
5) Provide necessary interlocks and time delays (operator adjustable) for system control.
6) Indicators and Alarms in accordance with this specification and Section 17100 - Control System Requirements.

c. Power systems:
1) Control power transformer with 120 VAC surge protection device (SPD) and fused primary and secondary.
2) Main circuit breaker flange-mounted power disconnect interlocked to the enclosure door:
a) CSP/CCP shall be labeled and rated to withstand the available fault current.
b) In accordance with Section 16100 - Electrical Requirements.
3) 600 VAC terminal block.
4) Surge protection device.

d. Wiring:
1) Factory assembly and wiring of the control panel such that field wiring shall consist only of connections to terminals.
2) Identify each end of each wire by a unique wire number printed on a heat shrink sleeve marker.

e. Remote inputs via EtherNet/IP communications:
1) As indicated in the I/O Tables and Drawings.

f. Remote outputs via EtherNet/IP communications:
1) As indicated in the I/O Tables and Drawings.

g. Provide contacts rated for 10 A at 120 VAC for remote monitoring of the status signals.

3. Indicators, alarms, and controls accessible through CSP/CCP Operator Interface Unit to provide complete monitoring and control including the following:
a. Status indication for all components.
b. Mode selection and indication.
c. Configuration screens for all set points.
d. Elapsed time meter.
e. Alarm indication providing description of specific faults.

G. Centrifuge Starter Panel:
1. Provide a Centrifuge Starter Panel for the centrifuge to interface with the centrifuge field equipment and the Centrifuge Control Panel.
2. Variable frequency drives:
a. A specified in Section 16100 - Electrical Requirements.
b. VFD Input harmonic mitigation: Filter to meet harmonic distortion levels in compliance with IEEE 519.
1) Manufacturer MTE or equal as approved by Engineer.
c. VFD Output harmonic mitigation: Load reactor.
3. Motor starters and associated components as specified in 16100 - Electrical Requirements.
4. Labelling shall be per 16100 - Electrical Requirements.
5. Enclosure: Galvanized steel, NEMA 12.

6. Door-mounted emergency stop pushbutton hardwired to associated centrifuge control panel PLC for emergency shutdown.
7. Electrical Service:
    a. A single 480-VAC, 300-amp, 3-phase, 60-Hz power feeder will be provided to power the Centrifuge Starter Panel. All power for main drive, backdrive, and all auxiliaries and controls in the Centrifuge Starter Panel and Centrifuge Control Panel shall be derived from this power source.
8. Flange mounted lockable main circuit breaker disconnect switch in accordance with Section 17100 - Control System Requirements:
    a. Minimum short circuit rating of 65 kAIC.
9. Centrifuge Starter Panel sizing based on selected components is the responsibility of the Centrifuge Manufacturer. It is the responsibility of the Contractor to coordinate with the Centrifuge Manufacturer to determine final dimensions of the panel and coordinate all work as specified in Section 16100 - Electrical Requirements.
10. Centrifuge Starter Panel interior components shall include the following at a minimum:
    a. Variable frequency drive (VFD) assemblies for both the centrifuge main drive motor and centrifuge back drive motor.
        1) VFDs shall be as specified above.
        2) The VFDs shall communicate with the Centrifuge Control Panel via Ethernet.
    b. Combination motor starter assemblies for the lubrication system, as applicable, including motor circuit protector type circuit breaker with adjustable instantaneous trip setting, contactor, and thermal overload.
        1) Thermal overload trip reset pushbuttons shall only be resettable from inside the control panel.
    c. Each motor starter or VFD assembly shall have a listed minimum RMS symmetrical short-circuit current rating of 65,000 amperes at 480 VAC.
    d. Branch circuit breaker for powering the diverter gate assembly.
    e. Control power transformers, terminal blocks, wiring, relays, signal converters, and all other components required for a complete assembly.
11. All internal component ratings per the requirements of the National Electrical Code and listing agency.

H. Centrifuge Control Panel:
1. Provide one centrifuge control panel for each centrifuge furnished to control and monitor the operation of the centrifuge.
    a. Provide a Modicon PLC within each control panel.
    b. PLCs must be independent/dedicated to each centrifuge.
    c. Must communicate to/from the PCS.
2. Power supply: 120-volt, 60-Hz, 1-phase sourced from Centrifuge Starter Panel.
3. The Centrifuge Control Panel shall include automatic PLC-based torque/differential speed control modules that shall maintain process optimization within adjustable preset limitations and operate in differential speed or torque modes.
4. Local Operator Interface (LOI):
    a. NEMA 4X rated.
    b. The panel shall be provided with an LOI in accordance with Section 17100 - Control System Requirements.

c. 32 MB Flash EPROM Memory.
d. Provide hinged, see-through, protective shield over LOI. Include latch device to hold shield open when using touch screen.
e. Minimum size: 12 inches.
f. Color, TFT LCD.
g. Resolution: 1,024 by 768 pixels.
h. Network communications over Ethernet.

5. Programmable logic controller:
   a. Modicon PLC. The PLC shall be provided in conformance with Section 17100 - Control System Requirements.
      1) 120 VAC Power Supply.
      2) Surge protection for all of the controls.
      3) EtherNet/IP Communications (connection to LOI).
      4) EtherNet/IP Communications (communication to Owner's Control system).
      5) 120 VAC or 24 VDC Isolated Discrete Inputs (16 points max/module) as needed for hardwired control.
      6) 120 VAC or 24 VDC Isolated Discrete Outputs (16 points max/module) as needed for hardwired control.
      7) 4-20 mA Isolated Analog Input module as needed for hardwired control.
      8) Capable of utilizing a second Ethernet module.
   b. Provide managed Ethernet switch for connecting to the plant control system:
      1) Rockwell Stratix 5700 series:
         a) Speed: 10/100 Mbps, auto-negotiating.
6. General Requirements and Arrangement for the Centrifuge Control Panel:
   a. As specified in Section 17100 - Control System Requirements.
   b. Arrange panel internal components for external conduit and piping to enter into panel either from above or below.
   c. Arrange panel instruments and control devices in a logical configuration associating pushbutton and selector switches with related readout devices.
   d. Mount internal control components on an internal back-panel.
   e. All control panel-mounted operator interface devices shall be mounted between 3 feet and 6 feet above the finished floor.
7. Centrifuge Control Panel sizing based on selected components is the responsibility of the Centrifuge Manufacturer. The Contractor is responsible for coordinating with the Centrifuge Manufacturer to determine the final dimensions of the panel and coordinate all work as specified in Section 16100 - Electrical Requirements.
8. Enclosure: Stainless steel, NEMA 4X.
9. Terminal points for interconnection.
10. All information monitored and displayed at the CCP LOI shall be available for monitoring and display at the PCS.
11. Centrifuge Control Panel wiring diagram laminated and affixed to the inside of the control panel.
12. Panel grounding lug; compression type.
13. Hardwired emergency stop pushbutton.
    a. Accommodate an additional emergency stop signal from a pilot device located at the centrifuge skid.

I. LCP Centrifuge E-Stop Panel:
   1. A local control panel must be provided and installed by the Contractor for the centrifuge. This panel information is provided here to provide the information for the Centrifuge manufacturer. Control panel will include:
      a. E-Stop mushroom pushbutton.
      b. Enclosure: Stainless steel, NEMA 4X.
      c. Ability to shut down hydraulic backdrive as well.

J. Vibration monitoring
   1. Provide the following instrumentation:
      a. The main bearings shall be equipped with temperature sensors which monitor the temperature of the bearing race directly.
      b. The sensors shall be 100 ohm platinum RTDs. Monitoring of the oil temperature shall not be an acceptable method of protection for the bearings.
      c. The sensors shall be interlocked with the controls to shut down the centrifuge if excessive bearing temperatures are sensed.
      d. The bearing temperatures shall be displayed and monitored at the Centrifuge Control Panel.
         1) Main bearing RTDs shall be prewired to unit mounted termination box. Contractor shall provide all cable and conduit between termination box and Centrifuge Control Panel.
      e. Each centrifuge shall be equipped with a vibration monitoring system consisting of an accelerometer, digital display, alert alarm, danger alarm, and 4-20 mA output for remote monitoring of vibration levels. Manufacturer: Bentley Nevada 3500 Series or approved equal.
      f. Main motor winding temperature detectors per Section 16100 - Electrical Requirements.
      g. Back drive motor winding temperature detectors per 16100 - Electrical Requirements.

K. Provide additional instrumentation as required to allow monitoring and control as described herein.

2.12 CONTROLS

A. At a minimum, Centrifuge Control Panel functions shall provide for selection of the following modes of operation for the respective centrifuge:
   1. Local/Off Mode.
   2. Backdrive Control Mode: Torque/Differential.
   3. Centrifuge Auto Start/Stop.
   4. Centrifuge Maintenance Mode.
   5. Centrifuge Clean-in-Place (CIP) Cycle Start.
   6. Centrifuge Pause.

B. The Centrifuge Control Panel shall provide the following outputs to the PCS via Ethernet data network:
   1. Centrifuge Control Mode: Local/Off or System Maintenance.
   2. Centrifuge Status: Start-Up Cycle/Idle/Production/Stop Cycle/CIP Cycle/Off/Failed.
   3. Main drive running/stopped.

4. Main drive fail.
5. Backdrive running/stopped.
6. Backdrive fail.
7. Lubrication Oil-Air valve open/closed (if applicable).
8. Backdrive Control Mode: Torque/Differential.
9. Centrifuge differential speed (RPM).
10. Centrifuge torque.
11. Torque/Differential speed setpoint reached.
12. Emergency Stop status.
13. Centrifuge main bearings (2):
    a. Horizontal and vertical vibration (in/sec).
    b. Temperature.
14. UPS fault.
15. Digested Sludge Transfer (Centrifuge Feed) Pump Start/Stop request.
16. Polymer Feed Pump Start/Stop request.
17. Diverter Gate Status (Opened/Closed).
18. Polymer Dose Setpoint (lb active/dry ton).
19. Operating Centrifuge Power Consumption (kW).
20. Daily Totalized Centrifuge Energy Consumption (kWhr/day).
21. All alarms and other data recommended by manufacturer for safe operation.

C. The Centrifuge Control Panel shall accept the following inputs from the PCS via Ethernet data network:
1. Auxiliary Equipment Ready.
2. Centrifuge Feed Flow Setpoint (gpm).
3. Centrifuge Feed Flow Rate (gpm and lb/hr).
4. Polymer Dose Setpoint (lb active/dry ton).
5. Polymer Pump Speed (as percent).
6. Polymer Solution Flow Rate (gpm).
7. Processing Stop Time (hour of day for each day).
8. Diverter Gate Flush Valve position (Opened/Closed).
9. Centrifuge Flush Valve position (Opened/Closed).
10. Centrifuge Controlled Shutdown.
11. Refer to the Digital I/O table in the Drawings.

D. At a minimum, the Centrifuge Control Panel LOI shall display for its respective centrifuge:
1. Centrifuge Control Mode: Local/Off/Remote or System Maintenance.
2. Centrifuge Status: Start-Up Cycle/Idle/Production/Stop Cycle/CIP Cycle/Off/Failed.
3. Backdrive Control Mode: Torque/Differential.
4. Lubrication System Mode: Maintenance/Automatic.
5. Bowl Motor Amperage (amps).
6. Bearing Temperatures (degrees Fahrenheit): For all bearings.
7. Centrifuge Vibration Velocity (in/sec) for each bearing in the horizontal and vertical directions.
8. Scroll Motor Torque (as percent): Setpoint and Actual.
9. Scroll Motor Frequency (hertz).
10. Bowl Speed (rpm).
11. Scroll Speed (rpm).
12. Torque: Setpoint and Actual.

13. Differential Speed (rpm): Setpoint and Actual.
14. Backdrive Gear Shaft Speed (rpm).
15. Centrifuge Flush Valve Position (Opened/Closed).
16. Diverter Gate Position (Opened/Closed).
17. Operating Centrifuge Power Consumption (kW/hour).
18. Daily Totalized Centrifuge Power Consumption (kW/day).
19. Centrifuge Feed Pump: Running.
20. Centrifuge Feed Flow Setpoint (gpm).
21. Centrifuge Feed Flow Rate (gpm and lb/hr).
22. Polymer Blending Unit: Running.
23. Polymer Dose Setpoint (lb active/dry ton).
24. Polymer Pump Speed (as percent).
25. Polymer Solution (as Dilution Water Flow) Flow Rate (gpm).
26. Cake Conveyors Status: Running/Stopped/Reverse/Failed.
27. All alarms.
28. Specific shutdown conditions causing centrifuge system to shut down and result in Failed status.
29. All other data recommended by the manufacturer for safe operation.

E. At a minimum the following points shall be adjustable at the Centrifuge Control Panel LOI:
   1. Centrifuge Control Mode: Local/Off/Remote, System Maintenance, Start-Up Cycle, Idle, Controlled Shutdown, CIP, Off.
   2. Selection of Differential or Torque Control.
   3. Torque set point to close diverter gate during start-up.
   4. Speed set point to annunciate to PCS to provide sludge to centrifuge.
   5. Torque set point to open diverter gate during shutdown.
   6. Mode initiation and shutdown, including CIP, Start/Stop, Emergency Stop, and CIP.
   7. Time Delay set points during different Modes.
   8. Diverter gate position.
   9. All alarm setpoints.
   10. Any additional set points to optimize Centrifuge Operation and Control.

F. Control System Operation:
   1. Local/Off/Remote control shall be provided:
      a. Under Local:
         1) When the centrifuge Local/Off/Remote selector is in the Local position, and all ancillary systems are in remote and ready, the operator shall be able to Auto Start / Auto Stop the centrifuge at the LOI. The operator may also initiate CIP cycle from the LOI.
      b. Under Remote:
         1) When the Local/Off/Remote selector is in the Remote position, the centrifuge shall receive Auto Stop commands from PCS.
   2. System Maintenance Mode:
      a. Allows centrifuge operation for troubleshooting purposes only without initiating sludge feed or polymer feed. When in System Maintenance Mode, the sludge feed and polymer feed systems associated with the centrifuge shall be shut down and not allowed to start.

b. Under maintenance mode:
    1) The oil/air system, if applicable, can be started at the Start button on the maintenance screen and will remain active until expiration of a timer or upon release of Start button.
    2) The main drive for the bowl can be started by pressing and holding the bowl main drive motor button on the maintenance screen.
    3) The backdrive for the scroll can be started by pressing and holding the scroll backdrive motor button on the maintenance screen.

G. Start-up (Auto Sequence):
1. The operator presses “Auto Start” key at the Centrifuge Control Panel LOI.
2. PCS signals that all auxiliary systems are in Auto and Ready.
3. The Centrifuge PLC sends signal it is ready to start.
4. The Centrifuge starts lubrication system, bowl, and scroll, and signals the PCS to start sludge feed pumps and polymer blenders (sludge/polymer feed start request).
5. Before setpoint torque is reached, diverter gate shall remain closed and diverter flush valve shall remain open.
6. Upon reaching the torque or differential set point the Centrifuge opens the diverter gate and closes the diverter flush valve.
7. If sludge feed does not arrive within a manufacturer determined time period, the Centrifuge PLC shall enter Idle mode. After 15 minutes of no sludge (or other time as determined by Centrifuge Manufacturer to prevent damage to the centrifuge), the Centrifuge PLC shall enter a Normal Stop.

H. Normal Stop (Auto Sequence):
1. A normal stop will be initiated when the operator presses the “Auto Stop” pushbutton at the LOI or PCS workstation or upon operator-input Processing Stop time per day. See Local and Remote Control for the pushbutton availability.
2. Upon initiation of “Auto Stop”, the following stop sequence will occur:
    a. The Centrifuge PLC shall send a shutdown signal to PCS.
    b. PCS will signal Centrifuge PLC that polymer blender(s) and digested sludge transfer pumps are OFF (sludge feed stop request).
    c. Upon reaching torque or differential set point the Centrifuge PLC will close the diverter gate and open the slop flush valve.
    d. The Centrifuge will initiate CIP clean cycle.
    e. The Centrifuge PLC shall stop the oil/air lubrication system (if applicable).
    f. Upon completion of a shutdown, the Centrifuge PLC shall send “Stopped” status to PCS.

I. Clean-In-Place (CIP) Procedure:
1. This procedure is used for optimal cleaning of the centrifuge and used during shutdown. The operator can start the CIP run cycle anytime the main drive motor is at rest and all faults are cleared.
2. The operator presses a “CIP Start” key at the operator interface to begin the CIP cycle. The Centrifuge PLC shall start the CIP procedure and send “CIP in Progress” status to PCS.
3. The Centrifuge PLC closes the diverter gate.
4. The process continues until the predetermined overall time ends, the operator presses the “CIP Stop” key, or a fault occurs. Any shutdown shall terminate

the CIP cycle. When complete, the Centrifuge PLC indicates “CIP Complete” to PCS.

5. The Centrifuge PLC sends open/close signals to the respective centrifuge flush valve as necessary during the cycle.

J. Controlled Shutdown:
   1. A controlled shutdown will be initiated upon specific alarm conditions within the Centrifuge Control Panel.
   2. Alarm conditions that may trigger controlled shutdown and a common failure alarm shall be transmitted to the PCS. Specific alarm conditions that will trigger this type of shutdown shall be coordinated with the manufacturer during submittal review:
      a. High-High Temperature for Liquid Side Main Bearing.
      b. High-High Temperature for Solids Side Main Bearing.
      c. High Bowl Speed.
      d. Low Bowl Speed.
      e. Low Differential Speed.
      f. Main Motor Breaker Tripped.
      g. Main Motor VFD Fault.
      h. High Temperature for Main Motor Winding.
      i. High-High Torque.
      j. High-High Vibration.
      k. Other alarm conditions shall as recommended by the Centrifuge Manufacturer and approved by the Owner and Engineer.
   3. Upon initiation of one of these alarm conditions, the following shutdown sequence will occur:
      a. The Centrifuge PLC shall send a stop request to the PCS (sludge feed stop request).
      b. The Centrifuge PLC shall start the centrifuge shutdown timer. The PLC shall stop the main drive motor and the bowl will coast to a stop.
      c. The Centrifuge PLC shall start the flush water sequence and flushing shall continue until expiration of flushing water duration timer. Sequence shall include opening and closing of flush water valves by the PLC.
      d. The Centrifuge PLC shall close the diverter gate when torque is below a setpoint value. The Centrifuge PLC starts the flushing cycle for the out-of-spec sludge.
      e. Once the centrifuge shutdown timer expires and the bowl speed is less than a specific value, the Centrifuge PLC shall stop the backdrive motor.
      f. The Centrifuge PLC shall stop the oil/air lubrication system (if applicable).
      g. The Centrifuge PLC shall signal the PCS when the centrifuge is stopped.

K. Immediate Shutdown:
   1. An immediate shutdown will be initiated upon specific alarm conditions.
   2. Alarm conditions that trigger immediate shutdown and a common failure alarm to be transmitted to the PCS system for centrifuge failure:
      a. Backdrive Motor Breaker Tripped.
      b. Backdrive Motor VFD Fault (or Hydraulic Power Unit Fail).
      c. High Temperature for Backdrive Motor Winding.
      d. Backdrive Motor Run Failure.
      e. Others as recommended by the Centrifuge Manufacturer.

3. Upon initiation of one of these alarm conditions, the following shutdown sequence will occur:
    a. The Centrifuge PLC shall send a “stop” command to the PCS (sludge feed stop request).
    b. The Centrifuge PLC shall stop the main drive motor and the bowl will coast to a stop. The Centrifuge PLC shall stop the backdrive motor and the scroll will stop.
    c. The Centrifuge PLC shall close the diverter gate when torque is below a setpoint value.
    d. The Centrifuge PLC shall stop the oil/air lubrication system (if applicable).
    e. The Centrifuge PLC shall signal the PCS that the centrifuge is stopped.

L. Emergency Shutdown:
1. Emergency shutdown will be issued with the E-stop pushbutton at the Centrifuge Control Panel, Centrifuge Starter Panel, local E-stop, or through the PCS. The centrifuge main and backdrives will come to a complete stop immediately as well as all auxiliary equipment (lubrication system).
2. The Centrifuge PLC shall send a “stop” command to the PCS (sludge feed stop request).
3. The Centrifuge PLC stops the inline mixer.
4. The Centrifuge PLC will signal to the PCS that the centrifuge is emergency stopped (e.g., Emergency Stop status).

2.13 SOURCE QUALITY CONTROL

A. Abrasion Testing: Centrifuge Manufacturer shall submit a certified test report from a qualified independent laboratory demonstrating that the abrasion resistant materials used on the wear face meet the following requirements:
1. A typical full-size sample of the materials used to protect the tips of the conveyor in the area from the feed zone to the solids discharge ports, the feed nozzle, and solid discharge inserts shall be submitted to a qualified laboratory. To be considered qualified, the laboratory must be independent and have apparatus qualified in accordance with ASTM G 65.
2. The qualifying test procedure is ASTM G 65, Procedure A, Standard Practice for Conducting Dry Sand/Rubber Wheel Abrasion Tests. This procedure ranks materials in their relative order of merit in an abrasion environment. Abrasion tests are reported as volume loss in cubic millimeters under a specific set of conditions. Materials of higher abrasion resistance have a lower volume loss.
3. Sintered tungsten carbide tiles shall be tested in accordance to ASTM G 65, Test Procedure A. The maximum volumetric loss not exceed 2 cubic millimeters on the scroll tile test specimen and 2 cubic millimeters on all other test specimens.

B. Factory Mechanical Performance Testing:
1. Shop testing shall be performed with the centrifuge to be provided, including its own drive motor, backdrive system and lube system. Shop testing of starter and control panels must be performed at their respective manufacture facilities.
2. General Performance Test shall be done to Level 3 requirements as specified in Section 15958 - Mechanical Equipment Testing.

3. Vibration Test shall be done to Level 3 requirements as specified in Section 15958 - Mechanical Equipment Testing. Vibration testing shall include:
   a. 4-hour test with bowl filled with water at operating bowl speed.
4. Noise Test shall be done to Level 2 requirements as specified in Section 15958 - Mechanical Equipment Testing.
5. Centrifuge Manufacturer shall provide written and certified Factory Mechanical Performance Test Report.
6. Test shall be not be witnessed by Owner.

C. Factory Instrumentation Acceptance Testing:
   1. The CCP and CSP shall be factory acceptance tested in accordance with Section 17100 - Control System Requirements.
      a. Centrifuge Control Panel and Centrifuge Starter Panel inputs and outputs shall be demonstrated along with system response and control from simulated inputs or commands.

D. Instrumentation and Controls Meeting:
   1. In addition to the field services required, the Centrifuge Manufacturer shall provide a qualified instrument and controls engineer or programmer to coordinate with the City's Programmer during construction for the following.
      a. Pre-Construction Meeting:
         1) To be scheduled once the submitted equipment has been reviewed and approved by the Engineer.
         2) Meeting to coordinate all controls required from and to centrifuge vendor control panels to PCS. Centrifuge Manufacturer shall share LOI screens and data tables with City's Programmer for duplication at PCS for monitoring.
         3) Minimum 1 trip, 4 hours.
      b. Programming Coordination.
         1) The same programmer assigned to the Pre-Construction Meeting shall provide a minimum of 40 hours telephone or electronic support or the integration of the PCS with the Centrifuge Control Panel.

PART 3 EXECUTION

3.01 PREPARATION

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

3.02 INSTALLATION

A. Centrifuges shall be installed in strict accordance with the manufacturer's written installation instructions.
   1. Centrifuges shall be installed under observation of Centrifuge Manufacturer.
   2. The Contractor shall install all electrical, instrumentation, and piping connections with inspection performed by the Centrifuge Manufacturer.

B. Apply finish coat in the field to the centrifuge exterior surfaces as specified in Section 09960 - High-Performance Coatings.

C. Operational Instructions and Training:
   1. The Centrifuge Manufacturer shall provide the services of a factory-trained and certified service representative to provide a minimum of 16 hours on site "hands on" training to the Owner's personnel in accordance with Section 01660 - Equipment and System Performance and Operational Testing and the requirements specified in this Section. Representative must allow Owner staff to witness Optimization and Min/Max Testing as additional to this training time. The Centrifuge Manufacturer shall submit a course outline plan, 3 months before training starts, with proposed class material and class schedule to the Owner for approval. Training will begin only if the class material and class schedule have been reviewed and approved by the Owner.
   2. Subjects of instruction shall include the following:
      a. Start-up procedures.
      b. Shutdown procedures.
      c. Troubleshooting.
      d. Selection of proper polymer types and dosages.
      e. Operating adjustments for performance optimization.
      f. Preventative maintenance.
      g. Maintenance procedures.
      h. Emergency procedures.
      i. Record keeping.
      j. Mechanical unit function and description.
      k. Variable frequency drives.
      l. System controls.
   3. Training: As defined in Section 01660 - Equipment and System Performance and Operational Testing and this Section:
      a. Operations: 4-hour class, 2 sessions.
      b. Mechanical Maintenance: 4-hour class, 1 session.
      c. Combined Electrical and I&C Maintenance: 4-hour class, 1 session.

3.03 FIELD QUALITY CONTROL, TESTING, AND INSPECTION

A. All test requirements listed in the Section are in addition or in complement to those listed in Section 01660 - Equipment and System Performance and Operational Testing.
   1. Manufacturer to provide special testing equipment to satisfy field testing requirements.

B. Factory-Certified Manufacturer's Representative:
   1. Each centrifuge shall undergo general, start-up, guaranteed performance acceptance testing (GPAT), optimization testing, and min/max testing.
   2. Each centrifuge must undergo start-up and GPAT separately.
   3. Contractor to coordinate field service work with the manufacturer's service representative, Owner, and Engineer prior to initiation such work.
   4. The Centrifuge Manufacturer shall furnish the services of a factory-trained and certified service representative experienced in the installation and operation of dewatering centrifuge.

5. Provide a minimum of the support requirements detailed in the tables below (exclusive of travel time):

Services Provided by Factory-trained and Certified Service Representative	Minimum Number of Trips	Minimum Time on Site per Trip (Hours)	Minimum Run Time (Hours)(1)
Centrifuge Installation	1	8	-
General Testing	1	8	4
Start-Up Testing	1	16	16
GPAT	1	32	32
Optimization Testing	1	8	8
Min/Max Testing	1	8	4 (2 per condition)
Training	1	16	Refer to Article 3.02, Paragraph C

Note:
1. Maximum of 8 hours per day.
2. Trainer to allow Owner witness of Optimization Testing/Min/Max Testing as additional to this training.

C. General Testing Requirements:
   1. In addition to the Start-Up and GPAT requirements below, the following testing shall be also be conducted:
      a. General Performance Test shall be done to Level 3 requirements as specified in Section 15958 - Mechanical Equipment Testing.
      b. Vibration Test shall be done to Level 3 requirements as specified in Section 15958 - Mechanical Equipment Testing. Vibration testing shall include:
         1) 4-hour test with bowl filled with water at operating bowl speed.
      c. Noise Test shall be done to Level 2 requirements as specified in Section 15958 - Mechanical Equipment Testing.
   2. Centrifuge Manufacturer shall provide written and certified Field Testing Report for all tests.

D. Start-Up Testing:
   1. The Centrifuge Manufacturer shall submit a start-up test procedure through the Contractor Test Engineer and schedule to the Owner for approval. Start-up will begin only if the start-up test procedure and schedule have been reviewed and approved by the Owner. The Centrifuge Manufacturer, Centrifuge Manufacturer's factory-trained and certified service representative, Owner's personnel, and Engineer shall be present for start-up testing.
   2. The Centrifuge Manufacturer's factory-trained and certified service representative shall be available on site for the tuning, monitoring, inspection, optimization, and restarting of each centrifuge during the entire start-up test duration.

3. The start-up procedure shall include:
    a. To begin initial start-up, each centrifuge shall be tuned and adjusted to undergo operation.
        1) For start-up, the Owner will provide (at the Owner's expense) personnel, sludge feed, polymer, water, dewatered sludge hauling and disposal, and electrical power.
        2) Owner shall provide up to two 275-gallon totes of neat polymer for start-up.
        3) Centrifuge Manufacturer shall select the neat polymer to be supplied by the Owner a minimum of 8 weeks prior to scheduled startup. Subsequent to proper tuning, an initial thorough inspection of all system components, including electrical and instrumentation controls, will be performed.
        4) Faulty components found during initial inspection shall be repaired or replaced within 48 hours by the Centrifuge Manufacturer at no cost to the Owner.
        5) Subsequent to initial inspection, each centrifuge shall be operated for a minimum of 16 hours of aggregate operation.
        6) If no malfunctions occur during the 16 hours of aggregate operation, the initial start-up testing shall be deemed complete.
    b. If malfunctions occur during the 16 hours of aggregate operations, the Centrifuge Manufacturer shall perform corrective action within 48 hours and restart the centrifuge for a minimum of 24 hours of additional aggregate operation (maximum 8 hours per day).
        1) If no problems are evident during the 24 hours of subsequent operation, the startup testing shall be deemed complete.
        2) If additional polymer is required for this additional testing, Contractor shall provide the necessary polymer.
    c. If malfunctions occur during the 24 hours of subsequent aggregate operation, the Centrifuge Manufacturer shall once again perform corrective action within 48 hours and restart the centrifuge for a minimum of 24 hours of additional aggregate operation.
        1) If additional polymer is required for this additional testing, Contractor shall provide the necessary polymer.
        2) This procedure shall be repeated until the start-up testing has been completed successfully.
        3) All additional start-up tests shall follow the same procedures as specified above and be subject to Owner's approval.
        4) The satisfactory completion of the start-up test shall be at the sole discretion of the Owner.

E. Guaranteed Performance Acceptance Testing:
    1. The Centrifuge Manufacturer shall submit a detailed procedure through the Contractor Test Engineer for the GPAT to the Owner for approval.
        a. This includes, but is not limited to, sample collection plan/schedule, example data summary sheets, and calculations to be used for development of test results.

2. The GPAT will be subject to facility construction, shut down, water production, and sludge availability.
    a. For the initial GPAT of each centrifuge, the Owner will provide (at the Owner's expense) personnel, sludge feed, polymer, dewatered sludge hauling and disposal, water, and electrical power.
    b. The Centrifuge Manufacturer shall provide personnel and all test equipment, including instruments and analyzers to facilitate the testing of each centrifuge.
    c. Owner shall provide up to four 275-gallon totes of neat polymer for GPAT testing.
    d. All polymer for the GPAT testing will be Polydyne Clarifloc WE-2634 and Owner shall be notified of selection a minimum of 8 weeks prior to GPAT.
    e. The Centrifuge Manufacturer, Centrifuge Manufacturer's factory-trained and certified service representative, the Owner's personnel, and Engineer shall be present for the GPAT testing described as follows.
3. To begin GPAT, the Centrifuge Manufacturer shall operate the centrifuge for 8 continuous hours per day over a period of 4 working days. During this time period, the Centrifuge Manufacturer will collect all required samples and document system performance.
4. The centrifuge system performance during GPAT shall meet or exceed the minimum performance requirements as defined within these specifications.
5. If, in the opinion of the Engineer, the GPAT results do not meet the performance requirements, the Owner or his designated representative shall notify the Contractor in writing of the non-acceptable performance.
6. In the case of non-acceptable performance, the Centrifuge Manufacturer shall then have 60 days in which to perform, at his expense, any supplemental testing, equipment adjustments, changes, or additions and request additional retest of the non-acceptable system. The Contractor shall notify the Engineer 5 days prior to the commencement of the retest.
7. Neat polymer required for GPAT retests shall be provided by the Centrifuge Manufacturer at his expense.
8. The cost of all laboratory tests necessary to confirm the dewatered sludge characteristics for the guaranteed performance acceptance tests for each centrifuge system shall be borne by the Centrifuge Manufacturer. All tests shall be carried out by a certified laboratory. The testing data shall be submitted to the Engineer for approval. All testing shall be carried out by a certified laboratory, approved by the Engineer.

F. Optimization Testing:
1. The Optimization Testing shall be carried out on one centrifuge after the GPAT. To begin Optimization Testing, the Centrifuge Manufacturer shall operate one centrifuge for 8 continuous hours per day over a period of 1 working day. Optimization Testing will be on only 1 centrifuge. During this time period, the Centrifuge Manufacturer will collect all required samples and document system performance. Owner (at Owner's cost) will provide all neat polymer.
2. Performance curves shall be developed based on the data generated during the optimization testing period.
    a. Performance curves shall show how dewatered sludge cake concentration and capture efficiency vary with polymer dose by plotting polymer dose

(pounds of active polymer per dry ton of solids) on the x-axis, cake solids on the y-axis, and capture efficiency on the secondary y-axis.
    1) The feed rate and operating torque shall be constant.
    2) At least 3 curves shall be developed. At least five consecutive points shall be plotted for each curve.
    3) Polymer dose shall be varied until the cake dryness and percent capture drop 20 percent below the minimum specified performance parameters and until cake dryness and percent capture exceed the minimum specified performance parameters by 10 percent.

b. Performance curves shall show how dewatered sludge cake concentration and capture efficiency vary with torque by plotting torque as a percentage of maximum torque on the x-axis, cake solids on the y-axis, and capture efficiency on the secondary y-axis.
    1) The feed rate and polymer dose shall be constant. Polymer dose shall be set at that value required to achieve the minimum specified performance parameters for cake dryness and percent capture.
    2) At least three curves shall be developed. At least 5 consecutive points shall be plotted for each curve.
    3) Torque shall be varied until the cake dryness and percent capture drop 20 percent below the minimum specified performance parameters and until cake dryness and percent capture exceed the minimum specified performance parameters by 10 percent.

G. Sampling and Analysis:
1. During Start-Up Testing, the centrifuge shall have its feed sludge, centrate and cake sampled at 2 different times (4 total samples). Testing, calculations and analysis required for collected samples as described herein.
2. During each day of GPAT and Min/Max Test, a minimum of 5 samples and related tests per centrifuge per day shall be required. Testing, calculations and analysis required for collected samples as described herein.
3. Contractor must provide sampling containers and coordinate lab analysis on behalf of the Centrifuge Manufacturer. Contractor shall be responsible for logistics of sample transport to laboratory and ensuring all testing is conducted and results are provided in a timely manner. Centrifuge Manufacturer shall collect all samples and store per requirements of Standard Methods.
4. Data collected during each test run shall include, as a minimum:
    a. Run number.
    b. Date.
    c. Time.
    d. Feed sludge percent total solids (TS), percent of TS (daily composite).
    e. Sludge feed rate, gpm.
    f. Polymer name.
    g. Polymer percent active, percent.
    h. Polymer density, pound per gallon.
    i. Polymer feed rate (neat), gph.
    j. Bowl speed, rpm.
    k. Scroll speed differential, rpm.
    l. Torque, percent.
    m. Amperage draw by the main drive, amps.
    n. Amperage draw by the scroll drive, amps.

o. Centrate percent total solids, percent of TS (= Centrate Total Suspended Solids Concentration in mg/L / 10,000 mg/L).
p. Cake percent total solids, percent of TS.

5. Provide calculated values for the following:
   a. Solids throughput, pounds TS per hour.
   b. Polymer dosage, active pound per dry ton TS.
   c. G force, g's and associated G-volume.
   d. Percent Solids Capture, percent, calculated as defined above
6. Solids concentrations shall be determined using "Standard Methods for the Examination of Water and Wastewater."
   a. Method 2540 G. Total solids in solid and semisolid samples for percent TS.
   b. Method 2540 D. Total suspended solids for TSS.

H. Post-start-up field visit:
   1. The Centrifuge Manufacturer shall coordinate with Owner to provide 1 post-start-up field visit within 90 days following Substantial Completion.
   2. The Centrifuge Manufacturer shall furnish the services of a factory-trained and certified service representative experienced in the installation and operation of dewatering centrifuge for a post-start-up field visit.
      a. Provide a minimum of the support requirements detailed in the table below (exclusive of travel time):

Services Provided by Factory-Trained and Certified Service Representative	**Minimum Number of Trips**	**Minimum Time on Site (Hours)**
Post-Start-Up Field Visit	1	16

END OF SECTION

SECTION 11372C

ROTARY SCREW AIR COMPRESSOR SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Rotary screw air compressor system.

B. Equipment tag numbers:
   1. As scheduled.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME).

B. International Organization for Standardization (ISO):
   1. 1217 - Displacement Compressors - Acceptance Tests.

C. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

D. Underwriters Laboratories, Inc. (UL):
   1. 508 - Standard for Industrial Control Equipment.
   2. 508A - Standard for Industrial Control Panels.

1.03 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Anchoring and bracing.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product Submittals:
   1. As specified in Section 01600 - Product Requirements.
   2. Product data.
   3. Shop Drawings.
      a. Vendor control panel (VCP):
         1) Wiring diagrams.
   4. Calculations.

C. Delegated Design Submittals:
   1. Anchoring and bracing: Provide project-specific calculations based on support conditions and requirements to resist loads specified in Section 01850 - Design Criteria.
      a. To structures for equipment installed in structures designated as seismic design category C, D, E, or F.
      b. For equipment installed outdoors.

D. Installation instructions:
   1. Detail the complete installation of the equipment including rigging, moving, and setting into place.
   2. Provide manufacturer's installation instructions.

E. Quality Control Submittals:
   1. Manufacturer's representative qualifications.
   2. Manufacturer's Certificate of Installation as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   3. Manufacturer's Certificate of Functional Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

F. Owner Training Submittals:
   1. As specified in Section 01660 - Equipment and System Performance and Operational Testing.

G. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

1.05 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements, Section 15050 - Common Work Results for Mechanical, and the manufacturer's instructions.

1.06 PROJECT OR SITE CONDITIONS

A. As specified in Section 01850 - Design Criteria.

1.07 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements and Section 15050 - Common Work Results for Mechanical Equipment.

B. System components:
   1. Air compressors.

2. Air dryers.
3. Air receivers.
4. Air filters.
5. Appurtenances.

2.02 MANUFACTURERS

A. As listed below for each type of equipment.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:
   1. Design equipment for environmental requirements as specified in Section 01850 - Design Criteria.
   2. Package system:
      a. Rated for continuous duty operation
   3. Air compressors:
      a. Type: Positive displacement, lubricated rotary screw.
   4. Air dryers:
      a. Type: Direct expansion refrigerated.
      b. Refrigeration capacity control: Design valve to control flow of refrigerant to evaporator to maintain design compressed air dew point and prevent dryer freeze-up under conditions of variable load from 0 percent to 100 percent of full capacity.
   5. Air receiver:
      a. Type: Vertical.
      b. Size: 200-gallon minimum.
      c. Design working pressure: 250 pounds per square inch gauge minimum at 450 degrees Fahrenheit.
      d. Certification: ASME stamped, National Board registered.
   6. Air filters:
      a. Type: In-line interceptor type, and in-line coalescing type.
      b. Rated pressure: 250 pounds per square inch gauge at 175 degrees Fahrenheit.

B. Performance requirements:
   1. Air compressors:
      a. Rated free air delivery: 46 cubic feet per minute minimum.
      b. Rated discharge pressure: 125 pounds per square inch gauge minimum.
      c. Coolant carryover: 5 parts per million maximum, downstream of aftercooler.
      d. Free-field sound level: 75 dBA maximum at any point 3 feet from compressor enclosure.
      e. Rate performance in accordance with acceptance test standard ISO 1217, based on 35 to 115 degrees Fahrenheit ambient, 14.4 pounds per square inch absolute, 80 degrees Fahrenheit cooling air temperature.
      f. Design aftercooler to cool compressed air to maximum of 15 degrees Fahrenheit above ambient temperature.
   2. Refrigerated air dryers:
      a. Rated capacity: 46 standard cubic feet per minute.
      b. Rated pressure dew point: 36 within 3 degrees Fahrenheit.

c. Rating conditions: 100 degrees Fahrenheit inlet temperature, 100 pounds per square inch gauge inlet pressure, 100 percent relative humidity, 100 degrees Fahrenheit ambient temperature, and 5 pounds per square inch gauge maximum pressure drop.

2.04 ROTARY SCREW AIR COMPRESSORS

A. Manufacturers: One of the following or approved equal as determined by the City Engineer:
   1. Kaeser SM 10T (basis of design).

B. Materials:
   1. Rotors: Forged steel.
   2. Rotor housings: Cast iron.
   3. Base: Carbon steel.

C. Components:
   1. Air inlet filter: Dry type, 99.9 percent removal efficiency on particles 3 microns and greater.
   2. Air end: Single stage, rotary screw.
   3. Bearings: Antifriction roller and tapered roller type, sized for maximum radial and thrust loads.
   4. Shaft seal: Triple lip type.
   5. Motor:
      a. Provide motors as specified in Section 16100 - Electrical Requirements and as specified in this Section.
      b. Horsepower: 10 minimum.
      c. Synchronous speed: 3,600 revolutions per minute.
      d. Enclosure: TEFC.
      e. Electrical characteristics: 460 volts, 3-phase, 60 hertz.
      f. Efficiency, service factor, insulation, and other motor characteristics: As specified in Section 16100 - Electrical Requirements .
      g. Motor accessories: As specified in Section 16100 - Electrical Requirements .
      h. Belt drive: As specified in Section 15050 - Common Work Results for Mechanical Equipment.
   6. Cooling system:
      a. Type: Recirculating coolant, air-cooled.
      b. Coolant: Provide food-grade coolant.
      c. Coolant filtration: Replaceable element with pressure by-pass.
      d. Coolant temperature control: Thermostatic control valve.
      e. Coolant/air separator: Provide 2-stage factory-mounted ASME separator with drain and fill ports, and sight level indicator.
      f. Aftercooler: Air-cooled, aluminum tube and fin type, integrally factory-mounted.

D. Accessories:
   1. Pressure relief valve: Factory-installed, sized as required for system protection.
   2. Flexible pipe connectors: Provide as required for connecting to existing piping.

E. Fabrication:
   1. Provide compressor package on a rigid steel base for base-mounted installation.
   2. Provide sound-insulated enclosure for compressor package as required to meet specified noise limits.
   3. Ship compressor package completely assembled, pre-wired and pre-piped, requiring only connection of power supply wiring, and discharge piping.

F. Finishes:
   1. Factory standard finish.

2.05 REFRIGERATED AIR DRYERS

A. Manufacturers: The following or equal:
   1. Ingersol-Rand Co., DXR Series.

B. Components:
   1. Refrigeration system:
      a. Compressor: Hermetic.
      b. Condenser: Air-cooled.
      c. Liquid refrigerant filter dryer, include the following:
         1) Constant pressure valve: Design for refrigeration capacity control.
         2) Refrigerant: Charge system with R134a or R513a.
   2. Compressor motor:
      a. Horsepower: 1/2.
      b. Voltage: 115 VAC.
      c. Cycles: 60 hertz.
      d. Phase: 1.
   3. Heat exchangers:
      a. Provide precool/reheat section to reheat cooled dry air and precool inlet air.
      b. Non fouling copper tube construction.
      c. Encapsulate in flexible closed cell insulation.
   4. Moisture separator:
      a. Factory installed centrifugal type.
      b. Insulated.
      c. Provide with electronically controlled automatic drain valve.

C. Electrical:
   1. UL approved components.
   2. NEMA Type 1 enclosure.
   3. Provide normally closed dry contact rated 5 amps, 120 volts, for remote indication of occurrence of Alarm, Warning, or Service, due status of dryer.

D. Fabrication:
   1. Provide dryer package on a rigid steel base for base-mounted installation.
   2. Provide sheet metal enclosure for dryer package.
   3. Ship dryer package completely assembled, pre-wired and pre-piped.

E. Finishes:
   1. Factory standard finish.

2.06 AIR FILTERS

A. Manufacturers: The following or equal:
   1. Finite Filter Division, Parker Hannifin Corp. H-Series.

B. Materials:
   1. Housing: Metallic.
   2. Element - interceptor type: Pleated cellulose.
   3. Element - coalescing type: Glass fiber.

C. Components:
   1. Housing: 2-piece, with threaded bowl to head.
   2. Elements: Replaceable. With resilient end seals.

D. Accessories:
   1. Drain trap: Internally mounted automatic mechanical type.
   2. Differential pressure indicator.

2.07 ANCHOR BOLTS

A. As specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.

2.08 VENDOR CONTROL PANELS

A. General:
   1. Provide a separate control panel for each compressor and air dryer.
   2. Provide components and equipment with UL 508 listing.
   3. Provide control panels with a UL 508A label.
   4. VCP shall be fully functional, wired, and factory tested prior to shipment.
      a. Provide field wiring terminal strips for external connections.
      b. Additional testing requirements as specified in Section 17100 - Control System Requirements
   5. Provide surge protection on the incoming power feed.
   6. Provide necessary control hardware, software, and components as required for a fully functional and operational installation.

B. Rotary screw air compressor(s):
   1. Provide microprocessor-based VCP mounted on compressor.
   2. Power supply:
      a. 480 VAC, 3-phase, 60 hertz.
   3. Enclosure: NEMA Type 4.
   4. Motor starter with overload protection.
   5. Control power transformer:
      a. VCP will be powered by a single power source. Provide a control power transformer as required.
      b. Primary voltage: 480 VAC, 3-phase, 60 hertz.
      c. Secondary voltages:
         1) 120 VAC for controls.
         2) Derive additional voltages as required by the application.
         3) Sized for all panel components plus 10 percent spare capacity.

4) Primary and secondary fuses.

6. Controls:
   a. Emergency stop pushbutton.
   b. Display screen with pushbutton controls.
   c. Indicators:
      1) Elapsed time hour meter.
      2) Pressure.
      3) Status:
         a) Power On.
         b) Ready.
         c) Running.
      4) Alarms:
         a) Motor overload.
         b) High discharge air temperature.
7. Monitoring and control:
   a. Dry contact rating: 24 VDC @ 6 A.
   b. VCP outputs:
      1) Status:
         a) Running.
      2) Alarms:
         a) Compressor Fail.
8. Control functions:
   a. Factory installed, load/unload control with time-delayed auto stop and start:
      1) Factory-set adjustable time delay to prevent excessive motor cycling.
      2) Factory installed, adjustable dual pressure switch for load/unload and auto start operation:
         a) Provide adjustment scale to facilitate pressure switch adjustment.
   b. Provide safety shutdowns for:
      1) High discharge air temperature.
      2) Motor overload.

C. Refrigerated air dryer(s):
   1. Provide microprocessor-based VCP mounted on the dryer enclosure.
   2. Power supply:
      a. 120 VAC, 1-phase, 60 hertz.
   3. Pilot devices:
      a. Controls:
         1) On-Off selector switch.
      b. Indicators:
         1) Elapsed time hour meter.
         2) Inlet air temperature.
         3) Refrigerant suction temperature.
         4) Refrigerant discharge temperature.
         5) Ambient air temperature.
         6) Status:
            a) Power On.
            b) Running.
         7) Alarms:
            a) Alarm:
               (1) High/low temperature of inlet air.
               (2) High/low temperature of ambient air.

(3) High/low temperature of refrigerant.
b) Warning:
(1) High discharge air dew point.
c) Service due:
(1) Pre-programmed maintenance schedule.

4. Monitoring and control:
   a. Dry contact rating: 24 VDC @ 6 A.
   b. VCP outputs:
      1) Status:
         a) Running.
      2) Alarms:
         a) Dryer Alarm.
         b) Dryer Warning.
         c) Dryer Service Due.
5. Control functions:
   a. Timer adjust controls for open/close operation of the automatic drain valve.
   b. Provide safety shutdowns for:
      1) Motor overload.
      2) High refrigerant pressure.

2.09 SPARE PARTS AND SPECIAL TOOLS

A. Spare parts:
   1. For each compressor furnished, provide the following:
      a. 2 sets of air intake filters.
      b. 2 lubrication oil filter cartridges.
      c. 1 set of drive belts.
      d. Coolant, quantity equal to 2 coolant changes.
   2. For each dryer furnished, provide the following:
      a. 1 automatic drain valve.
   3. For each air filter, provide the following:
      a. 2 elements.
      b. 1 automatic drain valve.

2.10 SOURCE QUALITY CONTROL

A. Source Testing (Factory Acceptance Tests):
   1. Not witnessed.
   2. Test as specified in Section 15958 - Mechanical Equipment Testing.
   3. Air compressor:
      a. Test witnessing: Not witnessed.
      b. Conduct Level 1 General Equipment Performance Test.
      c. Conduct Level 1 Vibration Test.
      d. Conduct Level 1 Noise Test.
   4. Tank:
      a. Not witnessed.
      b. Conduct Level 1 General Equipment Performance Test.
   5. Furnish test reports and Manufacturer’s Certificate of Source Testing.

PART 3 EXECUTION

3.01 PREPARATION

A. Anchoring and bracing to structures:
   1. Prepare equipment anchor setting template(s) and use to position anchors during construction of supporting structure(s).
   2. Install anchors of type and material indicated on approved anchoring designs.
   3. Install anchors with embedment indicated on approved anchoring designs.

3.02 INSTALLATION

A. Install condensate drain lines from moisture drain traps to nearest floor sink or drainage groove.

B. Install the equipment in accordance with the accepted installation instructions and anchorage details.

3.03 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, Section 15958 - Mechanical Equipment Testing, and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Source Testing.
      b. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements:
      a. Installation: 1 trip, 2-day minimum.
      b. Functional Testing: 1 trip, 2-day minimum each trip.
   3. Training: As defined in Section 01660 - Equipment and System Performance and Operational Testing and this Section:
      a. Maintenance: 4 hours per session, 2 sessions.
      b. Operation: 2 hours per session, 2 sessions.

C. Functional Testing:
   1. Witnessed.
   2. Test as specified in Section 15958 - Mechanical Equipment Testing.
   3. Air compressor system:
      a. Conduct Level 2 General Equipment Performance Test.
      b. Conduct Level 2 Vibration Test.
      c. Conduct Level 2 Noise Test.
   4. Furnish Manufacturer's Certificate of Functional Compliance.

3.04 SCHEDULES

Equipment	Tag Number
Air Compressor	DIG-CMP-07-591 DIG-CMP-07-592

END OF SECTION

SECTION 11395A

PACKAGED ODOR CONTROL SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. The work specified shall include furnishing all labor, design, materials, equipment, incidentals and testing of all equipment and materials necessary to provide the Owner with completely operational 2-stage packaged odor control system consisting of a primary-stage biotrickling filter system with second-stage activated carbon media scrubber, including requirements for system construction, components, materials, functional testing, quality and use for removal of hydrogen sulfide (H_2S) from the blend tanks as specified herein and indicated on the plans.

B. All materials, products, or devices shall be new and unused.

C. Unit responsibility: Contractor shall assign the scope of the odor control systems to an Odor Control Supplier (OCS) who shall have the single source responsibilities for providing the components described herein including design, fabrication, assembly, delivery, supervision of installation, startup and testing of the system and related accessories and appurtenances.
   1. However, Contractor shall have overall responsibilities of the odor control system and shall provide any other components and services that are not provided by the OCS but required for a complete operable system as specified and indicated on the drawings.

D. The OCS scope responsibilities shall include but not limited to the following components:
   1. Two FRP vessels for each scrubber stage (stage 1 and stage 2) with access hatches and decks and associated internal and external appurtenances.
   2. One Biotrickling filter system (stage 1).
      a. Irrigation spray nozzles and associated system assemblies.
      b. Water control panel including actuated valves, nutrient pump, pH probe and flow meters.
      c. Recirculation pump including pressure gauges and flow meter.
   3. Two FRP fans and associated VFDs.
   4. One activated carbon media scrubber (stage 2).
   5. Instruments, not limited to thermal mass flow meter, H2S gas sensor/analyzers
   6. Interconnecting FRP ductwork, dampers, flexible connections, and other components from the inlet damper at the odor control fan up to and including the final exhaust stacks.
   7. All interconnecting piping external to the vessel including the piping, valves, supports, and instruments associated with irrigation, and nutrient systems.

8. One local Vendor Water Control Panel (VWCP), ANSI 316SS NEMA 4X free standing with associated 316 stainless steel supports that house all components necessary for the controls and monitoring of the irrigation and nutrient systems.
    a. VWCP shall be located no closer than 3 feet to the vessel, all electrical components and control panel enclosure shall be rated for Class 1 Division 2 group D meeting NFPA 820 requirements.
    b. The VWCP shall include instruments, nutrient pump, piping, and equipment components that will provide as a minimum, an irrigation system capable of recirculation operation with makeup water and on/off timing of intermittent once through water system.
9. One Free standing Vendor Master Control Panel (VCP) with 316 stainless steel supports that houses the PLC, LOI, and the controls related to the processes including but not limited to the fan, vessel, nutrient, and irrigation systems.
    a. If the VCP is located on vessel, then all electrical components and control panel enclosure shall be rated for class 1 Div 2 group D meeting NFPA 820 requirements.
10. All other associated and required accessories as specified herein and elsewhere in these Specifications.

E. Electrical requirements: See Section 16100 - Electrical Requirements, which contains information and requirements that apply to the work specified herein and are mandatory for this project.

F. Reference Sections:
    1. 17100 - Control System Requirements.

1.02 PROCESS DESCRIPTION

A. The biological odor control system shall consist of an exhaust fan, FRP vessels for each scrubber stage, inorganic biological media, activated carbon media, air and irrigation system, control panel, exhaust stack, dampers, valves, piping and all other equipment and accessories for a complete system.

B. The complete odor control system shall be packaged.
    1. All components of the system shall be mounted on the vessel except for the water control panel and electrical master control panel.
    2. No exception to this requirement is allowed.

C. The packaged biological odor control system shall be a once-through system.
    1. The system is equipped with an exhaust fan that continuously draws the foul air from the process areas through the biological odor control system (stage 1) and push air through the carbon scrubber (stage 2) for treatment.
    2. The biological odor control system shall utilize an inert, porous and light material (expanded clay or plastic) designed to remove hydrogen sulfide (H2S) and resist compaction and degradation from the acidic sulfates of the biological oxidation of the hydrogen sulfide.
    3. Stage 2 shall utilize a pelletized coal activated virgin carbon media to remove any remaining hydrogen sulfide as well as other odorous organic compounds.

D. The first stage shall operate with an independently controlled irrigation process to provide Stage 1 media with adequate moisture to sustain bacterial growth and to remove toxic byproducts.
   1. The irrigation process shall be controlled by a programmed timing sequence that actuates a solenoid valve located on the water supply piping. Stage 1 shall include a pump and controls to allow the system to operate by cycling water from the sump to the top of the media.
   2. When operating in recirculation mode, makeup water will be trickled in by constant operator set flowrate and automatically added in greater amounts when the level in the sump or pH in the recirculated water falls below a pre-determined level.

E. Nutrients shall be added to irrigation piping to mix with irrigation water and trickle over the media to enhance and sustain the biological activity.
   1. The nutrients shall be housed in an FRP tank and shall be dosed into the system by a nutrient pump located in the VWCP.
   2. A pre-wired control panel shall be provided to ensure proper control and operation of the system. The cleaned air is discharged to the atmosphere through the stack(s) at the top of the unit.

1.03 REFERENCES

A. ASTM International (ASTM):
   1. ASTM D-883: "Definition of Terms Relating to Plastics."
   2. ASTM D-2583: "Test for Indentation Hardness of Rigid Plastics by Means of Barcol Impressor."
   3. ASTM D-2563: "Recommended Practice for Classifying Visual Defects in Glass Reinforced Plastic Laminate Parts."
   4. ASTM D-4097-82: "Standard Specifications for Contact Molded Glass Fiber Reinforced Thermoset Resin Chemical Resistant Tanks."
   5. ASTM E679: “Standard Practice of Odor and Taste Thresholds By a Forced-Choice Ascending Concentration Series Method of Limits.”
   6. ASTM C582: “Revision of C582-02 Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment.”
   7. ASTM D-3299: “Standard Specification for Filament-Wound Glass-Fiber-Reinforced Thermoset Resin Corrosion-Resistant Tanks.”
   8. ASTM D-3982: “Standard Specification for Contact Molded Fiberglass Ducts.”

B. National Fire Protection Association (NFPA):
   1. The system and its components shall meet the requirements of NFPA 820 and other relevant codes and standards.

1.04 SUBMITTALS

A. Submit shop drawings and literature describing the equipment and associated components for evaluation and approval.
   1. Fabrication of odor control system shall not begin until a written approval and notice to proceed is provided.
   2. If the selected manufacturer’s equipment layout, configuration, and/or piping requires changes from the bid documents, it is the responsibility of the

manufacturer to clearly submit all proposed changes in the submittals at no additional cost to Owner or Engineer.

3. All exceptions and/or deviations shall be fully identified and described.

B. General: Provide Shop Drawings, samples, administrative, quality control, and contract closeout submittals in accordance with the requirements of Section 01300 - Submittals, and as listed below.

C. Provide shop drawings and items as specified herein for review prior to approval:
   1. Detailed structural and mechanical layout drawings showing system fabrication, dimensions, size, and locations of connections to other work.
   2. Complete basis of design calculations for the FRP vessels, ladders, and media supports.
      a. Structural calculations and drawings for the vessel shall include wind and seismic load calculations and anchor bolt sizing.
   3. Description of the laminate and the type of reinforcing to be used and a letter from the manufacturer stating the laminate reinforcing material used will provide chemical resistance at least equal to the published chemical resistance for the resin for the intended application, and the resin will meet the performance requirements stated and is suitable for the service conditions specified herein and the fabrication technique proposed.
      a. Manufacturer shall also submit certification of applicable wind load design in accordance with current edition of the California Building Code and applicable specifications.
   4. Furnish a list of recommended spare parts for each piece of equipment in the scope of supply.
   5. Process control narrative. Include irrigation system summary of the operation mode of irrigation.
   6. Description of control system operation to demonstrate compliance with the Specifications.
   7. Equipment offloading and installation instructions with enough detail to allow the Contractor to complete the mechanical and electrical installation of all System components.
   8. Annual utility and nutrient usage calculations.
   9. Information on hazards associated with the System and appropriate safety precautions, including applicable Material Safety Data Sheets (MSDS).
   10. Installation guidelines for the Contractor.
   11. Manufacturer's catalog information, descriptive literature, specifications, and identification of materials of construction.
      a. Provide a detailed bill of materials.
   12. Manufacturer's Information on the biological and activated carbon media such as:
      a. Pressure drop data through media.
      b. Media physical characteristics, including:
         1) Media volume.
         2) Media depth for each bed/layer.
         3) Specific surface area.
         4) Void ratio.
         5) Media sieve analysis (if applicable).
         6) Carbon H_2S removal capacity.
         7) Weight per cubic foot.

c. Information on expected settling rates of the media per year (if applicable).
d. Odor control system pressure drop calculations to include from suction ductwork connection at fan to the final discharge of the odor unit.
e. Operating data from previous installations to substantiate media performance claims.

13. Manufacturer's information on spray nozzle, mist eliminator and all other mechanical components as applicable.
14. External utility requirements.
15. Complete instrumentation, control, logic, and power wiring diagrams in sufficient details to allow installation of the instrumentation, controls, and electrical components.
16. WCP and VCP external layouts, internal layouts, bill of materials, logic diagrams, HMIs, power and control wirings, PLC I/O, network connections, calculations, thermal management including air conditioners and heaters.
17. Coating systems: Including manufacturer's descriptive technical catalog literature and Specifications per Section 09960 - High-Performance Coatings.
18. Field-testing plan for meeting system performance requirements.

D. Provide quality control submittals per Sections 01300 - Submittals and 01660 - Equipment and System Performance and Operational Testing, and as follows:
1. Manufacturer's Certification of Compliance that the factory finish system is identical to the requirements specified herein.
2. Manufacturer's Certificate of Installation and Functionality Compliance.
3. Manufacturer's training program.
4. Equipment Testing and Field Start-Up Report.

E. Submit certification indicating the quality control, testing, and inspection has been completed and standards specified herein have been met prior to shipment to the jobsite.

F. Furnish 3 bound copies and 2 electronic copies of the Operation and Maintenance instructions for each odor control unit.
1. The information shall be sufficient to instruct personnel who are unfamiliar with such equipment in the operation and maintenance of the system.
2. It shall include diagnostic procedures to be used in the event of system shutdown or malfunction.
3. Comply also with Section 01670 - Operations, Maintenance, and Training Requirements.

G. Submit the performance guarantee and warranty for the system.

H. Submit results of all performance testing procedures and results.

1.05 WARRANTY AND PERFORMANCE GUARANTEE

A. As specified in Section 01783 - Warranties and Bonds.

B. Special Warranty:
   1. The biological odor control system and all associated components shall carry a 3-year “Full Replacement Warranty” that shall begin once the unit has been started, accepted by Owner, and met all performance requirements.
   2. The synthetic/inert biological media, vessels, and support gratings shall carry a 10-year non-pro-rated full replacement warranty.
   3. Cost of removal and replacement of media shall be by Owner.

C. Performance guarantee:
   1. The contractor and OCS shall guarantee the performance of each biological odor control system for 2 years from the final acceptance by the Owner.
   2. If, within the 2-year guarantee period, the system fails to meet the performance requirements specified herein, the contractor and OCS shall make all corrective actions necessary to improve system performance at no additional cost to the Owner.
   3. The corrective actions may include replacing equipment or parts, making operational adjustments, or replacing the entire system and all associated components.

1.06 SHIPPING, DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

PART 2 PRODUCTS

2.01 APPROVED MANUFACTURERS

A. The odor control systems manufacturer referred herein as the Odor Control Supplier (OCS) shall be experienced in the design, fabrication, construction, and successful operation of biological odor control systems for the removal of hydrogen sulfide gas and other odor producing compounds from air ventilated from wastewater treatment systems.
   1. All equipment shall be furnished by a single manufacturer/OCS with single-source responsibility.

B. Systems utilizing organic, lava rock, or stone media shall not be accepted.

C. Manufacturers: The following or approved equal.
   1. Daniel Company BioDan and DanAbsorb, Upland, California (basis of design).
   2. Biorem Environmental Mytilus + Carbon Scrubber, Victor, New York.
   3. Evoqua Water Technologies, BTF and single bed carbon adsorber, San Diego, California.

2.02 DESIGN CRITERIA

A. Each facility odor control system shall be designed to meet the following criteria and shall meet or exceed the minimum performance requirements listed. Systems not meeting minimum EBRT (Empty Bed Residence Time) will not be accepted.

Packaged Odor Control System	
Number of vessels	2
Tags	SLB-OCU-07-001, SLB-OCU-07-002 SLB-FAN-07-001 SLB-FAN-07-001
Vessel configuration	Cylindrical Upflow
Minimum Dimensions (not including stack and overall dimensions): Stage 1 Biological Trickling Filter Stage 1 Activated Carbon Scrubber	 8 feet diameter x 29 feet high 8 feet diameter x 9 feet high
Number of local water control panels, also referred to as BTF and Carbon Scrubber Vendor Water Control Panel (WCP)	1 Tag: SLB-WCP-07-001
Number of master electrical control panels, also referred to as BTF and Carbon Scrubber Master Vendor Control Panel (VCP)	1 Tag: SLB-VCP-007-021
Total design air flow rate	2,400 cfm
Maximum pressure loss, Stage 1 (in-w.c.)	3.0-inch w.c.
Maximum pressure loss, Stage 2 (in-w.c.)	5.0-inch w.c.
Maximum pressure loss, Mist Eliminator (Clean / Dirty) (in-w.c.)	1.0 / 2.0
Minimum Stage 1 biological media EBRT	20 seconds
Minimum Stage 2 carbon media EBRT	5.3 seconds
Inlet hydrogen sulfide Average Peak	 5 ppm 10 ppm
Minimum H_2S removal performance/24 hours Average	99% or 0.25 ppm for inlet H_2S between 1-10 ppm

2.03 SYSTEM COMPONENTS

A. Vessel:
   1. The Stage 1 and Stage 2 vessels shall be made of fiberglass reinforced plastic (FRP) material. Vessel and accessories shall be contact molded manufactured in accordance with NBS PS15-69, ASTM 4097 for contact molding.
      a. Resin used in fabrication shall be a premium vinyl ester resin fire retardant such as Derakane 510B-400P by Ashland Chemical, CoRezyn CORVE 8401 by Interplastics or approved equal.
      b. The resin shall be reinforced with an inner C-glass veil of suitable synthetic organic fiber.
      c. Any material of construction other than FRP with premium grade, fire retardant (Class 1), vinylester resin shall not be acceptable.
   2. Ultraviolet stabilizer:
      a. Add to the resin used for exterior surfaces in the type and amount recommended by the resin manufacturer for superior ultraviolet resistance in the specified environment.
   3. Reinforcement:
      a. Glass fiber reinforcement used shall be commercial grade corrosion resistant borosilicate glass.
   4. Fabrication: General:
      a. Fabrication shall be in accordance with NBS PS 15-69, ASTM D3299 and ASTM D4097.
      b. All non-molded surfaces shall be coated with resin incorporating paraffin to facilitate a full cure of the surface.
      c. All cut edges, bolt holes, secondary bonds shall be sealed with a resin coat prior to the final paraffinized resin coat.
   5. Corrosion Liner:
      a. The inner surface of all laminates shall be resin rich C-glass veil with a minimum thickness of 10 mils.
      b. The interior corrosion layer shall consist of 2 layers of 1 1/2 ounces per square foot chopped strand mat.
      c. The total corrosion liner thickness shall be a minimum of 200 mils.
   6. Structural Laminate:
      a. Structural laminates shall consist of alternating layers of 1-1/2 ounces per square foot mat of chopped glass and 24 ounces per square yard woven roving applied to reach a designed thickness.
      b. Cylindrical vessels shall have shells manufactured with structural laminate consisting of helically wound continuous filament roving and surface coated with white gel coat containing ultraviolet light inhibitors.
   7. Access Manways:
      a. The vessel shall be provided with access manways to allow access to the internals of the odor control system.
      b. As a minimum, access manways shall be provided between stages.
   8. Media support and screen:
      a. The system vessel shall be provided with an HDPE and FRP support system with polypropylene screen to accommodate the biological media and carbon media beds.
   9. Vessel Accessories:
      a. The system shall be provided with all piping, valves and internals.

b. Air inlet, air outlet, spray headers, drain and all vessel fittings shown on the drawings shall be provided by the Manufacturer.

10. Hardware and Gaskets:
    a. All hardware and anchor lugs shall be 316 stainless steel.
    b. All bolts shall be designed for the specified loads.
    c. Gaskets shall be a minimum of 1/8-inch thick, full face, EPDM, suitable for the intended service.
11. Neoprene Pad: A 1/4-inch thick, 60 durometer neoprene pad must be placed underneath the scrubber vessel during installation.

B. Vessel components shall be preassembled at the point of fabrication.
    1. Preassembly will not require all joints to be factory assembled, but all joints shall be prepared for field fabrication and square.

C. Odor Control Media:
    1. The media in Stage 1 shall be one of the following:
        a. Randomly oriented reticulated polyurethane foam media as the support substrate for selectively growing sulfur-oxidizing autotrophic bacteria.
            1) The media shall be randomly dumped in the vessel into discrete layers of not more than 7 feet tall, each supported by the manufacturers media support system comprised of a minimum 4-inch wide gusset supported ledge molded into the vessel interior sidewall, FRP grating and FRP molded box beams.
            2) Media support systems shall be capable of handling 250 pounds per square foot of live loading at not more than L/360 deflection.
            3) The media shall be porous and resistant to hydrogen sulfide (H_2S) and acidic conditions. The media shall be non-proprietary and commercially available.

    2. The system shall use in stage 2 a coconut shell based granular activated carbon media to adsorb residual H2S and other odor compounds.
        a. This stage shall provide final removal of odors to specified level.
    3. Overall media depth shall be a minimum of 144 inches.
        a. Minimum biological media depth shall be 108 inches.
        b. Minimum carbon media depth shall be 36 inches.

D. Exhaust Fan:
    1. General. Fan shall be centrifugal design manufactured of FRP with a backward inclined blade wheel.
        a. No other material of construction is acceptable.
        b. The wheel shall be statically and dynamically balanced.
        c. The fan inlet shall be slip type and the fan outlet shall have a flanged nozzle.
        d. The fan will be provided with a double lip type shaft seal.
    2. Fan shall be supplied with a TEFC motor with 1.15 service factor suitable for 3-phase/60-hertz/480 volt service.
        a. The fan shall be direct driven.
        b. The motor shall be inverter-duty driven by a variable frequency drive supplied by the OCS.
    3. Performance. The fan shall be tested and rated in accordance with AMCA and shall bear the AMCA seal.

4. The fan shall be New York Blower, Hartzell or equal.
5. The fan shall be designed for the following specifications:
    a. Airflow Rate: 2,400 cfm.
    b. Total Pressure Drop: 13-14 in w.c.
    c. Motor: 10 horsepower, 460 volt, 3-phase.
    d. VFD: Vendor supplied.

E. The scrubber system shall be provided with an exhaust stack manufactured of FRP.

F. The exhaust stack shall be contact molded and manufactured in accordance with NBS PS15-69 and ASTM D-4097 for contact molding.
1. The resin used in the fabrication of the exhaust stack shall be fire retardant and of the same as that used for the main vessel such as Derakane 510B-400P by Ashland Chemical, CoRezyn CORVE 8401 by Interplastics or approved equal.

G. An independent media irrigation system is incorporated into Stage 1 to provide the biological media with adequate moisture.
1. The system shall be designed to irrigate the top of the first media bed with complete and even coverage via spray nozzles.
2. Potable water or plant effluent water can be used provided that residual chlorine concentrations are less than 3 parts per million.
3. Vessel spray bars shall be easily removed from the outside of the vessel for cleaning and descaling.
4. Minimum of 2 each, 8-inch sight ports shall be provided to view the even distribution of spray water.

H. Piping: All make-up water and drain piping shall be SCH 80 PVC, unless noted otherwise on the drawings.

I. Integrated Nutrient Reservoir and Nutrient Pump:
1. Nutrient Addition:
    a. The packaged biological odor control system uses a non-proprietary, commercially available liquid fertilizer to provide essential nutrients to optimize the growth of sulfur-oxidizing bacteria.
    b. Nutrients supplied as a coating to the support media or proprietary nutrients shall not be allowed.
    c. The system shall be equipped with a nutrient addition system that provides a controlled dosage of nutrients that is automatically fed to the irrigation water during each irrigation cycle with the help of a nutrient pump.
2. The Nutrient reservoir shall be integral to the system and mounted on the system deck.
    a. The nutrient reservoir shall be made of FRP or HDPE include 316SS hold-down lugs and lifting lugs, 10-inch fill port and a 1-inch connection to a potable water supply. Tank shall be able to handle 55 gallons of volume or a 60-day supply of nutrients, whichever is greater.
    b. The nutrient reservoir shall have a float-type level switch to detect a low level. Loose nutrient tanks shall not be acceptable.
3. The Nutrient pump shall be diaphragm type and shall be mounted in the water cabinet.

J. NFPA 820:
   1. The system shall be designed and fabricated in compliance with National Fire and Protection Agency Code 820.
      a. As a minimum, all equipment installed on the system shall be rated for Class 1, Division 2, Group D.
      b. The VCP shall be located at least 3 ft from a vessel, duct or fan.
   2. All motors and equipment within 3 feet of the foul airstream shall be rated for Class 1, Division 2, Group D.
   3. The local control panels shall be remote as shown on the plans.
      a. The installation and wiring of the control panels to the fan, nutrient pump and solenoid valve shall be the responsibility of the contractor and supplier.
      b. Use of intrinsic safety barriers shall be as needed for instrumentation sending signals back to master control panel.

K. Vessels shall be provided with a permanently attached, 16-gauge stainless steel equipment identification plate or label laminated into the final fiberglass coat.
   1. The label shall state the following in 1/4-inch die-stamped lettering for the plate or 1-inch letter for the laminated label:
      a. Equipment identification (tag) number shown on submittals and vessel name.
      b. Manufacturers' name and address.
      c. Model number and serial number.
      d. Date of manufacture.
      e. Material of construction.
      f. Design pressure (vacuum).
      g. Operating weight.
      h. Vessel dimensions.

2.04 CONTROL SYSTEM

A. General:
   1. Refer to the electrical and P&IDs drawings for additional information as well as specified herein.
   2. The OCS shall provide 1 Vendor Master/Local Control Panel (VCP) and 1 Vendor Local Water Control Panel (WCP).
      a. Components for a complete packaged control system include but are not limited to OITs, PLCs, Motorized Valves and Actuator Controls, Timers, Relays, Nutrient Feed Pump Controls, Odor Control Fan Controls, level control interlocks in the Nutrient Tank, Local Operators, and Indicators, and as specified to meet the requirements and operational functionality of the vendor system.
   3. Control panels shall carry a UL label certifying the assembled industrial control panel complies with UL 508A.
   4. Labels shall be fixed to the face of the panel in such a manner that the function of each component shall be easily ascertained.
      a. Label terminal strips shall be provided to facilitate wiring of external devices such as switches, sensors, meters, and controllers.
      b. No more than 2 conductors shall be located in each termination point.
   5. All conductors shall be labeled with wire numbers and those numbers shall correspond with those provided in a wiring and panel layout diagram. All

components shall be labeled with the same symbol reference shown in the electrical wiring and instrument list.

6. Vendor Master Control Panel:
    a. The VCP shall house all required controls for the entire system, pre-assembled and pre-wired at the factory, and shipped loose to be remote mounted as a free standing on a concrete pad with 316 Stainless steel supports.
        1) Provide anchoring calculations meeting the local and state seismic zone requirements.
    b. The VCP enclosure shall be rated NEMA 4X, and shall be made of 316 Stainless steel.
        1) The VCP shall be located at least 3 feet from a vessel, duct or fan.
        2) The VCP shall be factory tested to full operation with all other components prior to shipment.
    c. Power supply to the VCP shall be 480 volt, 3-phase.
    d. Communicate with the plant control system over EtherNet/IP.
    e. An Ethernet Switch shall be provided in accordance with Section 17100 - Control System Requirements.
        1) A fiber patch panel shall be provided and accept the incoming 12-strand multimode fiber optic cable, for communicating back to the Plant PLC/SCADA system.
    f. Provide a surge protection device for incoming power. Provide surge protection for all power and control signals that are connected to devices outside a building.
    g. The VCP shall provide electrical control for the entire system with as a minimum the following switches, alarms and accessories:
        1) “On-Off” switch for Exhaust Fan.
        2) “Exhaust Fan Running” indicator light.
        3) VFD for exhaust fan.
        4) “Hand-Off-Auto” switch for Recirculation Pump.
        5) “Recirculation Pump Running” indicator light.
        6) “Hand-Off-Auto” switch for Nutrient Pump.
        7) “Nutrient Pump Running” indicator light.
        8) “Nutrient Tank Low” indicator light.
        9) Push button switches with status lights for irrigation water valve.
        10) Timer relay for on/off control of irrigation water valve.
        11) Control Transformer (480 volt to 120 volt).
        12) The power supply shall be 480 volt, 3-phase, 60 hertz.
        13) Control panel shall be provided with terminal strip as required for easy wiring connections by the contractor.
7. Instrumentation and water controls:
    a. The WCP shall house all required controls for the water and nutrient system, pre-assembled and pre-wired ad piped at the factory and shipped loose to be remote mounted as a free standing on a concrete pad.
    b. Power supply: 120 V, 1ph from the VCP.
    c. The WCP controls and equipment enclosure shall be FRP NEMA 4X or 316 Stainless Steel and shall consist of the following components:
    d. Ball valves.
    e. Pressure reducing valve.
    f. Pressure gauge.
    g. Solenoid valve.

h. Gate control valve.
i. Rotameter - Variable area type with a Teflon float, EPR O-rings and PVC fittings. The rotameter shall have a direct reading scale.
j. Nutrient injection connection.
k. Water fill piping for nutrient.
l. Nutrient pump.

B. System Control Philosophy:
1. General:
a. Hardwired interlocks to shut down the equipment in all modes of operation and activates Fail Alarms. Refer also to the P&IDs and electrical drawings for additional information.
2. Operating Modes:
a. Odor Control fan:
1) The fan is started and stopped manually at the VCP via the on-off switch. Once started the fan runs continuously until it is stopped by the off switch.
2) The speed of the fan will be manually adjusted via the speed potentiometer at the VCP.
b. Once-Through intermittent irrigation mode system operation:
1) The solenoid makeup or supply water valve will open and close the valve intermittently based on adjustable time cycle to irrigate the media periodically as programmed by the PLC.
2) If the nutrient pump HOA selector switch is set to Auto position, the controls will interlock the nutrient feed pump with the water supply valve to feed nutrient into the irrigation pipe when the makeup water supply valve opens.
3) If the nutrient pump HOA selector switch is set to Hand position, the nutrient pump will continuously run until it is manually stopped by the off switch.

PART 3 EXECUTION

3.01 EXAMINATION

A. Refer to Section 15050 - Common Work Results for Mechanical Equipment.

3.02 FIELD FINISHING

A. Coat equipment and piping per Section 09960 - High-Performance Coatings.

B. Field touch up in accordance with Section 09960 - High-Performance Coatings.

C. Damage to pigmented gel coat and/or exterior laminate on any FRP component shall be repaired in accordance with equipment fabricator’s recommendations. Exposed surfaces will be restored to a uniform texture and color-matched appearance. Color selection shall be subject to the Owner’s approval.

3.03 INSTALLATION

A. General: Follow manufacturer's written instructions for installation and adjustment of components.

B. FRP fans and duct: Airflow to each biological odor control system shall be dynamically tested and balanced in accordance with ASTM D-4167.
   1. Field balancing shall be done by the Contractor by qualified and certified air balancing contractor and in accordance with the air testing and balancing specifications (Section 15954 - Testing, Adjusting, and Balancing for HVAC).

C. As far as reasonably possible, all equipment should be pre-assembled prior to shipment, to minimize the need for on-site assembly.

C. Installation of all equipment will be performed by the Contractor and must be in accordance with OCS/Manufacturer's written installation and startup instructions and by workers experienced in the handling of fiberglass vessels, electrical work, plumbing, and instrumentation.
   1. The final installation must be certified by the Manufacturer/OCS as complete and correct.

D. The Manufacturer/OCS shall provide the Contractor with required clearances, tolerances, and limitations, such as smoothness/flatness of concrete pad and shall be available to answer questions prior to and during the installation of the equipment.

E. It is the contractor's (or Owner's) responsibility to provide:
   1. FRP inlet ductwork from pick-up point source to fan inlet connection.
   2. Wiring to/from system control panel to remote-mounted equipment, plant SCADA, etc.
   3. Power to system control panel (480 volt, 3-phase, 60 hertz, 25 amps minimum).
   4. Suitable concrete mounting pads and other incidentals as necessary to complete the installation.
   5. Drain: Minimum of 3 inches PVC gravity drain to sewer with a 12-inch seal water depth barometric trap.
   6. Water Supply: 2-inch water supply with backflow preventer is required. The nominal water requirements are at a rate of 25 gpm and a pressure of 30 psi. Hardness shall not exceed 200 mg/L as calcium carbonate. Free chlorine concentration shall not exceed 3 parts per million.

3.04 FACTORY ACCEPTANCE TEST

A. Odor Control System:
   1. The odor control system shall be inspected and tested at the factory prior to shipping for conformance to the following:
      a. Damage or imperfections to paint or fiberglass work, including cracking/crazing are minimal and in accordance with FRP specifications.
      b. VCP and WCP shall be inspected prior to shipping for conformance to the following:
         1) NEMA rating and UL508A label.

2) PLC program and LOI shall be tested for proper communication and functionality between WCP and PLC/SCADA as appropriate.
3) All wiring between panel components and terminal strips shall be checked for proper labeling and connection.

B. Engineer and/or Owner reserve the right to be present at the manufacturer's testing facility to witness the factory functional testing.
1. Engineer and/or Owner shall provide intent to witness functional testing at the time of the design submittal review and approval, and manufacturer shall provide notice to Engineer and/or Owner regarding the scheduled time of the functional testing at least five business days in advance of the proposed functional testing.

C. Factory testing shall include visual inspection of all equipment, complete assembly and functional operating testing of components including piping and equipment check, and verification of control panel wiring and operation.

3.05 FIELD TEST AND START-UP

A. OCS System's services:
1. The OCS system's representative for the equipment specified shall be present at the jobsite and/or classroom designated by the Owner for the minimum man-days listed for the following services, travel time excluded:
a. Provide 2 man-days for installation assistance, inspection, and certification of the installation.

B. Functional testing:
1. Test all system components for proper adjustment and operation in both the manual and automatic operating modes. Also, the air balancing contractor shall be present on site and shall have make any necessary corrections for proper air flow rates and pumping flows.
2. Allow the bioscrubber irrigation system to operate for a 48-hour period with the moisture control system in AUTO mode and adjust as necessary for proper irrigation moisture system operation.
3. All testing, adjusting, and balancing of the fan and VFD shall have been completed and approved.

C. Performance testing:
1. Performance testing shall not commence until the entire air conveyance system has been properly tested and balanced and the air flow rate to the vessel is confirmed. Also, the odor control system has been satisfactorily started up and enough time has been allowed for the acclimation of the bacteria.
2. After the odor control system has been satisfactorily started-up and switched to normal operation, the Odor Control Supplier shall conduct a performance test to verify that the system meets or exceeds the performance criteria.
a. The testing shall be witnessed by the Owner and Engineer.
3. The Contractor shall provide the Owner with a written test protocol for review by the Owner and Engineer.
4. The Contractor shall supply, install, and operate all equipment, sensors, and instrumentation required to complete the performance test.

5. H_2S Testing procedure:
    a. Measure airflow to the odor control unit and, if necessary, adjust dampers and fan speed to obtain the specified design airflow in each scrubber vessel (+/- 10 percent).
        1) Airflow shall be measured at the beginning of the test period. The set position on the damper(s) will be marked or noted.
        2) Airflow should not change if damper(s) remain in position.
    b. Measure pressures drop across each bioscrubber at beginning of test period.
    c. Measure temperature and humidity of the inlet, outlet, and ambient air.
    d. Performance test period to begin at a noted time and last for 24 hours.
        1) H_2S data from the inlet location of unit and from the outlet of each bioscrubber will be measured and logged once every 10 minutes to demonstrate performance during test period.
        2) Performance test shall be conducted using the naturally occurring H_2S provided by the plant processes.
    e. The inlet H_2S data will be logged with a pre-calibrated OdaLog or acrulog gas data logger with appropriate range and accuracy for the inlet air stream (0.0 to 200.0 ppmv range, 0.1 ppmv display resolution).
    f. The outlet H_2S data will be measured with a recently calibrated Acrulog PPB H2S Low-range monitor/ Analyzer with appropriate range and accuracy for the outlet air stream. Outlet readings shall be measured at 10-minute intervals.
    g. Include in the bid a minimum of 2 Tedlar bag tests where 1 bags test shall be collected at the inlet and 1 Tedlar bag samples shall be collected at the outlet of each odor control vessel. The Tedlar bag samples shall be sent to approved independent test lab for the analysis of 20 reduced sulfur compounds. The Tedlar bags samples shall be taken at 2 different time intervals during the 24 -hour testing period as directed by Engineer and Owner.

D. Odorous compounds removal Acceptance criteria:
    1. The odor control system's removal efficiency shall be determined by calculating the average inlet concentration and the average outlet concentration using the following formula: Removal efficiency (percent) = (1 - average outlet concentration/average inlet concentration) x 100. The system shall have passed the odorous compounds performance test if the removal efficiency meets or exceeds the specified removal criteria listed in Article 2.02.

3.06 TRAINING

A. Require manufacturer's representative to perform the following services in a minimum of two separate trips as described below and as specified in Section 01660 - Equipment and System Performance and Operational Testing. Specified durations are the minimum required time on the job site. Additional services and/or longer durations shall be provided as needed at no cost to Owner to meet the required quality of work: Work to be done in a minimum of 2 trips:
    1. Installation assistance: As required.
        a. Advise/observe the Contractor on the installation of the equipment.
        b. Provide additional assistance as required.

2. Installation inspection: 2 workdays.
3. Start-up/performance testing assistance: 2 workdays:
    a. Prior to start-up, the equipment shall be inspected for proper alignment, operation, and satisfactory performance.
    b. Provide additional start-up/testing assistance as required.
    c. Provide Certificate of Installation and Functionality Compliance per Section 01660 - Equipment and System Performance and Operational Testing.
4. Training: As defined in Specification Section 01660 - Equipment and System Performance and Operational Testing. Provide training as follows for each facility odor control system:
    a. Operations Training: 2 hour class, 2 sessions.
    b. Mechanical Maintenance Training: 4 hours, 1 session.
    c. Electrical and Controls Maintenance Training: 4 hours of training, 1 sessions).
5. Final acceptance checkout: 1 workday (trip may be combined with training).
6. Specified durations are the minimum required time on job site and do not include travel time.

END OF SECTION

SECTION 13122

CANOPY BUILDING SYSTEMS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Prefabricated canopy building systems.

1.02 REFERENCES

A. American Concrete Institute (ACI):
   1. 318 - Building Code Requirements for Structural Concrete and Commentary.

B. American Institute of Steel Construction (AISC):
   1. 303 - Code of Standard Practice for Steel Buildings and Bridges.
   2. 360 - Specification for Structural Steel Buildings.

C. American Iron and Steel Institute (AISI):
   1. SG02 - North American Specification for the Design of Cold-Formed Steel Structural Members.

D. American Welding Society (AWS):
   1. D1.1 - Structural Welding Code - Steel.
   2. D1.3 - Structural Welding Code - Sheet Steel.

E. ASTM International (ASTM):
   1. A123 - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   2. A653 - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process.
   3. A780 - Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
   4. A792 - Standard Specification for Steel Sheet, 55% Aluminum-Zinc Alloy-Coated by the Hot-Dip Process.
   5. B187 - Standard Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes.
   6. B633 - Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel.
   7. D1494 - Standard Test Method for Diffuse Light Transmission Factor of Reinforced Plastics Panels.
   8. F959 - Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners.
   9. F436 - Standard Specification for Hardened Steel Washers.
   10. F3125 - Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength.

F. California Code of Regulations (CCR):
   1. Title 24 - Building Standards Code.

G. Research Council on Structural Connections (RCSC):
   1. Specification for Structural Joints Using High Strength Bolts.

H. Society for Protective Coatings (SSPC):
   1. SSPC-SP 2 - Hand Tool Cleaning.

I. Underwriters Laboratories, Inc. (UL).
   1. 580 - Tests for Uplift Resistance of Roof Assemblies.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Primary framing: An assemblage of beams and columns that support the secondary framing members, and that collects loads to transfer to the foundation.
   2. Secondary framing: Members which directly support roof surfaces and convey loads to the primary framing.

1.04 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Calculations.

1.05 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Product data:
   1. Manufacturer’s standard color charts and profiles:
      a. Exterior roof panels.
      b. Interior roof liner panels.
      c. Gutters and downspout trim.
   2. Manufacturer’s list of approved clamps that may be used to hang suspended items from roof purlins and details of acceptable methods of attachment to purlins.

C. Shop Drawings:
   1. Catalog cuts, design and erection drawings, and other data needed to clearly describe design, materials, construction details, fasteners, and erection.
      a. Erection drawings shall include building dimensions, required foundation footprint, anchor bolt and base plate settings, bracing, main and secondary framing, and sections and details required to fully describe construction of building.
      b. Indicate quantity, size, grade, embedment, and projection, and location of anchor bolts.

2. Accessories, each type of flashing, trim closures, caps and similar items, roof openings, gutters, and downspouts.

D. Delegated Design Submittals:
   1. Provide project-specific calculations based on support conditions and requirements to resist loads specified in Section 01850 - Design Criteria.
   2. Calculations:
      a. Complete structural system.
         1) Clearly indicate foundation reactions at all columns. Identify applied loads, load factors, and load combinations used to develop the reactions.

E. Quality Control Submittals:
   1. Building manufacturer:
      a. If requested by the Engineer, submit a record of the manufacturer's building systems of similar design manufactured and erected in the 5-year period preceding the bid date for this project.
         1) Include date of installation, location of metal building, and name and address of the Owner.
      b. Submit evidence of the manufacturer's certification under IAS AC472 accreditation.
         1) Certification must be valid for the facility at which the building will be fabricated.
      c. Confirmation of UL 580 wind uplift rating.
   2. Erector:
      a. Submit welder qualification certificates.
   3. Certificate of Compliance: At the completion of the metal building manufacture, the manufacturer will furnish a letter to the inspector stating that the work was performed in accordance with the approved construction documents.

F. Record documents:
   1. As specified in Section 01700 - Contract Closeout.
   2. 1 set of reproducible record drawings for the erected structure.
      a. Stamped and signed by the Professional Engineer who provided responsible charge for the design.

G. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

1.06 QUALITY ASSURANCE

A. Manufacturer shall have been engaged in the design, manufacture, and erection of building systems of the type specified for at least 5 years preceding the Bid Date of this Contract.
   1. Building manufacturer shall be certified by IAS AC472 accreditation.

B. Erectors shall be trained, approved, and certified by the manufacturer prior to Bidding of the Project. Erectors shall demonstrate at least 3 years of experience in successfully erecting metal building systems of the type specified in this Section.

1.07 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements and the manufacturer's instructions.

B. Packing and shipping: Deliver materials and fabrications to the jobsite in the manufacturer's original containers with seals unbroken and labeled with the manufacturer's identification and number.

C. Delivery:
   1. Deliver materials dry and undamaged and store out of contact with ground.
   2. Cover materials with weathertight coverings and keep dry.
   3. Provide good air circulation and protection from surface staining for roof and wall covering sheets.

D. Storage and protection: Store materials in original, unopened containers in compliance with the manufacturer's printed instructions.

1.08 PROJECT OR SITE CONDITIONS

A. As specified in Section 01850 - Design Criteria.

1.09 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

B. Special warranty:
   1. Provide the Owner with warranty that the exterior finish system for metal panels shall be guaranteed against blister, peeling, cracking, chipping, or material rust-through for a period of 10 years from the date of Substantial Completion.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or equal:
   1. Behlen Building Systems.
   2. Butler Manufacturing Co.
   3. Nucor.
   4. Varco Pruden.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. System:
   1. Design: Furnish metal building with gable roof, and with column layout as indicated on the Drawings.
   2. Size:
      a. Furnish structure of the size and configuration indicated on the Drawings.

b. Coordinate the manufacturer's design dimensions for structural system components, including columns and details indicated on the Drawings.

3. Use a roof slope of 1 inch vertical in 24 inches horizontal or steeper.
4. Provide building with horizontal and vertical bracing as required per calculations.
5. Column reactions shall be vertical and horizontal only.
   a. No bending moments shall be transferred at column bases.
6. Building indicated on the Drawings is a roof canopy only.
   a. Wall framing and wall panels will not be provided under this Contract; however, design the structural framing and report frame reactions to accommodate both the present condition and the possibility of adding wall panels to enclose the structure at a future date.
7. Building roofing system will be listed for a UL 580, Class 90 designation.
8. Frame openings for doors, windows, louvers, equipment with structural framing to replace panels and secondary framing cut for opening.
   a. Provide curbs to suit roof-mounted equipment compatible with roof sheathing.

B. Performance requirements:
   1. General:
      a. Design of the structure and its appurtenances shall be in accordance with the requirements of the IBC, the Metal Building Systems Manual, and the requirements of this Section.
         1) Where the Metal Building Systems Manual conflicts with the requirements of this Section, the more restrictive requirements will govern.
      b. Do not include collateral or auxiliary loads in load combinations where dead loads offset other load effects (i.e., uplift due to wind loads).
      c. Hot-rolled structural steel sections or welded-up plate sections: Design in accordance with AISC 360.
      d. Cold-formed steel structural members: Design in accordance with the AISI North American Specification for the Design of Cold-Formed Steel Structural Members.
      e. Anchor bolt design:
         1) Resist column reactions reported from analysis.
         2) In accordance with ACI 318, Chapter 17, for cracked concrete to fail in a ductile manner, yielding the steel section before fracturing the surrounding concrete.
         3) Assume concrete foundation strength, f'c = 4,000 pounds per square inch at 28 days.
   2. Loading:
      a. General:
         1) Design building for dead load, live loads, and combinations of loads, including unbalanced loads in accordance with the IBC and the MBMA Metal Building Systems Manual, except as modified in this Section.
         2) Reduction in wind, live, or snow loads based on tributary loaded area will not be permitted.
      b . Roof loading requirements:
         1) Live load: Minimum 20 pounds per square foot assumed to act vertically on horizontal projected area of roof.

c. Collateral loading: Uniform roof load of 10 pounds per square foot assumed to act vertically on horizontal projected area of roof to account for miscellaneous accessories supported from the structure.
    1) Collateral loading shall be considered a live load.
    2) Design primary and secondary framing to support the additional weight of mechanical equipment such as fans, air conditioners, etc., shown on plans.
        a) Mechanical equipment weights are in addition to collateral loading.
d. Auxiliary loading:
    1) Structural members: Any single point along the secondary roof framing members shall be designed to carry a concentrated load of 200 pounds in addition to the roof live load.
    2) Roof panels: Design panels to support a 200 pound load uniformly distributed over a 2 square foot area centered between supporting framing members, without exceeding a panel deflection to span ratio of 1/180 in a 2-span condition.
    3) Auxiliary loading shall be considered a live load.
    4) Auxiliary is not to be considered concurrently with collateral loading.
e. Wind design criteria: As specified in Section 01850 - Design Criteria.
    1) Design roof purlins and structural frames for loads specified, but not less than 40 pounds per square foot uplift on horizontally projected roof area.
f. Seismic design criteria: As specified in Section 01850 - Design Criteria.
    1) Bolted joints subject to seismic loading shall be designated pretensioned joints.

3. Deflection limitations:
    a. Primary frames:
        1) Gravity deflection:
            a) Live load deflection: L/240.
            b) Total load deflection: L/180.
        2) Horizontal drift of rigid frames measured at ridge :
            a) Seismic drift limitation: H/60.
            b) Wind drift limitation: H/60.
    b. Secondary framing:
        1) Gravity deflection:
            a) Live load deflection: L/180.
            b) Snow load deflection: L/180.
            c) Total load deflection: L/150.
        2) Horizontal deflection: L/180.
    c. Deflection of roof panels: Span/180.
    d. Deflection calculations should be based on the wind loads presented in AISC Design Guide 3.
        1) Deflection calculations should be based on the unreduced wind loads required in the IBC (50-year reoccurrence intervals).
4. Climatic conditions:
    a. Gutters and downspouts: Design for a rainfall rate of 5 inches per hour.
    b. Temperature: Provide for movement (expansion or contraction) caused by a range of ambient temperature of 120 degrees Fahrenheit without detrimental effects.

2.03 MATERIALS

A. Primary framing (rigid frames):
   1. Welded plates or hot-rolled steel columns and roof beams, complete with necessary splice or connector plates for bolted field assembly.
      a. Minimum nominal thickness of structural shapes or their elements shall be 1/4 inch.
   2. Welding procedures, welder qualifications, and welding quality standards shall be in accordance with AWS D1.1 and AWS D1.3.
   3. Base, cap, compression plates, and stiffener plates shall be factory-welded in place and shall have shop-fabricated connection holes.
      a. Provide minimum 4 anchor bolts per column base.
   4. Columns and roof beams shall be fabricated complete with holes in webs and flanges for attaching bracing and roof and sidewall framing.
   5. Shop finishing:
      a. Shop primed for field painting:
         1) Clean ferrous surfaces of oil, grease, loose rust, loose mill scale, and other foreign substances, in accordance with the SSPC-SP 2.
         2) Apply 1 coat of shop primer in accordance with SSPC Paint Specification No. 15 for temporary corrosion protection.
            a) Remove shop primer as specified in Section 09960 - High-Performance Coatings prior to field coating.
      b. Shop primed and field-coated high solids epoxy coating system:
         1) Apply 1 coat of shop primer in accordance with SSPC Paint Specification No. 15 for temporary corrosion protection.
            a) Remove shop primer as specified in Section 09960 - High-Performance Coatings prior to field coating.
         2) Prepare surfaces and apply finishes as specified in Section 09960 - High-Performance Coatings.

B. Secondary framing (purlins, girts, framing at endwalls and openings, eave struts, bracing):
   1. Hot rolled structural steel or cold-formed members.
   2. Minimum thickness: 16 gauge.
   3. Bracing elements constructed of wire rope, stranded tendons, or other similar material is not permitted.
      a. Rolled angle sections or solid steel bar is permitted.
   4. Provide factory-punched holes for panel connections.
   5. Shop finishing - hot rolled sections:
      a. Shop-primed for field painting:
         1) Clean ferrous surfaces of oil, grease, loose rust, loose mill scale, and other foreign substances, in accordance with the SSPC-SP 2.
         2) Apply 1 coat of shop primer in accordance with SSPC Paint Specification No. 15 for temporary corrosion protection.
            a) Remove shop primer as specified in Section 09960 - High-Performance Coatings prior to field coating.
      b. Shop primed and field-coated high solids epoxy coating system:
         1) Apply 1 coat of shop primer in accordance with SSPC Paint Specification No. 15 for temporary corrosion protection. Remove shop primer as specified in Section 09960 - High-Performance Coatings prior to field coating.

2) Prepare surfaces and apply finishes as specified in Section 09960 - High-Performance Coatings.

6. Shop finishing (cold-formed sections):
   a. Shop primed for field painting:
      1) Clean ferrous surfaces of oil, grease, loose rust, loose mill scale, and other foreign substances, in accordance with the SSPC-SP 2.
      2) Apply 1 coat of shop primer in accordance with SSPC Paint Specification No. 15 for temporary corrosion protection.
         a) Remove shop primer as specified in Section 09960 - High-Performance Coatings prior to field coating.
   b. Shop-primed and field-coated high solids epoxy system:
      1) Apply 1 coat of shop primer in accordance with SSPC Paint Specification No. 15 for temporary corrosion protection.
         a) Remove shop primer as specified in Section 09960 - High-Performance Coatings prior to field coating.
      2) Prepare surfaces and apply coating as specified in Section 09960 - High-Performance Coatings.

C. Roof and wall panels:
   1. Roll-formed minimum 24-gauge steel, factory-finished each side.
   2. Panels shall have interlocking side seams and shall be the manufacturer's maximum standard width, factory cut to maximum possible length to minimize end laps.
   3. Factory pre-punched for fastening.
   4. Panel finish:
      a. Factory pre-painted, pre-finished coating consisting of a UV light-resistant polyvinylidene difluoride (PVDF) resin based paint and primer system having a total thickness not less than 1.0 mil on an approximately 55 percent aluminum-43 percent zinc-1 percent silicone galvanized coating complying with ASTM A792.
      b. Galvanized coating shall be deposited at a minimum rate of 0.50 ounces/square foot.
      c. Furnish the manufacturer's standard color chart for the Owner's selection.
   5. Ridge panel: 1-piece, factory-formed to match roof slope at each side, of same material as roof panels, and capable of completely sealing roof ridge.

D. Bolted joint components: High-strength steel bolts used for steel-to-steel structural connections.
   1. Bolts: ASTM F3125, Grade A325, Type 1 , or ASTM F3125, Grade A490, Type 1.
   2. Nuts: ASTM A563, heavy hex. Grade and finish to match bolts as specified in RCSC Specification for Structural Joints Using High Strength Bolts.
   3. Washers: ASTM F436; flat unless otherwise noted.
   4. Load indicator devices:
      a. Twist-off type tension-control bolt assemblies: ASTM F3125, Grade A1852 , or ASTM F3125, Grade F2280.
      b. Compressible washer direct tension indicators: ASTM F959, Type 325-1 for ASTM F3125, Grade A325 bolts , or ASTM F959, Type 490-1 for ASTM F3125, Grade A490 bolts.
   5. Bolts furnished for the project shall be a single size and grade.

E. Anchor bolts or anchor rods: As specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry, except that material shall be Type 316 stainless steel unless otherwise indicated on the Drawings.

F. Fasteners and washers:
   1. Used for attachment of wall and roof panels.
   2. Fasteners: Vinyl-coated steel or stainless steel.
   3. Washers: Neoprene or other accepted type washer capable of being used to ensure watertightness at fastening locations.

G. Gutters and downspouts:
   1. 24-gauge steel.
   2. Galvanized in accordance with ASTM A653 to G60 designation.
   3. Field painted. Color to be selected by the Owner to complement wall panels.

H. Touch-up painting materials:
   1. For structural elements:
      a. Shop primer: Manufacturer's standard primer.
      b. Touch-up paint: Same as shop primer.
   2. For sheet metal skin:
      a. Exterior finish paint: Match specified coating.
         1) Color as selected by the Engineer.

   3. Panels at roof must be capable of withstanding a 200-pound point load as required by OSHA 1910.23(e)(8), without the use of wire screens or external guardrail systems.
   4. Color shall be as selected by the Engineer.

I. Accessories:
   1. Bird screen.
   2. Flashing.

2.04 FABRICATION

A. Shop fabrication:
   1. Structural elements:
      a. Fabricate rigid frame of hot-rolled sections or continuously welded plate sections.
      b. Field connections shall be bolted unless otherwise accepted by the Engineer.

   2. Roof panels:
      a. Panels may be spliced with minimum end overlap of 9 inches at purlins.
      b. Provide 1-piece ridge panel, factory formed to match roof slope, of same material as roof panel, and capable of completely sealing roof ridge.
      c. Provide means to allow expansion of roof panels.
   3. Fasteners for roof panels:
      a. Secure with fasteners that ensure maximum weathertightness, proper bearing surface, and permanent seal at point of fastening.
      b. Use washers capable of assuring watertightness at fastening locations.

4. Accessories:
    a. Gutters, downspouts, and hangers:
        1) Provide 4-inch gutters, downspouts, and hangers.

B. Tolerances:
1. Hot-rolled sections: In accordance with AISC 303.
2. Cold-formed and built-up sections: In accordance with MBMA Metal Building Systems Manual.

2.05 SOURCE QUALITY CONTROL

A. General.
1. Components of the metal building system fabricated in the manufacturer's shop will be subject to special inspection, as specified in this Section.
2. Manufacturer shall communicate the proposed fabrication schedule to the Contractor with sufficient notice and lead time to schedule the required inspections.
3. Manufacturer shall cooperate with the inspection agencies and personnel and shall facilitate access for the inspector to the components requiring inspection.
4. Inspector will verify that the manufacturer maintains detailed fabrication and quality control procedures that provide a basis for inspection control of the workmanship and the manufacturer's ability to conform to approved construction documents and referenced standards.
    a. Inspector will review the procedures for completeness and adequacy relative to the code requirements for the manufacturer's scope of work.

B. Source inspection.
1. Special inspection of the metal building system components fabricated in the manufacturer's shop will be performed at the time and frequency outlined in Attachment A - Metal Building System Construction Special Inspection.
2. Components of the metal building system that will be subject to special inspection are as indicated in Attachment A - Metal Building System Construction Special Inspection.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verification of conditions:
1. Verify site conditions prior to start of Work. Unacceptable conditions shall be reported to the Engineer.
2. Starting of erection of metal building system work shall indicate acceptance of existing conditions.
    a. Manufacturer or the manufacturer's trained erector shall review and examine existing site conditions, foundation, and surface preparation, and adequacy of site-prepared components prior to commencing erection of the building.

3.02 ERECTION

A. General:
   1. Erect in accordance with the MBMA Metal Building Systems Manual and the manufacturer's instruction, except as modified in this Section.
   2. Separate dissimilar materials with gaskets or suitable insulating coatings.
   3. Keep exposed surfaces clean and free from sealant, metal cuttings, and other foreign materials.

B. Framing and structural members:
   1. Set anchor rods by template and securely tie into formwork before concrete placement.
   2. Grout below baseplates and sills with non-shrink cement grout as specified in Section 03600 - Grouting.

C. Walls and roof:
   1. Erect a structure that will be free from water leaks and meet design requirements.
   2. Direct side lap edges away from the prevailing winds at the Site.
   3. Do not exceed the maximum fastener spacings specified.
      a. Space fasteners uniformly not to exceed: 8 inches on center at ends of covering, 12 inches on center at intermediate supports and at roof covering side laps, and 18 inches on center at wall covering side laps.
   4. Install fasteners in straight lines within a tolerance of 1/2-inch per bay.
   5. Seal side laps, ends of roof, wall coverings, and joints at accessories.
      a. Drive fasteners to the surface and seat gasketed heads and washers.
   6. Fasten accessories to framing members, except as otherwise accepted by the Engineer.
   7. Wall panels shall be isolated from concrete floor slab and/or foundation.
   8. Flashing shall be provided at the base of wall panels to prevent wind-driven rain from entering the building envelope.

D. Gutters and downspouts:
   1. Attach securely to the building.
   2. Install gutters sloped to drain with adequate provisions for expansion and contraction.

E. Doors and roof openings:
   1. Anchor securely to the supporting construction.
   2. Install doors plumb and true and adjust to provide operation.

3.03 FIELD QUALITY CONTROL

A. General:
   1. Installation of metal building system will be subject to special inspection and evaluation during construction, as specified in this Section.

B. Site inspection:
   1. Special inspection of the metal building system components will be performed at the time and frequency outlined in Attachment A - Metal Building System Construction Special Inspection.

2. The elements of the metal building system construction that will be subject to special inspection are as indicated in Attachment A - Metal Building System Construction Special Inspection.

3.04 ADJUSTING

A. Field painting:
   1. Prepare and touch up abraded or corroded spots on shop-primed surfaces immediately after erection.
      a. Use the same material as was used for the shop coat.
   2. Paint shop-primed ferrous surfaces as specified in Section 09960 - High-Performance Coatings.

B. Field coated:
   1. Prepare and apply coating as specified in Section 09960 - High-Performance Coatings.

C. Touch-up factory finished surfaces of roof and wall panels with the manufacturers recommended paint where damaged or abraded.

D. Where shop processes such as shearing or punching leave edges of galvanized steel unprotected by galvanization, touch up unprotected edges as specified in this Section.

E. Repair damaged galvanized surfaces in accordance with ASTM A780.

3.05 CLEANING

A. Remove excess materials, equipment, and debris incidental to this work upon completion.

3.06 PROTECTION

A. During erection, the erector shall be responsible for the protection of this and all adjacent work from damage.

END OF SECTION

ATTACHMENT A - METAL BUILDING SYSTEM CONSTRUCTION SPECIAL INSPECTION

METAL BUILDING SYSTEM CONSTRUCTION SPECIAL INSPECTION

IBC Table 1704.3	Inspection Task	Frequency/Timing of Inspection	Criteria Reference
Prior to beginning installation of metal building, verify high-strength bolts, nuts, and washers:			
1.a.	Identification markings conform to ASTM standards required by approved design.	Periodic: Confirm from stockpile of materials delivered to site whether material furnished complies with the materials in the approved design.	
1.b.	Confirmation of manufacturer's certificate of compliance.	Periodic: Confirm that manufacturer has furnished the required Certificate of Compliance.	
Inspection of high-strength bolted joints:			
2.a.	Joints designated bearing-type connections by the approved design.	Periodic: Provide continuous inspection of the initial installation of each type and size of joint. Subsequent installations of the same type and size of joint may be inspected on a periodic basis with inspections of a minimum of 20 percent of installations, or once per calendar week, whichever is more frequent.	
2.b.	Joints designated slip-critical connections by the approved design.	Continuous: Provide continuous inspection as specified in Section 01455 - Regulatory Quality Assurance.	
Inspection of structural steel welding:			
5.a.1.	Complete and partial penetration groove welds.	Continuous: Provide continuous inspection as specified in Section 01455 - Regulatory Quality Assurance.	
5.a.2.	Multipass fillet welds.	Continuous: Provide continuous inspection as specified in Section 01455 - Regulatory Quality Assurance.	
5.a.3.	Single-pass fillet welds greater than 5/16 inch.	Continuous: Provide continuous inspection as specified in Section 01455 - Regulatory Quality Assurance.	

IBC Table 1704.3	Inspection Task	Frequency/Timing of Inspection	Criteria Reference
5.a.4.	Single-pass fillet welds less than or equal to 5/16 inch.	Periodic: Provide continuous inspection of the initial production of each type and size of welded joint. Subsequent production of the same type and size of joint may be inspected on a periodic basis with inspections of a minimum of 20 percent of installations, or once per calendar week, whichever is more frequent.	
5.a.5.	Floor and roof deck welds.	Periodic: Provide continuous inspection of the initial production of each type and size of welded joint. Subsequent production of the same type and size of joint may be inspected on a periodic basis with inspections of a minimum of 20 percent of installations, or once per calendar week, whichever is more frequent.	
Inspection of steel frame joint construction for compliance with approved design.			
6.a.	Bracing and stiffening details.	Periodic: Provide periodic inspection of any bracing and stiffening details of construction. Inspection should include, as a minimum, verification of member sizes and proper orientation. A minimum of 15 percent of locations should be verified.	
6.b.	Member locations.	Periodic: Provide periodic inspection of member locations. Inspection should include, as a minimum, verification of member sizes and proper spacing/location. A minimum of 15 percent of locations should be verified.	
6.c.	Connection joint details.	Periodic: Provide periodic inspection of joint details of construction. Inspection should include, as a minimum, verification of miscellaneous steel detailing, including stiffener plates, concrete pourstops, gusset plates and similar miscellaneous steel framing. A minimum of 15 percent of locations should be verified.	

SECTION 13236

STRUCTURALLY SUPPORTED MEMBRANE FABRIC COVER SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: The design, supply, and installation of flexible, arch supported, retractable, membrane fabric covers for the sludge blend tanks. Design, supply, and install any specified inspection and access hatches, louvers, perimeter attachment system and the erection and removal of any temporary works necessary for installation so as to make a complete and functional cover system. The covers shall open in the direction indicated on the drawings.

1.02 REFERENCES

A. ASTM B308/B308M - Standard Specification for Aluminum Alloy 6061-T6 Standard Structural Shapes.

1.03 DESIGN CRITERIA

A. Service conditions.

B. The cover system must be designed to support seismic and wind loads required by the codes applicable to the jurisdiction of installation and as specified in Section 01850 - Design Criteria.

C. The cover system, including fabric, arches, supports, and any required walkways shall be designed to support loads specified in the International Building Code and ASCE 7 for the site location, and any additional loads in this specification. Deflection shall not exceed L/180, where L is the span.

D. The cover must be sufficiently gas-tight so that gas from the tank contents can be withdrawn in a controlled manner by an exhaust system creating a normal operating vacuum under the cover of between 0 and -3/8 inch water gauge.

E. The cover system must withstand exposure to conditions of temperature, dust, and humidity normally experienced at the installation site.

F. The cover system must automatically remove rainwater, and prevent water from entering the tank.

G. The cover shall be design to support a live load of 300 pounds on any square foot of the covered area.

H. An extra layer of cover material shall be added over each structural support arch to provide cushioning against hailstone damage.

I. Other criteria to be as outlined in other portions of this specification.

1.04 SUBMITTALS

A. Shop drawings and technical product literature. Include the following:
   1. Dimensions, sizes, thicknesses, gauges, materials.
   2. Attachment and erection procedures.
   3. Member and locations of penetrations.
   4. Penetration details.

B. Schedule.

C. Operating and Maintenance Manual containing product data and operating instructions.

D. Warranty.

E. Record drawings.

F. Calculations: Signed by a qualified Registered Professional Engineer in State of California.

G. Fabricator qualifications.

1.05 QUALITY ASSURANCE

A. The Fabricator/Installer must have an established quality management system. The Engineer may require that applicable quality control procedures be submitted.

B. The structural support fabricator must have demonstrated experience in fabricating structural components. The Engineer may require that staff qualifications be submitted.

C. The membrane fabric fabricator must have demonstrated experience in fabricating arched membrane fabric cover systems. The Engineer may require that staff qualifications be submitted.

D. The membrane fabric fabricator must be recognized as an approved fabricator/installer by the membrane fabric manufacturer. The Engineer may require that proof of manufacturer approval be submitted.

1.06 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

1.07 PATENTS

A. All applicable patents for the system must be held by or licensed by the Supplier. Grant, to the Owner, the required licenses to use the system in perpetuity for this installation. The Owner will enter into a confidentiality agreement as required.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. One of the following or approved equal as determined by the City Engineer:
   1. ArchPro by Xylem.

B. The cover system shall be a low-profile construction that does not interfere with internal tank components. The cover system shall be designed and fabricated by the manufacturer. The cover system shall be installed by the contractor only after the contractor has received installation training from the manufacturer.

C. The system shall include support arches at intermittent locations along the tank to support membrane fabric cover panels, as specified by the manufacturer. The arches must be securely fastened to the tank walls. When required, walkways may contain hatches for access to tank components and liquid sampling.

D. Cover panels are to be retractable. The panels will be battened to the tank perimeter on one side and held in position by detachable connections on the other three sides.

2.02 MATERIALS

A. Cover Fabric:
   1. The cover shall be constructed of UV resistant reinforced membrane fabric which meets or exceeds the manufacturer's published specifications as listed below:
      a. The fabric portion of the cover system shall be constructed of high performance coated fabric manufactured by Seaman Corporation, either Seaman 8138 XR-5 coated fabric or Seaman 8028 Architectural Fabric.
      b. Ensure that the membrane fabric material meets or exceeds the stated performance requirements, is suitable for this application, and is repairable by the Owner without taking the tank out of service.
      c. Ensure that the materials used in the cover fabrication will lay tight and smooth over the supports.
      d. The cover system must allow access to tank internal components.

B. Support Arches:
   1. Arches are to be ASTM B221 Alloy 6061-T6 aluminum.
   2. Bracing/bridging and arch seat angle sections to be ASTM B221 Alloy 6061-T6 aluminum.
   3. Arches are to be made without defects, marring, kinking, or deformation detrimental to the strength of the arches.
   4. Any hatches in walkways are to withstand equal loading and foot traffic as other areas of the walkways. Hatches must not present an unsafe condition, and shall be watertight.
   5. Any walkways are to have non-skid surfaces.
   6. Ensure the materials chosen meet or exceed the stated performance requirements and are suitable for this application.
   7. Accessories and hardware are to be designed and located so as not to infringe on walking or working spaces or cause an unsafe condition.

C. Associated Parts
   1. All anchors and fasteners shall be ASTM A593 Type 316 stainless steel.
   2. Perimeter batten to be aluminum flat bar.
   3. Provide perimeter aluminum flashing with drip edge.
   4. Cover ends shall have diamond-plate surfaces; ASTM B209 Alloy 3003-H22 or ASTM B928, Alloy 5086-H116.
   5. Other unspecified products are to be as approved by the Engineer.

2.03 FABRICATION

A. General:
   1. Shop fabricate the various items of work in accordance with manufacturer's recommendations and reviewed shop drawings using qualified personnel.
   2. Fit and shop fabricate the various items of work in sections as large and complete as possible. Make inconspicuous connections and clearly mark matching surfaces to ensure correct assembly on site.
   3. Fabricate true to dimensions shown on reviewed shop drawings without unnecessary sections, patches or undulations, free from distortion, surface deterioration and defects detrimental to appearance and performance.

B. Cover Fabric:
   1. Fabricate covers to dimensions shown on reviewed shop drawings using equipment and methods approved by the membrane fabric manufacturer.
   2. Use fabrication methods to protect against damage or defects in all fitting and seaming procedures.

C. Support Arches and Walkways:
   1. Fabricate arches and walkways to dimensions shown on approved shop drawings.
   2. Use fabrication methods to protect against damage or defects in all bending, fitting and welding procedures.

D. Packaging and Shipping:
   1. Ensure all components are packaged properly to avoid damage during shipping.
   2. Clearly label all shipments.

PART 3 EXECUTION

3.01 SITE CONDITIONS

A. Verify and review field conditions with the Engineer and Owner prior to commencing work.

B. Cooperate with the Engineer and Owner to accommodate on-going operations.

C. Notify the Engineer immediately of any conflicts with the site conditions and installation program.

3.02 INSTALLATION

A. Install arches, walkways, covers, perimeter attachment, incidentals, and accessories so as to make a complete and functional system.

B. Install components in accordance with reviewed installation program and drawings.

C. Perform work in accordance with governing safety authority requirements.

3.03 INSPECTION

A. Inspect all shop fabricated components prior to and after installation.

B. The Engineer, on behalf of the Owner, may visually inspect the membrane fabric in the fabricator's shop and during field installation. The Engineer may direct that samples of any material or seams deemed questionable be removed and sent to an independent laboratory for testing. A two-week notification of fabrication shall be given to the Engineer.

C. Make membrane fabric modifications or repairs, if necessary, using equipment and methods approved by the membrane fabric manufacturer.

3.04 TRAINING

A. Manufacturer services:
   1. Manufacturer’s Representative onsite requirements:
      a. Contractor Training: 1 trip, 2 days minimum.
      b. Installation: 1 trip, 2 days minimum.

B. Manufacturer’s representative shall train and advise the contractor on the correct installation procedures for the covers system prior to the contractor beginning installation. Manufacturer’s minimum training trip requirements are as follows:
   1. Manufacturer’s Representative onsite requirements:
      a. Contractor Training: 1 trip, 2 day minimum each trip.
      b. Installation: 1 trip, 2 day minimum.

C. Provide an Operation and Maintenance Manual as specified in the Section 01670 - Operations, Maintenance, and Training Requirements.

D. Provide 2 set of tools used to open and close the retractable cover.

E. Provide a maintenance kit complete with equipment, supplies, and instructions to perform both temporary and permanent repairs to the cover fabric.

F. Provide the Owner's maintenance and operating personnel with a field demonstration and review of the equipment and supplies included in the repair kit.

Provide contact names and telephone numbers within the cover manufacturer's organization who may be contacted for maintenance or repair advice.

1. Onsite Training:
    a. Maintenance: 4 hours per session, 2 sessions.
    b. Operation: 2 hours per session, 2 sessions.

END OF SECTION

SECTION 13446

MANUAL ACTUATORS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Valve and gate actuators.
   2. Handwheel actuators.
   3. Hand-cranked geared actuators.
   4. Floor boxes.
   5. Floor stands.
   6. Key operated valves.
   7. Bench stands.
   8. Accessory equipment and floor boxes.

1.02 REFERENCES

A. Aluminum Association (AA):
   1. DAF-45 - Designation System for Aluminum Finishes.

B. American Water Works Association (AWWA).

C. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

D. National Fire Protection Association (NFPA):
   1. 70 - National Electrical Code (NEC).

1.03 SUBMITTALS

A. Shop Drawings: Include Drawings and product data with associated gate or valve as an integrated unit.

1.04 QUALITY ASSURANCE

A. Provide valve actuators integral with valve or gate, except for valve actuators utilizing T-wrenches or keys, and portable gate actuators intended to operate more than 1 valve.

B. Provide similar actuators by 1 manufacturer.

C. Provide gates and hand operating lifts by 1 manufacturer.

D. Provide hydraulic gate lifts by 1 manufacturer.

E. Provide hydraulic valve actuators and motorized actuators by 1 manufacturer.

1.05 MAINTENANCE

A. Extra materials:
   1. Key operated valve keys or wrenches: Furnish a minimum 4 keys with 4-foot shafts and 3-foot pipe handles or wrenches with 4-foot shafts and 3-foot handles for operating key operated valves.

PART 2 PRODUCTS

2.01 VALVE AND GATE ACTUATORS

A. Valve actuators:
   1. Cylinder actuators, motorized actuators, and portable gate actuators are specified in Section 13447 - Electric Motorized Actuators.
   2. Manual actuators:
      a. Material: Type 316 stainless steel.
      b. Design: Hand lever.
      c. Spring release handle: 12 inch.
      d. Notch plate: 10 position.
      e. Secure with mounting bolts.
      f. Locking device so that valve can be locked in any position with a wing nut.
   3. Stem and cover:
      a. For submerged valves, provide extension stem as indicated on the Drawings.
   4. Limit switches: On manually actuated valves where indicated on the Drawings:
      a. Heavy-duty, industrial grade, oiltight, with not less than 2 auxiliary contacts.
      b. Rating: 10 amps, 120 volts alternating current.
      c. Enclosure: NEMA Type 4X with stainless steel levers and arms. Provide switch with NEMA Type 7 enclosure when switch is located within areas with NEC Class I, Division 1; or Class I, Division 2 designations as indicated on the Drawings.

B. Stem covers:
   1. Aluminum pipe:
      a. Threaded cap on top.
      b. Bolted aluminum flange on bottom.
      c. Slots cut 1 by 12 inch at 18 inches on center in front and back of pipe.
      d. Capable of covering threaded portion of greased stems that project above actuators when gates or valves are opened or closed.
   2. Ultraviolet light resistant, clear butyrate plastic or polycarbonate pipe:
      a. Capped on the upper end.
      b. Either threaded into the top of the gate operators or held in place by bolt-down aluminum brackets.
      c. Capable of covering threaded portion of greased stems that project above actuators when gates or valves are opened or closed.
   3. Staff gauges:
      a. Adhesive-backed mylar, suitable for outdoor service.
      b. Calibrated in hundredths of feet.
      c. Read the weir crest elevations directly.
      d. Range: 1.5 feet minimum.

e. Indicate the following elevations on each staff gauge:
   1) -0.75, -0.50, -0.25, 0.0, 0.25, 0.50, 0.75.
f. Supplement with a stem-mounted pointer or indicator that permits direct observation of the weir gate crest elevation.
g. Apply to each stem cover after installation of the cover and after calibration and testing of the weir gates.
h. Set gauges precisely by a survey crew using instruments acceptable to the Engineer.

C. Stem cover flanges, pipes, and caps:
   1. After fabrication, etch and anodize to produce the following chemical finishes in accordance with AA DAF-45:
      a. A41 - Clear anodic coating.
      b. C22 - Medium matte finish.

D. Gate stem covers: Concentric with stem.

E. Position indicators:
   1. For aboveground worm gear or traveling nut manual actuators, provide position indication on the actuator enclosure.
   2. Tail rods on hydraulic cylinders, or dial indicators with clear full-open and closed position indicators, calibrated in number of turns or percentage of opening.

F. Manual or power actuator size:
   1. Sized to deliver maximum force required under most severe specified operating condition, including static and dynamic forces, seat and wedge friction, and seating and unseating forces with safety factor of 5, unless otherwise specified.

G. Actuator size: Capable of supporting weight of suspended shafting unless carried by bottom thrust bearings; shaft guides with wall mounting brackets.

H. Provisions for alternate operation: Where specified or indicated on the Drawings, position and equip crank or handwheel operated geared valve actuators or lifts for alternate operation with tripod mounted portable gate actuators.

I. Operation: Counterclockwise to open with suitable and adequate stops, capable of resisting at least twice normal operating force to prevent overrun of valve or gate in open or closed position.

J. Open direction indicator: Cast arrow and legend indicating direction to rotate actuator on handwheel, chain wheel rim, crank, or other prominent place.

K. Buried actuator housing: Oil and watertight, specifically designed for buried service, factory packed with suitable grease, completely enclosed space between actuator housing and valve body so that no moving parts are exposed to soil; provide actuators with 2-inch square AWWA operating nut.

L. Worm gear actuators: Provide gearing on worm gear actuators that is self-locking with gear ratio such that torque in excess of 160 foot-pounds will not need to be applied to operate valve at most adverse conditions for which valve is designed.

M. Traveling nut actuators: Capable of requiring maximum 100 foot-pounds of torque when operating valve under most adverse condition; limit stops on input shaft of manual actuators for fully open and closed positions; non-moving vertical axis of operating nut when opening or closing valve.

2.02 HANDWHEEL ACTUATORS

A. Manufacturers: One of the following or equal:
   1. Rodney Hunt.
   2. Waterman Valves, LLC.

B. Coating: As specified in Section 09960 - High-Performance Coatings.

C. Mounting: Floor stand or bench stand. Unless otherwise indicated on the Drawings position actuator 36 inches (nominal) above top of walkway surface.

D. Bearings above and below finished threaded bronze operating nut: Ball or roller.

E. Wheel diameter: Minimum 24 inches.

F. Indicator: Counterclockwise opening with arrow, and word OPEN cast on top of handwheel indicating direction for opening.

G. Pull to operate: Maximum 40-pound pull at most adverse design condition.

H. Stem travel limiting device: Setscrew locked stop nuts above and below lift nut.

I. Grease fittings: Suitable for lubrication of bearings.

2.03 HAND-CRANKED GEARED ACTUATORS

A. Type: Single removable crank; fully enclosed.

B. Mounting: Floor and bench stand. Unless otherwise indicated on the Drawings position actuator 36 inches (nominal) above top of walkway surface.

C. Operating nut: When scheduled for portable gate actuators.

D. Geared lifts: Single speed with minimum ratio of 2 to 1.

E. Teeth on gears, spur pinions, bevel gears, and bevel pinions: Cut.

F. Lift nuts: Cast manganese bronze.

G. Exterior surfaces on cast-iron lift parts: Smooth.

H. Bearings above and below flange on lift nuts: Ball or roller; capable of taking thrust developed by opening and closing of gates under maximum operating head; with bronze sleeve bearings and sufficient grease fittings for lubrication of moving parts, including bearings and gears.

I. Crank rotation indicator: Cast arrow with word OPEN in prominent location readily visible indicating correct rotation of crank to open gate.

J. Hand cranks: 15-inch radius; requiring maximum 25-pound pull to operate gate at maximum operating head; with:
   1. Revolving brass sleeves.
   2. Gears, spur pinions, bevel gears, and bevel pinions with cut teeth.
   3. Cast manganese bronze lift nuts.
   4. Cast-iron lift parts with smooth exterior surfaces.

K. Indicator: Dial position type mounted on gear actuator; enclosed in cast-iron or aluminum housing with clear plastic cover; marked with fully open, 3/4, 1/2, 1/4, and closed positions.

2.04 FLOOR BOXES

A. Manufacturers: The following or equal:
   1. Waterman Valves, LLC.

B. Cast-iron, with:
   1. Counter type indicator.
   2. Hinged, lockable lid with directional arrow.
   3. Two-inch square AWWA operating nut.
   4. Packing gland providing drip-tight seal around valve shaft.

2.05 FLOOR STAND

A. Manufacturers: One of the following or equal:
   1. Rodney Hunt.
   2. Waterman Valves, LLC.

B. Assemblies: Heavy-duty cast-iron, suitable for mounting specified actuator.

2.06 BENCH STANDS

A. Manufacturers: One of the following or equal:
   1. Rodney Hunt.
   2. Waterman Valves, LLC.

B. Handwheel actuators or hand crank, geared actuators conforming to hand-cranked geared actuator requirements, except capacity to be mounted on haunch, wall bracket, or self-contained gate yoke.

2.07 ACCESSORY EQUIPMENT

A. Wall brackets or haunches: As indicated on the Drawings.

B. Stems: Stainless steel; sized to match output of actuator; minimum gate or valve operating stem diameter; maximum 200 slenderness ratio.

C. Stem couplings: Stainless steel; internally threaded to match stem; lockable to stem by set screw.

D. Stem guides: Cast-iron with silicon bronze bushing; maximum 200 slenderness ratio; capable of being mounted with wall bracket; adjustable in 2 directions.

E. Wall brackets: Cast-iron, capable of withstanding output of actuator, adjustable in 2 directions.

F. Stem stuffing boxes: Cast-iron, with adjustable gland and packing.

G. Fasteners: Type 316 stainless steel.

H. Anchor bolts: As specified in Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry, except that the material shall be Type 316 stainless steel.

I. Geared valve actuators: Provided with cut gears, either spur or worm; sized to operate valves at most adverse design condition; with maximum 40-pound pull at handwheel or chain wheel rim.

J. Geared valve traveling nut actuators: Acceptable only where specified or indicated on the Drawings.

K. Accessory equipment for valves and gates requiring remote actuators: Operating stems, stem couplings, stem guides, wall brackets, and stem stuffing boxes.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install floor boxes in concrete floor with lid flush with floor.

B. After installation of gate and stem covers, mark stem covers at point where top of stems are at full-open position and at closed position.

C. Attach floor stand to structure with anchor bolts.

D. Install stem stuffing boxes where operating stems pass through intermediate concrete floor slabs.

3.02 SCHEDULES

A. Provide geared actuators for the following valves:
   1. Butterfly valves larger than 6 inches, nominal size, on liquid service.
   2. Butterfly valves larger than 10 inches, nominal size, on gas and air service.
   3. Plug valves 6 inches, nominal size, and larger.

B. Provide handwheel actuators for valves mounted 6 feet or less above floors.

C. Provide chain wheel actuators for valves mounted more than 6 feet to centerline above floors.

END OF SECTION

SECTION 13447

ELECTRIC ACTUATORS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Electric motor-driven actuators for valves and gates.

B. Equipment tag numbers:
   1. As scheduled.

1.02 REFERENCES

A. American Water Works Association (AWWA):
   1. C504 - Standard for Rubber-Seated Butterfly Valves.
   2. C542 - Standard for Electric Motor Actuators for Valves and Slide Gates.

B. International Organization for Standardization (ISO):
   1. 12944 - Paints and Varnishes.

C. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Provide a complete list/schedule of actuators being provided with their associated tag names, as indicated on the Drawings and/or Specifications, service process area and the size of the valve they are actuating.

C. Product data:
   1. Electrical ratings:
      a. Voltage and number of phases.
      b. Starting and running current.
      c. Voltage levels and source for control and status.
   2. Description of integral control interface.
   3. Remote control station components (If applicable).
   4. Environmental ratings, including NEMA enclosure rating and submergence capabilities.
   5. Gear ratios for both manual and motorized actuation.
   6. Opening and closing directions.
   7. Electric motor data.
   8. Allowable starts per hour.
   9. List of included options and accessories.

10. Full travel times.
11. Gearbox data, including gear ratio, and gearbox efficiency.

D. Shop Drawings:
   1. Wiring diagrams:
      a. Include all options and expansion cards furnished with each actuator.
   2. Configuration and dimensioned drawings of each valve and actuator combination, including gear box (if applicable) at each individual location.
      a. Configuration and orientation shall account for:
         1) Proximity of gate or valve to adjacent walls, piping, equipment, and other obstacles.
         2) Operation and maintenance access for all components of the actuator and gear box.
   3. Dimensioned drawings of each valve gearbox.
   4. Electric motor data.

E. Calculations:
   1. Operating torque.
   2. Maximum torque calculations for seating and unseating.
   3. Maximum operating torque at starting and normal operation.

F. Installation instructions:
   1. Detail the complete installation of the equipment, including rigging, moving, and setting into place.
   2. Provide manufacturer's installation instructions.

G. Quality Control Submittals:
   1. Manufacturer's representative qualifications.
   2. Manufacturer's Certificate of Source Testing as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   3. Manufacturer's Certificate of Installation as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   4. Manufacturer's Certificate of Functional Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

H. Owner Training Submittals:
   1. As specified in Section 01660 - Equipment and System Performance and Operational Testing.

I. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.
   2. Include a list of configurable parameters and the final values for each.
   3. Include a troubleshooting chart covering the complete valve and controls/electrical power systems, showing description of trouble, probable cause, and suggested remedy.

1.04 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements, Section 15050 - Common Work Results for Mechanical, and the manufacturer's instructions.

1.05 PROJECT OR SITE CONDITIONS

A. As specified in Section 01850 - Design Criteria.

1.06 MAINTENANCE

A. As specified in Section 01600 - Product Requirements.

B. Spare parts:
   1. Provide the following (minimum 10 percent of total number of actuators of each model type furnished, but not less than 1 for each model of actuator furnished):
      a. Stem nut.
      b. Worm shaft subassembly.
      c. Drive sleeve subassembly.
      d. Complete actuator seal kit.
      e. Actuator gearbox oil (sufficient quantity to fill 4 gearboxes).
      f. Encoder.
      g. Control module.
   2. Provide 1 spare motor for each size motor furnished.

C. Setting tool:
   1. If required for setting or configuring the actuator, provide a handheld setting tool.
      a. Furnish 1 setting tool for every 10 actuators.
      b. Capable of communicating with PC-based configuration software and transferring the following in either direction between the computer and programmer and setting tool, and between the setting tool and actuator.
      c. Actuator configurations:
         1) Capable of storing up to 10 different configurations.
      d. Diagnostic data:
         Capable of storing 4 complete sets of diagnostic data.

1.07 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Lines 3 inches and smaller:
   1. The following or equal:
      a. Rotork Controls Inc.
         1) ROMpak (Quarter-turn).

B. Lines 4 inches and larger:
   1. One of the following, or equal:
      a. Limitorque Corp.:
         1) Accutronix MX for multi-turn applications.
         2) Accutronix QX quarter-turn applications.

b. Rotork Controls Inc. IQ3 Range:
    1) IQ for multi-turn applications.
    2) IQT for quarter-turn applications.

2.02 MATERIALS

A. Enclosures:
1. Constructed of materials suitable for the environment where the actuator will be installed.
2. Stainless steel external fasteners.
3. Provide O-ring seals for each of the following areas:
    a. Between the terminal compartment and the internal electrical elements.
    b. Between the mechanical and electrical portions to protect from the ingress of oil, and to protect the mechanical components of oil from dust and moisture when the electrical terminal is open.

B. Coatings:
1. Material requirements:
    a. Factory prime and coat with an ISO 12944 classification coating of C5M (Marine, offshore estuaries with high salinity) coating with 15-year durability.
    b. Touch-up damaged coatings with manufacturer provided coating repair kit.
2. Application requirements:
    a. Painting shall commence within 4 hours of blast cleaning.
    b. Each paint coat within the system is to be applied in accordance with the paint manufacturer's instructions.
    c. Paint thickness shall be checked for each coat on each actuator.
3. Qualification requirements:
    a. Operators shall be experienced and proficient in surface preparation and coating application techniques.
    b. Personnel shall have relevant knowledge of health and safety hazard, use of protective equipment, coating materials, mixing and thinning coatings, coating pot life, surface requirements, etc.
    c. Personnel carrying out inspection or verification shall be certified as NACE coating inspector or equivalent such as ICorr.

2.03 CHARACTERISTICS FOR ACTUATORS ON LINES 3 INCHES AND SMALLER

A. Actuators for valves 3 inches and smaller:
1. Complete and operable with all components and accessories required for operation.
2. Power supply:
    a. Valve motion independent of power supply phase rotation.
    b. As indicated on the Drawings.
3. Size actuator to move valves from full open to closed position within the time indicated in the Actuator Schedule:
    a. If an operating time is not indicated on the Actuator Schedule, size the actuator to move valves at minimum 12 inches per minute under maximum load. Measure closure rate for valves at the maximum diameter of disc, plug, or ball.
4. For outdoor or vault installations, provide an integral anti-condensation heater when available as an option.

5. Control inputs:
    a. Capable of using discrete dry contacts.
    b. Controls the valve when local-stop-remote is in REMOTE.
    c. Material: Type 316 stainless steel.
    d. Provide the following inputs at the actuator:
        1) OPEN.
        2) CLOSE.
6. Status outputs:
    a. Dry contact outputs configured for the functions indicated on the Drawings. Provide the following outputs for all actuators:
        1) FULLY CLOSED.
        2) FULLY OPEN.
        3) REMOTE.
    b. Output contacts rated for 5 amps, 120 VAC.
7. Analog input:
    a. Provide a 4 to 20 analog input for analog modulating valves when indicated on the Drawings.
    b. Modulate valve to maintain position based on analog input value.
    c. Maximum input impedance 250 ohms.
8. Analog output:
    a. Provide an isolated 4 to 20 mA analog output when indicated on the Drawings.
9. Components:
    a. Motors:
        1) Torque ratings equal to or greater than that required for valve seating and dynamic torques with a 25 percent factor of safety.
        2) Rated for operating under the following conditions without exceeding temperature limits with ambient temperature of 40 degrees Celsius.
            a) Continuous operation for 15 minutes or twice the open-to-close operating time (whichever is greater) at normal operating torque or 33 percent of maximum torque (whichever is greater).
            b) 60 starts per hour minimum for open/close service.
    b. Manual actuation:
        1) Handwheel for manual operation.
    c. Gearing: Self-locking, high-alloy steel gears.
10. Communication options:
    a. As specified in the Contract Documents.

2.04 CHARACTERISTICS FOR ACTUATORS ON LINES 4 INCHES AND LARGER

A. Provide actuators complete and operable with all components and accessories required for operation.

B. Power supply:
    1. Voltage and phases as indicated in the Actuator Schedule.
    2. Valve or gate motion independent of power supply phase rotation.
    3. Provide an internal backup power source or mechanical indicator to maintain settings and track valve position when main power is off.
    4. Actuators shall incorporate major components such as the motor, starter, local controls, terminals, etc., housed within a self-contained, sealed enclosure.

C. Size actuator to move gates or valves from full open to closed position within the time indicated in the Actuator Schedule:
    1. If an operating time is not indicated on the Actuator Schedule, size the actuator to move gates or valves at minimum 12 inches per minute under maximum load. Measure rate of closure for valves at maximum diameter of disc, plug, or ball.
    2. Size actuators so that gear boxes are not required where possible.

D. Control interface:
    1. Configuration:
        a. Provide a non-intrusive, non-contacting interface for configuring input and output settings, control values, ranges, torque switch settings, valve positions switch settings, and options.
            1) Configurable from a handheld configuring tool or input devices on the actuator.
    2. Local interface, integral to actuator:
        a. Non-intrusive, non-contacting selector switches:
            1) LOCAL-STOP-REMOTE:
                a) Motor actuator operation is prevented with the switch in STOP.
            2) OPEN-CLOSE:
                a) Controls the valve when LOCAL-STOP-REMOTE is in LOCAL.
                b) Spring return to center.
                c) Configurable between maintained (actuator runs until end of travel, high torque, or a LOCAL-STOP-REMOTE is switched to STOP) and momentary (actuator stops when lever is released).
        b. Local display:
            1) Valve fully open and fully closed indicators.
            2) Numerical display showing actual valve or gate position in percent of travel.
    3. Remote control station - (VCP):
        a. For actuators located more than 5 feet above finished floor/grade or where indicated on the Drawings in the Schedule.
            1) NEMA rating to match those to the associated Actuator Schedule.
                a) Where the rating is not listed, use NEMA Type 4X enclosures for non-hazardous areas, and explosion-proof (XP) Class I, Division 1 for hazardous areas.
                b) Pilot devices shall be 30 millimeters and pilot lights shall be illuminated by LEDs.
            2) LOCAL-STOP-REMOTE selector switch.
            3) LOCAL mode control devices:
                a) Operate valve when LOCAL-STOP-REMOTE integral to the actuator is in REMOTE and LOCAL-STOP-REMOTE on remote control station is in LOCAL.
                b) OPEN-STOP-CLOSE maintained switch or OPEN, STOP, and CLOSE pushbuttons where Maintained operation is indicated in the Actuator Schedule.
                c) OPEN-CLOSE spring-return switch or OPEN and CLOSE pushbuttons where momentary operation is indicated in Attachment A - Actuator Schedule.
            4) Pilots' lights to indicate valve position:
                a) Fully open.

b) Fully closed.

4. Control inputs:
   a. Capable of using discrete 24 VDC or 120 VAC.
   b. Controls the valve when LOCAL-STOP-REMOTE is in REMOTE.
   c. Isolated inputs capable of operating from external control voltage source or internal power supply:
   d. Provide the following inputs:
      1) OPEN.
      2) CLOSE.
      3) STOP.
   e. OPEN and CLOSE inputs configurable between maintained (actuator runs until end of travel, high torque, or a STOP input) and momentary (actuator stops when command is removed).
5. Status outputs:
   a. Monitor relay output: Dry contact, normally closed, opens when actuator is not in REMOTE or in the event of any internal fault or alarm condition.
   b. Dry contact outputs configured for the functions indicated on the Drawings. Provide the following outputs for all actuators:
      1) Fully closed.
      2) Fully open.
      3) LOCAL-STOP-REMOTE in REMOTE position.
   c. Contacts and communications:
      1) As specified in the Contract Documents.
      2) Dry contacts rated for both 120 VAC and 24 VDC.
   d. Analog input:
      1) 4-20 mA analog input for analog modulating valves when indicated on the Drawings.
   e. Analog output:
      1) Isolated 4-20 mA analog output when indicated on the Drawings.
         a) Loop power sourced from the actuator power supply.
         b) Output proportional to process value(s) indicated on the Drawings.

E. Features:
   1. Time delay on reversal: Incorporate time delay between stopping actuator and starting in opposite direction to limit excessive current, torque, and heating from instantaneous reversal.
   2. Data logging:
      a. Store diagnostic data and reference data.
      b. Time-stamped historical operating data, including number of operations.
      c. Torque profiles showing actual torque at each valve position through the operating range
      d. Starting torque, maximum running torque, and end of travel torque.
         1) Store reference data (recorded during commissioning) and data from last operation.
   3. Provide display of logged data on the actuator, or provisions to download to a personal computer.

F. Components:
    1. Motors:
        a. Specifically designed for valve actuator service with high starting torque, totally enclosed non-ventilated construction.
        b. Torque ratings equal to or greater than that required for valve seating and dynamic torques with a 25 percent factor of safety.
            1) Design requirements for rubber-seated AWWA butterfly valves:
                a) Design actuators for maximum gate or valve operating torque, in accordance with and using safety factors required in AWWA C504 and AWWA C542.
                    (1) Valve actuator torque requirement for open-close service: Not less than the required valve-seating and dynamic torques under design operating conditions in accordance with AWWA C504.
                    (2) Valve actuator torque requirement for modulating service: Not less than twice the required valve dynamic torque under design operating conditions in accordance with AWWA C504.
            2) Design requirements for slide gates, gate valves, knife gate valves, globe valves, and diaphragm valves:
                a) Design valves and actuators for maximum operating torque in accordance with and using safety factors required in AWWA C542.
                b) Design for the maximum torque and thrust running load over the full cycle.
                c) Maximum torque or thrust rating: Actuator stall torque or maximum thrust output shall not exceed the torque or thrust capability of the valve or gate, as determined by the valve or gate manufacturer.
        c. Capable of being removed and replaced without draining the actuator gear case.
        d. Motor bearings shall be amply proportioned of the anti-friction type and permanently lubricated.
        e. Rated for operating under the following conditions without exceeding temperature limits with ambient temperature of 50 degrees Celsius.
            1) Continuous operation for 15 minutes or twice the open-to-close operating time (whichever is greater) at normal operating torque or 33 percent of maximum torque (whichever is greater).
            2) 60 starts per hour for open/close service or 1,200 starts per hour for modulating service.
        f. Provide the following motor protection features:
            1) Jammed valve (no valve motion detected through a time delay).
            2) High motor temperature (sensed by an embedded thermostats).
            3) High torque.
            4) Single phasing protection.

G. Position sensing:
    1. Electronic and adjustable using a solid-state encoder wheel.
        a. Mechanical limit switches and potentiometers are not acceptable.
    2. Capable of retaining position and monitoring valve or gate motion when valve is manually actuated and when main power is not present.

3. Valve range and position switch outputs field adjustable.

H. Torque sensing:
   1. Torque shutdown setting: 40 percent to 100 percent rated torque:
      a. Adjustable in 1 percent increments.
   2. Torque display: 0 to 100 percent-rated torque.
   3. Capable of interrupting control circuits during both opening and closing and when valve torque overload occurs.
   4. Electrical or electronic torque sensing.
   5. Independent of variations in frequency, voltage, or temperature.
   6. Actuator shall store actual operational torque curves for retrieval by plant maintenance staff.
   7. Provide a temporary inhibit of the torque sensing system during unseating or during starting in mid-travel against high inertia loads.
   8. Provide visible verification of torque switch status without any housing disassembly.

I. Manual actuators:
   1. Hand wheel for manual operation.
      a. Maximum 80-pound pull on rim when operating gate or valve under maximum load.
      b. Provide pull chain when motorized actuator is located more than 6 feet above floor surface.
         1) Chain shall be of sufficient length to reach approximately 4 feet above the operating level.
         2) Where the chain obstructs an aisle or walkway, provide holdback or other means to ensure chain does not create a nuisance or hazard to operating personnel.
         3) Provide Type 316 stainless steel.
   2. Declutch lever: Padlockable, capable of mechanically disengaging motor and related gearing and freeing hand wheel for manual operation.

J. Gearing: Hardened alloy steel spur or helical gears and self-locking, alloy bronze worm gear set.
   1. Accurately cut to ensure minimum backlash.

K. Bearings:
   1. Anti-friction bearing with caged balls or rollers throughout.
   2. Sealed-for-life type thrust bearings housed in a separate thrust base.

L. Drive bushing:
   1. Easily detachable for machining to suit the valve stem or gearbox input shaft.
   2. Positioned in a detachable base of the actuator.

M. Lubrication:
   1. Provide totally enclosed actuator gearing with oil or grease filled gear case suitable for operation at any angle.
   2. Actuators requiring special or exotic lubricants are not acceptable.

2.05 ACCESSORIES

A. Software:
   1. Furnish PC-based diagnostic and configuration software to display diagnostic data and configure actuators.
   2. Provide software communications to the valve actuator and handheld setting tool using Bluetooth wireless or IrDA infrared communications.
      a. Provide accessories and drivers required for operation and communications with a standard personal computer running Microsoft Windows.
      b. Where infrared communications are used, furnish an IrDA to USB adapter with a mounting device to secure the infrared element to the valve actuator IrDA port:
         1) Provide with a minimum cable length of 3 feet, capable of being extended with a standard USB extension cable.

B. Termination module cover:
   1. For actuators on a valve network, provide a means to keep the valve network in service, in the event where the actuator must be removed.
   2. Provide sunshades for outdoor installations of remote control stations that use an LCD or similar screen. Regular pushbutton, sector switches, and pilot light control stations will not require a sunshade.

2.06 SOURCE QUALITY CONTROL

A. Source Testing:
   1. Design and performance test reports in accordance with AWWA C542.
   2. Test each actuator with a simulated load.
      a. Simulate a typical valve load.
   3. Furnish test reports and the Manufacturer's Certificate of Source Testing.

PART 3 EXECUTION

3.01 INSTALLATION

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Install the equipment in accordance with the manufacturer's instructions.

C. Position visual indicators so that they are most easily visible.

D. Installation Verification:
   1. Furnish Manufacturer's Certificate of Installation Verification.

3.02 FIELD QUALITY CONTROL

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, Section 15958 - Mechanical Equipment Testing, and this Section.

B. Functional Testing:
    1. Installed actuator:
        a. Test witnessing: Witnessed.
        b. Conduct Level 2 General Equipment Performance Tests.
        c. Conduct Level 2 Vibration Tests.
        d. Conduct Level 2 Noise Tests.
    2. Electrical Instrumentation and Controls:
        a. Test witnessing: Witnessed.
        b. Conduct testing as specified in Section 17100 - Control System Requirements.
    3. Furnish test reports and the Manufacturer's Certificate of Functional Compliance.

3.03 OWNER TRAINING

A. Perform Owner Training as specified in Section 01660 - Equipment and System Performance and Operational Testing.
    1. Number of sessions:
        a. Operations: 1.
        b. Maintenance: 1.

3.04 ACTUATOR SCHEDULE

A. Provide actuators in this Section:
    1. Major process actuators are listed in the Actuator Schedule shown in Attachment A - Actuator Schedule.

END OF SECTION

ATTACHMENT A - ACTUATOR SCHEDULE

ACTUATOR SCHEDULE

Tag Number	Item	Reference DWG	Type	Size	Duty	NEMA Rating	Voltage/Phase/Hz	Notes	Service	Controls
THK-VAL-07-011	Thickener Flow Control Valve 1	07N21	PV	4”	MD	4X	480/3/60	1	CTRL	A
THK--VAL-07-021	Thickener Flow Control Valve 2	07N22	PV	4”	MD	4X	480/3/60	1	CTRL	A
THK--VAL-07-031	Thickener Flow Control Valve 3	07N23	PV	4”	MD	4X	480/3/60	1	CTRL	A
THK--VAL-07-012	Thickener Drain Valve 1	07N21	PV	4”	STD	4X	480/3/60	1	O/C	D
THK--VAL-07-022	Thickener Drain Valve 2	07N22	PV	4”	STD	4X	480/3/60	1	O/C	D
THK--VAL-07-032	Thickener Drain Valve 3	07N23	PV	4”	STD	4X	480/3/60	1	O/C	D
DEW-VAL-07-031	Centrifuge Inlet Valve 3	07N71	PV	3”	STD	4X	480/3/60	1	O/C	D
DEW-VAL-07-032	Centrifuge Inlet Valve 5	07N71	PV	3”	STD	4X	480/3/60	1	O/C	D

Notes:

(1) Verify field characteristics prior to sizing motor actuator.

Abbreviations:

Type:
BFV = Butterfly Valve.
BV = Ball Valve.
PV = Plug Valve.
SG = Slide Gate.

NEMA Rating:
4X for general locations.
6P for vaults and possible submergence.
XP for Class I, Division 1 and Division 2 locations.

Controls:
A = Analog.
D = Discrete.
DP = Profibus DP.
E-IP = Ethernet/IP.
E-TCP = Ethernet TCP or TCP/IP.
FF = Foundation Fieldbus H1.
MB = Modbus RTU (RS-485).
NET = Manufacturer’s proprietary network.
PA = Profibus PA.

Duty:
MD = Modulating duty (~1,200 starts/hr).
MOD = Modulating.
STD = Standard service (0-60 starts/hr) duty.

Service:
CTRL = Control.
O/C = Open/Close.

SECTION 14611

PORTABLE GANTRY HOISTS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Portable gantry hoist.

1.02 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals and Section 15050 - Common Work Results for Mechanical Equipment.

B. Product data: Specifications for system components, accessories, and protective coatings.

C. Shop drawings: Include erection, installation, and adjusting instructions and recommendations.

D. Commissioning submittals:
   1. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

E. Project closeout documents:
   1. Provide vendor operation and maintenance manual as specified in Section 01670 - Operations, Maintenance, and Training Requirements.

1.03 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

2.02 MANUFACTURERS

A. Portable gantry hoists:
   1. The following or equal:
      a. B. E. Wallace, model FA19-8AC,
         1) Complete with wheeled push crane trolley model 70-0315, and heavy duty hand-chain hook mounted manual crane hoist model 5-XTL-8.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. Portable gantry hoist shall include an adjustable gantry, with 4 position casters, trolley, hand chain hoist, transport cart, lifting frame jacks, and all other accessories required for a complete and operating system.

B. Design and performance requirements:
   1. General:
      a. Equipment and accessories provided shall be fabricated, assembled, erected, and placed in proper operating condition in full conformance with Drawings, Specifications, engineering data, instructions, and recommendations of the equipment manufacturer unless exceptions are noted by the Engineer.
      b. Equipment shall be suitable for indoor or outdoor use and shall be used for lifting pump, motor assembly and valves in the RDT Facility area.
      c. Loading, impact allowances and allowable stresses shall be in accordance with the governing standards for the gantry.
   2. Portable gantry:
      a. The portable gantry shall be designed with a safety factor of at least 1.5, and the monorail deflection under design load shall not exceed 1/450 of the span for the following criteria:

Capacity	1000 pounds
Maximum Chain Pull to Lift Maximum Load	46 pounds
Adjustable A-Frame	
Height Range	9.50 feet
Clear Span	6.83 feet
Caster Spread Range	4.60 feet
Caster Diameter	0.50 feet
Monorail	
Span	8 feet
Depth	6 inches
Net Weight	135 pounds

      b. Gantry height:
         1) Fully adjustable in 6-inch intervals and shall be locked on each leg by a spring-loaded bolt.
         2) Locks shall be designed to allow locking each leg in an unbolted position to facilitate height adjustment.
      c. Gantry spread width:
         1) Adjustable with a minimum of 5 different positions at 6-inch intervals.
         2) Have an inside straddle clearance of at least 44 inches in at least 1 of the 6 different positions.
         3) A cable shall be provided between each set of adjustable legs to prevent over-extension.

3. Gantry monorail shall be designed to align with off-center loads to prevent lifting frame and trolley distortion.
    a. The monorail shall be suspended from the lifting frame by a minimum of 4 points at each end of the monorail.
    b. A lifting bracket shall be provided on top of the monorail at mid-span to facilitate height adjustment.
4. Gantry shall be provided with 4 casters, each capable of rotating 360 degrees with a 4-position swivel lock.
    a. The lock on each caster shall prevent rolling and swiveling of the caster when engaged.
5. Gantry trolley and hoist shall be a hand-geared type, low headroom trolley hoist.
    a. Gantry trolley frame shall be rigid and shall contain the hoist.
6. Trolley wheels shall be of the single flange type of rolled, forged, or cast steel with machined universal crowned or tapered treads.
    a. Drive wheels shall have integrally cut spur gear teeth or machine cut gears pressed on hubs.
    b. Trolley wheel axles shall be of the fixed type, made from high carbon steel machined and ground to size to receive the wheel bearings.
    c. Wheel bearings shall be permanently shielded, lifetime-lubricated, anti-friction type, suitable for radial and end thrust loading.
7. Hoisting assembly:
    a. Hoisting assembly shall consist of the necessary gearing, guides, and sheaves, all built integrally with the trolley; a load chain equipped with a load hook; and hand chains.
    b. Anti-friction bearings shall be used throughout, and the assembly shall have facilities for proper lubrication.
8. Gantry hoist hook shall be slow opening, nonfracturing, forged steel, and shall be provided with a safety latch.
    a. The hook shall be mounted on anti-friction bearings to permit easy turning.

2.04 COMPONENTS

A. A-frame: Aluminum with adjustable height, span and tread, spring-loaded adjusting bolts and steel pin connections.

B. Monorail: Aluminum I-beam; freely hinged from A-frame.

C. Casters: 4-position, swivel lock with composition wheels.

D. Bearings: Anti-friction type; oil lubrication or lifetime grease packing.

E. Gearing: Spur or helical type; fully enclosed in oil tight housing equipped with load limiters for automatic overload protection.

F. Load brake: Fully enclosed in oil tight housing.

G. Operating chains: Welded steel link; zinc plated.

H. Load chains: Heat-treated alloy steel; welded link, zinc plated.

I. Lifting hook: Forged steel; slow opening nonfracturing with safety latch.

J. Sheave bearings: Anti-friction or sleeve type.

2.05 FINISHES

A. All iron and steel surfaces shall be protected by suitable paint or coatings applied in accordance with the General Equipment Stipulations.

B. Machined, polished, and nonferrous surfaces normally not painted by the manufacturer shall be coated with a rust preventative compound.

C. All equipment shall have a coating designed for durability under the specified service.
   1. Where applicable, coatings shall be standard systems of the manufacturer.

D. Color shall be manufacturer's standard.

E. Markings:
   1. The lifting frame and hoist shall have a conspicuous, easy to read marking showing manufacturer's name and rated capacity of equipment in pounds.

2.06 ACCESSORIES

A. Portable lifting frame jacks:
   1. 4 steel jacks designed to fit the gantry lifting frame shall be furnished.
   2. The jacks shall be permanently mounted on the frame legs and used to adjust the portable lifting frame height.

B. Transport cart: A lightweight cart, fabricated from structural members that attach into the caster frames of the gantry or other acceptable means, acceptable to the Engineer, shall be supplied with the adjustable height lifting frame.

PART 3 EXECUTION

3.01 GENERAL

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

3.02 INSTALLATION

A. The gantry and accessories shall be fully assembled, lubricated as required, and placed in proper operating condition.

B. After assembly, demonstrate that hoist, trolley, and frames operate in accordance with the requirements of these specifications.
   1. Then disassemble for transportation on the portable gantry cart and store as directed by the Engineer.

C. Do not use the portable gantry hoist or transport cart to install other equipment in the performance of the work.

3.03 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Installation and Functionality Compliance.
   2. Manufacturer's Representative onsite requirements:
      a. Not Required.
   3. Training:
      a. Not Required.

END OF SECTION

SECTION 14624

MONORAIL SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Monorail system with connections to structural members of the building.

1.02 REFERENCES

A. American Institute of Steel Construction (AISC):
   1. Specifications for Design, Fabrication, and Erection of Structural Steel for Buildings.

B. American Society of Mechanical Engineers (ASME):
   1. B30.11 - Monorails and Underhung Cranes.
   2. B30.16 - Overhead Hoists (Underhung).

C. American Welding Society (AWS).

D. Monorail Manufacturers Association (MMA):
   1. MH27.1 - Specifications for Underhung Cranes and Monorail Systems.

E. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

F. National Fire Protection Association (NFPA):
   1. 70 - National Electrical Code (NEC).
      a. Article 610 - Cranes and Hoists.

G. Occupational Safety and Health Administration (OSHA).

1.03 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Anchoring and bracing.

C. Rail, supports, bracing, connections and welding.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Delegated Design Submittals:
   1. Anchoring and bracing: Provide project-specific calculations based on support conditions and requirements to resist loads specified in Section 01850 - Design Criteria.
      a. To structures for equipment installed in structures designated as seismic design category C, D, E, or F.
      b. For equipment installed outdoors.
   2. Monorail design, including rail sizing, supports, bracing, connections and welding.

C. Commissioning Submittals:
   1. As specified in Section 01660 - Equipment and System Performance and Operational Testing, including the following:
      a. Manufacturer's representative qualifications.
      b. Certificates:
         1) Requirements as specified in this Section.
      c. Test Plans:
         1) Test requirements as specified in this Section.
      d. Test Reports.
      e. Manufacturer's representatives field notes and data.
      f. Owner training.

D. As specified in Section 01600 - Product Requirements:
   1. Product data.
   2. Shop Drawings:
      a. Include support types, sizes, spacing, bridging, connections, anchoring, bearing plates, and erection instructions.
   3. Calculations.

E. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.

F. Certificates:
   1. Certificate of tests conducted by the monorail manufacturer in accordance with industry standards and federal regulations prior to shipment of equipment.
   2. OSHA certificate upon completion of field load testing.

1.05 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements, Section 15050 - Common Work Results for Mechanical, and the manufacturer's instructions.

B. Assemble, paint, test, and adjust monorail system in the manufacturer's shop before shipment, as far as practical.

1.06 SEQUENCING AND SCHEDULING

A. Coordinate Work with restrictions as specified in Section 01140 - Work Restrictions.

1.07 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements and Section 15050 - Common Work Results for Mechanical Equipment.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. Design requirements:
   1. Hoisting system: In accordance with ASME B30.11, ASME B30.16, and OSHA standards.
   2. Structural steel construction: In accordance with AISC specifications.
   3. Safety factor of castings, forgings, and stampings: Minimum 5 with regard to ultimate strength.
   4. Perform welding in accordance with AWS standards.
   5. Electrification in accordance with NEC 610.
   6. Design equipment in accordance with MMA MH27.1.

B. Performance requirements:
   1. Service classification: Class A, standby or infrequent service.
   2. Capacity: 4 ton.
   3. Arrange working parts for convenient inspection, lubrication, adjustment, repair, or replacement.

2.03 MONORAIL

A. Manufacturers:
   1. One of the following or equal:
      a. Cleveland Tramrail by Gorbel.
      b. Trambeam Corp.

B. Maximum vertical deflection of monorail beam: Maximum span of monorail beam divided by 450.

C. Maximum lateral deflection of monorail beam: Maximum span of monorail beam divided by 360 when subjected to a lateral load of 20 percent of the lifted load.

D. Stops and bumpers: Adequate to absorb energy of and stop moving trolley at end of permitted travel.

E. Hangers: Adjustable, able to level and accurately align system within 1/8-inch tolerance, able to support monorail from building structure.

F. Length: 73 feet approximately.

G. Labeling: Paint hoist capacity on monorail with minimum 4-inch high letters and numbers where clearly visible from operating floor.

2.04 TROLLEY HOISTS

A. Manufacturers: One of the following or equal:
   1. Cleveland Tramrail.
   2. Columbus McKinnon.
   3. P&H Hevi-Lift.

B. Type: Combination electric motor-driven trolleys and hoists, single-speed with trolley cushioned start, including mechanical brake, electrical brake, and upper hoist limit stop and load limiting device, low headroom.

C. Hoisting speed: 16 feet per minute.

D. Distance from bottom of rail to inside of hook: Maximum 25 inches with hook in fully raised position.

E. Trolleys wheels: Single-flanged; forged steel, hardened to 425 Brinell; fitted with anti-friction bearings with lifetime seals; suitable for adjustment to monorails.

F. Safety lugs: Add to the manufacturer’s standard spread design.

G. Motors: 460 volt, 3-phase, 60 hertz, totally enclosed non-ventilated (TENV), squirrel-cage induction type operating at maximum 1,800 revolutions per minute, with Class B or F insulation, horsepower as follows:
   1. Hoist: 1 hp.
   2. Trolley: 3/4 hp.
      a. Actual horsepower requirement not to exceed the specified motor horsepower.

H. Drive units: Specially designed for monorail service with cushioned stop holding brakes.

I. Hoisting drum: Steel or cast iron with machined, 1/2 rope diameter deep grooves; adequate to provide minimum 2 complete rope wraps on drum with hook in lowest position, and to accommodate full length of rope without overlapping when in highest position.

J. Hoist drive speed reducer: With heat-treated steel helical gears; oil-lubricated with oiltight cases; shafts running in anti-friction bearings.

K. Limit switches and overload device: Manufacturer’s standard.

L. Hoisting rope: Specifically designed for specified service loads; preformed, improved plow steel with fiber core; double-reeved.

M. Hoisting block: Steel with forged or cast steel hook supported on ball or roller bearings for true vertical lift.

N. Hook: Safety type, able to rotate freely on bearing support with heavy-duty type safety latches.

O. Bottom block: Shrouded.

P. Lifting distance: 6 feet approximately.

2.05 ELECTRIFICATION AND CONTROL

A. Electrification type: Cable and spring-loaded swiveled cable reel-mounted on structure.

B. Cable run: From junction box to cable reel, then to control unit.

C. Control unit: Pendant pushbutton station hanging from hoist to maximum 4 feet above operation floor.

D. Control voltage: 120 volts alternating current, supplied from transformer on hoist.

E. Pushbuttons: Momentary-contact, maintain-pressure, automatically de-energizing upon relaxation of pressure; number and functions as follows:
   1. Pushbuttons for hoisting: 2; one for each direction.
   2. Pushbuttons for trolley: 2; one for each direction.

F. Enclosures for control unit, electrical control, and reel: NEMA Type 4X.

G. Control unit support: Steel cable.

H. Control accessories:
   1. Geared limit switch able to limit up and down travel with second switch operated by hook to stop hoist when highest safe point is reached.
   2. Magnetic contactors for up and down operation and control.

I. Junction boxes: Suitable for connection of field services with ground pads.

2.06 FINISHES

A. Coating: Provide prime coat, intermediate coat, and finish coat as specified in Section 09960 - High Performance Coatings.

PART 3 EXECUTION

3.01 GENERAL

A. As specified in Section 15050 - Common Work Results for Mechanical Equipment.

B. Do not use monorail crane system for construction.

3.02 PREPARATION

A. Anchoring and bracing to structures:
   1. Prepare equipment anchor setting template(s) and use to position anchors during construction of supporting structure(s).
   2. Install anchors of type and material indicated on approved anchoring designs.
   3. Install anchors with embedment indicated on approved anchoring designs.

3.03 INSTALLATION

A. Install the equipment in accordance with the accepted installation instructions and anchorage details.

3.04 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing.

B. Installation Verification:
   1. Load testing:
      a. Perform test in the presence of OSHA certified manufacturer's representative and the Engineer.
      b. Test equipment with minimum load of 25 percent above rated capacity.
      c. Provide load and slings for test:
         1) Remove when tests are completed.
      d. Operate equipment through complete lift and lowering cycle and through complete travel of trolley to demonstrate quiet, smooth, and safe hoisting, braking, and traveling.
   2. Furnish Manufacturer's Certificate of Installation Verification and load testing.

C. Owner Training:
   1. Perform Owner Training as specified in Section 01660 - Equipment and System Performance and Operational Testing.
   2. Number of sessions:
      a. Operations: 1.
      b. Maintenance: 1.

END OF SECTION

SECTION 15050

COMMON WORK RESULTS FOR MECHANICAL EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Mechanical equipment requirements for:
      a. Basic design and performance criteria.
      b. Prescriptive requirements for common components.
      c. Installation requirements.

1.02 REFERENCES

A. American Bearing Manufacturers Association (ABMA):
   1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
   2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

B. American Gear Manufacturers Association (AGMA) Standards.

C. American Petroleum Institute (API):
   1. 682 - Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps.

D. ASTM International (ASTM):
   1. A193 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
   2. A194 - Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   3. A320 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service.
   4. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
   5. F594 - Standard Specification for Stainless Steel Nuts.

E. Hydraulic Institute (HI):
   1. 9.6.8 - Guideline for Dynamics of Pumping Machinery.

F. International Concrete Repair Institute (ICRI):
   1. Guideline No. 310.2R, Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair.

G. International Organization for Standardization (ISO):
   1. 21940 - Mechanical Vibration - Rotor Balancing - Part 1: Introduction.

H. National Electrical Manufacturers Association (NEMA):
   1. MG-1 - Motors and Generators.

I. Society for Protective Coatings (SSPC):
    1. SP 1 - Solvent Cleaning.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
    1. Definitions used in this specification and equipment Submittals for terms related to rotor-dynamic pumps shall be in accordance with HI 9.6.8, Appendix A, as clarified below.
    2. These definitions shall be applied to equipment other than pumps, unless otherwise specified in Technical Sections.
    3. Resonant frequency:
        a. Frequency of a periodic excitation force that is close to the natural frequencies of an object. Also known as critical frequency, critical speed, or resonant speed.
        b. An undamped resonant frequency within the separation margin is always considered harmful under Level 1 analysis.
        c. A resonant frequency that occurs within a separation margin of 15 percent above or below the operating speed range and has a log decrement greater than +0.3 is considered harmful under Level 2 and Level 3 analysis.
    4. Rotordynamic analysis level:
        a. Level of detail required for rotordynamic analysis is indicated in the Technical Sections schedules as None (no analysis required), Analysis Level 1, Analysis Level 2, or Analysis Level 3, which correlate to increasing levels of required detailed equipment design analysis. Analysis Levels 1, 2, and 3 are based on HI 9.6.8.
        b. Where these specifications differ from HI the more stringent shall apply.
    5. Separation margin:
        a. Span of operating speeds within which interference between excitation orders and resonant frequencies indicate the possibility of harmful vibrations.
        b. Separation margin for a specific application extends 15 percent above and 15 percent below the span of operating speed required for the specified performance conditions.

1.04 ADMINISTRATIVE REQUIREMENTS

A. Roof coordination.
    1. Show roof penetrations for mechanical equipment on roof drawing Submittal and include mechanical equipment information:
        a. Type.
        b. Size.
        c. Location.
        d. Configuration of penetration and the surround.
        e. Weight.
        f. Anchoring and support details.

1.05 SUBMITTALS

A. Items in this Section are components of equipment or systems specified in other Sections.
   1. Include data for this Section's components with the equipment or system Submittal.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. General:
   1. Equipment manufacturer's responsibility extends to selection and mounting of gear drive units, motors or other prime movers, accessories, and auxiliaries to provide a complete, operable unit.
   2. Manufacturer shall analyze rubber-bearing vertical-column pumps and equipment identified as non-reversing in the Technical Sections for reverse rotation and provide non reversing motor ratchets.
   3. Equipment that prevents reverse rotation shall be capable of both:
      a. Handling 150 percent of the maximum torque at maximum operating speed.
      b. 150 percent of torque that will be generated in reverse direction due to equipment shutoff head as calculated by the manufacturer.
   4. Motor shall be designed to run safely in the reverse direction at up to 140 percent times the reverse runaway speed under shutoff head conditions.

B. Rotordynamic analysis and vibration testing:
   1. Submit information for the rotordynamic analysis level specified for each piece of equipment as shown in the Technical Sections prior to manufacture of the equipment.
   2. Rotordynamic analysis shall be performed on "like-new" and "as-worn" conditions, representing conditions when first installed and conditions when parts wear to the manufacturer's maximum allowable operating tolerances.
      a. Conditions assumed for the "as-worn" condition shall be 2 times the "like-new" tolerances unless specified otherwise.
   3. Rotordynamic analysis criteria:
      a. Torsional excitation forcing function magnitudes shall be no less than 1 percent of the maximum transmitted torque at given speed.
      b. Motor mass elastic information in accordance with NEMA MG-1 shall be obtained from the original equipment manufacturer and included in the analysis. Motors shall be precision balanced to ISO 21940 Grade G2.5.
      c. Bearings:
         1) At maximum bearing loads an L-10 life of 100,000 hours in accordance with ABMA 9-11 to be proven.
   4. Submit factory and field testing requirements as specified in the Technical Sections and specified in Section 15958 - Mechanical Equipment Testing after manufacture and installation respectively.

5. Repair, replace, and modify equipment exhibiting vibration performance that does not meet criteria specified in this Section at no additional cost to the Owner.
    a. Acceptable remedies include adjustments to equipment component geometry, materials, energy absorbing couplings, etc.
    b. Locking out speed interval(s) within equipment specified operating range is unacceptable.
6. Vibration analysis expert:
    a. Provide when specified in the equipment Technical Sections.
        1) Must be a 3rd party, unaffiliated with the equipment vendor or Contractor.
    b. Analysis shall be provided by one of the following or equal:
        1) Engineering Dynamics Inc. (EDI, Texas).
        2) Mechanical Solutions, Inc. (MSI, New Jersey).
    c. Analysis shall be:
        1) Stamped by a registered professional mechanical engineer.
        2) Verified in-situ by the vibration analysis expert, including certification that installation conforms to field conditions assumed in the reports.
        3) Verified in-situ by the vibration analysis expert, including witness of at least 1 field vibration test, and certification that vibration measurements corroborate the rotordynamic analysis.
        4) Supplemented with additional field investigation and analysis should conditions during field vibration testing activity indicate non-compliance with these specifications; supplemental field investigation and analysis shall indicate remedies to comply with the specifications and shall be stamped by a registered professional mechanical engineer.
7. Rotordynamic Analysis Level 1:
    a. Before the equipment is released for manufacture it shall be determined that the equipment/motor structures do not have any harmful resonant frequencies in the lateral and torsional modes. Representative analysis results for identical equipment may be submitted.
    b. Calculate rotor lateral and torsional and equipment structural components' lateral frequencies with a spreadsheet calculation or finite element analysis software.
        1) Equipment structure lateral frequency shall include the motor.
        2) Speed changing drive systems (belt, gear) effects on rotational inertia and stiffness shall be incorporated.
    c. Determine the equipment system components (rotor and structure) resonant frequencies.
    d. An intersection of an equipment component resonant frequency with the 1x run speed excitation order that occurs within separation margin is unacceptable.
8. Rotordynamic Analysis Level 2:
    a. Before the equipment and motor are released for manufacture it shall be determined that the equipment/motor structures do not have any harmful critical speeds in the lateral and torsional modes.
    b. Calculate rotor lateral and torsional and structure lateral frequencies with finite element analysis software.
        1) Equipment structure lateral frequency shall include the motor.

2) Speed changing drive systems (belt, gear) effects on rotational inertia and stiffness shall be incorporated.
3) Rotational inertia of water within the impeller, in the wet well, and inside the equipment structure, e.g., the column of a vertical pump, shall be included in the calculation at both the high level and low level conditions.

c. Potentially harmful critical speeds shall be investigated further with a forced, damped analysis to determine component stresses do not exceed material properties.

d. Forced damped analysis:
1) Forced lateral analysis shall include forcing function magnitudes at least 10 percent of rotor disc weight at each disc position and hydraulic imbalance at 5 operating conditions spaced equally over the equipment operating range. If synchronous motors are used ensure that the rotor analysis includes startup, shutdown, and motor control transients.
2) Forced torsional analysis shall include not less than 1 percent of the maximum permitted torque at any given speed. Damping shall be 1 percent of critical at all shaft elements.
3) Equipment rotor total stress (steady-state and alternating torque components plus lateral-bending stresses) shall not exceed:
a) Constant torque: Total stress limited to 30 percent of the material fatigue limit and to a maximum of 18 percent of ultimate tensile strength.
b) Variable torque (including variable speed equipment): Total stress limited to 50 percent of the material fatigue limit and to a maximum of 4 percent of the material ultimate tensile strength.
c) Submit documentation of material fatigue limit.

e. Report Submittals:
1) Confirmation of compliance with this Section, or detailed exceptions taken.
2) Software used for analysis.
3) Results with interpretation.
4) Preparer’s professional engineering stamp and seal.
5) Input data, including component properties, materials and connectivity to other components.
6) Schematic diagram of model mode shapes, nodes and elements.
7) Bearing stiffness and damping properties, impeller/diffuser interaction coefficients, and seal dynamic properties.
8) Campbell diagrams showing the system natural frequencies, excitation orders, and operating speed range for both lateral and torsional analysis.
a) Include equipment operating range; excitation lines at 1x, 2x run speed, and vane pass (or equivalent); and critical speeds associated with equipment system components, including the rotor, each major equipment structural component and the motor.
9) Forced, damped analysis indicating acceptable material stress limits are maintained at interference points shown on the Campbell diagram.

9. Rotordynamic Analysis Level 3:
    a. Before the equipment and motor are released for manufacture it shall be determined that the equipment/motor structures do not have any harmful critical speeds in the lateral and torsional modes.
    b. Calculate rotor lateral and torsional and structure lateral frequencies with finite element analysis software.
        1) Equipment structure lateral frequency shall include the motor.
        2) Speed changing drive systems (belt, gear) effects on rotational inertia and stiffness shall be incorporated.
        3) Rotational inertia of water within the impeller, in the wet well, and inside the equipment structure, e.g., the column of a vertical pump, shall be included in the calculation at both the high level and low level conditions.
    c. Potentially harmful critical speeds shall be investigated further with a forced, damped analysis to determine component stresses do not exceed material properties.
    d. Forced damped analysis:
        1) Forced lateral analysis shall include forcing function magnitudes at least 10 percent of rotor disc weight at each disc position and hydraulic imbalance at 5 operating conditions spaced equally over the equipment operating range. If synchronous motors are used ensure that the rotor analysis includes startup, shutdown, and motor control transients.
        2) Forced torsional analysis shall include 1 percent of the maximum permitted torque at any given speed. Damping shall be 1 percent of critical at all shaft elements.
        3) Equipment rotor total stress (steady-state and alternating torque components plus lateral-bending stresses) shall not exceed:
            a) Constant torque: Total stress limited to 30 percent of the material fatigue limit and to a maximum of 18 percent of ultimate tensile strength.
            b) Variable torque (including variable speed equipment): Total stress limited to 50 percent of the material fatigue limit and to a maximum of 4 percent of the material ultimate tensile strength.
            c) Submit documentation of material fatigue limit.
    e. Report Submittals:
        1) Report 1: Executive Summary, including:
            a) Confirmation of compliance with this Section, or detailed exceptions taken.
            b) Software used for analysis.
            c) Results with interpretation.
            d) Preparer’s professional engineering stamp and seal.
            e) Campbell diagrams showing the system natural frequencies, excitation orders, and operating speed range for both lateral and torsional analysis.
                (1) Include equipment operating range; excitation lines at 1x, 2x run speed, vane pass (or equivalent), line- and twice-line frequency, motor-pole frequency, torsional harmonics from reciprocating drivers (including up to 6 times operating speed), control pulse frequencies induced by variable frequency drives (VFDs) (with certification from VFD

manufacturer of frequencies up to 24 times motor running speed), any torque harmonic greater than 1 percent of steady torque at primary excitation, and synchronous motor requirements; and critical speeds associated with equipment system components, including the rotor and each major equipment structural component.

f) Report 1 shall not include detailed analysis elements listed for Submittal under Report 2 below, Submittal of full analysis details in Report 1 is unacceptable.

g) Following Submittal of Report 1, submit Report 2: Detailed Analysis, including responses to comments made on Report 1: Rotor-dynamic Executive Summary.

2) Report 2: Rotor-dynamic detailed analysis, including:

a) Input data, including component properties, materials and connectivity to other components.

b) Schematic diagram of model mode shapes, nodes and elements.

c) Bearing stiffness and damping properties, impeller/diffuser interaction coefficients, and seal dynamic properties.

d) Forced, damped analysis indicating acceptable material stress limits are maintained at interference points shown on the Campbell diagram.

e) Synchronous motor information, including time-integration study results showing transient peak stresses at startup, shutdown and motor control transient events. Provide tomographic diagrams, including root and keyway stress concentration locations and the corresponding speeds that result in reported peak stresses.

2.02 POWER TRANSMISSION SYSTEMS

A. V-belts, sheaves, shaft couplings, chains, sprockets, mechanical variable-speed drives, VFDs, gear reducers, open and enclosed gearing, clutches, brakes, intermediate shafting, intermediate bearings, and U-joints:

1. Rated for 24 hour-a-day continuous service, or for intermittent service with frequent stops-and-starts, whichever is most severe.
2. Sized with a service factor of 1.5 or greater:
   a. Apply service factor to nameplate horsepower and torque of prime source of power and not to actual equipment loading.
   b. Apply service factors in accordance with AGMA, or as specified in the Technical Sections.

2.03 BEARINGS

A. Oil or grease lubricated, ball or roller antifriction type, of standard manufacture.

1. Design lubrication system based on the equipment location to operate in the temperatures as specified in Section 01850 - Design Criteria.
   a. To safely start after being shut off for 24 hours and operate safely:
      1) Suitable for the outdoor winter temperature as specified in Section 01850 - Design Criteria.

B. Oil-lubricated:
   1. Provide either pressure lubricating system or separate oil reservoir splash-type system as specified in the Technical Section.
   2. Design system to safely absorb heat energy generated in bearings when equipment is operating in the following conditions:
      a. With the highest load and the temperature 15 degrees Fahrenheit above the outdoor summer temperature as specified in Section 01850 - Design Criteria.

C. Grease lubricated, except those specified to be factory sealed:
   1. Fit with easily accessible grease supply, flush, drain, and relief fittings.
   2. Lubrication lines and fittings:
      a. Lines: Minimum 1/4-inch diameter stainless steel tubing.
      b. Multiple fitting assemblies: Mount fittings together in easily accessible location.
      c. Use standard hydraulic-type grease supply fittings:
         1) Manufacturers: One of the following or equal:
            a) Alemite.
            b) Zerk.

D. Ratings: In accordance with ABMA 9 or ABMA 11 L10 life for bearings rating life of not less than 50,000 hours.

2.04 BELT DRIVES

A. Sheaves:
   1. Separately mounted on bushings by means of at least 3 pull-up bolts or cap tightening screws.
   2. When 2 sheave sizes are specified, provide separate belts sized for each set of sheaves.
   3. Statically balanced for all; dynamically balanced for sheaves that operate at a peripheral speed of more than 5,500 feet per minute.
   4. Key bushings to drive shaft.

B. Belts:
   1. Anti-static type when explosion-proof equipment or environment is specified.
   2. When spare belts are specified, furnish 1 spare belt for every different type and size of belt-driven unit:
      a. Where 2 or more belts are involved, furnish matched sets.
      b. Identify as to equipment, design, horsepower, speed, length, sheave size, and use.
      c. Package in boxes labeled with identification of contents.

C. Manufacturers: One of the following or equal:
   1. Dodge, Dyna-V belts with matching Dyna-V sheaves and Taper-Lock bushings.
   2. T.B. Woods, Ultra-V belts with matching Sure-Grip sheaves and Sure-Grip bushings.

2.05 FLANGED PIPING CONNECTIONS

A. Unless specified otherwise in the Technical Sections or indicated on the Drawings, provide flat face flanges.

2.06 ASSEMBLY FASTENERS

A. General service: Stainless steel, Type 316:
   1. Bolts: In accordance with ASTM F593, Alloy Group 2.
   2. Nuts: In accordance with ASTM F594, Alloy Group 2.
   3. Washers: Alloy group matching bolts and nuts.

B. High-temperature service or high-pressure service: Stainless steel, Type 316:
   1. Bolts: In accordance with ASTM A193, Grade B8M, Class 1, heavy hex.
   2. Nuts: In accordance with ASTM A194, Grade 8, heavy hex.
   3. Washers: Alloy group matching bolts and nuts.

C. Low-temperature service: Stainless steel, Type 316:
   1. Bolts: In accordance with ASTM A320, Grade B8M, Class 1, heavy hex.
   2. Nuts: In accordance with ASTM A194, Grade B8M, heavy hex.
   3. Washers: Alloy group matching bolts and nuts.

2.07 GUARDS AT HIGH-TEMPERATURE SURFACES

A. Exposed surfaces having an external surface temperature of 120 degrees Fahrenheit or higher and located within 7 feet, measured vertically from floor or working level, or within 15 inches measured horizontally from stairways, ramps, or fixed ladders.

B. Cover with a thermal insulating material unless otherwise guarded against contact.
   1. Insulation thickness such that the insulation exterior temperature is below 120 degrees Fahrenheit.
   2. Insulation Type 3 and cover Type 5 as specified in Section 15400 - Plumbing Systems.

2.08 GUARDS AT MOVING COMPONENTS

A. On rotating components that are within 7.5 vertical feet of an operating floor or platform.

B. Allow visual inspection of moving parts without removal.

C. Allow access to lubrication fittings.

D. Easily removable for maintenance.

E. Prevent entrance of rain or dripping water for outdoor locations.

F. Size belt and sheave guards to allow for installation of sheaves 15 percent larger and addition of 1 belt.

G. Materials:
   1. Sheet metal: Carbon steel, 12-gauge minimum thickness, hot-dip galvanized after fabrication.
   2. Fasteners: Type 316 stainless steel.

2.09 SHOP FINISHES

A. Manufacturer's standard primer and finish coatings.
   1. Primer only if field coatings are to be applied.

2.10 GEAR MOTORS

A. Parallel shaft drives: Helical gearing.

B. Right-angle drives: Worm gearing.

C. Manufacturers: One of the following or equal:
   1. Baldor Electric Company.
   2. Bodine Electric Company.

2.11 GEAR REDUCTION UNITS

A. Design and performance criteria:
   1. Gear type:
      a. Helical or herringbone.
   2. AGMA Class II service:
      a. Use more severe service condition when such is recommended by unit's manufacturer.
   3. Cast-iron housing with gears running in oil.
   4. Anti-friction bearings.
   5. Thermal horsepower rating based on maximum horsepower rating of prime mover, not actual load.

2.12 MOUNTING AND LIFTING PROVISIONS FOR EQUIPMENT

A. Equipment bases and base plates:
   1. Provide equipment bases with machined support pads, dowels for alignment for mating of adjacent items, openings for electrical conduits, and openings to facilitate grouting.
   2. Provide jacking screws in bases and supports for equipment and for equipment weighing 500 pounds or more.
   3. Materials:
      a. Match equipment material or steel.
      b. Coating: Match equipment.

B. Steel support frames:
   1. Carbon steel:
      a. At exterior locations and at interior wet or moist locations, provide continuous welds on both sides to close seams and edges between steel members.
      b. Grind closure welds smooth.

C. Lifting lugs or eyes:
    1. Equipment units weighing 50 pounds or more:
        a. Provide with lifting lugs or eyes to allow removal with lifting device.

2.13 NAMEPLATES

A. Fastened to equipment at factory in an accessible and visible location.

B. Metal engraved or stamped with text, holes drilled or punched for fasteners.

C. Material: Aluminum or stainless steel.

D. Fasteners: Number 4 or larger oval head stainless steel screws or drive pins.

E. Text:
    1. Manufacturer's name, equipment model number, equipment serial number, and identification tag number.
    2. Additional items indicated in the Technical Sections.
    3. Indicate the following additional information as applicable:
        a. Maximum and normal rotating speed.
        b. Service class in accordance with applicable standards.
    4. Include for pumps:
        a. Rated total dynamic head in feet of fluid.
        b. Rated flow in gallons per minute.
        c. Impeller, gear, screw, diaphragm, or piston size.
    5. Include for motors:
        a. Drive speed.
        b. Motor horsepower with rated capacity.
    6. Include for gear reduction units:
        a. AGMA class of service.
        b. Service factor.
        c. Input and output speeds.

2.14 PUMP SHAFT COUPLINGS

A. General:
    1. Type and ratings: Non-lubricated designed for not less than 50,000 hours of operating life.
    2. Sizes: Provide as recommended by manufacturer for specific application, considering horsepower, speed of rotation, balance, and type of service.
    3. Suitable for an ambient temperature range between -40 degrees to +200 degrees Fahrenheit.

B. Close-couplings for electric-motor-driven equipment:
    1. Manufacturers: One of the following or equal:
        a. Lovejoy.
        b. T.B. Woods.
    2. Provide flexible couplings designed to accommodate angular misalignment, parallel misalignment, and end float.
    3. Manufacture flexible component of coupling from synthetic rubber or urethane.
    4. Provide service factor of 2.5 for electric motor drives and 3.5 for engine drives.

5. Do not allow metal-to-metal contact between driver and driven equipment.

C. Flexible couplings for direct connected electric-motor-driven equipment:
   1. Manufacturers: One of the following or equal:
      a. Rexnord.
      b. T.B. Woods.
   2. Provide flexible couplings designed to accommodate shock loading, vibration, and shaft misalignment or offset.
   3. Provide flexible connecting element of rubber and reinforcement fibers.
   4. Provide service factor of 2.0.
   5. Connect stub shafts through collars or round flanges, firmly keyed to their shafts with neoprene cylinders held to individual flanges by through pins.

D. Spacer couplings:
   1. Where cartridge-type mechanical seals or non-split seals are specified, provide a spacer-type coupling of sufficient length to remove the seal without disturbing the driver or driven equipment.

2.15 PUMP SEAL CHAMBER AND SEALS

A. Seal chamber (stuffing box):
   1. Large enough to retrofit with double mechanical seal.

B. Seal types: Based on the following and as specified in the Technical Section:
   1. Type 1: Packing:
      a. Provide when specified in the Technical Section for wastewater, non-potable water, and sludge applications:
         1) Asbestos free.
         2) PTFE (Teflon™) free.
         3) Braided graphite.
         4) Manufacturers: One of the following or equal:
            a) Chesterton, 1400.
            b) John Crane.
      b. Provide when specified for drinking water service:
         1) Asbestos free.
         2) Material: Braided PTFE (Teflon™).
         3) Manufacturers: One of the following or equal:
            a) Chesterton, 1725.
            b) John Crane.
      c. Design:
         1) Packing gland to allow adjustment and repacking without dismantling pump, except to open up stuffing box.
         2) Seal chamber (stuffing box) large enough to retrofit with double mechanical seal.
         3) Manufacturers: One of the following or equal:
            a) Chesterton, 1725.
            b) John Crane.
   2. Type 2: Mechanical seal, flushing, cartridge, single O-ring.
      a. Manufacturers: One of the following or equal:
         1) Chesterton, S10.
         2) John Crane, 5610 Series.

3. Type 3: Mechanical seal, flushing, cartridge, double O-ring:
    a. Manufacturers: One of the following or equal:
        1) Chesterton, S20.
        2) John Crane, 5620 Series.
4. Type 4: Mechanical seal, flushing, cartridge, double split-ring:
    a. Manufacturers: One of the following or equal:
        1) Chesterton, S20.
        2) John Crane, 5620 Series.
5. Type 5: Mechanical seal, flushing, cartridge, single split-ring:
    a. Manufacturers: One of the following or equal:
        1) Chesterton, 442.
        2) John Crane, 5860.
6. Type 6: Mechanical seal, flushless, cartridge, single split-ring:
    a. Manufacturers: One of the following or equal:
        1) Chesterton, 156.
        2) John Crane, 3740 Series.

C. Mechanical seals, Types 2 to 6:
1. Balanced hydraulically.
2. Spring:
    a. Stationary, out of pumping fluid.
    b. Material as specified in the Technical Section. Hastelloy C; Type Elgiloy or 17-7 PH stainless steel for split seals.
3. O-ring: Viton™ 747.
4. Gland: Type 316L stainless steel.
5. Set screws: Type 316L stainless steel.
6. Faces: Reaction bonded, silicon carbide/carbon.
7. Minimum differential pressures in either direction: 300 pounds per square inch gauge.
    a. Manufacturers: One of the following or equal:
        1) Chesterton, 1400.
        2) John Crane, equivalent product.
8. Drinking water service:
    a. Asbestos free.
    b. Material: Braided PTFE (Teflon™).
    c. Manufacturers: One of the following or equal:
        1) Chesterton, 1725.
        2) John Crane, equivalent product.

D. Flushing system:
1. Provide flushing connections:
    a. 3/4-inch size.
    b. Provide API 682 seal water plan arrangement as specified in the Technical Section:
        1) Plan 11 - Product stream seal water from discharge thru seal.
        2) Plan 13 - Product stream seal water through seal to suction.
        3) Plan 23 - Closed loop seal water with cooler and pumping ring.
        4) Plan 32 - Production seal water discharged to product stream.
        5) Plan 54 - Production seal water excluded from product stream.

2.16 SAFETY SIGNS

A. Material, sign size, and text: As specified in Section 10400 - Signage.

2.17 SHIPPING

A. Prior to shipment of equipment:
   1. Bearings (and similar items):
      a. Pack separately or provide other protection during transport.
      b. Greased and lubricated.
   2. Gear boxes:
      a. Oil filled or sprayed with rust preventive protective coating.
   3. Fasteners:
      a. Inspect for proper torques and tightness.

PART 3 EXECUTION

3.01 PRE-INSTALLATION

A. Field measurements:
   1. Prior to Shop Drawings preparation, take measurements and verify dimensions indicated on the Drawings.
   2. Ensure equipment and ancillary appurtenances fit within available space.

B. Sequencing and scheduling:
   1. Coordinate details of equipment with other related parts of the Work, including verification that structures, piping, wiring, and equipment components are compatible.
   2. Equipment anchoring: Obtain anchoring material and setting drawings from equipment manufacturers in adequate time for templates to be constructed and anchors to be cast-in-place.

3.02 LUBRICATION LINES AND FITTINGS

A. Support and protect lines from source to point of use.

B. Fittings:
   1. Bring fittings to outside of equipment in manner such that they are readily accessible from outside without necessity of removing covers, plates, housings, or guards.
   2. Mount fittings together wherever possible using factory-mounted multiple fitting assemblies securely mounted, parallel with equipment lines, and protected from damage.
   3. For underwater bearings: Bring fittings above water surface and mount on edge of structure above.

3.03 ALIGNMENT OF DRIVERS AND EQUIPMENT

A. Where drive motors or other drivers are connected to driven equipment by flexible coupling, disconnect coupling halves and align driver and equipment after driven equipment has been leveled on its foundation.

B. Comply with procedures of appropriate HI, AGMA standards, alignment tolerances of equipment manufacturers and the following requirements to bring components into angular and parallel alignment:
   1. Maximum total coupling offset (not the per-plane offset): Not to exceed 0.5 mils per inch of coupling length for spacer couplings based on coupling length (not dial separation).
   2. Utilize jacking screws, wedges, or shims as recommended by the equipment manufacturer and as specified in the equipment sections.

C. Use reverse-indicator arrangement dial-type or laser-type alignment indicators:
   1. Mount on the driver/coupling flange and equipment/coupling flange.
   2. Alignment instrumentation accuracy shall be sufficient to read angular and radial misalignment at 10 percent or less of the manufacturer's recommended acceptable misalignment.

D. Alignment and calculations shall include measurement and allowance for thermal growth, spacer coupling length, indicator separation, and axial spacing tolerances of the coupling.

E. When alignment satisfies most stringent tolerance of system components, grout between base and foundation.
   1. Allow minimum 48 hours for grout to harden.
   2. After grout hardens, remove jacking screws, tighten anchor bolts and other connections, and recheck alignment.
   3. Correct alignment as required.

3.04 EQUIPMENT SUPPORT AND ANCHORING TO STRUCTURES

A. Anchor equipment to structures as indicated on the Drawings and as specified.

B. Obtain final anchor bolt layouts for equipment prior to:
   1. Detailing reinforcement for equipment pads.
   2. Preparation of Shop Drawings for metal structures supporting equipment.

C. Anchor bolt templates:
   1. Provide templates as specified in the Technical Sections.
   2. Use final anchor bolt layout to construct templates for setting anchor bolts.
   3. Make templates:
      a. Rigid, and non-deformable during use.
      b. With longitudinal axes of anchors parallel.
      c. With longitudinal axes of anchors perpendicular to surface supporting the equipment.
   4. Templates may be reused for multiple locations of the same equipment only if:
      a. Templates are in "like-new" condition prior to each reuse.

b. Anchor layout has not been deformed or damaged by previous installation, removal, or handling of templates.

5. Sequence:
   a. Set and support templates prior construction of structures surrounding anchors.
   b. Position anchors in templates to provide designated embedment in supporting structure, with required projection for installation of grout, base plates, and hardware for tightening.
   c. Construct concrete or masonry around anchors using methods that preserve required anchor positions and alignment, and clearances to edges of supports or structures.

D. Anchor adjustment sleeves:
   1. Use of adjustment sleeves around anchors:
      a. Is at the option of the Contractor.
      b. Does not relieve the Contractor of obligation to construct and use templates for setting of anchors.
      c. May required increased anchor embedment length to develop the strength of the anchor in the embedded length below the adjustment sleeve.
   2. Submittal requirements for anchor adjustment sleeves:
      a. Provide within sufficient time for Engineer approval and not less than 10 working days before setting those items.
      b. Proposed locations of sleeves.
      c. Details and dimensions of sleeves.
      d. Sleeve materials of construction, and coatings.
      e. Information on sleeve filler material and means of filler removal.
      f. Type, details, and dimensions of anchor bolts or anchor rods to be used with sleeves.
      g. Calculations showing development of anchor load capacity below the bottom of the sleeve.
      h. Plan for removal of sleeve fillers, if any.
      i. Plan for placement and consolidation of flowable grout inside sleeves and to a level equal to top of concrete slab or equipment pad surrounding the sleeve.

3.05 GROUTING UNDER EQUIPMENT BASES, BASE PLATES, SOLE PLATES, AND SKIDS

A. General:
   1. In accordance with the equipment manufacturer’s installation instructions, including:
      a. Tolerances for level.
      b. Tolerances for vertical and horizontal alignment.
      c. Requirements or recommendations for grouting spaces and grout installation.
      d. Recommendations for tightening of equipment anchors after grout has cured.
   2. Install equipment over grout as indicated on the Drawings or specified only after:
      a. Equipment is leveled and in proper alignment.

b. Piping connections are complete and in alignment with no strain transmitted to equipment.

3. Install flowable grout, as specified in Section 03600 - Grouting, placed with forms and head boxes.
   a. Use flowable, non-shrink cement grout.
   b. Use flowable, non-shrink epoxy grout, only where indicated on the Drawings, where specified in Technical Sections, or when approved in advance by the Engineer.
   c. Grouting with dry-pack materials is not permitted.

B. Prepare equipment bases, base plates, soleplates, and skids for grouting:
   1. Concrete equipment bases:
      a. Roughen surface in accordance with ICRI, Guideline No. 310.2R, Surface Preparation Profiles CSP-3 and CSP-4.
      b. Clean roughened concrete surfaces.
   2. Base plates, soleplates, and skids:
      a. Clean surfaces in accordance with SSPC-SP 1-Solvent Cleaning, to remove dirt, dust, oil, grease, paint, and other material.

C. Level equipment for grouting:
   1. Use removable jack screws, or removable steel wedges and shims to support and level equipment bases, base plates, sole plates, and skids.
      a. Do not use leveling nuts placed on equipment anchors to support or level equipment bases, base plates, sole plates, and skids.
   2. Removable jack screws:
      a. Provide number, size, and locations of jack screws required to support and level equipment in accordance with the manufacturer's recommendations.
      b. Drill and tap equipment base plates, sole plates, and skids for jack screws.
      c. Support jack screws on circular steel plates that have been epoxy bonded to the equipment foundation.
         1) Provide plates fabricated from Type 316 stainless steel where edges of support plates will have grout side cover of 3 inches or less in the finished Work.
      d. Make provision for removal of jack screws after grouting:
         1) Prevent grout from bonding to jack screws by wrapping jack screw threads that will be in contact with grout with multiple layers of tape or other material acceptable to the Engineer.
      e. Place and cure grout.
      f. After grout is placed and cured:
         1) Remove jack screws and material used to prevent grout from bonding to jack screws.
         2) Provide jack screws to the Owner for future use.
         3) Fill jack screw holes with grout.
         4) Cure grout as specified.
   3. Removable steel wedges and shims:
      a. Use for equipment bases, base plates, sole plates, and skids where it is not practical to use jack screws.
      b. Provide number, size, and locations of wedges and shims required to support and level equipment in accordance with the manufacturer's recommendations.

c. Make provision for removal of wedges and shims after grouting:
    1) Prevent grout from bonding to wedges and shims by wrapping wedges and shims that contact grout with multiple layers of tape or other material acceptable to the Engineer.
    2) Locate and orient wedges and shims to allow for removal after grouting, and to facilitate placement of grout in the remaining voids.
d. Place and cure grout.
e. After grout is placed and cured:
    1) Remove wedges and shims, and material used to prevent grout from bonding to them.
    2) Fill jack screw holes with grout.
    3) Cure grout as specified.

D. Construct grout forms:
1. Provide forms:
    a. Rigid with adequate strength to withstand placement of grout.
    b. With surfaces that will produce a smooth, uniform finish for grout edges exposed in the finished Work.
    c. That allow grout to flow horizontally beyond the perimeter of the equipment base plate a distance not less than the thickness of the grout, and not less than 1 inch.
2. Install forms:
    a. Seal form cracks and joints with elastomeric sealant to make form watertight.
    b. Line form surfaces in contact with grout with polyethylene film, or coat with 2 coats of heavy-duty paste wax.
3. Construct grout “head box” over entire length of one side of form.
    a. Make head box height sufficient to force grout to flow under full dimensions of equipment base and to the surrounding form faces.

E. Pre-grouting procedures:
1. Concrete surfaces receiving flowable, non-shrink cement grout:
    a. Saturate concrete surface in contact with grout and concrete surfaces extending not less than at least 6 inches beyond limits of grout with clean water for a minimum of 24 hours prior to grouting.
    b. Just prior to grout placement, remove standing water using clean rags or oil-free compressed air. Provide saturated surface dry (SSD) concrete for grout placement.
2. Concrete surfaces receiving flowable, non-shrink epoxy grout:
    a. Do not saturate concrete prior to grout placement.

F. Grout placement and curing:
1. Place and cure grout as specified in Section 03600 - Grouting and in this Section.
2. Grouting:
    a. Keep level of grout in head box above bottom of equipment bases, base plates, sole plates, and skids always to drive flow under base.
    b. Maintain continuous grout flow from head box to opposite sides of forms without trapping air or forming voids.
    c. Vibrate, rod, or chain grout to facilitate grout flow, to consolidate grout, and to remove entrapped air.

3. After grout sets, remove forms and trim grout edges at 45-degree angle from bottom edge of equipment bases, base plates, sole plates, and skids.
4. Cure grout as specified in Section 03600 - Grouting.

G. After grout is cured:
1. Remove jack screws or wedges and shims, and material used to prevent grout from bonding to leveling devices.
2. Fill pockets from removed leveling devices with grout.
3. Cure filled voids as specified in Section 03600 - Grouting.
4. Tighten equipment anchors in accordance with the equipment manufacturer's requirements.

3.06 FIELD FINISHES

A. When touchup or repair is required, apply primer and coating systems as recommended by the equipment manufacturer.

END OF SECTION

SECTION 15052

COMMON WORK RESULTS FOR GENERAL PIPING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Basic materials and methods for metallic and plastic piping systems.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 Through 24.
   2. B16.47 - Large Diameter Steel Flanges: NPS 26 Through NPS 60 Metric/Inch Standard.

B. American Water Work Association (AWWA):
   1. C11 - Rubber-Gasket Joints for Ductile-Iron Pressure Pipe.
   2. C105 - Polyethylene Encasement for Ductile-Iron Pipe Systems.
   3. C111 - Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
   4. C151 - Ductile-Iron Pipe, Centrifugally Cast.
   5. C207 - Standard for Steel Pipe Flanges for Waterworks Services-Size 4 In. Through 144 In.

C. ASTM International (ASTM):
   1. A74 - Standard Specification for Cast Iron Soil Pipe and Fittings.
   2. A193 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
   3. A194 - Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   4. A307 - Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength.
   5. A320 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service.
   6. A563 - Standard Specification for Carbon and Alloy Steel Nuts.
   7. B88 - Standard Specification for Seamless Copper Water Tube.
   8. F37 - Standard Test Methods for Sealability of Gasket Materials.
   9. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
   10. F594 - Standard Specification for Stainless Steel Nuts.
   11. F2329 - Standard Specification for Zinc Coating, Hot-Dip, Requirements of Application to Carbon and Alloy Steel Bolts, Screws, Washers, Nuts, and Special Threaded Fasteners.

D. California Health and Safety Code.

E. NSF International (NSF):
   1. 61 - Drinking Water System Components - Health. Effects.
   2. 372 - Drinking Water System Components - Lead Content.

1.03 DEFINITIONS

A. Buried pipes: Pipes that are buried in the soil with or without a concrete pipe encasement.

B. Exposed pipe: Pipes that are located above ground, or located inside a structure, supported by a structure, or cast into a concrete structure.

C. Underground pipes: Buried pipes - see A. above.

D. Underwater pipes: Pipes below the top of walls in basins or tanks containing water.

E. Wet wall: A wall with water on at least 1 side.

F. Pipes adjacent to a wet wall: Pipe centerline within 10 inches of the wet wall.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data:
   1. For each piping product in this Section as applicable:
      a. Design features.
      b. Load capacities.
      c. Material designations by UNS alloy number or ASTM Specification and Grade.
      d. Data needed to verify compliance with the Specifications.
      e. Catalog data.
      f. Clearly mark submittal information to show specific items, materials, and accessories or options being furnished.
      g. Detailed piping layout drawings.

C. Calculations:
   1. Provide calculations in accordance with NSF 372 for materials in contact with drinking water.

PART 2 PRODUCTS

2.01 GENERAL

A. Pipes:
   1. Provide new pipe.
   2. Piping provided from manufacturers/distributors inventory is subject to the following condition:
      a. Provide proof pipe manufactured more than 6 months prior to delivery was stored properly and the material and/or coating was not subjected to ultraviolet (UV) degradation.
   3. Mark each piece of pipe in accordance with applicable standards.

2.02 LINK TYPE SEALS

A. Characteristics:
   1. Modular mechanical type, consisting of interlocking neoprene or synthetic rubber links shaped to continuously fill the annular space between the pipe and wall opening.
   2. Links to form a continuous rubber belt around the pipe.
   3. Provide a nylon polymer pressure plate with Type 316 stainless steel hardware. Isolate pressure plate from contact with wall sleeve.
   4. Hardware to be Type 316 stainless steel.
      a. Provide anti-galling lubricant for threads.

B. One of the following or equal:
   1. Link-Seal.
   2. Pipe Linx.

2.03 FLANGE BOLTS AND NUTS

A. General:
   1. Washer:
      a. Provide a washer for each nut.
      b. Washer shall be of the same material as the nut.
   2. Nuts: Heavy hex-head:
      a. Stainless steel nuts shall be finished with TRIPAC 2000 coating system to minimize galling and provide proper torque.
   3. Cut and finish flange bolts to project:
      a. Face of the bolt shall exceed face of nut by 1/8 inch minimum.
      b. A maximum of 1/4 inch beyond outside face of nut after assembly.
   4. Tap holes for cap screws or stud bolts when used.
   5. Lubricant for stainless steel bolts and nuts:
      a. Chloride-free.
      b. Manufacturers: One of the following or equal:
         1) Huskey FG-1800 Anti-Seize.
         2) Weicon Anti-Seize High-Tech.

B. Ductile iron pipe:
   1. On exposed pipes with pressures equal to or less than 150 pounds per square inch gauge (psig):
      a. Bolts: In accordance with ASTM A307, Grade B.
      b. Nuts: In accordance with ASTM A563, Grade A.
      c. Bolts and Nuts: Hot-dip galvanized in accordance with ASTM F2329.
   2. On exposed pipes with pressures greater than 150 psig:
      a. Bolts: In accordance with ASTM A193, Grade B7.
      b. Nuts: In accordance with ASTM A194, Grade 2H.
      c. Bolts and nuts: Hot-dip galvanized in accordance with ASTM F2329.
   3. On underwater pipes and pipes adjacent to wet walls:
      a. Bolts: In accordance with ASTM A193, Grade B8M.
      b. Nuts: In accordance with ASTM A194, Grade 8M.
   4. On buried pipes:
      a. Bolts: In accordance with ASTM A193, Grade B8M.
      b. Nuts: In accordance with ASTM A194, Grade 8M for nuts.
      c. Encase in 2 layers of loose polyethylene wrap in accordance with AWWA C105.

C. Plastic pipe:
   1. On exposed pipes:
      a. Bolts: In accordance with ASTM A307, Grade B.
      b. Nuts: In accordance with ASTM A563, Grade A.
      c. Bolts and Nuts: Hot-dip galvanized in accordance with ASTM F2329.
   2. On underwater pipes and pipes adjacent to wet walls:
      a. Bolts: In accordance with ASTM A193, Grade B8M.
      b. Nuts: In accordance with ASTM A194, Grade 8M.

D. Steel pipe:
   1. On exposed pipes:
      a. For ASME B16.5 Class 150 flanges and AWWA C207 Class D flanges:
         1) Bolts: In accordance with ASTM A307, Grade B.
         2) Nuts: In accordance with ASTM A563, Grade A.
         3) Bolts and Nuts: Hot-dip galvanized in accordance with ASTM F2329.
      b. For ASME B16.5 and B16.47 Class 300 flanges and AWWA C207 Class E and F flanges:
         1) Bolts: In accordance with ASTM A193, Grade B7.
         2) Nuts: In accordance with ASTM A194, Grade 2H.
   2. On underwater pipes and pipes adjacent to wet walls:
      a. Bolts: In accordance with ASTM A193, Grade B8M.
      b. Nuts: In accordance with ASTM A194, Grade 8M.
   3. Low-temperature service: Stainless steel, Type 316:
      a. Bolts: In accordance with ASTM A320, Grade B8M, Class 1, heavy hex.
      b. Nuts: In accordance with ASTM A194, Grade B8M, heavy hex.
      c. Washers: Alloy group matching bolts and nuts.
   4. High-temperature service or high-pressure service: Stainless steel, Type 316:
      a. Bolts: In accordance with ASTM A193, Grade B8M, Class 1, heavy hex.
      b. Nuts: In accordance with ASTM A194, Grade 8, heavy hex.
      c. Washers: Alloy group matching bolts and nuts.

2.04 MECHANICAL JOINTS BOLTS AND NUTS

A. Bolts including T-Bolts:
   1. Type 316 stainless steel in accordance with ASTM F593.

B. Heavy Hex Nuts:
   1. Type 316 stainless steel in accordance with ASTM F594, finished with TRIPAC 2000 coating system to minimize galling and provide proper torque.

2.05 GASKETS

A. General:
   1. Gaskets shall be suitable for the specific fluids, pressure, and temperature conditions.
   2. Capable of being applied on surface of piping with cavities to provide for an improved seal with the internal piping pressure.

B. Gaskets for flanged joints in ductile iron and steel piping for sewage service:
   1. Suitable for pressures equal and less than 150 pounds per square inch gauge, temperatures equal and less than 250 degrees Fahrenheit, and raw sewage service.
   2. Gasket material:
      a. SBR or neoprene elastomer with minimum Shore A hardness value of 70.
      b. Reinforcement: Cloth or synthetic fiber.
      c. Thickness: Minimum 3/32-inch thick for less than 10-inch pipe; minimum 1/8 inch thick for 10-inch and larger pipe.
   3. Manufacturers: One of the following or equal:
      a. Pipe less than 48 inches in diameter:
         1) Garlock, Style 7797.
         2) John Crane, similar product.
      b. Pipe 48 inches in diameter and larger:
         1) Garlock, Style 3760.
         2) John Crane, similar product.

C. Gaskets for grooved end ductile iron and steel piping:
   1. Suitable for pressures equal to the encapsulating coupling or flange adapter.
   2. Material: Pressure responsive elastomer.
      a. Ductile iron piping: FlushSeal® type.
         1) Halogenated Butyl: Grade M; for temperatures to 200 degrees Fahrenheit.
         2) Nitrile: Grade S; for temperatures to 180 degrees Fahrenheit.
      b. Steel piping:
         1) EPDM: Grade E; for temperatures to 230 degrees Fahrenheit.
         2) EPDM-HP: Grade EHP, for temperatures to 250 degrees Fahrenheit.
         3) Nitrile: Grade T, for temperatures to 180 degrees Fahrenheit.
   3. Gaskets shall be verified as suitable for the intended service.
      a. Temperature ratings may vary depending on the fluid/media.
   4. Manufacturers: Gaskets shall be of the same manufacturer as the encapsulating couplings/flange adapters.
      a. Victaulic Company.

D. Gaskets for flanged joints in polyvinyl chloride and polyethylene piping:
   1. Suitable for pressures equal to and less than 150 pounds per square inch gauge, with low flange bolt loadings, temperatures equal to and less than 120 degrees Fahrenheit, and polymer, chlorine, caustic solutions, and other chemicals, except chemicals which liberate free fluorine including fluorochemicals and gaseous fluorine.
   2. Material:
      a. Chemical systems: 0.125-inch thick Viton™ rubber.
      b. Sewer and water: 0.125-inch thick SBR.
   3. Manufacturers: One of the following or equal:
      a. Garlock.
      b. John Crane, similar product.

E. Gaskets for flanged joints in low pressure air piping:
   1. Suitable for pressures equal to and less than 150 pounds per square inch gauge, temperatures equal to and less than 300 degrees Fahrenheit, and compressed air service.
   2. Material: EPDM elastomer, 1/8-inch thick, 60 Shore hardness, smooth surface.
   3. Manufacturers: One of the following or equal:
      a. Garlock, Style 8314.
      b. John Crane, similar product.

F. Gaskets for flanged joints in ductile iron or steel water piping:
   1. Suitable for hot or cold water, pressures equal to and less than 150 pounds per square inch gauge, and temperatures equal to and less than 160 degrees Fahrenheit.
   2. Material:
      a. SBR or neoprene elastomer, compressed, with non-asbestos fiber reinforcement.
   3. Manufacturers: One of the following or equal:
      a. Garlock, Bluegard 3300.
      b. John Crane, similar product.

G. Gaskets for flanged joints in ductile iron or steel drinking water piping meeting NSF 61 requirements:
   1. Suitable for hot or cold water, pressures equal to or less than 150 pounds per square inch gauge, and temperatures equal to or less than 160 degrees Fahrenheit.
   2. Material:
      a. EPDM material with 80 Shore A durometer rating.
   3. Manufacturers: One of the following or equal:
      a. Garlock, 98206.
      b. John Crane, similar product.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:
   1. Piping drawings:
      a. Except in details, piping is indicated diagrammatically. Not every offset and fitting, or structural difficulty that may be encountered has been indicated on the Drawings. Sizes and locations are indicated on the Drawings.
      b. Perform minor modifications to piping alignment where necessary to avoid structural, mechanical, or other type of obstructions that cannot be removed or changed.
         1) Modifications are intended to be of minor scope, not involving a change to the design concept or a change to the Contract Price or Contract Times.
   2. Piping alternatives:
      a. Provide piping as specified in this Section, unless indicated on the Drawings or specified otherwise.
      b. Alternative pipe ratings:
         1) Piping with greater pressure rating than specified may be substituted in lieu of specified piping without changes to the Contract Price.
         2) Piping of different material may not be substituted in lieu of specified piping.
      c. Valves in piping sections: Capable of withstanding specified test pressures for piping sections and fabricated with ends to fit piping.
      d. Grooved joints: Use couplings, flange adapters, and fittings of the same manufacturer.
         1) Manufacturer's factory trained representative:
            a) Provide on-site training for Contractor's field personnel.
            b) Periodically visit the jobsite to verify Contractor is following best recommended practices.
         2) Distributor's representative is not considered qualified to conduct the training or jobsite visits.
      e. Flanged joints: where 1 of the joining flanges is raised face type, provide a matching raised face type flange for the other joining flange.
         1) Wire brush and clean flange faces to remove all oil, grease, loose primer, mill scale, and any other foreign matter that could affect the proper seating of the gasket.
   3. Unless otherwise indicated on the Drawings, piping at pipe joints, fittings, couplings, and equipment shall be installed without rotation, angular deflection, vertical offset, or horizontal offset.

B. Wall and slab penetrations:
   1. Provide sleeves for piping penetrations through aboveground masonry and concrete walls, floors, ceilings, roofs, unless specified or otherwise indicated on the Drawings.
   2. For piping 1 inch in nominal diameter and larger, provide sleeves with minimum inside diameters of 1 inch plus outside diameter of piping. For piping

smaller than 1 inch in nominal diameter, provide sleeve of minimum twice the outside diameter of piping.
    a. Arrange sleeves and adjacent joints so piping can be pulled out of sleeves and replaced without disturbing the structure.
    b. Cut ends of sleeves flush with surfaces of concrete, masonry, or plaster.
    c. Conceal ends of sleeves with escutcheons where piping runs through floors, walls, or ceilings of finished spaces within buildings.
    d. Seal spaces between pipes and sleeves with link-type seals when not otherwise specified or indicated on the Drawings.
3. Provide flexibility in piping connecting to structures to accommodate movement due to soil settlement and earthquakes. Provide flexibility using details indicated on the Drawings.
4. Core drilled openings:
    a. Do not damage or cut existing reinforcing bars, electrical conduits, or other items embedded in the existing concrete without acceptance by Engineer.
    b. Determine location of reinforcing bars or other obstructions with a non-destructive indicator device.
    c. Remove dust and debris from hole using compressed air.

C. Exposed piping:
1. Install exposed piping in straight runs parallel to the axes of structures, unless otherwise indicated on the Drawings:
    a. Install piping runs plumb and level, unless otherwise indicated on the Drawings.
        1) Slope plumbing drain piping with a minimum of 1/4-inch per foot downward in the direction of flow.
2. Install exposed piping after installing equipment and after piping and fitting locations have been determined.
3. Support piping: As specified in Sections 15061 - Pipe Supports and 15062 - Preformed Channel Pipe Support System:
    a. Do not transfer pipe loads and strain to equipment.
4. In addition to the joints indicated on the Drawings, provide unions, flexible couplings, flanged joints, flanged coupling adapters, and other types of joints or means which are compatible with and suitable for the piping system, and necessary to allow ready assembly and disassembly of the piping.
5. Assemble piping without distortion or stresses caused by misalignment:
    a. Match and properly orient flanges, unions, flexible couplings, and other connections.
    b. Do not subject piping to bending or other undue stresses when fitting piping.
    c. Do not correct defective orientation or alignment by distorting flanged joints or subjecting flange bolts to bending or other undue stresses.
    d. Flange bolts, union halves, flexible connectors, and other connection elements shall slip freely into place.
    e. Alter piping assembly to fit when proper fit is not obtained.
    f. Install eccentric reducers or increasers with the top horizontal for pump suction piping.

D. Buried piping:
   1. Bury piping with minimum 3-foot cover without air traps, unless otherwise indicated on the Drawings.
   2. Where 2 similar services run parallel to each other, piping for such services may be laid in the same trench.
      a. Lay piping with sufficient room for assembly and disassembly of joints, for thrust blocks, for other structures, and to meet separation requirements of public health authorities having jurisdiction.
   3. Laying piping:
      a. Lay piping in finished trenches free from water or debris. Begin at the lowest point with bell ends up slope.
      b. Place piping with top or bottom markings with markings in proper position.
      c. Lay piping on an unyielding foundation with uniform bearing under the full length of barrels.
      d. Where joints require external grouting, banding, or pointing, provide space under and immediately in front of the bell end of each section laid with sufficient shape and size for grouting, banding, or pointing of joints.
      e. At the end of each day's construction, plug open ends of piping temporarily to prevent entrance of debris or animals.
   4. Concrete encase buried pipe installed under concrete slabs or structures.

E. Venting piping under pressure:
   1. Lay piping under pressure flat or at a continuous slope without air traps, unless otherwise indicated on the Drawings.
   2. Install plug valves as air bleeder cocks at high points in piping.
      a. Provide 1-inch plug valves for water lines, and 2-inch plug valves for sewage and sludge lines, unless otherwise indicated on the Drawings.
   3. Provide additional pipe taps with plug cocks and riser pipes along piping as required for venting during initial filling, disinfecting, and sampling.
   4. Before piping is placed into service, close plug valves and install plugs. Protect plugs and plug valves from corrosion in as specified in Section 09960 - High-Performance Coatings.

F. Restraining buried piping:
   1. Restrain piping at valves and at fittings where piping changes direction, changes sizes, and at ends:
      a. When piping is underground, use mechanical restraints or push-on restraints.
         1) Concrete thrust blocks shall not be used unless specifically called out with a note on the Drawings or specified.
      b. Determine thrust forces by multiplying the nominal cross-sectional area of the piping by design test pressure of the piping.
   2. Provide restraints with ample size to withstand thrust forces resulting from test pressures:
      a. During testing, provide suitable temporary restraints where piping does not require permanent restraints.
   3. Where thrust blocks are allowed, place concrete thrust blocks against undisturbed soil.

4. Where thrust blocks are allowed, place concrete so piping joints, fittings, and other appurtenances are accessible for assembly and disassembly.
5. Provide underground mechanical restraints where specified in Attachment A - Piping Schedule.

G. Restraining above ground and underwater piping:
   1. Restrain piping at valves and at fittings where piping changes direction, changes sizes, and at ends:
      a. When piping is aboveground or underwater, use mechanical or structural restraints.
      b. Determine thrust forces by multiplying the nominal cross-sectional area of the piping by design test pressure of the piping.
   2. Provide restraints with ample size to withstand thrust forces resulting from test pressures:
      a. During testing, provide suitable temporary restraints where piping does not require permanent restraints.

H. Connections to existing piping:
   1. Expose existing piping to which connections are to be made with sufficient time to permit, where necessary, field adjustments in line, grade, or fittings:
      a. Protect domestic water/potable water supplies from contamination:
         1) Make connections between domestic water supply and other water systems in accordance with requirements of public health authorities.
         2) Provide devices approved by Owner of domestic water supply system to prevent flow from other sources into the domestic supply system.
   2. Make connections to existing piping and valves after sections of new piping to be connected have been tested and found satisfactory.
   3. Provide sleeves, flanges, nipples, couplings, adapters, and other fittings needed to install or attach new fittings to existing piping and to make connections to existing piping.
   4. For flanged connections, provide stainless steel bolts with isolation bushings and washers, and full-face flange gaskets.

I. Connections between ferrous and nonferrous metals:
   1. Connect ferrous and nonferrous metal piping, tubing, and fittings with dielectric couplings especially designed for the prevention of chemical reactions between dissimilar metals.
   2. Nonferrous metals include aluminum, copper, and copper alloys.

J. Flanged connections between dissimilar metals such as ductile iron pipe and steel pipe:
   1. Provide stainless steel bolts with isolation bushings and washers, and full-face flange gaskets.

K. Where stainless steel bolts and/or nuts are in contact with non-stainless steel metals, use isolation bushings and washers.

3.02 CLEANING

A. Piping cleaning:
   1. Upon completion of installation, clean piping interior of foreign matter and debris.
   2. Perform special cleaning when required by the Contract Documents.

B. Cleaning potable water piping:
   1. Flush and disinfect potable water piping as specified in Section 01757 - Disinfection, and other regulatory requirements.

C. Cleaning air piping:
   1. Perform special cleaning of filtered air piping from the intake clean air plenums to the discharge points and high-pressure air piping.
      a. Protect surfaces from contamination.
   2. Special cleaning shall include wire brushing, power tool cleaning, wiping down with lint-free cloths, brooming, and vacuuming to remove rust, scale, weld spatter, dust, dirt, oil, and other matter deleterious to operation of the air system:
      a. Do not sandblast installed piping.
   3. To the greatest extent possible, clean piping immediately prior to final closure of piping systems:
      a. Enter piping, clean and wipe down surfaces, and vacuum out residue.
      b. Clean surfaces not accessible to this cleaning operation after installation within 6 hours preceding installation.
   4. Subsequent to cleaning, protect surfaces from contamination by dust, dirt, construction debris, and moisture, including atmospheric moisture:
      a. Whether or not pipe upstream has been cleaned, temporarily seal openings in partially completed work except when installation is actively in progress.
      b. When installation is actively in progress, seal openings at the end of each day's construction or when construction is temporarily stopped.
   5. Suspend cleaning and seal openings when inclement weather, including dust storms, is imminent.
   6. Use clean, dry air for testing the piping and other elements of the system.
   7. Prior to introduction of air to the system, blow piping clean.
      a. Blow with maximum discharge rate possible for minimum 4 hours, using new blowers or compressors and filters.
   8. Clean surfaces that become contaminated prior to acceptance.

D. Conduct pressure and leak test, as specified.

3.03 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Field testing:
   1. Piping system:
      a. Witnessed.
      b. Conduct pressure and leak test, as specified.

3.04 PIPING SCHEDULE

A. Provide piping As specified in Attachment A - Piping Schedule unless noted otherwise in the Specifications or indicated on the Drawings with a written callout or note.

END OF SECTION

ATTACHMENT A - PIPING SCHEDULE

PIPING SCHEDULE

Process Abbrev.	Service	Nominal Diameter (inches)	Material	Class or Schedule	Pipe Spec. Section	Joints/ Fittings	Test Pressure/ Method	Lining	Coating	Comments
1W	**Potable Water**									
	Buried	Under 4	PVC	SCH 80	15230	SW/PVC	100 psig/HH	None	None	Disinfect.
	Exposed	Under 4	CU	See Spec	15400	Soldered/CU	100 psig/HH	None	EPU-M-1	
3W	**Reclaimed Water (Chlorinated Plant Effluent)**									
	Buried	Under 4	PVC	SCH 80	15230	SW/PVC	100 psig/HH	None	None	
		4 and over	DI	CL 53	15211	RMJ or RPO/DI	100 psig/HH	CM	AC and Double PEE	
	Exposed	Under 4	GSP	SCH 40	15270	SC/300# MI	150 psig/HH	None	EPX-GM-1	
BSL	**Blended Sludge**									
	Buried	All	DI	CL 53	15211	RMJ or RPO/DI	100 psig/HH	CM	AC and Double PEE	
	Exposed	All	DI	CL 53	15211	FL or GE/DI	100 psig/HH	CM	EPU-M-1	For exposed service, at connections to pumps and valves, use flanged ends only. All 90 degree bends shall be long-radius unless specifically noted otherwise on the Drawings.
CAS	**Compressed Air - Service**									
	Buried	All	316 SST	SCH 40S	15286	SCRD	175 psig/AM	None	PCW	
	Exposed	All	316 SST	SCH 40S	15286	SCRD	175 psig/AM	None	None	
CD	**Condensate Drain**									
	Buried	All	PVC	SCH 80	15230	SW	25 feet/GR	None	None	
	Exposed (exterior)	All	316 SST	SCH 40	15286	Double pass full welded	25 feet/GR	None	None	
CEN	**Centrate**									
	Exposed	4 and over	Flexible Reinforced Hose			FL or Quick Connect	15 feet/GR	None	None	Hosecraft Model TD11 or equal.
DSL	**Digested Sludge**									
	Exposed	Under 3	316 SST	SCH 80	15286	Double pass full welded	100 psig/HH	None	None	
	Exposed	Under 4	Flexible reinforced hose			FL or Quick Connect	100 psig/HH	None	None	Where indicated on drawings. Hosecraft model Model RC2 UHMWPE.
	Exposed	3 and over	DI	CL 53	15211	FL or GE/DI	100 psig/HH	GL	EPU-M-1	For exposed service, at connections to pumps and valves, use flanged ends only.
DWS	**Dewatered Sludge**									
	Exposed	4 and over	Flexible Reinforced Hose			FL or Quick Connect	15 feet/GR	None	None	Where indicated on drawings. Hosecraft Model TD11 or equal.
FIL	**Filtrate**									
	Buried	4 and over	DI	CL 53	15211	RMJ or RPO/DI	25 feet/GR	CM	AC and Double PEE	
	Exposed	4 and over	DI	CL 53	15211	FL or GE/DI	25 feet/GR	CM	EPU-M-1	For exposed service, at connections to pumps and valves, use flanged ends only.
HW	**Hot Water**									
	Exposed (Interior)	All	CU	See Spec	15400	Soldered/CU	100 psig/HH	None	EPU-M-1	Insulate per Section 15400
PD	**Process Drain**									
	Buried	Under 4	PVC	SCH 80	15230	SW/PVC	25 psig/GR	None	None	

Process Abbrev.	Service	Nominal Diameter (inches)	Material	Class or Schedule	Pipe Spec. Section	Joints/ Fittings	Test Pressure/ Method	Lining	Coating	Comments
		4 and over	DI	CL 53	15211	RMJ or RPO/DI	25 psig/GR	CM	AC and Double PEE	
	Exposed	Under 4	GSP	SCH 40	15270	SC/300# MI	25 psig/GR	None	EPX-GM-1	
		4 and over	DI	CL 53	15211	FL or GE/DI	25 psig/GR	CM	EPU-M-1	
POL	**Neat Polymer**									
	Exposed	All	PVC	SCH 80	15230	SW or Flanged/PVC	15 psig/AM	None	ACR-PVC-1	
POS	**Polymer Solution**									
	Exposed	All	PVC	SCH 80	15230	SW or Flanged/PVC	125 psig/HH	None	ACR-PVC-1	
PS	**Primary Sludge**									
	Buried	All	DI	CL 53	15211	RMJ or RPO/DI	100 psig/HH	CM	AC and Double PEE	
	Exposed	All	DI	CL 53	15211	FL or GE/DI	100 psig/HH	CM	EPU-M-1	For exposed service, use flanged ends at connections to pumps, valves, and where shown on Drawings. All 90-degree bends shall be long-radius unless specifically noted otherwise on the Drawings.
PSC	**Primary Scum**									
	Buried	All	DI	CL 53	15211	RMJ or RPO/DI	100 psig/HH	GL	AC and Double PEE	
	Exposed	All	DI	CL 53	15211	FL or GE/DI	100 psig/HH	GL	EPU-M-1	For exposed service, use flanged ends at connections to pumps, valves, and where shown on Drawings. All 90-degree bends shall be long-radius unless specifically noted otherwise on the Drawings.
SAM	**Sample**									
	Exposed	All	316 SST	SCH 40S	15286	FL/316 SST	150 psig/HH	None	None	
SW	**Seal Water**									
	Buried	All	PVC	SCH 80	15230	SW/PVC	150 psig/HH	None	None	
	Exposed	All	CU	See Spec	15400	Soldered/CU	150 psig/HH	None	EPU-M-1	
TD	**Tank Drain**									
	Exposed	All	DI	CL 53	15211	FL or GE/DI	25 psig/GR	CM	EPU-M-1	
TSL	**Thickened Sludge**									
	Buried	All	DI	CL 53	15211	RMJ or RPO/DI	100 psig/HH	GL	AC and Double PEE	
	Exposed	All	DI	CL 53	15211	FL or GE/DI	100 psig/HH	GL	EPU-M-1	For exposed service, use flanged ends at connections to pumps, valves, and where shown on Drawings. All 90-degree bends shall be long-radius unless specifically noted otherwise on the Drawings.
V	**Vent**									
	Buried	All	PVC	SCH 80	15230	SW/PVC	25 psig/AM	None	None	
	Exposed	All	PVC	SCH 80	15230	SW/PVC	25 psig/AM	None	ACR-PVC-1	
	Exposed (dewatering)	All	Flexible reinforced hose			FL or Quick Connect	25 psig/AM	None	None	Where indicated on drawings. Hosecraft Model TD11 or equal.

Process Abbrev.	Service	Nominal Diameter (inches)	Material	Class or Schedule	Pipe Spec. Section	Joints/ Fittings	Test Pressure/ Method	Lining	Coating	Comments
WAS	**Waste Activated Sludge**									
	Buried	All	DI	CL 53	15211	RMJ or RPO/DI	100 psig/HH	CM	AC and Double PEE	
	Exposed	All	DI	CL 53	15211	FL	100 psig/HH	CM	EPU-M-1	
SD	**Storm Drain**									
	Buried	All	PVC	SDR 26	02705	RPO	10 psig/GR	None	None	
	Exposed	All	PVC	SDR 26	02705	RPO	10 psig/GR	None	None	

Notes:

1. The following abbreviations used in the column of test method refer to the respective methods as specified in Section 15956.

AM: Air method
GR: Gravity method
HH: High head method
LH: Low head method
SC: Special case

2. Abbreviations to designate piping include the following:

AC: Asphaltic coating
ACR-PVC-1: Refer to Section 09960 - High-Performance Coatings.
B&SP, BS: Bell and spigot
BSP: Black steel pipe
CI: Cast iron
CISP: Cast iron soil pipe
CL: Class, followed by the designation
CM: Cement mortar
CPVC: chlorinated polyvinyl chloride
CTP: Coal tar pitch
CU: Copper
DG: double gasketed
DI: Ductile iron
EP: Elastomeric polyurethane
EPU-M-1: Refer to Section 09960 - High-Performance Coatings.
EPX-GM-1: Refer to Section 09960 - High-Performance Coatings.
FL: Flange
FW: Fusion welded
GA: Gauge, preceded by the designation
GAL: Galvanized
GE: Grooved end joint
GL: Glass lined
GSP: Galvanized steel pipe
HSE: High Solids Epoxy system, refer to Section 09960 - High-Performance Coatings
I: Insulated
JT: Joint test
MI: Malleable iron
MJ: Mechanical joint
NPS: Nominal pipe size, followed by the number in inches
PCW: Plastic coating or wrapping
PE: Polyethylene
PEE: Polyethylene encasement
PO: Push-on
psi: pounds per square inch
psig: pounds per square inch gauge
PTW: Polyethylene tape wrap
PVC: Polyvinyl chloride
RCCP: Reinforced concrete cylinder pipe, AWWA C300
RMJ: Restrained Mechanical Joint
RPO: Restrained Push-on
SC: Screwed-on
SCH: Schedule, followed by the designation
SCW: Socket welded
SST: Stainless steel
STL: Steel
SW: Solvent welded
VCP: Vitrified clay piping
W, WLD: Weld
WAE: Waterborne acrylic emulsion
WT: Warning tape

3. All buried piping shall have underground warning tape per section 15076.

4. All buried non-metallic pipe shall have tracer wire per Section 15076.

SECTION 15053

SEISMIC RESTRAINTS FOR PIPING

PART 1 GENERAL

1.01 SUMMARY

A. This Section specifies seismic restraints for bracing all piping and ductwork.

B. Operating Conditions:
   1. Seismic restraints specified in this Section are provided to resist pipe movements and loads that result from an earthquake or other seismic event.
   2. All piping systems shall be provided with seismic restraints conforming to governing state and local codes.
   3. Seismic restraints shall conform to guidelines given in the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) Seismic Restraint Manual for the Seismic Hazard Level specified in Section 01850 - Design Criteria and, at a minimum, be consistent with requirements of governing state and local codes.
   4. In case of conflict, the more stringent requirements specified in Section 01850 - Design Criteria or governing state or local code shall be followed.

C. Restraint Selection:
   1. Piping systems shall not be braced to dissimilar parts of a building or to dissimilar building systems that may respond in a different mode during an earthquake. Examples: wall and a roof; solid concrete wall and a metal deck with lightweight concrete fill.
   2. Restraints shall be sized to fit outside diameter of pipe, tubing, or, where specified, outside diameter of insulation.
   3. There shall be no contact between a pipe and restraint component of dissimilar metals. Contractor shall prevent contact between dissimilar metals when restraining copper tubing by using copper-plated, rubber, plastic or vinyl-coated, or stainless steel restraint components.
   4. Branch lines shall not be used to brace main lines.
   5. Seismic bracing shall not limit expansion and contraction of the piping system.

1.02 REFERENCES

A. American Institute of Steel Construction (AISC):
   1. Manual of Steel Construction, Allowable Stress Design - 9th Edition.

B. Metal Framing Manufacturers Association (MFMA):
   1. MFMA-2 - Metal Framing Standards Publication.
   2. MFMA-101 - Guidelines for the Use of Metal Framing.

C. American National Standard Institute or Manufacturer's Standardization Society (ANSI/MSS):
   1. SP-58 - Standard for Pipe Hangers and Supports - Materials, Design, and Manufacture.
   2. SP-69 - Standard for Pipe Hangers and Supports - Selection and Application.
   3. SP-89 - Standard for Pipe Hangers and Supports - Fabrication and Installation Practices.

D. American National Standard Institute/National Fire Protection Association:
   1. ANSI/NFPA 70.

E. National Fire Protection Association (NFPA):
   1. NFPA 13 - Installation of Sprinkler Systems.
   2. NFPA 14 - Standpipe and Hose Systems.

F. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA):
   1. Seismic Restraint Guidelines for Mechanical Systems.

1.03 DEFINITIONS

A. Longitudinal Direction: Direction parallel to the pipe axis.

B. Lateral Direction: Direction perpendicular to the pipe axis.

1.04 DESIGN

A. Seismic restraint system shall be designed by the Design Professional as required in Section 15061 - Pipe Supports.

B. Seismic restraint details shall be designed in conjunction with preparation of pipe system hangers and drawings.

1.05 SUBMITTALS

A. As specified in Section 15061 - Pipe Supports.

1.06 QUALITY ASSURANCE

A. Submit inspection reports as defined in Section 15061 - Pipe Supports.

1.07 PROJECT CONDITIONS

A. Environmental requirements as specified in Section 01850 - Design Standards.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Standard pipe restraints and components shall be manufactured by Carpenter & Patterson, B-Line, Kin-Line, ITT Grinnell, Michigan, Pipe Shields Incorporated, Superstrut, Unistrut, or equal.

B. Pipe restraint materials, design, manufacture, testing, installation, and application shall conform to the requirements of MSS SP-58, MSS-SP-69, MSS-SP-89, MFMA-2, and MFMA-101.

2.02 MATERIALS

A. Unless otherwise specified, restraints, including braces, pipe and structural attachments, shall match the pipe support material as specified in Section 15061 - Pipe Supports.

B. Nuts, bolts, and washers shall match materials specified for the nuts, bolts, and washers in Section 15061 - Pipe Supports.

C. Concrete anchors shall be per Section 15061 - Pipe Supports.

D. For corrosive areas specifically requiring fiberglass materials, all pipe support, anchor, and brace components (not just fittings and accessories) shall be made of fiberglass.

2.03 THERMAL PIPE HANGER SHIELD

A. Thermal shields shall be provided at seismic restraint locations on pipe requiring insulation.

B. Thermal pipe hanger shields shall be as specified in Section 15061 - Pipe Supports.

C. Stainless steel band clamps shall be provided on thermal shields at longitudinal pipe restraint locations.

PART 3 EXECUTION

3.01 PIPE RESTRAINT LOCATIONS

A. The first seismic restraint on a piping system shall be located not more than 10 feet from the main riser, entrance to a building or piece of equipment.

B. Cast iron pipe shall be braced on each side of a change in direction of 90 degrees or more. Joints in risers shall be braced or stabilized between floors.

C. No-hub and bell-and-spigot cast iron soil pipe shall be braced longitudinally every 20 feet and laterally every 10 feet.

D. Lateral bracing for one pipe section may also act as longitudinal bracing for the pipe section connected perpendicular to it, if the bracing is installed within 24 inches of the elbow or tee of the same size.

3.02 INSTALLATION

A. Rod stiffener assemblies shall be used at seismic restraints for hanger rods over 6 inches in length.

B. A minimum of 2 rod stiffener clamps shall be used on any rod stiffener assembly.

C. Lateral and longitudinal bracing shall be installed between 45 degrees above and 45 degrees below horizontal, inclusive, relative to the horizontal centerline of the pipe.

D. Welded and bolted attachments to the building structural steel shall be in accordance with the requirements of the AISC Manual of Steel Construction.

E. There shall be no drilling or burning of holes in the building structural steel without approval of the Project Inspector.

F. Embedded anchor bolts shall be used instead of concrete inserts for seismic brace installations in areas below water surface or normally subject to submergence.

G. The Contractor shall install thermal pipe hanger shields on insulated piping at required locations during restraint installation.

H. Butt joint connections to pipe insulation shall be made at the time of insulation installation in accordance with the manufacturer's recommendations.

I. Restraint components in contact with plastic pipe shall be free of burrs and sharp edges.

J. Rollers shall roll freely without binding.

K. Plastic or rubber end caps shall be provided at the exposed ends of all framing channels that are located up to 7 feet above the floor.

END OF SECTION

SECTION 15057

FUSION BONDED EPOXY LINING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Fusion bonded epoxy lining for steel or ductile iron pipe and fittings.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. D1002 - Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimen by Tension Loading (Metal-to-Metal).
   2. G8 - Standard Test Methods for Cathodic Disbonding of Pipeline Coatings.

B. American Water Works Association (AWWA):
   1. C116 - Standard for Protective Fusion-Bonded Epoxy Coatings for the Interior and Exterior Surfaces of Ductile-Iron and Gray-Iron Fittings.
   2. C213 - Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines.

C. Society for Protective Coatings (SSPC):
   1. SP 7 - Brush-Off Blast Cleaning.
   2. SP 10 - Near-White Blast Cleaning.

1.03 SUBMITTALS

A. Product data.

B. Test reports: Include manufacturer's certification that lining passed tests.

C. Manufacturer's application instructions.

PART 2 PRODUCTS

2.01 EPOXY RESIN POWDER

A. Manufacturer: One of the following or equal:
   1. 3M.
   2. Morton Thiokol.

B. Material: Thermosetting, fusion bonded dry powder epoxy, 100 percent solids, with following performance characteristics when applied:
   1. Cathodic disbondment resistance: Average maximum 48 millimeters when tested in accordance with ASTM G8.

2. Adhesion shear resistance: Minimum 4,700 pounds per square inches when tested in accordance with ASTM D1002.

2.02 FABRICATION

A. Blast clean fitting interior surfaces of pipe and fittings in accordance with SSPC-SP 7 or SSPC-SP 10.

B. Apply epoxy resin powder to blasted surfaces by either fluidized bed method or electrostatic coating method in accordance with manufacturer's instructions and AWWA C116 or AWWA C213.

C. Fuse lining to piping in accordance with manufacturer's instructions and AWWA C116 or AWWA C213.

D. Pipe and fittings: Minimum lining thickness: 16-mil.

E. Valve: Lining thickness: 10 to 12 mils, except that:
   1. Lining thickness in grooves for gaskets: 5-mil.
   2. Do not coat seat grooves in valves with bonded seat.

2.03 SOURCE QUALITY CONTROL

A. Test lining with either 100 volt per mil thickness holiday detectors or low voltage wet sponge holiday detectors.

B. Reject pipe and fitting with linings that contain pinholes, discontinuities or other defects.

C. Lining thickness: Measured with a non-destructive magnetic type thickness gauge.

D. Verify lining integrity with a wet sponge-testing unit operating at approximately 60 volts, or as recommended by the lining manufacturer.

E. Consider tests successful when lining thickness meets specified requirements and when no pinholes are found.

F. Correct defective lining disclosed by unsuccessful tests, and repeat test.

G. Repair pinholes with liquid epoxy recommended by manufacturer of the epoxy used for lining.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install pipe and fitting as specified in Section 15052 - Common Work Results for General Piping.

END OF SECTION

SECTION 15061

PIPE SUPPORTS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Supports for pipe, fittings, valves, and appurtenances.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. A123 - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   2. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
   3. A967 - Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts.

B. Manufacturers Standardization Society (MSS):
   1. SP-58 - Pipe Hangers and Supports - Materials, Design, Manufacture, Selection, Application, and Installation.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Anchor: Elements (including hardware) connecting hangers and supports to the structure.
   2. Hardware: Nuts, bolts, straps, clamps, threaded rod, etc.
   3. Supports: Structural member on which the pipe is mounted.

1.04 PIPE SUPPORT DESIGN

A. Contractor shall provide final design, inspection, and certification for supports, and seismic restraints for this project:
   1. The design of these systems shall be the product of a qualified professional engineer licensed to practice in the State of California retained by Contractor, (hereinafter and in all referenced sections the Design Professional).
   2. The hanger and support design drawings and calculations shall be prepared and signed by the Design Professional and shall bear the Design Professional's registration seal.
   3. The Design Professional shall obtain and maintain professional liability insurance in the amount of $1,000,000 per incident with a $1,000,000 aggregate to be in effect the project duration plus 1 year.
   4. Design Professional shall have no less than 5 years of experience in type of piping work required for this project.

5. These requirements, however, shall not be construed as relieving Contractor of overall responsibility for this portion of the work.

B. In some cases, pipe supports are shown on the Drawings. In other cases, they are not shown, but are required. In general, seismic restraints are not shown, but are required. Contractor is responsible to supply complete pipe supports, and seismic restraints whether they are shown on the Drawings or not.

1.05 DESIGN/PERFORMANCE REQUIREMENTS

A. The pipe system drawings shall show the hanger and support locations as well as the details of the seismic restraints.

B. The pipe hanger and support system shall be coordinated with the seismic restraint specified in Section 15053 - Seismic Restraints for Piping.

C. Design supports to limit pipe deflection to L/240, and a spacing not to exceed 10 feet on center.

D. The Contractor shall coordinate the design of the hanger and support system with the design of the electrical support systems in Section 16100 - Electrical Requirements.

E. The Contactor shall coordinate the design for the hanger and support system with the of ductwork support systems.

F. The Contractor shall select pipe hangers and supports as specified in this Section and elsewhere in the Specifications or Drawings. Selections shall be based upon the pipe support classifications specified in MSS-SP69, and any special requirements that may be specified in other sections of the Specifications or Drawings.

G. The Contractor shall review the piping layout in the in relation to the surrounding structure and adjacent piping, ductwork, electrical support systems, and equipment before selecting the type of support to be used at each hanger point.

H. Where shown on the Drawings, supports are provided as guidance and may not meet minimum requirements. The Contractor shall provide, at no additional cost to the Owner, additional pipe supports as necessary and required by the Specifications. Supports shown on the Drawings shall be provided and shall be incorporated into the overall hanger and support system design.

1.06 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Contractor’s Design Professional Qualifications:
   1. Education, proof of registration, and previous experience in performing this type of work.
   2. Documentation shall be sufficient to demonstrate compliance with requirements of this Section.

C. Calculations:
   1. Calculations and other information to substantiate supports meet minimum design strength requirements for following:
      a. Pipe/ductwork loads, seismic bracing and expansion control.
      b. Connections and anchors.
   2. Seismic loads shall be as specified in Section 01850 - Design Criteria.
   3. Calculations shall be sealed by the Design Professional.

D. Product Data:
   1. Manufacturer's data sheets on each product used.
   2. As required by Section 05190 - Mechanical Anchoring and Fastening to Concrete and Masonry.
   3. Preparation instructions and recommendations by Manufacturer.
   4. Storage and handling requirements.
   5. Installation methods.

E. Shop Drawings:
   1. Include schedule, indicating where supports will be installed, where seismic bracing will be installed, and drawings of pipe support system components and seismic bracing.
   2. Piping and ductwork layout drawings, including supports and seismic restraints.
   3. Shop drawings shall be sealed by the Design Professional.

1.07 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements.

2.02 MATERIALS

A. General:
   1. Stainless steel:
      a. Fabricate as specified in Section 05500 - Metal Fabrications.
      b. Finish requirements: Remove free iron, heat tint oxides, weld scale, and other impurities, and obtain a passive finished surface.
      c. At the shop, perform pickling and passivation on all surfaces inside and out in accordance with ASTM A380 or ASTM A967.
      d. Field welding is prohibited unless specifically allowed by the Owner. All field welds shall be passivated.

B. Outdoor areas: Areas exposed to the natural outdoor environment:
   1. Type 316 stainless steel. Use Type 316L stainless steel if material will be welded.

C. Indoor areas: Areas exposed to an indoor environment, including galleries and tunnels:
   1. Type 316 stainless steel. Use Type 316L stainless steel if material will be welded.

D. Submerged, 3 feet or less above water level in a structure, or inside a water bearing structure:
   1. Type 316 stainless steel. Use Type 316L stainless steel if material will be welded.

E. Stainless steel piping system:
   1. Type 316 stainless steel. Use Type 316L stainless steel if material will be welded.

F. Chemical containment areas and chemical piping:
   1. Type 316 stainless steel. Use Type 316L stainless steel if material will be welded.

G. Fasteners:
   1. As specified in Section 05500 - Metal Fabrications.

2.03 PIPE SUPPORTS

A. Hanger rods: Sized to match suspended pipe hanger, or as indicated on the Drawings:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Bergen-Power, Figure 133.
         2) Nibco-Tolco, Figure 103.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 140.
         2) Bergen-Power, Figure 133.
         3) Cooper B-Line Systems, Inc., Figure B3205.

B. Hanger rods, continuously threaded: Sized to match suspended pipe hanger, or as indicated on the Drawings:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Bergen-Power, Figure 94.
         2) FM Stainless Fasteners.
      b. For steel and ductile iron piping:
         1) Anvil International, Figure 146.
         2) Bergen-Power, Figure 94.

C. Eye bolts:
   1. For stainless steel piping:
      a. Type 316 stainless steel, welded and rated equal to full load capacity of rod.
   2. For all other piping, unless indicated on the Drawings:
      a. Welded and rated equal to full load capacity of rod.

D. Welded eyebolt rod:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) FM Stainless Fasteners.
         2) Nibco-Tolco, Figure 101.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 278.
         2) Bergen-Power, Figure 93.
         3) Cooper B-Line Systems, Inc., Figure B3210.

E. Adjustable ring hangers: MSS SP-58, Type 7 or Type 9 (system dependent):
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Bergen-Power, Figure 100SS.
         2) Nibco-Tolco, Figure 1C.I.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 69.
         2) Cooper B-Line Systems, Inc., Figure B3172.

F. Adjustable clevis hangers: MSS SP-58, Type 1:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure B3100 or B3102.
         2) FM Stainless Fasteners, Figure 60.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 260 or Figure 590.
         2) Bergen-Power, Figure 100.
         3) Cooper B-Line Systems, Inc., Figure B3100 or B3102.

G. Adjustable clevis hangers for insulated pipe: Oversize:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Nibco-Tolco, Figure 1A.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 300.
         2) Bergen-Power, Figure 100EL.
         3) Cooper B-Line Systems, Inc. Figure B3108.

H. Single rod hangers for steam pipe: MSS SP-58, Type 43; malleable iron or steel yoke and roller hangers; swivel to allow rotation of yoke on rod:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure B3110.
         2) FM Fasteners, Figure 81.
         3) Nibco-Tolco, Figure 324.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 181.
         2) Cooper B-Line Systems, Inc., Figure B3110.

I. Double rod hangers for steam pipe: MSS SP-58, Type 41:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) FM Stainless Fasteners, Figure 71.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 171.
         2) Cooper B-Line Systems, Inc., Figure B3114.

J. Brackets: MSS SP-58, Type 32 with back plate; rated for 1,500 pounds:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure B3066.
         2) FM Stainless Fasteners, Figure 98.
         3) Nibco-Tolco, Figure 30M.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 195.
         2) Cooper B-Line Systems, Inc., Figure B3066.

K. Brackets, heavy duty: MSS SP-58, Type 33 with back plate; rated for 3,000 pounds:
   1. Manufacturers: One of the following or equal:
      a. Anvil International, Figure 199.
      b. Cooper B-Line Systems, Inc., Figure B3067.

L. Standard U-bolt: MSS SP-58, Type 24:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure B3188.
         2) FM Stainless Fasteners, Figure 37.
         3) Nibco-Tolco, Figure 110.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 137.
         2) Bergen-Power, Figure 283.
         3) Cooper B-Line Systems, Inc., Figure B3188.

M. Riser clamps: MSS SP-58, Type 8:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure B3373.
         2) FM Stainless Fasteners, Figure 61.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 261.
         2) Bergen-Power, Figure 126.
         3) Cooper B-Line Systems, Inc., Figure B3373.

N. Pipe clamps: MSS SP-58, Type 4:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure 3140.
         2) Nibco-Tolco, Figure 4.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 212.

2) Bergen-Power, Figure 175.
3) Cooper B-Line Systems, Inc., Figure B3140.

O. Adjustable offset pipe clamp:
1. Manufacturers: One of the following or equal:
a. For stainless steel piping:
1) Cooper B-Line Systems, Inc., Figure B3149.
2) FM Stainless Fasteners, Figure 63.
3) Nibco-Tolco, Figure 4.
b. For all other piping, unless indicated on the Drawings:
1) Anvil International, Figure 100.
2) Cooper B-Line Systems, Inc., Figure B3149.

P. Offset pipe clamp:
1. Manufacturers: One of the following or equal:
a. For stainless steel piping:
1) Cooper B-Line Systems, Inc., Figure 3148.
2) Nibco-Tolco, Figure 8.
b. For all other piping, unless indicated on the Drawings:
1) Anvil International, Figure 103.
2) Cooper B-Line Systems, Inc., Figure B3148.

Q. Floor stand or stanchion saddles: MSS SP-58, Type 37. Provided with U-bolt hold down yokes:
1. Manufacturers: One of the following or equal:
a. For stainless steel piping:
1) FM Stainless Fasteners, Figure 59.
2) Nibco-Tolco, Figure 318.
b. For all other piping, unless indicated on the Drawings:
1) Anvil International, Figure 259.
2) Bergen-Power, Figure 125.
3) Cooper B-Line Systems, Inc., Figure B3090.
c. Threaded pipe stand support stanchion. Match pipe support material:
1) Anvil International, Figure 63T.
2) Bergen-Power, Figure 138.
3) Cooper B-Line Systems Inc., Figure B3088ST.

R. Spring hangers:
1. Manufacturers: One of the following or equal:
a. For stainless steel piping:
1) Bergen-Power, Figure 920.
b. For all other piping, unless indicated on the Drawings:
1) Anvil International, Figure B-268, Type G.
2) Bergen-Power, Figure 920.

S. One hole pipe clamps:
1. Manufacturers: One of the following or equal:
a. For stainless steel piping: Engineer knows of no product.
b. For all other piping:
1) Anvil International, Figure 126.
2) Carpenter & Paterson, Figure 237S.

T. Welded beam attachment: MSS SP-58, Type 22:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Cooper B-Line Systems, Inc., Figure 3083.
         2) Nibco-Tolco, Figure 304.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 66.
         2) Bergen-Power, Figure 113A or 113B.
         3) Cooper B-Line Systems, Inc., Figure B3083.

U. Heavy pipe clamp: MSS SP-58, Type 4:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Nibco-Tolco, Figure 4H.
      b. For all other piping, unless otherwise indicated on the Drawings:
         1) Anvil International, Figure 216.
         2) Bergen-Power, Figure 298.

V. PTFE pipe slide assembly: MSS SP-58, Type 35 with lateral and vertical restraint:
   1. Manufacturers: One of the following or equal:
      a. For stainless steel piping:
         1) Nibco-Tolco, Figure 426.
      b. For all other piping, unless indicated on the Drawings:
         1) Anvil International, Figure 257, Type 3.
         2) Cooper B-Line Systems, Inc., Figure B3893.

W. Anchor bolts, concrete anchors, concrete inserts, powder-actuated fasteners, and sleeve anchors: As specified in Section 05120 - Structural Steel Framing.

2.04 THERMAL PIPE HANGER SHIELD

A. Provided at hanger, support, and guide locations on pipe requiring insulation.

B. Consists of an insulation layer encircling the entire circumference of the pipe and a steel jacket encircling the insulation layer.

C. Same thickness as the piping system insulation specified in Section 15400 - Plumbing Systems.

D. Provide the standard shield for hot systems and the vapor barrier shield for cold systems.

E. Stainless steel band clamps shall be used where specified to protect against slippage between the pipe wall and the thermal shield.

F. Standard shield:
   1. Insulation:
      a. Hydrous calcium silicate, high density, waterproof.
      b. Compressive strength: 100 pounds per square inch average.
      c. Flexural strength: 75 pounds per square inch average.
      d. K factor: 0.38 at 100 degrees Fahrenheit mean.

e. Temperature range: 20 degrees Fahrenheit to 500 degrees Fahrenheit.

2. Steel jacket:
   a. Jacket shall be galvanized steel.
   b. Gauge shall be the manufacturer's standard supplied for the given pipe size.
3. Connection:
   a. Shield shall have butt connection to pipe insulation.
   b. Steel jacket and insulation ends shall be flush.

G. Vapor barrier shield:
1. Insulation:
   a. Hydrous calcium silicate, high density, waterproof.
   b. Compressive strength: 100 pounds per square inch average.
   c. Flexural strength: 75 pounds per square inch average.
   d. K factor: 0.38 at 100 degrees Fahrenheit mean.
   e. Temperature range: 20 degrees Fahrenheit to 500 degrees Fahrenheit.
2. Steel jacket:
   a. Galvanized steel.
   b. Gauge shall be the manufacturer's standard supplied for the given pipe size.
3. Connection:
   a. Shield shall have butt connection to pipe insulation.

H. Extend the insulation 1 inch on each side of steel jacket for vapor tight connection to the pipe insulation vapor barrier.

PART 3 EXECUTION

3.01 INSTALLATION

A. Properly support, suspend, or anchor exposed pipe, fittings, valves, and appurtenances to prevent sagging, overstressing, or movement of piping; and to prevent thrusts or loads on or against connected pumps, blowers, and other equipment. Not all supports are shown on the Drawings. Provide supports shown in addition to the requirements herein.

B. Pipe supports shown on the Drawings do not show required seismic bracing. Provide seismic bracing as required.

C. Field verify support location, orientation, and configuration to eliminate interferences prior to fabrication of supports.

D. Determine locations of inserts. Anchor to formwork prior to placing concrete.

E. Use flush shells only where indicated on the Drawings.

F. Do not use anchors relying on deformation of lead alloy.

G. Do not use powder-actuated fasteners for securing metallic conduit or steel pipe larger than 1 inch to concrete, masonry, or wood.

H. Suspend pipe hangers from hanger rods and secure with double nuts.

I. Install continuously threaded hanger rods only where indicated on the Drawings.

J. Use adjustable ring hangers or adjustable clevis hangers for 4-inch and smaller diameter pipe.

K. Use adjustable clevis hangers for pipes larger than 4 inches in diameter.

L. Secure pipes with double nutted U-bolts or suspend pipes from hanger rods and hangers.
   1. For stainless steel piping, use stainless steel U-bolts.
   2. For all other piping, use galvanized U-bolts.

M. Support spacing:
   1. Support 2-inch and smaller piping on horizontal and vertical runs at maximum 5 feet on center, unless otherwise specified.
   2. Support larger than 2-inch piping on horizontal and vertical runs at maximum 10 feet on center, unless otherwise specified.
   3. Support exposed polyvinyl chloride and other plastic pipes at maximum 5 feet on center, regardless of size.
   4. Support tubing, PVC pipe 1-inch and smaller, copper pipe and tubing, fiber-reinforced plastic pipe or duct, and rubber hose and tubing at intervals close enough to prevent sagging greater than 1/4-inch between supports.
   5. Do not suspend or support valves, pipe and fittings from another pipe or conduit.

N. Install supports at:
   1. Any change in direction.
   2. Both sides of flexible pipe connections.
   3. Base of risers.
   4. Floor penetrations.
   5. Connections to pumps, blowers, and other equipment.
   6. Valves and appurtenances.

O. Securely anchor plastic pipe, valves, and headers to prevent movement during operation of valves.

P. Anchor plastic pipe between expansion loops and direction changes to prevent axial movement through anchors.

Q. Provide elbows or tees supported from floors with base fittings where indicated on the Drawings.

R. Support base fittings with metal supports or, when indicated on the Drawings, support on concrete piers.

S. Do not use chains, plumbers' straps, wire, or similar devices for permanently suspending, supporting, or restraining pipes.

T. Support plumbing drainage and vents in accordance with plumbing code as specified in Section 01410 - Regulatory Requirements.

U. Supports, clamps, brackets, and portions of support system bearing against copper pipe: Copper plated, copper throughout, or isolated with neoprene or polyvinyl chloride tape.

V. Where pipe is insulated, install over-sized supports and hangers.

W. Install thermal pipe shield in accordance with MSS SP-58, Type 40 on pipe supports for insulated pipes.

X. Install riser clamps at floor penetrations and where indicated on the Drawings.

Y. Coat support system components as specified in Section 09960 - High-Performance Coatings.

END OF SECTION

SECTION 15062

PREFORMED CHANNEL PIPE SUPPORT SYSTEM

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Preformed channel pipe support system consisting of preformed channels, fittings, straps, and fasteners engineered to support piping.

1.02 REFERENCES

A. American Institute of Steel Construction (AISC).

B. American Iron and Steel Institute (AISI).

C. Manufacturer's Standardization Society (MSS):
   1. SP-58 - Pipe Hangers and Supports - Materials, Design, and Manufacture.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data.

1.04 QUALITY ASSURANCE

A. Design preformed channel pipe support system for loads in accordance with applicable provisions of:
   1. AISC Manual of Steel Construction.
   2. AISI Cold-Formed Steel Design Manual.

B. Product standards:
   1. Pipe support materials: In accordance with MSS SP-58.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Fabricate preformed channel pipe support system using, as a minimum, parts specified below and meeting the requirements specified under Design Criteria.
   1. Manufacturers: One of the following or equal:
      a. Unistrut, Series P1000 or P1001; P5500 or P5501.
      b. Allied Support Systems, Power Strut, Figure PS-200 or PS-200 2TS; PS-150 or PS-150 2TS.
      c. Cooper Ind., B-Line, Channel Type B22 or B22A; B12 or B12A.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. Design responsibility:
   1. The manufacturer of the preformed channel pipe support system is responsible for the design of the support system.
   2. Prepare design calculations utilizing the design criteria included in these Specifications.
   3. Prepare detailed shop drawings illustrating the layout of the support system and identifying the components of the support system.

B. Design criteria:
   1. Include live, dead, and seismic loads associated with piping, valves, and appurtenances. Consider the content of the pipes in load calculations.
   2. Minimum gauge thickness: 12-gauge.
   3. Allowable stress of channels:
      a. Steel channels: The lesser of 25,000 pounds per square inch, or 0.66 times yield stress of steel.
      b. Stainless steel channels: 0.66 times the yield stress of the stainless steel alloy.
   4. Maximum deflection: 1/240 of span.
   5. Allowable column loads: As recommended by manufacturer in published instruction for column's unsupported height and "K" value for calculating effective column length of not less than 1.0.
   6. Future loads:
      a. Support systems indicated on the Drawings may include spaces intended to accommodate future pipes.
      b. Assume such spaces are occupied by 6-inch diameter ductile iron pipes. Only the number of pipes that would physically fit into the space need be considered.
      c. Include the weight of the pipe contents in determining future loads. Assume pipe contents are water.
   7. Seismic design criteria: As specified in Section 01850 - Design Criteria as specified for mechanical equipment.
   8. Spacing of supports: As required to comply with design requirements but not more than 5 feet.

C. Supports below the top of walls of water bearing structures: Use Type 316 stainless steel for support system components.
   1. Supports in other locations: Use hot-dipped galvanized components unless other materials are specifically indicated on the Drawings.

2.03 ACCESSORIES

A. Preformed channel concrete inserts: Minimum 12 inches long:
   1. Manufacturers: One of the following or equal:
      a. Unistrut, Series P-3200.
      b. Allied Support Systems, Figure 282.
      c. Cooper Ind., B-Line Series B32I.

B. 90-degree angle fittings:
   1. Manufacturers: One of the following or equal:
      a. Unistrut, P1026.
      b. Allied Support Systems, Power Strut, P603.

C. Pipe straps:
   1. For pipes 8 inches in diameter and smaller: Use 2-piece universal strap with slotted hex head screw and nut.
      a. Manufacturers: One of the following or equal:
         1) Unistrut, Series P1109 through P1126.
         2) Allied Support Systems, PS1100.
         3) Cooper Ind., B-Line Series B2000.
   2. For pipes greater than 8 inches in diameter: Unless different material is otherwise indicated on the Drawings use 1-piece 1-inch wide by 1/8-inch thick steel strap, hot-dip galvanized after fabrication.
   3. For stainless steel pipes: Use type of strap required for the pipe sizes specified above, but use Type 316 stainless steel materials.

D. Prefabricated double channel bracket:
   1. Manufacturers: One of the following or equal:
      a. Unistrut, P2542-P2546.
      b. Cooper Ind., B-Line Series B297.

E. Touch-up paint for galvanized surfaces:
   1. Manufacturers: The following or equal:
      a. Galvinox, Galvo-Weld.

F. Touch-up paint for painted surfaces: Same formulation as factory paint.

G. Cushion strip:
   1. For solvent welded plastic pipes in elevated temperatures, use a thermoplastic elastomer, cushion wrap designed for use from -50 degrees Fahrenheit to 275 degrees Fahrenheit. Contractor to add a cushion strip at each pipe support strap that meets these criteria.
      a. Manufacturers: One of the following or equal:
         1) Anvil, AS 3795.
         2) Unistrut, P2600 Unicushion.

2.04 FABRICATION

A. Hot-dip galvanize support system components after fabrication to required length and shape.

B. Do not galvanize or paint stainless steel components.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install preformed channel concrete inserts for vertical support, quantity based on manufacturer's structural design calculations.

B. Fasten preformed channel pipe supports to existing walls using Z-fittings and concrete anchors as indicated on the Drawings.

C. Fasten preformed channel pipe supports to preformed channel concrete inserts embedded in ceiling using U-shaped fittings.

D. Suspend threaded rods from concrete inserts embedded in ceiling. Support preformed channel pipe supports with threaded rods.

E. Touchup cut or damaged galvanized surfaces.

F. Prevent contact between pipes and support components of dissimilar metals. Utilize rubber coated, plastic coated, or vinyl coated components, stainless steel components, or wrap pipe with PVC or polyethylene tape.

G. Install support as near as possible to concentrated loads.

H. Install support within 2 feet of horizontal and vertical changes in pipe alignment.

I. Adjust supports or install shims to obtain specified slope or elevation.

END OF SECTION

SECTION 15076

PIPE IDENTIFICATION

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Pipe identification markers, flow direction arrows, tags, and bands.
   2. Underground warning tape.
   3. Tracer wire.
   4. Witness markers.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. A13.1 - Scheme for the Identification of Piping Systems.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product Submittals:
   1. As specified in Section 01600 - Product Requirements.
   2. Product data.
   3. Samples.
   4. Manufacturer's installation instructions.
   5. Submit the following as specified in Section 01700 - Contract Closeout:
      a. Operation and maintenance data.
      b. Warranty.
   6. Tracer wire access plan.

PART 2 PRODUCTS

2.01 EXPOSED AND IN-CHASE PIPE IDENTIFICATION

A. For piping with outer diameter greater than or equal to 3/4 inch, provide lettered pipe markers and flow direction arrows:
   1. General requirements:
      a. Pipe markers shall include the following, at a minimum:
         1) Printed text identifying the pipe fluid.
            a) Text shall be all capital letters matching the text listed in the "Service" column of the Pipe Schedule for the corresponding piping system.
         2) An arrow identifying the direction of fluid flow.
            a) Arrow can either be integral to the text marker or provided separately. If provided separately, the arrow must be placed

immediately adjacent to each text marker, with the arrow aligned with the text such that the text and arrow are both visible from the same viewpoint.

b) Arrow color shall match the text color, and the arrow background color shall match the text background color.

b. Suitable for outdoor application from -40 degrees to 180 degrees Fahrenheit; in accordance with ASME A13.1 requirements.

c. Lettering:

Outside Pipe Diameter, including Covering	Lettering Height
Less than 0.75 inches	N/A
0.75 to 1.5 inches	1/2 inch
1.5 to 2 inches	3/4 inch
2.5 to 6 inches	1-1/4 inches
8 to 10 inches	2-1/2 inches
Over 10 inches	3-1/2 inches

d. Marker colors:

Marker Color System ID(1)	Fluid Service	Text/Arrow Color	Background Color
1	Potable Water	White	Green
2	Recycled/Utility/Non-potable Water	White	Purple
3	Polymer	Black	White
4	Foul Air	Black	White
5	Pressured Air	White	Blue
6	Drain	White	Green
7	General Processes	Black	White

Notes:
(1) See Pipe Schedule.

2. Self-adhesive type markers:
   a. Manufacturers: One of the following or equal:
      1) Marking Services, Inc.
      2) Seton, (of Brady Corporation), Opti Code Pipe Markers.
   b. Materials:
      1) Self-adhesive vinyl.
3. Snap-on markers:
   a. Manufacturers: One of following or equal:
      1) Brady Snap-On.
      2) Seton (of Brady Corporation) Setmark.

B. For piping with outer diameter less than 3/4 inch, provide identification tags and flow direction arrows:
   1. Manufacturer: The following or equal:
      a. Seton (of Brady Corporation).
   2. Tag and chain materials:
      a. Copper piping: Brass.
      b. Ferrous piping: Type 316 stainless steel.
      c. Plastic piping**:** Type 316 Stainless steel.
   3. Flow direction arrow colors shall adhere to the same requirements as for piping with outer diameter greater than or equal to 3/4 inch, as specified in this Section.

C. Pipe bands:
   1. When bands are required by the Pipe Schedule for a specific piping system, provide solid-colored 4-inch wide bands.
      a. Color as specified in the Pipe Schedule.
   2. Self-adhesive type.
   3. Suitable for outdoor application from -40 degrees to 180 degrees Fahrenheit.

2.02 BURIED PIPELINE IDENTIFICATION

A. Underground warning tape:
   1. Manufacturer: One of the following or equal:
      a. Seton (of Brady Corporation).
      b. T. Christy Enterprises, Inc.
   2. Material:
      a. Polyethylene tape for prolonged underground use.
      b. Minimum tape thickness: 4 mils.
      c. Overall tape width: 4 inches.
      d. Message: “CAUTION” with the name of the service followed by “LINE BURIED BELOW.” in black lettering on colored background in accordance with approved American Wood Protection Association (APWA) colors.

Service	Color
Potable water	Blue
Reclaimed water, irrigation, and slurry lines	Purple
Sewers and drain lines	Green
Gas, oil, steam, petroleum, chemicals, or other service	Yellow

B. Tracer wire:
   1. Manufacturers: One of the following or equal:
      a. Aegion Corrpro.
      b. Kris-Tech Wire.
   2. Materials:
      a. Solid copper conductor.
      b. Thickness minimum: 10 gauge.
      c. Insulation:
         1) Match insulation color to the color of the pipe being installed.
         2) UF type, direct bury.
         3) 30-mil HMWPE.

3. Splicing kit:
    a. Manufacturers: The following or equal:
        1) 3M, Model 82 A1N.
4. Station box:
    a. Lid and collar materials: Cast iron.
    b. Lid type: Locking.
    c. Able to withstand heavy traffic loading.
    d. Manufacturers: One of the following or equal:
        1) CP Test & Valve Products, Inc., Glenn Test Station.
        2) Farwest Corrosion Control.

C. Witness markers:
1. Manufacturers: One of the following or equal:
    a. Carsonite Composites, Utility Marker.
2. Materials:
    a. Glass fiber and resin reinforced thermosetting composite material.
    b. UV resistant.
3. Constructed as a single piece.
4. Pointed at the bottom end.
5. Information to be included on the marker:
    a. “Caution” (type of service) “Pipeline”.
    b. Phone number for Underground Service Alert.
    c. Phone number for the Owner in case of emergency.
    d. Station number.
    e. Offset: Only provide offset if marker is not directly over the pipe.
    f. Name of appurtenance or fitting (e.g., 45, BO, ARV, etc.).

2.03 VALVE IDENTIFICATION

A. Provide valve schedule for each valve and gate in the Work with the following information:
1. Identification number.
2. Location.
3. Type.
4. Function.
5. Normal operating position.

B. Identification tag requirements:
1. Diameter: 2 inches.
2. Material:
    a. Buried applications: Stainless steel.
    b. Buried applications with concrete marker: Brass.
    c. Above ground and in-chase applications: 19-gauge aluminum or PVC.
3. Stamp tags in 1/4-inch high letter:
    a. Provide non-corrosive metal wire suitable for attaching the tag to the operator base.
4. Secure tags to valve or gate:
    a. Attach tags in such a way as to allow free and full operation of the valve or gate.
5. Buried applications with concrete marker: Secure tags to concrete marker.

C. Submittal requirements:
   1. Submit 2 samples of the type of tag proposed and the manufacturer's standard color chart and letter styles to the Engineer for review.

D. Manufacturer: The following or approved equal:
   1. Seton Name Plate Co.

PART 3 EXECUTION

3.01 EXAMINATION

A. Verify satisfactory conditions of substrate for applying identification.

B. Verify that conditions are satisfactory for installation and application of products as specified in Section 01600 - Product Requirements.

3.02 PREPARATION

A. Prepare and coat piping with the coating systems defined in the Pipe Schedule.

B. Prepare surface in accordance with the identification product manufacturer's instructions.

3.03 EXPOSED AND IN-CHASE PIPING IDENTIFICATION

A. Identify exposed and in-chase piping with flow direction arrows and lettering (for piping with outer diameter greater than or equal to 3/4 inch) or tags (for piping with outer diameter less than 3/4 inch).

B. Provide lettering (or tags for pipes with outer diameter less than 3/4 inch) and flow direction arrows near equipment served, adjacent to valves, both sides of walls and floors where pipe passes through, at each branch or tee, and at intervals of not more than 50 feet in straight runs of pipe.
   1. Label chemical tank fill pipelines at locations that are visible from chemical fill stations.
   2. Place markers on piping so they are visible from the operator's position in walkway or working platform near piping. Locate markers along horizontal centerline of pipe, unless better visibility is achieved elsewhere.
   3. Do not apply markers, arrows, or tags to piping that is regularly submerged.

C. Where scheduled in the Pipe Schedule, space solid-color bands along piping at 10-foot intervals.
   1. Do not apply bands to piping that is regularly submerged.

3.04 BURIED PIPING IDENTIFICATION

A. Underground warning tape:
   1. Non-detectable:
      a. Place continuous run of warning tape in pipe trench, 12 inches above the pipe.

2. Detectable:
    a. Place continuous run of warning tape in pipe trench, 12 inches above the pipe or a greater height if necessary to limit the tape bury depth to 36 inches. Do not bury detectable warning tape deeper than 36 inches.

B. Tracer wire:
1. Install on all non-metallic pipe.
2. Install an electrically continuous run of tracer wire along the entire length of the pipe with wire terminations in valve boxes, vaults, or structures.
3. Install tracer wire on top of the pipe and secure to pipe with tape a minimum of every 10 feet.
4. Where approved by the Engineer, splice sections of wire together using approved direct bury wire nuts.
    a. Twisting the wires together is not acceptable.
5. Install tracer wire access points at a maximum spacing of 500 LF. Locate station boxes in the median, sidewalk, or as indicated on the Drawings and approved by the Owner.
6. Provide 2-foot minimum slack of coiled wire in the station box after meeting final grade.
7. Ground the station box at dead ends such as manholes or dead-end pipe with 1.5 pound drive-in magnesium ground rod with a minimum of 20 feet of lead wire.
8. It is the Contractor's responsibility to protect the tracer wire from damage during pipe installation and backfill. All costs associated with finding discontinuities in the tracer wire and repair of the connections shall be borne by the Contractor.
9. Verify tracer wire installation by using low frequency (512 Hz or similar) line locating equipment.
    a. Provide 2 days advance notice to the Owner prior to testing.
    b. Test shall be witnessed and approved by the Owner.
    c. Test tracer wire for continuity between test stations and/or valve boxes prior to final paving.
10. As part of the as-built drawings, record station and pipe offset of station boxes.

C. Witness markers:
1. Install over pipe in unpaved open-space areas at intervals not greater than 200 feet.
2. Place markers at appurtenances located in unpaved areas.
3. Embed markers at least 18 inches into the soil.

END OF SECTION

SECTION 15110

COMMON WORK RESULTS FOR VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Basic requirements for valves.

1.02 REFERENCES

A. American Water Works Association (AWWA):
   1. C111/A21.11 - Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe Fittings.

B. ASTM International (ASTM):
   1. A126 - Standard Specification for Gray Iron Casting for Valves, Flanges, and Pipe Fittings.
   2. A480 - Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip.
   3. A536 - Standard Specification for Ductile Iron Castings.

C. NSF International (NSF):
   1. 61 - Drinking Water System Components - Health Effects.

D. Society for Protective Coatings (SSPC):
   1. SP 7 - Brush-Off Blast Cleaning.
   2. SP 10 - Near-White Blast Cleaning.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product data:
   1. Submit the following information for each valve:
      a. Type, size, pressure rating, Cv factor.
      b. Coatings.
      c. Power valve actuators:
         1) Information on valve actuator, including size, manufacturer, model number, limit switches, mounting and motor enclosure, seating and unseating torque coefficient, dynamic torque, and bearing friction for calculation of maximum operating torque.
         2) Complete wiring diagrams and control system schematics.
      d. Manual valve actuators:
         1) Information on valve actuator, including size, manufacturer, and model number.

e. Certified drawings with description of component parts, dimensions, weights, and materials of construction.
f. Certifications of reference standard compliance:
    1) Submit certification that the valves and coatings are suitable in potable water applications in accordance with NSF 61.
g. Clearly mark Submittal information to show specific items, materials, and accessories or options being furnished.
h. Factory test data.

C. Provide vendor operation and maintenance manual as specified in Section 01670 - Operations, Maintenance, and Training Requirements.
    1. Furnish bound sets of installation, operation, and maintenance instructions for each type of manual valve 4 inches in nominal size and larger, and non-manual valves. Include information on valve operators.

D. Provide Manufacturer's Certificate of Source Testing as specified in Section 01660 - Equipment and System Performance and Operational Testing.

E. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 QUALITY ASSURANCE

A. Manufacturer qualifications:
    1. Valves manufactured by manufacturers whose valves have had successful operational experience in comparable service.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Protect valves and protective coatings from damage during handling and installation. Repair coating where damaged.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Pressure rating:
    1. Suitable for service under minimum working pressures of 150 pounds per square inch gauge.
    2. When a piping system is specified in the Pipe Schedule to be tested at a pressure greater than 150 pounds per square inch gauge, provide valves for that piping system with design working pressure which is sufficient to withstand the test pressure.

B. Valve to piping connections:
    1. Metallic valves:
        a. 3 inches nominal size and larger: Flanged ends.
        b. Less than 3 inches nominal size: Screwed ends.

2. Plastic valves in plastic piping systems:
    a. Up to 4 inches: Provide solvent or heat welded unions, except for plastic butterfly valves.
    b. 6 inches and larger: Provide solvent or heat-welded flanges.

2.02 MATERIALS

A. Stainless steel: In accordance with ASTM A480, Type 316 or Type 304, UNS Alloy S31600 or S30400.

B. Valve and operator bolts and nuts, not including flange bolts and nuts as specified in Section 15052 - Common Work Results for General Piping:
    1. Fabricated of stainless steel for the following installation conditions:
        a. Submerged in sewage or water.
        b. In an enclosed space above sewage or water.
        c. In structures containing sewage or water, below top of walls.
        d. At openings in concrete or metal decks.
    2. Where dissimilar metals are being bolted, use stainless steel bolts with isolation bushings and washers.
    3. Underground bolts: Low-alloy steel in accordance with AWWA C111/A21.11.

C. Bronze and brass alloys: Not more than 6 percent zinc and not more than 2 percent aluminum in the manufacture of valve parts.
    1. UNS Alloy C83600 or C92200 unless specified otherwise.

D. Cast iron valve bodies: In accordance with ASTM A126, Class 30 minimum.

E. Ductile iron valve bodies: In accordance with ASTM A536, Grade 65-45-12 minimum, unless specified otherwise.

2.03 INTERIOR PROTECTIVE LINING

A. When specified in the particular valve Specification, provide valves with type of protective lining specified in the particular valve Specification.

B. Apply protective lining to interior, non-working surfaces, except stainless steel surfaces.

C. Lining types:
    1. Fusion bonded epoxy:
        a. Manufacturers: The following or equal:
            1) 3-M Company, ScotchKote 134.
        b. Clean surfaces in accordance with SSPC-SP 7 or SSPC-SP 10, as recommended by the epoxy manufacturer.
        c. Apply in accordance with the manufacturer’s published instructions.
        d. Lining thickness: 0.010 to 0.012 inch, except that:
            1) In grooves for gaskets: 0.005 inch.
            2) Do not coat seat grooves in valves with bonded seat.
        e. Quality control:
            1) Lining thickness: Measured with a non-destructive magnetic type thickness gauge.

2) Verify lining integrity with a wet sponge-testing unit operating at approximately 60 volts, or as recommended by the lining manufacturer.
3) Consider tests successful when lining thickness meets specified requirements and when no pinholes are found.
4) Correct defective lining disclosed by unsuccessful tests and repeat test.
5) Repair pinholes with liquid epoxy recommended by the manufacturer of the epoxy used for lining.

2. High solids epoxy:
   a. Product equivalent to high solids epoxy EPX-M-1 as specified in Section 09960 - High-Performance Coatings.
      1) Certified in accordance with NSF 61 for drinking water use.
      2) Interior: Coat valve interior with the manufacturer's equivalent high performance high solids epoxy coating system with a certifiable performance history for the service conditions and as approved by the Engineer.
         a) Manufacturer shall provide for approval, coating information sufficient to allow the Engineer to assess equivalence to the specified high solids epoxy EPX-M-1 as specified in Section 09960 - High-Performance Coatings.
   b. Clean surfaces in accordance with SSPC-SP 7 or SSPC-SP 10, or as recommended by the coating manufacturer.
   c. Quality control: After coating is cured, check coated surface for porosity with a holiday detector set at 1,800 volts, or as recommended by the coating manufacturer.
      1) Repair holidays and other irregularities and retest coating.
      2) Repeat procedure until holidays and other irregularities are corrected.

2.04 UNDERGROUND VALVES

A. Provide underground valves with flanged, mechanical, or other type of joint required for the type of pipe to which the valve is to be connected.

B. Coating and wrapping:
   1. Prior to installation, coat buried valves with 2 coats of protective coal tar as specified in Section 09960 - High-Performance Coatings.
   2. After installation, encase valves in polyethylene wrap as specified for ductile iron piping in Section 15211 - Ductile Iron Pipe: AWWA C151.
      a. Ensure polyethylene wrapping does not affect operation of valve.

2.05 VALVE BOXES

A. Provide cast-iron valve boxes at each buried valve to access valve and valve operators.

B. Do not support boxes on valve, valve operator, or pipe.

C. Boxes:
   1. Two-piece, fabricated of cast iron; provide cover, with asphalt varnish or enamel protective coating.

2. Adjustable to grade, install centered around the upper portions of the valve and valve operator.

D. Manufacturers: One of the following or equal:
   1. Neenah Foundry Co.
   2. Tyler Pipe Industries, Inc.

2.06 VALVE OPERATORS

A. Valve operator “Open” direction: Open counterclockwise.

B. Provide valves located below operating level or deck with extensions for key operation or floor stands and handwheels, as indicated on the Drawings.

C. Provide manually operated valves located not more than 6 feet above the operating level with tee handles, wrenches, or handwheels.
   1. Make the valve operator more conveniently accessible by rolling valves, located more than 5 feet but less than 6 feet above the operating level, toward the operating side.
   2. Secure tee handles and wrenches to the valve head or stem, except where a handle or wrench so secured constitutes a hazard to personnel; in which case, stow handle or wrench immediately adjacent to the valve on or in a suitable hanger, bracket, or receptacle.

D. Fit valves located more than 6 feet above operating level with chain-operated handles or valve wheels.
   1. Chains: Sufficient length to reach approximately 4 feet above the operating level.
   2. Where chains constitute a nuisance or hazard to operating personnel, provide holdbacks or other means for keeping the chains out of the way.

E. Provide an operator shaft extension from valve or valve operator to finished grade or deck level when buried valves and other valves located below the operating deck or level are specified or indicated on the Drawings to be key operated.
   1. Provide 2 inches square AWWA operating nut, and box and cover as specified, or a cover where a box is not required.

PART 3 EXECUTION

3.01 EXAMINATION

A. Preparation prior to installation:
   1. Determine after flanged valves and flanged check valves are selected, the face-to-face dimensions of flanged valves and flanged check valves.

B. Fabricate piping to lengths taking into account the dimensions of flanged valves and flanged check valves.

3.02 INSTALLATION

A. Install the valves in accordance with the manufacturer's installation instructions.

B. Provide incidental work and materials necessary for installation of valves, including flange gaskets, flange bolts and nuts, valve boxes and covers, concrete bases, blocking, and protective coating.

C. Provide additional valves for proper operation and maintenance of equipment and plant facilities under the following circumstances:
   1. Where such additional valves are required for operation and maintenance of the particular equipment furnished by the Contractor.
   2. Where such additional valves are required as a result of a substitution or change initiated by the Contractor.

D. Valve and actuator orientation:
   1. Coordinate with the valve supplier final orientation of valve and actuator assembly based on the Contractor's selection of equipment manufacturers and the valve and piping arrangement as indicated on the Drawings.
      a. Rotate valve and/or actuator mounting orientation as specified in this Section unless otherwise indicated on the Drawings.
   2. Install valves with their stems in vertical position above the pipe, except as follows:
      a. Butterfly valves, gate valves aboveground, globe valves, ball valves, and angle valves may be installed with their stems in the horizontal position.
      b. Install buried plug valves with geared operators with their stems in a horizontal position.
   3. Install valves so that handles clear obstructions when the valves are operated from fully open to fully closed.

E. Place top of valve boxes flush with finished grade or as otherwise indicated on the Drawings.

F. Valves with threaded connections:
   1. Install valves by applying wrench on end of valve nearest the joint to prevent distortion of the valve body.
   2. Apply pipe joint compound or Teflon™ tape on external (male) threads to prevent forcing compound into valve seat area.

G. Valves with flanged connections:
   1. Align flanges and gasket carefully before tightening flange bolts.
   2. When flanges are aligned, install bolts and hand tighten.
   3. Tighten nuts opposite each other with equal tension before moving to the next pair of nuts.

H. Valves with soldered connections:
   1. Do not overheat connection to prevent damage to resilient seats and metal seat rings.
   2. Position valves in full open position before starting soldering procedure.
   3. Apply heat to piping rather than to valve body.

3.03 FIELD APPLIED COATING OF VALVE EXTERIOR

A. Match color and be compatible with the manufacturer's coating system and as specified in Section 09960 - High-Performance Coatings.
   1. When shop-applied finish coating matches field applied coating on adjacent piping, touch up shop coating in damaged areas in accordance with instructions recommended by the paint manufacturer.
   2. When shop-applied coating does not match field coating on adjacent piping, or when damage has occurred to the shop-applied coating that requires more than touchup, blast clean valve surfaces or utilize other surface preparation recommended by the manufacturer of the coating material and apply the coating system used for coating adjacent piping.

3.04 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing, and this Section.

B. Manufacturer services from each manufacturer for all valves supplied:
   1. Provide Manufacturer's Certificate of Source Testing.
   2. Provide Manufacturer's Certificate of Installation and Functionality Compliance.

C. As specified elsewhere for specific valve types, sizes or actuators.
   1. Source testing.
   2. Manufacturers on-site services for Owner Training, Installation Testing, Functional Testing, and during the Process Operational Period.

END OF SECTION

SECTION 15111

BALL VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Ball valves.

B. As specified in Section 15110 - Common Work Results for Valves.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.1 - Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250.
   2. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through 24.

B. American Water Works Association (AWWA):
   1. C507 - Standard for Ball Valves 6 Inch Through 48 Inch.

C. ASTM International (ASTM):
   1. A48 - Standard Specification for Gray Iron Castings.
   2. A216 - Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service.
   3. A351 - Standard Specification for Castings, Austenitic, for Pressure-Containing Parts.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15110 - Common Work Results for Valves:
   1. Metal body ball valves: 6 inches and larger only: Submit affidavit of compliance in accordance with AWWA C507.
   2. Operation and maintenance manual.

C. Commissioning submittals:
   1. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. General: Unless otherwise indicated on the Drawings use:
   1. Metal body ball valves on metallic pipelines.
   2. Plastic body ball valves on plastic pipelines.

2.02 METAL BODY BALL VALVES – FULL PORT (BAV00)

A. Metal body ball valves, less than 6-inch size
   1. Manufacturers: One of the following, or equal:
      a. Conbraco Industries, Inc., Apollo Valves.
      b. Flow-Tek, Inc.
      c. Metso Automation/Jamesbury.
      d. NIBCO, Inc.
   2. General:
      a. Type: Non-lubricated, full port and capable of sealing in either direction.
      b. End connections:
         1) Threaded or solder ends for sizes 3-inch and smaller.
         2) Class 150 flanged for sizes larger than 3 inches.
            a) Flanges: In accordance with ASME B16.1 standards.
      c. Stem packing: Manually adjustable while valve is under pressure.
      d. Shafts:
         1) Rigidly connected to the ball by a positive means.
            a) Design connection to transmit torque equivalent to at least 75 percent of the torsional strength of the shaft.
      e. Handles: Stainless steel latch lock handle with vinyl grip and stainless steel nut designed to open and close the valve under operating conditions.
      f. Temperature limits: Suitable for operation between minus 20 and 350 degrees Fahrenheit.
   3. Materials:
      a. Valves in copper lines: Bronze body.
      b. Valves in steel and ductile iron piping: Ductile iron or cast steel body.
      c. Valves in stainless steel piping: Stainless steel body, material type to match piping material as specified in Section 15052 - Common Work Results for General Piping.
      d. Ball: Type 304 or 316 stainless steel, Type 316 in digester gas applications.
      e. Seats: PTFE.
      f. Stem seals: PTFE or Viton™.
      g. Bearings: Self-lubricated, corrosion resistant material that will not contaminate potable water.
      h. Valves for combustible fluid applications (digester gas, natural gas, fuel oil, etc.) must be of fire safe design.

2.03 PLASTIC BODY BALL VALVES – FULL PORT (BAV40)

A. Manufacturers: One of the following or equal:
   1. Asahi America.

2. Chemtrol Division, NIBCO, Inc.
3. Georg Fischer Piping Systems.
4. Hayward Flow Control.
    a. For sodium hypochlorite service, provide model TB-Z. Model TBH-Z shall not be used.
5. IPEX USA, LLC
6. Plast-O-Matic Valves, Inc.

B. General:
1. Type: Non-lubricated and capable of sealing in either flow direction.
2. End connections:
    a. 4 inches and smaller size: Socket end true unions for solvent welded connection to adjacent piping.
        1) For HDPE piping systems, also provide HDPE butt fusion to CPVC socket weld transition fitting such as Poly-Cam Series 735 with CPVC radial compression insert, or equal, for transition between HDPE piping and CPVC valve.
        2) For HDPE piping systems, valve shall have socket end true unions with attached flanges for flanged connection to adjacent HDPE flanges.
    b. 6-inch size: Socket end true unions with attached flanges for flanged connection to adjacent piping.
3. All valves shall have integral ISO 5211 mounting pad for actuator installation.
4. All valves shall have integral plate for lock-out/tag-out.
5. Stem: Double o-ring seal with shear point above seal.
6. Pressure rating: Suitable for the test pressure and maximum temperature of the corresponding piping system listed in the Piping Schedule.

C. Materials:
1. Body and ball:
    a. PVC piping systems: PVC.
    b. CPVC piping systems: CPVC.
    c. HDPE piping systems: CPVC.
2. Seats: PTFE (Teflon™).
3. O-rings: Match gasket material of corresponding piping system listed in the Piping Schedule.

D. Limit switches, when indicated on the Drawings:
1. Mechanical cam type with watertight enclosure and suited for remote indication of valve open-close status.
2. Mount on valve actuator.
3. Contacts: 120-volt alternating current, 20 amperes at 75 to 100 percent power factor and 24-volt direct current, 5 amperes minimum.

E. Valve actuator:
1. Valves shall be quarter turn operated with valve seat adjustability.
2. Manually operated valves: Lever.
Electric motor operated valves, when indicated on the Drawings: Provide electric motor operator as specified in Section 13447 - Electric Actuators.

PART 3 EXECUTION

3.01 INSTALLATION

A. General: Install each type of valve in accordance with manufacturers' printed instructions.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer's Certificate of Installation and Functionality Compliance.

C. Functional testing:
   1. Valves:
      a. Test witnessing: Witnessed.
      b. Conduct pressure and leak test, as specified in Section 15956 - Piping Systems Testing.

END OF SECTION

SECTION 15114

CHECK VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Swing check valves:
      a. General swing check valves.
      b. Thermoplastic swing check valves.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.1 - Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250.

B. American Water Works Association (AWWA):
   1. C508 - Standard for Swing-Check Valves for Waterworks Service 2 Inch Through 24 Inch NPS.

C. ASTM International (ASTM):
   1. A126 - Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
   2. A213 - Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes.
   3. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   4. A313 - Standard Specification for Stainless Steel Spring Wire.
   5. A536 - Standard Specification for Ductile Iron Castings.
   6. A582 - Standard Specification for Free-Machining Stainless Steel Bars.
   7. A743 - Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application.
   8. B16 - Standard Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines.
   9. B61 - Standard Specification for Steam or Valve Bronze Casting.
   10. B62 - Standard Specification for Composition Bronze or Q=Ounce Metal Castings.
   11. B584 - Standard Specification for Copper Alloy Sand Castings for General Applications.

D. National Electrical Manufacturers Association (NEMA).

E. NSF International (NSF):
   1. 61 - Drinking Water Components Health Effects.
   2. 372 - Drinking Water System Components - Lead Content.

F. Underwriters Laboratories, Inc. (UL).

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product data:
   1. As specified in Section 01600 - Product Requirements.

C. Quality Control Submittals
   1. Provide Manufacturer's Certificate of Installation Verification as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements and Section 15110 - Common Work Results for Valves.

B. Provide check valves as shown on the Check Valve Schedule and suitable for service:
   1. In either horizontal or vertical position.
   2. For working pressures up to 150 pounds per square inch.

C. Check valve materials as follows unless otherwise specified.
   1. Cast iron in accordance with ASTM A126, Grade B.
   2. Ductile iron in accordance with ASTM A536, Grade 65-45-12.
   3. Type 303 stainless steel in accordance with ASTM A582 (UNS S30300).
   4. Type 316 stainless steel in accordance with ASTM A313.

D. Flanges: Drilled in accordance with ASME B16.1 Class 125/150, unless otherwise specified or indicated on the Drawings.

E. Options:
   1. Provide pre-wired limit switch to indicate open/closed position to a remote location.
      a. Mechanical type limit switch shall be activated by the mechanical indicator.
      b. Rated for NEMA 4, 6, or 6P and shall have UL rated 5 amp, 125 or 250 VAC contacts.

2.02 GENERAL SWING CHECK VALVES (CKV00)

A. Valves 1/4 inch through 3 inches:
   1. Manufacturers: One of the following or equal:
      a. Crane Valve Co., Number 36.
      b. Lunkenheimer Co., Figure 554Y.

2. Design:
    a. Y-pattern body with integral seat.
    b. Female threaded ends.
    c. Renewable hinged disc.
    d. Threaded cap for access to valve seat without disassembly of piping.
    e. Integral seats suitable for regrinding.
3. Materials:
    a. Body: Bronze in accordance with ASTM B62-83600.
    b. Disc: Bronze in accordance with ASTM B62 C92200.
        1) On valves less than 1-inch: Brass in accordance with ASTM B16.
    c. Hinge: Bronze in accordance with ASTM B584 C 87600.
    d. Lock nut and hinge pin plug: Brass in accordance with ASTM B16 HO2.
    e. Hinge pin: Stainless steel in accordance with ASTM A276.
    f. Cap: Bronze in accordance with ASTM B61 C92200.
    g. If used for steam service:
        1) Body and disc: S1 steam bronze in accordance with ASTM B61.

B. Valves 4 inches through 24 inches:
1. Manufacturers: One of the following or equal:
    a. APCO Model 250.
    b. Crispin SWL Series.
    c. Kennedy, Figure 106LW or M&H, Model 159.
    d. Mueller Co., Model A-2600.
2. Design:
    a. In accordance with AWWA C508.
    b. Constructed to permit top entry and removal of internal components without removing the valve.
    c. Equipped with outside lever and weight.
3. Materials:
    a. Body: Cast iron, ASTM A126, Class B, or ASTM A536, Grade 65-45-12 ductile iron.
    b. Disc:
        1) Valve disc shall be ASTM A126 cast iron, ASTM A536 ductile iron, or ASTM B584 bronze.
        2) 4-inch valves: Bronze or stainless steel rings and seats.
        3) 6 inches and larger valves: Bronze-faced or stainless steel rings and seats.
        4) Rubber seat Buna-N or EPDM.
    c. Hinge pins: Stainless steel.

2.03 THERMOPLASTIC SWING CHECK VALVES

A. Manufacturers: One of the following or equal:
1. Asahi/America.
2. Ipex, Inc.
3. SIMTECH, VS Series.

B. Design:
1. Single disc design suitable for horizontal or vertical installation.

2. Top-entry bonnet design to allow maintenance without removal of valve body from pipe.
    a. Shall include a swing arm stop to prevent valve from opening too far.
3. Pressure rating:
    a. Rated to minimum 150 psig at 70 degrees Fahrenheit for sizes from 3/4 inch to 3 inches.
    b. Rated to minimum 100 psig at 70 degrees Fahrenheit for sizes from 4 inches to 6 inches.
    c. Rated for vacuum service.
4. External lever and weight to assist disc closure.
5. Flanged body with drilled and tapped bolt holes to match ASME B16.1, Class 125, and Class 150 flanged drilling dimensions.

C. Materials:
1. Valves:
    a. Body and bonnet: PVC, or CPVC.
    b. Shaft: PVC, or CPVC.
    c. Disc: PVC, or CPVC.
    d. All remaining wetted components: PVC, or CPVC.
    e. Seats, O-rings, gaskets: EPDM.
    f. Bolts, nuts, and washers: Type 304 stainless steel.
2. Lever and weight assembly:
    a. Shaft: Type 316 stainless steel.
    b. Set screws and bolts: Type 316 stainless steel.
    c. Counterweight and assembly fittings: PVC.
    d. Seals: EPDM.

2.04 INTERIOR PROTECTIVE LININGS

A. As shown in the valve schedules and as specified in Section 15110 - Common Work Results for Valves.

PART 3 EXECUTION

3.01 INSTALLATION

A. Thermoplastic swing check valves:
1. Install with proper orientation of flow direction arrow on valve body.
2. Installation in a vertical pipeline shall only be allowed where pressurized flow direction is up, through the valve. Vertical installation in lines where pressurized flow direction is down shall not be allowed.

3.02 FIELD QUALITY CONTROL

A. Manufacturer services:
1. Provide the Manufacturer’s Certificate of Installation Verification.

B. Functional Testing:
1. Test witnessing: Witnessed.

2. Conduct pressure and leak test, as specified in Section 15956 - Piping Systems Testing.

END OF SECTION

SECTION 15115

GATE, GLOBE, AND ANGLE VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Gate and globe (non-pilot controlled).
   2. As specified in Section 15110 - Common Work Results for Valves.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard.
   2. B16.47 - Large Diameter Steel Flanges: NPS 26 through NPS 60, Metric/Inch Standard.

B. American Water Works Association (AWWA):
   1. C515 - Standard for Reduced-Wall, Resilient-Seated Gate Valves for Water Supply Services.
   2. C550 - Protective Interior Coatings for Valves and Hydrants.

C. ASTM International (ASTM):
   1. B98 - Standard Specification for Copper-Silicon Alloy Rod, Bar, and Shapes.

D. Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry:
   1. SP-81 - Stainless-Steel or Stainless-Steel-Lined, Bonnetless, Knife Gate Valves with Flanged Ends.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data:
   1. As specified in Section 15110 - Common Work Results for Valves.

C. Commissioning Submittals:
   1. For valves larger than 16 inches:
      a. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

B. Interior epoxy coatings: Affidavit of compliance attesting that epoxy coatings applied to interior surfaces of valves comply in accordance with all provisions of AWWA C550.

PART 2 PRODUCTS

2.01 GATE VALVES - GENERAL SERVICE (GV00)

A. Underground:
   1. Manufacturers: One of the following or equal:
      a. American Flow Control.
      b. M&H/Kennedy Valve Co.
      c. Mueller Co.
   2. Design:
      a. Size, material, configuration: Indicated on the Drawings.
      b. Resilient wedge type in accordance with AWWA C515.
      c. Stem:
         1) Iron body, resilient seat, non-rising stem, double O-ring stem seal.
         2) Rising stem configuration with handwheel diameter sized to allow opening of valve with no more than a 40-pound pull.
      d. Ductile or cast iron wedge encapsulated in nitrile rubber and capable of sealing in either flow direction.
      e. Bronze stem with double or triple O-ring or braided packing stem seals.
      f. Coat interior and exterior surfaces of valve body and bonnet with fusion-bonded epoxy in accordance with AWWA C550.
      g. Valve operator: Provide standard AWWA 2-inch operating nut, matching valve key, and valve box for operating stem.

2.02 GLOBE VALVES - NON-PILOT-CONTROLLED (GLV00)

A. General (GLV00):
   1. Valves 3 inches and smaller:
      a. Manufacturers: One of the following or equal:
         1) Except in welded steel piping:
            a) Crane, No. 1 Globe or No. 2 Angle.
            b) Lunkenheimer Co. Figure No. 2140 Globe or No. 2141 Angle.
         2) In welded steel piping:
            a) Crane, No. 351.
            b) Lunkenheimer Co., Figure No. 1123; or equal with flanged ends.
      b. Design:
         1) Size and configuration: Indicated on the Drawings.
         2) Valve: Class 125 threaded ends, rated for 250 degrees Fahrenheit at pressure of 170 pounds per square inch.

B. Hose valves:
   1. Manufacturers:
      a. Globe threaded valve: One of the following or equal:
         1) Crane, No. 7TF.
         2) Stockham, Figure No. B22T.

b. Angle threaded valve: One of the following or equal:
   1) Crane, No. 17TF.
   2) Stockham, Figure No. B222T.

2. Design:
   a. Size and configuration: Indicated on the Drawings.
   b. Valve: Globe or angle valve with threaded ends.
   c. Disc: Renewable, made of Teflon™ or Buna-N.
   d. Threaded ends rated for a pressure of 200 pounds per square inch.

PART 3 EXECUTION

3.01 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services: For valves larger than 16 inches.
   1. Provide certificates:
      a. Manufacturer's Certificate of Installation and Functionality Compliance.

C. Functional Testing:
   1. Valves:
      a. Test witnessing: Witnessed.
      b. Conduct pressure and leak test as specified in Section 15110 - Common Work Results for Valves.

END OF SECTION

SECTION 15116

PLUG VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Non-lubricated plug valves.

1.02 REFERENCES

A. American Water Works Association (AWWA):
   1. C517 - Resilient-Seated Cast Iron Eccentric Plug Valves.
   2. C606 - Grooved and Shouldered Joints.

B. ASTM International (ASTM):
   1. A126 - Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
   2. A536 - Standard Specification for Ductile Iron Castings.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals and Section 15110 - Common Work Results for Valves.

B. Product data: As specified in Section 01600 - Product Requirements.

C. Shop Drawings: Installation arrangement of major component assemblies.

D. Calculations.

E. Vendor operation and maintenance manual as specified in Section 01670 - Operations, Maintenance, and Training Requirements.

F. Commissioning Submittals:
   1. Provide Manufacturer's Certificate of Source Testing as specified in Section 01660 - Equipment and System Performance and Operational Testing:
      a. Interior coating.
   2. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements and Section 15110 - Common Work Results for Valves.

2.02 NON-LUBRICATED PLUG VALVES (PV00)

A. Manufacturers: One of the following or equal:
   1. DeZurik, PEC.
   2. Clow Valve.
   3. Milliken Valve, Model 600/601.

B. Design:
   1. Type: Non-lubricated eccentric type, in accordance with AWWA C517.
   2. Plug face: Resilient material that operates satisfactorily at a temperature of 180 degrees Fahrenheit continuous and 215 degrees Fahrenheit intermittent, except for valves in compressed air or digester gas service.
      a. Valves in compressed air service: Resilient material suitable for continuous duty at 250 degrees Fahrenheit.
      b. Valves in digester gas service: Resilient material suitable for petroleum or digester gas at continuous duty at 180 degrees Fahrenheit.
   3. Compression washer: Provide flat compression washer made of Teflon™, or of a material having equal physical characteristics on valve stem between plug and bonnet.
   4. Stem seals: Provide stem seals serviceable without unbolting the valve bonnet assembly.
   5. Grit excluders: Provide PTFE grit excluders at upper plug journals to prevent entry of foreign solids in bearing area.
   6. Clearly mark valves to indicate their open and closed positions.
   7. Provide valves with ends as required by piping details indicated on the Drawings.
      a. Grooved end body valves:
         1) Usage: Plug valves with grooved ends may be used in piping systems specified in the Pipe Schedule to have grooved end joints and as indicated on the Drawings.
         2) Grooved end joint design: In accordance with AWWA C606.
   8. Interior Lining:
      a. Provide glass lining for valves installed in pipe services scheduled to receive glass lining. Refer to section 15052 - Piping Schedule.
      b. For all other applications, provide lining as specified in section 15110 - Common Work Results for Valves.

C. Materials:
   1. Body and plug: ASTM A536, Grade 65-45-12, ductile iron, with plug face of Buna N or material suitable for the intended service as specified under the “Design” article above.
   2. Body seats in valves 3-inch size and larger: Provide with overlay of not less than 90 percent nickel and minimum thickness of 1/8 inch on surfaces contacting the plug face.

3. Stem bearing and bottom bearing: Type 316 stainless steel.
4. Internal parts, except the body and plug: Type 316 stainless steel.
5. Exposed nuts, bolts, and washers: Zinc plated. Exception: Exposed nuts, bolts, and washers for buried service: Stainless steel.

2.03 NON-LUBRICATED PLUG VALVES, FULL PORT (PV05)

A. Manufacturers: One of the following or equal:
   1. DeZurik, PEF.
   2. Clow Valve.
   3. Milliken, 601F/600F.

B. Design:
   1. Type: Non-lubricated eccentric type, in accordance with AWWA C517.
   2. Pressure Rating: Suitable for service under minimum working pressures of 150 pounds per square inch gauge.
   3. Plug face: Resilient material that operates satisfactorily at a temperature of 180 degrees Fahrenheit continuous and 215 degrees Fahrenheit intermittent, except for valves in compressed air or digester gas service.
      a. Valves in compressed air service: Resilient material suitable for continuous duty at 250 degrees Fahrenheit.
      b. Valves in digester gas service: Resilient material suitable for petroleum or digester gas at continuous duty at 180 degrees Fahrenheit.
   4. Compression washer: Provide flat compression washer made of Teflon™, or of a material having equal physical characteristics on valve stem between plug and bonnet.
   5. Stem seals: Provide stem seals serviceable without unbolting the valve bonnet assembly.
   6. Grit excluders: Provide PTFE grit excluders at upper plug journals to prevent entry of foreign solids in bearing area.
   7. Clearly mark valves to indicate their open and closed positions.
   8. Provide valves with ends as required by piping details indicated on the Drawings.
      a. Grooved end body valves:
         1) Usage: Plug valves with grooved ends may be used in piping systems specified in the Pipe Schedule to have grooved end joints and as indicated on the Drawings.
         2) Grooved end joint design: In accordance with AWWA C606.
   9. Provide full (100 percent) port valves for the following pipe services:
      a. BSL:
         1) Except THK-VAL-07-011, THK-VAL-07-021, THK-VAL-07-031.
      b. DS
      c. FIL.
      d. PD.
      e. PS.
      f. TSL.
      g. WAS.
   10. Interior Lining:
      a. Provide glass lining for valves installed in pipe services scheduled to receive glass lining. Refer to section 15052 - Piping Schedule.

b. For all other applications, provide lining as specified in section 15110 - Common Work Results for Valves.

C. Materials:
1. Body and plug: ASTM A536, Grade 65-45-12, ductile iron, with plug face of Buna N or material suitable for the intended service as specified under the “Design” article above.
2. Body seats in valves 3-inch size and larger: Provide with overlay of not less than 90 percent nickel and minimum thickness of 1/8 inch on surfaces contacting the plug face.
3. Stem bearing and bottom bearing: Type 316 stainless steel.
4. Internal parts, except the body and plug: Type 316 stainless steel.
5. Exposed nuts, bolts, and washers: Zinc plated. Exception: Exposed nuts, bolts, and washers for buried service: Stainless steel.

2.04 VALVE OPERATORS

A. Furnish valves with an operating wrench or worm gear operator:
1. Equip valves 4-inch nominal size and smaller with a lever operator.
2. Equip valves 6-inch nominal size and larger with a worm gear operator.

2.05 COATING

A. Coat and test interior metal surfaces as specified in Section 15110 - Common Work Results for Valves.

B. Field applied coating of valve exterior:
1. Match color and be compatible with the manufacturer’s coating system and as specified in Section 09960 - High-Performance Coatings.
a. When shop applied finish coating matches field applied coating on adjacent piping, touch up shop coating in damaged areas in accordance with instructions recommended by the paint manufacturer.
b. When shop applied coating does not match field coating on adjacent piping, or when damage has occurred to the shop applied coating that requires more than touchup, blast clean valve surfaces or utilize other surface preparation recommended by the manufacturer of the coating material and apply the coating system used for coating adjacent piping.

2.06 SHIPMENT, SPARE PARTS, MAINTENANCE PRODUCTS, AND SPECIAL TOOLS

A. As specified in Section 01600 - Product Requirements.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install valves as specified in Section 15110 - Common Work Results for Valves and the manufacturer’s instructions.
1. Unless otherwise indicated on the Drawings, install valves so that in the closed position the pressure in the pipeline applies a seating head on the valves.

2. Install valves so that in the open position, the plug is located in the top half of the valve body.
3. Furnish Manufacturer's Certificate of Installation Verification.

B. For buried plug valves, provide with valve boxes, operating nuts, and tee-wrench handles. Install as specified in Section 15110 - Common Work Results for Valves.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Functional Testing:
1. Tests: Witnessed.
2. Conduct pressure and leak test as specified in Section 15110 - Common Work Results for Valves.
3. Furnish Manufacturer's Certificate of Functional Compliance.

END OF SECTION

SECTION 15117

SPECIALTY VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Specialty valves.

B. As specified in Section 15110 - Common Work Results for Valves.

1.02 REFERENCES

A. American Society of Civil Engineers (ASCE):
   1. 25 - Earthquake-Actuated Automatic Gas Shutoff Devices.

B. American Society of Mechanical Engineers (ASME):
   1. B16.42 - Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300.

C. American Water Works Association (AWWA):
   1. C511 - Standard for Reduced Pressure-Principle Backflow-Prevention Assembly.
   2. C800 - Underground Service Line Valves & Fittings (Also Included: Collected Standards For Service Line Materials).

D. ASTM International (ASTM):
   1. A48 - Standard Specification for Gray Iron Castings.
   2. A126 - Standard Specification for Gray Iron Casting for Valves, Flanges, and Pipe Fittings.
   3. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   4. A536 - Standard Specification for Ductile Iron Castings.
   5. B584 - Standard Specification for Copper Alloy Sand Castings for General Application.

E. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1000 V Maximum).

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15110 - Common Work Results for Valves.

C. Commissioning submittals:
   1. Backflow preventer certification.
   2. Provide Manufacturer’s Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 BACKFLOW PREVENTERS

A. Manufacturers: One of the following or equal:
   1. Febco backflow prevention:
      a. Model LF860 all sizes.
   2. Zurn/Wilkins:
      a. Model 975XL for 1/2-inch through 2-inch.
      b. Model 375AST for sizes 2 1/2 inch, 3 inch, 8 inch, and 10 inch.
      c. Model 375 and 375DA for sizes 4 inch and 6 inch.
   3. Watts regulator: Series LF909.

B. Design: Reduced pressure chamber type in accordance with AWWA C511.

C. Include shutoff valves at each end of backflow preventer with properly located test cocks.

D. Shutoff valves:
   1. Backflow preventers 2-inch and smaller: Provide with full-port, quarter turn, resilient seated ball valves.
   2. Backflow preventers larger than 2-inch: Provide with resilient seated, outside stem and yoke gate valves.

2.02 SOLENOID VALVES

A. 2-way solenoid valves:
   1. Manufacturers: One of the following or equal:
      a. Automatic Switch Co., Series 8210.
         1) Contractor shall provide external bypass to solenoid valve. External bypass shall use pipe of same material and size as main line and include a ball valve for manual operation.
      b. Skinner Electric Valve Division, Series C.

B. Design:
   1. Valves: Suitable for service under the following conditions:
      a. Fluid**:** potable/ reuse water.
      b. Temperature of fluid: 18 to 110 degrees Fahrenheit.
      c. Piping test pressure: TBC pounds per square inch gauge.
   2. Unless otherwise indicated on the Drawings, provide valves that meet the following requirements:
      a. Minimum NEMA Type 4 enclosure.
      b. 120 VAC operation.
      c. Suitable for use as indicated on the Drawings.
      d. Minimum Class F coil insulation.

3. Two-way valves: Furnish with openings of size equal to or larger than the nominal size designation of the valve.
4. Furnish with manual/bypass operators.

C. Materials:
1. Body: Brass or bronze.
2. Seats: Resilient material.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install as specified in Section 15110 - Common Work Results for Valves in accordance with manufacturer's published instructions.

B. Install with a minimum clearance of 12 inches and with maximum clearance of 30 inches between the relief port and the floor or finished grade or top of containment wall.

C. Backflow preventers:
1. Install with a minimum clearance of 12 inches and with maximum clearance of 30 inches between the relief port and the floor or finished grade or top of containment wall.
2. Install with sufficient side clearance for access for testing and maintenance.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
1. Provide certificates:
a. Manufacturer’s Certificate of Installation and Functionality Compliance.
2. Manufacturer’s Representative onsite requirements:
a. For the following valves:
1) Backflow preventer.
b. Installation: 1 trip, 1-day minimum.
c. Functional Testing: 1 trip, 1-day minimum each.
d. Training:
1) Maintenance: 2 hours per session, 1 session.
2) Operations: 2 hours per session, 1 session.

C. Functional testing:
1. Backflow preventer:
a. Test witnessing: Witnessed.
b. Conduct pressure and leak test as specified in Section 15110 - Common Work Results for Valves.

END OF SECTION

SECTION 15118

PRESSURE CONTROL VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Pressure reducing valves for water.

B. As specified in Section 15110 - Common Work Results for Valves.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.42 - Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300.

B. ASTM International (ASTM):
   1. A536 - Standard Specification for Ductile Iron Castings.

C. Underwriters Laboratories, Inc. (UL).

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15110 - Common Work Results for Valves.

C. Commissioning submittals:
   1. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 METAL BODY PRESSURE REDUCING VALVES - WATER SERVICE (PRV00)

A. Metallic pressure reducing valves for water service, 2 1/2 inches and smaller:
   1. Manufacturers: One of the following or equal:
      a. Watts, Series LF223.
      b. Zurn Wilkins, 500 Series.
   2. Direct operated, single seat type pressure reducing valve.
   3. Downstream pressure adjustment range: 30 to 125 pounds per square inch gauge (psig).

4. Materials:
    a. Body and spring cover: Bronze or brass alloy meeting the zinc and aluminum requirements of Section 15110 - Common Work Results for Valves.
    b. Valve seat: Series 300 stainless steel.
    c. Diaphragm: Reinforced Buna Nitrile.
    d. Disk: EPDM.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install as specified in Section 15110 - Common Work Results for Valves.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
    1. Provide certificates:
        a. Manufacturer's Certificate of Installation and Functionality Compliance.

C. Functional testing:
    1. Valves:
        a. Test witnessing: Witnessed.
        b. Conduct pressure and leak test as specified in Section 15110 - Common Work Results for Valves.

END OF SECTION

SECTION 15119

AIR AND VACUUM RELIEF VALVES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Combination air valves.

B. As specified in Section 15110 - Common Work Results for Valves.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.1 - Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250.
   2. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard.

B. American Water Works Association (AWWA).

C. ASTM International (ASTM):
   1. A126 - Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
   2. A240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
   3. A270 - Standard Specification for Seamless and Welded Austenitic Stainless Steel Sanitary Tubing.
   4. B584 - Standard Specification for Copper Alloy Sand Castings for General Applications.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15110 - Common Work Results for Valves.

C. Commissioning Submittals:
   1. Provide Manufacturer's Certificate of Installation and Functionality Compliance as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bond.

PART 2 PRODUCTS

2.01 METAL BODY COMBINATION AIR VALVES - SEWAGE SERVICE (CAV20)

A. Manufacturers: One of the following or equal:
   1. Multiplex Manufacturing Co., Crispin Series US.
   2. Valve and Primer Corp., DeZURIK/APCO, Series 440.

B. Design:
   1. Operation: Automatic exhaust and intake of large quantities of air during filling and draining of pipelines, respectively, and release of accumulated air while pipeline is under pressure.
   2. Utilize compound lever system in conjunction with large and small orifices.
   3. Internal parts removable through top cover without removing valve from pipeline.
   4. Pressure rating: 150 pounds per square inch.
   5. Connections: 2-inch threaded inlet and 1-inch threaded outlet.
   6. Accessories:
      a. Inlet shutoff valve.
      b. 2 blowoff valves for backflushing.
      c. 10 feet of hose with quick disconnect couplings.

C. Materials:
   1. Body: Cast iron.
   2. Float: Type 316 stainless steel.
   3. Needle: Buna-N or EPDM.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install as specified in Section 15110 - Common Work Results for Valves and the manufacturer’s instructions.

B. Install combination air valves with suitable discharge lines to nearest drainage system.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

B. Manufacturer services:
   1. Provide certificates:
      a. Manufacturer’s Certificate of Installation and Functionality Compliance.

C. Functional Testing:
   1. Valves:
      a. Test witnessing: Witnessed.
      b. Conduct pressure and leak test as specified in Section 15110 - Common Work Results for Valves.

END OF SECTION

SECTION 15120

PIPING SPECIALTIES

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Piping specialties, including:
      a. Rubber expansion joints.
      b. Transition fittings.
      c. Pipe saddles.
      d. Tapping sleeves.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard.

B. American Water Works Association (AWWA):
   1. C110 - Standard for Ductile-Iron and Gray-Iron Fittings.
   2. C151 - Standard for Ductile-Iron Pipe, Centrifugally Cast.

C. ASTM International (ASTM):
   1. A148 - Standard Specification for Steel Castings, High-Strength, for Structural Purposes.
   2. A193 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
   3. A194 - Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both.
   4. A536 - Standard Specification for Ductile Iron Castings.

D. NSF International (NSF):
   1. 61 - Drinking Water System Components - Health Effects, Includes Errata.
   2. 372 - Drinking Water System Components - Lead Content.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Product data:
   1. Design features.
   2. Load capacities.
   3. Material designations by UNS alloy number or ASTM Specification and Grade.
   4. Data needed to verify compliance with the Specifications.

5. Catalog data.

C. Installation instructions:
   1. Provide manufacturer's installation instructions.

D. Calculations:
   1. Provide calculations in accordance with NSF 372 for materials in contact with drinking water.

E. Quality Control Submittals:
   1. Manufacturer's Certificate of Installation Verification as specified in Section 01660 - Equipment and System Performance and Operational Testing.

1.04 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements.

1.05 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements.

B. Materials in contact with drinking waters: In accordance with NSF 61 and NSF 372.

2.02 RUBBER EXPANSION JOINTS

A. Manufacturers: One of the following or equal:
   1. Mercer Rubber Co., Style 500 or 700.
   2. Proco Products, Inc., Series 230 or 240.
   3. Red Valve Co., Inc., Type J-1.

B. Provide rubber expansion joints complete with control units and split retaining rings.

C. Design:
   1. Neoprene rubber, reinforced with embedded steel rings, and a strong synthetic fabric.
   2. Expansion rings, suitable for pressures of at least 125 pounds per square inch gauge, except as follows:
      a. Expansion joints in pump suction piping and where indicated on the Drawings suitable for minimum 90 pounds per square inch gauge pressure, and minimum 30 inches mercury vacuum.
      b. Ends of expansion joints: 1
      c. 50 pound ASME flanges with drilling to match that of the piping.
   3. Bolts, nuts, control rods/plates, and retaining rings shall be galvanized steel unless otherwise specified.

4. Bolts, nuts, control rods/plates, and retaining rings for low pressure air systems provide materials matching the piping system.
5. Bolts, nuts, control rods/plates, and retaining rings submerged in water or wastewater, buried, in wet vaults or structures, adjacent to wet walls, or above open water-containing structures shall be Type 316 stainless steel in accordance with ASTM A193, Grade B8M for bolts, and in accordance with ASTM A194, Grade 8M, for nuts.

D. For blowers: Butyl type rubber formulated for service application and for maximum temperature of 250 degrees Fahrenheit, suitable for minimum 40 pounds per square inch gauge pressure, and minimum 15 inches mercury vacuum.

2.03 TRANSITION FITTINGS

A. Manufacturers: One of the following or equal:
   1. Spears.

B. Materials:
   1. Slip socket: Schedule 80 PVC.
   2. Collar: Type 316 stainless steel.
   3. Threaded insert: Type 316 stainless steel.

2.04 PIPE SADDLES

A. For ductile iron pipe:
   1. Double strap brass type.
   2. Manufacturers: One of the following or equal:
      a. A.Y. McDonald, Style 3825.
      b. Mueller Company, Style BR2B.
      c. The Ford Meter Box Company, Style 202B.
   3. Materials:
      a. Pipe saddle body, straps, and nuts: Brass or silicon bronze.
      b. Gaskets: Rubber.

B. For PVC C900 or C905 pipe:
   1. Manufacturers: One of the following or equal:
      a. Romac Industries, Inc., Style 202S.
      b. Smith-Blair, Inc., Style 317.
   2. Materials:
      a. Pipe saddles: Ductile iron with fusion bonded epoxy finish.
      b. Straps, bolts, and nuts: Type 304 stainless steel with Teflon™ coating on nuts.
      c. Gaskets: Rubber.

2.05 TAPPING SLEEVES

A. Manufacturers: One of the following or equal:
   1. Romac Industries, Inc., Style FTS 420.
   2. Smith-Blair, Inc., Style 622.

B. Materials:
   1. Tapping sleeves: Steel construction.
   2. Bolts and nuts: Type 304 stainless steel.
   3. Nuts: Teflon™ coated.
   4. Gaskets: Rubber.
   5. Size of tapped boss: As indicated on the Drawings.

PART 3 EXECUTION

3.01 GENERAL

A. As specified in Section 01600 - Product Requirements.

B. Bellows type expansion joints and vibration control joints:
   1. Protect joints against damage during pressure test.

3.02 INSTALLATION

A. Rubber expansion joints:
   1. Provide control rods and additional guides where indicated on the Drawings.

B. Transition couplings:
   1. Application:
      a. Use with function and design similar to flexible couplings and flanged coupling adapters for connecting piping having different outside diameters.
   2. Install products specifically designed and manufactured for that application.

C. Pipe saddles:
   1. Coat threads on bolts with anti-gall coating prior to installation.

D. Tapping sleeves:
   1. Verify existing pipe material and outer diameter prior to ordering materials.
   2. Coat threads on bolts with anti-gall coating prior to installation.

E. Furnish Manufacturer’s Certificate of Installation Verification.

3.03 FIELD QUALITY CONTROL

A. Manufacturer services:
   1. Required only for:
      a. Transition couplings.
      b. Tapping sleeves for large diameter pipe.

B. Field testing:
   1. As specified in Section 15052 - Common Work Results for General Piping.
   2. Protect bellows type expansion joints and vibration control joints.

END OF SECTION

SECTION 15121

PIPE COUPLINGS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Pipe couplings for ductile iron piping.
   2. Pipe couplings for carbon steel piping.
   3. Pipe couplings for stainless steel piping.

1.02 REFERENCES

A. American National Standards Institute (ANSI).

B. American Society of Mechanical Engineers (ASME):
   1. B31.1 - Power Piping.
   2. B31.9 - Building Services Piping.

C. American Water Works Association (AWWA):
   1. C111 - Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
   2. C207 - Standard for Steel Pipe Flanges for Waterworks Service - Sizes 4 In. Through 144 In.
   3. C213 - Standard for Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings.
   4. C219 - Bolted, Sleeve-Type Couplings For Plain-End Pipe.
   5. C227 - Bolted, Split-Sleeve Couplings.
   6. C606 - Standard for Grooved and Shouldered Joints.

D. ASTM International (ASTM):
   1. A36 - Standard Specification for Carbon Structural Steel.
   2. A53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   3. A193 - Standard Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications.
   4. A240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
   5. A351 - Standard Specification for Castings, Austenitic, for Pressure-Containing Parts.
   6. A449 - Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/9 ksi Minimum Tensile Strength, General Use.
   7. A536 - Standard Specification for Ductile Iron Castings.
   8. A563 - Standard Specification for Carbon and Alloy Steel Nuts.

9. A576 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality.
10. A588 - Standard Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi (345 MPa) Minimum Yield Point, with Atmospheric Corrosion Resistance.
11. C425 - Standard Specification for Compression Joints for Vitrified Clay Pipe and Fittings.
12. C443 - Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets.
13. C564 - Standard Specification for Rubber Gasket for Cast Iron Pipe and Fittings.
14. C1173 - Standard Specification for Flexible Transition Couplings for Underground Piping Systems.
15. D1869 - Standard Specification for Rubber Rings for Asbestos-Cement Pipe.
16. D2000 - Standard Classification System for Rubber Products in Automotive Applications.
17. D5926 - Standard Specification for Poly (Vinyl Chloride) (PVC) Gaskets for Drain, Waste, and Vent (DWV), Sewer, Sanitary, and Storm Plumbing Systems.
18. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
19. F594 - Standard Specification for Stainless Steel Nuts.
20. F3125 - Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength.

E. NSF International (NSF):
1. 61 - Drinking Water System Components - Health Effects.
2. 372 - Drinking Water System Components - Lead Content.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product data:
1. For each product in this Section as applicable:
a. Design features.
b. Load capacities.
c. Material designations by UNS alloy number or ASTM specification and grade.
d. Data needed to verify compliance with the Specifications.
e. Catalog data.
f. Clearly mark Submittal information to show specific items, materials, and accessories or options being furnished.
g. For grooved joint couplings used in flexible radius-cut type joints, provide information on coupling axial and angular deflection values.

C. Calculations:
1. Provide calculations in accordance with NSF 372 for materials in contact with drinking water.

1.04 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements:
   1. Materials in contact with drinking waters: In accordance with NSF 61 and NSF 372.

B. Known acceptable manufacturers are listed by specific products.

C. Provide references as specified in this Section by specific product.

D. Manufacturer's representatives' requirements as specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section by specific product.

E. Gaskets for flexible couplings and flanged coupling adapters:
   1. Provide gasket materials for piping applications as follows:
      a. Low-pressure and high-pressure air, steam, hot water: EPDM.
      b. All other piping applications: Buna-N or EPDM.

F. Exterior coatings for underground and submerged applications:
   1. Manufacturers: One of the following or equal:
      a. Kop-Coat Co., Inc., Bitumastic Number 50.
      b. Tapecoat Co., Inc., T.C. Mastic.
   2. Thickness: Minimum 0.040 inch.

2.02 PIPE COUPLINGS FOR DUCTILE IRON PIPING

A. Dismantling joints:
   1. Manufacturers: One of the following or equal:
      a. Romac Ind., Inc., Style DJ400.
      b. Smith-Blair, Inc., Series 975.
   2. Materials:
      a. Flanged spool: AWWA C207 steel pipe:
         1) ASTM A53 for sizes 3 inches to 12 inches.
         2) ASTM A36 for sizes 14 inches to 72 inches.
      b. End ring and body:
         1) For sizes 3 inches to 12 inches: Ductile iron in accordance with ASTM A536.
         2) For sizes 14 inches to 72 inches: Steel in accordance with ASTM A36 or ASTM A53.
      c. Follower ring: Ductile iron in accordance with ASTM A536.
      d. Bolts and hex nuts:
         1) Aboveground: High strength, low alloy steel in accordance with ASTM A588.

2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.

e. Tie rods: High tensile steel in accordance with ASTM A193, Grade B7.

3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
4. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.

B. Equipment connection fittings:
1. Manufacturers: The following or equal:
   a. Romac Ind., Inc., Style ECF400.
2. Design:
   a. In accordance with AWWA C219.
   b. Suitable for minimum 150 pounds per square inch working pressure.
   c. Consist of 2 flanged coupling adapters, plain end section of pipe, thrust restraint rods, and associated fittings designed to transmit thrust without transmitting shear to the thrust restraint rods and without compromising provision for accommodating angular and parallel misalignment.
      1) Face to face length adjustment:
         a) For sizes 3 inches to 12 inches: 2 inches.
         b) For sizes 14 inches to 72 inches: 3 inches.
   d. Provide both lateral and angular misalignment adjustment between flanges.
      1) Shall accommodate a minimum of 1/4-inch lateral offset and 2 degrees deflection.
   e. Provide full pressure thrust restraint between flanges.
      1) Thrust rod:
         a) Selected to provide sufficient freedom of movement through all bolt holes to allow unrestricted maximum adjustment of equipment connection fittings.
         b) No transmission of any shear to the thrust rods.
         c) Allows full development of thrust restraint at thrust rod tension take-ups.
         d) Number and diameter selected as recommended by the manufacturer for the working pressure of the coupling.
3. Materials:
   a. Flanged spool: AWWA C207 steel pipe:
      1) ASTM A53 for sizes 3 inches to 12 inches.
      2) ASTM A36 for sizes 14 inches to 72 inches.
   b. End ring and body:
      1) For sizes 3 inches to 12 inches: Ductile iron in accordance with ASTM A536.
      2) For sizes 14 inches to 72 inches: Steel in accordance with ASTM A36 or ASTM A53.
   c. Bolts and hex nuts:
      1) Aboveground: Type 316 stainless steel bolts in accordance with ASTM F593.
   d. Tie rods: Type 316 stainless steel in accordance with ASTM A193 B8M.
   e. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
   f. Harness lugs: ASTM A36 steel.

g. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.

C. Flanged coupling adapters: 12-inch size and smaller:
   1. Manufacturers: One of the following or equal:
      a. Dresser, Inc., Style 227.
      b. Romac Ind., Inc., Style FCA501.
      c. Smith-Blair, Inc., Series 912.
   2. Materials:
      a. Flanged body: Ductile iron in accordance with ASTM A536.
      b. Follower ring: Ductile iron in accordance with ASTM A536.
      c. Bolts and hex nuts:
         1) Aboveground: High strength, low alloy steel in accordance with AWWA C111.
         2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.
   3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
   4. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.

D. Flanged coupling adapters: Greater than 12-inch size:
   1. Manufacturers: One of the following or equal:
      a. Dresser, Inc., Style 128-W.
      b. Romac Ind., Inc., Style FC400.
      c. Smith-Blair, Inc., Series 913.
   2. Materials:
      a. Flange and flanged body: Ductile iron or low carbon steel having a minimum yield strength of 30,000 pounds per square inch.
      b. Follower ring: Low carbon steel having a minimum yield strength of 30,000 pounds per square inch.
      c. Bolts and hex nuts:
         1) Aboveground: High strength, low alloy steel in accordance with AWWA C111.
         2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.
   3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
   4. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.

E. Flexible couplings:
   1. Manufacturers: One of the following or equal:
      a. Dresser, Inc., Style 253.
      b. Romac Ind., Inc., Style 501.
      c. Smith-Blair, Inc., Series 441.
   2. Materials:
      a. Center rings: Ductile iron in accordance with ASTM A536.
      b. Follower rings: Ductile iron in accordance with ASTM A536.

c. Bolts and hex nuts:
1) Aboveground: High strength, low alloy steel in accordance with AWWA C111.
2) Buried and underwater: Type 316 stainless steel in accordance with ASTM F593.

3. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.
4. Center sleeve dimensions: Provide center sleeves with lengths in accordance with the following table:

Nominal Pipe Size	Sleeve Length
3 inch and smaller	Manufacturer's standard
4 inch through 8 inch	7 inches
10 inch through 14 inch	12 inches
Greater than 16 inch	Use steel flexible coupling per pipe couplings for steel piping

F. Flexible couplings (gravity flow):
1. Manufacturers: The following or equal:
a. Fernco Flexible Coupling.
2. Materials:
a. In accordance with ASTM D5926, ASTM C1173, and applicable portions of ASTM C443, C425, C564, and D1869.
3. Requirements:
a. In underground and underwater installations, couplings shall be corrosion resistant or coated with a fusion applied epoxy coating in accordance with AWWA C213.
b. Bolts and hardware shall be stainless steel 18-8 Type 316 epoxy coated alloy hardware.

G. Restrained flange coupling adapter:
1. Manufacturers: One of the following or equal:
a. Romac Ind., Inc., Style RFCA.
b. Star Pipe Products, 3200 StarFlange™.
2. Materials:
a. Flange and flanged body: Ductile iron in accordance with ASTM A536.
b. Follower ring: Lug type restraint system.
1) Follower ring: Ductile iron in accordance with ASTM A536.
2) Restraining lugs: Ductile iron in accordance with ASTM A536.
a) Designed to contact the pipe and apply forces evenly.
3) Restraining bolts:
a) Ductile iron in accordance with ASTM A536.
b) Bolt heads shall be designed to twist off when the proper torque has been applied.
c. Bolts and hex nuts:
1) Aboveground: High strength, low alloy steel in accordance with AWWA C111.
2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.
3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.

4. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.

H. Grooved joint couplings:
   1. Manufacturers: The following or equal:
      a. Victaulic, Series 31 or equal.
   2. Materials:
      a. Housings: Ductile iron in accordance with ASTM A536.
      b. Gasket:
         1) Grade "M" FlushSeal® Elastomer in accordance with ASTM D2000.
         2) Halogenated butyl (brown color code).
         3) Temperature range: -20 to 200 degrees Fahrenheit.
         4) UL classified in accordance with NSF 61.
      c. Bolts and nuts: Electroplated steel in accordance with ASTM A449.
      d. Coating: As specified in Section 09960 - High-Performance Coatings.
   3. For use with rigid or flexible radius cut grooved joints in accordance with AWWA C606.
   4. For connection to IPS steel pipe sizes: Victaulic transition coupling Style 307.

2.03 PIPE COUPLINGS FOR CARBON STEEL PIPING

A. Dismantling joints:
   1. Manufacturers: One of the following or equal:
      a. Romac Ind., Inc., Style DJ400.
      b. Smith-Blair, Inc., Series 975.
   2. Materials:
      a. Flanged spool:
         1) For sizes 3 inches to 12 inches: AWWA C207 Schedule 40 pipe in accordance with ASTM A53.
         2) For sizes 14 inches to 72 inches: Steel for pipe in accordance with ASTM A36 or ASTM A53.
      b. End ring and body:
         1) For sizes 3 inches to 12 inches: Ductile iron in accordance with ASTM A536.
         2) For sizes 14 inches to 72 inches: Steel in accordance with ASTM A36.
      c. Follower ring: Ductile iron in accordance with ASTM A536 or steel in accordance with ASTM A36 or ASTM A576.
      d. Bolts and hex nuts:
         1) Aboveground: High strength, low alloy steel in accordance with AWWA C111.
         2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.
      e. Tie rods: High tensile steel in accordance with ASTM A193, Grade B7.
   3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
   4. Coating and lining: Fusion bonded epoxy certified in accordance with NSF 61.

B. Flanged coupling adapters:
   1. Manufacturers: One of the following or equal:
      a. Dresser, Inc., Style 128-W.

b. Romac Ind., Inc., Style FCA501 (10 inch and smaller) or Style FC400 (12 inch and larger).
c. Smith-Blair, Inc., Series 913.

2. Materials:
   a. Flange and flanged body: Ductile iron or low carbon steel having a minimum yield strength of 30,000 pounds per square inch.
   b. Follower ring: Low carbon steel having a minimum yield strength of 30,000 pounds per square inch.
   c. Bolts and hex nuts:
      1) Aboveground: High-strength, low-alloy steel in accordance with AWWA C111.
      2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.
3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
4. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.

C. Flexible couplings:
1. Manufacturers: One of the following or equal:
   a. Dresser, Inc., Style 38.
   b. Romac Ind., Inc., Style 511 or Style 400.
   c. Smith-Blair, Inc., Series 411.
2. Materials:
   a. Center sleeve and follower flanges: Ductile iron or low carbon steel having a minimum yield strength of 30,000 pounds per square inch.
   b. Bolts and hex nuts:
      1) Aboveground: High strength, low alloy steel in accordance with AWWA C111.
      2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.
3. Coating and lining: Manufacturer's standard fusion bonded epoxy, NSF 61 certified.
4. Center sleeve dimensions: Provide center sleeves with lengths in accordance with the following table:

Nominal Pipe Diameter	Sleeve Length
2-1/2 inch and smaller	Manufacturer's standard
3 inch through 6 inch	7 inch
8 inch through 14 inch	7 inch
Greater than 14 inches	10 inch

D. Restrained flange coupling adapters:
1. Manufacturers: One of the following or equal:
   a. Romac Ind. Inc., Style RFCA.
   b. Star Pipe Products, 3200 StarFlange™.
2. Materials:
   a. Flange and flanged body: Ductile iron in accordance with ASTM A536.
   b. Follower ring: Lug type restraint system.
      1) Follower ring: Ductile iron in accordance with ASTM A536.

2) Restraining lugs: Ductile iron in accordance with ASTM A536.
a) Designed to contact the pipe and apply forces evenly.
3) Restraining bolts: Ductile iron in accordance with ASTM A536. Bolt heads shall be designed to twist off when the proper torque has been applied.

c. Bolts and hex nuts:
1) Aboveground: High-strength, low-alloy steel in accordance with AWWA C111.
2) Buried and underwater: Type 316 stainless steel bolts in accordance with ASTM F593.

3. Flange design: Class D steel ring flange in accordance with AWWA C207, compatible with ANSI Class 125 and 150 bolt circles.
4. Coating and lining: Manufacturer's standard fusion bonded epoxy certified in accordance with NSF 61.

E. Grooved joint couplings:
1. Model numbers from 1 manufacturer are shown to indicate type only. Equivalent products of other manufacturers may be submitted for approval.
2. Coating: As specified in Section 09960 - High-Performance Coatings.
3. Sizes 2 inch through 12 inch:
a. Rigid type:
1) Housings shall be cast with offsetting angle-pattern bolt pads to provide rigidity and system support and hanging in accordance with ASME B31.1 and B31.9.
2) Installation-ready, for direct stab installation without field disassembly, with EHP gasket rated to 250 degrees Fahrenheit.
3) Manufacturers: One of the following or equal:
a) Victaulic, Style 107.
b) Victaulic, Zero-Flex Style 07.

b. Flexible type:
1) For use in locations where vibration attenuation and stress relief are required.
2) Three flexible couplings may be used in lieu of a flexible connector.
3) Couplings shall be placed in close proximity to the source of the vibration.
4) Installation-ready, for direct stab installation without field disassembly, with EHP gasket rated to 250 degrees Fahrenheit.
5) Manufacturers: One of the following or equal:
a) Victaulic, Style 77.
b) Victaulic, Style 177.

c. Flange adapter:
1) Flat face, ductile iron housings with elastomer pressure responsive gasket, for direct connection to ANSI Class 125 or 150 flanged components.
2) Manufacturers: The following or equal:
a) Victaulic, Style 741.

4. Sizes 14 inch through 24 inch:
a. Victaulic, AGS series, with lead-in chamfer on housing key and wide width FlushSeal® gasket.

b. Rigid type:
    1) Housing key shall fill the wedge shaped AGS groove and provide rigidity and system support and hanging in accordance with ASME B31.1 and B31.9.
    2) Manufacturers: The following or equal:
        a) Victaulic, Style W07.
c. Flexible type:
    1) Housing key shall fit into the wedge shaped AGS groove and allow for linear and angular pipe movement.
    2) Manufacturers: The following or equal:
        a) Victaulic, Style W77.
d. Flange adapter:
    1) Flat face, ductile iron housings with elastomer pressure responsive gasket, for direct connection to ANSI Class 125 or 150 flanged components.
    2) Manufacturers: The following or equal:
        a) Victaulic, Style W741.

5. Sizes 30 inch and larger:
    a. Manufacturers: The following or equal:
        1) Victaulic, Style AGS.

2.04 PIPE COUPLINGS FOR STAINLESS STEEL PIPING

A. Flexible couplings:
    1. Manufacturers: The following or equal:
        a. Dresser, Inc., Style 38.

B. Grooved joint couplings:
    1. Manufacturers: The following or equal:
        a. Victaulic.
    2. Materials:
        a. Housings:
            1) Ductile iron in accordance with ASTM A536.
            2) Stainless steel in accordance with ASTM A351.
        b. Gasket: Elastomer in accordance with ASTM D2000.
        c. Bolts and nuts:
            1) Electroplated steel in accordance with ASTM A449.
            2) Stainless steel in accordance with ASTM F593.
    3. Rigid type:
        a. Victaulic, Style 89 and W89 (ductile iron housings).
        b. Victaulic, Style 489 (stainless steel housings).
    4. Flexible type: Victaulic, Style 77S.

PART 3 EXECUTION

3.01 INSTALLATION

A. In underground and underwater installations, coat the exterior of coupling with a protective coating in accordance with the manufacturer's instructions.

B. Joints and flexible connections shall be installed centered with no angular deflection unless otherwise indicated on the Drawings.

C. Flexible couplings and flange coupling adapters: Install with gap between pipe ends in accordance with the following table unless a greater gap is indicated on the Drawings. Maximum gap tolerance shall be within 1/8 inch.
   1. Install flexible coupling with pipe gap located in middle of center sleeve.
   2. Install flanged coupling adapter with end of plain end pipe in middle of flanged coupling body.

Center Ring Length	Gap Dimension and Tolerance
4 inch through 6 inch	3/8 inch
7 inch	5/8 inch
10 inch and greater	7/8 inch

D. Provide harnesses (tie-downs) for flexible couplings unless otherwise indicated on the Drawings with a written note.
   1. Design harnesses (tie-downs) for the test pressures as specified in the Pipe Schedule in Section 15052 - Common Work Results for General Piping.

E. Grooved joint couplings:
   1. Grooved ends: Clean and free from indentations, projections, and roll marks in the area from pipe end to groove.
   2. Gaskets: Elastomer grade suitable for the intended service, and molded and produced by the coupling manufacturer.

F. Bolted, split-sleeve couplings:
   1. Inspect each coupling to ensure that there are no damaged portions of the coupling.
      a. Pay particular attention to the sealing pad/sealing plate area.
      b. Before installation, thoroughly clean each coupling of any foreign substance which may have collected thereon and shall be kept clean at all times.
   2. Wrenches:
      a. Conform to manufacturer instructions.
      b. Bolts and studs shall be tightened so as to secure a uniform gasket compression between the coupling and the body of the pipe with all bolts or studs tightened approximately the same amount.
      c. Final tightening shall be done by hand (no air impact wrenches) and is complete when the coupling is in uniform contact with the outside surface of the pipe all around the circumference of the pipe.
   3. No joint shall be misfit in any plane.
   4. On fixed ends of bolted, split-sleeve couplings, shoulders shall bear on restraint rings all around with no visible gap.
   5. Ends of piping where coupler are installed shall be smooth and free of defects.
      a. Remove weld splatter and grind smooth.
      b. Grind pipe seam welds flush with pipe wall and smooth.

END OF SECTION

SECTION 15125

STRAINERS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Y-type strainers.
   2. Basket type strainers.

1.02 REFERENCES

A. ASTM International (ASTM):
   1. A126 - Standard Specification for Gray Iron Castings for Valves, Flanges, and Pipe Fittings.
   2. A420 - Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service.

B. Society of Automotive Engineers (SAE).

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15052 - Common Work Results for General Piping.

PART 2 PRODUCTS

2.01 Y-TYPE STRAINERS

A. Y-type strainers less than 4 inches in diameter:
   1. Materials:
      a. Bodies: Cast iron or semi-steel.
      b. Ends: Flanged or threaded.
      c. Screen: Brass or Type 304 stainless steel.
   2. Suitable for maximum pressure of 250 pounds per square inch gauge.
   3. Screens: Perforations: 1/32 inch.
   4. Manufacturers: The following or equal:
      a. Armstrong, Y-Type Strainer.

B. Y-type strainers less than 3 inches in diameter for chemical service:
   1. Materials:
      a. Bodies: PVC.
      b. Ends: Socket end true unions.
      c. Screen: PVC.
      d. Seal material: FKM.

2. Suitable for a minimum pressure of 90 pounds per square inch gauge.
3. Screens: Perforations: 1/16 inch.
4. Manufacturers: One of the following or equal.
    a. Asahi American.
    b. Hayward Flow Control.
    c. Spears Manufacturing Co.

2.02 BASKET TYPE STRAINERS

A. Provide basket type strainers single or duplex as indicated on the Drawings.

B. Materials:
1. Bodies: PVC. Basket material shall match piping material.
2. Baskets: PVC. Basket material shall match piping material.

C. Pressure rating: Where not otherwise indicated on the Drawings, 125 pounds per square inch gauge, minimum.

D. Connections: Threaded or flanged, as required.

E. Covers:
1. For strainers 6 inches and smaller in size, secured by yokes or similar quick opening devices.
2. For strainers larger than 6 inches in size, bolted or hinged and bolted with slotted washers so that bolts or nuts need not be completely removed to open the strainer.
3. Provide lifting eyes on covers weighing more than 50 pounds.

F. Baskets:
1. Screen: Mesh or perforated sheet.
2. Openings: Not greater than 1/8 inch.
3. Free area: Not less than 30 percent.
4. Free area to pipe ratio: Not less than 3.

G. Provide duplex strainers with tapered plug transfer valve or with gate type transfer valves.
1. Where action on 2 valve actuators is required to transfer operation from one chamber to the other, provide actuators mechanically linked for simultaneous operation.

H. Manufacturers: One of the following or equal:
1. Basket strainers for chemical service:
    a. Hayward.
    b. Dual or simplex as indicated on the Drawings; baskets and bodies PVC; gaskets Viton or EPDM as required for the chemical service; basket mesh size to be specified by the Engineer during Shop Drawing review.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install in accordance with the manufacturer's recommendations.

3.02 COMMISSIONING

A. As specified in Section 01660 - Equipment and System Performance and Operational Testing and this Section.

END OF SECTION

SECTION 15211

DUCTILE IRON PIPE: AWWA C151

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Ductile iron pipe, joints, connections, fittings, and pipe linings and coatings.

B. As specified in Section 15052 - Common Work Results for General Piping.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.1 - Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250.

B. American Water Works Association (AWWA):
   1. C104 - Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings.
   2. C105 - Polyethylene Encasement for Ductile-Iron Pipe Systems.
   3. C110 - Standard for Ductile-Iron and Gray-Iron Fittings.
   4. C111 - Standard for Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings.
   5. C150 - Standard for Thickness Design of Ductile-Iron Pipe.
   6. C151 - Standard for Ductile-Iron Pipe, Centrifugally Cast.
   7. C210 - Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings.
   8. C222 - Polyurethane Coatings and Linings for Steel Water Pipe and Fittings.
   9. C600 - Installation of Ductile Iron Water Mains and Their Appurtenances.
   10. C606 - Standard for Grooved and Shouldered Joints.

C. American Welding Society (AWS):
   1. D11.2 - Guide for Welding Iron Castings.

D. ASTM International (ASTM):
   1. A536 - Standard Specifications for Ductile Iron Castings.
   2. B1000 - Standard Practices for Casting Preparation and Test Procedure of Porcelain Enamel-Lined Pipe, Fittings, and Valves for Use in the Municipal Wastewater, Sewage, and Water Treatment Industry.
   3. C33 - Standard Specification for Concrete Aggregates.
   4. C150 - Standard Specification for Portland Cement.
   5. C283 - Standard Test Methods for Resistance of Porcelain Enameled Utensils to Boiling Acid.
   6. D792 - Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
   7. D4541 - Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.

E. Ductile Iron Pipe Research Association (DIPRA):
   1. Thrust Restraint Design Manual.

F. International Organization for Standardization (ISO):
   1. 8179 - Ductile iron pipe, fittings, accessories and their joints - External zinc-based coating - Part 1: Metallic zinc with finishing layer.

G. National Association of Pipe Fabricators, Inc. (NAPF):
   1. 500-03 - Surface Preparation Standard for Ductile Iron Pipe and Fittings in Exposed Locations Receiving Special External Coatings and/or Special Internal Linings.

H. Society for Protective Coatings (SSPC):
   1. SP 5 - White Metal Blast Cleaning.
   2. SP 10 - Near White Wet Blast.
   3. SP 11 - Bare Metal Power Tool Cleaning.
   4. PA 2 - Measurement of Dry Coating Thickness with Magnetic Gages.
   5. QP 1 - Industrial Contractor Qualification.

1.03 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Product data.

C. Manufacturer's qualifications.
   1. Manufacturer qualifications and list of projects using the specified material: 5 years minimum.

D. Manufacturer's Quality Assurance Manual:
   1. Submit manufacturer's coating and lining application quality assurance manual to the Engineer prior to beginning coating application.
      a. Conformance to the requirements of the manual will be required.
      b. Deviation from the requirements of the manual will be grounds for the Engineer to reject the applied coating.

E. Shop Drawings:
   1. Detailed layout drawings showing alignment of pipes, location of valves, fittings, and appurtenances, types of joints, and connections to pipelines or structures.
   2. Thrust restraint systems.
   3. Photographs, drawings, and descriptions of fittings, gaskets, couplings, grooving of pipe and fittings.

F. Calculations:
   1. Thrust restraint system design.

G. Manufacturer's Certificate of Source Testing for ceramic epoxy, glass lined, plural component polyurethane, and zinc materials:
   1. Certify successful performance of holiday detection tests on 100 percent of lining in accordance with ASTM B1000.

2. Identify each test piece by mark designation and show the actual test results during the final inspection by the manufacturer prior to shipment.
3. Zinc coating: Regular measurements in accordance with ISO 8179 Part 4.4.
4. Include the coating manufacturer's technical representative's reports.

1.04 QUALITY ASSURANCE

A. Ductile iron pipe shall be supplied by a single manufacturer.

B. Hydrostatically test each joint of ductile iron pipe in accordance with AWWA C151.

C. Pre-installation meeting:
1. Arrange for the coating manufacturer's technical representative to attend preconstruction conferences and to make periodic visits to the factory or shop to inspect surface preparation of pipe, fittings, and accessories; and to inspect application of linings to interior and coatings to exterior of pipe, fittings, and accessories.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Block piping and associated fittings for shipment to prevent damage to coatings and linings.

B. Carefully handle piping and associated fittings during loading, unloading, and installation:
1. Do not drop piping material from cars or trucks.
2. Lower piping by mechanical means.
3. Do not drop or pound pipe to fit grade.

C. Handle pipe from the outside if lined with ceramic epoxy, glass or plural component polyurethane.
1. No forks, chains, straps, hooks, or other lifting device shall be placed inside the pipe or fittings for lifting, positioning, or laying.

D. Protect gaskets and polyethylene encasement from long-term exposure to sunlight.

E. Store piping, fittings, and other accessories such that they do not accumulate and hold rainwater, dirt, and debris.

PART 2 PRODUCTS

2.01 MANUFACTURED UNITS

A. Ductile iron piping:
1. Manufacturers: One of the following or equal:
a. American Cast Iron Pipe Co.
b. McWane Ductile.
c. U.S. Pipe.

2.02 THRUST RESTRAINT SYSTEM DESIGN

A. All piping shall be restrained.

B. Design pressure: Test pressure.

C. Laying condition: Type 5 in accordance with AWWA C150.

D. Soil type: Silt 1.

E. Unit friction resistance for polyethylene encasement of pipe: DIPRA factor multiplied by a safety factor of 1.5.

2.03 CONCRETE THRUST BLOCK RESTRAINT

A. Joint thrust restraint system designed by the Contractor.
   1. Concrete thrust blocks will only be permitted in certain locations where indicated on the Drawings.

2.04 DUCTILE IRON JOINTS AND CONNECTIONS

A. General:
   1. Pressure class or special thickness class as specified in the Pipe Schedule provided in Section 15052 - Common Work Results for General Piping.
   2. In accordance with AWWA C150 and AWWA C151.

B. Joints:
   1. Flanged joints:
      a. Screw-on flanges:
         1) Comply with the diameter, thickness, drilling, and other characteristics in accordance with ASME B16.1.
         2) Ductile iron.
         3) Long hub, threaded, and specially designed for ductile iron pipe.
         4) After attaching to pipe, machine flange face to make pipe end and flange even and perpendicular to the axis of the pipe.
      b. Bolt holes on flanges: 2-holed and aligned at both ends of pipe.
      c. Cap screw or stud bolt holes: Tapped.
      d. Bolts and nuts:
         1) As specified in Section 15052 - Common Work Results for General Piping.
      e. Gaskets:
         1) As specified in Section 15052 - Common Work Results for General Piping.
   2. Grooved joints:
      a. In accordance with AWWA C606, as complemented and modified below, radius-cut type.
      b. Couplings:
         1) Rigid type, cast from ductile iron in accordance with ASTM A536, Grade 65-45-12.

c. Bolts and nuts:
    1) As specified in Section 15052 - Common Work Results for General Piping.
d. Gaskets:
    1) As specified in Section 15052 - Common Work Results for General Piping.
e. Fittings:
    1) In accordance with AWWA C606, rigid radius-cut groove.
    2) Center-to-center dimensions: In accordance with AWWA C110.
    3) Wall thickness and other characteristics: In accordance with AWWA C606.
f. Flanged unit connections:
    1) Flanged to grooved joint adapters or a long enough spool with one end flanged and the other end grooved to prevent interference with the operation of adjacent valves, pumps, or other items.

3. Integrally restrained push-on joints:
    a. Application:
        1) Where designation restrained push-on is specified in the Pipe Schedule provided in Section 15052 - Common Work Results for General Piping, supply a restrained push-on joint piping system, which includes restrained push-on joints where necessary based upon thrust calculations.
        2) Standard push-on rubber gasket joints as specified above can be used where thrust calculations demonstrate restraint is not required.
    b. Design:
        1) Restrained push-on joints of the configuration which utilizes a gripping or friction force for restraint will not be acceptable.
        2) Suitable for the following working pressures:
            a) 4- through 24-inch pipe: 350 pounds per square inch gauge.
            b) 30- through 54-inch pipe: 250 pounds per square inch gauge.
    c. Gaskets:
        1) As specified in Section 15052 - Common Work Results for General Piping.
    d. Manufacturers: One of the following or equal:
        1) American Cast Iron Pipe Co., Flex Ring or Lok-Ring.
        2) McWane Ductile, TR Flex.
        3) U.S. Pipe, HDSS.
    e. Limit buried joints to half the manufacturer's published allowable angular joint deflection for purposes of pipeline alignment and elimination of fittings.

C. Connections:
    1. Tapping saddle as specified in the Owner's standard specification.
        a. If the Owner does not have a standard specification, provide tapping saddles as specified in Section 15120 - Piping Specialties.
    2. Tapping sleeve as specified in the Owner's standard specification.
        a. If the Owner does not have a standard specification, provide tapping sleeves as specified in Section 15120 - Piping Specialties.
    3. Welded outlet:
        a. Not allowed without Engineer approval.

D. Fittings:
   1. Ductile iron in accordance with AWWA C110.
   2. Joint type:
      a. Same as that of the associated piping as specified in Section 15052 - Common Work Results for General Piping.
   3. Plain end-to-flanged joint connectors using setscrews are not acceptable.

2.05 ASPHALT VARNISH

A. Coating:
   1. Factory apply.

2.06 CEMENT MORTAR

A. Line pipe with cement mortar in accordance with AWWA C104 and as specified in this Section.

B. Cement:
   1. Cement: In accordance with ASTM C150, Type II.

C. Water:
   1. In accordance with AWWA C104 and as specified in this Section.

D. Sand and aggregate:
   1. In accordance with AWWA C104.
   2. Provide silica sand or other aggregate that is not subject to leaching in accordance with ASTM C33.

E. Lining:
   1. Minimum thickness: Standard in accordance with AWWA C104.
   2. Apply cement mortar on clean bare metal surfaces.
   3. Extend to faces of flanges, ends of spigots, and shoulders of hubs.
   4. Line special pieces or fittings by mechanical, pneumatic, or hand placement.
      a. Extend to faces of flanges and ends of spigots.
      b. Less than 12 inches in width: Coat with epoxy bonding agent prior to applying cement mortar.
      c. Larger than 12 inches in width: Reinforced with 2-inch by 4-inch No. 13 gauge welded steel wire mesh prior to applying cement mortar.
   5. Provide plastic end caps of sufficient thickness and strength to resist shipping, handling, and storage stresses.
   6. Repair damage to the cement mortar lining, including disbondment, or cracking caused by improper curing, shipping, handling, or installation in accordance with AWWA C104 and approved by the Engineer.
      a. Reinforce coating with 2 layers spirally-wound steel wire positioned approximately in center of mortar coating positioned approximately at the third points of mortar coating:
         1) No. 12 gauge spaced at maximum 1-inch centers.
         2) No. 14 gauge steel wire at maximum 1/2-inch centers.

2.07 GLASS LINING

A. Manufacturers: One of the following or equal, having a minimum of 5 years of experience supplying this product to the wastewater and water industry:
   1. Vitco Corp., SG-14 Lining.
   2. Water Works Manufacturing, Ferrock MEH-32 Lining.

B. Material:
   1. Special glasses and inorganic materials suited for lining of sewage, sludge, and scum piping.
   2. Thickness: 0.008 to 0.012 inch.
   3. Hardness: 5 to 6 on the Mohs Scale.
   4. Density: 2.5 to 3.0 grams per cubic centimeter, measured in accordance with ASTM D792.
   5. Thermal shock resistance: Capable of withstanding 350 degrees Fahrenheit change from 430 degrees Fahrenheit to 80 degrees Fahrenheit without crazing, blistering, or spalling.
   6. Gloss retention: Capable of retaining gloss after immersion in an 8 percent sulfuric acid solution at 148 degrees Fahrenheit for 10 minutes.
   7. Weight loss: Maximum 3 milligrams per square inch when tested in accordance with ASTM C283.

C. Fabrication:
   1. Use piping that is suitable for glass lining with minimum Class 53 wall thickness after application of glass lining.
   2. Machine interior of pipe.
      a. Bore or grit blast in accordance with NAPF 500-03 prior to application of glass lining.
   3. Screw factory assembled flanges on pipe, align boltholes, and flange faces, unless otherwise specified.
   4. Apply lining to surfaces free of chemicals.
   5. Place piping in furnaces specially designed for heating piping until glass melts and fuses with an integral molecular bond to the base metal.
   6. Test 100 percent of the product in the factory in accordance with ASTM B1000.

2.08 POLYETHYLENE ENCASEMENT

A. General:
   1. Polyethylene encasement shall be supplied by the pipe manufacturer.

B. Materials: Supply one of the following polyethylene encasements:
   1. 2 layers of linear low-density polyethylene (LLDPE) film, minimum thickness of 8 mils in accordance with AWWA C105; or,
   2. Single layer of high-density, cross-laminated polyethylene (HDCLPE) film, minimum thickness of 4 mils in accordance with AWWA C105.
   3. Single layer of V-Bio® enhanced polyethylene encasement (3 layers of coextruded LLDPE film with anti-microbial additive and volatile corrosion inhibitor infused on the inside surface), meeting all requirements of AWWA C105.

2.09 SEAL COAT

A. Asphaltic seal coat:
   1. Apply over cement mortar linings and to outside surface of pipes that will not receive another coating.
   2. Apply in accordance with AWWA C151.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:
   1. Install ductile iron piping in accordance with AWWA C600, or as modified in Section 15052 - Common Work Results for General Piping.
   2. For underground piping, the trenching, backfill, and compaction:
      a. Inspect coating prior to backfill.
      b. As specified in Section 02318 - Trenching.

B. Joints:
   1. Install types of joints as specified in the Pipe Schedule provided in Section 15052 - Common Work Results for General Piping.
   2. Mechanical joints are not acceptable in above ground applications.
   3. Field closure for restrained push-on pipe:
      a. Locate field closures in areas where thrust calculations demonstrate restraint is not required.
   4. Grooved joints:
      a. Install piping with grooved joints as specified in the Pipe Schedule provided in Section 15052 - Common Work Results for General Piping.
      b. Assemble grooved joints in accordance with the manufacturer's published instructions.
      c. Support grooved-end pipe in accordance with the manufacturer's published instructions.
         1) Install at least 1 support between consecutive couplings.

C. Connection:
   1. Tapping ductile iron pipe:
      a. Direct tapping of ductile iron pipe may be performed but is limited to the following conditions:
         1) Maximum allowable tap diameter by pipe diameter and pressure class:

Pipe Size (inches)	Pressure Class				
	150	200	250	300	350
	Maximum Allowable Direct Tap Size (inches)				
3	-	-	-	-	3/4
4	-	-	-	-	3/4
6	-	-	-	-	1
8	-	-	-	-	1
10	-	-	-	-	1

Pipe Size (inches)	Pressure Class				
	150	200	250	300	350
	Maximum Allowable Direct Tap Size (inches)				
12	-	-	-	-	1-1/4
14	-	-	1-1/4	1-1/2	1-1/2
16	-	-	1-1/2	2	2
18	-	-	2	2	2
20	-	-	2	2	2
24	-	2	2	2	2

b. Maximum allowable tap diameter for pipelines greater than 24 inches is 2 inches.
c. 2 layers of 3-mil thread sealant are required to minimize the torque required to effect a watertight connection.

2. Direct tapping of glass lined ductile iron pipe may be performed only when approved in writing by the Engineer. Direct tapping of glass lined pipe shall be performed in accordance with the above conditions for tapping ductile iron pipe in addition to the following conditions:
   a. Drilling and tapping shall be performed using a hole saw.
      1) Use of a large drill bit is not acceptable.
   b. As the hole saw approaches the glass lining, lessen the inward pressure to avoid excess chipping or cracking of the lining.
   c. Minor chipping or spalling of the glass lining shall be repaired using an epoxy resin “glass repair kit” provided by the fabricator.
      1) Manufacturers: One of the following or equal:
         a) Devoe, Devran 224 HS.
         b) Sherwin-Williams Co., Sher-Tile High Solids Epoxy.
      2) Repair kit use is only allowed for areas of damage less than 1/2 inch in diameter.
         a) Larger areas of damage will require replacement.
      3) Surface shall be prepared and repair kit shall be applied in accordance with the manufacturer’s and/or fabricator’s instructions.
3. When direct tapping of ductile iron pipe is not possible due to limited wall thickness, a saddle tap shall be used.

3.02 DEFECTS IN COATINGS EXCEPT TAPE WRAP AND CEMENT MORTAR COATING

A. Engineer will identify defective coating to be field repaired in accordance with the applicable AWWA standard.
   1. Pipe joints exceeding the following defect maximum will be rejected.
      a. Minor defects:
         1) No more than 1.5 per 100 square feet of surface area.
         2) 2 or more minor repairs within an 8-inch diameter circle will be considered a single repair.
         3) Repairs for adhesion testing will not be included in the total number of repairs.
         4) Repair in accordance with the manufacturer’s requirements.

b. Major defects:
    1) No more than 3 major repairs on each pipe joint.
    2) No more than 30 percent repairs on the pipe surface area with defects.
2. Minor repairs:
    a. Less than 8 inches in the greatest dimension.
    b. Repair in accordance with the manufacturer's requirements.
3. Major repairs:
    a. Exceed 8 inches in the greatest dimension.
    b. Repair in accordance with the manufacturer's requirements.

3.03 POLYETHYLENE ENCASEMENT

A. Wrap buried ductile iron pipe and fittings in 2 layers of loose low-density polyethylene wrap, a single layer of high-density polyethylene wrap, or a single layer of V-Bio polyethylene wrap in accordance with AWWA C105 and as specified in this Section.

B. Wrap polyethylene encasement to be continuous and terminated neatly at connections to below grade equipment or structures.

C. At wall penetrations, extend encasement to the wall and neatly terminate.

D. At slab penetrations, extend encasement to 2 inches below the top of slab and neatly terminate.

E. When rising vertically in unimproved areas, extend encasement on pipe 6 inches above existing grade and neatly terminate.

F. Repair tears and make joints with 2 layers of plastic tape.

G. Work shall be inspected prior to backfilling of pipe and associated items.

3.04 FIELD QUALITY CONTROL

A. Testing ductile iron piping:
    1. Test as specified in Section 15052 - Common Work Results for General Piping and Section 15052 - Piping Systems Testing.

B. Repair damaged cement mortar lining to match quality, thickness, and bonding of original lining in accordance with AWWA C104.
    1. When lining cannot be repaired or repairs are defective, replace defective piping with undamaged piping.

C. Verify that interior surfaces of ceramic epoxy and glass lined pipe and fittings have continuous coverage:
    1. Test random samples, as directed by the Engineer, in accordance with ASTM B1000.
    2. Discard lined piping and fittings found to have pinholes, crazing, or fish scales, which expose the metal substrate.

END OF SECTION

SECTION 15230

PLASTIC PIPING AND TUBING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes: Plastic pipe, tubing, and fittings for systems that are not plumbing systems.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.12 - Cast Iron Threaded Drainage Fittings.

B. ASTM International (ASTM):
   1. D1248 - Standard Specification for Polyethylene Plastics Extrusion Materials For Wire and Cable.
   2. D1784 - Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
   3. D1785 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120.
   4. D1869 - Standard Specification for Rubber Rings for Asbestos-Cement Pipe.
   5. D2241 - Standard Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated (SDR Series.
   6. D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
   7. D2466 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
   8. D2467 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
   9. D2513 - Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings.
   10. D2564 - Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems.
   11. D2665 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.
   12. D2855 - Standard Practice for the Two-Step (Primer and Solvent Cement) Method of Joining Poly (Vinyl Chloride) (PVC) or Chlorinated Poly (Vinyl Chloride) (CPVC) Pipe and Piping Components with Tapered Sockets.
   13. D3034 - Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings.
   14. D3212 - Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals.
   15. D3261 - Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.
   16. D3350 - Standard Specification for Polyethylene Plastic Pipes and Fittings Materials.

17. D4101 - Standard Specification for Polypropylene Injection and Extrusion Materials.
18. F438 - Standard Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40.
19. F439 - Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80.
20. F441 - Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80.
21. F477 - Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe.
22. F493 - Standard Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings.
23. F645 - Standard Guide for Selection, Design and Installation of Thermoplastic Water-Pressure Piping Systems.
24. F679 - Standard Specification for Poly(Vinyl Chloride) (PVC) Large-Diameter Plastic Gravity Sewer Pipe and Fittings.
25. F714 - Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.

C. American Water Works Association (AWWA):
   1. C900 - Standard for Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 Inches to 12 Inches, for Water Transmission Distribution.

D. NSF International (NSF).

E. Plastics Pipe Institute (PPI):
   1. TR 31 - Underground Installation of Polyolefin Piping.

1.03 ABBREVIATIONS

A. ABS: Acrylonitrile-butadiene-styrene.

B. CPVC: Chlorinated polyvinyl chloride.

C. DR: Dimension ratio.

D. DWV: Drain, waste, and vent.

E. HDPE: High-density polyethylene.

F. ID: Inside diameter of piping or tubing.

G. NPS: Nominal pipe size followed by the size designation.

H. NS: Nominal size of piping or tubing.

I. PE: Polyethylene.

J. PP: Polypropylene.

K. PVC: Polyvinyl chloride.

L. SDR: Standard dimension ratio; the outside diameter divided by the pipe wall thickness.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15052 - Common Work Results for General Piping.

C. Shop Drawings:
   1. Describe materials, pipe, fittings, gaskets, and solvent cement.
   2. Installation instructions.

1.05 QUALITY ASSURANCE

A. Plastic pipe in potable water applications: Provide pipe and tubing bearing NSF seal.

B. Fusion machine technician qualifications: 1-year experience in the installation of similar PE piping systems from the same manufacturer.

C. Mark plastic pipe with nominal size, type, class, schedule, or pressure rating, manufacturer and all markings required in accordance with ASTM and AWWA standards.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Protect piping materials from sunlight, scoring, and distortion.

B. Do not allow surface temperatures on pipe and fittings to exceed 120 degrees Fahrenheit.

C. Store and handle PE pipe and fittings as recommended by manufacturer in published instructions.

PART 2 PRODUCTS

2.01 MATERIALS

A. Extruding and molding material: Virgin material containing no scrap, regrind, or rework material except where permitted in the referenced standards.

B. Fittings: Same material as the pipe and of equal or greater pressure rating, except that fittings used in drain, waste, and vent piping systems need not be pressure rated.

C. Unions 2-1/2 inches and smaller: Socket end screwed unions. Make unions 3 inches and larger of socket flanges with 1/8-inch full-face soft EPDM gasket.

2.02 PVC PIPING, SCHEDULE TYPE

A. The requirements for PVC piping used in plumbing systems are found in Section 15400 - Plumbing Systems.

B. Materials:
   1. PVC Pipe: Designation PVC 1120 in accordance with ASTM D1785 and appendices:
      a. Pipe and fittings: Extruded from Type I, Grade 1, Class 12454 material in accordance with ASTM D1784.
      b. PVC Pipe: Schedule 80 unless otherwise indicated on the Drawings or specified in the Piping Schedule in Section 15052 - Common Work Results for General Piping.
   2. Fittings:
      a. Supplied by pipe manufacturer.
      b. Pressure fittings: In accordance with ASTM D2466 or ASTM D2467.
      c. DWV fittings: In accordance with ASTM D2665.
   3. Solvent cement:
      a. In accordance with ASTM D2564.
      b. Manufacturers: The following or equal:
         1) IPS Corp.
            a) Primer: Type P70 or another primer certified by the manufacturer for chemical service.
            b) Cement: Type 724 or another cement certified by the manufacturer for chemical service.
      c. Certified by the manufacturer for the service of the pipe.
      d. In potable water applications: Provide solvent cement listed by NSF for potable water applications.

2.03 SOURCE QUALITY CONTROL

A. The requirements for PVC piping used in plumbing systems are found in Section 15400 - Plumbing Systems.

B. PVC piping, Schedule Type:
   1. Mark pipe and fittings in accordance with ASTM D1785.

PART 3 EXECUTION

3.01 INSTALLATION

A. General:
   1. Where not otherwise specified, install piping in accordance with ASTM F645, or manufacturer's published instructions for installation of piping, as applicable to the particular type of piping.
   2. Provide molded transition fittings for transitions from plastic to metal or IPS pipe. Do not thread plastic pipe.
   3. Locate unions where indicated on the Drawings, and elsewhere where required for adequate access and assembly of the piping system.
   4. Provide serrated nipples for transition from plastic pipe to rubber hose.

B. Installation of PVC piping, Schedule Type:
   1. The requirements for PVC piping used in plumbing systems are found in Section 15400 - Plumbing Systems.
   2. Solvent weld joints in accordance with ASTM D2855:
      a. For PVC pipe in chemical service use IPS Corp., Type 724 cement in accordance with manufacturer's instructions.
   3. Install piping in accordance with manufacturer's published instructions.

3.02 FIELD QUALITY CONTROL

A. Test pipe as specified in Section 15052 - Common Work Results for General Piping and Section 15956 - Piping Systems Testing.

END OF SECTION

SECTION 15270

STEEL PIPE: ASTM A53

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Steel pipe: Galvanized and black, ASTM A53.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.3 - Malleable-Iron Threaded Fittings: Classes 150 and 300.
   2. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard.
   3. B16.9 - Factory-Made Wrought Buttwelding Fittings.
   4. B16.11 - Forged Fittings, Socket-Welding and Threaded.

B. American Water Works Association (AWWA):
   1. C110 - Ductile-Iron and Gray-Iron Fittings.
   2. C203 - Coal-Tar Protective Coatings and Linings for Steel Water Pipelines-Enamel and Tape-Hot Applied.
   3. C205 - Standard for Cement-Mortar Protective Lining and Coating for Steel Water Pipe-4 Inches and Larger-Shop Applied.
   4. C206 - Field Welding of Steel Water Pipe.
   5. C210 - Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings.
   6. C214 - Tape Coatings for Steel Water Pipe.
   7. C216 - Heat-Shrinkable Cross-Linked Polyolefin Coatings for Steel Water Pipe and Fittings.
   8. C217 - Microcrystalline Wax and Petrolatum Tape Coating Systems for Steel Water Pipe and Fittings.
   9. C222 - Polyurethane Coatings and Linings for Steel Water Pipe and Fittings.
   10. C606 - Standard for Grooved and Shouldered Joints.

C. ASTM International (ASTM):
   1. A47 - Standard Specification for Ferritic Malleable Iron Casting.
   2. A53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   3. A105 - Standard Specification for Carbon Steel Forgings for Piping Applications.
   4. A153 - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   5. A183 - Standard Specification for Carbon Steel Track Bolts and Nuts.
   6. A536 - Standard Specification for Ductile Iron Castings.
   7. C150 - Standard Specification for Portland Cement.
   8. D2000 - Standard Classification System for Rubber Products in Automotive Applications.

9. D4541 - Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.
10. E165 - Standard Practice for Liquid Penetrant Testing for General Industry.

D. NSF International (NSF):
1. 61 - Drinking Water System Components - Health Effects.

E. Society for Protective Coatings (SSPC):
1. SP 1 - Solvent Cleaning.
2. SP 3 - Power Tool Cleaning.
3. SP 5 - White Metal Blast Cleaning.
4. SP 6 - Commercial Blast Cleaning.
5. SP 10 - Near White Wet Blast.
6. SP 11 - Bare Metal Power Tool Cleaning.
7. QP 1 - Industrial Contractor Qualification.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals.

B. Product data: As specified in Section 15052 - Common Work Results for General Piping.

C. Manufacturer's qualifications.
1. Manufacturer qualifications and list of projects using the specified material: 5 years minimum.

D. Manufacturer's Quality Assurance Manual.
1. Submit manufacturer's coating and lining application quality assurance manual to the Engineer prior to beginning coating application.
   a. Strict conformance to the requirements of the manual will be required.
   b. Deviation from the requirements of the manual will be grounds for the Engineer to reject the applied coating.

PART 2 PRODUCTS

2.01 MANUFACTURED UNITS

A. Steel pipe:
1. General:
   a. In accordance with ASTM A53.
      1) Type E - electric-resistance welded or Type S - seamless.
      2) Grade A or B.
   b. Schedule:
      1) As indicated on the Drawings or as specified in Section 15052 - Common Work Results for General Piping pipe schedule.
      2) Minimum Schedule unless otherwise indicated on the Drawings or as specified in Section 15052 - Common Work Results for General Piping pipe schedule:
         a) Pipe 6 inches and smaller: Schedule 40.

b) Pipe greater than 6 inch to 12 inch: Schedule 20.
c) Pipe greater than 12 inch: 0.25 inches.

B. Pipe fittings:
1. Flanged and welding fittings:
a. Butt-weld fittings in accordance with ASME B16.9.
b. Schedule of fittings: Same class or thickness as the pipe to which it connects.
2. Screwed fittings:
a. Malleable iron:
1) Class 150 or Class 300 in accordance with ASME B16.3, as specified in Section 15052 - Common Work Results for General Piping pipe schedule.
2) Galvanized in accordance with ASTM A153 where used with galvanized pipe.
3. Grooved joint fittings:
a. Fittings for grooved joint steel piping: Rigid-grooved type.
b. Fittings for grooved joint piping:
1) Manufacturers: One of the following or equal:
a) Victaulic Co. of America.
b) Anvil.
c) Grinnell.
2) Ductile iron fittings:
a) Larger than 4 inches in diameter: In accordance with ASTM A536, Grade 65-45-12, long radius, in accordance with AWWA C110.
b) Less than 4 inches in diameter: Malleable iron in accordance with ASTM A47, Grade 32510.
3) Where cast fittings are not made, forged steel in accordance with ASME B16.9, ASTM A105, Grade B with 0.375-inch minimum wall thickness.
a) Bends: Long radius.
4) Furnished by the manufacturer of the grooved joint coupling.
5) For rigid-grooved type joints.
6) Connection to flanged units shall be by means of a spool with one end flanged and the other grooved, long enough to prevent interference with adjacent valves, pumps, or other items, minimum length, 4 inches.

C. Pipe joints:
1. General:
a. Use type of pipe joints as indicated on the Drawings or as specified in Section 15052 - Common Work Results for General Piping pipe schedule.
b. In addition to the type of pipe joints indicated on the Drawings or as specified in Section 15052 - Common Work Results for General Piping pipe schedule, use flexible couplings, unions or flanged joints to allow ready assembly and disassembly of the piping.
2. Flanged joints:
a. In accordance with ASME B16.5, steel, 150 pounds, slip-on or weld neck, galvanized in accordance with ASTM A153 where used with galvanized pipe.

b. Companion flanges:
    1) In accordance with ASME B16.5, steel.
    2) Class 150 pounds, slip-on or welding neck.
c. Weld flanges to pipe or fittings before applying lining.
d. Machine flanges or provide tapered filler for changes in grade or to slope lines for drainage.
e. Match pipe flanges to the valve flanges.
f. Flange bolts: As specified in Section 15052 - Common Work Results for General Piping.
g. Gaskets: As specified in Section 15052 - Common Work Results for General Piping.

3. Grooved joints:
    a. Grooves: Cut grooves. Rolled grooves are not acceptable.
    b. Couplings housing: Cast in 2 or more segments of ductile iron in accordance with ASTM A536, Grade 65-45-12 or malleable iron in accordance with ASTM A47, Grade 32510.
    c. Bolts and nuts: In accordance with ASTM A183, Grade 2.
    d. Gaskets: Composition water sealing designed so that the internal piping pressure serves to increase the seal's watertightness.
        1) Gaskets for water service and oil-free air systems at temperatures less than 230 degrees Fahrenheit shall be made of ethylene propylene diene monomers (EPDM) in accordance with ASTM D2000 Line Call Out 2CA615A25B24.
    e. Perform grooving of the pipe wall only on standard or heavier schedule weight pipe.
        1) For pipe with wall thickness less than standard weight, weld a shouldered end on the pipe in accordance with AWWA C606.
        2) Shoulder: Type B or D in accordance with AWWA C606.
    f. Couplings and grooving:
        1) Manufacturers: One of the following or equal:
            a) Victaulic Co.
            b) Anvil.
            c) Grinnell.
    g. Grooved joint piping shall not be used in the following installations:
        1) In underground and underwater installations.
        2) In piping subject to test pressures of 150 pounds per square inch gauge, or more.
        3) In steam and gas piping.
        4) In sludge and scum piping designed to be steam cleaned.
4. Welded joints: Butt welds, 2 pass, full depth with beveled ends and no backing rings.

2.02 COATING AND LINING - GENERAL

A. Coating and lining shall be as indicated on the Drawings or as specified in Section 15052 - Common Work Results for General Piping.

B. Extend pipe coatings for underground piping 6 inches above finished grade or 3 inches above finished floor, and neatly terminate.

C. As specified in Section 01600 - Product Requirements.

D. Prepare, install, and repair in accordance with manufacturer's requirements.

E. Contractor is responsible for:
   1. Material selection suitable for the application conditions anticipated, such as temperature, humidity, etc.
   2. Managing the project schedule to allow adequate cure time before backfill or immersion based on surface temperatures at the time of application.

2.03 FABRICATION

A. Shop coat of primer:
   1. Flanges and portions of pipe not covered with cement-mortar shall be given a shop coating of primer.
   2. Primer compatible with finish coating system.

PART 3 EXECUTION

3.01 INSTALLATION

A. Joints:
   1. General:
      a. Steel pipe joints shall be screwed, welded, flanged, grooved, or made with flexible joints. Type of joint for piping is as specified in Section 15052 - Common Work Results for General Piping pipe schedule or as indicated on the Drawings.
      b. In addition to the joints indicated on the Drawings, provide unions, flexible couplings, flanged joints, and other types of joints or means necessary to allow ready assembly and disassembly of the piping.
      c. Unless otherwise indicated on the Drawings or as specified in Section 15052 - Common Work Results for General Piping pipe schedule, pipe joints shall be as follows:
         1) Pipe smaller than 2 inches in nominal diameter shall have screwed joints, welded joints, unions, or flexible couplings.
         2) Pipe 2 inches to 4 inches in nominal diameter shall have screwed joints, flanged joints, welded joints, or joints made with flexible couplings.
         3) Pipe larger than 4 inches in nominal diameter shall have flanged joints, welded joints, or joints made with flexible couplings.
   2. Flanged joints:
      a. Flanges shall come together at the proper orientation with no air gaps between the flanges after the gaskets are in place.
      b. Secure welding neck flanges with full penetration butt welds without backing rings.
      c. Secure slip-on flanges with both internal and external welds.
      d. After welding in place, the faces of flanges shall be perpendicular to the axis of the pipe, or, in the case of fittings, at the proper angle to each other, and bolt holes shall be in proper alignment.
   3. Grooved joints:
      a. Assemble in accordance with manufacturer's published instructions.

b. Support grooved joint pipe in accordance with manufacturer's recommendations. In addition, provide at least 1 support between consecutive couplings.

4. Screwed joints:
   a. Perform threading with clean, sharp dies.
      1) Wavy, rough, or otherwise defective pipe threads are not acceptable.
   b. Make screwed joints tight and clean with an application of Teflon™ tape or paste compound applied to the male threads only, except as follows:
      1) Make up liquid and liquefied petroleum gas lines, with litharge and glycerin.
   c. Provide railroad type unions with bronze-to-iron seat. Galvanized where used with galvanized pipe.
      1) Flanged joints may be used instead of unions.
5. Welded joints:
   a. Field welded joints: Electric arc welded in accordance with AWWA C206.
   b. Welder's qualification: Qualified in accordance with AWWA C206.
      1) Welders' testing shall be at the Contractor's expense, including cost of test nipples, welding rods, and equipment.
   c. Do not weld galvanized pipe.

3.02 DEFECTS IN COATINGS

A. Engineer will identify defective coating to be field repaired in accordance with the applicable AWWA standard.
   1. Pipe joints exceeding the following defect maximum will be rejected.
      a. Minor defects:
         1) No more than 1.5 per 100 square feet of surface area.
         2) 2 or more minor repairs within an 8-inches diameter circle will be considered a single repair.
         3) Repairs for adhesion testing will not be included in the total number of repairs.
         4) Repair in accordance with manufacturer's requirements.
      b. Major defects:
         1) No more than 3 major repairs on each pipe joint.
         2) No more than 30 percent repairs on the pipe surface area with defects.
   2. Minor repairs:
      a. Repairs less than 8 inches in the greatest dimension.
      b. Repair in accordance with manufacturer's requirements.
   3. Major repairs:
      a. Repairs that exceed 8 inches in the greatest dimension.
      b. Repair in accordance with manufacturer's requirements.

3.03 FIELD COAT

A. Aboveground steel pipe as specified in Section 09960 - High-Performance Coatings.

3.04 FIELD QUALITY CONTROL

A. Field test fabricated steel manifolds with the pipe to which they connect.

B. Weld testing:
    1. Liquid penetrant testing:
        a. As soon as possible after welding of pipeline joints, fillet welds shall be tested by the liquid penetrant inspection procedure in accordance with ASTM E165 under Method “B” and “Leak Testing”.
        b. Chip out defects, rebell, and retest.
            1) Upon retest, the repaired area shall show no leaks or other defects.

END OF SECTION

SECTION 15286

STAINLESS STEEL PIPE AND TUBING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Stainless steel piping and tubing.

1.02 REFERENCES

A. American National Standards Institute (ANSI).

B. American Society of Mechanical Engineers (ASME):
   1. B16.5 - Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24, Metric/Inch Standard.
   2. B16.11 - Forged Fittings, Socket-Welding and Threaded.
   3. B31.3 - Process Piping.
   4. B36.19 - Stainless Steel Pipe.

C. American Welding Society (AWS):
   1. D1.6 - Structural Welding Code - Stainless Steel.

D. ASTM International (ASTM):
   1. A123 - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
   2. A182 - Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service.
   3. A193 - Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications.
   4. A194 - Standard Specification for Carbon and Alloy Steel Nuts and Bolts for High Pressure or High Temperature Service, or Both.
   5. A240 - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications.
   6. A269 - Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.
   7. A276 - Standard Specification for Stainless Steel Bars and Shapes.
   8. A312 - Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes.
   9. A351 - Standard Specification for Castings, Austenitic, for Pressure-Containing Parts.
   10. A380 - Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems.
   11. A403 - Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings.

12. A743 - Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application.
13. A744 - Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service.
14. A774 - Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Services at Low and Moderate Temperatures.
15. A778 - Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products.
16. A789 - Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service.
17. A790 - Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe.
18. A928 - Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal.
19. A967 - Standard Specification for Chemical Passivation Treatments for Stainless Steel Parts.
20. B622 - Standard Specification for Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube.
21. B912 - Standard Specification for Passivation of Stainless Steels Using Electropolishing.
22. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
23. F594 - Standard Specification for Stainless Steel Nuts.

1.03 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

B. Product data.

C. Shop Drawings:
   1. Detailed layout drawings, including:
      a. Dimensions and alignment of pipes.
      b. Location of valves, fittings, and appurtenances.
      c. Location of field joints.
      d. Location of pipe hangars and supports.
      e. Connections to equipment and structures.
      f. Location and details of shop welds.
   2. Thickness and dimensions of fittings and gaskets.
   3. Photographs, drawings, and descriptions of pipe, fittings, welding procedures, and pickling and passivating procedures.
   4. Material specifications for pipe, gaskets, fittings, and couplings.
   5. Data on joint types and components used in the system, including flanged joints, grooved joint couplings and screwed joints.

D. Weld qualifications and procedures:
   1. Welder performance qualification records.
   2. Weld qualification records.
   3. Weld procedure specifications.

1.04 WELDER QUALIFICATIONS

A. Welders shall be qualified and tested to the material being welded.

B. Welders shall hold the following certifications:
   1. ASME Section IX.
   2. AWS D10.9 for level AR-1 or AR-3 and shall be qualified to position 6G.

1.05 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements and the manufacturer's instructions.

B. Storage: Segregate location of stainless steel piping from fabrication of any other piping materials.

C. Shipment to Site:
   1. Protect flanges and pipe ends by encapsulating in dense foam.
   2. Securely strap all elements to pallets with nylon straps. Use of metallic straps is prohibited.
   3. Cap ends of tube, piping, pipe spools, fittings, and valves with non-metallic plugs.
   4. Load pallets so no tube, piping, pipe spools, fittings, or valves bear the weight of pallets above.
   5. Notify the Engineer when deliveries arrive so they may inspect the shipping conditions.
   6. Engineer may reject material due to improper shipping methods or damage during shipment.

PART 2 PRODUCTS

2.01 DESIGN AND PERFORMANCE CRITERIA

A. Lay out and fabricate piping systems with sections as long as possible, while still allowing shipment, so that joints are minimized.
   1. Piping design indicated on the Drawings illustrates the piping layout and configuration and does not indicate the location of every joint and flexible coupling that may be needed to connect piping sections fabricated in the shop.
   2. Where joints and couplings are specifically indicated on the Drawings, design and shop-fabricate piping sections utilizing the joint or coupling indicated at the locations shown.
   3. Add joints and flexible couplings in a manner that achieves intent of maximizing size of individual piping sections.

B. Fabricate piping sections in the shop and pickle and passivate at point of manufacture.

C. Field assembly:
   1. Assemble shop-fabricated piping in the field using the joints designed into the piping layout or by using flexible couplings.

2. Field welding is prohibited.

2.02 STAINLESS STEEL PIPE

A. General:
   1. Pipe sizes specified in the Specifications and indicated on the Drawings are nominal.

B. Wall thickness:
   1. As specified in Section 15052 - Common Work Results for General Piping.
      a. With press fit joints:
         1) 3 inches in nominal diameter and less:
            a) Minimum wall thickness corresponding to Schedule 10S.

C. Piping material and manufacturing:
   1. Comply with the requirements outlined in the following table:

Service	Stainless Steel Grade	Pipe Manufacturing Process
All Service Applications (unless otherwise indicated in Section 15052 - Common Work Results for General Piping)		
Piping 3 inches in nominal diameter and larger	Type 316L or LDX 2101 stainless steel in accordance with ASTM A240	Type 316L in accordance with ASTM A778
		Type LDX 2101 in accordance with ASTM A790
Piping less than 3 inches in nominal diameter	Type 316L or LDX 2101 stainless steel in accordance with ASTM A240	Type 316L in accordance with ASTM A312
		Type LDX 2101 in accordance with ASTM A790
PREN: Pitting Resistance Equivalency Number. PREN = Cr% + (3.3 x Mo%) + (16 x N%)		

   2. Location of material fabrication.
   3. Chemical analysis certificates.

D. Fittings for piping 3 inches in nominal diameter and greater:
   1. Material: In accordance with ASTM A240 stainless steel, grade to match the pipe.
   2. Manufacturing standard:
      a. For piping sizes up to 36 inches: In accordance with ASTM A774.
   3. Wall thickness of fitting: In accordance with:
      a. For Schedule 5, 10, 40, and 80 piping up to 24-inch nominal diameter: ASME B36.19.
   4. End configuration: As needed to comply with specified type of joint.
   5. Dimensional standards:
      a. Fittings with weld ends: In accordance with ASME B16.11.
      b. Fittings with flanged ends: In accordance with ASME B16.5, Class 150.

E. Fittings for piping less than 3 inches in diameter:
   1. Material: In accordance with ASTM A240 stainless steel, grade to match the pipe.
   2. Manufacturing standard: In accordance with ASTM A403, Class WP.
   3. Wall thickness and dimensions of fitting: In accordance with ASME B16.11 and as required for the schedule of pipe specified.
   4. End configuration: As needed to comply with specified type of joint.
   5. Forgings in accordance with ASTM A182, or barstock in accordance with ASTM A276. Match forging or barstock material to the piping materials.

F. Piping joints:
   1. Joint types, piping greater than 2 inches in diameter:
      a. Where type of joint is specifically indicated on the Drawings or specified, design and shop-fabricate piping sections utilizing type of joint illustrated or scheduled.
      b. Joints at valves and pipe appurtenances:
         1) Provide flanged valves and flanged pipe appurtenances in stainless steel piping systems with flanged ends.
         2) Design and fabricate piping sections to make connections with flanged valves and pipe appurtenances using flanged coupling adapters or flanged joints.
            Flexible couplings and flanged coupling adapters: Provide stainless steel construction with materials matching the piping system and in accordance with requirements as specified in Section 15121 - Pipe Couplings.
   2. Joints in piping 2 inches in diameter and smaller: Flanged, grooved, press fit, or screwed with Teflon™ tape thread lubricant, as specified in Section 15052 - Common Work Results for General Piping.
   3. Welded joints:
      a. Weld method: Automatically weld joints using gas tungsten-arc procedures.
      b. Piping larger than 30 inches in diameter: Double butt-welded joints.
      c. Piping 30 inches in diameter and smaller: Single butt-welded joints.
      d. Mark each weld with a symbol that identifies the welder.
      e. Weld requirements:
         1) Full penetration welds, free of oxidation, crevices, overlaps, cold laps, pits and cracks, and without undercuts.
         2) Provide weld crowns of 1/16 inch with tolerance of plus 1/16 inch and minus 1/32 inch.
         3) Misalignment of the weld should be limited to 1/16 inch or half the wall thickness, whichever is less.
         4) Weld reinforcement and root convexity should be limited to 1/16 inch.
         5) Undercut and overcut should be limited to 1/32 inch or 10 percent of the base metal thickness, whichever is less.
   4. Flanged joints:
      a. For piping sizes up to 36 inches: Conforming to the requirements in accordance with ASME B16.5, Class 150, 300, or 600, as scheduled.

5. Flanges:
    a. Schedule 40S and Schedule 80S pipe:
        1) Provide forged stainless steel (type matching piping system) welding neck flanges or slip-on flanges in accordance with ASME B16.5 Class 150 , 300 or 600, as scheduled.
            a) Material: In accordance with ASTM A182.
6. Press fit joints:
    a. Pressures less than 500 pounds per square inch:
        1) Fittings:
            a) Manufacturers:
                (1) Victaulic Vic-Press™.
                (2) Viega MegaPress.
            b) ASTM A312, Type 316 stainless steel.
            c) Housings with ASTM A276 and/or ASTM A312 outlets and stainless steel plain or grooved ends.
            d) Flange adaptors:
                (1) ANSI Class 150, Van Stone type with stainless steel backup flange and press fit ends.
                (2) Rated for service up to 275 pounds per square inch gauge.
                    (a) Model: Victaulic, Style P566, or equal.
            e) Threaded unions with press fit ends.
                (1) Model: Victaulic, Style P585, or equal.
        2) Gaskets:
            a) Grade E EPDM rated for services up to 250 degrees Fahrenheit.
        3) Valves:
            a) Type 316 stainless steel ball valves with PTFE seats and press fit and/or grooved ends.
            b) Rated for services to 400 pounds per square inch (2,750 kilopascals).
            c) Swing-out design to facilitate in-line maintenance: 3-piece.
            d) Model: Victaulic, Series P569, or equal.

G. Gaskets:
    1. EPDM, nitrile, or other materials compatible with the process fluid.

H. Bolts for flanges :
    1. Bolts and nuts: Type 316 stainless steel in accordance with ASTM A193 heavy hex head.
        a. Bolt length such that after installation, end of bolt projects a minimum distance of 2 threads beyond outer face of nut.
        b. Nuts: In accordance with ASTM A194 heavy hex pattern.

I. Fabrication of pipe sections:
    1. Weld seams:
        a. Weld method in accordance with ASME B31.3 as specified below:
            1) Where internal weld seams are not accessible, use gas tungsten-arc procedures with internal gas purge.
            2) Where internal weld seams are accessible, weld seams inside and outside using manual gas metal-arc (e.g., metal inert gas) procedures.

b. Weld requirement:
    1) Full penetration welds, free of oxidation, crevices, overlaps, cold laps, pits and cracks, and without undercuts.
    2) Provide weld crowns of 1/16 inch with tolerance of plus 1/16 inch and minus 1/32 inch.
    3) Misalignment of the weld should be limited to 1/16 inch or half the wall thickness, whichever is less.
    4) Weld reinforcement and root convexity should be limited to 1/16 inch.
    5) Undercut and overcut should be limited to 1/32 inch or 10 percent of the base metal thickness, whichever is less.

J. Cleaning (pickling) and passivation:
1. Following shop fabrication of pipe sections, straight spools, fittings, and other piping components, clean (pickle) and passivate fabricated pieces.
2. Clean (pickle) and passivate in accordance with ASTM A380 or ASTM A967.
    a. If degreasing is required before cleaning to remove scale or iron oxide, cleaning (pickling) treatments with citric acid are permissible.
        1) However, these treatments must be followed by inorganic cleaners such as nitric acid/hydrofluoric acid.
    b. When citric acid is used for chemical passivation, only a heated citric acid process will be accepted.
3. Finish requirements: Remove free iron, heat tint oxides, weld scale, and other impurities, and obtain a passive finished surface.

2.03 STAINLESS STEEL TUBING

A. Stainless steel tubing:
1. Seamless, Type 316L stainless steel, in accordance with ASTM A269.
    a. Size: 2.5 inches and less.
    b. Wall thickness: Not less than 0.035 inch.

B. Fittings: Swage ferrule design:
1. Components made of:
    a. Type 316 stainless steel.
2. Double acting ferrule design, providing both a primary seal and a secondary bearing force.
3. Flare type fittings are not acceptable.
4. Manufacturers: One of the following or equal:
    a. Crawford Fitting Co., Swagelok.
    b. Hoke, Gyrolok.
    c. Parker, CPI.

C. Valves for use with stainless steel tubing:
1. Ball type valves with swage ends to match tubing diameter.
2. Constructed from:
    a. Type 316 stainless steel with TFE seats.
3. Manufacturers: The following or equal:
    a. Crawford Fitting Co., Swagelok.

2.04 SOURCE QUALITY CONTROL

A. Visually inspect pipe for welding defects such as crevices, pits, cracks, protrusions, and oxidation deposits.

B. Provide written certification that the pipe as supplied are in accordance with ASTM A778 and/or ASTM A312. Supplemental testing is not required.

C. Provide written certification that the fittings as supplied are in accordance with ASTM A774. Supplementary testing is not required.

D. Thoroughly clean any equipment before use in cleaning or fabrication of stainless steel.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install piping in such a manner as not to impart strain to connected equipment.

B. Install press fit joint systems in accordance with the manufacturer's latest recommendations.
   1. Pipe shall be square cut, plus or minus 0.030 inches, properly deburred and cleaned.
   2. Pipe ends shall be marked at the required location, using a manufacturer-supplied gauge, to ensure full insertion into the coupling or fitting during assembly.
   3. Use a manufacturer-supplied tool with the proper sized jaw for pressing joints.
      a. Tool shall be fitted with the proper size jaw for pressing.

C. Slope horizontal lines so that they can be drained completely.

D. Provide valve drains at low points in piping systems.

E. Install eccentric reducers where necessary to facilitate draining of piping system.

F. Provide access for inspection and flushing of piping systems to remove sediment, deposits, and debris.

3.02 FIELD ASSEMBLY OF SHOP-FABRICATED PIPING SECTIONS

A. Join shop-fabricated piping sections together using backing flanges, flexible couplings, flanged coupling adapters, grooved couplings, or flanges.

3.03 FIELD QUALITY CONTROL

A. Test piping to pressure and by method as specified in Section 15052 - Common Work Results for General Piping.
   1. If pressure testing is accomplished with water:
      a. Use only potable quality water.
      b. Piping: Thoroughly drained and dried or place immediately into service.

B. Visually inspect pipe for welding defects such as crevices, pits, cracks, protrusions, and oxidation deposits.

3.04 PROTECTION

A. Preserve appearance and finish of stainless steel piping by providing suitable protection during handling and installation and until final acceptance of the Work.
   1. Use handling methods and equipment to prevent damage to the coating, include the use of wide canvas slings and wide padded skids.
   2. Do not use bare cables, chains, hooks, metal bars, or narrow skids.
   3. Store stainless steel piping and fittings away from any other piping or metals. Storage in contact with ground or outside without projection from bad weather is prohibited.
   4. Protect stainless steel piping and fittings from carbon steel projections (when grinding carbon steel assemblies in proximity) and carbon steel contamination (do not contact stainless steel with carbon steel wire brush or other carbon steel tool).

END OF SECTION

SECTION 15400

PLUMBING SYSTEMS

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Requirements for materials and installation of plumbing systems.

1.02 REFERENCES

A. Abbreviations:
   1. gpf - gallons per flush.
   2. gph - gallons per hour.
   3. gpm - gallons per minute.
   4. psig - pounds per square inch, gauge.

B. Standards:
   1. American Concrete Institute (ACI).
   2. American Gas Association (AGA).
   3. American Society of Mechanical Engineers (ASME).
      a. B16.3 - Malleable Iron Threaded Fittings: Classes 150 and 300.
      b. B16.12 - Cast Iron Threaded Drainage Fittings.
      c. B16.18 - Cast Copper Alloy Solder Joint Pressure Fittings.
      d. B16.22 - Wrought Copper and Copper Alloy Solder Joint Pressure Fittings.
   4. American Society of Sanitary Engineering (ASSE):
      a. 1070 - Performance Requirements for Water Temperature Limiting Devices.
   5. American Water Works Association (AWWA):
      a. C511 - Reduced-Pressure Principle Backflow Prevention.
      b. C700 - Standard for Cold-Water Meters—Displacement Type, Bronze Main Case.
      c. C702 - Standard for Cold-Water Meters—Compound Type.
   6. Americans with Disabilities Act (ADA).
   7. ASTM International (ASTM):
      a. A48 - Standard Specification for Gray Iron Castings.
      b. A53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
      c. A74 - Standard Specification for Cast Iron Soil Pipe and Fittings.
      d. A153 - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
      e. A536 - Standard Specification for Ductile Iron Castings.
      f. A615 - Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.
      g. A888 - Standard Specification for Hubless Cast Iron Soil Pipe and Fittings for Sanitary and Storm Drain, Waste, and Vent Piping Applications.

h. B32 - Standard Specification for Solder Metal.
i. B88 - Standard Specification for Seamless Copper Water Tube.
j. B813 - Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube.
k. B828 - Standard Specification for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings.
l. C177 - Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus.
m. C518 - Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.
n. C547 - Standard Specification for Mineral Fiber Pipe Insulation.
o. C552 - Standard Specification for Cellular Glass Thermal Insulation.
p. C564 - Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings.
q. C1136 - Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation.
r. D256 - Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics.
s. D297 - Standard Test Methods for Rubber Products—Chemical Analysis.
t. D395 - Standard Test Methods for Rubber Property—Compression Set.
u. D412 - Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension.
v. D638 - Standard Test Method for Tensile Properties of Plastics.
w. D790 - Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
x. D792 - Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
y. D1784 - Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
z. D1785 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
aa. D2240 - Standard Test Method for Rubber Property—Durometer Hardness.
bb. D2466 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
cc. D2467 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
dd. D2564 - Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems.
ee. D2665 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.
ff. E84 - Standard Test Method for Surface Burning Characteristics of Building Materials.
gg. E96 - Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials.
hh. F438 - Standard Specification for Socket-Type Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 40.
ii. F439 - Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80.
jj. F441 - Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80.

kk. F493 - Standard Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings.
ll. F593 - Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs.
mm. F594 - Standard Specification for Stainless Steel Nuts.
nn. F645 - Standard Guide for Selection, Design, and Installation of Thermoplastic Water- Pressure Piping Systems.

8. California Code of Regulations (CCR):
   a. Title 24 - Building Standard Code.
9. International Association of Plumbing and Mechanical Officials (IAPMO):
   a. IS 03 - Copper plumbing Tube Pipe and Fittings.
10. National Electrical Manufacturers Association (NEMA):
   a. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).
11. Plumbing and Drainage Institute (PDI):
   a. WH-201 - Water Hammer Arresters Standard.
12. Underwriters Laboratories, Inc. (UL):
   a. 94 - Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances.
13. United States Environment Protection Agency (EPA): Water Sense.

1.03 TERMINOLOGY

A. The words and terms listed below are not defined terms that require initial capital letters, but, when used in this Section, have the indicated meaning.
   1. Buried: Piping that is installed below buildings, foundations, or finish grade, either in soil or encased in concrete in soil.
   2. Exterior: Piping that is installed outside a building or within a pipe trench or tunnel.
   3. Flame spread and smoke density: Burning characteristics determined in accordance with ASTM E84.
   4. Interior: Piping that is installed inside a building.
   5. K factor: Thermal conductivity determined in accordance with ASTM C177 or ASTM C518.
   6. Mineral fiber: Fibers manufactured of glass, rock, or slag processed from a molten state, with or without a binder.
   7. Water vapor permeance: Water vapor transmission determined in accordance with ASTM E96 and expressed in units of perm-inch.

1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Manufacturer’s instructions.

C. Shop Drawings:
   1. System layout, mechanical, electrical power, and control diagrams.
   2. Nameplate information.
   3. Materials.
   4. Coatings and linings.
   5. Rough-in drawings.
   6. Supports, vibration isolators, and details.

7. Primary and ancillary equipment.
8. Proposed cutting and patching.
9. Maximum recommended equipment vibration levels and field-testing method.
10. Copy of factory test results.

D. Certificates: As specified in Section 01600 - Product Requirements:
   1. American Backflow Prevention Association for backflow prevention assembly.
   2. National Science Foundation for products when specified.

E. Field testing documentation.

F. Warranties.

1.05 WARRANTY

A. Provide warranty as specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. Devices and fixtures shall be in accordance with CCR Title 24.

2.02 PLUMBING FIXTURES

A. General:
   1. ADA compliant unless specifically stated otherwise in the fixture requirements.
   2. Exposed fixture fittings and piping:
      a. Polished chrome.
   3. Stops:
      a. Fixtures, except showers, shall have stops at the fixtures' service.
      b. Stops for laboratory equipment, and for other equipment or fixtures for which stops have not been otherwise specified in this Section, shall be chrome-plated straight pattern compression stops or chrome-plated angle pattern compression stops.
   4. Faucets:
      a. Manual levers.
         1) Manual levers: Indexed.
      b. Brass construction, 1/4 turn ceramic disc valve cartridge.
      c. Vacuum breaker.
      d. Integral check valve.
      e. Flow rates specified for an inlet pressure of 60 psig.
   5. P-traps:
      a. Cast-iron, adjustable with metal strainer, gaskets, and cleanout plug.
   6. Escutcheons to be used for at wall, floor, and ceiling penetrations:
      a. Manufacturers: One of the following or equal:
         1) Keeney.
         2) Plumbing Products.
      b. IAPMO listed.
      c. Material: Chrome-plated steel plate.

d. Hinged, spring loaded, and sized appropriately for the piping.

7. Manufacturer to supply necessary mounting hardware and installation fittings suitable to complete the installation, including, but not limited to:
   a. Faucets.
   b. Brass braided hoses.
   c. Carriers.
   d. P-traps.
8. Drawings indicate fixtures using designated style identifiers.

B. Service sinks:
1. General:
   a. ADA compliance not required.
   b. Sink manufacturer to supply faucet, mounting hardware, and installation fittings.
   c. Faucet:
      1) Exposed yoke, wall- mounted, top braced.
      2) Rigid spout with 3/4-inch threaded hose end and bucket hook.
      3) Deliver not more than 15 gpm.
      4) Manual lever.
   d. Center drains with strainer.
   e. Provide 5-foot hose with wall hook and rigid end spout at each service sink.
2. Type SS-3: Free standing:
   a. Manufacturers: One of the following or equal:
      1) American Standard.
      2) E.L. Mustee, 19F Utilatub.
   b. Free standing.
   c. Bowl:
      1) One-piece molded thermoplastic.
      2) 13-inch tub with 18 gallon capacity.
   d. Dual lever, 6-inch swing spout faucet.
      1) With aerator and hose end.
      2) Not more than 15 gpm.

2.03 PLUMBING AND DRAINAGE PRODUCTS

A. Water hammer arrestors:
1. Manufacturers: One of the following or equal:
   a. Jay R. Smith.
   b. Josam.
   c. Zurn, Shoktrol.
2. Determine manufacturer model:
   a. Based on Table 1 in accordance with PDI WH-201.
   b. Working pressure: 125 psig.
   c. Static pressure: 250 psig.
3. Temperature: 300 degrees Fahrenheit.
4. Provide water hammer arrestors on each fixture supply line branch.
5. Casing and bellows.
   a. Material: Type 304 stainless steel.
   b. Welded bellows.
6. Hermetically sealed air cushion.

B. Type HB-1: Hose bib stations:
   1. Manufacturers: One of the following or equal:
      a. Flexon Pro Series.
      b. Gilmore Group.
   2. Hose bib: Size and mounting requirements as indicated on the Drawings.
   3. Hose rack: Type and installation as indicated on the Drawings.
   4. Hose:
      a. Length: 50 feet.
      b. Size: 3/4 inch.
      c. Commercial/industrial grade rubber hose.
   5. Hose nozzle:
      a. Spray: 7-pattern select-a-spray with vinyl grip.
      b. Hold-open clip for continuous spraying.
      c. Material: Rust resistant stainless steel spring.
      d. Lifetime leak proof seal.

C. Drains:
   1. Type, shape, and size as indicated on the Drawings with connections suitable for the piping system.
      a. Provide drains of 1 type from the same manufacturer.
   2. Type FD-3: Floor drain, sedimentation bucket:
      a. Manufacturers: One of the following or equal:
         1) Josam.
         2) Zurn Z610.
      b. Material: Coated cast-iron body and grate.
      c. Sedimentation bucket:
         1) Material: Polypropylene.
         2) Size: 12 inches square.
         3) Suspended.
   3. Type FS-2: Floor sink drain, heavy duty, indirect wastes:
      a. Manufacturers: One of the following or equal:
         1) Josam.
         2) Zurn Z1926.
      b. Heavy-duty, acid resistant floor sink for indirect wastes.
      c. Material: Cast iron body with acid resisting epoxy coated interior and exterior.
      d. Size: 16 inches square by 12 inches deep.

2.04 PLUMBING PIPING SYSTEMS

A. As indicated on the Drawings or specified in Section 15052 - Common Work Results for General Piping.

B. Seamless copper water tube:
   1. Type: ASTM B88:
      a. Exposed copper piping or tubing: Type L hard-drawn, rigid.
      b. Copper tubing buried in the ground or in plastic conduit: Type K soft annealed.
   2. Fittings: Solder type forged or wrought copper.
      a. Manufacturers: One of the following or equal:
         1) Crawford Fitting Co., Swagelok.

2) Hoke, Gyrolok.
3) Parker.

3. Solder: ASTM B32, Alloy Grade Sb5.
4. Flux: ASTM B813.
5. Grooved end fittings: ASME B16.22 wrought copper or ASME B16.18 bronze castings with copper tube dimensioned grooved ends (flaring of tube and fitting ends to IPS dimensions is not permitted).
   a. Manufacturers:
      1) Victaulic Company.
6. Grooved mechanical couplings:
   a. “Installation Ready” stab-on coupling designed for direct ‘stab’ installation onto roll grooved copper tube without prior field disassembly and no loose parts.
   b. Housings shall be ductile iron, cast with offsetting, angle-pattern bolt pads coated with copper-colored enamel.
   c. Gasket shall be Grade “EHP” EPDM suitable for water temperatures up to 250 degrees Fahrenheit, and plated steel bolts and nuts.
   d. Victaulic Style 607 QuickVic™
7. Grooved joint flange adapters:
   a. ASTM A 536 ductile iron casting coated with copper-colored enamel, flat faced, designed for connecting directly to ANSI Class 125 and 150 flanged components.
   b. Victaulic Style 641.
8. Dielectric insulating unions or or waterway fittings:
   a. Manufacturers: One of the following or equal:
      1) Mueller Co.
      2) Watts.
      3) Victaulic Co. Style 47
9. Special thread to tube adapters:
   a. Manufacturers: One of the following or equal:
      1) Crawford Fitting Co., Swagelok.
      2) Hoke, Gyrolok.
      3) Parker.

C. Black steel pipe piping system:
   1. Pipe:
      a. In accordance with ASTM A53.
      b. Type E - electric-resistance welded or Type S - seamless.
      c. Grade A or B.
      d. Schedule 40, unless otherwise specified.
   2. Fittings:
      a. Screwed fittings:
         1) Malleable iron:
            a) In accordance with ASME B16.3, Class 150 or Class 300 as specified.
            b) Galvanized in accordance with ASTM A153 when used with galvanized pipe.

D. PVC piping system:
   1. Pipe: Designation PVC 1120 in accordance with ASTM D1785:
      a. Pipe and fittings: Extruded from Type I, Grade 1, Class 12454 B material in accordance with ASTM D1784.
      b. PVC pipe: Schedule 40, unless otherwise specified.
   2. Fittings:
      a. Supplied by pipe manufacturer.
      b. Pressure fittings: In accordance with ASTM D2466 or ASTM D2467.
      c. DWV fittings: In accordance with ASTM D2665.
   3. Solvent cement: In accordance with ASTM D2564:
      a. Chemical service: For PVC pipe in chemical service, provide the following primer and cement, or equal:
         1) Primer: IPS Corp Type P-70™.
         2) Cement: IPS Corp Type 724™ cement or cement certified by the manufacturer for chemical service.
   4. Unions 4 inches and smaller:
      a. Socket end screwed unions.
   5. Unions 6 inches and larger:
      a. Socket flanges with 1/8-inch full-face soft EPDM gasket.

2.05 WATER HEATERS

A. Manufacturers: One of the following or equal:
   1. A.O. Smith Corp.
   2. State Ind., Inc.

B. General:
   1. Size and requirements as indicated on the Drawings.
   2. Provide with temperature limiting device in accordance with ASSE 1070.
   3. Tanks:
      a. Glass lined.
      b. Exterior steel casing with factory standard enamel finish.
      c. 2 inches minimum fiberglass insulation.
      d. Pressure tested to 150 psig.
      e. ASME rated temperature and pressure relief valve.
      f. Magnesium anode and tank cleanout.
      g. Adjustable to store up to 180 degrees Fahrenheit water.
      h. Water heaters shall meet the requirements in accordance with CCR Title 24.
      i. Provide the manufacturer’s standard bracing in accordance with applicable codes.
   4. Warranty:
      a. Special warranty:
         1) Duration: Provide 3-year warranty.

C. Tankless electric:
   1. High temperature limit switch with automatic reset.
   2. Flow switch.
   3. Maximum operating pressure of 150 psig.
   4. Heating elements:
      a. Material: Nichrome high efficiency.

b. Automatic temperature control.
c. Externally adjustable setting.
d. Replaceable configuration.
e. UL listed.

5. Compression fittings.
6. Water hammer arrestor.
7. Power: As indicated on the Drawings and as scheduled.
8. Type WH-2: Water heater, tanked, multiple fixtures:
   a. Manufacturers: One of the following or equal:
      1) Eemax, ProSeries XTP.
      2) Keltech, CNA series.
   b. Heating module with thermostatic control: 2 modules.
   c. Temperature rise 50 degrees Fahrenheit at 5.0 gpm.
   d. Flow actuated at 0.3 gpm.
      1) Power: As indicated on the Drawings and as scheduled.
9. Enclosure: NEMA 4X.

2.06 BACKFLOW PREVENTERS

A. Manufacturers: One of the following or equal:
   1. Febco backflow prevention:
      a. LF860, all sizes.
   2. Zurn/Wilkins:
      a. 975XL for 1/2 inch through 2 inch.
      b. 375AST for sizes 2-1/2 inch, 3 inch, 8 inch, and 10 inch.
      c. 375 and 375DA for sizes 4 inch and 6 inch.
   3. Watts regulator: Series LF909.

B. Design: Reduced pressure chamber type in accordance with AWWA C511.

C. Shutoff valves:
   1. Two-inch and smaller: Provide with full-port, quarter turn, resilient seated ball valves.
   2. Larger than 2-inch: Provide with resilient seated, outside stem and yoke gate valves.

2.07 PIPE INSULATION

A. General:
   1. Insulation thicknesses: Provide insulation thickness in inches in accordance with Table 1 in accordance with the 2021 International Energy Conservation Code (IECC). Insulation thickness shown is nominal. Manufacturing tolerance of 15 percent variation is permissible.
   2. Insulation conductivity and nominal pipe size as specified in Table 1.

Table 1 - Insulation Thickness Requirements							
Fluid Operating Temperature Range And Usage (°F)	**Insulation Conductivity**		**Nominal Pipe or Tube Size (inches)**				
	Conductivity Btu x in./(h x ft² x °F)	**Mean Rating Temperature (°F)**	**<1**	**1 to <1-1/2**	**1-1/2 to <4**	**4 to <8**	**>8**
>350	0.32-0.34	250	4.5	5.0	5.0	5.0	5.0
251-350	0.29-0.32	200	3.0	4.0	4.5	4.5	4.5
201-250	0.27-0.30	150	2.5	2.5	2.5	3.0	3.0
141-200	0.25-0.29	125	1.5	1.5	2.0	2.0	2.0
105-140	0.21-0.28	100	1.0	1.5	1.5	1.5	1.5
40-60	0.21-0.27	75	0.5	1.0	1.0	1.0	1.0
<40	0.20-0.26	50	1	1.5	1.5	1.5	1.5

3. Service designation and location requirements as specified in Table 2, including the following requirements.
   a. Insulation type.
   b. Jacket type.
   c. Vapor barrier requirements.

Table 2 - Insulation Schedule					
Service Designation(1)	**Location(2)**	**Insulation Type(3)**	**Jacket Type(3)**	**Service Temp. °F(4)**	**Vapor Barrier**
Hot Water (HW)	Interior or Exterior	1 or 2	Type 1	100-200	Install on Type 2 insulation
Tepid Water(6)	Interior or Exterior	1 or 2	Type 1	60-100	Install on Type 2 insulation

Notes:

(1) Refer to Plumbing Piping Schedule as indicated on the Drawings for service designations.
(2) Insulation jackets are not required for concealed interior installations in accordance with appliable plumbing code.
(3) Contractor may select from options listed.
(4) Unless noted otherwise, use service temperature range provided in this table to establish insulation thickness as required by Table 1.
(5) Insulate piping systems that are heat traced as indicated on the Drawings.
(6) Water pipe for Emergency Eyewash and Shower Station.

B. Type 1: Pipe insulation, closed cell elastomeric insulation:
   1. Manufacturers: One of the following or equal:
      a. Aeroflex USA Inc., Aerocel® AC.
      b. Armacell®, AP Armaflex.
   2. Insulation material: Closed cell elastomeric insulation.
   3. Minimum temperature range: -40 degrees Fahrenheit to 220 degrees Fahrenheit.
   4. K factor at 75 degrees Fahrenheit: Not more than 0.27 Btu-inch/hour-square feet-degrees Fahrenheit.

5. Fire ratings:
    a. Flame spread: 25 or less.
    b. Smoke density: 50 or less for insulation thicknesses up to 1.5 inches.
6. Joints: Seal with the manufacturer's recommended contact adhesive to form continuous water barrier.

C. Type 2: Pipe insulation, preformed mineral fiberglass:
1. Manufacturers: One of the following or equal:
    a. Johns Manville, Micro-Lok® HP.
    b. Knauf Insulation.
    c. Owens-Corning.
2. Insulation material: Preformed mineral fiberglass insulation made from glass fibers bonded with a thermosetting resin.
    a. In accordance with ASTM C547, Class 1.
    b. Provide with factory installed vapor barrier.
        1) Material: White Kraft paper bound to aluminum foil in accordance with ASTM C1136, Type I.
        2) Longitudinal lap seals: Pressure-sensitive, self-sealing longitudinal lap strip with factory applied adhesive.
        3) Circumferential butt seals: 4-inch wide tape or similar properties or 4-inch wide overlap with adhesive seal.
        4) Vapor barrier permeability: 0.02 perms or lower.
        5) Vapor barrier flame spread rating: 25 or less.
3. Minimum temperature range: -0 degrees Fahrenheit to 850 degrees Fahrenheit.
4. K factor at 75 degrees Fahrenheit: Not more than 0.23 Btu-inch/hour-square feet degrees Fahrenheit.
5. Maximum moisture absorption, volume percent: 5.

D. Insulation jackets:
1. Type 1: Pipe insulation jacket, ultraviolet-resistant polyvinyl chloride:
    a. Manufacturers: One of the following or equal:
        1) Johns Manville, Zeston® 2000 PVC.
        2) Proto Corp., LoSMOKE PVC.
        3) Speedline® Corp., Smoke-Safe™ PVC.
    b. Material: Ultraviolet-resistant polyvinyl chloride jacketing, 20 mil minimum thickness.
    c. Fire rating: 25 maximum flame spread, smoke developed 50 or less.
    d. Color: White.
    e. Overlap: 1 inch minimum at joints and fittings.
    f. Joint seal: PVC solvent welded or adhesive as recommended by the manufacturer.
    g. Fittings: Factory made with full thickness insulation.
2. Type 2: Pipe insulation jacket, aluminum:
    a. Manufacturers: One of the following or equal:
        1) Childers Products.
        2) Premetco International.
    b. Material: Aluminum, Alloy 5005; 0.016 inch (26-gauge) minimum thickness.
    c. Overlap: Overlap circumferential joints 4 inches minimum; overlap longitudinal joints 1-inch minimum; longitudinal joints oriented to minimize water entry.

d. Bands: 0.5 inch wide, 0.0508-inch (16-gauge) thick aluminum, same alloy as jacket or 0.0179-inch thick Type 304 stainless steel; install on 18-inch centers, uniformly spaced and at all fitting joints.
e. Joint seal: Apply waterproof adhesive at joints and overlaps.
f. Fittings: Custom fit of same materials.

PART 3 EXECUTION

3.01 GENERAL

A. Furnish and install vents required in drainage piping as part of the plumbing system, in accordance with Laws and Regulations.

B. Use anti-seize lubricant for stainless steel treads on fittings and fasteners.

3.02 INSTALLATION

A. Fixtures:
1. Rough-in fixtures and accessories in accordance with the dimensions supplied by the manufacturers of the fixtures.
2. Mount fixtures and accessories without cutting of finish surface.

B. Plumbing and drainage products:
1. Traps:
a. Install traps as near the fixtures as possible.
2. Sizes of equipment drains and of floor drains shall be as indicated on the Drawings.

C. Plumbing piping systems:
1. Cast iron soil pipe, PVC, polypropylene:
a. Where not specified otherwise, install horizontal piping with a grade of 1/4 inch per foot.
b. Provide vents, roof drains, and pipes flashed and made watertight at the roof with lead sheet flashings.
1) Minimum 4-pound lead sheet.
c. Extend flashing not less than 6 inches up the pipes, and counter flash with standard cast iron or malleable iron recessed roof couplings.
d. Extend flashing for vents up to the top of the vent and turn down into the pipe.
e. Extend flashing shields not less than 8 inches from vent and pipe in all directions.
2. Copper piping:
a. Connect copper pipe connected to ferrous pipe or valves, or other non-copper items, by means of dielectric insulating unions or fittings.
b. Where connections are made to meters or other devices having iron pipe size threaded fittings, provide special thread to tube adapters.
c. Grooved joint piping systems shall be installed in accordance with the manufacturer's (Victaulic) guidelines and recommendations.
1) Grooved couplings and fittings shall be the products of a single manufacturer.

2) Grooving tools shall be of the same manufacturer as the grooved components.
3) Gasket style and elastomeric material (grade) shall be verified as suitable for the intended service as specified.
4) Gaskets shall be molded and produced by Victaulic.
5) Grooved end shall be clean and free from indentations, projections, and roll marks in the area from pipe end to groove for proper gasket sealing.
6) A Victaulic factory-trained field representative shall provide on-site training for Contractor's field personnel in the proper use of grooving tools and installation of grooved piping products.
7) Factory-trained representative shall periodically review the product installation.
8) Remove and replace any improperly installed products.

3. Copper tubing:
   a. Install in accordance with ASTM B828 and IAPMO IS 03.
   b. Install in straight runs, supported at intervals close enough to avoid sagging.
   c. Make cuts square with a tubing cutter or with a 32-tooth hacksaw.
      1) Provide a sizing tool to correct distortions.
   d. Insulate piping as specified.
   e. Ream the inside of the tubing and remove burrs from the outside, holding the end of the tubing downward and preventing chips and fillings from entering the tubing.
   f. Perform flaring with a flare block and yoke type screw feed flaring tool:
      1) After removing the tubing from the flare block, inspect both surfaces of the flare for splits, cracks, or other imperfections.
      2) Where there are imperfections, cut off the imperfect flare, and prepare a new flare.
4. Black steel:
   a. Install in accordance with applicable codes and regulations.
5. CPVC:
   a. Install in accordance with ASTM F645 or the manufacturer’s published instructions for installation of piping, as applicable to the particular type of piping.
   b. Provide molded transition fittings for transitions from plastic to metal or IPS pipe.
      1) Do not thread pipe.
      2) Do not use flanged transition fittings unless specifically indicated on the Drawings.
   c. Locate unions where indicated on the Drawings, and elsewhere where required for adequate access and assembly of the piping system.
   d. Provide serrated nipples for transition from plastic pipe to rubber hose.
   e. Clean dirt and moisture from pipe and fittings.
   f. Bevel pipe ends in accordance with the manufacturer’s instructions with chamfering tool or file.
      1) Remove burrs.
   g. Use solvent cement and primer formulated for CPVC.
   h. Use primer on pressure and non-pressure joints.

i. Do not solvent weld joints when ambient temperatures are below 40 degrees Fahrenheit or above 90 degrees Fahrenheit unless solvent cements specially formulated for these conditions are utilized.

D. Pipe insulation:
1. Install insulation and jacket materials in accordance with the manufacturer's written instructions.
2. Fittings:
a. Insulate fittings by covering with mitered sections of insulation or utilize factory-made prefabricated fitting shapes.
b. Terminate preformed pipe jackets or covering at sufficient distance from flanges to permit removal of bolts.
c. Overlap flange and flanged fitting insulation on adjacent pipe covering by at least 2 inches.
3. Valves:
a. Insulate valves 3 inches in nominal size and larger with removable insulating blankets.
b. Size blanket to extend up to packing gland only so that replacement of packing does not require removal of insulating blanket.
4. Provide continuous insulation through and over pipe supports and provide protection saddles at supports.
5. Provide continuous pipe insulation and covering through sleeves or openings in walls and floors.
a. When buried pipe enters a building through a below grade wall or slab penetration, begin insulation system on interior side of penetration.
6. Apply pre-molded pipe insulation with extended legs when used on pipe traced with either tubing or electric cable type.
7. Thermally isolate insulation closure locations (end caps, transitions, etc.).
a. Type 1 or 2 jacket installation on piping with potential reach temperatures greater than 150 degrees Fahrenheit.
8. Apply piping identification on jackets as specified in Section 15076 - Pipe Identification.

E. Backflow preventers:
1. Include shutoff valves at each end of backflow preventer with properly located test cocks.

3.03 FIELD QUALITY CONTROL

A. Test water piping in accordance with the plumbing code as specified in Section 01410 - Regulatory Requirements.

B. Test drain, waste, and vent lines as specified and in accordance with the plumbing code as specified in Section 01410 - Regulatory Requirements.

C. Backflow preventer:
1. Test witnessing: Witnessed.
2. Conduct pressure and leak test as specified in Section 15110 - Common Work Results for Valves.
3. Certificate of backflow prevention from a tester listed by the American Backflow Prevention Association.

3.04 CLEANING

A. Upon completion of installation, clean piping interior of foreign matter and debris.

B. Flush and disinfect potable water piping as specified in Section 01757 - Disinfection.

3.05 SCHEDULES

A. As indicated on the Drawings.

END OF SECTION

SECTION 15430

EMERGENCY EYE/FACE WASH AND SHOWER EQUIPMENT

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Emergency shower and eyewash.
   2. Water heaters.

1.02 REFERENCES

A. American Gas Association (AGA) Standards.

B. American National Standards Institute (ANSI):
   1. Z358.1 - Emergency Eyewash and Shower Equipment.

C. American Society of Mechanical Engineers (ASME).

D. American Society of Sanitary Engineering's (ASSE):
   1. 1070 - Standard for devices that limit water temperature to a fixture or fixtures such as sinks, lavatories, or bathtubs to reduce the risk of scalding.
   2. 1071 - Performance Requirements for Temperature Actuated Mixing Valves for Plumbed Emergency Equipment.

E. Americans with Disabilities Act (ADA) Standards.

F. California Code of Regulations (CCR):
   1. Title 24 - Building Standards Code.

G. California Department of Occupational Safety and Health Administration (Cal-OSHA).

H. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

I. National Fire Protection Association (NFPA).

J. Occupational Safety and Health Administration (OSHA).

K. Underwriters Laboratories, Inc. (UL).

1.03 ABBREVIATIONS

A. IPS - Industrial Piping Systems.

1.04 SUBMITTALS

A. Submit as specified in Section 01300 - Submittals and Section 01600 - Product Requirements.

1.05 QUALITY ASSURANCE

A. Regulatory requirements:
   1. As applicable, equipment of this Section shall comply with requirements of public agencies of the state where the project is located including ASME, Cal-OSHA, and UL.

1.06 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Packing and shipping: Deliver to the job site in manufacturer's original containers.

B. Delivery: After wet operations in building are completed.

C. Storage and protection:
   1. Store materials in original, unopened containers in compliance with manufacturer's printed instructions.
   2. Keep materials dry until ready for use.
   3. Keep packages of material off the ground, under cover, and away from sweating walls and other damp surfaces.
   4. Protect finished surfaces from soiling and damage during handling and installation. Keep covered with a protective covering.

PART 2 PRODUCTS

2.01 EMERGENCY SHOWERS AND EYE/FACE WASHES

A. General design requirements:
   1. Combination unit emergency shower with eye/face wash:
      a. Floor mounted fixture consisting of pipe standard, showerhead assembly, and eyewash assembly.
      b. Provide stanchion and floor flange, with interconnecting piping.
   2. Showerhead flow: 20.0 gallons per minute flow, minimum.
   3. Eye/face wash flow: 3.0 gallons per minute flow, minimum.
   4. Meet or exceed all requirements of ANSI Z358.1.
   5. Provide ANSI compliant identification sign and markings.

B. Shower/eyewash unit with integral controls to alarm the system is in use.
   1. Flow switch:
      a. Construction:
         1) NEMA Type 4.
         2) Brass or Type 316 Stainless Steel.

b. Type: Magnetic proximity switch.
c. Alarm Contacts: Double pole, double throw contacts rated at 2.0 amps at 120 VAC configurable for either Normally Open or Normally Closed.

C. Combination unit emergency shower and eye/face wash:
1. Manufacturers: One of the following or equal:
a. Haws, Model No. 8309.
b. Guardian Equipment, Model No. G1950HFC.
c. Bradley, Model No. S19314AC.
2. Pipe standard:
a. 1-1/4-inch hot-dip galvanized steel pipe, and fittings with interconnecting piping, stanchion, and 9-inch diameter floor flange.
b. Corrosion protection:
1) Manufacturers: One of the following or equal:
a) Bradley Galvanized steel with BradTect® safety yellow coating.
b) Guardian Equipment "-GC" epoxy protective coating in corrosive environments.
c) Haws "-CRP".
3. Shower head:
a. Material and size: ABS plastic stainless steel, 10-inch diameter with 20 gallons per minute flow control.
b. Valve and actuator: Stay open chrome plated brass ball valve equipped with stainless steel ball and stem operated by a rigid stainless steel pull rod.
4. Eye/face wash receptor:
a. Valve and actuator: Stay open chrome plated brass ball valve with stainless steel ball and stem operated by a stainless steel or epoxy coated aluminum push handle and foot treadle.
b. Spray head(s): ABS plastic or polypropylene eye/face wash type heads, with integral flip top protective dust covers releasing with water pressure.
c. Receptor bowl: Stainless steel; 11 inches diameter.
5. Supply: 1-1/4-inch IPS.
6. Waste: 1-1/4-inch IPS.

2.02 WATER HEATERS

A. Size and requirements as indicated on the Drawings.

B. Provide with temperature limiting device meeting ASSE 1070.

C. Water heaters shall meet the requirements in accordance with CCR Title 24.

D. Tankless electric heater:
1. Modular heating chambers.
2. NEMA 4X Type 316 stainless steel cabinet:
a. Internal heater protection to -30 degrees Fahrenheit.
b. Free standing legs.
3. Flow actuated at 2.5 gpm.
4. Inlet flow:
a. Up to 23 gpm and 70 psig.
5. Outlet flow:
a. Minimum temperature rise: 21 degrees Fahrenheit at maximum inlet flow.

b. Factory set maximum temperature: 100 degrees Fahrenheit.
c. Temperature set point: 60 (within 1) degrees Fahrenheit.

6. Provide water heater piping components necessary for installation:
   a. Drain piping, material as indicated on Piping Schedule.
   b. Supply valve.
   c. Y strainer.
   d. Pressure regulating valve and gauge.
   e. Water hammer arrestor.
7. Manufacturers: One of the following or equal:
   a. Haws, Model 9327.
   b. EEMAX, similar models.

E. Safety shower tester:
1. Manufacturers: One of the following or equal:
   a. Bradley, Model No. S19-330ST.
   b. Guardian Equipment, Model No. AP250-005.
   c. Haws, Model No. 9010 with No. 9009.
2. Kit includes:
   a. Minimum 5 gallon plastic bucket.
   b. 7 foot long watertight 12-gallon translucent vinyl plastic bag for attaching over drench showerhead:
      1) Bag shall have drawstring at top and be hemmed at bottom.
   c. Testing record card.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install products in accordance with manufacturers' recommendations.

B. Install products in accordance with code requirements and ANSI Z358.1.

C. Plumbing and mechanical work as specified in Section 15400 - Plumbing Systems and Section 15050 - Common Work Results for Mechanical Equipment.

3.02 FIELD QUALITY CONTROL

A. Functional testing:
1. Shower/eyewash unit with integral controls:
   a. Test witnessing: Witnessed.
   b. Electrical Instrumentation and Controls:
      1) Test witnessing: Witnessed.
      2) Conduct testing as specified in Section 17100 - Control System Requirements.

END OF SECTION

SECTION 15500

COMMON WORK RESULTS FOR HVAC

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. General prescriptive, design, and performance requirements for products and mechanical equipment used to heat, ventilate, cool, or otherwise condition or distribute indoor air.
   2. Specific requirements for ductwork accessories:
      a. Dampers and damper operators.
      b. Diffusers, grills, and registers.
      c. Flexible connections.

1.02 REFERENCES

A. Air-Conditioning, Heating, and Refrigeration Institute (AHRI):
   1. 210/240 - Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment.
   2. 270 - Sound Rating of Outdoor Unitary Equipment.
   3. 340/360 - Performance Rating of Commercial and Industrial Unitary Air Conditioning and Heat Pump Equipment.
   4. 430 - Performance Rating of Central Station Air-handling Unit Supply Fans.

B. Air Movement and Control Association International, Inc. (AMCA):
   1. 11 - Certified Ratings Program Operating Manual.
   2. 210 - Laboratory Methods for Testing Fans for Certified Aerodynamic Performance Rating.
   3. 211 - Certified Ratings Program — Product Rating Manual for Fan Air Performance.
   4. 301 - Methods for Calculating Fan Sound Ratings from Laboratory Test Data.
   5. 311 - Certified Ratings Program — Product Rating Manual for Fan Sound Performance.
   6. 500 - Laboratory Methods of Testing Dampers for Rating.
   7. 511 - Certified Ratings Program Product Rating Manual for Air Control Devices.

C. American Bearing Manufacturers Association (ABMA):
   1. 9 - Load Ratings and Fatigue Life for Ball Bearings.
   2. 11 - Load Ratings and Fatigue Life for Roller Bearings.

D. American National Standards Institute (ANSI):
   1. Z21.47 - Gas Fired Central Furnaces (except Direct Vent Central Furnaces).

E. American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE):
   1. Standard 15 - Safety Standard for Refrigeration System.

2. Standard 52.2 - Methods of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.

F. American Society of Mechanical Engineers (ASME):
   1. RTP-1 - Reinforced Thermoset Plastic Corrosion-Resistant Equipment.

G. ASTM International (ASTM):
   1. B32 - Standard Specification for Solder Metal.
   2. B75 - Standard Specification for Seamless Copper Tube.
   3. B280 - Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service.
   4. B813 - Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube.
   5. B828 - Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fitting.
   6. C1136 - Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation.
   7. D1784 - Standard Classification System and Basis for Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds.
   8. D1785 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120.
   9. D2466 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40.
   10. D2467 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80.
   11. D2564 - Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems.
   12. D2665 - Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Drain, Waste, and Vent Pipe and Fittings.

H. California Energy Commission (CEC):
   1. Title 24 - Building Energy Efficiency Standards.

I. National Bureau of Standards: NBS PS15-69 - Custom Contact-Molded Reinforced-Polyester Chemical-Resistant Process Equipment.

J. National Electrical Manufacturers Association (NEMA):
   1. 250 - Enclosures for Electrical Equipment (1,000 V Maximum).

K. National Fire Protection Association (NFPA):
   1. 70 - National Electrical Code (NEC).
   2. 90A - Standard for the Installation of Air Conditioning and Ventilating Systems.

L. National Roofing Contractors Association (NRCA).

M. International Association of Plumbing and Mechanical Officials (IAPMO):
   1. IS 3 - Installation Standard for Copper Plumbing Tube, Pipe, and Fittings.

N. Sheet Metal and Air Conditioning Contractors National Association (SMACNA).

O. Underwriters Laboratories, Inc. (UL):
   1. 555 - Standard for Fire Dampers.
   2. 555C - Standard for Safety Ceiling Dampers.
   3. 555S - Standard for Smoke Dampers.
   4. 900 - Standard for Air Filter Units.
   5. 60335-2-40 - Safety Standard for Household and Similar Electrical Appliances.

1.03 ADMINISTRATIVE REQUIREMENTS

A. Coordination.
   1. Where required, provide roof mounted equipment information required in the preparation of roofing drawings, including, but not limited to:
      a. Location.
      b. Size.
      c. Weight.
      d. Anchoring and support details.

1.04 SUBMITTALS

A. Where items in this Section are components of equipment or systems specified in other sections, include data for this Section's components with the equipment or system Submittal.

B. When products are specified in this Section but are not referenced in other Technical Sections, submit:
   1. As specified in Section 01300 - Submittals.
   2. Product data:
      a. Sufficient to substantiate specified requirements.
   3. Description of coating system and instructions for field touch up and re-coating.

C. Projects subject to CEC Title 24:
   1. Damper operators:
      a. Electric: Wiring diagrams.
   2. Manufacturer's recommendation for testing and/or maintenance of product.

PART 2 PRODUCTS

2.01 GENERAL

A. Technical Sections product requirements supersede conflicting requirements in this Section.

B. As specified in Section 01600 - Product Requirements.

C. Electrical:
   1. Components and assemblies.
   2. Carry UL listing marking.
   3. In accordance with NEC requirements.

D. Fans:
   1. Rated and labeled in accordance with AMCA 210 and AMCA 211.
   2. Belt drive systems:
      a. Adjustable for minimum within 5 percent speed change.
      b. Rated for 150 percent of maximum motor horsepower.

E. Unitary air conditioners and heat pumps: Not Applicable.

F. Filters:
   1. Media: UL 900 listed.

G. Insulation and adhesives: In accordance with NFPA 90A requirements for flame spread and smoke generation.

H. Roof curbs: Supplied by the manufacturer of the product requiring the curb.

I. Factory coating: For equipment with factory coatings, manufacturer to supply 2 containers (each about a pint) of the paint for Contractor/Owner touch up.

2.02 DESIGN AND PERFORMANCE CRITERIA

A. General:
   1. Environmental conditions as specified in Section 01850 - Design Criteria.
   2. Provide instrumentation and controls to meet the equipment operating requirements as specified in Section 11395A - Package Odor Control System and Section 17101C - Specific Control Strategies - Odor Control System.

B. Fans:
   1. See Section 11395A - Package Odor Control System for odor control scrubber fan requirements.

C. Unitary air conditioners and heat pumps: Not Applicable

2.03 DAMPERS

A. General:
   1. Type, style, and size as indicated on the Drawings.
   2. Components: Include with each damper:
      a. Type, frame, actuators, clips, connectors, and other accessories necessary for mounting.
         1) Manual actuators: Factory supplied locking quadrant on factory mounted stand-off bracket.
            a) Bracket finish to match frame.
         2) Electric actuators when indicated on the Drawings.
   3. Leakage class, when specified, to be in accordance with AMCA 511 and product to bear AMCA Rating Seal for Air Leakage.
      a. Blade seals to be mechanically attached.
   4. Fire dampers and combination smoke/fire dampers to have duct access door near damper as specified in the Technical Sections.

B. Volume control and balancing type dampers (BD):
   1. BD-13, Style 13; fiberglass, inlet volume control damper:
      a. Manufacturers: One of the following or equal:
         1) Daniel Mechanical, DanElast.
      b. Frame: Vinyl ester resin fiberglass unitary channel.
         1) 100-mil corrosion barrier on internal surfaces.
         2) Flanged ends with bolt holes drilled to match duct or equipment.
      c. Blades:
         1) Vinyl ester resin fiberglass:
            a) 100-mil corrosion barrier.
         2) Flat capped hub:
            a) Material to match blades.
      d. Bearings: Molded graphite impregnated PTFE, flanged sleeve.
      e. Drive shaft: Type 316 stainless steel, solid, full-length rod.
      f. Axles: Type 316SS, solid, full-length rod.
      g. Shaft seals: Double O-ring.
      h. Linkage: Type 316 stainless steel, including swivels and bearings.
      i. Hub: Type 316 stainless steel or FRP flat panel.
      j. Hardware: Type 316 stainless steel.
      k. Operator:
         1) 12 inch and smaller: Lever arm with locking manual quadrant Type 316 stainless steel construction or epoxy coated worm gear.
         2) Larger than 12 inch: Epoxy coated worm gear.
      l. Connections: Type 316 stainless steel nuts, bolts, and washers.
      m. Field paint if scheduled and as specified in Section 09960 - High-Performance Coatings for surface preparation requirements.
   2. BD-14, Style 14; round fiberglass damper:
      a. Manufacturers: One of the following or equal:
         1) Daniel Mechanical.
         2) Engineered Composite Systems.
      b. Zero-leakage air isolation damper.
      c. Materials of construction:
         1) Body: Vinyl ester FRP.
         2) Blade: Vinyl ester FRP.
         3) Blade seal: PTFE encapsulated O-ring, EPDM O-ring.
         4) Blade stop: FRP integral to the damper body.
         5) Shaft: Type 316 stainless steel, FRP shaft materials are not allowed.
         6) Shaft seal: Viton™ O-ring.
         7) Bearings and bushings: Graphite impregnated PTFE.
         8) Hardware: Type 316 stainless steel.
         9) Maximum operating temperature: 175 degrees Fahrenheit.
         10) Minimum pressure: 30-inches water column.
         11) Resin system: Fire retardant vinyl ester with MEKP cure system.
         12) Internal corrosion barrier: Minimum 100-mil thickness.
         13) Connections: Flanged in accordance with NBS PS15-69 Table 2.
         14) External coating: Gel coat with ultraviolet inhibitors.
         15) Gaskets: EPDM.
      d. Maximum leakage: AMCA Tested and Certified Bubble-tight at not less than 20-inches water column.

e. Actuators:
    1) Dampers 24 inches and smaller:
        a) Hand quadrant actuator fabricated from Type 316 stainless steel with a fully adjustable slot with extra hole drilled in handle to permit locking pin once system has been balanced.
        b) Provide drilled hole in the actuator handle support plate to permit locking in the full open and full closed positions.
    2) Dampers larger than 24 inches: Epoxy coated gear operator with locking handwheel.
    3) Dampers below grade or located in areas not normally accessible (all sizes) such as in wetwells or junction boxes:
        a) Operator: Geared 1/4 turn, Dynatorque stainless steel series DT7 (no chain wheel) or DT21 (with chain wheel) or equal.
        b) Material:
            (1) Shaft: Type 316 stainless steel shaft, enclosure, and hardware.
            (2) Gears: Type 316 stainless steel.
        c) Extension:
            (1) Type 316 stainless steel with 2-inch operating nut, minimum 1-inch diameter or equal to the shaft diameter, whichever is larger.
            (2) Provide an indicator at the top of the extension stem to indicate full open and full closed positions.
    4) Dampers located 6 feet or more above finished floor or grade elevation shall use geared operators as specified above with chain wheel operator and chain extending to within 3 feet of finished floor or grade elevation.
        a) Manufacturers: One of the following or equal:
            (1) Babbitt.
            (2) Rotohammer.
        b) Aluminum chain wheels equipped with Type 316 stainless steel chain.
        c) For installations where operator and chain weight exceed 40 pounds the damper shall be reinforced to accommodate the added weight.

C. Backdraft dampers (BDD):
    1. BDD-2, Style 2; fiberglass, counterbalanced backdraft damper:
        a. Manufacturers: One of the following or equal:
            1) Daniel Mechanical.
        b. Frame:
            1) Minimum depth: 8 inches.
            2) Material: Vinyl ester resin fiberglass, Type II laminated, unitary body.
            3) Flange mount.
        c. Blades:
            1) Minimum thickness: 0.1875 inches.
            2) Minimum 0.75-inch diameter Type 316SS axles with PTFE graphite impregnated bearings.
            3) Blades require no more than 2 inches of clearance beyond frame when fully open.

d. Counterbalance:
    1) Type 316 stainless steel counterbalance weight and arm.
    2) Adjustable down to 0.02-inch w.c. opening.
e. Finish:
    1) 2 coats of PVDF with color selected by the Owner from the manufacturer's standard.

2.04 DAMPER OPERATORS

A. General: Provide manual or electric damper operator for each damper furnished as indicated on the Drawings.

B. Manual operators by damper manufacturer:
1. Operate damper manually with a force not exceeding 20 pounds.
2. Provide with locking quadrant.
3. Provide 3/8 inch, or larger, square double-ended drive shaft adequate for required damper torque, with machined keyways allowing for mounting in 2 positions, 90 degrees apart.
4. Provide sufficient number of operators for torque required to operate damper.

C. Electric damper operators:
1. Manufacturers: One of the following or equal:
    a. Honeywell.
    b. Johnson Controls.
2. 2-position spring return.
3. 1 internal single pole double throw auxiliary switch rated 5 A, 120 V.
4. Housed in die-cast aluminum case with mounting flange.
5. Motor and gear train components immersed in oil.
6. When required, provide auxiliary transformers factory wired to damper operator and installed in NEMA Type 4X enclosure fastened to motor housing.

2.05 DIFFUSERS, GRILLES, AND REGISTERS

A. Provide diffusers, grilles, and registers manufactured by the same manufacturer.

B. Provide style and size as indicated on the Drawings.

C. Components: Include specified style with frame, clips, connectors, and other accessories necessary for mounting.

D. Supply diffuser, grille, and register styles:
1. SR-10, Supply Register Style 10:
    a. Service: Supply air in corrosive environments.
    b. Type: Pultruded vinyl ester resin fiberglass.
    c. Installation: When duct mounted is indicated on the Drawings, provide 3-inch minimum and 6-inch maximum drop frame.
    d. Faceplate: Fiberglass retainer with a 1/2-inch by 1/2-inch styrene or acrylic grill lattice that occupies no more than 9 percent of the total grille area.
    e. Core: Fiberglass flange.
    f. Damper: Provide opposed blade volume control damper.

g. Materials: Pultruded vinyl ester resin fiberglass frame, core, damper, and faceplate.
h. Refer to Typical Detail HA550 for more information.

E. Return/exhaust diffuser, grille, and register styles:
1. RR-8/ER-8, Return/Exhaust Register Style 10:
a. Service: Exhaust air in corrosive environments.
b. Type: Pultruded vinyl ester resin fiberglass.
c. Installation: When duct mounted is indicated on the Drawings, provide 3-inch minimum and 6-inch maximum drop frame.
d. Faceplate: Fiberglass retainer with a 1/2-inch by 1/2-inch styrene or acrylic grill lattice that occupies no more than 9 percent of the total grille area.
e. Core: Fiberglass flange.
f. Damper: Provide opposed blade volume control damper.
g. Materials: Pultruded vinyl ester resin fiberglass frame, core, damper, and faceplate.

2.06 SCREENS

A. Required on all fans and louvers unless otherwise indicated on the Drawings.

B. Characteristics and features:
1. Bird screen: 1/2-inch mesh by 14 gauge.
a. For exhaust applications.
2. Insect screens: 18 by 14 mesh.
a. For intake applications.
3. Screens and frames, same material as ductwork, hood, louver, fan, or equipment connected to screen.
4. Screens secured in frames.

2.07 FLEXIBLE CONNECTORS

A. Provide flexible duct connectors at connections to fans and other air movement equipment as indicated on the Drawings.

B. FL-2, Duct to Duct Flexible Connection, Corrosive Environment:
1. Manufacturers: The following or equal:
a. Ventfabrics, Ventel.
2. Fabric for flexible connections exposed to chemicals shall be glass fabric coated with Teflon™ and suitable for a temperature range of -10 to 500 degrees Fahrenheit and shall have a weight of at least 14 ounces per square yard and a thickness of 0.014 inch.

2.08 CONDENSATE DRAIN PIPING

A. PVC:
1. PVC pipe: Designation PVC 1120 in accordance with ASTM D1785 and appendices:
a. Pipe and fittings: Extruded from Type I, Grade 1, Class 12454 B material in accordance with ASTM D1784.
b. PVC pipe: Schedule 80 unless otherwise indicated on the Drawings.

2. Fittings:
    a. Supplied by the pipe manufacturer.
    b. Pressure fittings: In accordance with ASTM D2466 or ASTM D2467.
    c. DWV fittings: In accordance with ASTM D2665.
3. Solvent cement: In accordance with ASTM D2564:
    a. Manufacturers: The following or equal:
        1) Primer: IPS Corp Type P-70™.
        2) Cement: IPS Corp Type 724™ cement or cement certified by the manufacturer for chemical service.

2.09 PIPE INSULATION

A. General:
1. As specified in Section 01600 - Product Requirements.
2. Insulation thicknesses: In inches as specified in the following table.
    a. Thickness shown is nominal.
    b. Manufacturing tolerance of 15 percent variation is permissible.

Table 1. Required Insulation Thicknesses (Inches)

Service Temperature Range(1)	Nominal Pipe Diameters	
	1 Inch and Less	1.25 to 2 Inches
100 to 200 degrees Fahrenheit	1.5	1.5
40 to 100 degrees Fahrenheit	0.5	1.0

Notes:
(1) As specified in Table 2. Insulation Schedule, at the end of this Section.

B. Insulation, Type 1:
1. Manufacturers: One of the following or equal:
    a. Aeroflex USA Inc., Aerocel® AC.
    b. Armacell®, AP Armaflex.
2. Insulation material: Closed cell elastomeric insulation.
3. Minimum temperature range: -40 degrees Fahrenheit to 220 degrees Fahrenheit.
4. K-factor at 75 degrees Fahrenheit: Not more than 0.27 Btu-inch/hour-square feet-degrees Fahrenheit.
5. Fire ratings:
    a. Flame spread: 25 or less.
    b. Smoke density: 50 or less for insulation thicknesses up to 1.5 inches.
6. Joints: Seal with the manufacturer's recommended contact adhesive to form a continuous water barrier.

C. Insulation jackets:
1. Type 1:
    a. Manufacturers: One of the following or equal:
        1) Johns Manville, Zeston® 2000 PVC.
        2) Proto Corp., LoSMOKE PVC.
        3) Speedline® Corp., Smoke-Safe™ PVC.
    b. Material: Ultraviolet-resistant polyvinyl chloride jacketing, 20-mil minimum thickness.

c. Fire rating: 25 maximum flame spread, smoke developed 50 or less.
d. Color: White.
e. Overlap: 1 inch minimum at joints and fittings.
f. Joint seal: PVC solvent welded or adhesive as recommended by the manufacturer.
g. Fittings: Factory made with full thickness insulation.

D. Vapor barriers:
1. Type 1:
a. Material: White Kraft paper bound to aluminum foil in accordance with ASTM C1136, Type 1.
b. Permeability: 0.02 perms or lower.
c. Maximum flame spread rating: 25.
d. Edge seal: Pressure-sensitive tape lap seal.
e. Circumferential joints: 4-inch wide tape or 4-inch overlap with adhesive seal.
2. Type 2:
a. Manufacturers: One of the following or equal:
1) Benjamin Foster, No. 30-76.
2) Childers Products, CP10/11 Vi-Acryl.
3) Foster Products, 36-10/46-10 Weatherite.
4) Insul-Coustic, No. I.C.-580.
b. Material: Mastic.

E. Insulation schedule: Not Applicable.

2.10 EQUIPMENT NAMEPLATES

A. Provide a nameplate with the following markings, plainly visible after installation:
1. Manufacturer’s name, trademark, or other descriptive marking to identify specific equipment.
2. Where equipment is electrically powered:
a. Supply voltage, phase, frequency, and full-load current.
b. Power source or circuit ID.
c. Short-circuit current rating based on one of the following:
1) Rating of a listed and labeled assembly.
2) Rating established utilizing an approved method.

2.11 SHIPPING, SPARE PARTS, MAINTENANCE PRODUCTS, AND SPECIAL TOOLS

A. As specified in Section 01600 - Product Requirements.

B. Inspect fasteners for proper tightness.

C. Ship units in one piece (or modular, if required), factory assembled, piped, internally wired, and factory tested.

D. Provide:
1. Filters: 2 extra (3 total) sets per each unit with filters.
2. Sheaves and belts: 1 set for change-out for final balance per unit installed.
3. Belts: 1 extra set for each unit installed as determined by final balance.

E. Provide a 2-year supply of maintenance products as specified in the manufacturer's maintenance literature.

PART 3 EXECUTION

3.01 GENERAL

A. Technical Sections execution requirements supersede conflicting requirements in this Section.

B. As specified in Section 01600 - Product Requirements.

C. Inspect fasteners for proper tightness.

D. Provide temporary closures for openings designed for airflow.

3.02 INSTALLATION

A. Examine and verify details and sections as indicated on the Drawings, ascertain adequacy, and determine conflicts in dimensions and clearances.
   1. Take measurements and verify dimensions to ascertain fit of installation.
   2. Ascertain structural sufficiency to support installation.
   3. Ascertain that supports and openings are correctly located; otherwise cut new openings where required.
   4. Confirm specified thermostat or other controls are compatible with specified equipment.

B. Install in accordance with the manufacturer's instructions.
   1. Electrical products installation in accordance with NFPA 70 NEC.
   2. If there are conflicts, the NEC supersedes the manufacturer's instruction.
      a. Notify the Engineer of conflicts.

C. Equipment supports and anchoring:
   1. General:
      a. Set equipment so that connecting flanges, screwed connections, or flexible connections will meet without strain or distortion.
      b. Equipment may not be grouted, nor equipment anchors finally tightened, until all service connections to equipment are complete and in satisfactory alignment with no strain transmitted to the equipment.
   2. Equipment supported on concrete slab:
      a. Install equipment and secure in place as recommended by the manufacturer, as indicated on the Drawings, and as shown in approved anchoring details for that equipment.
      b. Examine pads or supports and make required repairs, using means acceptable to the Engineer, prior to installation of equipment. Confirm:
         1) Correctly sized, regular, and even pads.
         2) Correct anchor bolt sizes and locations.
      c. Accurately align and level equipment over stainless steel shims and wedges placed near anchor bolts.

d. Tighten anchor bolts against shims and wedges and re-check for level and alignment before placing grout.
e. Place grout under equipment frame or base.
    1) Install non-shrink grout as specified in Section 03600 - Grouting, unless otherwise required by the equipment manufacturer or indicated on the Drawings.
    2) Before grouting, install block outs around anchor bolts and shims to prevent grouting in those areas.
    3) Finish grout and cure for not less than 3 days.
    4) After initial curing, loosen anchor bolts and fill block outs with non-shrink cement grout.
    5) Finish and cure grout at block outs for not less than 3 days.
f. Tighten anchors against grout.

3. Equipment supported on roof curb:
    a. Install in accordance with the NRCA manual.

D. Equipment and ducts:
1. Remove dust and debris before installation.
2. Protect from dust and debris by covering openings with tape or plastic during installation and until equipment is operated.
3. Adjust alignment of ducts to resolve conflicts with the work of other trades.
4. Install and wire unitary air conditioners, controls, and thermostats in accordance with the manufacturer's recommendations.
5. Lubrication lines and fittings:
    a. Support and protect lines from source to point of use.
    b. Fittings:
        1) Bring to outside of equipment in manner such that fittings are readily accessible from outside without necessity of removing covers, plates, housings, or guards.
        2) Mount together wherever possible using factory-mounted multiple fitting assemblies securely mounted, parallel with equipment lines, and protected from damage.
6. Remove dust and debris from ductwork and equipment at completion of installation.
7. Set grilles, dampers, and diffusers to achieve flows and flow patterns indicated on the Drawings.

E. Gas, water piping, drains, and venting in accordance with the authority having jurisdiction and applicable codes.

F. Completed equipment installations must have confirmation that:
1. Equipment is properly assembled.
2. Equipment moves or rotates in the proper direction.
3. Shafting, drive elements, and bearings are installed and lubricated in accordance with proper tolerances.
4. No unusual power consumption, lubrication temperatures, bearing temperatures, or other conditions are observed.
5. Installation meets the requirements for intended use as well as the specified vibration and noise tolerances.

END OF SECTION

SECTION 15814

FIBERGLASS REINFORCED PLASTIC DUCTWORK

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Fiberglass reinforced plastic (FRP) ductwork system.
      a. Ducts and fittings.
      b. Flexible connections.
      c. Expansion joints.
      d. Supports.

1.02 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. RTP-1 - Reinforced Thermoset Plastic Corrosion-Resistant Equipment.

B. American Water Works Association (AWWA):
   1. M45 - Fiberglass Pipe Design.

C. ASTM International (ASTM):
   1. C582 - Standard Specification for Contact-Molded Reinforced Thermosetting Plastic (RTP) Laminates for Corrosion-Resistant Equipment.
   2. D792 - Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
   3. D2105 - Standard Test Method for Longitudinal Tensile Properties of Fiberglass (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Tube.
   4. D2344 - Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates.
   5. D2412 - Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading.
   6. D2992 - Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings.
   7. D2996 - Standard Specification for Filament-Wound “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe.
   8. D3982 - Standard Specification for Contact Molded “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Ducts.
   9. E84 - Standard Test Method for Surface Burning Characteristics of Building Materials.

D. National Fire Protection Association (NFPA):
   1. 91 - Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids.

E. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA).

1.03 DELEGATED DESIGN

A. As specified in Section 01357 - Delegated Design Procedures.

B. Calculations.

1.04 SUBMITTALS

A. As specified in Section 01300 - Submittals and Section 15500 - Common Work Results for HVAC.

B. Shop Drawings:
   1. Scaled ductwork layout.
      a. Size, joint types, horizontal dimensions, and elevations.
      b. Support locations.
      c. External stiffeners and expansion joints locations.
   2. Fabrication details.
   3. Support, flexible connections, and external stiffeners.
      a. Materials and configuration.

C. Calculations:
   1. Wall thickness calculations based upon design criteria.
   2. Stresses and reaction loads at supports.

D. Delegated Design Submittals:
   1. Design calculations for FRP ductwork design and construction.

E. Manufacturer’s installation instructions.
   1. Detailed instructions for field butt joints, including lay-up sequence, width of each reinforcement layer, and total number of layers.

F. Quality Control Submittals:
   1. Test results as specified in Section 06608 - Fiberglass Reinforced Plastic, verifying that ductwork meets standards specified.
   2. As specified in Section 06608 - Fiberglass Reinforced Plastic as to the requirements of FRP manufacturing and standard testing.
   3. If there is a conflict between this Section and Section 06608 - Fiberglass Reinforced Plastic, the more stringent requirements shall govern.
      a. Test methods by the manufacturer shall be in accordance with ASTM 2996 and ASTM 2992 (buried pipe).

1.05 DELIVERY, STORAGE, AND HANDLING

A. As specified in Section 01600 - Product Requirements, Section 15500 - Common Work Results for HVAC, and the manufacturer’s instructions.

B. No ductwork or components shall be shipped prior to complete resin cure.

1.06 WARRANTY

A. As specified in Section 01783 - Warranties and Bonds.

PART 2 PRODUCTS

2.01 GENERAL

A. As specified in Section 01600 - Product Requirements with additional requirements in Section 15500 - Common Work Results for HVAC.

2.02 MANUFACTURERS

A. One of the following or equal:
   1. Daniel Mechanical.
   2. Engineered Composite Systems.
   3. NOV Fiber Glass Systems.

2.03 DESIGN AND PERFORMANCE CRITERIA

A. Ducting for HVAC and ventilation systems:
   1. Minimum internal pressure: 10.0 inches water gauge.
   2. Minimum internal vacuum: 6.0 inches water gauge.

B. Ducting for odor control systems:
   1. Minimum internal pressure: 20.0 inches water gauge.
   2. Minimum internal vacuum: 20.0 inches water gauge.

C. Support spacing: As needed to comply with wall thicknesses calculations but not greater than the following:
   1. Contact-molded ductwork: Not greater than 5 foot centers.
   2. Filament-wound ducts: In accordance with SMACNA standards below:

Duct Inside Diameter (Inches)	Maximum Span (Feet)
3 to 19	10
20 to 29	15
30 to 36	20

D. Minimum flooding: Design ductwork for water accumulation as follows:
   1. Rectangular: 1 inch deep across bottom of duct.
   2. Round: 2 inches deep across bottom of duct.

E. Physical and mechanical properties: Duct shall meet the following standards:

Pipe Property	Standard	Design Properties	
		Hoop (PSI)	Axial (PSI)
Ultimate Flexural Stress	ASTM D2412	50,000	18,000
Flexural Modulus		3.05×10^6	1.0×10^6
Ultimate Tensile Stress	ASTM D2105	52,000	7,485
Tensile Modulus		1.5×10^6	1.56×10^6
Ultimate Shear Strength		Approximate Typical Values (PSI)	

Pipe Property	Standard	Design Properties	
		Hoop (PSI)	Axial (PSI)
Interlaminar Cross	ASTM D2344	2,130 - 2,730 15,000	
Density	ASTM D792	0.065 - 0.072 lb./In^3	

F. Design tensile stress:
   1. Calculations for design of wall thickness assume a laminate ultimate tensile stress of 9,000 pounds per square inch maximum.
   2. Decrease ultimate tensile stress as appropriate to the laminate design.
      a. Round ducting: Maximum allowable design tensile stress shall be the ultimate tensile stress divided by 5.
      b. Rectangular ducting: Maximum allowable design tensile stress shall be the ultimate tensile stress divided by 10.

2.04 DUCTWORK MATERIALS

A. As specified in Section 06608 - Fiberglass Reinforced Plastic.

B. Minimum corrosion liner:
   1. Interior surfacing “C” or Nexus veil as specified for the service environment.
   2. Exterior surfacing: “C” or “A” veil.
   3. Remainder 1-1/2 ounce per square foot mat to total minimum thickness of 0.096 inches on surface exposed to the service environment.
   4. Duct shall be resistant to the following in accordance with ASTM C582:

Sulfuric Acid	75 percent	At 100 degrees Fahrenheit
Nitric Acid	20 percent	At 100 degrees Fahrenheit
Sodium Hydroxide	50 percent	At 100 degrees Fahrenheit
Hydrofluoric Acid	20 percent	At 100 degrees Fahrenheit

C. Ultraviolet stabilizer:
   1. Exposed external surfaces of FRP ductwork installed outdoors shall be provided with protection against ultraviolet degradation and weather erosion.
   2. Duct shall carry the flame spread rating of 25 or less in accordance with ASTM E84.
   3. External duct protection shall be provided by an ultraviolet stabilizer added to the final coat or resin that also incorporates paraffin wax curing elements and color pigment.

D. Resin:
   1. External surface and structural layers of FRP ductwork shall carry a flame spread rating of 25 or less in accordance with ASTM E84.
   2. Premium vinyl ester as follows unless otherwise recommended by the resin manufacturer for the service environment:
      a. For structural layers: With sufficient antimony trioxide or pentoxide for Class I fire rating.
      b. Manufacturers: One of the following or equal:
         1) Ashland, Hetron 992FR.

2) Reichhold Dion, VER 9300FR.

E. Color: Add pigment to the exterior surface resin coat such that the color of the duct will be similar to paint used for equipment, except that ducting for air conditioning systems which are concealed above suspended ceilings need not be pigmented.
   1. Color selected by the Owner.

F. Provide fasteners, field joints, expansion joints, and supports required for complete installation of a duct system.

G. Flanges:
   1. FRP flanges shall be made of the same materials as the FRP ductwork.
   2. Flange bolt hole pattern as well as flange dimensions, shall be in accordance with ASTM D3982, except for thickness. Thickness of flange shall be a minimum of 3/4 inch.
   3. Manufactured using the hand lay-up technique and shall be integral to the duct in accordance with ASME RTP-1. Filament-wound and/or random chopped methods of constructing flanges will not be acceptable.

2.05 DOUBLE-WALL INSULATED FRP DUCT

A. Not Required

2.06 DUCTWORK FABRICATION

A. Hand lay-up or filament wound construction as specified in Section 06608 - Fiberglass Reinforced Plastic.
   1. Provide wall thickness necessary to comply with design criteria but not less than the following minimum thicknesses.
   2. Structural wall thicknesses shall not include the thickness of the interior corrosion barrier, inner surface, and interior layer:

Duct Size	Round Ducting (Wall Thickness, Inches)	Rectangular Ducting (Wall Thickness, Inches)	Buried Ducting (Wall Thickness, Inches)
For 18 inch & smaller ducts	0.25	0.25	0.34
20 to 36 inch ducts	0.30	0.375	0.42
42 to 54 inch ducts	0.375	0.500	0.60
60 to 72 inch ducts	0.438	0.625	0.625

B. Fittings:
   1. Type: Hand lay-up contact molded.
   2. Resin: Identical to and with same strength as resin used for FRP ductwork.
   3. Wall thickness: At least equal to the thickness of the thickest adjacent ducting.
   4. Internal diameter: Equal to the adjacent duct.
   5. Tolerance:
      a. Angles for fittings shall be within:
         1) 1 degree for up to 30-inch diameter duct.
         2) 1/2 degree for over 30-inch diameter and above duct.

6. Round standard elbows:
    a. Centerline radius shall be equal to 1-1/2 times the diameter unless otherwise indicated on the Drawings.
    b. Up to 24-inch diameter: Smooth radius elbows.
    c. 26-inch diameter and greater: May be mitered sections as follows:
        1) 0- to 44-degree elbows: 1 mitered joint and 2 sections.
        2) 45- to 80-degree elbows: Minimum of 2 mitered joints and 3 sections.
        3) Elbows greater than 80 degrees: Minimum of 4 mitered joints and 5 sections.
    d. Provide turning vanes in round mitered elbows. Round elbow turning vanes shall be of FRP construction, solid or double wall construction with an airfoil shaped profile.
7. Rectangular elbows:
    a. Fittings shall be factory manufactured to meet the specified design criteria and in accordance with approved Submittals. Factory install reinforcing ribs as required to meet the specified deflection requirements and to provide a system free from pulsing, warpage, sagging, and undue vibration.
    b. Provide turning vanes in rectangular elbows.
        1) Shall be of FRP construction, solid or double wall construction with an airfoil shaped profile.

C. Joints:
1. Flanged:
    a. In accordance with ASTM D3982.
    b. Bolt hole patterns in accordance with ASTM D3982.
    c. Flanged joints shall be provided at the following locations:
        1) At each damper and each item of equipment to facilitate disassembly.
        2) At each change in material.
        3) Where indicated on the Drawings.
    d. Gaskets for flanged joints: 1/8-inch neoprene over full flange face.
    e. Bolt nuts and washers: Type 316 stainless steel.
2. Butt and strap welded:
    a. Field joints shall be provided at the following locations:
        1) 12 inches from any increasing or decreasing cross section of pipe.
        2) Pipe to be joined has the same diameter.
    b. Thickness of joint overlays:
        1) At least equal to the thickness of the thickest adjacent duct.
    c. Field weld kits:
        1) Necessary fiberglass and reinforcing material shall be supplied pre-cut and individually packaged for each joint.
        2) Bulk glass rolls will not be acceptable.

2.07 EXPANSION JOINTS

A. Provided as indicated on the Drawings. When not shown, they shall be provided at all duct to rotating equipment and in above grade duct at maximum spacing of 40-foot centers.

B. Construction:
1. Body: EPDM vulcanized rubber.
2. Reinforcing: Multiple layers (2 minimum) of impregnated polyester or Kevlar tire cord fabric, 1/4 inch thick.

3. Flange rings: 3/8-inch thick by 2-inch wide Type 316 stainless steel or minimum 3/4-inch thick FRP pre-drilled retaining rings/back-up bars to clamp the expansion joints into the ducting system.
4. Hardware/Fasteners: Type 316 stainless steel.
5. Minimum pressure rating: 1 pound per square inch.
6. Minimum vacuum rating: 1 pound per square inch.
7. Minimum operating temperature: 175 degrees Fahrenheit.
8. Connections: Flanged in accordance with ASTM D3982.
9. Seamless construction built as on continuous piece. Wrapped, seamed, or spliced type expansion joints are not acceptable.
10. Provide Type 316 stainless steel control rods.

C. Minimum movement:
1. Axial compression: 2.25 inches.
2. Axial extension: 1.25 inches.
3. Lateral offset: 1 inch.

D. Manufacturers: One of the following or equal:
1. Daniel Co., DanFLEX Model 101.
2. Mercer Rubber Co., Model ME for Rectangular, Model MI-9 for Round.

2.08 DUCT SUPPORTS

A. Provide duct supports as indicated on the Drawings.

B. Protect the duct from clamping force of strap hangers with a 1/8-inch thick layer of neoprene pad.

C. When anchors are required, they shall be externally bonded to the duct. Drive screws or other penetrations of the duct linter are not permitted.

D. When not indicated on the Drawings, provide supports and seismic bracing in accordance with the SMACNA design manual.

PART 3 EXECUTION

3.01 GENERAL

A. As specified in Section 01600 - Product Requirements with additional requirements in Section 15500 - Common Work Results for HVAC.

3.02 INSTALLATION

A. Ductwork shall be fabricated and erected where indicated on the Drawings or as specified in this Section.
1. Rigidly supported and secured in an approved manner.

B. Install ductwork parallel to walls and/or roof and vertically plumb.

C. Bracing and vibration isolators shall be installed, where necessary, to eliminate vibration, rattle and noise.
   1. Hangers shall be installed plumb and securely suspended from supplementary steel or inserts in concrete slabs.
   2. Lower ends of hanger rods shall be sufficiently threaded to allow for adequate vertical adjustment.
   3. Building siding and metal decking shall not be used to hang ductwork.

D. Contractor shall not install any equipment or materials until the Owner's designated representative has approved all Submittals. If any equipment or materials are installed prior to approval of the Submittals, it shall be at the Contractor's risk.

E. Wherever ducts are divided, the cross-sectional area shall be maintained. All such changes must be approved and installed as directed by the Owner's designated representative or as approved on Shop Drawings or erection drawings.

F. Do not remove or alter factory installed duct reinforcing ribs, except as required to accommodate duct alterations due to unexpected field conditions.
   1. Notify the Owner's designated representative prior to starting any field modifications involving ductwork structural reinforcing members.
   2. Submit additional design calculations to demonstrate structural design integrity of ductwork and fittings requiring reinforcing modifications in the field.

G. Cover ductwork openings with tape, plastic, or sheet metal to reduce the amount of dust or debris which may collect in the system at each of the following times:
   1. At the time of rough installation.
   2. During storage on the construction site.
   3. Until final start-up of the heating and cooling equipment.

H. Before installation remove dust and debris from ducts.

I. Install products in accordance with Shop Drawings and the manufacturer's instructions. Drawings indicate general routing only and shall be modified as necessary.

J. Duct drain traps shall be located at every localized low point within the ductwork. Piped with 2-inch Schedule 80 PVC and ball valve with a P-trap.

END OF SECTION

SECTION 15954

TESTING, ADJUSTING, AND BALANCING FOR HVAC

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Testing air systems installed as part of this Contract.
   2. Testing existing air systems affected by the installation of new equipment.

1.02 REFERENCES

A. Associated Air Balance Council (AABC):
   1. National Standards Total System Balance.

B. National Environmental Balancing Bureau (NEBB):
   1. Procedural Standards for Testing, Adjusting, and Balancing Environmental Systems.

C. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA):
   1. HVAC Systems - Testing, Adjusting, & Balancing.

D. Testing, Adjusting, and Balancing Bureau (TABB):
   1. TAB Procedural Guide.

1.03 SUBMITTALS

A. Resumes of proposed supervisor and personnel showing training and qualifications.
   1. Include courses, exams, or tests relating to HVAC testing - taken and passed.

B. Testing plan:
   1. At least 30 days prior to starting field work.
   2. Set of report forms completed with design flow values and installed equipment pressure drops, and required cubic feet per minute for air terminals.
   3. Heating, ventilating, and air conditioning system schematic similar to Figure 6-1 in SMACNA HVAC Testing, Adjusting, & Balancing.
   4. Complete list of instruments proposed to be used, organized in appropriate categories, with data sheets for each showing:
      a. Manufacturer and model number.
      b. Description and use when needed to further identify instrument.
      c. Size or capacity range.
      d. Latest calibration date.
   5. Proposed schedule for testing and balancing.

C. Report:
   1. Not more than 45 days prior to the Contractor's request for final inspection, submit the draft report on applicable reporting forms.
   2. At least 15 days prior to the Contractor's request for final inspection, submit 3 copies of final reports incorporating the Engineer's comments on the draft report.
   3. List of instruments used and last date of calibration of each.
   4. Procedures followed for testing, adjusting, and balancing.
   5. Identification and succinct description of systems included in report.
   6. Initial balance test results made with dampers and air control devices in full open positions.
   7. Description of final locations and sizes, including opening area and dimensioned configuration of orifices and other restrictions used to achieve final balanced flows.
   8. Description of final location and opening positions of dampers, registers, louvers, and valves.
   9. Schematics of systems included in report; use schematics as part of testing, adjusting, and balancing report to summarize design and final balanced flows.
   10. Testing, adjusting, and balancing report forms.
   11. Final field results established for system balancing, including airflow, fan speeds, and fan static pressures at the fan inlet and outlet.
   12. Appendices.
      a. Raw field data taken during testing.
      b. Sample calculation sheet for each type of calculation made to convert raw field data to final results.
      c. Initial air balance results with dampers and registers in full open position; include airflow at all inlets and outlet, initial fan speed, and fan suction and discharge pressures.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 EXAMINATION

A. Work of testing, adjusting, and balancing of heating, ventilation, and air conditioning systems to be by an independent testing agency and a certified member in good standing with AABC, NEBB, or TABB.

B. Field testing to be performed or directly supervised by personal who have passed a test and balance course or exam and is an AABC, NEBB, or TABB certified supervisor.

3.02 PREPARATION

A. Prior to start of testing, adjusting, and balancing, verify that:
   1. System installation is complete in accordance with the requirements for completed equipment installations specified in Section 11395A - Packaged Odor Control System and capable of full operation.

2. Outside conditions are within reasonable range relative to design conditions.
3. Lighting fixtures are energized.
4. Special equipment such as computers, laboratory equipment, and electronic equipment are in full operation.
5. Requirements for preparation for testing and balancing have been met for elements of each system which require testing.

3.03 FIELD QUALITY CONTROL

A. Test, adjust, and balance the complete odor control system.
   1. Include existing heating, ventilating, and air conditioning components when affected by the Work.

B. Perform testing, adjusting, and balancing cycles until airflows extraction from each unit process meets specifications criteria.
   1. Ascertain airflow balance between overall requirements and flow in individual supply and exhaust grilles.

C. Initial testing, adjusting, and balancing:
   1. Test each system with dampers, grilles, orifices, and other variable airflow devices in their full open position; measure and report initial airflows, fan speed, and fan static pressures at fan inlet and outlet.
   2. Adjust total system flow downward or upward by adjusting fan speed until one inlet or outlet is at indicated flow and all other flows exceed indicated flows.
   3. Adjust fan speed by changing fan drives or sheaves as necessary.

D. Subsequent testing, adjusting, and balancing:
   1. Perform adjustments by adjusting dampers, louvers, or size of orifices or plates.
   2. Measure and record air volume discharged at each inlet and outlet and adjust air inlets and outlets to design air volumes within 0 to 5 percent over design rates.
   3. Adjust fan speeds and motor drives within drive limitations, for required air volume.
   4. Measure air flow and static pressures and adjust air supply and exhaust fan units to deliver at least 100 to 105 percent of the design air volume.
   5. Measure and record static air pressure conditions on fans, including filter and coil pressure drops and total pressure across the fan.
   6. Evaluate unit process pressure conditions to determine adequate supply air conditions.
   7. Permanently mark final balance positions of balancing dampers.

E. Develop heating, ventilating, and air conditioning system schematics similar to Figure 6-1 in SMACNA Testing, Adjusting, and Balancing.

F. Accurately record the required data on AABC, NEBB, or TABB test and balance report forms.

G. Measure amperage draw of fan and pump motors at final balance.

H. Test primary source equipment in accordance with AABC, NEBB, or TABB procedures.
   1. Primary source equipment includes items listed in this Section not previously tested as part of this testing, adjusting, and balancing work.
   2. Complete appropriate AABC, NEBB, or TABB equipment test forms for each piece of equipment.
   3. Adjust equipment as needed to deliver specified extraction and performance loads.
   4. Record final equipment performing characteristics and adjustment settings in the final design report.

I. Testing, adjusting, and balancing acceptance criteria:
   1. Procedures successful and complete when odor control systems and components are functioning properly and within specified tolerances of design flows.

END OF SECTION

SECTION 15956

PIPING SYSTEMS TESTING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Test requirements for piping systems.

1.02 REFERENCES

A. American Water Work Association (AWWA):
   1. C600-17 - Installation of Ductile Iron Mains and Their Appurtenances.
   2. C605-21 - Underground Installation of PVC and PVCO Pressure Pipe and Fittings.

B. Underwriters Laboratories Inc. (UL).

1.03 TESTING REQUIREMENTS

A. General requirements:
   1. Testing requirements are stipulated in laws and regulations, specified in the Pipe Schedule in Section 15052 - Common Work Results for General Piping, specified in the Specifications covering the various types of piping, and are specified in this Section.
   2. Requirements in laws and regulations supersede other requirements of the Contract Documents, except where requirements of the Contract Documents are more stringent, including higher test pressures, longer test times, and lower leakage allowances.
   3. Test plumbing piping in accordance with laws and regulations, the plumbing code, as specified in Section 01410 - Regulatory Requirements, and UL requirements.
   4. Air test of natural gas piping:
      a. For less than 125 pounds per square inch gauge working pressure, test in accordance with mechanical code, as specified in Section 01410 - Regulatory Requirements, or the National Fuel Gas Code, whichever is more stringent.
   5. Air test of digester gas piping shall not exceed 25 psi.
   6. When testing with water, the specified test pressure is considered to be the pressure at the lowest point of the piping section under test.
      a. Lower test pressure as necessary (based on elevation) if testing is performed at a higher point of the pipe section.

B. Furnish necessary personnel, materials, and equipment, including bulkheads, restraints, anchors, temporary connections, pumps, water, pressure gauges, and other means and facilities required to perform tests.

C. Water for testing, cleaning, and disinfecting:
   1. As specified in Section 01500 - Temporary Facilities and Controls.
      a. Use potable water for all potable waterlines.
      b. Use 3W for all other pipes.

D. Pipes to be tested:
   1. Test only those portions of pipes that have been installed as part of this Contract.
   2. Test new pipe sections prior to making final connections to existing piping.
   3. Furnish and install test plugs, bulkheads, and restraints required to isolate new pipe sections.
   4. Do not use existing valves as test plug or bulkhead.

E. Unsuccessful tests:
   1. Correct defects or remove defective piping and appurtenances and install piping and appurtenances that comply with the specified requirements.
   2. Repeat testing until tests are successful.

F. Test completion: Drain and leave piping clean after successful testing.

G. Test water disposal:
   1. Dispose of testing water as directed by Owner in accordance with requirements of federal, state, county, and city regulations governing disposal of wastes in the location of the Project and disposal site.
   2. Requirements and costs associated with notifications and obtaining any discharge permit or approvals shall be the responsibility of the Contractor.

1.04 SUBMITTALS

A. Furnish Submittals as specified in Section 01300 - Submittals.

B. Schedule and notification of tests:
   1. Submit a list of scheduled piping tests by noon of the working day preceding the date of the scheduled tests.
   2. Notification of readiness to test: Immediately before testing, notify the Engineer in writing of readiness, not just intention, to test piping.
   3. Have personnel, materials, and equipment specified in place before submitting notification of readiness.

C. Pipe system test report:
   1. Submit a report for all piping tested. At a minimum, the test report shall include the following information:
      a. Description of piping being tested:
         1) Pipe material.
         2) Section of piping being tested:
            a) Date and time of pipe test.
            b) Name of person performing the pipe test.
            c) Specified test method and testing requirements (low-head, high-head, test pressure, test duration, etc.).
            d) Initial test pressure and time of pressure.
            e) Final test pressure and time of pressure.

f) Status of test: Pass or fail.
g) Signature of the Contractor and Owner's representative that witnessed the pipe test.

1.05 SEQUENCE

A. Clean piping before pressure or leak tests.

B. Test gravity piping underground, including sanitary sewers, for visible leaks before backfilling and compacting.

C. Underground pressure piping may be tested before or after backfilling when not indicated or specified otherwise.

D. Backfill and compact trench or provide blocking that prevents pipe movement before testing underground piping with a maximum leakage allowance.

E. Test underground piping before encasing piping in concrete or covering piping with slab, structure, or permanent improvement.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 TESTING ALIGNMENT, GRADE, AND DEFLECTION

A. Alignment and grade:
1. Visually inspect the interior of gravity piping with artificial light, reflected light, or laser beam.
2. Consider inspection complete when no broken or collapsed piping, no open or poorly made joints, no grade changes that affect the piping capacity, or no other defects are observed.

B. Deflection test:
1. Pull a mandrel through the clean piping section under test.
2. Perform the test not sooner than 30 days after installation and not later than 60 days after installation.
3. Use a 9-rod mandrel with a contact length of not less than the nominal diameter of the pipe within 1 percent plus or minus.
4. Consider test complete when the mandrel can be pulled through the piping with reasonable effort by 1 person, without the aid of mechanical equipment.

3.02 AIR TESTING METHOD FOR PRESSURE PIPING

A. Air test piping, indicated with "AM" in the Pipe Schedule, with air or another nonflammable or inert gas.

B. Test gas, air, liquefied petroleum gas, liquid chlorine, and chlorine gas piping by the air test method:
    1. Test chlorine piping with dry air or nitrogen having a dew point of -40 degrees Fahrenheit or less. Supply temporary air dryers as necessary.

C. Test at pressure as specified in the Pipe Schedule in Section 15052 - Common Work Results for General Piping:
    1. Provide temporary pressure relief valve for piping under test:
        a. Set at 110 percent of the test pressure.
    2. Gradually increase test pressure to an initial pressure of 1/2 the test pressure and inspect joint seals for leaks. If no leaks are found, gradually increase test pressure in 10 percent increments until target pressure is reached.
    3. At each step in the pressure, examine and test piping for leaks with soap solution.
    4. Consider examination complete when the piping section under test holds the test pressure for 15 minutes without losses.

3.03 TESTING GRAVITY FLOW PIPING

A. Test gravity flow piping, indicated with “GR” in the Pipe Schedule, as follows:
    1. Unless specified otherwise, subject gravity flow piping to the following tests:
        a. Alignment and grade.
        b. For plastic piping test for deflection.
        c. Visible leaks and pressure with maximum leakage allowance, except for storm drains and culverts.
    2. Inspect piping for visible leaks before backfilling.
    3. Provide temporary restraints when needed to prevent movement of piping.
    4. Pressure test piping with maximum leakage allowance after backfilling.
    5. With the lower end plugged, fill piping slowly with water while allowing air to escape from high points. Keep piping full under a slight head for the water at least 24 hours:
        a. Examine piping for visible leaks. Consider examination complete when no visible leaks are observed.
        b. Maintain piping with water or allow a new water absorption period of 24 hours for the performance of the pressure test with maximum leakage allowance.
        c. After successful completion of the test for visible leaks and after the piping has been restrained and backfilled, subject piping to the test pressure for a minimum of 4 hours while accurately measuring the volume of water added to maintain the test pressure:
            1) Consider the test complete when leakage is equal to or less than the following maximum leakage allowances:
                a) For concrete piping with rubber gasket joints: 80 gallons per day per inch of diameter per mile of piping under test:
                    (1) Advise the manufacturer of concrete piping with rubber gasket joints of more stringent than normal maximum leakage allowance.
                b) For vitrified clay piping: 500 gallons per day per inch of diameter per mile of piping under test.
                c) For polyvinyl chloride (PVC) gravity sewer pipe: 25 gallons per day per inch diameter per mile of piping under test.

d) For other piping: 80 gallons per day per inch diameter per mile of piping under test.

3.04 TESTING HIGH-HEAD PRESSURE PIPING

A. Test piping for which the specified test pressure in the Pipe Schedule is 20 pounds per square inch gauge or greater, by the high head pressure test method, indicated with “HH” in the Pipe Schedule.

B. General:
   1. Test connections, hydrants, valves, blowoffs, and closure pieces with the piping.
   2. Do not use installed valves for shutoff when the specified test pressure exceeds the valve’s maximum allowable seat differential pressure. Provide blinds or other means to isolate test sections.
   3. Do not include valves, equipment, or piping specialties in test sections if test pressure exceeds the valve, equipment, or piping specialty safe test pressure allowed by the item’s manufacturer.
   4. During the performance of the tests, test pressure shall not vary more than plus or minus 5 pounds per square inch gauge with respect to the specified test pressure.
   5. Select the limits of testing to sections of piping. Select sections that have the same piping material and test pressure.
   6. When test results indicate failure of selected sections, limit tests to piping:
      a. Between valves.
      b. Between a valve and the end of the piping.
      c. Less than 500 feet long.
   7. Test piping for a minimum of 2 hours for visible leaks test and a minimum of 2 hours for the pressure test with maximum leakage allowance.

C. Testing procedures:
   1. Fill piping section under test slowly with water while venting air.
   2. Before pressurizing for the tests, retain water in piping under slight pressure for a water absorption period of a minimum of 24 hours.
   3. Raise pressure to the specified test pressure and inspect piping visually for leaks:
      a. Consider visible leakage testing complete when no visible leaks are observed.

D. Pressure test with maximum leakage allowance:
   1. Leakage allowance is zero for piping systems using flanged, National Pipe Thread threaded and welded joints.
   2. Pressure test piping after completion of visible leaks test.
   3. For piping systems using joint designs other than flanged, threaded, or welded joints, accurately measure the makeup water necessary to maintain the pressure in the piping section under test during the pressure test period:
      a. Consider the pressure test to be complete when makeup water added is less than the allowable leakage and no damage to piping and appurtenances has occurred.
      b. Successful completion of the pressure test with maximum leakage allowance shall be achieved when the observed leakage during the test

period is equal or less than the allowable leakage and no damage to piping and appurtenances has occurred.

c. When leakage is allowed, calculate the allowable leakage in accordance with AWWA C605-21 or AWWA C600-17 by using the following formula:

$$L = \frac{\mathrm{SD}\sqrt{\mathrm{P}}}{148{,}000}$$

wherein the terms shall mean:

L = Allowable leakage in gallons per hour.

S = Length of the test section in feet.

D = Nominal diameter of the piping in inches.

P = Average observed test pressure in pounds per square inch gauge, at the lowest point of the test section, corrected for elevation of the pressure gauge.

3.05 TESTING LOW-HEAD PRESSURE PIPING

A. Test piping for which the specified test pressure is less than 20 pounds per square inch gauge, by the low head pressure test method, indicated with “LH” in the Pipe Schedule.

B. General:
   1. Test pressures shall be as scheduled in Section 15052 - Common Work Results for General Piping.
   2. During the performance of the tests, test pressure shall not vary more than plus or minus 2 pounds per square inch gauge with respect to the specified test pressure.
   3. Test connections, blowoffs, vents, closure pieces, and joints into structures, including existing bell rings and other appurtenances, with the piping.
   4. Test piping for a minimum of 2 hours for visible leaks test and a minimum of 2 hours for the pressure test with maximum leakage allowance.

C. Visible leaks test:
   1. Subject piping under test to specified pressure measured at the lowest end.
   2. Fill piping section under test slowly with water while venting air:
      a. Use potable water for all potable waterlines and where noted on the Pipe Schedule.
   3. Before pressurizing for the tests, retain water in piping under slight pressure for the water absorption period of a minimum of 24 hours.
   4. Raise pressure to the specified test pressure and inspect piping visually for leaks. Consider testing complete when no visible leaks are observed.

D. Pressure test with maximum leakage allowance:
   1. Pressure test piping after completion of visible leaks test.
   2. Accurately measure the makeup water necessary to maintain the pressure in the piping section under test during the pressure test period:
      a. Consider the pressure test to be complete when makeup water added is less than the allowable leakage of 80 gallons per inch of nominal

diameter, per mile of piping section under test after 24 hours, and no damage to piping and appurtenances has occurred.

b. Successful completion of the leakage test shall have been achieved when the observed leakage is equal or less than the allowable leakage and no damage to piping and appurtenances has occurred.

E. Optional joint test:
   1. When joint testing is allowed by note in the Pipe Schedule, the procedure shall be as follows:
      a. Allowed only for low head pressure piping.
      b. Does not replace and is not in lieu of any testing of the piping system or trust restraints.
   2. May be performed with water or air.
   3. Joint test piping after completion of backfill and compaction to the top of the trench.
   4. Joint testing with water:
      a. Measure test pressure at the invert of the pipe. Apply pressure of 4 feet plus the inside diameter of the pipe in water column within 0.20 feet in water column.
      b. Maintain test pressure for 1 minute.
      c. Base the allowable leakage per joint on 80 gallons per inch nominal diameter, per mile of piping, per 24 hours equally distributed to the actual number of joints per mile for the type of piping.
      d. Consider the pressure test to be complete when makeup water added is less than the allowable leakage.
      e. Successful completion of the joint test with water shall have been achieved when the observed leakage is equal or less than the allowable leakage.
   5. Joint testing with air:
      a. Apply test pressure of 3 pounds per square inch gauge with a maximum variation of plus 0.20 and minus 0.00 pounds per square inch.
      b. Maintain test pressure for 2 minutes.
      c. Consider the pressure test to be complete when the test pressure does not drop below 2.7 pounds per square inch for the duration of the test.

END OF SECTION

SECTION 15958

MECHANICAL EQUIPMENT TESTING

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
   1. Testing of mechanical equipment and systems.

1.02 REFERENCES

A. American Gear Manufacturers Association:
   1. AGMA 6000-B96 - Specification for Measurement of Linear Vibration on Gear Units.

B. American National Standards Institute (ANSI):
   1. S1.4 - Specification for Sound Level Meters.

C. Hydraulic Institute (HI).

D. National Institute of Standards and Technology (NIST).

1.03 SUBMITTALS

A. Provide Source Test Plans as specified in Section 01660 - Equipment and System Performance and Operational Testing.

B. Provide Installation and Functional Testing Plans as specified in Section 01660 - Equipment and System Performance and Operational Testing.

C. Operation and maintenance manuals:
   1. As specified in Section 01670 - Operations, Maintenance, and Training Requirements.
   2. Include motor rotor bar pass frequencies for motors larger than 500 horsepower.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.01 GENERAL

A. Commissioning of equipment as specified in:
   1. This Section.
   2. Section 01660 - Equipment and System Performance and Operational Testing.
   3. Equipment sections:
      a. If testing requirements are not specified, provide Level 1 tests.

B. Test and prepare piping as specified in Section 15956 - Piping Systems Testing prior to equipment testing.

C. Operation of related existing equipment:
   1. Owner will operate related existing equipment or facilities necessary to accomplish the testing.
   2. Schedule and coordinate testing as specified in Section 01660 - Equipment and System Performance and Operational Testing.

D. Provide necessary test instrumentation that has been calibrated within 1 year from date of test to recognized test standards traceable to the NIST or approved source.
   1. Properly calibrated field instrumentation permanently installed as a part of the Work may be utilized for tests.
   2. Prior to testing, provide signed and dated certificates of calibration for test instrumentation and equipment.

E. Test measurement and result accuracy:
   1. Use test instruments with accuracies as recommended in the appropriate referenced standards. When no accuracy is recommended in the referenced standard, use 1 percent or better accuracy test instruments.
      a. Improved (lower error tolerance) accuracies specified elsewhere prevail over this general requirement.
   2. Do not adjust results of tests for instrumentation accuracy.
      a. Measured values and values directly calculated from measured values shall be the basis for comparing actual equipment performance to specified requirements.

3.02 VARIABLE SPEED EQUIPMENT TESTS

A. Establish performance over the entire speed range and at the average operating condition.

B. Establish performance curves for the following speeds:
   1. Speed corresponding to the rated maximum capacity.
   2. Speed corresponding to the minimum capacity.
   3. Speed corresponding to the average operating conditions.

3.03 PUMP TESTS - ALL LEVELS OF TESTING

A. Test in accordance with the following:
   1. Applicable HI standards.
   2. This Section.
   3. Equipment sections.

B. Test tolerances: In accordance with appropriate HI standards, except the following modified tolerances apply:
   1. From 0 to plus 5 percent of head at the rated design point flow.
   2. From 0 to plus 5 percent of flow at the rated design point head.
   3. No tolerance for head and flow when ranges are specified.
   4. No negative tolerance for the efficiency at the rated design point, and other specified conditions.

5. Use of specified test tolerances shall not result in motor overload while operating at any point on the supplied pump operating head-flow curve, including runout.
6. No positive tolerance for vibration limits. Vibration limits and test methods in HI standards do not apply. Use limits and methods specified in this or other sections of the Specifications.

3.04 DRIVERS TESTS

A. Test motors as specified in Section 16100 - Electrical Requirements.

B. Test other drivers as specified in the equipment section.

3.05 NOISE REQUIREMENTS AND CONTROL

A. Perform noise tests in conjunction with vibration test analysis.

B. Make measurements in relation to reference pressure of 0.0002 microbar.

C. Make measurements of emitted noise levels on sound level meter meeting or exceeding ANSI S1.4, Type II.

D. Set sound level meter to slow response.

E. Unless otherwise specified, maximum free field noise level not to exceed 85 dBA measured as sound pressure level at 3 feet from the equipment.

3.06 PRESSURE TESTING

A. Hydrostatically pressure test pressure containing parts at the appropriate standard or code required level above the equipment component specified design pressure or operating pressure, whichever is higher.

3.07 INSPECTION AND BALANCING

A. Statically and dynamically balance each of the individual rotating parts as required to achieve the required field vibration limits.

B. Statically and dynamically balance the completed equipment rotating assembly and drive shaft components.

C. Furnish copies of material and component inspection reports, including balancing reports for equipment system components and for the completed rotating assembly.

D. Critical speed of rotating equipment:
   1. Satisfy the following:
      a. The first lateral and torsional critical speed of all constant, variable, and 2-speed driven equipment that is considered rigid such as horizontal pumps, non-clog pumps, blowers, air compressors, and engines shall be at least 25 percent above the equipment's maximum operating speed.
      b. The first lateral and torsional critical speed of all constant, variable, and 2-speed driven equipment that is considered flexible or flexibly mounted

such as vertical pumps (vertical in-line and vertical non-clog pumps excluded) and fans shall at least 25 percent below the equipment's lowest operating speed.

c. The second lateral and torsional critical speed of all constant, variable, and 2-speed equipment that is considered flexible or flexibly mounted shall be at least 25 percent above the maximum operating speed.

E. Vibration tests:

1. Definitions:
   a. Root mean square: For pumps operating at speeds greater than 600 revolutions per minute (rpm), the vibration measurement shall be measured as the overall velocity in inches per second root mean square (RMS).
   b. Peak-to-peak displacement: The root means squared average of the peak-to-peak displacement multiplied by the square root of 2.
   c. Peak velocity: The root mean squared average of the peak velocity multiplied by the square root of 2.
   d. Peak acceleration: The root mean squared average of the peak acceleration multiplied by the square root of 2.
   e. High-frequency enveloping: A process to extract very low amplitude time domain signals associated with impact or impulse events such as bearing or gear tooth defects and display them in a frequency spectrum of acceleration versus frequency.
      1) Manufacturers: One of the following or equal:
         a) CSI, PeakVue.
         b) Rockwell Automation, Entek Group, Spike Energy analysis.
   f. Rotor bar pass frequency (RBF): For detecting loose rotor bars.
   g. Low speed equipment: Equipment or components of equipment rotating at less than 600 rpm.
   h. High speed equipment: Equipment and equipment components operating at or above 600 rpm.
   i. Preferred operating range: Manufacturer's defined preferred operating range (POR) for the equipment.
   j. Allowable operating range: Manufacturer's defined allowable operating range (AOR) for the equipment.
2. Vibration instrumentation requirements:
   a. Analyzers: Use digital type analyzers or data collectors with anti-aliasing filter, 12-bit A/D converter, fast Fourier transform circuitry, phase measurement capability, time wave form data storage, high-frequency enveloping capabilities, 35 frequency ranges from 21 to 1,500,000 cycles per minute, adjustable fast Fourier transform resolution from 400 to 6,400 lines, storage for up to one hundred 3,200 line frequency spectra, data output port, circuitry for integration of acceleration data to velocity or double integration to displacement.
      1) Manufacturers: One of the following or equal:
         a) Computational Systems Inc., (CSI) Division of Emerson Process Management, Model 2120A, Data Collector/analyzer with applicable analysis software.
         b) Pruftechnik, VIBXPERT II.
   b. Analyzer settings:
      1) Units: English, inches/second, mils, and gravitational forces.

2) Fast Fourier transform lines: Most equipment 1,600 minimum; for motors, enough lines as required to distinguish motor current frequencies from rotational frequencies, use 3,200 lines for motors with a nominal speed of 3,600 rpm; 3,200 lines minimum for high-frequency enveloping; 1,600 lines minimum for low speed equipment.
3) Sample averages: 4 minimum.
4) Maximum frequency (Fmax): 40 times rotational frequency for rolling element bearings, 10 times rotational frequency for sleeve bearings.
5) Amplitude range: Auto select but full scale not more than twice the acceptance criteria or the highest peak, whichever is lower.
6) Fast Fourier transform windowing: Hanning window.
7) High pass filter: Minus 3 dB at 120 cycles per minute for high speed equipment. Minus 3 dB at 21 cycles per minute for low speed equipment.

c. Accelerometers:
1) For low speed equipment: Low frequency, shear mode accelerometer, 500 millivolts per gravitational force sensitivity, 10 gravitational force range, plus/minus 5 percent frequency response from 0.5 hertz to 850 hertz, magnetic mount.
a) Manufacturers: One of the following or equal:
(1) PCB, Model 393C.
(2) Wilcoxon Research, Model 797L.
2) For high speed equipment: General purpose accelerometer, 100 millivolts per gravitational force sensitivity, 50 gravitational force range, plus/minus 3 dB frequency response range from 2 hertz to 12,000 hertz when stud mounted, with magnetic mount holder.
a) Manufacturers: One of the following or equal:
(1) Entek-IRD, Model 943.
(2) Wilcoxon Research, Model 793.

3. Accelerometer mounting:
a. Use magnetic mounting or stud mounting.
b. Mount on bearing housing in location with best available direct path to bearing and shaft vibration.
c. Remove paint and mount transducer on flat metal surface or epoxy mount for high-frequency enveloping measurements.

4. Vibration acceptance criteria:
a. Testing of rotating mechanical equipment: Tests are to be performed by an experienced, factory trained, and independent authorized vibration analysis expert.
b. Vibration displacement limits: Unless otherwise specified, equipment operating at speeds 600 rpm or less is not to exhibit unfiltered readings in excess of the following:

Operating Conditions and Application Data	Overall Peak-to-Peak Displacement	
	Field (mils)	Factory (mils)
Operation within the POR	3.0	4.0
Operation within the AOR	4.0	5.0

Operating Conditions and Application Data	Overall Peak-to-Peak Displacement	
	Field (mils)	Factory (mils)
Additive value when measurement location is greater than 5 feet above foundation.	2.0	2.0
Additive value for solids-handling pumps	2.0	N/A
Additive value for slurry pumps	2.0	N/A

c. Vibration velocity limits: Unless otherwise specified, equipment operating at speeds greater than 600 rpm is not to exceed the following peak velocity limits:

HI Pump Type	Horsepower	Field Test	Factory Test
		Overall RMS	Overall RMS
Horizontal Solids Handling Centrifugal Pumps	Below 33 hp	0.25	0.28
Horizontal and Vertical In-Line Centrifugal Pumps (other than Non-Clog type)	Between 33 and 100 hp	0.28	0.31
	100 hp and above	0.31	0.34
Vertical Solids Handling Centrifugal Pumps	Below 33 hp	0.30	0.33
Vertical Turbine, Mixed Flow, and Propeller Pumps (solids-handling type pumps)	Between 33 and 100 hp	0.32	0.35
	100 hp and above	0.34	0.35
Non-Solids Handling Centrifugal Pumps HI Types BB1, BB2, BB3, BB4, BB5, OH1, OH2, OH3, OH4, OH5, and OH7	Below 268 hp	0.15	0.19
	268 hp and above	0.19	0.22
Vertical Turbine, Mixed Flow, and Propeller Pumps HI Types VS1, VS2, VS3, VS4, VS5, VS6, VS7, and VS8	Below 268 hp	0.13	
	268 hp and above	0.17	
Slurry Pumps		0.25	0.30
Motors		See applicable motor Specification	See applicable motor Specification
Gear Reducers, Radial		Not to exceed AGMA 6000-B96 limits	Not to exceed AGMA 6000-B96 limits
Other Reducers, Axial		0.1	N/A

d. Equipment operation: Measurements are to be obtained with equipment installed and operating within capacity ranges specified and without duplicate equipment running.

e. Additional criteria:
    1) No narrow band spectral vibration amplitude components, whether sub-rotational, higher harmonic, or synchronous multiple of running speed, are to exceed 40 percent of synchronous vibration amplitude component without the manufacturer's detailed verification of origin and ultimate effect of such excitation.
    2) The presence of discernable vibration amplitude peaks in test Level 2 or 3 vibration spectra at bearing inner or outer race frequencies shall be cause for rejection of the equipment.
    3) For motors, the following shall be cause for rejection:
        a) Stator eccentricity evidenced by a spectral peak at 2 times electrical line frequency that is more than 40 percent of the peak at rotational frequency.
        b) Rotor eccentricity evidenced by a spectral peak at 2 times electrical line frequency with spectra side bands at the pole pass frequency around the 2 times line frequency peak.
        c) Other rotor problems evidenced by pole pass frequency side bands around operating speed harmonic peaks or 2 times line frequency side bands around rotor bar pass frequency or around 2 times the rotor bar pass frequency.
        d) Phasing problems evidenced by 1/3 line frequency side band spectral peaks around the 2 times electrical line frequency peak.
    4) The presence of peaks in a high-frequency enveloping spectra plot corresponding to bearing, gear or motor rotor bar frequencies or harmonics of these frequencies shall be cause for rejection of the equipment; since inadequate lubrication of some equipment may be a cause of these peaks, lubrication shall be checked, corrected as necessary and the high-frequency envelope analysis repeated.

5. Vibration testing results presentation:
    a. Provide equipment drawing with location and orientation of measurement points indicated.
    b. For each vibration measurement take and include appropriate data on equipment operating conditions at the time vibration data is taken; for pumps, compressors, and blowers record suction pressure, discharge pressure, and flow.
    c. When vibration spectra data required:
        1) Plot peak vibration velocity versus frequency in cycles per minute.
        2) Label plots showing actual shaft or part rotation frequency, bearing inner and outer race ball pass frequencies, gear mesh frequencies and relevant equipment excitation frequencies on the plot; label probable cause of vibration peaks whether in excess of specification limits or not.
        3) Label plots with equipment identification and operating conditions such as tag number, capacity, pressure, driver horsepower, and point of vibration measurement.
        4) Plot motor spectra on a log amplitude scale versus frequency.
    d. For low speed equipment, plot peak vibration displacement versus frequency as well as velocity versus frequency.
    e. Provide name of the manufacturer and model number of the vibration instrumentation used, including analyzer and accelerometer used together with mounting type.

3.08 TESTING LEVELS

A. Level 1 tests:
   1. Level 1 Performance Test:
      a. General:
         1) For equipment, operate, rotate, or otherwise functionally test for 15 minutes minimum after components reach normal operating temperatures.
         2) Operate at rated design load conditions.
         3) Confirm that equipment is properly assembled.
         4) Confirm the equipment moves or rotates in the proper direction.
         5) Confirm shafting, drive elements, and bearings are installed and lubricated in accordance with proper tolerances.
         6) Confirm that no unusual power consumption, lubrication temperatures, bearing temperatures, or other conditions are observed.
      b. Pumps:
         1) In accordance with general performance test requirements as specified in this Section.
         2) Measure flow and head while operating at or near the rated condition; for factory testing, testing may be at reduced speeds with flow and head corresponding to the rated condition when adjusted for speed using the appropriate affinity laws.
            a) Use of a test driver is permitted for factory tests when actual driver is given a separate test at its point of manufacture as specified in Section 16100 - Electrical Requirements, or the applicable equipment section.
            b) Use actual driver for field tests.
         3) Record measured flow, suction pressure, discharge pressure, and make observations on bearing temperatures and noise levels.
   2. Level 1 Vibration Test:
      a. Test requirement:
         1) Measure filtered vibration spectra versus frequency in 3 perpendicular planes at each normally accessible bearing housing on the driven equipment, any gears and on the driver; 1 plane of measurement to be parallel to the axis of rotation of the component.
         2) Vibration spectra versus frequency shall be in accordance with vibration acceptance criteria.
      b. Equipment operating condition: Test at specified maximum speed.
   3. Level 1 Noise Test:
      a. Measure unfiltered overall A-weighted sound pressure level in dBA at 3 feet horizontally from the surface of the equipment and at a mid-point of the equipment height.

B. Level 2 tests:
   1. Level 2 Performance Test:
      a. General:
         1) For equipment, operate, rotate, or otherwise functionally test for at least 2 hours after components reach normal operating temperatures.
         2) Operate at rated design load conditions.
         3) Confirm that equipment is properly assembled.
         4) Confirm the equipment moves or rotates in the proper direction.

5) Confirm shafting, drive elements, and bearings are installed and lubricated in accordance with proper tolerances.
6) Confirm that no unusual power consumption, lubrication temperatures, bearing temperatures, or other conditions are observed.

b. Pumps:
1) In accordance with general performance test requirements as specified in this Section.
2) Test 2 hours minimum for flow and head at the rated condition; for factory testing, testing may be at a reduced speeds with flow and head corresponding to the rated condition when adjusted for speed using the appropriate affinity laws.
a) Use of a test driver is permitted for factory tests when actual driver is given a separate test at its point of manufacture as specified in Section 16100 - Electrical Requirements.
b) Use actual driver for field tests.
3) Test for flow and head at 2 additional conditions; one at 25 percent below the rated flow and one at 10 percent above the rated flow.
4) Record measured flow, suction pressure, discharge pressure, and observations on bearing temperatures and noise levels at each condition.

2. Level 2 Vibration Test:
a. Test requirement:
1) Measure filtered vibration spectra versus frequency and measure vibration phase in 3 perpendicular planes at each normally accessible bearing housing on the driven equipment, any gears and on the driver; 1 plane of measurement to be parallel to the axis of rotation of the component; measure actual rotational speeds for each vibration spectra measured using photometric or other tachometer input connected directly to the vibration data collector.
2) Vibration spectra versus frequency shall be in accordance with vibration acceptance criteria.

b. Equipment operating condition: Repeat test requirements at design specified maximum speed and at minimum speed for variable speed equipment.

c. Natural frequency test of field installed equipment:
1) Excite the installed equipment and support system in 3 perpendicular planes, use same planes as operating vibration measurement planes, and determine the as-installed natural resonant frequency of the driven equipment, the driver, gears, and supports.
2) Perform test at each bearing housing, at each support pedestal, and for pumps on the suction and discharge piping.
3) Perform with equipment and attached piping full of intended service or process fluid.

3. Level 2 Noise Test:
a. Measure filtered A-weighted overall sound pressure level in dBA for each of 8 octave band mid-points beginning at 63 hertz, measured at 3 feet horizontally from the surface of the equipment at mid-point height of the noise source.

C. Level 3 tests:
   1. Level 3 Performance Tests:
      a. General:
         1) For equipment, operate, rotate, or otherwise functionally test for at least 4 hours after components reach normal operating temperatures.
         2) Operate at rated design load conditions for 1/2 the specified time; operate at each of any other specified conditions for a proportionate share of the remaining test time.
         3) Confirm that equipment is properly assembled.
         4) Confirm the equipment moves or rotates in the proper direction.
         5) Confirm shafting, drive elements, and bearings are installed and lubricated in accordance with proper tolerances.
         6) Confirm that no unusual power consumption, lubrication temperatures, bearing temperatures, or other conditions are observed.
         7) Take appropriate capacity, power or fuel consumption, torque, revolutions per minute, pressure, and temperature readings using appropriate test instrumentation to confirm equipment meets specified performance requirements at the design rated condition.
         8) Bearing temperatures: During maximum speed or capacity performance testing, measure and record the exterior surface temperature of each bearing versus time.
      b. Pumps:
         1) In accordance with general performance test requirements as specified in this Section.
         2) Test 4 hours minimum for flow and head; begin tests at or near the rated condition; for factory and field-testing, test at full speed.
            a) Use of a test driver is permitted for factory tests when actual driver is given a separate test at its point of manufacture as specified in Section 16100 - Electrical Requirements
            b) Use actual driver for field tests.
         3) Test each specified flow and head condition at the rated speed and test at minimum as well as maximum specified speeds; operate at each test condition for a minimum of 15 minutes or longer as necessary to measure required performance, vibration, and noise data at each test condition.
         4) Record measured shaft revolutions per minute, flow, suction pressure, discharge pressure; record measured bearing temperatures (bearing housing exterior surface temperatures may be recorded when bearing temperature devices are not required by the equipment section) and record observations on noise levels.
         5) Perform efficiency and/or net positive suction head required (NPSHr) and/or priming time tests when specified in the equipment section in accordance with the appropriate HI standard and as follows:
            a) Perform NPSHr testing at maximum rated design speed, head and flow with test fluids at ambient conditions; at maximum rated speed, test at 15 percent above rated design flow, and 25 percent below rated design flow.
            b) Perform efficiency testing with test fluids at maximum rated speed.
            c) Perform priming time testing with test fluids at maximum rated speed.

2. Level 3 Vibration Test:
    a. Requirements: Same as Level 2 vibration test, except data taken at each operating condition tested and with additional requirements below.
    b. Perform high-frequency enveloping analysis for gears and bearings.
        1) Measure bearing element vibration directly on each bearing cap in a location close as possible to the bearing load zone that provides a smooth surface and direct path to the bearing to detect bearing defects.
        2) Report results in units of acceleration versus frequency in cycles per minute.
    c. Perform time wave form analysis for gears, low speed equipment and reciprocating equipment; plot true peak amplitude velocity and displacement versus time and label the period between peaks with the likely cause of the periodic peaks (relate the period to a cause).
    d. Plot vibration spectra on 3 different plots; peak displacement versus frequency, peak acceleration versus frequency and peak velocity versus frequency.
3. Level 3 Noise Test:
    a. Measure filtered, un-weighted overall sound pressure level in dB at 3 feet horizontally from the surface of the equipment at mid-point height and at 4 locations approximately 90 degrees apart in plain view; report results for each of 8 octave band mid-points beginning at 63 hertz.

D. Level 4 tests:
1. Level 4 Performance Test:
    a. General:
        1) For equipment, operate, rotate, or otherwise functionally test for at least 8 hours after components reach normal operating temperatures.
        2) Operate at rated design load conditions for 1/2 the specified time; operate at each of any other specified conditions for a proportionate share of the remaining test time.
        3) Confirm that equipment is properly assembled.
        4) Confirm the equipment moves or rotates in the proper direction.
        5) Confirm shafting, drive elements, and bearings are installed and lubricated in accordance with proper tolerances.
        6) Confirm that no unusual power consumption, lubrication temperatures, bearing temperatures, or other conditions are observed.
        7) Take appropriate capacity, power or fuel consumption, torque, revolutions per minute, pressure and temperature readings, using appropriate test instrumentation to confirm equipment meets specified performance requirements at the design rated condition.
        8) Bearing temperatures: During maximum speed or capacity testing, measure and record the exterior surface temperature of each bearing versus time.
    b. Pumps:
        1) In accordance with general performance test requirements as specified in this Section.
        2) Test 8 hours minimum for flow and head; begin tests at or near the rated condition; for factory and field-testing, test with furnished motor at full speed.

3) Test each specified flow and head condition at the rated speed and test at minimum as well as maximum specified speeds; operate at each test condition for a minimum of 20 minutes or longer as necessary to measure required performance, vibration, and noise data at each test condition.
4) Record measured shaft revolutions per minute, flow, suction pressure, discharge pressure; record measured bearing temperatures (bearing housing exterior surface temperatures may be recorded when bearing temperature devices not required by the equipment section) and record observations on noise levels.
5) Bearing temperatures: During maximum speed or capacity testing, measure and record the exterior surface temperature of each bearing versus time.
6) Perform efficiency and/or NPSHr and/or priming time tests when specified in the equipment section in accordance with the appropriate HI standard and as follows:
    a) Perform NPSHr testing at maximum rated design speed, head and flow with test fluids at ambient conditions; at maximum rated speed, test at 15 percent above rated design flow, and 25 percent below rated design flow.
    b) Perform efficiency testing with test fluids at maximum rated speed.
    c) Perform priming time testing with test fluids at maximum rated speed.

2. Level 4 Vibration Test: Same as Level 3 Vibration Test.
3. Level 4 Noise Test: Same as Level 3 Noise Test, except with data taken at each operating condition tested.

END OF SECTION

Appendix A – Exhibit 1 Insurance Requirements for Construction Contracts

Insurance Requirements for Construction Contracts

INSURANCE REQUIREMENTS

Contractor shall procure and maintain for the duration of the contract insurance against claims for injuries to persons or damages to property which may arise from or in connection with the performance of the work hereunder and the results of that work by the Contractor, his agents, representatives, employees or subcontractors.

Minimum Limits of Insurance: The Contractor shall maintain limits no less than:

Commercial General Liability

- Commercial General Liability Insurance with $5,000,000 minimum limit per occurrence.
- If a general aggregate limit applies, either the general aggregate limit shall apply separately to this project/location or the general aggregate limit shall be twice the required occurrence limit.
- Commercial General Liability Additional Insured Endorsement naming the following as insured ***on 2001 or earlier issued endorsement forms***:
  "City of Manteca, its officers, officials, employees, agents, and volunteers".

Automobile Liability

If the vehicles are brought onto city facilities, covering any auto, or of Contractor has no owned autos, hired, and non-owned autos, the Contractor shall maintain automobile liability with limits no less than:

- Automobile Liability Insurance with $5,000,000 minimum limit per accident for bodily injury and property damage.
- Automobile Liability Additional Insured Endorsement naming the following as additional insured:
  "City of Manteca, its officers, officials, employees, agents, and volunteers".

Worker's Compensation

As required by the State of California, with Statutory Limits, and Employer's Liability Insurance with limit of no less than $1,000,000 per accident for bodily injury or disease.

Builder's Risk *(Course of Construction)*

Utilizing an "All Risk" (Special Perils) coverage form, with limits equal to the completed value of the project and no coinsurance penalty provisions.

Surety Bond

As described below

Professional Liability *(If Design/Build)*

Insurance appropriates to the Contractor's profession, with limit no less than $1,000,000 per occurrence or claim, $2,000,000 aggregate

Contractors' Pollution Legal Liability

And/or Asbestos Legal Liability and/or Errors and Omissions (if project involves environmental hazards) with limits no less than $1,000,000 per occurrence or claim, and $2,000,000 policy aggregate.

Other Insurance Provisions:

The insurance policies are to contain, or be endorsed to contain, the following provisions:

1. The City of Manteca, its officers, officials, employees, agents and volunteers are to be covered as insured's as respect to: liability arising out of work or operations performed by or on behalf of the Contractor including materials, parts, or equipment furnished in connection with such work operations. General liability coverage can be provided in the form of an endorsement to the Contractor's insurance (at least as broad as ISO form CG 20 10 11 85 or if not available, through the addition of both CG 20 10 and CG 20 37 if a later edition is used).
2. For any claims related to this contract, the Contractor's insurance coverage shall be primary insurance as respects the City, its officers, officials, employees, agents and volunteers. Any insurance or self-insurance maintained by the City, its officers, officials, employees, agents or volunteers, shall be excess of the Contractor's insurance and shall not contribute with it.
3. The applicant's insurance shall apply separately to each insured against whom claim is made or suit is brought, except with respect to the limits of the insurer's liability.
4. Each insurance policy required by this clause shall be endorsed to state that coverage shall not be suspended, voided, canceled by either party, reduced in coverage or in limits except after thirty (30) days prior written notice by certified mail, return receipt requested, has been given to the City of Manteca.

If the contractor maintains higher limits than the minimums shown above, the City of Manteca requires and shall be entitled to coverage for the higher limits maintained by the contractor. Any available insurance proceeds in excess of the specified minimum limits of insurance and coverage shall be available to the City of Manteca.

Deductibles and Self-Insured Retentions
Any deductibles or self-insured retentions must be declared to and approved by the City of Manteca. At the option of the City of Manteca, either: the contractor shall cause the insurer shall reduce or eliminate such deductibles or self-insured retentions as respects to the City of Manteca, its officers, officials, employees, agents and volunteers; or the Contractor shall provide a financial guarantee satisfactory to the City of Manteca guaranteeing payment of losses and related investigations, claim administration, and defense expenses.

Builder's Risk (Course of Construction) Insurance
Contractor may submit evidence of Builder's Risk insurance in the form of Course of Construction coverage. Such coverage shall name the City of Manteca as a loss payee as their interest may appear.

If the project does not involve new or major reconstruction, at the option of the City of Manteca, an Installation Floater may be acceptable. For such projects, a Property Installation Floater shall be obtained that provides for the improvement, remodel, modification, alteration, conversion or adjustment to existing buildings, structures, processes, machinery and equipment. The Property Installation Floater shall provide property damage coverage for any building, structure, machinery or equipment damaged, impaired, broken, or destroyed during the performance of the Work, including during transit, installation, and testing at the City of Manteca's site.

Claims Made Policies
If any coverage required is written on a claims-made coverage form:

1. The retroactive date must be shown, and this date must be before the execution date of the contract or the beginning of contract work.
2. Insurance must be maintained and evidence of insurance must be provided for at least five (5) years after completion of contract work.
3. If coverage is canceled or non-renewed, and not placed with another claims-made policy form with a retroactive date prior to the contract effective, or start or work date, the Contractor must purchase extended reporting period coverage for a minimum of five (5) years after completion of contract work.
4. A copy of the claims reporting requirements must be submitted to the City of Manteca for review.

5. If the services involve lead-based paint or asbestos identification/remediation, the Contractors Pollution Liability policy shall not contain lead-based paint or asbestos exclusions. If the services involve mold identification/remediation, the Contractors Pollution Liability policy shall not contain a mod exclusion, and the definition of Pollution shall include microbial matter, including mold.

Subcontractors
Contractor shall require and verify that all subcontractors maintain insurance meeting all the requirements stated herein, and Contractor shall ensure that the City of Manteca is an additional insured on insurance required from subcontractors. For CGL coverage subcontractors shall provide coverage with a format least as broad as CG 20 38 04 13.

Surety Bonds
Contractor shall provide Surety Bonds:
1. Bid bond
2. Performance bond
3. Payment bond
4. Maintenance bond

The Payment Bond and the Performance Bond shall be in a sum equal to the contract price. If the Performance Bond provides for a one-year warranty a separate Maintenance Bond is not necessary. If the warranty period specified in the contract is for longer than one year a Maintenance Bond equal to 10% of the contract price is required. Bonds shall be duly executed by a responsible corporate surety, authorized to issue such bonds in the State of California and secured through an authorized agent with an office in California.

Verification of Coverage
Contractor shall furnish the City with original certificates and amendatory endorsements or copies of the applicable policy language effecting coverage required by this clause. All certificates and endorsements are to be received an approved by the Entity before work commences. However, failure to obtain the required documents prior to the work beginning shall not waive the Contractor's obligation to provide them. The City of Manteca reserves the right to require complete, certified copes of all required insurance policies, including endorsements required by these specifications, at any time.

Notice of Cancellation
Each insurance policy required above shall provide that coverage shall not be canceled, except with notice to the Entity.

Acceptability of Insurers
Insurance is to be placed with insurers with a current A.M. Best's rating of no less than A:VII, unless otherwise acceptable to the City of Manteca

Waiver of Subrogation
Contractor hereby grants to The City of Manteca a waiver of any right to subrogation which any insurer of said Contractor may acquire against the Entity by virtue of the payment of any loss under such insurance. Contractor agrees to obtain any endorsement that may be necessary to affect this waiver of subrogation, but this provision applies regardless of whether or not the Entity has received a waiver of subrogation endorsement from the insurer.

SPECIAL RISKS OR CIRCUMSTANCES
The City of Manteca reserves the right to modify these requirements based on the nature of the risk, prior events, insurance coverage, or other special circumstances.

Appendix B – CEQA Notice of Exemption (To Be Added via Addendum)

Appendix C – Geotechnical Report – Manteca WWTP Improvements – New Thickening Facility

MANTECA WASTEWATER TREATMENT PLANT IMPROVEMENTS
TASK I – NEW THICKENING FACILITY
2540 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA
KLEINFELDER PROJECT # 25001380.001A

JANUARY 16, 2025 (Revision 1)

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ONLY THE CLIENT OR ITS DESIGNATED REPRESENTATIVES MAY USE THIS DOCUMENT AND ONLY FOR THE SPECIFIC PROJECT FOR WHICH THIS REPORT WAS PREPARED.

A Report Prepared for:

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MANTECA WASTEWATER TREATMENT PLANT IMPROVEMENTS
TASK I – NEW THICKENING FACILITY
2540 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

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MANTECA WASTEWATER TREATMENT PLANT IMPROVEMENTS
TASK I – NEW THICKENING FACILITY
2540 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

1 INTRODUCTION

1.1 GENERAL

This report presents the results of our geotechnical investigation for the Manteca Wastewater Treatment Plant (WWTP) Improvements Project to be located at 2450 W Yosemite Avenue in Manteca, California. A Site Vicinity Map and Exploration Location Map showing the location of the project site are presented on Figures 1 and 2, respectively. This report contains a description of our site investigation methods and findings including field and laboratory data. It also provides our geotechnical conclusions and recommendations for earthwork, foundations, and other construction considerations. Conclusions and recommendations presented in this report are based on the subsurface conditions encountered at the locations of our explorations and our experience in the area.

1.2 PROJECT UNDERSTANDING

For this task, we understand the City of Manteca plans to add a new thickening facility. The thickening facility will be supported by a 60-foot by 60-foot conventional shallow reinforced mat foundation embedded mostly 2 to 3 ft below existing grade with a small section along the western side of the thickening facility embedded about 7½ ft. Structural loading will be about 1,000 psf foundation/soil contact pressure. Ancillary construction will include shallow spread footings loaded at 2,500 psf contact pressure, 6-inch below-grade ductile piping, and potentially concrete flatwork.

Project site topography is relatively flat. Accordingly, we anticipate fills to be up to 4 feet and cuts to be as deep as 7½ feet during earthwork to provide a level foundation pad with positive site drainage. Excavations for underground utilities are not anticipated to exceed 10 feet below final site grade. If grading conditions are significantly different from these assumptions, we should be given the opportunity to review our recommendations and provide supplemental recommendations, if appropriate.

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1.3 PURPOSE AND SCOPE OF SERVICES

The purpose of this investigation is to explore and evaluate the subsurface conditions at the site in order to provide geotechnical input for the design and construction of the proposed facility and the associated earthwork for this project. Our scope of services was outlined in our proposal dated May 31, 2024 (Proposal No.: LOCALMKT.WEOH/1082900) and consisted of pre-field activities, field exploration, laboratory testing, engineering analysis, and preparation of this report.

This investigation specifically excludes the assessment of site environmental characteristics or future environmental mitigations, particularly those involving hazardous chemicals.

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2 FIELD EXPLORATION AND LABORATORY TESTING

2.1 FIELD EXPLORATION

2.1.1 Pre-Field Activities

Prior to subsurface exploration, Kleinfelder filed an application for a drilling permit with the San Joaquin County Environmental Health Department (SJCEHD), marked exploration locations in the field, and contacted Underground Service Alert North (USAN) to provide utility clearance in the public right-of-way. We also employed the services of a private utility locator to assess the presence of unmarked/unknown buried utilities at the proposed subsurface exploration sites. We prepared a work plan and a site-specific health and safety plan for the field exploration activities. These plans were discussed with the field crews prior to the start of field exploration work.

2.1.2 Subsurface Explorations

To evaluate the subsurface conditions at the site for the proposed improvements, two borings (B-1 and B-2) were performed on July 25, 2024, and one seismic cone penetrometer test (sCPT) (CPT-1) was performed on July 29, 2024 at the approximate locations shown on Figure 2. The depth of the borings ranged from approximately 16½ to 31½ feet below ground surface (bgs) and the sCPT was advanced to approximately 50 feet bgs. The borings were advanced by Taber Drilling (Taber) of West Sacramento, California using a hand auger in the upper 5 feet and a Deidrich D-120 truck-mounted drill rig thereafter. Taber used a 4-inch outside diameter (O.D.) mud rotary drill bit and/or a 4-inch O.D. solid-stem auger. The sCPT was also advanced by Taber using a 20-ton electronic push CPT mounted on a ten-wheeled truck. Explorations were located in the field using a handheld GPS on a mobile device and should be considered approximate. Horizontal coordinates of the borings are approximate and were not surveyed.

A Kleinfelder geologist maintained logs of the borings, visually classified the soils encountered according to the Unified Soil Classification System (presented on Figure A-1 in Appendix A) and obtained samples of the subsurface materials. Soil classifications made in the field from samples and auger cuttings were in accordance with American Society for Testing and Materials (ASTM) Method D2488. These classifications were re-evaluated in the laboratory after further examination and testing in accordance with ASTM D2487. Sample classifications, blow counts recorded during sampling, and other related information were

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recorded on the boring logs. The blow counts listed on the boring logs are raw values and have not been corrected for the effects of overburden pressure, rod length, sampler size and type, or hammer efficiency.

Keys to the soil descriptions and symbols used on the boring logs are presented in Appendix A along with logs of the borings and CPT. The exploration locations are shown on Figure 2.

Upon completion, the borings and CPT voids were backfilled with neat cement grout in accordance with the SJCEHD drilling permit requirements.

2.1.3 Sampling Procedures

Soil samples were collected from the borings at depth intervals of approximately 2.5 to 5 feet or less at the discretion of the field geologist. Samples were collected from the borings at selected depths by driving either a1½-inch inside diameter (I.D.) Standard Penetration Test (STP) Sampler or a 2½-inch I.D. California sampler driven 18 inches into undisturbed soil. The samplers were driven using a 140-pound automatic hammer free-falling a distance of 30 inches. Blow counts were recorded at 6inch intervals for each sample attempt and are reported on the logs.

The 1½-inch I.D. STP samplers did not have space for liners. The 2½-inch I.D. California sampler contained stainless steel liners. Driven soil samples obtained using this sampler may have experienced some disturbance due to hammer impact, retrieval, and handling.

Soil samples obtained from the borings were packaged and sealed in the field to reduce moisture loss and disturbance. Following drilling, the samples were returned to our laboratory for further examination and testing.

2.2 LABORATORY TESTING

Kleinfelder performed laboratory tests on selected samples recovered from the soil borings to evaluate their physical and engineering characteristics. The following laboratory tests were performed:

- Moisture Content (ASTM D2216)
- Percent Passing No. 200 Sieve (ASTM D1140)
- Atterburg Limits (ASTM D4318)

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- Corrosion – Soluble Sulfate Content (CA DOT Test #417) – Performed by Sunland Analytical
- Corrosion – Soluble Chloride Content (CA DOT Test #422) – Performed by Sunland Analytical
- Corrosion – pH (CA DOT Test #643) – Performed by Sunland Analytical
- Corrosion – Minimum Resistivity (CA DOT Test #643) – Performed by Sunland Analytical

All laboratory test data are presented in Appendix B. The corrosion test results are also discussed in Section 5.7, Soil Corrosion.

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3 GEOLOGIC SETTING

3.1 REGIONAL GEOLOGY

The project site lies within the central portion of the Great Valley geomorphic province of California. The province is bordered to the north by the Cascade Range and Klamath Mountains, to the west by the structurally complex sedimentary and volcanic rock units of the Coast Ranges, to the east by the granitic and metamorphic basement rocks which form the gently sloping western foothills of the Sierra Nevada Mountains, and to the south by the east-west trending Transverse Ranges. About 645 km long and 80 km wide, the Great Valley is an asymmetrical, synclinal trough formed by tilting of the Sierran block during the late Tertiary and Quaternary periods with the western side dropping to form the valley and the eastern side uplifting to form the Sierra Nevada Mountains. Within the project area, erosion of the adjacent Sierra Nevada Mountains and Coast Ranges has in-filled this valley with a thick sequence of unconsolidated to semi-consolidated Quaternary (Pleistocene and Holocene) age alluvial, basin, and delta plain sediments deposited by the Sacramento and San Joaquin rivers and their tributaries. The thickness of the valley sediments varies from a thin veneer at the edges of the valley to thousands of meters in the western portion. The bedrock complex is likely composed of metamorphosed marine sediments similar to those found in the foothills of the western Sierra Nevada Mountains and the core of the Coast Ranges.

3.2 AREA AND SITE GEOLOGY

The project site is situated within the central portion of the San Joaquin Valley and within the Lathrop 7½-minute US Geological Survey quadrangle. This portion of the San Joaquin Valley consists of very gently sloping alluvial fans flanked on the west by the San Joaquin River and on the east by the foothills of the Sierra Nevada Mountain Ranges. Farther to the east are the Sierra Nevada Mountain Ranges and to the west lie the Coast Ranges.

Based on available published geologic maps covering the site and surrounding areas, the project site is mapped as being underlain by the Upper Member of the Modesto Formation (map symbol Qmu) (Delattre, M.P. et. al. [2023]) which is late Pleistocene age (between 11,000 and 2.6M years) and is adjacent the Pleistocene aged fine grained Lower Member of the Modesto Formation (map symbol Qmlb) and the Holocene (between 11,000 years to present) to late Pleistocene dune sand deposits (map symbol Qds). The Upper Member of the Modesto Formation is described as follows:

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- **Qmu** – Alluvium derived either from the interior of the Sierra Nevada along major west-flowing streams or contemporaneously, locally from small foothill watersheds deposited in fan, interdistributary area, and basin settings.

A portion of the Delattre, M.P. et al. (2023) geologic map is presented on Figure 3 detailing the surface geology at and near the project site.

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4 SITE AND SUBSURFACE CONDITIONS

4.1 SITE DESCRIPTION

The project site is located near the center of the Manteca WWTP which is mostly surrounded by agricultural land or vacant lots with West Yosemite Avenue on the north and an irrigation canal to the west. The area of the proposed improvements is currently a vacant portion of the WWTP between structures covered by imported gravel and an asphalt access path.

4.2 SUBSURFACE CONDITIONS

Surficial soils consist of loose to medium dense silty sand (SM) and poorly graded sand with silt (SP-SM) that extends to a depth of about 16 feet below the ground surface. These soils are underlain by cohesive layers of medium stiff to hard lean clay with sand and sandy lean clay. We also encountered a clayey sand layer near the bottom of boring B-1 at approximately 30 feet bgs.

The above is a description of the subsurface conditions encountered at the site during our geotechnical engineering investigation. Refer to the exploration logs in Appendix A for a more detailed description of the subsurface conditions encountered at our exploration points.

4.3 GROUNDWATER

Groundwater was encountered in both boring B-1 and boring B-2 during drilling at depths of about 13 feet and 11 feet bgs, respectively. Groundwater data presented on the Sustainable Groundwater Management Act website[1] monitored by the California Department Water Resources indicates that groundwater at the project site is typically between 17 and 25 feet below the ground surface. The higher groundwater encountered during our field explorations may have been locally perched groundwater above the less-permeable clayey layers.

It should be noted that perched groundwater may be encountered during construction, or groundwater levels can fluctuate depending on factors such as seasonal rainfall and runoff, groundwater

[1] *https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer#gwlevels*

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withdrawal/recharge, and construction and irrigation activities on this or adjacent sites. The evaluation of such factors is beyond the scope of this investigation.

4.4 VARIATIONS IN SUBSURFACE CONDITIONS

Our interpretations of soil and groundwater conditions at the site are based on the conditions encountered in our explorations at the site at the time of our investigation and our review of available geologic and geotechnical data. Soil conditions can deviate from those conditions encountered at the boring locations. The recommendations that follow are based on those interpretations. If significant variation in the subsurface conditions is encountered during construction, it may be necessary for Kleinfelder to review the recommendations presented herein and recommend adjustments as necessary.

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5 CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

Based on the results of our investigation it is our professional opinion that the site should be suitable from a geotechnical standpoint for support of the proposed lightly to moderately loaded structures, provided the recommendations contained herein are incorporated into the project design and construction. The primary geotechnical concern at the site is the presence of saturated near surface sands and shallow groundwater potentially resulting in liquefaction and consequential settlement during a seismic event. Specific conclusions and recommendations regarding this and other geotechnical aspects of design and construction are presented in the following sections of this report.

5.2 SITE PREPARATION AND EARTHWORK CONSTRUCTION

5.2.1 General

We anticipate site grading and excavations can be performed with conventional grading/earth moving equipment and techniques. General recommendations for site preparation and earthwork construction are presented in the following sections of this report. All references to compaction, maximum density and optimum moisture content are based on ASTM D1557, unless otherwise noted.

5.2.2 Stripping and Grubbing

Prior to general site grading, the existing imported gravel should be stripped from project site and stockpiled. The imported gravel may be reused if desired if it does not become contaminated with other materials during the process. The depth of stripping will be dependent upon the thickness of the loose gravels at the site. Although not observed during our investigation, any weeds, roots or other organic material encountered should also be stripped from the project area and discarded.

5.2.3 Disturbed Soil, Undocumented Fill and Subsurface Obstructions

Although these were not observed during our field investigation, as part of site development, any existing undocumented fills on site should be over-excavated to firm soil or to depths determined by the geotechnical engineer during construction. Any over-excavation should extend at least 5 feet beyond the

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perimeter of the proposed structure and 3 feet beyond the perimeter of pavement areas or to the edge of adjacent structures/flatwork if less than these recommended distances.

The exposed subgrades (existing and over-excavated) to receive engineered fills should be proof-rolled with a fully-loaded tandem-axle dump truck or water truck. Areas identified as being soft or yielding should be over-excavated to firm, native soil, or to depths determined by the geotechnical engineer during construction should pumping soils occur due to shallow groundwater. After proof-rolling, the subgrade should be scarified to a depth of 8 inches, moisture conditioned, and compacted as engineered fill. Deleterious materials encountered during over-excavation should be removed, and the excavated materials compacted to the requirements for engineered fill. This proof rolling, over-excavation and recompaction operation would serve to provide a uniform, stable subgrade throughout the development area thereby improving foundation design conditions and reducing settlement potential. The zone of proof rolling, over-excavation and compaction should extend horizontally at least 5 feet outside the perimeter of the proposed structure and at least 3 feet outside the perimeter of pavement areas or to the edge of adjacent structures/flatwork if less than these recommended distances.

All site grading should include a reasonable search to locate soil disturbed by previous activity and abandoned underground structures or existing utilities that may exist within the areas of construction. Any loose or disturbed soils, void spaces made by burrowing animals, or undocumented fill that may be encountered should be over-excavated to expose firm soil, as approved by a representative of Kleinfelder.

5.2.4 Scarification and Compaction

In areas requiring placement of fill, it is recommended the fill be placed and compacted as engineered fill. Following site stripping and grubbing and any required overexcavation, it is recommended areas to receive engineered fill be scarified to a depth of 8 inches, uniformly moisture conditioned to between about 1 and 4 percentage points above the optimum moisture content and be compacted to at least 90 percent relative compaction, as determined by ASTM D1557. Fills exceeding 10 feet in thickness should be compacted to at least 95 percent relative density.

5.2.5 Engineered Fill

5.2.5.1 Materials

All engineered fill soils should be nearly free of organics or other deleterious debris and less than 3 inches in maximum dimension. In general, mixtures of sand, silt, and clay are acceptable for use as engineered

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fill. Particles larger than 3 inches should be removed from engineered fill. In general, on-site native soils similar to those encountered in our test borings are anticipated to be suitable for use as engineered fill. Soils that have less than 3 percent organics by weight and are free of debris or other deleterious matter may be used as engineered fill. Any imported fill materials to be used for engineered fill should be sampled and tested by a representative of the project Geotechnical Engineer prior to being transported to the site. Table 5-1 provides general criteria for imported soil.

Table 5-1: Imported Engineered Fill Requirements

Fill Requirement		**Test Procedures**	
Gradation		**ASTM**[1]	**Caltrans**[2]
Sieve Size	**Percent Passing**		
3 inch	100	D6913	202
¾-inch	70-100	D6913	202
No. 200	15-70	D6913	202
Plasticity			
Liquid Limit	**Plasticity Index**		
<35	<12	D4318	204
R-Value			
30 or more		---	301
Organic Content			
No visible organics		---	---
Expansion Potential			---
20 or less		D4829	---
Soluble Sulfates			
Less than 2,000 ppm		---	417
Soluble Chloride			
Less than 300 ppm		---	422
Resistivity			
Greater than 2,000 ohm-cm		---	643

[1] American Society for Testing and Materials Standards (latest edition)
[2] State of California, Department of Transportation, Standard Test Methods (latest edition)

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5.2.5.2 Compaction Criteria

On-site or imported soils that meet the criteria outlined in Table 5-1 above that are to be used for engineered fill should be uniformly moisture conditioned to between 1 to 4 percentage points above the optimum moisture content, placed in horizontal lifts less than about 8 inches in loose thickness, and compacted to at least 90 percent relative compaction. Additional fill lifts should not be placed if the previous lift did not meet the required dry density or if soil conditions are not stable. Discing and/or blending may be required to uniformly moisture condition soils used for engineered fill.

5.2.6 Anticipated Excavation Conditions

5.2.6.1 General

This report does not represent a study of the excavatibility of the subsurface materials that may be encountered within the limits of the proposed project. The contractor should independently evaluate the condition of the subsurface materials in order to select the appropriate excavation equipment and techniques. Furthermore, the contractor should be aware of past development and activities within the project area that abandoned utility lines, wells, and/or foundations will be encountered within the proposed site. Excavation and removal of these features, if encountered, will require special consideration by the contractor.

5.2.6.2 Shallow Trenches

The near-surface materials encountered in the borings generally consisted of a loose to medium dense silty sand, poorly graded sand with silt, and sandy silt in the upper 16 feet below site grade. These materials can be excavated with conventional backhoes or track-mounted excavators. The trench side walls within the loose sand materials are expected to be susceptible to caving/raveling if not sloped. Groundwater was encountered in our explorations at 11 to 13 feet bgs and dewatering is anticipated to be needed for trenching operations below these depths. Constant dewatering may not be necessary if the groundwater encountered is determined to be perched. Dewatering recommendations for excavations are presented in Section 5.9.

Section 5.2.7 presents further recommendations regarding temporary excavations and should be followed.

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5.2.7 Temporary Excavations

5.2.7.1 General

All excavations should comply with applicable local, state, and federal safety regulations including the current Occupational Safety & Health Administration (OSHA) Excavation and Trench Safety Standards. Construction site safety generally is the responsibility of the Contractor, who is responsible for the means, methods, and sequencing of construction operations. Kleinfelder is providing the information below solely as a service to the client. Under no circumstances should the information provided be interpreted to mean that Kleinfelder is assuming responsibility for construction site safety or the Contractor's activities. Such responsibility is not being implied and should not be inferred.

To reduce the potential for settlement of existing foundations, the contractor should consider structural shoring and/or underpinning if the projected footing geometries fall within an imaginary 1½ to 1 (1.5:1) projection between the existing bottom of foundation and the proposed bottom of foundation. It is the contractor's responsibility through means and methods to prevent structural settlement of existing facilities during construction.

5.2.7.2 Excavation and Slopes

Excavated slope height, slope inclination, or excavation depths (including utility trench and wet well excavations) should in no case exceed those specified in local, state, and/or federal safety regulations (e.g., OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926, or successor regulations). Such regulations are strictly enforced and, if they are not followed, the Owner, Contractor, and/or earthwork and utility subcontractors could be liable for substantial penalties.

5.2.7.3 Wet Weather Considerations

Should construction be performed during or subsequent to wet weather, near-surface site soils may be significantly above the optimum moisture content. These conditions could hamper equipment maneuverability and efforts to compact site soils to the recommended compaction criteria. Disking to aerate, chemical treatment, replacement with drier material, stabilization with a geotextile fabric or geogrid, or other methods may be required to mitigate the effects of excessive soil moisture and facilitate earthwork and construction operations. If needed, Kleinfelder can provide supplemental recommendations for soil stabilization during construction.

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If construction is to proceed during the winter and spring months, one way to reduce the exposure of the pad and potential repairs is to leave the subgrade at least 1 foot above the proposed subgrade elevation, cutting it down immediately before processing subgrade and placing foundation materials. The cut areas should be proof rolled at the discretion of the Geotechnical Engineer of Record to identify whether undercutting of any remaining wet/unstable soils is required. Cut soils can be placed in landscape areas or disced and aerated (dried) during dry weather for placement in pavement, future pad, or other areas.

5.2.8 Materials

All trench backfill should be placed and compacted in accordance with recommendations provided for engineered fill (see Section 5.2.5). Mechanical compaction is recommended.

Pipe embedment zone backfill (i.e., bedding, haunching, pipe zone and initial backfill per ASTM D2321) should consist of soil compatible with design requirements for the specific types of pipes. Consideration should be given to use of Class III or better material. It is recommended the project designer or pipe supplier develop the material specifications based on planned pipe types, bedding conditions, tolerable deformation and other factors beyond the scope of this study. Final backfill (i.e., material placed between the embedment zone backfill and finished subgrade) may consist of native soil which meets the requirements for engineered fill.

5.3 2022 CBC SEISMIC DESIGN PARAMETERS

Based on information obtained from the investigation, published geologic literature and maps, and on our interpretation of the 2022 CBC criteria, the project sites may be classified as Site Class D, Stiff Soil, according to 2022 CBC and Table 20.3-1 of ASCE 7-16. Site Class D is defined as a soil profile consisting of a stiff soil profile with a shear wave velocity between 600 feet per second and 1,200 feet second, SPT blow counts (N-value) between 15 blows per foot and 50 blows per foot, or undrained shear strength between 1,000 pounds per square foot and 2,000 pound per square foot in the top 100 feet.

Seismic design parameters were developed consistent with the requirements of the 2022 CBC, ASCE/SEI 7-16, and Supplements 1 through 3 of that standard. We note that in accordance with Section 11.4.8 of ASCE/SEI 7-16 Supplement 3, a site-specific ground motion hazard analysis is required for Site Class D sites with a mapped S_1 value greater than or equal to 0.2g unless exceptions are taken by the project structural engineer. Based on the Site Class D designation, the exception of Section 11.4.8 of ASCE 7-16 Supplement 3 states that a ground motion hazard analysis is not required when the values of S_{M1} and S_{D1} are increased by 50 percent. Per Table 11.4-2 of ASCE 7-16 Supplement 3, a F_v value of 1.991 may be used in conjunction

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with the code-based S_1 value for purposes of calculating the T_S value, determination of the Seismic Design Category, and, when taking the exceptions of Section 11.4.8 of ASCE 7-16 Supplement 3, for calculation of S_{M1} and S_{D1} values. As such, code-based seismic design parameters provided in Table 5-2 for the spectral response acceleration at a period of 1.0 second include the 50 percent increase assuming that the exception of Section 11.4.8 of ASCE 7-16 Supplement 3 will be utilized. The parameters listed in the Table 5-2 are estimated using the Seismic Design Maps website maintained by SEAOC/OSHPD (https://www.seismicmaps.org) and the requirements of the 2022 CBC/ASCE 7-16.

Approximate coordinates for the site are noted below.

- Latitude: 37.723414°N
- Longitude: 121.506151°W

Table 5-2
Ground Motion Parameters Based on 2022 CBC/ASCE 7-16

Parameter	Value	Reference
S_S	0.825g	Fig 22-1
S_1	0.309g	Fig 22-2
Site Class	D	Table 20.3-1
F_a	1.200	Table 11.4-1
F_v	1.991	See Section 11.4.8
PGA	0.343g	Fig 22-9
S_{MS}	0.990g	Eq. 11.4-1
S_{M1}	0.923g*	See Section 11.4.8
S_{DS}	0.660g	Eq. 11.4-3
S_{D1}	0.615g*	See Section 11.4.8
F_{PGA}	1.257	Table 11.8-1
PGA_M	0.432g	Eq. 11.8-1
C_{RS}	0.945	Fig 22-18A
C_{R1}	0.951	Fig 22-19A
T_L	8 seconds	See Section 11.4.6

*Note: Section 11.4.8 of ASCE/SEI 7-16 Supplement 3 requires a site-specific ground motion hazard analysis be performed for Site Class D sites with S_1 greater than or equal to 0.2g unless an exception is taken in which the values of S_{M1} and S_{D1} are increased by 50 percent. Values of S_{M1} and S_{D1} provided in the table include this 50 percent increase assuming the exception will be taken. This value of F_v shall only be used for calculation of T_S, determination of Seismic Design Category, linear interpolation for intermediate values of S_1, and when taking the exceptions under Item 1 of Section 11.4.8 for the calculation of S_{D1}.

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5.4 LIQUEFACTION

Soil liquefaction is a condition where saturated, granular soils undergo a substantial loss of strength and deformation due to pore pressure increase resulting from cyclic stress application induced by earthquakes. In the process, the soil acquires mobility sufficient to permit both horizontal and vertical movements if the soil mass is not confined. Soils most susceptible to liquefaction are saturated, loose, clean, uniformly graded, and fine-grained sand deposits. If liquefaction occurs, foundations resting on or within the liquefiable layer may undergo settlements. This will result in reduction of foundation stiffness and capacities.

Liquefaction triggering analyses were performed using the methods proposed by Youd (2001), Cetin (2004/2009), and Idriss and Boulanger (2008). In order to perform liquefaction analysis, estimates of earthquake magnitude and peak ground acceleration (PGA_M) are needed. Using the U.S. Geological Survey (USGS) interactive deaggregation website, the earthquake magnitude Mw = 7.13 was estimated and used in the analysis. The peak ground acceleration (PGA_M) value for our analyses was calculated based on Equation 11.8-1 in Section 11.8.3 of the American Society of Civil Engineers (ASCE) 7-10 for the Risk-Targeted Maximum Considered Earthquake (MCER). The PGA_M value was calculated using the US Seismic Design Maps application assuming a Site Class D. The calculated PGA_M value used in our analysis was 0.432g for the MCER.

The evaluation of liquefaction in response to an earthquake is based on a comparison of a soil's resistance to liquefaction and the cyclic load or demand placed on the soil by the earthquake. A safety factor against liquefaction is commonly defined as the ratio of the cyclic shear stress required to cause liquefaction (cyclic resistance ratio, or CRR) to the equivalent cyclic shear stress induced by the earthquake (cyclic stress ratio, or CSR). We used a safety factor of 1.1 for this project.

Based on our analyses, the potentially liquefiable near surface soils will settle between 3 and 5½ inches during and directly following a design seismic event depending on methodology. We estimate differential settlements between adjacent supports (assumed to be about 50 feet) of about half the maximum total seismic settlement (1½ to 3½ inches) be considered for design. Should these settlements be considered too excessive, ground improvement or deep foundations can be considered as a mitigation measure. Deep foundations will likely be significantly more expensive than ground improvement but will make settlement negligible if properly designed to accommodate the upper 18 ft of drag loads. A likely more affordable option is to use ground improvement to a depth of 18 ft bgs. Ground improvement options include:

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- Rammed-Aggregate-Piers,
- Stone columns,
- Rigid inclusions, and
- A variety of grouting techniques.

The ground improvement design should be performed by a qualified ground improvement contractor licensed in the state of California. We should be allowed to review and comment on the design prior to mobilization. Contact this office for a list of design-build contractors. Our liquefaction analysis is presented in Appendix C.

5.5 FOUNDATION DESIGN

5.5.1 Mat Foundation

The reinforced concrete mat slab foundation may be designed for a net allowable bearing pressure of 1,000 psf due to dead plus live loads corresponding to a total settlement of under 3 inches. Differential settlement is on the order of 1½ inches across the mat foundation. The mat foundation should be founded at least 18 inches below lowest adjacent finished grade. The mat slab foundation should be supported on a minimum of 1 foot of engineered fill beneath foundations. The zone of engineered fill should extend laterally at least 3 feet beyond the perimeter of the foundations as permitted by adjacent structures. Kleinfelder should be contacted once grading plans are completed to provide additional consultation regarding the depth of overexcavation and recompaction required. A one-third increase may be applied to this value when considering the effects of transient loads such as wind or seismic.

5.5.2 Spread Foundations

Ancillary structures may be supported by shallow spread footings constructed of reinforced concrete founded on undisturbed native soil or engineered fill. Foundations should be embedded at least 18 inches below lowest adjacent subgrade. Without ground improvement, a net allowable bearing pressure of 2,500 pounds per square foot (psf) due to dead plus live loads may be used to size proposed footings. If ground improvement is implemented, this value may be increased to the allowable bearing pressure recommended by the geo-contractor selected to perform the ground improvement.

The allowable bearing pressure provided above is a net value. Therefore, the weight of the foundation that extends below grade may be neglected when computing dead loads. The allowable bearing pressure applies to dead plus live loads, includes a calculated factor of safety of at least 3, and may be increased

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by one-third for short-term loading due to wind or seismic forces. We anticipate total and differential settlement to be on the order 1 and ½ inch, respectively.

5.5.3 Lateral Load Resistance

Lateral loads may be resisted by a combination of friction between the foundation bottoms and the supporting subgrade, and by passive resistance acting against the vertical faces of the foundations. An allowable coefficient of sliding friction of 0.35 between the foundation and the supporting subgrade may be used for design. For allowable passive resistance, an equivalent fluid weight of 350 pounds per cubic foot (pcf) acting against the side of the foundation may be used. This value generally corresponds to a lateral deflection of less than about ½ inch. Passive resistance in the upper 12 inches of soil should be neglected unless the area in front of the footing is protected from disturbance by concrete or pavement. The allowable friction coefficient and passive resistance may be used concurrently.

5.5.4 Construction Considerations

Underground utilities paralleling the mat slab that are 4 feet deep or shallower generally should be located no closer than 2 feet outside of the perimeter edges of the slab. Deeper utilities should be located above a 1H:1V slope projected downward from the bottom edges of the slab. Utility plans should be reviewed by Kleinfelder prior to trenching to evaluate conformance with this requirement.

Beneath cast-in-place concrete mat foundations, we recommend the design include a base course of well-graded aggregate (such as Caltrans Class 2 Aggregate Base) at least 4 inches thick. The base course should be compacted to at least 95 percent relative compaction at a moisture content slightly above optimum. Mat slabs should have turned down or thickened edges at least 18 inches deep to reduce water infiltration beneath the slabs. Thickened slab edges should engage the building pad soil and should not be underlain by the gravel base course.

5.6 EXTERIOR FLATWORK

Following site stripping and undocumented fill removal, as a minimum all areas to support exterior concrete flatwork, i.e., sidewalks and the like, should be scarified to a depth of 12 inches, uniformly moisture conditioned to between 1 and 4 percent above the optimum moisture content, and compacted as engineered fill. Additional criteria regarding general earthwork are presented in Section 5.2.

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The near-surface soil conditions do not necessarily warrant the placement of aggregate base below flatwork from a geotechnical standpoint. Flatwork, however, tends to perform better during and following construction with less maintenance if it is underlain by a layer Class 2 aggregate base. The aggregate base serves to provide a firm/uniform surface directly below the flatwork where surcharge stresses are highest. As a result, we have found that flatwork supported on aggregate base tends to experience less stress cracking and movement or deflection at joints. If considered, the aggregate base should have a thickness of at least 4 inches and be compacted to at least 90 percent relative compaction. In areas where concrete flatwork will support construction equipment and/or vehicle traffic, we suggest that the aggregate base be increased to a thickness of 6- to 8-inches and be compacted to at least 95 percent relative compaction.

5.7 SOIL CORROSION

Laboratory chloride concentration, sulfate concentration, pH, and electrical resistivity tests were performed on a near surface soil sample obtain from Boring B-1. The results of the tests are summarized in Table 5-6.

Table 5-3: Soil Corrosion Potential Results

Exploration	Depth	Material	Resistivity ohm-cm	pH	Sulfate ppm	Chloride ppm
B-2	0.4-5	Silty Sand	6,160	7.06	12.8	2.3

Chemical tests performed on a near surface composite soil sample obtained from Boring B-1 indicated a pH of 7.06. The minimum resistivity test performed on the soil sample suggests that the soils in the vicinity of Boring B-2 are considered to be moderately corrosive to buried metal objects as indicated by a result of 6,160 ohm-centimeters.

As indicated in the 2006 edition (second edition) of “Corrosion Basics - An Introduction”, generally adopted corrosion-severity ratings are provided in Table 5-7 below.

Table 5-4: Soil Resistivity and Corrosivity Correlation

Soil Resistivity	Corrosivity
< 1,000 ohm-cm	Extremely corrosive
1,000 to 3,000 ohm-cm	Highly Corrosive
3,000 to 5,000 ohm-cm	Corrosive
5,000 to 10,000 ohm-cm	Moderately Corrosive
10,000 to 20,000 ohm-cm	Mildly Corrosive
>20,000 ohm-cm	Essentially Noncorrosive

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As noted in the above reference, soil resistivity is not the only parameter affecting the risk of corrosion damage; and a high soil resistivity will not guarantee the absence of serious corrosion. For example, the American Water Works Association (AWWA) has developed a numerical soil-corrosivity scale, applicable to cast-iron alloys.

Results from sulfate and chloride content tests performed by Sunland Analytical for the soil sample obtained from Boring B-2 yielded values of 12.8 parts per million (ppm) and 2.3 ppm, respectively.

In accordance with California Test 532, "if the chloride concentration is determined to be less than 500 ppm," "the influence of the chloride-ion at this level is considered to be non-corrosive." The ACI Manual of Concrete Practice, Section 201.2R-92, recommends using a Type I or II cement for foundations placed in these soils.

In accordance with "Guideline for Stabilization of Subgrade Soils in California, UCPRC-GL-2010—01, dated May 4, 2012" as published by Caltrans and the University of California Pavement Research Center (UC Davis/UC Berkeley), soluble sulfate concentrations less than 3,000 ppm have a "low" risk with respect to cementitious stabilization of subgrade soils.

ACI 318-11 provides the following exposure categories with respect to sulfate content and concrete.

Table 5-5: Sulfate Exposure Categories and Classes

Severity	Class	Water-Soluble Sulfate (SO_4) in soil, percent by mass[1]	Dissolved Sulfate (SO_4) in water, ppm[2]
Not Applicable	S0	$SO_4 < 0.10$	$SO_4 < 150$
Moderate	S1	$0.10 \leq SO_4 < 0.20$	$150 \leq SO4 < 1,500$
Severe	S2	$0.20 \leq SO_4 \leq 2.00$	$1,500 \leq SO4 \leq 10,000$
Very Severe	S3	$SO_4 > 2.00$	$SO4 > 10,000$

[1] Percent sulfate by mass in soil shall be determined by ASTM C1580.

[2] Concentration of dissolved sulfates in water in ppm shall be determined by ASTM D516 or ASTM D4130.

This report includes information obtained through laboratory testing regarding corrosivity of onsite soils. It is important to note that our scope does not include corrosion engineering and that detailed analysis of corrosion test results is not included in this report. A qualified corrosion engineer should be retained to review the test results and design protective systems that may be required.

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5.8 SITE DRAINAGE

Foundation and slab performance depend greatly on how well runoff water drains from the site. Accordingly, positive drainage should be provided away from the building pad toward appropriate drop inlets or other surface drainage devices without ponding. In general, we recommend consideration be given to providing at least 1 to 2 percent slope away from structure foundations or access ways for drainage. The drainage should be maintained both during construction and over the life span of the project. Roof draining should be installed with appropriate downspout extensions out falling on splash blocks so that water is directed a minimum of 5 feet horizontally away from the structures or be connected to the storm drain system for the development.

A number of post-construction landscape practices beyond the control of the design engineers can occur to cause distress to pavements. Potential man-made water sources, such as buried pipelines, drains and the like, should be periodically tested and/or examined for signs of leakage or damage. Any such leakage or damage should be promptly repaired.

5.9 CONSTRUCTION DEWATERING

Depending on the time of year construction is performed, the deepest portion of the thickening facility may be below groundwater. If exposed below the groundwater level, these soils could become unstable or even “quick” due to upward seepage forces, losing their ability to maintain stable excavation/trench slopes. Therefore, we anticipate that dewatering will be necessary to permit stable construction. The groundwater should be lowered and continuously maintained at least 2 to 3 feet below the bottom of the proposed excavation until the foundation underlayment, backfill, and structure weights are adequate to provide uplift resistance and backfill is complete at least 3 feet above the normal stabilized water level.

Temporary dewatering of the excavations can be accomplished using several methods. Well point or deep well systems that are installed around the periphery of the excavation are the most common dewatering systems in use today to permit stable construction in the dry. Where excavations are relatively shallow, gravel-filled gravity ditches with filtered, perforated pipes that drain to sumps that are pumped out may also be effective and likely sufficient for this application. The dewatering system for the project should be designed by an experienced consultant to appropriately filter the native soils and reduce any dispersion, piping, and associated loss of ground. The consultant should also account for any improvements near the project such as structures, buried pipelines, etc. The lowering of the groundwater table produces additional effective stresses on the soils below the original water table. These additional pressures may cause consolidation of the soils and settlement of the nearby improvements. It is often appropriate to

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institute a survey program before and during dewatering to monitor settlements in adjacent improvements and/or require recharge wells to reduce the effects of settlement. The minimum amount of dewatering necessary should be applied.

During initial earthwork, we have found that exposed soils at the base of the excavations, particularly in the case of gravity ditches, are often not fully drained by the dewatering and are wet and/or pliant. To facilitate construction, the contractor may need to cover the bottom of the excavation(s) with a 6- to 12-inch-thick stabilizing layer of clean, crushed gravel that is firmly tamped into place. The crushed gravel can also serve as a collection medium for rainwater or seepage that can be removed by pumping from shallow sumps. If the gravel will provide foundation support following construction, the material should be wrapped entirely with a geotextile filter fabric, such as Mirafi 140N or an equivalent substitute, to reduce the potential for soil infiltration into the gravel and loss of ground. Highly-wet and/or unstable soils encountered should be removed and replaced with compacted crushed rock, bedding material, or dryer soil. A second option would be to place a reinforcing geotextile fabric, such as Tensar HX145 between the subgrade soils and crushed gravel in accordance with the manufacturer's recommendations. Our firm should be consulted prior to implementing any remedial measure to observe the subgrade condition and provide site-specific recommendations.

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6 ADDITIONAL SERVICES

6.1 PLANS AND SPECIFICATIONS

Kleinfelder should conduct a general review of plans and specifications to evaluate that the earthwork and foundation recommendations presented in this report have been properly interpreted and implemented during design. In the event Kleinfelder is not retained to perform this recommended review, no responsibility for misinterpretation of the recommendations by Kleinfelder is accepted.

6.2 CONSTRUCTION OBSERVATION AND TESTING

It is recommended that all earthwork and foundation construction be monitored by a representative from Kleinfelder, including site preparation, placement of all engineered fill and trench backfill, construction of slab and pavement subgrade, and all foundation excavations. The purpose of these services is to observe the soil conditions encountered during construction, evaluate the applicability of the recommendations presented in this report to the soil conditions encountered, and recommend appropriate changes in design or construction procedures if conditions differ from those described herein.

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7 LIMITATIONS

This report presents information for planning, permitting, design, and construction of the proposed Manteca Wastewater Treatment Plant Improvements Project – Task 1 in Manteca, California. Recommendations contained in this report are based on materials encountered in exploratory borings, our previous experience in the area, geologic interpretation based on published articles and geotechnical data, and our present knowledge of the proposed construction.

It is possible that soil conditions could vary between and beyond the points explored. If the scope of the proposed construction, including the proposed location, changes from that described in this report, we should be notified immediately in order that a review may be made, and any supplemental recommendations provided.

We have prepared this report in accordance with the generally accepted geotechnical engineering practice as it exists in the site area at the time of our investigation. No warranty expressed or implied is made.

This report may be used only by the client and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on-site and off-site) or other factors may change over time, and additional work may be required with the passage of time. Any party other than the client who wishes to use this report shall notify Kleinfelder of such intended use. Based on the intended use of the report, Kleinfelder may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the client or anyone else will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party.

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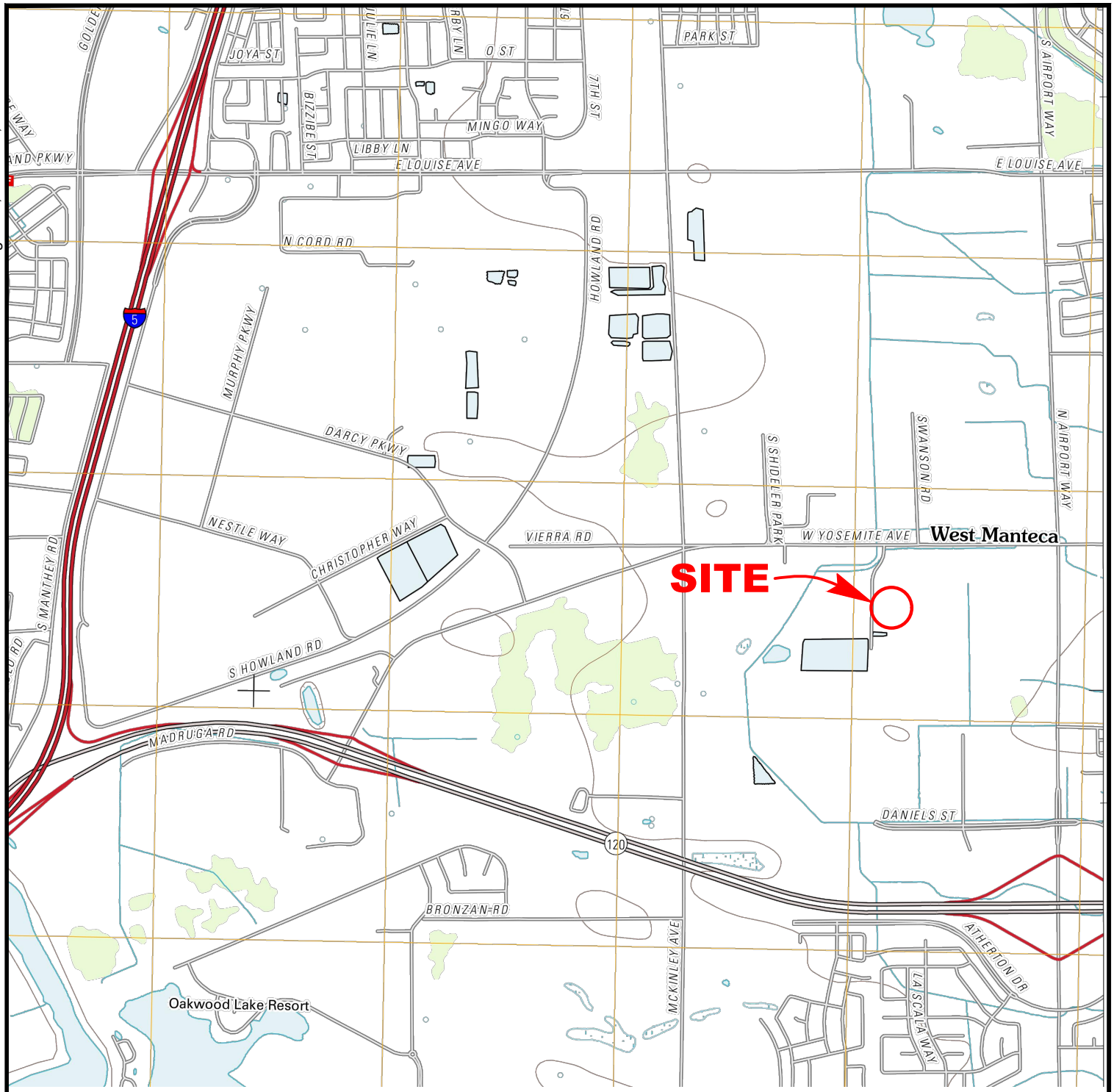
FIGURES

LIST OF ATTACHMENTS

The following figures are attached.

FIGURE 1	Site Vicinity Map
FIGURE 2	Exploration Location Map
FIGURE 3	Site Geologic Map



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SCALE: 1" = 2000' SCALE IN FEET

REFERENCE:
Lathrop, Ca. Quadrangle California 7.5-Minute Series

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PROJECT NO. 25001389.001A	
DRAWN: 8/6/2024	**SITE VICINITY MAP**
DRAWN BY: GG	
CHECKED BY: NF	MANTECA WWTP, TASK 1 2450 W. YOSEMITE AVENUE MANTECA, CALIFORNIA
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FIGURE
1

CAD FILE: W:\2500\25001380.001A - Manteca WWTP\PLANS\ LAYOUT: FIGURE 1
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ATTACHED IMAGES:
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OFFICE_NAME

Soil Boring Locations (Kleinfelder, 2024)

CPT Location (Kleinfelder, 2024)

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0 100 200

SCALE: 1" = 100' SCALE IN FEET

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CAD FILE: W:\25001\25001380.001A - Manteca WWTP\PLANS\ LAYOUT: FIGURE 2

ATTACHED IMAGES:
ATTACHED XREFS:
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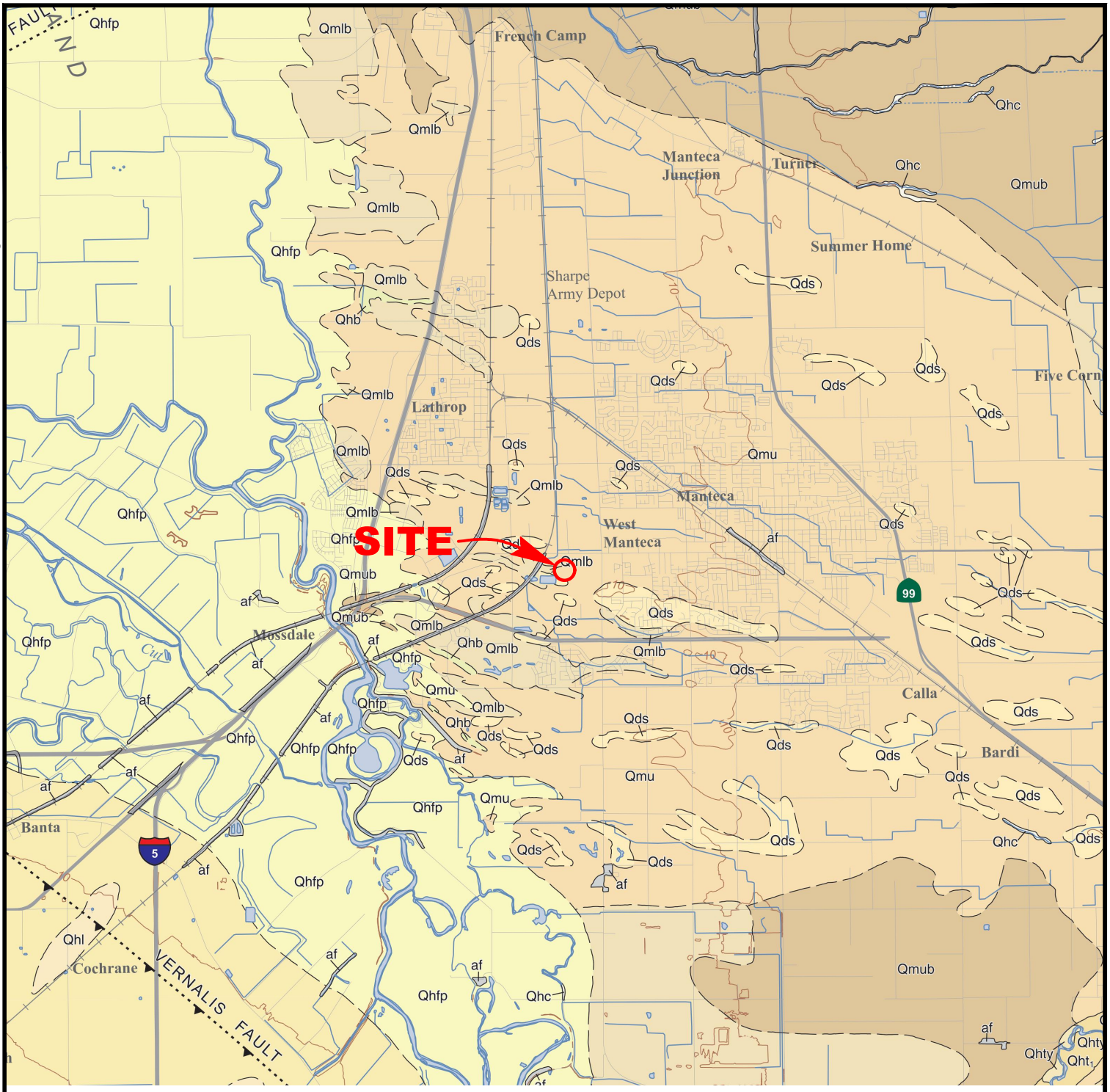
PROJECT NO. 25001389.001A	
DRAWN: 8/6/2024	
DRAWN BY: GG	
CHECKED BY: NF	
FILE NAME: STO24D055.CAD	

EXPLORATION LOCATION MAP

MANTECA WWTP, TASK 1
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE

2



af	Artificial fill
Qds	Holocene to late Pleistocene dune sand deposits
Qhb	Holocene basin deposits
Qhc	Latest Holocene stream channel deposits
Qhfp	Holocene flood plain deposits
Qhl	Holocene fan levee deposits
Qht_1	Holocene stream terrace deposits, Unit 1
Qhty	Latest Holocene stream terrace deposits

Modesto Formation (late Pleistocene)

Qmlb	Lower member, fine-graind
Qmu	Upper member, undivided alluvium
Qmub	Upper member, fine-grained

N

Citation:
Delattre, M.P., Graymer, R.W., Langenheim, V.E., Knudsen, K.L., Dawson, TE., Brabb, E.E., Wentworth, C.M., and Raymond, L.A., 2023, Geologic and geophysical maps of the Stockton Quadrangle," California: California Geological Survey Regional Geologic Map No. 5, Scale 1:100,000

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CAD FILE: W:\25001\25001380.001A - Manteca WWTP\PLANS\ LAYOUT: FIGURE 3
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FILE NAME: STO24D055.CAD	

GEOLOGIC MAP

MANTECA WWTP - TASK 1
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
3

APPENDIX A

LOGS OF EXPLORATIONS

LIST OF ATTACHMENTS

The following figures are attached and complete this appendix.

FIGURE A-1	Graphics Key
FIGURE A-2	Soil Description Key
FIGURES A-3 through A-5	Logs of Explorations

DRILLING METHOD/SAMPLER TYPE GRAPHICS

BULK SAMPLE

CALIFORNIA SAMPLER
(3 in. (76.2 mm.) outer diameter)

STANDARD PENETRATION SPLIT SPOON SAMPLER
(2 in. (50.8 mm.) outer diameter and 1-3/8 in. (34.9 mm.) inner diameter)

GROUND WATER GRAPHICS

WATER LEVEL (level where first observed)

WATER LEVEL (level after stabilizing period)

WATER LEVEL (additional levels after exploration)

OBSERVED SEEPAGE

NOTES

- The report and graphics key are an integral part of these logs. All data and interpretations in this log are subject to the explanations and limitations stated in the report.
- Solid lines separating strata on the logs represent approximate boundaries only, dashed lines are inferred or extrapolated boundaries. Actual transitions may be gradual or differ from those represented.
- No warranty is provided as to the continuity of soil or rock conditions between individual sample locations.
- Logs represent general soil or rock conditions observed at the point of exploration on the date indicated.
- In general, Unified Soil Classification System (ASTM D2488/D2487) designations presented on the logs were based on visual classification in the field and were modified where appropriate based on gradation and index property testing.
- Fine grained soils that plot within the hatched area on the Plasticity Chart, and coarse grained soils with between 5% and 12% passing the No. 200 sieve require dual USCS symbols, ie., CL-ML, GW-GM, GP-GM, GW-GC, GP-GC, GC-GM, SW-SM, SP-SM, SW-SC, SP-SC, SC-SM.
- If sampler is not able to be driven at least 6 inches then 50/X indicates number of blows required to drive the identified sampler X inches with a 140 pound hammer falling 30 inches.

ABBREVIATIONS
C_u - Coefficients of Uniformity
C_C - Coefficients of Curvature
WOH - Weight of Hammer
WOR - Weight of Rod

REFERENCES
1. American Society for Materials and Testing (ASTM), 2011, ASTM D2487: Classification of Soils for Engineering Purposes (Unified Soil Classification System).

UNIFIED SOIL CLASSIFICATION SYSTEM[1]

COARSE GRAINED SOILS (More than 50% retained on No. 200 Sieve)	**GRAVELS** (More than 50% of coarse fraction retained on No. 4 Sieve)	CLEAN GRAVEL WITH <5% FINES		**GW**	WELL-GRADED GRAVEL, WELL-GRADED GRAVEL WITH SAND
				GP	POORLY GRADED GRAVEL, POORLY GRADED GRAVEL WITH SAND
		GRAVELS WITH 5% TO 12% FINES		**GW-GM**	WELL-GRADED GRAVEL WITH SILT, WELL-GRADED GRAVEL WITH SILT AND SAND
				GW-GC	WELL-GRADED GRAVEL WITH CLAY (OR SILTY CLAY), WELL-GRADED GRAVEL WITH CLAY AND SAND (OR SILT CLAY AND SAND)
				GP-GM	POORLY GRADED GRAVEL WITH SILT, POORLY GRADED GRAVEL WITH SILT AND SAND
				GP-GC	POORLY GRADED GRAVEL WITH CLAY (OR SILTY CLAY), POORLY GRADED GRAVEL WITH CLAY AND (OR SILTY CLAY AND SAND)
		GRAVELS WITH > 12% FINES		**GM**	SILTY GRAVEL, SILTY GRAVEL WITH SAND
				GC	CLAYEY GRAVEL, CLAYEY GRAVEL WITH SAND
				GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL WITH SAND
	SANDS (50% or more of coarse fraction passes the No. 4 Sieve)	CLEAN SANDS WITH <5% FINES		**SW**	WELL-GRADED SAND, WELL-GRADED SAND WITH GRAVEL
				SP	POORLY GRADED SAND, POORLY GRADED SAND WITH GRAVEL
		SANDS WITH 5% TO 12% FINES		**SW-SM**	WELL-GRADED SAND WITH SILT, WELL-GRADED SAND WITH SILT AND GRAVEL
				SW-SC	WELL-GRADED SAND WITH CLAY (OR SILTY CLAY), WELL-GRADED SAND WITH CLAY AND GRAVEL (OR SILTY CLAY AND GRAVEL)
				SP-SM	POORLY GRADED SAND WITH SILT, POORLY GRADED SAND WITH SILT AND GRAVEL
				SP-SC	POORLY GRADED SAND WITH CLAY, POORLY GRADED SAND WITH CLAY AND GRAVEL (OR SILTY CLAY AND GRAVEL)
		SANDS WITH > 12% FINES		**SM**	SILTY SAND, SILTY SAND WITH GRAVEL
				SC	CLAYEY SAND, CLAYEY SAND WITH GRAVEL
				SC-SM	SILTY, CLAYEY SAND, SILTY, CLAYEY SAND WITH GRAVEL
FINE GRAINED SOILS (50% or more passes the No. #200 sieve)	SILTS AND CLAYS (Liquid Limit less than 50)			**ML**	SILT, SILT WITH SAND, SILT WITH GRAVEL
				CL	LEAN CLAY, LEAN CLAY WITH SAND, LEAN CLAY WITH GRAVEL
				CL-ML	SILTY CLAY, SILTY CLAY WITH SAND, SILTY CLAY WITH GRAVEL
				OL	ORGANIC CLAY, ORGANIC CLAY WITH SAND, ORGANIC CLAY WITH GRAVEL, ORGANIC SILT, ORGANIC SILT WITH SAND, ORGANIC SILT WITH GRAVEL
	SILTS AND CLAYS (Liquid Limit 50 or greater)			**MH**	ELASTIC SILT. ELASTIC SILT WITH SAND, ELASTIC SILT WITH GRAVEL
				CH	FAT CLAY, FAT CLAY WITH SAND, FAT CLAY WITH GRAVEL
				OH	ORGANIC CLAY, ORGANIC CLAY WITH SAND, ORGANIC CLAY WITH GRAVEL, ORGANIC SILT, ORGANIC SILT WITH SAND, ORGANIC SILT WITH GRAVEL

NOTE: USE MATERIAL DESCRIPTION ON THE LOG TO DEFINE A GRAPHIC THAT MAY NOT BE PROVIDED ON THIS LEGEND.

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PROJECT NO.: 25001380.001A
DRAWN BY: GG
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DATE:

GRAPHICS KEY

MANTECA WWTP IMPROVEMENTS, PHASE I
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
A-1

PLOTTED: 07/26/2024 10:38 AM BY: GGomez
PROJECT NUMBER: 25001389.001A
OFFICE FILTER: STOCKTON
gINT FILE: Klf_gint_master_2025
gINT TEMPLATE: E:\KLF_STANDARD_GINT_LIBRARY_2025.GLB [_KLF_GEO_LEG1_GRAPHICS_KEY_W_USCS]

GRAIN SIZE[1]

DESCRIPTION		SIEVE SIZE	GRAIN SIZE
Boulders		>12 in.	>12 in. (304.8 mm.)
Cobbles		3 - 12 in.	3 - 12 in. (76.2 - 304.8 mm.)
Gravel	coarse	3/4 -3 in.	3/4 -3 in. (19 - 76.2 mm.)
	fine	#4 - 3/4 in.	0.19 - 0.75 in. (4.8 - 19 mm.)
Sand	coarse	#10 - #4	0.079 - 0.19 in. (2 - 4.9 mm.)
	medium	#40 - #10	0.017 - 0.079 in. (0.43 - 2 mm.)
	fine	#200 - #40	0.0029 - 0.017 in. (0.07 - 0.43 mm.)
Fines		Passing #200	<0.0029 in. (<0.07 mm.)

SECONDARY CONSTITUENT[1]

Term of Use	AMOUNT	
	Secondary Constituent is Fine Grained	Secondary Constituent is Coarse Grained
Trace	<5%	<15%
With	≥5 to <15%	≥15 to <30%
Modifier	≥15%	≥30%

PLASTICITY[1]

DESCRIPTION	CRITERIA
Non-Plastic	A 1/8 in. (3 mm) thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

MOISTURE CONTENT[1]

DESCRIPTION	FIELD TEST
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

CONSISTENCY - FINE-GRAINED SOIL[2, 3]

CONSISTENCY	SPT - N (# blows / ft)	Pocket Pen (tsf)	UNCONFINED COMPRESSIVE STRENGTH (Q_u)(psf)	VISUAL / MANUAL CRITERIA
Very Soft	<2	PP < 0.25	<500	Easily penetrated several inches by fist
Soft	2 - 4	0.25 ≤ PP <0.5	500 - 1,000	Easily penetrated several inches by thumb
Medium Stiff	4 - 8	0.5 ≤ PP <1	1,000 - 2,000	Can be penetrated several inches by thumb with moderate effort
Stiff	8 - 15	1 ≤ PP <2	2,000 - 4,000	Readily indented by thumb but penetrated only with great effort
Very Stiff	15 - 30	2 ≤ PP <4	4,000 - 8,000	Readily indented by thumbnail
Hard	>30	4 ≤ PP	>8,000	Indented by thumbnail with difficulty

APPARENT DENSITY - COARSE-GRAINED SOIL[2]

APPARENT DENSITY	SPT-N (# blows / ft)
Very Loose	<4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

STRUCTURE[1]

DESCRIPTION	CRITERIA
Stratified	Alternating layers of varying material or color with layers at least 1/4-in. (6mm) thick, note thickness.
Laminated	Alternating layers of varying material or color with the layers less than 1/4-in. (6 mm) thick, note thickness.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown.
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay; note thickness.
Homogeneous	Same color and appearance throughout

ANGULARITY[1]

DESCRIPTION	CRITERIA
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have rounded edges.
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

REACTION WITH HYDROCHLORIC ACID[1]

DESCRIPTION	FIELD TEST
None	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

CEMENTATION[1]

DESCRIPTION	FIELD TEST
Weakly	Crumbles or breaks with handling or little finger pressure
Moderately	Crumbles or breaks with considerable finger pressure
Strongly	Will not crumble or break with finger pressure

REFERENCES

1. American Society for Materials and Testing (ASTM), 2017, ASTM D2488: Standard Practice for Description and Identification of Soils (Visual Manual Procedures).
2. Terzaghi, K and Peck, R., 1948, Soil Mechanics in Engineering Practice, John Wiley & Sons, New York.
3. United States Department of the Interior Bureau of Reclamation (USBR), 1998, Earth Manual, Part I.

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PROJECT NO.: 25001380.001A
DRAWN BY: GG
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DATE:

SOIL DESCRIPTION KEY
(For additional tables, see ASTM D2488)

MANTECA WWTP IMPROVEMENTS, PHASE I
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
A-2

PLOTTED: 07/26/2024 10:38 AM BY: GGomez
OFFICE FILTER: STOCKTON
PROJECT NUMBER: 25001389.001A
[KLF_GEO_LEG2_SOIL_DESC_KEY]
gINT FILE: Klf_gint_master_2025
gINT TEMPLATE: E:\KLF_STANDARD_GINT_LIBRARY_2025.GLB

BORING LOG B-1

Date Begin - End:	7/25/2024	**Drilling Company:**	Taber		
Logged By:	NF	**Drill Crew:**	Rick/Nick/Francisco		
Hor.-Vert. Datum:	- WGS 84 (Google Earth)	**Drilling Equipment:**	Diedrich 120 Truck	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Hand Auger/Solid Stem Auger/Mud Rotary		
Weather:	Sunny/Warm	**Exploration Diameter:**	4 in./8 in.		

Latitude: 37.79446°
Longitude: -121.26044°
Approximate Ground Surface Elevation (ft.): 28.00
Surface Condition: Gravel

Approximate Elevation (feet)	Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
25	0		Clean crushed gravel, approximately 1" minus	Bulk 1											Hand Auger to 5'
			Silty SAND (SM): fine to medium sand, olive brown, moist												
20	5		loose	1C 1B 1A		BC=6 6 7	18"		9.3			16			Switched to Solid Stem Auger
				2		BC=3 2 3	17"								
15	10		medium dense, weakly cemented lenses	3C 3B 3A		BC=4 7 7	18"								
10	15		**Poorly Graded SAND with Silt (SP-SM)**: medium to coarse sand, pale olive, wet, loose to medium dense	4B		BC=6 5 5	18"								Switched to Mud Rotary
				4A		PP=1.5									
			Lean CLAY with Sand (CL): fine sand, medium to high plasticity, no dilatancy, light brownish gray, wet, stiff, homogeneous	5		BC=5 6 7 PP=3.5, 2.5, 2.0	18"		32.6				45	21	
5	20		**Sandy Lean CLAY (CL)**: fine sand, medium plasticity, slow dilatancy, pale olive, moist, stiff to very stiff	6C 6B		BC=8 11 10									
			Lean CLAY with Sand (CL): fine to medium sand, medium to high plasticity, light brownish gray, wet, very stiff to hard	6A		PP=3.5, 4.5+									
0	25		slow dilatancy, medium stiff olive brown with mottled bluish gray, lensed sands	7		BC=2 2 3	18"								
-5	30		**Clayey SAND (SC)**: fine to medium sand, medium plasticity, bluish gray, wet, medium dense, homogeneous	8C 8B 8A		BC=11 15 22	18"								
	35		The boring was terminated at approximately 31.5 ft. below ground surface. The boring was backfilled with neat cement on July 25, 2024.												

GROUNDWATER LEVEL INFORMATION:
▽ Groundwater was observed at approximately 13 ft. below ground surface during drilling.
GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

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PROJECT NO.:	25001389.001A
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DATE:	7/26/2024

BORING LOG B-1

MANTECA WWTP IMPROVEMENTS, PHASE I
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
A-3

PAGE: 1 of 1

PLOTTED: 08/06/2024 09:38 AM BY: GGomez
PROJECT NUMBER: 25001380.001A OFFICE FILTER: STOCKTON
gINT FILE: Klf_gint_master_2025 gINT TEMPLATE: E:\KLF_STANDARD_GINT_LIBRARY_2025.GLB [_KLF_BORING/TEST PIT SOIL LOG]

BORING LOG B-2

Date Begin - End:	7/25/2024	**Drilling Company:**	Taber		
Logged By:	NF	**Drill Crew:**	Rick/Nick/Francisco		
Hor.-Vert. Datum:	- WGS 84 (Google Earth)	**Drilling Equipment:**	Diedrich 120 Truck	**Hammer Type - Drop:**	140 lb. Auto - 30 in.
Plunge:	-90 degrees	**Drilling Method:**	Hand Auger/Solid Stem Auger		
Weather:	Sunny/Warm	**Exploration Diameter:**	4 in.		

Latitude: 37.79694°
Longitude: -121.76035°
Approximate Ground Surface Elevation (ft.): 27.00
Surface Condition: Gravel

Approximate Elevation (feet)	Depth (feet)	Graphical Log	Lithologic Description	Sample Number	Sample Type	Blow Counts(BC)= Uncorr. Blows/6 in. Pocket Pen(PP)= tsf	Recovery (NR=No Recovery)	USCS Symbol	Water Content (%)	Dry Unit Wt. (pcf)	Passing #4 (%)	Passing #200 (%)	Liquid Limit	Plasticity Index (NP=NonPlastic)	Additional Tests/ Remarks
			Clean crushed gravel, approximately 1" minus												
25			**Silty SAND (SM)**: fine to medium sand, non-plastic, olive brown, moist	Bulk-1											Hand Auger to 5'
	5		loose, homogeneous	1		BC=5 5 4	18"								Switched to Solid Stem Auger
20			loose to medium dense	2C 2B		BC=7 8 7	16"		7.7			28			
	10		**Poorly Graded SAND with Silt (SP-SM)**: fine to medium sand, pale olive, moist, loose to medium dense, homogeneous	2A											
			Silty SAND (SM): fine to medium sand, olive brown, moist, loose, homogeneous	3B 3A		BC=3 2 2	15"								
15			**Poorly Graded SAND with Silt (SP-SM)**: fine to medium sand, pale olive, wet, loose, homogeneous												
	15		medium dense	4C 4B 4A		BC=3 9 14									
10															
	20														
5															
	25														
0															
	30														
-5															

The boring was terminated at approximately 16.5 ft. below ground surface. The boring was backfilled with neat cement on July 25, 2024.

GROUNDWATER LEVEL INFORMATION:
▽ Groundwater was observed at approximately 11 ft. below ground surface during drilling.
GENERAL NOTES:
The exploration location and elevation are approximate and were estimated by Kleinfelder.

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PROJECT NO.:	25001389.001A
DRAWN BY:	GG
CHECKED BY:	NF
DATE:	7/26/2024

BORING LOG B-2

MANTECA WWTP IMPROVEMENTS, PHASE I
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
A-4

PAGE: 1 of 1

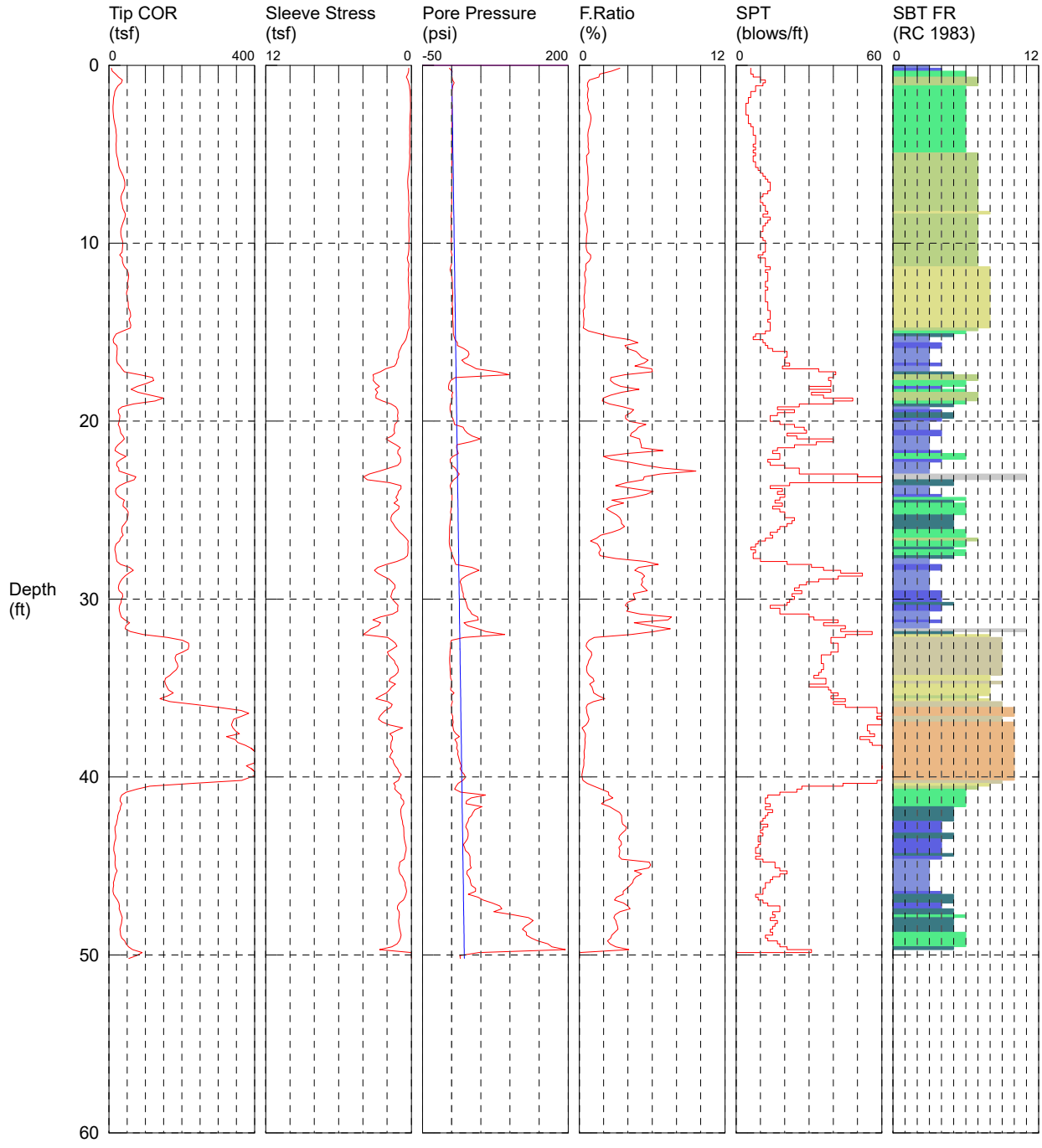
PLOTTED: 08/06/2024 09:38 AM BY: GGomez
OFFICE FILTER: STOCKTON
PROJECT NUMBER: 25001380.001A
gINT FILE: Klf_gint_master_2025
gINT TEMPLATE: E:\KLF_STANDARD_GINT_LIBRARY_2025.GLB [_KLF_BORING/TEST PIT SOIL LOG]

SOUNDING

SOUNDING
CUSTOMER: Taber Drilling
OPERATOR: David
CONE ID: DDG1652
LOCATION:

JOB NUMBER:
HOLE NUMBER: CPT-1
TEST DATE: 7/29/2024 7:59:02 AM
COMMENT: Auto Enhance On
COMMENT: Filter On

COMMENT:
GPS (LAT,LON,ALT): 0.00,0.00,0.0
LOCATION:
LOCATION:
LOCATION:



1 sensitive fine grained
2 organic material
3 clay
4 silty clay to clay
5 clayey silt to silty clay
6 sandy silt to clayey silt
7 silty sand to sandy silt
8 sand to silty sand
9 sand
10 gravelly sand to sand
11 very stiff fine grained (*)
12 sand to clayey sand (*)

*SBT/SPT CORRELATION: UBC-1983

FIGURE
A-5

APPENDIX B

LABORATORY TESTING RESULTS

LIST OF ATTACHMENTS

The following figures are attached.

FIGURE B-1	Laboratory Test Results Summary
FIGURE B-2	Atterberg Limits
FIGURE B-3	Corrosion Test Results

Exploration ID	Depth (ft.)	Sample No.	Sample Description	Water Content (%)	Dry Unit Wt. (pcf)	Sieve Analysis (%)			Atterberg Limits			Additional Tests
						Passing 3/4"	Passing #4	Passing #200	Liquid Limit	Plastic Limit	Plasticity Index	
B-1	6.0	1A	SILTY SAND (SM)	9.3				16				
B-1	17.0	5	SANDY LEAN CLAY (CL)	32.6					45	24	21	
B-2	0.4	Bulk-1	SILTY SAND (SM)									**pH=** 7.06
												Resistivity= 6.16
												Sulfates= 12.8
												Chlorides= 2.3
B-2	8.0	2B	SILTY SAND (SM)	7.7				28				

Refer to the Geotechnical Evaluation Report or the supplemental plates for the method used for the testing performed above.
NP = NonPlastic
NA = Not Available

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PROJECT NO.: 25001380.001A
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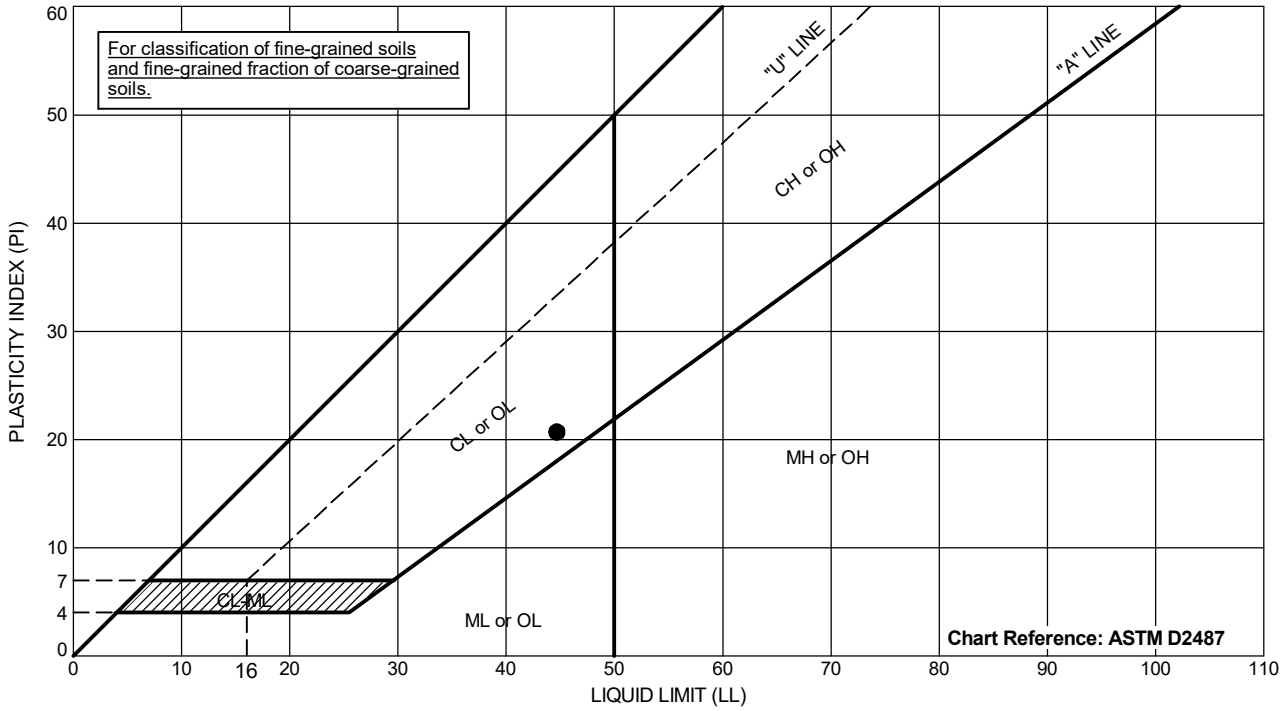
DATE:

LABORATORY TEST RESULT SUMMARY

MANTECA WWTP IMPROVEMENTS, TASK I
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
B-1



Exploration ID	Depth (ft.)	Sample Number	Sample Description	Passing #200	LL	PL	PI
● B-1	17	5	SANDY LEAN CLAY (CL)	NM	45	24	21

Testing performed in general accordance with ASTM D4318.
NP = Nonplastic
NA = Not Available
NM = Not Measured

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PROJECT NO.: 25001389.001A
DRAWN BY: GG
CHECKED BY: NF
DATE:

ATTERBERG LIMITS

MANTECA WWTP IMPROVEMENTS, TASK I
2450 W. YOSEMITE AVENUE
MANTECA, CALIFORNIA

FIGURE
B-2

PLOTTED: 08/06/2024 09:44 AM BY: GGomez
OFFICE FILTER: STOCKTON
PROJECT NUMBER: 25001380.001A
gINT FILE: Klf_gint_master_2025
gINT TEMPLATE: E:\KLF_STANDARD_GINT_LIBRARY_2025.GLB [KLF_ATTERBERG (ASTM)]

Sunland Analytical

11419 Sunrise Gold Circle, #10
Rancho Cordova, CA 95742
(916) 852-8557

Date Reported 08/14/2024
Date Submitted 08/07/2024

To: Adam Killinger
Kleinfelder-Sacramento
3130 Kilgore Road Ste 200
Rancho Cordova CA 95670

From: Gene Oliphant, Ph.D. \ Ty Bui
General Manager \ Lab Manager

The reported analysis was requested for the following location:
Location : 25001380.001A Site ID : B-2 BULK0.4-5FT.
Thank you for your business.

* For future reference to this analysis please use SUN # 92871-192343.

EVALUATION FOR SOIL CORROSION

Soil pH	7.06		
Minimum Resistivity	6.16 ohm-cm (x1000)		
Chloride	2.3 ppm	00.00023	%
Sulfate	12.8 ppm	00.00128	%

METHODS
pH and Min.Resistivity CA DOT Test #643
Sulfate CA DOT Test #417, Chloride CA DOT Test #422m

FIGURE
B-3

APPENDIX C

LIQUEFACTION ANALYSIS

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CPT 1 results

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Merarhias 56
http://www.geologismiki.gr

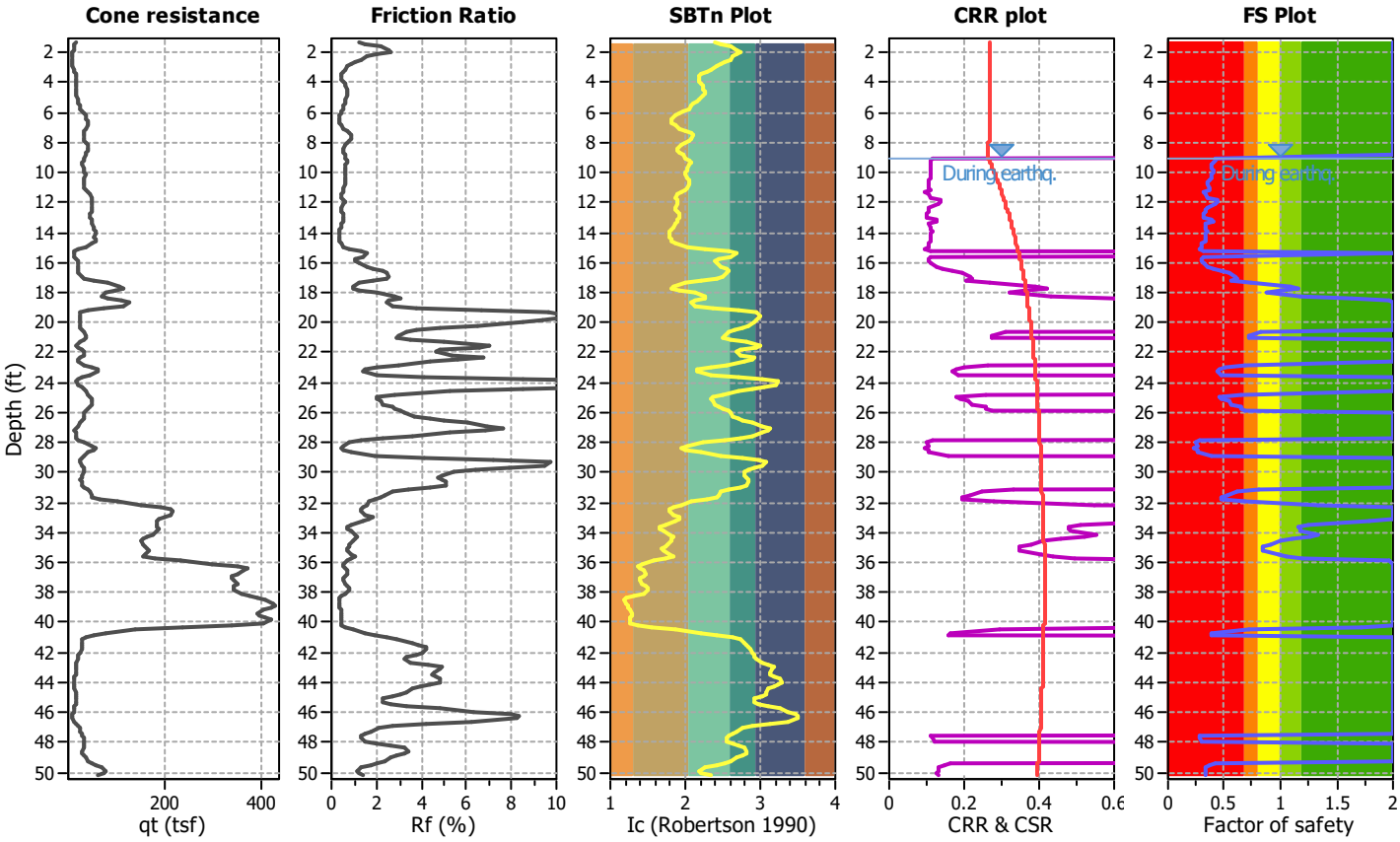
LIQUEFACTION ANALYSIS REPORT

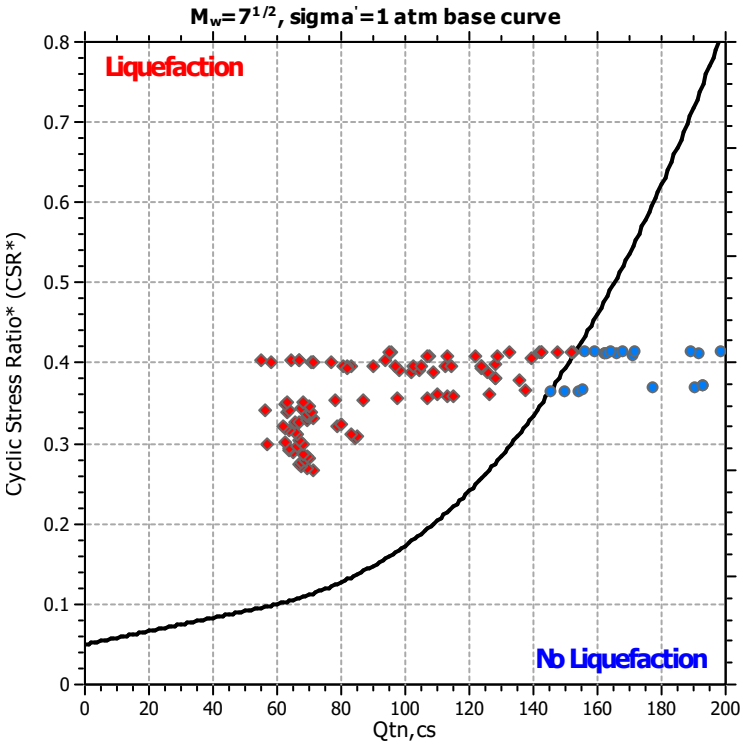
Project title : Manteca WWTP **Location : Manteca, CA**

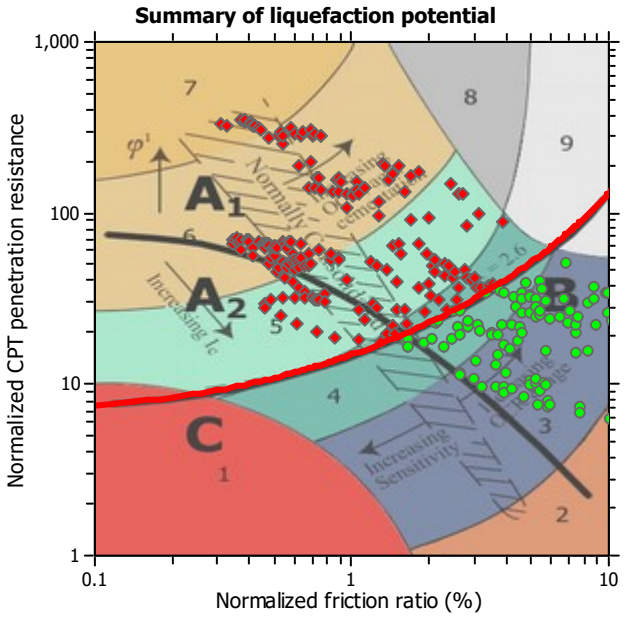
CPT file : CPT 1

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	11.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	9.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.13	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.43	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

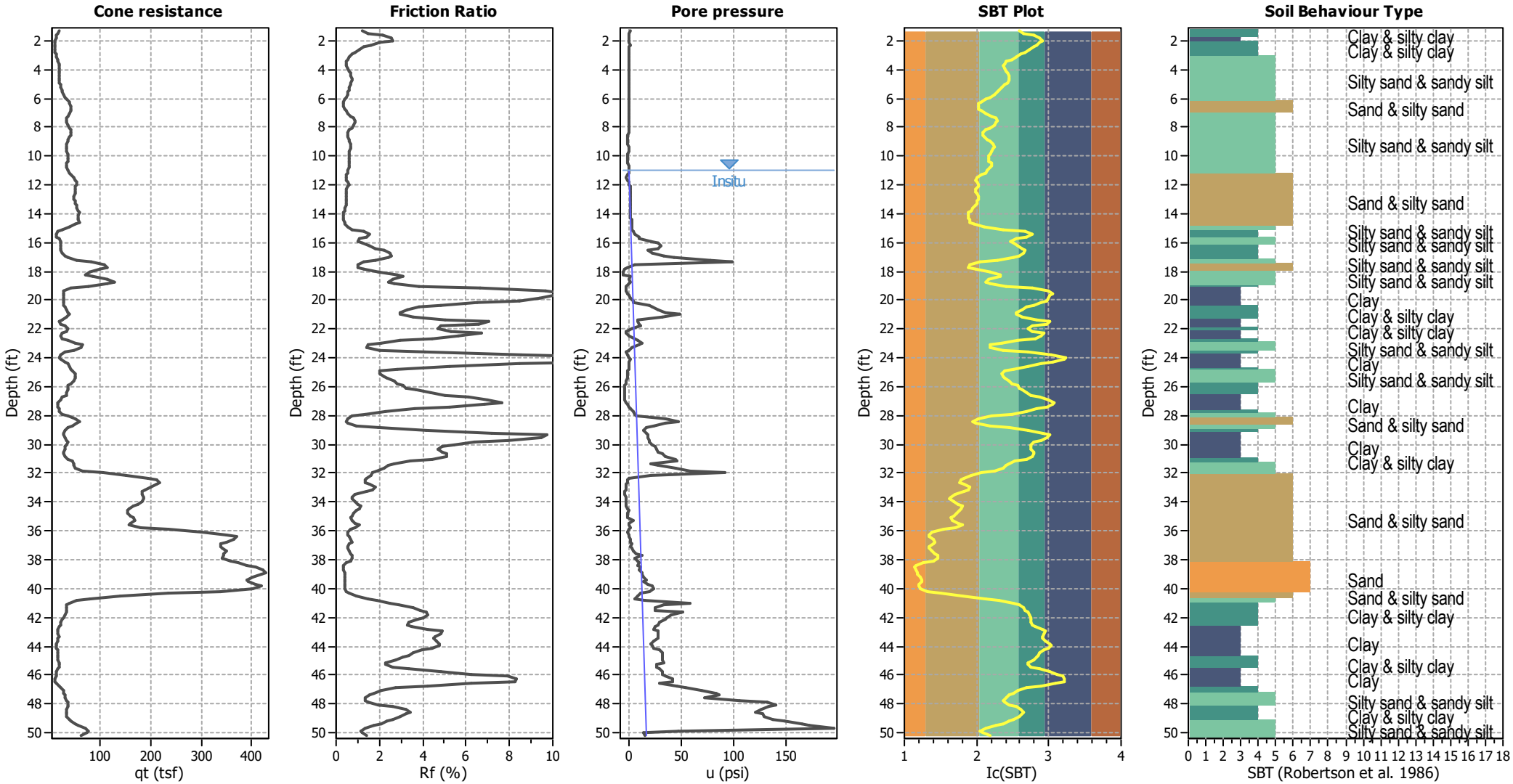






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



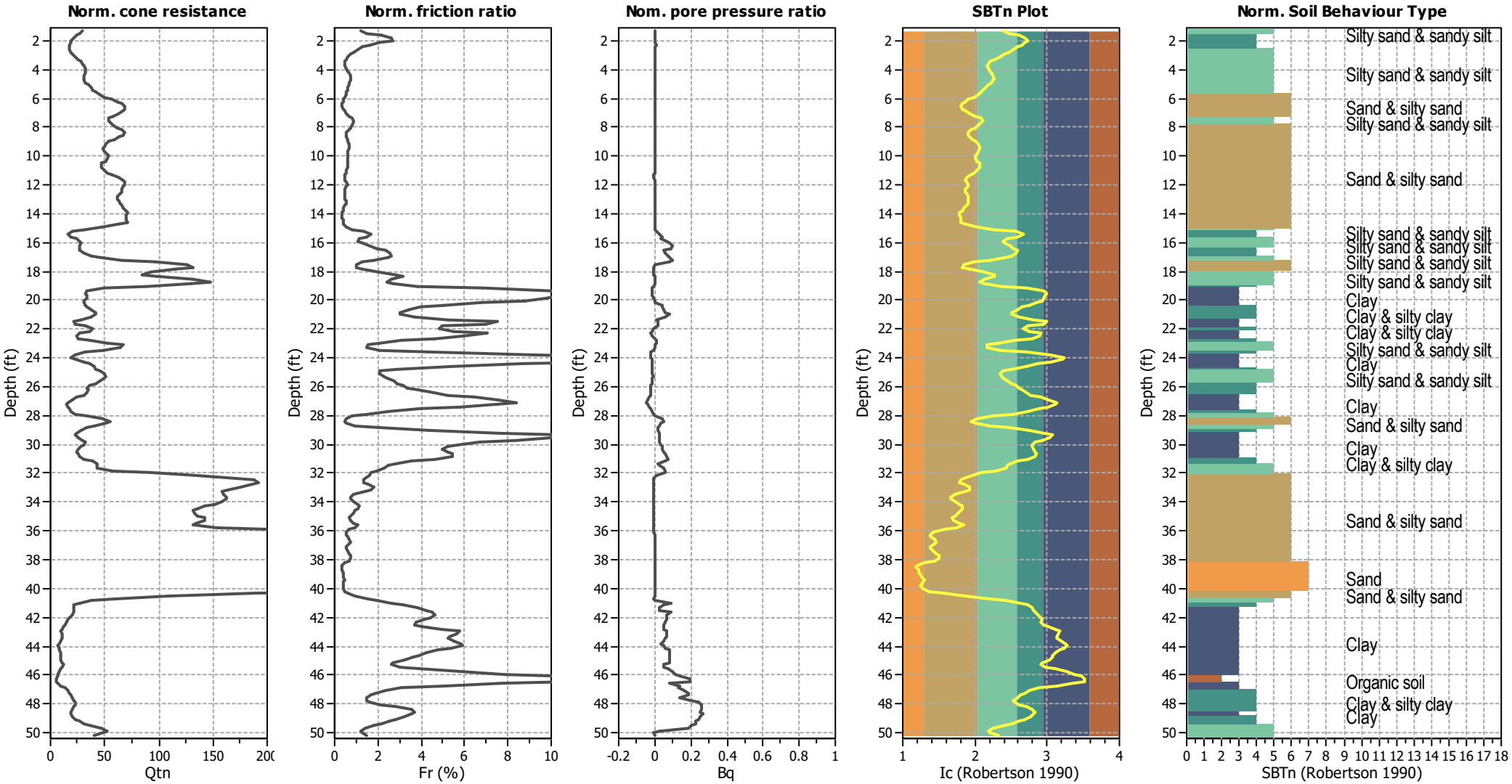
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



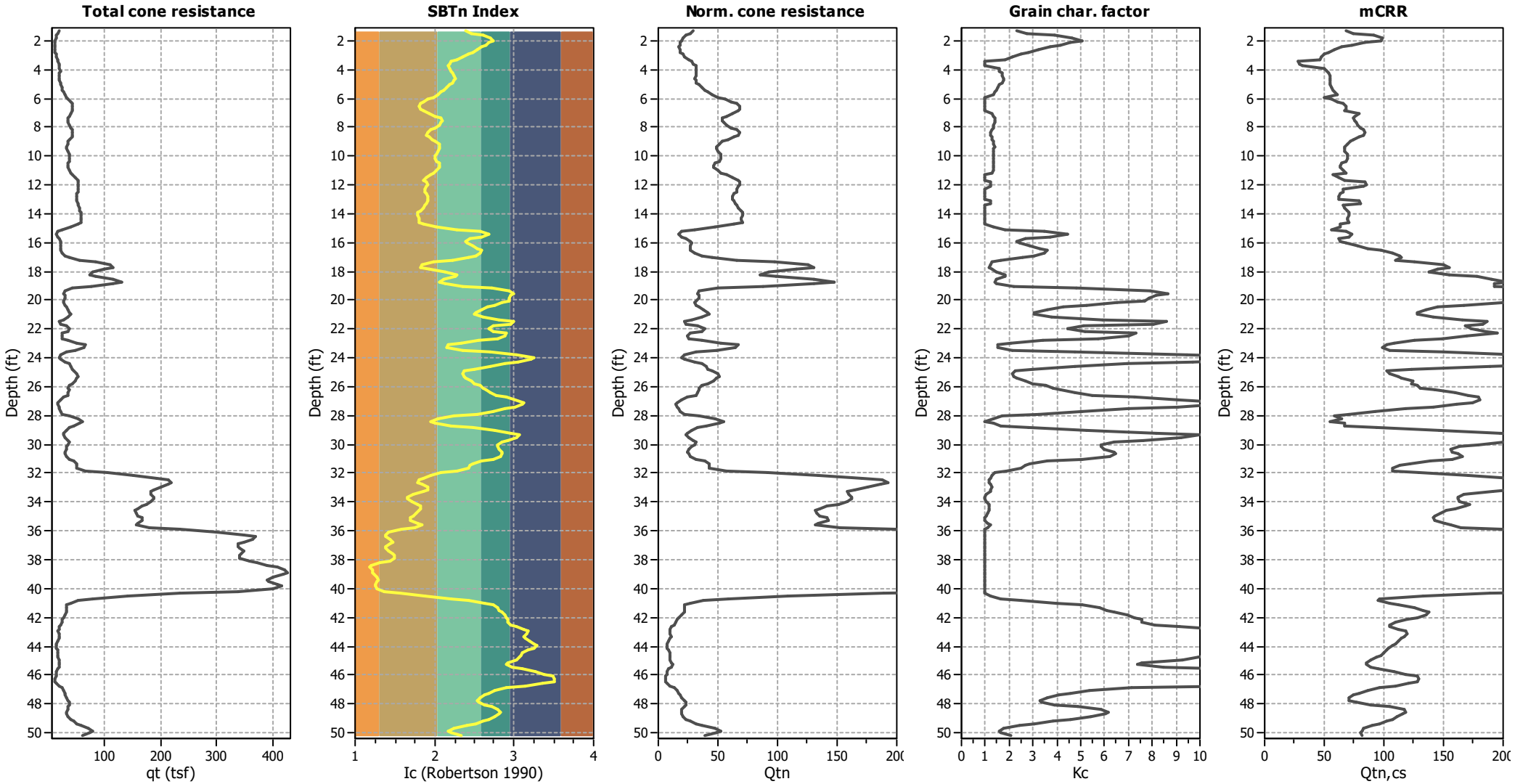
Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

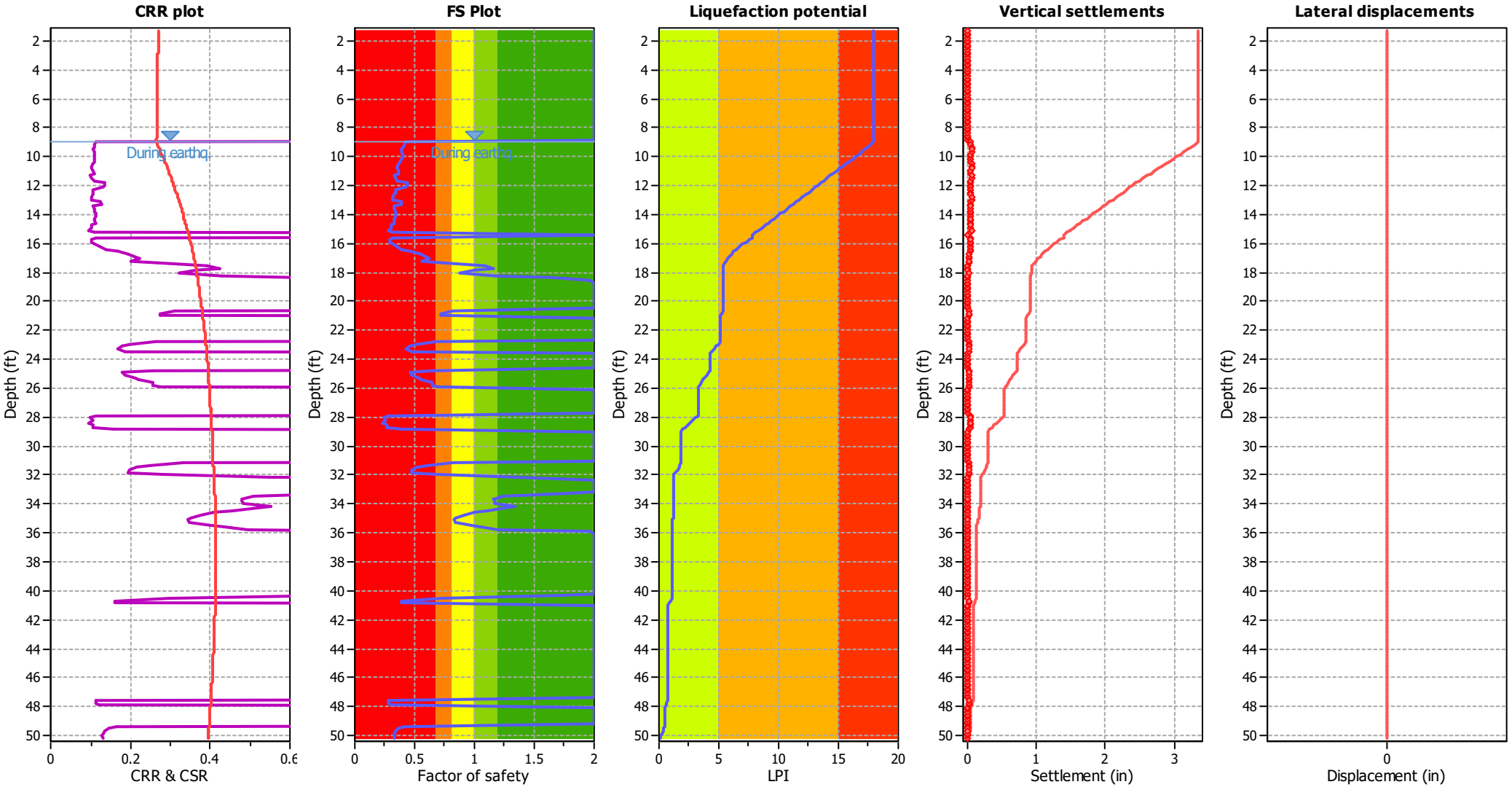
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

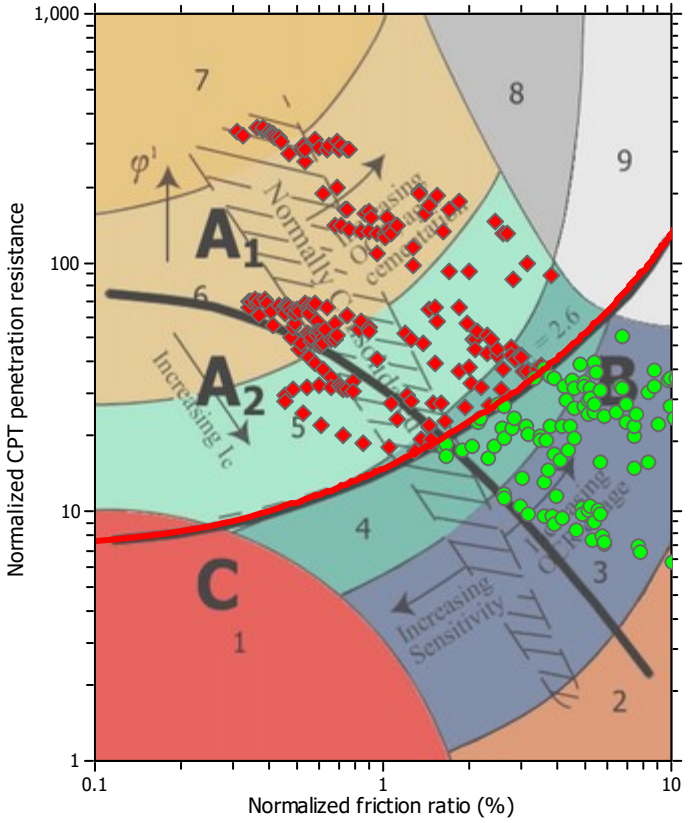
F.S. color scheme

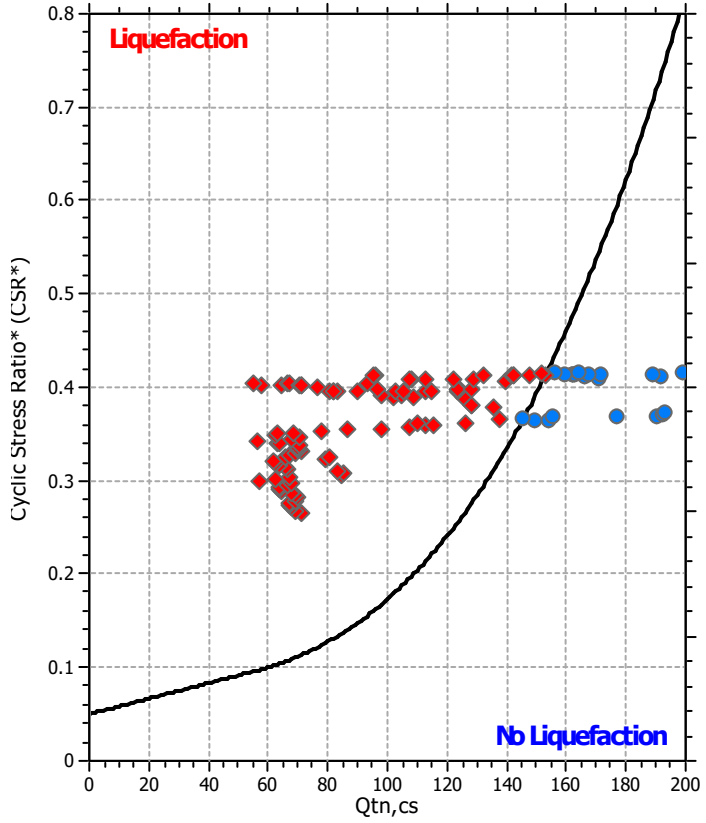
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

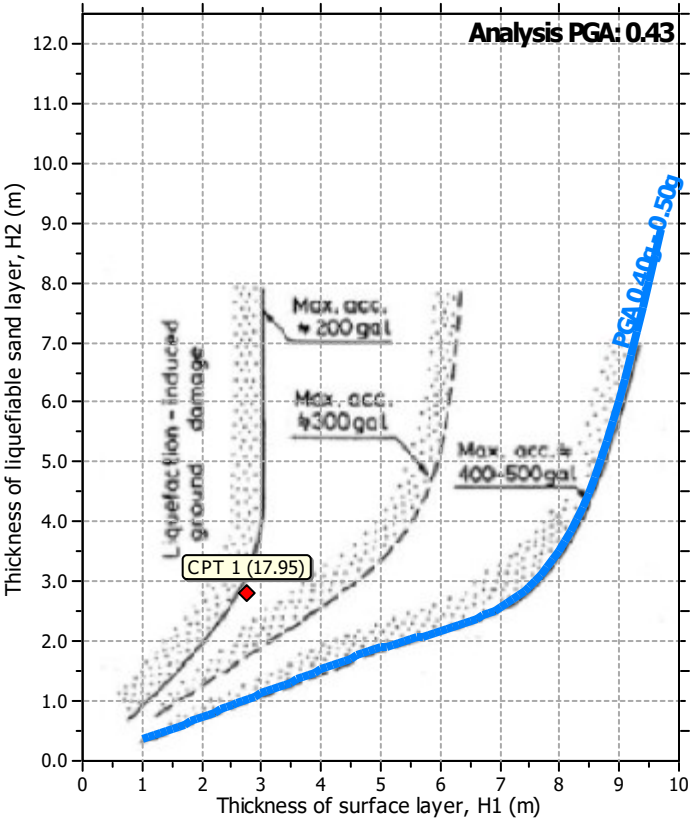
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



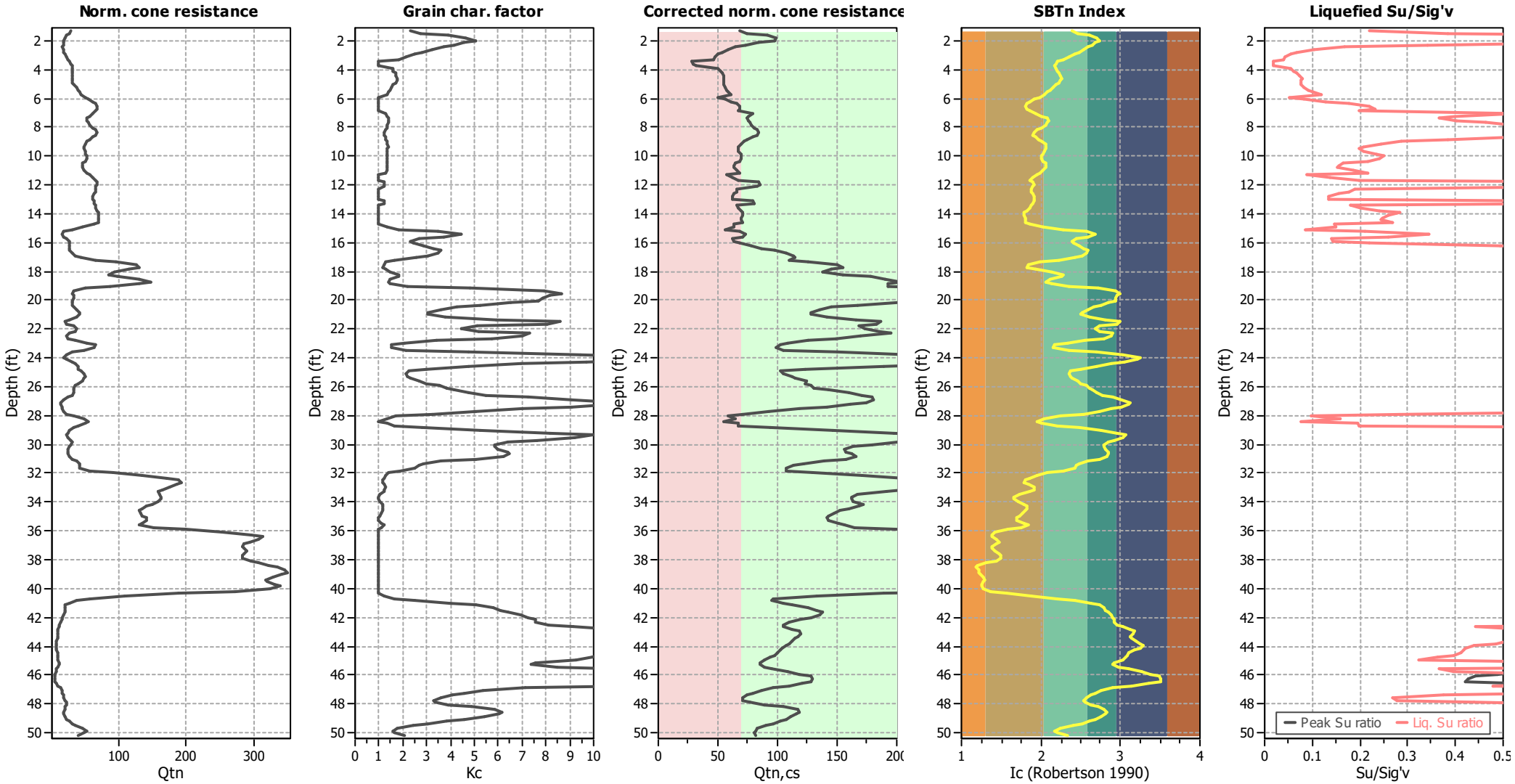




Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

:: Field input data ::

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
1	1.31	19.66	0.22	0.99	25.89	106.41
2	1.48	16.04	0.23	0.58	29.25	107.07
3	1.64	15.14	0.30	0.42	36.05	108.47
4	1.80	12.95	0.42	0.39	40.18	108.78
5	1.97	11.89	0.31	0.25	42.19	108.04
6	2.13	11.69	0.23	0.19	39.89	105.63
7	2.30	10.87	0.17	1.01	37.49	103.64
8	2.46	10.95	0.14	0.57	35.03	101.79
9	2.63	11.30	0.11	0.38	32.41	100.64
10	2.79	11.95	0.10	0.32	29.67	99.47
11	2.95	12.45	0.09	0.32	27.17	99.04
12	3.12	13.96	0.09	0.32	24.36	98.69
13	3.28	15.74	0.08	0.37	21.66	98.71
14	3.44	17.48	0.08	0.56	5.00	98.71
15	3.61	19.05	0.08	0.51	5.00	99.27
16	3.77	19.33	0.09	0.50	5.00	100.26
17	3.94	20.68	0.11	0.38	18.55	101.23
18	4.10	19.92	0.12	0.35	18.96	102.09
19	4.26	20.32	0.13	0.28	19.94	102.65
20	4.43	19.47	0.14	0.25	20.51	103.15
21	4.59	19.71	0.15	0.27	21.05	103.33
22	4.76	19.48	0.14	0.24	20.79	103.27
23	4.92	19.97	0.14	0.21	20.09	103.29
24	5.08	21.59	0.14	0.20	18.77	103.41
25	5.25	23.49	0.14	0.23	17.48	103.76
26	5.41	25.02	0.15	0.21	16.33	103.92
27	5.58	26.13	0.14	0.07	15.29	104.04
28	5.74	27.94	0.14	0.11	14.05	104.28
29	5.91	31.19	0.15	0.13	5.00	104.74
30	6.07	35.40	0.16	0.20	5.00	104.76
31	6.23	38.85	0.13	0.19	5.00	104.89
32	6.40	41.42	0.14	0.18	5.00	104.97
33	6.56	43.21	0.15	0.17	5.00	105.74
34	6.73	43.70	0.17	0.15	5.00	106.48
35	6.89	42.55	0.19	0.11	5.00	107.24
36	7.05	39.64	0.21	0.05	11.18	108.03
37	7.22	35.73	0.24	-0.03	13.27	108.72
38	7.38	32.75	0.28	-0.07	15.15	109.38
39	7.55	32.77	0.30	-0.08	15.83	109.91
40	7.71	34.96	0.31	-0.06	15.40	110.24
41	7.87	36.53	0.30	-0.10	14.46	110.24
42	8.04	37.71	0.29	-0.14	13.10	109.97
43	8.20	41.52	0.26	-0.20	11.47	109.56
44	8.37	45.15	0.24	-0.65	10.55	109.17
45	8.53	43.86	0.23	-1.23	10.50	108.89
46	8.69	41.20	0.23	-1.37	11.13	108.42
47	8.86	38.12	0.21	-0.94	12.16	108.16
48	9.02	35.46	0.23	-1.09	13.29	107.92

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
49	9.19	33.19	0.23	-0.96	14.50	108.03
50	9.35	32.09	0.23	-0.72	14.83	107.66
51	9.51	32.64	0.20	-0.64	14.68	107.51
52	9.68	33.97	0.21	-0.73	13.99	107.45
53	9.84	36.39	0.22	-0.80	13.50	107.81
54	10.01	38.00	0.22	-0.99	13.20	107.97
55	10.17	37.31	0.22	-1.08	13.22	107.95
56	10.34	36.86	0.21	-0.95	13.52	107.81
57	10.50	35.95	0.21	-0.87	14.64	107.35
58	10.66	29.10	0.20	0.58	14.63	107.15
59	10.83	36.65	0.20	-0.28	14.59	107.12
60	10.99	36.61	0.21	-0.20	13.49	107.55
61	11.15	38.29	0.22	-0.09	12.83	107.77
62	11.32	42.47	0.21	-1.73	5.00	108.11
63	11.48	48.98	0.21	-2.77	5.00	108.55
64	11.65	52.37	0.23	-1.52	5.00	109.41
65	11.81	54.03	0.27	-0.05	10.11	110.70
66	11.97	53.15	0.34	0.58	10.55	111.20
67	12.14	51.76	0.30	0.99	10.48	110.68
68	12.30	51.37	0.21	1.05	5.00	109.49
69	12.47	52.86	0.22	1.07	5.00	109.15
70	12.63	50.39	0.26	1.16	5.00	109.29
71	12.79	48.04	0.23	1.53	5.00	109.35
72	12.96	48.69	0.23	1.59	5.00	109.34
73	13.12	50.48	0.26	1.30	10.55	109.79
74	13.29	52.46	0.27	0.92	10.31	109.99
75	13.45	52.68	0.24	0.88	5.00	109.74
76	13.62	53.44	0.23	1.53	5.00	109.32
77	13.78	56.94	0.22	1.60	5.00	109.04
78	13.94	59.02	0.21	1.76	5.00	108.64
79	14.11	59.59	0.19	1.90	5.00	108.26
80	14.27	55.09	0.19	1.84	5.00	108.31
81	14.44	57.73	0.21	2.11	5.00	108.73
82	14.60	59.67	0.23	2.35	5.00	109.31
83	14.76	58.46	0.24	2.46	5.00	108.59
84	14.93	38.93	0.17	2.47	13.52	107.45
85	15.09	19.92	0.19	2.69	21.65	105.87
86	15.26	14.94	0.20	4.04	33.73	105.15
87	15.42	11.29	0.21	5.74	39.14	104.98
88	15.58	12.78	0.21	9.81	35.02	105.49
89	15.75	21.02	0.21	9.78	28.50	105.79
90	15.91	22.72	0.19	20.60	25.87	107.03
91	16.08	21.92	0.29	27.98	27.06	108.26
92	16.24	21.72	0.34	29.76	30.07	109.81
93	16.40	20.71	0.39	27.06	32.49	110.95
94	16.57	20.75	0.46	17.34	34.60	112.54
95	16.73	22.94	0.62	22.27	33.66	114.66
96	16.90	30.35	0.79	33.35	31.12	116.62

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
97	17.06	35.65	0.89	42.45	27.78	118.31
98	17.22	42.48	1.02	78.12	19.61	120.02
99	17.39	84.52	1.07	98.63	12.66	121.42
100	17.55	119.95	1.06	5.99	8.98	122.43
101	17.72	122.76	1.17	-1.71	8.67	122.89
102	17.88	101.92	1.22	-4.48	11.14	123.22
103	18.05	77.68	1.39	-5.61	16.94	124.30
104	18.21	60.49	2.13	-5.28	21.50	125.88
105	18.37	79.73	2.55	1.96	21.23	128.13
106	18.54	112.82	3.18	0.06	16.52	129.73
107	18.70	149.04	3.11	0.97	14.87	130.51
108	18.86	126.57	3.14	0.07	16.91	130.02
109	19.03	67.48	2.93	-2.31	24.90	128.65
110	19.19	35.59	2.64	-2.84	41.04	127.10
111	19.36	25.55	2.98	-3.11	54.98	126.02
112	19.52	26.05	2.78	-1.93	57.94	126.11
113	19.68	30.18	2.93	-0.33	56.03	126.18
114	19.85	29.27	2.93	1.69	54.73	125.89
115	20.01	28.01	2.39	3.77	53.89	124.54
116	20.18	25.02	1.67	4.67	48.99	122.57
117	20.34	28.73	1.29	19.52	43.19	120.72
118	20.50	30.76	1.14	22.11	38.15	119.83
119	20.67	32.17	1.10	27.08	34.52	119.79
120	20.83	38.41	1.15	34.75	31.31	119.98
121	21.00	42.18	1.11	48.90	31.05	120.13
122	21.16	34.22	1.15	32.11	35.68	120.29
123	21.32	24.96	1.37	8.55	46.15	120.17
124	21.49	18.04	1.39	8.24	57.79	120.02
125	21.65	16.19	1.43	9.52	55.57	120.19
126	21.82	28.97	1.38	11.38	42.54	121.46
127	21.98	46.58	1.61	2.03	39.27	122.89
128	22.15	33.17	2.10	-2.69	42.71	123.19
129	22.31	21.88	1.71	-2.38	52.58	122.00
130	22.47	20.72	1.27	0.13	51.20	119.87
131	22.64	26.79	0.92	5.95	45.46	118.84
132	22.80	27.32	1.11	8.43	33.39	119.37
133	22.97	51.96	1.13	12.89	23.73	120.27
134	23.13	74.04	0.93	9.37	17.76	120.27
135	23.29	69.17	0.87	3.21	17.72	119.60
136	23.46	45.94	0.90	-0.52	24.46	119.46
137	23.62	28.98	1.12	-2.61	40.57	120.55
138	23.79	19.36	1.85	-1.73	61.17	122.37
139	23.95	17.66	2.62	-0.30	76.34	124.60
140	24.11	20.46	3.48	0.63	74.45	126.70
141	24.28	28.96	3.95	0.59	62.01	128.16
142	24.44	42.09	3.64	0.43	50.90	127.40
143	24.61	39.40	1.78	-0.34	40.67	124.67
144	24.77	38.66	0.86	-0.68	30.87	120.50

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
145	24.93	47.15	0.86	-0.92	25.63	119.10
146	25.10	52.30	1.07	-2.12	24.34	119.99
147	25.26	52.33	1.13	-1.32	25.20	120.98
148	25.43	51.04	1.28	-1.97	25.99	121.04
149	25.59	48.86	1.13	-2.54	28.70	121.51
150	25.75	43.10	1.44	-2.94	30.80	120.73
151	25.92	36.62	1.02	-3.54	33.95	120.28
152	26.08	34.80	1.05	-3.76	35.83	119.98
153	26.25	35.61	1.37	-3.77	37.47	121.18
154	26.41	39.09	1.60	-3.89	40.82	122.21
155	26.57	31.67	1.70	-4.12	44.27	122.53
156	26.74	28.91	1.69	-4.46	52.24	121.84
157	26.90	19.77	1.50	-4.27	59.68	120.82
158	27.07	16.74	1.36	-3.27	67.51	119.39
159	27.23	16.08	1.16	-1.52	66.21	118.24
160	27.39	17.93	0.95	-0.10	59.58	116.78
161	27.56	19.21	0.69	1.44	51.04	114.83
162	27.72	20.36	0.45	3.40	42.29	112.06
163	27.89	22.01	0.26	5.13	32.17	110.12
164	28.05	31.91	0.29	7.00	20.34	109.70
165	28.21	56.43	0.27	34.60	13.90	110.68
166	28.38	66.87	0.28	46.91	5.00	110.95
167	28.54	54.16	0.29	34.47	13.28	111.23
168	28.71	43.44	0.33	24.11	19.42	113.01
169	28.87	35.76	0.61	16.63	29.69	116.62
170	29.04	30.68	1.20	14.22	43.22	120.57
171	29.20	26.96	2.07	16.12	55.93	123.50
172	29.36	25.41	2.76	17.28	63.22	125.37
173	29.53	27.84	3.04	18.11	60.18	126.27
174	29.69	36.44	2.78	19.84	53.67	126.21
175	29.86	37.73	2.34	19.87	48.39	125.18
176	30.02	33.74	1.84	22.60	46.07	123.76
177	30.18	33.56	1.60	24.54	46.06	122.22
178	30.35	29.16	1.37	26.18	46.56	121.30
179	30.51	28.01	1.36	27.41	48.46	121.10
180	30.68	28.86	1.56	31.77	48.72	121.56
181	30.84	30.89	1.62	34.29	47.60	122.25
182	31.00	33.70	1.70	44.58	42.25	122.60
183	31.17	43.59	1.55	45.66	34.54	122.66
184	31.33	56.31	1.33	20.85	30.02	121.86
185	31.50	46.70	1.10	27.32	28.52	121.07
186	31.66	44.47	1.14	44.83	27.28	120.69
187	31.82	58.86	1.13	58.47	21.92	122.25
188	31.99	93.50	1.54	90.90	15.46	125.69
189	32.15	160.96	2.55	21.11	11.86	129.02
190	32.32	201.79	3.18	-0.54	9.25	130.54
191	32.48	218.49	2.54	-2.05	8.11	130.93
192	32.64	219.33	2.73	-1.82	7.93	131.12

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
193	32.81	217.42	3.33	-2.57	9.15	131.92
194	32.97	202.02	3.62	-2.95	10.97	132.67
195	33.14	184.65	3.98	-3.19	10.83	131.54
196	33.30	181.25	1.96	-3.54	9.52	129.73
197	33.47	183.18	1.61	-3.69	6.61	126.58
198	33.63	187.79	1.33	-3.51	5.51	125.37
199	33.79	189.62	1.19	-3.05	5.42	125.29
200	33.96	185.00	1.57	-2.77	6.49	126.32
201	34.12	175.77	1.98	-2.42	7.87	127.22
202	34.28	167.03	1.89	-2.24	8.79	127.20
203	34.45	155.25	1.66	-1.95	8.71	126.28
204	34.61	153.18	1.40	0.28	8.31	125.35
205	34.78	155.13	1.33	-1.01	7.46	124.48
206	34.94	159.33	1.15	-1.47	6.73	123.92
207	35.10	163.58	1.09	-1.85	5.88	123.57
208	35.27	176.66	1.11	4.12	6.10	123.98
209	35.43	162.35	1.34	-0.69	7.67	125.10
210	35.60	139.95	1.74	-0.40	8.98	126.24
211	35.76	167.80	1.85	1.27	7.02	126.55
212	35.92	235.63	1.32	-0.40	4.00	127.02
213	36.09	301.09	1.64	-0.90	1.84	127.59
214	36.25	363.02	1.82	-0.04	1.23	129.04
215	36.42	383.79	2.07	-0.36	1.35	130.28
216	36.58	364.37	2.53	1.65	2.12	131.39
217	36.74	342.55	2.93	1.61	2.40	131.17
218	36.91	339.18	1.95	2.45	2.06	130.09
219	37.07	336.23	1.58	1.61	1.30	128.55
220	37.24	340.45	1.70	2.40	1.39	128.86
221	37.40	347.21	2.16	3.52	1.75	129.93
222	37.57	358.40	2.40	7.28	2.44	130.87
223	37.73	322.56	2.60	13.08	2.78	131.41
224	37.89	346.65	2.71	5.36	2.84	131.42
225	38.06	353.67	2.41	8.71	1.97	130.75
226	38.22	374.50	1.81	9.47	0.51	128.37
227	38.39	390.42	0.72	8.30	0.00	126.56
228	38.55	408.87	1.27	10.76	0.00	126.59
229	38.71	425.29	1.77	10.15	0.00	128.16
230	38.88	429.58	1.57	11.73	0.00	128.66
231	39.04	426.57	1.57	12.87	0.00	128.46
232	39.21	399.99	1.67	14.40	0.09	128.54
233	39.37	377.42	1.69	16.80	0.36	128.66
234	39.53	390.98	1.71	14.44	0.23	128.51
235	39.70	411.33	1.55	17.39	0.02	128.60
236	39.86	421.99	1.70	21.63	0.00	128.77
237	40.03	420.07	1.78	23.68	0.13	128.62
238	40.19	364.72	1.51	19.05	1.14	127.87
239	40.35	230.57	1.48	11.23	3.78	126.28
240	40.52	111.86	1.34	7.80	9.70	124.35

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
241	40.68	76.79	1.14	4.81	19.32	122.12
242	40.85	47.38	1.05	15.60	27.28	120.06
243	41.01	35.23	0.84	57.86	36.62	118.84
244	41.17	31.35	0.98	33.23	42.31	118.49
245	41.34	30.41	1.06	25.30	45.67	119.90
246	41.50	35.25	1.46	24.35	47.11	120.62
247	41.67	31.69	1.33	51.71	48.40	121.18
248	41.83	30.49	1.37	39.84	50.78	120.38
249	41.99	26.56	1.14	36.44	52.20	119.19
250	42.16	24.34	0.85	34.26	53.44	117.77
251	42.32	23.24	0.87	29.40	53.41	116.21
252	42.49	21.38	0.64	28.09	55.66	115.36
253	42.65	20.03	0.64	25.28	60.00	114.84
254	42.81	16.70	0.79	23.93	66.53	115.42
255	42.98	16.38	0.88	27.06	71.06	116.02
256	43.14	17.55	0.88	27.96	69.61	116.27
257	43.31	18.58	0.84	28.26	67.32	116.15
258	43.47	18.27	0.81	27.02	68.14	115.68
259	43.63	15.78	0.75	23.87	72.09	115.05
260	43.80	13.98	0.71	20.22	76.97	114.24
261	43.96	13.23	0.65	22.09	79.41	113.64
262	44.13	13.22	0.62	23.70	76.31	113.38
263	44.29	15.37	0.62	28.94	70.98	113.46
264	44.45	17.05	0.61	31.20	66.14	113.55
265	44.62	17.30	0.59	31.32	64.08	113.30
266	44.78	16.69	0.54	31.39	63.05	112.72
267	44.95	16.77	0.48	31.50	60.32	112.00
268	45.11	18.31	0.43	33.41	53.46	111.71
269	45.28	22.41	0.44	26.43	52.71	111.90
270	45.44	18.28	0.51	25.77	57.14	112.43
271	45.60	15.93	0.56	29.18	66.23	112.82
272	45.77	14.49	0.60	31.62	78.61	114.27
273	45.93	12.05	0.96	32.32	87.78	115.43
274	46.10	12.66	0.98	33.93	97.23	116.42
275	46.26	11.40	1.05	41.01	100.00	116.50
276	46.42	11.01	1.02	40.81	100.00	116.37
277	46.59	12.49	0.94	28.44	85.78	116.00
278	46.75	17.92	0.74	45.02	68.00	115.52
279	46.92	23.00	0.65	53.94	51.80	114.70
280	47.08	27.09	0.53	69.67	43.78	114.19
281	47.24	28.63	0.53	82.45	39.69	113.42
282	47.41	27.84	0.44	86.14	37.07	112.85
283	47.57	30.73	0.40	72.40	34.44	112.56
284	47.74	33.68	0.45	105.29	32.49	113.34
285	47.90	36.10	0.55	131.68	32.98	114.75
286	48.06	35.25	0.67	139.76	36.35	116.79
287	48.23	33.90	0.98	133.42	41.26	118.44
288	48.39	31.76	1.14	126.26	45.92	119.52

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
289	48.56	30.15	1.16	121.12	47.48	119.54
290	48.72	30.85	1.03	127.89	46.73	119.20
291	48.88	31.81	0.99	128.32	43.95	119.00
292	49.05	35.24	1.02	136.68	39.79	119.36
293	49.21	43.29	1.06	147.76	35.72	119.77
294	49.38	46.61	1.04	165.00	31.33	120.04
295	49.54	53.66	1.00	171.75	26.94	120.13
296	49.70	64.80	0.96	195.26	20.80	120.33
297	49.87	91.08	0.90	46.36	18.32	120.15
298	50.03	75.84	0.85	13.75	19.44	119.88
299	50.20	54.40	0.91	14.88	23.92	119.46

Abbreviations

Depth:	Depth from free surface, at which CPT was performed (ft)
q_c:	Measured cone resistance (tsf)
f_s:	Sleeve friction resistance (tsf)
u:	Pore pressure (tsf)
Fines content:	Percentage of fines in soil (%)
Unit weight:	Bulk soil unit weight (pcf)

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data ::

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
1	1.31	0.07	0.00	0.07	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
2	1.48	0.08	0.00	0.08	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
3	1.64	0.09	0.00	0.09	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
4	1.80	0.10	0.00	0.10	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
5	1.97	0.11	0.00	0.11	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
6	2.13	0.11	0.00	0.11	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
7	2.30	0.12	0.00	0.12	1.00	0.279	1.14	0.245	1.00	1.10	2.000	No
8	2.46	0.13	0.00	0.13	1.00	0.278	1.14	0.245	1.00	1.10	2.000	No
9	2.63	0.14	0.00	0.14	1.00	0.278	1.14	0.245	1.00	1.10	2.000	No
10	2.79	0.15	0.00	0.15	1.00	0.278	1.14	0.245	1.00	1.10	2.000	No
11	2.95	0.16	0.00	0.16	1.00	0.278	1.14	0.244	1.00	1.10	2.000	No
12	3.12	0.16	0.00	0.16	0.99	0.278	1.14	0.244	1.00	1.10	2.000	No
13	3.28	0.17	0.00	0.17	0.99	0.278	1.14	0.244	1.00	1.10	2.000	No
14	3.44	0.18	0.00	0.18	0.99	0.278	1.14	0.244	1.00	1.10	2.000	No
15	3.61	0.19	0.00	0.19	0.99	0.278	1.14	0.244	1.00	1.10	2.000	No
16	3.77	0.20	0.00	0.20	0.99	0.278	1.14	0.244	1.00	1.10	2.000	No
17	3.94	0.20	0.00	0.20	0.99	0.277	1.14	0.244	1.00	1.10	2.000	No
18	4.10	0.21	0.00	0.21	0.99	0.277	1.14	0.244	1.00	1.10	2.000	No
19	4.26	0.22	0.00	0.22	0.99	0.277	1.14	0.244	1.00	1.10	2.000	No
20	4.43	0.23	0.00	0.23	0.99	0.277	1.14	0.244	1.00	1.10	2.000	No
21	4.59	0.24	0.00	0.24	0.99	0.277	1.14	0.243	1.00	1.10	2.000	No
22	4.76	0.25	0.00	0.25	0.99	0.277	1.14	0.243	1.00	1.10	2.000	No
23	4.92	0.25	0.00	0.25	0.99	0.277	1.14	0.243	1.00	1.10	2.000	No
24	5.08	0.26	0.00	0.26	0.99	0.277	1.14	0.243	1.00	1.10	2.000	No
25	5.25	0.27	0.00	0.27	0.99	0.277	1.14	0.243	1.00	1.10	2.000	No
26	5.41	0.28	0.00	0.28	0.99	0.277	1.14	0.243	1.00	1.10	2.000	No
27	5.58	0.29	0.00	0.29	0.99	0.276	1.14	0.243	1.00	1.10	2.000	No
28	5.74	0.30	0.00	0.30	0.99	0.276	1.14	0.243	1.00	1.10	2.000	No
29	5.91	0.31	0.00	0.31	0.99	0.276	1.14	0.243	1.00	1.10	2.000	No
30	6.07	0.31	0.00	0.31	0.99	0.276	1.14	0.243	1.00	1.10	2.000	No
31	6.23	0.32	0.00	0.32	0.99	0.276	1.14	0.243	1.00	1.10	2.000	No
32	6.40	0.33	0.00	0.33	0.99	0.276	1.14	0.242	1.00	1.10	2.000	No
33	6.56	0.34	0.00	0.34	0.99	0.276	1.14	0.242	1.00	1.10	2.000	No
34	6.73	0.35	0.00	0.35	0.99	0.276	1.14	0.242	1.00	1.10	2.000	No
35	6.89	0.36	0.00	0.36	0.99	0.276	1.14	0.242	1.00	1.10	2.000	No
36	7.05	0.37	0.00	0.37	0.99	0.275	1.14	0.242	1.00	1.10	2.000	No
37	7.22	0.38	0.00	0.38	0.99	0.275	1.14	0.242	1.00	1.10	2.000	No
38	7.38	0.38	0.00	0.38	0.98	0.275	1.14	0.242	1.00	1.10	2.000	No
39	7.55	0.39	0.00	0.39	0.98	0.275	1.14	0.242	1.00	1.10	2.000	No
40	7.71	0.40	0.00	0.40	0.98	0.275	1.14	0.242	1.00	1.10	2.000	No
41	7.87	0.41	0.00	0.41	0.98	0.275	1.14	0.242	1.00	1.10	2.000	No
42	8.04	0.42	0.00	0.42	0.98	0.275	1.14	0.242	1.00	1.10	2.000	No
43	8.20	0.43	0.00	0.43	0.98	0.275	1.14	0.241	1.00	1.10	2.000	No
44	8.37	0.44	0.00	0.44	0.98	0.275	1.14	0.241	1.00	1.10	2.000	No
45	8.53	0.45	0.00	0.45	0.98	0.275	1.14	0.241	1.00	1.10	2.000	No
46	8.69	0.46	0.00	0.46	0.98	0.274	1.14	0.241	1.00	1.10	2.000	No
47	8.86	0.47	0.00	0.47	0.98	0.274	1.14	0.241	1.00	1.10	2.000	No
48	9.02	0.47	0.00	0.47	0.98	0.275	1.14	0.241	1.00	1.10	0.266	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
49	9.19	0.48	0.01	0.48	0.98	0.277	1.14	0.244	1.00	1.10	0.268	No
50	9.35	0.49	0.01	0.48	0.98	0.280	1.14	0.246	1.00	1.10	0.271	No
51	9.51	0.50	0.02	0.48	0.98	0.283	1.14	0.249	1.00	1.10	0.274	No
52	9.68	0.51	0.02	0.49	0.98	0.286	1.14	0.251	1.00	1.10	0.276	No
53	9.84	0.52	0.03	0.49	0.98	0.288	1.14	0.253	1.00	1.10	0.279	No
54	10.01	0.53	0.03	0.50	0.98	0.291	1.14	0.256	1.00	1.10	0.281	No
55	10.17	0.54	0.04	0.50	0.98	0.294	1.14	0.258	1.00	1.10	0.284	No
56	10.34	0.55	0.04	0.50	0.98	0.296	1.14	0.260	1.00	1.10	0.286	No
57	10.50	0.55	0.05	0.51	0.98	0.299	1.14	0.262	1.00	1.10	0.289	No
58	10.66	0.56	0.05	0.51	0.98	0.301	1.14	0.265	1.00	1.10	0.291	No
59	10.83	0.57	0.06	0.51	0.98	0.303	1.14	0.267	1.00	1.10	0.293	No
60	10.99	0.58	0.06	0.52	0.98	0.306	1.14	0.269	1.00	1.10	0.296	No
61	11.15	0.59	0.07	0.52	0.98	0.308	1.14	0.271	1.00	1.10	0.298	No
62	11.32	0.60	0.07	0.53	0.98	0.310	1.14	0.273	1.00	1.10	0.300	No
63	11.48	0.61	0.08	0.53	0.98	0.313	1.14	0.275	1.00	1.10	0.302	No
64	11.65	0.62	0.08	0.53	0.98	0.315	1.14	0.277	1.00	1.10	0.304	No
65	11.81	0.63	0.09	0.54	0.98	0.317	1.14	0.279	1.00	1.10	0.307	No
66	11.97	0.63	0.09	0.54	0.97	0.319	1.14	0.281	1.00	1.10	0.309	No
67	12.14	0.64	0.10	0.55	0.97	0.321	1.14	0.282	1.00	1.10	0.311	No
68	12.30	0.65	0.10	0.55	0.97	0.323	1.14	0.284	1.00	1.10	0.313	No
69	12.47	0.66	0.11	0.55	0.97	0.325	1.14	0.286	1.00	1.10	0.315	No
70	12.63	0.67	0.11	0.56	0.97	0.327	1.14	0.288	1.00	1.10	0.317	No
71	12.79	0.68	0.12	0.56	0.97	0.329	1.14	0.290	1.00	1.10	0.318	No
72	12.96	0.69	0.12	0.56	0.97	0.331	1.14	0.291	1.00	1.10	0.320	No
73	13.12	0.70	0.13	0.57	0.97	0.333	1.14	0.293	1.00	1.10	0.322	No
74	13.29	0.71	0.13	0.57	0.97	0.335	1.14	0.295	1.00	1.10	0.324	No
75	13.45	0.72	0.14	0.58	0.97	0.337	1.14	0.296	1.00	1.10	0.326	No
76	13.62	0.72	0.14	0.58	0.97	0.339	1.14	0.298	1.00	1.10	0.328	No
77	13.78	0.73	0.15	0.58	0.97	0.341	1.14	0.299	1.00	1.10	0.329	No
78	13.94	0.74	0.15	0.59	0.97	0.343	1.14	0.301	1.00	1.10	0.331	No
79	14.11	0.75	0.16	0.59	0.97	0.344	1.14	0.303	1.00	1.10	0.333	No
80	14.27	0.76	0.16	0.60	0.97	0.346	1.14	0.304	1.00	1.10	0.335	No
81	14.44	0.77	0.17	0.60	0.97	0.348	1.14	0.306	1.00	1.10	0.336	No
82	14.60	0.78	0.17	0.60	0.97	0.349	1.14	0.307	1.00	1.10	0.338	No
83	14.76	0.79	0.18	0.61	0.97	0.351	1.14	0.309	1.00	1.10	0.339	No
84	14.93	0.80	0.18	0.61	0.97	0.353	1.14	0.310	1.00	1.10	0.341	No
85	15.09	0.80	0.19	0.61	0.97	0.354	1.14	0.312	1.00	1.10	0.343	No
86	15.26	0.81	0.20	0.62	0.97	0.356	1.14	0.313	1.00	1.10	0.344	No
87	15.42	0.82	0.20	0.62	0.97	0.358	1.14	0.314	1.00	1.10	0.346	No
88	15.58	0.83	0.21	0.62	0.97	0.359	1.14	0.316	1.00	1.10	0.347	No
89	15.75	0.84	0.21	0.63	0.97	0.361	1.14	0.317	1.00	1.10	0.349	No
90	15.91	0.85	0.22	0.63	0.97	0.362	1.14	0.318	1.00	1.10	0.350	No
91	16.08	0.86	0.22	0.64	0.97	0.364	1.14	0.320	1.00	1.10	0.352	No
92	16.24	0.87	0.23	0.64	0.97	0.365	1.14	0.321	1.00	1.10	0.353	No
93	16.40	0.87	0.23	0.64	0.97	0.367	1.14	0.322	1.00	1.10	0.355	No
94	16.57	0.88	0.24	0.65	0.97	0.368	1.14	0.324	1.00	1.10	0.356	No
95	16.73	0.89	0.24	0.65	0.96	0.369	1.14	0.325	1.00	1.10	0.357	No
96	16.90	0.90	0.25	0.66	0.96	0.371	1.14	0.326	1.00	1.10	0.358	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
97	17.06	0.91	0.25	0.66	0.96	0.372	1.14	0.327	1.00	1.10	0.360	No
98	17.22	0.92	0.26	0.67	0.96	0.373	1.14	0.328	1.00	1.10	0.361	No
99	17.39	0.93	0.26	0.67	0.96	0.374	1.14	0.329	1.00	1.10	0.362	No
100	17.55	0.94	0.27	0.68	0.96	0.375	1.14	0.330	1.00	1.10	0.363	No
101	17.72	0.95	0.27	0.68	0.96	0.377	1.14	0.331	1.00	1.10	0.364	No
102	17.88	0.96	0.28	0.69	0.96	0.378	1.14	0.332	1.00	1.10	0.365	No
103	18.05	0.97	0.28	0.69	0.96	0.379	1.14	0.333	1.00	1.10	0.366	No
104	18.21	0.98	0.29	0.70	0.96	0.380	1.14	0.334	1.00	1.10	0.367	No
105	18.37	0.99	0.29	0.70	0.96	0.381	1.14	0.335	1.00	1.10	0.368	No
106	18.54	1.00	0.30	0.71	0.96	0.382	1.14	0.335	1.00	1.10	0.369	No
107	18.70	1.01	0.30	0.71	0.96	0.382	1.14	0.336	1.00	1.10	0.370	No
108	18.86	1.03	0.31	0.72	0.96	0.383	1.14	0.337	1.00	1.10	0.371	No
109	19.03	1.04	0.31	0.72	0.96	0.384	1.14	0.338	1.00	1.10	0.371	No
110	19.19	1.05	0.32	0.73	0.96	0.385	1.14	0.338	1.00	1.10	0.372	No
111	19.36	1.06	0.32	0.73	0.96	0.386	1.14	0.339	1.00	1.10	0.373	No
112	19.52	1.07	0.33	0.74	0.96	0.387	1.14	0.340	1.00	1.10	0.374	No
113	19.68	1.08	0.33	0.74	0.96	0.388	1.14	0.341	1.00	1.10	0.375	No
114	19.85	1.09	0.34	0.75	0.96	0.388	1.14	0.341	1.00	1.10	0.376	No
115	20.01	1.10	0.34	0.75	0.96	0.389	1.14	0.342	1.00	1.10	0.376	No
116	20.18	1.11	0.35	0.76	0.96	0.390	1.14	0.343	1.00	1.10	0.377	No
117	20.34	1.12	0.35	0.76	0.96	0.391	1.14	0.344	1.00	1.10	0.378	No
118	20.50	1.13	0.36	0.77	0.96	0.392	1.14	0.344	1.00	1.10	0.379	No
119	20.67	1.14	0.36	0.77	0.96	0.393	1.14	0.345	1.00	1.10	0.380	No
120	20.83	1.15	0.37	0.78	0.95	0.393	1.14	0.346	1.00	1.10	0.380	No
121	21.00	1.16	0.37	0.78	0.95	0.394	1.14	0.346	1.00	1.10	0.381	No
122	21.16	1.17	0.38	0.79	0.95	0.395	1.14	0.347	1.00	1.10	0.382	No
123	21.32	1.18	0.38	0.79	0.95	0.396	1.14	0.348	1.00	1.10	0.383	No
124	21.49	1.19	0.39	0.80	0.95	0.397	1.14	0.348	1.00	1.10	0.383	No
125	21.65	1.20	0.39	0.80	0.95	0.397	1.14	0.349	1.00	1.10	0.384	No
126	21.82	1.21	0.40	0.81	0.95	0.398	1.14	0.350	1.00	1.10	0.385	No
127	21.98	1.22	0.41	0.81	0.95	0.399	1.14	0.350	1.00	1.10	0.385	No
128	22.15	1.23	0.41	0.82	0.95	0.399	1.14	0.351	1.00	1.10	0.386	No
129	22.31	1.24	0.42	0.82	0.95	0.400	1.14	0.352	1.00	1.10	0.387	No
130	22.47	1.25	0.42	0.83	0.95	0.401	1.14	0.352	1.00	1.10	0.387	No
131	22.64	1.26	0.43	0.83	0.95	0.401	1.14	0.353	1.00	1.10	0.388	No
132	22.80	1.27	0.43	0.84	0.95	0.402	1.14	0.353	1.00	1.10	0.389	No
133	22.97	1.28	0.44	0.84	0.95	0.403	1.14	0.354	1.00	1.10	0.389	No
134	23.13	1.29	0.44	0.85	0.95	0.403	1.14	0.354	1.00	1.10	0.390	No
135	23.29	1.30	0.45	0.85	0.95	0.404	1.14	0.355	1.00	1.10	0.390	No
136	23.46	1.31	0.45	0.85	0.95	0.404	1.14	0.355	1.00	1.10	0.391	No
137	23.62	1.32	0.46	0.86	0.95	0.405	1.14	0.356	1.00	1.10	0.392	No
138	23.79	1.33	0.46	0.86	0.95	0.406	1.14	0.356	1.00	1.10	0.392	No
139	23.95	1.34	0.47	0.87	0.95	0.406	1.14	0.357	1.00	1.10	0.393	No
140	24.11	1.35	0.47	0.87	0.94	0.407	1.14	0.357	1.00	1.10	0.393	No
141	24.28	1.36	0.48	0.88	0.94	0.407	1.14	0.358	1.00	1.10	0.393	No
142	24.44	1.37	0.48	0.89	0.94	0.407	1.14	0.358	1.00	1.10	0.394	No
143	24.61	1.38	0.49	0.89	0.94	0.408	1.14	0.358	1.00	1.10	0.394	No
144	24.77	1.39	0.49	0.90	0.94	0.408	1.14	0.359	1.00	1.10	0.395	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
145	24.93	1.40	0.50	0.90	0.94	0.409	1.14	0.359	1.00	1.10	0.395	No
146	25.10	1.41	0.50	0.90	0.94	0.409	1.14	0.360	1.00	1.10	0.396	No
147	25.26	1.42	0.51	0.91	0.94	0.410	1.14	0.360	1.00	1.10	0.396	No
148	25.43	1.43	0.51	0.91	0.94	0.410	1.14	0.360	1.00	1.10	0.397	No
149	25.59	1.44	0.52	0.92	0.94	0.411	1.14	0.361	1.00	1.10	0.397	No
150	25.75	1.45	0.52	0.92	0.94	0.411	1.14	0.361	1.00	1.10	0.397	No
151	25.92	1.46	0.53	0.93	0.94	0.411	1.14	0.362	1.00	1.10	0.398	No
152	26.08	1.47	0.53	0.93	0.94	0.412	1.14	0.362	1.00	1.10	0.398	No
153	26.25	1.48	0.54	0.94	0.94	0.412	1.14	0.362	1.00	1.10	0.399	No
154	26.41	1.49	0.54	0.94	0.94	0.413	1.14	0.363	1.00	1.10	0.399	No
155	26.57	1.50	0.55	0.95	0.94	0.413	1.14	0.363	1.00	1.10	0.399	No
156	26.74	1.51	0.55	0.95	0.94	0.413	1.14	0.363	1.00	1.10	0.400	No
157	26.90	1.52	0.56	0.96	0.93	0.414	1.14	0.364	1.00	1.10	0.400	No
158	27.07	1.53	0.56	0.96	0.93	0.414	1.14	0.364	1.00	1.10	0.400	No
159	27.23	1.54	0.57	0.97	0.93	0.414	1.14	0.364	1.00	1.10	0.401	No
160	27.39	1.55	0.57	0.97	0.93	0.415	1.14	0.364	1.00	1.10	0.401	No
161	27.56	1.55	0.58	0.98	0.93	0.415	1.14	0.365	1.00	1.10	0.401	No
162	27.72	1.56	0.58	0.98	0.93	0.415	1.14	0.365	1.00	1.10	0.402	No
163	27.89	1.57	0.59	0.98	0.93	0.416	1.14	0.366	1.00	1.10	0.402	No
164	28.05	1.58	0.59	0.99	0.93	0.416	1.14	0.366	1.00	1.10	0.402	No
165	28.21	1.59	0.60	0.99	0.93	0.417	1.14	0.366	1.00	1.10	0.403	No
166	28.38	1.60	0.60	1.00	0.93	0.417	1.14	0.367	1.00	1.10	0.403	No
167	28.54	1.61	0.61	1.00	0.93	0.417	1.14	0.367	1.00	1.10	0.404	No
168	28.71	1.62	0.61	1.00	0.93	0.418	1.14	0.367	1.00	1.10	0.404	No
169	28.87	1.63	0.62	1.01	0.93	0.418	1.14	0.367	1.00	1.10	0.404	No
170	29.04	1.64	0.63	1.01	0.93	0.418	1.14	0.368	1.00	1.10	0.404	No
171	29.20	1.65	0.63	1.02	0.92	0.418	1.14	0.368	1.00	1.10	0.404	No
172	29.36	1.66	0.64	1.02	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
173	29.53	1.67	0.64	1.03	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
174	29.69	1.68	0.65	1.03	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
175	29.86	1.69	0.65	1.04	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
176	30.02	1.70	0.66	1.04	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
177	30.18	1.71	0.66	1.05	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
178	30.35	1.72	0.67	1.05	0.92	0.419	1.14	0.368	1.00	1.10	0.405	No
179	30.51	1.73	0.67	1.06	0.92	0.419	1.14	0.369	1.00	1.10	0.405	No
180	30.68	1.74	0.68	1.06	0.92	0.419	1.14	0.369	1.00	1.10	0.406	No
181	30.84	1.75	0.68	1.07	0.92	0.419	1.14	0.369	1.00	1.10	0.406	No
182	31.00	1.76	0.69	1.07	0.92	0.420	1.14	0.369	1.00	1.10	0.407	No
183	31.17	1.77	0.69	1.08	0.91	0.420	1.14	0.369	1.00	1.10	0.407	No
184	31.33	1.78	0.70	1.08	0.91	0.420	1.14	0.369	1.00	1.10	0.408	No
185	31.50	1.79	0.70	1.09	0.91	0.420	1.14	0.369	0.99	1.10	0.408	No
186	31.66	1.80	0.71	1.09	0.91	0.420	1.14	0.369	0.99	1.10	0.408	No
187	31.82	1.81	0.71	1.10	0.91	0.420	1.14	0.369	0.99	1.10	0.409	No
188	31.99	1.82	0.72	1.10	0.91	0.420	1.14	0.369	0.99	1.10	0.409	No
189	32.15	1.83	0.72	1.11	0.91	0.420	1.14	0.369	0.99	1.10	0.409	No
190	32.32	1.84	0.73	1.11	0.91	0.420	1.14	0.369	0.99	1.10	0.410	No
191	32.48	1.85	0.73	1.12	0.91	0.419	1.14	0.369	0.99	1.10	0.410	No
192	32.64	1.86	0.74	1.12	0.91	0.419	1.14	0.369	0.99	1.10	0.410	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
193	32.81	1.87	0.74	1.13	0.90	0.419	1.14	0.368	0.99	1.10	0.411	No
194	32.97	1.88	0.75	1.14	0.90	0.419	1.14	0.368	0.99	1.10	0.411	No
195	33.14	1.89	0.75	1.14	0.90	0.419	1.14	0.368	0.98	1.10	0.411	No
196	33.30	1.91	0.76	1.15	0.90	0.419	1.14	0.368	0.98	1.10	0.411	No
197	33.47	1.92	0.76	1.15	0.90	0.419	1.14	0.368	0.98	1.10	0.412	No
198	33.63	1.93	0.77	1.16	0.90	0.418	1.14	0.368	0.98	1.10	0.412	No
199	33.79	1.94	0.77	1.16	0.90	0.418	1.14	0.368	0.98	1.10	0.412	No
200	33.96	1.95	0.78	1.17	0.90	0.418	1.14	0.367	0.98	1.10	0.412	No
201	34.12	1.96	0.78	1.17	0.90	0.418	1.14	0.367	0.98	1.10	0.413	No
202	34.28	1.97	0.79	1.18	0.90	0.418	1.14	0.367	0.98	1.10	0.413	No
203	34.45	1.98	0.79	1.18	0.89	0.418	1.14	0.367	0.98	1.10	0.413	No
204	34.61	1.99	0.80	1.19	0.89	0.417	1.14	0.367	0.98	1.10	0.413	No
205	34.78	2.00	0.80	1.19	0.89	0.417	1.14	0.367	0.98	1.10	0.413	No
206	34.94	2.01	0.81	1.20	0.89	0.417	1.14	0.367	0.98	1.10	0.413	No
207	35.10	2.02	0.81	1.20	0.89	0.417	1.14	0.366	0.97	1.10	0.414	No
208	35.27	2.03	0.82	1.21	0.89	0.417	1.14	0.366	0.97	1.10	0.414	No
209	35.43	2.04	0.82	1.21	0.89	0.417	1.14	0.366	0.97	1.10	0.414	No
210	35.60	2.05	0.83	1.22	0.89	0.416	1.14	0.366	0.97	1.10	0.414	No
211	35.76	2.06	0.83	1.22	0.89	0.416	1.14	0.366	0.97	1.10	0.414	No
212	35.92	2.07	0.84	1.23	0.88	0.416	1.14	0.365	0.97	1.10	0.414	No
213	36.09	2.08	0.85	1.24	0.88	0.416	1.14	0.365	0.97	1.10	0.414	No
214	36.25	2.09	0.85	1.24	0.88	0.415	1.14	0.365	0.97	1.10	0.414	No
215	36.42	2.10	0.86	1.25	0.88	0.415	1.14	0.365	0.97	1.10	0.414	No
216	36.58	2.11	0.86	1.25	0.88	0.415	1.14	0.364	0.97	1.10	0.414	No
217	36.74	2.12	0.87	1.26	0.88	0.414	1.14	0.364	0.97	1.10	0.415	No
218	36.91	2.13	0.87	1.26	0.88	0.414	1.14	0.364	0.97	1.10	0.415	No
219	37.07	2.14	0.88	1.27	0.88	0.414	1.14	0.363	0.96	1.10	0.415	No
220	37.24	2.16	0.88	1.27	0.87	0.413	1.14	0.363	0.96	1.10	0.415	No
221	37.40	2.17	0.89	1.28	0.87	0.413	1.14	0.363	0.96	1.10	0.415	No
222	37.57	2.18	0.89	1.29	0.87	0.412	1.14	0.362	0.96	1.10	0.415	No
223	37.73	2.19	0.90	1.29	0.87	0.412	1.14	0.362	0.96	1.10	0.415	No
224	37.89	2.20	0.90	1.30	0.87	0.412	1.14	0.362	0.96	1.10	0.414	No
225	38.06	2.21	0.91	1.30	0.87	0.411	1.14	0.361	0.96	1.10	0.414	No
226	38.22	2.22	0.91	1.31	0.87	0.411	1.14	0.361	0.96	1.10	0.414	No
227	38.39	2.23	0.92	1.31	0.86	0.410	1.14	0.361	0.96	1.10	0.414	No
228	38.55	2.24	0.92	1.32	0.86	0.410	1.14	0.360	0.96	1.10	0.414	No
229	38.71	2.25	0.93	1.32	0.86	0.410	1.14	0.360	0.96	1.10	0.414	No
230	38.88	2.26	0.93	1.33	0.86	0.409	1.14	0.360	0.96	1.10	0.414	No
231	39.04	2.27	0.94	1.33	0.86	0.409	1.14	0.359	0.95	1.10	0.414	No
232	39.21	2.28	0.94	1.34	0.86	0.408	1.14	0.359	0.95	1.10	0.414	No
233	39.37	2.29	0.95	1.35	0.86	0.408	1.14	0.359	0.95	1.10	0.414	No
234	39.53	2.30	0.95	1.35	0.86	0.408	1.14	0.358	0.95	1.10	0.414	No
235	39.70	2.31	0.96	1.36	0.85	0.407	1.14	0.358	0.95	1.10	0.414	No
236	39.86	2.32	0.96	1.36	0.85	0.407	1.14	0.357	0.95	1.10	0.413	No
237	40.03	2.34	0.97	1.37	0.85	0.406	1.14	0.357	0.95	1.10	0.413	No
238	40.19	2.35	0.97	1.37	0.85	0.406	1.14	0.357	0.95	1.10	0.413	No
239	40.35	2.36	0.98	1.38	0.85	0.405	1.14	0.356	0.95	1.10	0.413	No
240	40.52	2.37	0.98	1.38	0.85	0.405	1.14	0.356	0.95	1.10	0.413	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
241	40.68	2.38	0.99	1.39	0.84	0.404	1.14	0.355	0.95	1.10	0.413	No
242	40.85	2.39	0.99	1.39	0.84	0.404	1.14	0.355	0.95	1.10	0.413	No
243	41.01	2.40	1.00	1.40	0.84	0.404	1.14	0.355	0.95	1.10	0.412	No
244	41.17	2.41	1.00	1.40	0.84	0.403	1.14	0.354	0.95	1.10	0.412	No
245	41.34	2.42	1.01	1.41	0.84	0.403	1.14	0.354	0.94	1.10	0.412	No
246	41.50	2.43	1.01	1.41	0.84	0.402	1.14	0.354	0.94	1.10	0.412	No
247	41.67	2.44	1.02	1.42	0.84	0.402	1.14	0.353	0.94	1.10	0.412	No
248	41.83	2.45	1.02	1.42	0.83	0.401	1.14	0.353	0.94	1.10	0.412	No
249	41.99	2.45	1.03	1.43	0.83	0.401	1.14	0.352	0.94	1.10	0.411	No
250	42.16	2.46	1.03	1.43	0.83	0.400	1.14	0.352	0.94	1.10	0.411	No
251	42.32	2.47	1.04	1.43	0.83	0.400	1.14	0.352	0.94	1.10	0.411	No
252	42.49	2.48	1.04	1.44	0.83	0.400	1.14	0.351	0.94	1.10	0.411	No
253	42.65	2.49	1.05	1.44	0.83	0.399	1.14	0.351	0.94	1.10	0.411	No
254	42.81	2.50	1.06	1.45	0.83	0.399	1.14	0.350	0.94	1.10	0.410	No
255	42.98	2.51	1.06	1.45	0.82	0.398	1.14	0.350	0.94	1.10	0.410	No
256	43.14	2.52	1.07	1.46	0.82	0.398	1.14	0.350	0.94	1.10	0.410	No
257	43.31	2.53	1.07	1.46	0.82	0.397	1.14	0.349	0.94	1.10	0.410	No
258	43.47	2.54	1.08	1.47	0.82	0.397	1.14	0.349	0.94	1.10	0.409	No
259	43.63	2.55	1.08	1.47	0.82	0.396	1.14	0.348	0.94	1.10	0.409	No
260	43.80	2.56	1.09	1.47	0.82	0.396	1.14	0.348	0.94	1.10	0.409	No
261	43.96	2.57	1.09	1.48	0.81	0.395	1.14	0.348	0.94	1.10	0.409	No
262	44.13	2.58	1.10	1.48	0.81	0.395	1.14	0.347	0.93	1.10	0.408	No
263	44.29	2.59	1.10	1.49	0.81	0.394	1.14	0.347	0.93	1.10	0.408	No
264	44.45	2.60	1.11	1.49	0.81	0.394	1.14	0.346	0.93	1.10	0.408	No
265	44.62	2.61	1.11	1.49	0.81	0.393	1.14	0.346	0.93	1.10	0.408	No
266	44.78	2.62	1.12	1.50	0.81	0.393	1.14	0.345	0.93	1.10	0.407	No
267	44.95	2.62	1.12	1.50	0.80	0.393	1.14	0.345	0.93	1.10	0.407	No
268	45.11	2.63	1.13	1.51	0.80	0.392	1.14	0.345	0.93	1.10	0.407	No
269	45.28	2.64	1.13	1.51	0.80	0.392	1.14	0.344	0.93	1.10	0.406	No
270	45.44	2.65	1.14	1.51	0.80	0.391	1.14	0.344	0.93	1.10	0.406	No
271	45.60	2.66	1.14	1.52	0.80	0.391	1.14	0.343	0.93	1.10	0.406	No
272	45.77	2.67	1.15	1.52	0.80	0.390	1.14	0.343	0.93	1.10	0.406	No
273	45.93	2.68	1.15	1.53	0.79	0.389	1.14	0.342	0.93	1.10	0.405	No
274	46.10	2.69	1.16	1.53	0.79	0.389	1.14	0.342	0.93	1.10	0.405	No
275	46.26	2.70	1.16	1.54	0.79	0.388	1.14	0.341	0.93	1.10	0.404	No
276	46.42	2.71	1.17	1.54	0.79	0.388	1.14	0.341	0.93	1.10	0.404	No
277	46.59	2.72	1.17	1.55	0.79	0.387	1.14	0.340	0.93	1.10	0.404	No
278	46.75	2.73	1.18	1.55	0.79	0.387	1.14	0.340	0.93	1.10	0.403	No
279	46.92	2.74	1.18	1.55	0.78	0.386	1.14	0.339	0.93	1.10	0.403	No
280	47.08	2.75	1.19	1.56	0.78	0.386	1.14	0.339	0.93	1.10	0.403	No
281	47.24	2.76	1.19	1.56	0.78	0.385	1.14	0.338	0.93	1.10	0.402	No
282	47.41	2.76	1.20	1.57	0.78	0.384	1.14	0.338	0.92	1.10	0.402	No
283	47.57	2.77	1.20	1.57	0.78	0.384	1.14	0.337	0.92	1.10	0.402	No
284	47.74	2.78	1.21	1.57	0.78	0.383	1.14	0.337	0.92	1.10	0.401	No
285	47.90	2.79	1.21	1.58	0.77	0.383	1.14	0.336	0.92	1.10	0.401	No
286	48.06	2.80	1.22	1.58	0.77	0.382	1.14	0.336	0.92	1.10	0.400	No
287	48.23	2.81	1.22	1.59	0.77	0.381	1.14	0.335	0.92	1.10	0.400	No
288	48.39	2.82	1.23	1.59	0.77	0.381	1.14	0.335	0.92	1.10	0.400	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
289	48.56	2.83	1.23	1.60	0.77	0.380	1.14	0.334	0.92	1.10	0.399	No
290	48.72	2.84	1.24	1.60	0.77	0.380	1.14	0.334	0.92	1.10	0.399	No
291	48.88	2.85	1.24	1.61	0.76	0.379	1.14	0.333	0.92	1.10	0.398	No
292	49.05	2.86	1.25	1.61	0.76	0.378	1.14	0.332	0.92	1.10	0.398	No
293	49.21	2.87	1.25	1.62	0.76	0.378	1.14	0.332	0.92	1.10	0.397	No
294	49.38	2.88	1.26	1.62	0.76	0.377	1.14	0.331	0.92	1.10	0.397	No
295	49.54	2.89	1.26	1.63	0.76	0.376	1.14	0.331	0.92	1.10	0.397	No
296	49.70	2.90	1.27	1.63	0.76	0.376	1.14	0.330	0.92	1.10	0.396	No
297	49.87	2.91	1.28	1.64	0.75	0.375	1.14	0.330	0.92	1.10	0.396	No
298	50.03	2.92	1.28	1.64	0.75	0.374	1.14	0.329	0.92	1.10	0.395	No
299	50.20	2.93	1.29	1.64	0.75	0.374	1.14	0.329	0.92	1.10	0.395	No

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
σ_v: Total overburden pressure at test point (tsf)
u_0: Water pressure at test point (tsf)
σ_v': Effective overburden pressure based on GWT during earthquake (tsf)
r_d: Nonlinear shear mass factor
CSR: Cyclic Stress Ratio
MSF: Magnitude Scaling Factor
CSR_{eq}: CSR adjusted for M=7.5
K_σ: Effective overburden stress factor
CSR^*: CSR fully adjusted

:: Cyclic Resistance Ratio (CRR) calculation data ::

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
1	1.31	18.47	2.39	1.21	0.72	29.56	2.31	68.19	4.000	No	No	2.00
2	1.48	16.96	2.47	1.49	0.75	27.12	2.76	74.96	4.000	No	No	2.00
3	1.64	14.72	2.61	2.18	0.79	23.50	3.88	91.11	4.000	No	Yes	2.00
4	1.80	13.33	2.69	2.60	0.82	21.26	4.65	98.94	4.000	No	Yes	2.00
5	1.97	12.18	2.73	2.65	0.83	19.40	5.05	98.04	4.000	No	Yes	2.00
6	2.13	11.49	2.69	2.07	0.81	18.28	4.60	84.01	4.000	No	Yes	2.00
7	2.30	11.18	2.64	1.63	0.80	17.76	4.14	73.53	4.000	No	Yes	2.00
8	2.46	11.05	2.59	1.29	0.79	17.54	3.69	64.81	4.000	No	No	2.00
9	2.63	11.41	2.54	1.06	0.77	18.10	3.25	58.87	4.000	No	No	2.00
10	2.79	11.90	2.48	0.85	0.75	18.89	2.83	53.37	4.000	No	No	2.00
11	2.95	12.79	2.42	0.73	0.73	20.30	2.47	50.21	4.000	No	No	2.00
12	3.12	14.05	2.35	0.61	0.71	22.32	2.12	47.40	4.000	No	No	2.00
13	3.28	15.73	2.28	0.53	0.69	25.00	1.84	46.00	4.000	No	No	2.00
14	3.44	17.43	2.21	0.46	0.67	27.72	1.00	27.72	4.000	No	No	2.00
15	3.61	18.63	2.18	0.45	0.66	29.63	1.00	29.63	4.000	No	No	2.00
16	3.77	19.69	2.17	0.48	0.66	31.33	1.00	31.33	4.000	No	No	2.00
17	3.94	19.98	2.19	0.54	0.66	31.78	1.58	50.27	4.000	No	No	2.00
18	4.10	20.31	2.20	0.60	0.67	32.29	1.61	52.04	4.000	No	No	2.00
19	4.26	19.91	2.23	0.66	0.68	31.63	1.69	53.37	4.000	No	No	2.00
20	4.43	19.84	2.24	0.71	0.68	31.50	1.74	54.68	4.000	No	No	2.00
21	4.59	19.56	2.26	0.74	0.69	31.04	1.78	55.34	4.000	No	No	2.00
22	4.76	19.72	2.25	0.73	0.68	31.29	1.76	55.09	4.000	No	No	2.00
23	4.92	20.35	2.23	0.70	0.68	32.29	1.70	54.88	4.000	No	No	2.00
24	5.08	21.69	2.19	0.65	0.67	34.42	1.60	55.00	4.000	No	No	2.00
25	5.25	23.37	2.15	0.62	0.65	37.11	1.51	56.08	4.000	No	No	2.00
26	5.41	24.88	2.12	0.58	0.64	39.53	1.45	57.13	4.000	No	No	2.00
27	5.58	26.37	2.08	0.55	0.63	41.90	1.39	58.41	4.000	No	No	2.00
28	5.74	28.42	2.04	0.51	0.62	45.19	1.34	60.73	4.000	No	No	2.00
29	5.91	31.51	1.98	0.48	0.60	50.14	1.00	50.14	4.000	No	No	2.00
30	6.07	35.15	1.91	0.41	0.58	55.97	1.00	55.97	4.000	No	No	2.00
31	6.23	38.56	1.86	0.37	0.57	61.43	1.00	61.43	4.000	No	No	2.00
32	6.40	41.16	1.82	0.34	0.55	65.60	1.00	65.60	4.000	No	No	2.00
33	6.56	42.78	1.81	0.36	0.55	68.18	1.00	68.18	4.000	No	No	2.00
34	6.73	43.16	1.83	0.40	0.56	68.77	1.00	68.77	4.000	No	No	2.00
35	6.89	41.96	1.87	0.46	0.57	66.85	1.00	66.85	4.000	No	No	2.00
36	7.05	39.31	1.93	0.56	0.59	62.56	1.26	78.70	4.000	No	No	2.00
37	7.22	36.04	2.01	0.69	0.61	57.30	1.32	75.47	4.000	No	No	2.00
38	7.38	33.75	2.08	0.82	0.63	53.60	1.39	74.41	4.000	No	No	2.00
39	7.55	33.49	2.10	0.89	0.64	53.18	1.42	75.50	4.000	No	No	2.00
40	7.71	34.75	2.09	0.89	0.63	55.19	1.40	77.22	4.000	No	No	2.00
41	7.87	36.40	2.05	0.83	0.62	57.82	1.36	78.62	4.000	No	No	2.00
42	8.04	38.58	2.01	0.74	0.61	61.32	1.31	80.44	4.000	No	No	2.00
43	8.20	41.46	1.94	0.64	0.59	65.91	1.27	83.42	4.000	No	No	2.00
44	8.37	43.50	1.91	0.57	0.58	67.80	1.24	84.16	4.000	No	No	2.00
45	8.53	43.39	1.90	0.55	0.58	66.80	1.24	82.83	4.000	No	No	2.00
46	8.69	41.04	1.93	0.55	0.59	62.83	1.26	78.95	4.000	No	No	2.00
47	8.86	38.24	1.97	0.59	0.60	58.40	1.28	74.99	4.000	No	No	2.00
48	9.02	35.58	2.01	0.63	0.61	54.20	1.32	71.44	0.114	No	No	0.43

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
49	9.19	33.57	2.06	0.69	0.63	51.03	1.36	69.46	0.111	No	No	0.41
50	9.35	32.63	2.07	0.68	0.63	49.14	1.37	67.55	0.109	No	No	0.40
51	9.51	32.89	2.06	0.66	0.63	48.92	1.37	66.95	0.108	No	No	0.39
52	9.68	34.32	2.04	0.62	0.62	50.26	1.34	67.43	0.109	No	No	0.39
53	9.84	36.11	2.02	0.61	0.61	52.10	1.32	69.02	0.111	No	No	0.40
54	10.01	37.22	2.01	0.60	0.61	53.04	1.32	69.75	0.112	No	No	0.40
55	10.17	37.38	2.01	0.59	0.61	52.72	1.32	69.36	0.111	No	No	0.39
56	10.34	36.69	2.02	0.59	0.61	51.33	1.33	68.05	0.109	No	No	0.38
57	10.50	33.96	2.06	0.62	0.63	47.34	1.37	64.71	0.105	No	No	0.36
58	10.66	33.90	2.06	0.60	0.63	46.77	1.37	63.89	0.104	No	No	0.36
59	10.83	34.12	2.06	0.60	0.63	46.60	1.36	63.60	0.104	No	No	0.35
60	10.99	37.18	2.02	0.56	0.61	50.01	1.32	66.24	0.107	No	No	0.36
61	11.15	39.11	2.00	0.54	0.61	52.19	1.30	68.04	0.109	No	No	0.37
62	11.32	43.22	1.94	0.50	0.59	57.00	1.00	57.00	0.097	No	No	0.32
63	11.48	47.91	1.89	0.46	0.58	62.46	1.00	62.46	0.103	No	No	0.34
64	11.65	51.77	1.87	0.47	0.57	67.01	1.00	67.01	0.108	No	No	0.35
65	11.81	53.18	1.89	0.54	0.57	68.81	1.23	84.58	0.136	No	No	0.44
66	11.97	52.99	1.91	0.58	0.58	68.50	1.24	85.03	0.137	No	No	0.44
67	12.14	52.11	1.90	0.55	0.58	67.05	1.24	83.10	0.133	No	No	0.43
68	12.30	52.01	1.87	0.47	0.57	66.34	1.00	66.34	0.107	No	No	0.34
69	12.47	51.56	1.87	0.45	0.57	65.48	1.00	65.48	0.106	No	No	0.34
70	12.63	50.45	1.89	0.48	0.57	64.01	1.00	64.01	0.104	No	No	0.33
71	12.79	49.06	1.91	0.50	0.58	62.20	1.00	62.20	0.102	No	No	0.32
72	12.96	49.09	1.91	0.50	0.58	62.01	1.00	62.01	0.102	No	No	0.32
73	13.12	50.56	1.91	0.51	0.58	63.60	1.24	78.94	0.126	No	No	0.39
74	13.29	51.89	1.90	0.50	0.58	64.95	1.23	80.20	0.128	No	No	0.39
75	13.45	52.88	1.88	0.47	0.57	65.79	1.00	65.79	0.106	No	No	0.33
76	13.62	54.37	1.85	0.43	0.56	67.16	1.00	67.16	0.108	No	No	0.33
77	13.78	56.49	1.82	0.40	0.55	69.27	1.00	69.27	0.111	No	No	0.34
78	13.94	58.54	1.79	0.36	0.55	71.25	1.00	71.25	0.114	No	No	0.34
79	14.11	57.93	1.79	0.34	0.55	70.24	1.00	70.24	0.112	No	No	0.34
80	14.27	57.50	1.80	0.35	0.55	69.56	1.00	69.56	0.111	No	No	0.33
81	14.44	57.53	1.81	0.37	0.55	69.47	1.00	69.47	0.111	No	No	0.33
82	14.60	58.65	1.81	0.39	0.55	70.65	1.00	70.65	0.113	No	No	0.33
83	14.76	52.39	1.87	0.41	0.57	63.26	1.00	63.26	0.104	No	No	0.31
84	14.93	39.14	2.02	0.52	0.61	47.86	1.33	63.44	0.104	No	No	0.30
85	15.09	24.64	2.28	0.79	0.69	30.69	1.84	56.44	0.097	No	No	0.28
86	15.26	15.44	2.57	1.36	0.78	19.51	3.47	67.72	0.109	No	No	0.32
87	15.42	13.10	2.68	1.68	0.81	16.54	4.45	73.61	3.600	No	Yes	2.00
88	15.58	15.15	2.59	1.47	0.79	19.01	3.69	70.21	0.112	No	No	0.32
89	15.75	19.03	2.45	1.12	0.74	23.61	2.66	62.73	0.103	No	No	0.30
90	15.91	22.17	2.39	1.07	0.72	27.34	2.31	63.04	0.103	No	No	0.29
91	16.08	22.50	2.42	1.24	0.73	27.74	2.46	68.20	0.110	No	No	0.31
92	16.24	21.86	2.49	1.60	0.75	27.04	2.89	78.02	0.124	No	No	0.35
93	16.40	21.42	2.54	1.92	0.77	26.52	3.27	86.60	0.140	No	No	0.40
94	16.57	21.79	2.58	2.34	0.78	27.01	3.62	97.77	0.167	No	No	0.47
95	16.73	25.03	2.56	2.58	0.78	30.97	3.46	107.16	0.194	No	No	0.54
96	16.90	30.12	2.51	2.62	0.76	37.07	3.05	112.90	0.214	No	No	0.60

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
97	17.06	36.90	2.43	2.50	0.74	45.04	2.56	115.11	0.222	No	No	0.62
98	17.22	55.27	2.22	1.83	0.67	66.08	1.66	109.74	0.203	No	No	0.56
99	17.39	83.19	1.99	1.28	0.60	97.09	1.30	126.09	0.266	No	No	0.74
100	17.55	109.57	1.84	1.01	0.56	125.63	1.19	149.69	0.392	No	No	1.08
101	17.72	114.88	1.83	1.01	0.56	131.07	1.18	154.51	0.423	No	No	1.16
102	17.88	100.73	1.93	1.26	0.59	115.62	1.26	145.33	0.365	No	No	1.00
103	18.05	79.96	2.14	2.00	0.65	93.11	1.48	137.72	0.323	No	No	0.88
104	18.21	72.59	2.27	2.82	0.69	85.19	1.82	155.47	0.429	No	No	1.17
105	18.37	84.33	2.26	3.14	0.69	98.59	1.80	177.45	0.600	No	No	1.63
106	18.54	113.88	2.12	2.61	0.65	131.08	1.46	190.76	0.726	No	No	1.97
107	18.70	129.48	2.07	2.45	0.63	147.74	1.38	203.34	4.000	No	No	2.00
108	18.86	114.36	2.14	2.70	0.65	130.55	1.48	192.83	0.747	No	No	2.00
109	19.03	76.52	2.36	3.85	0.72	88.34	2.19	193.20	0.751	No	No	2.00
110	19.19	42.83	2.71	6.82	0.82	50.17	4.82	241.93	3.600	No	Yes	2.00
111	19.36	29.03	2.95	10.01	0.89	34.08	7.92	269.79	3.600	No	Yes	2.00
112	19.52	27.23	2.99	11.07	1.00	32.66	8.65	282.46	3.600	No	Yes	2.00
113	19.68	28.50	2.96	10.50	1.00	34.00	8.17	277.94	3.600	No	Yes	2.00
114	19.85	29.18	2.94	9.78	0.89	33.63	7.86	264.17	3.600	No	Yes	2.00
115	20.01	27.48	2.93	8.82	0.89	31.38	7.65	240.11	3.600	No	Yes	2.00
116	20.18	27.39	2.85	6.78	0.86	30.90	6.51	201.28	3.600	No	Yes	2.00
117	20.34	28.39	2.75	5.01	0.83	31.67	5.26	166.58	3.600	No	Yes	2.00
118	20.50	30.88	2.66	3.96	0.80	34.15	4.26	145.57	3.600	No	Yes	2.00
119	20.67	34.18	2.58	3.42	0.78	37.56	3.61	135.43	0.311	No	No	0.82
120	20.83	38.12	2.51	3.03	0.76	41.64	3.08	128.08	0.275	No	No	0.72
121	21.00	38.83	2.51	3.02	0.76	42.23	3.03	128.16	0.276	No	No	0.72
122	21.16	34.22	2.61	3.67	0.79	37.13	3.81	141.48	3.600	No	Yes	2.00
123	21.32	25.97	2.80	5.27	0.85	28.09	5.89	165.39	3.600	No	Yes	2.00
124	21.49	19.86	2.99	7.50	1.00	21.72	8.61	187.03	3.600	No	Yes	2.00
125	21.65	21.21	2.96	7.00	0.89	22.66	8.06	182.62	3.600	No	Yes	2.00
126	21.82	30.69	2.74	5.00	0.83	32.81	5.13	168.15	3.600	No	Yes	2.00
127	21.98	36.29	2.68	4.83	0.81	38.71	4.48	173.22	3.600	No	Yes	2.00
128	22.15	33.86	2.74	5.54	0.83	35.98	5.16	185.70	3.600	No	Yes	2.00
129	22.31	25.23	2.91	7.06	0.88	26.57	7.34	195.09	3.600	No	Yes	2.00
130	22.47	23.15	2.89	5.94	0.87	24.11	7.02	169.23	3.600	No	Yes	2.00
131	22.64	25.01	2.79	4.64	0.85	25.91	5.74	148.68	3.600	No	Yes	2.00
132	22.80	35.49	2.56	3.08	0.78	36.73	3.41	125.43	0.264	No	No	0.68
133	22.97	51.25	2.33	2.11	0.71	52.85	2.05	108.47	0.199	No	No	0.51
134	23.13	65.18	2.16	1.53	0.66	66.80	1.53	102.11	0.179	No	No	0.46
135	23.29	63.11	2.16	1.45	0.66	64.40	1.53	98.29	0.168	No	No	0.43
136	23.46	48.03	2.35	2.07	0.71	48.91	2.13	104.42	0.186	No	No	0.48
137	23.62	31.40	2.70	4.29	0.82	31.84	4.73	150.60	3.600	No	Yes	2.00
138	23.79	21.98	3.04	9.04	1.00	22.29	9.47	211.12	3.600	No	Yes	2.00
139	23.95	19.15	3.24	14.87	1.00	19.13	13.73	262.52	3.600	No	Yes	2.00
140	24.11	22.36	3.22	15.94	1.00	22.44	13.16	295.27	3.600	No	Yes	2.00
141	24.28	30.51	3.05	12.65	1.00	30.94	9.69	299.83	3.600	No	Yes	2.00
142	24.44	36.82	2.88	8.81	0.87	36.89	6.95	256.44	3.600	No	Yes	2.00
143	24.61	40.05	2.70	5.41	0.82	39.83	4.75	189.12	3.600	No	Yes	2.00
144	24.77	41.73	2.50	2.89	0.76	41.13	3.01	123.69	0.256	No	No	0.65

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
145	24.93	46.02	2.38	2.09	0.72	45.17	2.27	102.75	0.181	No	No	0.46
146	25.10	50.57	2.35	2.08	0.71	49.55	2.12	105.15	0.188	No	No	0.48
147	25.26	51.86	2.37	2.30	0.72	50.69	2.22	112.68	0.213	No	No	0.54
148	25.43	50.72	2.39	2.39	0.72	49.37	2.32	114.55	0.220	No	No	0.55
149	25.59	47.63	2.45	2.77	0.74	46.18	2.68	123.97	0.257	No	No	0.65
150	25.75	42.82	2.50	2.89	0.76	41.25	3.00	123.60	0.256	No	No	0.64
151	25.92	38.12	2.57	3.18	0.78	36.47	3.51	127.96	0.275	No	No	0.69
152	26.08	35.62	2.61	3.35	0.79	33.88	3.84	129.96	3.600	No	Yes	2.00
153	26.25	36.45	2.64	3.83	0.80	34.57	4.13	142.91	3.600	No	Yes	2.00
154	26.41	35.40	2.71	4.59	0.82	33.43	4.78	159.75	3.600	No	Yes	2.00
155	26.57	33.16	2.77	5.25	0.84	31.11	5.49	170.66	3.600	No	Yes	2.00
156	26.74	26.72	2.90	6.45	0.88	24.72	7.26	179.53	3.600	No	Yes	2.00
157	26.90	21.75	3.02	7.49	1.00	19.84	9.09	180.27	3.600	No	Yes	2.00
158	27.07	17.49	3.13	8.39	1.00	15.58	11.17	174.04	3.600	No	Yes	2.00
159	27.23	16.89	3.11	7.54	1.00	14.92	10.81	161.36	3.600	No	Yes	2.00
160	27.39	17.74	3.02	5.76	1.00	15.67	9.06	141.99	3.600	No	Yes	2.00
161	27.56	19.19	2.88	3.95	0.87	16.95	6.98	118.36	3.600	No	Yes	2.00
162	27.72	20.57	2.73	2.45	0.83	18.20	5.07	92.35	3.600	No	Yes	2.00
163	27.89	24.83	2.53	1.44	0.77	22.18	3.21	71.26	0.114	No	No	0.28
164	28.05	37.01	2.24	0.78	0.68	33.66	1.72	57.94	0.098	No	No	0.24
165	28.21	52.16	2.03	0.56	0.62	47.92	1.34	64.14	0.105	No	No	0.26
166	28.38	59.71	1.95	0.48	0.59	54.93	1.00	54.93	0.095	No	No	0.24
167	28.54	55.33	2.01	0.56	0.61	50.67	1.32	66.76	0.108	No	No	0.27
168	28.71	44.81	2.21	0.95	0.67	40.62	1.65	66.89	0.108	No	No	0.27
169	28.87	36.89	2.48	2.03	0.75	33.04	2.83	93.45	0.156	No	No	0.39
170	29.04	31.36	2.75	4.36	0.83	27.72	5.27	145.98	3.600	No	Yes	2.00
171	29.20	27.91	2.96	7.66	1.00	24.32	8.15	198.17	3.600	No	Yes	2.00
172	29.36	26.98	3.07	10.36	1.00	23.34	10.01	233.58	3.600	No	Yes	2.00
173	29.53	30.16	3.02	10.04	1.00	26.13	9.22	240.81	3.600	No	Yes	2.00
174	29.69	34.28	2.93	8.34	0.89	29.87	7.60	227.05	3.600	No	Yes	2.00
175	29.86	36.27	2.84	6.71	0.86	31.59	6.38	201.54	3.600	No	Yes	2.00
176	30.02	35.33	2.80	5.72	0.85	30.62	5.87	179.68	3.600	No	Yes	2.00
177	30.18	32.51	2.80	5.21	0.85	27.93	5.87	163.86	3.600	No	Yes	2.00
178	30.35	30.62	2.81	4.99	0.85	26.11	5.98	156.01	3.600	No	Yes	2.00
179	30.51	29.09	2.84	5.22	0.86	24.61	6.40	157.41	3.600	No	Yes	2.00
180	30.68	29.70	2.85	5.40	0.86	25.06	6.45	161.73	3.600	No	Yes	2.00
181	30.84	31.68	2.83	5.43	0.86	26.74	6.20	165.85	3.600	No	Yes	2.00
182	31.00	36.66	2.73	4.65	0.83	31.12	5.07	157.65	3.600	No	Yes	2.00
183	31.17	45.07	2.58	3.53	0.78	38.60	3.61	139.32	0.331	No	No	0.81
184	31.33	49.32	2.49	2.80	0.75	42.33	2.88	121.82	0.248	No	No	0.61
185	31.50	49.61	2.45	2.49	0.74	42.49	2.66	112.95	0.214	No	No	0.52
186	31.66	50.64	2.42	2.30	0.73	43.29	2.49	107.73	0.196	No	No	0.48
187	31.82	66.54	2.28	1.96	0.69	57.42	1.86	107.06	0.194	No	No	0.47
188	31.99	105.26	2.09	1.68	0.63	91.98	1.40	128.97	0.279	No	No	0.68
189	32.15	152.62	1.96	1.61	0.60	134.22	1.28	171.27	0.547	No	No	1.34
190	32.32	193.84	1.85	1.44	0.56	170.99	1.20	205.49	4.000	No	No	2.00
191	32.48	213.18	1.80	1.33	0.55	188.03	1.15	216.69	4.000	No	No	2.00
192	32.64	218.38	1.79	1.32	0.55	192.20	1.14	219.60	4.000	No	No	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
193	32.81	212.89	1.85	1.53	0.56	186.45	1.20	223.39	4.000	No	No	2.00
194	32.97	201.32	1.92	1.83	0.59	175.24	1.25	219.47	4.000	No	No	2.00
195	33.14	189.26	1.92	1.70	0.58	164.21	1.25	205.07	4.000	No	No	2.00
196	33.30	182.98	1.86	1.39	0.57	158.62	1.21	192.05	0.739	No	No	1.80
197	33.47	184.02	1.73	0.90	0.53	160.04	1.04	166.53	0.510	No	No	1.24
198	33.63	186.81	1.67	0.74	0.51	162.54	1.00	162.54	0.479	No	No	1.16
199	33.79	187.43	1.66	0.73	0.51	162.75	1.00	162.75	0.481	No	No	1.17
200	33.96	183.42	1.72	0.87	0.52	158.47	1.03	163.02	0.483	No	No	1.17
201	34.12	175.90	1.79	1.04	0.54	151.06	1.14	172.04	0.554	No	No	1.34
202	34.28	165.98	1.83	1.12	0.56	141.83	1.18	167.92	0.520	No	No	1.26
203	34.45	158.47	1.83	1.05	0.56	135.02	1.18	159.44	0.457	No	No	1.11
204	34.61	154.51	1.81	0.96	0.55	131.42	1.16	152.74	0.411	No	No	1.00
205	34.78	155.87	1.77	0.84	0.54	132.56	1.11	147.52	0.379	No	No	0.92
206	34.94	159.33	1.73	0.76	0.53	135.50	1.05	142.60	0.350	No	No	0.85
207	35.10	166.53	1.69	0.68	0.51	141.74	1.00	141.74	0.345	No	No	0.83
208	35.27	167.54	1.70	0.71	0.52	142.21	1.00	142.21	0.347	No	No	0.84
209	35.43	159.67	1.78	0.89	0.54	134.55	1.13	151.62	0.404	No	No	0.98
210	35.60	156.70	1.84	1.06	0.56	131.26	1.19	156.39	0.436	No	No	1.05
211	35.76	181.13	1.75	0.91	0.53	152.47	1.08	164.45	0.494	No	No	1.19
212	35.92	234.84	1.58	0.69	0.50	199.03	1.00	199.03	0.813	No	No	1.96
213	36.09	299.91	1.43	0.53	0.50	254.13	1.00	254.13	4.000	No	No	2.00
214	36.25	349.29	1.38	0.53	0.50	295.65	1.00	295.65	4.000	No	No	2.00
215	36.42	370.40	1.39	0.58	0.50	312.94	1.00	312.94	4.000	No	No	2.00
216	36.58	363.58	1.45	0.69	0.50	306.48	1.00	306.48	4.000	No	No	2.00
217	36.74	348.73	1.47	0.71	0.50	293.24	1.00	293.24	4.000	No	No	2.00
218	36.91	339.35	1.44	0.64	0.50	284.70	1.00	284.70	4.000	No	No	2.00
219	37.07	338.65	1.38	0.52	0.50	283.53	1.00	283.53	4.000	No	No	2.00
220	37.24	341.33	1.39	0.53	0.50	285.19	1.00	285.19	4.000	No	No	2.00
221	37.40	348.75	1.42	0.60	0.50	290.82	1.00	290.82	4.000	No	No	2.00
222	37.57	342.84	1.47	0.70	0.50	285.25	1.00	285.25	4.000	No	No	2.00
223	37.73	342.66	1.50	0.75	0.50	284.50	1.00	284.50	4.000	No	No	2.00
224	37.89	341.09	1.50	0.76	0.50	282.58	1.00	282.58	4.000	No	No	2.00
225	38.06	358.39	1.44	0.65	0.50	296.39	1.00	296.39	4.000	No	No	2.00
226	38.22	372.99	1.31	0.44	0.50	307.92	1.00	307.92	4.000	No	No	2.00
227	38.39	391.40	1.21	0.33	0.50	322.58	1.00	322.58	4.000	No	No	2.00
228	38.55	408.33	1.18	0.31	0.50	335.97	1.00	335.97	4.000	No	No	2.00
229	38.71	421.40	1.22	0.37	0.50	346.10	1.00	346.10	4.000	No	No	2.00
230	38.88	427.31	1.23	0.39	0.50	350.28	1.00	350.28	4.000	No	No	2.00
231	39.04	418.90	1.23	0.39	0.50	342.68	1.00	342.68	4.000	No	No	2.00
232	39.21	401.54	1.27	0.41	0.50	327.75	1.00	327.75	4.000	No	No	2.00
233	39.37	389.68	1.30	0.44	0.50	317.40	1.00	317.40	4.000	No	No	2.00
234	39.53	393.48	1.28	0.42	0.50	319.88	1.00	319.88	4.000	No	No	2.00
235	39.70	408.36	1.26	0.41	0.50	331.40	1.00	331.40	4.000	No	No	2.00
236	39.86	418.10	1.25	0.40	0.50	338.70	1.00	338.70	4.000	No	No	2.00
237	40.03	402.57	1.27	0.42	0.50	325.42	1.00	325.42	4.000	No	No	2.00
238	40.19	338.71	1.37	0.47	0.50	272.98	1.00	272.98	4.000	No	No	2.00
239	40.35	235.90	1.56	0.62	0.50	189.19	1.00	189.19	0.710	No	No	1.72
240	40.52	139.85	1.87	0.96	0.57	108.80	1.22	132.37	0.296	No	No	0.72

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
241	40.68	78.81	2.21	1.54	0.67	58.47	1.64	95.82	0.162	No	No	0.39
242	40.85	53.51	2.42	1.98	0.73	38.24	2.49	95.13	0.160	No	No	0.39
243	41.01	38.50	2.63	2.65	0.80	26.41	3.98	105.10	3.600	No	Yes	2.00
244	41.17	32.89	2.73	3.15	0.83	22.01	5.08	111.80	3.600	No	Yes	2.00
245	41.34	32.73	2.79	3.84	0.85	21.71	5.78	125.55	3.600	No	Yes	2.00
246	41.50	32.94	2.82	4.20	0.85	21.73	6.10	132.49	3.600	No	Yes	2.00
247	41.67	33.03	2.84	4.53	0.86	21.68	6.38	138.39	3.600	No	Yes	2.00
248	41.83	30.19	2.88	4.61	0.87	19.53	6.92	135.21	3.600	No	Yes	2.00
249	41.99	27.66	2.90	4.44	0.88	17.65	7.25	128.02	3.600	No	Yes	2.00
250	42.16	25.19	2.92	4.18	0.89	15.84	7.55	119.58	3.600	No	Yes	2.00
251	42.32	23.43	2.92	3.75	0.88	14.57	7.54	109.82	3.600	No	Yes	2.00
252	42.49	21.95	2.96	3.68	1.00	12.97	8.08	104.79	3.600	No	Yes	2.00
253	42.65	19.74	3.02	4.01	1.00	11.46	9.17	105.06	3.600	No	Yes	2.00
254	42.81	18.07	3.11	4.94	1.00	10.31	10.90	112.38	3.600	No	Yes	2.00
255	42.98	17.26	3.17	5.76	1.00	9.74	12.17	118.51	3.600	No	Yes	2.00
256	43.14	17.90	3.16	5.64	1.00	10.13	11.76	119.11	3.600	No	Yes	2.00
257	43.31	18.53	3.13	5.27	1.00	10.51	11.12	116.83	3.600	No	Yes	2.00
258	43.47	17.92	3.14	5.21	1.00	10.07	11.35	114.26	3.600	No	Yes	2.00
259	43.63	16.35	3.19	5.49	1.00	9.01	12.47	112.33	3.600	No	Yes	2.00
260	43.80	14.65	3.25	5.81	1.00	7.87	13.92	109.52	3.600	No	Yes	2.00
261	43.96	13.79	3.28	5.89	1.00	7.29	14.67	106.89	3.600	No	Yes	2.00
262	44.13	14.30	3.24	5.37	1.00	7.59	13.72	104.11	3.600	No	Yes	2.00
263	44.29	15.62	3.17	4.75	1.00	8.41	12.15	102.22	3.600	No	Yes	2.00
264	44.45	17.01	3.11	4.22	1.00	9.28	10.79	100.22	3.600	No	Yes	2.00
265	44.62	17.46	3.08	3.92	1.00	9.54	10.24	97.71	3.600	No	Yes	2.00
266	44.78	17.37	3.07	3.66	1.00	9.45	9.96	94.19	3.600	No	Yes	2.00
267	44.95	17.72	3.03	3.22	1.00	9.64	9.25	89.23	3.600	No	Yes	2.00
268	45.11	19.60	2.92	2.66	0.89	11.31	7.55	85.42	3.600	No	Yes	2.00
269	45.28	20.08	2.91	2.64	0.88	11.61	7.37	85.65	3.600	No	Yes	2.00
270	45.44	19.26	2.98	3.02	1.00	10.53	8.45	88.95	3.600	No	Yes	2.00
271	45.60	16.65	3.11	3.97	1.00	8.84	10.82	95.70	3.600	No	Yes	2.00
272	45.77	14.60	3.27	5.92	1.00	7.53	14.42	108.50	3.600	No	Yes	2.00
273	45.93	13.54	3.38	7.82	1.00	6.83	17.38	118.65	3.600	No	Yes	2.00
274	46.10	12.55	3.48	10.11	1.00	6.18	20.72	128.15	3.600	No	Yes	2.00
275	46.26	12.25	3.51	10.64	1.00	5.97	21.64	129.22	3.600	No	Yes	2.00
276	46.42	12.16	3.51	10.58	1.00	5.90	21.74	128.17	3.600	No	Yes	2.00
277	46.59	14.36	3.36	7.73	1.00	7.24	16.71	120.95	3.600	No	Yes	2.00
278	46.75	18.41	3.13	4.95	1.00	9.73	11.31	110.02	3.600	No	Yes	2.00
279	46.92	23.48	2.90	3.08	0.88	13.52	7.16	96.78	3.600	No	Yes	2.00
280	47.08	27.23	2.76	2.32	0.84	16.20	5.38	87.16	3.600	No	Yes	2.00
281	47.24	29.00	2.69	1.91	0.81	17.49	4.56	79.70	3.600	No	Yes	2.00
282	47.41	30.22	2.63	1.66	0.80	18.38	4.06	74.67	3.600	No	Yes	2.00
283	47.57	32.02	2.58	1.47	0.78	19.68	3.59	70.69	0.113	No	No	0.28
284	47.74	34.99	2.54	1.44	0.77	21.75	3.27	71.02	0.113	No	No	0.28
285	47.90	36.82	2.55	1.63	0.77	22.90	3.34	76.60	0.122	No	No	0.30
286	48.06	37.03	2.62	2.14	0.79	22.77	3.93	89.50	3.600	No	Yes	2.00
287	48.23	35.55	2.72	2.84	0.82	21.46	4.87	104.44	3.600	No	Yes	2.00
288	48.39	33.76	2.80	3.54	0.85	20.01	5.84	116.77	3.600	No	Yes	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	I_c	Fr (%)	n	Q_{tn}	K_c	$Q_{tn,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
289	48.56	32.72	2.83	3.71	0.86	19.21	6.18	118.67	3.600	No	Yes	2.00
290	48.72	32.75	2.81	3.54	0.85	19.21	6.01	115.51	3.600	No	Yes	2.00
291	48.88	34.52	2.76	3.20	0.84	20.43	5.42	110.67	3.600	No	Yes	2.00
292	49.05	38.76	2.69	2.85	0.81	23.35	4.58	106.87	3.600	No	Yes	2.00
293	49.21	43.87	2.61	2.53	0.79	26.90	3.82	102.66	3.600	No	Yes	2.00
294	49.38	50.18	2.51	2.18	0.76	31.37	3.08	96.61	0.164	No	No	0.41
295	49.54	57.58	2.41	1.82	0.73	36.72	2.44	89.69	0.147	No	No	0.37
296	49.70	71.83	2.25	1.38	0.68	47.24	1.76	83.19	0.134	No	No	0.34
297	49.87	78.47	2.18	1.19	0.66	52.22	1.57	81.78	0.131	No	No	0.33
298	50.03	74.13	2.21	1.24	0.67	48.89	1.65	80.58	0.129	No	No	0.33
299	50.20	61.76	2.34	1.51	0.71	39.60	2.07	82.14	0.132	No	No	0.33

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
q_t: Total cone resistance
I_c: Soil behavior type index
Fr: Normalized friction ratio (%)
n: Stress exponent
Q_{tn}: Normalized cone resistance
K_c: Cone resistance correction factor due to fines
$Q_{tn,cs}$: Normalized and adjusted cone resistance
$CRR_{7.5}$: Cyclic resistance ratio for M_w=7.5
FS: Factor of safety against soil liquefaction

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
1.31	2.00	0.00	0.00	0.16	0.00	1.48	2.00	0.00	0.00	0.16	0.00
1.64	2.00	0.00	0.00	0.16	0.00	1.80	2.00	0.00	0.00	0.16	0.00
1.97	2.00	0.00	0.00	0.17	0.00	2.13	2.00	0.00	0.00	0.16	0.00
2.30	2.00	0.00	0.00	0.16	0.00	2.46	2.00	0.00	0.00	0.16	0.00
2.63	2.00	0.00	0.00	0.16	0.00	2.79	2.00	0.00	0.00	0.16	0.00
2.95	2.00	0.00	0.00	0.16	0.00	3.12	2.00	0.00	0.00	0.16	0.00
3.28	2.00	0.00	0.00	0.16	0.00	3.44	2.00	0.00	0.00	0.16	0.00
3.61	2.00	0.00	0.00	0.16	0.00	3.77	2.00	0.00	0.00	0.16	0.00
3.94	2.00	0.00	0.00	0.16	0.00	4.10	2.00	0.00	0.00	0.16	0.00
4.26	2.00	0.00	0.00	0.16	0.00	4.43	2.00	0.00	0.00	0.16	0.00
4.59	2.00	0.00	0.00	0.16	0.00	4.76	2.00	0.00	0.00	0.16	0.00
4.92	2.00	0.00	0.00	0.16	0.00	5.08	2.00	0.00	0.00	0.16	0.00
5.25	2.00	0.00	0.00	0.16	0.00	5.41	2.00	0.00	0.00	0.16	0.00
5.58	2.00	0.00	0.00	0.16	0.00	5.74	2.00	0.00	0.00	0.16	0.00
5.91	2.00	0.00	0.00	0.17	0.00	6.07	2.00	0.00	0.00	0.16	0.00
6.23	2.00	0.00	0.00	0.16	0.00	6.40	2.00	0.00	0.00	0.16	0.00
6.56	2.00	0.00	0.00	0.16	0.00	6.73	2.00	0.00	0.00	0.16	0.00
6.89	2.00	0.00	0.00	0.16	0.00	7.05	2.00	0.00	0.00	0.16	0.00
7.22	2.00	0.00	0.00	0.16	0.00	7.38	2.00	0.00	0.00	0.16	0.00
7.55	2.00	0.00	0.00	0.16	0.00	7.71	2.00	0.00	0.00	0.16	0.00
7.87	2.00	0.00	0.00	0.16	0.00	8.04	2.00	0.00	0.00	0.16	0.00
8.20	2.00	0.00	0.00	0.16	0.00	8.37	2.00	0.00	0.00	0.16	0.00
8.53	2.00	0.00	0.00	0.16	0.00	8.69	2.00	0.00	0.00	0.16	0.00
8.86	2.00	0.00	0.00	0.16	0.00	9.02	0.43	0.57	0.41	0.16	0.25
9.19	0.41	0.59	0.40	0.16	0.25	9.35	0.40	0.60	0.39	0.16	0.26
9.51	0.39	0.61	0.38	0.16	0.26	9.68	0.39	0.61	0.38	0.16	0.26
9.84	0.40	0.60	0.38	0.16	0.26	10.01	0.40	0.60	0.38	0.16	0.26
10.17	0.39	0.61	0.38	0.16	0.26	10.34	0.38	0.62	0.37	0.16	0.26
10.50	0.36	0.64	0.36	0.16	0.27	10.66	0.36	0.64	0.36	0.16	0.27
10.83	0.35	0.65	0.35	0.16	0.27	10.99	0.36	0.64	0.36	0.16	0.27
11.15	0.37	0.63	0.36	0.16	0.26	11.32	0.32	0.68	0.34	0.16	0.28
11.48	0.34	0.66	0.34	0.16	0.27	11.65	0.35	0.65	0.35	0.16	0.27
11.81	0.44	0.56	0.42	0.16	0.23	11.97	0.44	0.56	0.42	0.16	0.23
12.14	0.43	0.57	0.41	0.16	0.23	12.30	0.34	0.66	0.35	0.16	0.27
12.47	0.34	0.66	0.34	0.16	0.27	12.63	0.33	0.67	0.34	0.16	0.27
12.79	0.32	0.68	0.33	0.16	0.27	12.96	0.32	0.68	0.33	0.16	0.27
13.12	0.39	0.61	0.38	0.16	0.24	13.29	0.39	0.61	0.38	0.16	0.24
13.45	0.33	0.67	0.34	0.16	0.27	13.62	0.33	0.67	0.34	0.16	0.27
13.78	0.34	0.66	0.34	0.16	0.26	13.94	0.34	0.66	0.35	0.16	0.26
14.11	0.34	0.66	0.34	0.16	0.26	14.27	0.33	0.67	0.34	0.16	0.26
14.44	0.33	0.67	0.34	0.16	0.26	14.60	0.33	0.67	0.34	0.16	0.26
14.76	0.31	0.69	0.33	0.16	0.27	14.93	0.30	0.70	0.32	0.16	0.27
15.09	0.28	0.72	0.31	0.16	0.28	15.26	0.32	0.68	0.33	0.16	0.26
15.42	2.00	0.00	0.00	0.16	0.00	15.58	0.32	0.68	0.34	0.16	0.26
15.75	0.30	0.70	0.32	0.16	0.27	15.91	0.29	0.71	0.32	0.16	0.27
16.08	0.31	0.69	0.33	0.16	0.26	16.24	0.35	0.65	0.35	0.16	0.24
16.40	0.40	0.60	0.38	0.16	0.23	16.57	0.47	0.53	0.45	0.16	0.20
16.73	0.54	0.46	0.54	0.16	0.17	16.90	0.60	0.40	0.62	0.16	0.15

:: Liquefaction Potential Index calculation data :: (continued)

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
17.06	0.62	0.38	0.67	0.16	0.14	17.22	0.56	0.44	0.56	0.16	0.16
17.39	0.74	0.00	0.00	0.16	0.10	17.55	1.08	0.00	0.00	0.16	0.00
17.72	1.16	0.00	0.00	0.16	0.00	17.88	1.00	0.00	0.00	0.16	0.00
18.05	0.88	0.00	0.00	0.16	0.04	18.21	1.17	0.00	0.00	0.16	0.00
18.37	1.63	0.00	0.00	0.16	0.00	18.54	1.97	0.00	0.00	0.16	0.00
18.70	2.00	0.00	0.00	0.16	0.00	18.86	2.00	0.00	0.00	0.16	0.00
19.03	2.00	0.00	0.00	0.16	0.00	19.19	2.00	0.00	0.00	0.16	0.00
19.36	2.00	0.00	0.00	0.16	0.00	19.52	2.00	0.00	0.00	0.16	0.00
19.68	2.00	0.00	0.00	0.16	0.00	19.85	2.00	0.00	0.00	0.16	0.00
20.01	2.00	0.00	0.00	0.16	0.00	20.18	2.00	0.00	0.00	0.16	0.00
20.34	2.00	0.00	0.00	0.16	0.00	20.50	2.00	0.00	0.00	0.16	0.00
20.67	0.82	0.00	0.00	0.16	0.06	20.83	0.72	0.28	1.03	0.16	0.09
21.00	0.72	0.28	1.03	0.16	0.09	21.16	2.00	0.00	0.00	0.16	0.00
21.32	2.00	0.00	0.00	0.16	0.00	21.49	2.00	0.00	0.00	0.16	0.00
21.65	2.00	0.00	0.00	0.16	0.00	21.82	2.00	0.00	0.00	0.16	0.00
21.98	2.00	0.00	0.00	0.16	0.00	22.15	2.00	0.00	0.00	0.16	0.00
22.31	2.00	0.00	0.00	0.16	0.00	22.47	2.00	0.00	0.00	0.16	0.00
22.64	2.00	0.00	0.00	0.16	0.00	22.80	0.68	0.32	0.84	0.16	0.10
22.97	0.51	0.49	0.49	0.16	0.16	23.13	0.46	0.54	0.44	0.16	0.18
23.29	0.43	0.57	0.41	0.16	0.18	23.46	0.48	0.52	0.45	0.16	0.17
23.62	2.00	0.00	0.00	0.16	0.00	23.79	2.00	0.00	0.00	0.16	0.00
23.95	2.00	0.00	0.00	0.16	0.00	24.11	2.00	0.00	0.00	0.16	0.00
24.28	2.00	0.00	0.00	0.16	0.00	24.44	2.00	0.00	0.00	0.16	0.00
24.61	2.00	0.00	0.00	0.16	0.00	24.77	0.65	0.35	0.74	0.16	0.11
24.93	0.46	0.54	0.43	0.16	0.17	25.10	0.48	0.52	0.45	0.16	0.16
25.26	0.54	0.46	0.53	0.16	0.14	25.43	0.55	0.45	0.55	0.16	0.14
25.59	0.65	0.35	0.74	0.16	0.11	25.75	0.64	0.36	0.73	0.16	0.11
25.92	0.69	0.31	0.88	0.16	0.09	26.08	2.00	0.00	0.00	0.16	0.00
26.25	2.00	0.00	0.00	0.16	0.00	26.41	2.00	0.00	0.00	0.16	0.00
26.57	2.00	0.00	0.00	0.16	0.00	26.74	2.00	0.00	0.00	0.16	0.00
26.90	2.00	0.00	0.00	0.16	0.00	27.07	2.00	0.00	0.00	0.16	0.00
27.23	2.00	0.00	0.00	0.16	0.00	27.39	2.00	0.00	0.00	0.16	0.00
27.56	2.00	0.00	0.00	0.16	0.00	27.72	2.00	0.00	0.00	0.16	0.00
27.89	0.28	0.72	0.31	0.16	0.21	28.05	0.24	0.76	0.30	0.16	0.22
28.21	0.26	0.74	0.30	0.16	0.21	28.38	0.24	0.76	0.29	0.16	0.22
28.54	0.27	0.73	0.31	0.16	0.21	28.71	0.27	0.73	0.31	0.16	0.21
28.87	0.39	0.61	0.38	0.16	0.17	29.04	2.00	0.00	0.00	0.16	0.00
29.20	2.00	0.00	0.00	0.16	0.00	29.36	2.00	0.00	0.00	0.16	0.00
29.53	2.00	0.00	0.00	0.16	0.00	29.69	2.00	0.00	0.00	0.16	0.00
29.86	2.00	0.00	0.00	0.16	0.00	30.02	2.00	0.00	0.00	0.16	0.00
30.18	2.00	0.00	0.00	0.16	0.00	30.35	2.00	0.00	0.00	0.16	0.00
30.51	2.00	0.00	0.00	0.16	0.00	30.68	2.00	0.00	0.00	0.16	0.00
30.84	2.00	0.00	0.00	0.16	0.00	31.00	2.00	0.00	0.00	0.16	0.00
31.17	0.81	0.00	0.00	0.16	0.05	31.33	0.61	0.39	0.65	0.16	0.10
31.50	0.52	0.48	0.51	0.16	0.12	31.66	0.48	0.52	0.46	0.16	0.13
31.82	0.47	0.53	0.45	0.16	0.14	31.99	0.68	0.32	0.85	0.16	0.08
32.15	1.34	0.00	0.00	0.16	0.00	32.32	2.00	0.00	0.00	0.16	0.00
32.48	2.00	0.00	0.00	0.16	0.00	32.64	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data :: (continued)

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
32.81	2.00	0.00	0.00	0.16	0.00	32.97	2.00	0.00	0.00	0.16	0.00
33.14	2.00	0.00	0.00	0.16	0.00	33.30	1.80	0.00	0.00	0.16	0.00
33.47	1.24	0.00	0.00	0.16	0.00	33.63	1.16	0.00	0.00	0.16	0.00
33.79	1.17	0.00	0.00	0.16	0.00	33.96	1.17	0.00	0.00	0.16	0.00
34.12	1.34	0.00	0.00	0.16	0.00	34.28	1.26	0.00	0.00	0.16	0.00
34.45	1.11	0.00	0.00	0.16	0.00	34.61	1.00	0.00	0.00	0.16	0.00
34.78	0.92	0.00	0.00	0.16	0.02	34.94	0.85	0.00	0.00	0.16	0.04
35.10	0.83	0.00	0.00	0.16	0.04	35.27	0.84	0.00	0.00	0.16	0.04
35.43	0.98	0.00	0.00	0.16	0.01	35.60	1.05	0.00	0.00	0.16	0.00
35.76	1.19	0.00	0.00	0.16	0.00	35.92	1.96	0.00	0.00	0.16	0.00
36.09	2.00	0.00	0.00	0.16	0.00	36.25	2.00	0.00	0.00	0.16	0.00
36.42	2.00	0.00	0.00	0.16	0.00	36.58	2.00	0.00	0.00	0.16	0.00
36.74	2.00	0.00	0.00	0.16	0.00	36.91	2.00	0.00	0.00	0.16	0.00
37.07	2.00	0.00	0.00	0.16	0.00	37.24	2.00	0.00	0.00	0.16	0.00
37.40	2.00	0.00	0.00	0.16	0.00	37.57	2.00	0.00	0.00	0.16	0.00
37.73	2.00	0.00	0.00	0.16	0.00	37.89	2.00	0.00	0.00	0.16	0.00
38.06	2.00	0.00	0.00	0.16	0.00	38.22	2.00	0.00	0.00	0.16	0.00
38.39	2.00	0.00	0.00	0.16	0.00	38.55	2.00	0.00	0.00	0.16	0.00
38.71	2.00	0.00	0.00	0.16	0.00	38.88	2.00	0.00	0.00	0.16	0.00
39.04	2.00	0.00	0.00	0.16	0.00	39.21	2.00	0.00	0.00	0.16	0.00
39.37	2.00	0.00	0.00	0.16	0.00	39.53	2.00	0.00	0.00	0.16	0.00
39.70	2.00	0.00	0.00	0.16	0.00	39.86	2.00	0.00	0.00	0.16	0.00
40.03	2.00	0.00	0.00	0.16	0.00	40.19	2.00	0.00	0.00	0.16	0.00
40.35	1.72	0.00	0.00	0.16	0.00	40.52	0.72	0.28	0.99	0.16	0.05
40.68	0.39	0.61	0.38	0.16	0.12	40.85	0.39	0.61	0.38	0.16	0.12
41.01	2.00	0.00	0.00	0.17	0.00	41.17	2.00	0.00	0.00	0.16	0.00
41.34	2.00	0.00	0.00	0.16	0.00	41.50	2.00	0.00	0.00	0.16	0.00
41.67	2.00	0.00	0.00	0.16	0.00	41.83	2.00	0.00	0.00	0.16	0.00
41.99	2.00	0.00	0.00	0.16	0.00	42.16	2.00	0.00	0.00	0.16	0.00
42.32	2.00	0.00	0.00	0.16	0.00	42.49	2.00	0.00	0.00	0.16	0.00
42.65	2.00	0.00	0.00	0.16	0.00	42.81	2.00	0.00	0.00	0.16	0.00
42.98	2.00	0.00	0.00	0.16	0.00	43.14	2.00	0.00	0.00	0.16	0.00
43.31	2.00	0.00	0.00	0.16	0.00	43.47	2.00	0.00	0.00	0.16	0.00
43.63	2.00	0.00	0.00	0.16	0.00	43.80	2.00	0.00	0.00	0.16	0.00
43.96	2.00	0.00	0.00	0.16	0.00	44.13	2.00	0.00	0.00	0.16	0.00
44.29	2.00	0.00	0.00	0.16	0.00	44.45	2.00	0.00	0.00	0.16	0.00
44.62	2.00	0.00	0.00	0.16	0.00	44.78	2.00	0.00	0.00	0.16	0.00
44.95	2.00	0.00	0.00	0.16	0.00	45.11	2.00	0.00	0.00	0.16	0.00
45.28	2.00	0.00	0.00	0.16	0.00	45.44	2.00	0.00	0.00	0.16	0.00
45.60	2.00	0.00	0.00	0.16	0.00	45.77	2.00	0.00	0.00	0.16	0.00
45.93	2.00	0.00	0.00	0.16	0.00	46.10	2.00	0.00	0.00	0.16	0.00
46.26	2.00	0.00	0.00	0.16	0.00	46.42	2.00	0.00	0.00	0.16	0.00
46.59	2.00	0.00	0.00	0.16	0.00	46.75	2.00	0.00	0.00	0.16	0.00
46.92	2.00	0.00	0.00	0.16	0.00	47.08	2.00	0.00	0.00	0.16	0.00
47.24	2.00	0.00	0.00	0.16	0.00	47.41	2.00	0.00	0.00	0.16	0.00
47.57	0.28	0.72	0.31	0.16	0.10	47.74	0.28	0.72	0.31	0.16	0.10
47.90	0.30	0.70	0.32	0.16	0.09	48.06	2.00	0.00	0.00	0.16	0.00
48.23	2.00	0.00	0.00	0.16	0.00	48.39	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data :: (continued)

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
48.56	2.00	0.00	0.00	0.16	0.00	48.72	2.00	0.00	0.00	0.16	0.00
48.88	2.00	0.00	0.00	0.16	0.00	49.05	2.00	0.00	0.00	0.16	0.00
49.21	2.00	0.00	0.00	0.16	0.00	49.38	0.41	0.59	0.40	0.16	0.07
49.54	0.37	0.63	0.36	0.16	0.08	49.70	0.34	0.66	0.34	0.16	0.08
49.87	0.33	0.67	0.34	0.16	0.08	50.03	0.33	0.67	0.34	0.16	0.08
50.20	0.33	0.67	0.34	0.16	0.08						

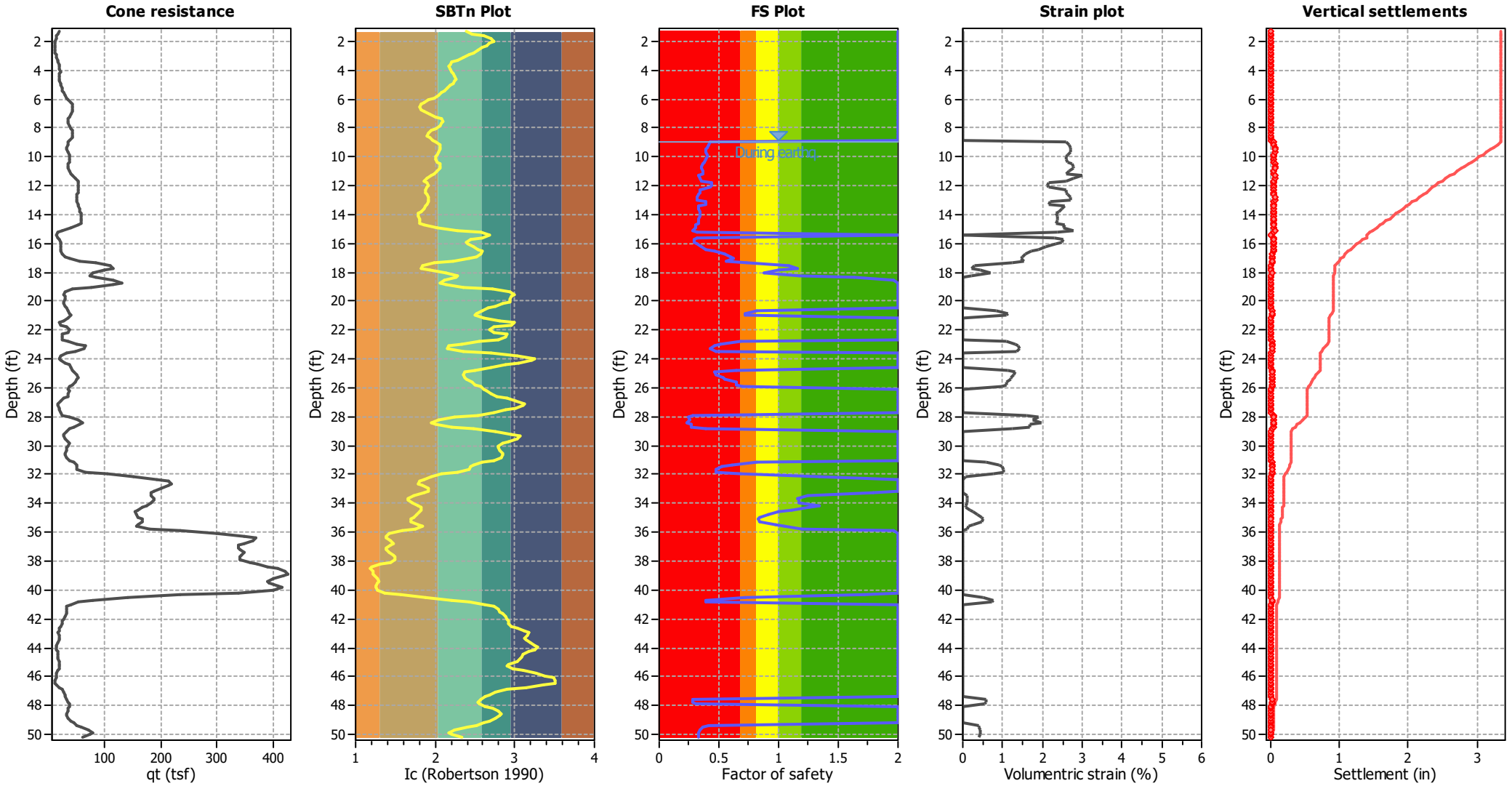
Overall liquefaction potential: 17.95

LPI = 0.00 - Liquefaction risk very low
LPI between 0.00 and 5.00 - Liquefaction risk low
LPI between 5.00 and 15.00 - Liquefaction risk high
LPI > 15.00 - Liquefaction risk very high

Abbreviations

FS: Calculated factor of safety for test point
F_L: 1 - FS
w_z: Function value of the extend of soil liquefaction according to depth
d_z: Layer thickness (ft)
LPI: Liquefaction potential index value for test point

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
9.02	71.44	0.43	2.61	0.85	0.05	9.19	69.46	0.41	2.66	0.84	0.05
9.35	67.55	0.40	2.71	0.84	0.05	9.51	66.95	0.39	2.72	0.84	0.05
9.68	67.43	0.39	2.70	0.84	0.05	9.84	69.02	0.40	2.64	0.83	0.05
10.01	69.75	0.40	2.61	0.83	0.05	10.17	69.36	0.39	2.61	0.83	0.05
10.34	68.05	0.38	2.64	0.82	0.05	10.50	64.71	0.36	2.74	0.82	0.05
10.66	63.89	0.36	2.76	0.82	0.05	10.83	63.60	0.35	2.77	0.82	0.05
10.99	66.24	0.36	2.67	0.81	0.05	11.15	68.04	0.37	2.60	0.81	0.05
11.32	57.00	0.32	2.99	0.81	0.06	11.48	62.46	0.34	2.77	0.81	0.05
11.65	67.01	0.35	2.60	0.80	0.05	11.81	84.58	0.44	2.14	0.80	0.04
11.97	85.03	0.44	2.13	0.80	0.04	12.14	83.10	0.43	2.16	0.79	0.04
12.30	66.34	0.34	2.59	0.79	0.05	12.47	65.48	0.34	2.61	0.79	0.05
12.63	64.01	0.33	2.65	0.79	0.05	12.79	62.20	0.32	2.70	0.78	0.05
12.96	62.01	0.32	2.70	0.78	0.05	13.12	78.94	0.39	2.21	0.78	0.04
13.29	80.20	0.39	2.17	0.77	0.04	13.45	65.79	0.33	2.54	0.77	0.05
13.62	67.16	0.33	2.49	0.77	0.05	13.78	69.27	0.34	2.42	0.77	0.05
13.94	71.25	0.34	2.36	0.76	0.05	14.11	70.24	0.34	2.38	0.76	0.05
14.27	69.56	0.33	2.39	0.76	0.05	14.44	69.47	0.33	2.38	0.76	0.05
14.60	70.65	0.33	2.34	0.75	0.05	14.76	63.26	0.31	2.55	0.75	0.05
14.93	63.44	0.30	2.54	0.75	0.05	15.09	56.44	0.28	2.78	0.74	0.05
15.26	67.72	0.32	2.39	0.74	0.05	15.42	73.61	2.00	0.00	0.74	0.00
15.58	70.21	0.32	2.30	0.74	0.05	15.75	62.73	0.30	2.51	0.73	0.05
15.91	63.04	0.29	2.49	0.73	0.05	16.08	68.20	0.31	2.33	0.73	0.05
16.24	78.02	0.35	2.08	0.72	0.04	16.40	86.60	0.40	1.90	0.72	0.04
16.57	97.77	0.47	1.71	0.72	0.03	16.73	107.16	0.54	1.58	0.72	0.03
16.90	112.90	0.60	1.51	0.71	0.03	17.06	115.11	0.62	1.48	0.71	0.03
17.22	109.74	0.56	1.53	0.71	0.03	17.39	126.09	0.74	1.25	0.71	0.02
17.55	149.69	1.08	0.30	0.70	0.01	17.72	154.51	1.16	0.21	0.70	0.00
17.88	145.33	1.00	0.43	0.70	0.01	18.05	137.72	0.88	0.68	0.69	0.01
18.21	155.47	1.17	0.21	0.69	0.00	18.37	177.45	1.63	0.00	0.69	0.00
18.54	190.76	1.97	0.00	0.69	0.00	18.70	203.34	2.00	0.00	0.68	0.00
18.86	192.83	2.00	0.00	0.68	0.00	19.03	193.20	2.00	0.00	0.68	0.00
19.19	241.93	2.00	0.00	0.67	0.00	19.36	269.79	2.00	0.00	0.67	0.00
19.52	282.46	2.00	0.00	0.67	0.00	19.68	277.94	2.00	0.00	0.67	0.00
19.85	264.17	2.00	0.00	0.66	0.00	20.01	240.11	2.00	0.00	0.66	0.00
20.18	201.28	2.00	0.00	0.66	0.00	20.34	166.58	2.00	0.00	0.66	0.00
20.50	145.57	2.00	0.00	0.65	0.00	20.67	135.43	0.82	0.85	0.65	0.02
20.83	128.08	0.72	1.12	0.65	0.02	21.00	128.16	0.72	1.11	0.64	0.02
21.16	141.48	2.00	0.00	0.64	0.00	21.32	165.39	2.00	0.00	0.64	0.00
21.49	187.03	2.00	0.00	0.64	0.00	21.65	182.62	2.00	0.00	0.63	0.00
21.82	168.15	2.00	0.00	0.63	0.00	21.98	173.22	2.00	0.00	0.63	0.00
22.15	185.70	2.00	0.00	0.62	0.00	22.31	195.09	2.00	0.00	0.62	0.00
22.47	169.23	2.00	0.00	0.62	0.00	22.64	148.68	2.00	0.00	0.62	0.00
22.80	125.43	0.68	1.09	0.61	0.02	22.97	108.47	0.51	1.34	0.61	0.03
23.13	102.11	0.46	1.40	0.61	0.03	23.29	98.29	0.43	1.43	0.61	0.03
23.46	104.42	0.48	1.36	0.60	0.03	23.62	150.60	2.00	0.00	0.60	0.00
23.79	211.12	2.00	0.00	0.60	0.00	23.95	262.52	2.00	0.00	0.59	0.00
24.11	295.27	2.00	0.00	0.59	0.00	24.28	299.83	2.00	0.00	0.59	0.00
24.44	256.44	2.00	0.00	0.59	0.00	24.61	189.12	2.00	0.00	0.58	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
24.77	123.69	0.65	1.14	0.58	0.02	24.93	102.75	0.46	1.32	0.58	0.03
25.10	105.15	0.48	1.29	0.57	0.03	25.26	112.68	0.54	1.21	0.57	0.02
25.43	114.55	0.55	1.19	0.57	0.02	25.59	123.97	0.65	1.11	0.57	0.02
25.75	123.60	0.64	1.11	0.56	0.02	25.92	127.96	0.69	0.97	0.56	0.02
26.08	129.96	2.00	0.00	0.56	0.00	26.25	142.91	2.00	0.00	0.56	0.00
26.41	159.75	2.00	0.00	0.55	0.00	26.57	170.66	2.00	0.00	0.55	0.00
26.74	179.53	2.00	0.00	0.55	0.00	26.90	180.27	2.00	0.00	0.54	0.00
27.07	174.04	2.00	0.00	0.54	0.00	27.23	161.36	2.00	0.00	0.54	0.00
27.39	141.99	2.00	0.00	0.54	0.00	27.56	118.36	2.00	0.00	0.53	0.00
27.72	92.35	2.00	0.00	0.53	0.00	27.89	71.26	0.28	1.63	0.53	0.03
28.05	57.94	0.24	1.92	0.52	0.04	28.21	64.14	0.26	1.75	0.52	0.03
28.38	54.93	0.24	1.98	0.52	0.04	28.54	66.76	0.27	1.68	0.52	0.03
28.71	66.89	0.27	1.67	0.51	0.03	28.87	93.45	0.39	1.26	0.51	0.02
29.04	145.98	2.00	0.00	0.51	0.00	29.20	198.17	2.00	0.00	0.51	0.00
29.36	233.58	2.00	0.00	0.50	0.00	29.53	240.81	2.00	0.00	0.50	0.00
29.69	227.05	2.00	0.00	0.50	0.00	29.86	201.54	2.00	0.00	0.49	0.00
30.02	179.68	2.00	0.00	0.49	0.00	30.18	163.86	2.00	0.00	0.49	0.00
30.35	156.01	2.00	0.00	0.49	0.00	30.51	157.41	2.00	0.00	0.48	0.00
30.68	161.73	2.00	0.00	0.48	0.00	30.84	165.85	2.00	0.00	0.48	0.00
31.00	157.65	2.00	0.00	0.47	0.00	31.17	139.32	0.81	0.59	0.47	0.01
31.33	121.82	0.61	0.93	0.47	0.02	31.50	112.95	0.52	0.99	0.47	0.02
31.66	107.73	0.48	1.02	0.46	0.02	31.82	107.06	0.47	1.02	0.46	0.02
31.99	128.97	0.68	0.78	0.46	0.02	32.15	171.27	1.34	0.09	0.46	0.00
32.32	205.49	2.00	0.00	0.45	0.00	32.48	216.69	2.00	0.00	0.45	0.00
32.64	219.60	2.00	0.00	0.45	0.00	32.81	223.39	2.00	0.00	0.44	0.00
32.97	219.47	2.00	0.00	0.44	0.00	33.14	205.07	2.00	0.00	0.44	0.00
33.30	192.05	1.80	0.00	0.44	0.00	33.47	166.53	1.24	0.12	0.43	0.00
33.63	162.54	1.16	0.12	0.43	0.00	33.79	162.75	1.17	0.12	0.43	0.00
33.96	163.02	1.17	0.12	0.42	0.00	34.12	172.04	1.34	0.08	0.42	0.00
34.28	167.92	1.26	0.08	0.42	0.00	34.45	159.44	1.11	0.17	0.42	0.00
34.61	152.74	1.00	0.25	0.41	0.00	34.78	147.52	0.92	0.36	0.41	0.01
34.94	142.60	0.85	0.49	0.41	0.01	35.10	141.74	0.83	0.49	0.41	0.01
35.27	142.21	0.84	0.49	0.40	0.01	35.43	151.62	0.98	0.24	0.40	0.00
35.60	156.39	1.05	0.16	0.40	0.00	35.76	164.45	1.19	0.11	0.39	0.00
35.92	199.03	1.96	0.00	0.39	0.00	36.09	254.13	2.00	0.00	0.39	0.00
36.25	295.65	2.00	0.00	0.39	0.00	36.42	312.94	2.00	0.00	0.38	0.00
36.58	306.48	2.00	0.00	0.38	0.00	36.74	293.24	2.00	0.00	0.38	0.00
36.91	284.70	2.00	0.00	0.37	0.00	37.07	283.53	2.00	0.00	0.37	0.00
37.24	285.19	2.00	0.00	0.37	0.00	37.40	290.82	2.00	0.00	0.37	0.00
37.57	285.25	2.00	0.00	0.36	0.00	37.73	284.50	2.00	0.00	0.36	0.00
37.89	282.58	2.00	0.00	0.36	0.00	38.06	296.39	2.00	0.00	0.35	0.00
38.22	307.92	2.00	0.00	0.35	0.00	38.39	322.58	2.00	0.00	0.35	0.00
38.55	335.97	2.00	0.00	0.35	0.00	38.71	346.10	2.00	0.00	0.34	0.00
38.88	350.28	2.00	0.00	0.34	0.00	39.04	342.68	2.00	0.00	0.34	0.00
39.21	327.75	2.00	0.00	0.34	0.00	39.37	317.40	2.00	0.00	0.33	0.00
39.53	319.88	2.00	0.00	0.33	0.00	39.70	331.40	2.00	0.00	0.33	0.00
39.86	338.70	2.00	0.00	0.32	0.00	40.03	325.42	2.00	0.00	0.32	0.00
40.19	272.98	2.00	0.00	0.32	0.00	40.35	189.19	1.72	0.00	0.32	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$Q_{tn,cs}$	FS	e_v (%)	DF	Settlement (in)
40.52	132.37	0.72	0.52	0.31	0.01	40.68	95.82	0.39	0.75	0.31	0.01
40.85	95.13	0.39	0.75	0.31	0.01	41.01	105.10	2.00	0.00	0.30	0.00
41.17	111.80	2.00	0.00	0.30	0.00	41.34	125.55	2.00	0.00	0.30	0.00
41.50	132.49	2.00	0.00	0.30	0.00	41.67	138.39	2.00	0.00	0.29	0.00
41.83	135.21	2.00	0.00	0.29	0.00	41.99	128.02	2.00	0.00	0.29	0.00
42.16	119.58	2.00	0.00	0.29	0.00	42.32	109.82	2.00	0.00	0.28	0.00
42.49	104.79	2.00	0.00	0.28	0.00	42.65	105.06	2.00	0.00	0.28	0.00
42.81	112.38	2.00	0.00	0.27	0.00	42.98	118.51	2.00	0.00	0.27	0.00
43.14	119.11	2.00	0.00	0.27	0.00	43.31	116.83	2.00	0.00	0.27	0.00
43.47	114.26	2.00	0.00	0.26	0.00	43.63	112.33	2.00	0.00	0.26	0.00
43.80	109.52	2.00	0.00	0.26	0.00	43.96	106.89	2.00	0.00	0.25	0.00
44.13	104.11	2.00	0.00	0.25	0.00	44.29	102.22	2.00	0.00	0.25	0.00
44.45	100.22	2.00	0.00	0.25	0.00	44.62	97.71	2.00	0.00	0.24	0.00
44.78	94.19	2.00	0.00	0.24	0.00	44.95	89.23	2.00	0.00	0.24	0.00
45.11	85.42	2.00	0.00	0.24	0.00	45.28	85.65	2.00	0.00	0.23	0.00
45.44	88.95	2.00	0.00	0.23	0.00	45.60	95.70	2.00	0.00	0.23	0.00
45.77	108.50	2.00	0.00	0.22	0.00	45.93	118.65	2.00	0.00	0.22	0.00
46.10	128.15	2.00	0.00	0.22	0.00	46.26	129.22	2.00	0.00	0.22	0.00
46.42	128.17	2.00	0.00	0.21	0.00	46.59	120.95	2.00	0.00	0.21	0.00
46.75	110.02	2.00	0.00	0.21	0.00	46.92	96.78	2.00	0.00	0.20	0.00
47.08	87.16	2.00	0.00	0.20	0.00	47.24	79.70	2.00	0.00	0.20	0.00
47.41	74.67	2.00	0.00	0.20	0.00	47.57	70.69	0.28	0.60	0.19	0.01
47.74	71.02	0.28	0.59	0.19	0.01	47.90	76.60	0.30	0.55	0.19	0.01
48.06	89.50	2.00	0.00	0.19	0.00	48.23	104.44	2.00	0.00	0.18	0.00
48.39	116.77	2.00	0.00	0.18	0.00	48.56	118.67	2.00	0.00	0.18	0.00
48.72	115.51	2.00	0.00	0.17	0.00	48.88	110.67	2.00	0.00	0.17	0.00
49.05	106.87	2.00	0.00	0.17	0.00	49.21	102.66	2.00	0.00	0.17	0.00
49.38	96.61	0.41	0.39	0.16	0.01	49.54	89.69	0.37	0.41	0.16	0.01
49.70	83.19	0.34	0.43	0.16	0.01	49.87	81.78	0.33	0.43	0.15	0.01
50.03	80.58	0.33	0.42	0.15	0.01	50.20	82.14	0.33	0.41	0.15	0.01

Total estimated settlement: 3.34

Abbreviations

$Q_{tn,cs}$: Equivalent clean sand normalized cone resistance
FS: Factor of safety against liquefaction
e_v (%): Post-liquefaction volumentric strain
DF: e_v depth weighting factor
Settlement: Calculated settlement

:: Strength loss calculation (Robertson (2009) ::

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
1.31	18.47	29.56	2.31	68.19	2.39	0.22	0.68
1.48	16.96	27.12	2.76	74.96	2.47	0.38	0.70
1.64	14.72	23.50	3.88	91.11	2.61	0.73	0.73
1.80	13.33	21.26	4.65	98.94	2.69	0.75	0.75
1.97	12.18	19.40	5.05	98.04	2.73	0.74	0.74
2.13	11.49	18.28	4.60	84.01	2.69	0.72	0.72
2.30	11.18	17.76	4.14	73.53	2.64	0.34	0.69
2.46	11.05	17.54	3.69	64.81	2.59	0.17	0.67
2.63	11.41	18.10	3.25	58.87	2.54	0.10	0.65
2.79	11.90	18.89	2.83	53.37	2.48	0.07	0.64
2.95	12.79	20.30	2.47	50.21	2.42	0.05	0.63
3.12	14.05	22.32	2.12	47.40	2.35	0.04	0.62
3.28	15.73	25.00	1.84	46.00	2.28	0.04	0.62
3.44	17.43	27.72	1.00	27.72	2.21	0.02	0.62
3.61	18.63	29.63	1.00	29.63	2.18	0.02	0.62
3.77	19.69	31.33	1.00	31.33	2.17	0.02	0.62
3.94	19.98	31.78	1.58	50.27	2.19	0.05	0.63
4.10	20.31	32.29	1.61	52.04	2.20	0.06	0.63
4.26	19.91	31.63	1.69	53.37	2.23	0.07	0.64
4.43	19.84	31.50	1.74	54.68	2.24	0.07	0.64
4.59	19.56	31.04	1.78	55.34	2.26	0.08	0.64
4.76	19.72	31.29	1.76	55.09	2.25	0.08	0.64
4.92	20.35	32.29	1.70	54.88	2.23	0.08	0.64
5.08	21.69	34.42	1.60	55.00	2.19	0.08	0.64
5.25	23.37	37.11	1.51	56.08	2.15	0.08	0.64
5.41	24.88	39.53	1.45	57.13	2.12	0.09	0.65
5.58	26.37	41.90	1.39	58.41	2.08	0.10	0.65
5.74	28.42	45.19	1.34	60.73	2.04	0.12	0.66
5.91	31.51	50.14	1.00	50.14	1.98	0.05	0.63
6.07	35.15	55.97	1.00	55.97	1.91	0.08	0.64
6.23	38.56	61.43	1.00	61.43	1.86	0.13	0.66
6.40	41.16	65.60	1.00	65.60	1.82	0.18	0.67
6.56	42.78	68.18	1.00	68.18	1.81	0.22	0.68
6.73	43.16	68.77	1.00	68.77	1.83	0.23	0.68
6.89	41.96	66.85	1.00	66.85	1.87	0.20	0.68
7.05	39.31	62.56	1.26	78.70	1.93	0.52	0.70
7.22	36.04	57.30	1.32	75.47	2.01	0.40	0.70
7.38	33.75	53.60	1.39	74.41	2.08	0.37	0.69
7.55	33.49	53.18	1.42	75.50	2.10	0.40	0.70
7.71	34.75	55.19	1.40	77.22	2.09	0.46	0.70
7.87	36.40	57.82	1.36	78.62	2.05	0.52	0.70
8.04	38.58	61.32	1.31	80.44	2.01	0.61	0.71
8.20	41.46	65.91	1.27	83.42	1.94	0.71	0.71
8.37	43.50	67.80	1.24	84.16	1.91	0.72	0.72
8.53	43.39	66.80	1.24	82.83	1.90	0.71	0.71
8.69	41.04	62.83	1.26	78.95	1.93	0.54	0.70
8.86	38.24	58.40	1.28	74.99	1.97	0.38	0.70
9.02	35.58	54.20	1.32	71.44	2.01	0.29	0.69

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
9.19	33.57	51.03	1.36	69.46	2.06	0.24	0.68
9.35	32.63	49.14	1.37	67.55	2.07	0.21	0.68
9.51	32.89	48.92	1.37	66.95	2.06	0.20	0.68
9.68	34.32	50.26	1.34	67.43	2.04	0.21	0.68
9.84	36.11	52.10	1.32	69.02	2.02	0.24	0.68
10.01	37.22	53.04	1.32	69.75	2.01	0.25	0.68
10.17	37.38	52.72	1.32	69.36	2.01	0.24	0.68
10.34	36.69	51.33	1.33	68.05	2.02	0.22	0.68
10.50	33.96	47.34	1.37	64.71	2.06	0.17	0.67
10.66	33.90	46.77	1.37	63.89	2.06	0.15	0.67
10.83	34.12	46.60	1.36	63.60	2.06	0.15	0.67
10.99	37.18	50.01	1.32	66.24	2.02	0.19	0.67
11.15	39.11	52.19	1.30	68.04	2.00	0.22	0.68
11.32	43.22	57.00	1.00	57.00	1.94	0.09	0.65
11.48	47.91	62.46	1.00	62.46	1.89	0.14	0.66
11.65	51.77	67.01	1.00	67.01	1.87	0.20	0.68
11.81	53.18	68.81	1.23	84.58	1.89	0.72	0.72
11.97	52.99	68.50	1.24	85.03	1.91	0.72	0.72
12.14	52.11	67.05	1.24	83.10	1.90	0.71	0.71
12.30	52.01	66.34	1.00	66.34	1.87	0.19	0.67
12.47	51.56	65.48	1.00	65.48	1.87	0.18	0.67
12.63	50.45	64.01	1.00	64.01	1.89	0.16	0.67
12.79	49.06	62.20	1.00	62.20	1.91	0.13	0.66
12.96	49.09	62.01	1.00	62.01	1.91	0.13	0.66
13.12	50.56	63.60	1.24	78.94	1.91	0.53	0.70
13.29	51.89	64.95	1.23	80.20	1.90	0.59	0.71
13.45	52.88	65.79	1.00	65.79	1.88	0.18	0.67
13.62	54.37	67.16	1.00	67.16	1.85	0.20	0.68
13.78	56.49	69.27	1.00	69.27	1.82	0.24	0.68
13.94	58.54	71.25	1.00	71.25	1.79	0.28	0.69
14.11	57.93	70.24	1.00	70.24	1.79	0.26	0.68
14.27	57.50	69.56	1.00	69.56	1.80	0.25	0.68
14.44	57.53	69.47	1.00	69.47	1.81	0.24	0.68
14.60	58.65	70.65	1.00	70.65	1.81	0.27	0.68
14.76	52.39	63.26	1.00	63.26	1.87	0.15	0.67
14.93	39.14	47.86	1.33	63.44	2.02	0.15	0.67
15.09	24.64	30.69	1.84	56.44	2.28	0.09	0.65
15.26	15.44	19.51	3.47	67.72	2.57	0.21	0.68
15.42	13.10	16.54	4.45	73.61	2.68	0.34	0.69
15.58	15.15	19.01	3.69	70.21	2.59	0.26	0.68
15.75	19.03	23.61	2.66	62.73	2.45	0.14	0.66
15.91	22.17	27.34	2.31	63.04	2.39	0.14	0.67
16.08	22.50	27.74	2.46	68.20	2.42	0.22	0.68
16.24	21.86	27.04	2.89	78.02	2.49	0.49	0.70
16.40	21.42	26.52	3.27	86.60	2.54	0.72	0.72
16.57	21.79	27.01	3.62	97.77	2.58	0.74	0.74
16.73	25.03	30.97	3.46	107.16	2.56	0.76	0.76
16.90	30.12	37.07	3.05	112.90	2.51	0.77	0.77

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
17.06	36.90	45.04	2.56	115.11	2.43	0.77	0.77
17.22	55.27	66.08	1.66	109.74	2.22	0.77	0.77
17.39	83.19	97.09	1.30	126.09	1.99	0.79	0.79
17.55	109.57	125.63	1.19	149.69	1.84	0.83	0.83
17.72	114.88	131.07	1.18	154.51	1.83	0.83	0.83
17.88	100.73	115.62	1.26	145.33	1.93	0.82	0.82
18.05	79.96	93.11	1.48	137.72	2.14	0.81	0.81
18.21	72.59	85.19	1.82	155.47	2.27	0.83	0.83
18.37	84.33	98.59	1.80	177.45	2.26	0.86	0.86
18.54	113.88	131.08	1.46	190.76	2.12	0.88	0.88
18.70	129.48	147.74	1.38	203.34	2.07	0.89	0.89
18.86	114.36	130.55	1.48	192.83	2.14	0.88	0.88
19.03	76.52	88.34	2.19	193.20	2.36	0.88	0.88
19.19	42.83	50.17	4.82	241.93	2.71	0.93	0.93
19.36	29.03	34.08	7.92	269.79	2.95	0.95	0.95
19.52	27.23	32.66	8.65	282.46	2.99	0.96	0.96
19.68	28.50	34.00	8.17	277.94	2.96	0.96	0.96
19.85	29.18	33.63	7.86	264.17	2.94	0.95	0.95
20.01	27.48	31.38	7.65	240.11	2.93	0.93	0.93
20.18	27.39	30.90	6.51	201.28	2.85	0.89	0.89
20.34	28.39	31.67	5.26	166.58	2.75	0.85	0.85
20.50	30.88	34.15	4.26	145.57	2.66	0.82	0.82
20.67	34.18	37.56	3.61	135.43	2.58	0.81	0.81
20.83	38.12	41.64	3.08	128.08	2.51	0.80	0.80
21.00	38.83	42.23	3.03	128.16	2.51	0.80	0.80
21.16	34.22	37.13	3.81	141.48	2.61	0.82	0.82
21.32	25.97	28.09	5.89	165.39	2.80	0.85	0.85
21.49	19.86	21.72	8.61	187.03	2.99	0.87	0.87
21.65	21.21	22.66	8.06	182.62	2.96	0.87	0.87
21.82	30.69	32.81	5.13	168.15	2.74	0.85	0.85
21.98	36.29	38.71	4.48	173.22	2.68	0.86	0.86
22.15	33.86	35.98	5.16	185.70	2.74	0.87	0.87
22.31	25.23	26.57	7.34	195.09	2.91	0.88	0.88
22.47	23.15	24.11	7.02	169.23	2.89	0.85	0.85
22.64	25.01	25.91	5.74	148.68	2.79	0.83	0.83
22.80	35.49	36.73	3.41	125.43	2.56	0.79	0.79
22.97	51.25	52.85	2.05	108.47	2.33	0.76	0.76
23.13	65.18	66.80	1.53	102.11	2.16	0.75	0.75
23.29	63.11	64.40	1.53	98.29	2.16	0.74	0.74
23.46	48.03	48.91	2.13	104.42	2.35	0.76	0.76
23.62	31.40	31.84	4.73	150.60	2.70	0.83	0.83
23.79	21.98	22.29	9.47	211.12	3.04	2.14	1.59
23.95	19.15	19.13	13.73	262.52	3.24	3.02	1.37
24.11	22.36	22.44	13.16	295.27	3.22	3.97	1.60
24.28	30.51	30.94	9.69	299.83	3.05	4.49	2.21
24.44	36.82	36.89	6.95	256.44	2.88	0.94	0.94
24.61	40.05	39.83	4.75	189.12	2.70	0.87	0.87
24.77	41.73	41.13	3.01	123.69	2.50	0.79	0.79

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
24.93	46.02	45.17	2.27	102.75	2.38	0.75	0.75
25.10	50.57	49.55	2.12	105.15	2.35	0.76	0.76
25.26	51.86	50.69	2.22	112.68	2.37	0.77	0.77
25.43	50.72	49.37	2.32	114.55	2.39	0.77	0.77
25.59	47.63	46.18	2.68	123.97	2.45	0.79	0.79
25.75	42.82	41.25	3.00	123.60	2.50	0.79	0.79
25.92	38.12	36.47	3.51	127.96	2.57	0.80	0.80
26.08	35.62	33.88	3.84	129.96	2.61	0.80	0.80
26.25	36.45	34.57	4.13	142.91	2.64	0.82	0.82
26.41	35.40	33.43	4.78	159.75	2.71	0.84	0.84
26.57	33.16	31.11	5.49	170.66	2.77	0.85	0.85
26.74	26.72	24.72	7.26	179.53	2.90	0.86	0.86
26.90	21.75	19.84	9.09	180.27	3.02	1.56	1.42
27.07	17.49	15.58	11.17	174.04	3.13	1.42	1.11
27.23	16.89	14.92	10.81	161.36	3.11	1.20	1.07
27.39	17.74	15.67	9.06	141.99	3.02	0.98	1.12
27.56	19.19	16.95	6.98	118.36	2.88	0.78	0.78
27.72	20.57	18.20	5.07	92.35	2.73	0.73	0.73
27.89	24.83	22.18	3.21	71.26	2.53	0.28	0.69
28.05	37.01	33.66	1.72	57.94	2.24	0.10	0.65
28.21	52.16	47.92	1.34	64.14	2.03	0.16	0.67
28.38	59.71	54.93	1.00	54.93	1.95	0.08	0.64
28.54	55.33	50.67	1.32	66.76	2.01	0.20	0.68
28.71	44.81	40.62	1.65	66.89	2.21	0.20	0.68
28.87	36.89	33.04	2.83	93.45	2.48	0.74	0.74
29.04	31.36	27.72	5.27	145.98	2.75	0.82	0.82
29.20	27.91	24.32	8.15	198.17	2.96	0.88	0.88
29.36	26.98	23.34	10.01	233.58	3.07	2.70	1.67
29.53	30.16	26.13	9.22	240.81	3.02	2.96	1.87
29.69	34.28	29.87	7.60	227.05	2.93	0.91	0.91
29.86	36.27	31.59	6.38	201.54	2.84	0.89	0.89
30.02	35.33	30.62	5.87	179.68	2.80	0.86	0.86
30.18	32.51	27.93	5.87	163.86	2.80	0.84	0.84
30.35	30.62	26.11	5.98	156.01	2.81	0.83	0.83
30.51	29.09	24.61	6.40	157.41	2.84	0.84	0.84
30.68	29.70	25.06	6.45	161.73	2.85	0.84	0.84
30.84	31.68	26.74	6.20	165.85	2.83	0.85	0.85
31.00	36.66	31.12	5.07	157.65	2.73	0.84	0.84
31.17	45.07	38.60	3.61	139.32	2.58	0.81	0.81
31.33	49.32	42.33	2.88	121.82	2.49	0.79	0.79
31.50	49.61	42.49	2.66	112.95	2.45	0.77	0.77
31.66	50.64	43.29	2.49	107.73	2.42	0.76	0.76
31.82	66.54	57.42	1.86	107.06	2.28	0.76	0.76
31.99	105.26	91.98	1.40	128.97	2.09	0.80	0.80
32.15	152.62	134.22	1.28	171.27	1.96	0.85	0.85
32.32	193.84	170.99	1.20	205.49	1.85	0.89	0.89
32.48	213.18	188.03	1.15	216.69	1.80	0.90	0.90
32.64	218.38	192.20	1.14	219.60	1.79	0.91	0.91

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
32.81	212.89	186.45	1.20	223.39	1.85	0.91	0.91
32.97	201.32	175.24	1.25	219.47	1.92	0.91	0.91
33.14	189.26	164.21	1.25	205.07	1.92	0.89	0.89
33.30	182.98	158.62	1.21	192.05	1.86	0.88	0.88
33.47	184.02	160.04	1.04	166.53	1.73	0.85	0.85
33.63	186.81	162.54	1.00	162.54	1.67	0.84	0.84
33.79	187.43	162.75	1.00	162.75	1.66	0.84	0.84
33.96	183.42	158.47	1.03	163.02	1.72	0.84	0.84
34.12	175.90	151.06	1.14	172.04	1.79	0.86	0.86
34.28	165.98	141.83	1.18	167.92	1.83	0.85	0.85
34.45	158.47	135.02	1.18	159.44	1.83	0.84	0.84
34.61	154.51	131.42	1.16	152.74	1.81	0.83	0.83
34.78	155.87	132.56	1.11	147.52	1.77	0.82	0.82
34.94	159.33	135.50	1.05	142.60	1.73	0.82	0.82
35.10	166.53	141.74	1.00	141.74	1.69	0.82	0.82
35.27	167.54	142.21	1.00	142.21	1.70	0.82	0.82
35.43	159.67	134.55	1.13	151.62	1.78	0.83	0.83
35.60	156.70	131.26	1.19	156.39	1.84	0.84	0.84
35.76	181.13	152.47	1.08	164.45	1.75	0.85	0.85
35.92	234.84	199.03	1.00	199.03	1.58	0.89	0.89
36.09	299.91	254.13	1.00	254.13	1.43	0.94	0.94
36.25	349.29	295.65	1.00	295.65	1.38	0.97	0.97
36.42	370.40	312.94	1.00	312.94	1.39	0.99	0.99
36.58	363.58	306.48	1.00	306.48	1.45	0.98	0.98
36.74	348.73	293.24	1.00	293.24	1.47	0.97	0.97
36.91	339.35	284.70	1.00	284.70	1.44	0.97	0.97
37.07	338.65	283.53	1.00	283.53	1.38	0.96	0.96
37.24	341.33	285.19	1.00	285.19	1.39	0.97	0.97
37.40	348.75	290.82	1.00	290.82	1.42	0.97	0.97
37.57	342.84	285.25	1.00	285.25	1.47	0.97	0.97
37.73	342.66	284.50	1.00	284.50	1.50	0.97	0.97
37.89	341.09	282.58	1.00	282.58	1.50	0.96	0.96
38.06	358.39	296.39	1.00	296.39	1.44	0.97	0.97
38.22	372.99	307.92	1.00	307.92	1.31	0.98	0.98
38.39	391.40	322.58	1.00	322.58	1.21	1.00	1.00
38.55	408.33	335.97	1.00	335.97	1.18	1.00	1.00
38.71	421.40	346.10	1.00	346.10	1.22	1.01	1.01
38.88	427.31	350.28	1.00	350.28	1.23	1.01	1.01
39.04	418.90	342.68	1.00	342.68	1.23	1.01	1.01
39.21	401.54	327.75	1.00	327.75	1.27	1.00	1.00
39.37	389.68	317.40	1.00	317.40	1.30	0.99	0.99
39.53	393.48	319.88	1.00	319.88	1.28	0.99	0.99
39.70	408.36	331.40	1.00	331.40	1.26	1.00	1.00
39.86	418.10	338.70	1.00	338.70	1.25	1.01	1.01
40.03	402.57	325.42	1.00	325.42	1.27	1.00	1.00
40.19	338.71	272.98	1.00	272.98	1.37	0.96	0.96
40.35	235.90	189.19	1.00	189.19	1.56	0.88	0.88
40.52	139.85	108.80	1.22	132.37	1.87	0.80	0.80

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
40.68	78.81	58.47	1.64	95.82	2.21	0.74	0.74
40.85	53.51	38.24	2.49	95.13	2.42	0.74	0.74
41.01	38.50	26.41	3.98	105.10	2.63	0.76	0.76
41.17	32.89	22.01	5.08	111.80	2.73	0.77	0.77
41.34	32.73	21.71	5.78	125.55	2.79	0.79	0.79
41.50	32.94	21.73	6.10	132.49	2.82	0.80	0.80
41.67	33.03	21.68	6.38	138.39	2.84	0.81	0.81
41.83	30.19	19.53	6.92	135.21	2.88	0.81	0.81
41.99	27.66	17.65	7.25	128.02	2.90	0.80	0.80
42.16	25.19	15.84	7.55	119.58	2.92	0.78	0.78
42.32	23.43	14.57	7.54	109.82	2.92	0.77	0.77
42.49	21.95	12.97	8.08	104.79	2.96	0.76	0.76
42.65	19.74	11.46	9.17	105.06	3.02	0.44	0.82
42.81	18.07	10.31	10.90	112.38	3.11	0.55	0.74
42.98	17.26	9.74	12.17	118.51	3.17	0.61	0.70
43.14	17.90	10.13	11.76	119.11	3.16	0.60	0.72
43.31	18.53	10.51	11.12	116.83	3.13	0.58	0.75
43.47	17.92	10.07	11.35	114.26	3.14	0.55	0.72
43.63	16.35	9.01	12.47	112.33	3.19	0.51	0.64
43.80	14.65	7.87	13.92	109.52	3.25	0.48	0.56
43.96	13.79	7.29	14.67	106.89	3.28	0.44	0.52
44.13	14.30	7.59	13.72	104.11	3.24	0.42	0.54
44.29	15.62	8.41	12.15	102.22	3.17	0.42	0.60
44.45	17.01	9.28	10.79	100.22	3.11	0.41	0.66
44.62	17.46	9.54	10.24	97.71	3.08	0.40	0.68
44.78	17.37	9.45	9.96	94.19	3.07	0.36	0.68
44.95	17.72	9.64	9.25	89.23	3.03	0.32	0.69
45.11	19.60	11.31	7.55	85.42	2.92	0.72	0.72
45.28	20.08	11.61	7.37	85.65	2.91	0.72	0.72
45.44	19.26	10.53	8.45	88.95	2.98	0.73	0.73
45.60	16.65	8.84	10.82	95.70	3.11	0.37	0.63
45.77	14.60	7.53	14.42	108.50	3.27	0.39	0.54
45.93	13.54	6.83	17.38	118.65	3.38	0.63	0.49
46.10	12.55	6.18	20.72	128.15	3.48	0.64	0.44
46.26	12.25	5.97	21.64	129.22	3.51	0.68	0.43
46.42	12.16	5.90	21.74	128.17	3.51	0.66	0.42
46.59	14.36	7.24	16.71	120.95	3.36	0.61	0.52
46.75	18.41	9.73	11.31	110.02	3.13	0.48	0.70
46.92	23.48	13.52	7.16	96.78	2.90	0.74	0.74
47.08	27.23	16.20	5.38	87.16	2.76	0.72	0.72
47.24	29.00	17.49	4.56	79.70	2.69	0.57	0.71
47.41	30.22	18.38	4.06	74.67	2.63	0.37	0.69
47.57	32.02	19.68	3.59	70.69	2.58	0.27	0.69
47.74	34.99	21.75	3.27	71.02	2.54	0.28	0.69
47.90	36.82	22.90	3.34	76.60	2.55	0.44	0.70
48.06	37.03	22.77	3.93	89.50	2.62	0.73	0.73
48.23	35.55	21.46	4.87	104.44	2.72	0.76	0.76
48.39	33.76	20.01	5.84	116.77	2.80	0.78	0.78

:: Strength loss calculation (Robertson (2009) :: (continued)

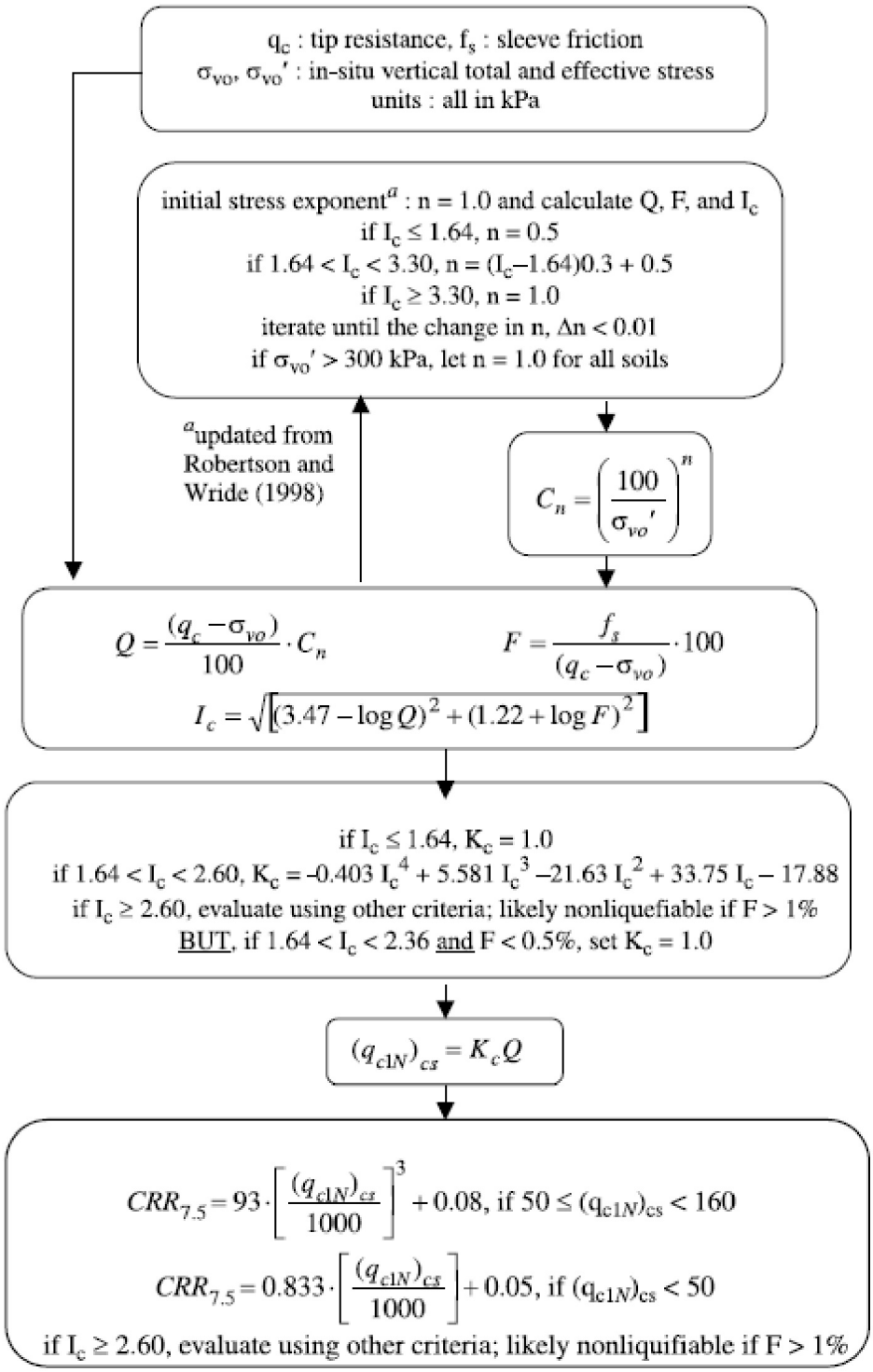
Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
48.56	32.72	19.21	6.18	118.67	2.83	0.78	0.78
48.72	32.75	19.21	6.01	115.51	2.81	0.78	0.78
48.88	34.52	20.43	5.42	110.67	2.76	0.77	0.77
49.05	38.76	23.35	4.58	106.87	2.69	0.76	0.76
49.21	43.87	26.90	3.82	102.66	2.61	0.75	0.75
49.38	50.18	31.37	3.08	96.61	2.51	0.74	0.74
49.54	57.58	36.72	2.44	89.69	2.41	0.73	0.73
49.70	71.83	47.24	1.76	83.19	2.25	0.71	0.71
49.87	78.47	52.22	1.57	81.78	2.18	0.68	0.71
50.03	74.13	48.89	1.65	80.58	2.21	0.61	0.71
50.20	61.76	39.60	2.07	82.14	2.34	0.70	0.71

Abbreviations

q_t:	Total cone resistance
K_c:	Cone resistance correction factor due to fines
$Q_{tn,cs}$:	Adjusted and corrected cone resistance due to fines
I_c:	Soil behavior type index
$S_{u(liq)}/\sigma'_v$:	Calculated liquefied undrained strength ratio
$S_{u(peak)}/\sigma'_v$:	Calculated peak undrained strength ratio

Procedure for the evaluation of soil liquefaction resistance, NCEER (1998)

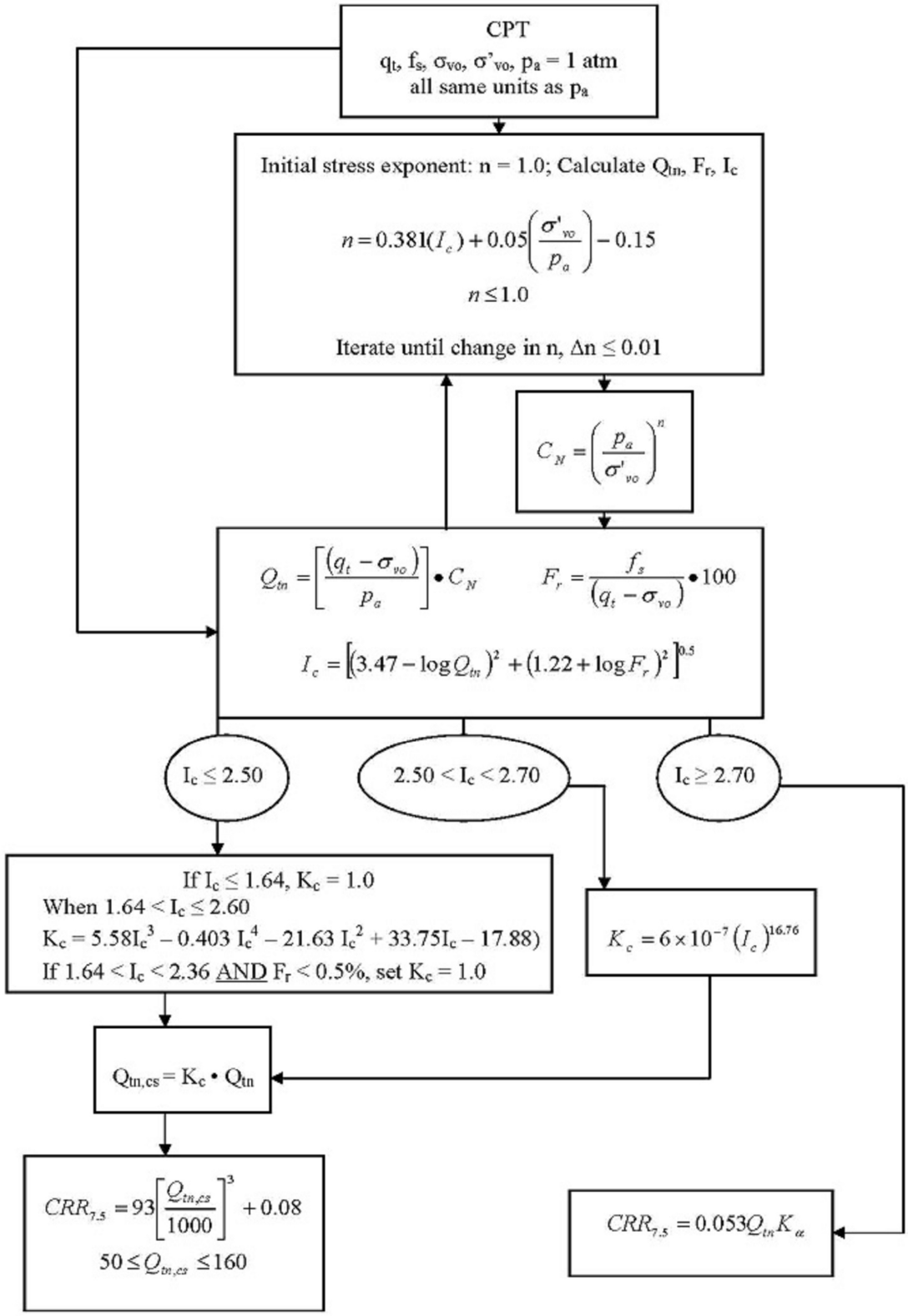
Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. The procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:



[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

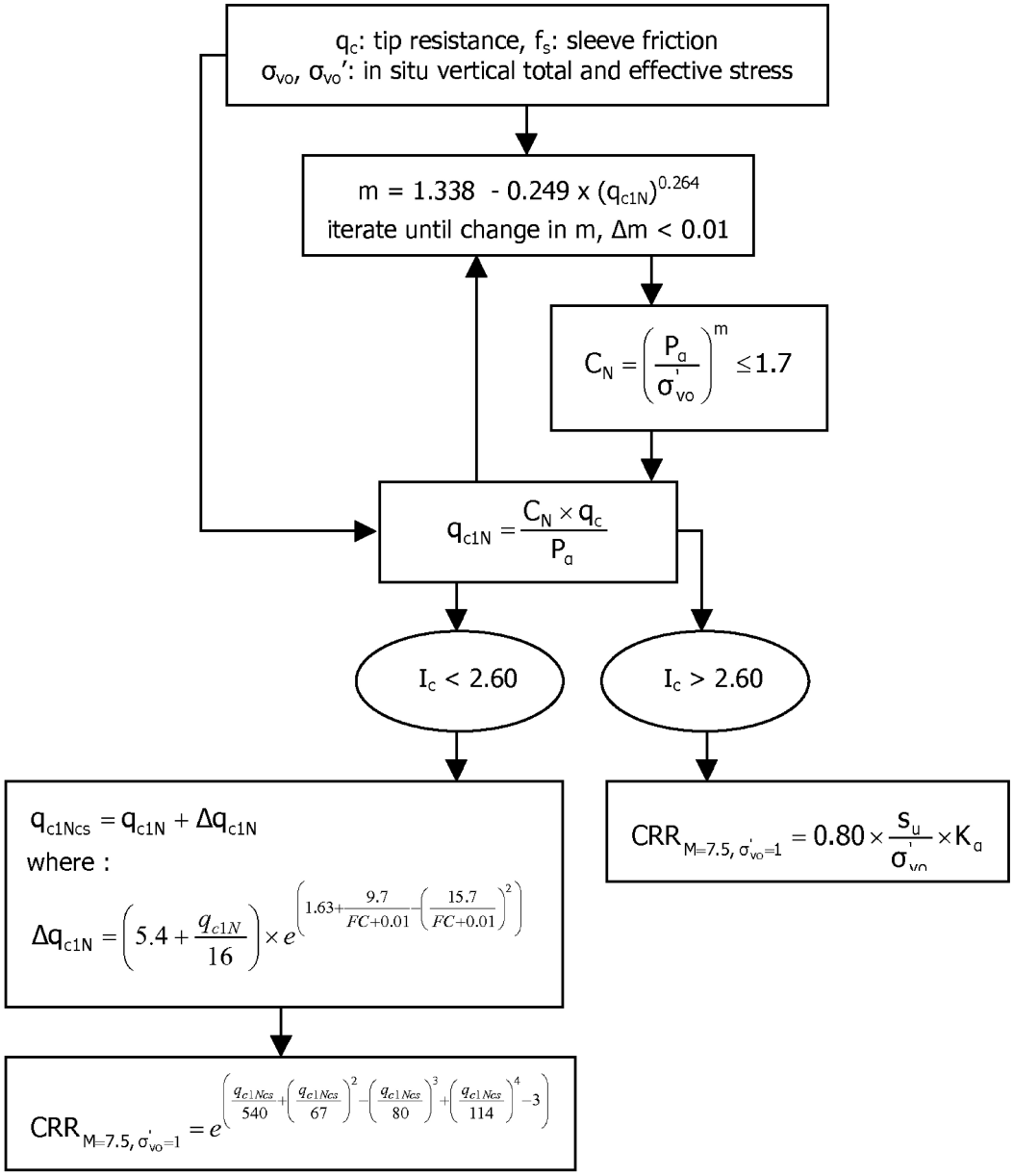
Procedure for the evaluation of soil liquefaction resistance (all soils), Robertson (2010)

Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. This procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:

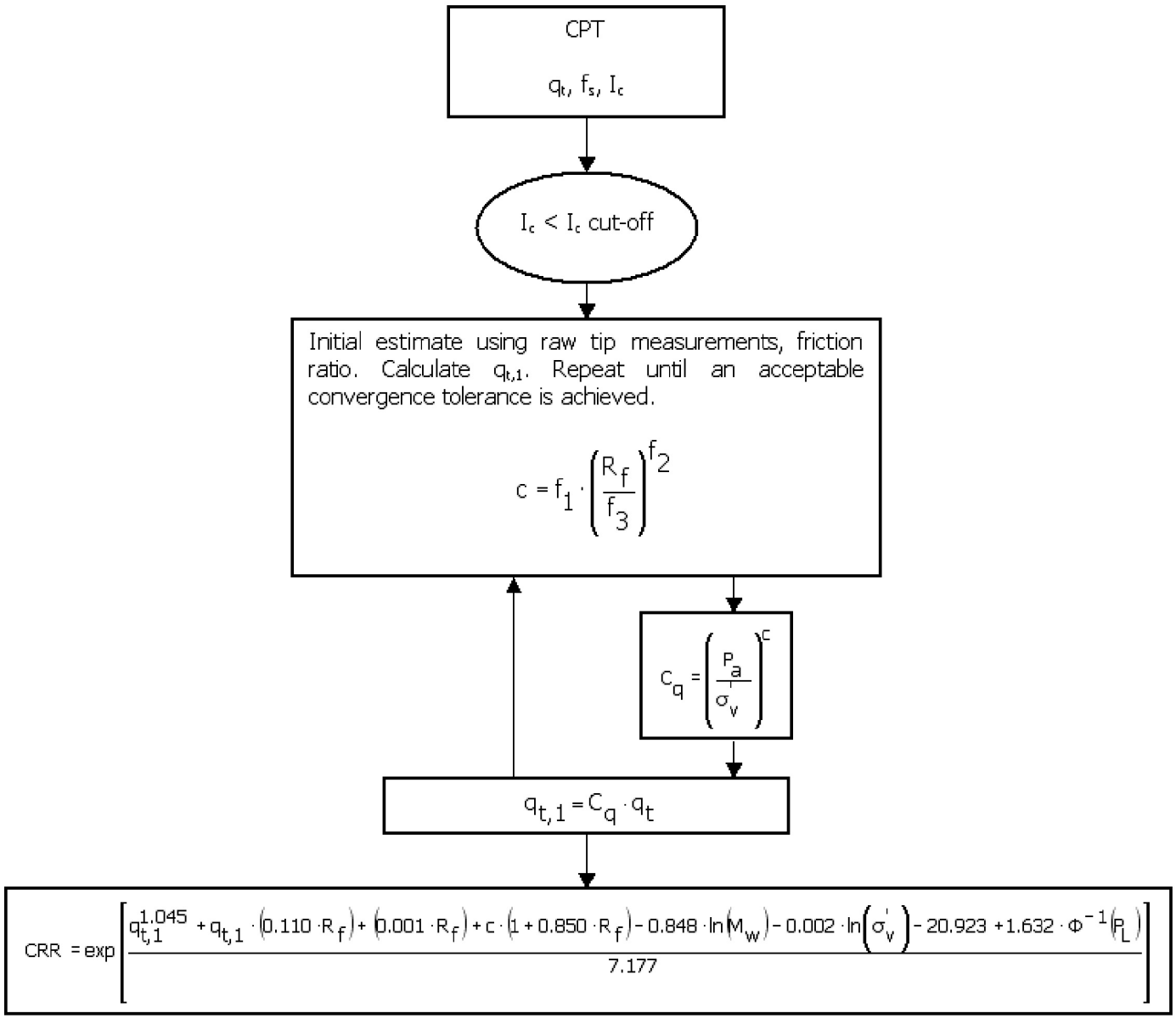


[1] P.K. Robertson, 2009. "Performance based earthquake design using the CPT", Keynote Lecture, International Conference on Performance-based Design in Earthquake Geotechnical Engineering – from case history to practice, IS-Tokyo, June 2009

Procedure for the evaluation of soil liquefaction resistance, Idriss & Boulanger (2008)



Procedure for the evaluation of soil liquefaction resistance (sandy soils), Moss et al. (2006)



Procedure for the evaluation of soil liquefaction resistance, Boulanger & Idriss(2014)

$$FS_{liq} = \frac{CRR_{M=7.5,\sigma'_v=1atm}}{CSR_{M=7.5,\sigma'_v=1atm}}$$

$$CSR_{M=7.5,\sigma'_v=1atm} = 0.65 \frac{\sigma_v}{\sigma'_v} \frac{a_{max}}{g} r_d \frac{1}{MSF} \frac{1}{K_\sigma}$$

$$r_d = \exp\left[\alpha(z) + \beta(z) \cdot M\right]$$

$$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$$

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \le 1.1$$

$$C_\sigma = \frac{1}{37.3 - 8.27\left(q_{c1Ncs}\right)^{0.264}} \le 0.3$$

$$MSF = 1 + \left(MSF_{max} - 1\right)\left(8.64 \exp\left(\frac{-M}{4}\right) - 1.325\right)$$

$$MSF_{max} = 1.09 + \left(\frac{q_{c1Ncs}}{180}\right)^3 \le 2.2$$

σ'_v *and* σ_v *at start of earthquake shaking*

$$CRR_{M=7.5,\sigma'_v=1atm} = \exp\left(\frac{q_{c1Ncs}}{113} + \left(\frac{q_{c1Ncs}}{1000}\right)^2 - \left(\frac{q_{c1Ncs}}{140}\right)^3 + \left(\frac{q_{c1Ncs}}{137}\right)^4 - 2.80\right)$$

$$q_{c1Ncs} = q_{c1N} + \Delta q_{c1N}$$

$$\Delta q_{c1N} = \left(11.9 + \frac{q_{c1N}}{14.6}\right) \exp\left(1.63 - \frac{9.7}{FC+2} - \left(\frac{15.7}{FC+2}\right)^2\right)$$

$$q_{c1N} = C_{Ne} \frac{q_c}{P_a}$$

$$C_{Ne} = \left(\frac{P_a}{\sigma'_v}\right)^m \le 1.7$$

$$m = 1.338 - 0.249\left(q_{c1Ncs}\right)^{0.264} \quad with \quad 0.264 \le m \le 0.782$$

$$FC = 80\left(I_C + C_{FC}\right) - 137 \quad with \quad 0\% \le FC \le 100\%$$

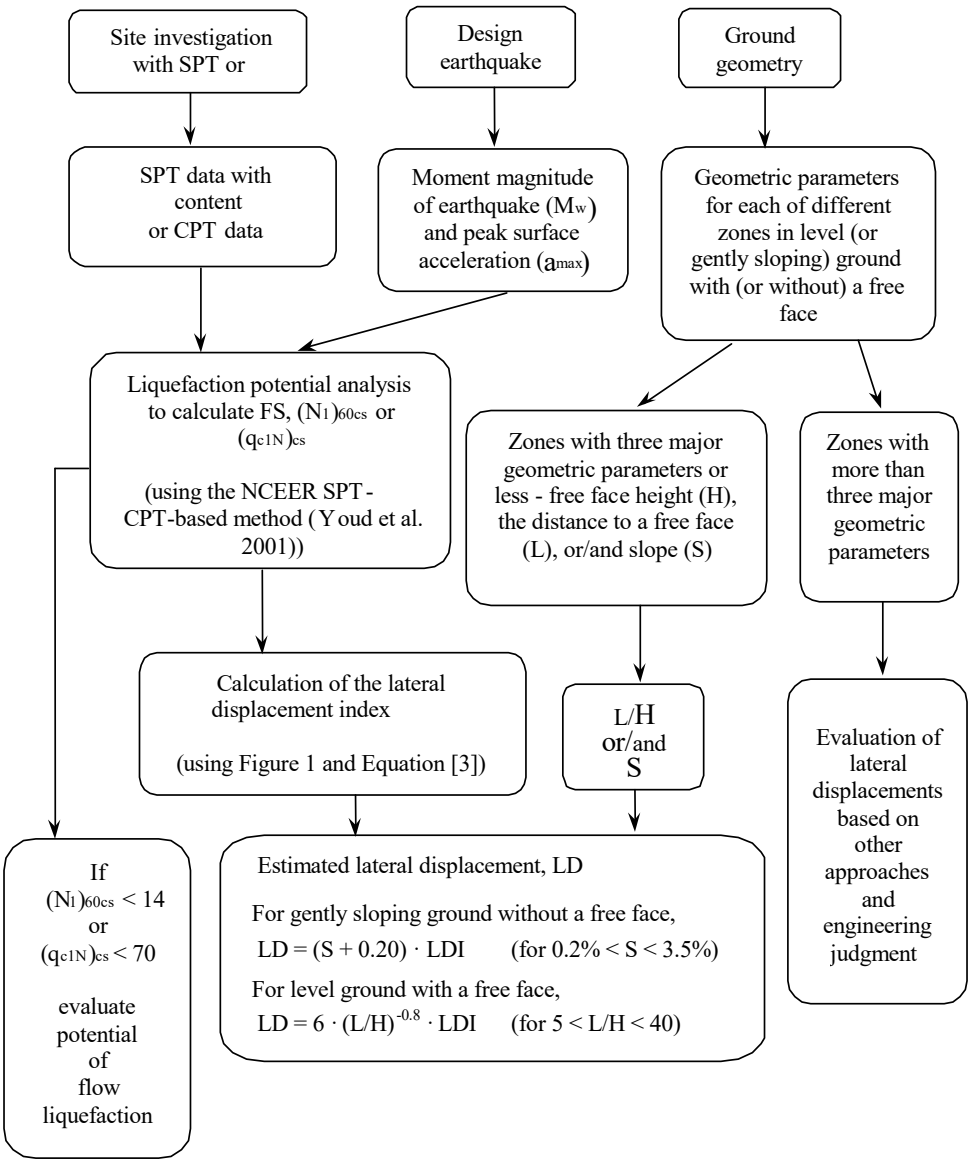
$$I_c = \left[\left(3.47 - \log\left(Q\right)\right)^2 + \left(1.22 + \log\left(F\right)\right)^2\right]^{0.5}$$

$$Q = \left(\frac{q_c - \sigma_{vc}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vc}}\right)^n \; with \; 0.5 \le n \le 1.0 \; per \; Robertson \; \& \; Wride \; (1998)$$

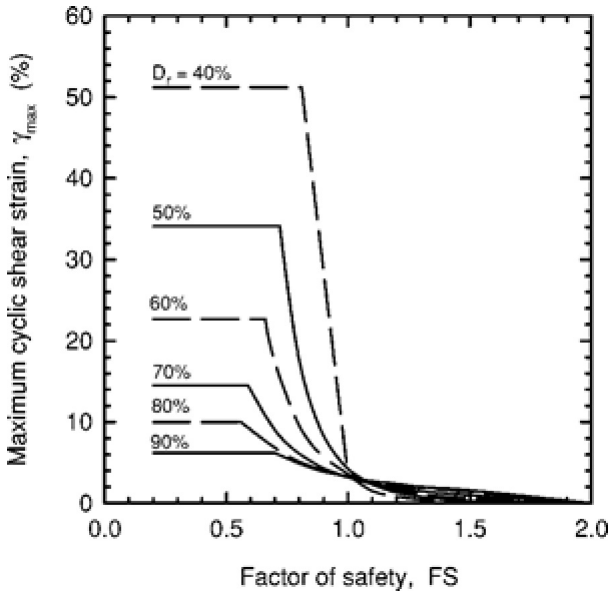
$$F = \left(\frac{f_s}{q_c - \sigma_{vc}}\right) \cdot 100\%$$

σ'_v *at time of CPT sounding*

Procedure for the evaluation of liquefaction-induced lateral spreading displacements



[1] Flow chart illustrating major steps in estimating liquefaction-induced lateral spreading displacements using the proposed approach



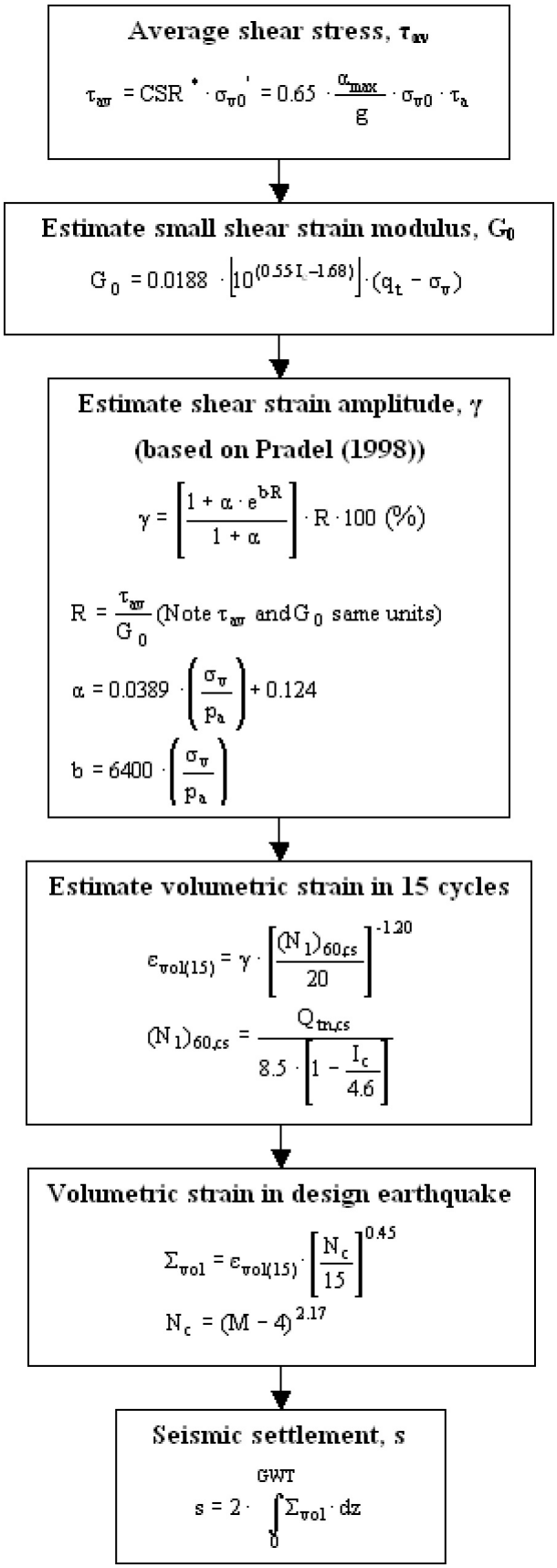
[1] Figure 1

$$LDI = \int_0^{z_{max}} \gamma_{max} dz$$

[1] Equation [3]

[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

Procedure for the estimation of seismic induced settlements in dry sands



Robertson, P.K. and Lisheng, S., 2010, "Estimation of seismic compression in dry soils using the CPT" FIFTH INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN GEOTECHNICAL EARTHQUAKE ENGINEERING AND SOIL DYNAMICS, Symposium in honor of professor I. M. Idriss, San Diego, CA

Liquefaction Potential Index (LPI) calculation procedure

Calculation of the Liquefaction Potential Index (LPI) is used to interpret the liquefaction assessment calculations in terms of severity over depth. The calculation procedure is based on the methology developed by Iwasaki (1982) and is adopted by AFPS.

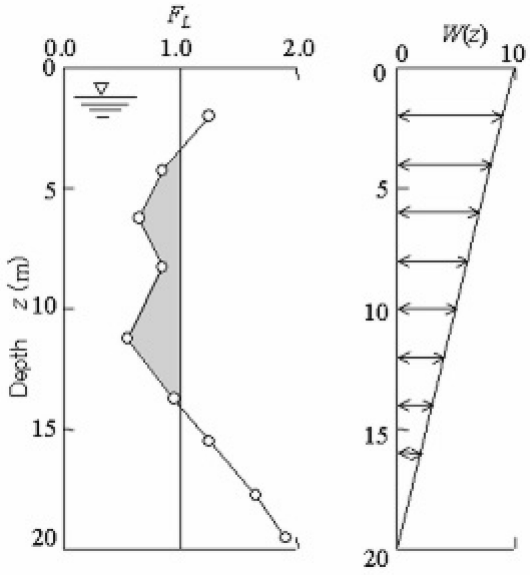
To estimate the severity of liquefaction extent at a given site, LPI is calculated based on the following equation:

$$\mathbf{LPI} = \int_0^{20} (10 - 0{,}5z) \times F_L \times dz$$

where:
F_L = 1 - F.S. when F.S. less than 1
F_L = 0 when F.S. greater than 1
z depth of measurment in meters

Values of LPI range between zero (0) when no test point is characterized as liquefiable and 100 when all points are characterized as susceptible to liquefaction. Iwasaki proposed four (4) discrete categories based on the numeric value of LPI:

- LPI = 0 : Liquefaction risk is very low
- 0 < LPI <= 5 : Liquefaction risk is low
- 5 < LPI <= 15 : Liquefaction risk is high
- LPI > 15 : Liquefaction risk is very high



Graphical presentation of the LPI calculation procedure

Shear-Induced Building Settlement (Ds) calculation procedure

The shear-induced building settlement (Ds) due to liquefaction below the building can be estimated using the relationship developed by Bray and Macedo (2017):

$$Ln(Ds) = c1 + c2 * LBS + 0.58 * Ln\left(Tanh\left(\frac{HL}{6}\right)\right) + 4.59 * Ln(Q) - 0.42 * Ln(Q)^2 - 0.02 * B + 0.84 * Ln(CAVdp) + 0.41 * Ln(Sa1) + \varepsilon$$

where Ds is in the units of mm, c1= -8.35 and c2= 0.072 for LBS ≤ 16, and c1= -7.48 and c2= 0.014 otherwise. Q is the building contact pressure in units of kPa, HL is the cumulative thickness of the liquefiable layers in the units of m, B is the building width in the units of m, CAVdp is a standardized version of the cumulative absolute velocity in the units of g-s, Sa1 is 5%-damped pseudo-acceleration response spectral value at a period of 1 s in the units of g, and ε is a normal random variable with zero mean and 0.50 standard deviation in Ln units. The liquefaction-induced building settlement index (LBS) is:

$$LBS = \sum W * \frac{\varepsilon_{shear}}{z} dz$$

where z (m) is the depth measured from the ground surface > 0, W is a foundation-weighting factor wherein W = 0.0 for z less than Df, which is the embedment depth of the foundation, and W = 1.0 otherwise. The shear strain parameter (ε_shear) is the liquefaction-induced free-field shear strain (in %) estimated using Zhang et al. (2004). It is calculated based on the estimated Dr of the liquefied soil layer and the calculated safety factor against liquefaction triggering (FSL).

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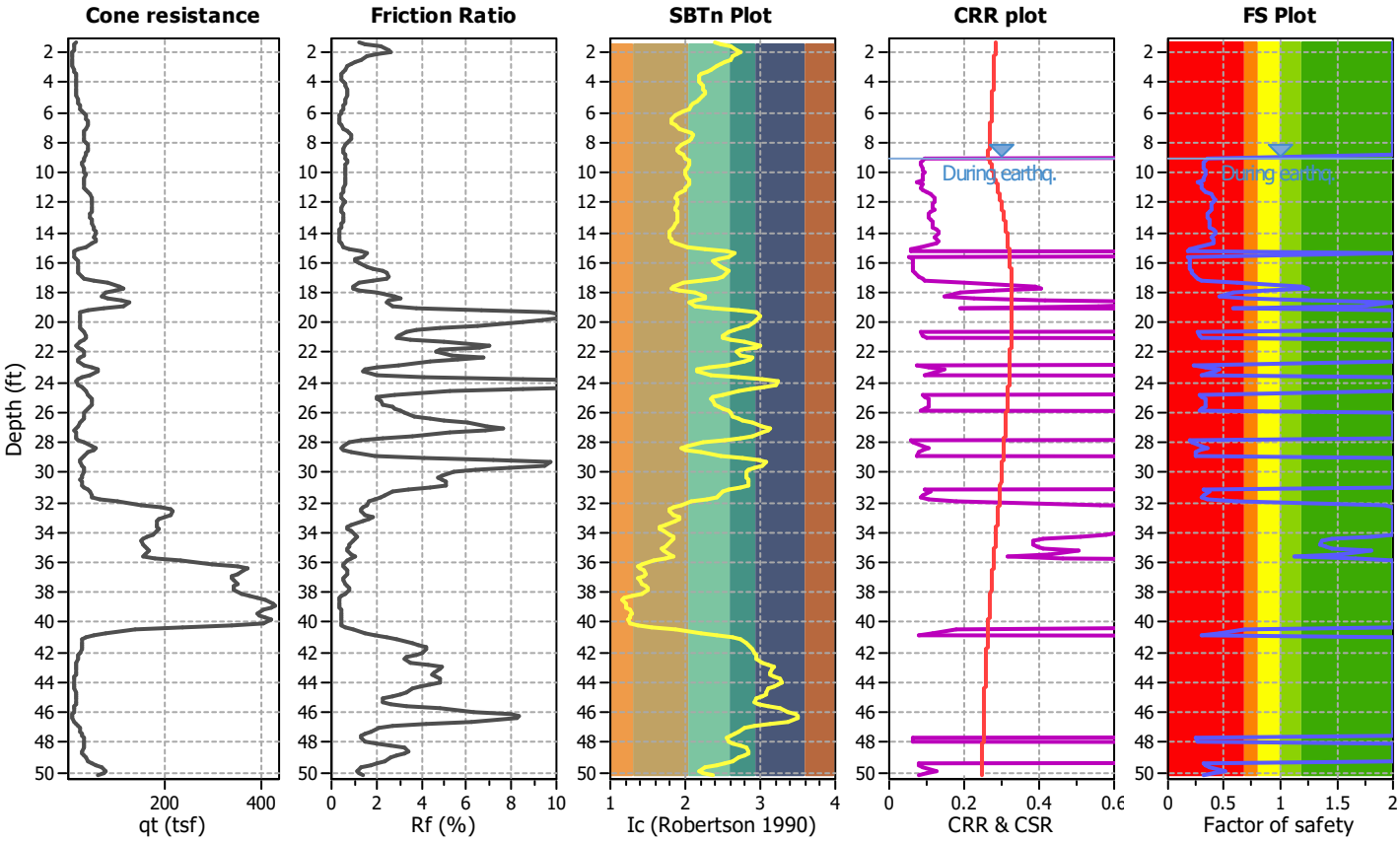
LIQUEFACTION ANALYSIS REPORT

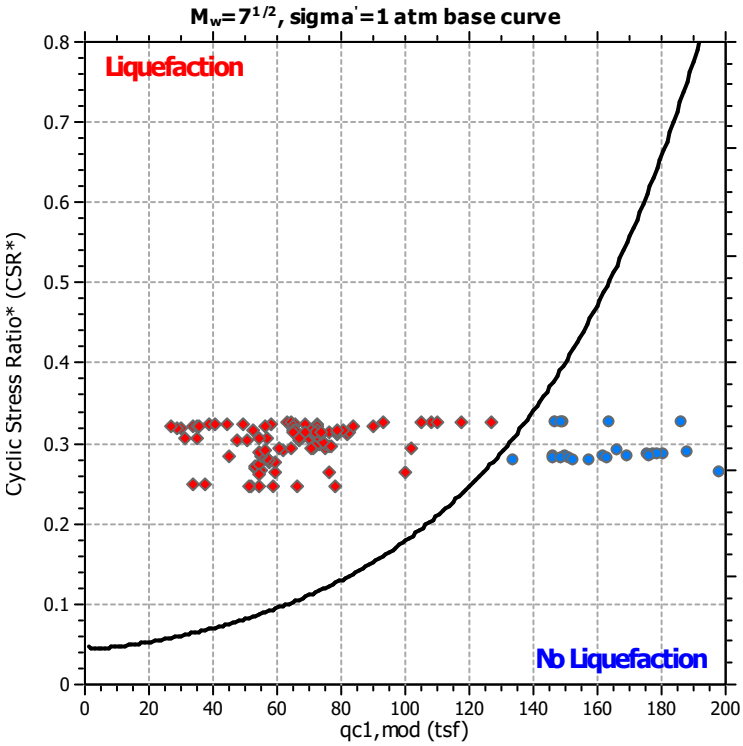
Project title : Manteca WWTP **Location : Manteca, CA**

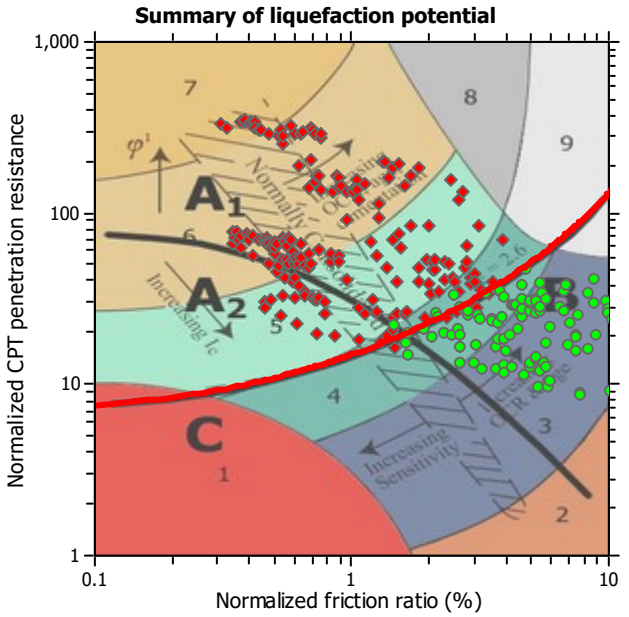
CPT file : CPT 1

Input parameters and analysis data

Analysis method:	Moss et al. (2006)	G.W.T. (in-situ):	11.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	Moss et al. (2006)	G.W.T. (earthq.):	9.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.13	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.43	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

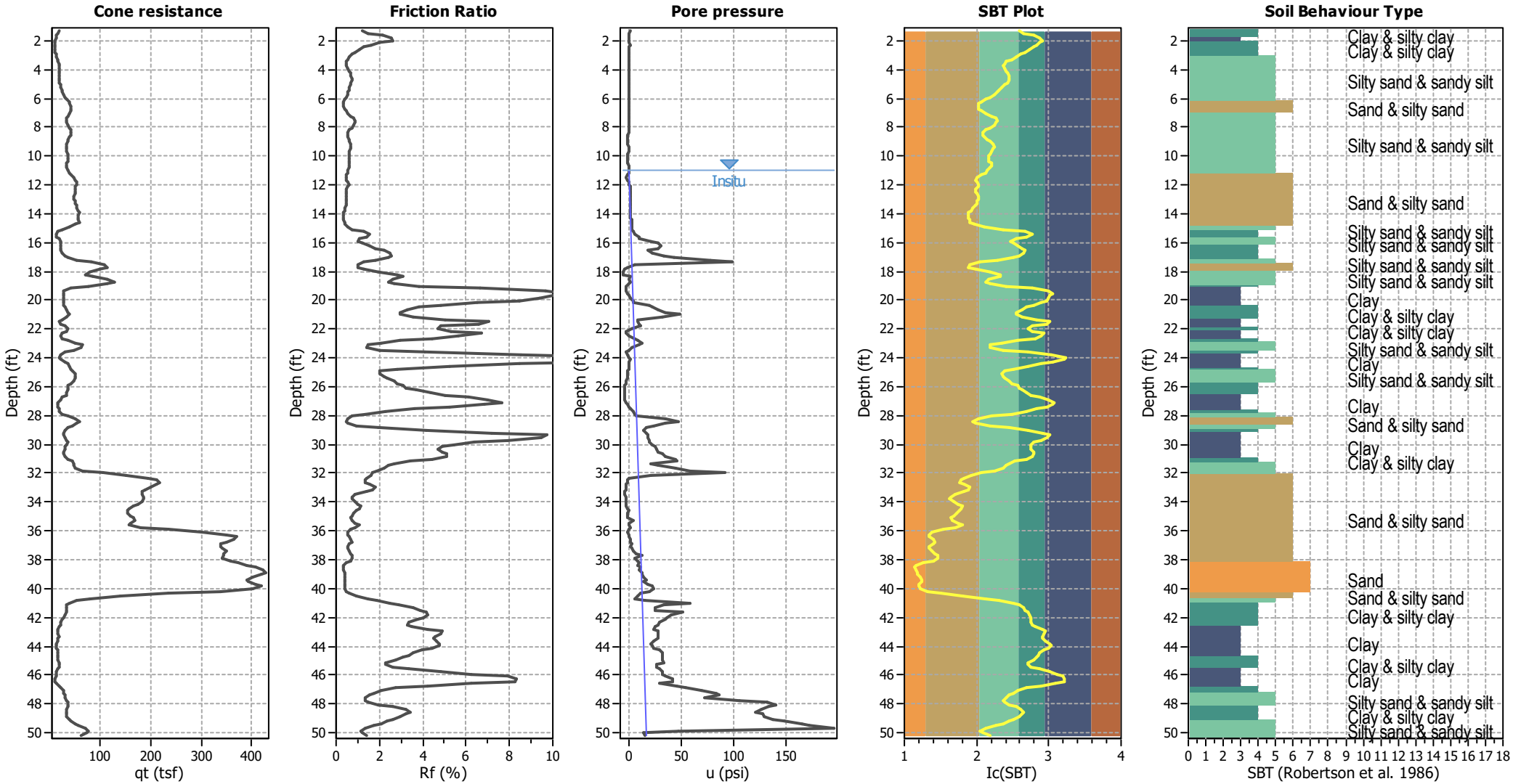






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

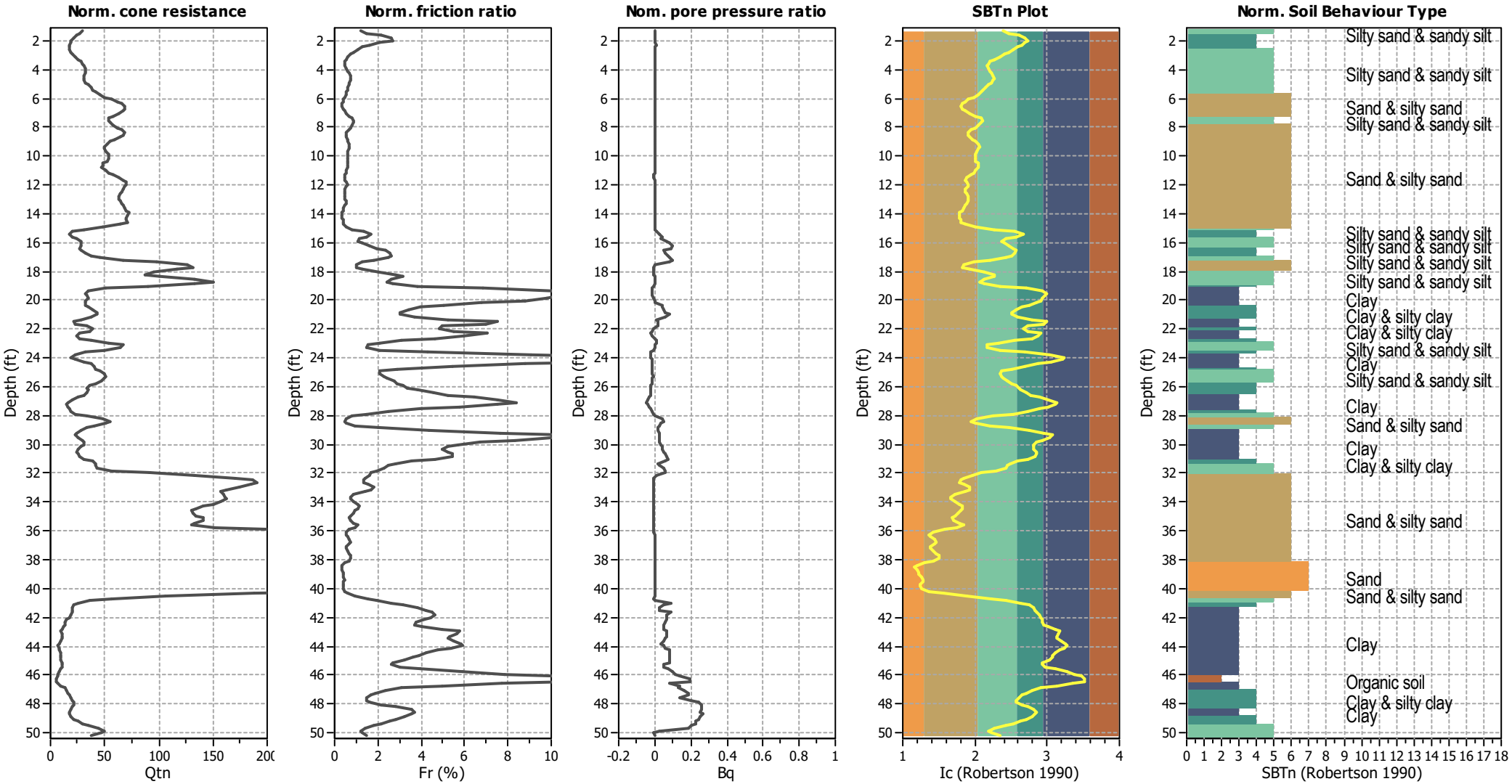
CPT basic interpretation plots



Input parameters and analysis data

Analysis method:	Moss et al. (2006)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	Moss et al. (2006)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

CPT basic interpretation plots (normalized)



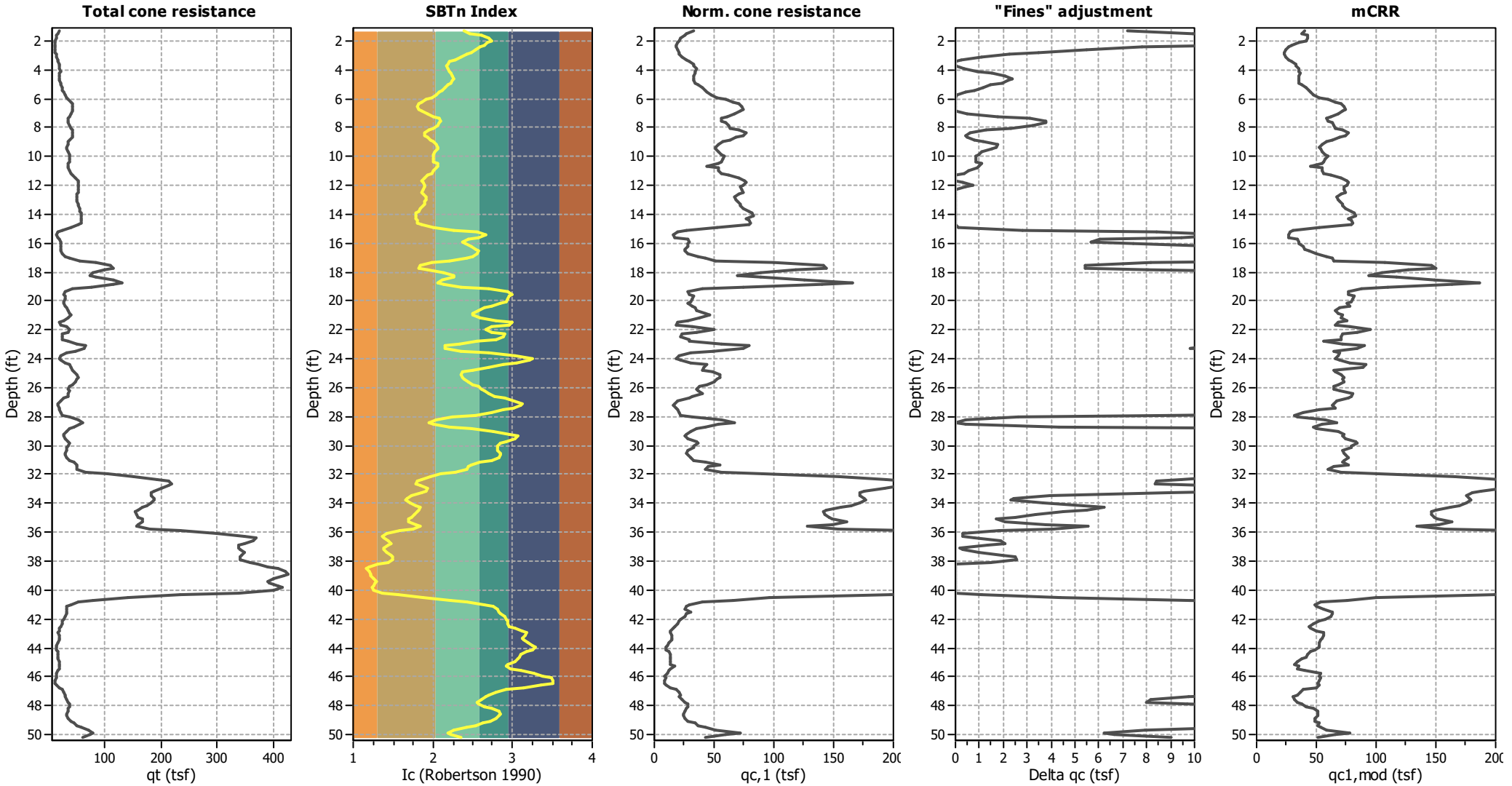
Input parameters and analysis data

Analysis method:	Moss et al. (2006)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	Moss et al. (2006)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

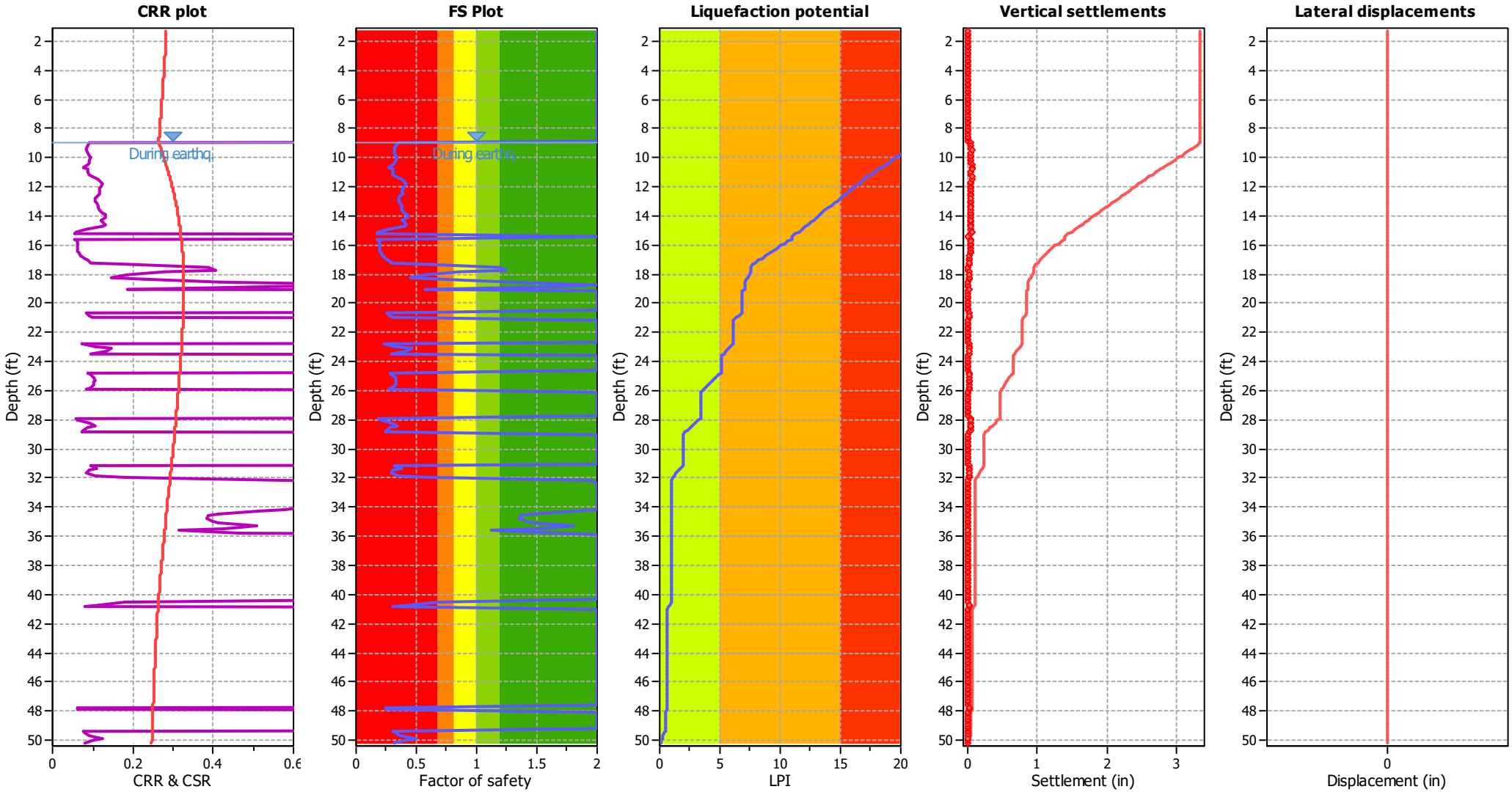
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	Moss et al. (2006)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	Moss et al. (2006)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	Moss et al. (2006)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	Moss et al. (2006)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

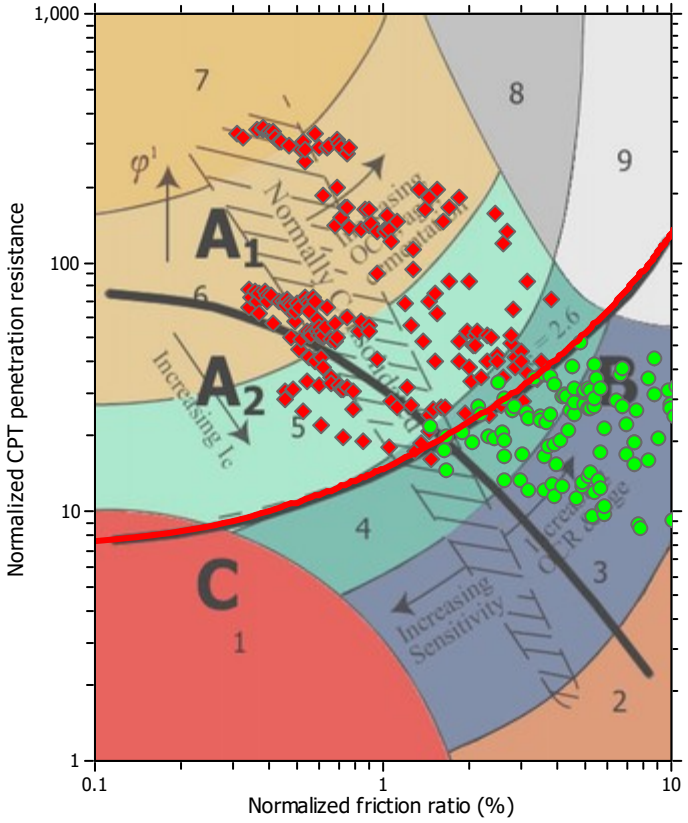
F.S. color scheme

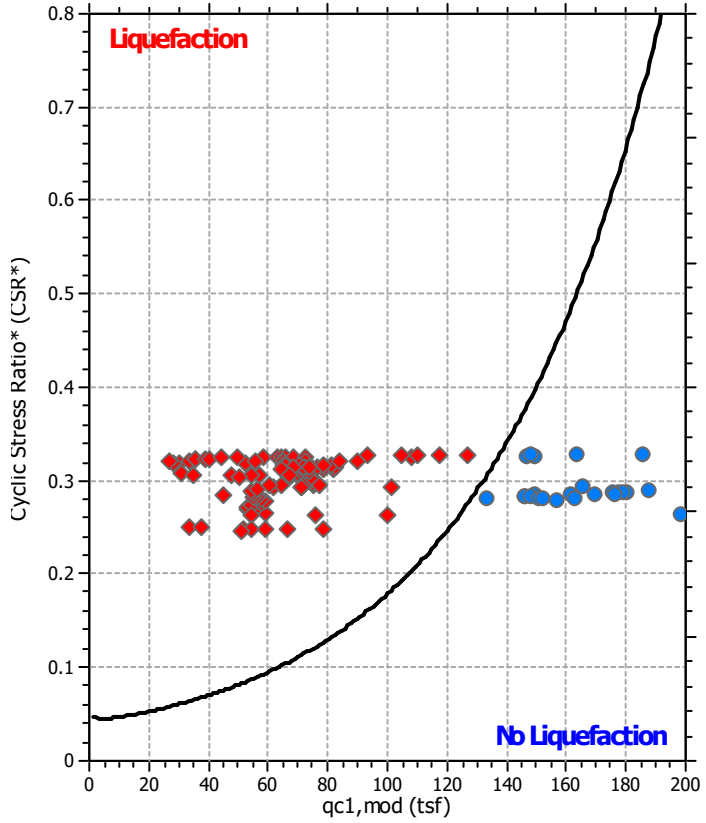
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

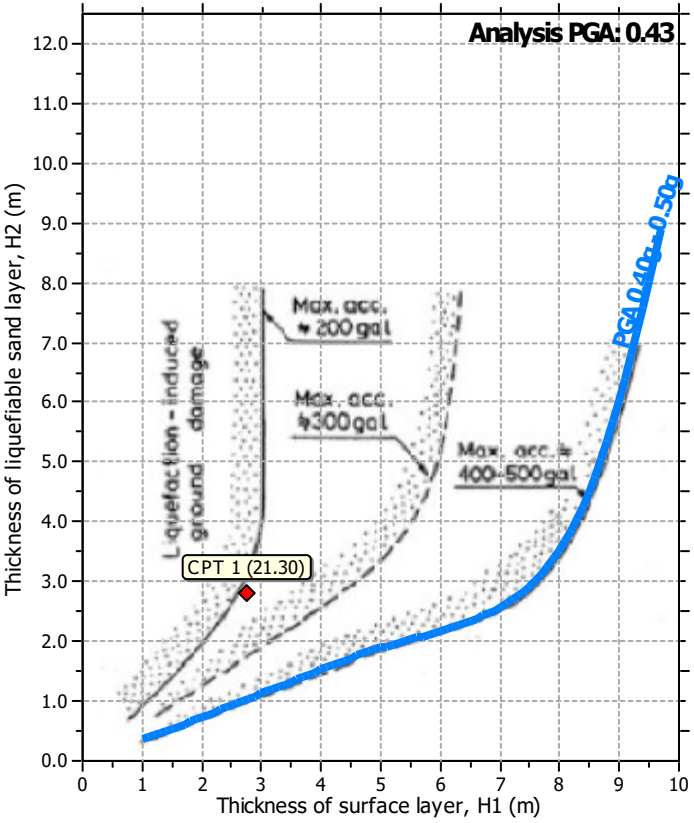
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



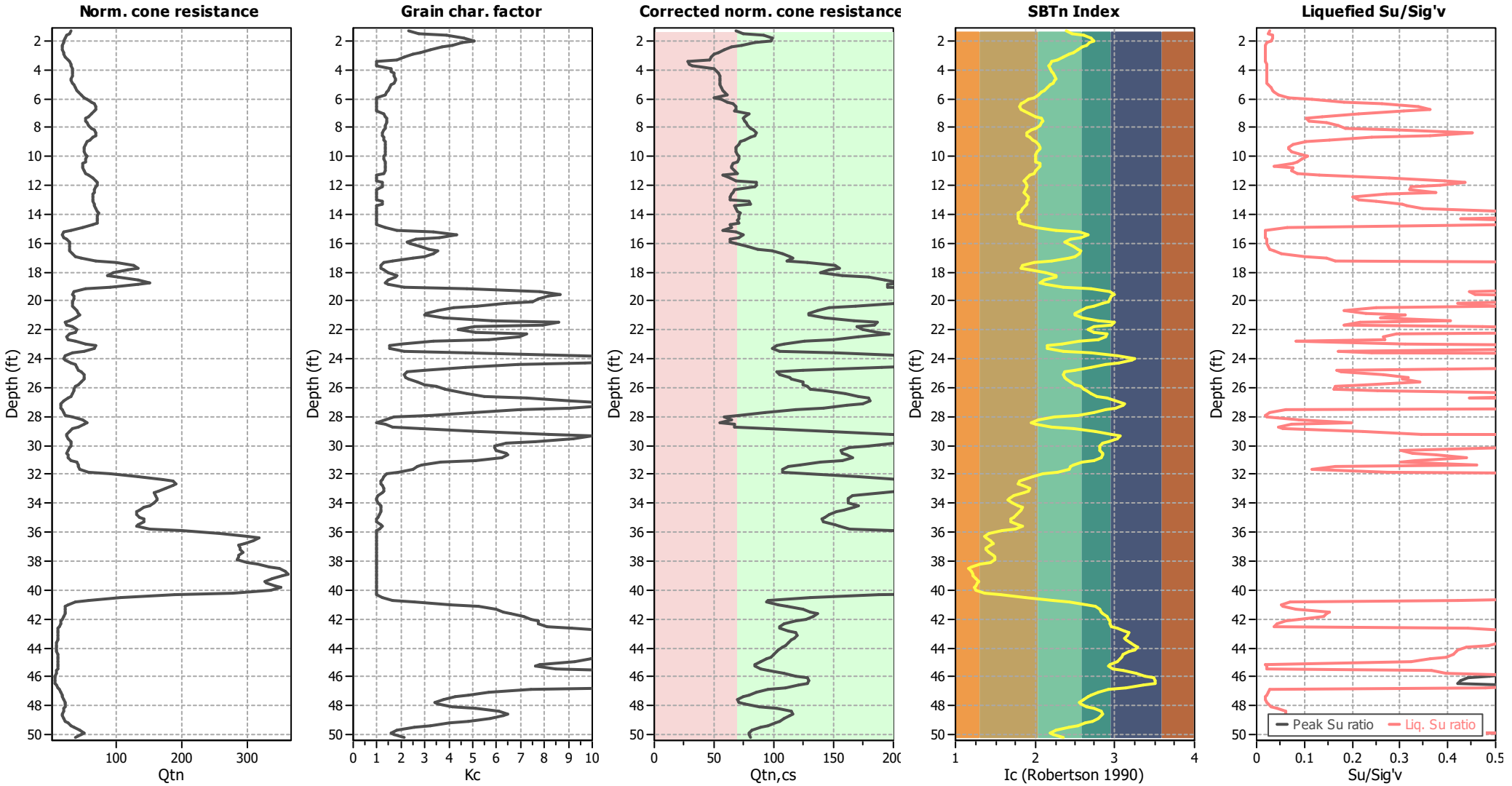




Input parameters and analysis data

Analysis method:	Moss et al. (2006)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	Moss et al. (2006)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

Check for strength loss plots (Robertson (2010))



Input parameters and analysis data

Analysis method:	Moss et al. (2006)	Depth to water table (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	Moss et al. (2006)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

:: Field input data ::

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
1	1.31	19.66	0.22	0.99	25.89	106.41
2	1.48	16.04	0.23	0.58	29.25	107.07
3	1.64	15.14	0.30	0.42	36.05	108.47
4	1.80	12.95	0.42	0.39	40.18	108.78
5	1.97	11.89	0.31	0.25	42.19	108.04
6	2.13	11.69	0.23	0.19	39.89	105.63
7	2.30	10.87	0.17	1.01	37.49	103.64
8	2.46	10.95	0.14	0.57	35.03	101.79
9	2.63	11.30	0.11	0.38	32.41	100.64
10	2.79	11.95	0.10	0.32	29.67	99.47
11	2.95	12.45	0.09	0.32	27.17	99.04
12	3.12	13.96	0.09	0.32	24.36	98.69
13	3.28	15.74	0.08	0.37	21.66	98.71
14	3.44	17.48	0.08	0.56	5.00	98.71
15	3.61	19.05	0.08	0.51	5.00	99.27
16	3.77	19.33	0.09	0.50	5.00	100.26
17	3.94	20.68	0.11	0.38	18.55	101.23
18	4.10	19.92	0.12	0.35	18.96	102.09
19	4.26	20.32	0.13	0.28	19.94	102.65
20	4.43	19.47	0.14	0.25	20.51	103.15
21	4.59	19.71	0.15	0.27	21.05	103.33
22	4.76	19.48	0.14	0.24	20.79	103.27
23	4.92	19.97	0.14	0.21	20.09	103.29
24	5.08	21.59	0.14	0.20	18.77	103.41
25	5.25	23.49	0.14	0.23	17.48	103.76
26	5.41	25.02	0.15	0.21	16.33	103.92
27	5.58	26.13	0.14	0.07	15.29	104.04
28	5.74	27.94	0.14	0.11	14.05	104.28
29	5.91	31.19	0.15	0.13	5.00	104.74
30	6.07	35.40	0.16	0.20	5.00	104.76
31	6.23	38.85	0.13	0.19	5.00	104.89
32	6.40	41.42	0.14	0.18	5.00	104.97
33	6.56	43.21	0.15	0.17	5.00	105.74
34	6.73	43.70	0.17	0.15	5.00	106.48
35	6.89	42.55	0.19	0.11	5.00	107.24
36	7.05	39.64	0.21	0.05	11.18	108.03
37	7.22	35.73	0.24	-0.03	13.27	108.72
38	7.38	32.75	0.28	-0.07	15.15	109.38
39	7.55	32.77	0.30	-0.08	15.83	109.91
40	7.71	34.96	0.31	-0.06	15.40	110.24
41	7.87	36.53	0.30	-0.10	14.46	110.24
42	8.04	37.71	0.29	-0.14	13.10	109.97
43	8.20	41.52	0.26	-0.20	11.47	109.56
44	8.37	45.15	0.24	-0.65	10.43	109.17
45	8.53	43.86	0.23	-1.23	10.38	108.89

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
46	8.69	41.20	0.23	-1.37	10.99	108.42
47	8.86	38.12	0.21	-0.94	11.99	108.16
48	9.02	35.46	0.23	-1.09	13.09	107.92
49	9.19	33.19	0.23	-0.96	14.27	108.03
50	9.35	32.09	0.23	-0.72	14.59	107.66
51	9.51	32.64	0.20	-0.64	14.44	107.51
52	9.68	33.97	0.21	-0.73	13.77	107.45
53	9.84	36.39	0.22	-0.80	13.29	107.81
54	10.01	38.00	0.22	-0.99	13.01	107.97
55	10.17	37.31	0.22	-1.08	13.02	107.95
56	10.34	36.86	0.21	-0.95	13.33	107.81
57	10.50	35.95	0.21	-0.87	14.42	107.35
58	10.66	29.10	0.20	0.58	14.40	107.15
59	10.83	36.65	0.20	-0.28	14.37	107.12
60	10.99	36.61	0.21	-0.20	13.30	107.55
61	11.15	38.29	0.22	-0.09	12.66	107.77
62	11.32	42.47	0.21	-1.73	5.00	108.11
63	11.48	48.98	0.21	-2.77	5.00	108.55
64	11.65	52.37	0.23	-1.52	5.00	109.41
65	11.81	54.03	0.27	-0.05	10.01	110.70
66	11.97	53.15	0.34	0.58	10.43	111.20
67	12.14	51.76	0.30	0.99	10.37	110.68
68	12.30	51.37	0.21	1.05	5.00	109.49
69	12.47	52.86	0.22	1.07	5.00	109.15
70	12.63	50.39	0.26	1.16	5.00	109.29
71	12.79	48.04	0.23	1.53	5.00	109.35
72	12.96	48.69	0.23	1.59	5.00	109.34
73	13.12	50.48	0.26	1.30	10.43	109.79
74	13.29	52.46	0.27	0.92	10.20	109.99
75	13.45	52.68	0.24	0.88	5.00	109.74
76	13.62	53.44	0.23	1.53	5.00	109.32
77	13.78	56.94	0.22	1.60	5.00	109.04
78	13.94	59.02	0.21	1.76	5.00	108.64
79	14.11	59.59	0.19	1.90	5.00	108.26
80	14.27	55.09	0.19	1.84	5.00	108.31
81	14.44	57.73	0.21	2.11	5.00	108.73
82	14.60	59.67	0.23	2.35	5.00	109.31
83	14.76	58.46	0.24	2.46	5.00	108.59
84	14.93	38.93	0.17	2.47	13.35	107.45
85	15.09	19.92	0.19	2.69	21.32	105.87
86	15.26	14.94	0.20	4.04	33.14	105.15
87	15.42	11.29	0.21	5.74	38.43	104.98
88	15.58	12.78	0.21	9.81	34.41	105.49
89	15.75	21.02	0.21	9.78	28.04	105.79
90	15.91	22.72	0.19	20.60	25.47	107.03

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
91	16.08	21.92	0.29	27.98	26.64	108.26
92	16.24	21.72	0.34	29.76	29.61	109.81
93	16.40	20.71	0.39	27.06	31.99	110.95
94	16.57	20.75	0.46	17.34	34.07	112.54
95	16.73	22.94	0.62	22.27	33.17	114.66
96	16.90	30.35	0.79	33.35	30.69	116.62
97	17.06	35.65	0.89	42.45	27.42	118.31
98	17.22	42.48	1.02	78.12	19.39	120.02
99	17.39	84.52	1.07	98.63	12.55	121.42
100	17.55	119.95	1.06	5.99	8.91	122.43
101	17.72	122.76	1.17	-1.71	8.61	122.89
102	17.88	101.92	1.22	-4.48	11.05	123.22
103	18.05	77.68	1.39	-5.61	16.79	124.30
104	18.21	60.49	2.13	-5.28	21.29	125.88
105	18.37	79.73	2.55	1.96	21.04	128.13
106	18.54	112.82	3.18	0.06	16.39	129.73
107	18.70	149.04	3.11	0.97	14.76	130.51
108	18.86	126.57	3.14	0.07	16.78	130.02
109	19.03	67.48	2.93	-2.31	24.68	128.65
110	19.19	35.59	2.64	-2.84	40.62	127.10
111	19.36	25.55	2.98	-3.11	54.42	126.02
112	19.52	26.05	2.78	-1.93	57.94	126.11
113	19.68	30.18	2.93	-0.33	56.03	126.18
114	19.85	29.27	2.93	1.69	54.20	125.89
115	20.01	28.01	2.39	3.77	53.34	124.54
116	20.18	25.02	1.67	4.67	48.49	122.57
117	20.34	28.73	1.29	19.52	42.76	120.72
118	20.50	30.76	1.14	22.11	37.78	119.83
119	20.67	32.17	1.10	27.08	34.20	119.79
120	20.83	38.41	1.15	34.75	31.03	119.98
121	21.00	42.18	1.11	48.90	30.78	120.13
122	21.16	34.22	1.15	32.11	35.37	120.29
123	21.32	24.96	1.37	8.55	45.74	120.17
124	21.49	18.04	1.39	8.24	57.79	120.02
125	21.65	16.19	1.43	9.52	55.13	120.19
126	21.82	28.97	1.38	11.38	42.20	121.46
127	21.98	46.58	1.61	2.03	38.97	122.89
128	22.15	33.17	2.10	-2.69	42.40	123.19
129	22.31	21.88	1.71	-2.38	52.18	122.00
130	22.47	20.72	1.27	0.13	50.81	119.87
131	22.64	26.79	0.92	5.95	45.13	118.84
132	22.80	27.32	1.11	8.43	33.17	119.37
133	22.97	51.96	1.13	12.89	23.58	120.27
134	23.13	74.04	0.93	9.37	17.66	120.27
135	23.29	69.17	0.87	3.21	17.63	119.60

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
136	23.46	45.94	0.90	-0.52	24.32	119.46
137	23.62	28.98	1.12	-2.61	40.33	120.55
138	23.79	19.36	1.85	-1.73	61.17	122.37
139	23.95	17.66	2.62	-0.30	76.34	124.60
140	24.11	20.46	3.48	0.63	74.45	126.70
141	24.28	28.96	3.95	0.59	62.01	128.16
142	24.44	42.09	3.64	0.43	50.67	127.40
143	24.61	39.40	1.78	-0.34	40.49	124.67
144	24.77	38.66	0.86	-0.68	30.74	120.50
145	24.93	47.15	0.86	-0.92	25.53	119.10
146	25.10	52.30	1.07	-2.12	24.26	119.99
147	25.26	52.33	1.13	-1.32	25.11	120.98
148	25.43	51.04	1.28	-1.97	25.91	121.04
149	25.59	48.86	1.13	-2.54	28.61	121.51
150	25.75	43.10	1.44	-2.94	30.71	120.73
151	25.92	36.62	1.02	-3.54	33.85	120.28
152	26.08	34.80	1.05	-3.76	35.73	119.98
153	26.25	35.61	1.37	-3.77	37.37	121.18
154	26.41	39.09	1.60	-3.89	40.73	122.21
155	26.57	31.67	1.70	-4.12	44.18	122.53
156	26.74	28.91	1.69	-4.46	52.15	121.84
157	26.90	19.77	1.50	-4.27	59.68	120.82
158	27.07	16.74	1.36	-3.27	67.51	119.39
159	27.23	16.08	1.16	-1.52	66.21	118.24
160	27.39	17.93	0.95	-0.10	59.58	116.78
161	27.56	19.21	0.69	1.44	50.99	114.83
162	27.72	20.36	0.45	3.40	42.26	112.06
163	27.89	22.01	0.26	5.13	32.15	110.12
164	28.05	31.91	0.29	7.00	20.34	109.70
165	28.21	56.43	0.27	34.60	13.90	110.68
166	28.38	66.87	0.28	46.91	5.00	110.95
167	28.54	54.16	0.29	34.47	13.28	111.23
168	28.71	43.44	0.33	24.11	19.43	113.01
169	28.87	35.76	0.61	16.63	29.70	116.62
170	29.04	30.68	1.20	14.22	43.26	120.57
171	29.20	26.96	2.07	16.12	55.93	123.50
172	29.36	25.41	2.76	17.28	63.22	125.37
173	29.53	27.84	3.04	18.11	60.18	126.27
174	29.69	36.44	2.78	19.84	53.74	126.21
175	29.86	37.73	2.34	19.87	48.48	125.18
176	30.02	33.74	1.84	22.60	46.16	123.76
177	30.18	33.56	1.60	24.54	46.17	122.22
178	30.35	29.16	1.37	26.18	46.68	121.30
179	30.51	28.01	1.36	27.41	48.60	121.10
180	30.68	28.86	1.56	31.77	48.87	121.56

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
181	30.84	30.89	1.62	34.29	47.75	122.25
182	31.00	33.70	1.70	44.58	42.39	122.60
183	31.17	43.59	1.55	45.66	34.66	122.66
184	31.33	56.31	1.33	20.85	30.13	121.86
185	31.50	46.70	1.10	27.32	28.63	121.07
186	31.66	44.47	1.14	44.83	27.40	120.69
187	31.82	58.86	1.13	58.47	22.01	122.25
188	31.99	93.50	1.54	90.90	15.52	125.69
189	32.15	160.96	2.55	21.11	11.90	129.02
190	32.32	201.79	3.18	-0.54	9.29	130.54
191	32.48	218.49	2.54	-2.05	8.14	130.93
192	32.64	219.33	2.73	-1.82	7.96	131.12
193	32.81	217.42	3.33	-2.57	9.19	131.92
194	32.97	202.02	3.62	-2.95	11.01	132.67
195	33.14	184.65	3.98	-3.19	10.88	131.54
196	33.30	181.25	1.96	-3.54	9.56	129.73
197	33.47	183.18	1.61	-3.69	6.64	126.58
198	33.63	187.79	1.33	-3.51	5.54	125.37
199	33.79	189.62	1.19	-3.05	5.45	125.29
200	33.96	185.00	1.57	-2.77	6.53	126.32
201	34.12	175.77	1.98	-2.42	7.92	127.22
202	34.28	167.03	1.89	-2.24	8.84	127.20
203	34.45	155.25	1.66	-1.95	8.77	126.28
204	34.61	153.18	1.40	0.28	8.36	125.35
205	34.78	155.13	1.33	-1.01	7.52	124.48
206	34.94	159.33	1.15	-1.47	6.78	123.92
207	35.10	163.58	1.09	-1.85	5.92	123.57
208	35.27	176.66	1.11	4.12	6.15	123.98
209	35.43	162.35	1.34	-0.69	7.73	125.10
210	35.60	139.95	1.74	-0.40	9.05	126.24
211	35.76	167.80	1.85	1.27	7.07	126.55
212	35.92	235.63	1.32	-0.40	4.01	127.02
213	36.09	301.09	1.64	-0.90	1.80	127.59
214	36.25	363.02	1.82	-0.04	1.18	129.04
215	36.42	383.79	2.07	-0.36	1.31	130.28
216	36.58	364.37	2.53	1.65	2.09	131.39
217	36.74	342.55	2.93	1.61	2.38	131.17
218	36.91	339.18	1.95	2.45	2.03	130.09
219	37.07	336.23	1.58	1.61	1.25	128.55
220	37.24	340.45	1.70	2.40	1.34	128.86
221	37.40	347.21	2.16	3.52	1.71	129.93
222	37.57	358.40	2.40	7.28	2.41	130.87
223	37.73	322.56	2.60	13.08	2.76	131.41
224	37.89	346.65	2.71	5.36	2.82	131.42
225	38.06	353.67	2.41	8.71	1.93	130.75

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
226	38.22	374.50	1.81	9.47	0.43	128.37
227	38.39	390.42	0.72	8.30	0.00	126.56
228	38.55	408.87	1.27	10.76	0.00	126.59
229	38.71	425.29	1.77	10.15	0.00	128.16
230	38.88	429.58	1.57	11.73	0.00	128.66
231	39.04	426.57	1.57	12.87	0.00	128.46
232	39.21	399.99	1.67	14.40	0.00	128.54
233	39.37	377.42	1.69	16.80	0.27	128.66
234	39.53	390.98	1.71	14.44	0.14	128.51
235	39.70	411.33	1.55	17.39	0.00	128.60
236	39.86	421.99	1.70	21.63	0.00	128.77
237	40.03	420.07	1.78	23.68	0.04	128.62
238	40.19	364.72	1.51	19.05	1.06	127.87
239	40.35	230.57	1.48	11.23	3.81	126.28
240	40.52	111.86	1.34	7.80	9.86	124.35
241	40.68	76.79	1.14	4.81	19.66	122.12
242	40.85	47.38	1.05	15.60	27.78	120.06
243	41.01	35.23	0.84	57.86	37.33	118.84
244	41.17	31.35	0.98	33.23	43.15	118.49
245	41.34	30.41	1.06	25.30	46.58	119.90
246	41.50	35.25	1.46	24.35	48.05	120.62
247	41.67	31.69	1.33	51.71	49.31	121.18
248	41.83	30.49	1.37	39.84	51.66	120.38
249	41.99	26.56	1.14	36.44	53.06	119.19
250	42.16	24.34	0.85	34.26	54.30	117.77
251	42.32	23.24	0.87	29.40	54.28	116.21
252	42.49	21.38	0.64	28.09	55.66	115.36
253	42.65	20.03	0.64	25.28	60.00	114.84
254	42.81	16.70	0.79	23.93	66.53	115.42
255	42.98	16.38	0.88	27.06	71.06	116.02
256	43.14	17.55	0.88	27.96	69.61	116.27
257	43.31	18.58	0.84	28.26	67.32	116.15
258	43.47	18.27	0.81	27.02	68.14	115.68
259	43.63	15.78	0.75	23.87	72.09	115.05
260	43.80	13.98	0.71	20.22	76.97	114.24
261	43.96	13.23	0.65	22.09	79.41	113.64
262	44.13	13.22	0.62	23.70	76.31	113.38
263	44.29	15.37	0.62	28.94	70.98	113.46
264	44.45	17.05	0.61	31.20	66.14	113.55
265	44.62	17.30	0.59	31.32	64.08	113.30
266	44.78	16.69	0.54	31.39	63.05	112.72
267	44.95	16.77	0.48	31.50	60.32	112.00
268	45.11	18.31	0.43	33.41	54.50	111.71
269	45.28	22.41	0.44	26.43	53.78	111.90
270	45.44	18.28	0.51	25.77	57.14	112.43

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
271	45.60	15.93	0.56	29.18	66.23	112.82
272	45.77	14.49	0.60	31.62	78.61	114.27
273	45.93	12.05	0.96	32.32	87.78	115.43
274	46.10	12.66	0.98	33.93	97.23	116.42
275	46.26	11.40	1.05	41.01	100.00	116.50
276	46.42	11.01	1.02	40.81	100.00	116.37
277	46.59	12.49	0.94	28.44	85.78	116.00
278	46.75	17.92	0.74	45.02	68.00	115.52
279	46.92	23.00	0.65	53.94	52.95	114.70
280	47.08	27.09	0.53	69.67	45.07	114.19
281	47.24	28.63	0.53	82.45	40.88	113.42
282	47.41	27.84	0.44	86.14	38.19	112.85
283	47.57	30.73	0.40	72.40	35.49	112.56
284	47.74	33.68	0.45	105.29	33.49	113.34
285	47.90	36.10	0.55	131.68	33.98	114.75
286	48.06	35.25	0.67	139.76	37.44	116.79
287	48.23	33.90	0.98	133.42	42.49	118.44
288	48.39	31.76	1.14	126.26	47.25	119.52
289	48.56	30.15	1.16	121.12	48.77	119.54
290	48.72	30.85	1.03	127.89	48.06	119.20
291	48.88	31.81	0.99	128.32	45.30	119.00
292	49.05	35.24	1.02	136.68	41.01	119.36
293	49.21	43.29	1.06	147.76	36.82	119.77
294	49.38	46.61	1.04	165.00	32.30	120.04
295	49.54	53.66	1.00	171.75	27.78	120.13
296	49.70	64.80	0.96	195.26	21.45	120.33
297	49.87	91.08	0.90	46.36	18.90	120.15
298	50.03	75.84	0.85	13.75	20.06	119.88
299	50.20	54.40	0.91	14.88	24.70	119.46

Abbreviations

Depth:	Depth from free surface, at which CPT was performed (ft)
q_c:	Measured cone resistance (tsf)
f_s:	Sleeve friction resistance (tsf)
u:	Pore pressure (tsf)
Fines content:	Percentage of fines in soil (%)
Unit weight:	Bulk soil unit weight (pcf)

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data ::

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
1	1.31	0.07	0.00	0.07	0.99	0.277	1.08	0.258	1.00	1.10	2.000	No
2	1.48	0.08	0.00	0.08	0.99	0.277	1.08	0.257	1.00	1.10	2.000	No
3	1.64	0.09	0.00	0.09	0.99	0.276	1.08	0.257	1.00	1.10	2.000	No
4	1.80	0.10	0.00	0.10	0.99	0.276	1.08	0.257	1.00	1.10	2.000	No
5	1.97	0.11	0.00	0.11	0.99	0.276	1.08	0.256	1.00	1.10	2.000	No
6	2.13	0.11	0.00	0.11	0.99	0.275	1.08	0.256	1.00	1.10	2.000	No
7	2.30	0.12	0.00	0.12	0.98	0.275	1.08	0.256	1.00	1.10	2.000	No
8	2.46	0.13	0.00	0.13	0.98	0.275	1.08	0.256	1.00	1.10	2.000	No
9	2.63	0.14	0.00	0.14	0.98	0.274	1.08	0.255	1.00	1.10	2.000	No
10	2.79	0.15	0.00	0.15	0.98	0.274	1.08	0.255	1.00	1.10	2.000	No
11	2.95	0.16	0.00	0.16	0.98	0.274	1.08	0.255	1.00	1.10	2.000	No
12	3.12	0.16	0.00	0.16	0.98	0.273	1.08	0.254	1.00	1.10	2.000	No
13	3.28	0.17	0.00	0.17	0.98	0.273	1.08	0.254	1.00	1.10	2.000	No
14	3.44	0.18	0.00	0.18	0.98	0.273	1.08	0.254	1.00	1.10	2.000	No
15	3.61	0.19	0.00	0.19	0.97	0.272	1.08	0.253	1.00	1.10	2.000	No
16	3.77	0.20	0.00	0.20	0.97	0.272	1.08	0.253	1.00	1.10	2.000	No
17	3.94	0.20	0.00	0.20	0.97	0.271	1.08	0.253	1.00	1.10	2.000	No
18	4.10	0.21	0.00	0.21	0.97	0.271	1.08	0.252	1.00	1.10	2.000	No
19	4.26	0.22	0.00	0.22	0.97	0.271	1.08	0.252	1.00	1.10	2.000	No
20	4.43	0.23	0.00	0.23	0.97	0.270	1.08	0.251	1.00	1.10	2.000	No
21	4.59	0.24	0.00	0.24	0.97	0.270	1.08	0.251	1.00	1.10	2.000	No
22	4.76	0.25	0.00	0.25	0.96	0.270	1.08	0.251	1.00	1.10	2.000	No
23	4.92	0.25	0.00	0.25	0.96	0.269	1.08	0.250	1.00	1.10	2.000	No
24	5.08	0.26	0.00	0.26	0.96	0.269	1.08	0.250	1.00	1.10	2.000	No
25	5.25	0.27	0.00	0.27	0.96	0.268	1.08	0.250	1.00	1.10	2.000	No
26	5.41	0.28	0.00	0.28	0.96	0.268	1.08	0.249	1.00	1.10	2.000	No
27	5.58	0.29	0.00	0.29	0.96	0.268	1.08	0.249	1.00	1.10	2.000	No
28	5.74	0.30	0.00	0.30	0.96	0.267	1.08	0.248	1.00	1.10	2.000	No
29	5.91	0.31	0.00	0.31	0.95	0.267	1.08	0.248	1.00	1.10	2.000	No
30	6.07	0.31	0.00	0.31	0.95	0.266	1.08	0.248	1.00	1.10	2.000	No
31	6.23	0.32	0.00	0.32	0.95	0.266	1.08	0.247	1.00	1.10	2.000	No
32	6.40	0.33	0.00	0.33	0.95	0.265	1.08	0.247	1.00	1.10	2.000	No
33	6.56	0.34	0.00	0.34	0.95	0.265	1.08	0.247	1.00	1.10	2.000	No
34	6.73	0.35	0.00	0.35	0.95	0.265	1.08	0.246	1.00	1.10	2.000	No
35	6.89	0.36	0.00	0.36	0.95	0.264	1.08	0.246	1.00	1.10	2.000	No
36	7.05	0.37	0.00	0.37	0.94	0.264	1.08	0.245	1.00	1.10	2.000	No
37	7.22	0.38	0.00	0.38	0.94	0.263	1.08	0.245	1.00	1.10	2.000	No
38	7.38	0.38	0.00	0.38	0.94	0.263	1.08	0.244	1.00	1.10	2.000	No
39	7.55	0.39	0.00	0.39	0.94	0.262	1.08	0.244	1.00	1.10	2.000	No
40	7.71	0.40	0.00	0.40	0.94	0.262	1.08	0.244	1.00	1.10	2.000	No
41	7.87	0.41	0.00	0.41	0.94	0.261	1.08	0.243	1.00	1.10	2.000	No
42	8.04	0.42	0.00	0.42	0.93	0.261	1.08	0.243	1.00	1.10	2.000	No
43	8.20	0.43	0.00	0.43	0.93	0.261	1.08	0.242	1.00	1.10	2.000	No
44	8.37	0.44	0.00	0.44	0.93	0.260	1.08	0.242	1.00	1.10	2.000	No
45	8.53	0.45	0.00	0.45	0.93	0.260	1.08	0.241	1.00	1.10	2.000	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
46	8.69	0.46	0.00	0.46	0.93	0.259	1.08	0.241	1.00	1.10	2.000	No
47	8.86	0.47	0.00	0.47	0.93	0.259	1.08	0.241	1.00	1.10	2.000	No
48	9.02	0.47	0.00	0.47	0.92	0.258	1.08	0.240	1.00	1.10	0.264	No
49	9.19	0.48	0.01	0.48	0.92	0.261	1.08	0.243	1.00	1.10	0.267	No
50	9.35	0.49	0.01	0.48	0.92	0.263	1.08	0.245	1.00	1.10	0.269	No
51	9.51	0.50	0.02	0.48	0.92	0.265	1.08	0.247	1.00	1.10	0.271	No
52	9.68	0.51	0.02	0.49	0.92	0.267	1.08	0.249	1.00	1.10	0.273	No
53	9.84	0.52	0.03	0.49	0.91	0.269	1.08	0.250	1.00	1.10	0.275	No
54	10.01	0.53	0.03	0.50	0.91	0.271	1.08	0.252	1.00	1.10	0.278	No
55	10.17	0.54	0.04	0.50	0.91	0.273	1.08	0.254	1.00	1.10	0.280	No
56	10.34	0.55	0.04	0.50	0.91	0.275	1.08	0.256	1.00	1.10	0.281	No
57	10.50	0.55	0.05	0.51	0.91	0.277	1.08	0.258	1.00	1.10	0.283	No
58	10.66	0.56	0.05	0.51	0.91	0.279	1.08	0.259	1.00	1.10	0.285	No
59	10.83	0.57	0.06	0.51	0.90	0.280	1.08	0.261	1.00	1.10	0.287	No
60	10.99	0.58	0.06	0.52	0.90	0.282	1.08	0.262	1.00	1.10	0.289	No
61	11.15	0.59	0.07	0.52	0.90	0.284	1.08	0.264	1.00	1.10	0.290	No
62	11.32	0.60	0.07	0.53	0.90	0.285	1.08	0.265	1.00	1.10	0.292	No
63	11.48	0.61	0.08	0.53	0.90	0.287	1.08	0.267	1.00	1.10	0.294	No
64	11.65	0.62	0.08	0.53	0.89	0.289	1.08	0.268	1.00	1.10	0.295	No
65	11.81	0.63	0.09	0.54	0.89	0.290	1.08	0.270	1.00	1.10	0.297	No
66	11.97	0.63	0.09	0.54	0.89	0.291	1.08	0.271	1.00	1.10	0.298	No
67	12.14	0.64	0.10	0.55	0.89	0.293	1.08	0.272	1.00	1.10	0.300	No
68	12.30	0.65	0.10	0.55	0.89	0.294	1.08	0.274	1.00	1.10	0.301	No
69	12.47	0.66	0.11	0.55	0.88	0.295	1.08	0.275	1.00	1.10	0.302	No
70	12.63	0.67	0.11	0.56	0.88	0.297	1.08	0.276	1.00	1.10	0.304	No
71	12.79	0.68	0.12	0.56	0.88	0.298	1.08	0.277	1.00	1.10	0.305	No
72	12.96	0.69	0.12	0.56	0.88	0.299	1.08	0.278	1.00	1.10	0.306	No
73	13.12	0.70	0.13	0.57	0.88	0.300	1.08	0.279	1.00	1.10	0.307	No
74	13.29	0.71	0.13	0.57	0.87	0.301	1.08	0.280	1.00	1.10	0.308	No
75	13.45	0.72	0.14	0.58	0.87	0.302	1.08	0.281	1.00	1.10	0.309	No
76	13.62	0.72	0.14	0.58	0.87	0.303	1.08	0.282	1.00	1.10	0.310	No
77	13.78	0.73	0.15	0.58	0.87	0.304	1.08	0.283	1.00	1.10	0.311	No
78	13.94	0.74	0.15	0.59	0.87	0.305	1.08	0.284	1.00	1.10	0.312	No
79	14.11	0.75	0.16	0.59	0.86	0.306	1.08	0.285	1.00	1.10	0.313	No
80	14.27	0.76	0.16	0.60	0.86	0.307	1.08	0.286	1.00	1.10	0.314	No
81	14.44	0.77	0.17	0.60	0.86	0.308	1.08	0.287	1.00	1.10	0.315	No
82	14.60	0.78	0.17	0.60	0.86	0.309	1.08	0.287	1.00	1.10	0.316	No
83	14.76	0.79	0.18	0.61	0.85	0.310	1.08	0.288	1.00	1.10	0.317	No
84	14.93	0.80	0.18	0.61	0.85	0.311	1.08	0.289	1.00	1.10	0.318	No
85	15.09	0.80	0.19	0.61	0.85	0.311	1.08	0.290	1.00	1.10	0.319	No
86	15.26	0.81	0.20	0.62	0.85	0.312	1.08	0.290	1.00	1.10	0.319	No
87	15.42	0.82	0.20	0.62	0.85	0.313	1.08	0.291	1.00	1.10	0.320	No
88	15.58	0.83	0.21	0.62	0.84	0.314	1.08	0.292	1.00	1.10	0.321	No
89	15.75	0.84	0.21	0.63	0.84	0.314	1.08	0.292	1.00	1.10	0.321	No
90	15.91	0.85	0.22	0.63	0.84	0.315	1.08	0.293	1.00	1.10	0.322	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
91	16.08	0.86	0.22	0.64	0.84	0.315	1.08	0.293	1.00	1.10	0.323	No
92	16.24	0.87	0.23	0.64	0.84	0.316	1.08	0.294	1.00	1.10	0.323	No
93	16.40	0.87	0.23	0.64	0.83	0.316	1.08	0.294	1.00	1.10	0.324	No
94	16.57	0.88	0.24	0.65	0.83	0.317	1.08	0.295	1.00	1.10	0.324	No
95	16.73	0.89	0.24	0.65	0.83	0.317	1.08	0.295	1.00	1.10	0.325	No
96	16.90	0.90	0.25	0.66	0.83	0.318	1.08	0.295	1.00	1.10	0.325	No
97	17.06	0.91	0.25	0.66	0.82	0.318	1.08	0.296	1.00	1.10	0.325	No
98	17.22	0.92	0.26	0.67	0.82	0.318	1.08	0.296	1.00	1.10	0.326	No
99	17.39	0.93	0.26	0.67	0.82	0.318	1.08	0.296	1.00	1.10	0.326	No
100	17.55	0.94	0.27	0.68	0.82	0.319	1.08	0.296	1.00	1.10	0.326	No
101	17.72	0.95	0.27	0.68	0.81	0.319	1.08	0.297	1.00	1.10	0.326	No
102	17.88	0.96	0.28	0.69	0.81	0.319	1.08	0.297	1.00	1.10	0.326	No
103	18.05	0.97	0.28	0.69	0.81	0.319	1.08	0.297	1.00	1.10	0.326	No
104	18.21	0.98	0.29	0.70	0.81	0.319	1.08	0.297	1.00	1.10	0.327	No
105	18.37	0.99	0.29	0.70	0.81	0.319	1.08	0.297	1.00	1.10	0.327	No
106	18.54	1.00	0.30	0.71	0.80	0.319	1.08	0.297	1.00	1.10	0.327	No
107	18.70	1.01	0.30	0.71	0.80	0.319	1.08	0.297	1.00	1.10	0.326	No
108	18.86	1.03	0.31	0.72	0.80	0.319	1.08	0.297	1.00	1.10	0.326	No
109	19.03	1.04	0.31	0.72	0.80	0.319	1.08	0.297	1.00	1.10	0.326	No
110	19.19	1.05	0.32	0.73	0.79	0.319	1.08	0.297	1.00	1.10	0.326	No
111	19.36	1.06	0.32	0.73	0.79	0.319	1.08	0.297	1.00	1.10	0.326	No
112	19.52	1.07	0.33	0.74	0.79	0.319	1.08	0.296	1.00	1.10	0.326	No
113	19.68	1.08	0.33	0.74	0.79	0.319	1.08	0.296	1.00	1.10	0.326	No
114	19.85	1.09	0.34	0.75	0.78	0.318	1.08	0.296	1.00	1.10	0.326	No
115	20.01	1.10	0.34	0.75	0.78	0.318	1.08	0.296	1.00	1.10	0.326	No
116	20.18	1.11	0.35	0.76	0.78	0.318	1.08	0.296	1.00	1.10	0.326	No
117	20.34	1.12	0.35	0.76	0.78	0.318	1.08	0.296	1.00	1.10	0.325	No
118	20.50	1.13	0.36	0.77	0.78	0.318	1.08	0.296	1.00	1.10	0.325	No
119	20.67	1.14	0.36	0.77	0.77	0.318	1.08	0.296	1.00	1.10	0.325	No
120	20.83	1.15	0.37	0.78	0.77	0.318	1.08	0.295	1.00	1.10	0.325	No
121	21.00	1.16	0.37	0.78	0.77	0.317	1.08	0.295	1.00	1.10	0.325	No
122	21.16	1.17	0.38	0.79	0.77	0.317	1.08	0.295	1.00	1.10	0.325	No
123	21.32	1.18	0.38	0.79	0.76	0.317	1.08	0.295	1.00	1.10	0.324	No
124	21.49	1.19	0.39	0.80	0.76	0.317	1.08	0.295	1.00	1.10	0.324	No
125	21.65	1.20	0.39	0.80	0.76	0.317	1.08	0.294	1.00	1.10	0.324	No
126	21.82	1.21	0.40	0.81	0.76	0.316	1.08	0.294	1.00	1.10	0.324	No
127	21.98	1.22	0.41	0.81	0.75	0.316	1.08	0.294	1.00	1.10	0.323	No
128	22.15	1.23	0.41	0.82	0.75	0.316	1.08	0.294	1.00	1.10	0.323	No
129	22.31	1.24	0.42	0.82	0.75	0.315	1.08	0.293	1.00	1.10	0.323	No
130	22.47	1.25	0.42	0.83	0.75	0.315	1.08	0.293	1.00	1.10	0.322	No
131	22.64	1.26	0.43	0.83	0.74	0.315	1.08	0.293	1.00	1.10	0.322	No
132	22.80	1.27	0.43	0.84	0.74	0.315	1.08	0.293	1.00	1.10	0.322	No
133	22.97	1.28	0.44	0.84	0.74	0.314	1.08	0.292	1.00	1.10	0.321	No
134	23.13	1.29	0.44	0.85	0.74	0.314	1.08	0.292	1.00	1.10	0.321	No
135	23.29	1.30	0.45	0.85	0.74	0.313	1.08	0.292	1.00	1.10	0.321	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
136	23.46	1.31	0.45	0.85	0.73	0.313	1.08	0.291	1.00	1.10	0.320	No
137	23.62	1.32	0.46	0.86	0.73	0.313	1.08	0.291	1.00	1.10	0.320	No
138	23.79	1.33	0.46	0.86	0.73	0.312	1.08	0.290	1.00	1.10	0.320	No
139	23.95	1.34	0.47	0.87	0.73	0.312	1.08	0.290	1.00	1.10	0.319	No
140	24.11	1.35	0.47	0.87	0.72	0.311	1.08	0.290	1.00	1.10	0.319	No
141	24.28	1.36	0.48	0.88	0.72	0.311	1.08	0.289	1.00	1.10	0.318	No
142	24.44	1.37	0.48	0.89	0.72	0.310	1.08	0.289	1.00	1.10	0.318	No
143	24.61	1.38	0.49	0.89	0.72	0.310	1.08	0.288	1.00	1.10	0.317	No
144	24.77	1.39	0.49	0.90	0.71	0.310	1.08	0.288	1.00	1.10	0.317	No
145	24.93	1.40	0.50	0.90	0.71	0.309	1.08	0.287	1.00	1.10	0.316	No
146	25.10	1.41	0.50	0.90	0.71	0.309	1.08	0.287	1.00	1.10	0.316	No
147	25.26	1.42	0.51	0.91	0.71	0.308	1.08	0.287	1.00	1.10	0.315	No
148	25.43	1.43	0.51	0.91	0.71	0.308	1.08	0.286	1.00	1.10	0.315	No
149	25.59	1.44	0.52	0.92	0.70	0.307	1.08	0.286	1.00	1.10	0.314	No
150	25.75	1.45	0.52	0.92	0.70	0.307	1.08	0.285	1.00	1.10	0.314	No
151	25.92	1.46	0.53	0.93	0.70	0.306	1.08	0.285	1.00	1.10	0.313	No
152	26.08	1.47	0.53	0.93	0.70	0.306	1.08	0.284	1.00	1.10	0.313	No
153	26.25	1.48	0.54	0.94	0.69	0.305	1.08	0.284	1.00	1.10	0.312	No
154	26.41	1.49	0.54	0.94	0.69	0.305	1.08	0.283	1.00	1.10	0.312	No
155	26.57	1.50	0.55	0.95	0.69	0.304	1.08	0.283	1.00	1.10	0.311	No
156	26.74	1.51	0.55	0.95	0.69	0.304	1.08	0.282	1.00	1.10	0.311	No
157	26.90	1.52	0.56	0.96	0.69	0.303	1.08	0.282	1.00	1.10	0.310	No
158	27.07	1.53	0.56	0.96	0.68	0.303	1.08	0.282	1.00	1.10	0.310	No
159	27.23	1.54	0.57	0.97	0.68	0.302	1.08	0.281	1.00	1.10	0.309	No
160	27.39	1.55	0.57	0.97	0.68	0.302	1.08	0.281	1.00	1.10	0.309	No
161	27.56	1.55	0.58	0.98	0.68	0.301	1.08	0.280	1.00	1.10	0.308	No
162	27.72	1.56	0.58	0.98	0.67	0.301	1.08	0.280	1.00	1.10	0.308	No
163	27.89	1.57	0.59	0.98	0.67	0.300	1.08	0.279	1.00	1.10	0.307	No
164	28.05	1.58	0.59	0.99	0.67	0.300	1.08	0.279	1.00	1.10	0.307	No
165	28.21	1.59	0.60	0.99	0.67	0.299	1.08	0.279	1.00	1.10	0.306	No
166	28.38	1.60	0.60	1.00	0.67	0.299	1.08	0.278	1.00	1.10	0.306	No
167	28.54	1.61	0.61	1.00	0.66	0.299	1.08	0.278	1.00	1.10	0.305	No
168	28.71	1.62	0.61	1.00	0.66	0.298	1.08	0.277	1.00	1.10	0.305	No
169	28.87	1.63	0.62	1.01	0.66	0.298	1.08	0.277	1.00	1.10	0.304	No
170	29.04	1.64	0.63	1.01	0.66	0.297	1.08	0.276	1.00	1.10	0.304	No
171	29.20	1.65	0.63	1.02	0.65	0.296	1.08	0.276	1.00	1.10	0.303	No
172	29.36	1.66	0.64	1.02	0.65	0.296	1.08	0.275	1.00	1.10	0.303	No
173	29.53	1.67	0.64	1.03	0.65	0.295	1.08	0.275	1.00	1.10	0.302	No
174	29.69	1.68	0.65	1.03	0.65	0.295	1.08	0.274	1.00	1.10	0.301	No
175	29.86	1.69	0.65	1.04	0.65	0.294	1.08	0.273	1.00	1.10	0.301	No
176	30.02	1.70	0.66	1.04	0.64	0.293	1.08	0.273	1.00	1.10	0.300	No
177	30.18	1.71	0.66	1.05	0.64	0.293	1.08	0.272	1.00	1.10	0.299	No
178	30.35	1.72	0.67	1.05	0.64	0.292	1.08	0.272	1.00	1.10	0.299	No
179	30.51	1.73	0.67	1.06	0.64	0.292	1.08	0.271	1.00	1.10	0.298	No
180	30.68	1.74	0.68	1.06	0.64	0.291	1.08	0.271	1.00	1.10	0.298	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
181	30.84	1.75	0.68	1.07	0.63	0.290	1.08	0.270	1.00	1.10	0.297	No
182	31.00	1.76	0.69	1.07	0.63	0.290	1.08	0.270	1.00	1.10	0.297	No
183	31.17	1.77	0.69	1.08	0.63	0.289	1.08	0.269	1.00	1.10	0.296	No
184	31.33	1.78	0.70	1.08	0.63	0.289	1.08	0.268	1.00	1.10	0.295	No
185	31.50	1.79	0.70	1.09	0.63	0.288	1.08	0.268	1.00	1.10	0.295	No
186	31.66	1.80	0.71	1.09	0.62	0.288	1.08	0.267	1.00	1.10	0.294	No
187	31.82	1.81	0.71	1.10	0.62	0.287	1.08	0.267	1.00	1.10	0.294	No
188	31.99	1.82	0.72	1.10	0.62	0.286	1.08	0.266	1.00	1.10	0.293	No
189	32.15	1.83	0.72	1.11	0.62	0.286	1.08	0.266	1.00	1.10	0.292	No
190	32.32	1.84	0.73	1.11	0.62	0.285	1.08	0.265	1.00	1.10	0.292	No
191	32.48	1.85	0.73	1.12	0.61	0.284	1.08	0.265	1.00	1.10	0.291	No
192	32.64	1.86	0.74	1.12	0.61	0.284	1.08	0.264	1.00	1.10	0.290	No
193	32.81	1.87	0.74	1.13	0.61	0.283	1.08	0.263	1.00	1.10	0.290	No
194	32.97	1.88	0.75	1.14	0.61	0.282	1.08	0.263	1.00	1.10	0.289	No
195	33.14	1.89	0.75	1.14	0.61	0.282	1.08	0.262	1.00	1.10	0.288	No
196	33.30	1.91	0.76	1.15	0.61	0.281	1.08	0.262	1.00	1.10	0.288	No
197	33.47	1.92	0.76	1.15	0.60	0.281	1.08	0.261	1.00	1.10	0.287	No
198	33.63	1.93	0.77	1.16	0.60	0.280	1.08	0.260	1.00	1.10	0.286	No
199	33.79	1.94	0.77	1.16	0.60	0.279	1.08	0.260	1.00	1.10	0.286	No
200	33.96	1.95	0.78	1.17	0.60	0.279	1.08	0.259	1.00	1.10	0.285	No
201	34.12	1.96	0.78	1.17	0.60	0.278	1.08	0.259	1.00	1.10	0.285	No
202	34.28	1.97	0.79	1.18	0.60	0.278	1.08	0.258	1.00	1.10	0.284	No
203	34.45	1.98	0.79	1.18	0.59	0.277	1.08	0.258	1.00	1.10	0.283	No
204	34.61	1.99	0.80	1.19	0.59	0.277	1.08	0.257	1.00	1.10	0.283	No
205	34.78	2.00	0.80	1.19	0.59	0.276	1.08	0.257	1.00	1.10	0.282	No
206	34.94	2.01	0.81	1.20	0.59	0.275	1.08	0.256	1.00	1.10	0.282	No
207	35.10	2.02	0.81	1.20	0.59	0.275	1.08	0.256	1.00	1.10	0.281	No
208	35.27	2.03	0.82	1.21	0.58	0.274	1.08	0.255	1.00	1.10	0.281	No
209	35.43	2.04	0.82	1.21	0.58	0.274	1.08	0.255	1.00	1.10	0.280	No
210	35.60	2.05	0.83	1.22	0.58	0.273	1.08	0.254	1.00	1.10	0.279	No
211	35.76	2.06	0.83	1.22	0.58	0.273	1.08	0.254	1.00	1.10	0.279	No
212	35.92	2.07	0.84	1.23	0.58	0.272	1.08	0.253	1.00	1.10	0.278	No
213	36.09	2.08	0.85	1.24	0.58	0.271	1.08	0.253	1.00	1.10	0.278	No
214	36.25	2.09	0.85	1.24	0.58	0.271	1.08	0.252	1.00	1.10	0.277	No
215	36.42	2.10	0.86	1.25	0.57	0.270	1.08	0.251	1.00	1.10	0.277	No
216	36.58	2.11	0.86	1.25	0.57	0.270	1.08	0.251	1.00	1.10	0.276	No
217	36.74	2.12	0.87	1.26	0.57	0.269	1.08	0.250	1.00	1.10	0.275	No
218	36.91	2.13	0.87	1.26	0.57	0.269	1.08	0.250	1.00	1.10	0.275	No
219	37.07	2.14	0.88	1.27	0.57	0.268	1.08	0.249	1.00	1.10	0.274	No
220	37.24	2.16	0.88	1.27	0.57	0.268	1.08	0.249	1.00	1.10	0.274	No
221	37.40	2.17	0.89	1.28	0.56	0.267	1.08	0.248	1.00	1.10	0.273	No
222	37.57	2.18	0.89	1.29	0.56	0.266	1.08	0.248	1.00	1.10	0.273	No
223	37.73	2.19	0.90	1.29	0.56	0.266	1.08	0.247	1.00	1.10	0.272	No
224	37.89	2.20	0.90	1.30	0.56	0.265	1.08	0.247	1.00	1.10	0.272	No
225	38.06	2.21	0.91	1.30	0.56	0.265	1.08	0.246	1.00	1.10	0.271	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
226	38.22	2.22	0.91	1.31	0.56	0.264	1.08	0.246	1.00	1.10	0.270	No
227	38.39	2.23	0.92	1.31	0.56	0.264	1.08	0.245	1.00	1.10	0.270	No
228	38.55	2.24	0.92	1.32	0.55	0.263	1.08	0.245	1.00	1.10	0.269	No
229	38.71	2.25	0.93	1.32	0.55	0.263	1.08	0.244	1.00	1.10	0.269	No
230	38.88	2.26	0.93	1.33	0.55	0.262	1.08	0.244	1.00	1.10	0.268	No
231	39.04	2.27	0.94	1.33	0.55	0.262	1.08	0.244	1.00	1.10	0.268	No
232	39.21	2.28	0.94	1.34	0.55	0.261	1.08	0.243	1.00	1.10	0.267	No
233	39.37	2.29	0.95	1.35	0.55	0.261	1.08	0.243	1.00	1.10	0.267	No
234	39.53	2.30	0.95	1.35	0.55	0.260	1.08	0.242	1.00	1.10	0.266	No
235	39.70	2.31	0.96	1.36	0.54	0.260	1.08	0.242	1.00	1.10	0.266	No
236	39.86	2.32	0.96	1.36	0.54	0.259	1.08	0.241	1.00	1.10	0.265	No
237	40.03	2.34	0.97	1.37	0.54	0.259	1.08	0.241	1.00	1.10	0.265	No
238	40.19	2.35	0.97	1.37	0.54	0.258	1.08	0.240	1.00	1.10	0.264	No
239	40.35	2.36	0.98	1.38	0.54	0.258	1.08	0.240	1.00	1.10	0.264	No
240	40.52	2.37	0.98	1.38	0.54	0.258	1.08	0.240	1.00	1.10	0.264	No
241	40.68	2.38	0.99	1.39	0.54	0.257	1.08	0.239	1.00	1.10	0.263	No
242	40.85	2.39	0.99	1.39	0.54	0.257	1.08	0.239	1.00	1.10	0.263	No
243	41.01	2.40	1.00	1.40	0.53	0.256	1.08	0.238	1.00	1.10	0.262	No
244	41.17	2.41	1.00	1.40	0.53	0.256	1.08	0.238	1.00	1.10	0.262	No
245	41.34	2.42	1.01	1.41	0.53	0.256	1.08	0.238	1.00	1.10	0.262	No
246	41.50	2.43	1.01	1.41	0.53	0.255	1.08	0.237	1.00	1.10	0.261	No
247	41.67	2.44	1.02	1.42	0.53	0.255	1.08	0.237	1.00	1.10	0.261	No
248	41.83	2.45	1.02	1.42	0.53	0.254	1.08	0.237	1.00	1.10	0.260	No
249	41.99	2.45	1.03	1.43	0.53	0.254	1.08	0.236	1.00	1.10	0.260	No
250	42.16	2.46	1.03	1.43	0.53	0.254	1.08	0.236	1.00	1.10	0.260	No
251	42.32	2.47	1.04	1.43	0.53	0.253	1.08	0.236	1.00	1.10	0.259	No
252	42.49	2.48	1.04	1.44	0.52	0.253	1.08	0.235	1.00	1.10	0.259	No
253	42.65	2.49	1.05	1.44	0.52	0.253	1.08	0.235	1.00	1.10	0.259	No
254	42.81	2.50	1.06	1.45	0.52	0.252	1.08	0.235	1.00	1.10	0.258	No
255	42.98	2.51	1.06	1.45	0.52	0.252	1.08	0.235	1.00	1.10	0.258	No
256	43.14	2.52	1.07	1.46	0.52	0.252	1.08	0.234	1.00	1.10	0.258	No
257	43.31	2.53	1.07	1.46	0.52	0.251	1.08	0.234	1.00	1.10	0.257	No
258	43.47	2.54	1.08	1.47	0.52	0.251	1.08	0.234	1.00	1.10	0.257	No
259	43.63	2.55	1.08	1.47	0.52	0.251	1.08	0.233	1.00	1.10	0.257	No
260	43.80	2.56	1.09	1.47	0.52	0.251	1.08	0.233	1.00	1.10	0.256	No
261	43.96	2.57	1.09	1.48	0.52	0.250	1.08	0.233	1.00	1.10	0.256	No
262	44.13	2.58	1.10	1.48	0.51	0.250	1.08	0.233	1.00	1.10	0.256	No
263	44.29	2.59	1.10	1.49	0.51	0.250	1.08	0.232	1.00	1.10	0.256	No
264	44.45	2.60	1.11	1.49	0.51	0.249	1.08	0.232	1.00	1.10	0.255	No
265	44.62	2.61	1.11	1.49	0.51	0.249	1.08	0.232	1.00	1.10	0.255	No
266	44.78	2.62	1.12	1.50	0.51	0.249	1.08	0.232	1.00	1.10	0.255	No
267	44.95	2.62	1.12	1.50	0.51	0.249	1.08	0.231	1.00	1.10	0.254	No
268	45.11	2.63	1.13	1.51	0.51	0.248	1.08	0.231	1.00	1.10	0.254	No
269	45.28	2.64	1.13	1.51	0.51	0.248	1.08	0.231	1.00	1.10	0.254	No
270	45.44	2.65	1.14	1.51	0.51	0.248	1.08	0.231	1.00	1.10	0.254	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
271	45.60	2.66	1.14	1.52	0.51	0.248	1.08	0.230	1.00	1.10	0.253	No
272	45.77	2.67	1.15	1.52	0.50	0.247	1.08	0.230	1.00	1.10	0.253	No
273	45.93	2.68	1.15	1.53	0.50	0.247	1.08	0.230	1.00	1.10	0.253	No
274	46.10	2.69	1.16	1.53	0.50	0.247	1.08	0.230	1.00	1.10	0.253	No
275	46.26	2.70	1.16	1.54	0.50	0.247	1.08	0.229	1.00	1.10	0.252	No
276	46.42	2.71	1.17	1.54	0.50	0.246	1.08	0.229	1.00	1.10	0.252	No
277	46.59	2.72	1.17	1.55	0.50	0.246	1.08	0.229	1.00	1.10	0.252	No
278	46.75	2.73	1.18	1.55	0.50	0.246	1.08	0.229	1.00	1.10	0.252	No
279	46.92	2.74	1.18	1.55	0.50	0.246	1.08	0.228	1.00	1.10	0.251	No
280	47.08	2.75	1.19	1.56	0.50	0.245	1.08	0.228	1.00	1.10	0.251	No
281	47.24	2.76	1.19	1.56	0.50	0.245	1.08	0.228	1.00	1.10	0.251	No
282	47.41	2.76	1.20	1.57	0.50	0.245	1.08	0.228	1.00	1.10	0.251	No
283	47.57	2.77	1.20	1.57	0.50	0.245	1.08	0.228	1.00	1.10	0.250	No
284	47.74	2.78	1.21	1.57	0.50	0.245	1.08	0.227	1.00	1.10	0.250	No
285	47.90	2.79	1.21	1.58	0.49	0.244	1.08	0.227	1.00	1.10	0.250	No
286	48.06	2.80	1.22	1.58	0.49	0.244	1.08	0.227	1.00	1.10	0.250	No
287	48.23	2.81	1.22	1.59	0.49	0.244	1.08	0.227	1.00	1.10	0.250	No
288	48.39	2.82	1.23	1.59	0.49	0.244	1.08	0.227	1.00	1.10	0.249	No
289	48.56	2.83	1.23	1.60	0.49	0.243	1.08	0.226	1.00	1.10	0.249	No
290	48.72	2.84	1.24	1.60	0.49	0.243	1.08	0.226	1.00	1.10	0.249	No
291	48.88	2.85	1.24	1.61	0.49	0.243	1.08	0.226	1.00	1.10	0.249	No
292	49.05	2.86	1.25	1.61	0.49	0.243	1.08	0.226	1.00	1.10	0.248	No
293	49.21	2.87	1.25	1.62	0.49	0.243	1.08	0.226	1.00	1.10	0.248	No
294	49.38	2.88	1.26	1.62	0.49	0.242	1.08	0.225	1.00	1.10	0.248	No
295	49.54	2.89	1.26	1.63	0.49	0.242	1.08	0.225	1.00	1.10	0.248	No
296	49.70	2.90	1.27	1.63	0.49	0.242	1.08	0.225	1.00	1.10	0.248	No
297	49.87	2.91	1.28	1.64	0.49	0.242	1.08	0.225	1.00	1.10	0.247	No
298	50.03	2.92	1.28	1.64	0.49	0.242	1.08	0.225	1.00	1.10	0.247	No
299	50.20	2.93	1.29	1.64	0.48	0.241	1.08	0.224	1.00	1.10	0.247	No

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
σ_v: Total overburden pressure at test point (tsf)
u_0: Water pressure at test point (tsf)
σ_v': Effective overburden pressure based on GWT during earthquake (tsf)
r_d: Nonlinear shear mass factor
CSR: Cyclic Stress Ratio
MSF: Magnitude Scaling Factor
CSR_{eq}: CSR adjusted for M=7.5
K_σ: Effective overburden stress factor
CSR^*: CSR fully adjusted

:: Cyclic Resistance Ratio (CRR) calculation data ::

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
1	1.31	18.47	0.07	0.59	1.70	33.42	7.20	40.62	4.000	No	No	2.00
2	1.48	16.96	0.08	0.60	1.70	27.27	9.97	37.24	4.000	No	No	2.00
3	1.64	14.72	0.09	0.56	1.70	25.74	16.91	42.65	4.000	No	Yes	2.00
4	1.80	13.33	0.10	0.57	1.70	22.02	21.09	43.10	4.000	No	Yes	2.00
5	1.97	12.18	0.11	0.58	1.70	20.21	21.60	41.82	4.000	No	Yes	2.00
6	2.13	11.49	0.11	0.62	1.70	19.87	15.66	35.54	4.000	No	Yes	2.00
7	2.30	11.18	0.12	0.66	1.70	18.48	11.31	29.79	4.000	No	Yes	2.00
8	2.46	11.05	0.13	0.69	1.70	18.61	7.84	26.45	4.000	No	No	2.00
9	2.63	11.41	0.14	0.71	1.70	19.21	5.50	24.71	4.000	No	No	2.00
10	2.79	11.90	0.15	0.73	1.70	20.32	3.45	23.76	4.000	No	No	2.00
11	2.95	12.79	0.16	0.75	1.70	21.16	2.23	23.39	4.000	No	No	2.00
12	3.12	14.05	0.16	0.75	1.70	23.73	1.07	24.80	4.000	No	No	2.00
13	3.28	15.73	0.17	0.75	1.70	26.76	0.23	26.98	4.000	No	No	2.00
14	3.44	17.43	0.18	0.76	1.70	29.72	0.00	29.72	4.000	No	No	2.00
15	3.61	18.63	0.19	0.75	1.70	32.38	0.00	32.38	4.000	No	No	2.00
16	3.77	19.69	0.20	0.73	1.70	32.86	0.00	32.86	4.000	No	No	2.00
17	3.94	19.98	0.20	0.70	1.70	35.16	0.36	35.51	4.000	No	No	2.00
18	4.10	20.31	0.21	0.69	1.70	33.86	0.90	34.77	4.000	No	No	2.00
19	4.26	19.91	0.22	0.67	1.70	34.54	1.55	36.09	4.000	No	No	2.00
20	4.43	19.84	0.23	0.67	1.70	33.10	2.04	35.14	4.000	No	No	2.00
21	4.59	19.56	0.24	0.66	1.70	33.51	2.37	35.87	4.000	No	No	2.00
22	4.76	19.72	0.25	0.67	1.70	33.12	2.22	35.34	4.000	No	No	2.00
23	4.92	20.35	0.25	0.67	1.70	33.95	1.94	35.89	4.000	No	No	2.00
24	5.08	21.69	0.26	0.67	1.70	36.70	1.47	38.18	4.000	No	No	2.00
25	5.25	23.37	0.27	0.66	1.70	39.93	1.15	41.08	4.000	No	No	2.00
26	5.41	24.88	0.28	0.66	1.70	42.53	0.78	43.31	4.000	No	No	2.00
27	5.58	26.37	0.29	0.67	1.70	44.42	0.44	44.86	4.000	No	No	2.00
28	5.74	28.42	0.30	0.67	1.70	47.50	0.08	47.58	4.000	No	No	2.00
29	5.91	31.51	0.31	0.67	1.70	53.02	0.00	53.02	4.000	No	No	2.00
30	6.07	35.15	0.31	0.68	1.70	60.18	0.00	60.18	4.000	No	No	2.00
31	6.23	38.56	0.32	0.69	1.70	66.05	0.00	66.05	4.000	No	No	2.00
32	6.40	41.16	0.33	0.69	1.70	70.41	0.00	70.41	4.000	No	No	2.00
33	6.56	42.78	0.34	0.68	1.70	73.46	0.00	73.46	4.000	No	No	2.00
34	6.73	43.16	0.35	0.66	1.70	74.29	0.00	74.29	4.000	No	No	2.00
35	6.89	41.96	0.36	0.64	1.70	72.33	0.00	72.33	4.000	No	No	2.00
36	7.05	39.31	0.37	0.61	1.70	67.39	0.50	67.89	4.000	No	No	2.00
37	7.22	36.04	0.38	0.59	1.70	60.74	1.78	62.52	4.000	No	No	2.00
38	7.38	33.75	0.38	0.57	1.70	55.67	3.10	58.78	4.000	No	No	2.00
39	7.55	33.49	0.39	0.56	1.70	55.71	3.80	59.50	4.000	No	No	2.00
40	7.71	34.75	0.40	0.55	1.70	59.43	3.75	63.19	4.000	No	No	2.00
41	7.87	36.40	0.41	0.56	1.69	61.87	3.23	65.10	4.000	No	No	2.00
42	8.04	38.58	0.42	0.57	1.69	63.90	2.34	66.24	4.000	No	No	2.00
43	8.20	41.46	0.43	0.59	1.69	70.35	1.31	71.66	4.000	No	No	2.00
44	8.37	43.50	0.44	0.60	1.69	76.29	0.62	76.90	4.000	No	No	2.00
45	8.53	43.39	0.45	0.61	1.68	73.81	0.43	74.24	4.000	No	No	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
46	8.69	41.04	0.46	0.61	1.67	68.85	0.48	69.33	4.000	No	No	2.00
47	8.86	38.24	0.47	0.61	1.65	62.99	0.80	63.80	4.000	No	No	2.00
48	9.02	35.58	0.47	0.61	1.63	57.88	1.19	59.07	0.093	No	No	0.35
49	9.19	33.57	0.48	0.61	1.61	53.37	1.78	55.15	0.087	No	No	0.33
50	9.35	32.63	0.49	0.61	1.60	51.32	1.70	53.02	0.085	No	No	0.31
51	9.51	32.89	0.50	0.62	1.59	51.78	1.50	53.28	0.085	No	No	0.31
52	9.68	34.32	0.51	0.62	1.58	53.55	1.10	54.65	0.087	No	No	0.32
53	9.84	36.11	0.52	0.62	1.56	56.60	0.99	57.59	0.091	No	No	0.33
54	10.01	37.22	0.53	0.62	1.54	58.45	0.88	59.33	0.094	No	No	0.34
55	10.17	37.38	0.54	0.62	1.53	56.97	0.84	57.81	0.092	No	No	0.33
56	10.34	36.69	0.55	0.62	1.51	55.78	0.87	56.65	0.090	No	No	0.32
57	10.50	33.96	0.55	0.62	1.50	53.80	1.12	54.92	0.087	No	No	0.31
58	10.66	33.90	0.56	0.65	1.51	43.96	0.96	44.93	0.075	No	No	0.26
59	10.83	34.12	0.57	0.63	1.47	53.98	0.89	54.87	0.087	No	No	0.30
60	10.99	37.18	0.58	0.64	1.47	53.72	0.57	54.29	0.087	No	No	0.30
61	11.15	39.11	0.58	0.64	1.46	55.98	0.36	56.34	0.090	No	No	0.31
62	11.32	43.22	0.59	0.64	1.46	61.93	0.00	61.93	0.098	No	No	0.34
63	11.48	47.91	0.59	0.64	1.45	71.04	0.00	71.04	0.112	No	No	0.38
64	11.65	51.77	0.60	0.63	1.44	75.27	0.00	75.27	0.120	No	No	0.41
65	11.81	53.18	0.60	0.61	1.41	76.22	0.31	76.53	0.123	No	No	0.41
66	11.97	52.99	0.60	0.60	1.40	74.27	0.73	75.01	0.120	No	No	0.40
67	12.14	52.11	0.61	0.61	1.40	72.48	0.45	72.93	0.116	No	No	0.39
68	12.30	52.01	0.61	0.63	1.42	72.73	0.00	72.73	0.115	No	No	0.38
69	12.47	51.56	0.62	0.64	1.41	74.68	0.00	74.68	0.119	No	No	0.39
70	12.63	50.45	0.62	0.64	1.41	70.80	0.00	70.80	0.112	No	No	0.37
71	12.79	49.06	0.62	0.63	1.40	67.16	0.00	67.16	0.106	No	No	0.35
72	12.96	49.09	0.63	0.63	1.39	67.78	0.00	67.78	0.107	No	No	0.35
73	13.12	50.56	0.63	0.63	1.38	69.75	0.01	69.76	0.111	No	No	0.36
74	13.29	51.89	0.63	0.62	1.37	72.12	0.00	72.12	0.115	No	No	0.37
75	13.45	52.88	0.64	0.63	1.38	72.51	0.00	72.51	0.115	No	No	0.37
76	13.62	54.37	0.64	0.65	1.38	73.81	0.00	73.81	0.117	No	No	0.38
77	13.78	56.49	0.65	0.66	1.38	78.71	0.00	78.71	0.126	No	No	0.40
78	13.94	58.54	0.65	0.67	1.39	81.87	0.00	81.87	0.132	No	No	0.42
79	14.11	57.93	0.65	0.68	1.39	82.60	0.00	82.60	0.133	No	No	0.42
80	14.27	57.50	0.66	0.68	1.38	76.25	0.00	76.25	0.121	No	No	0.38
81	14.44	57.53	0.66	0.67	1.37	79.04	0.00	79.04	0.126	No	No	0.40
82	14.60	58.65	0.67	0.66	1.36	80.92	0.00	80.92	0.130	No	No	0.41
83	14.76	52.39	0.67	0.65	1.35	78.74	0.00	78.74	0.126	No	No	0.40
84	14.93	39.14	0.67	0.66	1.35	52.38	0.13	52.51	0.085	No	No	0.27
85	15.09	24.64	0.68	0.69	1.36	27.13	2.80	29.93	0.059	No	No	0.19
86	15.26	15.44	0.68	0.67	1.35	20.11	8.40	28.51	0.056	No	No	0.18
87	15.42	13.10	0.68	0.71	1.36	15.37	11.40	26.77	4.000	No	Yes	2.00
88	15.58	15.15	0.69	0.70	1.35	17.26	9.46	26.72	0.055	No	No	0.17
89	15.75	19.03	0.69	0.64	1.31	27.61	6.03	33.64	0.061	No	No	0.19
90	15.91	22.17	0.69	0.63	1.30	29.64	5.66	35.30	0.063	No	No	0.20

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
91	16.08	22.50	0.70	0.62	1.29	28.35	7.42	35.77	0.063	No	No	0.19
92	16.24	21.86	0.70	0.59	1.27	27.65	11.06	38.71	0.064	No	No	0.20
93	16.40	21.42	0.71	0.57	1.26	26.14	14.37	40.51	0.064	No	No	0.20
94	16.57	21.79	0.71	0.55	1.25	25.87	18.61	44.48	0.066	No	No	0.20
95	16.73	25.03	0.71	0.52	1.23	28.20	21.24	49.44	0.070	No	No	0.21
96	16.90	30.12	0.72	0.48	1.20	36.55	21.85	58.40	0.080	No	No	0.25
97	17.06	36.90	0.72	0.46	1.19	42.52	20.79	63.31	0.088	No	No	0.27
98	17.22	55.27	0.73	0.48	1.20	50.77	13.91	64.67	0.094	No	No	0.29
99	17.39	83.19	0.73	0.45	1.18	99.74	8.17	107.91	0.201	No	No	0.62
100	17.55	109.57	0.74	0.45	1.18	141.30	5.41	146.70	0.389	No	No	1.19
101	17.72	114.88	0.74	0.45	1.17	144.10	5.40	149.50	0.408	No	No	1.25
102	17.88	100.73	0.75	0.44	1.16	118.65	8.05	126.70	0.278	No	No	0.85
103	18.05	79.96	0.75	0.41	1.15	89.18	15.80	104.98	0.188	No	No	0.58
104	18.21	72.59	0.76	0.39	1.14	68.93	24.50	93.43	0.146	No	No	0.45
105	18.37	84.33	0.76	0.36	1.12	89.55	27.92	117.47	0.227	No	No	0.69
106	18.54	113.88	0.77	0.35	1.12	126.08	22.36	148.44	0.417	No	No	1.28
107	18.70	129.48	0.77	0.34	1.11	165.56	20.65	186.21	0.857	No	No	2.00
108	18.86	114.36	0.78	0.34	1.11	140.28	23.32	163.59	0.559	No	No	1.71
109	19.03	76.52	0.79	0.35	1.11	74.94	35.30	110.23	0.188	No	No	0.58
110	19.19	42.83	0.79	0.37	1.11	39.64	48.20	87.84	4.000	No	Yes	2.00
111	19.36	29.03	0.80	0.39	1.12	28.51	48.20	76.71	4.000	No	Yes	2.00
112	19.52	27.23	0.80	0.37	1.11	28.91	48.19	77.10	4.000	No	Yes	2.00
113	19.68	28.50	0.81	0.36	1.10	33.26	48.18	81.45	4.000	No	Yes	2.00
114	19.85	29.18	0.81	0.37	1.10	32.27	48.18	80.45	4.000	No	Yes	2.00
115	20.01	27.48	0.82	0.38	1.10	30.94	48.17	79.11	4.000	No	Yes	2.00
116	20.18	27.39	0.82	0.43	1.11	27.86	48.16	76.02	4.000	No	Yes	2.00
117	20.34	28.39	0.83	0.43	1.11	31.97	46.17	78.14	4.000	No	Yes	2.00
118	20.50	30.88	0.83	0.45	1.11	34.25	35.45	69.70	4.000	No	Yes	2.00
119	20.67	34.18	0.84	0.45	1.11	35.80	30.05	65.86	0.085	No	No	0.26
120	20.83	38.12	0.84	0.44	1.11	42.53	26.10	68.62	0.092	No	No	0.28
121	21.00	38.83	0.85	0.43	1.10	46.47	25.96	72.43	0.099	No	No	0.30
122	21.16	34.22	0.85	0.44	1.10	37.67	32.52	70.19	4.000	No	Yes	2.00
123	21.32	25.97	0.85	0.45	1.10	27.49	48.10	75.59	4.000	No	Yes	2.00
124	21.49	19.86	0.86	0.48	1.10	19.93	48.08	68.01	4.000	No	Yes	2.00
125	21.65	21.21	0.86	0.51	1.11	17.94	48.07	66.01	4.000	No	Yes	2.00
126	21.82	30.69	0.87	0.43	1.09	31.55	45.93	77.49	4.000	No	Yes	2.00
127	21.98	36.29	0.87	0.37	1.07	50.03	44.53	94.56	4.000	No	Yes	2.00
128	22.15	33.86	0.88	0.41	1.08	35.76	48.02	83.78	4.000	No	Yes	2.00
129	22.31	25.23	0.88	0.45	1.08	23.72	48.00	71.73	4.000	No	Yes	2.00
130	22.47	23.15	0.89	0.48	1.09	22.52	47.99	70.51	4.000	No	Yes	2.00
131	22.64	25.01	0.89	0.46	1.08	28.95	41.65	70.60	4.000	No	Yes	2.00
132	22.80	35.49	0.90	0.50	1.08	29.64	26.34	55.98	0.074	No	No	0.23
133	22.97	51.25	0.90	0.45	1.07	55.80	16.62	72.42	0.106	No	No	0.33
134	23.13	65.18	0.91	0.45	1.07	79.34	10.60	89.93	0.147	No	No	0.46
135	23.29	63.11	0.91	0.46	1.07	74.09	9.84	83.93	0.134	No	No	0.42

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
136	23.46	48.03	0.92	0.47	1.07	49.12	16.06	65.18	0.094	No	No	0.29
137	23.62	31.40	0.92	0.45	1.06	30.85	38.42	69.28	4.000	No	Yes	2.00
138	23.79	21.98	0.93	0.46	1.06	20.57	47.83	68.40	4.000	No	Yes	2.00
139	23.95	19.15	0.93	0.43	1.06	18.66	47.80	66.46	4.000	No	Yes	2.00
140	24.11	22.36	0.94	0.40	1.05	21.47	47.78	69.25	4.000	No	Yes	2.00
141	24.28	30.51	0.94	0.36	1.04	30.19	47.75	77.93	4.000	No	Yes	2.00
142	24.44	36.82	0.95	0.34	1.04	43.68	47.72	91.40	4.000	No	Yes	2.00
143	24.61	40.05	0.95	0.39	1.04	41.04	47.69	88.73	4.000	No	Yes	2.00
144	24.77	41.73	0.96	0.45	1.05	40.46	24.32	64.78	0.087	No	No	0.28
145	24.93	46.02	0.96	0.47	1.05	49.28	16.17	65.45	0.094	No	No	0.30
146	25.10	50.57	0.97	0.45	1.04	54.48	16.06	70.55	0.103	No	No	0.33
147	25.26	51.86	0.97	0.44	1.04	54.34	18.36	72.69	0.105	No	No	0.33
148	25.43	50.72	0.98	0.44	1.04	52.88	19.26	72.14	0.104	No	No	0.33
149	25.59	47.63	0.98	0.43	1.03	50.47	23.13	73.60	0.103	No	No	0.33
150	25.75	42.82	0.99	0.44	1.03	44.46	24.16	68.63	0.094	No	No	0.30
151	25.92	38.12	0.99	0.45	1.03	37.73	27.03	64.76	0.086	No	No	0.27
152	26.08	35.62	1.00	0.46	1.03	35.78	28.62	64.40	4.000	No	Yes	2.00
153	26.25	36.45	1.00	0.44	1.02	36.50	33.47	69.97	4.000	No	Yes	2.00
154	26.41	35.40	1.01	0.41	1.02	39.92	41.03	80.95	4.000	No	Yes	2.00
155	26.57	33.16	1.01	0.43	1.02	32.30	47.36	79.66	4.000	No	Yes	2.00
156	26.74	26.72	1.02	0.42	1.02	29.42	47.33	76.75	4.000	No	Yes	2.00
157	26.90	21.75	1.02	0.48	1.02	20.12	47.30	67.42	4.000	No	Yes	2.00
158	27.07	17.49	1.02	0.51	1.02	17.01	47.27	64.28	4.000	No	Yes	2.00
159	27.23	16.89	1.03	0.53	1.01	16.32	47.24	63.56	4.000	No	Yes	2.00
160	27.39	17.74	1.03	0.53	1.01	18.15	47.21	65.36	4.000	No	Yes	2.00
161	27.56	19.19	1.04	0.55	1.01	19.42	32.81	52.22	4.000	No	Yes	2.00
162	27.72	20.57	1.04	0.60	1.01	20.55	18.51	39.06	4.000	No	Yes	2.00
163	27.89	24.83	1.05	0.65	1.01	22.17	8.93	31.11	0.058	No	No	0.19
164	28.05	37.01	1.05	0.66	1.01	32.08	2.61	34.69	0.064	No	No	0.21
165	28.21	52.16	1.05	0.64	1.00	56.58	0.45	57.02	0.091	No	No	0.30
166	28.38	59.71	1.06	0.64	1.00	66.88	0.00	66.88	0.106	No	No	0.34
167	28.54	55.33	1.06	0.64	1.00	54.04	0.43	54.46	0.087	No	No	0.29
168	28.71	44.81	1.07	0.59	1.00	43.25	4.32	47.57	0.076	No	No	0.25
169	28.87	36.89	1.07	0.52	0.99	35.55	15.01	50.56	0.074	No	No	0.24
170	29.04	31.36	1.08	0.46	0.99	30.46	37.90	68.35	4.000	No	Yes	2.00
171	29.20	27.91	1.08	0.42	0.99	26.73	46.89	73.62	4.000	No	Yes	2.00
172	29.36	26.98	1.09	0.41	0.99	25.15	46.85	72.00	4.000	No	Yes	2.00
173	29.53	30.16	1.09	0.39	0.99	27.51	46.82	74.33	4.000	No	Yes	2.00
174	29.69	34.28	1.10	0.37	0.99	35.97	46.78	82.75	4.000	No	Yes	2.00
175	29.86	36.27	1.10	0.38	0.98	37.16	46.74	83.90	4.000	No	Yes	2.00
176	30.02	35.33	1.11	0.41	0.98	33.13	46.71	79.83	4.000	No	Yes	2.00
177	30.18	32.51	1.11	0.43	0.98	32.87	45.97	78.84	4.000	No	Yes	2.00
178	30.35	30.62	1.12	0.45	0.98	28.47	43.63	72.10	4.000	No	Yes	2.00
179	30.51	29.09	1.12	0.46	0.97	27.29	45.70	72.99	4.000	No	Yes	2.00
180	30.68	29.70	1.13	0.45	0.97	28.07	46.57	74.64	4.000	No	Yes	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
181	30.84	31.68	1.13	0.44	0.97	30.01	46.53	76.54	4.000	No	Yes	2.00
182	31.00	36.66	1.14	0.44	0.97	32.68	40.57	73.25	4.000	No	Yes	2.00
183	31.17	45.07	1.14	0.43	0.97	42.22	29.85	72.07	0.096	No	No	0.32
184	31.33	49.32	1.14	0.42	0.97	54.47	22.65	77.12	0.111	No	No	0.38
185	31.50	49.61	1.15	0.46	0.96	44.95	19.60	64.55	0.091	No	No	0.31
186	31.66	50.64	1.15	0.47	0.96	42.67	17.67	60.34	0.086	No	No	0.29
187	31.82	66.54	1.16	0.46	0.96	56.45	14.49	70.94	0.105	No	No	0.36
188	31.99	105.26	1.16	0.43	0.96	89.75	11.88	101.63	0.181	No	No	0.62
189	32.15	152.62	1.17	0.39	0.96	154.78	11.20	165.98	0.566	No	No	1.93
190	32.32	193.84	1.18	0.39	0.96	193.69	9.48	203.17	1.085	No	No	2.00
191	32.48	213.18	1.18	0.39	0.96	209.23	8.42	217.65	1.386	No	No	2.00
192	32.64	218.38	1.19	0.39	0.96	209.62	8.33	217.95	1.392	No	No	2.00
193	32.81	212.89	1.19	0.38	0.96	207.83	10.40	218.23	1.440	No	No	2.00
194	32.97	201.32	1.20	0.36	0.96	193.16	13.40	206.56	1.208	No	No	2.00
195	33.14	189.26	1.20	0.37	0.95	175.94	12.10	188.04	0.850	No	No	2.00
196	33.30	182.98	1.21	0.40	0.95	171.80	8.95	180.75	0.725	No	No	2.00
197	33.47	184.02	1.21	0.46	0.94	171.93	3.96	175.89	0.636	No	No	2.00
198	33.63	186.81	1.22	0.48	0.93	175.26	2.42	177.68	0.647	No	No	2.00
199	33.79	187.43	1.23	0.49	0.93	176.56	2.31	178.87	0.659	No	No	2.00
200	33.96	183.42	1.23	0.46	0.93	172.52	3.67	176.19	0.638	No	No	2.00
201	34.12	175.90	1.24	0.44	0.93	164.14	5.38	169.52	0.578	No	No	2.00
202	34.28	165.98	1.24	0.43	0.93	155.85	6.19	162.04	0.511	No	No	1.80
203	34.45	158.47	1.25	0.45	0.93	144.27	5.49	149.75	0.412	No	No	1.45
204	34.61	154.51	1.25	0.46	0.93	141.74	4.53	146.27	0.387	No	No	1.37
205	34.78	155.87	1.26	0.48	0.92	142.82	3.36	146.18	0.384	No	No	1.36
206	34.94	159.33	1.26	0.49	0.92	146.04	2.51	148.56	0.397	No	No	1.41
207	35.10	166.53	1.27	0.51	0.91	149.24	1.74	150.98	0.412	No	No	1.46
208	35.27	167.54	1.27	0.50	0.91	161.23	2.07	163.30	0.507	No	No	1.81
209	35.43	159.67	1.28	0.47	0.92	148.62	3.81	152.43	0.427	No	No	1.53
210	35.60	156.70	1.28	0.46	0.92	128.23	5.55	133.78	0.314	No	No	1.12
211	35.76	181.13	1.29	0.46	0.91	153.21	4.07	157.28	0.465	No	No	1.67
212	35.92	234.84	1.29	0.48	0.91	213.84	1.83	215.67	1.220	No	No	2.00
213	36.09	299.91	1.30	0.51	0.90	271.21	0.31	271.52	3.047	No	No	2.00
214	36.25	349.29	1.30	0.50	0.90	326.88	0.28	327.17	4.000	No	No	2.00
215	36.42	370.40	1.31	0.48	0.90	346.17	0.79	346.96	4.000	No	No	2.00
216	36.58	363.58	1.31	0.46	0.91	329.79	1.92	331.71	4.000	No	No	2.00
217	36.74	348.73	1.32	0.46	0.90	309.48	2.09	311.58	4.000	No	No	2.00
218	36.91	339.35	1.33	0.48	0.90	304.61	1.35	305.96	4.000	No	No	2.00
219	37.07	338.65	1.33	0.51	0.89	298.96	0.15	299.12	4.000	No	No	2.00
220	37.24	341.33	1.34	0.51	0.89	302.49	0.32	302.81	4.000	No	No	2.00
221	37.40	348.75	1.34	0.48	0.89	309.36	0.98	310.34	4.000	No	No	2.00
222	37.57	342.84	1.35	0.46	0.89	320.67	1.96	322.63	4.000	No	No	2.00
223	37.73	342.66	1.35	0.45	0.89	288.47	2.50	290.97	4.000	No	No	2.00
224	37.89	341.09	1.36	0.45	0.89	309.79	2.55	312.33	4.000	No	No	2.00
225	38.06	358.39	1.36	0.47	0.89	313.59	1.45	315.04	4.000	No	No	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
226	38.22	372.99	1.37	0.53	0.87	326.22	0.00	326.22	4.000	No	No	2.00
227	38.39	391.40	1.38	0.59	0.86	334.35	0.00	334.35	4.000	No	No	2.00
228	38.55	408.33	1.38	0.60	0.85	348.58	0.00	348.58	4.000	No	No	2.00
229	38.71	421.40	1.39	0.56	0.86	365.26	0.00	365.26	4.000	No	No	2.00
230	38.88	427.31	1.39	0.55	0.86	369.12	0.00	369.12	4.000	No	No	2.00
231	39.04	418.90	1.40	0.55	0.86	365.69	0.00	365.69	4.000	No	No	2.00
232	39.21	401.54	1.40	0.54	0.86	343.07	0.00	343.07	4.000	No	No	2.00
233	39.37	389.68	1.41	0.54	0.86	323.72	0.00	323.72	4.000	No	No	2.00
234	39.53	393.48	1.41	0.54	0.85	334.21	0.00	334.21	4.000	No	No	2.00
235	39.70	408.36	1.42	0.55	0.85	350.44	0.00	350.44	4.000	No	No	2.00
236	39.86	418.10	1.42	0.55	0.85	358.71	0.00	358.71	4.000	No	No	2.00
237	40.03	402.57	1.43	0.54	0.85	356.92	0.00	356.92	4.000	No	No	2.00
238	40.19	338.71	1.43	0.53	0.85	310.77	0.00	310.77	4.000	No	No	2.00
239	40.35	235.90	1.44	0.51	0.86	197.25	1.10	198.35	0.903	No	No	2.00
240	40.52	139.85	1.45	0.49	0.86	95.88	4.38	100.26	0.179	No	No	0.68
241	40.68	78.81	1.45	0.47	0.86	66.24	9.81	76.05	0.118	No	No	0.45
242	40.85	53.51	1.45	0.50	0.85	40.39	13.69	54.08	0.080	No	No	0.31
243	41.01	38.50	1.46	0.52	0.85	29.85	19.52	49.37	4.000	No	Yes	2.00
244	41.17	32.89	1.46	0.52	0.85	26.50	23.79	50.29	4.000	No	Yes	2.00
245	41.34	32.73	1.47	0.50	0.85	25.81	30.10	55.91	4.000	No	Yes	2.00
246	41.50	32.94	1.47	0.46	0.86	30.24	33.35	63.59	4.000	No	Yes	2.00
247	41.67	33.03	1.48	0.47	0.85	27.04	36.26	63.30	4.000	No	Yes	2.00
248	41.83	30.19	1.48	0.48	0.85	25.92	36.65	62.57	4.000	No	Yes	2.00
249	41.99	27.66	1.49	0.51	0.84	22.29	34.76	57.05	4.000	No	Yes	2.00
250	42.16	25.19	1.49	0.54	0.83	20.21	32.08	52.29	4.000	No	Yes	2.00
251	42.32	23.43	1.50	0.57	0.82	19.10	28.00	47.10	4.000	No	Yes	2.00
252	42.49	21.95	1.50	0.59	0.81	17.40	27.07	44.47	4.000	No	Yes	2.00
253	42.65	19.74	1.51	0.60	0.81	16.22	29.36	45.59	4.000	No	Yes	2.00
254	42.81	18.07	1.51	0.62	0.80	13.38	36.79	50.16	4.000	No	Yes	2.00
255	42.98	17.26	1.51	0.61	0.80	13.15	43.23	56.37	4.000	No	Yes	2.00
256	43.14	17.90	1.52	0.60	0.81	14.15	42.48	56.63	4.000	No	Yes	2.00
257	43.31	18.53	1.52	0.59	0.81	15.00	39.60	54.59	4.000	No	Yes	2.00
258	43.47	17.92	1.53	0.60	0.80	14.68	38.74	53.42	4.000	No	Yes	2.00
259	43.63	16.35	1.53	0.63	0.79	12.48	40.30	52.78	4.000	No	Yes	2.00
260	43.80	14.65	1.54	0.67	0.78	10.89	41.91	52.80	4.000	No	Yes	2.00
261	43.96	13.79	1.54	0.69	0.77	10.21	41.86	52.07	4.000	No	Yes	2.00
262	44.13	14.30	1.54	0.70	0.77	10.14	38.05	48.19	4.000	No	Yes	2.00
263	44.29	15.62	1.55	0.66	0.78	11.94	33.71	45.65	4.000	No	Yes	2.00
264	44.45	17.01	1.55	0.64	0.78	13.31	29.95	43.26	4.000	No	Yes	2.00
265	44.62	17.46	1.56	0.65	0.78	13.46	27.60	41.07	4.000	No	Yes	2.00
266	44.78	17.37	1.56	0.67	0.77	12.86	25.34	38.21	4.000	No	Yes	2.00
267	44.95	17.72	1.57	0.68	0.76	12.83	21.79	34.61	4.000	No	Yes	2.00
268	45.11	19.60	1.57	0.68	0.76	13.99	17.53	31.52	4.000	No	Yes	2.00
269	45.28	20.08	1.57	0.63	0.78	17.46	17.38	34.84	4.000	No	Yes	2.00
270	45.44	19.26	1.58	0.67	0.77	14.00	20.42	34.42	4.000	No	Yes	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	σ_v' (tsf)	c	C_q	q_{c1} (tsf)	Δq_c	$q_{c,1,mod}$ (tsf)	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
271	45.60	16.65	1.58	0.68	0.76	12.13	27.51	39.64	4.000	No	Yes	2.00
272	45.77	14.60	1.59	0.66	0.76	11.07	42.08	53.15	4.000	No	Yes	2.00
273	45.93	13.54	1.59	0.70	0.75	9.05	43.65	52.70	4.000	No	Yes	2.00
274	46.10	12.55	1.59	0.66	0.76	9.67	43.63	53.30	4.000	No	Yes	2.00
275	46.26	12.25	1.60	0.70	0.75	8.55	43.61	52.16	4.000	No	Yes	2.00
276	46.42	12.16	1.60	0.71	0.74	8.19	43.59	51.78	4.000	No	Yes	2.00
277	46.59	14.36	1.61	0.69	0.75	9.35	43.58	52.93	4.000	No	Yes	2.00
278	46.75	18.41	1.61	0.62	0.77	13.82	35.94	49.76	4.000	No	Yes	2.00
279	46.92	23.48	1.62	0.60	0.77	17.80	21.51	39.31	4.000	No	Yes	2.00
280	47.08	27.23	1.62	0.60	0.77	20.96	15.32	36.28	4.000	No	Yes	2.00
281	47.24	29.00	1.62	0.62	0.77	21.98	11.86	33.84	4.000	No	Yes	2.00
282	47.41	30.22	1.63	0.64	0.76	21.11	9.78	30.89	4.000	No	Yes	2.00
283	47.57	32.02	1.63	0.64	0.76	23.30	8.16	31.47	4.000	No	Yes	2.00
284	47.74	34.99	1.64	0.62	0.76	25.69	8.00	33.69	0.061	No	No	0.24
285	47.90	36.82	1.64	0.59	0.77	27.87	9.71	37.58	0.064	No	No	0.25
286	48.06	37.03	1.65	0.56	0.78	27.57	14.24	41.81	4.000	No	Yes	2.00
287	48.23	35.55	1.65	0.53	0.79	26.81	20.39	47.20	4.000	No	Yes	2.00
288	48.39	33.76	1.66	0.51	0.79	25.23	26.45	51.69	4.000	No	Yes	2.00
289	48.56	32.72	1.66	0.52	0.79	23.86	27.87	51.73	4.000	No	Yes	2.00
290	48.72	32.75	1.66	0.52	0.79	24.37	26.36	50.73	4.000	No	Yes	2.00
291	48.88	34.52	1.67	0.53	0.79	25.02	23.45	48.46	4.000	No	Yes	2.00
292	49.05	38.76	1.67	0.52	0.79	27.76	20.61	48.36	4.000	No	Yes	2.00
293	49.21	43.87	1.68	0.50	0.79	34.40	17.97	52.37	4.000	No	Yes	2.00
294	49.38	50.18	1.68	0.50	0.79	36.88	14.95	51.82	0.077	No	No	0.31
295	49.54	57.58	1.69	0.51	0.79	42.38	11.84	54.22	0.082	No	No	0.33
296	49.70	71.83	1.69	0.52	0.78	50.86	7.93	58.78	0.090	No	No	0.36
297	49.87	78.47	1.70	0.49	0.79	72.10	6.24	78.33	0.125	No	No	0.50
298	50.03	74.13	1.70	0.51	0.78	59.50	6.67	66.16	0.102	No	No	0.41
299	50.20	61.76	1.71	0.53	0.78	42.23	9.01	51.24	0.079	No	No	0.32

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
q_t: Total cone resistance
I_c: Soil behavior type index
Fr: Normalized friction ratio (%)
n: Stress exponent
Q_{tn}: Normalized cone resistance
K_c: Cone resistance correction factor due to fines
$Q_{tn,cs}$: Normalized and adjusted cone resistance
$CRR_{7.5}$: Cyclic resistance ratio for M_w=7.5
FS: Factor of safety against soil liquefaction

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
1.31	2.00	0.00	0.00	0.16	0.00	1.48	2.00	0.00	0.00	0.16	0.00
1.64	2.00	0.00	0.00	0.16	0.00	1.80	2.00	0.00	0.00	0.16	0.00
1.97	2.00	0.00	0.00	0.17	0.00	2.13	2.00	0.00	0.00	0.16	0.00
2.30	2.00	0.00	0.00	0.16	0.00	2.46	2.00	0.00	0.00	0.16	0.00
2.63	2.00	0.00	0.00	0.16	0.00	2.79	2.00	0.00	0.00	0.16	0.00
2.95	2.00	0.00	0.00	0.16	0.00	3.12	2.00	0.00	0.00	0.16	0.00
3.28	2.00	0.00	0.00	0.16	0.00	3.44	2.00	0.00	0.00	0.16	0.00
3.61	2.00	0.00	0.00	0.16	0.00	3.77	2.00	0.00	0.00	0.16	0.00
3.94	2.00	0.00	0.00	0.16	0.00	4.10	2.00	0.00	0.00	0.16	0.00
4.26	2.00	0.00	0.00	0.16	0.00	4.43	2.00	0.00	0.00	0.16	0.00
4.59	2.00	0.00	0.00	0.16	0.00	4.76	2.00	0.00	0.00	0.16	0.00
4.92	2.00	0.00	0.00	0.16	0.00	5.08	2.00	0.00	0.00	0.16	0.00
5.25	2.00	0.00	0.00	0.16	0.00	5.41	2.00	0.00	0.00	0.16	0.00
5.58	2.00	0.00	0.00	0.16	0.00	5.74	2.00	0.00	0.00	0.16	0.00
5.91	2.00	0.00	0.00	0.17	0.00	6.07	2.00	0.00	0.00	0.16	0.00
6.23	2.00	0.00	0.00	0.16	0.00	6.40	2.00	0.00	0.00	0.16	0.00
6.56	2.00	0.00	0.00	0.16	0.00	6.73	2.00	0.00	0.00	0.16	0.00
6.89	2.00	0.00	0.00	0.16	0.00	7.05	2.00	0.00	0.00	0.16	0.00
7.22	2.00	0.00	0.00	0.16	0.00	7.38	2.00	0.00	0.00	0.16	0.00
7.55	2.00	0.00	0.00	0.16	0.00	7.71	2.00	0.00	0.00	0.16	0.00
7.87	2.00	0.00	0.00	0.16	0.00	8.04	2.00	0.00	0.00	0.16	0.00
8.20	2.00	0.00	0.00	0.16	0.00	8.37	2.00	0.00	0.00	0.16	0.00
8.53	2.00	0.00	0.00	0.16	0.00	8.69	2.00	0.00	0.00	0.16	0.00
8.86	2.00	0.00	0.00	0.16	0.00	9.02	0.35	0.65	0.35	0.16	0.28
9.19	0.33	0.67	0.34	0.16	0.29	9.35	0.31	0.69	0.33	0.16	0.29
9.51	0.31	0.69	0.33	0.16	0.29	9.68	0.32	0.68	0.33	0.16	0.29
9.84	0.33	0.67	0.34	0.16	0.29	10.01	0.34	0.66	0.34	0.16	0.28
10.17	0.33	0.67	0.34	0.16	0.28	10.34	0.32	0.68	0.33	0.16	0.29
10.50	0.31	0.69	0.33	0.16	0.29	10.66	0.26	0.74	0.30	0.16	0.31
10.83	0.30	0.70	0.32	0.16	0.29	10.99	0.30	0.70	0.32	0.16	0.29
11.15	0.31	0.69	0.33	0.16	0.29	11.32	0.34	0.66	0.34	0.16	0.27
11.48	0.38	0.62	0.37	0.16	0.25	11.65	0.41	0.59	0.39	0.16	0.24
11.81	0.41	0.59	0.40	0.16	0.24	11.97	0.40	0.60	0.39	0.16	0.24
12.14	0.39	0.61	0.38	0.16	0.25	12.30	0.38	0.62	0.37	0.16	0.25
12.47	0.39	0.61	0.38	0.16	0.25	12.63	0.37	0.63	0.36	0.16	0.25
12.79	0.35	0.65	0.35	0.16	0.26	12.96	0.35	0.65	0.35	0.16	0.26
13.12	0.36	0.64	0.36	0.16	0.26	13.29	0.37	0.63	0.37	0.16	0.25
13.45	0.37	0.63	0.37	0.16	0.25	13.62	0.38	0.62	0.37	0.16	0.25
13.78	0.40	0.60	0.39	0.16	0.24	13.94	0.42	0.58	0.40	0.16	0.23
14.11	0.42	0.58	0.40	0.16	0.23	14.27	0.38	0.62	0.37	0.16	0.24
14.44	0.40	0.60	0.39	0.16	0.23	14.60	0.41	0.59	0.39	0.16	0.23
14.76	0.40	0.60	0.38	0.16	0.23	14.93	0.27	0.73	0.31	0.16	0.28
15.09	0.19	0.81	0.27	0.16	0.31	15.26	0.18	0.82	0.27	0.16	0.32
15.42	2.00	0.00	0.00	0.16	0.00	15.58	0.17	0.83	0.27	0.16	0.32
15.75	0.19	0.81	0.27	0.16	0.31	15.91	0.20	0.80	0.28	0.16	0.30
16.08	0.19	0.81	0.27	0.16	0.30	16.24	0.20	0.80	0.28	0.16	0.30
16.40	0.20	0.80	0.28	0.16	0.30	16.57	0.20	0.80	0.28	0.16	0.30
16.73	0.21	0.79	0.28	0.16	0.29	16.90	0.25	0.75	0.30	0.16	0.28

:: Liquefaction Potential Index calculation data :: (continued)

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
17.06	0.27	0.73	0.31	0.16	0.27	17.22	0.29	0.71	0.32	0.16	0.26
17.39	0.62	0.38	0.67	0.16	0.14	17.55	1.19	0.00	0.00	0.16	0.00
17.72	1.25	0.00	0.00	0.16	0.00	17.88	0.85	0.00	0.00	0.16	0.05
18.05	0.58	0.42	0.59	0.16	0.15	18.21	0.45	0.55	0.42	0.16	0.20
18.37	0.69	0.31	0.89	0.16	0.11	18.54	1.28	0.00	0.00	0.16	0.00
18.70	2.00	0.00	0.00	0.16	0.00	18.86	1.71	0.00	0.00	0.16	0.00
19.03	0.58	0.42	0.59	0.16	0.15	19.19	2.00	0.00	0.00	0.16	0.00
19.36	2.00	0.00	0.00	0.16	0.00	19.52	2.00	0.00	0.00	0.16	0.00
19.68	2.00	0.00	0.00	0.16	0.00	19.85	2.00	0.00	0.00	0.16	0.00
20.01	2.00	0.00	0.00	0.16	0.00	20.18	2.00	0.00	0.00	0.16	0.00
20.34	2.00	0.00	0.00	0.16	0.00	20.50	2.00	0.00	0.00	0.16	0.00
20.67	0.26	0.74	0.30	0.16	0.25	20.83	0.28	0.72	0.31	0.16	0.24
21.00	0.30	0.70	0.32	0.16	0.24	21.16	2.00	0.00	0.00	0.16	0.00
21.32	2.00	0.00	0.00	0.16	0.00	21.49	2.00	0.00	0.00	0.16	0.00
21.65	2.00	0.00	0.00	0.16	0.00	21.82	2.00	0.00	0.00	0.16	0.00
21.98	2.00	0.00	0.00	0.16	0.00	22.15	2.00	0.00	0.00	0.16	0.00
22.31	2.00	0.00	0.00	0.16	0.00	22.47	2.00	0.00	0.00	0.16	0.00
22.64	2.00	0.00	0.00	0.16	0.00	22.80	0.23	0.77	0.29	0.16	0.25
22.97	0.33	0.67	0.34	0.16	0.22	23.13	0.46	0.54	0.44	0.16	0.17
23.29	0.42	0.58	0.40	0.16	0.19	23.46	0.29	0.71	0.32	0.16	0.23
23.62	2.00	0.00	0.00	0.16	0.00	23.79	2.00	0.00	0.00	0.16	0.00
23.95	2.00	0.00	0.00	0.16	0.00	24.11	2.00	0.00	0.00	0.16	0.00
24.28	2.00	0.00	0.00	0.16	0.00	24.44	2.00	0.00	0.00	0.16	0.00
24.61	2.00	0.00	0.00	0.16	0.00	24.77	0.28	0.72	0.31	0.16	0.23
24.93	0.30	0.70	0.32	0.16	0.22	25.10	0.33	0.67	0.34	0.16	0.21
25.26	0.33	0.67	0.34	0.16	0.20	25.43	0.33	0.67	0.34	0.16	0.21
25.59	0.33	0.67	0.34	0.16	0.20	25.75	0.30	0.70	0.32	0.16	0.21
25.92	0.27	0.73	0.31	0.16	0.22	26.08	2.00	0.00	0.00	0.16	0.00
26.25	2.00	0.00	0.00	0.16	0.00	26.41	2.00	0.00	0.00	0.16	0.00
26.57	2.00	0.00	0.00	0.16	0.00	26.74	2.00	0.00	0.00	0.16	0.00
26.90	2.00	0.00	0.00	0.16	0.00	27.07	2.00	0.00	0.00	0.16	0.00
27.23	2.00	0.00	0.00	0.16	0.00	27.39	2.00	0.00	0.00	0.16	0.00
27.56	2.00	0.00	0.00	0.16	0.00	27.72	2.00	0.00	0.00	0.16	0.00
27.89	0.19	0.81	0.27	0.16	0.23	28.05	0.21	0.79	0.28	0.16	0.23
28.21	0.30	0.70	0.32	0.16	0.20	28.38	0.34	0.66	0.35	0.16	0.19
28.54	0.29	0.71	0.31	0.16	0.20	28.71	0.25	0.75	0.30	0.16	0.21
28.87	0.24	0.76	0.30	0.16	0.21	29.04	2.00	0.00	0.00	0.16	0.00
29.20	2.00	0.00	0.00	0.16	0.00	29.36	2.00	0.00	0.00	0.16	0.00
29.53	2.00	0.00	0.00	0.16	0.00	29.69	2.00	0.00	0.00	0.16	0.00
29.86	2.00	0.00	0.00	0.16	0.00	30.02	2.00	0.00	0.00	0.16	0.00
30.18	2.00	0.00	0.00	0.16	0.00	30.35	2.00	0.00	0.00	0.16	0.00
30.51	2.00	0.00	0.00	0.16	0.00	30.68	2.00	0.00	0.00	0.16	0.00
30.84	2.00	0.00	0.00	0.16	0.00	31.00	2.00	0.00	0.00	0.16	0.00
31.17	0.32	0.68	0.33	0.16	0.18	31.33	0.38	0.62	0.37	0.16	0.16
31.50	0.31	0.69	0.33	0.16	0.18	31.66	0.29	0.71	0.32	0.16	0.18
31.82	0.36	0.64	0.36	0.16	0.17	31.99	0.62	0.38	0.67	0.16	0.10
32.15	1.93	0.00	0.00	0.16	0.00	32.32	2.00	0.00	0.00	0.16	0.00
32.48	2.00	0.00	0.00	0.16	0.00	32.64	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data :: (continued)

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
32.81	2.00	0.00	0.00	0.16	0.00	32.97	2.00	0.00	0.00	0.16	0.00
33.14	2.00	0.00	0.00	0.16	0.00	33.30	2.00	0.00	0.00	0.16	0.00
33.47	2.00	0.00	0.00	0.16	0.00	33.63	2.00	0.00	0.00	0.16	0.00
33.79	2.00	0.00	0.00	0.16	0.00	33.96	2.00	0.00	0.00	0.16	0.00
34.12	2.00	0.00	0.00	0.16	0.00	34.28	1.80	0.00	0.00	0.16	0.00
34.45	1.45	0.00	0.00	0.16	0.00	34.61	1.37	0.00	0.00	0.16	0.00
34.78	1.36	0.00	0.00	0.16	0.00	34.94	1.41	0.00	0.00	0.16	0.00
35.10	1.46	0.00	0.00	0.16	0.00	35.27	1.81	0.00	0.00	0.16	0.00
35.43	1.53	0.00	0.00	0.16	0.00	35.60	1.12	0.00	0.00	0.16	0.00
35.76	1.67	0.00	0.00	0.16	0.00	35.92	2.00	0.00	0.00	0.16	0.00
36.09	2.00	0.00	0.00	0.16	0.00	36.25	2.00	0.00	0.00	0.16	0.00
36.42	2.00	0.00	0.00	0.16	0.00	36.58	2.00	0.00	0.00	0.16	0.00
36.74	2.00	0.00	0.00	0.16	0.00	36.91	2.00	0.00	0.00	0.16	0.00
37.07	2.00	0.00	0.00	0.16	0.00	37.24	2.00	0.00	0.00	0.16	0.00
37.40	2.00	0.00	0.00	0.16	0.00	37.57	2.00	0.00	0.00	0.16	0.00
37.73	2.00	0.00	0.00	0.16	0.00	37.89	2.00	0.00	0.00	0.16	0.00
38.06	2.00	0.00	0.00	0.16	0.00	38.22	2.00	0.00	0.00	0.16	0.00
38.39	2.00	0.00	0.00	0.16	0.00	38.55	2.00	0.00	0.00	0.16	0.00
38.71	2.00	0.00	0.00	0.16	0.00	38.88	2.00	0.00	0.00	0.16	0.00
39.04	2.00	0.00	0.00	0.16	0.00	39.21	2.00	0.00	0.00	0.16	0.00
39.37	2.00	0.00	0.00	0.16	0.00	39.53	2.00	0.00	0.00	0.16	0.00
39.70	2.00	0.00	0.00	0.16	0.00	39.86	2.00	0.00	0.00	0.16	0.00
40.03	2.00	0.00	0.00	0.16	0.00	40.19	2.00	0.00	0.00	0.16	0.00
40.35	2.00	0.00	0.00	0.16	0.00	40.52	0.68	0.32	0.84	0.16	0.06
40.68	0.45	0.55	0.43	0.16	0.10	40.85	0.31	0.69	0.33	0.16	0.13
41.01	2.00	0.00	0.00	0.17	0.00	41.17	2.00	0.00	0.00	0.16	0.00
41.34	2.00	0.00	0.00	0.16	0.00	41.50	2.00	0.00	0.00	0.16	0.00
41.67	2.00	0.00	0.00	0.16	0.00	41.83	2.00	0.00	0.00	0.16	0.00
41.99	2.00	0.00	0.00	0.16	0.00	42.16	2.00	0.00	0.00	0.16	0.00
42.32	2.00	0.00	0.00	0.16	0.00	42.49	2.00	0.00	0.00	0.16	0.00
42.65	2.00	0.00	0.00	0.16	0.00	42.81	2.00	0.00	0.00	0.16	0.00
42.98	2.00	0.00	0.00	0.16	0.00	43.14	2.00	0.00	0.00	0.16	0.00
43.31	2.00	0.00	0.00	0.16	0.00	43.47	2.00	0.00	0.00	0.16	0.00
43.63	2.00	0.00	0.00	0.16	0.00	43.80	2.00	0.00	0.00	0.16	0.00
43.96	2.00	0.00	0.00	0.16	0.00	44.13	2.00	0.00	0.00	0.16	0.00
44.29	2.00	0.00	0.00	0.16	0.00	44.45	2.00	0.00	0.00	0.16	0.00
44.62	2.00	0.00	0.00	0.16	0.00	44.78	2.00	0.00	0.00	0.16	0.00
44.95	2.00	0.00	0.00	0.16	0.00	45.11	2.00	0.00	0.00	0.16	0.00
45.28	2.00	0.00	0.00	0.16	0.00	45.44	2.00	0.00	0.00	0.16	0.00
45.60	2.00	0.00	0.00	0.16	0.00	45.77	2.00	0.00	0.00	0.16	0.00
45.93	2.00	0.00	0.00	0.16	0.00	46.10	2.00	0.00	0.00	0.16	0.00
46.26	2.00	0.00	0.00	0.16	0.00	46.42	2.00	0.00	0.00	0.16	0.00
46.59	2.00	0.00	0.00	0.16	0.00	46.75	2.00	0.00	0.00	0.16	0.00
46.92	2.00	0.00	0.00	0.16	0.00	47.08	2.00	0.00	0.00	0.16	0.00
47.24	2.00	0.00	0.00	0.16	0.00	47.41	2.00	0.00	0.00	0.16	0.00
47.57	2.00	0.00	0.00	0.16	0.00	47.74	0.24	0.76	0.29	0.16	0.10
47.90	0.25	0.75	0.30	0.16	0.10	48.06	2.00	0.00	0.00	0.16	0.00
48.23	2.00	0.00	0.00	0.16	0.00	48.39	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data :: (continued)

Depth (ft)	FS	F_L	w_z	d_z	LPI	Depth (ft)	FS	F_L	w_z	d_z	LPI
48.56	2.00	0.00	0.00	0.16	0.00	48.72	2.00	0.00	0.00	0.16	0.00
48.88	2.00	0.00	0.00	0.16	0.00	49.05	2.00	0.00	0.00	0.16	0.00
49.21	2.00	0.00	0.00	0.16	0.00	49.38	0.31	0.69	0.33	0.16	0.09
49.54	0.33	0.67	0.34	0.16	0.08	49.70	0.36	0.64	0.36	0.16	0.08
49.87	0.50	0.50	0.48	0.16	0.06	50.03	0.41	0.59	0.39	0.16	0.07
50.20	0.32	0.68	0.33	0.16	0.08						

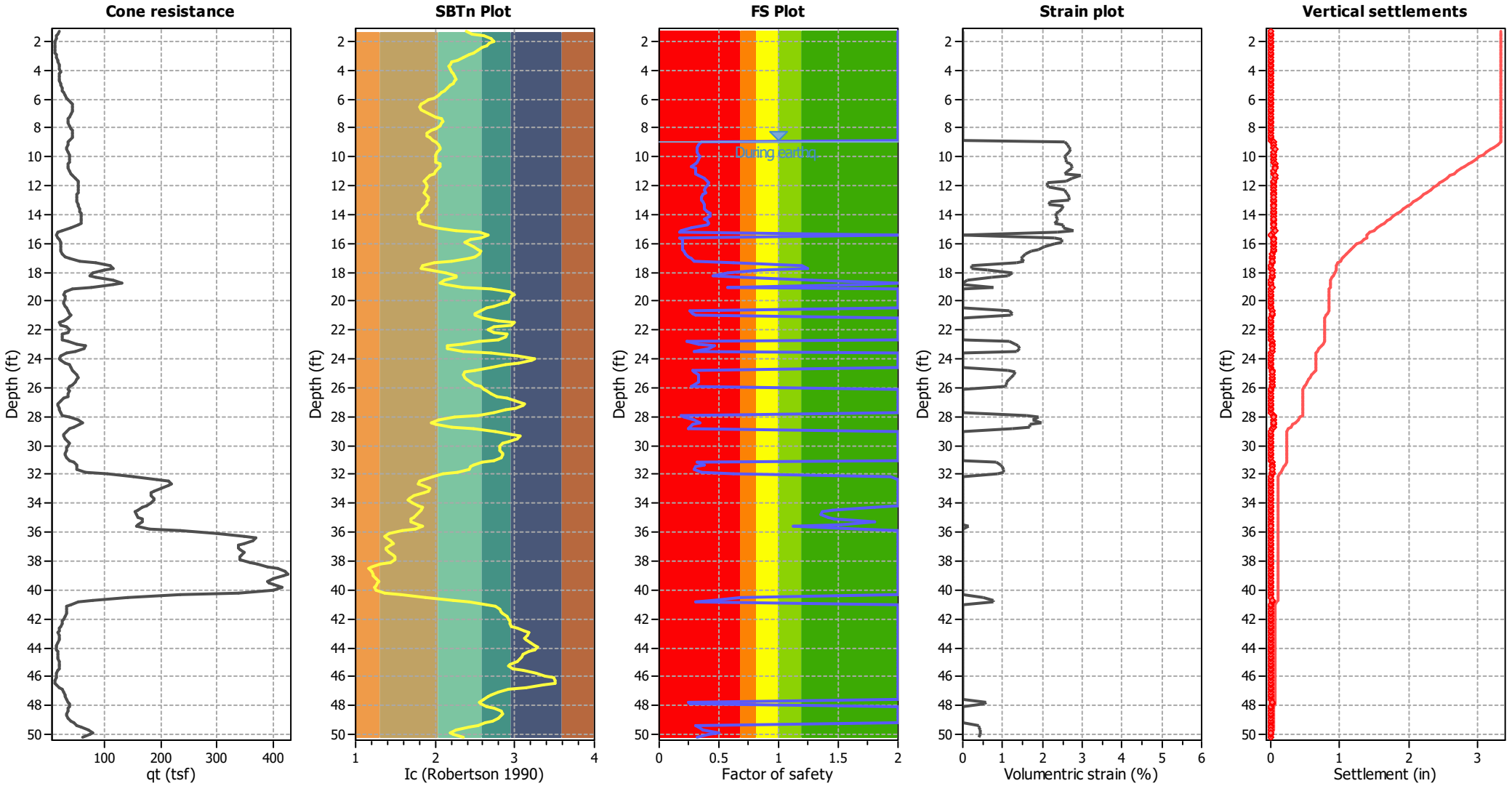
Overall liquefaction potential: 21.30

LPI = 0.00 - Liquefaction risk very low
LPI between 0.00 and 5.00 - Liquefaction risk low
LPI between 5.00 and 15.00 - Liquefaction risk high
LPI > 15.00 - Liquefaction risk very high

Abbreviations

FS: Calculated factor of safety for test point
F_L: 1 - FS
w_z: Function value of the extend of soil liquefaction according to depth
d_z: Layer thickness (ft)

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$q_{c,1,mod}$ (tsf)	$q_{c,1N,mod}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c,1,mod}$ (tsf)	$q_{c,1N,mod}$	FS	e_v (%)	DF	Settlement (in)
9.02	59.07	55.82	0.35	2.58	0.85	0.05	9.19	55.15	52.12	0.33	2.63	0.84	0.05
9.35	53.02	50.11	0.31	2.68	0.84	0.05	9.51	53.28	50.35	0.31	2.69	0.84	0.05
9.68	54.65	51.65	0.32	2.67	0.84	0.05	9.84	57.59	54.42	0.33	2.61	0.83	0.05
10.01	59.33	56.07	0.34	2.58	0.83	0.05	10.17	57.81	54.63	0.33	2.58	0.83	0.05
10.34	56.65	53.54	0.32	2.61	0.82	0.05	10.50	54.92	51.90	0.31	2.71	0.82	0.05
10.66	44.93	42.46	0.26	2.73	0.82	0.05	10.83	54.87	51.86	0.30	2.73	0.82	0.05
10.99	54.29	51.31	0.30	2.64	0.81	0.05	11.15	56.34	53.24	0.31	2.57	0.81	0.05
11.32	61.93	58.53	0.34	2.96	0.81	0.06	11.48	71.04	67.14	0.38	2.74	0.81	0.05
11.65	75.27	71.14	0.41	2.58	0.80	0.05	11.81	76.53	72.33	0.41	2.13	0.80	0.04
11.97	75.01	70.89	0.40	2.11	0.80	0.04	12.14	72.93	68.93	0.39	2.14	0.79	0.04
12.30	72.73	68.74	0.38	2.57	0.79	0.05	12.47	74.68	70.58	0.39	2.58	0.79	0.05
12.63	70.80	66.92	0.37	2.62	0.79	0.05	12.79	67.16	63.48	0.35	2.67	0.78	0.05
12.96	67.78	64.06	0.35	2.67	0.78	0.05	13.12	69.76	65.93	0.36	2.19	0.78	0.04
13.29	72.12	68.16	0.37	2.15	0.77	0.04	13.45	72.51	68.52	0.37	2.52	0.77	0.05
13.62	73.81	69.76	0.38	2.47	0.77	0.05	13.78	78.71	74.39	0.40	2.40	0.77	0.05
13.94	81.87	77.38	0.42	2.34	0.76	0.05	14.11	82.60	78.06	0.42	2.36	0.76	0.05
14.27	76.25	72.06	0.38	2.37	0.76	0.05	14.44	79.04	74.70	0.40	2.36	0.76	0.05
14.60	80.92	76.48	0.41	2.32	0.75	0.05	14.76	78.74	74.42	0.40	2.53	0.75	0.05
14.93	52.51	49.62	0.27	2.51	0.75	0.05	15.09	29.93	28.29	0.19	2.76	0.74	0.05
15.26	28.51	26.95	0.18	2.38	0.74	0.05	15.42	26.77	25.30	2.00	0.00	0.74	0.00
15.58	26.72	25.25	0.17	2.29	0.74	0.05	15.75	33.64	31.79	0.19	2.50	0.73	0.05
15.91	35.30	33.36	0.20	2.48	0.73	0.05	16.08	35.77	33.80	0.19	2.32	0.73	0.05
16.24	38.71	36.59	0.20	2.07	0.72	0.04	16.40	40.51	38.28	0.20	1.89	0.72	0.04
16.57	44.48	42.04	0.20	1.70	0.72	0.03	16.73	49.44	46.72	0.21	1.57	0.72	0.03
16.90	58.40	55.19	0.25	1.50	0.71	0.03	17.06	63.31	59.84	0.27	1.47	0.71	0.03
17.22	64.67	61.12	0.29	1.52	0.71	0.03	17.39	107.91	101.98	0.62	1.35	0.71	0.03
17.55	146.70	138.65	1.19	0.21	0.70	0.00	17.72	149.50	141.29	1.25	0.21	0.70	0.00
17.88	126.70	119.74	0.85	0.62	0.70	0.01	18.05	104.98	99.21	0.58	1.24	0.69	0.02
18.21	93.43	88.30	0.45	1.12	0.69	0.02	18.37	117.47	111.02	0.69	0.74	0.69	0.01
18.54	148.44	140.29	1.28	0.12	0.69	0.00	18.70	186.21	175.98	2.00	0.00	0.68	0.00
18.86	163.59	154.61	1.71	0.00	0.68	0.00	19.03	110.23	104.18	0.58	0.78	0.68	0.02
19.19	87.84	83.02	2.00	0.00	0.67	0.00	19.36	76.71	72.50	2.00	0.00	0.67	0.00
19.52	77.10	72.87	2.00	0.00	0.67	0.00	19.68	81.45	76.97	2.00	0.00	0.67	0.00
19.85	80.45	76.03	2.00	0.00	0.66	0.00	20.01	79.11	74.76	2.00	0.00	0.66	0.00
20.18	76.02	71.85	2.00	0.00	0.66	0.00	20.34	78.14	73.85	2.00	0.00	0.66	0.00
20.50	69.70	65.88	2.00	0.00	0.65	0.00	20.67	65.86	62.24	0.26	1.18	0.65	0.02
20.83	68.62	64.85	0.28	1.23	0.65	0.02	21.00	72.43	68.45	0.30	1.22	0.64	0.02
21.16	70.19	66.34	2.00	0.00	0.64	0.00	21.32	75.59	71.44	2.00	0.00	0.64	0.00
21.49	68.01	64.28	2.00	0.00	0.64	0.00	21.65	66.01	62.39	2.00	0.00	0.63	0.00
21.82	77.49	73.23	2.00	0.00	0.63	0.00	21.98	94.56	89.36	2.00	0.00	0.63	0.00
22.15	83.78	79.18	2.00	0.00	0.62	0.00	22.31	71.73	67.79	2.00	0.00	0.62	0.00
22.47	70.51	66.63	2.00	0.00	0.62	0.00	22.64	70.60	66.72	2.00	0.00	0.62	0.00
22.80	55.98	52.90	0.23	1.19	0.61	0.02	22.97	72.42	68.44	0.33	1.33	0.61	0.03
23.13	89.93	84.99	0.46	1.39	0.61	0.03	23.29	83.93	79.32	0.42	1.43	0.61	0.03
23.46	65.18	61.60	0.29	1.35	0.60	0.03	23.62	69.28	65.47	2.00	0.00	0.60	0.00
23.79	68.40	64.64	2.00	0.00	0.60	0.00	23.95	66.46	62.81	2.00	0.00	0.59	0.00
24.11	69.25	65.45	2.00	0.00	0.59	0.00	24.28	77.93	73.65	2.00	0.00	0.59	0.00
24.44	91.40	86.38	2.00	0.00	0.59	0.00	24.61	88.73	83.86	2.00	0.00	0.58	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$q_{c,1,mod}$ (tsf)	$q_{c,1N,mod}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c,1,mod}$ (tsf)	$q_{c,1N,mod}$	FS	e_v (%)	DF	Settlement (in)
24.77	64.78	61.22	0.28	1.14	0.58	0.02	24.93	65.45	61.86	0.30	1.32	0.58	0.03
25.10	70.55	66.67	0.33	1.29	0.57	0.03	25.26	72.69	68.70	0.33	1.21	0.57	0.02
25.43	72.14	68.17	0.33	1.19	0.57	0.02	25.59	73.60	69.56	0.33	1.11	0.57	0.02
25.75	68.63	64.86	0.30	1.11	0.56	0.02	25.92	64.76	61.20	0.27	1.07	0.56	0.02
26.08	64.40	60.87	2.00	0.00	0.56	0.00	26.25	69.97	66.13	2.00	0.00	0.56	0.00
26.41	80.95	76.50	2.00	0.00	0.55	0.00	26.57	79.66	75.29	2.00	0.00	0.55	0.00
26.74	76.75	72.53	2.00	0.00	0.55	0.00	26.90	67.42	63.72	2.00	0.00	0.54	0.00
27.07	64.28	60.75	2.00	0.00	0.54	0.00	27.23	63.56	60.07	2.00	0.00	0.54	0.00
27.39	65.36	61.77	2.00	0.00	0.54	0.00	27.56	52.22	49.36	2.00	0.00	0.53	0.00
27.72	39.06	36.91	2.00	0.00	0.53	0.00	27.89	31.11	29.40	0.19	1.63	0.53	0.03
28.05	34.69	32.78	0.21	1.92	0.52	0.04	28.21	57.02	53.89	0.30	1.75	0.52	0.03
28.38	66.88	63.21	0.34	1.98	0.52	0.04	28.54	54.46	51.47	0.29	1.68	0.52	0.03
28.71	47.57	44.96	0.25	1.67	0.51	0.03	28.87	50.56	47.78	0.24	1.26	0.51	0.02
29.04	68.35	64.60	2.00	0.00	0.51	0.00	29.20	73.62	69.57	2.00	0.00	0.51	0.00
29.36	72.00	68.05	2.00	0.00	0.50	0.00	29.53	74.33	70.25	2.00	0.00	0.50	0.00
29.69	82.75	78.21	2.00	0.00	0.50	0.00	29.86	83.90	79.30	2.00	0.00	0.49	0.00
30.02	79.83	75.45	2.00	0.00	0.49	0.00	30.18	78.84	74.51	2.00	0.00	0.49	0.00
30.35	72.10	68.14	2.00	0.00	0.49	0.00	30.51	72.99	68.98	2.00	0.00	0.48	0.00
30.68	74.64	70.54	2.00	0.00	0.48	0.00	30.84	76.54	72.34	2.00	0.00	0.48	0.00
31.00	73.25	69.23	2.00	0.00	0.47	0.00	31.17	72.07	68.11	0.32	0.84	0.47	0.02
31.33	77.12	72.88	0.38	0.93	0.47	0.02	31.50	64.55	61.01	0.31	0.99	0.47	0.02
31.66	60.34	57.02	0.29	1.02	0.46	0.02	31.82	70.94	67.04	0.36	1.02	0.46	0.02
31.99	101.63	96.05	0.62	0.87	0.46	0.02	32.15	165.98	156.87	1.93	0.00	0.46	0.00
32.32	203.17	192.01	2.00	0.00	0.45	0.00	32.48	217.65	205.70	2.00	0.00	0.45	0.00
32.64	217.95	205.98	2.00	0.00	0.45	0.00	32.81	218.23	206.25	2.00	0.00	0.44	0.00
32.97	206.56	195.22	2.00	0.00	0.44	0.00	33.14	188.04	177.71	2.00	0.00	0.44	0.00
33.30	180.75	170.82	2.00	0.00	0.44	0.00	33.47	175.89	166.23	2.00	0.00	0.43	0.00
33.63	177.68	167.92	2.00	0.00	0.43	0.00	33.79	178.87	169.05	2.00	0.00	0.43	0.00
33.96	176.19	166.51	2.00	0.00	0.42	0.00	34.12	169.52	160.21	2.00	0.00	0.42	0.00
34.28	162.04	153.14	1.80	0.00	0.42	0.00	34.45	149.75	141.53	1.45	0.00	0.42	0.00
34.61	146.27	138.24	1.37	0.00	0.41	0.00	34.78	146.18	138.15	1.36	0.00	0.41	0.00
34.94	148.56	140.40	1.41	0.00	0.41	0.00	35.10	150.98	142.69	1.46	0.00	0.41	0.00
35.27	163.30	154.34	1.81	0.00	0.40	0.00	35.43	152.43	144.06	1.53	0.00	0.40	0.00
35.60	133.78	126.43	1.12	0.16	0.40	0.00	35.76	157.28	148.64	1.67	0.00	0.39	0.00
35.92	215.67	203.83	2.00	0.00	0.39	0.00	36.09	271.52	256.61	2.00	0.00	0.39	0.00
36.25	327.17	309.20	2.00	0.00	0.39	0.00	36.42	346.96	327.91	2.00	0.00	0.38	0.00
36.58	331.71	313.49	2.00	0.00	0.38	0.00	36.74	311.58	294.47	2.00	0.00	0.38	0.00
36.91	305.96	289.16	2.00	0.00	0.37	0.00	37.07	299.12	282.69	2.00	0.00	0.37	0.00
37.24	302.81	286.18	2.00	0.00	0.37	0.00	37.40	310.34	293.30	2.00	0.00	0.37	0.00
37.57	322.63	304.91	2.00	0.00	0.36	0.00	37.73	290.97	274.99	2.00	0.00	0.36	0.00
37.89	312.33	295.18	2.00	0.00	0.36	0.00	38.06	315.04	297.74	2.00	0.00	0.35	0.00
38.22	326.22	308.31	2.00	0.00	0.35	0.00	38.39	334.35	315.99	2.00	0.00	0.35	0.00
38.55	348.58	329.44	2.00	0.00	0.35	0.00	38.71	365.26	345.20	2.00	0.00	0.34	0.00
38.88	369.12	348.85	2.00	0.00	0.34	0.00	39.04	365.69	345.61	2.00	0.00	0.34	0.00
39.21	343.07	324.23	2.00	0.00	0.34	0.00	39.37	323.72	305.94	2.00	0.00	0.33	0.00
39.53	334.21	315.86	2.00	0.00	0.33	0.00	39.70	350.44	331.19	2.00	0.00	0.33	0.00
39.86	358.71	339.01	2.00	0.00	0.32	0.00	40.03	356.92	337.32	2.00	0.00	0.32	0.00
40.19	310.77	293.70	2.00	0.00	0.32	0.00	40.35	198.35	187.45	2.00	0.00	0.32	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$q_{c,1,mod}$ (tsf)	$q_{c,1N,mod}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c,1,mod}$ (tsf)	$q_{c,1N,mod}$	FS	e_v (%)	DF	Settlement (in)
40.52	100.26	94.75	0.68	0.53	0.31	0.01	40.68	76.05	71.88	0.45	0.76	0.31	0.01
40.85	54.08	51.11	0.31	0.75	0.31	0.01	41.01	49.37	46.65	2.00	0.00	0.30	0.00
41.17	50.29	47.53	2.00	0.00	0.30	0.00	41.34	55.91	52.84	2.00	0.00	0.30	0.00
41.50	63.59	60.10	2.00	0.00	0.30	0.00	41.67	63.30	59.83	2.00	0.00	0.29	0.00
41.83	62.57	59.14	2.00	0.00	0.29	0.00	41.99	57.05	53.92	2.00	0.00	0.29	0.00
42.16	52.29	49.42	2.00	0.00	0.29	0.00	42.32	47.10	44.51	2.00	0.00	0.28	0.00
42.49	44.47	42.03	2.00	0.00	0.28	0.00	42.65	45.59	43.08	2.00	0.00	0.28	0.00
42.81	50.16	47.41	2.00	0.00	0.27	0.00	42.98	56.37	53.28	2.00	0.00	0.27	0.00
43.14	56.63	53.52	2.00	0.00	0.27	0.00	43.31	54.59	51.60	2.00	0.00	0.27	0.00
43.47	53.42	50.49	2.00	0.00	0.26	0.00	43.63	52.78	49.88	2.00	0.00	0.26	0.00
43.80	52.80	49.90	2.00	0.00	0.26	0.00	43.96	52.07	49.21	2.00	0.00	0.25	0.00
44.13	48.19	45.55	2.00	0.00	0.25	0.00	44.29	45.65	43.14	2.00	0.00	0.25	0.00
44.45	43.26	40.89	2.00	0.00	0.25	0.00	44.62	41.07	38.81	2.00	0.00	0.24	0.00
44.78	38.21	36.11	2.00	0.00	0.24	0.00	44.95	34.61	32.71	2.00	0.00	0.24	0.00
45.11	31.52	29.79	2.00	0.00	0.24	0.00	45.28	34.84	32.92	2.00	0.00	0.23	0.00
45.44	34.42	32.53	2.00	0.00	0.23	0.00	45.60	39.64	37.47	2.00	0.00	0.23	0.00
45.77	53.15	50.23	2.00	0.00	0.22	0.00	45.93	52.70	49.81	2.00	0.00	0.22	0.00
46.10	53.30	50.37	2.00	0.00	0.22	0.00	46.26	52.16	49.30	2.00	0.00	0.22	0.00
46.42	51.78	48.94	2.00	0.00	0.21	0.00	46.59	52.93	50.02	2.00	0.00	0.21	0.00
46.75	49.76	47.03	2.00	0.00	0.21	0.00	46.92	39.31	37.15	2.00	0.00	0.20	0.00
47.08	36.28	34.29	2.00	0.00	0.20	0.00	47.24	33.84	31.98	2.00	0.00	0.20	0.00
47.41	30.89	29.19	2.00	0.00	0.20	0.00	47.57	31.47	29.74	2.00	0.00	0.19	0.00
47.74	33.69	31.84	0.24	0.60	0.19	0.01	47.90	37.58	35.51	0.25	0.55	0.19	0.01
48.06	41.81	39.51	2.00	0.00	0.19	0.00	48.23	47.20	44.61	2.00	0.00	0.18	0.00
48.39	51.69	48.85	2.00	0.00	0.18	0.00	48.56	51.73	48.89	2.00	0.00	0.18	0.00
48.72	50.73	47.94	2.00	0.00	0.17	0.00	48.88	48.46	45.80	2.00	0.00	0.17	0.00
49.05	48.36	45.71	2.00	0.00	0.17	0.00	49.21	52.37	49.49	2.00	0.00	0.17	0.00
49.38	51.82	48.98	0.31	0.40	0.16	0.01	49.54	54.22	51.24	0.33	0.41	0.16	0.01
49.70	58.78	55.55	0.36	0.43	0.16	0.01	49.87	78.33	74.03	0.50	0.43	0.15	0.01
50.03	66.16	62.53	0.41	0.43	0.15	0.01	50.20	51.24	48.42	0.32	0.41	0.15	0.01

Total estimated settlement: 3.33

Abbreviations

$q_{c,1,mod}$: Equivalent clean sand cone resistance
$q_{c,1N,mod}$: Equivalent dean sand normalized cone resistance
FS: Factor of safety against liquefaction
e_v (%): Post-liquefaction volumentric strain
DF: e_v depth weighting factor
Settlement: Calculated settlement

:: Strength loss calculation (Robertson (2009) ::

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
1.31	18.47	29.56	2.31	68.19	2.39	0.03	0.62
1.48	16.96	27.12	2.76	74.96	2.47	0.02	0.62
1.64	14.72	23.50	3.88	91.11	2.61	0.03	0.62
1.80	13.33	21.26	4.65	98.94	2.69	0.03	0.62
1.97	12.18	19.40	5.05	98.04	2.73	0.03	0.62
2.13	11.49	18.28	4.60	84.01	2.69	0.02	0.62
2.30	11.18	17.76	4.14	73.53	2.64	0.02	0.62
2.46	11.05	17.54	3.69	64.81	2.59	0.02	0.62
2.63	11.41	18.10	3.25	58.87	2.54	0.02	0.62
2.79	11.90	18.89	2.83	53.37	2.48	0.02	0.62
2.95	12.79	20.30	2.47	50.21	2.42	0.02	0.62
3.12	14.05	22.32	2.12	47.40	2.35	0.02	0.62
3.28	15.73	25.00	1.84	46.00	2.28	0.02	0.62
3.44	17.43	27.72	1.00	27.72	2.21	0.02	0.62
3.61	18.63	29.63	1.00	29.63	2.18	0.02	0.62
3.77	19.69	31.33	1.00	31.33	2.17	0.02	0.62
3.94	19.98	31.78	1.58	50.27	2.19	0.02	0.62
4.10	20.31	32.29	1.61	52.04	2.20	0.02	0.62
4.26	19.91	31.63	1.69	53.37	2.23	0.02	0.62
4.43	19.84	31.50	1.74	54.68	2.24	0.02	0.62
4.59	19.56	31.04	1.78	55.34	2.26	0.02	0.62
4.76	19.72	31.29	1.76	55.09	2.25	0.02	0.62
4.92	20.35	32.29	1.70	54.88	2.23	0.02	0.62
5.08	21.69	34.42	1.60	55.00	2.19	0.03	0.62
5.25	23.37	37.11	1.51	56.08	2.15	0.03	0.62
5.41	24.88	39.53	1.45	57.13	2.12	0.03	0.62
5.58	26.37	41.90	1.39	58.41	2.08	0.04	0.62
5.74	28.42	45.19	1.34	60.73	2.04	0.04	0.62
5.91	31.51	50.14	1.00	50.14	1.98	0.07	0.64
6.07	35.15	55.97	1.00	55.97	1.91	0.11	0.66
6.23	38.56	61.43	1.00	61.43	1.86	0.18	0.67
6.40	41.16	65.60	1.00	65.60	1.82	0.26	0.68
6.56	42.78	68.18	1.00	68.18	1.81	0.34	0.69
6.73	43.16	68.77	1.00	68.77	1.83	0.36	0.69
6.89	41.96	66.85	1.00	66.85	1.87	0.31	0.69
7.05	39.31	62.56	1.26	78.70	1.93	0.21	0.68
7.22	36.04	57.30	1.32	75.47	2.01	0.14	0.66
7.38	33.75	53.60	1.39	74.41	2.08	0.10	0.65
7.55	33.49	53.18	1.42	75.50	2.10	0.11	0.66
7.71	34.75	55.19	1.40	77.22	2.09	0.15	0.67
7.87	36.40	57.82	1.36	78.62	2.05	0.17	0.67
8.04	38.58	61.32	1.31	80.44	2.01	0.19	0.67
8.20	41.46	65.91	1.27	83.42	1.94	0.29	0.69
8.37	43.50	68.71	1.24	85.06	1.90	0.45	0.70
8.53	43.39	67.70	1.24	83.72	1.90	0.36	0.69
8.69	41.04	63.77	1.25	79.91	1.92	0.24	0.68
8.86	38.24	59.42	1.28	76.03	1.96	0.15	0.67
9.02	35.58	55.28	1.31	72.50	2.01	0.11	0.65

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
9.19	33.57	52.16	1.35	70.53	2.05	0.08	0.64
9.35	32.63	50.26	1.36	68.58	2.06	0.07	0.64
9.51	32.89	50.02	1.36	67.97	2.05	0.07	0.64
9.68	34.32	51.31	1.33	68.44	2.03	0.07	0.64
9.84	36.11	53.13	1.32	70.02	2.01	0.09	0.65
10.01	37.22	54.05	1.31	70.75	2.00	0.11	0.65
10.17	37.38	53.71	1.31	70.34	2.00	0.10	0.65
10.34	36.69	52.32	1.32	69.01	2.01	0.09	0.65
10.50	33.96	48.34	1.36	65.64	2.05	0.08	0.64
10.66	33.90	47.74	1.36	64.79	2.05	0.04	0.62
10.83	34.12	47.55	1.36	64.48	2.05	0.08	0.64
10.99	37.18	50.93	1.32	67.14	2.01	0.07	0.64
11.15	39.11	53.09	1.30	68.93	1.99	0.08	0.65
11.32	43.22	57.84	1.00	57.84	1.94	0.13	0.66
11.48	47.91	63.24	1.00	63.24	1.89	0.28	0.69
11.65	51.77	67.78	1.00	67.78	1.86	0.39	0.70
11.81	53.18	69.66	1.23	85.39	1.88	0.44	0.70
11.97	52.99	69.39	1.24	85.91	1.90	0.39	0.70
12.14	52.11	67.91	1.24	83.95	1.90	0.32	0.69
12.30	52.01	67.11	1.00	67.11	1.87	0.32	0.69
12.47	51.56	66.23	1.00	66.23	1.87	0.38	0.69
12.63	50.45	64.79	1.00	64.79	1.89	0.27	0.69
12.79	49.06	63.00	1.00	63.00	1.91	0.20	0.68
12.96	49.09	62.81	1.00	62.81	1.91	0.21	0.68
13.12	50.56	64.41	1.24	79.74	1.90	0.25	0.68
13.29	51.89	65.75	1.23	80.98	1.89	0.30	0.69
13.45	52.88	66.55	1.00	66.55	1.88	0.31	0.69
13.62	54.37	67.86	1.00	67.86	1.85	0.35	0.69
13.78	56.49	69.91	1.00	69.91	1.82	0.52	0.70
13.94	58.54	71.83	1.00	71.83	1.79	0.68	0.71
14.11	57.93	70.81	1.00	70.81	1.79	0.71	0.71
14.27	57.50	70.13	1.00	70.13	1.79	0.43	0.70
14.44	57.53	70.08	1.00	70.08	1.81	0.54	0.70
14.60	58.65	71.27	1.00	71.27	1.81	0.63	0.71
14.76	52.39	63.93	1.00	63.93	1.86	0.53	0.70
14.93	39.14	48.62	1.32	64.18	2.01	0.06	0.63
15.09	24.64	31.45	1.81	56.85	2.27	0.02	0.62
15.26	15.44	20.19	3.37	68.06	2.55	0.02	0.62
15.42	13.10	17.17	4.32	74.10	2.66	0.02	0.62
15.58	15.15	19.68	3.59	70.59	2.58	0.02	0.62
15.75	19.03	24.32	2.59	63.02	2.44	0.02	0.62
15.91	22.17	28.09	2.26	63.37	2.38	0.02	0.62
16.08	22.50	28.53	2.40	68.56	2.41	0.02	0.62
16.24	21.86	27.85	2.82	78.44	2.48	0.03	0.62
16.40	21.42	27.36	3.18	87.12	2.53	0.03	0.62
16.57	21.79	27.89	3.53	98.43	2.57	0.04	0.62
16.73	25.03	31.95	3.38	107.92	2.55	0.05	0.62
16.90	30.12	38.17	2.98	113.70	2.50	0.10	0.65

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
17.06	36.90	46.26	2.51	115.95	2.42	0.15	0.67
17.22	55.27	67.41	1.64	110.80	2.21	0.16	0.67
17.39	83.19	98.39	1.30	127.44	1.99	0.76	0.76
17.55	109.57	126.76	1.19	150.72	1.84	0.82	0.82
17.72	114.88	132.18	1.18	155.48	1.82	0.83	0.83
17.88	100.73	116.92	1.25	146.69	1.93	0.79	0.79
18.05	79.96	94.67	1.47	139.17	2.13	0.76	0.76
18.21	72.59	86.91	1.81	156.90	2.27	0.74	0.74
18.37	84.33	100.52	1.78	179.14	2.26	0.78	0.78
18.54	113.88	133.13	1.45	192.79	2.12	0.82	0.82
18.70	129.48	149.80	1.37	205.50	2.06	0.87	0.87
18.86	114.36	132.57	1.47	194.82	2.13	0.84	0.84
19.03	76.52	90.15	2.16	194.80	2.36	0.77	0.77
19.19	42.83	51.59	4.74	244.46	2.70	0.72	0.72
19.36	29.03	35.14	7.78	273.41	2.94	0.44	0.70
19.52	27.23	32.66	8.65	282.46	2.99	0.46	0.70
19.68	28.50	34.00	8.17	277.94	2.96	0.66	0.71
19.85	29.18	34.61	7.73	267.48	2.93	0.61	0.71
20.01	27.48	32.31	7.52	243.04	2.92	0.54	0.71
20.18	27.39	31.76	6.40	203.35	2.84	0.42	0.70
20.34	28.39	32.47	5.17	167.92	2.74	0.50	0.70
20.50	30.88	34.94	4.19	146.51	2.65	0.25	0.68
20.67	34.18	38.35	3.55	136.18	2.58	0.18	0.67
20.83	38.12	42.45	3.03	128.73	2.51	0.23	0.68
21.00	38.83	43.02	2.99	128.79	2.50	0.31	0.69
21.16	34.22	37.88	3.76	142.26	2.60	0.26	0.68
21.32	25.97	28.74	5.80	166.65	2.80	0.40	0.70
21.49	19.86	21.72	8.61	187.03	2.99	0.22	0.68
21.65	21.21	23.15	7.95	184.15	2.95	0.18	0.67
21.82	30.69	33.47	5.06	169.24	2.73	0.47	0.70
21.98	36.29	39.44	4.42	174.24	2.67	0.74	0.74
22.15	33.86	36.68	5.10	186.90	2.74	0.72	0.72
22.31	25.23	27.14	7.25	196.67	2.90	0.29	0.69
22.47	23.15	24.60	6.93	170.46	2.88	0.27	0.68
22.64	25.01	26.39	5.67	149.53	2.78	0.27	0.68
22.80	35.49	37.28	3.38	125.90	2.55	0.08	0.64
22.97	51.25	53.46	2.04	108.89	2.33	0.31	0.69
23.13	65.18	67.40	1.52	102.63	2.16	0.73	0.73
23.29	63.11	64.97	1.52	98.77	2.16	0.72	0.72
23.46	48.03	49.44	2.12	104.76	2.35	0.17	0.67
23.62	31.40	32.30	4.68	151.23	2.70	0.24	0.68
23.79	21.98	22.29	9.47	211.12	3.04	2.14	1.59
23.95	19.15	19.13	13.73	262.52	3.24	3.02	1.37
24.11	22.36	22.44	13.16	295.27	3.22	3.97	1.60
24.28	30.51	30.94	9.69	299.83	3.05	4.49	2.21
24.44	36.82	37.38	6.90	257.83	2.88	0.73	0.73
24.61	40.05	40.27	4.71	189.81	2.70	0.73	0.73
24.77	41.73	41.50	2.99	123.97	2.50	0.17	0.67

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
24.93	46.02	45.51	2.26	102.97	2.38	0.18	0.67
25.10	50.57	49.90	2.11	105.37	2.35	0.27	0.68
25.26	51.86	51.03	2.21	112.91	2.37	0.32	0.69
25.43	50.72	49.70	2.31	114.77	2.39	0.30	0.69
25.59	47.63	46.48	2.67	124.19	2.45	0.34	0.69
25.75	42.82	41.51	2.98	123.80	2.50	0.23	0.68
25.92	38.12	36.71	3.49	128.17	2.57	0.17	0.67
26.08	35.62	34.08	3.82	130.17	2.61	0.16	0.67
26.25	36.45	34.77	4.12	143.14	2.64	0.25	0.68
26.41	35.40	33.61	4.76	160.02	2.71	0.63	0.71
26.57	33.16	31.28	5.47	170.96	2.77	0.57	0.71
26.74	26.72	24.84	7.24	179.86	2.90	0.45	0.70
26.90	21.75	19.84	9.09	180.27	3.02	1.56	1.42
27.07	17.49	15.58	11.17	174.04	3.13	1.42	1.11
27.23	16.89	14.92	10.81	161.36	3.11	1.20	1.07
27.39	17.74	15.67	9.06	141.99	3.02	0.98	1.12
27.56	19.19	16.99	6.97	118.45	2.88	0.06	0.63
27.72	20.57	18.23	5.07	92.38	2.73	0.03	0.62
27.89	24.83	22.21	3.21	71.28	2.53	0.02	0.62
28.05	37.01	33.68	1.72	57.96	2.24	0.02	0.62
28.21	52.16	47.93	1.34	64.15	2.03	0.09	0.65
28.38	59.71	54.93	1.00	54.93	1.95	0.20	0.68
28.54	55.33	50.66	1.32	66.75	2.01	0.07	0.64
28.71	44.81	40.60	1.65	66.88	2.21	0.04	0.62
28.87	36.89	33.01	2.83	93.43	2.48	0.05	0.63
29.04	31.36	27.67	5.27	145.89	2.75	0.22	0.68
29.20	27.91	24.32	8.15	198.17	2.96	0.34	0.69
29.36	26.98	23.34	10.01	233.58	3.07	2.70	1.67
29.53	30.16	26.13	9.22	240.81	3.02	2.96	1.87
29.69	34.28	29.75	7.62	226.69	2.93	0.71	0.71
29.86	36.27	31.43	6.40	201.17	2.84	0.72	0.72
30.02	35.33	30.45	5.89	179.35	2.80	0.58	0.71
30.18	32.51	27.76	5.89	163.54	2.80	0.53	0.70
30.35	30.62	25.94	6.00	155.68	2.81	0.30	0.69
30.51	29.09	24.43	6.43	157.03	2.84	0.33	0.69
30.68	29.70	24.87	6.49	161.30	2.85	0.37	0.69
30.84	31.68	26.52	6.24	165.39	2.83	0.44	0.70
31.00	36.66	30.86	5.10	157.25	2.74	0.33	0.69
31.17	45.07	38.29	3.63	139.02	2.59	0.30	0.69
31.33	49.32	42.01	2.89	121.57	2.49	0.46	0.70
31.50	49.61	42.15	2.67	112.72	2.45	0.16	0.67
31.66	50.64	42.94	2.50	107.50	2.42	0.12	0.66
31.82	66.54	56.99	1.87	106.75	2.29	0.28	0.69
31.99	105.26	91.40	1.40	128.39	2.09	0.75	0.75
32.15	152.62	133.45	1.28	170.45	1.96	0.85	0.85
32.32	193.84	170.13	1.20	204.65	1.85	0.89	0.89
32.48	213.18	187.12	1.15	215.93	1.80	0.91	0.91
32.64	218.38	191.24	1.14	218.83	1.79	0.91	0.91

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
32.81	212.89	185.37	1.20	222.35	1.85	0.91	0.91
32.97	201.32	174.04	1.25	218.18	1.93	0.89	0.89
33.14	189.26	163.05	1.25	203.83	1.92	0.87	0.87
33.30	182.98	157.55	1.21	190.99	1.86	0.87	0.87
33.47	184.02	159.17	1.04	166.17	1.73	0.86	0.86
33.63	186.81	161.72	1.00	161.72	1.67	0.86	0.86
33.79	187.43	161.91	1.00	161.91	1.66	0.86	0.86
33.96	183.42	157.51	1.03	162.66	1.72	0.86	0.86
34.12	175.90	149.99	1.14	171.22	1.79	0.85	0.85
34.28	165.98	140.70	1.19	166.90	1.83	0.84	0.84
34.45	158.47	133.92	1.18	158.46	1.83	0.83	0.83
34.61	154.51	130.35	1.17	151.86	1.81	0.82	0.82
34.78	155.87	131.52	1.12	146.85	1.77	0.82	0.82
34.94	159.33	134.48	1.06	142.16	1.73	0.83	0.83
35.10	166.53	140.74	1.00	140.74	1.69	0.83	0.83
35.27	167.54	141.16	1.00	141.16	1.70	0.84	0.84
35.43	159.67	133.36	1.13	150.78	1.78	0.83	0.83
35.60	156.70	129.94	1.19	155.18	1.84	0.80	0.80
35.76	181.13	151.11	1.08	163.71	1.75	0.84	0.84
35.92	234.84	198.53	1.00	198.53	1.58	0.90	0.90
36.09	299.91	256.57	1.00	256.57	1.42	0.95	0.95
36.25	349.29	299.74	1.00	299.74	1.37	1.00	1.00
36.42	370.40	317.08	1.00	317.08	1.38	1.01	1.01
36.58	363.58	308.97	1.00	308.97	1.45	1.00	1.00
36.74	348.73	295.12	1.00	295.12	1.47	0.99	0.99
36.91	339.35	287.19	1.00	287.19	1.44	0.98	0.98
37.07	338.65	287.62	1.00	287.62	1.38	0.98	0.98
37.24	341.33	289.17	1.00	289.17	1.38	0.98	0.98
37.40	348.75	294.12	1.00	294.12	1.41	0.99	0.99
37.57	342.84	287.08	1.00	287.08	1.47	1.00	1.00
37.73	342.66	285.66	1.00	285.66	1.49	0.97	0.97
37.89	341.09	283.63	1.00	283.63	1.50	0.99	0.99
38.06	358.39	299.39	1.00	299.39	1.43	0.99	0.99
38.22	372.99	315.08	1.00	315.08	1.30	1.00	1.00
38.39	391.40	333.68	1.00	333.68	1.20	1.00	1.00
38.55	408.33	348.70	1.00	348.70	1.17	1.01	1.01
38.71	421.40	357.98	1.00	357.98	1.21	1.03	1.03
38.88	427.31	362.07	1.00	362.07	1.22	1.03	1.03
39.04	418.90	354.08	1.00	354.08	1.22	1.03	1.03
39.21	401.54	337.52	1.00	337.52	1.26	1.01	1.01
39.37	389.68	325.97	1.00	325.97	1.29	1.00	1.00
39.53	393.48	329.08	1.00	329.08	1.27	1.00	1.00
39.70	408.36	341.92	1.00	341.92	1.25	1.02	1.02
39.86	418.10	349.96	1.00	349.96	1.24	1.02	1.02
40.03	402.57	335.48	1.00	335.48	1.26	1.02	1.02
40.19	338.71	278.32	1.00	278.32	1.36	0.99	0.99
40.35	235.90	188.35	1.00	188.35	1.57	0.89	0.89
40.52	139.85	106.64	1.22	130.26	1.88	0.75	0.75

:: Strength loss calculation (Robertson (2009) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
40.68	78.81	56.77	1.67	94.52	2.22	0.42	0.70
40.85	53.51	36.90	2.56	94.33	2.43	0.07	0.64
41.01	38.50	25.34	4.11	104.11	2.64	0.05	0.62
41.17	32.89	21.04	5.25	110.50	2.75	0.05	0.63
41.34	32.73	20.71	5.98	123.82	2.81	0.08	0.64
41.50	32.94	20.71	6.30	130.53	2.84	0.15	0.67
41.67	33.03	20.70	6.59	136.33	2.86	0.15	0.67
41.83	30.19	18.71	7.13	133.31	2.89	0.14	0.66
41.99	27.66	16.94	7.46	126.30	2.92	0.09	0.65
42.16	25.19	15.23	7.75	118.05	2.94	0.06	0.63
42.32	23.43	14.00	7.75	108.46	2.94	0.04	0.62
42.49	21.95	12.97	8.08	104.79	2.96	0.04	0.62
42.65	19.74	11.46	9.17	105.06	3.02	0.44	0.82
42.81	18.07	10.31	10.90	112.38	3.11	0.55	0.74
42.98	17.26	9.74	12.17	118.51	3.17	0.61	0.70
43.14	17.90	10.13	11.76	119.11	3.16	0.60	0.72
43.31	18.53	10.51	11.12	116.83	3.13	0.58	0.75
43.47	17.92	10.07	11.35	114.26	3.14	0.55	0.72
43.63	16.35	9.01	12.47	112.33	3.19	0.51	0.64
43.80	14.65	7.87	13.92	109.52	3.25	0.48	0.56
43.96	13.79	7.29	14.67	106.89	3.28	0.44	0.52
44.13	14.30	7.59	13.72	104.11	3.24	0.42	0.54
44.29	15.62	8.41	12.15	102.22	3.17	0.42	0.60
44.45	17.01	9.28	10.79	100.22	3.11	0.41	0.66
44.62	17.46	9.54	10.24	97.71	3.08	0.40	0.68
44.78	17.37	9.45	9.96	94.19	3.07	0.36	0.68
44.95	17.72	9.64	9.25	89.23	3.03	0.32	0.69
45.11	19.60	10.81	7.80	84.34	2.94	0.02	0.62
45.28	20.08	11.08	7.63	84.54	2.93	0.02	0.62
45.44	19.26	10.53	8.45	88.95	2.98	0.02	0.62
45.60	16.65	8.84	10.82	95.70	3.11	0.37	0.63
45.77	14.60	7.53	14.42	108.50	3.27	0.39	0.54
45.93	13.54	6.83	17.38	118.65	3.38	0.63	0.49
46.10	12.55	6.18	20.72	128.15	3.48	0.64	0.44
46.26	12.25	5.97	21.64	129.22	3.51	0.68	0.43
46.42	12.16	5.90	21.74	128.17	3.51	0.66	0.42
46.59	14.36	7.24	16.71	120.95	3.36	0.61	0.52
46.75	18.41	9.73	11.31	110.02	3.13	0.48	0.70
46.92	23.48	12.83	7.43	95.34	2.92	0.03	0.62
47.08	27.23	15.19	5.65	85.88	2.78	0.02	0.62
47.24	29.00	16.44	4.79	78.74	2.71	0.02	0.62
47.41	30.22	17.30	4.27	73.89	2.66	0.02	0.62
47.57	32.02	18.55	3.78	70.04	2.60	0.02	0.62
47.74	34.99	20.52	3.43	70.38	2.56	0.02	0.62
47.90	36.82	21.59	3.51	75.84	2.57	0.02	0.62
48.06	37.03	21.40	4.13	88.40	2.64	0.03	0.62
48.23	35.55	20.09	5.11	102.77	2.74	0.04	0.62
48.39	33.76	18.69	6.13	114.53	2.82	0.06	0.63

:: Strength loss calculation (Robertson (2009) :: (continued)

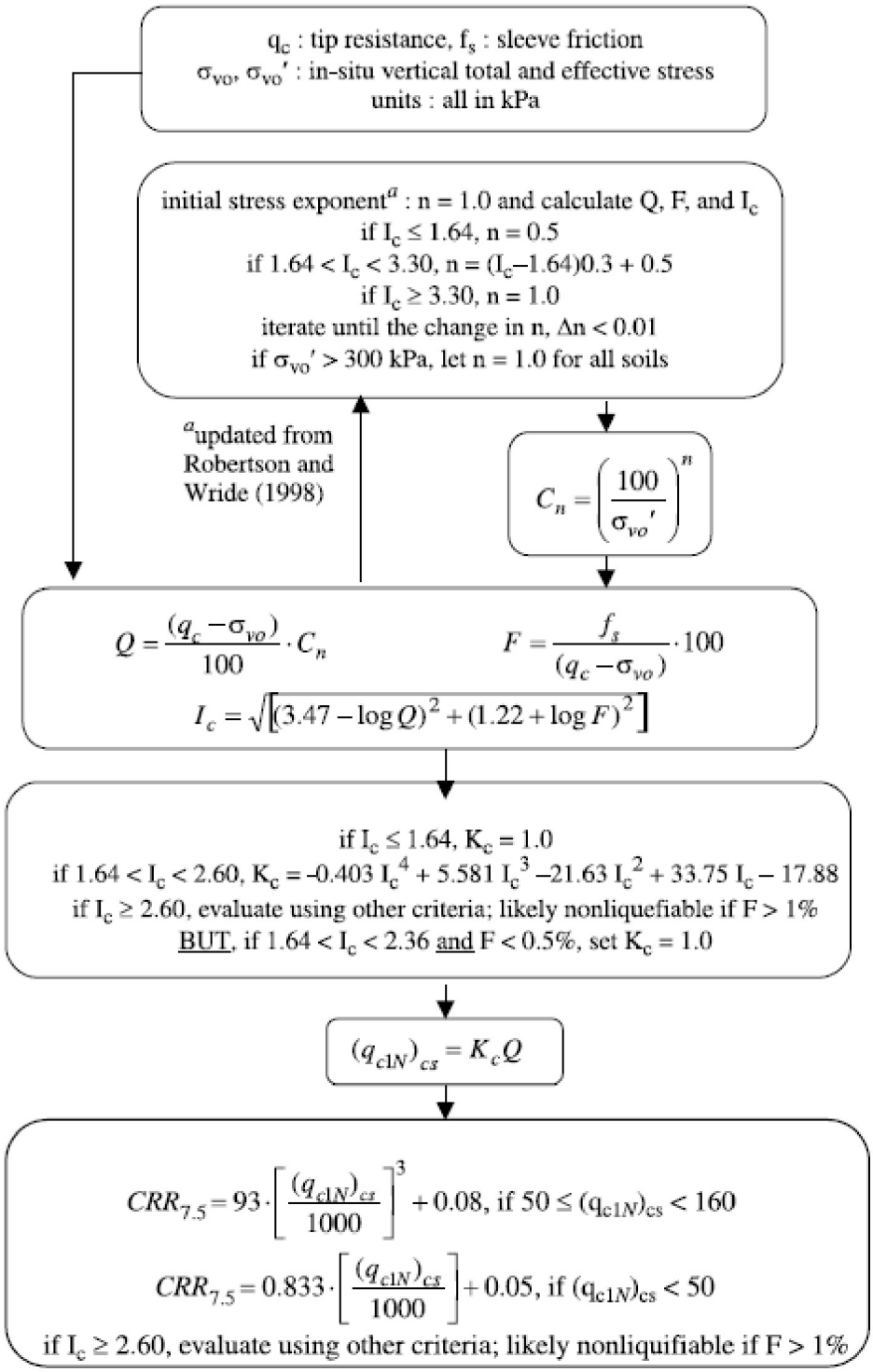
Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
48.56	32.72	18.01	6.47	116.42	2.85	0.06	0.63
48.72	32.75	17.97	6.31	113.31	2.84	0.06	0.63
48.88	34.52	19.04	5.70	108.62	2.79	0.05	0.62
49.05	38.76	21.82	4.82	105.14	2.71	0.05	0.62
49.21	43.87	25.21	4.01	101.20	2.63	0.06	0.63
49.38	50.18	29.49	3.23	95.36	2.54	0.06	0.63
49.54	57.58	34.63	2.56	88.50	2.43	0.07	0.64
49.70	71.83	44.83	1.82	81.59	2.27	0.10	0.65
49.87	78.47	49.68	1.61	79.84	2.20	0.51	0.70
50.03	74.13	46.43	1.70	78.83	2.23	0.19	0.67
50.20	61.76	37.40	2.16	80.89	2.36	0.06	0.63

Abbreviations

q_t: Total cone resistance
K_c: Cone resistance correction factor due to fines
$Q_{tn,cs}$: Adjusted and corrected cone resistance due to fines
I_c: Soil behavior type index
$S_{u(liq)}/\sigma'_v$: Calculated liquefied undrained strength ratio
$S_{u(peak)}/\sigma'_v$: Calculated peak undrained strength ratio

Procedure for the evaluation of soil liquefaction resistance, NCEER (1998)

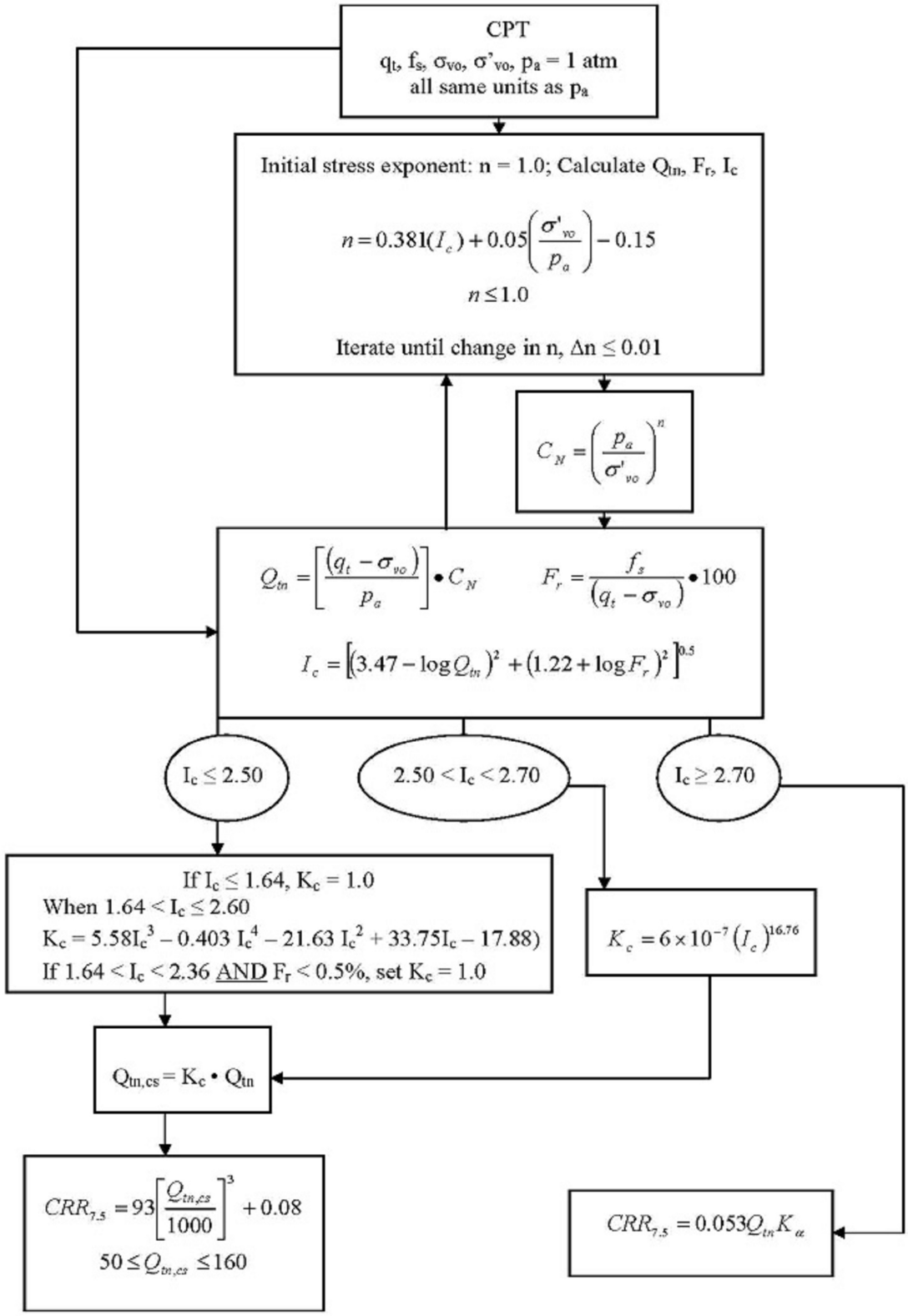
Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. The procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:



[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

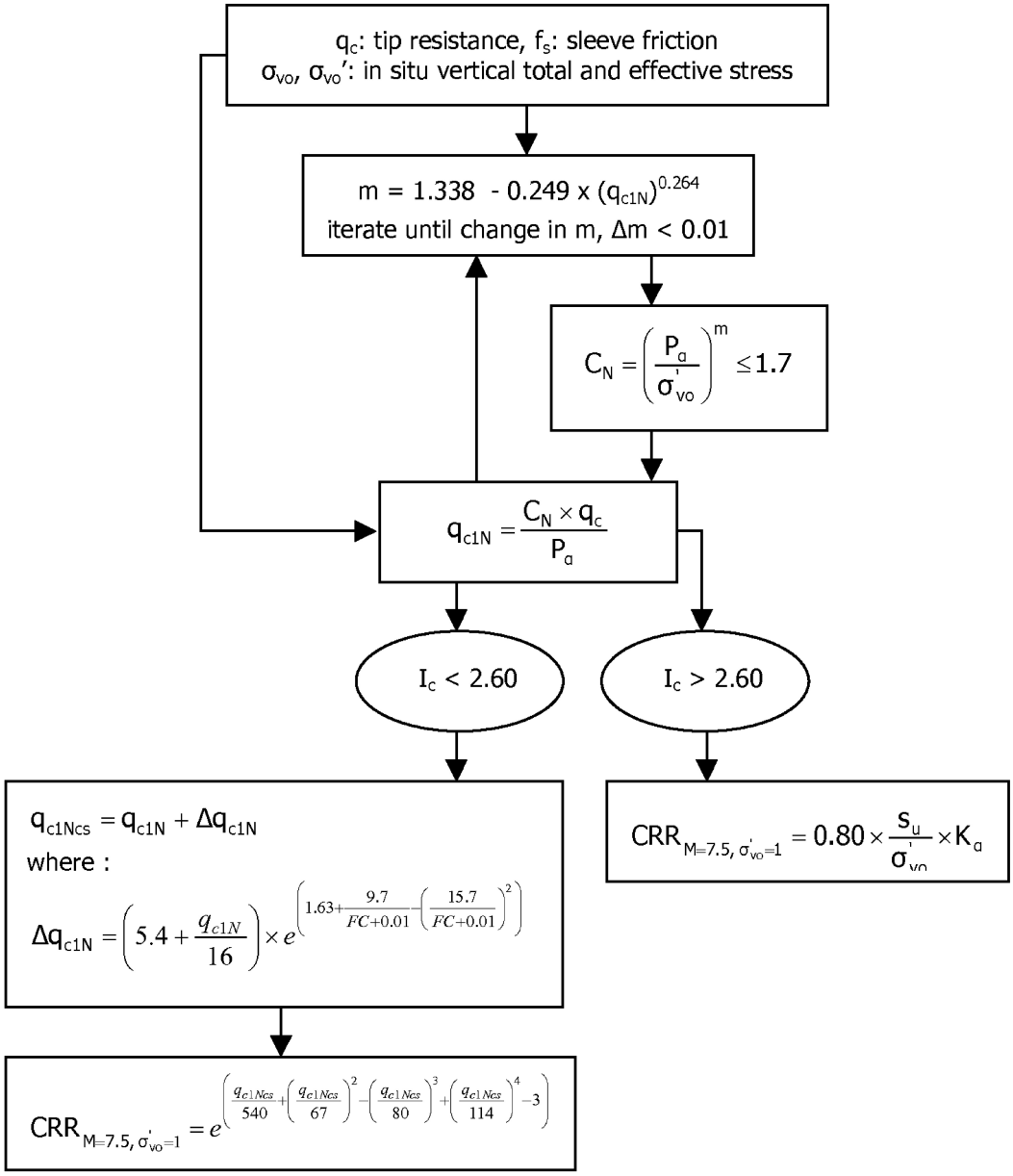
Procedure for the evaluation of soil liquefaction resistance (all soils), Robertson (2010)

Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. This procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:

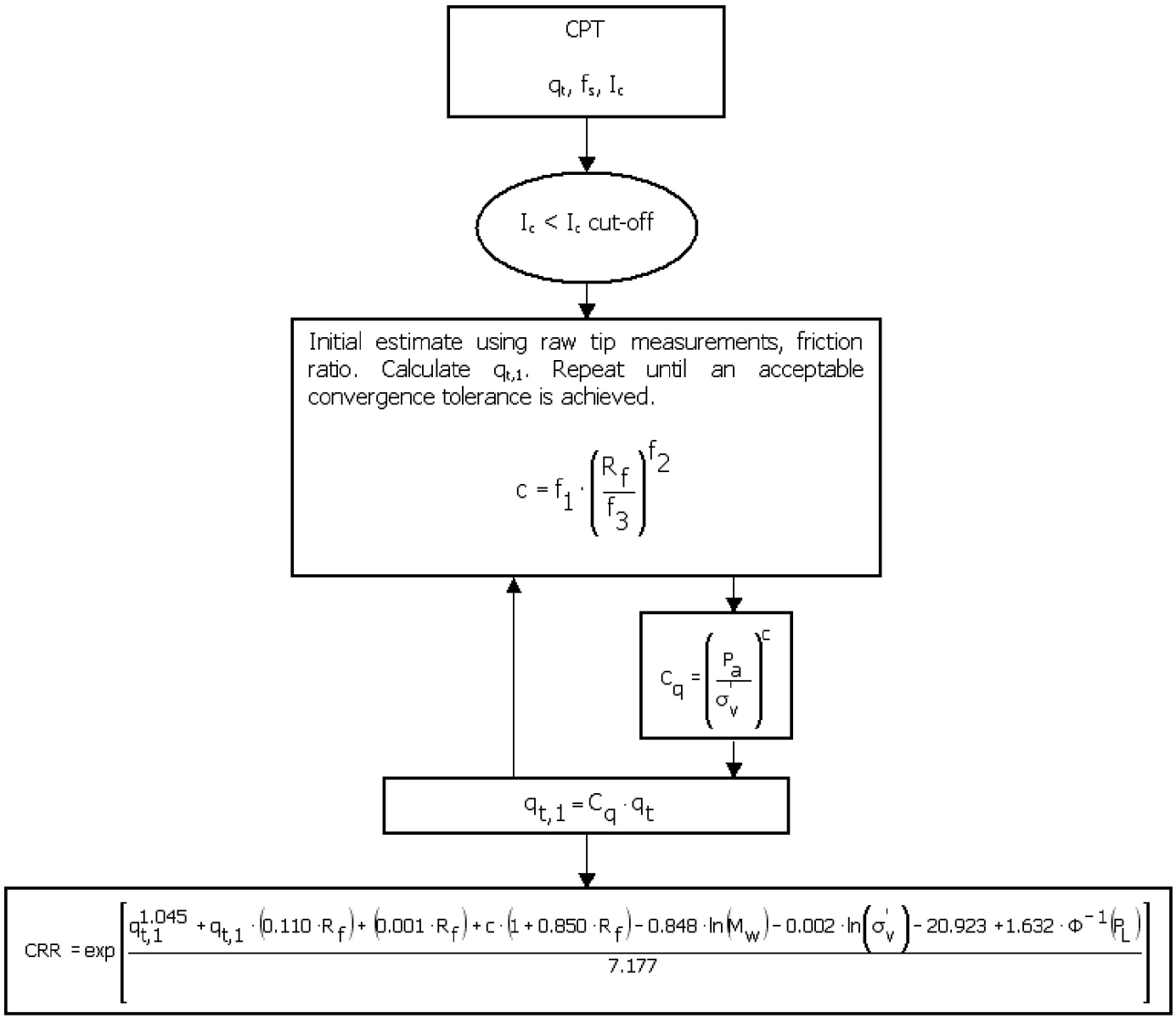


[1] P.K. Robertson, 2009. "Performance based earthquake design using the CPT", Keynote Lecture, International Conference on Performance-based Design in Earthquake Geotechnical Engineering – from case history to practice, IS-Tokyo, June 2009

Procedure for the evaluation of soil liquefaction resistance, Idriss & Boulanger (2008)



Procedure for the evaluation of soil liquefaction resistance (sandy soils), Moss et al. (2006)



Procedure for the evaluation of soil liquefaction resistance, Boulanger & Idriss(2014)

$$FS_{liq} = \frac{CRR_{M=7.5,\sigma'_v=1atm}}{CSR_{M=7.5,\sigma'_v=1atm}}$$

$$CSR_{M=7.5,\sigma'_v=1atm} = 0.65 \frac{\sigma_v}{\sigma'_v} \frac{a_{max}}{g} r_d \frac{1}{MSF} \frac{1}{K_\sigma}$$

$$r_d = \exp\left[\alpha(z) + \beta(z) \cdot M\right]$$

$$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$$

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \le 1.1$$

$$C_\sigma = \frac{1}{37.3 - 8.27\left(q_{c1Ncs}\right)^{0.264}} \le 0.3$$

$$MSF = 1 + \left(MSF_{max} - 1\right)\left(8.64 \exp\left(\frac{-M}{4}\right) - 1.325\right)$$

$$MSF_{max} = 1.09 + \left(\frac{q_{c1Ncs}}{180}\right)^3 \le 2.2$$

σ'_v *and* σ_v *at start of earthquake shaking*

$$CRR_{M=7.5,\sigma'_v=1atm} = \exp\left(\frac{q_{c1Ncs}}{113} + \left(\frac{q_{c1Ncs}}{1000}\right)^2 - \left(\frac{q_{c1Ncs}}{140}\right)^3 + \left(\frac{q_{c1Ncs}}{137}\right)^4 - 2.80\right)$$

$$q_{c1Ncs} = q_{c1N} + \Delta q_{c1N}$$

$$\Delta q_{c1N} = \left(11.9 + \frac{q_{c1N}}{14.6}\right) \exp\left(1.63 - \frac{9.7}{FC+2} - \left(\frac{15.7}{FC+2}\right)^2\right)$$

$$q_{c1N} = C_{Ne} \frac{q_c}{P_a}$$

$$C_{Ne} = \left(\frac{P_a}{\sigma'_v}\right)^m \le 1.7$$

$$m = 1.338 - 0.249\left(q_{c1Ncs}\right)^{0.264} \quad with \quad 0.264 \le m \le 0.782$$

$$FC = 80\left(I_C + C_{FC}\right) - 137 \quad with \quad 0\% \le FC \le 100\%$$

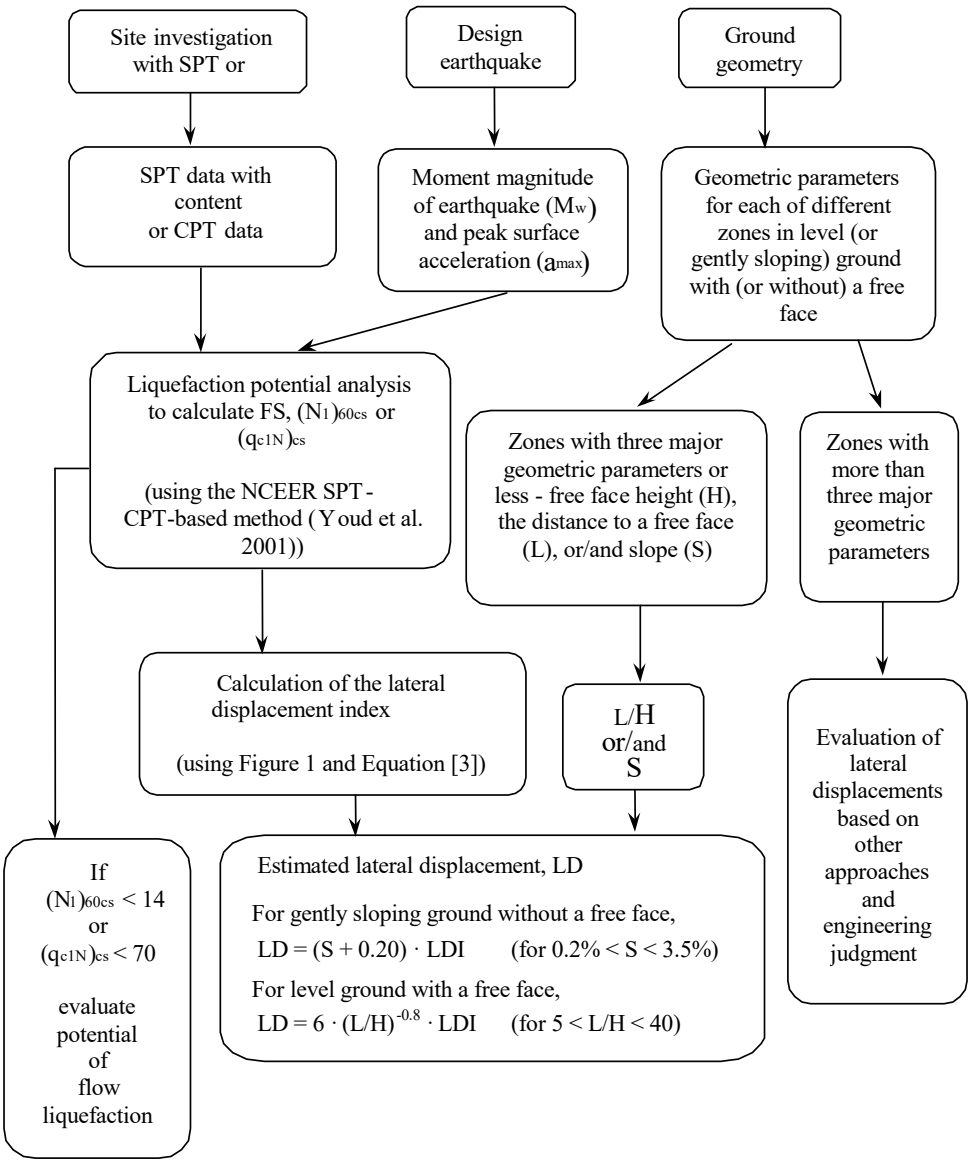
$$I_c = \left[\left(3.47 - \log\left(Q\right)\right)^2 + \left(1.22 + \log\left(F\right)\right)^2\right]^{0.5}$$

$$Q = \left(\frac{q_c - \sigma_{vc}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vc}}\right)^n \; with \; 0.5 \le n \le 1.0 \; per \; Robertson \; \& \; Wride \; (1998)$$

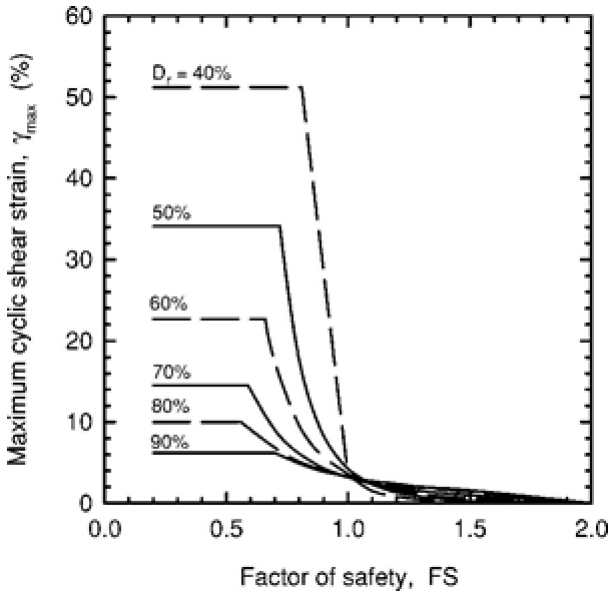
$$F = \left(\frac{f_s}{q_c - \sigma_{vc}}\right) \cdot 100\%$$

σ'_v *at time of CPT sounding*

Procedure for the evaluation of liquefaction-induced lateral spreading displacements



[1] Flow chart illustrating major steps in estimating liquefaction-induced lateral spreading displacements using the proposed approach



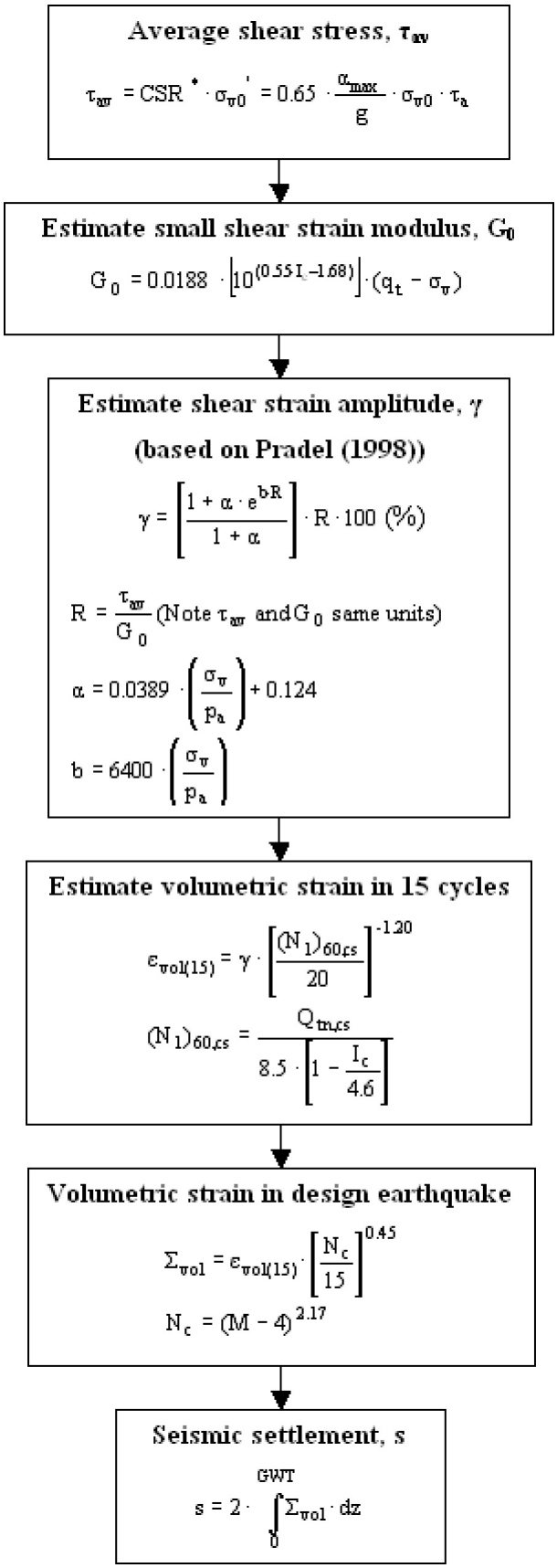
[1] Figure 1

$$LDI = \int_0^{z_{max}} \gamma_{max} dz$$

[1] Equation [3]

[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

Procedure for the estimation of seismic induced settlements in dry sands



Robertson, P.K. and Lisheng, S., 2010, "Estimation of seismic compression in dry soils using the CPT" FIFTH INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN GEOTECHNICAL EARTHQUAKE ENGINEERING AND SOIL DYNAMICS, Symposium in honor of professor I. M. Idriss, San Diego, CA

Liquefaction Potential Index (LPI) calculation procedure

Calculation of the Liquefaction Potential Index (LPI) is used to interpret the liquefaction assessment calculations in terms of severity over depth. The calculation procedure is based on the methology developed by Iwasaki (1982) and is adopted by AFPS.

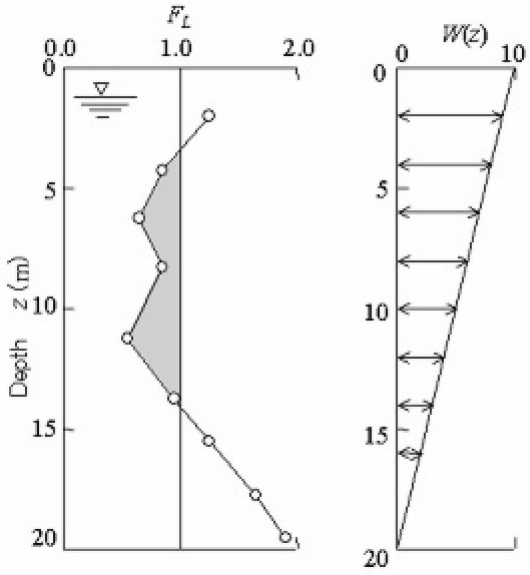
To estimate the severity of liquefaction extent at a given site, LPI is calculated based on the following equation:

$$\mathbf{LPI} = \int_0^{20} (10 - 0{,}5z) \times F_L \times dz$$

where:
F_L = 1 - F.S. when F.S. less than 1
F_L = 0 when F.S. greater than 1
z depth of measurment in meters

Values of LPI range between zero (0) when no test point is characterized as liquefiable and 100 when all points are characterized as susceptible to liquefaction. Iwasaki proposed four (4) discrete categories based on the numeric value of LPI:

- LPI = 0 : Liquefaction risk is very low
- 0 < LPI <= 5 : Liquefaction risk is low
- 5 < LPI <= 15 : Liquefaction risk is high
- LPI > 15 : Liquefaction risk is very high



Graphical presentation of the LPI calculation procedure

Shear-Induced Building Settlement (Ds) calculation procedure

The shear-induced building settlement (Ds) due to liquefaction below the building can be estimated using the relationship developed by Bray and Macedo (2017):

$$Ln(Ds) = c1 + c2 * LBS + 0.58 * Ln\left(Tanh\left(\frac{HL}{6}\right)\right) + 4.59 * Ln(Q) - 0.42 * Ln(Q)^2 - 0.02 * B + 0.84 * Ln(CAVdp) + 0.41 * Ln(Sa1) + \varepsilon$$

where Ds is in the units of mm, c1= -8.35 and c2= 0.072 for LBS ≤ 16, and c1= -7.48 and c2= 0.014 otherwise. Q is the building contact pressure in units of kPa, HL is the cumulative thickness of the liquefiable layers in the units of m, B is the building width in the units of m, CAVdp is a standardized version of the cumulative absolute velocity in the units of g-s, Sa1 is 5%-damped pseudo-acceleration response spectral value at a period of 1 s in the units of g, and ε is a normal random variable with zero mean and 0.50 standard deviation in Ln units. The liquefaction-induced building settlement index (LBS) is:

$$LBS = \sum W * \frac{\varepsilon_{shear}}{z} dz$$

where z (m) is the depth measured from the ground surface > 0, W is a foundation-weighting factor wherein W = 0.0 for z less than Df, which is the embedment depth of the foundation, and W = 1.0 otherwise. The shear strain parameter (ε_shear) is the liquefaction-induced free-field shear strain (in %) estimated using Zhang et al. (2004). It is calculated based on the estimated Dr of the liquefied soil layer and the calculated safety factor against liquefaction triggering (FSL).

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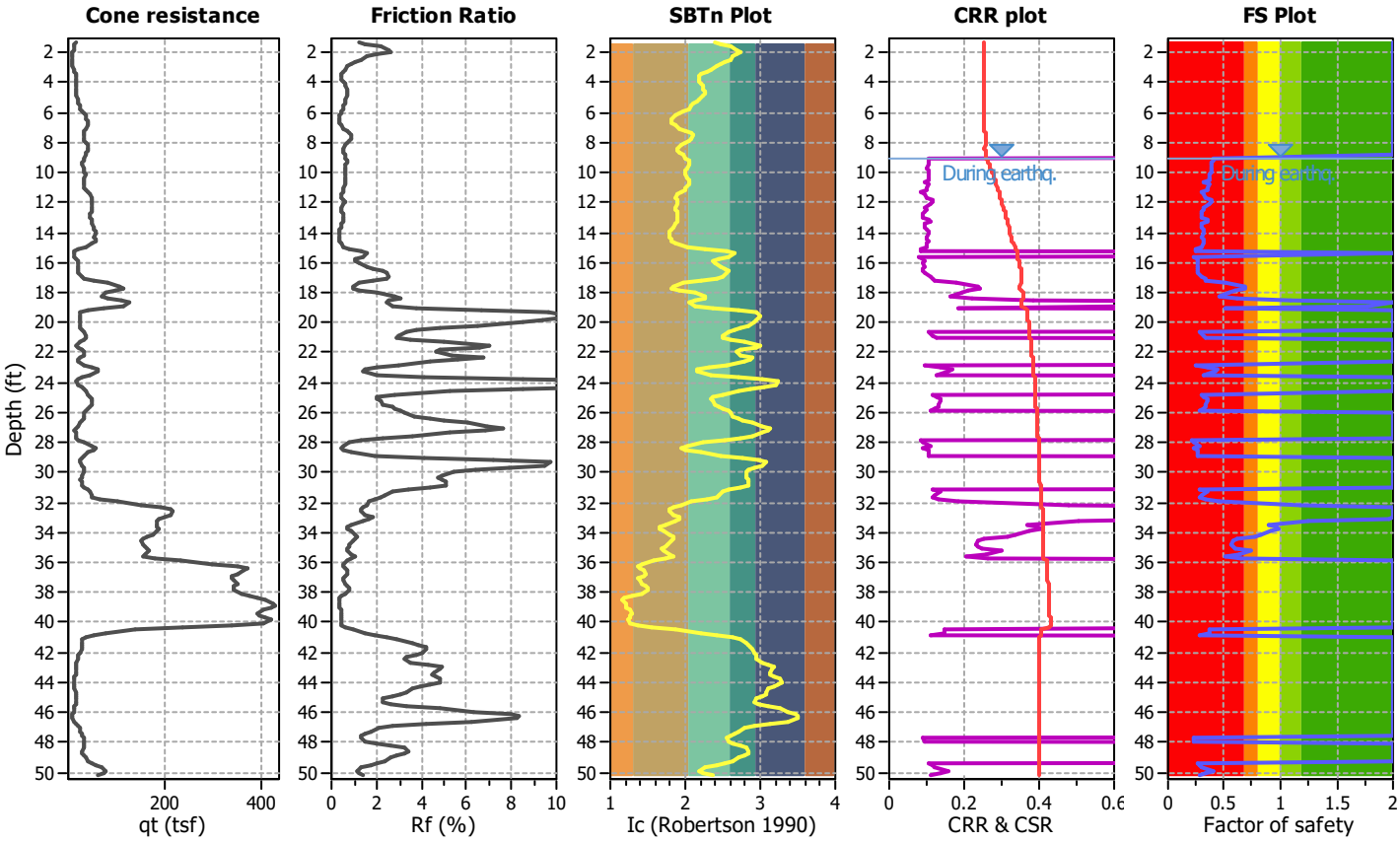
LIQUEFACTION ANALYSIS REPORT

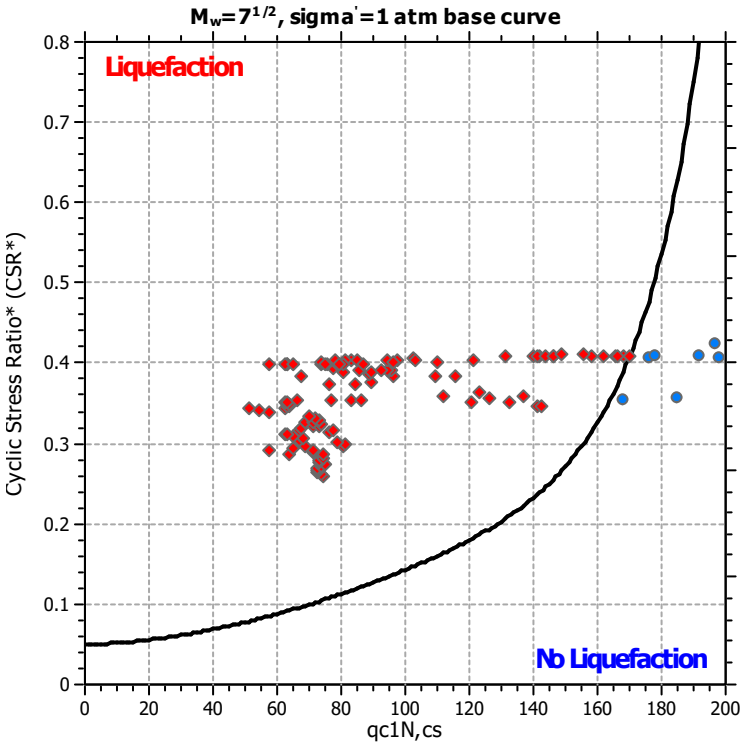
Project title : Manteca WWTP **Location : Manteca, CA**

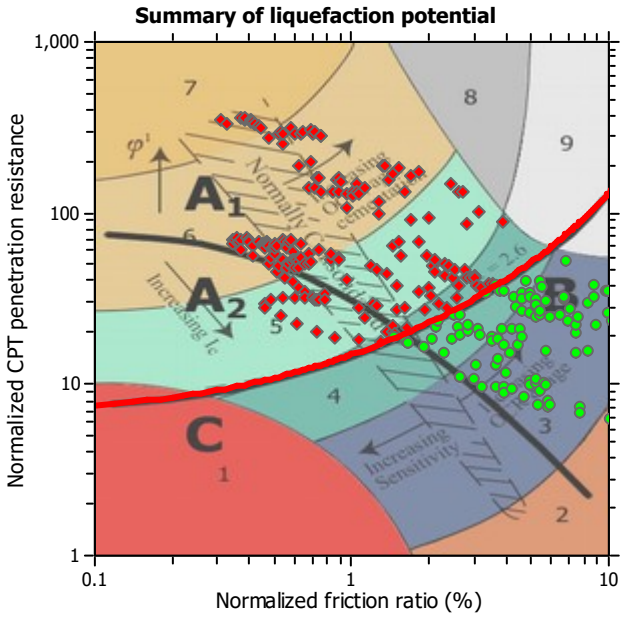
CPT file : CPT 1

Input parameters and analysis data

Analysis method:	I&B (2008)	G.W.T. (in-situ):	11.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	R&W (1998)	G.W.T. (earthq.):	9.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.13	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.43	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

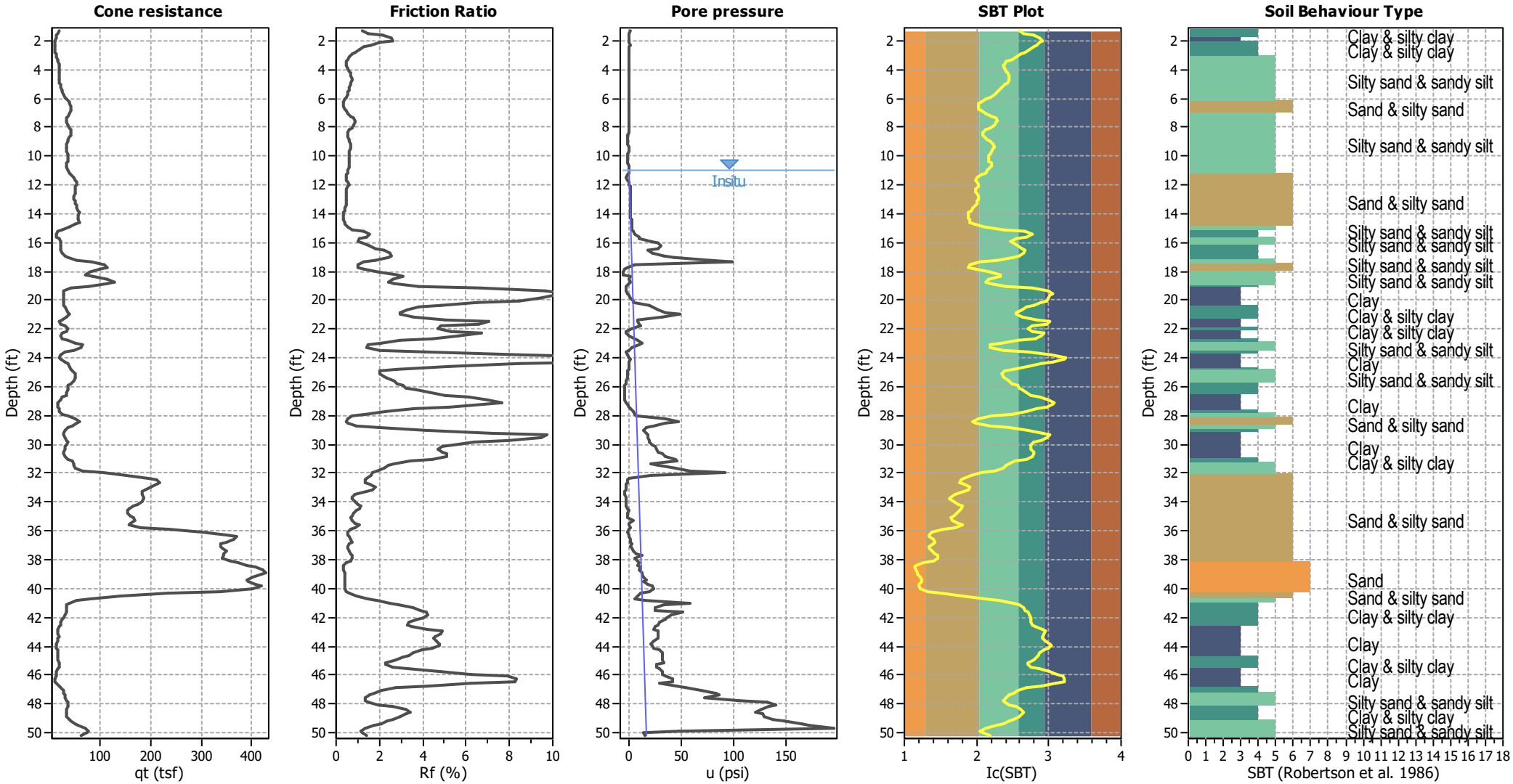






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



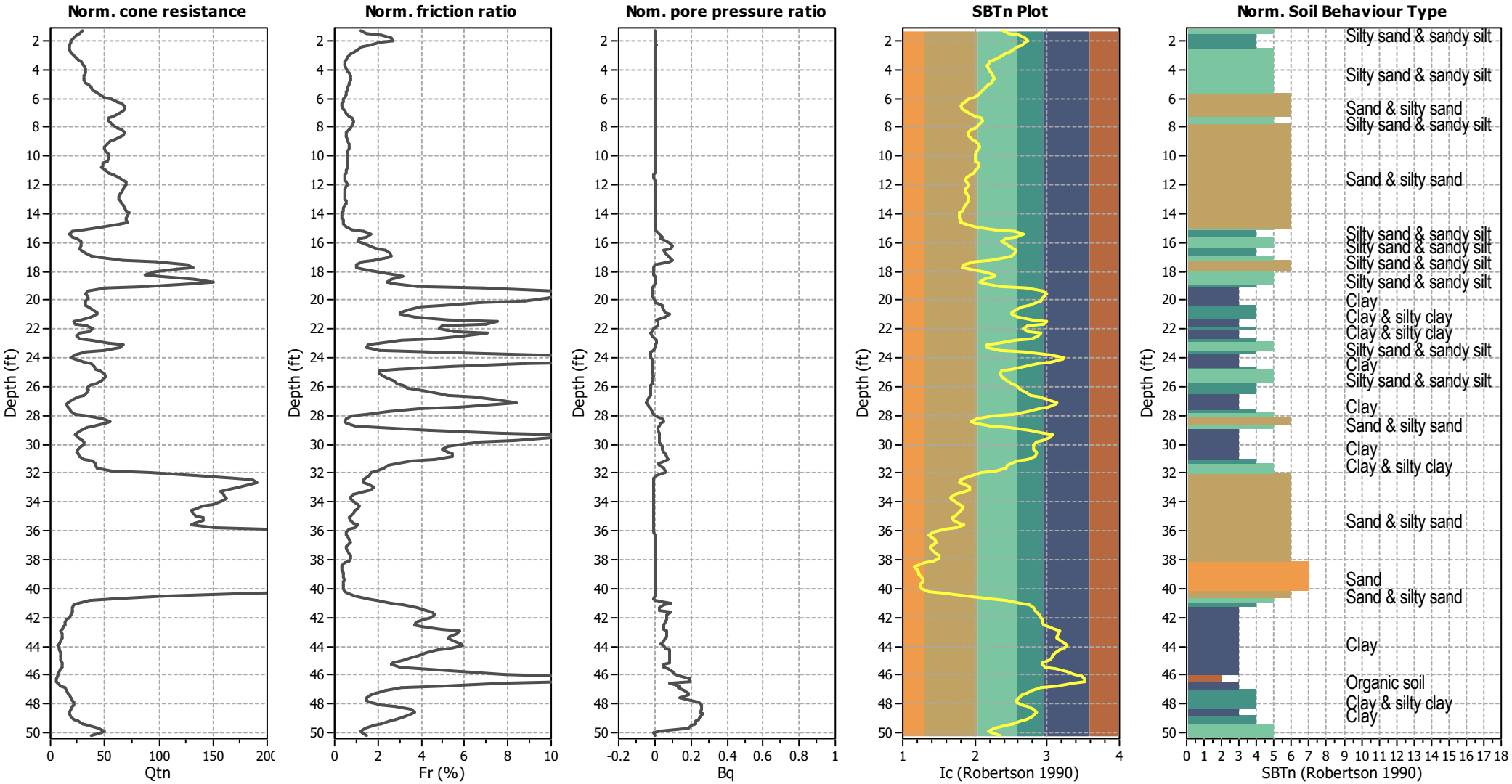
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



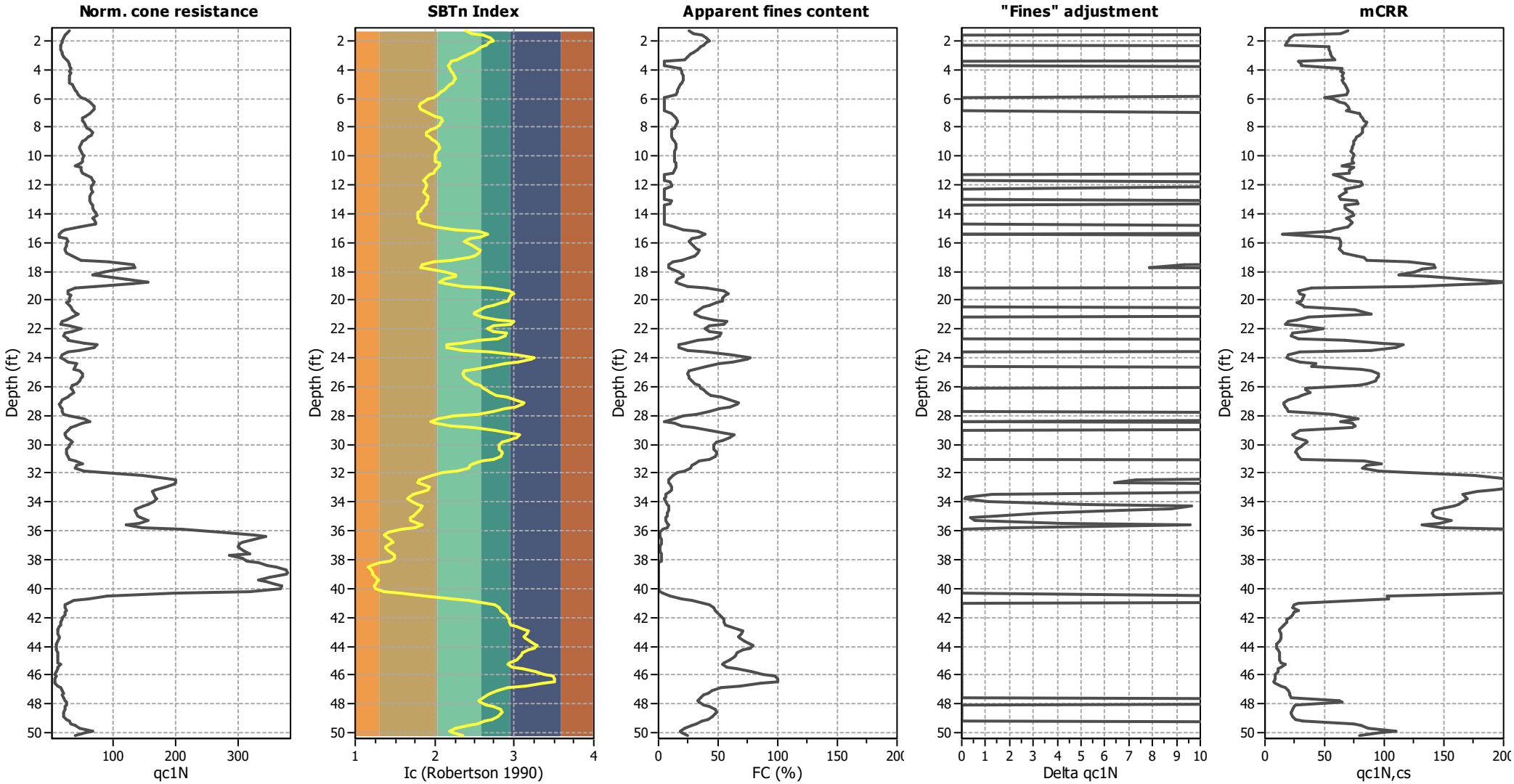
Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

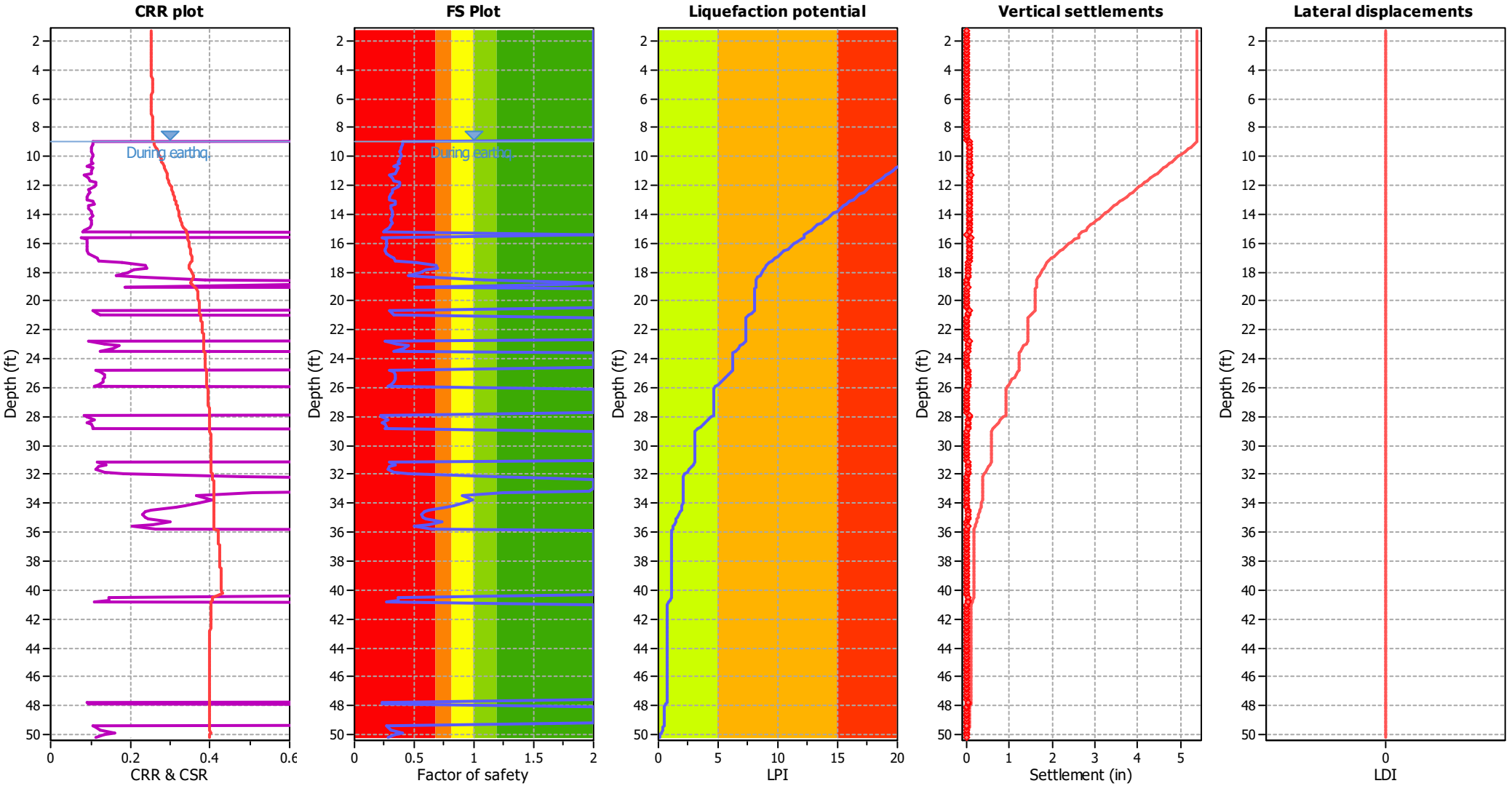
Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

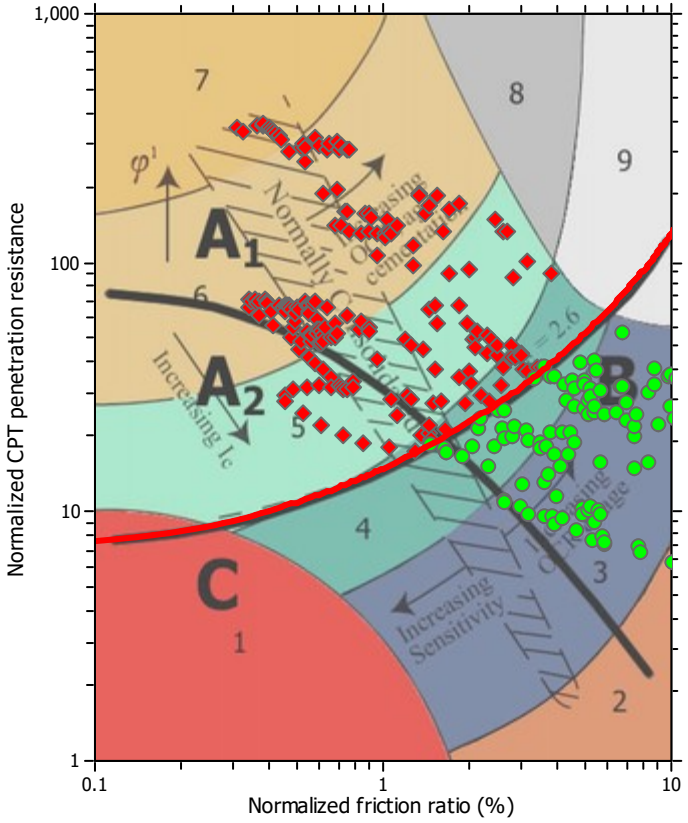
F.S. color scheme

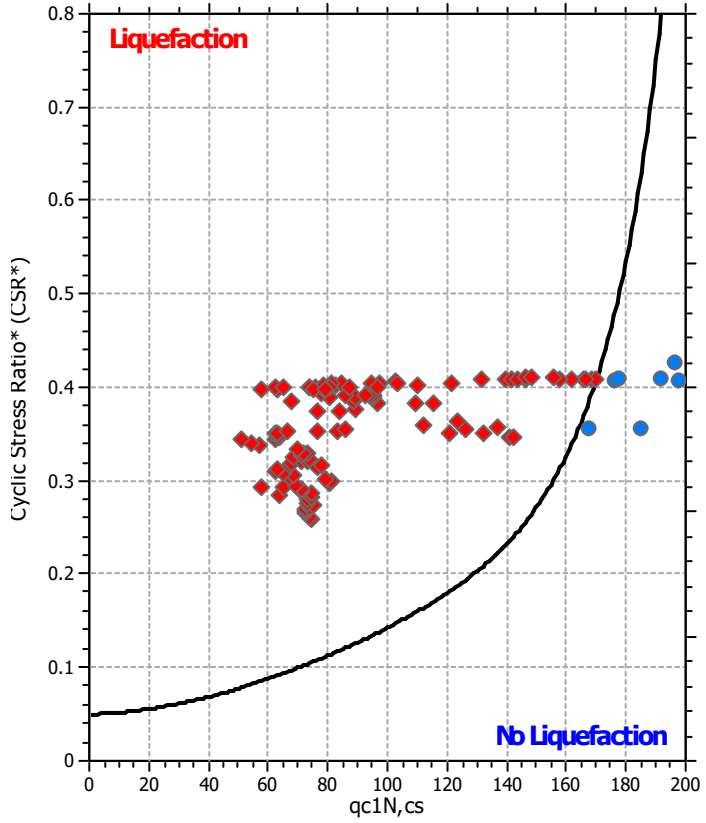
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

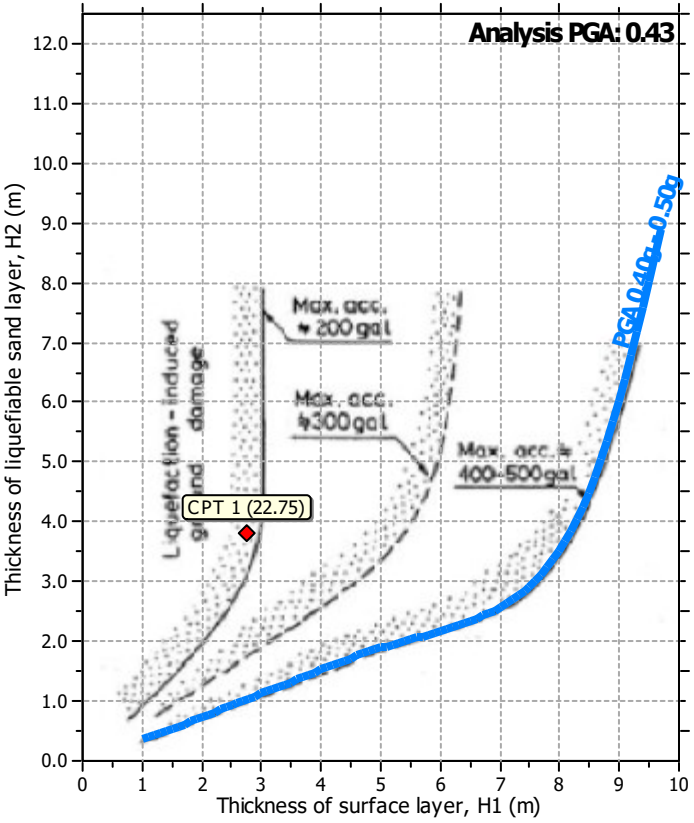
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots



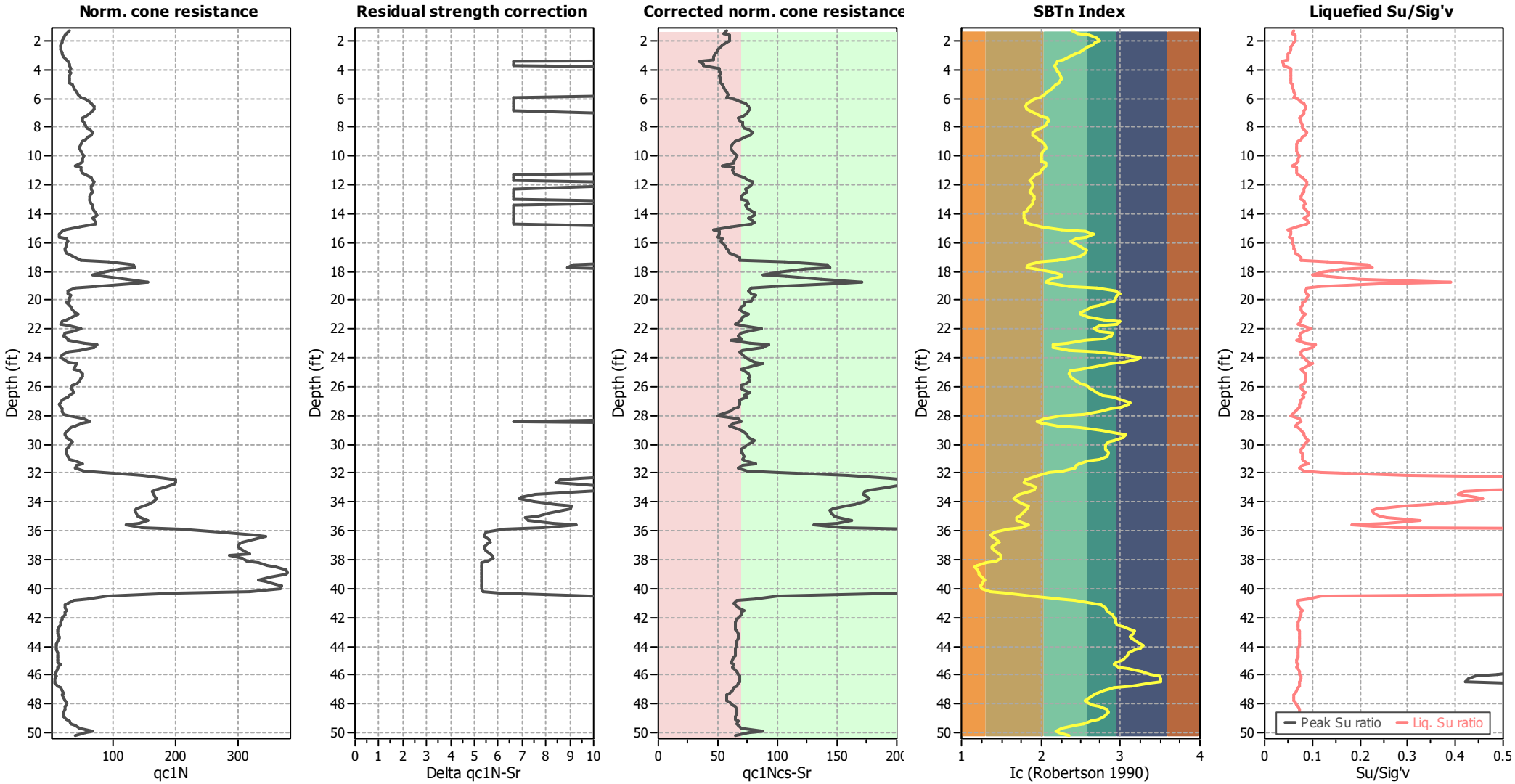




Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

Check for strength loss plots (Idriss & Boulanger (2008))



Input parameters and analysis data

Analysis method:	I&B (2008)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	R&W (1998)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

:: Field input data ::

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
1	1.31	19.66	0.22	0.99	25.89	106.41
2	1.48	16.04	0.23	0.58	29.25	107.07
3	1.64	15.14	0.30	0.42	36.05	108.47
4	1.80	12.95	0.42	0.39	40.18	108.78
5	1.97	11.89	0.31	0.25	42.19	108.04
6	2.13	11.69	0.23	0.19	39.89	105.63
7	2.30	10.87	0.17	1.01	37.49	103.64
8	2.46	10.95	0.14	0.57	35.03	101.79
9	2.63	11.30	0.11	0.38	32.41	100.64
10	2.79	11.95	0.10	0.32	29.67	99.47
11	2.95	12.45	0.09	0.32	27.17	99.04
12	3.12	13.96	0.09	0.32	24.36	98.69
13	3.28	15.74	0.08	0.37	21.66	98.71
14	3.44	17.48	0.08	0.56	5.00	98.71
15	3.61	19.05	0.08	0.51	5.00	99.27
16	3.77	19.33	0.09	0.50	5.00	100.26
17	3.94	20.68	0.11	0.38	18.55	101.23
18	4.10	19.92	0.12	0.35	18.96	102.09
19	4.26	20.32	0.13	0.28	19.94	102.65
20	4.43	19.47	0.14	0.25	20.51	103.15
21	4.59	19.71	0.15	0.27	21.05	103.33
22	4.76	19.48	0.14	0.24	20.79	103.27
23	4.92	19.97	0.14	0.21	20.09	103.29
24	5.08	21.59	0.14	0.20	18.77	103.41
25	5.25	23.49	0.14	0.23	17.48	103.76
26	5.41	25.02	0.15	0.21	16.33	103.92
27	5.58	26.13	0.14	0.07	15.29	104.04
28	5.74	27.94	0.14	0.11	14.05	104.28
29	5.91	31.19	0.15	0.13	5.00	104.74
30	6.07	35.40	0.16	0.20	5.00	104.76
31	6.23	38.85	0.13	0.19	5.00	104.89
32	6.40	41.42	0.14	0.18	5.00	104.97
33	6.56	43.21	0.15	0.17	5.00	105.74
34	6.73	43.70	0.17	0.15	5.00	106.48
35	6.89	42.55	0.19	0.11	5.00	107.24
36	7.05	39.64	0.21	0.05	11.18	108.03
37	7.22	35.73	0.24	-0.03	13.27	108.72
38	7.38	32.75	0.28	-0.07	15.15	109.38
39	7.55	32.77	0.30	-0.08	15.83	109.91
40	7.71	34.96	0.31	-0.06	15.40	110.24
41	7.87	36.53	0.30	-0.10	14.46	110.24
42	8.04	37.71	0.29	-0.14	13.10	109.97
43	8.20	41.52	0.26	-0.20	11.47	109.56
44	8.37	45.15	0.24	-0.65	10.43	109.17
45	8.53	43.86	0.23	-1.23	10.38	108.89
46	8.69	41.20	0.23	-1.37	10.99	108.42
47	8.86	38.12	0.21	-0.94	11.99	108.16
48	9.02	35.46	0.23	-1.09	13.09	107.92

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
49	9.19	33.19	0.23	-0.96	14.27	108.03
50	9.35	32.09	0.23	-0.72	14.59	107.66
51	9.51	32.64	0.20	-0.64	14.44	107.51
52	9.68	33.97	0.21	-0.73	13.77	107.45
53	9.84	36.39	0.22	-0.80	13.29	107.81
54	10.01	38.00	0.22	-0.99	13.01	107.97
55	10.17	37.31	0.22	-1.08	13.02	107.95
56	10.34	36.86	0.21	-0.95	13.33	107.81
57	10.50	35.95	0.21	-0.87	14.42	107.35
58	10.66	29.10	0.20	0.58	14.40	107.15
59	10.83	36.65	0.20	-0.28	14.37	107.12
60	10.99	36.61	0.21	-0.20	13.30	107.55
61	11.15	38.29	0.22	-0.09	12.66	107.77
62	11.32	42.47	0.21	-1.73	5.00	108.11
63	11.48	48.98	0.21	-2.77	5.00	108.55
64	11.65	52.37	0.23	-1.52	5.00	109.41
65	11.81	54.03	0.27	-0.05	10.01	110.70
66	11.97	53.15	0.34	0.58	10.43	111.20
67	12.14	51.76	0.30	0.99	10.37	110.68
68	12.30	51.37	0.21	1.05	5.00	109.49
69	12.47	52.86	0.22	1.07	5.00	109.15
70	12.63	50.39	0.26	1.16	5.00	109.29
71	12.79	48.04	0.23	1.53	5.00	109.35
72	12.96	48.69	0.23	1.59	5.00	109.34
73	13.12	50.48	0.26	1.30	10.43	109.79
74	13.29	52.46	0.27	0.92	10.20	109.99
75	13.45	52.68	0.24	0.88	5.00	109.74
76	13.62	53.44	0.23	1.53	5.00	109.32
77	13.78	56.94	0.22	1.60	5.00	109.04
78	13.94	59.02	0.21	1.76	5.00	108.64
79	14.11	59.59	0.19	1.90	5.00	108.26
80	14.27	55.09	0.19	1.84	5.00	108.31
81	14.44	57.73	0.21	2.11	5.00	108.73
82	14.60	59.67	0.23	2.35	5.00	109.31
83	14.76	58.46	0.24	2.46	5.00	108.59
84	14.93	38.93	0.17	2.47	13.35	107.45
85	15.09	19.92	0.19	2.69	21.32	105.87
86	15.26	14.94	0.20	4.04	33.14	105.15
87	15.42	11.29	0.21	5.74	38.43	104.98
88	15.58	12.78	0.21	9.81	34.41	105.49
89	15.75	21.02	0.21	9.78	28.04	105.79
90	15.91	22.72	0.19	20.60	25.47	107.03
91	16.08	21.92	0.29	27.98	26.64	108.26
92	16.24	21.72	0.34	29.76	29.61	109.81
93	16.40	20.71	0.39	27.06	31.99	110.95
94	16.57	20.75	0.46	17.34	34.07	112.54
95	16.73	22.94	0.62	22.27	33.17	114.66
96	16.90	30.35	0.79	33.35	30.69	116.62

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
97	17.06	35.65	0.89	42.45	27.42	118.31
98	17.22	42.48	1.02	78.12	19.39	120.02
99	17.39	84.52	1.07	98.63	12.55	121.42
100	17.55	119.95	1.06	5.99	8.91	122.43
101	17.72	122.76	1.17	-1.71	8.61	122.89
102	17.88	101.92	1.22	-4.48	11.05	123.22
103	18.05	77.68	1.39	-5.61	16.79	124.30
104	18.21	60.49	2.13	-5.28	21.29	125.88
105	18.37	79.73	2.55	1.96	21.04	128.13
106	18.54	112.82	3.18	0.06	16.39	129.73
107	18.70	149.04	3.11	0.97	14.76	130.51
108	18.86	126.57	3.14	0.07	16.78	130.02
109	19.03	67.48	2.93	-2.31	24.68	128.65
110	19.19	35.59	2.64	-2.84	40.62	127.10
111	19.36	25.55	2.98	-3.11	54.42	126.02
112	19.52	26.05	2.78	-1.93	57.94	126.11
113	19.68	30.18	2.93	-0.33	56.03	126.18
114	19.85	29.27	2.93	1.69	54.20	125.89
115	20.01	28.01	2.39	3.77	53.34	124.54
116	20.18	25.02	1.67	4.67	48.49	122.57
117	20.34	28.73	1.29	19.52	42.76	120.72
118	20.50	30.76	1.14	22.11	37.78	119.83
119	20.67	32.17	1.10	27.08	34.20	119.79
120	20.83	38.41	1.15	34.75	31.03	119.98
121	21.00	42.18	1.11	48.90	30.78	120.13
122	21.16	34.22	1.15	32.11	35.37	120.29
123	21.32	24.96	1.37	8.55	45.74	120.17
124	21.49	18.04	1.39	8.24	57.79	120.02
125	21.65	16.19	1.43	9.52	55.13	120.19
126	21.82	28.97	1.38	11.38	42.20	121.46
127	21.98	46.58	1.61	2.03	38.97	122.89
128	22.15	33.17	2.10	-2.69	42.40	123.19
129	22.31	21.88	1.71	-2.38	52.18	122.00
130	22.47	20.72	1.27	0.13	50.81	119.87
131	22.64	26.79	0.92	5.95	45.13	118.84
132	22.80	27.32	1.11	8.43	33.17	119.37
133	22.97	51.96	1.13	12.89	23.58	120.27
134	23.13	74.04	0.93	9.37	17.66	120.27
135	23.29	69.17	0.87	3.21	17.63	119.60
136	23.46	45.94	0.90	-0.52	24.32	119.46
137	23.62	28.98	1.12	-2.61	40.33	120.55
138	23.79	19.36	1.85	-1.73	61.17	122.37
139	23.95	17.66	2.62	-0.30	76.34	124.60
140	24.11	20.46	3.48	0.63	74.45	126.70
141	24.28	28.96	3.95	0.59	62.01	128.16
142	24.44	42.09	3.64	0.43	50.67	127.40
143	24.61	39.40	1.78	-0.34	40.49	124.67
144	24.77	38.66	0.86	-0.68	30.74	120.50

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
145	24.93	47.15	0.86	-0.92	25.53	119.10
146	25.10	52.30	1.07	-2.12	24.26	119.99
147	25.26	52.33	1.13	-1.32	25.11	120.98
148	25.43	51.04	1.28	-1.97	25.91	121.04
149	25.59	48.86	1.13	-2.54	28.61	121.51
150	25.75	43.10	1.44	-2.94	30.71	120.73
151	25.92	36.62	1.02	-3.54	33.85	120.28
152	26.08	34.80	1.05	-3.76	35.73	119.98
153	26.25	35.61	1.37	-3.77	37.37	121.18
154	26.41	39.09	1.60	-3.89	40.73	122.21
155	26.57	31.67	1.70	-4.12	44.18	122.53
156	26.74	28.91	1.69	-4.46	52.15	121.84
157	26.90	19.77	1.50	-4.27	59.68	120.82
158	27.07	16.74	1.36	-3.27	67.51	119.39
159	27.23	16.08	1.16	-1.52	66.21	118.24
160	27.39	17.93	0.95	-0.10	59.58	116.78
161	27.56	19.21	0.69	1.44	50.99	114.83
162	27.72	20.36	0.45	3.40	42.26	112.06
163	27.89	22.01	0.26	5.13	32.15	110.12
164	28.05	31.91	0.29	7.00	20.34	109.70
165	28.21	56.43	0.27	34.60	13.90	110.68
166	28.38	66.87	0.28	46.91	5.00	110.95
167	28.54	54.16	0.29	34.47	13.28	111.23
168	28.71	43.44	0.33	24.11	19.43	113.01
169	28.87	35.76	0.61	16.63	29.70	116.62
170	29.04	30.68	1.20	14.22	43.26	120.57
171	29.20	26.96	2.07	16.12	55.93	123.50
172	29.36	25.41	2.76	17.28	63.22	125.37
173	29.53	27.84	3.04	18.11	60.18	126.27
174	29.69	36.44	2.78	19.84	53.74	126.21
175	29.86	37.73	2.34	19.87	48.48	125.18
176	30.02	33.74	1.84	22.60	46.16	123.76
177	30.18	33.56	1.60	24.54	46.17	122.22
178	30.35	29.16	1.37	26.18	46.68	121.30
179	30.51	28.01	1.36	27.41	48.60	121.10
180	30.68	28.86	1.56	31.77	48.87	121.56
181	30.84	30.89	1.62	34.29	47.75	122.25
182	31.00	33.70	1.70	44.58	42.39	122.60
183	31.17	43.59	1.55	45.66	34.66	122.66
184	31.33	56.31	1.33	20.85	30.13	121.86
185	31.50	46.70	1.10	27.32	28.63	121.07
186	31.66	44.47	1.14	44.83	27.40	120.69
187	31.82	58.86	1.13	58.47	22.01	122.25
188	31.99	93.50	1.54	90.90	15.52	125.69
189	32.15	160.96	2.55	21.11	11.90	129.02
190	32.32	201.79	3.18	-0.54	9.29	130.54
191	32.48	218.49	2.54	-2.05	8.14	130.93
192	32.64	219.33	2.73	-1.82	7.96	131.12

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
193	32.81	217.42	3.33	-2.57	9.19	131.92
194	32.97	202.02	3.62	-2.95	11.01	132.67
195	33.14	184.65	3.98	-3.19	10.88	131.54
196	33.30	181.25	1.96	-3.54	9.56	129.73
197	33.47	183.18	1.61	-3.69	6.64	126.58
198	33.63	187.79	1.33	-3.51	5.54	125.37
199	33.79	189.62	1.19	-3.05	5.45	125.29
200	33.96	185.00	1.57	-2.77	6.53	126.32
201	34.12	175.77	1.98	-2.42	7.92	127.22
202	34.28	167.03	1.89	-2.24	8.84	127.20
203	34.45	155.25	1.66	-1.95	8.77	126.28
204	34.61	153.18	1.40	0.28	8.36	125.35
205	34.78	155.13	1.33	-1.01	7.52	124.48
206	34.94	159.33	1.15	-1.47	6.78	123.92
207	35.10	163.58	1.09	-1.85	5.92	123.57
208	35.27	176.66	1.11	4.12	6.15	123.98
209	35.43	162.35	1.34	-0.69	7.73	125.10
210	35.60	139.95	1.74	-0.40	9.05	126.24
211	35.76	167.80	1.85	1.27	7.07	126.55
212	35.92	235.63	1.32	-0.40	4.01	127.02
213	36.09	301.09	1.64	-0.90	1.80	127.59
214	36.25	363.02	1.82	-0.04	1.18	129.04
215	36.42	383.79	2.07	-0.36	1.31	130.28
216	36.58	364.37	2.53	1.65	2.09	131.39
217	36.74	342.55	2.93	1.61	2.38	131.17
218	36.91	339.18	1.95	2.45	2.03	130.09
219	37.07	336.23	1.58	1.61	1.25	128.55
220	37.24	340.45	1.70	2.40	1.34	128.86
221	37.40	347.21	2.16	3.52	1.71	129.93
222	37.57	358.40	2.40	7.28	2.41	130.87
223	37.73	322.56	2.60	13.08	2.76	131.41
224	37.89	346.65	2.71	5.36	2.82	131.42
225	38.06	353.67	2.41	8.71	1.93	130.75
226	38.22	374.50	1.81	9.47	0.43	128.37
227	38.39	390.42	0.72	8.30	0.00	126.56
228	38.55	408.87	1.27	10.76	0.00	126.59
229	38.71	425.29	1.77	10.15	0.00	128.16
230	38.88	429.58	1.57	11.73	0.00	128.66
231	39.04	426.57	1.57	12.87	0.00	128.46
232	39.21	399.99	1.67	14.40	0.00	128.54
233	39.37	377.42	1.69	16.80	0.27	128.66
234	39.53	390.98	1.71	14.44	0.14	128.51
235	39.70	411.33	1.55	17.39	0.00	128.60
236	39.86	421.99	1.70	21.63	0.00	128.77
237	40.03	420.07	1.78	23.68	0.04	128.62
238	40.19	364.72	1.51	19.05	1.06	127.87
239	40.35	230.57	1.48	11.23	3.81	126.28
240	40.52	111.86	1.34	7.80	9.86	124.35

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
241	40.68	76.79	1.14	4.81	19.66	122.12
242	40.85	47.38	1.05	15.60	27.78	120.06
243	41.01	35.23	0.84	57.86	37.33	118.84
244	41.17	31.35	0.98	33.23	43.15	118.49
245	41.34	30.41	1.06	25.30	46.58	119.90
246	41.50	35.25	1.46	24.35	48.05	120.62
247	41.67	31.69	1.33	51.71	49.31	121.18
248	41.83	30.49	1.37	39.84	51.66	120.38
249	41.99	26.56	1.14	36.44	53.06	119.19
250	42.16	24.34	0.85	34.26	54.30	117.77
251	42.32	23.24	0.87	29.40	54.28	116.21
252	42.49	21.38	0.64	28.09	55.66	115.36
253	42.65	20.03	0.64	25.28	60.00	114.84
254	42.81	16.70	0.79	23.93	66.53	115.42
255	42.98	16.38	0.88	27.06	71.06	116.02
256	43.14	17.55	0.88	27.96	69.61	116.27
257	43.31	18.58	0.84	28.26	67.32	116.15
258	43.47	18.27	0.81	27.02	68.14	115.68
259	43.63	15.78	0.75	23.87	72.09	115.05
260	43.80	13.98	0.71	20.22	76.97	114.24
261	43.96	13.23	0.65	22.09	79.41	113.64
262	44.13	13.22	0.62	23.70	76.31	113.38
263	44.29	15.37	0.62	28.94	70.98	113.46
264	44.45	17.05	0.61	31.20	66.14	113.55
265	44.62	17.30	0.59	31.32	64.08	113.30
266	44.78	16.69	0.54	31.39	63.05	112.72
267	44.95	16.77	0.48	31.50	60.32	112.00
268	45.11	18.31	0.43	33.41	54.50	111.71
269	45.28	22.41	0.44	26.43	53.78	111.90
270	45.44	18.28	0.51	25.77	57.14	112.43
271	45.60	15.93	0.56	29.18	66.23	112.82
272	45.77	14.49	0.60	31.62	78.61	114.27
273	45.93	12.05	0.96	32.32	87.78	115.43
274	46.10	12.66	0.98	33.93	97.23	116.42
275	46.26	11.40	1.05	41.01	100.00	116.50
276	46.42	11.01	1.02	40.81	100.00	116.37
277	46.59	12.49	0.94	28.44	85.78	116.00
278	46.75	17.92	0.74	45.02	68.00	115.52
279	46.92	23.00	0.65	53.94	52.95	114.70
280	47.08	27.09	0.53	69.67	45.07	114.19
281	47.24	28.63	0.53	82.45	40.88	113.42
282	47.41	27.84	0.44	86.14	38.19	112.85
283	47.57	30.73	0.40	72.40	35.49	112.56
284	47.74	33.68	0.45	105.29	33.49	113.34
285	47.90	36.10	0.55	131.68	33.98	114.75
286	48.06	35.25	0.67	139.76	37.44	116.79
287	48.23	33.90	0.98	133.42	42.49	118.44
288	48.39	31.76	1.14	126.26	47.25	119.52

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
289	48.56	30.15	1.16	121.12	48.77	119.54
290	48.72	30.85	1.03	127.89	48.06	119.20
291	48.88	31.81	0.99	128.32	45.30	119.00
292	49.05	35.24	1.02	136.68	41.01	119.36
293	49.21	43.29	1.06	147.76	36.82	119.77
294	49.38	46.61	1.04	165.00	32.30	120.04
295	49.54	53.66	1.00	171.75	27.78	120.13
296	49.70	64.80	0.96	195.26	21.45	120.33
297	49.87	91.08	0.90	46.36	18.90	120.15
298	50.03	75.84	0.85	13.75	20.06	119.88
299	50.20	54.40	0.91	14.88	24.70	119.46

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
q_c: Measured cone resistance (tsf)
f_s: Sleeve friction resistance (tsf)
u: Pore pressure (tsf)
Fines content: Percentage of fines in soil (%)
Unit weight: Bulk soil unit weight (pcf)

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data ::

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
1	1.31	0.07	0.00	0.07	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
2	1.48	0.08	0.00	0.08	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
3	1.64	0.09	0.00	0.09	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
4	1.80	0.10	0.00	0.10	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
5	1.97	0.11	0.00	0.11	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
6	2.13	0.11	0.00	0.11	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
7	2.30	0.12	0.00	0.12	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
8	2.46	0.13	0.00	0.13	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
9	2.63	0.14	0.00	0.14	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
10	2.79	0.15	0.00	0.15	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
11	2.95	0.16	0.00	0.16	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
12	3.12	0.16	0.00	0.16	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
13	3.28	0.17	0.00	0.17	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
14	3.44	0.18	0.00	0.18	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
15	3.61	0.19	0.00	0.19	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
16	3.77	0.20	0.00	0.20	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
17	3.94	0.20	0.00	0.20	1.00	0.278	1.10	0.252	1.10	1.10	2.000	No
18	4.10	0.21	0.00	0.21	1.00	0.278	1.10	0.252	1.10	1.10	2.000	No
19	4.26	0.22	0.00	0.22	0.99	0.278	1.10	0.252	1.09	1.10	2.000	No
20	4.43	0.23	0.00	0.23	0.99	0.278	1.10	0.252	1.09	1.10	2.000	No
21	4.59	0.24	0.00	0.24	0.99	0.278	1.10	0.252	1.09	1.10	2.000	No
22	4.76	0.25	0.00	0.25	0.99	0.278	1.10	0.252	1.09	1.10	2.000	No
23	4.92	0.25	0.00	0.25	0.99	0.278	1.10	0.252	1.09	1.10	2.000	No
24	5.08	0.26	0.00	0.26	0.99	0.277	1.10	0.252	1.09	1.10	2.000	No
25	5.25	0.27	0.00	0.27	0.99	0.277	1.10	0.251	1.09	1.10	2.000	No
26	5.41	0.28	0.00	0.28	0.99	0.277	1.10	0.251	1.09	1.10	2.000	No
27	5.58	0.29	0.00	0.29	0.99	0.277	1.10	0.251	1.09	1.10	2.000	No
28	5.74	0.30	0.00	0.30	0.99	0.277	1.10	0.251	1.09	1.10	2.000	No
29	5.91	0.31	0.00	0.31	0.99	0.277	1.10	0.251	1.09	1.10	2.000	No
30	6.07	0.31	0.00	0.31	0.99	0.277	1.10	0.251	1.09	1.10	2.000	No
31	6.23	0.32	0.00	0.32	0.99	0.276	1.10	0.251	1.09	1.10	2.000	No
32	6.40	0.33	0.00	0.33	0.99	0.276	1.10	0.250	1.09	1.10	2.000	No
33	6.56	0.34	0.00	0.34	0.99	0.276	1.10	0.250	1.09	1.10	2.000	No
34	6.73	0.35	0.00	0.35	0.99	0.276	1.10	0.250	1.09	1.10	2.000	No
35	6.89	0.36	0.00	0.36	0.99	0.276	1.10	0.250	1.09	1.10	2.000	No
36	7.05	0.37	0.00	0.37	0.99	0.276	1.10	0.250	1.08	1.10	2.000	No
37	7.22	0.38	0.00	0.38	0.99	0.275	1.10	0.250	1.08	1.10	2.000	No
38	7.38	0.38	0.00	0.38	0.98	0.275	1.10	0.250	1.07	1.10	2.000	No
39	7.55	0.39	0.00	0.39	0.98	0.275	1.10	0.250	1.07	1.10	2.000	No
40	7.71	0.40	0.00	0.40	0.98	0.275	1.10	0.249	1.07	1.10	2.000	No
41	7.87	0.41	0.00	0.41	0.98	0.275	1.10	0.249	1.07	1.10	2.000	No
42	8.04	0.42	0.00	0.42	0.98	0.275	1.10	0.249	1.07	1.10	2.000	No
43	8.20	0.43	0.00	0.43	0.98	0.275	1.10	0.249	1.07	1.10	2.000	No
44	8.37	0.44	0.00	0.44	0.98	0.274	1.10	0.249	1.07	1.10	2.000	No
45	8.53	0.45	0.00	0.45	0.98	0.274	1.10	0.249	1.07	1.10	2.000	No
46	8.69	0.46	0.00	0.46	0.98	0.274	1.10	0.249	1.07	1.10	2.000	No
47	8.86	0.47	0.00	0.47	0.98	0.274	1.10	0.248	1.06	1.10	2.000	No
48	9.02	0.47	0.00	0.47	0.98	0.274	1.10	0.249	1.06	1.10	0.258	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
49	9.19	0.48	0.01	0.48	0.98	0.277	1.10	0.251	1.06	1.10	0.262	No
50	9.35	0.49	0.01	0.48	0.98	0.280	1.10	0.254	1.05	1.10	0.265	No
51	9.51	0.50	0.02	0.48	0.98	0.282	1.10	0.256	1.05	1.10	0.267	No
52	9.68	0.51	0.02	0.49	0.98	0.285	1.10	0.258	1.05	1.10	0.270	No
53	9.84	0.52	0.03	0.49	0.98	0.287	1.10	0.261	1.05	1.10	0.272	No
54	10.01	0.53	0.03	0.50	0.98	0.290	1.10	0.263	1.06	1.10	0.274	No
55	10.17	0.54	0.04	0.50	0.98	0.292	1.10	0.265	1.05	1.10	0.277	No
56	10.34	0.55	0.04	0.50	0.97	0.295	1.10	0.267	1.05	1.10	0.279	No
57	10.50	0.55	0.05	0.51	0.97	0.297	1.10	0.270	1.05	1.10	0.282	No
58	10.66	0.56	0.05	0.51	0.97	0.300	1.10	0.272	1.05	1.10	0.285	No
59	10.83	0.57	0.06	0.51	0.97	0.302	1.10	0.274	1.05	1.10	0.287	No
60	10.99	0.58	0.06	0.52	0.97	0.304	1.10	0.276	1.05	1.10	0.289	No
61	11.15	0.59	0.07	0.52	0.97	0.306	1.10	0.278	1.05	1.10	0.291	No
62	11.32	0.60	0.07	0.53	0.97	0.309	1.10	0.280	1.05	1.10	0.292	No
63	11.48	0.61	0.08	0.53	0.97	0.311	1.10	0.282	1.06	1.10	0.294	No
64	11.65	0.62	0.08	0.53	0.97	0.313	1.10	0.284	1.06	1.10	0.295	No
65	11.81	0.63	0.09	0.54	0.97	0.315	1.10	0.286	1.06	1.10	0.297	No
66	11.97	0.63	0.09	0.54	0.97	0.317	1.10	0.288	1.06	1.10	0.300	No
67	12.14	0.64	0.10	0.55	0.97	0.319	1.10	0.289	1.05	1.10	0.302	No
68	12.30	0.65	0.10	0.55	0.97	0.321	1.10	0.291	1.05	1.10	0.304	No
69	12.47	0.66	0.11	0.55	0.97	0.323	1.10	0.293	1.05	1.10	0.306	No
70	12.63	0.67	0.11	0.56	0.97	0.325	1.10	0.295	1.05	1.10	0.308	No
71	12.79	0.68	0.12	0.56	0.97	0.327	1.10	0.296	1.05	1.10	0.310	No
72	12.96	0.69	0.12	0.56	0.96	0.329	1.10	0.298	1.05	1.10	0.312	No
73	13.12	0.70	0.13	0.57	0.96	0.330	1.10	0.300	1.05	1.10	0.314	No
74	13.29	0.71	0.13	0.57	0.96	0.332	1.10	0.301	1.05	1.10	0.316	No
75	13.45	0.72	0.14	0.58	0.96	0.334	1.10	0.303	1.05	1.10	0.317	No
76	13.62	0.72	0.14	0.58	0.96	0.336	1.10	0.304	1.05	1.10	0.319	No
77	13.78	0.73	0.15	0.58	0.96	0.337	1.10	0.306	1.05	1.10	0.320	No
78	13.94	0.74	0.15	0.59	0.96	0.339	1.10	0.307	1.05	1.10	0.322	No
79	14.11	0.75	0.16	0.59	0.96	0.341	1.10	0.309	1.05	1.10	0.323	No
80	14.27	0.76	0.16	0.60	0.96	0.342	1.10	0.310	1.05	1.10	0.326	No
81	14.44	0.77	0.17	0.60	0.96	0.344	1.10	0.312	1.05	1.10	0.327	No
82	14.60	0.78	0.17	0.60	0.96	0.345	1.10	0.313	1.05	1.10	0.329	No
83	14.76	0.79	0.18	0.61	0.96	0.347	1.10	0.314	1.05	1.10	0.330	No
84	14.93	0.80	0.18	0.61	0.96	0.348	1.10	0.316	1.04	1.10	0.335	No
85	15.09	0.80	0.19	0.61	0.96	0.350	1.10	0.317	1.03	1.10	0.339	No
86	15.26	0.81	0.20	0.62	0.96	0.351	1.10	0.319	1.03	1.10	0.341	No
87	15.42	0.82	0.20	0.62	0.95	0.353	1.10	0.320	1.03	1.10	0.343	No
88	15.58	0.83	0.21	0.62	0.95	0.354	1.10	0.321	1.03	1.10	0.344	No
89	15.75	0.84	0.21	0.63	0.95	0.356	1.10	0.323	1.03	1.10	0.345	No
90	15.91	0.85	0.22	0.63	0.95	0.357	1.10	0.324	1.03	1.10	0.346	No
91	16.08	0.86	0.22	0.64	0.95	0.358	1.10	0.325	1.03	1.10	0.347	No
92	16.24	0.87	0.23	0.64	0.95	0.360	1.10	0.326	1.03	1.10	0.349	No
93	16.40	0.87	0.23	0.64	0.95	0.361	1.10	0.327	1.03	1.10	0.350	No
94	16.57	0.88	0.24	0.65	0.95	0.362	1.10	0.328	1.03	1.10	0.352	No
95	16.73	0.89	0.24	0.65	0.95	0.363	1.10	0.329	1.03	1.10	0.353	No
96	16.90	0.90	0.25	0.66	0.95	0.364	1.10	0.331	1.03	1.10	0.353	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
97	17.06	0.91	0.25	0.66	0.95	0.366	1.10	0.332	1.03	1.10	0.354	No
98	17.22	0.92	0.26	0.67	0.95	0.367	1.10	0.332	1.03	1.10	0.354	No
99	17.39	0.93	0.26	0.67	0.95	0.368	1.10	0.333	1.05	1.10	0.350	No
100	17.55	0.94	0.27	0.68	0.95	0.369	1.10	0.334	1.06	1.10	0.346	No
101	17.72	0.95	0.27	0.68	0.94	0.370	1.10	0.335	1.06	1.10	0.347	No
102	17.88	0.96	0.28	0.69	0.94	0.370	1.10	0.336	1.05	1.10	0.352	No
103	18.05	0.97	0.28	0.69	0.94	0.371	1.10	0.337	1.04	1.10	0.356	No
104	18.21	0.98	0.29	0.70	0.94	0.372	1.10	0.338	1.03	1.10	0.359	No
105	18.37	0.99	0.29	0.70	0.94	0.373	1.10	0.338	1.04	1.10	0.358	No
106	18.54	1.00	0.30	0.71	0.94	0.374	1.10	0.339	1.05	1.10	0.355	No
107	18.70	1.01	0.30	0.71	0.94	0.374	1.10	0.340	1.07	1.10	0.350	No
108	18.86	1.03	0.31	0.72	0.94	0.375	1.10	0.340	1.05	1.10	0.355	No
109	19.03	1.04	0.31	0.72	0.94	0.376	1.10	0.341	1.03	1.10	0.363	No
110	19.19	1.05	0.32	0.73	0.94	0.377	1.10	0.342	1.02	1.10	0.367	No
111	19.36	1.06	0.32	0.73	0.94	0.377	1.10	0.342	1.02	1.10	0.369	No
112	19.52	1.07	0.33	0.74	0.94	0.378	1.10	0.343	1.02	1.10	0.369	No
113	19.68	1.08	0.33	0.74	0.94	0.379	1.10	0.343	1.02	1.10	0.370	No
114	19.85	1.09	0.34	0.75	0.93	0.379	1.10	0.344	1.02	1.10	0.371	No
115	20.01	1.10	0.34	0.75	0.93	0.380	1.10	0.345	1.02	1.10	0.372	No
116	20.18	1.11	0.35	0.76	0.93	0.381	1.10	0.345	1.02	1.10	0.373	No
117	20.34	1.12	0.35	0.76	0.93	0.381	1.10	0.346	1.02	1.10	0.373	No
118	20.50	1.13	0.36	0.77	0.93	0.382	1.10	0.347	1.02	1.10	0.374	No
119	20.67	1.14	0.36	0.77	0.93	0.383	1.10	0.347	1.02	1.10	0.375	No
120	20.83	1.15	0.37	0.78	0.93	0.383	1.10	0.348	1.02	1.10	0.375	No
121	21.00	1.16	0.37	0.78	0.93	0.384	1.10	0.348	1.02	1.10	0.375	No
122	21.16	1.17	0.38	0.79	0.93	0.385	1.10	0.349	1.02	1.10	0.377	No
123	21.32	1.18	0.38	0.79	0.93	0.385	1.10	0.349	1.02	1.10	0.378	No
124	21.49	1.19	0.39	0.80	0.93	0.386	1.10	0.350	1.01	1.10	0.379	No
125	21.65	1.20	0.39	0.80	0.93	0.387	1.10	0.351	1.01	1.10	0.380	No
126	21.82	1.21	0.40	0.81	0.93	0.387	1.10	0.351	1.02	1.10	0.380	No
127	21.98	1.22	0.41	0.81	0.93	0.388	1.10	0.352	1.02	1.10	0.380	No
128	22.15	1.23	0.41	0.82	0.92	0.388	1.10	0.352	1.02	1.10	0.381	No
129	22.31	1.24	0.42	0.82	0.92	0.389	1.10	0.352	1.01	1.10	0.382	No
130	22.47	1.25	0.42	0.83	0.92	0.389	1.10	0.353	1.01	1.10	0.383	No
131	22.64	1.26	0.43	0.83	0.92	0.390	1.10	0.353	1.01	1.10	0.383	No
132	22.80	1.27	0.43	0.84	0.92	0.390	1.10	0.354	1.01	1.10	0.384	No
133	22.97	1.28	0.44	0.84	0.92	0.391	1.10	0.354	1.02	1.10	0.383	No
134	23.13	1.29	0.44	0.85	0.92	0.391	1.10	0.355	1.02	1.10	0.383	No
135	23.29	1.30	0.45	0.85	0.92	0.392	1.10	0.355	1.02	1.10	0.384	No
136	23.46	1.31	0.45	0.85	0.92	0.392	1.10	0.356	1.01	1.10	0.385	No
137	23.62	1.32	0.46	0.86	0.92	0.393	1.10	0.356	1.01	1.10	0.387	No
138	23.79	1.33	0.46	0.86	0.92	0.393	1.10	0.356	1.01	1.10	0.388	No
139	23.95	1.34	0.47	0.87	0.92	0.393	1.10	0.357	1.01	1.10	0.388	No
140	24.11	1.35	0.47	0.87	0.91	0.394	1.10	0.357	1.01	1.10	0.389	No
141	24.28	1.36	0.48	0.88	0.91	0.394	1.10	0.357	1.01	1.10	0.389	No
142	24.44	1.37	0.48	0.89	0.91	0.394	1.10	0.358	1.01	1.10	0.389	No
143	24.61	1.38	0.49	0.89	0.91	0.395	1.10	0.358	1.01	1.10	0.389	No
144	24.77	1.39	0.49	0.90	0.91	0.395	1.10	0.358	1.01	1.10	0.390	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
145	24.93	1.40	0.50	0.90	0.91	0.395	1.10	0.358	1.01	1.10	0.390	No
146	25.10	1.41	0.50	0.90	0.91	0.396	1.10	0.359	1.01	1.10	0.390	No
147	25.26	1.42	0.51	0.91	0.91	0.396	1.10	0.359	1.01	1.10	0.391	No
148	25.43	1.43	0.51	0.91	0.91	0.396	1.10	0.359	1.01	1.10	0.391	No
149	25.59	1.44	0.52	0.92	0.91	0.397	1.10	0.360	1.01	1.10	0.392	No
150	25.75	1.45	0.52	0.92	0.91	0.397	1.10	0.360	1.01	1.10	0.392	No
151	25.92	1.46	0.53	0.93	0.91	0.397	1.10	0.360	1.01	1.10	0.393	No
152	26.08	1.47	0.53	0.93	0.91	0.398	1.10	0.361	1.01	1.10	0.394	No
153	26.25	1.48	0.54	0.94	0.90	0.398	1.10	0.361	1.01	1.10	0.394	No
154	26.41	1.49	0.54	0.94	0.90	0.398	1.10	0.361	1.01	1.10	0.394	No
155	26.57	1.50	0.55	0.95	0.90	0.398	1.10	0.361	1.01	1.10	0.395	No
156	26.74	1.51	0.55	0.95	0.90	0.399	1.10	0.361	1.01	1.10	0.395	No
157	26.90	1.52	0.56	0.96	0.90	0.399	1.10	0.362	1.01	1.10	0.396	No
158	27.07	1.53	0.56	0.96	0.90	0.399	1.10	0.362	1.00	1.10	0.396	No
159	27.23	1.54	0.57	0.97	0.90	0.399	1.10	0.362	1.00	1.10	0.397	No
160	27.39	1.55	0.57	0.97	0.90	0.400	1.10	0.362	1.00	1.10	0.397	No
161	27.56	1.55	0.58	0.98	0.90	0.400	1.10	0.363	1.00	1.10	0.397	No
162	27.72	1.56	0.58	0.98	0.90	0.400	1.10	0.363	1.00	1.10	0.398	No
163	27.89	1.57	0.59	0.98	0.90	0.401	1.10	0.363	1.00	1.10	0.398	No
164	28.05	1.58	0.59	0.99	0.90	0.401	1.10	0.364	1.00	1.10	0.398	No
165	28.21	1.59	0.60	0.99	0.89	0.401	1.10	0.364	1.00	1.10	0.398	No
166	28.38	1.60	0.60	1.00	0.89	0.402	1.10	0.364	1.00	1.10	0.399	No
167	28.54	1.61	0.61	1.00	0.89	0.402	1.10	0.364	1.00	1.10	0.399	No
168	28.71	1.62	0.61	1.00	0.89	0.402	1.10	0.365	1.00	1.10	0.400	No
169	28.87	1.63	0.62	1.01	0.89	0.402	1.10	0.365	1.00	1.10	0.400	No
170	29.04	1.64	0.63	1.01	0.89	0.403	1.10	0.365	1.00	1.10	0.401	No
171	29.20	1.65	0.63	1.02	0.89	0.403	1.10	0.365	1.00	1.10	0.401	No
172	29.36	1.66	0.64	1.02	0.89	0.403	1.10	0.365	1.00	1.10	0.401	No
173	29.53	1.67	0.64	1.03	0.89	0.403	1.10	0.365	1.00	1.10	0.401	No
174	29.69	1.68	0.65	1.03	0.89	0.403	1.10	0.365	1.00	1.10	0.401	No
175	29.86	1.69	0.65	1.04	0.89	0.403	1.10	0.365	1.00	1.10	0.402	No
176	30.02	1.70	0.66	1.04	0.89	0.403	1.10	0.366	1.00	1.10	0.402	No
177	30.18	1.71	0.66	1.05	0.88	0.403	1.10	0.366	1.00	1.10	0.402	No
178	30.35	1.72	0.67	1.05	0.88	0.403	1.10	0.366	1.00	1.10	0.402	No
179	30.51	1.73	0.67	1.06	0.88	0.403	1.10	0.366	1.00	1.10	0.402	No
180	30.68	1.74	0.68	1.06	0.88	0.403	1.10	0.366	1.00	1.10	0.403	No
181	30.84	1.75	0.68	1.07	0.88	0.404	1.10	0.366	1.00	1.10	0.403	No
182	31.00	1.76	0.69	1.07	0.88	0.404	1.10	0.366	1.00	1.10	0.403	No
183	31.17	1.77	0.69	1.08	0.88	0.404	1.10	0.366	1.00	1.10	0.403	No
184	31.33	1.78	0.70	1.08	0.88	0.404	1.10	0.366	1.00	1.10	0.403	No
185	31.50	1.79	0.70	1.09	0.88	0.404	1.10	0.366	1.00	1.10	0.404	No
186	31.66	1.80	0.71	1.09	0.88	0.404	1.10	0.366	1.00	1.10	0.404	No
187	31.82	1.81	0.71	1.10	0.88	0.404	1.10	0.366	1.00	1.10	0.404	No
188	31.99	1.82	0.72	1.10	0.88	0.404	1.10	0.366	1.00	1.10	0.404	No
189	32.15	1.83	0.72	1.11	0.87	0.404	1.10	0.366	0.99	1.10	0.406	No
190	32.32	1.84	0.73	1.11	0.87	0.404	1.10	0.366	0.99	1.10	0.407	No
191	32.48	1.85	0.73	1.12	0.87	0.404	1.10	0.366	0.99	1.10	0.409	No
192	32.64	1.86	0.74	1.12	0.87	0.404	1.10	0.366	0.98	1.10	0.409	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
193	32.81	1.87	0.74	1.13	0.87	0.404	1.10	0.366	0.98	1.10	0.409	No
194	32.97	1.88	0.75	1.14	0.87	0.403	1.10	0.366	0.98	1.10	0.409	No
195	33.14	1.89	0.75	1.14	0.87	0.403	1.10	0.366	0.99	1.10	0.408	No
196	33.30	1.91	0.76	1.15	0.87	0.403	1.10	0.366	0.99	1.10	0.408	No
197	33.47	1.92	0.76	1.15	0.87	0.403	1.10	0.366	0.98	1.10	0.409	No
198	33.63	1.93	0.77	1.16	0.87	0.403	1.10	0.366	0.98	1.10	0.409	No
199	33.79	1.94	0.77	1.16	0.87	0.403	1.10	0.366	0.98	1.10	0.409	No
200	33.96	1.95	0.78	1.17	0.87	0.403	1.10	0.365	0.98	1.10	0.409	No
201	34.12	1.96	0.78	1.17	0.86	0.403	1.10	0.365	0.98	1.10	0.409	No
202	34.28	1.97	0.79	1.18	0.86	0.403	1.10	0.365	0.98	1.10	0.409	No
203	34.45	1.98	0.79	1.18	0.86	0.403	1.10	0.365	0.98	1.10	0.408	No
204	34.61	1.99	0.80	1.19	0.86	0.403	1.10	0.365	0.98	1.10	0.408	No
205	34.78	2.00	0.80	1.19	0.86	0.403	1.10	0.365	0.98	1.10	0.409	No
206	34.94	2.01	0.81	1.20	0.86	0.403	1.10	0.365	0.98	1.10	0.409	No
207	35.10	2.02	0.81	1.20	0.86	0.403	1.10	0.365	0.98	1.10	0.410	No
208	35.27	2.03	0.82	1.21	0.86	0.402	1.10	0.365	0.98	1.10	0.411	No
209	35.43	2.04	0.82	1.21	0.86	0.402	1.10	0.365	0.98	1.10	0.410	No
210	35.60	2.05	0.83	1.22	0.86	0.402	1.10	0.365	0.98	1.10	0.409	No
211	35.76	2.06	0.83	1.22	0.86	0.402	1.10	0.365	0.98	1.10	0.411	No
212	35.92	2.07	0.84	1.23	0.85	0.402	1.10	0.365	0.96	1.10	0.420	No
213	36.09	2.08	0.85	1.24	0.85	0.402	1.10	0.365	0.95	1.10	0.421	No
214	36.25	2.09	0.85	1.24	0.85	0.402	1.10	0.364	0.95	1.10	0.421	No
215	36.42	2.10	0.86	1.25	0.85	0.402	1.10	0.364	0.95	1.10	0.421	No
216	36.58	2.11	0.86	1.25	0.85	0.401	1.10	0.364	0.95	1.10	0.422	No
217	36.74	2.12	0.87	1.26	0.85	0.401	1.10	0.364	0.95	1.10	0.422	No
218	36.91	2.13	0.87	1.26	0.85	0.401	1.10	0.364	0.95	1.10	0.423	No
219	37.07	2.14	0.88	1.27	0.85	0.401	1.10	0.364	0.95	1.10	0.423	No
220	37.24	2.16	0.88	1.27	0.85	0.401	1.10	0.363	0.94	1.10	0.423	No
221	37.40	2.17	0.89	1.28	0.85	0.401	1.10	0.363	0.94	1.10	0.424	No
222	37.57	2.18	0.89	1.29	0.85	0.400	1.10	0.363	0.94	1.10	0.424	No
223	37.73	2.19	0.90	1.29	0.85	0.400	1.10	0.363	0.94	1.10	0.425	No
224	37.89	2.20	0.90	1.30	0.84	0.400	1.10	0.363	0.94	1.10	0.425	No
225	38.06	2.21	0.91	1.30	0.84	0.400	1.10	0.363	0.94	1.10	0.425	No
226	38.22	2.22	0.91	1.31	0.84	0.400	1.10	0.362	0.94	1.10	0.426	No
227	38.39	2.23	0.92	1.31	0.84	0.400	1.10	0.362	0.94	1.10	0.426	No
228	38.55	2.24	0.92	1.32	0.84	0.399	1.10	0.362	0.93	1.10	0.427	No
229	38.71	2.25	0.93	1.32	0.84	0.399	1.10	0.362	0.93	1.10	0.427	No
230	38.88	2.26	0.93	1.33	0.84	0.399	1.10	0.362	0.93	1.10	0.427	No
231	39.04	2.27	0.94	1.33	0.84	0.399	1.10	0.362	0.93	1.10	0.428	No
232	39.21	2.28	0.94	1.34	0.84	0.399	1.10	0.362	0.93	1.10	0.428	No
233	39.37	2.29	0.95	1.35	0.84	0.398	1.10	0.361	0.93	1.10	0.428	No
234	39.53	2.30	0.95	1.35	0.84	0.398	1.10	0.361	0.93	1.10	0.429	No
235	39.70	2.31	0.96	1.36	0.83	0.398	1.10	0.361	0.93	1.10	0.429	No
236	39.86	2.32	0.96	1.36	0.83	0.398	1.10	0.361	0.92	1.10	0.429	No
237	40.03	2.34	0.97	1.37	0.83	0.398	1.10	0.361	0.92	1.10	0.430	No
238	40.19	2.35	0.97	1.37	0.83	0.398	1.10	0.360	0.92	1.10	0.430	No
239	40.35	2.36	0.98	1.38	0.83	0.397	1.10	0.360	0.93	1.10	0.425	No
240	40.52	2.37	0.98	1.38	0.83	0.397	1.10	0.360	0.97	1.10	0.407	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
241	40.68	2.38	0.99	1.39	0.83	0.397	1.10	0.360	0.98	1.10	0.405	No
242	40.85	2.39	0.99	1.39	0.83	0.397	1.10	0.360	0.98	1.10	0.403	No
243	41.01	2.40	1.00	1.40	0.83	0.397	1.10	0.360	0.98	1.10	0.402	No
244	41.17	2.41	1.00	1.40	0.83	0.397	1.10	0.360	0.98	1.10	0.402	No
245	41.34	2.42	1.01	1.41	0.83	0.397	1.10	0.360	0.98	1.10	0.402	No
246	41.50	2.43	1.01	1.41	0.83	0.396	1.10	0.359	0.98	1.10	0.402	No
247	41.67	2.44	1.02	1.42	0.82	0.396	1.10	0.359	0.98	1.10	0.402	No
248	41.83	2.45	1.02	1.42	0.82	0.396	1.10	0.359	0.98	1.10	0.402	No
249	41.99	2.45	1.03	1.43	0.82	0.396	1.10	0.359	0.98	1.10	0.401	No
250	42.16	2.46	1.03	1.43	0.82	0.396	1.10	0.359	0.98	1.10	0.401	No
251	42.32	2.47	1.04	1.43	0.82	0.396	1.10	0.359	0.98	1.10	0.401	No
252	42.49	2.48	1.04	1.44	0.82	0.396	1.10	0.359	0.98	1.10	0.401	No
253	42.65	2.49	1.05	1.44	0.82	0.396	1.10	0.359	0.98	1.10	0.401	No
254	42.81	2.50	1.06	1.45	0.82	0.395	1.10	0.359	0.99	1.10	0.400	No
255	42.98	2.51	1.06	1.45	0.82	0.395	1.10	0.358	0.99	1.10	0.400	No
256	43.14	2.52	1.07	1.46	0.82	0.395	1.10	0.358	0.98	1.10	0.400	No
257	43.31	2.53	1.07	1.46	0.82	0.395	1.10	0.358	0.98	1.10	0.400	No
258	43.47	2.54	1.08	1.47	0.81	0.395	1.10	0.358	0.98	1.10	0.400	No
259	43.63	2.55	1.08	1.47	0.81	0.395	1.10	0.358	0.98	1.10	0.400	No
260	43.80	2.56	1.09	1.47	0.81	0.395	1.10	0.358	0.98	1.10	0.400	No
261	43.96	2.57	1.09	1.48	0.81	0.395	1.10	0.358	0.98	1.10	0.400	No
262	44.13	2.58	1.10	1.48	0.81	0.394	1.10	0.358	0.98	1.10	0.400	No
263	44.29	2.59	1.10	1.49	0.81	0.394	1.10	0.358	0.98	1.10	0.400	No
264	44.45	2.60	1.11	1.49	0.81	0.394	1.10	0.357	0.98	1.10	0.400	No
265	44.62	2.61	1.11	1.49	0.81	0.394	1.10	0.357	0.98	1.10	0.400	No
266	44.78	2.62	1.12	1.50	0.81	0.394	1.10	0.357	0.98	1.10	0.400	No
267	44.95	2.62	1.12	1.50	0.81	0.394	1.10	0.357	0.98	1.10	0.399	No
268	45.11	2.63	1.13	1.51	0.81	0.394	1.10	0.357	0.98	1.10	0.400	No
269	45.28	2.64	1.13	1.51	0.81	0.394	1.10	0.357	0.98	1.10	0.400	No
270	45.44	2.65	1.14	1.51	0.80	0.394	1.10	0.357	0.98	1.10	0.399	No
271	45.60	2.66	1.14	1.52	0.80	0.393	1.10	0.357	0.98	1.10	0.399	No
272	45.77	2.67	1.15	1.52	0.80	0.393	1.10	0.357	0.98	1.10	0.399	No
273	45.93	2.68	1.15	1.53	0.80	0.393	1.10	0.356	0.98	1.10	0.399	No
274	46.10	2.69	1.16	1.53	0.80	0.393	1.10	0.356	0.98	1.10	0.399	No
275	46.26	2.70	1.16	1.54	0.80	0.393	1.10	0.356	0.98	1.10	0.398	No
276	46.42	2.71	1.17	1.54	0.80	0.393	1.10	0.356	0.98	1.10	0.398	No
277	46.59	2.72	1.17	1.55	0.80	0.392	1.10	0.356	0.98	1.10	0.398	No
278	46.75	2.73	1.18	1.55	0.80	0.392	1.10	0.356	0.98	1.10	0.398	No
279	46.92	2.74	1.18	1.55	0.80	0.392	1.10	0.356	0.98	1.10	0.399	No
280	47.08	2.75	1.19	1.56	0.80	0.392	1.10	0.355	0.98	1.10	0.399	No
281	47.24	2.76	1.19	1.56	0.79	0.392	1.10	0.355	0.98	1.10	0.399	No
282	47.41	2.76	1.20	1.57	0.79	0.392	1.10	0.355	0.98	1.10	0.399	No
283	47.57	2.77	1.20	1.57	0.79	0.391	1.10	0.355	0.98	1.10	0.399	No
284	47.74	2.78	1.21	1.57	0.79	0.391	1.10	0.355	0.98	1.10	0.399	No
285	47.90	2.79	1.21	1.58	0.79	0.391	1.10	0.355	0.98	1.10	0.399	No
286	48.06	2.80	1.22	1.58	0.79	0.391	1.10	0.355	0.98	1.10	0.399	No
287	48.23	2.81	1.22	1.59	0.79	0.391	1.10	0.354	0.98	1.10	0.399	No
288	48.39	2.82	1.23	1.59	0.79	0.391	1.10	0.354	0.98	1.10	0.398	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
289	48.56	2.83	1.23	1.60	0.79	0.390	1.10	0.354	0.98	1.10	0.398	No
290	48.72	2.84	1.24	1.60	0.79	0.390	1.10	0.354	0.98	1.10	0.398	No
291	48.88	2.85	1.24	1.61	0.79	0.390	1.10	0.354	0.98	1.10	0.398	No
292	49.05	2.86	1.25	1.61	0.79	0.390	1.10	0.353	0.98	1.10	0.398	No
293	49.21	2.87	1.25	1.62	0.78	0.389	1.10	0.353	0.97	1.10	0.399	No
294	49.38	2.88	1.26	1.62	0.78	0.389	1.10	0.353	0.97	1.10	0.399	No
295	49.54	2.89	1.26	1.63	0.78	0.389	1.10	0.353	0.97	1.10	0.399	No
296	49.70	2.90	1.27	1.63	0.78	0.389	1.10	0.353	0.97	1.10	0.400	No
297	49.87	2.91	1.28	1.64	0.78	0.388	1.10	0.352	0.96	1.10	0.402	No
298	50.03	2.92	1.28	1.64	0.78	0.388	1.10	0.352	0.97	1.10	0.400	No
299	50.20	2.93	1.29	1.64	0.78	0.388	1.10	0.352	0.97	1.10	0.398	No

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
σ_v: Total overburden pressure at test point (tsf)
u_0: Water pressure at test point (tsf)
σ_v': Effective overburden pressure based on GWT during earthquake (tsf)
r_d: Nonlinear shear mass factor
CSR: Cyclic Stress Ratio
MSF: Magnitude Scaling Factor
CSR_{eq}: CSR adjusted for M=7.5
K_σ: Effective overburden stress factor
CSR^*: CSR fully adjusted

:: Cyclic Resistance Ratio (CRR) calculation data ::

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
1	1.31	18.47	25.89	2.39	0.58	1.70	31.59	37.90	69.49	4.000	No	No	2.00
2	1.48	16.96	29.25	2.47	0.59	1.70	25.77	37.38	63.15	4.000	No	No	2.00
3	1.64	14.72	36.05	2.61	0.60	1.70	24.32	0.00	24.32	4.000	No	Yes	2.00
4	1.80	13.33	40.18	2.69	0.61	1.70	20.81	0.00	20.81	4.000	No	Yes	2.00
5	1.97	12.18	42.19	2.73	0.62	1.70	19.10	0.00	19.10	4.000	No	Yes	2.00
6	2.13	11.49	39.89	2.69	0.62	1.70	18.78	0.00	18.78	4.000	No	Yes	2.00
7	2.30	11.18	37.49	2.64	0.63	1.70	17.46	0.00	17.46	4.000	No	Yes	2.00
8	2.46	11.05	35.03	2.59	0.63	1.70	17.59	35.79	53.39	4.000	No	No	2.00
9	2.63	11.41	32.41	2.54	0.63	1.70	18.16	35.58	53.74	4.000	No	No	2.00
10	2.79	11.90	29.67	2.48	0.62	1.70	19.20	35.31	54.51	4.000	No	No	2.00
11	2.95	12.79	27.17	2.42	0.62	1.70	20.00	34.74	54.74	4.000	No	No	2.00
12	3.12	14.05	24.36	2.35	0.62	1.70	22.43	34.13	56.56	4.000	No	No	2.00
13	3.28	15.73	21.66	2.28	0.61	1.70	25.29	32.98	58.27	4.000	No	No	2.00
14	3.44	17.43	5.00	2.21	0.74	1.70	28.08	0.01	28.10	4.000	No	No	2.00
15	3.61	18.63	5.00	2.18	0.72	1.70	30.61	0.01	30.62	4.000	No	No	2.00
16	3.77	19.69	5.00	2.17	0.72	1.70	31.06	0.01	31.07	4.000	No	No	2.00
17	3.94	19.98	18.55	2.19	0.59	1.70	33.23	31.46	64.69	4.000	No	No	2.00
18	4.10	20.31	18.96	2.20	0.59	1.70	32.00	31.75	63.76	4.000	No	No	2.00
19	4.26	19.91	19.94	2.23	0.59	1.70	32.65	33.24	65.89	4.000	No	No	2.00
20	4.43	19.84	20.51	2.24	0.59	1.70	31.28	33.54	64.82	4.000	No	No	2.00
21	4.59	19.56	21.05	2.26	0.59	1.70	31.67	34.24	65.91	4.000	No	No	2.00
22	4.76	19.72	20.79	2.25	0.59	1.70	31.30	33.86	65.16	4.000	No	No	2.00
23	4.92	20.35	20.09	2.23	0.59	1.70	32.08	33.27	65.35	4.000	No	No	2.00
24	5.08	21.69	18.77	2.19	0.58	1.70	34.69	32.19	66.88	4.000	No	No	2.00
25	5.25	23.37	17.48	2.15	0.58	1.70	37.74	30.81	68.55	4.000	No	No	2.00
26	5.41	24.88	16.33	2.12	0.58	1.70	40.20	29.05	69.25	4.000	No	No	2.00
27	5.58	26.37	15.29	2.08	0.58	1.70	41.98	26.93	68.91	4.000	No	No	2.00
28	5.74	28.42	14.05	2.04	0.58	1.70	44.89	23.99	68.88	4.000	No	No	2.00
29	5.91	31.51	5.00	1.98	0.64	1.70	50.11	0.02	50.13	4.000	No	No	2.00
30	6.07	35.15	5.00	1.91	0.61	1.70	56.88	0.02	56.89	4.000	No	No	2.00
31	6.23	38.56	5.00	1.86	0.60	1.70	62.42	0.02	62.44	4.000	No	No	2.00
32	6.40	41.16	5.00	1.82	0.58	1.70	66.55	0.02	66.57	4.000	No	No	2.00
33	6.56	42.78	5.00	1.81	0.58	1.70	69.42	0.02	69.44	4.000	No	No	2.00
34	6.73	43.16	5.00	1.83	0.57	1.70	70.21	0.02	70.23	4.000	No	No	2.00
35	6.89	41.96	5.00	1.87	0.58	1.70	68.36	0.02	68.38	4.000	No	No	2.00
36	7.05	39.31	11.18	1.93	0.55	1.70	63.69	15.89	79.58	4.000	No	No	2.00
37	7.22	36.04	13.27	2.01	0.54	1.70	57.41	23.52	80.93	4.000	No	No	2.00
38	7.38	33.75	15.15	2.08	0.54	1.70	52.62	28.76	81.38	4.000	No	No	2.00
39	7.55	33.49	15.83	2.10	0.54	1.70	52.65	30.64	83.29	4.000	No	No	2.00
40	7.71	34.75	15.40	2.09	0.53	1.67	55.21	30.01	85.22	4.000	No	No	2.00
41	7.87	36.40	14.46	2.05	0.53	1.65	57.09	27.59	84.67	4.000	No	No	2.00
42	8.04	38.58	13.10	2.01	0.54	1.65	58.64	23.11	81.75	4.000	No	No	2.00
43	8.20	41.46	11.47	1.94	0.54	1.63	63.92	17.20	81.12	4.000	No	No	2.00
44	8.37	43.50	10.43	1.90	0.54	1.61	68.65	13.04	81.69	4.000	No	No	2.00
45	8.53	43.39	10.38	1.90	0.55	1.60	66.36	12.64	79.00	4.000	No	No	2.00
46	8.69	41.04	10.99	1.92	0.55	1.59	61.96	14.90	76.86	4.000	No	No	2.00
47	8.86	38.24	11.99	1.96	0.56	1.58	56.91	18.51	75.42	4.000	No	No	2.00
48	9.02	35.58	13.09	2.01	0.56	1.57	52.49	22.09	74.58	0.105	No	No	0.41

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
49	9.19	33.57	14.27	2.05	0.56	1.55	48.68	25.37	74.06	0.105	No	No	0.40
50	9.35	32.63	14.59	2.06	0.56	1.54	46.73	25.96	72.69	0.103	No	No	0.39
51	9.51	32.89	14.44	2.05	0.57	1.53	47.06	25.60	72.66	0.103	No	No	0.39
52	9.68	34.32	13.77	2.03	0.57	1.51	48.54	23.76	72.29	0.102	No	No	0.38
53	9.84	36.11	13.29	2.01	0.56	1.49	51.32	22.63	73.95	0.105	No	No	0.38
54	10.01	37.22	13.01	2.00	0.56	1.48	52.99	21.87	74.86	0.106	No	No	0.39
55	10.17	37.38	13.02	2.00	0.56	1.47	51.69	21.73	73.42	0.104	No	No	0.38
56	10.34	36.69	13.33	2.01	0.56	1.45	50.62	22.62	73.24	0.104	No	No	0.37
57	10.50	33.96	14.42	2.05	0.56	1.44	48.80	25.85	74.66	0.106	No	No	0.37
58	10.66	33.90	14.40	2.05	0.59	1.45	39.93	24.11	64.04	0.092	No	No	0.32
59	10.83	34.12	14.37	2.05	0.56	1.41	48.90	25.72	74.62	0.105	No	No	0.37
60	10.99	37.18	13.30	2.01	0.57	1.41	48.72	22.23	70.96	0.101	No	No	0.35
61	11.15	39.11	12.66	1.99	0.57	1.40	50.76	20.26	71.01	0.101	No	No	0.35
62	11.32	43.22	5.00	1.94	0.61	1.43	57.51	0.02	57.52	0.085	No	No	0.29
63	11.48	47.91	5.00	1.89	0.59	1.41	65.14	0.02	65.15	0.094	No	No	0.32
64	11.65	51.77	5.00	1.86	0.58	1.39	68.89	0.02	68.90	0.098	No	No	0.33
65	11.81	53.18	10.01	1.88	0.54	1.36	69.52	11.22	80.75	0.114	No	No	0.38
66	11.97	52.99	10.43	1.90	0.54	1.36	68.11	13.02	81.13	0.114	No	No	0.38
67	12.14	52.11	10.37	1.90	0.55	1.36	66.31	12.58	78.88	0.111	No	No	0.37
68	12.30	52.01	5.00	1.87	0.58	1.38	66.79	0.02	66.81	0.096	No	No	0.31
69	12.47	51.56	5.00	1.87	0.58	1.37	68.31	0.02	68.33	0.098	No	No	0.32
70	12.63	50.45	5.00	1.89	0.59	1.37	65.24	0.02	65.26	0.094	No	No	0.30
71	12.79	49.06	5.00	1.91	0.60	1.37	62.28	0.02	62.29	0.090	No	No	0.29
72	12.96	49.09	5.00	1.91	0.60	1.37	62.83	0.02	62.85	0.091	No	No	0.29
73	13.12	50.56	10.43	1.90	0.56	1.33	63.59	12.63	76.22	0.108	No	No	0.34
74	13.29	51.89	10.20	1.89	0.55	1.33	65.74	11.81	77.55	0.109	No	No	0.35
75	13.45	52.88	5.00	1.88	0.58	1.34	66.79	0.02	66.81	0.096	No	No	0.30
76	13.62	54.37	5.00	1.85	0.58	1.34	67.46	0.02	67.47	0.097	No	No	0.30
77	13.78	56.49	5.00	1.82	0.57	1.32	71.24	0.02	71.26	0.101	No	No	0.32
78	13.94	58.54	5.00	1.79	0.56	1.32	73.39	0.02	73.41	0.104	No	No	0.32
79	14.11	57.93	5.00	1.79	0.56	1.31	73.81	0.02	73.83	0.104	No	No	0.32
80	14.27	57.50	5.00	1.79	0.58	1.32	68.51	0.02	68.53	0.098	No	No	0.30
81	14.44	57.53	5.00	1.81	0.57	1.31	71.28	0.02	71.30	0.101	No	No	0.31
82	14.60	58.65	5.00	1.81	0.56	1.30	73.25	0.02	73.27	0.104	No	No	0.32
83	14.76	52.39	5.00	1.86	0.57	1.30	71.68	0.02	71.70	0.102	No	No	0.31
84	14.93	39.14	13.35	2.01	0.57	1.30	47.70	22.23	69.93	0.100	No	No	0.30
85	15.09	24.64	21.32	2.27	0.61	1.32	24.77	32.50	57.27	0.085	No	No	0.25
86	15.26	15.44	33.14	2.55	0.62	1.32	18.60	35.86	54.45	0.082	No	No	0.24
87	15.42	13.10	38.43	2.66	0.64	1.32	14.13	0.00	14.13	4.000	No	Yes	2.00
88	15.58	15.15	34.41	2.58	0.63	1.32	15.89	35.13	51.02	0.078	No	No	0.23
89	15.75	19.03	28.04	2.44	0.60	1.29	25.62	36.91	62.53	0.091	No	No	0.26
90	15.91	22.17	25.47	2.38	0.59	1.28	27.55	36.39	63.94	0.092	No	No	0.27
91	16.08	22.50	26.64	2.41	0.59	1.28	26.53	36.64	63.16	0.091	No	No	0.26
92	16.24	21.86	29.61	2.48	0.59	1.28	26.18	37.62	63.80	0.092	No	No	0.26
93	16.40	21.42	31.99	2.53	0.60	1.27	24.91	37.79	62.70	0.091	No	No	0.26
94	16.57	21.79	34.07	2.57	0.59	1.27	24.86	38.16	63.02	0.091	No	No	0.26
95	16.73	25.03	33.17	2.55	0.58	1.26	27.29	38.83	66.12	0.095	No	No	0.27
96	16.90	30.12	30.69	2.50	0.55	1.24	35.55	41.08	76.63	0.108	No	No	0.31

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
97	17.06	36.90	27.42	2.42	0.54	1.23	41.35	41.82	83.17	0.117	No	No	0.33
98	17.22	55.27	19.39	2.21	0.53	1.22	48.97	36.98	85.95	0.121	No	No	0.34
99	17.39	83.19	12.55	1.99	0.46	1.18	94.44	26.17	120.61	0.181	No	No	0.52
100	17.55	109.57	8.91	1.84	0.42	1.16	131.85	9.33	141.18	0.236	No	No	0.68
101	17.72	114.88	8.61	1.82	0.42	1.16	134.46	7.85	142.31	0.240	No	No	0.69
102	17.88	100.73	11.05	1.93	0.43	1.16	112.00	20.29	132.29	0.209	No	No	0.59
103	18.05	79.96	16.79	2.13	0.45	1.16	85.43	40.76	126.19	0.194	No	No	0.54
104	18.21	72.59	21.29	2.27	0.47	1.17	66.95	44.80	111.75	0.163	No	No	0.45
105	18.37	84.33	21.04	2.26	0.43	1.15	86.60	50.16	136.76	0.222	No	No	0.62
106	18.54	113.88	16.39	2.12	0.38	1.13	120.22	47.61	167.83	0.387	No	No	1.09
107	18.70	129.48	14.76	2.06	0.32	1.11	155.85	48.16	204.01	1.380	No	No	2.00
108	18.86	114.36	16.78	2.13	0.35	1.11	133.09	52.03	185.12	0.631	No	No	1.78
109	19.03	76.52	24.68	2.36	0.45	1.14	72.94	50.25	123.19	0.187	No	No	0.51
110	19.19	42.83	40.62	2.70	0.54	1.17	39.34	0.00	39.34	4.000	No	Yes	2.00
111	19.36	29.03	54.42	2.94	0.58	1.18	28.46	0.00	28.46	4.000	No	Yes	2.00
112	19.52	27.23	57.94	2.99	0.58	1.17	28.89	0.00	28.89	4.000	No	Yes	2.00
113	19.68	28.50	56.03	2.96	0.56	1.16	33.20	0.00	33.20	4.000	No	Yes	2.00
114	19.85	29.18	54.20	2.93	0.56	1.16	32.12	0.00	32.12	4.000	No	Yes	2.00
115	20.01	27.48	53.34	2.92	0.57	1.16	30.67	0.00	30.67	4.000	No	Yes	2.00
116	20.18	27.39	48.49	2.84	0.58	1.16	27.39	0.00	27.39	4.000	No	Yes	2.00
117	20.34	28.39	42.76	2.74	0.57	1.15	31.24	0.00	31.24	4.000	No	Yes	2.00
118	20.50	30.88	37.78	2.65	0.56	1.14	33.28	0.00	33.28	4.000	No	Yes	2.00
119	20.67	34.18	34.20	2.58	0.56	1.14	34.67	41.54	76.21	0.108	No	No	0.29
120	20.83	38.12	31.03	2.51	0.54	1.13	41.06	43.03	84.10	0.118	No	No	0.32
121	21.00	38.83	30.78	2.50	0.52	1.12	44.84	44.23	89.07	0.126	No	No	0.33
122	21.16	34.22	35.37	2.60	0.55	1.13	36.47	0.00	36.47	4.000	No	Yes	2.00
123	21.32	25.97	45.74	2.80	0.58	1.13	26.72	0.00	26.72	4.000	No	Yes	2.00
124	21.49	19.86	57.79	2.99	0.62	1.14	19.38	0.00	19.38	4.000	No	Yes	2.00
125	21.65	21.21	55.13	2.95	0.63	1.13	17.36	0.00	17.36	4.000	No	Yes	2.00
126	21.82	30.69	42.20	2.73	0.57	1.12	30.62	0.00	30.62	4.000	No	Yes	2.00
127	21.98	36.29	38.97	2.67	0.51	1.10	48.52	0.00	48.52	4.000	No	Yes	2.00
128	22.15	33.86	42.40	2.74	0.55	1.11	34.74	0.00	34.74	4.000	No	Yes	2.00
129	22.31	25.23	52.18	2.90	0.60	1.11	23.03	0.00	23.03	4.000	No	Yes	2.00
130	22.47	23.15	50.81	2.88	0.60	1.11	21.76	0.00	21.76	4.000	No	Yes	2.00
131	22.64	25.01	45.13	2.78	0.58	1.10	27.93	0.00	27.93	4.000	No	Yes	2.00
132	22.80	35.49	33.17	2.55	0.58	1.10	28.40	39.22	67.62	0.097	No	No	0.25
133	22.97	51.25	23.58	2.33	0.51	1.08	53.22	43.15	96.37	0.137	No	No	0.36
134	23.13	65.18	17.66	2.16	0.47	1.07	75.16	40.53	115.68	0.171	No	No	0.45
135	23.29	63.11	17.63	2.16	0.48	1.07	70.18	39.20	109.38	0.159	No	No	0.41
136	23.46	48.03	24.32	2.35	0.52	1.08	46.81	41.75	88.55	0.125	No	No	0.32
137	23.62	31.40	40.33	2.70	0.57	1.08	29.65	0.00	29.65	4.000	No	Yes	2.00
138	23.79	21.98	61.17	3.04	0.61	1.08	19.85	0.00	19.85	4.000	No	Yes	2.00
139	23.95	19.15	76.34	3.24	0.62	1.08	18.07	0.00	18.07	4.000	No	Yes	2.00
140	24.11	22.36	74.45	3.22	0.61	1.08	20.83	0.00	20.83	4.000	No	Yes	2.00
141	24.28	30.51	62.01	3.05	0.57	1.07	29.26	0.00	29.26	4.000	No	Yes	2.00
142	24.44	36.82	50.67	2.88	0.53	1.06	42.16	0.00	42.16	4.000	No	Yes	2.00
143	24.61	40.05	40.49	2.70	0.54	1.06	39.40	0.00	39.40	4.000	No	Yes	2.00
144	24.77	41.73	30.74	2.50	0.54	1.06	38.58	42.11	80.69	0.114	No	No	0.29

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
145	24.93	46.02	25.53	2.38	0.52	1.05	46.83	42.58	89.41	0.126	No	No	0.32
146	25.10	50.57	24.26	2.35	0.51	1.05	51.75	43.25	95.00	0.135	No	No	0.34
147	25.26	51.86	25.11	2.37	0.51	1.04	51.65	43.84	95.49	0.135	No	No	0.35
148	25.43	50.72	25.91	2.39	0.51	1.04	50.26	43.91	94.17	0.133	No	No	0.34
149	25.59	47.63	28.61	2.45	0.52	1.04	48.00	44.54	92.54	0.131	No	No	0.33
150	25.75	42.82	30.71	2.50	0.53	1.04	42.29	43.35	85.64	0.121	No	No	0.31
151	25.92	38.12	33.85	2.57	0.55	1.04	35.89	41.90	77.79	0.110	No	No	0.28
152	26.08	35.62	35.73	2.61	0.56	1.03	34.03	0.00	34.03	4.000	No	Yes	2.00
153	26.25	36.45	37.37	2.64	0.55	1.03	34.72	0.00	34.72	4.000	No	Yes	2.00
154	26.41	35.40	40.73	2.71	0.54	1.03	37.98	0.00	37.98	4.000	No	Yes	2.00
155	26.57	33.16	44.18	2.77	0.57	1.03	30.73	0.00	30.73	4.000	No	Yes	2.00
156	26.74	26.72	52.15	2.90	0.58	1.02	27.99	0.00	27.99	4.000	No	Yes	2.00
157	26.90	21.75	59.68	3.02	0.62	1.02	19.11	0.00	19.11	4.000	No	Yes	2.00
158	27.07	17.49	67.51	3.13	0.63	1.02	16.15	0.00	16.15	4.000	No	Yes	2.00
159	27.23	16.89	66.21	3.11	0.63	1.02	15.47	0.00	15.47	4.000	No	Yes	2.00
160	27.39	17.74	59.58	3.02	0.63	1.01	17.20	0.00	17.20	4.000	No	Yes	2.00
161	27.56	19.19	50.99	2.88	0.62	1.01	18.37	0.00	18.37	4.000	No	Yes	2.00
162	27.72	20.57	42.26	2.73	0.62	1.01	19.43	0.00	19.43	4.000	No	Yes	2.00
163	27.89	24.83	32.15	2.53	0.61	1.01	20.95	36.48	57.43	0.085	No	No	0.21
164	28.05	37.01	20.34	2.24	0.59	1.00	30.30	33.06	63.36	0.092	No	No	0.23
165	28.21	52.16	13.90	2.03	0.55	1.00	53.45	25.06	78.51	0.111	No	No	0.28
166	28.38	59.71	5.00	1.95	0.59	1.00	63.21	0.02	63.23	0.092	No	No	0.23
167	28.54	55.33	13.28	2.01	0.56	1.00	51.09	22.55	73.64	0.104	No	No	0.26
168	28.71	44.81	19.43	2.21	0.56	1.00	40.89	34.84	75.72	0.107	No	No	0.27
169	28.87	36.89	29.70	2.48	0.56	0.99	33.58	40.12	73.70	0.104	No	No	0.26
170	29.04	31.36	43.26	2.75	0.58	0.99	28.73	0.00	28.73	4.000	No	Yes	2.00
171	29.20	27.91	55.93	2.96	0.59	0.99	25.17	0.00	25.17	4.000	No	Yes	2.00
172	29.36	26.98	63.22	3.07	0.60	0.98	23.65	0.00	23.65	4.000	No	Yes	2.00
173	29.53	30.16	60.18	3.02	0.59	0.98	25.85	0.00	25.85	4.000	No	Yes	2.00
174	29.69	34.28	53.74	2.93	0.56	0.98	33.78	0.00	33.78	4.000	No	Yes	2.00
175	29.86	36.27	48.48	2.84	0.55	0.98	34.89	0.00	34.89	4.000	No	Yes	2.00
176	30.02	35.33	46.16	2.80	0.57	0.98	31.10	0.00	31.10	4.000	No	Yes	2.00
177	30.18	32.51	46.17	2.80	0.57	0.97	30.85	0.00	30.85	4.000	No	Yes	2.00
178	30.35	30.62	46.68	2.81	0.58	0.97	26.72	0.00	26.72	4.000	No	Yes	2.00
179	30.51	29.09	48.60	2.84	0.59	0.97	25.59	0.00	25.59	4.000	No	Yes	2.00
180	30.68	29.70	48.87	2.85	0.59	0.96	26.31	0.00	26.31	4.000	No	Yes	2.00
181	30.84	31.68	47.75	2.83	0.58	0.96	28.10	0.00	28.10	4.000	No	Yes	2.00
182	31.00	36.66	42.39	2.74	0.57	0.96	30.60	0.00	30.60	4.000	No	Yes	2.00
183	31.17	45.07	34.66	2.59	0.54	0.96	39.57	43.30	82.87	0.117	No	No	0.29
184	31.33	49.32	30.13	2.49	0.50	0.96	51.14	46.15	97.29	0.138	No	No	0.34
185	31.50	49.61	28.63	2.45	0.53	0.96	42.22	42.63	84.85	0.119	No	No	0.30
186	31.66	50.64	27.40	2.42	0.54	0.95	40.09	41.40	81.49	0.115	No	No	0.28
187	31.82	66.54	22.01	2.29	0.51	0.95	53.09	41.58	94.67	0.134	No	No	0.33
188	31.99	105.26	15.52	2.09	0.45	0.96	84.60	36.65	121.24	0.182	No	No	0.45
189	32.15	152.62	11.90	1.96	0.36	0.96	146.67	29.55	176.22	0.480	No	No	1.18
190	32.32	193.84	9.29	1.85	0.33	0.97	184.15	14.15	198.30	1.054	No	No	2.00
191	32.48	213.18	8.14	1.80	0.32	0.97	199.32	7.34	206.66	1.580	No	No	2.00
192	32.64	218.38	7.96	1.79	0.32	0.96	199.76	6.38	206.14	1.538	No	No	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
193	32.81	212.89	9.19	1.85	0.31	0.96	197.90	14.15	212.05	2.133	No	No	2.00
194	32.97	201.32	11.01	1.93	0.32	0.96	183.57	27.30	210.87	1.992	No	No	2.00
195	33.14	189.26	10.88	1.92	0.34	0.96	166.99	24.65	191.64	0.799	No	No	1.96
196	33.30	182.98	9.56	1.86	0.36	0.95	163.24	14.90	178.14	0.507	No	No	1.24
197	33.47	184.02	6.64	1.73	0.38	0.95	164.29	1.30	165.60	0.367	No	No	0.90
198	33.63	186.81	5.54	1.67	0.37	0.95	168.26	0.15	168.42	0.392	No	No	0.96
199	33.79	187.43	5.45	1.66	0.37	0.95	169.68	0.13	169.81	0.406	No	No	0.99
200	33.96	183.42	6.53	1.72	0.38	0.94	165.15	1.11	166.26	0.373	No	No	0.91
201	34.12	175.90	7.92	1.79	0.38	0.94	156.49	5.21	161.70	0.338	No	No	0.83
202	34.28	165.98	8.84	1.83	0.39	0.94	148.32	9.64	157.96	0.313	No	No	0.77
203	34.45	158.47	8.77	1.83	0.41	0.94	137.20	8.79	145.99	0.254	No	No	0.62
204	34.61	154.51	8.36	1.81	0.42	0.93	134.97	6.68	141.65	0.238	No	No	0.58
205	34.78	155.87	7.52	1.77	0.42	0.93	136.38	3.32	139.70	0.231	No	No	0.57
206	34.94	159.33	6.78	1.73	0.42	0.93	139.90	1.43	141.33	0.237	No	No	0.58
207	35.10	166.53	5.92	1.69	0.41	0.93	143.51	0.34	143.85	0.246	No	No	0.60
208	35.27	167.54	6.15	1.70	0.39	0.93	155.29	0.56	155.85	0.301	No	No	0.73
209	35.43	159.67	7.73	1.78	0.41	0.93	142.07	4.18	146.25	0.255	No	No	0.62
210	35.60	156.70	9.05	1.84	0.44	0.92	121.65	9.60	131.25	0.206	No	No	0.50
211	35.76	181.13	7.07	1.75	0.41	0.92	146.45	2.15	148.60	0.265	No	No	0.65
212	35.92	234.84	4.01	1.58	0.32	0.94	208.94	0.00	208.94	1.788	No	No	2.00
213	36.09	299.91	1.80	1.42	0.26	0.95	269.61	0.00	269.61	4.000	No	No	2.00
214	36.25	349.29	1.18	1.37	0.26	0.95	324.71	0.00	324.71	4.000	No	No	2.00
215	36.42	370.40	1.31	1.38	0.26	0.95	342.90	0.00	342.90	4.000	No	No	2.00
216	36.58	363.58	2.09	1.45	0.26	0.94	325.18	0.00	325.18	4.000	No	No	2.00
217	36.74	348.73	2.38	1.47	0.26	0.94	305.36	0.00	305.36	4.000	No	No	2.00
218	36.91	339.35	2.03	1.44	0.26	0.94	302.02	0.00	302.02	4.000	No	No	2.00
219	37.07	338.65	1.25	1.38	0.26	0.94	299.07	0.00	299.07	4.000	No	No	2.00
220	37.24	341.33	1.34	1.38	0.26	0.94	302.50	0.00	302.50	4.000	No	No	2.00
221	37.40	348.75	1.71	1.41	0.26	0.94	308.17	0.00	308.17	4.000	No	No	2.00
222	37.57	342.84	2.41	1.47	0.26	0.94	317.75	0.00	317.75	4.000	No	No	2.00
223	37.73	342.66	2.76	1.49	0.26	0.94	285.66	0.00	285.66	4.000	No	No	2.00
224	37.89	341.09	2.82	1.50	0.26	0.94	306.65	0.00	306.65	4.000	No	No	2.00
225	38.06	358.39	1.93	1.43	0.26	0.94	312.52	0.00	312.52	4.000	No	No	2.00
226	38.22	372.99	0.43	1.30	0.26	0.93	330.58	0.00	330.58	4.000	No	No	2.00
227	38.39	391.40	0.00	1.20	0.26	0.93	344.29	0.00	344.29	4.000	No	No	2.00
228	38.55	408.33	0.00	1.17	0.26	0.93	360.20	0.00	360.20	4.000	No	No	2.00
229	38.71	421.40	0.00	1.21	0.26	0.93	374.28	0.00	374.28	4.000	No	No	2.00
230	38.88	427.31	0.00	1.22	0.26	0.93	377.66	0.00	377.66	4.000	No	No	2.00
231	39.04	418.90	0.00	1.22	0.26	0.93	374.63	0.00	374.63	4.000	No	No	2.00
232	39.21	401.54	0.00	1.26	0.26	0.93	350.93	0.00	350.93	4.000	No	No	2.00
233	39.37	389.68	0.27	1.29	0.26	0.93	330.79	0.00	330.79	4.000	No	No	2.00
234	39.53	393.48	0.14	1.27	0.26	0.93	342.33	0.00	342.33	4.000	No	No	2.00
235	39.70	408.36	0.00	1.25	0.26	0.93	359.78	0.00	359.78	4.000	No	No	2.00
236	39.86	418.10	0.00	1.24	0.26	0.92	368.73	0.00	368.73	4.000	No	No	2.00
237	40.03	402.57	0.04	1.26	0.26	0.92	366.68	0.00	366.68	4.000	No	No	2.00
238	40.19	338.71	1.06	1.36	0.26	0.92	318.05	0.00	318.05	4.000	No	No	2.00
239	40.35	235.90	3.81	1.57	0.33	0.90	196.57	0.00	196.57	0.977	No	No	2.00
240	40.52	139.85	9.86	1.88	0.49	0.86	90.66	12.00	102.66	0.147	No	No	0.36

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
241	40.68	78.81	19.66	2.22	0.49	0.86	62.15	41.03	103.19	0.148	No	No	0.37
242	40.85	53.51	27.78	2.43	0.55	0.84	37.58	40.75	78.33	0.110	No	No	0.27
243	41.01	38.50	37.33	2.64	0.58	0.83	27.61	0.00	27.61	4.000	No	Yes	2.00
244	41.17	32.89	43.15	2.75	0.59	0.82	24.43	0.00	24.43	4.000	No	Yes	2.00
245	41.34	32.73	46.58	2.81	0.60	0.82	23.63	0.00	23.63	4.000	No	Yes	2.00
246	41.50	32.94	48.05	2.84	0.58	0.82	27.48	0.00	27.48	4.000	No	Yes	2.00
247	41.67	33.03	49.31	2.86	0.59	0.82	24.56	0.00	24.56	4.000	No	Yes	2.00
248	41.83	30.19	51.66	2.89	0.60	0.82	23.55	0.00	23.55	4.000	No	Yes	2.00
249	41.99	27.66	53.06	2.92	0.61	0.81	20.38	0.00	20.38	4.000	No	Yes	2.00
250	42.16	25.19	54.30	2.94	0.62	0.81	18.59	0.00	18.59	4.000	No	Yes	2.00
251	42.32	23.43	54.28	2.94	0.62	0.81	17.69	0.00	17.69	4.000	No	Yes	2.00
252	42.49	21.95	55.66	2.96	0.63	0.80	16.21	0.00	16.21	4.000	No	Yes	2.00
253	42.65	19.74	60.00	3.02	0.64	0.80	15.13	0.00	15.13	4.000	No	Yes	2.00
254	42.81	18.07	66.53	3.11	0.65	0.79	12.53	0.00	12.53	4.000	No	Yes	2.00
255	42.98	17.26	71.06	3.17	0.65	0.79	12.26	0.00	12.26	4.000	No	Yes	2.00
256	43.14	17.90	69.61	3.16	0.65	0.79	13.13	0.00	13.13	4.000	No	Yes	2.00
257	43.31	18.53	67.32	3.13	0.64	0.79	13.90	0.00	13.90	4.000	No	Yes	2.00
258	43.47	17.92	68.14	3.14	0.64	0.79	13.63	0.00	13.63	4.000	No	Yes	2.00
259	43.63	16.35	72.09	3.19	0.65	0.79	11.71	0.00	11.71	4.000	No	Yes	2.00
260	43.80	14.65	76.97	3.25	0.66	0.78	10.32	0.00	10.32	4.000	No	Yes	2.00
261	43.96	13.79	79.41	3.28	0.67	0.78	9.74	0.00	9.74	4.000	No	Yes	2.00
262	44.13	14.30	76.31	3.24	0.67	0.78	9.71	0.00	9.71	4.000	No	Yes	2.00
263	44.29	15.62	70.98	3.17	0.66	0.78	11.31	0.00	11.31	4.000	No	Yes	2.00
264	44.45	17.01	66.14	3.11	0.65	0.78	12.56	0.00	12.56	4.000	No	Yes	2.00
265	44.62	17.46	64.08	3.08	0.65	0.78	12.73	0.00	12.73	4.000	No	Yes	2.00
266	44.78	17.37	63.05	3.07	0.65	0.78	12.25	0.00	12.25	4.000	No	Yes	2.00
267	44.95	17.72	60.32	3.03	0.65	0.78	12.29	0.00	12.29	4.000	No	Yes	2.00
268	45.11	19.60	54.50	2.94	0.64	0.78	13.42	0.00	13.42	4.000	No	Yes	2.00
269	45.28	20.08	53.78	2.93	0.63	0.78	16.50	0.00	16.50	4.000	No	Yes	2.00
270	45.44	19.26	57.14	2.98	0.64	0.77	13.36	0.00	13.36	4.000	No	Yes	2.00
271	45.60	16.65	66.23	3.11	0.65	0.77	11.57	0.00	11.57	4.000	No	Yes	2.00
272	45.77	14.60	78.61	3.27	0.66	0.77	10.48	0.00	10.48	4.000	No	Yes	2.00
273	45.93	13.54	87.78	3.38	0.67	0.76	8.66	0.00	8.66	4.000	No	Yes	2.00
274	46.10	12.55	97.23	3.48	0.67	0.76	9.09	0.00	9.09	4.000	No	Yes	2.00
275	46.26	12.25	100.00	3.51	0.68	0.76	8.15	0.00	8.15	4.000	No	Yes	2.00
276	46.42	12.16	100.00	3.51	0.68	0.75	7.85	0.00	7.85	4.000	No	Yes	2.00
277	46.59	14.36	85.78	3.36	0.67	0.76	8.92	0.00	8.92	4.000	No	Yes	2.00
278	46.75	18.41	68.00	3.13	0.65	0.76	12.89	0.00	12.89	4.000	No	Yes	2.00
279	46.92	23.48	52.95	2.92	0.63	0.77	16.66	0.00	16.66	4.000	No	Yes	2.00
280	47.08	27.23	45.07	2.78	0.61	0.77	19.70	0.00	19.70	4.000	No	Yes	2.00
281	47.24	29.00	40.88	2.71	0.61	0.77	20.83	0.00	20.83	4.000	No	Yes	2.00
282	47.41	30.22	38.19	2.66	0.61	0.77	20.20	0.00	20.20	4.000	No	Yes	2.00
283	47.57	32.02	35.49	2.60	0.60	0.77	22.34	0.00	22.34	4.000	No	Yes	2.00
284	47.74	34.99	33.49	2.56	0.60	0.77	24.54	37.95	62.49	0.091	No	No	0.23
285	47.90	36.82	33.98	2.57	0.59	0.77	26.35	38.65	65.00	0.094	No	No	0.23
286	48.06	37.03	37.44	2.64	0.59	0.77	25.67	0.00	25.67	4.000	No	Yes	2.00
287	48.23	35.55	42.49	2.74	0.59	0.77	24.61	0.00	24.61	4.000	No	Yes	2.00
288	48.39	33.76	47.25	2.82	0.60	0.76	22.95	0.00	22.95	4.000	No	Yes	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
289	48.56	32.72	48.77	2.85	0.61	0.76	21.70	0.00	21.70	4.000	No	Yes	2.00
290	48.72	32.75	48.06	2.84	0.60	0.76	22.18	0.00	22.18	4.000	No	Yes	2.00
291	48.88	34.52	45.30	2.79	0.60	0.76	22.87	0.00	22.87	4.000	No	Yes	2.00
292	49.05	38.76	41.01	2.71	0.59	0.76	25.41	0.00	25.41	4.000	No	Yes	2.00
293	49.21	43.87	36.82	2.63	0.57	0.77	31.49	0.00	31.49	4.000	No	Yes	2.00
294	49.38	50.18	32.30	2.54	0.56	0.77	33.97	40.94	74.91	0.106	No	No	0.27
295	49.54	57.58	27.78	2.43	0.54	0.78	39.33	41.32	80.65	0.114	No	No	0.28
296	49.70	71.83	21.45	2.27	0.53	0.78	47.79	39.39	87.17	0.123	No	No	0.31
297	49.87	78.47	18.90	2.20	0.48	0.80	68.72	41.48	110.20	0.160	No	No	0.40
298	50.03	74.13	20.06	2.23	0.51	0.79	56.35	40.05	96.40	0.137	No	No	0.34
299	50.20	61.76	24.70	2.36	0.55	0.77	39.56	39.73	79.29	0.112	No	No	0.28

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
q_t: Total cone resistance
FC: Fines content (%)
I_c: Soil behavior type index
m: Stress exponent
C_N: Overburden correction factor
q_{c1N}: Normalized and adjusted cone resistance
Δq_{c1N}: Cone resistance correction factor due to fines
$q_{c1N,cs}$: Normalized and adjusted cone resistance
$CRR_{7.5}$: Cyclic resistance ratio for M_w=7.5
FS: Factor of safety against soil liquefaction

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
1.31	2.00	0.00	0.00	0.16	0.00	1.48	2.00	0.00	0.00	0.16	0.00
1.64	2.00	0.00	0.00	0.16	0.00	1.80	2.00	0.00	0.00	0.16	0.00
1.97	2.00	0.00	0.00	0.17	0.00	2.13	2.00	0.00	0.00	0.16	0.00
2.30	2.00	0.00	0.00	0.16	0.00	2.46	2.00	0.00	0.00	0.16	0.00
2.63	2.00	0.00	0.00	0.16	0.00	2.79	2.00	0.00	0.00	0.16	0.00
2.95	2.00	0.00	0.00	0.16	0.00	3.12	2.00	0.00	0.00	0.16	0.00
3.28	2.00	0.00	0.00	0.16	0.00	3.44	2.00	0.00	0.00	0.16	0.00
3.61	2.00	0.00	0.00	0.16	0.00	3.77	2.00	0.00	0.00	0.16	0.00
3.94	2.00	0.00	0.00	0.16	0.00	4.10	2.00	0.00	0.00	0.16	0.00
4.26	2.00	0.00	0.00	0.16	0.00	4.43	2.00	0.00	0.00	0.16	0.00
4.59	2.00	0.00	0.00	0.16	0.00	4.76	2.00	0.00	0.00	0.16	0.00
4.92	2.00	0.00	0.00	0.16	0.00	5.08	2.00	0.00	0.00	0.16	0.00
5.25	2.00	0.00	0.00	0.16	0.00	5.41	2.00	0.00	0.00	0.16	0.00
5.58	2.00	0.00	0.00	0.16	0.00	5.74	2.00	0.00	0.00	0.16	0.00
5.91	2.00	0.00	0.00	0.17	0.00	6.07	2.00	0.00	0.00	0.16	0.00
6.23	2.00	0.00	0.00	0.16	0.00	6.40	2.00	0.00	0.00	0.16	0.00
6.56	2.00	0.00	0.00	0.16	0.00	6.73	2.00	0.00	0.00	0.16	0.00
6.89	2.00	0.00	0.00	0.16	0.00	7.05	2.00	0.00	0.00	0.16	0.00
7.22	2.00	0.00	0.00	0.16	0.00	7.38	2.00	0.00	0.00	0.16	0.00
7.55	2.00	0.00	0.00	0.16	0.00	7.71	2.00	0.00	0.00	0.16	0.00
7.87	2.00	0.00	0.00	0.16	0.00	8.04	2.00	0.00	0.00	0.16	0.00
8.20	2.00	0.00	0.00	0.16	0.00	8.37	2.00	0.00	0.00	0.16	0.00
8.53	2.00	0.00	0.00	0.16	0.00	8.69	2.00	0.00	0.00	0.16	0.00
8.86	2.00	0.00	0.00	0.16	0.00	9.02	0.41	0.59	0.39	0.16	0.26
9.19	0.40	0.60	0.39	0.16	0.26	9.35	0.39	0.61	0.38	0.16	0.26
9.51	0.39	0.61	0.37	0.16	0.26	9.68	0.38	0.62	0.37	0.16	0.26
9.84	0.38	0.62	0.37	0.16	0.26	10.01	0.39	0.61	0.38	0.16	0.26
10.17	0.38	0.62	0.37	0.16	0.26	10.34	0.37	0.63	0.36	0.16	0.26
10.50	0.37	0.63	0.37	0.16	0.26	10.66	0.32	0.68	0.34	0.16	0.28
10.83	0.37	0.63	0.36	0.16	0.26	10.99	0.35	0.65	0.35	0.16	0.27
11.15	0.35	0.65	0.35	0.16	0.27	11.32	0.29	0.71	0.32	0.16	0.29
11.48	0.32	0.68	0.33	0.16	0.28	11.65	0.33	0.67	0.34	0.16	0.27
11.81	0.38	0.62	0.37	0.16	0.25	11.97	0.38	0.62	0.37	0.16	0.25
12.14	0.37	0.63	0.36	0.16	0.26	12.30	0.31	0.69	0.33	0.16	0.28
12.47	0.32	0.68	0.33	0.16	0.28	12.63	0.30	0.70	0.32	0.16	0.28
12.79	0.29	0.71	0.32	0.16	0.29	12.96	0.29	0.71	0.32	0.16	0.28
13.12	0.34	0.66	0.35	0.16	0.26	13.29	0.35	0.65	0.35	0.16	0.26
13.45	0.30	0.70	0.32	0.16	0.28	13.62	0.30	0.70	0.32	0.16	0.28
13.78	0.32	0.68	0.33	0.16	0.27	13.94	0.32	0.68	0.33	0.16	0.27
14.11	0.32	0.68	0.33	0.16	0.27	14.27	0.30	0.70	0.32	0.16	0.27
14.44	0.31	0.69	0.33	0.16	0.27	14.60	0.32	0.68	0.33	0.16	0.27
14.76	0.31	0.69	0.33	0.16	0.27	14.93	0.30	0.70	0.32	0.16	0.27
15.09	0.25	0.75	0.30	0.16	0.29	15.26	0.24	0.76	0.29	0.16	0.29
15.42	2.00	0.00	0.00	0.16	0.00	15.58	0.23	0.77	0.29	0.16	0.29
15.75	0.26	0.74	0.30	0.16	0.28	15.91	0.27	0.73	0.31	0.16	0.28
16.08	0.26	0.74	0.30	0.16	0.28	16.24	0.26	0.74	0.30	0.16	0.28
16.40	0.26	0.74	0.30	0.16	0.28	16.57	0.26	0.74	0.30	0.16	0.28
16.73	0.27	0.73	0.31	0.16	0.27	16.90	0.31	0.69	0.33	0.16	0.26

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
17.06	0.33	0.67	0.34	0.16	0.25	17.22	0.34	0.66	0.35	0.16	0.24
17.39	0.52	0.48	0.50	0.16	0.18	17.55	0.68	0.32	0.85	0.16	0.12
17.72	0.69	0.31	0.89	0.16	0.11	17.88	0.59	0.41	0.62	0.16	0.15
18.05	0.54	0.46	0.54	0.16	0.17	18.21	0.45	0.55	0.43	0.16	0.20
18.37	0.62	0.38	0.67	0.16	0.14	18.54	1.09	0.00	0.00	0.16	0.00
18.70	2.00	0.00	0.00	0.16	0.00	18.86	1.78	0.00	0.00	0.16	0.00
19.03	0.51	0.49	0.50	0.16	0.17	19.19	2.00	0.00	0.00	0.16	0.00
19.36	2.00	0.00	0.00	0.16	0.00	19.52	2.00	0.00	0.00	0.16	0.00
19.68	2.00	0.00	0.00	0.16	0.00	19.85	2.00	0.00	0.00	0.16	0.00
20.01	2.00	0.00	0.00	0.16	0.00	20.18	2.00	0.00	0.00	0.16	0.00
20.34	2.00	0.00	0.00	0.16	0.00	20.50	2.00	0.00	0.00	0.16	0.00
20.67	0.29	0.71	0.32	0.16	0.24	20.83	0.32	0.68	0.33	0.16	0.23
21.00	0.33	0.67	0.34	0.16	0.23	21.16	2.00	0.00	0.00	0.16	0.00
21.32	2.00	0.00	0.00	0.16	0.00	21.49	2.00	0.00	0.00	0.16	0.00
21.65	2.00	0.00	0.00	0.16	0.00	21.82	2.00	0.00	0.00	0.16	0.00
21.98	2.00	0.00	0.00	0.16	0.00	22.15	2.00	0.00	0.00	0.16	0.00
22.31	2.00	0.00	0.00	0.16	0.00	22.47	2.00	0.00	0.00	0.16	0.00
22.64	2.00	0.00	0.00	0.16	0.00	22.80	0.25	0.75	0.30	0.16	0.24
22.97	0.36	0.64	0.36	0.16	0.21	23.13	0.45	0.55	0.42	0.16	0.18
23.29	0.41	0.59	0.40	0.16	0.19	23.46	0.32	0.68	0.34	0.16	0.22
23.62	2.00	0.00	0.00	0.16	0.00	23.79	2.00	0.00	0.00	0.16	0.00
23.95	2.00	0.00	0.00	0.16	0.00	24.11	2.00	0.00	0.00	0.16	0.00
24.28	2.00	0.00	0.00	0.16	0.00	24.44	2.00	0.00	0.00	0.16	0.00
24.61	2.00	0.00	0.00	0.16	0.00	24.77	0.29	0.71	0.32	0.16	0.22
24.93	0.32	0.68	0.34	0.16	0.21	25.10	0.34	0.66	0.35	0.16	0.20
25.26	0.35	0.65	0.35	0.16	0.20	25.43	0.34	0.66	0.35	0.16	0.20
25.59	0.33	0.67	0.34	0.16	0.20	25.75	0.31	0.69	0.33	0.16	0.21
25.92	0.28	0.72	0.31	0.16	0.22	26.08	2.00	0.00	0.00	0.16	0.00
26.25	2.00	0.00	0.00	0.16	0.00	26.41	2.00	0.00	0.00	0.16	0.00
26.57	2.00	0.00	0.00	0.16	0.00	26.74	2.00	0.00	0.00	0.16	0.00
26.90	2.00	0.00	0.00	0.16	0.00	27.07	2.00	0.00	0.00	0.16	0.00
27.23	2.00	0.00	0.00	0.16	0.00	27.39	2.00	0.00	0.00	0.16	0.00
27.56	2.00	0.00	0.00	0.16	0.00	27.72	2.00	0.00	0.00	0.16	0.00
27.89	0.21	0.79	0.28	0.16	0.23	28.05	0.23	0.77	0.29	0.16	0.22
28.21	0.28	0.72	0.31	0.16	0.21	28.38	0.23	0.77	0.29	0.16	0.22
28.54	0.26	0.74	0.30	0.16	0.21	28.71	0.27	0.73	0.31	0.16	0.21
28.87	0.26	0.74	0.30	0.16	0.21	29.04	2.00	0.00	0.00	0.16	0.00
29.20	2.00	0.00	0.00	0.16	0.00	29.36	2.00	0.00	0.00	0.16	0.00
29.53	2.00	0.00	0.00	0.16	0.00	29.69	2.00	0.00	0.00	0.16	0.00
29.86	2.00	0.00	0.00	0.16	0.00	30.02	2.00	0.00	0.00	0.16	0.00
30.18	2.00	0.00	0.00	0.16	0.00	30.35	2.00	0.00	0.00	0.16	0.00
30.51	2.00	0.00	0.00	0.16	0.00	30.68	2.00	0.00	0.00	0.16	0.00
30.84	2.00	0.00	0.00	0.16	0.00	31.00	2.00	0.00	0.00	0.16	0.00
31.17	0.29	0.71	0.32	0.16	0.19	31.33	0.34	0.66	0.35	0.16	0.17
31.50	0.30	0.70	0.32	0.16	0.18	31.66	0.28	0.72	0.31	0.16	0.19
31.82	0.33	0.67	0.34	0.16	0.17	31.99	0.45	0.55	0.43	0.16	0.14
32.15	1.18	0.00	0.00	0.16	0.00	32.32	2.00	0.00	0.00	0.16	0.00
32.48	2.00	0.00	0.00	0.16	0.00	32.64	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
32.81	2.00	0.00	0.00	0.16	0.00	32.97	2.00	0.00	0.00	0.16	0.00
33.14	1.96	0.00	0.00	0.16	0.00	33.30	1.24	0.00	0.00	0.16	0.00
33.47	0.90	0.00	0.00	0.16	0.02	33.63	0.96	0.00	0.00	0.16	0.01
33.79	0.99	0.00	0.00	0.16	0.00	33.96	0.91	0.00	0.00	0.16	0.02
34.12	0.83	0.00	0.00	0.16	0.04	34.28	0.77	0.00	0.00	0.16	0.06
34.45	0.62	0.38	0.68	0.16	0.09	34.61	0.58	0.42	0.60	0.16	0.10
34.78	0.57	0.43	0.57	0.16	0.10	34.94	0.58	0.42	0.59	0.16	0.10
35.10	0.60	0.40	0.63	0.16	0.09	35.27	0.73	0.27	1.08	0.16	0.06
35.43	0.62	0.38	0.68	0.16	0.09	35.60	0.50	0.50	0.48	0.16	0.11
35.76	0.65	0.35	0.74	0.16	0.08	35.92	2.00	0.00	0.00	0.16	0.00
36.09	2.00	0.00	0.00	0.16	0.00	36.25	2.00	0.00	0.00	0.16	0.00
36.42	2.00	0.00	0.00	0.16	0.00	36.58	2.00	0.00	0.00	0.16	0.00
36.74	2.00	0.00	0.00	0.16	0.00	36.91	2.00	0.00	0.00	0.16	0.00
37.07	2.00	0.00	0.00	0.16	0.00	37.24	2.00	0.00	0.00	0.16	0.00
37.40	2.00	0.00	0.00	0.16	0.00	37.57	2.00	0.00	0.00	0.16	0.00
37.73	2.00	0.00	0.00	0.16	0.00	37.89	2.00	0.00	0.00	0.16	0.00
38.06	2.00	0.00	0.00	0.16	0.00	38.22	2.00	0.00	0.00	0.16	0.00
38.39	2.00	0.00	0.00	0.16	0.00	38.55	2.00	0.00	0.00	0.16	0.00
38.71	2.00	0.00	0.00	0.16	0.00	38.88	2.00	0.00	0.00	0.16	0.00
39.04	2.00	0.00	0.00	0.16	0.00	39.21	2.00	0.00	0.00	0.16	0.00
39.37	2.00	0.00	0.00	0.16	0.00	39.53	2.00	0.00	0.00	0.16	0.00
39.70	2.00	0.00	0.00	0.16	0.00	39.86	2.00	0.00	0.00	0.16	0.00
40.03	2.00	0.00	0.00	0.16	0.00	40.19	2.00	0.00	0.00	0.16	0.00
40.35	2.00	0.00	0.00	0.16	0.00	40.52	0.36	0.64	0.36	0.16	0.12
40.68	0.37	0.63	0.36	0.16	0.12	40.85	0.27	0.73	0.31	0.16	0.14
41.01	2.00	0.00	0.00	0.17	0.00	41.17	2.00	0.00	0.00	0.16	0.00
41.34	2.00	0.00	0.00	0.16	0.00	41.50	2.00	0.00	0.00	0.16	0.00
41.67	2.00	0.00	0.00	0.16	0.00	41.83	2.00	0.00	0.00	0.16	0.00
41.99	2.00	0.00	0.00	0.16	0.00	42.16	2.00	0.00	0.00	0.16	0.00
42.32	2.00	0.00	0.00	0.16	0.00	42.49	2.00	0.00	0.00	0.16	0.00
42.65	2.00	0.00	0.00	0.16	0.00	42.81	2.00	0.00	0.00	0.16	0.00
42.98	2.00	0.00	0.00	0.16	0.00	43.14	2.00	0.00	0.00	0.16	0.00
43.31	2.00	0.00	0.00	0.16	0.00	43.47	2.00	0.00	0.00	0.16	0.00
43.63	2.00	0.00	0.00	0.16	0.00	43.80	2.00	0.00	0.00	0.16	0.00
43.96	2.00	0.00	0.00	0.16	0.00	44.13	2.00	0.00	0.00	0.16	0.00
44.29	2.00	0.00	0.00	0.16	0.00	44.45	2.00	0.00	0.00	0.16	0.00
44.62	2.00	0.00	0.00	0.16	0.00	44.78	2.00	0.00	0.00	0.16	0.00
44.95	2.00	0.00	0.00	0.16	0.00	45.11	2.00	0.00	0.00	0.16	0.00
45.28	2.00	0.00	0.00	0.16	0.00	45.44	2.00	0.00	0.00	0.16	0.00
45.60	2.00	0.00	0.00	0.16	0.00	45.77	2.00	0.00	0.00	0.16	0.00
45.93	2.00	0.00	0.00	0.16	0.00	46.10	2.00	0.00	0.00	0.16	0.00
46.26	2.00	0.00	0.00	0.16	0.00	46.42	2.00	0.00	0.00	0.16	0.00
46.59	2.00	0.00	0.00	0.16	0.00	46.75	2.00	0.00	0.00	0.16	0.00
46.92	2.00	0.00	0.00	0.16	0.00	47.08	2.00	0.00	0.00	0.16	0.00
47.24	2.00	0.00	0.00	0.16	0.00	47.41	2.00	0.00	0.00	0.16	0.00
47.57	2.00	0.00	0.00	0.16	0.00	47.74	0.23	0.77	0.29	0.16	0.11
47.90	0.23	0.77	0.29	0.16	0.10	48.06	2.00	0.00	0.00	0.16	0.00
48.23	2.00	0.00	0.00	0.16	0.00	48.39	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
48.56	2.00	0.00	0.00	0.16	0.00	48.72	2.00	0.00	0.00	0.16	0.00
48.88	2.00	0.00	0.00	0.16	0.00	49.05	2.00	0.00	0.00	0.16	0.00
49.21	2.00	0.00	0.00	0.16	0.00	49.38	0.27	0.73	0.31	0.16	0.09
49.54	0.28	0.72	0.31	0.16	0.09	49.70	0.31	0.69	0.33	0.16	0.08
49.87	0.40	0.60	0.38	0.16	0.07	50.03	0.34	0.66	0.35	0.16	0.08
50.20	0.28	0.72	0.31	0.16	0.08						

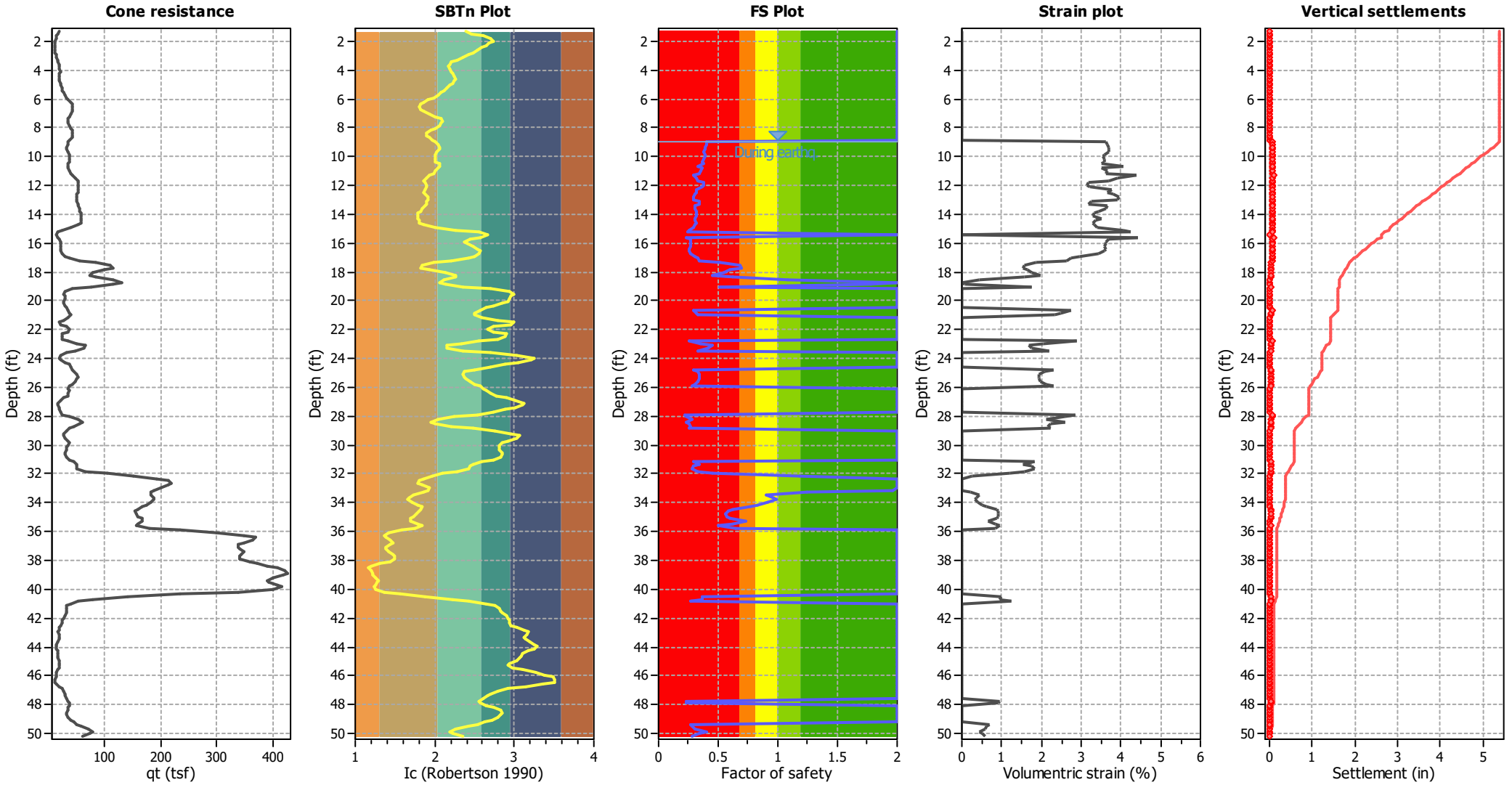
Overall liquefaction potential: 22.75

LPI_{ISH} > 5.0 - Liquefaction manifestation is expected

Abbreviations

FS: Calculated factor of safety for test point
d_z: Layer thickness (ft)
LPI: Liquefaction potential index value for test point

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)
9.02	74.58	0.41	3.63	0.85	0.07	9.19	74.06	0.40	3.64	0.84	0.07
9.35	72.69	0.39	3.70	0.84	0.07	9.51	72.66	0.39	3.68	0.84	0.07
9.68	72.29	0.38	3.69	0.84	0.07	9.84	73.95	0.38	3.60	0.83	0.07
10.01	74.86	0.39	3.55	0.83	0.07	10.17	73.42	0.38	3.60	0.83	0.07
10.34	73.24	0.37	3.60	0.82	0.07	10.50	74.66	0.37	3.52	0.82	0.07
10.66	64.04	0.32	4.04	0.82	0.08	10.83	74.62	0.37	3.50	0.82	0.07
10.99	70.96	0.35	3.65	0.81	0.07	11.15	71.01	0.35	3.64	0.81	0.07
11.32	57.52	0.29	4.39	0.81	0.09	11.48	65.15	0.32	3.91	0.81	0.08
11.65	68.90	0.33	3.70	0.80	0.07	11.81	80.75	0.38	3.18	0.80	0.06
11.97	81.13	0.38	3.15	0.80	0.06	12.14	78.88	0.37	3.23	0.79	0.06
12.30	66.81	0.31	3.76	0.79	0.07	12.47	68.33	0.32	3.67	0.79	0.07
12.63	65.26	0.30	3.81	0.79	0.08	12.79	62.29	0.29	3.96	0.78	0.08
12.96	62.85	0.29	3.92	0.78	0.08	13.12	76.22	0.34	3.26	0.78	0.06
13.29	77.55	0.35	3.20	0.77	0.06	13.45	66.81	0.30	3.67	0.77	0.07
13.62	67.47	0.30	3.62	0.77	0.07	13.78	71.26	0.32	3.43	0.77	0.07
13.94	73.41	0.32	3.32	0.76	0.07	14.11	73.83	0.32	3.29	0.76	0.06
14.27	68.53	0.30	3.52	0.76	0.07	14.44	71.30	0.31	3.38	0.76	0.07
14.60	73.27	0.32	3.28	0.75	0.06	14.76	71.70	0.31	3.34	0.75	0.07
14.93	69.93	0.30	3.40	0.75	0.07	15.09	57.27	0.25	4.06	0.74	0.08
15.26	54.45	0.24	4.23	0.74	0.08	15.42	14.13	2.00	0.00	0.74	0.00
15.58	51.02	0.23	4.44	0.74	0.09	15.75	62.53	0.26	3.70	0.73	0.07
15.91	63.94	0.27	3.61	0.73	0.07	16.08	63.16	0.26	3.64	0.73	0.07
16.24	63.80	0.26	3.59	0.72	0.07	16.40	62.70	0.26	3.63	0.72	0.07
16.57	63.02	0.26	3.60	0.72	0.07	16.73	66.12	0.27	3.43	0.72	0.07
16.90	76.63	0.31	2.98	0.71	0.06	17.06	83.17	0.33	2.74	0.71	0.05
17.22	85.95	0.34	2.65	0.71	0.05	17.39	120.61	0.52	1.86	0.71	0.04
17.55	141.18	0.68	1.56	0.70	0.03	17.72	142.31	0.69	1.54	0.70	0.03
17.88	132.29	0.59	1.66	0.70	0.03	18.05	126.19	0.54	1.75	0.69	0.03
18.21	111.75	0.45	1.98	0.69	0.04	18.37	136.76	0.62	1.59	0.69	0.03
18.54	167.83	1.09	0.46	0.69	0.01	18.70	204.01	2.00	0.00	0.68	0.00
18.86	185.12	1.78	0.07	0.68	0.00	19.03	123.19	0.51	1.75	0.68	0.03
19.19	39.34	2.00	0.00	0.67	0.00	19.36	28.46	2.00	0.00	0.67	0.00
19.52	28.89	2.00	0.00	0.67	0.00	19.68	33.20	2.00	0.00	0.67	0.00
19.85	32.12	2.00	0.00	0.66	0.00	20.01	30.67	2.00	0.00	0.66	0.00
20.18	27.39	2.00	0.00	0.66	0.00	20.34	31.24	2.00	0.00	0.66	0.00
20.50	33.28	2.00	0.00	0.65	0.00	20.67	76.21	0.29	2.73	0.65	0.05
20.83	84.10	0.32	2.47	0.65	0.05	21.00	89.07	0.33	2.33	0.64	0.05
21.16	36.47	2.00	0.00	0.64	0.00	21.32	26.72	2.00	0.00	0.64	0.00
21.49	19.38	2.00	0.00	0.64	0.00	21.65	17.36	2.00	0.00	0.63	0.00
21.82	30.62	2.00	0.00	0.63	0.00	21.98	48.52	2.00	0.00	0.63	0.00
22.15	34.74	2.00	0.00	0.62	0.00	22.31	23.03	2.00	0.00	0.62	0.00
22.47	21.76	2.00	0.00	0.62	0.00	22.64	27.93	2.00	0.00	0.62	0.00
22.80	67.62	0.25	2.88	0.61	0.06	22.97	96.37	0.36	2.04	0.61	0.04
23.13	115.68	0.45	1.68	0.61	0.03	23.29	109.38	0.41	1.77	0.61	0.03
23.46	88.55	0.32	2.19	0.60	0.04	23.62	29.65	2.00	0.00	0.60	0.00
23.79	19.85	2.00	0.00	0.60	0.00	23.95	18.07	2.00	0.00	0.59	0.00
24.11	20.83	2.00	0.00	0.59	0.00	24.28	29.26	2.00	0.00	0.59	0.00
24.44	42.16	2.00	0.00	0.59	0.00	24.61	39.40	2.00	0.00	0.58	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)
24.77	80.69	0.29	2.31	0.58	0.05	24.93	89.41	0.32	2.08	0.58	0.04
25.10	95.00	0.34	1.94	0.57	0.04	25.26	95.49	0.35	1.93	0.57	0.04
25.43	94.17	0.34	1.94	0.57	0.04	25.59	92.54	0.33	1.97	0.57	0.04
25.75	85.64	0.31	2.11	0.56	0.04	25.92	77.79	0.28	2.31	0.56	0.05
26.08	34.03	2.00	0.00	0.56	0.00	26.25	34.72	2.00	0.00	0.56	0.00
26.41	37.98	2.00	0.00	0.55	0.00	26.57	30.73	2.00	0.00	0.55	0.00
26.74	27.99	2.00	0.00	0.55	0.00	26.90	19.11	2.00	0.00	0.54	0.00
27.07	16.15	2.00	0.00	0.54	0.00	27.23	15.47	2.00	0.00	0.54	0.00
27.39	17.20	2.00	0.00	0.54	0.00	27.56	18.37	2.00	0.00	0.53	0.00
27.72	19.43	2.00	0.00	0.53	0.00	27.89	57.43	0.21	2.87	0.53	0.06
28.05	63.36	0.23	2.61	0.52	0.05	28.21	78.51	0.28	2.13	0.52	0.04
28.38	63.23	0.23	2.59	0.52	0.05	28.54	73.64	0.26	2.24	0.52	0.04
28.71	75.72	0.27	2.17	0.51	0.04	28.87	73.70	0.26	2.21	0.51	0.04
29.04	28.73	2.00	0.00	0.51	0.00	29.20	25.17	2.00	0.00	0.51	0.00
29.36	23.65	2.00	0.00	0.50	0.00	29.53	25.85	2.00	0.00	0.50	0.00
29.69	33.78	2.00	0.00	0.50	0.00	29.86	34.89	2.00	0.00	0.49	0.00
30.02	31.10	2.00	0.00	0.49	0.00	30.18	30.85	2.00	0.00	0.49	0.00
30.35	26.72	2.00	0.00	0.49	0.00	30.51	25.59	2.00	0.00	0.48	0.00
30.68	26.31	2.00	0.00	0.48	0.00	30.84	28.10	2.00	0.00	0.48	0.00
31.00	30.60	2.00	0.00	0.47	0.00	31.17	82.87	0.29	1.83	0.47	0.04
31.33	97.29	0.34	1.55	0.47	0.03	31.50	84.85	0.30	1.77	0.47	0.03
31.66	81.49	0.28	1.82	0.46	0.04	31.82	94.67	0.33	1.56	0.46	0.03
31.99	121.24	0.45	1.20	0.46	0.02	32.15	176.22	1.18	0.24	0.46	0.00
32.32	198.30	2.00	0.00	0.45	0.00	32.48	206.66	2.00	0.00	0.45	0.00
32.64	206.14	2.00	0.00	0.45	0.00	32.81	212.05	2.00	0.00	0.44	0.00
32.97	210.87	2.00	0.00	0.44	0.00	33.14	191.64	1.96	0.01	0.44	0.00
33.30	178.14	1.24	0.20	0.44	0.00	33.47	165.60	0.90	0.43	0.43	0.01
33.63	168.42	0.96	0.37	0.43	0.01	33.79	169.81	0.99	0.34	0.43	0.01
33.96	166.26	0.91	0.41	0.42	0.01	34.12	161.70	0.83	0.51	0.42	0.01
34.28	157.96	0.77	0.61	0.42	0.01	34.45	145.99	0.62	0.89	0.42	0.02
34.61	141.65	0.58	0.92	0.41	0.02	34.78	139.70	0.57	0.92	0.41	0.02
34.94	141.33	0.58	0.91	0.41	0.02	35.10	143.85	0.60	0.88	0.41	0.02
35.27	155.85	0.73	0.65	0.40	0.01	35.43	146.25	0.62	0.85	0.40	0.02
35.60	131.25	0.50	0.96	0.40	0.02	35.76	148.60	0.65	0.83	0.39	0.02
35.92	208.94	2.00	0.00	0.39	0.00	36.09	269.61	2.00	0.00	0.39	0.00
36.25	324.71	2.00	0.00	0.39	0.00	36.42	342.90	2.00	0.00	0.38	0.00
36.58	325.18	2.00	0.00	0.38	0.00	36.74	305.36	2.00	0.00	0.38	0.00
36.91	302.02	2.00	0.00	0.37	0.00	37.07	299.07	2.00	0.00	0.37	0.00
37.24	302.50	2.00	0.00	0.37	0.00	37.40	308.17	2.00	0.00	0.37	0.00
37.57	317.75	2.00	0.00	0.36	0.00	37.73	285.66	2.00	0.00	0.36	0.00
37.89	306.65	2.00	0.00	0.36	0.00	38.06	312.52	2.00	0.00	0.35	0.00
38.22	330.58	2.00	0.00	0.35	0.00	38.39	344.29	2.00	0.00	0.35	0.00
38.55	360.20	2.00	0.00	0.35	0.00	38.71	374.28	2.00	0.00	0.34	0.00
38.88	377.66	2.00	0.00	0.34	0.00	39.04	374.63	2.00	0.00	0.34	0.00
39.21	350.93	2.00	0.00	0.34	0.00	39.37	330.79	2.00	0.00	0.33	0.00
39.53	342.33	2.00	0.00	0.33	0.00	39.70	359.78	2.00	0.00	0.33	0.00
39.86	368.73	2.00	0.00	0.32	0.00	40.03	366.68	2.00	0.00	0.32	0.00
40.19	318.05	2.00	0.00	0.32	0.00	40.35	196.57	2.00	0.00	0.32	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)
40.52	102.66	0.36	0.98	0.31	0.02	40.68	103.19	0.37	0.97	0.31	0.02
40.85	78.33	0.27	1.26	0.31	0.02	41.01	27.61	2.00	0.00	0.30	0.00
41.17	24.43	2.00	0.00	0.30	0.00	41.34	23.63	2.00	0.00	0.30	0.00
41.50	27.48	2.00	0.00	0.30	0.00	41.67	24.56	2.00	0.00	0.29	0.00
41.83	23.55	2.00	0.00	0.29	0.00	41.99	20.38	2.00	0.00	0.29	0.00
42.16	18.59	2.00	0.00	0.29	0.00	42.32	17.69	2.00	0.00	0.28	0.00
42.49	16.21	2.00	0.00	0.28	0.00	42.65	15.13	2.00	0.00	0.28	0.00
42.81	12.53	2.00	0.00	0.27	0.00	42.98	12.26	2.00	0.00	0.27	0.00
43.14	13.13	2.00	0.00	0.27	0.00	43.31	13.90	2.00	0.00	0.27	0.00
43.47	13.63	2.00	0.00	0.26	0.00	43.63	11.71	2.00	0.00	0.26	0.00
43.80	10.32	2.00	0.00	0.26	0.00	43.96	9.74	2.00	0.00	0.25	0.00
44.13	9.71	2.00	0.00	0.25	0.00	44.29	11.31	2.00	0.00	0.25	0.00
44.45	12.56	2.00	0.00	0.25	0.00	44.62	12.73	2.00	0.00	0.24	0.00
44.78	12.25	2.00	0.00	0.24	0.00	44.95	12.29	2.00	0.00	0.24	0.00
45.11	13.42	2.00	0.00	0.24	0.00	45.28	16.50	2.00	0.00	0.23	0.00
45.44	13.36	2.00	0.00	0.23	0.00	45.60	11.57	2.00	0.00	0.23	0.00
45.77	10.48	2.00	0.00	0.22	0.00	45.93	8.66	2.00	0.00	0.22	0.00
46.10	9.09	2.00	0.00	0.22	0.00	46.26	8.15	2.00	0.00	0.22	0.00
46.42	7.85	2.00	0.00	0.21	0.00	46.59	8.92	2.00	0.00	0.21	0.00
46.75	12.89	2.00	0.00	0.21	0.00	46.92	16.66	2.00	0.00	0.20	0.00
47.08	19.70	2.00	0.00	0.20	0.00	47.24	20.83	2.00	0.00	0.20	0.00
47.41	20.20	2.00	0.00	0.20	0.00	47.57	22.34	2.00	0.00	0.19	0.00
47.74	62.49	0.23	0.96	0.19	0.02	47.90	65.00	0.23	0.92	0.19	0.02
48.06	25.67	2.00	0.00	0.19	0.00	48.23	24.61	2.00	0.00	0.18	0.00
48.39	22.95	2.00	0.00	0.18	0.00	48.56	21.70	2.00	0.00	0.18	0.00
48.72	22.18	2.00	0.00	0.17	0.00	48.88	22.87	2.00	0.00	0.17	0.00
49.05	25.41	2.00	0.00	0.17	0.00	49.21	31.49	2.00	0.00	0.17	0.00
49.38	74.91	0.27	0.70	0.16	0.01	49.54	80.65	0.28	0.64	0.16	0.01
49.70	87.17	0.31	0.58	0.16	0.01	49.87	110.20	0.40	0.45	0.15	0.01
50.03	96.40	0.34	0.51	0.15	0.01	50.20	79.29	0.28	0.60	0.15	0.01

Total estimated settlement: 5.39

Abbreviations

$Q_{tn,cs}$: Equivalent clean sand normalized cone resistance
FS: Factor of safety against liquefaction
e_v (%): Post-liquefaction volumentric strain
DF: e_v depth weighting factor
Settlement: Calculated settlement

:: Strength loss calculation Idriss & Boulanger (2008) ::

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
1.31	18.47	29.56	2.31	68.19	2.39	0.06	0.68
1.48	16.96	27.12	2.76	74.96	2.47	0.06	0.67
1.64	14.72	23.50	3.88	91.11	2.61	0.06	0.62
1.80	13.33	21.26	4.65	98.94	2.69	0.06	0.62
1.97	12.18	19.40	5.05	98.04	2.73	0.06	0.62
2.13	11.49	18.28	4.60	84.01	2.69	0.06	0.62
2.30	11.18	17.76	4.14	73.53	2.64	0.06	0.62
2.46	11.05	17.54	3.69	64.81	2.59	0.06	0.64
2.63	11.41	18.10	3.25	58.87	2.54	0.05	0.64
2.79	11.90	18.89	2.83	53.37	2.48	0.05	0.64
2.95	12.79	20.30	2.47	50.21	2.42	0.05	0.64
3.12	14.05	22.32	2.12	47.40	2.35	0.05	0.65
3.28	15.73	25.00	1.84	46.00	2.28	0.05	0.65
3.44	17.43	27.72	1.00	27.72	2.21	0.04	0.62
3.61	18.63	29.63	1.00	29.63	2.18	0.04	0.62
3.77	19.69	31.33	1.00	31.33	2.17	0.04	0.62
3.94	19.98	31.78	1.58	50.27	2.19	0.05	0.67
4.10	20.31	32.29	1.61	52.04	2.20	0.05	0.67
4.26	19.91	31.63	1.69	53.37	2.23	0.06	0.67
4.43	19.84	31.50	1.74	54.68	2.24	0.06	0.67
4.59	19.56	31.04	1.78	55.34	2.26	0.06	0.67
4.76	19.72	31.29	1.76	55.09	2.25	0.06	0.67
4.92	20.35	32.29	1.70	54.88	2.23	0.06	0.67
5.08	21.69	34.42	1.60	55.00	2.19	0.06	0.68
5.25	23.37	37.11	1.51	56.08	2.15	0.06	0.68
5.41	24.88	39.53	1.45	57.13	2.12	0.06	0.68
5.58	26.37	41.90	1.39	58.41	2.08	0.06	0.68
5.74	28.42	45.19	1.34	60.73	2.04	0.06	0.68
5.91	31.51	50.14	1.00	50.14	1.98	0.06	0.63
6.07	35.15	55.97	1.00	55.97	1.91	0.07	0.65
6.23	38.56	61.43	1.00	61.43	1.86	0.08	0.66
6.40	41.16	65.60	1.00	65.60	1.82	0.08	0.67
6.56	42.78	68.18	1.00	68.18	1.81	0.08	0.68
6.73	43.16	68.77	1.00	68.77	1.83	0.09	0.68
6.89	41.96	66.85	1.00	66.85	1.87	0.08	0.68
7.05	39.31	62.56	1.26	78.70	1.93	0.08	0.71
7.22	36.04	57.30	1.32	75.47	2.01	0.08	0.71
7.38	33.75	53.60	1.39	74.41	2.08	0.07	0.71
7.55	33.49	53.18	1.42	75.50	2.10	0.07	0.71
7.71	34.75	55.19	1.40	77.22	2.09	0.08	0.72
7.87	36.40	57.82	1.36	78.62	2.05	0.08	0.72
8.04	38.58	61.32	1.31	80.44	2.01	0.08	0.71
8.20	41.46	65.91	1.27	83.42	1.94	0.08	0.71
8.37	43.50	68.71	1.24	85.06	1.90	0.09	0.71
8.53	43.39	67.70	1.24	83.72	1.90	0.09	0.70
8.69	41.04	63.77	1.25	79.91	1.92	0.08	0.70
8.86	38.24	59.42	1.28	76.03	1.96	0.08	0.70
9.02	35.58	55.28	1.31	72.50	2.01	0.07	0.69

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
9.19	33.57	52.16	1.35	70.53	2.05	0.07	0.69
9.35	32.63	50.26	1.36	68.58	2.06	0.07	0.69
9.51	32.89	50.02	1.36	67.97	2.05	0.07	0.69
9.68	34.32	51.31	1.33	68.44	2.03	0.07	0.69
9.84	36.11	53.13	1.32	70.02	2.01	0.07	0.69
10.01	37.22	54.05	1.31	70.75	2.00	0.07	0.70
10.17	37.38	53.71	1.31	70.34	2.00	0.07	0.69
10.34	36.69	52.32	1.32	69.01	2.01	0.07	0.69
10.50	33.96	48.34	1.36	65.64	2.05	0.07	0.69
10.66	33.90	47.74	1.36	64.79	2.05	0.06	0.67
10.83	34.12	47.55	1.36	64.48	2.05	0.07	0.69
10.99	37.18	50.93	1.32	67.14	2.01	0.07	0.69
11.15	39.11	53.09	1.30	68.93	1.99	0.07	0.69
11.32	43.22	57.84	1.00	57.84	1.94	0.07	0.65
11.48	47.91	63.24	1.00	63.24	1.89	0.08	0.67
11.65	51.77	67.78	1.00	67.78	1.86	0.08	0.68
11.81	53.18	69.66	1.23	85.39	1.88	0.09	0.71
11.97	52.99	69.39	1.24	85.91	1.90	0.09	0.71
12.14	52.11	67.91	1.24	83.95	1.90	0.09	0.70
12.30	52.01	67.11	1.00	67.11	1.87	0.08	0.68
12.47	51.56	66.23	1.00	66.23	1.87	0.08	0.68
12.63	50.45	64.79	1.00	64.79	1.89	0.08	0.67
12.79	49.06	63.00	1.00	63.00	1.91	0.08	0.66
12.96	49.09	62.81	1.00	62.81	1.91	0.08	0.66
13.12	50.56	64.41	1.24	79.74	1.90	0.08	0.70
13.29	51.89	65.75	1.23	80.98	1.89	0.08	0.70
13.45	52.88	66.55	1.00	66.55	1.88	0.08	0.68
13.62	54.37	67.86	1.00	67.86	1.85	0.08	0.68
13.78	56.49	69.91	1.00	69.91	1.82	0.09	0.69
13.94	58.54	71.83	1.00	71.83	1.79	0.09	0.69
14.11	57.93	70.81	1.00	70.81	1.79	0.09	0.69
14.27	57.50	70.13	1.00	70.13	1.79	0.08	0.68
14.44	57.53	70.08	1.00	70.08	1.81	0.09	0.69
14.60	58.65	71.27	1.00	71.27	1.81	0.09	0.69
14.76	52.39	63.93	1.00	63.93	1.86	0.09	0.69
14.93	39.14	48.62	1.32	64.18	2.01	0.07	0.68
15.09	24.64	31.45	1.81	56.85	2.27	0.05	0.65
15.26	15.44	20.19	3.37	68.06	2.55	0.05	0.64
15.42	13.10	17.17	4.32	74.10	2.66	0.05	0.62
15.58	15.15	19.68	3.59	70.59	2.58	0.05	0.63
15.75	19.03	24.32	2.59	63.02	2.44	0.06	0.66
15.91	22.17	28.09	2.26	63.37	2.38	0.06	0.67
16.08	22.50	28.53	2.40	68.56	2.41	0.06	0.67
16.24	21.86	27.85	2.82	78.44	2.48	0.06	0.67
16.40	21.42	27.36	3.18	87.12	2.53	0.06	0.66
16.57	21.79	27.89	3.53	98.43	2.57	0.06	0.66
16.73	25.03	31.95	3.38	107.92	2.55	0.07	0.67
16.90	30.12	38.17	2.98	113.70	2.50	0.07	0.70

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
17.06	36.90	46.26	2.51	115.95	2.42	0.08	0.71
17.22	55.27	67.41	1.64	110.80	2.21	0.07	0.72
17.39	83.19	98.39	1.30	127.44	1.99	0.13	0.78
17.55	109.57	126.76	1.19	150.72	1.84	0.22	0.81
17.72	114.88	132.18	1.18	155.48	1.82	0.22	0.82
17.88	100.73	116.92	1.25	146.69	1.93	0.16	0.80
18.05	79.96	94.67	1.47	139.17	2.13	0.12	0.79
18.21	72.59	86.91	1.81	156.90	2.27	0.10	0.77
18.37	84.33	100.52	1.78	179.14	2.26	0.13	0.81
18.54	113.88	133.13	1.45	192.79	2.12	0.20	0.85
18.70	129.48	149.80	1.37	205.50	2.06	0.39	0.89
18.86	114.36	132.57	1.47	194.82	2.13	0.25	0.87
19.03	76.52	90.15	2.16	194.80	2.36	0.12	0.79
19.19	42.83	51.59	4.74	244.46	2.70	0.09	0.62
19.36	29.03	35.14	7.78	273.41	2.94	0.08	0.62
19.52	27.23	32.66	8.65	282.46	2.99	0.09	0.62
19.68	28.50	34.00	8.17	277.94	2.96	0.09	0.62
19.85	29.18	34.61	7.73	267.48	2.93	0.09	0.62
20.01	27.48	32.31	7.52	243.04	2.92	0.09	0.62
20.18	27.39	31.76	6.40	203.35	2.84	0.08	0.62
20.34	28.39	32.47	5.17	167.92	2.74	0.08	0.62
20.50	30.88	34.94	4.19	146.51	2.65	0.08	0.62
20.67	34.18	38.35	3.55	136.18	2.58	0.08	0.70
20.83	38.12	42.45	3.03	128.73	2.51	0.08	0.72
21.00	38.83	43.02	2.99	128.79	2.50	0.08	0.73
21.16	34.22	37.88	3.76	142.26	2.60	0.08	0.62
21.32	25.97	28.74	5.80	166.65	2.80	0.08	0.62
21.49	19.86	21.72	8.61	187.03	2.99	0.08	0.62
21.65	21.21	23.15	7.95	184.15	2.95	0.07	0.62
21.82	30.69	33.47	5.06	169.24	2.73	0.08	0.62
21.98	36.29	39.44	4.42	174.24	2.67	0.10	0.62
22.15	33.86	36.68	5.10	186.90	2.74	0.08	0.62
22.31	25.23	27.14	7.25	196.67	2.90	0.08	0.62
22.47	23.15	24.60	6.93	170.46	2.88	0.07	0.62
22.64	25.01	26.39	5.67	149.53	2.78	0.08	0.62
22.80	35.49	37.28	3.38	125.90	2.55	0.07	0.68
22.97	51.25	53.46	2.04	108.89	2.33	0.09	0.74
23.13	65.18	67.40	1.52	102.63	2.16	0.11	0.78
23.29	63.11	64.97	1.52	98.77	2.16	0.10	0.77
23.46	48.03	49.44	2.12	104.76	2.35	0.08	0.73
23.62	31.40	32.30	4.68	151.23	2.70	0.08	0.62
23.79	21.98	22.29	9.47	211.12	3.04	0.08	1.59
23.95	19.15	19.13	13.73	262.52	3.24	0.08	1.37
24.11	22.36	22.44	13.16	295.27	3.22	0.08	1.60
24.28	30.51	30.94	9.69	299.83	3.05	0.09	2.21
24.44	36.82	37.38	6.90	257.83	2.88	0.10	0.62
24.61	40.05	40.27	4.71	189.81	2.70	0.09	0.62
24.77	41.73	41.50	2.99	123.97	2.50	0.08	0.71

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
24.93	46.02	45.51	2.26	102.97	2.38	0.08	0.73
25.10	50.57	49.90	2.11	105.37	2.35	0.08	0.74
25.26	51.86	51.03	2.21	112.91	2.37	0.09	0.74
25.43	50.72	49.70	2.31	114.77	2.39	0.09	0.74
25.59	47.63	46.48	2.67	124.19	2.45	0.09	0.73
25.75	42.82	41.51	2.98	123.80	2.50	0.08	0.72
25.92	38.12	36.71	3.49	128.17	2.57	0.08	0.70
26.08	35.62	34.08	3.82	130.17	2.61	0.08	0.62
26.25	36.45	34.77	4.12	143.14	2.64	0.08	0.62
26.41	35.40	33.61	4.76	160.02	2.71	0.09	0.62
26.57	33.16	31.28	5.47	170.96	2.77	0.08	0.62
26.74	26.72	24.84	7.24	179.86	2.90	0.08	0.62
26.90	21.75	19.84	9.09	180.27	3.02	0.08	1.42
27.07	17.49	15.58	11.17	174.04	3.13	0.08	1.11
27.23	16.89	14.92	10.81	161.36	3.11	0.07	1.07
27.39	17.74	15.67	9.06	141.99	3.02	0.07	1.12
27.56	19.19	16.99	6.97	118.45	2.88	0.07	0.62
27.72	20.57	18.23	5.07	92.38	2.73	0.06	0.62
27.89	24.83	22.21	3.21	71.28	2.53	0.06	0.65
28.05	37.01	33.68	1.72	57.96	2.24	0.05	0.67
28.21	52.16	47.93	1.34	64.15	2.03	0.07	0.70
28.38	59.71	54.93	1.00	54.93	1.95	0.08	0.67
28.54	55.33	50.66	1.32	66.75	2.01	0.07	0.69
28.71	44.81	40.60	1.65	66.88	2.21	0.06	0.70
28.87	36.89	33.01	2.83	93.43	2.48	0.07	0.69
29.04	31.36	27.67	5.27	145.89	2.75	0.08	0.62
29.20	27.91	24.32	8.15	198.17	2.96	0.08	0.62
29.36	26.98	23.34	10.01	233.58	3.07	0.08	1.67
29.53	30.16	26.13	9.22	240.81	3.02	0.08	1.87
29.69	34.28	29.75	7.62	226.69	2.93	0.09	0.62
29.86	36.27	31.43	6.40	201.17	2.84	0.09	0.62
30.02	35.33	30.45	5.89	179.35	2.80	0.08	0.62
30.18	32.51	27.76	5.89	163.54	2.80	0.08	0.62
30.35	30.62	25.94	6.00	155.68	2.81	0.08	0.62
30.51	29.09	24.43	6.43	157.03	2.84	0.08	0.62
30.68	29.70	24.87	6.49	161.30	2.85	0.08	0.62
30.84	31.68	26.52	6.24	165.39	2.83	0.08	0.62
31.00	36.66	30.86	5.10	157.25	2.74	0.08	0.62
31.17	45.07	38.29	3.63	139.02	2.59	0.08	0.71
31.33	49.32	42.01	2.89	121.57	2.49	0.09	0.74
31.50	49.61	42.15	2.67	112.72	2.45	0.08	0.72
31.66	50.64	42.94	2.50	107.50	2.42	0.07	0.71
31.82	66.54	56.99	1.87	106.75	2.29	0.08	0.74
31.99	105.26	91.40	1.40	128.39	2.09	0.12	0.78
32.15	152.62	133.45	1.28	170.45	1.96	0.30	0.86
32.32	193.84	170.13	1.20	204.65	1.85	0.76	0.89
32.48	213.18	187.12	1.15	215.93	1.80	0.92	0.89
32.64	218.38	191.24	1.14	218.83	1.79	0.92	0.89

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
32.81	212.89	185.37	1.20	222.35	1.85	0.92	0.90
32.97	201.32	174.04	1.25	218.18	1.93	0.78	0.90
33.14	189.26	163.05	1.25	203.83	1.92	0.47	0.88
33.30	182.98	157.55	1.21	190.99	1.86	0.42	0.86
33.47	184.02	159.17	1.04	166.17	1.73	0.41	0.85
33.63	186.81	161.72	1.00	161.72	1.67	0.44	0.85
33.79	187.43	161.91	1.00	161.91	1.66	0.46	0.85
33.96	183.42	157.51	1.03	162.66	1.72	0.41	0.85
34.12	175.90	149.99	1.14	171.22	1.79	0.34	0.84
34.28	165.98	140.70	1.19	166.90	1.83	0.29	0.84
34.45	158.47	133.92	1.18	158.46	1.83	0.24	0.82
34.61	154.51	130.35	1.17	151.86	1.81	0.23	0.82
34.78	155.87	131.52	1.12	146.85	1.77	0.23	0.81
34.94	159.33	134.48	1.06	142.16	1.73	0.24	0.81
35.10	166.53	140.74	1.00	140.74	1.69	0.26	0.82
35.27	167.54	141.16	1.00	141.16	1.70	0.33	0.83
35.43	159.67	133.36	1.13	150.78	1.78	0.25	0.82
35.60	156.70	129.94	1.19	155.18	1.84	0.18	0.80
35.76	181.13	151.11	1.08	163.71	1.75	0.27	0.83
35.92	234.84	198.53	1.00	198.53	1.58	0.93	0.90
36.09	299.91	256.57	1.00	256.57	1.42	0.97	0.95
36.25	349.29	299.74	1.00	299.74	1.37	0.99	1.00
36.42	370.40	317.08	1.00	317.08	1.38	1.00	1.01
36.58	363.58	308.97	1.00	308.97	1.45	1.00	1.00
36.74	348.73	295.12	1.00	295.12	1.47	0.99	0.98
36.91	339.35	287.19	1.00	287.19	1.44	0.99	0.98
37.07	338.65	287.62	1.00	287.62	1.38	0.99	0.98
37.24	341.33	289.17	1.00	289.17	1.38	0.99	0.98
37.40	348.75	294.12	1.00	294.12	1.41	0.99	0.98
37.57	342.84	287.08	1.00	287.08	1.47	0.99	0.99
37.73	342.66	285.66	1.00	285.66	1.49	0.99	0.97
37.89	341.09	283.63	1.00	283.63	1.50	0.99	0.98
38.06	358.39	299.39	1.00	299.39	1.43	0.99	0.99
38.22	372.99	315.08	1.00	315.08	1.30	1.00	1.00
38.39	391.40	333.68	1.00	333.68	1.20	1.01	1.01
38.55	408.33	348.70	1.00	348.70	1.17	1.02	1.02
38.71	421.40	357.98	1.00	357.98	1.21	1.02	1.03
38.88	427.31	362.07	1.00	362.07	1.22	1.03	1.03
39.04	418.90	354.08	1.00	354.08	1.22	1.02	1.03
39.21	401.54	337.52	1.00	337.52	1.26	1.01	1.02
39.37	389.68	325.97	1.00	325.97	1.29	1.01	1.00
39.53	393.48	329.08	1.00	329.08	1.27	1.01	1.01
39.70	408.36	341.92	1.00	341.92	1.25	1.02	1.02
39.86	418.10	349.96	1.00	349.96	1.24	1.02	1.03
40.03	402.57	335.48	1.00	335.48	1.26	1.01	1.03
40.19	338.71	278.32	1.00	278.32	1.36	0.98	0.99
40.35	235.90	188.35	1.00	188.35	1.57	0.92	0.88
40.52	139.85	106.64	1.22	130.26	1.88	0.12	0.75

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
40.68	78.81	56.77	1.67	94.52	2.22	0.09	0.75
40.85	53.51	36.90	2.56	94.33	2.43	0.07	0.70
41.01	38.50	25.34	4.11	104.11	2.64	0.07	0.62
41.17	32.89	21.04	5.25	110.50	2.75	0.07	0.62
41.34	32.73	20.71	5.98	123.82	2.81	0.07	0.62
41.50	32.94	20.71	6.30	130.53	2.84	0.08	0.62
41.67	33.03	20.70	6.59	136.33	2.86	0.08	0.62
41.83	30.19	18.71	7.13	133.31	2.89	0.08	0.62
41.99	27.66	16.94	7.46	126.30	2.92	0.07	0.62
42.16	25.19	15.23	7.75	118.05	2.94	0.07	0.62
42.32	23.43	14.00	7.75	108.46	2.94	0.07	0.62
42.49	21.95	12.97	8.08	104.79	2.96	0.07	0.62
42.65	19.74	11.46	9.17	105.06	3.02	0.07	0.82
42.81	18.07	10.31	10.90	112.38	3.11	0.07	0.74
42.98	17.26	9.74	12.17	118.51	3.17	0.07	0.70
43.14	17.90	10.13	11.76	119.11	3.16	0.07	0.72
43.31	18.53	10.51	11.12	116.83	3.13	0.07	0.75
43.47	17.92	10.07	11.35	114.26	3.14	0.07	0.72
43.63	16.35	9.01	12.47	112.33	3.19	0.07	0.64
43.80	14.65	7.87	13.92	109.52	3.25	0.07	0.56
43.96	13.79	7.29	14.67	106.89	3.28	0.07	0.52
44.13	14.30	7.59	13.72	104.11	3.24	0.07	0.54
44.29	15.62	8.41	12.15	102.22	3.17	0.07	0.60
44.45	17.01	9.28	10.79	100.22	3.11	0.07	0.66
44.62	17.46	9.54	10.24	97.71	3.08	0.07	0.68
44.78	17.37	9.45	9.96	94.19	3.07	0.07	0.68
44.95	17.72	9.64	9.25	89.23	3.03	0.07	0.69
45.11	19.60	10.81	7.80	84.34	2.94	0.07	0.62
45.28	20.08	11.08	7.63	84.54	2.93	0.07	0.62
45.44	19.26	10.53	8.45	88.95	2.98	0.07	0.62
45.60	16.65	8.84	10.82	95.70	3.11	0.07	0.63
45.77	14.60	7.53	14.42	108.50	3.27	0.07	0.54
45.93	13.54	6.83	17.38	118.65	3.38	0.07	0.49
46.10	12.55	6.18	20.72	128.15	3.48	0.08	0.44
46.26	12.25	5.97	21.64	129.22	3.51	0.07	0.43
46.42	12.16	5.90	21.74	128.17	3.51	0.07	0.42
46.59	14.36	7.24	16.71	120.95	3.36	0.07	0.52
46.75	18.41	9.73	11.31	110.02	3.13	0.07	0.70
46.92	23.48	12.83	7.43	95.34	2.92	0.07	0.62
47.08	27.23	15.19	5.65	85.88	2.78	0.07	0.62
47.24	29.00	16.44	4.79	78.74	2.71	0.06	0.62
47.41	30.22	17.30	4.27	73.89	2.66	0.06	0.62
47.57	32.02	18.55	3.78	70.04	2.60	0.06	0.62
47.74	34.99	20.52	3.43	70.38	2.56	0.06	0.66
47.90	36.82	21.59	3.51	75.84	2.57	0.06	0.67
48.06	37.03	21.40	4.13	88.40	2.64	0.07	0.62
48.23	35.55	20.09	5.11	102.77	2.74	0.07	0.62
48.39	33.76	18.69	6.13	114.53	2.82	0.07	0.62

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

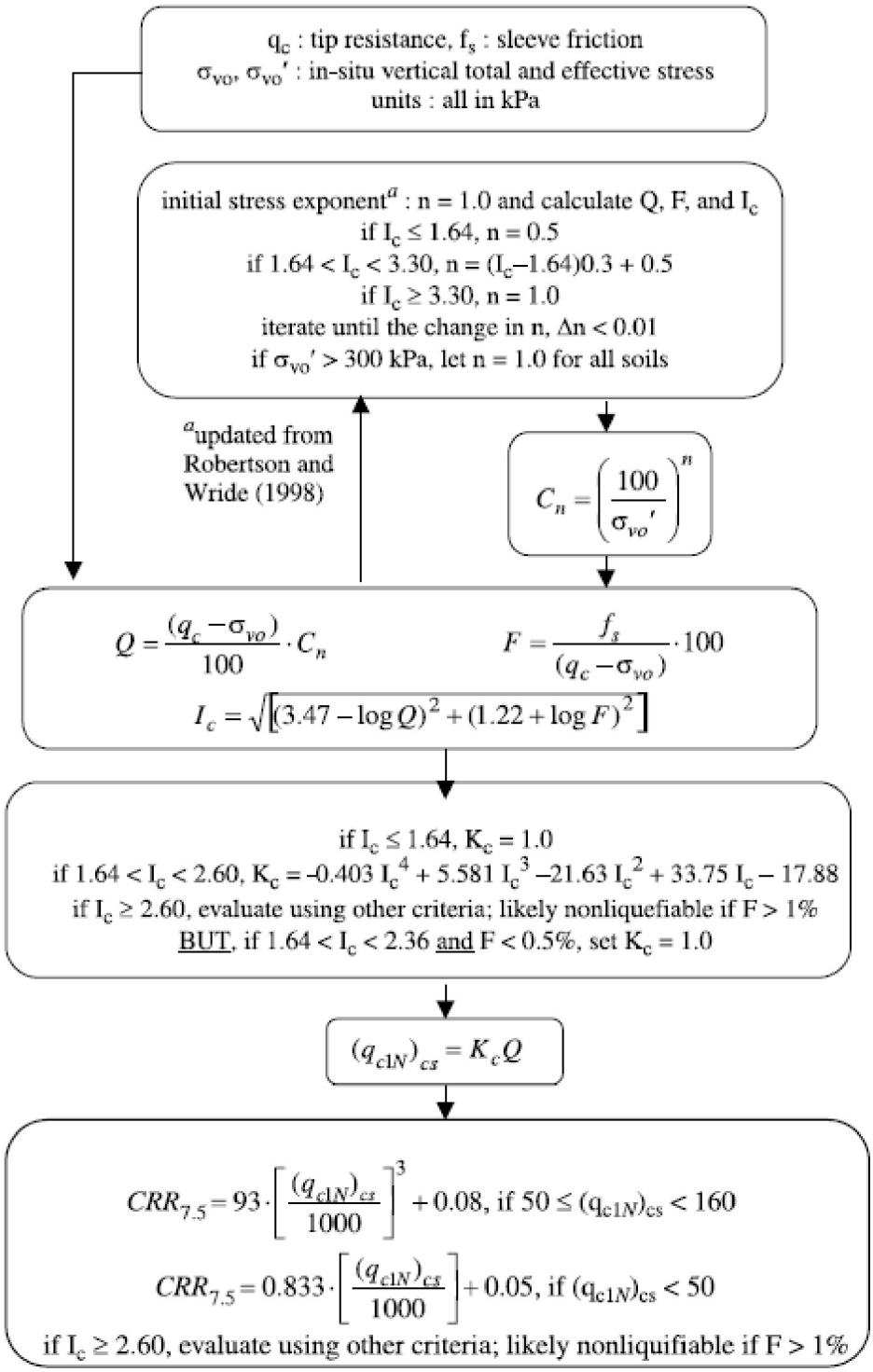
Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
48.56	32.72	18.01	6.47	116.42	2.85	0.07	0.62
48.72	32.75	17.97	6.31	113.31	2.84	0.07	0.62
48.88	34.52	19.04	5.70	108.62	2.79	0.07	0.62
49.05	38.76	21.82	4.82	105.14	2.71	0.07	0.62
49.21	43.87	25.21	4.01	101.20	2.63	0.07	0.62
49.38	50.18	29.49	3.23	95.36	2.54	0.07	0.70
49.54	57.58	34.63	2.56	88.50	2.43	0.07	0.71
49.70	71.83	44.83	1.82	81.59	2.27	0.08	0.72
49.87	78.47	49.68	1.61	79.84	2.20	0.10	0.77
50.03	74.13	46.43	1.70	78.83	2.23	0.09	0.74
50.20	61.76	37.40	2.16	80.89	2.36	0.07	0.71

Abbreviations

q_t: Total cone resistance
K_c: Cone resistance correction factor due to fines
$Q_{tn,cs}$: Adjusted and corrected cone resistance due to fines
I_c: Soil behavior type index
$S_{u(liq)}/\sigma'_v$: Calculated liquefied undrained strength ratio
$S_{u(peak)}/\sigma'_v$: Calculated peak undrained strength ratio

Procedure for the evaluation of soil liquefaction resistance, NCEER (1998)

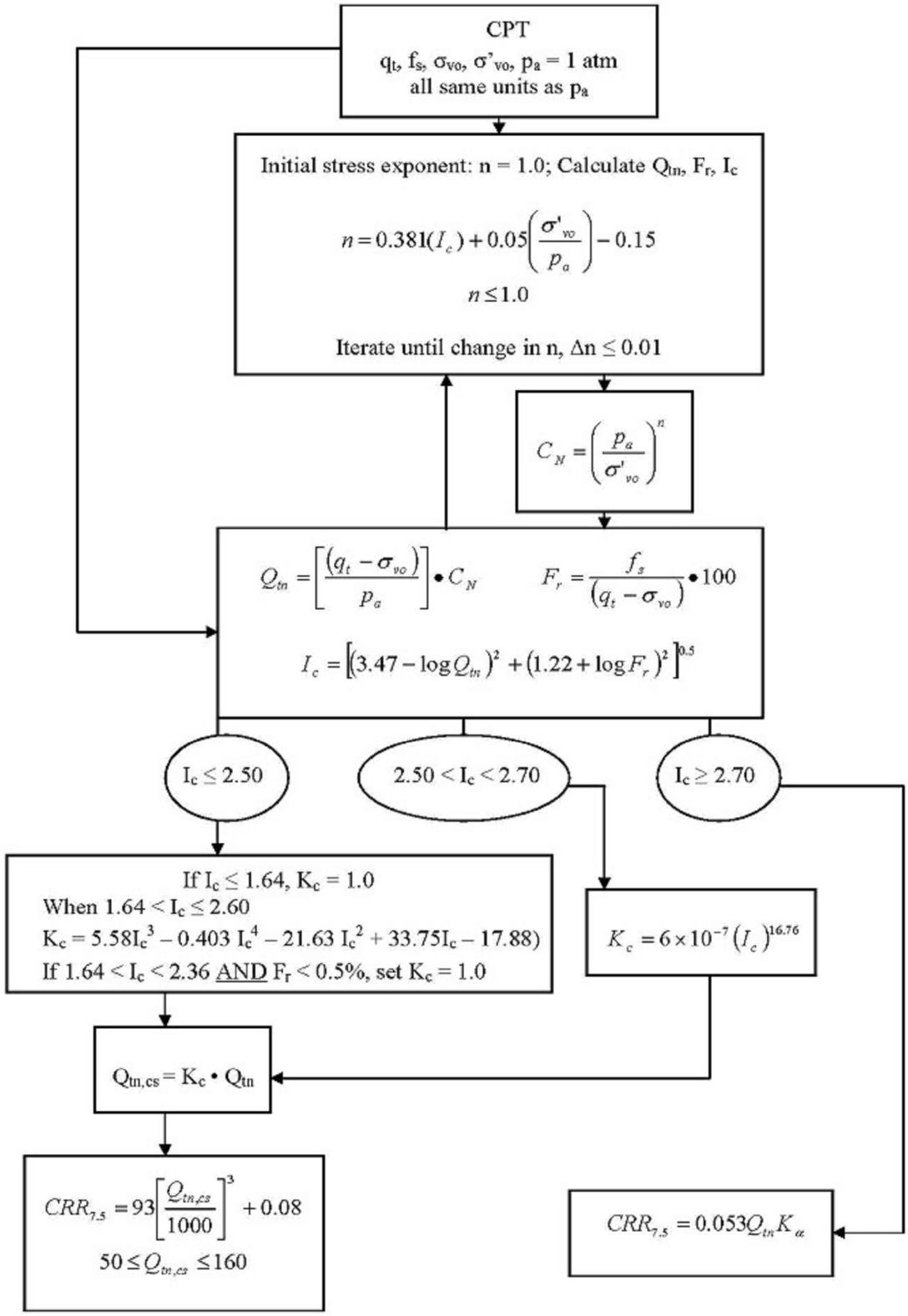
Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. The procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:



[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

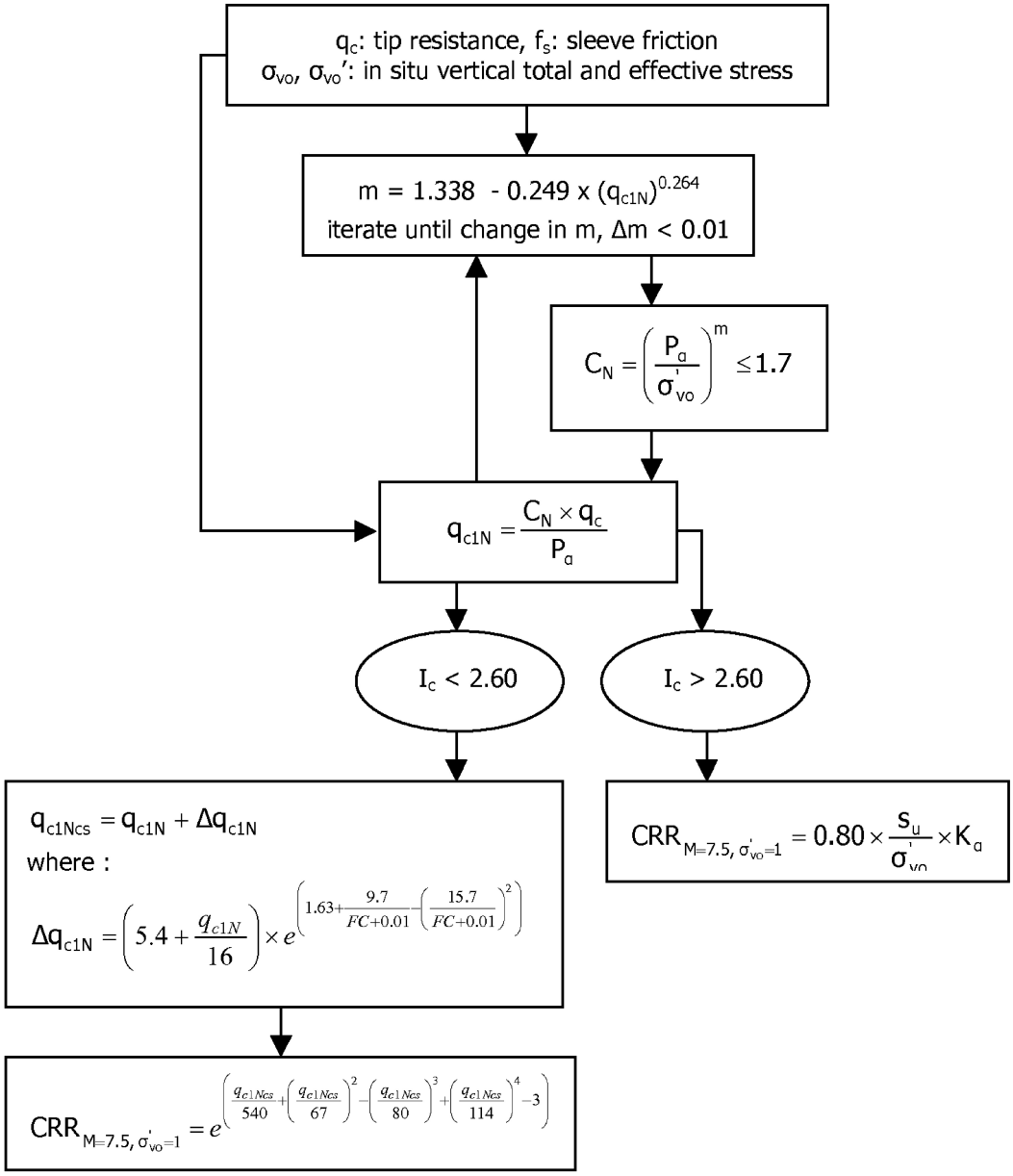
Procedure for the evaluation of soil liquefaction resistance (all soils), Robertson (2010)

Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. This procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:

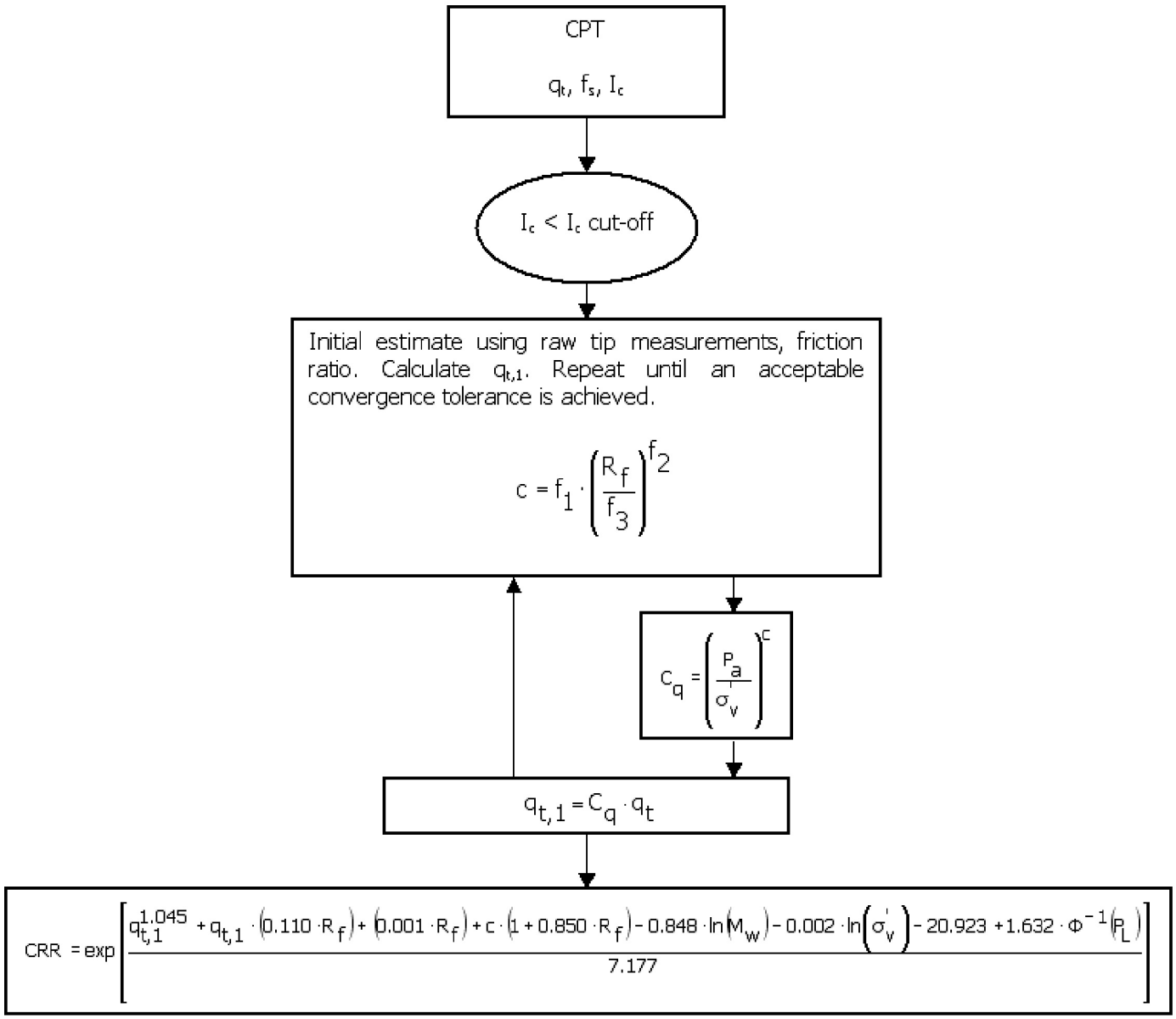


[1] P.K. Robertson, 2009. "Performance based earthquake design using the CPT", Keynote Lecture, International Conference on Performance-based Design in Earthquake Geotechnical Engineering – from case history to practice, IS-Tokyo, June 2009

Procedure for the evaluation of soil liquefaction resistance, Idriss & Boulanger (2008)



Procedure for the evaluation of soil liquefaction resistance (sandy soils), Moss et al. (2006)



Procedure for the evaluation of soil liquefaction resistance, Boulanger & Idriss(2014)

$$FS_{liq} = \frac{CRR_{M=7.5,\sigma'_v=1atm}}{CSR_{M=7.5,\sigma'_v=1atm}}$$

$$CSR_{M=7.5,\sigma'_v=1atm} = 0.65 \frac{\sigma_v}{\sigma'_v} \frac{a_{max}}{g} r_d \frac{1}{MSF} \frac{1}{K_\sigma}$$

$$r_d = \exp\left[\alpha(z) + \beta(z) \cdot M\right]$$

$$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$$

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \le 1.1$$

$$C_\sigma = \frac{1}{37.3 - 8.27\left(q_{c1Ncs}\right)^{0.264}} \le 0.3$$

$$MSF = 1 + \left(MSF_{max} - 1\right)\left(8.64 \exp\left(\frac{-M}{4}\right) - 1.325\right)$$

$$MSF_{max} = 1.09 + \left(\frac{q_{c1Ncs}}{180}\right)^3 \le 2.2$$

σ'_v *and* σ_v *at start of earthquake shaking*

$$CRR_{M=7.5,\sigma'_v=1atm} = \exp\left(\frac{q_{c1Ncs}}{113} + \left(\frac{q_{c1Ncs}}{1000}\right)^2 - \left(\frac{q_{c1Ncs}}{140}\right)^3 + \left(\frac{q_{c1Ncs}}{137}\right)^4 - 2.80\right)$$

$$q_{c1Ncs} = q_{c1N} + \Delta q_{c1N}$$

$$\Delta q_{c1N} = \left(11.9 + \frac{q_{c1N}}{14.6}\right) \exp\left(1.63 - \frac{9.7}{FC+2} - \left(\frac{15.7}{FC+2}\right)^2\right)$$

$$q_{c1N} = C_{Ne} \frac{q_c}{P_a}$$

$$C_{Ne} = \left(\frac{P_a}{\sigma'_v}\right)^m \le 1.7$$

$$m = 1.338 - 0.249\left(q_{c1Ncs}\right)^{0.264} \quad with \quad 0.264 \le m \le 0.782$$

$$FC = 80\left(I_C + C_{FC}\right) - 137 \quad with \quad 0\% \le FC \le 100\%$$

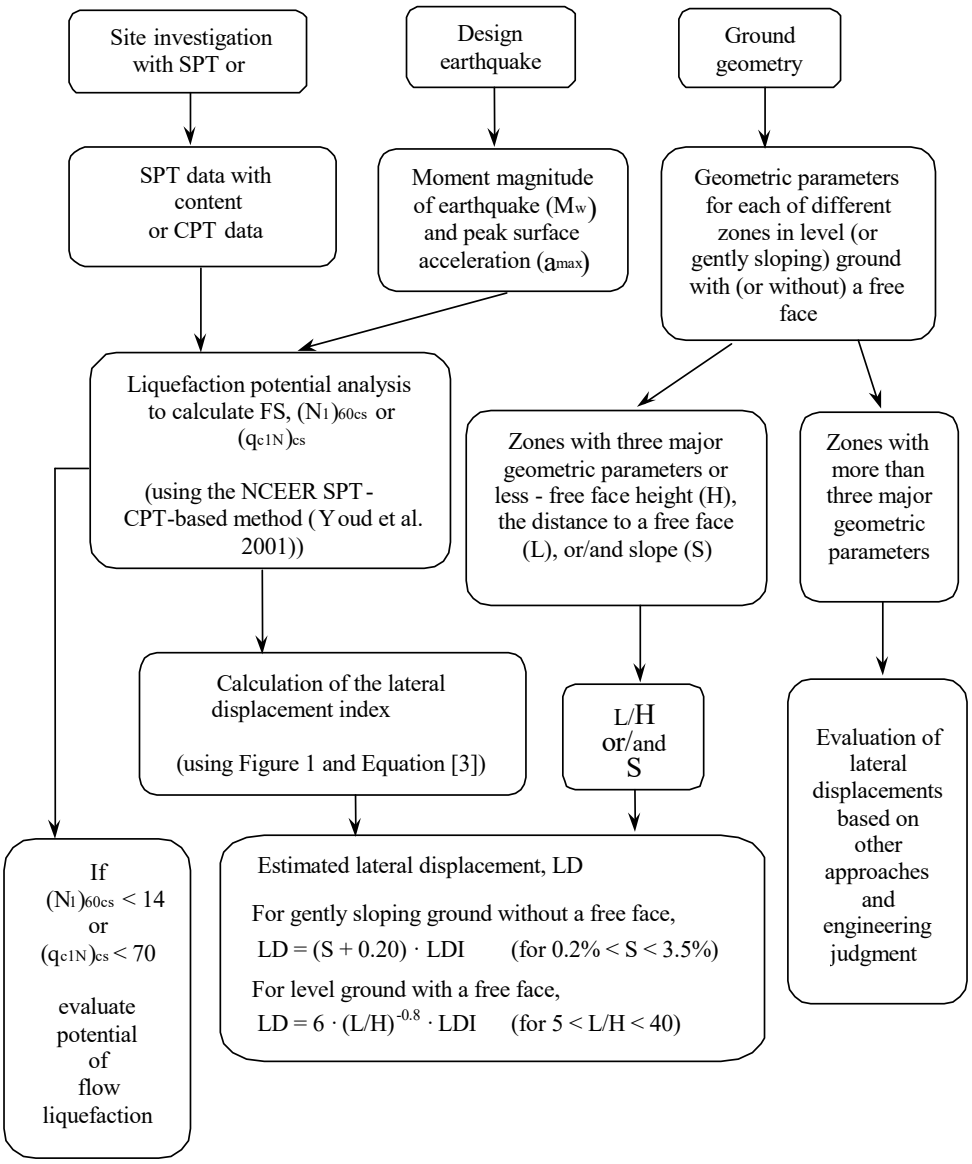
$$I_c = \left[\left(3.47 - \log\left(Q\right)\right)^2 + \left(1.22 + \log\left(F\right)\right)^2\right]^{0.5}$$

$$Q = \left(\frac{q_c - \sigma_{vc}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vc}}\right)^n \; with \; 0.5 \le n \le 1.0 \; per \; Robertson \; \& \; Wride \; (1998)$$

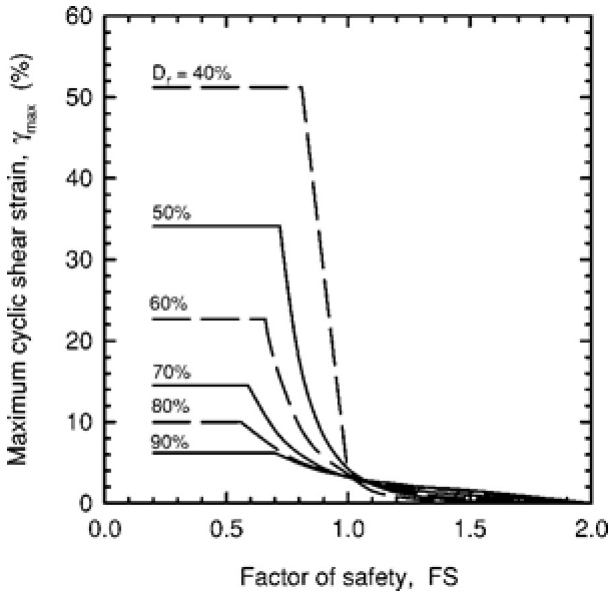
$$F = \left(\frac{f_s}{q_c - \sigma_{vc}}\right) \cdot 100\%$$

σ'_v *at time of CPT sounding*

Procedure for the evaluation of liquefaction-induced lateral spreading displacements



[1] Flow chart illustrating major steps in estimating liquefaction-induced lateral spreading displacements using the proposed approach



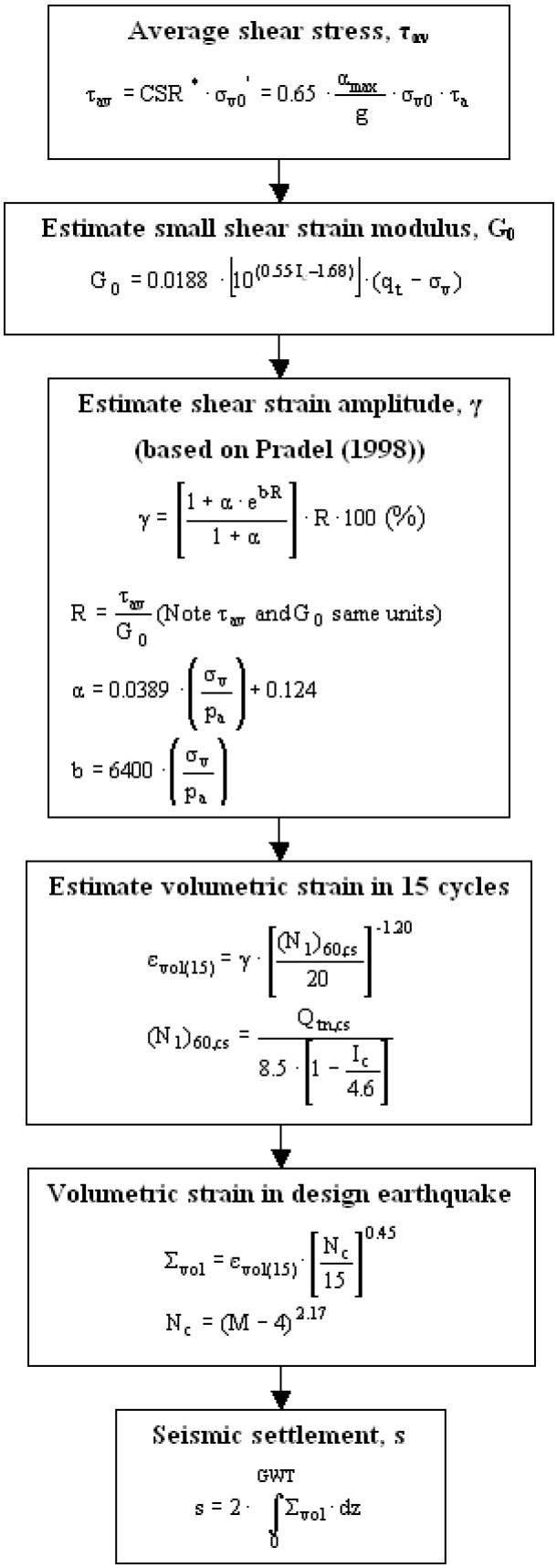
[1] Figure 1

$$LDI = \int_0^{z_{max}} \gamma_{max} dz$$

[1] Equation [3]

[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

Procedure for the estimation of seismic induced settlements in dry sands



Robertson, P.K. and Lisheng, S., 2010, "Estimation of seismic compression in dry soils using the CPT" FIFTH INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN GEOTECHNICAL EARTHQUAKE ENGINEERING AND SOIL DYNAMICS, Symposium in honor of professor I. M. Idriss, San Diego, CA

Liquefaction Potential Index (LPI) calculation procedure

Calculation of the Liquefaction Potential Index (LPI) is used to interpret the liquefaction assessment calculations in terms of severity over depth. The calculation procedure is based on the methology developed by Iwasaki (1982) and is adopted by AFPS.

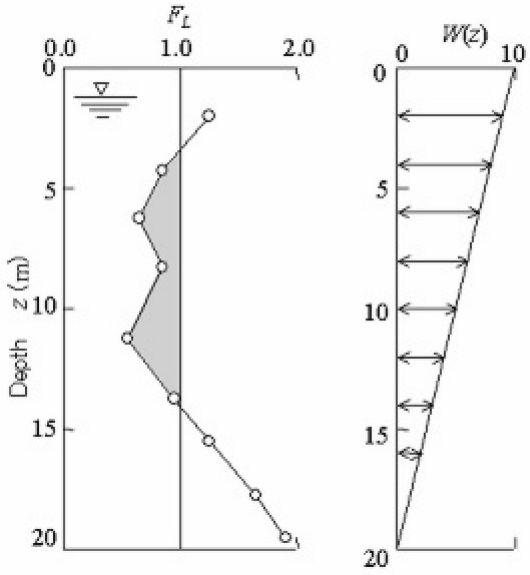
To estimate the severity of liquefaction extent at a given site, LPI is calculated based on the following equation:

$$\mathbf{LPI} = \int_0^{20} (10 - 0{,}5z) \times F_L \times dz$$

where:
F_L = 1 - F.S. when F.S. less than 1
F_L = 0 when F.S. greater than 1
z depth of measurment in meters

Values of LPI range between zero (0) when no test point is characterized as liquefiable and 100 when all points are characterized as susceptible to liquefaction. Iwasaki proposed four (4) discrete categories based on the numeric value of LPI:

- LPI = 0 : Liquefaction risk is very low
- 0 < LPI <= 5 : Liquefaction risk is low
- 5 < LPI <= 15 : Liquefaction risk is high
- LPI > 15 : Liquefaction risk is very high



Graphical presentation of the LPI calculation procedure

Shear-Induced Building Settlement (Ds) calculation procedure

The shear-induced building settlement (Ds) due to liquefaction below the building can be estimated using the relationship developed by Bray and Macedo (2017):

$$Ln(Ds) = c1 + c2 * LBS + 0.58 * Ln\left(Tanh\left(\frac{HL}{6}\right)\right) + 4.59 * Ln(Q) - 0.42 * Ln(Q)^2 - 0.02 * B + 0.84 * Ln(CAVdp) + 0.41 * Ln(Sa1) + \varepsilon$$

where Ds is in the units of mm, c1= -8.35 and c2= 0.072 for LBS ≤ 16, and c1= -7.48 and c2= 0.014 otherwise. Q is the building contact pressure in units of kPa, HL is the cumulative thickness of the liquefiable layers in the units of m, B is the building width in the units of m, CAVdp is a standardized version of the cumulative absolute velocity in the units of g-s, Sa1 is 5%-damped pseudo-acceleration response spectral value at a period of 1 s in the units of g, and ε is a normal random variable with zero mean and 0.50 standard deviation in Ln units. The liquefaction-induced building settlement index (LBS) is:

$$LBS = \sum W * \frac{\varepsilon_{shear}}{z} dz$$

where z (m) is the depth measured from the ground surface > 0, W is a foundation-weighting factor wherein W = 0.0 for z less than Df, which is the embedment depth of the foundation, and W = 1.0 otherwise. The shear strain parameter (ε_shear) is the liquefaction-induced free-field shear strain (in %) estimated using Zhang et al. (2004). It is calculated based on the estimated Dr of the liquefied soil layer and the calculated safety factor against liquefaction triggering (FSL).

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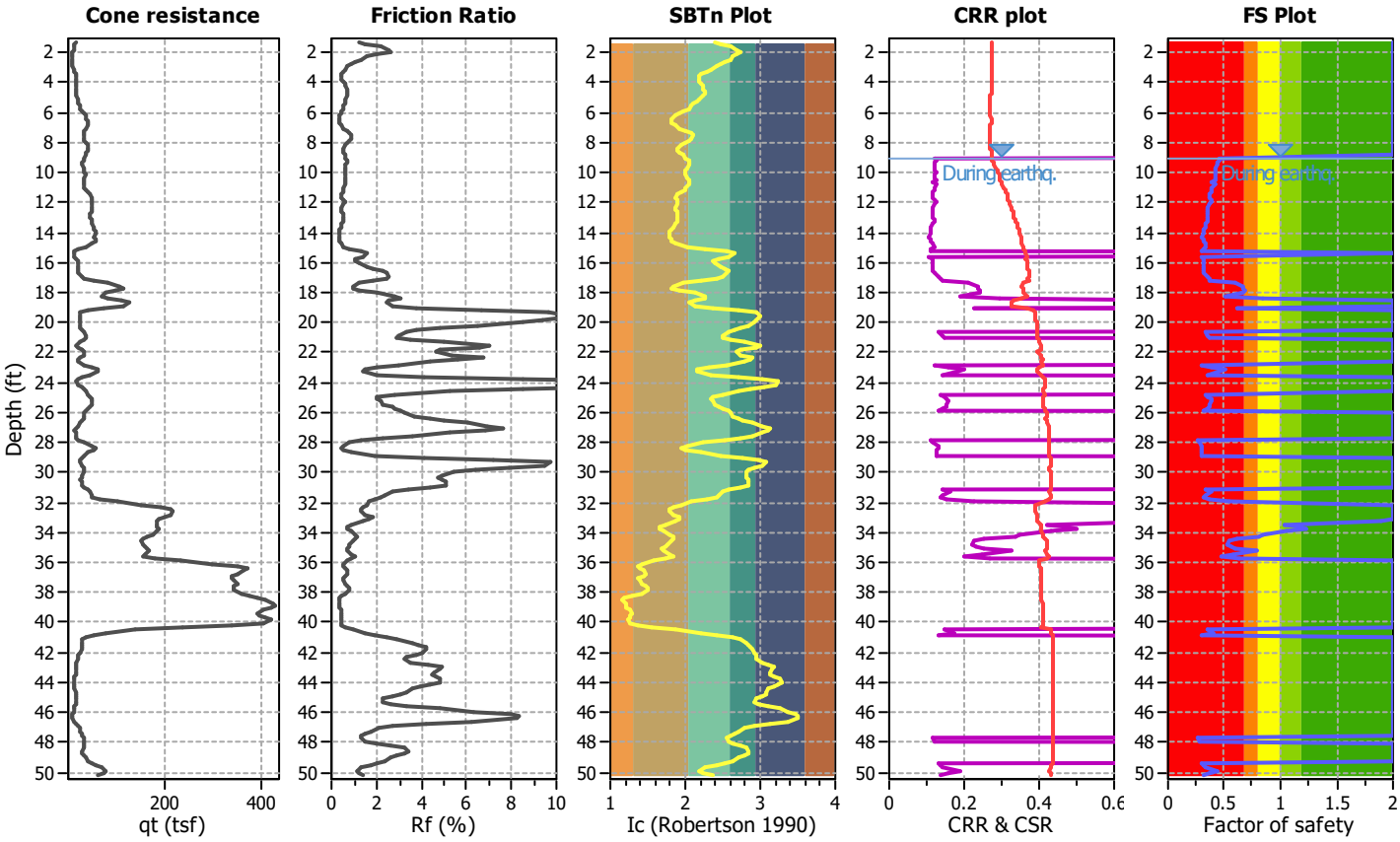
LIQUEFACTION ANALYSIS REPORT

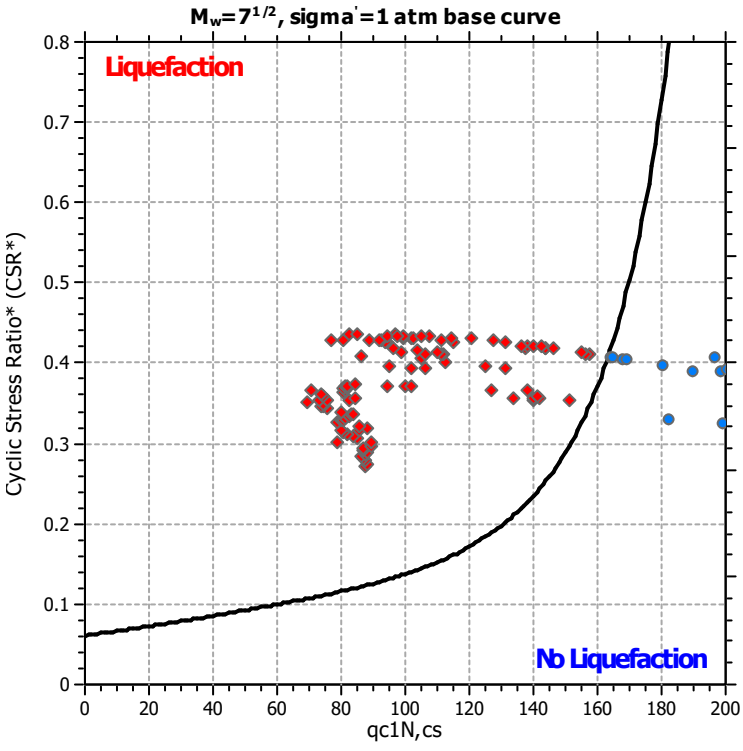
Project title : Manteca WWTP **Location : Manteca, CA**

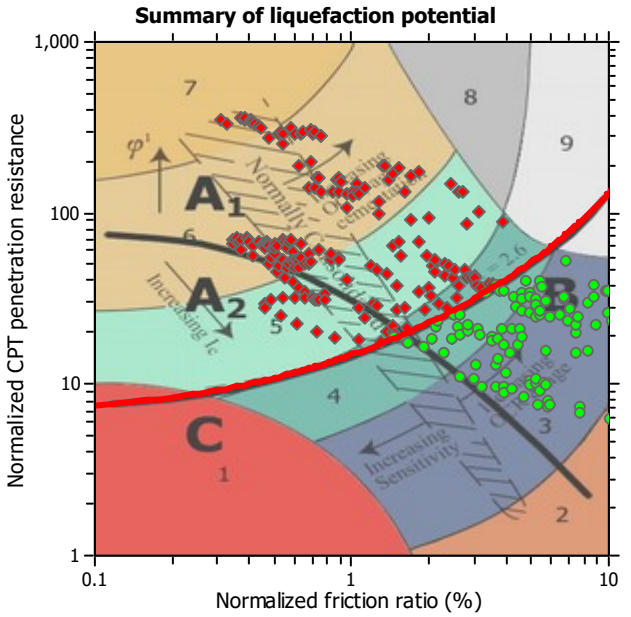
CPT file : CPT 1

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	11.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	9.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	7.13	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.43	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

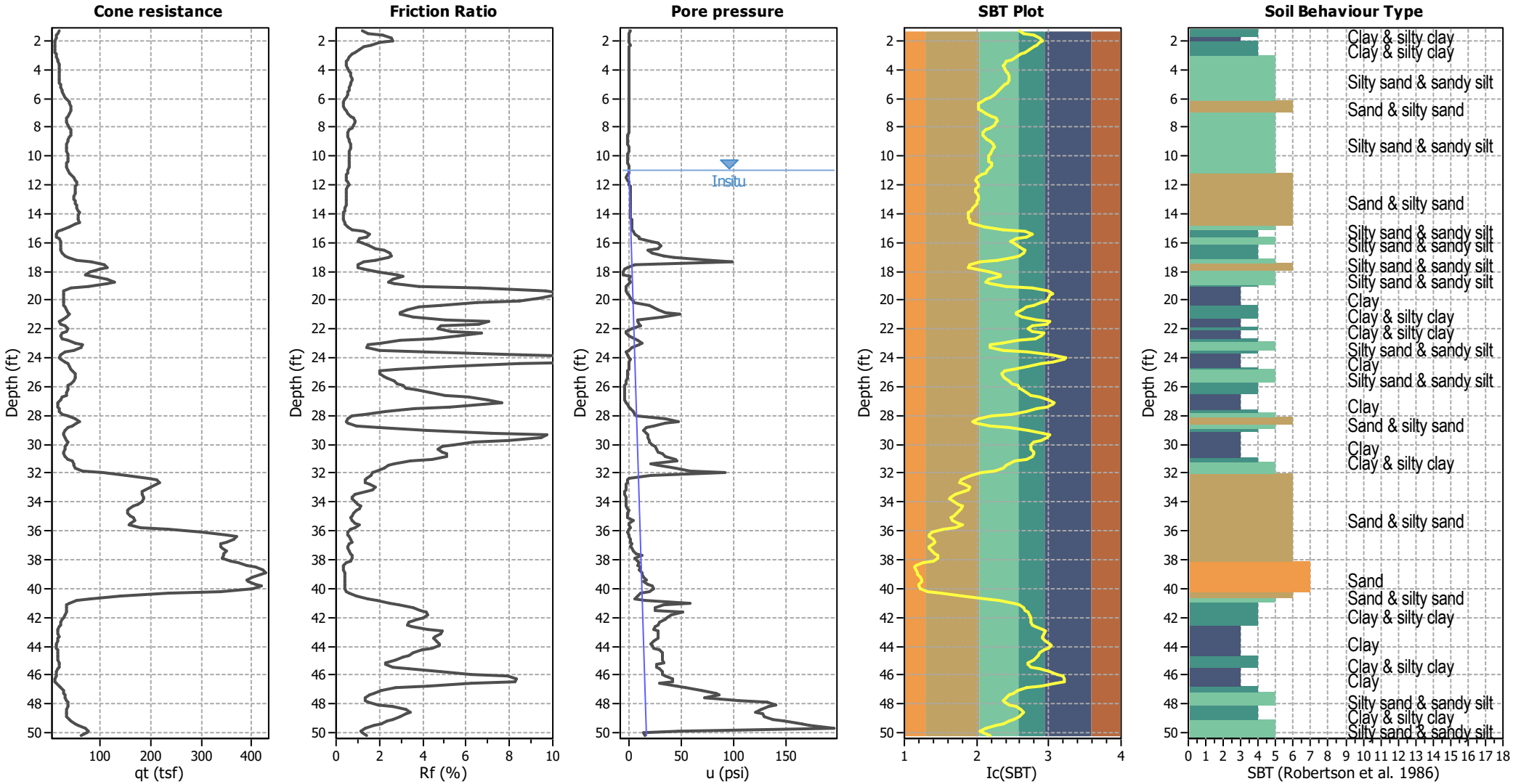






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

CPT basic interpretation plots



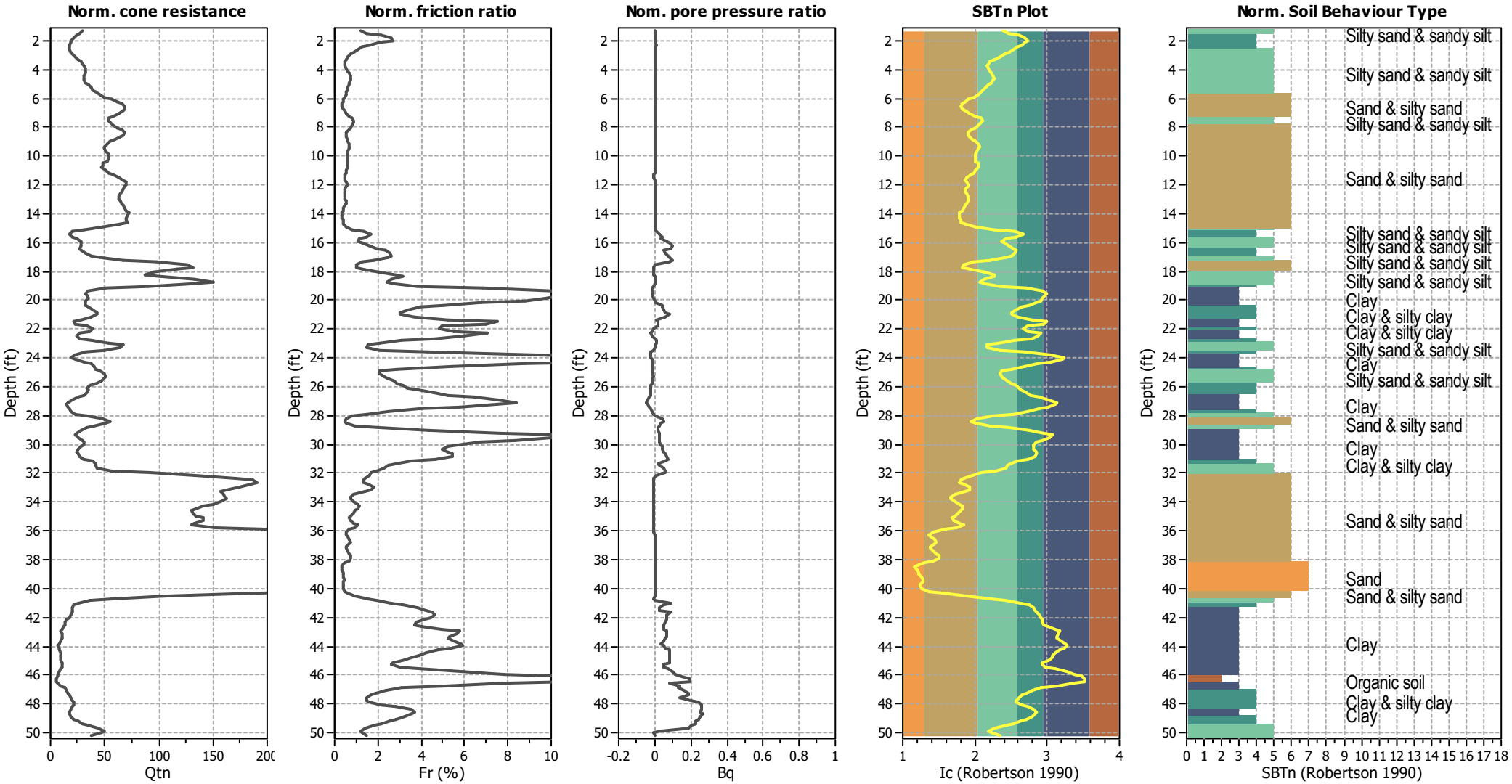
Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBT legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

CPT basic interpretation plots (normalized)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
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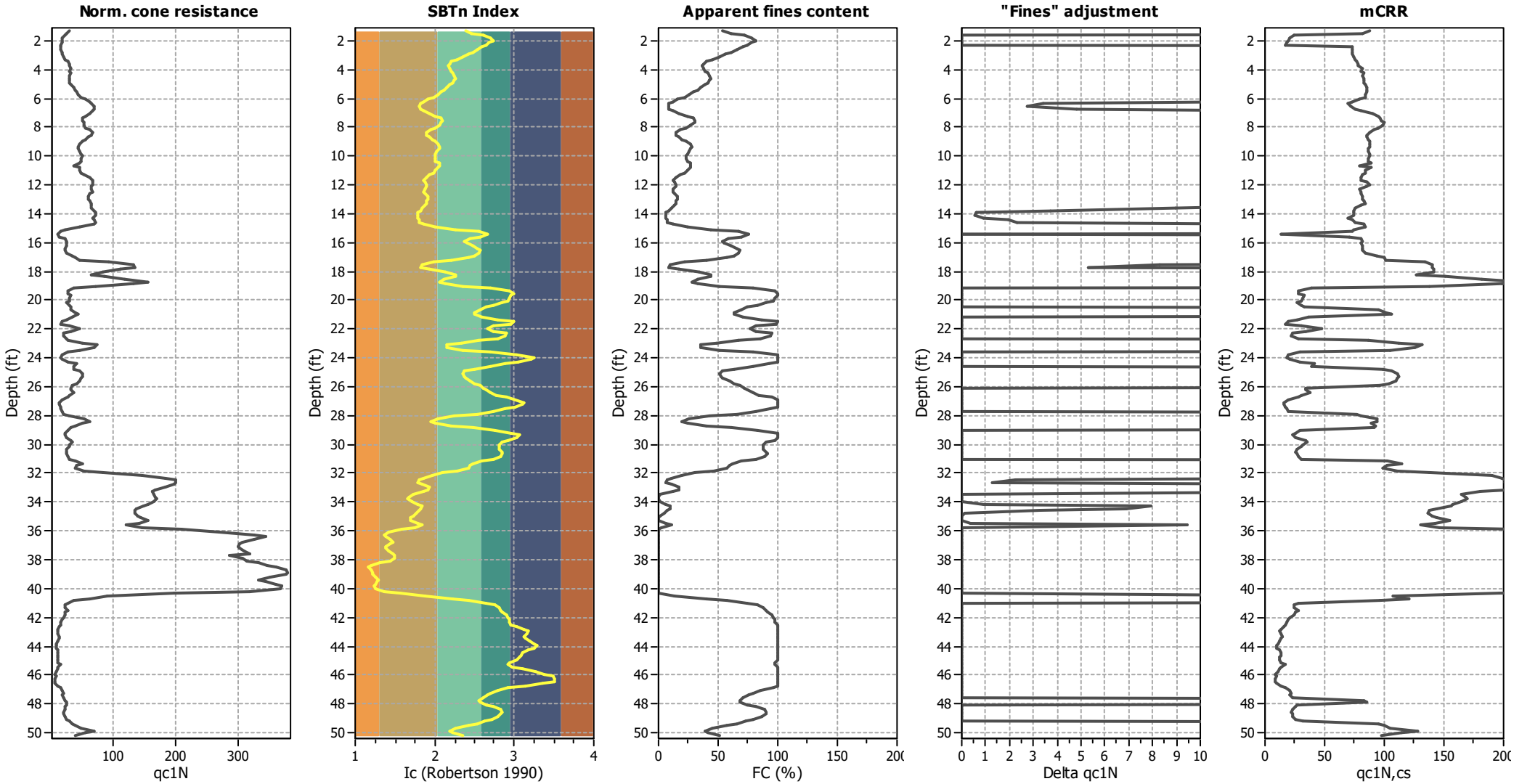
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to
9. Very stiff fine grained

Liquefaction analysis overall plots (intermediate results)



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	7.13	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
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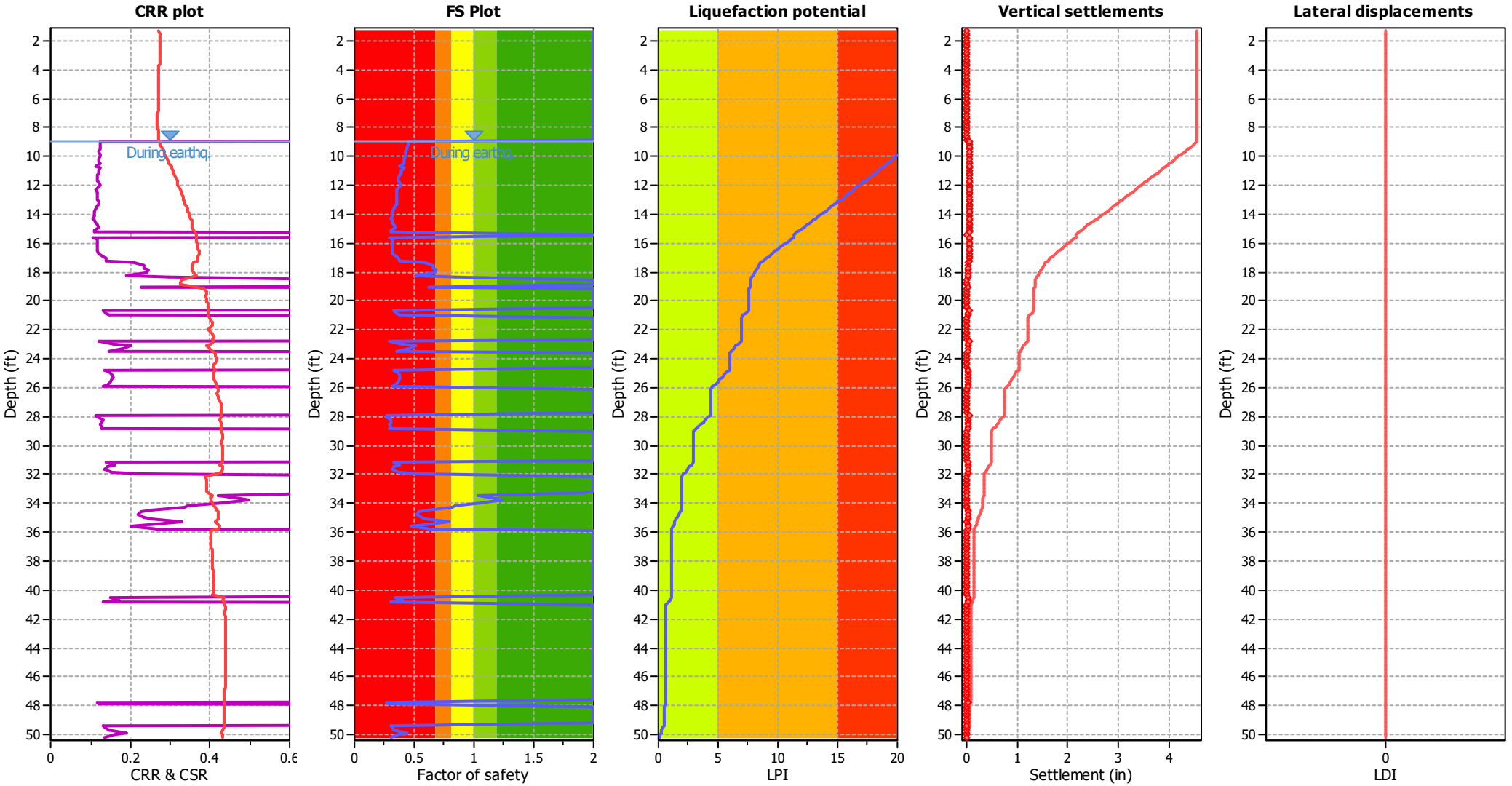
Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	9.00 ft	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
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Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

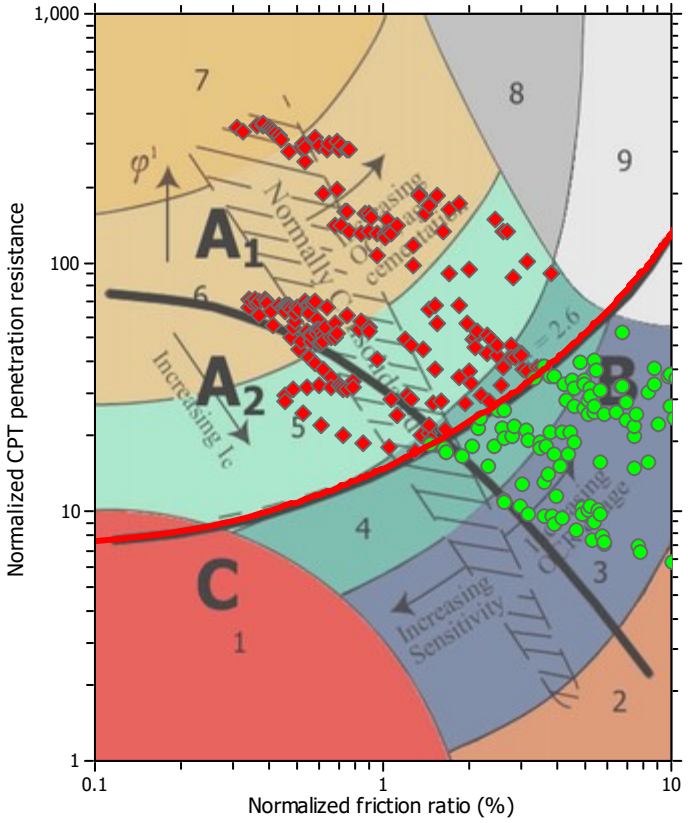
F.S. color scheme

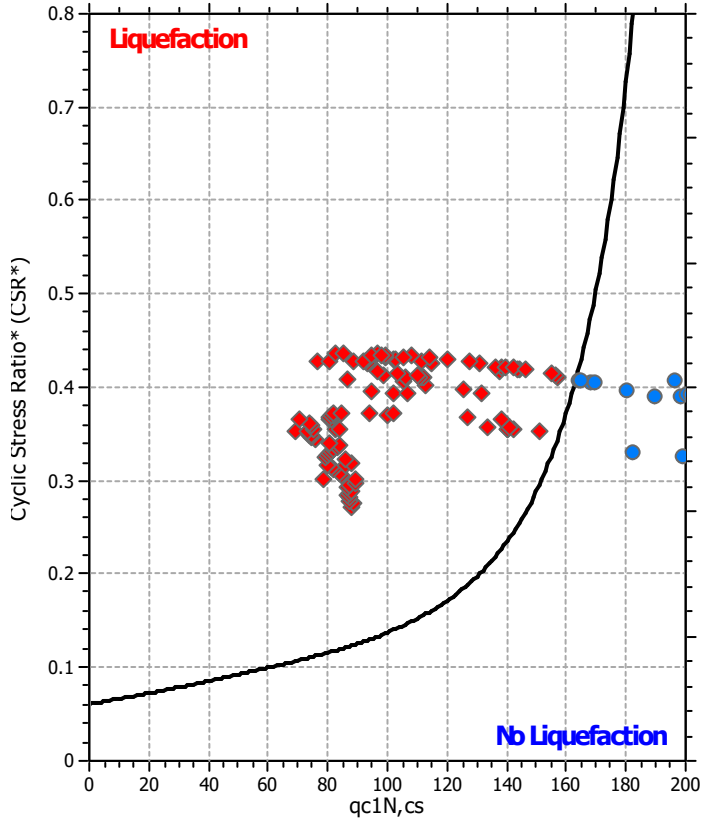
- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

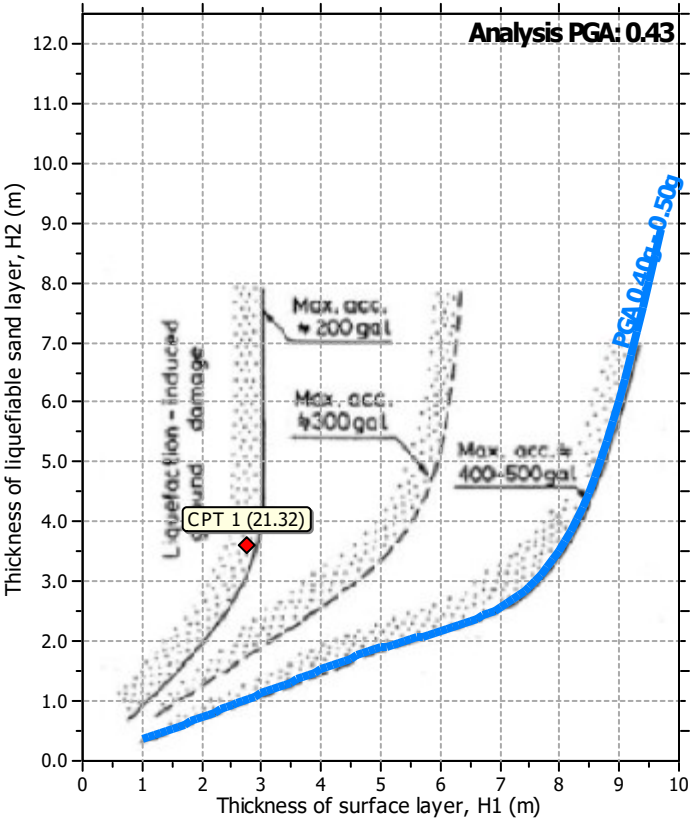
LPI color scheme

- Very high risk
- High risk
- Low risk

Liquefaction analysis summary plots







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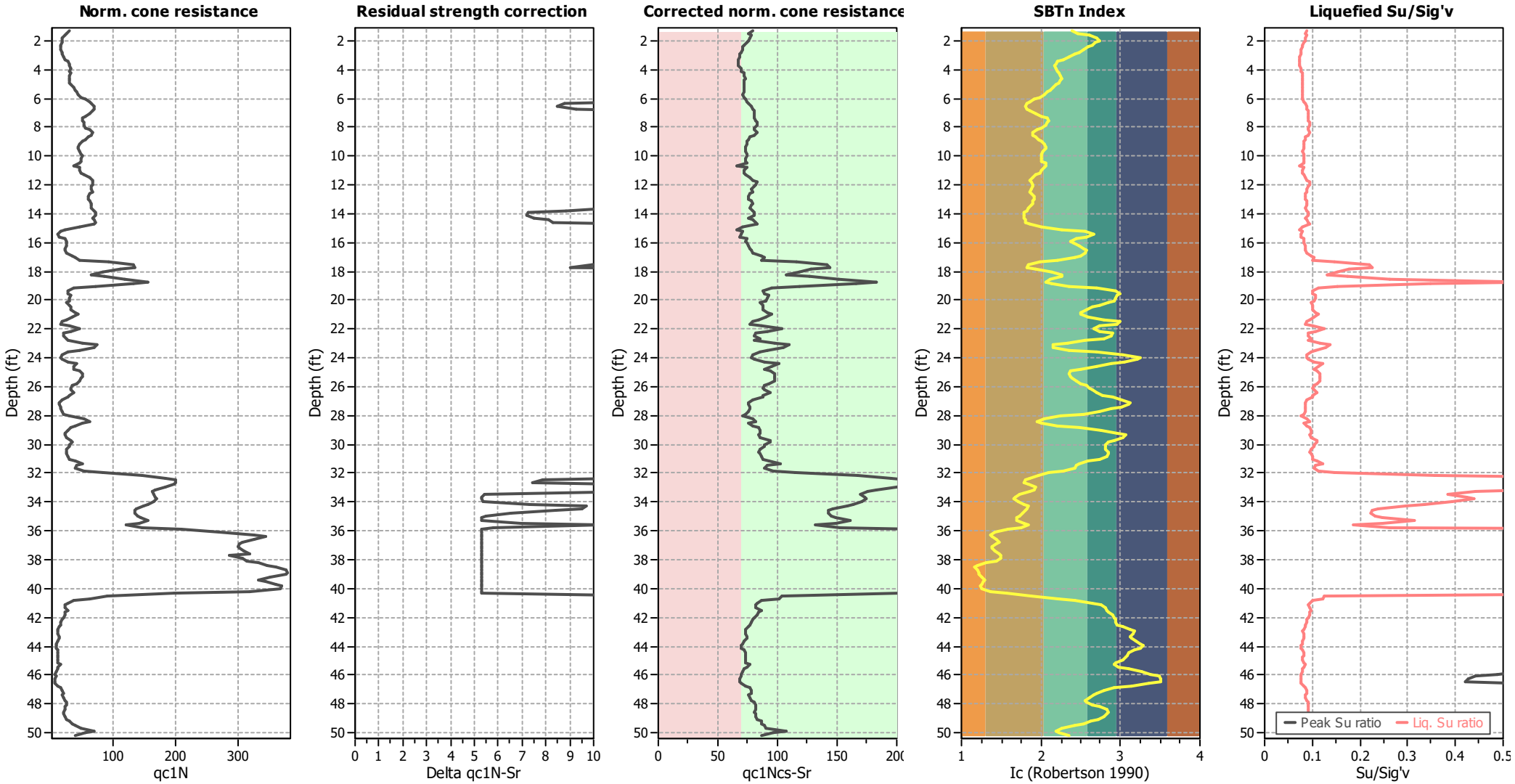
Check for strength loss plots (Idriss & Boulanger (2008))



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Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
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Peak ground acceleration:	0.43	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	11.00 ft	Fill height:	N/A	Limit depth:	N/A

:: Field input data ::

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
1	1.31	19.66	0.22	0.99	25.89	106.41
2	1.48	16.04	0.23	0.58	29.25	107.07
3	1.64	15.14	0.30	0.42	36.05	108.47
4	1.80	12.95	0.42	0.39	40.18	108.78
5	1.97	11.89	0.31	0.25	42.19	108.04
6	2.13	11.69	0.23	0.19	39.89	105.63
7	2.30	10.87	0.17	1.01	37.49	103.64
8	2.46	10.95	0.14	0.57	35.03	101.79
9	2.63	11.30	0.11	0.38	32.41	100.64
10	2.79	11.95	0.10	0.32	29.67	99.47
11	2.95	12.45	0.09	0.32	27.17	99.04
12	3.12	13.96	0.09	0.32	24.36	98.69
13	3.28	15.74	0.08	0.37	21.66	98.71
14	3.44	17.48	0.08	0.56	5.00	98.71
15	3.61	19.05	0.08	0.51	5.00	99.27
16	3.77	19.33	0.09	0.50	5.00	100.26
17	3.94	20.68	0.11	0.38	18.55	101.23
18	4.10	19.92	0.12	0.35	18.96	102.09
19	4.26	20.32	0.13	0.28	19.94	102.65
20	4.43	19.47	0.14	0.25	20.51	103.15
21	4.59	19.71	0.15	0.27	21.05	103.33
22	4.76	19.48	0.14	0.24	20.79	103.27
23	4.92	19.97	0.14	0.21	20.09	103.29
24	5.08	21.59	0.14	0.20	18.77	103.41
25	5.25	23.49	0.14	0.23	17.48	103.76
26	5.41	25.02	0.15	0.21	16.33	103.92
27	5.58	26.13	0.14	0.07	15.29	104.04
28	5.74	27.94	0.14	0.11	14.05	104.28
29	5.91	31.19	0.15	0.13	5.00	104.74
30	6.07	35.40	0.16	0.20	5.00	104.76
31	6.23	38.85	0.13	0.19	5.00	104.89
32	6.40	41.42	0.14	0.18	5.00	104.97
33	6.56	43.21	0.15	0.17	5.00	105.74
34	6.73	43.70	0.17	0.15	5.00	106.48
35	6.89	42.55	0.19	0.11	5.00	107.24
36	7.05	39.64	0.21	0.05	11.18	108.03
37	7.22	35.73	0.24	-0.03	13.27	108.72
38	7.38	32.75	0.28	-0.07	15.15	109.38
39	7.55	32.77	0.30	-0.08	15.83	109.91
40	7.71	34.96	0.31	-0.06	15.40	110.24
41	7.87	36.53	0.30	-0.10	14.46	110.24
42	8.04	37.71	0.29	-0.14	13.10	109.97
43	8.20	41.52	0.26	-0.20	11.47	109.56
44	8.37	45.15	0.24	-0.65	10.43	109.17
45	8.53	43.86	0.23	-1.23	10.38	108.89
46	8.69	41.20	0.23	-1.37	10.99	108.42
47	8.86	38.12	0.21	-0.94	11.99	108.16
48	9.02	35.46	0.23	-1.09	13.09	107.92

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
49	9.19	33.19	0.23	-0.96	14.27	108.03
50	9.35	32.09	0.23	-0.72	14.59	107.66
51	9.51	32.64	0.20	-0.64	14.44	107.51
52	9.68	33.97	0.21	-0.73	13.77	107.45
53	9.84	36.39	0.22	-0.80	13.29	107.81
54	10.01	38.00	0.22	-0.99	13.01	107.97
55	10.17	37.31	0.22	-1.08	13.02	107.95
56	10.34	36.86	0.21	-0.95	13.33	107.81
57	10.50	35.95	0.21	-0.87	14.42	107.35
58	10.66	29.10	0.20	0.58	14.40	107.15
59	10.83	36.65	0.20	-0.28	14.37	107.12
60	10.99	36.61	0.21	-0.20	13.30	107.55
61	11.15	38.29	0.22	-0.09	12.66	107.77
62	11.32	42.47	0.21	-1.73	5.00	108.11
63	11.48	48.98	0.21	-2.77	5.00	108.55
64	11.65	52.37	0.23	-1.52	5.00	109.41
65	11.81	54.03	0.27	-0.05	10.01	110.70
66	11.97	53.15	0.34	0.58	10.43	111.20
67	12.14	51.76	0.30	0.99	10.37	110.68
68	12.30	51.37	0.21	1.05	5.00	109.49
69	12.47	52.86	0.22	1.07	5.00	109.15
70	12.63	50.39	0.26	1.16	5.00	109.29
71	12.79	48.04	0.23	1.53	5.00	109.35
72	12.96	48.69	0.23	1.59	5.00	109.34
73	13.12	50.48	0.26	1.30	10.43	109.79
74	13.29	52.46	0.27	0.92	10.20	109.99
75	13.45	52.68	0.24	0.88	5.00	109.74
76	13.62	53.44	0.23	1.53	5.00	109.32
77	13.78	56.94	0.22	1.60	5.00	109.04
78	13.94	59.02	0.21	1.76	5.00	108.64
79	14.11	59.59	0.19	1.90	5.00	108.26
80	14.27	55.09	0.19	1.84	5.00	108.31
81	14.44	57.73	0.21	2.11	5.00	108.73
82	14.60	59.67	0.23	2.35	5.00	109.31
83	14.76	58.46	0.24	2.46	5.00	108.59
84	14.93	38.93	0.17	2.47	13.35	107.45
85	15.09	19.92	0.19	2.69	21.32	105.87
86	15.26	14.94	0.20	4.04	33.14	105.15
87	15.42	11.29	0.21	5.74	38.43	104.98
88	15.58	12.78	0.21	9.81	34.41	105.49
89	15.75	21.02	0.21	9.78	28.04	105.79
90	15.91	22.72	0.19	20.60	25.47	107.03
91	16.08	21.92	0.29	27.98	26.64	108.26
92	16.24	21.72	0.34	29.76	29.61	109.81
93	16.40	20.71	0.39	27.06	31.99	110.95
94	16.57	20.75	0.46	17.34	34.07	112.54
95	16.73	22.94	0.62	22.27	33.17	114.66
96	16.90	30.35	0.79	33.35	30.69	116.62

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
97	17.06	35.65	0.89	42.45	27.42	118.31
98	17.22	42.48	1.02	78.12	19.39	120.02
99	17.39	84.52	1.07	98.63	12.55	121.42
100	17.55	119.95	1.06	5.99	8.91	122.43
101	17.72	122.76	1.17	-1.71	8.61	122.89
102	17.88	101.92	1.22	-4.48	11.05	123.22
103	18.05	77.68	1.39	-5.61	16.79	124.30
104	18.21	60.49	2.13	-5.28	21.29	125.88
105	18.37	79.73	2.55	1.96	21.04	128.13
106	18.54	112.82	3.18	0.06	16.39	129.73
107	18.70	149.04	3.11	0.97	14.76	130.51
108	18.86	126.57	3.14	0.07	16.78	130.02
109	19.03	67.48	2.93	-2.31	24.68	128.65
110	19.19	35.59	2.64	-2.84	40.62	127.10
111	19.36	25.55	2.98	-3.11	54.42	126.02
112	19.52	26.05	2.78	-1.93	57.94	126.11
113	19.68	30.18	2.93	-0.33	56.03	126.18
114	19.85	29.27	2.93	1.69	54.20	125.89
115	20.01	28.01	2.39	3.77	53.34	124.54
116	20.18	25.02	1.67	4.67	48.49	122.57
117	20.34	28.73	1.29	19.52	42.76	120.72
118	20.50	30.76	1.14	22.11	37.78	119.83
119	20.67	32.17	1.10	27.08	34.20	119.79
120	20.83	38.41	1.15	34.75	31.03	119.98
121	21.00	42.18	1.11	48.90	30.78	120.13
122	21.16	34.22	1.15	32.11	35.37	120.29
123	21.32	24.96	1.37	8.55	45.74	120.17
124	21.49	18.04	1.39	8.24	57.79	120.02
125	21.65	16.19	1.43	9.52	55.13	120.19
126	21.82	28.97	1.38	11.38	42.20	121.46
127	21.98	46.58	1.61	2.03	38.97	122.89
128	22.15	33.17	2.10	-2.69	42.40	123.19
129	22.31	21.88	1.71	-2.38	52.18	122.00
130	22.47	20.72	1.27	0.13	50.81	119.87
131	22.64	26.79	0.92	5.95	45.13	118.84
132	22.80	27.32	1.11	8.43	33.17	119.37
133	22.97	51.96	1.13	12.89	23.58	120.27
134	23.13	74.04	0.93	9.37	17.66	120.27
135	23.29	69.17	0.87	3.21	17.63	119.60
136	23.46	45.94	0.90	-0.52	24.32	119.46
137	23.62	28.98	1.12	-2.61	40.33	120.55
138	23.79	19.36	1.85	-1.73	61.17	122.37
139	23.95	17.66	2.62	-0.30	76.34	124.60
140	24.11	20.46	3.48	0.63	74.45	126.70
141	24.28	28.96	3.95	0.59	62.01	128.16
142	24.44	42.09	3.64	0.43	50.67	127.40
143	24.61	39.40	1.78	-0.34	40.49	124.67
144	24.77	38.66	0.86	-0.68	30.74	120.50

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
145	24.93	47.15	0.86	-0.92	25.53	119.10
146	25.10	52.30	1.07	-2.12	24.26	119.99
147	25.26	52.33	1.13	-1.32	25.11	120.98
148	25.43	51.04	1.28	-1.97	25.91	121.04
149	25.59	48.86	1.13	-2.54	28.61	121.51
150	25.75	43.10	1.44	-2.94	30.71	120.73
151	25.92	36.62	1.02	-3.54	33.85	120.28
152	26.08	34.80	1.05	-3.76	35.73	119.98
153	26.25	35.61	1.37	-3.77	37.37	121.18
154	26.41	39.09	1.60	-3.89	40.73	122.21
155	26.57	31.67	1.70	-4.12	44.18	122.53
156	26.74	28.91	1.69	-4.46	52.15	121.84
157	26.90	19.77	1.50	-4.27	59.68	120.82
158	27.07	16.74	1.36	-3.27	67.51	119.39
159	27.23	16.08	1.16	-1.52	66.21	118.24
160	27.39	17.93	0.95	-0.10	59.58	116.78
161	27.56	19.21	0.69	1.44	50.99	114.83
162	27.72	20.36	0.45	3.40	42.26	112.06
163	27.89	22.01	0.26	5.13	32.15	110.12
164	28.05	31.91	0.29	7.00	20.34	109.70
165	28.21	56.43	0.27	34.60	13.90	110.68
166	28.38	66.87	0.28	46.91	5.00	110.95
167	28.54	54.16	0.29	34.47	13.28	111.23
168	28.71	43.44	0.33	24.11	19.43	113.01
169	28.87	35.76	0.61	16.63	29.70	116.62
170	29.04	30.68	1.20	14.22	43.26	120.57
171	29.20	26.96	2.07	16.12	55.93	123.50
172	29.36	25.41	2.76	17.28	63.22	125.37
173	29.53	27.84	3.04	18.11	60.18	126.27
174	29.69	36.44	2.78	19.84	53.74	126.21
175	29.86	37.73	2.34	19.87	48.48	125.18
176	30.02	33.74	1.84	22.60	46.16	123.76
177	30.18	33.56	1.60	24.54	46.17	122.22
178	30.35	29.16	1.37	26.18	46.68	121.30
179	30.51	28.01	1.36	27.41	48.60	121.10
180	30.68	28.86	1.56	31.77	48.87	121.56
181	30.84	30.89	1.62	34.29	47.75	122.25
182	31.00	33.70	1.70	44.58	42.39	122.60
183	31.17	43.59	1.55	45.66	34.66	122.66
184	31.33	56.31	1.33	20.85	30.13	121.86
185	31.50	46.70	1.10	27.32	28.63	121.07
186	31.66	44.47	1.14	44.83	27.40	120.69
187	31.82	58.86	1.13	58.47	22.01	122.25
188	31.99	93.50	1.54	90.90	15.52	125.69
189	32.15	160.96	2.55	21.11	11.90	129.02
190	32.32	201.79	3.18	-0.54	9.29	130.54
191	32.48	218.49	2.54	-2.05	8.14	130.93
192	32.64	219.33	2.73	-1.82	7.96	131.12

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
193	32.81	217.42	3.33	-2.57	9.19	131.92
194	32.97	202.02	3.62	-2.95	11.01	132.67
195	33.14	184.65	3.98	-3.19	10.88	131.54
196	33.30	181.25	1.96	-3.54	9.56	129.73
197	33.47	183.18	1.61	-3.69	6.64	126.58
198	33.63	187.79	1.33	-3.51	5.54	125.37
199	33.79	189.62	1.19	-3.05	5.45	125.29
200	33.96	185.00	1.57	-2.77	6.53	126.32
201	34.12	175.77	1.98	-2.42	7.92	127.22
202	34.28	167.03	1.89	-2.24	8.84	127.20
203	34.45	155.25	1.66	-1.95	8.77	126.28
204	34.61	153.18	1.40	0.28	8.36	125.35
205	34.78	155.13	1.33	-1.01	7.52	124.48
206	34.94	159.33	1.15	-1.47	6.78	123.92
207	35.10	163.58	1.09	-1.85	5.92	123.57
208	35.27	176.66	1.11	4.12	6.15	123.98
209	35.43	162.35	1.34	-0.69	7.73	125.10
210	35.60	139.95	1.74	-0.40	9.05	126.24
211	35.76	167.80	1.85	1.27	7.07	126.55
212	35.92	235.63	1.32	-0.40	4.01	127.02
213	36.09	301.09	1.64	-0.90	1.80	127.59
214	36.25	363.02	1.82	-0.04	1.18	129.04
215	36.42	383.79	2.07	-0.36	1.31	130.28
216	36.58	364.37	2.53	1.65	2.09	131.39
217	36.74	342.55	2.93	1.61	2.38	131.17
218	36.91	339.18	1.95	2.45	2.03	130.09
219	37.07	336.23	1.58	1.61	1.25	128.55
220	37.24	340.45	1.70	2.40	1.34	128.86
221	37.40	347.21	2.16	3.52	1.71	129.93
222	37.57	358.40	2.40	7.28	2.41	130.87
223	37.73	322.56	2.60	13.08	2.76	131.41
224	37.89	346.65	2.71	5.36	2.82	131.42
225	38.06	353.67	2.41	8.71	1.93	130.75
226	38.22	374.50	1.81	9.47	0.43	128.37
227	38.39	390.42	0.72	8.30	0.00	126.56
228	38.55	408.87	1.27	10.76	0.00	126.59
229	38.71	425.29	1.77	10.15	0.00	128.16
230	38.88	429.58	1.57	11.73	0.00	128.66
231	39.04	426.57	1.57	12.87	0.00	128.46
232	39.21	399.99	1.67	14.40	0.00	128.54
233	39.37	377.42	1.69	16.80	0.27	128.66
234	39.53	390.98	1.71	14.44	0.14	128.51
235	39.70	411.33	1.55	17.39	0.00	128.60
236	39.86	421.99	1.70	21.63	0.00	128.77
237	40.03	420.07	1.78	23.68	0.04	128.62
238	40.19	364.72	1.51	19.05	1.06	127.87
239	40.35	230.57	1.48	11.23	3.81	126.28
240	40.52	111.86	1.34	7.80	9.86	124.35

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
241	40.68	76.79	1.14	4.81	19.66	122.12
242	40.85	47.38	1.05	15.60	27.78	120.06
243	41.01	35.23	0.84	57.86	37.33	118.84
244	41.17	31.35	0.98	33.23	43.15	118.49
245	41.34	30.41	1.06	25.30	46.58	119.90
246	41.50	35.25	1.46	24.35	48.05	120.62
247	41.67	31.69	1.33	51.71	49.31	121.18
248	41.83	30.49	1.37	39.84	51.66	120.38
249	41.99	26.56	1.14	36.44	53.06	119.19
250	42.16	24.34	0.85	34.26	54.30	117.77
251	42.32	23.24	0.87	29.40	54.28	116.21
252	42.49	21.38	0.64	28.09	55.66	115.36
253	42.65	20.03	0.64	25.28	60.00	114.84
254	42.81	16.70	0.79	23.93	66.53	115.42
255	42.98	16.38	0.88	27.06	71.06	116.02
256	43.14	17.55	0.88	27.96	69.61	116.27
257	43.31	18.58	0.84	28.26	67.32	116.15
258	43.47	18.27	0.81	27.02	68.14	115.68
259	43.63	15.78	0.75	23.87	72.09	115.05
260	43.80	13.98	0.71	20.22	76.97	114.24
261	43.96	13.23	0.65	22.09	79.41	113.64
262	44.13	13.22	0.62	23.70	76.31	113.38
263	44.29	15.37	0.62	28.94	70.98	113.46
264	44.45	17.05	0.61	31.20	66.14	113.55
265	44.62	17.30	0.59	31.32	64.08	113.30
266	44.78	16.69	0.54	31.39	63.05	112.72
267	44.95	16.77	0.48	31.50	60.32	112.00
268	45.11	18.31	0.43	33.41	54.50	111.71
269	45.28	22.41	0.44	26.43	53.78	111.90
270	45.44	18.28	0.51	25.77	57.14	112.43
271	45.60	15.93	0.56	29.18	66.23	112.82
272	45.77	14.49	0.60	31.62	78.61	114.27
273	45.93	12.05	0.96	32.32	87.78	115.43
274	46.10	12.66	0.98	33.93	97.23	116.42
275	46.26	11.40	1.05	41.01	100.00	116.50
276	46.42	11.01	1.02	40.81	100.00	116.37
277	46.59	12.49	0.94	28.44	85.78	116.00
278	46.75	17.92	0.74	45.02	68.00	115.52
279	46.92	23.00	0.65	53.94	52.95	114.70
280	47.08	27.09	0.53	69.67	45.07	114.19
281	47.24	28.63	0.53	82.45	40.88	113.42
282	47.41	27.84	0.44	86.14	38.19	112.85
283	47.57	30.73	0.40	72.40	35.49	112.56
284	47.74	33.68	0.45	105.29	33.49	113.34
285	47.90	36.10	0.55	131.68	33.98	114.75
286	48.06	35.25	0.67	139.76	37.44	116.79
287	48.23	33.90	0.98	133.42	42.49	118.44
288	48.39	31.76	1.14	126.26	47.25	119.52

:: Field input data :: (continued)

Point ID	Depth (ft)	q_c (tsf)	f_s (tsf)	u (tsf)	Fines content (%)	Unit weight (pcf)
289	48.56	30.15	1.16	121.12	48.77	119.54
290	48.72	30.85	1.03	127.89	48.06	119.20
291	48.88	31.81	0.99	128.32	45.30	119.00
292	49.05	35.24	1.02	136.68	41.01	119.36
293	49.21	43.29	1.06	147.76	36.82	119.77
294	49.38	46.61	1.04	165.00	32.30	120.04
295	49.54	53.66	1.00	171.75	27.78	120.13
296	49.70	64.80	0.96	195.26	21.45	120.33
297	49.87	91.08	0.90	46.36	18.90	120.15
298	50.03	75.84	0.85	13.75	20.06	119.88
299	50.20	54.40	0.91	14.88	24.70	119.46

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
q_c: Measured cone resistance (tsf)
f_s: Sleeve friction resistance (tsf)
u: Pore pressure (tsf)
Fines content: Percentage of fines in soil (%)
Unit weight: Bulk soil unit weight (pcf)

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data ::

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
1	1.31	0.07	0.00	0.07	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
2	1.48	0.08	0.00	0.08	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
3	1.64	0.09	0.00	0.09	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
4	1.80	0.10	0.00	0.10	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
5	1.97	0.11	0.00	0.11	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
6	2.13	0.11	0.00	0.11	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
7	2.30	0.12	0.00	0.12	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
8	2.46	0.13	0.00	0.13	1.00	0.280	1.10	0.253	1.10	1.10	2.000	No
9	2.63	0.14	0.00	0.14	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
10	2.79	0.15	0.00	0.15	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
11	2.95	0.16	0.00	0.16	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
12	3.12	0.16	0.00	0.16	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
13	3.28	0.17	0.00	0.17	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
14	3.44	0.18	0.00	0.18	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
15	3.61	0.19	0.00	0.19	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
16	3.77	0.20	0.00	0.20	1.00	0.279	1.10	0.253	1.10	1.10	2.000	No
17	3.94	0.20	0.00	0.20	1.00	0.278	1.10	0.252	1.10	1.10	2.000	No
18	4.10	0.21	0.00	0.21	1.00	0.278	1.10	0.252	1.10	1.10	2.000	No
19	4.26	0.22	0.00	0.22	0.99	0.278	1.10	0.252	1.10	1.10	2.000	No
20	4.43	0.23	0.00	0.23	0.99	0.278	1.10	0.252	1.10	1.10	2.000	No
21	4.59	0.24	0.00	0.24	0.99	0.278	1.10	0.252	1.10	1.10	2.000	No
22	4.76	0.25	0.00	0.25	0.99	0.278	1.10	0.252	1.10	1.10	2.000	No
23	4.92	0.25	0.00	0.25	0.99	0.278	1.10	0.252	1.10	1.10	2.000	No
24	5.08	0.26	0.00	0.26	0.99	0.277	1.10	0.252	1.10	1.10	2.000	No
25	5.25	0.27	0.00	0.27	0.99	0.277	1.10	0.251	1.10	1.10	2.000	No
26	5.41	0.28	0.00	0.28	0.99	0.277	1.10	0.251	1.10	1.10	2.000	No
27	5.58	0.29	0.00	0.29	0.99	0.277	1.10	0.251	1.10	1.10	2.000	No
28	5.74	0.30	0.00	0.30	0.99	0.277	1.10	0.251	1.10	1.10	2.000	No
29	5.91	0.31	0.00	0.31	0.99	0.277	1.10	0.251	1.10	1.10	2.000	No
30	6.07	0.31	0.00	0.31	0.99	0.277	1.10	0.251	1.10	1.10	2.000	No
31	6.23	0.32	0.00	0.32	0.99	0.276	1.10	0.251	1.10	1.10	2.000	No
32	6.40	0.33	0.00	0.33	0.99	0.276	1.10	0.250	1.10	1.10	2.000	No
33	6.56	0.34	0.00	0.34	0.99	0.276	1.10	0.250	1.10	1.10	2.000	No
34	6.73	0.35	0.00	0.35	0.99	0.276	1.10	0.250	1.10	1.10	2.000	No
35	6.89	0.36	0.00	0.36	0.99	0.276	1.10	0.250	1.10	1.10	2.000	No
36	7.05	0.37	0.00	0.37	0.99	0.276	1.10	0.250	1.10	1.10	2.000	No
37	7.22	0.38	0.00	0.38	0.99	0.275	1.10	0.250	1.10	1.10	2.000	No
38	7.38	0.38	0.00	0.38	0.98	0.275	1.10	0.250	1.10	1.10	2.000	No
39	7.55	0.39	0.00	0.39	0.98	0.275	1.10	0.250	1.10	1.10	2.000	No
40	7.71	0.40	0.00	0.40	0.98	0.275	1.10	0.249	1.10	1.10	2.000	No
41	7.87	0.41	0.00	0.41	0.98	0.275	1.10	0.249	1.10	1.10	2.000	No
42	8.04	0.42	0.00	0.42	0.98	0.275	1.10	0.249	1.09	1.10	2.000	No
43	8.20	0.43	0.00	0.43	0.98	0.275	1.10	0.249	1.09	1.10	2.000	No
44	8.37	0.44	0.00	0.44	0.98	0.274	1.10	0.249	1.09	1.10	2.000	No
45	8.53	0.45	0.00	0.45	0.98	0.274	1.10	0.249	1.08	1.10	2.000	No
46	8.69	0.46	0.00	0.46	0.98	0.274	1.10	0.249	1.08	1.10	2.000	No
47	8.86	0.47	0.00	0.47	0.98	0.274	1.10	0.248	1.08	1.10	2.000	No
48	9.02	0.47	0.00	0.47	0.98	0.274	1.10	0.249	1.08	1.10	0.273	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
49	9.19	0.48	0.01	0.48	0.98	0.277	1.10	0.251	1.08	1.10	0.275	No
50	9.35	0.49	0.01	0.48	0.98	0.280	1.10	0.254	1.08	1.10	0.279	No
51	9.51	0.50	0.02	0.48	0.98	0.282	1.10	0.256	1.07	1.10	0.281	No
52	9.68	0.51	0.02	0.49	0.98	0.285	1.10	0.258	1.07	1.10	0.285	No
53	9.84	0.52	0.03	0.49	0.98	0.287	1.10	0.261	1.07	1.10	0.287	No
54	10.01	0.53	0.03	0.50	0.98	0.290	1.10	0.263	1.07	1.10	0.289	No
55	10.17	0.54	0.04	0.50	0.98	0.292	1.10	0.265	1.07	1.10	0.293	No
56	10.34	0.55	0.04	0.50	0.97	0.295	1.10	0.267	1.07	1.10	0.295	No
57	10.50	0.55	0.05	0.51	0.97	0.297	1.10	0.270	1.07	1.10	0.297	No
58	10.66	0.56	0.05	0.51	0.97	0.300	1.10	0.272	1.07	1.10	0.303	No
59	10.83	0.57	0.06	0.51	0.97	0.302	1.10	0.274	1.07	1.10	0.302	No
60	10.99	0.58	0.06	0.52	0.97	0.304	1.10	0.276	1.07	1.10	0.306	No
61	11.15	0.59	0.07	0.52	0.97	0.306	1.10	0.278	1.07	1.10	0.309	No
62	11.32	0.60	0.07	0.53	0.97	0.309	1.10	0.280	1.06	1.10	0.312	No
63	11.48	0.61	0.08	0.53	0.97	0.311	1.10	0.282	1.06	1.10	0.314	No
64	11.65	0.62	0.08	0.53	0.97	0.313	1.10	0.284	1.06	1.10	0.317	No
65	11.81	0.63	0.09	0.54	0.97	0.315	1.10	0.286	1.06	1.10	0.317	No
66	11.97	0.63	0.09	0.54	0.97	0.317	1.10	0.288	1.06	1.10	0.319	No
67	12.14	0.64	0.10	0.55	0.97	0.319	1.10	0.289	1.06	1.10	0.322	No
68	12.30	0.65	0.10	0.55	0.97	0.321	1.10	0.291	1.06	1.10	0.326	No
69	12.47	0.66	0.11	0.55	0.97	0.323	1.10	0.293	1.06	1.10	0.328	No
70	12.63	0.67	0.11	0.56	0.97	0.325	1.10	0.295	1.06	1.10	0.330	No
71	12.79	0.68	0.12	0.56	0.97	0.327	1.10	0.296	1.06	1.10	0.332	No
72	12.96	0.69	0.12	0.56	0.96	0.329	1.10	0.298	1.06	1.10	0.334	No
73	13.12	0.70	0.13	0.57	0.96	0.330	1.10	0.300	1.06	1.10	0.335	No
74	13.29	0.71	0.13	0.57	0.96	0.332	1.10	0.301	1.06	1.10	0.337	No
75	13.45	0.72	0.14	0.58	0.96	0.334	1.10	0.303	1.06	1.10	0.340	No
76	13.62	0.72	0.14	0.58	0.96	0.336	1.10	0.304	1.05	1.10	0.343	No
77	13.78	0.73	0.15	0.58	0.96	0.337	1.10	0.306	1.05	1.10	0.346	No
78	13.94	0.74	0.15	0.59	0.96	0.339	1.10	0.307	1.05	1.10	0.348	No
79	14.11	0.75	0.16	0.59	0.96	0.341	1.10	0.309	1.05	1.10	0.349	No
80	14.27	0.76	0.16	0.60	0.96	0.342	1.10	0.310	1.05	1.10	0.352	No
81	14.44	0.77	0.17	0.60	0.96	0.344	1.10	0.312	1.05	1.10	0.353	No
82	14.60	0.78	0.17	0.60	0.96	0.345	1.10	0.313	1.05	1.10	0.355	No
83	14.76	0.79	0.18	0.61	0.96	0.347	1.10	0.314	1.05	1.10	0.354	No
84	14.93	0.80	0.18	0.61	0.96	0.348	1.10	0.316	1.05	1.10	0.356	No
85	15.09	0.80	0.19	0.61	0.96	0.350	1.10	0.317	1.05	1.10	0.360	No
86	15.26	0.81	0.20	0.62	0.96	0.351	1.10	0.319	1.05	1.10	0.362	No
87	15.42	0.82	0.20	0.62	0.95	0.353	1.10	0.320	1.04	1.10	0.365	No
88	15.58	0.83	0.21	0.62	0.95	0.354	1.10	0.321	1.04	1.10	0.366	No
89	15.75	0.84	0.21	0.63	0.95	0.356	1.10	0.323	1.05	1.10	0.365	No
90	15.91	0.85	0.22	0.63	0.95	0.357	1.10	0.324	1.05	1.10	0.366	No
91	16.08	0.86	0.22	0.64	0.95	0.358	1.10	0.325	1.05	1.10	0.368	No
92	16.24	0.87	0.23	0.64	0.95	0.360	1.10	0.326	1.05	1.10	0.369	No
93	16.40	0.87	0.23	0.64	0.95	0.361	1.10	0.327	1.05	1.10	0.371	No
94	16.57	0.88	0.24	0.65	0.95	0.362	1.10	0.328	1.05	1.10	0.372	No
95	16.73	0.89	0.24	0.65	0.95	0.363	1.10	0.329	1.05	1.10	0.373	No
96	16.90	0.90	0.25	0.66	0.95	0.364	1.10	0.331	1.05	1.10	0.371	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
97	17.06	0.91	0.25	0.66	0.95	0.366	1.10	0.332	1.05	1.10	0.371	No
98	17.22	0.92	0.26	0.67	0.95	0.367	1.10	0.332	1.05	1.10	0.371	No
99	17.39	0.93	0.26	0.67	0.95	0.368	1.10	0.333	1.06	1.10	0.357	No
100	17.55	0.94	0.27	0.68	0.95	0.369	1.10	0.334	1.07	1.10	0.355	No
101	17.72	0.95	0.27	0.68	0.94	0.370	1.10	0.335	1.06	1.10	0.356	No
102	17.88	0.96	0.28	0.69	0.94	0.370	1.10	0.336	1.06	1.10	0.356	No
103	18.05	0.97	0.28	0.69	0.94	0.371	1.10	0.337	1.06	1.10	0.358	No
104	18.21	0.98	0.29	0.70	0.94	0.372	1.10	0.338	1.06	1.10	0.367	No
105	18.37	0.99	0.29	0.70	0.94	0.373	1.10	0.338	1.07	1.10	0.354	No
106	18.54	1.00	0.30	0.71	0.94	0.374	1.10	0.339	1.09	1.10	0.330	No
107	18.70	1.01	0.30	0.71	0.94	0.374	1.10	0.340	1.10	1.10	0.324	No
108	18.86	1.03	0.31	0.72	0.94	0.375	1.10	0.340	1.10	1.10	0.325	No
109	19.03	1.04	0.31	0.72	0.94	0.376	1.10	0.341	1.06	1.10	0.366	No
110	19.19	1.05	0.32	0.73	0.94	0.377	1.10	0.342	1.04	1.10	0.385	No
111	19.36	1.06	0.32	0.73	0.94	0.377	1.10	0.342	1.04	1.10	0.390	No
112	19.52	1.07	0.33	0.74	0.94	0.378	1.10	0.343	1.04	1.10	0.390	No
113	19.68	1.08	0.33	0.74	0.94	0.379	1.10	0.343	1.04	1.10	0.390	No
114	19.85	1.09	0.34	0.75	0.93	0.379	1.10	0.344	1.04	1.10	0.391	No
115	20.01	1.10	0.34	0.75	0.93	0.380	1.10	0.345	1.03	1.10	0.393	No
116	20.18	1.11	0.35	0.76	0.93	0.381	1.10	0.345	1.03	1.10	0.395	No
117	20.34	1.12	0.35	0.76	0.93	0.381	1.10	0.346	1.03	1.10	0.395	No
118	20.50	1.13	0.36	0.77	0.93	0.382	1.10	0.347	1.03	1.10	0.395	No
119	20.67	1.14	0.36	0.77	0.93	0.383	1.10	0.347	1.03	1.10	0.396	No
120	20.83	1.15	0.37	0.78	0.93	0.383	1.10	0.348	1.03	1.10	0.395	No
121	21.00	1.16	0.37	0.78	0.93	0.384	1.10	0.348	1.03	1.10	0.394	No
122	21.16	1.17	0.38	0.79	0.93	0.385	1.10	0.349	1.03	1.10	0.398	No
123	21.32	1.18	0.38	0.79	0.93	0.385	1.10	0.349	1.03	1.10	0.402	No
124	21.49	1.19	0.39	0.80	0.93	0.386	1.10	0.350	1.03	1.10	0.405	No
125	21.65	1.20	0.39	0.80	0.93	0.387	1.10	0.351	1.02	1.10	0.406	No
126	21.82	1.21	0.40	0.81	0.93	0.387	1.10	0.351	1.03	1.10	0.403	No
127	21.98	1.22	0.41	0.81	0.93	0.388	1.10	0.352	1.03	1.10	0.396	No
128	22.15	1.23	0.41	0.82	0.92	0.388	1.10	0.352	1.03	1.10	0.403	No
129	22.31	1.24	0.42	0.82	0.92	0.389	1.10	0.352	1.02	1.10	0.408	No
130	22.47	1.25	0.42	0.83	0.92	0.389	1.10	0.353	1.02	1.10	0.409	No
131	22.64	1.26	0.43	0.83	0.92	0.390	1.10	0.353	1.02	1.10	0.408	No
132	22.80	1.27	0.43	0.84	0.92	0.390	1.10	0.354	1.02	1.10	0.409	No
133	22.97	1.28	0.44	0.84	0.92	0.391	1.10	0.354	1.03	1.10	0.401	No
134	23.13	1.29	0.44	0.85	0.92	0.391	1.10	0.355	1.03	1.10	0.393	No
135	23.29	1.30	0.45	0.85	0.92	0.392	1.10	0.355	1.03	1.10	0.397	No
136	23.46	1.31	0.45	0.85	0.92	0.392	1.10	0.356	1.02	1.10	0.406	No
137	23.62	1.32	0.46	0.86	0.92	0.393	1.10	0.356	1.02	1.10	0.412	No
138	23.79	1.33	0.46	0.86	0.92	0.393	1.10	0.356	1.02	1.10	0.415	No
139	23.95	1.34	0.47	0.87	0.92	0.393	1.10	0.357	1.02	1.10	0.416	No
140	24.11	1.35	0.47	0.87	0.91	0.394	1.10	0.357	1.02	1.10	0.416	No
141	24.28	1.36	0.48	0.88	0.91	0.394	1.10	0.357	1.02	1.10	0.414	No
142	24.44	1.37	0.48	0.89	0.91	0.394	1.10	0.358	1.02	1.10	0.409	No
143	24.61	1.38	0.49	0.89	0.91	0.395	1.10	0.358	1.02	1.10	0.411	No
144	24.77	1.39	0.49	0.90	0.91	0.395	1.10	0.358	1.02	1.10	0.413	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
145	24.93	1.40	0.50	0.90	0.91	0.395	1.10	0.358	1.02	1.10	0.411	No
146	25.10	1.41	0.50	0.90	0.91	0.396	1.10	0.359	1.02	1.10	0.410	No
147	25.26	1.42	0.51	0.91	0.91	0.396	1.10	0.359	1.02	1.10	0.411	No
148	25.43	1.43	0.51	0.91	0.91	0.396	1.10	0.359	1.02	1.10	0.412	No
149	25.59	1.44	0.52	0.92	0.91	0.397	1.10	0.360	1.02	1.10	0.413	No
150	25.75	1.45	0.52	0.92	0.91	0.397	1.10	0.360	1.01	1.10	0.415	No
151	25.92	1.46	0.53	0.93	0.91	0.397	1.10	0.360	1.01	1.10	0.418	No
152	26.08	1.47	0.53	0.93	0.91	0.398	1.10	0.361	1.01	1.10	0.419	No
153	26.25	1.48	0.54	0.94	0.90	0.398	1.10	0.361	1.01	1.10	0.419	No
154	26.41	1.49	0.54	0.94	0.90	0.398	1.10	0.361	1.01	1.10	0.418	No
155	26.57	1.50	0.55	0.95	0.90	0.398	1.10	0.361	1.01	1.10	0.421	No
156	26.74	1.51	0.55	0.95	0.90	0.399	1.10	0.361	1.01	1.10	0.422	No
157	26.90	1.52	0.56	0.96	0.90	0.399	1.10	0.362	1.01	1.10	0.425	No
158	27.07	1.53	0.56	0.96	0.90	0.399	1.10	0.362	1.01	1.10	0.427	No
159	27.23	1.54	0.57	0.97	0.90	0.399	1.10	0.362	1.01	1.10	0.427	No
160	27.39	1.55	0.57	0.97	0.90	0.400	1.10	0.362	1.01	1.10	0.427	No
161	27.56	1.55	0.58	0.98	0.90	0.400	1.10	0.363	1.01	1.10	0.428	No
162	27.72	1.56	0.58	0.98	0.90	0.400	1.10	0.363	1.01	1.10	0.428	No
163	27.89	1.57	0.59	0.98	0.90	0.401	1.10	0.363	1.01	1.10	0.429	No
164	28.05	1.58	0.59	0.99	0.90	0.401	1.10	0.364	1.01	1.10	0.428	No
165	28.21	1.59	0.60	0.99	0.89	0.401	1.10	0.364	1.01	1.10	0.426	No
166	28.38	1.60	0.60	1.00	0.89	0.402	1.10	0.364	1.01	1.10	0.426	No
167	28.54	1.61	0.61	1.00	0.89	0.402	1.10	0.364	1.01	1.10	0.428	No
168	28.71	1.62	0.61	1.00	0.89	0.402	1.10	0.365	1.01	1.10	0.428	No
169	28.87	1.63	0.62	1.01	0.89	0.402	1.10	0.365	1.00	1.10	0.428	No
170	29.04	1.64	0.63	1.01	0.89	0.403	1.10	0.365	1.00	1.10	0.429	No
171	29.20	1.65	0.63	1.02	0.89	0.403	1.10	0.365	1.00	1.10	0.430	No
172	29.36	1.66	0.64	1.02	0.89	0.403	1.10	0.365	1.00	1.10	0.431	No
173	29.53	1.67	0.64	1.03	0.89	0.403	1.10	0.365	1.00	1.10	0.430	No
174	29.69	1.68	0.65	1.03	0.89	0.403	1.10	0.365	1.00	1.10	0.428	No
175	29.86	1.69	0.65	1.04	0.89	0.403	1.10	0.365	1.00	1.10	0.428	No
176	30.02	1.70	0.66	1.04	0.89	0.403	1.10	0.366	1.00	1.10	0.430	No
177	30.18	1.71	0.66	1.05	0.88	0.403	1.10	0.366	1.00	1.10	0.430	No
178	30.35	1.72	0.67	1.05	0.88	0.403	1.10	0.366	1.00	1.10	0.432	No
179	30.51	1.73	0.67	1.06	0.88	0.403	1.10	0.366	1.00	1.10	0.433	No
180	30.68	1.74	0.68	1.06	0.88	0.403	1.10	0.366	1.00	1.10	0.433	No
181	30.84	1.75	0.68	1.07	0.88	0.404	1.10	0.366	1.00	1.10	0.432	No
182	31.00	1.76	0.69	1.07	0.88	0.404	1.10	0.366	1.00	1.10	0.432	No
183	31.17	1.77	0.69	1.08	0.88	0.404	1.10	0.366	1.00	1.10	0.430	No
184	31.33	1.78	0.70	1.08	0.88	0.404	1.10	0.366	1.00	1.10	0.426	No
185	31.50	1.79	0.70	1.09	0.88	0.404	1.10	0.366	1.00	1.10	0.430	No
186	31.66	1.80	0.71	1.09	0.88	0.404	1.10	0.366	1.00	1.10	0.431	No
187	31.82	1.81	0.71	1.10	0.88	0.404	1.10	0.366	1.00	1.10	0.428	No
188	31.99	1.82	0.72	1.10	0.88	0.404	1.10	0.366	0.99	1.10	0.418	No
189	32.15	1.83	0.72	1.11	0.87	0.404	1.10	0.366	0.99	1.10	0.389	No
190	32.32	1.84	0.73	1.11	0.87	0.404	1.10	0.366	0.99	1.10	0.390	No
191	32.48	1.85	0.73	1.12	0.87	0.404	1.10	0.366	0.99	1.10	0.391	No
192	32.64	1.86	0.74	1.12	0.87	0.404	1.10	0.366	0.98	1.10	0.391	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
193	32.81	1.87	0.74	1.13	0.87	0.404	1.10	0.366	0.98	1.10	0.392	No
194	32.97	1.88	0.75	1.14	0.87	0.403	1.10	0.366	0.98	1.10	0.393	No
195	33.14	1.89	0.75	1.14	0.87	0.403	1.10	0.366	0.98	1.10	0.392	No
196	33.30	1.91	0.76	1.15	0.87	0.403	1.10	0.366	0.98	1.10	0.395	No
197	33.47	1.92	0.76	1.15	0.87	0.403	1.10	0.366	0.98	1.10	0.406	No
198	33.63	1.93	0.77	1.16	0.87	0.403	1.10	0.366	0.98	1.10	0.404	No
199	33.79	1.94	0.77	1.16	0.87	0.403	1.10	0.366	0.98	1.10	0.403	No
200	33.96	1.95	0.78	1.17	0.87	0.403	1.10	0.365	0.98	1.10	0.407	No
201	34.12	1.96	0.78	1.17	0.86	0.403	1.10	0.365	0.98	1.10	0.411	No
202	34.28	1.97	0.79	1.18	0.86	0.403	1.10	0.365	0.98	1.10	0.412	No
203	34.45	1.98	0.79	1.18	0.86	0.403	1.10	0.365	0.98	1.10	0.418	No
204	34.61	1.99	0.80	1.19	0.86	0.403	1.10	0.365	0.98	1.10	0.421	No
205	34.78	2.00	0.80	1.19	0.86	0.403	1.10	0.365	0.98	1.10	0.422	No
206	34.94	2.01	0.81	1.20	0.86	0.403	1.10	0.365	0.98	1.10	0.421	No
207	35.10	2.02	0.81	1.20	0.86	0.403	1.10	0.365	0.98	1.10	0.419	No
208	35.27	2.03	0.82	1.21	0.86	0.402	1.10	0.365	0.98	1.10	0.414	No
209	35.43	2.04	0.82	1.21	0.86	0.402	1.10	0.365	0.98	1.10	0.420	No
210	35.60	2.05	0.83	1.22	0.86	0.402	1.10	0.365	0.98	1.10	0.425	No
211	35.76	2.06	0.83	1.22	0.86	0.402	1.10	0.365	0.98	1.10	0.419	No
212	35.92	2.07	0.84	1.23	0.85	0.402	1.10	0.365	0.96	1.10	0.401	No
213	36.09	2.08	0.85	1.24	0.85	0.402	1.10	0.365	0.95	1.10	0.402	No
214	36.25	2.09	0.85	1.24	0.85	0.402	1.10	0.364	0.95	1.10	0.402	No
215	36.42	2.10	0.86	1.25	0.85	0.402	1.10	0.364	0.95	1.10	0.403	No
216	36.58	2.11	0.86	1.25	0.85	0.401	1.10	0.364	0.95	1.10	0.403	No
217	36.74	2.12	0.87	1.26	0.85	0.401	1.10	0.364	0.95	1.10	0.403	No
218	36.91	2.13	0.87	1.26	0.85	0.401	1.10	0.364	0.95	1.10	0.404	No
219	37.07	2.14	0.88	1.27	0.85	0.401	1.10	0.364	0.95	1.10	0.404	No
220	37.24	2.16	0.88	1.27	0.85	0.401	1.10	0.363	0.94	1.10	0.405	No
221	37.40	2.17	0.89	1.28	0.85	0.401	1.10	0.363	0.94	1.10	0.405	No
222	37.57	2.18	0.89	1.29	0.85	0.400	1.10	0.363	0.94	1.10	0.405	No
223	37.73	2.19	0.90	1.29	0.85	0.400	1.10	0.363	0.94	1.10	0.406	No
224	37.89	2.20	0.90	1.30	0.84	0.400	1.10	0.363	0.94	1.10	0.406	No
225	38.06	2.21	0.91	1.30	0.84	0.400	1.10	0.363	0.94	1.10	0.406	No
226	38.22	2.22	0.91	1.31	0.84	0.400	1.10	0.362	0.94	1.10	0.407	No
227	38.39	2.23	0.92	1.31	0.84	0.400	1.10	0.362	0.94	1.10	0.407	No
228	38.55	2.24	0.92	1.32	0.84	0.399	1.10	0.362	0.93	1.10	0.408	No
229	38.71	2.25	0.93	1.32	0.84	0.399	1.10	0.362	0.93	1.10	0.408	No
230	38.88	2.26	0.93	1.33	0.84	0.399	1.10	0.362	0.93	1.10	0.408	No
231	39.04	2.27	0.94	1.33	0.84	0.399	1.10	0.362	0.93	1.10	0.409	No
232	39.21	2.28	0.94	1.34	0.84	0.399	1.10	0.362	0.93	1.10	0.409	No
233	39.37	2.29	0.95	1.35	0.84	0.398	1.10	0.361	0.93	1.10	0.409	No
234	39.53	2.30	0.95	1.35	0.84	0.398	1.10	0.361	0.93	1.10	0.410	No
235	39.70	2.31	0.96	1.36	0.83	0.398	1.10	0.361	0.93	1.10	0.410	No
236	39.86	2.32	0.96	1.36	0.83	0.398	1.10	0.361	0.92	1.10	0.410	No
237	40.03	2.34	0.97	1.37	0.83	0.398	1.10	0.361	0.92	1.10	0.411	No
238	40.19	2.35	0.97	1.37	0.83	0.398	1.10	0.360	0.92	1.10	0.411	No
239	40.35	2.36	0.98	1.38	0.83	0.397	1.10	0.360	0.93	1.10	0.406	No
240	40.52	2.37	0.98	1.38	0.83	0.397	1.10	0.360	0.97	1.10	0.434	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
241	40.68	2.38	0.99	1.39	0.83	0.397	1.10	0.360	0.97	1.10	0.431	No
242	40.85	2.39	0.99	1.39	0.83	0.397	1.10	0.360	0.97	1.10	0.436	No
243	41.01	2.40	1.00	1.40	0.83	0.397	1.10	0.360	0.97	1.10	0.437	No
244	41.17	2.41	1.00	1.40	0.83	0.397	1.10	0.360	0.97	1.10	0.437	No
245	41.34	2.42	1.01	1.41	0.83	0.397	1.10	0.360	0.97	1.10	0.437	No
246	41.50	2.43	1.01	1.41	0.83	0.396	1.10	0.359	0.97	1.10	0.437	No
247	41.67	2.44	1.02	1.42	0.82	0.396	1.10	0.359	0.97	1.10	0.437	No
248	41.83	2.45	1.02	1.42	0.82	0.396	1.10	0.359	0.97	1.10	0.437	No
249	41.99	2.45	1.03	1.43	0.82	0.396	1.10	0.359	0.97	1.10	0.438	No
250	42.16	2.46	1.03	1.43	0.82	0.396	1.10	0.359	0.97	1.10	0.438	No
251	42.32	2.47	1.04	1.43	0.82	0.396	1.10	0.359	0.97	1.10	0.438	No
252	42.49	2.48	1.04	1.44	0.82	0.396	1.10	0.359	0.97	1.10	0.438	No
253	42.65	2.49	1.05	1.44	0.82	0.396	1.10	0.359	0.97	1.10	0.438	No
254	42.81	2.50	1.06	1.45	0.82	0.395	1.10	0.359	0.97	1.10	0.438	No
255	42.98	2.51	1.06	1.45	0.82	0.395	1.10	0.358	0.97	1.10	0.438	No
256	43.14	2.52	1.07	1.46	0.82	0.395	1.10	0.358	0.97	1.10	0.438	No
257	43.31	2.53	1.07	1.46	0.82	0.395	1.10	0.358	0.97	1.10	0.438	No
258	43.47	2.54	1.08	1.47	0.81	0.395	1.10	0.358	0.97	1.10	0.438	No
259	43.63	2.55	1.08	1.47	0.81	0.395	1.10	0.358	0.97	1.10	0.438	No
260	43.80	2.56	1.09	1.47	0.81	0.395	1.10	0.358	0.97	1.10	0.438	No
261	43.96	2.57	1.09	1.48	0.81	0.395	1.10	0.358	0.97	1.10	0.438	No
262	44.13	2.58	1.10	1.48	0.81	0.394	1.10	0.358	0.97	1.10	0.438	No
263	44.29	2.59	1.10	1.49	0.81	0.394	1.10	0.358	0.97	1.10	0.438	No
264	44.45	2.60	1.11	1.49	0.81	0.394	1.10	0.357	0.97	1.10	0.438	No
265	44.62	2.61	1.11	1.49	0.81	0.394	1.10	0.357	0.97	1.10	0.438	No
266	44.78	2.62	1.12	1.50	0.81	0.394	1.10	0.357	0.97	1.10	0.438	No
267	44.95	2.62	1.12	1.50	0.81	0.394	1.10	0.357	0.97	1.10	0.438	No
268	45.11	2.63	1.13	1.51	0.81	0.394	1.10	0.357	0.97	1.10	0.438	No
269	45.28	2.64	1.13	1.51	0.81	0.394	1.10	0.357	0.97	1.10	0.438	No
270	45.44	2.65	1.14	1.51	0.80	0.394	1.10	0.357	0.97	1.10	0.438	No
271	45.60	2.66	1.14	1.52	0.80	0.393	1.10	0.357	0.97	1.10	0.438	No
272	45.77	2.67	1.15	1.52	0.80	0.393	1.10	0.357	0.97	1.10	0.438	No
273	45.93	2.68	1.15	1.53	0.80	0.393	1.10	0.356	0.97	1.10	0.438	No
274	46.10	2.69	1.16	1.53	0.80	0.393	1.10	0.356	0.97	1.10	0.438	No
275	46.26	2.70	1.16	1.54	0.80	0.393	1.10	0.356	0.97	1.10	0.438	No
276	46.42	2.71	1.17	1.54	0.80	0.393	1.10	0.356	0.97	1.10	0.438	No
277	46.59	2.72	1.17	1.55	0.80	0.392	1.10	0.356	0.97	1.10	0.438	No
278	46.75	2.73	1.18	1.55	0.80	0.392	1.10	0.356	0.97	1.10	0.437	No
279	46.92	2.74	1.18	1.55	0.80	0.392	1.10	0.356	0.97	1.10	0.437	No
280	47.08	2.75	1.19	1.56	0.80	0.392	1.10	0.355	0.97	1.10	0.437	No
281	47.24	2.76	1.19	1.56	0.79	0.392	1.10	0.355	0.96	1.10	0.437	No
282	47.41	2.76	1.20	1.57	0.79	0.392	1.10	0.355	0.96	1.10	0.437	No
283	47.57	2.77	1.20	1.57	0.79	0.391	1.10	0.355	0.96	1.10	0.437	No
284	47.74	2.78	1.21	1.57	0.79	0.391	1.10	0.355	0.96	1.10	0.436	No
285	47.90	2.79	1.21	1.58	0.79	0.391	1.10	0.355	0.96	1.10	0.436	No
286	48.06	2.80	1.22	1.58	0.79	0.391	1.10	0.355	0.96	1.10	0.436	No
287	48.23	2.81	1.22	1.59	0.79	0.391	1.10	0.354	0.96	1.10	0.436	No
288	48.39	2.82	1.23	1.59	0.79	0.391	1.10	0.354	0.96	1.10	0.436	No

:: Cyclic Stress Ratio fully adjusted (CSR*) calculation data :: (continued)

Point ID	Depth (ft)	σ_v (tsf)	u_0 (tsf)	σ_v' (tsf)	r_d	CSR	MSF	CSR_{eq}	K_σ	User FS	CSR^*	Belongs to transition
289	48.56	2.83	1.23	1.60	0.79	0.390	1.10	0.354	0.96	1.10	0.436	No
290	48.72	2.84	1.24	1.60	0.79	0.390	1.10	0.354	0.96	1.10	0.436	No
291	48.88	2.85	1.24	1.61	0.79	0.390	1.10	0.354	0.96	1.10	0.436	No
292	49.05	2.86	1.25	1.61	0.79	0.390	1.10	0.353	0.96	1.10	0.435	No
293	49.21	2.87	1.25	1.62	0.78	0.389	1.10	0.353	0.96	1.10	0.435	No
294	49.38	2.88	1.26	1.62	0.78	0.389	1.10	0.353	0.96	1.10	0.434	No
295	49.54	2.89	1.26	1.63	0.78	0.389	1.10	0.353	0.95	1.10	0.434	No
296	49.70	2.90	1.27	1.63	0.78	0.389	1.10	0.353	0.95	1.10	0.433	No
297	49.87	2.91	1.28	1.64	0.78	0.388	1.10	0.352	0.94	1.10	0.429	No
298	50.03	2.92	1.28	1.64	0.78	0.388	1.10	0.352	0.95	1.10	0.431	No
299	50.20	2.93	1.29	1.64	0.78	0.388	1.10	0.352	0.95	1.10	0.433	No

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
σ_v: Total overburden pressure at test point (tsf)
u_0: Water pressure at test point (tsf)
σ_v': Effective overburden pressure based on GWT during earthquake (tsf)
r_d: Nonlinear shear mass factor
CSR: Cyclic Stress Ratio
MSF: Magnitude Scaling Factor
CSR_{eq}: CSR adjusted for M=7.5
K_σ: Effective overburden stress factor
CSR^*: CSR fully adjusted

:: Cyclic Resistance Ratio (CRR) calculation data ::

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
1	1.31	18.47	53.97	2.39	0.53	1.70	31.59	55.79	87.37	4.000	No	No	2.00
2	1.48	16.96	60.40	2.47	0.54	1.70	25.77	56.04	81.81	4.000	No	No	2.00
3	1.64	14.72	72.13	2.61	0.54	1.70	24.32	0.00	24.32	4.000	No	Yes	2.00
4	1.80	13.33	78.59	2.69	0.55	1.70	20.81	0.00	20.81	4.000	No	Yes	2.00
5	1.97	12.18	81.57	2.73	0.55	1.70	19.10	0.00	19.10	4.000	No	Yes	2.00
6	2.13	11.49	78.15	2.69	0.56	1.70	18.78	0.00	18.78	4.000	No	Yes	2.00
7	2.30	11.18	74.44	2.64	0.56	1.70	17.46	0.00	17.46	4.000	No	Yes	2.00
8	2.46	11.05	70.46	2.59	0.56	1.70	17.59	55.82	73.41	4.000	No	No	2.00
9	2.63	11.41	66.04	2.54	0.56	1.70	18.16	55.15	73.31	4.000	No	No	2.00
10	2.79	11.90	61.16	2.48	0.56	1.70	19.20	54.38	73.58	4.000	No	No	2.00
11	2.95	12.79	56.48	2.42	0.56	1.70	20.00	53.39	73.39	4.000	No	No	2.00
12	3.12	14.05	50.88	2.35	0.56	1.70	22.43	52.27	74.69	4.000	No	No	2.00
13	3.28	15.73	45.12	2.28	0.56	1.70	25.29	50.68	75.97	4.000	No	No	2.00
14	3.44	17.43	39.90	2.21	0.55	1.70	28.08	48.64	76.72	4.000	No	No	2.00
15	3.61	18.63	37.61	2.18	0.55	1.70	30.61	47.79	78.39	4.000	No	No	2.00
16	3.77	19.69	36.70	2.17	0.55	1.70	31.06	47.27	78.32	4.000	No	No	2.00
17	3.94	19.98	37.93	2.19	0.54	1.70	33.23	48.62	81.85	4.000	No	No	2.00
18	4.10	20.31	38.92	2.20	0.54	1.70	32.00	48.98	80.98	4.000	No	No	2.00
19	4.26	19.91	41.22	2.23	0.54	1.70	32.65	50.52	83.17	4.000	No	No	2.00
20	4.43	19.84	42.54	2.24	0.54	1.70	31.28	50.91	82.19	4.000	No	No	2.00
21	4.59	19.56	43.76	2.26	0.54	1.70	31.67	51.64	83.30	4.000	No	No	2.00
22	4.76	19.72	43.18	2.25	0.54	1.70	31.30	51.25	82.55	4.000	No	No	2.00
23	4.92	20.35	41.57	2.23	0.54	1.70	32.08	50.58	82.66	4.000	No	No	2.00
24	5.08	21.69	38.47	2.19	0.54	1.70	34.69	49.32	84.01	4.000	No	No	2.00
25	5.25	23.37	35.31	2.15	0.53	1.70	37.74	47.75	85.49	4.000	No	No	2.00
26	5.41	24.88	32.37	2.12	0.53	1.70	40.20	45.77	85.97	4.000	No	No	2.00
27	5.58	26.37	29.60	2.08	0.53	1.70	41.98	43.35	85.33	4.000	No	No	2.00
28	5.74	28.42	26.18	2.04	0.53	1.70	44.89	39.71	84.60	4.000	No	No	2.00
29	5.91	31.51	21.78	1.98	0.54	1.70	50.11	33.65	83.76	4.000	No	No	2.00
30	6.07	35.15	16.13	1.91	0.55	1.70	56.88	22.29	79.17	4.000	No	No	2.00
31	6.23	38.56	11.61	1.86	0.56	1.70	62.42	10.70	73.12	4.000	No	No	2.00
32	6.40	41.16	8.43	1.82	0.57	1.70	66.55	3.44	69.99	4.000	No	No	2.00
33	6.56	42.78	8.01	1.81	0.57	1.70	69.42	2.75	72.17	4.000	No	No	2.00
34	6.73	43.16	9.10	1.83	0.56	1.70	70.21	4.80	75.02	4.000	No	No	2.00
35	6.89	41.96	12.24	1.87	0.54	1.70	68.36	12.69	81.06	4.000	No	No	2.00
36	7.05	39.31	17.55	1.93	0.52	1.70	63.69	26.52	90.21	4.000	No	No	2.00
37	7.22	36.04	23.93	2.01	0.51	1.69	57.20	38.49	95.69	4.000	No	No	2.00
38	7.38	33.75	29.22	2.08	0.51	1.67	51.68	44.86	96.53	4.000	No	No	2.00
39	7.55	33.49	31.05	2.10	0.50	1.65	50.95	46.74	97.69	4.000	No	No	2.00
40	7.71	34.75	29.89	2.09	0.50	1.62	53.50	45.99	99.49	4.000	No	No	2.00
41	7.87	36.40	27.35	2.05	0.50	1.60	55.40	43.23	98.63	4.000	No	No	2.00
42	8.04	38.58	23.44	2.01	0.51	1.60	57.02	37.65	94.67	4.000	No	No	2.00
43	8.20	41.46	18.48	1.94	0.52	1.59	62.56	28.59	91.15	4.000	No	No	2.00
44	8.37	43.50	15.12	1.90	0.52	1.59	67.69	20.66	88.35	4.000	No	No	2.00
45	8.53	43.39	14.97	1.90	0.53	1.58	65.45	20.05	85.50	4.000	No	No	2.00
46	8.69	41.04	16.95	1.92	0.53	1.56	60.84	24.74	85.58	4.000	No	No	2.00
47	8.86	38.24	20.09	1.96	0.53	1.54	55.59	31.19	86.78	4.000	No	No	2.00
48	9.02	35.58	23.42	2.01	0.53	1.53	51.11	36.64	87.75	0.123	No	No	0.45

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
49	9.19	33.57	26.80	2.05	0.52	1.51	47.32	40.99	88.32	0.124	No	No	0.45
50	9.35	32.63	27.69	2.06	0.53	1.50	45.42	41.78	87.20	0.123	No	No	0.44
51	9.51	32.89	27.29	2.05	0.53	1.48	45.77	41.35	87.12	0.123	No	No	0.44
52	9.68	34.32	25.38	2.03	0.53	1.47	47.27	39.03	86.30	0.122	No	No	0.43
53	9.84	36.11	24.01	2.01	0.53	1.46	50.07	37.43	87.51	0.123	No	No	0.43
54	10.01	37.22	23.17	2.00	0.53	1.44	51.77	36.34	88.11	0.124	No	No	0.43
55	10.17	37.38	23.22	2.00	0.53	1.43	50.50	36.22	86.73	0.122	No	No	0.42
56	10.34	36.69	24.10	2.01	0.53	1.42	49.45	37.48	86.93	0.123	No	No	0.42
57	10.50	33.96	27.22	2.05	0.52	1.40	47.65	41.61	89.25	0.125	No	No	0.42
58	10.66	33.90	27.17	2.05	0.55	1.41	38.89	39.90	78.80	0.115	No	No	0.38
59	10.83	34.12	27.08	2.05	0.52	1.38	47.79	41.45	89.24	0.125	No	No	0.41
60	10.99	37.18	24.04	2.01	0.53	1.38	47.67	37.08	84.75	0.120	No	No	0.39
61	11.15	39.11	22.14	1.99	0.54	1.37	49.73	34.24	83.97	0.120	No	No	0.39
62	11.32	43.22	18.06	1.94	0.54	1.37	55.14	26.73	81.88	0.118	No	No	0.38
63	11.48	47.91	14.06	1.89	0.54	1.37	63.47	17.42	80.89	0.117	No	No	0.37
64	11.65	51.77	12.14	1.86	0.55	1.37	67.70	12.38	80.08	0.116	No	No	0.37
65	11.81	53.18	13.70	1.88	0.53	1.35	69.02	16.84	85.86	0.121	No	No	0.38
66	11.97	52.99	15.14	1.90	0.53	1.34	67.45	20.68	88.13	0.124	No	No	0.39
67	12.14	52.11	14.92	1.90	0.53	1.34	65.68	19.93	85.62	0.121	No	No	0.38
68	12.30	52.01	12.55	1.87	0.55	1.35	65.57	13.40	78.97	0.115	No	No	0.35
69	12.47	51.56	12.37	1.87	0.55	1.34	67.13	13.00	80.13	0.116	No	No	0.35
70	12.63	50.45	13.85	1.89	0.54	1.34	63.74	16.87	80.61	0.116	No	No	0.35
71	12.79	49.06	15.46	1.91	0.54	1.33	60.50	20.93	81.43	0.117	No	No	0.35
72	12.96	49.09	15.53	1.91	0.54	1.33	61.05	21.15	82.20	0.118	No	No	0.35
73	13.12	50.56	15.13	1.90	0.54	1.32	62.99	20.29	83.28	0.119	No	No	0.35
74	13.29	51.89	14.37	1.89	0.54	1.32	65.22	18.41	83.63	0.119	No	No	0.35
75	13.45	52.88	13.00	1.88	0.55	1.32	65.56	14.66	80.22	0.116	No	No	0.34
76	13.62	54.37	10.87	1.85	0.56	1.32	66.69	8.93	75.63	0.112	No	No	0.33
77	13.78	56.49	8.53	1.82	0.56	1.32	70.92	3.69	74.61	0.111	No	No	0.32
78	13.94	58.54	6.12	1.79	0.56	1.31	73.33	0.62	73.95	0.111	No	No	0.32
79	14.11	57.93	6.00	1.79	0.56	1.31	73.77	0.55	74.31	0.111	No	No	0.32
80	14.27	57.50	6.54	1.79	0.57	1.31	68.43	0.93	69.36	0.107	No	No	0.30
81	14.44	57.53	7.44	1.81	0.56	1.30	71.12	1.93	73.05	0.110	No	No	0.31
82	14.60	58.65	7.72	1.81	0.56	1.30	73.05	2.34	75.40	0.112	No	No	0.32
83	14.76	52.39	11.93	1.86	0.54	1.28	70.73	11.97	82.70	0.118	No	No	0.33
84	14.93	39.14	24.19	2.01	0.54	1.27	46.89	37.17	84.06	0.120	No	No	0.34
85	15.09	24.64	44.36	2.27	0.56	1.29	24.20	50.05	74.26	0.111	No	No	0.31
86	15.26	15.44	67.29	2.55	0.56	1.28	18.12	55.39	73.51	0.110	No	No	0.30
87	15.42	13.10	75.91	2.66	0.58	1.29	13.72	0.00	13.72	4.000	No	Yes	2.00
88	15.58	15.15	69.44	2.58	0.57	1.28	15.47	55.02	70.49	0.108	No	No	0.29
89	15.75	19.03	58.14	2.44	0.55	1.26	25.07	55.25	80.32	0.116	No	No	0.32
90	15.91	22.17	53.14	2.38	0.54	1.26	26.99	54.27	81.26	0.117	No	No	0.32
91	16.08	22.50	55.45	2.41	0.54	1.25	25.98	54.73	80.71	0.117	No	No	0.32
92	16.24	21.86	61.05	2.48	0.54	1.25	25.64	56.17	81.81	0.118	No	No	0.32
93	16.40	21.42	65.31	2.53	0.54	1.25	24.39	56.79	81.18	0.117	No	No	0.32
94	16.57	21.79	68.87	2.57	0.54	1.24	24.34	57.49	81.84	0.118	No	No	0.32
95	16.73	25.03	67.35	2.55	0.53	1.23	26.75	57.89	84.64	0.120	No	No	0.32
96	16.90	30.12	63.00	2.50	0.51	1.22	34.96	59.28	94.24	0.130	No	No	0.35

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
97	17.06	36.90	56.95	2.42	0.50	1.21	40.73	59.24	99.97	0.137	No	No	0.37
98	17.22	55.27	39.93	2.21	0.49	1.20	48.29	53.53	101.82	0.140	No	No	0.38
99	17.39	83.19	21.81	1.99	0.43	1.17	93.60	40.25	133.85	0.210	No	No	0.59
100	17.55	109.57	9.90	1.84	0.42	1.16	131.93	8.29	140.21	0.236	No	No	0.66
101	17.72	114.88	8.79	1.82	0.42	1.16	134.66	5.28	139.94	0.234	No	No	0.66
102	17.88	100.73	17.15	1.93	0.42	1.16	111.34	30.67	142.01	0.244	No	No	0.68
103	18.05	79.96	33.54	2.13	0.42	1.15	84.65	56.57	141.22	0.240	No	No	0.67
104	18.21	72.59	44.30	2.27	0.44	1.16	66.29	60.66	126.95	0.189	No	No	0.51
105	18.37	84.33	43.73	2.26	0.40	1.14	85.91	65.26	151.17	0.297	No	No	0.84
106	18.54	113.88	32.51	2.12	0.35	1.12	119.38	62.90	182.28	0.798	No	No	2.00
107	18.70	129.48	28.18	2.06	0.31	1.10	154.95	63.56	218.51	4.000	No	No	2.00
108	18.86	114.36	33.52	2.13	0.33	1.11	132.30	66.97	199.27	1.816	No	No	2.00
109	19.03	76.52	51.53	2.36	0.42	1.13	72.35	65.86	138.21	0.227	No	No	0.62
110	19.19	42.83	79.24	2.70	0.49	1.15	38.83	0.00	38.83	4.000	No	Yes	2.00
111	19.36	29.03	98.06	2.94	0.52	1.16	28.00	0.00	28.00	4.000	No	Yes	2.00
112	19.52	27.23	100.00	2.99	0.52	1.16	28.44	0.00	28.44	4.000	No	Yes	2.00
113	19.68	28.50	100.00	2.96	0.51	1.15	32.72	0.00	32.72	4.000	No	Yes	2.00
114	19.85	29.18	97.78	2.93	0.51	1.14	31.66	0.00	31.66	4.000	No	Yes	2.00
115	20.01	27.48	96.71	2.92	0.51	1.14	30.24	0.00	30.24	4.000	No	Yes	2.00
116	20.18	27.39	90.41	2.84	0.53	1.14	27.01	0.00	27.01	4.000	No	Yes	2.00
117	20.34	28.39	82.41	2.74	0.52	1.14	30.84	0.00	30.84	4.000	No	Yes	2.00
118	20.50	30.88	74.89	2.65	0.51	1.13	32.90	0.00	32.90	4.000	No	Yes	2.00
119	20.67	34.18	69.08	2.58	0.51	1.13	34.29	60.43	94.72	0.131	No	No	0.33
120	20.83	38.12	63.62	2.51	0.49	1.12	40.67	61.06	101.73	0.140	No	No	0.35
121	21.00	38.83	63.17	2.50	0.48	1.11	44.44	62.02	106.46	0.147	No	No	0.37
122	21.16	34.22	71.03	2.60	0.50	1.12	36.11	0.00	36.11	4.000	No	Yes	2.00
123	21.32	25.97	86.65	2.80	0.53	1.12	26.40	0.00	26.40	4.000	No	Yes	2.00
124	21.49	19.86	100.00	2.99	0.55	1.12	19.11	0.00	19.11	4.000	No	Yes	2.00
125	21.65	21.21	98.94	2.95	0.56	1.12	17.12	0.00	17.12	4.000	No	Yes	2.00
126	21.82	30.69	81.59	2.73	0.52	1.11	30.31	0.00	30.31	4.000	No	Yes	2.00
127	21.98	36.29	76.74	2.67	0.47	1.09	48.15	0.00	48.15	4.000	No	Yes	2.00
128	22.15	33.86	81.88	2.74	0.50	1.10	34.43	0.00	34.43	4.000	No	Yes	2.00
129	22.31	25.23	95.23	2.90	0.54	1.10	22.78	0.00	22.78	4.000	No	Yes	2.00
130	22.47	23.15	93.46	2.88	0.54	1.10	21.53	0.00	21.53	4.000	No	Yes	2.00
131	22.64	25.01	85.79	2.78	0.52	1.09	27.67	0.00	27.67	4.000	No	Yes	2.00
132	22.80	35.49	67.34	2.55	0.53	1.09	28.17	58.30	86.47	0.122	No	No	0.30
133	22.97	51.25	49.26	2.33	0.47	1.08	52.93	59.71	112.63	0.157	No	No	0.39
134	23.13	65.18	35.76	2.16	0.44	1.07	74.82	56.53	131.35	0.202	No	No	0.51
135	23.29	63.11	35.67	2.16	0.45	1.07	69.86	55.33	125.18	0.184	No	No	0.46
136	23.46	48.03	50.79	2.35	0.49	1.07	46.56	58.66	105.22	0.145	No	No	0.36
137	23.62	31.40	78.82	2.70	0.52	1.07	29.43	0.00	29.43	4.000	No	Yes	2.00
138	23.79	21.98	100.00	3.04	0.55	1.08	19.68	0.00	19.68	4.000	No	Yes	2.00
139	23.95	19.15	100.00	3.24	0.55	1.07	17.91	0.00	17.91	4.000	No	Yes	2.00
140	24.11	22.36	100.00	3.22	0.54	1.07	20.66	0.00	20.66	4.000	No	Yes	2.00
141	24.28	30.51	100.00	3.05	0.52	1.06	29.06	0.00	29.06	4.000	No	Yes	2.00
142	24.44	36.82	93.29	2.88	0.48	1.05	41.94	0.00	41.94	4.000	No	Yes	2.00
143	24.61	40.05	79.05	2.70	0.49	1.05	39.21	0.00	39.21	4.000	No	Yes	2.00
144	24.77	41.73	63.10	2.50	0.50	1.05	38.41	60.29	98.70	0.136	No	No	0.33

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
145	24.93	46.02	53.25	2.38	0.48	1.05	46.66	59.63	106.29	0.146	No	No	0.36
146	25.10	50.57	50.66	2.35	0.47	1.04	51.59	59.95	111.53	0.155	No	No	0.38
147	25.26	51.86	52.42	2.37	0.47	1.04	51.49	60.62	112.11	0.156	No	No	0.38
148	25.43	50.72	54.00	2.39	0.47	1.04	50.11	60.83	110.95	0.154	No	No	0.37
149	25.59	47.63	59.21	2.45	0.48	1.04	47.87	61.91	109.78	0.152	No	No	0.37
150	25.75	42.82	63.04	2.50	0.49	1.04	42.17	61.34	103.51	0.142	No	No	0.34
151	25.92	38.12	68.50	2.57	0.51	1.03	35.78	60.74	96.52	0.133	No	No	0.32
152	26.08	35.62	71.62	2.61	0.51	1.03	33.93	0.00	33.93	4.000	No	Yes	2.00
153	26.25	36.45	74.25	2.64	0.51	1.03	34.63	0.00	34.63	4.000	No	Yes	2.00
154	26.41	35.40	79.41	2.71	0.50	1.03	37.89	0.00	37.89	4.000	No	Yes	2.00
155	26.57	33.16	84.45	2.77	0.52	1.02	30.65	0.00	30.65	4.000	No	Yes	2.00
156	26.74	26.72	95.19	2.90	0.52	1.02	27.92	0.00	27.92	4.000	No	Yes	2.00
157	26.90	21.75	100.00	3.02	0.55	1.02	19.07	0.00	19.07	4.000	No	Yes	2.00
158	27.07	17.49	100.00	3.13	0.56	1.02	16.11	0.00	16.11	4.000	No	Yes	2.00
159	27.23	16.89	100.00	3.11	0.56	1.02	15.44	0.00	15.44	4.000	No	Yes	2.00
160	27.39	17.74	100.00	3.02	0.56	1.01	17.17	0.00	17.17	4.000	No	Yes	2.00
161	27.56	19.19	93.70	2.88	0.55	1.01	18.35	0.00	18.35	4.000	No	Yes	2.00
162	27.72	20.57	81.68	2.73	0.55	1.01	19.41	0.00	19.41	4.000	No	Yes	2.00
163	27.89	24.83	65.59	2.53	0.55	1.01	20.94	55.86	76.80	0.113	No	No	0.26
164	28.05	37.01	42.14	2.24	0.54	1.00	30.29	50.45	80.74	0.117	No	No	0.27
165	28.21	52.16	25.75	2.03	0.51	1.00	53.45	40.66	94.10	0.130	No	No	0.31
166	28.38	59.71	19.17	1.95	0.51	1.00	63.21	30.23	93.44	0.129	No	No	0.30
167	28.54	55.33	23.98	2.01	0.52	1.00	51.10	37.56	88.65	0.124	No	No	0.29
168	28.71	44.81	40.04	2.21	0.51	1.00	40.90	51.82	92.72	0.129	No	No	0.30
169	28.87	36.89	61.23	2.48	0.52	0.99	33.60	58.46	92.05	0.128	No	No	0.30
170	29.04	31.36	83.13	2.75	0.52	0.99	28.76	0.00	28.76	4.000	No	Yes	2.00
171	29.20	27.91	99.93	2.96	0.53	0.99	25.20	0.00	25.20	4.000	No	Yes	2.00
172	29.36	26.98	100.00	3.07	0.53	0.99	23.69	0.00	23.69	4.000	No	Yes	2.00
173	29.53	30.16	100.00	3.02	0.53	0.98	25.90	0.00	25.90	4.000	No	Yes	2.00
174	29.69	34.28	97.21	2.93	0.50	0.98	33.84	0.00	33.84	4.000	No	Yes	2.00
175	29.86	36.27	90.40	2.84	0.50	0.98	34.96	0.00	34.96	4.000	No	Yes	2.00
176	30.02	35.33	87.24	2.80	0.51	0.98	31.17	0.00	31.17	4.000	No	Yes	2.00
177	30.18	32.51	87.24	2.80	0.51	0.98	30.93	0.00	30.93	4.000	No	Yes	2.00
178	30.35	30.62	87.95	2.81	0.53	0.97	26.80	0.00	26.80	4.000	No	Yes	2.00
179	30.51	29.09	90.55	2.84	0.53	0.97	25.68	0.00	25.68	4.000	No	Yes	2.00
180	30.68	29.70	90.91	2.85	0.53	0.97	26.40	0.00	26.40	4.000	No	Yes	2.00
181	30.84	31.68	89.41	2.83	0.52	0.97	28.21	0.00	28.21	4.000	No	Yes	2.00
182	31.00	36.66	81.87	2.74	0.52	0.96	30.71	0.00	30.71	4.000	No	Yes	2.00
183	31.17	45.07	69.85	2.59	0.49	0.96	39.70	62.15	101.86	0.140	No	No	0.33
184	31.33	49.32	62.00	2.49	0.47	0.96	51.29	63.66	114.95	0.161	No	No	0.38
185	31.50	49.61	59.25	2.45	0.49	0.96	42.37	60.38	102.75	0.141	No	No	0.33
186	31.66	50.64	56.91	2.42	0.50	0.96	40.24	59.10	99.33	0.137	No	No	0.32
187	31.82	66.54	45.88	2.29	0.47	0.96	53.27	58.20	111.47	0.155	No	No	0.36
188	31.99	105.26	30.22	2.09	0.42	0.96	84.84	52.76	137.60	0.224	No	No	0.54
189	32.15	152.62	19.84	1.96	0.34	0.97	146.95	42.88	189.83	1.117	No	No	2.00
190	32.32	193.84	11.23	1.85	0.33	0.97	184.17	14.69	198.86	1.775	No	No	2.00
191	32.48	213.18	7.08	1.80	0.33	0.96	199.17	2.25	201.42	2.051	No	No	2.00
192	32.64	218.38	6.40	1.79	0.33	0.96	199.61	1.25	200.86	1.986	No	No	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
193	32.81	212.89	10.89	1.85	0.31	0.96	197.89	13.87	211.76	3.925	No	No	2.00
194	32.97	201.32	17.03	1.93	0.30	0.96	183.89	38.01	221.89	4.000	No	No	2.00
195	33.14	189.26	16.60	1.92	0.33	0.96	167.29	34.71	202.00	2.122	No	No	2.00
196	33.30	182.98	12.19	1.86	0.36	0.95	163.32	17.50	180.82	0.751	No	No	1.90
197	33.47	184.02	1.19	1.73	0.38	0.95	164.25	0.00	164.25	0.420	No	No	1.03
198	33.63	186.81	0.00	1.67	0.37	0.95	168.26	0.00	168.26	0.476	No	No	1.18
199	33.79	187.43	0.00	1.66	0.37	0.95	169.68	0.00	169.68	0.499	No	No	1.24
200	33.96	183.42	0.73	1.72	0.38	0.94	165.11	0.00	165.11	0.431	No	No	1.06
201	34.12	175.90	6.22	1.79	0.39	0.94	156.32	0.93	157.25	0.345	No	No	0.84
202	34.28	165.98	9.65	1.83	0.39	0.94	148.26	7.95	156.21	0.336	No	No	0.82
203	34.45	158.47	9.38	1.83	0.41	0.93	137.12	6.92	144.04	0.254	No	No	0.61
204	34.61	154.51	7.90	1.81	0.42	0.93	134.83	3.27	138.10	0.226	No	No	0.54
205	34.78	155.87	4.69	1.77	0.43	0.93	136.24	0.10	136.34	0.219	No	No	0.52
206	34.94	159.33	1.74	1.73	0.42	0.93	139.84	0.00	139.84	0.234	No	No	0.56
207	35.10	166.53	0.00	1.69	0.41	0.93	143.49	0.00	143.49	0.251	No	No	0.60
208	35.27	167.54	0.00	1.70	0.39	0.93	155.26	0.00	155.26	0.328	No	No	0.79
209	35.43	159.67	5.53	1.78	0.42	0.92	141.89	0.39	142.28	0.245	No	No	0.58
210	35.60	156.70	10.38	1.84	0.44	0.92	121.64	9.45	131.09	0.201	No	No	0.47
211	35.76	181.13	2.94	1.75	0.41	0.92	146.35	0.00	146.35	0.266	No	No	0.64
212	35.92	234.84	0.00	1.58	0.32	0.94	208.94	0.00	208.94	3.254	No	No	2.00
213	36.09	299.91	0.00	1.42	0.26	0.95	269.61	0.00	269.61	4.000	No	No	2.00
214	36.25	349.29	0.00	1.37	0.26	0.95	324.71	0.00	324.71	4.000	No	No	2.00
215	36.42	370.40	0.00	1.38	0.26	0.95	342.90	0.00	342.90	4.000	No	No	2.00
216	36.58	363.58	0.00	1.45	0.26	0.94	325.18	0.00	325.18	4.000	No	No	2.00
217	36.74	348.73	0.00	1.47	0.26	0.94	305.36	0.00	305.36	4.000	No	No	2.00
218	36.91	339.35	0.00	1.44	0.26	0.94	302.02	0.00	302.02	4.000	No	No	2.00
219	37.07	338.65	0.00	1.38	0.26	0.94	299.07	0.00	299.07	4.000	No	No	2.00
220	37.24	341.33	0.00	1.38	0.26	0.94	302.50	0.00	302.50	4.000	No	No	2.00
221	37.40	348.75	0.00	1.41	0.26	0.94	308.17	0.00	308.17	4.000	No	No	2.00
222	37.57	342.84	0.00	1.47	0.26	0.94	317.75	0.00	317.75	4.000	No	No	2.00
223	37.73	342.66	0.00	1.49	0.26	0.94	285.66	0.00	285.66	4.000	No	No	2.00
224	37.89	341.09	0.00	1.50	0.26	0.94	306.65	0.00	306.65	4.000	No	No	2.00
225	38.06	358.39	0.00	1.43	0.26	0.94	312.52	0.00	312.52	4.000	No	No	2.00
226	38.22	372.99	0.00	1.30	0.26	0.93	330.58	0.00	330.58	4.000	No	No	2.00
227	38.39	391.40	0.00	1.20	0.26	0.93	344.29	0.00	344.29	4.000	No	No	2.00
228	38.55	408.33	0.00	1.17	0.26	0.93	360.20	0.00	360.20	4.000	No	No	2.00
229	38.71	421.40	0.00	1.21	0.26	0.93	374.28	0.00	374.28	4.000	No	No	2.00
230	38.88	427.31	0.00	1.22	0.26	0.93	377.66	0.00	377.66	4.000	No	No	2.00
231	39.04	418.90	0.00	1.22	0.26	0.93	374.63	0.00	374.63	4.000	No	No	2.00
232	39.21	401.54	0.00	1.26	0.26	0.93	350.93	0.00	350.93	4.000	No	No	2.00
233	39.37	389.68	0.00	1.29	0.26	0.93	330.79	0.00	330.79	4.000	No	No	2.00
234	39.53	393.48	0.00	1.27	0.26	0.93	342.33	0.00	342.33	4.000	No	No	2.00
235	39.70	408.36	0.00	1.25	0.26	0.93	359.78	0.00	359.78	4.000	No	No	2.00
236	39.86	418.10	0.00	1.24	0.26	0.92	368.73	0.00	368.73	4.000	No	No	2.00
237	40.03	402.57	0.00	1.26	0.26	0.92	366.68	0.00	366.68	4.000	No	No	2.00
238	40.19	338.71	0.00	1.36	0.26	0.92	318.05	0.00	318.05	4.000	No	No	2.00
239	40.35	235.90	0.00	1.57	0.33	0.90	196.57	0.00	196.57	1.568	No	No	2.00
240	40.52	139.85	13.20	1.88	0.48	0.86	90.98	16.82	107.80	0.149	No	No	0.34

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
241	40.68	78.81	40.57	2.22	0.46	0.87	62.85	57.48	120.33	0.172	No	No	0.40
242	40.85	53.51	57.65	2.43	0.51	0.85	38.13	58.74	96.86	0.134	No	No	0.31
243	41.01	38.50	74.17	2.64	0.53	0.84	28.10	0.00	28.10	4.000	No	Yes	2.00
244	41.17	32.89	82.97	2.75	0.53	0.84	24.91	0.00	24.91	4.000	No	Yes	2.00
245	41.34	32.73	87.81	2.81	0.54	0.84	24.11	0.00	24.11	4.000	No	Yes	2.00
246	41.50	32.94	89.81	2.84	0.52	0.84	28.02	0.00	28.02	4.000	No	Yes	2.00
247	41.67	33.03	91.50	2.86	0.53	0.84	25.08	0.00	25.08	4.000	No	Yes	2.00
248	41.83	30.19	94.56	2.89	0.53	0.84	24.06	0.00	24.06	4.000	No	Yes	2.00
249	41.99	27.66	96.35	2.92	0.54	0.83	20.85	0.00	20.85	4.000	No	Yes	2.00
250	42.16	25.19	97.91	2.94	0.55	0.83	19.04	0.00	19.04	4.000	No	Yes	2.00
251	42.32	23.43	97.89	2.94	0.55	0.83	18.13	0.00	18.13	4.000	No	Yes	2.00
252	42.49	21.95	99.59	2.96	0.56	0.82	16.63	0.00	16.63	4.000	No	Yes	2.00
253	42.65	19.74	100.00	3.02	0.56	0.82	15.53	0.00	15.53	4.000	No	Yes	2.00
254	42.81	18.07	100.00	3.11	0.57	0.82	12.88	0.00	12.88	4.000	No	Yes	2.00
255	42.98	17.26	100.00	3.17	0.57	0.81	12.61	0.00	12.61	4.000	No	Yes	2.00
256	43.14	17.90	100.00	3.16	0.57	0.81	13.50	0.00	13.50	4.000	No	Yes	2.00
257	43.31	18.53	100.00	3.13	0.57	0.81	14.29	0.00	14.29	4.000	No	Yes	2.00
258	43.47	17.92	100.00	3.14	0.57	0.81	14.02	0.00	14.02	4.000	No	Yes	2.00
259	43.63	16.35	100.00	3.19	0.57	0.81	12.06	0.00	12.06	4.000	No	Yes	2.00
260	43.80	14.65	100.00	3.25	0.58	0.81	10.64	0.00	10.64	4.000	No	Yes	2.00
261	43.96	13.79	100.00	3.28	0.58	0.80	10.05	0.00	10.05	4.000	No	Yes	2.00
262	44.13	14.30	100.00	3.24	0.58	0.80	10.03	0.00	10.03	4.000	No	Yes	2.00
263	44.29	15.62	100.00	3.17	0.58	0.80	11.67	0.00	11.67	4.000	No	Yes	2.00
264	44.45	17.01	100.00	3.11	0.57	0.80	12.94	0.00	12.94	4.000	No	Yes	2.00
265	44.62	17.46	100.00	3.08	0.57	0.80	13.12	0.00	13.12	4.000	No	Yes	2.00
266	44.78	17.37	100.00	3.07	0.57	0.80	12.63	0.00	12.63	4.000	No	Yes	2.00
267	44.95	17.72	100.00	3.03	0.57	0.80	12.67	0.00	12.67	4.000	No	Yes	2.00
268	45.11	19.60	98.16	2.94	0.57	0.80	13.83	0.00	13.83	4.000	No	Yes	2.00
269	45.28	20.08	97.26	2.93	0.56	0.80	16.98	0.00	16.98	4.000	No	Yes	2.00
270	45.44	19.26	100.00	2.98	0.57	0.80	13.77	0.00	13.77	4.000	No	Yes	2.00
271	45.60	16.65	100.00	3.11	0.57	0.79	11.95	0.00	11.95	4.000	No	Yes	2.00
272	45.77	14.60	100.00	3.27	0.58	0.79	10.83	0.00	10.83	4.000	No	Yes	2.00
273	45.93	13.54	100.00	3.38	0.59	0.79	8.97	0.00	8.97	4.000	No	Yes	2.00
274	46.10	12.55	100.00	3.48	0.58	0.79	9.41	0.00	9.41	4.000	No	Yes	2.00
275	46.26	12.25	100.00	3.51	0.59	0.78	8.45	0.00	8.45	4.000	No	Yes	2.00
276	46.42	12.16	100.00	3.51	0.59	0.78	8.14	0.00	8.14	4.000	No	Yes	2.00
277	46.59	14.36	100.00	3.36	0.59	0.78	9.24	0.00	9.24	4.000	No	Yes	2.00
278	46.75	18.41	100.00	3.13	0.57	0.79	13.32	0.00	13.32	4.000	No	Yes	2.00
279	46.92	23.48	96.21	2.92	0.56	0.79	17.17	0.00	17.17	4.000	No	Yes	2.00
280	47.08	27.23	85.71	2.78	0.55	0.79	20.26	0.00	20.26	4.000	No	Yes	2.00
281	47.24	29.00	79.63	2.71	0.55	0.79	21.40	0.00	21.40	4.000	No	Yes	2.00
282	47.41	30.22	75.53	2.66	0.55	0.79	20.75	0.00	20.75	4.000	No	Yes	2.00
283	47.57	32.02	71.22	2.60	0.55	0.79	22.92	0.00	22.92	4.000	No	Yes	2.00
284	47.74	34.99	67.89	2.56	0.54	0.79	25.15	57.54	82.70	0.118	No	No	0.27
285	47.90	36.82	68.71	2.57	0.53	0.79	27.00	58.24	85.24	0.121	No	No	0.28
286	48.06	37.03	74.36	2.64	0.53	0.79	26.33	0.00	26.33	4.000	No	Yes	2.00
287	48.23	35.55	82.01	2.74	0.53	0.79	25.28	0.00	25.28	4.000	No	Yes	2.00
288	48.39	33.76	88.73	2.82	0.54	0.79	23.61	0.00	23.61	4.000	No	Yes	2.00

:: Cyclic Resistance Ratio (CRR) calculation data :: (continued)

Point ID	Depth (ft)	q_t (tsf)	FC (%)	Ic	m	C_N	q_{c1N}	Δq_{c1N}	$q_{c1N,cs}$	$CRR_{7.5}$	Belongs to trans. layer	Clay-like behaviour	FS
289	48.56	32.72	90.78	2.85	0.54	0.78	22.34	0.00	22.34	4.000	No	Yes	2.00
290	48.72	32.75	89.83	2.84	0.54	0.78	22.84	0.00	22.84	4.000	No	Yes	2.00
291	48.88	34.52	86.03	2.79	0.54	0.78	23.53	0.00	23.53	4.000	No	Yes	2.00
292	49.05	38.76	79.84	2.71	0.53	0.78	26.10	0.00	26.10	4.000	No	Yes	2.00
293	49.21	43.87	73.36	2.63	0.51	0.79	32.27	0.00	32.27	4.000	No	Yes	2.00
294	49.38	50.18	65.85	2.54	0.51	0.79	34.77	59.89	94.65	0.131	No	No	0.30
295	49.54	57.58	57.64	2.43	0.50	0.79	40.16	59.30	99.46	0.137	No	No	0.32
296	49.70	71.83	44.65	2.27	0.49	0.80	48.71	56.40	105.11	0.145	No	No	0.33
297	49.87	78.47	38.78	2.20	0.44	0.81	69.83	57.87	127.70	0.191	No	No	0.44
298	50.03	74.13	41.51	2.23	0.47	0.80	57.36	56.75	114.11	0.159	No	No	0.37
299	50.20	61.76	51.57	2.36	0.50	0.79	40.42	57.32	97.74	0.135	No	No	0.31

Abbreviations

Depth: Depth from free surface, at which CPT was performed (ft)
q_t: Total cone resistance
FC: Fines content (%)
I_c: Soil behavior type index
m: Stress exponent
C_N: Overburden correction factor
q_{c1N}: Normalized and adjusted cone resistance
Δq_{c1N}: Cone resistance correction factor due to fines
$q_{c1N,cs}$: Normalized and adjusted cone resistance
$CRR_{7.5}$: Cyclic resistance ratio for M_w=7.5
FS: Factor of safety against soil liquefaction

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
1.31	2.00	0.00	0.00	0.16	0.00	1.48	2.00	0.00	0.00	0.16	0.00
1.64	2.00	0.00	0.00	0.16	0.00	1.80	2.00	0.00	0.00	0.16	0.00
1.97	2.00	0.00	0.00	0.17	0.00	2.13	2.00	0.00	0.00	0.16	0.00
2.30	2.00	0.00	0.00	0.16	0.00	2.46	2.00	0.00	0.00	0.16	0.00
2.63	2.00	0.00	0.00	0.16	0.00	2.79	2.00	0.00	0.00	0.16	0.00
2.95	2.00	0.00	0.00	0.16	0.00	3.12	2.00	0.00	0.00	0.16	0.00
3.28	2.00	0.00	0.00	0.16	0.00	3.44	2.00	0.00	0.00	0.16	0.00
3.61	2.00	0.00	0.00	0.16	0.00	3.77	2.00	0.00	0.00	0.16	0.00
3.94	2.00	0.00	0.00	0.16	0.00	4.10	2.00	0.00	0.00	0.16	0.00
4.26	2.00	0.00	0.00	0.16	0.00	4.43	2.00	0.00	0.00	0.16	0.00
4.59	2.00	0.00	0.00	0.16	0.00	4.76	2.00	0.00	0.00	0.16	0.00
4.92	2.00	0.00	0.00	0.16	0.00	5.08	2.00	0.00	0.00	0.16	0.00
5.25	2.00	0.00	0.00	0.16	0.00	5.41	2.00	0.00	0.00	0.16	0.00
5.58	2.00	0.00	0.00	0.16	0.00	5.74	2.00	0.00	0.00	0.16	0.00
5.91	2.00	0.00	0.00	0.17	0.00	6.07	2.00	0.00	0.00	0.16	0.00
6.23	2.00	0.00	0.00	0.16	0.00	6.40	2.00	0.00	0.00	0.16	0.00
6.56	2.00	0.00	0.00	0.16	0.00	6.73	2.00	0.00	0.00	0.16	0.00
6.89	2.00	0.00	0.00	0.16	0.00	7.05	2.00	0.00	0.00	0.16	0.00
7.22	2.00	0.00	0.00	0.16	0.00	7.38	2.00	0.00	0.00	0.16	0.00
7.55	2.00	0.00	0.00	0.16	0.00	7.71	2.00	0.00	0.00	0.16	0.00
7.87	2.00	0.00	0.00	0.16	0.00	8.04	2.00	0.00	0.00	0.16	0.00
8.20	2.00	0.00	0.00	0.16	0.00	8.37	2.00	0.00	0.00	0.16	0.00
8.53	2.00	0.00	0.00	0.16	0.00	8.69	2.00	0.00	0.00	0.16	0.00
8.86	2.00	0.00	0.00	0.16	0.00	9.02	0.45	0.55	0.43	0.16	0.24
9.19	0.45	0.55	0.43	0.16	0.24	9.35	0.44	0.56	0.42	0.16	0.24
9.51	0.44	0.56	0.41	0.16	0.24	9.68	0.43	0.57	0.41	0.16	0.24
9.84	0.43	0.57	0.41	0.16	0.24	10.01	0.43	0.57	0.41	0.16	0.24
10.17	0.42	0.58	0.40	0.16	0.25	10.34	0.42	0.58	0.40	0.16	0.25
10.50	0.42	0.58	0.40	0.16	0.24	10.66	0.38	0.62	0.37	0.16	0.26
10.83	0.41	0.59	0.40	0.16	0.24	10.99	0.39	0.61	0.38	0.16	0.25
11.15	0.39	0.61	0.38	0.16	0.25	11.32	0.38	0.62	0.37	0.16	0.26
11.48	0.37	0.63	0.37	0.16	0.26	11.65	0.37	0.63	0.36	0.16	0.26
11.81	0.38	0.62	0.37	0.16	0.25	11.97	0.39	0.61	0.38	0.16	0.25
12.14	0.38	0.62	0.37	0.16	0.25	12.30	0.35	0.65	0.35	0.16	0.26
12.47	0.35	0.65	0.35	0.16	0.26	12.63	0.35	0.65	0.35	0.16	0.26
12.79	0.35	0.65	0.35	0.16	0.26	12.96	0.35	0.65	0.35	0.16	0.26
13.12	0.35	0.65	0.35	0.16	0.26	13.29	0.35	0.65	0.35	0.16	0.26
13.45	0.34	0.66	0.35	0.16	0.26	13.62	0.33	0.67	0.34	0.16	0.27
13.78	0.32	0.68	0.33	0.16	0.27	13.94	0.32	0.68	0.33	0.16	0.27
14.11	0.32	0.68	0.33	0.16	0.27	14.27	0.30	0.70	0.32	0.16	0.27
14.44	0.31	0.69	0.33	0.16	0.27	14.60	0.32	0.68	0.33	0.16	0.27
14.76	0.33	0.67	0.34	0.16	0.26	14.93	0.34	0.66	0.34	0.16	0.26
15.09	0.31	0.69	0.33	0.16	0.27	15.26	0.30	0.70	0.32	0.16	0.27
15.42	2.00	0.00	0.00	0.16	0.00	15.58	0.29	0.71	0.32	0.16	0.27
15.75	0.32	0.68	0.33	0.16	0.26	15.91	0.32	0.68	0.33	0.16	0.26
16.08	0.32	0.68	0.33	0.16	0.26	16.24	0.32	0.68	0.33	0.16	0.26
16.40	0.32	0.68	0.33	0.16	0.26	16.57	0.32	0.68	0.33	0.16	0.26
16.73	0.32	0.68	0.33	0.16	0.25	16.90	0.35	0.65	0.35	0.16	0.24

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
17.06	0.37	0.63	0.36	0.16	0.23	17.22	0.38	0.62	0.37	0.16	0.23
17.39	0.59	0.41	0.61	0.16	0.15	17.55	0.66	0.34	0.79	0.16	0.12
17.72	0.66	0.34	0.77	0.16	0.13	17.88	0.68	0.32	0.86	0.16	0.11
18.05	0.67	0.33	0.81	0.16	0.12	18.21	0.51	0.49	0.50	0.16	0.18
18.37	0.84	0.00	0.00	0.16	0.06	18.54	2.00	0.00	0.00	0.16	0.00
18.70	2.00	0.00	0.00	0.16	0.00	18.86	2.00	0.00	0.00	0.16	0.00
19.03	0.62	0.38	0.67	0.16	0.14	19.19	2.00	0.00	0.00	0.16	0.00
19.36	2.00	0.00	0.00	0.16	0.00	19.52	2.00	0.00	0.00	0.16	0.00
19.68	2.00	0.00	0.00	0.16	0.00	19.85	2.00	0.00	0.00	0.16	0.00
20.01	2.00	0.00	0.00	0.16	0.00	20.18	2.00	0.00	0.00	0.16	0.00
20.34	2.00	0.00	0.00	0.16	0.00	20.50	2.00	0.00	0.00	0.16	0.00
20.67	0.33	0.67	0.34	0.16	0.23	20.83	0.35	0.65	0.35	0.16	0.22
21.00	0.37	0.63	0.37	0.16	0.21	21.16	2.00	0.00	0.00	0.16	0.00
21.32	2.00	0.00	0.00	0.16	0.00	21.49	2.00	0.00	0.00	0.16	0.00
21.65	2.00	0.00	0.00	0.16	0.00	21.82	2.00	0.00	0.00	0.16	0.00
21.98	2.00	0.00	0.00	0.16	0.00	22.15	2.00	0.00	0.00	0.16	0.00
22.31	2.00	0.00	0.00	0.16	0.00	22.47	2.00	0.00	0.00	0.16	0.00
22.64	2.00	0.00	0.00	0.16	0.00	22.80	0.30	0.70	0.32	0.16	0.23
22.97	0.39	0.61	0.38	0.16	0.20	23.13	0.51	0.49	0.49	0.16	0.16
23.29	0.46	0.54	0.44	0.16	0.17	23.46	0.36	0.64	0.36	0.16	0.21
23.62	2.00	0.00	0.00	0.16	0.00	23.79	2.00	0.00	0.00	0.16	0.00
23.95	2.00	0.00	0.00	0.16	0.00	24.11	2.00	0.00	0.00	0.16	0.00
24.28	2.00	0.00	0.00	0.16	0.00	24.44	2.00	0.00	0.00	0.16	0.00
24.61	2.00	0.00	0.00	0.16	0.00	24.77	0.33	0.67	0.34	0.16	0.21
24.93	0.36	0.64	0.35	0.16	0.20	25.10	0.38	0.62	0.37	0.16	0.19
25.26	0.38	0.62	0.37	0.16	0.19	25.43	0.37	0.63	0.37	0.16	0.19
25.59	0.37	0.63	0.36	0.16	0.19	25.75	0.34	0.66	0.35	0.16	0.20
25.92	0.32	0.68	0.33	0.16	0.21	26.08	2.00	0.00	0.00	0.16	0.00
26.25	2.00	0.00	0.00	0.16	0.00	26.41	2.00	0.00	0.00	0.16	0.00
26.57	2.00	0.00	0.00	0.16	0.00	26.74	2.00	0.00	0.00	0.16	0.00
26.90	2.00	0.00	0.00	0.16	0.00	27.07	2.00	0.00	0.00	0.16	0.00
27.23	2.00	0.00	0.00	0.16	0.00	27.39	2.00	0.00	0.00	0.16	0.00
27.56	2.00	0.00	0.00	0.16	0.00	27.72	2.00	0.00	0.00	0.16	0.00
27.89	0.26	0.74	0.30	0.16	0.21	28.05	0.27	0.73	0.31	0.16	0.21
28.21	0.31	0.69	0.33	0.16	0.20	28.38	0.30	0.70	0.32	0.16	0.20
28.54	0.29	0.71	0.32	0.16	0.20	28.71	0.30	0.70	0.32	0.16	0.20
28.87	0.30	0.70	0.32	0.16	0.20	29.04	2.00	0.00	0.00	0.16	0.00
29.20	2.00	0.00	0.00	0.16	0.00	29.36	2.00	0.00	0.00	0.16	0.00
29.53	2.00	0.00	0.00	0.16	0.00	29.69	2.00	0.00	0.00	0.16	0.00
29.86	2.00	0.00	0.00	0.16	0.00	30.02	2.00	0.00	0.00	0.16	0.00
30.18	2.00	0.00	0.00	0.16	0.00	30.35	2.00	0.00	0.00	0.16	0.00
30.51	2.00	0.00	0.00	0.16	0.00	30.68	2.00	0.00	0.00	0.16	0.00
30.84	2.00	0.00	0.00	0.16	0.00	31.00	2.00	0.00	0.00	0.16	0.00
31.17	0.33	0.67	0.34	0.16	0.18	31.33	0.38	0.62	0.37	0.16	0.16
31.50	0.33	0.67	0.34	0.16	0.17	31.66	0.32	0.68	0.33	0.16	0.18
31.82	0.36	0.64	0.36	0.16	0.16	31.99	0.54	0.46	0.53	0.16	0.12
32.15	2.00	0.00	0.00	0.16	0.00	32.32	2.00	0.00	0.00	0.16	0.00
32.48	2.00	0.00	0.00	0.16	0.00	32.64	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
32.81	2.00	0.00	0.00	0.16	0.00	32.97	2.00	0.00	0.00	0.16	0.00
33.14	2.00	0.00	0.00	0.16	0.00	33.30	1.90	0.00	0.00	0.16	0.00
33.47	1.03	0.00	0.00	0.16	0.00	33.63	1.18	0.00	0.00	0.16	0.00
33.79	1.24	0.00	0.00	0.16	0.00	33.96	1.06	0.00	0.00	0.16	0.00
34.12	0.84	0.00	0.00	0.16	0.04	34.28	0.82	0.00	0.00	0.16	0.04
34.45	0.61	0.39	0.64	0.16	0.09	34.61	0.54	0.46	0.53	0.16	0.11
34.78	0.52	0.48	0.50	0.16	0.11	34.94	0.56	0.44	0.55	0.16	0.10
35.10	0.60	0.40	0.63	0.16	0.09	35.27	0.79	0.00	0.00	0.16	0.05
35.43	0.58	0.42	0.60	0.16	0.10	35.60	0.47	0.53	0.45	0.16	0.12
35.76	0.64	0.36	0.71	0.16	0.08	35.92	2.00	0.00	0.00	0.16	0.00
36.09	2.00	0.00	0.00	0.16	0.00	36.25	2.00	0.00	0.00	0.16	0.00
36.42	2.00	0.00	0.00	0.16	0.00	36.58	2.00	0.00	0.00	0.16	0.00
36.74	2.00	0.00	0.00	0.16	0.00	36.91	2.00	0.00	0.00	0.16	0.00
37.07	2.00	0.00	0.00	0.16	0.00	37.24	2.00	0.00	0.00	0.16	0.00
37.40	2.00	0.00	0.00	0.16	0.00	37.57	2.00	0.00	0.00	0.16	0.00
37.73	2.00	0.00	0.00	0.16	0.00	37.89	2.00	0.00	0.00	0.16	0.00
38.06	2.00	0.00	0.00	0.16	0.00	38.22	2.00	0.00	0.00	0.16	0.00
38.39	2.00	0.00	0.00	0.16	0.00	38.55	2.00	0.00	0.00	0.16	0.00
38.71	2.00	0.00	0.00	0.16	0.00	38.88	2.00	0.00	0.00	0.16	0.00
39.04	2.00	0.00	0.00	0.16	0.00	39.21	2.00	0.00	0.00	0.16	0.00
39.37	2.00	0.00	0.00	0.16	0.00	39.53	2.00	0.00	0.00	0.16	0.00
39.70	2.00	0.00	0.00	0.16	0.00	39.86	2.00	0.00	0.00	0.16	0.00
40.03	2.00	0.00	0.00	0.16	0.00	40.19	2.00	0.00	0.00	0.16	0.00
40.35	2.00	0.00	0.00	0.16	0.00	40.52	0.34	0.66	0.35	0.16	0.13
40.68	0.40	0.60	0.39	0.16	0.11	40.85	0.31	0.69	0.33	0.16	0.13
41.01	2.00	0.00	0.00	0.17	0.00	41.17	2.00	0.00	0.00	0.16	0.00
41.34	2.00	0.00	0.00	0.16	0.00	41.50	2.00	0.00	0.00	0.16	0.00
41.67	2.00	0.00	0.00	0.16	0.00	41.83	2.00	0.00	0.00	0.16	0.00
41.99	2.00	0.00	0.00	0.16	0.00	42.16	2.00	0.00	0.00	0.16	0.00
42.32	2.00	0.00	0.00	0.16	0.00	42.49	2.00	0.00	0.00	0.16	0.00
42.65	2.00	0.00	0.00	0.16	0.00	42.81	2.00	0.00	0.00	0.16	0.00
42.98	2.00	0.00	0.00	0.16	0.00	43.14	2.00	0.00	0.00	0.16	0.00
43.31	2.00	0.00	0.00	0.16	0.00	43.47	2.00	0.00	0.00	0.16	0.00
43.63	2.00	0.00	0.00	0.16	0.00	43.80	2.00	0.00	0.00	0.16	0.00
43.96	2.00	0.00	0.00	0.16	0.00	44.13	2.00	0.00	0.00	0.16	0.00
44.29	2.00	0.00	0.00	0.16	0.00	44.45	2.00	0.00	0.00	0.16	0.00
44.62	2.00	0.00	0.00	0.16	0.00	44.78	2.00	0.00	0.00	0.16	0.00
44.95	2.00	0.00	0.00	0.16	0.00	45.11	2.00	0.00	0.00	0.16	0.00
45.28	2.00	0.00	0.00	0.16	0.00	45.44	2.00	0.00	0.00	0.16	0.00
45.60	2.00	0.00	0.00	0.16	0.00	45.77	2.00	0.00	0.00	0.16	0.00
45.93	2.00	0.00	0.00	0.16	0.00	46.10	2.00	0.00	0.00	0.16	0.00
46.26	2.00	0.00	0.00	0.16	0.00	46.42	2.00	0.00	0.00	0.16	0.00
46.59	2.00	0.00	0.00	0.16	0.00	46.75	2.00	0.00	0.00	0.16	0.00
46.92	2.00	0.00	0.00	0.16	0.00	47.08	2.00	0.00	0.00	0.16	0.00
47.24	2.00	0.00	0.00	0.16	0.00	47.41	2.00	0.00	0.00	0.16	0.00
47.57	2.00	0.00	0.00	0.16	0.00	47.74	0.27	0.73	0.31	0.16	0.10
47.90	0.28	0.72	0.31	0.16	0.10	48.06	2.00	0.00	0.00	0.16	0.00
48.23	2.00	0.00	0.00	0.16	0.00	48.39	2.00	0.00	0.00	0.16	0.00

:: Liquefaction Potential Index calculation data ::

Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}	Depth (ft)	FS	m(FS)	H_1*m(FS)	d_z	LPI_{ISH}
48.56	2.00	0.00	0.00	0.16	0.00	48.72	2.00	0.00	0.00	0.16	0.00
48.88	2.00	0.00	0.00	0.16	0.00	49.05	2.00	0.00	0.00	0.16	0.00
49.21	2.00	0.00	0.00	0.16	0.00	49.38	0.30	0.70	0.32	0.16	0.09
49.54	0.32	0.68	0.33	0.16	0.08	49.70	0.33	0.67	0.34	0.16	0.08
49.87	0.44	0.56	0.42	0.16	0.07	50.03	0.37	0.63	0.36	0.16	0.07
50.20	0.31	0.69	0.33	0.16	0.08						

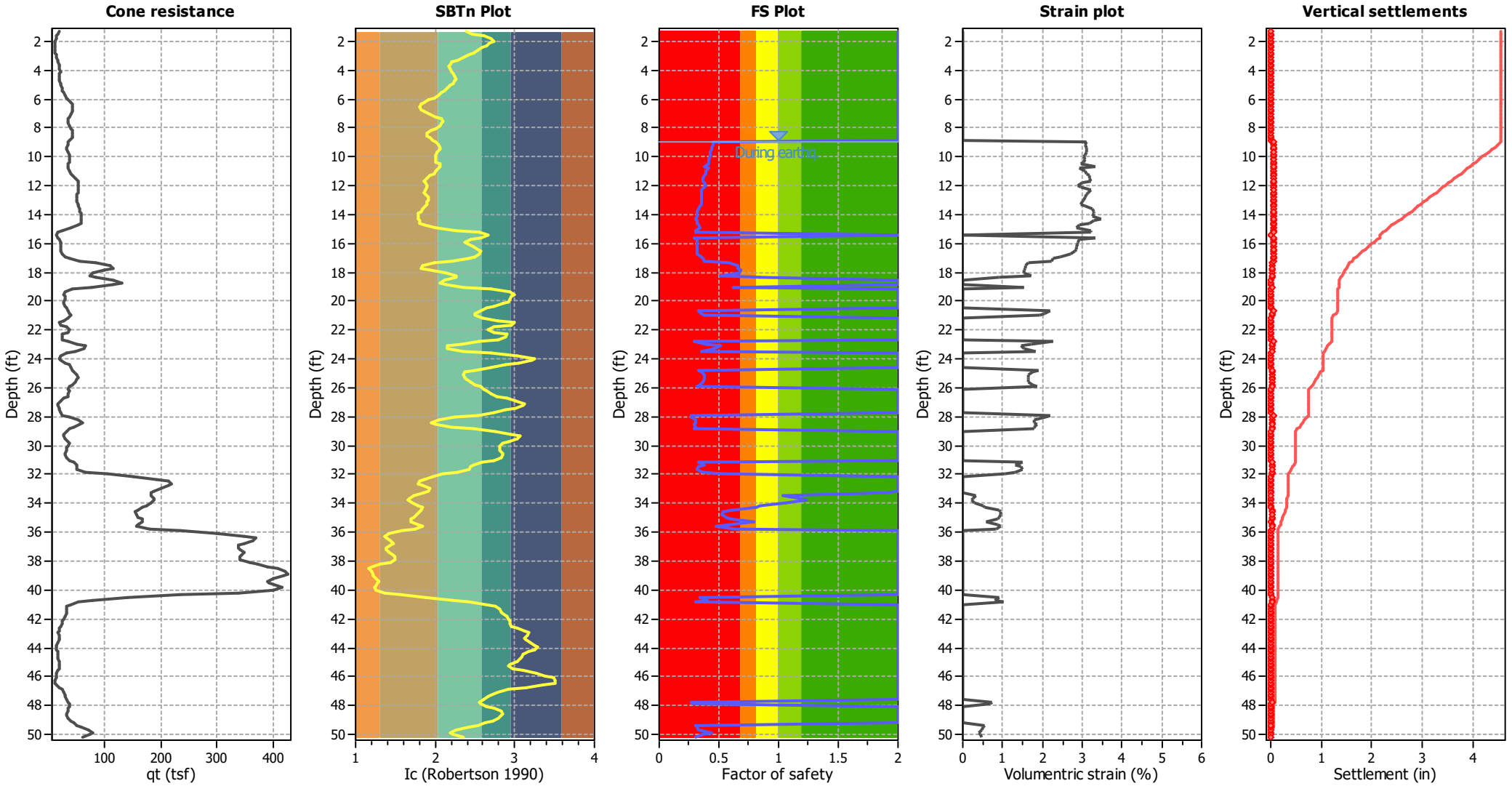
Overall liquefaction potential: 21.32

LPI_{ISH} > 5.0 - Liquefaction manifestation is expected

Abbreviations

FS: Calculated factor of safety for test point
d_z: Layer thickness (ft)
LPI: Liquefaction potential index value for test point

Estimation of post-earthquake settlements



Abbreviations

q_t:	Total cone resistance (cone resistance q_c corrected for pore water effects)
I_c:	Soil Behaviour Type Index
FS:	Calculated Factor of Safety against liquefaction
Volumentric strain:	Post-liquefaction volumentric strain

:: Post-earthquake settlement due to soil liquefaction ::

Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)
9.02	87.75	0.45	3.10	0.85	0.06	9.19	88.32	0.45	3.07	0.84	0.06
9.35	87.20	0.44	3.10	0.84	0.06	9.51	87.12	0.44	3.09	0.84	0.06
9.68	86.30	0.43	3.11	0.84	0.06	9.84	87.51	0.43	3.06	0.83	0.06
10.01	88.11	0.43	3.03	0.83	0.06	10.17	86.73	0.42	3.07	0.83	0.06
10.34	86.93	0.42	3.05	0.82	0.06	10.50	89.25	0.42	2.96	0.82	0.06
10.66	78.80	0.38	3.33	0.82	0.07	10.83	89.24	0.41	2.94	0.82	0.06
10.99	84.75	0.39	3.08	0.81	0.06	11.15	83.97	0.39	3.10	0.81	0.06
11.32	81.88	0.38	3.17	0.81	0.06	11.48	80.89	0.37	3.19	0.81	0.06
11.65	80.08	0.37	3.21	0.80	0.06	11.81	85.86	0.38	2.99	0.80	0.06
11.97	88.13	0.39	2.91	0.80	0.06	12.14	85.62	0.38	2.98	0.79	0.06
12.30	78.97	0.35	3.21	0.79	0.06	12.47	80.13	0.35	3.16	0.79	0.06
12.63	80.61	0.35	3.13	0.79	0.06	12.79	81.43	0.35	3.09	0.78	0.06
12.96	82.20	0.35	3.05	0.78	0.06	13.12	83.28	0.35	3.00	0.78	0.06
13.29	83.63	0.35	2.98	0.77	0.06	13.45	80.22	0.34	3.09	0.77	0.06
13.62	75.63	0.33	3.25	0.77	0.06	13.78	74.61	0.32	3.28	0.77	0.07
13.94	73.95	0.32	3.30	0.76	0.06	14.11	74.31	0.32	3.27	0.76	0.06
14.27	69.36	0.30	3.48	0.76	0.07	14.44	73.05	0.31	3.30	0.76	0.06
14.60	75.40	0.32	3.19	0.75	0.06	14.76	82.70	0.33	2.91	0.75	0.06
14.93	84.06	0.34	2.85	0.75	0.06	15.09	74.26	0.31	3.20	0.74	0.06
15.26	73.51	0.30	3.22	0.74	0.06	15.42	13.72	2.00	0.00	0.74	0.00
15.58	70.49	0.29	3.33	0.74	0.07	15.75	80.32	0.32	2.93	0.73	0.06
15.91	81.26	0.32	2.88	0.73	0.06	16.08	80.71	0.32	2.89	0.73	0.06
16.24	81.81	0.32	2.84	0.72	0.06	16.40	81.18	0.32	2.85	0.72	0.06
16.57	81.84	0.32	2.82	0.72	0.06	16.73	84.64	0.32	2.72	0.72	0.05
16.90	94.24	0.35	2.44	0.71	0.05	17.06	99.97	0.37	2.28	0.71	0.04
17.22	101.82	0.38	2.23	0.71	0.04	17.39	133.85	0.59	1.66	0.71	0.03
17.55	140.21	0.66	1.57	0.70	0.03	17.72	139.94	0.66	1.57	0.70	0.03
17.88	142.01	0.68	1.54	0.70	0.03	18.05	141.22	0.67	1.54	0.69	0.03
18.21	126.95	0.51	1.73	0.69	0.03	18.37	151.17	0.84	0.91	0.69	0.02
18.54	182.28	2.00	0.00	0.69	0.00	18.70	218.51	2.00	0.00	0.68	0.00
18.86	199.27	2.00	0.00	0.68	0.00	19.03	138.21	0.62	1.54	0.68	0.03
19.19	38.83	2.00	0.00	0.67	0.00	19.36	28.00	2.00	0.00	0.67	0.00
19.52	28.44	2.00	0.00	0.67	0.00	19.68	32.72	2.00	0.00	0.67	0.00
19.85	31.66	2.00	0.00	0.66	0.00	20.01	30.24	2.00	0.00	0.66	0.00
20.18	27.01	2.00	0.00	0.66	0.00	20.34	30.84	2.00	0.00	0.66	0.00
20.50	32.90	2.00	0.00	0.65	0.00	20.67	94.72	0.33	2.21	0.65	0.04
20.83	101.73	0.35	2.04	0.65	0.04	21.00	106.46	0.37	1.94	0.64	0.04
21.16	36.11	2.00	0.00	0.64	0.00	21.32	26.40	2.00	0.00	0.64	0.00
21.49	19.11	2.00	0.00	0.64	0.00	21.65	17.12	2.00	0.00	0.63	0.00
21.82	30.31	2.00	0.00	0.63	0.00	21.98	48.15	2.00	0.00	0.63	0.00
22.15	34.43	2.00	0.00	0.62	0.00	22.31	22.78	2.00	0.00	0.62	0.00
22.47	21.53	2.00	0.00	0.62	0.00	22.64	27.67	2.00	0.00	0.62	0.00
22.80	86.47	0.30	2.28	0.61	0.04	22.97	112.63	0.39	1.73	0.61	0.03
23.13	131.35	0.51	1.46	0.61	0.03	23.29	125.18	0.46	1.54	0.61	0.03
23.46	105.22	0.36	1.84	0.60	0.04	23.62	29.43	2.00	0.00	0.60	0.00
23.79	19.68	2.00	0.00	0.60	0.00	23.95	17.91	2.00	0.00	0.59	0.00
24.11	20.66	2.00	0.00	0.59	0.00	24.28	29.06	2.00	0.00	0.59	0.00
24.44	41.94	2.00	0.00	0.59	0.00	24.61	39.21	2.00	0.00	0.58	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)
24.77	98.70	0.33	1.89	0.58	0.04	24.93	106.29	0.36	1.74	0.58	0.03
25.10	111.53	0.38	1.65	0.57	0.03	25.26	112.11	0.38	1.63	0.57	0.03
25.43	110.95	0.37	1.64	0.57	0.03	25.59	109.78	0.37	1.65	0.57	0.03
25.75	103.51	0.34	1.75	0.56	0.03	25.92	96.52	0.32	1.87	0.56	0.04
26.08	33.93	2.00	0.00	0.56	0.00	26.25	34.63	2.00	0.00	0.56	0.00
26.41	37.89	2.00	0.00	0.55	0.00	26.57	30.65	2.00	0.00	0.55	0.00
26.74	27.92	2.00	0.00	0.55	0.00	26.90	19.07	2.00	0.00	0.54	0.00
27.07	16.11	2.00	0.00	0.54	0.00	27.23	15.44	2.00	0.00	0.54	0.00
27.39	17.17	2.00	0.00	0.54	0.00	27.56	18.35	2.00	0.00	0.53	0.00
27.72	19.41	2.00	0.00	0.53	0.00	27.89	76.80	0.26	2.20	0.53	0.04
28.05	80.74	0.27	2.08	0.52	0.04	28.21	94.10	0.31	1.78	0.52	0.04
28.38	93.44	0.30	1.79	0.52	0.04	28.54	88.65	0.29	1.87	0.52	0.04
28.71	92.72	0.30	1.78	0.51	0.04	28.87	92.05	0.30	1.78	0.51	0.04
29.04	28.76	2.00	0.00	0.51	0.00	29.20	25.20	2.00	0.00	0.51	0.00
29.36	23.69	2.00	0.00	0.50	0.00	29.53	25.90	2.00	0.00	0.50	0.00
29.69	33.84	2.00	0.00	0.50	0.00	29.86	34.96	2.00	0.00	0.49	0.00
30.02	31.17	2.00	0.00	0.49	0.00	30.18	30.93	2.00	0.00	0.49	0.00
30.35	26.80	2.00	0.00	0.49	0.00	30.51	25.68	2.00	0.00	0.48	0.00
30.68	26.40	2.00	0.00	0.48	0.00	30.84	28.21	2.00	0.00	0.48	0.00
31.00	30.71	2.00	0.00	0.47	0.00	31.17	101.86	0.33	1.49	0.47	0.03
31.33	114.95	0.38	1.30	0.47	0.03	31.50	102.75	0.33	1.46	0.47	0.03
31.66	99.33	0.32	1.50	0.46	0.03	31.82	111.47	0.36	1.32	0.46	0.03
31.99	137.60	0.54	1.05	0.46	0.02	32.15	189.83	2.00	0.00	0.46	0.00
32.32	198.86	2.00	0.00	0.45	0.00	32.48	201.42	2.00	0.00	0.45	0.00
32.64	200.86	2.00	0.00	0.45	0.00	32.81	211.76	2.00	0.00	0.44	0.00
32.97	221.89	2.00	0.00	0.44	0.00	33.14	202.00	2.00	0.00	0.44	0.00
33.30	180.82	1.90	0.02	0.44	0.00	33.47	164.25	1.03	0.33	0.43	0.01
33.63	168.26	1.18	0.24	0.43	0.00	33.79	169.68	1.24	0.21	0.43	0.00
33.96	165.11	1.06	0.30	0.42	0.01	34.12	157.25	0.84	0.52	0.42	0.01
34.28	156.21	0.82	0.55	0.42	0.01	34.45	144.04	0.61	0.90	0.42	0.02
34.61	138.10	0.54	0.94	0.41	0.02	34.78	136.34	0.52	0.95	0.41	0.02
34.94	139.84	0.56	0.92	0.41	0.02	35.10	143.49	0.60	0.88	0.41	0.02
35.27	155.26	0.79	0.57	0.40	0.01	35.43	142.28	0.58	0.88	0.40	0.02
35.60	131.09	0.47	0.96	0.40	0.02	35.76	146.35	0.64	0.84	0.39	0.02
35.92	208.94	2.00	0.00	0.39	0.00	36.09	269.61	2.00	0.00	0.39	0.00
36.25	324.71	2.00	0.00	0.39	0.00	36.42	342.90	2.00	0.00	0.38	0.00
36.58	325.18	2.00	0.00	0.38	0.00	36.74	305.36	2.00	0.00	0.38	0.00
36.91	302.02	2.00	0.00	0.37	0.00	37.07	299.07	2.00	0.00	0.37	0.00
37.24	302.50	2.00	0.00	0.37	0.00	37.40	308.17	2.00	0.00	0.37	0.00
37.57	317.75	2.00	0.00	0.36	0.00	37.73	285.66	2.00	0.00	0.36	0.00
37.89	306.65	2.00	0.00	0.36	0.00	38.06	312.52	2.00	0.00	0.35	0.00
38.22	330.58	2.00	0.00	0.35	0.00	38.39	344.29	2.00	0.00	0.35	0.00
38.55	360.20	2.00	0.00	0.35	0.00	38.71	374.28	2.00	0.00	0.34	0.00
38.88	377.66	2.00	0.00	0.34	0.00	39.04	374.63	2.00	0.00	0.34	0.00
39.21	350.93	2.00	0.00	0.34	0.00	39.37	330.79	2.00	0.00	0.33	0.00
39.53	342.33	2.00	0.00	0.33	0.00	39.70	359.78	2.00	0.00	0.33	0.00
39.86	368.73	2.00	0.00	0.32	0.00	40.03	366.68	2.00	0.00	0.32	0.00
40.19	318.05	2.00	0.00	0.32	0.00	40.35	196.57	2.00	0.00	0.32	0.00

:: Post-earthquake settlement due to soil liquefaction :: (continued)

Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)	Depth (ft)	$q_{c1N,cs}$	FS	e_v (%)	DF	Settlement (in)
40.52	107.80	0.34	0.93	0.31	0.02	40.68	120.33	0.40	0.82	0.31	0.02
40.85	96.86	0.31	1.02	0.31	0.02	41.01	28.10	2.00	0.00	0.30	0.00
41.17	24.91	2.00	0.00	0.30	0.00	41.34	24.11	2.00	0.00	0.30	0.00
41.50	28.02	2.00	0.00	0.30	0.00	41.67	25.08	2.00	0.00	0.29	0.00
41.83	24.06	2.00	0.00	0.29	0.00	41.99	20.85	2.00	0.00	0.29	0.00
42.16	19.04	2.00	0.00	0.29	0.00	42.32	18.13	2.00	0.00	0.28	0.00
42.49	16.63	2.00	0.00	0.28	0.00	42.65	15.53	2.00	0.00	0.28	0.00
42.81	12.88	2.00	0.00	0.27	0.00	42.98	12.61	2.00	0.00	0.27	0.00
43.14	13.50	2.00	0.00	0.27	0.00	43.31	14.29	2.00	0.00	0.27	0.00
43.47	14.02	2.00	0.00	0.26	0.00	43.63	12.06	2.00	0.00	0.26	0.00
43.80	10.64	2.00	0.00	0.26	0.00	43.96	10.05	2.00	0.00	0.25	0.00
44.13	10.03	2.00	0.00	0.25	0.00	44.29	11.67	2.00	0.00	0.25	0.00
44.45	12.94	2.00	0.00	0.25	0.00	44.62	13.12	2.00	0.00	0.24	0.00
44.78	12.63	2.00	0.00	0.24	0.00	44.95	12.67	2.00	0.00	0.24	0.00
45.11	13.83	2.00	0.00	0.24	0.00	45.28	16.98	2.00	0.00	0.23	0.00
45.44	13.77	2.00	0.00	0.23	0.00	45.60	11.95	2.00	0.00	0.23	0.00
45.77	10.83	2.00	0.00	0.22	0.00	45.93	8.97	2.00	0.00	0.22	0.00
46.10	9.41	2.00	0.00	0.22	0.00	46.26	8.45	2.00	0.00	0.22	0.00
46.42	8.14	2.00	0.00	0.21	0.00	46.59	9.24	2.00	0.00	0.21	0.00
46.75	13.32	2.00	0.00	0.21	0.00	46.92	17.17	2.00	0.00	0.20	0.00
47.08	20.26	2.00	0.00	0.20	0.00	47.24	21.40	2.00	0.00	0.20	0.00
47.41	20.75	2.00	0.00	0.20	0.00	47.57	22.92	2.00	0.00	0.19	0.00
47.74	82.70	0.27	0.74	0.19	0.01	47.90	85.24	0.28	0.71	0.19	0.01
48.06	26.33	2.00	0.00	0.19	0.00	48.23	25.28	2.00	0.00	0.18	0.00
48.39	23.61	2.00	0.00	0.18	0.00	48.56	22.34	2.00	0.00	0.18	0.00
48.72	22.84	2.00	0.00	0.17	0.00	48.88	23.53	2.00	0.00	0.17	0.00
49.05	26.10	2.00	0.00	0.17	0.00	49.21	32.27	2.00	0.00	0.17	0.00
49.38	94.65	0.30	0.55	0.16	0.01	49.54	99.46	0.32	0.52	0.16	0.01
49.70	105.11	0.33	0.48	0.16	0.01	49.87	127.70	0.44	0.38	0.15	0.01
50.03	114.11	0.37	0.43	0.15	0.01	50.20	97.74	0.31	0.49	0.15	0.01

Total estimated settlement: 4.55

Abbreviations

$Q_{tn,cs}$: Equivalent clean sand normalized cone resistance
FS: Factor of safety against liquefaction
e_v (%): Post-liquefaction volumentric strain
DF: e_v depth weighting factor
Settlement: Calculated settlement

:: Strength loss calculation Idriss & Boulanger (2008) ::

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
1.31	18.47	29.56	2.31	68.19	2.39	0.09	0.72
1.48	16.96	27.12	2.76	74.96	2.47	0.08	0.71
1.64	14.72	23.50	3.88	91.11	2.61	0.09	0.62
1.80	13.33	21.26	4.65	98.94	2.69	0.09	0.62
1.97	12.18	19.40	5.05	98.04	2.73	0.08	0.62
2.13	11.49	18.28	4.60	84.01	2.69	0.08	0.62
2.30	11.18	17.76	4.14	73.53	2.64	0.08	0.62
2.46	11.05	17.54	3.69	64.81	2.59	0.08	0.69
2.63	11.41	18.10	3.25	58.87	2.54	0.08	0.69
2.79	11.90	18.89	2.83	53.37	2.48	0.08	0.69
2.95	12.79	20.30	2.47	50.21	2.42	0.08	0.69
3.12	14.05	22.32	2.12	47.40	2.35	0.07	0.69
3.28	15.73	25.00	1.84	46.00	2.28	0.07	0.70
3.44	17.43	27.72	1.00	27.72	2.21	0.07	0.70
3.61	18.63	29.63	1.00	29.63	2.18	0.07	0.70
3.77	19.69	31.33	1.00	31.33	2.17	0.07	0.70
3.94	19.98	31.78	1.58	50.27	2.19	0.08	0.71
4.10	20.31	32.29	1.61	52.04	2.20	0.08	0.71
4.26	19.91	31.63	1.69	53.37	2.23	0.08	0.71
4.43	19.84	31.50	1.74	54.68	2.24	0.08	0.71
4.59	19.56	31.04	1.78	55.34	2.26	0.08	0.71
4.76	19.72	31.29	1.76	55.09	2.25	0.08	0.71
4.92	20.35	32.29	1.70	54.88	2.23	0.08	0.71
5.08	21.69	34.42	1.60	55.00	2.19	0.08	0.72
5.25	23.37	37.11	1.51	56.08	2.15	0.08	0.72
5.41	24.88	39.53	1.45	57.13	2.12	0.08	0.72
5.58	26.37	41.90	1.39	58.41	2.08	0.08	0.72
5.74	28.42	45.19	1.34	60.73	2.04	0.08	0.72
5.91	31.51	50.14	1.00	50.14	1.98	0.08	0.72
6.07	35.15	55.97	1.00	55.97	1.91	0.08	0.71
6.23	38.56	61.43	1.00	61.43	1.86	0.08	0.69
6.40	41.16	65.60	1.00	65.60	1.82	0.08	0.68
6.56	42.78	68.18	1.00	68.18	1.81	0.09	0.69
6.73	43.16	68.77	1.00	68.77	1.83	0.09	0.70
6.89	41.96	66.85	1.00	66.85	1.87	0.09	0.71
7.05	39.31	62.56	1.26	78.70	1.93	0.09	0.73
7.22	36.04	57.30	1.32	75.47	2.01	0.09	0.74
7.38	33.75	53.60	1.39	74.41	2.08	0.09	0.74
7.55	33.49	53.18	1.42	75.50	2.10	0.09	0.74
7.71	34.75	55.19	1.40	77.22	2.09	0.09	0.75
7.87	36.40	57.82	1.36	78.62	2.05	0.09	0.75
8.04	38.58	61.32	1.31	80.44	2.01	0.09	0.74
8.20	41.46	65.91	1.27	83.42	1.94	0.09	0.73
8.37	43.50	68.71	1.24	85.06	1.90	0.09	0.73
8.53	43.39	67.70	1.24	83.72	1.90	0.09	0.72
8.69	41.04	63.77	1.25	79.91	1.92	0.09	0.72
8.86	38.24	59.42	1.28	76.03	1.96	0.08	0.72
9.02	35.58	55.28	1.31	72.50	2.01	0.08	0.72

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
9.19	33.57	52.16	1.35	70.53	2.05	0.08	0.73
9.35	32.63	50.26	1.36	68.58	2.06	0.08	0.72
9.51	32.89	50.02	1.36	67.97	2.05	0.08	0.72
9.68	34.32	51.31	1.33	68.44	2.03	0.08	0.72
9.84	36.11	53.13	1.32	70.02	2.01	0.08	0.72
10.01	37.22	54.05	1.31	70.75	2.00	0.08	0.72
10.17	37.38	53.71	1.31	70.34	2.00	0.08	0.72
10.34	36.69	52.32	1.32	69.01	2.01	0.08	0.72
10.50	33.96	48.34	1.36	65.64	2.05	0.08	0.73
10.66	33.90	47.74	1.36	64.79	2.05	0.07	0.70
10.83	34.12	47.55	1.36	64.48	2.05	0.08	0.73
10.99	37.18	50.93	1.32	67.14	2.01	0.08	0.72
11.15	39.11	53.09	1.30	68.93	1.99	0.08	0.72
11.32	43.22	57.84	1.00	57.84	1.94	0.08	0.71
11.48	47.91	63.24	1.00	63.24	1.89	0.09	0.71
11.65	51.77	67.78	1.00	67.78	1.86	0.09	0.71
11.81	53.18	69.66	1.23	85.39	1.88	0.09	0.72
11.97	52.99	69.39	1.24	85.91	1.90	0.09	0.72
12.14	52.11	67.91	1.24	83.95	1.90	0.09	0.72
12.30	52.01	67.11	1.00	67.11	1.87	0.09	0.70
12.47	51.56	66.23	1.00	66.23	1.87	0.09	0.71
12.63	50.45	64.79	1.00	64.79	1.89	0.09	0.71
12.79	49.06	63.00	1.00	63.00	1.91	0.08	0.71
12.96	49.09	62.81	1.00	62.81	1.91	0.09	0.71
13.12	50.56	64.41	1.24	79.74	1.90	0.09	0.71
13.29	51.89	65.75	1.23	80.98	1.89	0.09	0.72
13.45	52.88	66.55	1.00	66.55	1.88	0.09	0.71
13.62	54.37	67.86	1.00	67.86	1.85	0.09	0.70
13.78	56.49	69.91	1.00	69.91	1.82	0.09	0.69
13.94	58.54	71.83	1.00	71.83	1.79	0.09	0.69
14.11	57.93	70.81	1.00	70.81	1.79	0.09	0.69
14.27	57.50	70.13	1.00	70.13	1.79	0.08	0.68
14.44	57.53	70.08	1.00	70.08	1.81	0.09	0.69
14.60	58.65	71.27	1.00	71.27	1.81	0.09	0.70
14.76	52.39	63.93	1.00	63.93	1.86	0.09	0.71
14.93	39.14	48.62	1.32	64.18	2.01	0.08	0.72
15.09	24.64	31.45	1.81	56.85	2.27	0.07	0.69
15.26	15.44	20.19	3.37	68.06	2.55	0.08	0.69
15.42	13.10	17.17	4.32	74.10	2.66	0.08	0.62
15.58	15.15	19.68	3.59	70.59	2.58	0.08	0.68
15.75	19.03	24.32	2.59	63.02	2.44	0.08	0.71
15.91	22.17	28.09	2.26	63.37	2.38	0.08	0.71
16.08	22.50	28.53	2.40	68.56	2.41	0.08	0.71
16.24	21.86	27.85	2.82	78.44	2.48	0.08	0.71
16.40	21.42	27.36	3.18	87.12	2.53	0.09	0.71
16.57	21.79	27.89	3.53	98.43	2.57	0.09	0.71
16.73	25.03	31.95	3.38	107.92	2.55	0.09	0.72
16.90	30.12	38.17	2.98	113.70	2.50	0.10	0.74

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
17.06	36.90	46.26	2.51	115.95	2.42	0.10	0.75
17.22	55.27	67.41	1.64	110.80	2.21	0.10	0.75
17.39	83.19	98.39	1.30	127.44	1.99	0.15	0.80
17.55	109.57	126.76	1.19	150.72	1.84	0.22	0.81
17.72	114.88	132.18	1.18	155.48	1.82	0.23	0.81
17.88	100.73	116.92	1.25	146.69	1.93	0.18	0.82
18.05	79.96	94.67	1.47	139.17	2.13	0.15	0.81
18.21	72.59	86.91	1.81	156.90	2.27	0.13	0.79
18.37	84.33	100.52	1.78	179.14	2.26	0.17	0.83
18.54	113.88	133.13	1.45	192.79	2.12	0.26	0.87
18.70	129.48	149.80	1.37	205.50	2.06	0.55	0.91
18.86	114.36	132.57	1.47	194.82	2.13	0.35	0.89
19.03	76.52	90.15	2.16	194.80	2.36	0.15	0.81
19.19	42.83	51.59	4.74	244.46	2.70	0.11	0.62
19.36	29.03	35.14	7.78	273.41	2.94	0.10	0.62
19.52	27.23	32.66	8.65	282.46	2.99	0.10	0.62
19.68	28.50	34.00	8.17	277.94	2.96	0.11	0.62
19.85	29.18	34.61	7.73	267.48	2.93	0.11	0.62
20.01	27.48	32.31	7.52	243.04	2.92	0.10	0.62
20.18	27.39	31.76	6.40	203.35	2.84	0.10	0.62
20.34	28.39	32.47	5.17	167.92	2.74	0.10	0.62
20.50	30.88	34.94	4.19	146.51	2.65	0.10	0.62
20.67	34.18	38.35	3.55	136.18	2.58	0.10	0.74
20.83	38.12	42.45	3.03	128.73	2.51	0.11	0.75
21.00	38.83	43.02	2.99	128.79	2.50	0.11	0.76
21.16	34.22	37.88	3.76	142.26	2.60	0.10	0.62
21.32	25.97	28.74	5.80	166.65	2.80	0.10	0.62
21.49	19.86	21.72	8.61	187.03	2.99	0.09	0.62
21.65	21.21	23.15	7.95	184.15	2.95	0.09	0.62
21.82	30.69	33.47	5.06	169.24	2.73	0.10	0.62
21.98	36.29	39.44	4.42	174.24	2.67	0.13	0.62
22.15	33.86	36.68	5.10	186.90	2.74	0.11	0.62
22.31	25.23	27.14	7.25	196.67	2.90	0.09	0.62
22.47	23.15	24.60	6.93	170.46	2.88	0.09	0.62
22.64	25.01	26.39	5.67	149.53	2.78	0.10	0.62
22.80	35.49	37.28	3.38	125.90	2.55	0.09	0.72
22.97	51.25	53.46	2.04	108.89	2.33	0.12	0.77
23.13	65.18	67.40	1.52	102.63	2.16	0.14	0.80
23.29	63.11	64.97	1.52	98.77	2.16	0.13	0.79
23.46	48.03	49.44	2.12	104.76	2.35	0.11	0.76
23.62	31.40	32.30	4.68	151.23	2.70	0.10	0.62
23.79	21.98	22.29	9.47	211.12	3.04	0.09	1.59
23.95	19.15	19.13	13.73	262.52	3.24	0.09	1.37
24.11	22.36	22.44	13.16	295.27	3.22	0.09	1.60
24.28	30.51	30.94	9.69	299.83	3.05	0.10	2.21
24.44	36.82	37.38	6.90	257.83	2.88	0.12	0.62
24.61	40.05	40.27	4.71	189.81	2.70	0.11	0.62
24.77	41.73	41.50	2.99	123.97	2.50	0.10	0.75

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
24.93	46.02	45.51	2.26	102.97	2.38	0.11	0.76
25.10	50.57	49.90	2.11	105.37	2.35	0.11	0.77
25.26	51.86	51.03	2.21	112.91	2.37	0.12	0.77
25.43	50.72	49.70	2.31	114.77	2.39	0.11	0.77
25.59	47.63	46.48	2.67	124.19	2.45	0.12	0.77
25.75	42.82	41.51	2.98	123.80	2.50	0.11	0.75
25.92	38.12	36.71	3.49	128.17	2.57	0.10	0.74
26.08	35.62	34.08	3.82	130.17	2.61	0.10	0.62
26.25	36.45	34.77	4.12	143.14	2.64	0.10	0.62
26.41	35.40	33.61	4.76	160.02	2.71	0.11	0.62
26.57	33.16	31.28	5.47	170.96	2.77	0.10	0.62
26.74	26.72	24.84	7.24	179.86	2.90	0.10	0.62
26.90	21.75	19.84	9.09	180.27	3.02	0.09	1.42
27.07	17.49	15.58	11.17	174.04	3.13	0.09	1.11
27.23	16.89	14.92	10.81	161.36	3.11	0.08	1.07
27.39	17.74	15.67	9.06	141.99	3.02	0.09	1.12
27.56	19.19	16.99	6.97	118.45	2.88	0.09	0.62
27.72	20.57	18.23	5.07	92.38	2.73	0.08	0.62
27.89	24.83	22.21	3.21	71.28	2.53	0.08	0.70
28.05	37.01	33.68	1.72	57.96	2.24	0.08	0.71
28.21	52.16	47.93	1.34	64.15	2.03	0.09	0.74
28.38	59.71	54.93	1.00	54.93	1.95	0.09	0.74
28.54	55.33	50.66	1.32	66.75	2.01	0.08	0.73
28.71	44.81	40.60	1.65	66.88	2.21	0.09	0.73
28.87	36.89	33.01	2.83	93.43	2.48	0.10	0.73
29.04	31.36	27.67	5.27	145.89	2.75	0.10	0.62
29.20	27.91	24.32	8.15	198.17	2.96	0.10	0.62
29.36	26.98	23.34	10.01	233.58	3.07	0.10	1.67
29.53	30.16	26.13	9.22	240.81	3.02	0.10	1.87
29.69	34.28	29.75	7.62	226.69	2.93	0.11	0.62
29.86	36.27	31.43	6.40	201.17	2.84	0.11	0.62
30.02	35.33	30.45	5.89	179.35	2.80	0.10	0.62
30.18	32.51	27.76	5.89	163.54	2.80	0.10	0.62
30.35	30.62	25.94	6.00	155.68	2.81	0.10	0.62
30.51	29.09	24.43	6.43	157.03	2.84	0.10	0.62
30.68	29.70	24.87	6.49	161.30	2.85	0.10	0.62
30.84	31.68	26.52	6.24	165.39	2.83	0.10	0.62
31.00	36.66	30.86	5.10	157.25	2.74	0.10	0.62
31.17	45.07	38.29	3.63	139.02	2.59	0.11	0.75
31.33	49.32	42.01	2.89	121.57	2.49	0.12	0.77
31.50	49.61	42.15	2.67	112.72	2.45	0.11	0.75
31.66	50.64	42.94	2.50	107.50	2.42	0.10	0.75
31.82	66.54	56.99	1.87	106.75	2.29	0.11	0.77
31.99	105.26	91.40	1.40	128.39	2.09	0.15	0.81
32.15	152.62	133.45	1.28	170.45	1.96	0.36	0.88
32.32	193.84	170.13	1.20	204.65	1.85	0.81	0.89
32.48	213.18	187.12	1.15	215.93	1.80	0.92	0.89
32.64	218.38	191.24	1.14	218.83	1.79	0.92	0.89

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
32.81	212.89	185.37	1.20	222.35	1.85	0.92	0.90
32.97	201.32	174.04	1.25	218.18	1.93	0.91	0.91
33.14	189.26	163.05	1.25	203.83	1.92	0.56	0.89
33.30	182.98	157.55	1.21	190.99	1.86	0.44	0.87
33.47	184.02	159.17	1.04	166.17	1.73	0.38	0.85
33.63	186.81	161.72	1.00	161.72	1.67	0.42	0.85
33.79	187.43	161.91	1.00	161.91	1.66	0.44	0.85
33.96	183.42	157.51	1.03	162.66	1.72	0.39	0.85
34.12	175.90	149.99	1.14	171.22	1.79	0.33	0.84
34.28	165.98	140.70	1.19	166.90	1.83	0.30	0.84
34.45	158.47	133.92	1.18	158.46	1.83	0.24	0.82
34.61	154.51	130.35	1.17	151.86	1.81	0.22	0.81
34.78	155.87	131.52	1.12	146.85	1.77	0.22	0.81
34.94	159.33	134.48	1.06	142.16	1.73	0.23	0.81
35.10	166.53	140.74	1.00	140.74	1.69	0.25	0.82
35.27	167.54	141.16	1.00	141.16	1.70	0.31	0.83
35.43	159.67	133.36	1.13	150.78	1.78	0.25	0.82
35.60	156.70	129.94	1.19	155.18	1.84	0.19	0.80
35.76	181.13	151.11	1.08	163.71	1.75	0.26	0.82
35.92	234.84	198.53	1.00	198.53	1.58	0.93	0.90
36.09	299.91	256.57	1.00	256.57	1.42	0.97	0.95
36.25	349.29	299.74	1.00	299.74	1.37	0.99	1.00
36.42	370.40	317.08	1.00	317.08	1.38	1.00	1.01
36.58	363.58	308.97	1.00	308.97	1.45	1.00	1.00
36.74	348.73	295.12	1.00	295.12	1.47	0.99	0.98
36.91	339.35	287.19	1.00	287.19	1.44	0.99	0.98
37.07	338.65	287.62	1.00	287.62	1.38	0.99	0.98
37.24	341.33	289.17	1.00	289.17	1.38	0.99	0.98
37.40	348.75	294.12	1.00	294.12	1.41	0.99	0.98
37.57	342.84	287.08	1.00	287.08	1.47	0.99	0.99
37.73	342.66	285.66	1.00	285.66	1.49	0.99	0.97
37.89	341.09	283.63	1.00	283.63	1.50	0.99	0.98
38.06	358.39	299.39	1.00	299.39	1.43	0.99	0.99
38.22	372.99	315.08	1.00	315.08	1.30	1.00	1.00
38.39	391.40	333.68	1.00	333.68	1.20	1.01	1.01
38.55	408.33	348.70	1.00	348.70	1.17	1.02	1.02
38.71	421.40	357.98	1.00	357.98	1.21	1.02	1.03
38.88	427.31	362.07	1.00	362.07	1.22	1.03	1.03
39.04	418.90	354.08	1.00	354.08	1.22	1.02	1.03
39.21	401.54	337.52	1.00	337.52	1.26	1.01	1.02
39.37	389.68	325.97	1.00	325.97	1.29	1.01	1.00
39.53	393.48	329.08	1.00	329.08	1.27	1.01	1.01
39.70	408.36	341.92	1.00	341.92	1.25	1.02	1.02
39.86	418.10	349.96	1.00	349.96	1.24	1.02	1.03
40.03	402.57	335.48	1.00	335.48	1.26	1.01	1.03
40.19	338.71	278.32	1.00	278.32	1.36	0.98	0.99
40.35	235.90	188.35	1.00	188.35	1.57	0.92	0.88
40.52	139.85	106.64	1.22	130.26	1.88	0.13	0.76

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
40.68	78.81	56.77	1.67	94.52	2.22	0.12	0.78
40.85	53.51	36.90	2.56	94.33	2.43	0.10	0.74
41.01	38.50	25.34	4.11	104.11	2.64	0.09	0.62
41.17	32.89	21.04	5.25	110.50	2.75	0.09	0.62
41.34	32.73	20.71	5.98	123.82	2.81	0.09	0.62
41.50	32.94	20.71	6.30	130.53	2.84	0.10	0.62
41.67	33.03	20.70	6.59	136.33	2.86	0.10	0.62
41.83	30.19	18.71	7.13	133.31	2.89	0.09	0.62
41.99	27.66	16.94	7.46	126.30	2.92	0.09	0.62
42.16	25.19	15.23	7.75	118.05	2.94	0.09	0.62
42.32	23.43	14.00	7.75	108.46	2.94	0.09	0.62
42.49	21.95	12.97	8.08	104.79	2.96	0.09	0.62
42.65	19.74	11.46	9.17	105.06	3.02	0.08	0.82
42.81	18.07	10.31	10.90	112.38	3.11	0.08	0.74
42.98	17.26	9.74	12.17	118.51	3.17	0.08	0.70
43.14	17.90	10.13	11.76	119.11	3.16	0.08	0.72
43.31	18.53	10.51	11.12	116.83	3.13	0.08	0.75
43.47	17.92	10.07	11.35	114.26	3.14	0.08	0.72
43.63	16.35	9.01	12.47	112.33	3.19	0.08	0.64
43.80	14.65	7.87	13.92	109.52	3.25	0.08	0.56
43.96	13.79	7.29	14.67	106.89	3.28	0.08	0.52
44.13	14.30	7.59	13.72	104.11	3.24	0.08	0.54
44.29	15.62	8.41	12.15	102.22	3.17	0.08	0.60
44.45	17.01	9.28	10.79	100.22	3.11	0.08	0.66
44.62	17.46	9.54	10.24	97.71	3.08	0.08	0.68
44.78	17.37	9.45	9.96	94.19	3.07	0.08	0.68
44.95	17.72	9.64	9.25	89.23	3.03	0.08	0.69
45.11	19.60	10.81	7.80	84.34	2.94	0.08	0.62
45.28	20.08	11.08	7.63	84.54	2.93	0.09	0.62
45.44	19.26	10.53	8.45	88.95	2.98	0.08	0.62
45.60	16.65	8.84	10.82	95.70	3.11	0.08	0.63
45.77	14.60	7.53	14.42	108.50	3.27	0.08	0.54
45.93	13.54	6.83	17.38	118.65	3.38	0.08	0.49
46.10	12.55	6.18	20.72	128.15	3.48	0.08	0.44
46.26	12.25	5.97	21.64	129.22	3.51	0.08	0.43
46.42	12.16	5.90	21.74	128.17	3.51	0.07	0.42
46.59	14.36	7.24	16.71	120.95	3.36	0.08	0.52
46.75	18.41	9.73	11.31	110.02	3.13	0.08	0.70
46.92	23.48	12.83	7.43	95.34	2.92	0.09	0.62
47.08	27.23	15.19	5.65	85.88	2.78	0.09	0.62
47.24	29.00	16.44	4.79	78.74	2.71	0.09	0.62
47.41	30.22	17.30	4.27	73.89	2.66	0.08	0.62
47.57	32.02	18.55	3.78	70.04	2.60	0.09	0.62
47.74	34.99	20.52	3.43	70.38	2.56	0.09	0.71
47.90	36.82	21.59	3.51	75.84	2.57	0.09	0.72
48.06	37.03	21.40	4.13	88.40	2.64	0.09	0.62
48.23	35.55	20.09	5.11	102.77	2.74	0.09	0.62
48.39	33.76	18.69	6.13	114.53	2.82	0.09	0.62

:: Strength loss calculation (Idriss & Boulanger (2008) :: (continued)

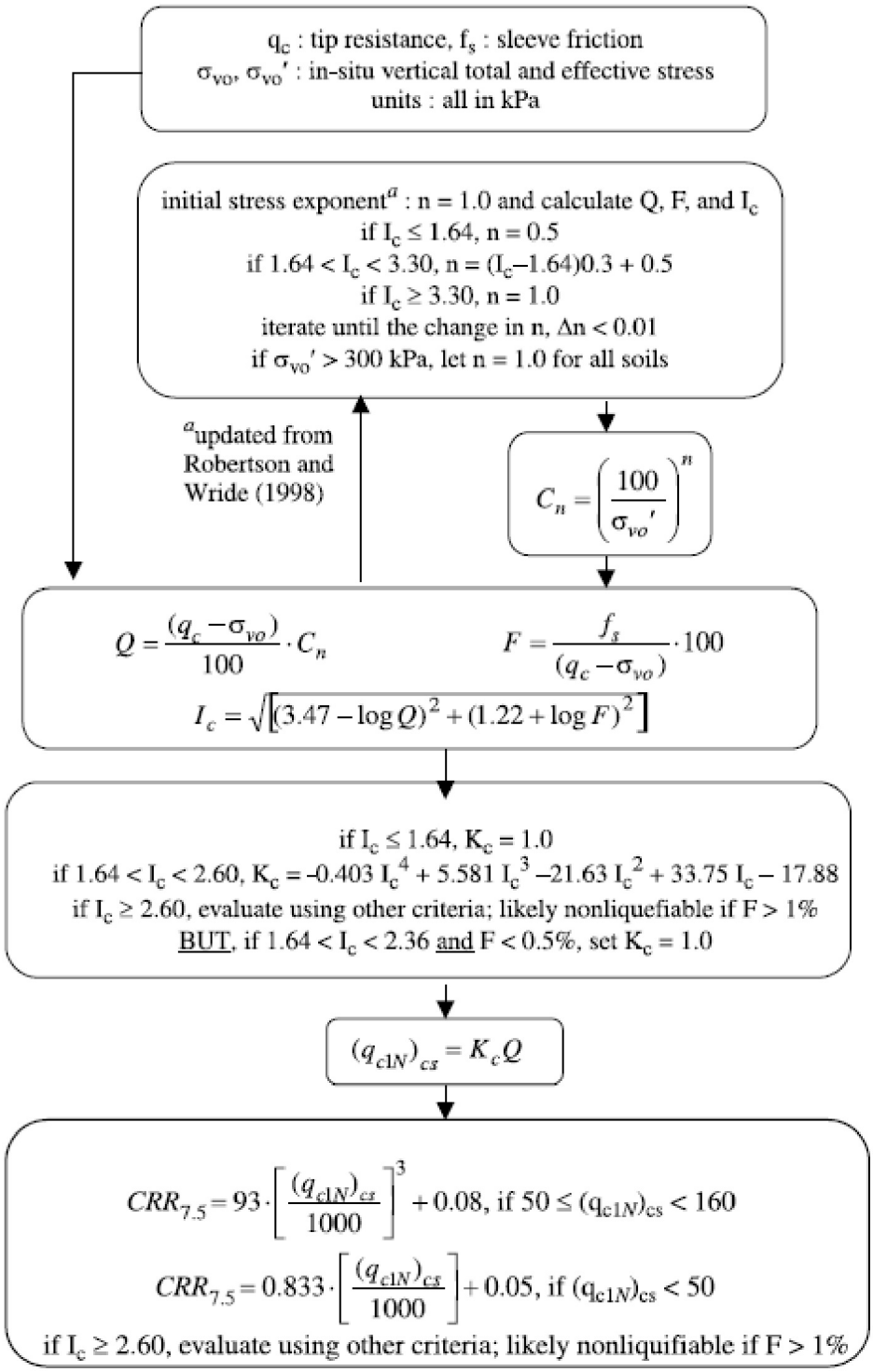
Depth (ft)	q_t (tsf)	Q_{tn}	K_c	$Q_{tn,cs}$	I_c	$S_{u(liq)}/\sigma'_v$	$S_{u(peak)}/\sigma'_v$
48.56	32.72	18.01	6.47	116.42	2.85	0.09	0.62
48.72	32.75	17.97	6.31	113.31	2.84	0.09	0.62
48.88	34.52	19.04	5.70	108.62	2.79	0.09	0.62
49.05	38.76	21.82	4.82	105.14	2.71	0.09	0.62
49.21	43.87	25.21	4.01	101.20	2.63	0.10	0.62
49.38	50.18	29.49	3.23	95.36	2.54	0.10	0.74
49.54	57.58	34.63	2.56	88.50	2.43	0.10	0.75
49.70	71.83	44.83	1.82	81.59	2.27	0.10	0.76
49.87	78.47	49.68	1.61	79.84	2.20	0.13	0.79
50.03	74.13	46.43	1.70	78.83	2.23	0.11	0.77
50.20	61.76	37.40	2.16	80.89	2.36	0.10	0.74

Abbreviations

q_t: Total cone resistance
K_c: Cone resistance correction factor due to fines
$Q_{tn,cs}$: Adjusted and corrected cone resistance due to fines
I_c: Soil behavior type index
$S_{u(liq)}/\sigma'_v$: Calculated liquefied undrained strength ratio
$S_{u(peak)}/\sigma'_v$: Calculated peak undrained strength ratio

Procedure for the evaluation of soil liquefaction resistance, NCEER (1998)

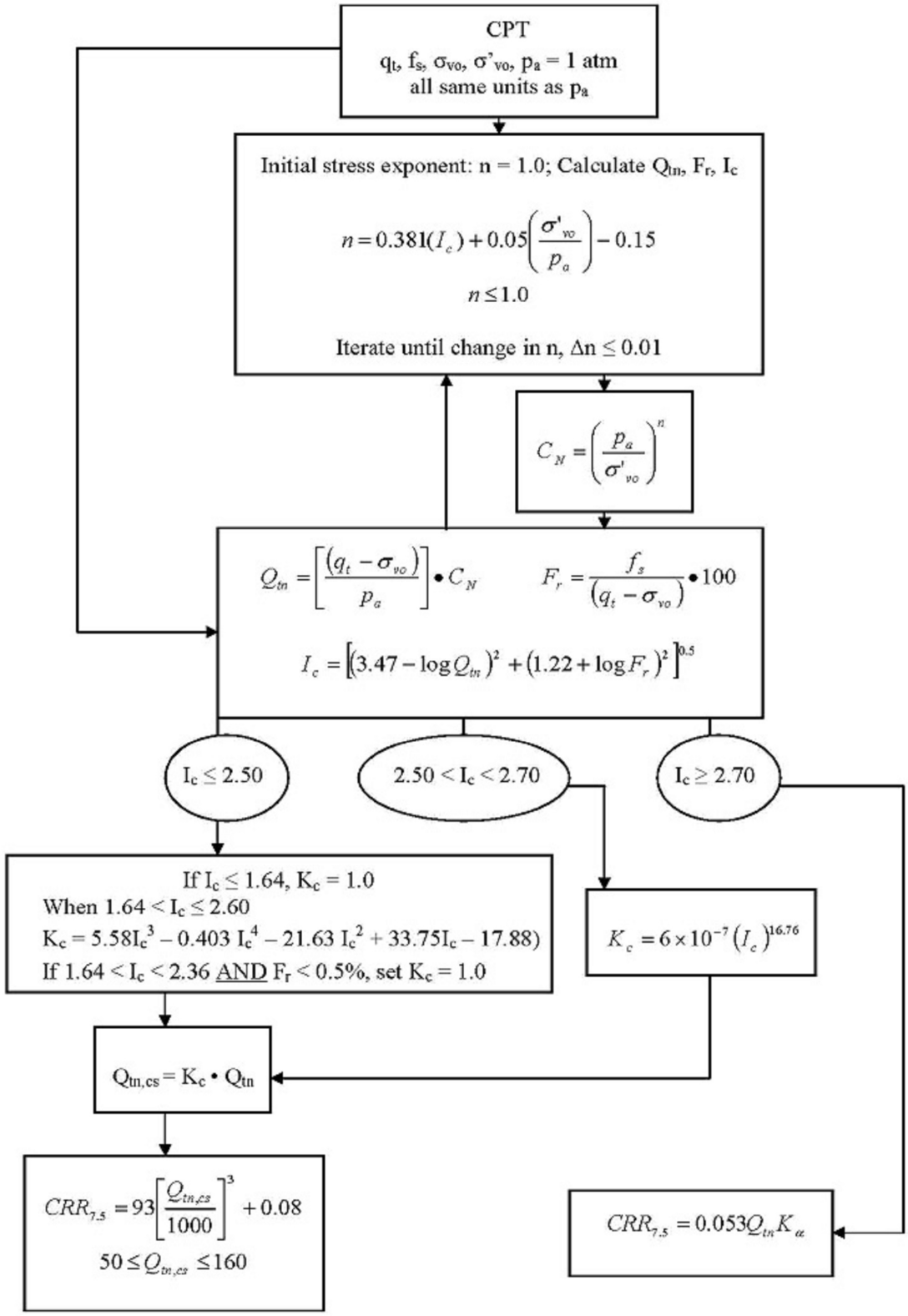
Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. The procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:



[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

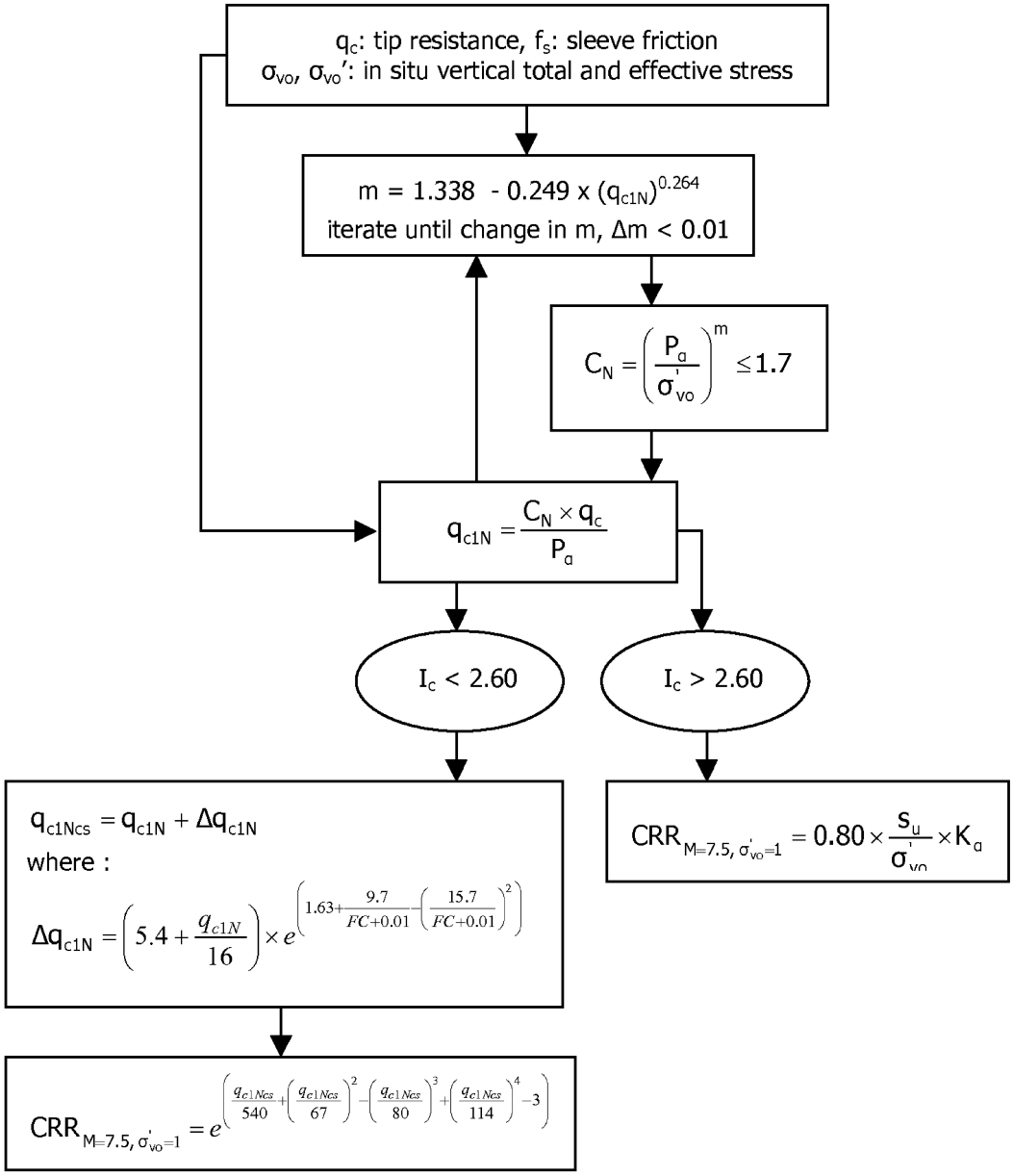
Procedure for the evaluation of soil liquefaction resistance (all soils), Robertson (2010)

Calculation of soil resistance against liquefaction is performed according to the Robertson & Wride (1998) procedure. This procedure used in the software, slightly differs from the one originally published in NCEER-97-0022 (Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils). The revised procedure is presented below in the form of a flowchart[1]:

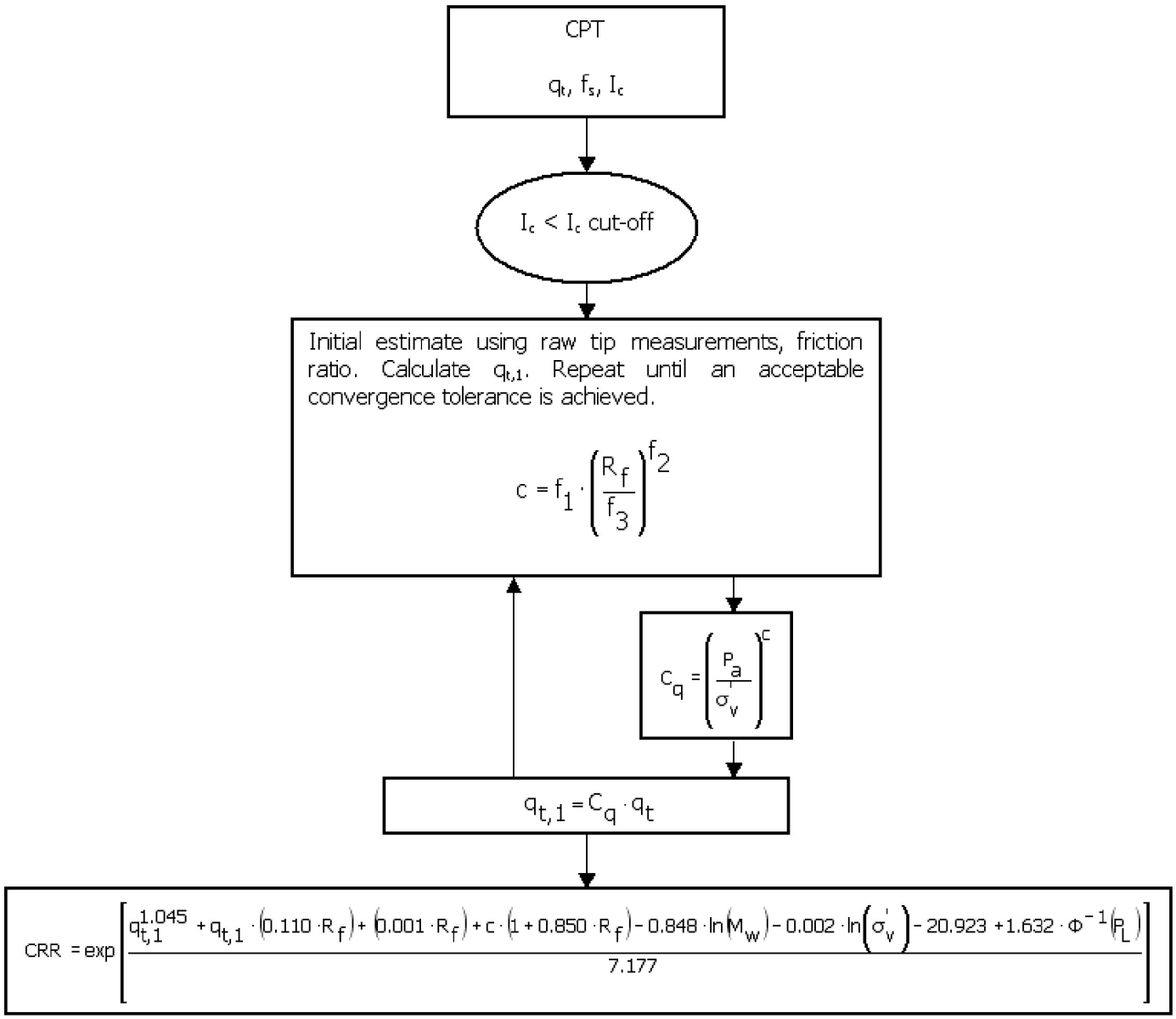


[1] P.K. Robertson, 2009. "Performance based earthquake design using the CPT", Keynote Lecture, International Conference on Performance-based Design in Earthquake Geotechnical Engineering – from case history to practice, IS-Tokyo, June 2009

Procedure for the evaluation of soil liquefaction resistance, Idriss & Boulanger (2008)



Procedure for the evaluation of soil liquefaction resistance (sandy soils), Moss et al. (2006)



Procedure for the evaluation of soil liquefaction resistance, Boulanger & Idriss(2014)

$$FS_{liq} = \frac{CRR_{M=7.5,\sigma'_v=1atm}}{CSR_{M=7.5,\sigma'_v=1atm}}$$

$$CSR_{M=7.5,\sigma'_v=1atm} = 0.65 \frac{\sigma_v}{\sigma'_v} \frac{a_{max}}{g} r_d \frac{1}{MSF} \frac{1}{K_\sigma}$$

$$r_d = \exp\left[\alpha(z) + \beta(z) \cdot M\right]$$

$$\alpha(z) = -1.012 - 1.126 \sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118 \sin\left(\frac{z}{11.28} + 5.142\right)$$

$$K_\sigma = 1 - C_\sigma \ln\left(\frac{\sigma'_v}{P_a}\right) \le 1.1$$

$$C_\sigma = \frac{1}{37.3 - 8.27\left(q_{c1Ncs}\right)^{0.264}} \le 0.3$$

$$MSF = 1 + \left(MSF_{max} - 1\right)\left(8.64 \exp\left(\frac{-M}{4}\right) - 1.325\right)$$

$$MSF_{max} = 1.09 + \left(\frac{q_{c1Ncs}}{180}\right)^3 \le 2.2$$

σ'_v *and* σ_v *at start of earthquake shaking*

$$CRR_{M=7.5,\sigma'_v=1atm} = \exp\left(\frac{q_{c1Ncs}}{113} + \left(\frac{q_{c1Ncs}}{1000}\right)^2 - \left(\frac{q_{c1Ncs}}{140}\right)^3 + \left(\frac{q_{c1Ncs}}{137}\right)^4 - 2.80\right)$$

$$q_{c1Ncs} = q_{c1N} + \Delta q_{c1N}$$

$$\Delta q_{c1N} = \left(11.9 + \frac{q_{c1N}}{14.6}\right) \exp\left(1.63 - \frac{9.7}{FC+2} - \left(\frac{15.7}{FC+2}\right)^2\right)$$

$$q_{c1N} = C_{Ne} \frac{q_c}{P_a}$$

$$C_{Ne} = \left(\frac{P_a}{\sigma'_v}\right)^m \le 1.7$$

$$m = 1.338 - 0.249\left(q_{c1Ncs}\right)^{0.264} \quad with \quad 0.264 \le m \le 0.782$$

$$FC = 80\left(I_C + C_{FC}\right) - 137 \quad with \quad 0\% \le FC \le 100\%$$

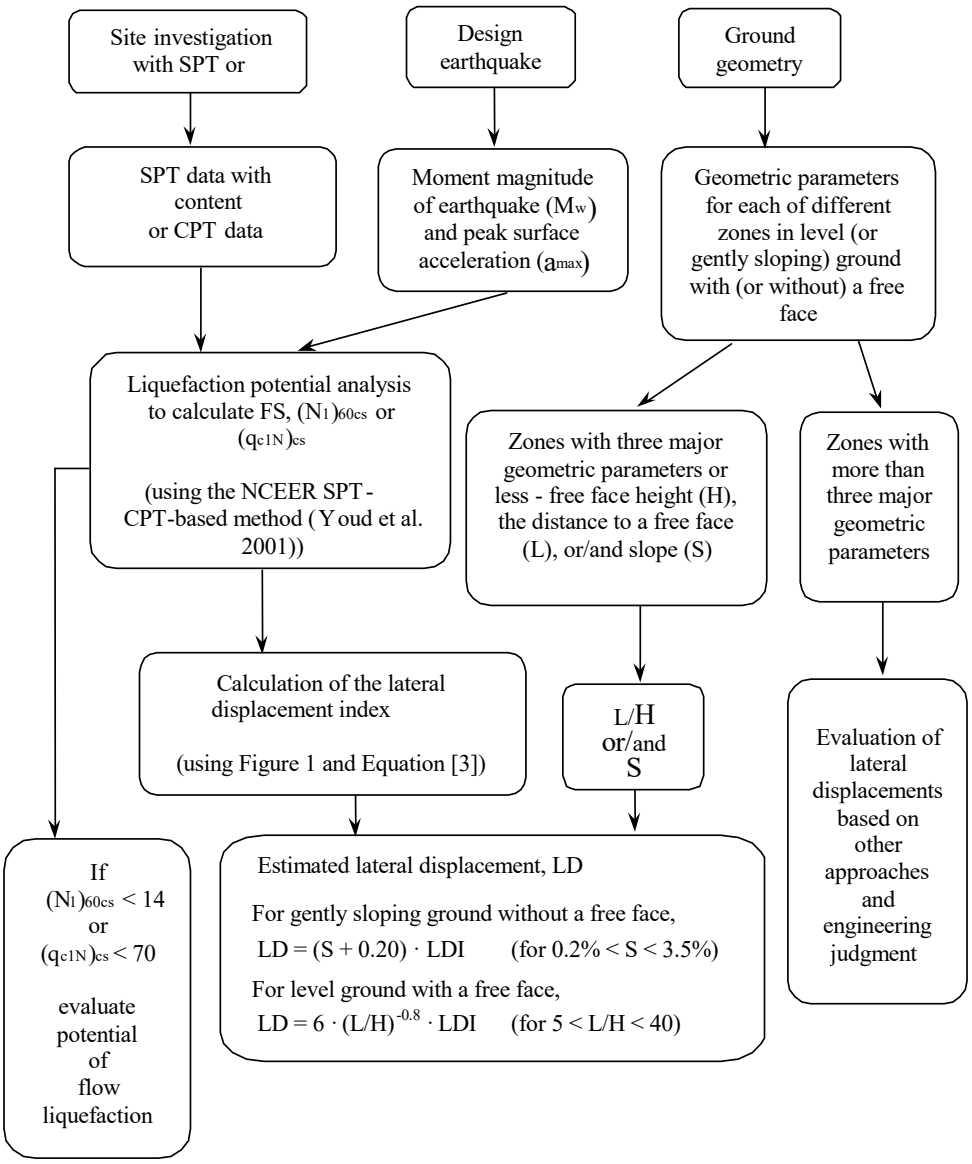
$$I_c = \left[\left(3.47 - \log\left(Q\right)\right)^2 + \left(1.22 + \log\left(F\right)\right)^2\right]^{0.5}$$

$$Q = \left(\frac{q_c - \sigma_{vc}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vc}}\right)^n \; with \; 0.5 \le n \le 1.0 \; per \; Robertson \; \& \; Wride \; (1998)$$

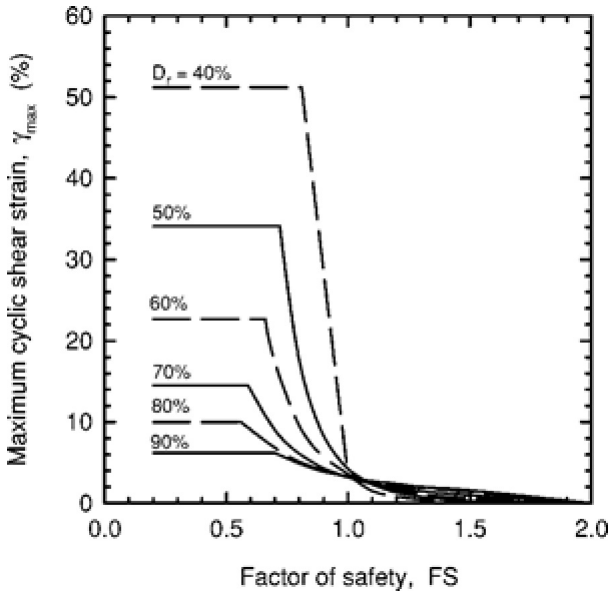
$$F = \left(\frac{f_s}{q_c - \sigma_{vc}}\right) \cdot 100\%$$

σ'_v *at time of CPT sounding*

Procedure for the evaluation of liquefaction-induced lateral spreading displacements



[1] Flow chart illustrating major steps in estimating liquefaction-induced lateral spreading displacements using the proposed approach



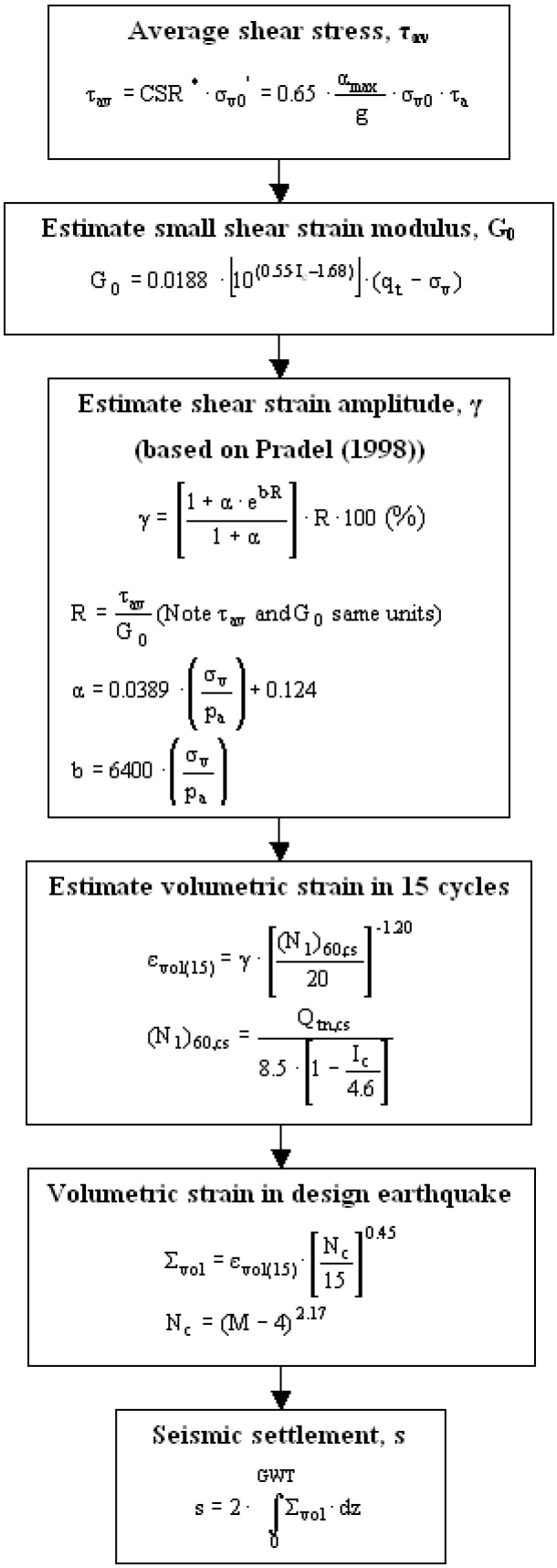
[1] Figure 1

$$LDI = \int_0^{z_{max}} \gamma_{max} dz$$

[1] Equation [3]

[1] "Estimating liquefaction-induced ground settlements from CPT for level ground", G. Zhang, P.K. Robertson, and R.W.I. Brachman

Procedure for the estimation of seismic induced settlements in dry sands



Robertson, P.K. and Lisheng, S., 2010, "Estimation of seismic compression in dry soils using the CPT" FIFTH INTERNATIONAL CONFERENCE ON RECENT ADVANCES IN GEOTECHNICAL EARTHQUAKE ENGINEERING AND SOIL DYNAMICS, Symposium in honor of professor I. M. Idriss, San Diego, CA

Liquefaction Potential Index (LPI) calculation procedure

Calculation of the Liquefaction Potential Index (LPI) is used to interpret the liquefaction assessment calculations in terms of severity over depth. The calculation procedure is based on the methology developed by Iwasaki (1982) and is adopted by AFPS.

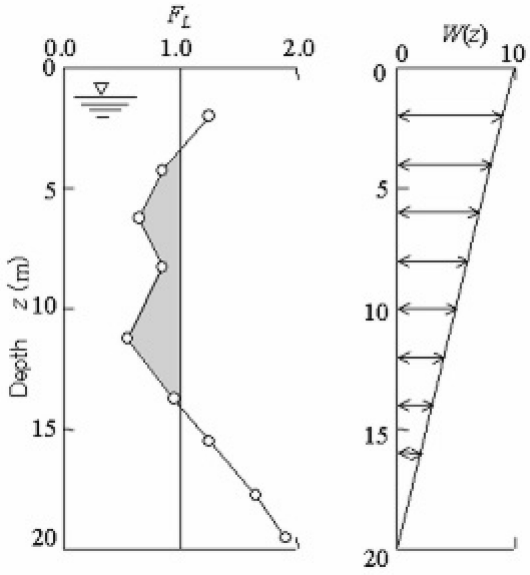
To estimate the severity of liquefaction extent at a given site, LPI is calculated based on the following equation:

$$\mathbf{LPI} = \int_0^{20} (10 - 0{,}5z) \times F_L \times dz$$

where:
F_L = 1 - F.S. when F.S. less than 1
F_L = 0 when F.S. greater than 1
z depth of measurment in meters

Values of LPI range between zero (0) when no test point is characterized as liquefiable and 100 when all points are characterized as susceptible to liquefaction. Iwasaki proposed four (4) discrete categories based on the numeric value of LPI:

- LPI = 0 : Liquefaction risk is very low
- 0 < LPI <= 5 : Liquefaction risk is low
- 5 < LPI <= 15 : Liquefaction risk is high
- LPI > 15 : Liquefaction risk is very high



Graphical presentation of the LPI calculation procedure

Shear-Induced Building Settlement (Ds) calculation procedure

The shear-induced building settlement (Ds) due to liquefaction below the building can be estimated using the relationship developed by Bray and Macedo (2017):

$$Ln(Ds) = c1 + c2 * LBS + 0.58 * Ln\left(Tanh\left(\frac{HL}{6}\right)\right) + 4.59 * Ln(Q) - 0.42 * Ln(Q)^2 - 0.02 * B + 0.84 * Ln(CAVdp) + 0.41 * Ln(Sa1) + \varepsilon$$

where Ds is in the units of mm, c1= -8.35 and c2= 0.072 for LBS ≤ 16, and c1= -7.48 and c2= 0.014 otherwise. Q is the building contact pressure in units of kPa, HL is the cumulative thickness of the liquefiable layers in the units of m, B is the building width in the units of m, CAVdp is a standardized version of the cumulative absolute velocity in the units of g-s, Sa1 is 5%-damped pseudo-acceleration response spectral value at a period of 1 s in the units of g, and ε is a normal random variable with zero mean and 0.50 standard deviation in Ln units. The liquefaction-induced building settlement index (LBS) is:

$$LBS = \sum W * \frac{\varepsilon_{shear}}{z} dz$$

where z (m) is the depth measured from the ground surface > 0, W is a foundation-weighting factor wherein W = 0.0 for z less than Df, which is the embedment depth of the foundation, and W = 1.0 otherwise. The shear strain parameter (ε_shear) is the liquefaction-induced free-field shear strain (in %) estimated using Zhang et al. (2004). It is calculated based on the estimated Dr of the liquefied soil layer and the calculated safety factor against liquefaction triggering (FSL).

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APPENDIX D

GBA REPORT INSERT

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Understand the Geotechnical-Engineering Services Provided for this Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will not likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will not be adequate to develop geotechnical design recommendations for the project.

Do not rely on this report if your geotechnical engineer prepared it:

- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do not rely on an executive summary. Do not read selective elements only. *Read and refer to the report in full.*

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:

- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept*

responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface using various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are not final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals' plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for information purposes only.* To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures.* If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer's services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will not of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration*** by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are not building-envelope or mold specialists.***

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