Geotechnical Design Report
Highway 7 over Nicomen Slough Dewdney Bridge 00596 Replacement Project
Dewdney, BC

PRESENTED TO

British Columbia Ministry of Transportation and Infrastructure

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EXECUTIVE SUMMARY

Tetra Tech Canada Inc. (Tetra Tech) was retained by the British Columbia Ministry of Transportation and Infrastructure (BC MoTI) to provide geotechnical engineering services for the Highway 7 over Nicomen Slough Dewdney Bridge No. 00596 Replacement Project. The site is located along Highway 7 in Dewdney, BC, approximately 12 km east of Mission, BC. This project involves the replacement of the existing Dewdney Bridge with a two-lane pile supported bridge. Approach fills will be required to create vehicle access to the bridge.

To determine the soil strata properties for the conceptual design, Tetra Tech completed a geotechnical site exploration between September 3 and 27, 2019, which consisted of 21 testholes (solid stem auger and sonic) and four (4) CPT/SCPT soundings, conducted either along Highway 7, on the existing dikes or on the existing bridge. Additional geotechnical exploration was performed between December 21, 2020 and January 20, 2021 in order to infill the gaps and/or extend the existing geotechnical information to resolve uncertainties in the soil profiles for the final detailed design. The encountered soils generally comprise granular fill overlaying thick layers of interbedded sand and silt, with a potential for liquefaction triggering to depth of about 40 m below the top of the existing dikes for the 1:2,475 event. Neither till nor bedrock were encountered during drilling. Groundwater depths on either side of the slough are similar to the water level in the slough.

Tetra Tech carried out site-specific seismic ground response analyses using SHAKE2000 (Ordóñez 2012). The firm-soil (Class C) input for the site response evaluation was defined in accordance with the local seismic conditions provided by the NBCC 2015. Site-specific results are presented in the following table.

Return Period	Sa(<0.6)	Sa(0.9)	Sa(1.1)	Sa(2.0)	Sa(2.5)	Sa(3.0)	Sa(5.0)	Sa(>10.0)	PGA
475 years	0.37g	0.32g	0.27g	0.27g	0.17g	0.080g	0.029g	0.0094g	0.12g
975 years	0.43g	0.40g	0.33g	0.33g	0.23g	0.12g	0.047g	0.016g	0.15g
2,475 years	0.50g	0.48g	0.39g	0.39g	0.34g	0.24g	0.076g	0.026g	0.19g

The liquefaction triggering results indicated that, with liquefied soil conditions below the water table, combined with seismic shaking for the 1:2,475 events, lateral spread would occur as the liquefied soils underlying the approach fills lose strength allowing the approach fills to flow into the slough. Lateral spread would also impart large lateral forces on abutment piles. Liquefaction triggering was not indicated for 1:475 events at the abutments but will occur in the slough to depth of about 30 m. A significant thickness of potentially liquefiable soil was also indicated in the slough for the 1:975 event, but liquefaction in not expected at the abutments or approach fills for this event.

Because of this, additional stability analyses were performed which included selective ground improvement to control flow sliding. The analyses indicated that limited movements of improved soil were likely to occur, even with stone columns extending to the bottom of the liquefied layers. Lateral displacements were estimated using the Newmark method for the case of 1:2,475-year, 1:975-year and 1:475-year seismic events. The ground improvement design therefore includes:

- Stone column treatment of about 40 m long at the west abutment and about 36m long at the east abutment. The width of the proposed treatment zone is approximately 25 m at the West abutment and 31 m at the east abutment. The treatment should reach 35-36 m deep at each abutment.
- To minimize the impacts of the ground improvement on the existing bridge during construction, a 6-m wide ground improvement zone using ICP piles is also considered at the west abutment, which will be also used to complement the stone column zone.

The proposed bridge will be supported on four (4) 914 mm diameter steel pipe piles at each abutment, and on three (3) steel pipe piles at each of the four in-slough reaching elevations of El. -45 m and El. -55 m, respectively.

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

APPENDIX SECTIONS

FIGURES

APPENDICES

LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of British Columbia Ministry of Transportation and Infrastructure and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than BC Ministry of Transportation and Infrastructure, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

1.0 INTRODUCTION

Tetra Tech Canada Inc. (Tetra Tech) was retained by the British Columbia Ministry of Transportation and Infrastructure (BC MoTI) to provide geotechnical engineering services for the Highway 7 over Nicomen Slough Dewdney Bridge No. 00596 Replacement Project. The site is located along Highway 7 in Dewdney, BC, approximately 12 km east of Mission, BC.

Tetra Tech has completed the 90% detailed design in February 2021. Further to the 90% design submission, McElhanney (Civil and Structural designer) was requested by BC MoTI to evaluate the design of the bridge and approach fills considering potential changes to the design criteria that include reducing the design speed to 50 km/h, and setting the 200-year design flood hydraulic clearance as 100 mm. The changes result in reduction of the approach fill heights by approximately 2.0-2.5 m from previous design. In addition, the bridge alignment was slightly adjusted to increase the distance between the existing east abutment and the proposed new abutment, which minimize the impact on land requirements.

Tetra Tech was requested to provide additional geotechnical design services, under Contract No. 861-CS-1179, to complete the detailed design of the proposed bridge and associated structures based on the above changes.

The factual geotechnical data for the initial conceptual design are presented in "Geotechnical Data Report – Highway 7 Over Nicomen Slough Dewdney Bridge 00596 Replacement Project", dated March 2020. The conceptual geotechnical design recommendations are presented in "Conceptual Geotechnical Design Report – Highway 7 Over Nicomen Slough Dewdney Bridge 00596 Replacement Project", dated April 2020. Additional geotechnical factual data result from the 2020/2021 site exploration are presented in "Geotechnical Data Report for Final Design – Highway 7 Over Nicomen Slough Dewdney Bridge 00596 Replacement Project", dated April 19, 2023.

The purpose of this geotechnical design report is to update the geotechnical aspects of the bridge foundation design and to provide geotechnical input and recommendations for the 100% design submission for the new Dewdney Bridge. Geotechnical engineering services may also be required for the evaluation of the shoreline at the bridge location to satisfy possible dike authority requirements. The scope for this service will be discussed with BC MoTI at a later stage.

The Limitations on the Use of this Document, attached in Appendix A, forms an integral part of this report.

2.0 PROJECT DESCRIPTION

This project involves the replacement of the existing Dewdney Bridge with a two-lane bridge. We understand the existing bridge was constructed in the late 1950s comprising a 19.8 m main steel I-girder span and 15 "inverted bathtub" concrete spans approximately 8.5 m each, founded on timber piles. Available drawings for the bridge suggest that the timber piles extend to approximately 15 m below mudline, however pile installation or driving logs were not made available. We understand the existing bridge has required numerous repairs in recent years and is in poor condition.

The proposed bridge will be located at about 25 m upstream from the existing bridge and will consist of five-span prestressed concrete I-girder bridge that has an overall length of 183.5 m. The bridge will be supported on four 914 mm diameter steel pipe piles at each abutment, and on three steel pipe piles at each of the four in-slough piers. The proposed bridge will require additional fills to raise the road grade along Highway 7 as well as the approaches. The bridge approaches will tie-into the existing dikes – the Dewdney Dike (#47) at the west abutment and the

Nicomen Island Dike (#144) at the east abutment. Noted that the Nicomen Island Dike is considered to be a non-standard dike, which has a lower level of protection than a standard dike.

Details of the Dewdney Bridge Replacement project are presented in the following documents:

- 0596 Dewdney Bridge Replacement – HWY 7 Over Nicomen Slough – 50% Hydrotechnical Design Brief, Northwest Hydraulic Consultants Ltd. (NHC), November 2020.
- 0596 Dewdney Bridge Replacement – 50Km/hr Redesign – Conceptual Design Report for H7 over Nicomen Slough (Dewdney Bridge) No. 00596 Replacement by McElhanney, October 2021.

The general site location in presented in the site Key Plan on Figure 1.

3.0 INFORMATION REVIEWED

The following information sources were reviewed as part of a desktop study completed early in the project:

- Information provided by BC MoTI, including existing structural drawings and site photos.
- Published water well logs from the BC Water Resources Atlas (http://maps.gov.bc.ca/ess/hm/wrbc).
- Fraser Valley Regional District (FVRD) Geographical Information System (GIS) data.
- Relevant geological maps and papers published by the Geological Survey of Canada, BC Geological Survey and other information sources.

4.0 DESIGN CRITERIA

The following design codes and documents have been used to develop the basis of design:

- Canadian Highway Bridge Design Code (CHBDC), CAN/CSA S6-14.
- BC MoTI Bridge Standards and Procedures Manual, Volume 1, Supplement to CAN/CSA S6-14.
- BC MoTI Technical Circular T-04/17 “Geotechnical Design Criteria”.
- National Building Code of Canada (NBCC), 2015.
- American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Design Specifications, 7th Edition, 2014.
- Canadian Foundation Engineering Manual (CFEM), 4th Edition, 2006.

4.1 Seismic Performance

Based on the scope of the completed site explorations and the observed variability of the soil conditions between the testholes, we consider the Degree of Understanding of ‘Typical’ as the testhole and CPT locations in the slough will be offset about 25 m from the actual bridge locations.

It is understood that a 'Typical' consequence factor should be considered in the design of the proposed bridge per CAN/CSA S6-14 (S6-14). As such, the consequence factor for the design of piles and embankments adjacent to the structures will be 'Typical' and the corresponding consequence factor is 1.0 for both static and seismic design.

We understand that the proposed bridge is to be classified as an 'Major-route bridge' per S6-14.

The minimum seismic performance levels for a major route bridge are summarized in Table 4-1.

Table 4-1: Major Route Bridge Seismic Performance Levels and Resistance Factors

Seismic ground motion probability of exceedance in 50 years (return period)	Service	Damage
10% (475 years)	Immediate	Minimal Foundation movements shall be limited to only slight misalignment of spans or settlement of some piers or approaches that does not interfere with normal traffic, provided that no repairs are required.
5% (975 years)	Service Limited*	Repairable (*) Foundation offsets shall be limited such that repairs can bring the structure back to the original operational capacity.
2% (2,475 years)	Service Disruption	Extensive Foundation lateral and vertical movements must be limited such that the bridge can be used by restricted emergency traffic. Foundation offsets shall be limited such that repairs can bridge the structure back to the original operational capacity.

* Optional performance level unless approved by BC MoTI.

Slopes and embankments will be designed in accordance with CAN/CSA S6-14 and BC MoTI Supplement. For the approach slope embankment within close proximity to the bridge, the seismic performance should consider that the displacements shall be limited to meet the performance requirements for Structures.

For slopes/embankments outside the bridge abutments, the following recommendations from BC MoTI Supplement should be considered:

- Pseudo-static Factor of Safety (FoS) > 1.1 under 975-year earthquake for slopes/embankments.

4.2 200-Year Design Flood and Scour

Where applicable, slope stability analyses for the dike will consider the 200-year return period flood elevation at El. +10.4 m.

Given that the bridge abutment is part of the dike system, which is protected by riprap armouring, scour was not considered at the bridge abutments. However, scour will be considered at the piers for the static condition and no scour will be considered for the seismic conditions, as directed by the hydrotechnical team.

5.0 SUBSURFACE CONDITIONS

5.1 Surficial Geology

The Dewdney Bridge was built circa 1958 over the Nicomen Slough. The bridge connects Dewdney on the west side to Nicomen Island on the east side. Based on Geological Survey of Canada (GSC) surficial geology Map 1485A (Armstrong 1980), the general area at the Dewdney Bridge is characterized by deposits from the Quaternary period (< 1.6 million year). These deposits include Holocene and Pleistocene sediments which may reach thickness of up to one hundred meter and overlie the bedrock from Tertiary period. The subsurface soils within the project site are likely to consist of Fraser River Sediments (channel fill and floodplain deposits) comprising silts and sands. The Fraser River Sediments are underlain by glaciomarine sediments, glacial till and bedrock. Glacial till and bedrock are expected to be on the order of 100 m depth or more in this area. To the east/west banks of the slough, the channel fill is overlain by overbank deposits of silt and clay. At the ground surface, man-made fills are present along Highway 7 and dike fills are also present along the banks of the slough.

5.2 Geotechnical Conditions

The results of the geotechnical site exploration are generally consistent with the soil conditions anticipated from the published surficial geology mapping. The extent of the geotechnical subsurface exploration and location of boreholes is shown on Figure 2. The interpreted soil stratigraphy is described below.

- **Asphalt Concrete**: Testholes conducted along Highway 7 encountered approximately 130 mm to 150 mm of asphalt concrete at the west approach, and 150 mm to 260 mm of asphalt concrete at the east approach. Testholes conducted on River Road South encountered 80 mm of asphalt concrete.
- **Granular Fill (Road Base)**: Along Highway 7 north of the existing bridge, the asphalt concrete was underlain by granular fill generally comprising gravel, some sand, some cobbles, between approximately 1.05 m and 2.85 m thick. Along Highway 7 south of the bridge, granular fill generally comprised sandy gravel, trace to some silt, between approximately 0.75 m and 2.52 m thick. Granular fill thickness increased towards the bridge deck approaches at both ends along Highway 7. Coarse gravel and cobbles were encountered in five test holes along Highway 7, which got refusal at about 1m depth.
- **Fill (Dike)**: Dike fill at the west side of the bridge (BH19-01 to BH19-04) generally comprises compact gravel and sand, some cobbles, some boulders, with traces of silt up to 3.5 m thick. Dike fill at the east side of the bridge (BH19-05 to BH19-08) generally comprises compact / firm, silty sand to sandy silt, up to 4.6 m thick.
- **Silt/Clay:** At the west approach, a silt/clay layer was found below the fill layer. The thickness of the silt/clay layer is up to about 3 m and is to be medium to high plasticity with Plasticity Index (PI) between 14% and 26%.
- **Sand and Silt:** At the east approach, an interbedded layer of sand and silt was encountered to about elevation El.-8 m. This interbedded sand and silt layer was also encountered in the slough. Intermittent wood layers, wood inclusions and debris, as well as organic silt layers about 0.4 m thick were also encountered within the top 10 m below mudline.
- **Sand to Silty Sand:** Below the silt/clay at the east approach and below the interbedded sand/silt at the west approach, sand to silty sand was encountered down to approximately elevation El. -85 m. The sand layer becomes silty and interbedded sand/silt below elevation El. -31 m.

The results of the 2021 site exploration program indicated the following:

- The thickness of the sand and silt layer reduced from the east abutment towards the east end of the project site; and
- The sand to silty sand layer extends down to approximately elevation El. -85 m.

Neither glacial till nor bedrock were encountered during drilling. The depth to bedrock recorded at a water well approximately 200 m to the south of the existing bridge was 118 m. This has been used as the depth to firm ground for the purposes of this report. Existing ground conditions inferred from the data gathered at the site are presented in the soil profiles on Figures 3a to 3c.

5.3 Groundwater Conditions

Based on porewater pressure readings and dissipation data obtained during the site exploration work at SCPT21-01 and SCPT21-02 at either approach, groundwater levels were measured at approximately 4.8 m and 7.2 m below existing road grade, respectively, as measured from the top of the existing bridge approach fills. In the slough, the results of the subsurface exploration indicated that the depth of water was varying from 1.0 m to 1.9 m. Additional measurements were taken at the piezometers installed on each side of the slough and were summarized in Table 5-1.

Table 5-1: Groundwater measurements

Location	Groundwater depth below Existing Ground Surface	
	March 14, 2022 at 13:20 p.m.	May 24, 2022 at 12:50 p.m.
MW21-01	5.4	4.6
MW21-02	7.2	7.0

For the holes completed on the dikes, the water level was measured for the ground surface when observed in the auger hole. These water level measurements are presented in the data report and are varying from 5.5 m to 7.0 m below the existing ground surface.

We anticipate that seasonal fluctuations in the Fraser River, seasonal runoff from Dewdney Peak and Nicomen Mountain, as well as periods of wet weather, will have an influence on groundwater levels and water levels within the slough. Water levels observed at the CPTu sounding locations and boreholes locations are presented schematically on the soil profiles (Figures 3a to 3c)

5.4 Geotechnical Design Parameters

Geotechnical design parameters have been determined using the results of the site exploration and experience with similar materials. Details of the in-situ and laboratory testing are presented in the reference geotechnical data report. The values presented in Table 5-2 are primarily based on the CPT data, published literature and our previous experience with similar soils.

Table 5-2: Representative Geotechnical Design Parameters

Layer	Bulk Unit Weight (kN/m^3)	Shear Strength	
		ϕ' (degrees)	c / Su (kPa)
Granular Fill (Road Base)	20	35	-
Fill (West)	19	34 - 36	-
Fill (East)	19	32 - 34	-
Silty Clay to Clayey Silt (West)	18	-	40 - 60
Sand and Silt (East)	18	32 - 33	-
Sand to Silty Sand	18	32 - 34	-

5.4.1 Fines Content

Fines contents were estimated from the CPT data using the correlation proposed by Boulanger and Idriss (2014). Both the CPT-interpreted fines contents and those obtained from laboratory tests on recovered samples are presented on Figures 4a to 4c. The fines content is an important parameter in determining the liquefaction resistance of granular soils.

The information suggests that the CPT-interpreted fines contents are in reasonable agreement with those determined from laboratory tests. There is also considerable variability in the fines content within the sand and silt unit, which may reflect the interbedded nature of this unit, as indicated by the CPT data.

5.4.2 Undrained Shear Strength (Su)

The undrained shear strength of the silt/clay was estimated based on the results of the in-situ field vanes and the CPT data with an Nkt value of 15. The undrained shear strength of the silt/clay at the west approach is estimated to be about 40-60 kPa, which will be used for foundation design and slope stability analyses.

5.4.3 Friction Angle

The peak friction angle values of the granular soils were determined using the CPT-based correlations. The CPT data suggest that the fill layer near the ground surface is dense to very dense. Below the fill, the granular soils are generally loose to compact with friction angles varying between 32 and 34 degrees.

5.4.4 Shear Wave Velocity

The variation of the shear wave velocity (V_s) with depth was obtained from in-situ measurements performed during the CPT soundings. The measured values are shown on Figures 5a and 5b and were used to determine the site class and as input to the liquefaction assessment, as discussed in the following section.

6.0 SEISMIC ASSESSMENT

6.1 Seismicity and Site Classification

For seismic design, S6-14 (Section 4.4.3.1) refers to the National Building Code of Canada (NBCC) and the seismic spectral parameters are required to be determined following the recommendations provided by the Geological Survey of Canada (GSC), which currently adopts the ground motion parameters from the 5th Generation seismic hazard model. Seismic design parameters from the GSC's 5th Generation model were obtained from the website http://www.earthquakescanada.nrcan.gc.ca/index-en.php maintained by Natural Resources Canada (NRCan). The parameters include the Peak Ground Acceleration (PGA), Peak Ground Velocity (PGV), and 5% damped Spectral Acceleration (Sa(T), where T is the period in seconds) values for the return periods noted in Section 5.0. The seismic parameters provided by GSC are referred to a firm ground defined by a shear wave velocity Vs=450 m/s (Site Class C).

Using the Vs data obtained from the site exploration (Figures 5a and 5b), the average Vs over the upper 30m was estimated to be about 200 m/s, which designates the site as Class D. Liquefiable soils, which are interpreted to be present at the project site as discussed in more detail in Section 6.3, are designated as Site Class F ground conditions. S6-14 requires that site-specific seismic ground response analyses be carried out to estimate the design response spectrum for a structure on Site Class F ground conditions. We understand that the fundamental period of the proposed bridge will likely be greater than 0.5 s; therefore, site-specific analysis is required.

Seismic hazard deaggregation for the site was obtained from the Geological Survey of Canada (GSC). Based on the deaggregation data corresponding to the PGA, an earthquake magnitude of 7.0 and 8.6 were selected to carry out the liquefaction triggering analyses for Crustal/Inslab and Subduction Interface earthquakes, respectively.

6.2 Seismic Ground Response

6.2.1 Site-Specific Analyses

Tetra Tech carried out site-specific seismic ground response analyses using SHAKE2000 (Ordóñez 2012), which uses a one-dimensional, equivalent-linear, total-stress method to compute the response of soils to dynamic loading. Inputs to the SHAKE2000 analyses included earthquake time histories, small strain shear modulus values, and curves defining the shear modulus reduction and damping characteristics of soils over a range of shear strains.

Table 6-1 below provides summary information regarding the earthquake time histories used in our analyses. The crustal and intraslab records consisted of spectrally matched records from the Massey Tunnel replacement project, scaled to approximately match target response spectra representing the short period (i.e., <2 s) portions of the Uniform Hazard Spectra (UHSs) on outcropping rock for the applicable return periods. The interface records also consisted of spectrally matched records from the Massey Tunnel replacement project, scaled to approximately match target response spectra representing the long-period (i.e., >2 s) portions of the UHSs on outcropping rock for the applicable return periods. We have considered that the shapes of the target spectra at the Massey Tunnel and Dewdney Bridge locations are similar. The response spectra for the input motions (NBCC Site Class B) for the three design return periods are provided for reference in Appendix B. It can be seen in Appendix B that the spectra are slightly conservative for the period range of 0.2 s to 2.0 s.

Table 6-1: Summary of Input Earthquake Motions

Event	Date	Station	Comp.	Type	Mag.	Dist. (km)	V_{s30} (m/s)	PGA (g)
Hector Mine	1999-10-16	Joshua Tree	090	Crustal	7.1	31	380	0.14
Landers	1992-06-28	Joshua Tree	000	Crustal	7.3	11	380	0.27
Landers	1992-06-28	Morongo Valley Hall	000	Crustal	7.3	41	370	0.17
San Fernando	1971-02-09	Seismol. Laboratory	180	Crustal	6.6	22	970	0.09
SMART1Taiwan	1986-11-14	O06	EW	Crustal	7.3	54	295	0.17
El Salvador	2001-01-13	Ciudadela Don Bosco	180	Intraslab	7.6	110	Rock	0.23
El Salvador	2001-01-13	Relaciones Exteriores	090	Intraslab	7.6	114	Rock	0.21
Miyagi-Oki	2005-08-16	MYG006	NS	Intraslab	7.2	110	205	0.15
Nisqually	2001-02-28	7032-1416	050	Intraslab	6.8	58	-	0.10
Tarapaca	2005-06-13	Iquique Idiem	L	Intraslab	7.8	140	450	0.23
Michoacan	1985-09-19	La Union	000	Interface	8.1	50	Rock	0.18
Tohoku	2011-03-11	YMT008	EW	Interface	9.0	178	295	0.08
Tohoku	2011-03-11	IWT022	EW	Interface	9.0	168	760	0.10
Tokachi-oki	2003-09-26	HKD107	EW	Interface	8.0	92	560	0.08
Tokachi-oki	2003-09-26	HKD181	EW	Interface	8.0	193	255	0.09

1. V_{s30} denotes the travel-time average of shear wave velocities in the top 30 m of soil.
2. PGA denotes the peak horizontal ground acceleration.

Small strain shear moduli of soils were estimated using shear wave velocity measurements from SCPT19-01 and SCPT19-02. The small-strain shear modulus for bedrock was estimated using a shear wave velocity of 1,100 m/s, which corresponds to the characteristic V_{s30} value used to define Site Class B motions in S6-14. This assumes there is no till in the soil column which is confirmed by nearby water well logs. The upper bound shear modulus reduction and lower bound damping curves by Seed and Idriss (1970) were used to model the behavior of sands over a range of shear strains. The shear modulus reduction and damping curves by Vucetic and Dobry (1991) for soil with a plasticity index of 15 were used to model the behavior of silt and clay soils over a range of shear strains.

6.2.2 Design Response Spectra

Table 6-2 presents the ordinates of the design response spectra for the proposed bridge based on the results of our site-specific seismic ground response analyses. Sa(T) and PGA values for intermediate periods may be calculated by means of linear interpolation between these ordinates.

Table 6-2: Ordinates of Design Response Spectra (5% Damping)

Return Period	Sa(<0.6)	Sa(0.9)	Sa(1.1)	Sa(2.0)	Sa(2.5)	Sa(3.0)	Sa(3.7)	Sa(5.0)	Sa(>10.0)	PGA
475 years	0.37g	0.32g	0.27g	0.27g	0.17g	0.080g	0.063g	0.029g	0.0094g	0.12g
975 years	0.43g	0.40g	0.33g	0.33g	0.23g	0.12g	0.093g	0.047g	0.016g	0.15g
2,475 years	0.50g	0.48g	0.39g	0.39g	0.34g	0.24g	0.14g	0.076g	0.026g	0.19g

Figures 6a to 6c present the design response spectra graphically, along with the average of the crustal/intraslab and interface response spectra computed in our analyses, the results of our analyses for each individual earthquake record, the Site Class D response spectra, and 80% of the Site Class D response spectra. The design response spectra were taken as the greater of the average response spectra from our site-specific analyses or 80% of the Site Class D response spectra for the applicable return periods.

6.3 Liquefaction Triggering Analysis

Based on the CPT/SCPT soundings carried out during the field exploration in September 2019 and subsequently during December 2020 and January 2021, a liquefaction analysis was conducted. The cyclic resistance ratio (CRR) was calculated using the method presented by Boulanger & Idriss (2014) using CPT data obtained from geotechnical site exploration. The equivalent clean sand adjustments were determined using the values interpreted from the CPT data.

To evaluate the liquefaction triggering potential, the calculated cyclic stress ratio (CSR) derived from the site response analyses were compared with the calculated CRR values. For CRR < CSR (i.e., FoS < 1), the layer is susceptible to initial liquefaction. The results of the liquefaction triggering analyses are presented on Figures 7a to 7f for the west abutment, east abutment, and slough locations, respectively.

The liquefaction resistance of granular soils increases with the fines content and plasticity characteristics of the fine fraction. It has been also observed that the resistance to liquefaction in granular soils with fines contents above 15% is larger than that predicted by CPT data. For silty sand/sandy silt, the liquefaction assessment was also considered the laboratory results (Cyclic Direct Simple Shear tests) obtained from Fraser River sediments with similar characteristics as those present at the Dewdney Bridge. The results of the laboratory tests are also presented on Figure 7.

The analysis results indicate liquefaction is not anticipated on land (abutments) for the 475- and 975-year earthquakes, but potentially liquefaction is expected for the 2475-year seismic events. At the over-water locations (piers), variable thicknesses of potentially liquefiable layers are expected. A summary of the extent of liquefaction is provided in Table 6-3.

Table 6-3: Summary of Liquefaction Assessment

Location	Extent of Liquefaction, Elevations (m)		
	475-yr	975-yr	2475-yr
West Abutment	No Liquefaction	No Liquefaction	+2 to -31 m
East Abutment	No Liquefaction	No Liquefaction	-7 to -23 m
Slough	+0.5 to -17m and -24 to -31 m	+0.5 to -31 m	+0.5 to -31 m

6.4 Flow Sliding

Based on the liquefaction assessment the approach fills are expected to undergo large deformations and lateral movements, allowing the approach fills to flow into the slough. Such an occurrence would impact access to the bridge after a seismic event in that emergency vehicles would likely not be able to access the bridge. In addition, flow sliding would impart large lateral forces on abutment piles.

To control flow failure and to minimize the seismic deformations for the abutments and piers, different ground improvement options were considered in the conceptual design. The ground improvement methods using vibro-replacement (stone columns) were selected in order to meet the seismic performance requirements for the bridge. Details of the ground improvement will be discussed in Section 7.0.

6.5 Post-seismic Reconsolidation Settlements

The soils in the profile that liquefy during the earthquake will dissipate the excess pore pressures once the ground motion cease. Hence, the liquefied soils will undergo reconsolidation and cause settlement.

The post-seismic reconsolidation settlements outside of the improved zone have been estimated using the approach recommended by Idriss & Boulanger (2008) based on the in-situ CPT data. The CPT data indicated that the post-seismic volumetric strain of about 3% and the post-seismic settlement due to the dissipation of excess pore pressure is estimated to be about 400-550 mm at the east and 850-1,100 mm at the west for the 2475-year seismic event in the slough, the free-field settlements expected under post-seismic condition are in the order of 900 mm to 1,000 mm.

7.0 BRIDGE ABUTMENT SLOPE STABILITY ANALYSIS

7.1 General

A slope stability assessment of the new bridge abutment was carried out. Two (2) sections at each abutment (east and west) were analyzed: one (1) along the longitudinal direction of the bridge abutment, and one (1) transverse to the bridge abutment.

Stability analyses were completed using the limit equilibrium software Slope/W (GeoStudio 2021). The failure surfaces analyzed in Slope/W were created through the circular slip surface search method. The "Entry and Exit" method was used for determining the location of critical slip surfaces. The evaluation and design of the ground improvement at the bridge abutments under static and seismic conditions was performed considering:

- A FoS greater than or equal to 1.54 under static conditions with a traffic surcharge of 16 kPa;
- A FoS greater than or equal to 1.1 under pseudo-static conditions considering a horizontal seismic coefficient (kh) equal to half of the PGA, as per CSA-S6-14 C4.6.7;
- A FoS greater than 1.0 under post-liquefaction conditions (with only gravity loads) to avoid flow failure; and
- Seismic-related ground displacements were estimated using the Newmark method.

Slope/W model results are attached in Appendix C.

7.2 Slope Stability Results

In the conceptual design stage, several stability models were developed with various configurations of ground improvement to limit embankment deformation due to flow sliding. Ground densification with timber piles was investigated, however, the improvement did not extend sufficiently deep to significantly arrest the deformations of the approach fill. Stone columns were then modelled. The stone column scheme considers the extension of ground improvement below the dike fill elevation (~ El.+4.6 m) to the bottom of the liquefiable layer (~El. -31 m). This scheme is based on the possibility of partially removing the dike fill to install the stone columns to the proposed depth, or the ability of a contractor to properly install stone columns to a depth of about 35-36 m below the existing grade to avoid removing the dike fill.

The geotechnical parameters used for ground improvement are presented in the following Table 7-1. The stone columns were considered to be installed on a triangular array with an initial spacing of 2.75 m center to center (i.e., replacement ratio of about 10%), but should be adjusted based on the result of the densification trial.

Table 7-1: Ground Improvement Geotechnical Parameters

Stone Column				Improved soils	
Diameter (m)	Spacing (m)	Unit Weight (kN/m^3)	Friction Angle (degrees)	Average Unit Weight (kN/m^3)	Average Friction Angle (degrees)
0.9	2.75	18	48	18	36

Additionally, a protective barrier of concrete piles (ICP piles) has been considered at the west abutment in the transversal direction to complete the required ground improvement layout and protect the existing structures, including the existing bridge, from the possible detrimental effects of the stone column construction. The ICP piles were considered to be 300 mm diameter and to be installed on a triangular array with a spacing of 1.2m center to center. The extension of the ICP piles scheme is the same in the longitudinal direction as the stone columns, with a width of 6 m in the transversal direction and an extension from about El +5 to +6 m to about El. – 31 m.

Static and pseudo-static factors of safety were determined for stone columns 36 m (east abutment) and 40 m (west abutment) long along the alignment from the bridge abutment and are presented in Table 7-2.

Table 7-2: Critical Factors of Safety with Ground Improvement

Section	Critical Factor of Safety			
	Static Conditions	Pseudo-Static (1:475)	Pseudo-Static (1:975)	Pseudo-Static (1:2,475)
		PGA = 0.12	PGA = 0.15	PGA = 0.19
Longitudinal	> 2	> 1.1	> 1.1	> 1.1
Transverse	> 2	> 1.1	> 1.1	> 1.1

Results indicate that the profile section meet the acceptable FoS for a pseudo-static condition under the considered seismic events when the ground improvement scheme has been implemented.

For the seismic conditions under the extensive liquefaction during the 1:2475-yr EQ event, the resultant factor of safety is FoS<1 when considering the full effect of the horizontal acceleration (kh=PGA). This is considered conservative as peak free-field shaking and liquefaction will likely not occur at the same time. Instead of using the full effect of PGA, the yield accelerations were estimated to calculate the seismic ground movements.

The lateral displacement of the embankment was then estimated using the method by Newmark in CSA-S6-14 for the 1:2,475-year event. The yield acceleration under the 1:2,475-yr EQ liquefaction was determined to be k_y=0.086 g. Under the mentioned acceleration, the stability analysis yielded an acceptable factor of safety FoS=1 for the 2475-yr EQ event on the abutments, which would yield a horizontal displacement of about 150 mm. For the 1:475-yr and 1:975-yr EQ events the expected movements are estimated to be between 17 mm and 50 mm. In the transverse direction, the FS is larger than 1 and the lateral displacements are expected to be small (< 10 mm). Results may be found in Table 7-3 below. A summary of the slope stability analyses with ground improvement for static conditions and 2475-yr EQ can be found in Appendix C.

Table 7-3: Seismic Horizontal Displacements

Section	Displacement (mm) – K_y=0.086		
	1:475	1:975	1:2,475
Longitudinal	17	50	150
Transverse	< 10	< 10	< 10

The design of the ground improvement layout has been performed based on the results of the limit equilibrium stability analyses as discussed in this section. A summary of the extent of ground improvement is presented in Table 7-4. The final ground improvement array should be confirmed/defined based on a stone column trial program.

Table 7-4: Ground Improvement Layouts

Bridge Abutment	Stone Columns & ICP Piles	
	Station	Tip of Ground Improvement
East Abutment	Sta. 7+785 to Sta. 7+821	El. -31 m
West Abutment	Sta. 7+595 to Sta. 7+635	El. -31 m

8.0 PILE DESIGN

This section provides the geotechnical input that is required to develop the pile-supported foundations for the bridge. Analyses have been performed to determine the axial capacity and lateral load-deflection characteristics for the use of the piled foundations. The pile configuration and loading conditions were provided by McElhanney. Four (4) steel pipe piles with a diameter of 914 mm, wall thickness of 19 mm and center to center separation of 4.135 m are considered as the piled foundation at each abutment. The piers have a configuration of three (3) steel pipe piles with a diameter of 914 mm, wall thickness of 19 mm and center to center separation of 5.05 m.

The Canadian Foundation Engineering Manual, 4th Edition (CFEM 2006) has been used as a general reference for the geotechnical analyses. The API RP 2A (2000) method was used to calculate the pile capacity and to define the p-y curves required for assessing the axial and lateral responses of a single pile.

The geotechnical resistance factors used to perform the foundation analyses are based on the recommendations provided in the BC MoTI Supplement to CSA-S6-14. Table 8-1 presents the geotechnical resistance factors for pile design under both static and seismic loading conditions.

Table 8-1: Summary of geotechnical resistance factors for pile design (for Major Route Bridge, Typical Degree of Understanding)

Limit State	Test Method	Static Loading	Seismic Event Return Period		
			1:475	1:975	1:2475
Axial Compression	Static analysis	0.40	0.50	0.60	0.65
	Dynamic analysis (PDA testing)	0.50	0.60	0.70	0.75
	Static Load Test	0.60	0.70	0.80	0.85
Axial Tension	Static analysis	0.30	0.40	0.50	0.55
	Static Load Test	0.50	0.60	0.70	0.75
Lateral Load	Static analysis	0.50	0.60	0.70	0.75
Settlement or Lateral Deflection	Static analysis	0.80	0.90	1.0	1.0

TETRA TECH

8.1 Axial Pile Resistance

Open ended, 914 mm diameter by 19 mm wall thickness, driven steel pipe piles were used to estimate axial pile capacities for bridge support. Unfactored axial pile resistances at the Ultimate Limit State (ULS) were calculated in general accordance with CAN/CSA-Z19902-09 (more commonly known as the American Petroleum Institute or API method) using soil shear strength information from Table 5-2. The axial capacities for the pier foundations were also calculated using the CPT approach (namely LCPC method). Given the effect of the ground improvement on the CPT results, the LCPC method was not used to estimate the axial capacity at the abutments.

The variation in the ultimate axial capacity (unfactored shaft and end bearing) with depth for the static and seismic conditions for each profile are presented on Figure 8. The axial pile capacities should be multiplied by the appropriate geotechnical resistance factor in Table 8-1 and appropriate pile capacity test method used during construction. The values for PDA testing or Static Load testing may only be used for design when such site-specific information is available prior to construction.

In accordance with CFEM (2006), the group efficiency of 1.0 can be used for driven piles in cohesionless soils. Hence, the individual pile capacities are used without any reduction in group factor for axial loading condition.

8.2 Lateral Load-Deflection Characteristics

For soil-structure interaction analyses, the response of the piles to lateral loading was defined by means of non-linear p-y curves, determined in accordance with the recommendation provided in API RP 2A (2000). The post-liquefaction p-y curves have been determined using the residual strength and the “soft-clay criteria” as defined in the API RP 2A (2000). The p-y curves were provided to McElhanney for use in the structural models.

The p-y curves are the ultimate values since the geotechnical resistance factor has not been considered. The ultimate p-y curves should be multiplied by the appropriate geotechnical resistance factor in Table 8-1 to evaluate the pile foundation performance for static and seismic conditions. Similarly, no factor to consider group effects has been included in the p-y curves presented in this report. The GROUP software (Ensoft v2019) was used to determine the group reduction factors based on the pile configuration (pile spacing-to-diameter ratio of 4.135 m and 5.05 m for abutments and piers, respectively) provided by McElhanney. To consider the potential scour under static condition, the depths of the static p-y curves for the piers should be defined based on the estimated scour elevations.

Both, the geotechnical resistance factor and the group reduction factors should be applied to the p-y curves by the structural designer as p-multipliers should the pile foundation performance is considered in the structural analyses. The structural designer may select to use a geotechnical resistance factor equal to one if the maximum response of the lateral pile foundation is required to bound the structural analyses. Should this be the case, the pile design should be also checked considering the recommended geotechnical resistance factors and the loading condition estimated on the pile foundation. The p-y data for single pile are presented in Appendix D.

8.3 Lateral Pile Loading

The lateral ground movements induced by liquefaction are expected to impose a lateral (kinematic) load on the pile foundation as the soil moves downslope. The impact of kinematic loading on the abutment piles due to lateral approach fill movement was analyzed with the program GROUP (Ensoft v2019). The GROUP analyses were also used to check the required length of the pile. In the GROUP analysis, the connection between piles and pile cap was modelled as a fixed connection. The soil response to pile loading is modelled using the p-y curves for lateral loading, and t-z and Q-z curves for axial loading. The lateral pile loading was applied in the form of a lateral soil movement profile. Based on the estimated failure surface results from the slope stability analyses, lateral soil movements of 150 mm were applied:

- At the abutments from ground surface to about half of the liquefied layer (about 20 m depth), and linearly decreasing to zero to the bottom of the liquefied layer (about 40 m depth).
- At the piers from mudline to about half of the liquefied layer (about 17 m depth), and linearly reduced to zero at the bottom of the liquefied layer (about 33 m depth).
- This is considered conservative as this concentrates the lateral soil movement over a limited vertical distance whereas the stone columns may undergo some deflection or tilting during a seismic event.

The computed responses in terms of moments, shear and lateral pile displacements are summarized on Figures 9a to 9c. The maximum pile moment is 3,500 kN-m, the maximum shear is about 1150 kN. These values should be checked for structural suitability.

In accordance with Section 4.4.5.3.1 of the BC MoTI Supplement, the following load cases should also be considered for the design:

- +/- 50% inertial demands plus 100% kinematic demands;
- 100% inertial demands; and
- 100% kinematic demands (Figure 9).

Tetra Tech recommend the structural engineer team to evaluate the above loading conditions to confirm the pile design meets the seismic performance requirements of the bridge.

8.4 Downdrag Consideration

The post-seismic settlement of soil around the piles (downdrag) will induce a drag load on the piles. At the east and west abutments, since ground improvement will be formed around the piles, the seismic-induced downdrag is considered negligible. The downdrag and the drag force developed at the piers (P1 to P4) have been considered in the pile design.

As discussed in Section 6.5, the post-seismic settlements were estimated to be about 900-1,000 mm at the pier locations. The associated drag load acting on each pile with a diameter of 914 mm is estimated to be about 4,500 kN. The results of the downdrag analyses are presented on Figure 10 (a and b). The pile should be structurally designed to withstand the combined effect of dead load and drag load. The unfactored dead load values provided by the structural designer (McElhanney) are shown on Figure 10 and should be confirmed by McElhanney during the structural checking. If the dead load values are larger than 3.0 MN, the downdrag analyses should be reviewed by the geotechnical designer.

8.5 Anticipated Pile Length

The results obtained from the axial capacity, lateral pile loading and downdrag were used to check the minimum requirement of the pile embedment length. The impact of the scour at the pier locations has also been considered in checking the required length of the pile.

Based on the loading condition provided by McElhanney, the anticipated pile lengths for the abutment and piers have been evaluated to support both static and seismic conditions. As indicated in Table 8-1, the geotechnical resistance factors of 0.40 and 0.65 were used for axial compression for static and 2475-year seismic conditions, respectively. For lateral loading condition, geotechnical resistance factors of 0.50 and 0.75 were used for static and 2475-year seismic conditions, respectively. A summary of the pile lengths is presented in Table 8-2. Note that the pile lengths may be required to verify with the combined kinematic and inertia loading conditions.

Table 8-2: Summary of Anticipated Pile Length

Bridge Foundation	Max. Axial Load (kN) at Pile Top ULS1 / ULS5	Max. Axial Load (kN) at Pile Tip ULS1 / ULS5	Approx. Ground Elevation	Pile Top Elevation	Depth from Pile Top (m)	Min. Pile Embedment (m)	Pile Tip Elevation
Abutments	1400 / 2340	2440 / 3380	El. +9 m	El. +9 m	54	54 *	El. -45 m
Pier 1/4	4005 / 3075	5095 / 4165	El. +0.5 m	El. +9.3 m	64	55 *	El. -54.5 m
Pier 2/3	4165 / 3355	5255 / 4445	El. +0.5 m	El. +10.3 m	65	55 *	El. -54.5 m

* This minimum pile embedment is based on axial loads provided by McElhanney and seismic kinematic loads.

8.6 Pile Settlements

Given that the piles are to be installed to the compact sand to silty sand below the pile tip, the long-term settlement is considered to be small. The elastic pile settlement is also considered to be small and is estimated to be less than 25 mm for the 914-mm diameter piles.

The static total ground settlements at the abutments are about 25-35mm and are considered to occur during construction. The long-term post-construction settlements are considered to be less than 25 mm. The static differential settlements between the approach and abutments are considered to be less than 25 mm. The differential settlements are minimal between the piers.

For the seismic condition, the ground around the piers will be settled due to the dissipation of the excess pore pressures from the liquefied layers. However, the neutral plan is below the liquefied layers and the pile settlements are considered to be small. Hence, the differential settlements between the piers are also considered to be small for the seismic conditions.

8.7 Pile Driveability

Driveability analyses were performed using wave equation analyses presented in the commercially available program GRLWEAP (PDI 2010). The program models the behavior of a pile and the surrounding soil in response to impact driving based on selected hammer characteristics. Driveability analyses have been performed for the piles at the abutment and at the pier. These correspond to a 914-mm diameter steel pipe pile with 19 mm wall thickness, installed to 54-55 m below the existing ground surfaces. Due to the structural requirement of a reinforced concrete section in the piles, as recommended by the structural designer, the piles are considered to be cleaned out at the abutments and piers. Based on the results of the driveability analyses, it is recommended the clean out for the top 40m and 30m of the pile at the abutments and piers, respectively during pile driving to avoid overstresses the piles. Otherwise, the pile wall thickness should be increased. It is also recommended to reinforce the last meter of the piles increasing the wall thickness to about 25 mm to avoid damage due to the possible presence of coarse-grained material and facilitate pile installation.

The driveability analyses were performed using a diesel hammer APE D180-42 (or equivalent). The hammer efficiency at the impact block was assumed to be 80% and a hammer stroke of 3.4 m was used in the analyses. The cushion and helmet assembly was considered as recommended by the hammer manufacturer. The best-estimate soil profile was analyzed with 0.8 reduction factor for the foundation soils during pile installations. The profiles of predicated blow count, stress in the pile section, and hammer stroke are presented on Figure 11 (a and b). The results of the driveability analyses indicate that the APE D180-42 hammer could be used to drive the pile to the final depth with a maximum set of about 140 blow/m (3-4 blow/inch).

The maximum stresses in the pile section during pile driving were estimated to be 285 MPa, which is less than the yield stress of the ASTM A252 Grade 3 steel (310 MPa). The hammer selection and driveability of the piles should be reviewed and verified by the piling contractor. It may be required additional clean-out for the abutment piles during driving.

9.0 APPROACH EMBANKMENTS

As discussed in Section 7.0, the bridge abutments will be constructed with bridge end fill with ground improvement. Based on the design information provided by McElhanney, the bridge abutments will transition to slope embankments using mineral fill. The east and west approach to the bridge abutment requires raising the existing ground by up to 4 m.

9.1 Slope Stability

The slope stability analyses for the approach embankment were performed with the following considerations and assumptions:

- The embankments are considered to be built with mineral fill that has a minimum friction angle of 36 degrees.
- The embankment side slopes are considered to be 2H:1V or flatter.
- A traffic load of 16 kPa was applied across the width of the highway for the stability analyses under static condition.
- The required FoS for global stability are considered to be 1.54 for typical degree of understanding, considering typical consequence and following the recommendations provided in BC MoTI Supplement to CHBDC S6-14.
- The slope stability analyses have been performed for the critical sections at east and west approaches:
  - Sta. 7+580 West approach embankment; and
  - Sta. 7+820 East approach embankment.
- For 975-year earthquake, pseudo-static stability analyses were performed with half of the PGA considering a FS greater than or equal to 1.1.

The results of the stability analyses are presented in Appendix E and are summarized as follow:

- For the 475-year and 975-year earthquakes, the FoS is greater than 1.1 for the cases analyzed.

9.2 Settlements

The east and west approaches to the bridge require raising the road grade by up to about 4m using mineral fill. The compressibility of the silt/clay at the west approach is expected to dominate the settlement. Given the ground water level is below the compressible silt/clay layer, the settlement of the approach fill is considered to be “immediate” and will occur during the construction of the approach fills.

The settlement analyses were performed using the commercially-available program Rocscience Settle3. The consolidation parameters were evaluated based on the empirical correlations and the results from the CPT soundings. Lower and upper bound parameters were used to estimate the settlements due to the placement of embankment fill.

The maximum settlements are anticipated to be 215-285 mm at the west approach and 130-160 mm at the east approach. It is estimated the settlements will be occurred in the first 1-3 months of construction. Settlement monitoring is recommended during construction to facilitate the constructions of the embankments. Long-term post-construction settlements are considered to be small (< 25 mm). The construction settlement profiles along the centerline of the new L100 alignment are presented in Appendix F.

9.3 Lateral Earth Pressure

Bridge end fill (BEF) should be used at the abutments and the BEF should consist of material with properties and graduation in accordance with the Design-Build Standard Specification (DBSS) Section 202.04 and 202.05. Active, at-rest and passive lateral earth pressure coefficients have been estimated considering that the friction angle of BEF is 38 degrees. The lateral pressure coefficients for the static condition are summarized on Table 9-1.

Table 9-1: Static Coefficients of Lateral Earth Pressure

Condition	Coefficient of Lateral Earth Pressure
Active, Ka	0.24
At-rest, Ko	0.38
Passive, Kp	4.20

For the seismic conditions, it is considered that the abutment can undergo lateral displacements of about 25-50mm and hence develop the full active (i.e. yielding condition). Therefore, a reduction factor of 0.5 was used to estimate the horizontal seismic coefficients. The seismic coefficient of active (Kae) and passive (Kpe) for each seismic event was estimated using the Mononobe-Okabe equation and are summarized in Table 9-2.

Table 9-2: Seismic Coefficients of Lateral Earth Pressure

Condition	Coefficient of Lateral Earth Pressure	
	Active, Kae	Passive, Kpe
475-year EQ	0.27	4.08
975-year EQ	0.28	4.05
2475-year EQ	0.29	4.00

10.0 PAVEMENT DESIGN

10.1 Existing Pavement Structure

Fourteen testholes were advanced through the existing pavement structure during the conceptual and design phases in 2019 and 2020, respectively. The range of pavement structural layer thicknesses and a description of the granular road base and fill materials is provided in Section 5.2. Table 10-1 summarizes the Asphalt Concrete Pavement (ACP) thickness and the combined granular road base and fill thicknesses measured at each testhole location.

Table 10-1: ACP and Granular Fill Thickness Summary

Approach	Testhole	Approximate Station	Lane	ACP (mm)	Road Base and/or Granular Fill[1] (mm)
West Approach	BH19-09	7+478	Westbound	150	750[2]
	AH20-01	7+495	Westbound	180	1,340
	BH19-10	7+510	Westbound	150	1,050
	BH19-11	7+538	Westbound	130	1,370
	BH19-12	7+565	Westbound	130	1,370[2]
	SH19-01	7+610	Westbound	150	2,850
East Approach	SH19-02	7+800	Westbound	180	2,520
	BH19-13	7+842	Westbound	180	620[2]
	BH19-14	7+882	Westbound	180	720[2]
	BH19-15	7+920	Westbound	260	940[2]
	BH19-16	7+955	Westbound	150	750[3]
	AH20-04	7+990	Westbound	230	1,270
	AH20-05	8+040	Westbound	230	840
	AH20-06	8+090	Westbound	230	300[3]

1. Granular fill generally consisted of sand and gravel to sandy gravel, trace silt, some cobbles
2. Shallow auger refusal
3. Underlain with 1.1 m (BH19-16) and 1.6 m (AH20-06) of sand fill with trace to some gravel, trace to some silt

10.2 Traffic Data Review and Anticipated Loading

Available Traffic Data

McElhanney provided turning movement data for the Highway 7 and Hawkins Pickle Road intersection, and the Highway 7 and S River Road intersection. Both intersections are located on the west of the bridge. The data was collected on November 12, 2020 during peak periods (7:00-9:00, 11:00-13:00, 15:00-18:00), and included classified total volume counts for each lane from which the Average Annual Daily Traffic (AADT), heavy vehicle percentages and truck factors were calculated.

Traffic count information was also obtained from the BC MoTI website. Traffic data in terms of AADT was obtained from Traffic Count Stations 17-038EW and 17-039EW. Both stations were located approximately 10 km to 11 km east of the project site on Highway 7 in Deroche, BC. Traffic Count Station 17-038EW also included of 24-hour Vehicle Classification volume counts.

Available AADT data from these stations is summarized in Table 10-2.

Table 10-2: Summary of Available AADT Data

Traffic Count Station	Year Reported	Two-Way AADT
Highway 7 and Hawkins Pickle Road	2020	5,305[1]
Highway 7 and S River Road	2020	5,375[1]
17-038EW	2007	5,603
	2013	4,632
17-039EW	2003	4,257
	2007	4,959
	2013	5,128
	2016	4,440

1. McElhanney traffic data. AADT calculated by multiplying the average peak hourly traffic count by 10

The vehicle length distribution data from both McElhanney traffic counts and Station 17-038EW was reviewed to estimate the percentage of heavy vehicles longer than 6.0 m in length. This data is summarized in Table 10-3.

Table 10-3: Summary of Classification Data

Traffic Count Station	Year Reported	Two-Way Heavy Vehicle Percentage
Highway 7 and Pickle Road (West Approach)	2020	11%[1]
Highway 7 and S River Road (East Approach)	2020	11%[1]
17-038EW	2007	8%
	2013	15%

20-Year Design ESALs

The traffic data as summarized above was used to determine the Equivalent Singe Axle Loads (ESALs). A 20-year analysis period was used as per BC MoTI's Pavement Structure Design Guidelines (Technical Circular T-01/15). The 20-year design ESALs were calculated using the following assumptions:

- The 2020 AADT determined from the McElhanney peak hour traffic counts from the station located at the intersection of Highway 7 and S River Road intersection was considered as the base AADT;
- Direction factor of 50%;
- A traffic growth rate of 2% compounded annually to allow for growth and future changes in traffic patterns as per the BC MoTI's Pavement Structure Design Guidelines;
- An average truck factor of 1.8 ESALs/truck based on review of available vehicle length distribution data and our experience on similar roadways; and
- Heavy vehicle traffic of 12% based on review of available traffic data and engineering judgement.

The 20-year design ESALs based on available data and parameters as described above are presented in Table 10-4.

Table 10-4: 20-Year Design ESALs

Direction	Two-way AADT (2020)	Growth Rate	Estimated AADT (2021)	Direction Factor	Commercial Traffic	Truck Factor	ESALs / Direction
Both	5,375	2%	5,483	50%	12%	1.8	5.25×10^6

The 20-year ESALs of 5.25 million corresponds to a "Type B" **Medium to High Volume Road** as per BC MoTI's Pavement Structure Design Guidelines.

10.3 Climate Data Review

Local climate information including average daily high and low temperatures and average monthly rainfall was reviewed. The data is used primarily for the selection of an appropriate asphalt binder.

The closest Environment Canada weather recording station to the project site with reportable data was located in Chilliwack, BC (Climate ID # 1101530), situated approximately 20 km southeast of the project roadway at an elevation of 11 m above mean sea level. The climate data from this weather station is summarized in Table 10-5.

Table 10-5: Climate Data

Weather Station	Average Annual Precipitation (mm)	Mean Annual Temperature (ºC)	Winter[1] and Summer[2] Mean Monthly Temperature (°C)	Extreme Temperature (°C)
Chilliwack (Station ID # 1101530)	1,667 mm	10.8 °C	3.8°C to 18.0°C	-21.7°C to 38.0 °C

1. The Winter Average Monthly Temperature is based on the daily average temperatures in December, January and February
2. The Summer Average Monthly Temperature is based on the daily average temperatures in June, July and August

The weather data from this station indicated that the area receive an average annual precipitation of 1,667 mm, which include 1,582 mm of rainfall and 85 mm of snowfall. According to the C-SHRP Environmental Zones plan, the roadway is located in a Wet-No-Freeze environmental zone.

10.4 New Pavement Structure Design

The new asphalt pavement structures were designed following the AASHTO flexible pavement design methodology, as outlined in the Guide for Design of Pavement Structures (1993). The design parameters required by the AASHTO (1993) method are summarized in Table 10-6.

Table 10-6: AASHTO Pavement Design Inputs

Criteria	Value		Rationale
Reliability	90%		Based on engineering judgement, 20-year design ESALs and BC MoTI Pavement Structure Design Guidelines.
Serviceability			In accordance with generally accepted pavement engineering principles, AASHTO practice and BC MoTI Pavement Structure Design Guidelines.
Initial Serviceability (Pi)	4.2		
Terminal Serviceability (Pt)	2.5		
Serviceability Loss (ΔPSI)	1.7		
Overall Standard Deviation (S_0)	0.45		In accordance with generally accepted pavement engineering principles, AASHTO practice and BC MoTI Pavement Structure Design Guidelines.
20-Year Design ESALs (million)	5.25		Based on traffic data as summarized in Section 11.3.
Structural and Drainage Layer Coefficients			In accordance with generally accepted pavement engineering principles, AASHTO practice and BC MoTI Pavement Structure Design Guidelines.
New ACP	0.40	1	
New Crushed Base Course (CBC)	0.14	0.95[1]	
New Select Granular Subbase (SGSB)	0.10	0.95[1]	

1. Drainage coefficient of 0.95 reflects the drainage condition for high quality granular material with less than 5% fines passing the 0.075 mm sieve.

10.5 Subgrade Support Conditions

The subsurface information from the geotechnical subsurface exploration program described in Section 5.0 was reviewed to assess the subgrade support conditions for input in the design of the pavement structures. The subgrade support conditions consisted of:

- On the west approach the subgrade immediately below the existing pavement structure generally ranged from medium to high plasticity soft-clay to a non-plastic to medium plasticity silt underlain by poorly graded silty sand to sand.
- On the east approach, the subgrade generally consisted of high plasticity clay and non-plastic silt closer to the bridge, and transitioned to silt to silty sand towards the east. These soils were underlain by poorly graded sand.

Based on review of the soil conditions identified on the testhole logs and groundwater table, a subgrade resilient modulus of 25 MPa was considered appropriate for pavement structures.

10.6 Recommended Pavement Structures

The recommended minimum pavement structures are presented in Table 10-7.

Table 10-7: Minimum Pavement Structures

Subgrade Support Condition	Layer Thickness			Total Pavement Thickness (mm)
	ACP (mm)	Crushed Base Course (mm)	Select Granular Subbase (mm)	
Highway Approach Fill	175	300	400	875
Minor Roads	150	300	400	850
Driveways	100	300	400	800

The thickness of the pavement structure at the tie-in locations within the existing roadway and pavement structure will need to allow for continuity of the lateral drainage of the existing structure by ensuring the subgrade elevation of the new portion of the alignment is at or below the existing subgrade elevation. If necessary, additional crushed granular subbase or pit run gravel should be added to the design subbase thickness to provide lateral drainage at the bottom of the pavement.

10.7 Construction Considerations

Within the greenfield construction areas, it is recommended that surface organics, topsoil, soft soils and soils containing roots and/or wood debris be removed. After stripping, the exposed subgrade soils should be compacted and reviewed by a qualified geotechnical engineer prior to the placement of subbase. It is recommended that the prepared subgrade be proof rolled under the observations of a qualified geotechnical engineer where practical. Soft spots should be subexcavated and replaced with engineered fill or granular base or crushed granular subbase.

At the tie-in locations with the existing roadway, the construction joint between lifts of pavement should be staggered to minimize the potential for reflective cracking at the joint between old and new pavement structures. Additionally, construction joints should not be located within the wheel paths.

10.8 Asphalt Mix and Asphalt Cement Recommendations

The use of a 19 mm Class 1 Medium Mix as per Section 502 of BC MoTI's 2020 Standard Specifications for Highway Construction is recommended for the project.

The Husky Performance Graded Asphalt Cement (PGAC) Calculator was used to determine design pavement temperatures based on the Long-Term Pavement Performance (LTPP) High Temperature Model and the Transportation Association of Canada (TAC) Low Temperature Model as shown in Table 10-8. A high temperature reliability of 99% is widely accepted as necessary to reduce the potential for rutting. At this reliability, a high temperature environmental performance grade (PG) of 55° is required for long term pavement performance, based on the Chilliwack Climate Station.

Table 10-8: Temperature Model

Weather Station	Latitude (N)	Longitude (W)	Elevation (m)	LTPP High Temperature (°C)	TAC Low Temperature (°C)	High Temperature Reliability	Low Temperature Reliability
Chilliwack	49.17	-121.93	11	55	-18	99%	99%

The posted speed limit is 50 km/hr. One grade bump (one 6°C increment increase) is recommended to the High Temperature environmental grade due considering slower moving traffic through the project, specifically at the Hawkins Pickle Road intersection.

Based on the climate, roadway characteristics, existing conditions, speed limits, traffic volumes and traffic patterns, the use of a PG 64-22 asphalt binder is recommended.

11.0 ADDITIONAL GEOTECHNICAL DESIGN RECOMMENDATIONS

Prior to commencing any construction work, all utilities within the construction zone should be located and exposed, if necessary. The contractor should be aware of all utilities, buried structures, and sensitive building/structure in the area to avoid potential damage.

11.1 Ground Improvement

As a general guideline, no ground improvement should be installed within 10m of any existing utilities, structures and buildings. Specific utilities should be reviewed on a case-by-case basis to define acceptable levels of encroachment for the stone column or ICP installation. Any utilities, buildings or structures found to be located within 10 m of the works should be reviewed and should be assessed if vibration monitoring and/or other control measurements is required.

A protective barrier of concrete ICP piles has been proposed at west abutment to complete the required ground improvement layout and protect the existing bridge from the effects of the vibration during the stone column construction. It is recommended that vibration monitoring be performed during the stone column densification trials to provide field information that could be used to evaluate the effect of vibration levels induced by the stone column installation.

The array of the stone columns at the abutments should be defined considering the space for the installation of the proposed piles. Pile installation should not be performed before stone column installation to avoid excessive deformations on the pile. However, if pile installation is required before ground improvement, the ground improvement process shall be monitored, and the pile design reviewed to evaluate the effect of the deformations on the expected structural performance.

It should be noted that the adjacent ground may settle due to the installation of the stone columns. Localized maintenance of drainage, pavements and finished surfaces may be required during and/or after ground improvement works.

11.2 Dike Considerations

The liquefaction assessment described above indicates that the existing dikes extending to either side of the existing and replacement bridges (i.e. outside of the ground improvement zones) will undergo large displacement into the slough during seismic event. It is assumed that they will then be quickly repaired or replaced prior to a major flood event. The seismic performances of the dike outside of the proposed bridge are not included in the scope of this study.

All construction work related to the dike should be completed in accordance with "Dike Design and Construction Guide – Best Management Practices for British Columbia". A consideration of the following construction aspects is recommended:

- The dike fill should be compatible with material forming the body of the existing dike. In general, Tetra Tech recommend using material indicated in Table 11-1. Alternative dike fill may be used subjected to engineer's approval.

Table 11-1: Gradation Limits for Dike Fill

Sieve Size (mm)	Gradation Limits % Passing by Dry Weight
19.0	100
4.75	80 – 100
0.42	25 – 90
0.149	18 – 50
0.075	15 – 30

- Care will need to be exercised during the placement and compaction of the dike fill. Moisture control will be required since the relatively large fines content may hinder compaction if the water content is too high relative to optimum.
- If a riprap filter layer is not used, a non-woven geotextile should be placed at the interface between the dike fill and the riprap in order to avoid migration of fines across the material interface. The geotextile should be minimum Nilex 4553 (or equivalent); higher strength geotextile may be required depending on the riprap used for the dike as specified by the hydrotechnical engineer.
- The dike fill should be placed with a maximum compacted lift thickness of 200 mm and be compacted to a minimum of 95% Standard Proctor Maximum Dry Density (SPMDD). The top 300 mm lift should be compacted to 100% SPMDD.

- Benching of the side slopes should be performed to provide a stepped surface and ensure adequate bonding between the existing and new dike fill layers. The slope should be over-built and then trimmed back to the design profile to provide sufficient compaction to the face of the slope.

11.3 Construction Staging of the Bridge Abutments

As discussed with McElhanney, the construction staging for the bridge abutments are considered to be as follow:

- Excavation will likely be required, especially on the west, where coarse materials (gravel and cobbles) were encountered. The thickness of the gravel is about 3.5 m from the ground surface;
- Temporary shoring may be required to maintain the traffic on the existing highway, if excavation is required;
- A temporary trestle or working fill platform will be required to install ground improvement (stone columns and ICP piles) at the abutments;
- Install ICP piles to protect the existing bridge;
- Install stone columns. The abutment piles are to be installed within the ground improvement zone. The locations of the piles should be at the center of the triangular array of stone columns and should be blocked out in order to avoid installing piles through a stone column;
- Install abutment piles;
- Construct abutment caps and back wall;
- Complete conventional fill;
- Install roadway drainage;
- Install roadway structure to underside of moment/transition slabs;
- Cast moment/transition slabs;
- Complete roadway base structure;
- Pavement.

11.4 Earthworks

Site preparation for the proposed bridge approach and abutment will require removal of topsoil near surface. Significant excavation into the existing ground for the bridge approach is not expected, but a nominal stripping of 0.3m is likely required to remove the topsoil containing organics. The topsoil is not considered suitable for re-use as engineered fill due to its organic content. The materials below the existing highway may be re-used but may require some processing. Once removed, the materials should be stockpiled separately from the construction debris, organics and other unsuitable materials and should be approved by the geotechnical engineer for re-use as engineering fill.

No surface surcharge or temporary loading should be placed within a distance equal to twice the depth of any temporary excavation unless the excavation support system has been designed to accommodate such surface loading.

No vertical cuts higher than 1.2 m are considered. Any unsupported excavation above water level should not be steeper than 2H:1V. Any excavation requiring support will be a temporary works requirement for which the contractor is responsible.

12.0 CLOSURE

We trust this report meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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PERMIT NUMBER: 1001972

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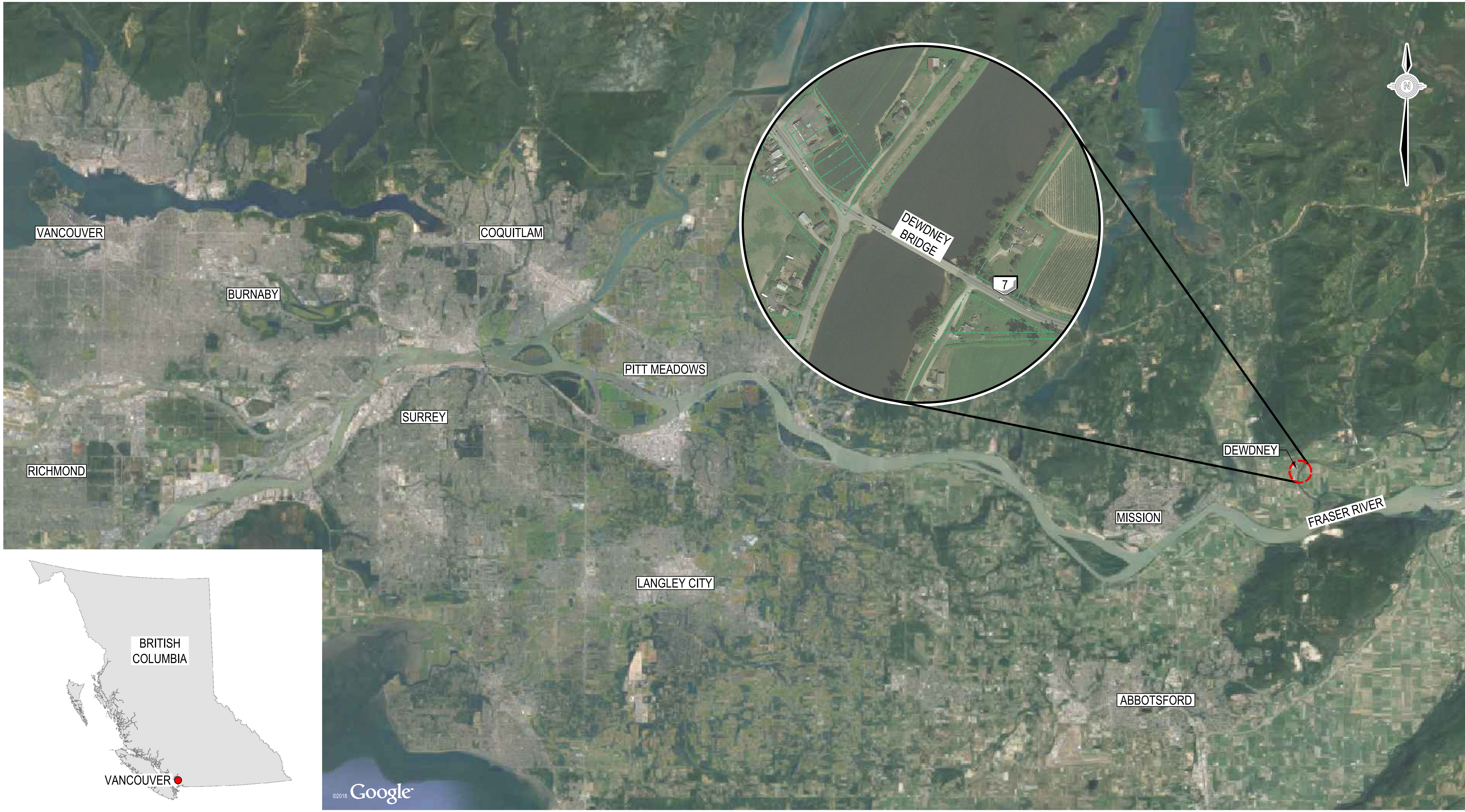
FIGURES



LEGEND
- Site location

NOTES
1. Imagery from Google Earth Pro.

ISSUED FOR USE

0 10,000m
Scale: 1:200,000 @ 11"x17"

CLIENT
BRITISH COLUMBIA Ministry of Transportation and Infrastructure

TETRA TECH

DEWDNEY BRIDGE REPLACEMENT PROJECT
DEWDNEY, BC

KEY PLAN

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03551-01	RH	AL	3
OFFICE	DATE		
VANC	April 17, 2023		

Figure 1

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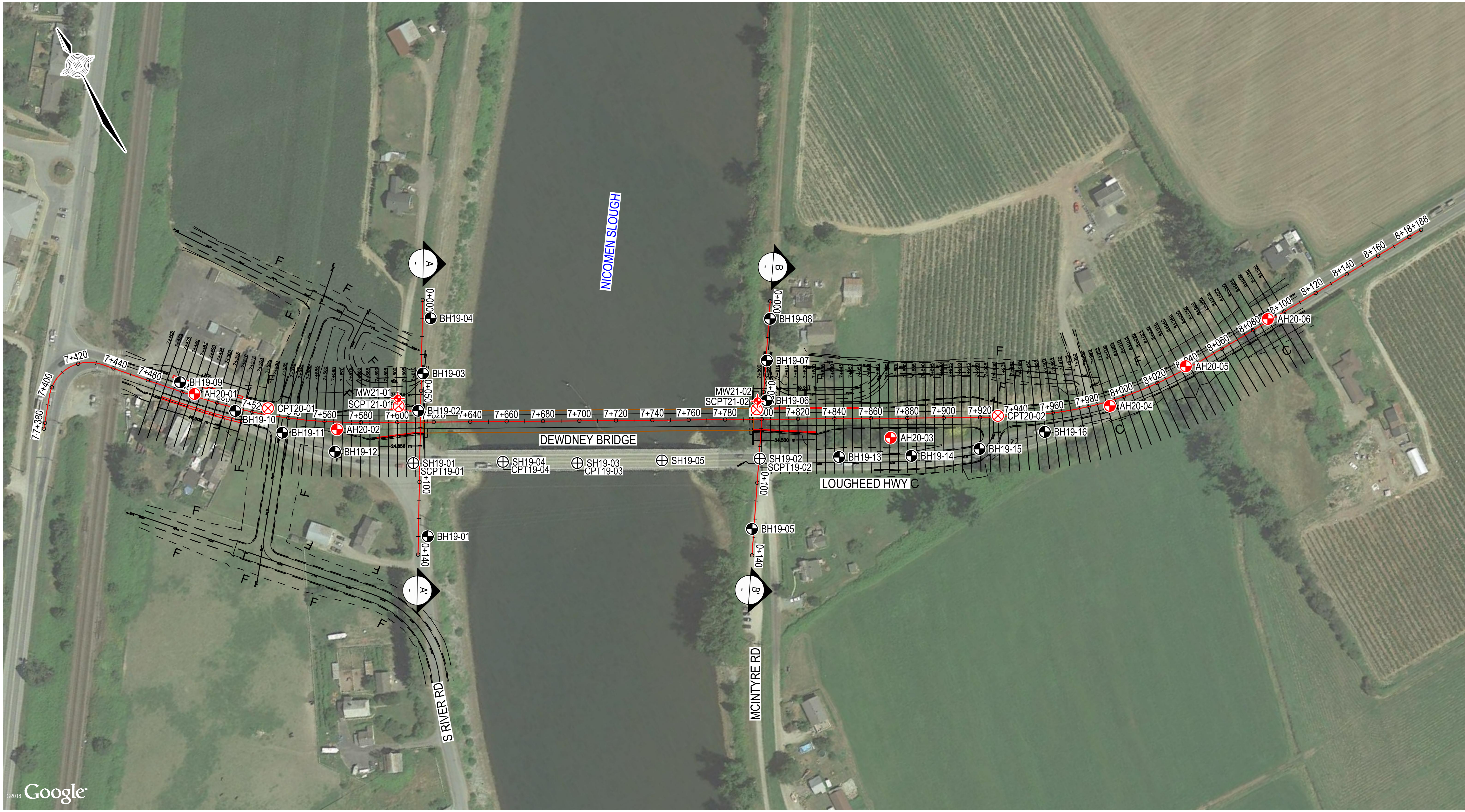


LEGEND

- 2020-2021 Auger testholes
- 2020-2021 CPT/SCPT testholes
- 2020-2021 Monitoring wells
- 2019 Auger testholes
- 2019 Sonic testholes
- 2019 CPT/SCPT testholes
- Proposed wall locations

NOTES

1. Imagery from Google Earth pro.
2. Layout based on DWG. "TYPICAL WALL SECTIONS" received October 23, 2020.

ISSUED FOR USE

0 — 100m

Scale: 1:2,000 @ 11"x17"

CLIENT

British Columbia — Ministry of Transportation and Infrastructure

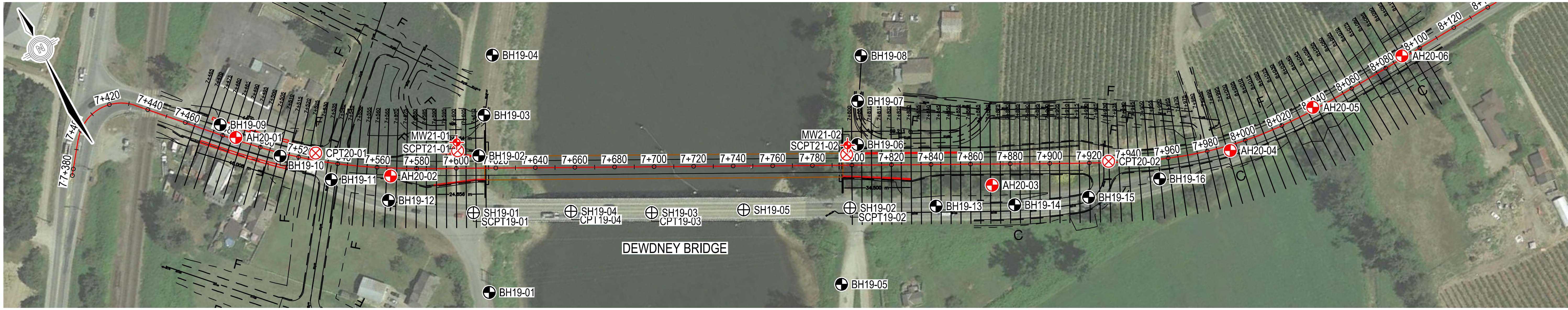
TETRA TECH

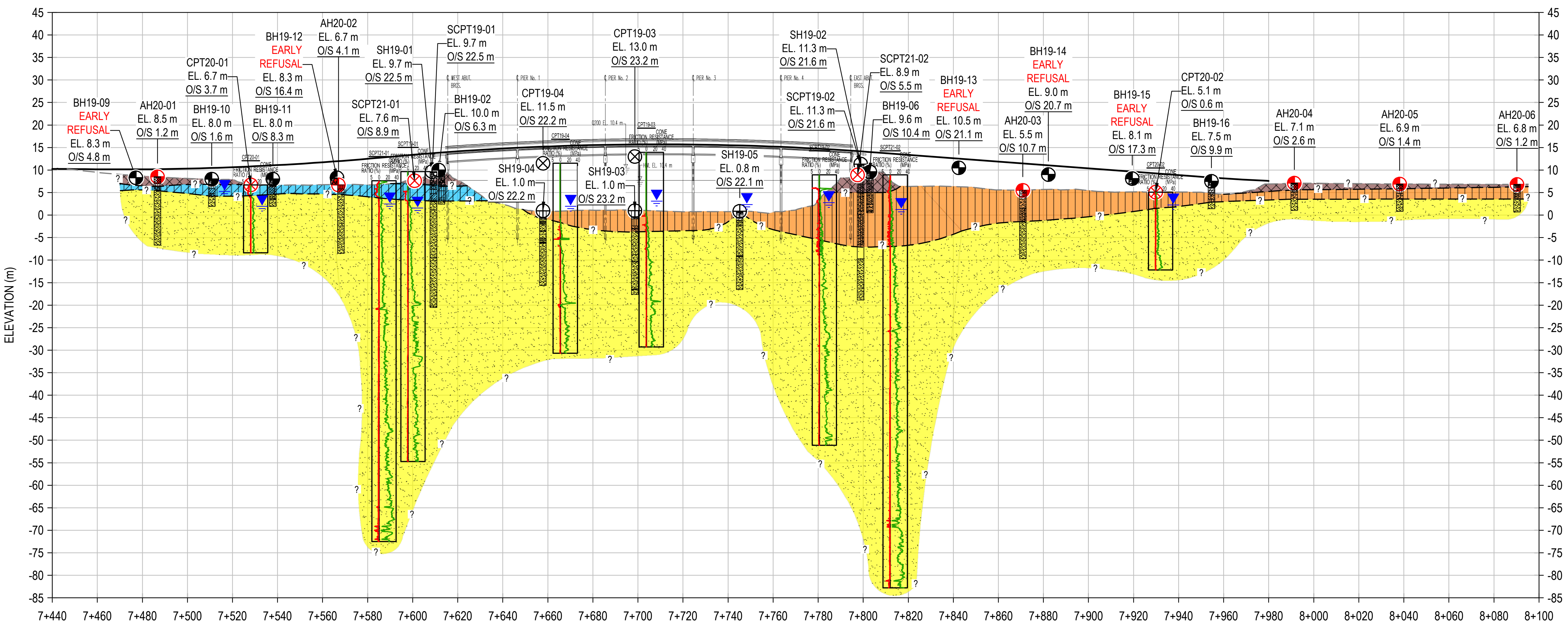
DEWDNEY BRIDGE REPLACEMENT PROJECT
DEWDNEY, BC

TESTHOLE LOCATION PLAN

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03551-01	RH	AL	3
OFFICE	DATE		
VANC	April 17, 2023		

Figure 2





LEGEND

- 2020-2021 Auger testholes
- 2020-2021 CPT/SCPT testholes
- 2019 Auger testholes
- 2019 Sonic testholes
- 2019 CPT/SCPT testholes
- Existing ground and mudline
- L100 profile
- Water level
- Proposed wall locations

LEGEND

- Asphalt
- Gravel
- Sand and gravel
- Organics
- Silt
- Clay
- Sand
- Sand and silt
- Fill
- Silt and clay
- Sand and silt
- Sand

NOTES

1. Imagery from Google Earth pro.
2. Layout based on DWG. "TYPICAL WALL SECTIONS" received October 23, 2020.
3. Layout from Dwg. 596-302 "Dewdney Bridge No. 00596 General Arrangement" by McElhanney.

ISSUED FOR USE

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0 100m
Horizontal Scale: 1:2000 @ 11"x17"

CLIENT

BRITISH COLUMBIA Ministry of Transportation and Infrastructure

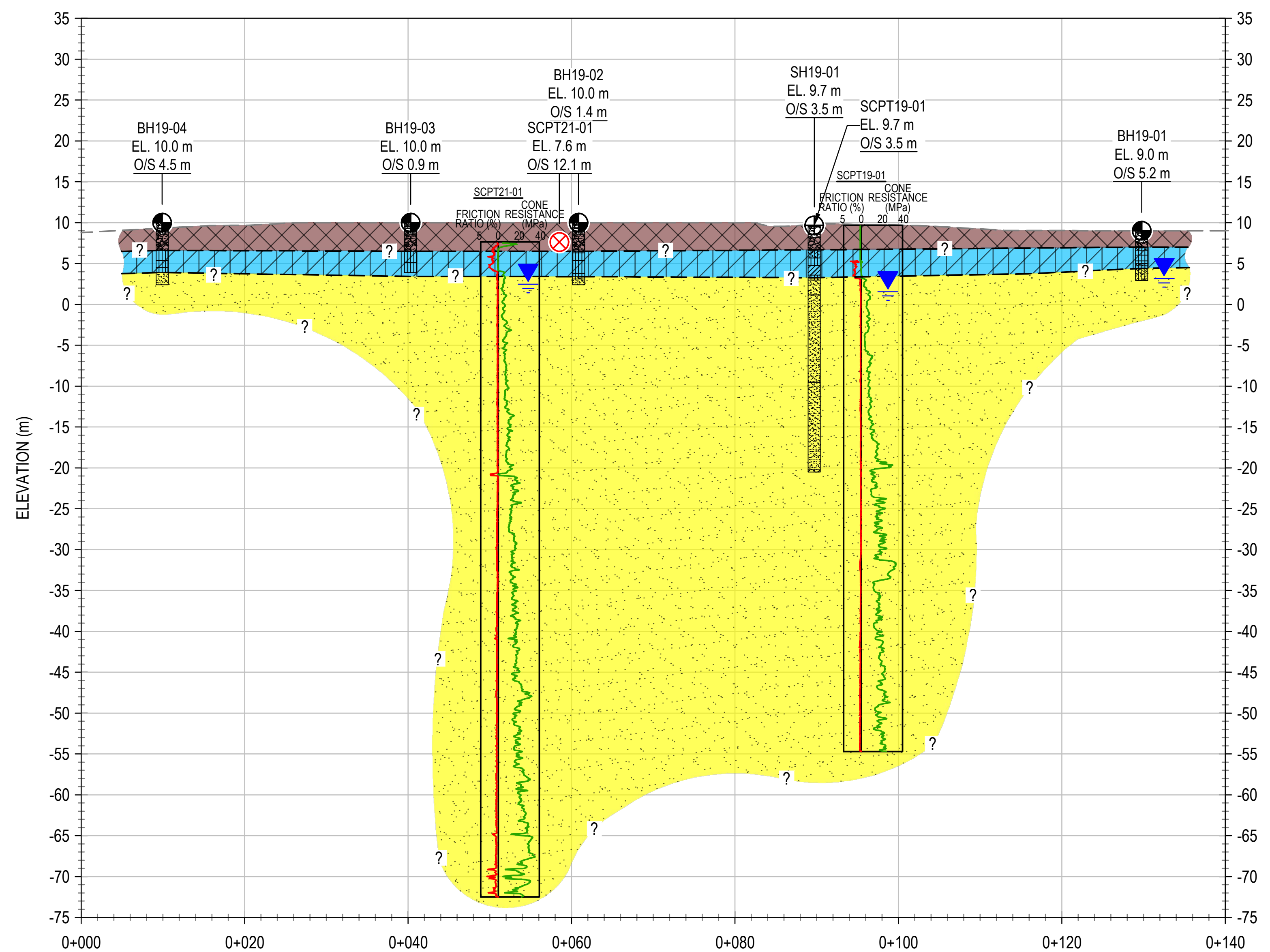
TETRA TECH

DEWDNEY BRIDGE REPLACEMENT PROJECT
DEWDNEY, BC

SOIL PROFILE
BRIDGE ALIGNMENT L100

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03551-01	RH	AL	3
OFFICE	DATE		
VANC	April 17, 2023		

Figure 3a



LEGEND

- 2020-2021 Auger testholes
- 2020-2021 CPT/SCPT testholes
- 2019 Auger testholes
- 2019 Sonic testholes
- 2019 CPT/SCPT testholes
- Existing ground
- Water level
- Proposed wall locations

LEGEND

- Asphalt
- Gravel
- Sand and gravel
- Organics
- Silt
- Clay
- Sand
- Sand and silt
- Fill
- Silt and clay
- Sand and silt
- Sand

NOTES

1. Imagery from Google Earth pro.
2. Layout based on DWG. "TYPICAL WALL SECTIONS" received October 23, 2020.

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Horizontal and Vertical Scale: 1:750 @ 11"x17"

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British Columbia — Ministry of Transportation and Infrastructure

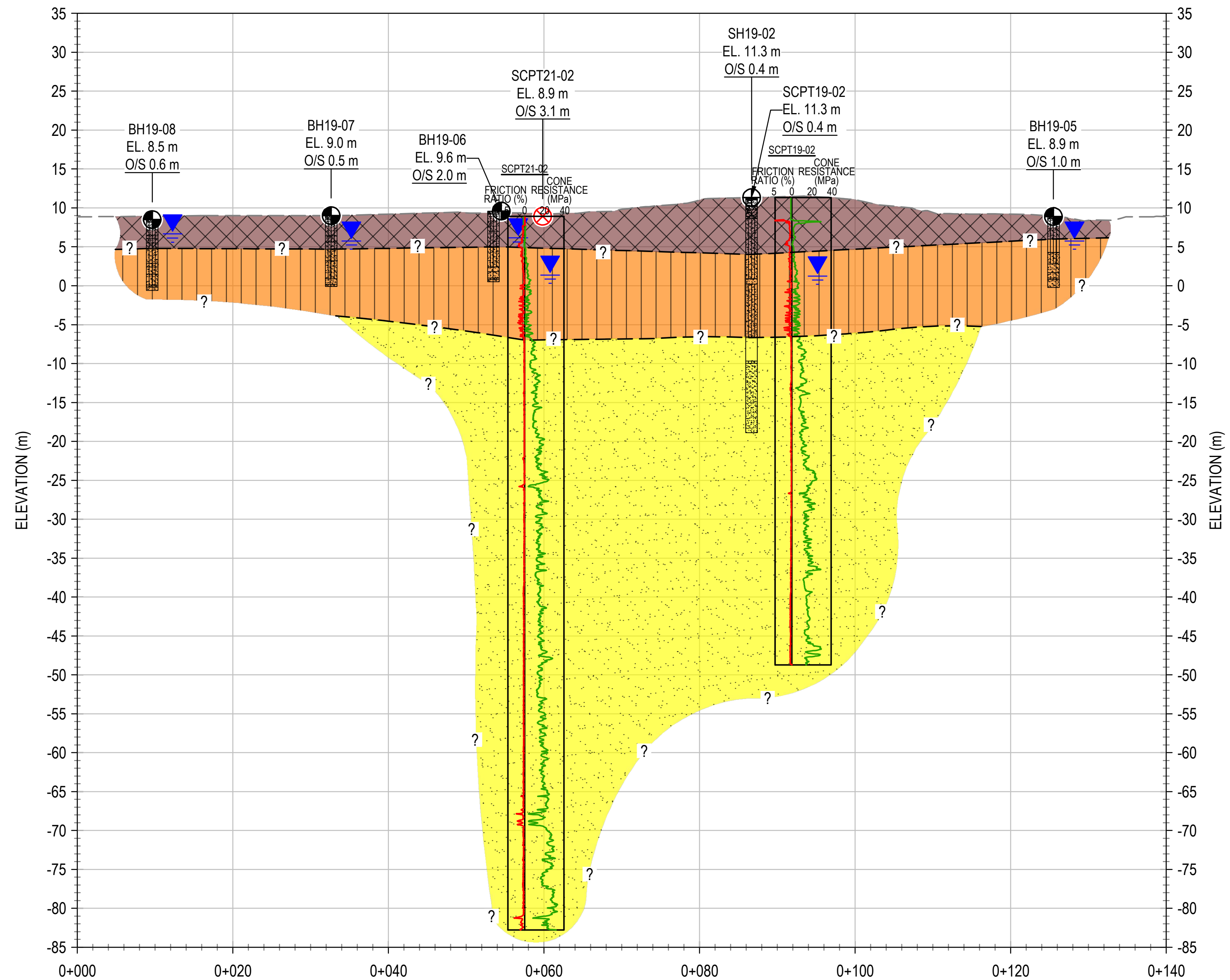
TETRA TECH

DEWDNEY BRIDGE REPLACEMENT PROJECT
DEWDNEY, BC

SOIL PROFILE
WEST ABUTMENT (SECTION A-A')

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03551-01	RH	AL	3
OFFICE	DATE		
VANC	April 17, 2023		

Figure 3b



LEGEND
- 2020-2021 Auger testholes
- 2020-2021 CPT/SCPT testholes
- 2019 Auger testholes
- 2019 Sonic testholes
- 2019 CPT/SCPT testholes
- Existing ground
- Water level
- Proposed wall locations

LEGEND
- Asphalt
- Gravel
- Sand and gravel
- Organics
- Silt
- Clay
- Sand
- Sand and silt
- Fill
- Silt and clay
- Sand and silt
- Sand

NOTES
1. Imagery from Google Earth pro.
2. Layout based on DWG. "TYPICAL WALL SECTIONS" received October 23, 2020.

ISSUED FOR USE

0 25m

Horizontal and Vertical Scale: 1:750 @ 11"x17"

CLIENT

British Columbia Ministry of Transportation and Infrastructure

TETRA TECH

DEWDNEY BRIDGE REPLACEMENT PROJECT DEWDNEY, BC

SOIL PROFILE EAST ABUTMENT (SECTION B-B')

PROJECT NO.	DWN	CKD	REV
ENG.VGEO03551-01	RH	AL	3
OFFICE	DATE		
VANC	April 17, 2023		

Figure 3c

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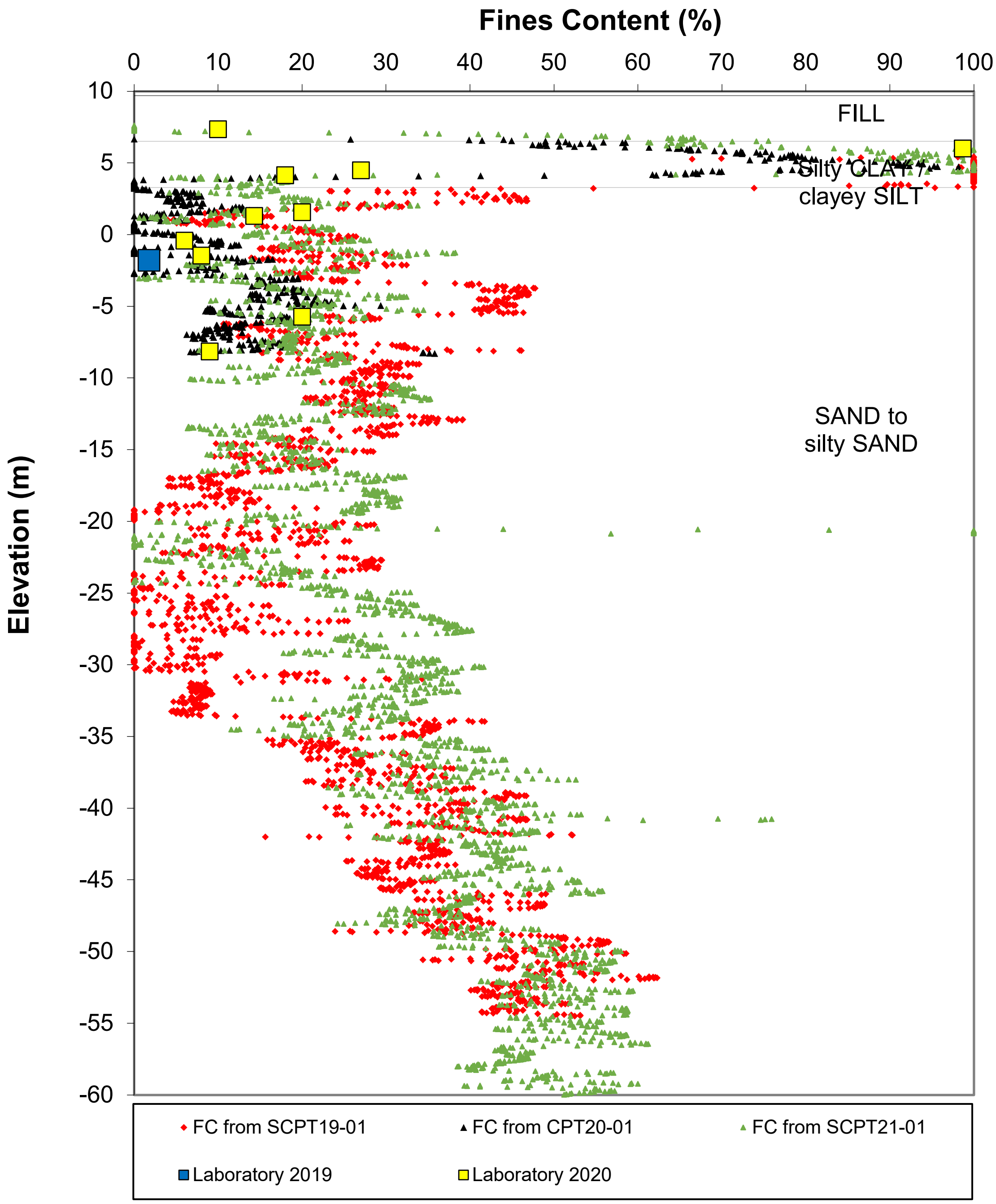
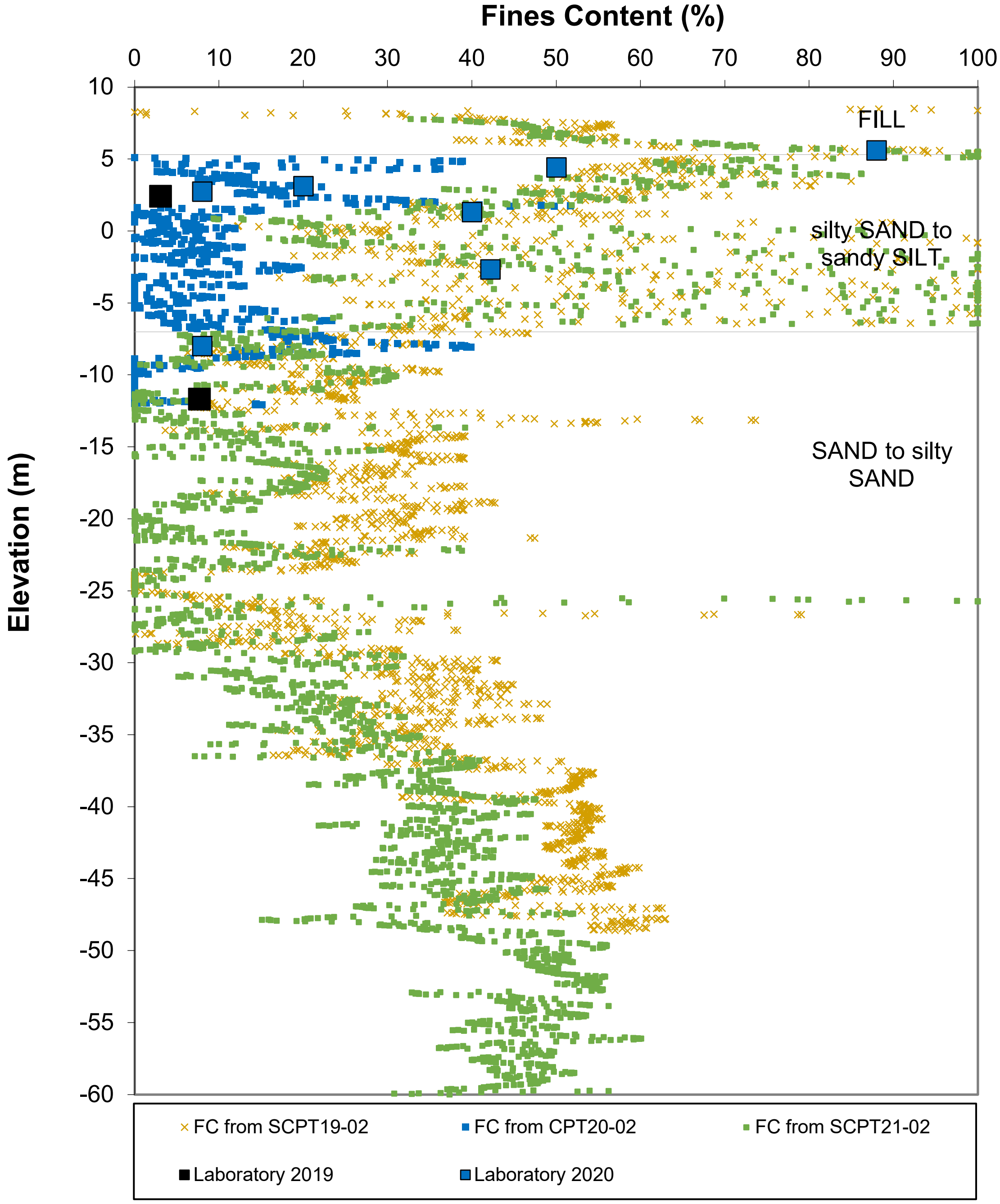


Notes: Fines Content from CPT data based on correlation by Idriss & Boulanger (2014)

FINES CONTENT
West Abutment and Approach

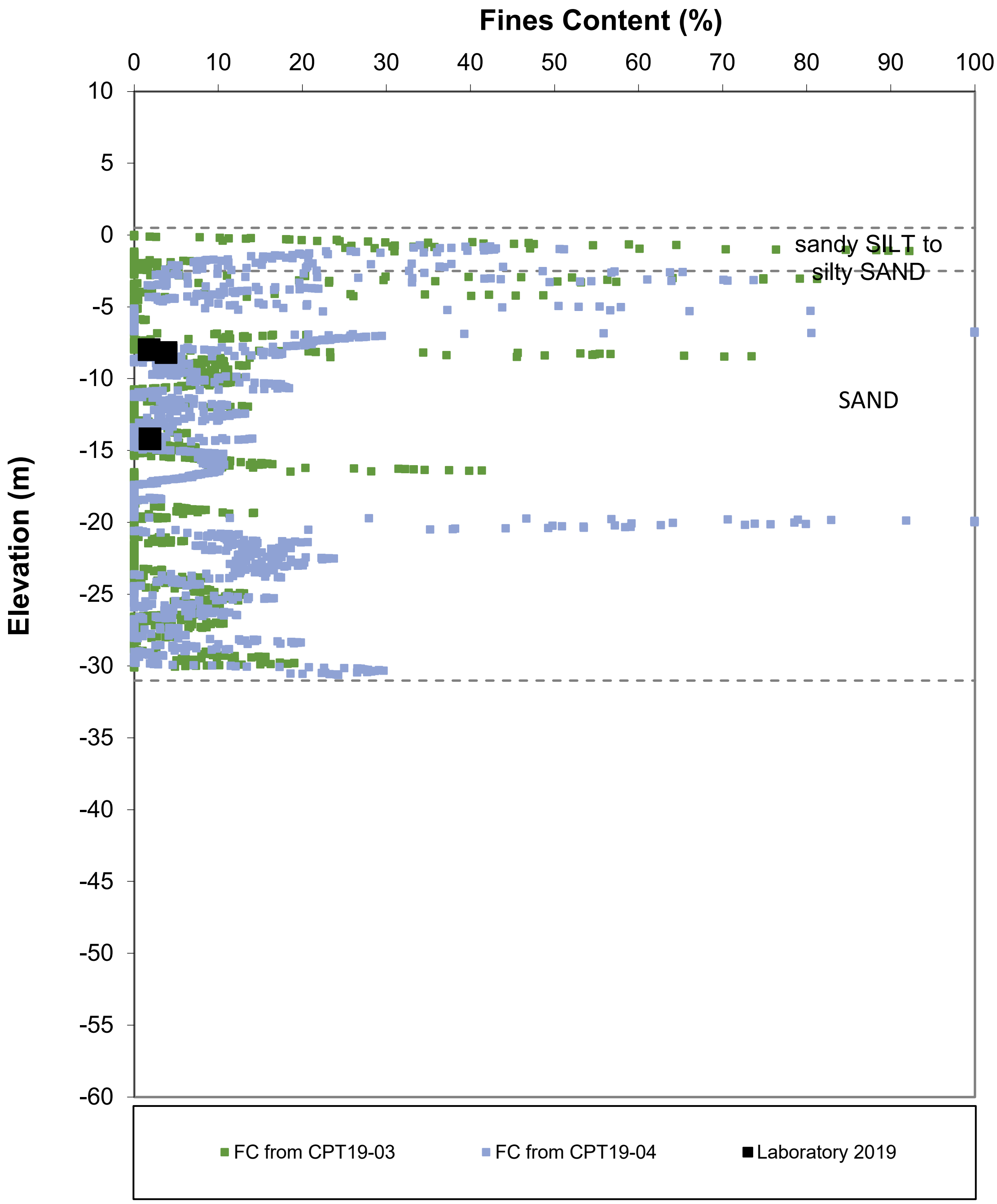
Figure 4a



Notes: Fines Content from CPT data based on correlation by Idriss & Boulanger (2014)

FINES CONTENT
East Abutment and Approach

Figure 4b

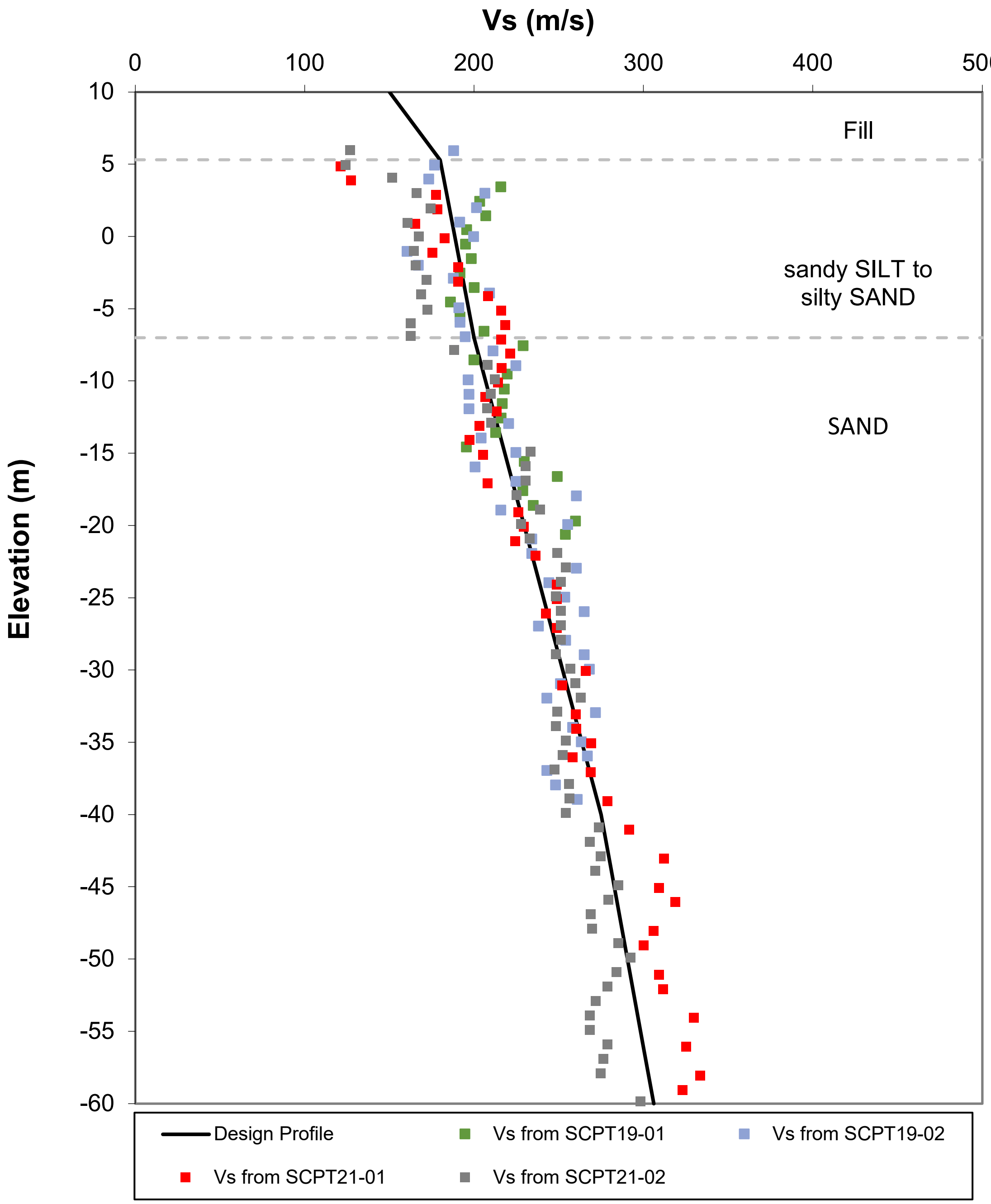


Notes: Fines Content from CPT data based on correlation by Idriss & Boulanger (2014)

TETRA TECH

FINES CONTENT
Slough

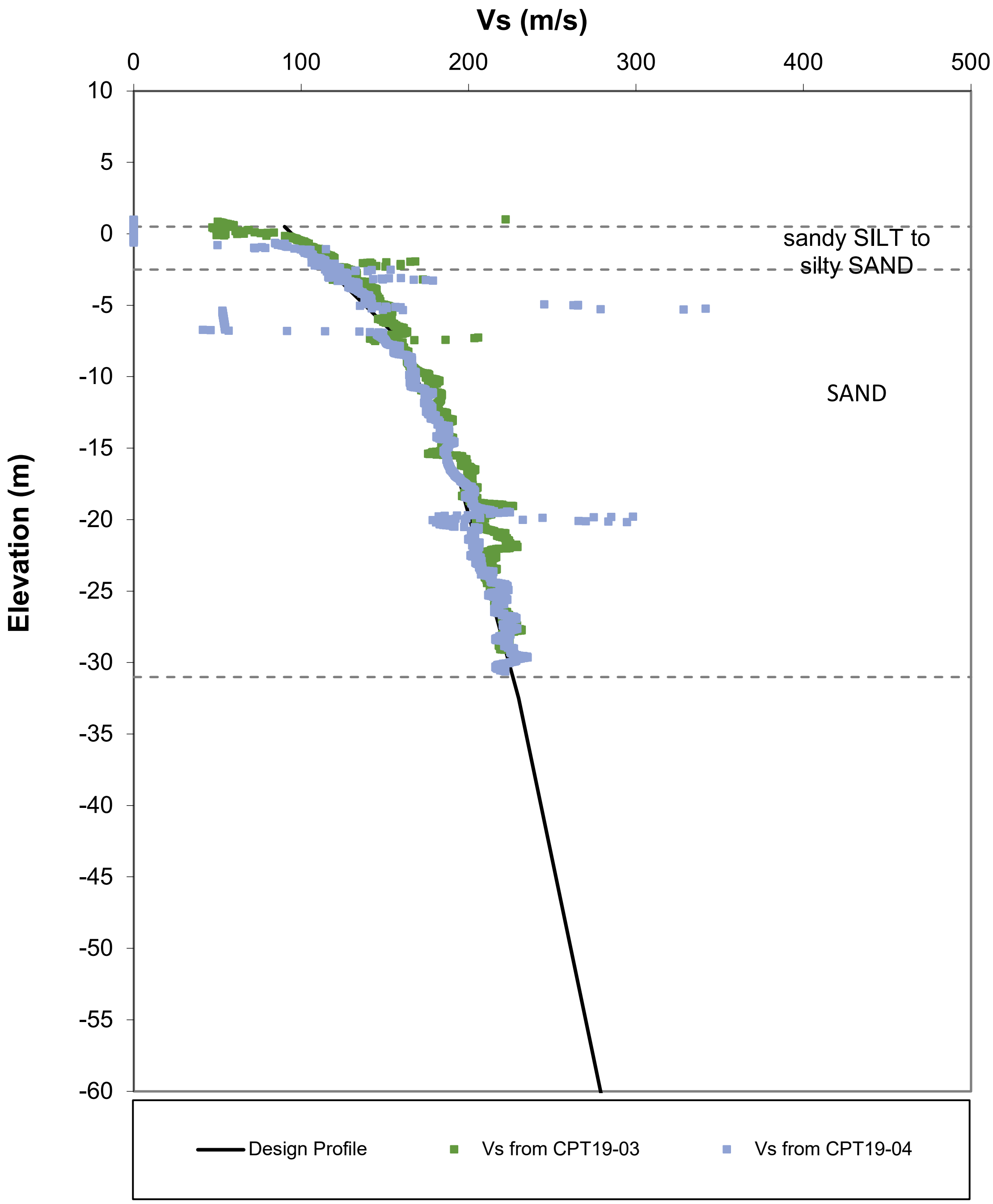
Figure 4c



TETRA TECH

SHEAR WAVE VELOCITY PROFILE
Abutment

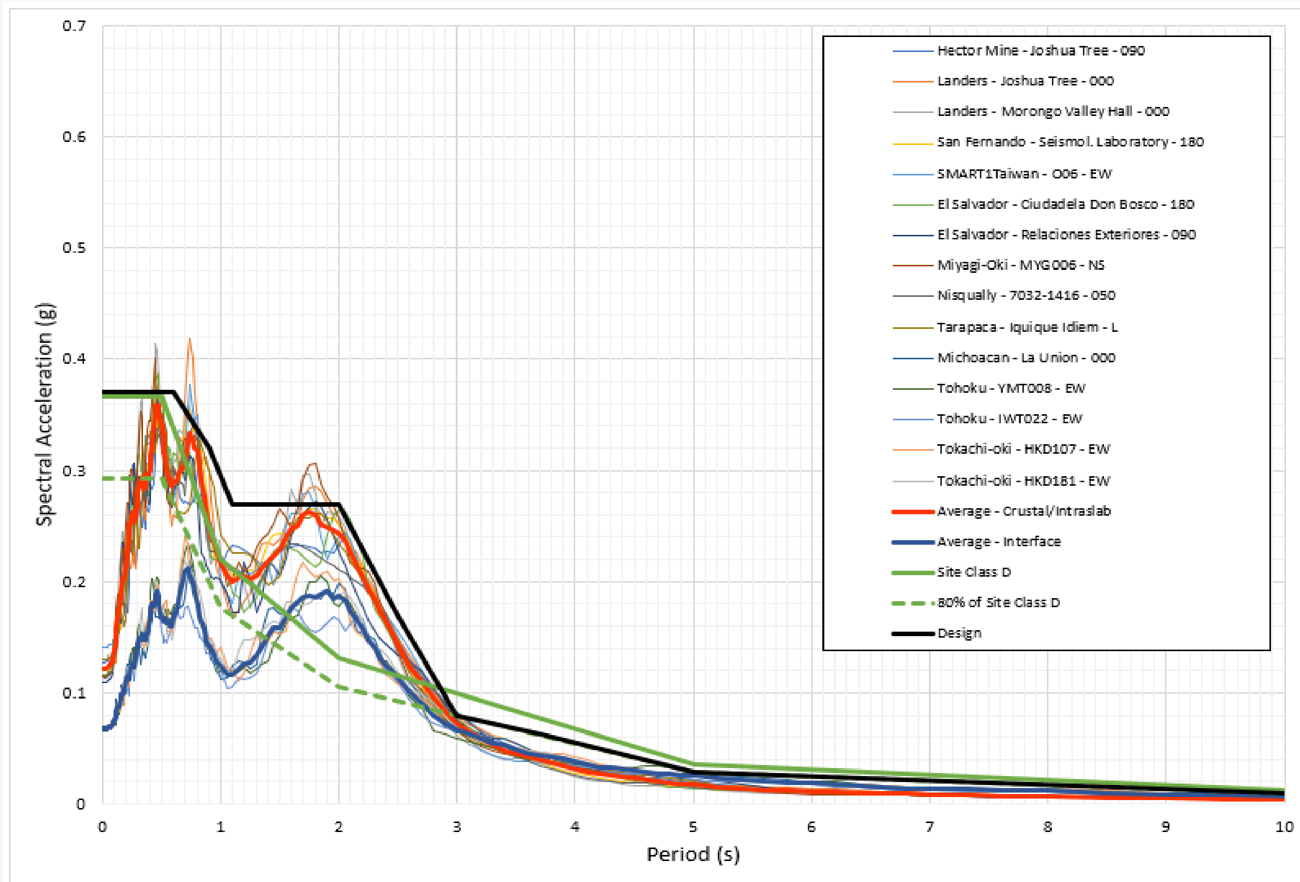
Figure 5a



* Vs interpreted from CPT data

SHEAR WAVE VELOCITY PROFILE
Slough

Figure 5b

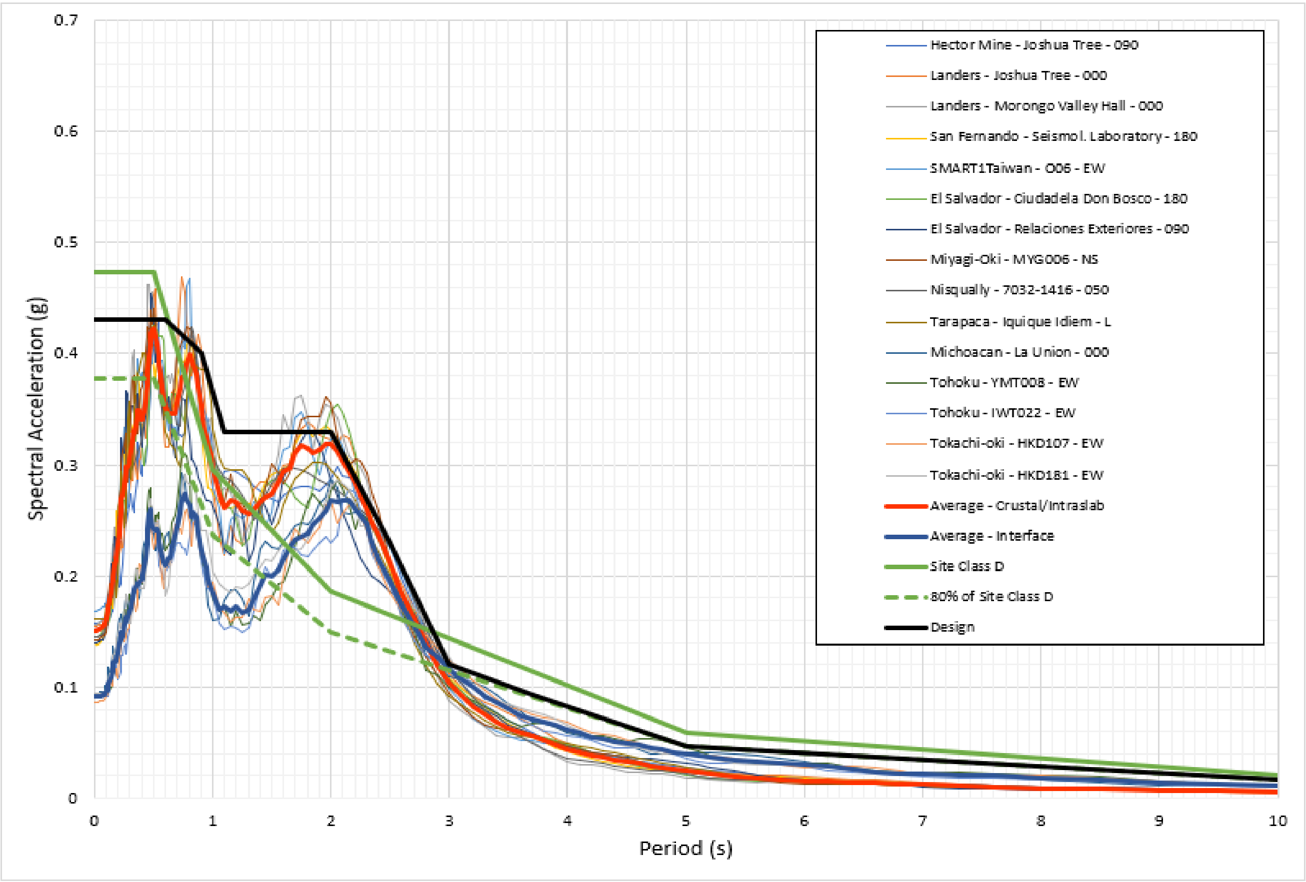


TETRA TECH

DESIGN RESPONSE SPECTRUM

475-Year Return Period

Figure 6a

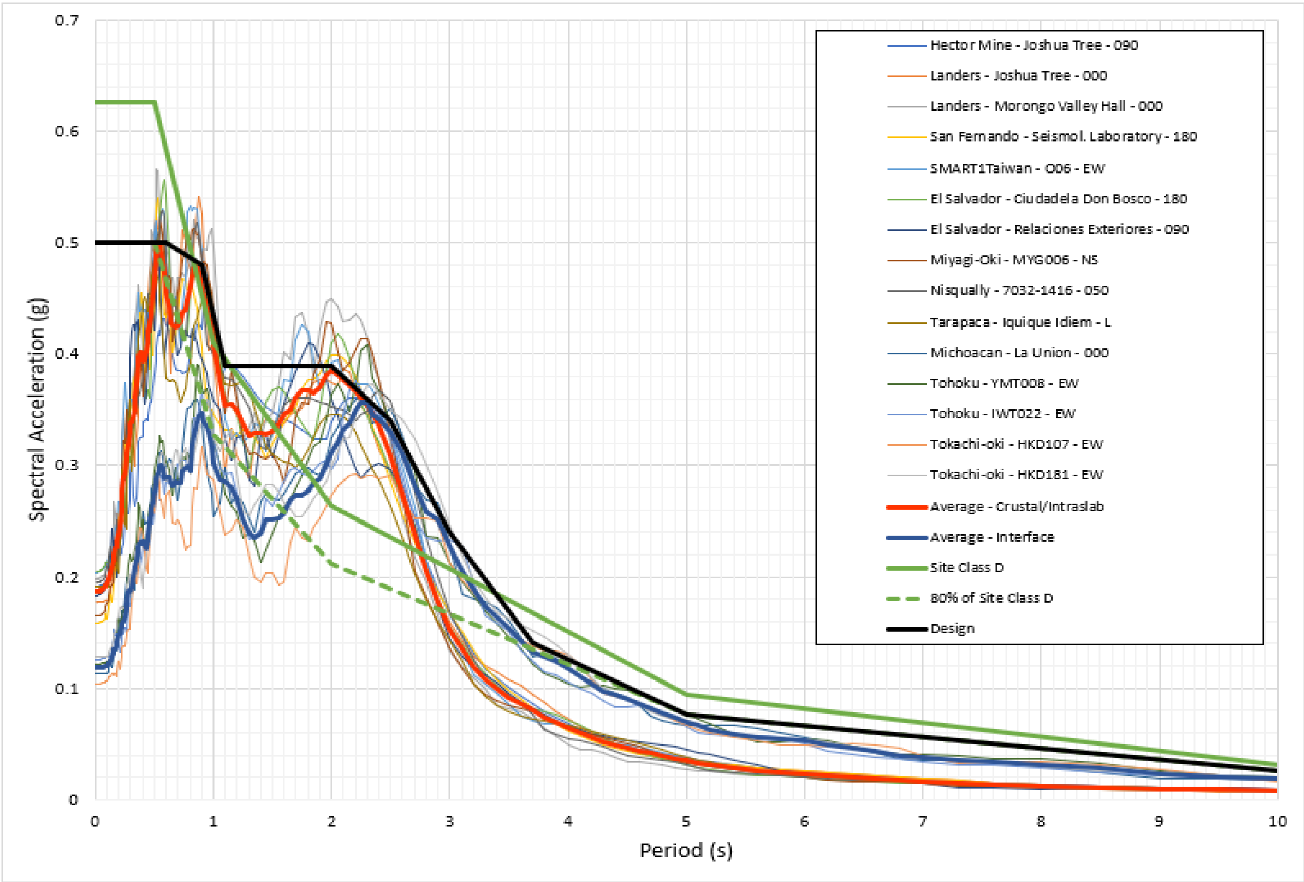


TETRA TECH

DESIGN RESPONSE SPECTRUM

975-Year Return Period

Figure 6b

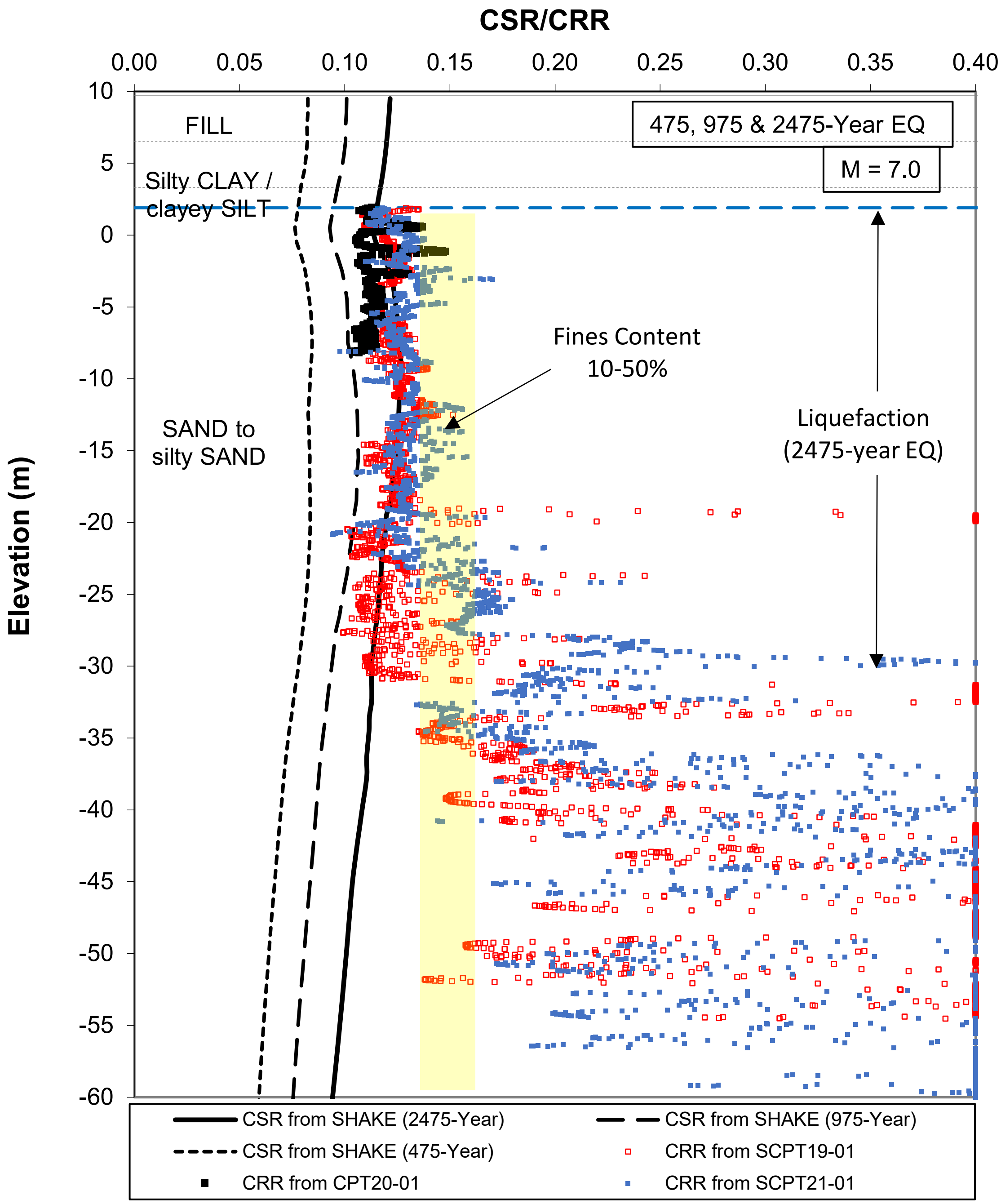


TETRA TECH

DESIGN RESPONSE SPECTRUM

2475-Year Return Period

Figure 6c

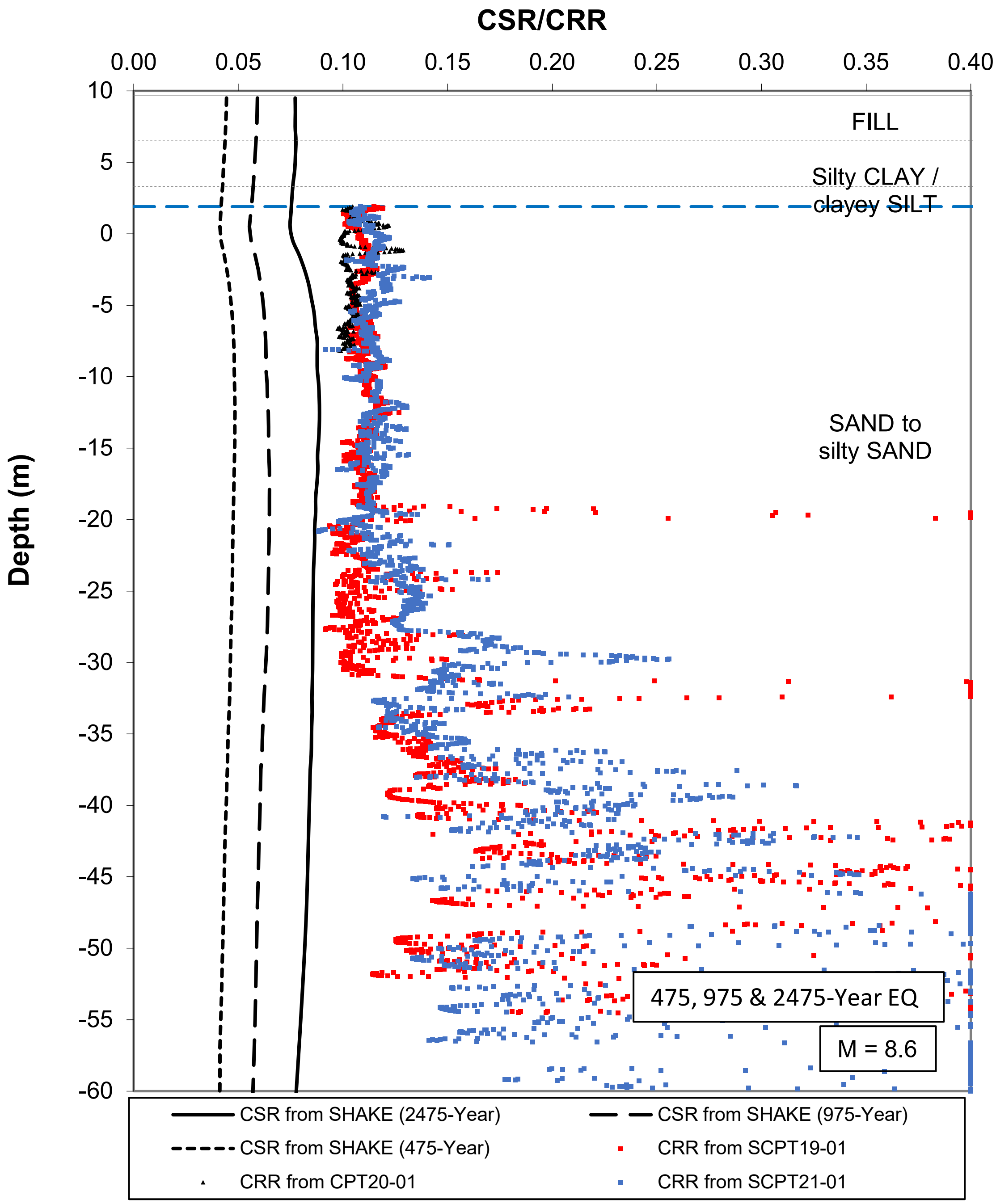


Notes: Liquefaction triggering based on method proposed by Idriss & Boulanger (2014)

LIQUEFACTION ASSESSMENT
2475-Year EQ Event - Crustal/Inslab
West Abutment and Approach

TETRA TECH

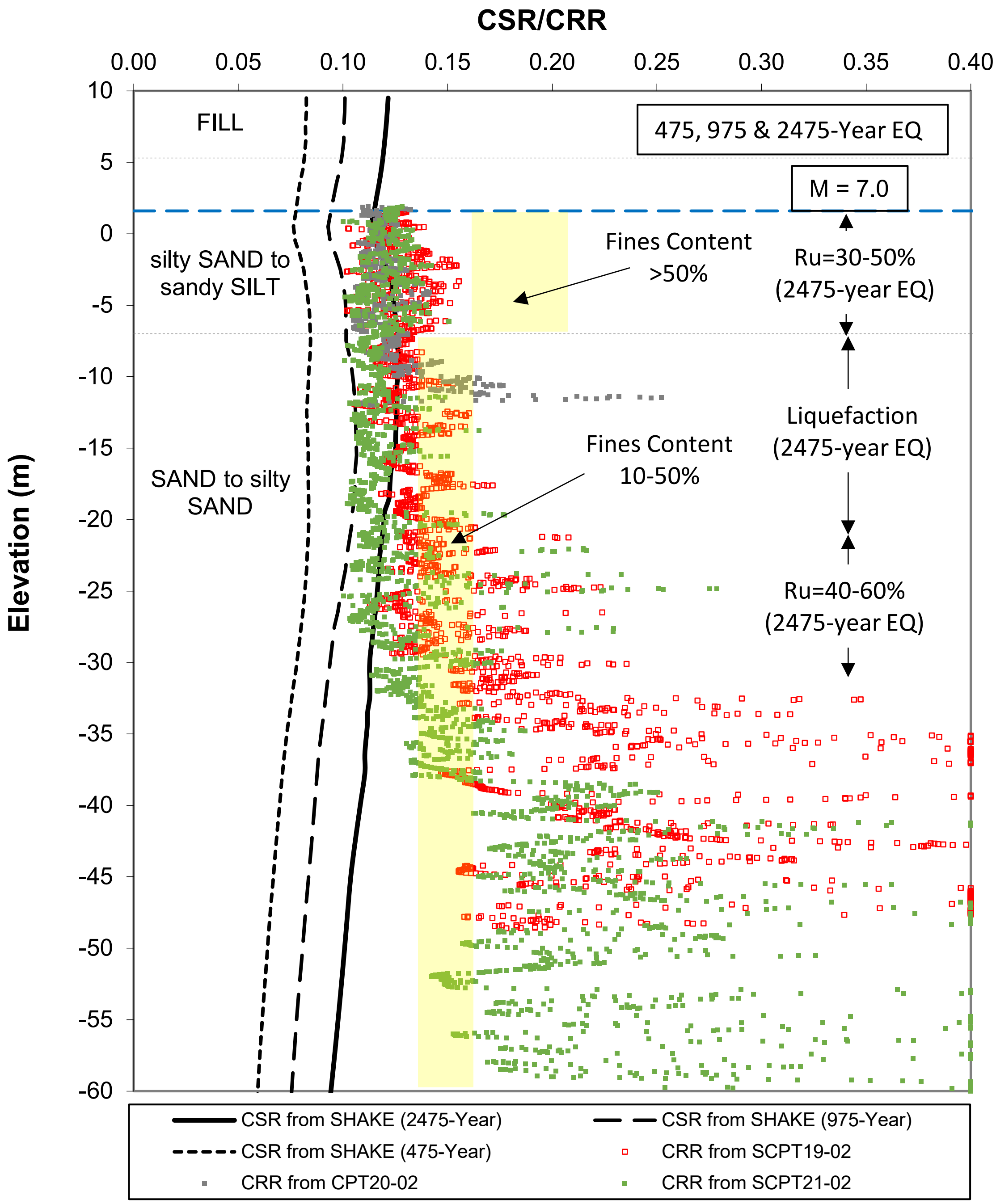
Figure 7a



Notes: Liquefaction triggering based on method proposed by Idriss & Boulanger (2014)

LIQUEFACTION ASSESSMENT
2475-Year EQ Event - Subduction
West Abutment and Approach

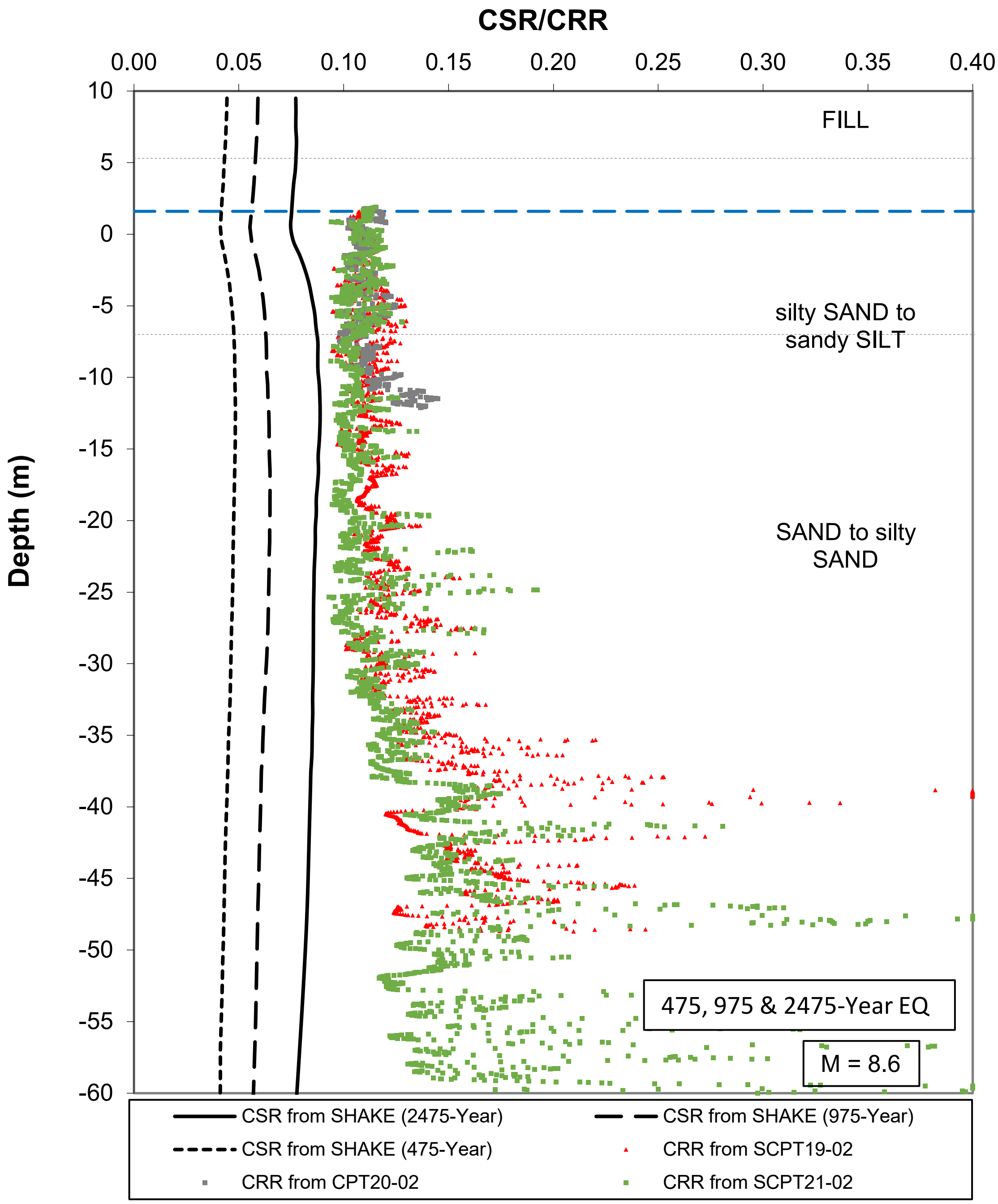
Figure 7b



Notes: Liquefaction triggering based on method proposed by Idriss & Boulanger (2014)

LIQUEFACTION ASSESSMENT
2475-Year EQ Event - Crustal/Inslab
East Abutment and Approach

Figure 7c

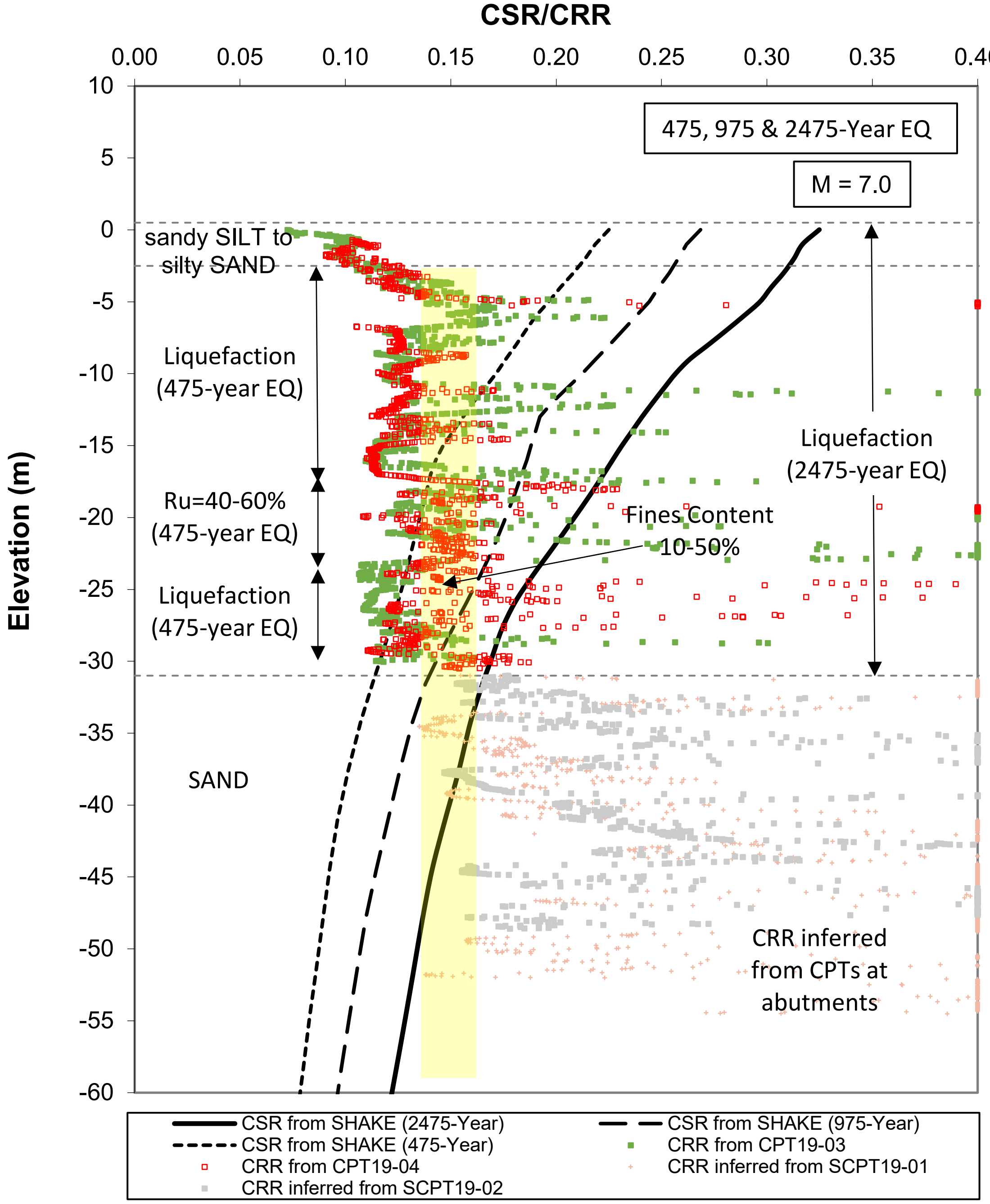


Notes: Liquefaction triggering based on method proposed by Idriss & Boulanger (2014)

LIQUEFACTION ASSESSMENT
2475-Year EQ Event - Subduction
East Abutment and Approach

TETRA TECH

Figure 7d

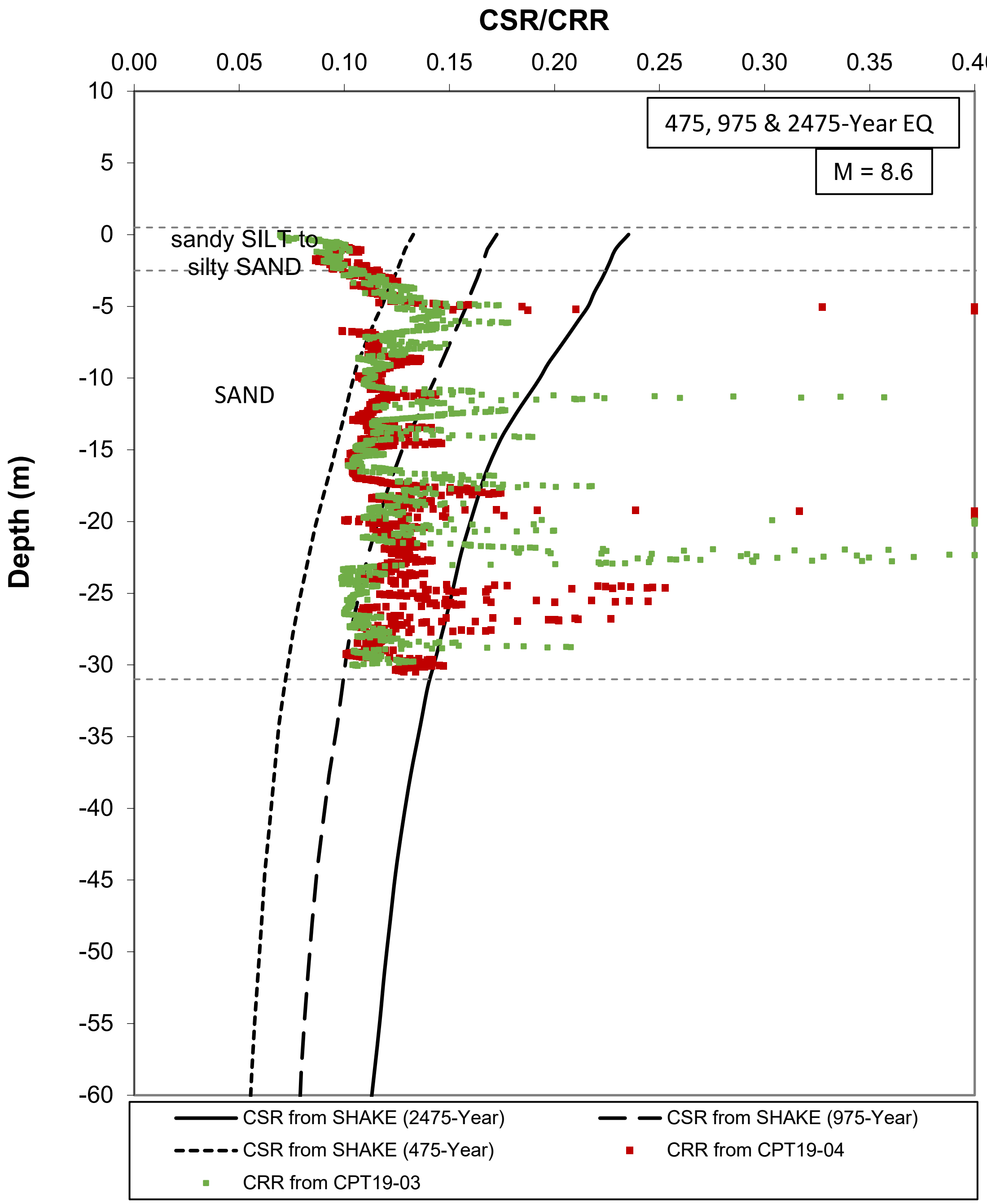


Notes: Liquefaction triggering based on method proposed by Idriss & Boulanger (2014)

LIQUEFACTION ASSESSMENT
475 & 2475-Year EQ Event - Crustal/Inslab
Slough

TETRA TECH

Figure 7e

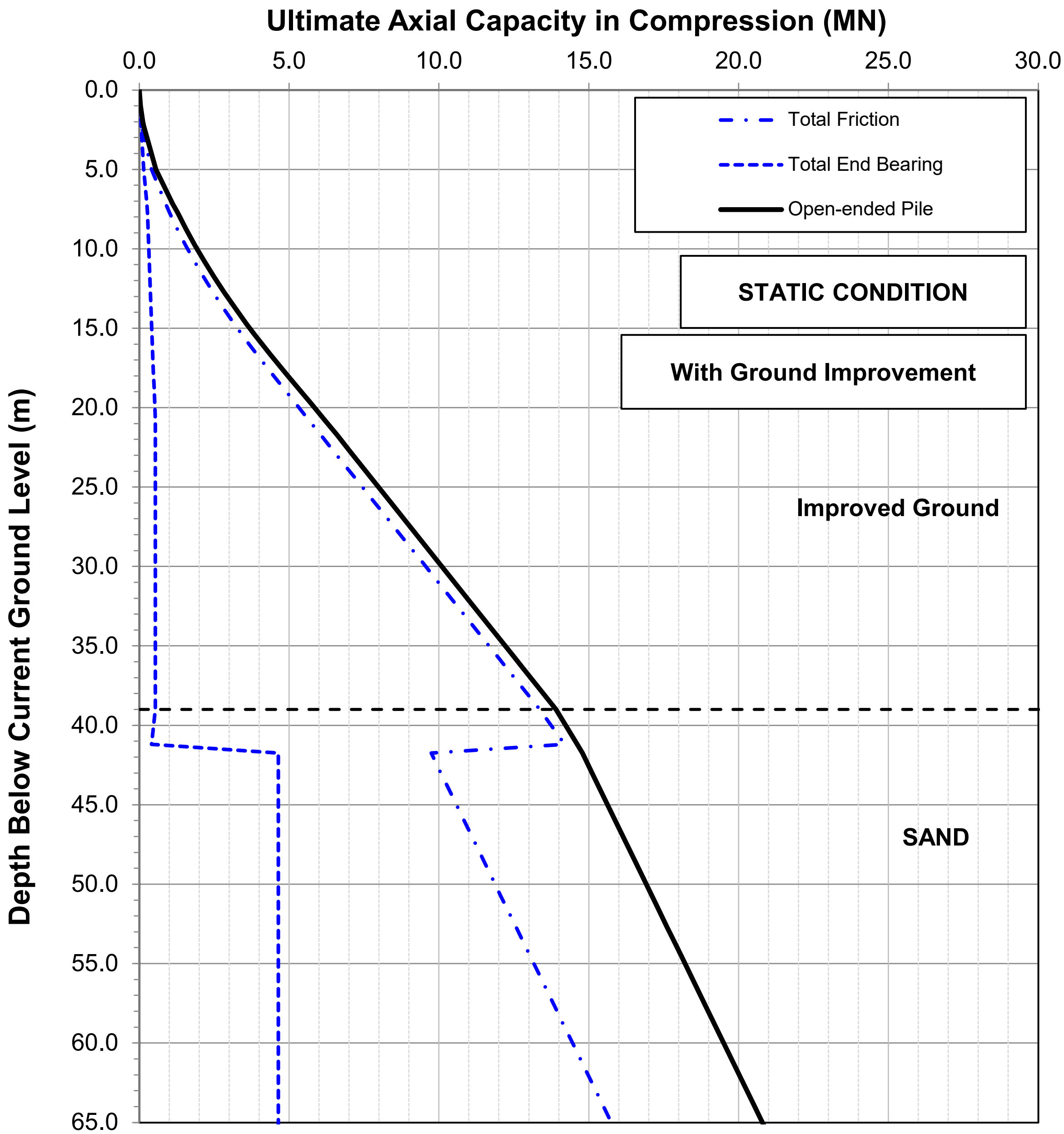


Notes: Liquefaction triggering based on method proposed by Idriss & Boulanger (2014)

LIQUEFACTION ASSESSMENT
475 & 2475-Year EQ Event - Subduction
Slough

TETRA TECH

Figure 7f

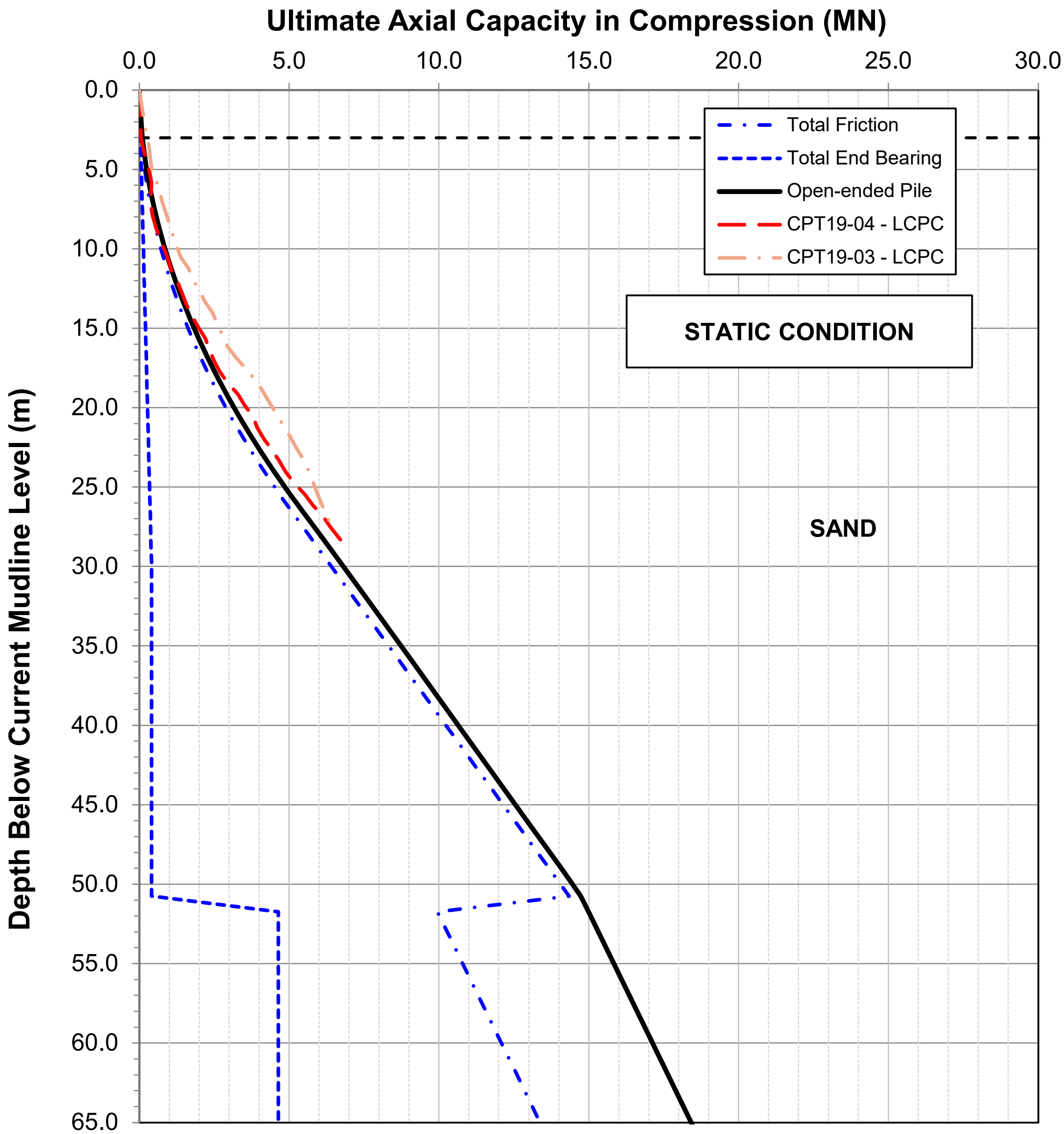


Note: - For open-ended pile, inside shaft friction is taken as 50% of the out side shaft friction
- At 41 m depth the open-ended pile behaves as plugged.

ULTIMATE AXIAL CAPACITY IN COMPRESSION
914mmx19mm Open-ended Pipe Pile
Static Condition - Abutment With Ground Improvement

TETRA TECH

Figure 8a

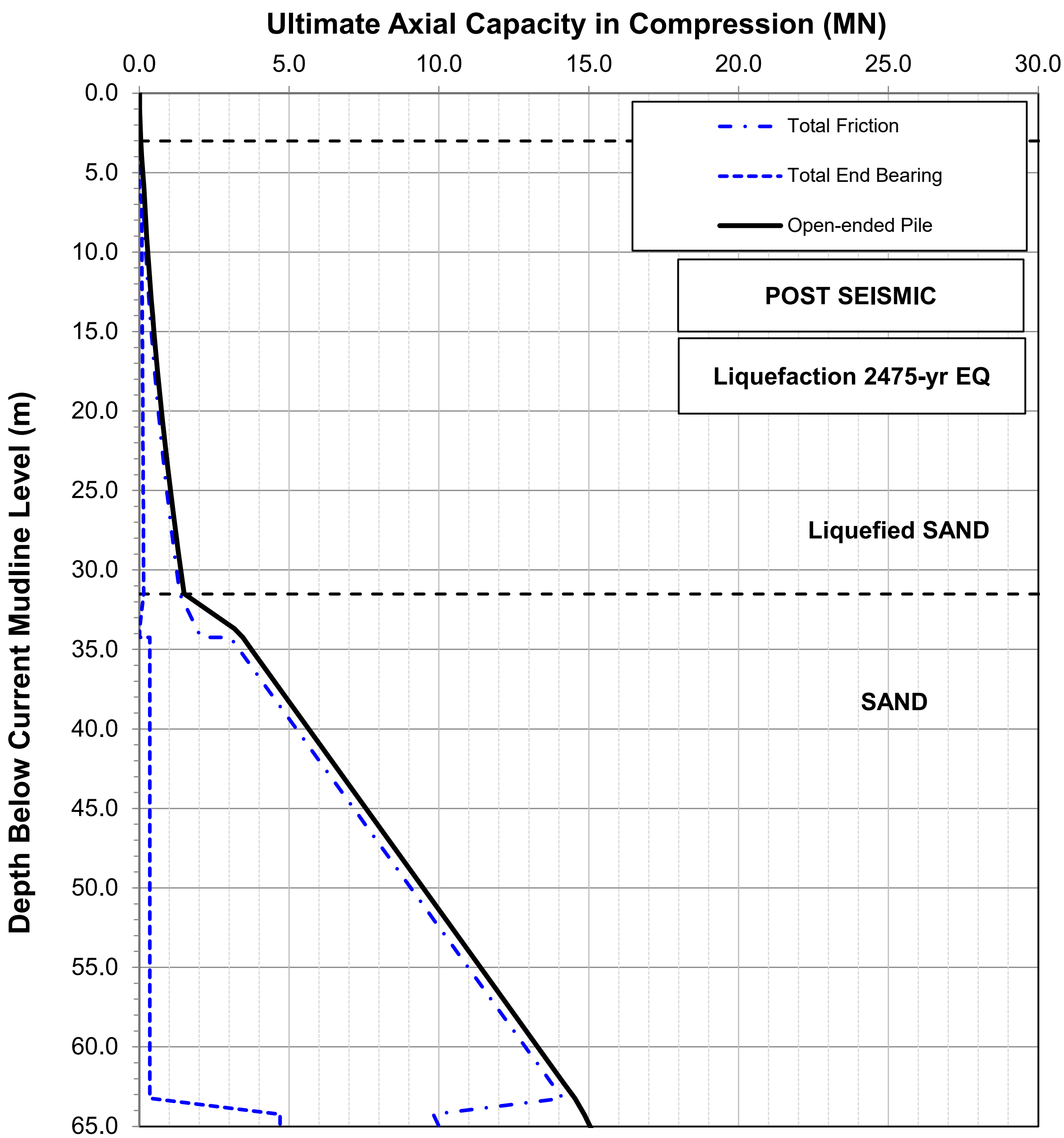


Note: - For open-ended pile, inside shaft friction is taken as 50% of the out side shaft friction
- At 50 m depth the open-ended pile behaves as plugged.

ULTIMATE AXIAL CAPACITY IN COMPRESSION
914mmx19mm Open-ended Pipe Pile
Static Condition - Slough

TETRA TECH

Figure 8b

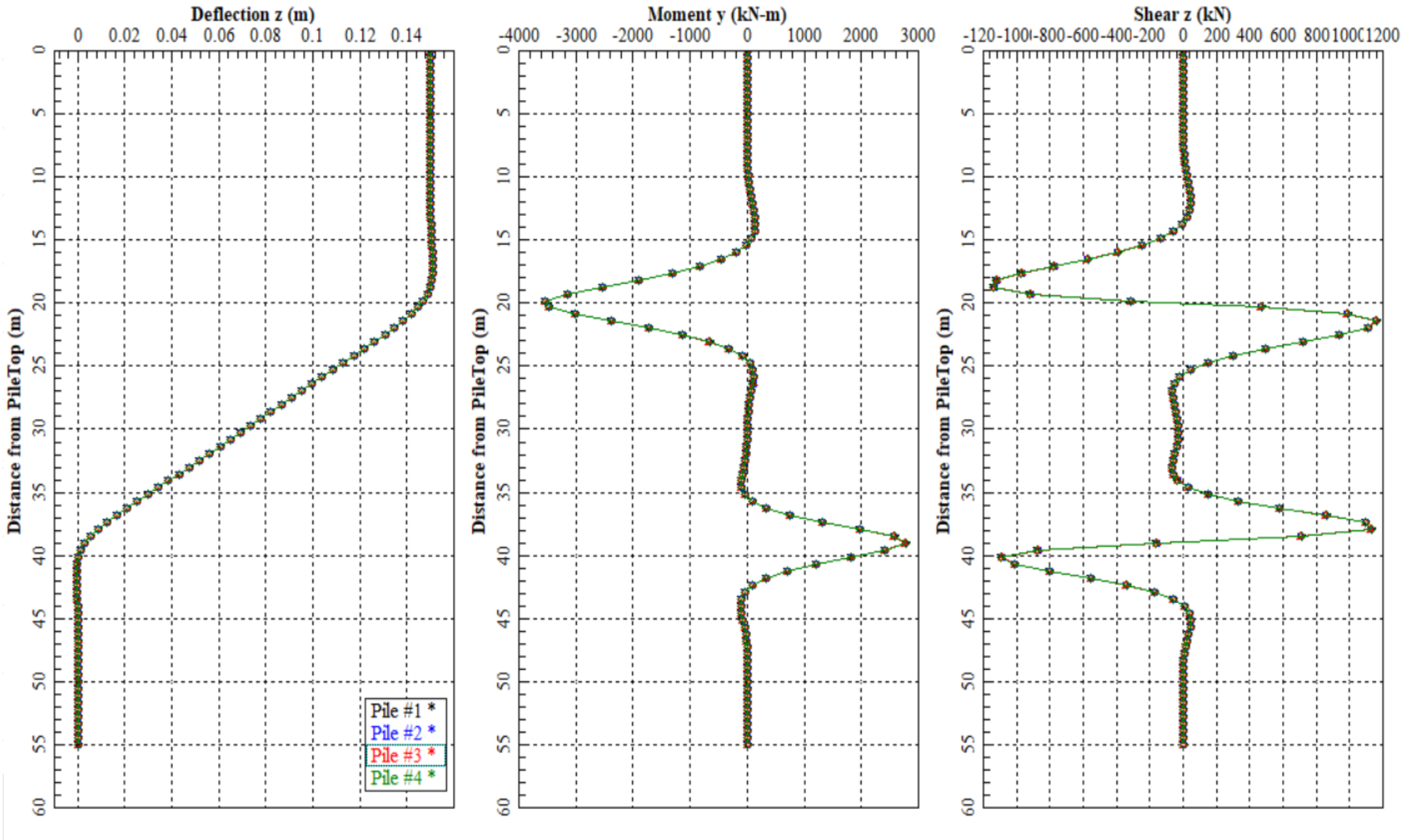


Note: - For open-ended pile, inside shaft friction is taken as 50% of the out side shaft friction
- At 64 m depth the open-ended pile behaves as plugged.

ULTIMATE AXIAL CAPACITY IN COMPRESSION
914mmx19mm Open-ended Pipe Pile
Post Seismic Condition 2475-yr EQ- Slough

TETRA TECH

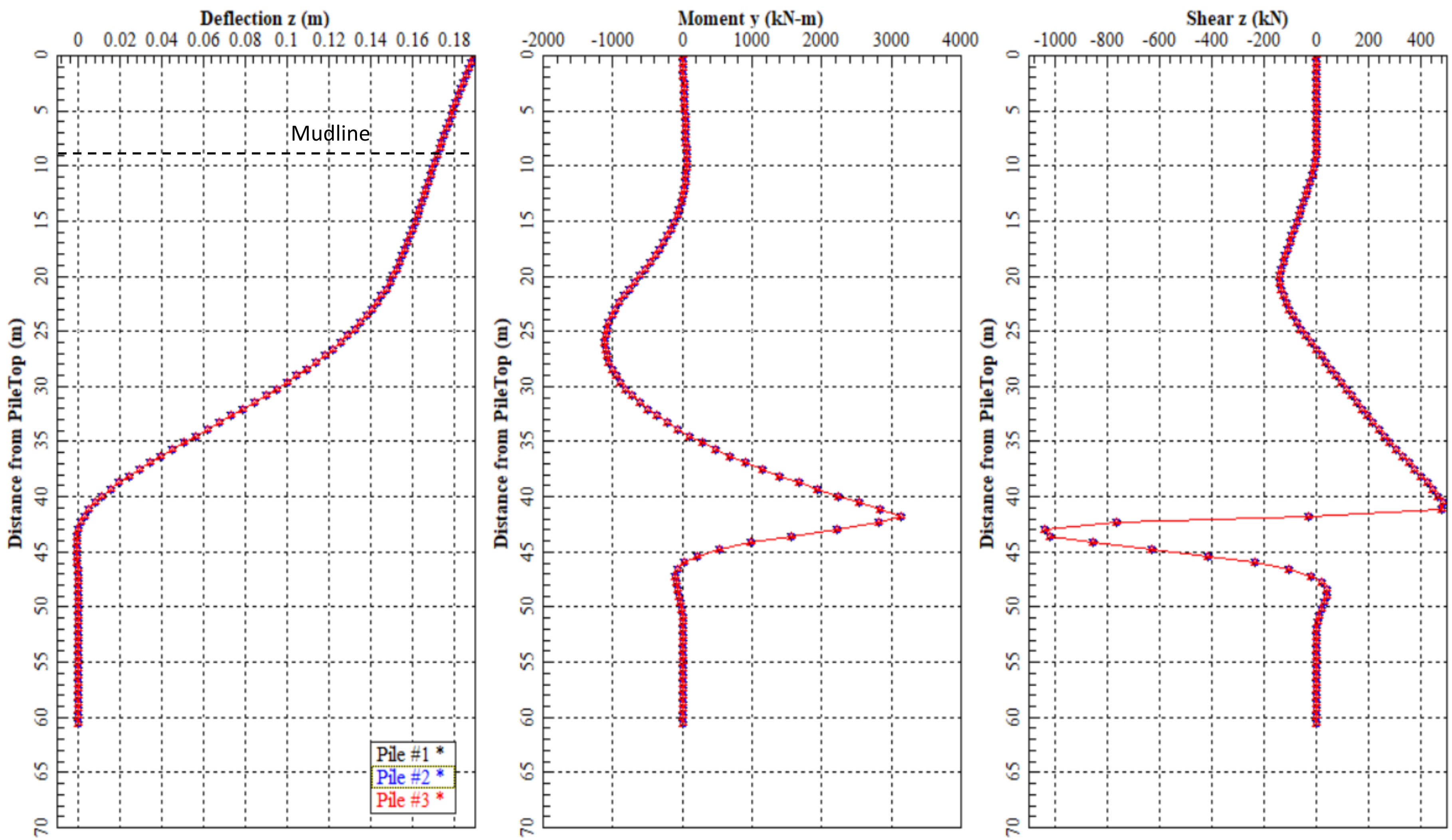
Figure 8c



TETRA TECH

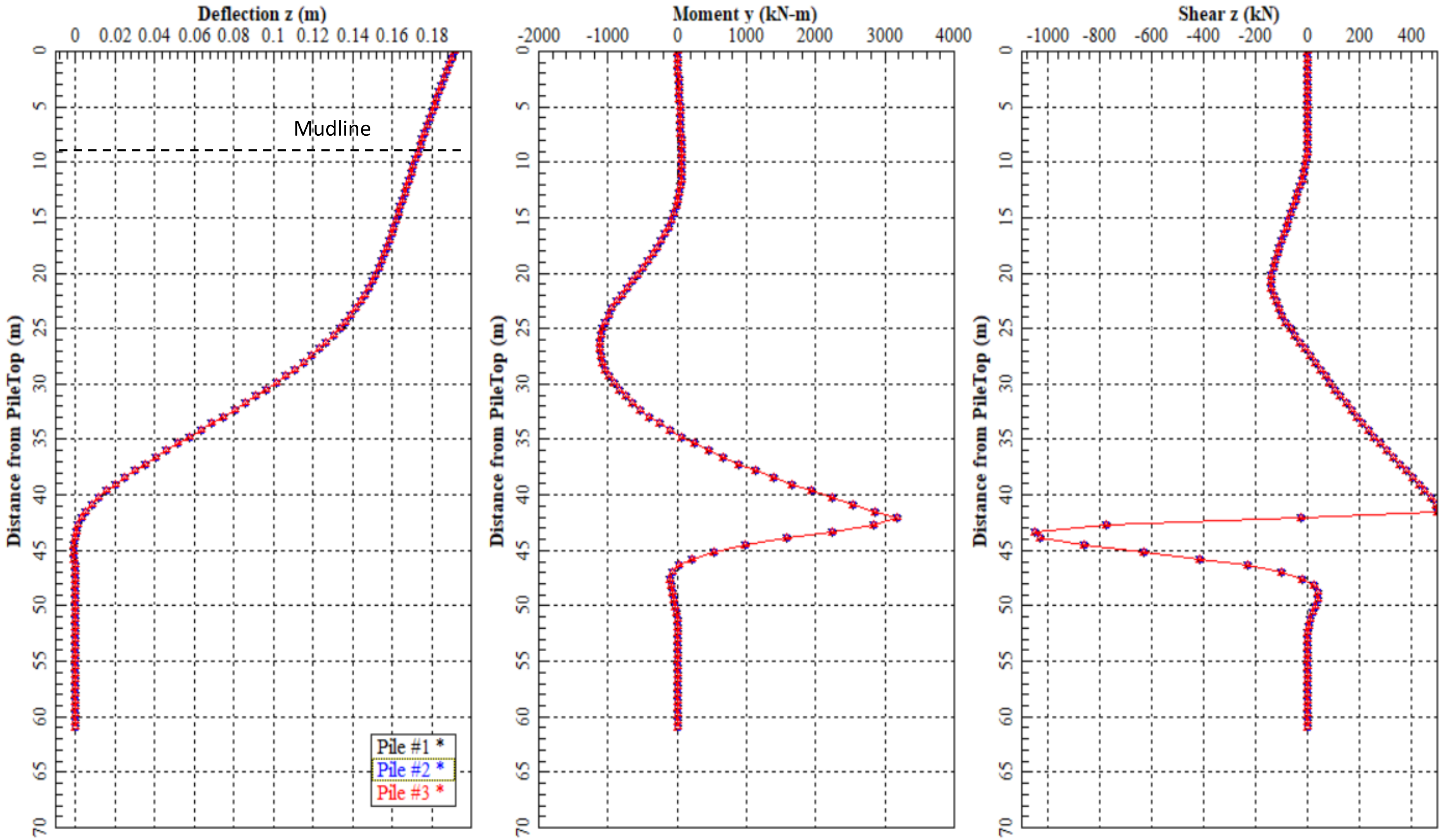
LATERAL PILE REACTIONS
Abutment Piles 914mmx19mm

Figure 9a



LATERAL PILE REACTIONS
Pier 1 and 4 Piles 914mmx19mm

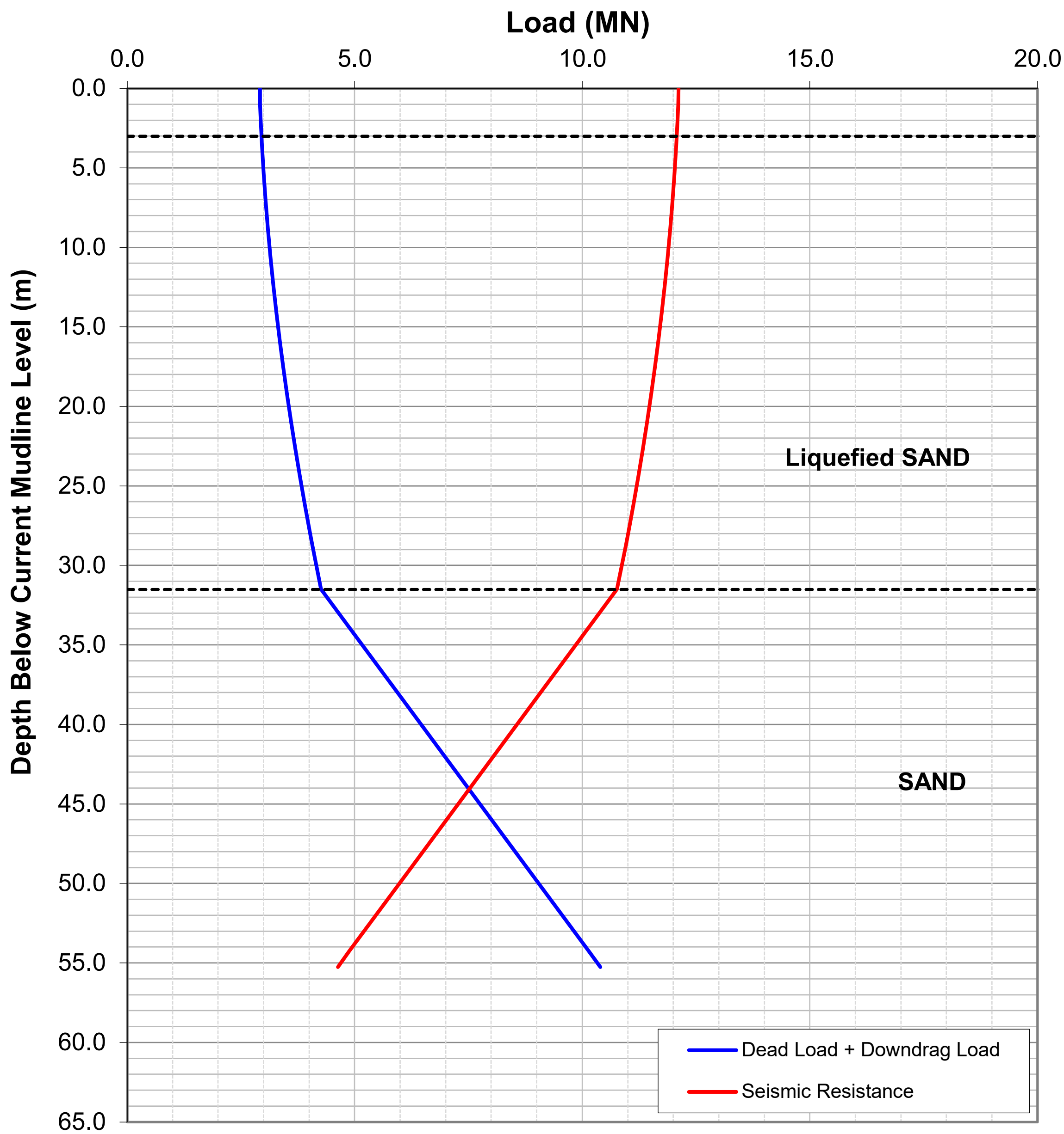
Figure 9b



TETRA TECH

LATERAL PILE REACTIONS
Pier 2 and 3 Piles 914mmx19mm

Figure 9c

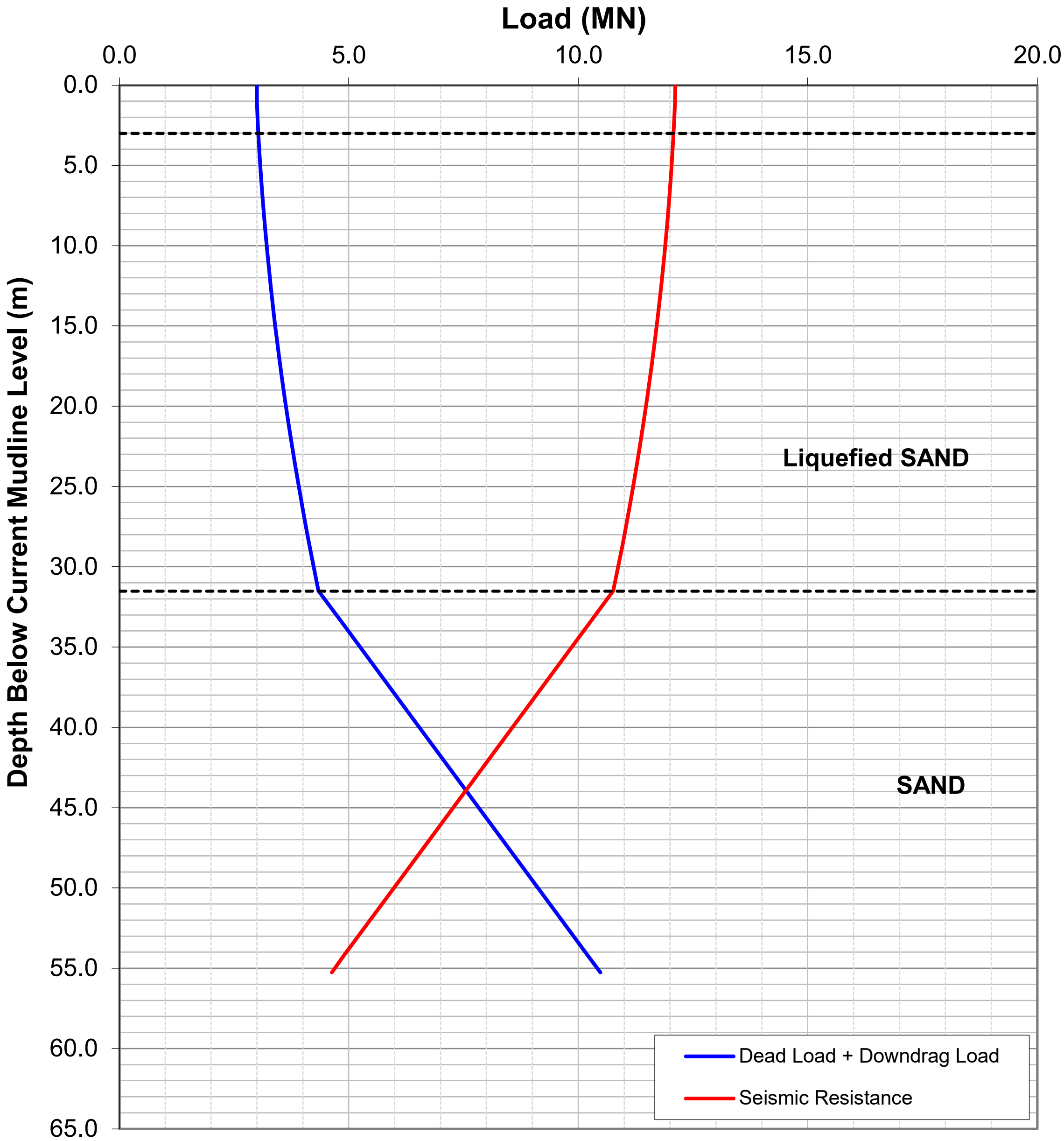


Note: - Assumed pile embedment length of 55 m
- Unfactored Dead load is assumed to be a total of 2915 kN

NEUTRAL PLANE ANALYSIS FOR DOWNDRAG
914mmx19mm Open-ended Pipe Pile
Pier 1 and 4

TETRA TECH

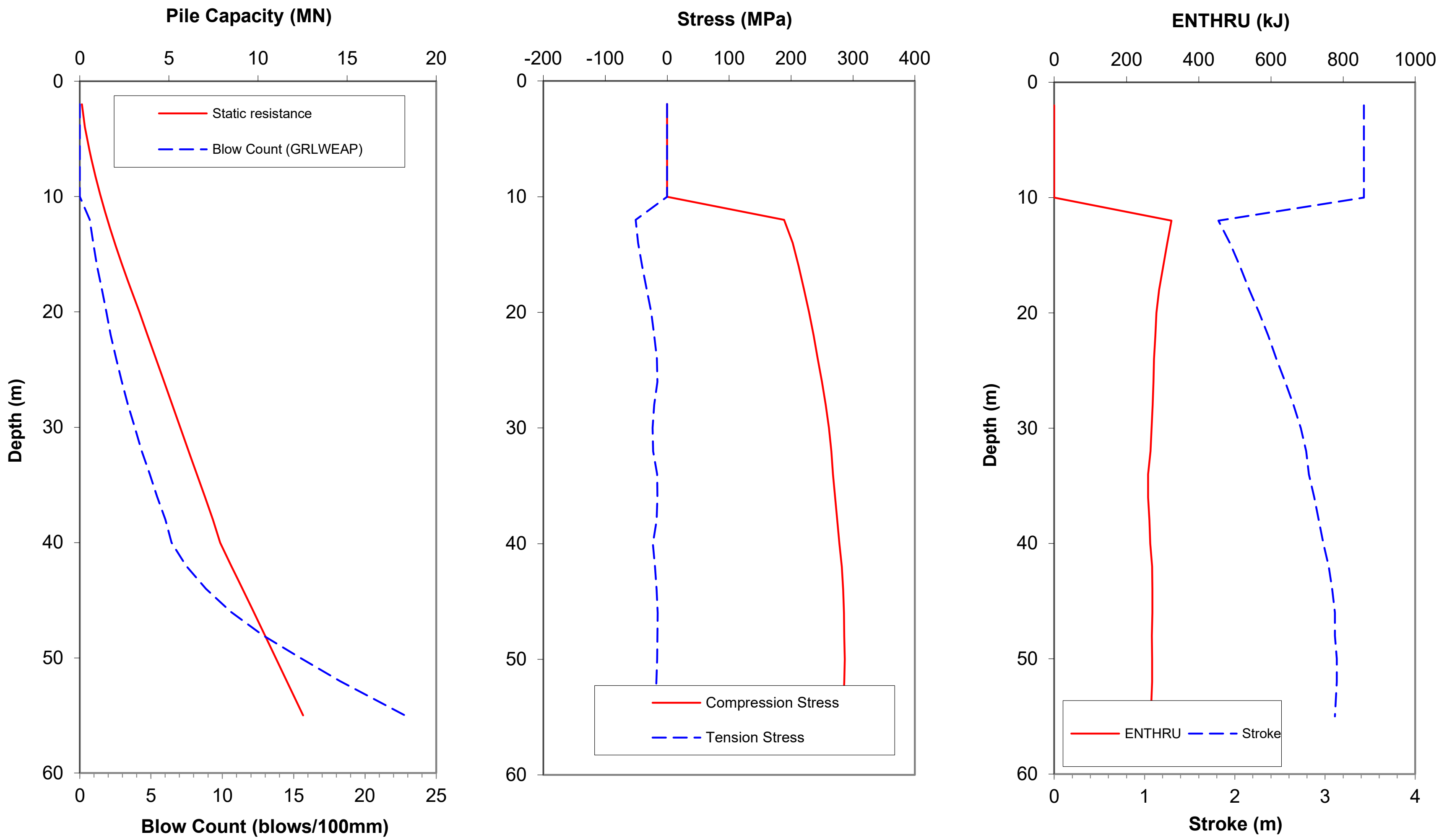
Figure 10a



Note: - Assumed pile embedment length of 55 m
- Unfactored Dead load is assumed to be a total of 2995 kN

NEUTRAL PLANE ANALYSIS FOR DOWNDRAG
914mmx19mm Open-ended Pipe Pile
Pier 2 and 3

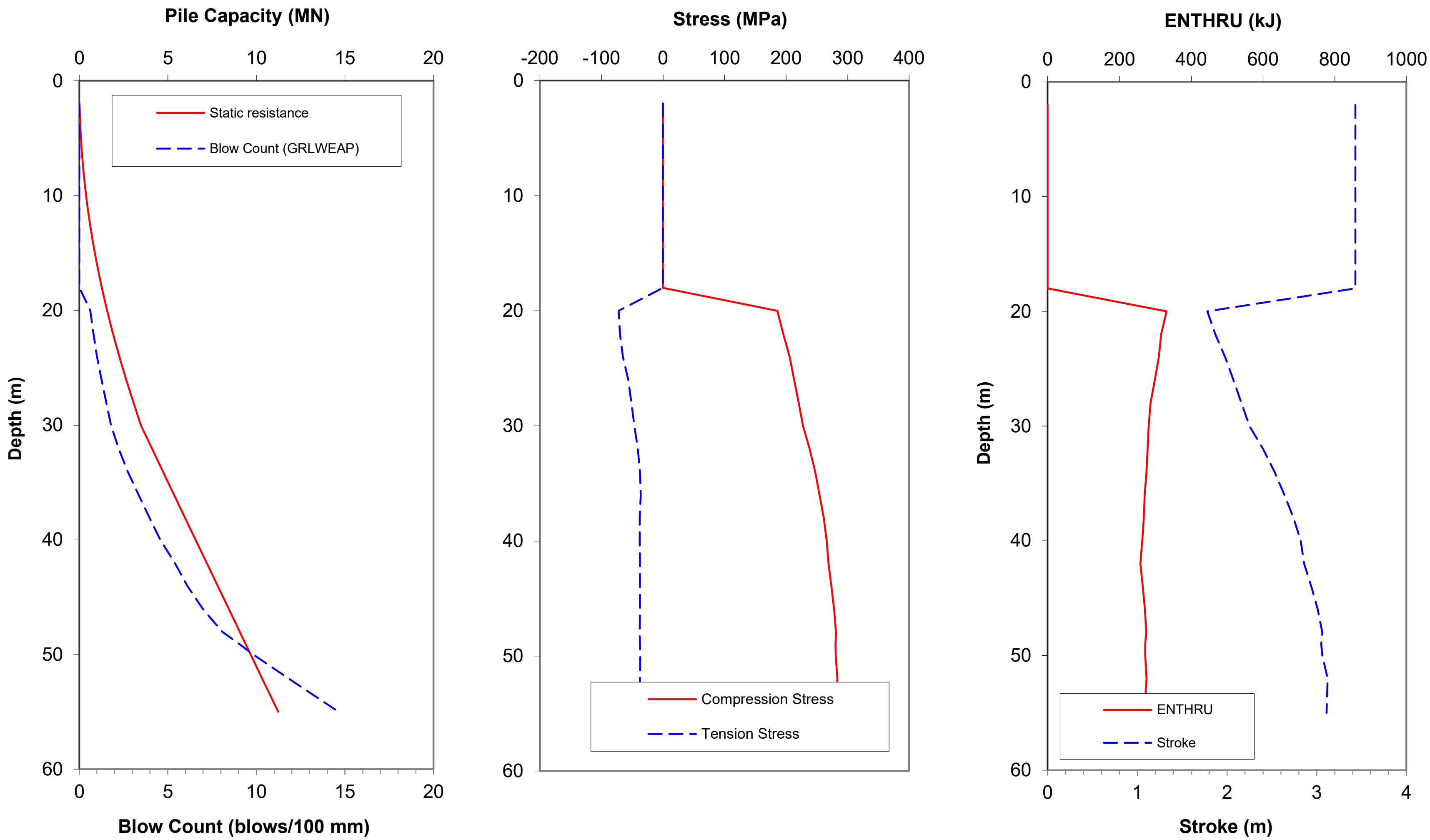
Figure 10b



DRIVEABILITY ANALYSIS - APE D180-42
Abutment Soil Profile, 0.8 Reduction for Shaft/Toe
Steel Pipe Pile, d = 914 mm, t = 19 mm, Pile Clean-Out to depth of 40m

TETRA TECH

Figure 11a



DRIVEABILITY ANALYSIS - APE D180-42
Pier Soil Profile, 0.8 Reduction for Shaft/Toe
Steel Pipe Pile, d = 914 mm, t = 19 mm, Pile Clean-Out to depth of 30m

TETRA TECH

Figure 11b

APPENDIX A

TETRA TECH'S LIMITATIONS ON THE USE OF THIS DOCUMENT

LIMITATIONS ON USE OF THIS DOCUMENT

GEOTECHNICAL

1.1 USE OF DOCUMENT AND OWNERSHIP

This document pertains to a specific site, a specific development, and a specific scope of work. The document may include plans, drawings, profiles and other supporting documents that collectively constitute the document (the "Professional Document").

The Professional Document is intended for the sole use of TETRA TECH's Client (the "Client") as specifically identified in the TETRA TECH Services Agreement or other Contractual Agreement entered into with the Client (either of which is termed the "Contract" herein). TETRA TECH does not accept any responsibility for the accuracy of any of the data, analyses, recommendations or other contents of the Professional Document when it is used or relied upon by any party other than the Client, unless authorized in writing by TETRA TECH.

Any unauthorized use of the Professional Document is at the sole risk of the user. TETRA TECH accepts no responsibility whatsoever for any loss or damage where such loss or damage is alleged to be or, is in fact, caused by the unauthorized use of the Professional Document.

Where TETRA TECH has expressly authorized the use of the Professional Document by a third party (an "Authorized Party"), consideration for such authorization is the Authorized Party's acceptance of these Limitations on Use of this Document as well as any limitations on liability contained in the Contract with the Client (all of which is collectively termed the "Limitations on Liability"). The Authorized Party should carefully review both these Limitations on Use of this Document and the Contract prior to making any use of the Professional Document. Any use made of the Professional Document by an Authorized Party constitutes the Authorized Party's express acceptance of, and agreement to, the Limitations on Liability.

The Professional Document and any other form or type of data or documents generated by TETRA TECH during the performance of the work are TETRA TECH's professional work product and shall remain the copyright property of TETRA TECH.

The Professional Document is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of TETRA TECH. Additional copies of the Document, if required, may be obtained upon request.

1.2 ALTERNATIVE DOCUMENT FORMAT

Where TETRA TECH submits electronic file and/or hard copy versions of the Professional Document or any drawings or other project-related documents and deliverables (collectively termed TETRA TECH's "Instruments of Professional Service"), only the signed and/or sealed versions shall be considered final. The original signed and/or sealed electronic file and/or hard copy version archived by TETRA TECH shall be deemed to be the original. TETRA TECH will archive a protected digital copy of the original signed and/or sealed version for a period of 10 years.

Both electronic file and/or hard copy versions of TETRA TECH's Instruments of Professional Service shall not, under any circumstances, be altered by any party except TETRA TECH. TETRA TECH's Instruments of Professional Service will be used only and exactly as submitted by TETRA TECH.

Electronic files submitted by TETRA TECH have been prepared and submitted using specific software and hardware systems. TETRA TECH makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

1.3 STANDARD OF CARE

Services performed by TETRA TECH for the Professional Document have been conducted in accordance with the Contract, in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Professional judgment has been applied in developing the conclusions and/or recommendations provided in this Professional Document. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of the Professional Document.

If any error or omission is detected by the Client or an Authorized Party, the error or omission must be immediately brought to the attention of TETRA TECH.

1.4 DISCLOSURE OF INFORMATION BY CLIENT

The Client acknowledges that it has fully cooperated with TETRA TECH with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The Client further acknowledges that in order for TETRA TECH to properly provide the services contracted for in the Contract, TETRA TECH has relied upon the Client with respect to both the full disclosure and accuracy of any such information.

1.5 INFORMATION PROVIDED TO TETRA TECH BY OTHERS

During the performance of the work and the preparation of this Professional Document, TETRA TECH may have relied on information provided by third parties other than the Client.

While TETRA TECH endeavours to verify the accuracy of such information, TETRA TECH accepts no responsibility for the accuracy or the reliability of such information even where inaccurate or unreliable information impacts any recommendations, design or other deliverables and causes the Client or an Authorized Party loss or damage.

1.6 GENERAL LIMITATIONS OF DOCUMENT

This Professional Document is based solely on the conditions presented and the data available to TETRA TECH at the time the data were collected in the field or gathered from available databases.

The Client, and any Authorized Party, acknowledges that the Professional Document is based on limited data and that the conclusions, opinions, and recommendations contained in the Professional Document are the result of the application of professional judgment to such limited data.

The Professional Document is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site conditions present, or variation in assumed conditions which might form the basis of design or recommendations as outlined in this document, at or on the development proposed as of the date of the Professional Document requires a supplementary exploration, investigation, and assessment.

TETRA TECH is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the Client.

1.7 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, TETRA TECH has not been retained to explore, address or consider and has not explored, addressed or considered any environmental or regulatory issues associated with development on the subject site.

1.8 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems, methods and standards employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. TETRA TECH does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

1.9 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

1.10 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historical environment. TETRA TECH does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional exploration and review may be necessary.

1.11 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

1.12 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

1.13 INFLUENCE OF CONSTRUCTION ACTIVITY

Construction activity can impact structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques, and construction sequence are known.

1.14 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, and the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

1.15 DRAINAGE SYSTEMS

Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function. Where temporary or permanent drainage systems are installed within or around a structure, these systems must protect the structure from loss of ground due to mechanisms such as internal erosion and must be designed so as to assure continued satisfactory performance of the drains. Specific design details regarding the geotechnical aspects of such systems (e.g. bedding material, surrounding soil, soil cover, geotextile type) should be reviewed by the geotechnical engineer to confirm the performance of the system is consistent with the conditions used in the geotechnical design.

1.16 DESIGN PARAMETERS

Bearing capacities for Limit States or Allowable Stress Design, strength/stiffness properties and similar geotechnical design parameters quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition used in this report. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions considered in this report in fact exist at the site.

1.17 SAMPLES

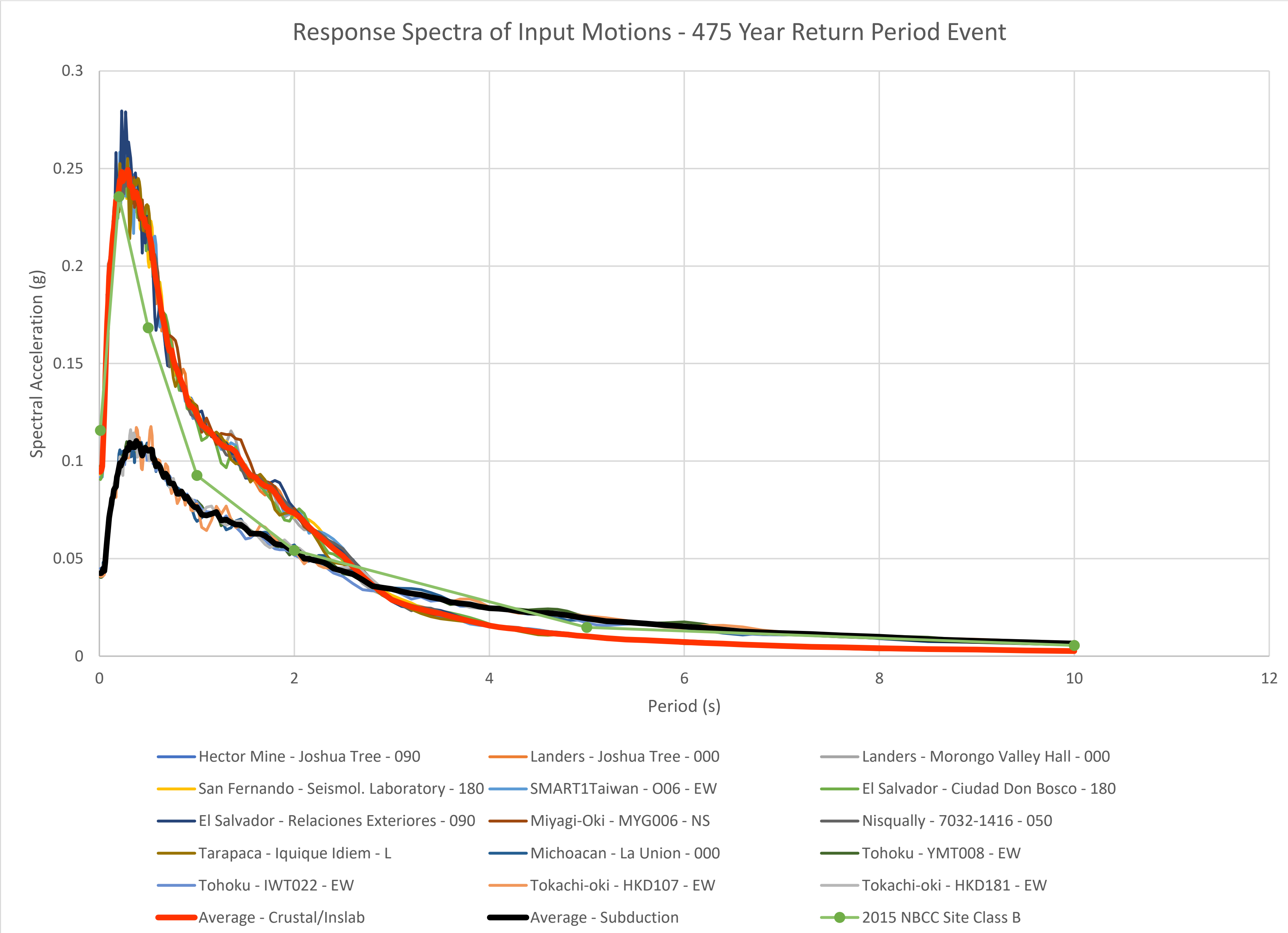
TETRA TECH will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

1.18 APPLICABLE CODES, STANDARDS, GUIDELINES & BEST PRACTICE

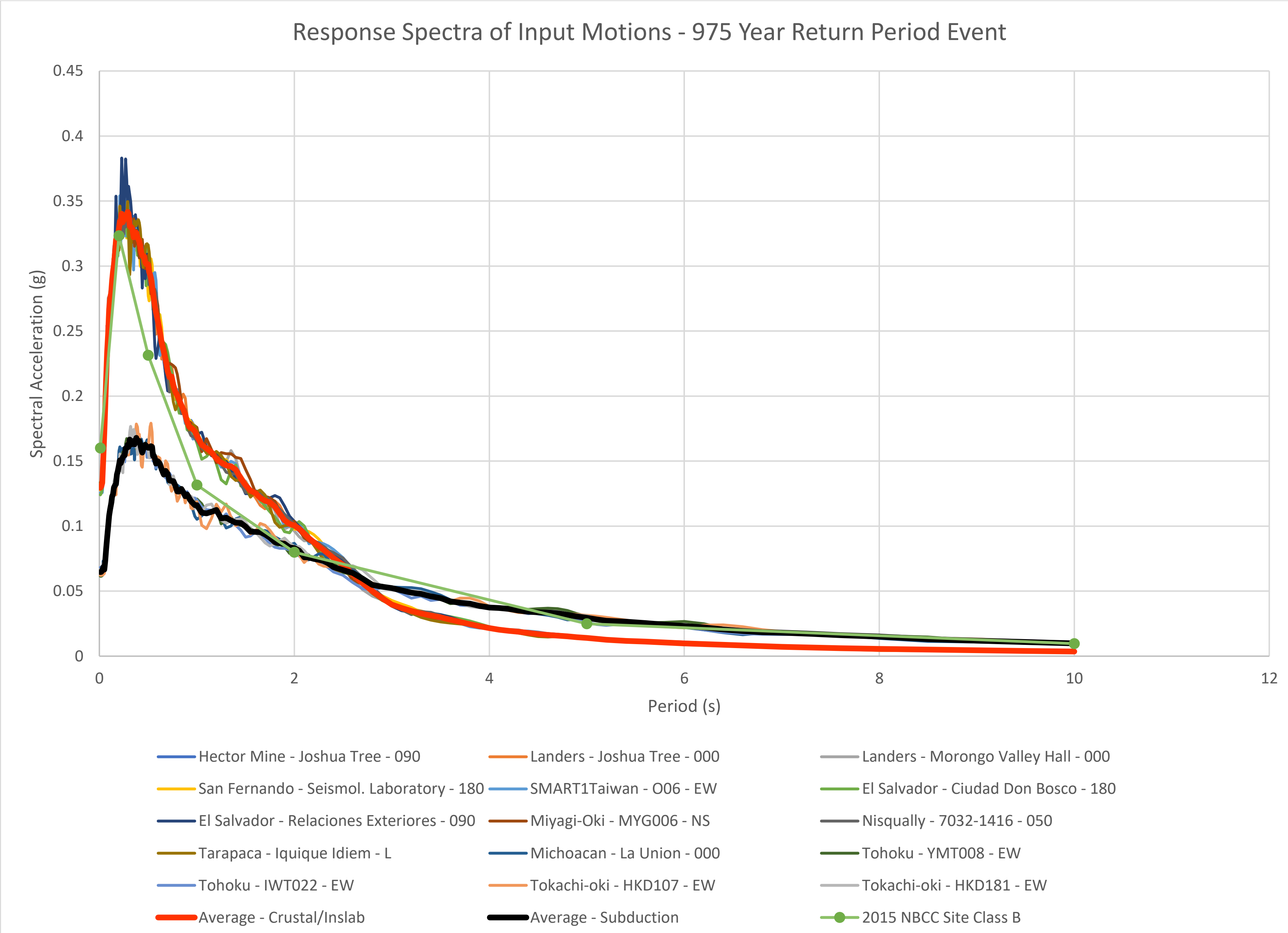
This document has been prepared based on the applicable codes, standards, guidelines or best practice as identified in the report. Some mandated codes, standards and guidelines (such as ASTM, AASHTO Bridge Design/Construction Codes, Canadian Highway Bridge Design Code, National/Provincial Building Codes) are routinely updated and corrections made. TETRA TECH cannot predict nor be held liable for any such future changes, amendments, errors or omissions in these documents that may have a bearing on the assessment, design or analyses included in this report.

APPENDIX B

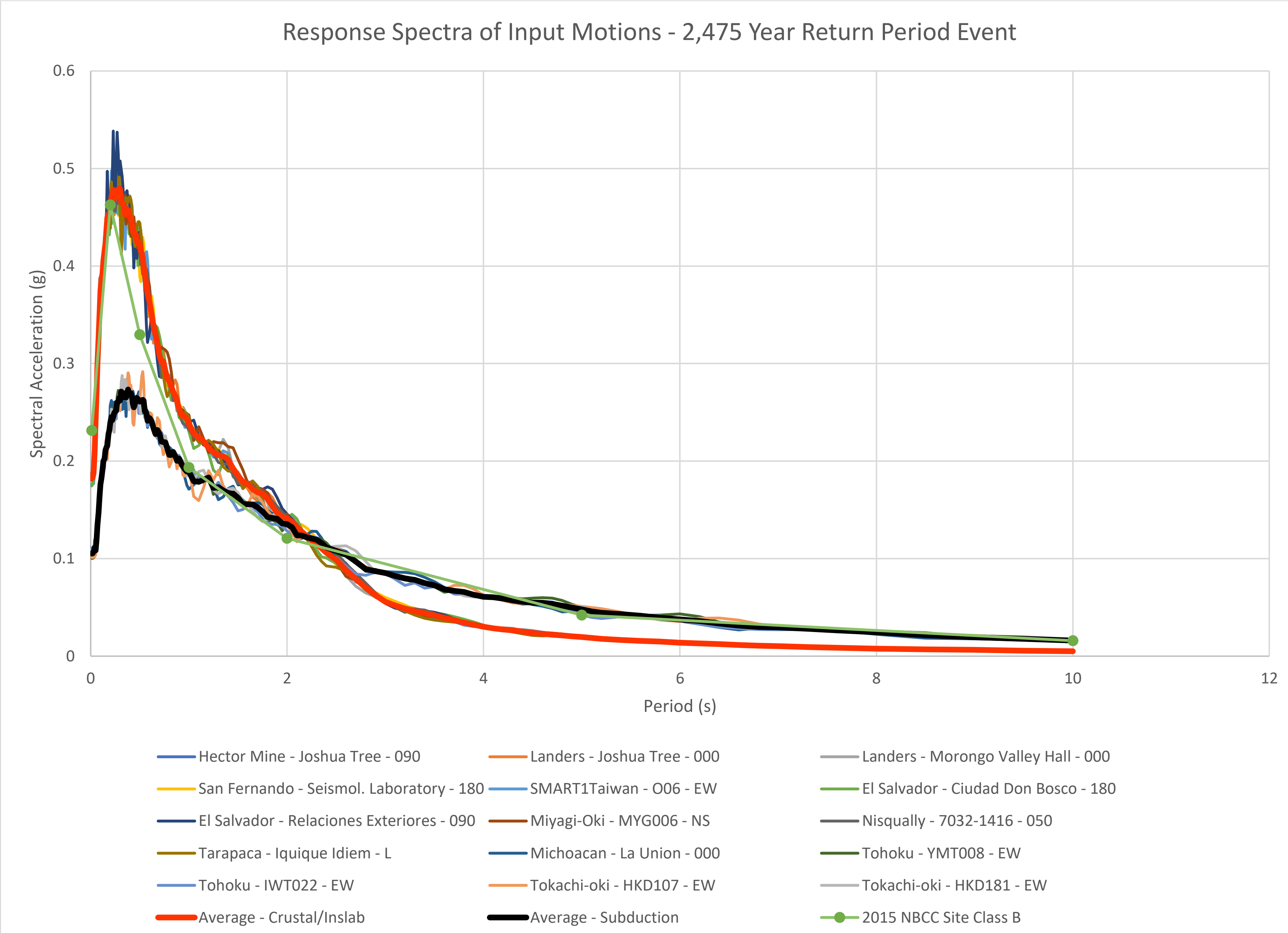
INPUT MOTION RESPONSE SPECTRUM



Response Spectra of Input Motions - 475 Year Return Period Event
Spectral Acceleration (g)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
Period (s)
Hector Mine - Joshua Tree - 090
Landers - Joshua Tree - 000
Landers - Morongo Valley Hall - 000
San Fernando - Seismol. Laboratory - 180
SMART1Taiwan - O06 - EW
El Salvador - Ciudad Don Bosco - 180
El Salvador - Relaciones Exteriores - 090
Miyagi-Oki - MYG006 - NS
Nisqually - 7032-1416 - 050
Tarapaca - Iquique Idiem - L
Michoacan - La Union - 000
Tohoku - YMT008 - EW
Tohoku - IWT022 - EW
Tokachi-oki - HKD107 - EW
Tokachi-oki - HKD181 - EW
Average - Crustal/Inslab
Average - Subduction
2015 NBCC Site Class B



Response Spectra of Input Motions - 975 Year Return Period Event
Spectral Acceleration (g)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
Period (s)
Hector Mine - Joshua Tree - 090
Landers - Joshua Tree - 000
Landers - Morongo Valley Hall - 000
San Fernando - Seismol. Laboratory - 180
SMART1Taiwan - O06 - EW
El Salvador - Ciudad Don Bosco - 180
El Salvador - Relaciones Exteriores - 090
Miyagi-Oki - MYG006 - NS
Nisqually - 7032-1416 - 050
Tarapaca - Iquique Idiem - L
Michoacan - La Union - 000
Tohoku - YMT008 - EW
Tohoku - IWT022 - EW
Tokachi-oki - HKD107 - EW
Tokachi-oki - HKD181 - EW
Average - Crustal/Inslab
Average - Subduction
2015 NBCC Site Class B

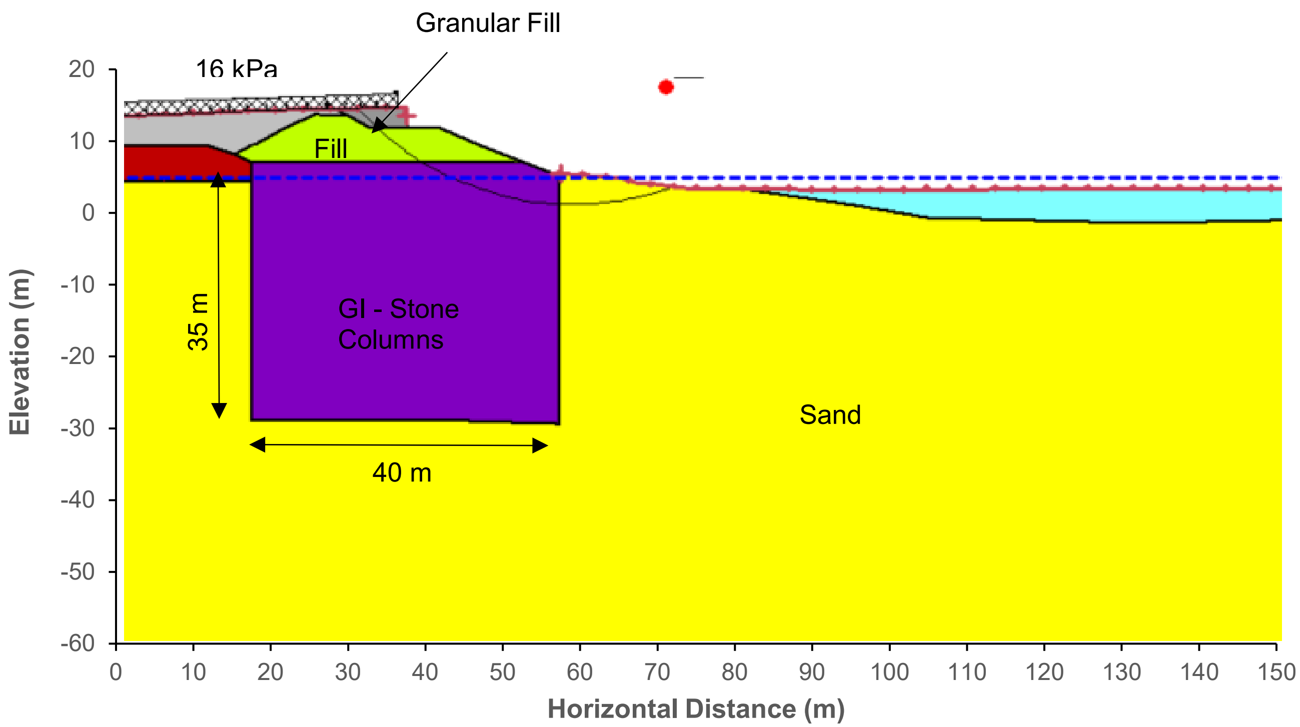

Response Spectra of Input Motions - 2,475 Year Return Period Event
Spectral Acceleration (g)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
Period (s)
Hector Mine - Joshua Tree - 090
Landers - Joshua Tree - 000
Landers - Morongo Valley Hall - 000
San Fernando - Seismol. Laboratory - 180
SMART1Taiwan - O06 - EW
El Salvador - Ciudad Don Bosco - 180
El Salvador - Relaciones Exteriores - 090
Miyagi-Oki - MYG006 - NS
Nisqually - 7032-1416 - 050
Tarapaca - Iquique Idiem - L
Michoacan - La Union - 000
Tohoku - YMT008 - EW
Tohoku - IWT022 - EW
Tokachi-oki - HKD107 - EW
Tokachi-oki - HKD181 - EW
Average - Crustal/Inslab
Average - Subduction
2015 NBCC Site Class B

APPENDIX C

SLOPE STABILITY ANALYSIS – BRIDGE ABUTMENT

Static

FS > 2



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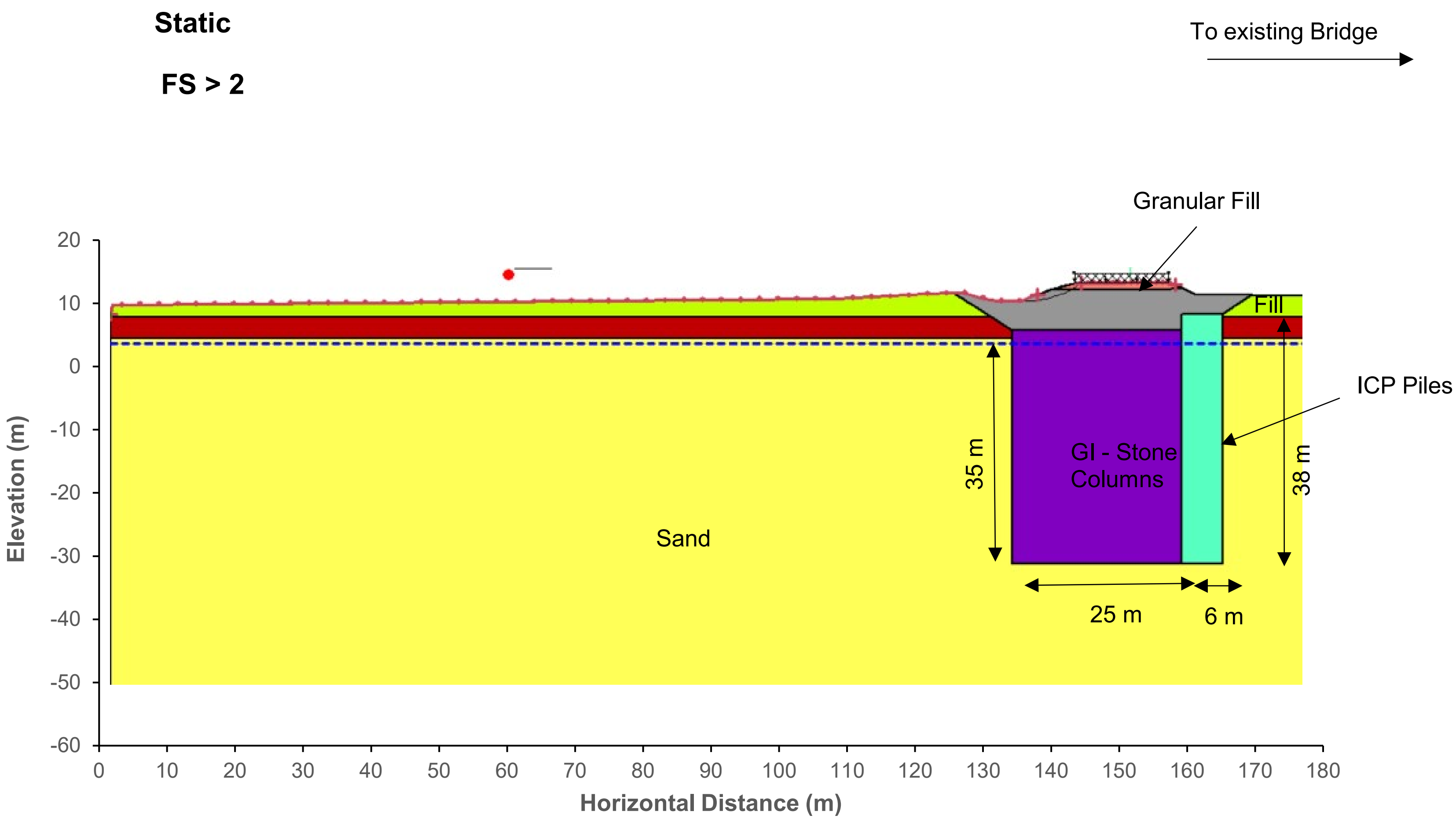
GLOBAL STABILITY - WEST ABUTMENT
Static - Ground Improvement

Figure C-1a



TETRA TECH

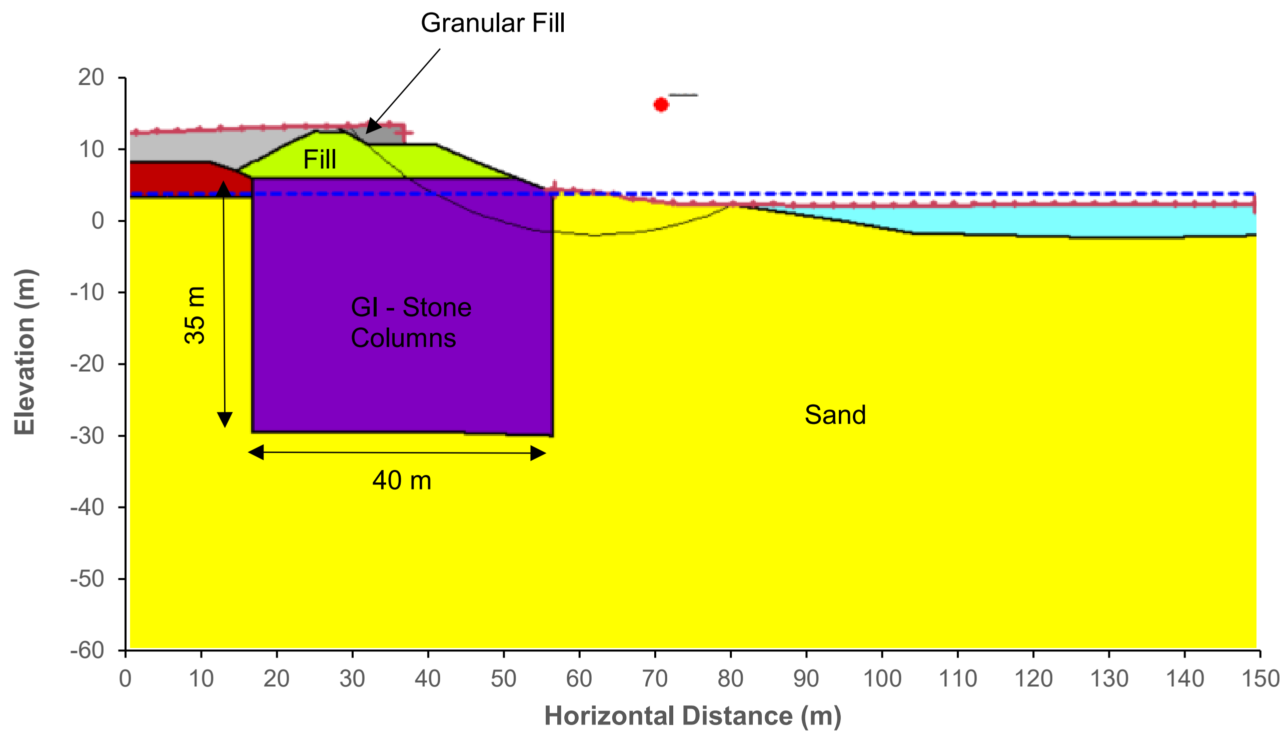
GLOBAL STABILITY - WEST ABUTMENT
Static - Ground Improvement

Figure C-1b

Pseudo-Static - 2475-yr

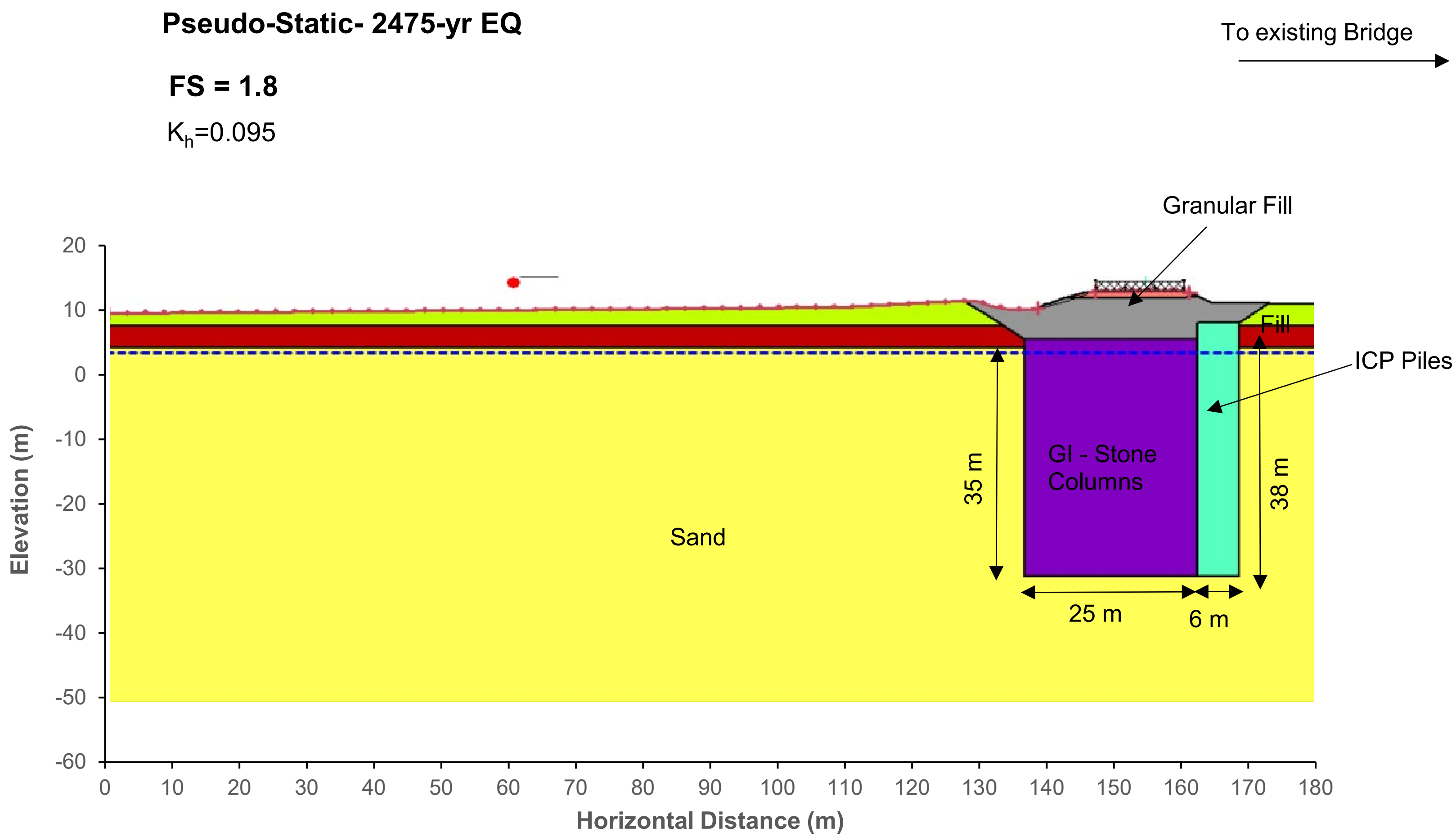
FS = 2.0

K_h=0.095



GLOBAL STABILITY - WEST ABUTMENT
Pseudo-Static - 2475-yr EQ

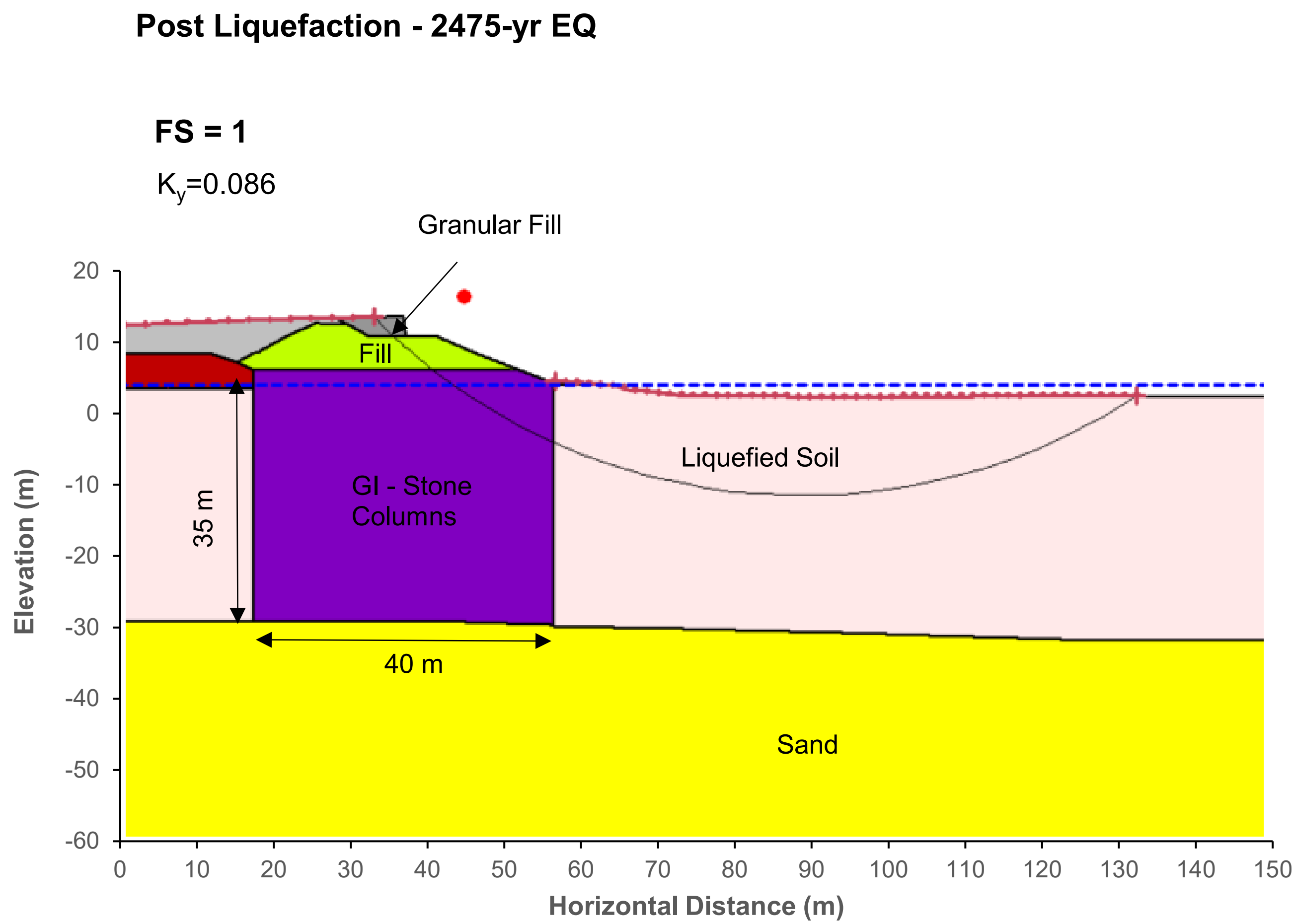
Figure C-2a



TETRA TECH

GLOBAL STABILITY - WEST ABUTMENT
Pseudo-Static - 2475-yr EQ

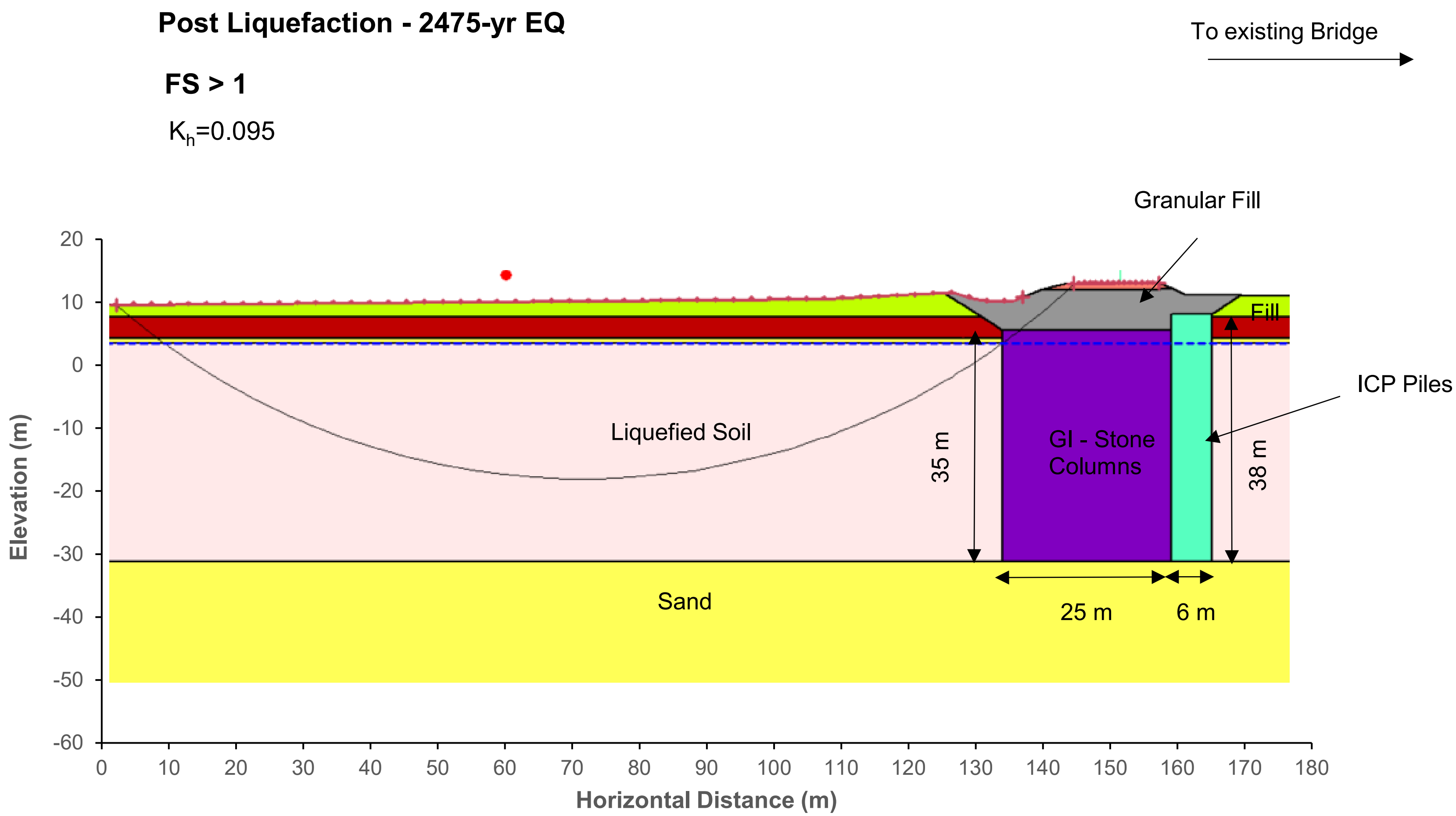
Figure C-2b



TETRA TECH

GLOBAL STABILITY - WEST ABUTMENT
Post Liquefaction - 2475-yr EQ

Figure C-3a



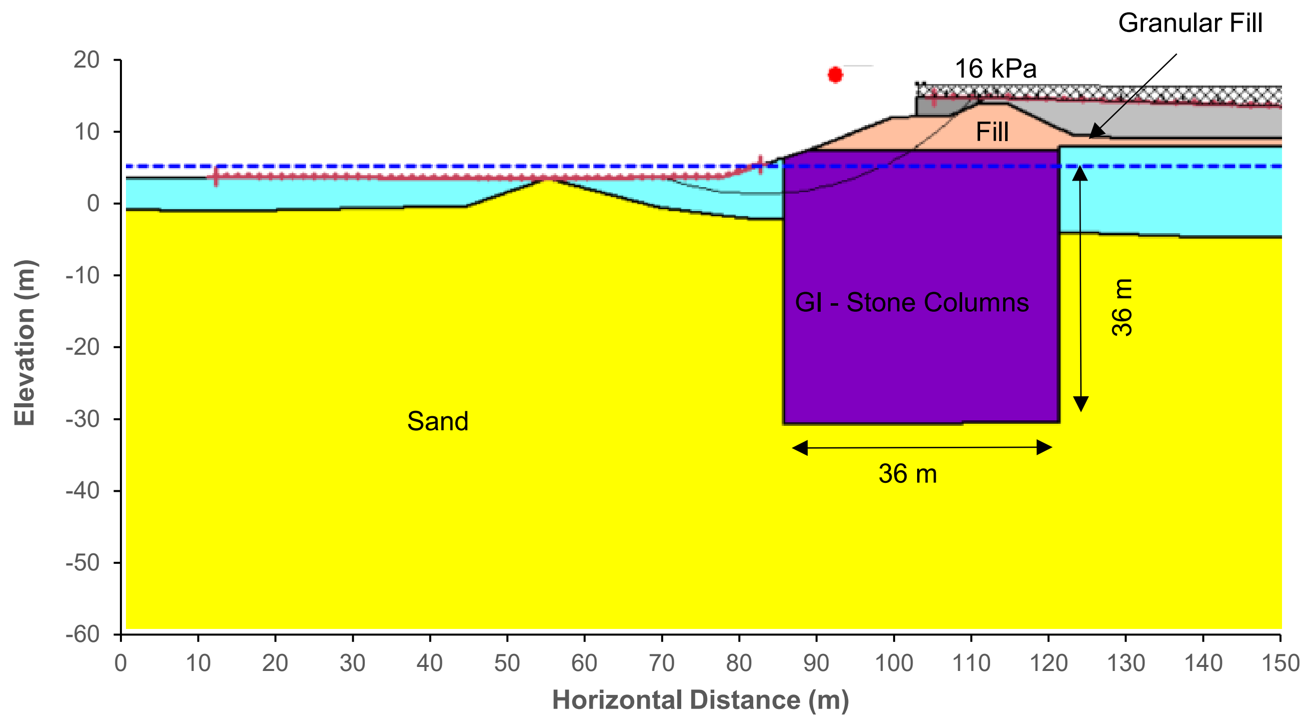
TETRA TECH

GLOBAL STABILITY - WEST ABUTMENT
Post Liquefaction - 2475-yr EQ

Figure C-3b

Static

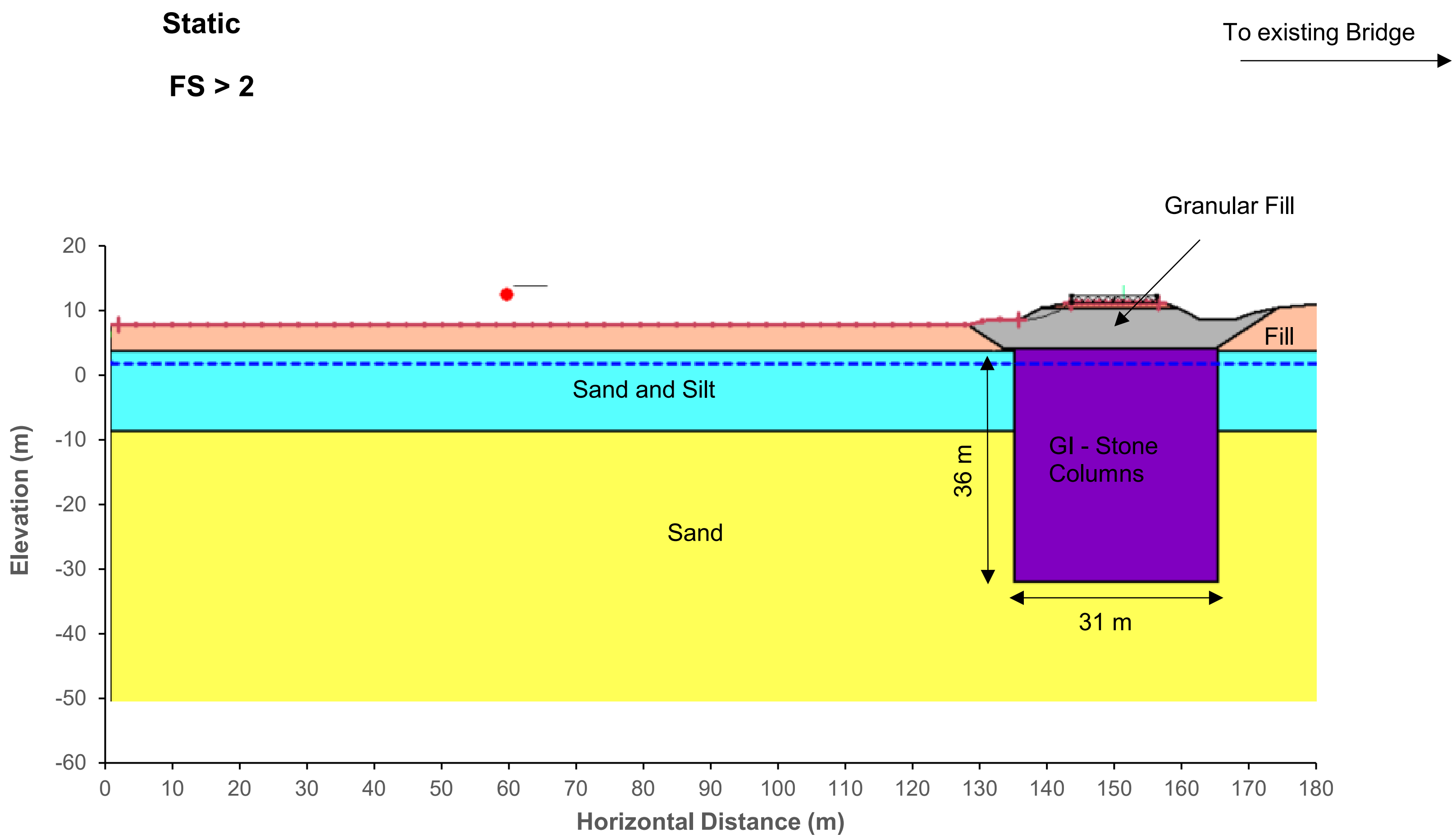
FS > 2



TETRA TECH

GLOBAL STABILITY - EAST ABUTMENT
Static - Ground Improvement

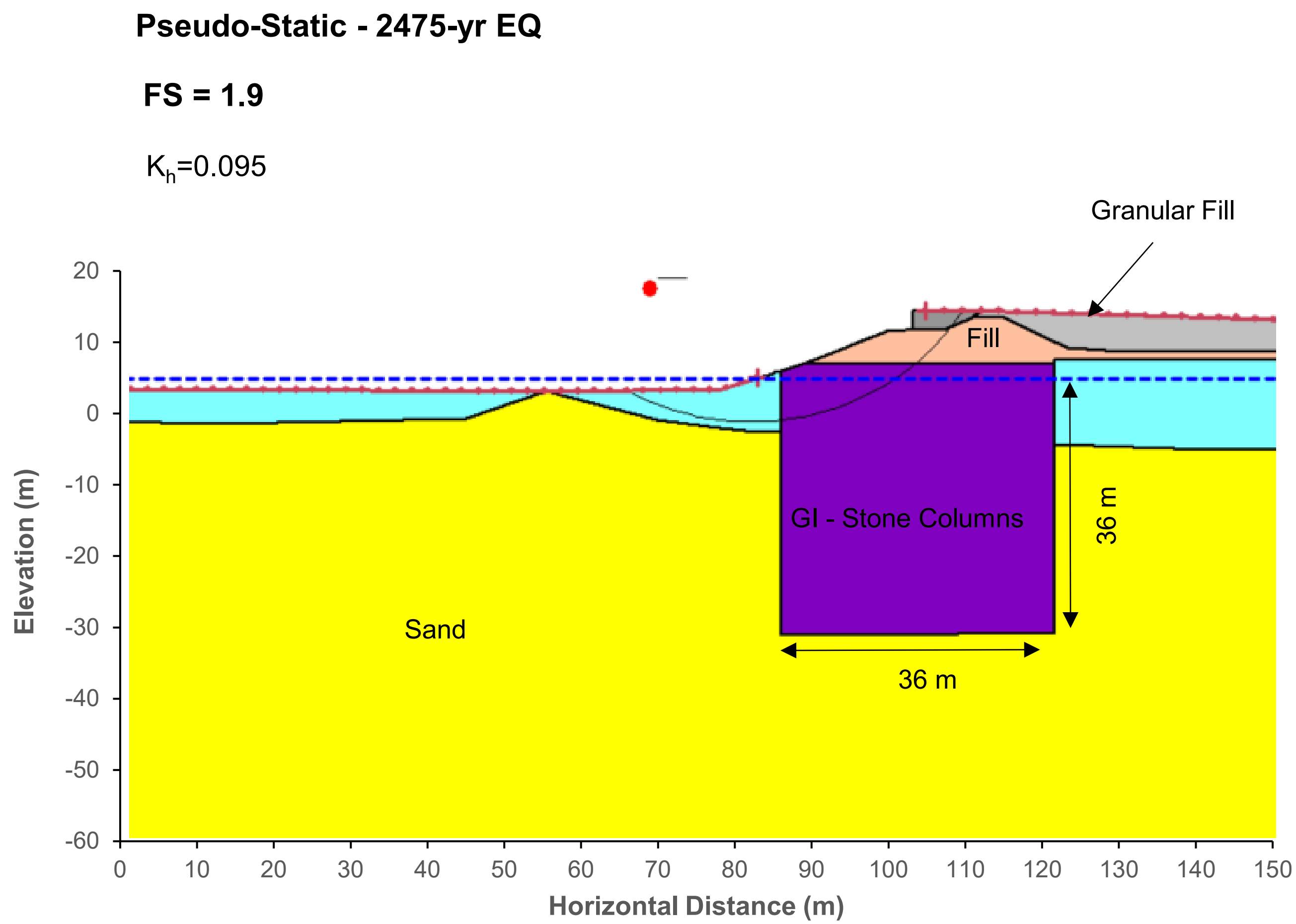
Figure C-4a



TETRA TECH

GLOBAL STABILITY - EAST ABUTMENT
Static - Ground Improvement

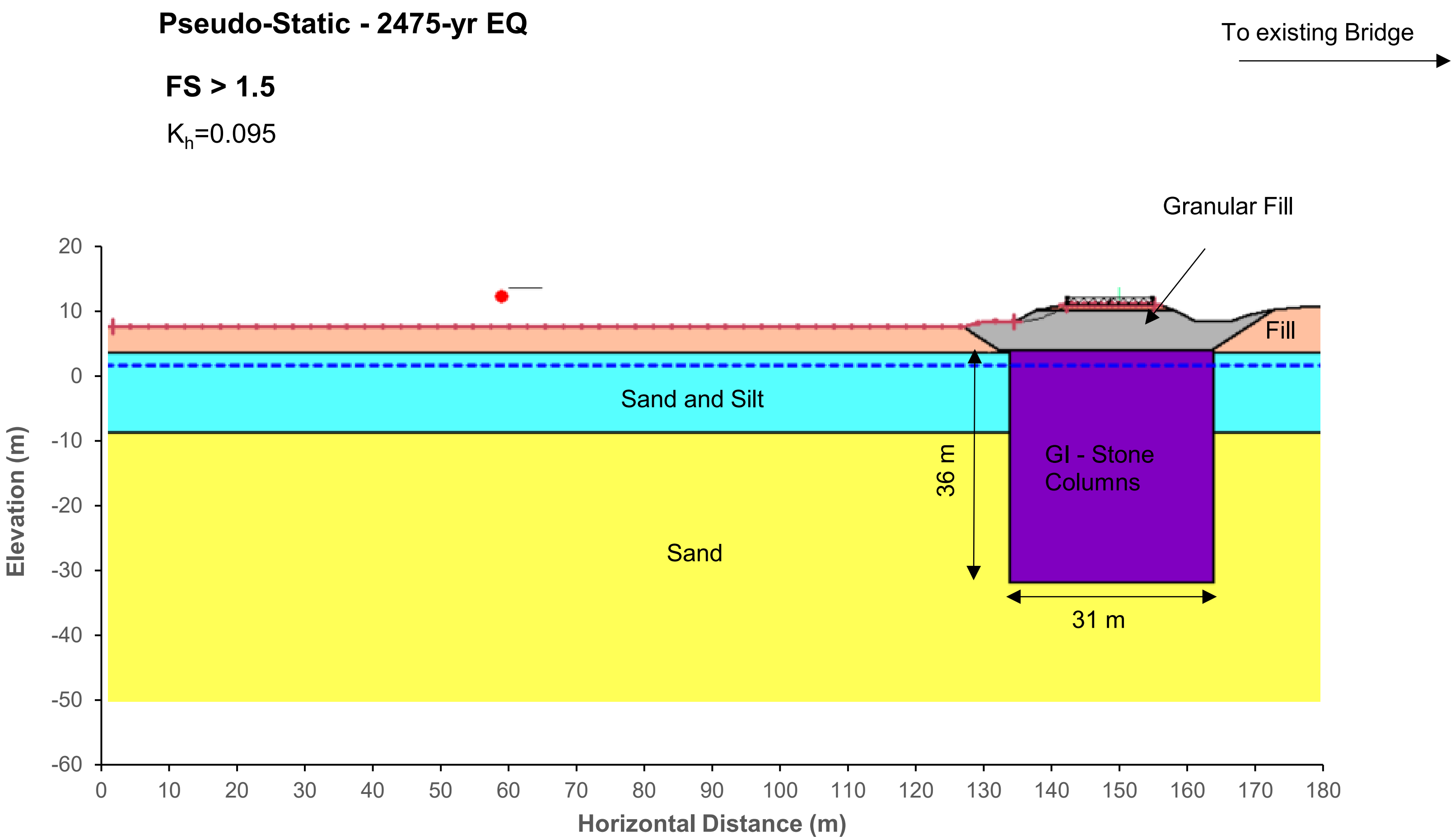
Figure C-4b



TETRA TECH

GLOBAL STABILITY - EAST ABUTMENT
Pseudo-Static - 2475-yr EQ

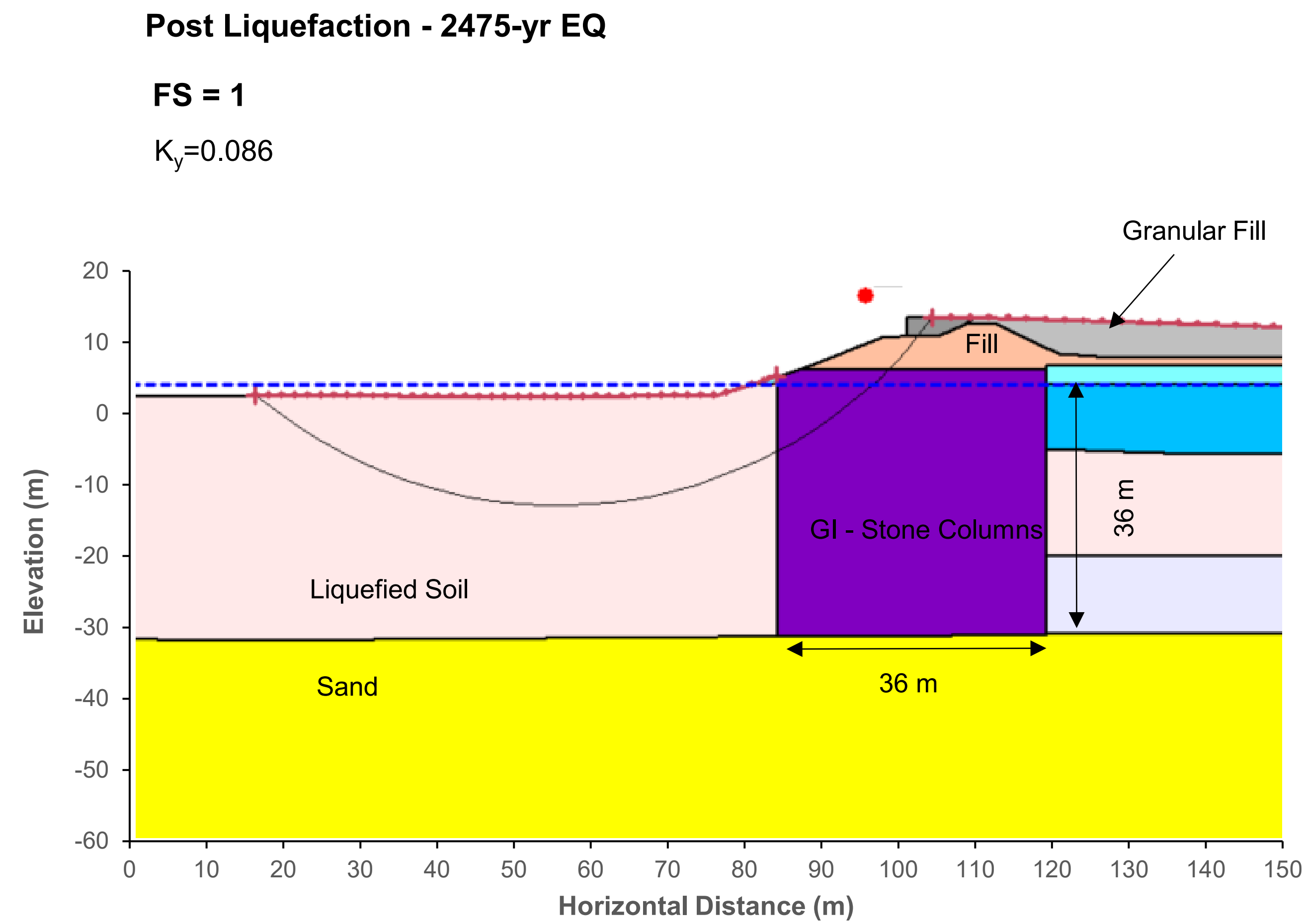
Figure C-5a



TETRA TECH

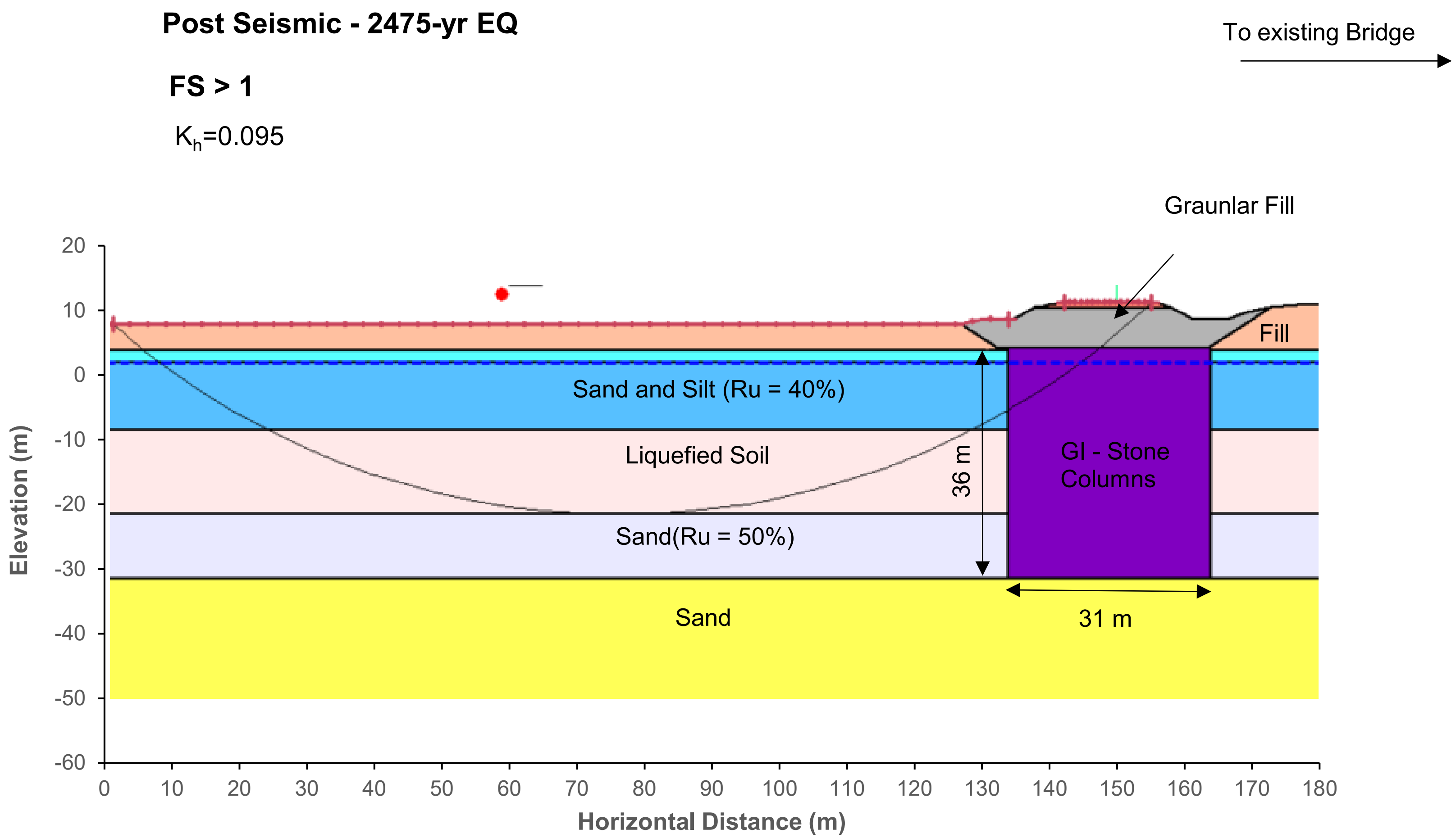
GLOBAL STABILITY - EAST ABUTMENT
Pseudo-Static - 2475-yr EQ

Figure C-5b



GLOBAL STABILITY - EAST ABUTMENT
Post Liquefaction - 2475-yr EQ

Figure C-6a



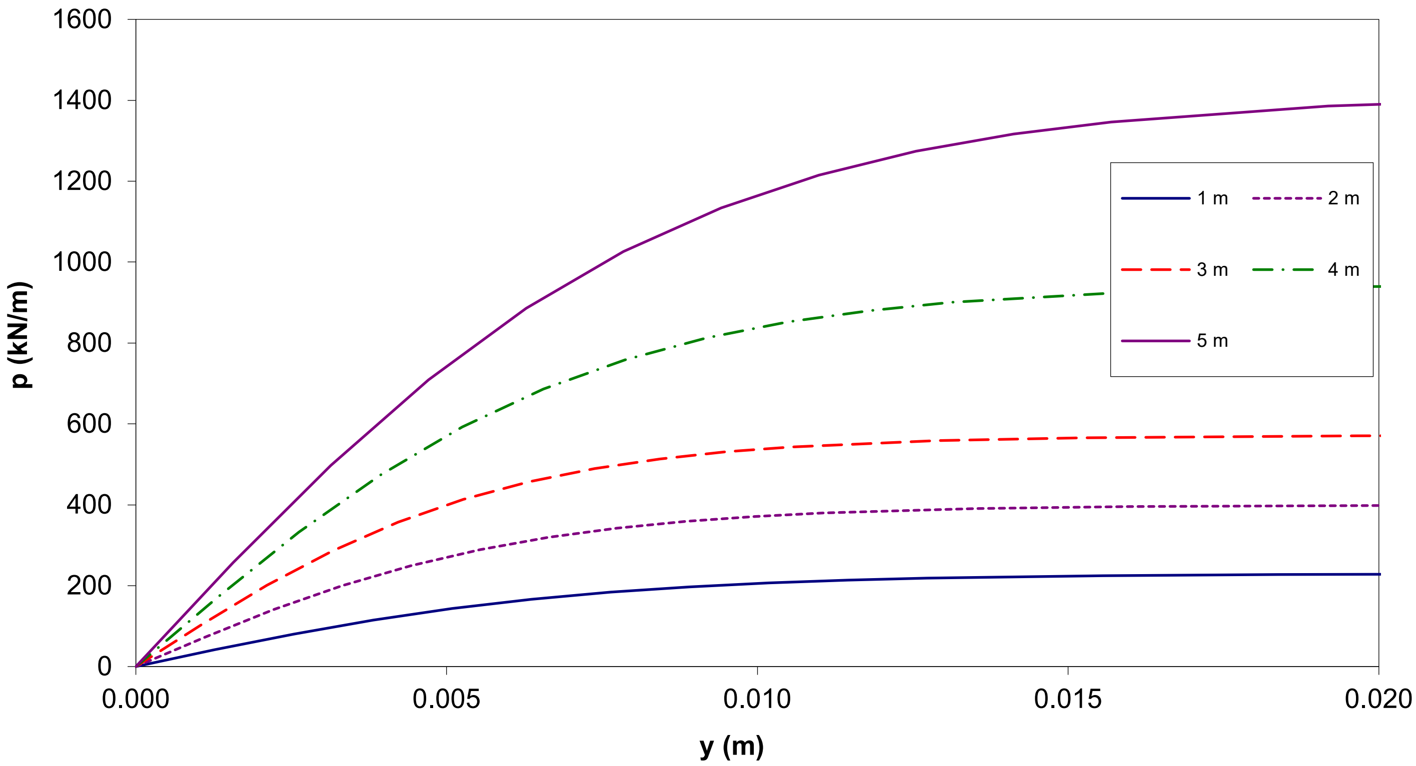
TETRA TECH

GLOBAL STABILITY - EAST ABUTMENT
Post Liquefaction - 2475-yr EQ

Figure C-6b

APPENDIX D

P-Y CURVES



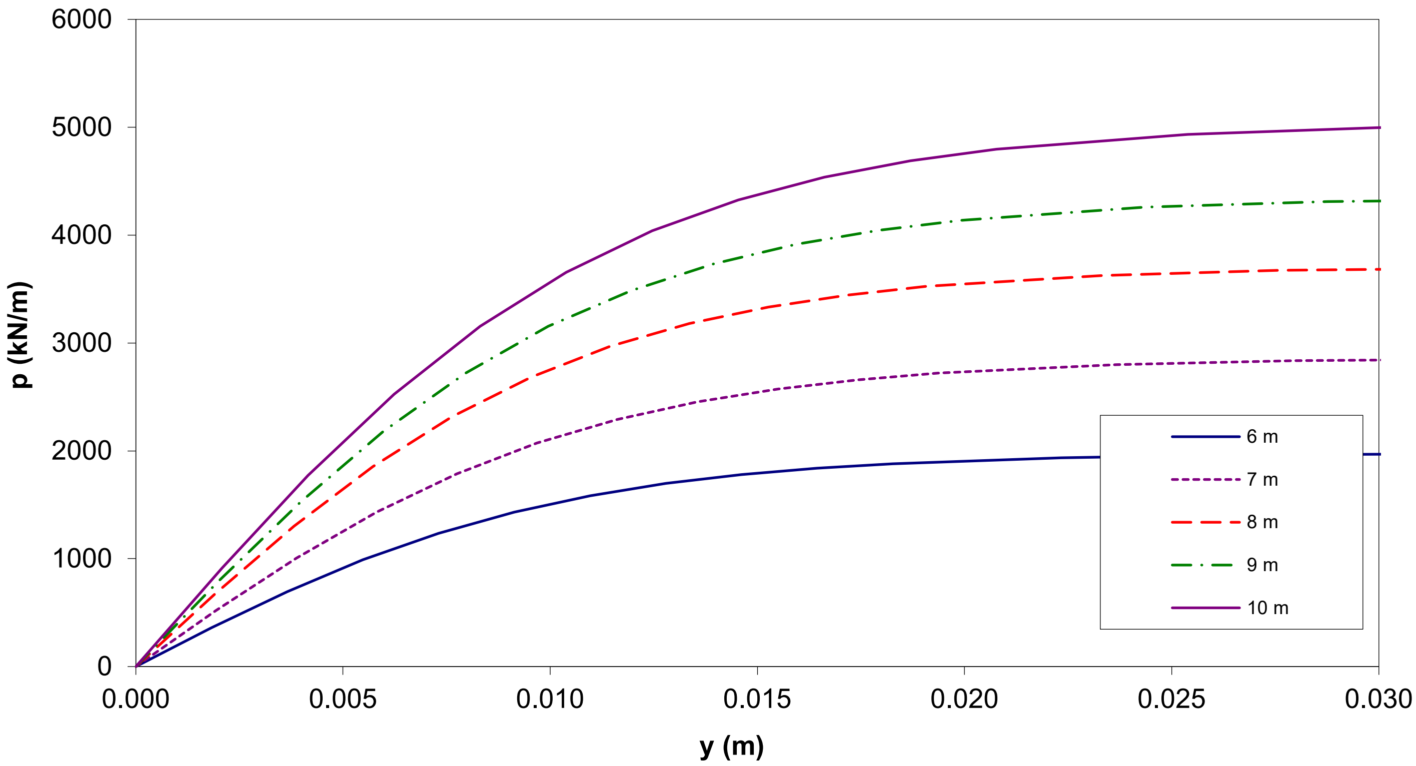
1 m		2 m		3 m		4 m		5 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.001273	41.64828	0.001106	72.38119	0.001054	103.4872	0.001312	171.6913	0.001569	256.7496
0.002546	80.64982	0.002212	140.1626	0.002108	200.3978	0.002623	332.4717	0.003139	497.1828
0.003818	114.9905	0.003318	199.8437	0.003163	285.7271	0.003935	474.038	0.004708	708.8831
0.005091	143.625	0.004424	249.6081	0.004217	356.8779	0.005247	592.0813	0.006277	885.4067
0.006364	166.4372	0.00553	289.2538	0.005271	413.5614	0.006559	686.1225	0.007846	1026.037
0.007637	183.9596	0.006636	319.7062	0.006325	457.1008	0.00787	758.357	0.009416	1134.058
0.008909	197.0452	0.007742	342.4479	0.007379	489.6158	0.009182	812.3013	0.010985	1214.727
0.010182	206.6135	0.008848	359.0767	0.008434	513.3909	0.010494	851.7455	0.012554	1273.712
0.011455	213.5024	0.009954	371.0491	0.009488	530.5084	0.011806	880.1445	0.014123	1316.181
0.012728	218.4072	0.01106	379.5733	0.010542	542.6959	0.013117	900.3642	0.015693	1346.417
0.015559	224.7416	0.01352	390.5819	0.012887	558.4355	0.016035	926.4771	0.019183	1385.467
0.01839	227.6033	0.01598	395.5553	0.015232	565.5462	0.018953	938.2743	0.022673	1403.109
0.023728	229.4059	0.020619	398.688	0.019653	570.0252	0.024454	945.7052	0.029256	1414.221
0.029067	229.7954	0.025258	399.3651	0.024075	570.9933	0.029956	947.3112	0.035838	1416.623
0.034405	229.8793	0.029897	399.5109	0.028497	571.2017	0.035458	947.657	0.04242	1417.14
0.041287	229.8991	0.035876	399.5453	0.034196	571.2509	0.04255	947.7387	0.050904	1417.262
0.1	229.8991	0.1	399.5453	0.1	571.2509	0.1	947.7387	0.1	1417.262

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

TETRA TECH

Figure Abutment D1-a



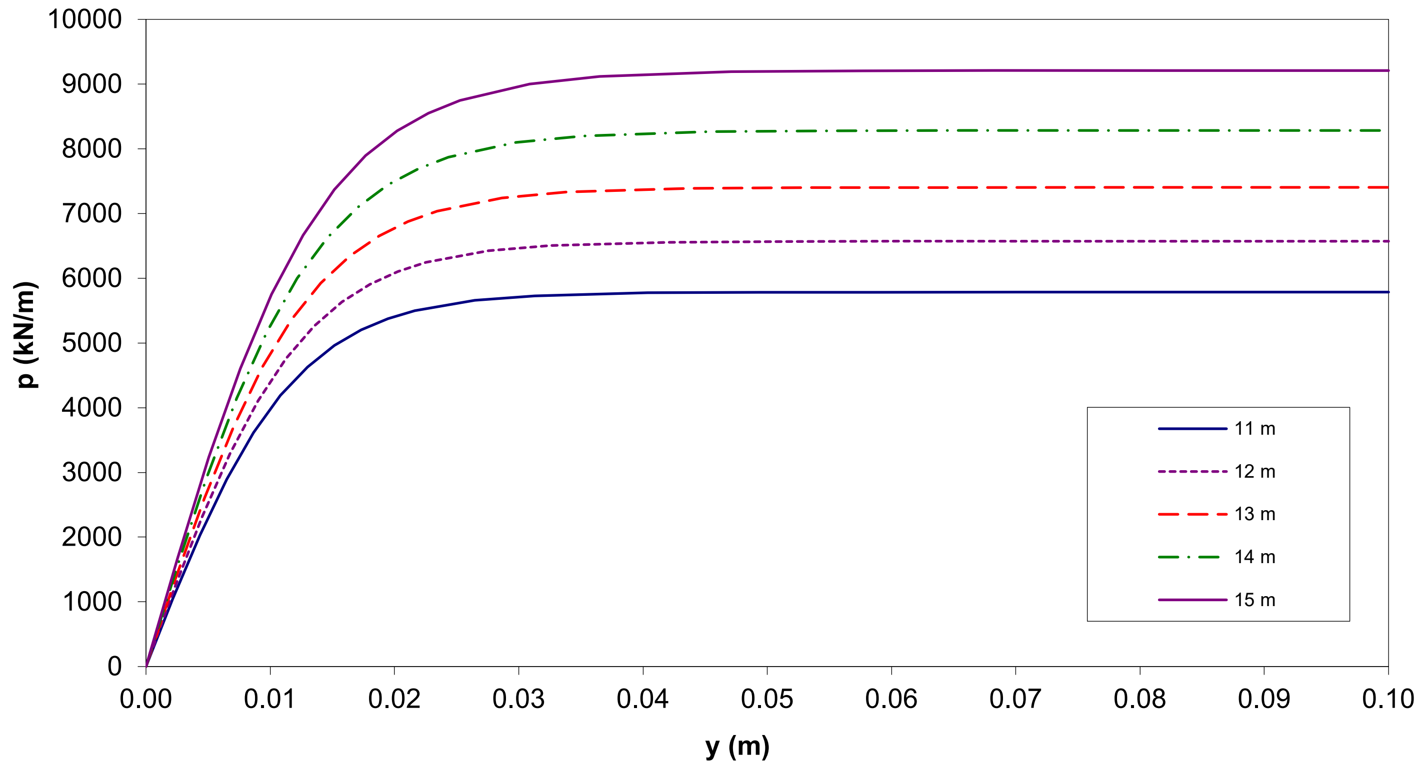
6 m		7 m		8 m		9 m		10 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.001827	358.6621	0.001936	518.6537	0.001908	672.0392	0.001991	788.97	0.002077	914.3627
0.003654	694.5313	0.003873	1004.347	0.003816	1301.37	0.003982	1527.801	0.004154	1770.618
0.00548	990.2625	0.005809	1431.998	0.005724	1855.493	0.005974	2178.338	0.006231	2524.546
0.007307	1236.854	0.007746	1788.589	0.007633	2317.542	0.007965	2720.781	0.008308	3153.2
0.009134	1433.306	0.009682	2072.673	0.009541	2685.641	0.009956	3152.927	0.010385	3654.028
0.010961	1584.203	0.011619	2290.883	0.011449	2968.383	0.011947	3484.865	0.012462	4038.722
0.012788	1696.893	0.013555	2453.841	0.013357	3179.534	0.013939	3732.754	0.014539	4326.008
0.014614	1779.291	0.015492	2572.996	0.015265	3333.927	0.01593	3914.011	0.016616	4536.073
0.016441	1838.617	0.017428	2658.785	0.017173	3445.088	0.017921	4044.513	0.018692	4687.316
0.018268	1880.855	0.019365	2719.865	0.019081	3524.232	0.019912	4137.428	0.020769	4794.998
0.022331	1935.405	0.023672	2798.749	0.023326	3626.444	0.024341	4257.424	0.025389	4934.065
0.026394	1960.049	0.02798	2834.386	0.02757	3672.621	0.02877	4311.635	0.030009	4996.893
0.034057	1975.572	0.036102	2856.834	0.035573	3701.707	0.037123	4345.782	0.03872	5036.467
0.041719	1978.927	0.044225	2861.685	0.043577	3707.993	0.045475	4353.162	0.047432	5045.02
0.049382	1979.65	0.052347	2862.73	0.05158	3709.347	0.053827	4354.751	0.056143	5046.862
0.059258	1979.821	0.062816	2862.977	0.061897	3709.667	0.064592	4355.127	0.067372	5047.297
0.1	1979.821	0.1	2862.977	0.1	3709.667	0.1	4355.127	0.1	5047.297

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-b



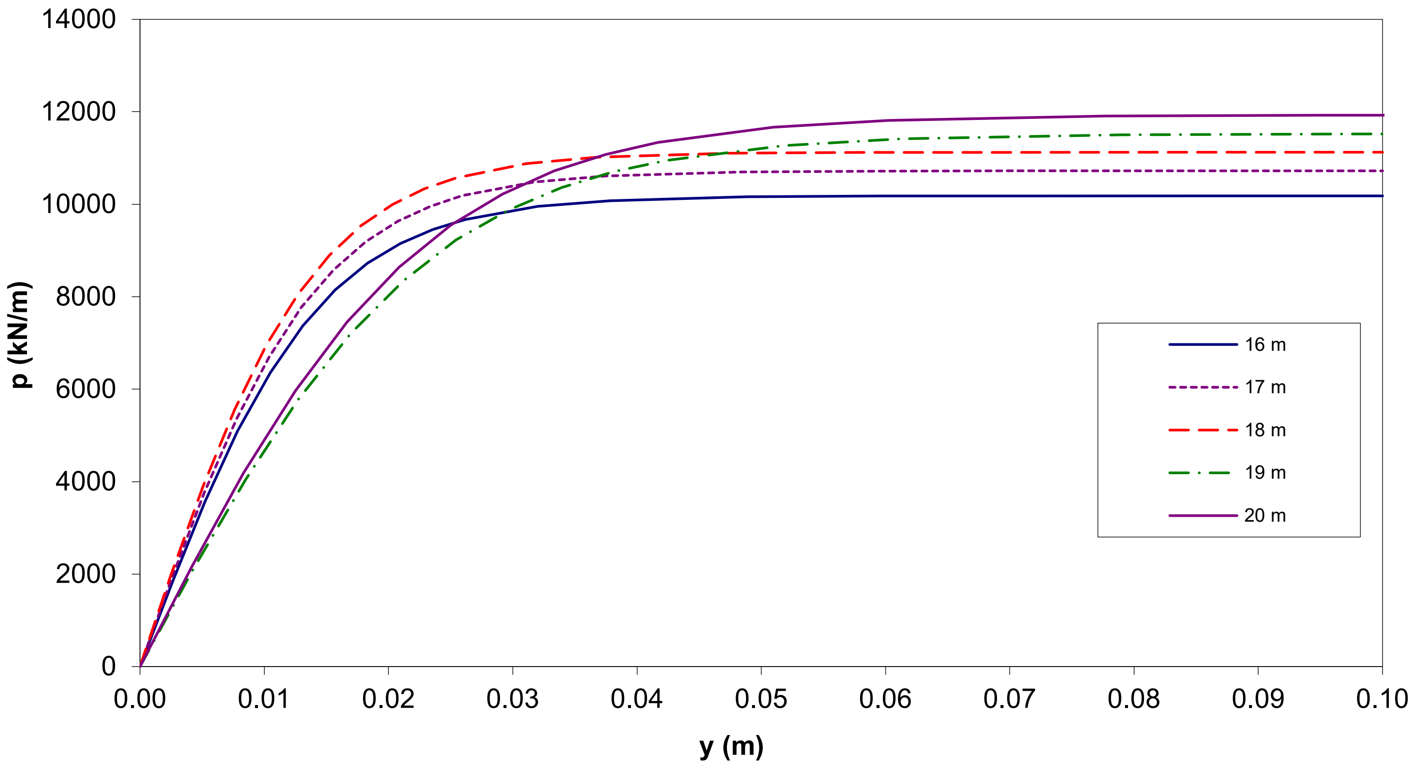
11 m		12 m		13 m		14 m		15 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002165	1048.217	0.002254	1190.534	0.002344	1341.312	0.002435	1500.552	0.002526	1668.254
0.004329	2029.821	0.004507	2305.409	0.004687	2597.384	0.004869	2905.744	0.005053	3230.491
0.006494	2894.117	0.006761	3287.052	0.007031	3703.349	0.007304	4143.009	0.007579	4606.033
0.008658	3614.801	0.009014	4105.582	0.009375	4625.544	0.009738	5174.687	0.010105	5753.011
0.010823	4188.945	0.011268	4757.678	0.011718	5360.226	0.012173	5996.591	0.012631	6666.771
0.012987	4629.954	0.013521	5258.563	0.014062	5924.548	0.014608	6627.908	0.015158	7368.644
0.015152	4959.297	0.015775	5632.621	0.016406	6345.979	0.017042	7099.371	0.017684	7892.798
0.017316	5200.114	0.018028	5906.133	0.018749	6654.131	0.019477	7444.107	0.02021	8276.062
0.019481	5373.497	0.020282	6103.056	0.021093	6875.994	0.021911	7692.309	0.022736	8552.003
0.021645	5496.943	0.022535	6243.263	0.023436	7033.957	0.024346	7869.026	0.025263	8748.469
0.02646	5656.368	0.027548	6424.333	0.028649	7237.96	0.029761	8097.248	0.030882	9002.198
0.031274	5728.393	0.03256	6506.137	0.033862	7330.124	0.035176	8200.353	0.036501	9116.826
0.040353	5773.761	0.042013	6557.664	0.043692	7388.176	0.045388	8265.298	0.047097	9189.029
0.049432	5783.566	0.051465	6568.8	0.053523	7400.723	0.0556	8279.334	0.057693	9204.634
0.058511	5785.677	0.060917	6571.198	0.063353	7403.425	0.065812	8282.357	0.068289	9207.994
0.070213	5786.176	0.073101	6571.765	0.076024	7404.063	0.078974	8283.071	0.081947	9208.788
0.1	5786.176	0.1	6571.765	0.1	7404.063	0.1	8283.071	0.1	9208.788

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-c



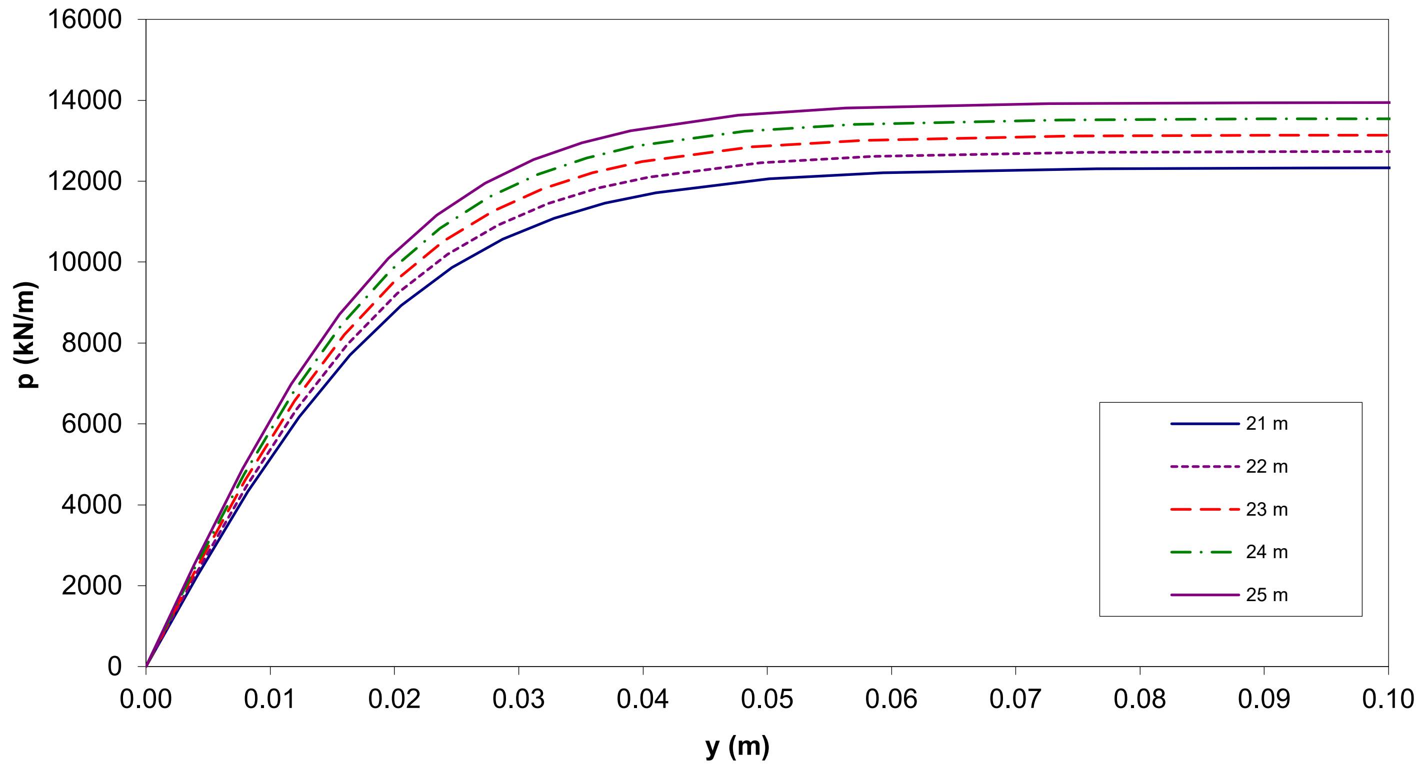
16 m		17 m		18 m		19 m		20 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002618	1844.418	0.002596	1942.576	0.002543	2015.537	0.00424	2088.497	0.004169	2161.458
0.005237	3571.623	0.005191	3761.702	0.005087	3902.987	0.00848	4044.271	0.008337	4185.556
0.007855	5092.419	0.007787	5363.434	0.00763	5564.877	0.01272	5766.321	0.012506	5967.764
0.010474	6360.516	0.010382	6699.017	0.010174	6950.624	0.01696	7202.23	0.016674	7453.836
0.013092	7370.766	0.012978	7763.033	0.012717	8054.602	0.021199	8346.171	0.020843	8637.741
0.015711	8146.756	0.015573	8580.32	0.015261	8902.585	0.025439	9224.851	0.025012	9547.116
0.018329	8726.26	0.018169	9190.664	0.017804	9535.854	0.029679	9881.043	0.02918	10226.23
0.020948	9149.995	0.020765	9636.95	0.020348	9998.902	0.033919	10360.85	0.033349	10722.8
0.023566	9455.075	0.02336	9958.267	0.022891	10332.29	0.038159	10706.31	0.037517	11080.33
0.026185	9672.288	0.025956	10187.04	0.025435	10569.65	0.042399	10952.26	0.041686	11334.88
0.032009	9952.809	0.031729	10482.49	0.031092	10876.2	0.051829	11269.91	0.050958	11663.62
0.037833	10079.54	0.037502	10615.97	0.036749	11014.69	0.06126	11413.41	0.06023	11812.13
0.048816	10159.37	0.048389	10700.04	0.047417	11101.92	0.079044	11503.8	0.077715	11905.68
0.059799	10176.62	0.059276	10718.21	0.058086	11120.78	0.096828	11523.34	0.0952	11925.9
0.070782	10180.34	0.070163	10722.13	0.068754	11124.84	0.114612	11527.55	0.112685	11930.25
0.084938	10181.22	0.084196	10723.05	0.082505	11125.8	0.137534	11528.54	0.135222	11931.28
0.1	10181.22	0.1	10723.05	0.1	11125.8				

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-d



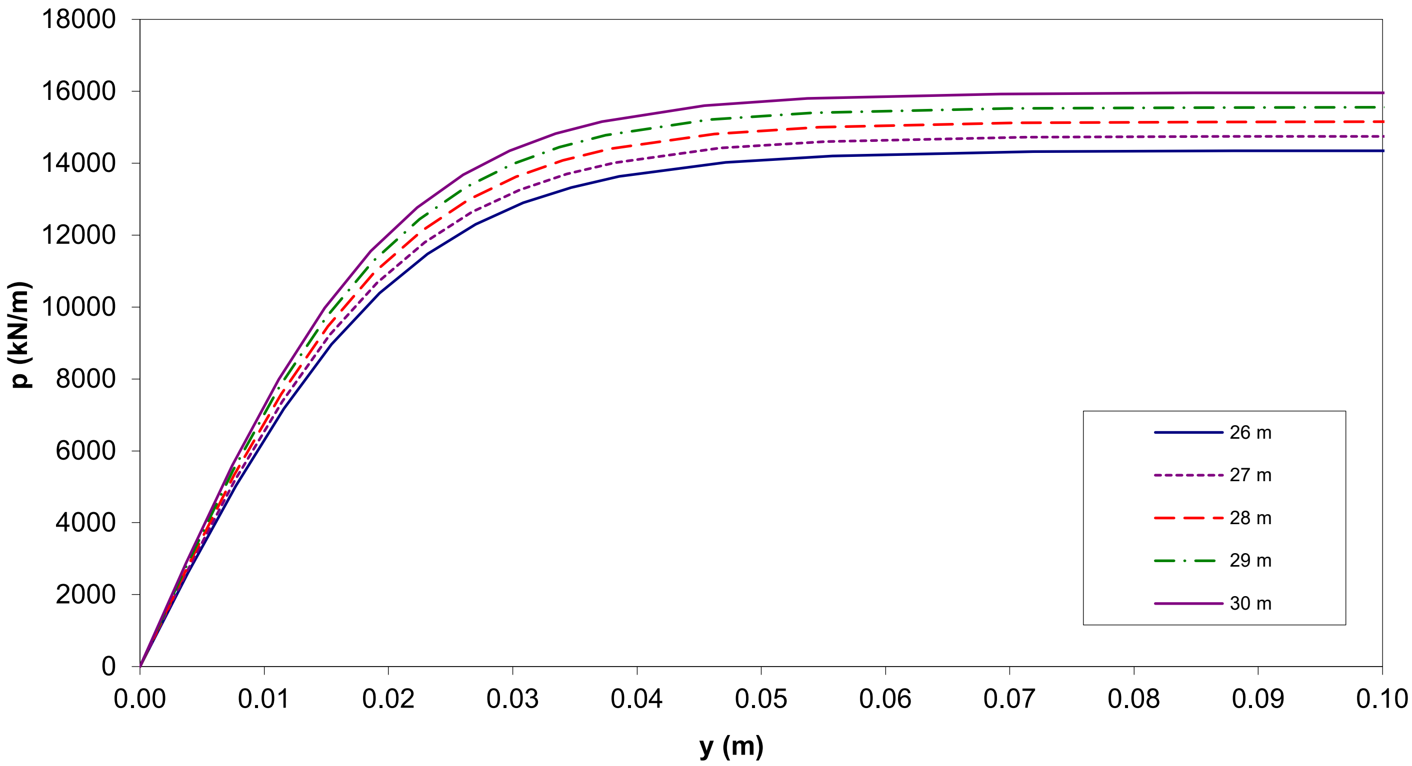
21 m		22 m		23 m		24 m		25 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.004104	2234.419	0.004045	2307.379	0.003992	2380.34	0.003943	2453.3	0.003898	2526.261
0.008208	4326.841	0.008091	4468.125	0.007984	4609.41	0.007886	4750.694	0.007795	4891.979
0.012312	6169.208	0.012136	6370.651	0.011976	6572.095	0.011829	6773.538	0.011693	6974.982
0.016416	7705.443	0.016182	7957.049	0.015968	8208.655	0.015771	8460.261	0.015591	8711.868
0.020521	8929.31	0.020227	9220.879	0.01996	9512.449	0.019714	9804.018	0.019489	10095.59
0.024625	9869.382	0.024273	10191.65	0.023952	10513.91	0.023657	10836.18	0.023386	11158.44
0.028729	10571.42	0.028318	10916.61	0.027944	11261.8	0.0276	11606.99	0.027284	11952.18
0.032833	11084.76	0.032364	11446.71	0.031936	11808.66	0.031543	12170.61	0.031182	12532.56
0.036937	11454.34	0.036409	11828.36	0.035927	12202.38	0.035486	12576.4	0.03508	12950.42
0.041041	11717.49	0.040455	12100.1	0.039919	12482.71	0.039429	12865.32	0.038977	13247.93
0.05017	12057.32	0.049453	12451.03	0.048799	12844.74	0.048199	13238.45	0.047647	13632.16
0.059298	12210.86	0.058451	12609.58	0.057678	13008.3	0.056969	13407.02	0.056316	13805.74
0.076513	12307.56	0.07542	12709.44	0.074422	13111.32	0.073507	13513.2	0.072665	13915.08
0.093727	12328.46	0.092388	12731.02	0.091166	13133.59	0.090045	13536.15	0.089014	13938.71
0.110941	12332.96	0.109357	12735.67	0.107909	13138.38	0.106583	13541.09	0.105363	13943.8
0.13313	12334.03	0.131228	12736.77	0.129491	13139.51	0.1279	13542.26	0.126435	13945

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-e

TETRA TECH



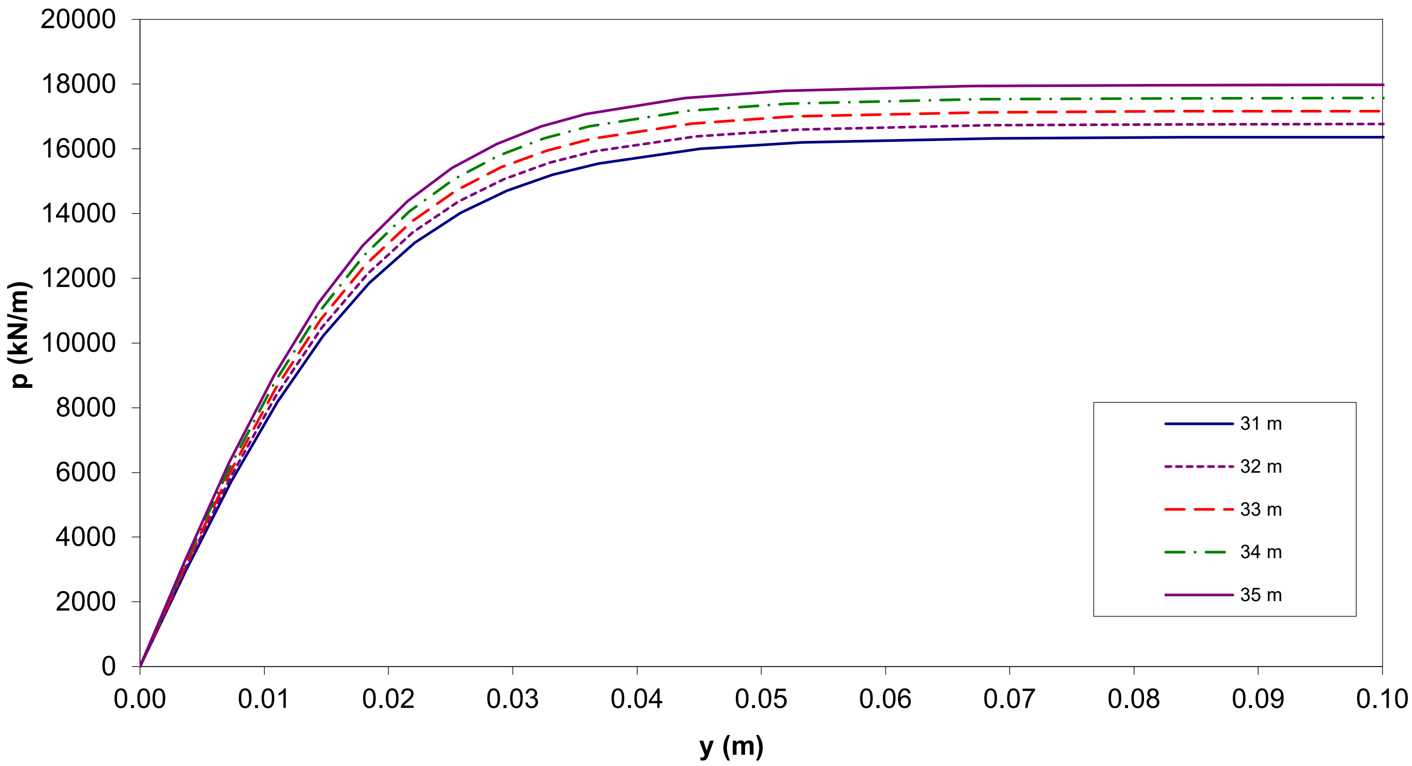
26 m		27 m		28 m		29 m		30 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
3.86E-03	2599.222	3.82E-03	2672.182	3.78E-03	2745.143	3.75E-03	2818.104	0.003717	2891.064
0.007712	5033.264	0.007635	5174.548	0.007563	5315.833	0.007497	5457.117	0.007434	5598.402
0.011568	7176.425	0.011452	7377.869	0.011345	7579.312	0.011245	7780.756	0.011151	7982.199
0.015424	8963.474	0.01527	9215.08	0.015127	9466.687	0.014993	9718.293	0.014869	9969.899
0.01928	10387.16	0.019087	10678.73	0.018908	10970.3	0.018741	11261.86	0.018586	11553.43
0.023136	11480.71	0.022905	11802.98	0.02269	12125.24	0.02249	12447.51	0.022303	12769.77
0.026992	12297.37	0.026722	12642.56	0.026471	12987.75	0.026238	13332.94	0.02602	13678.13
0.030848	12894.51	0.03054	13256.46	0.030253	13618.41	0.029986	13980.37	0.029737	14342.32
0.034704	13324.44	0.034357	13698.46	0.034035	14072.48	0.033735	14446.5	0.033454	14820.52
0.038561	13630.55	0.038175	14013.16	0.037816	14395.77	0.037483	14778.38	0.037171	15160.99
0.047137	14025.87	0.046666	14419.58	0.046228	14813.28	0.04582	15206.99	0.045439	15600.7
0.055714	14204.46	0.055157	14603.19	0.054639	15001.91	0.054157	15400.63	0.053707	15799.35
0.071888	14316.96	0.071169	14718.84	0.070501	15120.72	0.069879	15522.6	0.069299	15924.48
0.088062	14341.27	0.087181	14743.84	0.086363	15146.4	0.085601	15548.96	0.08489	15951.52
0.104236	14346.51	0.103193	14749.22	0.102225	15151.93	0.101323	15554.64	0.100481	15957.34
0.125083	14347.75	0.123832	14750.49	0.122669	15153.23	0.121587	15555.98	0.120577	15958.72

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-f

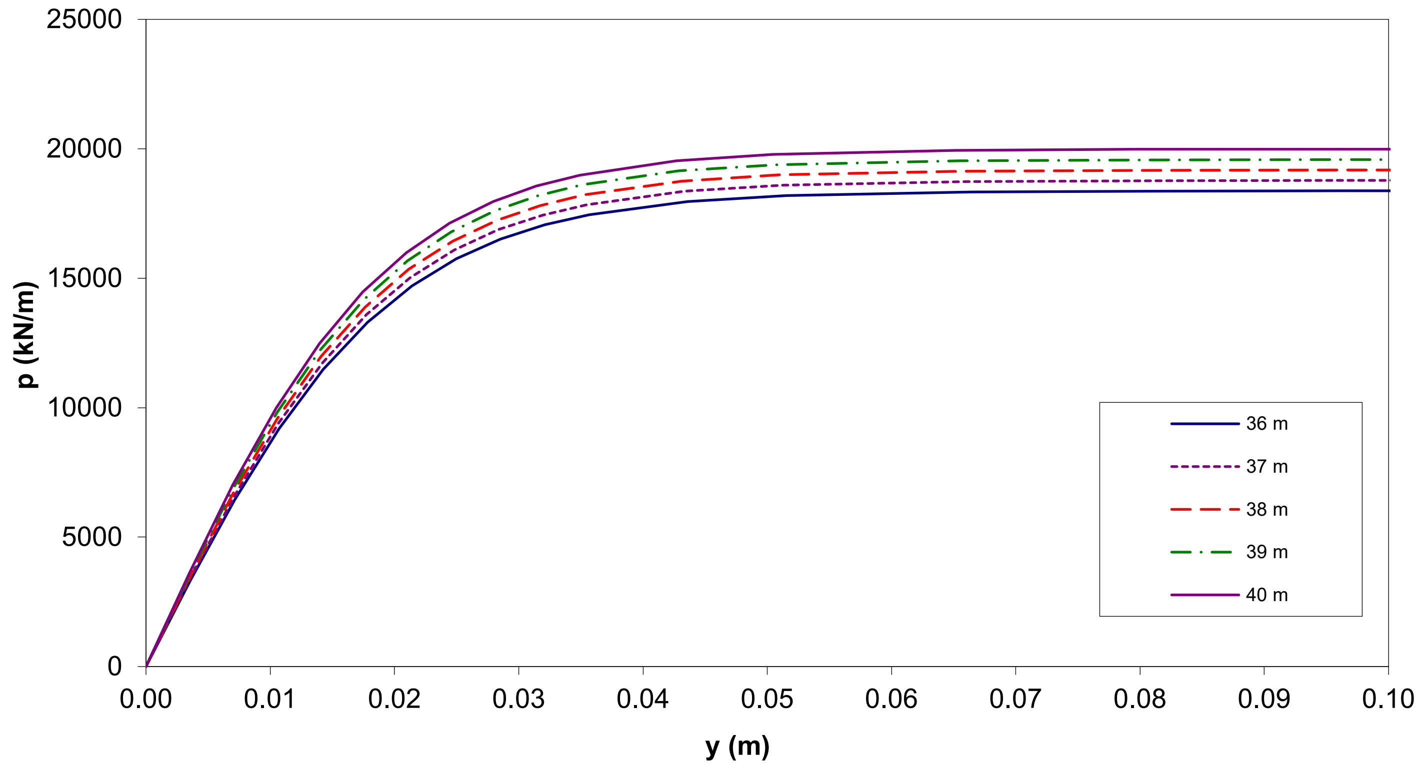


31 m		32 m		33 m		34 m		35 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.003688	2964.025	0.003661	3036.985	0.003635	3109.946	0.003611	3182.907	0.003588	3255.867
0.007376	5739.686	0.007321	5880.971	0.00727	6022.256	0.007222	6163.54	0.007176	6304.825
0.011064	8183.643	0.010982	8385.086	0.010905	8586.53	0.010833	8787.973	0.010764	8989.417
0.014752	10221.51	0.014643	10473.11	0.01454	10724.72	0.014444	10976.32	0.014353	11227.93
0.01844	11845	0.018304	12136.57	0.018175	12428.14	0.018055	12719.71	0.017941	13011.28
0.022128	13092.04	0.021964	13414.3	0.02181	13736.57	0.021666	14058.83	0.021529	14381.1
0.025816	14023.31	0.025625	14368.5	0.025445	14713.69	0.025276	15058.88	0.025117	15404.07
0.029504	14704.27	0.029286	15066.22	0.029081	15428.17	0.028887	15790.12	0.028705	16152.07
0.033192	15194.54	0.032946	15568.56	0.032716	15942.58	0.032498	16316.6	0.032293	16690.62
0.03688	15543.61	0.036607	15926.22	0.036351	16308.83	0.036109	16691.44	0.035882	17074.05
0.045083	15994.41	0.04475	16388.12	0.044436	16781.83	0.044141	17175.54	0.043863	17569.24
0.053286	16198.07	0.052892	16596.79	0.052521	16995.52	0.052172	17394.24	0.051844	17792.96
0.068756	16326.36	0.068247	16728.24	0.067768	17130.12	0.067318	17532	0.066894	17933.88
0.084225	16354.08	0.083601	16756.65	0.083015	17159.21	0.082464	17561.77	0.081944	17964.33
0.099694	16360.05	0.098956	16762.76	0.098262	17165.47	0.09761	17568.18	0.096994	17970.89
0.119633	16361.46	0.118747	16764.21	0.117915	17166.95	0.117132	17569.7	0.116393	17972.44

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-g



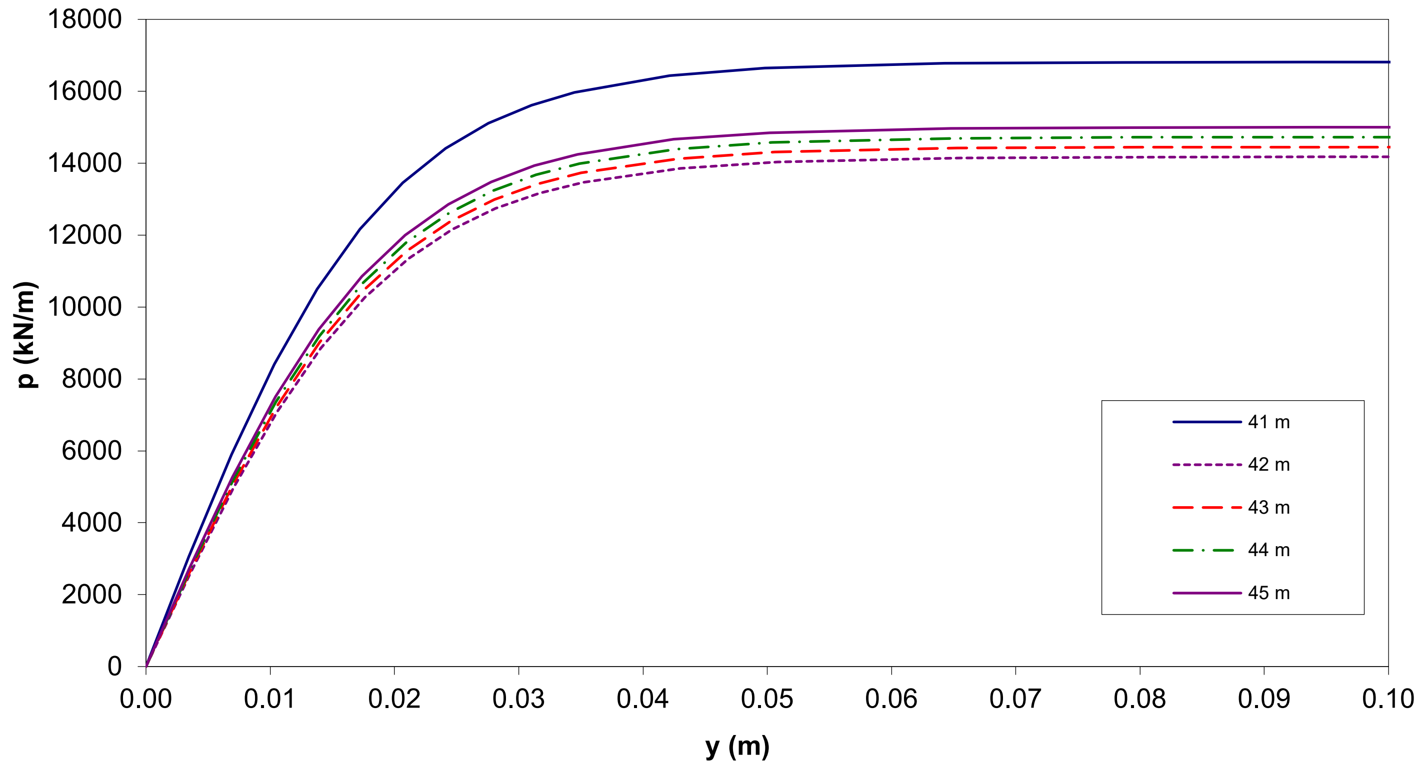
36 m		37 m		38 m		39 m		40 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.003567	3328.828	0.003546	3401.788	0.003527	3474.749	0.003509	3547.71	0.003491	3620.67
0.007133	6446.109	0.007093	6587.394	0.007054	6728.679	0.007018	6869.963	0.006983	7011.248
0.0107	9190.86	0.010639	9392.304	0.010581	9593.748	0.010526	9795.191	0.010474	9996.635
0.014267	11479.54	0.014185	11731.14	0.014108	11982.75	0.014035	12234.36	0.013966	12485.96
0.017833	13302.85	0.017732	13594.42	0.017635	13885.99	0.017544	14177.56	0.017457	14469.13
0.0214	14703.37	0.021278	15025.63	0.021162	15347.9	0.021053	15670.16	0.020949	15992.43
0.024967	15749.26	0.024824	16094.45	0.024689	16439.64	0.024561	16784.83	0.02444	17130.02
0.028533	16514.02	0.028371	16875.97	0.028216	17237.93	0.02807	17599.88	0.027931	17961.83
0.0321	17064.64	0.031917	17438.66	0.031744	17812.67	0.031579	18186.69	0.031423	18560.71
0.035667	17456.66	0.035463	17839.28	0.035271	18221.89	0.035088	18604.5	0.034914	18987.11
0.0436	17962.95	0.043351	18356.66	0.043116	18750.37	0.042892	19144.08	0.04268	19537.79
0.051533	18191.68	0.051239	18590.4	0.050961	18989.13	0.050697	19387.85	0.050446	19786.57
0.066493	18335.75	0.066114	18737.63	0.065755	19139.51	0.065414	19541.39	0.06509	19943.27
0.081453	18366.89	0.080989	18769.46	0.080549	19172.02	0.080131	19574.58	0.079735	19977.14
0.096413	18373.6	0.095864	18776.31	0.095343	19179.02	0.094849	19581.73	0.094379	19984.43
0.115696	18375.18	0.115036	18777.93	0.114411	19180.67	0.113819	19583.41	0.113255	19986.16

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-h



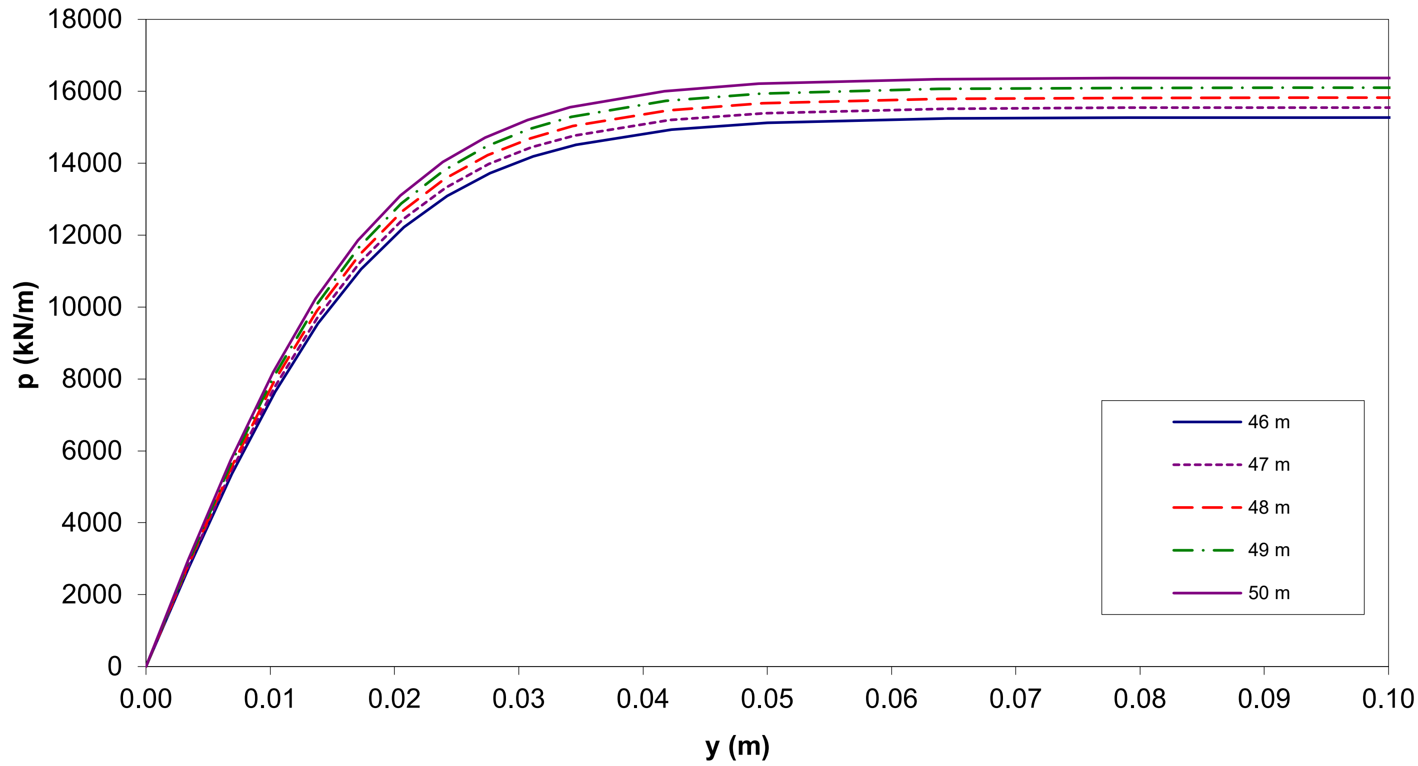
41 m		42 m		43 m		44 m		45 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.003446	3045.351	0.003518	2567.995	0.003503	2617.738	0.003488	2667.481	0.003474	2717.224
0.006893	5897.171	0.007036	4972.794	0.007005	5069.119	0.006976	5165.444	0.006948	5261.77
0.010339	8408.185	0.010554	7090.207	0.010508	7227.548	0.010464	7364.889	0.010423	7502.229
0.013785	10501.96	0.014072	8855.786	0.014011	9027.327	0.013953	9198.868	0.013897	9370.408
0.017231	12170.01	0.01759	10262.37	0.017513	10461.15	0.017441	10659.94	0.017371	10858.73
0.020678	13451.26	0.021108	11342.78	0.021016	11562.5	0.020929	11782.21	0.020845	12001.92
0.024124	14408.08	0.024626	12149.63	0.024519	12384.97	0.024417	12620.32	0.02432	12855.66
0.02757	15107.72	0.028144	12739.6	0.028022	12986.37	0.027905	13233.14	0.027794	13479.91
0.031016	15611.44	0.031662	13164.36	0.031524	13419.36	0.031393	13674.36	0.031268	13929.36
0.034463	15970.09	0.035179	13466.79	0.035027	13727.65	0.034881	13988.5	0.034742	14249.36
0.042128	16433.26	0.043004	13857.36	0.042818	14125.78	0.04264	14394.21	0.04247	14662.63
0.049793	16642.51	0.050829	14033.81	0.050609	14305.65	0.050398	14577.49	0.050197	14849.34
0.064248	16774.32	0.065585	14144.95	0.065301	14418.95	0.065029	14692.94	0.06477	14966.94
0.078704	16802.8	0.080341	14168.98	0.079992	14443.44	0.07966	14717.9	0.079342	14992.36
0.093159	16808.94	0.095097	14174.15	0.094684	14448.71	0.094291	14723.27	0.093915	14997.83
0.11179	16810.39	0.114116	14175.37	0.113621	14449.95	0.113149	14724.54	0.112697	14999.12

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-i



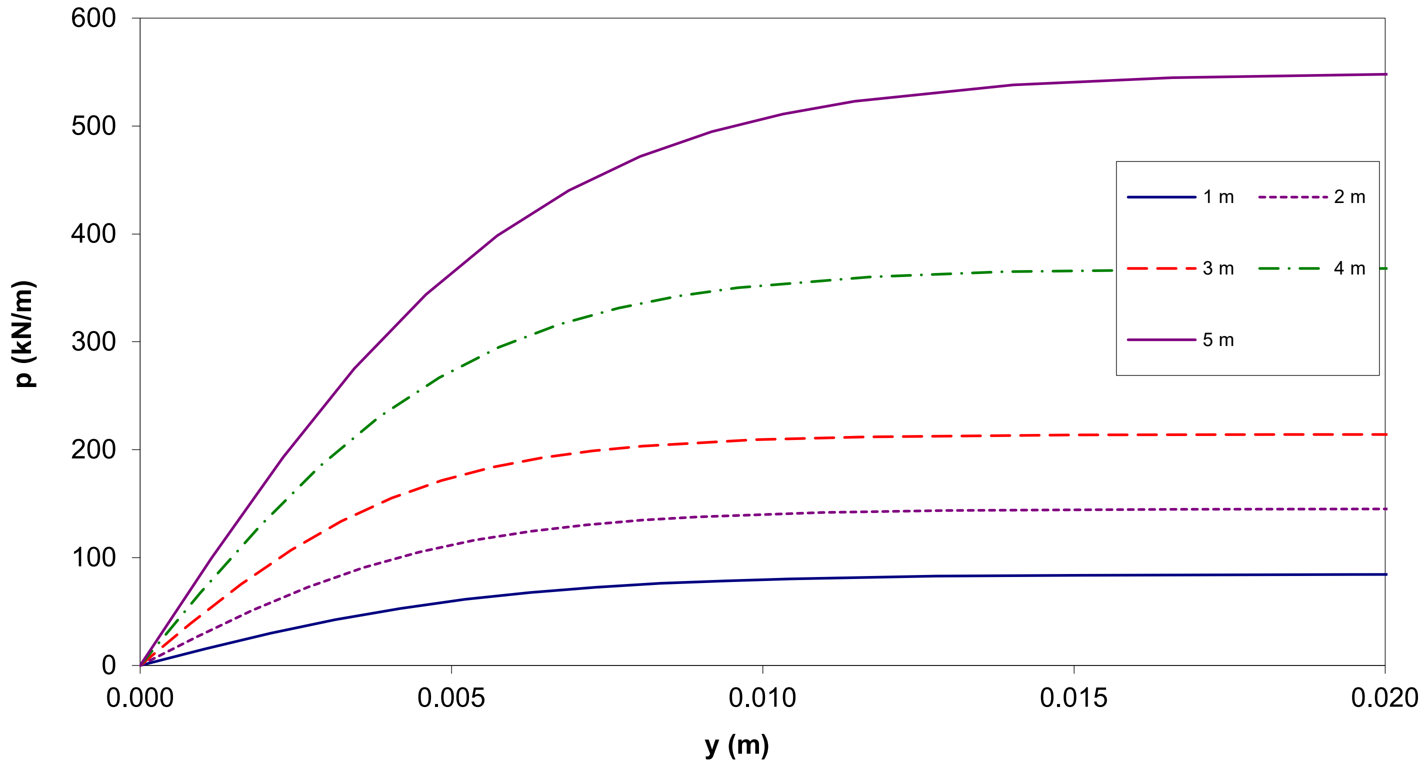
46 m		47 m		48 m		49 m		50 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.003461	2766.967	0.003448	2816.711	0.003436	2866.454	0.003424	2916.197	0.003413	2965.94
0.006922	5358.095	0.006896	5454.42	0.006872	5550.746	0.006848	5647.071	0.006826	5743.396
0.010383	7639.57	0.010345	7776.91	0.010308	7914.251	0.010273	8051.592	0.010239	8188.932
0.013844	9541.949	0.013793	9713.49	0.013744	9885.03	0.013697	10056.57	0.013652	10228.11
0.017305	11057.51	0.017241	11256.3	0.01718	11455.09	0.017121	11653.87	0.017065	11852.66
0.020765	12221.64	0.020689	12441.35	0.020616	12661.07	0.020545	12880.78	0.020478	13100.5
0.024226	13091	0.024137	13326.35	0.024052	13561.69	0.02397	13797.03	0.023891	14032.38
0.027687	13726.68	0.027585	13973.46	0.027488	14220.23	0.027394	14467	0.027304	14713.77
0.031148	14184.36	0.031034	14439.36	0.030924	14694.36	0.030818	14949.36	0.030717	15204.36
0.034609	14510.22	0.034482	14771.08	0.03436	15031.94	0.034242	15292.79	0.03413	15553.65
0.042307	14931.05	0.042151	15199.48	0.042002	15467.9	0.041859	15736.32	0.041721	16004.75
0.050005	15121.18	0.049821	15393.02	0.049645	15664.86	0.049475	15936.7	0.049313	16208.54
0.064522	15240.93	0.064284	15514.93	0.064056	15788.92	0.063838	16062.91	0.063629	16336.91
0.079038	15266.81	0.078747	15541.27	0.078468	15815.73	0.078201	16090.19	0.077944	16364.65
0.093555	15272.39	0.09321	15546.95	0.09288	15821.51	0.092564	16096.07	0.09226	16370.63
0.112266	15273.7	0.111852	15548.29	0.111456	15822.87	0.111076	16097.46	0.110712	16372.04

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Abutment - Static with Ground Improvement
Pile Diameter = 914mm

Figure Abutment D1-j

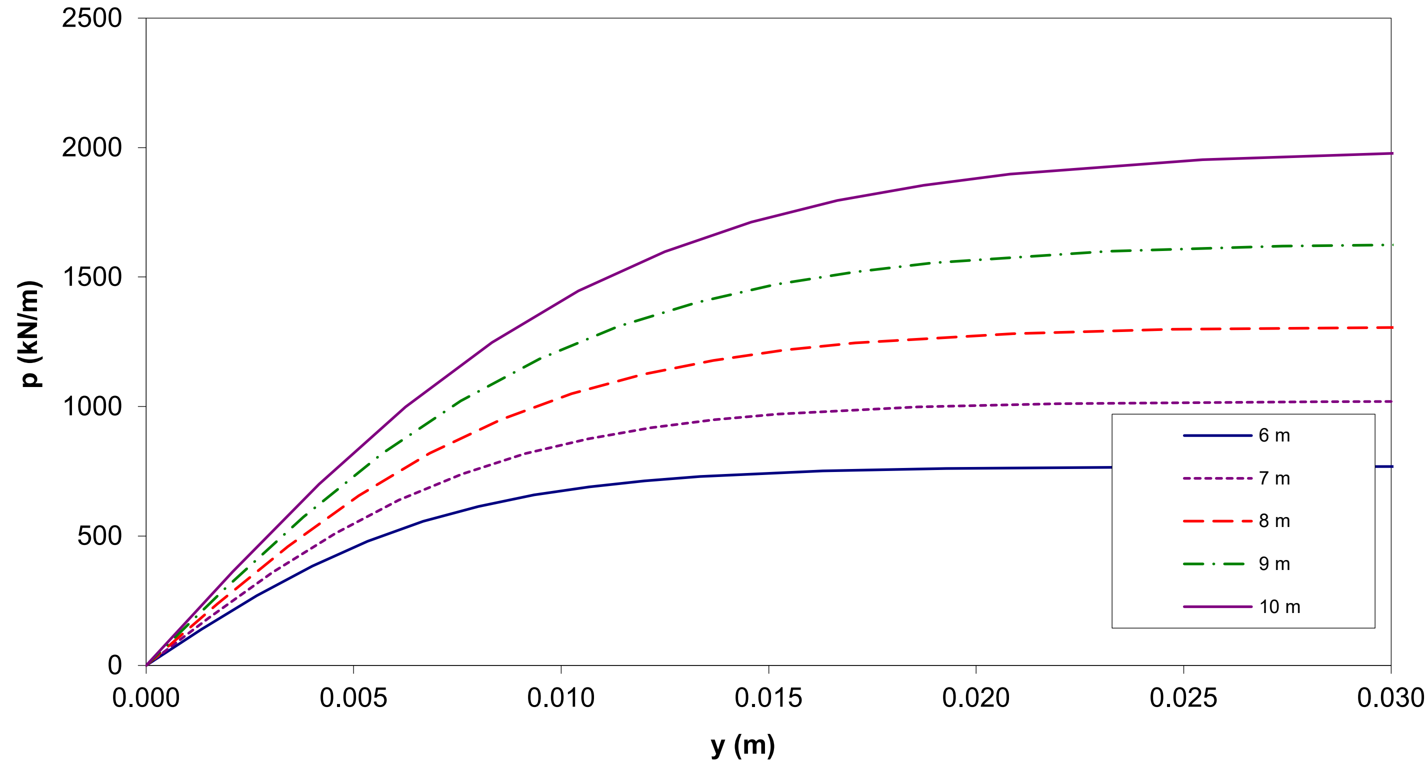


1 m		2 m		3 m		4 m		5 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.001045	15.31995	0.000896	26.27988	0.000807	38.79256	0.00096	66.76193	0.001147	99.69992
0.002089	29.66632	0.001792	50.88967	0.001615	75.11985	0.001921	129.2812	0.002295	193.0639
0.003134	42.29823	0.002688	72.55848	0.002422	107.1059	0.002881	184.329	0.003442	275.2705
0.004179	52.83119	0.003584	90.62674	0.003229	133.777	0.003841	230.23	0.004589	343.8174
0.005223	61.22245	0.00448	105.0211	0.004036	155.025	0.004802	266.7978	0.005736	398.4265
0.006268	67.66791	0.005376	116.0777	0.004844	171.3459	0.005762	294.8861	0.006884	440.3725
0.007313	72.48133	0.006272	124.3346	0.005651	183.5343	0.006722	315.8623	0.008031	471.6976
0.008357	76.00093	0.007168	130.3722	0.006458	192.4465	0.007683	331.2001	0.009178	494.6026
0.009402	78.53496	0.008064	134.7191	0.007265	198.863	0.008643	342.243	0.010326	511.0937
0.010447	80.33915	0.00896	137.814	0.008073	203.4316	0.009603	350.1054	0.011473	522.8351
0.01277	82.6692	0.010953	141.8109	0.009868	209.3316	0.011739	360.2594	0.014025	537.9987
0.015094	83.72186	0.012946	143.6167	0.011664	211.9971	0.013875	364.8467	0.016577	544.8492
0.019476	84.38491	0.016704	144.7541	0.01505	213.6761	0.017903	367.7362	0.021389	549.1643
0.023857	84.52822	0.020463	144.9999	0.018436	214.0389	0.021931	368.3607	0.026201	550.0969
0.028239	84.55907	0.024221	145.0528	0.021822	214.1171	0.025959	368.4952	0.031013	550.2977
0.033887	84.56636	0.029065	145.0653	0.026186	214.1355	0.031151	368.5269	0.037216	550.3451

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-a



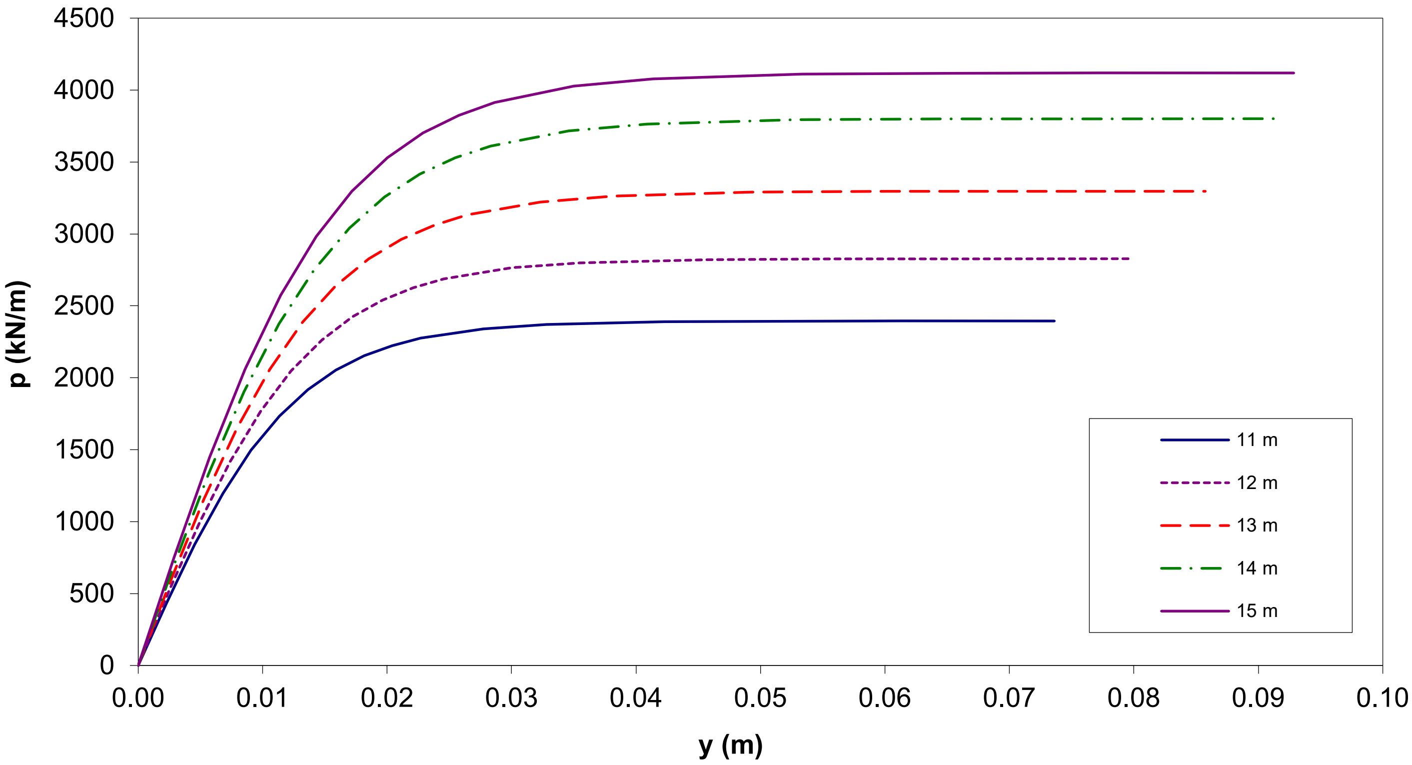
6 m		7 m		8 m		9 m		10 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.001334	139.1369	0.001521	185.0729	0.001708	237.5079	0.001895	296.4419	0.002082	361.8749
0.002668	269.4317	0.003042	358.3845	0.003416	459.9222	0.00379	574.0449	0.004164	700.7527
0.004003	384.1556	0.004564	510.9844	0.005125	655.7569	0.005685	818.4731	0.006246	999.1329
0.005337	479.8167	0.006085	638.228	0.006833	819.0512	0.007581	1022.286	0.008328	1247.934
0.006671	556.0268	0.007606	739.5988	0.008541	949.1424	0.009476	1184.658	0.010411	1446.145
0.008005	614.5649	0.009127	817.4632	0.010249	1049.068	0.011371	1309.378	0.012493	1598.394
0.00934	658.2808	0.010648	875.6119	0.011957	1123.691	0.013266	1402.518	0.014575	1712.093
0.010674	690.246	0.01217	918.1304	0.013665	1178.256	0.015161	1470.622	0.016657	1795.23
0.012008	713.2603	0.013691	948.7428	0.015374	1217.541	0.017056	1519.656	0.018739	1855.086
0.013342	729.6461	0.015212	970.5384	0.017082	1245.512	0.018951	1554.567	0.020821	1897.703
0.01631	750.8077	0.018596	998.6866	0.020881	1281.635	0.023167	1599.654	0.025452	1952.742
0.019278	760.3681	0.021979	1011.403	0.024681	1297.955	0.027382	1620.023	0.030083	1977.607
0.024874	766.39	0.02836	1019.413	0.031845	1308.234	0.035331	1632.853	0.038817	1993.269
0.030471	767.6915	0.03474	1021.145	0.03901	1310.456	0.04328	1635.626	0.04755	1996.654
0.036067	767.9717	0.041121	1021.517	0.046175	1310.934	0.051229	1636.223	0.056283	1997.383
0.04328	768.0379	0.049345	1021.605	0.05541	1311.047	0.061475	1636.364	0.06754	1997.555

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-b

TETRA TECH



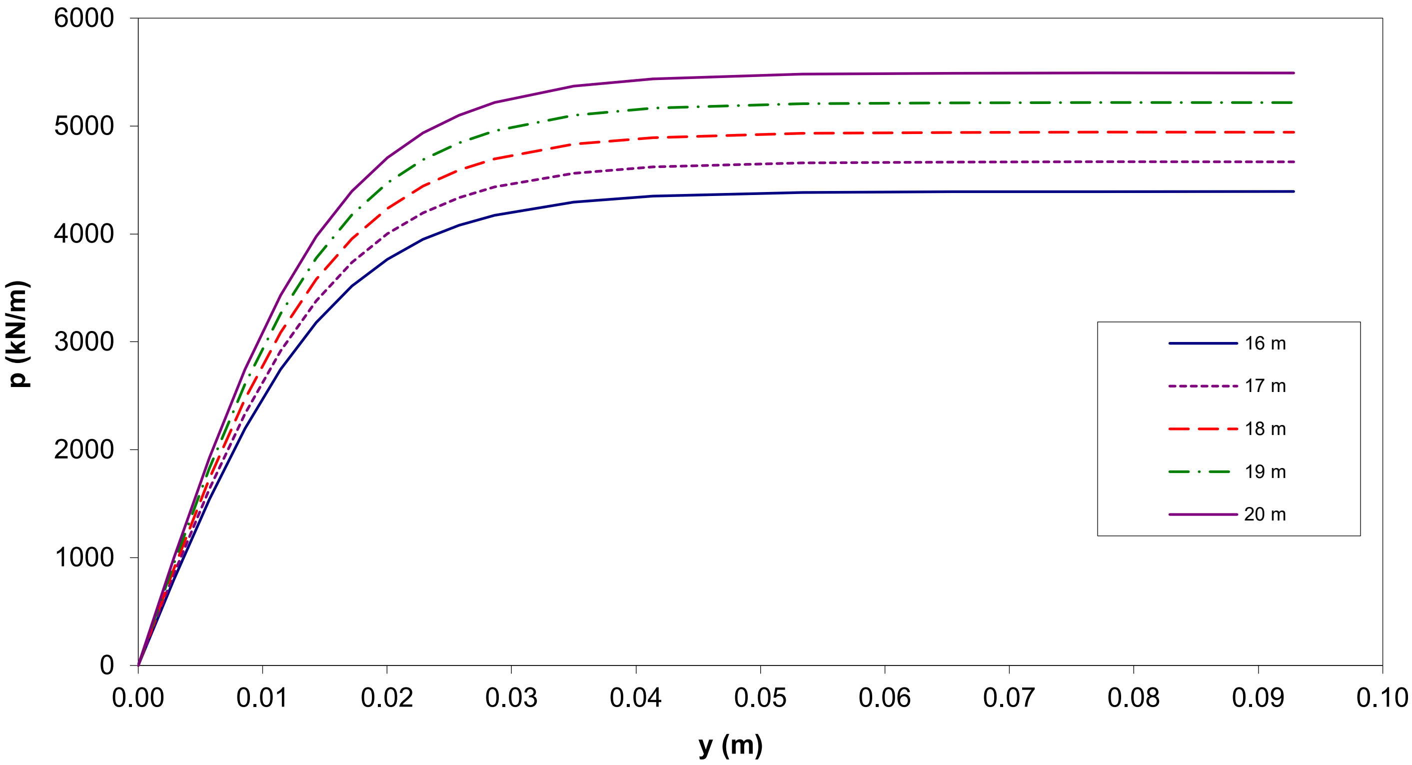
11 m		12 m		13 m		14 m		15 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002269	433.8069	0.002456	512.2379	0.002643	597.1678	0.00283	688.5968	0.002862	746.1485
0.004538	840.0454	0.004912	991.9231	0.005286	1156.386	0.00566	1333.434	0.005724	1444.88
0.006807	1197.736	0.007368	1414.284	0.007929	1648.775	0.00849	1901.209	0.008586	2060.109
0.009076	1495.993	0.009824	1766.464	0.010572	2059.347	0.01132	2374.642	0.011448	2573.11
0.011345	1733.604	0.01228	2047.034	0.013215	2386.436	0.01415	2751.81	0.01431	2981.801
0.013614	1916.116	0.014736	2262.544	0.015858	2637.678	0.01698	3041.518	0.017172	3295.723
0.015884	2052.415	0.017192	2423.486	0.018501	2825.305	0.01981	3257.871	0.020034	3530.158
0.018153	2152.078	0.019648	2541.167	0.021144	2962.497	0.02264	3416.069	0.022896	3701.578
0.020422	2223.833	0.022104	2625.895	0.023787	3061.273	0.02547	3529.968	0.025759	3824.996
0.022691	2274.921	0.02456	2686.22	0.02643	3131.6	0.0283	3611.062	0.028621	3912.868
0.027738	2340.9	0.030023	2764.127	0.032309	3222.425	0.034594	3715.792	0.034987	4026.351
0.032785	2370.707	0.035486	2799.324	0.038187	3263.457	0.040889	3763.107	0.041353	4077.621
0.042302	2389.483	0.045788	2821.494	0.049273	3289.303	0.052759	3792.91	0.053357	4109.914
0.05182	2393.541	0.056089	2826.286	0.060359	3294.889	0.064629	3799.351	0.065362	4116.894
0.061337	2394.414	0.066391	2827.317	0.071445	3296.092	0.076499	3800.738	0.077367	4118.397
0.073605	2394.621	0.079669	2827.561	0.085734	3296.376	0.091799	3801.066	0.09284	4118.752

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-c



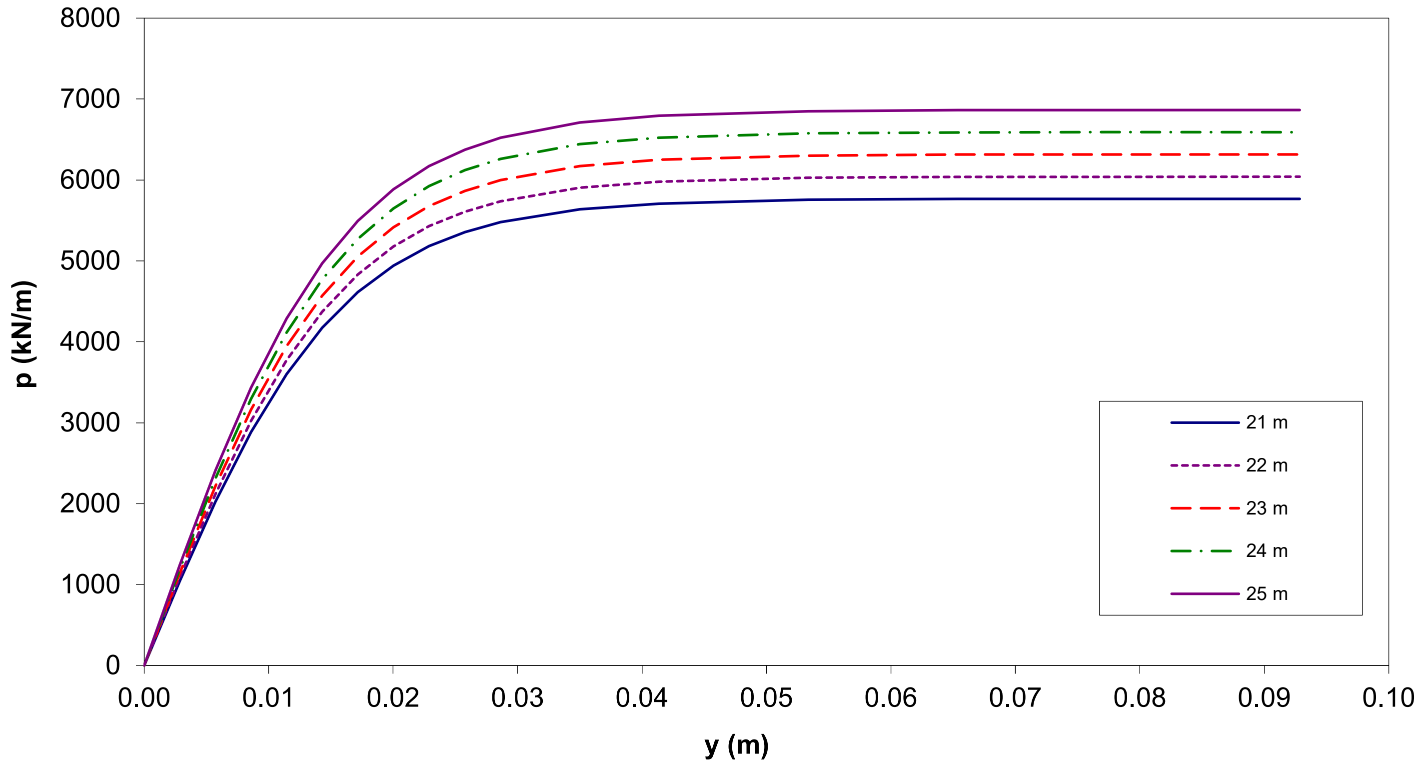
16 m		17 m		18 m		19 m		20 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	795.8918	0.002862	845.635	0.002862	895.3782	0.002862	945.1215	0.002862	994.8647
0.005724	1541.205	0.005724	1637.53	0.005724	1733.855	0.005724	1830.181	0.005724	1926.506
0.008586	2197.449	0.008586	2334.79	0.008586	2472.13	0.008586	2609.471	0.008586	2746.812
0.011448	2744.651	0.011448	2916.191	0.011448	3087.732	0.011448	3259.273	0.011448	3430.813
0.01431	3180.588	0.01431	3379.374	0.01431	3578.161	0.01431	3776.948	0.01431	3975.735
0.017172	3515.438	0.017172	3735.153	0.017172	3954.868	0.017172	4174.582	0.017172	4394.297
0.020034	3765.502	0.020034	4000.846	0.020034	4236.19	0.020034	4471.533	0.020034	4706.877
0.022896	3948.349	0.022896	4195.121	0.022896	4441.893	0.022896	4688.665	0.022896	4935.437
0.025759	4079.996	0.025759	4334.995	0.025759	4589.995	0.025759	4844.995	0.025759	5099.995
0.028621	4173.726	0.028621	4434.584	0.028621	4695.442	0.028621	4956.3	0.028621	5217.157
0.034987	4294.775	0.034987	4563.198	0.034987	4831.622	0.034987	5100.045	0.034987	5368.469
0.041353	4349.462	0.041353	4621.303	0.041353	4893.145	0.041353	5164.986	0.041353	5436.827
0.053357	4383.908	0.053357	4657.903	0.053357	4931.897	0.053357	5205.891	0.053357	5479.886
0.065362	4391.353	0.065362	4665.813	0.065362	4940.273	0.065362	5214.732	0.065362	5489.192
0.077367	4392.956	0.077367	4667.516	0.077367	4942.076	0.077367	5216.636	0.077367	5491.196
0.09284	4393.335	0.09284	4667.919	0.09284	4942.502	0.09284	5217.086	0.09284	5491.669

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-d

TETRA TECH

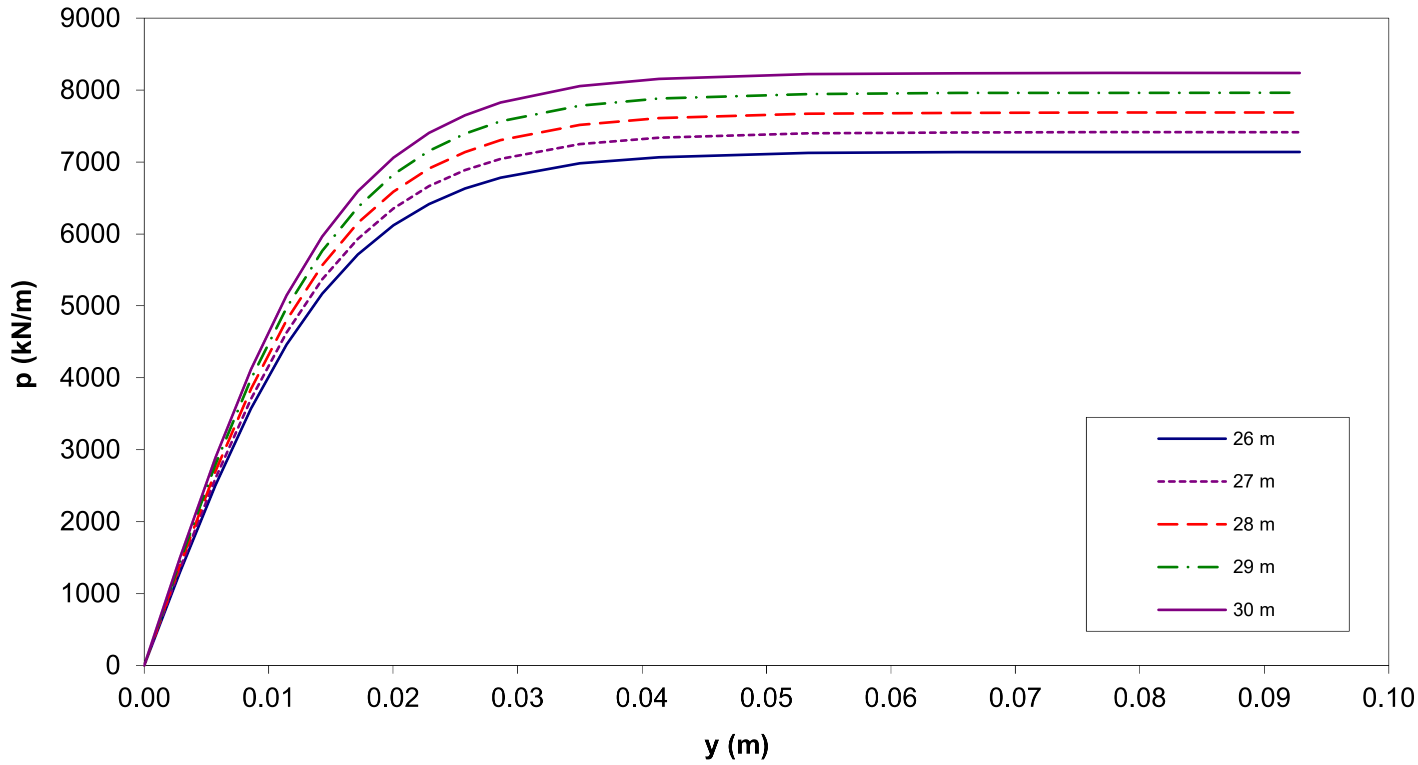


21 m		22 m		23 m		24 m		25 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	1044.608	0.002862	1094.351	0.002862	1144.094	0.002862	1193.838	0.002862	1243.581
0.005724	2022.831	0.005724	2119.157	0.005724	2215.482	0.005724	2311.807	0.005724	2408.133
0.008586	2884.152	0.008586	3021.493	0.008586	3158.833	0.008586	3296.174	0.008586	3433.515
0.011448	3602.354	0.011448	3773.894	0.011448	3945.435	0.011448	4116.976	0.011448	4288.516
0.01431	4174.521	0.01431	4373.308	0.01431	4572.095	0.01431	4770.881	0.01431	4969.668
0.017172	4614.012	0.017172	4833.727	0.017172	5053.442	0.017172	5273.157	0.017172	5492.872
0.020034	4942.221	0.020034	5177.565	0.020034	5412.909	0.020034	5648.253	0.020034	5883.597
0.022896	5182.209	0.022896	5428.98	0.022896	5675.752	0.022896	5922.524	0.022896	6169.296
0.025759	5354.994	0.025759	5609.994	0.025759	5864.994	0.025759	6119.993	0.025759	6374.993
0.028621	5478.015	0.028621	5738.873	0.028621	5999.731	0.028621	6260.589	0.028621	6521.447
0.034987	5636.892	0.034987	5905.315	0.034987	6173.739	0.034987	6442.162	0.034987	6710.586
0.041353	5708.669	0.041353	5980.51	0.041353	6252.351	0.041353	6524.193	0.041353	6796.034
0.053357	5753.88	0.053357	6027.874	0.053357	6301.868	0.053357	6575.863	0.053357	6849.857
0.065362	5763.651	0.065362	6038.111	0.065362	6312.57	0.065362	6587.03	0.065362	6861.49
0.077367	5765.755	0.077367	6040.315	0.077367	6314.875	0.077367	6589.435	0.077367	6863.994
0.09284	5766.252	0.09284	6040.836	0.09284	6315.419	0.09284	6590.003	0.09284	6864.586

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-e



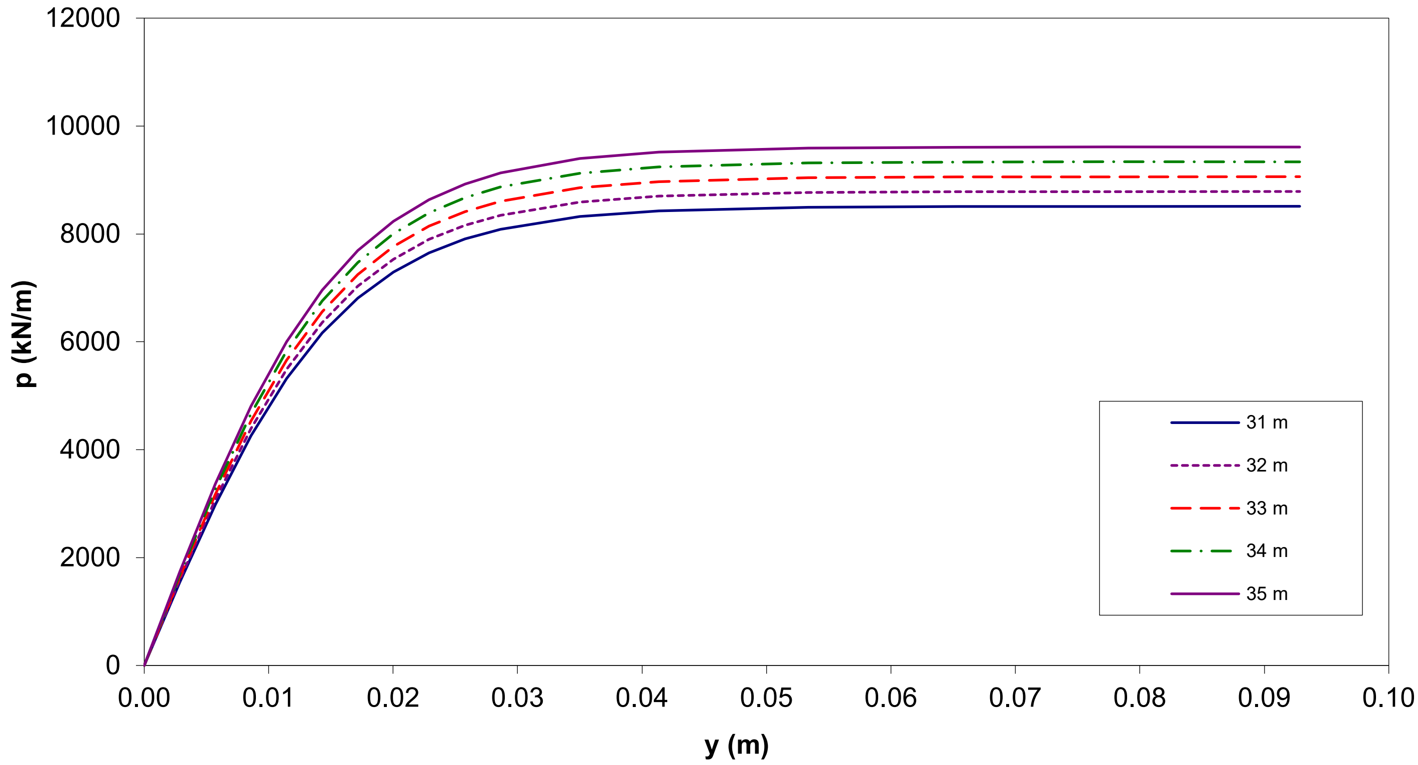
26 m		27 m		28 m		29 m		30 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
2.86E-03	1293.324	2.86E-03	1343.067	2.86E-03	1392.811	2.86E-03	1442.554	0.002862	1492.297
0.005724	2504.458	0.005724	2600.783	0.005724	2697.108	0.005724	2793.434	0.005724	2889.759
0.008586	3570.855	0.008586	3708.196	0.008586	3845.536	0.008586	3982.877	0.008586	4120.217
0.011448	4460.057	0.011448	4631.598	0.011448	4803.138	0.011448	4974.679	0.011448	5146.22
0.01431	5168.455	0.01431	5367.242	0.01431	5566.028	0.01431	5764.815	0.01431	5963.602
0.017172	5712.586	0.017172	5932.301	0.017172	6152.016	0.017172	6371.731	0.017172	6591.446
0.020034	6118.94	0.020034	6354.284	0.020034	6589.628	0.020034	6824.972	0.020034	7060.316
0.022896	6416.068	0.022896	6662.84	0.022896	6909.611	0.022896	7156.383	0.022896	7403.155
0.025759	6629.993	0.025759	6884.993	0.025759	7139.992	0.025759	7394.992	0.025759	7649.992
0.028621	6782.305	0.028621	7043.163	0.028621	7304.02	0.028621	7564.878	0.028621	7825.736
0.034987	6979.009	0.034987	7247.433	0.034987	7515.856	0.034987	7784.279	0.034987	8052.703
0.041353	7067.876	0.041353	7339.717	0.041353	7611.558	0.041353	7883.4	0.041353	8155.241
0.053357	7123.851	0.053357	7397.845	0.053357	7671.84	0.053357	7945.834	0.053357	8219.828
0.065362	7135.949	0.065362	7410.409	0.065362	7684.868	0.065362	7959.328	0.065362	8233.788
0.077367	7138.554	0.077367	7413.114	0.077367	7687.674	0.077367	7962.233	0.077367	8236.793
0.09284	7139.17	0.09284	7413.753	0.09284	7688.337	0.09284	7962.92	0.09284	8237.503

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-f



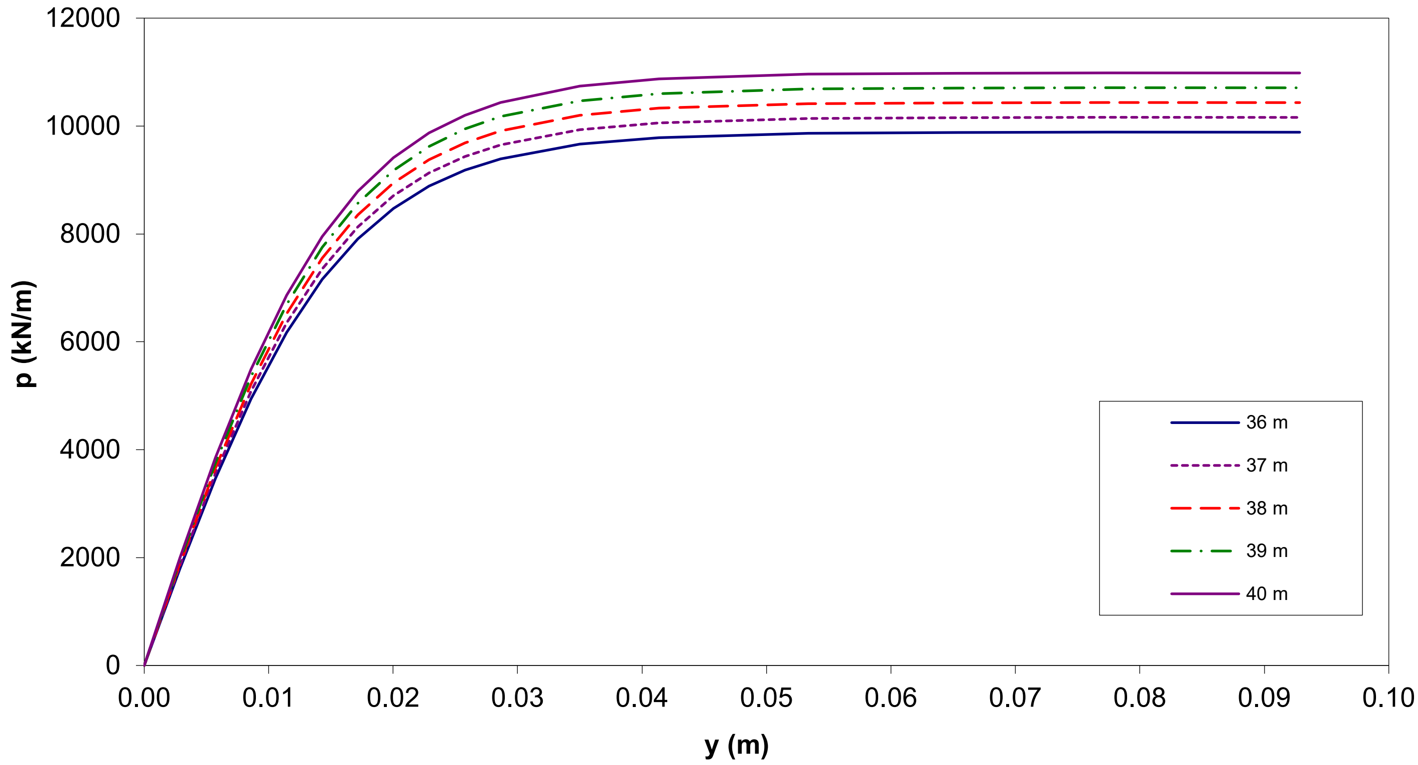
31 m		32 m		33 m		34 m		35 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	1542.04	0.002862	1591.784	0.002862	1641.527	0.002862	1691.27	0.002862	1741.013
0.005724	2986.084	0.005724	3082.41	0.005724	3178.735	0.005724	3275.06	0.005724	3371.386
0.008586	4257.558	0.008586	4394.899	0.008586	4532.239	0.008586	4669.58	0.008586	4806.92
0.011448	5317.76	0.011448	5489.301	0.011448	5660.842	0.011448	5832.382	0.011448	6003.923
0.01431	6162.389	0.01431	6361.175	0.01431	6559.962	0.01431	6758.749	0.01431	6957.535
0.017172	6811.161	0.017172	7030.876	0.017172	7250.59	0.017172	7470.305	0.017172	7690.02
0.020034	7295.66	0.020034	7531.004	0.020034	7766.347	0.020034	8001.691	0.020034	8237.035
0.022896	7649.927	0.022896	7896.699	0.022896	8143.471	0.022896	8390.242	0.022896	8637.014
0.025759	7904.992	0.025759	8159.991	0.025759	8414.991	0.025759	8669.991	0.025759	8924.99
0.028621	8086.594	0.028621	8347.452	0.028621	8608.31	0.028621	8869.168	0.028621	9130.026
0.034987	8321.126	0.034987	8589.55	0.034987	8857.973	0.034987	9126.396	0.034987	9394.82
0.041353	8427.082	0.041353	8698.924	0.041353	8970.765	0.041353	9242.607	0.041353	9514.448
0.053357	8493.823	0.053357	8767.817	0.053357	9041.811	0.053357	9315.805	0.053357	9589.8
0.065362	8508.247	0.065362	8782.707	0.065362	9057.166	0.065362	9331.626	0.065362	9606.085
0.077367	8511.353	0.077367	8785.913	0.077367	9060.473	0.077367	9335.032	0.077367	9609.592
0.09284	8512.087	0.09284	8786.67	0.09284	9061.254	0.09284	9335.837	0.09284	9610.421

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-g

TETRA TECH



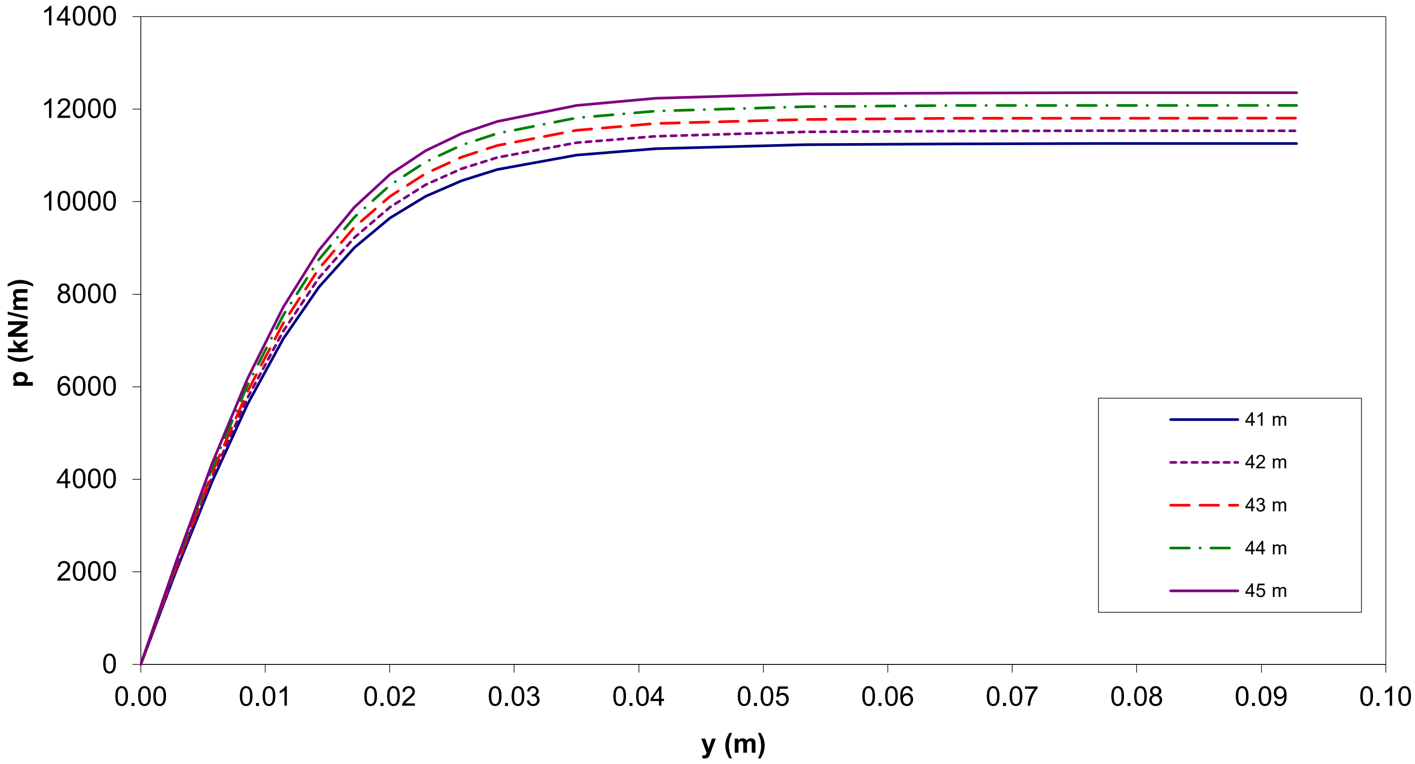
36 m		37 m		38 m		39 m		40 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	1790.757	0.002862	1840.5	0.002862	1890.243	0.002862	1939.986	0.002862	1989.729
0.005724	3467.711	0.005724	3564.036	0.005724	3660.361	0.005724	3756.687	0.005724	3853.012
0.008586	4944.261	0.008586	5081.601	0.008586	5218.942	0.008586	5356.283	0.008586	5493.623
0.011448	6175.464	0.011448	6347.004	0.011448	6518.545	0.011448	6690.086	0.011448	6861.626
0.01431	7156.322	0.01431	7355.109	0.01431	7553.896	0.01431	7752.682	0.01431	7951.469
0.017172	7909.735	0.017172	8129.45	0.017172	8349.165	0.017172	8568.88	0.017172	8788.594
0.020034	8472.379	0.020034	8707.723	0.020034	8943.067	0.020034	9178.411	0.020034	9413.754
0.022896	8883.786	0.022896	9130.558	0.022896	9377.33	0.022896	9624.102	0.022896	9870.873
0.025759	9179.99	0.025759	9434.99	0.025759	9689.99	0.025759	9944.989	0.025759	10199.99
0.028621	9390.883	0.028621	9651.741	0.028621	9912.599	0.028621	10173.46	0.028621	10434.32
0.034987	9663.243	0.034987	9931.667	0.034987	10200.09	0.034987	10468.51	0.034987	10736.94
0.041353	9786.289	0.041353	10058.13	0.041353	10329.97	0.041353	10601.81	0.041353	10873.66
0.053357	9863.794	0.053357	10137.79	0.053357	10411.78	0.053357	10685.78	0.053357	10959.77
0.065362	9880.545	0.065362	10155.01	0.065362	10429.46	0.065362	10703.92	0.065362	10978.38
0.077367	9884.152	0.077367	10158.71	0.077367	10433.27	0.077367	10707.83	0.077367	10982.39
0.09284	9885.004	0.09284	10159.59	0.09284	10434.17	0.09284	10708.75	0.09284	10983.34

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-h



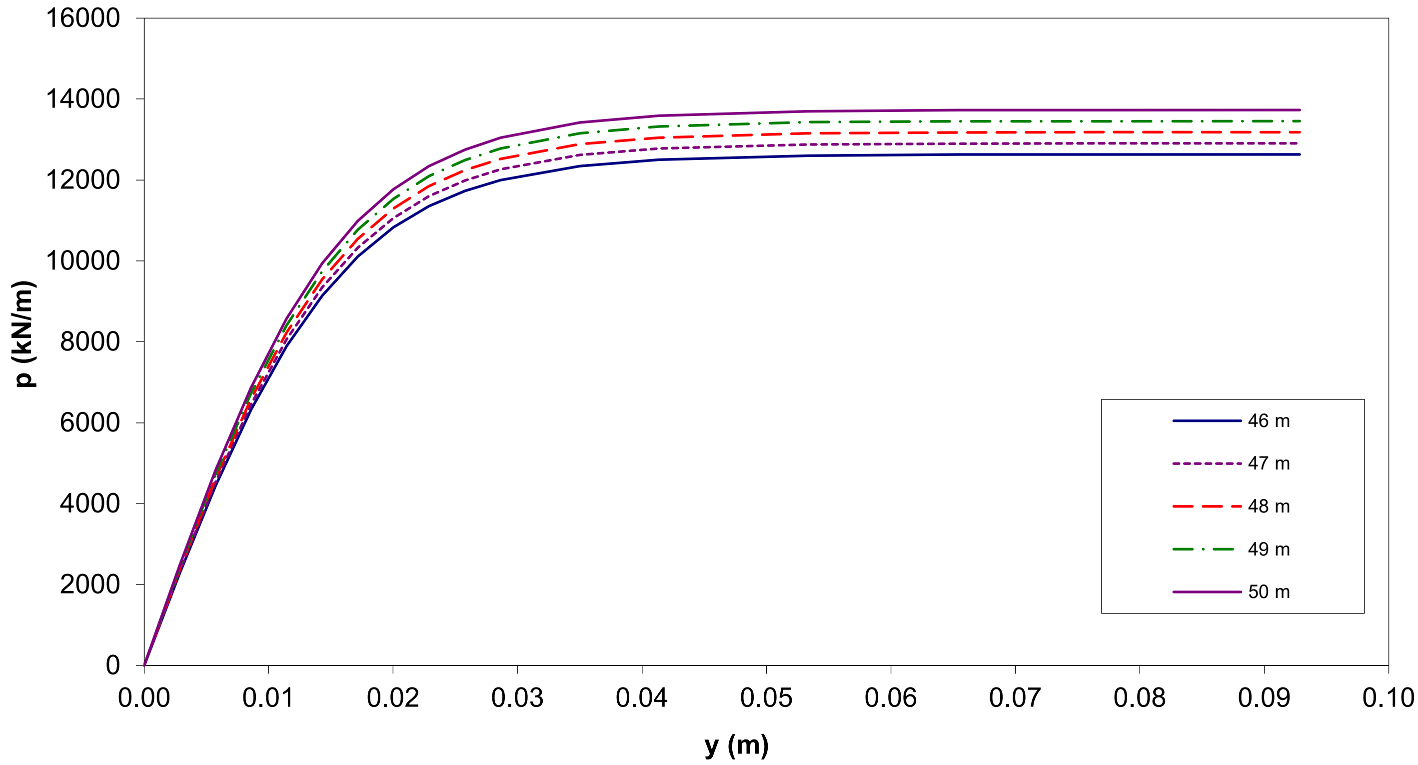
41 m		42 m		43 m		44 m		45 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	2039.473	0.002862	2089.216	0.002862	2138.959	0.002862	2188.702	0.002862	2238.446
0.005724	3949.337	0.005724	4045.663	0.005724	4141.988	0.005724	4238.313	0.005724	4334.639
0.008586	5630.964	0.008586	5768.304	0.008586	5905.645	0.008586	6042.986	0.008586	6180.326
0.011448	7033.167	0.011448	7204.708	0.011448	7376.248	0.011448	7547.789	0.011448	7719.33
0.01431	8150.256	0.01431	8349.043	0.01431	8547.829	0.01431	8746.616	0.01431	8945.403
0.017172	9008.309	0.017172	9228.024	0.017172	9447.739	0.017172	9667.454	0.017172	9887.169
0.020034	9649.098	0.020034	9884.442	0.020034	10119.79	0.020034	10355.13	0.020034	10590.47
0.022896	10117.65	0.022896	10364.42	0.022896	10611.19	0.022896	10857.96	0.022896	11104.73
0.025759	10454.99	0.025759	10709.99	0.025759	10964.99	0.025759	11219.99	0.025759	11474.99
0.028621	10695.17	0.028621	10956.03	0.028621	11216.89	0.028621	11477.75	0.028621	11738.6
0.034987	11005.36	0.034987	11273.78	0.034987	11542.21	0.034987	11810.63	0.034987	12079.05
0.041353	11145.5	0.041353	11417.34	0.041353	11689.18	0.041353	11961.02	0.041353	12232.86
0.053357	11233.77	0.053357	11507.76	0.053357	11781.75	0.053357	12055.75	0.053357	12329.74
0.065362	11252.84	0.065362	11527.3	0.065362	11801.76	0.065362	12076.22	0.065362	12350.68
0.077367	11256.95	0.077367	11531.51	0.077367	11806.07	0.077367	12080.63	0.077367	12355.19
0.09284	11257.92	0.09284	11532.51	0.09284	11807.09	0.09284	12081.67	0.09284	12356.26

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

Figure Piers D2-i



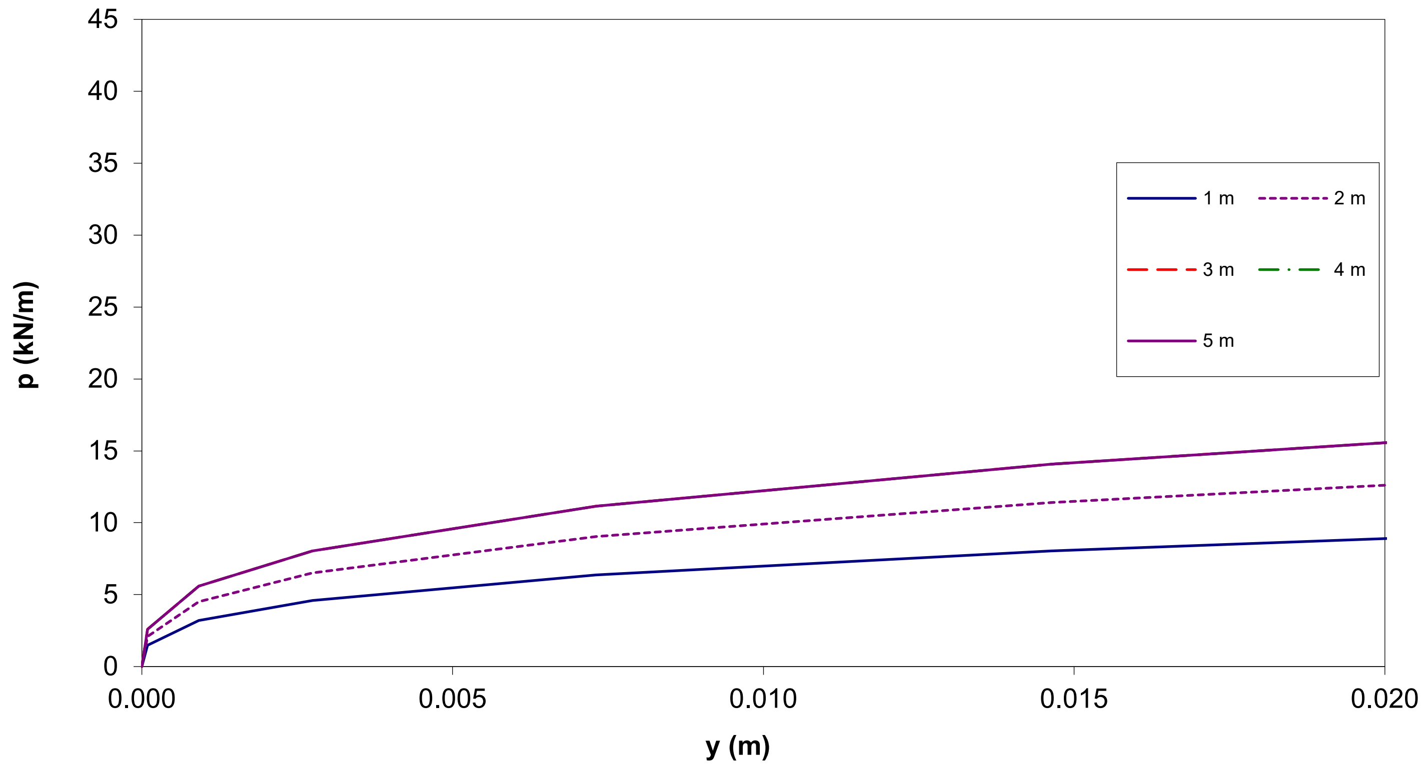
46 m		47 m		48 m		49 m		50 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	2288.189	0.002862	2337.932	0.002862	2387.675	0.002862	2437.419	0.002862	2487.162
0.005724	4430.964	0.005724	4527.289	0.005724	4623.614	0.005724	4719.94	0.005724	4816.265
0.008586	6317.667	0.008586	6455.007	0.008586	6592.348	0.008586	6729.688	0.008586	6867.029
0.011448	7890.87	0.011448	8062.411	0.011448	8233.952	0.011448	8405.492	0.011448	8577.033
0.01431	9144.189	0.01431	9342.976	0.01431	9541.763	0.01431	9740.55	0.01431	9939.336
0.017172	10106.88	0.017172	10326.6	0.017172	10546.31	0.017172	10766.03	0.017172	10985.74
0.020034	10825.82	0.020034	11061.16	0.020034	11296.51	0.020034	11531.85	0.020034	11767.19
0.022896	11351.5	0.022896	11598.28	0.022896	11845.05	0.022896	12091.82	0.022896	12338.59
0.025759	11729.99	0.025759	11984.99	0.025759	12239.99	0.025759	12494.99	0.025759	12749.99
0.028621	11999.46	0.028621	12260.32	0.028621	12521.18	0.028621	12782.04	0.028621	13042.89
0.034987	12347.48	0.034987	12615.9	0.034987	12884.32	0.034987	13152.75	0.034987	13421.17
0.041353	12504.7	0.041353	12776.54	0.041353	13048.39	0.041353	13320.23	0.041353	13592.07
0.053357	12603.74	0.053357	12877.73	0.053357	13151.73	0.053357	13425.72	0.053357	13699.71
0.065362	12625.14	0.065362	12899.6	0.065362	13174.06	0.065362	13448.52	0.065362	13722.98
0.077367	12629.75	0.077367	12904.31	0.077367	13178.87	0.077367	13453.43	0.077367	13727.99
0.09284	12630.84	0.09284	12905.42	0.09284	13180.01	0.09284	13454.59	0.09284	13729.17

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Static
Pile Diameter = 914mm

TETRA TECH

Figure Piers D2-j



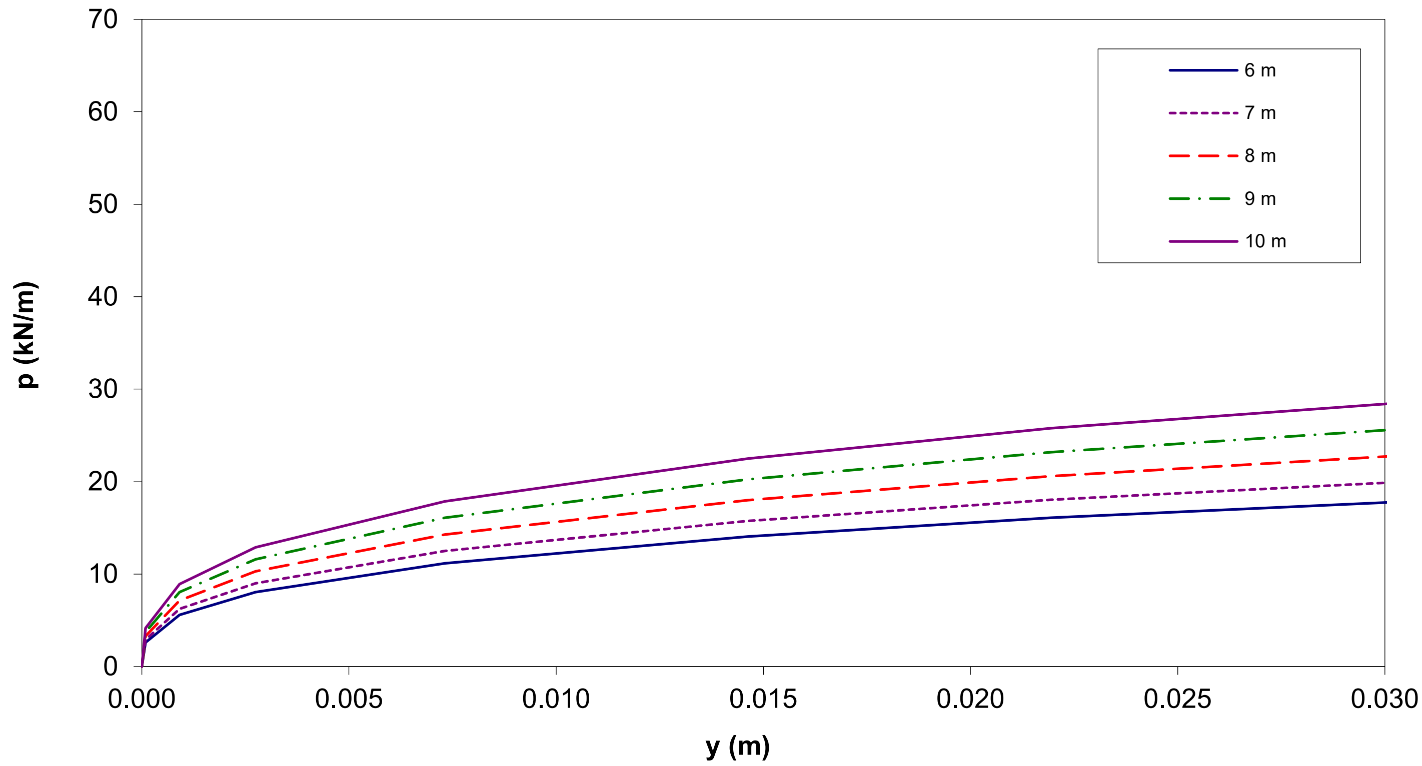
1 m		2 m		3 m		4 m		5 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	1.481793	9.14E-05	2.09991	9.14E-05	2.591028	9.14E-05	2.591028	9.14E-05	2.591028
0.000914	3.192426	0.000914	4.52412	0.000914	5.5822	0.000914	5.5822	0.000914	5.5822
0.002742	4.604276	0.002742	6.52491	0.002742	8.050925	0.002742	8.050925	0.002742	8.050925
0.007312	6.384853	0.007312	9.04824	0.007312	11.1644	0.007312	11.1644	0.007312	11.1644
0.014624	8.044411	0.014624	11.40007	0.014624	14.06626	0.014624	14.06626	0.014624	14.06626
0.021936	9.208552	0.021936	13.04982	0.021936	16.10185	0.021936	16.10185	0.021936	16.10185
0.03656	10.91795	0.03656	15.47227	0.03656	19.09086	0.03656	19.09086	0.03656	19.09086
0.05484	12.49793	0.05484	17.71133	0.05484	21.85357	0.05484	21.85357	0.05484	21.85357
0.08226	14.30656	0.08226	20.27441	0.08226	25.0161	0.08226	25.0161	0.08226	25.0161
0.10968	15.7464	0.10968	22.31488	0.10968	27.53378	0.10968	27.53378	0.10968	27.53378
0.14624	17.33116	0.14624	24.5607	0.14624	30.30484	0.14624	30.30484	0.14624	30.30484
0.1828	18.66942	0.1828	26.45721	0.1828	32.6449	0.1828	32.6449	0.1828	32.6449
0.23764	20.37568	0.23764	28.87521	0.23764	35.62842	0.23764	35.62842	0.23764	35.62842
0.29248	21.83589	0.29248	30.94455	0.29248	38.18171	0.29248	38.18171	0.29248	38.18171
0.3656	23.522	0.3656	33.334	0.3656	41.13	0.3656	41.13	0.3656	41.13
0.43872	23.522	0.43872	33.334	0.43872	41.13	0.43872	41.13	0.43872	41.13

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-a



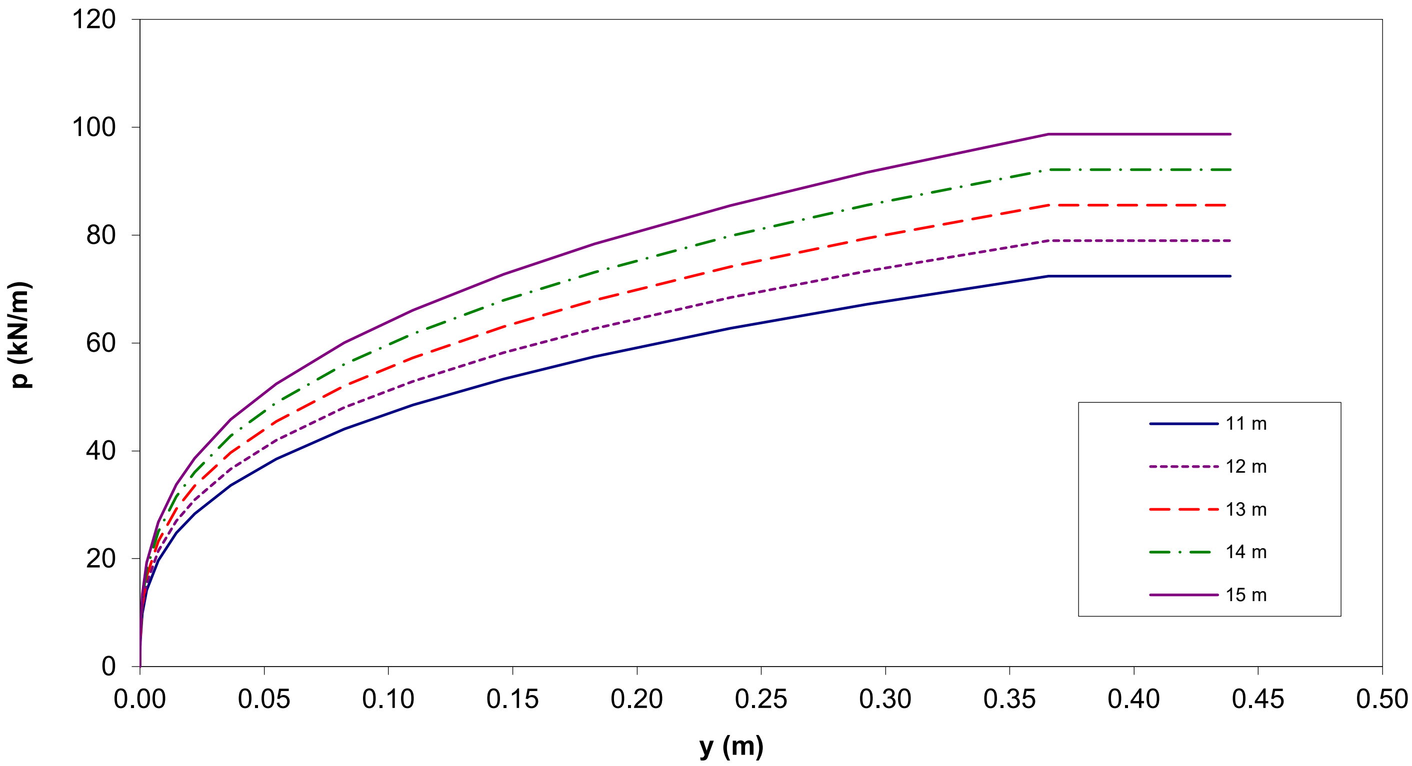
6 m		7 m		8 m		9 m		10 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	2.591028	9.14E-05	2.901951	9.14E-05	3.316515	9.14E-05	3.73108	9.14E-05	4.145644
0.000914	5.5822	0.000914	6.252064	0.000914	7.145215	0.000914	8.038367	0.000914	8.931519
0.002742	8.050925	0.002742	9.017036	0.002742	10.30518	0.002742	11.59333	0.002742	12.88148
0.007312	11.1644	0.007312	12.50413	0.007312	14.29043	0.007312	16.07674	0.007312	17.86304
0.014624	14.06626	0.014624	15.75421	0.014624	18.00482	0.014624	20.25542	0.014624	22.50602
0.021936	16.10185	0.021936	18.03407	0.021936	20.61037	0.021936	23.18667	0.021936	25.76296
0.03656	19.09086	0.03656	21.38176	0.03656	24.43629	0.03656	27.49083	0.03656	30.54537
0.05484	21.85357	0.05484	24.476	0.05484	27.97257	0.05484	31.46915	0.05484	34.96572
0.08226	25.0161	0.08226	28.01803	0.08226	32.0206	0.08226	36.02318	0.08226	40.02576
0.10968	27.53378	0.10968	30.83783	0.10968	35.24324	0.10968	39.64864	0.10968	44.05405
0.14624	30.30484	0.14624	33.94143	0.14624	38.7902	0.14624	43.63898	0.14624	48.48775
0.1828	32.6449	0.1828	36.56229	0.1828	41.78548	0.1828	47.00866	0.1828	52.23185
0.23764	35.62842	0.23764	39.90382	0.23764	45.60437	0.23764	51.30492	0.23764	57.00546
0.29248	38.18171	0.29248	42.76352	0.29248	48.87259	0.29248	54.98166	0.29248	61.09074
0.3656	41.13	0.3656	46.0656	0.3656	52.6464	0.3656	59.2272	0.3656	65.808
0.43872	41.13	0.43872	46.0656	0.43872	52.6464	0.43872	59.2272	0.43872	65.808

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-b



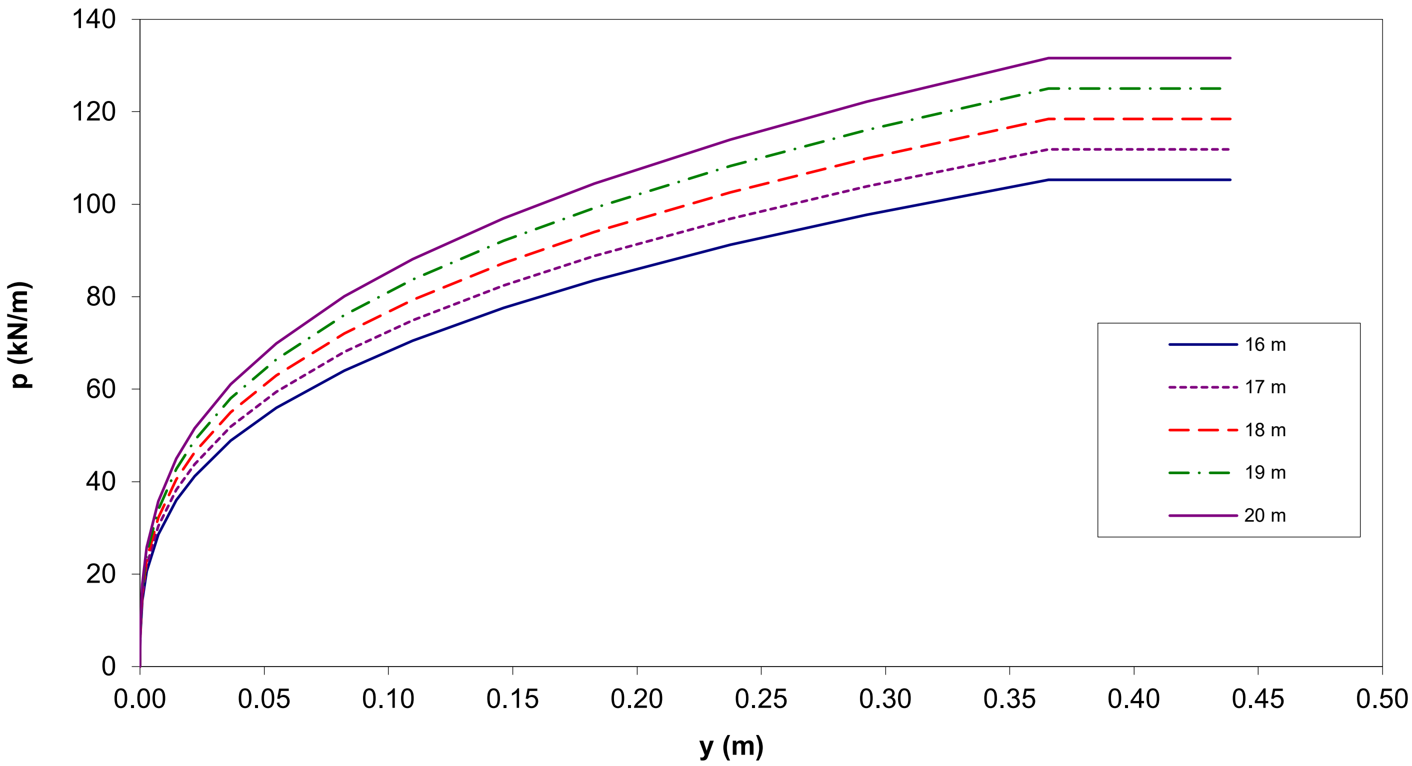
11 m		12 m		13 m		14 m		15 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	4.560208	9.14E-05	4.974773	9.14E-05	5.389337	9.14E-05	5.803902	9.14E-05	6.218466
0.000914	9.824671	0.000914	10.71782	0.000914	11.61098	0.000914	12.50413	0.000914	13.39728
0.002742	14.16963	0.002742	15.45778	0.002742	16.74592	0.002742	18.03407	0.002742	19.32222
0.007312	19.64934	0.007312	21.43565	0.007312	23.22195	0.007312	25.00826	0.007312	26.79456
0.014624	24.75662	0.014624	27.00722	0.014624	29.25783	0.014624	31.50843	0.014624	33.75903
0.021936	28.33926	0.021936	30.91555	0.021936	33.49185	0.021936	36.06815	0.021936	38.64444
0.03656	33.59991	0.03656	36.65444	0.03656	39.70898	0.03656	42.76352	0.03656	45.81805
0.05484	38.46229	0.05484	41.95886	0.05484	45.45543	0.05484	48.95201	0.05484	52.44858
0.08226	44.02833	0.08226	48.03091	0.08226	52.03348	0.08226	56.03606	0.08226	60.03863
0.10968	48.45945	0.10968	52.86485	0.10968	57.27026	0.10968	61.67566	0.10968	66.08107
0.14624	53.33653	0.14624	58.1853	0.14624	63.03408	0.14624	67.88285	0.14624	72.73163
0.1828	57.45503	0.1828	62.67821	0.1828	67.9014	0.1828	73.12458	0.1828	78.34777
0.23764	62.70601	0.23764	68.40656	0.23764	74.1071	0.23764	79.80765	0.23764	85.5082
0.29248	67.19981	0.29248	73.30888	0.29248	79.41796	0.29248	85.52703	0.29248	91.63611
0.3656	72.3888	0.3656	78.9696	0.3656	85.5504	0.3656	92.1312	0.3656	98.712
0.43872	72.3888	0.43872	78.9696	0.43872	85.5504	0.43872	92.1312	0.43872	98.712

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-c



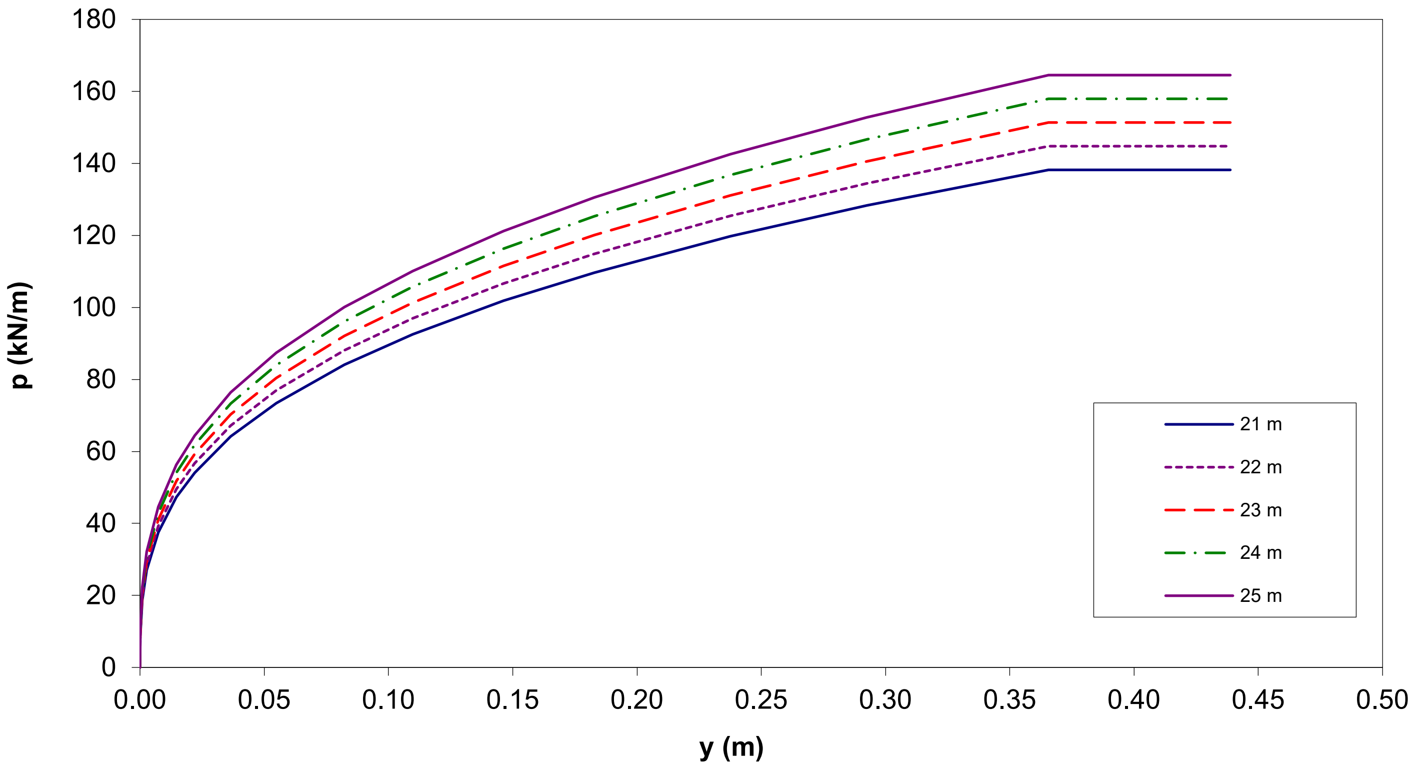
16 m		17 m		18 m		19 m		20 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	6.633031	9.14E-05	7.047595	9.14E-05	7.462159	9.14E-05	7.876724	9.14E-05	8.291288
0.000914	14.29043	0.000914	15.18358	0.000914	16.07674	0.000914	16.96989	0.000914	17.86304
0.002742	20.61037	0.002742	21.89852	0.002742	23.18666	0.002742	24.47481	0.002742	25.76296
0.007312	28.58086	0.007312	30.36717	0.007312	32.15347	0.007312	33.93977	0.007312	35.72608
0.014624	36.00963	0.014624	38.26023	0.014624	40.51083	0.014624	42.76144	0.014624	45.01204
0.021936	41.22074	0.021936	43.79703	0.021936	46.37333	0.021936	48.94963	0.021936	51.52592
0.03656	48.87259	0.03656	51.92713	0.03656	54.98166	0.03656	58.0362	0.03656	61.09074
0.05484	55.94515	0.05484	59.44172	0.05484	62.93829	0.05484	66.43486	0.05484	69.93144
0.08226	64.04121	0.08226	68.04378	0.08226	72.04636	0.08226	76.04893	0.08226	80.05151
0.10968	70.48647	0.10968	74.89188	0.10968	79.29728	0.10968	83.70269	0.10968	88.10809
0.14624	77.5804	0.14624	82.42918	0.14624	87.27795	0.14624	92.12673	0.14624	96.9755
0.1828	83.57095	0.1828	88.79414	0.1828	94.01732	0.1828	99.24051	0.1828	104.4637
0.23764	91.20874	0.23764	96.90929	0.23764	102.6098	0.23764	108.3104	0.23764	114.0109
0.29248	97.74518	0.29248	103.8543	0.29248	109.9633	0.29248	116.0724	0.29248	122.1815
0.3656	105.2928	0.3656	111.8736	0.3656	118.4544	0.3656	125.0352	0.3656	131.616
0.43872	105.2928	0.43872	111.8736	0.43872	118.4544	0.43872	125.0352	0.43872	131.616

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-d

TETRA TECH



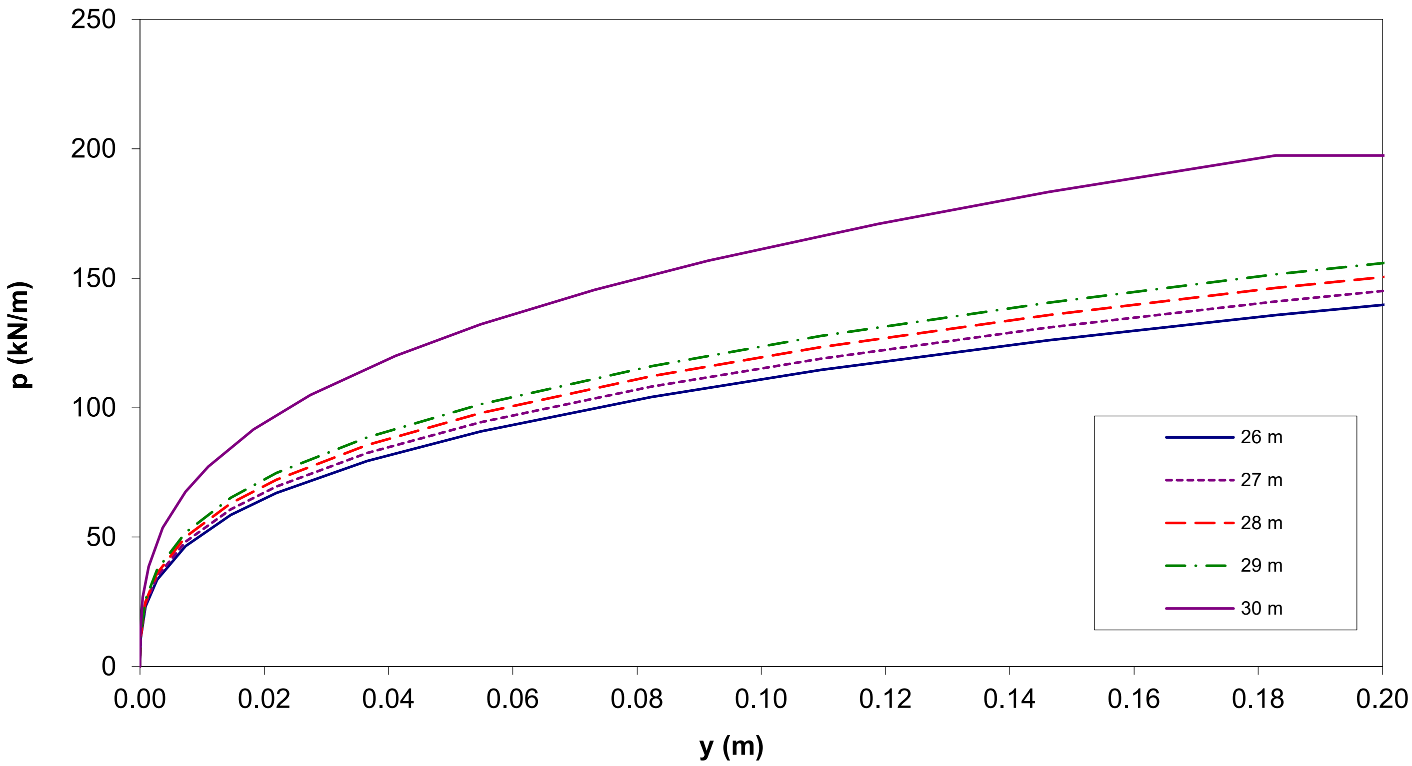
21 m		22 m		23 m		24 m		25 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	8.705853	9.14E-05	9.120417	9.14E-05	9.534981	9.14E-05	9.949546	9.14E-05	10.36411
0.000914	18.75619	0.000914	19.64934	0.000914	20.54249	0.000914	21.43565	0.000914	22.3288
0.002742	27.05111	0.002742	28.33926	0.002742	29.6274	0.002742	30.91555	0.002742	32.2037
0.007312	37.51238	0.007312	39.29869	0.007312	41.08499	0.007312	42.87129	0.007312	44.6576
0.014624	47.26264	0.014624	49.51324	0.014624	51.76384	0.014624	54.01445	0.014624	56.26505
0.021936	54.10222	0.021936	56.67851	0.021936	59.25481	0.021936	61.83111	0.021936	64.4074
0.03656	64.14527	0.03656	67.19981	0.03656	70.25435	0.03656	73.30888	0.03656	76.36342
0.05484	73.42801	0.05484	76.92458	0.05484	80.42115	0.05484	83.91772	0.05484	87.4143
0.08226	84.05409	0.08226	88.05666	0.08226	92.05924	0.08226	96.06181	0.08226	100.0644
0.10968	92.51349	0.10968	96.9189	0.10968	101.3243	0.10968	105.7297	0.10968	110.1351
0.14624	101.8243	0.14624	106.6731	0.14624	111.5218	0.14624	116.3706	0.14624	121.2194
0.1828	109.6869	0.1828	114.9101	0.1828	120.1332	0.1828	125.3564	0.1828	130.5796
0.23764	119.7115	0.23764	125.412	0.23764	131.1126	0.23764	136.8131	0.23764	142.5137
0.29248	128.2906	0.29248	134.3996	0.29248	140.5087	0.29248	146.6178	0.29248	152.7268
0.3656	138.1968	0.3656	144.7776	0.3656	151.3584	0.3656	157.9392	0.3656	164.52
0.43872	138.1968	0.43872	144.7776	0.43872	151.3584	0.43872	157.9392	0.43872	164.52

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-e



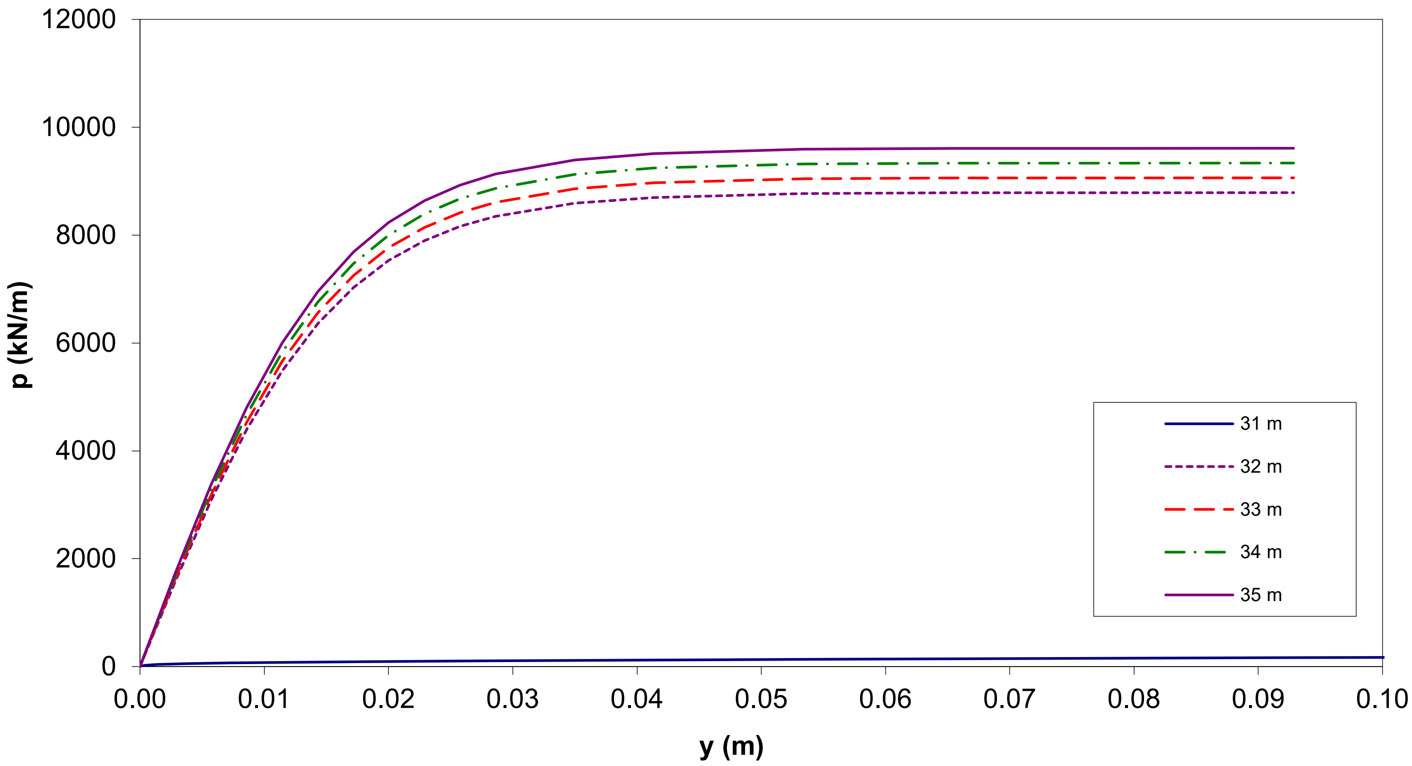
26 m		27 m		28 m		29 m		30 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	10.77867	9.14E-05	11.19324	9.14E-05	11.6078	9.14E-05	12.02237	4.57E-05	12.43693
0.000914	23.22195	0.000914	24.1151	0.000914	25.00825	0.000914	25.90141	0.000457	26.79456
0.002742	33.49185	0.002742	34.78	0.002742	36.06814	0.002742	37.35629	0.001371	38.64444
0.007312	46.4439	0.007312	48.23021	0.007312	50.01651	0.007312	51.80281	0.003656	53.58912
0.014624	58.51565	0.014624	60.76625	0.014624	63.01685	0.014624	65.26746	0.007312	67.51806
0.021936	66.9837	0.021936	69.55999	0.021936	72.13629	0.021936	74.71259	0.010968	77.28888
0.03656	79.41796	0.03656	82.47249	0.03656	85.52703	0.03656	88.58157	0.01828	91.6361
0.05484	90.91087	0.05484	94.40744	0.05484	97.90401	0.05484	101.4006	0.02742	104.8972
0.08226	104.067	0.08226	108.0695	0.08226	112.0721	0.08226	116.0747	0.04113	120.0773
0.10968	114.5405	0.10968	118.9459	0.10968	123.3513	0.10968	127.7567	0.05484	132.1621
0.14624	126.0682	0.14624	130.9169	0.14624	135.7657	0.14624	140.6145	0.07312	145.4633
0.1828	135.8028	0.1828	141.026	0.1828	146.2492	0.1828	151.4724	0.0914	156.6955
0.23764	148.2142	0.23764	153.9148	0.23764	159.6153	0.23764	165.3158	0.11882	171.0164
0.29248	158.8359	0.29248	164.945	0.29248	171.0541	0.29248	177.1631	0.14624	183.2722
0.3656	171.1008	0.3656	177.6816	0.3656	184.2624	0.3656	190.8432	0.1828	197.424
0.43872	171.1008	0.43872	177.6816	0.43872	184.2624	0.43872	190.8432	0.21936	197.424

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-f



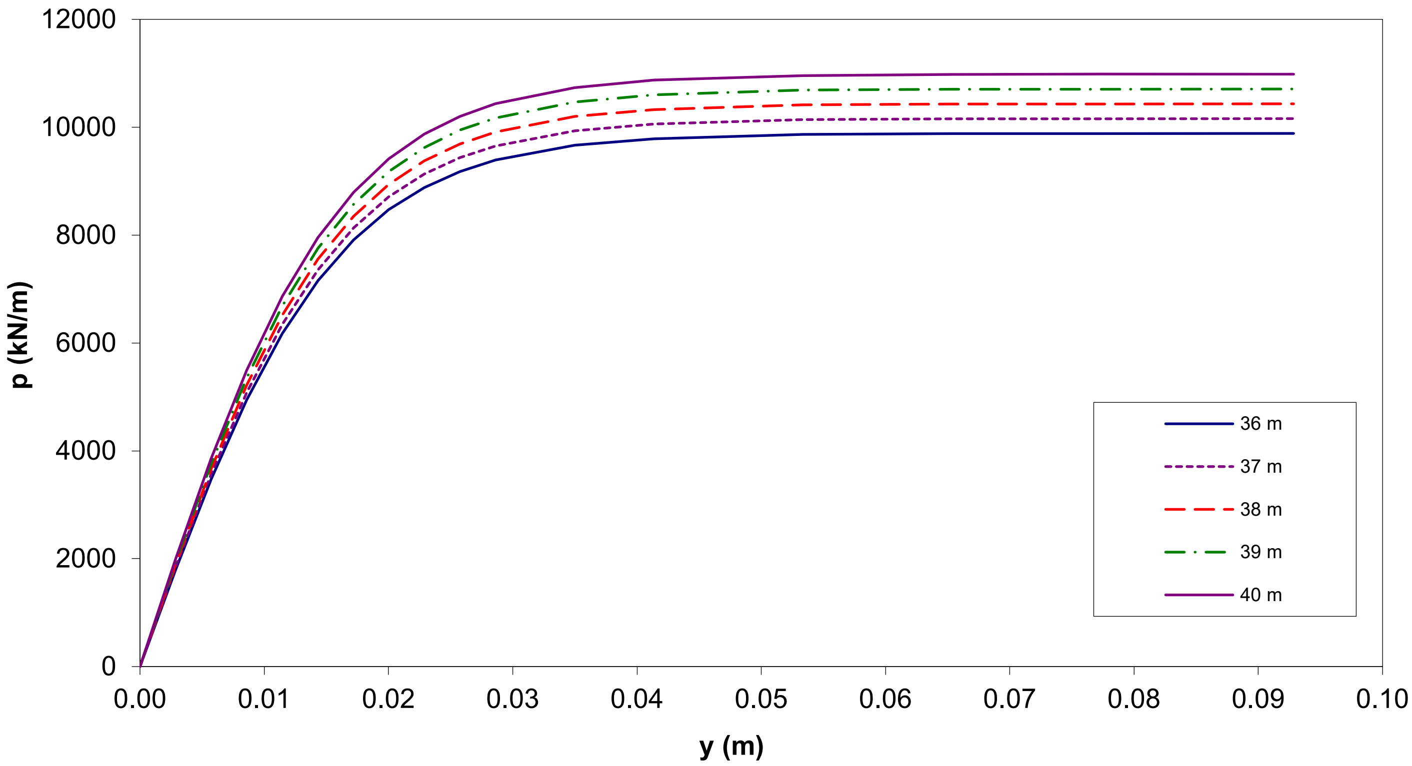
31 m		32 m		33 m		34 m		35 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
4.57E-05	12.8515	0.002862	1591.784	0.002862	1641.527	0.002862	1691.27	0.002862	1741.013
0.000457	27.68771	0.005724	3082.41	0.005724	3178.735	0.005724	3275.06	0.005724	3371.386
0.001371	39.93259	0.008586	4394.899	0.008586	4532.239	0.008586	4669.58	0.008586	4806.92
0.003656	55.37542	0.011448	5489.301	0.011448	5660.842	0.011448	5832.382	0.011448	6003.923
0.007312	69.76866	0.01431	6361.175	0.01431	6559.962	0.01431	6758.749	0.01431	6957.535
0.010968	79.86518	0.017172	7030.876	0.017172	7250.59	0.017172	7470.305	0.017172	7690.02
0.01828	94.69064	0.020034	7531.004	0.020034	7766.347	0.020034	8001.691	0.020034	8237.035
0.02742	108.3937	0.022896	7896.699	0.022896	8143.471	0.022896	8390.242	0.022896	8637.014
0.04113	124.0798	0.025759	8159.991	0.025759	8414.991	0.025759	8669.991	0.025759	8924.99
0.05484	136.5675	0.028621	8347.452	0.028621	8608.31	0.028621	8869.168	0.028621	9130.026
0.07312	150.312	0.034987	8589.55	0.034987	8857.973	0.034987	9126.396	0.034987	9394.82
0.0914	161.9187	0.041353	8698.924	0.041353	8970.765	0.041353	9242.607	0.041353	9514.448
0.11882	176.7169	0.053357	8767.817	0.053357	9041.811	0.053357	9315.805	0.053357	9589.8
0.14624	189.3813	0.065362	8782.707	0.065362	9057.166	0.065362	9331.626	0.065362	9606.085
0.1828	204.0048	0.077367	8785.913	0.077367	9060.473	0.077367	9335.032	0.077367	9609.592
0.21936	204.0048	0.09284	8786.67	0.09284	9061.254	0.09284	9335.837	0.09284	9610.421

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-g



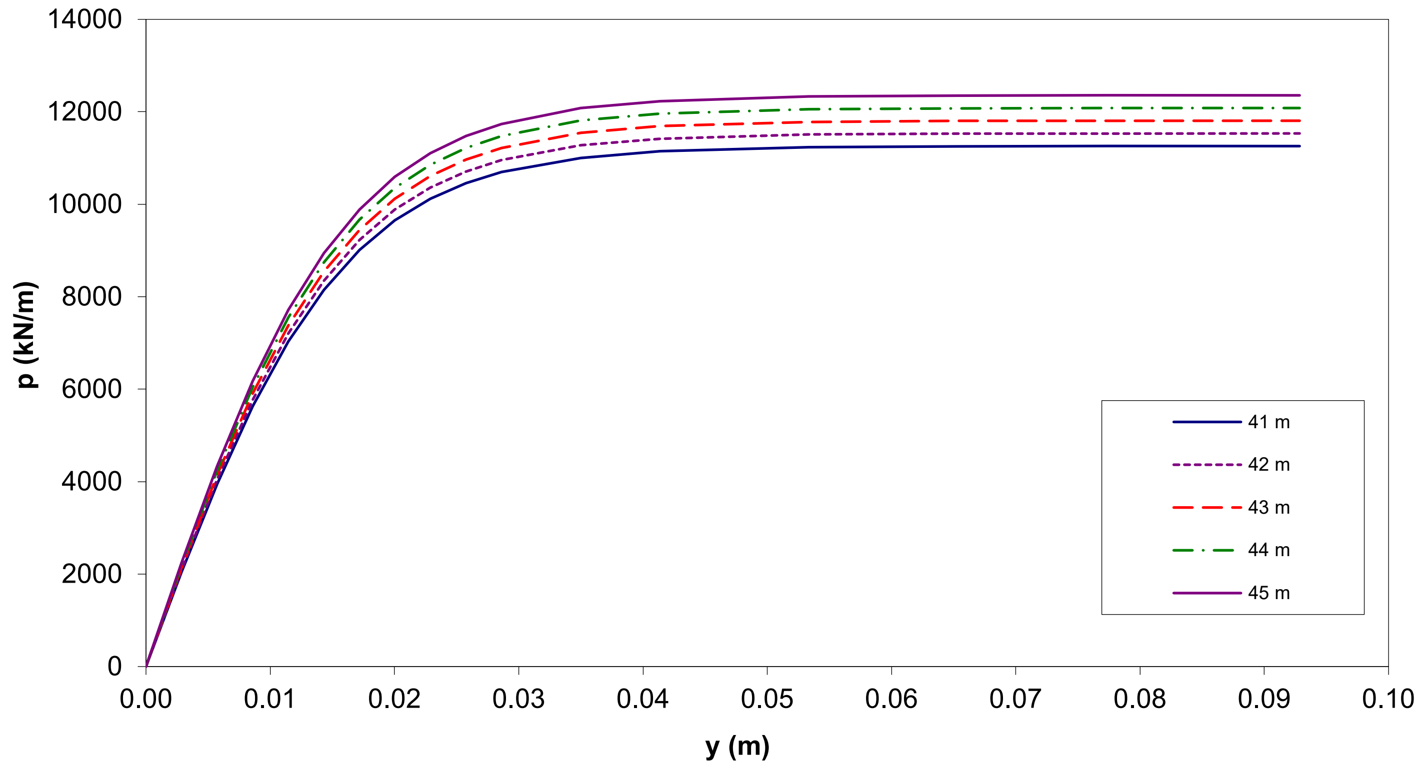
36 m		37 m		38 m		39 m		40 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	1790.757	0.002862	1840.5	0.002862	1890.243	0.002862	1939.986	0.002862	1989.729
0.005724	3467.711	0.005724	3564.036	0.005724	3660.361	0.005724	3756.687	0.005724	3853.012
0.008586	4944.261	0.008586	5081.601	0.008586	5218.942	0.008586	5356.283	0.008586	5493.623
0.011448	6175.464	0.011448	6347.004	0.011448	6518.545	0.011448	6690.086	0.011448	6861.626
0.01431	7156.322	0.01431	7355.109	0.01431	7553.896	0.01431	7752.682	0.01431	7951.469
0.017172	7909.735	0.017172	8129.45	0.017172	8349.165	0.017172	8568.88	0.017172	8788.594
0.020034	8472.379	0.020034	8707.723	0.020034	8943.067	0.020034	9178.411	0.020034	9413.754
0.022896	8883.786	0.022896	9130.558	0.022896	9377.33	0.022896	9624.102	0.022896	9870.873
0.025759	9179.99	0.025759	9434.99	0.025759	9689.99	0.025759	9944.989	0.025759	10199.99
0.028621	9390.883	0.028621	9651.741	0.028621	9912.599	0.028621	10173.46	0.028621	10434.32
0.034987	9663.243	0.034987	9931.667	0.034987	10200.09	0.034987	10468.51	0.034987	10736.94
0.041353	9786.289	0.041353	10058.13	0.041353	10329.97	0.041353	10601.81	0.041353	10873.66
0.053357	9863.794	0.053357	10137.79	0.053357	10411.78	0.053357	10685.78	0.053357	10959.77
0.065362	9880.545	0.065362	10155.01	0.065362	10429.46	0.065362	10703.92	0.065362	10978.38
0.077367	9884.152	0.077367	10158.71	0.077367	10433.27	0.077367	10707.83	0.077367	10982.39
0.09284	9885.004	0.09284	10159.59	0.09284	10434.17	0.09284	10708.75	0.09284	10983.34

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-h



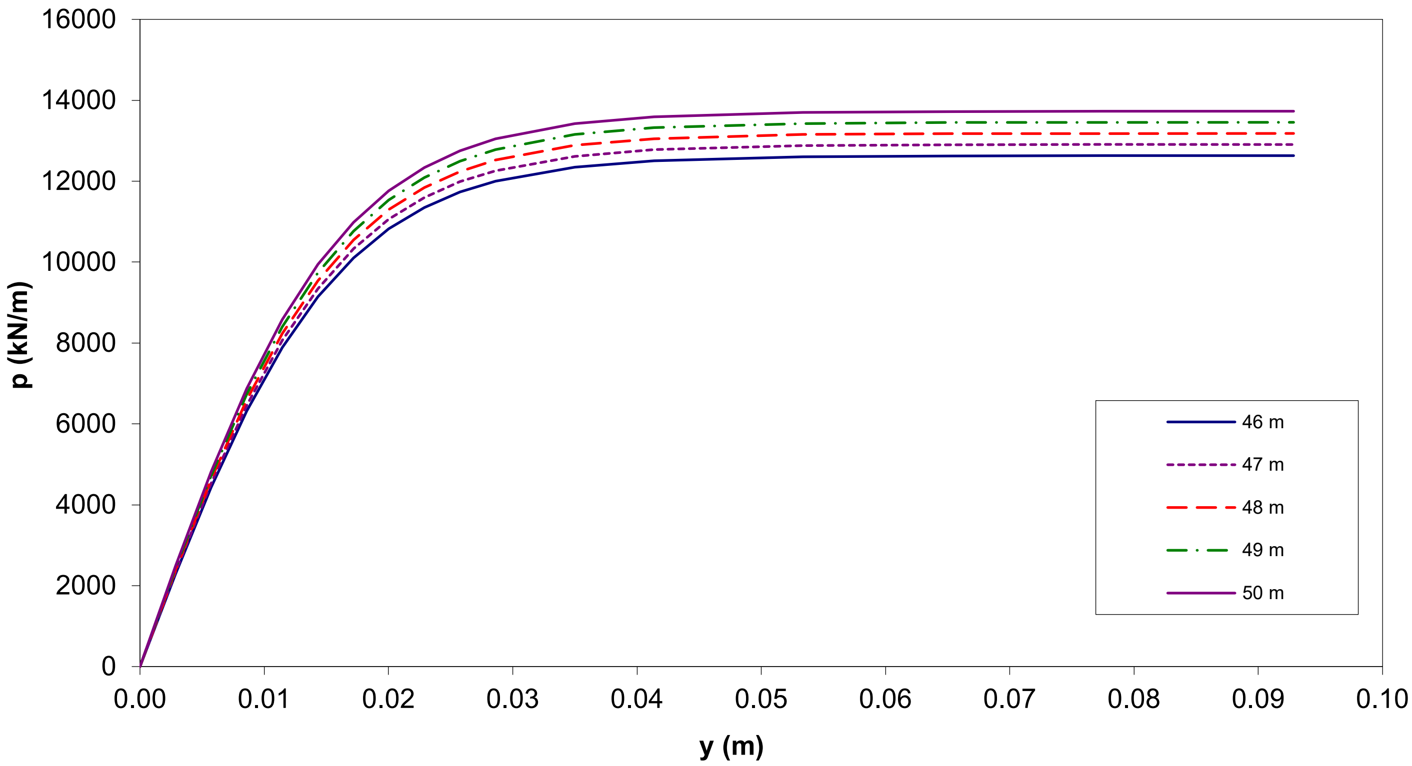
41 m		42 m		43 m		44 m		45 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	2039.473	0.002862	2089.216	0.002862	2138.959	0.002862	2188.702	0.002862	2238.446
0.005724	3949.337	0.005724	4045.663	0.005724	4141.988	0.005724	4238.313	0.005724	4334.639
0.008586	5630.964	0.008586	5768.304	0.008586	5905.645	0.008586	6042.986	0.008586	6180.326
0.011448	7033.167	0.011448	7204.708	0.011448	7376.248	0.011448	7547.789	0.011448	7719.33
0.01431	8150.256	0.01431	8349.043	0.01431	8547.829	0.01431	8746.616	0.01431	8945.403
0.017172	9008.309	0.017172	9228.024	0.017172	9447.739	0.017172	9667.454	0.017172	9887.169
0.020034	9649.098	0.020034	9884.442	0.020034	10119.79	0.020034	10355.13	0.020034	10590.47
0.022896	10117.65	0.022896	10364.42	0.022896	10611.19	0.022896	10857.96	0.022896	11104.73
0.025759	10454.99	0.025759	10709.99	0.025759	10964.99	0.025759	11219.99	0.025759	11474.99
0.028621	10695.17	0.028621	10956.03	0.028621	11216.89	0.028621	11477.75	0.028621	11738.6
0.034987	11005.36	0.034987	11273.78	0.034987	11542.21	0.034987	11810.63	0.034987	12079.05
0.041353	11145.5	0.041353	11417.34	0.041353	11689.18	0.041353	11961.02	0.041353	12232.86
0.053357	11233.77	0.053357	11507.76	0.053357	11781.75	0.053357	12055.75	0.053357	12329.74
0.065362	11252.84	0.065362	11527.3	0.065362	11801.76	0.065362	12076.22	0.065362	12350.68
0.077367	11256.95	0.077367	11531.51	0.077367	11806.07	0.077367	12080.63	0.077367	12355.19
0.09284	11257.92	0.09284	11532.51	0.09284	11807.09	0.09284	12081.67	0.09284	12356.26

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-i



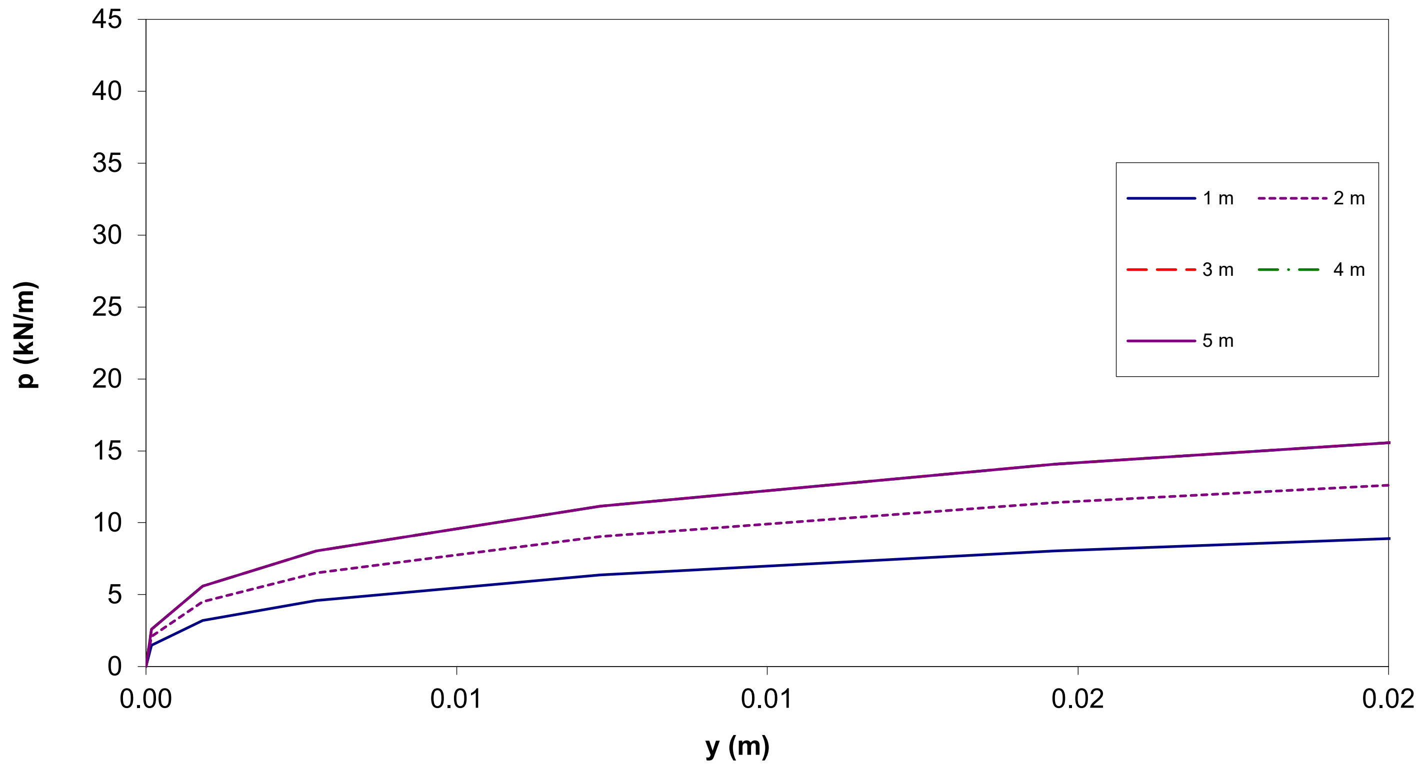
46 m		47 m		48 m		49 m		50 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	2288.189	0.002862	2337.932	0.002862	2387.675	0.002862	2437.419	0.002862	2487.162
0.005724	4430.964	0.005724	4527.289	0.005724	4623.614	0.005724	4719.94	0.005724	4816.265
0.008586	6317.667	0.008586	6455.007	0.008586	6592.348	0.008586	6729.688	0.008586	6867.029
0.011448	7890.87	0.011448	8062.411	0.011448	8233.952	0.011448	8405.492	0.011448	8577.033
0.01431	9144.189	0.01431	9342.976	0.01431	9541.763	0.01431	9740.55	0.01431	9939.336
0.017172	10106.88	0.017172	10326.6	0.017172	10546.31	0.017172	10766.03	0.017172	10985.74
0.020034	10825.82	0.020034	11061.16	0.020034	11296.51	0.020034	11531.85	0.020034	11767.19
0.022896	11351.5	0.022896	11598.28	0.022896	11845.05	0.022896	12091.82	0.022896	12338.59
0.025759	11729.99	0.025759	11984.99	0.025759	12239.99	0.025759	12494.99	0.025759	12749.99
0.028621	11999.46	0.028621	12260.32	0.028621	12521.18	0.028621	12782.04	0.028621	13042.89
0.034987	12347.48	0.034987	12615.9	0.034987	12884.32	0.034987	13152.75	0.034987	13421.17
0.041353	12504.7	0.041353	12776.54	0.041353	13048.39	0.041353	13320.23	0.041353	13592.07
0.053357	12603.74	0.053357	12877.73	0.053357	13151.73	0.053357	13425.72	0.053357	13699.71
0.065362	12625.14	0.065362	12899.6	0.065362	13174.06	0.065362	13448.52	0.065362	13722.98
0.077367	12629.75	0.077367	12904.31	0.077367	13178.87	0.077367	13453.43	0.077367	13727.99
0.09284	12630.84	0.09284	12905.42	0.09284	13180.01	0.09284	13454.59	0.09284	13729.17

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Seismic (2475-year EQ)
Pile Diameter = 914mm

Figure Piers D3-j

TETRA TECH



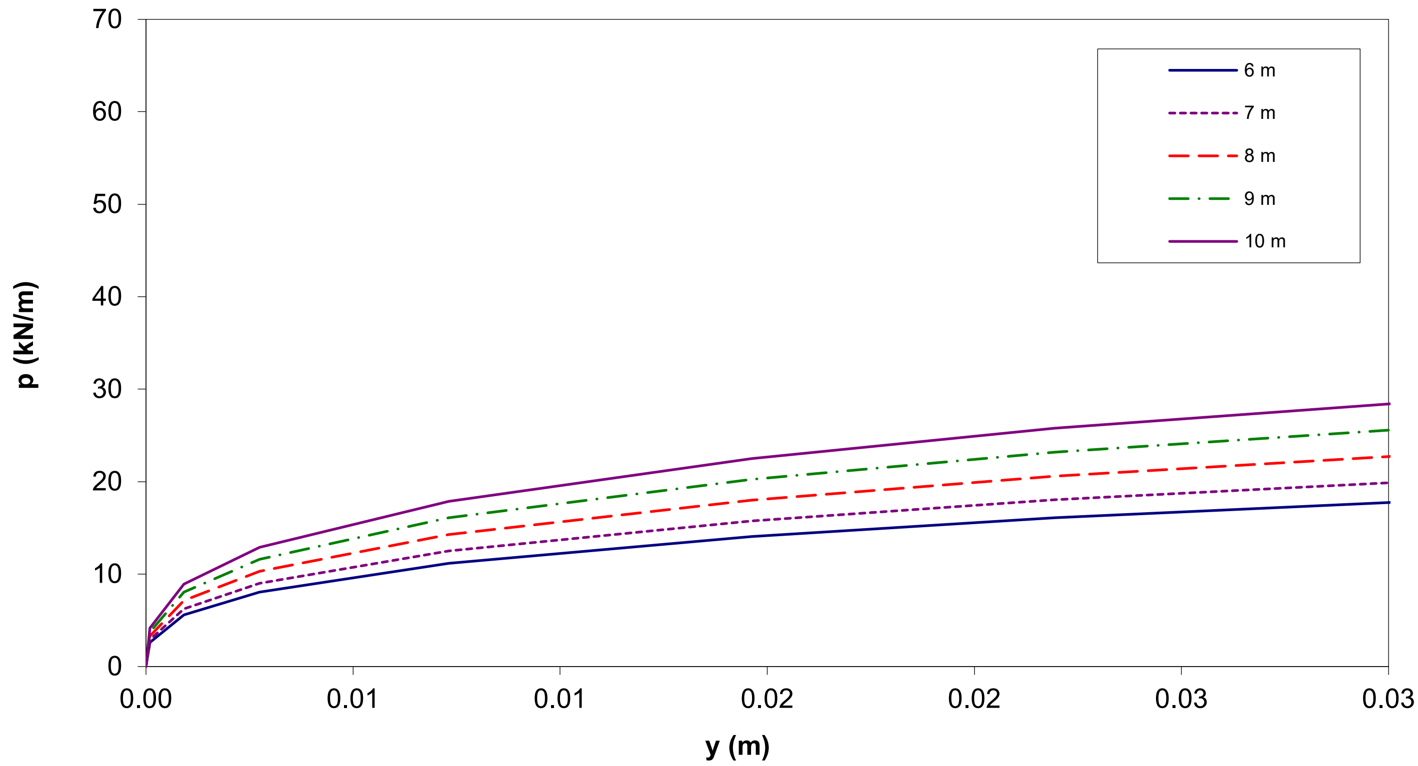
1 m		2 m		3 m		4 m		5 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	1.481793	9.14E-05	2.09991	9.14E-05	2.591028	9.14E-05	2.591028	9.14E-05	2.591028
0.000914	3.192426	0.000914	4.52412	0.000914	5.5822	0.000914	5.5822	0.000914	5.5822
0.002742	4.604276	0.002742	6.52491	0.002742	8.050925	0.002742	8.050925	0.002742	8.050925
0.007312	6.384853	0.007312	9.04824	0.007312	11.1644	0.007312	11.1644	0.007312	11.1644
0.014624	8.044411	0.014624	11.40007	0.014624	14.06626	0.014624	14.06626	0.014624	14.06626
0.021936	9.208552	0.021936	13.04982	0.021936	16.10185	0.021936	16.10185	0.021936	16.10185
0.03656	10.91795	0.03656	15.47227	0.03656	19.09086	0.03656	19.09086	0.03656	19.09086
0.05484	12.49793	0.05484	17.71133	0.05484	21.85357	0.05484	21.85357	0.05484	21.85357
0.08226	14.30656	0.08226	20.27441	0.08226	25.0161	0.08226	25.0161	0.08226	25.0161
0.10968	15.7464	0.10968	22.31488	0.10968	27.53378	0.10968	27.53378	0.10968	27.53378
0.14624	17.33116	0.14624	24.5607	0.14624	30.30484	0.14624	30.30484	0.14624	30.30484
0.1828	18.66942	0.1828	26.45721	0.1828	32.6449	0.1828	32.6449	0.1828	32.6449
0.23764	20.37568	0.23764	28.87521	0.23764	35.62842	0.23764	35.62842	0.23764	35.62842
0.29248	21.83589	0.29248	30.94455	0.29248	38.18171	0.29248	38.18171	0.29248	38.18171
0.3656	23.522	0.3656	33.334	0.3656	41.13	0.3656	41.13	0.3656	41.13
0.43872	23.522	0.43872	33.334	0.43872	41.13	0.43872	41.13	0.43872	41.13

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-a



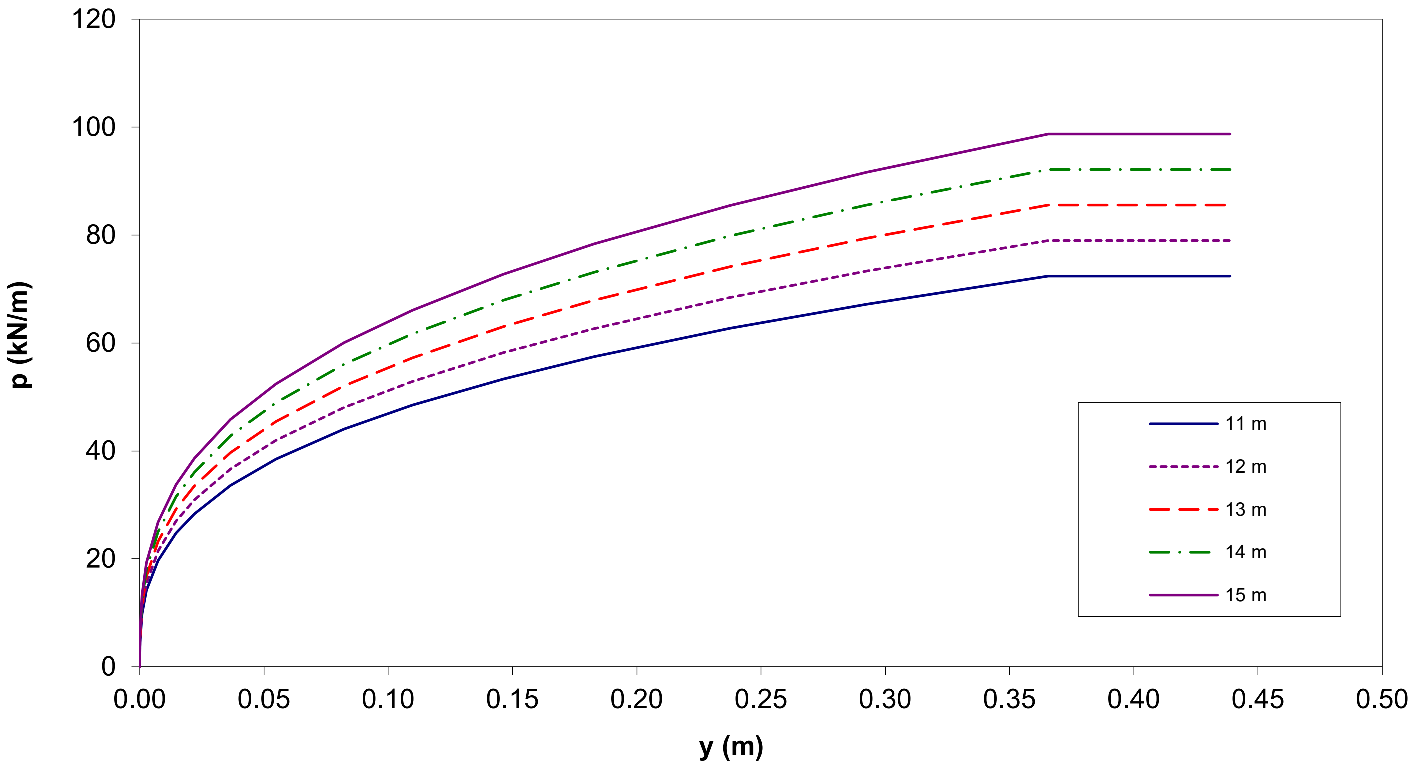
6 m		7 m		8 m		9 m		10 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	2.591028	9.14E-05	2.901951	9.14E-05	3.316515	9.14E-05	3.73108	9.14E-05	4.145644
0.000914	5.5822	0.000914	6.252064	0.000914	7.145215	0.000914	8.038367	0.000914	8.931519
0.002742	8.050925	0.002742	9.017036	0.002742	10.30518	0.002742	11.59333	0.002742	12.88148
0.007312	11.1644	0.007312	12.50413	0.007312	14.29043	0.007312	16.07674	0.007312	17.86304
0.014624	14.06626	0.014624	15.75421	0.014624	18.00482	0.014624	20.25542	0.014624	22.50602
0.021936	16.10185	0.021936	18.03407	0.021936	20.61037	0.021936	23.18667	0.021936	25.76296
0.03656	19.09086	0.03656	21.38176	0.03656	24.43629	0.03656	27.49083	0.03656	30.54537
0.05484	21.85357	0.05484	24.476	0.05484	27.97257	0.05484	31.46915	0.05484	34.96572
0.08226	25.0161	0.08226	28.01803	0.08226	32.0206	0.08226	36.02318	0.08226	40.02576
0.10968	27.53378	0.10968	30.83783	0.10968	35.24324	0.10968	39.64864	0.10968	44.05405
0.14624	30.30484	0.14624	33.94143	0.14624	38.7902	0.14624	43.63898	0.14624	48.48775
0.1828	32.6449	0.1828	36.56229	0.1828	41.78548	0.1828	47.00866	0.1828	52.23185
0.23764	35.62842	0.23764	39.90382	0.23764	45.60437	0.23764	51.30492	0.23764	57.00546
0.29248	38.18171	0.29248	42.76352	0.29248	48.87259	0.29248	54.98166	0.29248	61.09074
0.3656	41.13	0.3656	46.0656	0.3656	52.6464	0.3656	59.2272	0.3656	65.808
0.43872	41.13	0.43872	46.0656	0.43872	52.6464	0.43872	59.2272	0.43872	65.808

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

TETRA TECH

Figure Piers D4-b



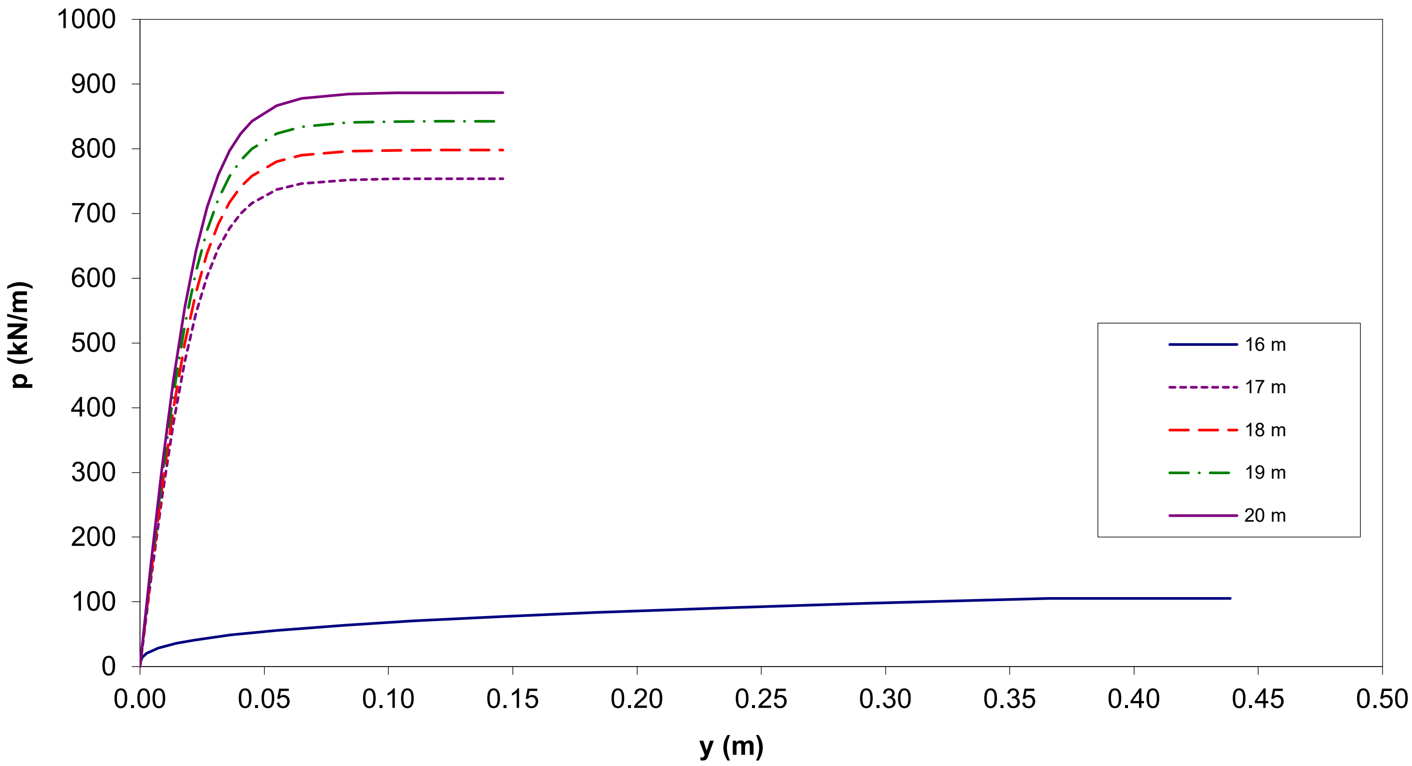
11 m		12 m		13 m		14 m		15 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	4.560208	9.14E-05	4.974773	9.14E-05	5.389337	9.14E-05	5.803902	9.14E-05	6.218466
0.000914	9.824671	0.000914	10.71782	0.000914	11.61098	0.000914	12.50413	0.000914	13.39728
0.002742	14.16963	0.002742	15.45778	0.002742	16.74592	0.002742	18.03407	0.002742	19.32222
0.007312	19.64934	0.007312	21.43565	0.007312	23.22195	0.007312	25.00826	0.007312	26.79456
0.014624	24.75662	0.014624	27.00722	0.014624	29.25783	0.014624	31.50843	0.014624	33.75903
0.021936	28.33926	0.021936	30.91555	0.021936	33.49185	0.021936	36.06815	0.021936	38.64444
0.03656	33.59991	0.03656	36.65444	0.03656	39.70898	0.03656	42.76352	0.03656	45.81805
0.05484	38.46229	0.05484	41.95886	0.05484	45.45543	0.05484	48.95201	0.05484	52.44858
0.08226	44.02833	0.08226	48.03091	0.08226	52.03348	0.08226	56.03606	0.08226	60.03863
0.10968	48.45945	0.10968	52.86485	0.10968	57.27026	0.10968	61.67566	0.10968	66.08107
0.14624	53.33653	0.14624	58.1853	0.14624	63.03408	0.14624	67.88285	0.14624	72.73163
0.1828	57.45503	0.1828	62.67821	0.1828	67.9014	0.1828	73.12458	0.1828	78.34777
0.23764	62.70601	0.23764	68.40656	0.23764	74.1071	0.23764	79.80765	0.23764	85.5082
0.29248	67.19981	0.29248	73.30888	0.29248	79.41796	0.29248	85.52703	0.29248	91.63611
0.3656	72.3888	0.3656	78.9696	0.3656	85.5504	0.3656	92.1312	0.3656	98.712
0.43872	72.3888	0.43872	78.9696	0.43872	85.5504	0.43872	92.1312	0.43872	98.712

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-c



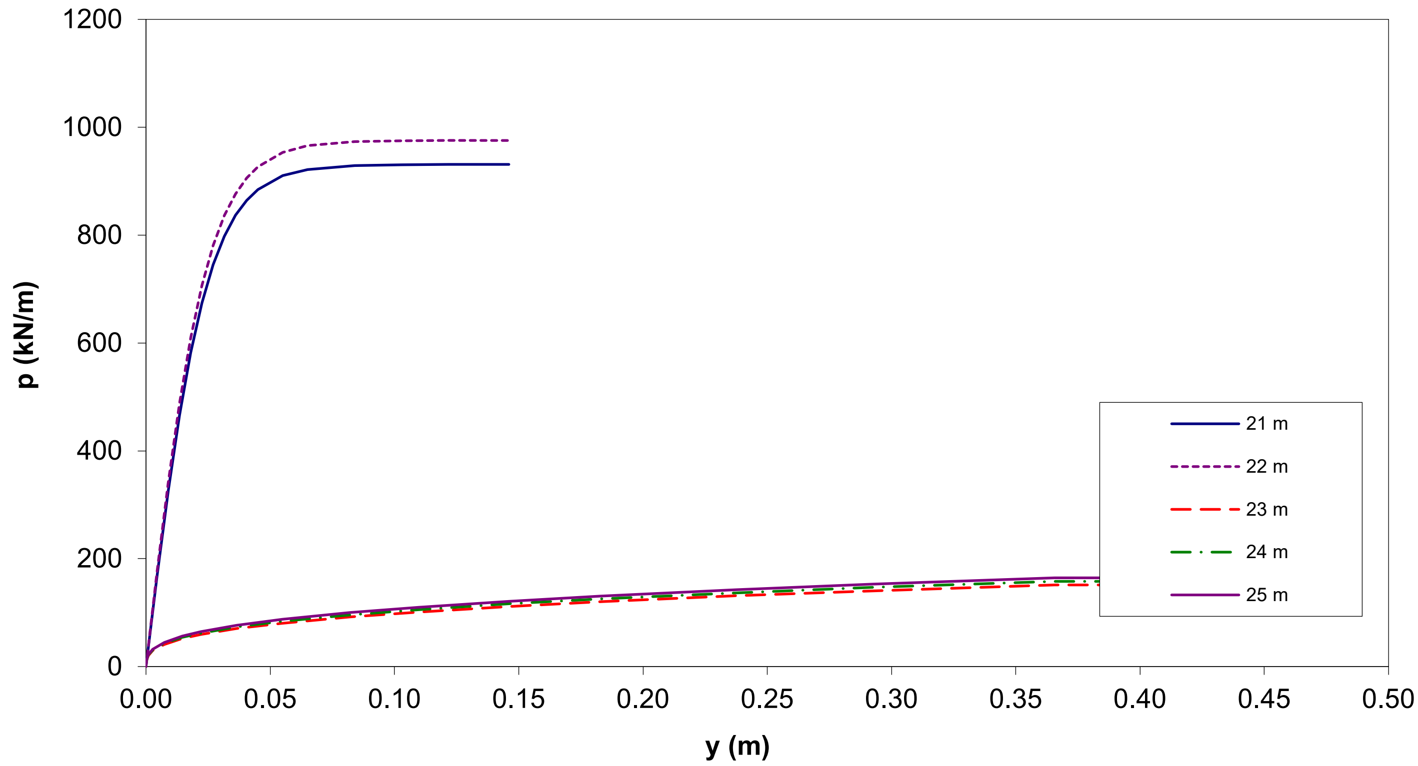
16 m		17 m		18 m		19 m		20 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	6.633031	4.50E-03	136.5442	4.50E-03	144.5762	4.50E-03	152.6082	4.50E-03	160.6403
0.000914	14.29043	0.009003	264.4111	0.009003	279.9647	0.009003	295.5183	0.009003	311.0719
0.002742	20.61037	0.013505	376.9972	0.013505	399.1735	0.013505	421.3498	0.013505	443.5261
0.007312	28.58086	0.018007	470.8758	0.018007	498.5743	0.018007	526.2729	0.018007	553.9715
0.014624	36.00963	0.022508	545.6657	0.022508	577.7637	0.022508	609.8617	0.022508	641.9596
0.021936	41.22074	0.02701	603.113	0.02701	638.5903	0.02701	674.0675	0.02701	709.5447
0.03656	48.87259	0.031512	646.0143	0.031512	684.0152	0.031512	722.016	0.031512	760.0168
0.05484	55.94515	0.036013	677.3839	0.036013	717.23	0.036013	757.0761	0.036013	796.9222
0.08226	64.04121	0.040515	699.9693	0.040515	741.144	0.040515	782.3186	0.040515	823.4933
0.10968	70.48647	0.045017	716.0498	0.045017	758.1704	0.045017	800.2909	0.045017	842.4115
0.14624	77.5804	0.05503	736.8171	0.05503	780.1593	0.05503	823.5014	0.05503	866.8436
0.1828	83.57095	0.065043	746.1993	0.065043	790.0933	0.065043	833.9874	0.065043	877.8815
0.23764	91.20874	0.083925	752.109	0.083925	796.3507	0.083925	840.5924	0.083925	884.8341
0.29248	97.74518	0.102806	753.3862	0.102806	797.7031	0.102806	842.0199	0.102806	886.3367
0.3656	105.2928	0.121688	753.6612	0.121688	797.9943	0.121688	842.3273	0.121688	886.6603
0.43872	105.2928	0.146026	753.7262	0.146026	798.0631	0.146026	842.3999	0.146026	886.7367

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-d

TETRA TECH



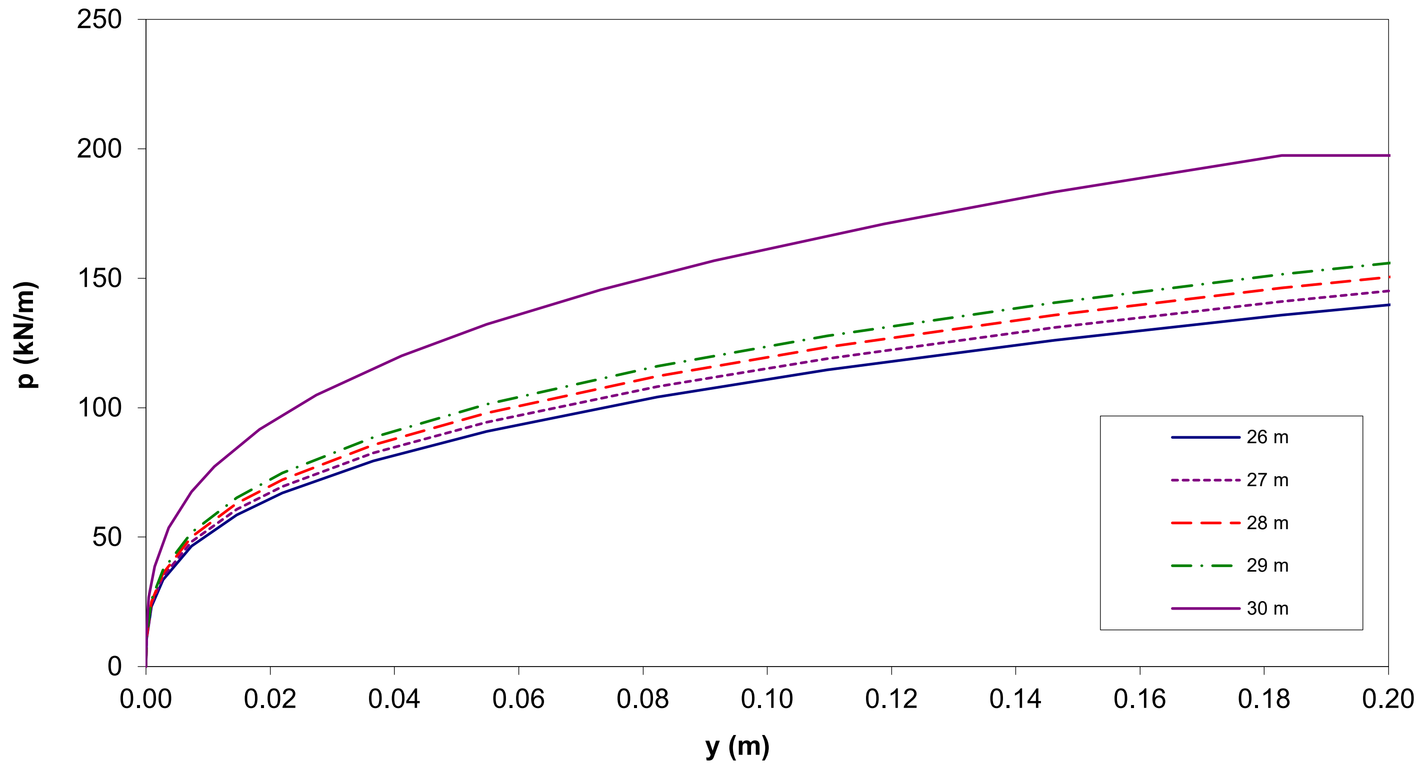
21 m		22 m		23 m		24 m		25 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.004502	168.6723	0.004502	176.7043	9.14E-05	9.534981	9.14E-05	9.949546	9.14E-05	10.36411
0.009003	326.6255	0.009003	342.179	0.000914	20.54249	0.000914	21.43565	0.000914	22.3288
0.013505	465.7024	0.013505	487.8788	0.002742	29.6274	0.002742	30.91555	0.002742	32.2037
0.018007	581.6701	0.018007	609.3686	0.007312	41.08499	0.007312	42.87129	0.007312	44.6576
0.022508	674.0576	0.022508	706.1556	0.014624	51.76384	0.014624	54.01445	0.014624	56.26505
0.02701	745.022	0.02701	780.4992	0.021936	59.25481	0.021936	61.83111	0.021936	64.4074
0.031512	798.0177	0.031512	836.0185	0.03656	70.25435	0.03656	73.30888	0.03656	76.36342
0.036013	836.7683	0.036013	876.6144	0.05484	80.42115	0.05484	83.91772	0.05484	87.4143
0.040515	864.6679	0.040515	905.8426	0.08226	92.05924	0.08226	96.06181	0.08226	100.0644
0.045017	884.5321	0.045017	926.6527	0.10968	101.3243	0.10968	105.7297	0.10968	110.1351
0.05503	910.1858	0.05503	953.528	0.14624	111.5218	0.14624	116.3706	0.14624	121.2194
0.065043	921.7756	0.065043	965.6696	0.1828	120.1332	0.1828	125.3564	0.1828	130.5796
0.083925	929.0758	0.083925	973.3175	0.23764	131.1126	0.23764	136.8131	0.23764	142.5137
0.102806	930.6536	0.102806	974.9704	0.29248	140.5087	0.29248	146.6178	0.29248	152.7268
0.121688	930.9933	0.121688	975.3263	0.3656	151.3584	0.3656	157.9392	0.3656	164.52
0.146026	931.0736	0.146026	975.4104	0.43872	151.3584	0.43872	157.9392	0.43872	164.52

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-e

TETRA TECH



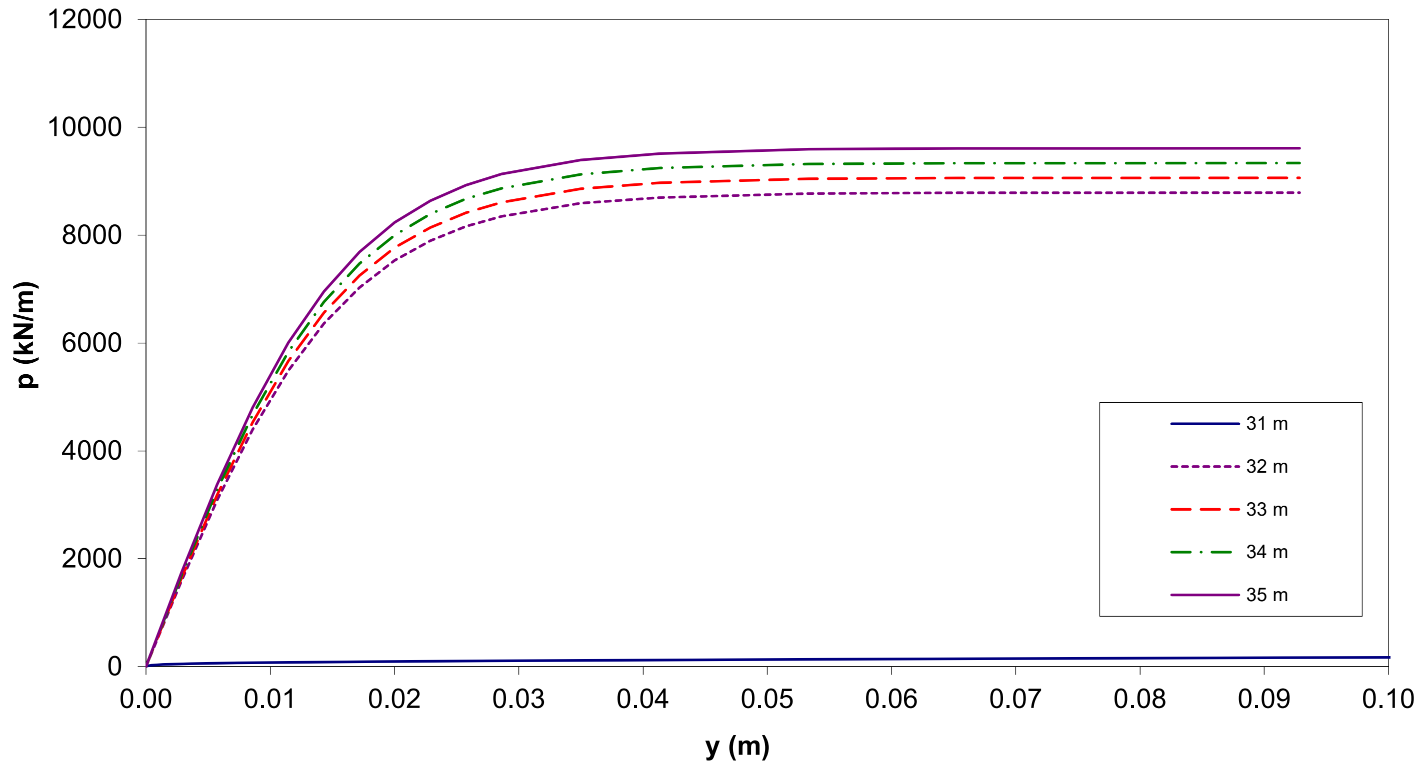
26 m		27 m		28 m		29 m		30 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
9.14E-05	10.77867	9.14E-05	11.19324	9.14E-05	11.6078	9.14E-05	12.02237	4.57E-05	12.43693
0.000914	23.22195	0.000914	24.1151	0.000914	25.00825	0.000914	25.90141	0.000457	26.79456
0.002742	33.49185	0.002742	34.78	0.002742	36.06814	0.002742	37.35629	0.001371	38.64444
0.007312	46.4439	0.007312	48.23021	0.007312	50.01651	0.007312	51.80281	0.003656	53.58912
0.014624	58.51565	0.014624	60.76625	0.014624	63.01685	0.014624	65.26746	0.007312	67.51806
0.021936	66.9837	0.021936	69.55999	0.021936	72.13629	0.021936	74.71259	0.010968	77.28888
0.03656	79.41796	0.03656	82.47249	0.03656	85.52703	0.03656	88.58157	0.01828	91.6361
0.05484	90.91087	0.05484	94.40744	0.05484	97.90401	0.05484	101.4006	0.02742	104.8972
0.08226	104.067	0.08226	108.0695	0.08226	112.0721	0.08226	116.0747	0.04113	120.0773
0.10968	114.5405	0.10968	118.9459	0.10968	123.3513	0.10968	127.7567	0.05484	132.1621
0.14624	126.0682	0.14624	130.9169	0.14624	135.7657	0.14624	140.6145	0.07312	145.4633
0.1828	135.8028	0.1828	141.026	0.1828	146.2492	0.1828	151.4724	0.0914	156.6955
0.23764	148.2142	0.23764	153.9148	0.23764	159.6153	0.23764	165.3158	0.11882	171.0164
0.29248	158.8359	0.29248	164.945	0.29248	171.0541	0.29248	177.1631	0.14624	183.2722
0.3656	171.1008	0.3656	177.6816	0.3656	184.2624	0.3656	190.8432	0.1828	197.424
0.43872	171.1008	0.43872	177.6816	0.43872	184.2624	0.43872	190.8432	0.21936	197.424

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-f



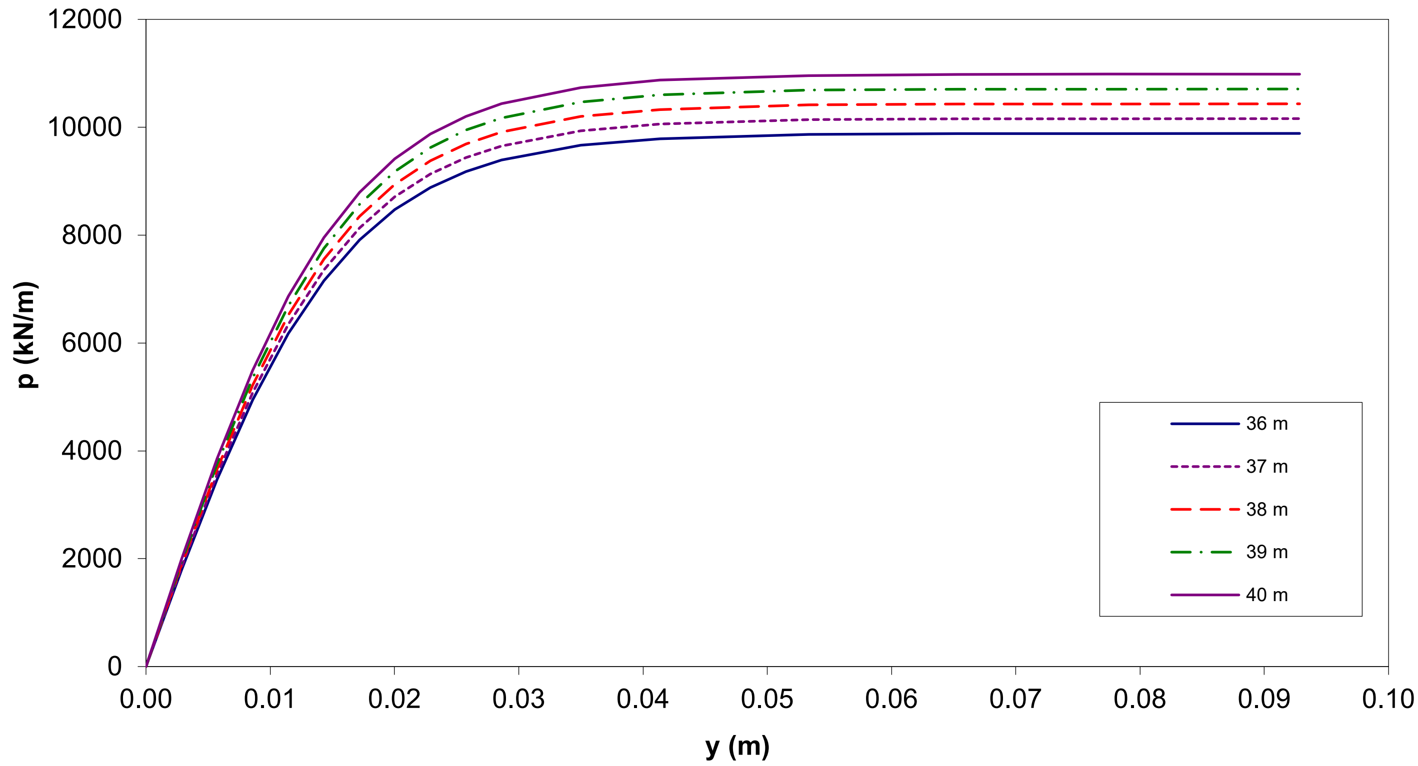
31 m		32 m		33 m		34 m		35 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
4.57E-05	12.8515	2.86E-03	1591.784	0.002862	1641.527	0.002862	1691.27	0.002862	1741.013
0.000457	27.68771	0.005724	3082.41	0.005724	3178.735	0.005724	3275.06	0.005724	3371.386
0.001371	39.93259	0.008586	4394.899	0.008586	4532.239	0.008586	4669.58	0.008586	4806.92
0.003656	55.37542	0.011448	5489.301	0.011448	5660.842	0.011448	5832.382	0.011448	6003.923
0.007312	69.76866	0.01431	6361.175	0.01431	6559.962	0.01431	6758.749	0.01431	6957.535
0.010968	79.86518	0.017172	7030.876	0.017172	7250.59	0.017172	7470.305	0.017172	7690.02
0.01828	94.69064	0.020034	7531.004	0.020034	7766.347	0.020034	8001.691	0.020034	8237.035
0.02742	108.3937	0.022896	7896.699	0.022896	8143.471	0.022896	8390.242	0.022896	8637.014
0.04113	124.0798	0.025759	8159.991	0.025759	8414.991	0.025759	8669.991	0.025759	8924.99
0.05484	136.5675	0.028621	8347.452	0.028621	8608.31	0.028621	8869.168	0.028621	9130.026
0.07312	150.312	0.034987	8589.55	0.034987	8857.973	0.034987	9126.396	0.034987	9394.82
0.0914	161.9187	0.041353	8698.924	0.041353	8970.765	0.041353	9242.607	0.041353	9514.448
0.11882	176.7169	0.053357	8767.817	0.053357	9041.811	0.053357	9315.805	0.053357	9589.8
0.14624	189.3813	0.065362	8782.707	0.065362	9057.166	0.065362	9331.626	0.065362	9606.085
0.1828	204.0048	0.077367	8785.913	0.077367	9060.473	0.077367	9335.032	0.077367	9609.592
0.21936	204.0048	0.09284	8786.67	0.09284	9061.254	0.09284	9335.837	0.09284	9610.421

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-g

TETRA TECH



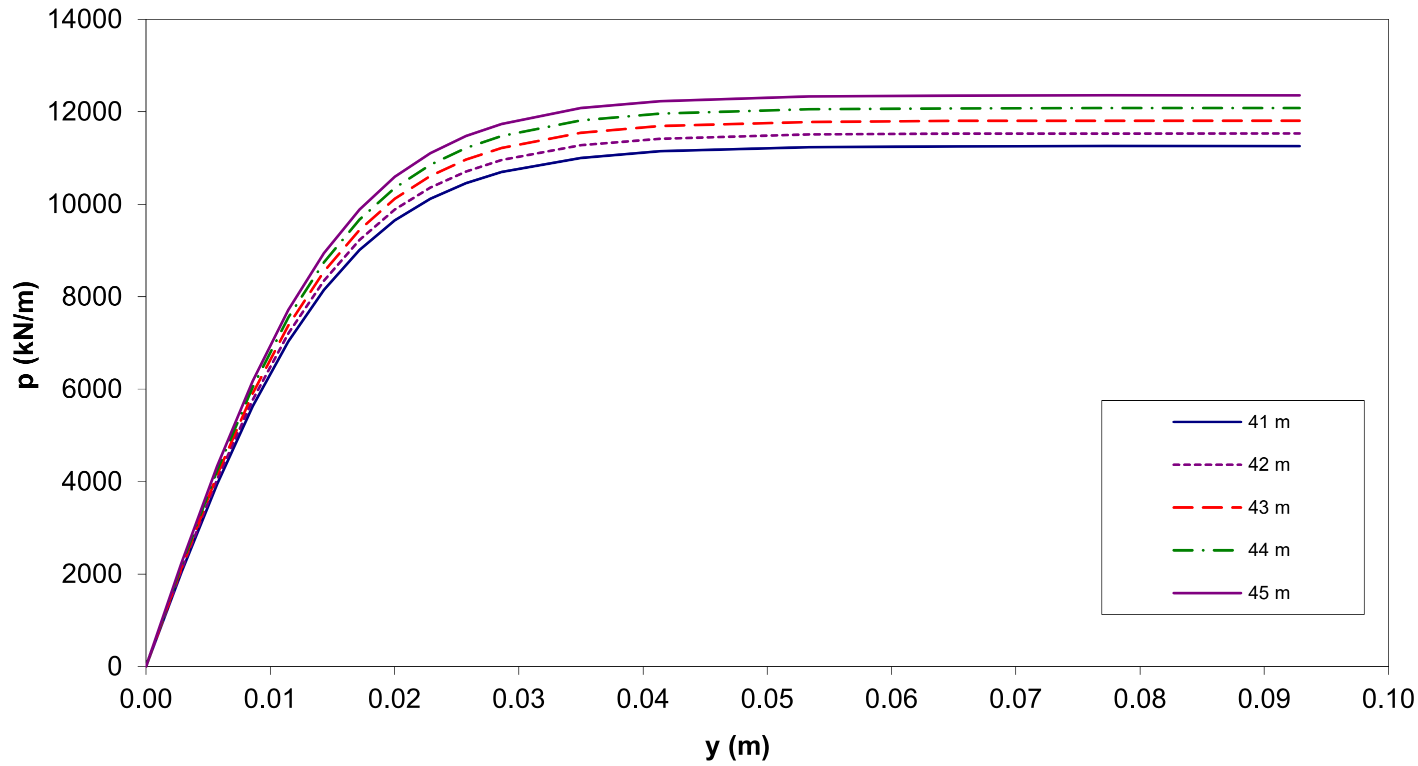
36 m		37 m		38 m		39 m		40 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	1790.757	0.002862	1840.5	0.002862	1890.243	0.002862	1939.986	0.002862	1989.729
0.005724	3467.711	0.005724	3564.036	0.005724	3660.361	0.005724	3756.687	0.005724	3853.012
0.008586	4944.261	0.008586	5081.601	0.008586	5218.942	0.008586	5356.283	0.008586	5493.623
0.011448	6175.464	0.011448	6347.004	0.011448	6518.545	0.011448	6690.086	0.011448	6861.626
0.01431	7156.322	0.01431	7355.109	0.01431	7553.896	0.01431	7752.682	0.01431	7951.469
0.017172	7909.735	0.017172	8129.45	0.017172	8349.165	0.017172	8568.88	0.017172	8788.594
0.020034	8472.379	0.020034	8707.723	0.020034	8943.067	0.020034	9178.411	0.020034	9413.754
0.022896	8883.786	0.022896	9130.558	0.022896	9377.33	0.022896	9624.102	0.022896	9870.873
0.025759	9179.99	0.025759	9434.99	0.025759	9689.99	0.025759	9944.989	0.025759	10199.99
0.028621	9390.883	0.028621	9651.741	0.028621	9912.599	0.028621	10173.46	0.028621	10434.32
0.034987	9663.243	0.034987	9931.667	0.034987	10200.09	0.034987	10468.51	0.034987	10736.94
0.041353	9786.289	0.041353	10058.13	0.041353	10329.97	0.041353	10601.81	0.041353	10873.66
0.053357	9863.794	0.053357	10137.79	0.053357	10411.78	0.053357	10685.78	0.053357	10959.77
0.065362	9880.545	0.065362	10155.01	0.065362	10429.46	0.065362	10703.92	0.065362	10978.38
0.077367	9884.152	0.077367	10158.71	0.077367	10433.27	0.077367	10707.83	0.077367	10982.39
0.09284	9885.004	0.09284	10159.59	0.09284	10434.17	0.09284	10708.75	0.09284	10983.34

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-h



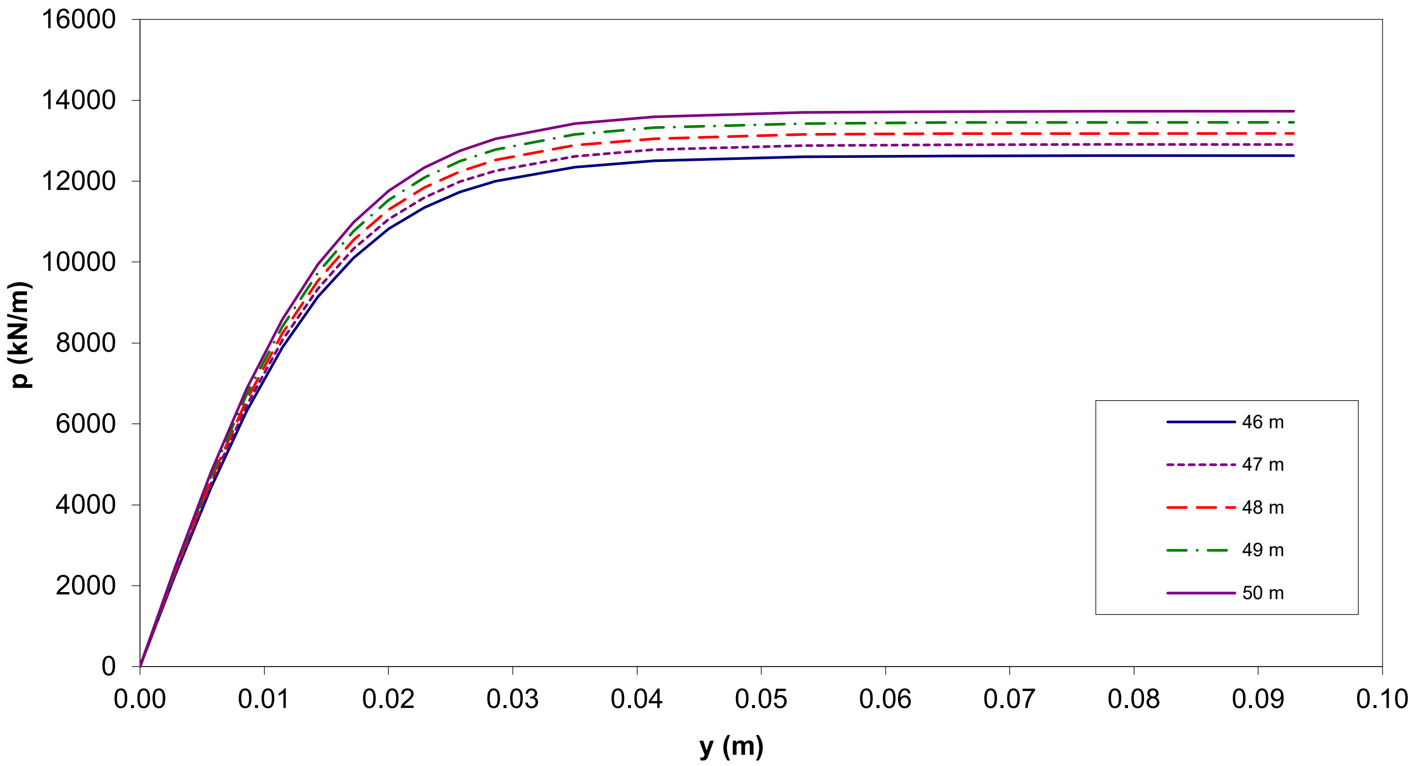
41 m		42 m		43 m		44 m		45 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	2039.473	0.002862	2089.216	0.002862	2138.959	0.002862	2188.702	0.002862	2238.446
0.005724	3949.337	0.005724	4045.663	0.005724	4141.988	0.005724	4238.313	0.005724	4334.639
0.008586	5630.964	0.008586	5768.304	0.008586	5905.645	0.008586	6042.986	0.008586	6180.326
0.011448	7033.167	0.011448	7204.708	0.011448	7376.248	0.011448	7547.789	0.011448	7719.33
0.01431	8150.256	0.01431	8349.043	0.01431	8547.829	0.01431	8746.616	0.01431	8945.403
0.017172	9008.309	0.017172	9228.024	0.017172	9447.739	0.017172	9667.454	0.017172	9887.169
0.020034	9649.098	0.020034	9884.442	0.020034	10119.79	0.020034	10355.13	0.020034	10590.47
0.022896	10117.65	0.022896	10364.42	0.022896	10611.19	0.022896	10857.96	0.022896	11104.73
0.025759	10454.99	0.025759	10709.99	0.025759	10964.99	0.025759	11219.99	0.025759	11474.99
0.028621	10695.17	0.028621	10956.03	0.028621	11216.89	0.028621	11477.75	0.028621	11738.6
0.034987	11005.36	0.034987	11273.78	0.034987	11542.21	0.034987	11810.63	0.034987	12079.05
0.041353	11145.5	0.041353	11417.34	0.041353	11689.18	0.041353	11961.02	0.041353	12232.86
0.053357	11233.77	0.053357	11507.76	0.053357	11781.75	0.053357	12055.75	0.053357	12329.74
0.065362	11252.84	0.065362	11527.3	0.065362	11801.76	0.065362	12076.22	0.065362	12350.68
0.077367	11256.95	0.077367	11531.51	0.077367	11806.07	0.077367	12080.63	0.077367	12355.19
0.09284	11257.92	0.09284	11532.51	0.09284	11807.09	0.09284	12081.67	0.09284	12356.26

Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-i



46 m		47 m		48 m		49 m		50 m	
y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)	y (m)	p (kN/m)
0	0	0	0	0	0	0	0	0	0
0.002862	2288.189	0.002862	2337.932	0.002862	2387.675	0.002862	2437.419	0.002862	2487.162
0.005724	4430.964	0.005724	4527.289	0.005724	4623.614	0.005724	4719.94	0.005724	4816.265
0.008586	6317.667	0.008586	6455.007	0.008586	6592.348	0.008586	6729.688	0.008586	6867.029
0.011448	7890.87	0.011448	8062.411	0.011448	8233.952	0.011448	8405.492	0.011448	8577.033
0.01431	9144.189	0.01431	9342.976	0.01431	9541.763	0.01431	9740.55	0.01431	9939.336
0.017172	10106.88	0.017172	10326.6	0.017172	10546.31	0.017172	10766.03	0.017172	10985.74
0.020034	10825.82	0.020034	11061.16	0.020034	11296.51	0.020034	11531.85	0.020034	11767.19
0.022896	11351.5	0.022896	11598.28	0.022896	11845.05	0.022896	12091.82	0.022896	12338.59
0.025759	11729.99	0.025759	11984.99	0.025759	12239.99	0.025759	12494.99	0.025759	12749.99
0.028621	11999.46	0.028621	12260.32	0.028621	12521.18	0.028621	12782.04	0.028621	13042.89
0.034987	12347.48	0.034987	12615.9	0.034987	12884.32	0.034987	13152.75	0.034987	13421.17
0.041353	12504.7	0.041353	12776.54	0.041353	13048.39	0.041353	13320.23	0.041353	13592.07
0.053357	12603.74	0.053357	12877.73	0.053357	13151.73	0.053357	13425.72	0.053357	13699.71
0.065362	12625.14	0.065362	12899.6	0.065362	13174.06	0.065362	13448.52	0.065362	13722.98
0.077367	12629.75	0.077367	12904.31	0.077367	13178.87	0.077367	13453.43	0.077367	13727.99
0.09284	12630.84	0.09284	12905.42	0.09284	13180.01	0.09284	13454.59	0.09284	13729.17

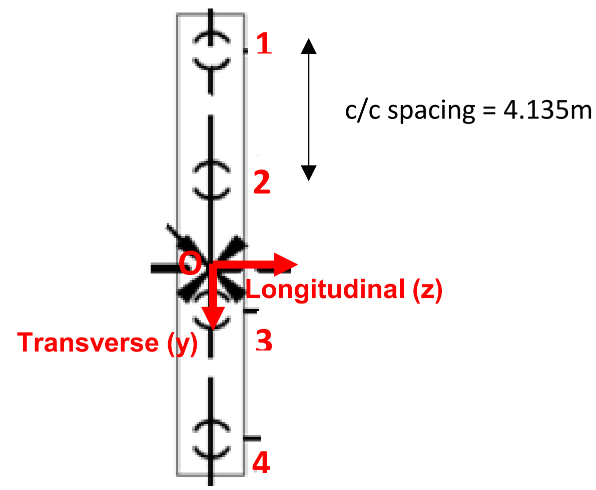
Note - The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

TETRA TECH

ULTIMATE p-y CURVES
Piers - Seismic (475-year EQ)
Pile Diameter = 914mm

Figure Piers D4-j

Pile No.	Pile Group Factors for Lateral Load - At Pile Cap [1]	
	Transverse (+y) direction	Longitudinal (+z) direction
1	0.85	1.00
2	0.85	1.00
3	0.85	1.00
4	1.00	1.00



Note: The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

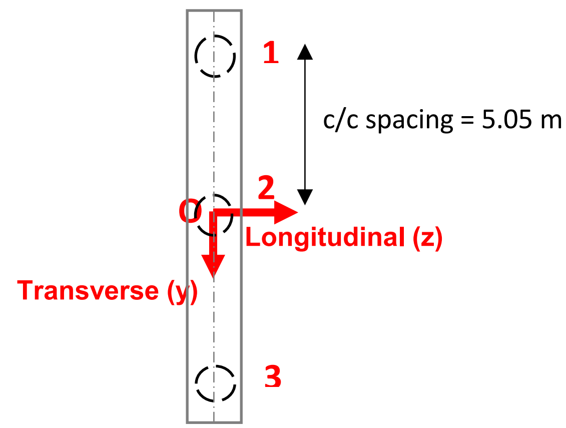
[1] The pile group factors are derived for lateral loads applied in the positive directions (+y & +z) at the center (Point O) of the pile cap.

TETRA TECH

SUMMARY OF PILE GROUP FACTORS AT PILE CAP
Abutments

Figure D-5

Pile No.	Pile Group Factors for Lateral Load - At Pile Cap [1]	
	Transverse (+y) direction	Longitudinal (+z) direction
1	0.92	1.00
2	0.92	1.00
3	1.00	1.00



Note: The combined effect of pile group factor and geotechnical resistance factors should be applied as p-multipliers on the ultimate p-y curves.

[1] The pile group factors are derived for lateral loads applied in the positive directions (+y & +z) at the center (Point O) of the pile cap.

TETRA TECH

SUMMARY OF PILE GROUP FACTORS AT PILE CAP
Piers

Figure D6

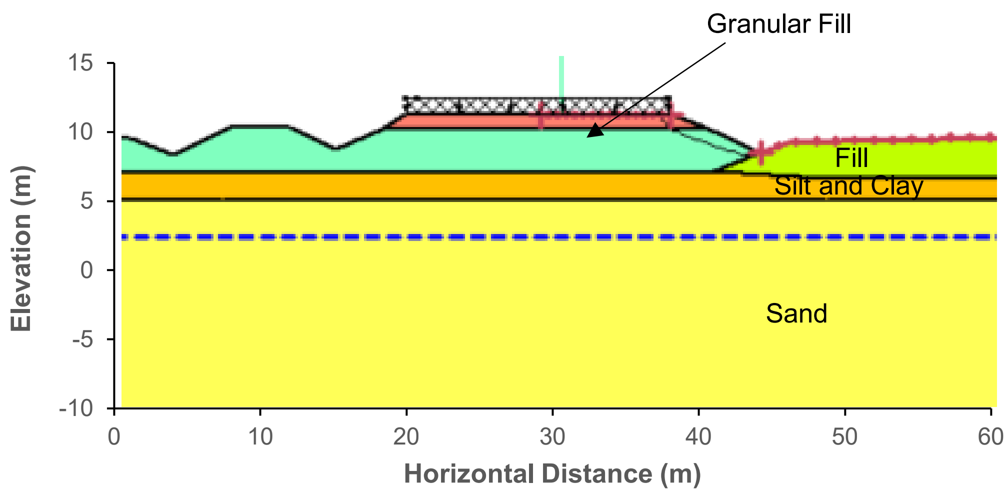
APPENDIX E

SLOPE STABILITY ANALYSIS – APPROACH EMBANKMENT

Static

Sta 7+595

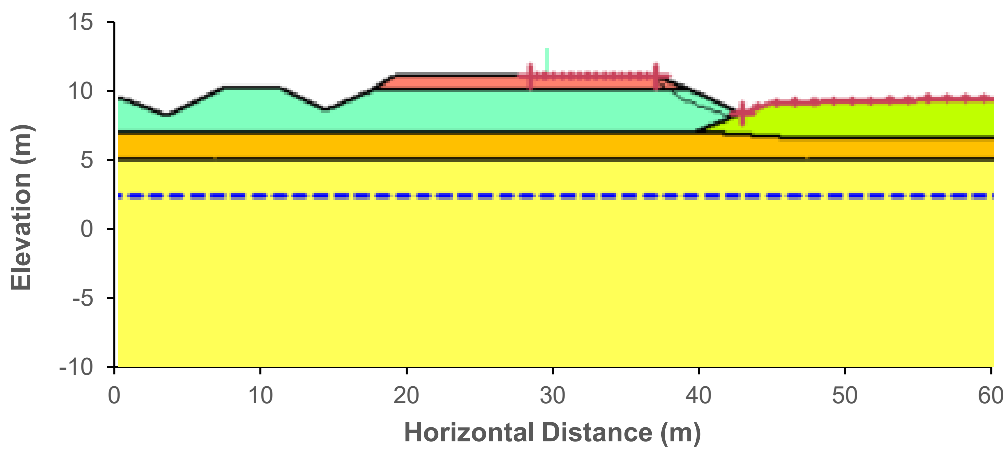
FS = 1.6



Pseudo Static - 975-yr EQ

Kh = 0.075

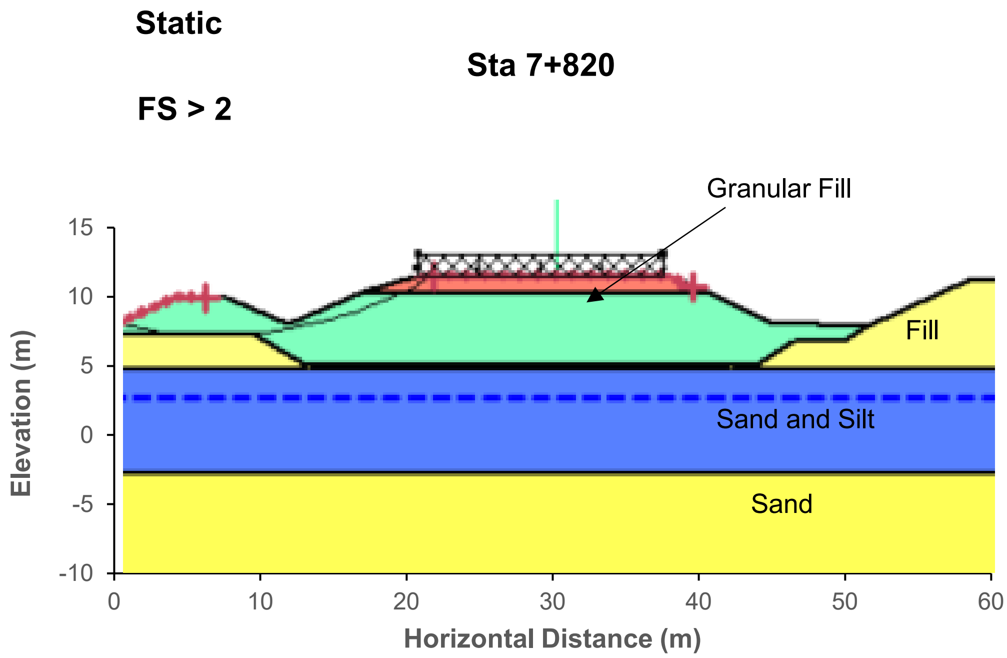
FS > 1.1

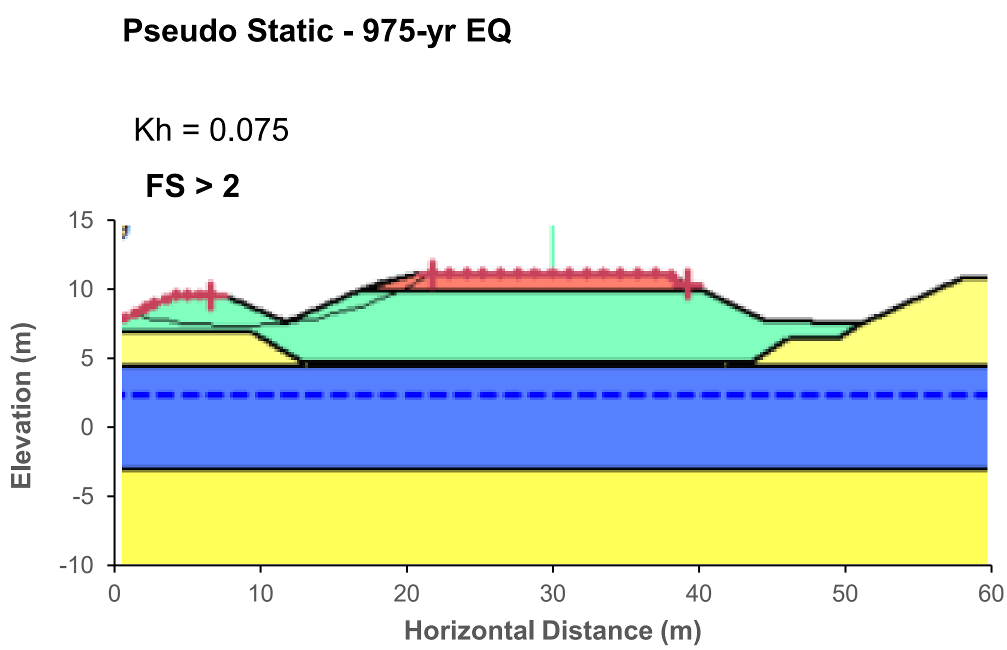


TETRA TECH

GLOBAL STABILITY - EMBANKMENT
West Approach - Sta 7+590

Figure E-1





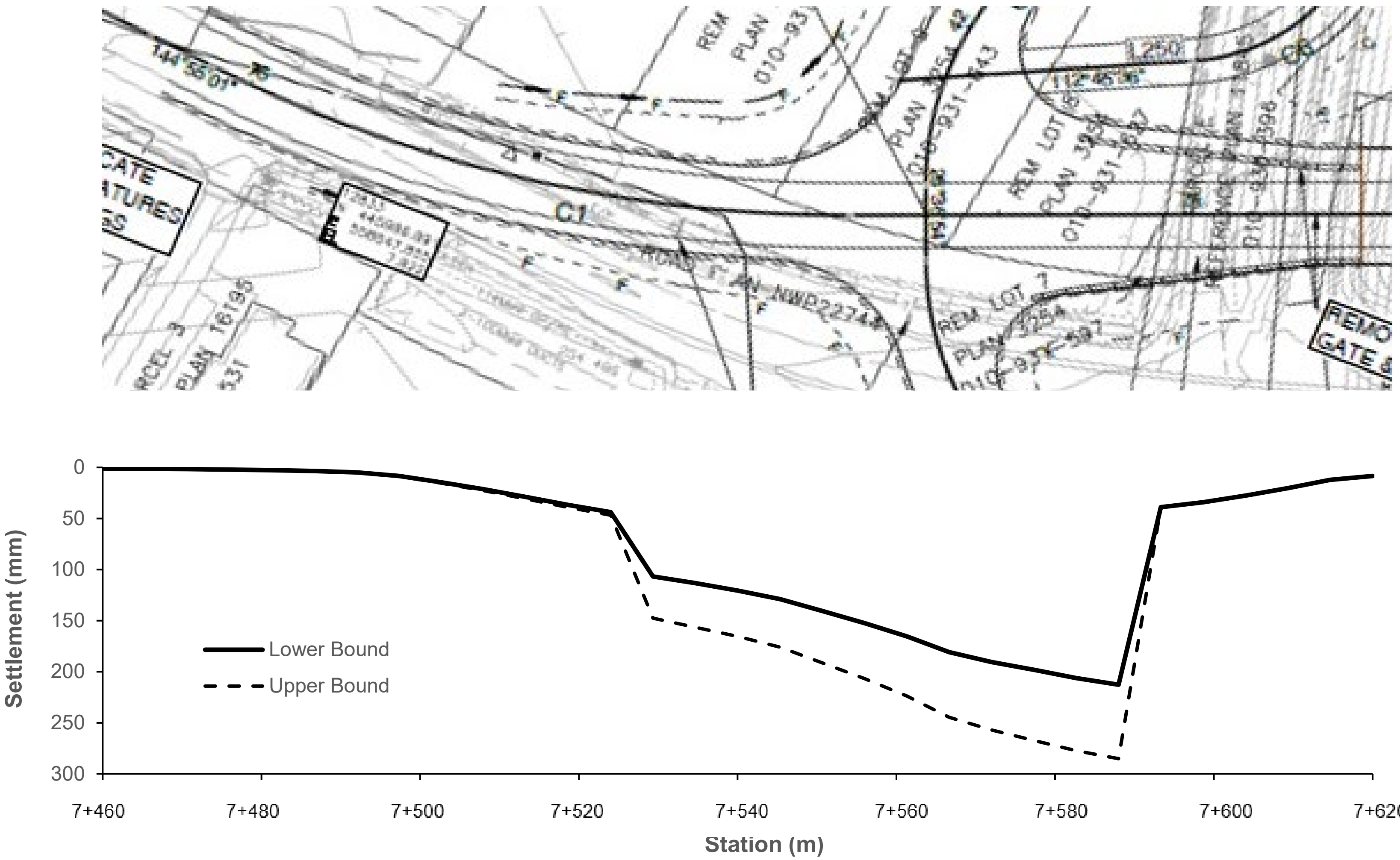
TETRA TECH

GLOBAL STABILITY - EMBANKMENT
East Approach - Sta 7+820

Figure E-2

APPENDIX F

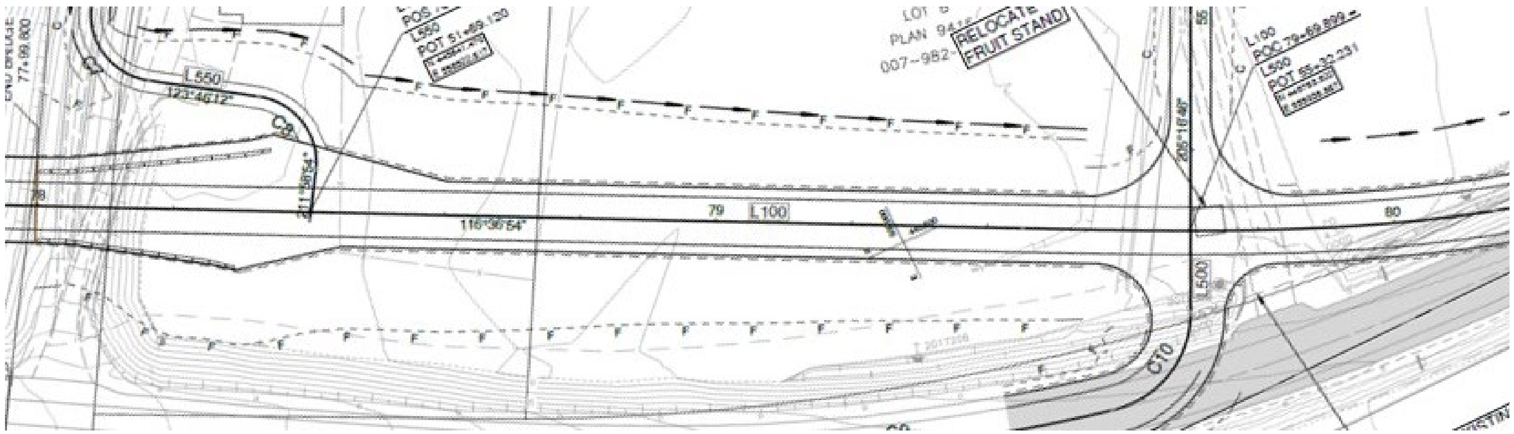
SETTLEMENT ANALYSIS

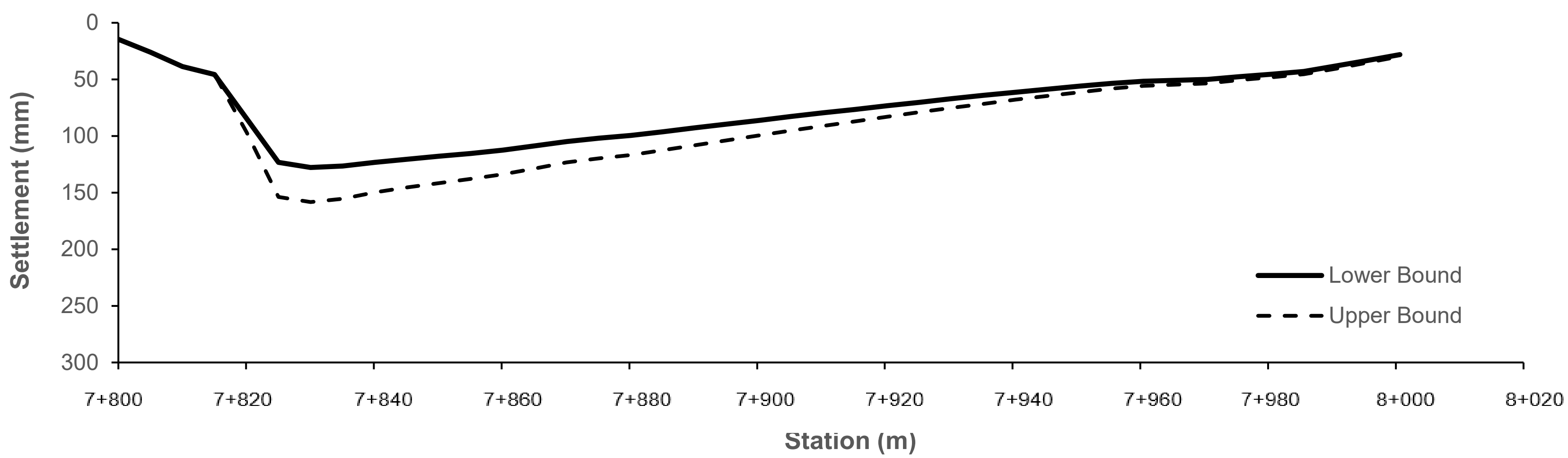


TETRA TECH

SETTLEMENT
West Approach

Figure F-1





TETRA TECH

SETTLEMENT
East Approach

Figure F-2