Appendix H GEOTECHNICAL REPORT

Seaspan Outfitting Pier – Preliminary Geotechnical Design Report

Seaspan Outfitting Pier Expansion
North Vancouver, British Columbia

October 16, 2020

Prepared for:

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1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) has been retained by Seaspan Vancouver Shipyards (Seaspan) to provide design and engineering services for the proposed Vancouver Shipyards Outfitting Pier (hereafter "the Project") at the Seaspan Vancouver Shipyards in North Vancouver, British Columbia. This report presents the results of the geotechnical marine exploration, preliminary geotechnical engineering analyses and design recommendations for the Project.

The work was completed in general accordance with the geotechnical scope of work in our proposal "Vancouver Shipyards Outfitting Pier – Feasibility Study and Project Permitting", dated March 10, 2020. This report should be read in conjunction with the Statement of General Conditions, which are included In **Appendix A**.

1.1 SCOPE OF WORK

In brief, the scope of work for the geotechnical assessment, as outlined in the above-referenced proposals, includes the following:

- Review of project drawings and available geotechnical and geological information for the Project site and the surrounding area;
- Geotechnical marine exploration and laboratory testing;
- Geotechnical engineering analyses including:

    - Liquefaction and seismic-induced ground lateral displacements;
    - Slope stability for dredged slopes and rip rap shoreline;
    - Seismic-induced settlement;
    - Bearing capacity of pile foundations;

- Preparation of this report to provide recommendations to support detailed design and construction of the Project, including pile foundation design, seismic performance requirements of the pier, as well as ground improvement requirements.

2.0 PROJECT DESCRIPTION

Seaspan is considering the construction of a new Outfitting Pier at their Vancouver Shipyards facility located in North Vancouver, BC (hereafter "the Site"). The new pier will be a major investment in the Canadian shipbuilding industry by making local shipbuilding operations more efficient and improving upon delivery dates of new builds which have been awarded as part of the National Shipbuilding Strategy.

It is our understanding that the proposed Outfitting Pier will be located along the same north-south alignment of the existing Outfitting Pier. The north end of the proposed (and existing) pier will be located approximately 90 m west of the existing Load Out Pier. The dimensions of the proposed pier are approximately 300 m in length (north-south direction) by 20 m in width (east-west direction). The design top of deck elevation of the pier is El. 7.0 m CD.

The proposed Outfitting Pier will be supported on vertical steel pipe piles near the extend western and eastern edges of the pier. The center of the pier will be supported on raking steel pipe piles.

We understand that the water lot around the proposed Outfitting Pier would be dredged to accommodate large vessels on both sides of the new pier. The dredging would be completed in two phases.

- Phase 1: An area approximately 210 m long (north-south direction) by 34.8 m wide (east-west direction) west of the pier will be dredged to El. -9.0 m CD. An area approximately 290 m long by 25 m to 35 m wide east of the pier will be dredged to El. 9.0 m CD.
- Phase 2: Within the water lot east of the pier, an area of approximately 170 m long by 35 m wide at the southern half of the pier will be further dredged to a final design elevation of El. -11.6 m CD.

The dredged areas will have perimeter cut-slopes graded at approximately 3H:1V (horizontal to vertical) with any slope protection or at 2H:1V with rock armor.

An approximately 100 m long by 55 m wide area immediately south of the Load Out Pier and east of the proposed Outfitting Pier will be filled with gravel up to a design elevation of El. -1.0 m CD. The gravel bed will have a perimeter fill-slope graded at 2H:1V.

The layout of the proposed Outfitting Pier is shown in Figure 1.

2.1 REFERENCE DOCUMENTS

The following list of documents were referenced in the preparation of this report.

- “Basis of Design – Outfitting Pier”, dated June 2020, prepared by Stantec Consulting Ltd.
- “Marine Geotechnical Factual Report – Vancouver Shipyard Facility, Modernization Project – Load Out”, dated January 25, 2013, prepared by Stantec Consulting Ltd.
- “Geotechnical Design Report – Vancouver Shipyard Facility, Modernization Project”, dated July 12, 2012, prepared by Stantec Consulting Ltd.
- “Geotechnical Factual Report – Vancouver Shipyard Facility, Modernization Project”, dated July 12, 2012, prepared by Stantec Consulting Ltd.
- “Geotechnical Investigation for JSS Facilities – Seaspan International Ltd., Vancouver Shipyards, North Vancouver, BC”, dated December 2007, prepared by MEG Consulting Limited.
- “Site General Arrangement”, Drawing No. 115619249-101, Revision A, prepared by Stantec Consulting Ltd.
- “General Arrangement Section”, Drawing No. 115619249-102, dated April 15, 2020, Revision A, prepared by Stantec Consulting Ltd.
- “Phase 1 Dredge Plan”, Drawing No. 115619249-103, Revision A, prepared by Stantec Consulting Ltd.
- “Phase 2 Dredge Plan”, Drawing No. 115619249-104, Revision A, prepared by Stantec Consulting Ltd.
- “Pier Plan”, Drawing No. 115619249-301, Revision A, prepared by Stantec Consulting Ltd.

- “Pier Sections”, Drawing No. 115619249-302, Revision A, prepared by Stantec Consulting Ltd.

2.2 DESIGN CODES AND STANDARDS

The geotechnical engineering analyses and design recommendations provided in this report are in accordance with the following design Codes and Standards:

- British Columbia Building Code (BCBC, 2018)
- National Building Code of Canada (NBCC, 2015)
- Canadian Highway Bridge Design Code (CAN/CSA-S6-14, 2014)

3.0 GEOTECHNICAL MARINE EXPLORATION

3.1 PREVIOUS GEOTECHNICAL EXPLORATION WORK

Previous subsurface investigations were carried out at the Vancouver Shipyard by Stantec and others. Pertinent subsurface geotechnical data in the general vicinity of the current study area were reviewed for the purpose of providing additional information related to the subsurface conditions. The relevant test holes used in this report from the previous investigations are shown on the cross-section in Figure 2. Subsurface information from previous investigations was provided in the following reports:

- “Marine Geotechnical Factual Report – Vancouver Shipyard Facility, Modernization Project – Load Out”, dated January 25, 2013, prepared by Stantec Consulting Ltd.
- “Geotechnical Design Report – Vancouver Shipyard Facility, Modernization Project”, dated July 12, 2012, prepared by Stantec Consulting Ltd.
- “Geotechnical Factual Report – Vancouver Shipyard Facility, Modernization Project”, dated July 12, 2012, prepared by Stantec Consulting Ltd.
- “Geotechnical Investigation for JSS Facilities – Seaspan International Ltd., Vancouver Shipyards, North Vancouver, BC”, dated December 2007, prepared by MEG Consulting Limited.

3.2 RECENT GEOTECHNICAL EXPLORATION WORK

The geotechnical marine exploration was carried out between May 5 and 9, 2020. Marine equipment, including barge, tugboat, crew boat, drill rig and drilling supplies were mobilized to Site on May 4 and demobilized off site on May 9 upon the completion of the final test hole. The as-completed scope of the supplementary geotechnical exploration consists of the following:

- Two (2) Cone Penetration Test (CPTu) soundings (CPT20-02 and CPT20-04),
- Three (3) Seismic Cone Penetration Test (SCPTu) soundings (SCPT20-01, SCPT20-03, and SCPT2-05),
- Three (3) mud-rotary boreholes (BH20-01 to BH20-03).

The target depth for the CPTu and SCPTu soundings was 50 m below the existing mudline or until practical equipment refusal. The target depth for boreholes BH20-01 and BH20-02 was upon reaching the glacial till layer (approximately 50 to 60 m depth). The target depth for borehole BH20-03 was 10 m.

A 10 m deep mud-rotary borehole (BH20-04) was originally scoped at the Northeast Infill Area, an area approximately 40 m southeast of the Load Out Pier, for a separate scope. Upon discussion with Seaspan, a SCPTu sounding (SCPT20-05) was completed to a depth of practical equipment refusal in lieu of a borehole. Test hole locations are shown on Figure 1.

All test holes were completed with a track-mounted Fraste mud-rotary drill rig operated by ConeTec Investigations Ltd. and Mud Bay Drilling Co. Ltd. (ConeTec | Mud Bay) mounted on a spud barge operated by Saltair Marine Services Ltd. (Saltair), both subcontracted by Stantec.

Test hole coordinates and elevations were recorded by ConeTec | Mud Bay using a Real Time Kinetic (RTK) Survey device with an accuracy of approximately +/- 0.05 m horizontal and +/- 0.05 m vertical. Coordinates were measured using the Universal Transverse Mercator (UTM, Zone N) NAD83 coordinate system. Elevations were measured as meters Geodetic Datum (GD) in the field and subsequently converted to Chart Datum (CD) for data processing, analyses, and reporting. Chart Datum is also referred to as Lowest Low Water Level (LLWL) which is 3.045 m lower than Geodetic Datum at the project site as noted within the Basis of Design (Stantec, 2020).

Stantec geotechnical field engineers observed the marine exploration, coordinated with ConeTec | Mud Bay, provided ConeTec | Mud Bay with guidance on ASTM and industry standards and procedures, classified the soils encountered, prepared borehole records, and obtained soil samples for laboratory testing. SPT split-spoon samples were returned to the Stantec laboratory in Burnaby, BC for further classification and index testing.

3.2.1 Cone Penetration Testing

The CPTu soundings with pore water pressure measurement involved hydraulically pushing a stainless-steel piezocone with a cross sectional area of 15 cm^2 into the ground at approximately 20 mm/s. 38.1 mm outer diameter (OD). CPTu rods were added every meter as the piezocone was advanced. The piezocone was equipped with load cells for measurement of tip resistance and sleeve friction, a pressure transducer for measurement of pore water pressure, and inclinometers for measurements of inclination. Measurements of tip resistance, sleeve friction, inclination, and pore water pressure induced above the piezocone tip (i.e., at the u2 position) were recorded by an on-board computer at 25 mm intervals along the depths of all test holes. Porewater pressure dissipation tests were completed at selected depths at the discretion of the Stantec field engineer. The CPTu soundings were carried out in general accordance with ASTM D5778.

The SCPTu soundings collected shear wave velocity data in addition to the CPT data. These were advanced in the same manner as the CPTu soundings, with additional recordings every meter of the time interval of shear waves travelling between a wave source and the geophones in the piezocone. The wave source, Water-Seis, was lowered to the mudline on one side of the barge for the duration of each SCPTu sounding. Water-Seis is a sealed, electrically powered source that uses an internal hammer that strikes an anvil to generate seismic waves.

CPTu and SCPTu results are presented in **Appendix C** and include plots of tip resistance (q_t), sleeve friction (f_s), friction ratio (R_f), pore water pressure (u), soil behavior type (based on the method by Robertson, 2009 and 2010), dissipation test plots, and SCPTu shear wave velocity data**. Table 1** summarizes the CPTu and SCPTu soundings.

Table 1 Summary of CPTu/SCPTu Soundings

Test Hole ID	UTM Coordinates		Mudline Elevation (m CD)	Termination Elevation (m CD)	Termination Depth (m below mudline)
	Northing	Easting			
SCPT20-01	5,462,013.4	492,343.4	-4.57	-32.17	27.6
CPT20-02	5,462,126.5	492,346.6	-5.32	-37.72	32.4
SCPT20-03	5,462,267.4	492,349.3	-7.06	-43.46	36.4
CPT20-04	5,462,326.5	492,346.6	-5.91	-42.51	36.6*
SCPT20-05	5,462,322.4	492,457.3	-3.06	-37.26*	34.2

NOTES:
* CPT20-04 was drilled out from 31.5 m to 32.3 m depth below existing mudline (El. -37.4 m to -38.2 m CD)

Practical CPTu/SCPTu refusal was identified by excessive rod deflection and/or excessive lifting of the drill rig generally combined with high (>20 MPa) tip resistance (qt) and drill-rig feed pressure at the discretion of the ConeTec CPTu technician.

When practical CPTu/SCPTu refusal was incurred at SCPT20-01, CPT20-02, SCPT20-03, and SCPT20-05 at the above-referenced depths, a decision was made by the Stantec design team to terminate the soundings. At CPT20-04, when practical CPTu refusal was incurred at 31.5 m depth below the existing mudline, a decision was made to conduct a drill-out in hopes of continue to advance the CPTu below the drill-out zone. At the initial refusal, the piezocone was retracted to surface, and the test hole was drilled-out beyond the termination depth of the CPTu to 32.3 m depth, at which point the Mud Bay driller noticed a decrease in drilling resistance. The piezocone was then lowered back down inside of casing to the bottom of the drill-out, and the CPTu sounding was continued.

3.2.2 Borehole Drilling, Sampling, and Testing

The boreholes were advanced by ConeTec | Mud Bay using the same Fraste track-mounted drill rig used to conduct the CPTu/SCPTu soundings and drill-outs. Borehole records describing the soil conditions encountered and the results of laboratory classification and index testing are included in **Appendix B**. Soil descriptions presented on the borehole records are based on the samples collected from SPT split-spoon, and are in general accordance with ASTM D2487 and D2488 for the Unified Soil Classification System (USCS) and the information presented on the “Symbols and Terms Used in Borehole and Test Pit Records” in **Appendix B**. A summary of the borehole locations is provided in **Table 2**.

Table 2 Summary of Boreholes

Test Hole ID	UTM Coordinates		Mudline Elevation (m CD)	Termination Elevation (m CD)	Termination Depth (m below mudline)
	Northing	Easting			
BH20-01	5,462,061.8	492,349.5	-5.3	-67.3	62.0
BH20-02	5,462,192.1	492,349.0	-6.9	-63.6	56.7
BH20-03	5,462,324.8	492,366.1	-6.3	-17.6	11.3

- **Standard Penetration Testing**

SPTs were completed in general accordance with ASTM D1586. SPTs were performed using a 51 mm outer diameter, un-lined split-spoon sampler driven with an automatic 63.5 kg safety hammer, falling from a height of 760 mm. Blow counts were recorded over four consecutive 150 mm intervals of penetration. The SPT blow counts (i.e., blows per 0.3 m of penetration, or blows per actual penetration if less than 0.3 m) are reported on the borehole records in **Appendix B**.

Overburden soil samples were obtained via Standard Penetration Testing (SPT) using a split-spoon sampler. In general, samples were obtained at 1.0 m intervals to a depth of 3.0 m, and at 1.5 m intervals from 3.0 m to 10 m depth. The samples obtained in the upper 6.0 m of mudline were for the environmental scope of the project. Beyond 10 m depth, samples were obtained at 3.0 m intervals.

4.0 LABORATORY TESTING

4.1 SUMMARY

Geotechnical index laboratory testing was conducted on samples collected in the three boreholes, with the exception of the environmental soil samples, at the Stantec laboratory in Burnaby, BC. A summary of the geotechnical laboratory testing is presented in **Table 3**.

Table 3 Summary of Geotechnical Laboratory Testing

Laboratory Test Description	ASTM	Number of Tests Completed
Moisture Content	ASTM D2216	11
Atterberg Limits	ASTM D4318	2
Particle Size Distribution	ASTM D6913 (Sieve) ASTM D7928 (Hydrometer)	7
Fines Content Measurement	ASTM D1140	17

4.2 MOISTURE CONTENT

Moisture Content (w) of soil is defined as the ratio of the mass of water contained in the pore spaces of the soil to the mass of solids in the soil, expressed as a percentage. Measurement of moisture content was performed in general accordance with ASTM D2216. Moisture content measurements are presented on the borehole records in **Appendix B**.

4.3 ATTERBERG LIMITS

Atterberg Limits describe the consistency and plasticity of fine-grained soils with varying degrees of moisture. Atterberg limits tests are used to determine the moisture contents at which soil behavior becomes liquid or brittle. The Liquid Limit (LL) represents the moisture content at which the soil begins to flow like a liquid, and the Plastic Limit (PL) represents the moisture content at which it ceases to be plastic and becomes brittle. Subtracting the plastic limit from the liquid limit yields the Plasticity Index (PI).

The Atterberg limits were measured using the multi-point method (Method A) as described in ASTM D4318. Atterberg limits test results are presented on the borehole records in **Appendix B** and in **Appendix D**.

4.4 PARTICLE SIZE DISTRIBUTION (AND FINES CONTENT)

Tests were performed to obtain particle size distributions for selected soil samples. The tests were performed in general accordance with ASTM D1140, ASTM D6913 and ASTM D7928. A summary of particle size distribution and fines content test results are presented on the borehole records in **Appendix B**. Particle size distribution test results are presented in **Appendix D**.

Laboratory test results for the soil samples obtained for environmental purposes are presented in a separate report.

5.0 SUBSURFACE CONDITIONS

5.1 SURFICIAL GEOLOGY

Based on our past projects at the Shipyards facility near the proposed Outfitting Pier and our knowledge of the regional marine surficial geology, marine soils in the vicinity of the pier are anticipated to be thick deposits of sand and silt, with interbedded silty sand and sandy silt, extended down to depth in the order of 50 m to 60 m below the existing mudline, underlain by glacial till deposits which overlay sandstone and siltstone bedrock formations.

5.2 SOIL CONDITIONS

The subsurface conditions from the current geotechnical exploration typically consist of a thick deposit of poorly graded sand and silty sand underlain by 10 m to 20 m thick of silty soil, which in turn is underlain by a deposit of gravelly soil. The gravelly soil is underlain by till deposits observed at boreholes BH20-01 and BH20-02 at approximately 58 m to 62 m depth below the existing ground surface.

Further discussion of the subsurface soil layers is provided in the following section. The soil stratigraphy along the pier is presented in Figure 2.

5.2.1 Poorly graded Sand

Poorly graded sand deposit with varying amounts of silt was encountered below the existing mudline in BH20-01 and BH20-02 and below a shallow silt layer in BH20-03. This deposit extends to depths ranging from 7.6 m to 18.6 m, below the existing mudline (i.e., El. -12.9 m CD, and El. -25.5 m CD), respectively.

In borehole BH20-03 at the north side of the out-fitting pier, approximately 4.6 m thick silt is presented below the existing mudline. The silt is very loose based on SPT N values. The poorly graded sand layer was encountered below silt layer at El. -10.9 m CD. and extended beyond the termination depth of the borehole at El. -17.6 m CD.

SPT N values within this layer generally ranged from 1 to 25, indicating this soil layer is very loose to compact.

5.2.2 Silty Sand

The poorly graded sand layer is underlain by a deposit of silty sand in BH20-01 and BH20-02. The silty sand layer is approximately 29.0 m and 17.9 m thick extending to El. -41.9 m CD and El. -43.4 m CD in BH20-01 and BH20-02, respectively. Some amounts of gravel were encountered at 9.1 m, between 24.7 and 24.8 m and 27.2 m depths below the existing ground surface in borehole BH20-01.

SPT N values in this deposit generally ranged from 5 to 26, indicating this soil layer is loose to compact. However, some higher SPT N values were recorded that likely reflect the presence of gravel, rather than the general compactness of this deposit.

5.2.3 Silt

Low-plastic silt deposit with varying amounts of sand with thickness of approximately 17.4 m and 15.0 m underlies the silty sand deposit and extends to El. -59.3 m and El. -58.4 m (CD), in BH20-01 and BH20-02, respectively.

SPT N values generally ranged from 7 to greater than 50 blows indicating that silt loose at the top, transitioning to dense and very dense, below 45.4 m and 42.5 m depth below the existing ground surface (i.e., El. -50.7 m CD, and El. -49.4 m CD) in BH20-01 and BH20-02, respectively. However, the SPT tests could have been affected by the presence of gravels and cobbles, which could have resulted in higher resistance to penetration and artificially higher N values. One SPT N value of 1 blow was recorded at El. -41.9 m CD, in borehole BH20-01 represented the very loose compactness of silt layer at this depth.

Occasional boulders were encountered within the silt layer in borehole BH20-01 at approximate depths of 51.2 m to 52.4 m below the existing ground surface.

The bottom 5.9 m of the silt deposit consists of silty sand and sand at borehole BH20-02. A measured water contents of one sample of this material is 22%. Two 'N' values of greater than 55 blows and 36 blows were measured in this layer, indicating a dense to very dense compactness. One higher 'N' value could reflect the presence of gravel, rather than the general compactness of the soil matrix.

Measured moisture contents of the five samples of silt ranged from 18% to 24%.

5.2.4 Silty Gravel with Sand

A silty gravel with sand deposit is encountered beneath the low-plastic silt deposit with the thickness of 4.8 m and 3.2 m extends to El. -64.1 m CD and El.-61.6 m CD, BH20-01 and BH20-02, respectively. Based on in-situ blow counts, this soil is generally very dense. This gravelly soil can be a transition to the Till-like soils.

5.2.5 Till-like Soils

Till-like soils consisting of silty gravel with sand, clay with gravel, and silty sand/sandy silt with gravel are presented in BH20-01 and BH20-02. Measured moisture contents of the four samples collected within the Till deposit ranged from 11% to 26%. The results of Atterberg Limits testing performed on one sample of till were liquid and plastic limits of 30% and 18%, respectively (i.e., plasticity index of 12%). Based on in-situ blow counts, the till is generally very dense.

5.3 TIDE CONDITIONS

The tide levels measured from local Hydrographic Tide and Chart Datum. The tides and water levels have been taken from CHS Nautical Chart 3494 for Vancouver. These tide elevations are as follows:

- Higher High Water Level (Large Tide) – HHWLT at El. +5.0 m CD
- Higher High Water Level (Mean Tide) – HHWMT at El. +4.4 m CD
- Mean Sea Level (MSL) at El. +3.1 m CD
- Lower Low Water Level (Mean Tide) – LLWMT at El. +1.1 m CD
- Lower Low Water Level (Large Tide) – LLWLT at El. 0.0 m CD

6.0 ENGINEERING ANALYSIS AND RECOMMENDATIONS

The Outfitting Pier will meet two-level seismic criteria that include the following earthquake events:

- Operating Basis Earthquake (OBE) defined as the seismic event that produces ground motions associated with the 224-year return period. During the OBE event, the marine facilities should remain elastic, experience minimal damage, and be operable afterward.
- Life Safety Earthquake (LSE) defined as a rare and extreme seismic event that produces ground motions associated with the 2,475-year return period. During the LSE event, the outfitting pier may be damaged, but the level of damage shall preclude the collapse of the pier.

6.1 SEISMIC HAZARD

Seismic hazard to the site consists of ground motions resulting from the following three types of earthquakes as defined in NBCC (2015):

- Shallow Crustal earthquakes that occur in the Continental Plate, magnitudes up to M7.5 and distance of 10 km to 20 km,
- Deep Inslab earthquakes that occur in the subducting Juan de Fuca Plate, magnitudes up to M7.5 and distance of 50 km to 70 km.
- Interface subduction earthquakes that occur at the interface of the Continental and the Juan de Fuca Plates, magnitudes of M7.5 to M9.0 and distance of more than 120 km from southwestern British Columbia.

The seismic hazard parameters for the site were obtained from the Natural Resources Canada (NRC) website maintained by the Geological Survey of Canada. The parameters are in the form of 5% damped horizontal spectral response acceleration, $S_a(T)$, and T is the period in seconds. The $S_a(T)$ values are determined for very dense soil or soft bedrock, taken as the reference ground condition corresponding to Site Class C. The $S_a(T)$ values would have to be adjusted to account for local site conditions and to obtain design spectral values S(T).

The NRC website provides the seismic hazard parameters for 100, 475 and 2475-years return periods. The seismic hazard parameters for the 224-year return period were obtained using the log-log interpolation method using the values of the 100 and 475-year return periods as recommended by the NRC.

The seismic hazard parameters for the 224 and 2475-year return periods at Site Class C conditions per NBCC (2015) are summarized in **Table 4**.

Table 4 Seismic Design Parameters For 5% Damping at Site Class C per NBCC (2015)

Period, T (s)	Sa(T) (g)	
	224-Year Return Period	2475-Year Return Period
PGA	0.121	0.355
0.05	0.145	0.435
0.1	0.222	0.662
0.2	0.281	0.819

Period, T (s)	**Sa(T) (g)**	
	224-Year Return Period	**2475-Year Return Period**
0.3	0.283	0.821
0.5	0.239	0.726
1.0	0.125	0.411
2.0	0.07	0.25
5.0	0.016	0.079

6.2 SEISMIC SITE CLASSIFICATION

Liquefaction assessment discussed later in Section 6.4 indicates the presence of the liquefiable soil at the site under the 224 and 2475-year return periods. Therefore, the site is defined as Site Class F and site-specific seismic ground response analysis would be performed to develop design response spectrum per NBCC (2015).

6.3 SITE-SPECIFIC SEISMIC GROUND RESPONSE ANALYSIS

Site-specific seismic ground response analysis was carried out as per NBCC (2015) for the following purposes:

- To evaluate the response of the subsurface soils under the design earthquake motions
- To develop site-specific design response spectrum for structural analyses
- To develop parameters for liquefaction assessment of the subsurface soils.

The analysis was performed using the one-dimensional, equivalent-linear method using the computer program SHAKE2000 (Geomotion LLC). Description of input soil parameters, input acceleration records and the results are given in the following sections.

6.3.1 Input Soil Parameters

The soil parameters for the seismic analysis were derived using the site-specific test holes. The required soil parameters for the analysis are:

- Shear wave velocity (Vs).
- Depth of the 1-D soil column and depth to the Site C firm ground.
- Unit weight.
- Variation of shear modulus and damping with shear strain.

The design shear wave velocity profile was developed based on the velocity measurement at SCPT20-01, SCPT20-03, and SCPT20-05 and estimated shear wave velocity from corrected SPT blowcount $(N_1)_{60}$ at BH20-01 and BH20-02. The shear wave velocity estimated from $(N_1)_{60}$ was based on the correlation proposed by Seed and Idriss (1970) and calibrated to the velocity measurement at the SCPTs.

The measured shear wave velocity at the existing ground surface was corrected for the final vertical effective stress at the proposed dredge level using the following equation (Idriss and Boulanger, 2008):

$$V_{s(corrected)} = V_{s(measured)} \left(\frac{\sigma'_{v(final)}}{\sigma'_{v(existing)}} \right)^{0.25}$$

Where $\sigma'_{v(final)}$ is the vertical effective stress at the proposed dredge line and $\sigma'_{v(existing)}$ is the vertical effective stress at the existing ground surface.

The depth to the Till deposits (Site Class C condition) was taken at 50 m below the proposed dredge level for the seismic ground response analysis. The soil unit weights were estimated based on soil type and compactness. Shear modulus reduction and damping data for the analysis were taken from published data on similar soils. The Seed and Idriss (1970) upper bound modulus reduction and lower bound damping curves were used for soils above the Till deposits. The Profiles of the shear wave velocity, soil unit weight and the soil model used in the analysis are shown in Figure 3.

6.3.2 Input Earthquake Records

The analysis was carried out using a suite of input earthquake records, representative for Site Class C conditions for the 224 and 2,475-year return periods in accordance with NBCC (2015). The records were developed for the George Massey Crossing (GMC) project. Stantec obtained the records from the British Columbia Ministry of Transportation and Infrastructure (MOTI) and modified them for use at this site. The original records are for Site Class C soil conditions and include 10 crustal, 10 inslab and 10 interface records for each of the 475 and 2,475-year return periods.

The design earthquake records for this site for the 2,475-year return period were obtained by uniformly scaling the GMC records for the same return period using the ratio of PGA at this site, 0.355 g, to the PGA at GMC, 0.393 g.

The design earthquake records for this site for the 224-year return period were obtained by uniformly scaling the GMC records for the 475-year return period using the ratio of PGA at this site, 0.121 g, for 224-year return periods, to the PGA at GMC, 0.206 g, for 475-year return period.

The response spectra of the uniformly scaled records for the 2,475 and 224-year return periods are shown in Figures 4 and 5, respectively. The NBCC (2015) Site Class C response spectrum at the are also shown in those figures for comparison.

6.3.3 Results of the Seismic Ground Response Analysis

As mentioned in the previous section a total of 30 records were developed for each of the 224 and 2,475-year return periods. The seismic ground response analysis was carried out using all 30 scaled records for the 224 and 2,475-year return periods.

The results were then assembled separately for each of the three seismic input sources, i.e. crustal, inslab, and interface, and the average of each of the three sets of response was then calculated for each probable earthquake event.

The results of the seismic ground response analyses are shown in Figures 6 to 9 for the 2,475-year return period and in Figures 10 to 13 for the 224-year return period. The figures include Cyclic Stress Ratio (CSR), PGA, and maximum shear stress (τ_{max}) profiles and their average profiles. The acceleration response spectra of the crustal, inslab and interface records and their average profiles, taken at the dredged ground surface are shown in Figures 14 and 15 for the 2,475 and 224-year return periods, respectively. The envelope of the three average responses is shown in Figure 16.

6.4 LIQUEFACTION ASSESSMENT

Liquefaction assessment of the subsurface soils was carried out using the simplified method presented in Boulanger and Idriss (2014) together with the “mean magnitude method” suggested by Finn et al. (2016). The liquefaction simplified method involves a comparison of the cyclic shear stress in the ground (Cyclic Stress Ratio, CSR) induced by the earthquake loading (i.e., demand) to the soil shear resistance (Cyclic Resistance Ratio, CRR). The CRR was estimated using the CPT and SPT approaches proposed by Boulanger and Idriss (2014). The CSR was obtained from the site-specific seismic ground response analysis as the average profile of the CSR of all 30 earthquake records.

The mean earthquake magnitudes of 7.0 and 6.86 under the 2,475 and 224-year return period, respectively were used in the analysis based on the deaggregation data provided by the Geological Survey of Canada (GSC), which considers the contributions of the crustal, inslab, and interface earthquakes.

The factor of safety (FS) against liquefaction was derived as the ratio of CRR to CSR and the results are shown in Figures 17 to 32. Under the 2475-year return period, liquefaction is estimated to occur from the dredged ground surface to El. -37 m CD. Under the 224-year return period, liquefaction is estimated to occur from the dredged ground surface to El. -20 m CD.

6.5 SLOPE STABILITY ANALYSIS

Slope stability analysis was carried out using the limit equilibrium Morgenstern–Price method within the computer program Slope/W (GeoStudio, 2018).

The slope stability was analyzed for a cross section along the pier in the north-south direction. The ground surface is generally at approximately El. 6.7 m CD at the yard, and then sloped down toward the marine to a dredged level of El. -9 m. A marine slope is observed about 140 m south from the end of the proposed pier. Available bathymetric data does not cover the marine slope beyond Station 0 in the slope stability model. It was assumed in the slope stability analysis that the ground slope extends further to El. -35 m CD.

Preliminary slope stability analyses were carried out for two design water levels including Higher High Water Level (HHWLT) at El. +5.0 m CD and Lower Low Water Level (LLWLT) at El. -0.2 m CD, which indicate that the LLWLT provided the lowest Factor of Safety and was the governing case from a slope stability perspective. Therefore, subsequent slope stability analyses were performed using the LLWLT.

Unit weights of 19 kN/m^3 and 21 kN/m^3 were used in the analysis for the existing soils and granular fill soils above El. 5 m CD, respectively.

A horizontal seismic coefficient (k_h) equal to 50% of the average PGA of all the Crustal, Inslab, and Interface earthquakes at the ground surface was used in pseudo-static analysis as follow:

- k_h = 0.058 g under the 224-year return period.
- k_h = 0.111 g under the 2,475-year return period.

The shear strength profile of the soils under the static condition was estimated from the borehole and CPT data using correlations proposed by Hatanaka and Uchida (1996) for SPT-approach and Robertson (2015) for CPT-approach. The design soil strength parameters are shown in Figure 33 and **Table 5**.

Table 5: Design Soil Strength Parameters of Soils – Static Condition

El. (m CD)		**Effective friction angle ϕ' (°)**
From	**To**	
6.7	5	35
5	-31	35
-31	-37	32
-37	-42	38
-42	-47	29
-47	-66	40

The residual shear strength of liquefied soils was calculated using the empirical equation presented in Idriss and Boulanger (2014) and shown in Figure 34. A residual shear strength ratio S_{ur}/σ'_v of 0.1 was estimated based on the average profile of the CPT and SPT data points to represent the residual shear strength of the liquefied soil under the post-seismic condition.

The results of the stability analyses are summarized in **Table 6** and shown in Figures 35 to 49.

Table 6:Results of Slope Stability Analyses

		FoS under different loading condition					Yield acceleration FoS=1	
			224-year return period		2,475-year return period			
Cross Section	**Slope location**	**Static**	**Pseudo-Static**	**Post-liquefaction**	**Pseudo-Static**	**Post-liquefaction**	**224-year return period**	**2,475-year return period**
Along the pier	Overall Slope (entire pier)	12.4	3.85	2.16	2.33	1.92	0.035	0.03
	Marine Slope (south of pier)	4.04	2.32	3.83	1.65	2.90	0.115	0.170
	Nearshore Slope (north of pier)	4.64	2.80	0.69	2.03	0.69	N/A	N/A

Minimum FoS values of 1.5, 1.0 and 1.0 are considered adequate for static, pseudo static, and post-seismic conditions respectively in accordance with standard engineering practice. The analysis indicated that the FoS for the static and pseudo-static conditions are larger than 1.6 for both the 224 and 2,475-year return period for all slopes. Under the post-liquefaction condition, the estimated FoS are larger than 1.9 for the stability of the overall and marine slopes; however, a FoS less than 1 was estimated for the nearshore slope.

Yield acceleration (k_y) was obtained from the slope stability analysis to estimate the seismic-induced soil displacement using the Newmark sliding block method (1965). The yield acceleration is the horizontal seismic coefficient applied to the post-earthquake slope stability model that yields FoS of approximately 1.0. The yield acceleration was estimated for all slopes were the FoS of slope stability under the post-earthquake condition is greater than 1. The residual shear strength was assigned for liquefied soils as proposed by Olson and Johnson (2008). The estimated yield accelerations are presented in Figures 50 to 53 and summarized in Table 6. The results of the Newmark ground displacement analysis are presented in the following section.

6.6 POST-SEISMIC LATERAL SOIL DISPLACEMENT

Post-seismic lateral displacement of the ground surface along the pier was estimated using the Newmark sliding block method (1965) and the empirical method proposed by Youd et al. (2002). Seismic numerical modelling was also analyzed to provide further detail on the seismic-induced soil displacement, which is presented in section 6.9.

6.6.1 Newmark Sliding Block Method

The post-seismic soil displacement was evaluated using the computer software SLAMMER (2014) developed by U.S. Geological Survey (USGS). A regression rigid block Newmark method was used to estimate the post-seismic horizontal ground displacement based on the specified ground motion at the ground surface and the yield acceleration. The Newmark analysis considered a total of 30 earthquake records at the proposed dredge level. The earthquake records were obtained from the site-specific seismic ground response analysis presented in section 6.3. The yield accelerations of 0.035g and 0.03g under the 224 and 2,475- year return periods, respectively, were used to calculate the soil displacement.

The average displacements under the 224 and 2,475-year return period are summarized in **Table 7**.

Table 7: Post-Seismic Lateral Ground Displacements using Newmark method

	Seismic slope displacement (m)	
Earthquake record	**224-year return period**	**2,475-year return period**
Average - Crustal (10 records)	0.15	1.56
Average - Inslab (10 records)	0.13	1.39
Average - Interface (10 records)	0.01	1.79
Average - All 30 motions	0.09 (use 0.15 m on the safe side)	1.58

6.6.2 Youd's Method

The empirical method proposed by Youd et al. (2002) considers the earthquake magnitude, the seismic source distance, the thickness of the liquefiable layers, and the ground slope.

The input parameters used to estimate the lateral soil displacement are shown below:

- Earthquake magnitudes of 7 and 6.86 corresponding to the 2,475 and 224-year return periods based on the deaggregation data provided by the NRC.
- PGA of 0.222 g and 0.115 g corresponding to the 2,475 and 224-year return periods. The PGA values are based on the results of the site-specific seismic ground response analysis as the average of all the surface PGA of all earthquake records.
- Equivalent Distance to the seismic energy source, R, (as a Function of M_w and PGA) of 43 km and 26 km corresponding to the 2,475 and 224-year return periods.
- Ground slope of 13% taken as the slope of the marine slope to be on the safe side.
- Cumulative thicknesses of cohesionless soil layers with $(N_1)_{60} < 15$, $T_{15} = 27$ m.
- Average fines content for soils in the T_{15} layer, $F_{15} = 5\%$
- Mean grain size for soils in the T_{15} layer, $D_{50(15)} = 0.35$ mm

Post-seismic lateral displacement is estimated to approximately 0.4 m and 2 m under the 224- and 2,475-year return periods, respectively. The soil displacements obtained from the Youd's method can be considered the upper bound values as the ground slope used in the calculation was taken on the conservative side.

6.6.3 Design Soil Displacement Profiles

The soil lateral displacements at the ground surface obtained from the Newmark sliding block method were used to develop the soil displacement profiles with depth. The soil lateral movement profiles were estimated from the "lateral displacement index" (LDI) presented in Idriss & Boulanger (2008) by integrating maximum shear strains that develop during liquefaction versus depth. This method provides an estimate of the potential lateral displacement based on estimated maximum shear strains (which are a function of penetration resistance) of the soil at each borehole location. The LDI profiles were then scaled to match the horizontal displacement at the ground surface to evaluate the post-seismic pile deflection. The scaled LDI profiles are shown in Figure 54.

6.7 POST-SEISMIC SOIL SETTLEMENT

The post-seismic ground settlement due to the dissipation of excess pore pressure during earthquake was estimated using the CPT approach proposed in Idriss and Boulanger (2014). The settlement in each layer was estimated and the cumulative settlement was calculated as a function of depth. The magnitude of the cumulative settlement increases towards the ground surface as the contribution from each liquefiable layer is added.

Post-seismic settlements of 0.2 m to 0.5 m along the pier were estimated under the 224-year return period, and post-seismic settlements of 0.4 m to 1.3 m along the pier were estimated under the 2475-year return period.

6.8 PILE AXIAL CAPACITY

Both the API and LCPC methods were used to estimate the pile axial capacity. The API method estimates the shaft resistance and end bearing capacity factors which consider the soil density, soil-pile interface friction angle, lateral earth pressure, and soil overburden stress. The LCPC method uses the CPT tip resistance, which is available to about 30 m depth, to calculate the shaft and end-bearing resistance of the pile. The results of the LCPC method were used to estimate the shaft resistance and end bearing capacity factors of the API method, and the calibrated parameters were then used to estimate the pile capacity at greater depths.

Under the post-seismic condition, a residual soil strength of $0.1\sigma'_v$ was used for the liquefied soils to estimate the pile capacity, where σ'_v is the initial soil vertical effective stress.

The ultimate axial capacities in compression under the static and seismic conditions (2475-year return period) of 1220 mm diameter and 25.4 mm thick steel pipe piles are shown in Figure 55. Significant increase in the pile capacity is estimated if the piles are driven into the till deposits. For a pile embedment in the till deposits of 3 m, the ultimate axial capacities in compression under the 2475-year return period is estimated to be in the order of 20,000 kN.

6.9 SEISMIC NUMERICAL MODELING

6.9.1 Seismic model

Two-dimensional (2D) seismic numerical modeling was carried out to provide further details of the seismic response of the subsurface soils and verify the results of the simplified seismic analyses presented in the previous sections. The numerical modeling was performed using the FLAC finite difference program (Itasca Inc.).

The FLAC modeling was carried out for a cross section along the pier in the north-south direction. The FLAC model covers the onshore yard, the pier and the marine slope, and extends to the Till deposits. Free field boundaries were applied at both sides of the model, and compliant boundary was applied at the base of the model. The Till deposits were modeled using the Elastic model. The soils that are susceptible to liquefaction were modeled using the PM4SAND model (Boulanger and Ziotopoulou, 2015), and the Mohr-Coulomb model was used for non-liquefiable soils above the design ground water level (i.e., LLWL at El. -0.2 m CD).

The primary input parameters including soil relative density (Dr) and Shear modulus coefficient (Go) were estimated from the measured shear wave velocity (Vs), SPT $(N_1)_{60}$ and CPT q_{C1N} using the correlations proposed in Boulanger and Idriss (2014) and Boulanger and Ziotopoulou (2015). The contraction rate parameter h_{po} of the PM4SAND model was calibrated to the liquefaction triggering curve presented in Boulanger and Idriss (2014) using the element cyclic direct simple shear test (CDSS) modeled in FLAC. The design profiles of the input parameters are shown in Figures 56 and 57.

Three select earthquake records including one crustal, one inslab, and one interface corresponding to the 2,475-year return period were applied at the base of the model as shear stress time-histories. The records were selected based on the results of the Newmark sliding block and Site-specific seismic ground response analyses that may present the seismic responses that are close to the average of all 30 earthquake records. The numerical modeling using all 30 earthquake records would be performed in the next design phase.

6.9.2 Modeling results

- **Post-seismic lateral soil displacement**

The post-seismic lateral soil displacements were estimated from the FLAC analysis using the selected 2,475-year return period earthquake records.

The post-seismic soil lateral displacements are estimated to increase from close to zero at the onshore yard to about 2.3 m at the nearshore slope, and then decrease as the effect of the nearshore slope diminishes to about 1.1 m at the middle of the pier and about 0.9 m at the south end of the pier. The soil displacements then increase toward the marine slope. The soil horizonal displacements are shown in Figures 58 and 59.

- **Liquefaction extent**

The representative contours of the excess pore water pressure ratio R_u are shown in Figure 60. The excess pore water pressure ratio (R_u) estimated at the three pile locations (at station. 0+462 where maximum soil displacement was observed, at station. 0+340 - middle of the pier, and at station. 0+220 near the marine slope) are presented in Figure 61.

The soils are considered liquefied when the excess pore water pressure ratio (R_u) is greater than 0.7. The FLAC analysis estimates soil liquefaction extending from the final dredge level to approximately El. – 32 m CD, which is consistent with the results of the simplified seismic analysis which estimates the liquefaction from the final dredge level to El. -37 m CD.

6.10 GROUND IMPROVEMENT

The results of the seismic slope stability and numerical modeling assessments indicate that the nearshore slope can cause seismic-induced ground displacement that affect the pile foundations of the proposed pier. Ground improvement at the nearshore slope can help reduce the seismic-induced ground and pile displacements. Alternatively, structural design can be performed to address the seismic-induced load and ground displacements without ground improvement. The two approaches mentioned above should be analyzed in the detail design phase of the project.

7.0 CONCLUSIONS

Stantec has completed a preliminary geotechnical assessment on a new Outfitting Pier in North Vancouver for Seaspan Vancouver Shipyards. The overall results of the geotechnical assessment are summarized as following:

- Liquefaction is estimated to occur from the dredged ground surface to El. -20 m CD and El. -37 m CD under the 224- and 2475-year return period, respectively.
- The average soil lateral displacements at the ground surface are estimated to be approximately 0.15 m and 1.58 m under the 224 and 2,475-year return periods, respectively.
- Post-seismic settlements of 0.2 m to 0.5 m along the pier are estimated under the 224-year return period, and post-seismic settlements of 0.4 m to 1.3 m along the pier were estimated under the 2475-year return period.
- The ultimate axial capacities in compression of 1220 mm diameter and 25.4 mm thick steel pipe piles are approximately 30 MPa and 28 MPa for a 55 m pile length under the static and seismic conditions (2475-year return period), respectively.
- The slope stability analysis of a cross section along the pier in the north-south direction indicated that the Factor of Safety (FoS) for the static and pseudo-static conditions are larger than 1.6 for both the 224 and 2,475-year return period for all slopes. Under the post-liquefaction condition, the estimated FoS are larger than 1.9 for the overall and marine slope stability; however, a FoS less than 1 was estimated for the nearshore slope.
- The results of post-seismic lateral soil displacement and liquefaction extent obtained from the numerical modeling using representative earthquake records indicated a good agreement with those estimated from the simplified methods.

8.0 CLOSURE

This report was prepared for the exclusive use of the Seaspan Vancouver Shipyards (Seaspan) and its agents for specific application to proposed Outfitting Pier at the Seaspan Vancouver Shipyards in North Vancouver, British Columbia. Any use of this report or the material contained herein by third parties, or for other than the intended purpose, should first be approved in writing by Stantec.

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Regards,

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9.0 REFERENCES

1. Boulanger, R.W. and Idriss, I.M. (2014). CPT and SPT Based Liquefaction Triggering Procedures. Davis: University of California at Davis.

2. Boulanger, R. W., and Ziotopoulou, K. (2015). PM4Sand (Version 3): A sand plasticity model for earthquake engineering applications. Center for Geotechnical Modeling Report No. UCD/CGM-15/01, Department of Civil and Environmental Engineering, University of California, Davis, Calif.

3. Canadian Geotechnical Society. Canadian Foundation Engineering Manual. (2006).

4. Finn, W.L., Dowling, J. and Ventura, C.E. (2016). Evaluating liquefaction potential and lateral spreading in a probabilistic ground motion environment. Soil Dynamics and Earthquake Engineering, 91, pp.202-208.

5. GeoStudio (2018). SLOPE/W: Computer program for slope stability analysis, Version 9.04.15639. Developed by GEOSLOPE International Ltd., Calgary, Alberta.

6. Hatanaka, M., & Uchida, A. (1996). Empirical correlation between penetration resistance and internal friction angle of sandy soils. Soils and foundations, 36(4), 1-9.

7. Idriss, I.M., and Boulanger, R.W. (2008). Soil Liquefaction during Earthquakes. Earthquake Engineering Research Institute.

8. Lpile (2019) Computer program for analyzing stress and deformation of individual piles or drilled shaft under lateral load, Version 2019.11.01. Developed by Ensoft, Inc.

9. Natural Resources Canada (2020). National Building Code of Canada seismic hazard values. http://www.earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php.

10. NBCC (2015). National Building Code of Canada. Published by the National Research Council of Canada, 1200 Montreal Road, Ottawa, ON, K1A 0R6.

11. Robertson, P.K., and Cabal, K.L. (2015). "Guide to Cone Penetration Testing for Geotechnical Engineering." 6th Edition, Gregg Drilling & Testing, Inc.

12. Jibson, R. W., Rathje, E. M., Jibson, M. W., and Lee, Y. W., 2013, SLAMMER -- Seismic Land Movement Modeled using Earthquake Records: U.S. Geological Survey Techniques and Methods, book 12, chap. B1.

13. Olson, S. M., & Johnson, C. I. (2008). Analyzing liquefaction-induced lateral spreads using strength ratios. Journal of geotechnical and geoenvironmental engineering, 134(8), 1035-1049.

14. Ordonez, G.A. (2012) SHAKE2000 – A Computer Program for the 1-D Analysis of Geotechnical Earthquake Engineering Problems. GeoMotions, LLC; Lacey, Washington, USA.

15. Seed, H. B., and Idriss, I. M. (1970). Soil moduli and damping factors for dynamic response analysis. Rep. No. EERC 70-10. Earthquake Engineering Research Centre, Berkeley, CA.

16. Youd, T.L., Hansen, C.M., and Bartlett, S.F. (2002). "Revised Multilinear Regression Equations for Prediction of Lateral Spread Displacement." Journal of Geotechnical and Geoenvironmental Engineering 128 (12): 1007-1017.

FIGURES

Reference Drawing List:

Existing wood & concrete Pile Plan from 216131-201 -1- C.dwg
Outfitting Pier Layout from Concept Layout Draft6.dwg
Geotech Investigation Map From VFPA S2019-013.dwg
Vancouver shipyard Base Plan from Simplified Site Plan.dwg
Borehole and CPT/SCPT from Test_Hole_Plan.dwg
Bathymetric data from Merged-Bathy-Contours.dwg

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Revision	By	Appd.	YY.MM.DD

LEGEND:

⊕ BOREHOLE 60m	— — DREDGE POCKET
⊕ BOREHOLE 10m	VESSEL OUTLINES
— GROUND IMPROVEMENT	▨ RIP RAP
— OUTFITTING PIER	▼ CPT/SCPT
🟥 BUILDINGS	
▨ MARINE TRANSPORTATION SERVICES	

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seaspan

SEASPAN VANCOUVER SHIPYARDS
OUTFITTING PIER EXPANSION
NORTH VANCOUVER, BRITISH COLUMBIA

File Name: 115619249_001.DWG	DWN	CHK	DSG	DTE
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Title

SITE GENERAL ARRANGEMENT

Project No.
115619249

Scale 1:750 0 7.5 22.5 37.5m

Drawing No.
FIGURE 1

Revision
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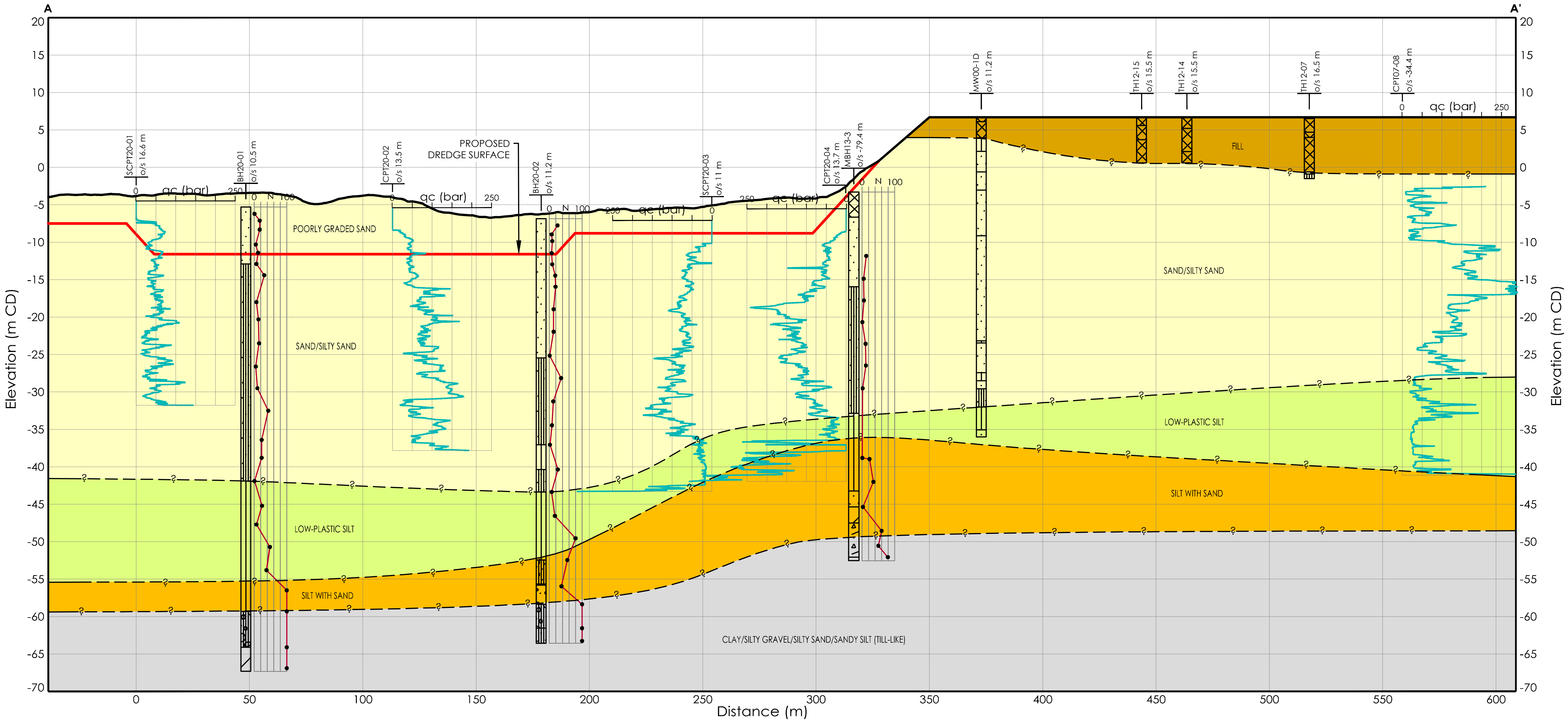
ORIGINAL SHEET - ARCH D



CROSS SECTION A-A' - ALONG THE PIER

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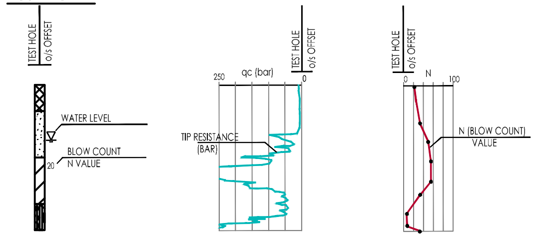
VERTICAL EXAGGERATION: APPROX. 3V:1H

POST LEGEND



MATERIAL SYMBOLS

- ⁙ Sand - poorly graded
- ▥ Sand - silty
- ▥ Silt - inorganic
- ▦ Gravel - silty
- ◪ Clay
- ▥ Sand - poorly graded
- ⁙ Sand - well graded
- ■ Asphalt
- ☒ Fill

LEGEND

- 🟧 Fill
- 🟨 Sand/Silty Sand
- 🟧 Silt with Sand
- 🟩 Low-Plastic Silt
- ⬜ Till-like Soils
- 🟥 Proposed Dredge Surface

NOTE: Elevation in Chart Datum (CD)

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Sources
- Bathymetry Surface from Bathymetric Data from Merged-Bathy-Contours.dwg
- Proposed Dredge Surface from Stantec Drawing 115619249-102 Rev. A, Dated 2020.05.11
- Borehole and CPT/SCPT from Test_Hole_Plan.dwg

Project Information

Project No.:	115619249
Scale:	1:2000
Date:	2020-OCT-01
Drawn by:	G. HUYNH
Checked by:	N. GAUTAM

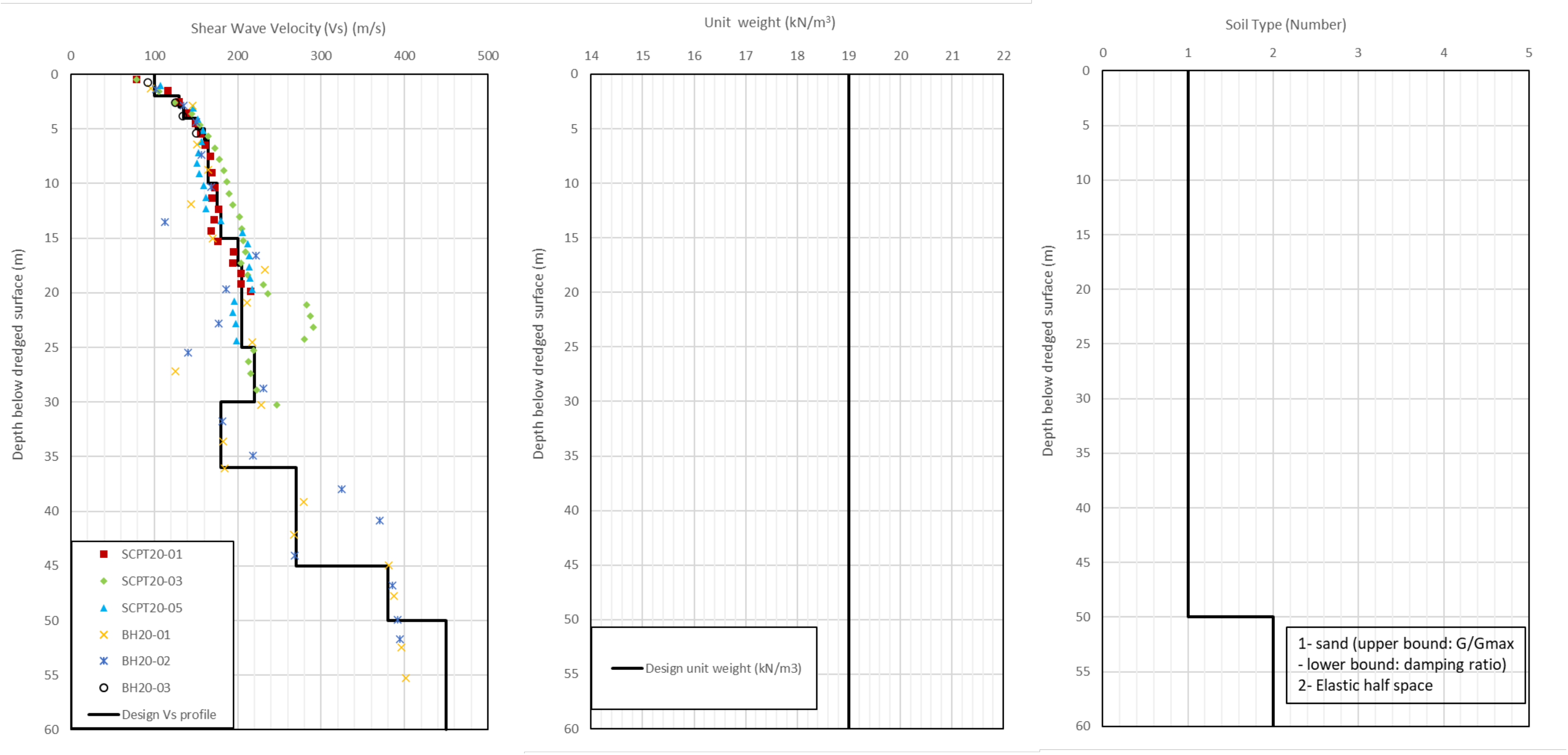
Project Location
NORTH VANCOUVER, BRITISH COLUMBIA

Client/Project
SEASPAN VANCOUVER SHIPYARDS

SEASPAN OUTFITTING PIER EXPANSION

TITLE
CROSS SECTION A-A'

Figure No.
2



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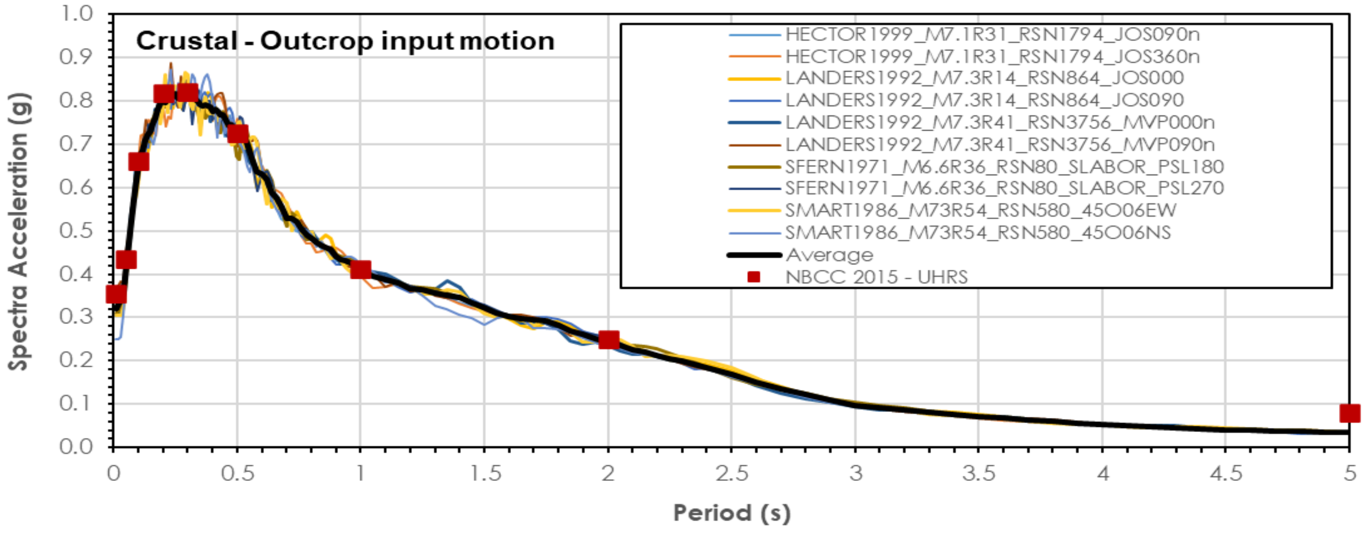
Prepared by: SM
Checked by: VT

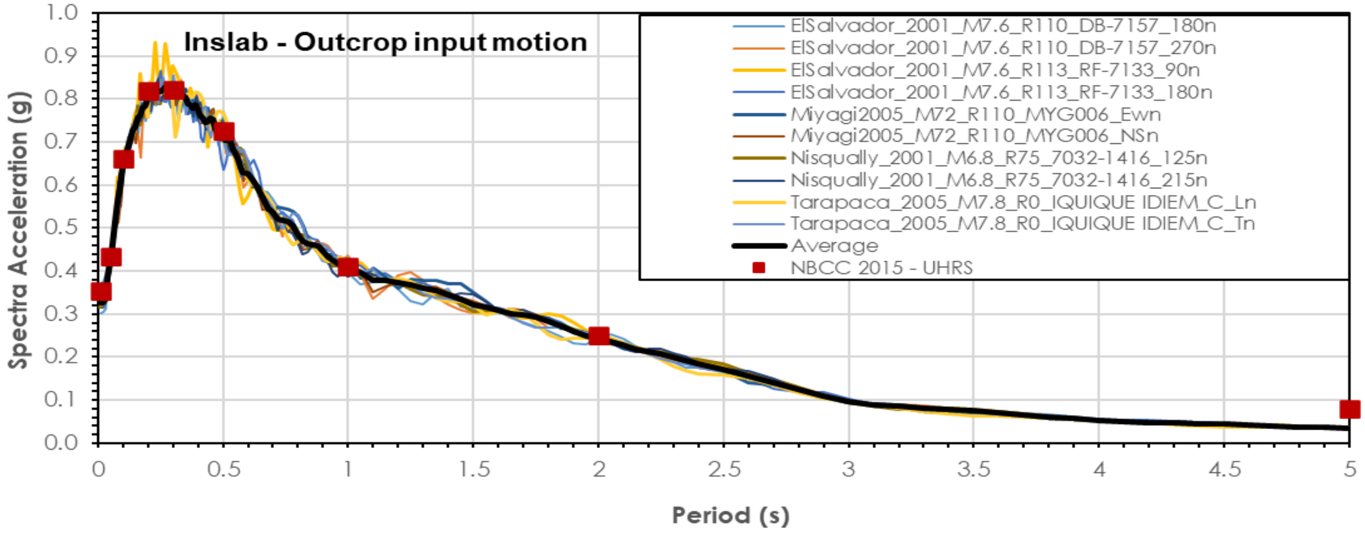
Client/Project
Seaspan Vancouver Shipyards

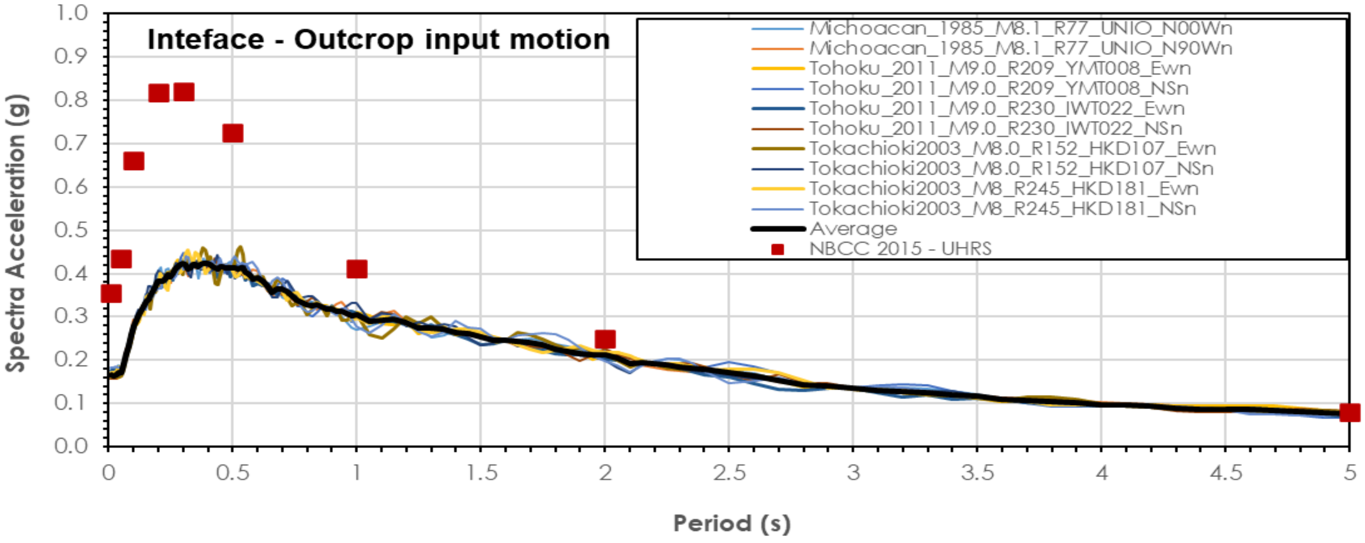
Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Design Profile for Seismic Ground Response Analysis

Figure No.
3







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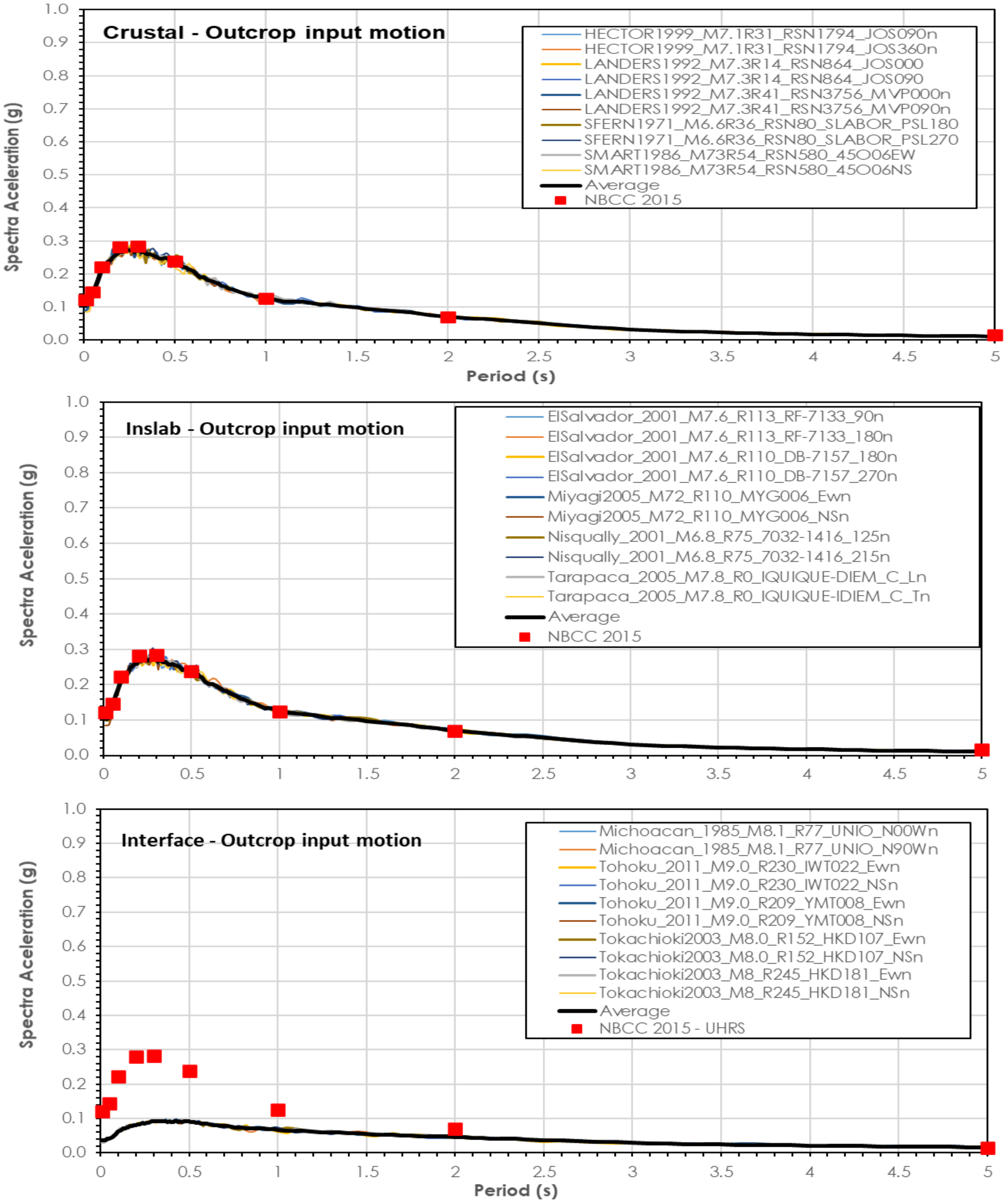
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Spectral Acceleration for 5% Damping
Earthquake Outcrop Records
2475-Year Return Period

Figure No.
4



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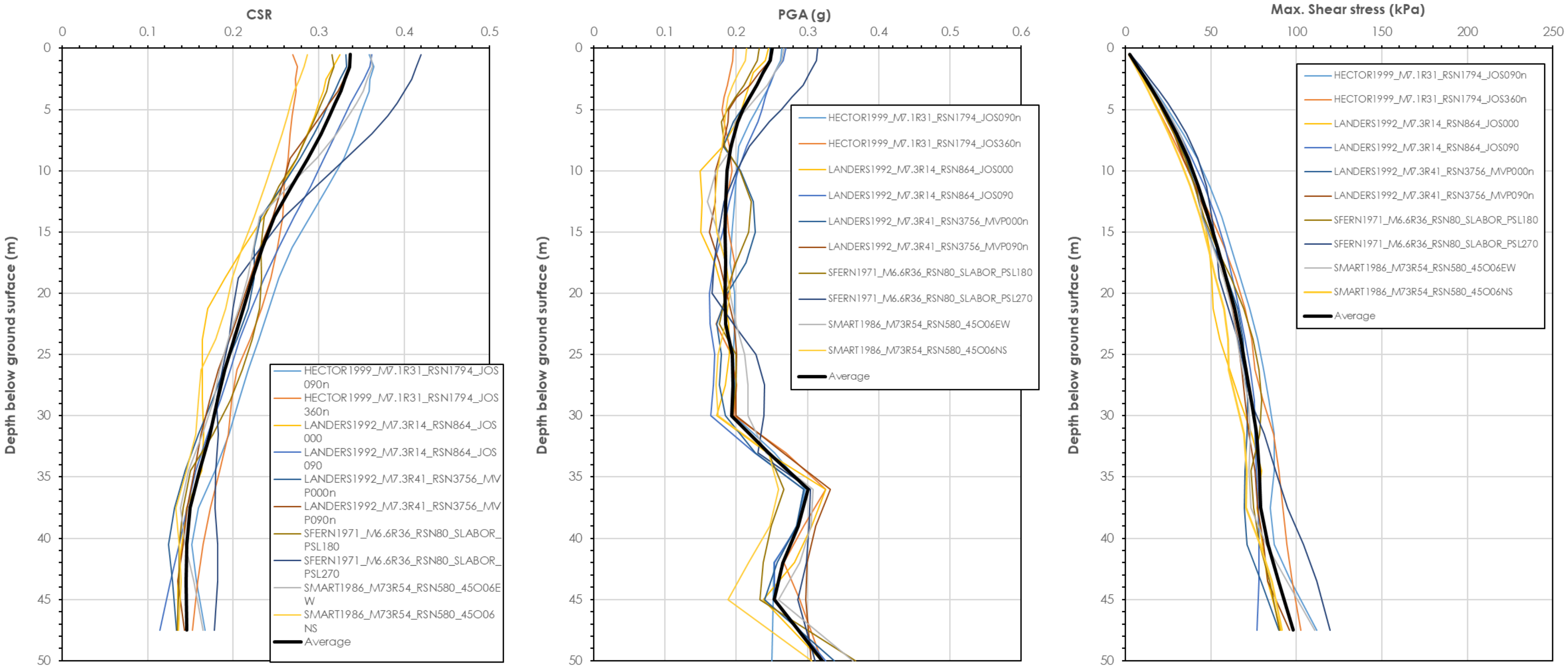
Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Spectral Acceleration for 5% Damping
Earthquake Outcrop Records
224-Year Return Period

Figure No.
5



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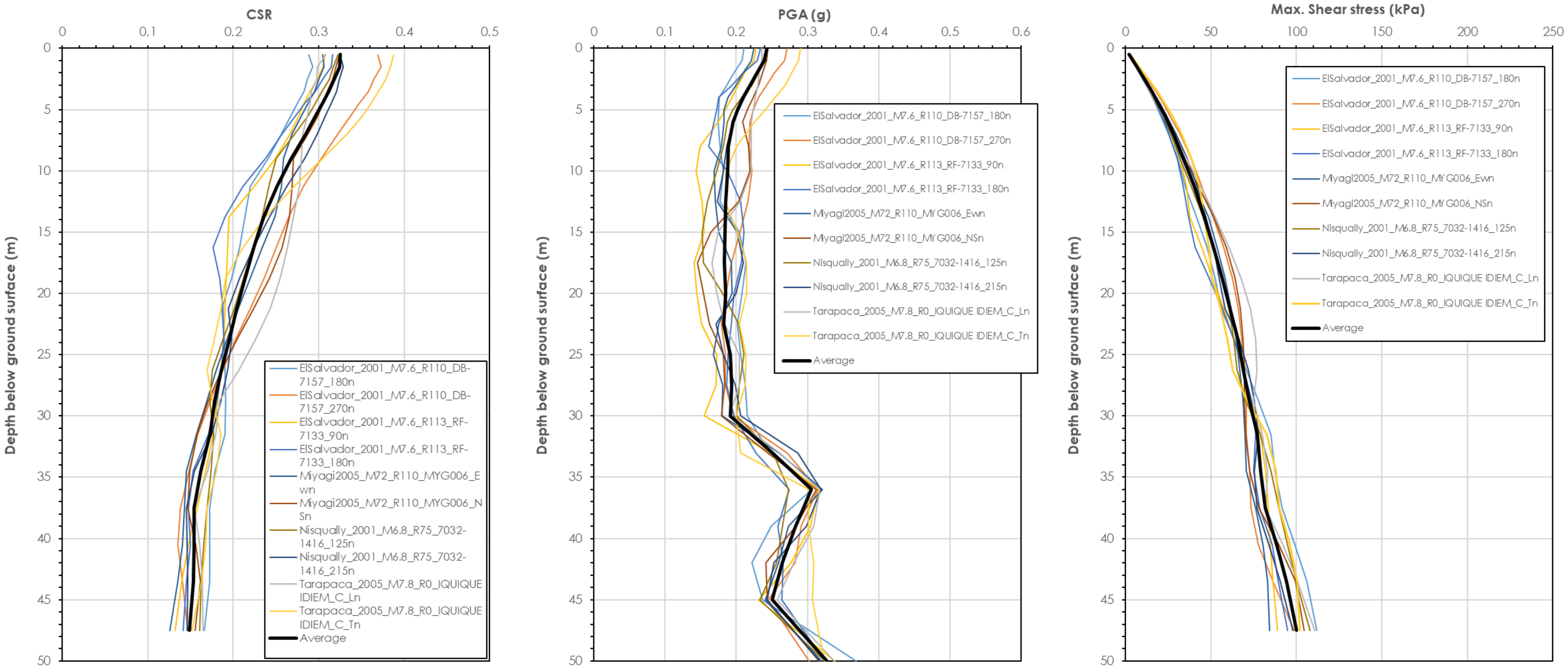
Outfitting Pier Expansion
North Vancouver, British Columbia

Title
CSR, PGA, and τ_{max} Profiles
Crustal Earthquake Records
2475-Year Return Period

Figure No.
6



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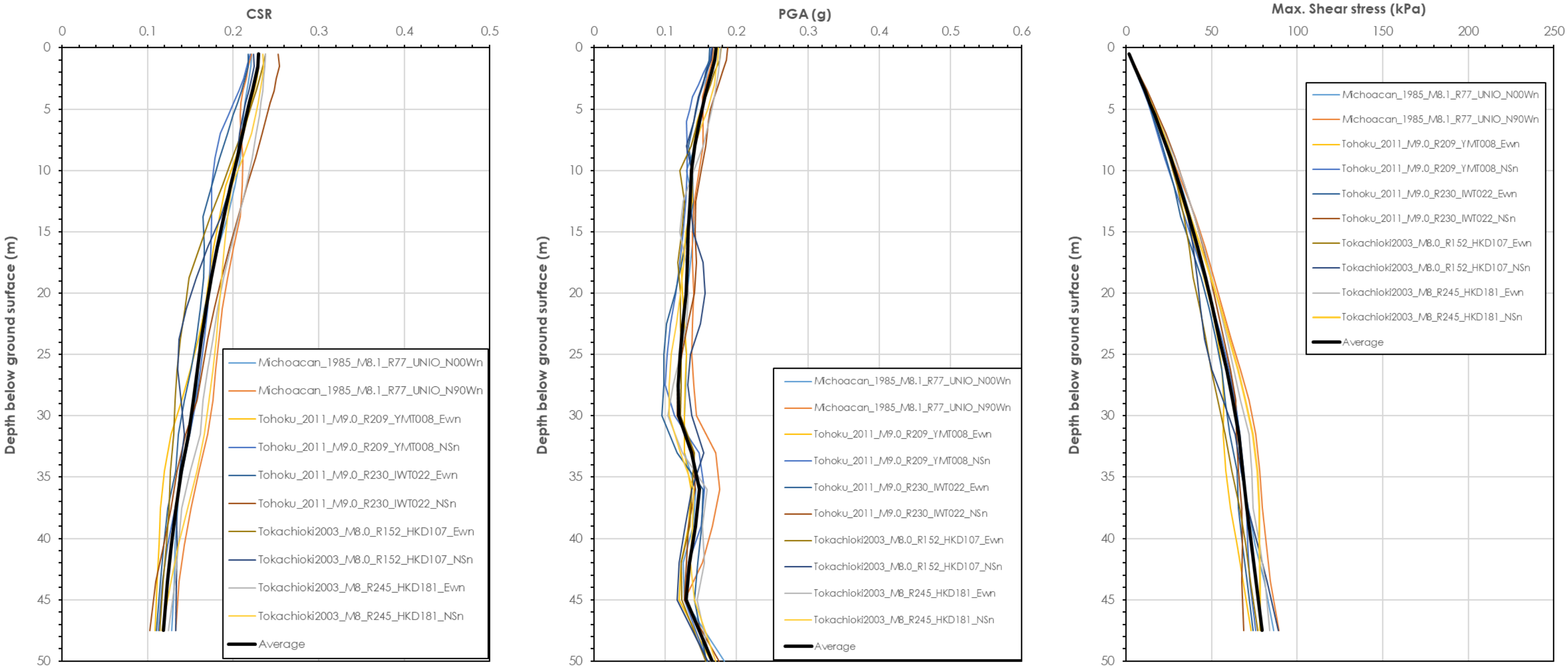
Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
CSR, PGA, and τ_{max} Profiles
Inslab Earthquake Records
2475-Year Return Period

Figure No.
7



Stantec

Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project

Seaspan Vancouver Shipyards

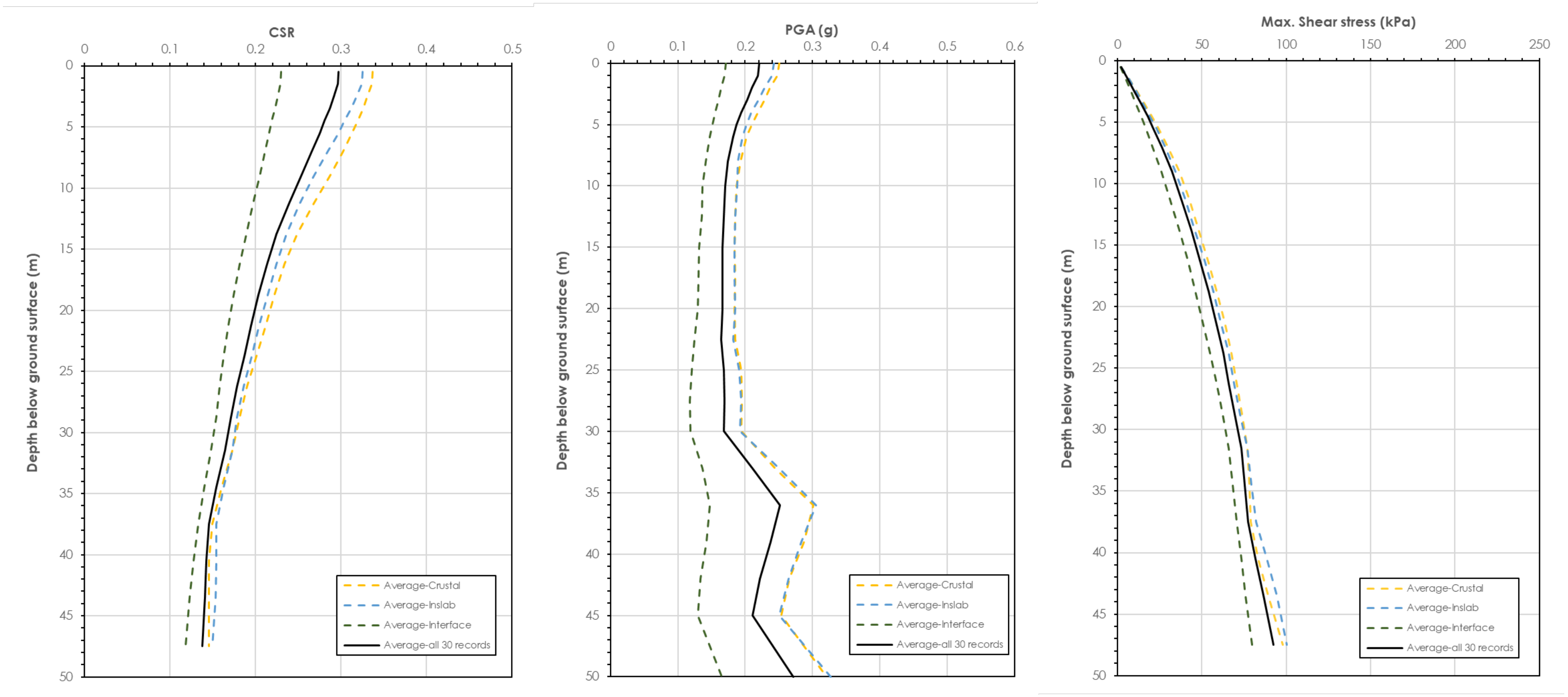
Outfitting Pier Expansion
North Vancouver, British Columbia

Title

CSR, PGA, and τ_{max} Profiles
Interface Earthquake Records
2475-Year Return Period

Figure No.

8



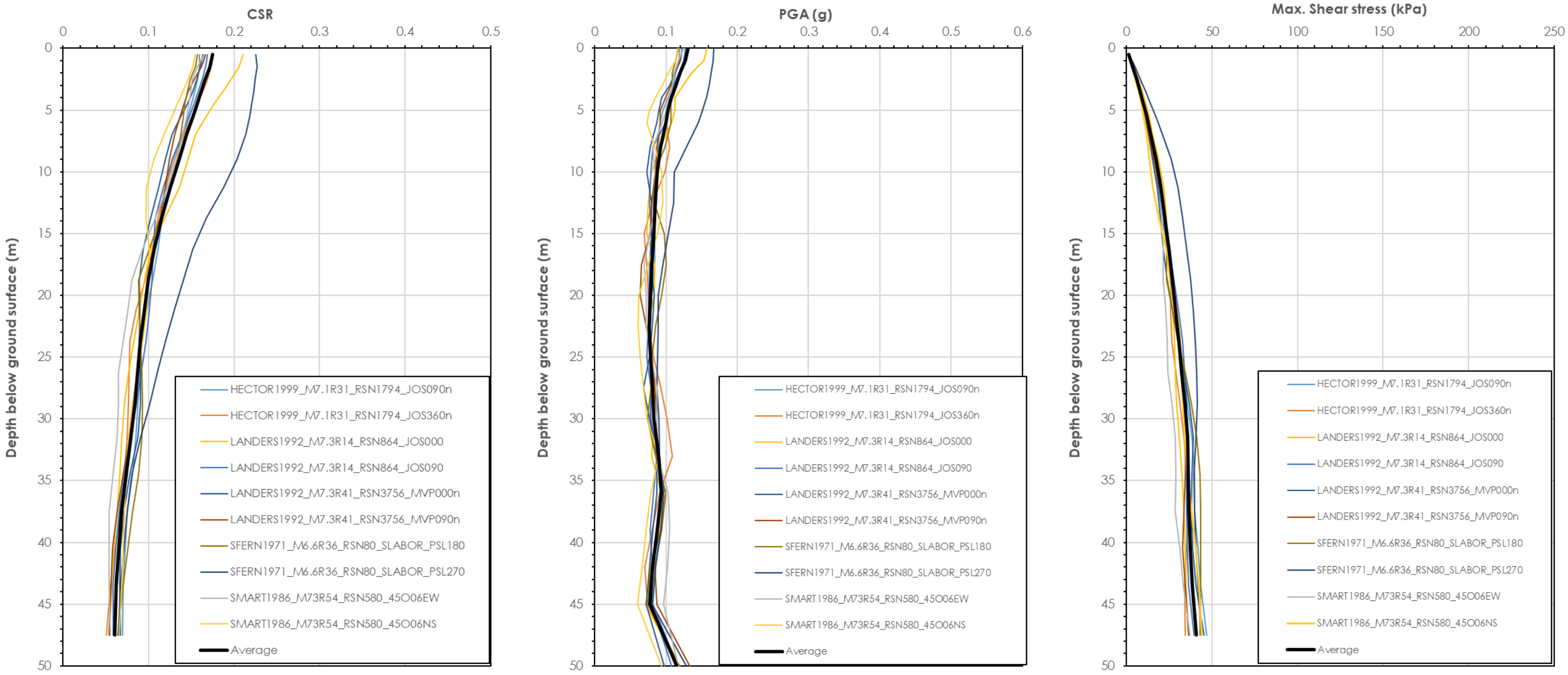
Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
CSR, PGA, and τ_{max} profiles
Average of Crustal, Inslab and Interface Records
2475-Year Return Period

Figure No.
9



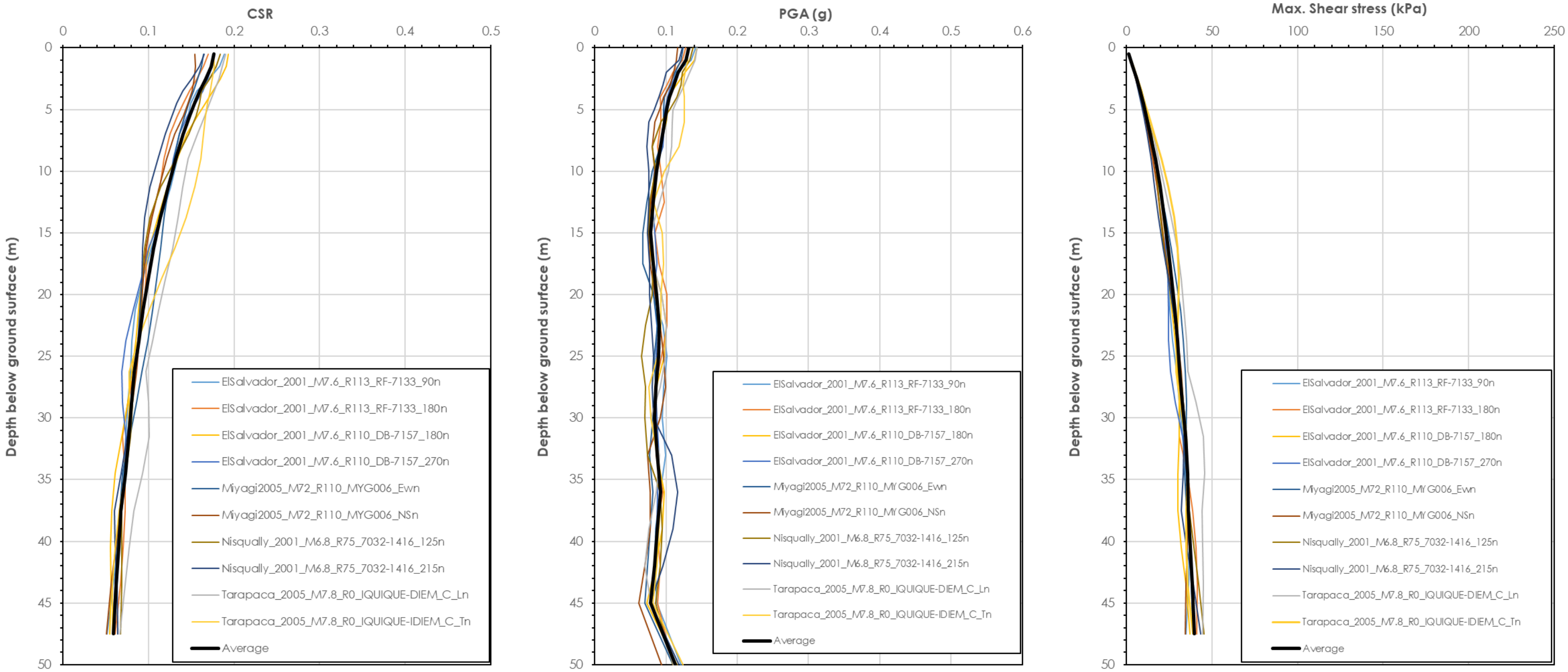
Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
CSR, PGA, and τ_{max} Profiles
Crustal Earthquake Records
224-Year Return Period

Figure No.
10



Stantec

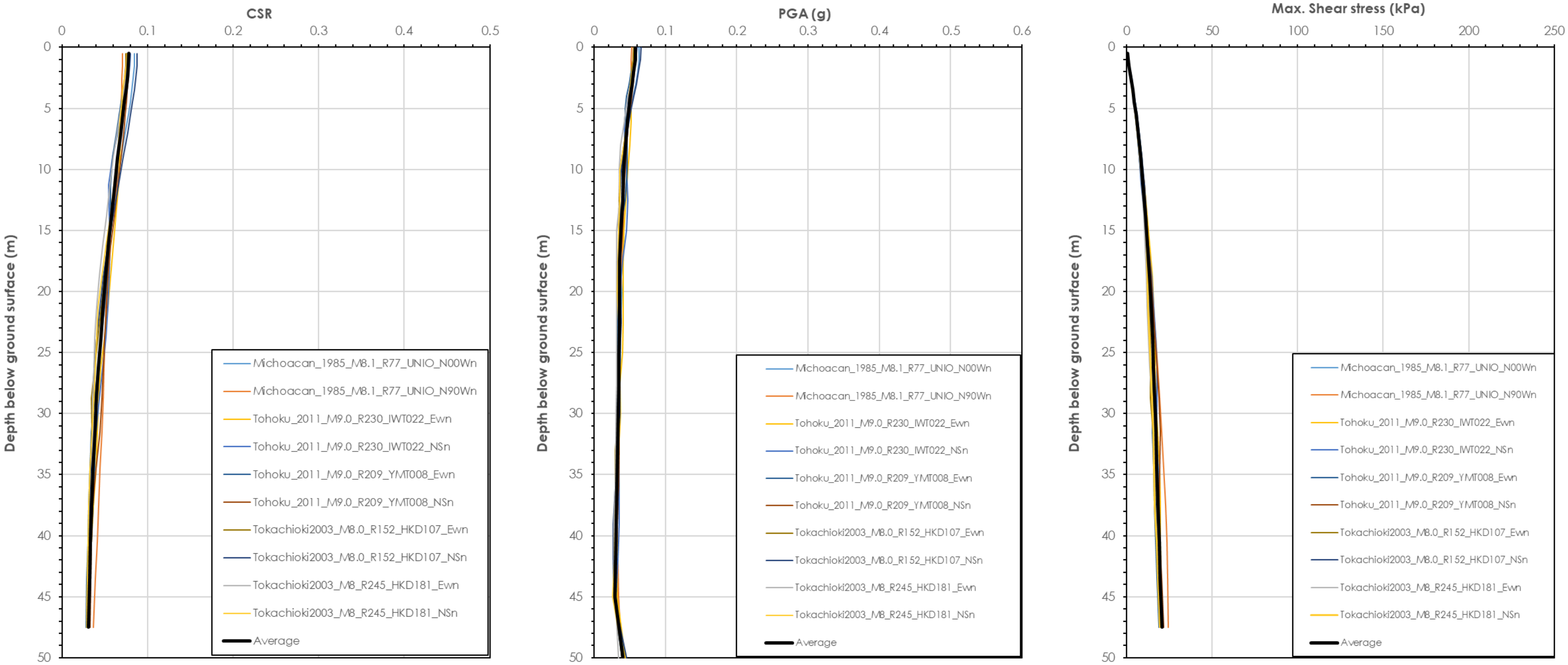
Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
CSR, PGA, and τ_{max} Profiles
Inslab Earthquake Records
224-Year Return Period

Figure No.
11



Stantec

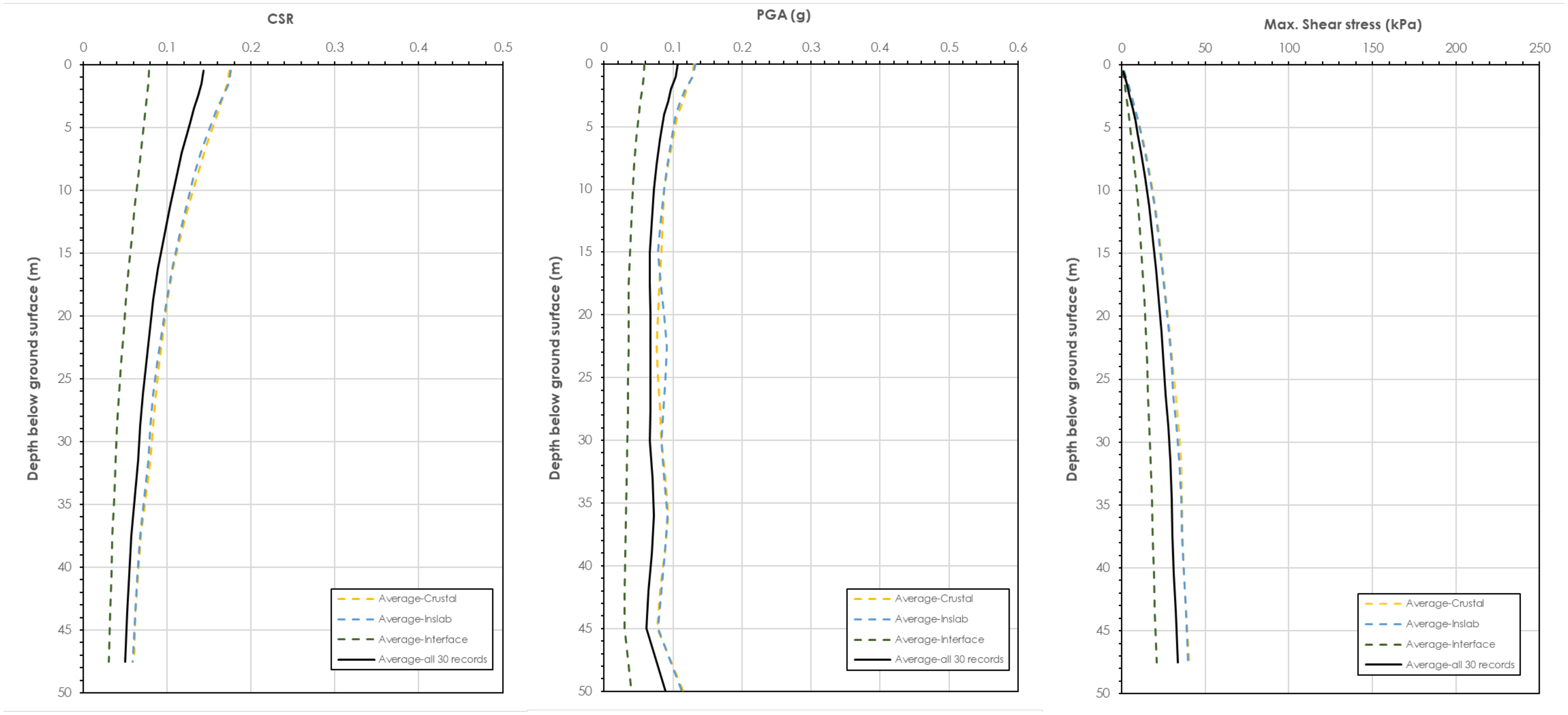
Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
CSR, PGA, and τ_{max} Profiles
Interface Earthquake Records
224-Year Return Period

Figure No.
12



Project No.:	115619249
Scale:	---
Date:	06-Oct-20
Prepared by:	SM
Checked by:	VT

Client/Project

Seaspan Vancouver Shipyards

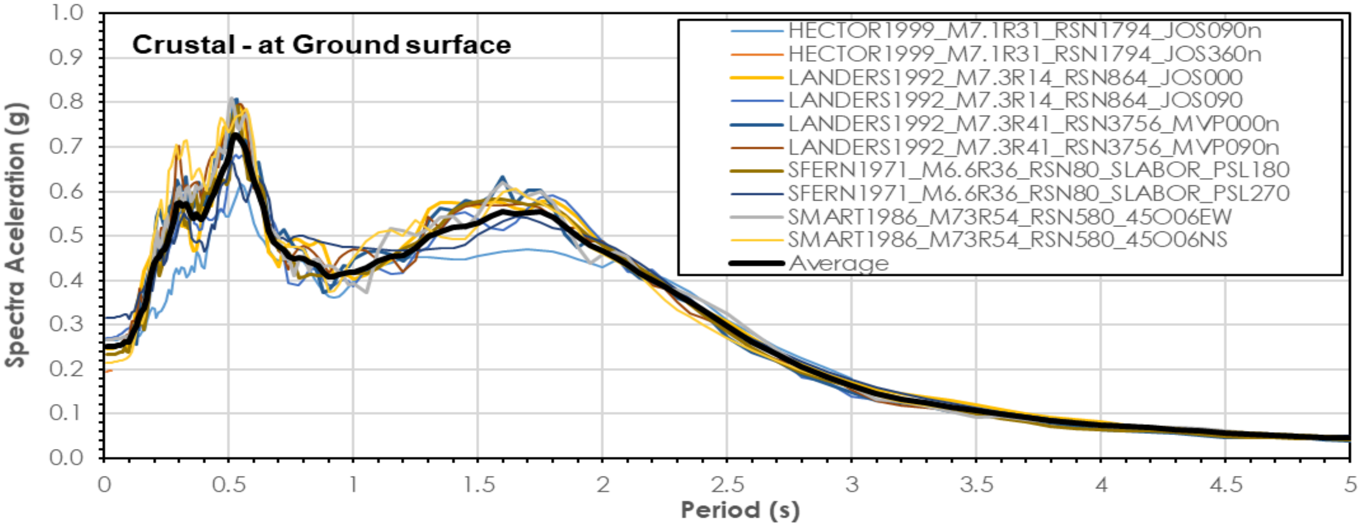
Outfitting Pier Expansion
North Vancouver, British Columbia

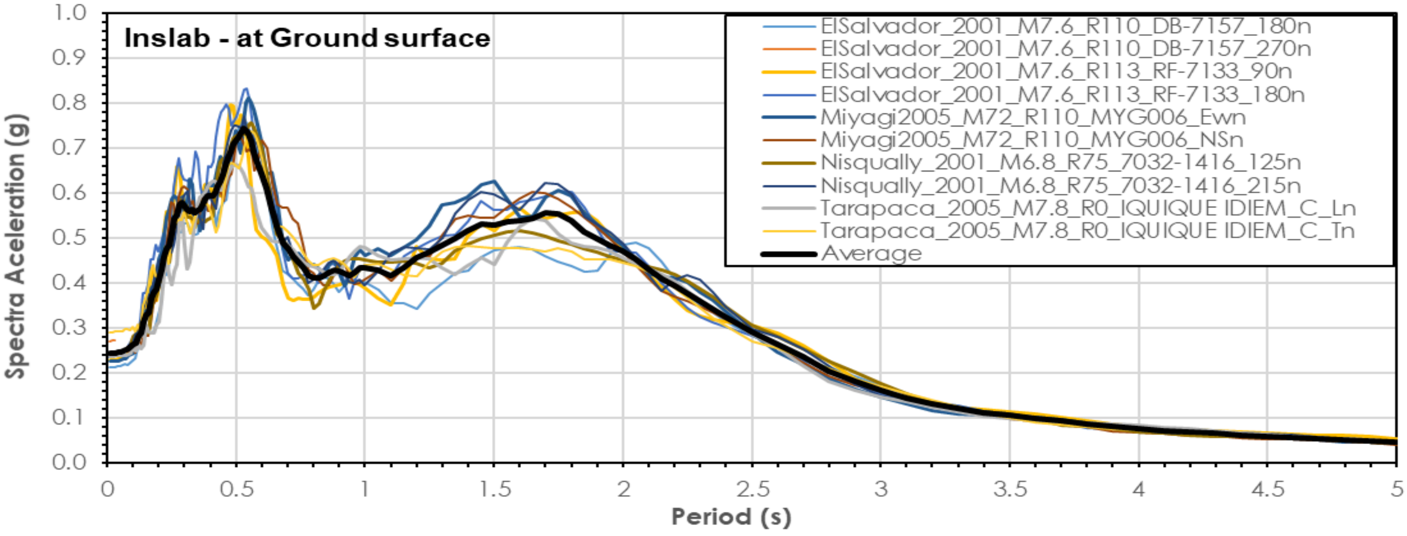
Title

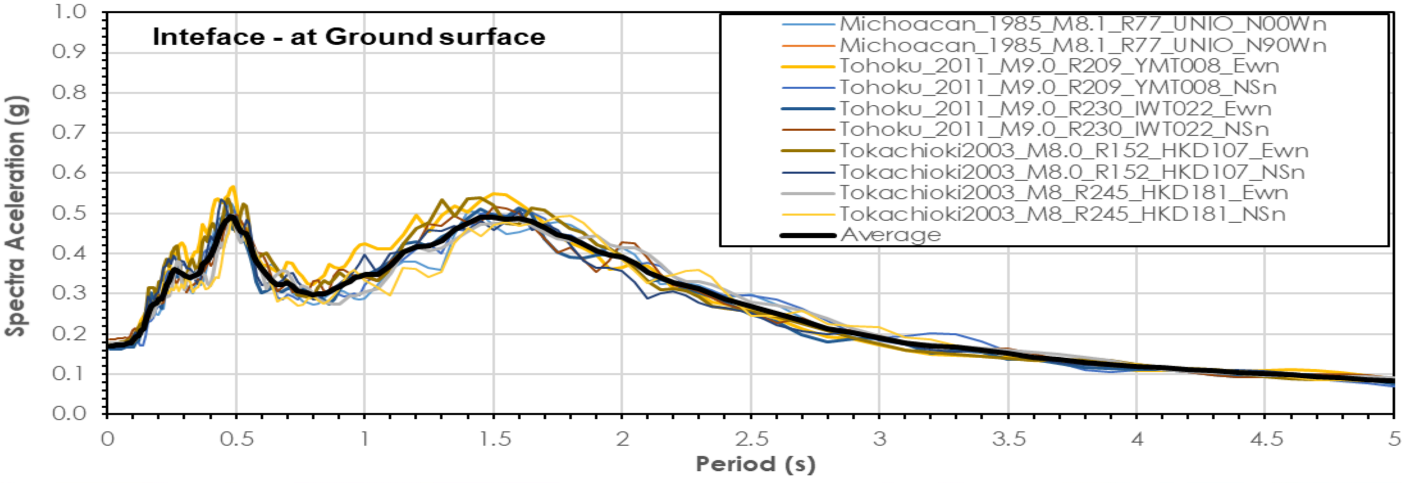
CSR, PGA, and τ_{max} profiles
Average of Crustal, Inslab and Interface Records
224-Year Return Period

Figure No.

13







Stantec

Project No.:	115619249
Scale:	---
Date:	06-Oct-20
Prepared by:	SM
Checked by:	VT

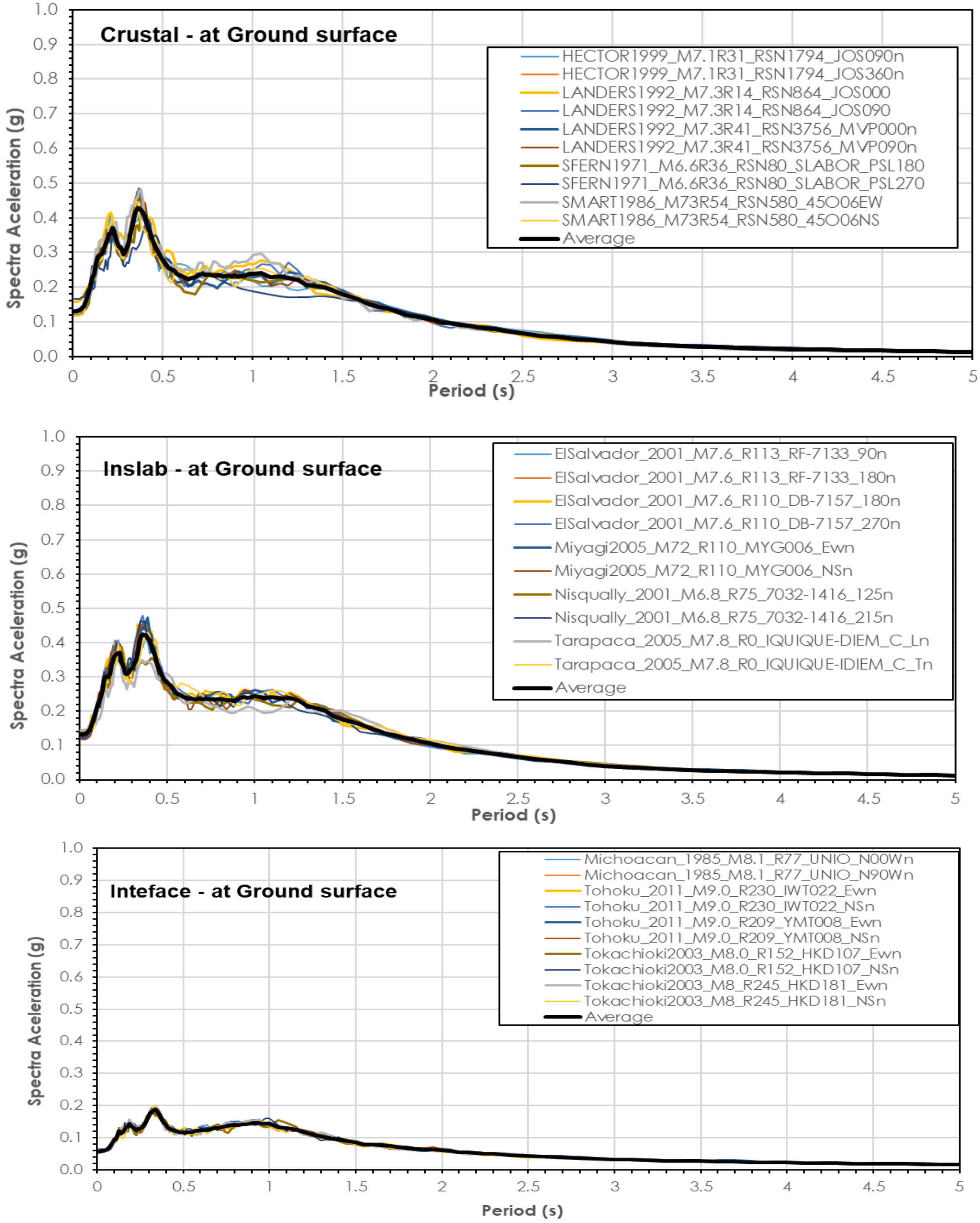
Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Acceleration Response Spectra
for 5% Damping at Ground Surface
2475-Year Return Period

Figure No.
14



Stantec

Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

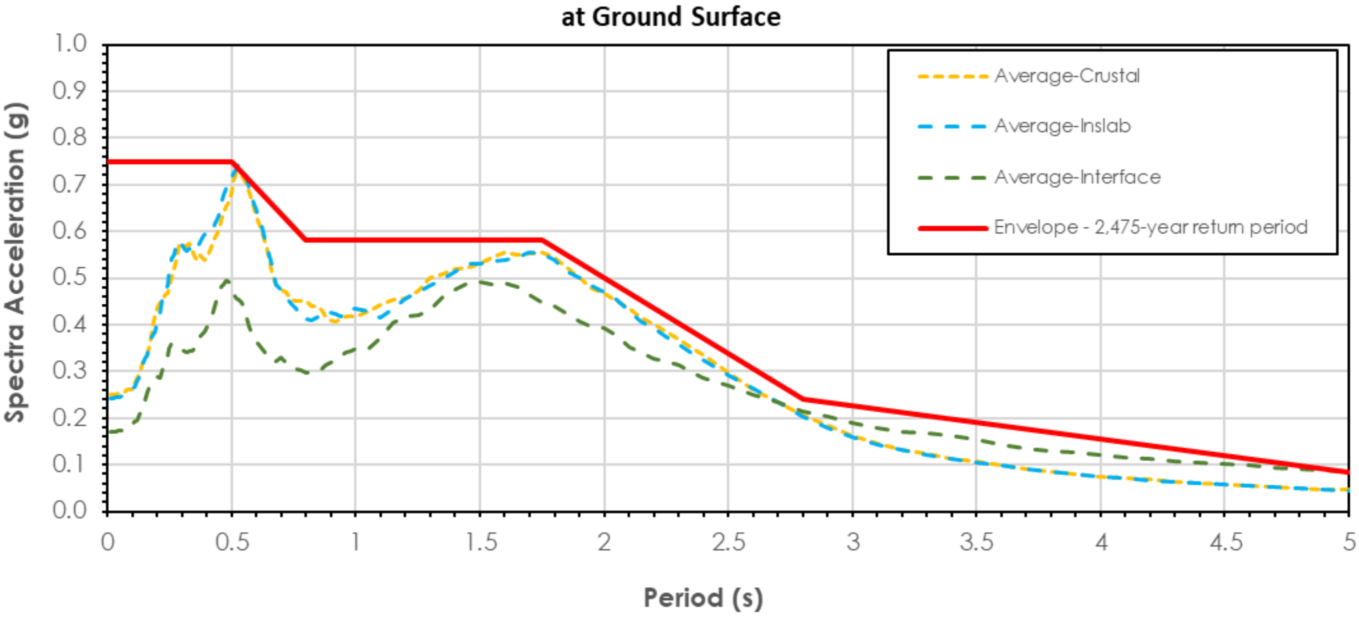
Client/Project

Seaspan Vancouver Shipyards

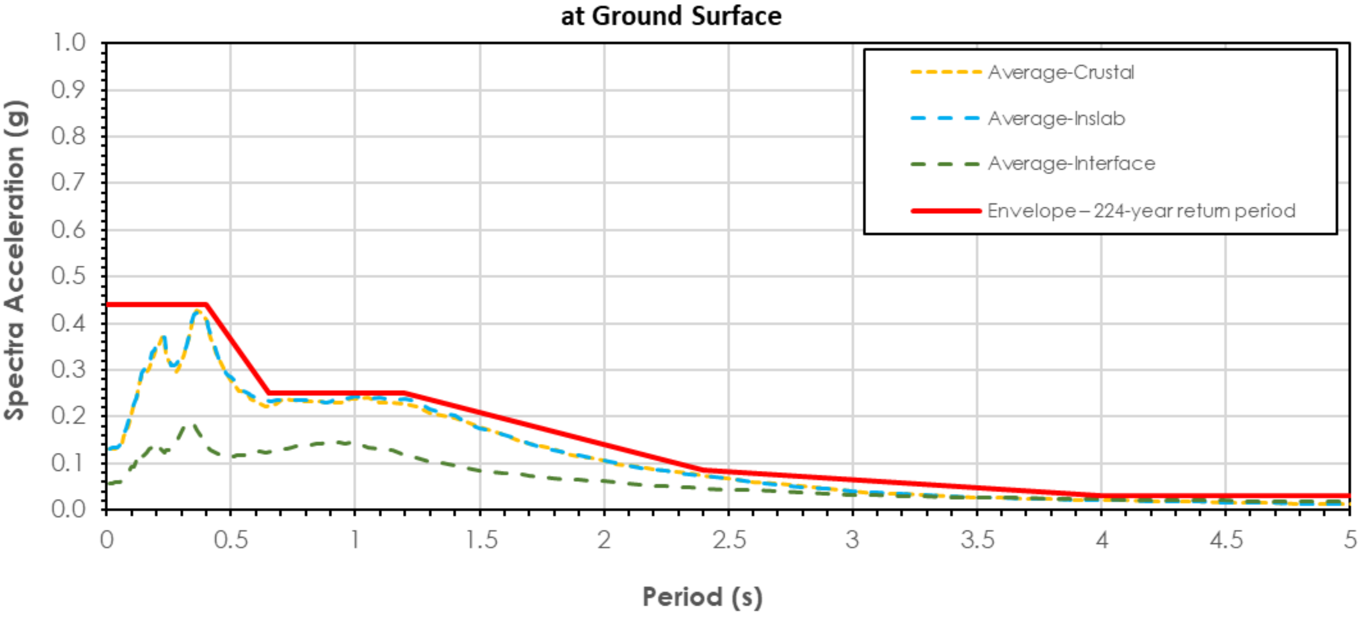
Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Acceleration Response Spectra
for 5% Damping at Ground Surface
224-Year Return Period

Figure No.
15



a) 2,475-year return period



b) 224-year return period

Stantec

Project No.: 115619249
Scale: ---
Date: 06-Oct-20
Prepared by: SM
Checked by: VT

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

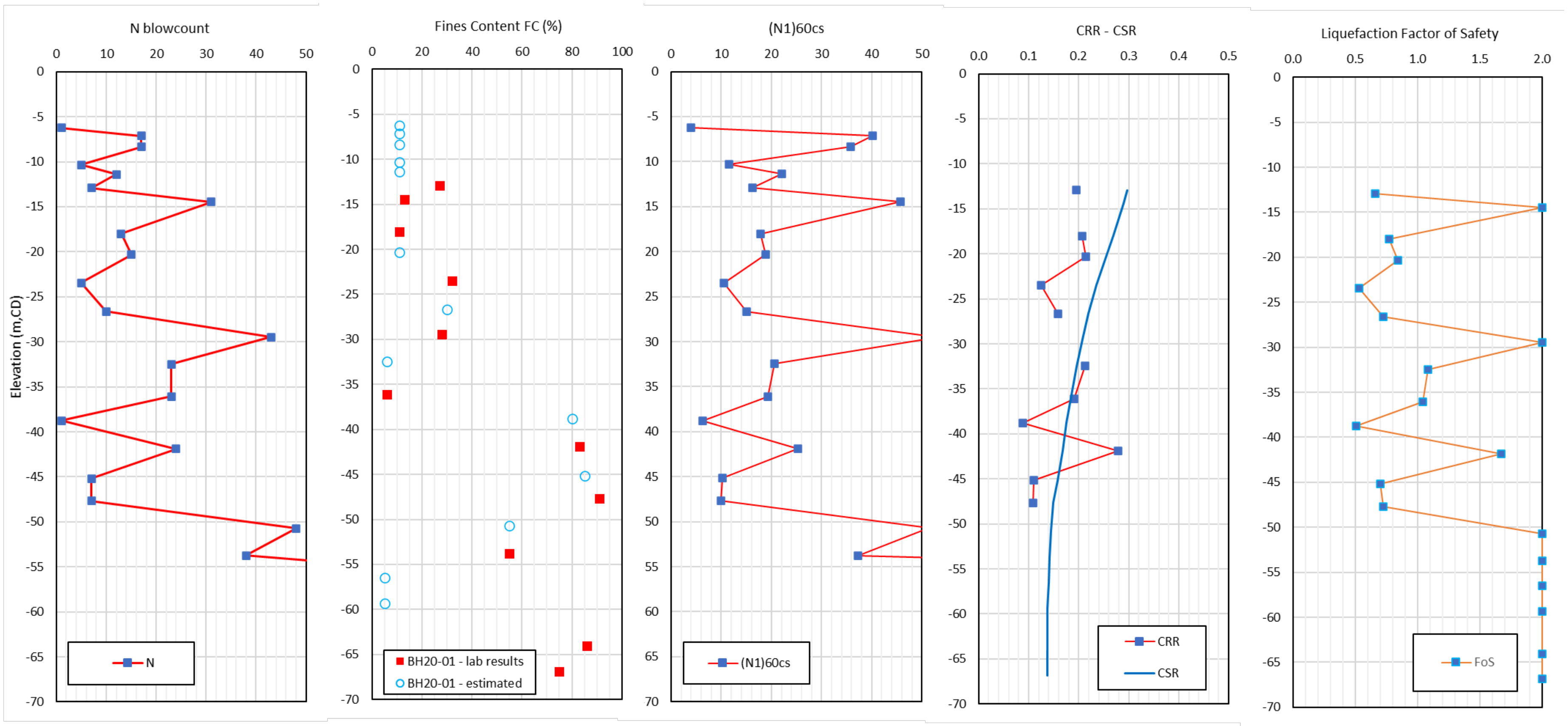
Title

Acceleration Response Spectra
for 5% Damping at dredged ground surface

Figure No.

16

BH 20-01



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

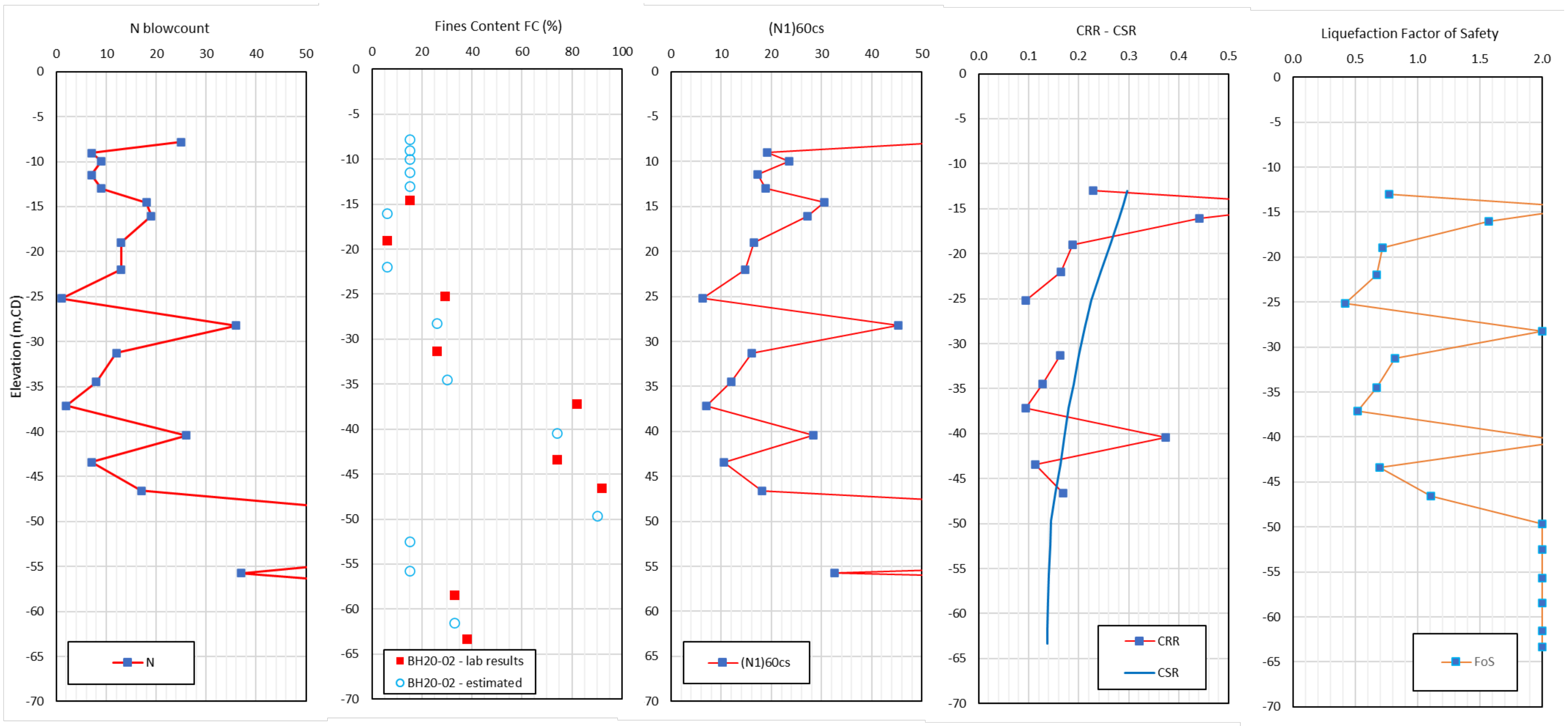
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Liquefaction assessment results
BH20-01 – 2,475-year return period

Figure No.
17

BH 20-02



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

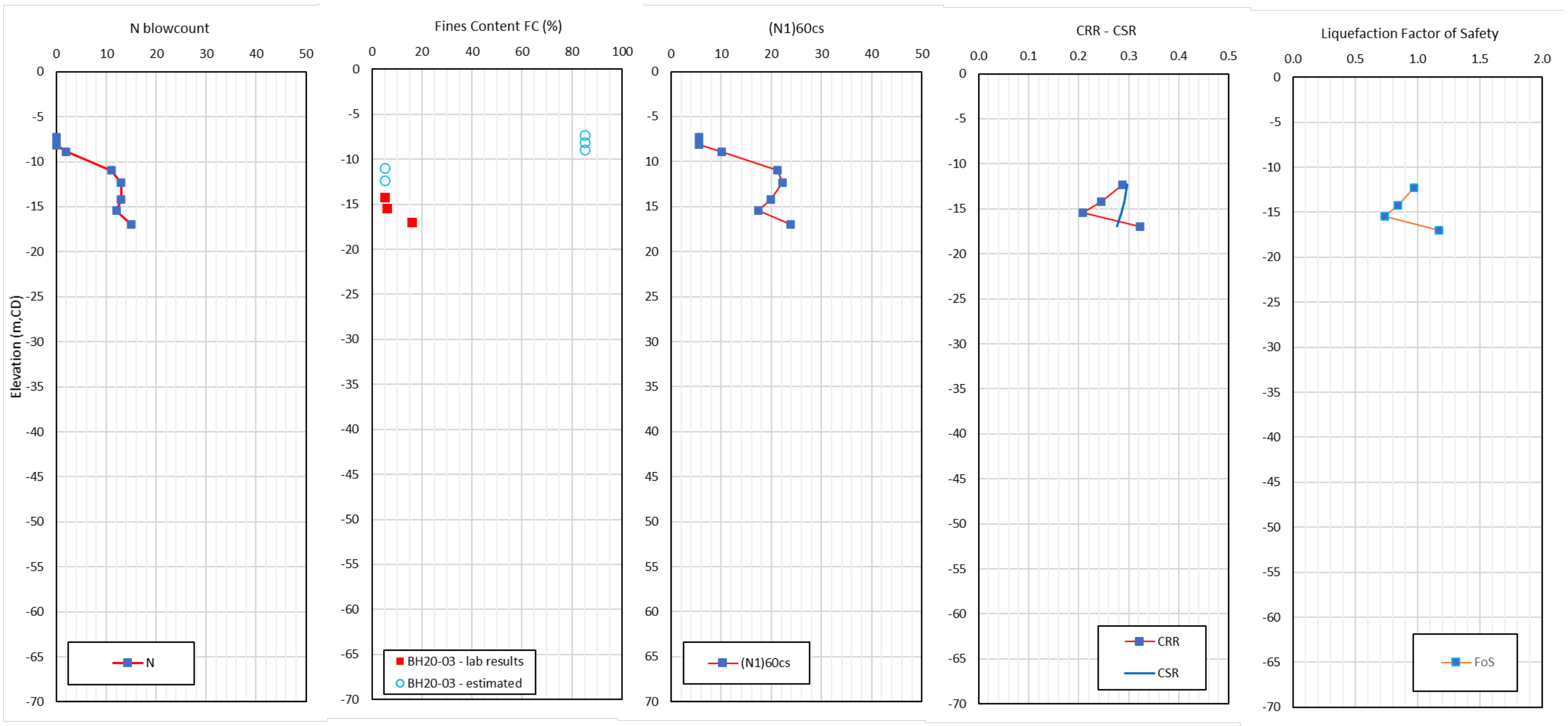
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Liquefaction assessment results
BH20-02 – 2,475-year return period

Figure No.
18

BH 20-03



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

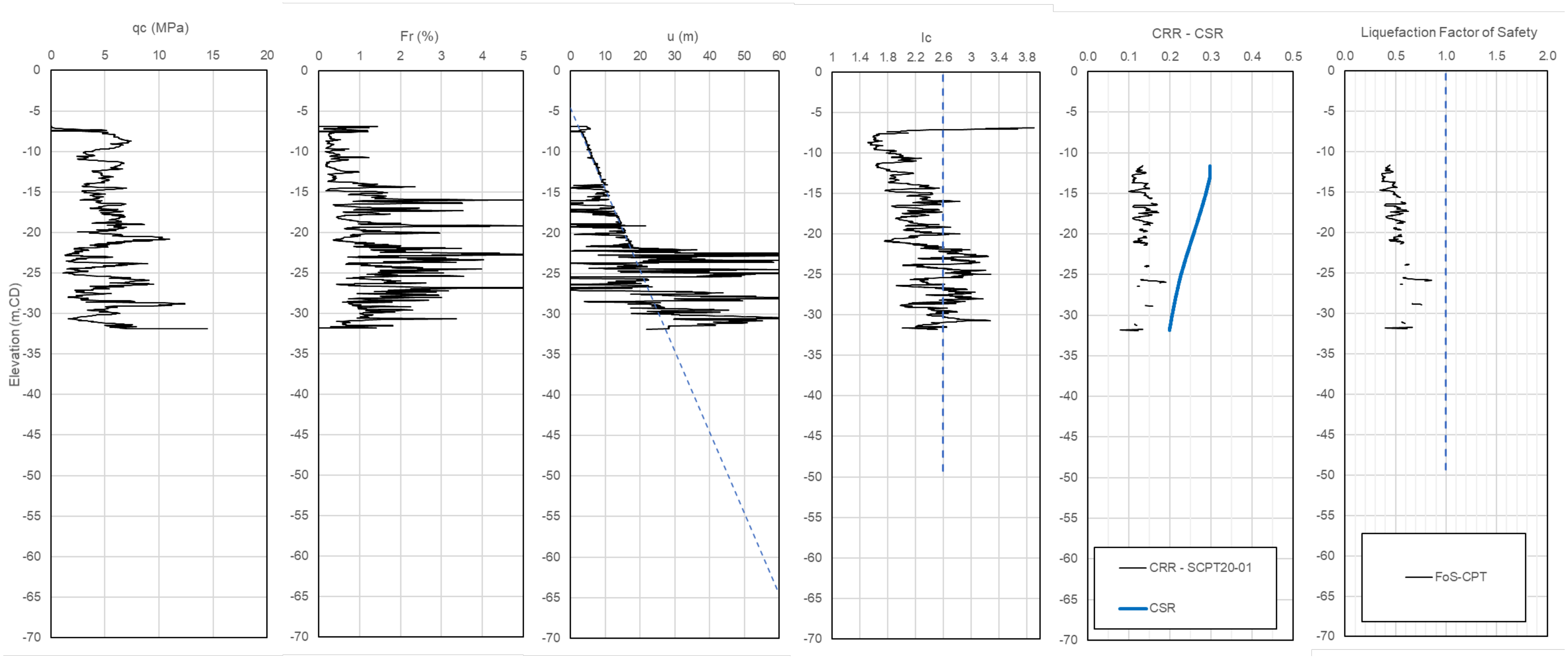
Title

Liquefaction assessment results
BH20-03 – 2,475-year return period

Figure No.

19

SCPT 20-01



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

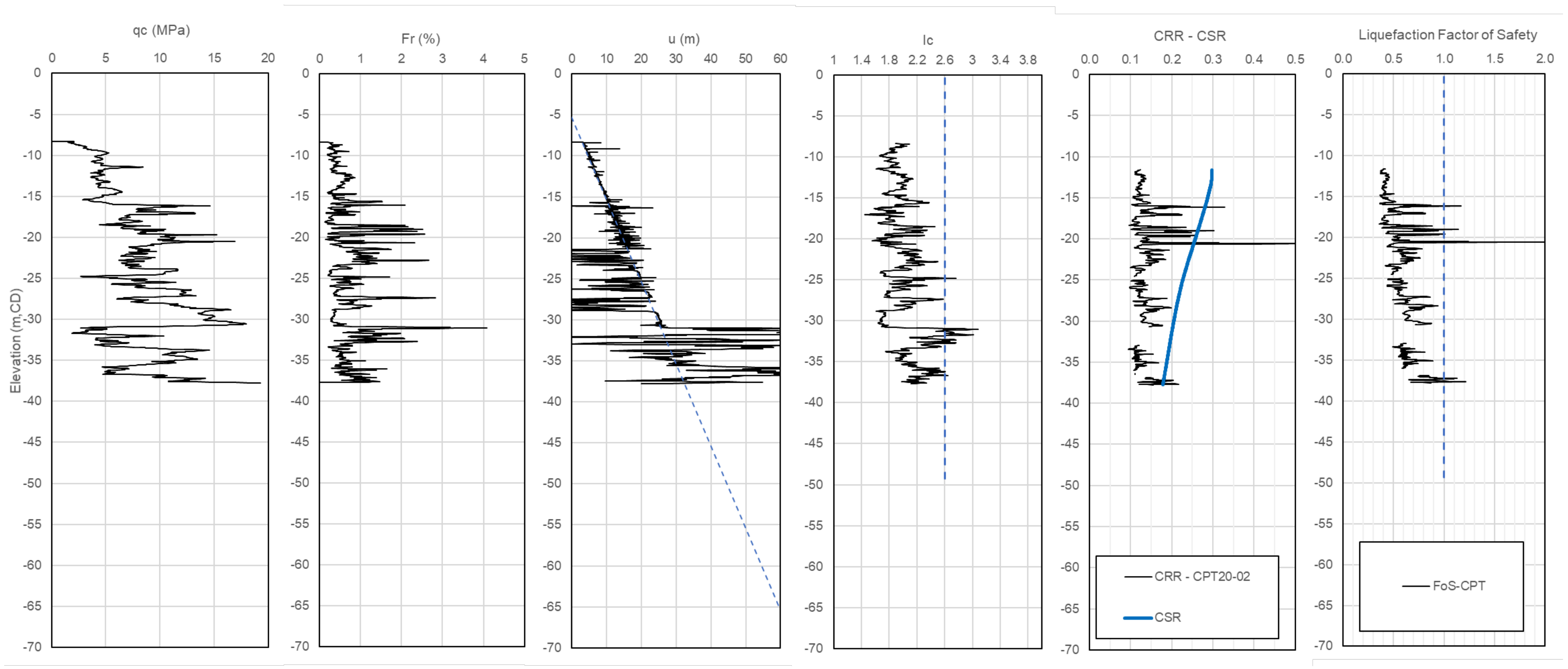
Title

Liquefaction assessment results
SCPT20-01 – 2,475-year return period

Figure No.

20

CPT 20-02



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

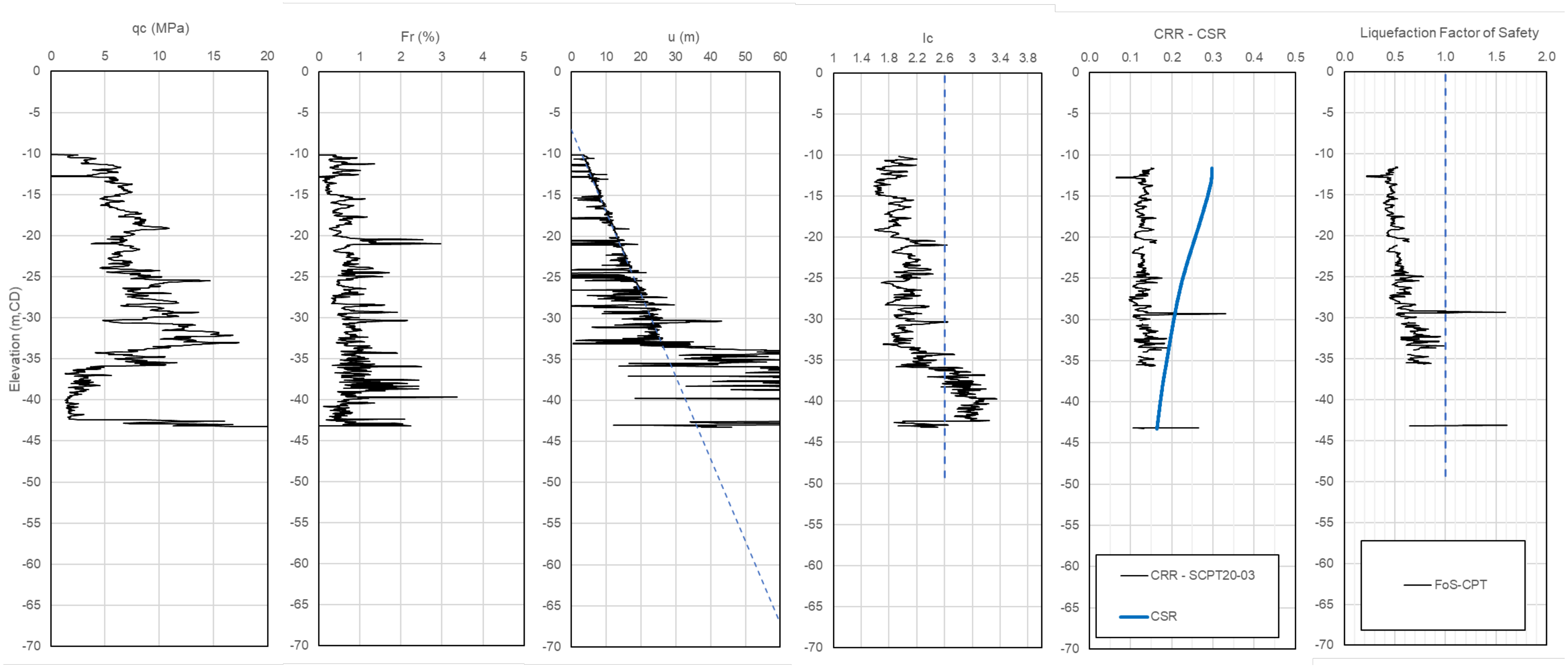
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Liquefaction assessment results
CPT20-02 – 2,475-year return period

Figure No.
21

SCPT 20-03



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

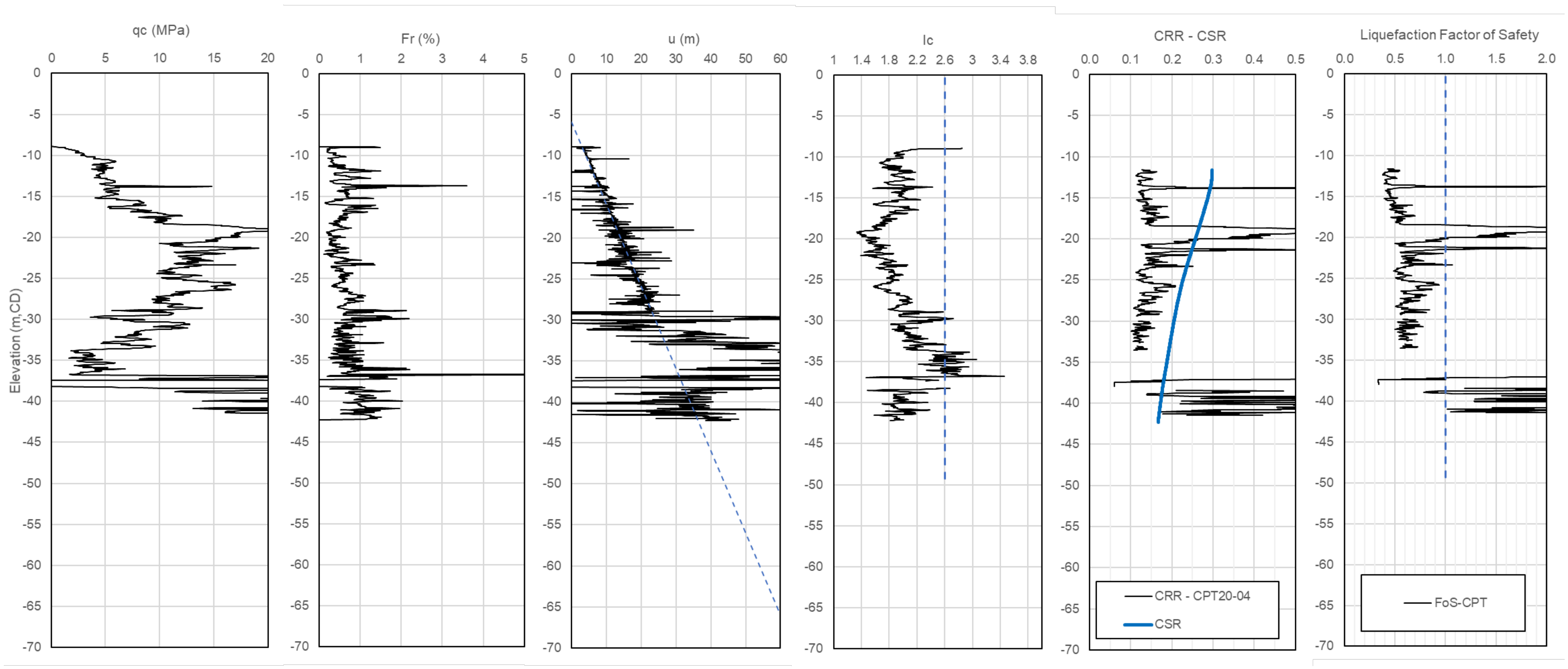
Title

Liquefaction assessment results
SCPT20-03 – 2,475-year return period

Figure No.

22

CPT 20-04



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

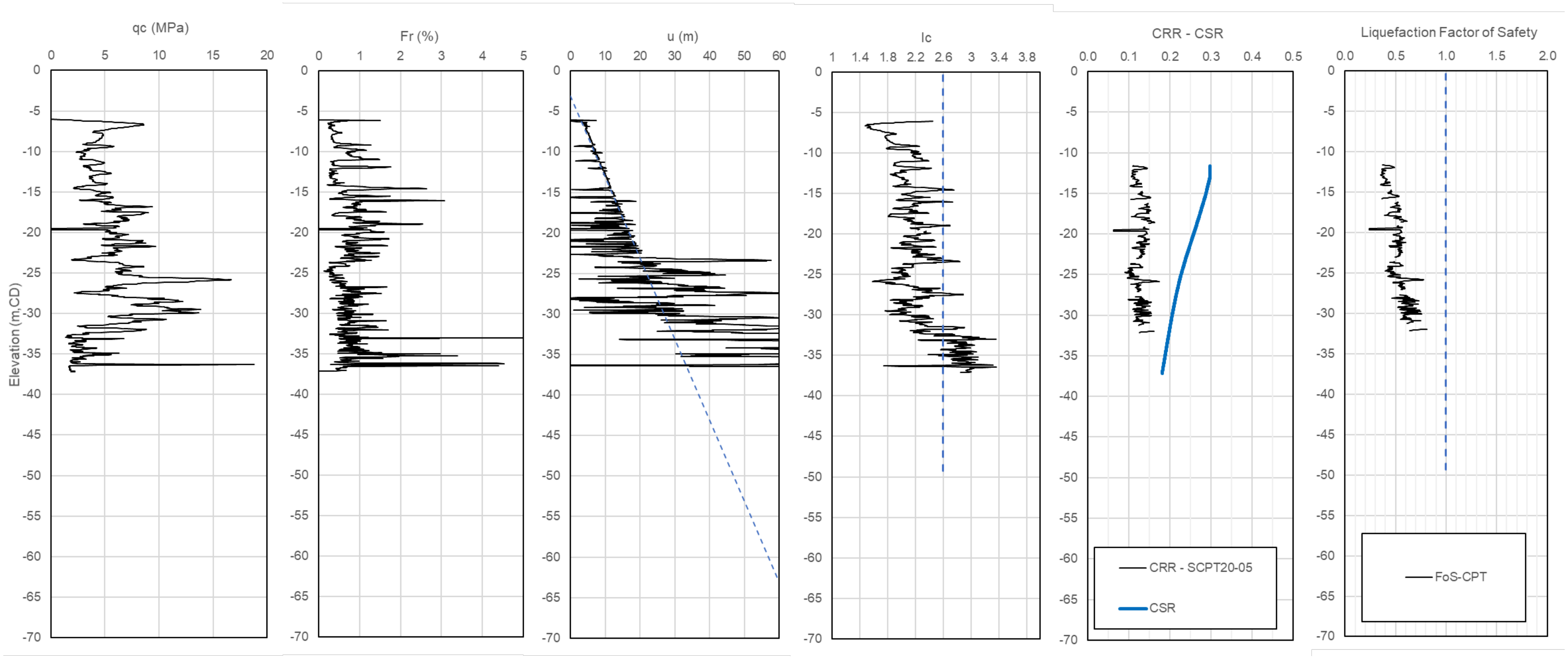
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Liquefaction assessment results
CPT20-04 – 2,475-year return period

Figure No.
23

SCPT 20-05



Notes:

- CSR obtained from the seismic ground response analysis - 2,475-year return period.
- Earthquake magnitude Mw = 7.0

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

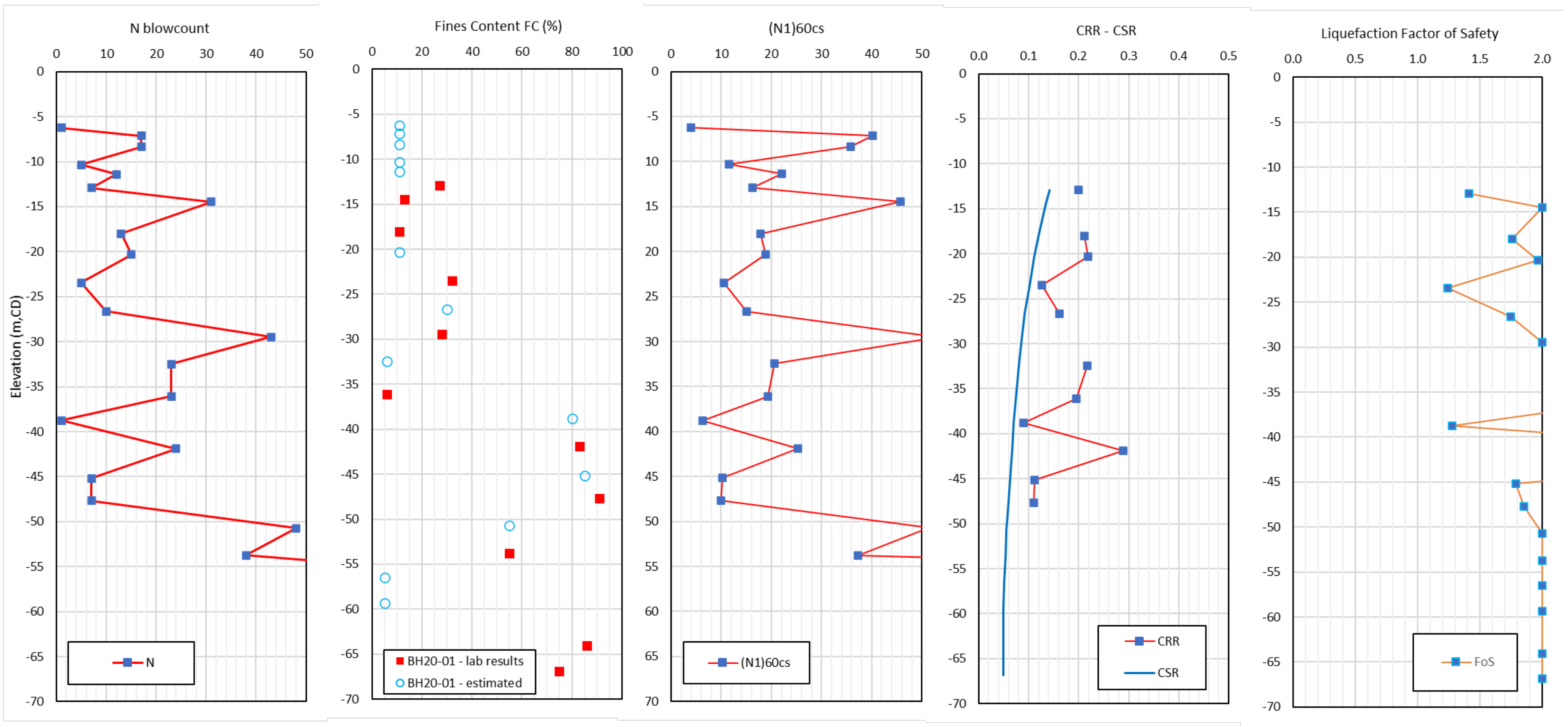
Title

Liquefaction assessment results
SCPT20-05 – 2,475-year return period

Figure No.

24

BH 20-01



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

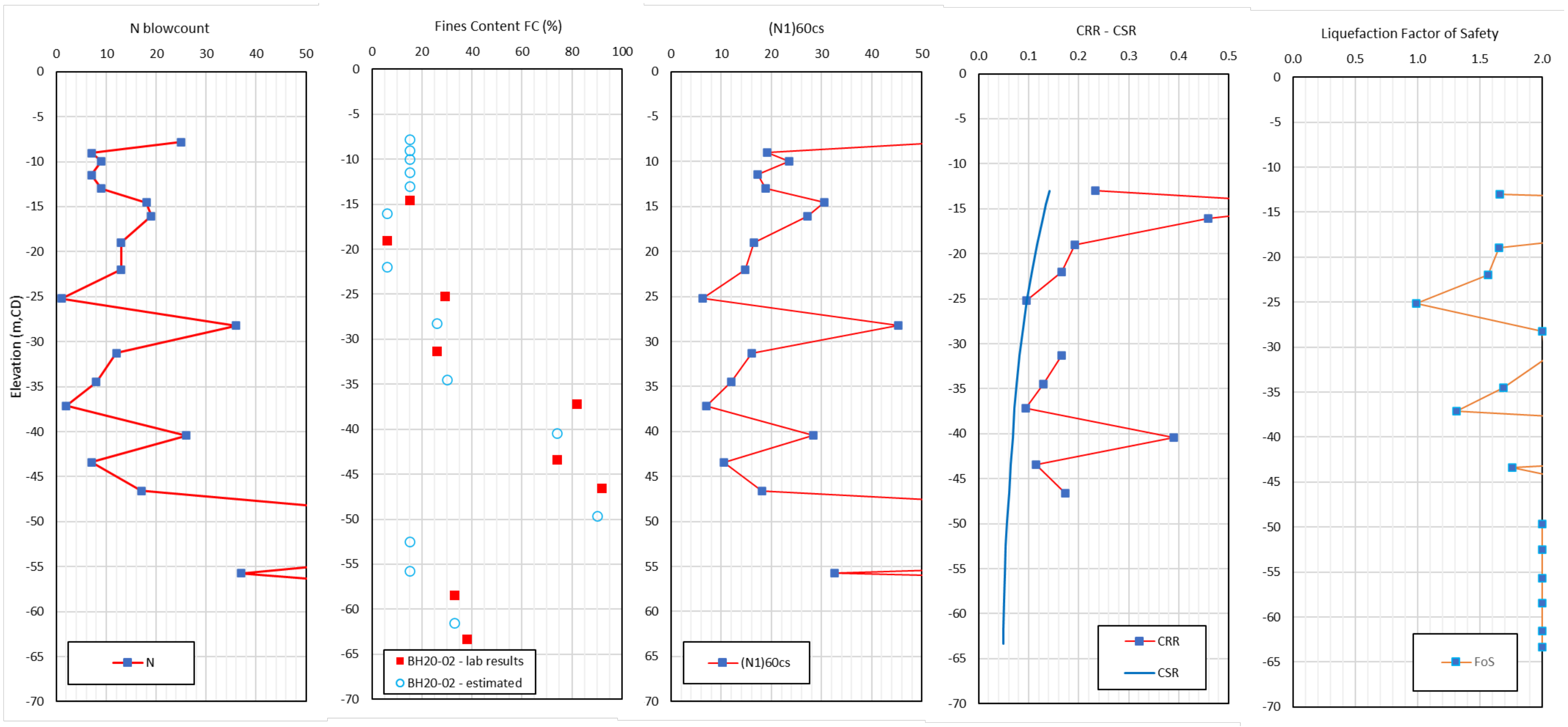
Title

Liquefaction assessment results
BH20-01 - 224-year return period

Figure No.

25

BH 20-02



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

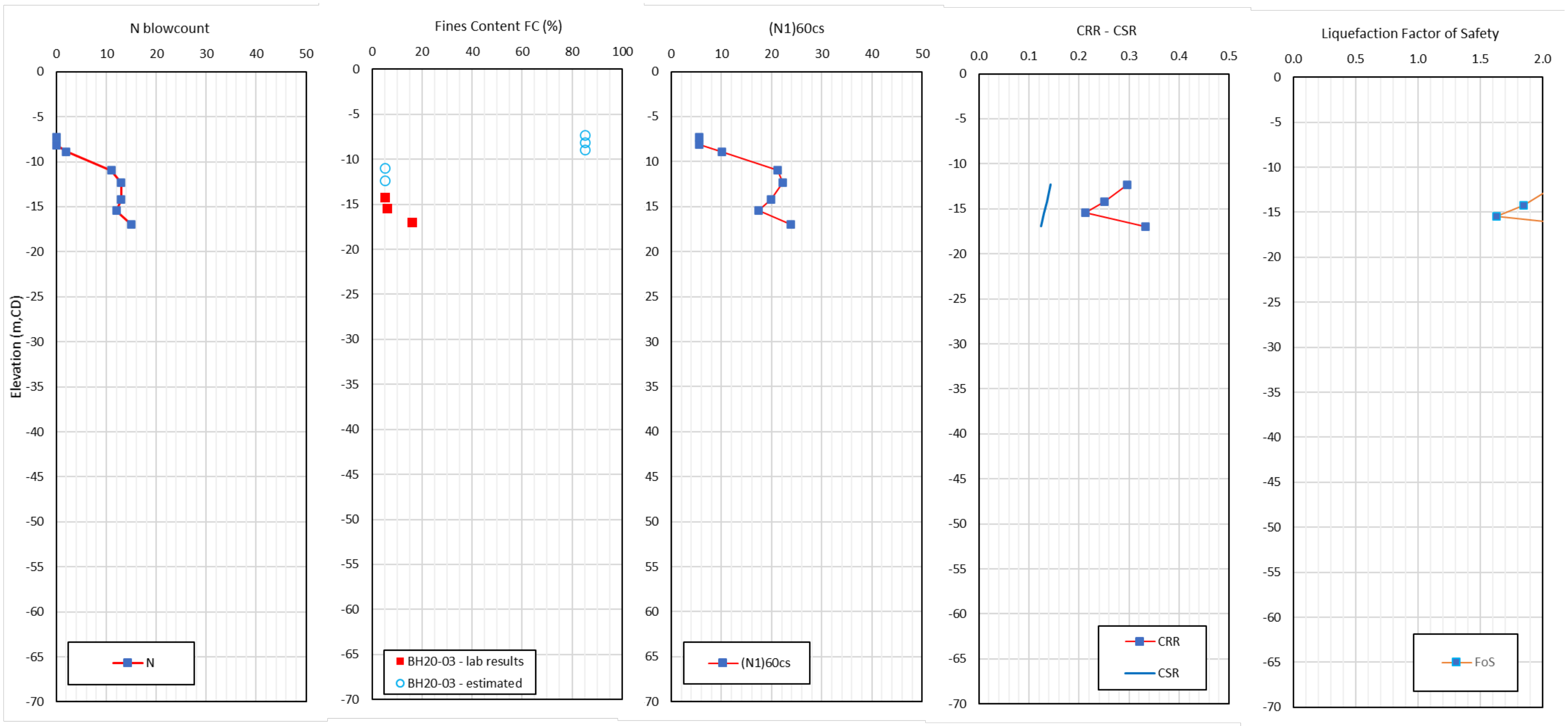
Title

Liquefaction assessment results
BH20-02 - 224-year return period

Figure No.

26

BH 20-03



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Project No.:	115619249
Scale:	---
Date:	02-Oct-20
Prepared by:	VT
Checked by:	ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

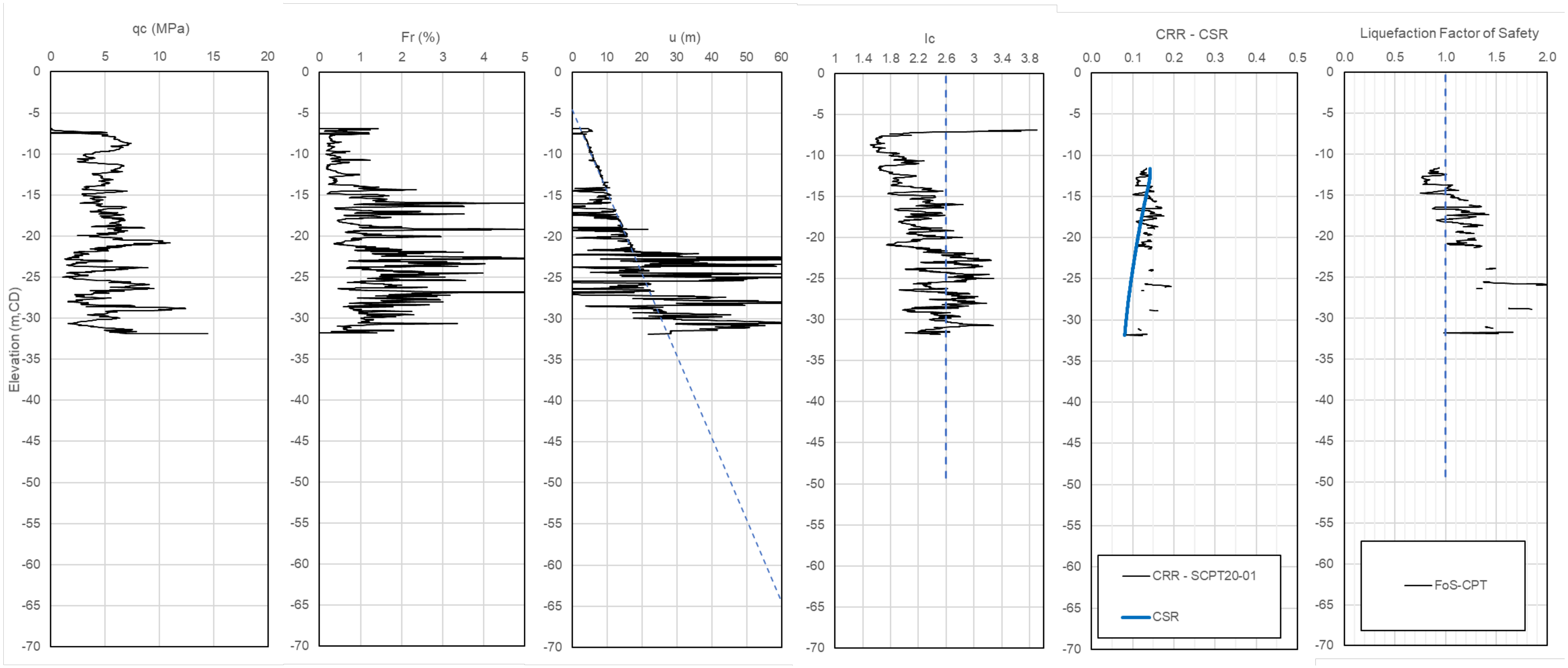
Title

Liquefaction assessment results
BH20-03 - 224-year return period

Figure No.

27

SCPT 20-01



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

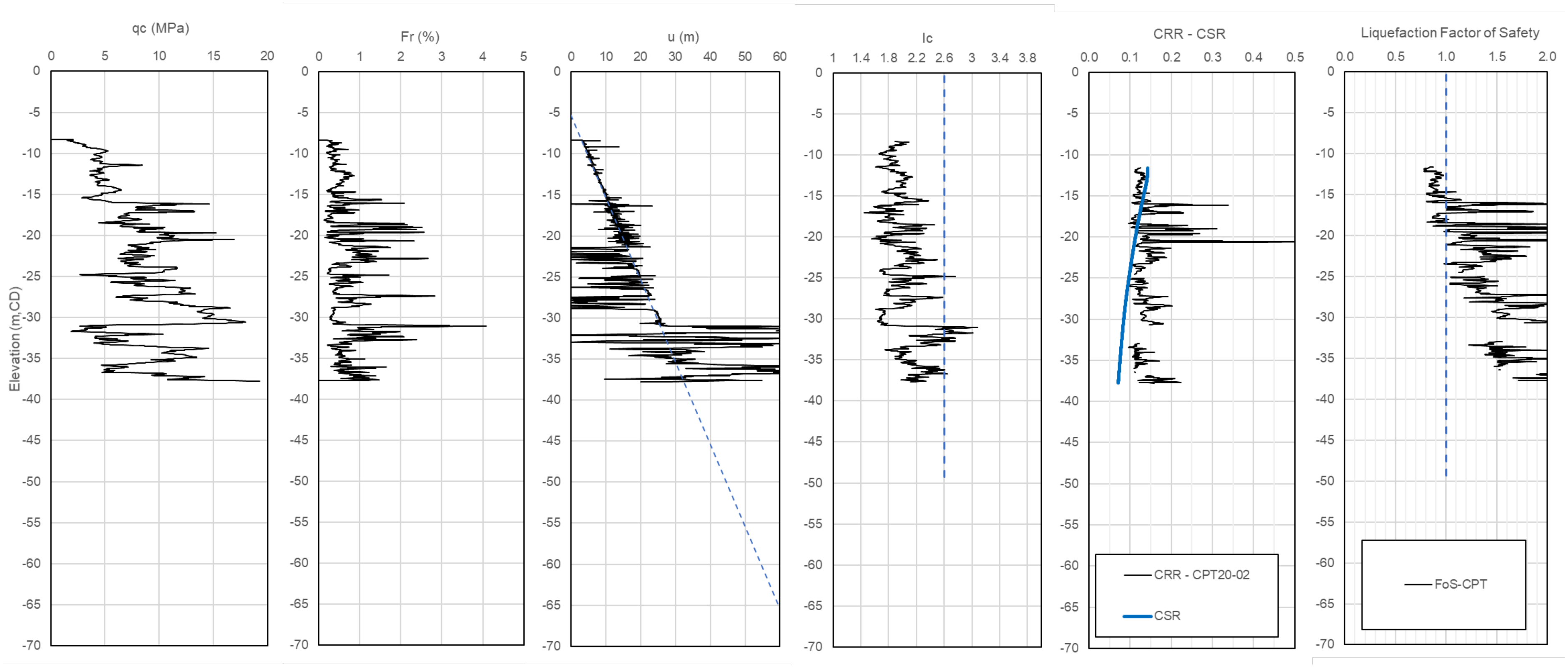
Title

Liquefaction assessment results
SCPT20-01 - 224-year return period

Figure No.

28

CPT 20-02



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

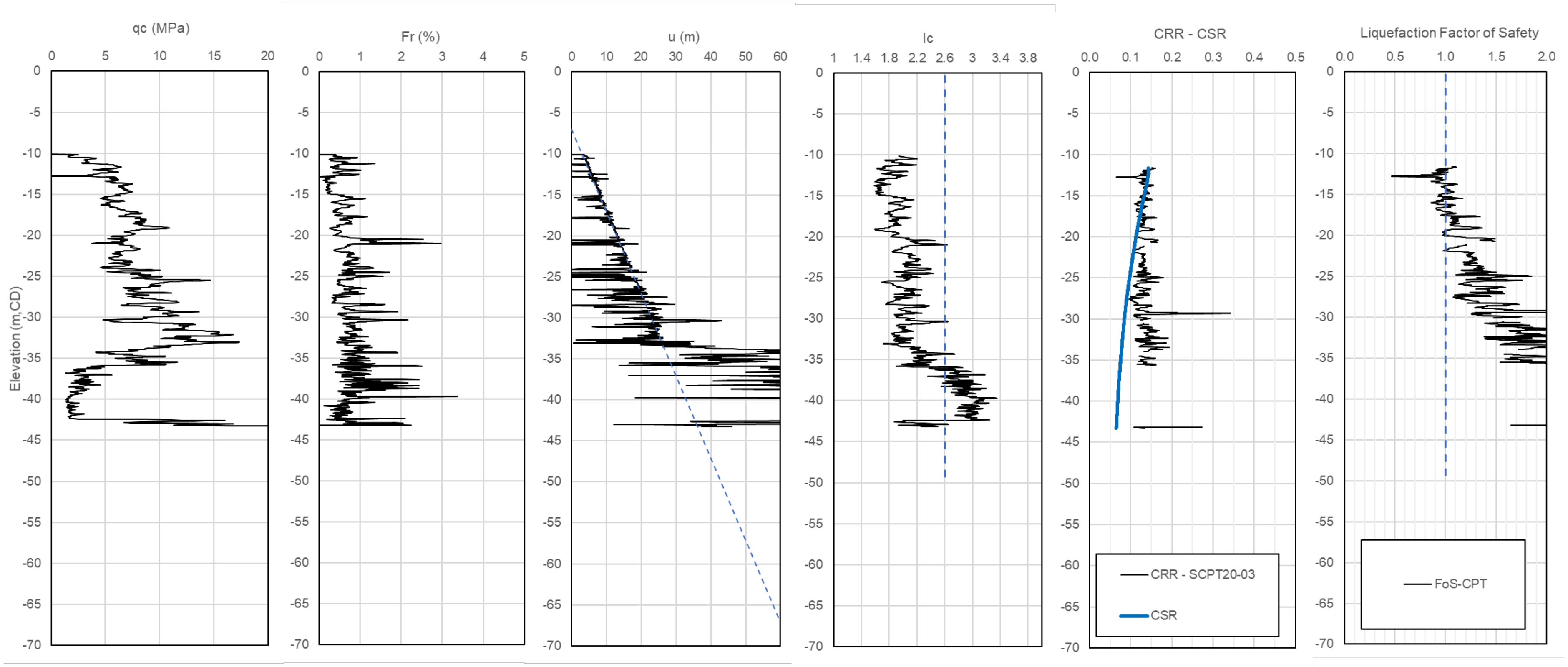
Title

Liquefaction assessment results
CPT20-02 - 224-year return period

Figure No.

29

SCPT 20-03



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

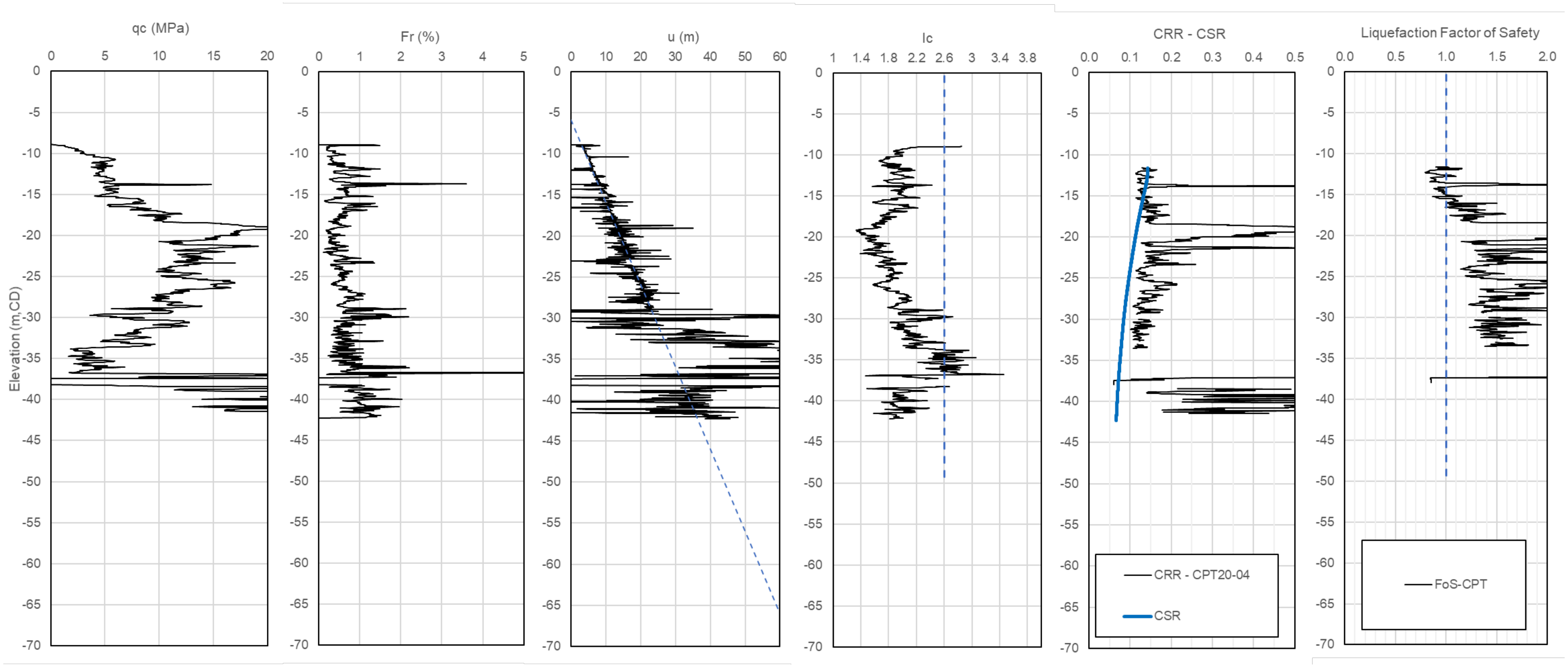
Title

Liquefaction assessment results
SCPT20-03 - 224-year return period

Figure No.

30

CPT 20-04



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

Client/Project

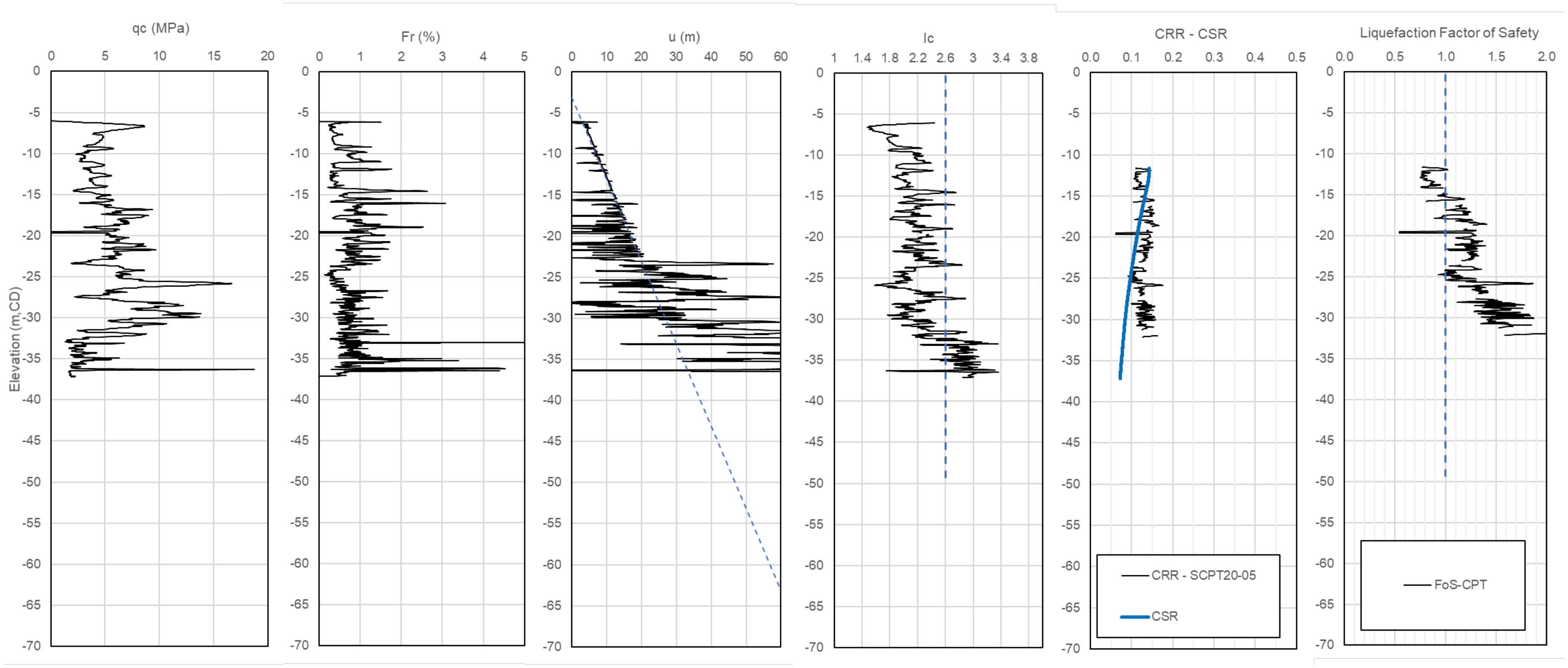
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Liquefaction assessment results
CPT20-04 - 224-year return period

Figure No.
31

SCPT 20-05



Notes:

- CSR obtained from the seismic ground response analysis- 224-year return period.
- Earthquake magnitude Mw = 6.86

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

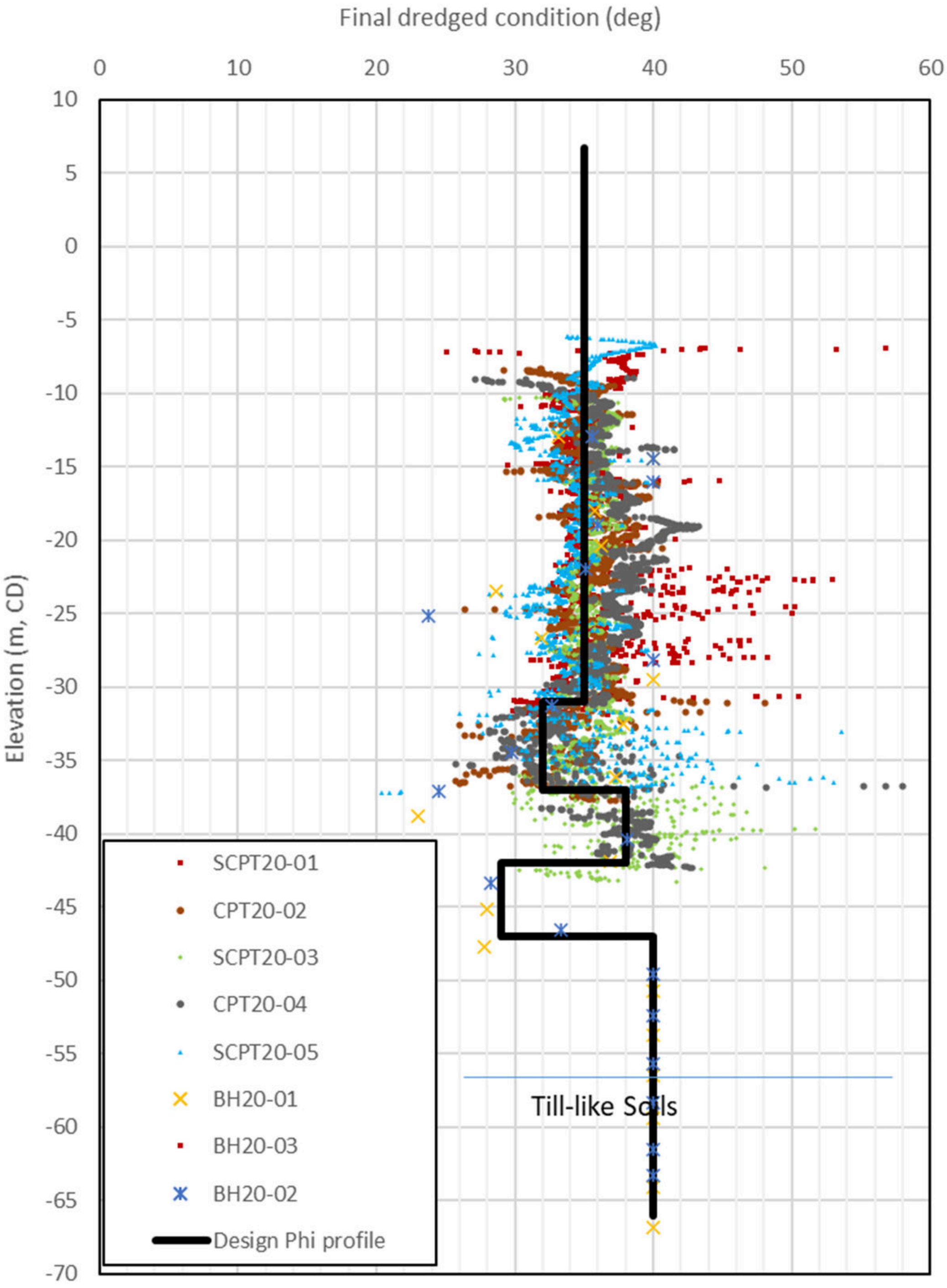
Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Liquefaction assessment results
SCPT20-05 - 224-year return period

Figure No.
32



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Project No.: 115619249
Scale: ---
Date: 19-June-20
Prepared by: SM
Checked by: VT

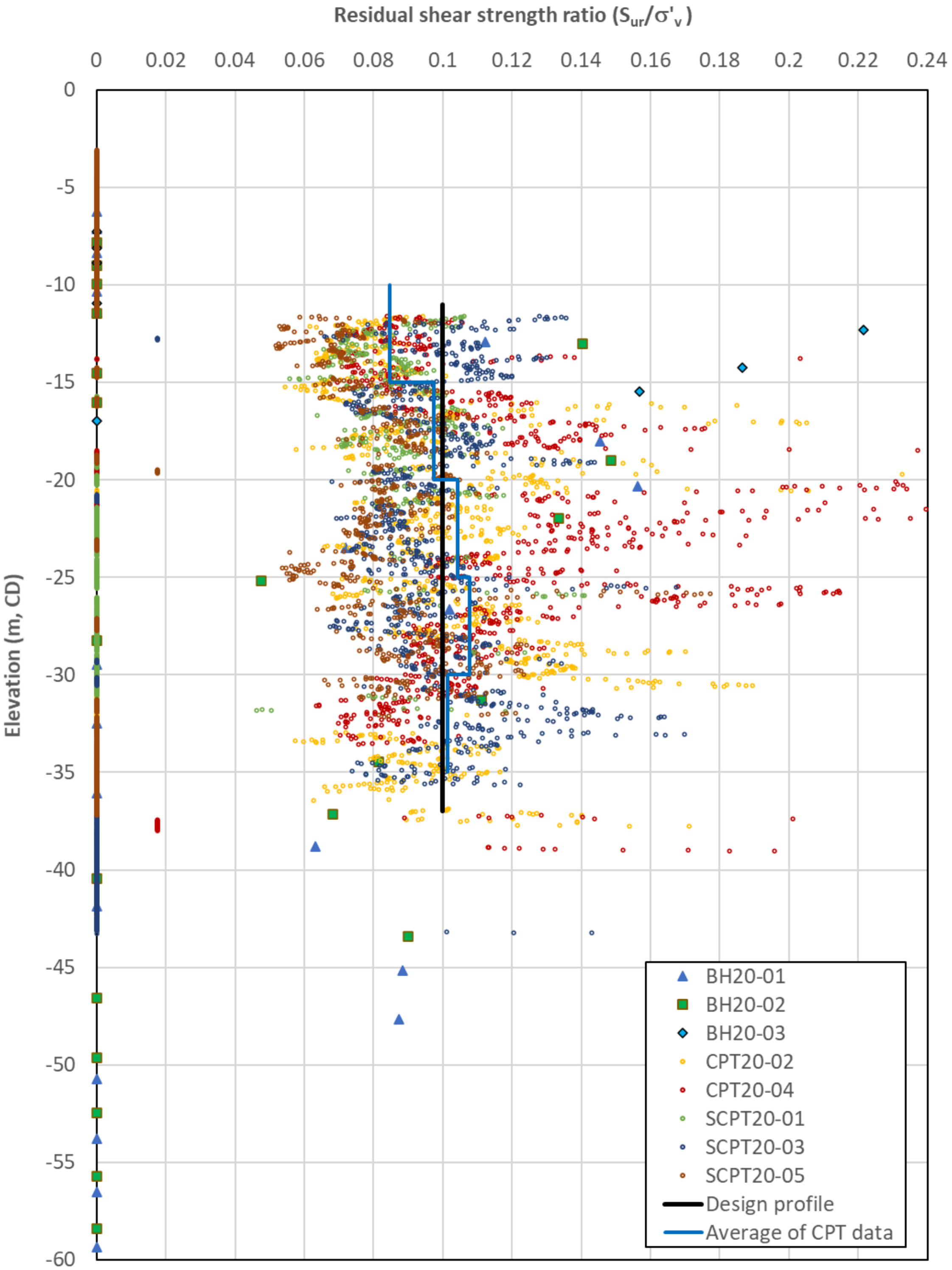
Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title Drain Effective Friction Angle Design Profile

Figure No.
33



Project No.: 115619249
Scale: ---
Date: 19-June-20
Prepared by: SM
Checked by: VT

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title

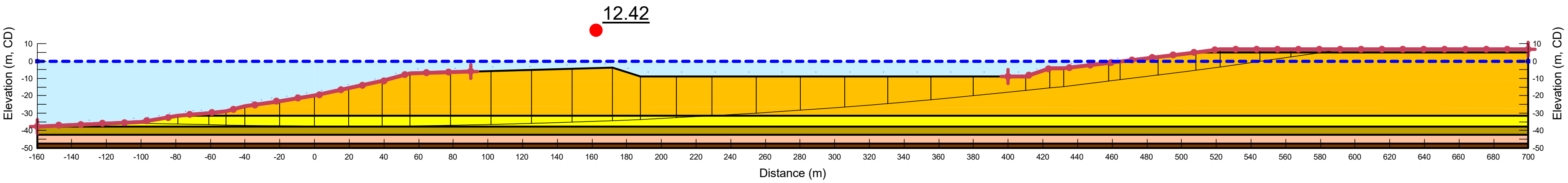
Residual Shear Strength Ratio
(S_{ur}/σ'_v)

Figure No.

34

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
⬛	fill	Mohr-Coulomb	21	0	35	1
🟧	sand-29	Mohr-Coulomb	19	0	29	1
🟨	sand-32	Mohr-Coulomb	19	0	32	1
🟧	sand-35	Mohr-Coulomb	19	0	35	1
🟫	sand-38	Mohr-Coulomb	19	0	38	1
🟫	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

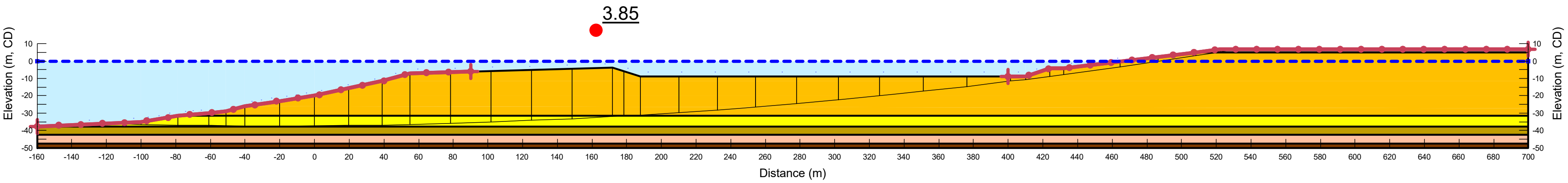
Title
Overall Slope Stability
Static condition

Fig No.
35

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\overal-stability\224-year\115619249-overl-stability-section-A-A-R2-224-yr-r1.gsz
05/29/2020 09:47:20 AM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	fill	Mohr-Coulomb	21	0	35	1
■	sand-29	Mohr-Coulomb	19	0	29	1
■	sand-32	Mohr-Coulomb	19	0	32	1
■	sand-35	Mohr-Coulomb	19	0	35	1
■	sand-38	Mohr-Coulomb	19	0	38	1
■	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0.058 g



Notes

Project Infomation

Project No.:	115619249
Scale:	N/A
Date:	29May20
Drawn by:	SM
Reviewed by:	VT

Project Location

North Vancouver
British Columbia

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title

Overall Slope Stability

Pseudo-static condition,
k(h)=0.5PGA 224-year return period

Fig No.

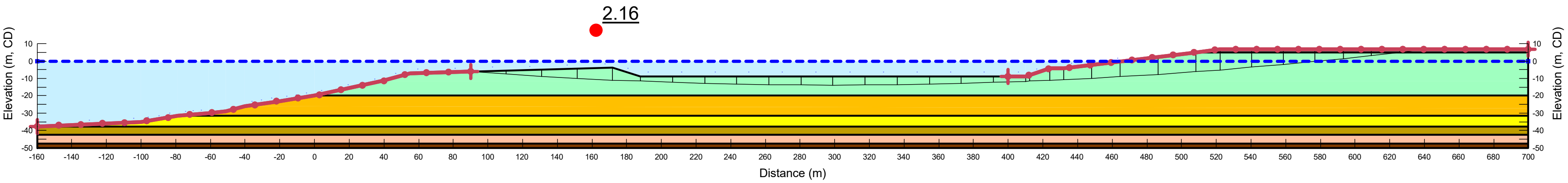
36

Stantec

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\overal-stability\224-year\115619249-overl-stability-section-A-A-R2-224-yr-r1.gsz
05/29/2020 09:47:20 AM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion' (kPa)	Phi' (°)	Piezometric Line
⬛	fill	Mohr-Coulomb	21			0	35	1
🟩	liquefiable sand	SHANSEP	19	0	0.1			1
🟧	sand-29	Mohr-Coulomb	19			0	29	1
🟨	sand-32	Mohr-Coulomb	19			0	32	1
🟧	sand-35	Mohr-Coulomb	19			0	35	1
🟨	sand-38	Mohr-Coulomb	19			0	38	1
🟫	sand-40	Mohr-Coulomb	19			0	40	1

Horz Seismic Coef.: 0 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

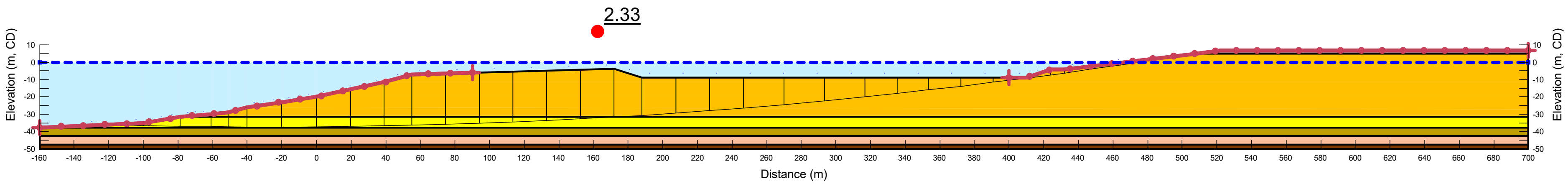
Title
Overall Slope Stability
Post-seismic condition
224-year return period

Fig No.
37

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\overal-stability\224-year\115619249-overl-stability-section-A-A-R2-224-yr-r1.gsz
05/29/2020 09:47:20 AM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
⬛	fill	Mohr-Coulomb	21	0	35	1
🟧	sand-29	Mohr-Coulomb	19	0	29	1
🟨	sand-32	Mohr-Coulomb	19	0	32	1
🟧	sand-35	Mohr-Coulomb	19	0	35	1
🟫	sand-38	Mohr-Coulomb	19	0	38	1
🟫	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0.111 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 25May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Overall Slope Stability
Pseudo-static condition,
k(h)=0.5PGA 2,475-year return period

Fig No.
38

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\overal-stability\2475-year\115619249-overl-stability-section-A-A-R3-2475-yr.gsz
05/29/2020 03:37:59 PM By: Meshkinfar, Shokouh

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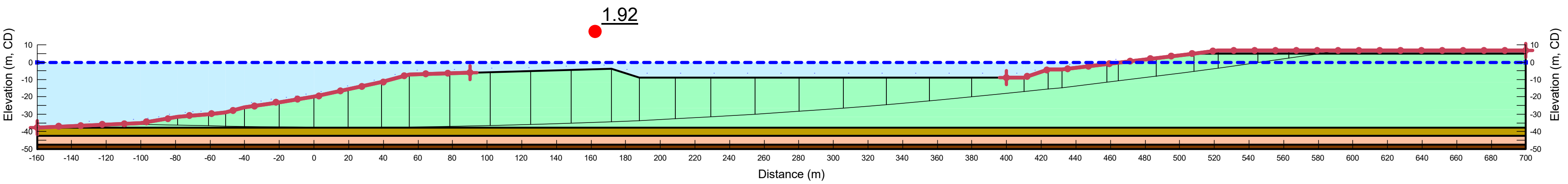
05/25/2020 04:52:30 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion' (kPa)	Phi' (°)	Piezometric Line
⬛	fill	Mohr-Coulomb	21			0	35	1
🟩	liquefiable sand	SHANSEP	19	0	0.1			1
🟧	sand-29	Mohr-Coulomb	19			0	29	1
🟨	sand-38	Mohr-Coulomb	19			0	38	1
🟫	sand-40	Mohr-Coulomb	19			0	40	1

Horz Seismic Coef.: 0 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 25May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

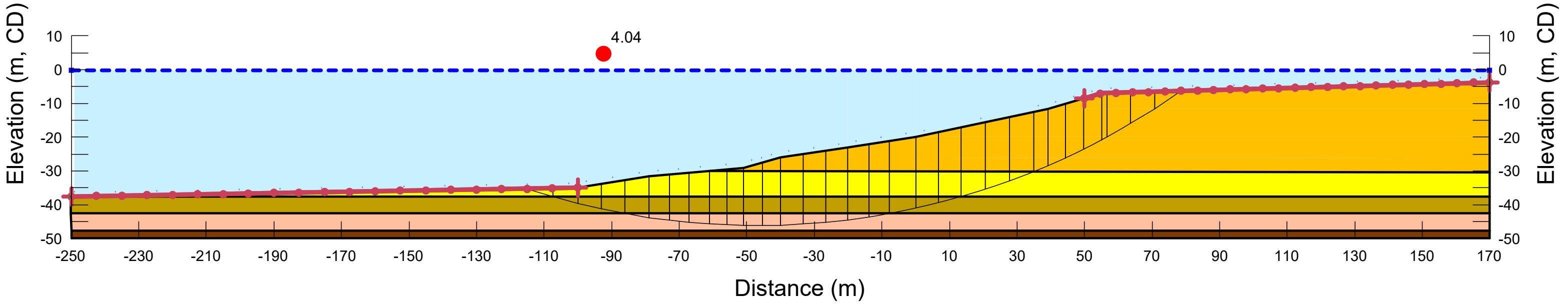
Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Overall Slope Stability
Post-seismic condition
2,475-year return period

Fig No.
39

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	sand-29	Mohr-Coulomb	19	0	29	1
■	sand-32	Mohr-Coulomb	19	0	32	1
■	sand-35	Mohr-Coulomb	19	0	35	1
■	sand-38	Mohr-Coulomb	19	0	38	1
■	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

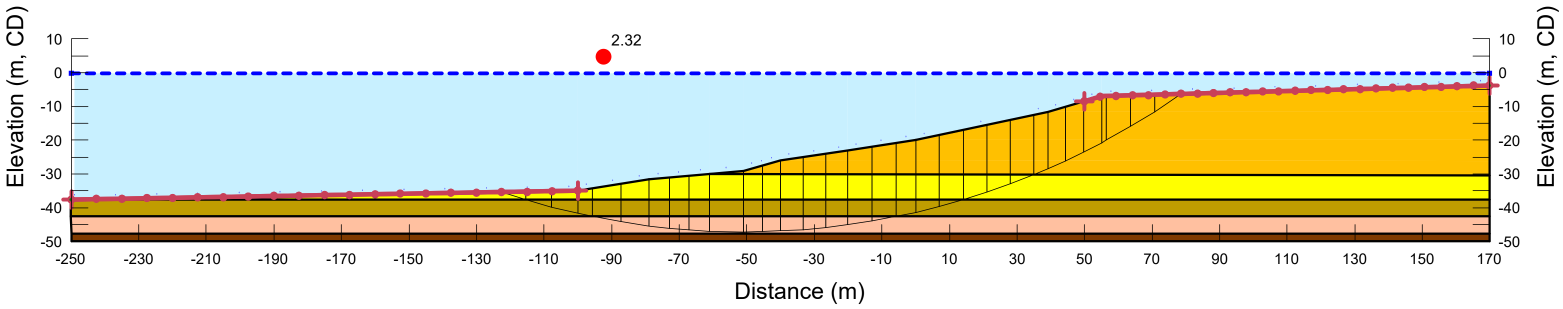
Title
Marine slope stability
Static condition

Fig No.
40

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\224-year\115619249-section-A-A-marine-R-1-224-yr.gsz
05/29/2020 01:27:53 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟧	sand-29	Mohr-Coulomb	19	0	29	1
🟨	sand-32	Mohr-Coulomb	19	0	32	1
🟧	sand-35	Mohr-Coulomb	19	0	35	1
🟫	sand-38	Mohr-Coulomb	19	0	38	1
🟫	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0.058 g



Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

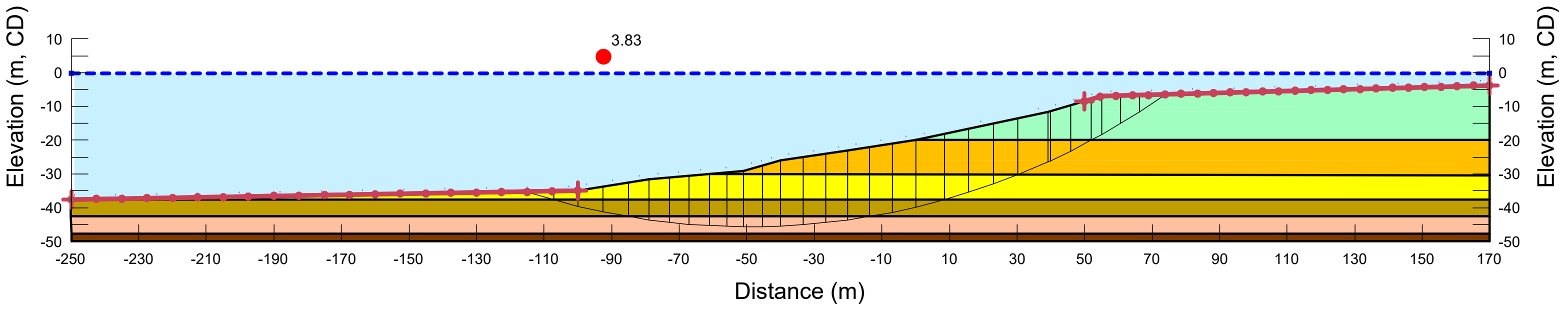
Title
Marine slope stability
Pseudo-static condition,
k(h)=0.5PGA 224-year return period

Fig No.
41

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\224-year\115619249-section-A-A-marine-R-1-224-yr.gsz
05/29/2020 01:27:53 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Minimum Strength (kPa)	Tau/Sigma Ratio	Piezometric Line
🟩	liquefiable sand	SHANSEP	19			0	0.1	1
🟧	sand-29	Mohr-Coulomb	19	0	29			1
🟨	sand-32	Mohr-Coulomb	19	0	32			1
🟧	sand-35	Mohr-Coulomb	19	0	35			1
🟫	sand-38	Mohr-Coulomb	19	0	38			1
🟫	sand-40	Mohr-Coulomb	19	0	40			1

Horz Seismic Coef.: 0 g



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Notes

Project Infomation

Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location

North Vancouver
British Columbia

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title

Marine slope stability
Post-seismic condition
224-year return period

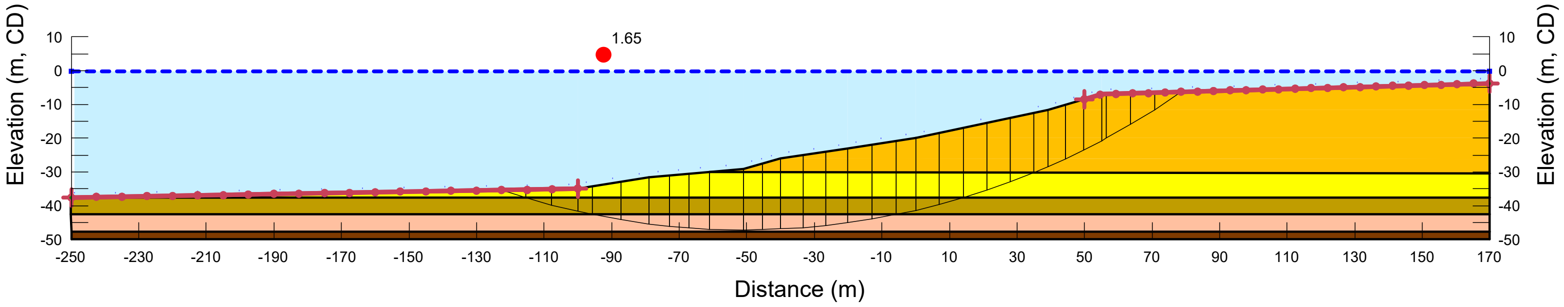
Fig No.

42

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\224-year\115619249-section-A-A-marine-R-1-224-yr.gsz
05/29/2020 01:27:53 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	sand-29	Mohr-Coulomb	19	0	29	1
■	sand-32	Mohr-Coulomb	19	0	32	1
■	sand-35	Mohr-Coulomb	19	0	35	1
■	sand-38	Mohr-Coulomb	19	0	38	1
■	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0.111 g



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Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 22May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

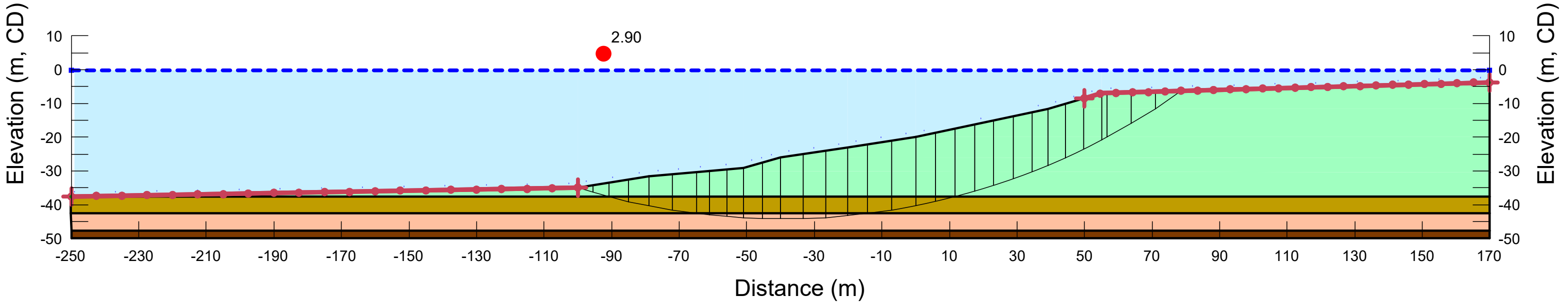
Title
Marine slope stability
Pseudo-static condition,
k(h)=0.5PGA 2,475-year return period

Fig No.
43

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\2475-year\115619249-section-A-A-marine-R-1-2475-yr.gsz
05/29/2020 01:08:31 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Minimum Strength (kPa)	Tau/Sigma Ratio	Piezometric Line
🟩	liquefiable sand	SHANSEP	19			0	0.1	1
🟧	sand-29	Mohr-Coulomb	19	0	29			1
🟨	sand-38	Mohr-Coulomb	19	0	38			1
🟫	sand-40	Mohr-Coulomb	19	0	40			1

Horz Seismic Coef.: 0 g



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Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 22May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

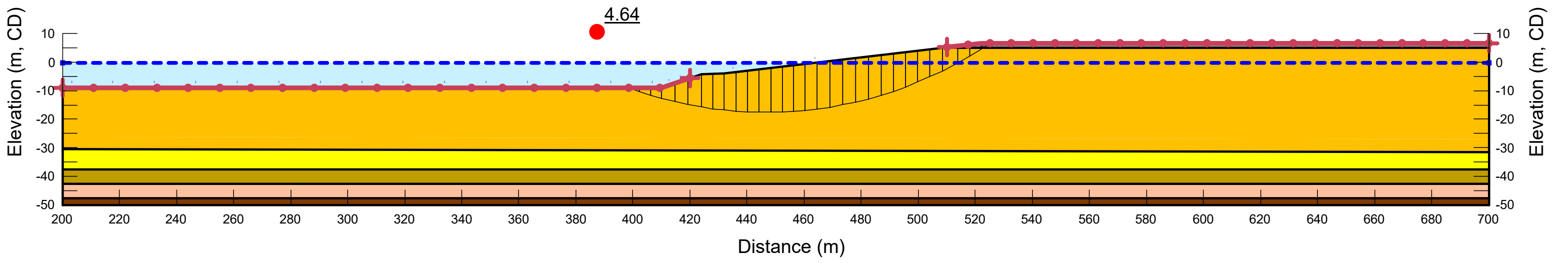
Title
Marine slope stability
Post-seismic condition
2,475-year return period

Fig No.
44

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\115619249-section-A-A-marine-R-1.gsz
05/25/2020 07:14:52 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	fill	Mohr-Coulomb	21	0	35	1
■	sand-29	Mohr-Coulomb	19	0	29	1
■	sand-32	Mohr-Coulomb	19	0	32	1
■	sand-35	Mohr-Coulomb	19	0	35	1
■	sand-38	Mohr-Coulomb	19	0	38	1
■	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0 g



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Notes

Project Infomation

Project No.:	115619249
Scale:	N/A
Date:	29May20
Drawn by:	SM
Reviewed by:	VT

Project Location

North Vancouver
British Columbia

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title

Near shore slope stability
Static condition

Fig No.

45

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\near-shore\224-year\115619249-section-A-A-near-shore-R1-224-yr.gsz
05/29/2020 12:54:41 PM By: Meshkinfar, Shokouh

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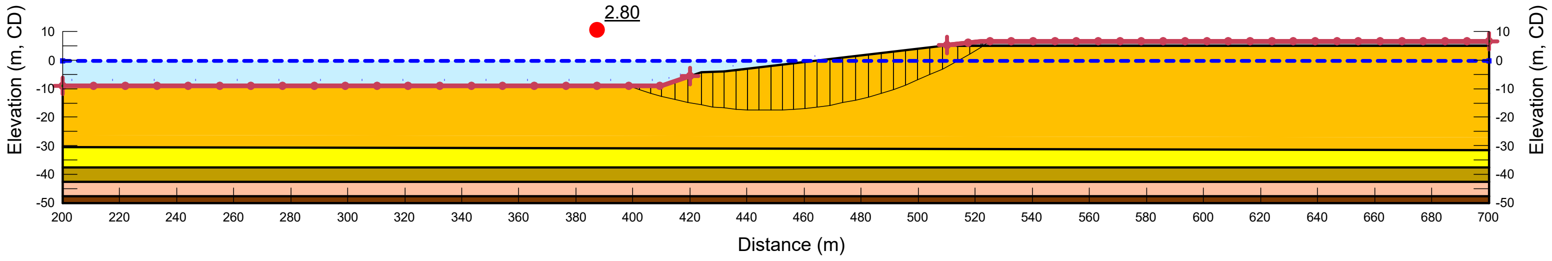
05/29/2020 12:54:41 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	fill	Mohr-Coulomb	21	0	35	1
🟧	sand-29	Mohr-Coulomb	19	0	29	1
🟨	sand-32	Mohr-Coulomb	19	0	32	1
🟧	sand-35	Mohr-Coulomb	19	0	35	1
🟫	sand-38	Mohr-Coulomb	19	0	38	1
🟫	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0.058 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

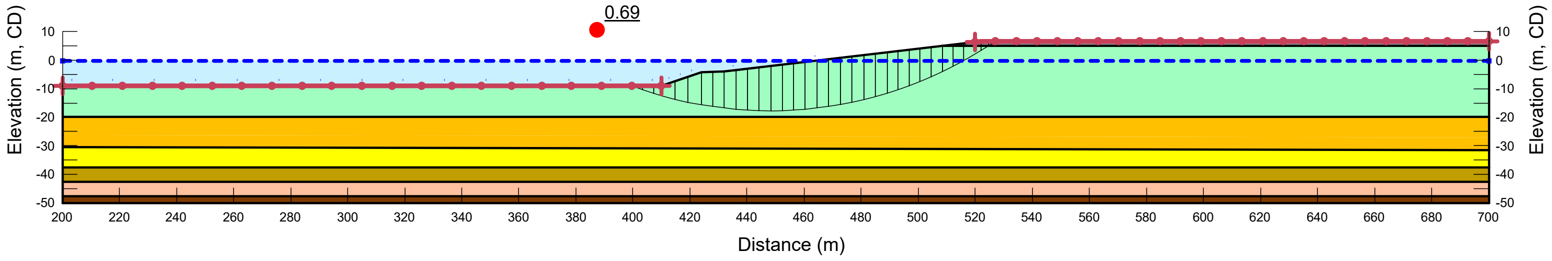
Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Near shore slope stability
Pseudo-static condition,
k(h)=0.5 PGA ,224-year return period

Fig No.
46

Color	Name	Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion' (kPa)	Phi' (°)	Piezometric Line
⬛	fill	Mohr-Coulomb	21			0	35	1
🟩	liquefiable sand	SHANSEP	19	0	0.1			1
🟧	sand-29	Mohr-Coulomb	19			0	29	1
🟨	sand-32	Mohr-Coulomb	19			0	32	1
🟧	sand-35	Mohr-Coulomb	19			0	35	1
🟫	sand-38	Mohr-Coulomb	19			0	38	1
🟫	sand-40	Mohr-Coulomb	19			0	40	1

Horz Seismic Coef.: 0 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

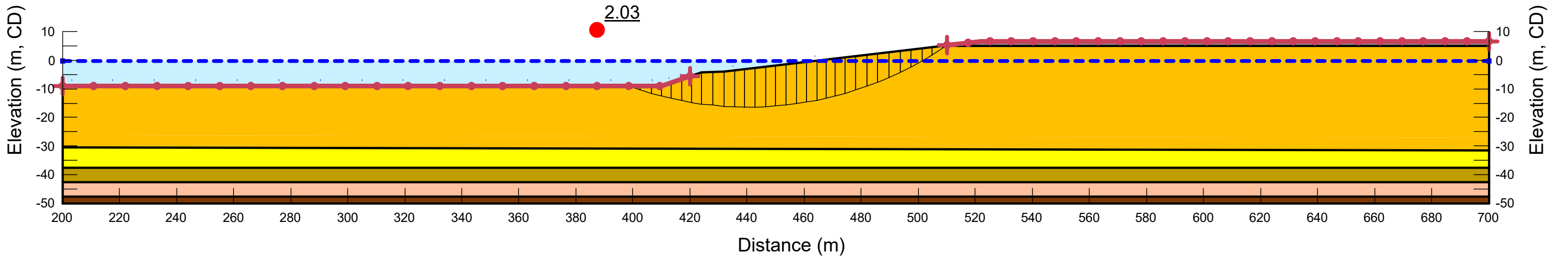
Title
Near shore slope stability
Post-seismic condition
224-year return period

Fig No.
47

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\near-shore\224-year\115619249-section-A-A-near-shore-R1-224-yr.gsz
05/29/2020 12:54:41 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	fill	Mohr-Coulomb	21	0	35	1
■	sand-29	Mohr-Coulomb	19	0	29	1
■	sand-32	Mohr-Coulomb	19	0	32	1
■	sand-35	Mohr-Coulomb	19	0	35	1
■	sand-38	Mohr-Coulomb	19	0	38	1
■	sand-40	Mohr-Coulomb	19	0	40	1

Horz Seismic Coef.: 0.111 g



Notes

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Project Infomation

Project No.: 115619249
Scale: N/A
Date: 25May20
Drawn by: SM
Reviewed by: VT

Project Location

North Vancouver
British Columbia

Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title

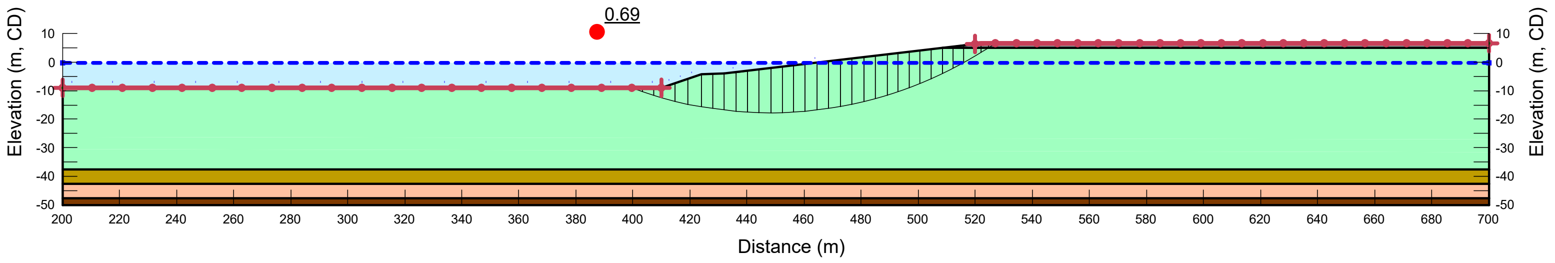
Near shore slope stability
Pseudo-static condition,
k(h)=0.5PGA 2,475-year return period

Fig No.
48

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\near-shore\2475-year\115619249-section-A-A-near-shore-R1-2475-yr.gsz
05/29/2020 01:05:23 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion' (kPa)	Phi' (°)	Piezometric Line
■	fill	Mohr-Coulomb	21			0	35	1
🟩	liquefiable sand	SHANSEP	19	0	0.1			1
🟧	sand-29	Mohr-Coulomb	19			0	29	1
🟨	sand-38	Mohr-Coulomb	19			0	38	1
🟫	sand-40	Mohr-Coulomb	19			0	40	1

Horz Seismic Coef.: 0 g



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Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 25May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

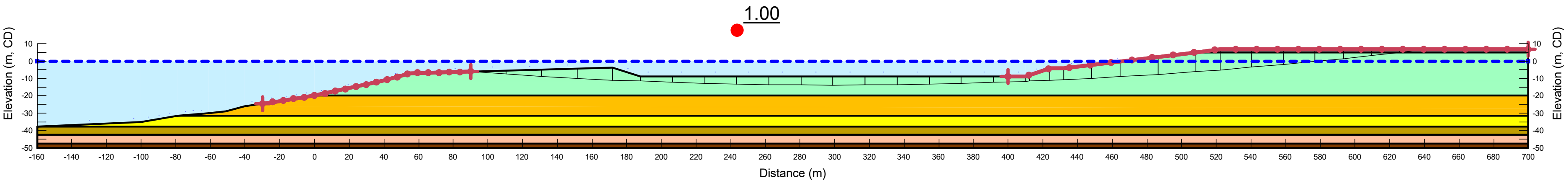
Title
Near shore slope stability
Post-seismic condition
2,475-year return period

Fig No.
49

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\near-shore\115619249-section-A-A-near-shore-R1.gsz
05/25/2020 07:57:25 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion' (kPa)	Phi' (°)	Piezometric Line
◼	fill	Mohr-Coulomb	21			0	35	1
🟩	liquefiable sand	SHANSEP	19	0	0.1			1
🟧	sand-29	Mohr-Coulomb	19			0	29	1
🟨	sand-32	Mohr-Coulomb	19			0	32	1
🟧	sand-35	Mohr-Coulomb	19			0	35	1
🟫	sand-38	Mohr-Coulomb	19			0	38	1
🟫	sand-40	Mohr-Coulomb	19			0	40	1

Horz Seismic Coef.: 0.035 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

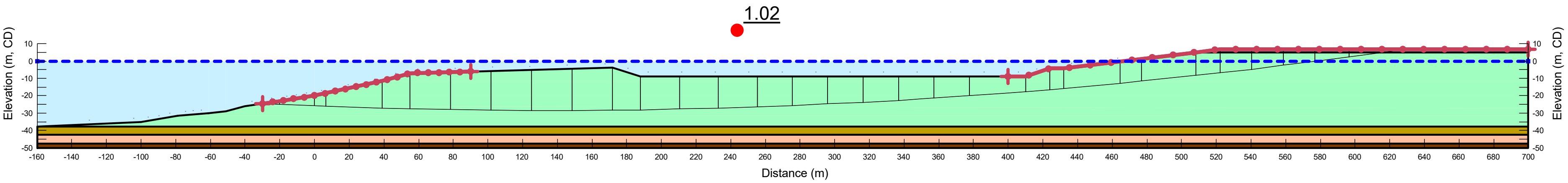
Title
Overall Slope Stability
Seismic - yield acceleration
224-year return period

Fig No.
50

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\overal-stability\224-year\115619249-overl-stability-section-A-A-R2-224-yr-r1.gsz
05/29/2020 09:47:20 AM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Cohesion' (kPa)	Phi' (°)	Piezometric Line
⬛	fill	Mohr-Coulomb	21			0	35	1
🟩	liquefiable sand	SHANSEP	19	0	0.1			1
🟧	sand-29	Mohr-Coulomb	19			0	29	1
🟨	sand-38	Mohr-Coulomb	19			0	38	1
🟫	sand-40	Mohr-Coulomb	19			0	40	1

Horz Seismic Coef.: 0.03 g



Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 25May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Overall Slope Stability
Seismic - yield acceleration
2,475-year return period

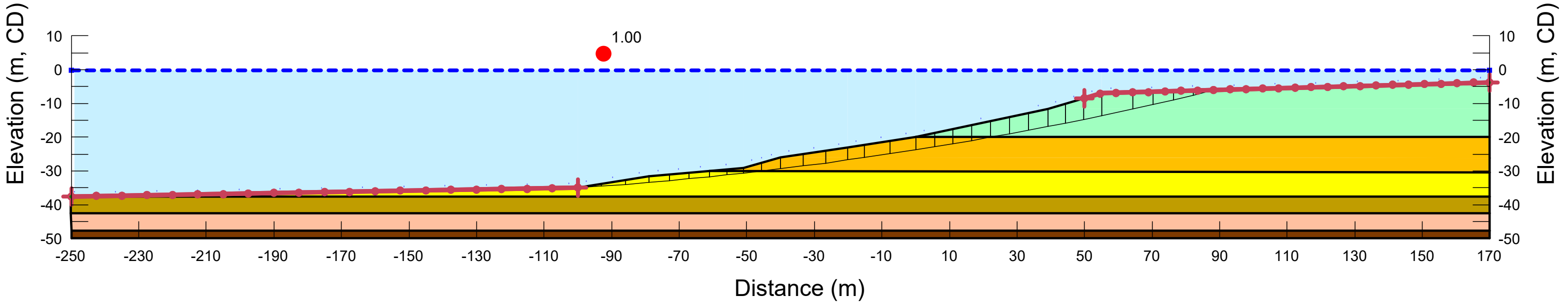
Fig No.
51

Stantec

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\overal-stability\2475-year\115619249-overl-stability-section-A-A-R3-2475-yr.gsz
05/27/2020 06:13:41 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Minimum Strength (kPa)	Tau/Sigma Ratio	Piezometric Line
🟩	liquefiable sand	SHANSEP	19			0	0.1	1
🟧	sand-29	Mohr-Coulomb	19	0	29			1
🟨	sand-32	Mohr-Coulomb	19	0	32			1
🟧	sand-35	Mohr-Coulomb	19	0	35			1
🟨	sand-38	Mohr-Coulomb	19	0	38			1
🟫	sand-40	Mohr-Coulomb	19	0	40			1

Horz Seismic Coef.: 0.115 g



Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 29May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

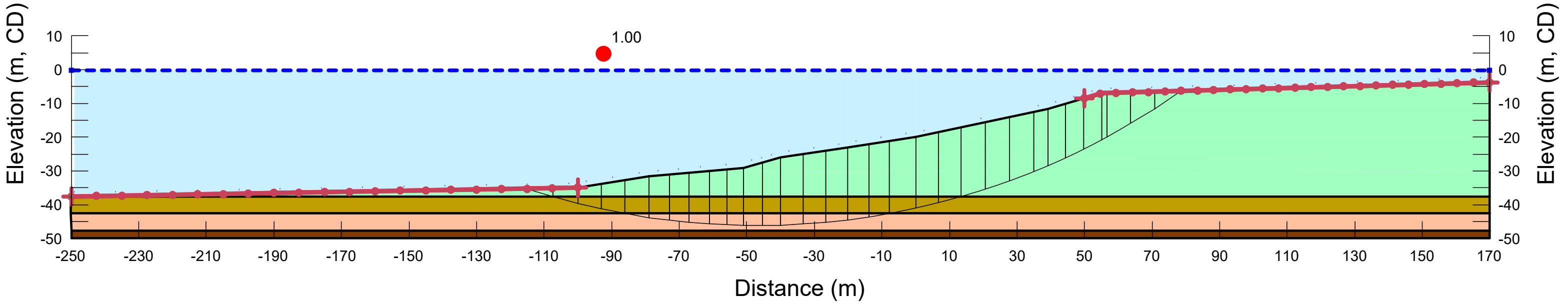
Title
Marine slope stability
Seismic - yield acceleration
224-year return period

Fig No.
52

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\224-year\115619249-section-A-A-marine-R-1-224-yr.gsz
05/29/2020 01:27:53 PM By: Meshkinfar, Shokouh

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Minimum Strength (kPa)	Tau/Sigma Ratio	Piezometric Line
🟩	liquefiable sand	SHANSEP	19			0	0.1	1
🟧	sand-29	Mohr-Coulomb	19	0	29			1
🟨	sand-38	Mohr-Coulomb	19	0	38			1
🟫	sand-40	Mohr-Coulomb	19	0	40			1

Horz Seismic Coef.: 0.17 g



Stantec

Notes

Project Infomation
Project No.: 115619249
Scale: N/A
Date: 22May20
Drawn by: SM
Reviewed by: VT

Project Location
North Vancouver
British Columbia

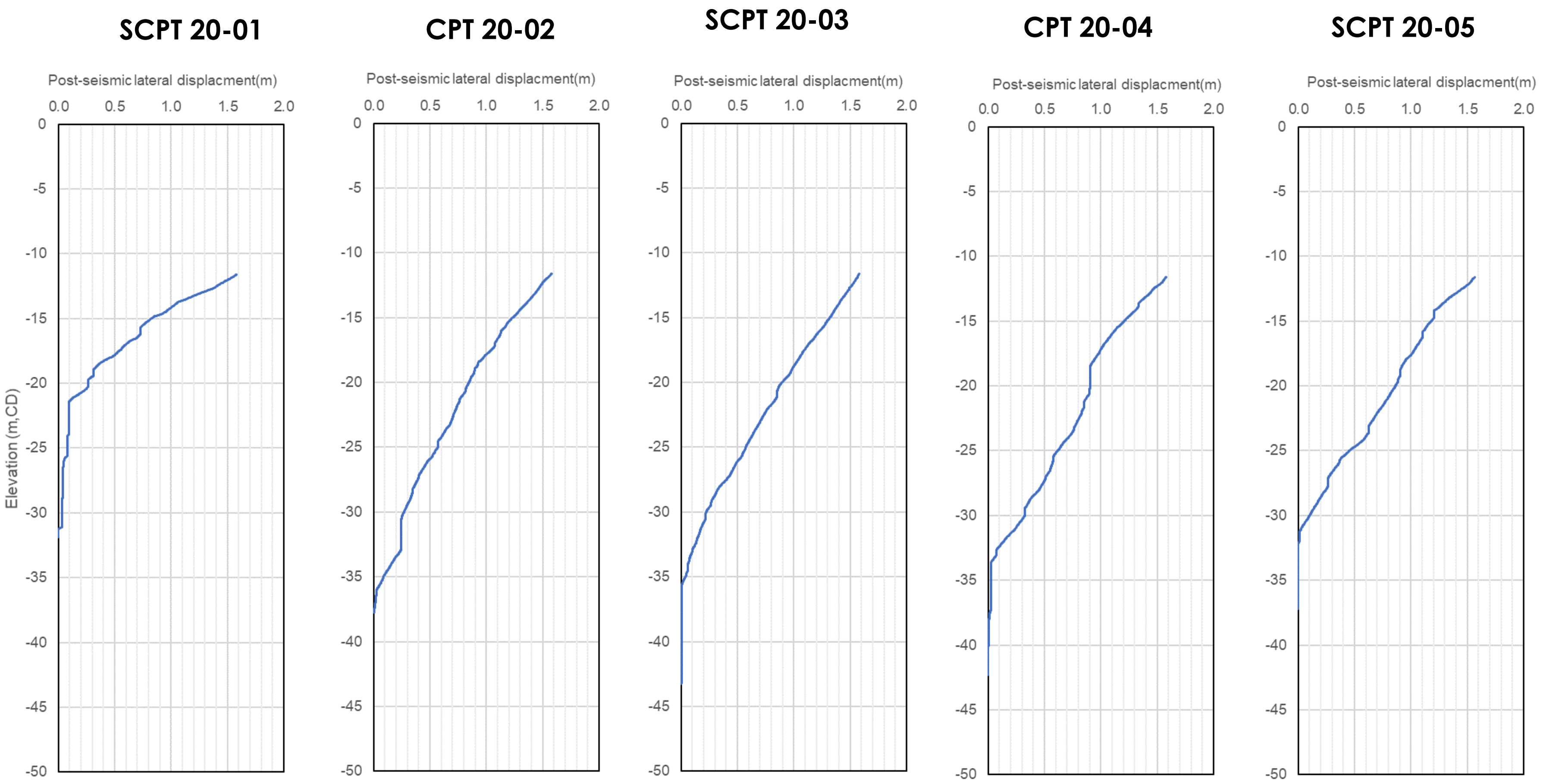
Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Marine slope stability
Seismic - yield acceleration
2,475-year return period

Fig No.
53

\\ca0183-ppfss01\SHARED_PROJECTS\1156\115619249_vsy\03_data\analytical\slope-stability\SectionA-A\marine\115619249-section-A-A-marine-R-1.gsz
05/25/2020 07:36:51 PM By: Meshkinfar, Shokouh



<u>Note</u>: the lateral displacement index (LDI) was scaled to match the estimated horizontal displacement at the ground surface

Stantec

Project No.: 115619249
Scale: ---
Date: 02-Oct-20
Prepared by: VT
Checked by: ND

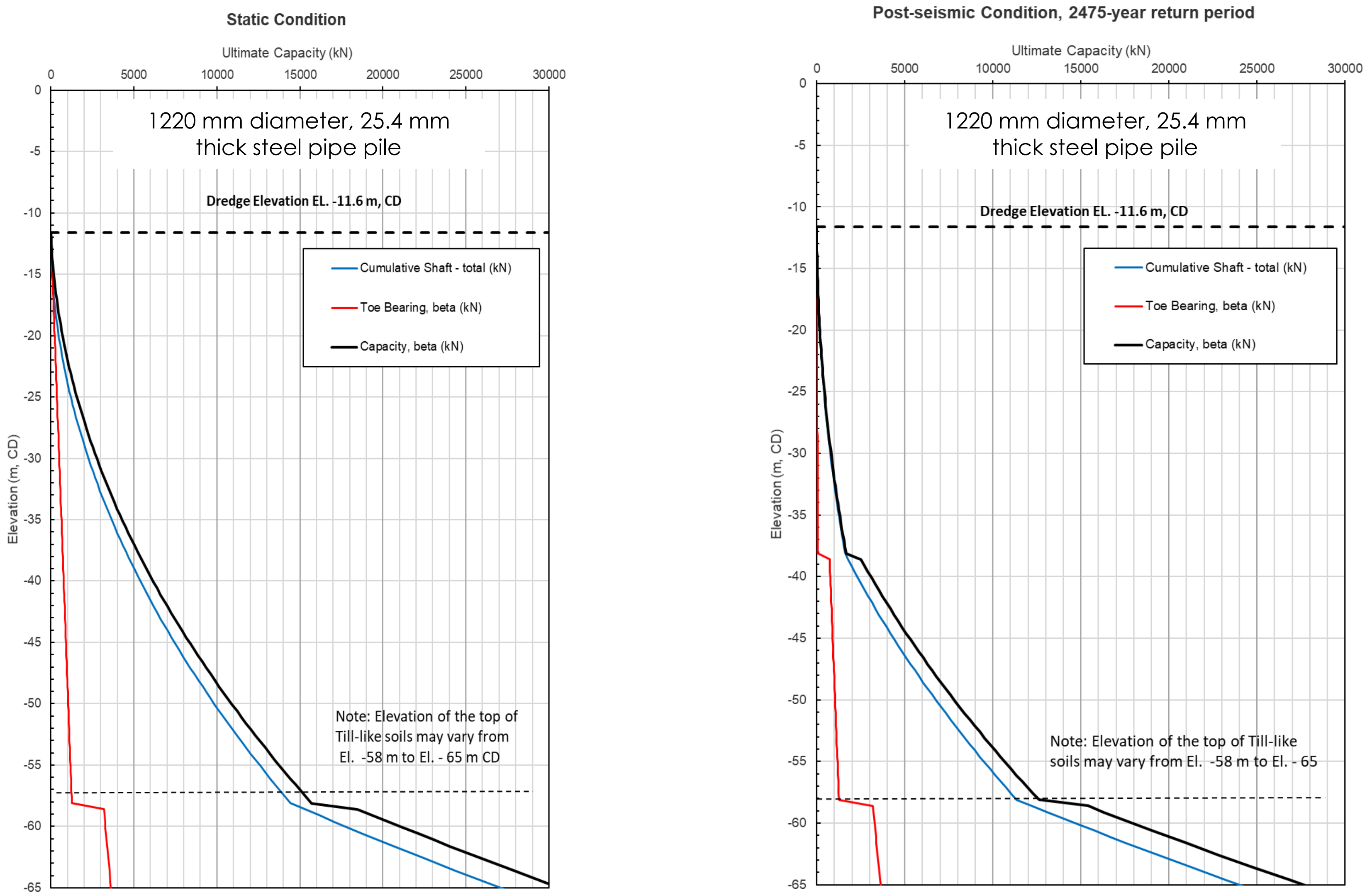
Client/Project

Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Scaled Lateral Displacement Index (LDI)
2,475-year return period

Figure No.
54


Static Condition

Post-seismic Condition, 2475-year return period

Note: Elevation of the top of Till-like soils may vary from El. -58 m to El. - 65 m CD

Note: Elevation of the top of Till-like soils may vary from El. -58 m to El. - 65

Stantec

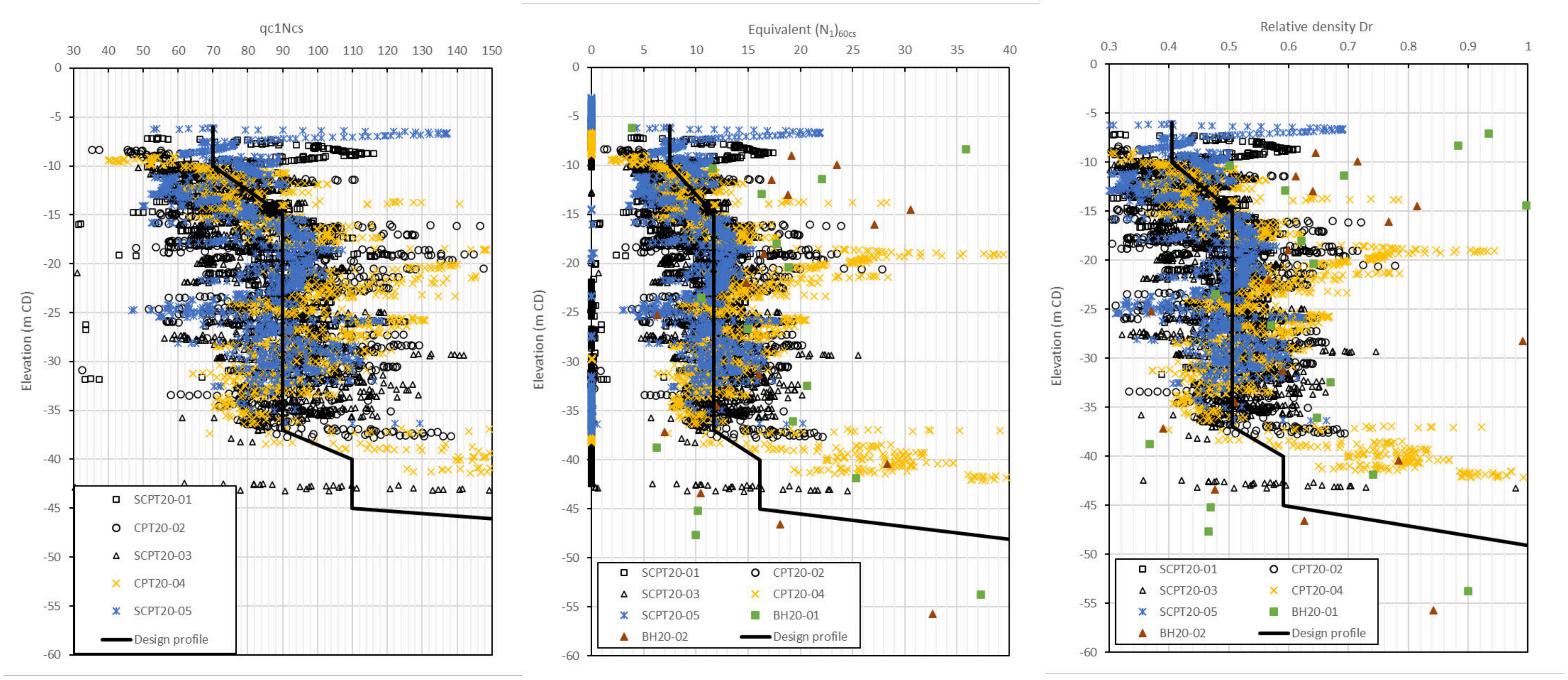
Project No.: 115619249
Scale: ---
Date: 24-June-20
Prepared by: VT
Checked by: ND

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Pile Axial Capacity in Compression, Static and Post-Seismic (2,475-Year Return Period) conditions

Figure No.
55



Stantec

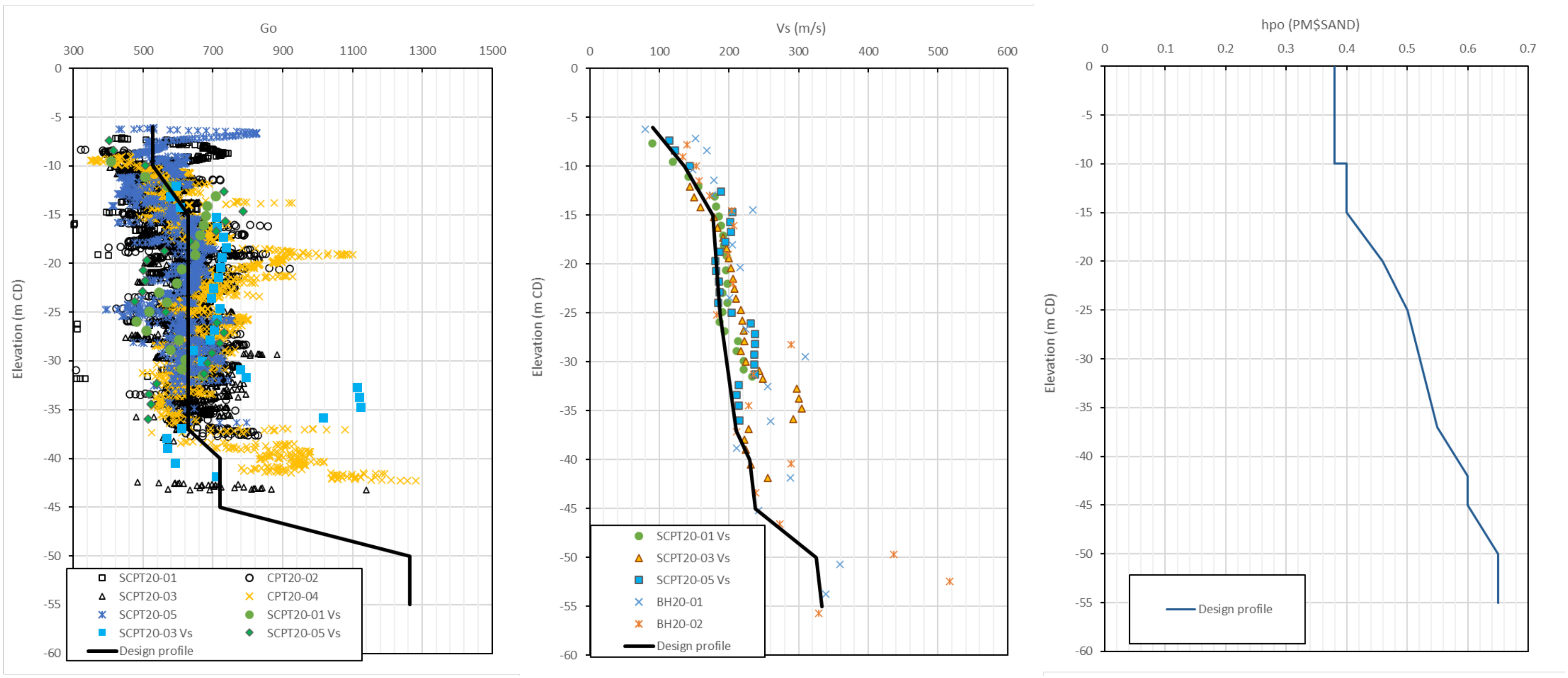
Project No.: 115619249
Scale: ---
Date: 20-June-20
Prepared by: VT
Checked by: ND

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Design profiles of soil parameters

Figure No.
56



Stantec

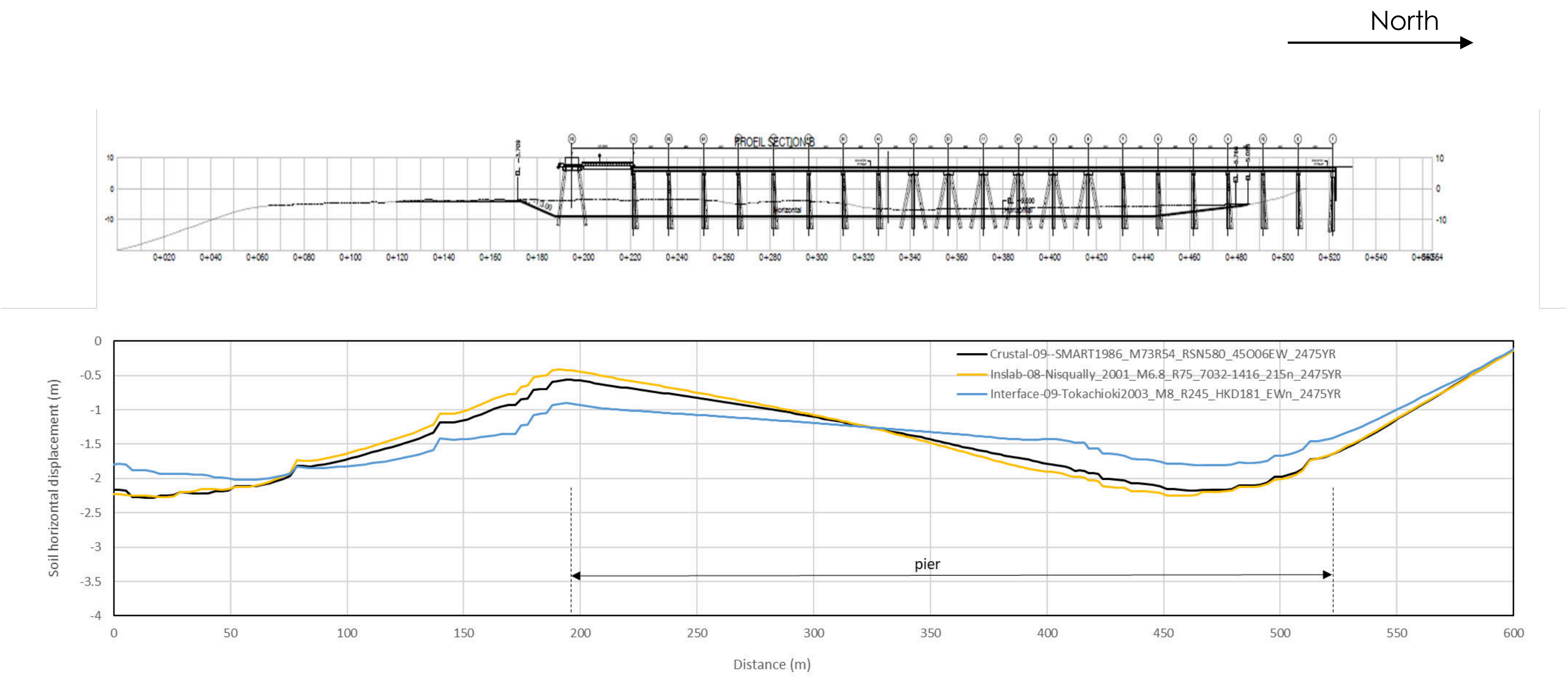
Project No.: 115619249
Scale: ---
Date: 20-June-20
Prepared by: VT
Checked by: ND

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Design profiles of soil parameters

Figure No.
57



Note:
- Three earthquake records (1 Crustal, 1 Inslab, and 1 Interface) under the 2,475-year return period were analyzed. The selected motions may present the seismic responses that are close to the average of all 30 earthquake records.

Stantec

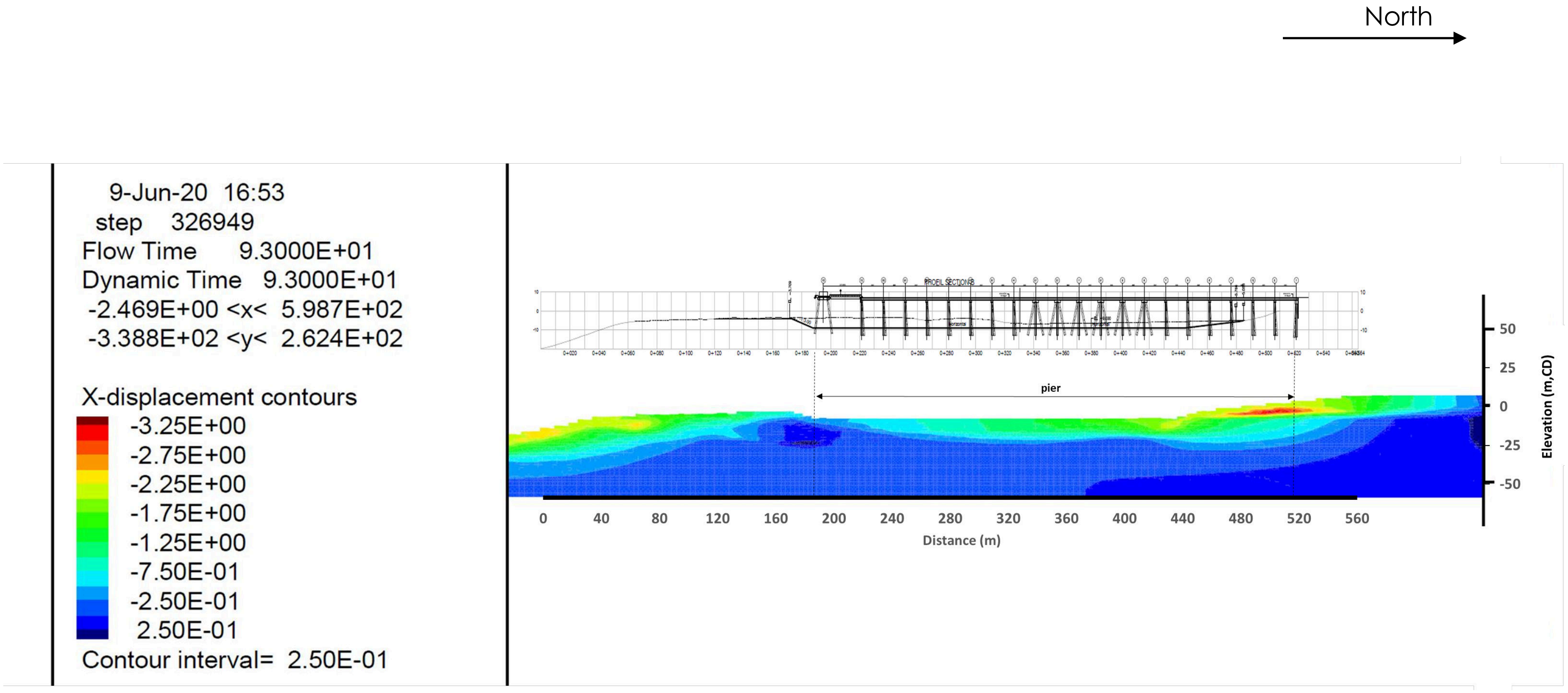
Project No.: 115619249
Scale: ---
Date: 20-June-20
Prepared by: VT
Checked by: ND

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Post-Seismic Lateral Soil Displacements,
Numerical Seismic Analysis,
2,475-Year Return Period

Figure No.
58



Representative horizontal displacement contours (from Inslab-08 record)

Stantec

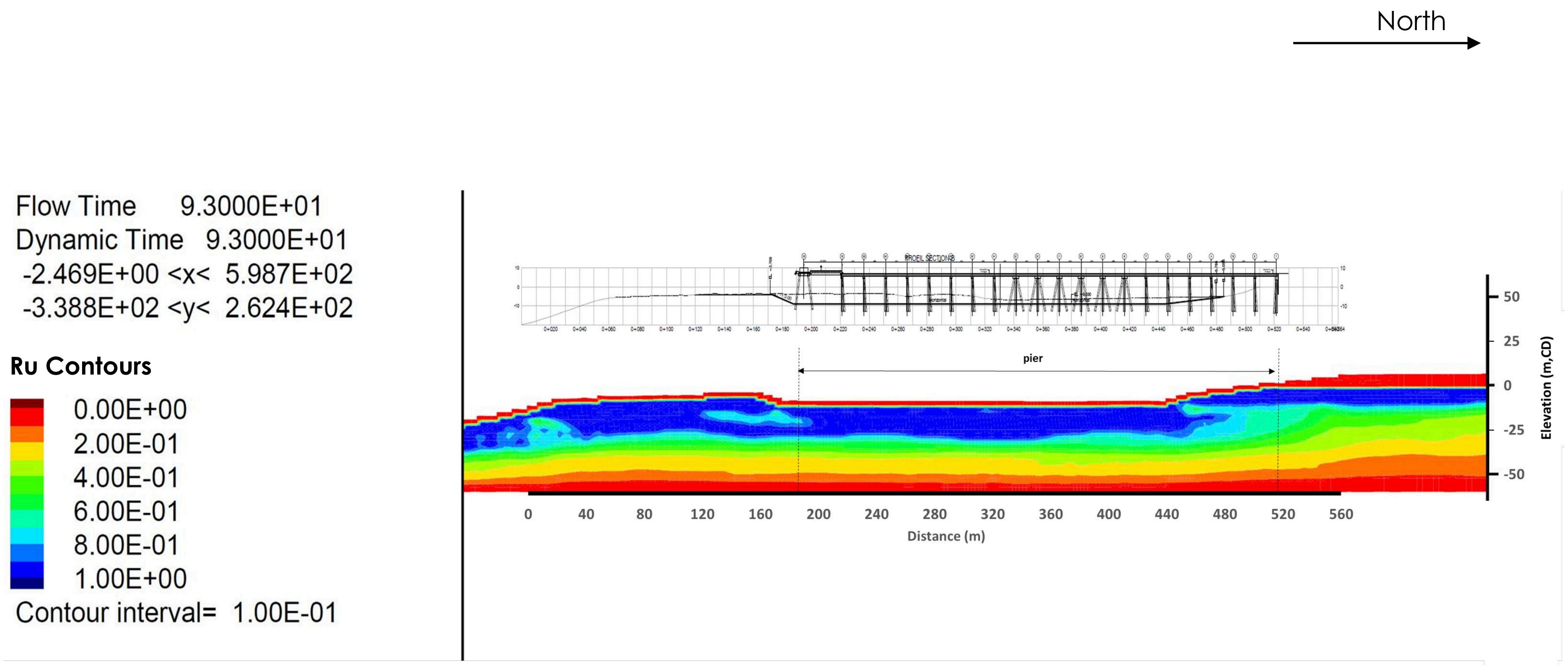
Project No.: 115619249
Scale: ---
Date: 20-June-20
Prepared by: VT
Checked by: ND

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Representative soil horizontal displacement contours - 2,475-Year Return Period

Figure No.
59



Representative excess pore water pressure ratio (Ru) contours (from Inslab-08 record)

Project No.:	115619249
Scale:	---
Date:	20-June-20
Prepared by:	VT
Checked by:	ND

Client/Project

Seaspan Vancouver Shipyards

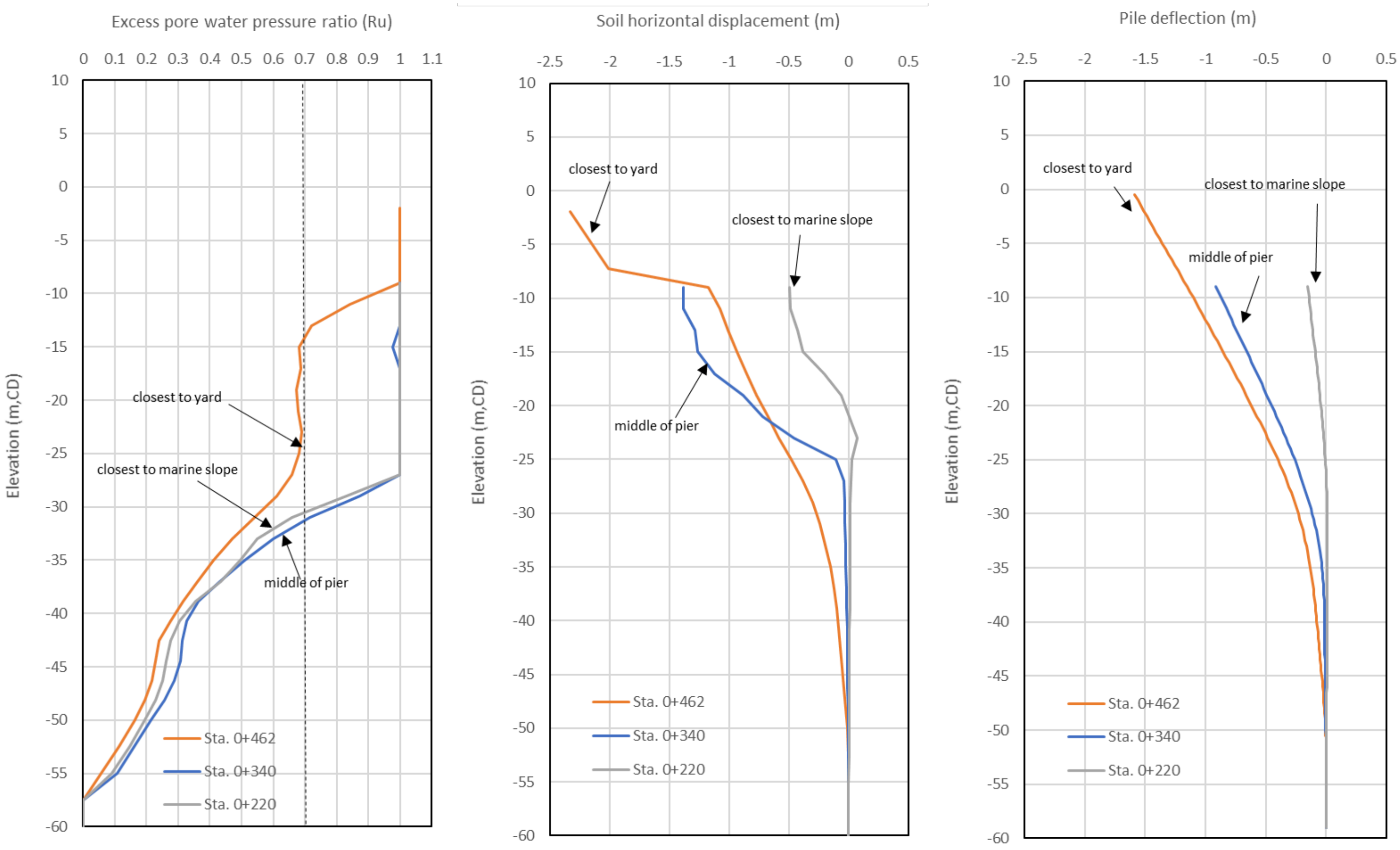
Outfitting Pier Expansion
North Vancouver, British Columbia

Title

Representative excess pore water pressure
ratio contours - 2,475-Year Return Period

Figure No.

60



Note:
- The results are from the Inslab-08 record, which provided largest soil displacements among the three select earthquake records.

Stantec

Project No.: 115619249
Scale: ---
Date: 20-June-20
Prepared by: VT
Checked by: ND

Client/Project
Seaspan Vancouver Shipyards

Outfitting Pier Expansion
North Vancouver, British Columbia

Title
Ru, horizontal soil and pile displacements
2,475-Year Return Period

Figure No.
61

Appendix A STATEMENT OF GENERAL CONDITIONS

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present

Appendix B BOREHOLE RECORDS

SYMBOLS AND TERMS USED ON BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Terminology describing common soil genesis

Rootmat	vegetation, roots and moss with organic matter and topsoil typically forming a mattress at the ground surface
Topsoil	mixture of soil and humus capable of supporting vegetative growth
Peat	mixture of visible and invisible fragments of decayed organic matter
Till	unstratified glacial deposit which may range from clay to boulders
Fill	material below the surface identified as placed by humans (excluding buried services)

Terminology describing soil structure

Desiccated	having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.
Fissured	having cracks, and hence a blocky structure
Varved	composed of regular alternating layers of silt and clay
Stratified	composed of alternating successions of different soil types, e.g. silt and sand
Layer	> 75 mm in thickness
Seam	2 mm to 75 mm in thickness
Parting	< 2 mm in thickness

Terminology describing soil types

The classification of soil types are made on the basis of grain size and plasticity in accordance with the Unified Soil Classification System (USCS) (ASTM D 2487 or D 2488) which excludes particles larger than 75 mm. For particles larger than 75 mm, and for defining percent clay fraction in hydrometer results, definitions proposed by Canadian Foundation Engineering Manual, 4th Edition are used. The USCS provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification.

Terminology describing cobbles, boulders, and non-matrix materials (organic matter or debris)

Terminology describing materials outside the USCS, (e.g. particles larger than 75 mm, visible organic matter, and construction debris) is based upon the proportion of these materials present:

Trace, or occasional	Less than 10%
Some	10-20%
Frequent	> 20%

Terminology describing compactness of cohesionless soils

The standard terminology to describe cohesionless soils includes compactness (formerly "relative density"), as determined by the Standard Penetration Test (SPT) N-Value - also known as N-Index. The SPT N-Value is described further on Page 2. A relationship between compactness condition and N-Value is shown in the following table.

Compactness Condition	SPT N-Value
Very Loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very Dense	>50

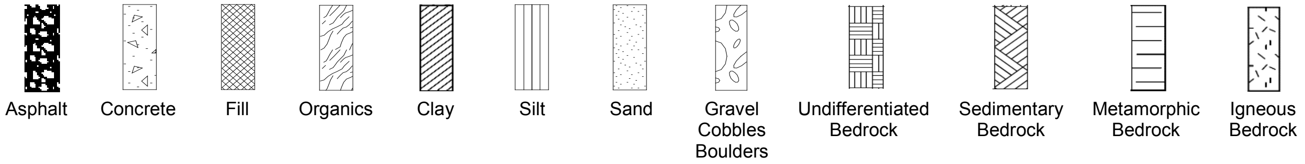
Terminology describing consistency of cohesive soils

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by *in situ* vane tests, penetrometer tests, or unconfined compression tests. Consistency may be crudely estimated from SPT N-Value based on the correlation shown in the following table (Terzaghi and Peck, 1967). The correlation to SPT N-Value is used with caution as it is only very approximate.

Consistency	Undrained Shear Strength		Approximate SPT N-Value
	kg/cm^2 or kips/sq.ft.	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25 - 0.5	12.5 - 25	2-4
Firm	0.5 - 1.0	25 - 50	4-8
Stiff	1.0 - 2.0	50 – 100	8-15
Very Stiff	2.0 - 4.0	100 - 200	15-30
Hard	>4.0	>200	>30

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



SAMPLE TYPE

AS, BS, GS	Auger sample; bulk sample; grab sample
DP	Direct-Push sample (small diameter tube sampler hydraulically advanced)
PS	Piston sample
SO	Sonic tube
SS	Split spoon sample (obtained by performing the Standard Penetration Test)
ST	Shelby Tube or thin wall tube
SV	Shear vane
RC *HQ, NQ, BQ, etc.*	Rock Core; samples obtained with the use of standard size diamond coring bits.

WATER LEVEL

▼ **Measured**: in standpipe, piezometer, or well

▽ **Inferred**: seepage noted, or; measured during or at completion of drilling

RECOVERY FOR SOIL SAMPLES

The recovery is recorded as the length of the soil sample recovered in the direct push, split spoon sampler, Shelby Tube, or sonic tube.

N-VALUE

Numbers in this column are the field results of the Standard Penetration Test (SPT): the number of blows of a 140-pound (63.5 kg) hammer falling 30 inches (760 mm), required to drive a 2 inch (50.8 mm) O.D. split spoon sampler one foot (300 mm) into the soil. In accordance with ASTM D1586, the N-Value equals the sum of the number of blows (N) required to drive the sampler over the interval of 6 to 18 in. (150 to 450 mm). However, when a 24 in. (610 mm) sampler is used, the number of blows (N) required to drive the sampler over the interval of 12 to 24 in. (300 to 610 mm) may be reported if this value is lower. For split spoon samples where insufficient penetration was achieved and N-Values cannot be presented, the number of blows are reported over sampler penetration in millimetres (e.g. 50 for 75 mm or 50/75 mm). Some design methods make use of N-values corrected for various factors such as overburden pressure, energy ratio, borehole diameter, etc. No corrections have been applied to the N-values presented on the log.

DYNAMIC CONE PENETRATION TEST (DCPT)

Dynamic cone penetration tests are performed using a standard 60-degree apex cone connected to ‘A’ size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone one foot (300 mm) into the soil. The DCPT is used as a probe to assess soil variability.

OTHER TESTS

S	Sieve analysis
H	Hydrometer analysis
k	Laboratory permeability
γ	Unit weight
G_s	Specific gravity of soil particles
CD	Consolidated drained triaxial
CU	Consolidated undrained triaxial with pore pressure measurements
UU	Unconsolidated undrained triaxial
DS	Direct Shear
C	Consolidation
Q_u	Unconfined compression
I_p	Point Load Index (I_p on Borehole Record equals $I_p(50)$ in which the index is corrected to a reference diameter of 50 mm)

	Single packer permeability test; test interval from depth shown to bottom of borehole
	Double packer permeability test; test interval as indicated
	Falling head permeability test using casing
	Falling head permeability test using well point or piezometer

ROCK DESCRIPTION

Except where specified below, terminology for describing rock is as defined by the International Society for Rock Mechanics (ISRM) 2007 publication "The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006"

Total Core Recovery (TCR) denotes the sum of all measurable rock core recovered in one drill run. The value is noted as a percentage of recovered rock core based on the total length of the drill run.

Solid Core Recovery (SCR) is defined as total length of solid core divided by the total drilled length, presented as a percentage. Solid core is defined as core with one full diameter.

Rock Quality Designation (RQD) is a modified core recovery that incorporates only pieces of solid core that are equal to or greater than 10 cm (4") along the core axis. It is calculated as the total cumulative length of solid core (> 10 cm) as measured along the centerline of the core divided by the total length of borehole drilled for each drill run or geotechnical interval, presented as a percentage. RQD is determined in accordance with ASTM D6032.

Fracture Index (FI) is defined as the number of naturally occurring fractures within a given length of core. The Fracture Index is reported as a simple count of natural occurring fractures.

Terminology describing rock quality

Rock Mass Quality	Rock Quality Designation Number (RQD)	Alternate (Colloquial) Rock Mass Quality	
Very Poor Quality	0-25	*Very Severely Fractured*	*Crushed*
Poor Quality	25-50	*Severely Fractured*	*Shattered or Very Blocky*
Fair Quality	50-75	*Fractured*	*Blocky*
Good Quality	75-90	*Moderately Jointed*	*Sound*
Excellent Quality	90-100	*Intact*	*Very Sound*

Terminology describing rock strength

Strength Classification	Grade	Unconfined Compressive Strength (MPa)
Extremely Weak	R0	<1
Very Weak	R1	1 – 5
Weak	R2	5 – 25
Medium Strong	R3	25 – 50
Strong	R4	50 – 100
Very Strong	R5	100 – 250
Extremely Strong	R6	>250

Terminology describing rock weathering

Term	Symbol	Description
Fresh	W1	No visible signs of rock weathering. Slight discoloration along major discontinuities
Slightly	W2	Discoloration indicates weathering of rock on discontinuity surfaces. All the rock material may be discolored.
Moderately	W3	Less than half the rock is decomposed and/or disintegrated into soil.
Highly	W4	More than half the rock is decomposed and/or disintegrated into soil.
Completely	W5	All the rock material is decomposed and/or disintegrated into soil. The original mass structure is still largely intact.
Residual Soil	W6	All the rock converted to soil. Structure and fabric destroyed.

Terminology describing rock with respect to discontinuity and bedding spacing

Spacing (mm)	Discontinuities Spacing	Bedding
>6000	*Extremely Wide*	-
2000-6000	*Very Wide*	*Very Thick*
600-2000	*Wide*	*Thick*
200-600	*Moderate*	*Medium*
60-200	*Close*	*Thin*
20-60	*Very Close*	*Very Thin*
<20	*Extremely Close*	*Laminated*
<6	-	*Thinly Laminated*

Stantec

BOREHOLE RECORD

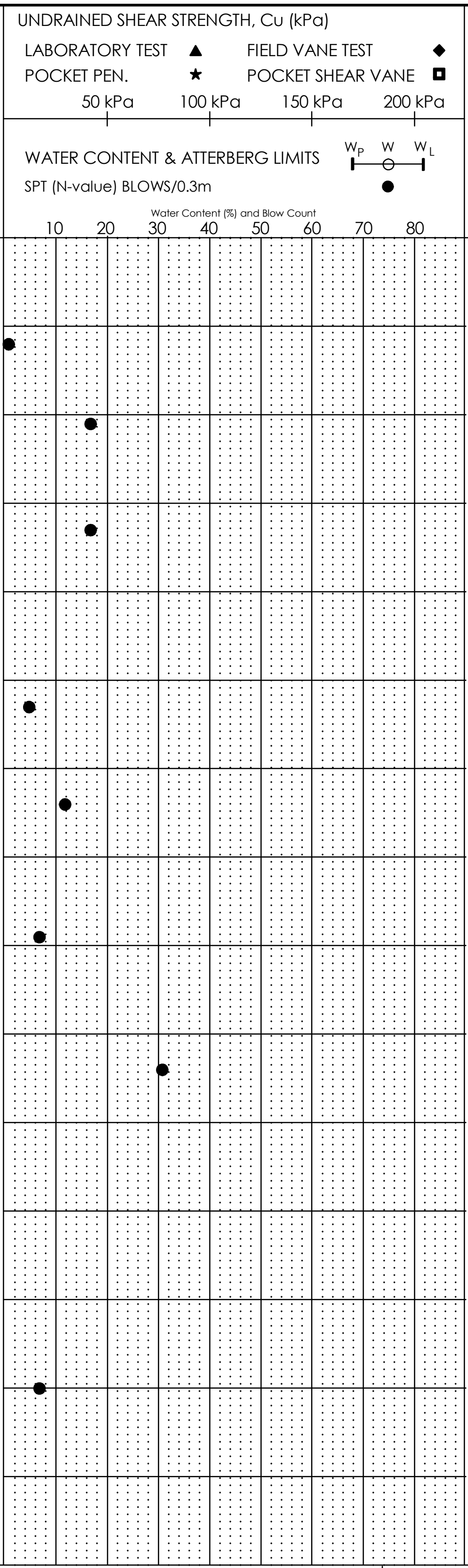
BH20-01

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/5/2020 to 5/7/2020**

BH COORDINATES
[UTM]
5462061.8N 492349.5E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-5.31m**
DATUM: **Chart**

ELEVATION (m)	SOIL DESCRIPTION (USCS)	STRATA PLOT	TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
-5.3	Very loose to compact, grey, poorly graded SAND (SP) - traces of silt	⁙					
			SS	1	200	1	
			SS	2	250	17	
			SS	3	600	17	
			SS	4	550	5	
			SS	5	450	12	
-12.9	Loose to compact, grey, SILTY SAND (SM)		SS	6	550	7	Grain Size Analysis: G S Fines 0% 73% 27%
	- traces of gravel at 9.1 m		SS	7	600	31	Percent Passing #200: 13%
			SS	8	50		SPT hammer malfunction at SS-08; repair hammer, clean out borehole and conduct SS-09.
	- grey poorly graded SAND (SP) with silt at 12.7 m - traces of shell fragments below 12.7 m		SS	9	425	7	Percent Passing #200: 11%



BACKFILL SYMBOL ▩ ASPHALT ▦ GROUT ◺ CONCRETE
■ BENTONITE ☒ DRILL CUTTINGS ⁙ SAND ▩ SLOUGH

Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY
Drilling Method: Mud Rotary	Reviewed By: BH
Completion Depth: 62 m	Page 1 of 5

BOREHOLE RECORD

Stantec

BH20-01

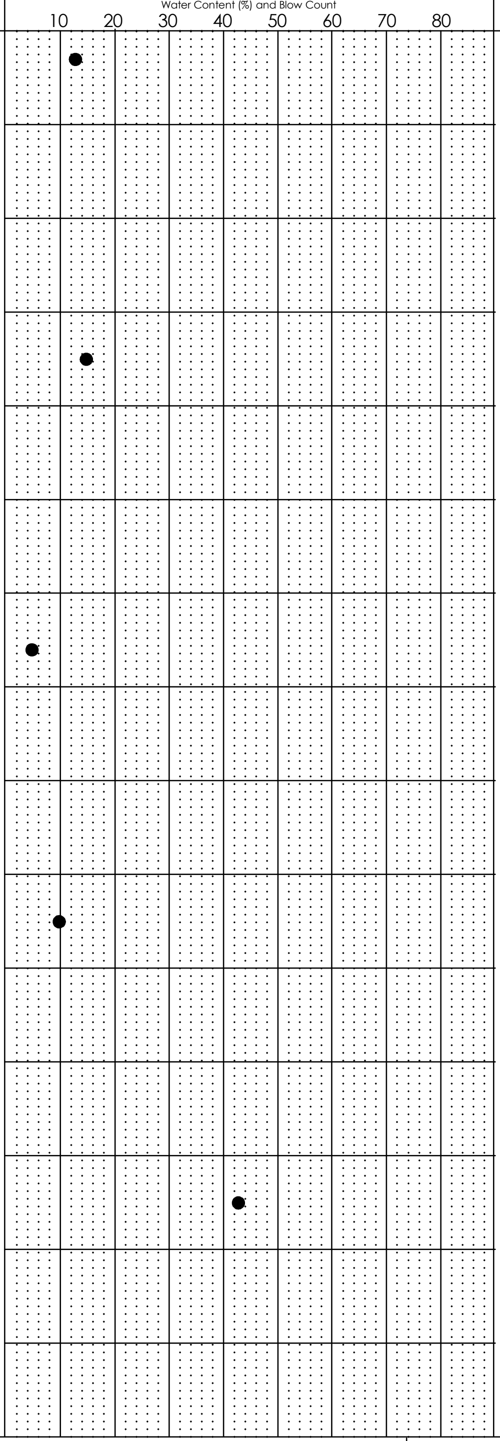
CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/5/2020 to 5/7/2020**

BH COORDINATES
[UTM]
5462061.8N 492349.5E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-5.31m**
DATUM: **Chart**

SOIL DESCRIPTION (USCS)	SAMPLES TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
Loose to compact, grey, SILTY SAND (SM)	SS	10	425	13	
	SS	11	450	15	Grain Size Analysis: G 9% S 60% Fines 31%
	SS	12	600	5	
	SS	13	600	10	Percent Passing #200: 28%
- gravelly between 24.7 m to 24.8 m					
- traces of gravel at 27.2 m	SS	14	400	43	

UNDRAINED SHEAR STRENGTH, Cu (kPa)
LABORATORY TEST ▲ FIELD VANE TEST ◆
POCKET PEN. ★ POCKET SHEAR VANE ◘
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
SPT (N-value) BLOWS/0.3m ●



DEPTH (m): 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
ELEVATION (m): -21 -22 -23 -24 -25 -26 -27 -28 -29 -30 -31 -32 -33 -34 -35

STRATA PLOT
BACKFILL/ MONITOR WELL/ PIEZOMETER

BACKFILL SYMBOL
▨ ASPHALT
▨ GROUT
▨ CONCRETE
■ BENTONITE
☒ DRILL CUTTINGS
▨ SAND
▨ SLOUGH

Drilling Contractor: Mud Bay Drilling / ConeTec
Drilling Method: Mud Rotary
Completion Depth: 62 m
Logged By: NG/MY
Reviewed By: BH

Printed Jun 19 2020 10:33:51 STANTEC GEO 2016 LOGS_115619249.GPJ MASTER1.GDT 6/19/20

BOREHOLE RECORD

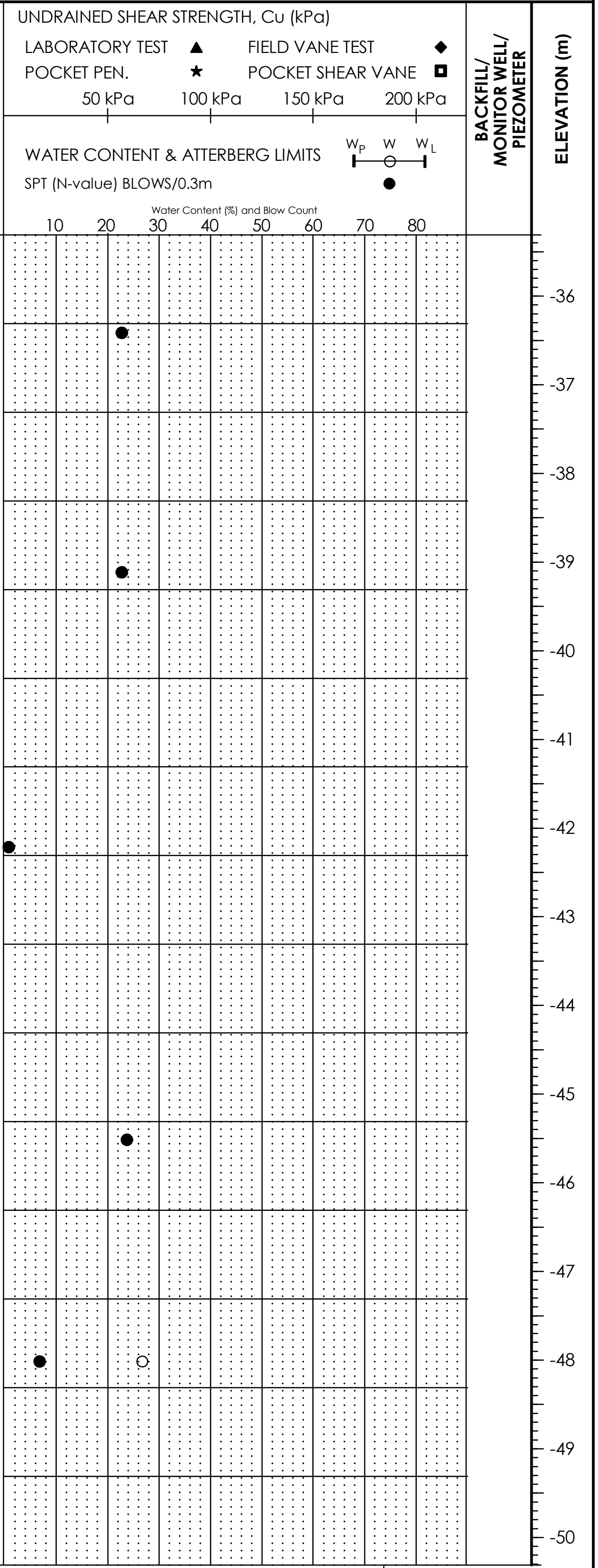
BH20-01

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/5/2020 to 5/7/2020**

BH COORDINATES
[UTM]
5462061.8N 492349.5E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-5.31m**
DATUM: **Chart**

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION (USCS)	TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
30		Loose to compact, grey, SILTY SAND (SM)					
			SS	15A	150		Percent Passing #200: 6%
31			SS	15B	450	23	Grain Size Analysis: G S Fines 1% 59% 40%
33			SS	16	500	23	
36	-41.9						
		Very loose to very dense, grey, low-plastic, SILT (ML) - with sand to sandy	SS	17	600	1	Percent Passing #200: 83%
40			SS	18	350	24	
42			SS	19	600	7	Percent Passing #200: 91%
45							



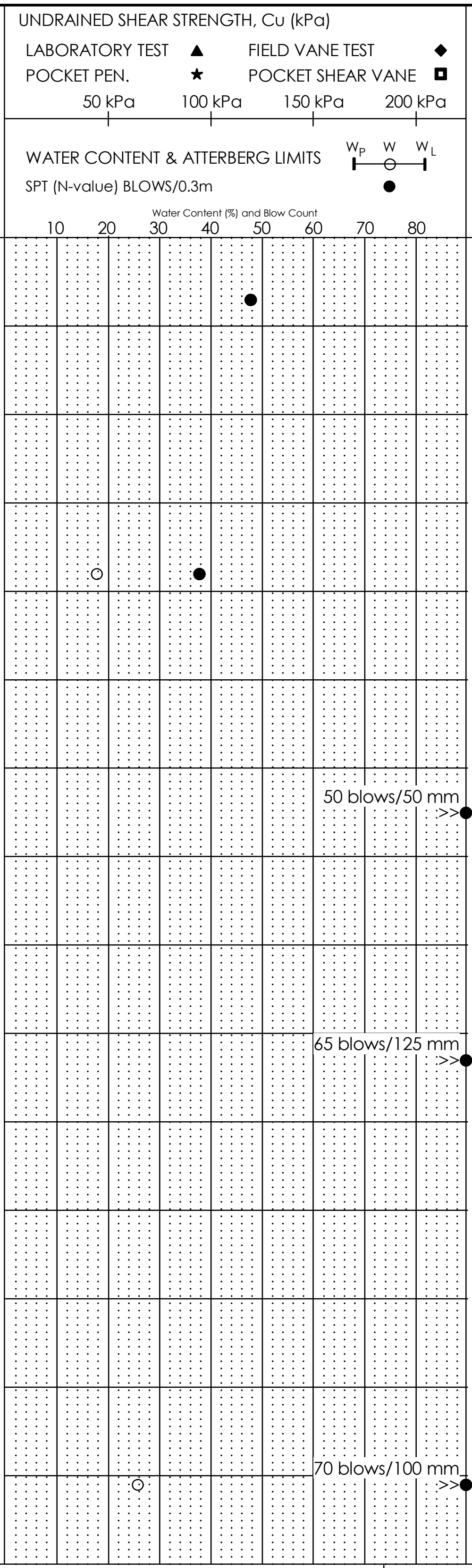
	Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY
BACKFILL SYMBOL ▦ ASPHALT ▩ GROUT ◫ CONCRETE	Drilling Method: Mud Rotary	Reviewed By: BH
■ BENTONITE ☒ DRILL CUTTINGS ⛆ SAND ▩ SLOUGH	Completion Depth: 62 m	Page 3 of 5

BOREHOLE RECORD

BH20-01

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/5/2020 to 5/7/2020**
BH COORDINATES
[UTM]
5462061.8N 492349.5E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**
PROJECT NO. : **115619249**
BH ELEVATION: **-5.31m**
DATUM: **Chart**

ELEVATION (m)	SOIL DESCRIPTION (USCS)	TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
	Very loose to very dense, grey, low-plastic, SILT (ML) - with sand to sandy - hard below 45.4 m	SS	20	300	48	
	- sandy below 48.5 m	SS	21	500	38	Percent Passing #200: 55%
	- inferred boulder from 51.2 m to 52.4 m - difficult drilling below 51.2 m	SS	22	125	R	
-59.3	Very dense, grey, SILTY GRAVEL (GM) with sand	SS	23	200	R	
-64.1	Hard, grey, sandy, lean CLAY (CL) with gravel (Till-like)	SS	24	250	R	Percent Passing #200: 86%



DEPTH (m): 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60

ELEVATION (m): -51, -52, -53, -54, -55, -56, -57, -58, -59, -60, -61, -62, -63, -64, -65

BACKFILL/ MONITOR WELL/ PIEZOMETER

BACKFILL SYMBOL ▨ ASPHALT ▨ GROUT ▨ CONCRETE
■ BENTONITE ☒ DRILL CUTTINGS ▨ SAND ▨ SLOUGH

Drilling Contractor: Mud Bay Drilling / ConeTec
Drilling Method: Mud Rotary
Completion Depth: 62 m
Logged By: NG/MY
Reviewed By: BH

Stantec

BOREHOLE RECORD

BH20-01

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/5/2020 to 5/7/2020**

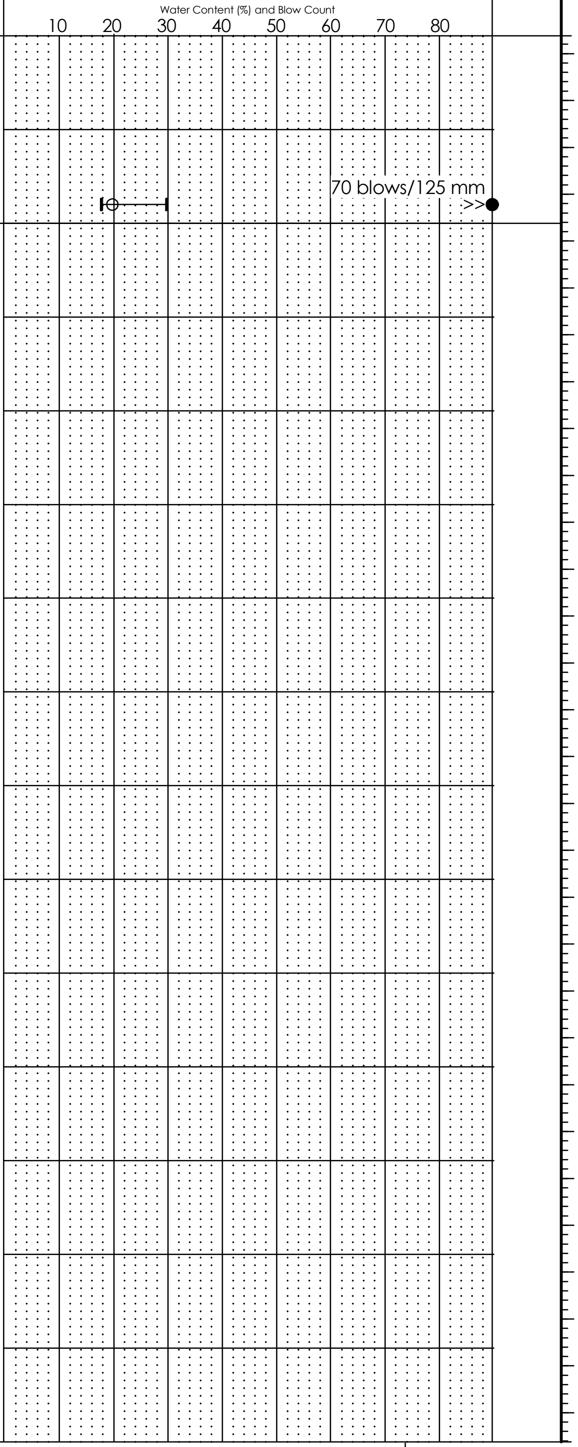
BH COORDINATES
[UTM]
5462061.8N 492349.5E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-5.31m**
DATUM: **Chart**

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION (USCS)	STRATA PLOT	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm) or TCR %	SAMPLES N-VALUE or RQD %	OTHER TESTS / REMARKS
60		Hard, grey, sandy, lean CLAY (CL) with gravel (Till-like)	▨					
61.6			▨	SS	25	400	R	Percent Passing #200: 75%
62	-67.3	End of borehole BH20-01 at 62.0 m below existing mudline						

UNDRAINED SHEAR STRENGTH, Cu (kPa)
LABORATORY TEST ▲ FIELD VANE TEST ◆
POCKET PEN. ★ POCKET SHEAR VANE ◘
50 kPa 100 kPa 150 kPa 200 kPa
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
SPT (N-value) BLOWS/0.3m ●

BACKFILL/ MONITOR WELL/ PIEZOMETER



Depth (m): 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75

BACKFILL SYMBOL ▩ ASPHALT ▦ GROUT ◫ CONCRETE
■ BENTONITE ☒ DRILL CUTTINGS ⛆ SAND ▩ SLOUGH

Drilling Contractor: Mud Bay Drilling / ConeTec
Drilling Method: Mud Rotary
Completion Depth: 62 m

Logged By: NG/MY
Reviewed By: BH
Page 5 of 5

BOREHOLE RECORD

BH20-02

CLIENT:	Seaspan Vancouver Shipyards	BH COORDINATES	PROJECT NO. : 115619249
PROJECT:	Seaspan Outfitting Pier Expansion	[UTM]	BH ELEVATION: -6.86m
LOCATION:	North Vancouver, British Columbia	5462192.1N 492349.0E	DATUM: Chart
DATE BORED:	5/7/2020 to 5/8/2020	WATER LEVEL: EL. 3.1 m Mean Sea Level	

DEPTH (m) 0 – ELEVATION (m) -6.9

SOIL DESCRIPTION (USCS)

Very loose to compact, grey, poorly graded SAND (SP)
- traces of silt to with silt
- silty at 7.6 m

SAMPLES TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
SS	1	150	25	
SS	2	325	7	SS-03: duplicate sample of SS-02 for blind chemical testing
~~SS~~	~~3~~	~~0~~		
SS	4	325	9	
SS	5	350	7	
SS	6	375	9	
SS	7	350	18	Grain Size Analysis: G S Fines 0% 85% 15%
SS	8	400	19	
SS	9	350	13	Percent Passing #200: 6%

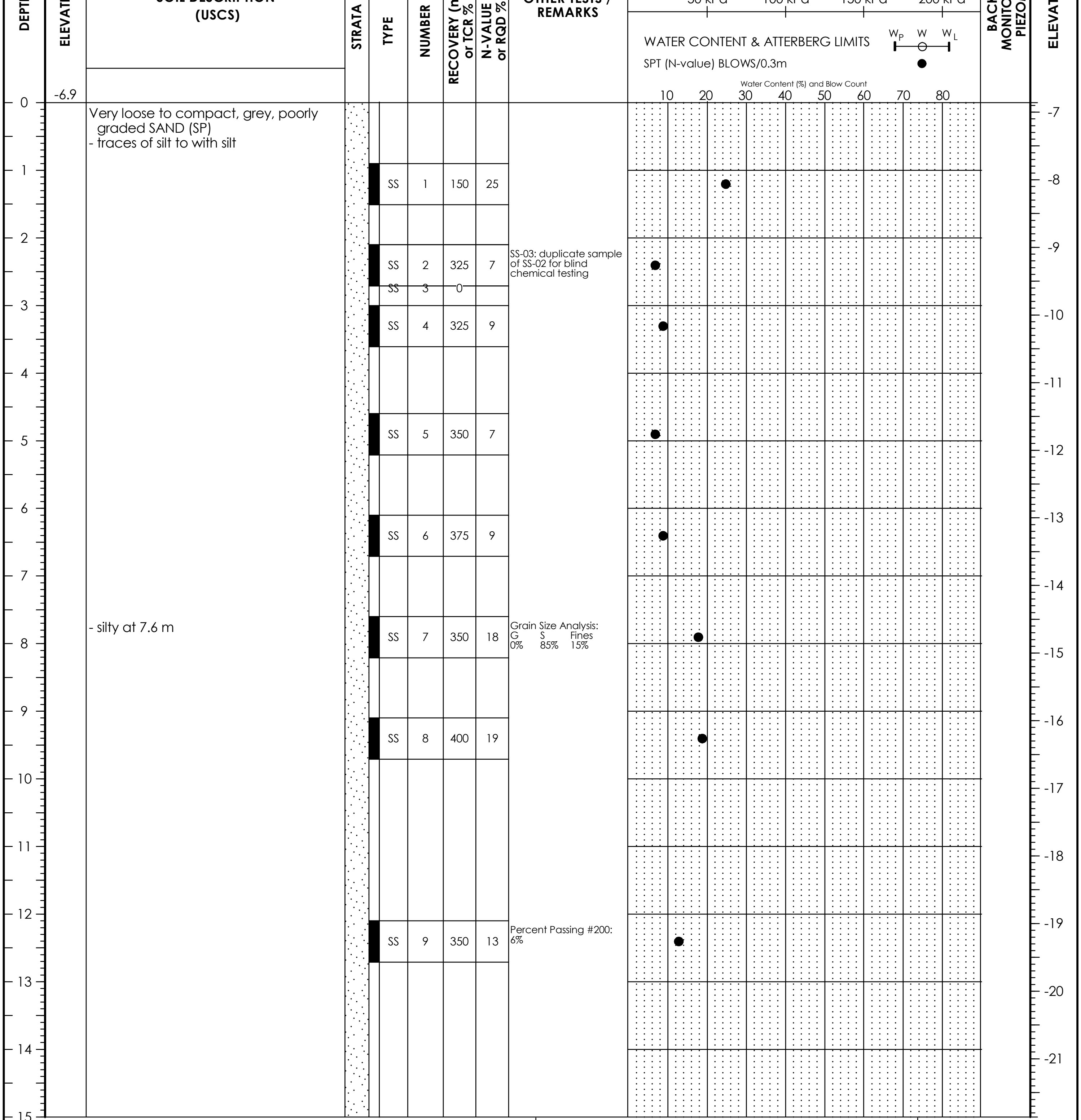
UNDRAINED SHEAR STRENGTH, Cu (kPa)

LABORATORY TEST ▲ FIELD VANE TEST ◆

POCKET PEN. ★ POCKET SHEAR VANE ◘

WATER CONTENT & ATTERBERG LIMITS W_P W W_L

SPT (N-value) BLOWS/0.3m ●



BACKFILL SYMBOL	Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY
▦ ASPHALT ▩ GROUT ▨ CONCRETE	Drilling Method: Mud Rotary	Reviewed By: BH
■ BENTONITE ☒ DRILL CUTTINGS ⛆ SAND ▩ SLOUGH	Completion Depth: 56.7 m	Page 1 of 4

Stantec

BOREHOLE RECORD

BH20-02

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/7/2020 to 5/8/2020**

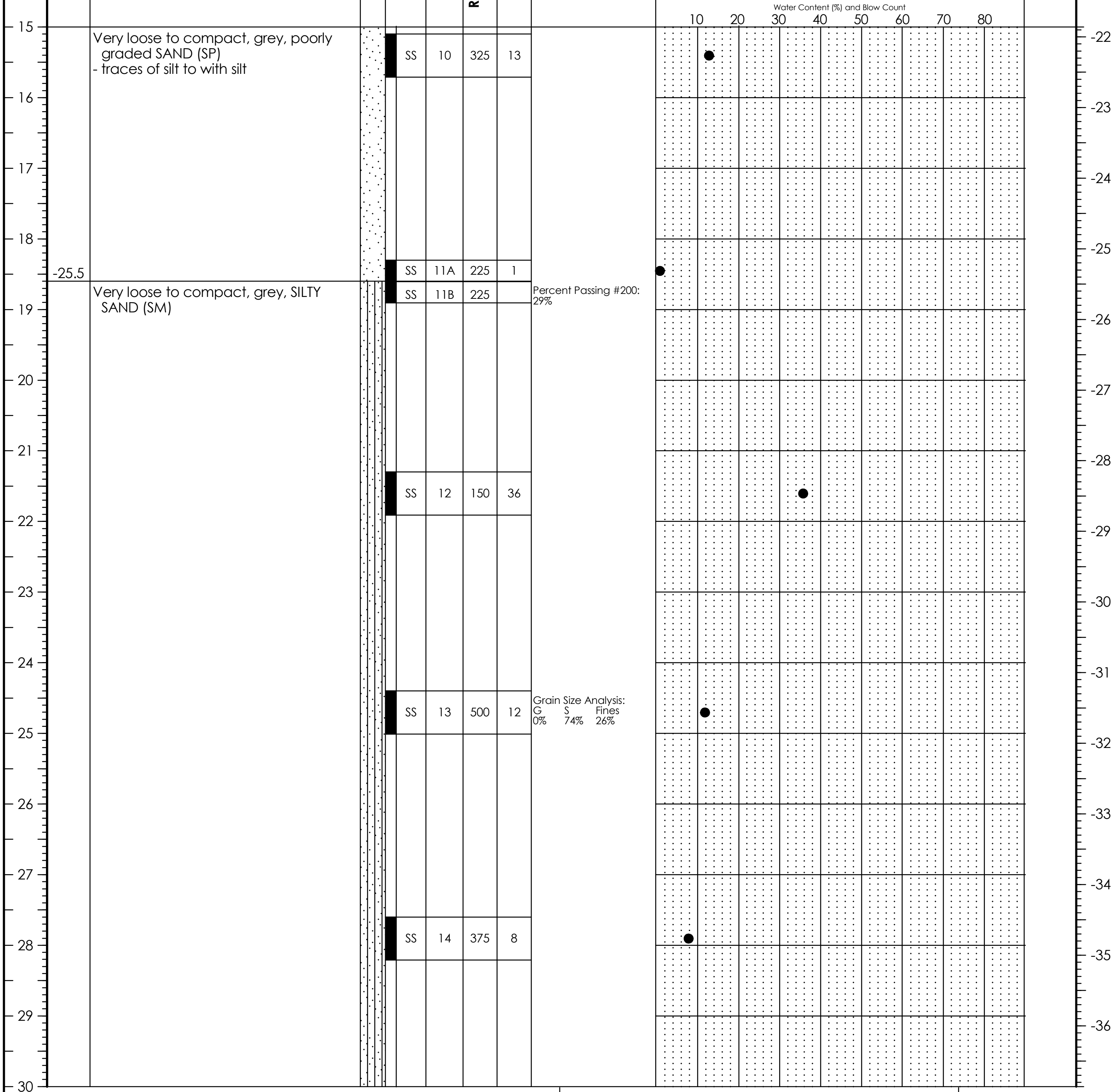
BH COORDINATES
[UTM]
5462192.1N 492349.0E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-6.86m**
DATUM: **Chart**

ELEVATION (m)	SOIL DESCRIPTION (USCS)	TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
	Very loose to compact, grey, poorly graded SAND (SP) - traces of silt to with silt	SS	10	325	13	
		SS	11A	225	1	
-25.5	Very loose to compact, grey, SILTY SAND (SM)	SS	11B	225		Percent Passing #200: 29%
		SS	12	150	36	
		SS	13	500	12	Grain Size Analysis: G S Fines 0% 74% 26%
		SS	14	375	8	

UNDRAINED SHEAR STRENGTH, Cu (kPa)
LABORATORY TEST ▲ FIELD VANE TEST ◆
POCKET PEN. ★ POCKET SHEAR VANE ◘
50 kPa 100 kPa 150 kPa 200 kPa
WATER CONTENT & ATTERBERG LIMITS W_P W W_L
SPT (N-value) BLOWS/0.3m ●

BACKFILL/ MONITOR WELL/ PIEZOMETER



Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY
Drilling Method: Mud Rotary	Reviewed By: BH
Completion Depth: 56.7 m	Page 2 of 4

BACKFILL SYMBOL
■ BENTONITE
▩ ASPHALT
☒ DRILL CUTTINGS
▨ GROUT
⁘ SAND
◩ CONCRETE
▩ SLOUGH

Printed Jun 19 2020 10:34:4 STANTEC GEO 2016 LOGS_115619249.GPJ MASTER1.GDT 6/19/20

Stantec

BOREHOLE RECORD

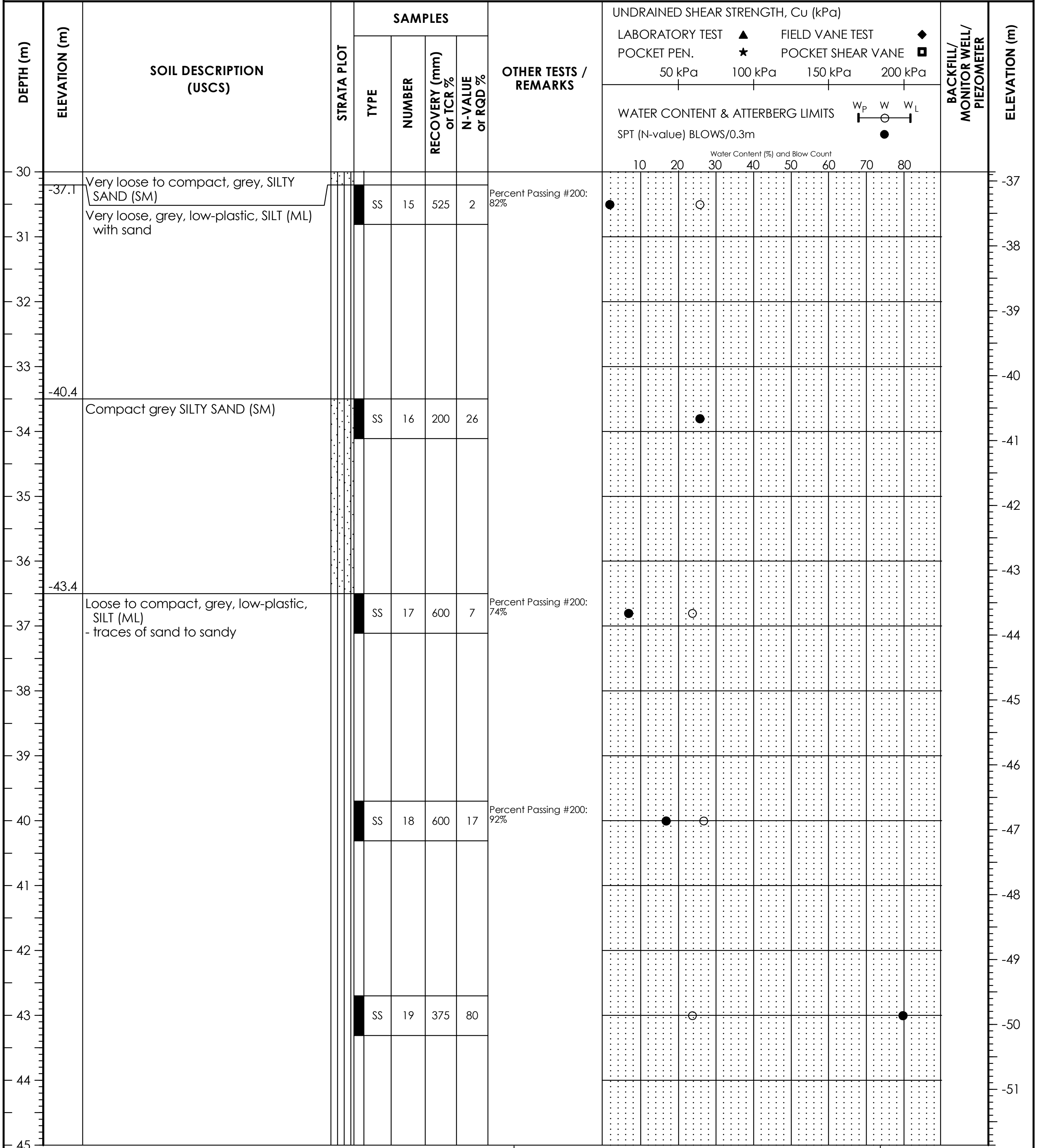
BH20-02

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/7/2020 to 5/8/2020**

BH COORDINATES
[UTM]
5462192.1N 492349.0E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-6.86m**
DATUM: **Chart**

ELEVATION (m)	SOIL DESCRIPTION (USCS)	SAMPLES TYPE	SAMPLES NUMBER	SAMPLES RECOVERY (mm) or TCR %	SAMPLES N-VALUE or RQD %	OTHER TESTS / REMARKS
	Very loose to compact, grey, SILTY SAND (SM)					
-37.1	Very loose, grey, low-plastic, SILT (ML) with sand	SS	15	525	2	Percent Passing #200: 82%
-40.4	Compact grey SILTY SAND (SM)	SS	16	200	26	
-43.4	Loose to compact, grey, low-plastic, SILT (ML) - traces of sand to sandy	SS	17	600	7	Percent Passing #200: 74%
		SS	18	600	17	Percent Passing #200: 92%
		SS	19	375	80	



Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY		
Drilling Method: Mud Rotary	Reviewed By: BH		
Completion Depth: 56.7 m	Page 3 of 4		

BACKFILL SYMBOL
- ■ BENTONITE
- ASPHALT
- ☒ DRILL CUTTINGS
- ▨ GROUT
- SAND
- CONCRETE
- ▩ SLOUGH

Stantec

BOREHOLE RECORD

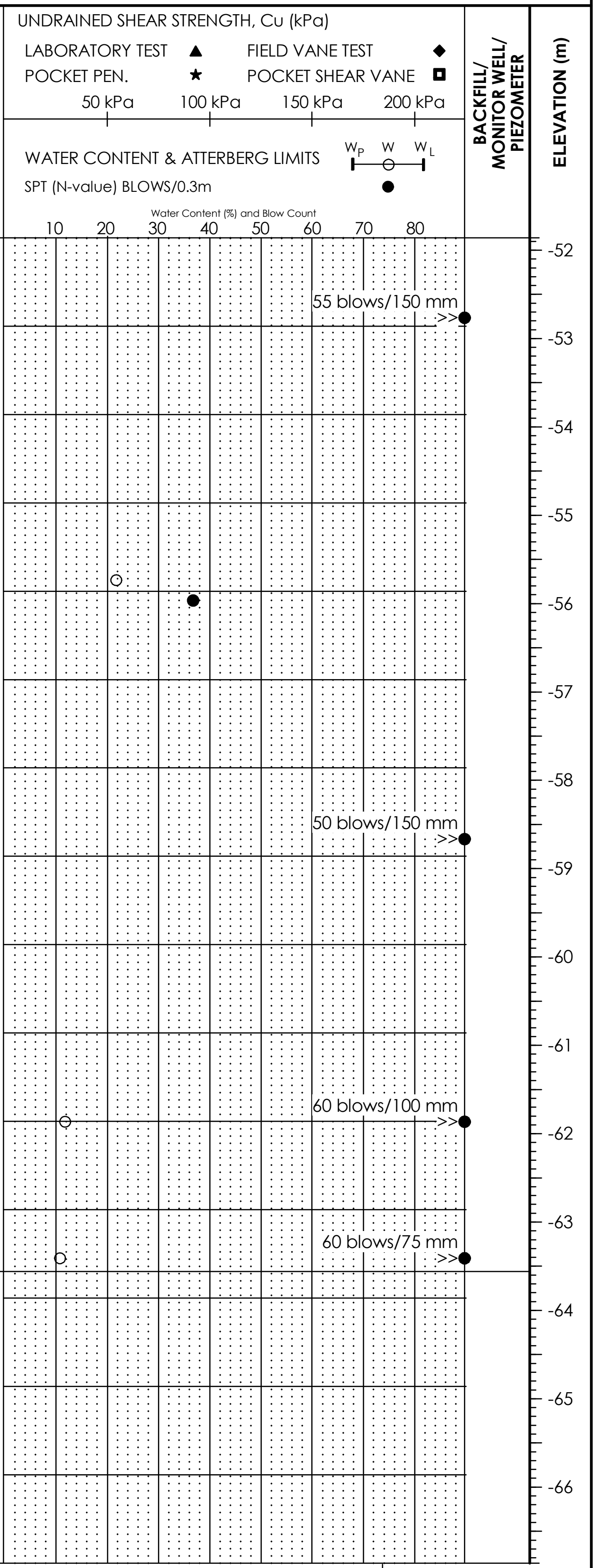
BH20-02

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/7/2020 to 5/8/2020**

BH COORDINATES
[UTM]
5462192.1N 492349.0E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**

PROJECT NO. : **115619249**
BH ELEVATION: **-6.86m**
DATUM: **Chart**

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION (USCS)	SAMPLES TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
45	-52.5	Compact, grey, low-plastic, SILT (ML) - traces of sand to sandy					
46	-55.7	Very dense grey poorly graded SAND with silt (SP-SM)	SS	20	300	R	
49	-55.8	Dense, grey, low-plastic, SILT (ML) - traces of sand	SS	21A	175	37	
	-58.4	Very dense grey well graded SAND (SW) - traces of silt	SS	21B	200		
52	-61.6	Very dense grey SILTY GRAVEL (GM) with sand	SS	22	250	R	Grain Size Analysis: G 40% S 27% Fines 33%
55		Very dense grey SILTY SAND (SM) with gravel (Till-like)	SS	23	200	R	
56.7	-63.6		SS	24	225	R	Percent Passing #200: 38%
57		End of borehole BH20-02 at 56.7 m below existing mudline					



BACKFILL SYMBOL ▨ ASPHALT ▨ GROUT ▨ CONCRETE
▨ BENTONITE ☒ DRILL CUTTINGS ▨ SAND ▩ SLOUGH

Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY
Drilling Method: Mud Rotary	Reviewed By: BH
Completion Depth: 56.7 m	Page 4 of 4

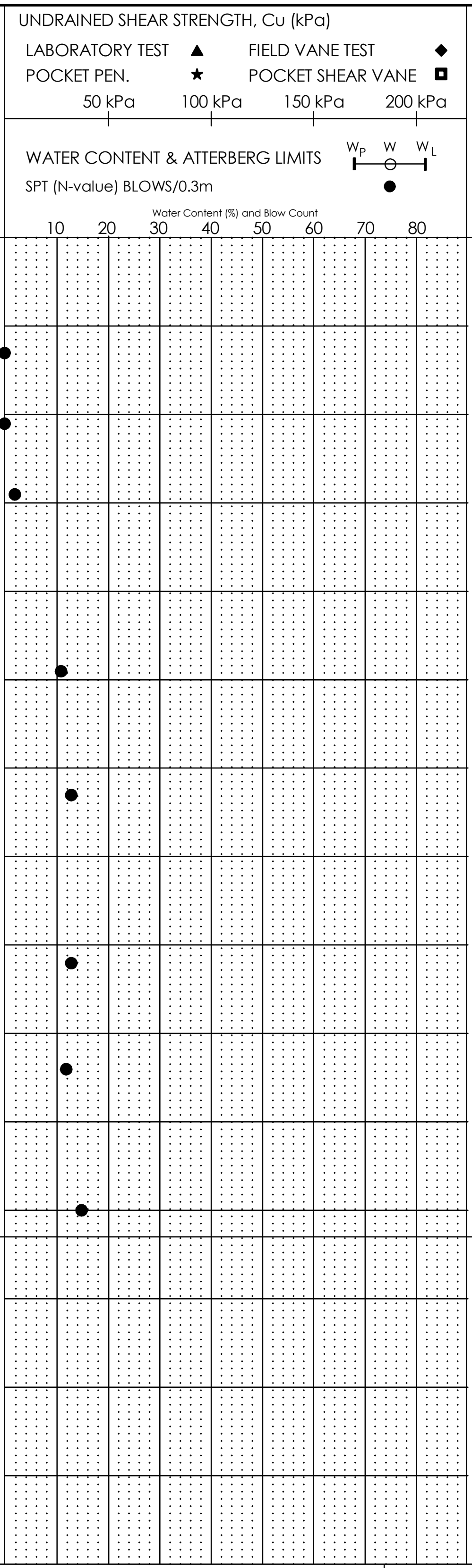
Stantec

BOREHOLE RECORD

BH20-03

CLIENT: **Seaspan Vancouver Shipyards**
PROJECT: **Seaspan Outfitting Pier Expansion**
LOCATION: **North Vancouver, British Columbia**
DATE BORED: **5/9/2020 to 5/9/2020**
BH COORDINATES
[UTM]
5462324.8N 492366.1E
WATER LEVEL: **EL. 3.1 m Mean Sea Level**
PROJECT NO. : **115619249**
BH ELEVATION: **-6.30m**
DATUM: **Chart**

ELEVATION (m)	SOIL DESCRIPTION (USCS)	SAMPLES TYPE	NUMBER	RECOVERY (mm) or TCR %	N-VALUE or RQD %	OTHER TESTS / REMARKS
-6.3	Very loose, dark grey, non-plastic, SILT (ML) with organics and peat					
		SS	1	150	0	Split spoon penetrates soil by weight of rods
		SS	2	100	0	Split spoon penetrates soil by weight of rods
		SS	3	0	2	
-10.9	Compact grey poorly graded SAND (SP) - traces of shell fragments - traces of silt to silty	SS	4	600	11	SS-05: duplicate sample of SS-04 for blind chemical testing
		SS	5			
		SS	6	600	13	
	- with silt below 7.9 m	SS	7	350	13	Grain Size Analysis: G S Fines 4% 91% 5%
	- traces of wood fragments at 9.1 m	SS	8	325	12	Percent Passing #200: 6%
	Compact grey poorly graded SAND (SP) - traces of shell fragments - traces of silt to silty - silty at 10.7 m	SS	9	375	15	Percent Passing #200: 16%
-17.6	End of borehole BH20-03 at 11.3 m below existing mudline					



DEPTH (m): 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

ELEVATION (m): -7 -8 -9 -10 -11 -12 -13 -14 -15 -16 -17 -18 -19 -20 -21

STRATA PLOT

BACKFILL/ MONITOR WELL/ PIEZOMETER

Drilling Contractor: Mud Bay Drilling / ConeTec	Logged By: NG/MY
Drilling Method: Mud Rotary	Reviewed By: BH
Completion Depth: 11.3 m	Page 1 of 1

BACKFILL SYMBOL
- ■ BENTONITE
- ASPHALT
- ☒ DRILL CUTTINGS
- ▨ GROUT
- SAND
- CONCRETE
- ▩ SLOUGH

Appendix C CONE PENETRATION TESTING PLOTS

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

Job No:	20-02-20794
Client:	Stantec Consulting Ltd.
Project:	Seaspan Vancouver Shipyard
Start Date:	05-May-2020
End Date:	09-May-2020

CONE PENETRATION TEST SUMMARY

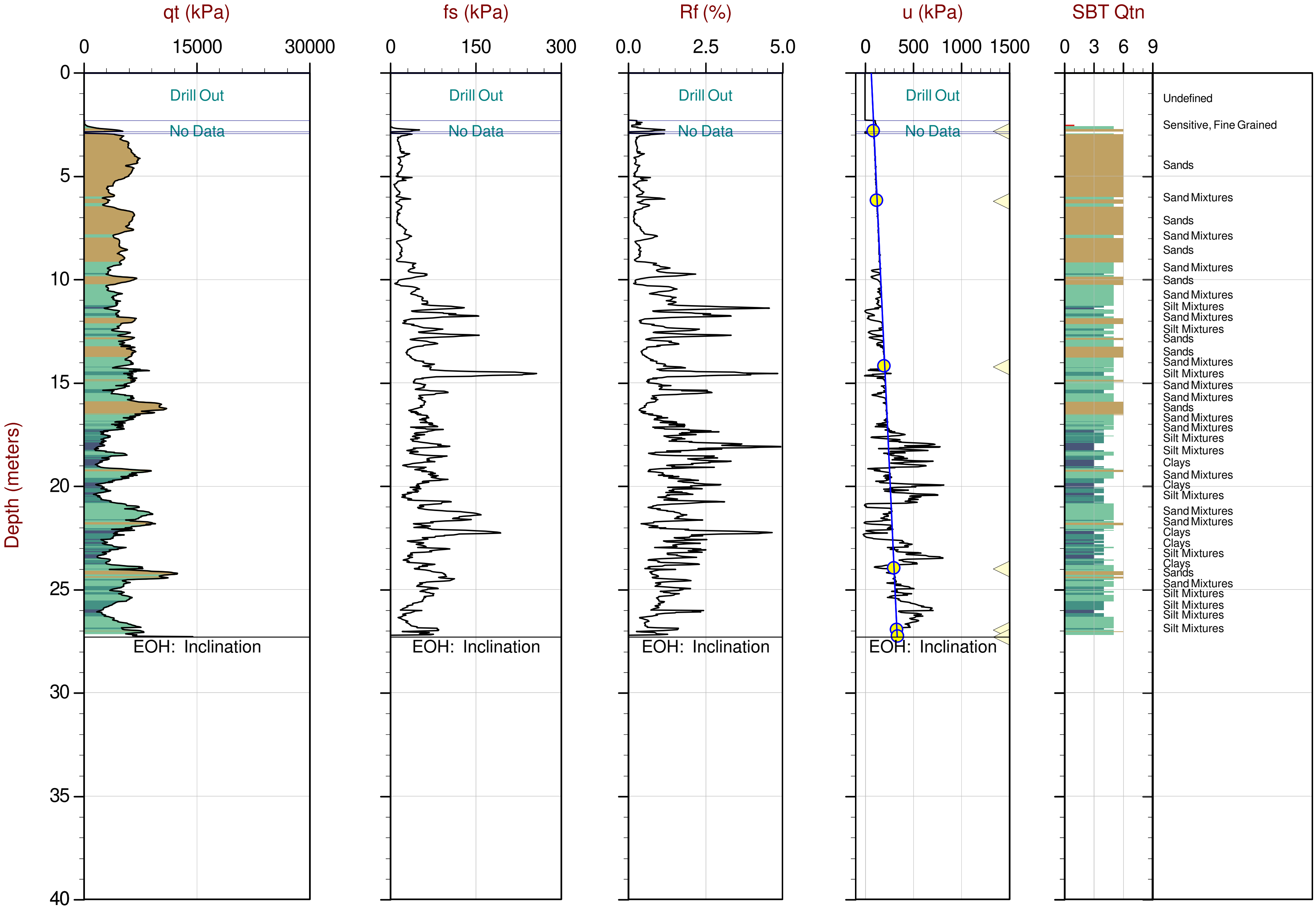
Sounding ID	File Name	Date	Cone	Assumed Phreatic Surface[1] (m)	Final Depth[2] (m)	Northing[3] (m)	Easting[3] (m)	Mudline Elevation[4] (m)	Refer to Notation Number
SCPT20-01	20-02-20794_SP01	05-May-2020	622:T1500F15U500	-6.6	27.300	5462013.38	492343.41	-7.61	5
CPT20-02	20-02-20794_CP02	07-May-2020	622:T1500F15U500	-10.0	32.450	5462126.54	492346.62	-8.36	
SCPT20-03	20-02-20794_SP03	08-May-2020	622:T1500F15U500	-9.5	36.200	5462267.40	492349.26	-10.11	6
CPT20-04	20-02-20794_CP04	08-May-2020	622:T1500F15U500	-10.1	36.400	5462326.52	492346.56	-8.95	
SCPT20-05	20-02-20794_SP05	09-May-2020	622:T1500F15U500	-7.1	34.150	5462322.41	492457.33	-6.10	7

1. The assumed phreatic surface was based on pore pressure dissipation tests, unless otherwise noted. Hydrostatic conditions were assumed for the calculated parameters.
2. The penetration depths are referenced to the existing mudline at the time of testing.
3. Coordinates were collected using a Can-Net survey in WGS1984/ UTM Zone 10 North. Geoid: HT2_0.
4. Mudline elevation was derived from the deck elevation collected using a Can-Net survey (Geoid: HT2_0).
5. No data presented from 2.850m-2.925m due to equipment issues.
6. No data presented from 5.675m-5.750m due to equipment issues.
7. No data presented from 16.425m-16.600m due to equipment issues.

Stantec

Job No: 20-02-20794
Date: 2020-05-05 09:11
Site: North Vancouver

Sounding: SCPT20-01
Cone: 622:T1500F15U500



Max Depth: 27.300 m / 89.57 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_SP01.COR
Unit Wt: SBTQtn (PKR2009)

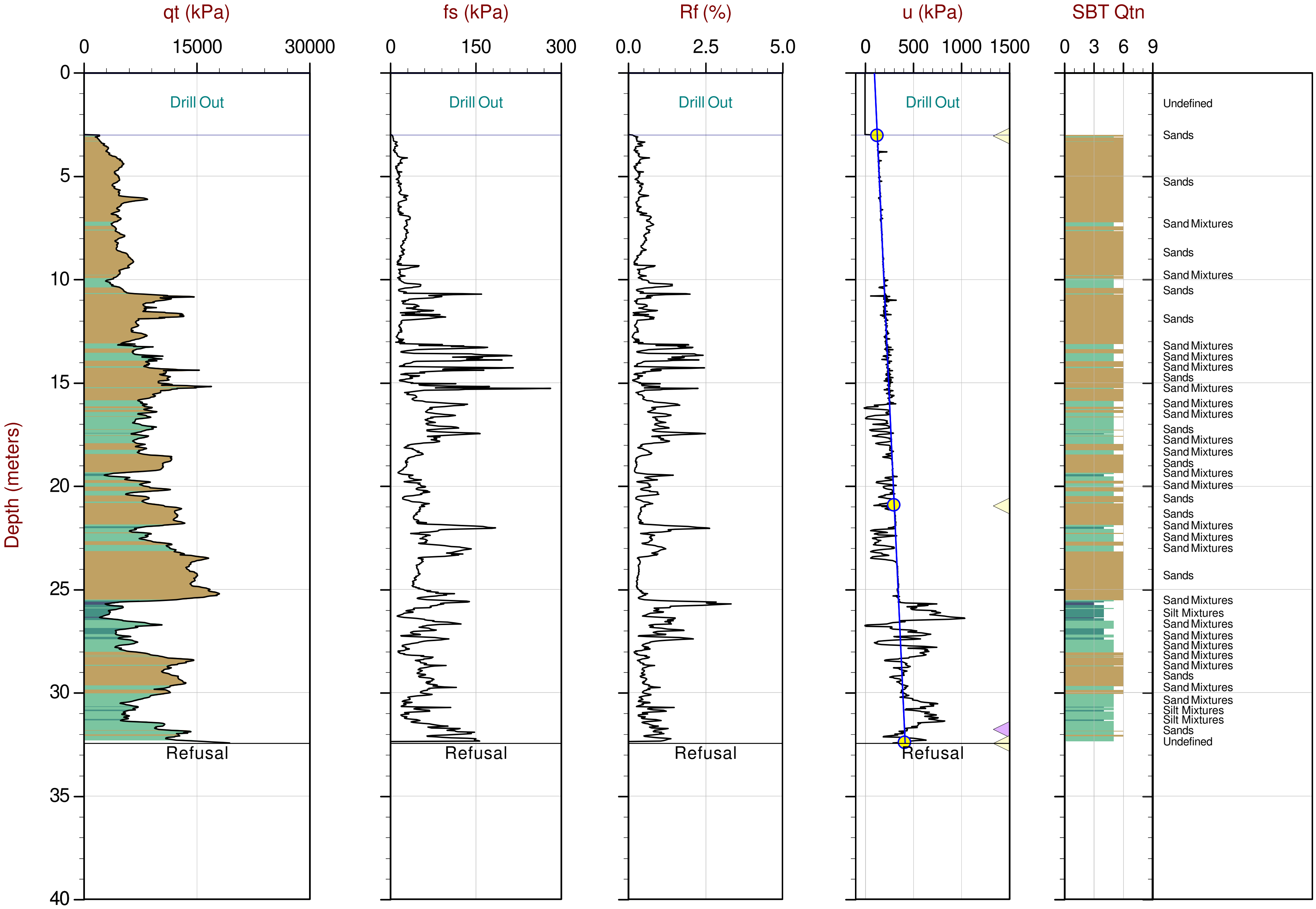
SBT: Robertson, 2009 and 2010
Coords: UTM 10N N:5462013.38m E:492343.41m Elev:-7.61m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved — Hydrostatic Line

Stantec

Job No: 20-02-20794
Date: 2020-05-07 04:13
Site: North Vancouver

Sounding: CPT20-02
Cone: 622:T1500F15U500



Max Depth: 32.450 m / 106.46 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_CP02.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N:5462126.54m E:492346.62m Elev:-8.36m
Sheet No: 1 of 1

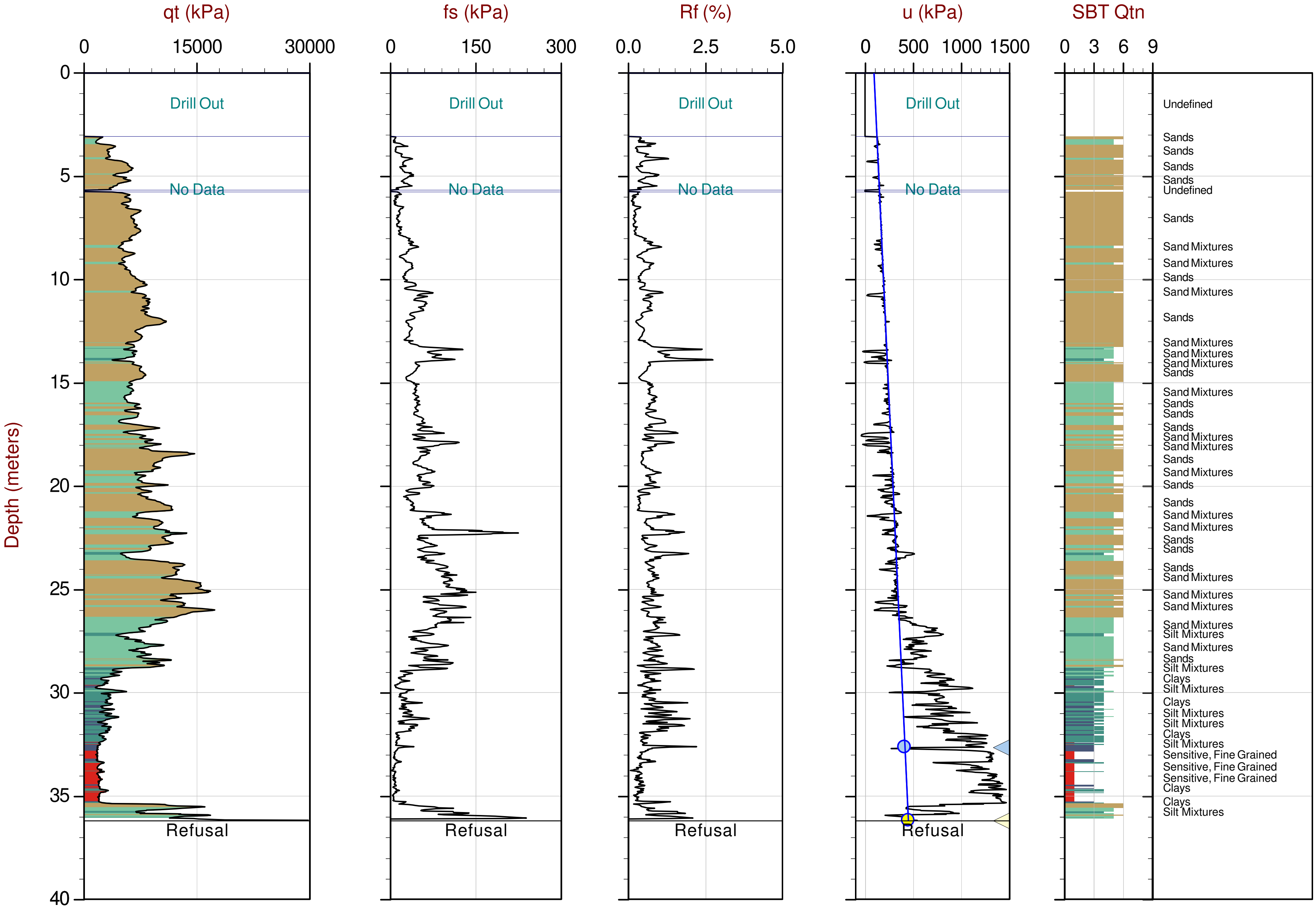
● Equilibrium Pore Pressure (Ueq)   ● Assumed Ueq   ◁ Dissipation, Ueq achieved   ◁ Dissipation, Ueq not achieved   — Hydrostatic Line

CONETEC

Stantec

Job No: 20-02-20794
Date: 2020-05-08 09:43
Site: North Vancouver

Sounding: SCPT20-03
Cone: 622:T1500F15U500



Max Depth: 36.200 m / 118.76 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 5462267.40m E: 492349.26m Elev: -10.11m
Sheet No: 1 of 1

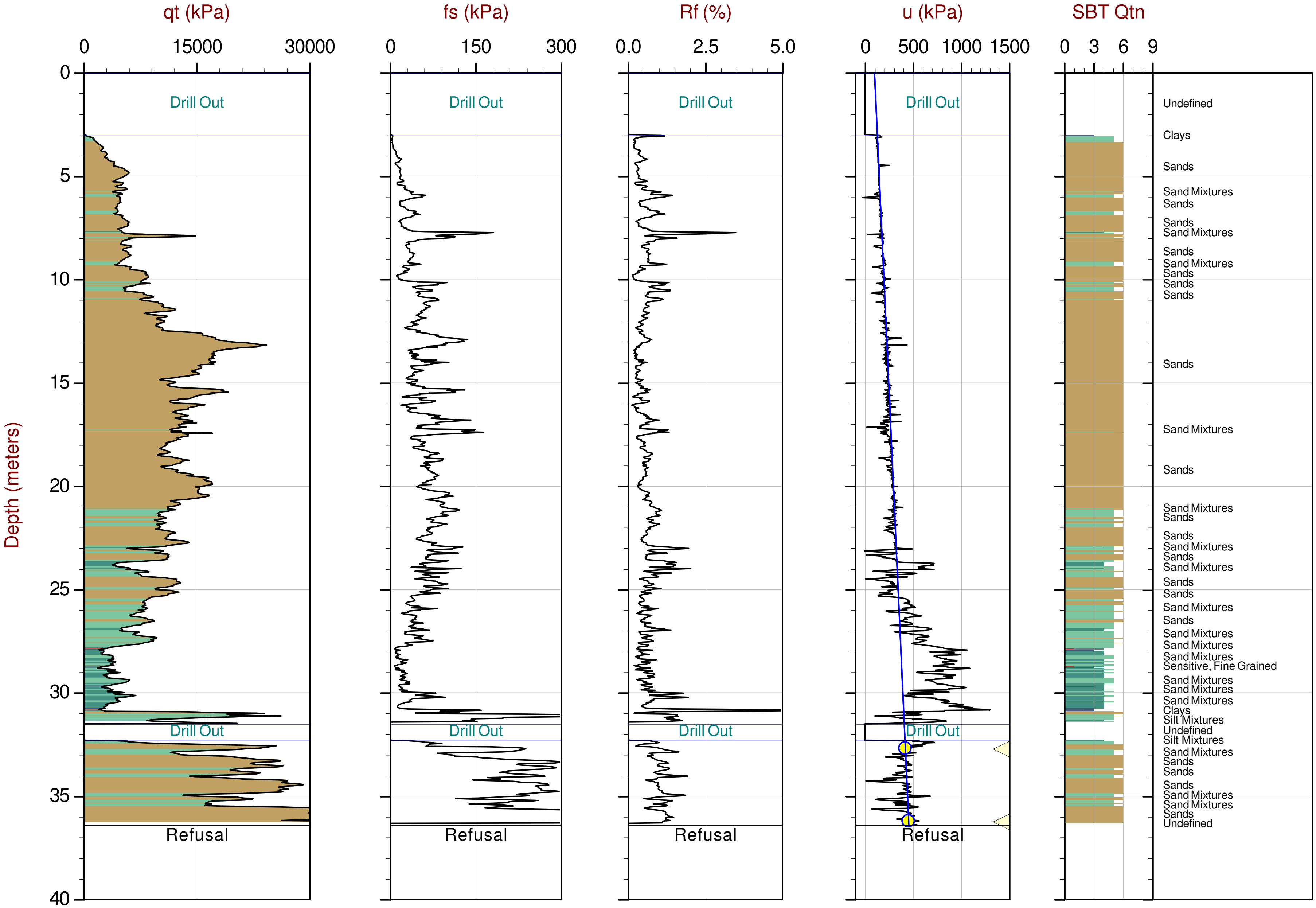
Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Hydrostatic Line

CONETEC

Stantec

Job No: 20-02-20794
Date: 2020-05-08 18:18
Site: North Vancouver

Sounding: CPT20-04
Cone: 622:T1500F15U500



Max Depth: 36.400 m / 119.42 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_CP04.COR
Unit Wt: SBTQtn (PKR2009)

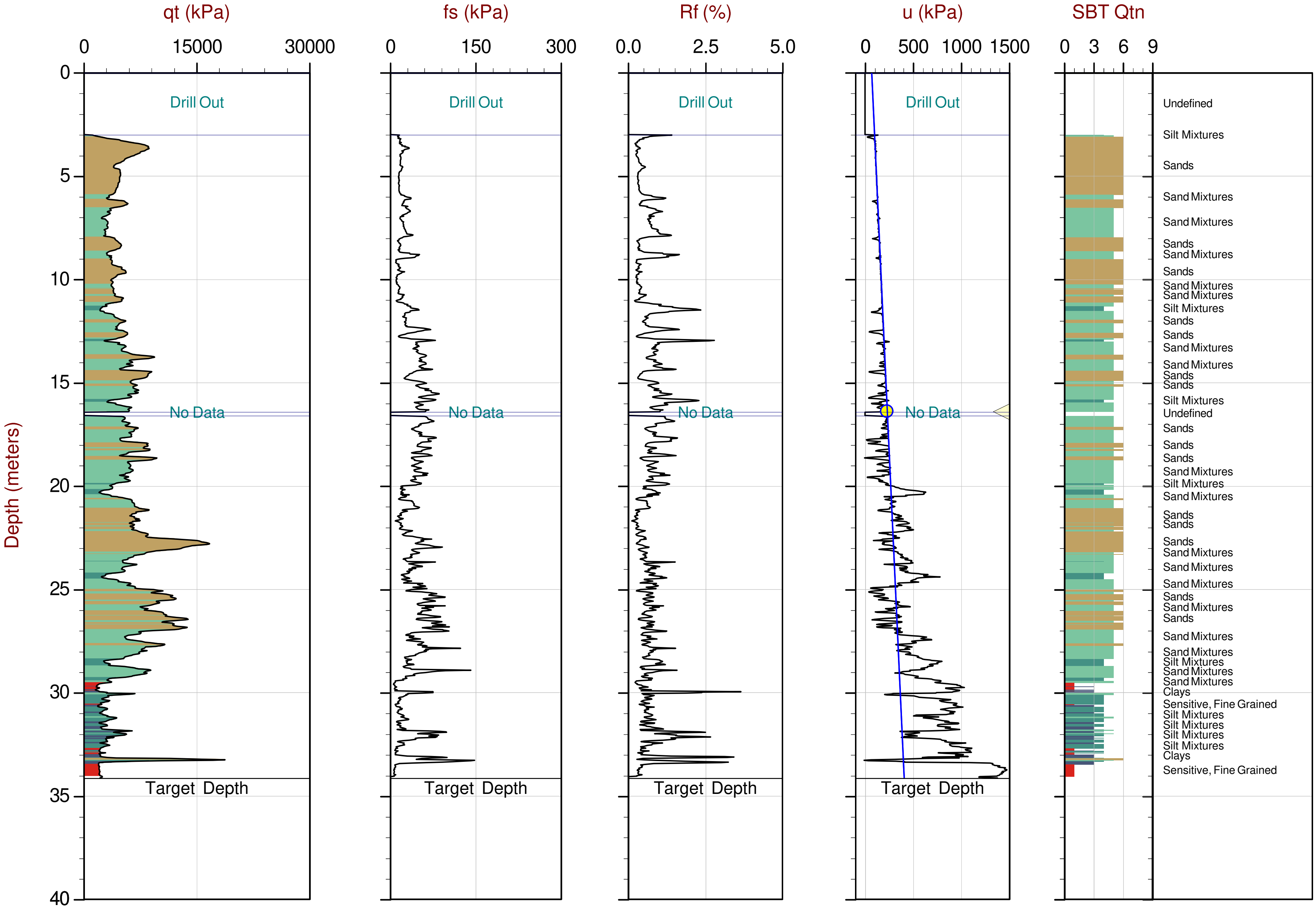
SBT: Robertson, 2009 and 2010
Coords: UTM 10N N:5462326.52m E:492346.56m Elev: -8.95m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved — Hydrostatic Line

Stantec

Job No: 20-02-20794
Date: 2020-05-09 09:45
Site: North Vancouver

Sounding: SCPT20-05
Cone: 622:T1500F15U500



Max Depth: 34.150 m / 112.04 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_SP05.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 5462322.41m E: 492457.33m Elev: -6.10m
Sheet No: 1 of 1

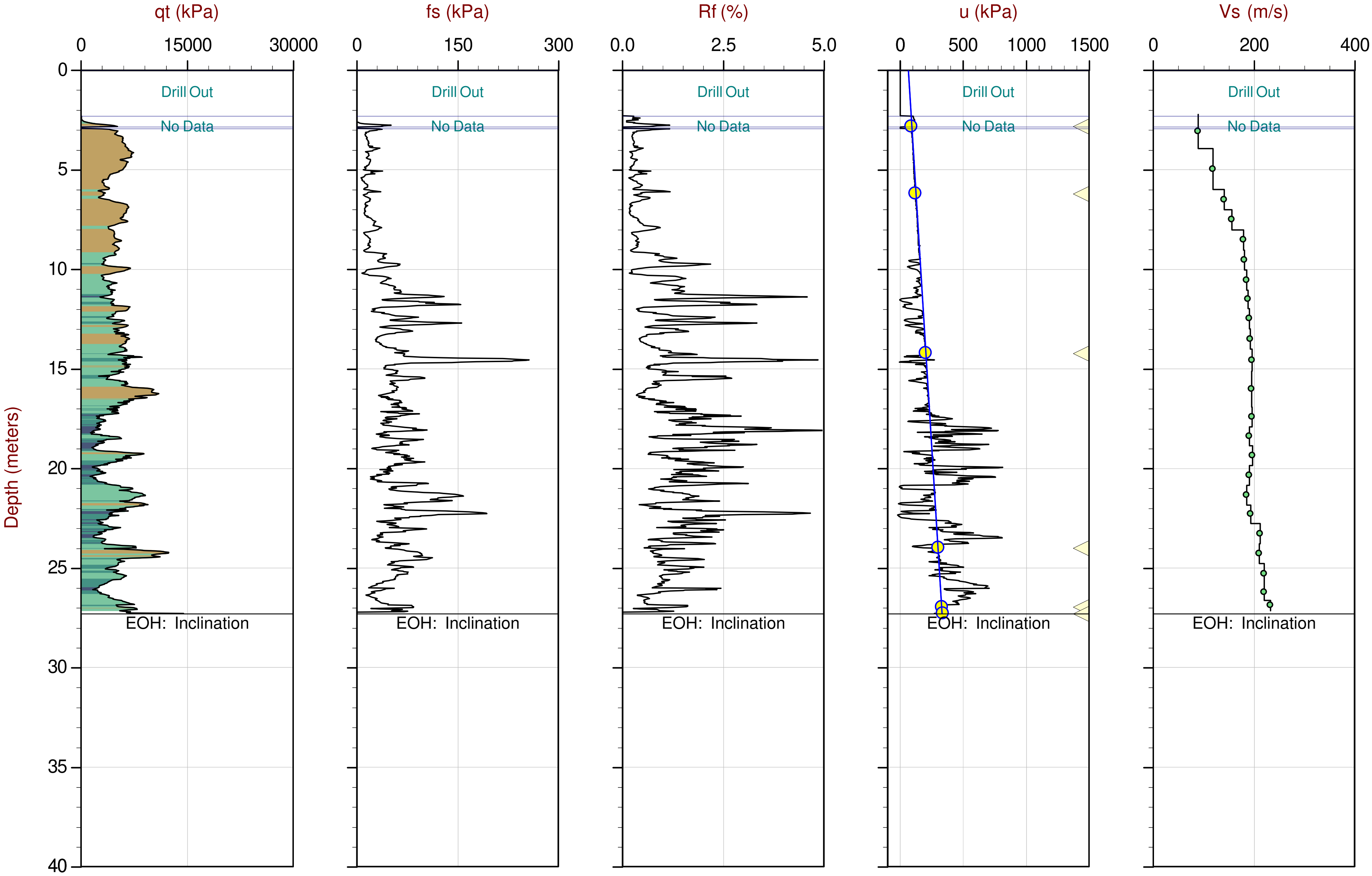
● Equilibrium Pore Pressure (Ueq)   ● Assumed Ueq   ◁ Dissipation, Ueq achieved   ◁ Dissipation, Ueq not achieved   — Hydrostatic Line

Seismic Cone Penetration Test Plots

Stantec

Job No: 20-02-20794
Date: 2020-05-05 09:11
Site: North Vancouver

Sounding: SCPT20-01
Cone: 622:T1500F15U500



Max Depth: 27.300 m / 89.57 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_SP01.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N: 5462013.38m E: 492343.41m Elev: -7.61m
Sheet No: 1 of 1

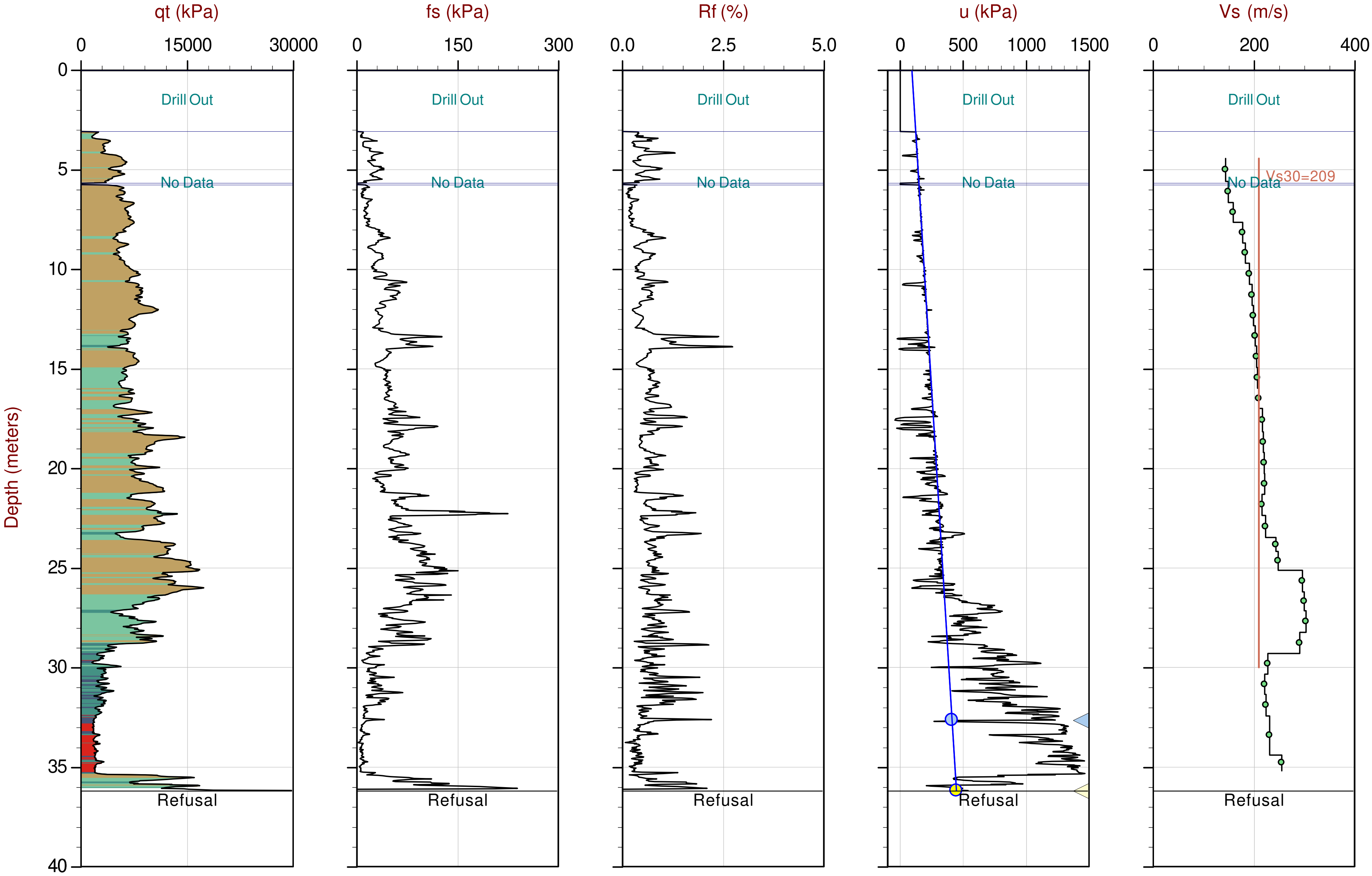
● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved — Hydrostatic Line

CONETEC

Stantec

Job No: 20-02-20794
Date: 2020-05-08 09:43
Site: North Vancouver

Sounding: SCPT20-03
Cone: 622:T1500F15U500



Max Depth: 36.200 m / 118.76 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_SP03.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N:5462267.40m E:492349.26m Elev:-10.11m
Sheet No: 1 of 1

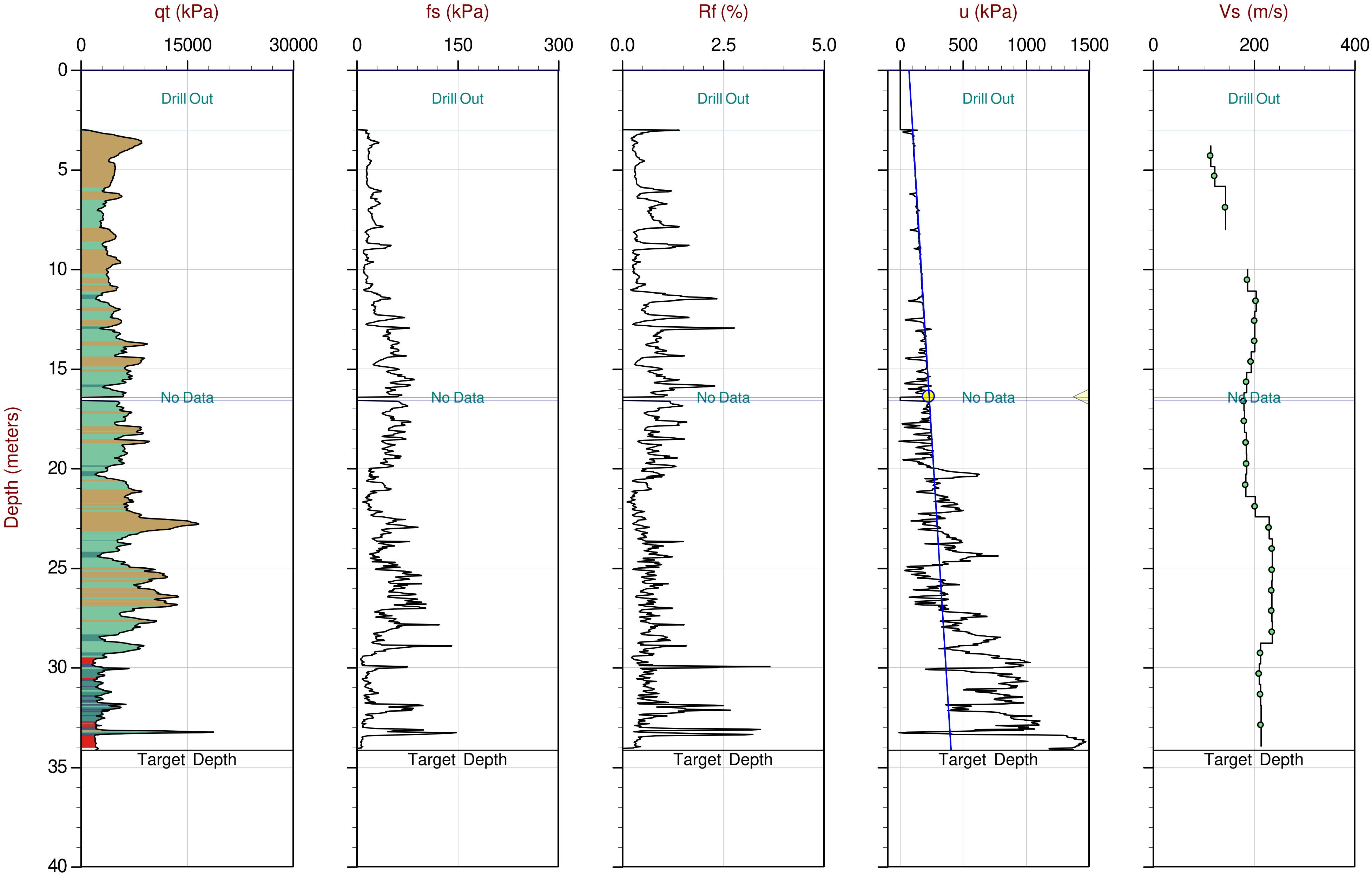
Overplot Item: ● Ueq ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved ◁ Dissipation, Ueq assumed — Hydrostatic Line

CONETEC

Stantec

Job No: 20-02-20794
Date: 2020-05-09 09:45
Site: North Vancouver

Sounding: SCPT20-05
Cone: 622:T1500F15U500



Max Depth: 34.150 m / 112.04 ft
Depth Inc: 0.025 m / 0.082 ft
Avg Int: Every Point

File: 20-02-20794_SP05.COR
Unit Wt: SBTQtn (PKR2009)

SBT: Robertson, 2009 and 2010
Coords: UTM 10N N:5462322.41m E:492457.33m Elev: -6.10m
Sheet No: 1 of 1

● Equilibrium Pore Pressure (Ueq) ● Assumed Ueq ◁ Dissipation, Ueq achieved ◁ Dissipation, Ueq not achieved — Hydrostatic Line

Seismic Cone Penetration Test Tabular Results

Job No: 20-02-20794
Client: Stantec Consulting Ltd.
Project: Seaspan Vancouver Shipyard
Sounding ID: SCPT20-01
Date: 05-May-2020

Seismic Source: WaterSeis
Seismic Offset (m): 5.00
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
2.43	2.23	5.47			
4.15	3.95	6.37	0.90	9.98	90
6.20	6.00	7.81	1.44	12.06	119
7.22	7.02	8.62	0.81	5.71	142
8.22	8.02	9.45	0.83	5.32	156
9.25	9.05	10.34	0.89	4.94	180
10.25	10.05	11.23	0.89	4.87	182
11.25	11.05	12.13	0.90	4.87	186
12.18	11.98	12.98	0.85	4.52	189
13.20	13.00	13.93	0.95	4.94	191
14.22	14.02	14.89	0.96	4.96	193
15.32	15.12	15.93	1.04	5.29	197
17.13	16.93	17.65	1.73	8.83	196
18.13	17.93	18.61	0.96	4.87	197
19.07	18.87	19.52	0.91	4.75	191
20.07	19.87	20.49	0.97	4.89	198
21.05	20.85	21.44	0.95	4.98	191
22.05	21.85	22.42	0.97	5.23	186
22.98	22.78	23.32	0.91	4.68	194
24.00	23.80	24.32	1.00	4.68	213
24.98	24.78	25.28	0.96	4.55	211
26.02	25.82	26.30	1.02	4.62	221
26.85	26.65	27.12	0.82	3.69	221
27.35	27.15	27.61	0.49	2.11	233

Job No: 20-02-20794
Client: Stantec Consulting Ltd.
Project: Seaspan Vancouver Shipyard
Sounding ID: SCPT20-03
Date: 08-May-2020

Seismic Source: WaterSeis
Seismic Offset (m): 5.00
Source Depth (m): 0.00
Geophone Offset (m): 0.20

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
4.63	4.43	6.68			
5.78	5.58	7.49	0.81	5.64	144
6.85	6.65	8.32	0.83	5.54	150
7.85	7.65	9.14	0.82	5.14	159
8.88	8.68	10.02	0.88	4.93	178
9.90	9.70	10.91	0.90	4.88	184
10.97	10.77	11.87	0.96	5.03	191
12.03	11.83	12.84	0.97	4.92	197
13.05	12.85	13.79	0.95	4.73	200
14.05	13.85	14.73	0.94	4.62	203
15.15	14.95	15.76	1.04	5.04	206
16.18	15.98	16.74	0.98	4.72	208
17.20	17.00	17.72	0.98	4.64	210
18.38	18.18	18.86	1.14	5.22	217
19.40	19.20	19.84	0.99	4.49	219
20.48	20.28	20.89	1.05	4.74	221
21.50	21.30	21.88	0.99	4.47	222
22.57	22.37	22.92	1.04	4.81	217
23.68	23.48	24.01	1.08	4.84	224
24.38	24.18	24.69	0.69	2.81	244
25.32	25.12	25.61	0.92	3.71	249
26.40	26.20	26.67	1.06	3.57	297
27.35	27.15	27.61	0.93	3.11	301
28.45	28.25	28.69	1.08	3.56	304
29.50	29.30	29.72	1.04	3.55	292
30.55	30.35	30.76	1.04	4.53	228
31.57	31.37	31.77	1.01	4.53	222
32.65	32.45	32.83	1.07	4.76	224
34.60	34.40	34.76	1.93	8.33	232
35.40	35.20	35.55	0.79	3.09	256

Job No:	20-02-20794
Client:	Stantec Consulting Ltd.
Project:	Seaspan Vancouver Shipyard
Sounding ID:	SCPT20-05
Date:	09-May-2020

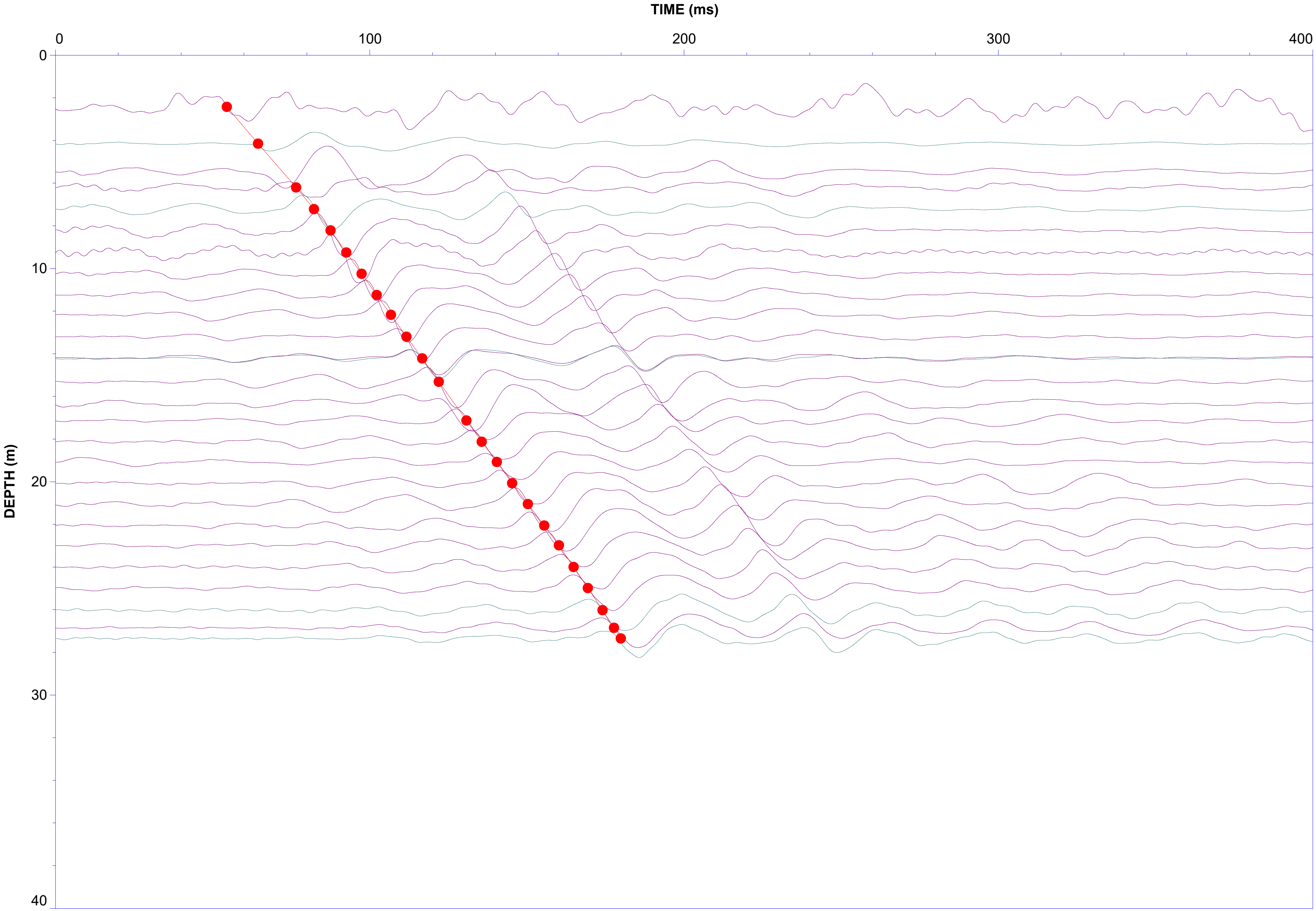
Seismic Source:	WaterSeis
Seismic Offset (m):	5.00
Source Depth (m):	0.00
Geophone Offset (m):	0.20

SCPTu SHEAR WAVE VELOCITY TEST RESULTS - Vs

Tip Depth (m)	Geophone Depth (m)	Ray Path (m)	Ray Path Difference (m)	Travel Time Interval (ms)	Interval Velocity (m/s)
4.00	3.80	6.28			
5.05	4.85	6.97	0.69	6.00	114
6.03	5.83	7.68	0.71	5.83	123
8.20	8.00	9.43	1.75	12.16	144
11.30	11.10	12.17	0.98	5.19	188
12.32	12.12	13.11	0.94	4.57	205
13.32	13.12	14.04	0.93	4.60	202
14.35	14.15	15.01	0.97	4.78	202
15.38	15.18	15.98	0.98	5.00	195
16.40	16.20	16.95	0.97	5.22	186
17.30	17.10	17.82	0.86	4.78	180
18.40	18.20	18.87	1.06	5.83	182
19.48	19.28	19.92	1.04	5.63	185
20.50	20.30	20.91	0.99	5.31	186
21.63	21.43	22.01	1.10	5.95	185
22.65	22.45	23.00	0.99	4.89	204
23.75	23.55	24.08	1.08	4.65	231
24.80	24.60	25.10	1.03	4.34	237
25.85	25.65	26.13	1.03	4.34	237
26.88	26.68	27.14	1.01	4.28	236
27.90	27.70	28.15	1.00	4.25	236
28.98	28.78	29.21	1.06	4.49	237
30.02	29.82	30.24	1.03	4.80	214
31.07	30.87	31.27	1.04	4.91	211
32.10	31.90	32.29	1.02	4.75	214
34.15	33.95	34.32	2.03	9.43	215

Seismic Cone Penetration Test Wave Traces

Job No: 20-02-20794 Client: Stantec Consulting Ltd. Project: Seaspan Vancouver Shipyard Filter: 0-200Hz Sounding: SCPT20-01
Date: 05-May-2020



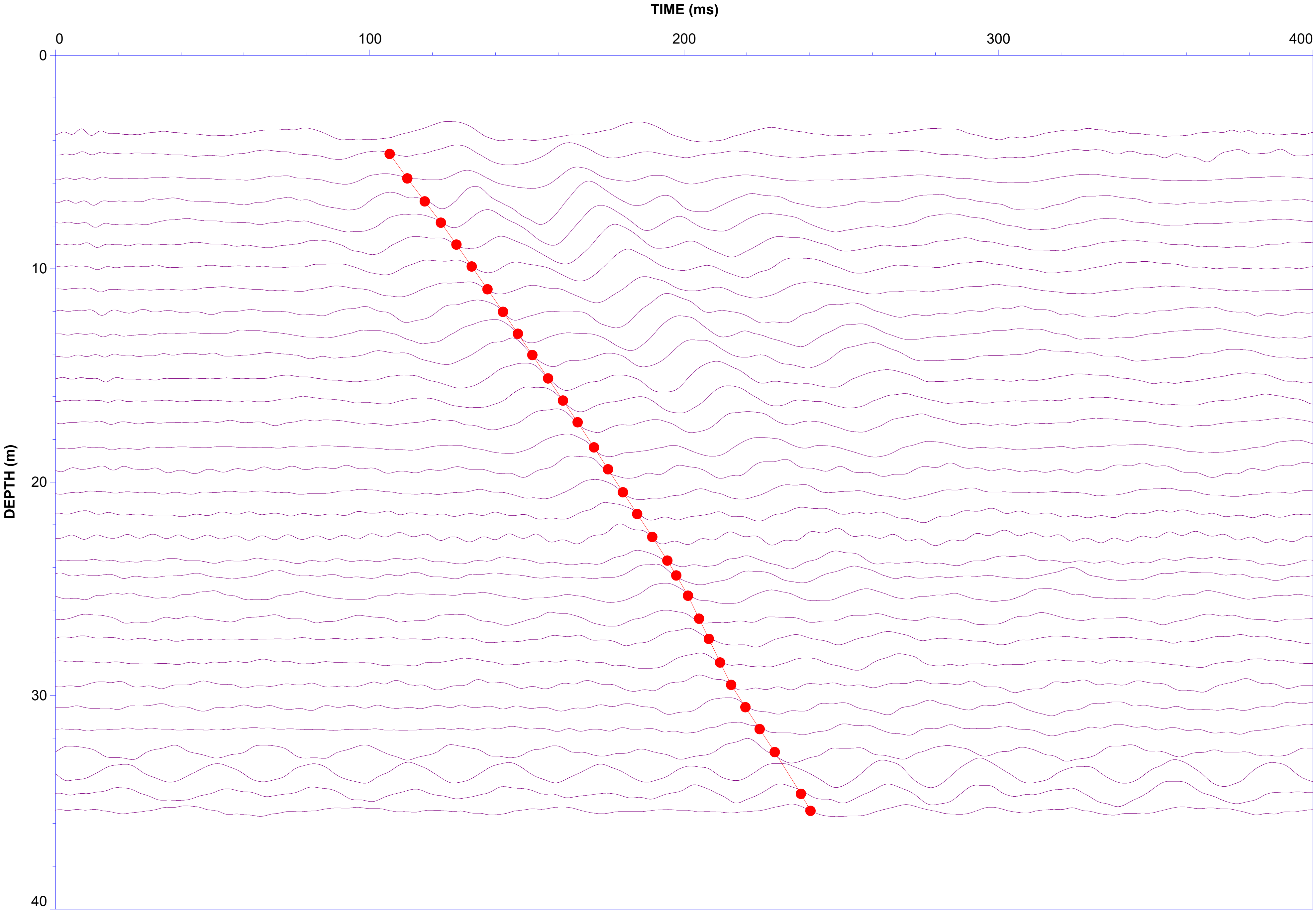
Job No: 20-02-20794
Date: 08-May-2020

Client: Stantec Consulting Ltd.

Project: Seaspan Vancouver Shipyard

Filter: 10-200Hz

Sounding: SCPT20-03



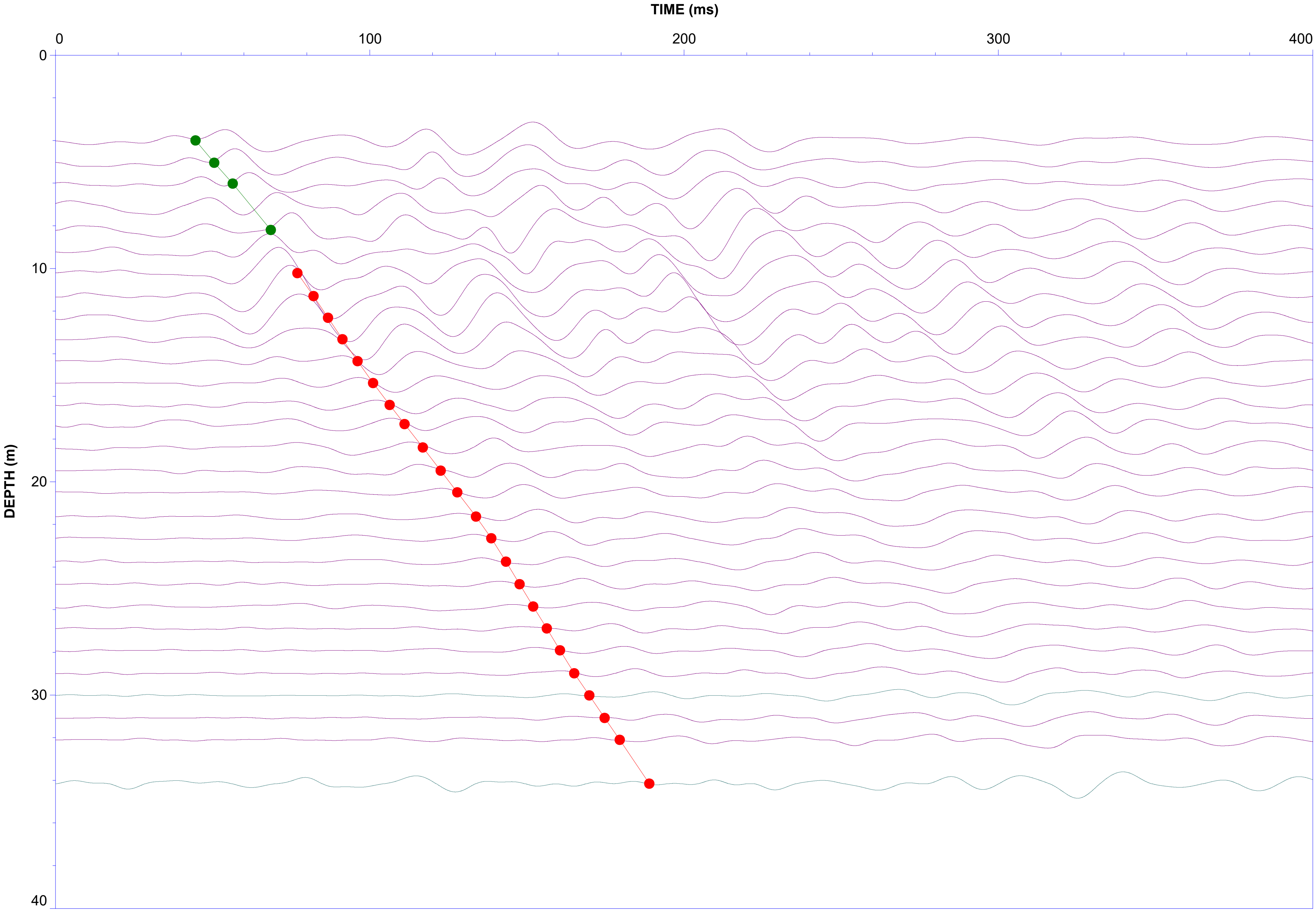
Job No: 20-02-20794
Date: 09-May-2020

Client: Stantec Consulting Ltd.

Project: Seaspan Vancouver Shipyard

Filter: 0-100Hz

Sounding: SCPT20-05



Appendix D LABORATORY TESTING RESULTS

Moisture Content of Soil or Aggregate

CSA A23.2-11A
ASTM D2216

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Tel: (604) 436-3014

Client: Seaspan ULC
Project: Vancouver Shipyard Outfitting Pier
Project No.: 115619249.200.300
Date Tested: 12-May-20
Tested By: WdC / HQ

Moisture Content Worksheet

Borehole / Test Pit No.	**BH20-01**	**BH20-01**	**BH20-01**	**BH20-01**	**BH20-02**	**BH20-02**	**BH20-02**
Sample	**SS-19**	**SS-21**	**SS-24**	**SS-25**	**SS-15**	**SS-17**	**SS-18**
Tare No.							
Mass Tare Container	191.3	220.5	92.3	348.8	194.6	500	330.5
Mass Sample (Wet+Tare) (g)	609	1042.3	459.2	898.9	971.5	1648	911.9
Mass Sample (Dry+Tare) (g)	519.1	916.3	384.4	807.1	812.3	1428.5	788.6
Mass of Water (g)	89.90	126.00	74.80	91.80	159.20	219.50	123.30
Mass Dry Sample (g)	327.80	695.80	292.10	458.30	617.70	928.50	458.10
Moisture Content (%)	**27.4%**	**18.1%**	**25.6%**	**20.0%**	**25.8%**	**23.6%**	**26.9%**
Depth	42.37 m - 42.97 m	48.46 m - 49.07 m	58.77 m - 58.98 m	61.57 m - 62.00 m	30.25 m - 30.86 m	36.50 m - 37.11 m	39.67 m - 39.98 m
Borehole / Test Pit No.	**BH20-02**	**BH20-02**	**BH20-02**	**BH20-02**			
Sample	**SS-19**	**SS-21A**	**SS-23**	**SS-24**			
Tare No.							
Mass Tare Container	2.6	2.6	11.1	482.7			
Mass Sample (Wet+Tare) (g)	270.6	193.8	216.5	927.5			
Mass Sample (Dry+Tare) (g)	218.844	159.114	193.9	884.1			
Mass of Water (g)	51.76	34.69	22.60	43.40			
Mass Dry Sample (g)	216.24	156.51	182.80	401.40			
Moisture Content (%)	**23.9%**	**22.2%**	**12.4%**	**10.8%**			
Depth	42.75 m - 43.36 m	48.82 m - 49.43 m	54.66 m - 54.91 m	56.44 m - 56.67 m			
Borehole / Test Pit No.							
Sample							
Tare No.							
Mass Tare Container							
Mass Sample (Wet+Tare) (g)							
Mass Sample (Dry+Tare) (g)							
Mass of Water (g)							
Mass Dry Sample (g)							
Moisture Content (%)							
Depth							
Borehole / Test Pit No.							
Sample							
Tare No.							
Mass Tare Container							
Mass Sample (Wet+Tare) (g)							
Mass Sample (Dry+Tare) (g)							
Mass of Water (g)							
Mass Dry Sample (g)							
Moisture Content (%)							
Depth							

Reviewed By:

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Passing #200
Fines Content Determination
ASTM D1140

Project: Vancouver Shipyard Outfitting Pier
Client: Seaspan ULC
Project No.: 115619249.200.300

Date Tested: 5/13-14/2020
Tested By: HQ/WdC
Reviewed By:

Fines Content Worksheet

Borehole/Test Pit No.	BH20-01	BH20-01	BH20-01	BH20-01	BH20-01
Sample	SS-07 9.14 m - 9.75 m	SS-09 12.70 m - 13.31 m	SS-13 24.18 m - 24.79 m	SS-15A 30.78 m -30.94 m	SS-17 36.57 m -37.18 m
Tare No.					
Mass Tare Container (g)	854.1	851.2	851	854.2	856.4
Mass Sample+Tare Before Wash (g)	1401.4	1240.9	1249.3	1103.7	1216.8
Mass Sample+Tare After Wash (g)	1333.1	1197.2	1138.8	1088.0	918.8
Percent Passing	12.5%	11.2%	27.7%	6.3%	82.7%
Borehole/Test Pit No.	BH20-01	BH20-01	BH20-01	BH20-01	BH20-02
Sample	SS-19 42.37 m -42.97 m	SS-21 48.46 m -49.07 m	SS-24 58.77 m - 58.98 m	SS-25 61.57 m - 62.00 m	SS-09 12.09 m - 12.70 m
Tare No.	0				
Mass Tare Container (g)	846.8	847.1	847	854	854.6
Mass Sample+Tare Before Wash (g)	1174.6	1542.9	1139.1	1312.3	1278.4
Mass Sample+Tare After Wash (g)	877.6	1161.3	888.1	971	1251.6
Percent Passing	90.6%	54.8%	85.9%	74.5%	6.3%
Borehole/Test Pit No.	BH20-02	BH20-02	BH20-02	BH20-02	BH20-02
Sample	SS-11B 18.59 m - 18.90 m	SS-15 30.25 m - 30.86 m	SS-17 36.50 m - 37.11 m	SS-18 39.67 m - 39.98 m	SS-24 56.44 m - 56.67 m
Tare No.					
Mass Tare Container (g)	851	854.2	856.6	846.8	854
Mass Sample+Tare Before Wash (g)	1226.6	1471.9	1785.1	1304.9	1255.5
Mass Sample+Tare After Wash (g)	1117.4	965	1100.3	884.4	1103.3
Percent Passing	29.1%	82.1%	73.8%	91.8%	37.9%
Borehole/Test Pit No.	BH20-03	BH20-03			
Sample	SS-08 9.14 m - 9.75 m	SS-09 10.67 m - 11.28 m			
Tare No.					
Mass Tare Container (g)	851.6	851			
Mass Sample+Tare Before Wash (g)	1364	1230.9			
Mass Sample+Tare After Wash (g)	1332.4	1172.1			
Percent Passing	6.2%	15.5%			

Stantec

Atterberg Limits
ASTM D4318
Method A- Multi-Point

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300
Date Received: May 11, 2020
Date Tested: May 15, 2020
Tested By: HQ / WdC

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Sample : BH20-01, SS-25, 61.51m -62.00m

LIQUID LIMIT

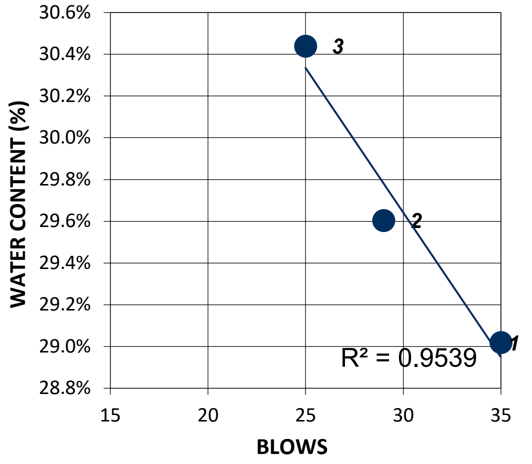
Trial	1	2	3
No. of Blows	35	29	25
Tare No.			
Wt. Sa. (wet+tare)(g)	11.04	11.48	11.03
Wt. Sa. (dry+tare)(g)	8.85	9.15	8.76
Wt. Tare (g)	1.28	1.29	1.28
Wt. Dry Soil (g)	7.6	7.9	7.5
Wt. Water (g)	2.2	2.3	2.3
Water Content (%)	29.0%	29.6%	30.4%

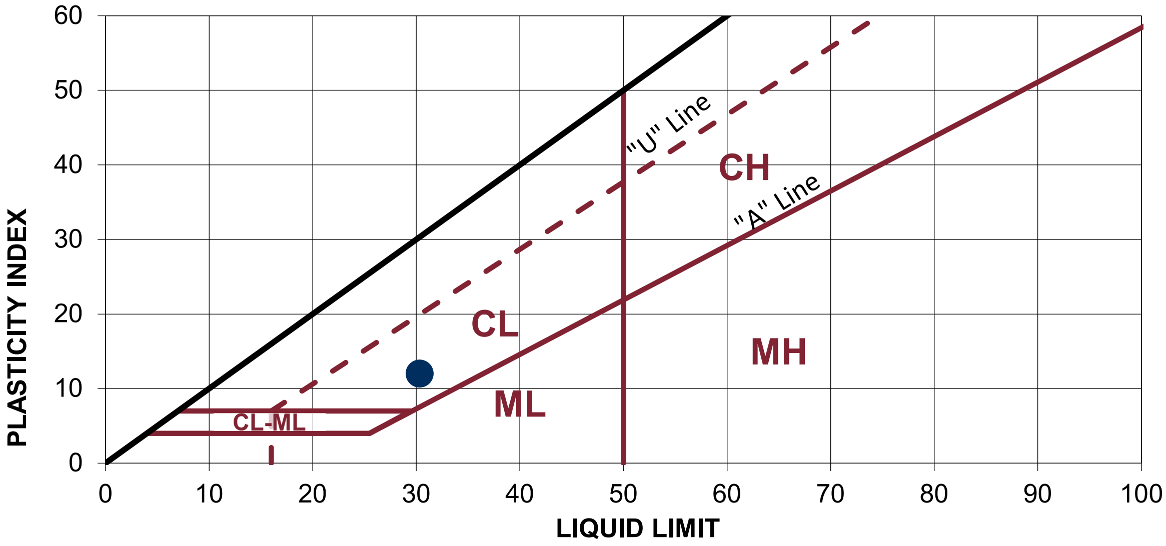
PLASTIC LIMIT

Trial	1	2
Tare No.		
Wt. Sa. (wet+tare)(g)	38.08	38.961
Wt. Sa. (dry+tare)(g)	35.46	36.254
Wt. Tare (g)	20.86	21.035
Wt. Dry Soil (g)	14.6	15.2
Wt. Water (g)	2.6	2.7
Water Content (%)	17.9%	17.8%

RESULTS

LL	**30**
PL	**18**
PI	**12**
Natural MC (%)	
20.0%	





Reviewed By: ______________________

Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300

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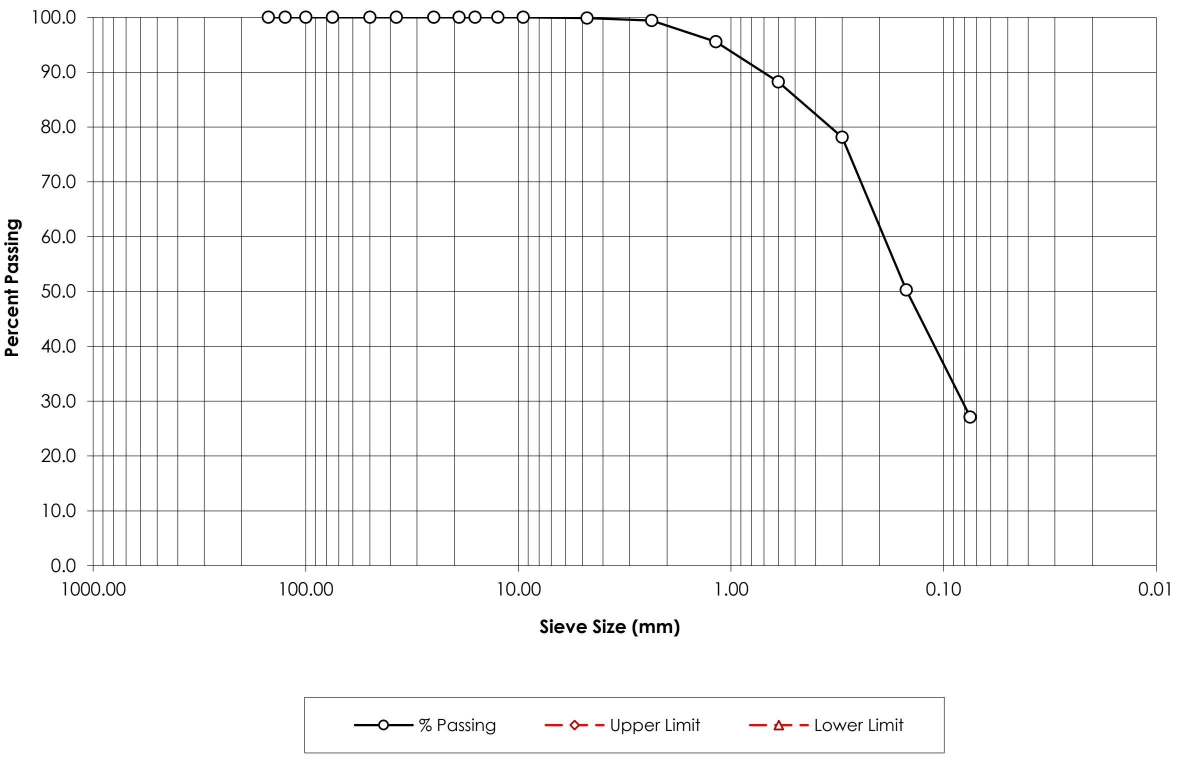
Canada V5J 5J2

Tel: (604) 436-3014

SAMPLE No.: BH20-01, SS-06, 7.62m-8.23m
SOURCE: -
TESTED BY: Wil de Castro
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: silty SAND, SM



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	-	-	-
125.0	-	-	-
100.0	-	-	-
75.0	-	-	-
50.0	-	-	-
37.5	-	-	-
25.0	-	-	-
19.0	-	-	-
16.0	-	-	-
12.5	-	-	-
9.5	**100.0**	-	-
4.75	**99.9**	-	-
2.36	**99.4**	-	-
1.18	**95.5**	-	-
0.600	**88.2**	-	-
0.300	**78.1**	-	-
0.150	**50.3**	-	-
0.075	**27.1**	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.1%	D_{30}:	0.0873
Sand:	72.7%	D_{60}:	0.2101
Fines:	27.2%	C_U:	-
		C_C:	-

Comments: traces of wood and shell fragments

Reviewed by:

Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300

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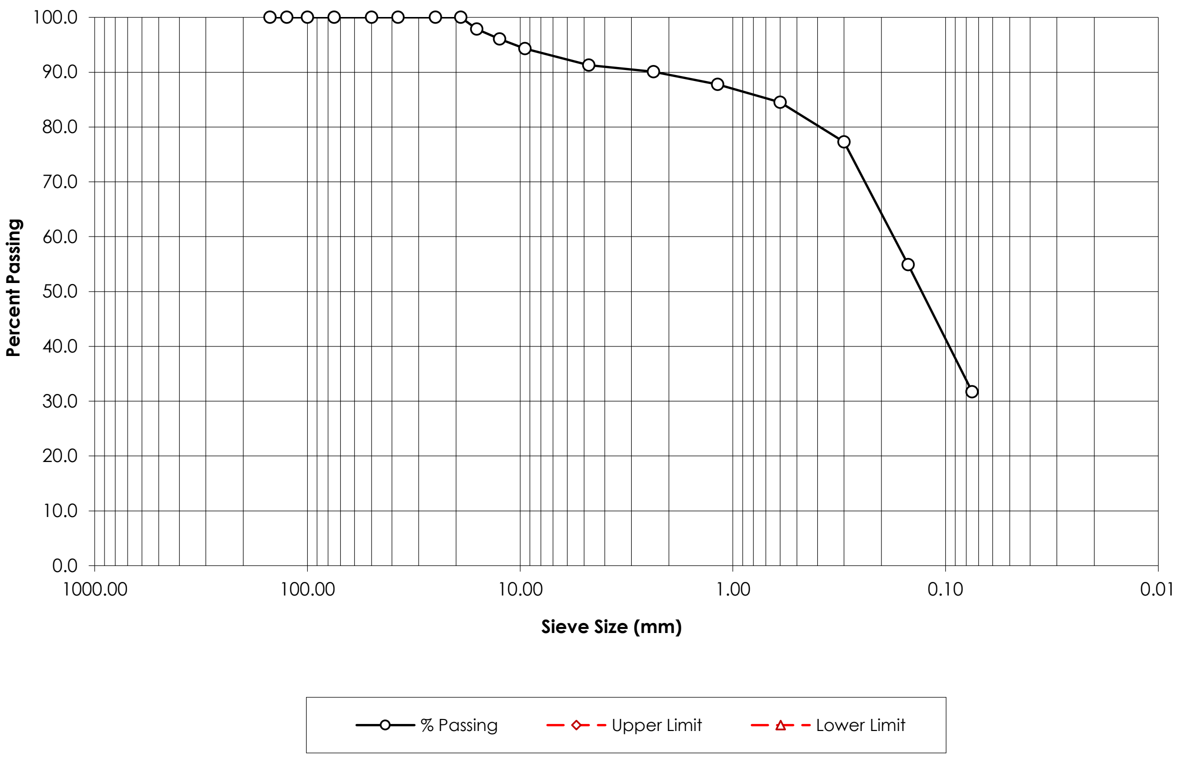
SAMPLE No.: BH20-01, SS-11, 18.17m-18.74m
SOURCE: -
TESTED BY: Wil de Castro
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: silty SAND, SM



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	**-**	-	-
125.0	**-**	-	-
100.0	**-**	-	-
75.0	**-**	-	-
50.0	**-**	-	-
37.5	**-**	-	-
25.0	**-**	-	-
19.0	**100.0**	-	-
16.0	**97.8**	-	-
12.5	**96.0**	-	-
9.5	**94.3**	-	-
4.75	**91.3**	-	-
2.36	**90.1**	-	-
1.18	**87.8**	-	-
0.600	**84.5**	-	-
0.300	**77.3**	-	-
0.150	**54.9**	-	-
0.075	**31.7**	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	8.7%	D_{30}:	-
Sand:	59.6%	D_{60}:	0.1891
Fines:	31.7%	C_U:	-
		C_C:	-

Comments: trace of wood and shell fragments

Reviewed by:

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request. The data presented above is for the sole use of the client stipulated above. Stantec is not responsible, nor can be held liable, for the use of this report by any other party, with or without the knowledge of Stantec.

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Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300

OFFICE	**LABORATORY**
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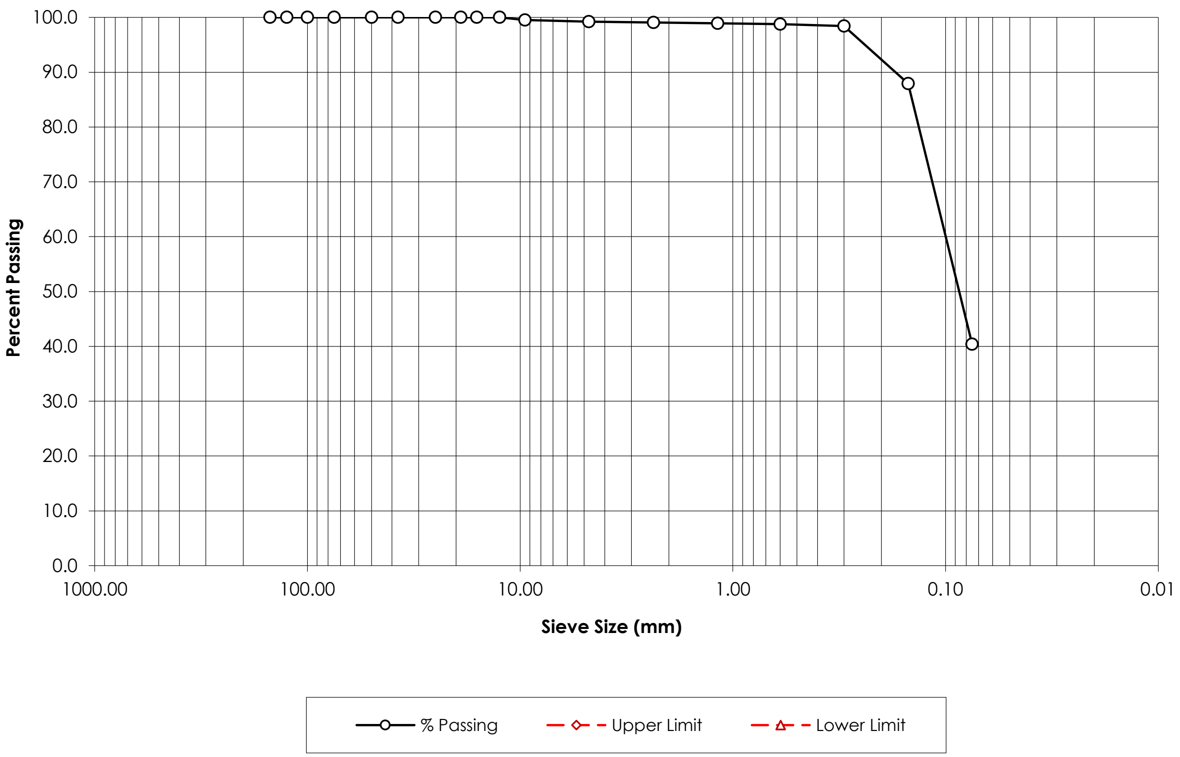
Suite 500	Suite 400
Burnaby, BC	Burnaby, BC
Canada V5H 0C6	Canada V5J 5J2
Tel: (604) 436-3014	Tel: (604) 436-3014

SAMPLE No.: BH20-01, SS-15B, 30.94m-31.39m
SOURCE: -
TESTED BY: Wil de Castro
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: silty SAND, SM



Sieve (mm)	Sample % Passing	Specifications Lower	Upper
150.0	-	-	-
125.0	-	-	-
100.0	-	-	-
75.0	-	-	-
50.0	-	-	-
37.5	-	-	-
25.0	-	-	-
19.0	-	-	-
16.0	-	-	-
12.5	**100.0**	-	-
9.5	**99.5**	-	-
4.75	**99.2**	-	-
2.36	**99.1**	-	-
1.18	**98.9**	-	-
0.600	**98.8**	-	-
0.300	**98.4**	-	-
0.150	**87.9**	-	-
0.075	**40.4**	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.8%	D_{30}:	-
Sand:	58.8%	D_{60}:	0.1132
Fines:	40.4%	C_U:	-
		C_C:	-

Comments:

Reviewed by:

Stantec

Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300

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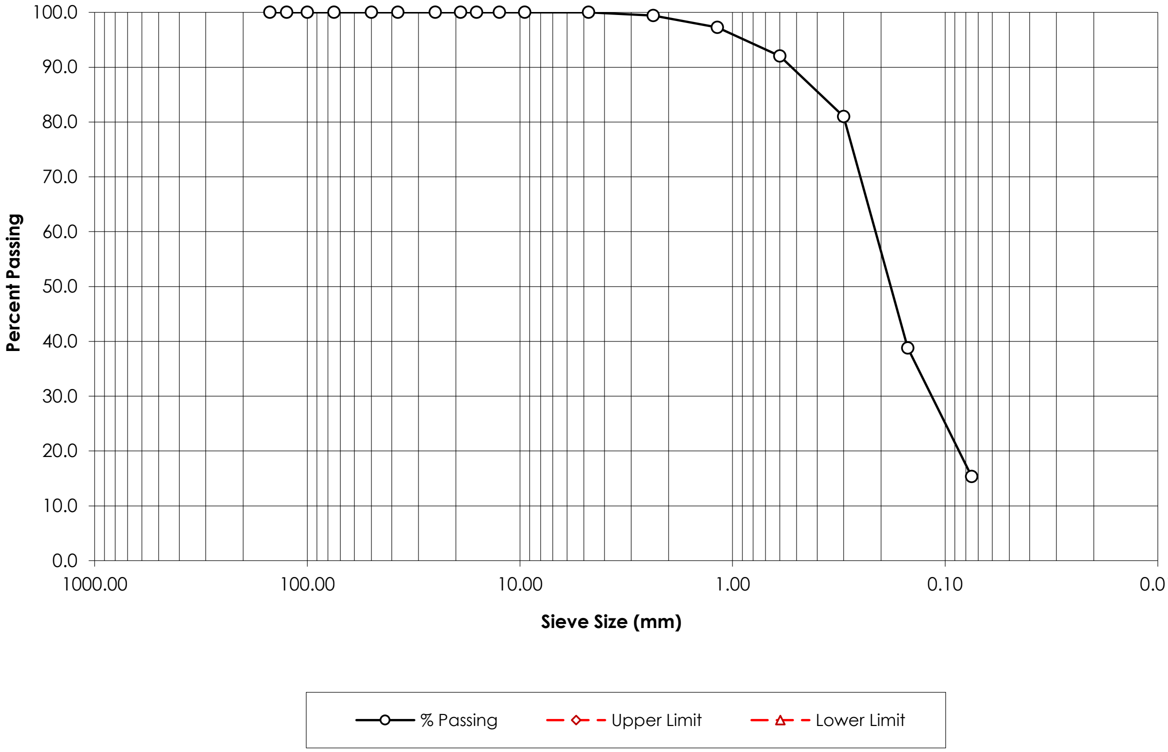
SAMPLE No.: BH20-02, SS-07, 7.62m-8.23m
SOURCE: -
TESTED BY: HQ/WdC
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: silty SAND, SM



Sieve	Sample	Specifications	
(mm)	% Passing	Lower	Upper
150.0	**-**	-	-
125.0	**-**	-	-
100.0	**-**	-	-
75.0	**-**	-	-
50.0	**-**	-	-
37.5	**-**	-	-
25.0	**-**	-	-
19.0	**-**	-	-
16.0	**-**	-	-
12.5	**-**	-	-
9.5	**-**	-	-
4.75	**100.0**	-	-
2.36	**99.4**	-	-
1.18	**97.3**	-	-
0.600	**92.0**	-	-
0.300	**81.0**	-	-
0.150	**38.8**	-	-
0.075	**15.3**	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.0%	D_{30}:	0.1293
Sand:	84.7%	D_{60}:	0.2389
Fines:	15.3%	C_U:	-
		C_C:	-

Comments: trace of wood and shell fragments

Reviewed by:

Stantec

Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300

OFFICE
4730 Kingsway
Suite 500
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LABORATORY
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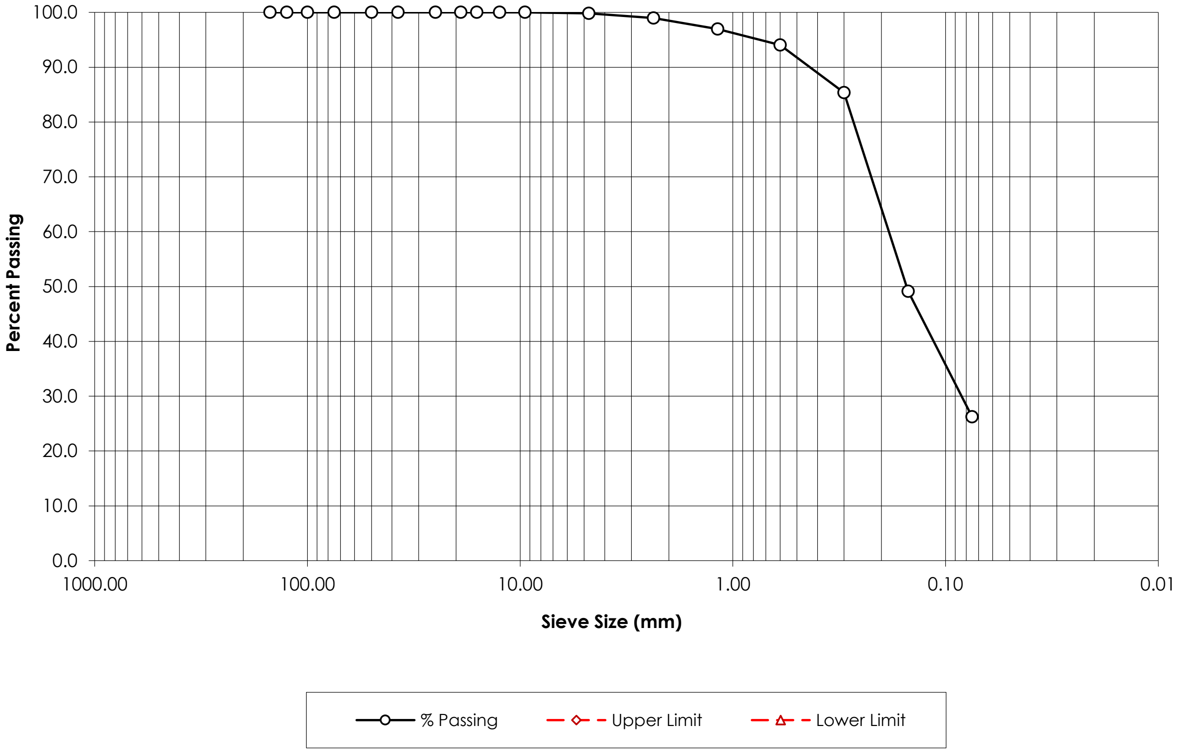
SAMPLE No.: BH20-02, SS-13, 24.38m-24.99m
SOURCE: -
TESTED BY: HQ/WdC
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: silty SAND, SM



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	-	-	-
125.0	-	-	-
100.0	-	-	-
75.0	-	-	-
50.0	-	-	-
37.5	-	-	-
25.0	-	-	-
19.0	-	-	-
16.0	-	-	-
12.5	-	-	-
9.5	**100.0**	-	-
4.75	**99.8**	-	-
2.36	**98.9**	-	-
1.18	**97.0**	-	-
0.600	**94.0**	-	-
0.300	**85.4**	-	-
0.150	**49.1**	-	-
0.075	**26.2**	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	0.2%	D_{30}:	0.0911
Sand:	73.6%	D_{60}:	0.2043
Fines:	26.2%	C_u:	-
		C_c:	-

Comments: trace of wood and shell fragments

Reviewed by:

Stantec

Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
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Project No: 115619249.200.300

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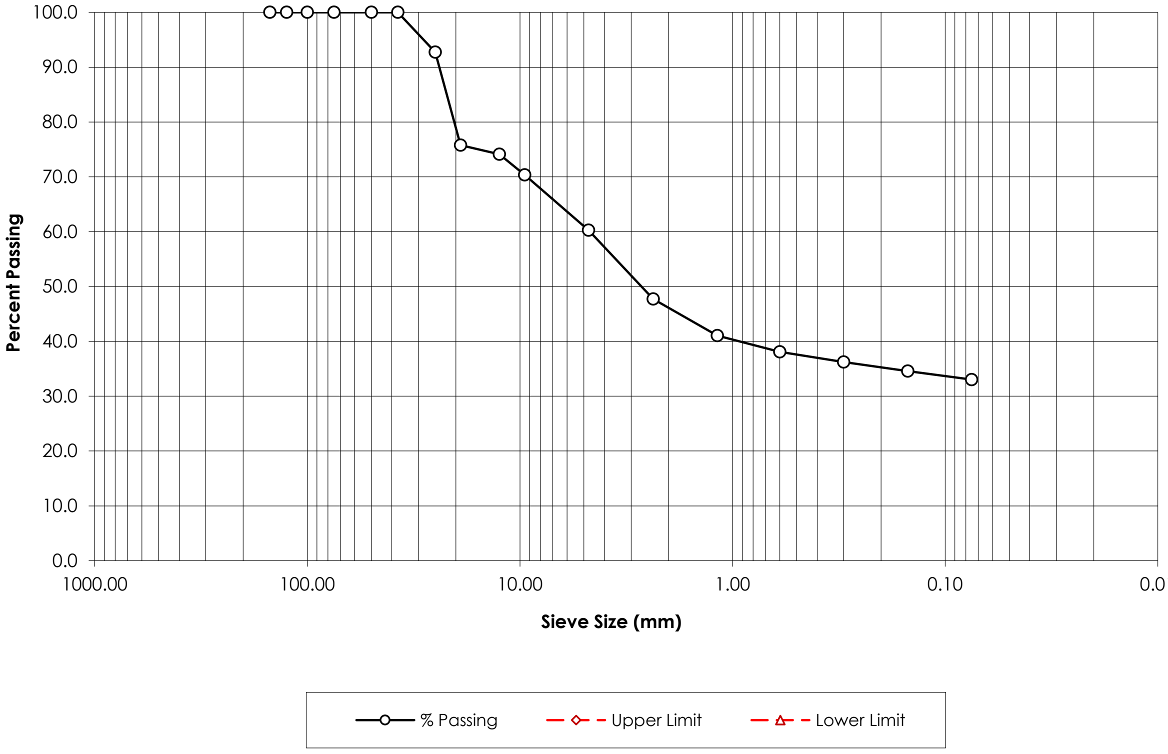
SAMPLE No.: BH20-02, SS-22, 51.51m-51.97m
SOURCE: -
TESTED BY: HQ/WdC
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: silty GRAVEL with sand, GM



Sieve (mm)	Sample % Passing	Specifications Lower	Specifications Upper
150.0	**-**	-	-
125.0	**-**	-	-
100.0	**-**	-	-
75.0	**-**	-	-
50.0	**-**	-	-
37.5	**100.0**	-	-
25.0	**92.7**	-	-
19.0	**75.8**	-	-
16.0	**-**	-	-
12.5	**74.1**	-	-
9.5	**70.3**	-	-
4.75	**60.2**	-	-
2.36	**47.7**	-	-
1.18	**41.1**	-	-
0.600	**38.1**	-	-
0.300	**36.2**	-	-
0.150	**34.6**	-	-
0.075	**33.0**	-	-

Cobble:	0.0%	D_{10}:	-
Gravel:	39.8%	D_{30}:	-
Sand:	27.2%	D_{60}:	4.7078
Fines:	33.0%	C_U:	-
		C_C:	-

Comments:

Reviewed by:

Stantec

Grain Size Analysis

ASTM C136, ASTM C117

Client: Seaspan ULC
Project Name: Vancouver Shipyard Outfitting Pier
Project No: 115619249.200.300

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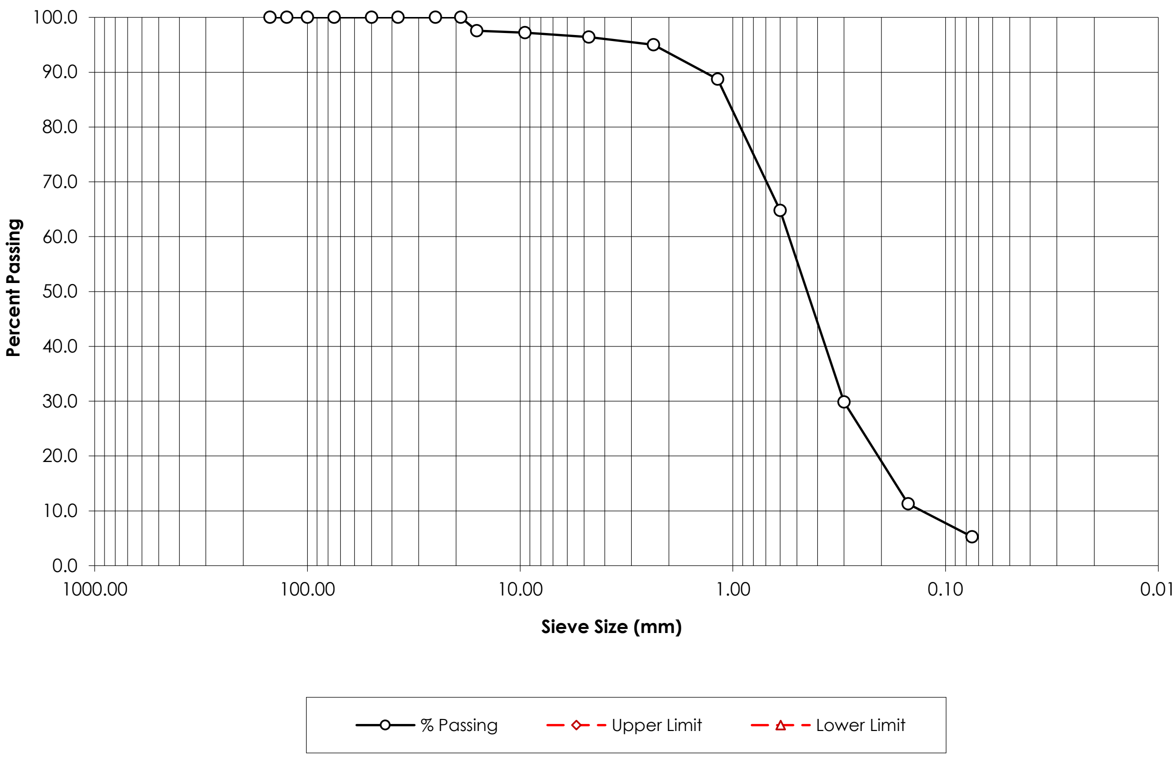
SAMPLE No.: BH20-03, SS-07, 7.92m-8.53m
SOURCE: -
TESTED BY: HQ/WdC
DATE RECEIVED: May 11, 2020
DATE TESTED: May 13, 2020
SAMPLE DESCRIPTION: poorly graded SAND with silt, SP-SM



Sieve	Sample	Specifications	
(mm)	% Passing	Lower	Upper
150.0	-	-	-
125.0	-	-	-
100.0	-	-	-
75.0	-	-	-
50.0	-	-	-
37.5	-	-	-
25.0	-	-	-
19.0	**100.0**	-	-
16.0	**97.6**	-	-
12.5	-	-	-
9.5	**97.2**	-	-
4.75	**96.4**	-	-
2.36	**95.0**	-	-
1.18	**88.7**	-	-
0.600	**64.8**	-	-
0.300	**29.9**	-	-
0.150	**11.3**	-	-
0.075	**5.3**	-	-

Cobble:	0.0%	D_{10}:	0.1382
Gravel:	3.6%	D_{30}:	0.3018
Sand:	91.1%	D_{60}:	0.5702
Fines:	5.3%	C_U:	4.1246
		C_C:	1.1555

Comments:

Reviewed by: