FOUNDATION REPORTS
For
EARTH RETAINING SYSTEMS
(ERS)

January 2021

DIVISION OF ENGINEERING SERVICES
GEOTECHNICAL SERVICES

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1. INTRODUCTION

The intent of this document is to define the Department's standard of practice for preparation of the Structures Preliminary Geotechnical Report (SPGR), the Preliminary Foundation Report (PFR), and the Foundation Report (FR) for earth retaining systems (ERS). Standardized and consistent report presentations for projects statewide benefit the Department's staff, engineering consultants, bidders, and contractors. Geotechnical Services staff as well as any other organization preparing these reports must comply with the requirements presented herein.

1.1 Reporting for Caltrans Project Delivery

Geotechnical investigation and reporting generally occurs at three stages of the project development process:

- A Structures Preliminary Geotechnical Report (SPGR) to support Advanced Planning Studies, performed during the WBS 150.15 (K Phase).
- A Preliminary Foundation Report (PFR) to support Type Selection, performed during the WBS 160.10 (0 Phase) or 240.70 (1 Phase).
- A Foundation Report (FR) to support the design and construction of the ERS, performed during the WBS 240.80 (1 Phase).

Prepare a separate foundation report for each ERS. If requested by the client, multiple ERS may be placed in one report provided that the report is archived separately at each location along with the applicable LOTB.

Prepare reports to succinctly communicate information pertinent to the recommendations in accordance with the report preparation requirements. The following rules must be followed:

- Use proper grammar, spelling and punctuation.
- Present only useful specific information that is relevant to the recommendations.
- Reference or cite existing standards, specifications or policy only when clarifying, modifying, or disallowing the standard, specification or policy.
- Do not include unsubstantiated disclaimers.
- Provide titles for all figures and tables.
- Tables and figures must be included within the body of the report and located as near as possible to the place where they are first referenced.
- All depth references must have a corresponding elevation in parenthesis.

1.1.1 Reports Prepared by Caltrans Staff

Foundation Reports are written to the Structure Designer, Specification Engineer, and Structure Construction, and are part of the contract.

For reports prepared by Geotechnical Services staff, Foundation Reports must be prepared using the current departmental memorandum format with the subject line of "Foundation Report for ERS Name" or "Preliminary Foundation Report for ERS Name" or "Structures Preliminary Geotechnical Report for ERS Name". Do not include section numbers in the report. First-level and second-level section titles presented in this document (e.g., Geologic and Geotechnical Conditions, and Geology) must be included in the report. Other section titles are optional.

Do not include the Log of Test Borings (LOTB) and/or As-built LOTB as part of the FR. The Engineering Graphics Unit will send Microstation LOTB files and scanned copies of the As-built LOTB sheets to the Structure Designer for inclusion within the Contract Plans.

Sign and stamp reports in accordance with the *Communications and Reporting* section of the *Offices of Geotechnical Design – Quality Management Plan*.

1.1.2 **Reports Prepared by Consultants**

Foundation Reports must include the following: cover sheet, table of contents, main contents per this document, and appendices. The cover of the report and any addenda/amendments to the report must include the following information: Caltrans District, County, Route, Post Mile, Structure Number, Structure Name, and Expenditure Authorization (EA) number.

The LOTB and/or As-built LOTB must be submitted as part of the FR. Refer to the Caltrans Soil and Rock Logging, Classification, and Presentation Manual for direction on the preparation of the LOTB and As-built LOTB.

2. STRUCTURE PRELIMINARY GEOTECHNICAL REPORT (SPGR)

The SPGR is required during the early stages of a project to assist Structure Design in the preparation of an Advanced Planning Study and cost estimate for the District. Often the number, location, and type of ERS are not completely known. As a result, recommendations may be general, and detailed field investigations are usually not warranted. Typical fieldwork consists of a site visit only. The SPGR provides an overview of the existing foundations, site geology, seismic information, and recommendations regarding suitable and unsuitable wall types. If appropriate, the SPGR should also discuss the anticipated field and laboratory work required to support the PFR and FR.

The following topics should be addressed in all Structure Preliminary Geotechnical Reports (SPGR).

2.1 Introduction

Summarize the purpose, scope, and types of work performed to obtain the information supporting the preliminary recommendations. Reference the request memo and applicable plans by date so the reader knows on what plans the recommendations are based. Do not present an exhaustive list of tasks performed, a few sentences are sufficient.

2.2 Project Description

Describe the project location, existing and/or proposed ERS and structures, and pertinent project information, such as the reason for constructing the ERS. A table such as the one below may be used to present the information.

ERS Information Table

ERS ID No.	ERS Type	Begin Station. or PM	End Station. or PM	Length, (feet)	Max. Design Height (feet)	Notes

2.3 Exceptions to Policies and Procedures

List exceptions to Departmental policies and procedures relating to the SPGR. Approved *Request for Exception* forms must be included in the Appendix. Omit this section if there are no exceptions.

2.4 Geotechnical Investigation

Provide an overview of the geotechnical investigation(s) to support the preliminary ERS recommendations.

2.5 Geotechnical Conditions

2.5.1 Geology

Identify the pertinent geologic map and the prominent geologic unit(s) at the structure site. Describe relevant geologic features such as faults, bedding, major joint attitudes, and folds if they influence the design and construction of the structure.

2.5.2 Surface Conditions

Describe site topography, surface water and drainage conditions, cuts and fills, geologic hazards such as landslides and rockfall, and land use history that may affect the proposed structure. Identify existing structures, facilities, and utilities near the proposed structure that may affect its design and construction.

2.5.3 Subsurface Conditions

Provide a generalized description of the known subsurface conditions. The information included within this section may include, but is not be limited to:

- Types of soil/rock, depths to generalized layer breaks, and corresponding elevations
- Pertinent soil/rock conditions such as unsuitable materials (collapsible, expansive foundation materials)

Do not re-create an As-built LOTB in detail in this section. A generalized discussion or table is sufficient.

Example

The Geologic Map of Santa Ana 30' x 60' Quadrangle shows that the site is underlain by Quaternary alluvium. The topography is relatively flat and the site appears free of geologic hazards.

Based on the 1968 As-built Log of Test Borings located approximately 500 feet from the ERS, the alluvial soil at the site can generally be separated into three units. The upper unit consists of very loose to slightly compact silty sand with gravel that extends from the ground surface to a depth of about 15 feet (~ Elev. 950 feet). The middle unit consists of slightly compact to dense sand to a depth of approximately 35 feet (~ Elev. 930 feet). The lowermost unit consists of dense to very dense gravelly sand and sandy gravel with isolated zones of sandy silt and gravel. This unit extends to the maximum explored depth of the borings, which is approximately 60 feet below the ground surface (~ Elev. 905 feet).

2.6 Groundwater

Report groundwater elevation(s) and dates of measurements. Use of a table is recommended if there are numerous borings and/or measurements.

Summary of Groundwater Data

Location or Boring ID	Ground Surface Elevation, (feet)	Date Measured	Depth to Groundwater (feet)	Groundwater Surface Elevation (feet)

Example: Groundwater Present

During the 1998 subsurface investigation at the adjacent bridge, groundwater was encountered in both borings. Groundwater levels varied from elevation 945 feet in February to elevation 938 feet in August. Recent groundwater measurements by the Department of Water Resources at a well located roughly 1300 feet north of ERS site are generally consistent with the 1998 measurements.

Example: Groundwater Not Present

During the 1998 subsurface investigation at the adjacent bridge, groundwater was not encountered in either boring within the explored depth of 100 feet (~ Elev. 900 feet).

Example: Groundwater Information Not Available

Groundwater information was not available based upon the literature search performed.

Example: Groundwater Information Available Nearby

Groundwater measurements available from a DWR monitoring well, located 800 feet northwest of the proposed ERS, had groundwater elevations that varied between 930 ft and 920 feet from 2015 to present.

2.7 As-Built Data

Include brief discussion of relevant As-Built data, such as:

- As-Built LOTB
- Existing or nearby ERS and foundation types
- Other man-made features
- Construction records such as pile driving logs, settlement monitoring data, etc.

2.8 Scour Data

For cases where the ERS is adjacent to a waterway, report the pertinent scour information, including the potential for scour and the predicted magnitude of scour. Otherwise, omit this section.

2.9 Corrosion Evaluation

Report and discuss pertinent site corrosion data.

Example: No information available

Historical corrosion data is not available. For preliminary design purposes the site should be considered non-corrosive based on the presence of predominantly cohesionless material. Corrosion samples will be obtained during the design phase to evaluate the corrosion potential of the site.

Example: Non-Corrosive

Three soil samples and one water sample were collected for corrosion testing during the 2011 subsurface investigation. Corrosion test results for those samples are shown below in Table 1. Based on current Caltrans' standards, the site is considered to be non-corrosive.

Example: Corrosive

During the 2011 subsurface investigation four soil samples were collected for corrosion testing. Corrosion test results for the samples collected from borings RC-11-001 and RC-11-002 are shown below in Table 1. Due to chloride content being greater than 500 ppm in two of the samples tested, the site is considered corrosive based on current Caltrans' standards, and corrosion mitigation is required.

Table 1: Soil Corrosion Test Summary

Boring ID	*Elevation (feet)*	*Minimum Resistivity (Ohm-Cm)*	*pH*	*Chloride Content (ppm)*	*Sulfate Content (ppm)*	*Corrosive?*
RC-11-001	*15.8 to 14.3*	*1544*	*7.24*	*N/A*	*N/A*	*No*
RC-11-001	*-4.2 to -3.2*	*683*	*7.94*	*384*	*432*	*No*
RC-11-002	*-69.1 to -70.6*	*73*	*6.86*	***850***	***1500***	*Yes*
RC-11-002	*-104.1 to -105.6*	*78*	*7.71*	***1000***	***1600***	*Yes*

Caltrans currently defines a corrosive environment as an area where the soil has either a chloride concentration of 500 ppm or greater, a sulfate concentration of 1500 ppm or greater, or has a pH of 5.5 or less. With the exception of MSE walls, soil and water are not tested for chlorides and sulfates if the minimum resistivity is greater than 1,100 ohm-cm.

2.10 **Seismic Information**

Report all information required in Section 2.10.1 in the SPGR. Referencing a Seismic Report that was delivered separately is not acceptable. Information required in Section 2.10.2 should be summarized while referencing the reader to the applicable report (e.g., Fault Rupture Report).

2.10.1 **Ground Motion Hazard**

Include the following information:

a. Site coordinates (latitude and longitude in decimal degrees)

b. The estimated time-average shear wave velocity V_{S30} and how it was determined (e.g., CPT or SPT correlations). See *Design Acceleration Response Spectrum (ARS)* module.
c. For 5% probability of exceedance in 50 years (Return Period = 975 years).
    - The horizontal peak ground acceleration (HPGA or PGA).
    - Deaggregated mean earthquake moment magnitude (M) for the PGA and the mean site-to source distance (R) for the 1.0 second period spectral acceleration.
d. A statement of whether the K_h used in the standardized ERS designs is applicable to the site.

<u>Example</u>

The site is susceptible to strong earthquake induced ground motions during the design life of the ERS.

Based on available subsurface information and Standard Penetration Test (SPT) correlations for determining shear wave velocity, the time-average shear wave velocity (VS30) for the upper 100 feet of soil at the site is estimated to be 980 ft/sec.

The Horizontal Peak Ground Acceleration (PGA) is the ground motion at the site with a 5% probability of exceedance in 50 years (return period = 975 years). The USGS's 2014 NSHM is used as the basis to determine the ground motion. Adjustments for near-fault and basin effects were implemented, when applicable, as per Appendix B of the SDC v2.0.

Caltrans web-based tool ARS Online v3.0 was utilized to determine the preliminary horizontal PGA = 0.27g motion parameters, including the ARS, for the subject structure site.

2.10.2 **Other Seismic Hazards**

The section must include information on the following seismic hazards, as applicable at the site:

a. Surface fault rupture potential (see *Fault Rupture* module)
b. Liquefaction potential (see *Liquefaction Evaluation* module)
c. Seismically induced total and differential ground settlements
d. Lateral spreading potential (see *Lateral Spreading* module)
e. Seismic slope instability
f. Tsunami risk

<u>Example</u>

The structure is not located within an Alquist-Priolo Earthquake Fault Zone or 1000 feet from any Holocene or younger aged fault. Therefore, per MTD 20-10, the structure is not considered susceptible to surface fault rupture hazards.

Groundwater was not encountered within the As-built borings drilled to depths ranging from 70 to 100 feet (~ Elev. 90 to 60 feet) from the existing ground surface. Dense and/or stiff soils were encountered in these borings below a depth of about 60 feet (~Elev. 100 feet) from the existing ground surface. Based on these groundwater and subsurface soil conditions, the project site is not considered susceptible to liquefaction or related seismic hazards, including seismic total or differential ground settlement, and lateral spreading.

The project site and the adjacent areas are relatively flat. The site is located more than 0.5 miles from the nearest coastline and is situated above elevation 40 feet, therefore the risk for tsunami does not exist (per MTD 20-13).

2.11 Geotechnical Recommendations

Provide preliminary recommendations for the ERS. Recommendations must include the following:

- ERS types considered, and advantages and disadvantages of each
- Recommended ERS and alternatives
- ERS location (begin and end station, if available) and geometry (length, height)
- Description of external loadings (surcharge, landslide, groundwater)
- Description of site constraints (environmental, right-of-way, utilities, traffic, construction, etc.)

2.12 Additional Field Work and Laboratory Testing

Describe the anticipated scope and types of fieldwork and testing that may be required to complete the geotechnical investigation. Discuss the potential need for entry permits, task orders, groundwater monitoring, access road construction, lane closures, etc.

2.13 Report Copy List

The SPGR must be addressed to the Structure Designer and copies provided to those listed under Report Distribution in the *Communications and Reporting* module.

3. PRELIMINARY FOUNDATION REPORT (PFR) and FOUNDATION REPORT (FR)

The PFR is prepared after completion of the SPGR and Advanced Planning Study, and prior to the Structure Type Selection. The ERS location, type, height, and length will be better defined, and the site investigation may be complete. The amount of information provided in the PFR will be relative to the information provided by Structure Design and the extent of geotechnical investigation completed.

The FR expands on data provided in the PFR and updates the foundation recommendations based upon final design details provided by Structure Design. The FR becomes part of the contract documents via its inclusion in the Information Handout per Standard Special Provision 2-1.06B, “Supplemental Project Information.”

The following topics, if applicable, must be addressed in the Preliminary Foundation Report and Foundation Report.

3.1 Introduction

Summarize the scope and types of work performed to obtain the information supporting the foundation recommendations.

Example: Preliminary Foundation Report with 0-Phase Drilling

Per the request dated May 3, 2020, this Preliminary Foundation Report has been prepared for the proposed ground anchor wall. The purpose of this report is to summarize the investigations performed and to provide preliminary foundation recommendations. The recommendations presented in this report are based on the draft layout plan dated June 15, 2020, and a subsurface investigation consisting of borings along the wall layout line.

This Preliminary Foundation Report supersedes the Structure Preliminary Geotechnical Report for (Structure Name) dated (Date).

Example: Foundation Report

Per the request dated May 3, 2020, this Foundation Report has been prepared for the proposed ground anchor wall. The purpose of this report is to summarize the investigations performed and to provide foundation recommendations. The recommendations presented in this report are based on the layout plan dated June 15, 2020, and a subsurface investigation.

This Foundation Report supersedes the Preliminary Foundation Report for (Structure Name) dated (Date) and the Structure Preliminary Geotechnical Report for (Structure Name) dated (Date).

3.2 Project Description

Describe the project location, existing and/or proposed ERS, and pertinent project information, such as the reason for constructing the ERS and site constraints, including adjacent structures. Provide project vertical datum reference. A table such as the one below may be used to present the information.

ERS Information Table

ERS ID No.	ERS Type	Begin Northing/Easting Latitude /Longitude		End Northing/Easting (Latitude /Longitude)		Length, (feet)	Maximum Design Height (feet)	Notes

3.3 **Exceptions to Policies and Procedures**

Discuss exceptions to Departmental policies and procedures relating to the PFR/FR. Approved Request for Exception forms must be included in the Appendix. Omit this section if there are no exceptions.

3.4 **Geotechnical Investigation**

Provide an overview of the geotechnical investigation(s) performed to support the foundation recommendations including the number of boreholes/CPT soundings, the maximum depth and elevation, and the types of field and/or downhole testing (e.g., in-situ, geophysical).

<u>*Example*</u>
Geotechnical Investigation was done by reviewing the as-built borings from the 1966 investigation of the adjacent bridge and by drilling three borings along the proposed wall layout line in June 2020. The 1966 foundation investigation consists of one 3-inch mud rotary boring and eight 1-inch driven soil tube borings. In June 2020, three mud rotary borings were drilled to a maximum depth of 50 feet (~ Elev. 230 feet) using a CS2000 drill rig. Standard Penetration Test (SPT) testing was performed at regular intervals to evaluate the engineering properties of the earth materials. The type(s) and location(s) of field testing are shown on the LOTB sheets.

3.5 **Laboratory Testing Program**

Provide an overview of the laboratory testing program, if performed, to support the ERS recommendations. Briefly explain what the tests were used for (e.g. soil classification, settlement, strength parameters).

<u>*Example*</u>
During the most recent field investigation, soil samples were collected from borings RC-20-001 and RC-20-002 for soil classification and liquefaction evaluation. A summary of the test results will be provided in the Appendix, and the test sample locations are shown on the Log of Test Borings.

3.6 **Geotechnical Conditions**

3.6.1 **Geology**

Identify the pertinent geologic map and the prominent geologic unit(s) at the structure site. Describe relevant geologic features such as faults, bedding, major joint attitudes, and folds if they may influence the design and construction of the structure.

3.6.2 **Surface Conditions**

Describe site topography, surface water and drainage conditions, cuts and fills, geologic hazards such as landslides and rockfall, and land use history that may affect the proposed structure. Identify existing structures, facilities, and utilities near the proposed structure that may affect its design and construction.

3.6.3 **Subsurface Conditions**

Provide a generalized description of the known subsurface conditions. The information included within this section may include, but is not be limited to:

- Types of soil/rock, depths to generalized layer breaks, and corresponding elevations
- Pertinent soil/rock conditions such as unsuitable materials (collapsible, expansive foundation materials) or rock rippability.

Do not re-create the LOTB(s) in detail in this section. A generalized discussion or table is sufficient.

Example

The Geologic Map of Santa Ana 30’ x 60’ Quadrangle shows that the site is underlain by Quaternary alluvium. The topography is relatively flat and the site appears free of geologic hazards.

Based on the recent site investigation, the alluvial soil at the site can generally be separated into three units. The upper unit consists of very loose silty sand with gravel that extends from the ground surface to a depth of about 15 feet (~ Elev. 950 feet). The middle unit consists of dense sand to a depth of approximately 35 feet (~ Elev. 930 feet). The lowermost unit consists of dense to very dense gravelly sand and sandy gravel with isolated zones of sandy silt and gravel. This unit extends to the maximum explored depth of the borings, which is approximately 60 feet below the ground surface (~ Elev. 905 feet).

3.7 **Groundwater**

Report groundwater elevation(s) and dates of measurements. Use of the following table is recommended if there are numerous borings and/or measurements. Include discussions relating to the presence of wet or saturated soil when groundwater measurements were not made. Discuss surface water conditions that might influence the design or construction of the foundations. State the groundwater elevation(s) used for analyses and design.

Summary of Groundwater Data

Location or Boring ID	Ground Surface Elevation, (feet)	Date Measured	Depth to Groundwater (feet)	Groundwater Surface Elevation (feet)

Example

As-built LOTB's from the April 1968 subsurface investigation of the adjacent bridge indicate that groundwater was encountered in several borings at that time, and ranged from elevation 19.0 feet to elevation 21.2 feet (NAVD88 datum). During the 2020 subsurface investigation groundwater was measured in Boring RC-20-001 at elevation 15.3 feet, and in Boring RC-20-002 at elevation 13.9 feet. The groundwater elevation used for design was 21 feet.

3.8 As-Built Data

Include brief discussion of relevant As-Built data, such as:

- As-Built LOTB
- Existing or nearby ERS and foundation types
- Other man-made features
- Construction records such as pile driving logs, settlement monitoring data, etc.

3.9 Scour Data

For cases where the ERS is adjacent to a waterway, report the pertinent scour information, including the potential for scour and the predicted magnitude of scour. This information may come from hydraulics reports, geotechnical investigations, BIRIS records, etc. Otherwise, omit this section.

If the field investigation reveals geologic information that contradicts the hydraulics report for this project, then the Geoprofessional must discuss the findings in the PFR/FR and provide that information to author of the hydraulics report so that the scour recommendations can be re-evaluated.

Example: Scour Data Available

The ERS site is underlain by alluvial soil, which are considered potentially scourable. The Structure Hydraulics Branch provided scour information in a report dated January 15, 2020, which states the Long Term (Degradation and Contraction) scour extends to elevation 2285 feet, and the Short Term (Local) scour depth is 3 feet.

<u>*Example: Scour Data Unavailable*</u>

The ERS is adjacent to the Russian River. BIRIS records do not identify any historic scour issues. The Structures Hydraulics Branch has not yet provided a Hydraulic Report to this Office.

3.10 **Corrosion Evaluation**

Include and update the corrosion data from the SPGR based on new findings and field investigations. If corrosion testing was not completed during the geotechnical investigation, provide justification for the corrosion recommendations.

<u>*Example: Non-Corrosive*</u>

Three soil samples and one water sample were collected for corrosion testing during the 2020 subsurface investigation. Corrosion test results for those samples are shown below in Table 1. Based on current Caltrans' standards, the site is considered non-corrosive.

<u>*Example: Corrosive*</u>

During the 2020 subsurface investigation four soil samples were collected for corrosion testing. Corrosion test results for the samples collected from borings RC-20-001 and RC-20-002 are shown below in Table 1. Due to chloride content being greater than 500 ppm in two of the samples tested, the site is considered corrosive based on current Caltrans' standards, and corrosion mitigation is required.

Table 1: Soil Corrosion Test Summary

Boring ID	*Elevation (feet)*	*Minimum Resistivity (Ohm-Cm)*	*pH*	*Chloride Content (ppm)*	*Sulfate Content (ppm)*	*Corrosive?*
RC-11-001	*15.8 to 14.3*	*1544*	*7.24*	*N/A*	*N/A*	*No*
RC-11-001	*-4.2 to -3.2*	*683*	*7.94*	*384*	*432*	*No*
RC-11-002	*-69.1 to -70.6*	*73*	*6.86*	***850***	***1500***	*Yes*
RC-11-002	*-104.1 to -105.6*	*78*	*7.71*	***1000***	***1600***	*Yes*

Caltrans currently defines a corrosive environment as an area where the soil has either a chloride concentration of 500 ppm or greater, a sulfate concentration of 1500 ppm or greater, or has a pH of 5.5 or less. With the exception of MSE walls, soil and water are not tested for chlorides and sulfates if the minimum resistivity is greater than 1,100 ohm-cm.

3.11 **Seismic Information**

Update the seismic information required for the SPGR based on new findings and/or investigations. Summarize analyses and evaluations performed, and recommendations relating to seismic design.

3.11.1 Ground Motion Hazard

Include the following information:

a. Site coordinates (latitude and longitude in decimal degrees)
b. The estimated time-average shear wave velocity V_{S30} and how it was determined (e.g., geophysics, seismic CPT or SPT correlations). See *Design Acceleration Response Spectrum (*ARS) module.
c. For 5% probability of exceedance in 50 years (Return Period = 975 years).
   - The horizontal peak ground acceleration (HPGA or PGA).
   - Deaggregated mean earthquake moment magnitude (M) for the PGA and the mean site-to source distance (R) for the 1.0 second period spectral acceleration.
d. A statement of whether the K_h used in the standardized ERS designs is applicable to the site.

<u>*Example*</u>

The site is susceptible to strong earthquake induced ground motions during the design life of the ERS.

Based on available subsurface information and Standard Penetration Test (SPT) correlations for determining shear wave velocity, the time-average shear wave velocity (VS30) for the upper 100 feet of soil at the site is estimated to be 980 ft/sec.

The Horizontal Peak Ground Acceleration (PGA) is the ground motion at the site with a 5% probability of exceedance in 50 years (return period = 975 years). The USGS's 2014 NSHM is used as the basis to determine the ground motion. Adjustments for near-fault and basin effects were implemented, when applicable, as per Appendix B of the SDC v2.0.

Caltrans web-based tool ARS Online v3.0 was utilized to determine the horizontal PGA = 0.27g motion parameters, including the ARS, for the subject structure site.

3.11.2 Other Seismic Hazards

The section must include information on the following seismic hazards:

a. Surface fault rupture potential (see *Fault Rupture* module)
b. Liquefaction potential (see *Liquefaction Evaluation* module)
c. Effects of Liquefaction, including
   i. Seismically-induced ground surface settlement
   ii. Downdrag of pile foundations (see *Downdrag* module)
   iii. Lateral spreading potential (see *Lateral Spreading* module)
d. Seismic slope stability
e. Tsunami risk (if applicable)

Discuss the findings and results of other seismic-design analyses, all applicable and necessary geotechnical seismic design recommendations (e.g., residual shear strengths for liquefied soil layers, p-y, t-z and q-w curves, seismic downdrag, lateral spreading loads/displacements, nominal bearing resistances of foundations with and without considering liquefaction for seismic retrofit projects, seismic lateral earth pressures, liquefaction mitigation measures, etc.).

<u>*Example: No Hazards*</u>

The site has been determined not to have potential for surface fault rupture, liquefaction, seismic-induced slope failure, or tsunami.

<u>*Example: No Surface Fault Rupture*</u>

The structure is not located within an Alquist-Priolo Earthquake Fault Zone or 1000 feet from any Holocene or younger aged fault. Therefore, per MTD 20-10, the structure is not considered susceptible to surface fault rupture hazards.

<u>*Example: Surface Fault Rupture*</u>

The structure is located within an Alquist-Priolo Earthquake Fault Zone. Therefore, per MTD 20-10, the structure is susceptible to surface fault rupture hazards. Per the attached Fault Rupture Report dated March 15, 2020, the horizontal displacement is estimated to be one foot and the vertical displacement is estimated to be 4 inches.

<u>*Example: Liquefaction*</u>

Due to the presence of loose to medium dense alluvial material and shallow ground water beneath the site, the potential for soil liquefaction is present at the site. Liquefiable zone elevations are summarized in Table 1.

<u>*Example: Effects of Liquefaction*</u>

Liquefaction-induced settlement of the ground surface and pile downdrag are anticipated and summarized in Table 1. Implications of liquefaction on the pile tip elevations will be addressed in the Geotechnical Recommendations section.

Table 1: Liquefaction Potential at Retaining Wall 3

Location	*Liquefaction Elevation (feet)*	*Estimated Seismic-induced Settlement (inches)*	*Downdrag Zone Bottom Elevation (feet)*	*Estimated Downdrag Load (kips/pile)*
Station 0+00 to 0+50	*Elev. 20 to 15 Elev. 0 to -10*	*3*	*-5*	*150*
Station 0+50 to 0+80	*Elev. 10 to -5*	*4*	*-3*	*50*
Station 0+80 to 1+30	*Elev. 20 to 10*	*3*	*12*	*100*

Note: Downdrag loads calculated for 24-inch CIDH concrete piles.

<u>*Example: Lateral Spreading Potential*</u>

Due to the presence of liquefiable soils at shallow depths and relatively high design horizontal peak ground acceleration, an initial lateral spreading hazard assessment was performed by ignoring all lateral resistance contributions from the foundation piles. The analysis was performed in accordance with Steps 1 through 4 of the Lateral Spreading Analysis Example of the Geotechnical Manual. Results of the analysis indicate a lateral spreading hazard potential.

Additional lateral spreading analyses were performed in accordance with MTD 20-15 and the Lateral Spreading Analysis Example module of the Geotechnical Manual. The pile *restraining force versus displacement plot (MTD 20-15 Figure 5, Curve 3) is shown in Figures X and Y.*

Example: Seismic Slope Stability

Seismic slope stability analyses were performed to evaluate the overall stability. The pseudo static analysis with a horizontal seismic coefficient (kh) equal to 0.15g was performed.

Two-dimensional slope stability analyses were performed and the results are included in the appendix. The analyses found the minimum value of factor of safety at the ERS to be approximately 1.25 (resistance factor = 0.8), which meets the accepted minimums for stable abutment slopes (per AASHTO LRFD).

Example: No Tsunami Risk

The site is located about 0.25 miles from the nearest coastline. However, the ground surface elevation at the ERS location ranges from 100 to 120 feet above mean sea level. The site is not located within the tsunami inundation zone shown in California Official Tsunami Inundation Map for the X County (Interactive Map accessed on mm/dd/year).

Based on the above information and per MTD 20-13, a tsunami hazard does not exist at the site.

Example: Tsunami Risk

The site is located about 0.25 miles from the nearest coastline and the ground surface elevation at the ERS location ranges from 10 to 50 feet above mean sea level. The site is located within the tsunami inundation zone shown in California Official Tsunami Inundation Map for the X County (Interactive Map accessed on mm/dd/year).

Based on the above information and per MTD 20-13, a tsunami hazard exists at the site.

3.12 Geotechnical Recommendations

Provide complete and concise recommendations by addressing the applicable topics of this section. At the beginning of the recommendations section, discuss the following:

1. Date of plans used for analysis (e.g., General Plan, Retaining Wall Layout Sheets)
2. Description of the recommended ERS
    a. Location (begin and end station, length, and alignment)
    b. Design Height (maximum and minimum)
    c. Describe the representative cross-sectional geometry and external loads. Reference the plan sheets when possible.
3. Geotechnical design parameters
    a. Soil and rock parameters used for geotechnical and structural analyses, presented in the table below. If applicable, provide parameters for short term and long-term design.
    b. Ground water conditions used for both short term and long-term analyses, including results of seepage or flow analyses.
    c. Description of external loads (surcharge, landslide)
        i. Surcharge load locations, magnitudes, types (line, uniform, etc.) and inclinations

ii. Landslide geometry (depth, location), failure mode, and material properties (strength parameters, unit weights). For structures that stabilize slopes, provide maps and cross sections of the slope modeling.

Design Soil Parameters

Layer No.	Layer boundaries	Group Name	Engineering Parameters
1	Finished grade to elev. 300	Silty Sand (fill)	Φ = 34 degrees, γ = 120 pcf
2	Elev. 285 to 300	Silty Sand	Φ = 33 degrees, γ = 113 pcf
3	Elev. 272 to 285	Poorly-graded Sand	Φ = 34 degrees, γ = 120 pcf
4	Elev. 250 to 272	Silty Sand	Φ= 34 degrees, γ = 114 pcf

3.12.2.1 Conventional Retaining Walls

Foundation recommendations for conventional retaining walls (standard detail or modified standard plan) founded on spread footings must include the following:

- Factored gross nominal bearing resistances (strength and extreme event limit states)
- Total and differential settlement as a result of application of the net bearing pressure (service limit state). Differential settlement should be examined both along the alignment of the ERS and between the front and back of the ERS. Effects of ERS construction on adjacent ground and/or existing structures, utilities and other structures, both above and below ground.
- Permissible net contact stress (service limit state)
- Calculated resistance factor for overall global stability and local slope stability (service and extreme event limit states). Provide the method of analysis.
- Susceptibility of foundation material to erosion and recommended mitigation
- Seismic stability of foundation material: seismic settlement, liquefaction impacts to overall stability (including estimated permanent lateral displacement) and bearing resistance. Provide recommended mitigation measures.
- Surface and subsurface drainage systems – describe locations and system configuration. Reference the Standard Specifications for permeable material and geosynthetic filter fabric type.
- Corrosiveness of foundation and retained soils and/or rock and water sources or drainage systems.
- Foundation improvements required to meet geotechnical design objectives, such as sub-excavation, foundation preloading and surcharge delay periods.
- Minimum unbonded ground anchor length for Type 7 walls that incorporate ground anchors.

The geotechnical analysis results, ERS configuration, and factored load demands (provided in the standard plans or standard detail sheets) must be presented in the table below. A summary *Spread Footing Data Table* must also be provided.

Design Data for Retaining Wall (ERS ID)

ERS Station Limits (feet)	Design Height (feet)	Bottom of Footing Elevation (feet)	Footing Width (feet)	Minimum Footing Embedment Depth (feet)	Limit State	Effective Footing Width (B') (feet)	Gross Uniform Bearing Stress (psf)	Factored Bearing Resistance (psf) Φ_b (q_N) Φ_b =	Net Bearing Stress (psf)	Calculated Settlement at Net Bearing Pressure (inches)	Total Permissible Settlement (inches)
					Service		N/A	N/A			
					Strength IA				N/A	N/A	N/A
					Strength IB				N/A	N/A	N/A
					Extreme I				N/A	N/A	N/A
					Extreme II				N/A	N/A	N/A

Spread Footing Data Table (ERS ID)

ERS Station Limits (feet)	Design Height (feet)	Service Permissible Net Contact Stress (Settlement) (ksf)	Strength/Construction Factored Gross Nominal Bearing Resistance (φ_b=) (ksf)	Extreme Event Factored Gross Nominal Bearing Resistance (φ_b=0.8) (ksf)

Foundation recommendations for conventional retaining walls (standard plan, standard detail or modified standard plan) founded on piles must include the following:

- Design tip elevation for service limit state (settlement)
- Design tip elevations for strength limit state (compression and tension)
- Design tip elevations for extreme event limit state (compression and tension)
- Susceptibility of foundation material to erosion and recommended mitigation
- Seismic stability of foundation material: seismic settlement, liquefaction impacts to overall stability (including estimated permanent lateral displacement) and development of pile down drag loads. Provide recommended mitigation measures.
- Discuss the groundwater condition anticipated over the design life of the ERS. Describe the drainage system location and configuration. Reference the Standard

Specifications for permeable material and geosynthetic filter fabric type. If horizontal drains or underdrains are recommended, include details and specifications.

- Corrosiveness of foundation and retained soils and/or rock and water sources or drainage systems.
- Foundation improvements required to meet geotechnical design objectives, such as sub-excavation, foundation preloading and surcharge delay periods.

The geotechnical analysis results and factored load demands (provided by the structure designer) must be presented in the following tables.

Pile Foundation Design Recommendations

ERS Station Limits (feet)	Pile Type	Cut-off Elevation (feet)	Service-I Limit State Load per Segment (kips)		Total Permissible Segment Settlement (inches)	Required Nominal Resistance (kips)				Design Tip Elevations (feet)	Specified Tip Elevation (feet)	Required Nominal Driving Resistance (kips)
						Strength Limit		Extreme Event				
			Total	Permanent		Comp. ($\varphi_{qs}=0.7$) ($\varphi_{qp}=0.7$)	Tension ($\varphi_{qs}=0.7$)	Comp. ($\varphi_{qs}=1$) ($\varphi_{qp}=1$)	Tension ($\varphi_{qs}=1$)			
										(a-I) (b-I) (a-II) (b-II) (c)		
										(a-I) (b-I) (a-II) (b-II) (c)		

Present the following notes under the Foundation Design Recommendations table. Edit to include only those load cases provided in the table:

- Design tip elevations are controlled by (a-I) Compression (Strength), (b-I) Tension (Strength), (a-II) Compression (Extreme Event), (b-II) Tension (Extreme Event), (c) Settlement

If the design tip elevation for settlement is not calculated because the pile tip is in rock, add the following note:

- Design Tip Elevations for Settlement were not calculated because the piles are tipped in rock.

If applicable:

- The specified tip elevations shall not be raised above the design tip elevations for Tension, Settlement and Lateral Load.
- The lateral design tip elevations provided by Structure Design are the lowest design tip elevation, and are therefore the Specified Tip Elevations. The Required Nominal Driving Resistances are based on the lateral design tip elevations.

Pile Data Table

ERS Station Limits (feet)	Pile Type	Nominal Resistance (kips)		Design Tip Elevation (feet)	Specified Tip Elevation (feet)	Nominal Driving Resistance (kips)
		Compression	Tension			
				(a) (b) (c)		
				(a) (b) (c)		

Present the following Notes under the Pile Data Table. Edit to include only those load cases provided in the table:

- Design tip elevations are controlled by (a) Compression, (b) Tension, (c) Settlement

If the design tip elevations for settlement are not calculated because the pile tips are in rock, add the following note:

- Design Tip Elevations for Settlement not calculated because the piles are tipped in rock.

If applicable, add the following note:

- The specified tip elevations shall not be raised above the design tip elevations for Tension, Settlement and Lateral Load.
- The lateral design tip elevations provided by Structure Design are the lowest design tip elevations, and are therefore the Specified Tip Elevations. The Required Nominal Driving Resistances are based on the lateral design tip elevations.

3.12.2.2 Non-gravity Cantilever Systems

Non-gravity cantilever systems include sheet pile walls, soldier pile walls with or without lagging, tangent pile walls, and secant pile walls.

Foundation recommendations for non-gravity cantilever retaining systems (soldier pile, secant, and tangent or slurry diaphragm retaining walls) must include the following:

- Soil and/or rock parameters for the internal and structural design (unit weight, friction angle and cohesion for soil, and unit weight and shear strength of the rock mass). This applies to the foundation and retained materials.
- Recommended material models, per AASHTO Bridge Design Specifications Section 3.11.5.6, "*Lateral Earth Pressures for Non-Gravity Cantilevered Walls*", for developing the lateral earth pressure distribution (active and passive).
- For designs utilizing vertical piles that carry vertical loads, the factored nominal bearing resistance for piles having a specified tip elevation or embedment length
- For designs utilizing soldier piles, recommendation for minimum pile embedment depth and/or pile tip elevations based on global stability or erosion considerations.
- Total and differential settlement in the retained zone as a result of the placement of fills (service limit state) and pile lateral deflection.
- Calculated resistance factor for overall (global) and local stability (service and extreme event limit states). Provide the method of analysis.

- Seismic stability of foundation material: seismic settlement, liquefaction impacts to overall stability (including estimated permanent lateral displacement) and bearing resistance. Provide recommended mitigation measures.
- Recommended arching factors for all soil and rock types in which soldier piles are embedded.
- A recommendation for lagging or wall face embedment below finish grade based on erosion, local stability and global stability considerations.
- Discuss the groundwater condition anticipated over the design life of the ERS. Describe the drainage system location and configuration. Reference the Standard Specifications for permeable material and geosynthetic filter fabric type. If horizontal drains or underdrains are recommended, include details and specifications.
- Corrosiveness of foundation and retained soils and/or rock and water sources or drainage systems.
- Down drag loads on the piles as a result of the addition of overburden pressure.

3.12.2.3 Anchored Pile Systems

The anchored systems category includes ground anchored pile systems, anchored diaphragm walls, and soil nail walls.

<u>Ground Anchored Pile Systems</u>

Anchored pile systems include a row of drilled vertical soldier piles and sub-horizontal drilled ground anchors installed into an anchorage zone behind the retained soil or rock. Recommendation for anchored pile systems must include:

- Soil and/or rock parameters for the internal and structural design (unit weight, friction angle and cohesion for soil, and unit weight and shear strength of the rock mass). This applies to the foundation and retained materials.
- Recommended material models, per AASHTO Bridge Design Specifications Section 3.11.5.7, "*Apparent Earth Pressure (AEP) for Anchored Walls*", for developing the lateral earth pressure distribution (active and passive).
- For designs utilizing vertical piles that carry vertical loads, the factored nominal bearing resistance for piles having a specified tip elevation or embedment length.
- For designs utilizing soldier piles, recommendation for minimum pile embedment depth and/or pile tip elevations based on global stability or erosion considerations.
- Total and differential settlement in the retained zone as a result of the placement of fills (service limit state) and pile lateral deflection.
- Calculated resistance factor for overall (global) and local stability (service and extreme event limit states). Provide the method of analysis.
- Seismic stability of foundation material: seismic settlement, liquefaction impacts to overall stability (including estimated permanent lateral displacement) and bearing resistance. Provide recommended mitigation measures.
- Recommended arching factors for all soil and rock types in which soldier piles are embedded.
- A recommendation for lagging or wall face embedment below finish grade based on erosion, local stability and global stability considerations.
- Discuss the groundwater condition anticipated over the design life of the ERS. Describe the drainage system location and configuration. Reference the Standard Specifications for permeable material and geosynthetic filter fabric type. If horizontal drains or underdrains are recommended, include details and specifications.

- Corrosiveness of foundation and retained soils and/or rock and water sources or drainage systems.
- The minimum unbonded ground anchor lengths to satisfy static and seismic overall stability (consider providing in tabular format)
- Recommended ground anchor inclination.
- For ERS constructed to retain slope failures, provide the total required earth retention force and the associated global stability resistance factor.
- Recommended location of ground anchors subject to performance testing.
- Down drag loads on the piles as a result of the addition of overburden pressure.

Anchored Diaphragm Walls

Anchored diaphragm walls utilize a reinforced concrete diaphragm as the facing with no pile foundation. The facing typically bears on foundation soil, embedded below a toe bench. Recommendations for anchored diaphragm wills must include:

- Soil and/or rock parameters for the internal and structural design (unit weight, friction angle and cohesion for soil, and unit weight and shear strength of the rock mass). This applies to the foundation and retained materials.
- Total and differential settlement in the retained zone as a result of the placement of fills (service limit state) and wall lateral deflection.
- Calculated resistance factor for overall (global) and local stability (service and extreme event limit states). Provide the method of analysis.
- Seismic stability of foundation material: seismic settlement, liquefaction impacts to overall stability (including estimated permanent lateral displacement) and bearing resistance. Provide recommended mitigation measures.
- A recommendation for lagging or wall face embedment below finish grade based on erosion, local stability and global stability considerations.
- Discuss the groundwater condition anticipated over the design life of the ERS. Describe the drainage system location and configuration. Reference the Standard Specifications for permeable material and geosynthetic filter fabric type. If horizontal drains or underdrains are recommended, include details and specifications.
- Corrosiveness of foundation and retained soils and/or rock and water sources or drainage systems.
- The minimum unbonded ground anchor lengths to satisfy static and seismic overall stability (consider providing in tabular format)
- Recommended ground anchor inclination.
- For ERS constructed to retain slope failures, provide the total required earth retention force and the associated global stability resistance factor.
- Recommended location of ground anchors subject to performance testing.
- Down drag loads on the wall elements as a result of the addition of overburden pressure.

Soil Nail Walls

Soil Nail Wall recommendations must be reported in accordance with this document and the *Soil Nail Wall* module of the Geotechnical Manual.

3.12.2.4 Mechanically Stabilized Embankment (MSE)

MSE recommendations must be reported in accordance with this document and the applicable Geotechnical Manual module.

- *Mechanically Stabilized Embankment (Caltrans Pre-Designed)*
- *Mechanically Stabilized Embankment (Non-Standard Design)*

3.12.2.5 Prefabricated Modular Walls

Prefabricated modular wall types typically used by Caltrans include crib walls, gabion walls, and mortarless concrete block gravity walls. Typically crib walls utilize a geometry shown in the Caltrans Standard Plans. Geotechnical Services typically determines the geometry and detailing of gabion walls and mortarless concrete block walls.

Foundation recommendations for all types of Prefabricated Modular Walls must include the following:

- Soil and/or rock parameters for the internal and structural design (unit weight, friction angle and cohesion for soil, and unit weight and shear strength of the rock mass). This applies to the foundation and retained materials.
- Factored gross nominal bearing resistances (strength and extreme event limit states)
- Total and differential settlement as a result of application of the net bearing pressure (service limit state). Differential settlement should be examined both along the alignment of the wall face and between the front and back of the system. Effects of ERS construction on adjacent ground and/or existing structures, utilities and other structures, both above and below ground.
- Permissible net contact stress (service limit state)
- Calculated resistance factor for overall (global) and local stability (service and extreme event limit states). Provide the method of analysis.
- Seismic stability of foundation material: seismic settlement, liquefaction impacts to overall stability (including estimated permanent lateral displacement) and bearing resistance. Provide recommended mitigation measures.
- Foundation improvements required to meet geotechnical design objectives, such as sub-excavation, foundation preloading and surcharge delay periods.
- The minimum embedment depth of the prefabricated modular wall and toe bench width based on erosion, overall stability, bearing resistance and settlement analyses.
- Minimum base width to meet overall stability requirements
- Discuss the groundwater condition anticipated over the design life of the ERS, and if a blanket drain is required. Describe the drainage system location and configuration. Reference the Standard Specifications for permeable material and geosynthetic filter fabric type.
- Slope or batter of the face used in slope modeling, grades and slopes analyzed.
- Corrosiveness of foundation and retained soils and/or rock and water sources or drainage systems.
- Foundation improvements required to meet geotechnical design objectives, such as sub-excavation, foundation preloading and surcharge delay periods.
- Type of crib or configuration of the gabions (such as stepped front, or smooth front and stepped rear).
- Infill considerations, or facing closure recommendations

- Indicate the weight of the mature landscaping included in the ERS modeling and stability calculations.

Foundation recommendations for Geotechnical Services designed gabion and mortarless concrete block walls include all those listed above for prefabricated modular walls, and the following:

- Cross sections showing wall geometry. For gabion walls this includes the thickness and number of baskets, the basket dimensions and the size of the rock infill.
- Wall batter
- Analysis of base sliding
- Active earth pressure coefficient (k_a) and passive earth pressure coefficient (k_p)
- Maximum external loading
- Design criteria for the General notes on the contract plans
- Information for estimating purposes
- Specifications requirements/additions including manufacturers information when necessary

3.12.2.6 Other ERS Technologies

Reports for ERS not previously discussed should include applicable topics listed for any of the ERS discussed here, as well as additional ERS specific information necessary to prepare a design that is in compliance with LRFD specifications.

3.13 Notes for Specifications

Omit this section for the Preliminary Foundation Report.

This section provides recommendations to the Specifications Engineer for inclusion and editing of Standard Special Provisions and developing NSSPs. Refer to the *Geotechnical Notes for Specifications* module for guidance on how to prepare this report section.

<u>Note:</u> This is a new section in this reporting standard. The information placed in this section used to be placed in the “Construction Considerations” section. This updated version of FR for ERS separates communication to the Specifications Engineer (Notes for Specifications) and to Construction (Notes for Construction).

3.14 Notes for Construction

Omit this section for the Preliminary Foundation Report.

Notes for Construction are written to State construction personnel and contractors. Specific geologic conditions that are relevant to construction inspection should be cited in this section to ensure that both the intent of the geotechnical design is met and construction is successful.

Address topics when applicable, such as:

- Recommended construction inspection to be performed by Geotechnical Services personnel
- Instructions to contact Geotechnical Services if a geologic condition is not encountered. For example, the top of rock elevation varies from what was assumed.

3.15 **Report Copy List**

Reports must be addressed to the Structure Designer and copies provided to those listed under Report Distribution in the Communications and Reporting section of the Offices of Geotechnical Design – Quality Management Plan.

3.16 Appendices

The Foundation Report appendices provide detailed information supporting ERS type selection, analyses, and recommendations. Reports prepared by Geotechnical Services staff must include the following (in the order presented, numerated as Appendix I, Appendix II, …), if produced during the investigation:

- Approved "Request for Exception" forms
- Field-generated Geologic Map and Cross-Sections: Do not include copies of published maps. Limit to 8 ½ x 11.
- Geophysical Test Reports
- Laboratory Test Data (including Corrosion Test Report) – Organized by test type. In addition to the raw laboratory test results, organize and provide the summary tables and graphs of the interpretation of laboratory test results.
- Pile Drivability Study
- Soil parameters for Lateral analysis and/or P-Y Curves

Optional:

- Photos: Relevant to the investigation findings, design recommendations, and construction. Photos that supplement text should be embedded in the report if feasible.
- Photos of Rock Cores

Reports prepared by consultants must include the following (in the order presented, numerated as Appendix I, Appendix II, …):

All Foundation Reports:

- Appendix I: Site Map showing project location
- Appendix II: Log of Test Borings (including as-built LOTB)
- Appendix III: Field Exploration and Testing: Data acquired from field exploration and testing such as surface geologic mapping and surface geophysical surveys, logs from the Cone Penetration Test, Pressuremeter, Dilatometer, and in-situ Vane Shear Tests, Borehole Geophysical logging, indicator pile tests, Piezometer Readings, etc.
- Appendix IV: Calculation Package
    - The objectives of each calculation, such as time rate of settlement or bearing capacity.
    - List assumptions used to simplify the calculation
    - The developed geotechnical model for each calculation
    - The equations used and meaning of the terms used in the equations
    - A copy of the curves or tables used in the calculation and their source or reference.
    - The load and resistance factors, or factor of safety, used for the design
    - If the calculation is performed using computer spreadsheets – step-by-step calculation for one example to demonstrate the basis of the spreadsheet. A computer spreadsheet is not a substitute for the step-by-step calculation.
    - Summary of the calculation results that form the basis of geotechnical recommendations, including a sketch of the design, if appropriate.
- Previous Caltrans review comments and responses

If produced during the investigation:

- Approved "Request for Exception" forms
- Field-generated Geologic Map and Cross-Sections: Do not include copies of published maps. Limit to 8 ½ x 11.
- Photos: Relevant to the investigation findings, design recommendations, and construction. Photos that supplement text should be embedded in the report if feasible.
- Photos of Rock Cores
- Geophysical Test Reports
- Laboratory Test Data (including corrosion) – Organized by test type. In addition to the laboratory test results, summarize and provide the summary tables and graphs of the interpretation of laboratory test results.
- Pile Drivability Study
- Soil parameters for Lateral analysis and/or P-Y Curves