REPORT

Geotechnical Assessment and Design for Culvert Replacement

Craig Brook Culvert Replacement Project - Fraser-Fort George Regional District, BC

Submitted to:

BC Ministry of Transportation & Transit

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Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

WSP Canada Inc. (WSP), was retained by the British Columbia Ministry of Transportation & Transit (MOT) to carry out geotechnical services to support replacement of the existing Craig Brook culvert which crosses beneath Highway 16, approximately 44 km southeast of McBride, BC.

The purpose of this project is to improve the resiliency of this culvert crossing by replacing the existing, deteriorated closed culvert system. The existing culvert system currently consists of 1400 mm diameter corrugated steel pipe (CSP) culverts. One culvert section crosses under the highway, and another is within the slope above the highway, with the two sections connected by a concrete manhole buried below the westbound highway ditch. The section of CSP above the highway ditch has a relatively steep gradient of 35%, while the section of CSP below Highway 16 has a gentler gradient of 1-2%. WSP understands the proposed plan for the culvert replacement work is to replace the culvert below the highway with a larger diameter culvert capable of handling higher flow volumes, with the manhole and inclined section of the culvert upstream of the highway proposed to be replaced with a new section of open channel. RF Binnie & Associates Ltd. (Binnie) is currently designing the replacement culvert and associated channel improvements. The current culverts and manhole are located within the Highway 16 right-of-way (ROW) within the jurisdiction of MOT, while the property on either side of the ROW is located within the Regional District of Fraser-Fort George. The location of the Craig Brook project site is shown in Figure 1. A site plan including the locations of the boreholes completed as part of the geotechnical site investigation is provided in Figure 2.

The work described in this report was carried out in general accordance with WSP's proposed scope of work for the culvert replacement geotechnical assessment dated July 13, 2023. MOT authorized WSP to proceed with the work under As-and-When contract 863-CS-1152. This report includes a description of the scope of services, a summary of the field investigation and laboratory testing, and geotechnical recommendations to support highway alignment upgrades and culvert replacement.

2.0 SCOPE OF WORK

The general scope of WSP's geotechnical assessment for the culvert replacement was described in the proposed geotechnical scope and cost estimate document dated July 13, 2023 and included the following:

- Attendance at project team meetings.
- Review of relevant project background data, including any publicly available aerial photography and geological maps of the project site.
- Preparation of a site-specific health and safety plan for the geotechnical field investigation.
- Coordination of subcontractor equipment and support services for the geotechnical field investigation in cooperation with MOT.
- Obtain clearances regarding underground and overhead utilities.
- Coordination and monitoring of the geotechnical field investigation which included three boreholes near the proposed location for the replacement culvert.

- Conduct a laboratory testing program on selected soil samples collected during the preliminary field investigation.
- Geotechnical analysis to develop appropriate design recommendations including the following:
  - General geotechnical characterization of the site
  - Settlement considerations for the proposed culvert
  - Frost penetration design considerations
  - Discussion around seepage and sloughing and potential impact on design and construction
  - Bearing capacity and lateral soil pressures for headwalls
  - Fill slope and subgrade preparation recommendations for new road embankment fills and cut slopes along Highway 16
  - Settlement analyses for the new highway fills
  - Pavement structure recommendations
- Provide geotechnical input to drawings and special provisions at the request of the design team.
- Compilation of this report.

A terrain hazard assessment was also completed for the Craig Brook site, with this assessment being reported under separate cover (WSP, 2024).

3.0 GEOTECHNICAL FIELD INVESTIGATIONS

The geotechnical field investigation for the Craig Brook culvert replacement consisted of three boreholes drilled adjacent to the existing culvert system from August 28 to August 29, 2023. One borehole was drilled through the eastbound shoulder of the road (BH23-01), one borehole was drilled through the westbound shoulder of the road (BH23-02), and one borehole was drilled in the highway ROW near the inlet of the existing closed culvert system (BH23-03). Locations of the boreholes relative to the existing culvert system are shown in Figure 2. A summary of the field investigation is presented in the following sections.

3.1 Borehole Drilling and Sampling

The two boreholes drilled in the highway shoulders were advanced to depths of 12.8 m below the existing road surface (BH23-01 and BH23-02). The borehole drilled near the existing culvert inlet was advanced to a depth of 15.9 m (BH23-03). Prior to drilling, a BC OneCall was completed. Results of the BC OneCall indicated that no underground utilities were present within the investigation area. First Call Locating & Underground Services Ltd. completed a private utility scan to confirm that no buried utilities were present at any of the borehole locations. Traffic control was provided by All Nations Group Holdings LLP (ANG) on August 28, 2023 to safely facilitate single lane alternating traffic during drilling activities in the highway shoulder (BH23-01 and BH23-02). ANG also provided a medic for the two days of drilling.

The boreholes were advanced by Uncharted Drilling Solutions Inc. using a truck-mounted drill. The boreholes were advanced using the ODEX drilling technique. The drilling program was coordinated and monitored by a representative of WSP, who laid out the borehole locations, obtained and classified samples of the materials encountered in the boreholes, maintained detailed logs of the boreholes, recorded groundwater conditions, and observed pertinent site features. Soil samples obtained from the boreholes were classified in general accordance with the BC MOT Soils Classification System, a copy of which is provided in Appendix A. Upon completion, each borehole was backfilled with cuttings and sealed with bentonite chips in accordance with the BC Water Sustainability Act. An asphalt patch was used for both boreholes drilled through the highway shoulders.

Soil samples were obtained via Standard Penetration Testing (SPT). SPT blow counts were used to establish SPT N-values for the design analysis work. The SPT was conducted as per ASTM D1586 (140 lb./623 N automatic trip hammer, 50.8 mm diameter split spoon sampler) using NWJ (67 mm outside diameter) rods. Based on the drilling technique used (ODEX), it is possible that the in-situ soils could have been disturbed before conducting the SPT, potentially resulting in recorded SPT blow counts that were less than what would have been expected had the soils not been disturbed before testing. While soil disturbance from drilling could have resulted in slightly lower than expected SPT blow counts and estimated N-values, it is very difficult to quantify the extent to which drilling disturbance could have impacted the SPT blow counts. As such, no corrections were made to the SPT blow counts and the estimated N-values carried forward through the analysis.

Selected soil samples collected during the field investigation were sent to WSP's Prince George laboratory for the following tests:

- Water (Moisture) Content, ASTM D2216
- Atterberg Limits, ASTM D4318
- Grain Size Distribution Analysis, ASTM C136/C117 and ASTM D7928

Borehole logs describing subsurface conditions encountered during the geotechnical site investigation are presented in Appendix B. The borehole logs also include sampling depths and laboratory testing information. Detailed laboratory testing results are presented in Appendix C.

4.0 SITE CONDITIONS

The Craig Brook culvert crossing site is located on Highway 16 in the Robson Valley, approximately 44 km southeast of the town of McBride, BC. The current culvert system consists of two 1400 mm diameter corrugated steel pipe (CSP) sections connected via a concrete manhole structure. The first section of the culvert is located upstream of the highway ditch and has a gradient of approximately 35%, while the second section is below the highway and has a much gentler gradient of 1-2%. The concrete manhole structure connecting the two culvert sections is located below the westbound (upstream) highway ditch and collects water from the ditch. The culvert system conveys Craig Brook stream flows that originate high in the Rocky Mountains and ultimately drain into the Fraser River. The upper reaches of the Craig Brook stream are in a deeply incised, mainly bedrock-controlled mountain valley; the stream then flows onto an alluvial fan located in the Robson Valley. The stream channel is located on the western side of the fan and crosses through residential property directly upstream and downstream of the highway culvert system. The highway crosses Craig Brook Stream, approximately 280 m from the fan's apex. Downstream of the highway, the stream flows through a second culvert below a private property driveway before connecting with Wardman Creek approximately 700 m southwest of the highway culvert. The stream ultimately discharges into the Fraser River approximately 1.25 km southwest of the highway. At the project site, the highway gradually increases in elevation from northwest to southwest as it crosses the larger Craig Brook fan complex.

4.1 Bedrock and Surficial Geology

Bedrock geology mapping, from iMapBC[1], identifies the site as generally underlain by Miette Group coarse clastic sedimentary rocks from the upper Proterozoic. The clastic sedimentary rocks within this formation range from sandstones to pebble conglomerates, siltstones, argillites, and phyllites. This section of the Rocky Mountains is also underlain by rock from the Lower Cambrian Gog Group. These Gog Group deposits typically overlie the Miette group and consist of quartz arenite and quartz granule sedimentary rocks most often deposited in shallow marine environments. Bedrock bluffs are visible along the Craig Brook valley as it ascends the mountain slopes.

Surficial geology, from iMapBC[1], indicates that quaternary deposits within the valley between the Rocky Mountains (to the north) and the Cariboo Mountains (to the south) mainly consist of alluvial and glacial deposits. At the Craig Brook site, the boreholes drilled along the highway and near the culvert inlet encountered alluvial fan deposits consisting of interlayered sands, silts, and gravels to depths of 15 m below the existing ground surface. Further details regarding the subsurface material encountered in the three boreholes are discussed in the following sections of the report.

4.2 Aerial Photographs and LIDAR

Based on a review of historic aerial photographs, there does not appear to be any signs of ground or vegetation disturbance having occurred at the culvert crossing location since the earliest aerial photographs were taken in in 1946[2]. The only signs of vegetation disturbance along the channel and fan since 1946 have been limited to some clearing near the highway to establish the current residential properties located just upslope of the highway between approximately 1958 and 1970.

A review of LIDAR hillshade imagery generated from data collected on July 22, 2022 and provided by MOT for the Craig Brook site shows numerous inactive stream channels on the surface of the alluvial fan, indicating that channel changes, or avulsion, is a geological process on the fan. A review of the LIDAR hillshade imagery also identified geological features along the upper reaches of the stream channel (above the alluvial fan) that could represent geological processes that might result in debris/material entering the stream channel. Based on this information, a geotechnical field terrain assessment was carried out for this project site to assess the potential of geohazards impacting the culvert crossing location (e.g., stream avulsion, debris flood/flow). Detailed observations from the geohazard assessment are presented in our final report dated February 26, 2025 entitled Craig Brook Culvert Replacement – Geotechnical Terrain Hazard Assessment (WSP, 2025). Also included in the terrain hazard assessment report are recommendations for addressing the identified hazards (e.g. vertical debris rack, step pools).

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[1] Maps.gov.bc.ca, access January 16, 2024.

[2] Based on Province of BC aerial photographs dated 1946, 1955, 1958, 1970, 1979, 1986, 1991, 1996, 2000, 2005, 2006.

4.3 Subsurface Conditions

Subsurface conditions encountered in the two boreholes advanced along Highway 16 (BH23-01 and BH23-02) generally consisted of approximately 125 mm to 150 mm of asphalt, overlying approximately 2.3 m to 2.7 m of granular embankment fills, which were in turn underlain by alluvial fan deposits that consisted of varying amounts of silt, sand, and gravel to borehole termination at a depth of 12.9 m. In BH23-02, which was drilled through the westbound shoulder on the west side of the culvert, buried concrete was encountered in the existing embankment fills between depths of 0.75 m to 1.5 m. Subsurface soils encountered in the borehole drilled upslope of the highway to the south of the existing culvert inlet (BH23-03) appeared to generally consist of alluvial fan silts, sands, and gravels from the ground surface to borehole termination at a depth of 15.9 m.

A detailed description of the subsurface conditions encountered in the boreholes is provided below:

Asphalt: Approximately 100 mm to 115 mm of asphalt at the top of the pavement structure in the two boreholes drilled through the eastbound and westbound highway shoulders. Note that the asphalt could be thicker below the travel lanes.

Highway Embankment Fills: Underlying the asphalt were highway embankment fills that extended to depths of 2.3 m to 2.7 m below the existing highway grade. The highway embankment fills generally consisted of poorly graded sands and gravels with trace silt, with occasional cobbles and some coal fragments encountered in BH23-01 below a depth of 1.5 m. As mentioned above, what appeared to be buried concrete was discovered in BH23-02 between depths of 0.75 m to 1.5 m below the highway surface. It was assumed to be concrete based on the light grey dust being produced during the ODEX drilling between these depths. The lateral extent of this buried concrete was not well defined beyond the depths at which it was encountered during the drilling. It is possible that it could be an unidentified utility or abandoned material that was buried below the highway prism during the construction of the existing culvert system. Based on this finding, it is possible that more buried concrete or other materials could be encountered during construction. The embankment fills were generally dense with SPT N-values ranging from 25 to 46 and dry to damp with natural water contents of 2% to 10%.

Alluvial Fan Deposits: The highway embankment fills in BH23-01 and BH23-02 were underlain by interlayered alluvial fan deposits that ranged in composition from silt and sand with trace to some gravel to sand and gravel with some silt. In BH23-03, alluvial fan deposits were encountered starting at the existing ground surface. These deposits were generally loose to very dense with SPT N blow counts ranging from 8 to greater than 50 and dry to damp with measured natural water contents ranging from 3% to 17%. SPT N blow counts recorded in these deposits indicated that they generally increased in density with depth. A summary of grain size distribution tests completed on select samples of this material, along with measured natural water contents and recorded SPT N blow counts, are summarized in Table 1.

Table 1: Alluvial Fan Deposit Soil Testing Summary

Hole ID	Sample ID	Material Classification	Sample Depth Interval (mbgs)		Sieve Analysis			Moisture Content (%)	SPT N-value
			Top	Bottom	Gravel (%)	Sand (%)	Fines (%)		
BH23-01	3	SM4	2.3	2.9	-	-	-	6	25
BH23-01	4	SM4 / SM-GM[1]	3.0	3.7	-	-	-	10	25
BH23-01	5	SM-GM	3.8	4.4	41	39	20	8	11

Hole ID	Sample ID	Material Classification	Sample Depth Interval (mbgs)		Sieve Analysis			Moisture Content (%)	SPT N-value
			Top	Bottom	Gravel (%)	Sand (%)	Fines (%)		
BH23-01	6	SM4	4.6	5.2	16	42	42	17	8
BH23-01	7	SM4	6.1	6.7	-	-	-	14	17
BH23-01	8	SM2	7.6	8.2	38	44	18	5	27
BH23-01	9	SM2	9.1	9.8	-	-	-	9	27
BH23-01	10	SM2	10.7	11.3	-	-	-	10	25
BH23-01	11	SM2	12.2	12.8	42	40	18	5	29
BH23-02	3	SM2	2.3	2.9				10	8
BH23-02	4a	SM4	3.0	3.5				10	8
BH23-02	4b	ML	3.5	3.7				16	8
BH23-02	5	SM2	3.8	4.4	43	41	16	4	19
BH23-02	6	SM2	4.6	5.2				8	13
BH23-02	7	SM2	6.1	6.7				12	11
BH23-02	8	SM2	7.6	8.2				9	16
BH23-02	9	SM2	9.1	9.8				10	35
BH23-02	10	SM2	10.7	11.3	35	48	17	6	25
BH23-02	11	SM2	12.2	12.8				5	35
BH23-03	1	SM3	0.8	1.4				5	32
BH23-03	2	SM3	1.5	2.1				3	16
BH23-03	3	SM3	2.3	2.9	28	39	33	12	11
BH23-03	4	SM3	3.0	3.7				14	15
BH23-03	5b	SM1	4.0	4.4				9	21
BH23-03	6	SM2	4.6	5.2	37	41	22	8	18
BH23-03	7	SM2	6.1	6.7				9	16
BH23-03	9	SM2	9.1	9.8				3	40
BH23-03	10	SM2	10.7	11.3	25	53	22	4	61
BH23-03	11	SM2	12.2	12.8				9	17
BH23-03	12	SM2	13.7	14.3				4	51
BH23-03	13	SM2	15.2	15.8	34	46	20	4	47

4.4 Groundwater Conditions

No groundwater was encountered in the three boreholes during the geotechnical site investigation. SPT samples collected during the drilling were generally dry to damp, and a tape measure lowered into the boreholes after completing each hole did not encounter any water. Note that groundwater levels can fluctuate seasonally and that it is possible that groundwater levels could be higher during wetter periods such as freshet.

4.5 Frost Conditions

The actual depth of frost penetration depends on numerous factors, such as soil type, water content and depth of groundwater table, extent of snow cover, winter severity, and number of days with sub-zero temperatures. For structural elements that can tolerate some frost action in the event of an unusually rigorous winter, a design frost penetration depth of 2.5 m should be considered.

4.6 Site Classification for Seismic Site Response

For the culvert replacement location, subsurface conditions were only assessed through standard penetration testing to depths of 12.8 m to 15.9 m below the existing ground surface. Since the subsurface assessment only extended to a maximum depth of 15.9 m, the seismic site class was estimated based on the assumption that soil conditions below a depth of 15.9 m would be similar to those encountered in the boreholes. Based on the subsurface conditions encountered in the boreholes and assumptions regarding conditions to a depth of 30 m for seismic site response, this culvert replacement location is considered to be Site Class D.

For the seismic analysis, horizontal spectral response acceleration values for return periods of 475, 975, and 2475 years were obtained from the 2020 National Building Code of Canada (NBCC) online hazard calculator tool. CHBDC S6:19 has adopted the use of amplification factors, which are applied to the spectral acceleration values provided by the NBCC hazard calculator tool. Table 2 provides factored (for Site Class D) horizontal spectral response acceleration values for 475, 975 and 2,475 return periods.

Table 2: Spectral Accelerations for Craig Brook Culvert Replacement Site (Site Class D - 2020 NBCC)

Seismic Ground Motion Probability of Exceedance in 50 Years (Return Period)	SA (0.2)	SA (0.5)	SA (1.0)	SA (2.0)	SA (5.0)	SA (10.0)	PGA (G)	PGV (m/s)
2% (2475 years)	0.426	0.365	0.204	0.113	0.0559	0.0299	0.172	0.196
5% (975 years)	0.257	0.214	0.119	0.068	0.0310	0.0143	0.101	0.122
10% (475 years)	0.157	0.133	0.0762	0.044	0.0181	0.00715	0.0619	0.0804

4.7 Geotechnical Soil Model

A geotechnical soil model was developed for the Craig Brook culvert replacement site to assess the stability of design cuts and highway embankment fills. The soil model was developed using the subsurface information obtained from the three boreholes. The alluvial fan deposits were split into two different units. One unit represents the loose silt and sand that was typically encountered just below the embankment fills or existing ground surface. The second unit represents the dense to very dense sand and gravel that was typically encountered deeper in the boreholes below the looser silt and sand layer. Geotechnical properties for effective stress conditions, including internal angle of friction, were estimated for the embankment fill and underlying alluvial fan deposits using correlations between energy and overburden-corrected SPT N-Values (N1(60)) values (Peck et al., 1974). Soil unit thicknesses and depths to the top of each of the soil units were based on the depths below the existing ground/road surface that each of the different soil units were encountered during drilling.

A summary of the geotechnical soil parameters determined for each of the different soil units are provided in Table 3.

Table 3: Geotechnical Soil Model

Soil Type	Unit Weight (kN/m^3)	Angle of Internal Friction (°)	Limit Equilibrium Shear Strength Model
Highway Embankment Fills (new and existing)	21	37	Mohr-Coulomb
Loose Alluvial Silt and Sand	19	31	Mohr-Coulomb
Compact to Dense Alluvial Sand and Gravel	20	34	Mohr-Coulomb

5.0 GEOTECHNICAL DESIGN CONSIDERATIONS AND RECOMMENDATIONS

The 100% detailed geometric design drawings provided by R.F. Binnie Associates Ltd. (Binnie) include details for the replacement of the existing CSP and concrete manhole culvert system with a new 2700 mm CSP culvert below the highway and replacing the concrete manhole and culvert section upstream of the highway with a stepped channel. Also included in the drawings are details for upgrading the highway embankment, drainage, and pavement structure near the culvert crossing to meet current MOT design standards. In addition to the permanent works outlined above, it is understood that a detour will be implemented to accommodate construction activities at the site.

Based on the background review and field investigations completed to date, there are no significant geotechnical conditions that would preclude the construction of the Craig Brook culvert replacement as proposed. This report provides a discussion of the subsurface conditions encountered at the highway culvert crossing location, along with geotechnical design recommendations for general site preparation and highway pavement structure design. Note that a geohazard assessment was carried out for the Craig Brook channel upslope of the culvert crossing, with findings from the geohazard assessment included in a separate draft geotechnical terrain hazard assessment report dated November 15, 2024.

It is assumed that construction activities will generally follow BC MOT's 2025 Standard Specifications for Highway Construction (SS2025).

5.1 Highway Fill Embankments

For permanent highway fill embankment slopes within the project limits of construction, a slope stability analysis was carried out to determine minimum slope gradient requirements to meet a design target factor of safety of 1.54. The design target factor of safety of 1.54 was based on the value provided in Table 6.2b of the BC Supplement to the Canadian Highway Bridge Design Code (CHBDC S6:19) for a typical consequence level and a typical level of understanding. A typical consequence level was used for the highway embankments and cut slopes on the upstream (north) side of the highway based on the anticipated level of effort required to fix an issue that arises.

The results of the preliminary analyses indicate that a target factor of safety of 1.54 can be achieved using 2 Horizontal to 1 Vertical (2H:1V) fill embankment slope within the project limits of construction. The fill embankment analysis assumed that all loose and unsuitable existing material would be stripped to a depth of approximately 0.3 m and that all new embankment fill would consist of free draining granular fill (as defined in Section 5.2, below) that is compacted and constructed as per the guidelines set out in Section 201.37 of SS 2025. Stripping depths greater than 0.3 m may be required where loose or unsuitable material extends to a depth of more than 0.3 m below the existing grade.

A settlement analysis was completed to assess the impact of widening the existing embankments to accommodate new 2H:1V embankment fill slopes and the addition of new highway flares. Where the highway will be widened by approximately 3 m for the new flares, settlement under the new embankment fills was calculated to be less than 50 mm (fill embankment height of roughly 2 m). Any grade changes to the highway are anticipated to be minor and are expected to have a correspondingly minor contribution to settlement. The following subsections provide further recommendations for subgrade preparation and construction of the new embankment fills within the project limits of construction.

5.2 Embankment Fill Construction Recommendations

The following recommendations are provided for the construction of new 2H:1V fill slopes and any fills required to be placed as part of the culvert replacement and channel improvement work. These recommendations are based on current and anticipated surface and subsurface conditions expected to be encountered along the highway alignment.

- All areas to receive road embankment fill should be stripped to a depth sufficient to expose a subgrade surface consisting of undisturbed natural granular soils or compact to dense existing road fills. This includes the outside face of the existing fill slopes where new fill is to be keyed into the existing embankment. For the purposes of design, a minimum average stripping depth of 300 mm should be assumed, though, in some areas, this could be greater depending on conditions encountered during construction (e.g., existing ditches and wet areas). Any wet, weakened, rutted, organic or fine-grained soils encountered should be removed during site preparation to expose a suitable subgrade as described above. Removal of these soils should be observed by the geotechnical engineer, who will confirm and approve the depth of required stripping.
- Embankment fills should be keyed into the existing road fills as per Section 201.37 of SS2025. No thin sliver fills should be placed on the outside of existing road fills to widen the road surface.

- It is recommended that all embankment fills for highway construction consist of free-draining soil or rock having less than 8% fines (particles passing 0.075 mm sieve). All embankment fills should be placed and compacted as per Section 201.37 of SS2025.
- In general, site drainage works should be implemented during the early stages of the work. Water should not be allowed to enter excavations or pond on subgrades. Any soils softened by standing water in the bottom of excavations or by water ponded on subgrades should be removed and replaced with free draining fill before subsequent construction. While groundwater is not anticipated to be encountered within the depths of construction based on groundwater conditions observed during the geotechnical site investigation, it is recommended that the contractor have a water management plan in place to keep the bottom of the excavations dry should groundwater ingress issues arise. Note that the contractor will need to address any creek flow that may be present at the time of construction.
- Positive surface drainage away from the existing highway pavement structure must be maintained. Fill placed on the outside of an existing granular pavement structure (e.g. SGSB) should be free-draining granular material (having less than 8% passing 0.075 mm sieve) and extend a minimum 100 mm in elevation below the bottom of adjacent SGSB to not block internal drainage.

Drainage from under an embankment area should be directed to an exposed face of the ditch, but should not be directed over the face of potentially unstable or erodible slopes without additional armoring and/or riprap.

5.3 Culvert Subgrade Preparation

Based on a review of the 50% detailed design drawings and proposed elevations for the new culvert, there is the potential that the new culvert may be founded on a subgrade surface consisting of loose to compact sand and silt. As such, it is recommended that subgrade preparation for the new culvert consist of the placement of a layer of biaxial geogrid on top of the prepared natural subgrade surface, followed by a 300 mm lift of WGB or SGSB, which will be overlain by a layer of non-woven geotextile. The biaxial geogrid and non-woven geotextile shall meet the specifications provided in Table 5 and Table 6 of this report.

5.4 Design Cut Slopes

The proposed highway design also includes cuts into the existing ditch slopes adjacent to the highway to accommodate the widening of the highway ditches and the construction of the new stepped channel. A slope stability analysis was conducted to determine cut slope angles that would also meet design target factors of safety. A typical consequence level was used for the highway's upstream (north) side, given that a slope failure could overtop the road. This results in a target factor of safety of 1.54 for cuts on the upstream side of the highway. A low consequence level was used for the downstream (south) side of the highway, given that the slopes were typically less than 2 m to 3 m in height and would likely not overtop the highway embankment. This results in a design target factor of safety of 1.34 for the downstream cut slopes.

The stability analysis results indicated that the cut slopes on the upstream side of the highway shall be no steeper than 2.5H:1V. On the downstream side of the highway and for channel slopes that will not impact the highway embankment, cut slopes shall be no steeper than 2H:1V. For ditch and channel cut slopes that will not be lined with riprap, it is recommended that they be hydroseeded to minimize long-term erosion impacts.

5.5 Temporary Excavations

Temporary excavations greater than 1.2 m deep and where worker entry is required should be constructed per Part 20 of the Occupational Health and Safety Regulation, BC Regulation 296/97, as currently amended by the Workers Compensation Board (WCB) of British Columbia. All temporary excavations more than three meters deep should be made in accordance with the recommendations of a qualified professional engineer. Flatter slopes than those required by the regulation may be necessary if seepage or sloughing conditions are observed in the sidewalls of the excavation. The excavation sidewalls must remain stable or be suitably supported by shoring or bracing before worker entry as required by the regulation. The contractor is ultimately responsible for ensuring all excavations are safe and legal.

Equipment shall, in general, not be allowed within a horizontal distance equal to the depth of the excavation, as measured from the crest of the excavation. Where construction equipment is required to operate at closer distances from the upper edge of the excavation, the influence of this construction equipment on excavation stability shall be reviewed by a qualified geotechnical engineer registered in the Province of British Columbia, with appropriate measures taken to ensure excavation stability.

5.6 Lateral Earth Pressures

Earth retaining structures, including lock block wing walls and any other permanent or temporary structures around the bridge abutment or along the road alignments, must be designed to resist lateral earth pressures. Lateral earth pressures can be estimated by:

$$P = k(\sigma'_{v0} + q)$$

Where:

$$p = lateral\ earth\ pressure\ (kPa)\ at\ depth\ h$$

$$k = lateral\ earth\ pressure\ coefficient\ (active, at\ rest, passive)$$

$$\sigma'_{v0} = effective\ overburden\ pressure\ at\ depth\ h$$

$$q = surcharge\ load\ at\ the\ ground\ surface$$

The active earth pressure coefficient (k_a) is used to determine lateral earth pressures acting on structures that are permitted to translate or rotate slightly outwards, such as cantilever or gravity retaining walls. According to CHBDC S6:19, to attain active earth pressure (k_a) conditions, there either needs to be outwards displacement at the top of the wall that is equal to at least 0.005 times the height of the wall, or there needs to be rotation of 0.002 times the height of the wall or translation of 0.001 times the height of the wall.

The at-rest lateral earth pressure coefficient (k_o) should be used to determine lateral earth pressures acting on structures that undergo minimal movements (deflections, rotations, translations) when subjected to lateral earth pressure. Structures with movements smaller than those required to develop active earth pressures should be designed using the at-rest lateral earth pressure coefficient.

Frost heave and the formation of ice lenses between the retaining wall and the retained earth can create significant lateral pressures on unyielding retaining walls. The lateral pressures are greater for completely restrained walls and can approach 200 kPa or higher. Frost pressures are generally mitigated by providing for a fully drained non frost-susceptible backfill. In the case of unyielding walls exposed to frost penetration with frost-susceptible soils and no sub-drainage provided behind the wall, the retaining wall's ability to resist frost-induced lateral pressures should be assessed.

The passive earth pressure coefficient (k_p) is applied to determine the resistance of the soil in front of the permanently buried portion of a structure to resist translation and overturning. Relatively large wall displacements would be necessary to mobilize full passive resistances. The lateral movement required to mobilize full passive resistance in loose sand is about 5% of the wall height (0.05 times the wall height). It is less than 5% for dense sand, but 5% is a conservative estimate; however, CHBDC S6:19 indicates that the resistance factor for passive pressure of 0.5 includes an allowance for limiting movement. The resistance factor 0.5 is provided in Table 6.2 of CHBDC S6:19. For resistance against sliding, a concrete-subgrade interface friction angle of 20° and a geotechnical resistance factor of 0.8 can be used.

Recommended lateral earth pressure coefficients for highway embankment material anticipated to be retained by the headwall retaining structures are provided in Table 4. Given that the headwalls are expected to be constructed completely in fill (with backfill placed behind the wall), lateral earth pressure coefficients have not been included for the natural alluvial fan deposit materials encountered at the site.

Table 4: Lateral Earth Pressure Coefficients

Soil Type	Lateral Earth Pressure Coefficients				Unit Weight		Soil Friction Angle (°)
	At-Rest k_o	Active k_a	Passive k_p	Incremental Seismic k_{ae}	Total (kN/m^3)	Buoyant (kN/m3)	
Compacted Free-Draining Highway Embankment Fill – flat ground surface above retaining structure	0.41	0.26	3.85	0.02	21	11.2	36
Compacted Free- Draining Highway Embankment Fill – 2H:1V slope above retaining structure	0.41	0.36	11.7	0.05	21	11.2	36

Table 4 includes earth pressure coefficients calculated using the Rankine solution for horizontal backfill conditions, vertical walls, and fill embankment slopes of 2H:1V above the top retaining structures (Canadian Geotechnical Society, 2023). Below the groundwater table, or in the case where drainage will not be provided behind a wall, buoyant soil unit weights should be used, and a hydrostatic pressure component will need to be included in the design. Buoyant soil unit weights are given in Table 4.

For retained backfill placed and compacted in layers, the lateral force caused by compaction must be considered. As per CHBDC S6:19, the compaction surcharge should be modeled as a triangular distribution with 12 kPa at the ground surface, linearly decreasing to zero at a depth of 2 m below the surface being compacted.

A rectangular pressure distribution equal to the vertical surcharge pressure (q) multiplied by the appropriate lateral earth pressure coefficient can be used to model the horizontal pressure from a surface surcharge such as construction traffic loads. WSP recommends modeling construction and normal post-construction traffic loads as a vertical surcharge of at least 12 kPa.

The incremental dynamic active earth pressure coefficient provided in Table 4 was based on the Mononobe-Okabe equations (Mononobe, 1929). In consultation with Table 4.15 of CHBDC S6:19 and the assumption that this culvert would need to remain in service following a seismic event, the PGA provided in Table 2 for the 1 in 475-year event was used to calculate the incremental seismic active earth pressure coefficient for the headwall structure. The additional seismic component of earth pressure can be modeled as an inverted hydrostatic pressure distribution.

For Limit States Design of walls, the following Load Factors should be applied to destabilizing loads calculated from the pressure distributions above.

- For earth loads acting on walls, a Load Factor of 1.25 is recommended for sustained loads.
- For hydrostatic loads acting on walls, a Load Factor of 1.1 is recommended.
- For live surcharge loads acting on walls, the Load Factor of 1.5 should be used.

In general, the design of the retaining walls will be an iterative process between the structural engineer and WSP.

5.7 Culvert Headwall Bearing Resistance

The proposed concrete headwall proposed for the culvert inlet can be proportioned for an unfactored ultimate limit states (ULS) bearing resistance of 1000 kPa, assuming a minimum burial depth of 1.7 m and approximate footing dimensions of 5 m deep by 9 m wide (approximate bearing surface area of 45 m^2). A geotechnical resistance factor of 0.5 should be applied to the unfactored ULS bearing resistance. A serviceability limit states (SLS) bearing pressure of 25 kPa has been calculated for the culvert headwall, assuming a bearing surface area of 5 m deep by 9 m wide and a maximum total settlement of 25 mm. If the dimensions of the headwall change as the project proceeds (e.g. surface area in contact with bearing decreases), WSP should be informed such that the calculated ULS bearing resistance and SLS bearing pressures can be re-evaluated and adjusted if necessary.

5.8 Concrete Sulphate Exposure and Soil Resistivity

No laboratory testing has been completed to assess the sulphate attack potential for concrete or the corrosion potential of the site soils. As such, it is recommended that concrete components such as culvert headwalls be conservatively designed to address the potential for sulphate attack, while steel structural members such as the culvert and vertical debris rack be designed considering corrosion. It should also be noted that the Binnie draft Drainage Report (R.F. Binnie & Associates Ltd., 2023) identified culvert barrel rust during an inspection of the existing culvert.

5.9 Geogrid and Geotextile Specifications

Where non-woven geotextiles are recommended above fine-grained subgrades or in soft or wet areas identified during the stripping and subgrade preparation, the recommended specifications listed in Table 5 should be used. Such conditions could be encountered at the bottom of the culvert excavation or at the base of the existing ditches, where new fills will be placed to widen the highway embankment. Non-woven geotextile should be used below all applications of riprap.

Table 5: Non-Woven Geotextile Specifications

Property	Test Method	Class 1	Class 2
Material Type		Non-woven[1]	Non-woven[1]
Grab Tensile Strength[2]	ASTM D 4632	≥ 1300 N	≥ 700 N
Sewn Seam Strength[2]	ASTM D 4632	≥ 810 N	≥ 630 N
Tear Strength[2]	ASTM D 4533	≥ 500 N	≥ 250 N
Puncture Strength[2]	ASTM D 6241	≥ 3700 N	≥ 1375 N
Permittivity	ASTM D 4491	≥ 0.2 sec-1	≥ 0.1 sec-1
Apparent Opening Size[2]	ASTM D 4751	< 0.15 mm	< 0.22 mm
Recommended Application		+ 50 kg class riprap	Drainage layers Subgrade Separation - 50 kg class riprap

1. Elongation > 50%, as per ASTM D 4632.
2. Based on minimum average roll values (as per ASTM C 4759) in the weaker principal direction.
3. Based on maximum average roll values

Where geogrid may be recommended for subgrade improvement based on conditions encountered during construction, the recommended specifications for a biaxial polypropylene geogrid are provided in Table 6.

Table 6: Biaxial Propylene Geogrid Specification

Property	Test Method	Class 1
Tensile Strength @ 5% Strain, Machine Direction[1]	ASTM D 6637	≥ 11.8 kN/m
Tensile Strength @ 5% Strain, Cross Machine Direction[1]	ASTM D 6637	≥ 18.8 kN/m
Maximum Aperture Size		50 mm
Minimum Aperture Size		15 mm
Minimum Joint Design Strength		4 kN/m
Flexural Rigidity (Resistance to Bending)[1]	ASTM D 5732	≥ 700 g-cm
Roll Width		4.0 +/- 0.1 m

1. Based on minimum average roll values (as per ASTM C 4759)

5.10 Pavement Structure

The pavement structure identified in the Binnie detailed design drawings consists of 150 mm of asphalt above 300 mm of well-graded base course (WGB) and 600 mm of select granular sub-base (SGSB). Based on subsurface conditions encountered in the boreholes drilled through the highway shoulders near the existing culvert, this pavement structure is suitable for this section of the highway. Given that the existing road fills were generally thicker than 0.9 m, ranging from approximately 2.7 m thick in BH22-01 to 2.3 m thick in BH23-02, it is recommended that new fill embankments be constructed entirely of free-draining granular fill. Free-draining granular fill used as Type D embankment fill will help prevent drainage issues between the existing road structure and new embankment fills. It should be noted that in BH23-02, the borehole appeared to encounter buried concrete (origin unknown), which must be removed before placing new embankment and pavement structure fills. The extent of concrete and the amount of effort to remove this material is not well defined as the borehole drilling only identified the thickness of this material at the location of the borehole.

6.0 CLOSURE

Comments and recommendations presented herein are based on a geotechnical evaluation of the available information as noted. If conditions other than those reported are noted in subsequent phases of the project, WSP should be notified and be given the opportunity to review and revise the current comments and recommendations if necessary. Recommendations presented herein may not be valid if an adequate level of review or inspection is not provided during construction.

This report has been prepared for the exclusive use of British Columbia Ministry of Transportation and Infrastructure and their appointed agents for specific application to the area covered within this report. Any use which a third party makes of this report or any reliance on or decisions made based on it are the responsibility of such third parties. WSP accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions taken based on this report. It has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

The report is subject to the Limitations in Appendix D.

If you have any questions concerning our geotechnical comments or require additional information, please do not hesitate to contact the undersigned.

WSP Canada Inc.

C. J. BANKS
42503
C Banks
2025-02-27

Eric Mohlmann

WSP Canada Inc.
Engineers & Geoscientists BC
Permit #1000200

Craig Banks, P.Eng.
Lead Geotechnical Engineer

Eric Mohlmann, P.Eng.
Principal Geotechnical

CB/EM/jts

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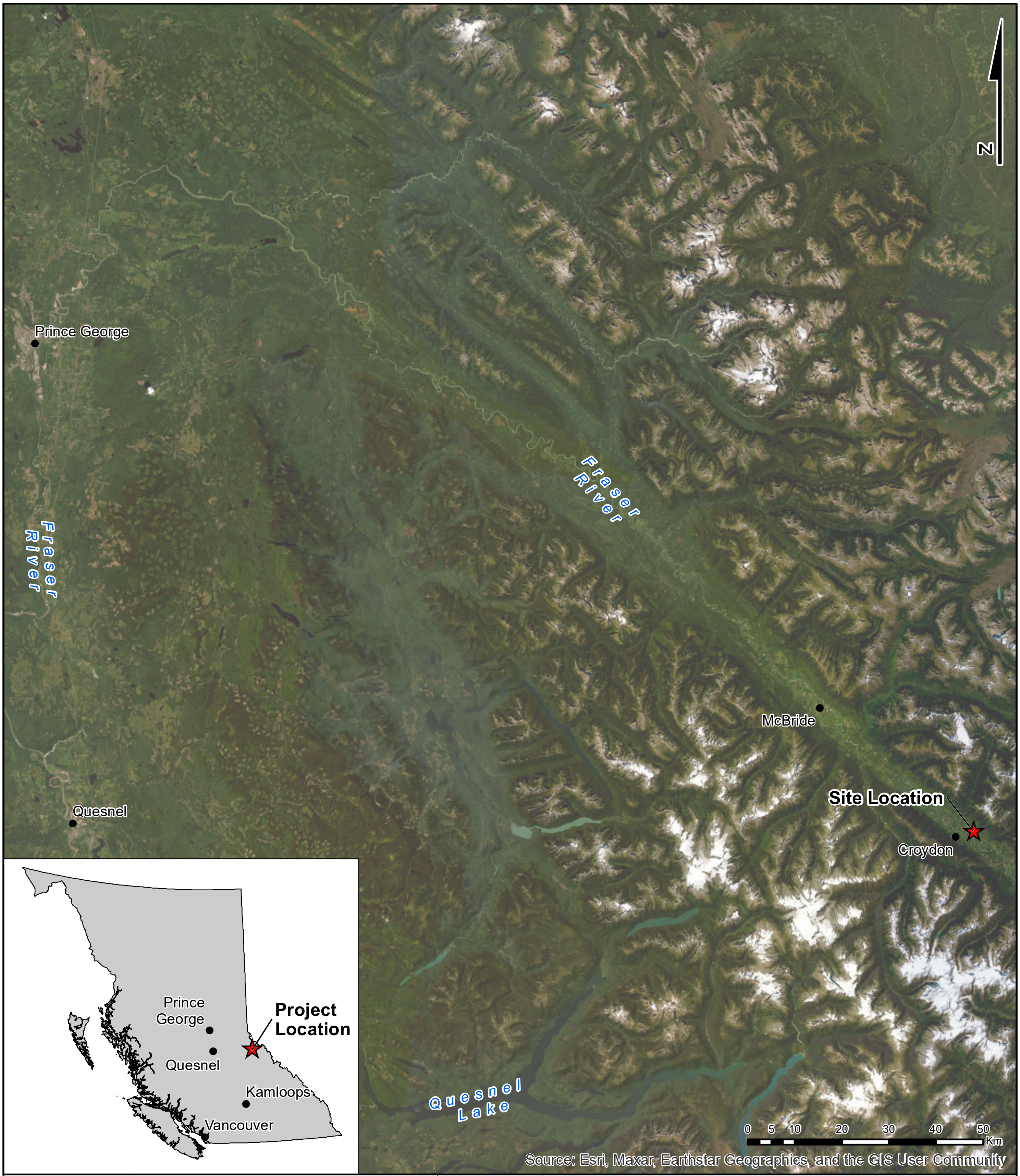

Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

CLIENT:
BC MINISTRY OF
TRANSPORTATION
AND TRANSIT

WSP Canada Inc.
3456 Opie Crescent
Prince George, BC, CANADA V2N 2P9
Tel:+1 250-564-3243

DWN BY: BB

CHK'D BY: CB

DATUM: NAD 83

PROJECTION: UTM Zone 11

MAIN VIEW SCALE: 1:1,100,000

TITLE:
SITE LOCATION PLAN

PROJECT:
CRAIG BROOK
CULVERT REPLACEMENT

DATE: FEBRUARY 2025

PROJECT NO.: CA0034434.0468

REV NO.: 0

FIGURE 1

C:\0 PG CAD\Internal\KX05605-MoTI-CraigBrook-GIS\CA-EI-KX05605-2024-Fig1-SiteLocationPlan.mxd

This drawing was originally produced in colour.

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CLIENT: BC MINISTRY OF TRANSPORTATION AND TRANSIT	DWN BY: BB	TITLE: SITE INVESTIGATION PLAN	DATE: FEBRUARY 2025
	CHK'D BY: CB		PROJECT NO.: CA0034434.0468
WSP Canada Inc. 3456 Opie Crescent Prince George, BC, CANADA V2N 2P9 Tel:+1 250-564-3243	DATUM: NAD 83	PROJECT: CRAIG BROOK CULVERT REPLACEMENT	REV NO.: 0
	PROJECTION: UTM Zone 11		
	SCALE: 1:2,000		FIGURE 2

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This drawing was originally produced in colour.

APPENDIX A

MOT Soil Classification

SOIL CLASSIFICATION

Major Divisions		Symbol	Soil Type
Coarse Grained Soils	Gravel and Gravelly Soils	GW	Well-graded gravels or gravel-sand mixtures, little or no fines
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines
		GM*	Silty gravels, gravel-sand-silt mixtures
		GC*	Clayey gravels, gravel-sand-clay mixtures
	Sand and Sandy Soils	SW*	Well-graded sands or gravelly sands, little to no fines
		SP	Poorly-graded sands or gravelly sands, little or no fines
		SM*	Silty sands, sand-silt mixtures
		SC*	Clayey sands, sand-clay mixtures
Fine Grained Soils	Silts and Clays LL<50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts with slight plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silt-clays of low palsticity
	Silts and Clays LL>50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silts
Organic Soils		Pt	Peat and other highly organic soils
Topsoil		TS	Topsoil with roots, etc.
Cobbles		SB	Rock fragments and cobbles, particle size 75mm to 300mm diameter
Boulders		LB	Boulders, particle size over 300mm in diameter

*GP-GM ; GP-GC; SP-SM; SP-SC; 6-12% Passing #200 (0.075mm) Sieve

* GM1; GC1; SM1; SC1; 12-20% Passing #200 (0.075mm) Sieve

* GM2; GC2; SM2; SC2; 20-30% Passing #200 (0.075mm) Sieve

* GM3; GC3; SM3; SC3; 30-40% Passing #200 (0.075mm) Sieve

* GM4; GC4; SM4; SC4; 40-50% Passing #200 (0.075mm) Sieve

APPENDIX B

Borehole Logs

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

SUMMARY LOG

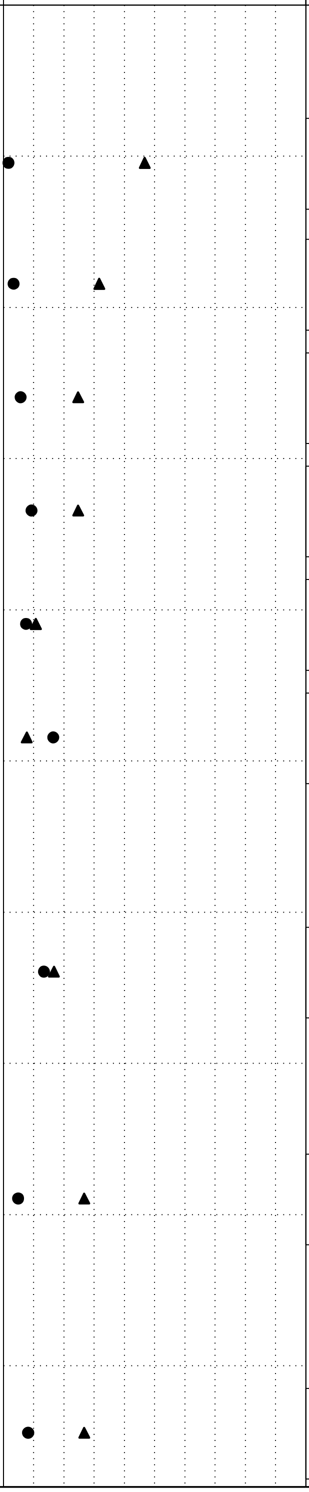
Drill Hole#: BH23-01

Project: **Craig Brook Culvert Replacement**
Location: Craig Brook - BC
Datum: UTM Zone 11N , NAD83
Northing/Easting: 5884332.0 m , 321799.0 m
Elevation: 792.3 m - based on road grade from design cross-sections
Alignment: Highway 16 - L1000A1
Station/Offset: Approximately 1005+00 - EB Shoulder

Prepared by: CA-EI-KX05605 V2
WSP Canada Inc.
Logged by: CB Reviewed by: EM

Date(s) Drilled: 28 Aug 2023
Company: Uncharted Drilling
Driller: Reuben Soames
Drill Make/Model: B-59
Drilling Method: ODEX

x Pocket Penetrometer ⊗ Shear Strength (kPa): 100 200 300 400
+ Natural Vane ⊕ Remold Vane
▲ SPT "N" (BLOWS/300 mm)▲
W%
W_p%|——●——|W_l%: 20 40 60 80



DEPTH (m)	BLOWS/150mm	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)
1	10 16 31 50	☒	S01	20
2	14 17 15 18	☒	S02	67
	11 14 11 6	☒	S03	67
3	13 9 16 10	☒	S04	58
4	2 5 6 6	☒	S05	58
5	2 3 5 9	☒	S06	63
6	3 9 8 6	☒	S07	78
7–8	44 16 11 11	☒	S08	53
9	5 17 10	☒	S09	25

SOIL DESCRIPTION		CLASSIFICATION	COMMENTS TESTING Drillers Estimate (G % S % F %)
ASPHALT.	0.10m		
SAND (fine to coarse grained) and GRAVEL (fine grained), trace silt, well graded, brown, damp to dry, dense [FILL]. - 1.5 m: trace cobbles - 2.3 m: some coal fragments, gravel pieces consist of darker igneous rock	2.70m	SW-GW	
SILT and SAND (fine grained), poorly graded, trace gravel (fine grained), grey, moist, compact.	3.30m	SM4	
SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), some silt, grey, damp, compact.	4.60m	SM2	Sieve (S05) G:41% S:39% F:20%
SAND (fine to coarse grained) and SILT, some gravel, sub-rounded, non-plastic, grey, moist, loose.	7.60m	SM4	Sieve (S06) G:16% S:42% F:42%
SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), poorly graded, some silt, grey to brown, damp, compact. - 9.1 m: trace cobbles, moist			Sieve (S08) G:38% S:44% F:18%

ELEVATION: 792 791 790 789 788 787 786 785 784 783

Legend Sample Type:
A-Auger
B-Becker
C-Core
G-grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Continued on Next Page

Final Depth of Hole: 12.8
Depth to Top of Rock:

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

Prepared by: CA-EI-KX05605 V2
WSP Canada Inc.
Logged by: CB Reviewed by: EM

SUMMARY LOG

Drill Hole#: **BH23-01**

Project: **Craig Brook Culvert Replacement**
Location: Craig Brook - BC
Datum: UTM Zone 11N , NAD83
Northing/Easting: 5884332.0 m , 321799.0 m
Elevation: 792.3 m - based on road grade from design cross-sections
Alignment: Highway 16 - L1000A1
Station/Offset: Approximately 1005+00 - EB Shoulder

Date(s) Drilled: 28 Aug 2023
Company: Uncharted Drilling
Driller: Reuben Soames
Drill Make/Model: B-59
Drilling Method: ODEX

DEPTH (m)	DRILLING DETAILS	BLOWS/150mm	x Pocket Penetrometer ⊗ Shear Strength (kPa) 100 200 300 400 + Natural Vane ⊕ Remold Vane ▲ SPT "N" (BLOWS/300 mm)▲ W% W_p%|———●———|W_l% 20 40 60 80	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate (G % S % F %)	ELEVATION
		40						SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), poorly graded, some silt, grey to brown, damp, compact.	SM1		
10											
											782
								- 10.7 m: damp			
11		14 13 12 10	● ▲	☒	S10	47					
											781
12											
											780
		10 13 16	● ▲	☒	S11	67				Sieve (S11) G:42% S:40% F:18%	
		17						End of hole at 12.80 m. No groundwater flow / groundwater table observed during drilling. No standpipe installed. Backfilled with cuttings and bentonite.			
13											
											779
14											
											778
15											
											777
16											
											776
17											
											775
18											
											774
19											
											773

Legend Sample Type:
A-Auger
B-Becker
C-Core
G-grab
V-Vane
L#-Lab Sample
S-Split Spoon
O-Odex (air rotary)
W-Wash (mud return)
T-Shelby Tube

Final Depth of Hole: 12.8
Depth to Top of Rock:

Ministry of Transportation and Infrastructure
BRITISH COLUMBIA

SUMMARY LOG

Drill Hole#: **BH23-02**

Project: **Craig Brook Culvert Replacement**

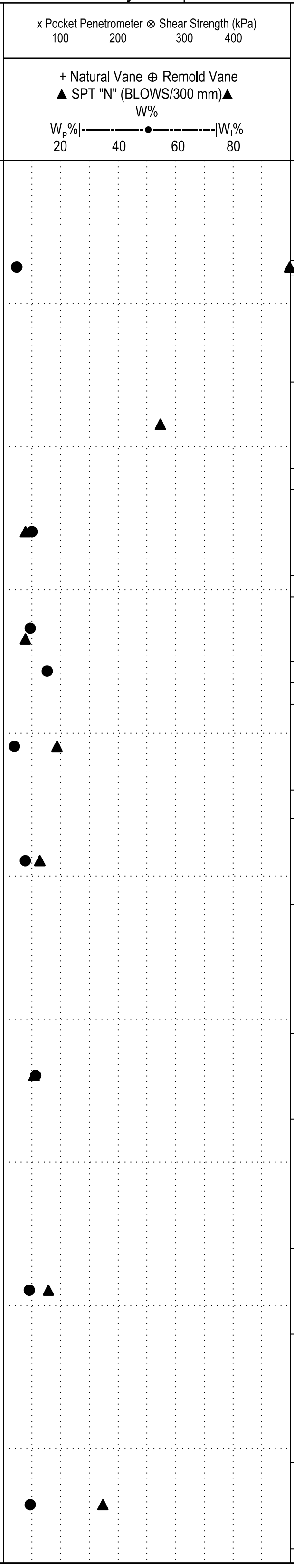
Location: Craig Brook - BC

Prepared by: CA-EI-KX05605 V2
WSP Canada Inc.
Logged by: CB Reviewed by: EM

Datum: UTM Zone 11N , NAD83
Northing/Easting: 5884347.0 m , 321802.0 m
Elevation: 792.0 m- based on road grade from design cross-sections

Alignment: Highway 16 - L1000A1
Station/Offset: Approximately 1004+95 - WB Shoulder

Date(s) Drilled: 28 Aug 2023
Company: Uncharted Drilling
Driller: Reuben Soames
Drill Make/Model: B-59
Drilling Method: ODEX



DRILLING DETAILS BLOWS/150mm	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate (G % S % F %)
				ASPHALT. 0.10m		
				SAND (very fine to fine grained), poorly graded, some silt to silty, non-plastic, some gravel (fine to coarse grained), brown to light grey, damp, very dense.	SM2	
50	☒	S01	0	- 0.8 to 1.5 m: drilled through 0.75 m of buried concrete		
28 30 25 16	☒	S02	83			Sieve (S02) G:15% S:60% F:25%
5 4 4 3	☒	S03	72	2.30m SAND (fine to coarse grained) and SILT, poorly graded, angular to sub-rounded, non-plastic, trace to some gravel (fine to coarse grained), grey, moist, loose.	SM4	Sieve (S03) G:10% S:50% F:40%
3 5 3 7	☒	S04a S04b	72	3.50m SILT, low to non-plastic, sandy, grey, brown mottling, moist, firm to stiff.	ML	
6 7 12 6	☒	S05	50	3.80m SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), poorly graded, angular to sub-rounded, some silt, trace cobbles, grey to brown, damp, compact to dense.		Sieve (S05) G:43% S:41% F:16%
6 7 6 3	☒	S06	22			
13 7 4 5	☒	S07	75	- 6.5 m: 200 mm SILT and SAND, non-plastic, grey, moist, firm to stiff.		
7 9 7 6	☒	S08	50	- 8.1 m: 150mm SAND and SILT, non plastic, some gravel, moist, compact.	SM2	
14 22 13	☒	S09	50	- 9.1 m: 100 mm of SAND (fine grained), silty, non-plastic, brown, wet, loose. - 9.3 m: 200 mm thick cobble fragments		

DEPTH (m)	ELEVATION
1	791
2	790
3	789
4	788
5	787
6	786
7	785
8	784
9	783

Legend Sample Type: A-Auger B-Becker C-Core G-grab V-Vane L#-Lab Sample S-Split Spoon O-Odex (air rotary) W-Wash (mud return) T-Shelby Tube

Continued on Next Page

Final Depth of Hole: 12.8
Depth to Top of Rock:

SUMMARY LOG

Drill Hole#: **BH23-02**

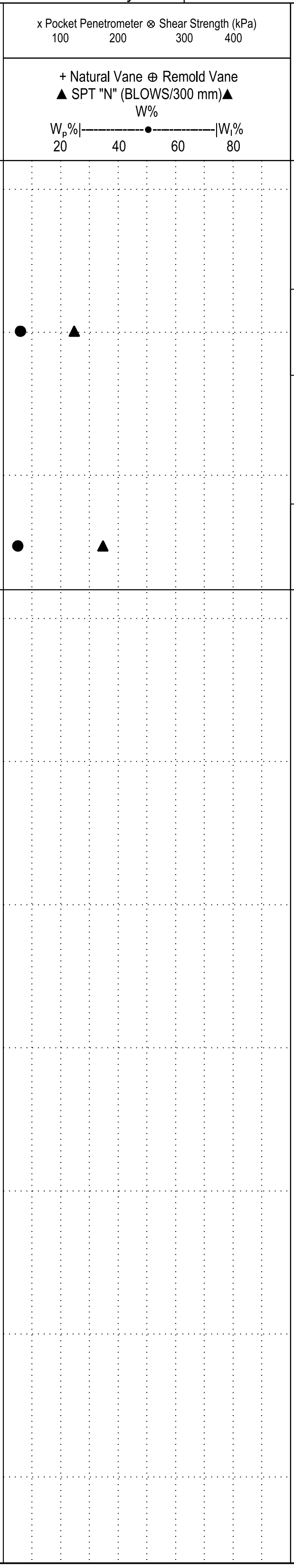
Ministry of Transportation and Infrastructure – British Columbia

Project: **Craig Brook Culvert Replacement**
Location: Craig Brook - BC

Date(s) Drilled: 28 Aug 2023
Company: Uncharted Drilling
Driller: Reuben Soames
Drill Make/Model: B-59
Drilling Method: ODEX

Prepared by: CA-EI-KX05605 V2
WSP Canada Inc.
Logged by: CB Reviewed by: EM

Datum: UTM Zone 11N , NAD83
Northing/Easting: 5884347.0 m , 321802.0 m
Elevation: 792.0 m- based on road grade from design cross-sections
Alignment: Highway 16 - L1000A1
Station/Offset: Approximately 1004+95 - WB Shoulder



DEPTH (m)	DRILLING DETAILS	BLOWS/150mm	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate (G % S % F %)	ELEVATION
		21					SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), poorly graded, angular to sub-rounded, some silt, trace cobbles, grey to brown, damp, compact to dense.			
10										782
11		10 13 12 17	☒	S10	67				Sieve (S10) G:35% S:48% F:17%	781
12										780
		12 19 16	☒	S11	72					
		22					End of hole at 12.80 m. No groundwater flow / groundwater table observed during drilling. No standpipe installed. Backfilled with cuttings and bentonite.			
13										779
14										778
15										777
16										776
17										775
18										774
19										773

Legend Sample Type:
A-Auger **B**-Becker **C**-Core **G**-grab **V**-Vane
L#-Lab Sample ☒ **S**-Split Spoon **O**-Odex (air rotary) **W**-Wash (mud return) **T**-Shelby Tube

Final Depth of Hole: 12.8
Depth to Top of Rock:

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure

SUMMARY LOG

Drill Hole#: BH23-03

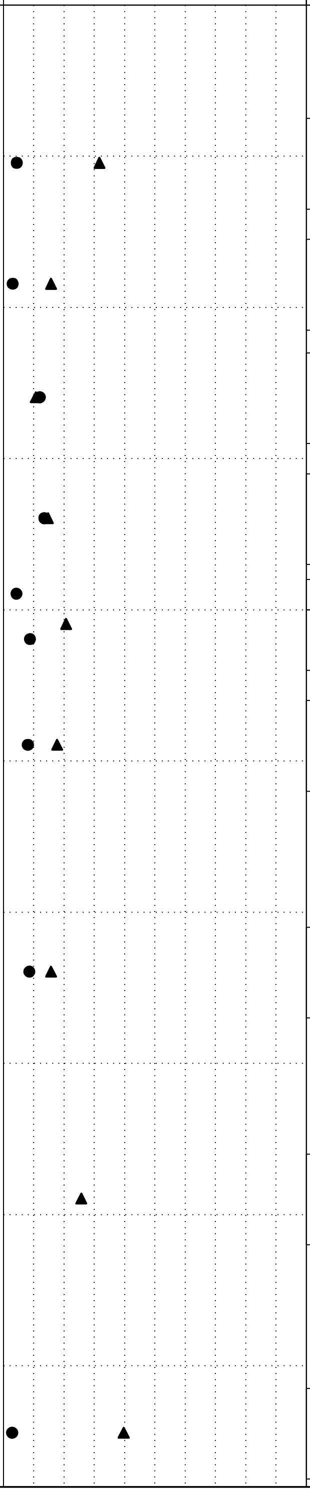
Project: **Craig Brook Culvert Replacement**
Location: Craig Brook - BC

Date(s) Drilled: 29 Aug 2023
Company: Uncharted Drilling
Driller: Reuben Soames
Drill Make/Model: B-59
Drilling Method: ODEX

Prepared by: CA-EI-KX05605 V2
WSP Canada Inc.
Logged by: CB Reviewed by: EM

Datum: UTM Zone 11N , NAD83
Northing/Easting: 5884337.0 m , 321835.0 m
Alignment: Highway 16 - ROW
Station/Offset: Approximately 1005+15 - NE of C/L ~ 15.00
Elevation: 797.5 m - based on ground elevation from design cross-sections

x Pocket Penetrometer ⊗ Shear Strength (kPa) 100 200 300 400
+ Natural Vane ⊕ Remold Vane
▲ SPT "N" (BLOWS/300 mm)▲
W%
Wp%|------●------|Wl%
20 40 60 80



DEPTH (m)	DRILLING DETAILS	BLOWS/150mm	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate (G % S % F %)	ELEVATION
							SAND (fine grained) and GRAVEL (fine to coarse grained), poorly graded, some silt to silty, trace cobbles, brown, trace rootlets, damp, dense.			
										797
1		19 18 14 7	☒	S01	72					
										796
		5 8 8 6	☒	S02	72					
2								SM3		
										795
		5 6 5 25	☒	S03	67		- 2.7 m: silty, angular to sub-rounded gravel, silt and clay clasts.		Sieve (S03) G:28% S:39% F:33%	
3										
		5 4 11 8	☒	S04	67		- 3.4 m: silty to and SILT, find to medium grained gravel			794
			☒	S05a			- 3.8 m: medium to coarse grained sand and gravel			
4							4.00m SAND (fine grained) and SILT, non-plastic, brown with orange mottling, moist, loose to compact.			
		22 14 7 3	☒	S05b	63			SM3	Sieve (S05b) G:13% S:50% F:38%	
										793
							4.60m SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), poorly graded, some silt, trace cobbles, brown, damp, compact.			
5		7 8 10 9	☒	S06	47				Sieve (S06) G:37% S:40% F:22%	
										792
6							- 6.1 m: some silt to silty, grey			
		10 7 9 38	☒	S07	47					791
							- 6.6 m: some cobbles			
7										
										790
8		19 16 10 14	☒	S08	0					
										789
9										
		9 18 22	☒	S09	72					788

Continued on Next Page

Legend Sample Type:
A-Auger B-Becker C-Core G-grab V-Vane
L#-Lab Sample S-Split Spoon O-Odex (air rotary) W-Wash (mud return) T-Shelby Tube

Final Depth of Hole: 15.9
Depth to Top of Rock:

SUMMARY LOG

Drill Hole#: **BH23-03**

British Columbia Ministry of Transportation and Infrastructure

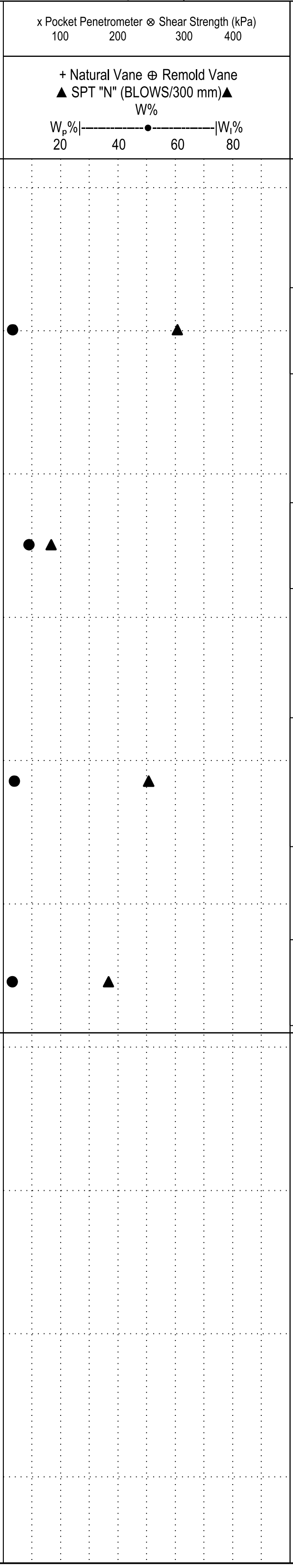
Project: **Craig Brook Culvert Replacement**
Location: Craig Brook - BC

Prepared by: CA-EI-KX05605 V2
WSP Canada Inc.
Logged by: CB Reviewed by: EM

Datum: UTM Zone 11N , NAD83
Northing/Easting: 5884337.0 m , 321835.0 m
Elevation: 797.5 m - based on ground elevation from design cross-sections

Alignment: Highway 16 - ROW
Station/Offset: Approximately 1005+15 - NE of C/L ~ 15.00

Date(s) Drilled: 29 Aug 2023
Company: Uncharted Drilling
Driller: Reuben Soames
Drill Make/Model: B-59
Drilling Method: ODEX



DEPTH (m)	DRILLING DETAILS	BLOWS/150mm	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING Drillers Estimate (G % S % F %)	ELEVATION
10		47				SAND (fine to coarse grained) and GRAVEL (fine to coarse grained), poorly graded, some silt, trace cobbles, brown, damp, compact.	SM2		787
11		8 20 41 52	☒	S10	53	- 10.7 m: SAND (medium to coarse grained), gravelly (fine to medium grained), some silt, trace cobbles, light grey, damp to moist, very dense		Sieve (S10) G:24% S:53% F:22%	786
12		5 8 9 22	☒	S11	50	- 12.2 m: some silt to silty, brown, moist, compact			785
13									784
14		20 31 20 22	☒	S12	11	- 13.7 m: trace to some silt			783
15		16 20 17 18	☒	S13	83	- 15.2 m: trace to some cobbles		Sieve (S13) G:34% S:46% F:20%	782
16						End of hole at 15.90 m. No groundwater flow / groundwater table observed during drilling. No standpipe installed. Backfilled with cuttings and bentonite.			781
17									780
18									779
19									778

Legend Sample Type: A-Auger B-Becker C-Core G-grab V-Vane L#-Lab Sample S-Split Spoon O-Odex (air rotary) W-Wash (mud return) T-Shelby Tube

Final Depth of Hole: 15.9
Depth to Top of Rock:

APPENDIX C

Laboratory Test Results

Client: BC Ministry of Transportation
Project: Craig Brook
Office: Prince George, BC

Project Number: KX05605
Reported by: G. Michaud
Reviewed by: B. McLeod

MOISTURE CONTENT - ASTM D2216

Hole No.	Sample No.	Sampled Date	Test Date	Technician	Top Depth (m)	Bottom Depth (m)	Wt. of Tare	Wt. Sample Wet	Wt. Sample Dry	Wt. Water	Moisture Content %	Comments
BH23-01	S01	28-Aug-2023	18-Sep-2023	S. Chen	0.8	1.4	17.51	293.22	287.76	5.46	2.0%	
BH23-01	S02	28-Aug-2023	18-Sep-2023	S. Chen	1.5	2.1	17.68	470.07	453.92	16.15	3.7%	
BH23-01	S03	28-Aug-2023	18-Sep-2023	S. Chen	2.3	2.9	17.74	740.81	700.12	40.69	6.0%	
BH23-01	S04	28-Aug-2023	18-Sep-2023	S. Chen	3.0	3.7	17.60	389.56	357.07	32.49	9.6%	
BH23-01	S05	28-Aug-2023	18-Sep-2023	S. Chen	3.8	4.4	390.4	1005.2	960.8	44.4	7.8%	
BH23-01	S06	28-Aug-2023	18-Sep-2023	S. Chen	4.6	5.2	394.2	1002.6	915.2	87.4	16.8%	
BH23-01	S07	28-Aug-2023	18-Sep-2023	S. Chen	6.1	6.7	17.67	425.77	376.58	49.19	13.7%	
BH23-01	S08	28-Aug-2023	18-Sep-2023	S. Chen	7.6	8.2	396.4	959.1	931.3	27.8	5.2%	
BH23-01	S09	28-Aug-2023	18-Sep-2023	S. Chen	9.1	9.8	17.56	280.66	260.15	20.51	8.5%	
BH23-01	S10	28-Aug-2023	18-Sep-2023	S. Chen	10.7	11.3	17.76	499.55	456.28	43.27	9.9%	
BH23-01	S11	28-Aug-2023	18-Sep-2023	S. Chen	12.2	12.8	400.5	1165.8	1131.2	34.6	4.7%	

Client: BC Ministry of Transportation
Project: Craig Brook
Office: Prince George, BC

Project Number: KX05605
Reported by: G. Michaud
Reviewed by: B. McLeod

MOISTURE CONTENT - ASTM D2216

Hole No.	**Sample No.**	**Sampled Date**	**Test Date**	**Technician**	**Top Depth (m)**	**Bottom Depth (m)**	**Wt. of Tare**	**Wt. Sample Wet**	**Wt. Sample Dry**	**Wt. Water**	**Moisture Content %**	**Comments**
BH23-02	S02	28-Aug-2023	14-Sep-2023	S. Chen	1.5	2.1	17.69	441.57	421.56	20.01	5.0%	
BH23-02	S03	28-Aug-2023	14-Sep-2023	S. Chen	2.3	2.9	17.60	760.94	691.42	69.52	10.3%	
BH23-02	S04A	28-Aug-2023	14-Sep-2023	S. Chen	3.0	3.5	17.72	271.69	249.29	22.40	9.7%	
BH23-02	S04B	28-Aug-2023	18-Sep-2023	S. Chen	3.5	3.7	17.74	286.37	250.04	36.33	15.6%	
BH23-02	S05	28-Aug-2023	18-Sep-2023	S. Chen	3.8	4.4	395.0	819.8	802.5	17.3	4.2%	
BH23-02	S06	28-Aug-2023	18-Sep-2023	S. Chen	4.6	5.2	17.53	184.65	172.25	12.40	8.0%	
BH23-02	S07	28-Aug-2023	18-Sep-2023	S. Chen	6.1	6.7	17.75	344.60	310.72	33.88	11.6%	
BH23-02	S08	28-Aug-2023	18-Sep-2023	S. Chen	7.6	8.2	17.48	459.20	421.38	37.82	9.4%	
BH23-02	S09	28-Aug-2023	18-Sep-2023	S. Chen	9.1	9.8	17.66	331.43	303.63	27.80	9.7%	
BH23-02	S10	28-Aug-2023	18-Sep-2023	S. Chen	10.7	11.3	384.0	990.1	954.3	35.8	6.3%	
BH23-02	S11	28-Aug-2023	18-Sep-2023	S. Chen	12.2	12.8	17.70	447.01	425.16	21.85	5.4%	

Client: BC Ministry of Transportation
Project: Craig Brook
Office: Prince George, BC

Project Number: KX05605
Reported by: G. Michaud
Reviewed by: B. McLeod

MOISTURE CONTENT - ASTM D2216

Hole No.	Sample No.	Sampled Date	Test Date	Technician	Top Depth (m)	Bottom Depth (m)	Wt. of Tare	Wt. Sample Wet	Wt. Sample Dry	Wt. Water	Moisture Content %	Comments
BH23-03	S01	29-Aug-2023	13-Sep-2023	S. Chen	0.8	1.4	23.25	139.27	134.04	5.23	4.7%	
BH23-03	S02	29-Aug-2023	13-Sep-2023	S. Chen	1.5	2.1	23.57	170.24	165.39	4.85	3.4%	
BH23-03	S03	29-Aug-2023	13-Sep-2023	S. Chen	2.3	2.9	389.0	1017.4	948.6	68.8	12.3%	
BH23-03	S04	29-Aug-2023	13-Sep-2023	S. Chen	3.0	3.7	23.18	134.75	121.24	13.51	13.8%	
BH23-03	S05A	29-Aug-2023	13-Sep-2023	S. Chen	3.8	4.0	17.68	436.20	417.80	18.40	4.6%	
BH23-03	S05B	29-Aug-2023	13-Sep-2023	S. Chen	4.0	4.4	395.5	567.2	552.8	14.4	9.1%	
BH23-03	S06	29-Aug-2023	13-Sep-2023	S. Chen	4.6	5.2	395.9	610.8	594.1	16.7	8.4%	
BH23-03	S07	29-Aug-2023	13-Sep-2023	S. Chen	6.1	6.7	17.58	368.60	339.87	28.73	8.9%	
BH23-03	S09	29-Aug-2023	14-Sep-2023	S. Chen	9.1	9.8	17.71	358.74	348.32	10.42	3.2%	
BH23-03	S10	29-Aug-2023	14-Sep-2023	S. Chen	10.7	11.3	393.2	987.1	966.6	20.5	3.6%	
BH23-03	S11	29-Aug-2023	14-Sep-2023	S. Chen	12.2	12.8	17.55	291.64	268.40	23.24	9.3%	
BH23-03	S12	29-Aug-2023	14-Sep-2023	S. Chen	13.7	14.3	23.28	102.50	99.34	3.16	4.2%	
BH23-03	S13	29-Aug-2023	14-Sep-2023	S. Chen	15.2	15.8	389.3	1204.2	1176.5	27.7	3.5%	

GRAIN SIZE DISTRIBUTION

ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-01	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S05	**DATE SAMPLED:**	28-Aug-2023
DEPTH:	3.8m - 4.4m	**DATE TESTED:**	18-Sep-2023

SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	94.0
19.0	86.2
12.5	75.1
9.5	72.8
4.75	59.3
2.00	46.2
0.850	38.4
0.425	33.2
0.250	29.5
0.150	26.1
0.075	20.0

GRAVEL = **40.7%**
SAND = **39.3%**
FINES = **20.0%**

D10 = **N/A**
D30 = **0.27**
D60 = **4.92**

Cu = **N/A**
Cc = **N/A**

Moisture = **7.8%**

Tested Weight (g) = **570.4**

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

GRAIN SIZE DISTRIBUTION

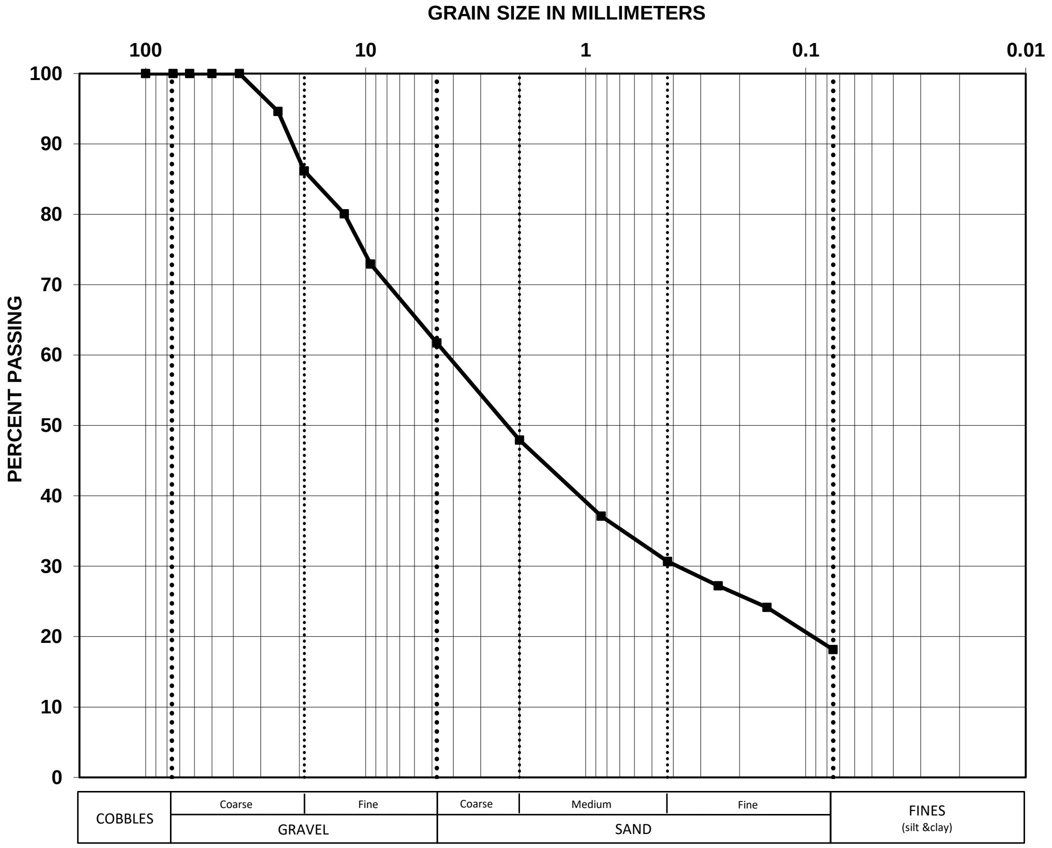
ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-01	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S08	**DATE SAMPLED:**	28-Aug-2023
DEPTH:	7.6m - 8.2m	**DATE TESTED:**	18-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	94.6
19.0	86.2
12.5	80.1
9.5	72.9
4.75	61.7
2.00	47.9
0.850	37.1
0.425	30.7
0.250	27.2
0.150	24.2
0.075	18.2

GRAVEL = **38.3%**
SAND = **43.6%**
FINES = **18.2%**

D10 = **N/A**
D30 = **0.38**
D60 = **4.26**

Cu = **N/A**
Cc = **N/A**

Moisture = **5.2%**

Tested Weight (g) = **534.9**

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

GRAIN SIZE DISTRIBUTION

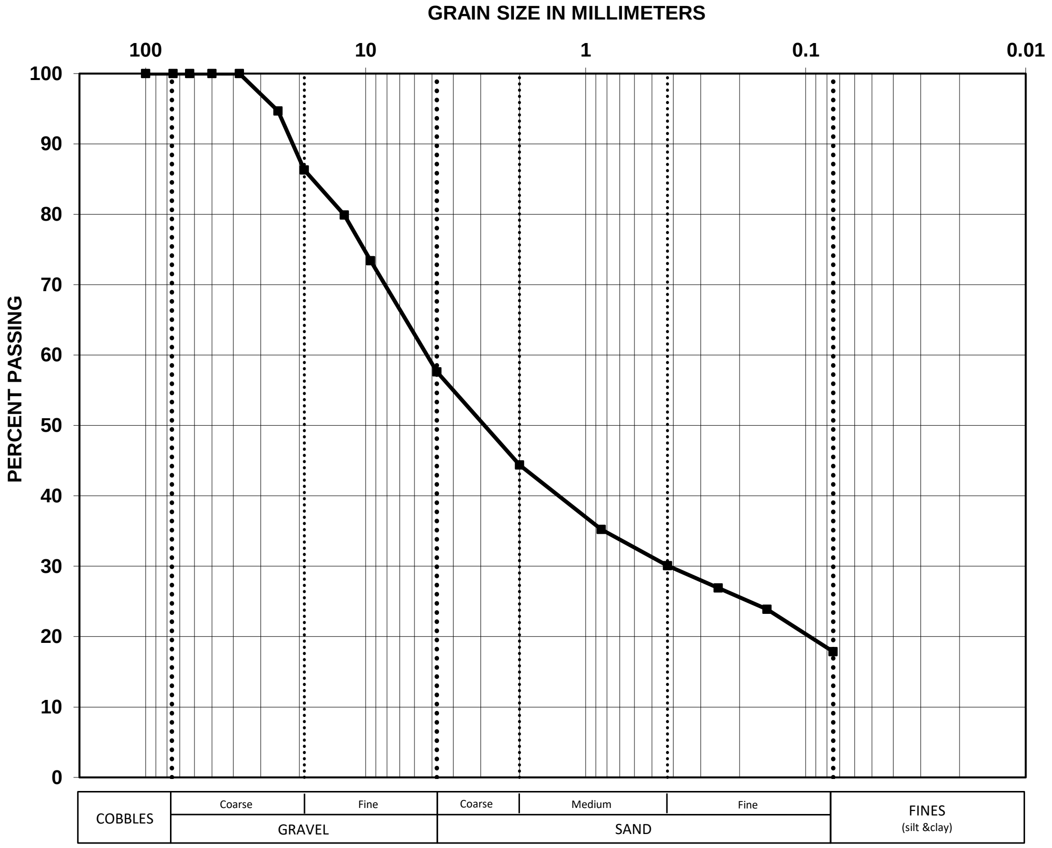
ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-01	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S11	**DATE SAMPLED:**	28-Aug-2023
DEPTH:	12.2m - 12.8m	**DATE TESTED:**	18-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	94.7
19.0	86.3
12.5	79.9
9.5	73.4
4.75	57.6
2.00	44.4
0.850	35.2
0.425	30.1
0.250	26.9
0.150	23.9
0.075	17.9

GRAVEL = 42.4%
SAND = 39.8%
FINES = 17.9%

D10 = N/A
D30 = 0.42
D60 = 5.27

Cu = N/A
Cc = N/A

Moisture = 4.7%

Tested Weight (g) = 730.7

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

GRAIN SIZE DISTRIBUTION

ASTM C136/ASTM C117

BC Ministry of Transportation

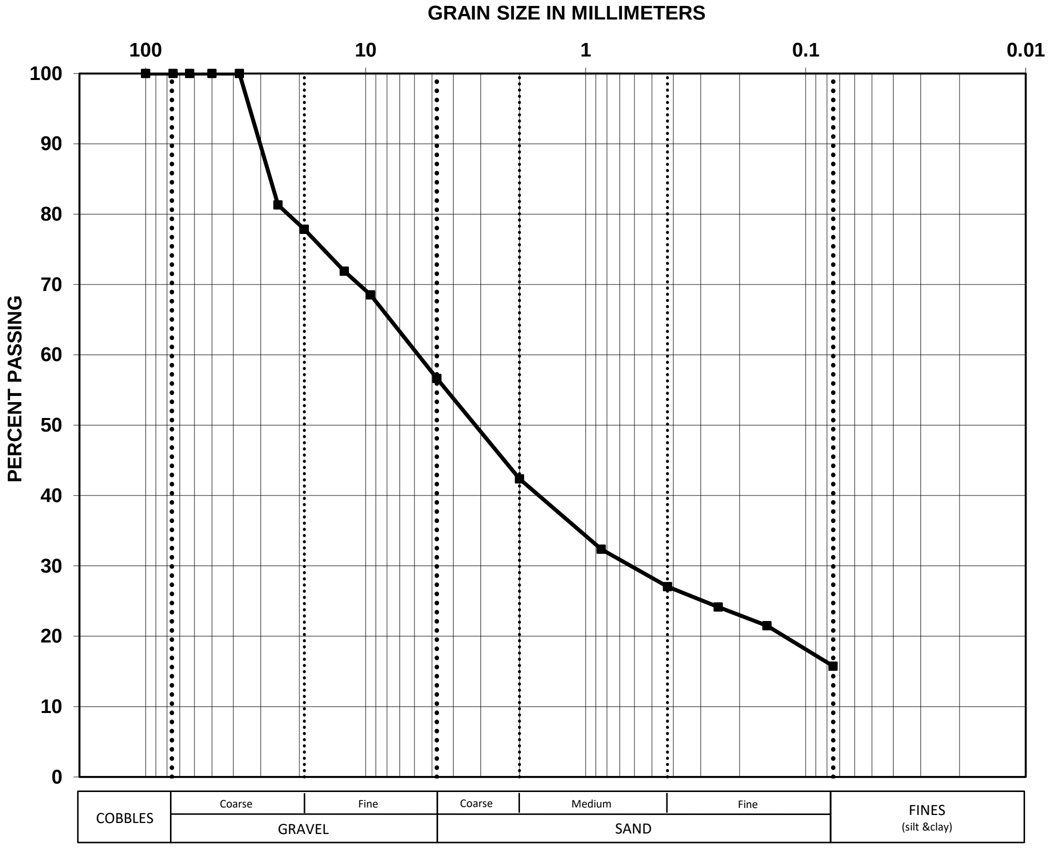
PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER: BH23-02
SAMPLED BY: C. Banks

SAMPLE NUMBER: S05
DATE SAMPLED: 28-Aug-2023

DEPTH: 3.8m - 4.4m
DATE TESTED: 18-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	81.3
19.0	77.8
12.5	71.9
9.5	68.5
4.75	56.6
2.00	42.4
0.850	32.4
0.425	27.0
0.250	24.1
0.150	21.5
0.075	15.8

GRAVEL = 43.4%
SAND = 40.9%
FINES = 15.8%

D10 = N/A
D30 = 0.62
D60 = 5.78

Cu = N/A
Cc = N/A

Moisture = 4.2%

Tested Weight (g) = 407.5

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

GRAIN SIZE DISTRIBUTION

ASTM C136/ASTM C117

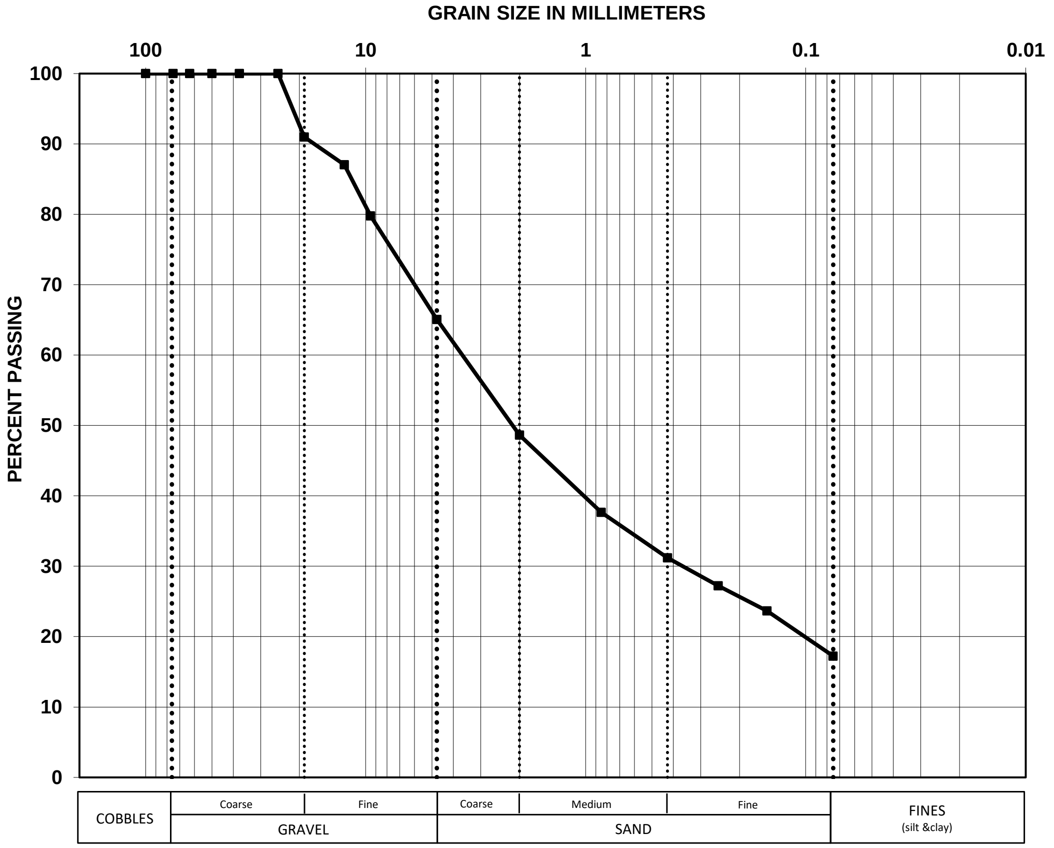
WSP

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-02	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S10	**DATE SAMPLED:**	28-Aug-2023
DEPTH:	10.7m - 11.3m	**DATE TESTED:**	18-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	91.0
12.5	87.1
9.5	79.8
4.75	65.1
2.00	48.6
0.850	37.6
0.425	31.2
0.250	27.2
0.150	23.7
0.075	17.2

GRAVEL = **34.9%**
SAND = **47.8%**
FINES = **17.2%**

D10 = **N/A**
D30 = **0.36**
D60 = **3.64**

Cu = **N/A**
Cc = **N/A**

Moisture = **6.3%**

Tested Weight (g) = **570.3**

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

CERTIFIED BY CCIL

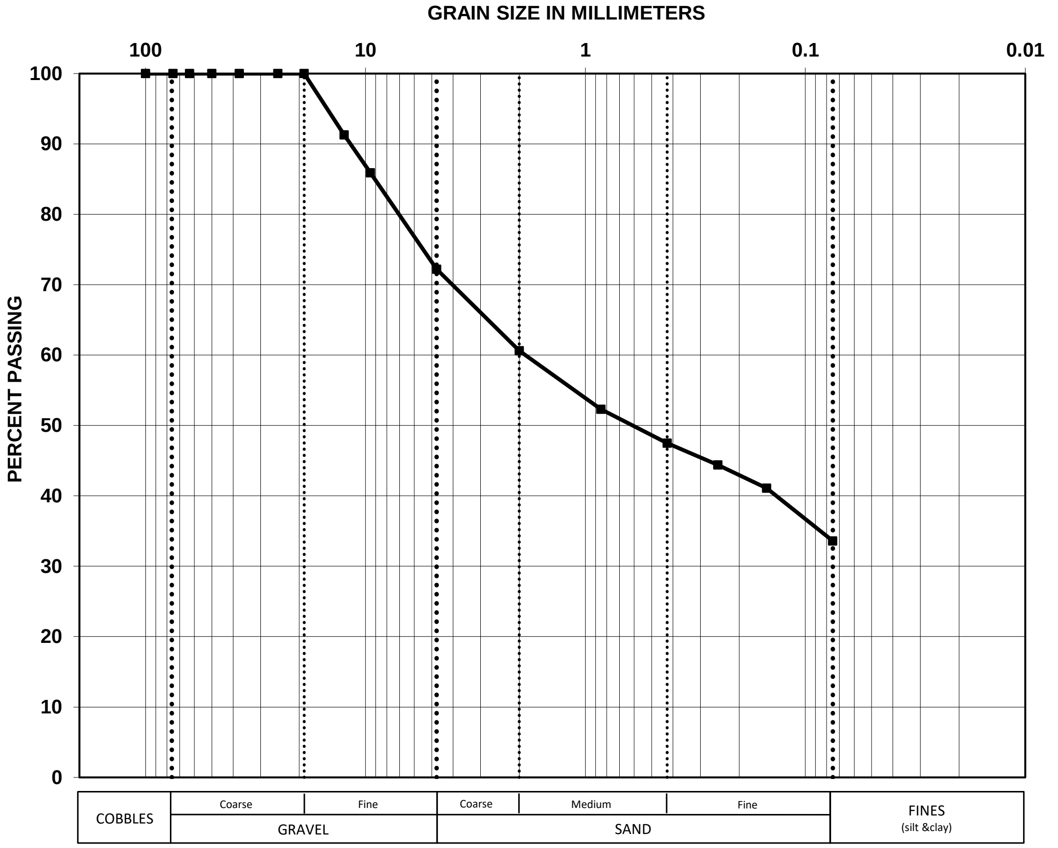
GRAIN SIZE DISTRIBUTION
ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER: BH23-03
SAMPLED BY: C. Banks
SAMPLE NUMBER: S03
DATE SAMPLED: 29-Aug-2023
DEPTH: 2.3m - 2.9m
DATE TESTED: 13-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	100.0
12.5	91.3
9.5	85.9
4.75	72.2
2.00	60.6
0.850	52.3
0.425	47.5
0.250	44.4
0.150	41.1
0.075	33.6

GRAVEL = **27.8%**
SAND = **38.6%**
FINES = **33.6%**

D10 = **N/A**
D30 = **N/A**
D60 = **1.87**

Cu = **N/A**
Cc = **N/A**

Moisture = **12.3%**

Tested Weight (g) = **559.6**

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

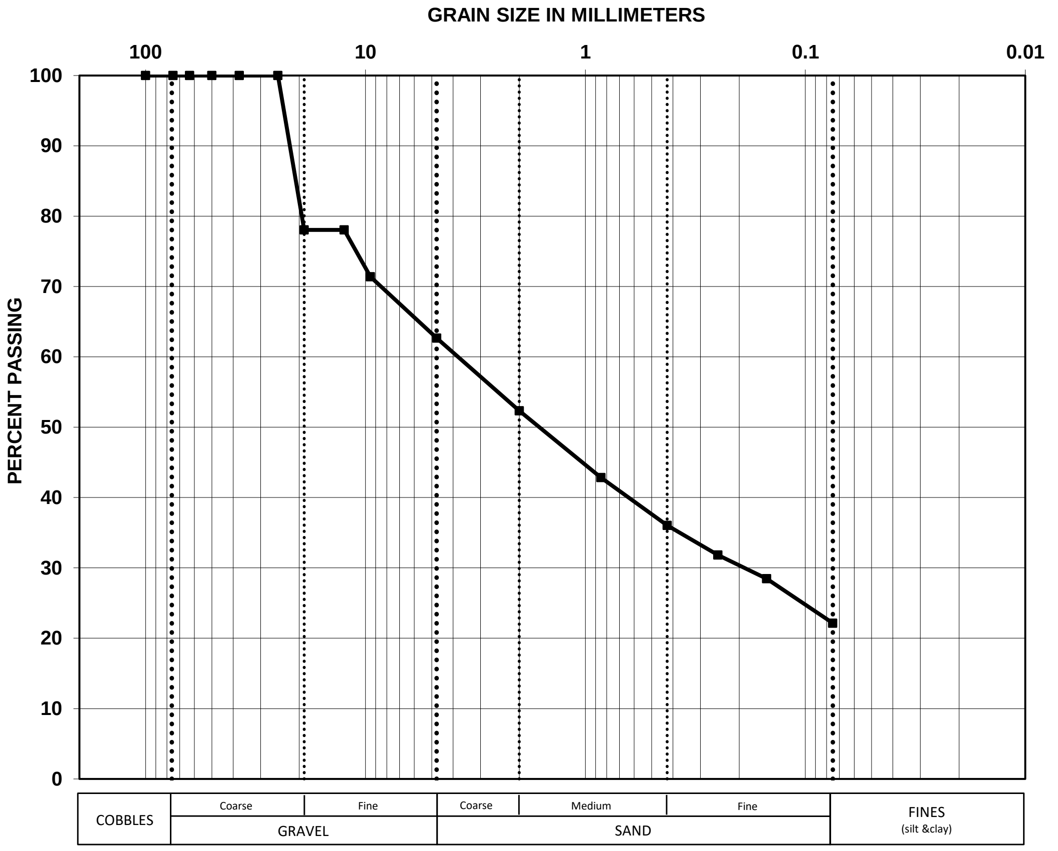
GRAIN SIZE DISTRIBUTION
ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-03	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S06	**DATE SAMPLED:**	29-Aug-2023
DEPTH:	5.5m - 5.8m	**DATE TESTED:**	13-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	78.1
12.5	78.1
9.5	71.4
4.75	62.7
2.00	52.3
0.850	42.8
0.425	36.0
0.250	31.8
0.150	28.5
0.075	22.1

GRAVEL = 37.3%
SAND = 40.5%
FINES = 22.1%

D10 = N/A
D30 = 0.19
D60 = 3.80

Cu = N/A
Cc = N/A

Moisture = 8.4%

Tested Weight (g) = 198.2

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

GRAIN SIZE DISTRIBUTION

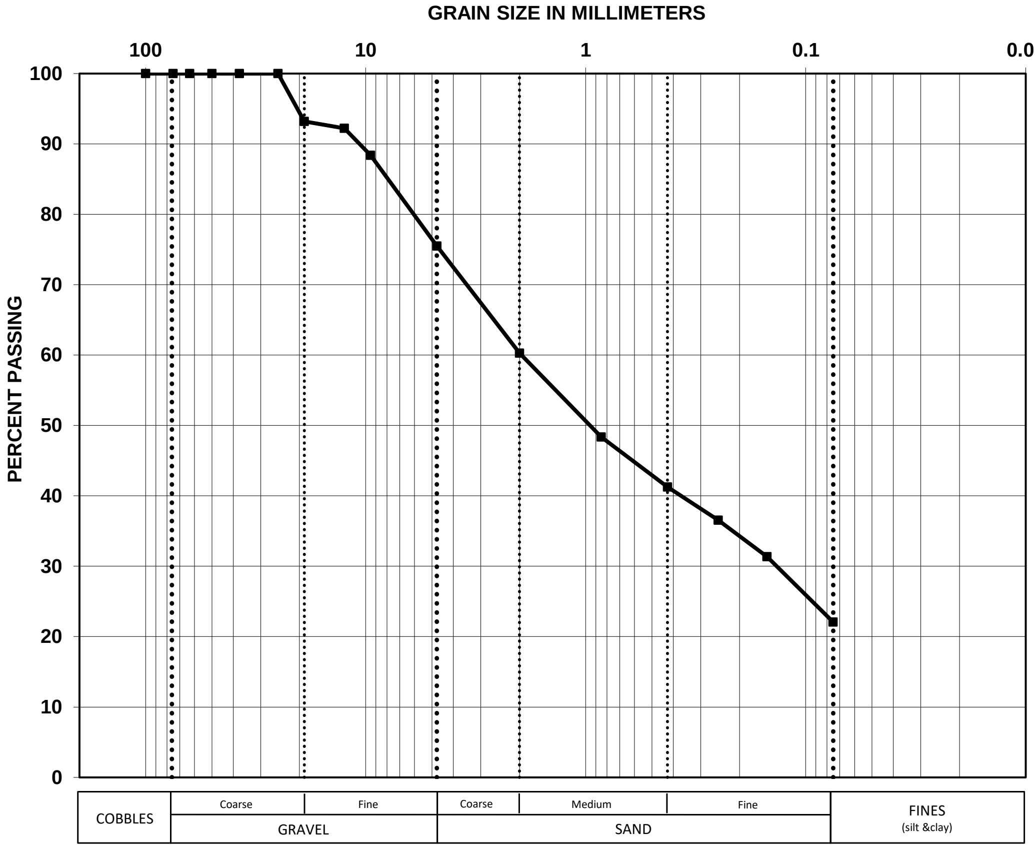
ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-03	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S10	**DATE SAMPLED:**	29-Aug-2023
DEPTH:	10.7m - 11.3m	**DATE TESTED:**	14-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	93.2
12.5	92.2
9.5	88.4
4.75	75.5
2.00	60.3
0.850	48.4
0.425	41.3
0.250	36.6
0.150	31.4
0.075	22.1

GRAVEL = 24.5%
SAND = 53.4%
FINES = 22.1%

D10 = N/A
D30 = 0.14
D60 = 1.96

Cu = N/A
Cc = N/A

Moisture = 3.6%

Tested Weight (g) = 573.4

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

CERTIFIED BY CCIL
Canadian Council of Independent Laboratories
For specific tests as listed on www.ccil.com

GRAIN SIZE DISTRIBUTION

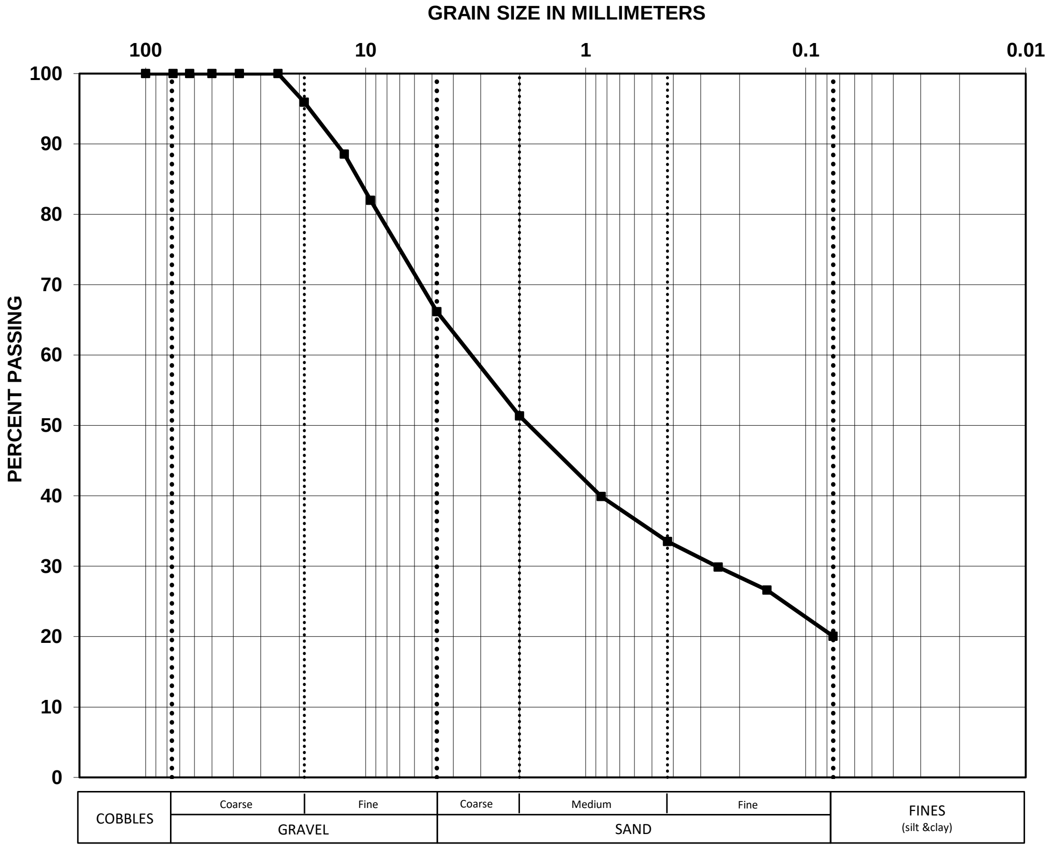
ASTM C136/ASTM C117

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-03	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S13	**DATE SAMPLED:**	29-Aug-2023
DEPTH:	15.2m - 15.8m	**DATE TESTED:**	14-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
63.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	95.9
12.5	88.5
9.5	82.0
4.75	66.2
2.00	51.4
0.850	39.9
0.425	33.5
0.250	29.9
0.150	26.6
0.075	20.0

GRAVEL = **33.8%**
SAND = **46.1%**
FINES = **20.0%**

D10 = **N/A**
D30 = **0.25**
D60 = **3.31**

Cu = **N/A**
Cc = **N/A**

Moisture = **3.5%**

Tested Weight (g) = 787.2

COMMENTS:

Reported by: Brian McLeod

Reviewed by: GMichaud
Glenda Michaud

GRAIN SIZE DISTRIBUTION

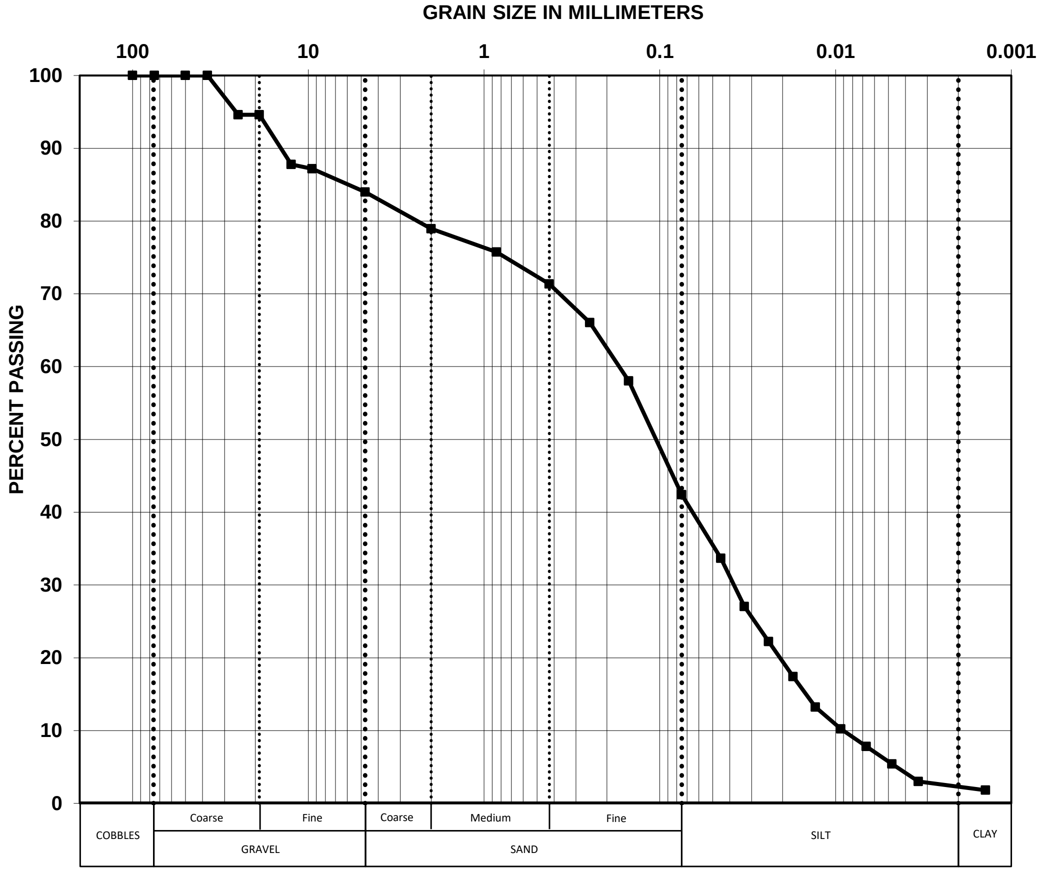
ASTM D7928 - Wet Method

BC Ministry of Transportation

PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER:	BH23-01	**SAMPLED BY:**	C. Banks
SAMPLE NUMBER:	S06	**DATE SAMPLED:**	29-Aug-2023
DEPTH:	4.6m - 5.2m	**DATE TESTED:**	26-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
50.0	100.0
37.5	100.0
25.0	94.6
19.0	94.6
12.50	87.8
9.50	87.2
4.75	84.0
2.00	78.9
0.850	75.7
0.425	71.3
0.250	66.1
0.150	58.0
0.075	42.4
0.0449	33.7
0.0330	27.0
0.0240	22.2
0.0174	17.4
0.0130	13.2
0.0093	10.2
0.0067	7.8
0.0048	5.4
0.0034	3.0
0.0014	1.8

GRAVEL=	**16.0%**
SAND =	**41.6%**
SILT =	**40.3%**
CLAY =	**2.1%**
Moisture =	**16.8%**
D10 =	**0.009**
D30 =	**0.038**
D60 =	**0.170**

COMMENTS:

Specific gravity estimated at 2.65

Reported by: GMichaud
Glenda Michaud

Reviewed by:
Brian McLeod

GRAIN SIZE DISTRIBUTION

ASTM D7928 - Wet Method

BC Ministry of Transportation

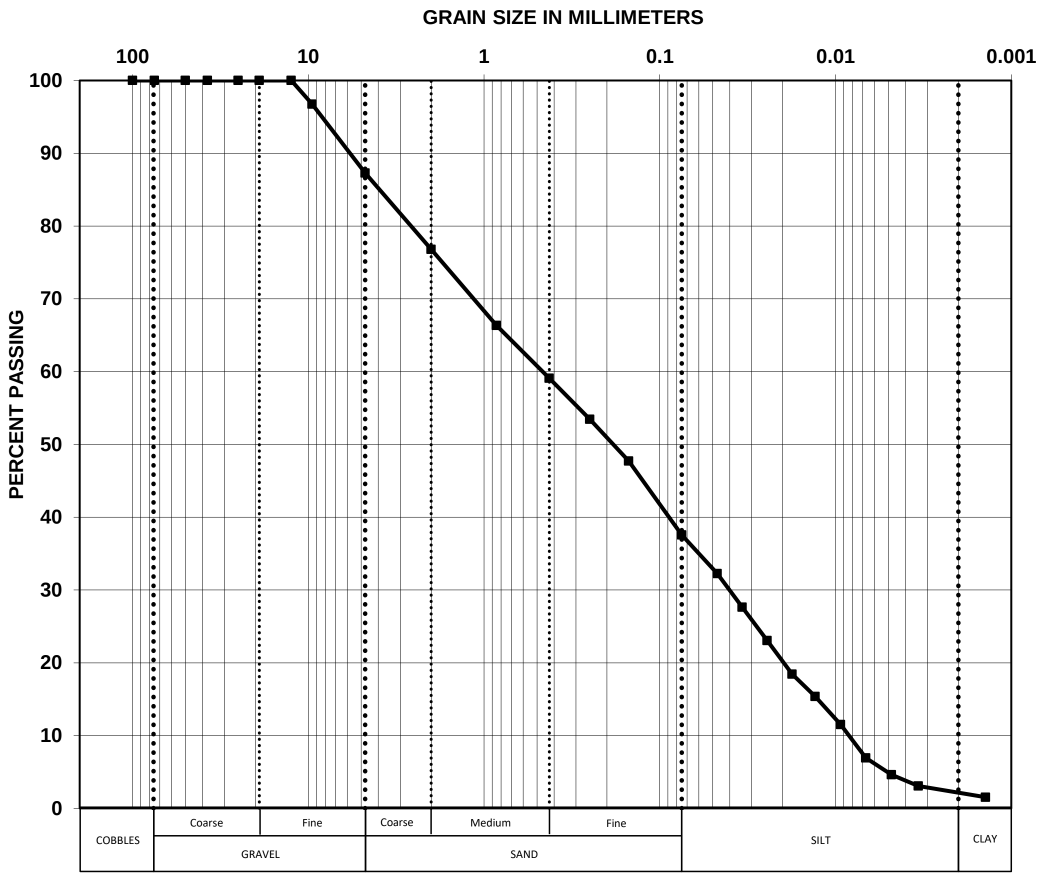
PROJECT: KX05605
OFFICE: Prince George, BC
TECHNICIAN: WSP E&I Canada Limited Lab
DATE: 4-Oct-2023

PROJECT NAME: Craig Brook

BOREHOLE NUMBER: BH23-03
SAMPLED BY: C. Banks

SAMPLE NUMBER: S05b
DATE SAMPLED: 29-Aug-2023

DEPTH: 4.0m - 4.4m
DATE TESTED: 26-Sep-2023



SUMMARY

Grain size (mm)	Passing (%)
100.0	100.0
75.0	100.0
50.0	100.0
37.5	100.0
25.0	100.0
19.0	100.0
12.50	100.0
9.50	96.8
4.75	87.3
2.00	76.8
0.850	66.4
0.425	59.1
0.250	53.4
0.150	47.7
0.075	37.6
0.0470	32.3
0.0339	27.6
0.0245	23.0
0.0176	18.4
0.0130	15.4
0.0094	11.5
0.0067	6.9
0.0048	4.6
0.0034	3.1
0.0014	1.5

GRAVEL= **12.7%**
SAND = **49.7%**
SILT = **35.7%**
CLAY = **1.9%**

Moisture = **9.1%**

D10 = **0.008**
D30 = **0.040**
D60 = **0.464**

COMMENTS:

Specific gravity estimated at 2.65

Reported by: GMichaud
Glenda Michaud

Reviewed by:
Brian McLeod

APPENDIX D

Important Information and Limitations of this Report

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: WSP Canada Inc. (WSP) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to WSP by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. WSP can not be responsible for use of this report, or portions thereof, unless WSP is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without WSP's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, WSP may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to WSP. The report, all plans, data, drawings and other documents as well as all electronic media prepared by WSP are considered its professional work product and shall remain the copyright property of WSP, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of WSP. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client cannot rely upon the electronic media versions of WSP's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to WSP by the Client, communications between WSP and the Client, and to any other reports prepared by WSP for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. WSP can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Groundwater Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, WSP does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions

that WSP interprets to exist between and beyond sampling points may differ from those that actually exist.
In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. **The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report.** The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: WSP will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of WSP's report. WSP should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of WSP's report.

During construction, WSP should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of WSP's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in WSP's report. Adequate field review, observation and testing during construction are necessary for WSP to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, WSP's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that WSP be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that WSP be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. WSP takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

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