Final Geotechnical Investigation Report

Old Kamloops Rd. Crossing Over Stump Lake Creek
South of Kamloops, BC
Project No. KX13772A11

Prepared for:

Ministry of Transportation and Infrastructure
Kamloops, BC
Final Geotechnical Investigation Report

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Project No. KX13772A11

Prepared for:

Ministry of Transportation and Infrastructure

Prepared by:

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1.0 Introduction

Wood Environment & Infrastructure Solutions (Wood), a division of Wood Canada Limited was retained by the Ministry of Transportation and Infrastructure (MOTI) of British Columbia (BC) to conduct a geotechnical investigation for a proposed road crossing where Old Kamloops Road passes over Stump Lake Creek. Old Kamloops Road is located 43.6 km south of Kamloops on Highway 5A. The location of the project site is shown in Figure 1.

The crossing consisted of two culverts, and the culverts were overtopped and washed out on April 28, 2018. Four crossing options are being considered for the re-construction of the road crossing, including (1) a 4.5m Round Corrugated Steel Pipe (CSP) with 40% embedment; (2) a Pre-Cast Concrete Box Culvert with over 4 m span; (3) Closed/Open bottom Low-Profile Arch; and (4) a bridge.

The purpose of the geotechnical investigation was to investigate the subsoil and groundwater conditions at the crossing site and to provide the geotechnical parameters and recommendations necessary for design and construction of the foundations and associated earth works. This report summarizes the results of the field investigation and laboratory work and provides discussion and recommendations for site and subgrade preparation, excavation and filling procedures, shallow and deep foundation design parameters, pavement, seismic site classification, and cement type for concrete.

2.0 Geotechnical Investigation

2.1 Field Drilling Program

Prior to the field activities, a Hazard Assessment and Safety Plan (HASP) was completed to identify and mitigate the likely hazards during the field activities. Underground utilities clearances were obtained through One-Call to identify underground utilities prior to initiating drilling.

The field investigation program was conducted on June 3 and 4, 2019 and was supervised by a Wood geotechnical technician from Wood’s Kamloops office. The field investigation program consisted of two boreholes, one borehole located on each side of the culvert/bridge, to a termination depth of approximately 18.4 m. The borehole locations are presented on Figure 2.

Borehole drilling was completed by Mud Bay Drilling Ltd of Kelowna, BC using a truck mounted Odex drill rig. Standard Penetration Tests (SPTs) were conducted at approximately 1.5 m intervals to measure the soil strength. Soil cuttings and samples from the SPT split-spoon samplers were visually logged in accordance ASTM D2488 and the Modified Unified Soil Classification System (MUSCS). SPT soil samples were collected for further laboratory testing. Groundwater seepage was monitored during drilling. The boreholes were backfilled with drill cuttings and sealed with bentonite chips from 3.0 m depth to the ground surface. The borehole logs are presented in Appendix A.

2.2 Laboratory Tests

Laboratory testing included soil moisture contents, grain size distribution, and soluble sulfate content. Laboratory results are presented in Appendix B.
3.0 Subsurface Conditions

3.1 Site Stratigraphy

The site stratigraphy generally comprised gravel fill, topsoil, underlain by sand and gravel to the drilling termination depth.

The fill thickness was approximately 1.2 m on the west side of the creek, and 1.1 m on the east side of the creek. The gravel fill was sandy, contained silt varying from trace to silty, and was moist to damp. The density of the gravel fill varied from loose to compact.

Topsoil was encountered below the gravel fill in both boreholes, and ranged in thickness from about 0.1 m to 0.6 m. The topsoil was silty, contained some fine sand, and was dark-brown to black in color. The topsoil was loose in density, and moist in moisture content.

Alternating sand and gravel layers were encountered below the topsoil. The sand was well graded, containing gravel contents varying from some gravel to gravelly. The fines contents in the sand varied from approximately 7% to 9%. The gravel was also well graded, containing sand content of approximately 41% and fines content of approximately 7%.

The SPT N values obtained from the sand and gravel indicated that the density of the sand and gravel increased significantly from the depth of approximately 8.0 m, as shown in Figure 3. A default N value of 100 was selected for tests that encountered refusal. The SPT N values varied from 3 to 43 for the sand and gravel deposits located above a depth of approximately 8.0 m, and the majority of the N values were between 10 and 30. The SPT N values indicated that the sand and gravel deposits located above 8.0 m depth generally were compact in density. However, the SPT tests obtained below 8.0 m depth all reached refusal, indicating a very dense in-situ condition.

3.2 Groundwater

The variation of the in-situ moisture contents was observed during the drilling process. Moisture content tests were completed for all the extracted SPT samples. Based on the field observations and the lab test results, the estimated groundwater levels in the boreholes are presented in Table 1 below.

<table>
<thead>
<tr>
<th>Borehole No.</th>
<th>Estimated Groundwater Depth (m bgs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH19-01</td>
<td>2.4</td>
</tr>
<tr>
<td>BH19-02</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Note: bgs is below ground surface

It is expected that the groundwater levels correspond to the water level in Stump Lake Creek at the time of drilling. It should be noted that the groundwater table may fluctuate throughout the year, depending on precipitation, infiltration, and hydrogeological conditions.
4.0  Geotechnical Evaluation and Recommendations

The soil deposits at the subject site are considered suitable for the proposed installation of culverts or a bridge. The following Subsections provide recommendations for: site and subgrade preparation, excavation and backfilling procedures, shallow and deep foundation design parameters, pavement, seismic site classification, and cement type for concrete.

4.1  Site Preparation

Due to the presence of water in the Stump Lake Creek, the construction should be scheduled at a period of time when the flow in the creek is low. Even though, it is expected that there is water in the creek year-round. Installation of culverts will require diversion of some of, or all of, the creek flow during construction. Construction of a single span bridge could be accomplished without diverting the creek flow depending on the construction methodology used. Available systems to divert the creek flow for culvert installation could include earth-fill cofferdams, hydro-fill dams (water filled geomembrane tubes) and driven sheet piles. Earth-fill cofferdams could be constructed of either local sandy gravel soil or clay fill from an off-site borrow area. The amount of water that would flow through an earth-fill coffer dam would depend on the type of material used for construction and the width of the dam. In any event water would also continue to flow into the construction area from the streambed, and pumping would be required to control water flows.

Wood can provide additional information regarding geotechnical aspects of dewatering the construction site, upon request, when design details of the selected crossing and dewatering systems are available.

4.2  Construction Dewatering

It is expected that the groundwater level will be close to the existing creek bed surface even after any site dewatering measures are deployed. In order to minimize the disturbance to the subgrade due to construction activities, construction dewatering is required for the excavation and subsequent culvert installation. The groundwater level should be lowered to approximately 1.0 m below the subgrade level of the culvert. A well point system, or similar system, is recommended for construction dewatering. Construction dewatering is the responsibility of the construction contractor or its dewatering subcontractor.

Hydraulic conductivity of the sand and gravel deposits is required for the design of the dewatering system. Hydraulic conductivity can be estimated using the following empirical method (Hazen, 1892):

\[ K = 0.01 \times (d_{10})^2 \]

Where \( d_{10} \) is the grain size in mm where 10% of the sample is finer.

Table 2 summarizes the interpreted K values using the grain size distribution data obtained from samples taken from the site.

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Depth (m)</th>
<th>Soil Type</th>
<th>( d_{10} ) (mm)</th>
<th>Hydraulic Conductivity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH19-01</td>
<td>3.05 – 3.66</td>
<td>gravelly sand</td>
<td>0.08</td>
<td>6.4\times10^{-5}</td>
</tr>
<tr>
<td>BH19-01</td>
<td>6.1 – 6.71</td>
<td>gravelly sand</td>
<td>0.075</td>
<td>5.6\times10^{-5}</td>
</tr>
<tr>
<td>BH19-02</td>
<td>3.05 – 3.66</td>
<td>gravel and sand</td>
<td>0.16</td>
<td>2.6\times10^{-4}</td>
</tr>
<tr>
<td>BH19-02</td>
<td>6.1 – 6.71</td>
<td>sand</td>
<td>0.1</td>
<td>1.0\times10^{-4}</td>
</tr>
</tbody>
</table>

The above presented K values can be used for the preliminary design of the dewatering system. A slug test or pump test is recommended for the final design.
4.3 Excavation

It is expected that excavation up to approximately 1.8 m (e.g. Crossing option 1 that requires 40% embedment) below the existing creek bed surface will be required for installation of the culverts. The excavation slopes are expected to consist of sand and gravel deposits. Excavation slopes should be no steeper than 1.5H:1V. All excavation shall meet the minimum requirements as set out in the Occupational Health and Safety Regulation.

Excavation spoil piles should be set back at least 2 m from the crest of slope for excavations. Where excavation equipment subjecting the top of the excavation to significant wheel loads is anticipated, the impact of these wheel loads on excavation stability should be reviewed by the geotechnical engineer. Surface drainage should be directed away from the crest of the excavation.

It should be noted that soils lose strength over time due to weathering and groundwater effects; therefore, excavation slopes should be regularly monitored and inspected for any change in the soil conditions. Local flattening of the excavation slopes may be required where instabilities of the cut slopes are observed.

4.4 Subgrade Preparation

All organic soils at the subgrade of the culvert should be removed and replaced with construction fill, as recommended in Section 4.5. Loose zones in the subgrade should be over-excavated to underlying competent soil and backfilled and compacted with engineered fill.

It may be necessary to place geosynthetic over weak subgrade to improve stability. Geosynthetics could include geotextiles or geogrids. The geosynthetics should be capable of sustaining loads from typical equipment and vehicles that will travel on the site.

4.5 Engineered Fill

Engineered fill should consist of well-graded, granular soils or inorganic low to medium plastic clays. While granular soils are present at the project site, low to medium plastic clays were not encountered at the project site. Low to medium plastic clays are required for the construction of the seepage barriers (i.e. clay plug) around the upstream end of the culvert(s). Therefore, low to medium plastic clays will need to be imported from a borrow area outside of the project site.

4.5.1 Granular Fill

Except for the topsoil, the in-situ native soils and gravel fill are considered suitable as engineered granular fill for foundation support and backfill around the culvert. Engineered fill should be free of organic material, large cobbles and boulders, high plastic clays, and deleterious materials. Frozen soil should not be incorporated into engineered fill, and placement of fill on frozen surfaces should be avoided.

Generally, engineered fill should be placed in lifts not exceeding 300 mm (loose) and compacted to minimum 98 percent of SPMDD at placement moisture contents between -2 percent and+2 percent of optimum moisture content (OMC). In order to control the compaction induced lateral earth pressure on the culvert structure, engineered fill placed immediately around the culvert structure (i.e. within 0.5 m distance from the culvert) may be compacted to minimum 95 percent of SPMDD at moisture contents within ± 2 percent of the optimum moisture content.

Vibratory, smooth drum compactors should be used to compact sand and gravel soils. For compaction adjacent to the culvert, lighter weight compaction equipment is recommended. It should be noted that reduction in loose lift thickness may be required when lighter equipment is used.
4.5.2 Clay Fill

Low to medium plastic clays are required for the clay plug surrounding the upstream end of the culvert. Engineered low to medium plastic clay fill should be free of organic material, large cobbles and boulders, high plastic clays, and deleterious materials. Frozen soil should not be incorporated into engineered fill, and placement of fill on frozen surfaces should be avoided.

Generally, engineered fill should be placed in lifts not exceeding 300 mm (loose) and compacted to minimum 98 percent of SPMDD at placement moisture contents between OMC and OMC+3 percent. Engineered fill placed immediately around the culvert structure (i.e. within 0.5 m distance from the culvert) may be compacted to minimum 95 percent of SPMDD.

Sheepfoot compactors should be used to compact clay soils. For compaction adjacent to the culvert, lighter weight compaction equipment is recommended. It should be noted that reduction in loose lift thickness may be required when lighter equipment is used.

4.6 Embankment Slope and Erosion Protection

The embankment slopes should be no steeper than 2H:1V if the slopes consist of sandy gravel or gravelly sand, similar to the soils encountered in the boreholes. Riprap is required for slopes exposed to stream flow to prevent erosion and subsequent slope instability. The riprap should be placed up to the design flood elevation, plus an allowance for freeboard. A geotextile separator should be placed on the prepared 2H:1V slope prior to the placement of riprap to prevent migration of the embankment fill into the riprap material. A non-woven geotextile Propex 4551 or approved equal is recommended.

If the slope soils are not consistent with those encountered in the advanced boreholes, the embankment slopes should be reviewed in the field by a geotechnical engineer.

4.7 Internal Erosion along Culvert

Compacting soils adjacent to a culvert is difficult, and pathways for concentrated flow at the fill-culvert interface may exist. Therefore, water can migrate along the outside of the culvert under hydraulic forces, and with time internal erosion of the soil particles could develop. To prevent internal erosion of the soils surrounding the culvert, a clay plug is recommended for the culvert structure. It is recommended that the clay plug should be a minimum of 2.0 m thick and extend a minimum of 2.0 meters from the culvert outside surface. The clay plug should be constructed with low to medium plastic clays, placed and compacted meeting the requirements described in Section 4.5.2.

As an alternative to the clay plug option, a concrete head wall and cut-off wall can be included in the culvert design to prevent internal erosion. The concrete head wall and cut-off wall should extend beyond the culvert far enough to be below the scour depth, and to reduce the hydraulic gradient sufficiently to avoid having conditions for piping develop. One empirical approach for sizing cutoff walls is the weighted creep-head ratio method\(^1\).

4.8 Shallow Foundations for the Culvert

The base of the concrete box culvert (i.e. crossing option 2) can be treated as a strip footing. Strip footings can also be used to support the Low-profile Arch structure (i.e. crossing option 3). Footings foundation placed on the native undisturbed sand or gravel deposits may be designed using a recommended unfactored Ultimate Limit State (ULS) static bearing pressure of 300 kPa. A factored ULS static bearing pressure of 150 kPa can be used for design when applying a geotechnical resistance factor of 0.5. The minimum footing width should be 1.0 m for the above recommendations. If smaller size footings are used, the bearing capacity should be checked after the footing size and loads are determined. The base of the footing is recommended to be embedded below the scour depth.
Foundation settlement is a function of bearing pressure as well as the foundation size. The settlement of shallow foundations designed based on the above recommended factored ULS static bearing pressure is expected to be less than 25 mm.

Footing subgrades must be protected from frost, and foundations should not be placed on a frozen subgrade. Foundation subgrades should be inspected by the geotechnical engineer prior to placing culverts or foundation concrete to confirm that the bearing soils are competent and in keeping with those found during the site investigation and assumptions made during the preparation of this report. Consideration should be given to the use of a mud slab to protect the bearing surface once it is prepared and approved.

### 4.9 Lateral Earth Pressures for Concrete Box Culvert

The following soil parameters provided in Table 3 may be used in design of concrete box culvert with granular backfill directly contact with the back of the concrete wall. It is assumed that the concrete box culvert is relatively rigid and will experience at-rest soil conditions.

**Table 3: Soil Parameters for Estimate Lateral Earth Pressure**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>At-rest Earth Pressure Coefficient (K0)</th>
<th>Soil Friction Angle, (degree)</th>
<th>Soil Unit Weight (kN/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered granular Fill</td>
<td>0.43</td>
<td>35</td>
<td>21.0</td>
</tr>
</tbody>
</table>

### 4.10 Structural Integrity of the Culvert

Based on the preliminary drawing provided to us, a minimum 800 mm thick soil cover is proposed for the culvert. The bending moments, stresses, and deflections in the culvert structure are a function of properties of the structure (e.g. the corrugation size and thickness, the thrust area, the moment of inertia of the culvert section, and the section modulus), the magnitude of the traffic load, the thickness of the soil cover, and the interaction between the culvert structure and the backfill material. It is recommended that the bending moment, stress, deflection, and buckling thrust should be checked after the type of culvert, the configurations of the culvert, and the loading conditions are determined. However, it is noted that this assessment is not part of the current work scope.

### 4.11 Pile Foundation for Bridge Option

Driven steel piles are considered a suitable foundation type for the soil conditions encountered at the project site.

#### 4.11.1 Axial Resistance of Piles

Table 4 below presents the recommended unfactored ULS geotechnical resistance to calculate static axial capacity for driven steel piles. Geotechnical resistance factors of 0.4 and 0.3 should be applied to calculate the factored compressive and uplift capacities, respectively. Only shaft resistance should be used for calculating pile uplift capacity.
Table 4: Unfactored ULS Resistance for Steel Piles

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Depth (m)</th>
<th>Shaft Resistance (kPa)</th>
<th>End Bearing Resistance (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/Gravel (within frost penetration depth)</td>
<td>0.0 – 2.5</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Compact Sand/Gravel (below frost penetration depth)</td>
<td>2.5 – 8.0</td>
<td>Vary from 20 kPa at 2.5m depth to 40 kPa at 8.0m depth</td>
<td>--</td>
</tr>
<tr>
<td>Very Dense Sand/Gravel</td>
<td>Below 8.0 m</td>
<td>150</td>
<td>2,000</td>
</tr>
</tbody>
</table>

For H-Piles and open-ended pipe piles driven below certain depths soil plugs will develop and contribute to the end bearing resistance of the piles. The cross-sectional area of the pile toe would include the cross-sectional area of the steel plus the area of the soil within the pipe for pipe piles or between the flanges of the H-Piles. Above these depths, only the cross-sectional area of the steel should be considered when estimating the pile end bearing resistance. For the soil conditions encountered at site, contribution of soil plugs to end bearing resistance should only be considered once the piles are driven to a depth at least 30 times the width between the flanges for H-Piles, or inside pipe diameter for pipe piles.

When designing piles for the required embedment depth to resist frost uplift forces, a frost jacking stress of 80 kPa should be applied along the surface perimeter of the top 2.5 m of the pile. Lightly loaded driven steel piles should be installed to at least 10.0 m bgs to ensure adequate resistance against frost jacking forces.

Pile settlement is difficult to predict and is a function of soil conditions, loading conditions, and properties of the piles. Generally, shaft resistance is fully mobilized after 5 to 10 mm of settlement has occurred, while settlements up to 5% to 10% of the pile diameter is required before end bearing resistance is fully mobilized. The settlement of a pile designed based on the above recommended factored ULS geotechnical resistance is expected to be 1~2% of the pile diameter. Settlements of piles under other loading conditions should be checked case-by-case after the loading conditions and pile configurations are determined.

Analytical methods using soil/pile load interaction curves (t-z curves for shaft resistance vs. pile shaft movement, and q-z curves for end bearing resistance vs. pile end movement) offer a widely accepted basis for predicting pile-soil interaction with practical accuracy and simplicity. However, to use the t-z and q-z curves method to assess pile axial resistance capacity, the pile configurations need to be known. Upon request, Wood can conduct the analysis using the UniPile computer software after the pile configurations and loading conditions are known. It is noted that this assessment is not part of the current work scope.

4.11.2 Lateral Resistance of Piles

The lateral load resistance of driven steel piles depends essentially both on the stiffness of the pile and the strength of the soil. The lateral load capacity of vertical piles can be limited by three different mechanisms:

- The capacity of the soil may be exceeded, resulting in large horizontal movements of the piles:
- The bending moments and/or shear stress may generate excessive bending moment or shear stresses in the pile material, resulting in structural failure of the piles; or
- The deflection of the pile heads may be too large to be compatible with the superstructure supported by the piles.
Analytical methods using soil/pile load interaction curves (p-y curves) offer a widely accepted basis for predicting pile-soil interaction with practical accuracy and simplicity. However, to use the p-y curve method to assess pile lateral resistance capacity, the pile configurations need to be known. Upon request, Wood can conduct the analysis using the LPile computer software after the pile configurations and loading conditions are known. It is noted that this assessment is not part of the current work scope.

At the current project stage, as a preliminary guide, the coefficient of horizontal subgrade reaction method is a simplified and somewhat conservative method that can be used to analyze pile response to lateral loads and moments. This method requires that strength/deformation characteristics of the adjacent soil be modeled by springs for which values of the coefficient of horizontal subgrade reaction (k_h) are required. The recommended k_h values for the project site are presented in Table 5.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Depth (m)</th>
<th>Modulus of Horizontal Subgrade Reaction, k_h (MN/m^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand/Gravel (within frost penetration depth)</td>
<td>0.0 – 2.5</td>
<td>2.2×(z/d)</td>
</tr>
<tr>
<td>Compact Sand/Gravel (below frost penetration depth)</td>
<td>2.5 – 8.0</td>
<td>4.4×(z/d)</td>
</tr>
<tr>
<td>Very Dense Sand/Gravel</td>
<td>Below 8.0 m</td>
<td>11×(z/d)</td>
</tr>
</tbody>
</table>

Notes:
z= depth varying from 0 m to depth under consideration
d= Pipe pile diameter or H-Pile width

### 4.11.3 Pile Groups

Generally, piles will behave individually (i.e. Group efficiency=1.0) in compression when a minimum center-to-center spacing of 5 shaft diameters is provided between adjacent piles regardless of number of piles in the group, and will behave individually in lateral directions when the center-to-center spacing is greater than 3 shaft diameters in the direction transverse to loading (side-by-side), and greater than 6 shaft diameters in the direction parallel to loading (in-line). However, for circumstances in which piles are closely spaced and/or the piles are connected by a rigid pile cap, forcing equal deformation behavior at the pile heads, interaction between the piles will occur.

Pile groups with complex configurations and layouts under combinations of axial loads, lateral loads and bending moments can be readily analyzed using GROUP 3D software. GROUP analyses may be completed for detail design for the pile groups on a case-by-case basis. Wood can carry out GROUP analysis upon request when the pile layout and pile loading conditions have been determined. It is noted that GROUP analysis is not part of the current work scope.

For the current level of design, the group reduction factor (or efficiency factor) method, which is a simple but conservative method, is recommended as follows.

#### 4.11.3.1 Group Effects Under Axial Loading Conditions

To account for stress-overlap between adjacent piles where piles are spaced closer than 5 shaft diameters, the geotechnical resistance of a 2x2 or larger pile group (acting in either compression or tension) may be determined in accordance with the following:

$$ P_{\text{group}} = P_{\text{single}} \cdot n \cdot \eta $$

where:
- $P_{\text{group}}$ = vertical load for the entire group
- $P_{\text{single}}$ = vertical load for a single pile
- $n$ = number of piles in the group
$\eta$ = group reduction factor as defined in Table 6
The group reduction factor is the ratio of the vertical resistance of the pile group to the sum of vertical resistances of individual piles.

### Table 6: Group Efficiency for Vertically Loaded Pile Groups

<table>
<thead>
<tr>
<th>Center to Center Spacing (pile shaft diameters)</th>
<th>Group efficiency Factor, $\eta$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2x2 and 2x3</td>
</tr>
<tr>
<td>5 or greater</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
</tr>
<tr>
<td>2.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>

#### 4.11.3.2 Group Effects Under Lateral Loading Conditions
Group effects should be considered for pile spacing less than 6 pile shaft diameters in the direction of the lateral load, and less than 3 pile shaft diameters normal to the direction of the lateral load.

$$P_{\text{group}} = P_{\text{single}} \cdot n \cdot \alpha$$

where:
- $P_{\text{group}}$ = allowable lateral load for the entire group
- $P_{\text{single}}$ = allowable lateral load for the acceptable level of deflection or moment
- $n$ = number of piles in the group
- $\alpha$ = group reduction factor as defined in Table 7

### Table 7: Laterally Loaded Group Reduction Factors

<table>
<thead>
<tr>
<th>Pile Group</th>
<th>Loading Direction</th>
<th>Pile Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3d</td>
</tr>
<tr>
<td>2 x 1</td>
<td>y</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>z</td>
<td>0.9</td>
</tr>
<tr>
<td>2 x 2</td>
<td>either direction</td>
<td>0.75</td>
</tr>
<tr>
<td>2 x 3</td>
<td>y</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>z</td>
<td>0.7</td>
</tr>
<tr>
<td>2 x 4</td>
<td>y</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td>z</td>
<td>0.7</td>
</tr>
<tr>
<td>3 x 3</td>
<td>either direction</td>
<td>0.65</td>
</tr>
<tr>
<td>3 x 4</td>
<td>y</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>z</td>
<td>0.65</td>
</tr>
<tr>
<td>4 x 4</td>
<td>either direction</td>
<td>0.6</td>
</tr>
<tr>
<td>4 x 5</td>
<td>y</td>
<td>0.6</td>
</tr>
<tr>
<td></td>
<td>z</td>
<td>0.6</td>
</tr>
<tr>
<td>5 x 5</td>
<td>either direction</td>
<td>0.55</td>
</tr>
<tr>
<td>6 x 6</td>
<td>either direction</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Notes: d = pile diameter, pile spacing is measured from center to center
The group reduction factor should be applied to the lateral load capacity, and not to the lateral deflection.

4.11.4 Pile Installation Considerations

Driven steel piles should be driven using maximum hammer energies of 400 to 600 J per blow for each square centimeter of steel in the pile cross-section. This is a preliminary guide to estimate the size of pile driving hammer that may be required for construction. The piles should not be driven beyond practical refusal, which may be taken as 12 blows per each 25 mm interval for the last 300 mm for the above maximum hammer energies. The ability of a pile driving hammer to drive the proposed piles to the required capacity should be confirmed using wave equation analysis once the information for the proposed hammer and pile configuration are available. The required termination criteria should also be determined using wave equation analyses once hammer energies, hammer type and pile details are known.

Once the pile type and length have been chosen to meet the foundation design requirements, and the pile driving contractors are determined (i.e. the hammer type, hammer energy, etc. are known), it is recommended that a WEAP (Wave Equation Analysis of Pile Driving) analysis be performed to verify that:

- The chosen pile type(s) can be successfully driven to the required penetration depths at a reasonable driving resistance without excessive driving stress;
- The pile driving equipment that the contractor intends to use for the job can provide the driving energies required; and
- The necessary pile driving criteria is achievable.

For driven steel piles installed during winter months, pre-drilling will be required to penetrate the frozen soil. The frost depth should be observed during the initial predrilling process and evaluated by a geotechnical engineer to determine if predrilling is required for all piles. The hole diameter for the predrilling should be no larger than 75% of an H-pile flange width, or approximately 95% of the pile diameter for pipe piles and should only extend to the bottom of the frost penetration depth.

Where groups of piles are to be installed, the piles should be installed starting at the center with the outer piles installed last. The elevation of the tops of previously installed piles should be monitored as adjacent piles are driven in order to determine if heaving of the previously installed piles occurs. Piles that have heaved greater than or equal to 6 mm must be re-driven to their initial embedment depths.

Prior to the pile installation, the piles should be inspected to confirm that the appropriate material specifications are satisfied. The piles should be free from protrusions, including protruding welds in the case of welded spiral pipe. Such protrusions could create voids in the soil around the pile during driving, thereby compromising the frictional resistance. If a driving shoe is used, it must not protrude beyond the outside diameter of the pile.

Monitoring of the pile installation by an experienced geotechnical engineer or technician is recommended to verify that the piles are installed in accordance with design assumptions and that the specified driving criteria are satisfied. For each pile, a complete driving record in terms of the number
of blows per 300 mm of penetration should be recorded and at smaller intervals near termination. Driving records and other relevant installation information should be reviewed during pile installation by the geotechnical engineer.

4.12 Road Pavement and Roadway

A minimum asphalt thickness of 100 mm is recommended for the pavement based on an estimated soaked CBR of 20 for the road subgrade (i.e. sandy gravel encountered in the advanced boreholes). No provisions are required for the road base and sub-base materials since the subgrade sandy gravel can also serve as the base and sub-base of the roadway. Maximum wheel loads are understood to be within provincial highway standards.

The roadway surface should be shaped and graded to direct surface runoff away from road embankments. Roadways should be centre-crowned or graded with a unidirectional cross slope over the entire section width to convey runoff from the traveled way. Roadways should be paralleled by ditches with inverts being a minimum 0.5 m below the road subgrade. Ditch slopes and backslopes of 2H:1V are recommended if the slopes consist of sandy gravel or gravelly sand soils, same as the soils encountered at the borehole locations. Flatter sideslopes may be required for safety or maintenance purposes. Ditch slopes and road slopes may require erosion protection.

4.13 Seismic Site Classification

The seismic response of the site is classified according to the National Building Code of Canada 2015 (NBCC), which categorizes the soil conditions into 6 types - Class ‘A’ to ‘F’. This classification is based on the average shear wave velocity, energy-corrected SPT N-values, or undrained shear strength over the top 30 m of the soil profile. The boreholes were not advanced to a depth of 30 m; therefore, it was assumed that soils below the borehole termination depth are very dense (i.e. similar as the soils between 8.0 m depth and the termination depth). Based on the measured SPT N values and the above assumption, the site is categorized as Class ‘C’ according to the NBCC 2015.

4.14 Soil Corrosion Potential to Concrete

All concrete design and construction should be carried out in accordance with current CAN/CSA-A23.1 specification. Tests for water-soluble sulfates were performed on two soil samples. The measured sulfate concentrations were both less than 0.05%. According to the CAN/CSA-A23.1 specification, the potential degree of sulfate attack on concrete is considered to be negligible. Accordingly, Type GU (formerly Type 10) cement may be used in the manufacture of concrete placed in contact with the soil at this site. Air entrainment is also recommended for all concrete exposed to freezing temperatures to enhance durability.

If soil material will be imported to the site for use as fill/backfill, it should be tested to obtain its chemical parameters and the recommendations provided herein be modified accordingly.

4.15 Testing and Inspection

All engineering design recommendations presented are based on the assumption that a qualified contractor will be retained to carry out the work, and that an adequate level of monitoring will be provided by the geotechnical consultant during construction. An adequate level of inspection is considered to be:

- For shallow foundations: inspection of all bearings surfaces prior to concrete placement;
- For deep foundations: design review and full-time monitoring of foundation installation;
- For earthworks: full time monitoring and compaction testing for any engineered fill; and
• For concrete construction: testing of plastic and hardened concrete in accordance with CSA A23.1-00 & A23.2-00 and review of concrete supplier’s mix designs for conformance with project specifications.

Wood requests the opportunity to review the design drawings and the installation of the piles and footings used on the project, to confirm that the recommendations have been correctly interpreted. We would be pleased to provide any further information that may be needed during design and to advise on the geotechnical aspects of specifications for inclusions in contract documents.

5.0 Limitations & Closure

5.1 Limitations

1. The work performed in the preparation of this report and the conclusions presented herein are subject to the following:

   a) The contract between Wood and the Client, including any subsequent written amendment or Change Order duly signed by the parties (hereinafter together referred as the “Contract”);

   b) Any and all time, budgetary, access and/or site disturbance, risk management preferences, constraints or restrictions as described in the contract, in this report, or in any subsequent communication sent by Wood to the Client in connection to the Contract; and

   c) The limitations stated herein.

2. Standard of care: Wood has prepared this report in a manner consistent with the level of skill and care ordinarily exercised by reputable members of Wood’s profession, practicing in the same or similar locality at the time of performance, and subject to the time limits and physical constraints applicable to the scope of work, and terms and conditions for this assignment. No other warranty, guarantee, or representation, expressed or implied, is made or intended in this report, or in any other communication (oral or written) related to this project. The same are specifically disclaimed, including the implied warranties of merchantability and fitness for a particular purpose.

3. Limited locations: The information contained in this report is restricted to the site and structures evaluated by Wood and to the topics specifically discussed in it, and is not applicable to any other aspects, areas or locations.

4. Information utilized: The information, conclusions and estimates contained in this report are based exclusively on: i) information available at the time of preparation, ii) the accuracy and completeness of data supplied by the Client or by third parties as instructed by the Client, and iii) the assumptions, conditions and qualifications/limitations set forth in this report.

5. Accuracy of information: No attempt has been made to verify the accuracy of any information provided by the Client or third parties, except as specifically stated in this report (hereinafter “Supplied Data”). Wood cannot be held responsible for any loss or damage, of either contractual or extra-contractual nature, resulting from conclusions that are based upon reliance on the Supplied Data.

6. Report interpretation: This report must be read and interpreted in its entirety, as some sections could be inaccurately interpreted when taken individually or out-of-context. The contents of this report are based upon the conditions known and information provided as of the date of preparation. The text of the final version of this report supersedes any other previous versions produced by Wood.

7. No legal representations: Wood makes no representations whatsoever concerning the legal significance of its findings, or as to other legal matters touched on in this report, including but not limited to, ownership of any property, or the application of any law to the facts set forth herein. With respect to regulatory compliance issues, regulatory statutes are subject to interpretation and change. Such interpretations and regulatory changes should be reviewed with legal counsel.

8. Decrease in property value: Wood shall not be responsible for any decrease, real or perceived, of the property or site’s value or failure to complete a transaction, as a consequence of the information contained in this report.
9. **No third-party reliance:** This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or Contract. Any use or reproduction which any third party makes of the report, in whole or in part, or any reliance thereon or decisions made based on any information or conclusions in the report is the sole responsibility of such third party. Wood does not represent or warrant the accuracy, completeness, merchantability, fitness for purpose or usefulness of this document, or any information contained in this document, for use or consideration by any third party. Wood accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on this report or anything set out therein. Including without limitation, any indirect, special, incidental, punitive or consequential loss, liability or damage of any kind.

10. **Assumptions:** Where design recommendations are given in this report, they apply only if the project contemplated by the Client is constructed substantially in accordance with the details stated in this report. It is the sole responsibility of the Client to provide to Wood changes made in the project, including but not limited to, details in the design, conditions, engineering or construction that could in any manner whatsoever impact the validity of the recommendations made in the report. Wood shall be entitled to additional compensation from Client to review and assess the effect of such changes to the project.

11. **Time dependence:** If the project contemplated by the Client is not undertaken within a period of 18 months following the submission of this report, or within the time frame understood by Wood to be contemplated by the Client at the commencement of Wood’s assignment, and/or, if any changes are made, for example, to the elevation, design or nature of any development on the site, its size and configuration, the location of any development on the site and its orientation, the use of the site, performance criteria and the location of any physical infrastructure, the conclusions and recommendations presented herein should not be considered valid unless the impact of the said changes is evaluated by Wood, and the conclusions of the report are amended or are validated in writing accordingly.

Advancements in the practice of geotechnical engineering, engineering geology and hydrogeology and changes in applicable regulations, standards, codes or criteria could impact the contents of the report, in which case, a supplementary report may be required. The requirements for such a review remain the sole responsibility of the Client or their agents.

Wood will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

12. **Limitations of visual inspections:** Where conclusions and recommendations are given based on a visual inspection conducted by Wood, they relate only to the natural or man-made structures, slopes, etc. inspected at the time the site visit was performed. These conclusions cannot and are not extended to include those portions of the site or structures, which were not reasonably available, in Wood’s opinion, for direct observation.

13. **Limitations of site investigations:** Site exploration identifies specific subsurface conditions only at those points from which samples have been taken and only at the time of the site investigation. Site investigation programs are a professional estimate of the scope of investigation required to provide a general profile of subsurface conditions.

The data derived from the site investigation program and subsequent laboratory testing are interpreted by trained personnel and extrapolated across the site to form an inferred geological representation and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite this investigation, conditions between and beyond the borehole/test hole locations may differ from those encountered at the borehole/test hole locations and the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration program, no matter how comprehensive, can reveal all subsurface details and anomalies.

Final sub-surface/bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports.

Bedrock, soil properties and groundwater conditions can be significantly altered by environmental remediation and/or construction activities such as the use of heavy equipment or machinery, excavation,
blasting, pile-driving or draining or other activities conducted either directly on site or on adjacent terrain. These properties can also be indirectly affected by exposure to unfavorable natural events or weather conditions, including freezing, drought, precipitation and snowmelt.

During construction, excavation is frequently undertaken which exposes the actual subsurface and groundwater conditions between and beyond the test locations, which may differ from those encountered at the test locations. It is recommended practice that Wood be retained during construction to confirm that the subsurface conditions throughout the site do not deviate materially from those encountered at the test locations, that construction work has no negative impact on the geotechnical aspects of the design, to adjust recommendations in accordance with conditions as additional site information is gained and to deal quickly with geotechnical considerations if they arise.

Interpretations and recommendations presented herein may not be valid if an adequate level of review or inspection by Wood is not provided during construction.

14. **Factors that may affect construction methods, costs and scheduling:** The performance of rock and soil materials during construction is greatly influenced by the means and methods of construction. Where comments are made relating to possible methods of construction, construction costs, construction techniques, sequencing, equipment or scheduling, they are intended only for the guidance of the project design professionals, and those responsible for construction monitoring. The number of test holes may not be sufficient to determine the local underground conditions between test locations that may affect construction costs, construction techniques, sequencing, equipment, scheduling, operational planning, etc.

Any contractors bidding on or undertaking the works should draw their own conclusions as to how the subsurface and groundwater conditions may affect their work, based on their own investigations and interpretations of the factual soil data, groundwater observations, and other factual information.

15. **Groundwater and Dewatering:** Wood will accept no responsibility for the effects of drainage and/or dewatering measures if Wood has not been specifically consulted and involved in the design and monitoring of the drainage and/or dewatering system.

16. **Environmental and Hazardous Materials Aspects:** Unless otherwise stated, the information contained in this report in no way reflects on the environmental aspects of this project, since this aspect is beyond the Scope of Work and the Contract. Unless expressly included in the Scope of Work, this report specifically excludes the identification or interpretation of environmental conditions such as contamination, hazardous materials, wild life conditions, rare plants or archeology conditions that may affect use or design at the site. This report specifically excludes the investigation, detection, prevention or assessment of conditions that can contribute to moisture, mold or other microbial contaminant growth and/or other moisture related deterioration, such as corrosion, decay, rot in buildings or their surroundings. Any statements in this report or on the boring logs regarding odours, colours, and unusual or suspicious items or conditions are strictly for informational purposes.
5.2 Closure

This report has been prepared for the exclusive use of Wood, MOTI and their agents, for the specific application to the design and construction of the subject road crossing. Recommendations presented herein are based on a geotechnical evaluation of the findings in two (2) boreholes advanced at the site. Soils by their nature can be highly variable across a construction site. The placement of fill and prior construction activities on a site can contribute to variable near-surface soil conditions. If conditions other than those reported are noted during subsequent phases of the work, Wood should be notified and given the opportunity to review the current recommendations in light of any new findings. Recommendations presented herein may not be valid if an adequate level of inspection is not provided during construction or if relevant building code requirements are not met.

Sincerely,

Wood Environment & Infrastructure Solutions

Hui Wang MEng, P.Eng.
Senior Geotechnical Engineer

Reviewed by:

Kevin Spencer, MEng, P. Eng.
Senior Associate Geotechnical Engineer
6.0 REFERENCES

Old Kamloops Rd. Crossing Over Stump Lake Creek

Project Site Location

DATE: July 2019
JOB No.: KX13772A11
FIGURE No.: N/A
REV.: 1

CLIENT:

Ministry of Transportation and Infrastructure
Variation of SPT N Values with Depth

SPT N Values in Sand and Gravel

Depth below Existing Ground Surface (m)

BH19-01

BH19-02
Appendix A

Borehole Logs and Explanation of Terms and Symbols
SUMMARY LOG

Project: Old Kamloops Road Washout #24753
Location: West Side of Creek

Datum: UTM, 10U
Northing/Easting: 5585047, 690441
Elevation: 758.0 m

Drill Hole #: BH19-01
Date(s) Drilled: June 3, 2019
Drilling Company: Mud Bay Drilling
Driller: KX 13772 A11
Drill Make/Model: Fraste Track Rig
Drilling Method: Track Rig

SOIL DESCRIPTION

0.0 m
GRAVEL, sandy, trace silt, loose to compact, brown, moist. [FILL]

1.2 m
SILT, some fine sand, loose, dark brown-black, moist. [TOPSOIL]

1.37 m
SAND, gravely, trace silt, compact, brown, moist.

1.4 m
... becoming wet at 2.4 m.

1.55 m
... wet at 3.0 m.

1.6 m
... medium to fine grained, trace gravel.
### SUMMARY LOG

**Project:** Old Kamloops Road Washout #24753  
**Location:** West Side of Creek  
**Datum:** UTM, 10U  
**Northing/Easting:** 5585047, 690441  
**Elevation:** 758.0 m  
**Date(s) Drilled:** June 3, 2019  
**Alignment:**  
**Proposed Station/Offset:** /  
**Driller:** Mud Bay Drilling  
**Drilling Company:** Mud Bay Drilling  
**Elevation (m):**  

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>SPT 'N (BLOWS/300 mm)</th>
<th>Type</th>
<th>Recovery (%)</th>
<th>Soil Symbol</th>
<th>Soil Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.4</td>
<td></td>
<td>S4</td>
<td>83</td>
<td>GRAVEL</td>
<td>Silty, sandy, dense to very dense, brown, moist to wet.</td>
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<tr>
<td>7.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>At 6.1 m, SPT stopped penetration due to rock in the spoon</td>
</tr>
<tr>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>At 7.9 m, split spoon refusal.</td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rock observed in bottom of split spoon.</td>
</tr>
<tr>
<td>10.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>At 9.3 m, split spoon refusal.</td>
</tr>
</tbody>
</table>

**SOIL SYMBOL**

- **S** - Silt
- **S** - Sand
- **G** - gravel
- **S** - Silt
- **F** - Fine-
- **G** - Gravel
- **S** - Silt
- **G** - Gravel
- **S** - Silt
- **F** - Fine

**CLASSIFICATION**

- **SOIL TYPE**
  - Sand: gravelly, trace silt, compact, brown, moist. (continued)
  - Gravel: Silty, sandy, dense to very dense, brown, moist to wet.

**COMMENTS TESTING**

- Rock observed in bottom of split spoon.
- Silt (Silt55)
  - 32% Silt, 58% Fine, 10% Gravel
- At 6.1 m, SPT stopped penetration due to rock in the spoon
- At 7.9 m, split spoon refusal.
- Rock observed in bottom of split spoon.
- At 9.3 m, split spoon refusal.

**L E G E N D**

- **S** - Silt
- **S** - Sand
- **G** - Gravel
- **S** - Silt
- **F** - Fine
- **G** - Gravel
- **S** - Silt
- **G** - Gravel
- **S** - Silt
- **F** - Fine

**SUMMARY LOG**

- **Drill Hole #: BH19-01**
- **Datum:** UTM, 10U  
- **Northing/Easting:** 5585047, 690441  
- **Elevation:** 758.0 m  
- **Final Depth of Hole:** 18.4 m  
- **Depth to Top of Rock:**

---

**Prepared by:** Wood Environment & Infrastructure Solutions  
**Logged by:** BJ  
**Reviewed by:** HW
### SUMMARY LOG

**Project:** Old Kamloops Road Washout #24753  
**Location:** West Side of Creek  
**Datum:** UTM, 10U  
**Northing/Easting:** 5585047, 690441  
**Elevation:** 758.0 m

**Alignment:**
- Datum: UTM, 10U
- Northing/Easting: 5585047, 690441
- Proposed Station/Offset: /
- Elevation: 758.0 m

**Drilling Method:**
- Drill Make/Model: Fraste Track Rig
- Driller: Mud Bay Drilling
- Drilling Company: Wood Environment & Infrastructure Solutions
- Prepared by: XX0379A11
- Logged by: BJ
- Reviewed by: HW

---

#### SUMMARY

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Symbol</th>
<th>Soil Description</th>
<th>Recovery (%)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>S7</td>
<td>Gravel, silty, sandy, dense to very dense, brown, moist to wet. (continued)</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>S8</td>
<td>Sand, silty, trace to some gravel, very dense, grey, moist to wet.</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>S9</td>
<td></td>
<td>67</td>
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<tr>
<td>16</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Laboratory Results**

- **G %:**
- **S %:**
- **F %:**

**Soil Classification**

- **GM:**
  - At 10.8 m split spoon refusal.
  - At 11.6 m observed large quantities of water and difficult drilling.
  - At 12.2 m split spoon refusal. No sample recovery.
  - At 12.9 m split spoon refusal.
  - At 14.6 m observed difficult drilling.

**Final Depth of Hole:** 18.4 m  
**Depth to Top of Rock:** 7.4 m

---

**Drill Hole #: BH19-01**

- **Date(s) Drilled:** June 3 2019
- **Alignment:**
  - Datum: UTM, 10U
  - Northing/Easting: 5585047, 690441
  - Proposed Station/Offset: /
  - Elevation: 758.0 m

---

**Drilling Method:**
- **Drill Make/Model:** Fraste Track Rig
- **Driller:** Mud Bay Drilling
- **Drilling Company:** Wood Environment & Infrastructure Solutions
- **Prepared by:** XX0379A11
- **Logged by:** BJ
- **Reviewed by:** HW
At 15.3 m split spoon refusal.

At 18.4 m split spoon refusal.

SAND, silty, trace to some gravel, very dense, grey, moist to wet. (continued)

End of hole at 18.4 m.
Backfilled with soil cuttings from bottom of hole to 3.0 m.
Backfilled with hydrated bentonite between 3.0 m to surface.

... some silt, wet.

Final Depth of Hole: 18.4 m
Depth to Top of Rock: 3.0 m

Cart: Fraste Track Rig

SUMMARY LOG

Project: Old Kamloops Road Washout #24753
Location: West Side of Creek

Datum: UTM, 10U
Northing/Easting: 5585047, 690441
Elevation: 758.0 m

Date(s) Drilled: June 3, 2019
Drilling Company: Mud Bay Drilling
Driller:
Drill Make/Model: Fraste Track Rig
Drilling Method:
**SUMMARY LOG**

**Project:** Old Kamloops Road Washout #24753  
**Location:** East Side of Creek

<table>
<thead>
<tr>
<th>DEPTH (m)</th>
<th>DRILLING DETAILS</th>
<th>SOIL DESCRIPTION</th>
<th>SOIL CLASSIFICATION</th>
<th>COMMENTS TESTING</th>
<th>BACKFILL INFORMATION</th>
<th>ELEVATION (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
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<td>SAND, some gravel, trace silt, compact, brown, wet. (continued)</td>
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<td></td>
<td></td>
<td>758.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>... trace fine and medium grained sand layers.</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>... fine to medium grained sand, loose to compact.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>SAND, gravelly, trace silt, dense to very dense, brown, wet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>At 9.3 m split spoon refusal.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Drill Hole #: BH19-02**

- **Date(s) Drilled:** June 3 2019
- **Drilling Company:** Mud Bay Drilling
- **Driller:**
- **Drill Make/Model:** Fraste Track Rig
- **Datum:** UTM, 10U
- **Elevation:** 758.0 m
- **Northing/Easting:** 5585029, 690449
- **Location:** East Side of Creek
- **Project:** Old Kamloops Road Washout #24753
- **Final Depth of Hole:** 18.4 m
- **Drilling Method:**

**SOIL SYMBOL**

- A-Auger
- C-Core
- G-Grab
- V-Vane
- O-Cutex
- W-Wash
- T-Shelby

**RECOVERY (%)**

- Sample No: S4, Sample Recovery: 100%
- Sample No: S5, Sample Recovery: 100%
- Sample No: S6, Sample Recovery: 80%

**SOIL DESCRIPTION**

- SAND, some gravel, trace silt, compact, brown, wet. (continued)

**CLASSIFICATION**

- Sieve (Silt/S): G11% S32% F7%

**Proposed Station/Offset:** /
SUMMARY LOG

Project: Old Kamloops Road Washout #24753
Location: East Side of Creek
Datum: UTM, 10U
 Northing/Easting: 5585029, 690449
Elevation: 758.0 m

Drill Hole #: BH19-02
Date(s) Drilled: June 3 2019
Drilling Company: Mud Bay Drilling
Drill Make/Model: Fraste Track Rig

Driller: Drill Make/Model: Fraste Track Rig
Elevation: 758.0 m

Drilling Details
- Depth: 10 m
- Soil Type: S7
- Recovery: 0%
- Soil Description: At 10.7 m split spoon refusal. No sample recovery.
- ... some gravel, dense.

Depth: 11 m
- Soil Type: S8
- Recovery: 88%
- Soil Description: At 12.5 m split spoon refusal.

Depth: 12 m
- Soil Type: S9
- Recovery: 0%
- Soil Description: At 14.3 m split spoon refusal. No sample recovery.

Final Depth of Hole: 18.4 m
Depth to Top of Rock: 7.84 m

Managed by: BJ
Reviewed by: HW

Wood Environment & Infrastructure Solutions
Prepared by: KX072A11
Logged by: BJ

ELEVATION (m) 746 747 745 744

SPT ‘N’ (BL O W S /3 0 0 m m)

W % W % W %

Drill Hole #: BH19-02

Sample Type: A-Auger, C-Core, G-Grab, V-Vane, T-Shelby
Sample Symbol: S-1.0, O-0.2, W-Wash, M-Mud, T-Tube

Classification: Laboratory Results (G % S % F %)

Comments:
- At 10.7 m split spoon refusal. No sample recovery.
- At 12.5 m split spoon refusal.
- At 14.3 m split spoon refusal. No sample recovery.

Backfill Information:
- Final Depth of Hole: 18.4 m
- Depth to Top of Rock: 7.84 m

Datum: UTM, 10U
Proposed Station/Offset: /
### SUMMARY LOG

**Project:** Old Kamloops Road Washout #24753  
**Location:** East Side of Creek

**Date(s) Drilled:** June 3, 2019  
**Drilling Company:** Mud Bay Drilling

**Datum:** UTM, 10U  
**Drill Make/Model:** Fraste Track Rig

**Noting/Easting:** 5585029, 690449  
**Drilling Method:**

<table>
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<tr>
<th>DEPTH (m)</th>
<th>DRILLING DETAILS</th>
<th>W%</th>
<th>W%</th>
<th>W%</th>
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<tr>
<td>15</td>
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<td>20</td>
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<td>60</td>
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<tr>
<td>19</td>
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<td>20</td>
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**SOIL SYMBOL**

<table>
<thead>
<tr>
<th>SOIL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>... grey.</td>
</tr>
<tr>
<td>... very dense.</td>
</tr>
<tr>
<td>... coarse to medium grained.</td>
</tr>
<tr>
<td>... medium to fine grained sand bed between 16.9 m and 17.1 m depth</td>
</tr>
<tr>
<td><strong>SAND</strong>, fine grained, some silt, trace gravel, very dense, grey wet.</td>
</tr>
</tbody>
</table>

**Class:**  
**Comments:**  
**Backfill Information:**

- At 15.5 m split spoon refusal.
- At 17.4 m split spoon bouncing on a rock.
- At 18.3 m split spoon refusal.

**Final Depth of Hole:** 18.4 m  
**Depth to Top of Rock:**

---

**Legend:**

- **A-Auger**
- **C-Core**
- **G-Grab**
- **W-Vane**
- **T-Shelby Tube**

**Legen:**

- **S-Split**
- **S-Spoon**
- **C-Core (air rotary)**
- **I-Wash (mud return)**

**Installation:**

- **Drill**
- **Cuttings**
- **Slotted**
- **Roughed**
- **Hexometer**

**Prepared by:** Wood Environment & Infrastructure Solutions  
**Logged by:** BJ  
**Reviewed by:** HW

---

**Diagram:**

- **Datum:** UTM, 10U  
- **Elevation:** 758.0 m  
- **Proposed Station/Offset:** /  
- **Backfilled with hydrated bentonite between 3.0 m to surface.**

---

**Final Depth of Hole:** 18.4 m  
**Depth to Top of Rock:**

---

**Page 4 of 4**
EXPLANATION OF TERMS AND SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of field investigation and subsequent laboratory testing are described in these pages.

It should be noted that materials, boundaries and conditions have been established only at the borehole locations at the time of investigation and are not necessarily representative of subsurface conditions elsewhere across the site.

TEST DATA

Data obtained during the field investigation and from laboratory testing are shown at the appropriate depth interval.

Abbreviations, graphic symbols, and relevant test method designations are as follows:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*C</td>
<td>Consolidation test</td>
<td></td>
</tr>
<tr>
<td>DR</td>
<td>Relative density</td>
<td></td>
</tr>
<tr>
<td>*k</td>
<td>Permeability coefficient</td>
<td></td>
</tr>
<tr>
<td>*MA</td>
<td>Mechanical grain size analysis and hydrometer test</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Standard Penetration Test (CSA A119.1-60)</td>
<td></td>
</tr>
<tr>
<td>Ns</td>
<td>Dynamic cone penetration test</td>
<td></td>
</tr>
<tr>
<td>NP</td>
<td>Non plastic soil</td>
<td></td>
</tr>
<tr>
<td>pp</td>
<td>Pocket penetrometer strength (kg/cm²)</td>
<td></td>
</tr>
<tr>
<td>*q</td>
<td>Triaxial compression test</td>
<td></td>
</tr>
<tr>
<td>qU</td>
<td>Unconfined compressive strength</td>
<td></td>
</tr>
<tr>
<td>*SB</td>
<td>Shearbox test</td>
<td></td>
</tr>
<tr>
<td>SO₄</td>
<td>Concentration of water-soluble sulphate</td>
<td></td>
</tr>
</tbody>
</table>

| *ST    | Swelling test |  |
| TV     | Torvane shear strength |  |
| VS     | Vane shear strength |  |
| w      | Natural Moisture Content (ASTM D2216) |  |
| w₁     | Liquid limit (ASTM D 423) |  |
| wₚ     | Plastic Limit (ASTM D 424) |  |
| E₁     | Unit strain at failure |  |
| γ      | Unit weight of soil or rock |  |
| γₚ     | Density of soil or rock |  |
| ρₚ     | Dry Density of soil or rock |  |
| C₀     | Undrained shear strength |  |
| Cᵤ     | Undrained shear strength |  |
| Seepage|  |
| ▼      | Observed water level |  |

* The results of these tests are usually reported separately

Soils are classified and described according to their engineering properties and behaviour.

The Soil of each stratum is described using the Unified Soil Classification System\(^1\) modified slightly so that an inorganic clay of “medium plasticity” is recognized.

The modifying adjectives used to define the actual or estimated percentage range by weight of minor components are consistent with the Canadian Foundation Engineering Manual\(^2\).

Relative Density and Consistency:

<table>
<thead>
<tr>
<th>Cohesionless Soils</th>
<th>Consistency</th>
<th>Cohesive Soils</th>
<th>Approximate SPT (N) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Density</td>
<td>SPT (N) Value</td>
<td>Undrained Shear Strength cₜ (kPa)</td>
<td>SPT (N) Value</td>
</tr>
<tr>
<td>Very Loose</td>
<td>0-4</td>
<td>Very Soft</td>
<td>0-12</td>
</tr>
<tr>
<td>Loose</td>
<td>4-10</td>
<td>Soft</td>
<td>12-25</td>
</tr>
<tr>
<td>Compact</td>
<td>10-30</td>
<td>Firm</td>
<td>25-50</td>
</tr>
<tr>
<td>Dense</td>
<td>30-50</td>
<td>Stiff</td>
<td>50-100</td>
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<tr>
<td>Very Dense</td>
<td>&gt;50</td>
<td>Very Stiff</td>
<td>100-200</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hard</td>
<td>&gt;200</td>
</tr>
</tbody>
</table>

Standard Penetration Resistance (“N” value)

The number of blows by a 63.6kg hammer dropped 760 mm to drive a 50 mm diameter open sampler attached to “A” drill rods for a distance of 300 mm.

---

\(^1\) “Unified Soil Classification System”, Technical Memorandum 36-357 prepared by Waterways Experiment Station, Vicksburg, Mississippi, Corps of Engineers, U.S. Army. Vol. 1 March 1953.

Appendix B

Laboratory Test Results
GRAIN SIZE DISTRIBUTION

Ministry of Transportation & Infrastructure
441 Columbia Street
Kamloops, BC
V2C 2T9

Project No: KX13772A11
Date: June 10, 2019

Project Name: Stump Creek Crossing, Old Kamloops Road, Stump Lake, BC

Test No.: 19-079-1
Source: BH19-01 @ 10-12'
Sample Type: SPT
Date Rec’d: June 4, 2019
By: BJ
Date Tested: June 5, 2019

Wash Sieve Analysis

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percent Retained</th>
<th>Percent Passing</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>150.0</td>
<td>0.0</td>
<td>100.0</td>
<td>Upper</td>
</tr>
<tr>
<td>125.0</td>
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<td>Lower</td>
</tr>
<tr>
<td>100.0</td>
<td>0.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>75.0</td>
<td>0.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>50.0</td>
<td>0.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>37.5</td>
<td>0.0</td>
<td>100.0</td>
<td></td>
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<tr>
<td>25.0</td>
<td>10.5</td>
<td>89.5</td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>2.2</td>
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</tr>
<tr>
<td>12.5</td>
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<td></td>
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<tr>
<td>9.5</td>
<td>4.1</td>
<td>80.7</td>
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</tr>
<tr>
<td>4.75</td>
<td>5.7</td>
<td>75.0</td>
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</tr>
<tr>
<td>2.000</td>
<td>11.2</td>
<td>63.8</td>
<td></td>
</tr>
<tr>
<td>0.850</td>
<td>15.4</td>
<td>48.3</td>
<td></td>
</tr>
<tr>
<td>0.425</td>
<td>13.7</td>
<td>34.6</td>
<td></td>
</tr>
<tr>
<td>0.250</td>
<td>10.5</td>
<td>24.0</td>
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<td>0.150</td>
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<td>16.3</td>
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<tr>
<td>0.075</td>
<td>7.0</td>
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</tr>
<tr>
<td>PAN</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sieve Mass (g): 441.2

Gravel 25.0 %
Sand 65.7 %
Fines 9.3 %

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Jackman

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.
GRAIN SIZE DISTRIBUTION

Ministry of Transportation & Infrastructure
441 Columbia Street
Kamloops, BC
V2C 2T9

Project No: KX13772A11
Date: June 10, 2019

Project Name: Stump Creek Crossing, Old Kamloops Road, Stump Lake, BC

Test No.: 19-079-2
Source: BH19-01 @ 20-22'
Sample Type: SPT
Date Rec'd: June 4, 2019
By: BJ
Date Tested: June 5, 2019

Wash Sieve Analysis

| Sieve Size (mm) | Percent Retained | Percent Passing | Limits
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
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<td>Upper</td>
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<td>0.0</td>
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<td>Upper</td>
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<td>100.0</td>
<td>Upper</td>
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<tr>
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<td>0.0</td>
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<td>Upper</td>
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<tr>
<td>50.0</td>
<td>0.0</td>
<td>100.0</td>
<td>Upper</td>
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<td>37.5</td>
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<td>100.0</td>
<td>Upper</td>
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<tr>
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<td>Upper</td>
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<td>Upper</td>
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<td>Upper</td>
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<td>92.4</td>
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<td>Upper</td>
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<tr>
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<td>89.6</td>
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<td>88.5</td>
<td>Upper</td>
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</tbody>
</table>

Sieve Mass (g): 462.7

| Gravel | 32.5 % |
| Sand   | 57.6 % |
| Fines  | 10.0 % |

COMMENTS

Wood Environment & infrastructure Solutions

Per: B. Jackman

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Engineering interpretation or evaluation of the test results is provided only on written request.
GRAIN SIZE DISTRIBUTION

Ministry of Transportation & Infrastructure
441 Columbia Street
Kamloops, BC
V2C 2T9

Project No: KX13772A11
Date: June 10, 2019

Project Name: Stump Creek Crossing, Old Kamloops Road, Stump Lake, BC

Test No.: 19-079-3
Source: BH19-02 @ 10-12'
Sample Type: SPT
Date Rec'd: June 4, 2019
By: BJ
Date Tested: June 5, 2019

Wash Sieve Analysis

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<th>Sieve Size (mm)</th>
<th>Percent Retained</th>
<th>Percent Passing</th>
<th>Limits</th>
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</tr>
</tbody>
</table>

Sieve Mass (g): 368.6

| Gravel | 51.9 % |
| Sand   | 41.3 % |
| Fines  | 6.7 %  |

COMMENTS

Wood Environment & Infrastructure Solutions

Per: B. Jackman

Reporting of these test results constitutes a testing service only. Engineering interpretation or evaluation of the test results is provided only on written request.
GRAIN SIZE DISTRIBUTION

Ministry of Transportation & Infrastructure
441 Columbia Street
Kamloops, BC
V2C 2T9

Project No: KX13772A11
Date: June 10, 2019

Project Name: Stump Creek Crossing, Old Kamloops Road, Stump Lake, BC

Test No.: 19-079-4  
Source: BH19-02 @ 20-22'  
Sample Type: SPT

Date Rec'd: June 4, 2019  
By: BJ  
Date Tested: June 5, 2019

Wash Sieve Analysis

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percent Retained</th>
<th>Percent Passing</th>
<th>Limits</th>
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<tr>
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<td>6.9</td>
<td>93.1</td>
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</tr>
</tbody>
</table>

Sieve Mass (g): 516.3

| Gravel | 11.4 % |
| Sand   | 81.7 % |
| Fines  | 6.9 %  |

COMMENTS

Wood Environment & Infrastructure Solutions
Per: B. Jackman

Reporting of these test results constitutes a testing service only.
Engineering interpretation or evaluation of the test results is provided only on written request.
# MOISTURE CONTENT WORKSHEET

## Project: KX13772A11

**Lab. Order No:** 19-079  
**Technician:** BJ/BS  
**Date:** June 5, 2019

<table>
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<th>Hole No.</th>
<th>BH19-01</th>
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<tbody>
<tr>
<td>Depth(ft)</td>
<td>5-7</td>
<td>10-12</td>
<td>15-17</td>
<td>20-22</td>
<td>25-26</td>
<td>30-30'6&quot;</td>
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<tr>
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<td>12.0%</td>
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<td>29.2%</td>
<td>16.0%</td>
<td>24.1%</td>
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CERTIFICATE OF ANALYSIS

REPORTED TO
Wood E&I Solutions (Kamloops)
913 Laval Crescent
Kamloops, BC V2C 5P4

ATTENTION
Bradley Jackman

PO NUMBER
KX13772A.11

WORK ORDER
9060700

RECEIVED / TEMP
2019-06-07 09:18 / 21°C

REPORTED
2019-06-14 17:09

Introduction:
CARO Analytical Services is a testing laboratory full of smart, engaged scientists driven to make the world a safer and healthier place. Through our clients’ projects we become an essential element for a better world. We employ methods conducted in accordance with recognized professional standards using accepted testing methodologies and quality control efforts. CARO is accredited by the Canadian Association for Laboratories Accreditation (CALA) to ISO 17025:2005 for specific tests listed in the scope of accreditation approved by CALA.

Big Picture Sidekicks
You know that the sample you collected after snowshoeing to site, digging 5 meters, and racing to get it on a plane so you can submit it to the lab for time sensitive results needed to make important and expensive decisions (whew) is VERY important. We know that too.

We've Got Chemistry
It's simple. We figure the more you enjoy working with our fun and engaged team members; the more likely you are to give us continued opportunities to support you.

Ahead of the Curve
Through research, regulation knowledge, and instrumentation, we are your analytical centre for the technical knowledge you need, BEFORE you need it, so you can stay up to date and in the know.

If you have any questions or concerns, please contact me at teamcaro@caro.ca

Authorized By:
Team CARO
Client Service Representative
## TEST RESULTS

**REPORTED TO**  Wood E&I Solutions (Kamloops)  
**PROJECT**  KX13772A.11  
**WORK ORDER**  9060700  
**REPORTED**  2019-06-14 17:09

<table>
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<tr>
<th>Analyte</th>
<th>Result</th>
<th>RL</th>
<th>Units</th>
<th>Analyzed</th>
<th>Qualifier</th>
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<tbody>
<tr>
<td>BH19-01 @ 10-12ft (3.0-3.6m) (9060700-01)</td>
<td>Sulfate, Water-Soluble</td>
<td>&lt; 0.050</td>
<td>0.050</td>
<td>%</td>
<td>2019-06-14</td>
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<tr>
<td>BH19-02 @ 10-12ft (3.0-3.6m) (9060700-02)</td>
<td>Sulfate, Water-Soluble</td>
<td>&lt; 0.050</td>
<td>0.050</td>
<td>%</td>
<td>2019-06-14</td>
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</table>
## APPENDIX 1: SUPPORTING INFORMATION

**REPORTED TO**  
Wood E&I Solutions (Kamloops)

**PROJECT**  
KX13772A.11

**WORK ORDER**  
9060700

**REPORTED**  
2019-06-14 17:09

### Analysis Description | Method Ref. | Technique | Location
--- | --- | --- | ---
Sulfate, Water-Soluble in Soil | CSA A23.2-3B / CSA A23.2-2B | Extraction (HCl) / Gravimetry (Barium Sulfate Precipitation) | Richmond

### Glossary of Terms:

<table>
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<th>Abbreviation</th>
<th>Definition</th>
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<td>RL</td>
<td>Reporting Limit (default)</td>
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<tr>
<td>%</td>
<td>Percent</td>
</tr>
<tr>
<td>&lt;</td>
<td>Less than the specified Reporting Limit (RL) - the actual RL may be higher than the default RL due to various factors</td>
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<tr>
<td>CSA</td>
<td>Canadian Standards Association Chemical Test Methods</td>
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### General Comments:

The results in this report apply to the samples analyzed in accordance with the Chain of Custody document. This analytical report must be reproduced in its entirety. CARO is not responsible for any loss or damage resulting directly or indirectly from error or omission in the conduct of testing. Liability is limited to the cost of analysis. Samples will be disposed of 30 days after the test report has been issued unless otherwise agreed to in writing.

Results in **Bold** indicate values that are above CARO’s method reporting limits. Any results that are above regulatory limits are highlighted **red**. Please note that results will only be highlighted red if the regulatory limits are included on the CARO report. Any Bold and/or highlighted results do **not** take into account method uncertainty. If you would like method uncertainty or regulatory limits to be included on your report, please contact your Account Manager: **teamcaro@caro.ca**
The following section displays the quality control (QC) data that is associated with your sample data. Groups of samples are prepared in “batches” and analyzed in conjunction with QC samples that ensure your data is of the highest quality. Common QC types include:

- **Method Blank (Blk):** A blank sample that undergoes sample processing identical to that carried out for the test samples. Method blank results are used to assess contamination from the laboratory environment and reagents.

- **Duplicate (Dup):** An additional or second portion of a randomly selected sample in the analytical run carried through the entire analytical process. Duplicates provide a measure of the analytical method's precision (reproducibility).

- **Blank Spike (BS):** A sample of known concentration which undergoes processing identical to that carried out for test samples, also referred to as a laboratory control sample (LCS). Blank spikes provide a measure of the analytical method's accuracy.

- **Matrix Spike (MS):** A second aliquot of sample is fortified with a known concentration of target analytes and carried through the entire analytical process. Matrix spikes evaluate potential matrix effects that may affect the analyte recovery.

- **Reference Material (SRM):** A homogenous material of similar matrix to the samples, certified for the parameter(s) listed. Reference Materials ensure that the analytical process is adequate to achieve acceptable recoveries of the parameter(s) tested.

Each QC type is analyzed at a 5-10% frequency, i.e. one blank/duplicate/spike for every 10-20 samples. For all types of QC, the specified recovery (% Rec) and relative percent difference (RPD) limits are derived from long-term method performance averages and/or prescribed by the reference method.

<table>
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<tr>
<th>Analyte</th>
<th>Result</th>
<th>RL Units</th>
<th>Spike Level</th>
<th>Source Result</th>
<th>% REC</th>
<th>REC Limit</th>
<th>% RPD</th>
<th>RPD Limit</th>
<th>Qualifier</th>
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<tr>
<td>Sulfate, Water-Soluble</td>
<td>&lt; 0.050</td>
<td>0.050 %</td>
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<td>Matrix Spike (B9F0852-MS1)</td>
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<td>Sulfate, Water-Soluble</td>
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