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FWS Group
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March 29, 2018
File: 15657

Attention: Robert Schwetzke

Re: Geotechnical Investigation Report for Proposed Fraser Grain Terminal Fraser Surrey Docks, Surrey, B.C.

1.0 INTRODUCTION

We understand that a new grain terminal is proposed at the above referenced site. Preliminary design drawings indicate that the terminal will consist of 20 large grain storage bins, 5 small bins, a receiving pit and ship loader which will be interconnected with an overhead conveyor system. We further understand that the silos are envisioned to be supported on a large raft foundation.

This report has been prepared exclusively for FWS Group, for their use and the use of others on their design and construction team for this project and for the Vancouver Fraser Port Authority for the permitting process. This report includes an evaluation of the soil and groundwater conditions at the proposed grain terminal site and provides preliminary recommendations for the design and construction of the proposed structures.

2.0 SITE DESCRIPTION

The site is located on port land operated by Fraser Surrey Docks in Surrey, B.C. The site is roughly bounded by Elevator Road to the south, Robson Road to the east, the Fraser River to the west and Plywood Road to the north. The site is currently occupied by several buildings with paved access and storage areas surrounding these structures. The site is generally flat except for local grading at some of the building locations.

The site location relative to the surrounding improvements is shown on our Drawing No. 15657-01, following the text of this report.

3.0 SITE INVESTIGATION

An investigation of the subsurface soil and groundwater conditions was completed by EXP on September 10, 2010 and between December 9 and 17 of 2014 . At that time, a total of 5 mud rotary test holes were completed to depths of between 11.3 and 30.5 metres below grade. In addition, 9 Cone Penetration Test (CPT) soundings were completed to depths of between 20 and 40 metres below grade. A shear wave velocity profile was collected at one of the CPT sounding locations.

GeoPacific completed a supplementary investigation of the site on March 6, 7, and 13, 2018, which included a total of 11 solid stem auger test holes and 9 CPT soundings to depths of up to 12.2 and 30.3 metres bleow grade. The test holes and CPT soundings were advanced using a truck-mounted drill rig supplied and operated by Ontrack Drilling of Coquitlam, B.C. All test holes were backfilled in accordance with provincial abandonment requirements following the completion of testing, logging and sampling. The on-site work was supervised by a geologist from our office.

The approximate locations of the test holes and CPT soundings are shown on our Drawing No. 15657-01 attached to this report.

4.0 SUBSURFACE CONDITIONS

4.1 Subsurface Conditions

The subsurface soil conditions generally consist of granular fills over overbank silt then channel deposited sand. The site is surfaced with asphalt or concrete at the test hole locations. The asphalt is underlain by dense to loose, sand and gravel to sand fill which extends to a depth of between 3.0 and 7.3 metres below grade. The fills are underlain by firm to stiff overbank silt to sandy silt, except in the ship loader area where the silt layer is absent. Laboratory testing indicates that the silt generally has a moisture content of between 35 and 59 percent. A 0.2 metre thick layer described as peat organic silt was recorded at a depth of 4.3 metres at BH14-01 with a moisture content of 90 to 220 percent. The overbank silt extends to a depth of between approximately 5 and 11 metres below grade. The silt is underlain by channel deposited sand, which is generally compact to dense. Based on the high CPT tip resistance encountered at approximately 40 metres below grade as well as geology mapping of the area, we expect that the sand is underlain by dense glacial till at a depth of about 40 metres below grade in the area of CPT14-07 and deeper towards the foreshore.

For a more detailed description of the subsurface soil conditions encountered refer to the test hole logs and laboratory test results presented in Appendiices A.1 and A.2, the CPT sounding logs in Appendix B, the interpreted strength parameters in Appendix C of this report.

4.2 Groundwater Conditions

The static groundwater table was noted at depths of between 2.5 and 4.5 metres below present site grades at the location of the test holes. The variation in groundwater depth is due to varying ground elevations at each test hole location as well as some tidal influences, particularly near the foreshore. Perched groundwater is expected to form within the fills during wetter periods of the year.

5.0 DISCUSSION

5.1 General

The proposed grain handling facilities essentially consist of new silos, railcar receiving pit, ship loader and an overhead conveyor system. The large and small silos are expected to have a height of approximately 32 and 17 metres, respectively, above the raft slab and will be constructed of steel. The bins will conical bases supported on steel framing over the raft and the conical roofs rise above to a conveyor system at a height of approximately 50 metres above the raft. The large and small silos will have a diameter of approximately 15 and 7 to 10 metres, respectively. Service stresses at the underside of the raft slab are expected to be less than 190 kPa. The railcar receiving pit is expected to be up to 14 metres below grade.

The ship loader will be supported by three fixed towers constructed in the existing wharf area. Based on the preliminary Marine Structures design by WorleyParsons, dated March 29, 2017, the wharf is approximately 17 metres above the dredge line of the ship berths. Based on the historical record drawings provided (Fraser River Harbour Commission, dated January 12, 1968), the wharf is supported on battered and vertical piles with concrete, sheet pile, and timber pile bulkheads.

Based on the anticipated loading and soil conditions beneath the site, we expect that the new silos can be supported on-grade using a contiguous reinforced concrete raft foundation following ground improvement. We expect that raft foundation and ground improvement would be most economical in comparison to piled foundations, however some post-construction settlement would need to be accepted. Ground improvement would include rammed aggregate piers to reduce post construction settlement, provide adequate bearing resistance and mitigate liquefaction induced displacements of the structures. Alternatively, pile foundations could be used to support the new silos and further reduce post-construction settlements.

We understand that pile foundations will be used to support the new ship loader due to the close proximity of the ship loader towers to the foreshore. We recommend that ground improvement be completed on the inland side of the existing wharf to minimize the potential for liquefaction induced lateral spread.

We confirm that the proposed grain terminal is feasible from a geotechnical perspective provided that our recommendations are adhered to during the design and construction of the proposed structures.

5.2 Seismic Considerations

5.2.1 Liquefaction

It is generally accepted that loose to compact and saturated non-plastic silts and sands are prone to liquefaction or strain softening during cyclic loading caused by earthquakes. The strength reduction caused by soil liquefaction can cause foundations to punch. Furthermore, once liquefaction has been triggered, experience has shown that significant, permanent vertical and horizontal movements may be experienced.

We understand that the structures will be designed using a performance-based criteria under 100, 200, 475 and 2,475 year return period design earthquakes. We have obtained seismic hazard deagreggations for the 100, 475 and 2,475 year return periods directly from the Geological Survey of Canada under the latest seismic model for the National Building Code of Canada (NBCC) 2015. This data was used to interpolate the 200 year return period hazard as well as estimate the source contributions, moment magnitude and peak ground acceleration (PGA) for each return period of interest.

We have conducted a liquefaction assessment based on the NBCC 2015 design earthquakes for each return period. The design earthquake is expected to generate horizontal PGAs of between 0.08g and 0.36g on firm ground with a design moment magnitudes of between 6.7 and 7.0. However, our site specific dynamic analysis indicates significant de-amplification of the peak ground acceleration under the 475 and 2,475 year return period earthquakes and slight amplification under the 100 and 200 year earthquakes. Liquefaction potential and predicted post liquefaction ground settlements are presented in Appendix D of this report.

The results of our analyses are summarized in Table 1 below:

Table 1: PGA and Moment Magnitude

Return Period (years)	PGA (g)	Moment Magnitude	Liquefaction Induced Settlement (mm)
100	0.1	6.7	0
200	0.13	6.8	0 to 10
475	0.17	7	0 to 80[1]
2475	0.24	7	20 to 150[1]

[1]Except at CPT18-03, where liquefaction induced settlement is estimated to be 150 and 250 mm for the 475 and 2475 year return periods, respectively.

Liquefaction is also expected to induce lateral movements which decrease with distance from the foreshore. For structures located at least 30 metres from the foreshore, we estimate lateral spread would be relatively consistent and on the order of 500 to 800 mm for the 2,475 year event and 200 to 400 mm for the 475 year event. Lateral spread is expected to be negligible beyond 30 metres for the 100 and 200 year events.

Liquefaction induced lateral spread is estimated to be several metres for the shiploader, therefore we recommend that a densification berm be completed in this area to minimize lateral spread. The densification berm would not completely prevent lateral spread but is intended to minimize differential lateral movement and therefore limit damage to the structure.

Foundation punching is not anticipated provided that the structures are supported on raft slabs or piled foundations.

The predicted movements are based on empirical observations from other earthquake sites around the world on relatively flat ground away from the influence of surrounding structures and should not be taken as exact calculations of movement but rather order of magnitude estimates. Our calculations of ground movements are based on Tokimatsu & Seed, 1987 and Youd et al., 2002. We suggest that the design team review the predicted ground movements and confirm that they are acceptable.

5.2.2 Global Stability Analysis of Shiploader Area

We have conducted a seismic slope stability assessment for the foreshore slopes considering the 1 in 2,475 year return period NBCC2015 design earthquake. We modelled a critical cross-section using the commercial software, Slope/W by GEO-SLOPE, to complete a limit equilibrium analysis of the proposed shiploader area and adjacent slope under static and seismic conditions. The subsurface stratigraphy was estimated based on our test hole information.

The results of our analysis indicate that the shiploader area has a global factor of safety of about 1.7 and 1.2 under static and seismic conditions, respectively.

Based on our liquefaction analysis we expect that the sands beneath the site will liquefy during the design earthquake, resulting is a significant strength reduction. The residual strength of the liquefied soil was estimated based on the recommendations in the Greater Vancouver Liquefaction Task Force Report (May 2007). The critical cross-section was re-analysed using the residual strengths, which resulted in a factor of safety slightly above unity.

Based on the results of our global stability analyses, we are of the opinion that adequate factors of safety are achieved considering the shiploader configuration with the recommended densification. However, the structural design team will need to evaluate the structures with respect to the seismic performance-based criteria for the project. Our global stability analysis does not account for the wharf structure and we have not analysed the internal stability or adequacy of the existing wharf or bulkheads.

The results of our global stability analyses are presented in Appendix F of this report.

6.0 RECOMMENDATIONS

6.1 Grade Supported Foundations

6.1.1 Stripping and Grading Fills

The site should be stripped of asphalt, debris, and any other organic, loose or soft soils prior to placement of any engineered fills that will support foundations and new pavement structures.

Any grade reinstatement below the slab elevations should be completed using engineered fill. In the context of this report, engineered fill is clean sand placed in controlled 300 mm thick lifts and compacted to a standard of 100 percent of ASTM D698 (Standard Proctor) maximum dry density. Compaction testing should be completed on all lifts to confirm that the required standard has been met.

6.1.2 Preloading

Preloading is not expected to be required provided that some long term settlement can be tolerated by the structural designer and the owner.

If required to reduce post-construction settlement, the structure silo areas could be preloaded to a stress level that is consistent with the average weight of the structures as well as the foundation types recommended.

6.1.3 Subgrade Improvement

We anticipate subgrade improvement to be required to strengthen the soils beneath grade supported foundations. This can be achieved using rammed aggregate piers which consist of 0.6 metre diameter stone columns. For the steel silos option, the piers would be spaced at approximately 2.4 metres on-centre (triangular) to a depth of approximately 12 metres below grade.

In addition to providing subgrade improvement, the piers would mitigate liquefaction potential and therefore liquefaction-induced displacements.

We expect that the silos will be required to resist overturning demands from transient loading. Therefore, we recommend that any uplift loads be resisted using rammed aggregate pier anchors. The anchors would consist of steel plates installed at the base of individual rammed aggregate piers with tie-rods extending to the footing elevation to provide uplift resistance. For rammed aggregate pier anchors installed to a depth of 12 metres below grade, we expect service uplift capacities of 150 kN per anchor. Load testing would be required to optimize the pier design capacity.

We recommend a pre-production subgrade load test be completed to confirm the 2.4 metre size and spacing of the rammed aggregate piers is sufficient to achieve the bearing capacity requirements.

6.1.4 Raft Foundations

For raft foundations supported on a rammed aggregate pier improved subgrade of engineered fill or sand and gravel fill, we recommend that the raft foundations be designed based on a serviceability limit states (SLS) bearing pressure of 190 kPa for the 2.4 metre triangular pier spacing.

The factored Ultimate Limit States (ULS) bearing pressure may be taken as 1.5 times the SLS bearing pressure given above. Under seismic conditions, the factored ULS bearing pressure can be taken as 2 times the SLS bearing pressure given above.

We estimate that post-construction settlements will be about 50 to 150 mm with 1:300 differential provided that foundations are designed as recommended. Our settlement estimate can be refined once the raft stress distribution has been provided by the structural engineer. We expect that total settlements can be reduced by preloading or using grouted piers throughout the raft footprint.

Reinforced concrete raft foundations can be designed using an unfactored modulus of subgrade of 15 MPa/m.

The raft slabs should be underlain by a minimum 150 mm thick layer of 19 mm clear crush gravel.

6.2 Pile Foundations

6.2.1 Site Preparation

For pile supported structures, no special site preparation is required. However, densification will be necessary along the foreshore to minimize liquefaction induced displacements after large earthquakes depending on the design criteria for the project.

6.2.2 Pile Design

We expect that a number of pile types are suitable to support the proposed structures, including steel pipe piles, helical piles and cast-in-place concrete piles. We expect that steel pipe piles would be most economical for this project.

We expect that nominal 200 mm, 300 mm and 600 mm diameter steel pipe piles driven to depths of approximately 15 to 19 metres below grade would be suitable to support factored Ultimate Limit States (ULS) compression loads of 400 kN, 800 kN, and 2,000 kN respectively. The 200 and 300 mm diameter piles could be driven open-ended assuming that a soil plug will form to develop adequate toe resistance. The 600 mm diameter piles would require closed-ended driving to prevent the loss of tip capacity from soil plug relaxation.

We estimate long-term settlements would be less than 25 mm total and 1:500 differential for pile supported structures, provided that no grade increases, including stockpiles, are placed near the proposed structures.

Larger diameter, open-ended piles driven to refusal in the dense till deposits at depth would be suitable to support much higher design loads, though the pile depths would likely be in the range of 40 to 50 metres, depending on the layout of the silos and strength of the till. For piles driven to refusal in till, factored ULS pile capacities would be 110 N per sq.mm. of steel area. Further investigation would be required to estimate the till depth in the ship loader area.

All piles should be spaced at a minimum of 3 times the pile diameter, centre-to-centre. The ULS tensile capacities under seismic conditions should be taken as 0.4 times the factored ULS capacities given above. For the pile capacities given above, we recommend that pre-production pile load testing be completed to confirm the pile capacities.

Lateral pile analyses should be carried out once the pile design loads, sizes and arrangement are known. Pile designed as recommended above will not require any further reduction for downdrag effects due to liquefaction.

6.2.3 Pile Supported Structures to Exterior Grade Transitions

We recommend that hinged slabs be provided in any loading areas that transition between grade supported slabs and pile supported slabs. Alternatively, regrading of the area surrounding the structure could be completed periodically to adjust the transition areas.

6.2.4 Densification for Ship Loader

Densification along the foreshore for the ship loader is intended to minimize liquefaction induced lateral spread. Lateral spread can be minimized using a densification berm along the foreshore. We understand that groundwater discharge is to be minimized due to environmental constraints, therefore the densification method employed should minimize waste water. Standard stone columns are not considered suitable in this case. We expect that the following methods and densification patterns would be suitable for the shiploader area:

- 300 to 400 mm butt diameter timber piles at 1.8 m triangular spacing
- 600 mm diameter RAPs at 2.4 m triangular spacing
- 900 mm diameter bottom feed stone columns at 2.7 m triangular spacing

The densification berm should be at least 10 metres in width and extend a minimum of 10 metres beyond the edges of each of the ship loader towers. All densification points should extend to a depth of 14 metres below grade.

6.3 Temporary Excavations

Shallow excavations for utilities, pile caps and raft slabs can be done using open cuts at 1 horizontal to 1 vertical (1H:1V) above the water table. WorkSafeBC approved shoring cages would also be suitable to support trench excavations. Review of the cut slopes by a professional engineer is required prior to worker-entry into excavations exceeding 1.2 metres in depth.

Temporary excavations for the receiving pit would require shoring and groundwater control given the contemplated depth of up to 14 metres below grade. A number of methods could be utilized including sheet pile walls, secant pile wall or jet grout wall. A sheet pile shoring system is expected to be most economical however it is also likely to allow the most seepage through joints of the wall and through the base. Given the environmental constraints on the project, we expect it will be preferred to minimize groundwater discharge from the site. In this case, we recommend that a jet grout cutoff wall be considered. The shoring walls and base slab could be constructed in advance of any excavations to minimize seepage into the excavation. We expect that internal bracing would be preferred to using tie backs since the tie backs would introduce perforations in the wall that would need to be sealed.

GeoPacific can prepare a detailed shoring design upon request.

6.4 Site and Foundation Drainage

We expect that the top of the raft slabs will be slightly above surrounding grades and any below grade structures, including the receiving pit, would be tanked. Therefore site and foundation drainage systems are not required for any of the structures.

6.5 New Asphalt Pavements

In our experience, the minimum asphalt pavement structure required for truck traffic is presented in Table 2, below.

Table 2: Recommended Minimum Pavement Structure

MATERIAL	THICKNESS (mm)
Asphaltic Concrete	85
19 mm minus crushed gravel base course	100
75 mm minus sand/sand and gravel	300

All base and subbase course materials should be systematically compacted in thin lifts to a minimum density equivalent to 95% of their "Modified Proctor" maximum dry density, at water contents within 2% of their "optimum" moisture contents for compaction, determined in accordance with ASTM D1557. The base and subbase materials should be tested to confirm a minimum Soaked California Bearing Ratio value of 80 and 20, respectively.

6.6 Utilities

We expect typical bedding and backfilling of utilities for the project. We do not anticipate the need for de-watering, though deeper installations such as storm and sanitary sewers may encounter groundwater. This de-watering should be done with pumped sumps so as not to impact local groundwater levels.

6.7 Seismic Design

The soils underlying this site are prone to liquefaction and as defined in Table 4.1.8.4.A. of NBCC 2015 are classified as Site Class F. In accordance with the NBCC 2015, a site specific dynamic analysis is required to ascertain a design spectral response at the ground surface for use in the seismic structural design.

The seismic hazard at the site is comprised of crustal, in-slab and interface sources. For our site specific dynamic analysis, a total of eleven pairs of horizontal earthquake time histories for each return period of interest were proportionally selected based on the source contributions, magnitude, hypocentral distance, recording station geology and spectral shape from sites throughout the world. We have assumed that the structures will have fundamental periods on the order of 0.5 to 2.0 seconds. The time histories were spectrally matched to the NBCC 2015 Site Class C design spectrum for the Fraser Delta area.

Utilizing the available soil information we established a soil column model employing the equivalent-linear site specific analysis computer software SHAKE 2000 (Version 9.99.9910 by GeoMotions). The spectrally matched time histories were applied to the base of the model.

The results from our analysis as well as the referenced NBCC 2015 design spectra for Site Class D and Site Class E sites are presented in Appendix E. Based on the results of our analysis we recommend that the "Recommended Design Spectrum" shown on each figure be employed in the structural design. The recommended design spectra are based on the existing soil profile with densification as recommended above.

For the ship loader towers constructed along the foreshore, we recommend that grade beams be provided to minimize the potential impacts of lateral spread on the structures.

6.8 Utilities

Flexible connections would be required between the pile supported elements and the grade supported slab and exterior grades to allow for future differential settlements. Underground services connected to any pile supported elements must be attached to the pile caps. Pile supported services should be backfilled with pea gravel only. Bedding and backfill of grade supported services should be in accordance with MMCD documents.

7.0 FIELD REVIEWS

We have recommended the review of certain aspects of the work. It is the responsibility of the contractor to advise GeoPacific Consultants Ltd. (a minimum of 48 hours in advance) that a field review is required.

Geotechnical field reviews are normally required at the time of the following:

1. Stripping – Review of stripped subgrade prior to any fill placement
2. Fill – Review of engineered fill materials and compaction
3. Subgrade Improvement – Review of impact pier installation and testing
4. Densification – Review of densification berm installation along foreshore
5. Excavations – Review of any excavations in excess of 1.2 metres prior to worker-entry
6. Shoring – Review of shoring installation for receiving pit
7. Foundations – Review of foundation subgrades for raft foundations
8. Piles – Review of pile installations and testing.

It is critical that these reviews are carried out to ensure that our intentions have been adequately communicated. It is also critical that contractors working on the site view this document in advance of any work being carried out so that they become familiarised with the sensitive aspects of the works proposed. It is the responsibility of the developer to notify GeoPacific Consultants Ltd. when conditions or situations not outlined within this document are encountered.

8.0 CLOSURE

We are pleased to be of assistance to you on this project and we trust that our comments and recommendations are both helpful and sufficient for this project. If you would like further details or require clarification, please do not hesitate to contact us.

For:
GeoPacific Consultants Ltd.

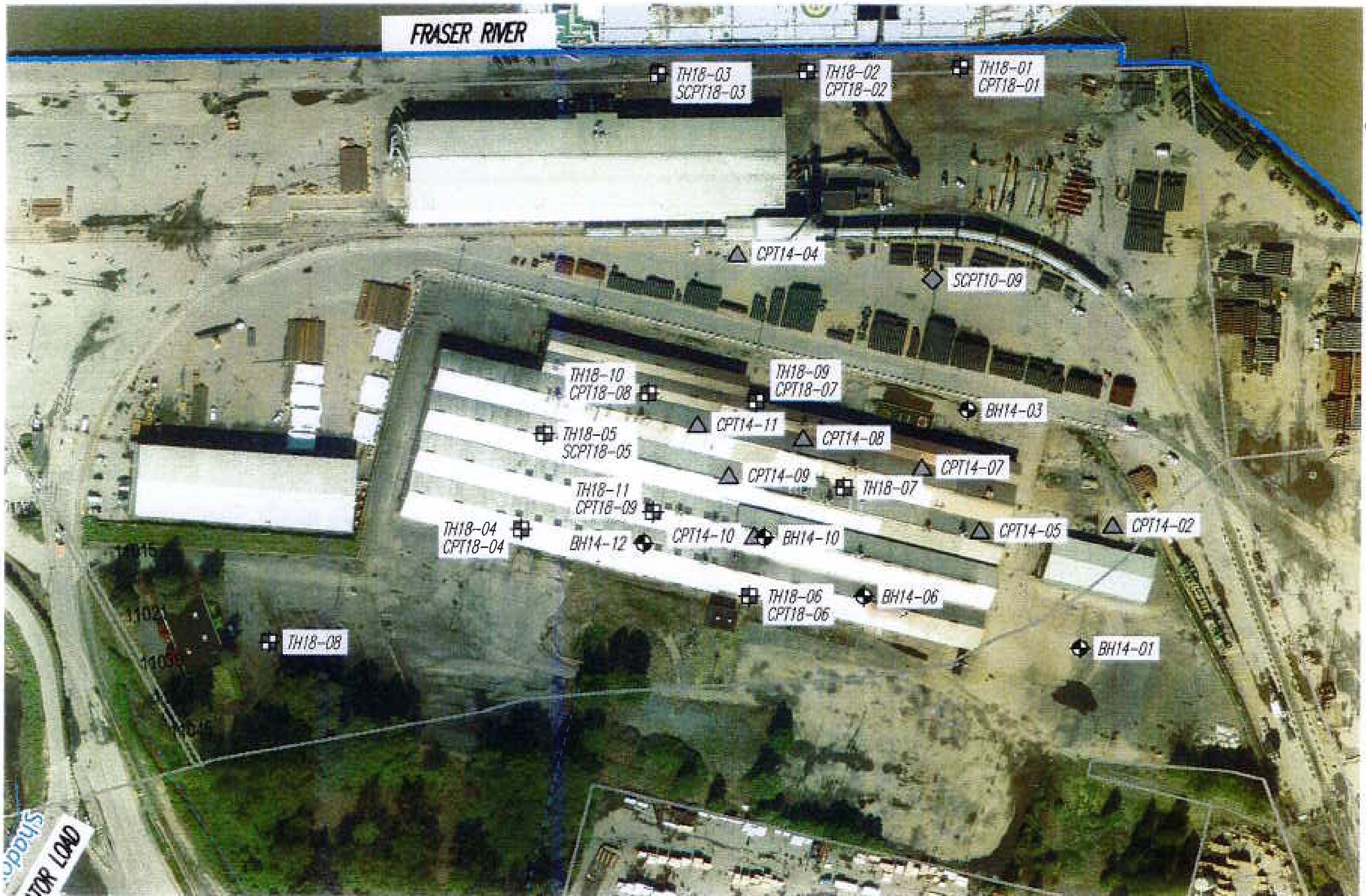
Reviewed by:

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA K.J.L. BODNAR #37915

MAR 2 9 2018

Kevin Bodnar, M.Eng., P.Eng.
Principal

Matt Kokan, M.A.Sc., P.Eng.
Principal



*HOLE LOCATIONS ARE APPROXIMATE

L E G E N D :

- BH14-# – BORE HOLE (TH) LOCATION (BY EXP)
- CPT14-# – CONE PENETRATION TEST (CPT) LOCATION (BY EXP)
- SCPT10-# – SEISMIC CONE PENETRATION TEST (SCPT) LOCATION (BY CONETEC)
- TH18-# – TEST HOLE (TH) LOCATION (2018, BY GEOPACIFIC)

SITE PLAN

N.T.S.

REFERENCE:

GEOPACIFIC
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DATE	NOVEMBER 30, 2017	
DRAWN BY: H.S.	APPROVED BY: K.B.	REVIEWED BY: K.B.
SCALE:	AS SHOWN	

FRASER SURREY DOCKS
FRASER SURREY DOCKS, SURREY, BC
TEST HOLE LOCATION PLAN

FILE NO: 15657
DWG. NO: 15657-01

REVISIONS:
A MARCH 28, 2018
B
C

APPENDIX A.1 – TEST HOLE LOGS BY GEOPACIFIC

Test Hole Log: TH18-01 (CPT18-01)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

SOIL DESCRIPTION	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
Ground Surface					
Asphalt (380 mm)	0.0				
Sand and gravel [FILL] compact to dense SAND and GRAVEL fill, brown, dry					
Sand [FILL] compact SAND fill, brown, medium grained, trace silt, dry	0.9				
Sand compact SAND, medium grained, trace subangular gravel <10 mm, grey, moist to wet	3.0			▼	3.6 m estimated water table depth based on CPT pore pressure data
becomes dense @ 5.0 m					
some subrounded gravel <40 mm @ 7.3 m					
becomes fine grained after 7.6 m					
End of Borehole	12.2				

Logged: ZH
Method: Solid stem auger
Date: 6-Mar-2018

Datum: Ground elevation
Figure Number: A.01
Page: 1 of 1

Test Hole Log: TH18-02 (CPT18-02)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax 604-439-9189

INFERRED PROFILE

Depth (m)	Soil Description	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0	Ground Surface					
0	**Asphalt (360 mm)**	0.0				
0.36	**Sand and gravel [FILL]** compact to dense SAND and GRAVEL fill, some cobbles, brown, dry					
0.9	**Sand [FILL]** compact SAND fill, brown, medium grained, trace silt, dry; trace subangular gravel < 30mm @ 1.5 m	0.9				
3.0					▼	3.0 m estimated water table depth based on CPT pore pressure data
3.4	**Sand** compact to dense SAND, medium grained, trace subangular gravel <10 mm, grey, moist to wet	3.4				
6.7	becomes fine grained from 6.7 m to 10.7 m					
11.0	becomes dense after 11.0 m					
12.2	End of Borehole	12.2				

Logged: ZH
Method: Solid stem auger
Date: 6-Mar-2018

Datum: Ground elevation
Figure Number: A.02
Page: 1 of 1

Test Hole Log: TH18-03 (SCPT18-03)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
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Depth (m)	SOIL DESCRIPTION (INFERRED PROFILE)	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0	Ground Surface					
0.0	***Asphalt (380 mm)***	0.0				
	Sand and gravel [FILL] compact to dense SAND and GRAVEL fill, trace cobbles, brown, dry					
0.9	***Sand [FILL]*** dense to compact SAND fill, brown, medium grained, some subangular gravel <20 mm, dry	0.9				
3.0	***Sand*** compact SAND, medium grained, trace silt, grey, moist to wet	3.0			▼	3.4 m estimated water table depth based on CPT pore pressure data
	trace subangular gravel <10 mm from 8.0 m to 9.1 m					
9.1	End of Borehole	9.1				

Logged: ZH
Method: Solid stem auger
Date: 6-Mar-2018

Datum: Ground elevation
Figure Number: A.03
Page: 1 of 1

Test Hole Log: TH18-04 (CPT18-04)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
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Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (ft / m)	SOIL DESCRIPTION	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0 ft / 0 m	Ground Surface					
	Concrete (300 mm)	0.0				
	Gravel [FILL]					
	Sand [FILL] compact SAND fill, medium grained, brown, slightly moist to dry					
	Sand compact SAND, fine to medium grained, grey, moist	3.4			▼	3.7 m estimated water table depth based on CPT pore pressure data
	Sand loose to compact silty SAND, grey, moist to wet; trace wood fiber @ 4.9 m	4.3				
	Silt stiff sandy SILT, grey, moist	5.2				
	Sand compact SAND, medium grained, trace silt, grey, moist; fine grained after 6.7 m	5.8				
41 ft / 12 m	End of Borehole	12.2				

Logged: ZH
Method: Solid stem auger
Date: 7-Mar-2018

Datum: Ground elevation
Figure Number: A.04
Page: 1 of 1

Test Hole Log: TH18-05 (SCPT18-05)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
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INFERRED PROFILE							
Depth (ft / m)	Symbol	SOIL DESCRIPTION	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0 / 0		Ground Surface					
		Concrete (300 mm)	0.0				
		Gravel [FILL]					
		Sand [FILL] compact SAND fill, medium grained, brown, dry slightly moist @ 3.0 m					
13 / 4		**Silt** stiff sandy SILT, trace wood fiber, grey, moist	4.0			▼	4.0 m estimated water table depth based on CPT pore pressure data
20 / 6		**Sand** compact SAND, medium grained, trace silt, grey, moist	6.1				
30 / 9		End of Borehole	9.1				

Logged: ZH
Method: Solid stem auger
Date: 7-Mar-2018

Datum: Ground elevation
Figure Number: A.05
Page: 1 of 1

Test Hole Log: TH18-06 (CPT18-06)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (m)	Soil Description	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0	Ground Surface					
0	**Concrete (350 mm)**	0.0				
	Gravel [FILL]					
	Sand [FILL] compact SAND fill, medium grained, brown, dry; moist to wet @ 3.7 m; grey @ 3.7 m				▼ (4.5 m)	4.5 m estimated water table depth based on CPT pore pressure data
4.9	**Silt** stiff sandy SILT, grey, moist	4.9				
5.8	**Sand** compact SAND, medium grained, grey, moist	5.8				
9.1	End of Borehole	9.1				

Logged: ZH
Method: Solid stem auger
Date: 7-Mar-2018

Datum: Ground elevation
Figure Number: A.06
Page: 1 of 1

Test Hole Log: TH18-07

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE							
Depth (ft / m)	Symbol	SOIL DESCRIPTION	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0 ft / 0 m		Ground Surface					
		Concrete (270 mm)	0.0				
		Gravel [FILL]					
		Sand [FILL] compact SAND fill, medium grained, brown, dry					
12 ft / 3.7 m		**Sand** compact SAND, medium grained, grey, moist silty from 4.3 m to 4.9 m becomes fine grained from 6.1 m to 6.7 m	3.7			▼	3.7 m estimated water table depth
40 ft / 12.2 m		End of Borehole	12.2				

Logged: ZH
Method: Solid stem auger
Date: 7-Mar-2018

Datum: Ground elevation
Figure Number: A.07
Page: 1 of 1

Test Hole Log: TH18-08

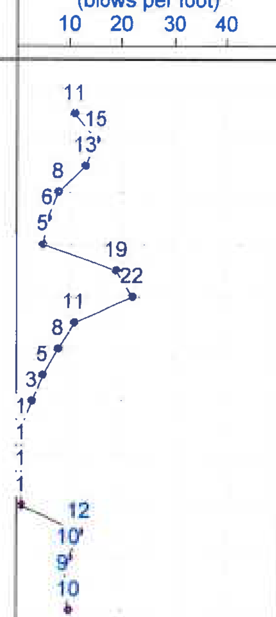
File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (m)	Soil Description	Depth (m)/Elev (m)	Moisture Content (%)	Groundwater / Well	Remarks
0	Ground Surface				
0	**Asphalt (30 mm)**	0.0			
0.03	**Sand [FILL]** compact to loose SAND fill, medium grained, brown, dry				
3.4	grey and moist @ 3.4 m			▼	3.4 m estimated water table depth
4.1	**Silt** firm SILT, grey, some fine sand, moist to wet	4.1			
4.9	**Sand** compact SAND, medium grained, grey, moist to wet	4.9			
6.1	End of Borehole	6.1			

DCPT (blows per foot)



Logged: ZH
Method: Solid stem auger
Date: 13-Mar-2018

Datum: Ground elevation
Figure Number: A.08
Page: 1 of 1

Test Hole Log: TH18-09 (CPT18-07)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (m)	Symbol	Soil Description	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0		Ground Surface					
0.0–0.05		***Asphalt (50 mm)***	0.0				
		Gravel [FILL]					
		Sand [FILL] compact SAND fill, medium grained, brown, dry becomes moist and grey @ 3.5 m					
4.0		***Silt*** stiff sandy SILT, grey, moist	4.0			▼	4.0 m estimated water table depth based on CPT pore pressure data
4.6		***Sand*** compact SAND, medium grained, some silt, grey, moist	4.6				
6.1		End of Borehole	6.1				

Logged: ZH
Method: Solid stem auger
Date: 13-Mar-2018

Datum: Ground elevation
Figure Number: A.07
Page: 1 of 1

Test Hole Log: TH18-10 (CPT18-08)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

Depth (ft / m)	Symbol	INFERRED PROFILE – SOIL DESCRIPTION	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0 ft / 0 m		Ground Surface					
		Concrete (250 mm)	0.0				
		Gravel [FILL]					
		Sand [FILL] compact SAND fill, medium grained, brown, dry becomes moist and grey @ 3.7 m					
		Silt stiff sandy SILT, grey, moist	4.0			▼	4.4 m estimated water table depth based on CPT pore pressure data
		Sand compact SAND, medium grained, grey, moist to wet silty from 4.3 m to 5.2 m					
		End of Borehole	9.1				

Logged: ZH
Method: Solid stem auger
Date: 13-Mar-2018

Datum: Ground elevation
Figure Number: A.10
Page: 1 of 1

Test Hole Log: TH18-11 (CPT18-09)

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Site Location: FRASER SURREY DOCKS, SURREY, BC

GEOPACIFIC CONSULTANTS
1779 West 75th Avenue, Vancouver, BC, V6P 6P2
Tel: 604-439-0922 Fax:604-439-9189

INFERRED PROFILE

Depth (m)	Soil Description	Depth (m)/Elev (m)	Moisture Content (%)	DCPT (blows per foot) 10 20 30 40	Groundwater / Well	Remarks
0	Ground Surface					
0	**Concrete (270 mm)**	0.0				
	Gravel [FILL]					
	Sand [FILL] compact SAND fill, medium grained, brown, dry becomes moist and grey @ 3.4 m				▼ (4.0 m)	4.0 m estimated water table depth based on CPT pore pressure data
4.3	**Silt** stiff sandy SILT, grey, moist	4.3				
4.9	**Sand** compact SAND, medium grained, grey, moist to wet some silt 4.9 m to 5.8 m trace subangular gravel <10 mm @ 7.0 m	4.9				
9.1	End of Borehole	9.1				

Logged: ZH
Method: Solid stem auger
Date: 13-Mar-2018

Datum: Ground elevation
Figure Number: A.11
Page: 1 of 1

APPENDIX A.2 – TEST HOLE LOGS BY OTHERS

RECORD OF BOREHOLE : BH14-01

exp. exp Services Inc

CLIENT: Parrish & Hiembercker Ltd.
PROJECT NUMBER: VAN-0222989-A0
DRILLING DATE: 2014-12-16 to 2014-12-17
DRILLING CONTRACTOR: Sea to Sky Drilling Ltd.
DRILLING METHOD: Mud Rotary
LOGGED BY: RK CHECKED BY: BW

PROJECT NAME: Proposed P&H Fraser Terminal
PROJECT LOCATION: Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION: N: E:
ELEVATION:
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 2.6m (Dec. 17)
▼ AFTER DRILLING 2.6m (Jan. 6) Inferred from nearby MW

DEPTH (m)	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m	FINES CONTENT (%) / MOISTURE CONTENT (%)
0	25mm Asphalt							
	SAND and GRAVEL, trace silt, brownish grey, damp (FILL)	0.1	S01					MC 3
	SAND, trace silt, brown, damp, fine to medium grained (compact to loose) (FILL)	0.3	S02					
1			S03	SPT			10	
2.6	- becomes grey and wet		S04	SPT			7	
4.0	SILT, some clay to clayey, grey, firm to stiff	4.0	S06 S05 S07	SPT			5	MC 48, 90, 210
	- 0.2m thick peat organic silt layer at 4.3m							
5	FV > 50 kPa (initial), too stiff for remoulded		S08	ST				MC 42
	- SILT, some organics							
5.5	SAND, some silt to silty, grey, wet (loose)	5.5	S09	SPT			5	50
7.3	- becomes interlayered organic silt and sand below 7.3m		S10	SPT			6	55
9			S11	SPT			7	50
10	- becomes SAND, trace silt, grey, wet, fine grained (compact)		S12	SPT			13	30
12	- silt content decreases to none		S13	SPT			10	

(Continued Next Page)

RECORD OF BOREHOLE : BH14-01

exp. exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-16 to 2014-12-17
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK CHECKED BY BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ∇ AT TIME OF DRILLING 2.6m (Dec. 17)
∇ AFTER DRILLING 2.6m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m ▲ (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) □ (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		SAND, trace silt, grey, wet, fine to medium grained (loose)							
13		- silt content increases to some (becomes loose)							
		- at least 150mm of woody organics		S14	SPT			7	
14									
15		- trace of silt and gravel (becomes compact)		S15	SPT			21	
16									
17									
18		- 50mm layer of organics		S16	SPT			12	
19									
20									
21				S17	SPT			21	

Bottom of hole at 21.3m.

RECORD OF BOREHOLE : BH14-03

exp Services Inc

CLIENT: Parrish & Hiembercker Ltd.
PROJECT NUMBER: VAN-0222989-A0
DRILLING DATE: 2014-12-15 to 2014-12-16
DRILLING CONTRACTOR: Sea to Sky Drilling Ltd.
DRILLING METHOD: Mud Rotary
LOGGED BY: RK CHECKED BY: BW

PROJECT NAME: Proposed P&H Fraser Terminal
PROJECT LOCATION: Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION: N: E:
ELEVATION:
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 3.3m (Dec. 16)
▼ AFTER DRILLING 3.2m (Jan. 6) inferred from nearby MW

SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	SAMPLE TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT, MOISTURE CONTENT (PL, MC ●, LL)
38mm Asphalt layer	0.0	S01	GB				
GRAVEL and SAND, brown (compact) (FILL)	0.2	S02	GB				4
SAND, trace silt and gravel, brown, damp (compact to loose) (FILL) - becomes grey, moist - gravel content decreases to none		S03	SPT			10	
- becomes brownish grey		S04	SPT			9	
▼ No Recovery	3.0	S05	SPT			6	
SILT, trace to some sand, some clay, grey, plastic (soft to firm)	5.5	S06	SPT			6	39
		S07	ST				
SAND, some silt to silty, grey (very loose)	6.6						
SILTY SAND to SANDY SILT interlayers, grey (loose/firm) - becomes some organics	7.0	S08	SPT			4	43
SAND, trace silt to some silt in interlayers, grey, wet (loose)	8.5	S09	SPT			5	37
- becomes SAND, trace silt, grey, wet, fine to medium grained (compact)		S10	SPT			12	10 (fines)
		S11	SPT			12	

(Continued Next Page)

RECORD OF BOREHOLE : BH14-03

exp Services Inc

CLIENT: Parrish & Hiembercker Ltd.
PROJECT NUMBER: VAN-0222989-A0
DRILLING DATE: 2014-12-15 to 2014-12-16
DRILLING CONTRACTOR: Sea to Sky Drilling Ltd.
DRILLING METHOD: Mud Rotary
LOGGED BY: RK CHECKED BY: BW

PROJECT NAME: Proposed P&H Fraser Terminal
PROJECT LOCATION: Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION: N: E:
ELEVATION:
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 3.3m (Dec. 16)
▼ AFTER DRILLING 3.2m (Jan. 6) Inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT, MOISTURE CONTENT (PL, MC, LL) (20 40 60 80)
		SAND, trace silt, grey, wet, fine to medium grained (compact)							
13		- 100mm peat inclusion at 13.3m		S12	SPT			9	103
14									
15		- some gravel below 15m		S13	SPT			15	
16									
17									
18		- gravel content becomes none		S14	SPT			15	
19									
20									
21				S15	SPT			16	

Bottom of hole at 21.3m.

RECORD OF BOREHOLE : BH14-06

exp Services Inc

CLIENT: Parrish & Hiembercker Ltd.
PROJECT NUMBER: VAN-0222989-A0
DRILLING DATE: 2014-12-11 to 2014-12-12
DRILLING CONTRACTOR: Sea to Sky Drilling Ltd.
DRILLING METHOD: Mud Rotary
LOGGED BY: RK CHECKED BY: BW

PROJECT NAME: Proposed P&H Fraser Terminal
PROJECT LOCATION: Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION: N: E:
ELEVATION:
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 2.8m (Dec. 12)
▼ AFTER DRILLING 2.7m (Jan. 6) inferred from nearby MW

SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m	MOISTURE CONTENT (%)
177mm Concrete Slab with ~6mm void below		S01	GB				
GRAVELLY SAND, brown, dry, subangular gravel (FILL)	0.2					24	
SAND, some fine gravel, dry, fine to medium grained (compact) (FILL)	0.5	S02 / S03	SPT				
- gravel conent becomes none		S04	SPT			14	
- becomes damp							
- becomes wet (compact to loose)		S05	SPT			10	
		S06	SPT			8	
CLAYEY SILT, grey, wet (soft)	5.5	S07	SPT			1	59
SILT, some sand to sandy (firm)	7.0	S08	SPT			5	50
SILT with fine sand, trace to some organics, grey, non-plastic (firm)	8.5	S09	SPT			5	44
FV = 48 kPa (initial), 2 kPa (remoulded)		S10	ST				
SILTY SAND, grey, wet, sand is fine grained (loose)	10.1	S11	SPT			5	47
SAND, some silt, with fiberous organics/peat	10.5						
interlayered SILTY SAND and ORGANICS and CLAYEY SILT, trace fine sand (firm) FV > 50 kPa (initial), too stiff for remoulded	10.6	S12	ST				
SILTY SAND, some organics, grey, wet (compact) - Organics content decreases to none below 11.8m	11.6 11.6	S13	SPT			10	63

(Continued Next Page)

CLIENT: Parrish & Hiembercker Ltd.	PROJECT NAME: Proposed P&H Fraser Terminal
PROJECT NUMBER: VAN-0222989-A0	PROJECT LOCATION: Fraser Surrey Docks, Surrey, BC
DRILLING DATE: 2014-12-11 to 2014-12-12	BOREHOLE LOCATION: N: E:
DRILLING CONTRACTOR: Sea to Sky Drilling Ltd.	ELEVATION:
DRILLING METHOD: Mud Rotary	GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 2.8m (Dec. 12)
LOGGED BY: RK CHECKED BY: BW	▼ AFTER DRILLING 2.7m (Jan. 6) inferred from nearby MW

DEPTH (m)	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN. (kPa)	SPT N VALUE BLOWS/0.3m ▲ (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) □ (20 40 60 80) / PLASTIC & LIQUID LIMIT, MOISTURE CONTENT PL MC LL (20 40 60 80)
	SILTY SAND, some organics, grey, wet (compact) *(continued)*							
13			S14	SPT			16	
14								
15	SAND, trace silt and gravel, grey, wet, fine grained (compact)	14.6	S15	SPT			16	
16			S16	SPT			22	6
17								
18			S17	SPT			14	
19			S18	SPT			13	
20								
21	- sand becomes fine to medium grained		S19	SPT			15	
22			S20	SPT			19	
23								
24			S21	SPT			22	

(Continued Next Page)

exp. exp Services Inc

RECORD OF BOREHOLE : BH14-06

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-11 to 2014-12-12
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK CHECKED BY BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 2.8m (Dec. 12)
▼ AFTER DRILLING 2.7m (Jan. 6) inferred from nearby MW

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		SAND, trace silt and gravel, grey, wet, fine grained (compact) *(continued)*							
25									
		CLAYEY SILT, wet, grey (firm to stiff)	25.3	S22	SPT			8	32
26		SAND, grey, wet, fine grained (compact)	25.6	S23	SPT				2[illegible]
27		- becomes some to trace silt		S24	SPT			14	30
		- organics lense							
28									
		Interlayered SILTY SAND and SILT (compact/stiff)	28.3	S25	SPT			12	33
29		SAND, trace silt, grey, wet, sand is fine grained (dense)	28.7	S26	SPT			31	32
30									

Bottom of hole at 30.5m.

RECORD OF BOREHOLE : BH14-10

exp Services Inc

CLIENT: Parrish & Heimbercker Ltd.
PROJECT NUMBER: VAN-0222989-A0
DRILLING DATE: 2014-12-17 to 2014-12-17
DRILLING CONTRACTOR: Sea to Sky Drilling Ltd.
DRILLING METHOD: Solid Stem Auger to 7.6m, Mud Rotary below
LOGGED BY: RK CHECKED BY: BW

PROJECT NAME: Proposed P&H Fraser Terminal
PROJECT LOCATION: Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION: N: E:
ELEVATION:
GROUND WATER LEVELS: ∇ AT TIME OF DRILLING 3.3m Inferred
∇ AFTER DRILLING —

DEPTH (m)	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLE NUMBER	TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m / DYNAMIC CONE BLOWS/0.3m	FINES CONTENT (%) / PLASTIC & LIQUID LIMIT, MOISTURE CONTENT
0	140mm CONCRETE SLAB							
	SAND, trace silt, brown, dry, fine to medium grained (FILL)	0.1						
1			S01	GB				
	- becomes damp to moist							
2			S02	GB				
3	- becomes wet (∇)							
4	- silt content becomes trace to some		S03	GB				Fines 5
5			S04	GB				Fines 2
6	- 25mm organic lense							
7	- 100mm organic lense		S05	GB				MC 48
	- 152mm organic lense							
	SILT, trace clay to clayey, grey, moist, plastic	7.5	S06	GB				MC 46
8			S07	ST				MC 43 (PL/LL shown)
	FV > 50 kPa (initial), 15 kPa (remoulded)							
9								
10			S08	SPT			3	MC 40
	SILT, some organics to orgnic silt, trace silt, grey, wet, firm	10.1						
	SAND, some silt to silty, grey, wet (loose to compact)	10.2						
11	- 50mm SILT lense		S09	SPT			10	

Bottom of hole at 11.3m.

exp. exp Services Inc

RECORD OF BOREHOLE : BH14-12

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-12 to 2014-12-15
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK CHECKED BY BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 2.7m (Dec. 15)
▼ AFTER DRILLING 2.7m (Jan. 6)

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m ▲ / DYNAMIC CONE BLOWS/0.3m	FINES CONTENT (%) □ / PLASTIC & LIQUID LIMIT, MOISTURE CONTENT (PL, MC, LL)
0	Concrete	190mm Concete Slab (No rebar found)		S01	GB				
	FILL	SAND, trace silt, brown, damp, fine to medium grained (compact to loose) (FILL)	0.2						
1				S02	SPT			11	
2–3		▼ - becomes wet - silt content becomes trace to some		S03	SPT			8	
4		- silt content becomes trace		S04	SPT			8	6
5									
6	SILT	SILT, some sand to sandy, grey, wet, fine to medium grained (firm to stiff)	5.5	S05	SPT			4	MC 40
7				S06	SPT			6	MC 35
8		- 127mm layer of SILT, some sand to sandy, some organics							
9	SILTY SAND	SILTY SAND, grey wet, loose	8.5	S07	SPT			4	MC 37
		- organics content becomes some - No recovery		S08	ST				
10	SAND	SAND, some silt, grey, wet, fine grained sand (loose to compact)	10.1	S09	SPT			7	MC 36
11–12		- Silt content decreases to trace		S10	SPT			10	8

(Continued Next Page)

RECORD OF BOREHOLE : BH14-12

exp. exp Services Inc

CLIENT Parrish & Hiembercker Ltd.
PROJECT NUMBER VAN-0222989-A0
DRILLING DATE 2014-12-12 to 2014-12-15
DRILLING CONTRACTOR Sea to Sky Drilling Ltd.
DRILLING METHOD Mud Rotary
LOGGED BY RK CHECKED BY BW

PROJECT NAME Proposed P&H Fraser Terminal
PROJECT LOCATION Fraser Surrey Docks, Surrey, BC
BOREHOLE LOCATION N: E:
ELEVATION
GROUND WATER LEVELS: ▽ AT TIME OF DRILLING 2.7m (Dec. 15)
▼ AFTER DRILLING 2.7m (Jan. 6)

DEPTH (m)	STRATA	SOIL DESCRIPTION	ELEV. DEPTH (m)	SAMPLES NUMBER	SAMPLES TYPE	RECOVERY %	POCKET PEN (kPa)	SPT N VALUE BLOWS/0.3m ▲ (20 40 60 80) / DYNAMIC CONE BLOWS/0.3m (20 40 60 80)	FINES CONTENT (%) □ (20 40 60 80) / PLASTIC & LIQUID LIMIT MOISTURE CONTENT PL MC LL (20 40 60 80)
		SAND, some silt, grey, wet, fine grained (compact)							
13		- Silt content decreases to trace to some		S11	SPT			14	
14									
15		- Silt content decreases to trace, becomes fine to medium grained with trace fine gravel (compact)		S12	SPT			18	
16				S13	SPT			19	
17									
18		- Silt content increases some silt to silty		S14	SPT	75		20	
19		- Silt content decreases to trace to some silt		S15	SPT			15	
20									
21		- trace silt		S16	SPT			24	

Bottom of hole at 21.3m.

exp.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

CCIL
CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC
ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

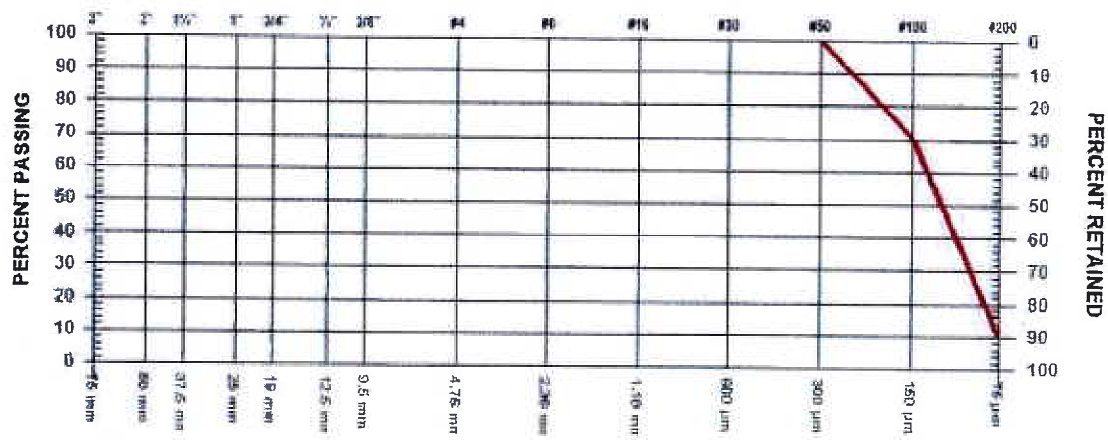
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 1 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 16,2014

SUPPLIER SITE
SOURCE TH14-03, SPT @ 33'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY H. WU
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm		
No. 16	1.18 mm		
No. 30	600 µm	100.0	
No. 50	300 µm	99.9	
No. 100	150 µm	70.6	
No. 200	75 µm	9.6	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp.
275-3001 Wayburne Drive
Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
250-372-5321

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CERTIFIED TESTING LABORATORY

SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
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C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC
ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 2 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 15,2014

SUPPLIER SITE
SOURCE TH14-06, SPT @ 53'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT, TRACE GRAVEL

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED

GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm	100.0	
3/8"	9.5 mm	98.5	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	96.8	
No. 8	2.36 mm	95.0	
No. 16	1.18 mm	92.7	
No. 30	600 µm	88.7	
No. 50	300 µm	65.9	
No. 100	150 µm	12.9	
No. 200	75 µm	6.1	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp.
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Burnaby, BC V5G 4W3
604-874-1245
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SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
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ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

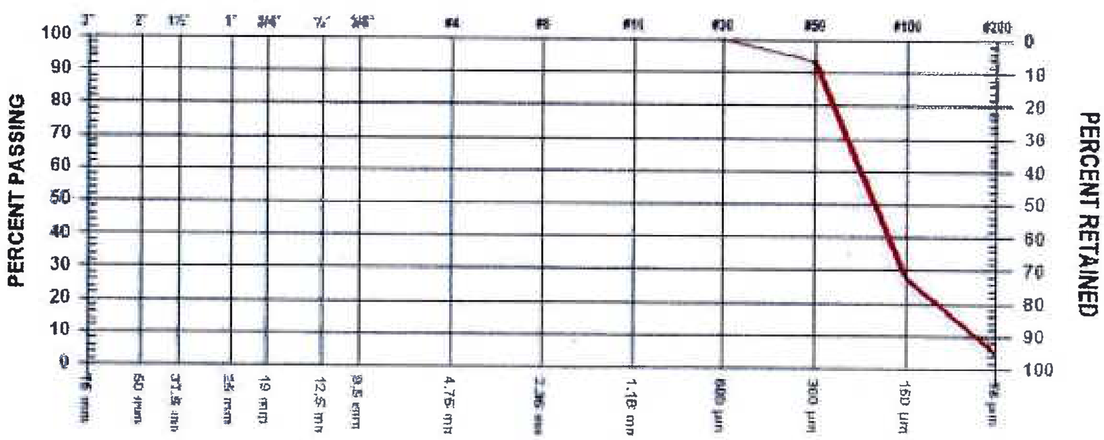
PROJECT PO #1419-302
GEOTECHNICAL
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 3 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 17,2014

SUPPLIER SITE
SOURCE TH14-10, SPT @ 17'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm		
No. 16	1.18 mm	100.0	
No. 30	600 µm	99.8	
No. 50	300 µm	93.4	
No. 100	150 µm	27.7	
No. 200	75 µm	4.8	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp.
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Kamloops Branch
250-372-5321

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SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC
ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

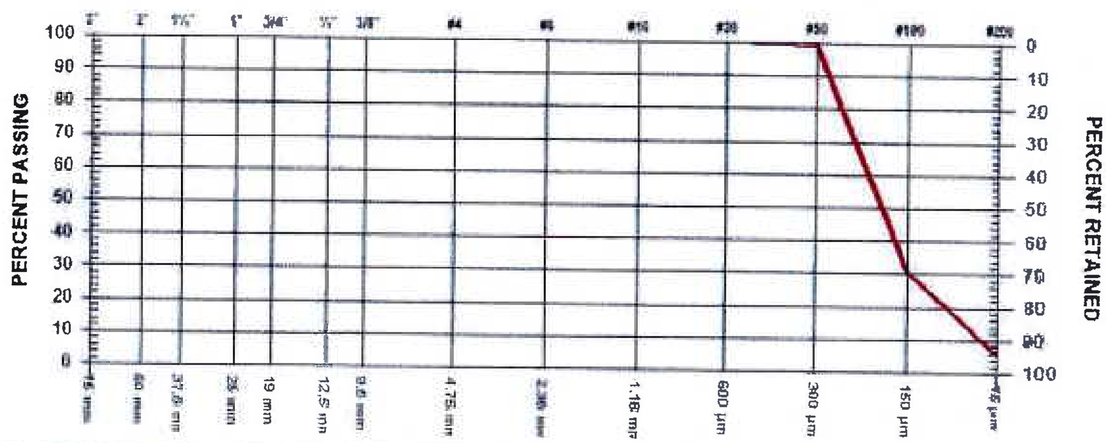
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 4 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 15,2014

SUPPLIER SITE
SOURCE TH14-12, SPT @ 13'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm		
No. 16	1.18 mm	100.0	
No. 30	600 µm	99.9	
No. 50	300 µm	98.9	
No. 100	150 µm	30.7	
No. 200	75 µm	5.5	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
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Burnaby, BC V5G 4W3
604-874-1245

Kamloops Branch
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SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC
ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

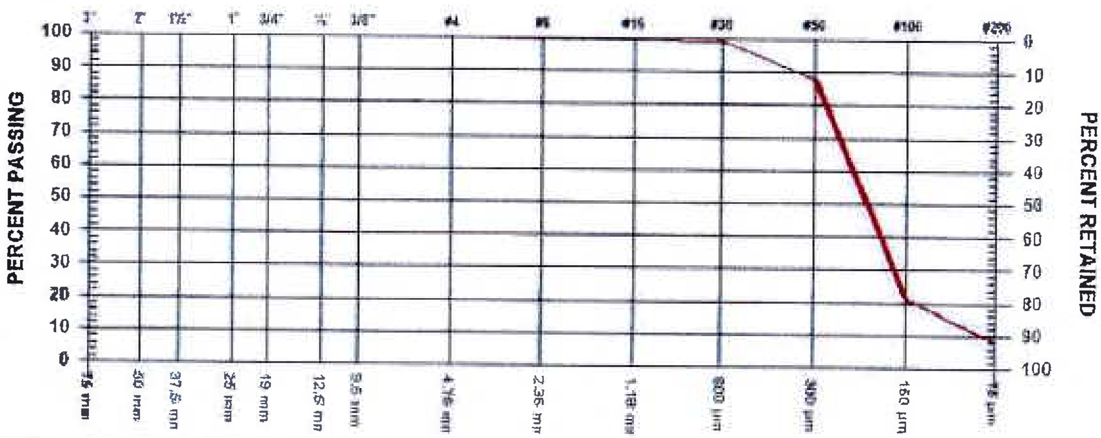
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 5 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 15,2014

SUPPLIER SITE
SOURCE TH14-12, SPT @ 38'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT, TRACE GRAVEL

SAMPLED BY R. KORHONEN
TESTED BY L. JEAN, AScT
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm		
1/2"	12.5 mm		
3/8"	9.5 mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	100.0	
No. 8	2.36 mm	99.6	
No. 16	1.18 mm	99.5	
No. 30	600 µm	99.0	
No. 50	300 µm	88.0	
No. 100	150 µm	21.3	
No. 200	75 µm	8.0	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp.

exp Services Inc.
275-3001 Wayburne Drive
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Kamloops Branch
250-372-5321

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SIEVE ANALYSIS REPORT
8 16 30 50 SERIES

PROJECT NO. 002-22989
CLIENT PARRISH & HEIMBECKER LTD. C/O
C.C. exp - BEN WEISS

TO
PARRISH & HEIMBECKER LTD. C/O CMC
ENGINEERING
#300 - 1160 DOUGLAS ROAD
BURNABY, BC
V5C 4Z6

ATTN: MR. MICHEL VANDER NOOT

PROJECT PO #1419-302
GEOTECHNICAL

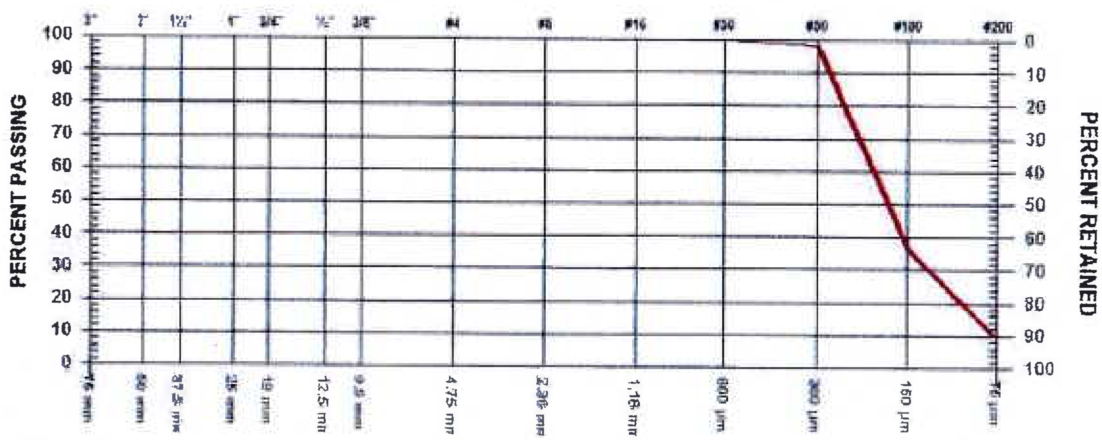
FRASER SURREY DOCKS
SURREY

CONTRACTOR

SIEVE TEST NO. 6 DATE RECEIVED Jan 22,2015 DATE TESTED Jan 23,2015 DATE SAMPLED Dec 17,2014

SUPPLIER SITE
SOURCE TH14-10, SPT @ 12.5'
SPECIFICATION
MATERIAL TYPE SAND, TRACE SILT

SAMPLED BY R. KORHONEN
TESTED BY H. WU
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
3"	75	mm		
2"	50	mm		
1 1/2"	37.5	mm		
1"	25	mm		
3/4"	19	mm		
1/2"	12.5	mm		
3/8"	9.5	mm		

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm		
No. 8	2.36 mm	100.0	
No. 16	1.18 mm	99.9	
No. 30	600 µm	99.8	
No. 50	300 µm	98.4	
No. 100	150 µm	36.7	
No. 200	75 µm	9.1	

COMMENTS
TEST METHOD: ASTM C136, C117.

 Jan 27,2015 exp Services Inc. BRIAN GRAY, AScT PER.

exp Services Inc.
Parrish and Heimbecker Ltd.

Atterberg Limits ASTM D4318
AGEX Pre-Feed Development at
Bekaert Building
Fraser Surrey Docks

VAN-00222989-A0
January 06, 2015

(1)
Sample Source: BH1 @ 16.5'
Sample ID: grey clay

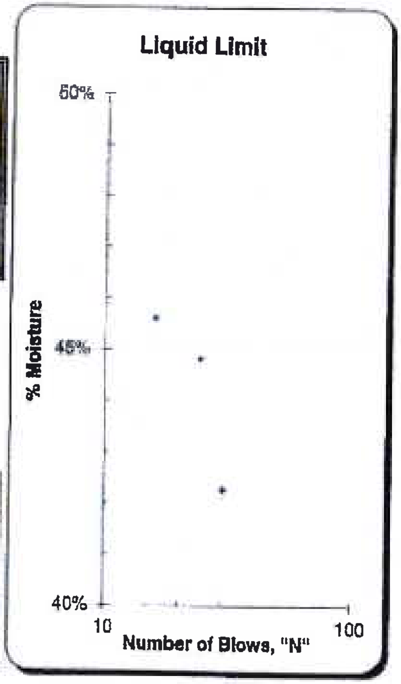
Liquid Limit Determination

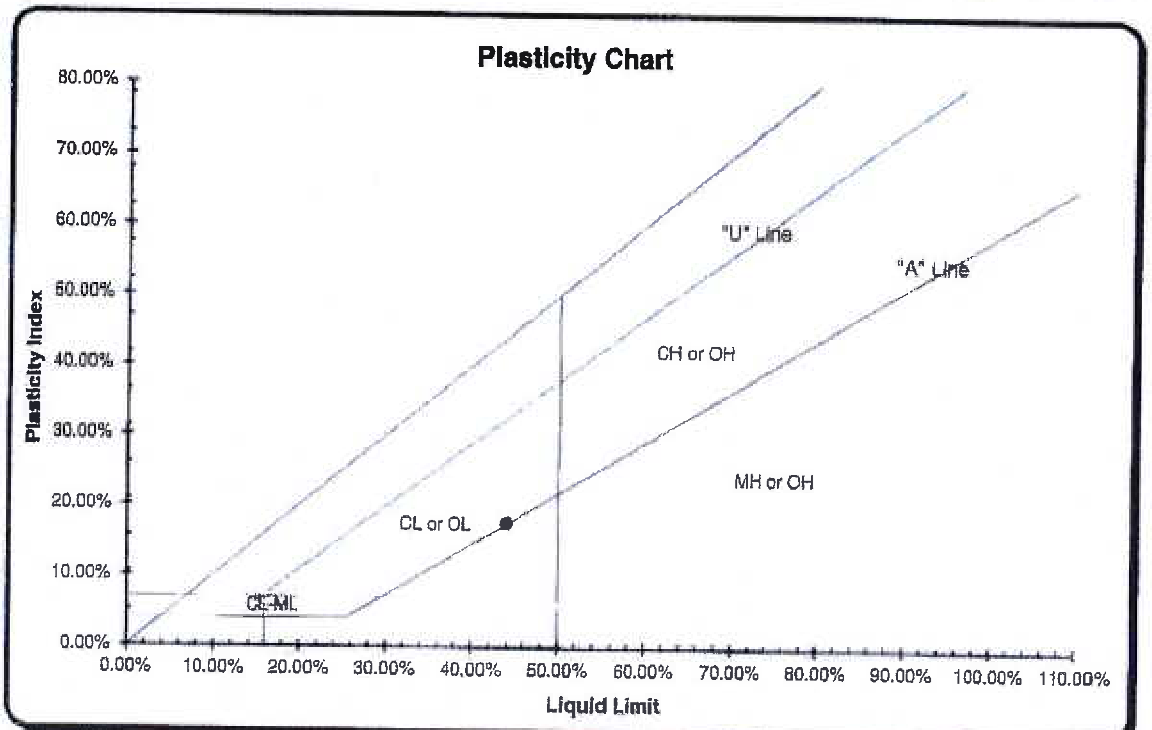
	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	27.09	20.90	104.17			
Weight of Dry Soils + Pan:	23.62	17.96	101.41			
Weight of Pan:	16.01	11.40	94.88			
Weight of Dry Soils:	7.61	6.56	6.53			
Weight of Moisture:	3.47	2.94	2.76			
% Moisture:	45.60%	44.82%	42.27%			
N:	16	24	30			

Liquid Limit @ 25 Blows: 43.85%
Plastic Limit: 26.20%
Plasticity Index, I_P: 17.65%
Moisture Content, M_C: 41.50%

Plastic Limit Determination

	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	98.88	103.25				
Weight of Dry Soils + Pan:	97.05	100.96				
Weight of Pan:	90.05	92.24				
Weight of Dry Soils:	7.00	8.72				
Weight of Moisture:	1.83	2.29				
% Moisture:	26.14%	26.26%				





Reported by: ____________
Kevin Bowyer, CTech

Reviewed by: ____________
Brian Gray, AScT

exp Services Inc.
Parrish and Heimbecker Ltd.

Atterberg Limits ASTM D4318
AGEX Pre-Feed Development at
Bekaert Building
Fraser Surrey Docks

VAN-00222989-A0
January 06, 2015

(2)
Sample Source: BH3 @ 21.5'
Sample ID: grey clay silt

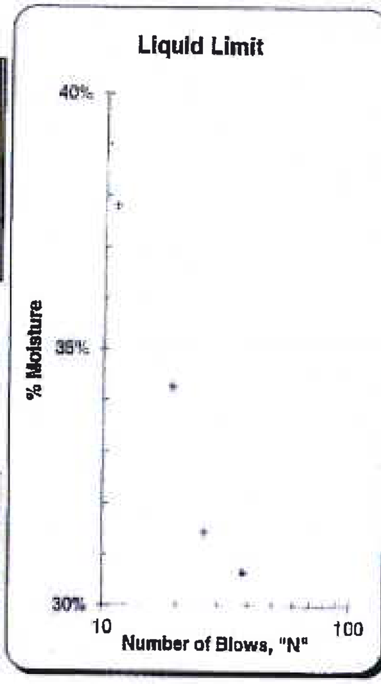
Liquid Limit Determination

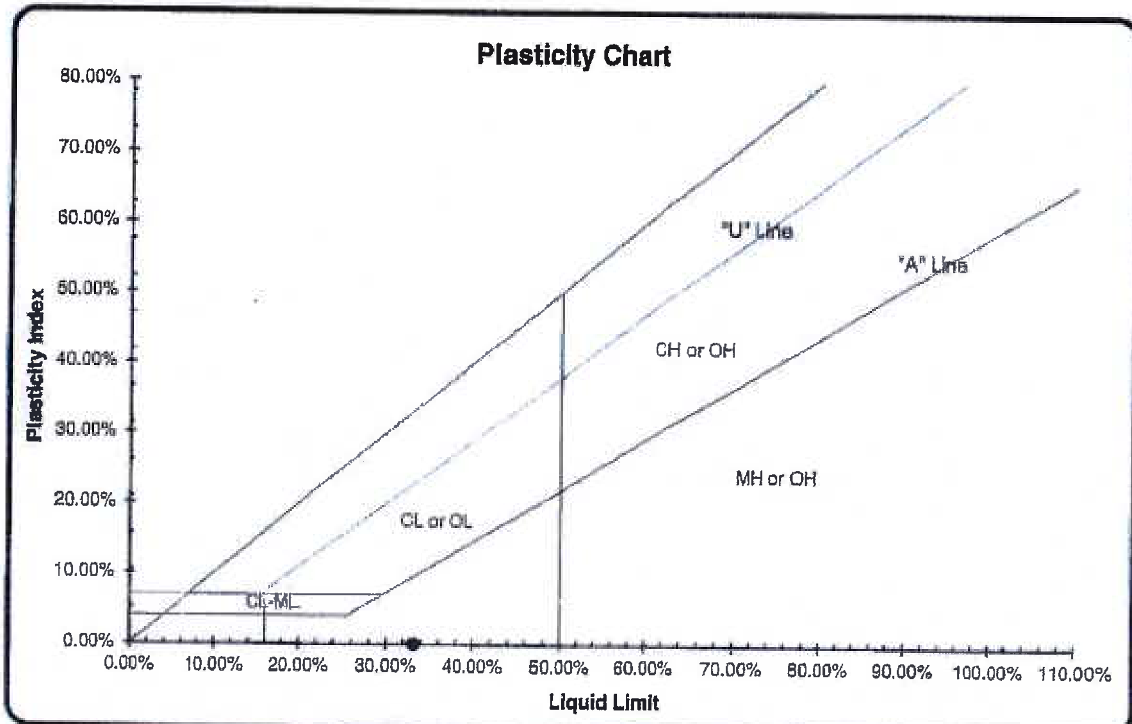
	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	99.17	107.77	106.14	102.16		
Weight of Dry Soils + Pan:	95.55	104.84	103.81	99.04		
Weight of Pan:	85.97	96.29	96.40	88.86		
Weight of Dry Soils:	9.58	8.55	7.41	10.18		
Weight of Moisture:	3.62	2.93	2.33	3.12		
% Moisture:	37.79%	34.27%	31.44%	30.7 %		
N:	11	19	26	38		

Liquid Limit @ 25 Blows:	33.14%
Plastic Limit:	N/A
Plasticity Index, I_P:	N/A
Moisture Content, M_C:	42.20%

Plastic Limit Determination

	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:						
Weight of Dry Soils + Pan:						
Weight of Pan:						
Weight of Dry Soils:						
Weight of Moisture:						
% Moisture:						





Reported by: Kevin Bowyer, CTech

Reviewed by: Brian Gray, AScT

exp Services Inc.
Parrish and Heimbecker Ltd.

Atterberg Limits ASTM D4318
AGEX Pre-Feed Development at
Bekaert Building
Fraser Surrey Docks

VAN-00222989-A0
January 06, 2015

(3)
Sample Source: BH10 @ 27'
Sample ID: grey clay

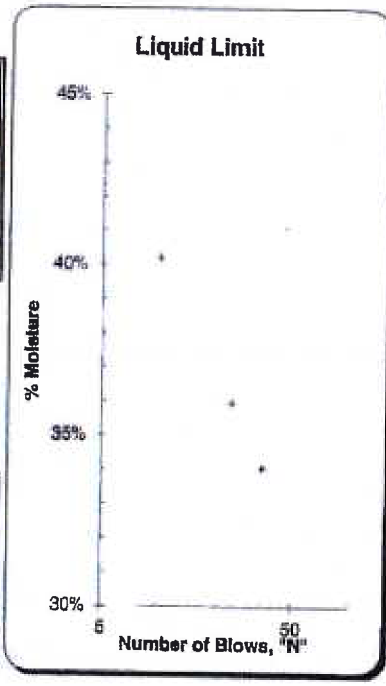
Liquid Limit Determination

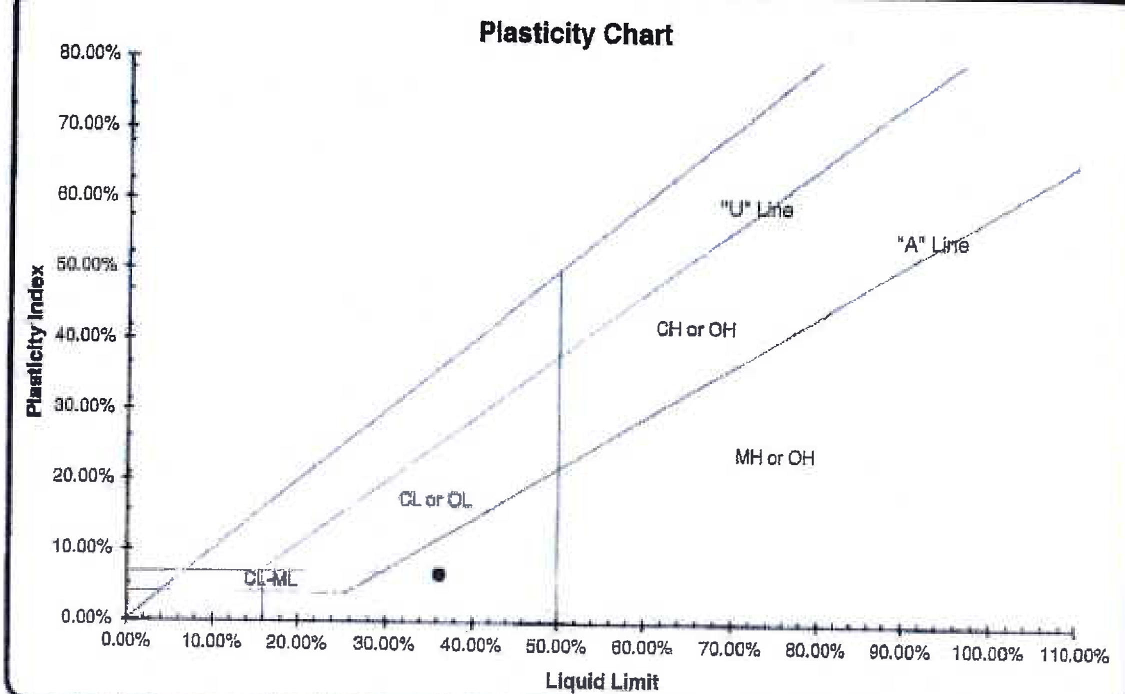
	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	20.34	103.47	103.21			
Weight of Dry Soils + Pan:	17.94	100.81	100.65			
Weight of Pan:	11.97	93.41	93.13			
Weight of Dry Soils:	5.97	7.40	7.52			
Weight of Moisture:	2.40	2.66	2.56			
% Moisture:	40.20%	35.95%	34.04%			
N:	10	24	35			

Liquid Limit @ 25 Blows:	36.23%
Plastic Limit:	29.42%
Plasticity Index, I_P:	6.81%
Moisture Content, M_C:	43.40%

Plastic Limit Determination

	#1	#2	#3	#4	#5	#6
Weight of Wet Soils + Pan:	110.41	107.07				
Weight of Dry Soils + Pan:	107.64	104.42				
Weight of Pan:	98.27	95.37				
Weight of Dry Soils:	9.37	9.05				
Weight of Moisture:	2.77	2.65				
% Moisture:	29.56%	29.28%				





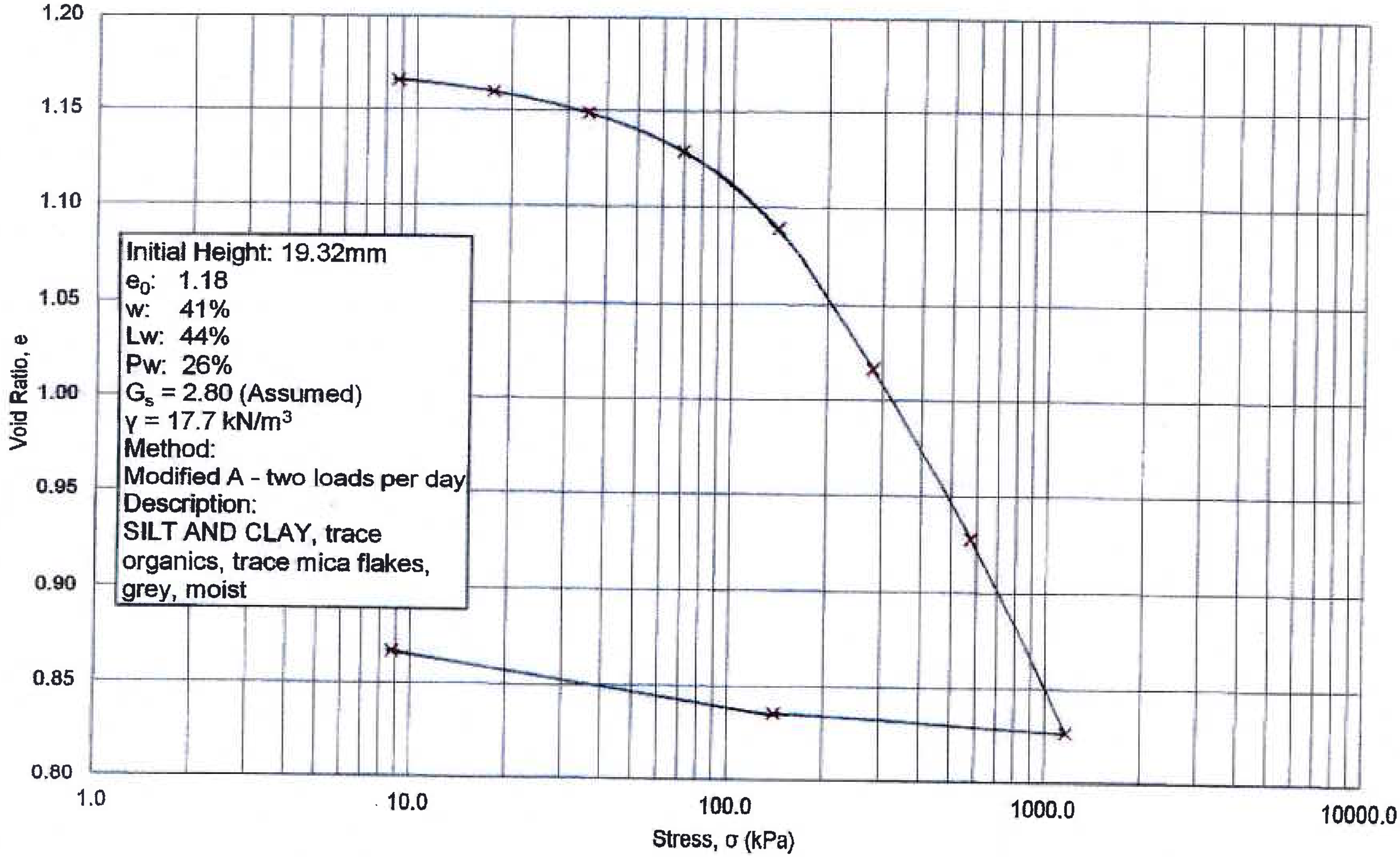
Reported by: Kevin Bowyer, CTech

Reviewed by: Brian Gray, AScT

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

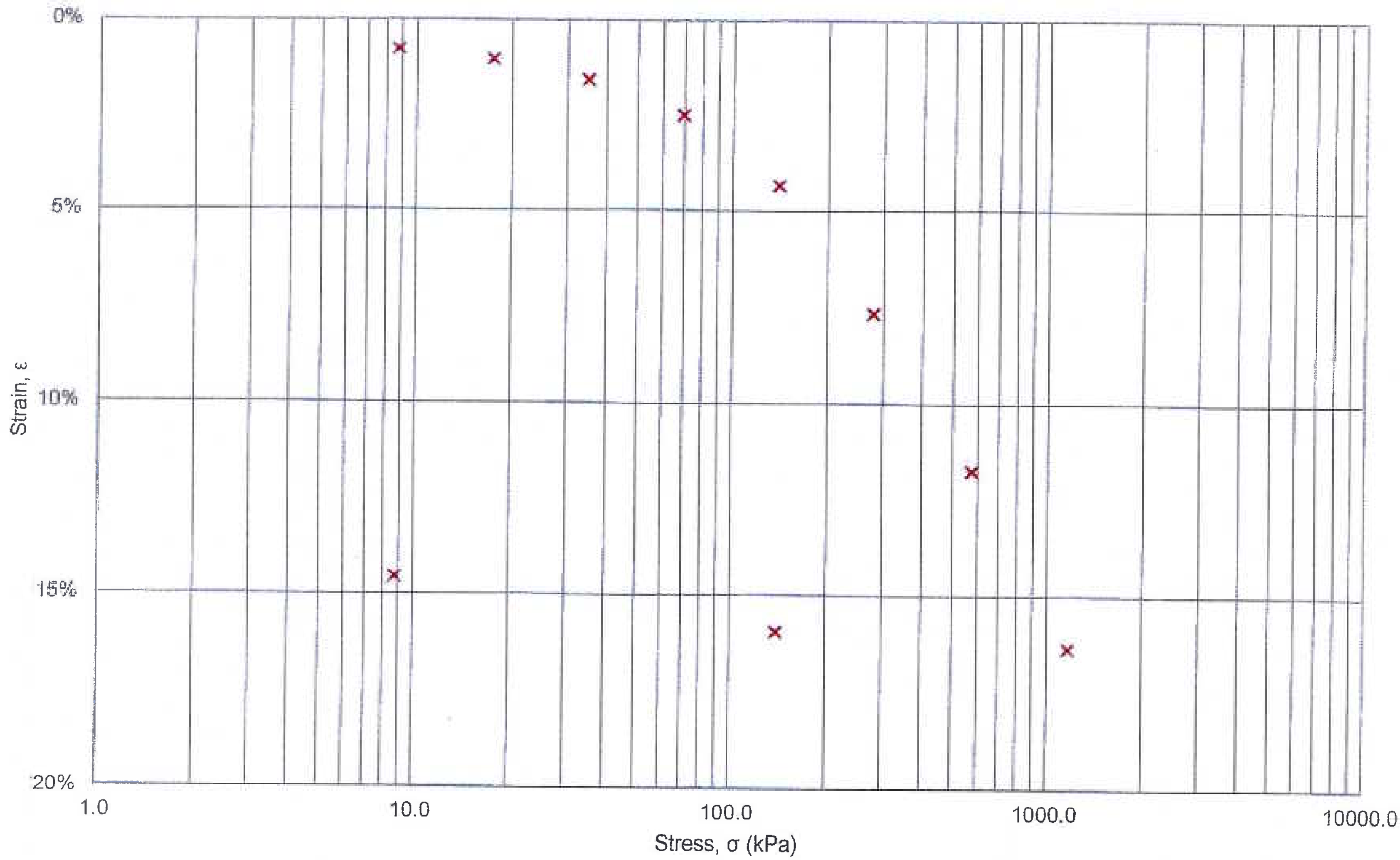
BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Strain v. Applied Stress

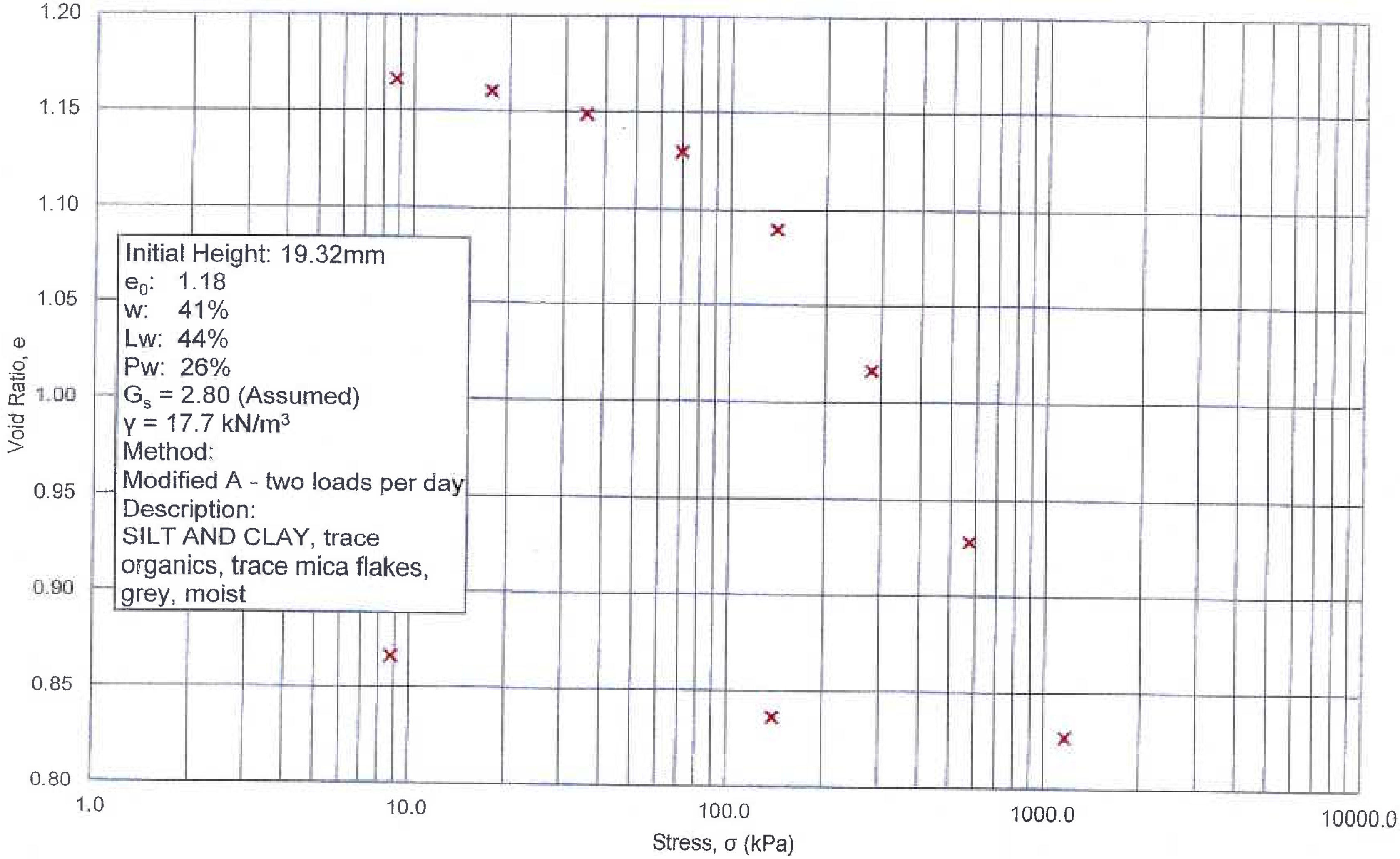
BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

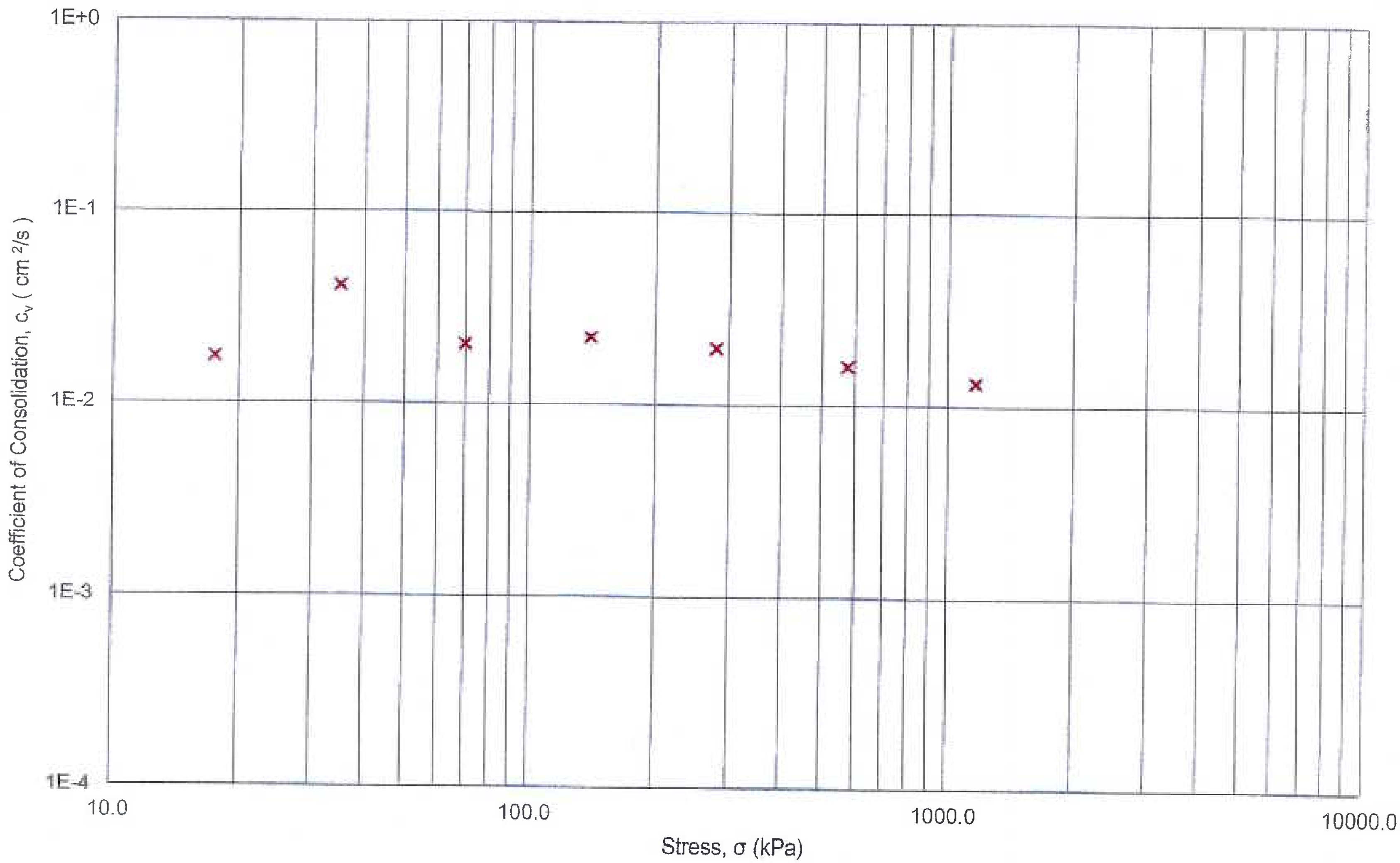
BH14-01, 5.03m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Coefficient of Consolidation v. Applied Stress

BH14-01, 5.03m



exp.

Consolidation Data Sheet

BH14-01, 5.03m

Sample Dimensions	
H_o =	19.32 mm
D_o =	63.36 mm
A =	31.53 cm²
V_o =	60.92 cm³
G_s =	2.80
H_s =	8.85 mm

Moisture Content of Specimen	(Initial)	(End)
Wet Soil + Tare	244.76 g	385.41 g
Dry Soil + Tare	212.94 g	359.61 g
Water	31.82 g	25.80 g
Tare	134.84	281.97 g
Wet Soil	109.92 g	103.44 g
Dry Soil	78.10 g	77.64 g
w(%)	40.74%	33.23%
Saturation	0.96	

Moisture Content of Cuttings			
Tare #	114	79	134
Wet Soil + Tare	280.79 g	292.68 g	304.56 g
Dry Soil + Tare	243.78 g	250.17 g	259.08 g
Water	37.01 g	42.51 g	45.48 g
Tare	150.27 g	149.04 g	147.11 g
Wet Soil	130.52 g	143.64 g	157.45 g
Dry Soil	93.51 g	101.13 g	111.97 g
w(%)	39.58%	42.04%	40.62%

Total Load (kg)	Pressure (kPa)	Correction (mm)	Deformation* (mm)	delta-H (mm)	Strain %	H (H_o - delta-H)	$H-H_s$	e $(H-H_s)/H_s$	t_{90} (min) for Cv	Cv (cm²/s)
			0	0.000	0.0%	19.32	10.474	1.18		
0.375	8.7	0.000	0.159	0.159	0.8%	19.161	10.315	1.17	0.25	5.23E-02
0.75	17.5	0.002	0.213	0.212	1.1%	19.109	10.262	1.16	0.73	1.77E-02
1.5	34.9	0.011	0.323	0.313	1.6%	19.007	10.161	1.15	0.31	4.14E-02
3.0	69.8	0.020	0.505	0.485	2.5%	18.835	9.989	1.13	0.61	2.07E-02
6.0	139.8	0.031	0.867	0.836	4.3%	18.484	9.637	1.09	0.54	2.28E-02
12.0	279.6	0.043	1.522	1.479	7.7%	17.841	8.994	1.02	0.58	2.01E-02
24.7	575.8	0.061	2.328	2.267	11.7%	17.053	8.206	0.93	0.66	1.63E-02
50.1	1167.4	0.069	3.229	3.159	16.4%	16.161	7.314	0.83	0.73	1.34E-02
6.0	139.8	0.031	3.110	3.080	15.9%	16.241	7.394	0.84		
0.375	8.7	0.000	2.809	2.809	14.5%	16.511	7.665	0.87		

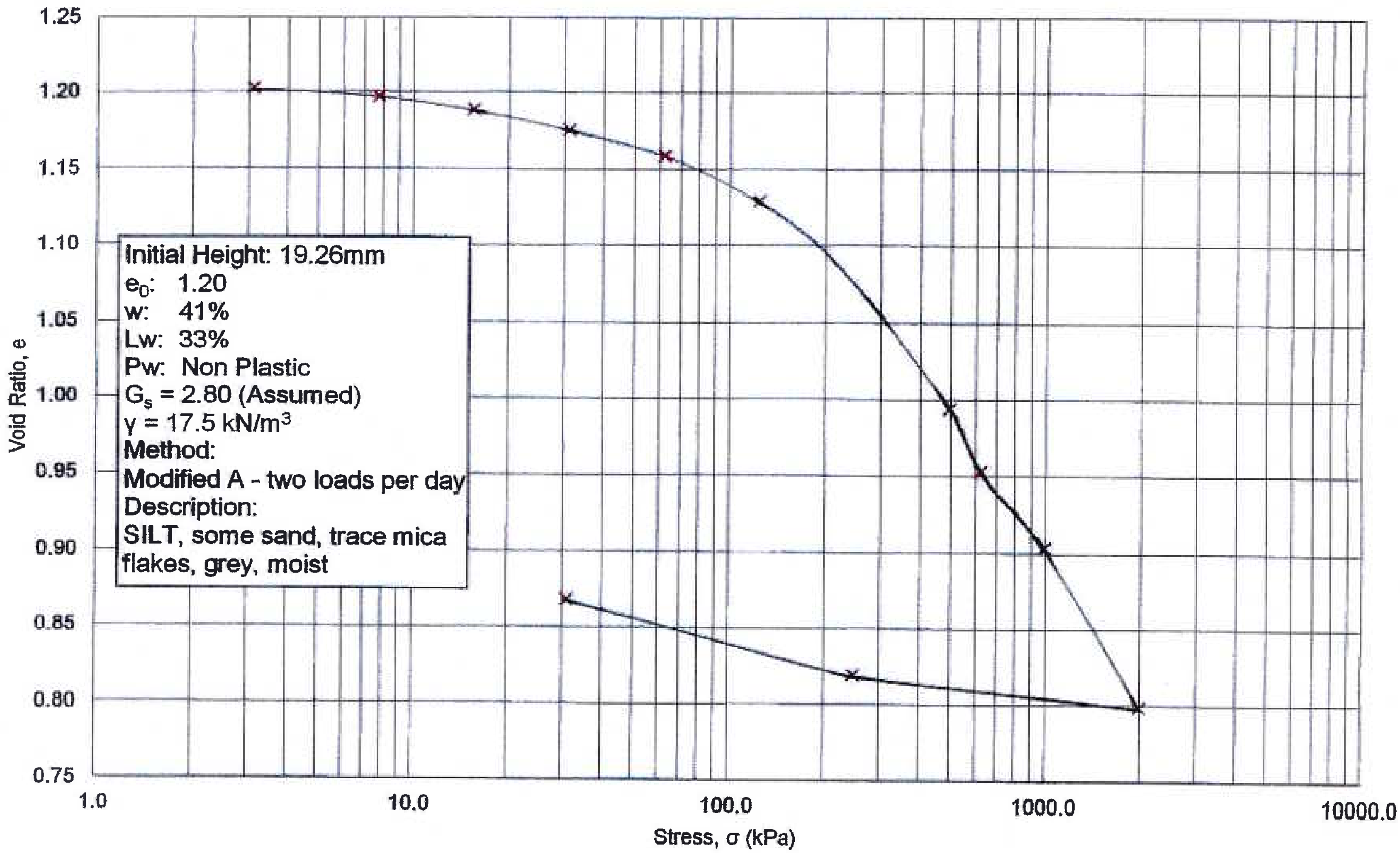
Notes
* Deformation at end of each load increment

Consolidometer: B **Linear Voltmeter:** J15192
Method: Modified A - two loads per day
Comments:

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

BH14-03, 6.54m



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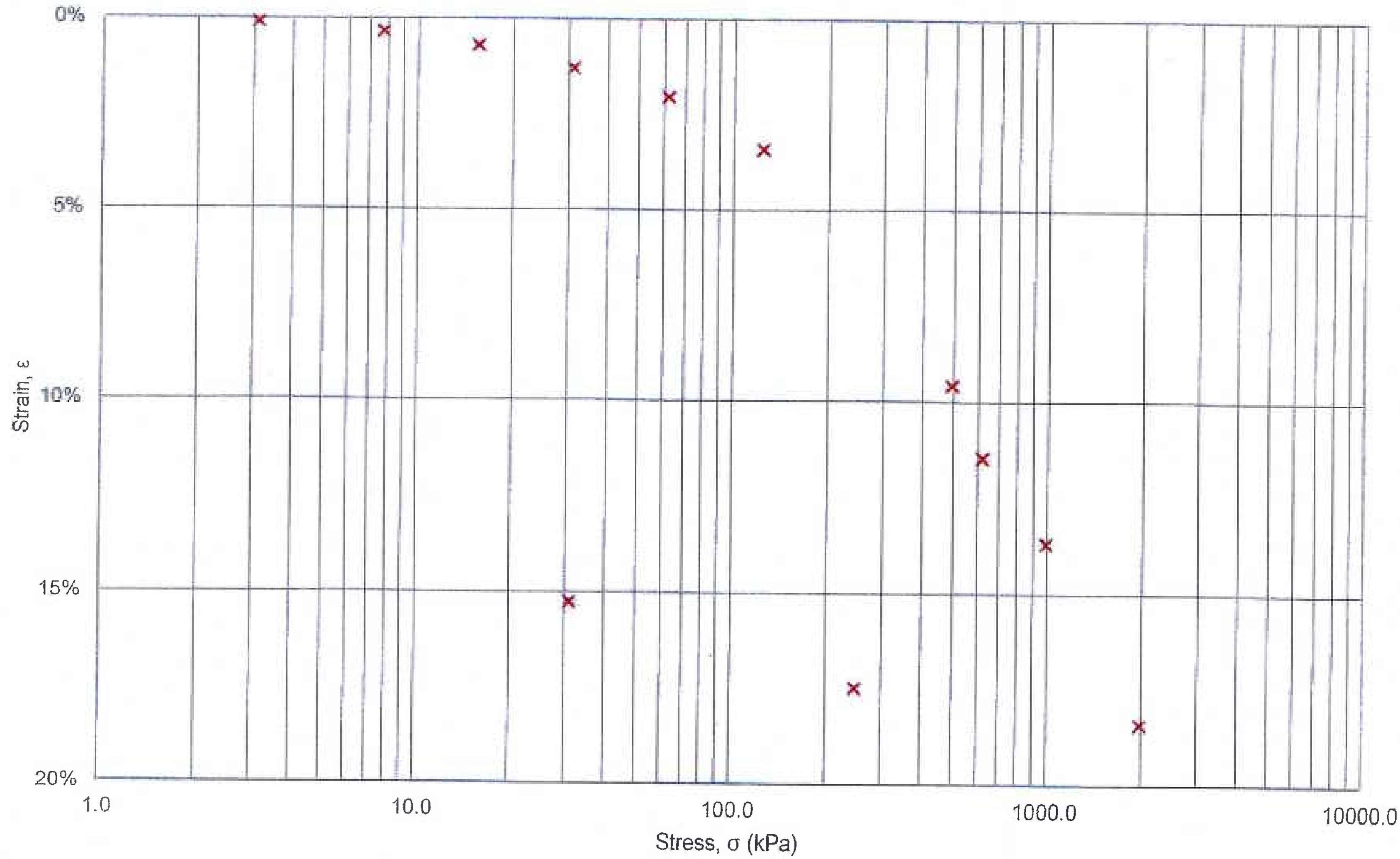
VAN-0222989-A0
2015-01-15 SCD

Consolidation: Strain v. Applied Stress

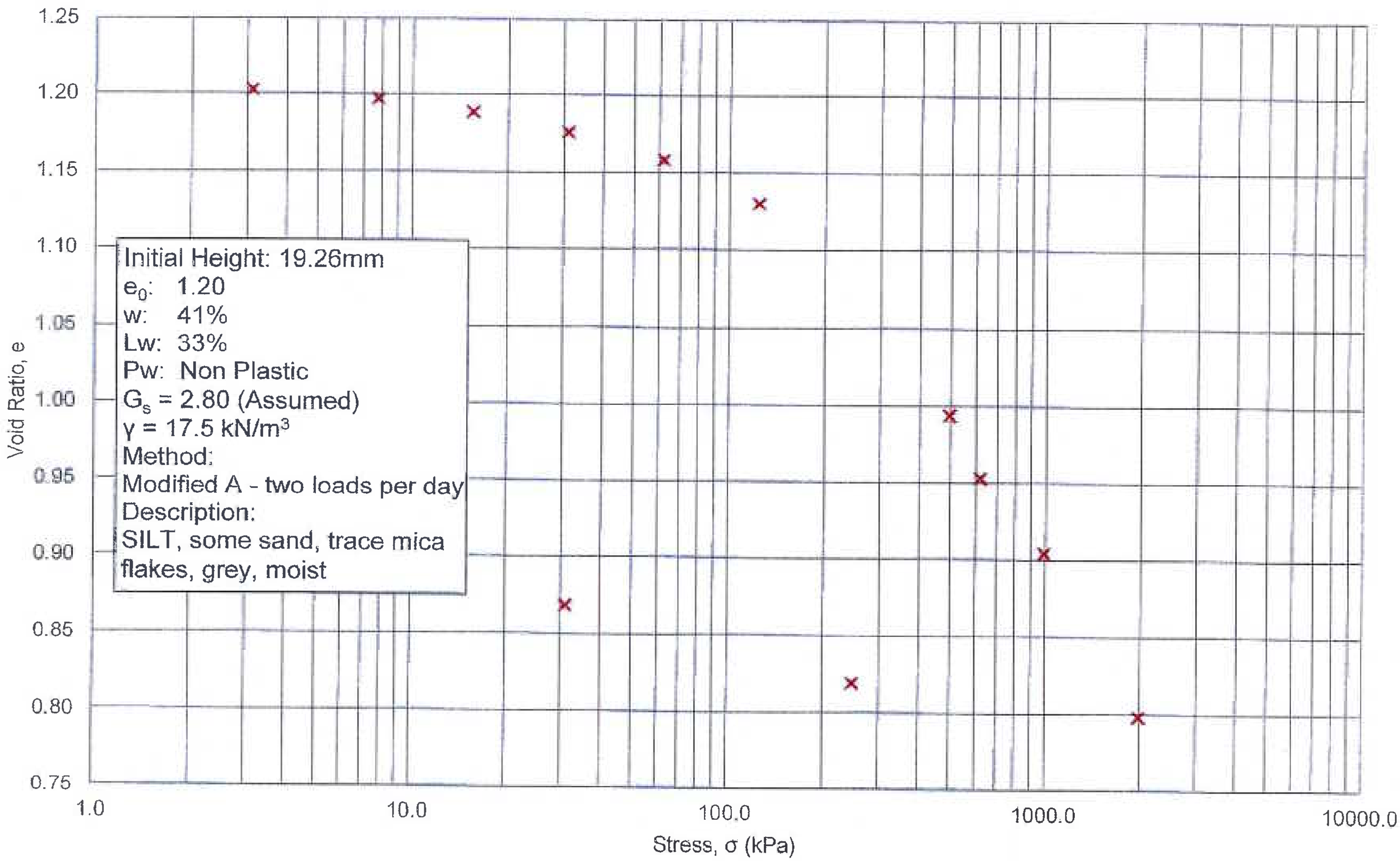
BH14-03, 6.54m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

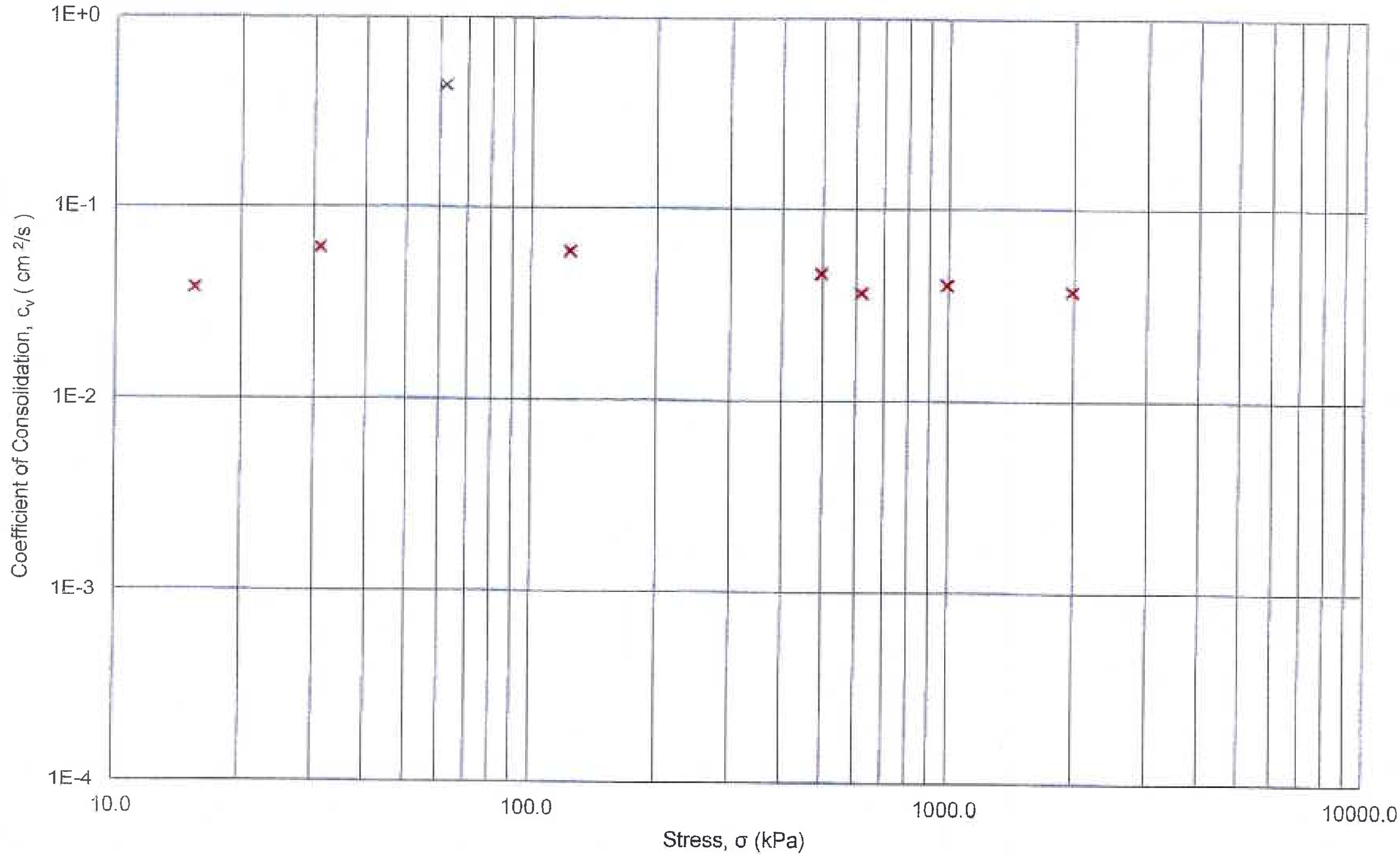
BH14-03, 6.54m



VAN-0222989-A0
2015-01-15 SCD

Consolidation: Coefficient of Consolidation v. Applied Stress

BH14-03, 6.54m



exp.

VAN-0222989-A0
2015-01-15 SCD

Consolidation Data Sheet

BH14-03, 6.54m

Sample Dimensions	
H_o =	19.26 mm
D_o =	63.48 mm
A =	31.65 cm²
V_o =	60.96 cm³
G_s =	2.80
H_s =	8.74 mm

Moisture Content of Specimen		
	(Initial)	(End)
Wet Soil + Tare	241.73 g	399.64 g
Dry Soil + Tare	210.26 g	373.23 g
Water	31.47 g	26.41 g
Tare	132.85	298.08 g
Wet Soil	108.88 g	101.56 g
Dry Soil	77.41 g	75.15 g
w(%)	40.65%	35.14%
Saturation	0.94	

Moisture Content of Cuttings			
Tare #	123	140	135
Wet Soil + Tare	322.99 g	336.66 g	347.34 g
Dry Soil + Tare	273.05 g	280.62 g	294.09 g
Water	49.94 g	56.04 g	53.25 g
Tare	149.38 g	144.46 g	162.29 g
Wet Soil	173.61 g	192.20 g	185.05 g
Dry Soil	123.67 g	136.16 g	131.80 g
w(%)	40.38%	41.16%	40.4 %

Total Load (kg)	Pressure (kPa)	Correction (mm)	Deformation* (mm)	delta-H (mm)	Strain %	H (H_o - delta-H)	$H-H_s$	e $(H-H_s)/H_s$	t_{90} (min) for Cv	Cv (cm²/s)
			0	0.000	0.0%	19.26	10.524	1.20		
0.1	3.1	0.000	0.021	0.021	0.1%	19.239	10.504	1.20	0.12	1.12E-01
0.25	7.7	0.000	0.068	0.068	0.4%	19.192	10.456	1.20	0.23	5.77E-02
0.5	15.5	0.000	0.141	0.141	0.7%	19.119	10.384	1.19	0.34	3.78E-02
1.0	31.0	0.017	0.271	0.254	1.3%	19.006	10.270	1.18	0.21	6.11E-02
2.0	62.0	0.025	0.430	0.405	2.1%	18.855	10.120	1.16	0.03	4.37E-01
4.0	123.9	0.035	0.694	0.659	3.4%	18.601	9.865	1.13	0.21	5.90E-02
16.0	495.6	0.065	1.905	1.840	9.6%	17.420	8.684	0.99	0.25	4.58E-02
20.0	619.5	0.069	2.268	2.199	11.4%	17.061	8.325	0.95	0.29	3.62E-02
32.0	991.3	0.083	2.712	2.629	13.7%	16.631	7.895	0.90	0.25	4.01E-02
64.0	1982.5	0.111	3.658	3.548	18.4%	15.712	6.977	0.80	0.25	3.70E-02
8.0	247.8	0.049	3.418	3.369	17.5%	15.891	7.156	0.82		
1.0	31.0	0.017	2.955	2.938	15.3%	16.322	7.586	0.87		

Notes
* Deformation at end of each load increment

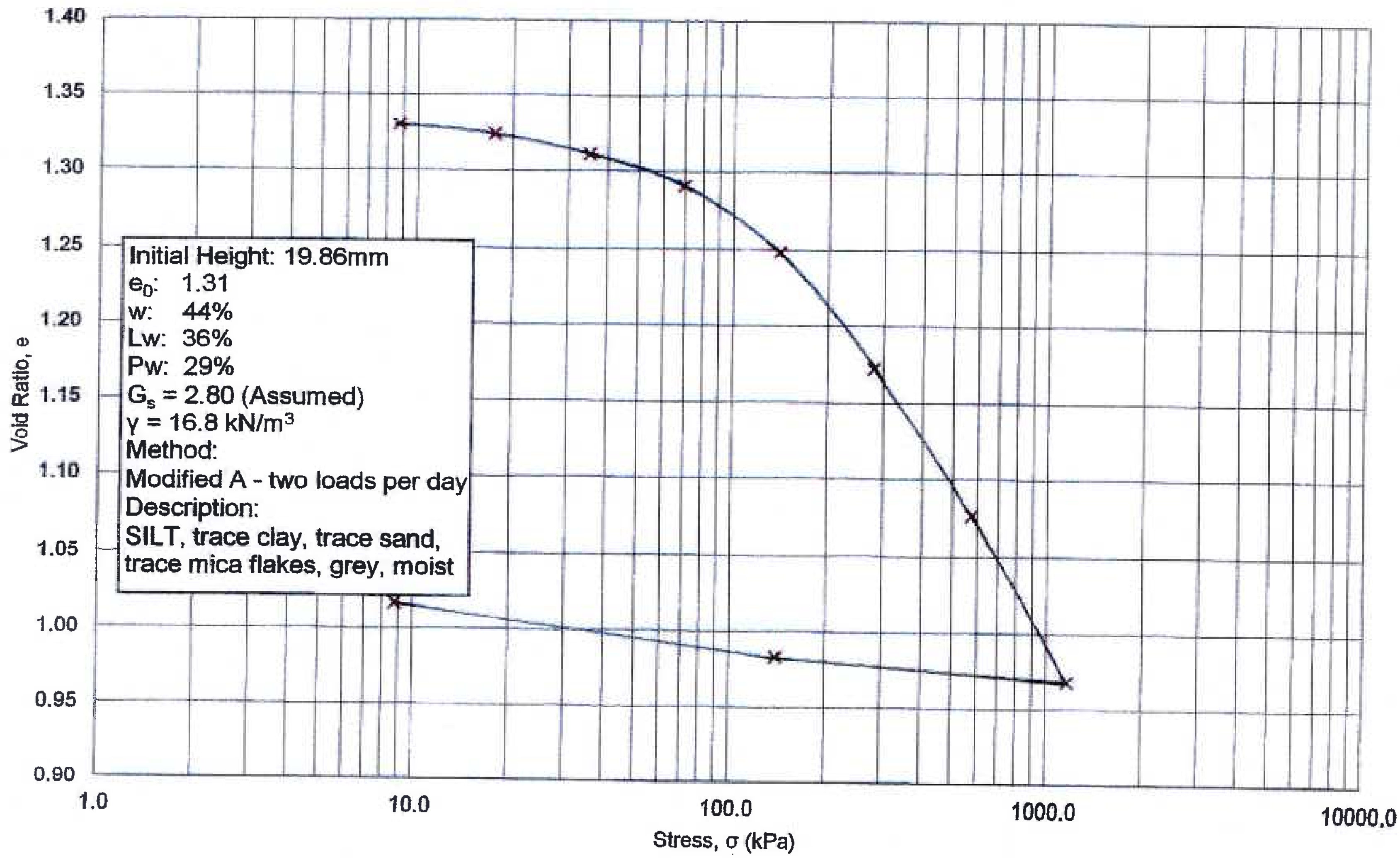
Consolidometer: C **Linear Voltmeter:** J15192
Method: Modified A - two loads per day
Comments:

exp.

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Void Ratio v. Applied Stress

BH14-10, 8.23m

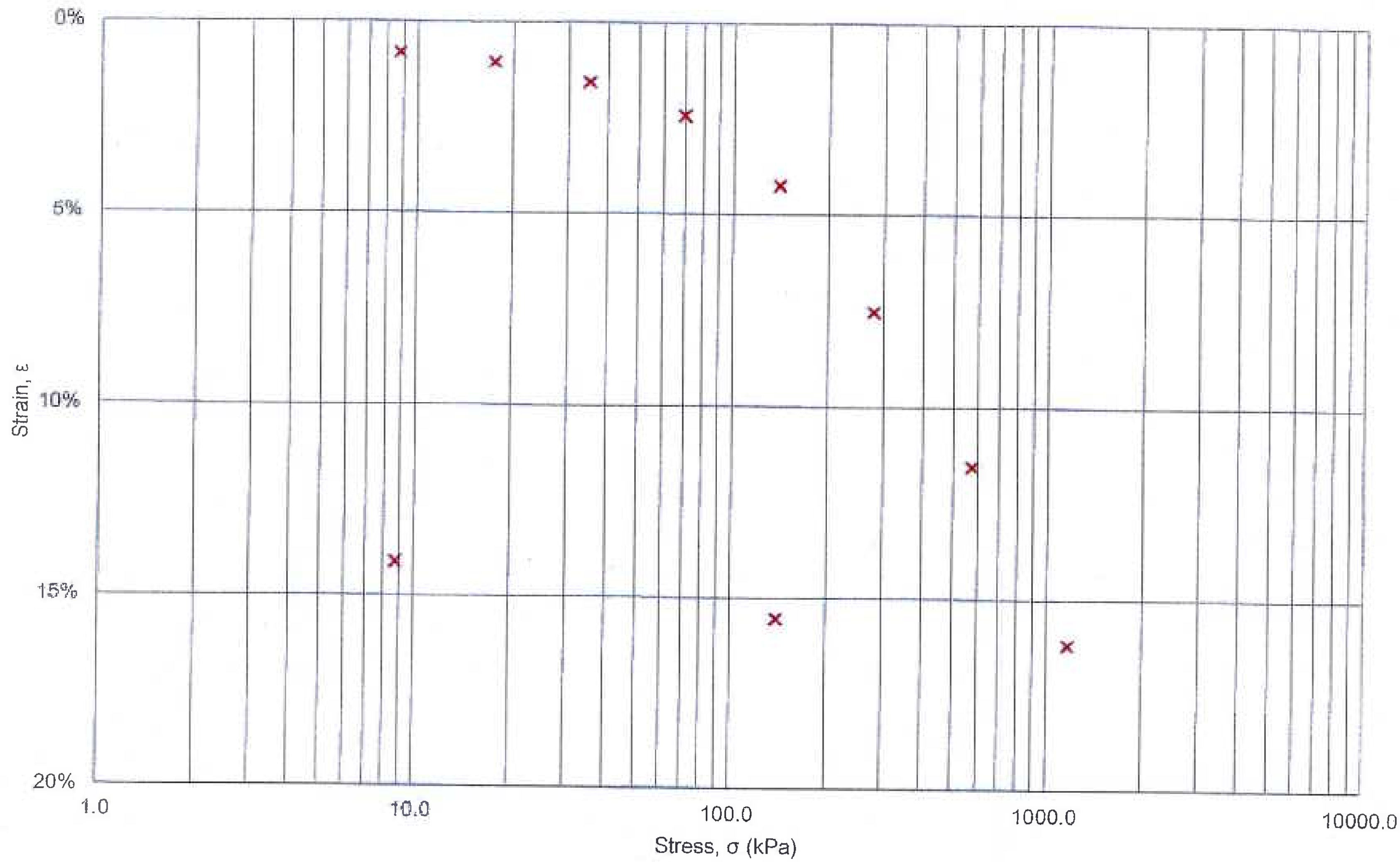


L:\2014 (Starting at 0216767-A0)\0222989-A0 BW AGEX Pre-Feed Development at Bekaert Building\Factual Data\Consolidation\BH14-10 8.23m A\Plotting Sheet, BH14-10 8.23m A.xlsm e-log(p)

VAN-0222989-A0
2015-01-15 SCD

Consolidation: Strain v. Applied Stress

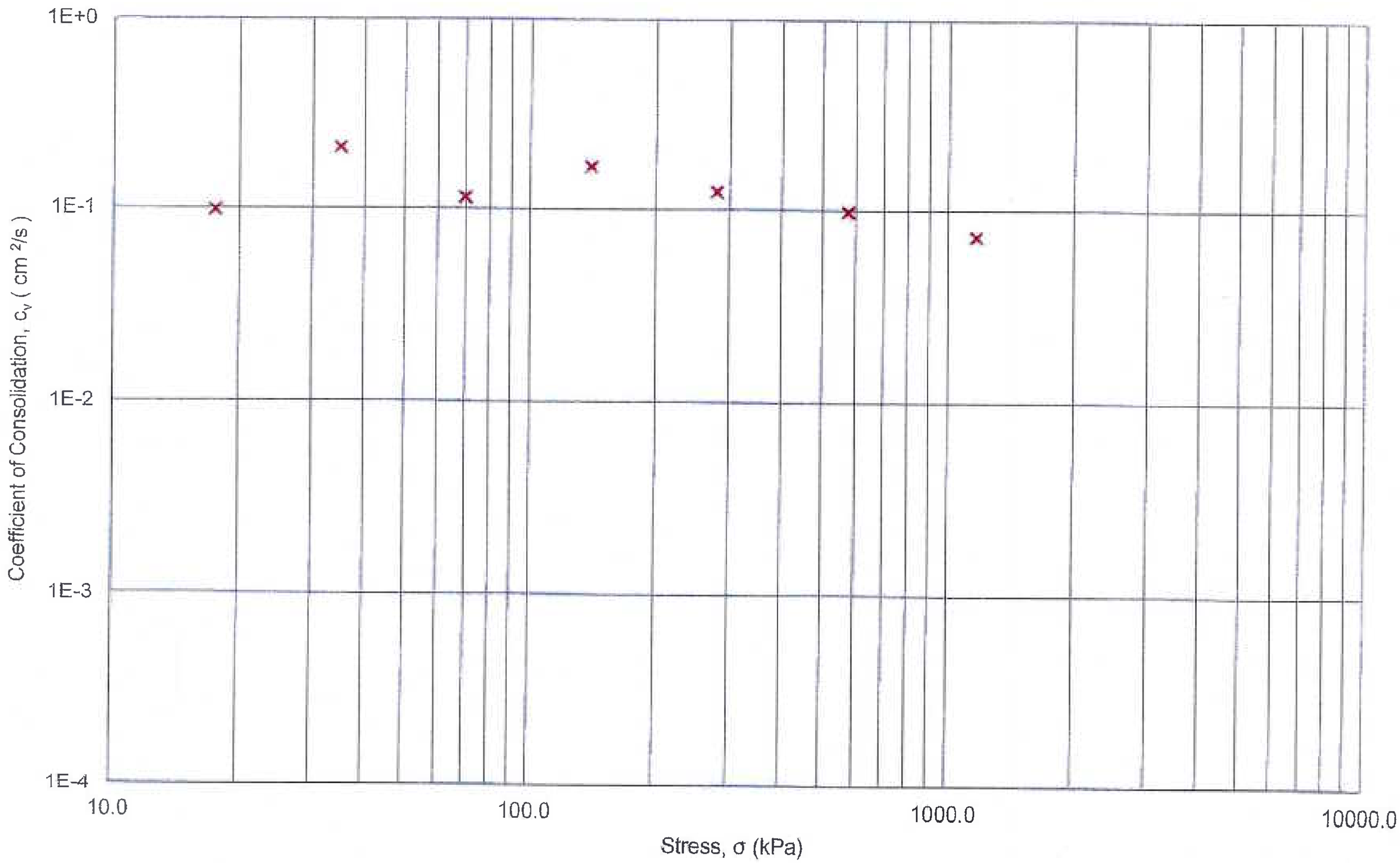
BH14-10, 8.23m



VAN-0222989-A0
2013-09-21

Consolidation: Coefficient of Consolidation v. Applied Stress

BH14-10, 8.23m



exp.

VAN-0222989-A0
2015-01-15 SCD

Consolidation Data Sheet

BH14-10, 8.23m

Sample Dimensions	
H_o =	19.86 mm
D_o =	63.00 mm
A =	31.17 cm²
V_o =	61.91 cm³
G_s =	2.80
H_s =	8.46 mm

Moisture Content of Specimen	(Initial)	(End)
Wet Soil + Tare	235.81 g	379.07 g
Dry Soil + Tare	203.43 g	352.52 g
Water	32.38 g	26.55 g
Tare	129.61	279.85 g
Wet Soil	106.20 g	99.22 g
Dry Soil	73.82 g	72.67 g
w(%)	43.87%	36.54%
Saturation	0.91	

Moisture Content of Cuttings			
Tare #	114	79	134
Wet Soil + Tare	248.39 g	250.33 g	340.29 g
Dry Soil + Tare	200.77 g	203.41 g	282.62 g
Water	47.62 g	46.92 g	57.67 g
Tare	92.44 g	96.65 g	150.67 g
Wet Soil	155.95 g	153.68 g	189.62 g
Dry Soil	108.33 g	106.76 g	131.95 g
w(%)	43.96%	43.95%	43.71%

Total Load (kg)	Pressure (kPa)	Correction (mm)	Deformation* (mm)	delta-H (mm)	Strain %	H (H_o - delta-H)	$H-H_s$	e $(H-H_s)/H_s$	t_{90} for Cv	Cv (cm²/s)
			0	0.000	0.0%	19.86	11.403	1.35		
0.375	8.7	0.002	0.160	0.158	0.8%	19.702	11.245	1.33	0.04	3.46E-01
0.75	17.5	0.004	0.213	0.210	1.1%	19.651	11.193	1.32	0.14	9.77E-02
1.5	34.9	0.009	0.323	0.315	1.6%	19.546	11.088	1.31	0.07	2.06E-01
3.0	69.8	0.015	0.505	0.490	2.5%	19.370	10.913	1.29	0.12	1.14E-01
6.0	139.8	0.021	0.867	0.846	4.3%	19.014	10.557	1.25	0.08	1.65E-01
12.0	279.6	0.025	1.522	1.497	7.5%	18.363	9.906	1.17	0.10	1.23E-01
24.7	575.8	0.031	2.328	2.297	11.6%	17.563	9.106	1.08	0.12	9.74E-02
50.1	1167.4	0.036	3.254	3.218	16.2%	16.642	8.185	0.97	0.14	7.23E-02
6.0	139.8	0.021	3.110	3.089	15.6%	16.771	8.313	0.98		
0.375	8.7	0.002	2.809	2.808	14.1%	17.052	8.595	1.02		

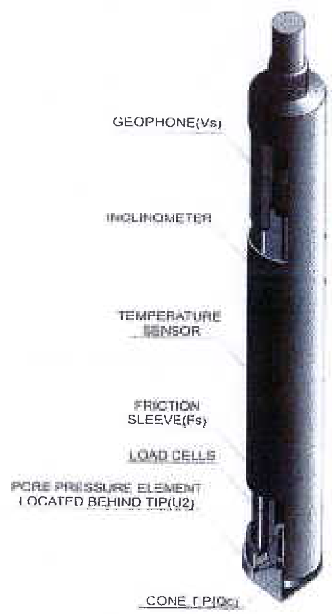
Notes
* Deformation at end of each load increment

Consolidometer: A **Linear Voltmeter:** J15192
Method: Modified A - two loads per day
Comments:

APPENDIX B - ELECTRONIC CONE PENETRATION RESULTS

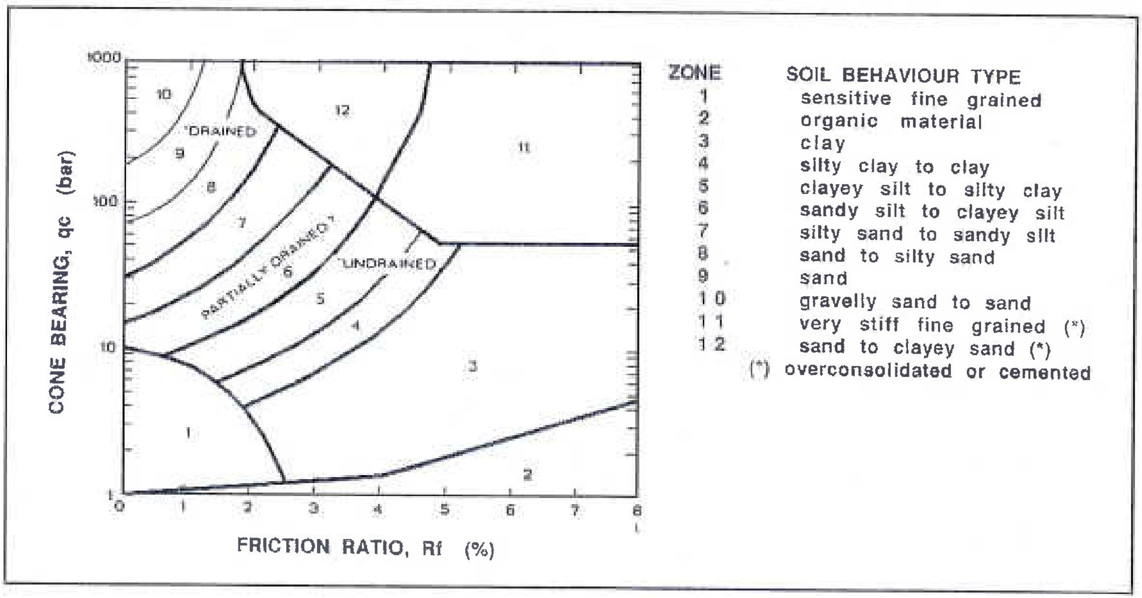
The system used is owned and operated by GeoPacific and employs a 35.7 mm diameter cone that records tip resistance, sleeve friction, dynamic pore pressure, inclination and temperature at 5 cm intervals on a digital computer system. The system is a Hogentogler electronic cone system and the cone used was a 10 ton cone with pore pressure element located behind the tip and in front of the sleeve as shown on the adjacent figure.

Electronic Cone Penetrometer



In addition to the capabilities described above, the cone can be stopped at specified depths and dissipation tests carried out. These dissipation tests can be used to determine the groundwater pressures at the specified depth. This is very useful for identifying artesian pressures within specific layers below the ground surface.

Interpretation of the cone penetration test results are carried out by computer using the interpretation chart presented below by Robertson[1]. Raw data collected by the field computer includes tip resistance, sleeve friction and pore pressure. The tip resistance is corrected for water pressure and the friction ratio is calculated as the ratio of the sleeve friction on the side of the cone to the corrected tip resistance expressed as a percent. These two parameters are used to determine the soil behaviour type as shown in the chart below. The interpreted soil type may be different from other classification systems such as the Unified Soil Classification that is based upon grain size and plasticity.



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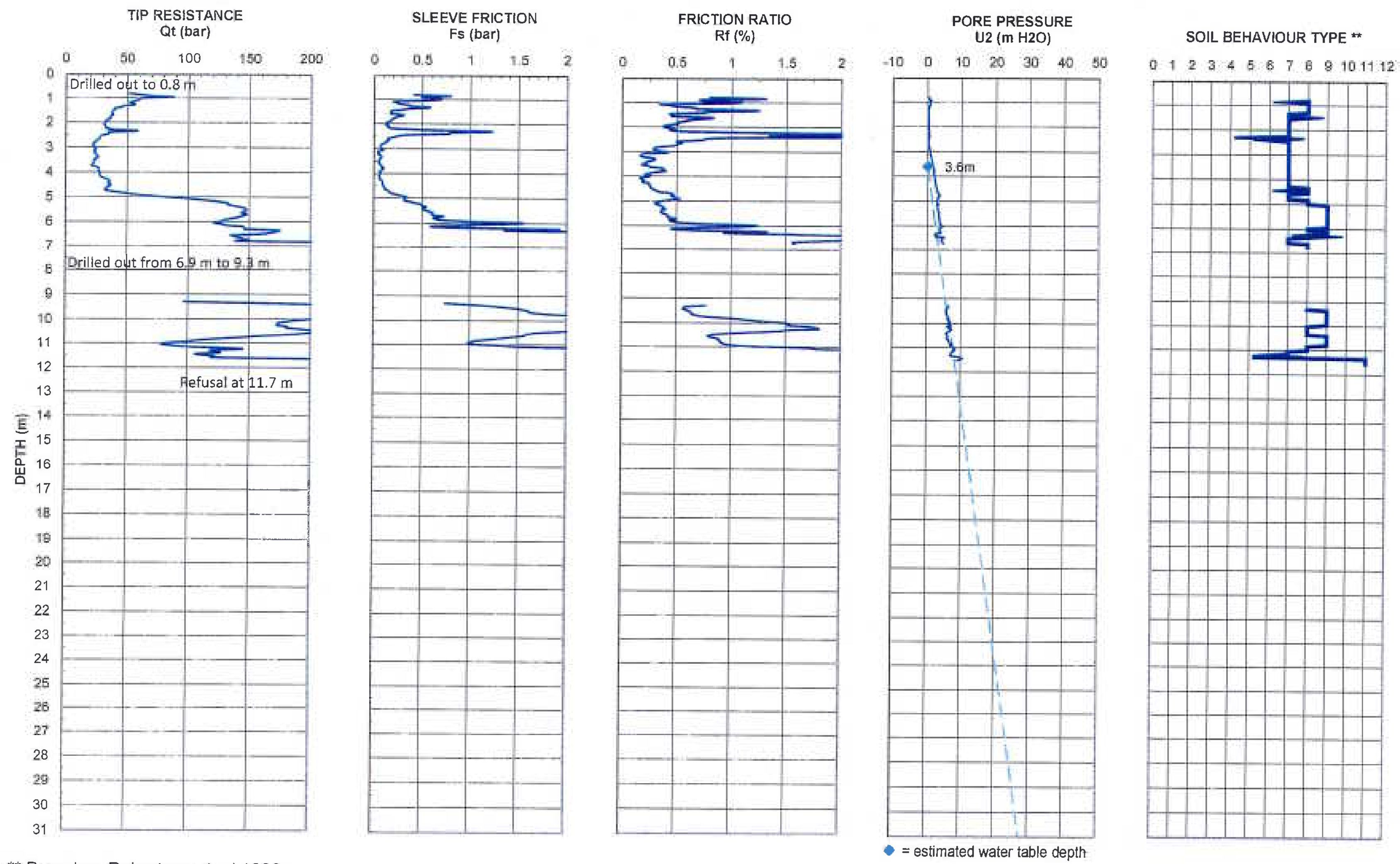
1 Robertson, P.K., 1990, "Soil Classification using the cone penetration test", 1990 Canadian Geotechnical Colloquium, Canadian Geotechnical Journal, Vol. 27, No. 1, 1990

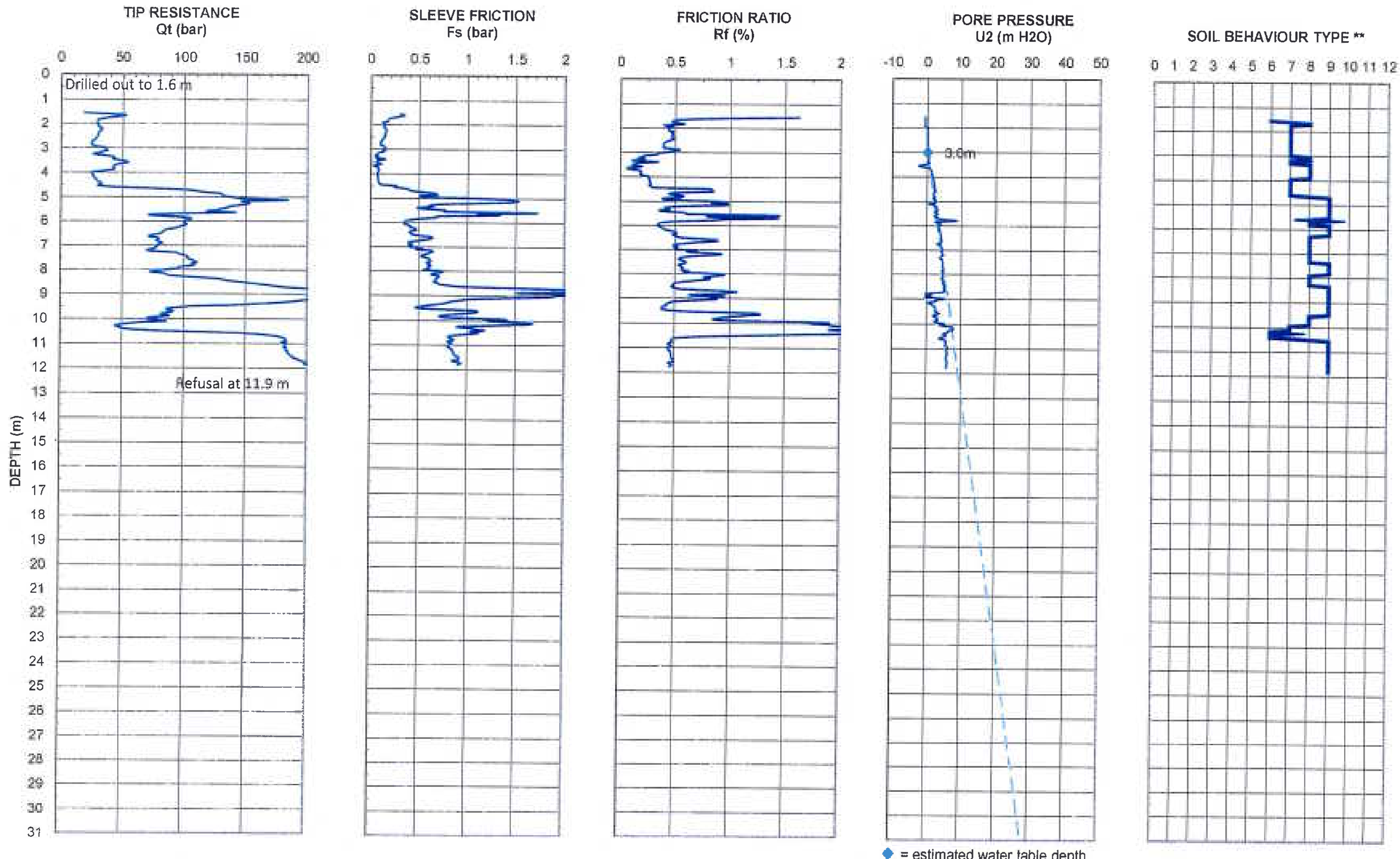
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-01	FRASER SURREY DOCKS, SURREY, BC	Figure: B.01



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-02	FRASER SURREY DOCKS, SURREY, BC	Figure: B.02



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
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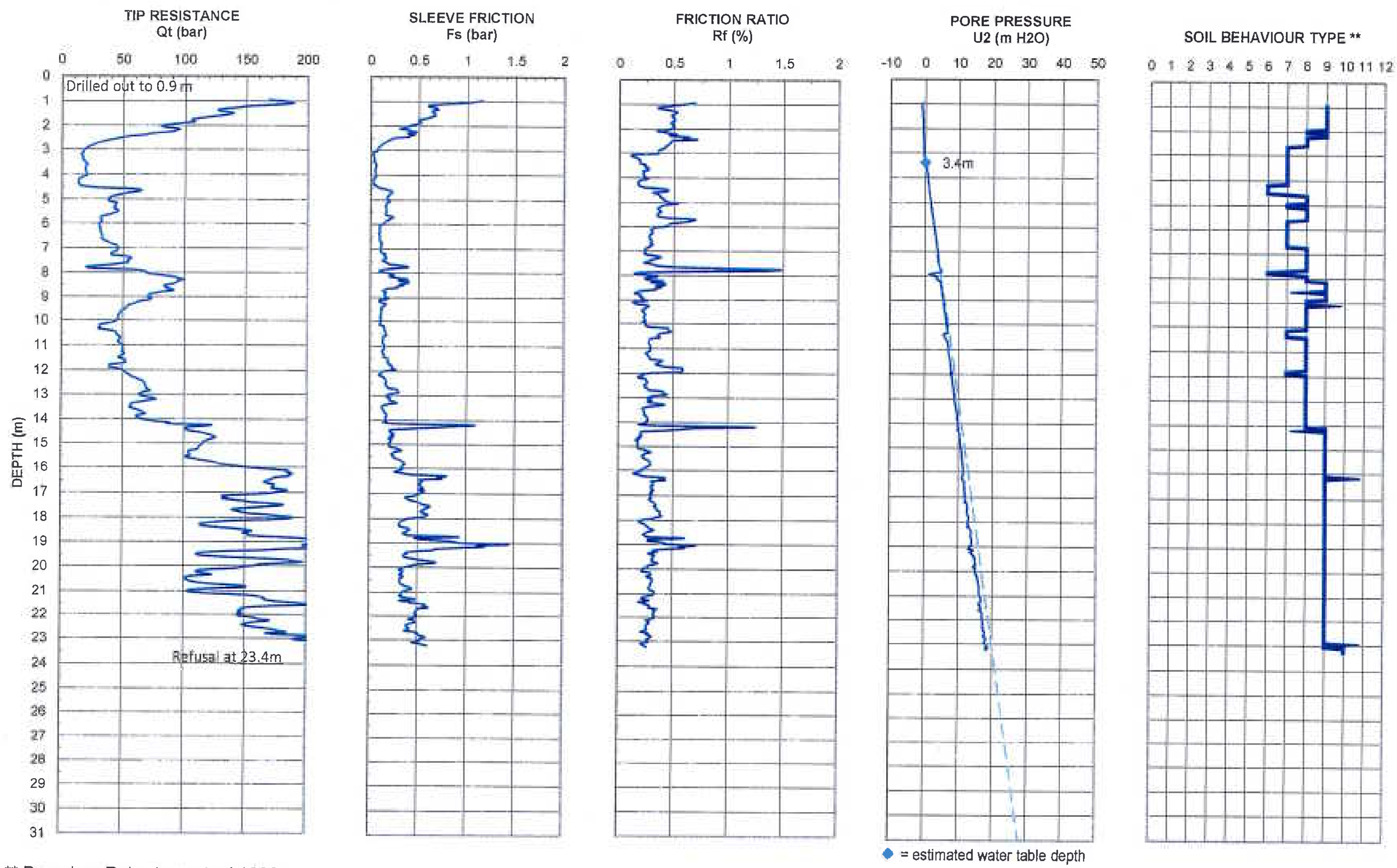
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-03	FRASER SURREY DOCKS, SURREY, BC	Figure: B.03



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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4 Silty Clay to Clay
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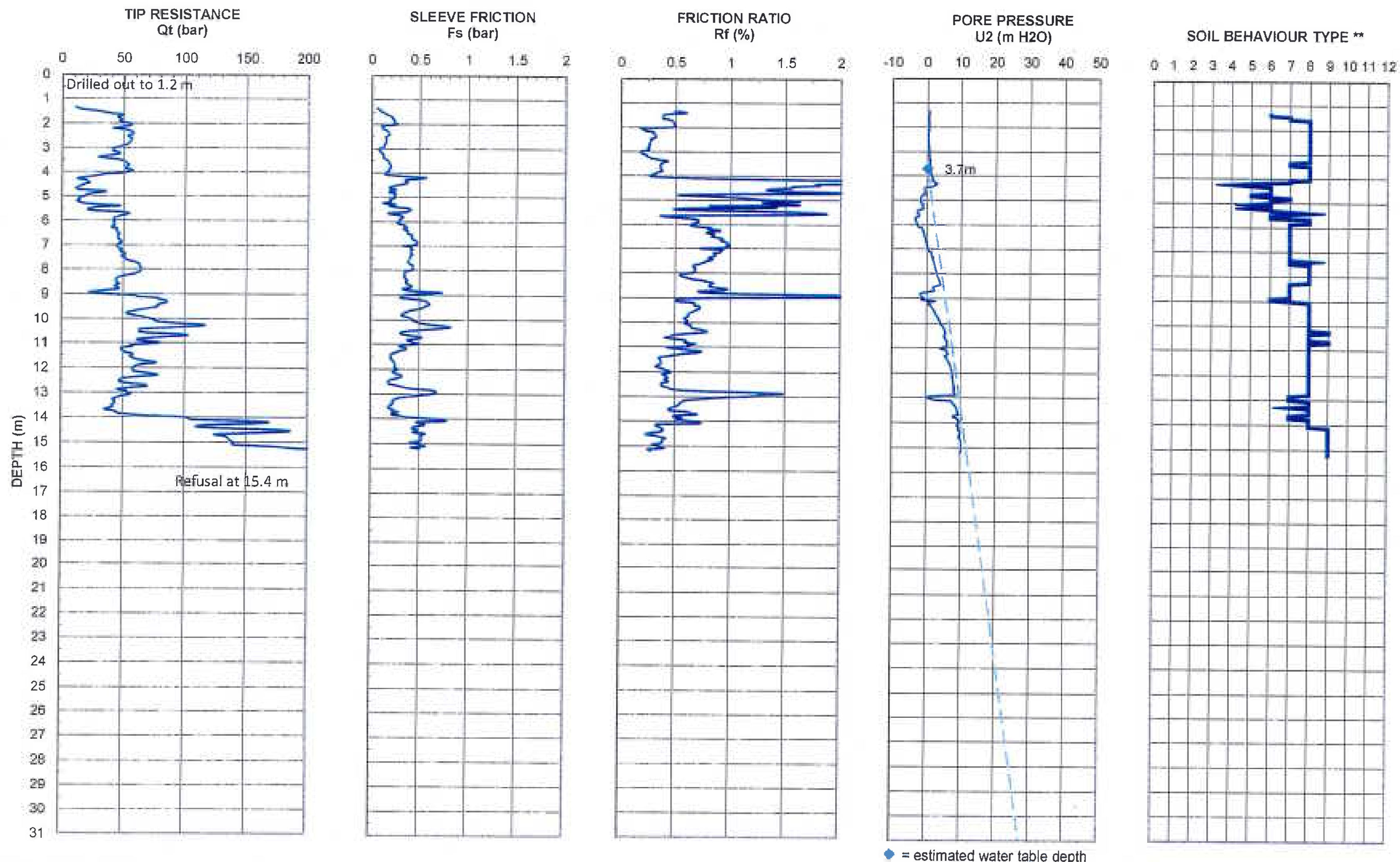
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

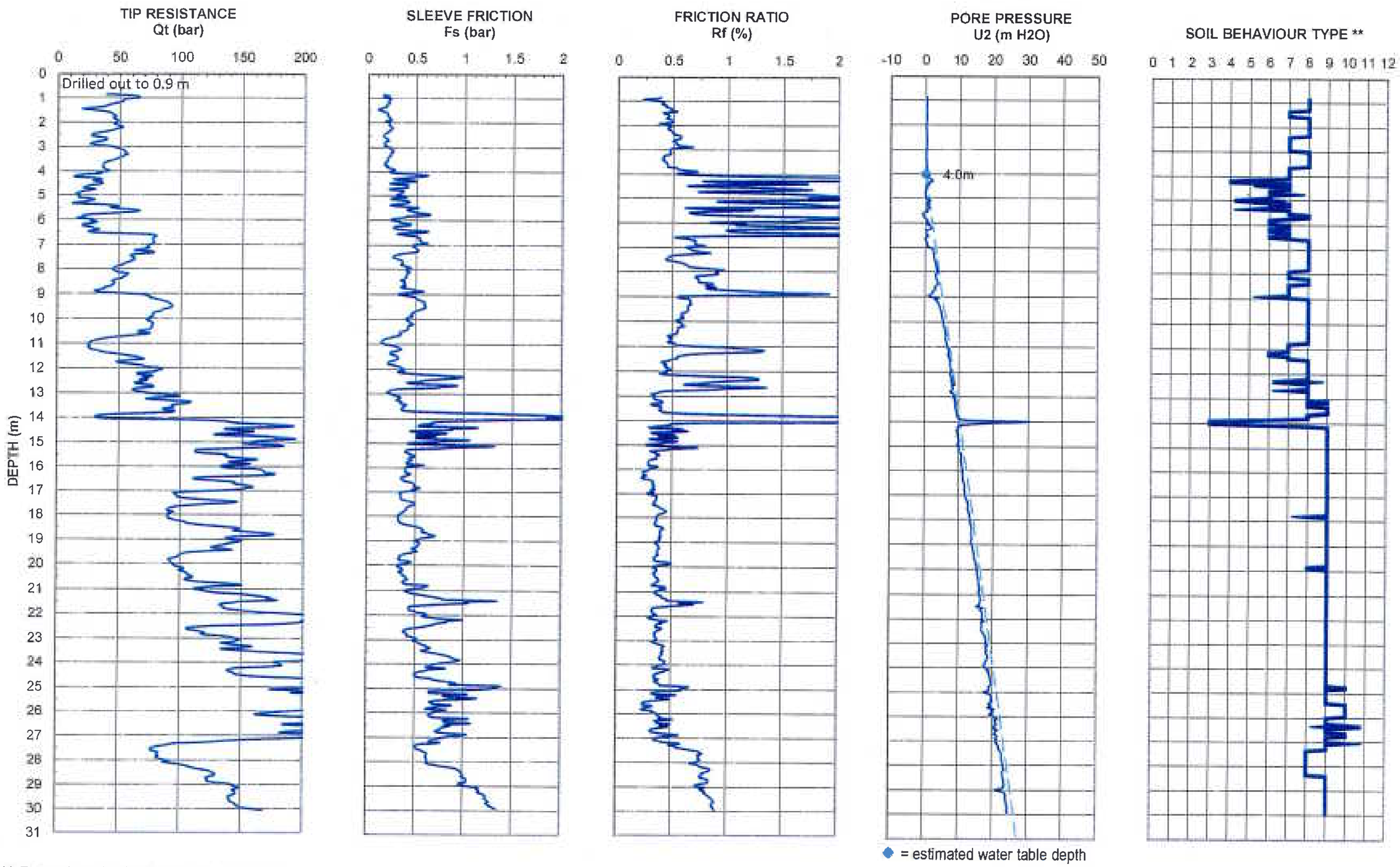
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-04	FRASER SURREY DOCKS, SURREY, BC	Figure: B.04



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

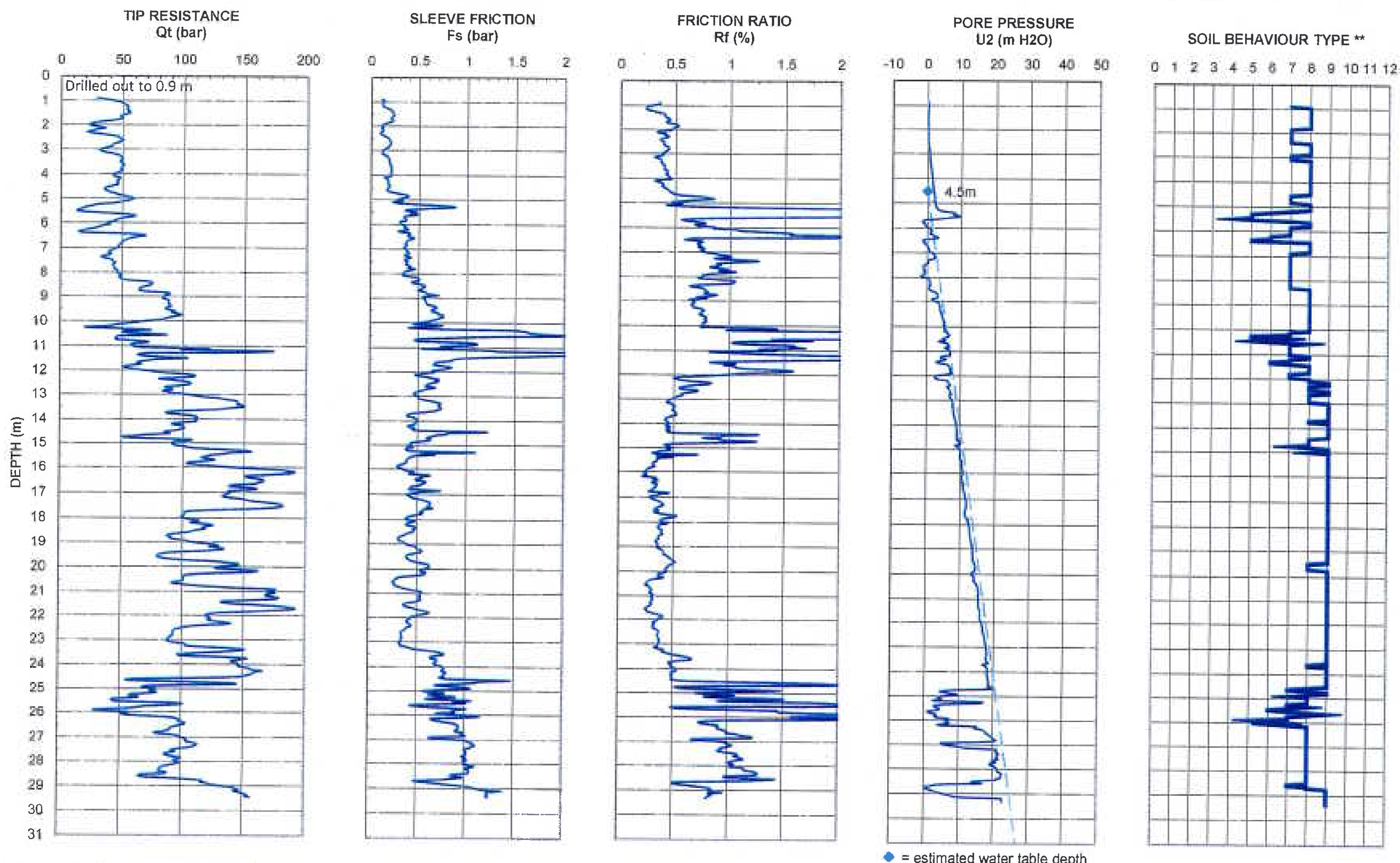
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-05	FRASER SURREY DOCKS, SURREY, BC	Figure: B.05



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-06	FRASER SURREY DOCKS, SURREY, BC	Figure: B.06



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
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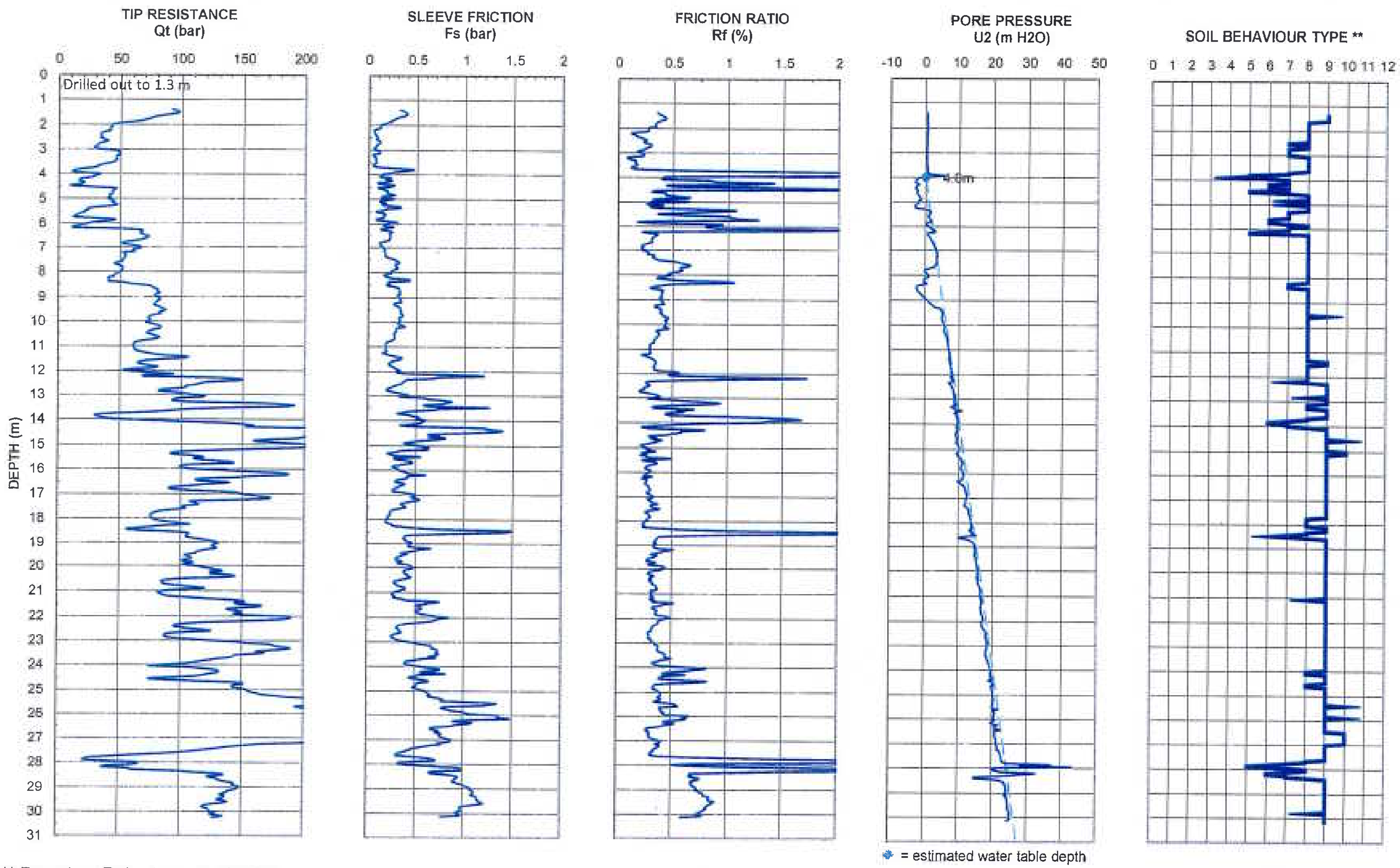
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-07	FRASER SURREY DOCKS, SURREY, BC	Figure: B.07



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
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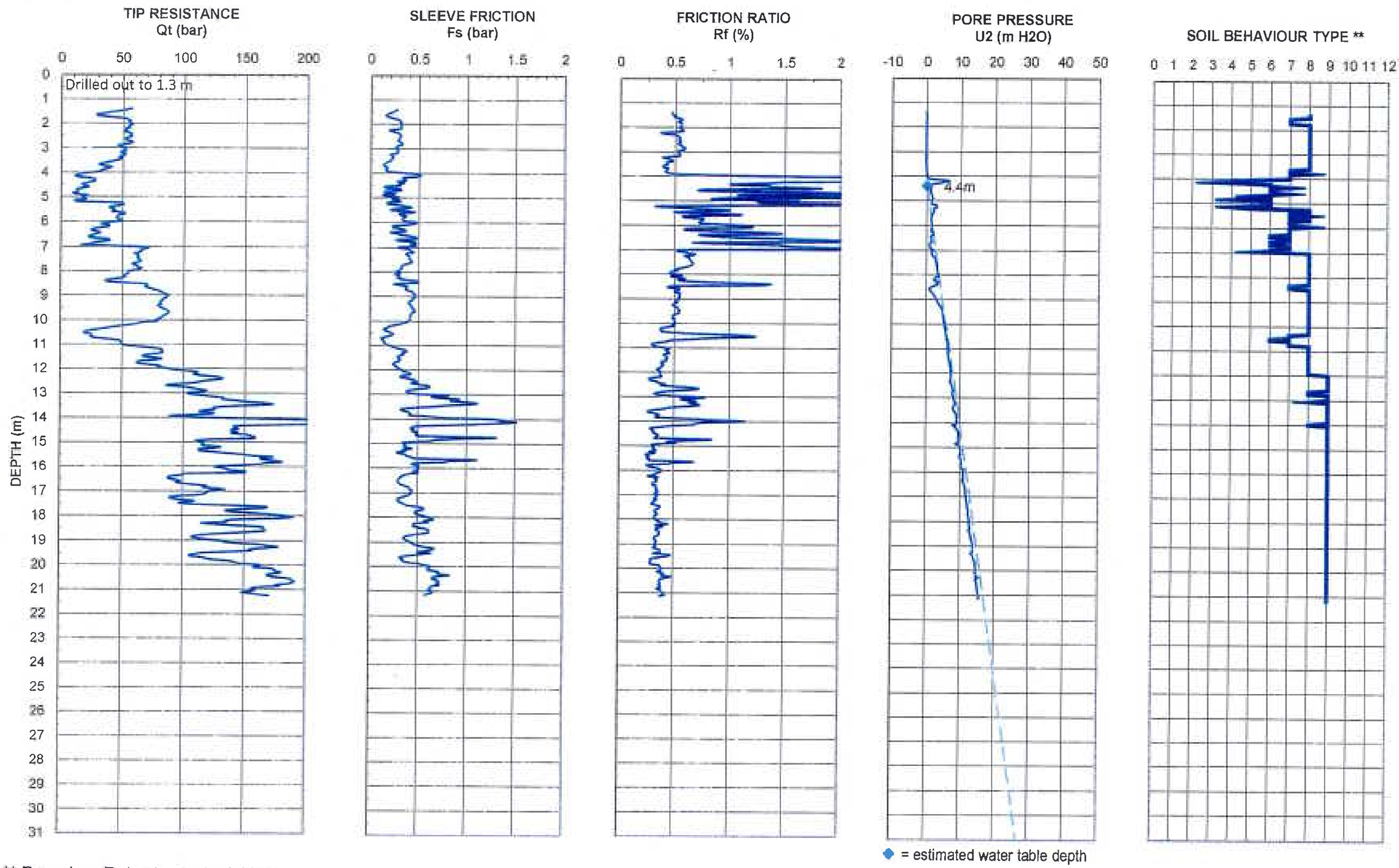

** Based on Robertson et. al 1986

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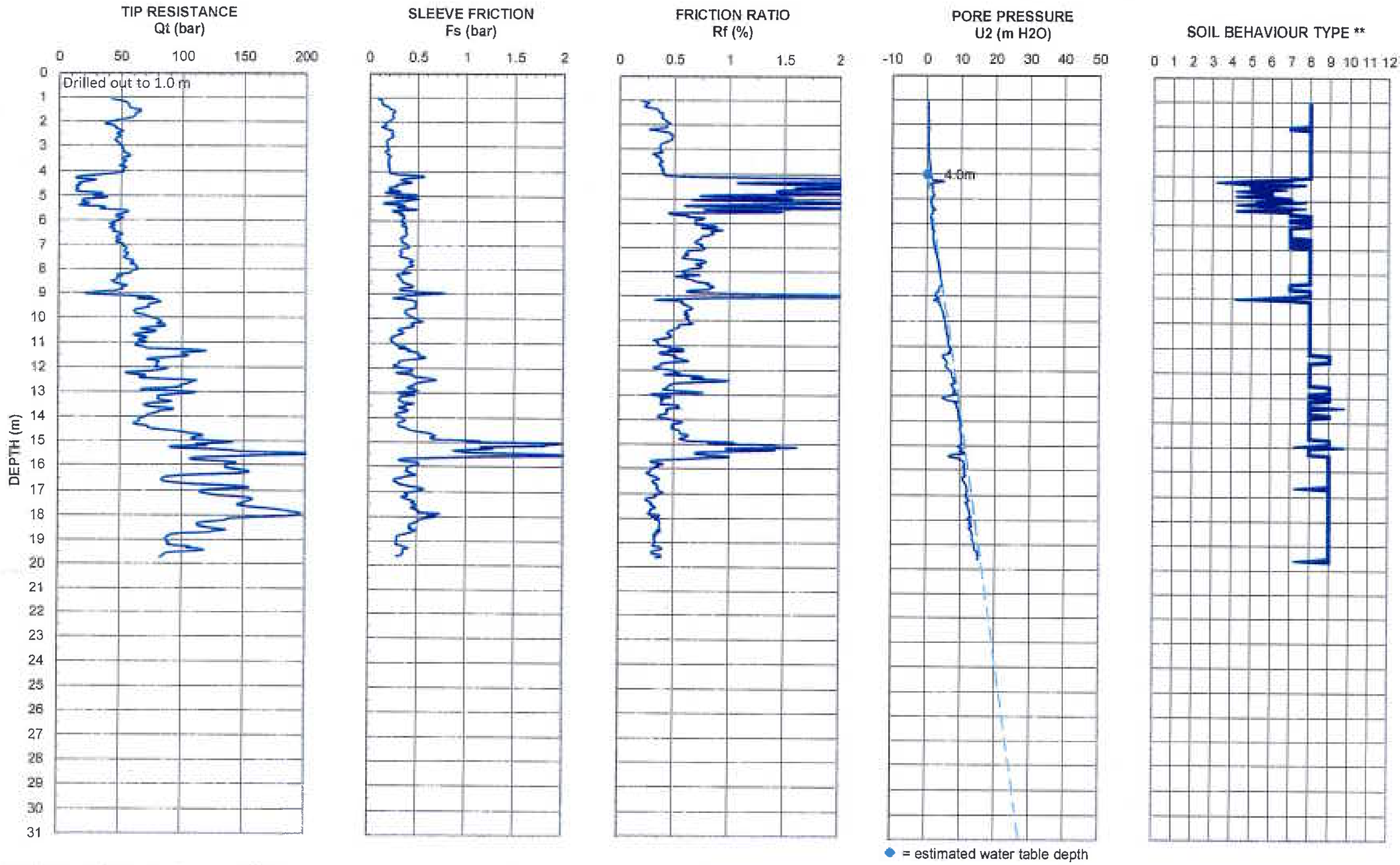
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-09	FRASER SURREY DOCKS, SURREY, BC	Figure: B.09



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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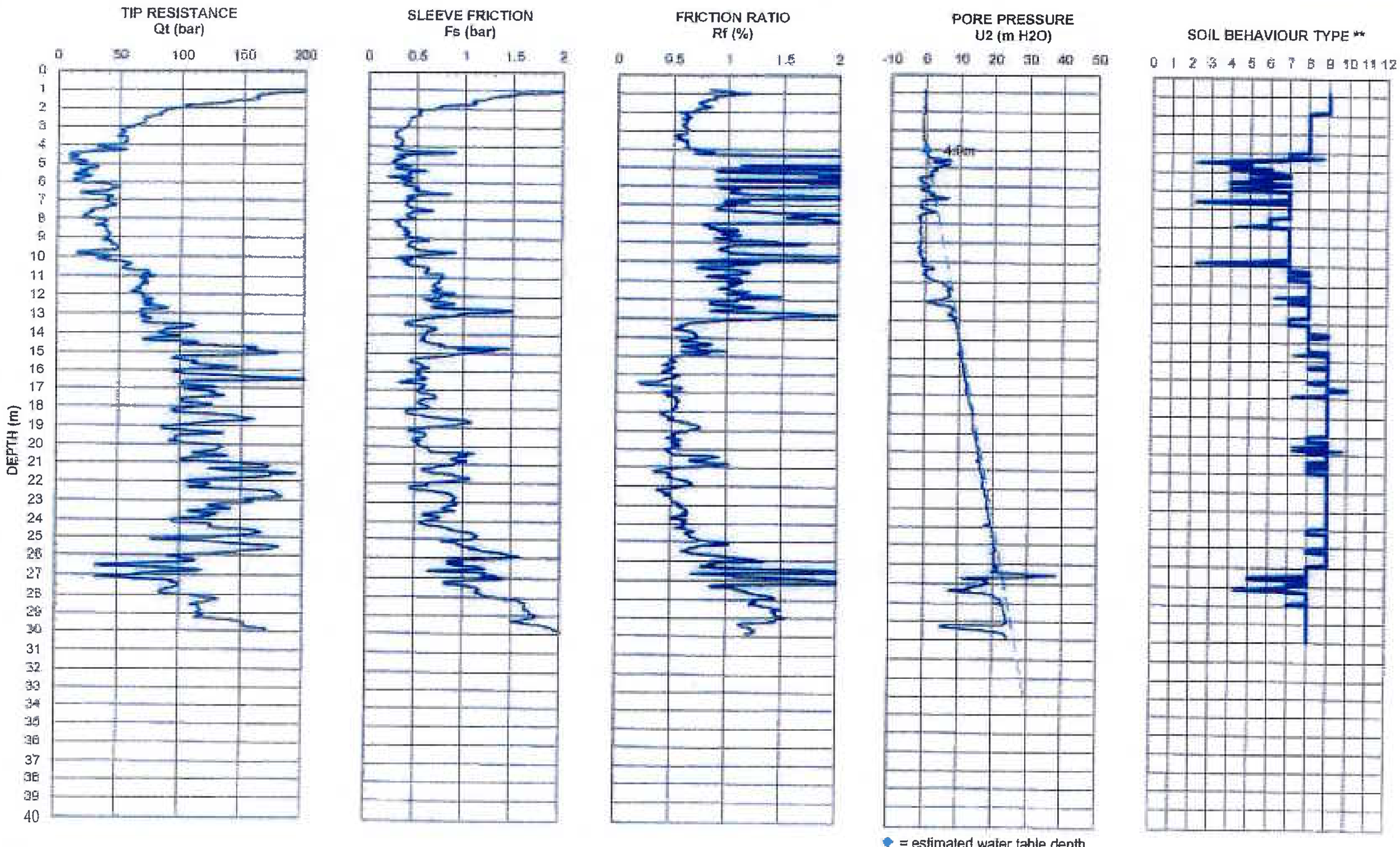
GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-02	FRASER SURREY DOCKS, SURREY, BC	Figure: B.02



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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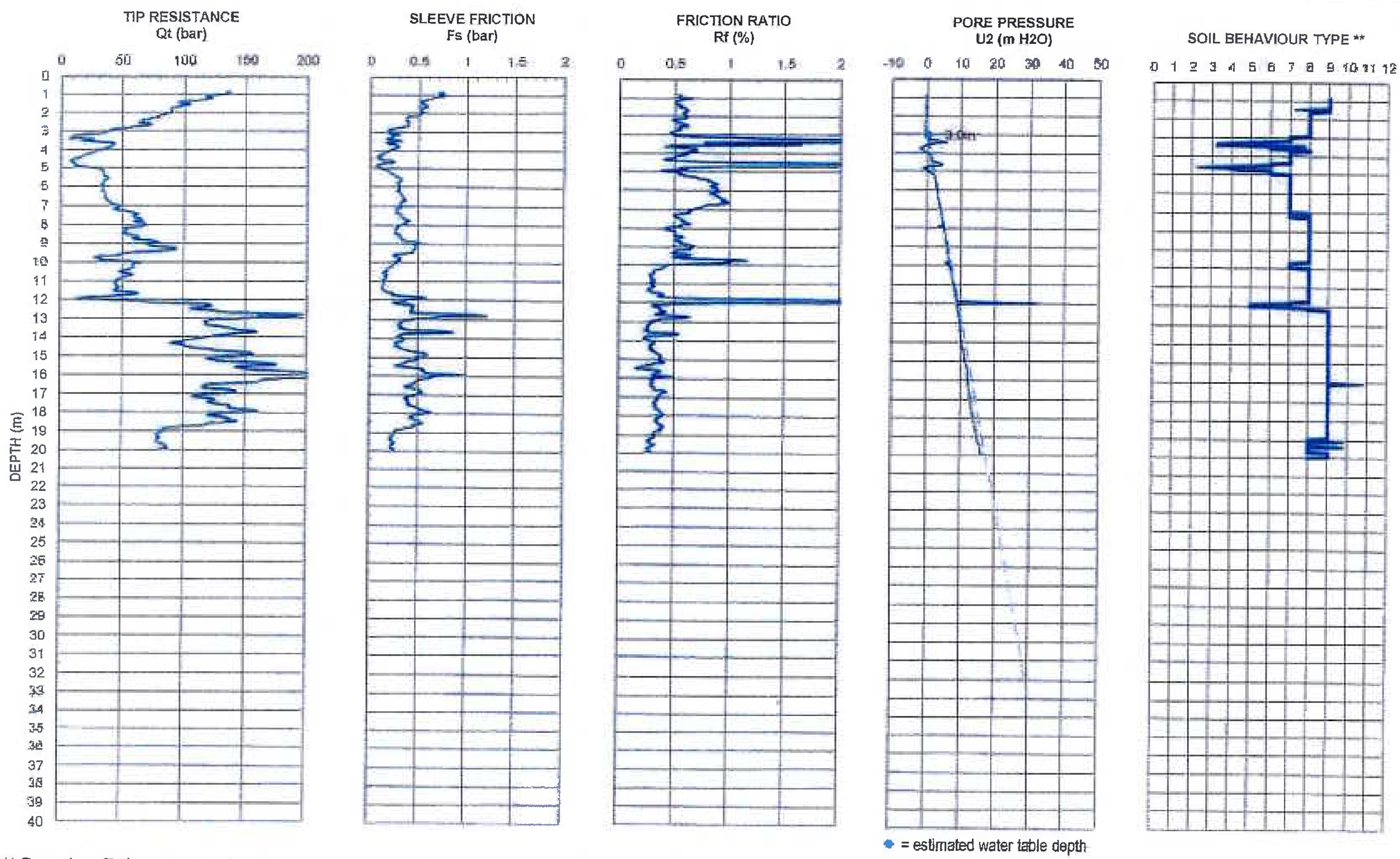
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-04	FRASER SURREY DOCKS, SURREY, BC	Figure: B.04



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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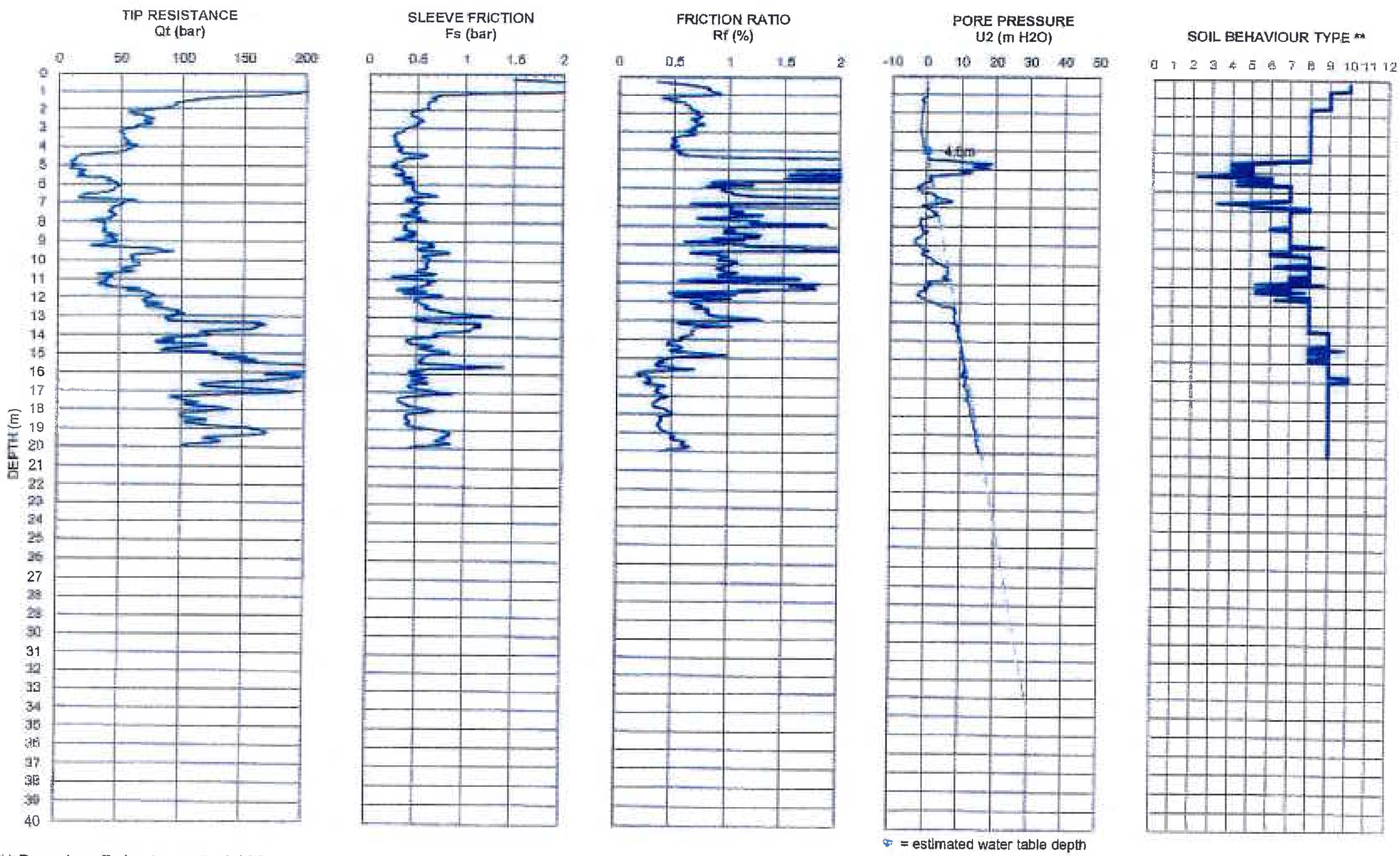
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-05	FRASER SURREY DOCKS, SURREY, BC	Figure: B.05



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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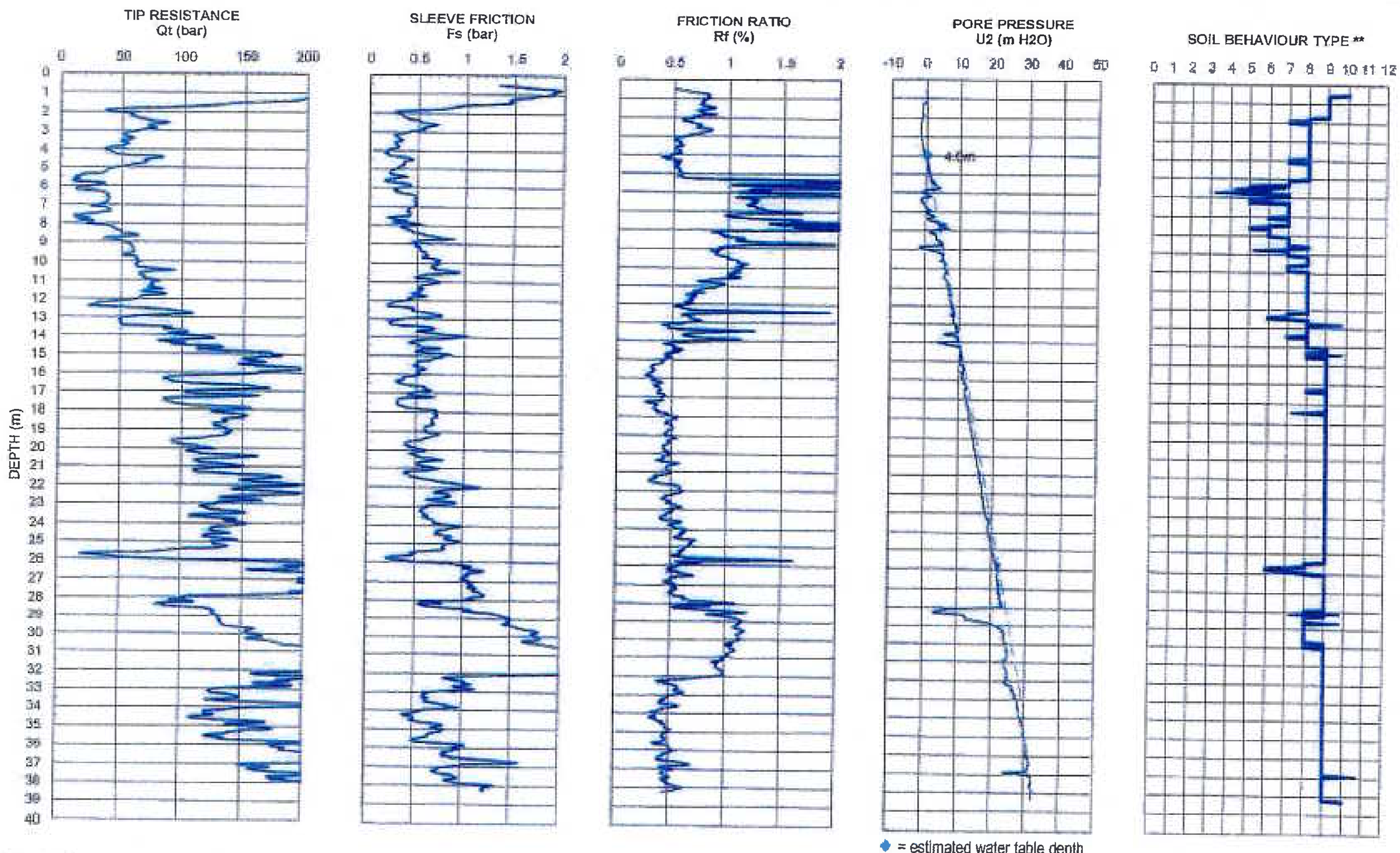
GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-07	FRASER SURREY DOCKS, SURREY, BC	Figure: B.07



◆ = estimated water table depth

** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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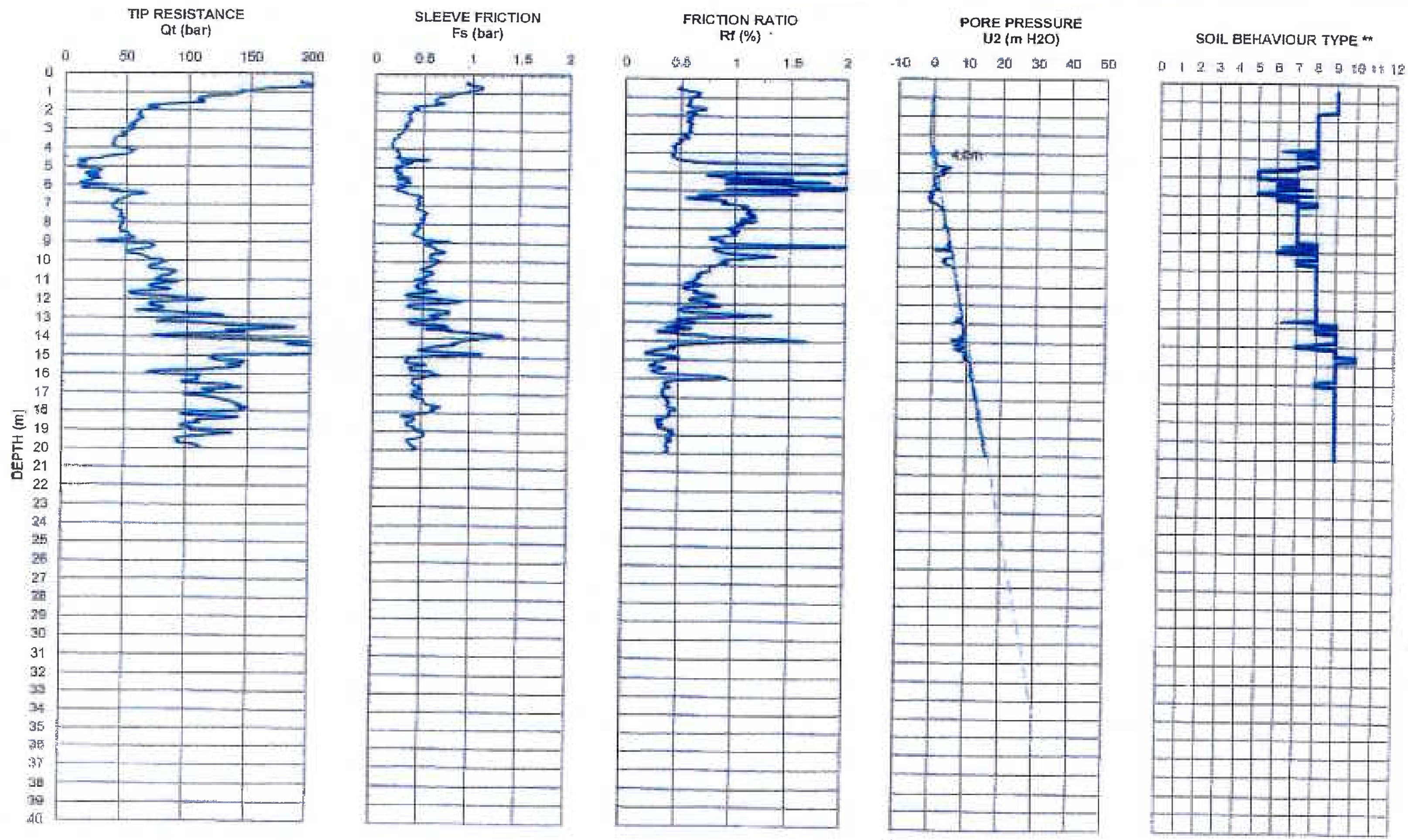
GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-08	FRASER SURREY DOCKS, SURREY, BC	Figure: B.08



= estimated water table depth

** Based on Robertson et. al 1986

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GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
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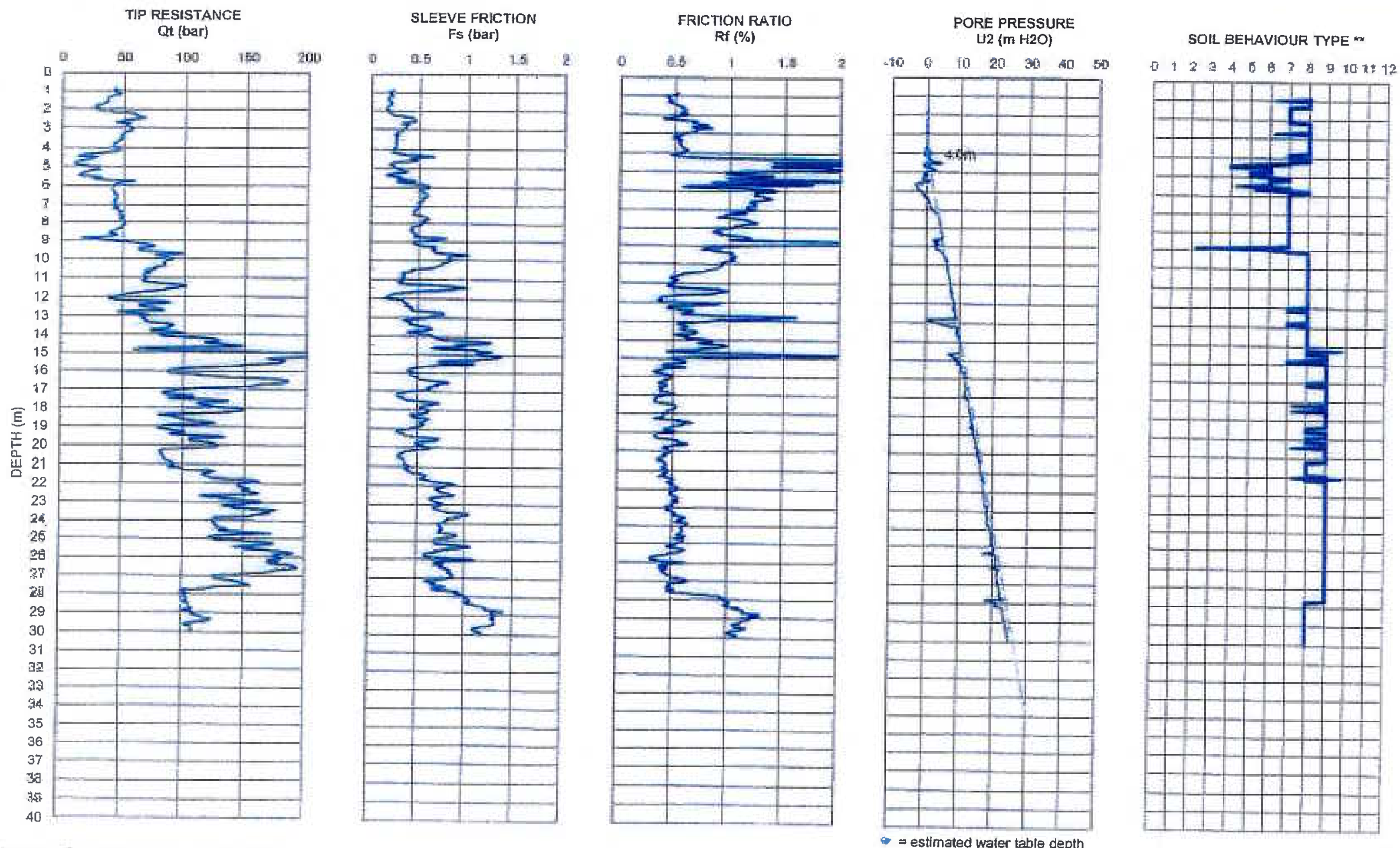

** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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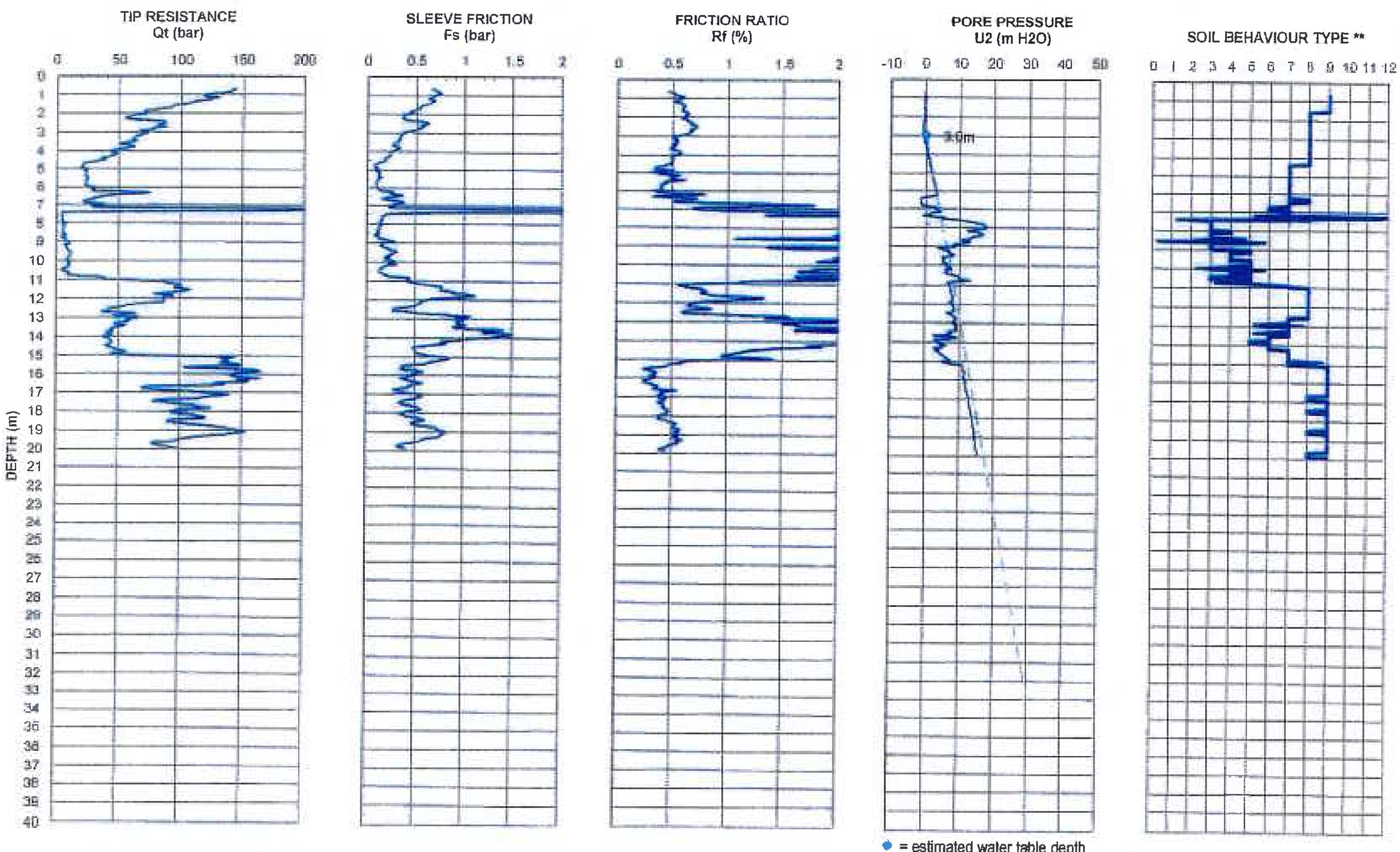
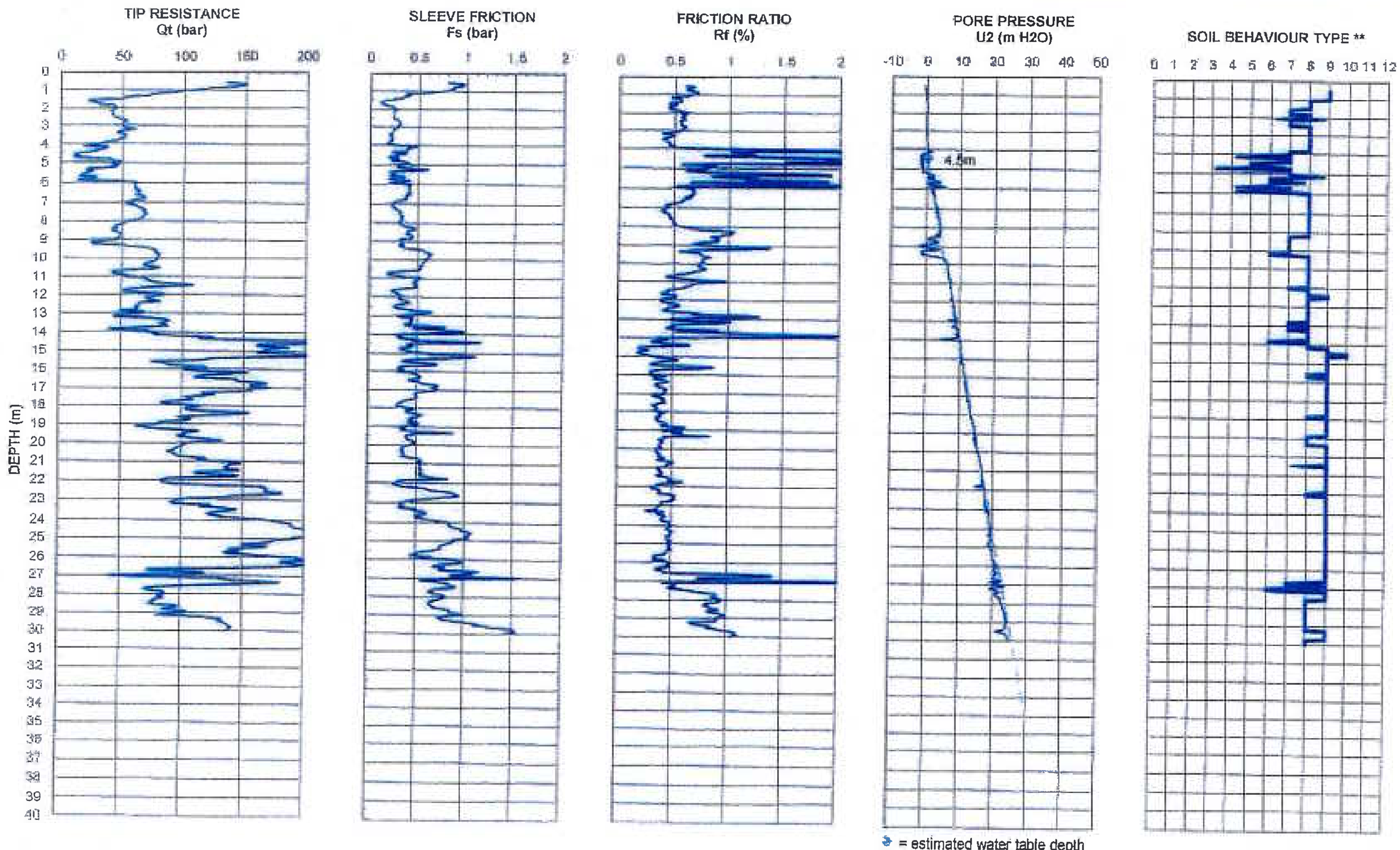
GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-10	FRASER SURREY DOCKS, SURREY, BC	Figure: B.10



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-11	FRASER SURREY DOCKS, SURREY, BC	Figure: B.11



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
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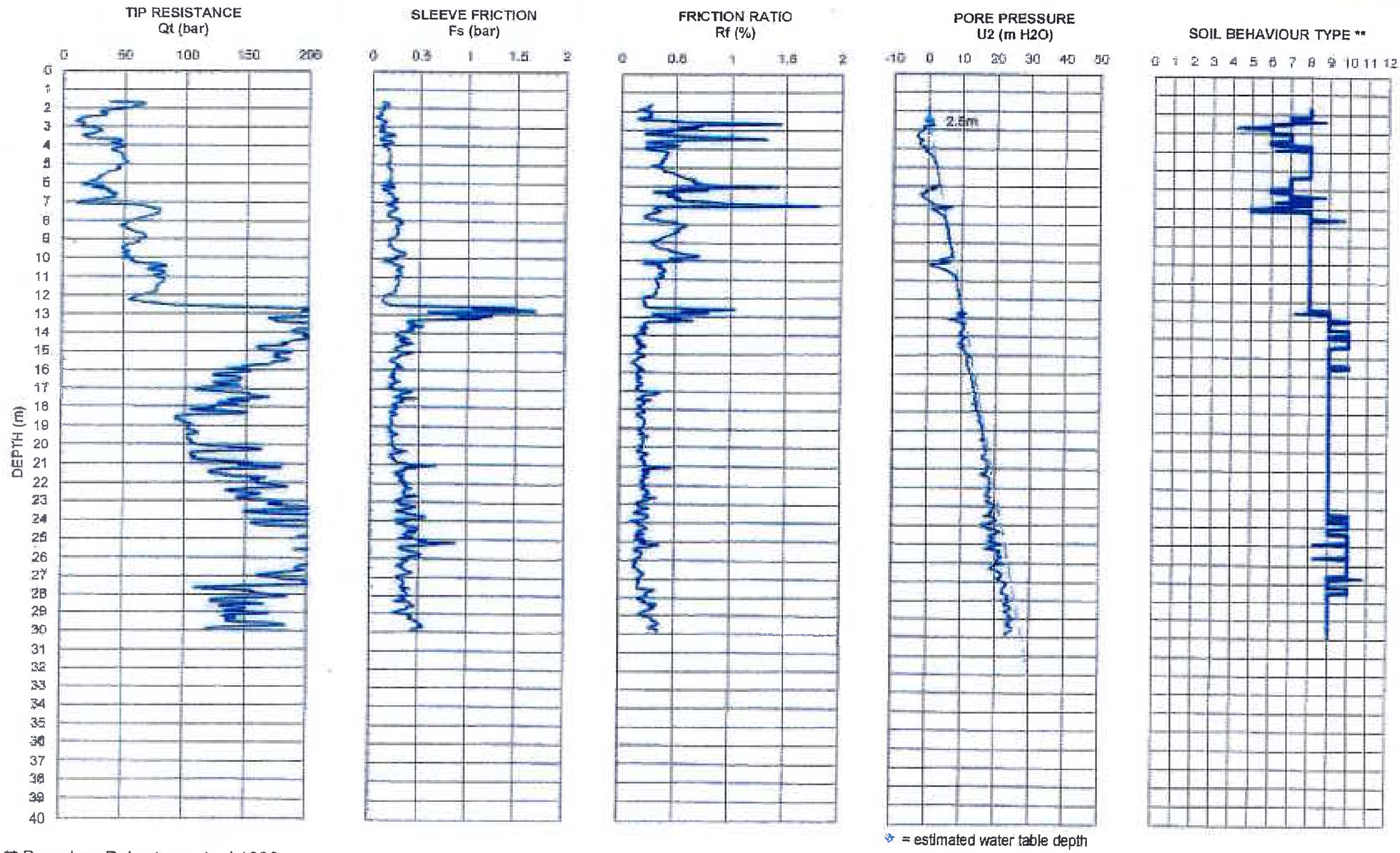
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC (Vancouver Kamloops Calgary)	2010-Sep-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT10-09	FRASER SURREY DOCKS, SURREY, BC	Figure: B.09



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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4 Silty Clay to Clay
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7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC
VANCOUVER KAMLOOPS CALGARY

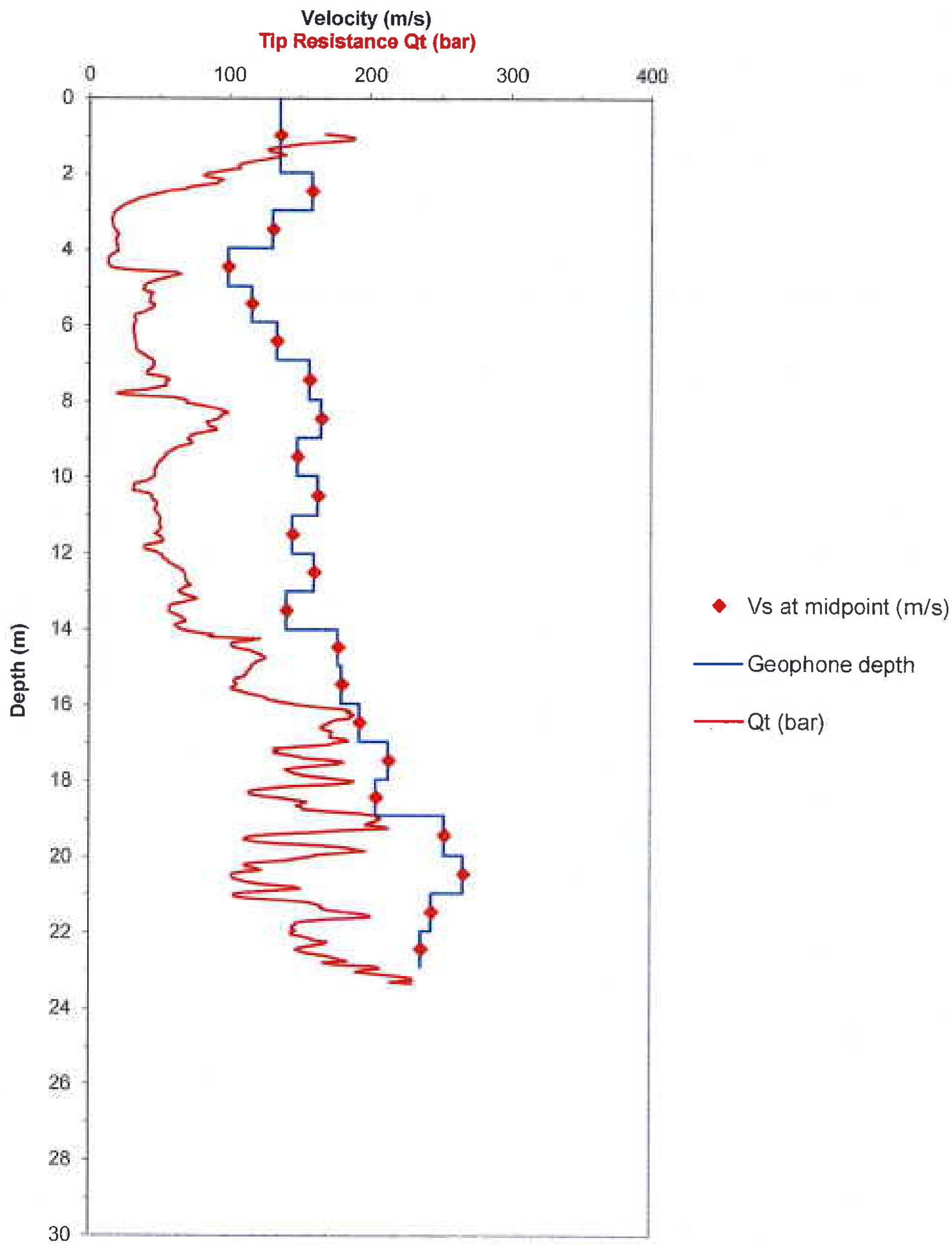
File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Location: FRASER SURREY DOCKS, SURREY, BC
Sounding: SCPT18-03
Date: 2018-Mar-16

Seismic Source: Beam
Source to cone (m): 0.4

Shear Wave Velocity Data (Vs)

Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference d (m)	Midpoint (m)	Time Difference (ms)	Shear Wave Velocity Vs (m/s)	d/Vs
2.15	1.95	1.99	1.99	0.98	14.65	136	0.0147
3.15	2.95	2.98	0.99	2.45	6.21	159	0.0062
4.15	3.95	3.97	0.99	3.45	7.61	131	0.0076
5.15	4.95	4.97	1.00	4.45	10.08	99	0.0101
6.10	5.90	5.91	0.95	5.43	8.20	116	0.0082
7.10	6.90	6.91	1.00	6.40	7.46	134	0.0075
8.15	7.95	7.96	1.05	7.43	6.67	157	0.0067
9.15	8.95	8.96	1.00	8.45	6.03	166	0.0060
10.15	9.95	9.96	1.00	9.45	6.72	149	0.0067
11.20	11.00	11.01	1.05	10.48	6.43	163	0.0064
12.20	12.00	12.01	1.00	11.50	6.89	145	0.0069
13.20	13.00	13.01	1.00	12.50	6.22	161	0.0062
14.20	14.00	14.01	1.00	13.50	7.09	141	0.0071
15.15	14.95	14.96	0.95	14.48	5.35	178	0.0054
16.15	15.95	15.96	1.00	15.45	5.55	180	0.0056
17.15	16.95	16.95	1.00	16.45	5.19	193	0.0052
18.15	17.95	17.95	1.00	17.45	4.69	213	0.0047
19.10	18.90	18.90	0.95	18.43	4.65	204	0.0047
20.15	19.95	19.95	1.05	19.43	4.16	252	0.0042
21.15	20.95	20.95	1.00	20.45	3.75	267	0.0038
22.15	21.95	21.95	1.00	21.45	4.11	244	0.0041
23.10	22.90	22.90	0.95	22.43	4.02	236	0.0040
						Σ(d/Vs)	0.1417
						average Vs = Σd / Σ(d/Vs)	162

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Location: FRASER SURREY DOCKS, SURREY, BC
Sounding: SCPT18-03
Date: 2018-Mar-16



GEOPACIFIC
VANCOUVER KAMLOOPS CALGARY

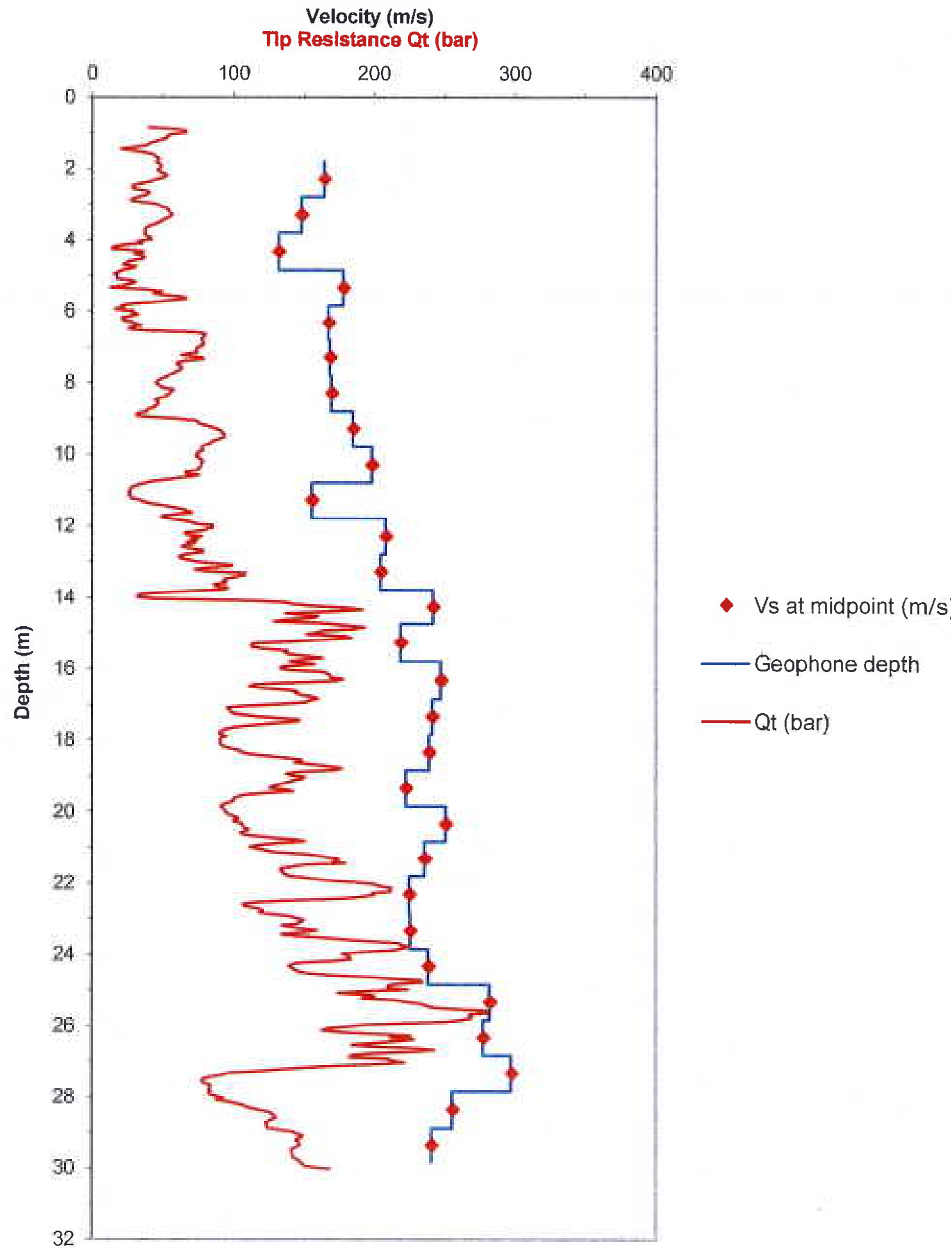
File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Location: FRASER SURREY DOCKS, SURREY, BC
Sounding: SCPT18-05
Date: 2018-Mar-16

Seismic Source: Beam
Source to cone (m): 0.4

Shear Wave Velocity Data (Vs)

Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference d (m)	Midpoint (m)	Time Difference (ms)	Shear Wave Velocity Vs (m/s)	d/Vs
2.00	1.80	1.84					
3.00	2.80	2.83	0.98	2.30	6.02	164	0.0060
4.00	3.80	3.82	0.99	3.30	6.74	147	0.0067
5.05	4.85	4.87	1.05	4.33	7.93	132	0.0079
6.05	5.85	5.86	1.00	5.35	5.63	177	0.0056
7.00	6.80	6.81	0.95	6.33	5.69	167	0.0057
8.00	7.80	7.81	1.00	7.30	5.96	168	0.0060
9.00	8.80	8.81	1.00	8.30	5.92	169	0.0059
10.00	9.80	9.81	1.00	9.30	5.41	185	0.0054
11.00	10.80	10.81	1.00	10.30	5.04	198	0.0050
12.00	11.80	11.81	1.00	11.30	6.45	155	0.0065
13.00	12.80	12.81	1.00	12.30	4.80	208	0.0048
14.00	13.80	13.81	1.00	13.30	4.89	205	0.0049
14.95	14.75	14.76	0.95	14.28	3.93	242	0.0039
16.00	15.80	15.81	1.05	15.28	4.80	219	0.0048
17.05	16.85	16.85	1.05	16.33	4.24	248	0.0042
18.05	17.85	17.85	1.00	17.35	4.14	241	0.0041
19.05	18.85	18.85	1.00	18.35	4.18	239	0.0042
20.05	19.85	19.85	1.00	19.35	4.49	223	0.0045
21.05	20.85	20.85	1.00	20.35	3.98	251	0.0040
22.00	21.80	21.80	0.95	21.33	4.03	236	0.0040
23.05	22.85	22.85	1.05	22.33	4.66	225	0.0047
24.05	23.85	23.85	1.00	23.35	4.43	226	0.0044
25.05	24.85	24.85	1.00	24.35	4.19	239	0.0042
26.05	25.85	25.85	1.00	25.35	3.54	282	0.0035
27.05	26.85	26.85	1.00	26.35	3.60	278	0.0036
28.05	27.85	27.85	1.00	27.35	3.36	298	0.0034
29.10	28.90	28.90	1.05	28.38	4.10	256	0.0041
30.05	29.85	29.85	0.95	29.38	3.94	241	0.0039
						Σ(d/Vs)	0.1360
						average Vs = Σd / Σ(d/Vs)	206

File: 15657
Project: PROPOSED FRASER GRAIN TERMINAL
Client: FWS GROUP
Location: FRASER SURREY DOCKS, SURREY, BC
Sounding: SCPT18-05
Date: 2018-Mar-16



APPENDIX C - INTERPRETED PARAMETERS

The following charts plot the Standard Penetration Test (SPT) values and the undrained strength of fine grained soils based upon generally accepted correlations. The methods of correlation are presented below.

STANDARD PENETRATION TEST CORRELATION

The Standard Penetration Test $N_{1(60)}$ value is related to the cone tip resistance through a Qc/N ratio that depends upon the mean grain size of the soil particles. The soil type is determined from the interpretation described in Appendix B and the data of Table C.1 below is used to calculate the value of $N_{(60)}$.

Table C.1. Tablulated Qc/$N_{1(60)}$ Ratios for Interpreted Soil Types

Soil Type	Qc/N Ratio
Organic soil - Peat	1.0
Sensitive Fine Grained	2.0
Clay	1.0
Silty Clay to Clay	1.5
Clayey Silt to Silty Clay	2.0
Silt	2.5
Silty Sand to Sandy Silt	3.0
Clean Sand to Silty Sand	4.0
Clean Sand	5.0
Gravelly Sand to Sand	6.0
Very Stiff Fine Grained	1.0
Sand to Clayey Sand	2.0

The Qc/$N_{1(60)}$ ratio is based upon the published work of Robertson (1985)[2]. The values of N are corrected for overburden pressure in accordance with the correction suggested by Liao and Whitman using a factor of 0.5. Where the correction is of the form:

$$N_1 = \sigma^{0.5} * N$$

All calculations are carried out by computer using the software program CPTint.exe developed by UBC Civil Engineering Department. The results of the interpretation are presented on the following Figures.

UNDRAINED SHEAR STRENGTH CORRELATION

It is generally accepted that there is a correlation between undrained shear strength of clay and the tip resistance as determined from the cone penetration testing. Generally the correlation is of the form:

$$S_u = \frac{(q_c - \sigma_v)}{N_k}$$

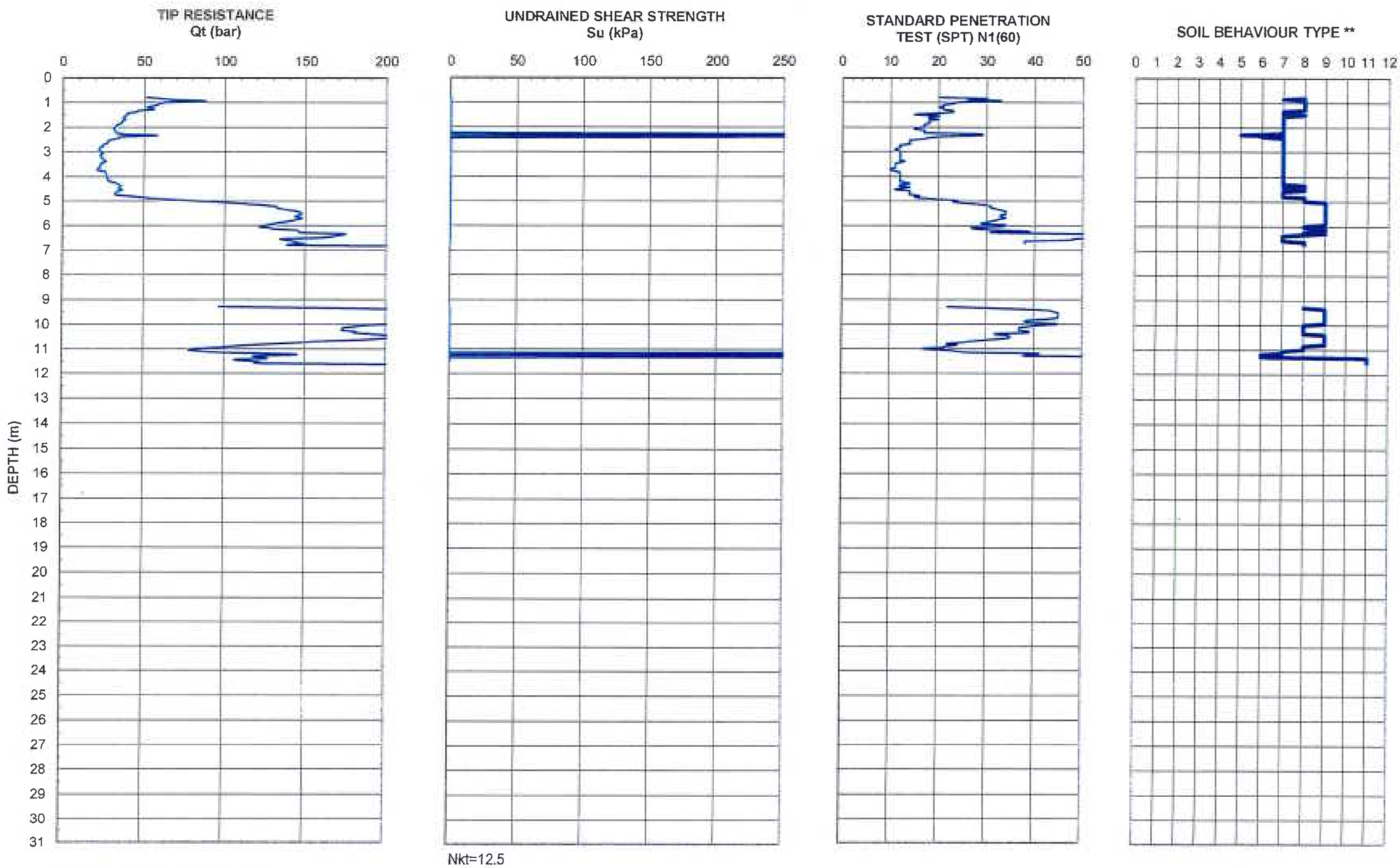
where q_c = cone tip resistance, σ = in situ total stress, N_k = cone constant

The undrained shear strength of the clay has been calculated using the cone tip resistance and an N_k factor of 12.5. All calculations have been carried out automatically using the program CPTint.exe. The results are presented on the Figures following.

---

2 Robertson, P.K., 1985, "In-Situ Testing and Its Application to Foundation Engineering", 1985 Canadian Geotechnical Colloquium, Canadian Geotechnical Journal, Vol. 23, No. 23, 1986

GEOPACIFIC	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-01	FRASER SURREY DOCKS, SURREY, BC	Figure: C.01



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
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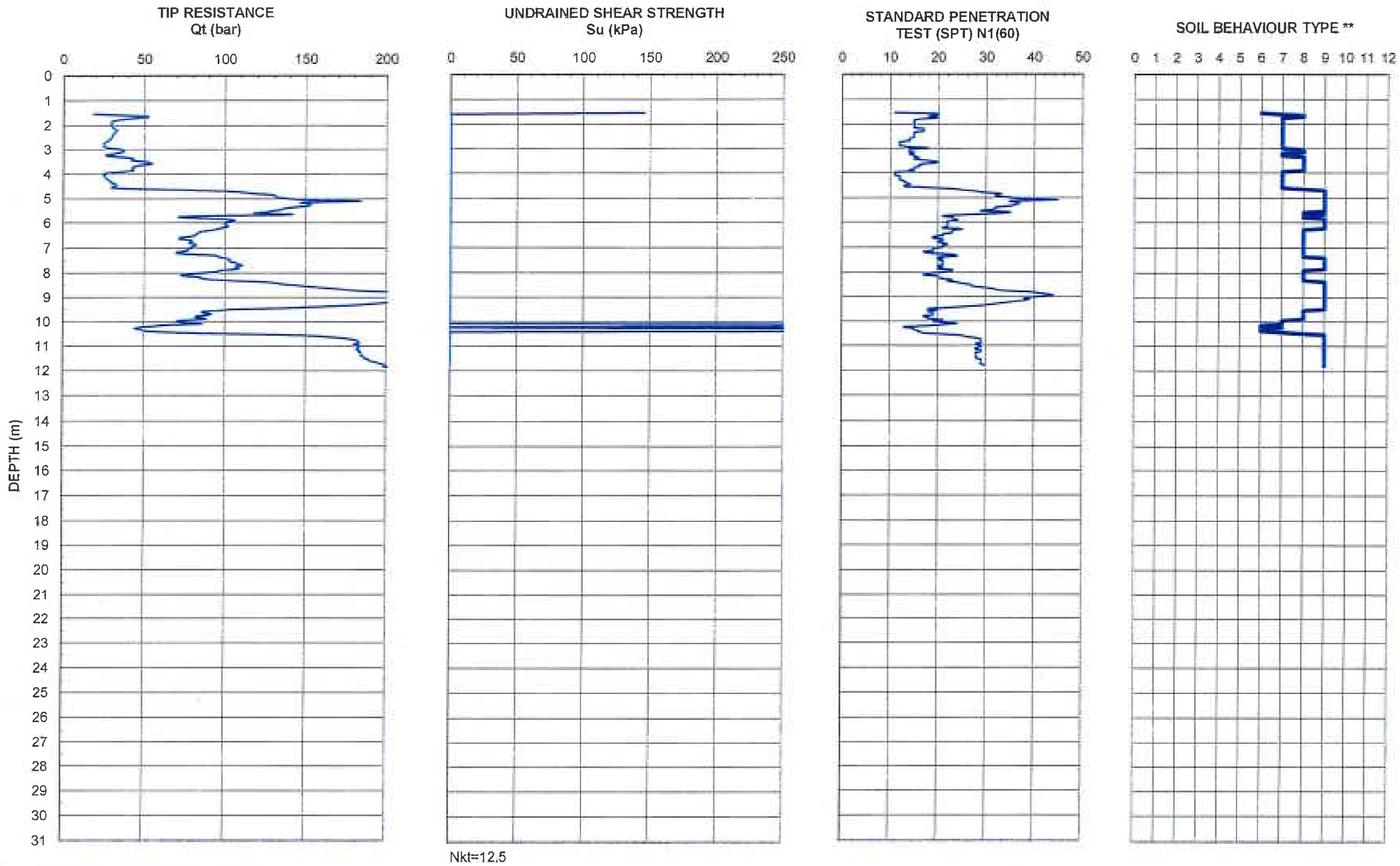
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-02	FRASER SURREY DOCKS, SURREY, BC	Figure: C.02



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
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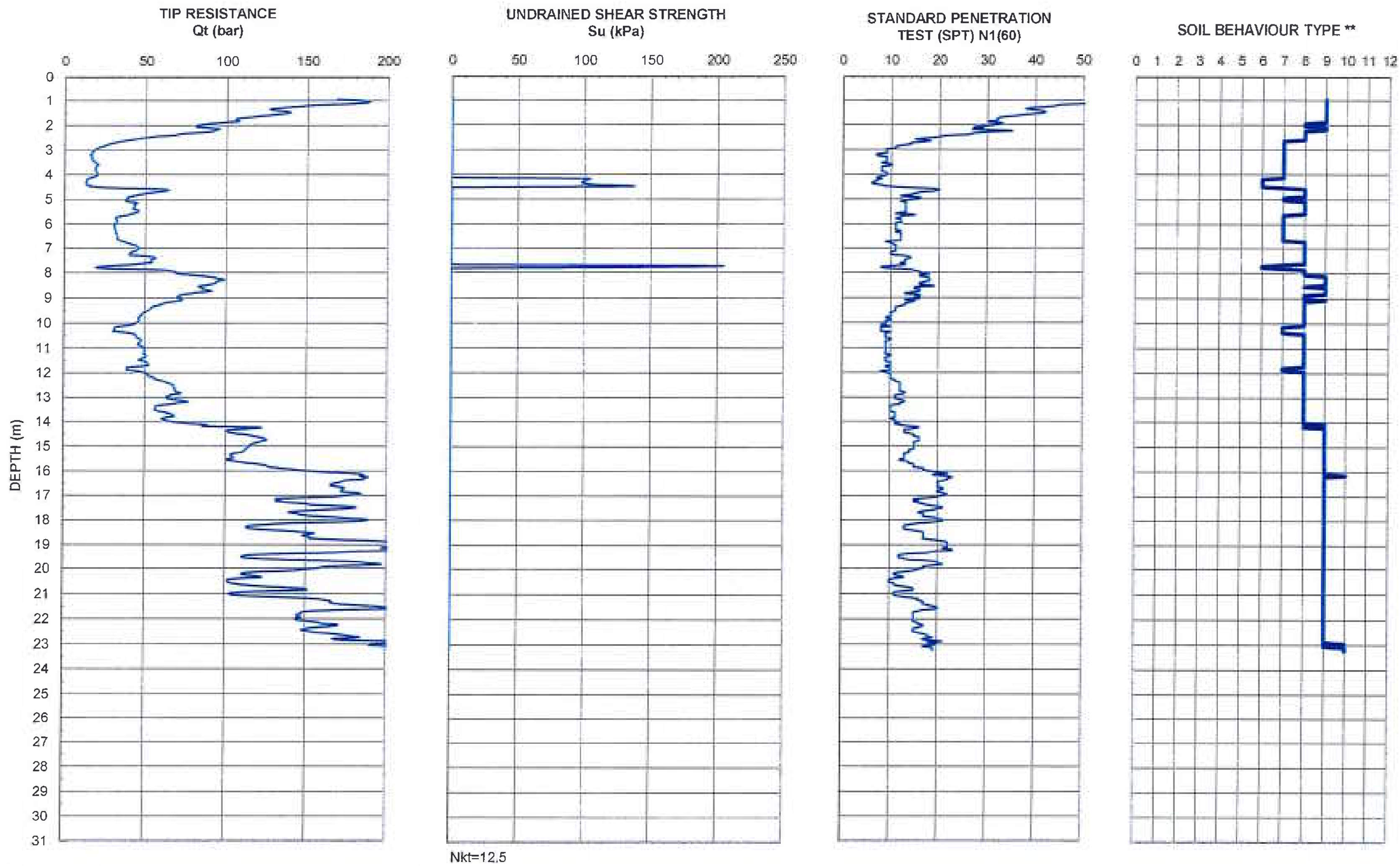
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

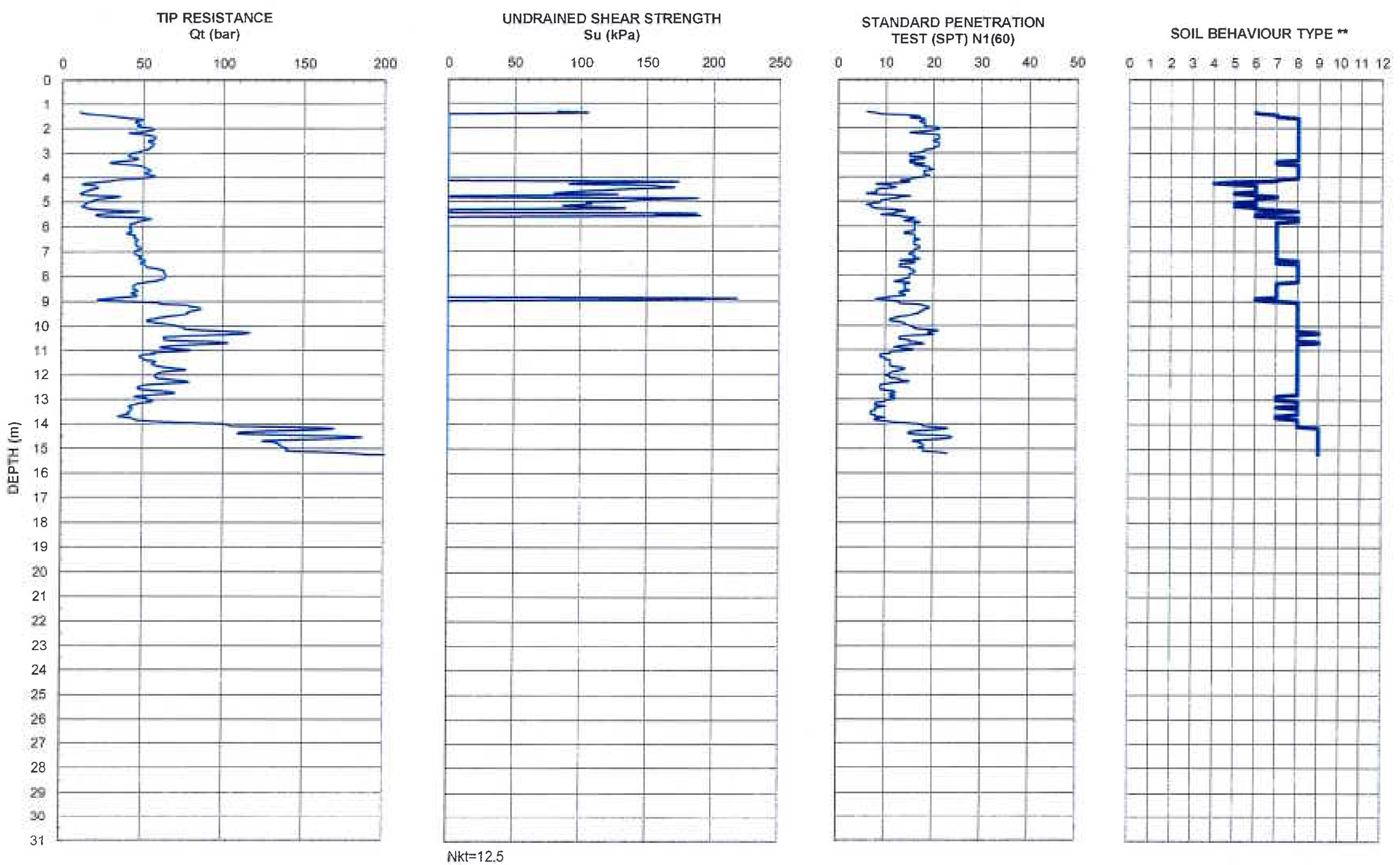
GEOPACIFIC (Vancouver Kamloops Calgary)	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-03	FRASER SURREY DOCKS, SURREY, BC	Figure: C.03



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-04	FRASER SURREY DOCKS, SURREY, BC	Figure: C.04



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
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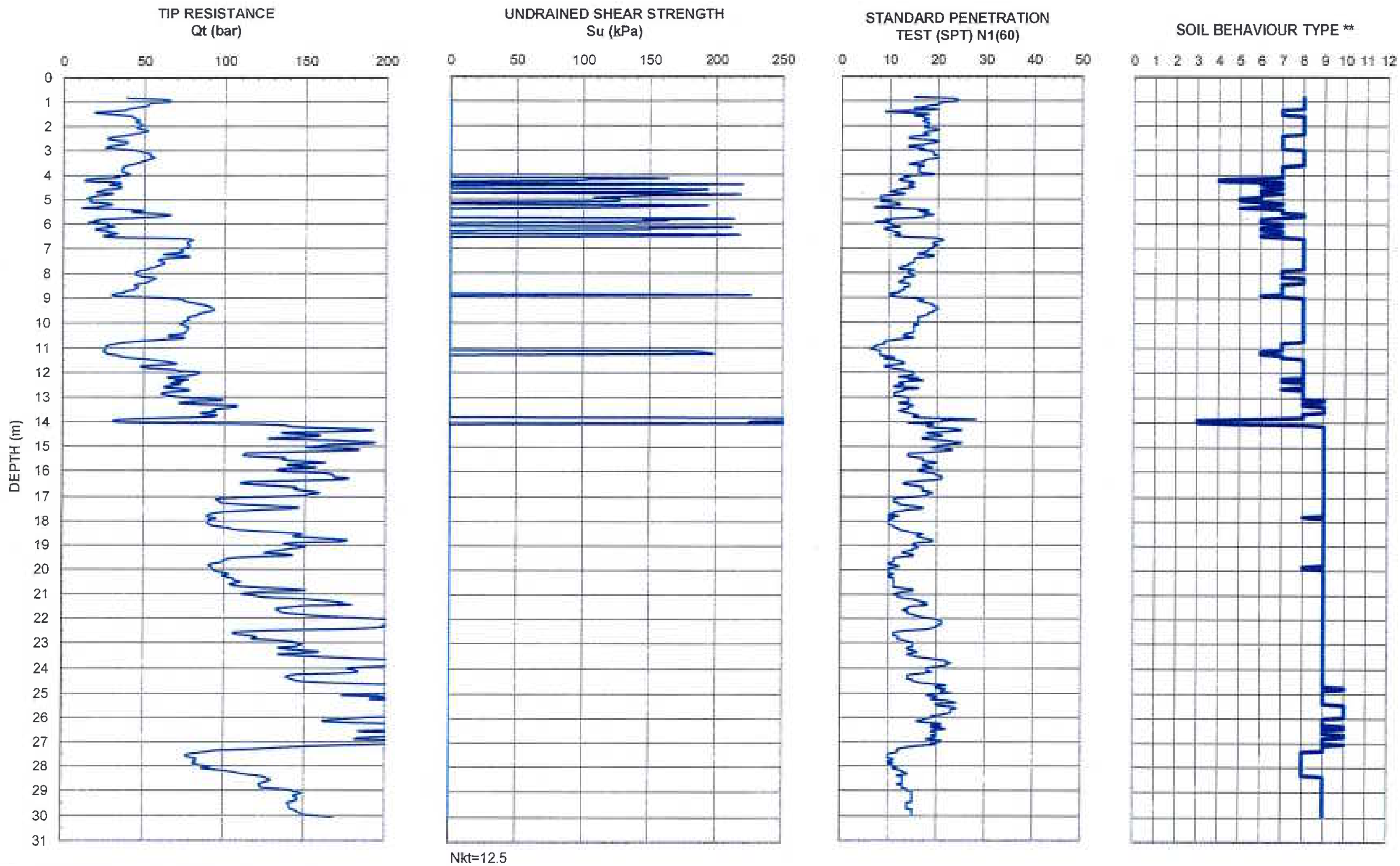
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-05	FRASER SURREY DOCKS, SURREY, BC	Figure: C.05



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
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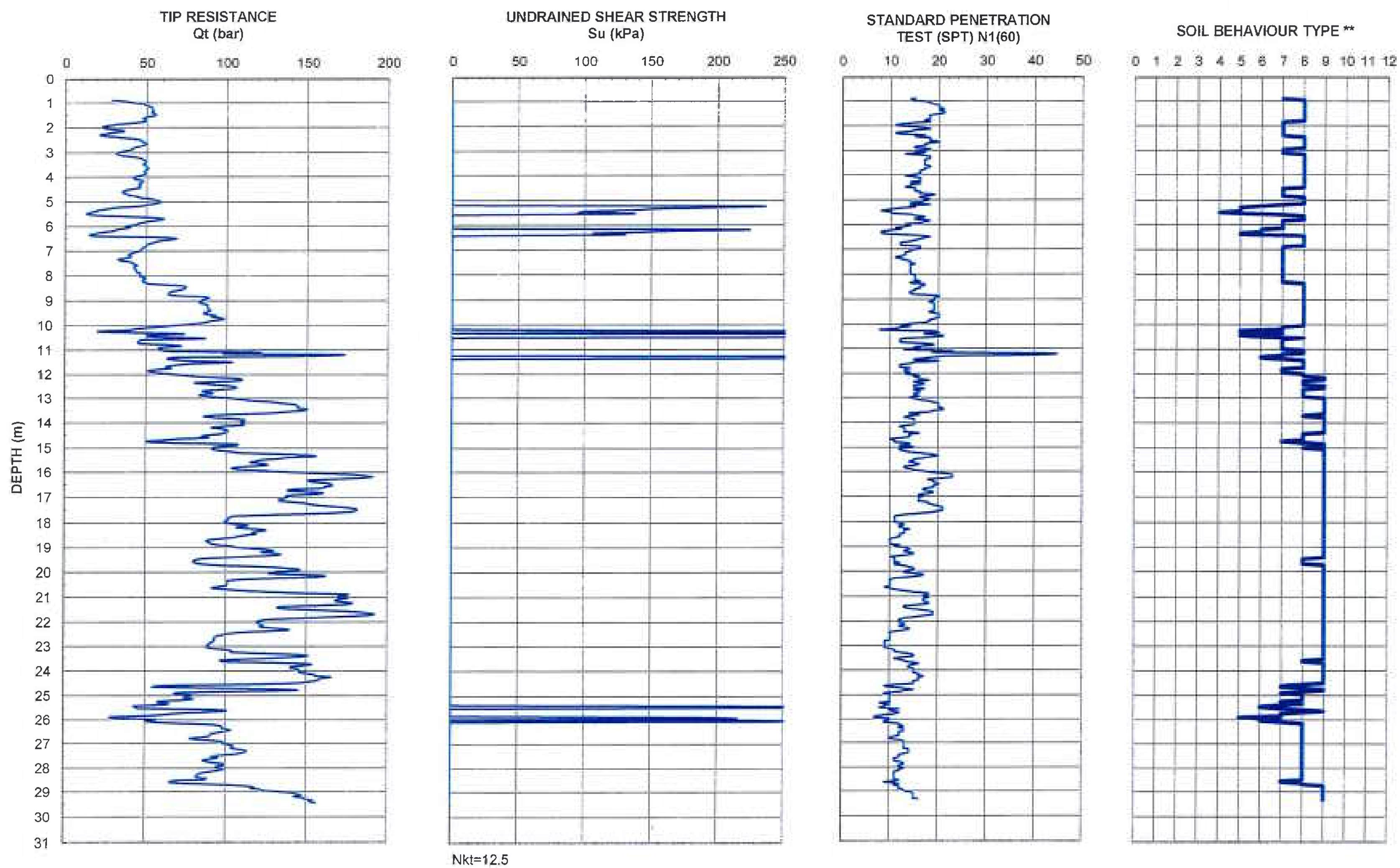
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

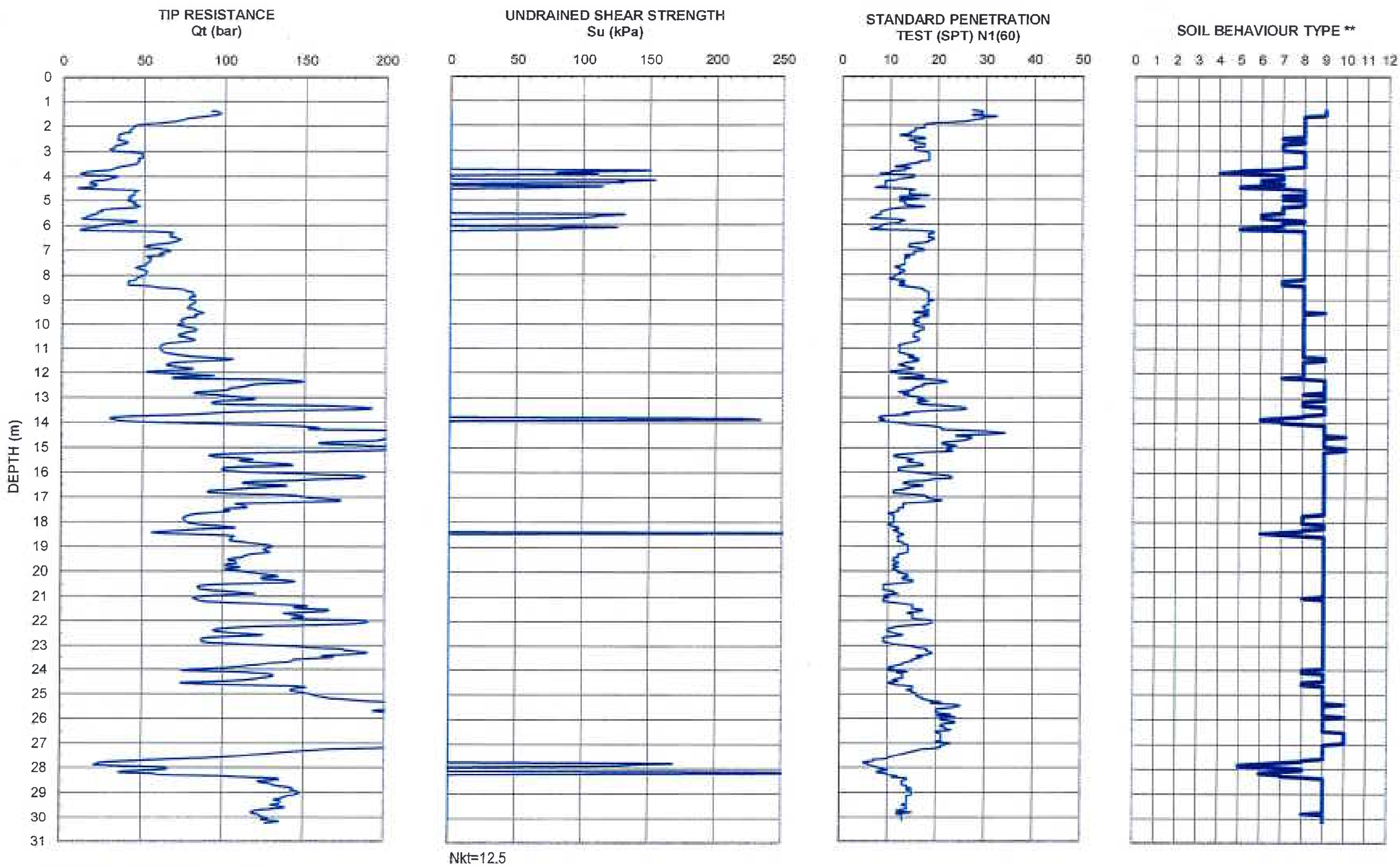
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-06	FRASER SURREY DOCKS, SURREY, BC	Figure: C.06



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-07	FRASER SURREY DOCKS, SURREY, BC	Figure: C.07



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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3 Clay
4 Silty Clay to Clay
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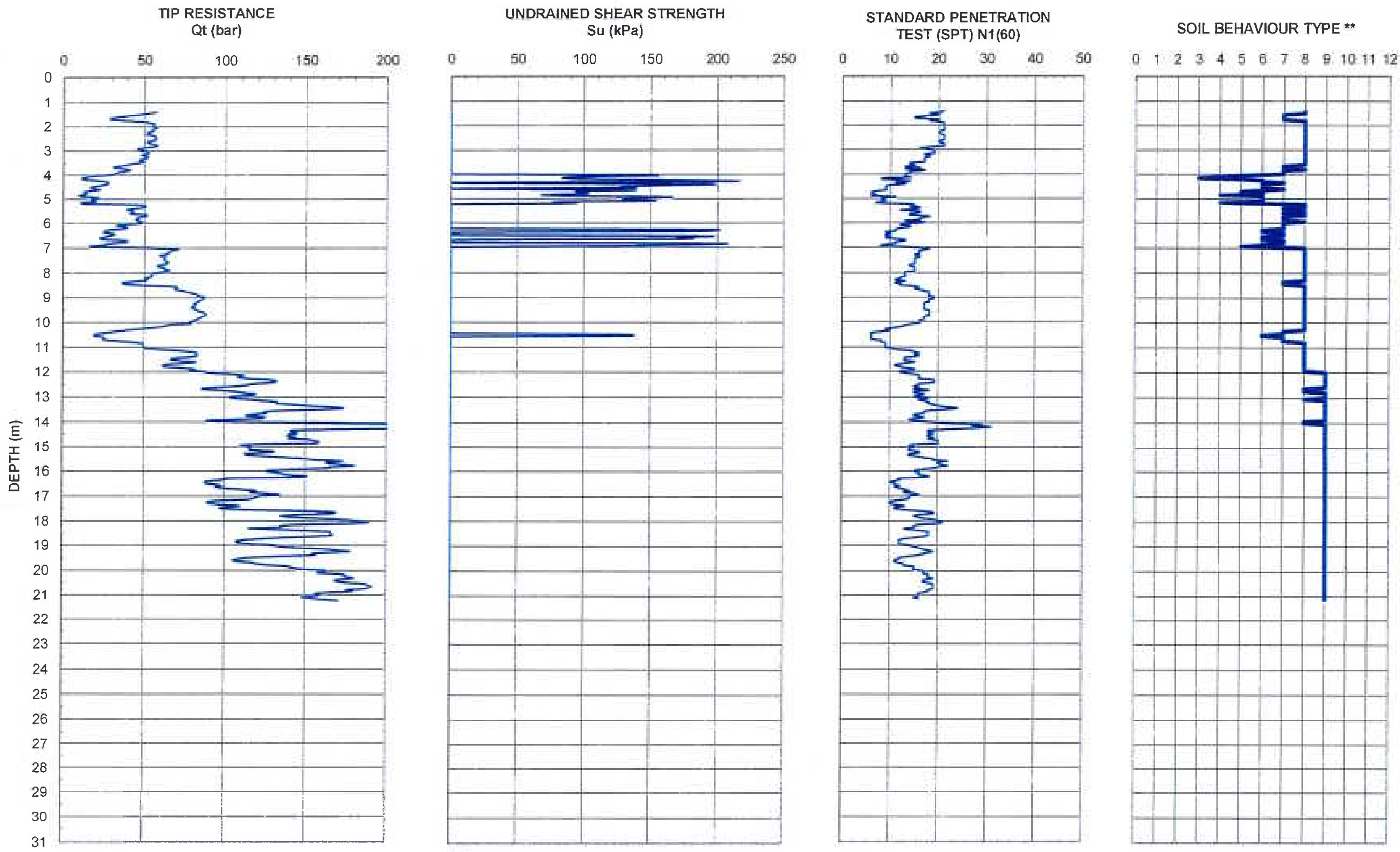
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-08	FRASER SURREY DOCKS, SURREY, BC	Figure: C.08



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
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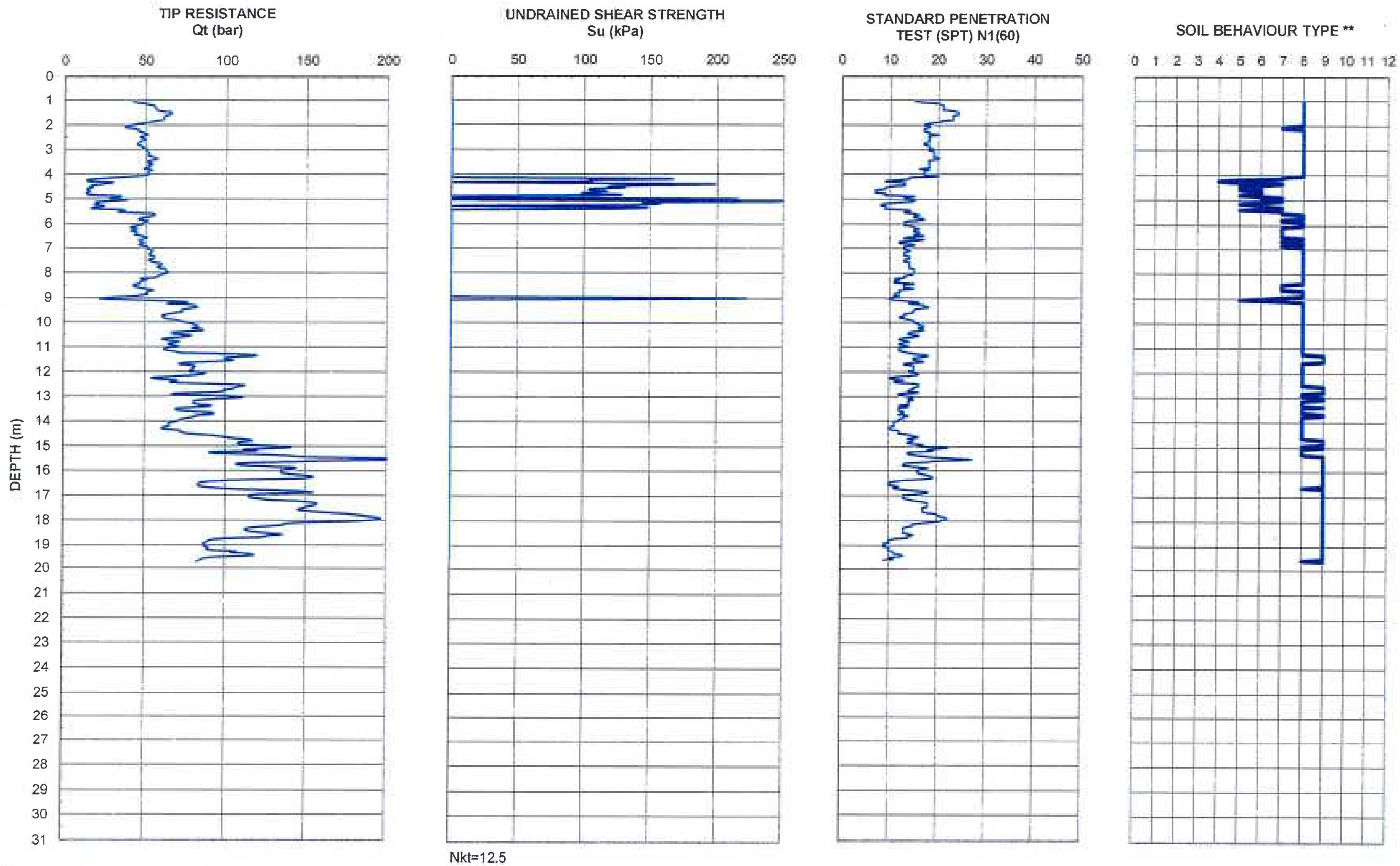
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-09	FRASER SURREY DOCKS, SURREY, BC	Figure: C.09



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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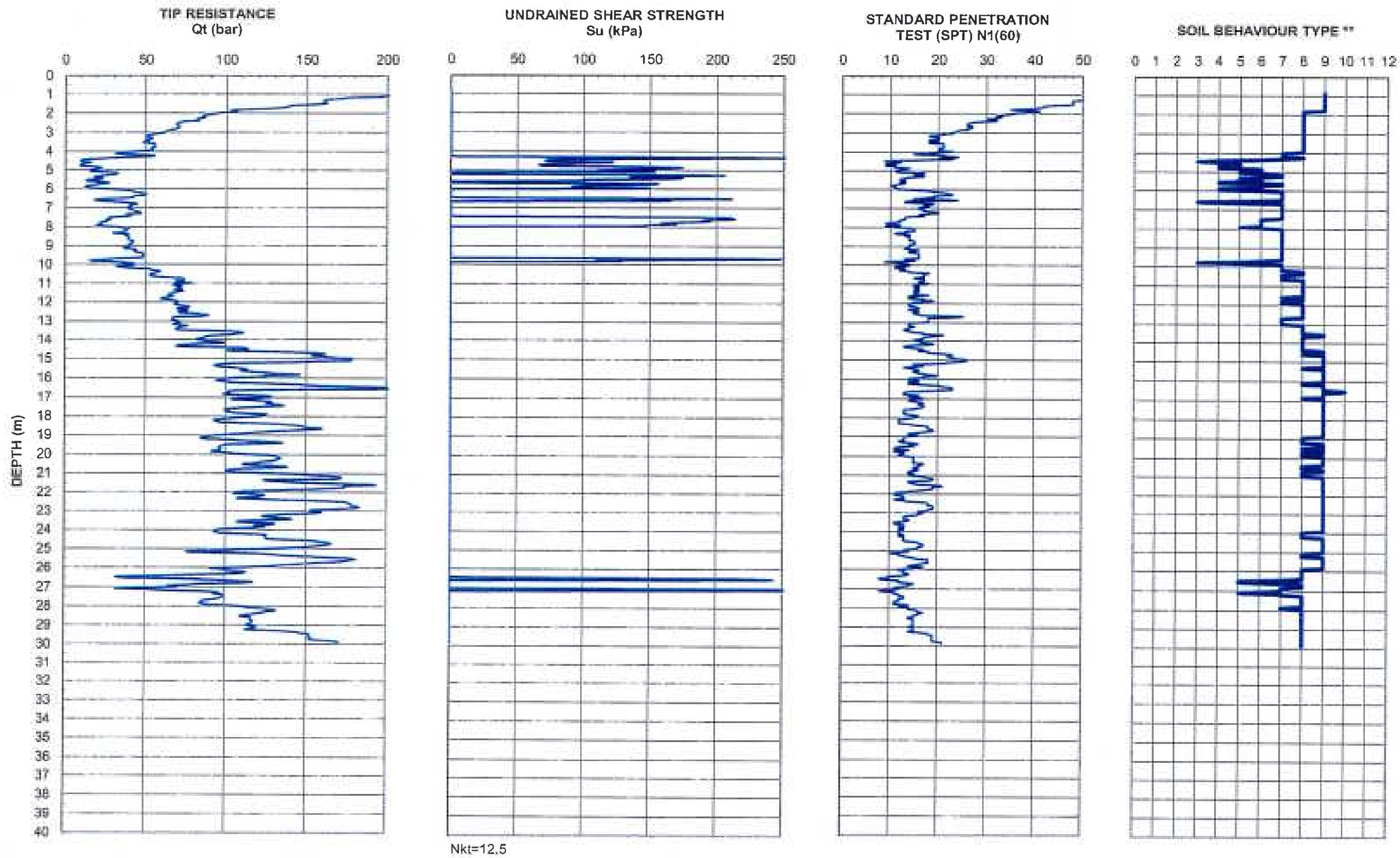
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-02	FRASER SURREY DOCKS, SURREY, BC	Figure: C.02



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
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11 Very Stiff Fine Grained
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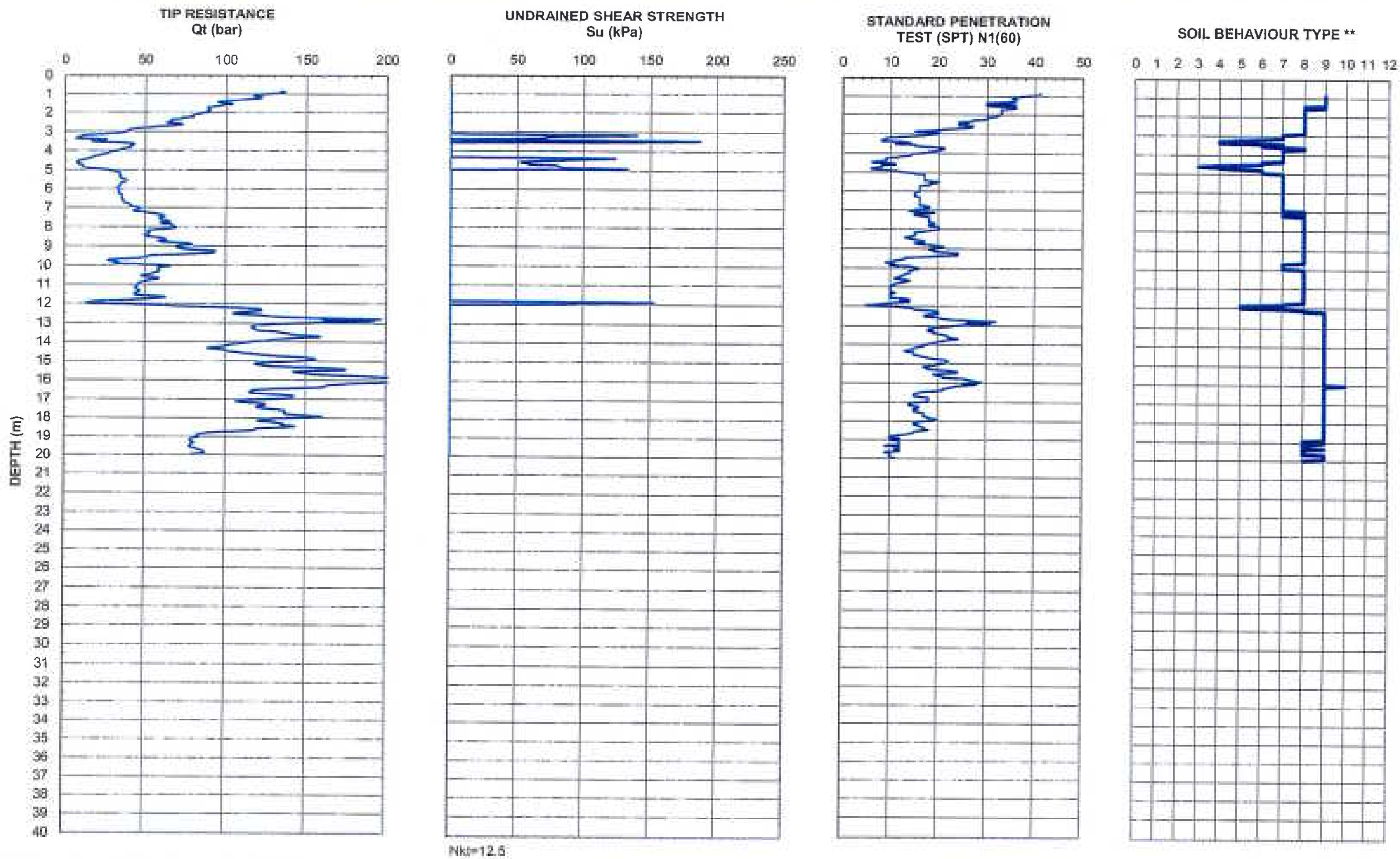
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-04	FRASER SURREY DOCKS, SURREY, BC	Figure: C.04



** Based on Robertson et. al 1986

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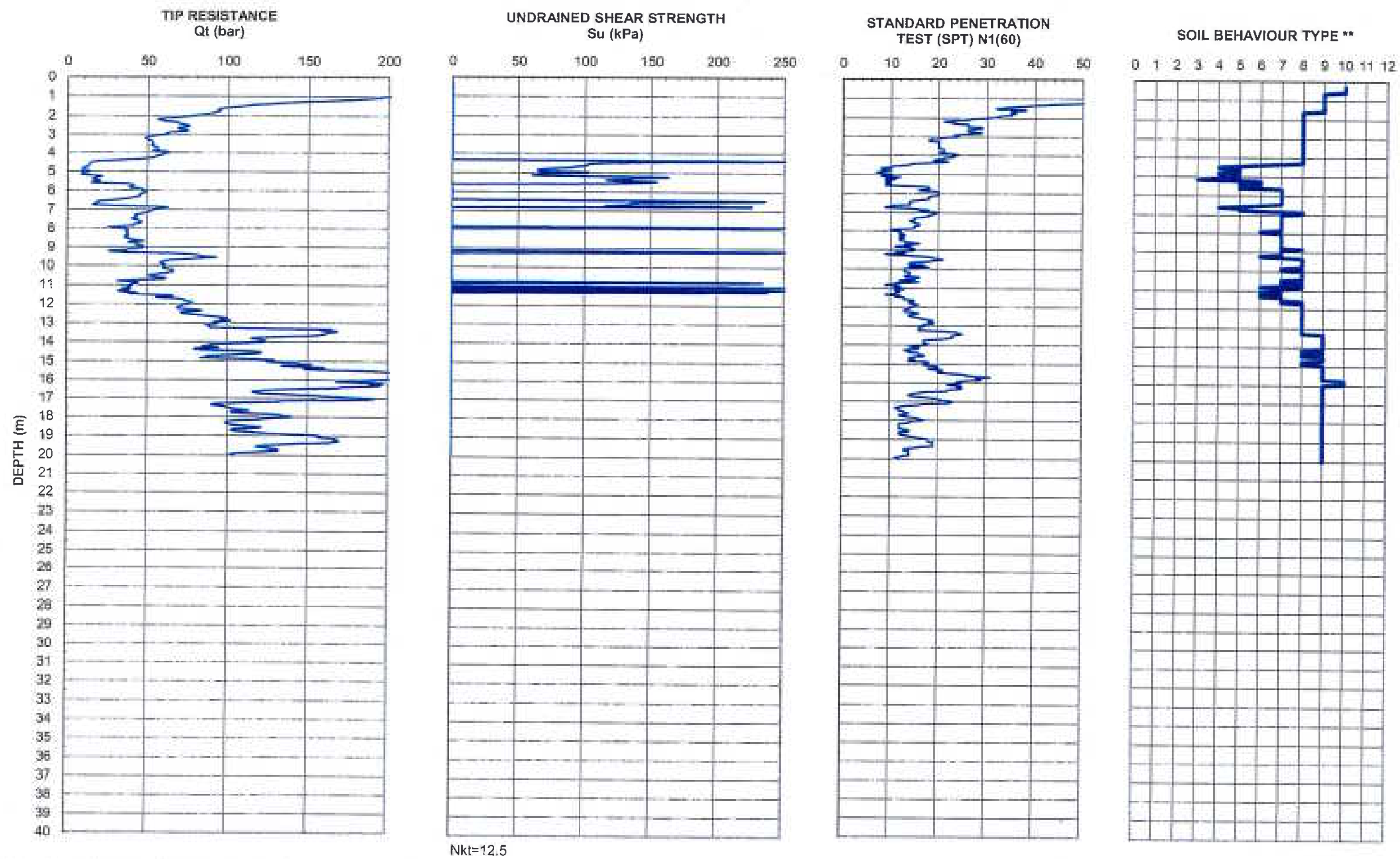
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-05	FRASER SURREY DOCKS, SURREY, BC	Figure: C.05



** Based on Robertson et. al 1986

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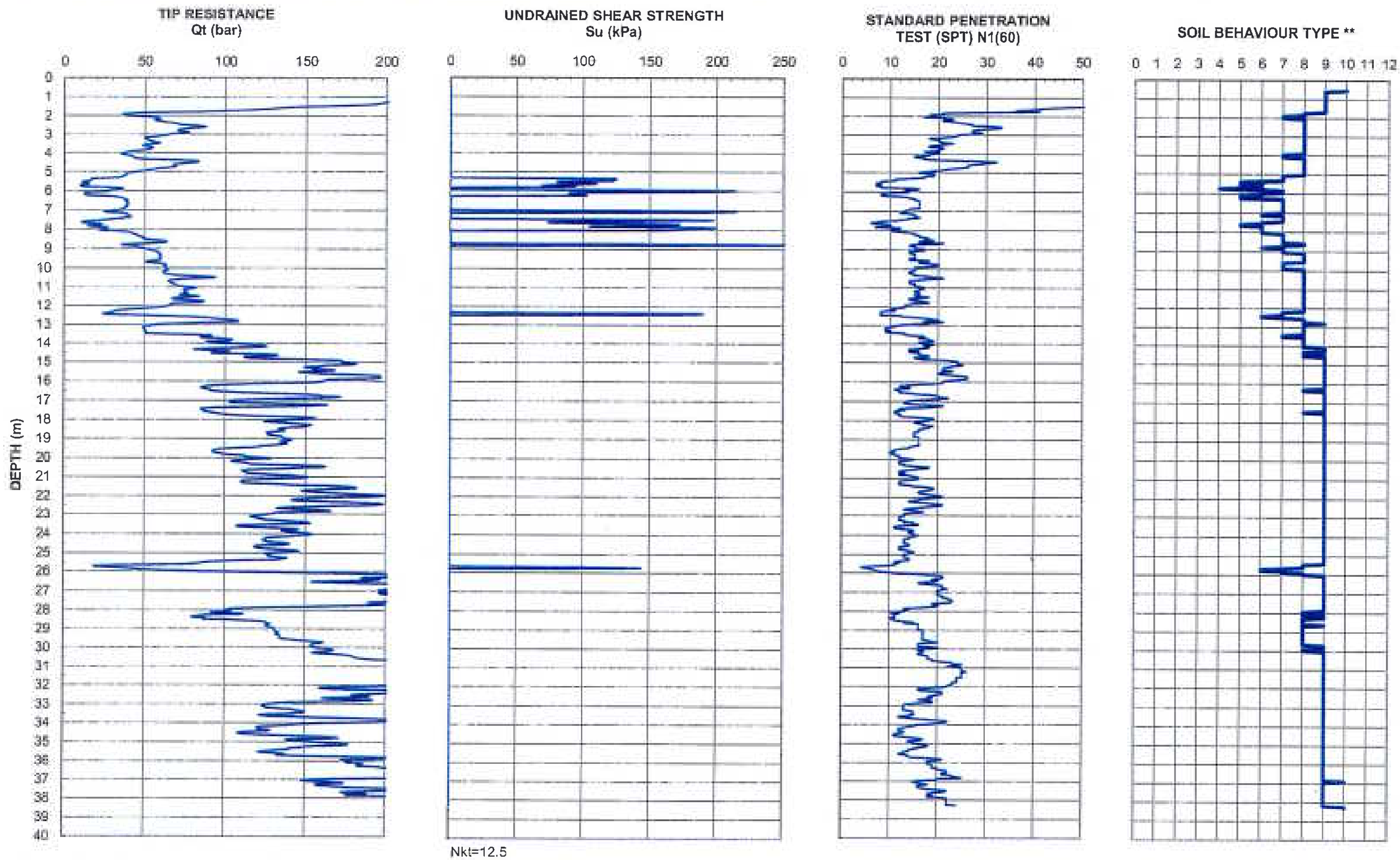
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-07	FRASER SURREY DOCKS, SURREY, BC	Figure: C.07



** Based on Robertson et. al 1986

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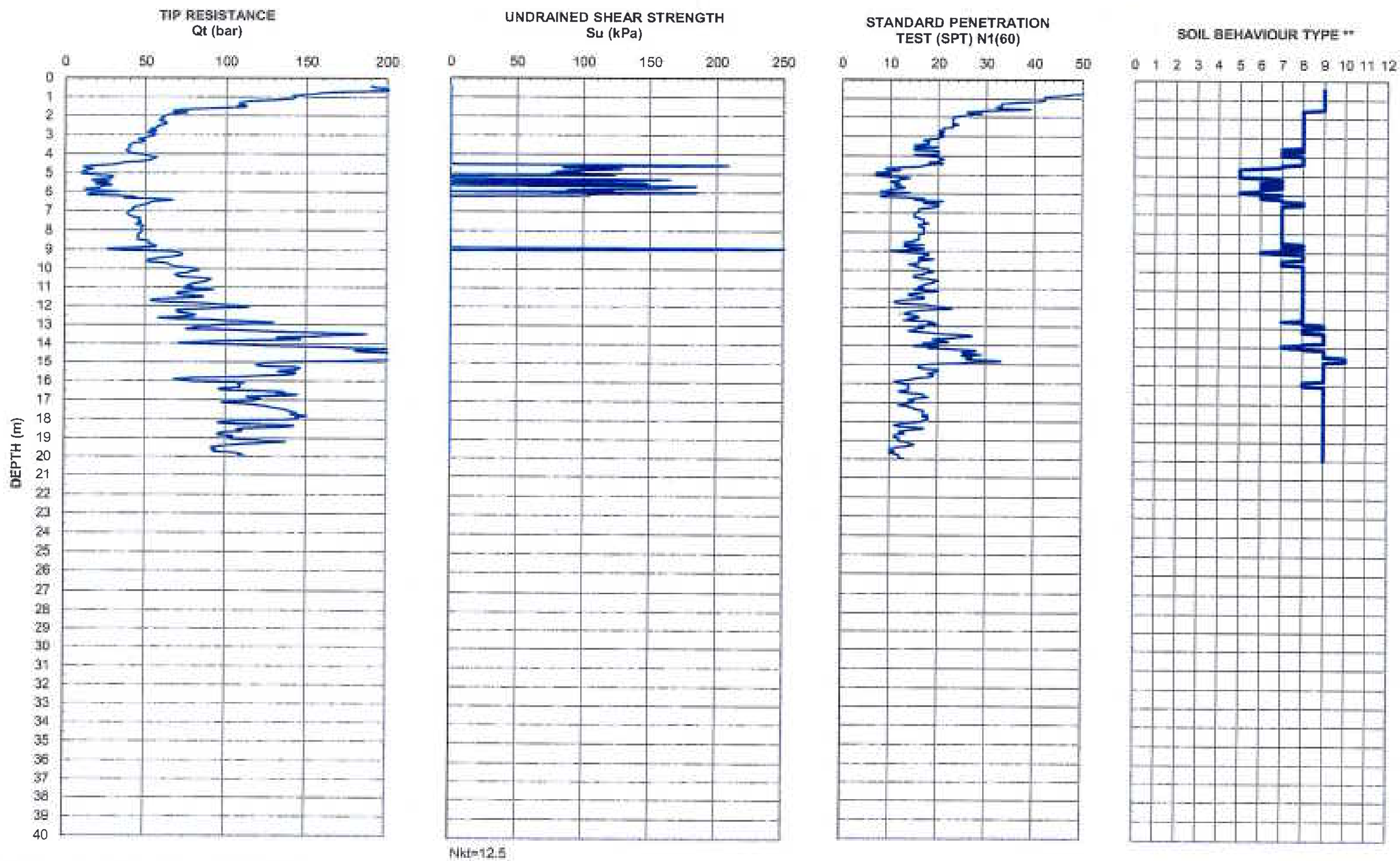
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-08	FRASER SURREY DOCKS, SURREY, BC	Figure: C.08



** Based on Robertson et. al 1986

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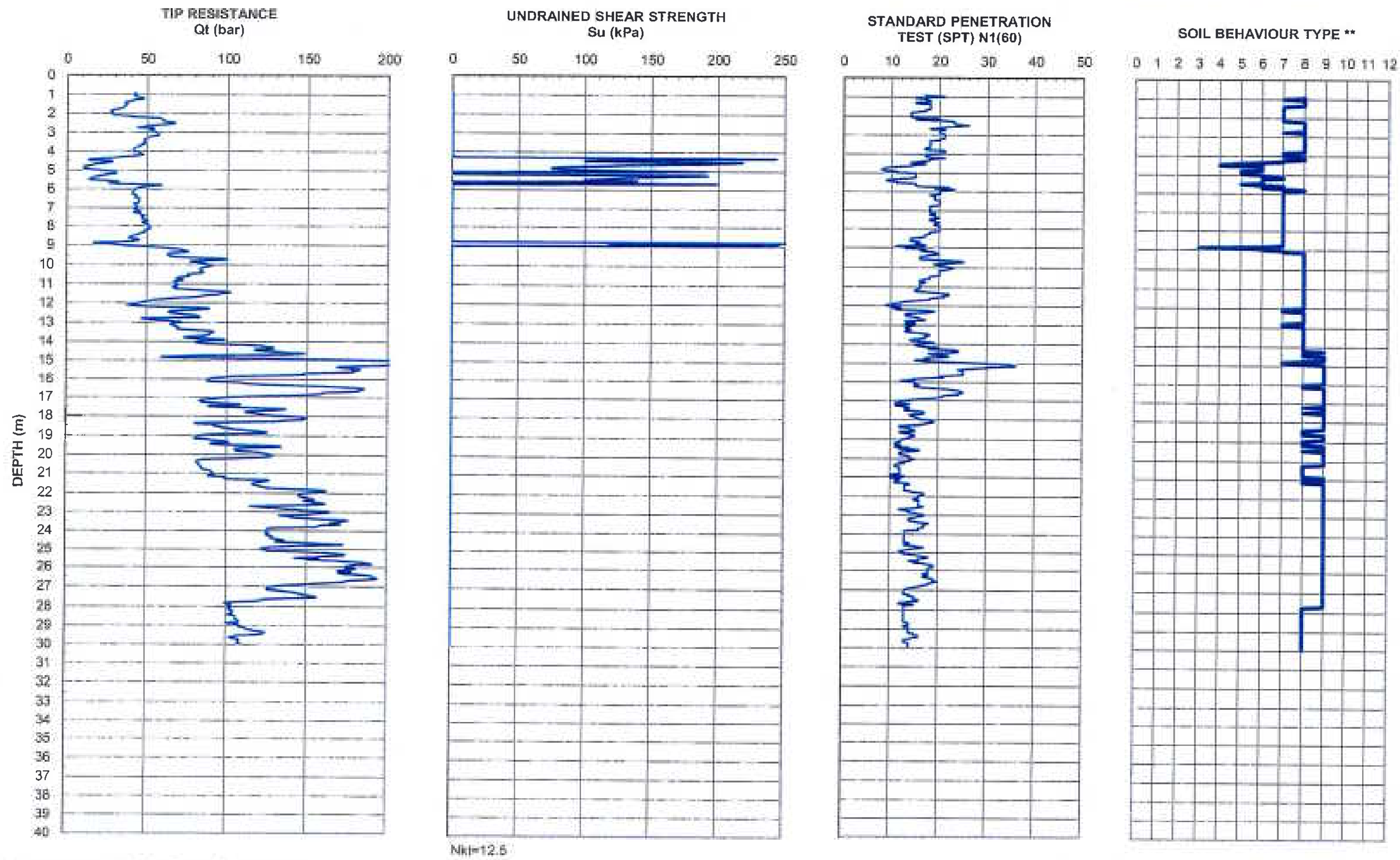
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-09	FRASER SURREY DOCKS, SURREY, BC	Figure: C.09



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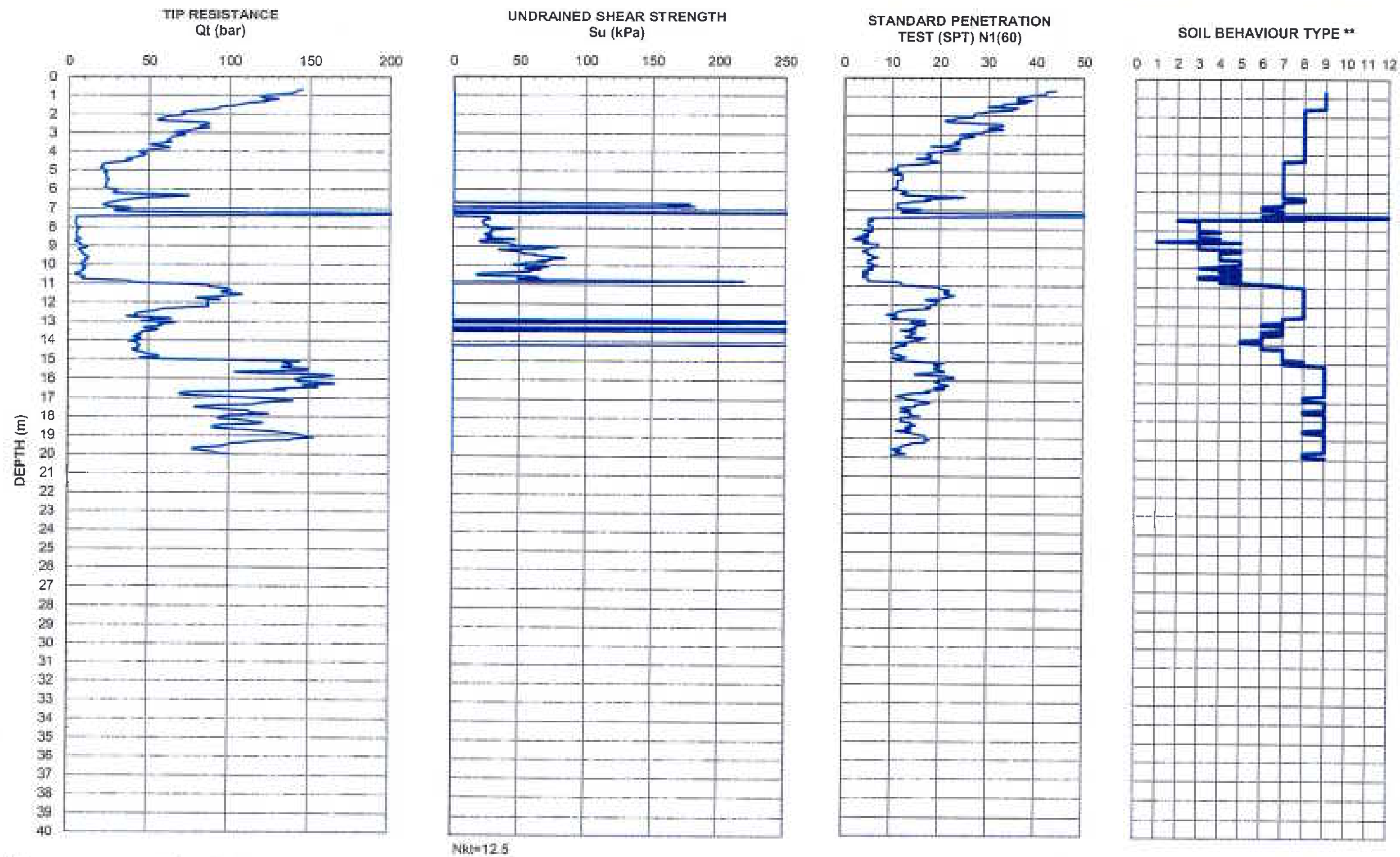
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-10	FRASER SURREY DOCKS, SURREY, BC	Figure: C.10



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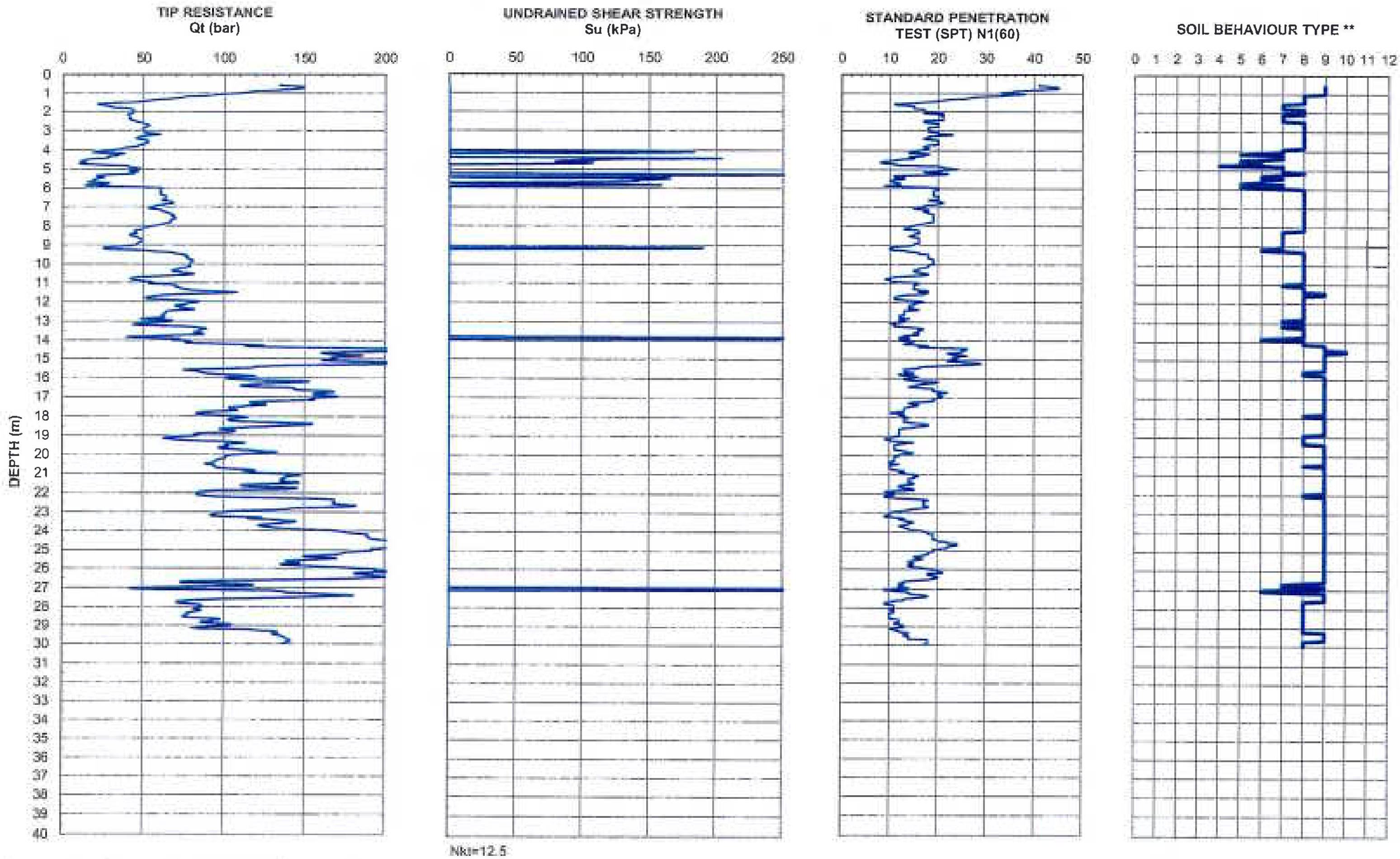
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

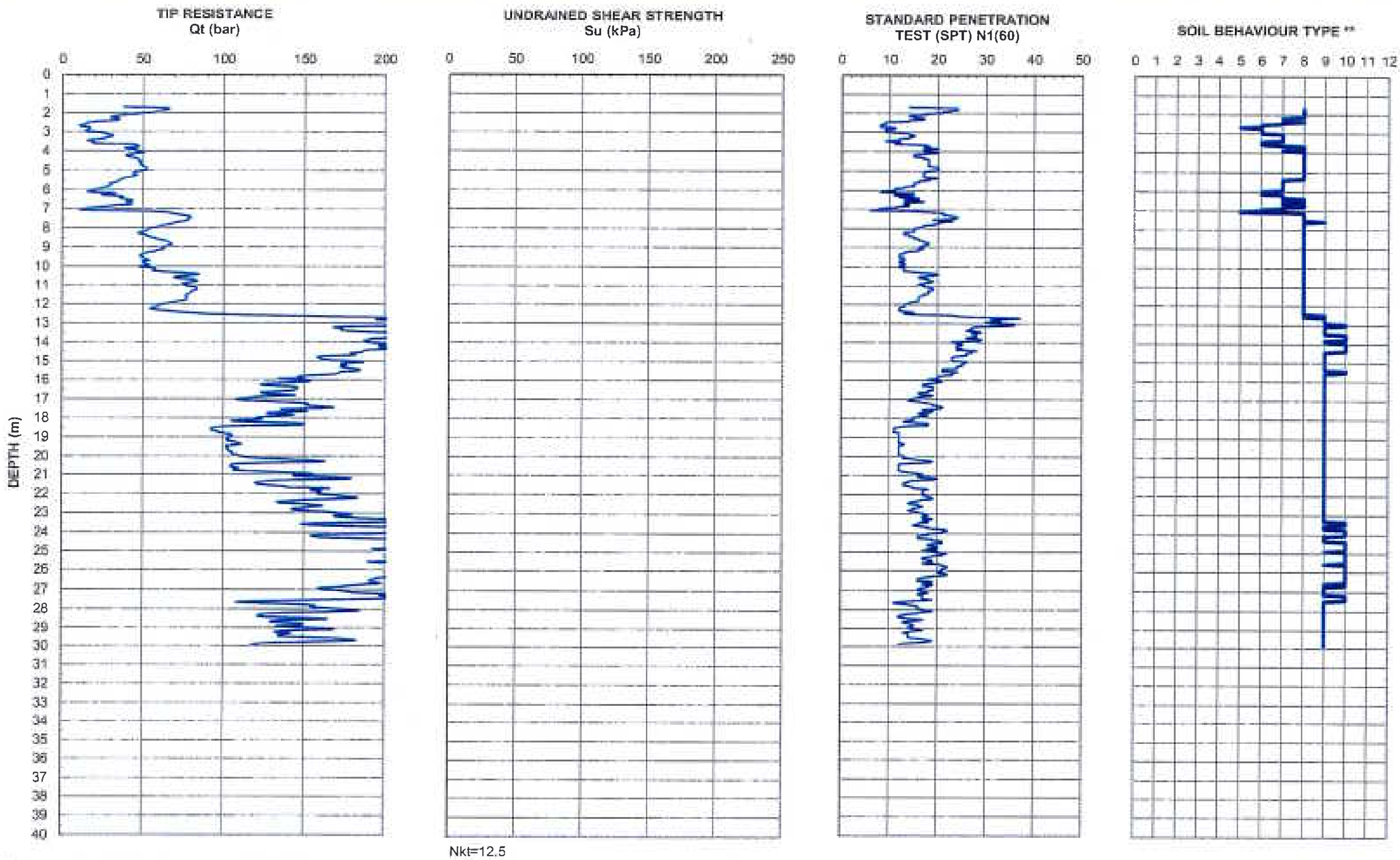
GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-11	FRASER SURREY DOCKS, SURREY, BC	Figure: C.11



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2010-Sep-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT10-09	FRASER SURREY DOCKS, SURREY, BC	Figure: C.09



** Based on Robertson et. al 1986

1 Sensitive Fine Grained
2 Organic Material
3 Clay
4 Silty Clay to Clay
5 Clayey Silt to Silty Clay
6 Sandy Silt to Clayey Silt
7 Silty Sand to Sandy Silt
8 Sand to Silty Sand
9 Sand
10 Gravelly Sand to Sand
11 Very Stiff Fine Grained
12 Sand to Clayey Sand

APPENDIX D - LIQUEFACTION ANALYSIS

Assessment of the liquefaction potential of the ground has been determined by the Cone Penetration Test (CPT). The method of analysis is presented in the following sections.

FACTOR OF SAFETY AGAINST LIQUEFACTION

The factor of safety against liquefaction calculated here is the ratio of the cyclic resistance of the soil (CRR) to the cyclic stresses induced by the design earthquake (CSR). Where the ratio of CRR/CSR is greater than unity the soils ability to resist cyclic stresses is greater than the cyclic stresses induced by the earthquake and liquefaction will be unlikely. Where the CRR/CSR is less than unity then liquefaction could occur. This ratio is presented as the FOS against Liquefaction on the following charts. Calculation of the factor of safety is based on NCEER (1998)[1] which evaluates the CRR directly from cone penetration test sounding data. The value of the cyclic stress ratio has been calculated based on peak horizontal ground acceleration of the 2015 National Building Code interpolated seismic hazard value.

SEISMIC INDUCED SETTLEMENT

In the event of a significant earthquake, settlement of the ground surface could occur as a result of densification of the looser soil layers as a result of liquefaction or due to the expulsion of sand in the form of sand dykes or sills from beneath the site. Tokimatsu and Seed (1987)[2] suggest a method of analysis for estimating vertical settlements as a result of earthquake induced accelerations. In this method the normalized standard penetration blow counts ($N_{1(60)}$) is compared with the cyclic stress ratio for the induced earthquake to determine the volumetric strain resulting from the earthquake shaking. The volumetric strain is assumed to result in only vertical settlement. The vertical settlement is summed for each depth at which settlement is predicted to occur and accumulated from the bottom of the test hole. The results are presented on the following charts labelled as Settlement.

HORIZONTAL DISPLACEMENT

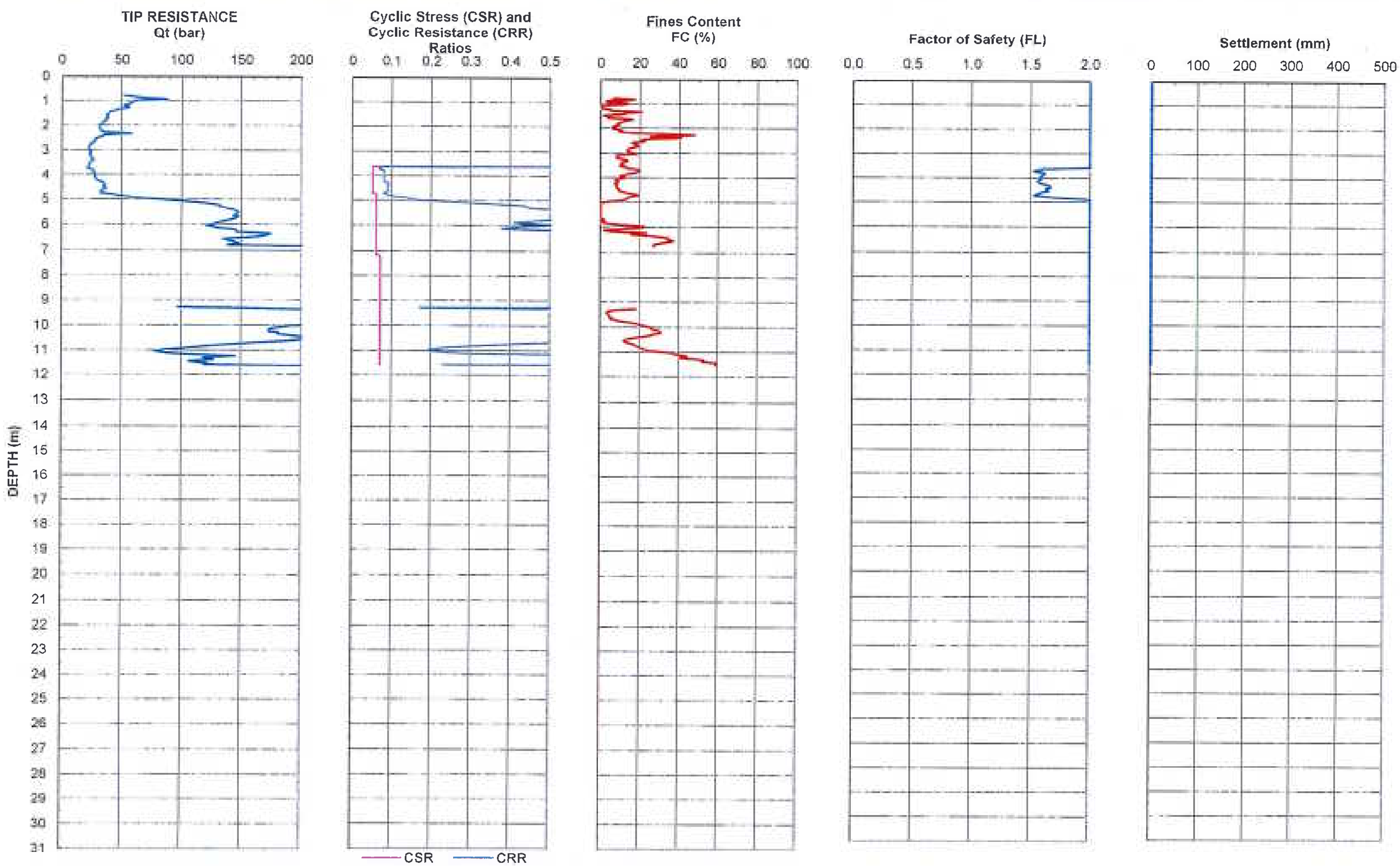
Horizontal ground displacements known as "free field" displacements occur as a result of liquefaction of the ground and are assumed to occur without the influence of any structures. The horizontal displacements presented in our report are generally based upon the lateral spread method by of Youd, Bartlett, & Hansen (2002). Displacements are calculated based on an empirical relationship developed from observations from other earthquake sites on sloping ground or near a free face, such as an abrupt slope. The presence of the proposed embankment on-site is expected to induce a static bias within the soils at the margin of the embankment making the soils and embankment in this area subject to lateral spread induced movements. In the event of a real earthquake of significant magnitude to cause limited liquefaction, actual movements will be influenced by a wide variety of factors including the characteristics of the earthquake including duration, number of significant cycles, variations in peak particle velocity, wavelength, amplitude and frequencies as well as soil damping and variations in density and continuity of the soil layers.

1 Youd, T. L., Idriss, I. M. (2001). "Liquefaction Resistance of Soils: Summary Report from the 1996 and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils", Journal of Geotechnical and Geoenvironmental Engineering, Vol 127, 10, pp. 817-833

2 Tokimatsu, K.A.M. and Seed, H.B., 1987. "Evaluation of Settlement in Sands Due to Earthquake Shaking", Journal of Geotechnical Engineering, ASCE, Vol. 113, No. 8, pp. 861-878.

3 Youd, T.L., Bartlett, S.F., Hansen, C.M. (2002), "Revised MultiLinear Regression Equations for Prediction of Lateral Spread Displacements", Journal of Geotechnical and GeoEnvironmental Engineering, Vol. 128, No. 12, pp. 1007-1017

GEOPACIFIC	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-01	FRASER SURREY DOCKS, SURREY, BC	Figure: D.01

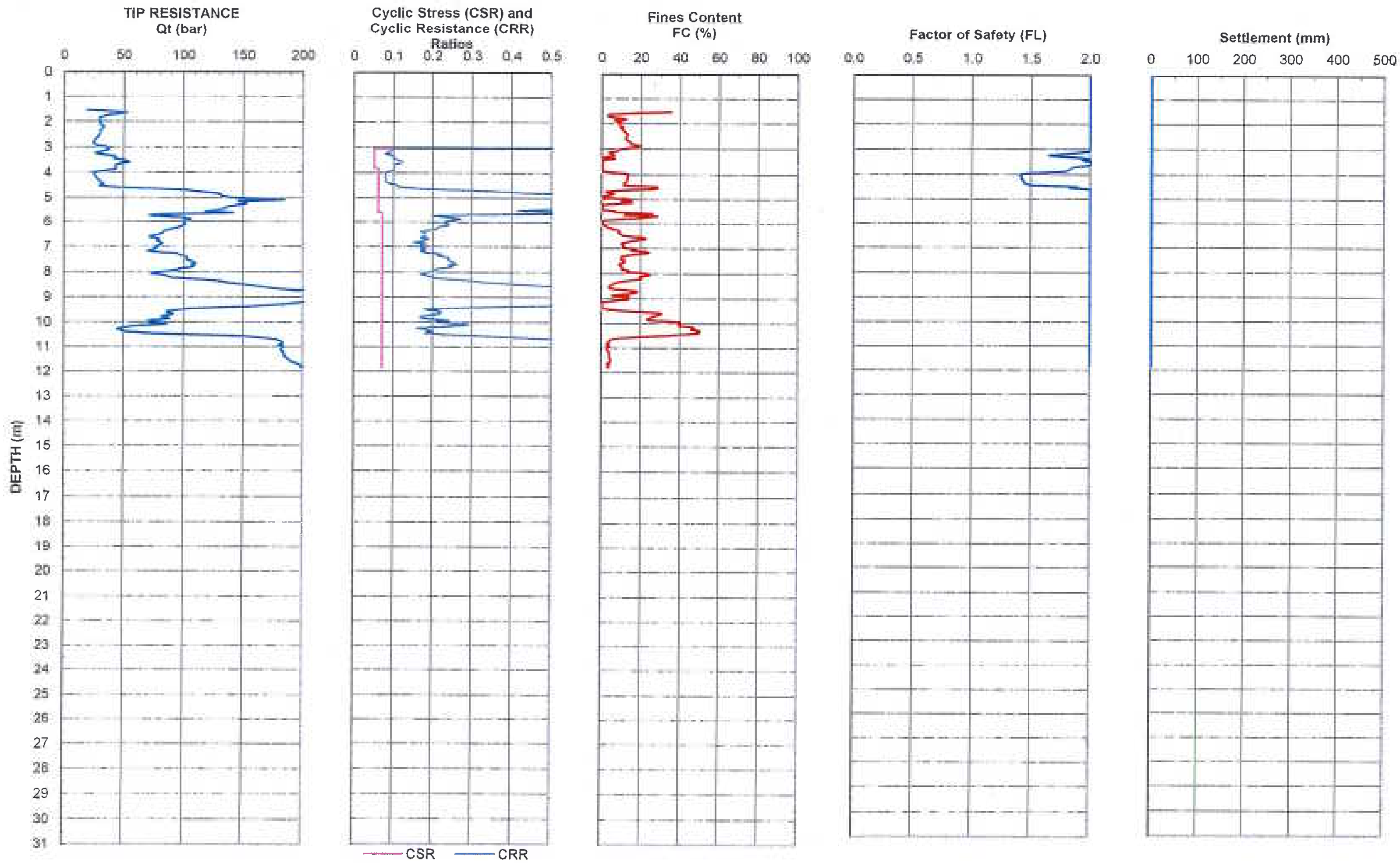


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

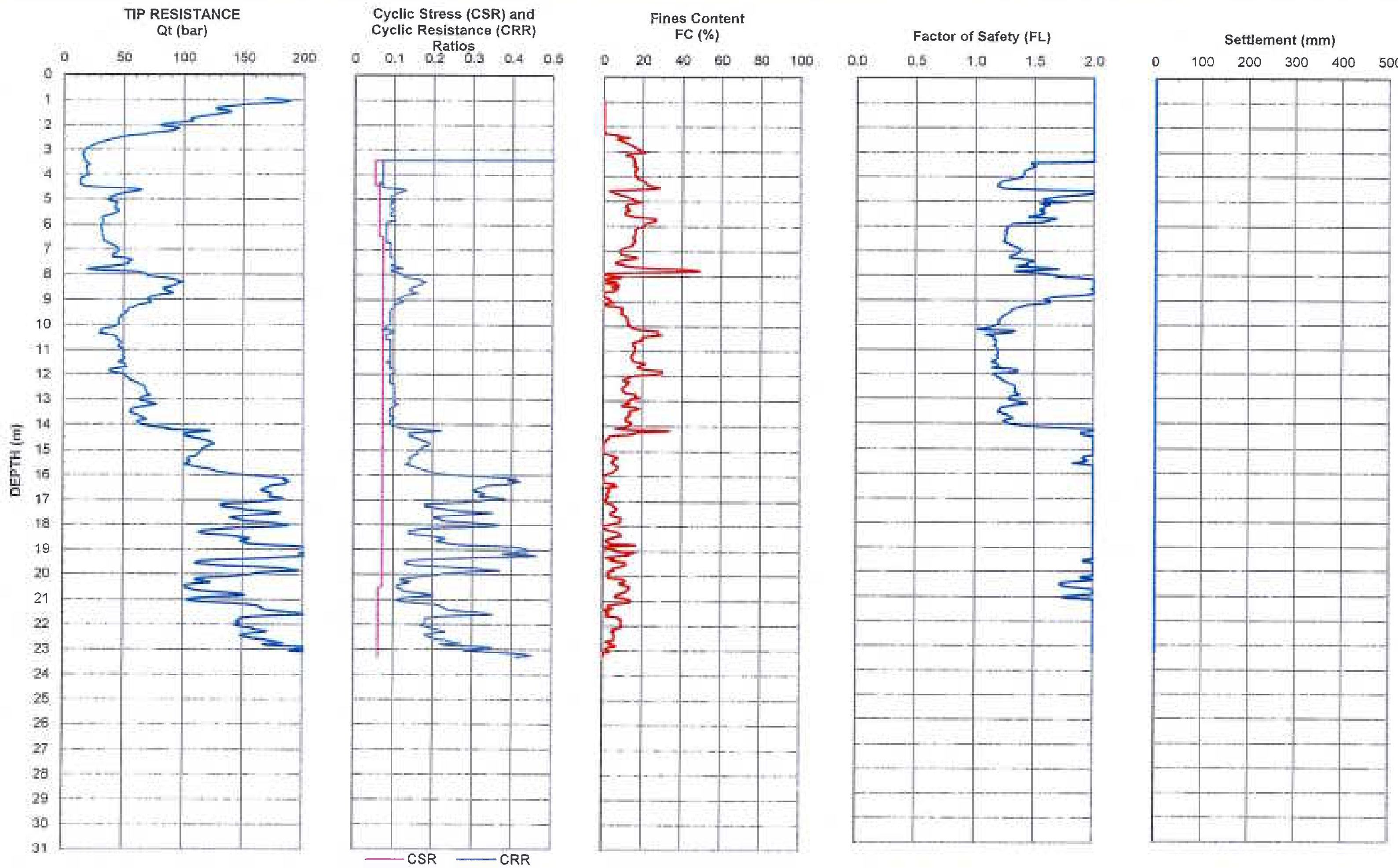


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-03	FRASER SURREY DOCKS, SURREY, BC	Figure: D.03

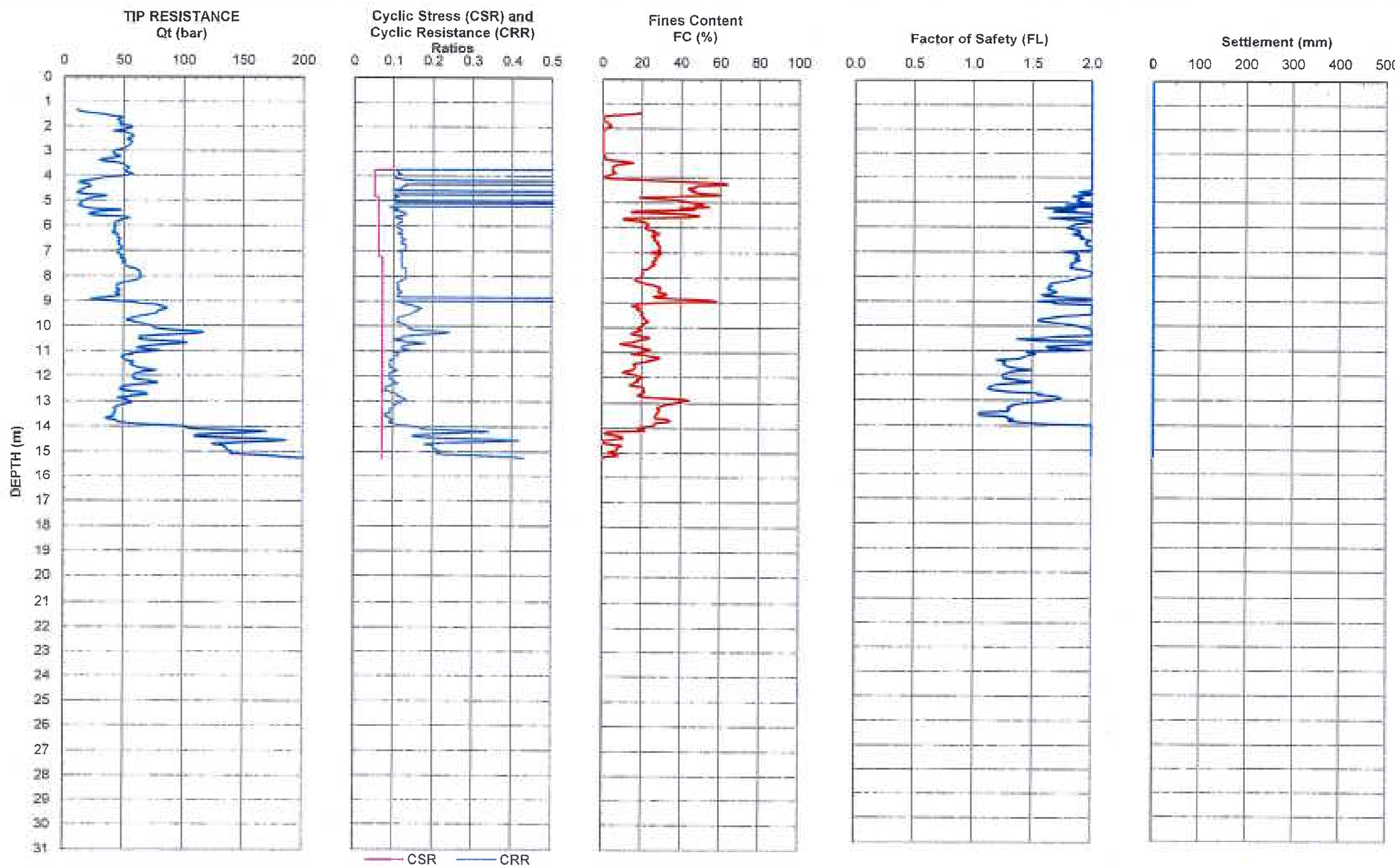


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

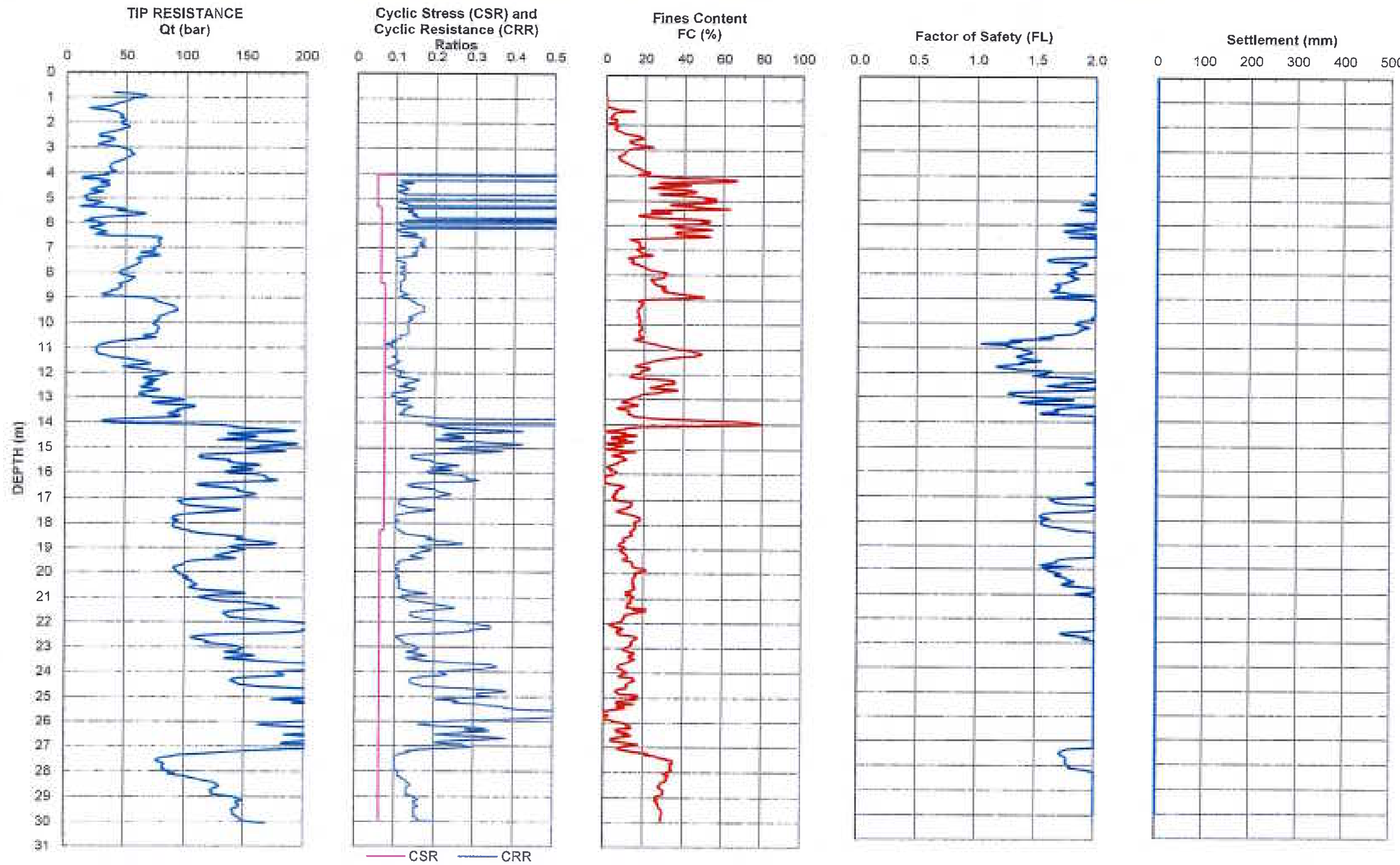


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

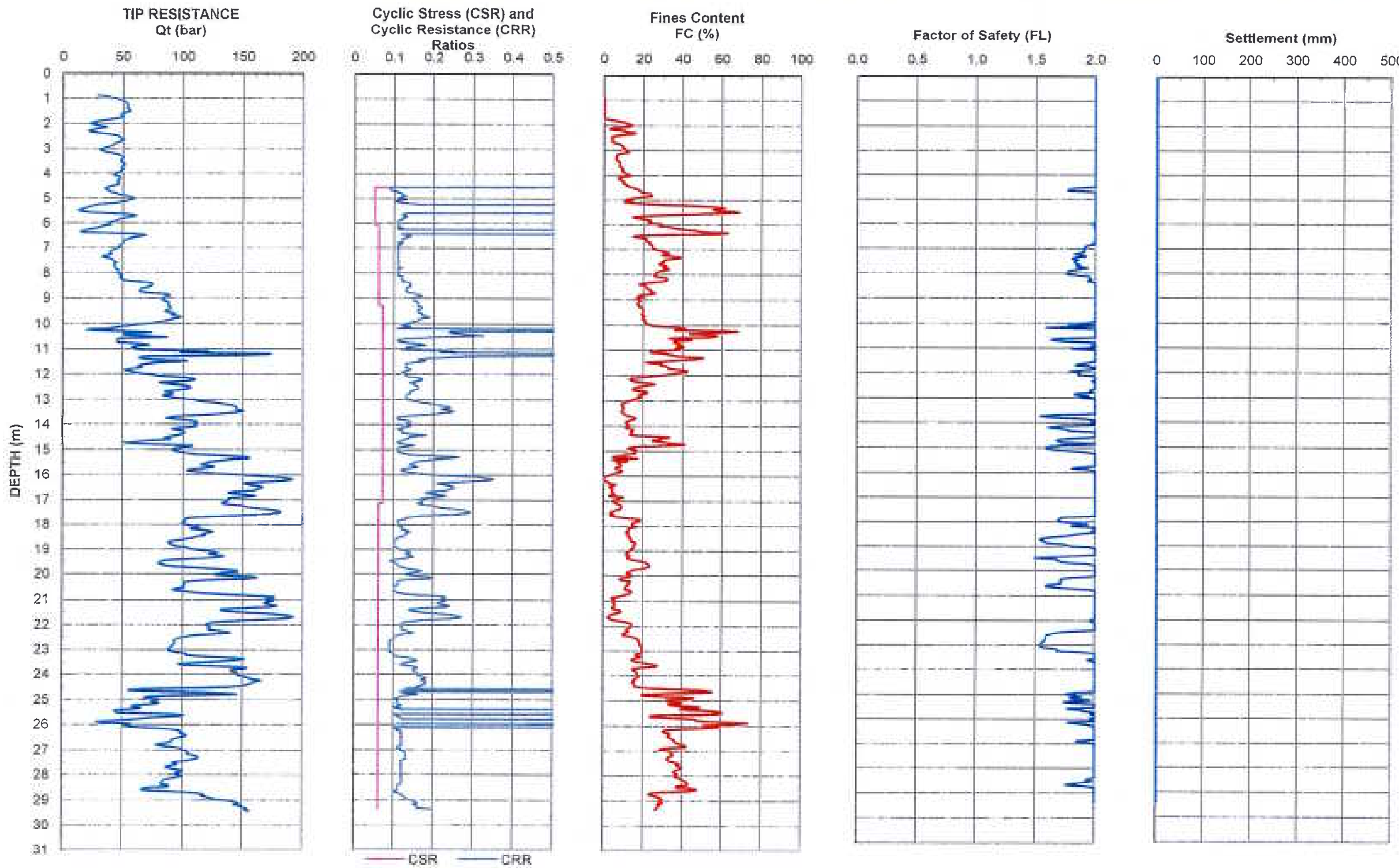


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-06	FRASER SURREY DOCKS, SURREY, BC	Figure: D.06

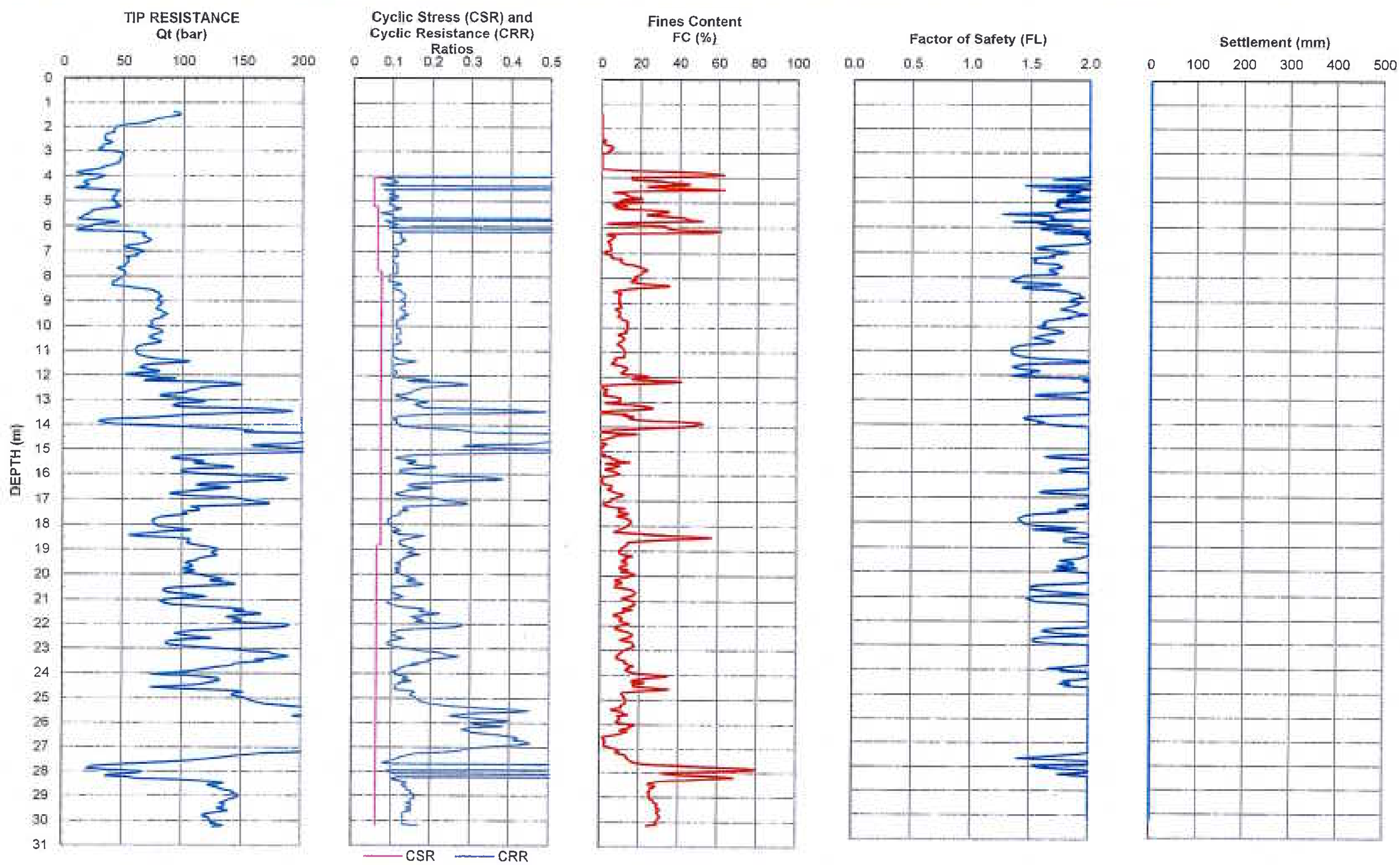


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

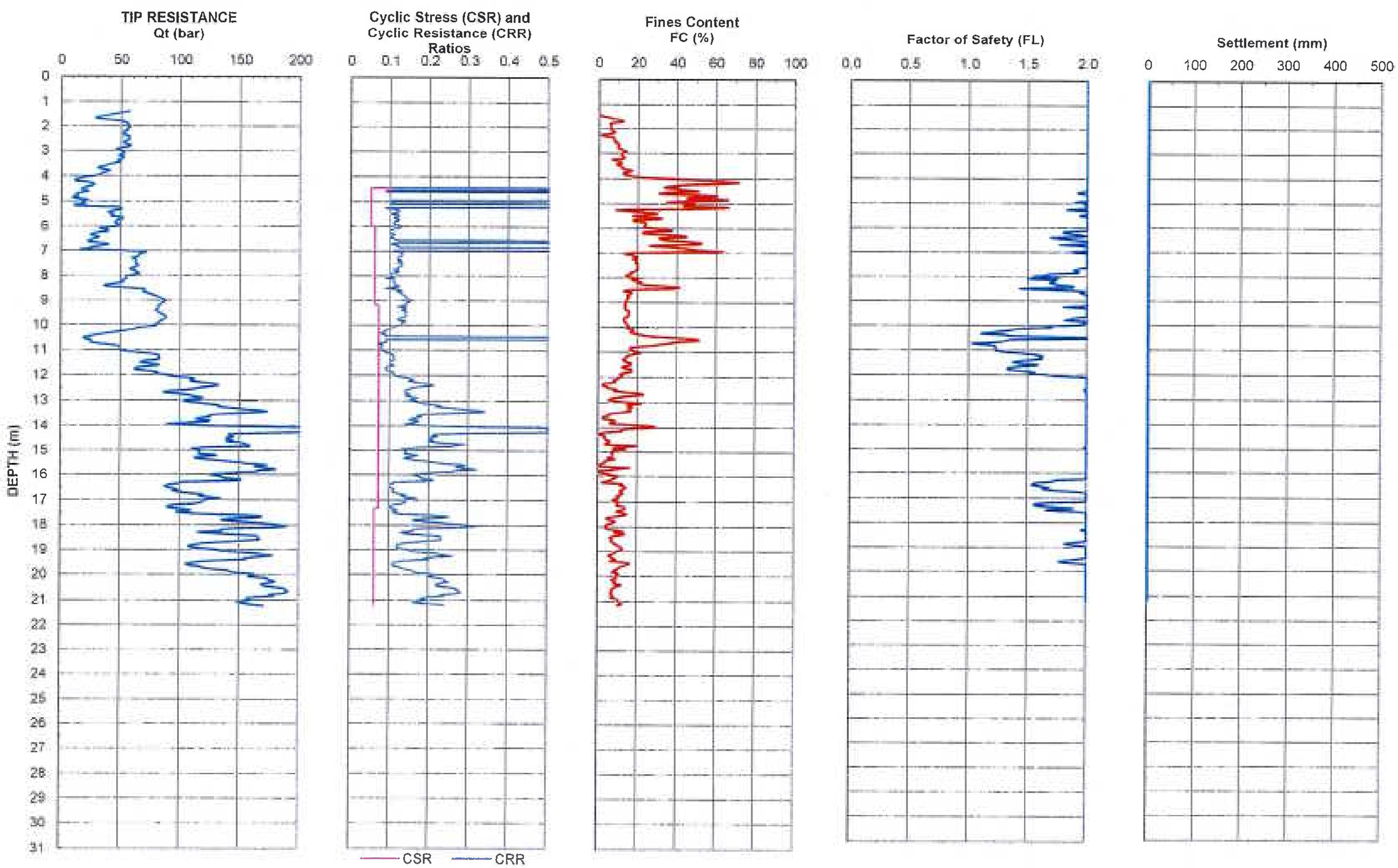


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08

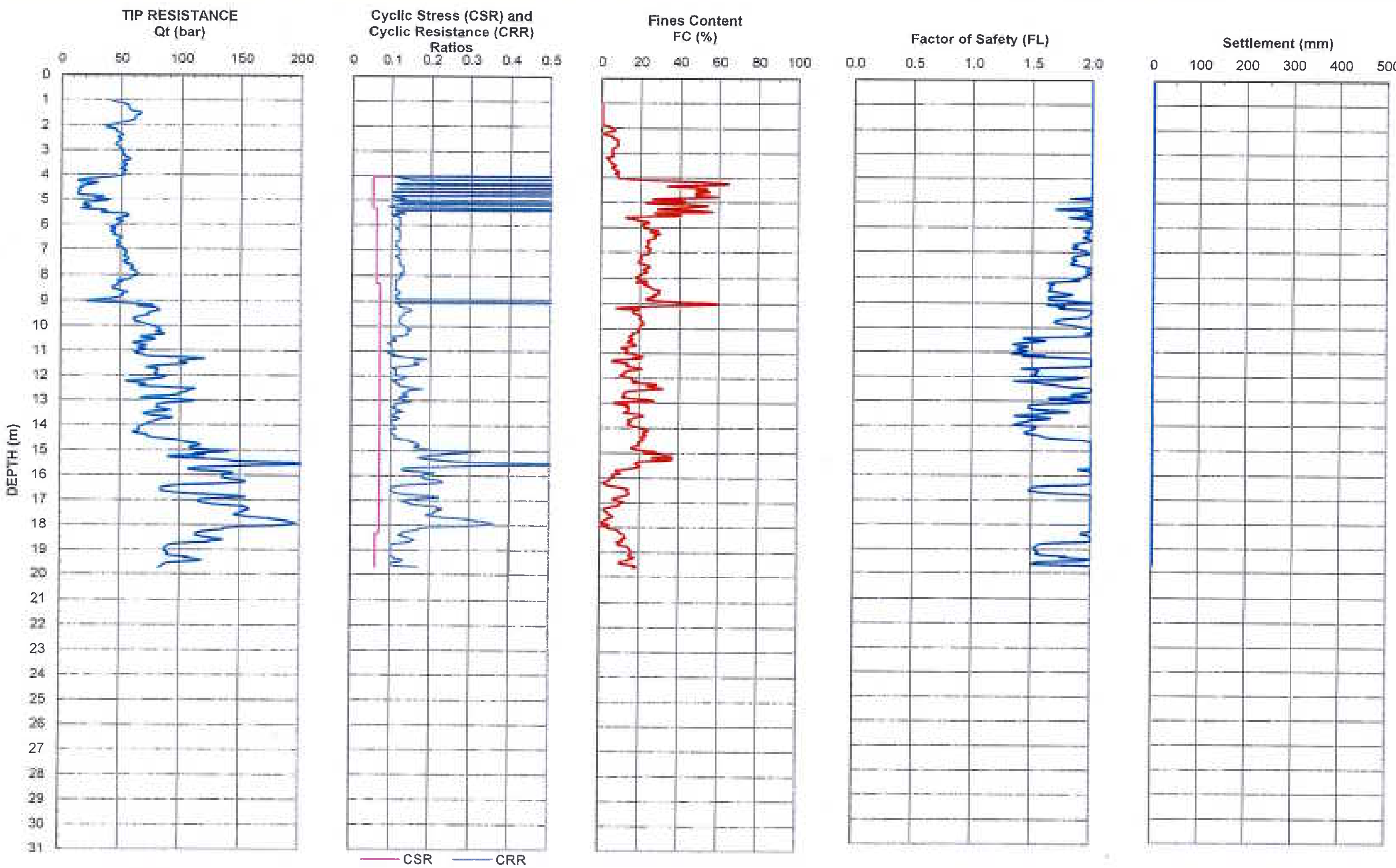


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

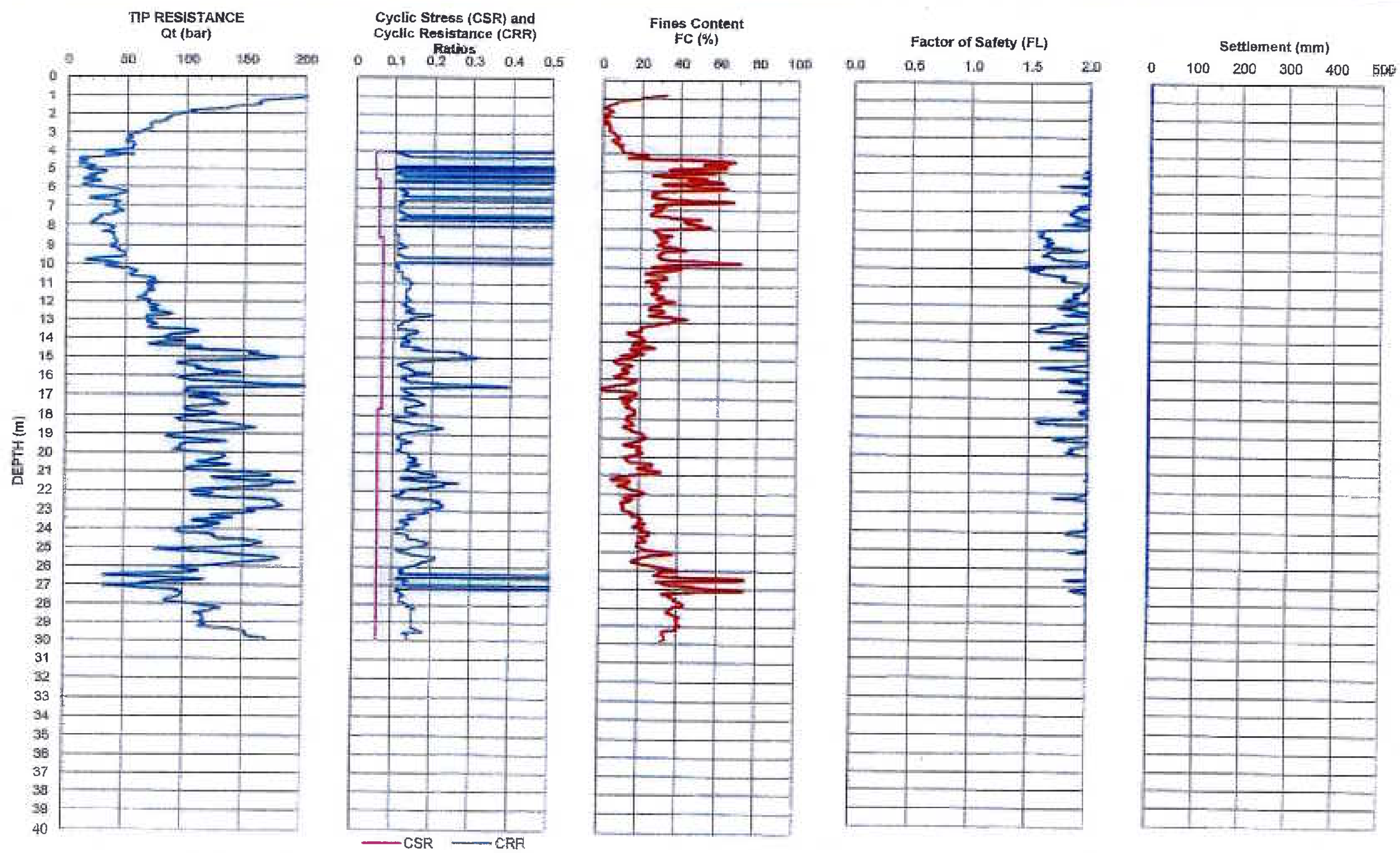


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

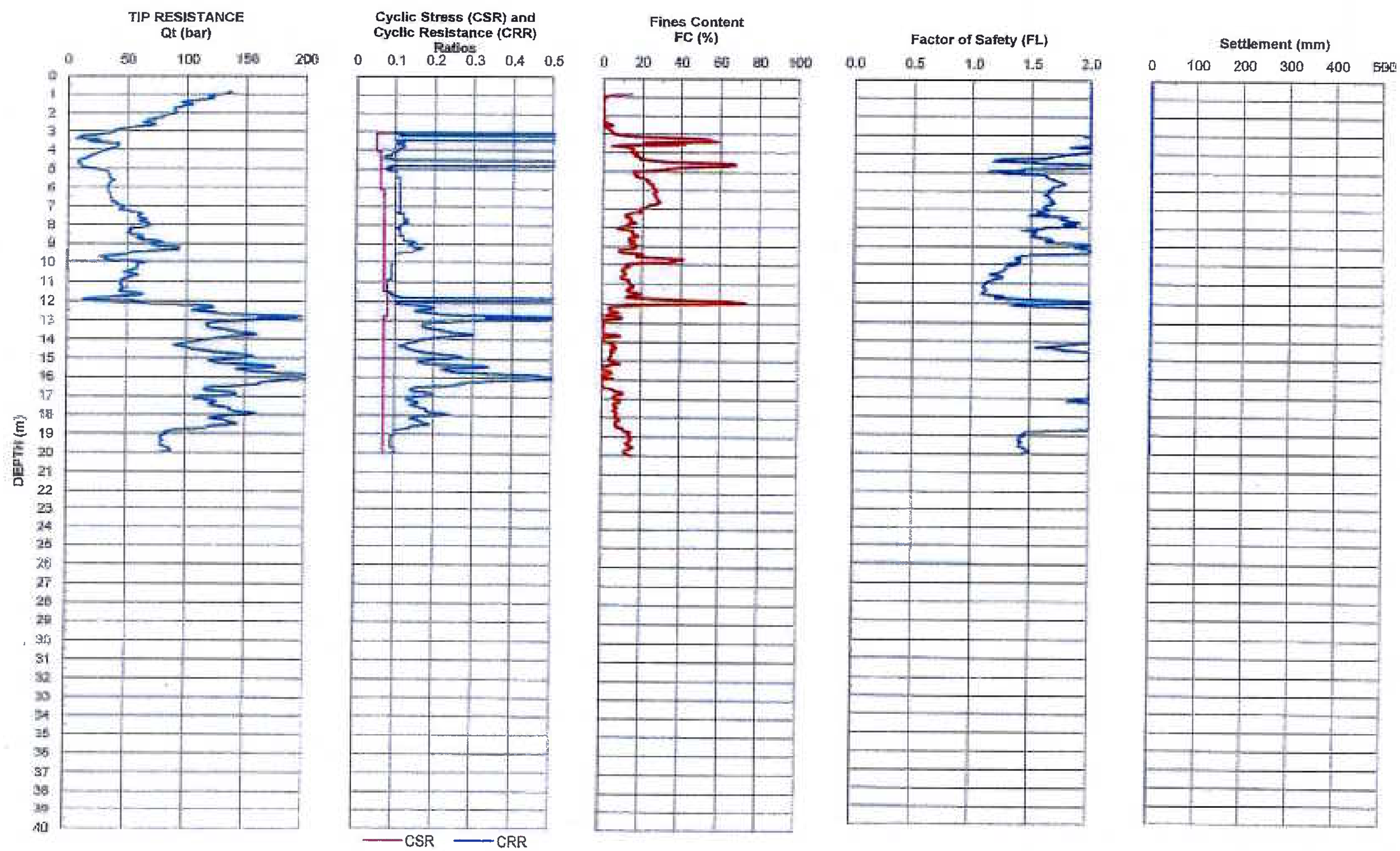


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

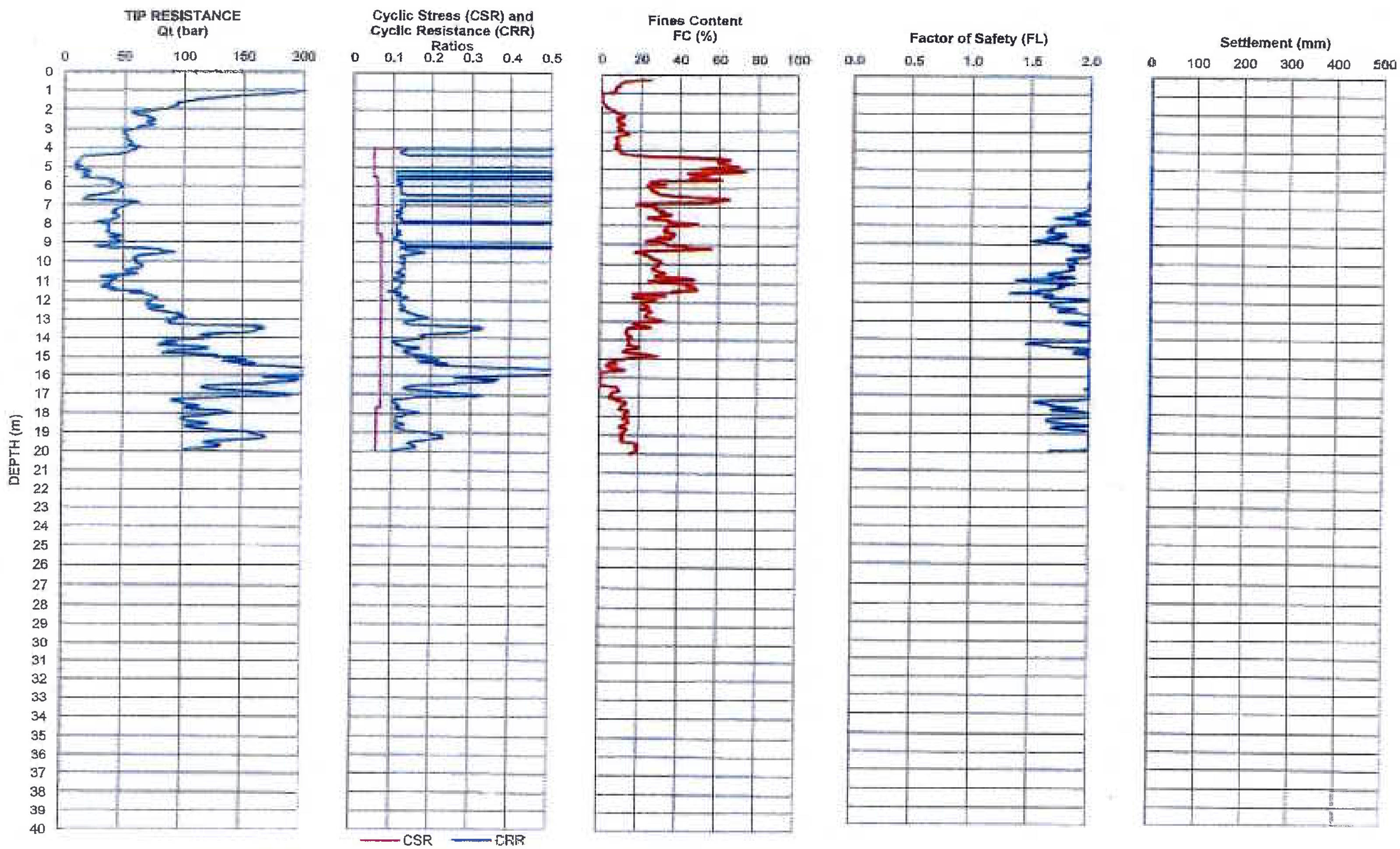


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

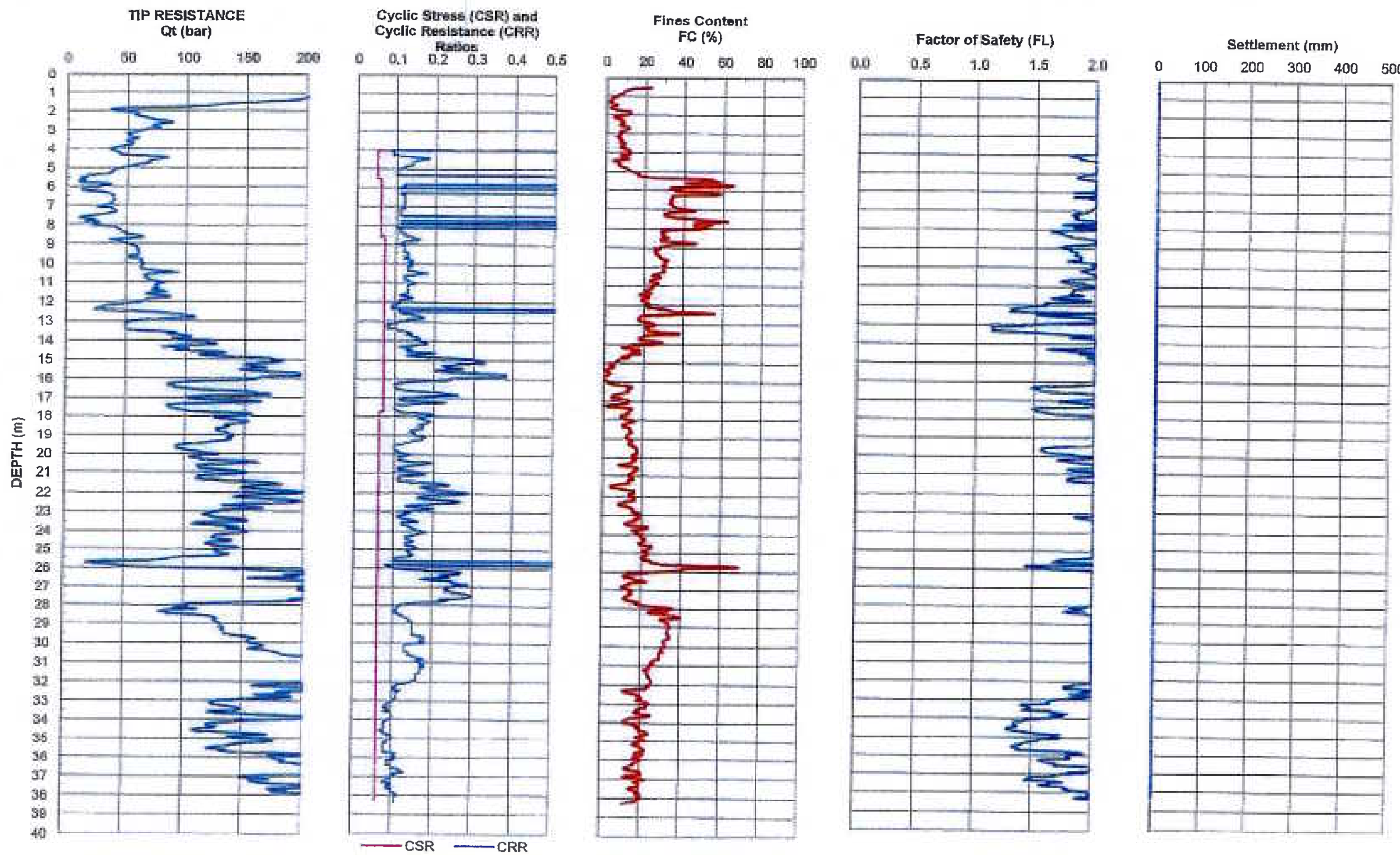


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

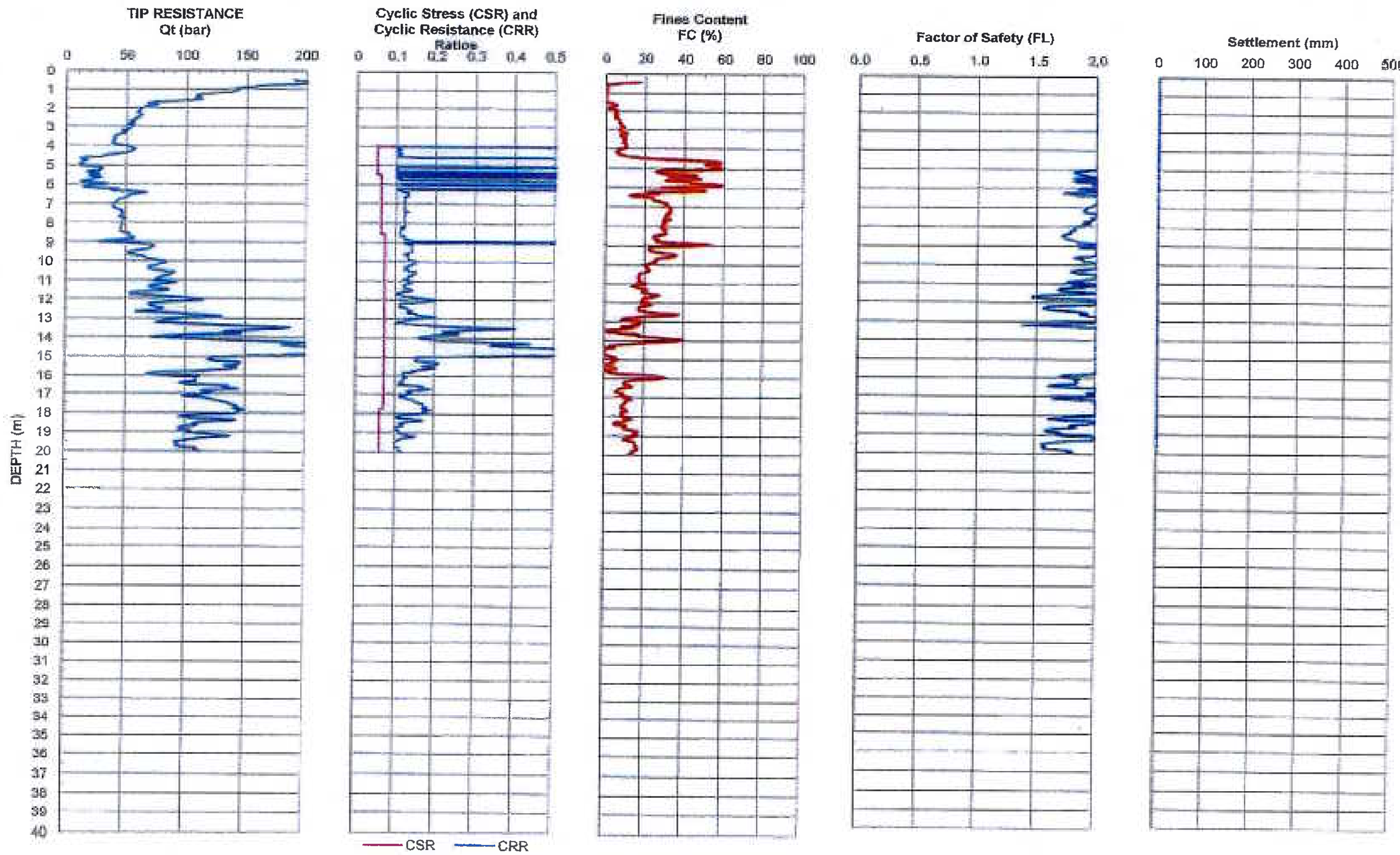


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08

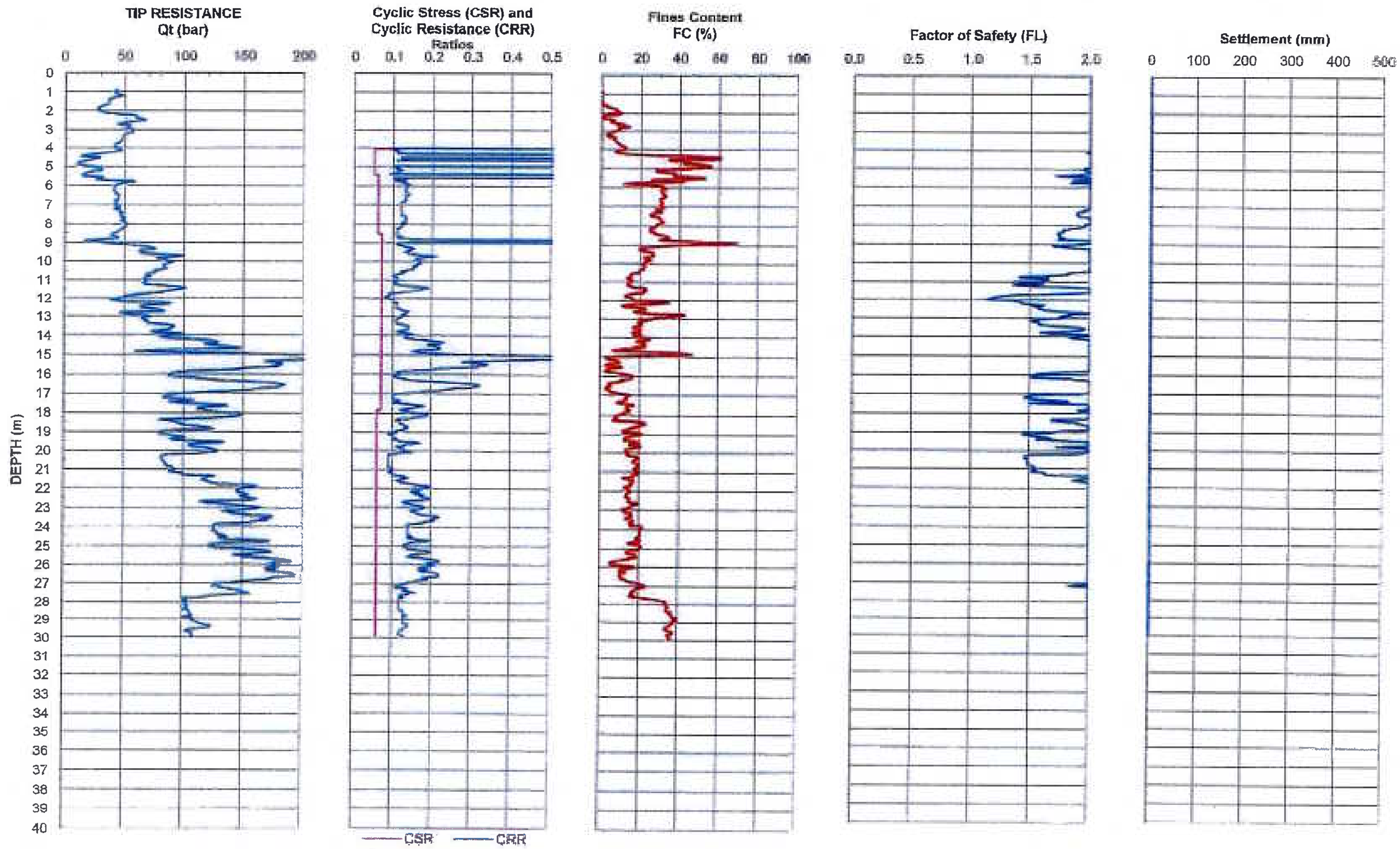


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

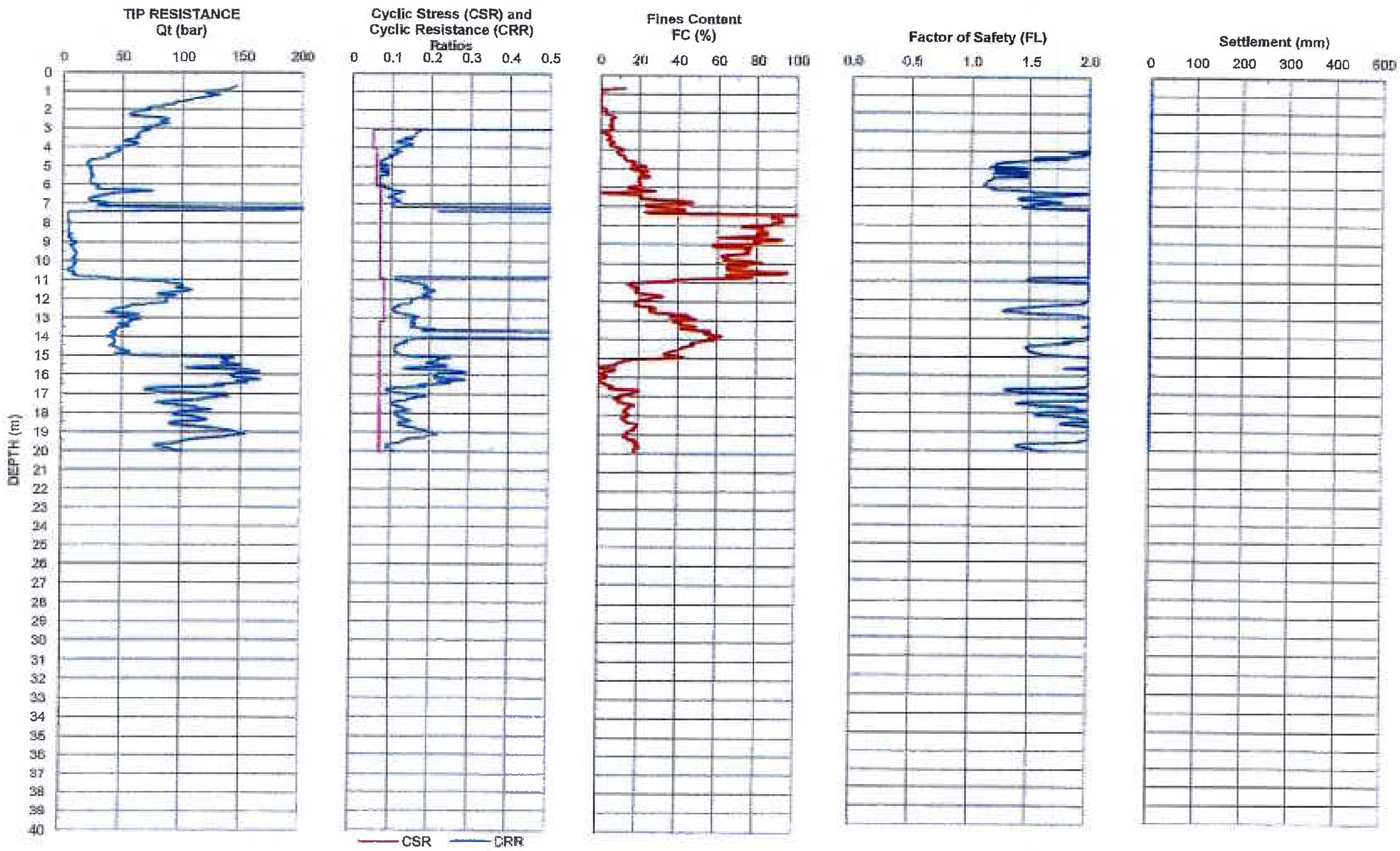


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-10	FRASER SURREY DOCKS, SURREY, BC	Figure: D.10

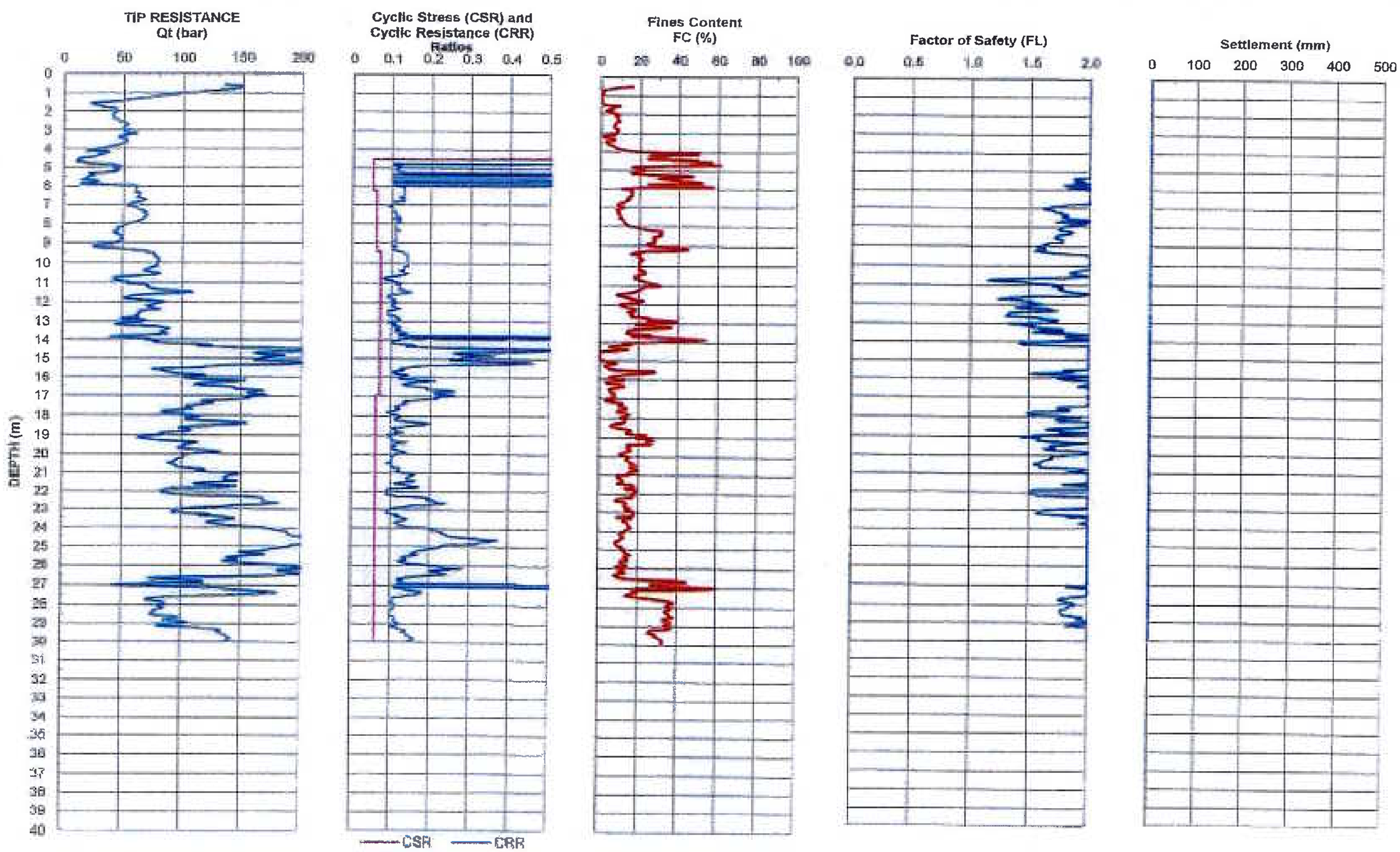


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-11	FRASER SURREY DOCKS, SURREY, BC	Figure: D.11

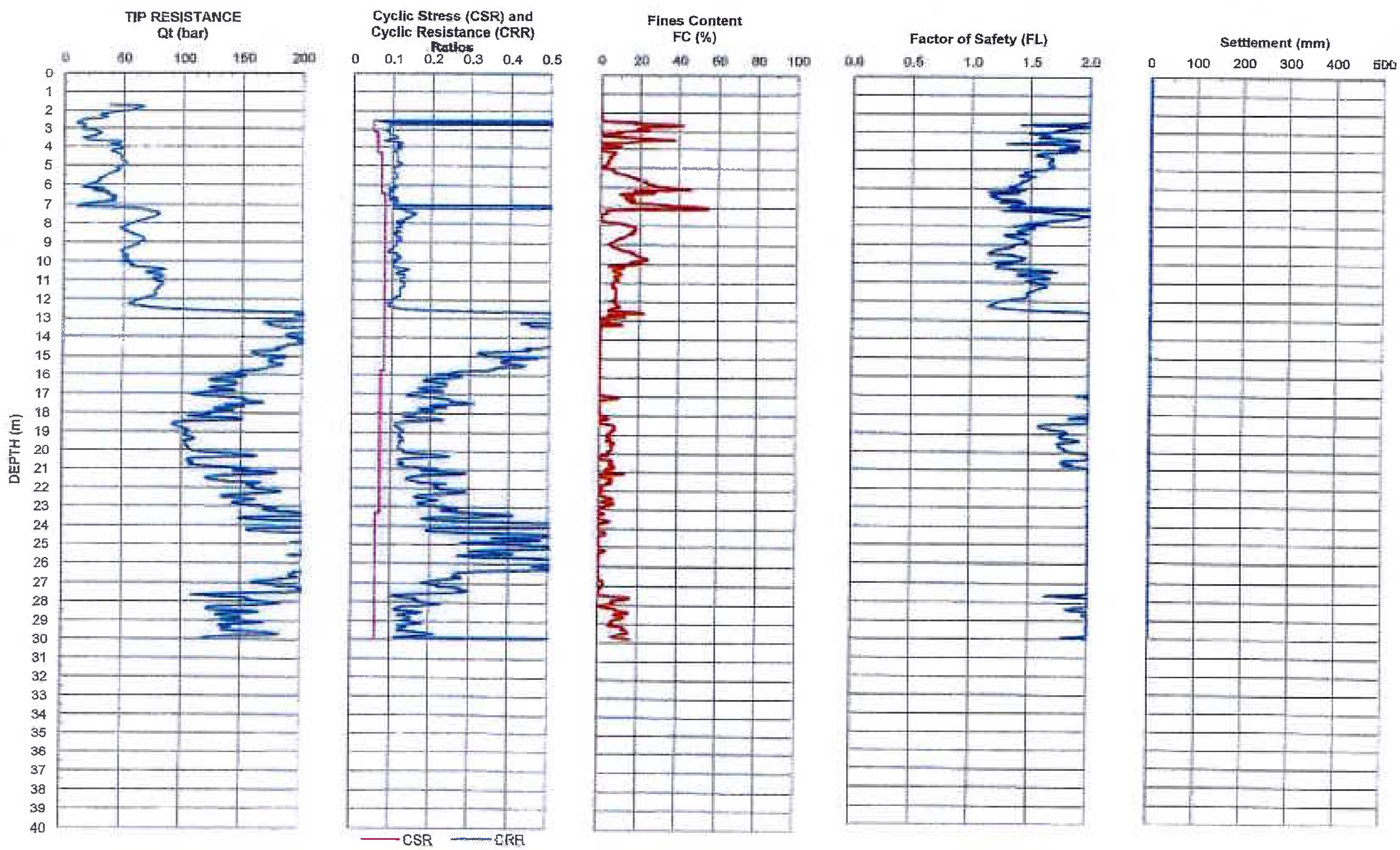


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

settlement accumulation max depth = 15m

GEOPACIFIC	2010-Sep-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT10-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

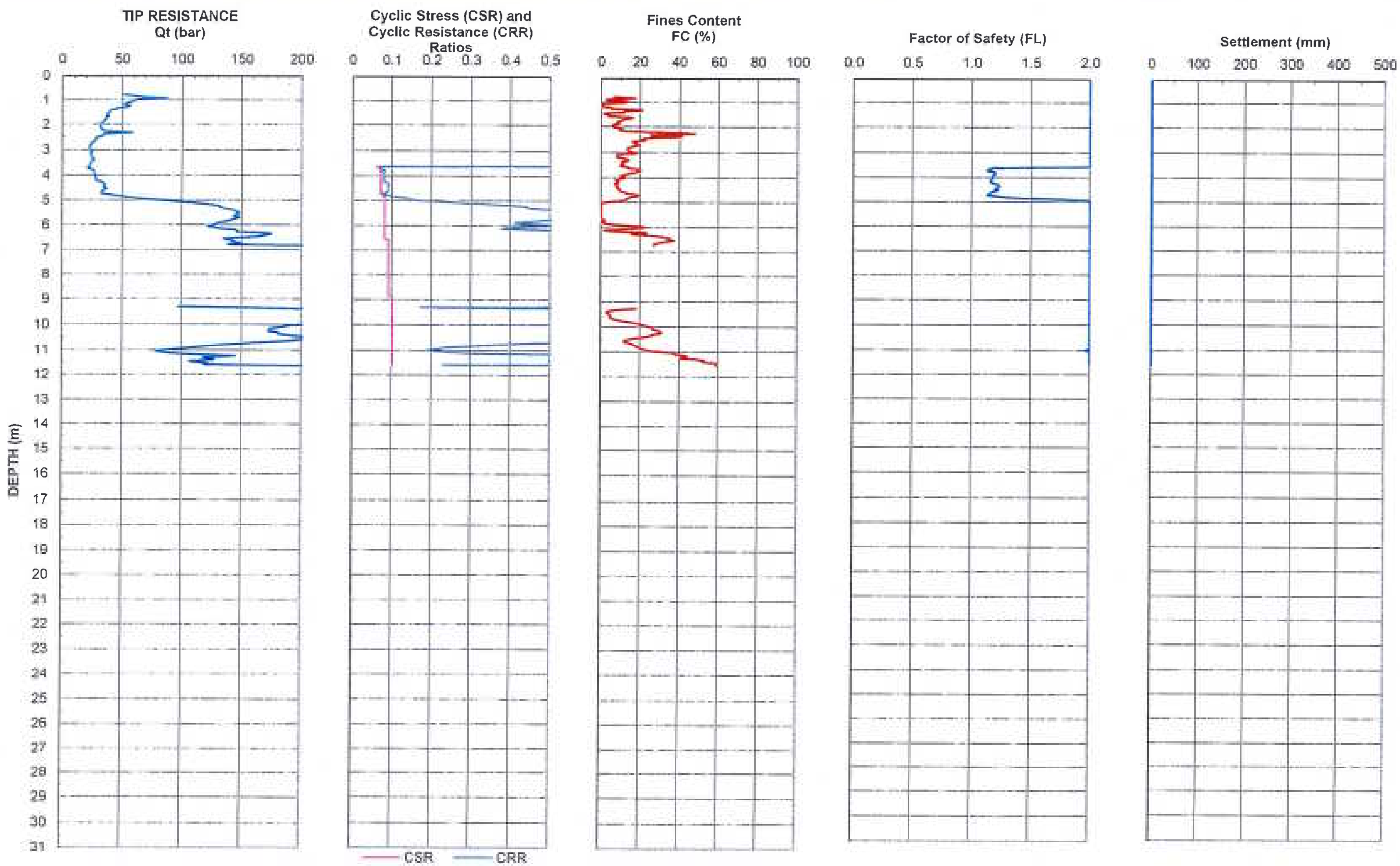


Liquefaction interpretation: PGA = 0.10

magnitude = 6.7

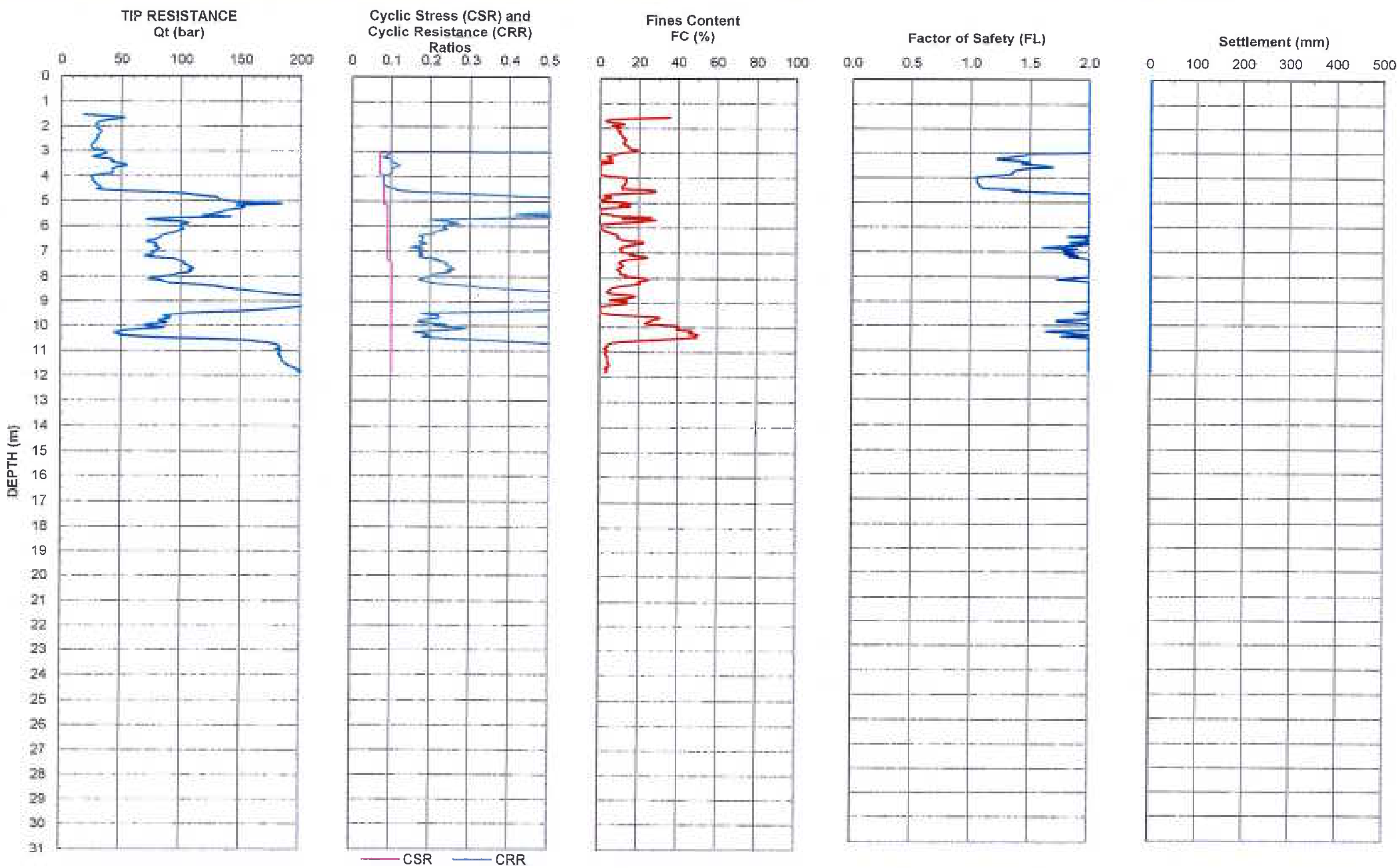
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-01	FRASER SURREY DOCKS, SURREY, BC	Figure: D.01



Liquefaction interpretation: PGA = 0.13
magnitude = 6.8
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

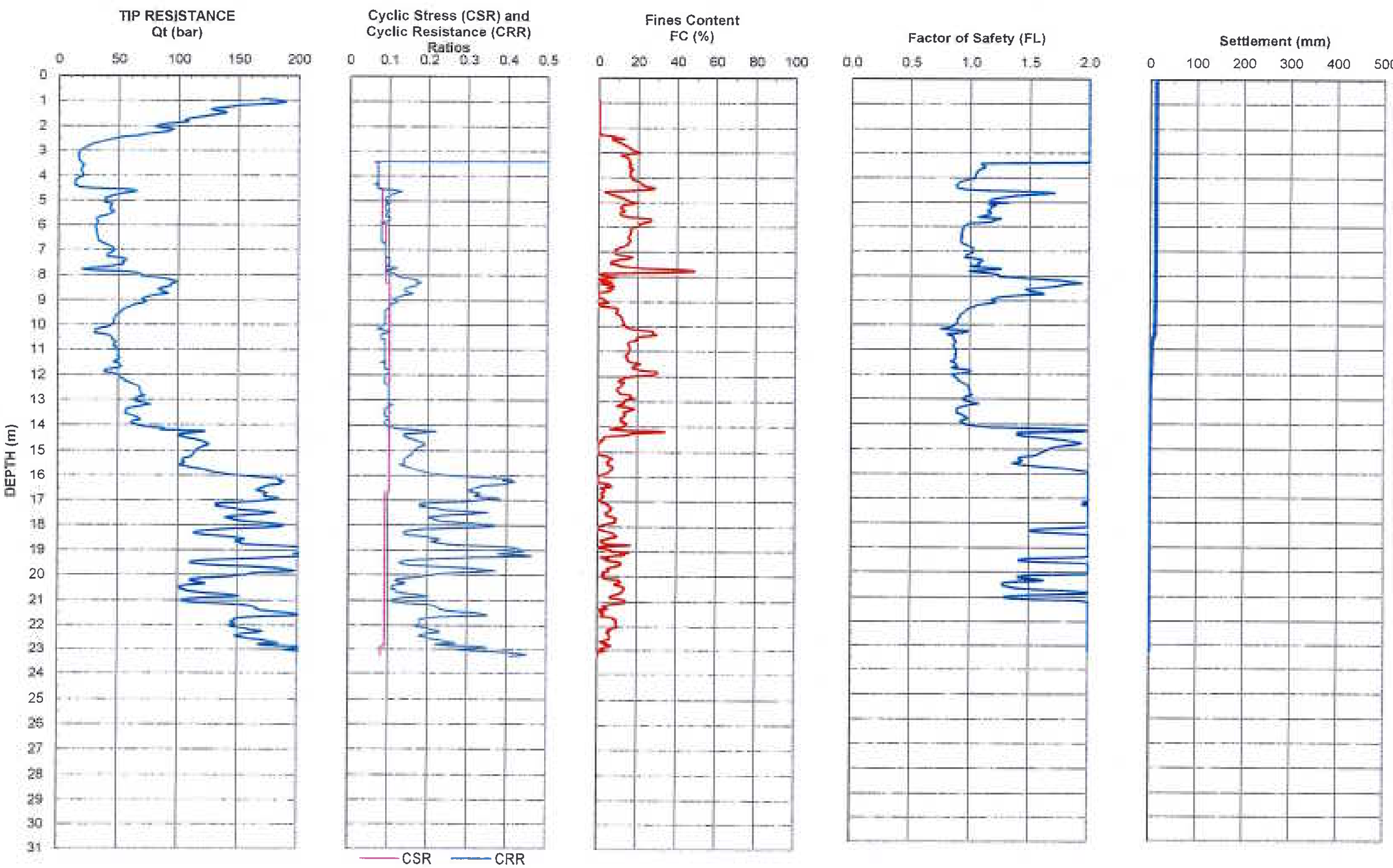


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-03	FRASER SURREY DOCKS, SURREY, BC	Figure: D.03

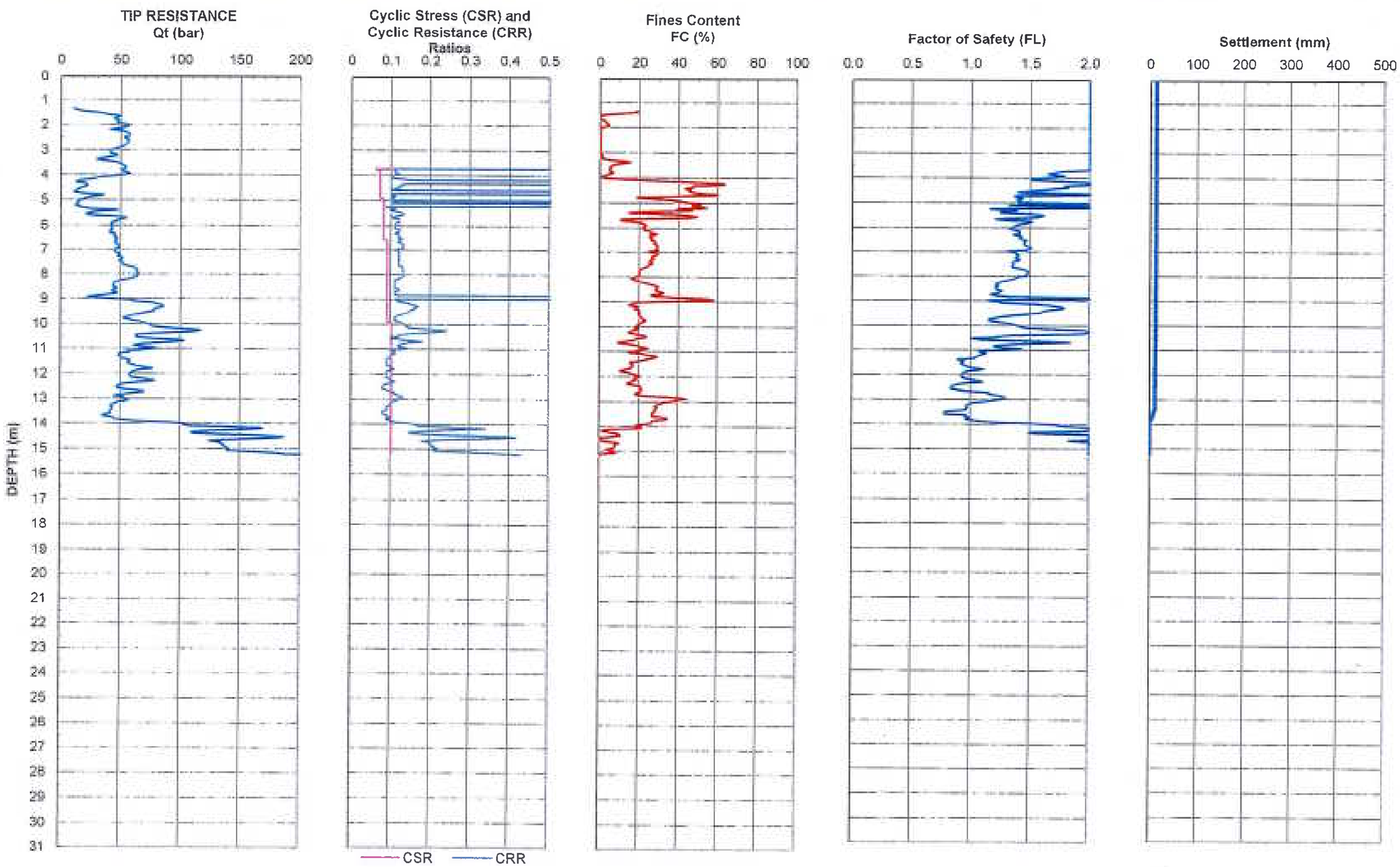


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

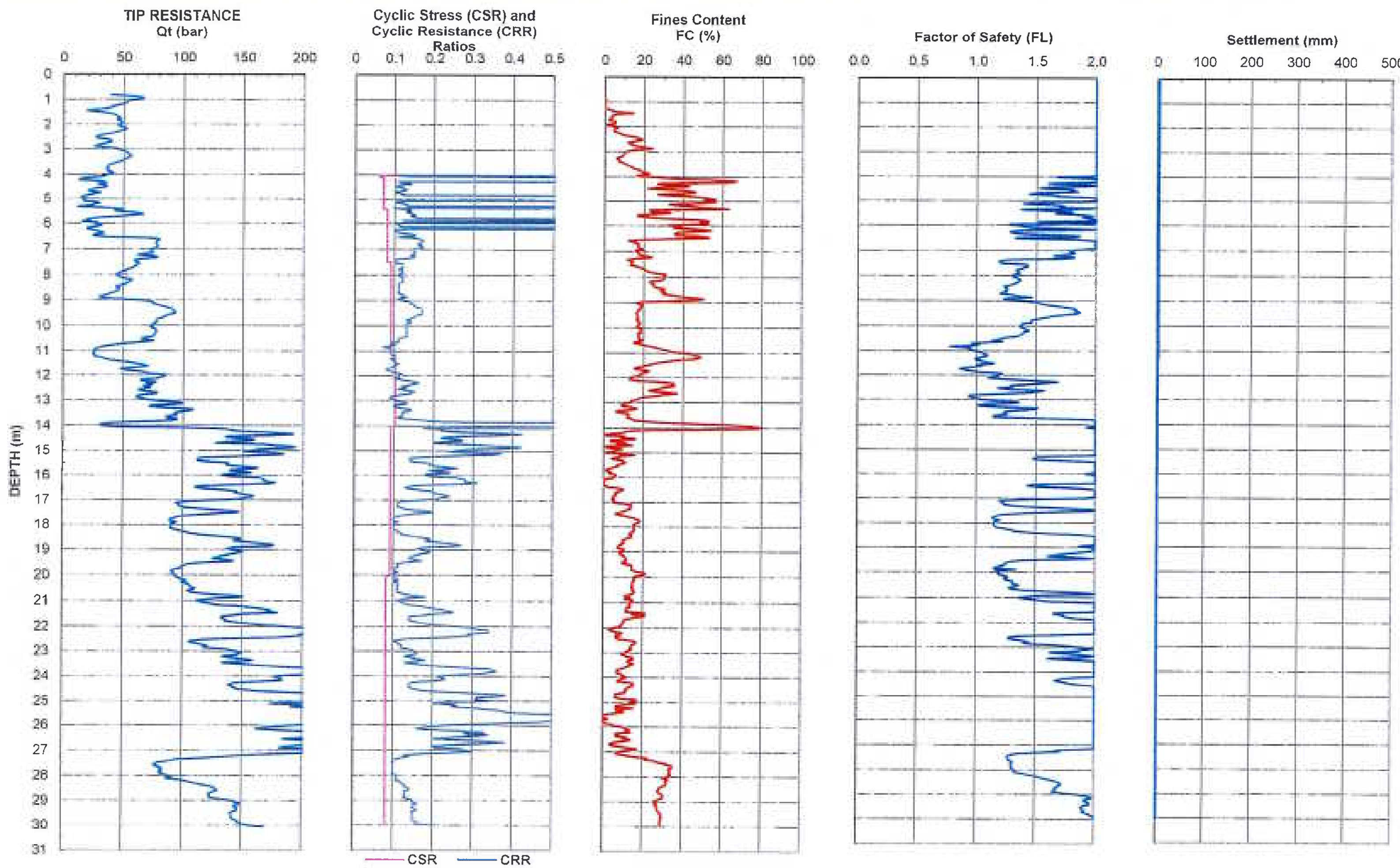


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

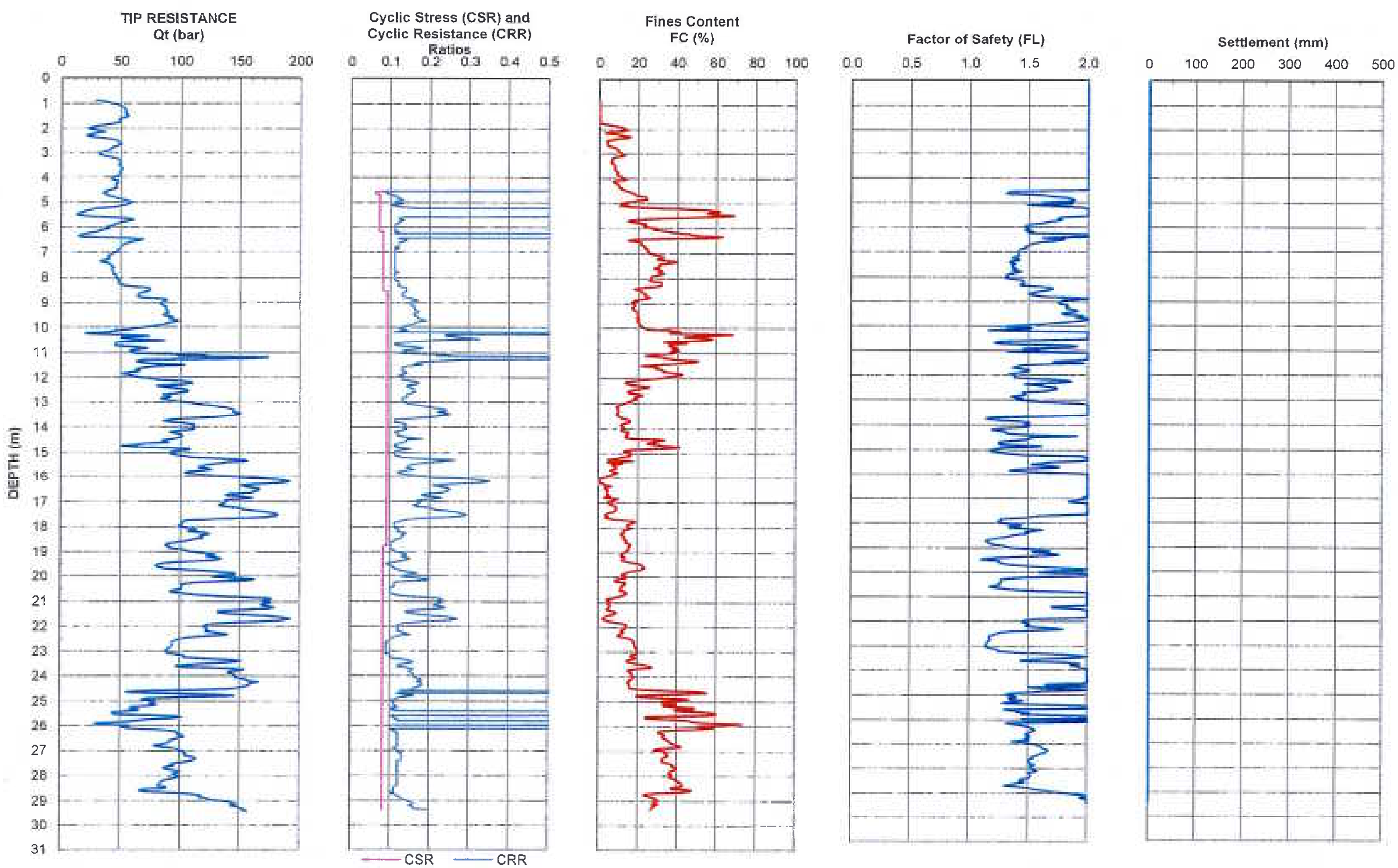


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-06	FRASER SURREY DOCKS, SURREY, BC	Figure: D.06

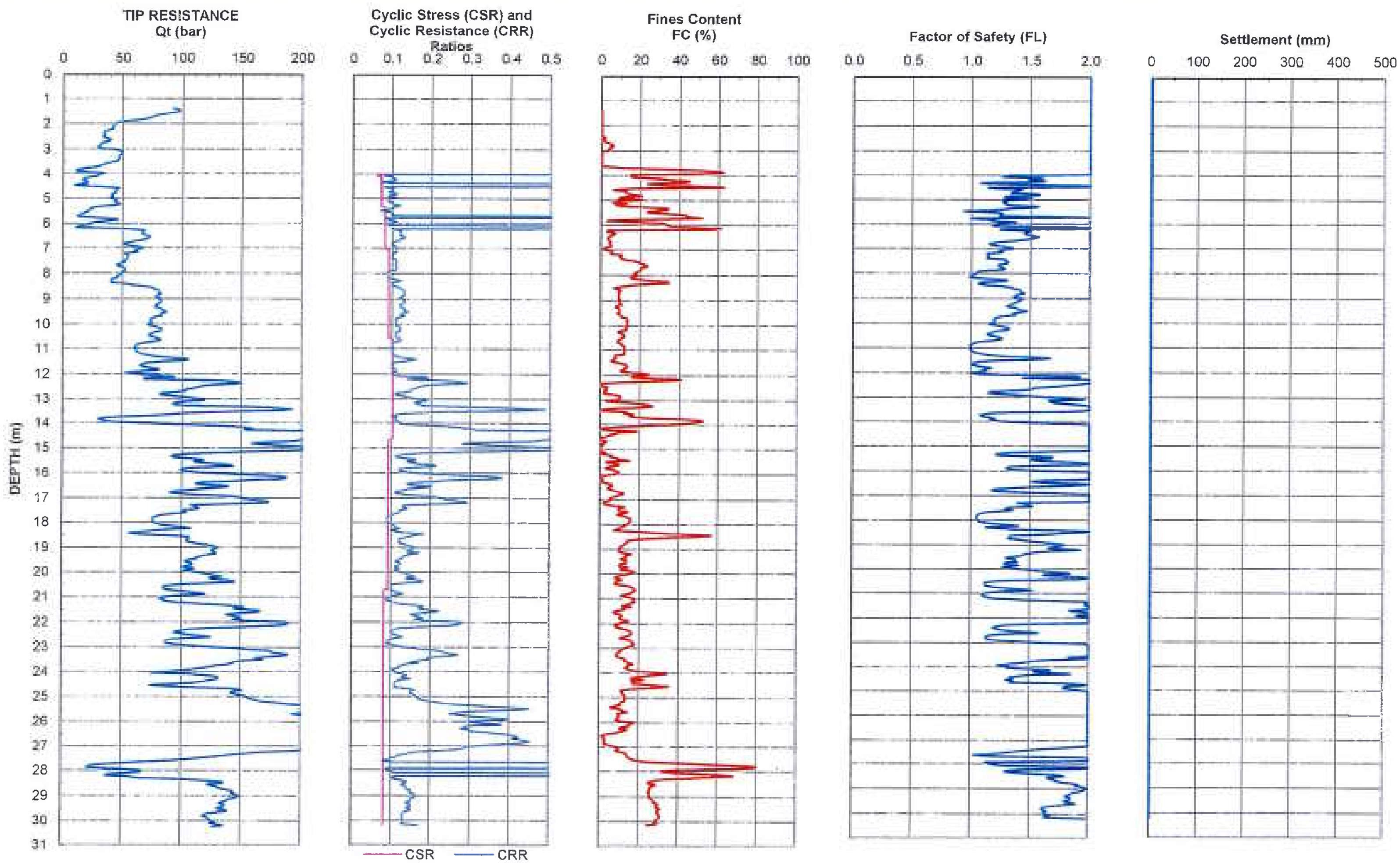


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

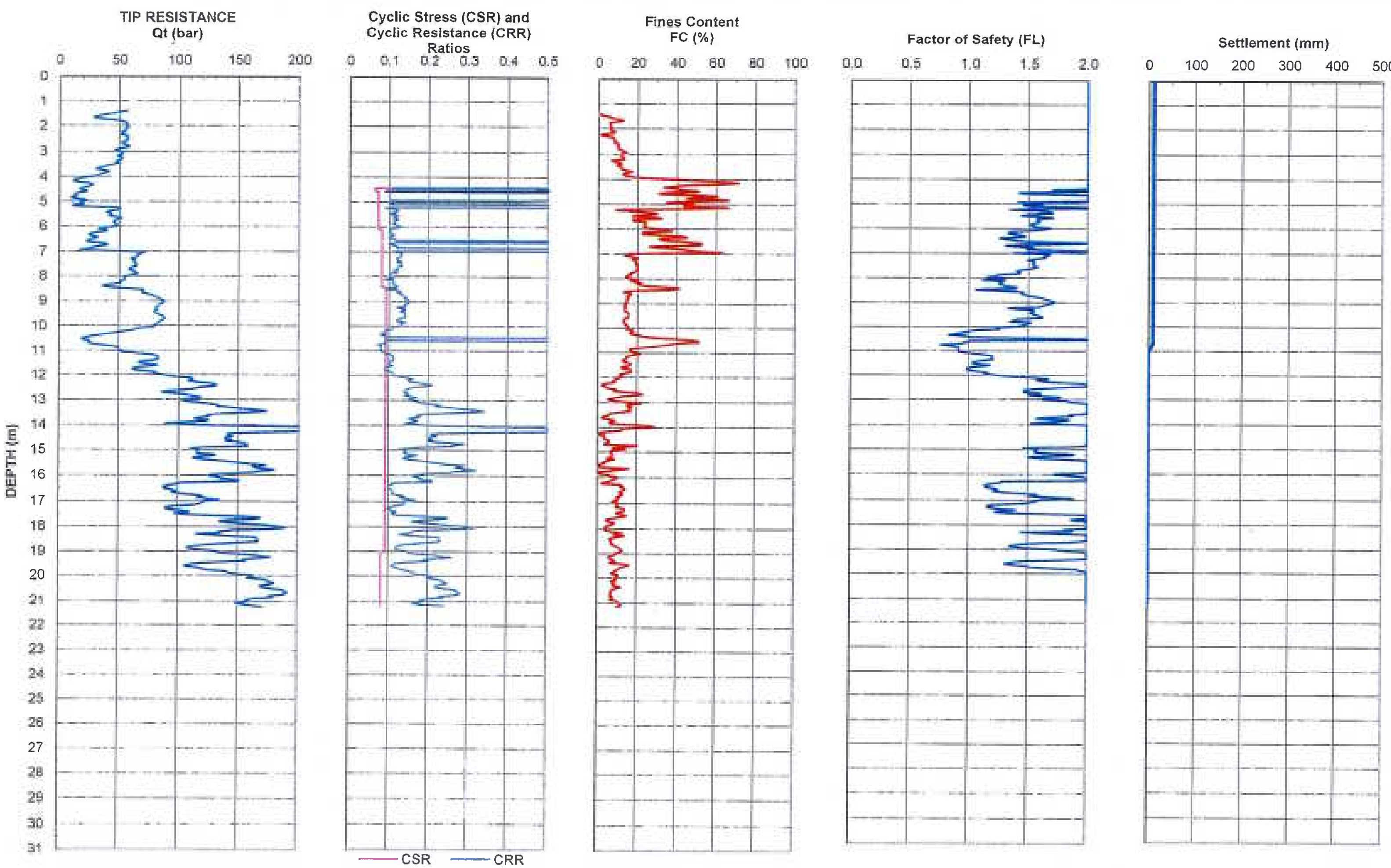


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

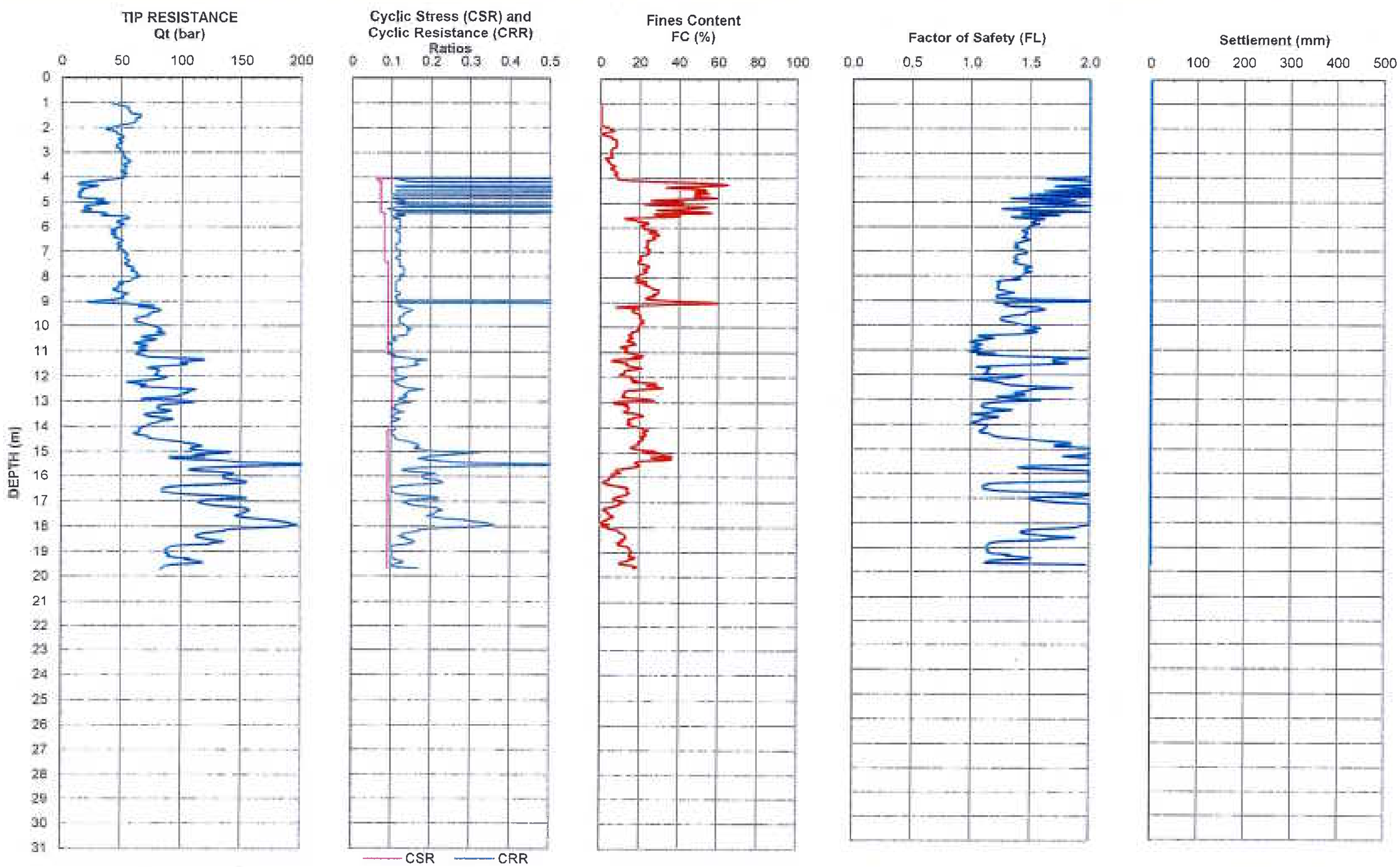
settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08



Liquefaction interpretation: PGA = 0.13
magnitude = 6.8
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

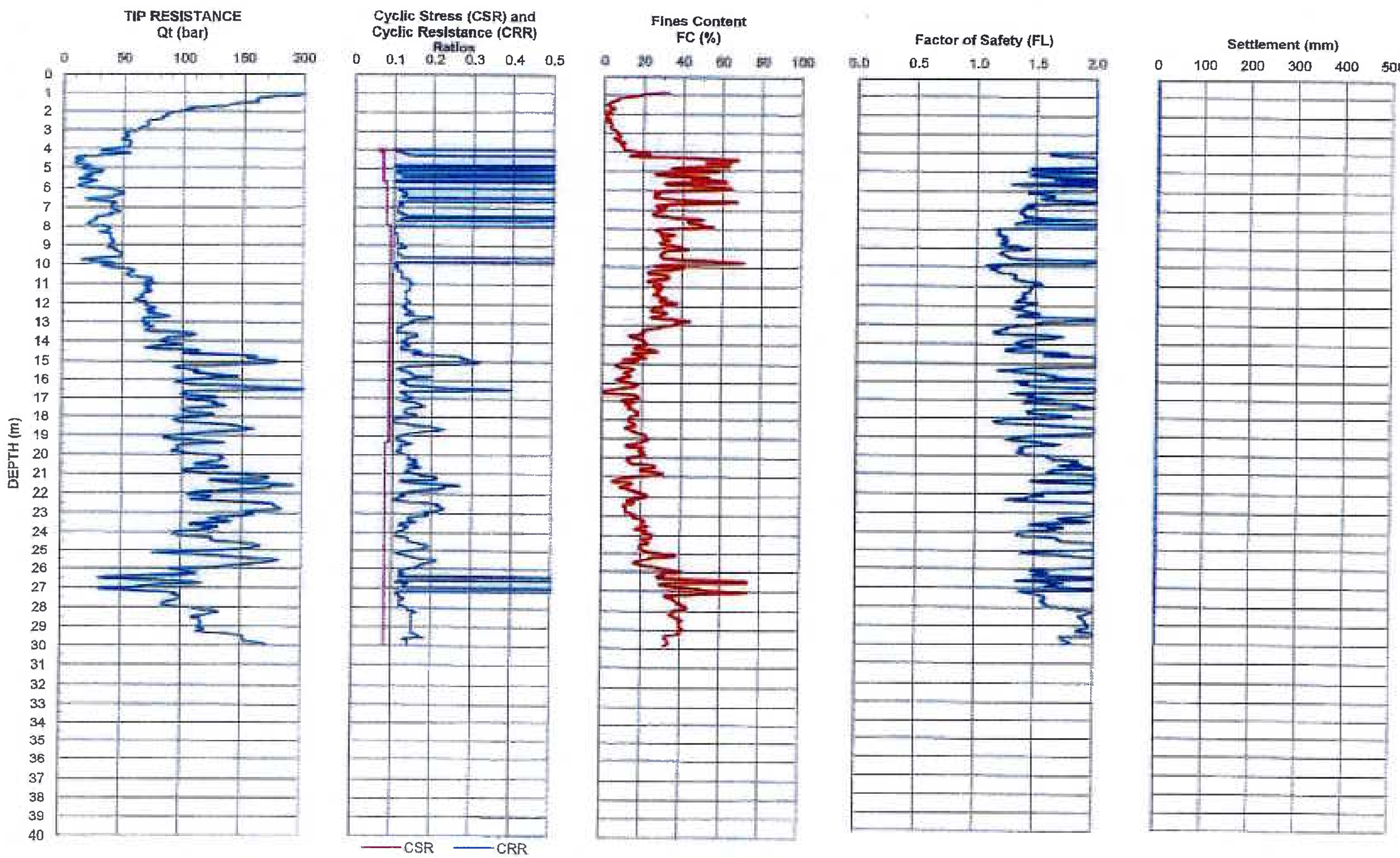


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

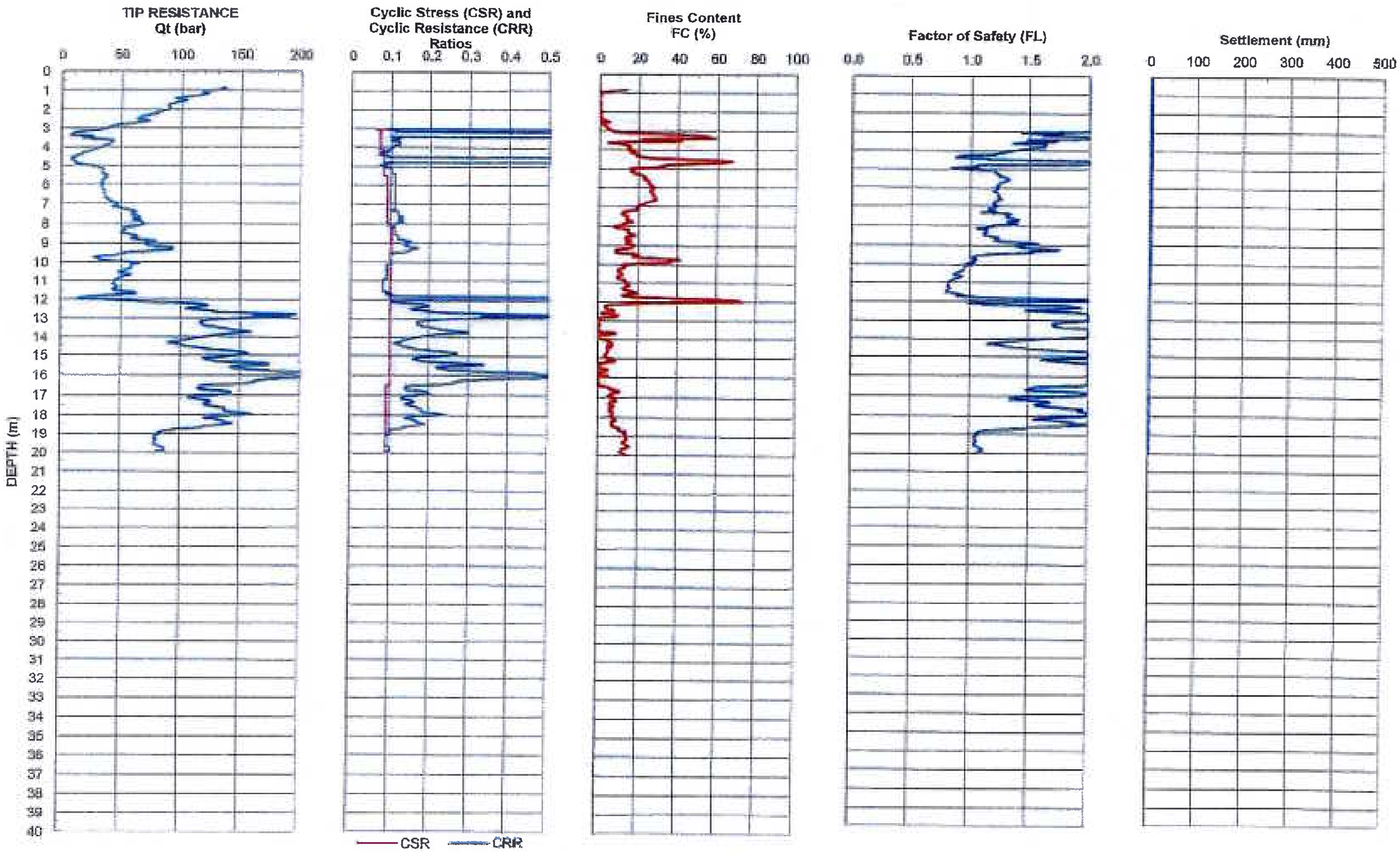
settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02



Liquefaction interpretation: PGA = 0.13
magnitude = 6.8
settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

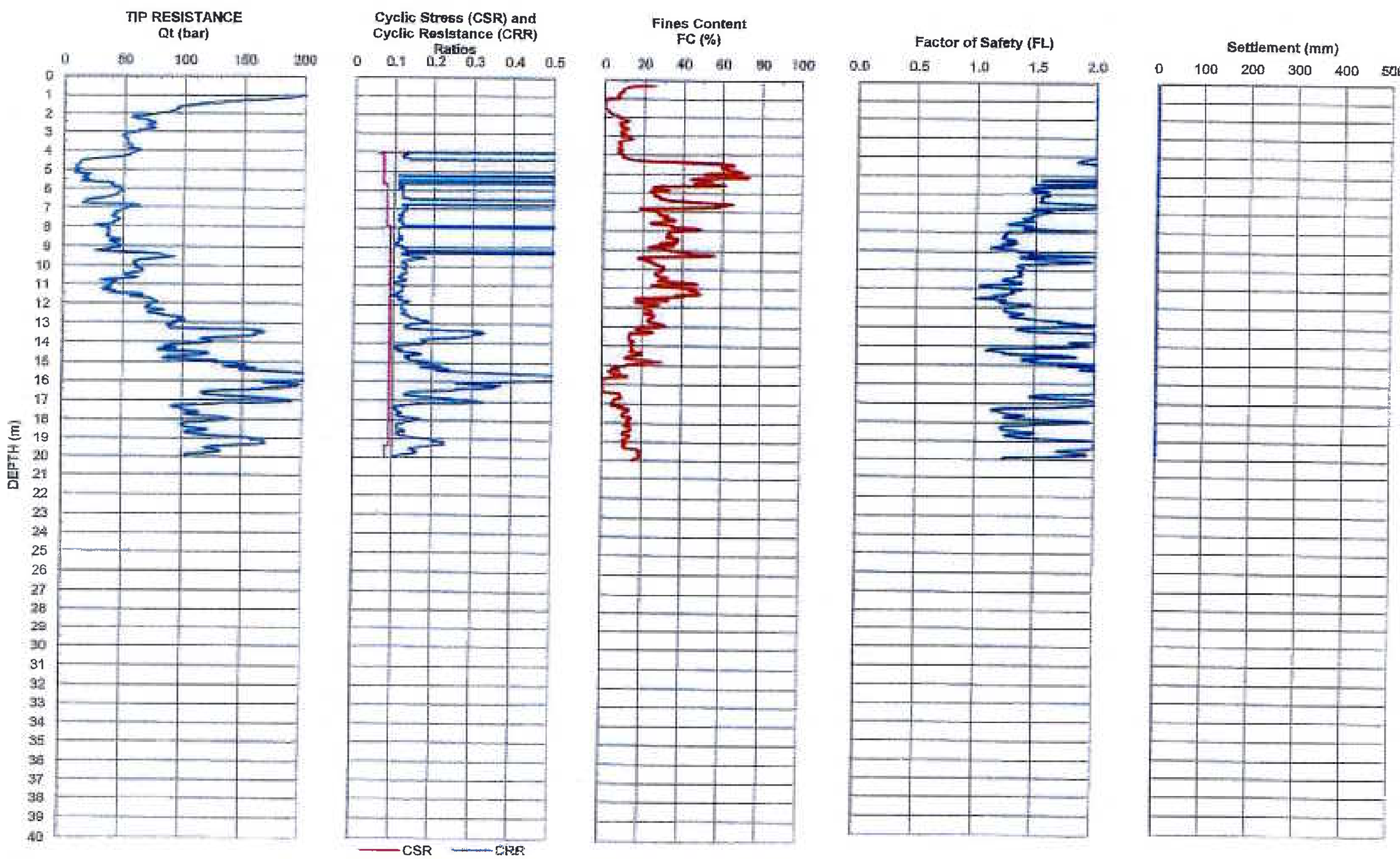


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

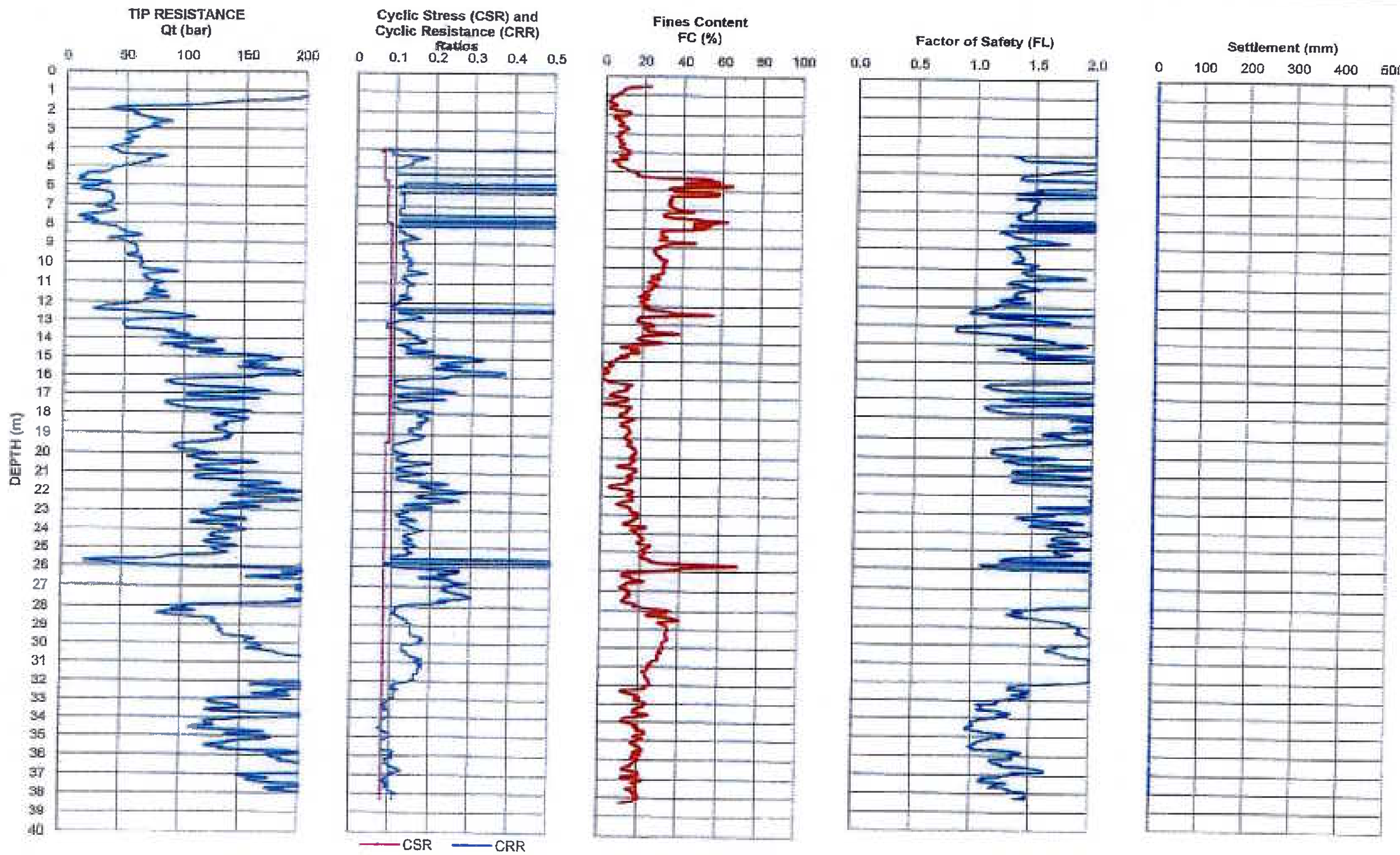


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

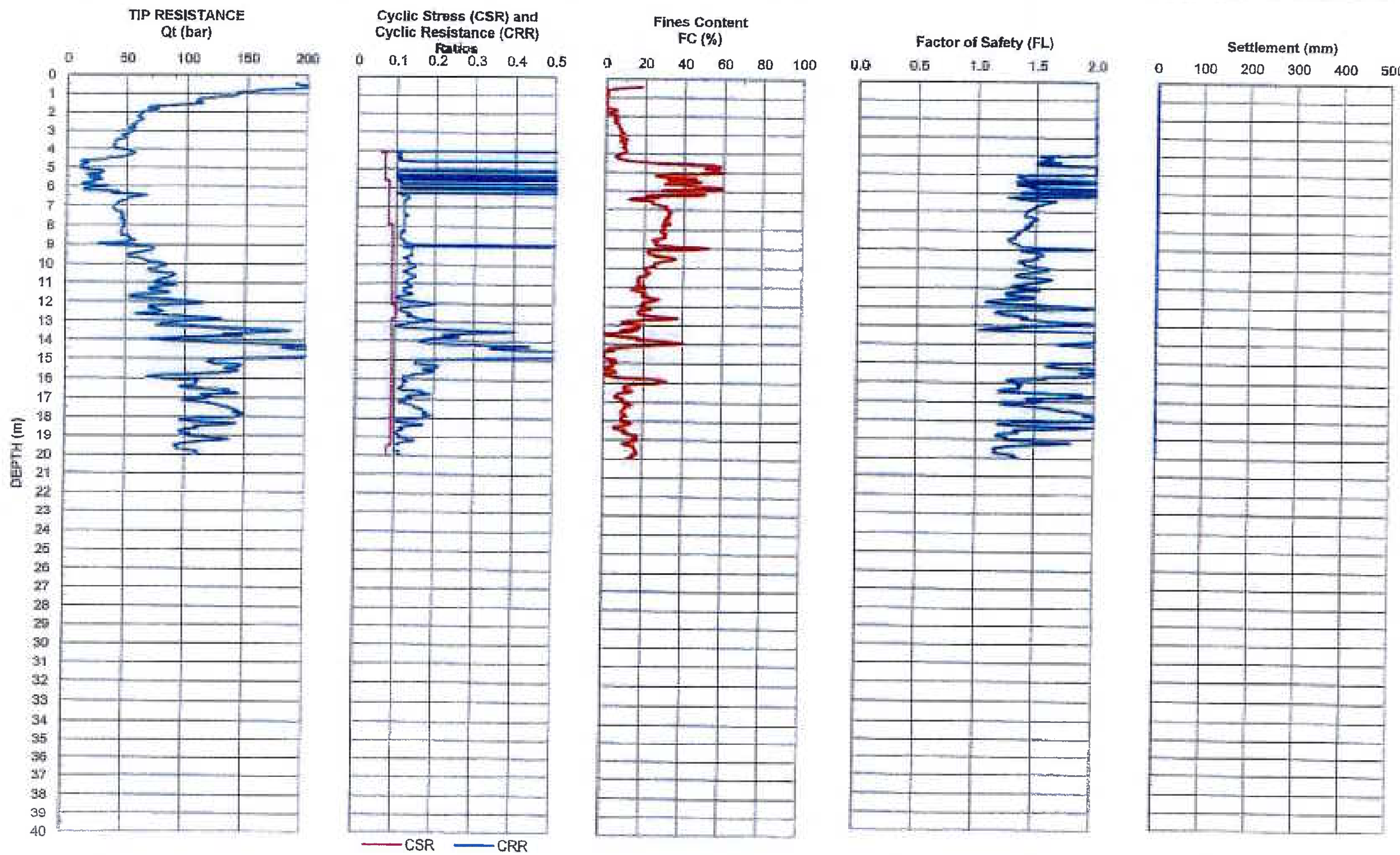


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08

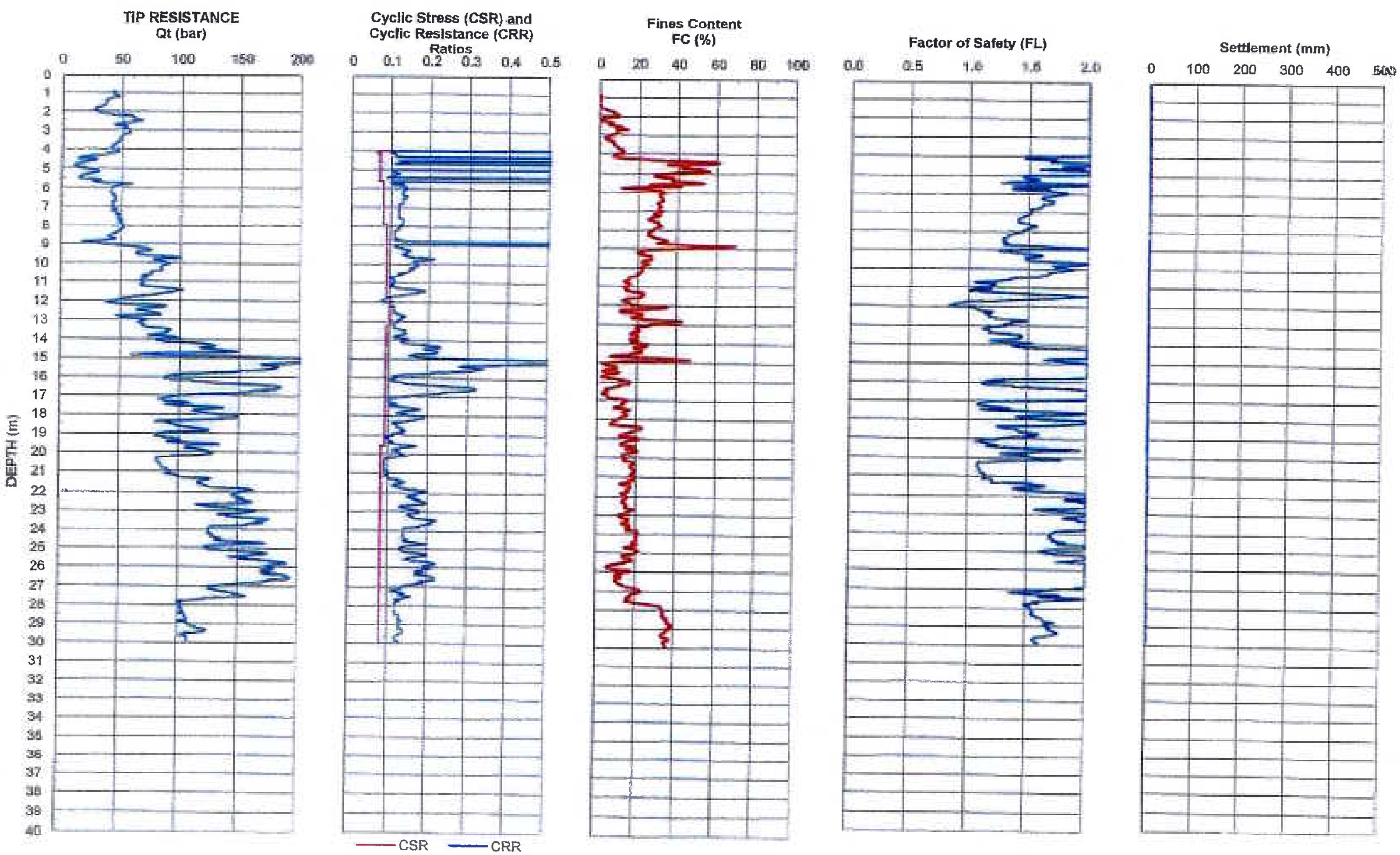


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

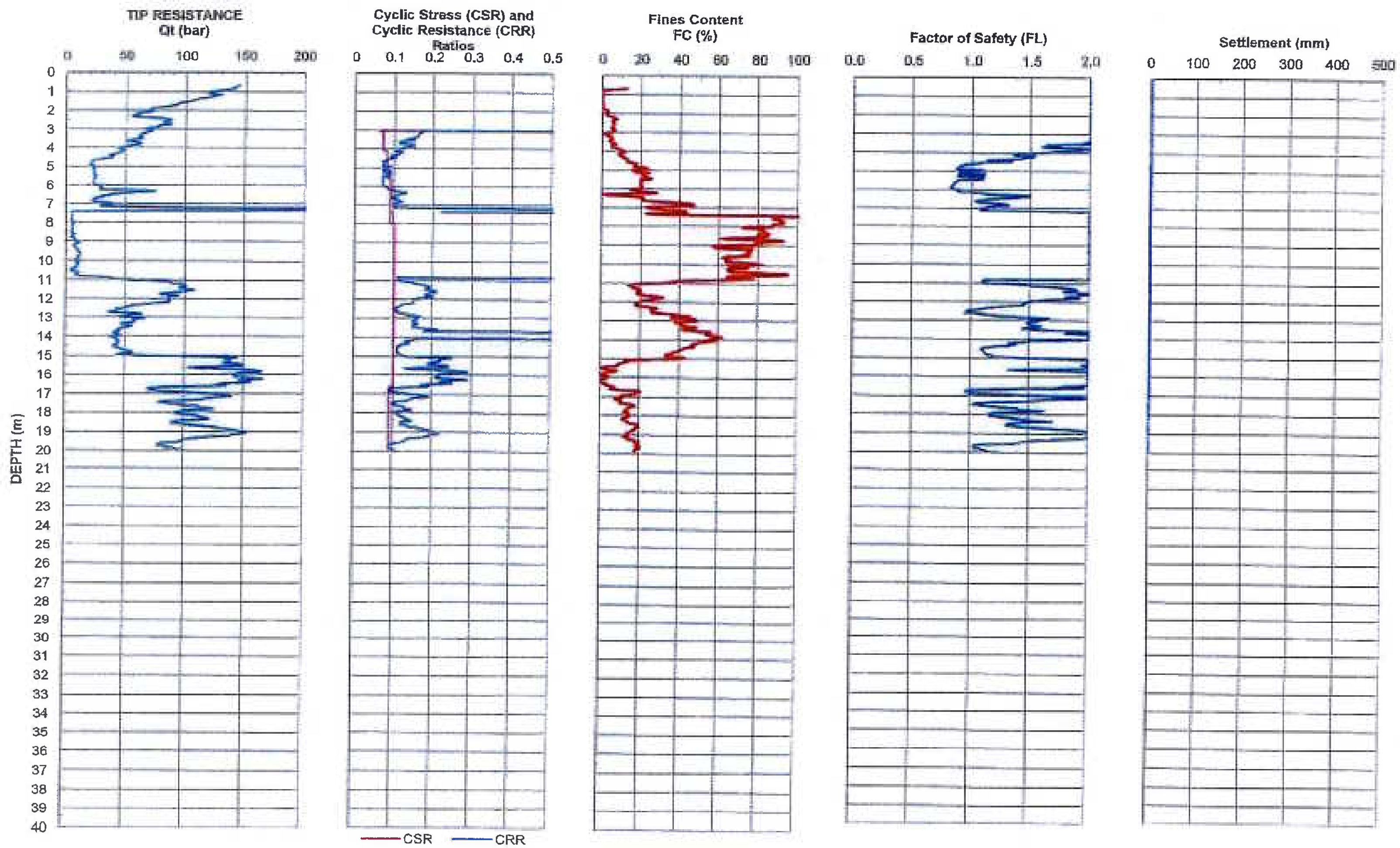


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-10	FRASER SURREY DOCKS, SURREY, BC	Figure: D.10

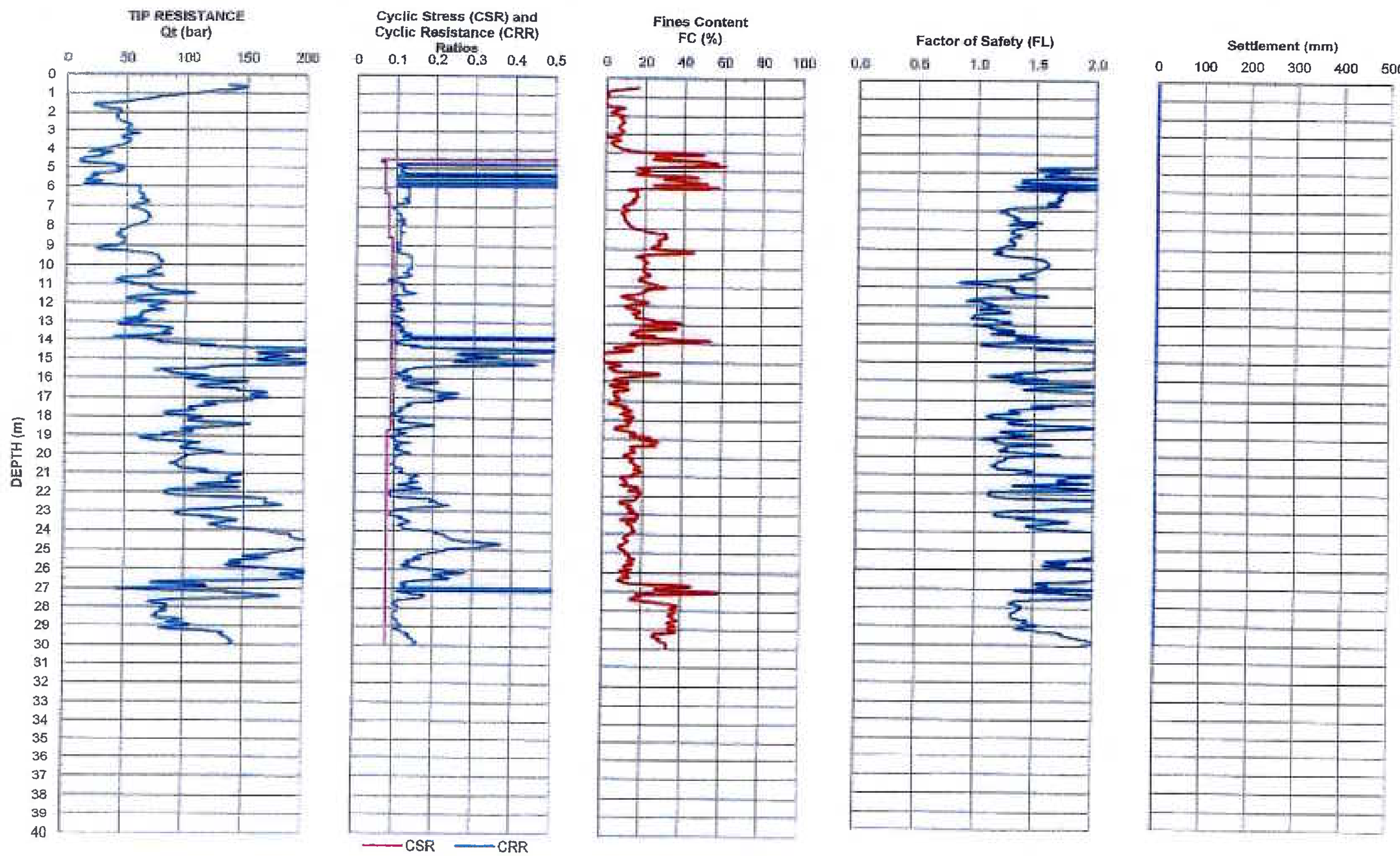


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-11	FRASER SURREY DOCKS, SURREY, BC	Figure: D.11

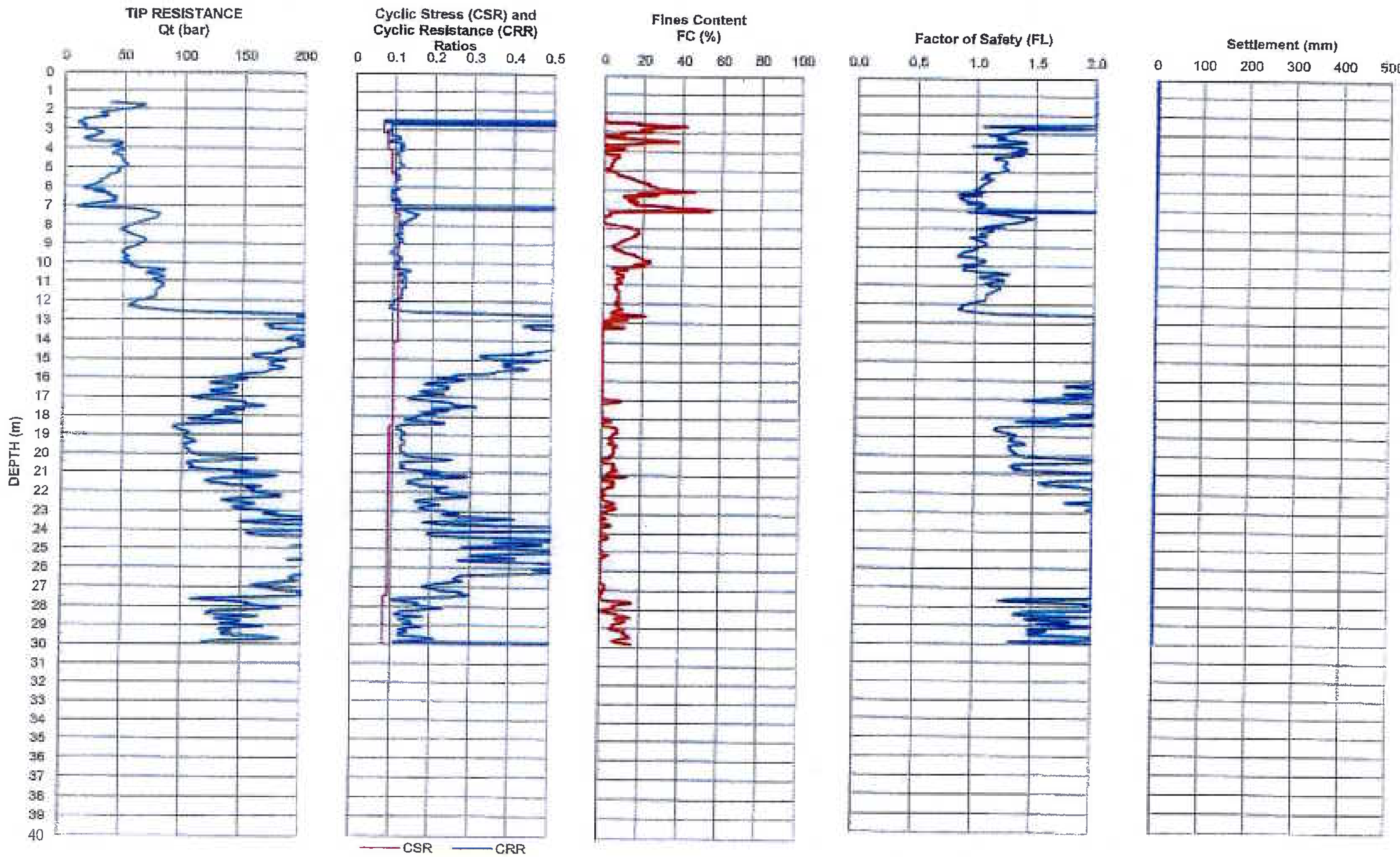


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC	2010-Sep-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT10-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

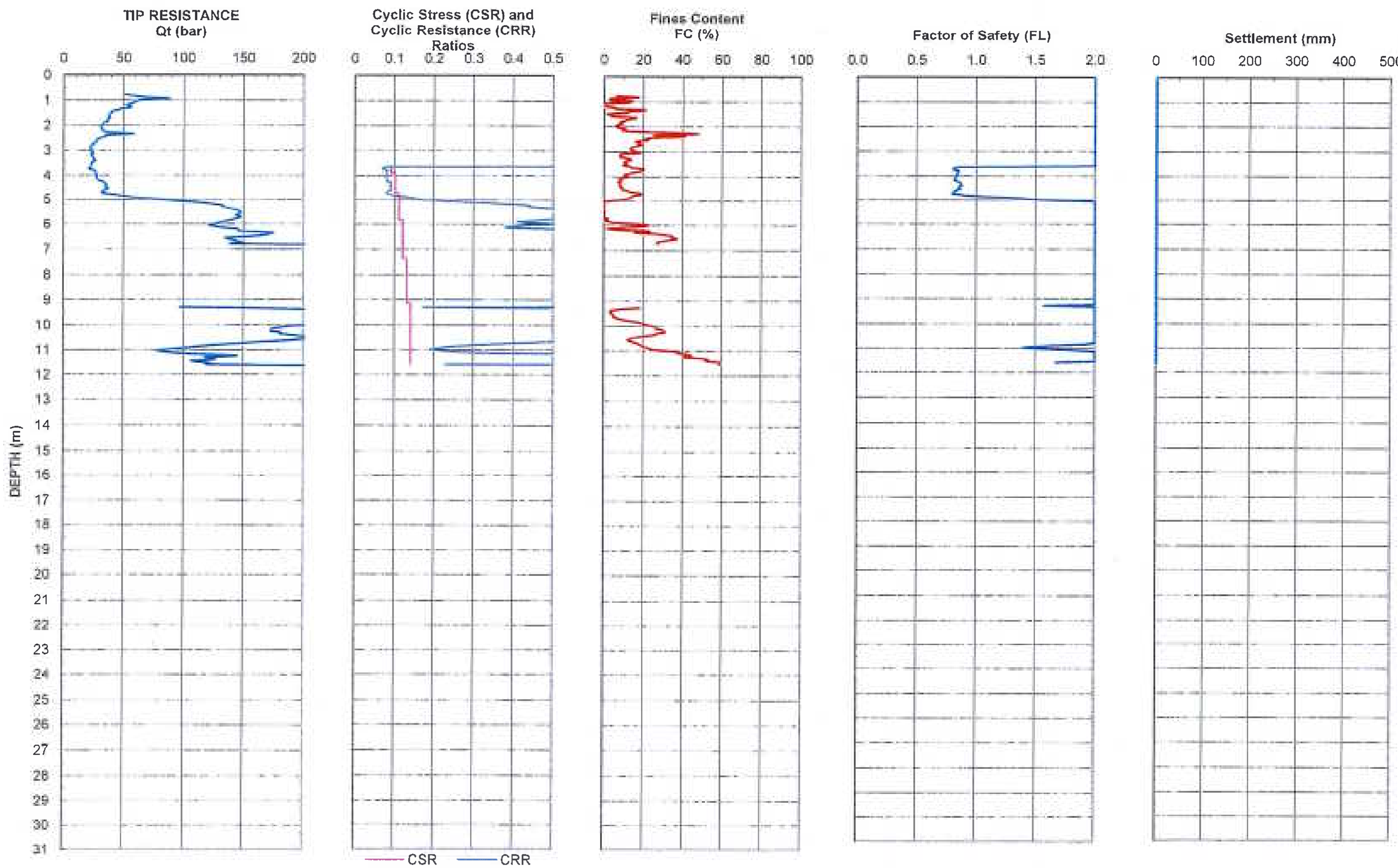


Liquefaction interpretation: PGA = 0.13

magnitude = 6.8

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-01	FRASER SURREY DOCKS, SURREY, BC	Figure: D.01

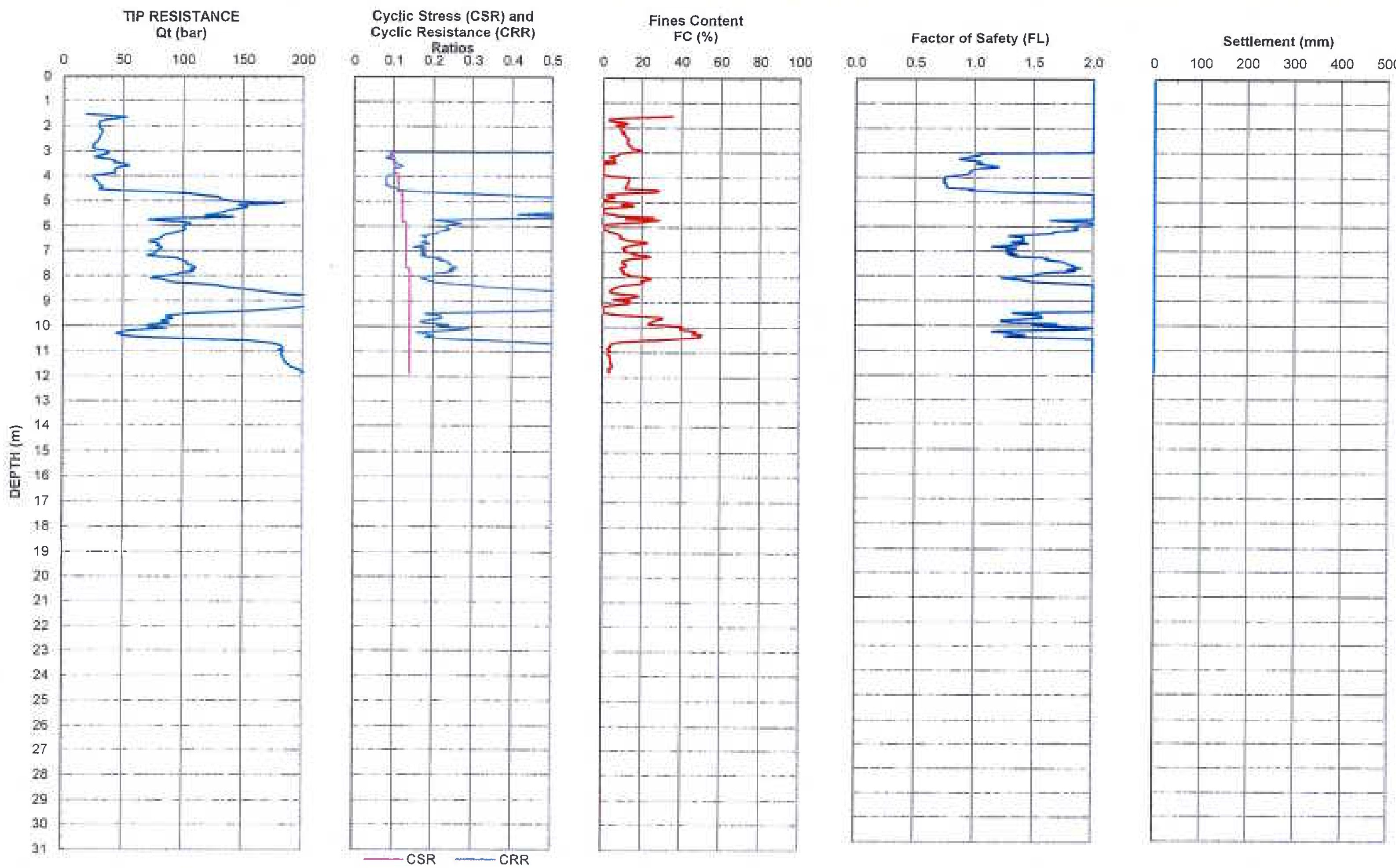


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

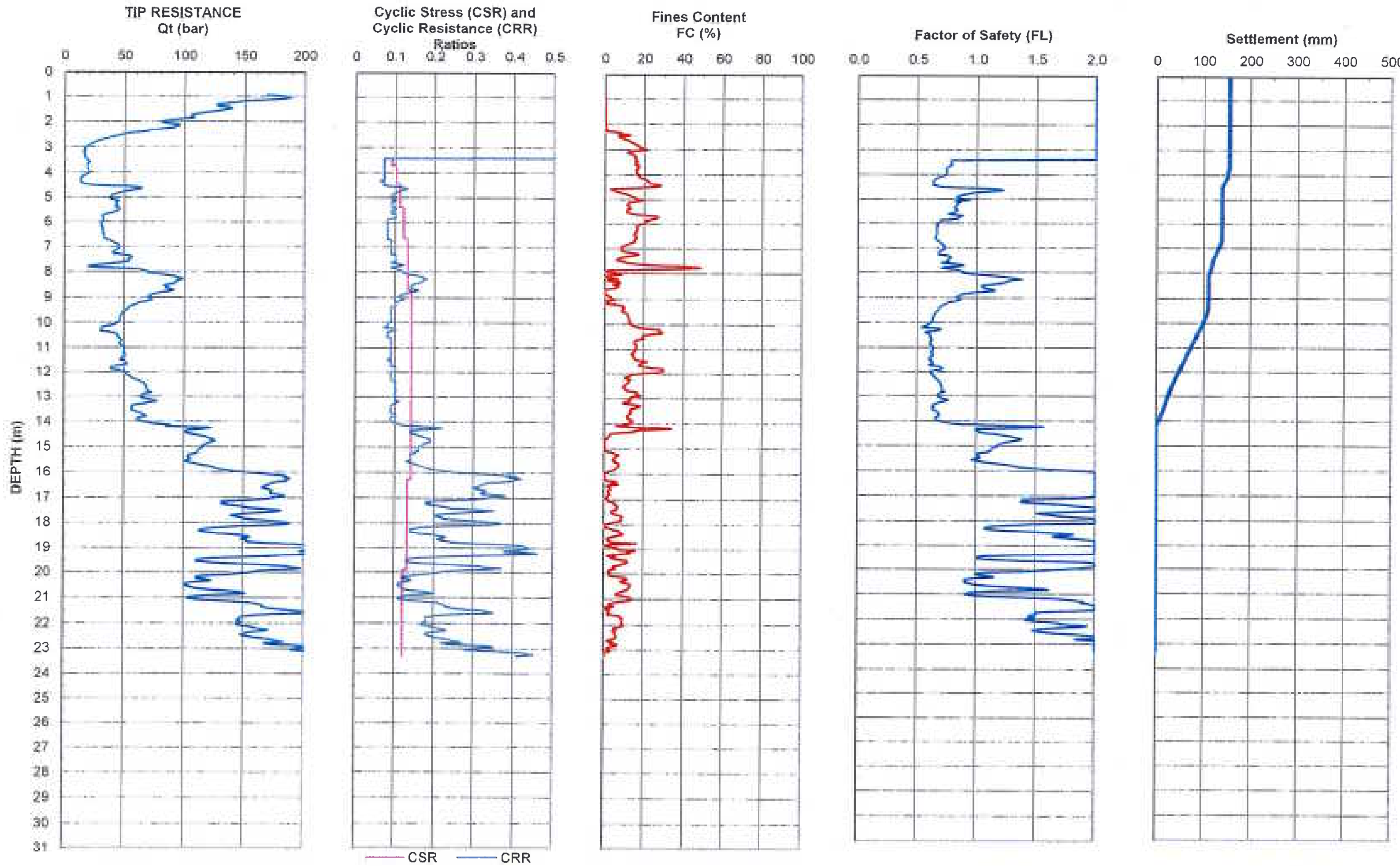


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-03	FRASER SURREY DOCKS, SURREY, BC	Figure: D.03

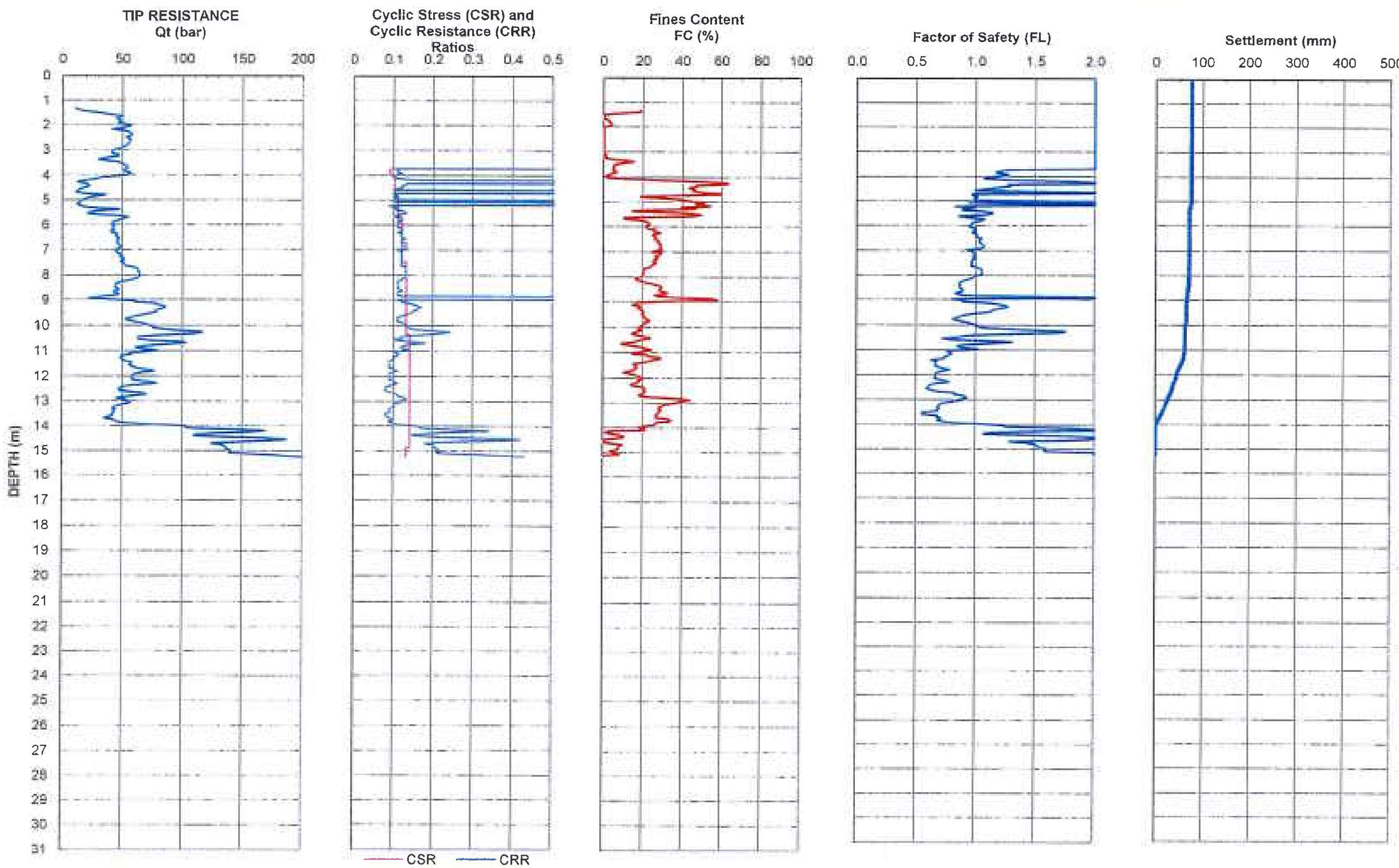


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

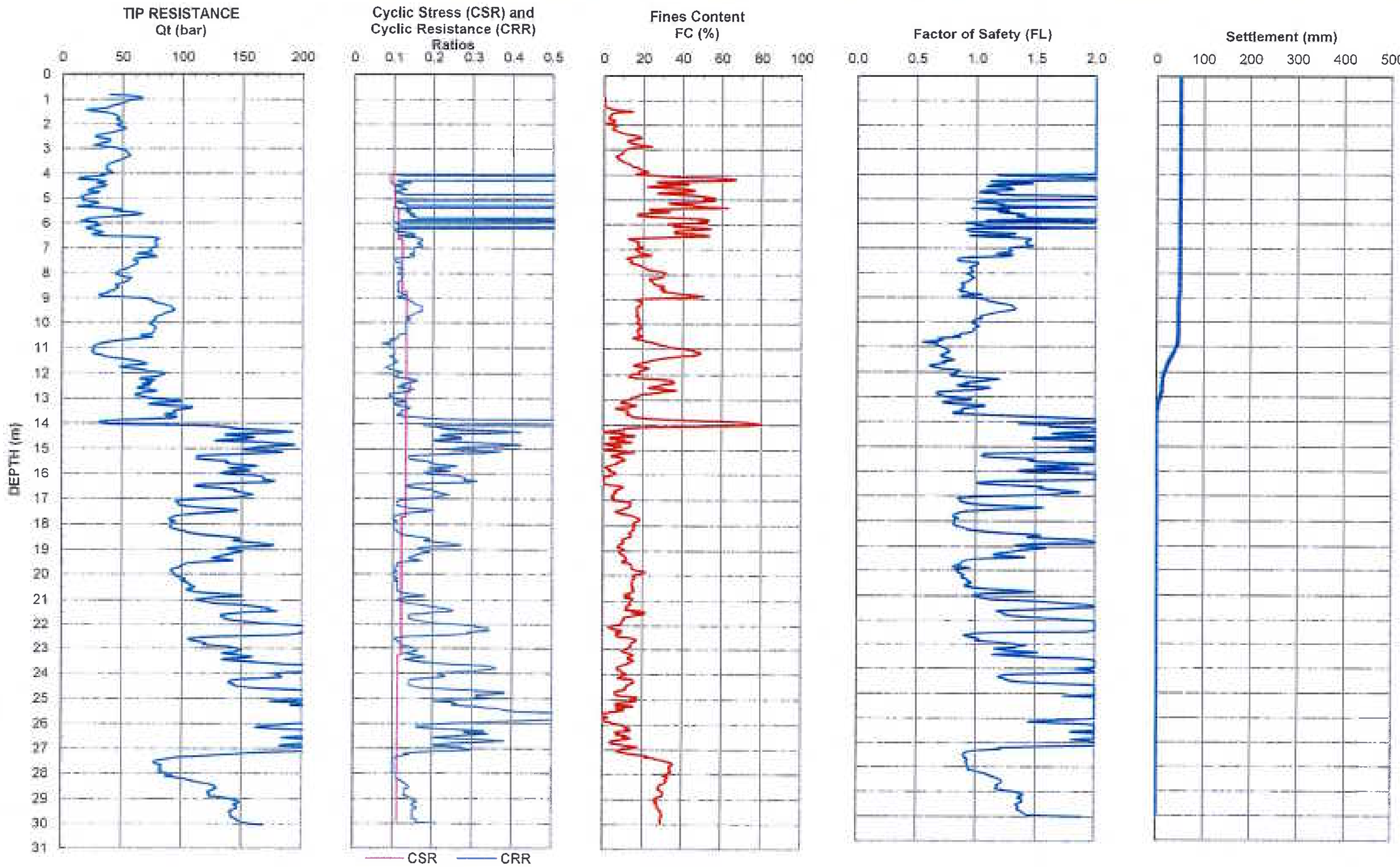


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

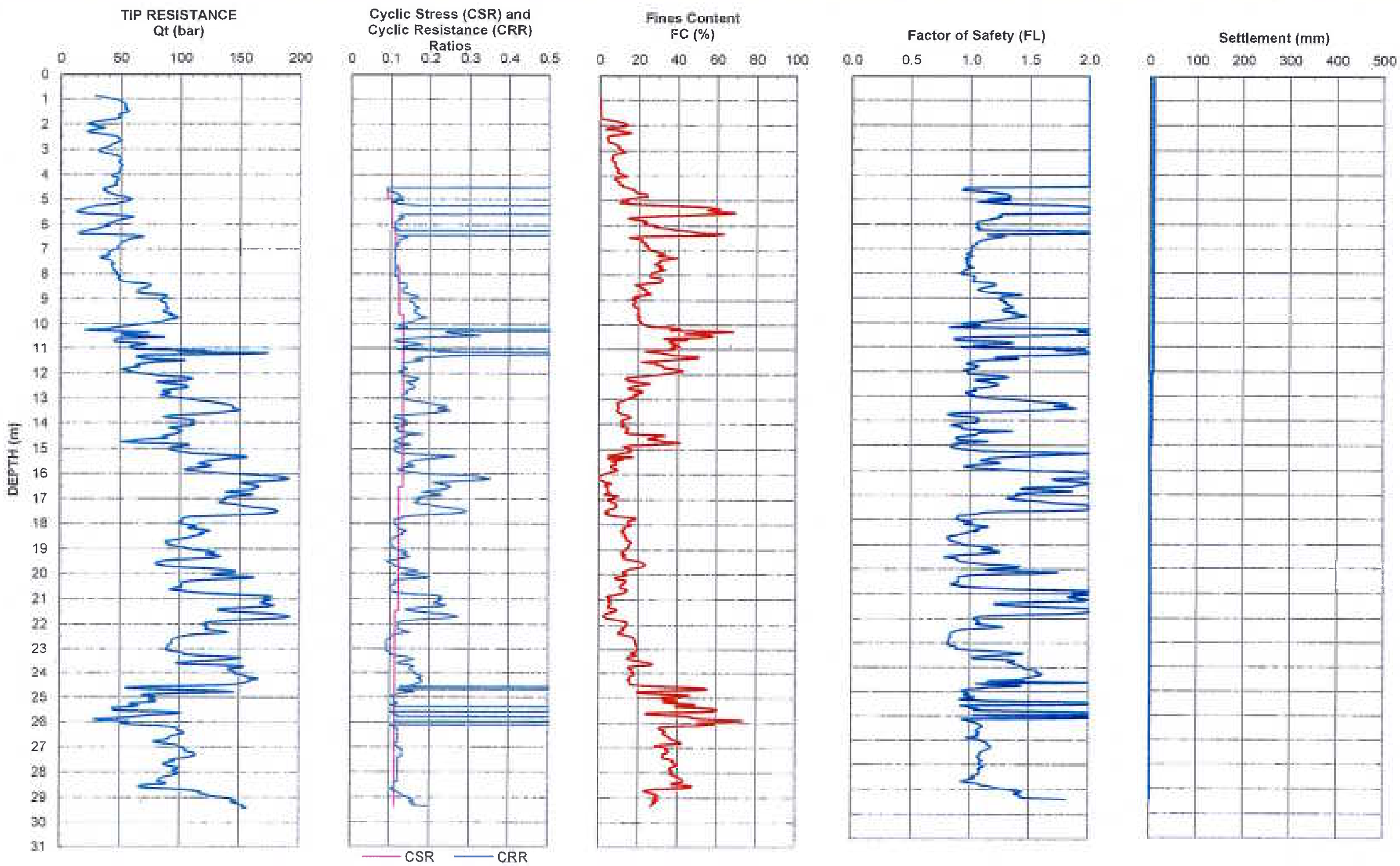


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-06	FRASER SURREY DOCKS, SURREY, BC	Figure: D.06

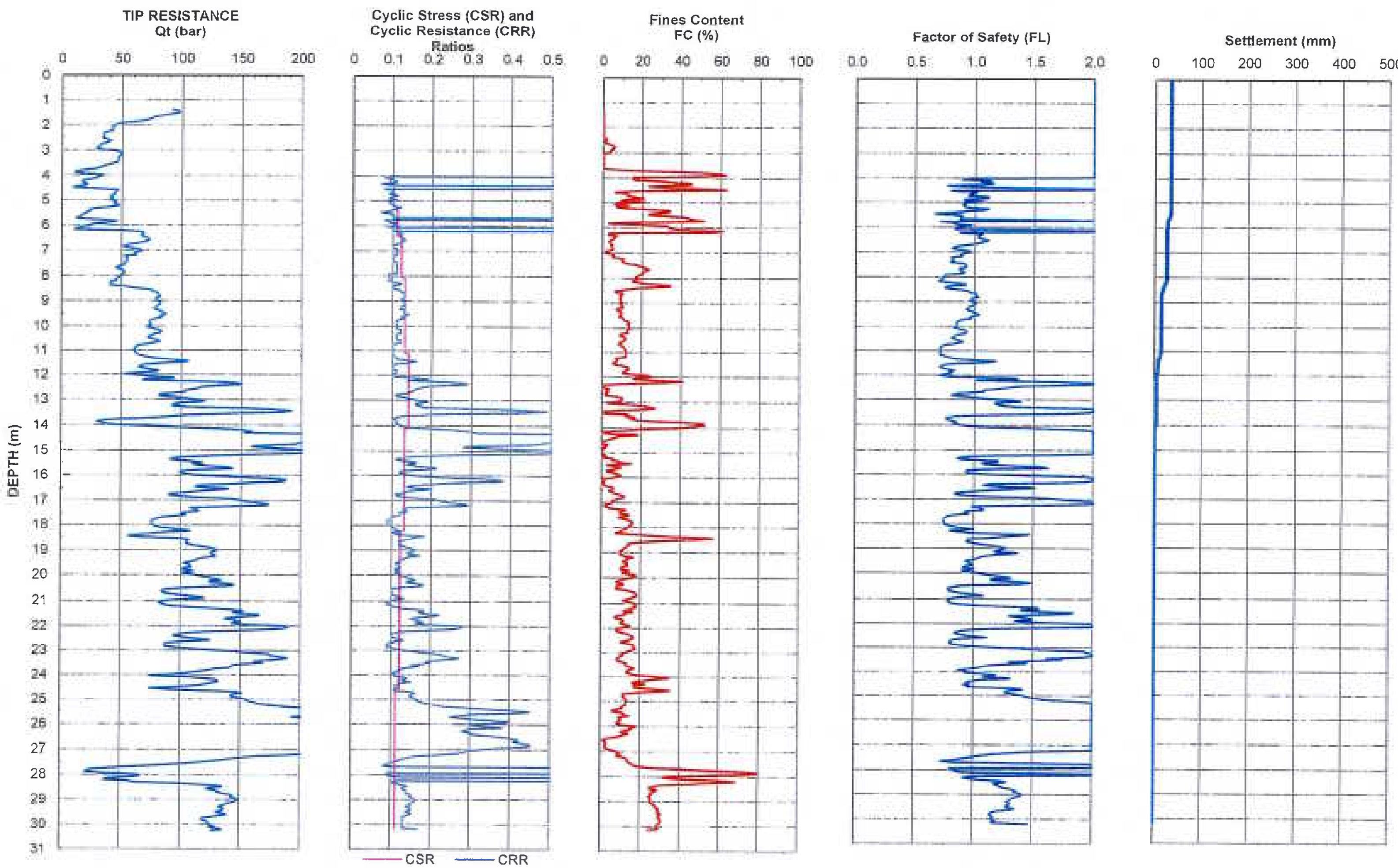


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

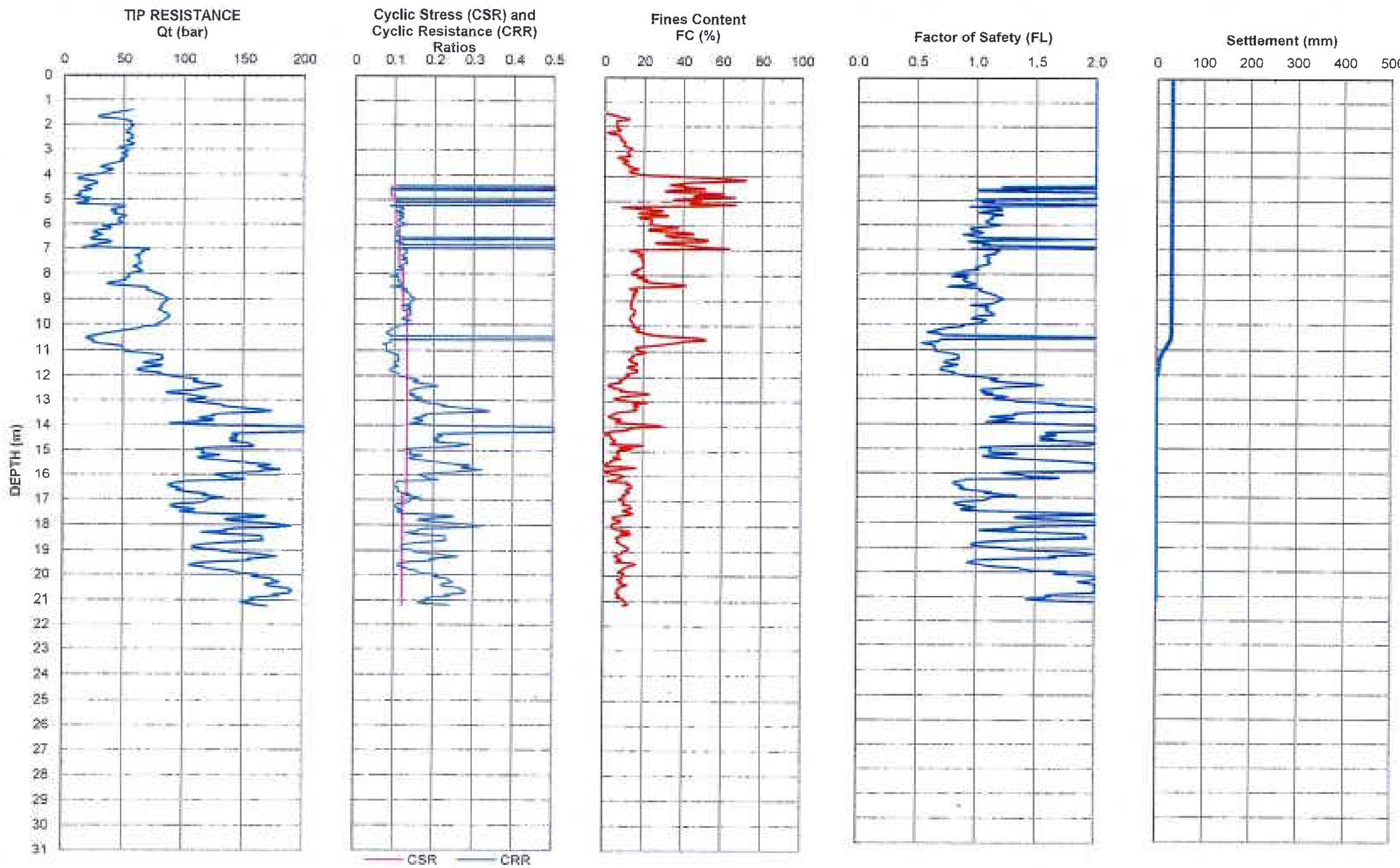


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

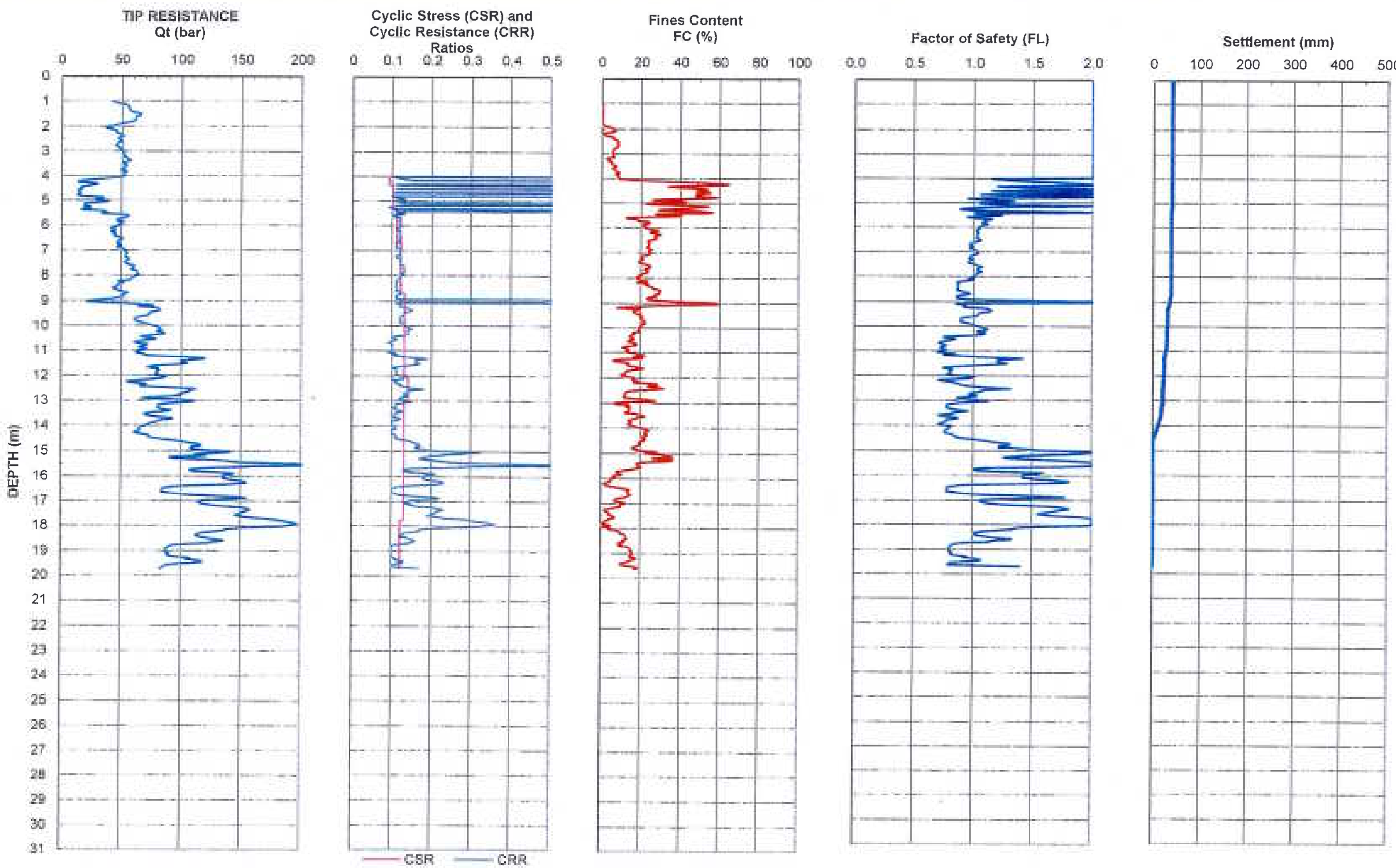
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08



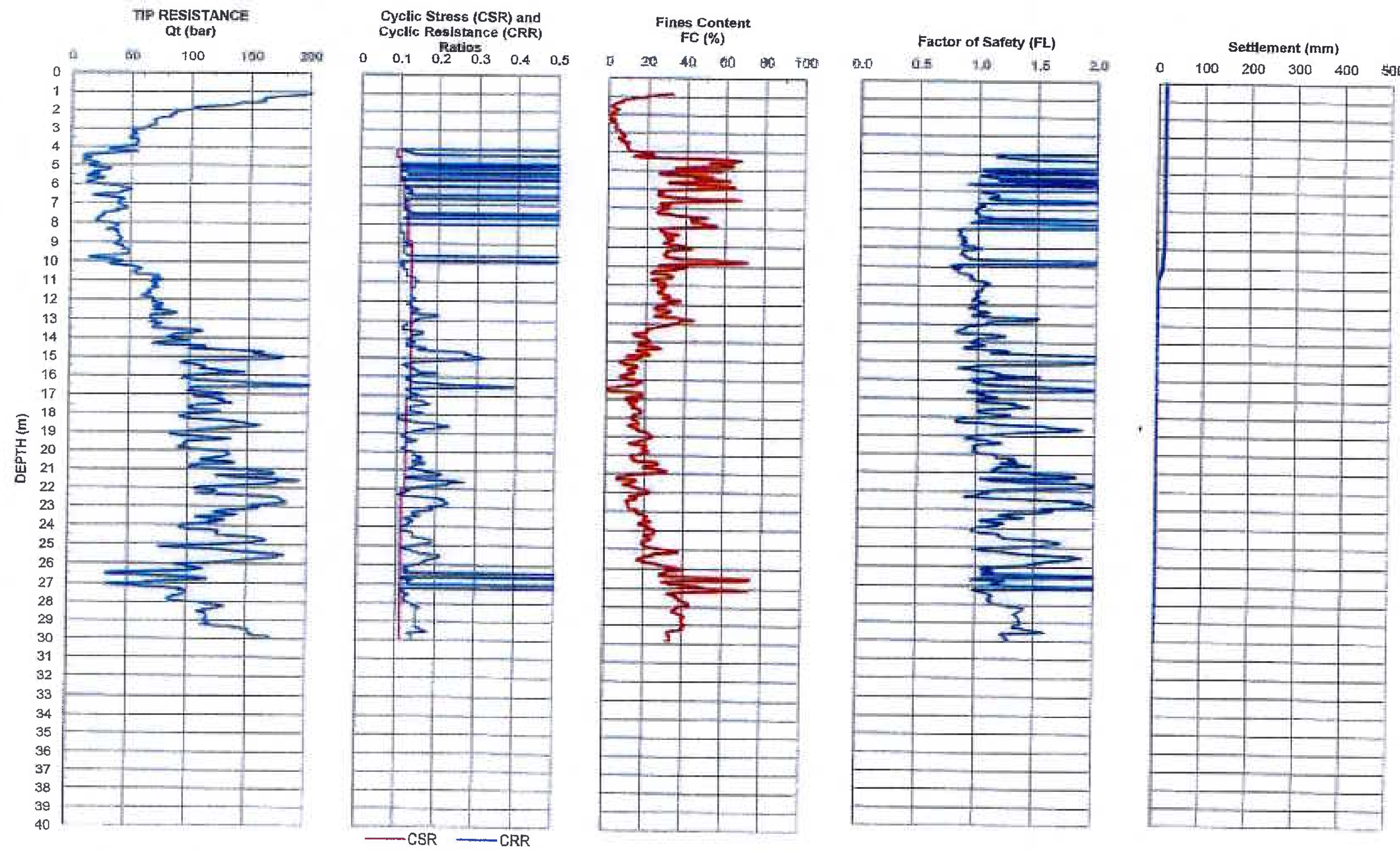
Liquefaction interpretation: PGA = 0.17
magnitude = 7.0
settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09



Liquefaction interpretation: PGA = 0.17
magnitude = 7.0
settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

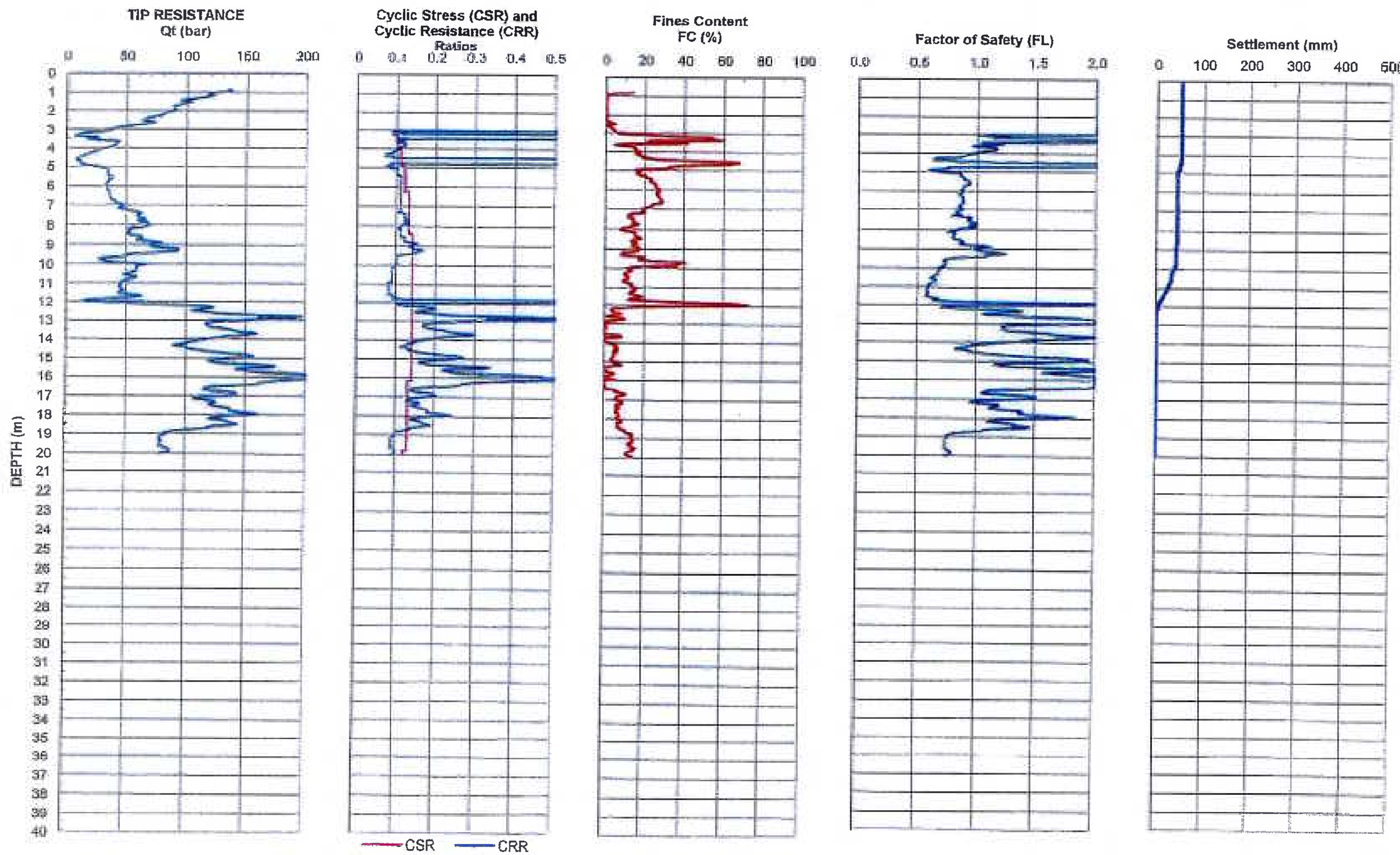


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

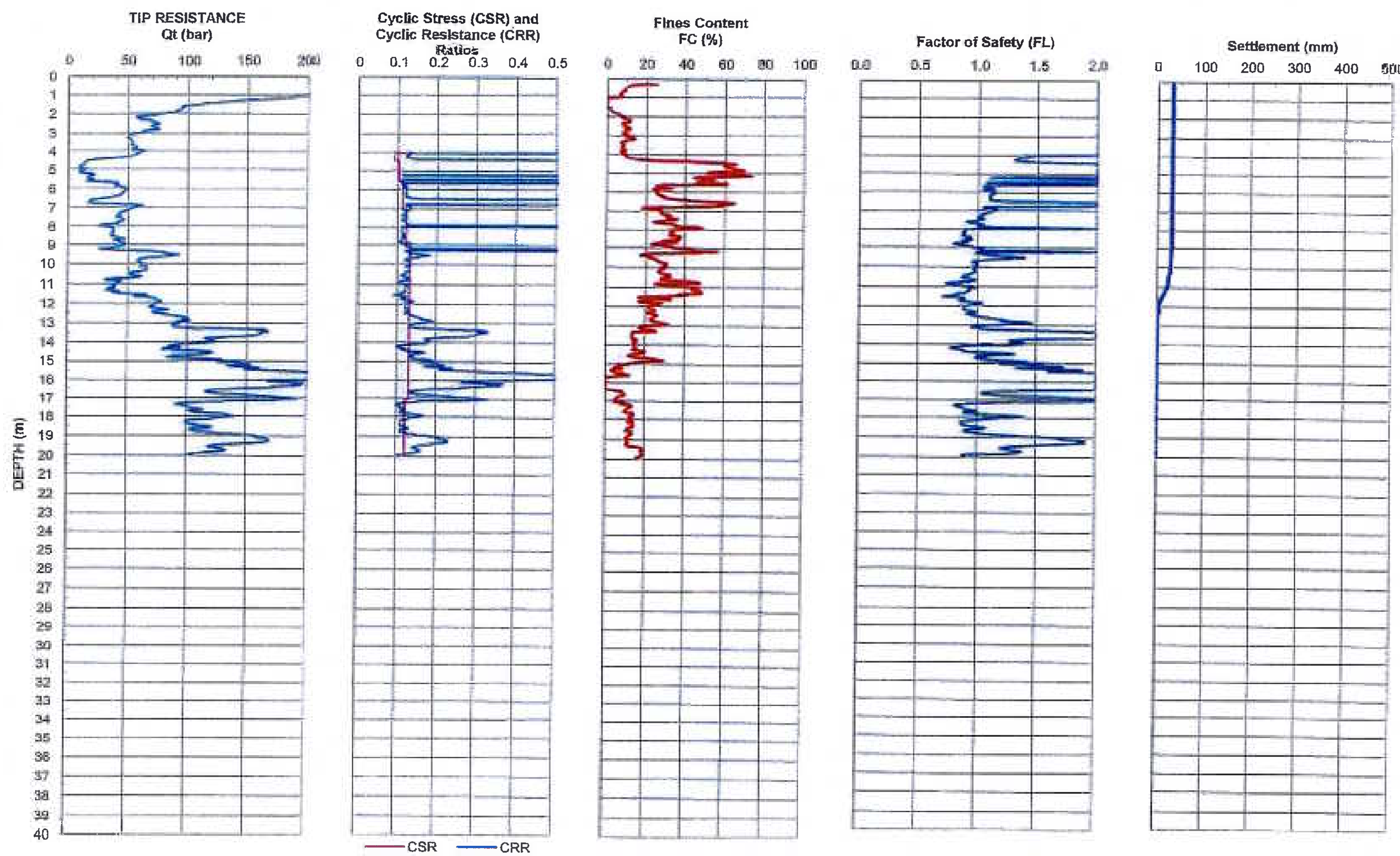


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

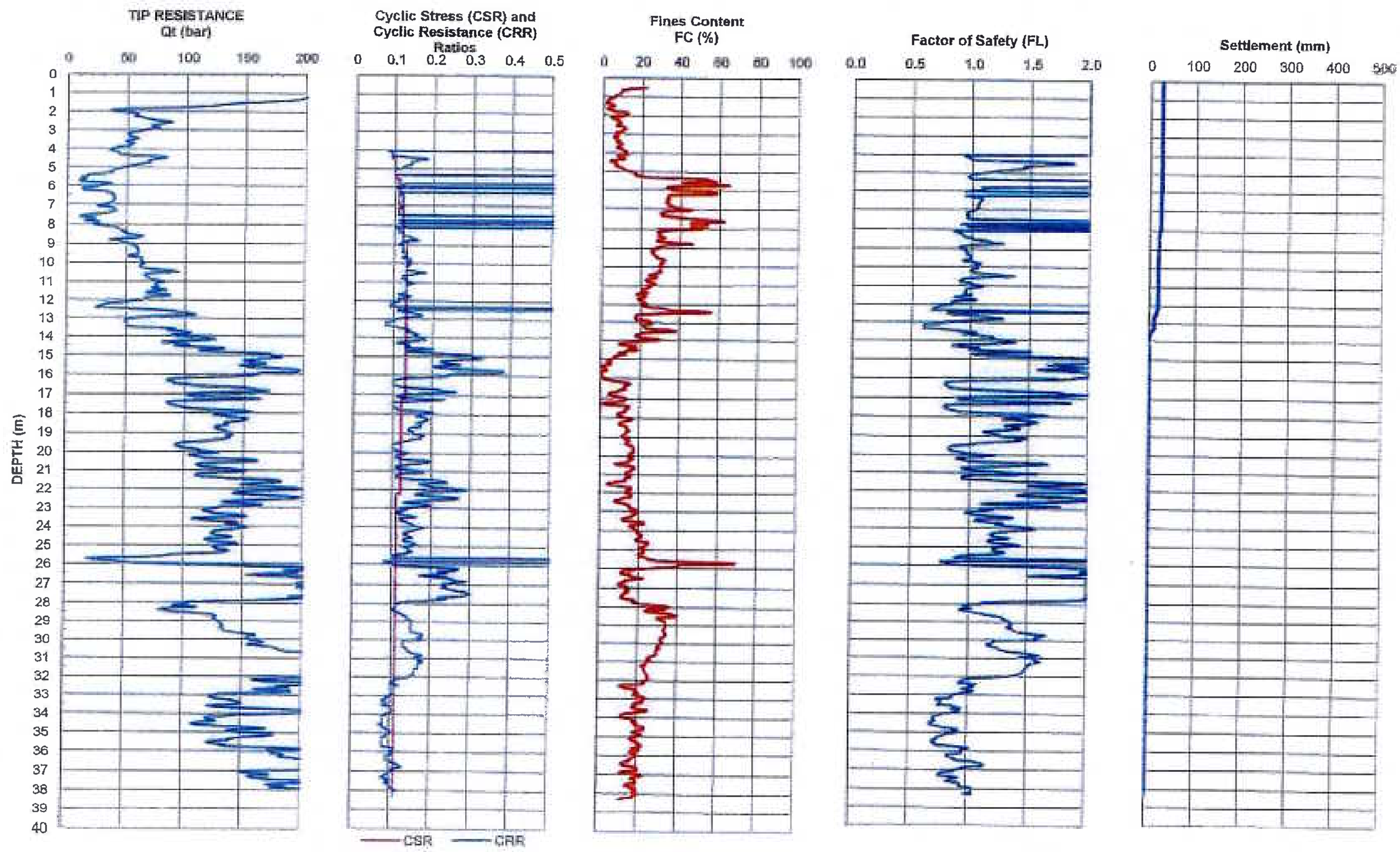


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

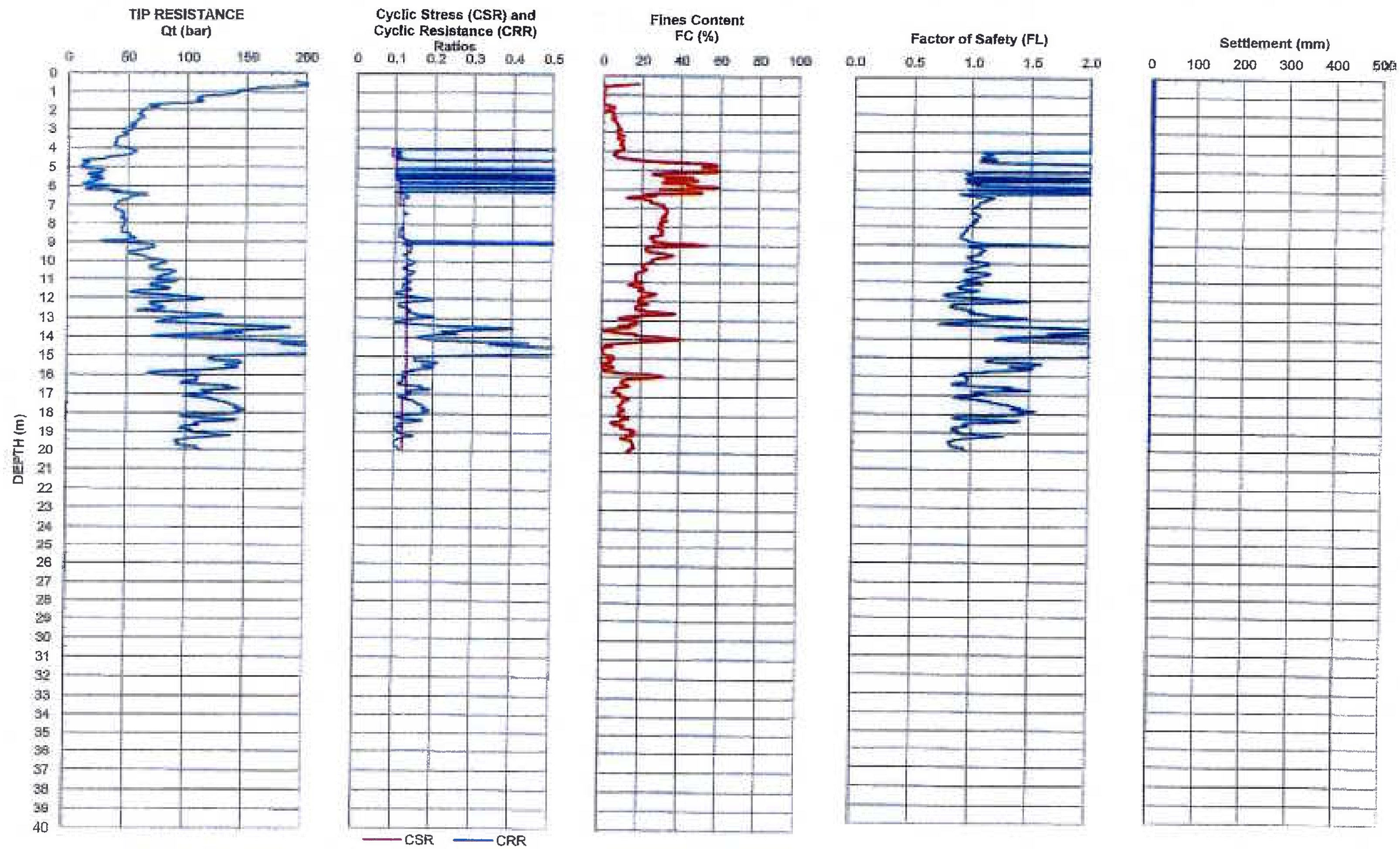


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

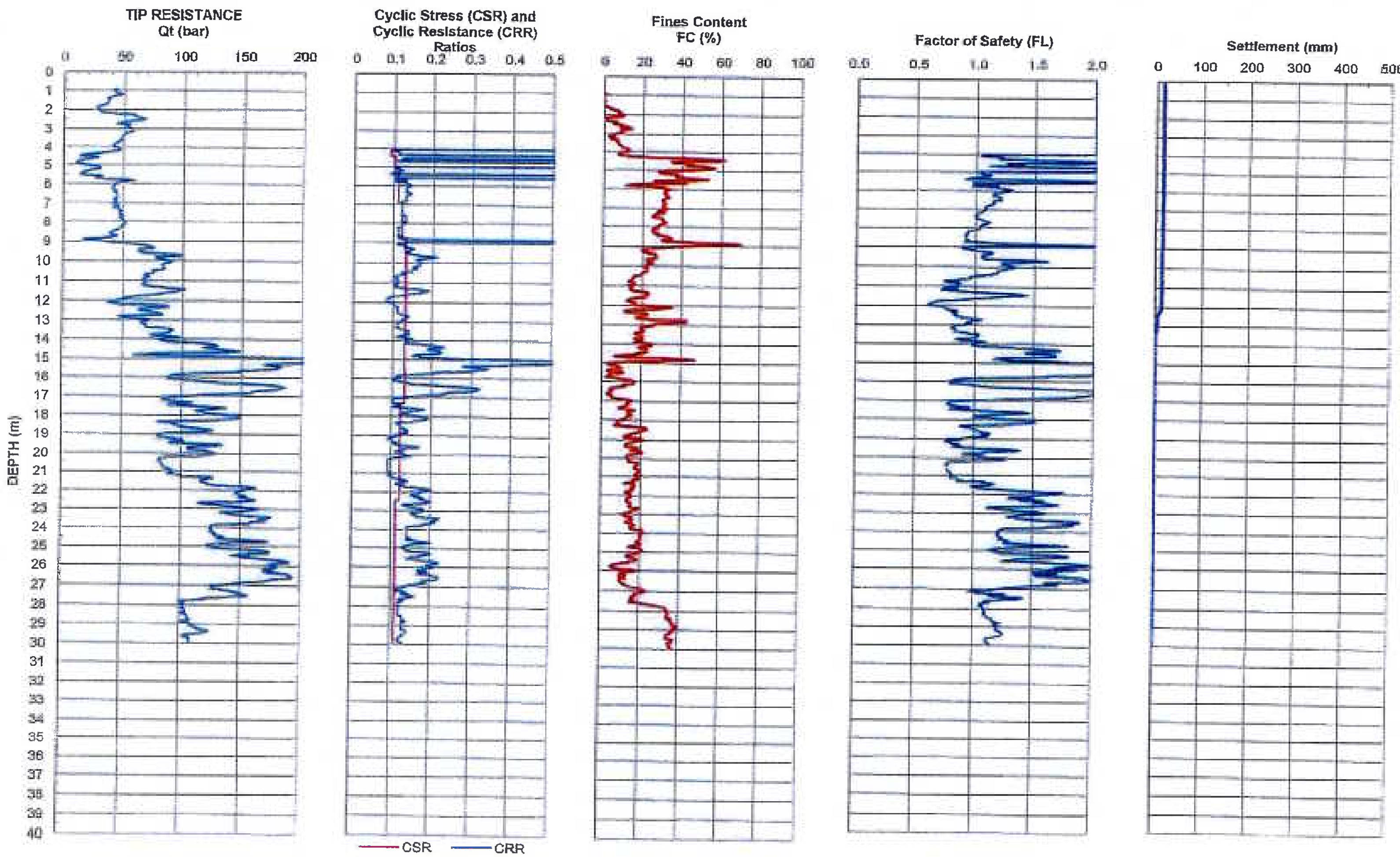
settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08



Liquefaction interpretation: PGA = 0.17
magnitude = 7.0
settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

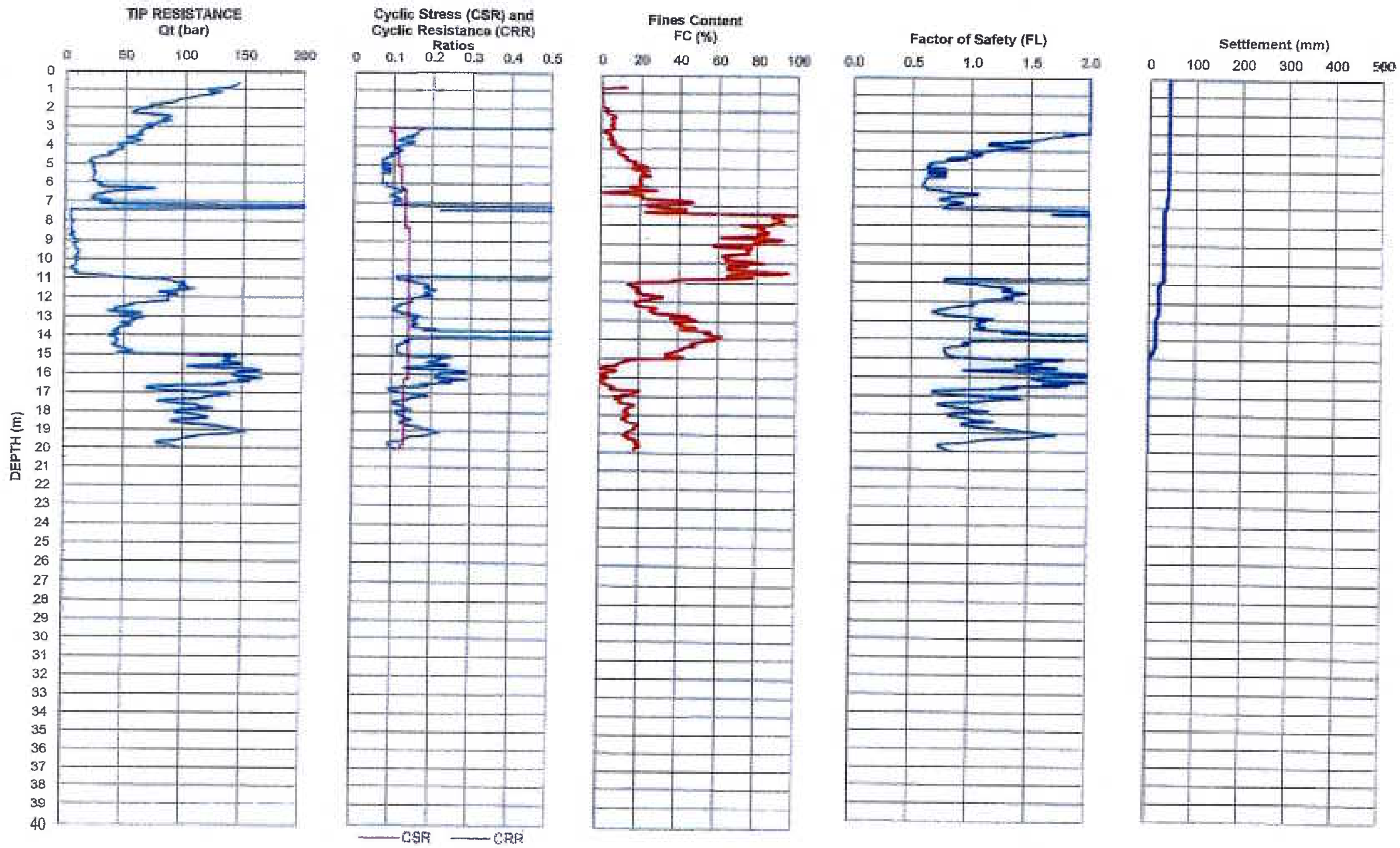


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-10	FRASER SURREY DOCKS, SURREY, BC	Figure: D.10

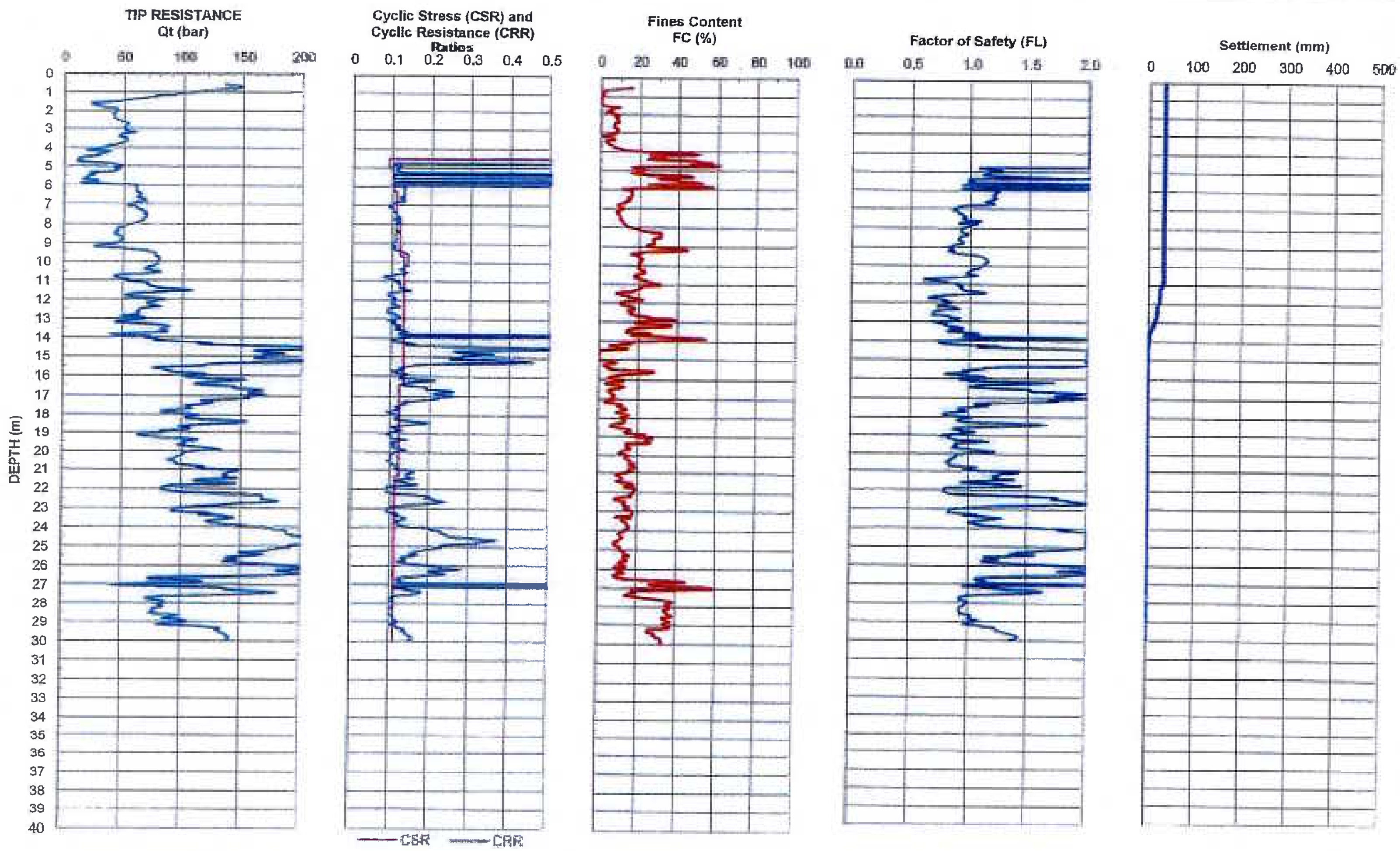


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-11	FRASER SURREY DOCKS, SURREY, BC	Figure: D.11

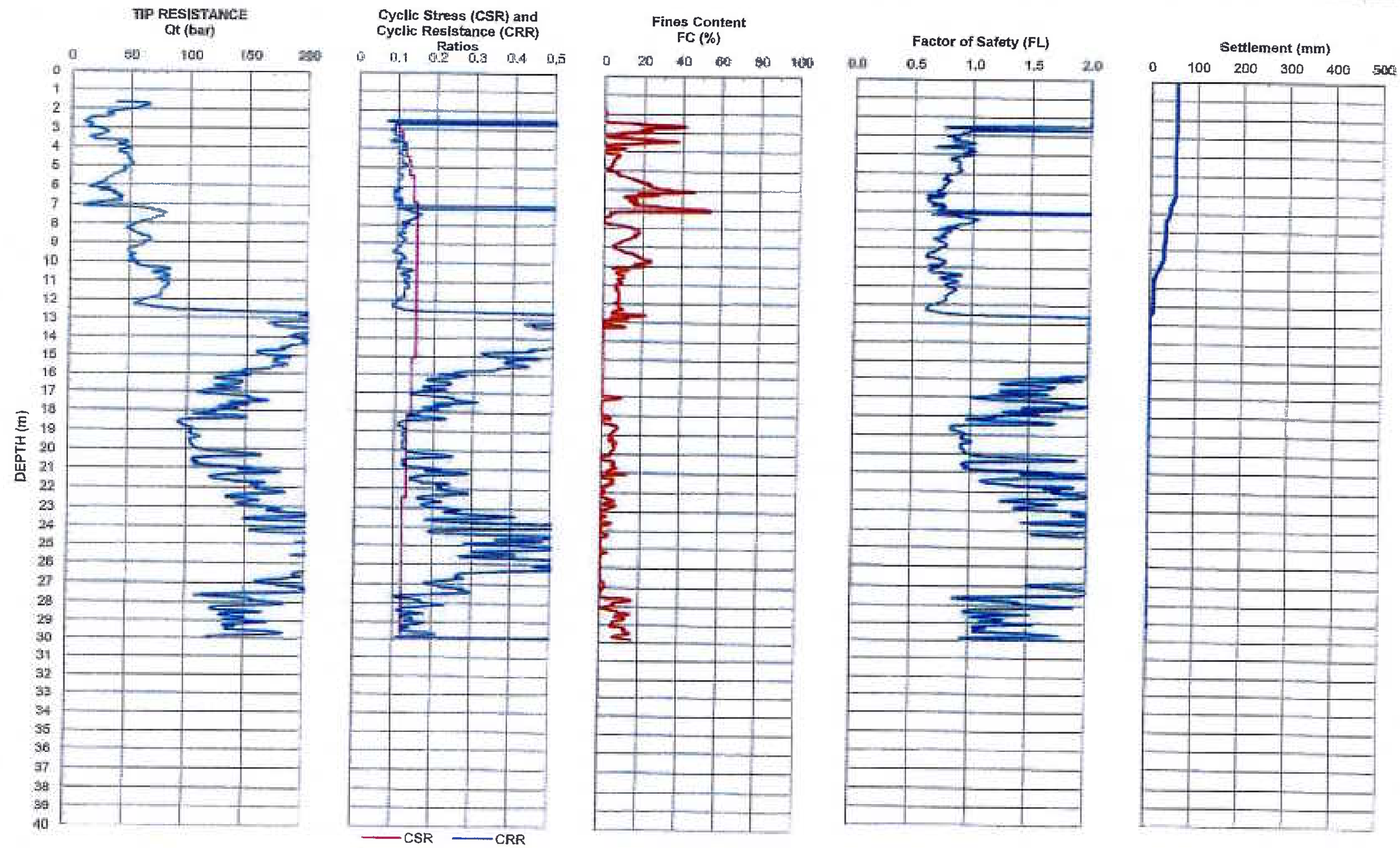


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2010-Sep-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT10-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

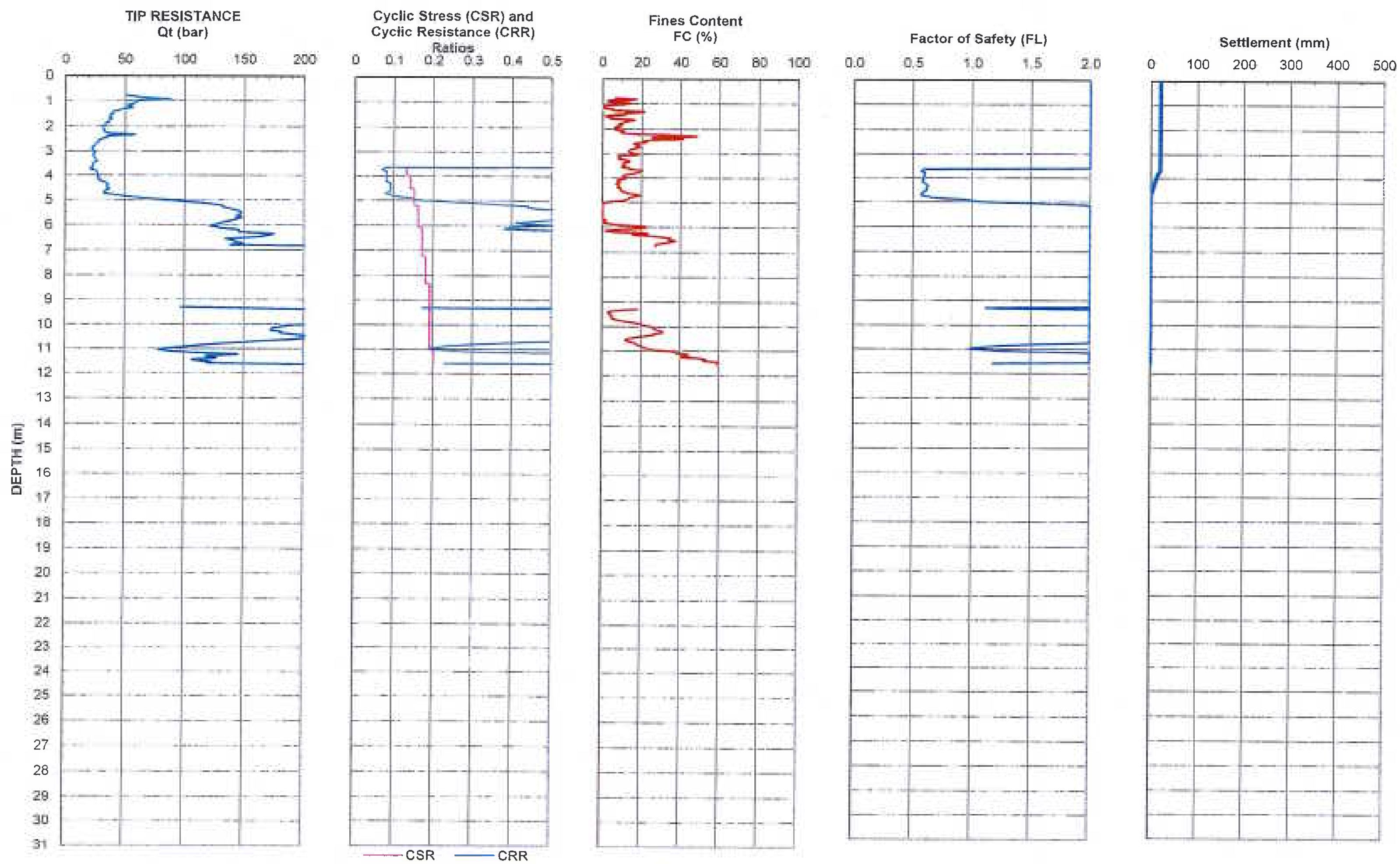


Liquefaction interpretation: PGA = 0.17

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-01	FRASER SURREY DOCKS, SURREY, BC	Figure: D.01

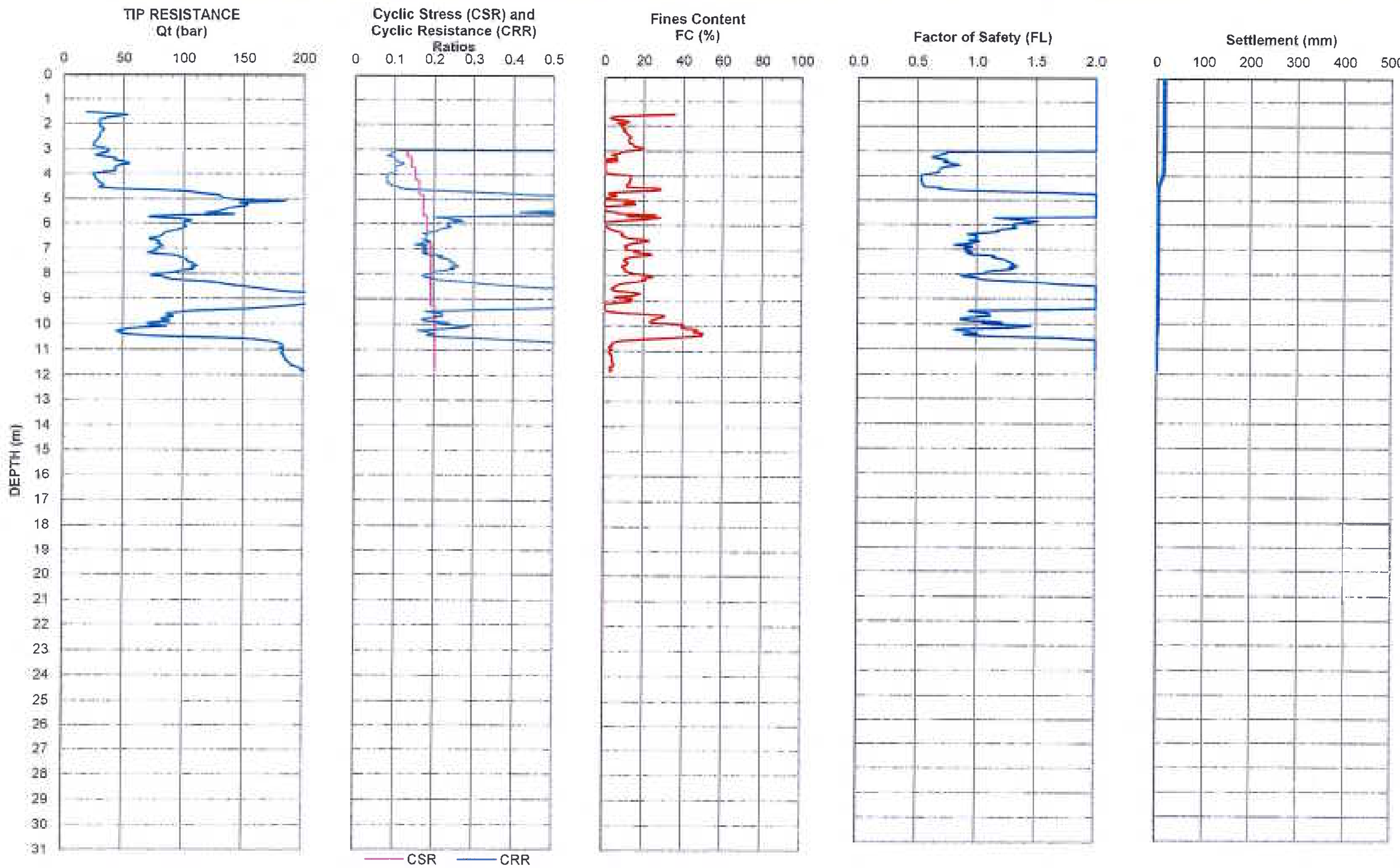


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

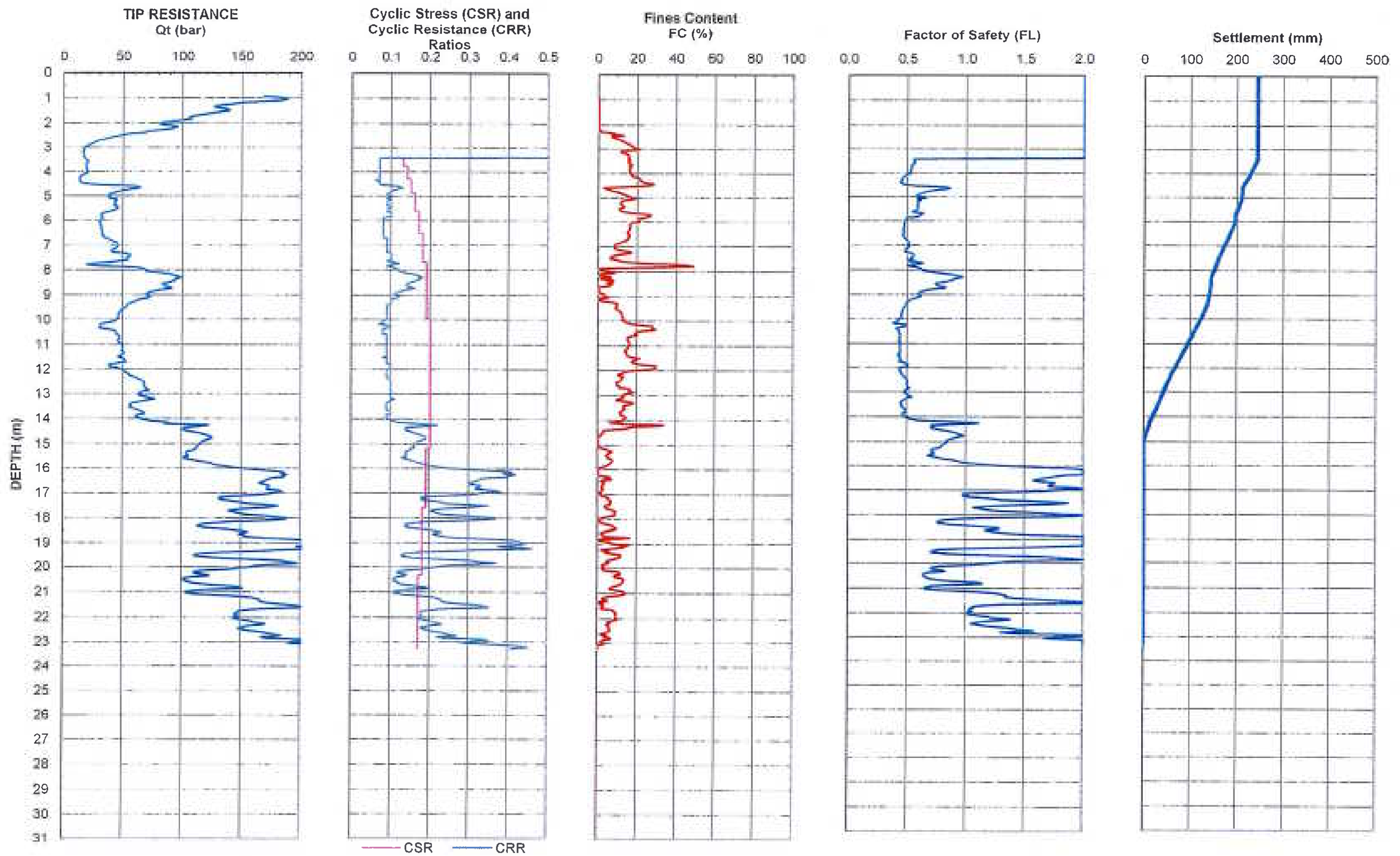


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-6	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-03	FRASER SURREY DOCKS, SURREY, BC	Figure: D.03

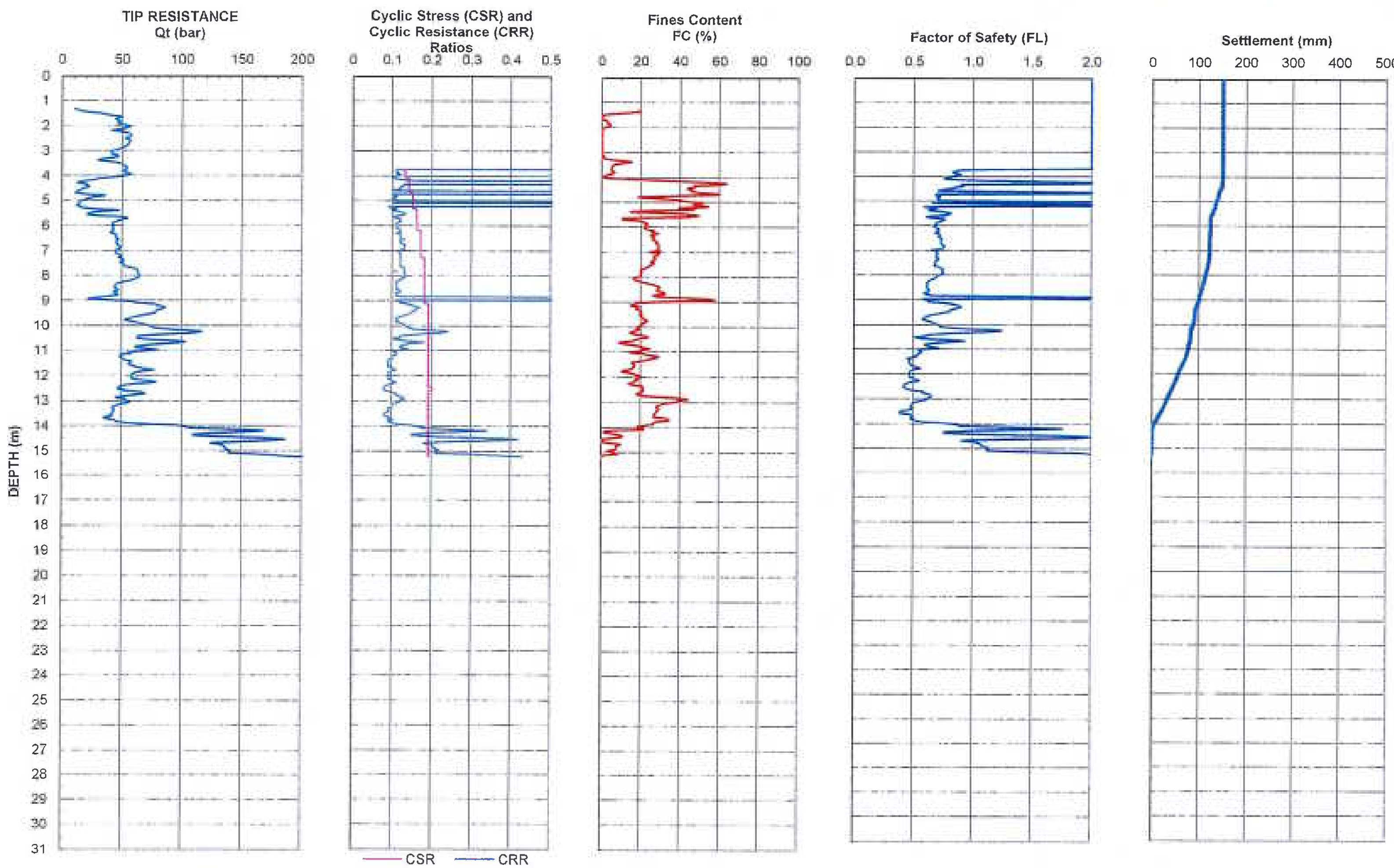


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

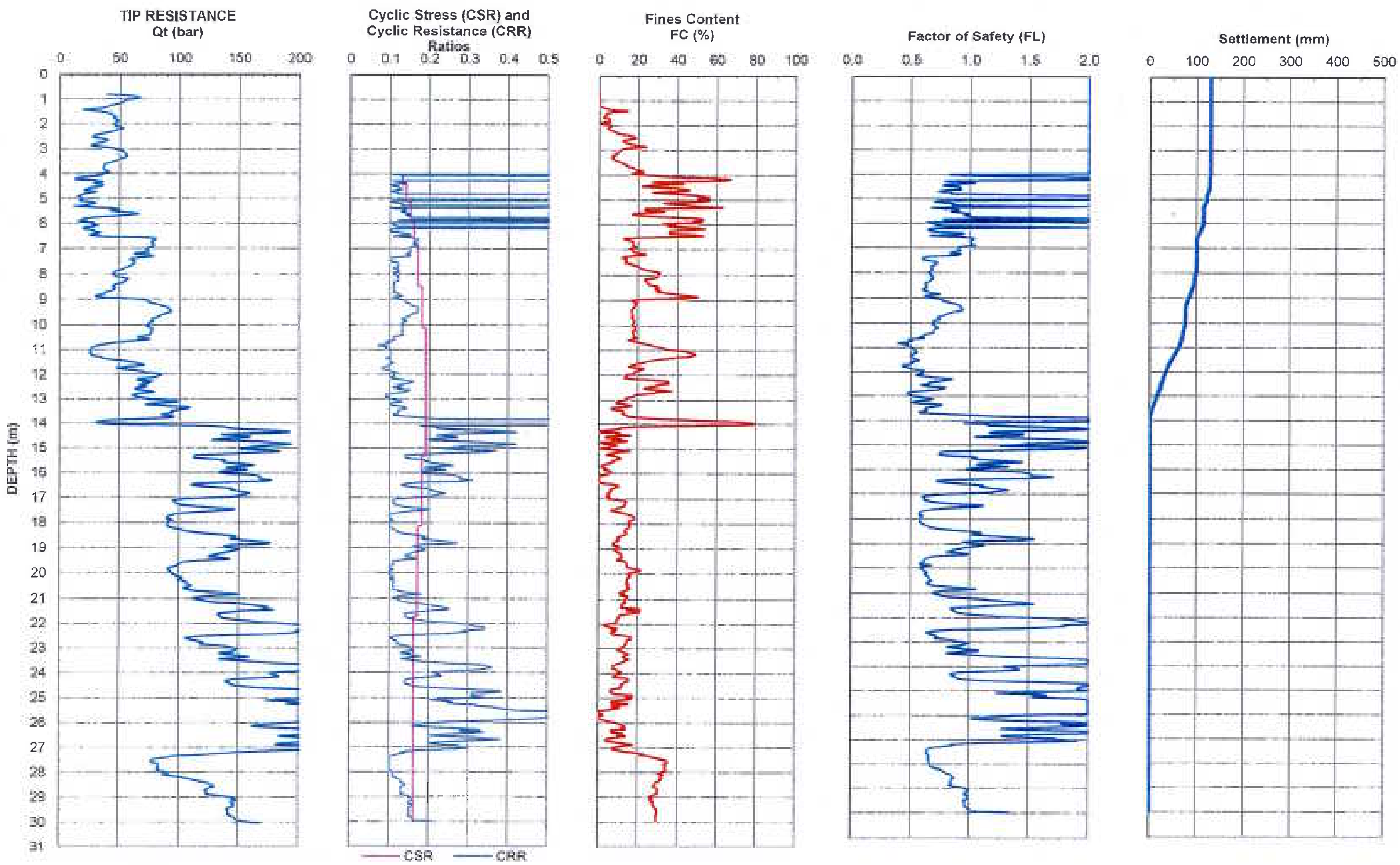


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

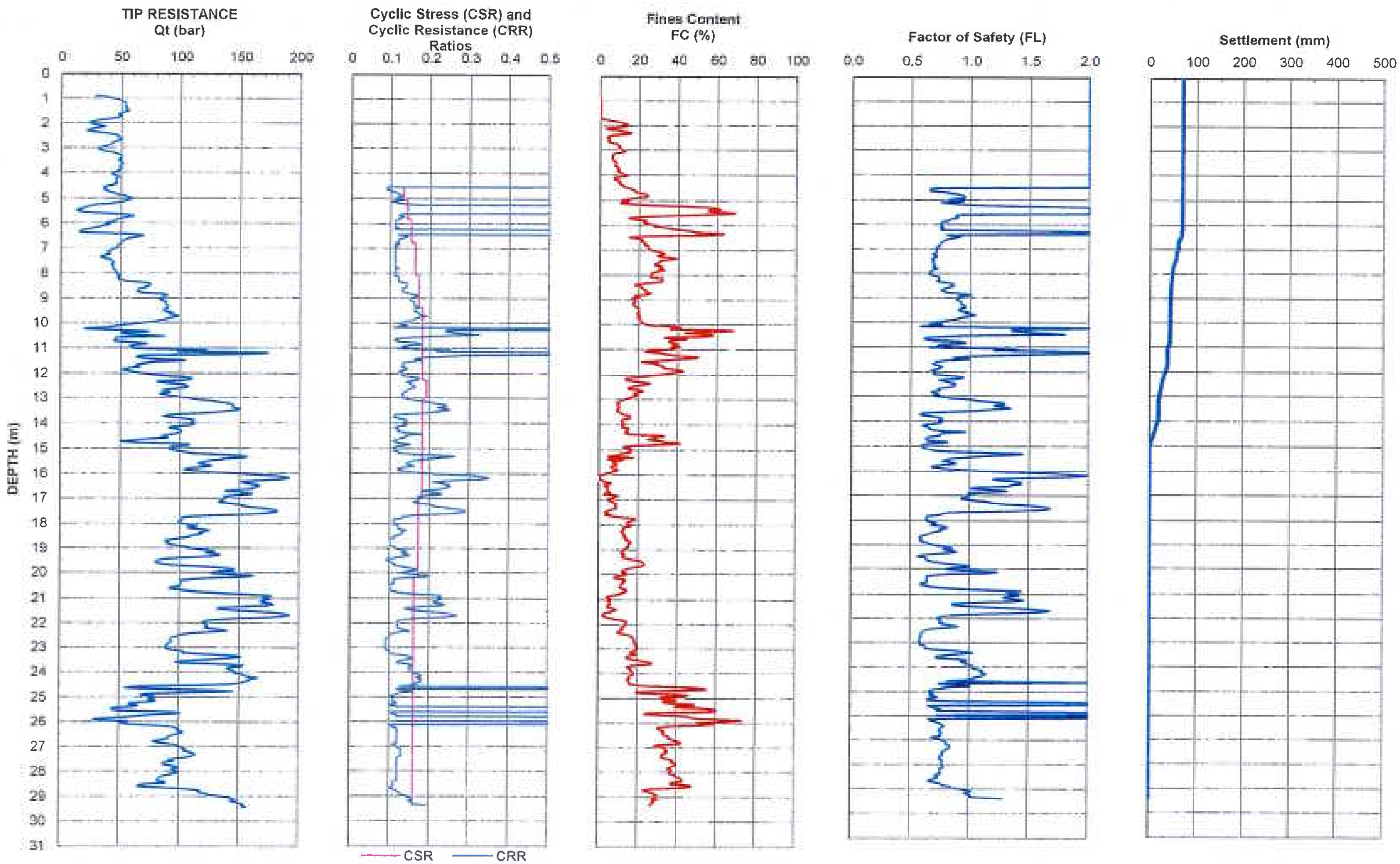
settlement accumulation max depth = 15m

GEOPACIFIC	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT18-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05



Liquefaction interpretation: PGA = 0.24
magnitude = 7.0
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-7	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-06	FRASER SURREY DOCKS, SURREY, BC	Figure: D.06

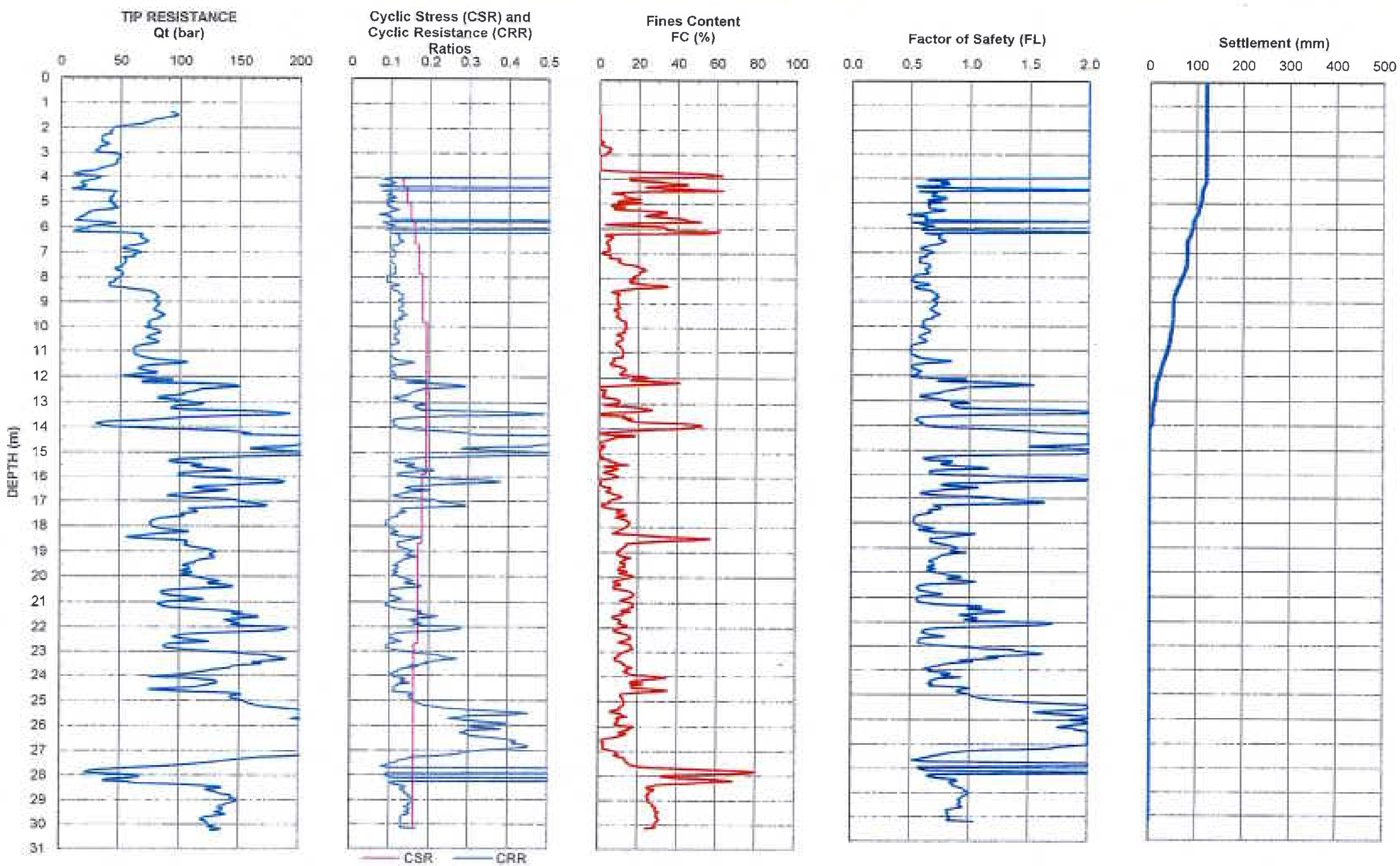


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

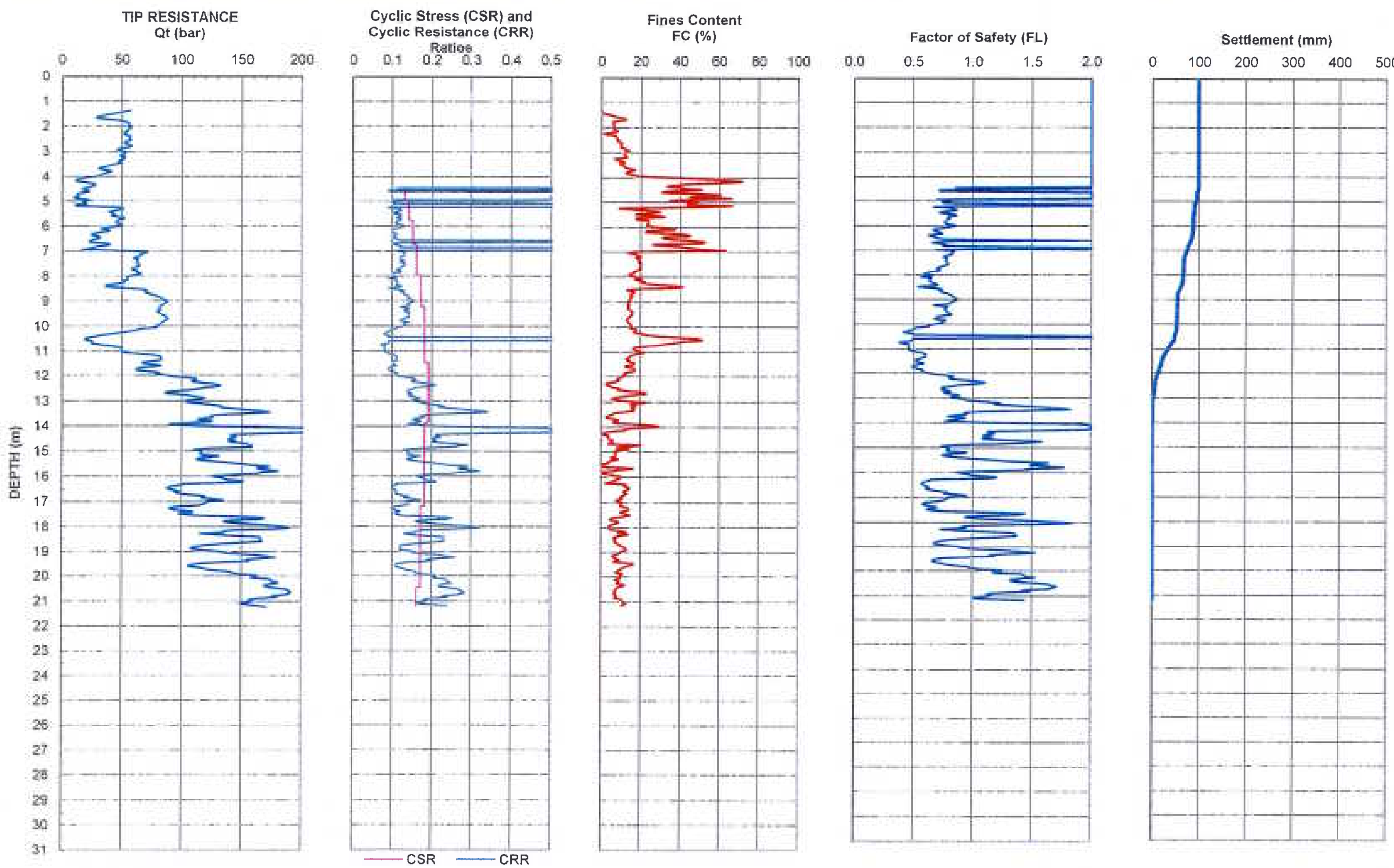
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07



Liquefaction interpretation: PGA = 0.24
magnitude = 7.0
settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08

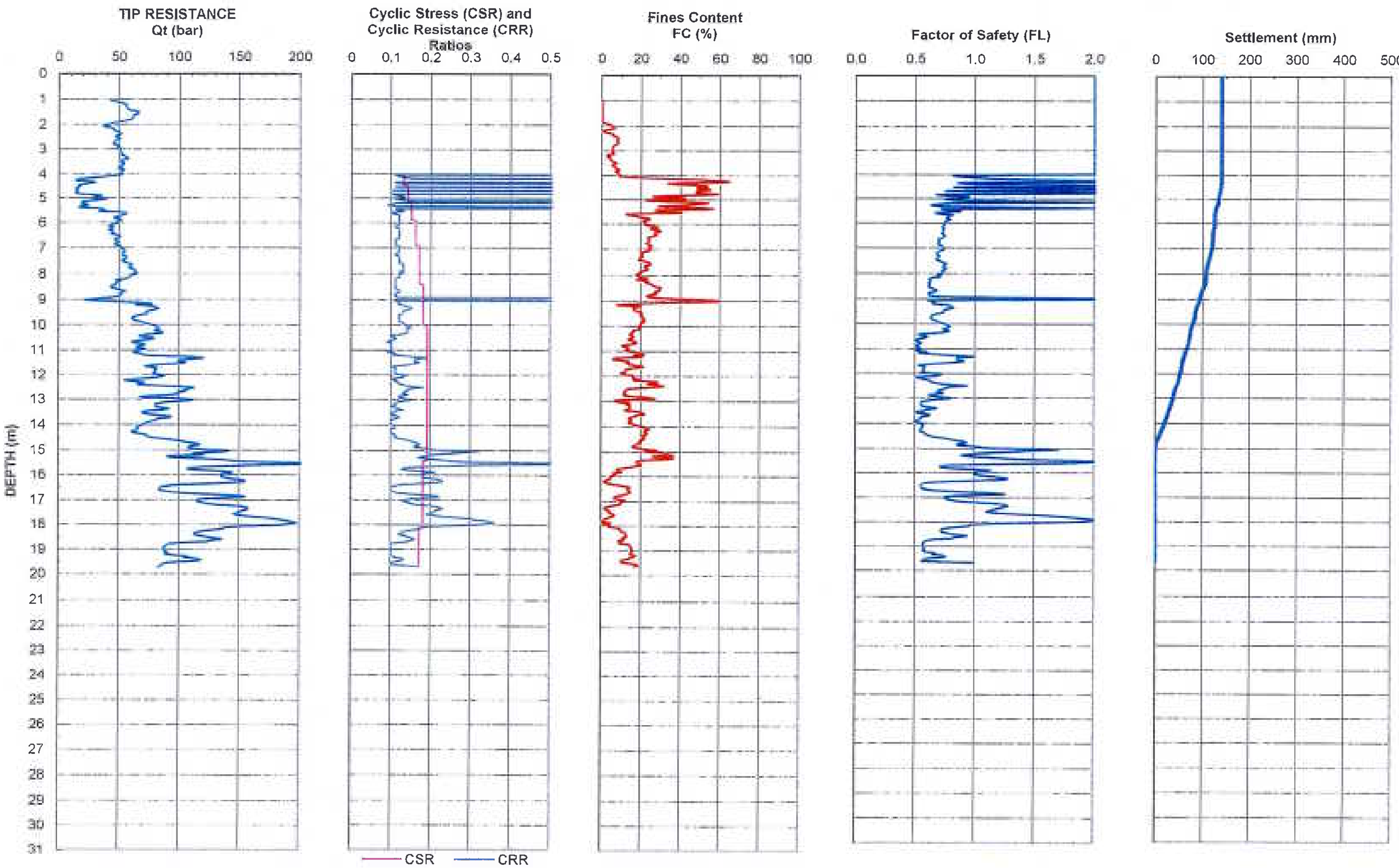


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2018-Mar-13	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT18-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

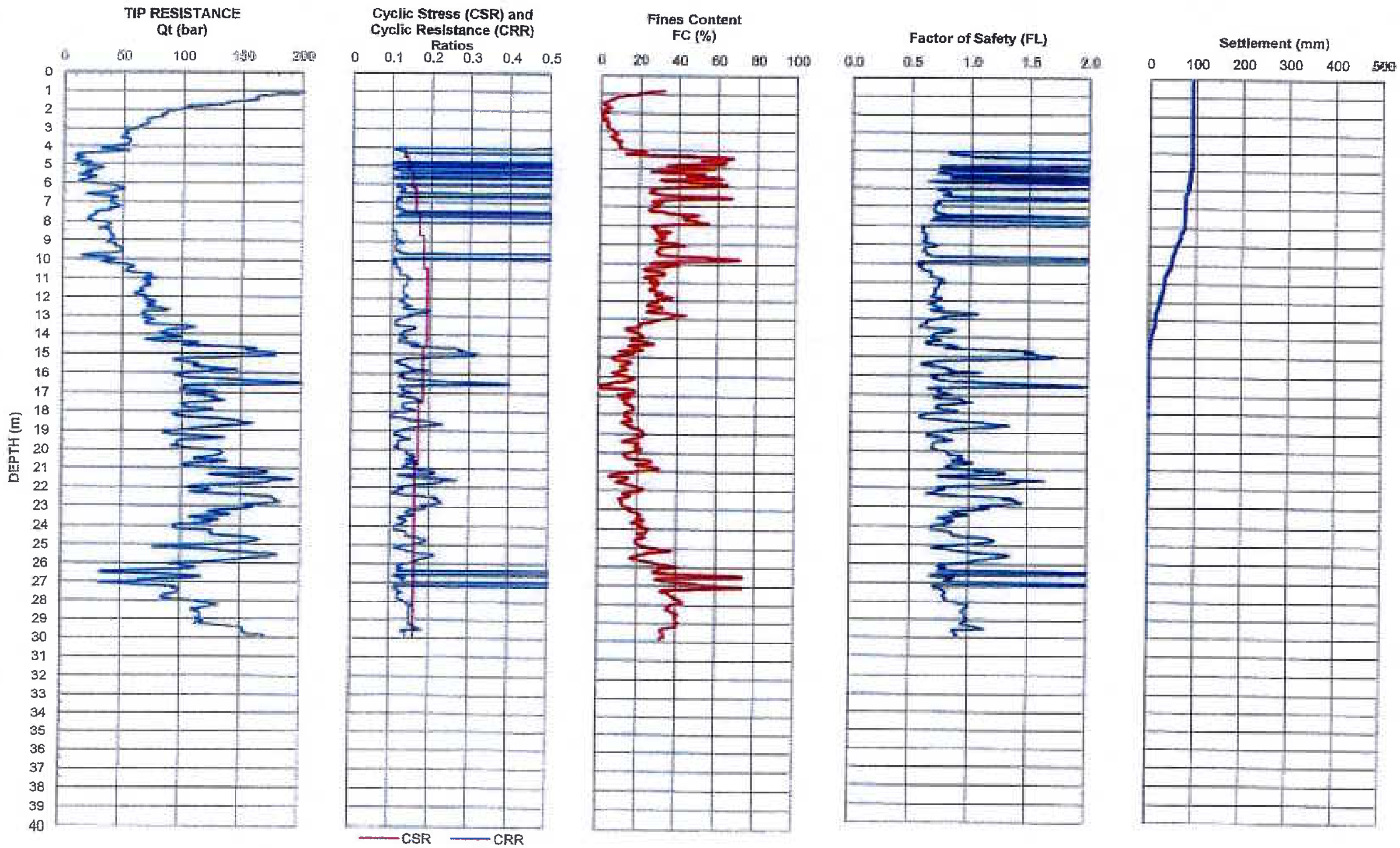


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-02	FRASER SURREY DOCKS, SURREY, BC	Figure: D.02

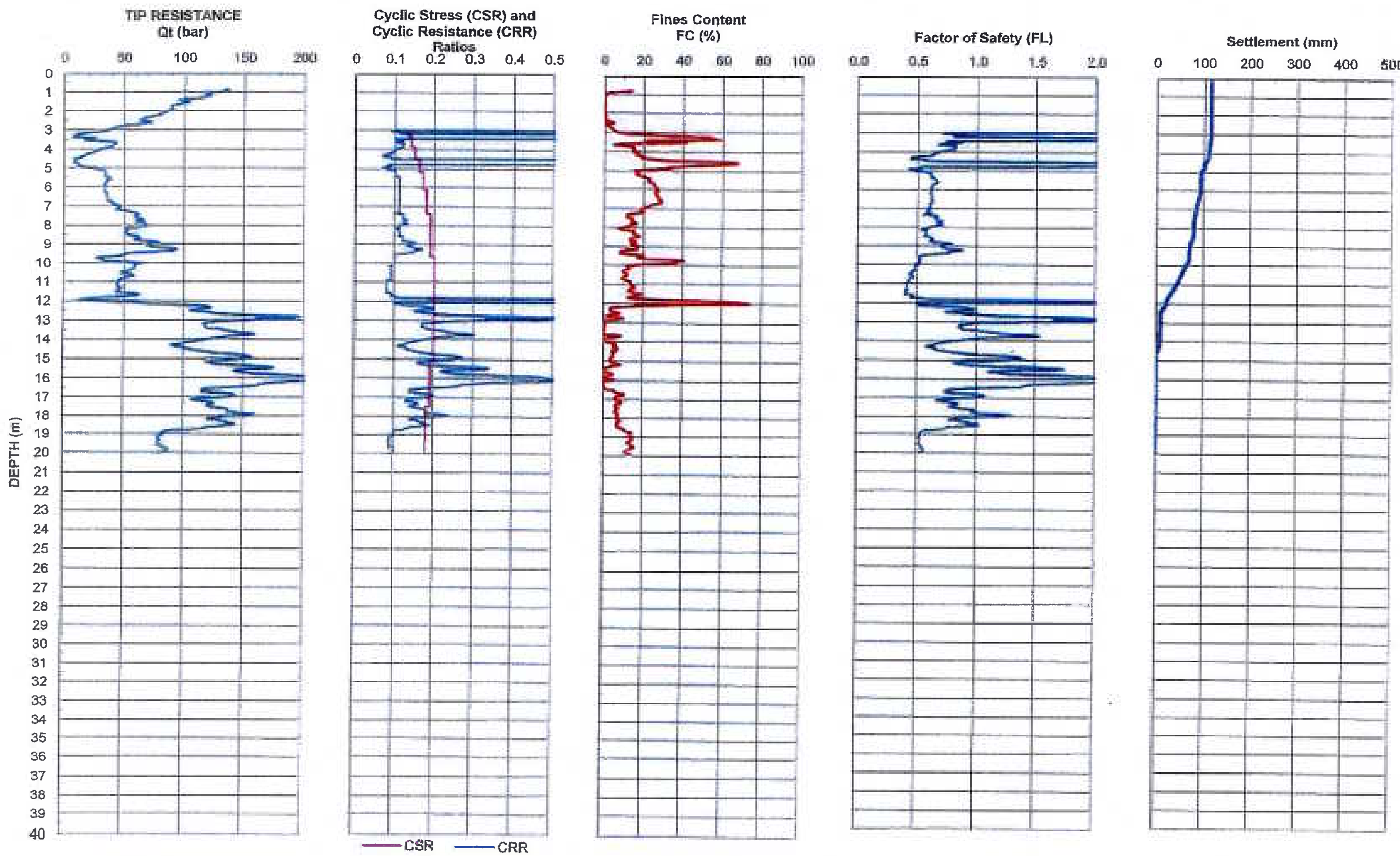


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC VANCOUVER KAMLOOPS CALGARY	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-04	FRASER SURREY DOCKS, SURREY, BC	Figure: D.04

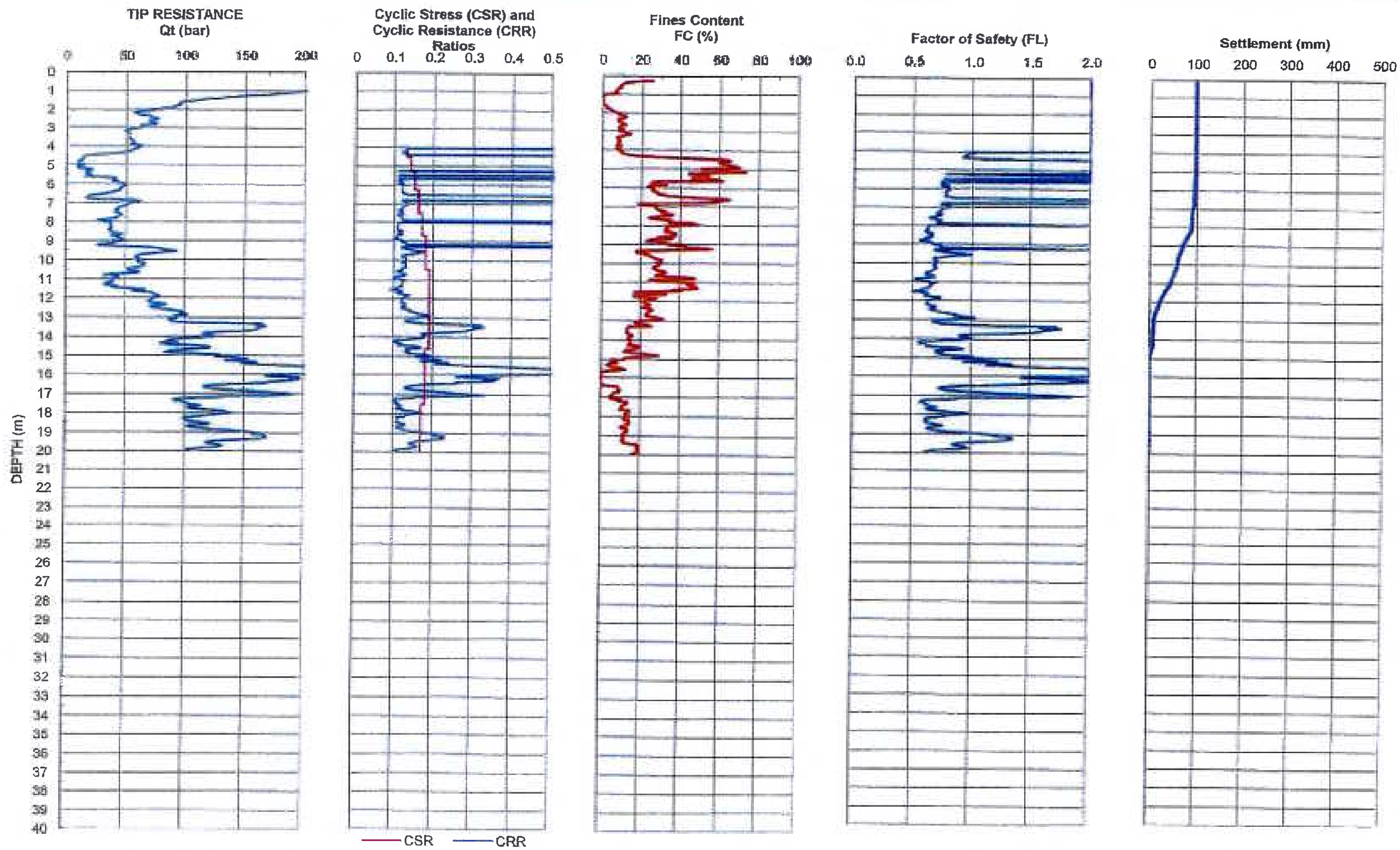


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-05	FRASER SURREY DOCKS, SURREY, BC	Figure: D.05

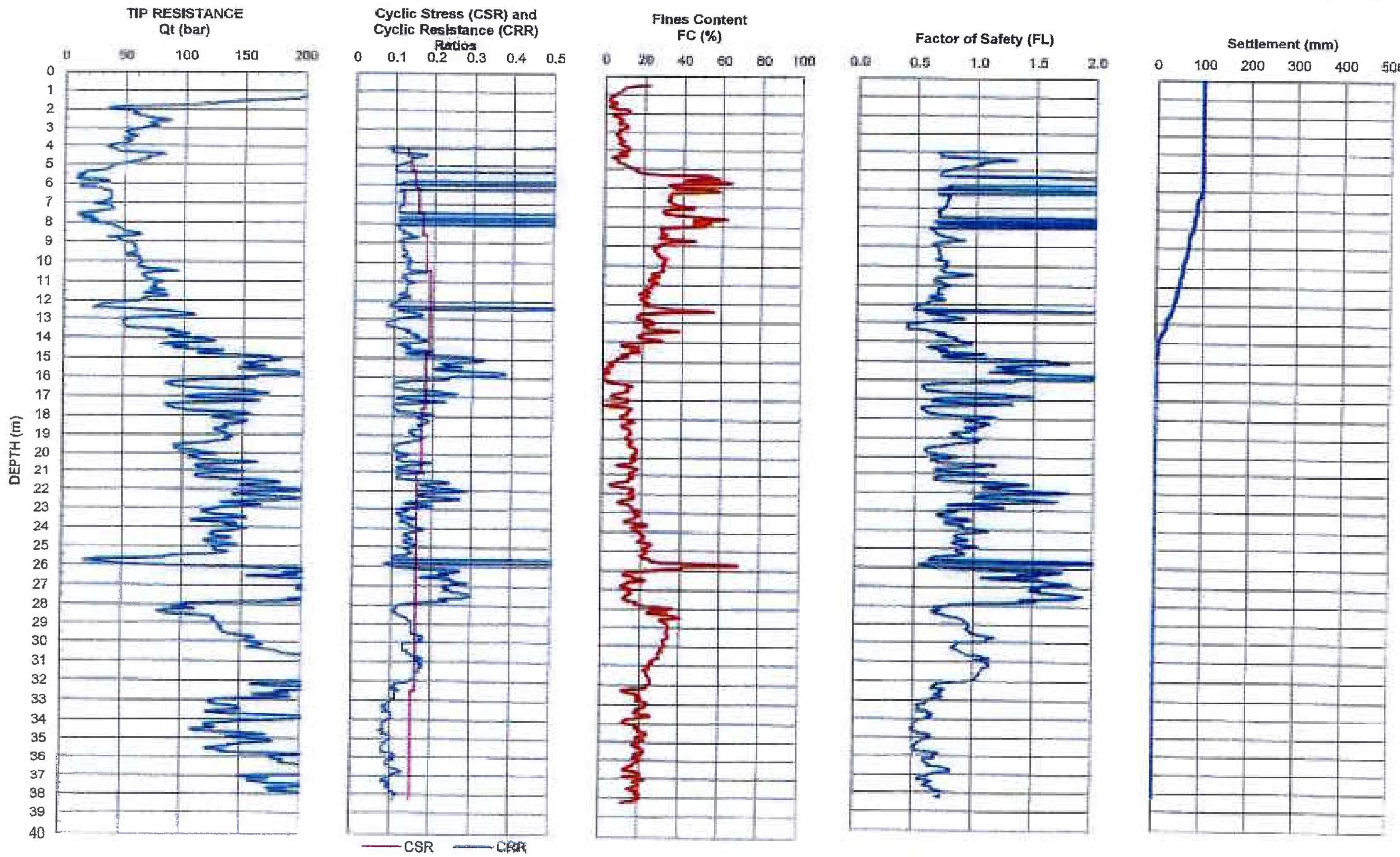


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-07	FRASER SURREY DOCKS, SURREY, BC	Figure: D.07

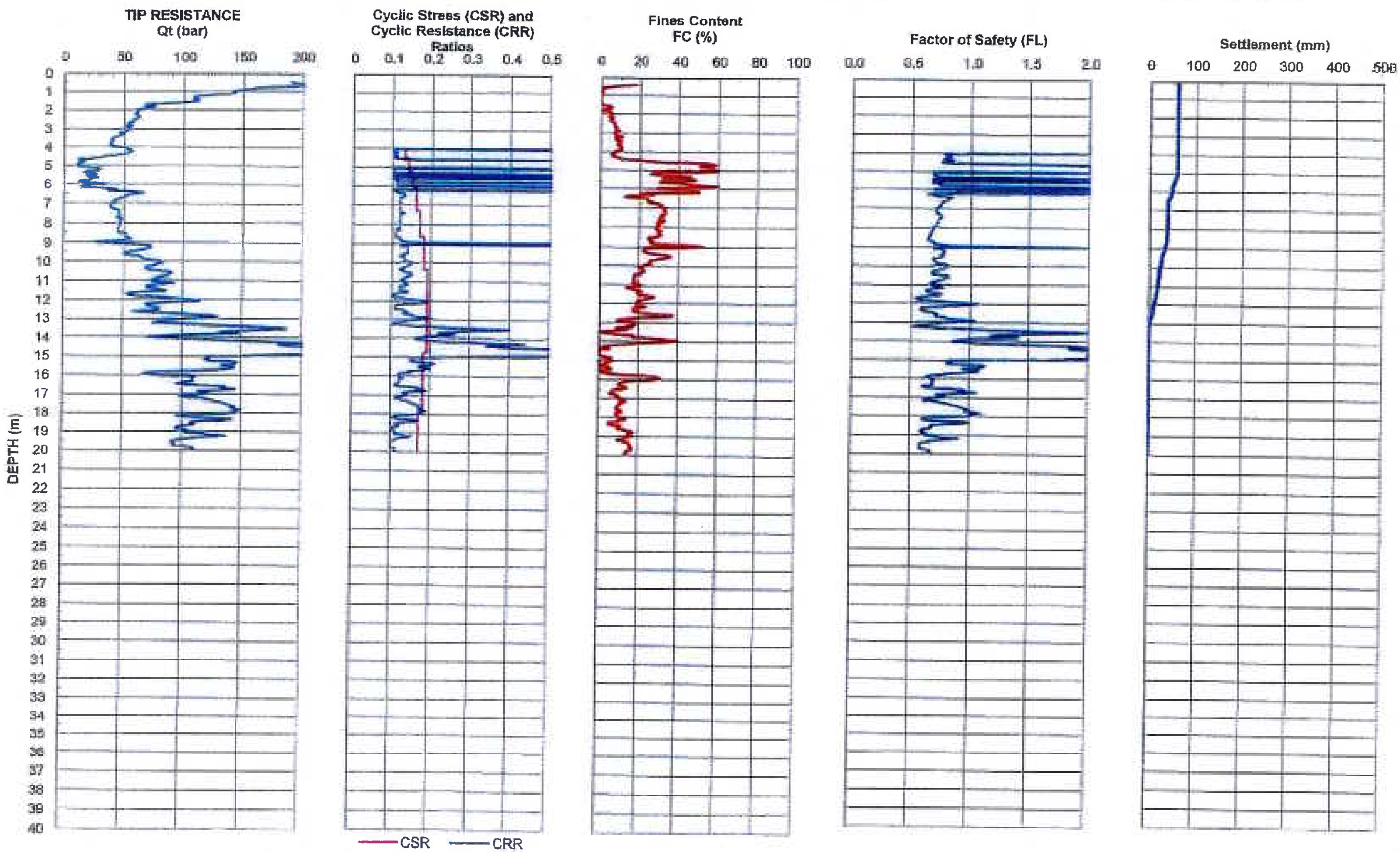


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-08	FRASER SURREY DOCKS, SURREY, BC	Figure: D.08

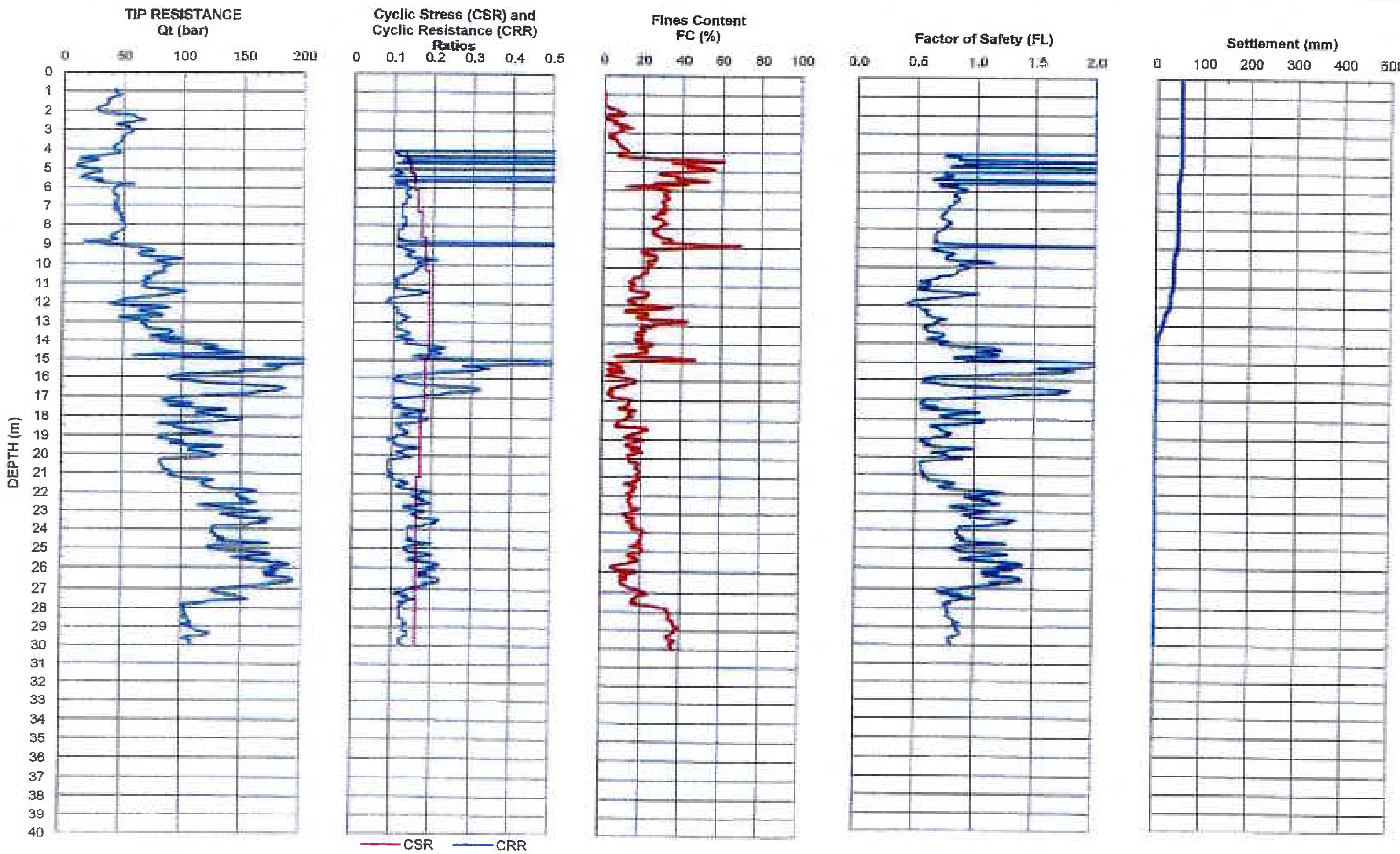


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

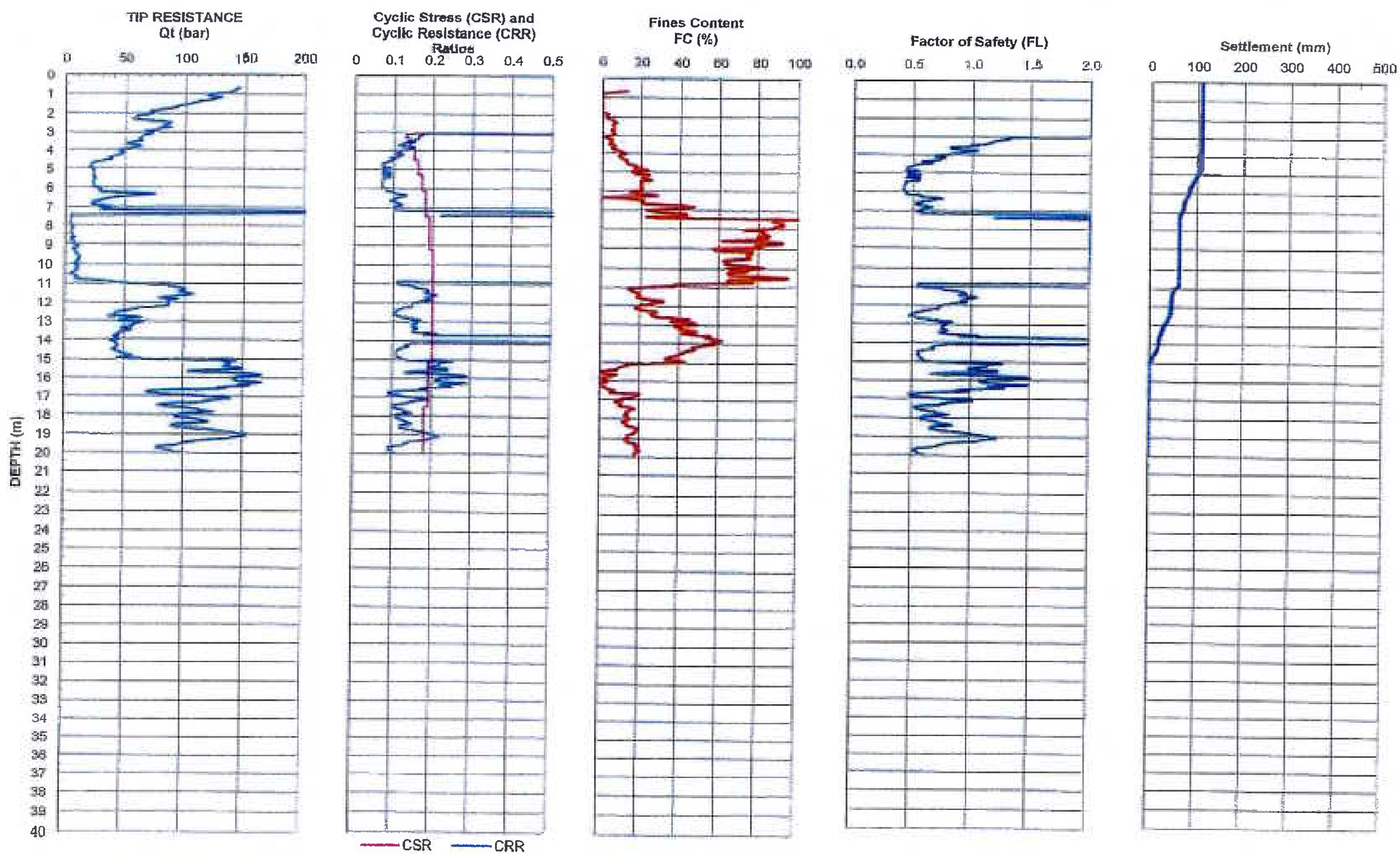


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-9	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-10	FRASER SURREY DOCKS, SURREY, BC	Figure: D.10

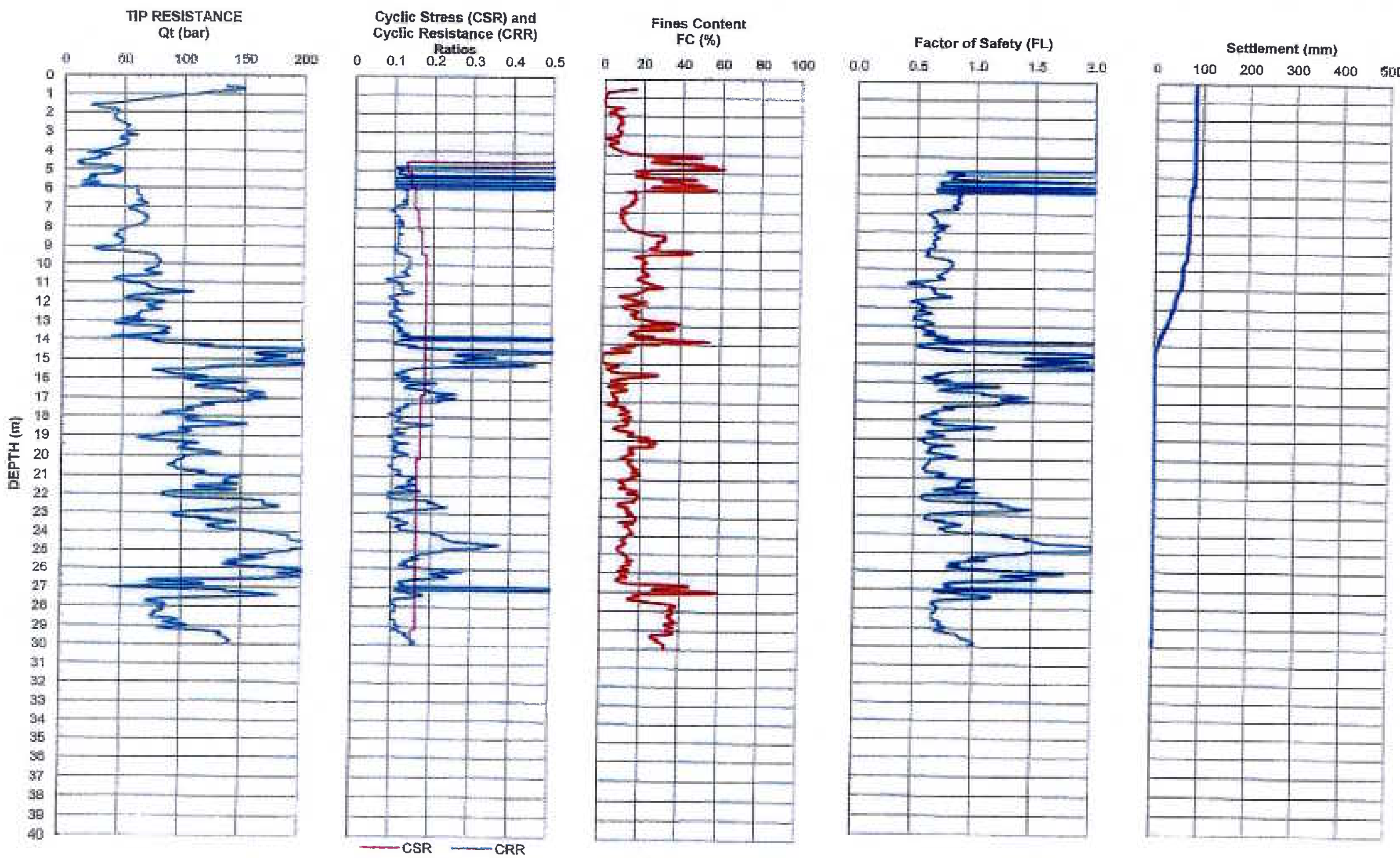


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2014-Dec-11	FWS GROUP	GeoPacific Project #: 15657
	Sounding: CPT14-11	FRASER SURREY DOCKS, SURREY, BC	Figure: D.11

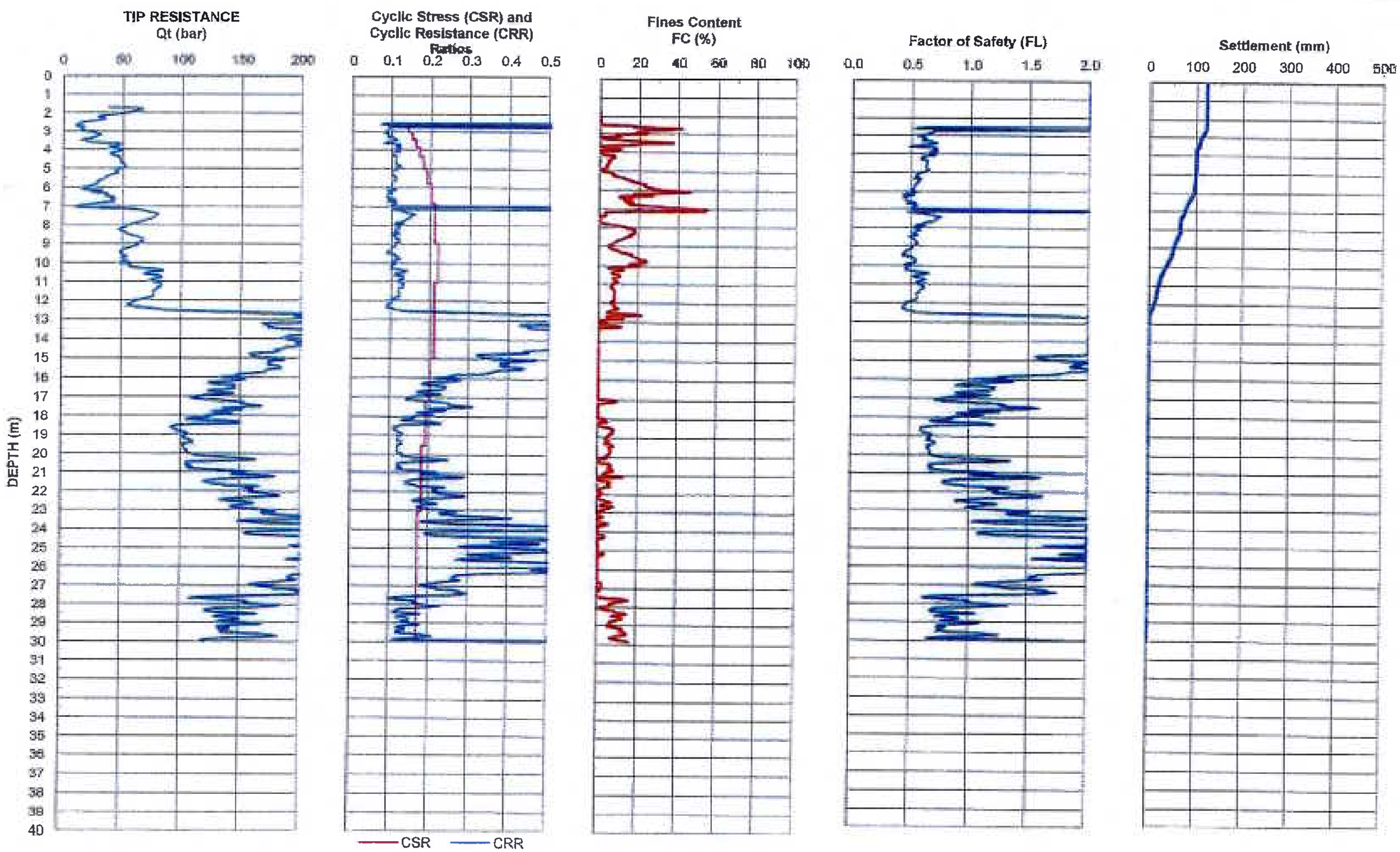


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

GEOPACIFIC	2010-Sep-10	FWS GROUP	GeoPacific Project #: 15657
	Sounding: SCPT10-09	FRASER SURREY DOCKS, SURREY, BC	Figure: D.09

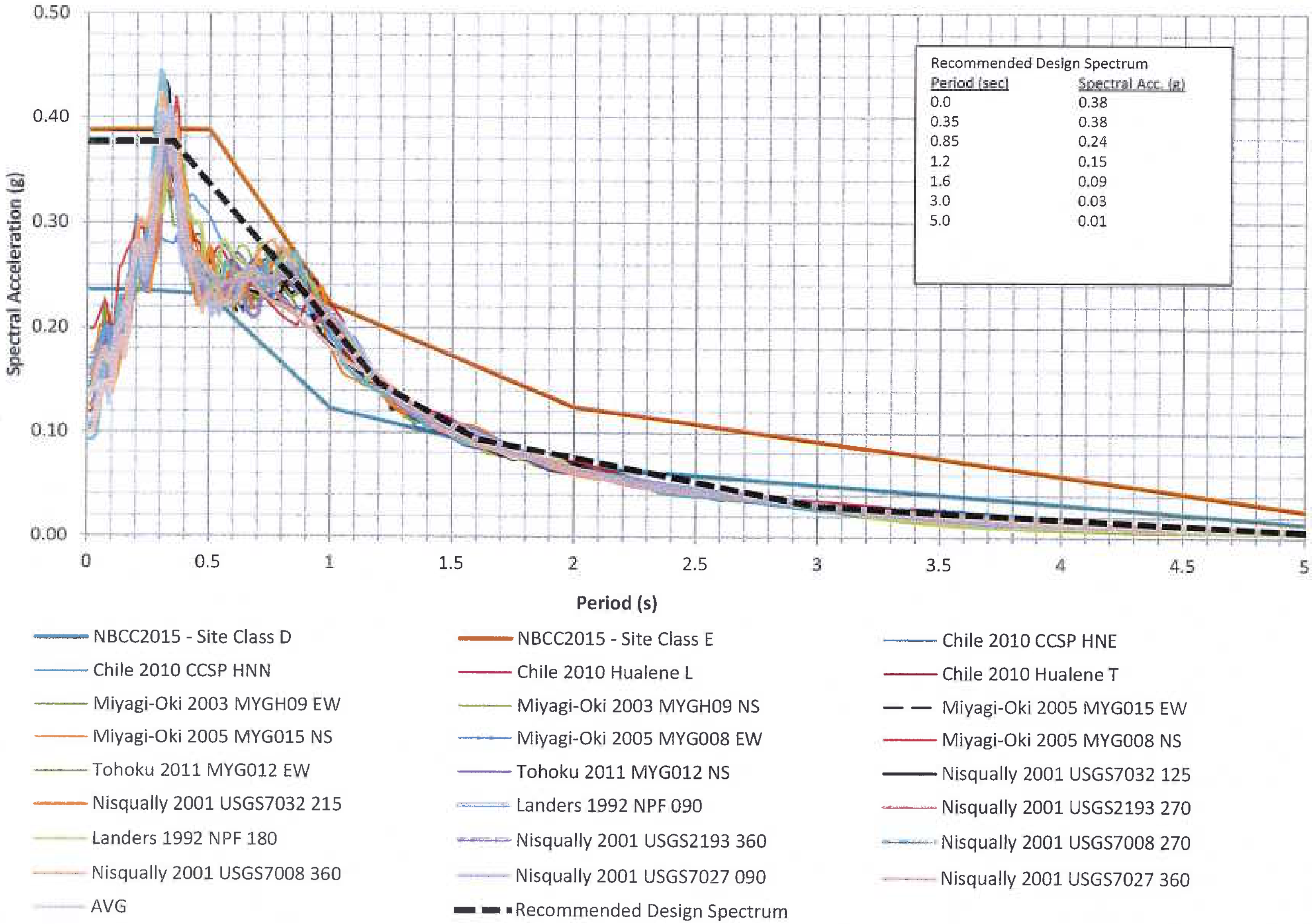


Liquefaction interpretation: PGA = 0.24

magnitude = 7.0

settlement accumulation max depth = 15m

Figure 4: Site Specific Spectral Acceleration at Surface (with densification)
(1:100 return period, structural damping = 5%)
Fraser Grain Terminal at Fraser Surrey Docks, Surrey, B.C.



Recommended Design Spectrum

Period (sec)	Spectral Acc. (g)
0.0	0.38
0.35	0.38
0.85	0.24
1.2	0.15
1.6	0.09
3.0	0.03
5.0	0.01

Figure 4: Site Specific Spectral Acceleration at Surface (with densification)
(1:200 return period, structural damping = 5%)
Fraser Grain Terminal at Fraser Surrey Docks, Surrey, B.C.

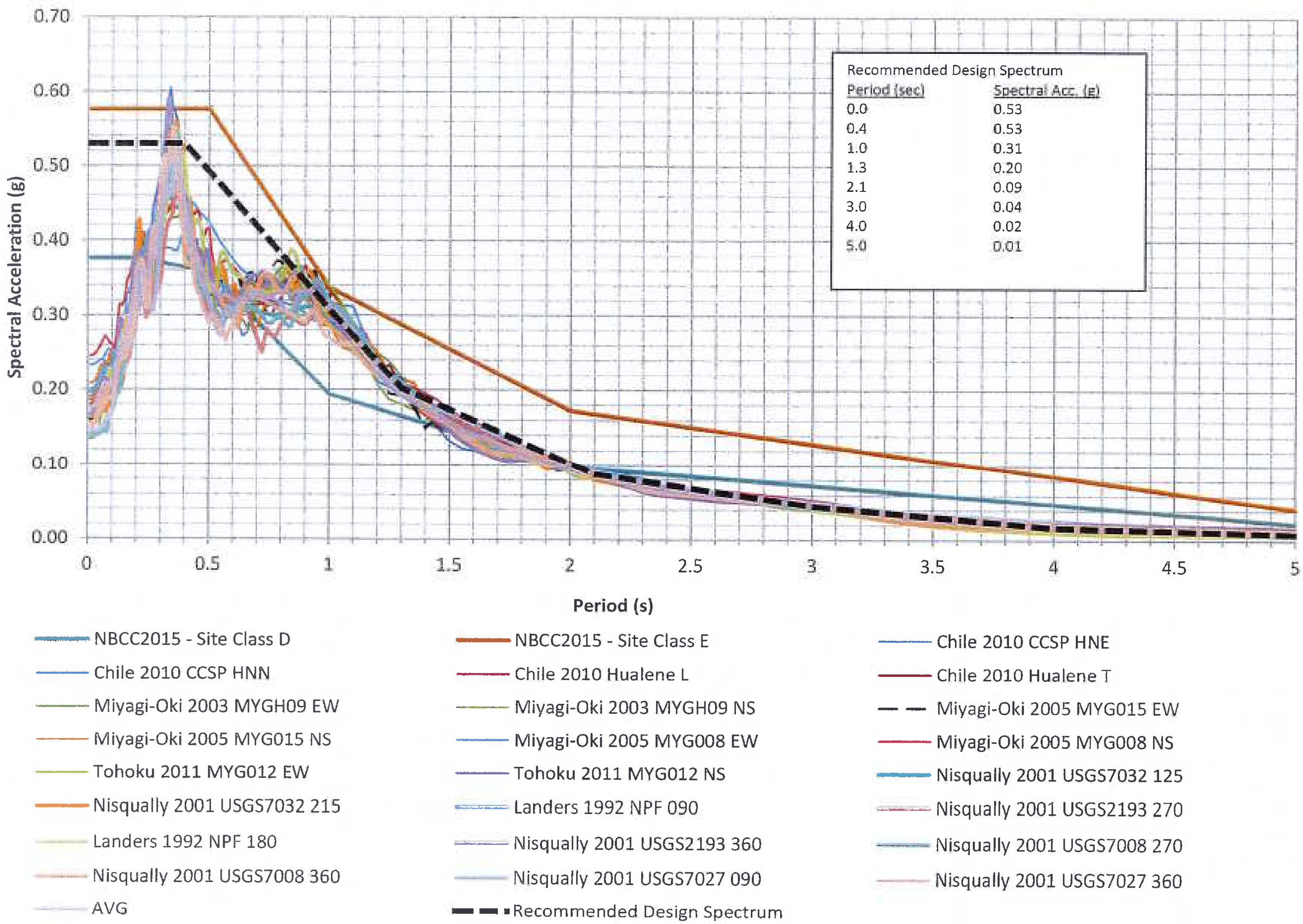


Figure 4: Site Specific Spectral Acceleration at Surface (with densification)
(1:475 return period, structural damping = 5%)
Fraser Grain Terminal at Fraser Surrey Docks, Surrey, B.C.

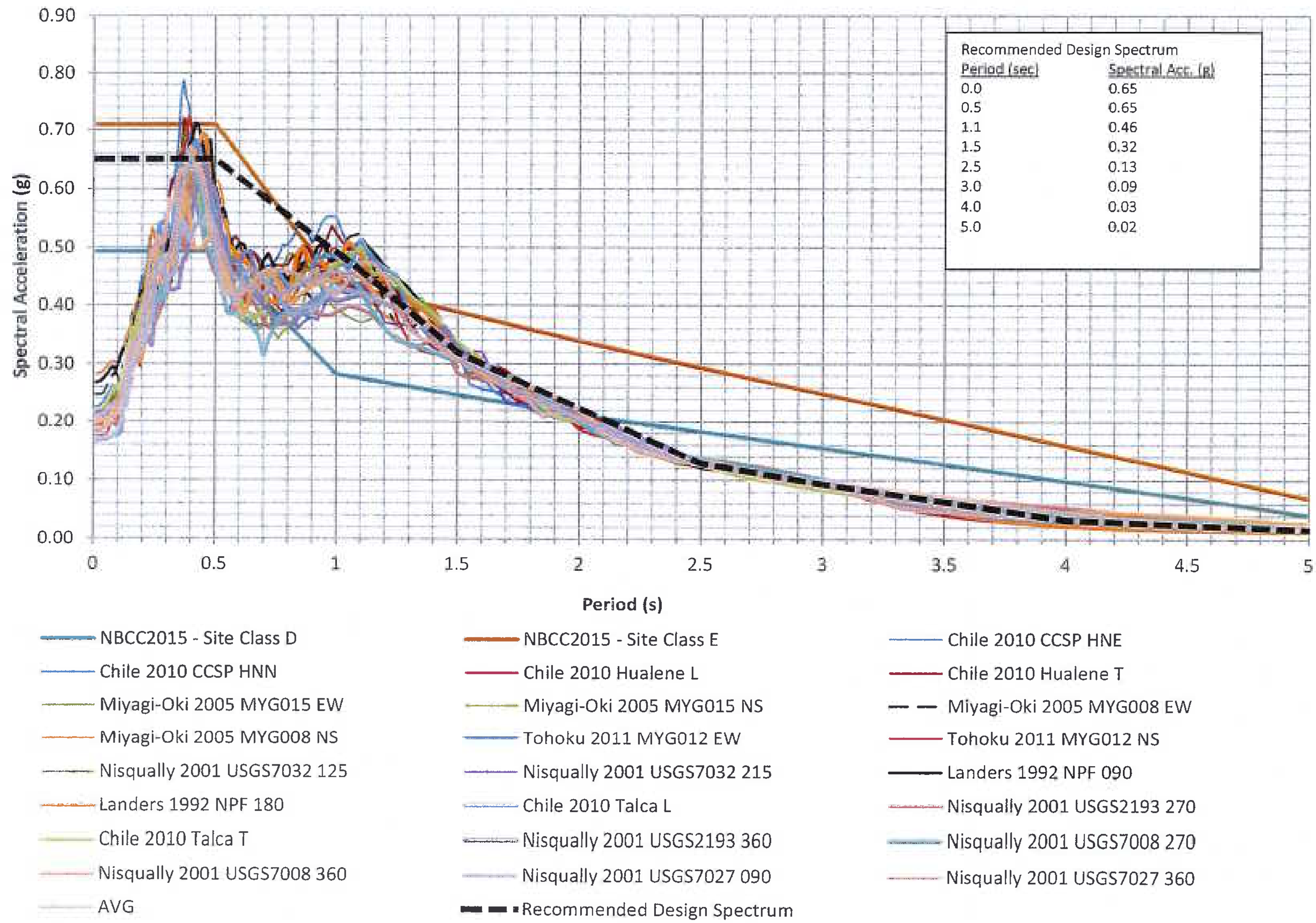
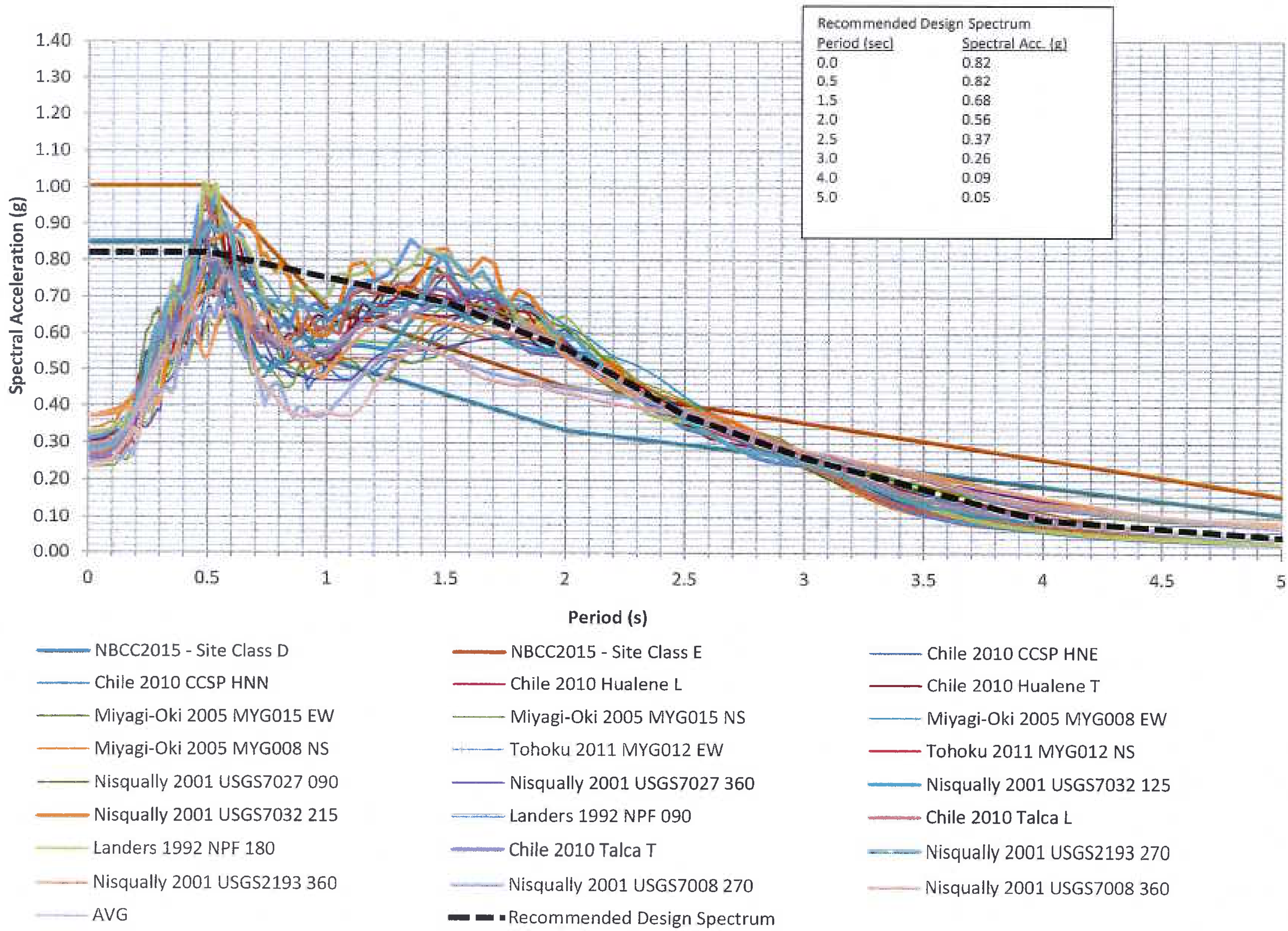


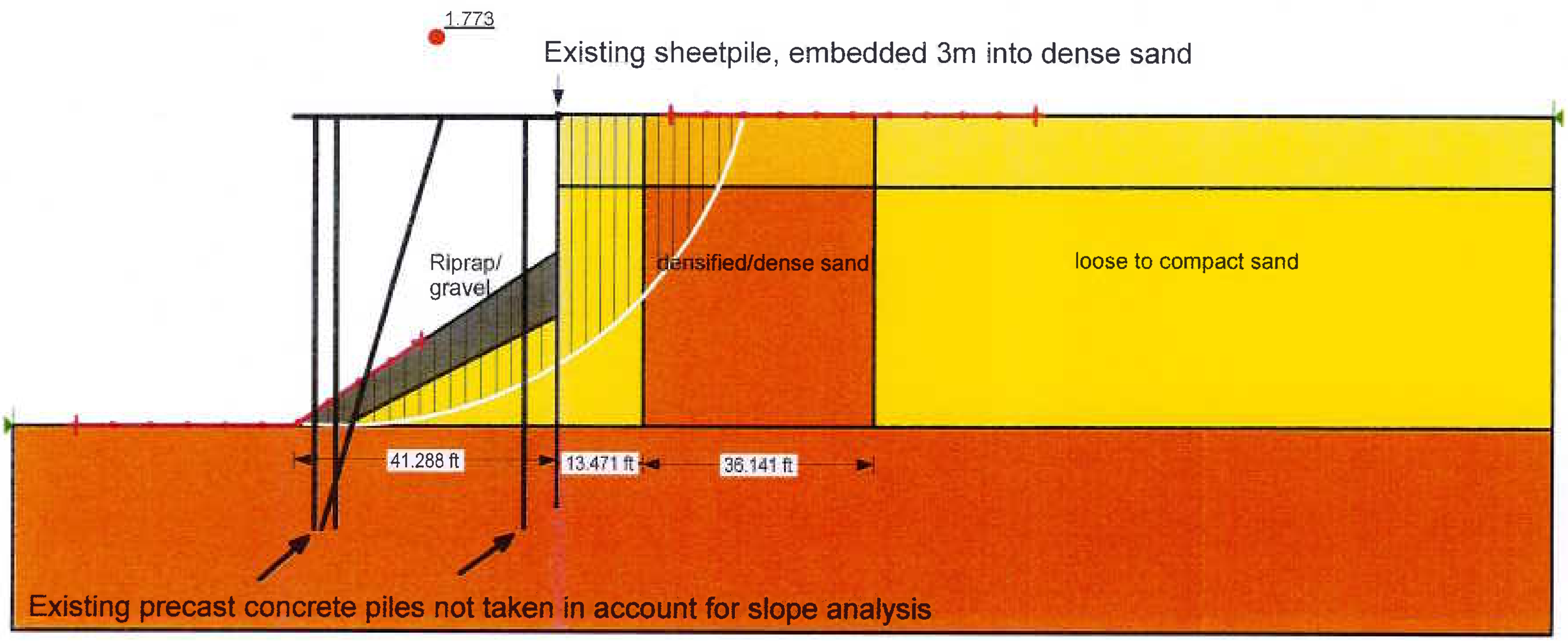
Figure 4: Site Specific Spectral Acceleration at Surface (with densification)
(1:2475 return period, structural damping = 5%)
Fraser Grain Terminal at Fraser Surrey Docks, Surrey, B.C.



APPENDIX F – GLOBAL STABILITY ANALYSIS FOR SHIP LOADER AREA

Client: FWS Group
Project: Fraser Grain Terminal
Address: Fraser Surrey Docks, Surrey, B.C.
File: 15657

GeoPacific Consultants Ltd
1779 W 75th Ave
Vancouver , B.C., V6P 6P2



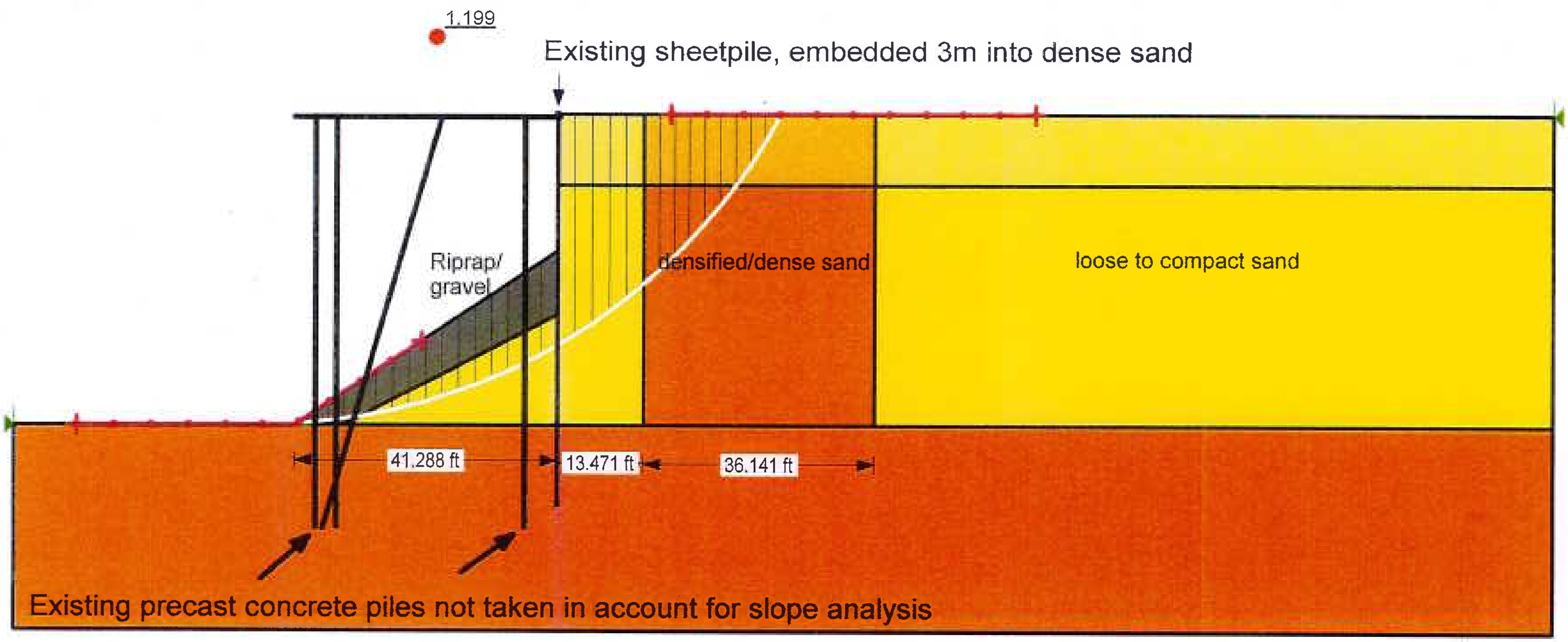
Material parameters:

Name: Riprap and Gravel Model: Mohr-Coulomb Unit Weight: 75 pcf Cohesion': 0 psf Phi': 45 °
Name: loose to compact Sand Model: Mohr-Coulomb Unit Weight: 75 pcf Cohesion': 0 psf Phi': 30 °
Name: densified/dense Sand Model: Mohr-Coulomb Unit Weight: 75 pcf Cohesion': 0 psf Phi': 37.5 °
Name: loose to compact Sand above Groundwater Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion': 0 psf Phi': 30 °
Name: densified/dense Sand above Groundwater Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion': 0 psf Phi': 37.5 °

STATIC SLOPE STABILITY

Client: FWS Group
Project: Fraser Grain Terminal
Address: Fraser Surrey Docks, Surrey, B.C.
File: 15657

GeoPacific Consultants Ltd
1779 W 75th Ave
Vancouver , B.C., V6P 6P2



Material parameters:

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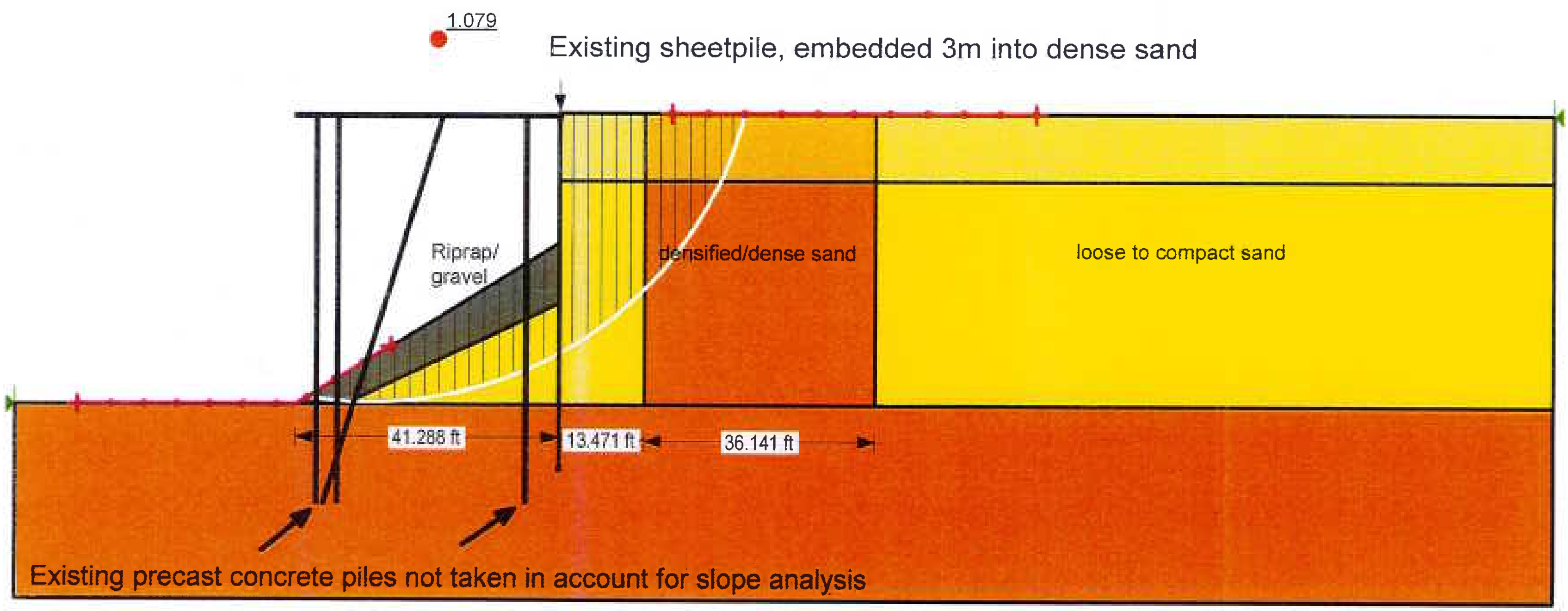
Name: loose to compact Sand	Model: Mohr-Coulomb	Unit Weight: 75 pcf	Cohesion': 0 psf	Phi': 30 °
Name: densified/dense Sand	Model: Mohr-Coulomb	Unit Weight: 75 pcf	Cohesion': 0 psf	Phi': 37.5 °
Name: loose to compact Sand above Groundwater	Model: Mohr-Coulomb	Unit Weight: 124 pcf	Cohesion': 0 psf	Phi': 30 °
Name: densified/dense Sand above Groundwater	Model: Mohr-Coulomb	Unit Weight: 124 pcf	Cohesion': 0 psf	Phi': 37.5 °

PRE-LIQUEFACTION SLOPE STABILITY
seismic horizontal ground acceleration of 2/3 PGA

Client: FWS Group
Project: Fraser Grain Terminal
Address: Fraser Surrey Docks, Surrey, B.C.
File: 15657

GeoPacific Consultants Ltd
1779 W 75th Ave
Vancouver , B.C., V6P 6P2



Material parameters:

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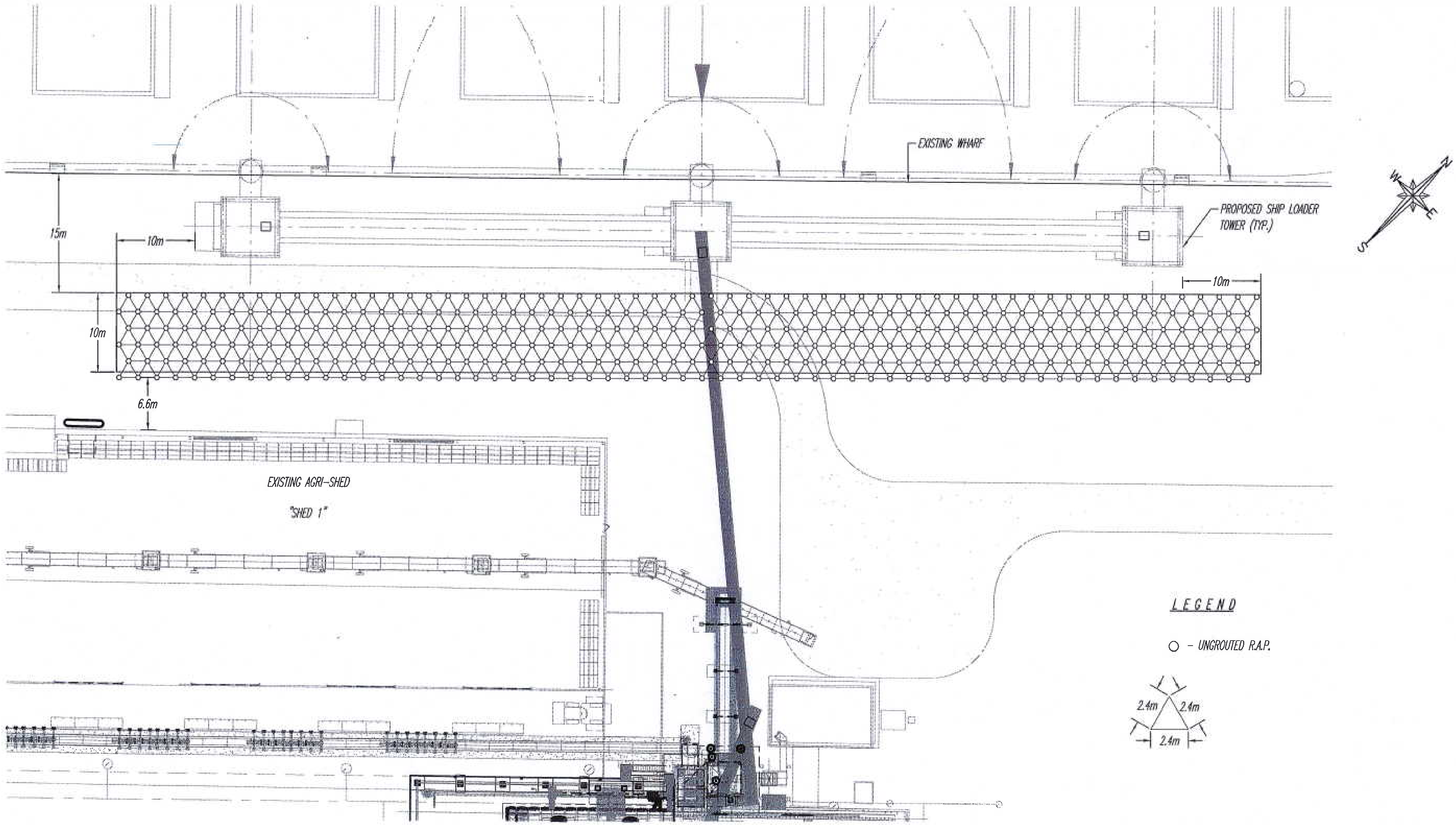
Name: loose to compact Sand Model: Mohr-Coulomb Unit Weight: 75 pcf Cohesion': 333 psf Phi': 0 °
Name: densified/dense Sand Model: Mohr-Coulomb Unit Weight: 75 pcf Cohesion': 0 psf Phi': 37.5 °
Name: loose to compact Sand above Groundwater Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion': 0 psf Phi': 30 °
Name: densified/dense Sand above Groundwater Model: Mohr-Coulomb Unit Weight: 124 pcf Cohesion': 0 psf Phi': 37.5 °

POST-LIQUEFACTION SLOPE STABILITY



MAR 2 9 2018

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REFERENCE:
FWS INDUSTRUAL PROJECTS CANADA LTD.
PROJECT No.:08-17-075C
PROJECT DATE: 03/15/2018

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1779 W. 75th Avenue
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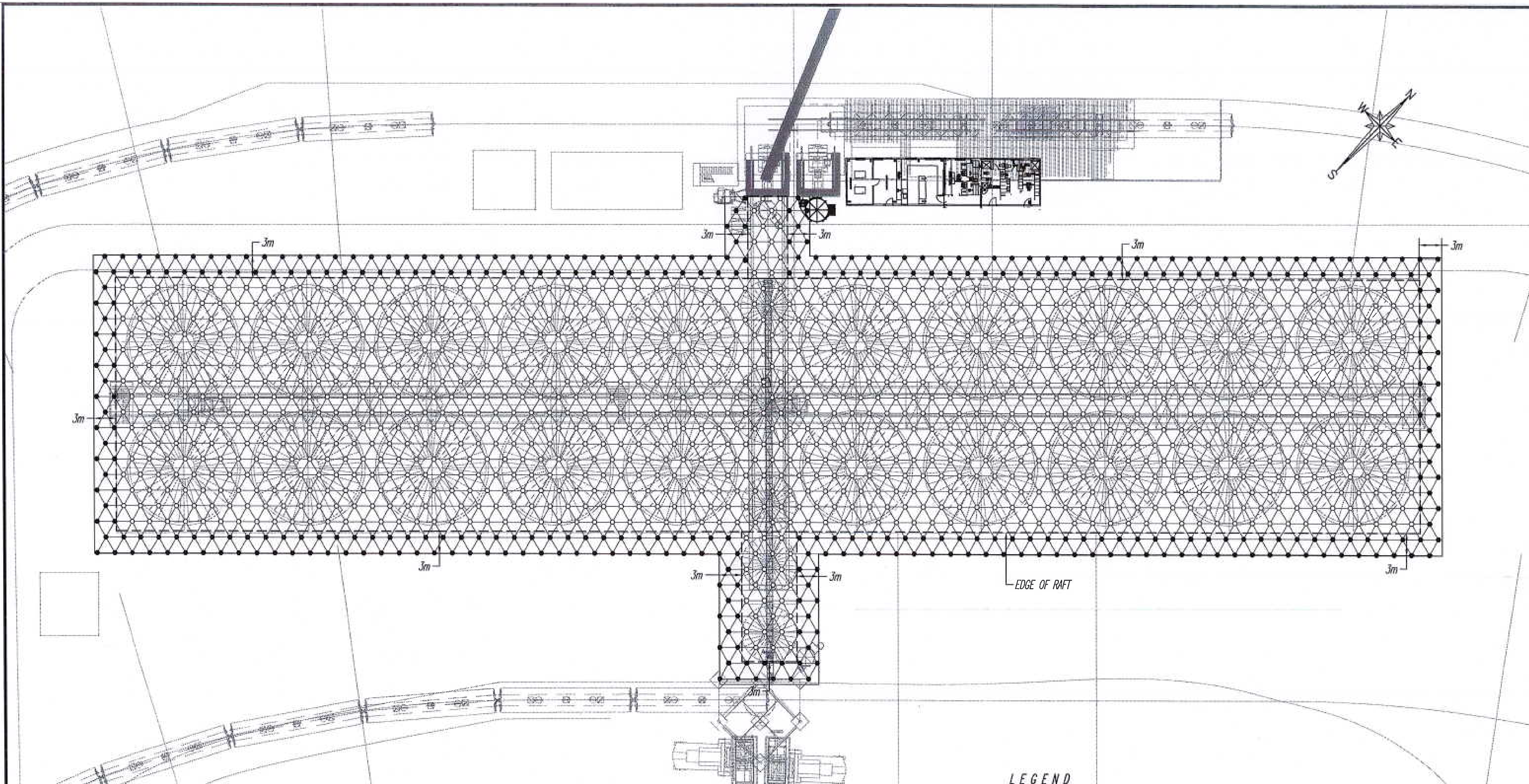
DATE: MARCH 28, 2018		
DRAWN BY: M.S.	APPROVED BY: K.B.	REVIEWED BY: K.B.
SCALE: 1:500		

FRASER GRAIN TERMINAL
FRASER SURREY DOCKS, SURREY, B.C.
DENSIFICATION PLAN

FILE NO.: 15657
DWG. NO.: G-D1A

REVISIONS:
A.
B.
C.

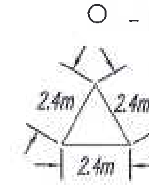
PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
K. J. L. BODNAR
37915



LEGEND

● – GROUTED R.A.P.

○ – UNGROUTED R.A.P.



* GROUTED AND UNGROUTED R.A.P. INSTALLATION PHASING PER ENVIRONMENTAL CONSULTANT.

MAR 2 9 2018

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — K. J. L. BODNAR # 37915

ORIGINAL PAPER SIZE: 11"x17"

REFERENCE: FWS INDUSTRIAL PROJECTS CANADA LTD. PROJECT No.:08-17-075C PROJECT DATE: 03/15/2018	GEOPACIFIC VANCOUVER KAMLOOPS CALGARY — 1779 W. 75th Avenue Vancouver, B.C. V6P 6P2 P 604.439.0922 F 604.439.9189	DATE: MARCH 28, 2018 DRAWN BY: M.S. — APPROVED BY: K.B. — REVIEWED BY: K.B. SCALE: 1:500	**FRASER GRAIN TERMINAL** FRASER SURREY DOCKS, SURREY, B.C. **DENSIFICATION PLAN**	FILE NO.: 15657 DWG. NO.: G-D1B	REVISIONS: A. B. C.

1.0 PREAMBLE

.1 A new grain storage bin cluster and ship loader are proposed at the above noted site. The subsurface soil conditions generally consist of granular fills over overbank silt then channel deposited sand. The soil conditions are summarized in the Engineer's (GeoPacific Consultants Ltd.) Geotechnical Investigation Report, dated March 29, 2018, for this project. Rammed Aggregate Piers are required to densify the underlying sand which is susceptible to liquefaction and sufficiently strengthen all soil beneath the proposed footing elevation(s) to meet the design foundation bearing pressures and subgrade modulus criteria for the project.

.2 Rammed Aggregate Piers (RAPs) are required to a depth of 12 metres below grade. The top and bottom of RAP elevations are to be determined.

Any open holes left between the top of column and ground surface shall be filled by the contractor. Fill shall consist of crushed gravel. Alternative fills may be permitted. The Engineer shall pre-approve any alternate fills.

The specialty ground improvement Contractor shall densify the ground by "rammed aggregate piers" or other full displacement, bottom gravel feed, dry methods pre-approved by GeoPacific Consultants Ltd. to the depths as detailed herein and in the locations shown on GeoPacific's Drawing 15657 G-D1A and G-D1B.

As required to achieve the desired improvement **only full displacement installation methods will be accepted**. In addition, the contractor is required to achieve the required CPT penetration resistance and load testing requirements as described in this specification. The specialty ground improvement Contractor may be required to provide representative case histories during the tender period that demonstrate to the Owner and Engineer that the CPT penetration resistance and load testing requirements can be achieved using the equipment and methodology intended for use at the site.

.3 The installation of the points in the locations and to the dimensions described on our drawings is a "performance" specification requiring the Contractor to complete the work as described on the drawings and to supply sufficient gravel at each column location and adequate equipment to the site to achieve the specification for strengthening outlined in Sections 3.3 and 3.4.

.4 Gravel columns shall be no less than 0.6 metres in diameter.

.5 The contractor shall confirm the locations of all utilities that may be impacted by the strengthening work in advance. The contractor will advise the Engineer immediately of any conflicts.

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ENGINEER

MAR 2 9 2018

.6 This specification is to be used in conjunction with all contract documents. In the event of conflict, the Contractor shall inform the Engineer as soon as possible. Generally, the technical requirements of this specification shall govern.

.7 The Contractor shall demonstrate the performance of the equipment to determine its optimal characteristics by installing a minimum of 30 points in the location chosen by the Engineer. The gravel quantities used and the production rate of the equipment shall be recorded in real time and used to develop a method for the remainder of the work. The Engineer's representative will monitor the construction of the points which shall be installed in accordance with the approved method.

1.2 DOCUMENTS

.1 This specification and the drawings listed in Section 1.7 form part of the Contract Documents and are to be read, interpreted and co-ordinated with all other parts of the Contract.

1.3 DESCRIPTION OF WORK INCLUDED

.1 The work described in this specification shall include providing all supervision, labour, materials, tools, equipment, temporary facilities, permits and related services necessary to densify and strengthen the ground as described on the drawings by installing "rammed aggregate piers" or alternative methods in accordance with the Engineer's method.

The principal items of work included in this specification are:

.1 Mobilization and demobilization of all required equipment.

.2 Providing all equipment and electrical or other power plant and any other items necessary to complete the work.

.3 Providing any granular fill or other materials required to complete the work.

.4 Strengthening of the soils within the specified zones by installing the points in accordance with the drawing listed in Section 1.7

.5 Control/Disposal of surface or subsurface water resulting from construction.

.6 Construction and maintenance of silt settling ponds or similar facilities as required and final removal of the ponds.

.7 Backfill and compaction of any surface depressions in the ground surface at any time with clean granular fill or approved alternative.

.8 Removal of any silts or clays derived from these operations from the site.

.9 Completion of an as-built survey of the location of all gravel columns. The as-built survey shall be undertaken by a registered BCLS.

.10 Supply, installation, operation and decommissioning of a reaction frame testing apparatus.

.2 The Contractor shall provide to the Owner a weekly statement showing the status of the work.

.3 The work shall be carried out using metric units of measurement. All elevations in these specifications are referenced to geodetic datum.

.4 All work shall take place within the limits of the Owner's property. All storage of materials shall be within the Owner's property.

1.4 SUBMITTALS

.1 The Contractor shall provide a statement describing the equipment and methodology to be used to achieve the required criteria and any compression test results for piers installed in similar soil conditions. Such statement shall not relieve the Contractor of any responsibilities under their Contract.

.2 A daily log shall be submitted to the Engineer by the Contractor showing the point designation, the start and finish time for each point, the lowest elevation of the tip of the probe, gravel pile or mandrel, the quantity of any backfill placed at each point.

.3 The Contractor shall maintain a set of up-to-date drawings throughout the Contract to show the work as constructed. The as-built drawing shall be delivered to the Engineer on completion of the work.

.4 The Contractor shall submit fixed prices for the work described in this specification and shown on the drawings. Fixed unit rates for additional or deleted lengths shall also be included in the Contractor's tender.

1.5 QUALITY ASSURANCE and QUALITY CONTROL REQUIREMENTS

.1 The Owner's Engineer shall monitor full time during the installation of all gravel columns.

Before the soil strengthening work commences, a test area shall be established by the Engineer. The Contractor shall install a minimum of 30 points in the pattern defined by the Engineer. A minimum of 2 electronic piezo-cone penetration tests (CPT's) shall be carried out to confirm that the spacing can achieve the required penetration resistance and to confirm that the work carried out complies with this specification. Pier compresson testing will be required in two locations in the test area to confirm the piers achieve the design criteria. The test area requirements may be waived at the discretion of the Engineer. This testing work will be monitored by the Engineer and a method will be developed based on the optimal characteristics of the equipment to achieve the specified requirements.

The Engineer's method will be based on building the points using the maximum energy requirements for the optimal time while inserting the required amount of stone or alternatives at the test locations. The approved method based on the test pattern shall be accepted by the Contractor for use for the remainder of the work.

.2 All testing to determine compliance with the soil strengthening portion of the specification shall be carried out by the Owner and shall consist of electronic piezo-cone penetration tests (CPT) and in general accordance with ASTM D3441 and compression testing of the piers in accordance with the specifications stated herein. These CPT's shall be carried out to the same depth as the proposed RAPs or effective refusal.

.3 During the Contract a minimum of 10 CPTs, 2 pier modulus tests, and 2 subgrade load tests shall be carried out to confirm that the work carried out complies with this specification.

.4 Any monitoring and testing of the soil strengthening work by the Owner does not relieve the Contractor of any responsibility for submittals of information under 1.4.

.5 If tests indicate the specified penetration resistance has not been achieved and/or the compression test results do not meet the specified criteria, then additional testing shall be carried out to define the extent of the area requiring remediation. In addition, post-remediation testing shall be carried out by the Owner to confirm compliance with these specifications. Tests which show that the work is not in compliance with this specification shall be paid for by the Contractor.

1.6 RESTRICTIONS

.1 The Contractor shall be responsible for obtaining all Permits and for conforming to all Federal, Provincial, City and local regulations. The Contractor shall also be responsible for determining all obstructions to the work from existing utilities. Clearance from Utility Companies shall also be the responsibility of the Contractor. All pre-approved Permit costs will be reimbursed by the Owner.

.2 The Contractor's methods and techniques shall ensure that solid matter, contaminants, debris and other pollutants and wastes do not enter or accidentally spill into local drainage systems.

.3 No silt shall be allowed to enter sewers or drainage systems. Silty material and other debris washed out of the soil during the strengthening process must not be incorporated in the Work and must not be allowed to contaminate the existing soils on the site. Such materials shall be disposed of off-site at the Contractor's cost.

1.7 LIST OF DRAWINGS AND APPLICABLE DOCUMENTS

.1 Figured dimensions only shall be used; the Drawings shall not be scaled. Should any dimensions be unobtainable from the Drawings the Contractor shall obtain them from the Engineer.

.2 The extent of the work is shown on the following GeoPacific Drawings:

Drawing Number	Title
15657 G-D1A	Densification Plan
15657 G-D1B	Densification Plan

2.0 PRODUCTS

2.1 BACKFILL

.1 The full displacement gravel column backfill shall consist of well-graded clean hard durable crushed rock, crushed gravel and sand with a maximum size of 37.5 mm and with less than 5% by weight smaller than 10 mm. Alternative methods, will provide the details of their products to the Engineer for review.

The backfill shall be free from organic and other deleterious materials.

.2 A sample and gradation curve of the backfill material to be used shall be submitted to the Engineer for review at least seven days before work begins.

3.0 EXECUTION

3.1 SITE PREPARATION

.1 Submit to the Engineer a list of temporary construction facilities the Contractor intends to bring onto the site.

.2 Ensure that the existing or excavated subgrade is suitable to support the heavy equipment required by the Contractor's operations.

.3 Supply and install all temporary power required for this operation.

.4 Establish all lines and grades required to set out the work from the master grid established by the Owner and accurately stake out the treatment areas as indicated on the Drawings.

.5 The Owner will provide and maintain access for the Contractor's equipment and delivery of materials to the work site.

3.2 EQUIPMENT AND PROCEDURES

.1 The Ground Improvement work shall improve the areas to be treated as specified herein and shall include rig set-up, placement of backfill and all work required to complete the Work.

.2 The Contractor shall discuss the equipment capabilities and expectations with the Engineer before the work commences.

.3 Exercise all reasonable care at all times to avoid damaging or interfering with existing buildings, installations and underground services. The Contractor shall be fully responsible for carrying out the work in such a manner that existing structures are not damaged.

.4 The Contractor shall make good, at their cost, any damage to services, buildings, structures, road surfaces and/or equipment damaged in the course of their work.

.5 The Contractor shall fill all cavities, depressions and irregularities resulting from the work described herein with the clean granular fill or materials otherwise approved by the Engineer to a minimum level of compaction equivalent to 98% Standard Proctor Maximum Dry Density (ASTM D698) up to a predetermined post-work finished grade.

.6 All work must comply with the most current Work Safe BC regulations.

3.3 REQUIRED PENETRATION RESISTANCE OF SANDS

.1 The following specifications refer to the soil as described in section 1.1 of these specifications.

.2 Soil strengthening as described on the densification drawings and as described in these specifications is required.

.3 The Contractor shall densify the soils beneath the specified areas such that the minimum CPT tip resistance, q_c, measured in-situ, is as follows:

- for soils for which the undensified friction ratio is less than 0.5% ("clean sands"):

q_c shall not be less than 70 bars at the ground surface (approx. 1 metre geodetic elevation), increasing at the rate of 6 bars per metre in depth.

- for soils for which the undensified friction ratio is between 0.5% and 1.5% :

q_c shall not be less than 42 bars at the ground surface (approx. 1 metre geodetic elevation), increasing at the rate of 2.5 bars per metre in depth

It is assumed that soils with a natural friction ratio greater than 1.5% cannot be densified significantly by vibration and therefore all improvement in these areas will be achieved through the use of full displacement methods only.

For simplicity of Quality Control this Specification has been developed on the assumption that soils with a friction ratio of less than 0.5% have less than 5% by weight of soil particles smaller than 0.074 mm and soils with a friction ratio of less than 1.5% have less than 15% by weight of particles smaller than 0.074 mm. In the event of a dispute concerning achievement of the specified penetration resistance, the Owner will obtain representative samples of the soil from the disputed horizons and carry out soil gradation tests to measure

the percentage by weight smaller than 0.074 mm. The specification will then be applied using the actual soil grading.

3.4 REQUIRED COMPRESSIVE RESISTANCE OF PIERS AND SUBGRADE

.1 A total of two pier modulus compression tests and two subgrade compression tests will be required at locations determined by the Engineer.

.2 The tests must be completed with the test footing bearing at the elevation of the proposed footings for the building on a subgrade of sand to sand and gravel fill, protected with a 50 mm thick layer of 19 mm clear crush gravel. The excavation cuts should be sloped at 1 horizontal to 1 vertical. Sumps and sump pumps may be required prevent groundwater accumulation at the base of the excavation.

3. The subgrade compression tests shall be done using a hexagonal, reinforced concrete footing centered over a primary pier with six sides measuring 1.39 metres each. The hexagonal area will be approximately 5.0 square metres. The hexagon size is such that it is representative of the area replacement ratio of the densification pattern.

4. The pier modulus compression tests shall be done using a circular, reinforced concrete footing centered over a single primary pier with a diameter of 0.6 metres. The circular footing will have an area of 0.28 square metres.

5. All compression tests will require an anchored reaction frame to resist at least 120 percent of the maximum test load of 2,400 kN. A load test schedule will be provided by the Engineer prior to testing and will require 9 hours of continuous loading at varying

load increments per test. The test apparatus and movement monitoring must be in accordance with ASTM D1143 Sections 6 and 7. A design drawing of the test apparatus including reaction anchors must be provided by the testing contractor to the Engineer for review.

6. In addition to all other safety and security measures applicable to the site and the work being performed, the contractor must comply with the ASTM D1143 Section 9 Safety Requirements.

7. A minimum period of 72 hours should be provided between the installation of the piers in the test areas and the start of pier testing.

8. The subgrade test and modulus test results must confirm, based on the Engineer's analysis and interpretation, that the design foundation bearing pressures and subgrade modulus stated in the structural design drawings have been achieved.

3.5 AREAS REQUIRING REMEDIATION

.1 Areas of the site that do not achieve the required penetration resistance and/or compressive resistance shall be remedied by the Contractor at the Contractor's cost. In addition, the cost of failed penetration tests, sieve analyses, and compression tests shall be reimbursed to the Owner by the Contractor.

3.6 SCHEDULE

.1 The Contractor shall identify in the Tender a proposed start date and construction duration.