R.F. BINNIE & ASSOCIATES LTD.

GEOTECHNICAL REPORT

ROCKWELL DRIVE FLOOD RECOVERY CULVERT REPLACEMENT SITES: DF1, DF2, DF3

FEBRUARY 2023

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R.F. BINNIE & ASSOCIATES LTD.

PROJECT NO.: VG07795.300
DATE: FEBRUARY 2023

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"Effective September 21, 2022, Wood Environment & Infrastructure Solutions Canada Limited is now operating as WSP E&I Canada Limited. No other aspects of our legal entity, contractual terms or capabilities have changed in relation to this report submission."

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APPENDICES

1 INTRODUCTION

WSP E&I Canada Limited (formerly Wood Environment and Infrastructure Solutions Canada Limited) was retained by R.F. Binnie & Associates Ltd. (Binnie) to carry out geotechnical services to support flood recovery design activities at sites identified as DF1, DF2 and DF3 on Rockwell Drive, northeast of the community of Harrison Hot Springs. The sites consist of existing culvert crossings that were damaged during flooding and debris movement from a rainstorm on or around 15 November 2021. Initial work consisted of terrain assessments at each of the sites, the results of which are presented under separate covers[1]. This report presents the results of a geotechnical subsurface investigation and provides recommendations for geotechnical aspects of proposed culvert replacements.

Rockwell Drive is within the jurisdiction of the Ministry of Transportation and Infrastructure (MoTI) and is located within the District of Kent. Sites DF1, DF2 and DF3 are located 3.7, 4.2 and 5.5 km northeast of Harrison Hot Springs, respectively. Site locations are shown on Figure 1, in Appendix A.

At the three sites, Rockwell Drive is located near the base of a steep hillside at the base of Bear Mountain and crosses numerous drainages and associated alluvial fans on the shore of Harrison Lake. In general, the road crosses the fans near their apexes with residential development located between the road and the lake. In some areas, there is development on the slopes above the road.

Recovery options will need to consider geohazards and consider the potential impact the recovery option may have on the existing hazards affecting the downstream residential development. WSP understands that the design of hazard mitigation measures on downstream residential properties is outside of the work scope. Based on the terrain assessment work, the recovery designs discussed in this report will likely not satisfy present geohazard standards with respect to property development and there will likely be a residual level of geohazard risk that is above present standards. Geohazard recommendations included in this report are summarized from the earlier noted terrain assessment results that are presented under sperate covers.

The work described in this report was carried out in general accordance with WSP's proposal dated 21 January 2022. Binnie authorized WSP to proceed with the work through contract 21-1067 dated February 2022.

[1] Wood Environment & Infrastructure Solutions Limited, *Rockwell Drive Flood Recovery, Site DF1, near Harrison Lake, Geotechnical Terrain Assessment*. 6 September 2022. Submitted to R.F. Binnie & Associates Ltd.
Wood Environment & Infrastructure Solutions Limited, *Rockwell Drive Flood Recovery, Site DF2, near Harrison Lake, Geotechnical Terrain Assessment*. 6 September 2022. Submitted to R.F. Binnie & Associates Ltd.
Wood Environment & Infrastructure Solutions Limited, *Rockwell Drive Flood Recovery, Site DF3, near Harrison Lake, Geotechnical Terrain Assessment*. 6 September 2022. Submitted to R.F. Binnie & Associates Ltd.

2 BACKGROUND INFORMATION

To obtain background information, WSP reviewed bedrock and surficial geology maps available through iMapBC[2] and historic aerial photographs.

Bear Mountain is generally between 900 and 1,000 m in elevation and borders the southeast end of Harrison Lake. Bedrock geology mapping identify the mountain as being generally underlain by Gambier Group volcanic and sedimentary rocks from the lower to middle Cretaceous. The Gambier Group was formed by a volcanic arc on a fringe of Wrangalia in Cretaceous time. The rock was transported onto the coast by plate tectonics and has been metamorphosed (moderate grades) and is frequently moderately to intensely fractured and jointed. In isolated areas, much younger granodioritic intrusive rocks are identified from the Miocene to Oligocene. Bear Mountain has an average slope profile of approximately 2 Horizontal to 1 Vertical (2H:1V); however steep bedrock bluffs can make the slope irregular. A surface portal to the historic RN gold mine is located approximately 4.5 km northeast of Harrison Hot Springs, between sites DF2 and DF3.

Surficial geology, from iMapBC[2], does not identify any surficial sediment polygons in the site areas, likely due to the scale of the mapping. The sites are located on sedimentary fans located between the base of Bear Mountain and shore of Harrison Lake. The fans likely continue underwater, below the surface of the lake. The fans also likely cover an irregular bedrock profile. The irregular slope profile of Bear Mountain and steep bedrock bluffs suggest that the buried bedrock surface could be steeply dipping.

Based on historic aerial photographs, Bear Mountain was largely logged between approximately 1953 and 1963[3]. It appears that logging was mechanised using spar poles and with the cut logs trucked off the mountain. A series of trails and roads were constructed to access the trees. The trails and roads gradually climb up the side of the mountain in a series of switchbacks. This results in a relatively high density of roads crisscrossing the side of the mountain with roads and trails crossing many of the natural water courses several times. Aerial photographs taken shortly after logging show frequent erosion and shallow instability, particularly near trails, roads, and stream crossings. A precursor road to Rockwell Drive appears to have been constructed at the time of logging.

[2] Maps.gov.bc.ca, accessed 3 June 2022
[3] Based on BC aerial photograph flight line BC1623 (dated 1953) and flight line BC5059 (dated 1963)

3 SURFACE CONDITIONS

3.1 SITE DF1

Site DF1 is located on a fan at the base of Bear Mountain and near the shore of Harrison Lake. Immediately upstream of the culvert crossing, the stream cascades down a bedrock bluff approximately 20 m high. The toe of the bluff is approximately 10 m east from the edge of Rockwell Drive. Upstream of the crossing, the stream flows through 6535 Rockwell Drive, and downstream of the crossing the stream flows near the boundary between 6535 and 6545 Rockwell Drive[4].

The stream is not well constrained where it flows over the bedrock bluff above Rockwell Drive and the stream could change channels in the future, or secondary channels could become active during times of high flow. A potential avulsion event could result in stream flow intersecting the road anywhere between approximately 30 m north and 10 m south of the current crossing location.

3.2 SITE DF2

Site DF2 is located at the base of Bear Mountain and near the shore of Harrison Lake. Immediately upstream of the culvert crossing two streams converge, a larger northern stream and a smaller southern stream. Near the site, the northern stream flows through properties at 7000, 6960 and 6950 Rockwell Drive, and the southern stream flows through 6880 Rockwell Drive; both streams then converge at 6900 Rockwell Drive, located immediately upstream of the culvert crossing[4]. Downstream of the culvert crossing, the creek flows near the southern boundary of an undeveloped parcel (PID: 002-402-068). A bedrock bluff is located approximately 3 m east from the edge of Rockwell Drive and approximately 3 m south of the stream confluence.

A large debris flow occurred along the northern channel. The debris flow initiation zone is greater than 500 m upstream of the crossing. The debris flow has resulted in loose sediment and woody debris in the stream channel. Future rain events will mobilize this sediment and woody debris and transport it downstream towards the crossing at Rockwell Drive. Higher than usual amounts of sediment and debris will be transported until the channel is revegetated and stabilized. Future debris flow events are also possible.

3.3 SITE DF3

Site DF3 is located on a fan at the base of Bear Mountain and near the shore of Harrison Lake. The fan is approximately 120 m wide at Rockwell Drive with the apex approximately 20 m upslope of the road. At the apex of the fan, the stream emerges from a steep-sided bedrock-controlled gully. The part of the fan above Rockwell Drive is generally within a property identified by PID 001-062-549, and the part of the fan below Rockwell Drive is generally within 7340 and 7370 Rockwell Drive, and 7381, 7391, 7388 and 7402 Rockwell Place[4]. The stream currently flows down the southwest side of the fan, through PID 001-062-549 and 7340 Rockwell Drive. A bedrock exposure is located approximately 20 m south of the crossing location.

[4] Street addresses obtained from District of Kent Online Mapping System accessed on 3 June 2022

The fan above Rockwell Drive is subject to stream avulsions that result in stream flow intersecting Rockwell Drive at locations other than the present and proposed culvert crossing. Avulsion stream flows could cross Rockwell Drive, or flow along Rockwell Drive to low areas. Although indications of recent debris flow activity were not observed, it is possible that the stream is also susceptible to future debris flow events, particularly if landslide debris dams the upper steep-sided reaches of the stream.

4 SITE INVESTIGATION

On October 26, a total of seven boreholes were completed by Blue Max Drilling using a track-mounted drill rig using Sonic drill methods. Traffic control was provided by 604 Traffic Control and underground utility location was provided by Quadra Utility Locating Limited. WSP obtained BC One Call tickets prior to the investigation.

The boreholes were completed within the existing roadway to characterize the existing pavement structure and subgrade soils. Drill holes depths ranged between approximately 3.7 and 5.2 m. Two drill holes were advanced at each site. At DF3 a third borehole was added to the investigation scope at the request of MoTI, the borehole is denoted BH22-07 and is located approximately 80 m north of the proposed culvert location. This borehole will not be discussed further in this report.

A WSP representative observed the drilling, sampling, and hole closure process, and completed visual identification of grab and Standard Penetration Test (SPT, ASTM D1596) samples, as well as noting drill reaction and SPT blowcounts. Drill hole logs are provided in Appendix B. The thickness of the existing asphalt, base and subbase layers were estimated from visual inspection of the boreholes and drill core. The depths noted on the borehole logs are referenced to the road surface.

Upon completion, the boreholes were backfilled with compacted drill cuttings and bentonite seals, asphalt cold patch was used at the road surface. All boreholes were backfilled in general accordance with the requirements of the *Water Protection Act*.

The locations of the completed boreholes were determined using a handheld GPS device with an accuracy of approximately +/- 3 m. Borehole locations are shown on Figures 2A to 2C, in Appendix A.

5 LABORATORY TESTING

Soil samples collected during the field program were transported to the WSP office in Surrey for review, and select samples were submitted to the WSP laboratory for testing. Completed laboratory index tests include:

- Moisture content (ASTM D2216); and
- Particle size distribution (ASTM C117/C136).

Visual soil classifications were compared to field logs and results of the laboratory tests for calibration and consistency, according to BCMoTI's Modified Unified Soil Classification System. The results of the laboratory tests are noted on the borehole logs contained in Appendix B and the detailed lab test sheets are provided in Appendix C.

Water-soluble sulfate testing based on CSA A23.2-3B/-2B was carried out by CARO Analytical Services from soil samples collected at sites DF1 and DF2. The results of the testing are included in Table 1, below, and detailed results are included in Appendix C.

Table 1: Water Soluble Sulfate Testing Results

BOREHOLE AND DEPTH (M)	SULFATE, WATER-SOLUBLE (%)
BH22-02 at 4.4 m	< 0.050[1]
BH22-03 at 3.9 m	< 0.050[1]

Note: [1]Reporting limit is 0.050%

6 SUBSURFACE CONDITIONS

Due to the inherent heterogeneity of fan deposits, ground disturbance from the precursor road to Rockwell Drive and a likely higher frequency of stream deposition post-logging, it is difficult to determine if the soil below the existing pavement structure is a constructed fill, or a pre/post-logging deposit. Where there was uncertainty in the origin of the soil below the pavement structure, it was classified as a 'Fill'.

As noted above, fan deposits can be heterogeneous which can result in variable soil composition over relatively short distances and along the length of the proposed culverts.

6.1 SITE DF1

Two boreholes, BH22-01 and -02, were drilled to a depth of 5.2 m on the southwest and northeast sides of the culvert crossing, respectfully. Locations are shown in Figure 2A. The subsurface conditions encountered by the boreholes are summarized below.

Asphalt: Thickness between 0.12 and 0.14 m.

Base: Gravel and sand with trace fines[5], thickness between 0.3 and 0.4 m.

Subbase: Gravel and sand with trace fines, thickness between 0.3 and 0.7 m.

Subgrade Fill: Sand and gravel with trace fines, moist, loose to compact, with occasional cobbles, thickness between 0.9 and 1.4 m.

Natural Gravelly Sand: Gravelly sand with trace fines, occasional cobbles and boulders, moist, loose to compact, thickness between 0.9 and 1.5 m. In BH22-02, an organic rich layer approximately 0.2 m thick was observed on the top of this deposit, this organic layer is interpreted as a natural ground surface.

Gravelly Silt: Gravelly silt, moist, loose to compact. A boulder was found between the natural gravelly sand and gravelly silt in BH22-02. The thickness of the boulder as encountered by the drill was approximately 0.7 m.

Groundwater: Groundwater was not observed during drilling. Seasonal perched groundwater tables may be present on layers of lower permeable soils (e.g. gravelly silt).

Bedrock: The boreholes did not encounter bedrock. Note that bedrock bluffs are located approximately 10 m from Rockwell Drive.

Note that the boreholes may not accurately reflect the frequency of boulders or cobbles at the site.

6.2 SITE DF2

Two boreholes, BH22-03 and -04, were drilled to depths of 3.9 to 4.3 m on the southeast and northwest sides of the culvert crossing, respectfully. Locations are shown in Figure 2B. The subsurface conditions encountered by the boreholes are summarized below.

[5] Fines are defined as particle sizes less than 0.075 mm (passing a #200 size screen) and include particles described as silt and clay

Asphalt: Thickness between 0.15 and 0.24 m.

Base: Gravel and sand with trace fines, thickness between 0.3 and 0.4 m.

Subbase: Gravel and sand with trace fines, thickness between 0.4 and 0.5 m.

Subgrade Fill: Gravelly sand or sand and gravel, with trace fines, moist, loose to dense, with occasional cobbles, thickness between 1.2 and 1.3 m.

Natural Gravelly Sand: Gravelly sand with trace fines, occasional cobbles, moist, loose to compact, encountered thickness between 1 and 1.7 m.

Groundwater: Groundwater was not observed during drilling.

Bedrock: The boreholes did not encounter bedrock. Note that bedrock bluffs are located approximately 3 m southeast of the culvert location.

Note that the boreholes may not accurately reflect the frequency of boulders or cobbles at the site.

6.3 SITE DF3

Two boreholes, BH22-05 and -06, were drilled to a depth of 3.7 m on the southwest and northeast sides of the culvert crossing, respectfully. Locations are shown in Figure 2C. The subsurface conditions encountered by the boreholes are summarized below.

Asphalt: Thickness between 0.11 and 0.18 m.

Base: Gravel and sand with trace fines, thickness 0.3 m.

Subbase: Gravel and sand, some fines, thickness between 0.3 and 0.6 m.

Subgrade Fill: Gravelly sand, trace silt, moist, loose to compact, with occasional cobbles, 1.3 m thick in BH22-05, subgrade fill was encountered to the bottom of BH22-06.

Natural Gravelly Sand: In BH22-05, natural gravelly sand with trace fines, moist, very loose to loose, 1.5 m encountered thickness.

Groundwater: Groundwater was not observed during drilling.

Bedrock: The boreholes did not encounter bedrock. Note that a bedrock exposure is located approximately 20 m south of the culvert location.

Note that the boreholes may not accurately reflect the frequency of boulders or cobbles at the site.

7 GEOTECHNICAL RECOMMENDATIONS

The following recommendations are based on the necessary assumption that subsurface conditions encountered by the boreholes are generally representative of conditions at each of the sites. Subsurface conditions that may not be reflected by the boreholes include locally variable areas of site disturbance or existing fill. The sites are located on fans which can be heterogeneous resulting in variable soil composition over relatively short distances and along the length of the proposed culverts.

Although the boreholes did not encounter bedrock, bedrock exposures are located near each of the sites. If bedrock is encountered during construction, then splitting or blasting may be required. Construction contract documents should note that excavations could encounter bedrock. If bedrock is encountered during construction, then Acid Rock Drainage and Metal Leaching assessment should be considered, see Section 7.2.

Although the boreholes did not encounter groundwater, the culvert replacement work will require stream diversion, and temporary excavation may encounter groundwater associated with the streams. In addition to stream diversion, temporary excavation de-watering will likely be required.

Unforeseen conditions could exist due to previous site use. Unforeseen conditions could include buried logging equipment such as cables, woody debris such as stumps, and old culverts that have since been buried and abandoned as part of previous road repairs/improvements or upgrades. If old culverts are encountered, they should be assessed by the geotechnical engineer and may need to be removed. Old culverts may be constructed using treated wood, an environmental assessment may be required if treated wood is encountered during construction. If unanticipated conditions are encountered during construction, WSP should be consulted and retained to provide revised or additional recommendations.

Construction plans and/or installation methodologies should carefully consider the potential for encountering boulders within planned earthworks for the culvert replacements.

The following recommendations assume that construction will generally follow the latest iteration of MoTI Standard Specifications for Highway Construction (currently v2020).

7.1 GEOHAZARDS

The recommendations noted below are summarized from terrain assessment reports presented under separate covers. Note the terrain assessment reports are under the *Wood Environment & Infrastructure Solutions Limited Canada* cover.

7.1.1 SITE DF1

The recommendations noted below are summarized from terrain assessment report *Rockwell Drive Flood Recovery, Site DF1, near Harrison Lake, Geotechnical Terrain Assessment*, dated 6 September 2022, submitted to Binnie.

- A sediment basin is recommended between the toe of the bedrock bluff and the culvert inlet.
- Consideration should be given to incorporating a vertical debris rack at the culvert inlet.
- Stream avulsion cannot likely be addressed at its source, efforts to recapture the stream could include enlarged ditches and concrete Jersey barriers separating the ditch and the road.
- The new culvert crossing will result in higher downstream flow. The owner of the downstream property should be advised of the potential downstream effects of the new culvert.

7.1.2 SITE DF2

The recommendations are summarized from terrain assessment report *Rockwell Drive Flood Recovery, Site DF2, near Harrison Lake, Geotechnical Terrain Assessment*, dated 6 September 2022, submitted to Binnie.

- Nearby properties are subject to appreciable debris flow hazards. Additional hazard assessments should be carried out specific to those properties. The jurisdiction having authority for those properties should be involved with this work.
- Until the north channel stabilizes there will likely be higher than usual amount of sediment and woody debris transported down the channel. It is recommended the new culvert design at DF2 consider this higher than usual sediment and debris transport.
- Concrete Jersey barriers can be used to separate the northern channel from the road and help reduce future flow events from spilling onto the road.

7.1.3 SITE DF3

The recommendations are summarized from terrain assessment report *Rockwell Drive Flood Recovery, Site DF3, near Harrison Lake, Geotechnical Terrain Assessment*, dated 6 September 2022, submitted to Binnie.

- Between the apex of the fan and Rockwell Drive, a sediment basin and armored channel should be incorporated into the fan.
- If it is not feasible to incorporate a basin and channel into the fan, then enlarge the ditch along Rockwell Drive to capture any future avulsion. Concrete Jersey barriers could be used to deflect stream flow into the enlarged ditch.
- Recently placed riprap has visible sulphide mineralization. The presence of sulphides does not directly indicate that ARD/ML potential is present due to the possible neutralizing potential of the rock; however, the presence of sulphides does indicate that caution should be used.

7.2 ARD/ML

Bedrock is not anticipated to be encountered during the planned earthworks for the culvert recoveries.

Acid Rock Drainage (ARD) and Metal Leaching (ML) testing has not been carried out on bedrock near the site locations. It is therefore recommended that, unless proven otherwise, all bedrock encountered during construction be considered potentially acid generating (PAG).

Recently placed riprap at site DF3 had visible sulphide mineralization. WSP recommends that any future riprap for the project be evaluated for ARD/ML potential, particularly if the riprap comes from the same quarry used to source the existing riprap at site DF3.

MoTI Technical Circular T-04/13 notes that an ARD/ML evaluation is required where rock volumes exceed 1,000 m^3.

7.3 CUT AND FILL SLOPES

Preliminary design drawings by Binnie show nominal cut and fill slopes. Granular soils are generally anticipated in areas of cut and fill. For design, WSP recommends using a cut slope no steeper than 2 Horizontal to 1 Vertical (2H:1V) and a fill slope no steeper than 2H:1V.

Cut slopes that encounter seepage must be reviewed by a geotechnical engineer.

7.4 TEMPORARY EXCAVATIONS

Temporary excavations where worker entry is required must be in accordance with Part 20 of the WorkSafe BC OHS Regulations. Project contract documents should establish that the Contractor is responsible for the assessment of temporary excavation slopes and/or issuance of safe work procedures for worker entry and should engage their own geotechnical engineering services in this regard as necessary. WSP cannot be responsible for specific means, methods, techniques, sequences, operations of construction, or any site safety programs related to temporary excavations of the Contractor.

7.5 BOX CULVERTS

Concrete box culverts are proposed at sites DF1 and DF2. At site DF1 the proposed box culvert is approximately 9.5 m long, 2.7 m wide and 2.4 m high. At site DF2 the proposed box culvert is approximately 28.5 m long, 2.1 m wide and 1.8 m high.

To provide a uniform bearing surface below the box culvert and headwalls, the subgrade surface should be sub-excavated to at least 0.5 m depth. The sub-excavated surface should be lined with a non-woven geotextile with a geogrid placed on top of the geotextile, and then covered with a 0.5 m thick layer of 25 mm Well Graded Base (WGB), or other suitable bedding material accepted by the Ministry Representative, and compacted to 100% Standard Proctor Maximum Dry Density (SPMDD, ASTM D698). Specifications for the geotextile and geogrid are included in Section 7.8.

It is anticipated the geotextile, geogrid, and 0.5 m thick layer of compacted WGB, over the underlaying soil, will have adequate bearing capacity for the box culverts. As the highway grade near the box culverts will not significantly change, it is anticipated that there will be no appreciable increase in vertical stress and the corresponding settlement is anticipated to be negligible.

As per Table 7.3 in the 2019 Canadian Highway Bridge Design Manual[6], the minimum height of cover over the box culvert shall be 0.3 m.

7.6 CORRUGATED STEEL PIPE CULVERT

A corrugated steel pipe (CSP) culvert is proposed at site DF3. The proposed CSP culvert is approximately 14 m long and 2 m in diameter. The culvert will include pre-cast concrete headwalls at either end.

To provide a uniform bearing surface below the culvert and headwalls, the subgrade surface should be sub-excavated to at least 0.5 m depth, lined with a non-woven geotextile with a geogrid place on top of the geotextile and then covered with a 0.5 m thick layer of 25 mm WGB, or other suitable bedding material accepted by the Ministry Representative, compacted to 100% SPMDD (ASTM D698). Specifications for the geotextile and geogrid are included in Section 7.8.

As the highway grade near the CSP culvert will not significantly change, it is anticipated that there will be no appreciable increase in vertical stress and corresponding settlement is anticipated to be negligible.

As per Table 7.3 in the 2019 Canadian Highway Bridge Design Manual[6], the minimum height of cover over the corrugated steel pipe culvert shall be 0.6 m.

It is anticipated that the culvert headwalls and apron slabs approximately 2 by 4 m in plan. Note the downstream headwall will be located above a 1.5H:1V slope. Assuming the headwall will be founded on a 0.5 m thick layer of compacted 25 mm WGB, over natural granular soil, it is recommended that the headwalls be designed using a factored ultimate bearing capacity of 40 kPa. The factored ultimate bearing capacity includes a geotechnical resistance factor of 0.55.

7.7 SUBGRADE PREPARATION

Due to the heterogeneous nature of fans, subgrade conditions may vary from what is described below and may vary over relatively short distances. If conditions other than what is described below are encountered during construction, WSP should be consulted and retained to provide revised or additional recommendations.

7.7.1 ROAD SUBGRADE

Remove all deleterious soils (e.g. soft, wet, weakened, and organic soils or loose fill) from the subgrade surface. A geotechnical engineer or their representative should review subgrade surfaces to confirm that deleterious soil has been removed. Areas of unsuitable subgrade soils that are determined to be too deep to be practically removed will require additional subgrade improvements as directed by the geotechnical engineer at time of construction.

Anticipated road subgrade soils are summarized in Table 2.

[6] Canadian Standards Association, 2019. S6:19, Canadian Highway Bridge Design Code.

Table 2: Anticipated Road Subgrade Soils

Location	Anticipated Subgrade
DF1 (BH22-01 and -02)	GP, Gravel and Sand with trace Fines
DF2 (BH22-03 and -04)	SP/SM1, Sand and Gravel/Gravelly with trace to some Fines
DF3 (BH22-05 and -06)	SP/SM1, Sand and Gravel/Gravelly with trace to some Fines

7.7.2 CULVERT SUBGRADE

Remove all deleterious soils (e.g. soft, wet, weakened, and organic soils or loose fill) from below the proposed sub-excavated surface below the culverts and headwalls. Areas of unsuitable subgrade soils that are determined to be too deep to be practically removed will require additional subgrade improvements as directed by the geotechnical engineer at time of construction.

The sub-excavated surface below the culverts and headwalls should be lined with a non-woven geotextile and then a geogrid placed on the geotextile prior to placement of the compacted 25 mm WGB. Specifications for the geotextile and geogrid are included in Section 7.8.

Anticipated culvert subgrade soils are summarized in Table 3.

Table 3: Anticipated Culvert Subgrade Soils

Location	Anticipated Subgrade
DF1 (BH22-01 and -02)	SP, possibly ML, Gravelly Sand with trace Fines, possibly Gravelly Silt
DF2 (BH22-03 and -04)	SP/SC1, Gravelly Sand with trace Fines/Gravelly Sand with some Clay
DF3 (BH22-05 and -06)	SP/SM1, Sand and Gravel/Gravelly with trace to some fines

7.8 SPECIFICATIONS FOR GEOTEXTILE AND GEOGRID

Non-woven geotextile is required to line the sub-excavations below the culverts and headwalls, the geotextile should meet the specifications noted in Table 4.

Table 4: Non-Woven Geotextile Specifications

Property	Test Method	Value
Grab Tensile Strength[1]	ASTM D 4632	≥ 700 N
Sewn Seam Strength[1]	ASTM D 4632	≥ 630 N
Tear Strength[1]	ASTM D 4533	≥ 250 N
Puncture Strength[1]	ASTM D 6241	≥ 1,375 N
Permittivity	ASTM D 4491	≥ 0.1 sec^{-1}
Apparent Opening Size[2]	ASTM D 4751	< 0.22 mm

Notes: [1]Based on minimum average roll values (as per ASTM C 4759) in the weaker principal direction

[2]Based on maximum average roll values

Geogrid should meet the specification for biaxial polypropylene geogrid as provided in Table 5.

Table 5: Biaxial Polypropylene Geogrid Specifications

Property	Test Method	Value
Tensile Strength at 5% Strain, Machine Direction[1]	ASTM D 6637	≥ 11.8 kN/m
Tensile Strength at 5% Strain, Cross Machine Direction[1]	ASTM D 6637	≥ 18.8 kN/m
Maximum Aperture Size	-	50 mm
Minimum Aperture Size	-	15 mm
Flexural Stiffness[1]	ASTM D 7748	≥ 700 g-cm
Roll Width Tolerance	-	+/- 0.1 m

Note: [1]Based on minimum average roll values (as per ASTM C4759)

7.9 PAVEMENT STRUCTURE

WSP has assessed the pavement structure requirements following MoTI Technical Circular T-01/15 “Pavement Structure Design Guidelines”, WSP’s experience, and the condition of the existing road surface and pavement structure observed in the boreholes. Traffic data was not available for Rockwell Drive at the time of preparing this report; however, it is anticipated the road will experience mostly residential and seasonal vacation traffic with occasional logging trucks or other heavier resource loads. Note that loaded logging trucks were observed travelling southbound on Rockwell Drive during the site investigation. WSP recommends the following pavement structure for the culvert crossings. Note the pavement structure assumes a compacted granular subgrade.

Pavement Structure (from surface):

- 100 mm thickness of asphalt;
- 300 mm thickness of 25 mm Well-Graded Base Course (WGB); and
- 300 mm thickness of Select Granular Subbase (SGSB); and
- Compacted granular subgrade.

Shallow culverts can result in transverse cracking of the asphalt surface above the sides of the culvert. To reduce the potential for this type of transverse cracking, WSP recommends the subgrade fill (e.g. embedment and backfill material around culverts) below the pavement structure be compacted to 100% Standard Proctor Dry Density (SPDD) (ASTM D698).

Transition the new pavement structure from subgrade above the new culvert fill at a slope of 6H:1V in the direction of the travelled lanes, such that where culvert replacement occurs, the existing pavement structure should be transitioned to the new structure at an 6H:1V slope from the base of the recommended pavement structure thickness noted above.

8 CLOSURE

This letter is subject to the attached limitations.

This letter has been prepared for the exclusive use of R.F. Binnie & Associates Ltd. and B.C. Ministry of Transportation and Infrastructure for the specific application described herein. Any use which a third party makes of this letter, or any reliance on or decision made based on it, are the responsibility of such third parties. WSP E&I Canada Limited accepts no responsibility for damages suffered by any third party as a result of decisions made or actions based on this letter.

Subsurface conditions may vary over time and with distance from the borehole. If the site conditions vary from those described and assumed in this letter, WSP should be contacted to review such conditions and revise the recommendations included in this letter accordingly. This letter was prepared in accordance with generally accepted geotechnical engineering principles and practice. No other warranty, express or implied, is made.

Please do not hesitate to contact the undersides should there be any questions about the information provided in this letter.

Sincerely,

WSP E&I Canada Limited
EGBC Permit to Practice No. 1004452

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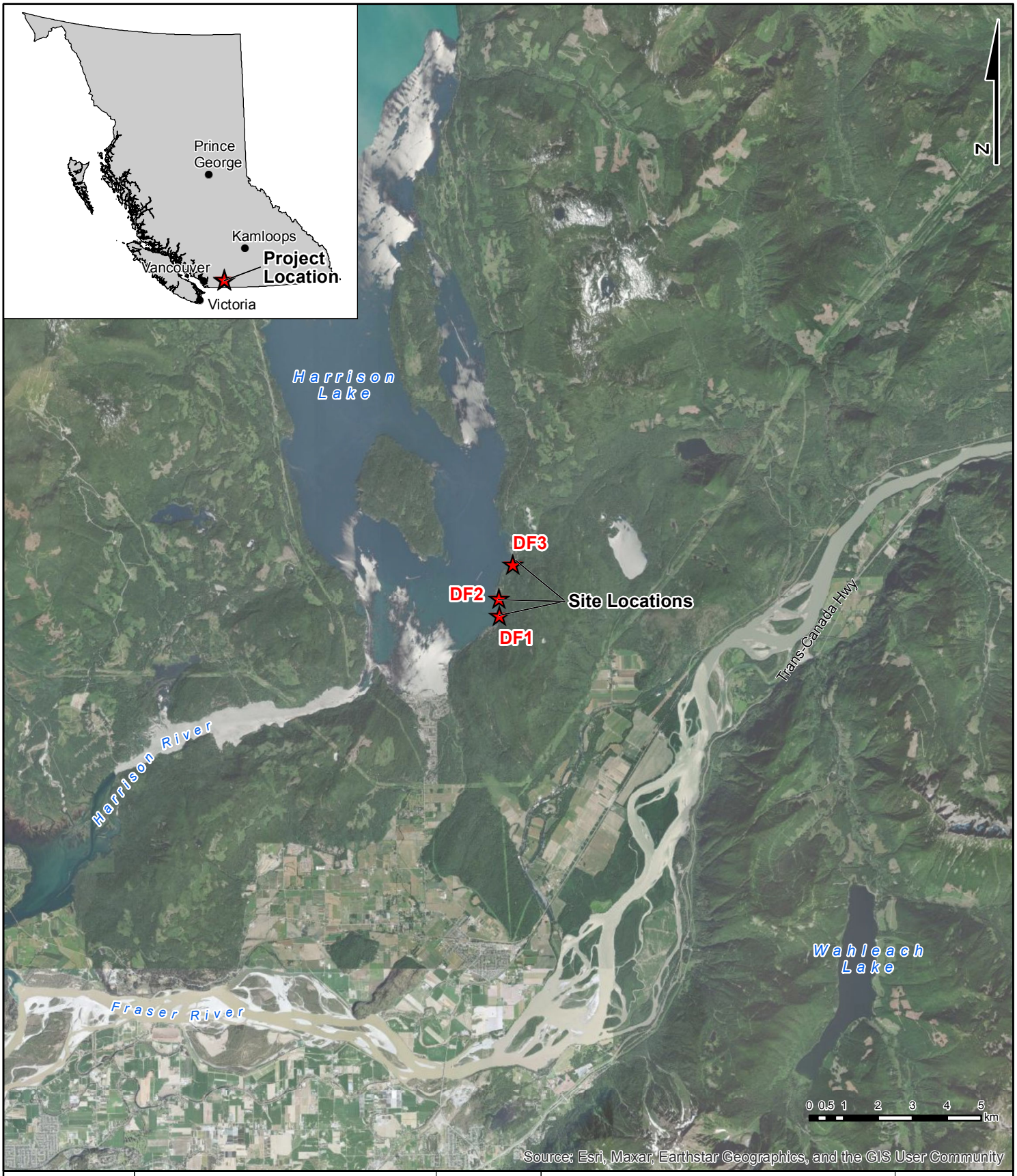
Appendix A

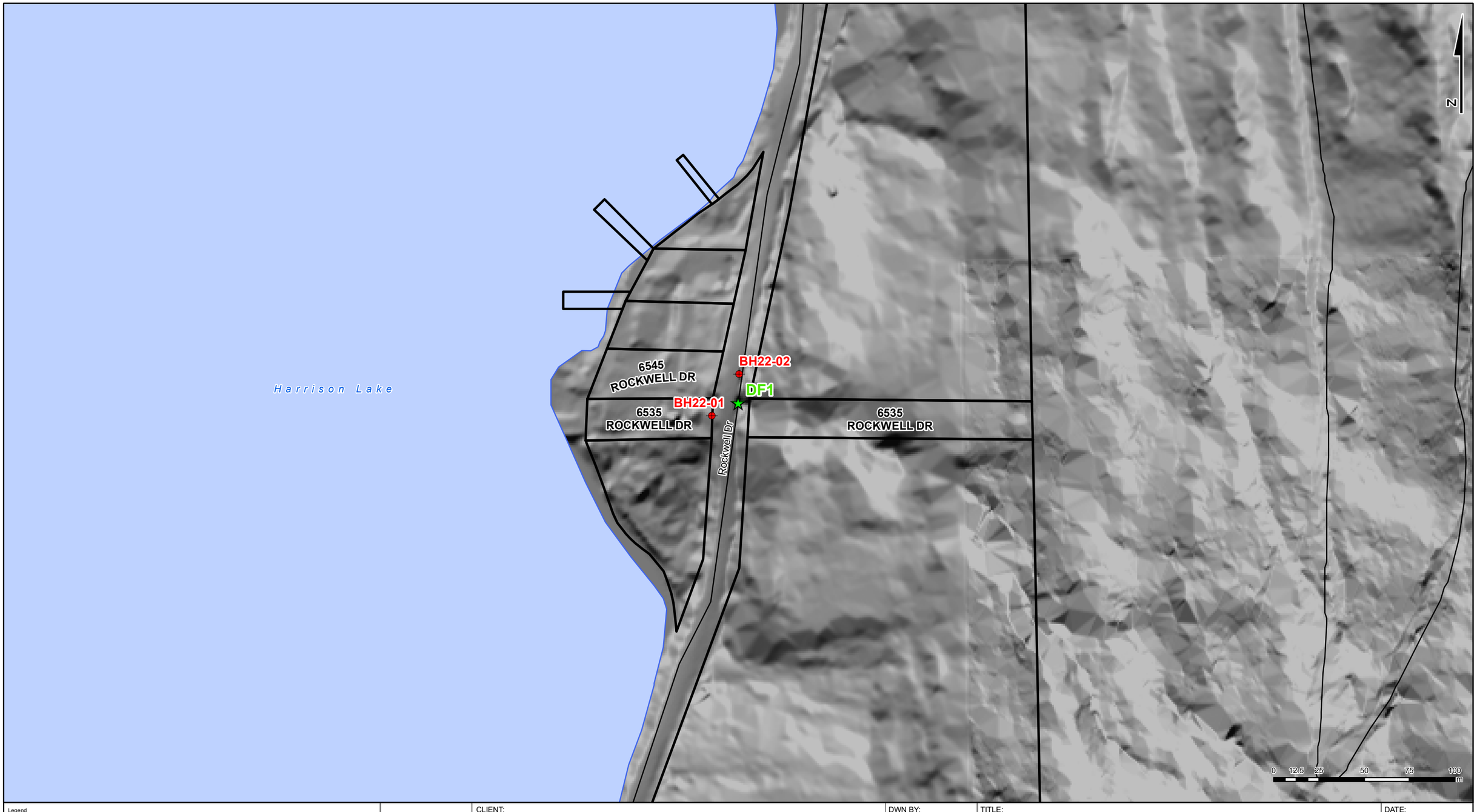
Figures



WSP	CLIENT: BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE c/o R.F. BINNIE & ASSOCIATES LTD.	DWN BY: BB CHK'D BY: EM	TITLE: SITE LOCATION PLAN SITE INVESTIGATION	DATE: FEBRUARY 2023 PROJECT NO.: VG07795.300 REV NO.: A
	WSP E&I Canada Limited 111 Dunsmuir Street Suite 400 Vancouver, BC, CANADA V6B 5W3 Main: +1 604 664 4315	DATUM: NAD 83 PROJECTION: UTM Zone 10 MAIN VIEW SCALE: 1:150,000	PROJECT: ROCKWELL DRIVE FLOOD RECOVERY HARRISON LAKE, BC	FIGURE 1

S:\External\VG07795.300-Binnie&MoTI-SCR-AAW-Rockwell-GIS\VG07795.300-SiteInvestigation-Fig1-SiteLocationPlan.mxd

This drawing was originally produced in colour.



Legend

- Borehole Location
- Site Location
- Road
- Parcel
- Lake

Notes:
1. LIDAR hillshade processed from LIDAR downloaded from LidarBC, Province of British Columbia, 10 May 2022.
2. Parcels downloaded from District of Kent ('districtofkent.maps.arcgis.com') 21 June 2022.

CLIENT:
BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE c/o R.F. BINNIE & ASSOCIATES LTD.

WSP E&I Canada Limited
111 Dunsmuir Street Suite 400
Vancouver, BC, CANADA V6B 5W3
Main: +1 604 664 4315

DWN BY: BB
CHK'D BY: EM
DATUM: NAD 83
PROJECTION: UTM Zone 10
SCALE: 1:2,000

TITLE:
SITE PLAN
DF1

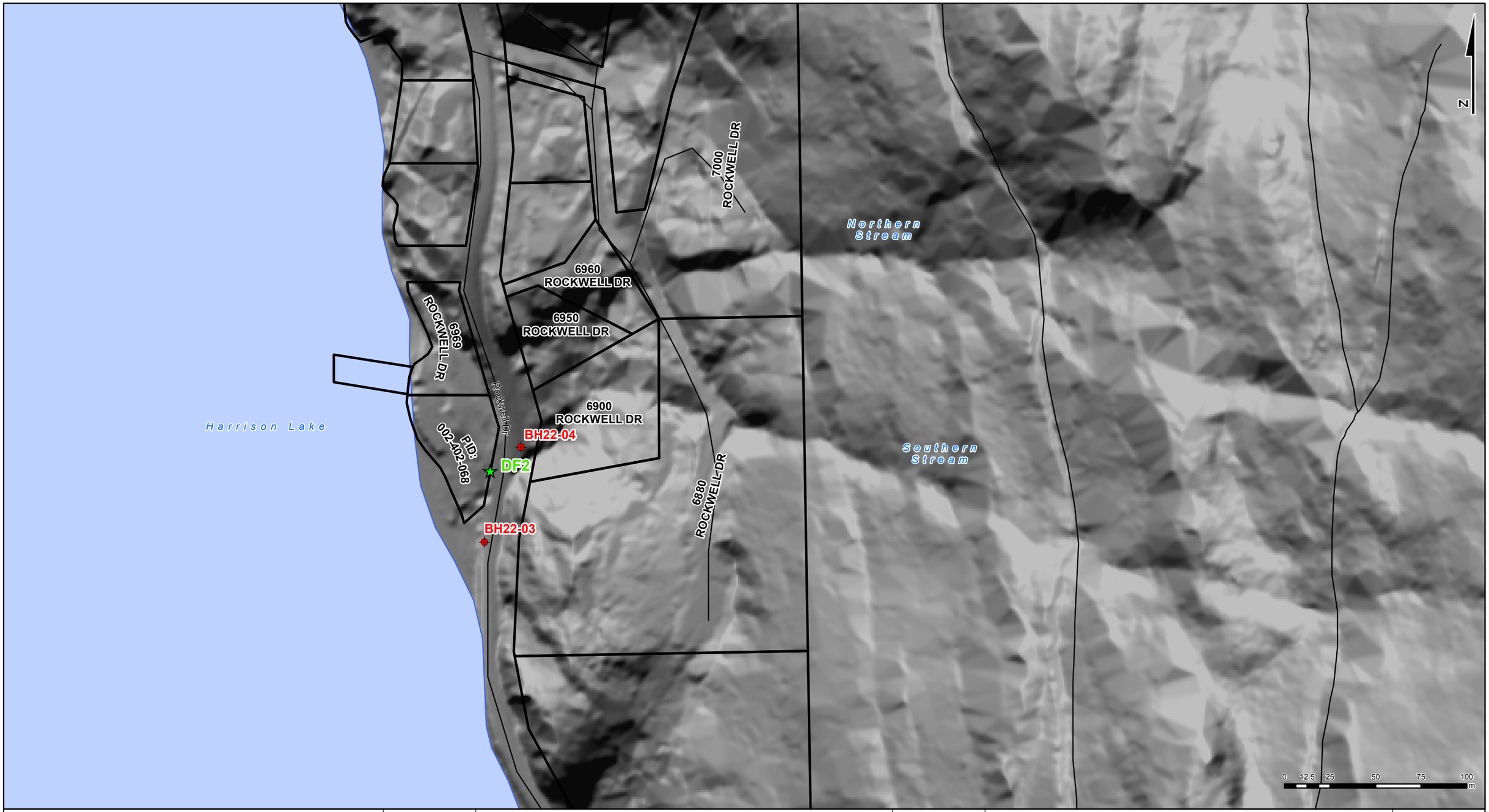
PROJECT:
ROCKWELL DRIVE FLOOD RECOVERY
HARRISON LAKE, BC

DATE: FEBRUARY 2023
PROJECT NO.: VG07795.300
REV NO.: A

FIGURE 2A

S:\External\VG07795.300-Binnie&MoTI-SCR-AAW-Rockwell-GIS\VG07795.300-SiteInvestigation-Fig2A-SitePlan-DF1.mxd

This drawing was originally produced in colour.



Legend

- Borehole Location
- SiteLocation
- Road
- Parcel
- Lake

Notes:
1. LIDAR hillshade processed from LIDAR downloaded from LidarBC, Province of British Columbia, 10 May 2022.
2. Parcels downloaded from District of Kent ('districtofkent.maps.arcgis.com') 21 June 2022.

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111 Dunsmuir Street Suite 400
Vancouver, BC, CANADA V6B 5W3
Main: +1 604 664 4315

DWN BY:	BB
CHK'D BY:	EM
DATUM:	NAD 83
PROJECTION:	UTM Zone 10
SCALE:	1:2,000

TITLE: SITE PLAN DF2

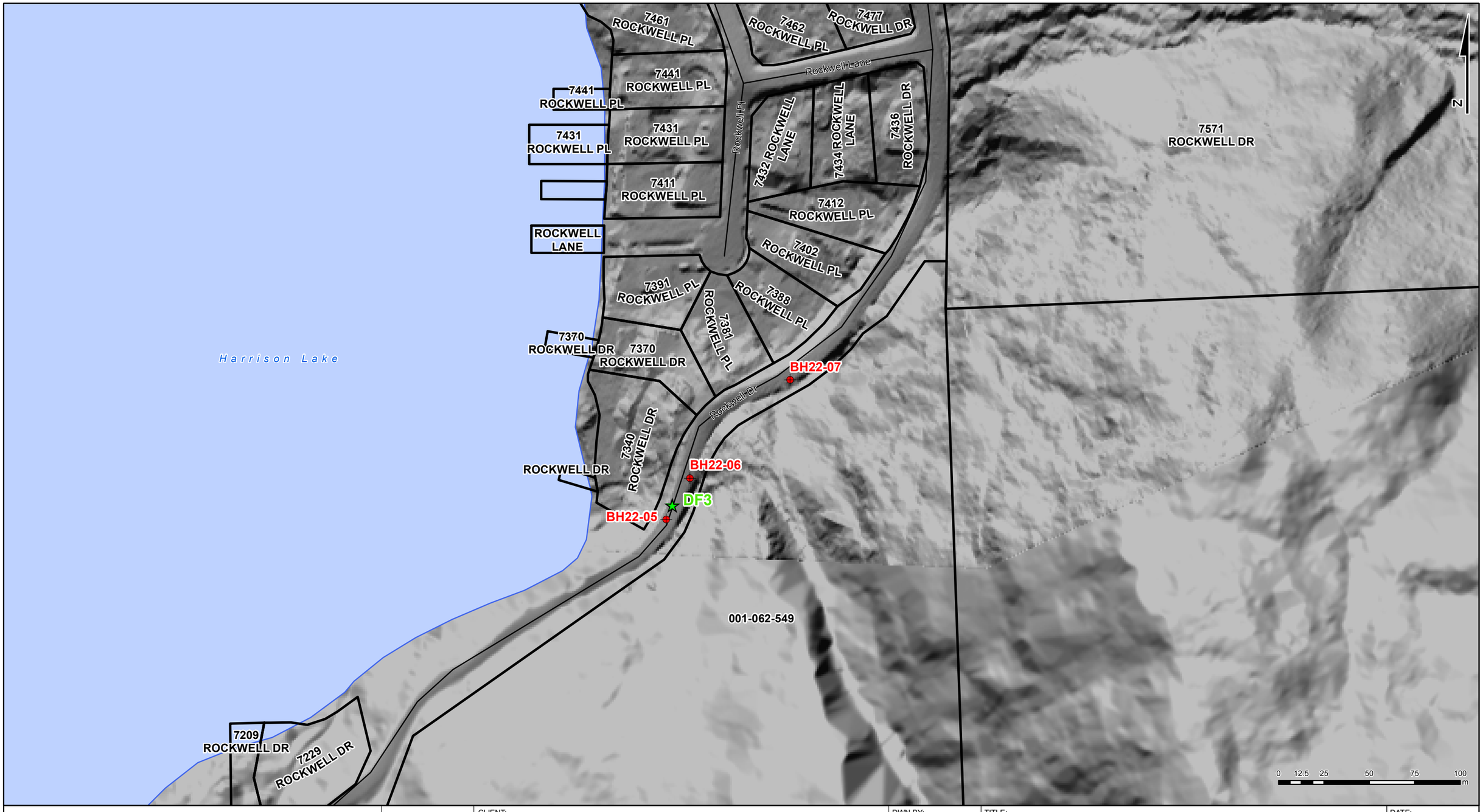
PROJECT: ROCKWELL DRIVE FLOOD RECOVERY HARRISON LAKE, BC

DATE:	FEBRUARY 2023
PROJECT NO.:	VG07795.300
REV NO.:	A

FIGURE 2B

S:\External\VG07795.300-Binnie&MoTI-SCR-AAW-Rockwell-GIS\VG07795.300-SiteInvestigation-Fig2B-SitePlan-DF2.mxd

This drawing was originally produced in colour.



Legend

- Borehole Location
- SiteLocation
- Road
- Parcel
- Lake

Notes:
1. LIDAR hillshade processed from LIDAR downloaded from LidarBC, Province of British Columbia, 10 May 2022.
2. Parcels downloaded from District of Kent ('districtofkent.maps.arcgis.com') 21 June 2022.

CLIENT: BC MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE c/o R.F. BINNIE & ASSOCIATES LTD.

WSP E&I Canada Limited
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Vancouver, BC, CANADA V6B 5W3
Main: +1 604 664 4315

DWN BY:	BB
CHK'D BY:	EM
DATUM:	NAD 83
PROJECTION:	UTM Zone 10
SCALE:	1:2,000

TITLE: SITE PLAN
DF3

PROJECT: ROCKWELL DRIVE FLOOD RECOVERY
HARRISON LAKE, BC

DATE:	FEBRUARY 2023
PROJECT NO.:	VG07795.300
REV NO.:	A

FIGURE 2C

S:\External\VG07795.300-Binnie&MoTI-SCR-AAW-Rockwell-GIS\VG07795.300-SiteInvestigation-Fig2C-SitePlan-DF3.mxd

This drawing was originally produced in colour.

Appendix B

Borehole Logs

SUMMARY LOG

Drill Hole #: **BH22-01**

Ministry of Transportation and Infrastructure

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Location: Harrison Hot Spring, BC

Prepared by: WSP

Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-100

Northing/Easting: 5464252 , 590692 Station/Offset: 4 m right

Elevation: NA *Coordinates taken with GPS*

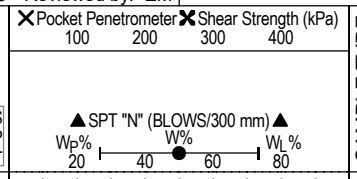
Date(s) Drilled: 10/26/2022

Company: Blue Max Drilling

Driller: NA

Drill Make/Model: Boat Longyear

Drilling Method: Sonic



DEPTH (m)	DRILLING DETAILS (SPT)	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING (Drillers Estimate {G % S % F %})	DEPTH (m)
0	2					**ASPHALT**- 115 mm thick — 0.12m	AC		0
			1			**SAND and GRAVEL**- , poorly graded, subangular, trace silt, brown, compact (405 mm road base materials) — 0.52m	GP		
1	8		2			**SAND and GRAVEL**- poorly graded, subangular, trace to some silt, brown, compact (740 mm road sub-base materials) — 1.26m	GP-GM	**Sieve** (Sa#2) G:47% S:41% F:12%	1
	2,5,3,6 / 8,7		1	42		**SAND an GRAVEL**- occasional cobble, subangular, loose, brown/grey, moist (Fill) — 2.13m	GP		
2						**SAND**- Gravelly, subangular, trace clay, some wood/organic, brown, moist, loose — 2.33m	SP		2
						Gravelly, subangular, isolated cobble, trace clay, brown/grey, moist, loose to compact	SP		
3	4,9,13,16 / 22 / 6		2	92		**SAND**- Gravelly, subangular, trace silt, brown/grey, moist, compact — 3.05m - Soil grades brown below 3.8 m depth - Soil grades grey below 4.3 m depth	SP	Wash (Sa#3) Fines: 6%	3
4	6		3						4
	6,10,16,12 / 26 / 6		3	42					
5						5.18m **End of borehole at 5.18 m**. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface. Notes: Borehole was advanced using SONIC to termination depth. **SPT Details**: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods. **Sample Recovery "REC"** is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.			5
6									6
7									7
8									8
9									9
10									

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: 5.8 m

Depth to Top of Rock:

MOTI-SOIL-REV3 MOTI_ROCKWELL.GPJ MOTI_DATATEMPLATE_REV3.GDT 2/15/23

SUMMARY LOG

Drill Hole #: **BH22-02**

BRITISH COLUMBIA — Ministry of Transportation and Infrastructure

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**
Location: Harrison Hot Spring, BC

Prepared by: WSP
Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-100
Northing/Easting: 5464275 , 590707 Station/Offset: 3 m left
Elevation: NA *Coordinates taken with GPS*

Date(s) Drilled: 10/26/2022
Company: Blue Max Drilling
Driller: NA
Drill Make/Model: Boart Longyear
Drilling Method: Sonic

DEPTH (m)	DRILLING DETAILS (SPT)	Pocket Penetrometer / Shear Strength (kPa) 100 200 300 400 / SPT "N" (BLOWS/300 mm) / Wp% 20 W% 40 60 WL% 80	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING — Drillers Estimate {G % S % F %}	DEPTH (m)
0							**ASPHALT**- 135 mm thick — 0.14m	AC		0
	3	3		1			**GRAVEL and SAND**- poorly graded, subangular, trace silt, brown, compact (305 mm road base materials) — 0.44m	GP		
	7	7		2			— 0.74m	GP		
1							**GRAVEL and SAND**- subangular, trace silt, brown/grey, moist, compact (300 mm road sub-base materials)	GP		1
	6 7 6 10	13 7		1	42		**GAVEL and SAND**- subangular, brown/grey, moist, compact (Fill)			
2							— 2.13m	SC1		2
							SAND- Gravelly, subangular, some clay, trace organic, brown, moist, compact — 2.35m			
							SAND- Gravelly, subangular, trace cobble, trace clay, , brown/grey, moist, loose to compact	SP		
3	3 6 12 10	18 5		2	25					3
							— 3.66m			
	1	1		3			**BOULDER**- Granite, weathered, white/grey, dry - hard drilling	LB		
4							— 4.36m			4
	5 8 7 9	15 4		3	33		**SILT**- gravelly, subangular, trace to some sand, brown, moist, compact	ML	Wash (Sa#3) Fines: 54%	
5							— 5.18m			5
							End of borehole at 5.18 m. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface.			
6							Notes: Borehole was advanced using SONIC to termination depth.			6
7							**SPT Details**: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods.			7
8							**Sample Recovery "REC"** is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.			8
9										9
10										

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: 5.8 m
Depth to Top of Rock:

MOTI-SOIL-REV3 MOTI_ROCKWELL.GPJ MOTI_DATATEMPLATE_REV3.GDT 2/15/23

SUMMARY LOG

Drill Hole #: **BH22-03**

Ministry of Transportation and Infrastructure

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Location: Harrison Hot Spring, BC

Prepared by: WSP

Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-200

Northing/Easting: 5464710 , 590685 Station/Offset: 4 m right

Elevation: NA *Coordinates taken with GPS*

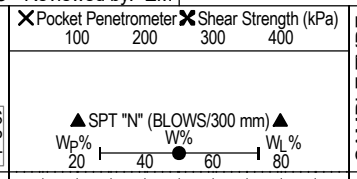
Date(s) Drilled: 10/26/2022

Company: Blue Max Drilling

Driller: NA

Drill Make/Model: Boat Longyear

Drilling Method: Sonic



DEPTH (m)	DRILLING DETAILS (SPT)	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING (Drillers Estimate {G % S % F %})	DEPTH (m)
0	9, 1		1			**ASPHALT**- 152 mm thick	AC		0
						0.15m			
			2			**GRAVEL and SAND**- poorly graded, subangular, trace silt, brown, moist, compact (408 mm road base materials)	GP		
						0.56m			
1						**GRAVEL and SAND**- poorly graded, subangular, trace silt, brown, compact (350 mm road sub-base materials)	GP		1
						0.91m			
	5, 6, 5, 3 (11)		1	50		**SAND and GRAVEL**- occasional cobble, subangular, brown/grey, moist, loose (Fill)	SP		
2	8					2.13m			2
			3			**SAND**- Gravelly, subangular, occasional cobble, trace clay, some wood/organic, brown, moist, loose to compact - Grade to loose between 3.05 m to 3.66 m depth - Grade to dense from 3.7 m to 3.9 m depth	SP		
3	4								3
	4, 2, 3, 3 (5)		2	33					
	5, 30 (8), R		3						
						3.9m			
4						**End of borehole at 3.9 m**. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface. Notes: Borehole was advanced using SONIC to termination depth. **SPT Details**: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods. **Sample Recovery "REC"** is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.			4
5									5
6									6
7									7
8									8
9									9
10									

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: 3.9 m

Depth to Top of Rock:

MOTI-SOIL-REV3 MOTI_ROCKWELL.GPJ MOTI_DATATEMPLATE_REV3.GDT 2/15/23

SUMMARY LOG

Drill Hole #: **BH22-04**

Ministry of Transportation and Infrastructure

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Location: Harrison Hot Spring, BC

Prepared by: WSP

Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-200

Northing/Easting: 5464751 , 590704 Station/Offset: 3 m left

Elevation: NA *Coordinates taken with GPS*

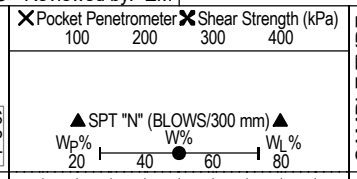
Date(s) Drilled: 10/26/2022

Company: Blue Max Drilling

Driller: NA

Drill Make/Model: Boat Longyear

Drilling Method: Sonic



DEPTH (m)	DRILLING DETAILS (SPT)	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING (Drillers Estimate {G % S % F %})	DEPTH (m)
0						**ASPHALT**- 241 mm thick	AC		0
						0.24m			
	9, 2		1			**GRAVEL and SAND**- poorly graded, subangular, trace silt, brown moist to dry, compact (309 mm road base materials)	GP		
			2			0.55m	GP		
1						**GRAVEL and SAND**- poorly graded, subangular, trace silt, brown, compact (450 mm road sub-base materials)			1
						1.0m			
	28, 26, 13, 11 / 4, 39		1	92		**SAND**- Gravelly, subangular, some silt, brown, moist, dense (Fill)	SM1		
2						2.3m			2
	1		3			**SAND**- Gravelly, subangular, occasional cobble, some clay, low plasticity, some wood/organic, brown, moist, compact	SC1	Wash (Sa#3) Fines: 12%	
3	13, 8, 8, 5 / 16, 16		2	67					3
	9, 9, 8, 8 / 7, 17		3	42					
4						4.27m			4
						End of borehole at 4.27 m. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface.			
5						Notes: Borehole was advanced using SONIC to termination depth.			5
6						**SPT Details**: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods.			6
7						**Sample Recovery "REC"** is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.			7
8									8
9									9
10									

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: 4.3 m

Depth to Top of Rock:

MOTI-SOIL-REV3 MOTI_ROCKWELL.GPJ MOTI_DATATEMPLATE_REV3.GDT 2/15/23

SUMMARY LOG

Drill Hole #: **BH22-05**

Ministry of Transportation and Infrastructure — British Columbia

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Location: Harrison Hot Spring, BC

Prepared by: WSP

Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-300

Northing/Easting: 5465728 , 591088 Station/Offset: 3 m right

Elevation: NA *Coordinates taken with GPS*

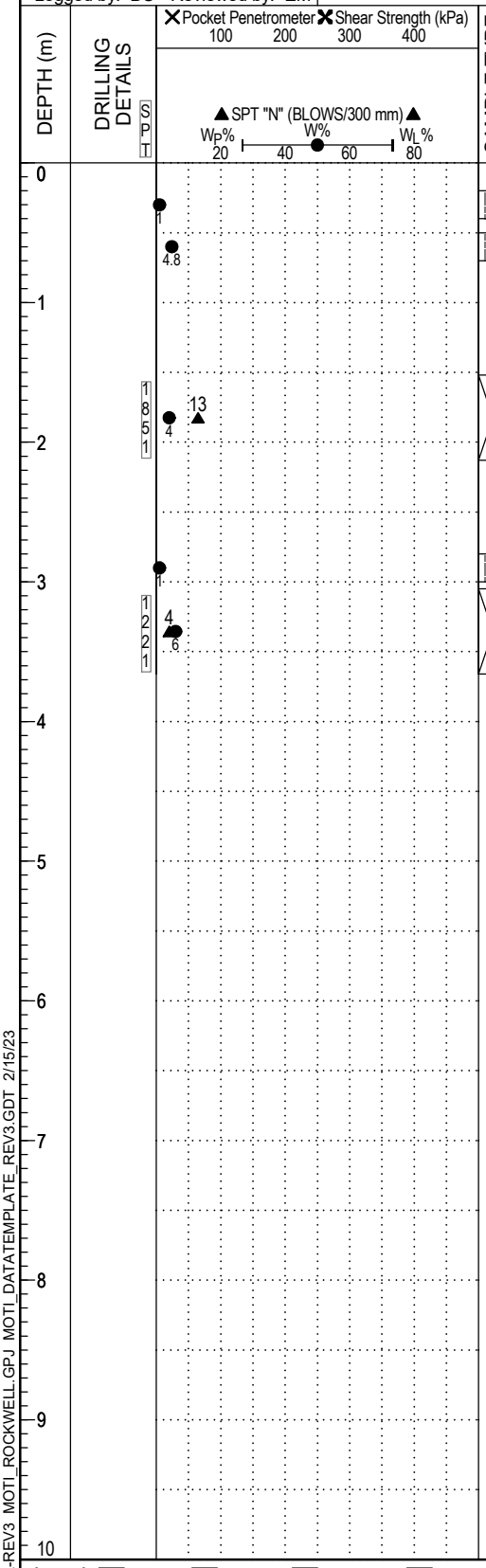
Date(s) Drilled: 10/26/2022

Company: Blue Max Drilling

Driller: NA

Drill Make/Model: Boat Longyear

Drilling Method: Sonic



SOIL DESCRIPTION		CLASSIFICATION	COMMENTS TESTING Drillers Estimate *{G % S % F %}*
ASPHALT- 178 mm thick	0.18m	AC	
GRAVEL and SAND- poorly graded, subangular, trace silt, brown, dry, compact (302 mm road base materials)	0.48m	GP	
GRAVEL and SAND- poorly graded, subangular, some silt, brown, compact (300 mm road sub-base materials)	0.8m	GM1	
SAND- Gravelly, subangular, brown/grey, moist, compact (Fill)		SP	
...Occasional cobble and very loose below 2.0 m depth	2.13m		
SAND- Gravelly, subangular, trace clay, moist, very loose		SP	
	3.66m		

End of borehole at 3.66 m. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface.

Notes:
Borehole was advanced using SONIC to termination depth.

SPT Details: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods.

Sample Recovery "REC" is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.

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: 3.7 m

Depth to Top of Rock:

SUMMARY LOG

Drill Hole #: **BH22-06**

Ministry of Transportation and Infrastructure — BRITISH COLUMBIA

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Location: Harrison Hot Spring, BC

Prepared by: WSP

Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-300

Northing/Easting: 5465751 , 591101 Station/Offset: 3 m left

Elevation: NA *Coordinates taken with GPS*

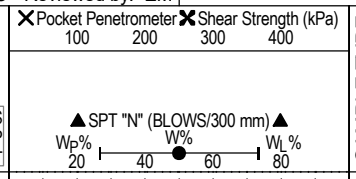
Date(s) Drilled:

Company:

Driller:

Drill Make/Model:

Drilling Method:



DEPTH (m)	DRILLING DETAILS (SPT)	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING (Drillers Estimate {G % S % F %})	DEPTH (m)
0	5		1			**ASPHALT**- 108 mm thick — 0.11m	AC		0
						GRAVEL and SAND- poorly graded, subangular, trace silt, brown, moist, compact (312 mm road base materials) — 0.42m	GP		
1	2		2			**GRAVEL and SAND**- subangular, some silt, brown/grey, moist, compact (580 mm road sub-base materials) — 1.0m	GM1		1
	28 29 23 24		1	79		**SAND**- Gravelly, subangular, some silt, brown/grey, moist, compact (Fill)			
2	4 52					...Soil grades to reddish/ brown between 2.6 m and 2.9 m depth	SM1		2
	4		3						
3	3 4 4 3		2	21		...Soil grades to trace silt and loose below 3.05 m depth			3
	8 8					— 3.66m			
4						**End of borehole at 3.66 m**. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface.			4
5						Notes: Borehole was advanced using SONIC to termination depth.			5
6						**SPT Details**: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods.			6
7						**Sample Recovery "REC"** is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.			7
8									8
9									9
10									

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: 3.6 m

Depth to Top of Rock:

MOTI-SOIL-REV3 MOTI_ROCKWELL.GPJ MOTI_DATATEMPLATE_REV3.GDT 2/15/23

SUMMARY LOG

Drill Hole #: **BH22-07**

Ministry of Transportation and Infrastructure

Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Location: Harrison Hot Spring, BC

Prepared by: WSP

Logged by: BC Reviewed by: EM

Datum: UTM NAD83 Alignment: L-300

Northing/Easting: 5465799 , 591143 Station/Offset: 3 m right

Elevation: NA *Coordinates taken with GPS*

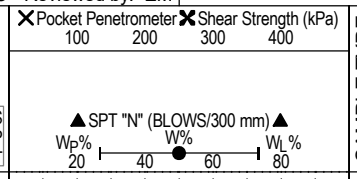
Date(s) Drilled: 10/26/2022

Company: Blue Max Drilling

Driller: NA

Drill Make/Model: Boat Longyear

Drilling Method: Sonic



DEPTH (m)	DRILLING DETAILS (SPT)	SAMPLE TYPE	SAMPLE NO	RECOVERY (%)	SOIL SYMBOL	SOIL DESCRIPTION	CLASSIFICATION	COMMENTS TESTING (Drillers Estimate {G % S % F %})	DEPTH (m)
0						**ASPHALT**- 108 mm thick — 0.11m	AC		0
	3		1			**GRAVEL and SAND**- poorly graded, subangular, trace silt, brown, moist, compact (312 mm road base materials) — 0.42m	GP		
1	8		2			**GRAVEL and SAND**- subangular, some silt, brown/grey, moist, compact (580 mm road sub-base materials) — 1.0m	GP		1
	8 13 7 14 — 20 — 3		1	17		**SAND**- Gravelly, subangular, some silt, brown/grey, moist, compact (Fill)			
2						...Soil grades to reddish/ brown between 2.6 m and 2.9 m depth	SM1		2
3	4 9 14 8 — 23 — 7		2	25		...Soil grades to trace silt and loose below 3.05 m depth			3
4			3			**End of borehole at 3.66 m**. No groundwater encountered. The borehole backfilled with bentonite chips and patched at surface. — 3.66m		Wash (Sa#3) Fines: 14%	4
	3 4 4 6 — 8 — 8		3	46		Notes: Borehole was advanced using SONIC to termination depth.			
5						**SPT Details**: 51 mm O.D. by 35 mm I.D. by 914 mm lg. unlined split spoon sampler driven using a 64 kg automatic trip hammer dropped 762 mm to strike a safety anvil attached to NWJ rods.			5
6						**Sample Recovery "REC"** is reported as the ratio of recovered sample length to the total driven length of the split spoon sample.			6
7									7
8									8
9									9
10									

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: 5.2 m

Depth to Top of Rock:

MOTI-SOIL-REV3 MOTI_ROCKWELL.GPJ MOTI_DATATEMPLATE_REV3.GDT 2/15/23

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 C

Laboratory Testing Results

WSP E&I Canada Limited
#110 - 18568 - 96th Avenue
Surrey, British Columbia
Canada, V4N 3P9

Water Content of Soil by Mass (ASTM D2216)

Client: **Binnie/MoTI**
Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Project Number: VG07795.300
Date : 7-Nov-22
Lab No.: L6831

Date Sampled: 26-Oct-22
Sampled by: BC

Date Tested: 2022/11/02
Tested by: WK

Hole #	Grab Sample	Depth (m)	Moisture Content (%)	Remarks
BH01/1-1	G	0.115-0.52	2.1%	
BH01/1-2	G	0.6-1.2	8.1%	
BH01/1-3	SPT	1.52	7.3%	
BH01/K	SPT	3.05	5.7%	
BH01/T	G	3.7-4.0	6.0%	
BH01/Q	SPT	4.57	5.6%	
BH02/B	G	0.135-0.44	3.1%	
BH02/A	G	0.44-0.74	6.5%	
BH02/C	SPT	1.52	6.5%	
BH02/D	SPT	3.05	5.4%	
BH02/13'	G	3.7-3.9	0.3%	
BH02/15'	SPT	4.57	4.1%	
BH03/E	SPT	1.52	8.7%	
BH03/B	G	0.2-0.6	1.4%	
BH03/A	G	0.7-0.9	7.7%	
BH03/D	SPT	3.05	4.3%	
BH03/C	G	2.7-3.0	8.4%	
BH03/12'	SPT	3.66	7.8%	
BH04/B	SPT	1.52	9.4%	
BH04/A	G	0.3-0.5	1.7%	
BH04/D	G	0.6-1.0	4.1%	
BH04/C	SPT	3.05	7.5%	
BH04/E	G	2.4-2.6	16.2%	
BH04/12'	SPT	3.66	7.3%	
BH05/D	G	0.2-0.4	0.3%	
BH05/A	G	0.5-0.7	4.8%	
BH05/B	SPT	1.52	3.7%	
BH05/C	SPT	3.05	1.1%	
BH05/9'	G	2.8-3.0	6.3%	

Reported by: Wenjing Ke

Reviewed by: Scott Forsyth

WSP E&I Canada Limited
#110 - 18568 - 96th Avenue
Surrey, British Columbia
Canada, V4N 3P9

Water Content of Soil by Mass (ASTM D2216)

Client: **Binnie/MoTI**
Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Project Number: VG07795.300
Date : 7-Nov-22
Lab No.: L6831

Date Sampled: 26-Oct-22
Sampled by: BC

Date Tested: 2022/11/02
Tested by: WK

Hole #	Grab Sample	Depth (m)	Moisture Content (%)	Remarks
BH06/C	SPT	1.52	5.1%	
BH06/D	G	0.2-0.4	1.5%	
BH06/A	G	0.5-0.9	3.5%	
BH06/B	SPT	3.05	4.1%	
BH06/9'	G	2.8-3.0	7.8%	
BH07/C	SPT	1.52	3.2%	
BH07/E	G	0.2-0.6	2.7%	
BH07/D	G	0.8-1.0	7.8%	
BH07/B	SPT	3.05	7.2%	
BH07/15'	SPT	4.57	8.1%	

Reported by: Wenjing Ke

Reviewed by: Scott Forsyth

WSP E&I Canada Ltd.
#110 - 18568 - 96th Avenue
Surrey, British Columbia
Canada, V4N 3P9

Materials Finer than 75-µm Sieve by Wash (ASTM C117)

Client: **Binnie/MoTI**
Project: **Rockwell Drive Flood Recovery - DF1 to DF3**

Project Number: VG07795-300
Date: 8-Nov-22
Lab No.: L6831

Date Sampled: 26-Oct-22
Sampled by: BC

Date Tested: 2022/11/02
Tested by: WK

Hole #	Grab Sample	Depth (m)	Material Finer than 75 µm (%)	Remarks
BH 01/T	G	3.7-4.0	5.8%	
BH 04/E	G	2.4-2.6	11.8%	
BH 07/A	G	3.66-3.96	14.3%	
BH 02/15'	SPT	4.6	54.1%	

Comments:

Reported by: Wenjing Ke

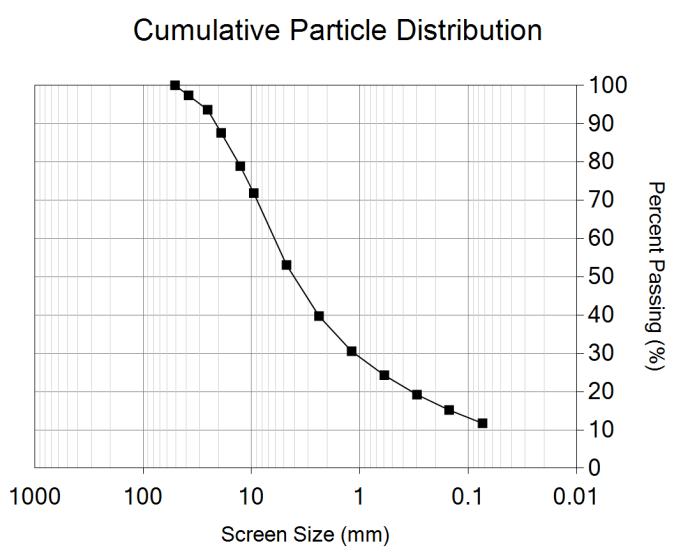
Reviewed by: Scott Forsyth

Sieve Analysis

Report Date: November 09, 2022

Client		Project	
Name:	BC Ministry Of Transportation and Infrastructure	**Name:**	(VG07795) Rockwell Drive Flood Recovery - DF1 to DF 3
Address:	310 - 1500 Woolridge Street Coquitlam, BC V3K 0B8	**Address:**	NA, British Columbia
Attention:	-	**Phase:**	300 **Task:**
PO Number:		**Manager:**	Eric Mohlmann
Sample Date:	10/26/2022 by Brad Cheng	**Lab/Ref. #:**	L6831
Source:	BH 01/1-2 Grab Depth: 0.6-1.2 m	**Description:**	Poorly graded gravel with fines and sand

Type of Specification: No project specification was provided.



Sieve Analysis: (ASTM C117-17/C136-19)

200 Wash Procedure: A

Sieve Size	Passing	Specification Min	Specification Max
50mm	100%		
37.5mm	97%		
25mm	94%		
19.0mm	88%		
12.5mm	79%		
9.5mm	72%		
4.75mm	53%		
2.36mm	40%		
1.18mm	31%		
600µm	24%		
300µm	19%		
150µm	15%		
75µm	12%		

Particle Size (bold indicates value was interpolated)							
Over 3" / 76mm	Gravel		Sand			Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0%	12.0%	35.0%	**16.0%**	**16.0%**	**9.0%**	12.0%	

Remarks:

Distribution: Surrey

Reviewed By: Scott Forsyth, P.Eng.

WSP E&I Canada Limited. - #110 - 18568 - 96th Avenue - Surrey, BC - V4N 3P9 Canada. Phone: (604) 219-1674

CERTIFICATE OF ANALYSIS

REPORTED TO	Wood Plc. (Vancouver) 400-111 Dunsmuir Street Vancouver, BC V6B 5W3		
ATTENTION	Soheil Sayedinazad	**WORK ORDER**	22K3070
PO NUMBER		**RECEIVED / TEMP**	2022-11-25 09:50 / 18.5°C
PROJECT	VG07795.300	**REPORTED**	2022-12-06 13:47
PROJECT INFO			

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/IEC 17025:2017 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.

By engaging our services, you are agreeing to CARO Analytical Service's Standard Terms and Conditions outlined here: https://www.caro.ca/terms-conditions

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 Plc. (Vancouver)	**WORK ORDER**	22K3070
PROJECT	VG07795.300	**REPORTED**	2022-12-06 13:47

Analyte	Result	RL	Units	Analyzed	Qualifier
BH22-02@4.4m (22K3070-01) | Matrix: Soil | Sampled: 2022-11-24					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2022-12-05	
BH22-03@2.9m (22K3070-02) | Matrix: Soil | Sampled: 2022-11-24					
General Parameters					
Sulfate, Water-Soluble	< 0.050	0.050	%	2022-12-05	

APPENDIX 1: SUPPORTING INFORMATION

REPORTED TO	Wood Plc. (Vancouver)	**WORK ORDER**	22K3070
PROJECT	VG07795.300	**REPORTED**	2022-12-06 13:47

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

Glossary of Terms:

RL	Reporting Limit (default)
%	Percent
<	Less than the specified Reporting Limit (RL) - the actual RL may be higher than the default RL due to various factors
CSA	Canadian Standards Association Chemical Test Methods

General Comments:

The results in this report apply to the received 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 or once samples expire, whichever comes first. Longer hold is possible if 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

Please note any regulatory guidelines applied to this report are added as a convenience to the client, at their request, to help provide some initial context to analytical results obtained. Although CARO makes every effort to ensure accuracy of the associated regulatory guideline(s) applied, the guidelines applied cannot be assumed to be correct due to a variety of factors and as such CARO Analytical Services assumes no liability or responsibility for the use of those guidelines to make any decisions. The original source of the regulation should be verified and a review of the guideline(s) should be validated as correct in order to make any decisions arising from the comparison of the analytical data obtained to the relevant regulatory guideline for one's particular circumstances. Further, CARO Analytical Services assumes no liability or responsibility for any loss attributed from the use of these guidelines in any way.

APPENDIX 2: QUALITY CONTROL RESULTS

REPORTED TO	Wood Plc. (Vancouver)	**WORK ORDER**	22K3070
PROJECT	VG07795.300	**REPORTED**	2022-12-06 13:47

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.

Analyte	Result	RL	Units	Spike Level	Source Result	% REC	REC Limit	% RPD	RPD Limit	Qualifier
General Parameters, Batch B2L0112										
Blank (B2L0112-BLK1)				Prepared: 2022-12-01, Analyzed: 2022-12-05						
Sulfate, Water-Soluble	< 0.050	0.050	%							
Duplicate (B2L0112-DUP1)		**Source: 22K3070-01**		Prepared: 2022-12-01, Analyzed: 2022-12-05						
Sulfate, Water-Soluble	< 0.050	0.050	%		< 0.050				19	
Matrix Spike (B2L0112-MS1)		**Source: 22K3070-02**		Prepared: 2022-12-01, Analyzed: 2022-12-05						
Sulfate, Water-Soluble	0.534	0.050	%	0.667	< 0.050	80	63-117			

Appendix D

Limitations

Limitations

1. The work performed in the preparation of this report and the conclusions presented are subject to the following:
   a. The Standard Terms and Conditions which form a part of our Professional Services Contract;
   b. The Scope of Services;
   c. Time and Budgetary limitations as described in our Contract; and
   d. The Limitations stated herein.
2. No other warranties or representations, either expressed or implied, are made as to the professional services provided under the terms of our Contract, or the conclusions presented.
3. The conclusions presented in this report were based, in part, on visual observations of the Site and attendant structures. Our conclusions cannot and are not extended to include those portions of the Site or structures, which are not reasonably available, in WSP's opinion, for direct observation.
4. The environmental conditions at the Site were assessed, within the limitations set out above, having due regard for applicable environmental regulations as of the date of the inspection. A review of compliance by past owners or occupants of the Site with any applicable local, provincial or federal bylaws, orders-in-council, legislative enactments and regulations was not performed.
5. The Site history research included obtaining information from third parties and employees or agents of the owner. No attempt has been made to verify the accuracy of any information provided, unless specifically noted in our report.
6. Where testing was performed, it was carried out in accordance with the terms of our contract providing for testing. Other substances, or different quantities of substances testing for, may be present on-site and may be revealed by different or other testing not provided for in our contract.
7. Because of the limitations referred to above, different environmental conditions from those stated in our report may exist. Should such different conditions be encountered, WSP must be notified in order that it may determine if modifications to the conclusions in the report are necessary.
8. The utilization of WSP's services during the implementation of any remedial measures will allow WSP to observe compliance with the conclusions and recommendations contained in the report. WSP's involvement will also allow for changes to be made as necessary to suit field conditions as they are encountered.
9. 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 which any third party makes of the report, in whole or the 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. WSP 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 the report or anything set out therein.
10. This report is not to be given over to any third party for any purpose whatsoever without the written permission of WSP.
11. Provided that the report is still reliable, and less than 12 months old, WSP will issue a third-party reliance letter to parties that the client identifies in writing, upon payment of the then current fee for such letters. All third parties relying on WSP's report, by such reliance agree to be bound by our proposal and WSP's standard reliance letter. WSP's standard reliance letter indicates that in no event shall WSP be liable for any damages, howsoever arising, relating to third-party reliance on WSP's report. No reliance by any party is permitted without such agreement.