PTP# 1002594

Revision Date: December 3, 2021

Foundations, Excavation & Shoring Specialists

Braun Geotechnical
102 - 19049 95A Ave.
Surrey, BC
V4N 4P3
Tel: 604-513-4190
Fax: 604-513-4195
info@braungeo.com

www.braungeo.com

Foundations

Excavation & Shoring

Slope Stability

Natural Hazards

Pavement Design and Management

Reinforced Soil Walls and Slopes

2021 WET WEATHER/ FREEZE-THAW SHUTDOWN GUIDELINES TRANSFER STATION – QUADLING ROAD, ABBOTSFORD, BC

(Use BCTS Chinook Area Wet Zone):

> ***Note:*** *decisions should be based on daily-recorded measurements from an instrument onsite, or at the representative station - Abbotsford Airport Station (Lat 49°01'31"N Long 122°21'36"W).*

I. Indicators of Potentially Hazardous Conditions.

Work should cease if any of the following conditions are observed at the site or on adjacent areas of questionable stability. Key observations by site workers are highlighted below:

1. Extremely heavy rainfall or prolonged heavy rain, according to **Table A**.
2. Freeze-thaw periods of concern, according to **Table C.**
3. Strong wind conditions (**Table D** - Environment Canada wind warning).
4. Appearance and/or excessive seepage on rock/soil slopes.
5. The occurrence of natural soil slides or rockfall in the vicinity.
6. Debris fan ravelling, fresh rockfall fragments or other debris in yard, access roads or on slopes.
7. Sudden change of slope or rock gully runoff to brown colour.
8. Unusual low flow rate (or no flow) observed in the rock gully.

Any of these conditions indicate an increased likelihood of a debris flow, debris fan slide or rockfall occurring. Activities should remain shut down until Recommencement Criteria discussed below in Section III are met, and a site review can be made by a Qualified Professional (QP).

II. Rainfall/Snowmelt/Freeze-Thaw/ Wind Operational Shutdown limits.

When the rainfall/snowmelt limits in Table A are exceeded, all operations must stop within and downslope of slide debris and debris fan areas that are potentially unstable.

Table A. Combined Rainfall/Snowmelt Operational Shutdown Criteria

Time Period	Limit for wet zone	Limit for dry zone	Limit for unstable terrain upslope
12 hours	n/a	n/a	10 mm
24 hours	n/a	n/a	20 mm
48 hours	n/a	n/a	30 mm
72 hours	n/a	n/a	40 mm

Note: Rainfall should preferably be measured at work area.

Include snowmelt water if snow is present as a continuous cover within the site or on upslope areas that are potentially unstable, and when temperature is above freezing. Estimate snowmelt using **Table B** below in combination with observed site conditions. Use temperature measured at automated stations or measured at worksite.

Table B. Estimated Snowmelt (add to measured rainfall)

	Clearcut/ Rockslope Areas		Forested or Second Growth Areas	
Average Air Temperature	Low Wind	High Wind	Low Wind	High Wind
1 °C	5 mm	15 mm	5 mm	10 mm
5 °C	30 mm	75 mm	20 mm	35 mm
10 °C	60 mm	145 mm	40 mm	75 mm

Note: Average air temperature is average of mid-afternoon (warmest) and early morning (coolest) readings, and can be taken from a max/min thermometer. Low winds may cause branches to sway and are less than 15 km/hr; High winds cause trees to sway and are greater than 15 km/hr.

Table C. Freeze-Thaw Criteria for Elevated Rockfall Hazard (after Macciotta, et al, 2015)

Freeze-Thaw Criteria for Elevated Rockfall Activity[1]		**3-day Cumulative Precipitation**[2]	
		≤ 5mm	> 5mm
Criteria 1: Freeze-thaw cycle within 3-days?	No	Non-Hazardous Period	Hazardous Period[3]
	Yes	Hazardous Period	Hazardous Period
Criteria 2: Within first two weeks of Spring thaw period?	No	Non-Hazardous Period	
	Yes	Hazardous Period	

Notes: **1. Environment Canada freeze-thaw cycle: daily maximum temperature (Tmax) > 0°C and daily minimum temperature (Tmin) ≤ -1°C**

2. Modified from Dry Zone (Lytton) 2mm over 3-day criteria

3. ~90% of weather-induced rockfall activity expected to occur within Hazardous Periods

Table D. Wind Criteria for Potential Rockfall Concerns

Wind Criteria for Potential Rockfall Concerns[1]	
Criteria 1: Sustained Wind	60km/hr
Criteria 2: Wind Gusts	90km/hr or greater

1. **Environment Canada Inland Wind Warning**

Movement of the tree stem due to wind forces can initiate rockfall via an additional wedge effect of the roots (Gerber 1998). Available weather data does not typically include wind speed and direction such that established wind trigger correlations are not available. In view of the above the Environment Canada national criteria for issuance of wind warnings has been adopted as a trigger for review of the slopes and rock gully above the worksite area by a QP.

III. Recommencement of Operations

Resume operations when measured rainfall drops below 50 mm in 24 hours, and cumulative rainfall drops below limits in **Table A,** when freeze-thaw criteria in for non-hazardous periods are met (**Table C**), and/or when wind levels drop below criteria in **Table D.** A review of the rock gully by the QP prior to occupying the site is required for Indicators I.4 to 8.

DESIGN REPORT

EVANS QUARRY DEBRIS MANAGEMENT AND DRAINAGE IMPROVEMENTS

MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

PROJECT NO.: VG07794.200
DATE: FEBRUARY 2023

WSP E&I Canada Limited
400 – 111 Dunsmuir St
Vancouver, BC V6B 6A3

T: +1 604-664-4315

WSP.com

13 February 2023

Mr Satish Prasad, P.Geo.
BC Ministry of Transportation and Infrastructure
Suite 310 – 1500 Woolridge Street
Coquitlam, British Columbia
V3K 0B8

Dear Mr Prasad:

Subject: Design Report for Evans Quarry Debris Management and Drainage Improvements

We are pleased to attach our design report for the Evans Quarry Debris Management and Drainage Improvements project. The report includes information gathered from various site visits held in 2021 and 2022. The report Appendices contains the Issue for Permit (IFP) drawing set, a copy of a memo sent to MOTI regarding the temporary drainage and infiltration tests done on site, as well as recommendations for site shutdown in inclement weather.

We trust this information is sufficient for permit applications; however, if you require any additional information or clarification, please contact the undersigned.

Yours sincerely,

Geoff Graham, P.Eng.
Senior Associate Water Resources Engineer
Tel: 604-785-2282
Email: geoff.graham@wsp.com

Enc.

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APPENDICES

1 INTRODUCTION

WSP E&I Canada Ltd (WSP) (formerly Wood Environment and Infrastructure Canada Limited) is pleased to present this design report to the British Columbia Ministry of Transportation and Infrastructure (MOTI) and accompanying issue for permit drawings (IFP) for the Evans Quarry Debris Management and Drainage Improvements project on the east side of Sumas Mountain in Abbotsford, BC to the British Columbia Ministry of Transportation and Infrastructure. WSP completed this work as part of the existing MOTI "as and when" contract 861CS1181.

Two landslide (debris flow) events occurred between 14 and 19 November 2021 burying portions of the MOTI Evans Quarry property, portions of assets of the current leaseholders (West Coast Reduction Ltd. (WCRL)) and portions of an adjacent quarry operation (Mountainside Quarries Group Ltd (MSQG)) with indirect impacts to several residences along Quadling Road arising in part from changed or overloaded surface and ground water drainage paths. The debris slide altered drainage paths from the site and created a small permanent impoundment in the WCRL parking area. The slide also blocked access to the rear of the site; causing disruption to the movement of transport trucks on the site.

This report is intended to support permit applications for the restoration of drainage on the site and the construction of a debris slide protection berm to reduce the potential consequence of future slides to the WCRL operation.

2 SCOPE OF WORK

The overall scope of the work was to assess the residual landslide geotechnical hazard on the MOTI site, provide geotechnical and hydrotechnical recommendations relative to removal of the debris on the MOTI site and to undertake permit level design for the restoration of drainage across the site.

MOTI plans to remove the debris from the two slides on the MOTI property with the overall goal of restoring work areas, allowing damaged infrastructure to be rebuilt and potentially providing room for future debris catchment. The design considers the surface and ground water flows which have been altered due to the debris flow. The disposal of water from the MOTI site and indirectly from the quarry to the south was affecting adjacent properties in the area and this is an additional consideration for the design.

This report provides the results of the field work, geotechnical assessment, hydrotechnical assessment and provides "Issue for Permit" (IFP) level design report and drawings for the proposed drainage measures and debris flow protection berms. Previous letters have been issued to MOTI as part of this work (Wood, 2022a, 2022b and WSP, 2023).

This work is in reference to the MOTI property only. Work, including geohazards assessments, on the adjacent active MSQG is being carried out by others. References to MSQG and the adjacent residences are for the purposes of general information relative to this report. This report does not provide engineering recommendations for the neighbouring properties and comments in this report are not meant as geohazard assessments or engineering recommendations with respect to the neighbouring properties.

It should be noted that this has report considered the following general guidelines published by Engineers and Geoscientists of BC:

Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC, May 2010. The property under discussion is not a residential development; however, the general aspects of landslides relative to nearby structures and land use are of interest. It is specifically noted, as discussed later in this report, that due to the limited area available, it is not possible to achieve the level of property or personnel protection contemplated in the guidelines. Further discussion and recommendations appear in the report.

2.1 SITE VISITS

WSP, MOTI and survey contractors reviewed the site on several occasions between December 2021 and November 2022 including the following work:

1. Initial ground based geotechnical assessment of the slides following the occurrence of the landslide events to map extents of debris and assess residual hazard.
2. Helicopter reconnaissance to review upper reaches of drainages and identify landslide source areas.
3. Ground based reconnaissance to observe landslide impacted surface water flows following heavy rain and to review emergency ditching measures. During this trip, the spoil pile on the WCRL facility was sampled (near surface only) for grain size tests to determine potential for alternate uses.
4. Review of the site following survey of property boundaries to complete rough layout of drainage ditches and sedimentation pond.
5. Two days on site for "field fitting" temporary drainage infrastructure to provide relief from standing water on the site.
6. Follow up field visit to inspect the effectiveness of the temporary drainage following a major rainstorm.

3 AVAILABLE INFORMATION

The following information was used for the design and generation of this report.

1. LiDAR pre-slide from July 2017 and November 2022 provided by MOTI.
2. Air photos at 5 to 9-year intervals from 1940 to 2016 provided by University of British Columbia.
3. Published surficial and bedrock geology maps.
4. Interviews with staff from MSQG and WCRL.
5. Evans Quarry pit development plan in PDF and AutoCAD format provided by MOTI.
6. Topographic survey undertaken by McElhanney during the field fitting of temporary drainage infrastructure.

4 PHYSIOGRAPHIC SETTING

4.1 TOPOGRAPHY AND SITE DESCRIPTION

The Evans Quarry property is located near the base of the eastern side of Sumas Mountain – a flat top mountain rising about 900 m above the Fraser River/Sumas Prairie floodplain. Slopes are generally between 30 and 45 degrees on the mountain side with some steeper bluff sections at higher elevations.

An unnamed stream drains portions of the east side of Sumas Mountain into the property. The channel gradient is typically 30 degrees with sections approaching 40 degrees in upper areas near the height of land. The catchment is divided into two areas, one that is directly upslope and linear (suspected to be controlled by a structural feature in the rock), and a tributary catchment to the south which has a more dendritic drainage pattern. The catchments coalesce in a wide open "trough" area about 300 m above the valley floor and discharge just north of the WCRL operation prior to the landslide events. The overall catchment drainage area for the system is about 0.67 km^2 (67 hectares).

Slopes adjacent to the drainage are moderately steep. On the north side there are a series of old skid trails which climb up the slope to about 150 m above the valley floor along a moderately steep slope suspected to be the old backwall of the "northern Evans Quarry" operation within and north of the property boundary. Just south of the drainage is the MSQG quarry operation which has removed overburden and exposed subvertical rock faces presently being drilled and blasted.

WCRL operates a meat rendering transfer station at the base of the slope with operations conducted primarily from a site building where materials from B-train sized trucks are transferred. The yard allows for truck turnaround and parking for trailers and had a drilled well behind the main building that was destroyed by the landslides. The portion of the yard that was not buried forms a low angle basin surfaced in gravel used for parking and turnaround. A spoil pile of rejected material from previous gravel pit operations is stored on the site. This pile was about 70 × 60 × 10 m high with 2H:1V slopes.

The WCRL buildings and operations are generally within area mined out by former sand and gravel operations – see Section 7 for further details on site history.

The southern property boundary is fenced adjacent to a drop of about 2 m into the MSQG property. North of the WCRL yard there is an a disturbed area forested in alder with a closed depression where surface water infiltrates. Prior to the slide, this infiltration area collected runoff from the upstream catchment as well as directly from the site. There is no culvert or other outlet from this closed depression. On the northern part of the property there is an open area where beehives are kept. Beyond the property boundary to the north there is a residence behind a steel gate in the "north Evans Quarry area".

The site is bordered to the east by Quadling Road. On the far side (east) of the road there are residences between the road and the Sumas River. The residence at the southern end appears to be located on fill. The Barrowtown Pump Station is located a short distance south/upstream along the river.

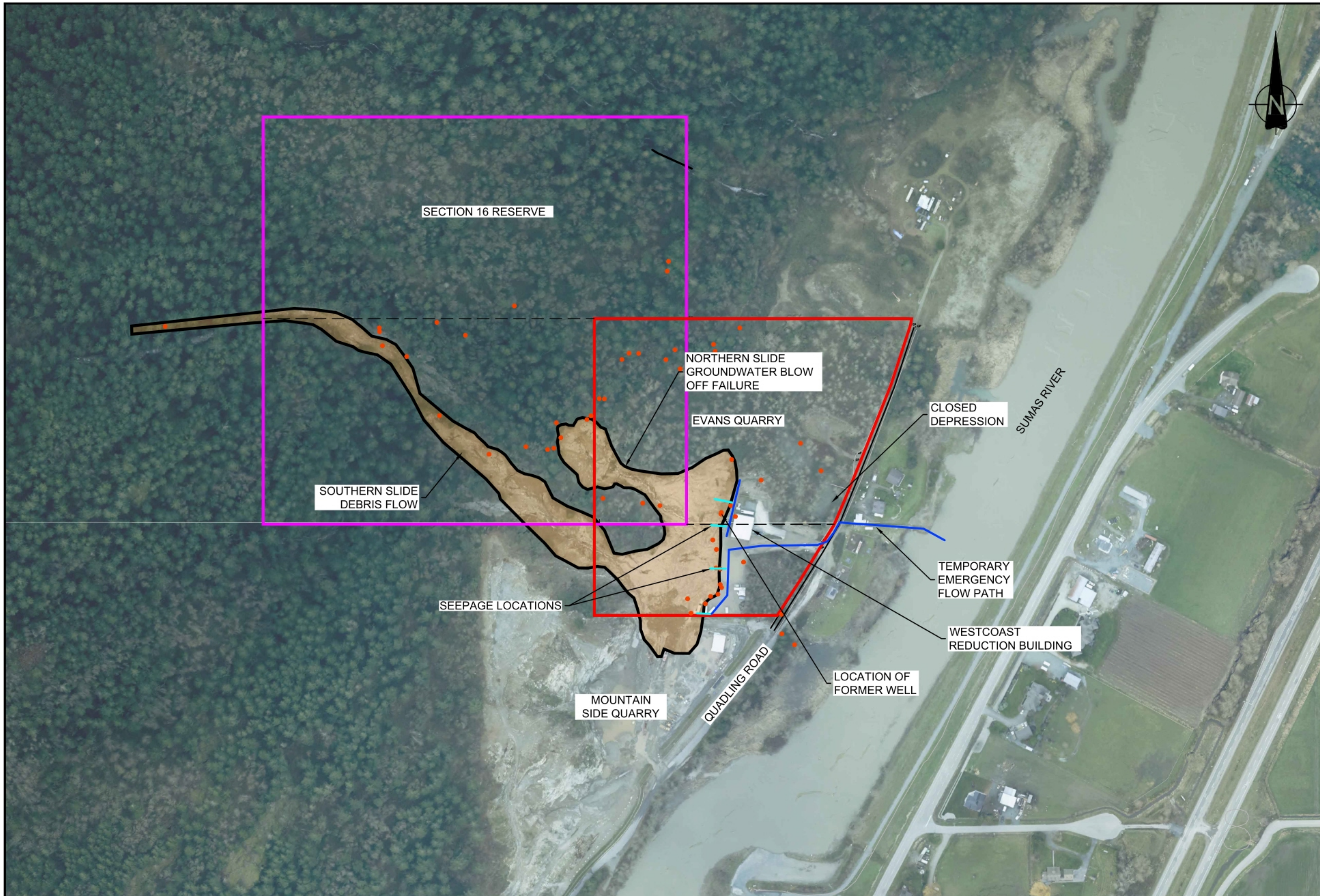
Figure 1 and Photo 1 (below) show the general location of the site and various details.

4.2 GEOLOGY

The east slope of Sumas Mountain near the study area was mapped by Armstrong (1959) as shallow rock except for a small fan of post glacial slope wash deposits of alluvial and landslide debris expected to contain mostly of gravel and sand – likely the primary deposit mined during the former operations at Evans Quarry.

During the field reconnaissance, thick granular material (colluvium) was noted near the unnamed stream in the lower and middle reaches of the infilled trough section described in Section 4.1. Talus or scree cones at the toes of bedrock slope segments were common in upper reaches. Lower slopes north of the stream were mantled in sand and gravel. The MSQG site has exposed rock; however, it is understood that the area was stripped. Bedrock appeared to be shallow or was exposed at higher elevations. Further details are presented in Section 5.

Bedrock is mapped as a quartz diorite with hornblende as the dominant mafic mineral (Roddick, 1965). Diorites with a pinkish color indicating high potassium feldspar content (might be described as granite) were observed during the field reconnaissance. The LiDAR shows what appears to be a major east west trending bedrock structure along the main drainage that extends across Sumas Mountain; no known faults are mapped in the area based on review of available data.



LEGEND

- MOTI FEE SIMPLE BOUNDARY
- SECTION 16 BOUNDARY
- SLIDE EXTENTS
- WAYPOINT SURVEY

NOTES:

AERIAL PHOTOGRAPH PROVIDED BY MOTI, DATED FEB. 2021.

0m 40 80 120 160

1 : 4000

NOTE: TO BE READ IN CONJUNCTION WITH WOOD REPORT DATED MARCH 2022

CLIENT: MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

wood.
Environment & Infrastructure Solutions
Suite 600 - 4445 Lougheed Highway, Burnaby, BC V5C 0E4
Tel: 1-604-294-3811

	SM
CHK'D BY:	CD
DATUM:	-
PROJECTION:	-
SCALE:	AS SHOWN

PROJECT: EVANS QUARRY RESIDUAL DEBRIS FLOW ASSESSMENT ABBOTSFORD, BC

TITLE: SITE PLAN

DATE:	MARCH 2022
PROJECT NO:	VG07794.200
REV. NO.:	A
FIGURE No.	FIGURE 1

5 FIELD OBSERVATIONS

5.1 GENERAL

There were two main failures, both of which were debris flows or slides. Figure 1 above shows a crude survey of the site based on handheld GPS points overlain on the provided Pit Development Plan and available orthophotos. Photo 1 below shows the overall layout of the area and various features discussed in the following sections.

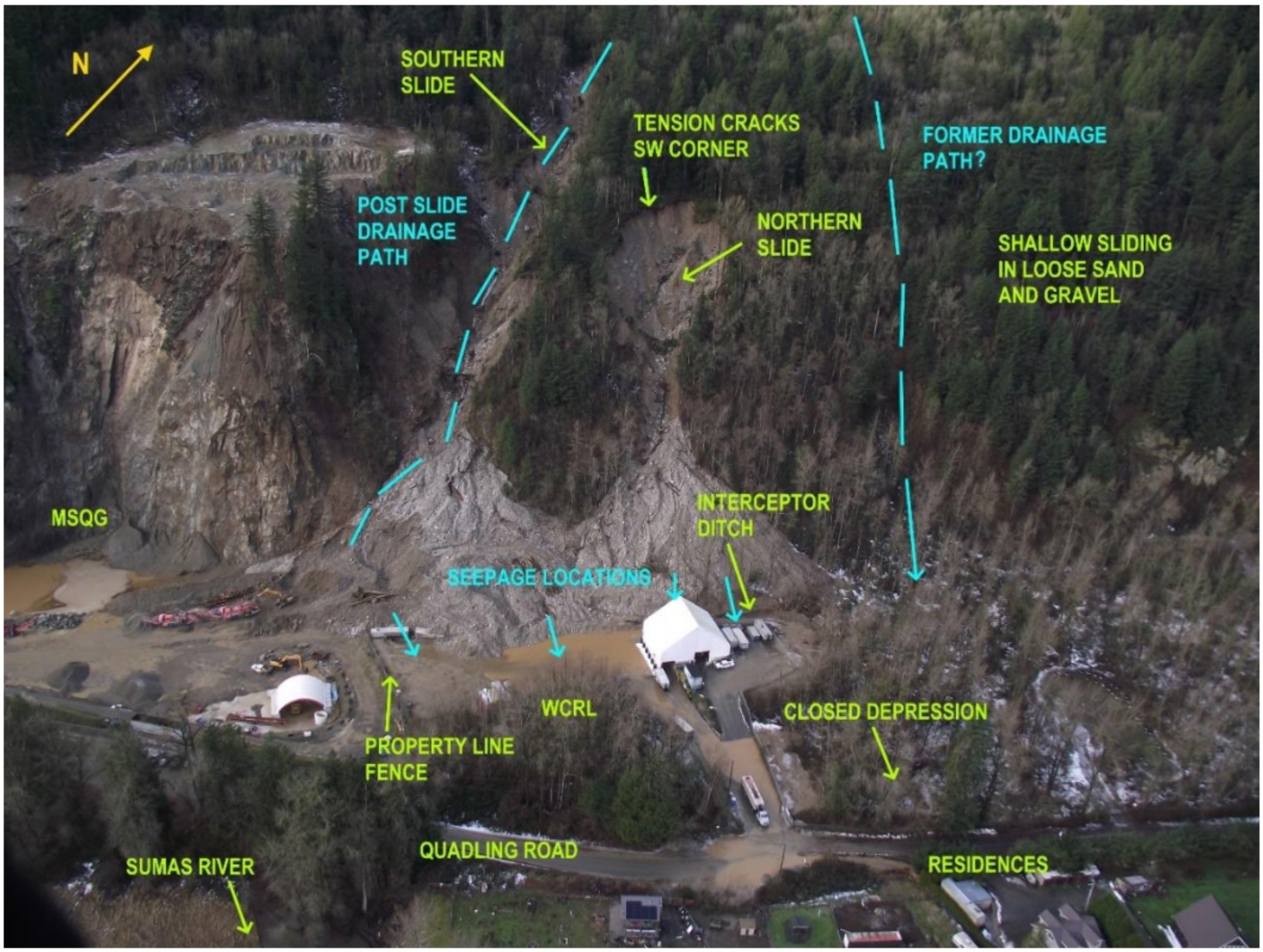


Photo 1: Oblique photo from the air looking west towards the site taken on 23 December 2021. The photo has been annotated to provide reference to the discussion below.

5.2 NORTHERN SLIDE

The northern slide feature was an open slope failure with an amphitheater shaped depletion zone about 40 m wide (max.), 80 m long and 4 to 6 m deep. Over steepened cobbly sand and gravel was visible in the head scarp with patches of exposed bedrock along the moderately steep slide path. The path funnelled into a narrow mid point below which the debris spread out onto lower slopes. Minor groundwater springs were observed where rock was exposed on the slide path – this water disappeared downslope and apparently flowed underground in the slide debris. The debris cone was about 80 m long and 80 m wide at the toe and apparently infilled a drainage ditch, covered a well and stopped short just of the main WCRL structure. Two areas of minor seepage were present at the toe of the northern slide on 17 December 2021. The overall slope of the debris cone was 25 degrees with a slightly steeper front.

Redirection and concentration of water by an old skid trail is thought to have been a contributing factor to the slide as evidenced by a switchback near the crest which would have directed surface water towards the top of the slide. Buildup of groundwater pressures below surficial materials on the slope is also suspected based on the amphitheatre morphology suggesting this may have been a "blow-off" type failure involving build up of pore pressures and groundwater storage in buried aquifers with drainage to the surface impeded by the surficial sediments combined with ongoing reduction of surficial permeability due to surface creep and root mixing/weathering.

Tension cracks were observed behind the southwest corner of the slide which appeared to be older and may represent a portion of the slide which did not fail during the main slide event but may be prone to future failure. An open crack was noted during the site visit in January suggesting displacement during the slide event. Shallow sliding in loose, coarse granular material was observed on nearby slopes to the north, sometimes associated with fills along old skid trails. Photo 2 shows a view down the northern failure. The initial failure likely had much steeper slopes in the upper part of the slide. Subsequent local failures have likely reduced the slope angles and contributed to the accumulation of colluvium visible in the centre of the image.

Photo 2: View looking downslope from the crest of the northern slide east toward the WCRL structure, and the Sumas River on December 17, 2021.

5.3 SOUTHERN SLIDE

The southern slide is a debris flow that originated part way up Sumas Mountain at higher elevation than the northern slide. The debris on the valley floor was about 100 m long and 100 m wide at the toe covering the southern part of the MOTI property and the adjacent MSQG quarry. The central axis of the alluvial fan was within the MOTI property. The alluvial fan was coalescent with the adjacent open slope failure to the north. The debris wedge partially buried a truck trailer at the toe and thickened appreciably upslope (see discussion of LiDAR analysis below which provides an estimate debris thickness). The overall slope of the debris cone for the southern slide was 20 degrees, slightly shallower than the northern slide.

Surface water was visible flowing down a bedrock reach just above the main debris, but the water disappeared and apparently flowed underground through the granular debris on December 17, 2021. By December 23, there was overland flow due to increased surface flows resulting from rain and snowmelt at the time. The water daylighted in various areas at the toe of the debris and was primarily impacting WCRL yard on the MOTI property with pooling in low areas and surface flow occurring across Quadling Road and then along the property line between the two residences before draining into the Sumas River (see Figure 1). The main point of seepage and overland flow was near the fence line along the southern edge of the Evans Quarry property following the new debris flow channel.

Immediately above the main debris accumulation, the debris flow followed a steep channelized reach with bedrock exposed in the channel at some locations. About 250 m upstream (or 125 m above) the valley floor, the terrain was less steep and more open. Lobes of debris had spilled out into forested areas along outside bends of the main debris flow in this area in an open trough area. Levees and channels from previous events were observed and were vegetated with young cedars and vine maple.

The source area was viewed during the helicopter reconnaissance. It appeared that surficial flows originally flowing farther north avulsed to flow slightly further south. The material in the debris flow appears to have originated from shallow sliding and sloughing of talus-like materials and/or mobilization of bedload within an open southern tributary channel about 400 m elevation above the valley floor. Contribution of additional stored groundwater may have occurred as the channel eroded down to bedrock.

MSQG was in the process of removing the debris from their property at the time of the site visits, apparently with approval by Braun Geotechnical Ltd, their retained geotechnical consultant. The quarry owner had reported frequent shallow slides, ravelling and rolling rock coming down both slide areas which agrees with field observations of over steepened soil slopes and in some cases unfavorable bedrock structure exposed by scour. They reported more active instability in the northern blow off failure.

Based on review of debris toe relative to recent orthophotos, it appears that debris from the southern slide covered about 30 m of the east portion of WCRL and the northeast portion of MSQL that was apparently used for tractor trailer storage and turnaround space.

5.4 SURFACE AND GROUND WATER FLOW

It is understood (based on discussion with the quarry operator) that prior to the landslide events, surface water previously flowed north into a closed depression on the north side of the MOTI properly near Quadling Road where it infiltrated into the ground. A catchment ditch was also previously installed north of the WCRL structure to assist in diverting seepages or surface water to the same closed depression.

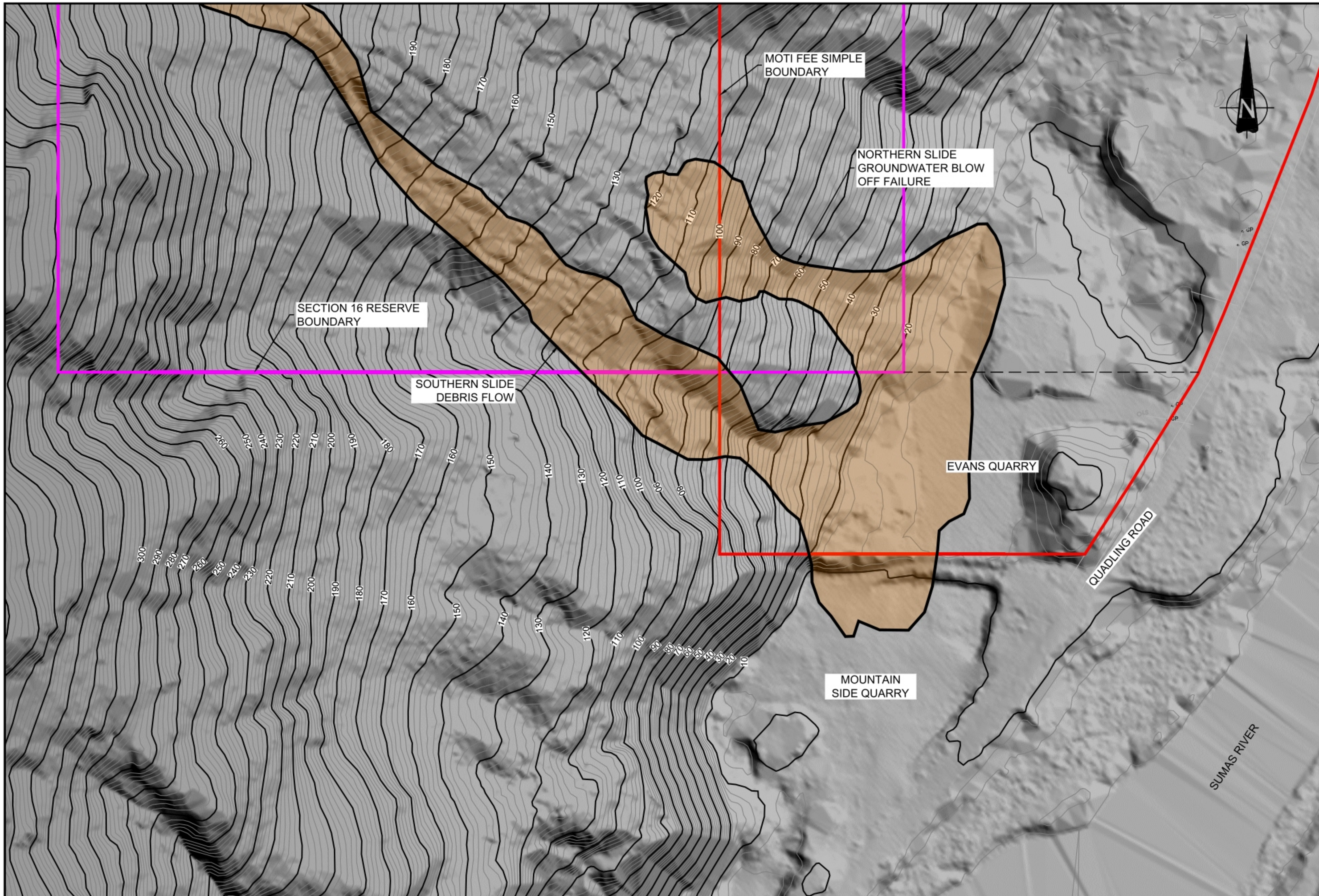
Emergency water management was installed following the landslides and associated changes in surface and groundwater flow paths. A steep sided interceptor ditch about 50 m long was dug above the WCRL structure to assist in diverting water to the north. The ditch captured two of the four seepage areas noted during the field reconnaissance.

At the time of the reconnaissance visits, most of the surface water flowed down the new southern debris flow channel and daylighted/flowed from the debris near the WCRL/MSQG fence line. There was significant ponding of water in the WCRL lot which flowed down the WCRL entranceway across Quadling Road and then through neighbouring residential properties to Sumas River along a rough ditch dug along property line between the two residences. During later site visits in February and March 2022, the ponding water was being routed from the site entranceway to the depression. See Figure 1 and Photo 1 for site references.

6 LIDAR ANALYSIS

An isopach map showing thicknesses of landslide debris was created by comparing the bare earth digital elevation models from before and after the landslide events (July 2017 and November 2021). The comparison was made by subtracting elevations in one digital terrain model from the other. The analysis shows a depletion zone up to 15 m deep on the northern slide and scour up to 20 m deep along the southern debris flow track. The available LiDAR did not extend to the source area of the southern slide. Debris accumulations of up to 15 and 20 m thick for the northern and southern slides, respectively occur at the middle portions of the debris fans. Figures 2, 3 and 4 attached show the pre-slide and post slide LiDAR and results of the DEM subtraction.

Eyewitness accounts of the slide events observed that the slides came down in a series of surges over a few days. Debris presumably stacked up over previous deposits resulting in thick accumulations and slight convex profile at the front. It may also suggest the landslides had a moderate water content as higher water contents might have resulted in flatter runout angles.



LEGEND

- MOTI FEE SIMPLE BOUNDARY
- SECTION 16 BOUNDARY
- SLIDE EXTENTS

NOTES:

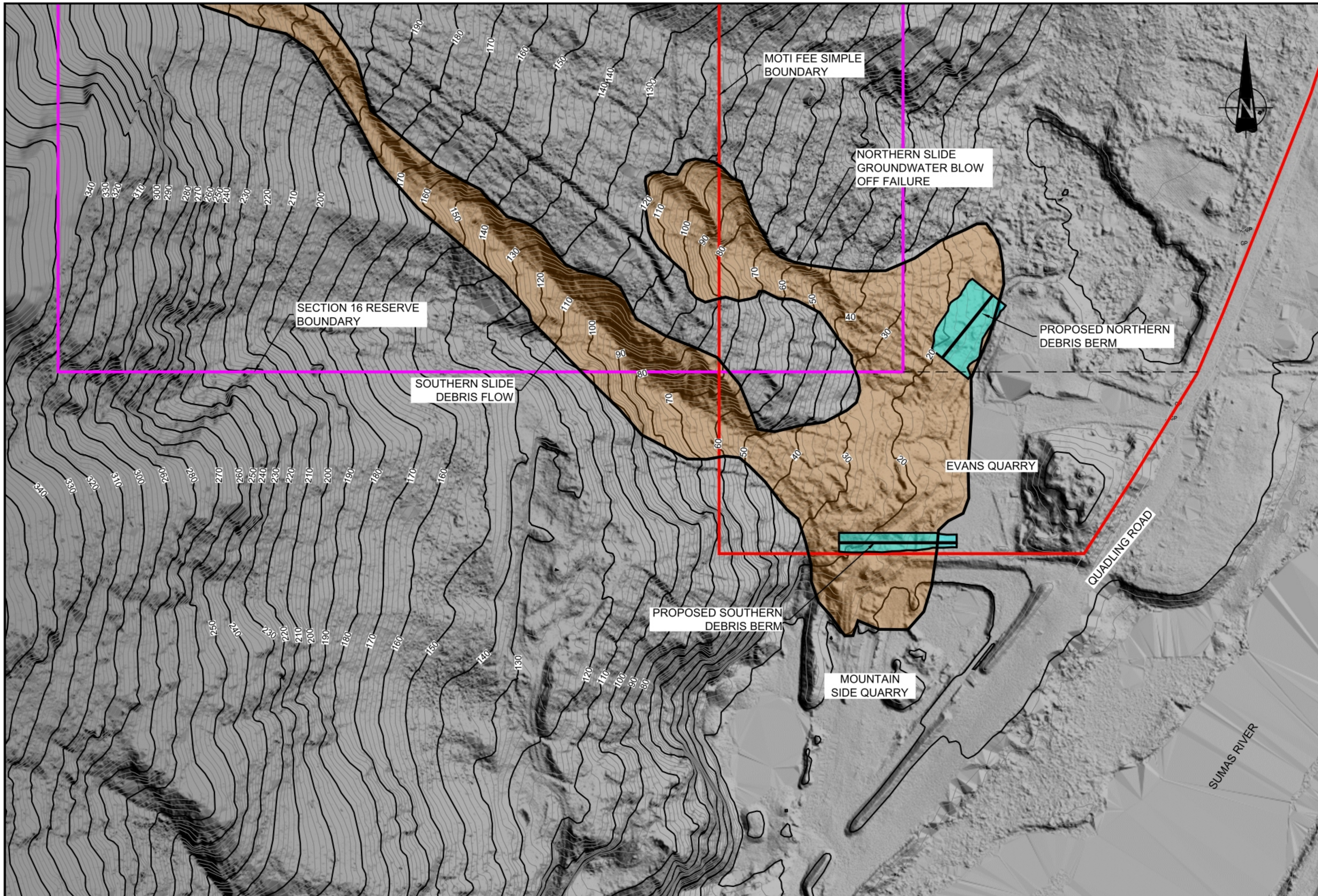
LIDAR TOPOGRAPHY PROVIDED BY MOTI, DATED JULY 13, 2017.

0m 20 40 60 80

1 : 2000

NOTE: TO BE READ IN CONJUNCTION WITH WOOD REPORT DATED MARCH 2022

CLIENT: MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE	SM	PROJECT: EVANS QUARRY RESIDUAL DEBRIS FLOW ASSESSMENT ABBOTSFORD, BC	DATE: MARCH 2022
	CHK'D BY: CD		PROJECT NO: VG07794.200
wood. Environment & Infrastructure Solutions Suite 600 - 4445 Lougheed Highway, Burnaby, BC V5C 0E4 Tel: 1-604-294-3811	DATUM: -	TITLE: JULY 13, 2017 TOPOGRAPHY	REV. NO.: A
	PROJECTION: -		FIGURE No. FIGURE 2
	SCALE: AS SHOWN		



LEGEND

- MOTI FEE SIMPLE BOUNDARY
- SECTION 16 BOUNDARY
- SLIDE EXTENTS
- PROPOSED SLIDE DEBRIS BERMS

NOTES:

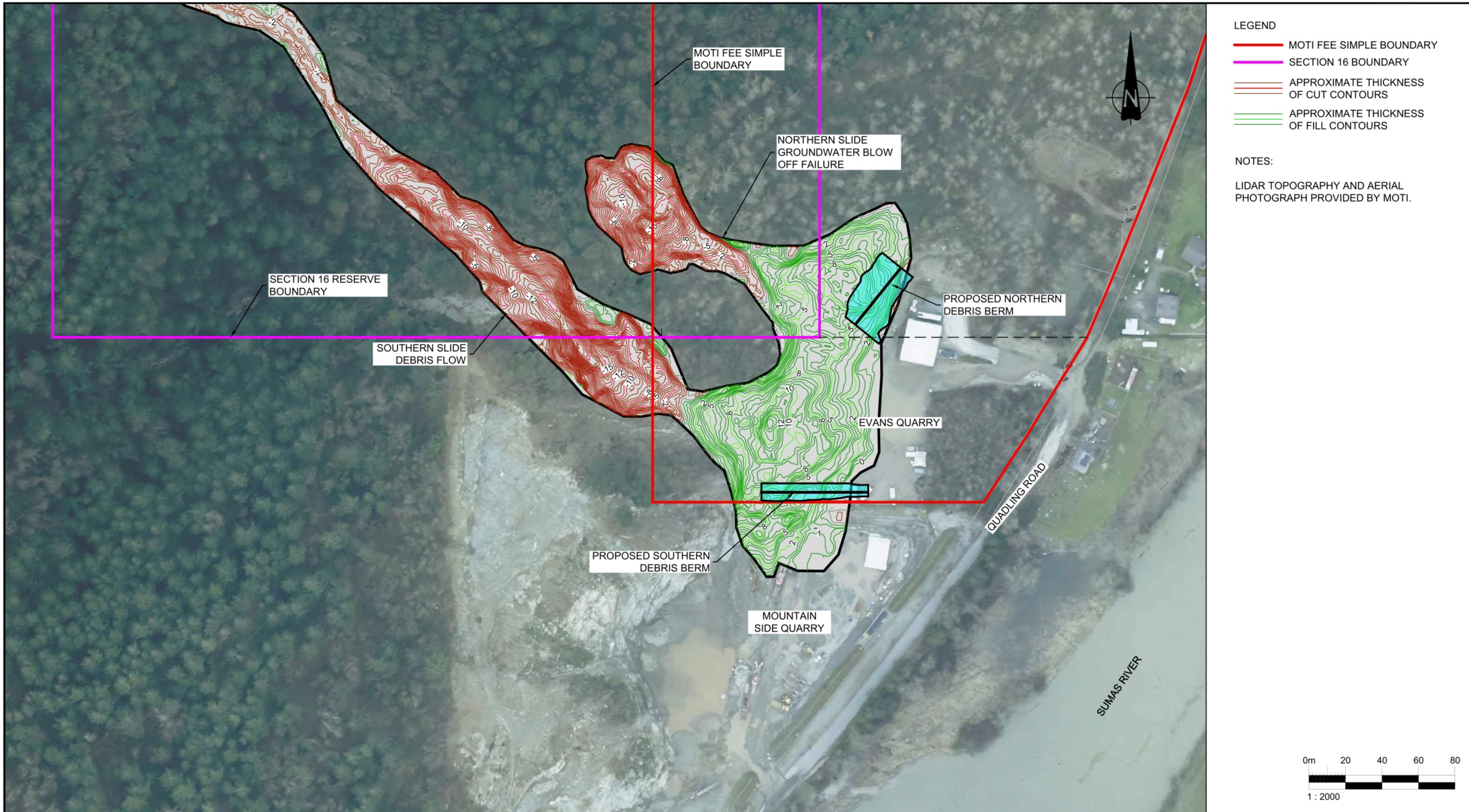
LIDAR TOPOGRAPHY PROVIDED BY MOTI, DATED DECEMBER 23, 2021.

0m 20 40 60 80

1 : 2000

NOTE: TO BE READ IN CONJUNCTION WITH WOOD REPORT DATED MARCH 2022

CLIENT: MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE	SM	PROJECT: EVANS QUARRY RESIDUAL DEBRIS FLOW ASSESSMENT ABBOTSFORD, BC	DATE: MARCH 2022
	CHK'D BY: CD		PROJECT NO: VG07794.200
wood. Environment & Infrastructure Solutions Suite 600 - 4445 Lougheed Highway, Burnaby, BC V5C 0E4 Tel: 1-604-294-3811	DATUM: -	TITLE: DECEMBER 23, 2021 TOPOGRAPHY	REV. NO.: A
	PROJECTION: -		FIGURE No. FIGURE 3
	SCALE: AS SHOWN		



NOTE: TO BE READ IN CONJUNCTION WITH WOOD REPORT DATED MARCH 2022	CLIENT: MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE	SM	PROJECT: EVANS QUARRY RESIDUAL DEBRIS FLOW ASSESSMENT ABBOTSFORD, BC	DATE: MARCH 2022
		CHK'D BY: CD		PROJECT NO: VG07794.200
	wood. Environment & Infrastructure Solutions Suite 600 - 4445 Lougheed Highway, Burnaby, BC V5C 0E4 Tel: 1-604-294-3811	DATUM: -	TITLE: ISOPACH BETWEEN JULY 13, 2017 TOPOGRAPHY AND DEC. 23, 2021	REV. NO.: A
		PROJECTION: -		FIGURE No. FIGURE 4
		SCALE: AS SHOWN		

7 AIR PHOTO REVIEW

WSP has reviewed stereo pair air photos for the site between 1940 and 2016 at 4 to 9-year intervals. The area of interest included from Barrowtown pump station north to the confluence of the Sumas River with the Vedder Canal and up to the height of land to the west. The purpose was to document historical landslide activity for context relative to the November 2021 events. Summary notes are presented below:

1940 – shallow sliding and accumulation of scree in main catchment area above Evans Quarry; the site was an undeveloped forested alluvial fan; Barrowtown Pump Station present; drainage appeared to flow on south side of fan closer to pump station; active sliding in Kennedy creek catchment further south.

1949 – shallow sliding and accumulation of scree in main and south catchments; craggy rock visible; narrow rockslide on north side of main catchment – runout did not extend to valley floor. Wide debris fan from Barorrowtown north; Quadling Road had been road built; single small structure had been built alongside road.

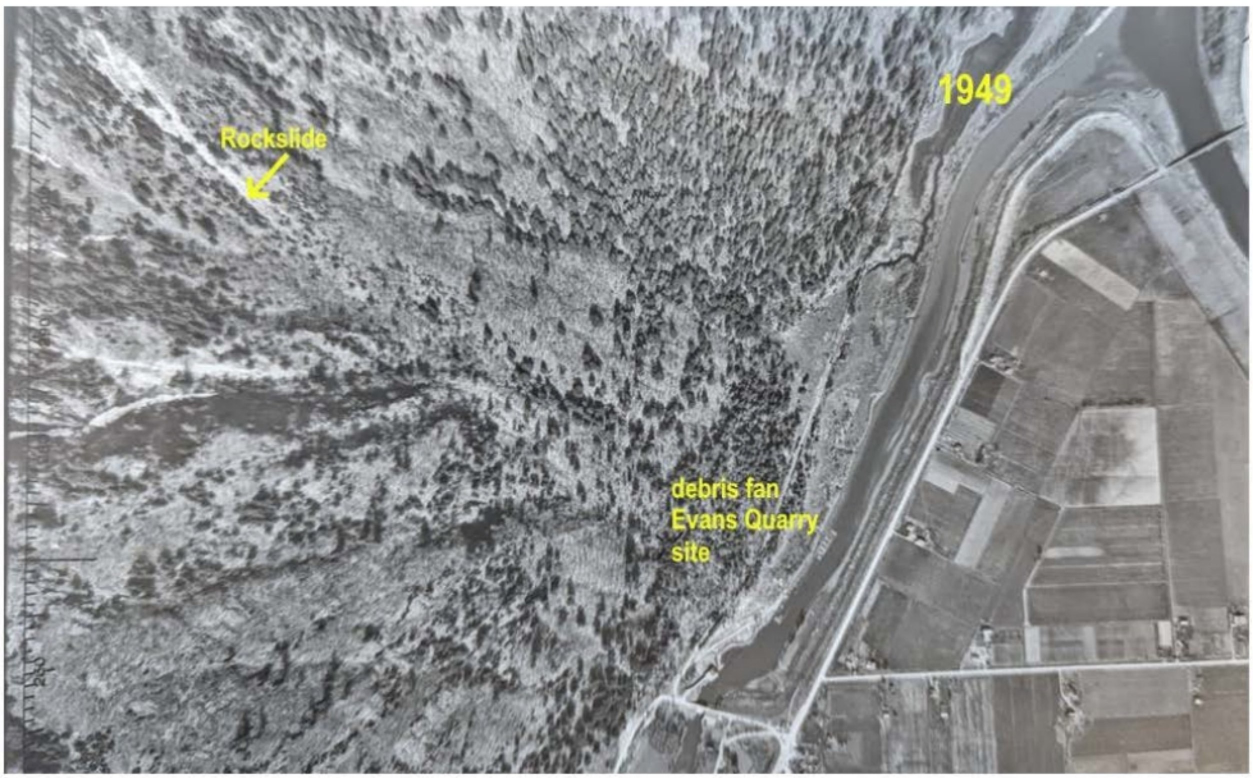


Photo 3 Air photo from 1949

1954 – As above.

1963 – Major pit development at Evans quarry had mined out debris fan; one main and two or three smaller benches above developed into granular material; distal end of a recent debris flow finger entered the pit on the west side.

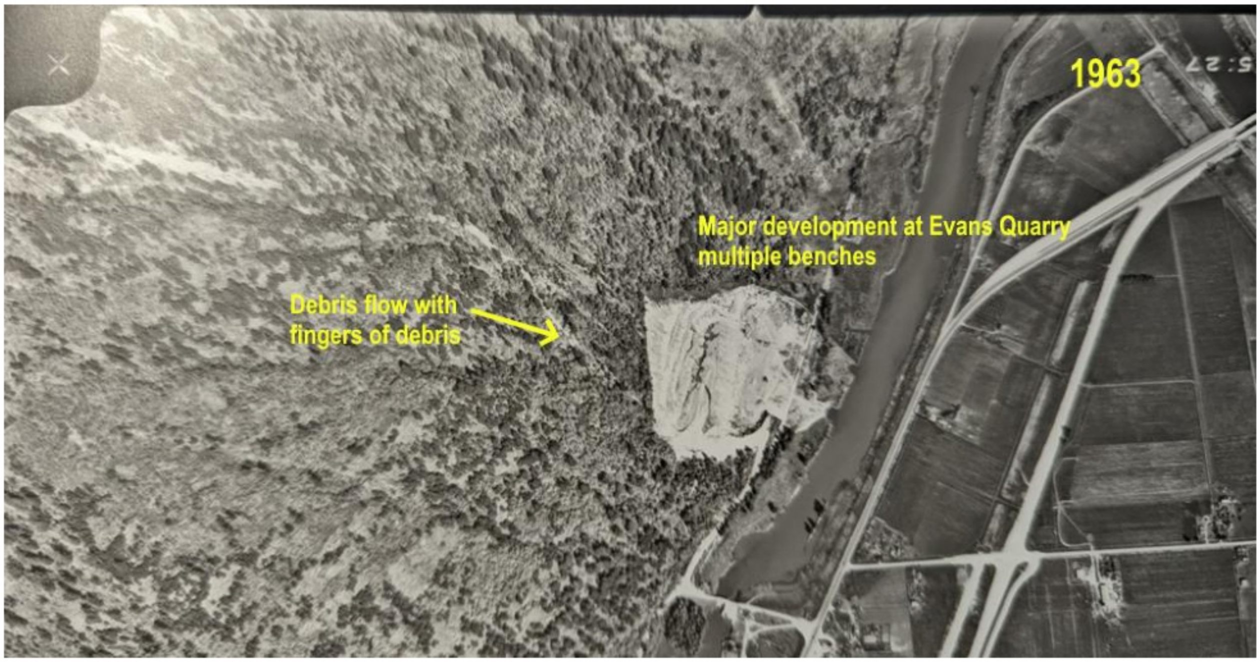


Photo 4 Air photo from 1963

1969 – Evans's quarry pit appears to have expanded to the north. Winter photo, snow, difficult to see ground conditions.

1974 – New clearing and gravel/quarry development on Quadling Road just north of Evans Quarry. Finger of debris visible upslope of pit but disappears below canopy – difficult to determine if extended into pit area as only partially visible below forest canopy. Photo was taken during a period of high water, Sumas River below the pump station was at high elevation Quadling Road.

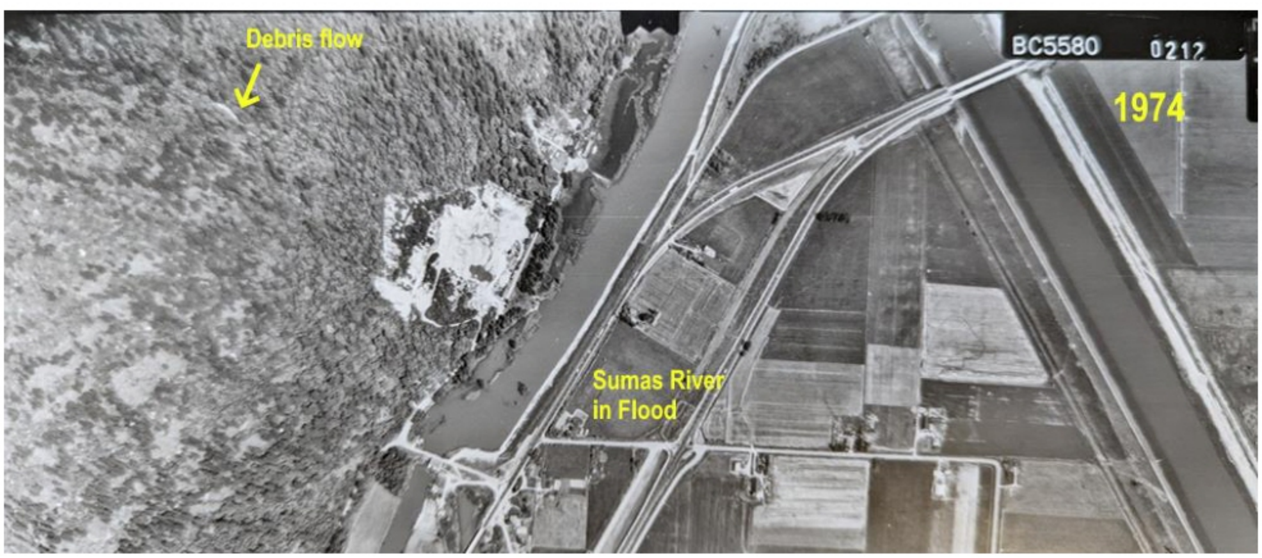


Photo 5 Air photo from 1974

1979 – Expanded gravel pit operations in north part of Evans Quarry property where the present home is situated behind the gate. The drainage appeared to discharge through the middle portion of the main pit – no evidence of culverts below the road. Craggy rock in headwaters of catchments – some fresh scree on north side of main catchment.

1982 – Expanded operations in northern pit. Appeared that new access was being developed to access upper areas of the main pit. Fresh linear debris / rockslide in main catchment headwall, did not appear to have reached the channel.

1986 – North pit has been reclaimed and is vegetated. Main pit appears spent – no sign of active working face. New linear debris / rockslide on the northern headwall of the southern catchment basins. Fill has been placed on section below Quadling Road where current residences are located.

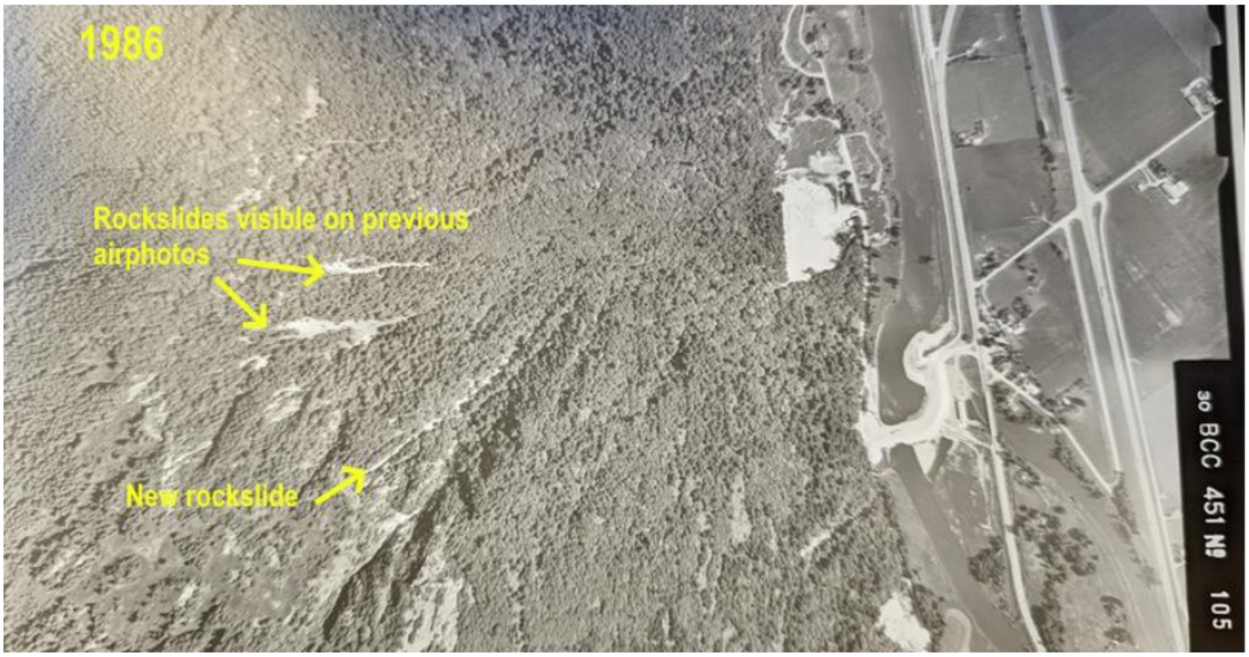


Photo 6 Air photo from 1986

1990 – Main pit is partially reclaimed. Older slide scars starting to heal.

1996 – Clearcut logging on top of Sumas Mountain on plateau above the drainage. Continued reclamation of the main pit. Failures on back of pit wall. Structures located in the reclaimed north pit site. Development of MSQG property to the south.

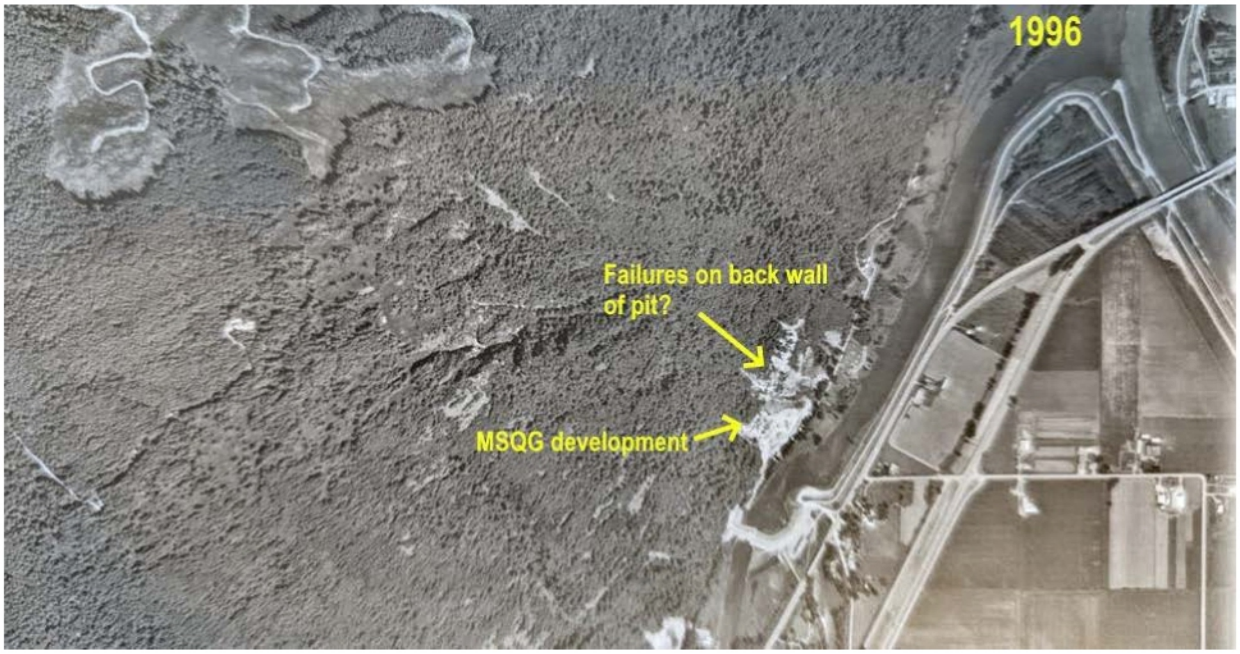


Photo 7 Air photo from 1996

2002 – modified and reduced gravel operations in main pit with Infill of forest in reclaimed areas. Southward expansion of MSQG. No change in drainage aside from ongoing healing of slide scars.

2008 – WCRL operations visible.

2016 – As above.

8 DESIGN CONSIDERATIONS

The overall mitigation will involve partial removal of the slide debris and regrading of materials to develop ditches, berms and debris flow/slide deflection or catchment structures. The potential for increased surface water flow and the routing of surface water flows are key issues that need to be resolved in addition to the slide and other geohazard issues at the site.

8.1 RESIDUAL SLIDE HAZARD

There is a remaining landslide hazard which must be considered during cleanup and for long term planning. The following considerations are noted:

1 Debris flow and open slope blow off failures are typically cyclical events requiring sufficient recharge of channel materials or build up of groundwater pressures, respectively. It is unlikely that events of similar magnitude will occur at the at the same locations in the short term since local groundwater pressures and groundwater drainage issues have been relieved in the short term, there has been some scour in the channel facilitating future groundwater drainage, and some stored materials along the channel have been removed. In the long term, as drainage channels become infilled and groundwater drainage is impeded, there is the

potential for future events. The re-occurrence interval of blow-off failures on other sites has been found on other sites to range from about 30 to 50 years. High precipitation and runoff, in part due to atmospheric rivers and/or warm rain on wet snow events are also major influences on slide occurrences and may occur more often.

2 The erosion and slides have resulted in over steepened soil slopes along the scarps and sides of the debris flow channels. Ongoing ravelling and shallow sliding are anticipated which has also been reported by MSQG. Tension cracks behind the southwest corner of the northern (blow off) failure may result in additional areas of sliding. Ravelled materials ranging from silt or sand to boulders may roll, bounce, slide or transported by flowing water down onto and possibly beyond the present area of debris. Trees or other larger debris may also come down.

3 The forested slopes immediately north of the north (blow off) failure appear to be unstable and show signs of shallow movement. There may also be a hazard of sliding in the "forested peninsula" between the two slides. These movements could contribute additional colluvial or alluvial debris.

4 There is the potential for additional groundwater blow off failures elsewhere on the slope north of the subject property, particularly in areas away from the two present failures that are presently providing some degree of groundwater drainage.

5 Groundwater blow off failures appear to have previously occurred on the back wall of Evans Quarry as seen in the 1996 air photo. The November 2021 event appears to have been the largest to date, at least over the period covered by the air photos.

6 The southern debris flow was initiated by shallow sliding in the gully headwall which travelled down to a open middle reach overlain by thick colluvial deposits. Following the event, only a small fraction of the colluvium stored in the middle reaches had been eroded and there appeared to be potential for future sliding on gully sidewalls and headwalls in both the main and southern drainages. Future debris flows do not appear to be limited by supply.

7 There have been frequent shallow slides in the gully sidewalls and headwalls in the drainage above Evans Quarry based on the air photo review. Most did not initiate high runout debris flows probably because of marginal channel confinement (required for debris flow initiation).

8 Some slides did trigger debris flows which travelled down to the base of Sumas Mountain about halfway across the MOTI fee simple property. If we include 2021, and those visible in 1963 and 1974 air photos this would translate to a return period of 1 in 27 years for that portion of the property. Return period would be higher (more frequent) on upper slopes and lower (less frequent) down on the valley floor and dependant on proximity to the drainage. Future changes due to climate change may occur.

9 Debris flows have occurred in this system previously suggesting that the recent event is the latest of a succession of events. Evans Quarry was likely partly established on a colluvial fan consisting of successive debris flow deposits that have been occurring since deglaciation. The WCRL facilities are likely within the footprint of the former fan.

10 Because of the open middle reach, it should not be assumed that future debris flows will discharge on the valley floor at the same location as the 2021 event. The lateral extent of the hazard appears to extend from near the MSQG property to just north of the closed depression (about 250 m wide area).

Mitigation therefore needs to consider future gravitational falls/sliding as well as future debris flows and debris slides.

In the short term, gravitational falls of individual particles will tend to occur out to a line of about 27° to the horizontal extending from the bottom of the over steepened pitch to the toe area. Debris flows or water laden slides may occur to much flatter angles (depositional angles of 10 to 15° are typical). These runout footprints roughly cover much of the parking lot and existing structures. Work within this area should proceed with caution and suitable safety precautions should be taken. See further discussion below.

Portions of the MOTI fee simple land at the base of Sumas Mountain are subject to longer term hazard from landslides and debris flows. Detailed runout analysis is beyond the scope of this report, but significant hazard appears to extend to the present WCRL building and beyond for a 250 m wide swath for debris flows and slightly wider for open slope failures.

While there is no provincial legislation that pertains to acceptable landslide hazard for commercial and industrial use, the EGBC guidelines for Landslide Assessments for Proposed Residential Developments (2010) provide a framework to evaluate the hazard. The guideline references a 1973 BC Supreme Court ruling for residential development on the Sea to Sky corridor which could not proceed based on an estimated return period of 1/10,000 for a major landslide. There is also discussion of the MOTI adopted threshold of less than 10% in 50 years or annual return period of not more than 1/475 for landslide assessments for residential developments.

The Fraser Valley Regional District has published "Hazard Acceptability Thresholds" for development approvals. For a new development, areas subject to debris flows at frequencies greater than 1/50 are categorized as "Not Approvable" regardless of mitigation. Areas subject to return periods between 1/50 and 1/10,000 have a matrix which may allow for some repair, reconstruction or new buildings stipulating siting requirements or protective works and dependant on level of hazard. Only areas with less than 1/10,000 annual return frequencies from debris flow hazard are approvable without condition.

The level of hazard posed by debris flows and landslides would vary depending on proximity to the channel and toe of the slope but would be considered unsuitable for residential development based on the guidelines discussed above.

The proposed landslide protection berms discussed in Section 10 would be positioned above the main building area and along the southern property boundary. These have been sized according to the maximum available room but should not be considered as adequate to protect the building from all eventualities. Nothing is proposed for the yard as it does not appear possible / practical to fit in a berm while maintaining adequate room for truck turnaround and other essential site operations.

To address these shortcomings, it is strongly recommended that MOTI / WCRL adopt a site usage restrictions and site evacuation / shutdown criteria during severe storms. Further preliminary details are provided in Section 9.0.

8.2 HYDROTECHNICAL CONSIDERATIONS

The pre-slide water management configuration apparently routed surface and seepage water to a depression located north of the WCRL structure and west of Quadling Road. Discussions with MOTI and WCRL indicate that the water seeped into the ground at this location. The groundwater presumably flowed underground to Sumas

River; there is no knowledge of a culvert conveying flow from the depression. Following heavy rain, this area remained ponded for several days as the water infiltrated into the ground. It is not possible to quantify the statistical probability (or return period) of ponding in this area; however, informal discussions with those familiar with the site suggested that ponding occurred on a regular basis and that the infiltration capacity of the underlying ground would not meet any kind of reasonable design standard for drainage of the site.

Following the landslide, there was significant ponding of water in the centre of the MOTI site. This ponded water was flowing across the site entrance to a temporary ditch leading to the depression to the north. The ponding may have been caused by surface runoff, but there may also have been a significant component of groundwater seepage. Water management infrastructure should therefore aim to address these water flow conditions where practical, although a complete removal of the groundwater inflow, such as installing a cut-off wall combined with pumping, is unlikely to be feasible.

Drainage paths in the area appear to have been permanently altered due to the landslides, and returning the site to pre-slide drainage conditions is not considered practical or desirable due to uncertainties associated with the capacity and route of the subsurface flow paths out of the receiving infiltration depression. Moreover, it is likely that the incised gullies will have higher flows due to reduced times of concentration, reduced groundwater conveyance through the surficial materials on the slope and increased groundwater seepage from the bedrock. The southern slide area is now a deeply incised gully and attempting to convey surface water to the north across the MOTI property is likely to lead to issues during high flow events. Consideration also needs to be given to private residences that are located between the previous infiltration area and the Sumas River and directing water away from this area is likely to carry less risk to these properties.

Suspended sediments in stormwater runoff may be a concern, particularly if the water is discharged directly to Sumas River. Sediment loading is anticipated to be highest in the period after the debris slide, as the slide has exposed significant volumes of sand and finer particles. Over time, finer particles will be washed out leaving the larger gravel and cobbles, resulting in the slope 'self-armouring'. However, further ground movement in the catchment in the future or higher flows would expose new sediments and additional sediment transport.

Installation of a sediment pond or area would help to settle out sediment that is contained in the storm water runoff, before discharge to Sumas River. Land area at the site is very limited, so a pond large enough to allow settlement of finer particles such as clays or glacial flour particles and fine silts is not practical.

Collection of any runoff from the MSQG quarry property is not recommended, as the quarry runoff may be subject to additional environmental regulations and considerations.

9 TEMPORARY SITE DRAINAGE

In October 2022 WSP was requested to attend the Evans Quarry site to determine if there were temporary measures that could be put in place to reduce the amount of ponded water on the site and to provide temporary drainage until permanent drainage structures could be permitted and constructed for the site.

Following the debris slide and flooding in November 2021, there has been no drainage outlet for water from the west side of the site. Occasionally, during periods of heavy or prolonged rainfall, water would eventually spill over across the site entrance and reach a small outlet to a soakaway pit northeast of the site.

On November 2nd and 3rd, WSP attended site to excavate test pits and undertake infiltration tests to determine if a temporary ditch and soakaway (infiltration area) could be constructed on site.

Four infiltration tests were undertaken as described in detail in Appendix B. Infiltration testing showed that the underlying soil hydraulic conductivity had an average *k* value of 3.18×10^{-4} m/s

A general rule of thumb is that a soakaway is feasible if the hydraulic conductivity is greater than 1×10^{-5} m/s and if there are suitably low groundwater conditions in the surrounding area. All four tests resulted in hydraulic conductivity values greater than 10^{-4} m/s; therefore a soakaway will work effectively at least as a temporary measure for site drainage. As discussed below, a soakaway was constructed and at the time of writing, was successful in reducing local ponding.

10 DRAINAGE DESIGN

10.1 OVERVIEW

Following the initial site visits and a visual review of the large volume of water that was reporting to the closed depression which handled most of the runoff from the catchment, WSP was concerned that in the long term, the amount of water infiltrating in this zone could have adverse effects on the residences that were constructed between the site and the Sumas River. These impacts could be related to flooding, foundation issues and impacts to water quality in the residential wells (if there are any). For this reason, rather than reinstating the pre-slide drainage paths, water was diverted away from this area, across the road with a positive outlet to the Sumas River.

This section describes the permit level design for drainage improvements on the site. The drainage system comprises four primary components. These are:

- Collection ditches
- Infiltration area
- Culvert Section
- Outfall Area

Each of the primary components and their design considerations is described below following a description of the hydrology.

10.1.1 HYDROLOGY

Runoff calculations were undertaken using the Soil Conservation Service (SCS) methodology in HEC-HMS software to estimate the flows for the design. Estimation of model parameters were as follows:

- **Drainage Area:** The total drainage area to the site, shown in Figure 5 below, was derived from Light Detection and Ranging (LiDAR) topographic data. The catchment area was estimated to be 0.67 km^2 or 67 hectares.
- **Rainfall depth:** Two nearby Environment Canada Intensity Duration Frequency curve locations were considered for estimating rainfall depth. The site is close to Mission West Abbey (1105192) and Huntingdon

Vye Road (1103636). It was concluded that the Mission site is more appropriate for use because of the proximity to steep mountains in comparison to the Huntingdon site.

The 1 in 200 year rainfall event was adopted for the design. Including an allowance for orographic effects at the site and an allowance for snowmelt, the total 24 hr rainfall depth was estimated to be 185 mm.

- **Catchment Time of Concentration (T_c):** There are several methods to estimate T_c for runoff estimation. The methods typically are not suitable for use in forested, mountainous terrain and can give unrealistically short T_c which leads to an overestimation of flows from the catchment. Methods have been developed for use in British Columbia. Coulson (1998)[1] provides curves for the estimation of T_c for steep forested terrain typically found in British Columbia. From the curves provided, T_c was estimated to be 50 minutes.
- **SCS Runoff Curve Number:** Estimating the runoff curve number (CN) is largely a matter of judgement on the engineers part and depends on the surface cover (hard standing area such as pavement or concrete), infiltration capacity of the soil and the steepness of the topography. The underlying sands and gravels have a high infiltration capacity; however, site visits to the upper part of the basin revealed that, although there is not a well-defined stream in the upper catchment, surface water infiltrates and then exfiltrates at various locations. Given the very steep terrain, the runoff is much higher than might typically be expected for sand and gravel. A judgement was made to adopt a CN of 55 for use in the HEC-HMS model.
- **Rainfall Distribution Type:** The SCS provides four different rainfall distributions for a 24 hr rainfall event. The SCS recommends a Type 1A distribution for the Pacific Northwest which was therefore adopted for use in the runoff calculation.

Using HEC-HMS, the peak discharge was estimated to be 3.0 m^3/s for a 1 in 200-year storm with an additional allowance for snowmelt. The rainfall hyetograph and flow hydrograph for a 24-hour rainfall event are shown in Figure 6.

[1] Coulson, C.H. Manual of Operational Hydrology in British Columbia, Ministry of Environment, Lands and Parks. 1988.

Figure 5 Catchment Area to Site

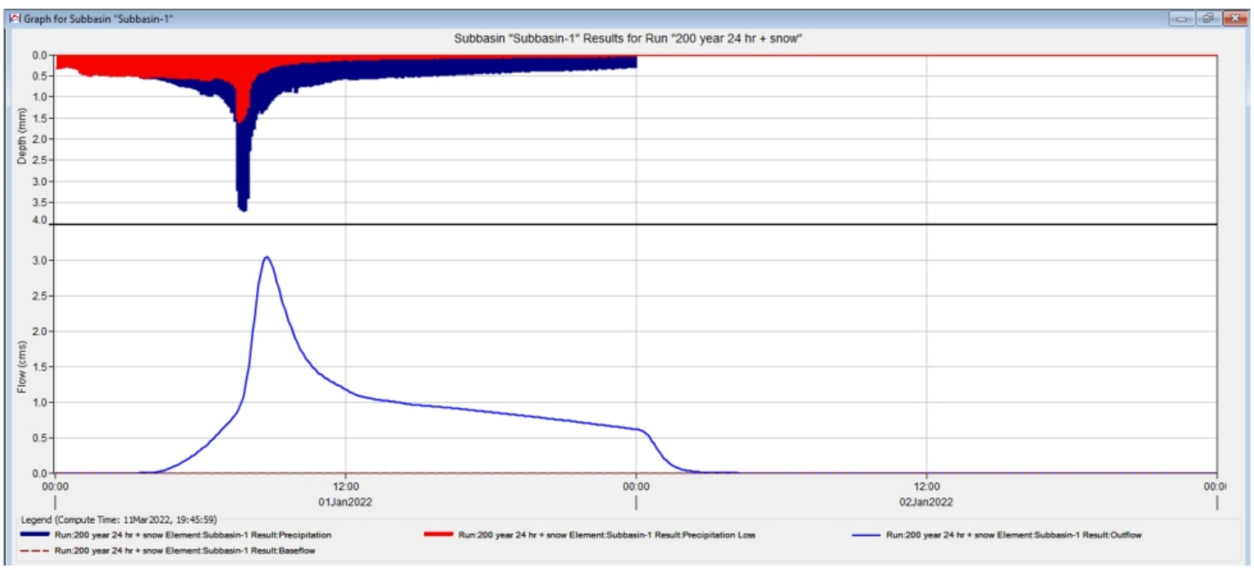


Figure 6 Modelled 1 in 200 Year plus Snowmelt Runoff Hydrograph

10.1.2 COLLECTION DITCHES

WSP has prepared issue for permit (IFP) drawings that show the proposed layout and configuration of ditches and berms. These are included in Appendix B. Figure 7 shows an overview of the various component on the site. The main ditch upstream of the confluence with the secondary ditch has the following geometric properties and rationale for the design:

- The main channel gradient was kept as low as reasonably possible at 1% to limit the ultimate depth of excavation across the road and through the trees at the culvert outlet. The deposition of sediment transported from the upper basin is likely and the frequency of maintenance will depend largely on movement of remaining colluvium in the drainage area. Trapping sediment is a desirable trait to reduce overall total suspended solids (TSS) reaching the Sumas River.

  The main channel is designed with a trapezoidal channel shape with 1.5 m wide bottom width and 1.2 m minimum depth. Side slopes are 1.7H:1V. Upstream of the infiltration zone, the channel will be lined with geomembrane to reduce seepage losses resulting from the slack gradient. Over the geomembrane, a protective geotextile layer will be covered with 100 mm to 200 mm cobbles to provide ballast for the lining and to provide armour protection to the ditch which will be constructed over easily erodible materials.
- The secondary channel will have similar geometric characteristics however the gradient will vary between 15% and 7% depending by following the terrain to connect to the main ditch.

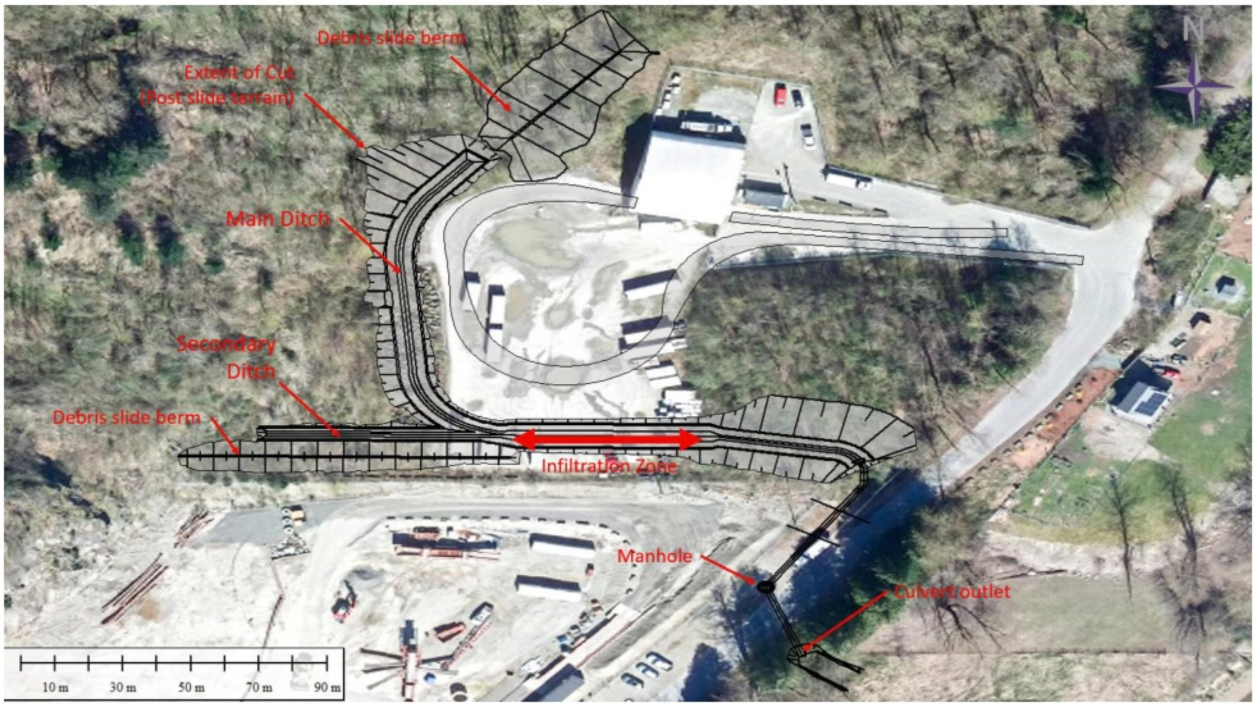


Figure 7 Drainage Features

10.1.3 INFILTRATION AREA

The infiltration zone has a trapezoidal channel shape with a bottom width of 3 m. The gradient of the infiltration area will be flat; a positive hydraulic gradient will form when the infiltration capacity of the system is exceeded and flow spills over into the downstream culvert. Geotextile fabric will underly the riprap armouring; however there will be no impermeable geomembrane to allow for infiltration of low flows. The invert has been designed to be at approximately the same level as the current adjacent quarry floor to reduce the chance that water from the infiltration area will seep into the quarry area. The temporary infiltration area constructed in November 2022 appears to be functioning well. WSP has not calculated the design capacity of the infiltration area; it is intended to reduce the total suspended solids getting to the Sumas River under normal low flow conditions. During a storm event, the depth will rise in the infiltration area and spill over into a culverted section.

Occasional maintenance may be required if the infiltration zone becomes filled with sediment.

10.1.4 CULVERT SECTION

Excess flow from the infiltration area will flow into a culverted section under Quadling Road to the Sumas River. The culvert has been designed with the following components and design considerations:

- The culvert will be 1.2 m diameter concrete, laid at a gradient of 1% to reduce the depth of excavation at the outlet to the Sumas River.
- There will be a precast concrete headwall at the upstream end. There will be no headwall at the outlet for reasons described below.
- From the boundary of the site, the culvert will parallel alongside Quadling Road; where a ditch is not practical for space reasons
- The culvert will cross Quadling Road obliquely at an approximate angle of 45 degrees. There will be a 2.4 m diameter manhole at the bend.
- The culvert will feature trash screens at both ends to prevent debris from entering and to prevent public access.

10.1.5 OUTFALL AREA

The outfall has been designed to limit, as far as possible, the impact on mature cedar trees that line Quadling Road in this location and to place the point of discharge from the system on City of Abbotsford land. This has been achieved by limiting the gradient of the upstream drainage system to reduce the depth of excavation. The culvert outlet will not have a headwall and will project from the slope; discharging to a riprapped apron. The apron will extend down the embankment onto the Sumas River floodplain. During periods of high flow, the Sumas River floods this area. There is an existing indistinct flow path across the floodplain to the Sumas River. It is expected that over time, a minor channel may form from the culvert outlet to the Sumas River. However, it is expected that most minor flow events will soak into the infiltration area and only higher flows will reach the outfall directly. During these periods of high flow, the discharge area will likely be well saturated or flooded; reducing the impact of the discharge.

10.2 RECOMMENDATIONS FOR DEBRIS REMOVAL AND PROTECTION BERMS

The following preliminary recommendations are made in relation to debris removal and the proposed protection berms:

- Due to the residual slide and debris fall hazard, persons on foot should not be permitted on the slide debris or near the crests of the slopes over steepened from the slides (i.e., stay away from the head scarp or gully sidewalls and runout areas on crests of the slide debris).

- Cleanup may be considered using tracked equipment equipped with protective screens on the cab to provide some degree of protection from possible debris impact. It is recommended that all work should be completed under dry or low precipitation conditions using a spotter. Larger equipment fitted with caged cabs is recommended. The operator should work from a position of safety and wherever possible on higher ground away from potential paths for rolling rock or slide debris.
- Debris should be removed and brought down to the approximate pre-landslide surface considering positive drainage for the water management design and protection berms. Temporary cuts should be no steeper or higher than 1H:1V and 3 m high. Cuts above 3 m high should not exceed 1.5H:1V. The work will likely need to proceed from the apex of the debris cone down so access is not blocked by over steepened slopes created as it would occur if a face was advanced into the toe.
- A berm should parallel the ditch on the downslope side to provide some level of protection to the WCRL facilities and other assets using available material. It appears that it will not be possible to protect the MOTI area from a similar-sized or even smaller event in the future without encroaching on the previously existing level work area (note that the debris was up to 15 m thick). The berm is proposed in behind the main building for WCRL and along the fence line between MSQG to help guide debris away from this higher use MSQG area. The following comments are made regarding berms.
  - Berms should be oriented at an angle relative to the anticipated slide to help deflect material to the extent possible.
  - Berms should be constructed as high as possible given the space constraints. WSP anticipates the berms may be 3 to 4 m high.
  - Side slopes should be appropriate to the material used. The material from the rejected material from previous gravel pit operations may be used however slopes should not exceed 1.7H:1V due to high fines content. If the granular slide materials are to be used side slopes may be steepened to 1.5H:1V. Berms should be constructed in lifts not thicker than 0.3 m and compacted to 90% proctor density. Fronts should be faced with erosion resistant material.

10.3 SITE USAGE AND SHUTDOWN CRITERIA

The yard area should be considered as a high-hazard area with respect to landslides, debris flows and rolling rock, particularly under high precipitation conditions. Usage should be limited to temporary activities (e.g., turning a truck around, unhooking a trailer etc.). No buildings or site offices should be constructed in this area.

As discussed above, the landslide berms behind the WCRL building will offer limited protection to the building area. Operations should be halted, and personnel evacuated from the site in the event of a major storm event. WSP recommends adopting the British Columbia Timber Sales Wet Weather Shutdown Criteria (WWSC) described in Statlu (2018) appended for reference. The site falls into what is considered Zone 3 climatic zone in which the following shutdown criteria apply:

- 40 mm of rain at start or before end of shift (12 hours);
- 70 mm of rain over a 24 hour period;
- 100 mm of rain over a 48 hour period; and
- 130 mm of rain over a 72 hour period.

Once shutdown criteria have been exceeded, work should remain shut down for at least 24 hours after the hazardous conditions end. If the 48 or 72-hour rainfall criteria are exceeded, work should remain shut down for at least two days (48 hours).

Note that the Statlu report contains a section of additional risk factors. The presence of each additional risk factor shifts the Zone down one level (increases the Zone number by 1), hence, resulting in shutdown at lower levels of precipitation. The most likely risk factors at the Evans Quarry sites are RoS (rain on snow) and WS (warm temperatures with snow at site).

Table 1 WWSC adapted from Statlu March 2018 report. Based on climate data from online Climate WNA Evans Quarry is within Zone 3 (~ 1800 mm/yr).

ZONE	ZONE (ANNUAL PRECIPITATION)	TIME PERIOD			
		AT START OF OR END OF SHIFT (12-HR)	24-HR	48-HR	72-HR
1	Very wet (3000 mm to 4000 mm or more)	60 mm	100 mm	150 mm	200 mm
2	Wet (2500 mm to 3000 mm)	50 mm	80 mm	120 mm	160 mm
3	Average (1500 mm to 2500 mm)	40 mm	70 mm	100 mm	130 mm
4	Dry (750 mm to 1500 mm)	30 mm	50 mm	80 mm	110 mm
5	Very dry (less than 750 mm)	20 mm	30 mm	50 mm	80 mm
6	Identified Unstable Conditions	10 mm	20 mm	30 mm	40 mm

Workers should check forecasts and predicted or reported high rainfall and snowfall (particularly Public Weather Alerts published by Environment Canada on the Environment Canada website) when periods of adverse weather may potentially occur.

The total rainfall and temperature should be measured with a rain gauge and thermometer at the site and recorded a minimum of twice per day (the gauge should only be emptied at 12-hour intervals to preserve the 12-hour totals). Siting of the gauge should preferably in an open area and not under the tree canopy. Alternatively, automatic recording weather instruments such as those available from Davis Instruments could be used. It should be noted that higher elevations will have greater rainfall amounts than that recorded at the project sites. However, the shutdown criteria allows for this variation. A Wet Weather Shutdown Guidance (WWSG) Field Table is attached to this report for data recording purposes.

Workers should also monitor the stream, a sudden increase (or decrease) in flow or increased muddying of the water may signal an impending debris flow and the site should be evacuated.

11 CLOSURE

This report is intended to provide the design basis and considerations for the permitting of drainage improvements at the Evans Quarry site on Quadling Road.

This report has been prepared for the exclusive use of the Ministry of Transportation and Infrastructure for specific application to the project described herein. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. WSP E&I Canada Limited accepts no responsibility for damages suffered by a third party as a result of decisions made or actions based on this report. This report has been prepared in accordance with accepted practices in the oil sands industry. No other warranty, expressed or implied, is made.

Sincerely,
WSP E&I Canada Limited

Geotechnical:

Prepared by:

PROFESSIONAL PROVINCE OF C. A. DAVIDSON # 35158 BRITISH COLUMBIA GEOSCIENTIST

Feb 16, 2023

Chris Davidson, MSc, PGeo
Engineering Geologist

Reviewed by:

Drum Cavers, MEng, PEng, PGeo
Principal Engineer

Hydrotechnical:

Prepared by:

PROFESSIONAL PROVINCE OF G. P. GRAHAM # 43934 BRITISH COLUMBIA ENGINEER

16/02/23

Geoff Graham, PEng
Associate Water Resources Engineer

EGBC Permit to Practice: 1004452

12 REFERENCES

- Association of Professional Engineers and Geoscientists of British Columbia. 2010. Guidelines for Legislated Landslide Assessment for Proposed Residential Developments in BC.
- Armstrong, J.E. 1959. Surficial Geology, Chilliwack, Sumas and Kent Municipalities, New Westminster and Yale Districts, British Columbia.
- City of Abbotsford, 2011. Development Bylaw No. 2070-2011 Schedule F – Engineering Standards and Specifications.
- Roddick, J.A. 1965. Geology Pitt Lake. Vancouver East Half. British Columbia. Map 1151A.
- Statlu Environmental Consulting. 2018, Wet Weather Shutdown Criteria Harmonization – BCTS Chinook and Strait of Georgia Business Areas March 15, 2018.
- Wood Environment & Infrastructure Solutions. 2022a. Preliminary Geotechnical and Hydrotechnical Comments Based on Recent Field Reconnaissance's – Evans Quarry Residual Debris Flow Assessment, Abbotsford BC – Rev 0. 27 January 2022.
- Wood Environment & Infrastructure Solutions. 2022b. Emergency Drainage and Additional Hydrotechnical Considerations – Evans Quarry Residual Debris Flow Assessment, Abbotsford BC – Rev 0. 10 February 2022.
- WSP E&I Canada Ltd. 2023. Site Visit and Field Fitting of Temporary Drainage. Memo to MOTI. 22 January 2023.

Appendix A

Temporary Site Drainage Memo

MEMO

TO:	Satish Prasad, P.Eng.
COMPANY:	Ministry of Transportation and Infrastructure
FROM:	Geoff Graham, P.Eng.
DATE:	22 January 2023
CC:	
PROJECT NO.:	VG07794.200
SUBJECT:	Evans Quarry, Quadling Road, Abbotsford Site Visit and Field Fitting of Temporary Drainage

1 INTRODUCTION

In October 2022 WSP E&I Ltd (WSP, formerly Wood) was requested to attend the Evans Quarry site to determine if there were temporary measures that could be put in place to reduce the amount of ponded water on the site and to provide temporary drainage until permanent drainage structures could be permitted and constructed for the site.

Following the debris slide and flooding in November 2021, there has been no drainage outlet for water from the west side of the site. Occasionally, during periods of heavy or prolonged rainfall, water would eventually spill over across the site entrance and reach a small outlet to a soakaway pit northeast of the site.

On November 2nd and 3rd, 2022 Geoff Graham, P.Eng. and Chris Davidson, P.Geo., attended site to excavate test pits and undertake infiltration tests to determine if a temporary ditch and soakaway (infiltration area) could be constructed on site.

This memo describes the activities undertaken on site and the temporary measures that were put in place.

2 OVERVIEW

WSP staff arrived on site at approximately 9am and met with a survey crew from McElhanney. Weather was clear and sunny. After a tailgate safety meeting, the surveyors were asked to lay out the proposed ditch as shown in blue on Figure 1. The surveyors were also asked to survey levels on the existing ditch that flows northeast across the back of the site and to collect general topography around the ponded area.

With no drainage on site, Figure 2 shows the ponded water that has been typically present at various times since the flood and debris slide.

At approximately 10am, contractor McDonald Ross arrived with a John Deere 245 excavator to excavate test pits at the locations shown in red on Figure 1. The test pits could not be excavated perfectly in line with the ditch because of wood debris and other material piled on the site that was in the way and also to keep the infiltration pit as far from the adjacent quarry as practical.

Test pits were excavated to a depth that matched the base of the adjacent quarry floor; approximately 9.1 m elevation. The excavation revealed densely compacted gravel and shattered rock. At a depth of approximately 0.5 m below surface there was a band of very dense, compact material that was assumed to be the original ground level before the slide and mud deposition on the site. This effectively impermeable layer was probably informally compacted by heavy equipment used on site and was probably the main reason standing water would not infiltrate appreciably over time in this area. Below the densely compacted shallow layer, the excavation revealed

WSP E&I Canada Limited
111 Dunsmuir Street
Vancouver BC V6B 6A3

T: +1 604-664-4315
wsp.com

surficial geology that appeared at first glance to be suitable for the construction of an infiltration pit to provide temporary relief from surface water runoff at the site. To check this, four infiltration (or percolation) tests were undertaken at the bottom of the test pit. The procedure is described below.

Figure 1 Image showing extent of proposed ditch on Evans Quarry site

Figure 2 Ponded water on site on November 2nd 2022.

Figure 3 Excavating the test pit

3 INFILTRATION (PERCOLATION) TESTS

To determine if the ground conditions are suitable for a soakaway, the hydraulic conductivity '*K*' (rate at which water will flow through a medium) of the underlying soil must first be determined. The *k* value of the soil can be estimated by undertaking an infiltration test at the site where the soakaway is to be constructed. The procedure for the infiltration test was as follows:

1. A large pit was excavated to the desired depth for the soakaway which, in this case, was level with the bottom of the adjacent quarry floor (Elevation 9.1 m). The pit was approximately 2.7 m deep. The pit walls appeared stable; however, to allow safe entry for testing, the sides of the pit were battered back at an approximate 2H:1V slope above 1.2m from the pit floor. As shown in Figure 3, the pit was dry and there were no visible seeps or wetting of the soil.
2. In the bottom of the large pit, a 300 mm cubic volume was hand excavated using a small hand shovel and trowel.
3. The small cube was then filled with water and allowed to drain to initially wet the cube prior to timed testing.
4. The cube was then filled to 75% full and allowed to drain to 25% full and the time for the water level to drop 150 mm was recorded. The cube was refilled three more times for a total of four tests (a minimum of three is normally undertaken).

As expected, the time for the water level to drop steadily increased until the fourth test. At this point, the sides of the small cube had deteriorated to an extent that the recorded time was suspect. The average time for the water level to drop on the fourth run was 3 min 56 sec (236 seconds).

Table 1 Infiltration Test Data

TEST	TIME (HH:MM:SS)	ESTIMATED HYDRAULIC CONDUCTIVITY '*K*'
1	0:02:54	4.31×10^{-4} m/s
2	0:03:40	3.41×10^{-4} m/s
3	0:05:15	2.38×10^{-4} m/s
4	~~0:03:04~~	
Average of first three tests	0:03:56	3.18×10^{-4} m/s

A general rule of thumb is that a soakaway is feasible if the hydraulic conductivity *k* value is consistently greater than 1×10^{-5} m/s and if there are suitably low groundwater conditions in the surrounding area. Given that all four tests resulted in values greater than 10^{-4} m/s, a soakaway will work effectively at least as a temporary measure for site drainage.

4 TEMPORARY DRAINAGE CONSTRUCTION

Upon determining that the underlying soil conditions were suitable for a soakaway, the focus turned to providing a temporary drainage solution for the site. To achieve this, the surveyors were asked to survey the flooded area to determine the low point which would be the "outlet" for the ponded area and the start of a ditch connecting to the soakaway. From this point, a ditch with approximate gradient of 1:100 (1%) was dug across the back of the site to connect to the soakaway pit (Figure 4).

On completion, the ditch successfully drained the flooded area into the soakaway (Figure 5). On November 3rd, Chris Davidson, P.Geo., returned to site with the excavator operator. The parking lot area, which had been flooded since the November 2021 event, was cleaned of mud for use by West Coast Reductions Limited.

As a safety measure, some of the large logs that had been stockpiled on site were placed around the soakaway to prevent vehicles or pedestrians from falling into the pit accidentally.

Figure 4 Looking back along the ditch from near the soakaway entrance

Figure 5 Water flowing into the soakaway (note small water fall in right centre)

Figure 6 Photo showing site after the ditch and infiltration pit had been constructed

5 FOLLOW UP VISIT

Between 3rd and 6th November 2022, heavy rainfall in the Fraser Valley was experienced. The Sumas Canal Environment Canada weather station observed 25 mm rain on November 3rd and 30 mm on November 6th. Data is missing on 4th and 5th but data from other stations show that the storm persisted through the weekend so rainfall totals may have been close to 100 mm. The event provided an opportunity to observe the condition of the site and the temporary drainage work installed the previous week. On Monday November 7th, Geoff Graham, P.Eng. attended site and discussed the conditions with staff on site. The staff informed Mr. Graham that the ditch and soakaway functioned well and that water in the soakaway pit did not exceed approximately "1 foot" depth and the previously flooded area held no ponded water.

6 CONCLUSION

The drainage measures installed in November 2022 will provide temporary relief from periodic rainfall events. The design standard for the system has not been calculated; however anecdotal evidence gathered on site after the November 3rd-6th event demonstrates that the system should cope with substantial rainfall. If the soakaway performs well over the 2022/23 winter period, the structure could be formalized into a permanent feature incorporated into the proposed permanent drainage scheme.

This report is subject to the attached Limitations.

Prepared by,

Original Signed and Sealed By Geoff Graham,
P.Eng.

Geoff Graham, P.Eng.
Senior Associate Water Resources Engineer

Reviewed by

Original Signed by Drum Cavers, P.Eng., P.Geo.

Drum Cavers, P.Eng., P.Geo.
Principal Geotechnical Engineer

Attachment: Limitations

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."

LIMITATIONS

1. The work performed in the preparation of this report and the conclusions presented are subject to the following:
   a) The contract between WSP 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 WSP to the Client in connection to the Contract; and
   c) The limitations stated herein.
2. **Standard of care:** WSP has prepared this report in a manner consistent with the level of skill and are ordinarily exercised by reputable members of WSP'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, guaranty, 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 WSP 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"). WSP 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 WSP.
7. **No legal representations:** WSP 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:** WSP 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.
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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. WSP 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. 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 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 WSP 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. WSP 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 WSP to be contemplated by the Client at the commencement of WSP'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 WSP, 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.

    WSP 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 WSP, 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 WSP'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 that WSP 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 WSP 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:** WSP will accept no responsibility for the effects of drainage and/or dewatering measures if WSP has not been specifically consulted and involved in the design and monitoring of the drainage and/or dewatering system.

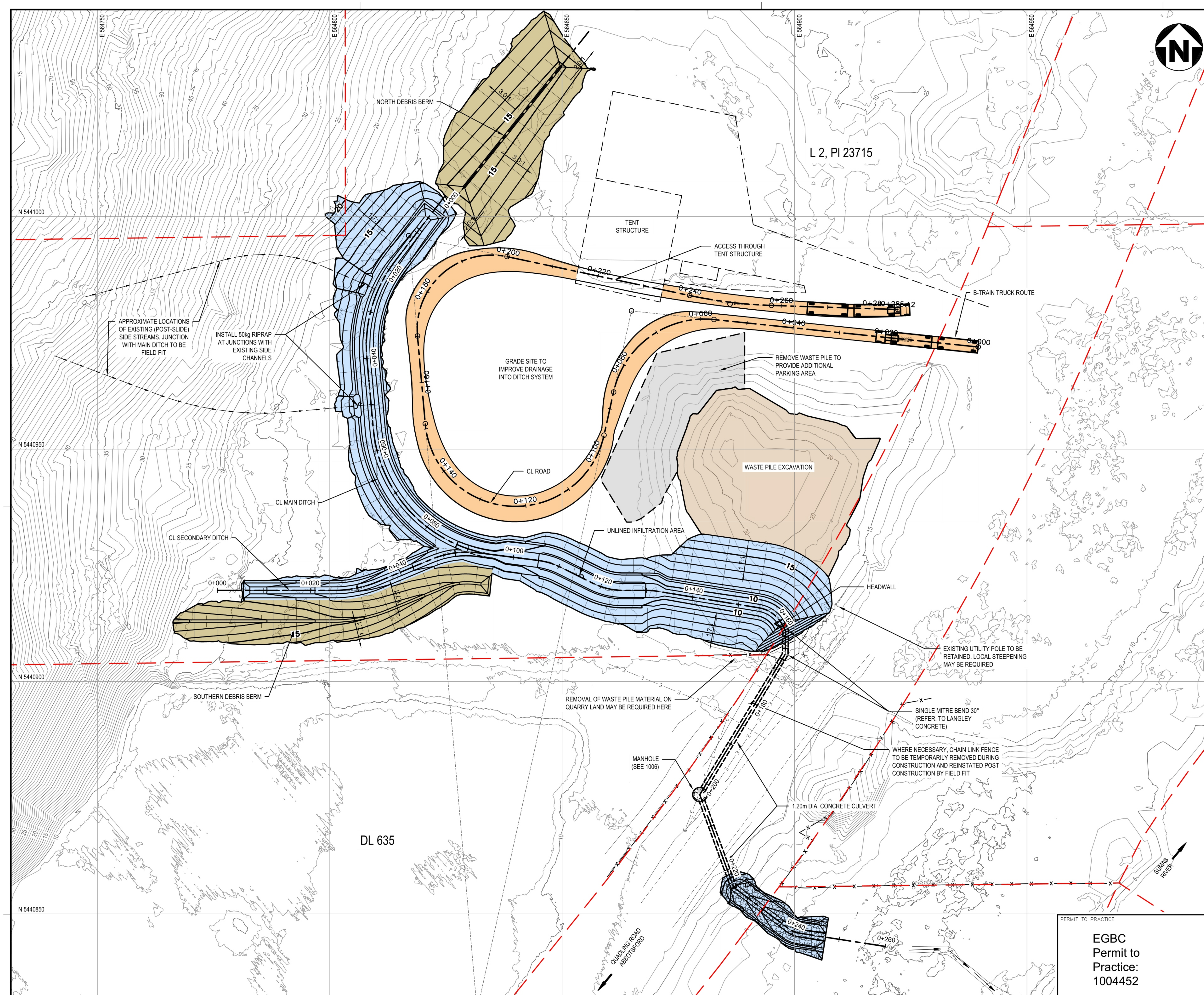
16. **Environmental and Hazardous Materials Aspects:** Unless otherwise stated, the information contained in this report in no way reflects on the environmental aspects of this project, since this aspect is beyond the Scope of Work and the Contract. Unless expressly included in the Scope of Work, this 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, mould 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.

17. **Sample Disposal:** WSP will dispose of all uncontaminated soil and rock samples after 30 days following the release of the final geotechnical report. Should the Client request that the samples be retained for a longer time, the Client will be billed for such storage at an agreed upon rate. Contaminated samples of soil, rock or groundwater are the property of the Client, and the Client will be responsible for the proper disposal of these samples, unless previously arranged for with WSP or a third party.

Appendix B

Issue for Permit Drawings



NOTES:

1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.
3. CONTOURS ARE INTERPOLATED FROM 2017 GEOBC LIDAR SURVEY.
4. TOPOGRAPHIC SURVEY DATA AROUND ROAD CROSSING PROVIDED BY MoTI. SURVEY DATE 9 MARCH 2022.
5. TRUCK ROUTE CALCULATED USING 16m RADIUS (MIN.) CURVE TYPICAL FOR B-TRAIN TRUCKS.

LEGEND:

EXISTING:

- LAND PARCEL BOUNDARY
- EXISTING DRAINAGE PATH
- POWER LINE
- FENCE
- ROAD

ISSUE FOR PERMIT
NOT FOR CONSTRUCTION

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Rev	Date	Description	Init

REVISIONS

BRITISH COLUMBIA | Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
EVANS QUARRY DRAINAGE IMPROVEMENTS
DITCH AND POND
LAYOUT

40435 QUADLING RD, ABBOTSFORD BC V3G 2T2

PERMIT TO PRACTICE
EGBC
Permit to
Practice:
1004452

PREPARED UNDER THE DIRECTION OF

ENGINEER OF RECORD

DATE

PROFESSIONAL PROVINCE OF G. P. GRAHAM # 43934 BRITISH COLUMBIA ENGINEER
2023-02-16

DESIGNED ______ DATE ______
CHECKED ______ DATE ______
DRAWN ______ DATE ______
REVIEWED ______ DATE ______
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	1001

H-308i-r1-c(03-07)

CANCEL PRINTS BEARING PREVIOUS LETTER

NOTES:

1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.

LEGEND:

EXISTING:

- LAND PARCEL BOUNDARY
- EXISTING DRAINAGE PATH
- POWER LINE
- FENCE

ISSUE FOR PERMIT
NOT FOR CONSTRUCTION

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wsp

Rev	Date	Description	Init

REVISIONS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
EVANS QUARRY DRAINAGE IMPROVEMENTS
DITCH AND POND
LAYOUT WITH IMAGERY

40435 QUADLING RD, ABBOTSFORD BC V3G 2T2

PERMIT TO PRACTICE
EGBC Permit to Practice: 1004452

PREPARED UNDER THE DIRECTION OF

ENGINEER OF RECORD

DATE

PROFESSIONAL PROVINCE OF BRITISH COLUMBIA G. P. GRAHAM # 43934 ENGINEER
EGBC Permit to Practice 1004452 2023-02-16

DESIGNED ______ DATE ______
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REVIEWED ______ DATE ______
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FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	1002

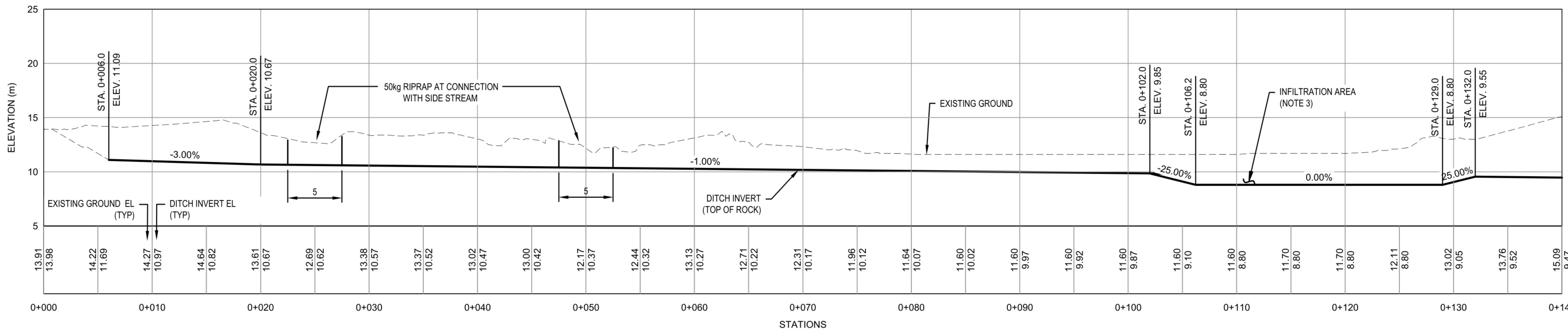
H-308i-r1-c(03-07)

CANCEL PRINTS BEARING PREVIOUS LETTER

NOTES:

1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.
3. CONTOURS ARE INTERPOLATED FROM 2017 GEOBC LIDAR SURVEY.
4. UNLINED INFILTRATION AREA IS AT QUARRY FLOOR ELEVATION TO PRESENT.

MAIN - DITCH



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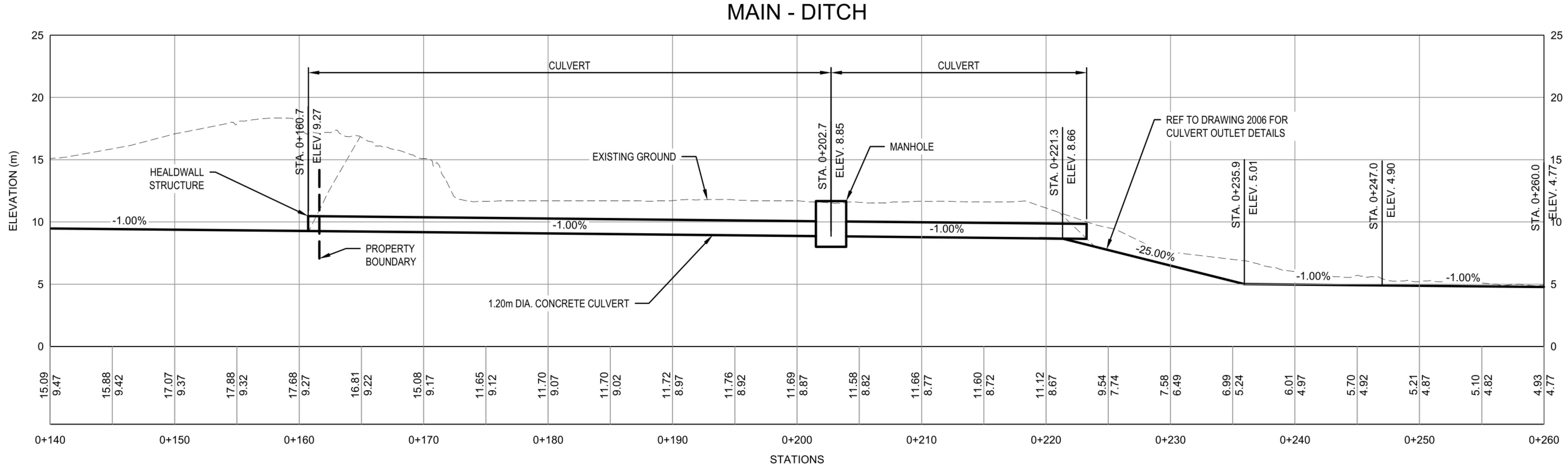

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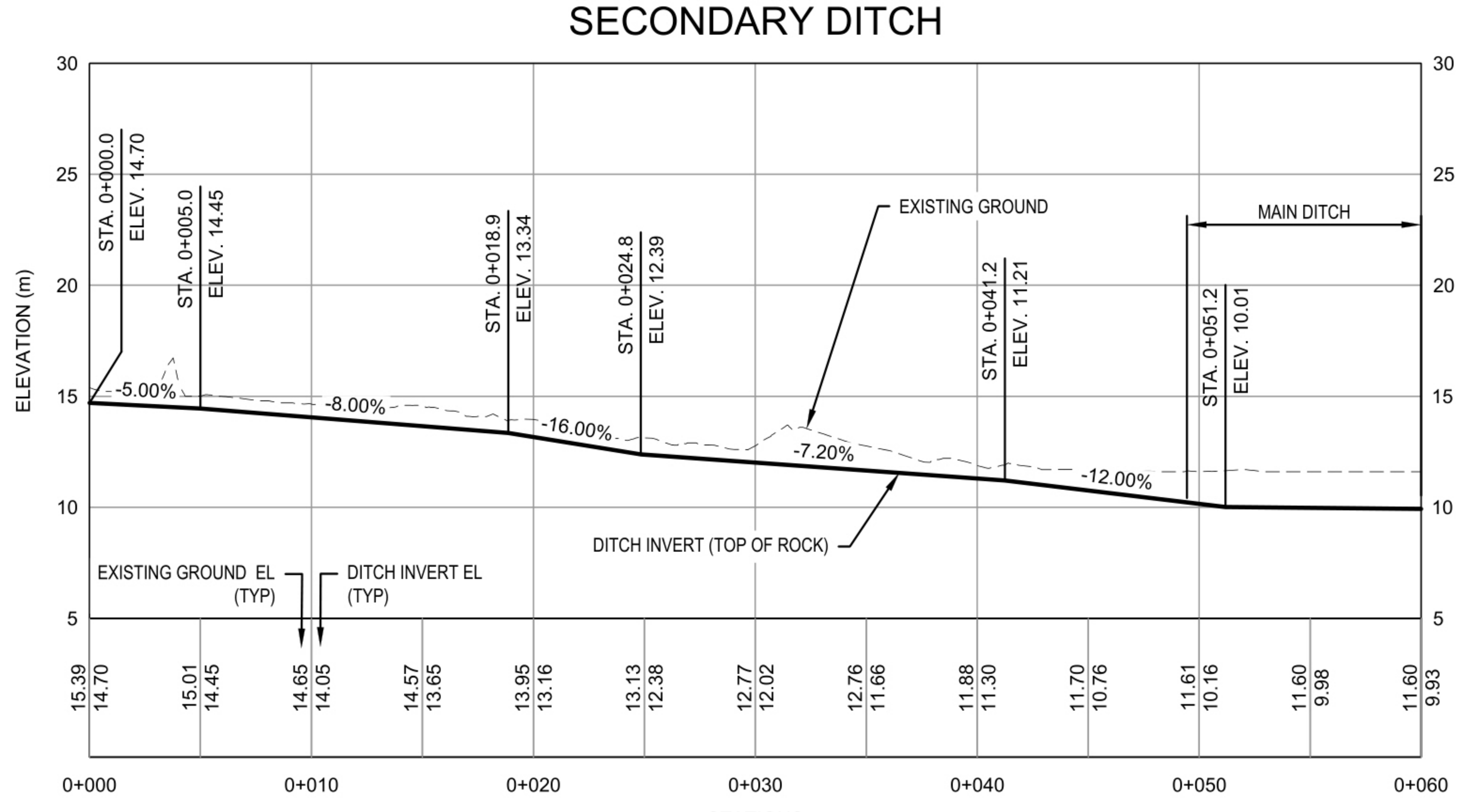

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REVISIONS

BRITISH COLUMBIA
Ministry of Transportation and Infrastructure
South Coast Region

LOWER MAINLAND DISTRICT
EVANS QUARRY DRAINAGE IMPROVEMENTS
MAIN SECONDARY AND ROADSIDE DITCH (CULVERT)
PROFILES

40435 QUADLING RD, ABBOTSFORD BC V3G 2T2

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Permit to
Practice:
1004452

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ENGINEER OF RECORD

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G. P. GRAHAM
43934

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NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	2000

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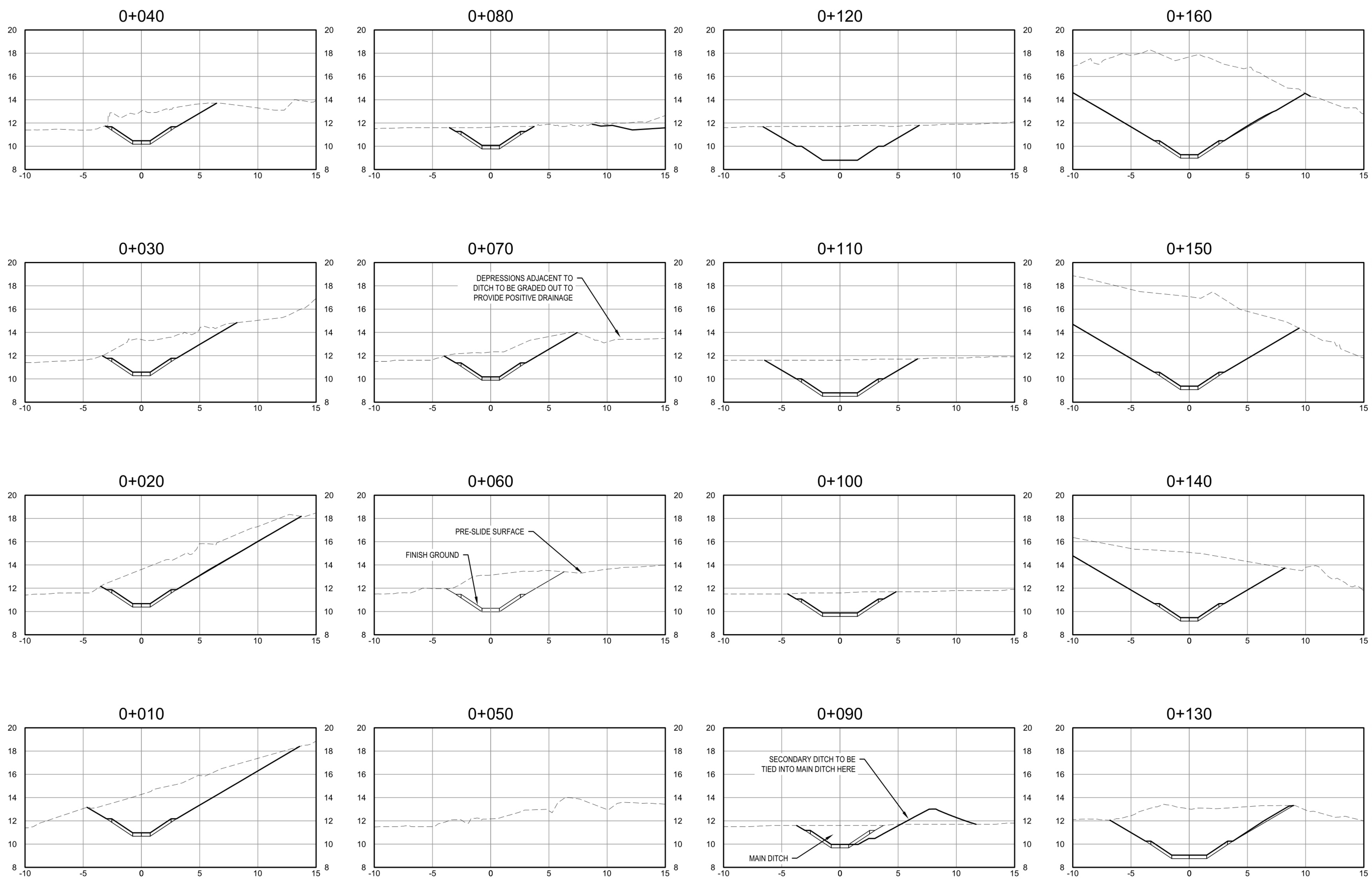

NOTES:

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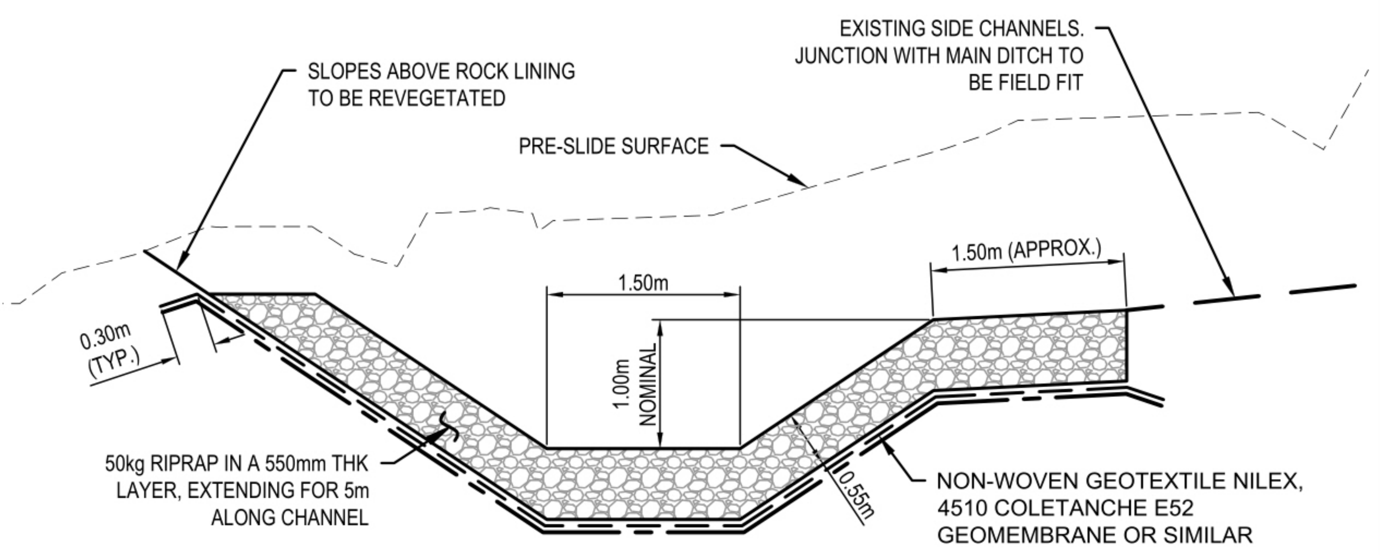

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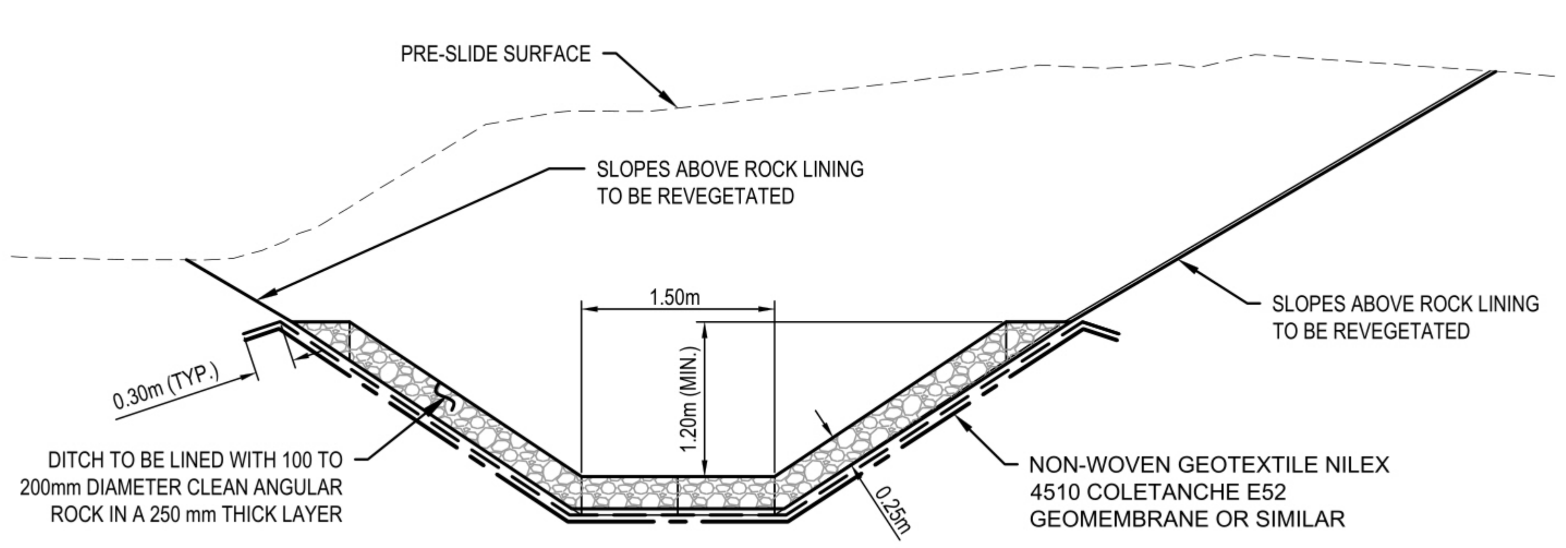

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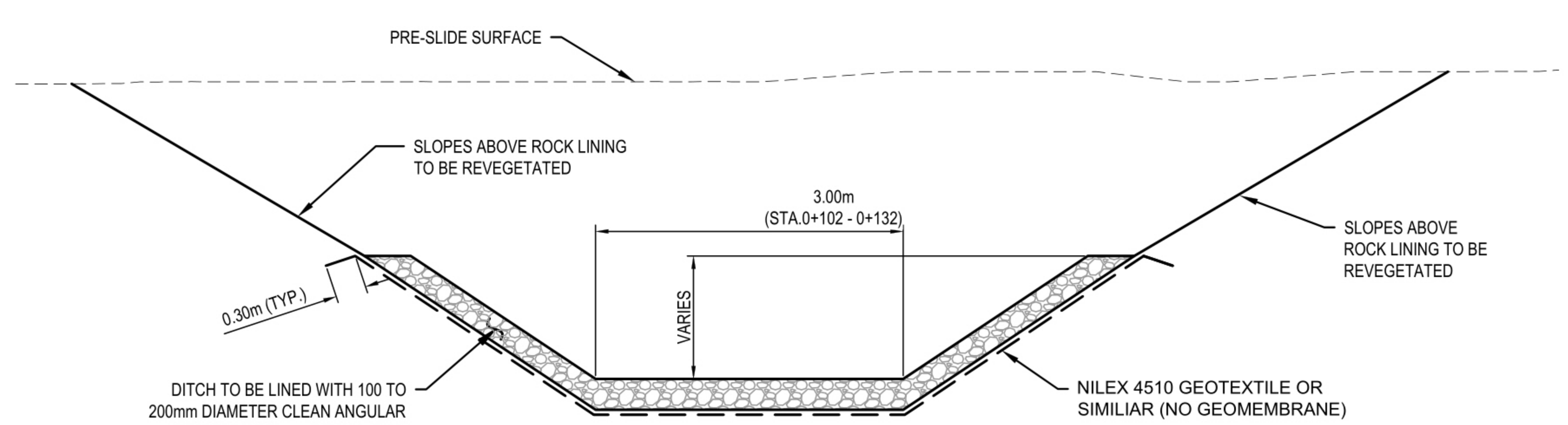

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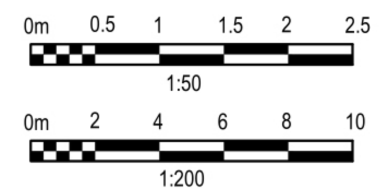

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REVISIONS

BRITISH COLUMBIA — Ministry of Transportation and Infrastructure, South Coast Region

LOWER MAINLAND DISTRICT
EVANS QUARRY DRAINAGE IMPROVEMENTS
MAIN DITCH
CROSS SECTIONS

40435 QUADLING RD, ABBOTSFORD BC V3G 2T2

PERMIT TO PRACTICE

EGBC Permit to Practice: 1004452

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ENGINEER OF RECORD

DATE

PROFESSIONAL ENGINEER, PROVINCE OF BRITISH COLUMBIA — G. P. GRAHAM # 43934 — EGBC Permit to Practice 1004452 — 2023-02-16

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REVIEWED ______ DATE ______
NEGATIVE No.

FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	2001

H-308i-r1-c(03-07)

CANCEL PRINTS BEARING PREVIOUS LETTER

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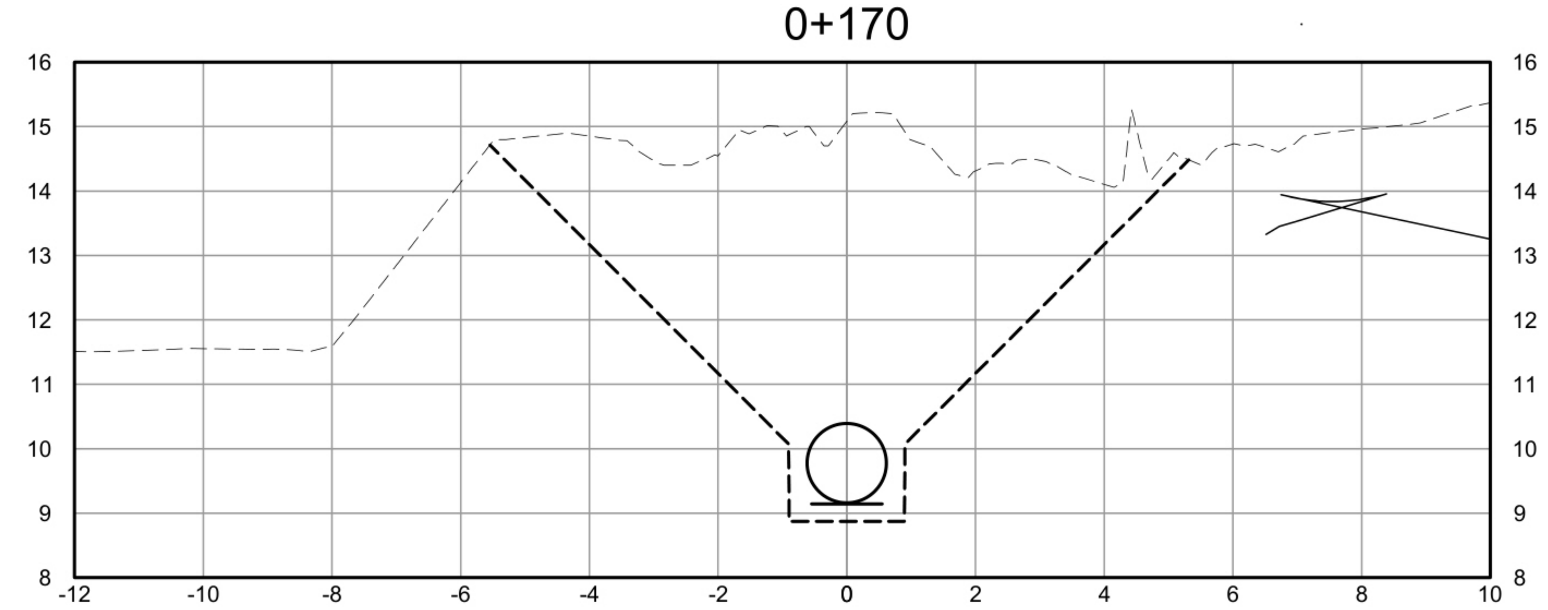

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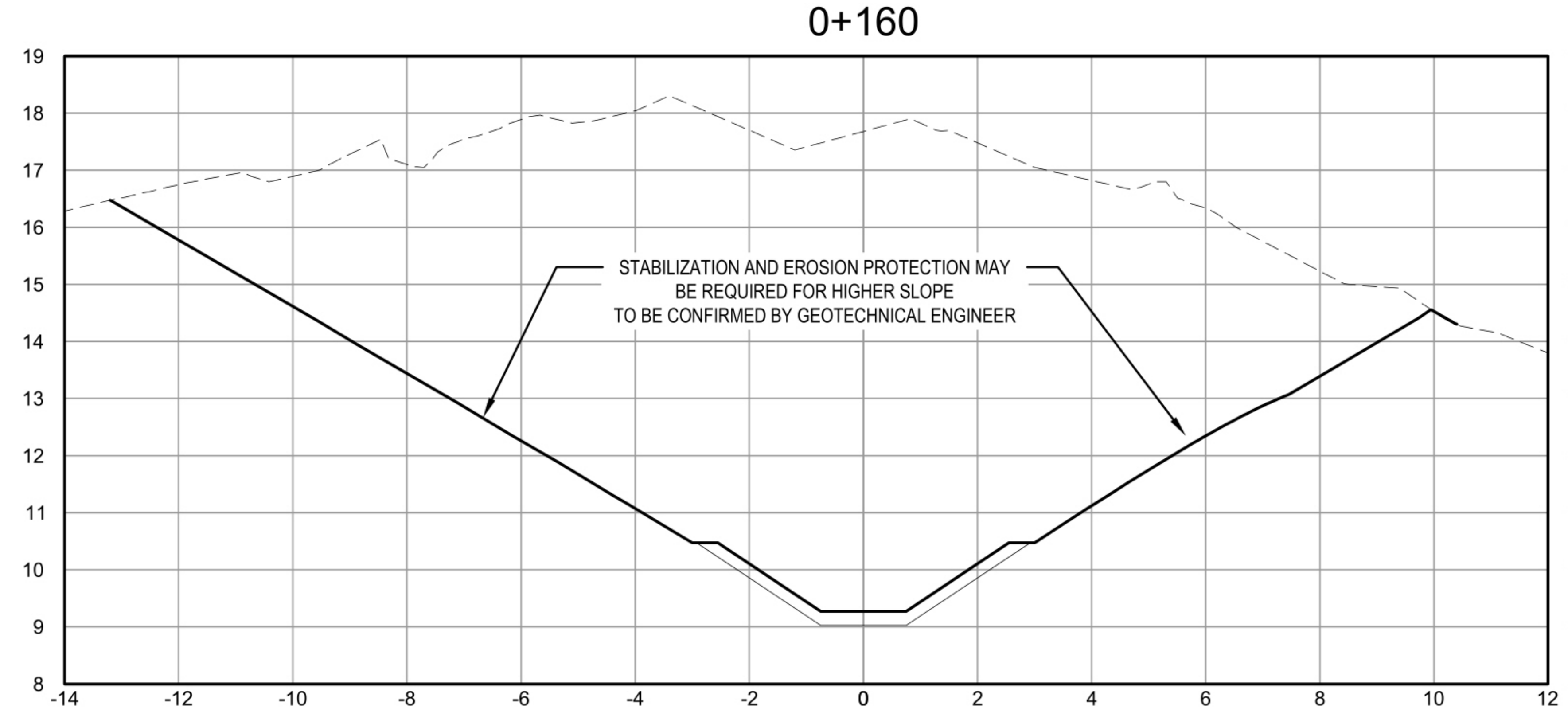

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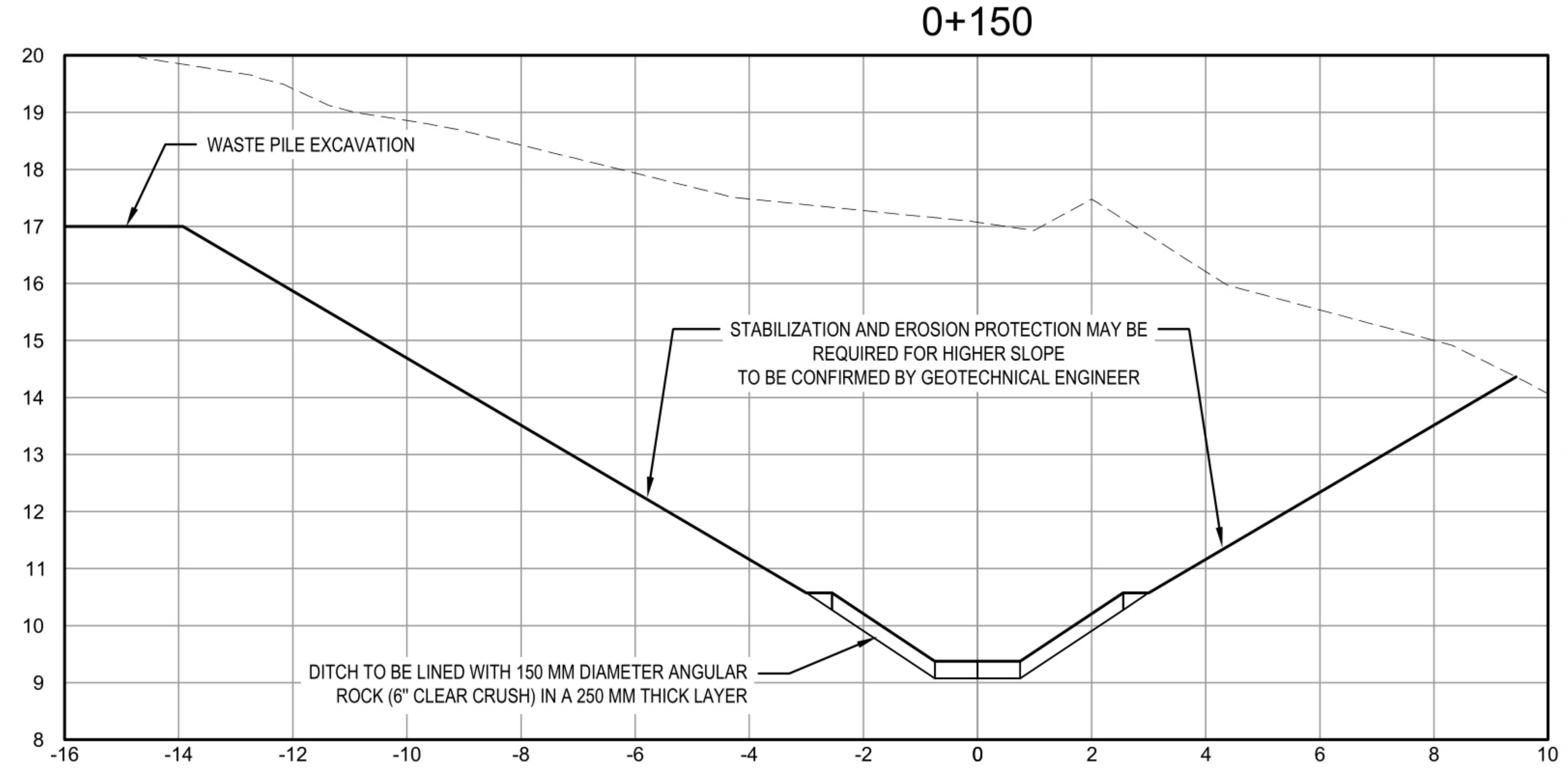

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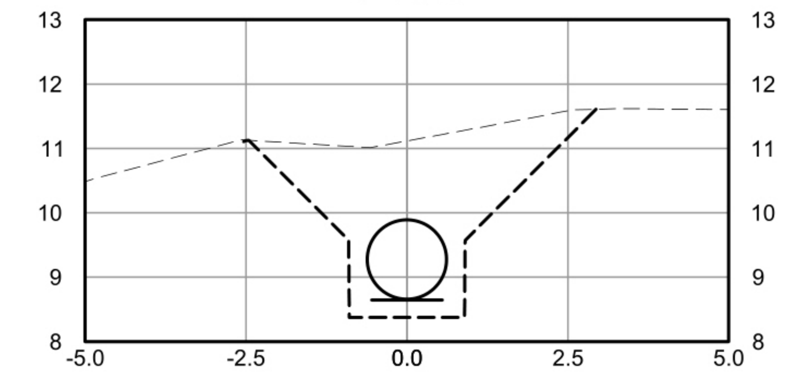

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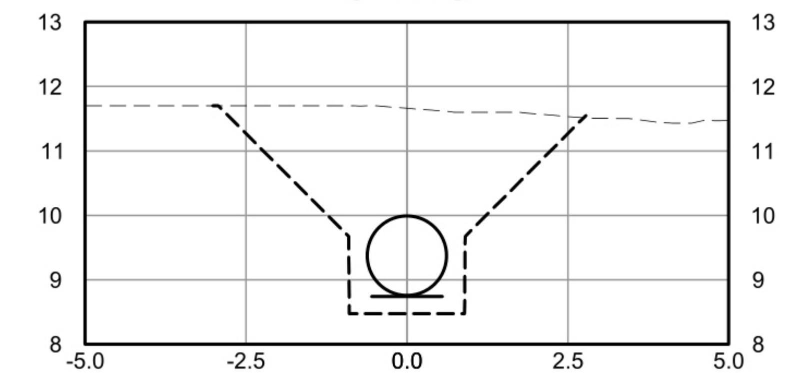

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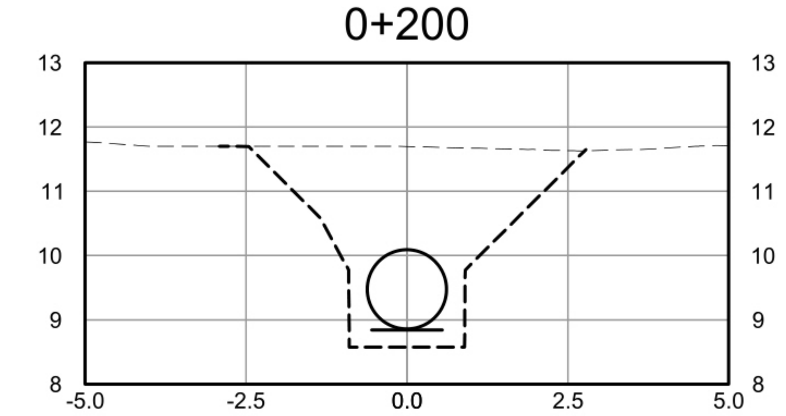

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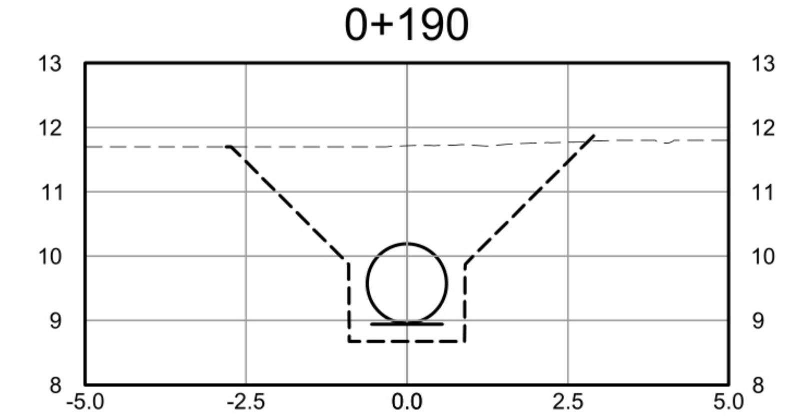

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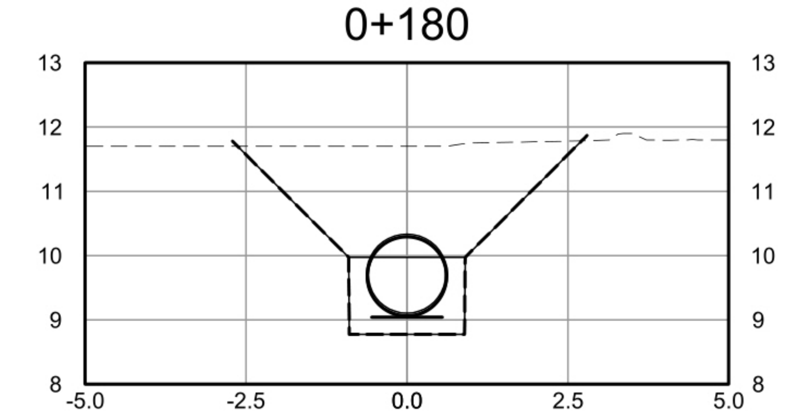

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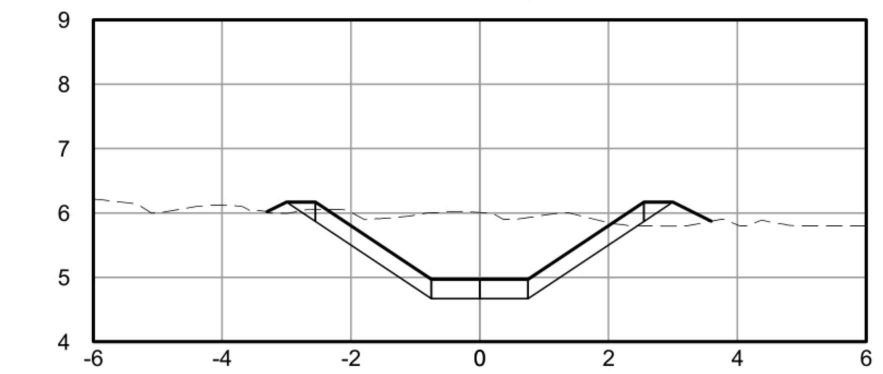

NOTES:

1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.
3. CONTOURS ARE INTERPOLATED FROM 2017 GEOBC LIDAR SURVEY.

ISSUE FOR PERMIT
NOT FOR CONSTRUCTION

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1:100

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REVISIONS

BRITISH COLUMBIA — Ministry of Transportation and Infrastructure, South Coast Region

LOWER MAINLAND DISTRICT
EVANS QUARRY DRAINAGE IMPROVEMENTS
ROAD SIDE
CROSS SECTIONS
40435 QUADLING RD, ABBOTSFORD BC V3G 2T2

PERMIT TO PRACTICE
EGBC
Permit to
Practice:
1004452

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ENGINEER OF RECORD
DATE

G. P. GRAHAM # 43934 ENGINEER

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FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	2002

H-308-1-c(03-07)

CANCEL PRINTS BEARING PREVIOUS LETTER

NOTES:

1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.
3. CONTOURS ARE INTERPOLATED FROM 2017 GEOBC LIDAR SURVEY.

SECONDARY DITCH SECTIONS

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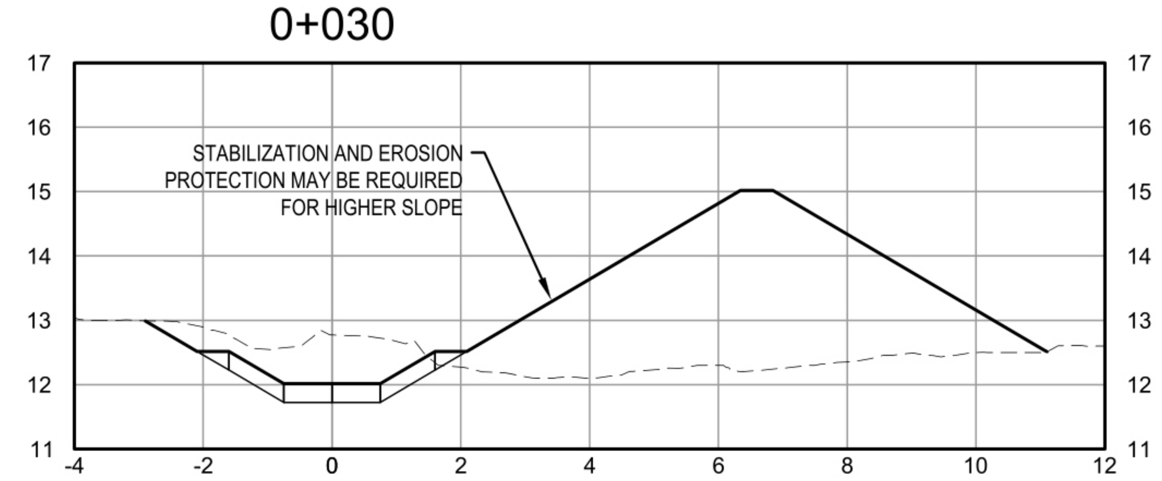

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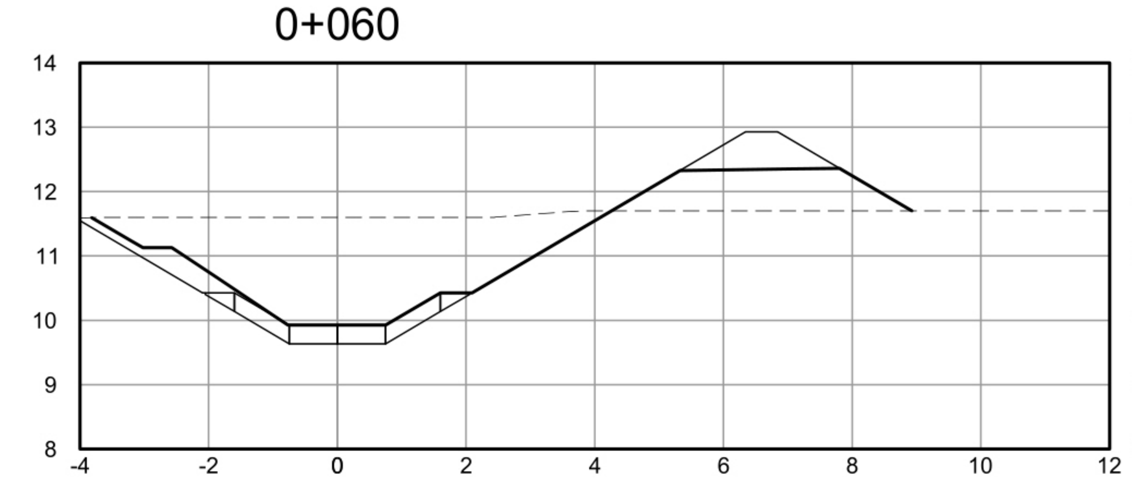

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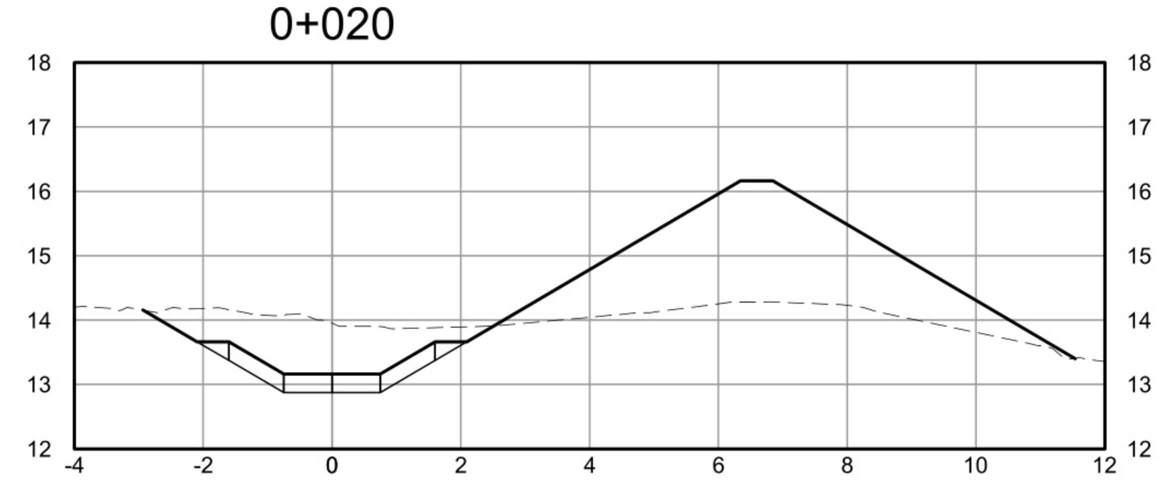

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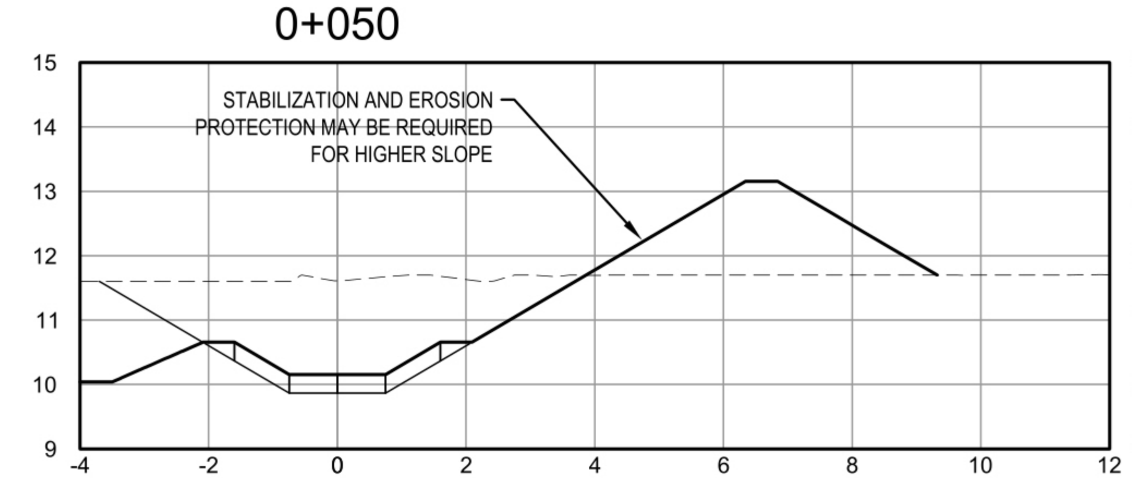

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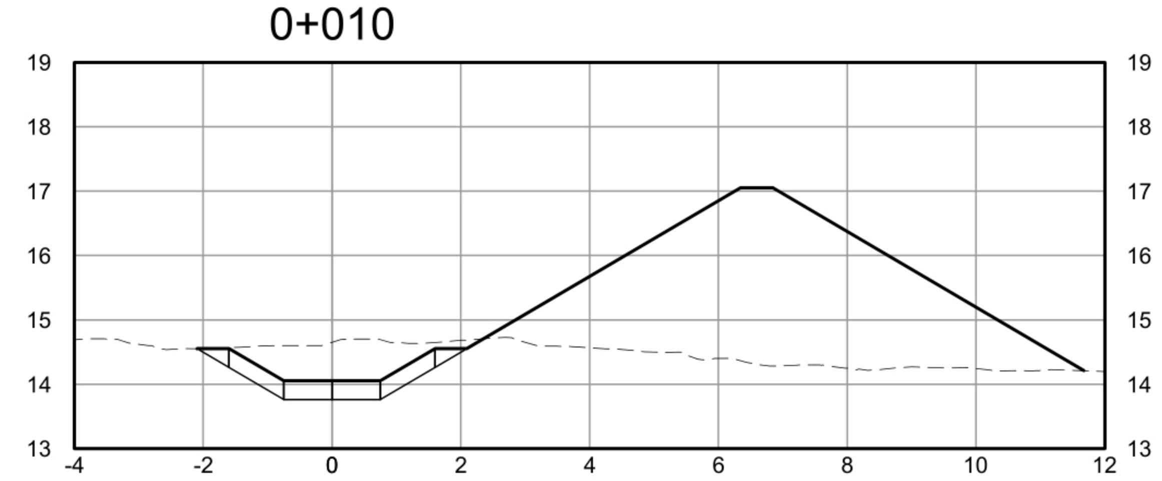

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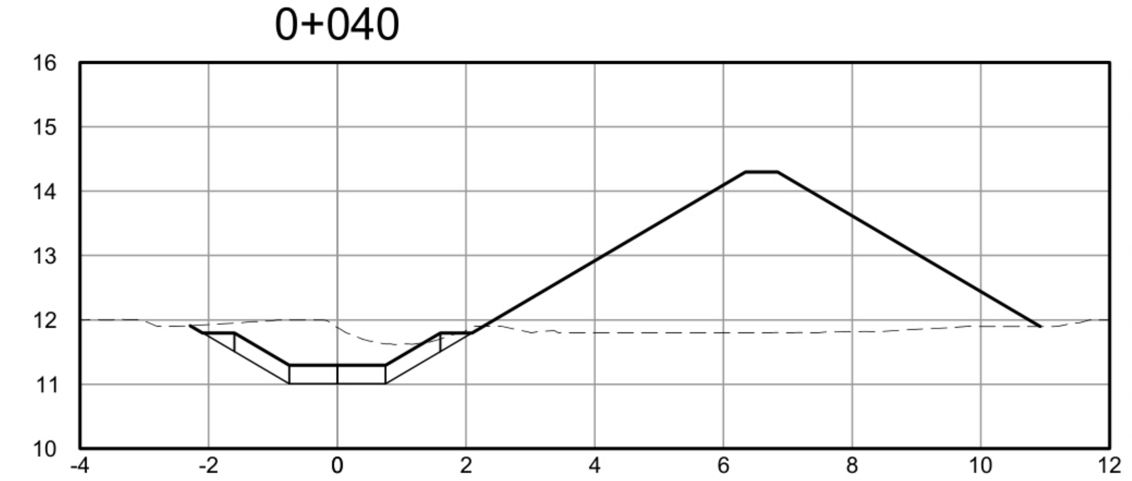

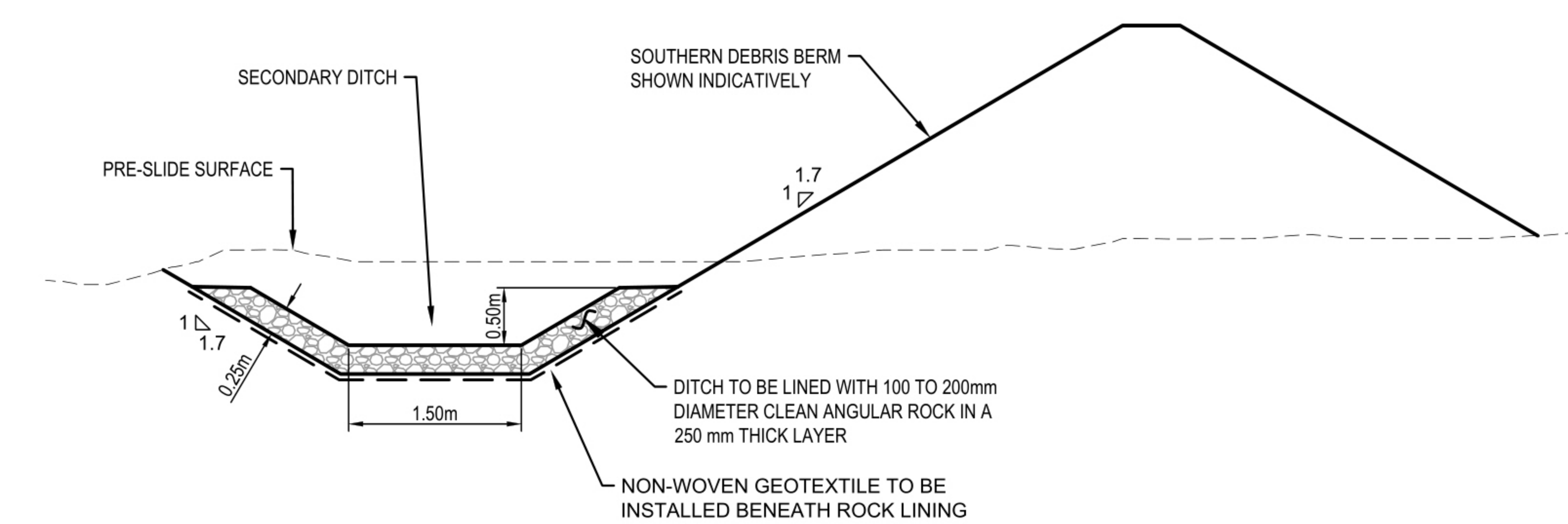

TYPICAL SECTION

SCALE 1:50

1:50

1:100

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South Coast Region

LOWER MAINLAND DISTRICT
EVANS QUARRY DRAINAGE IMPROVEMENTS
SECONDARY DITCH
CROSS SECTIONS

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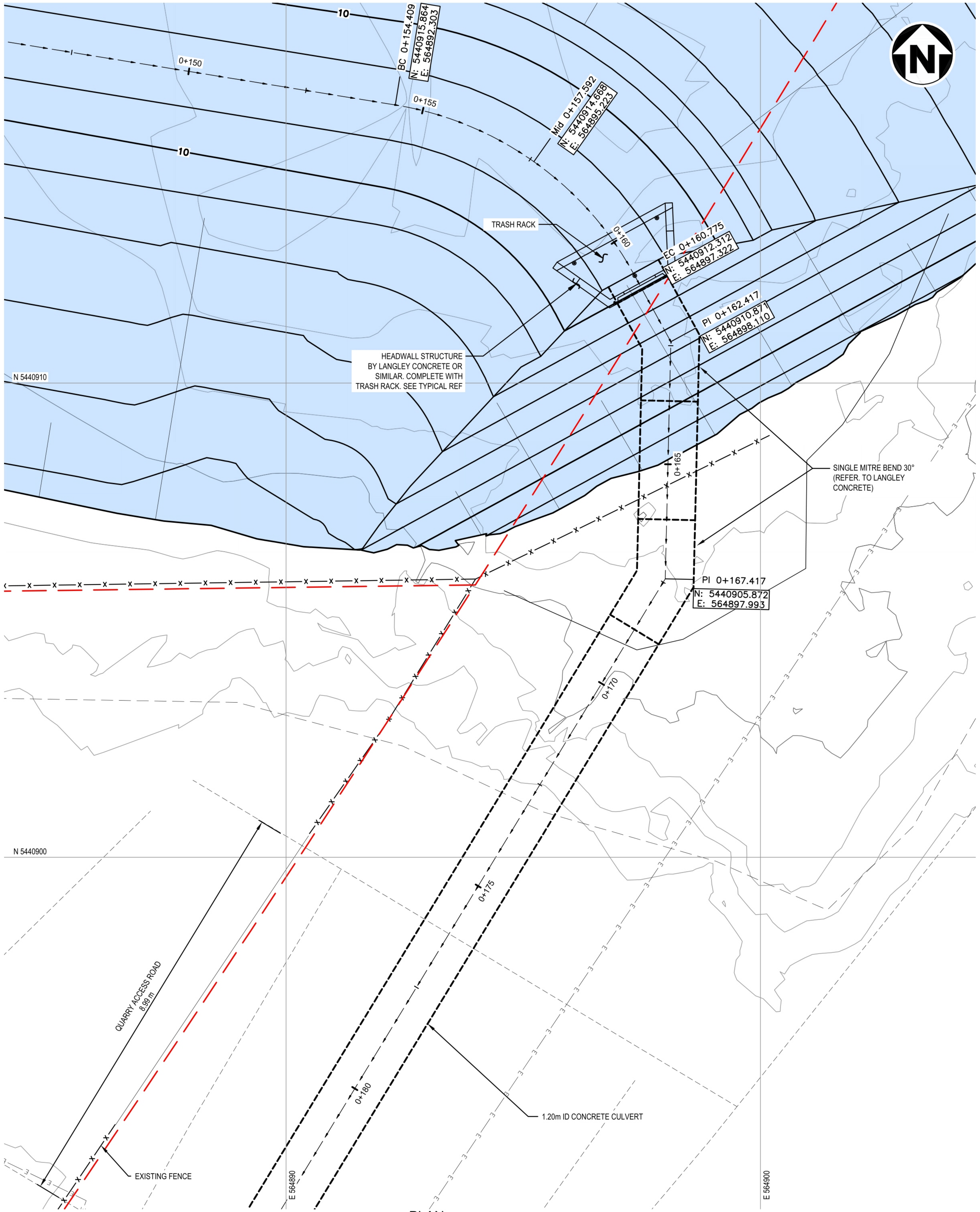
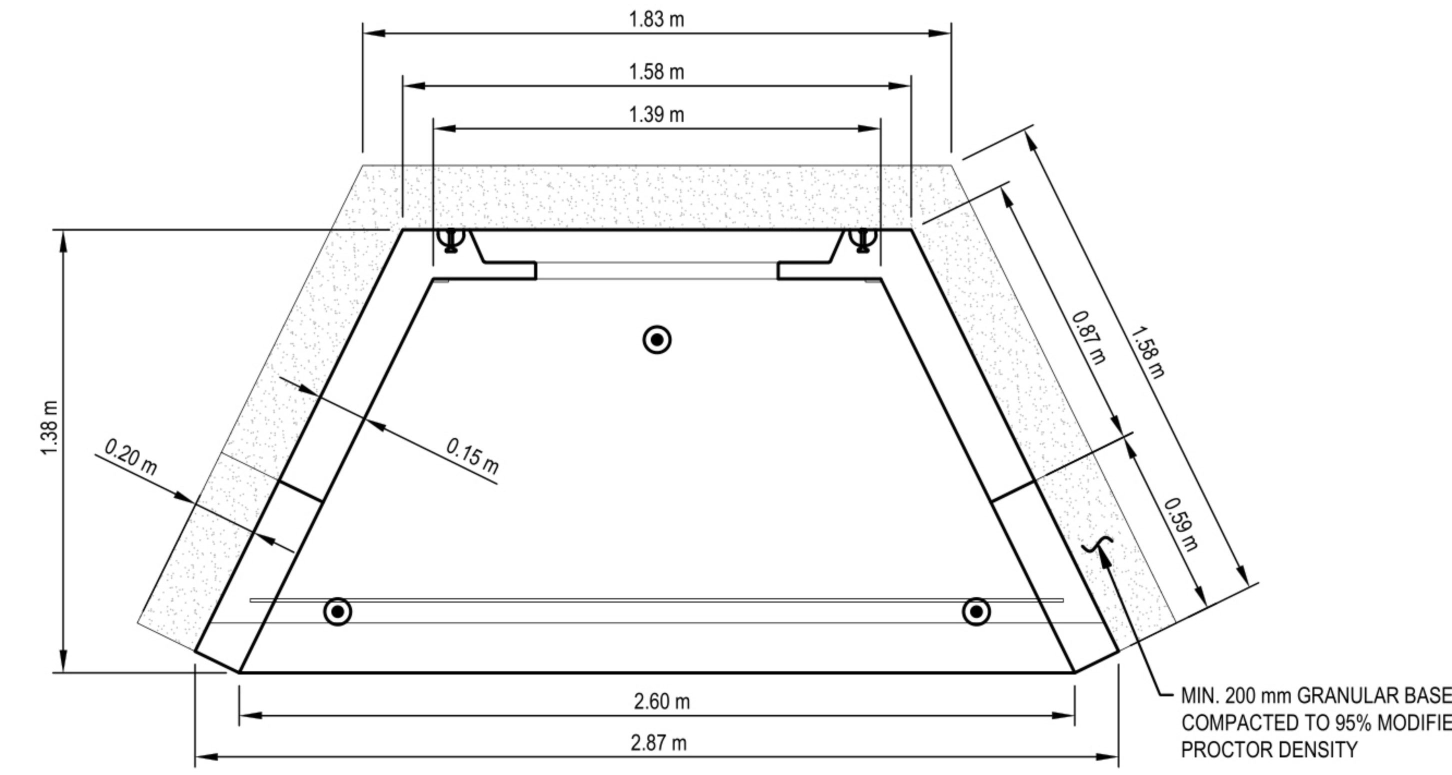


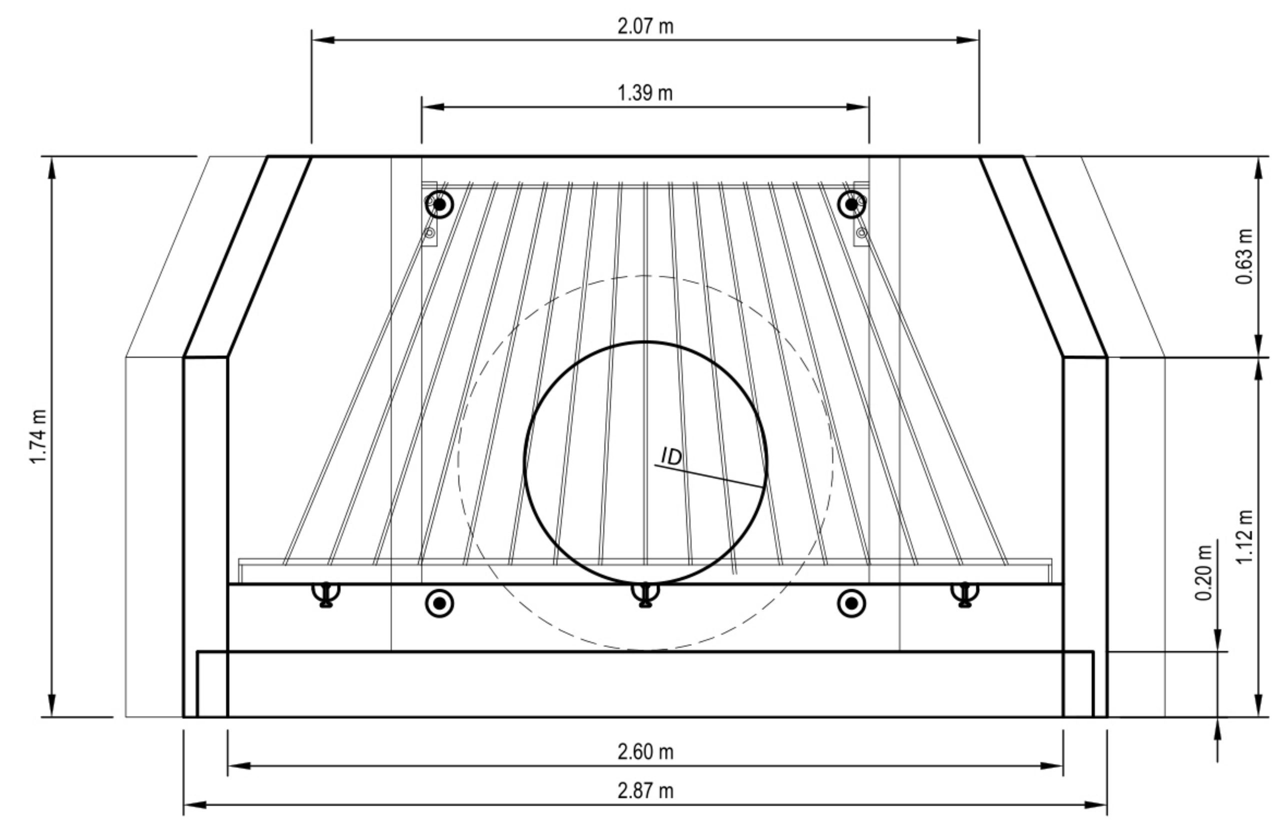
PLAN

SCALE 1:50



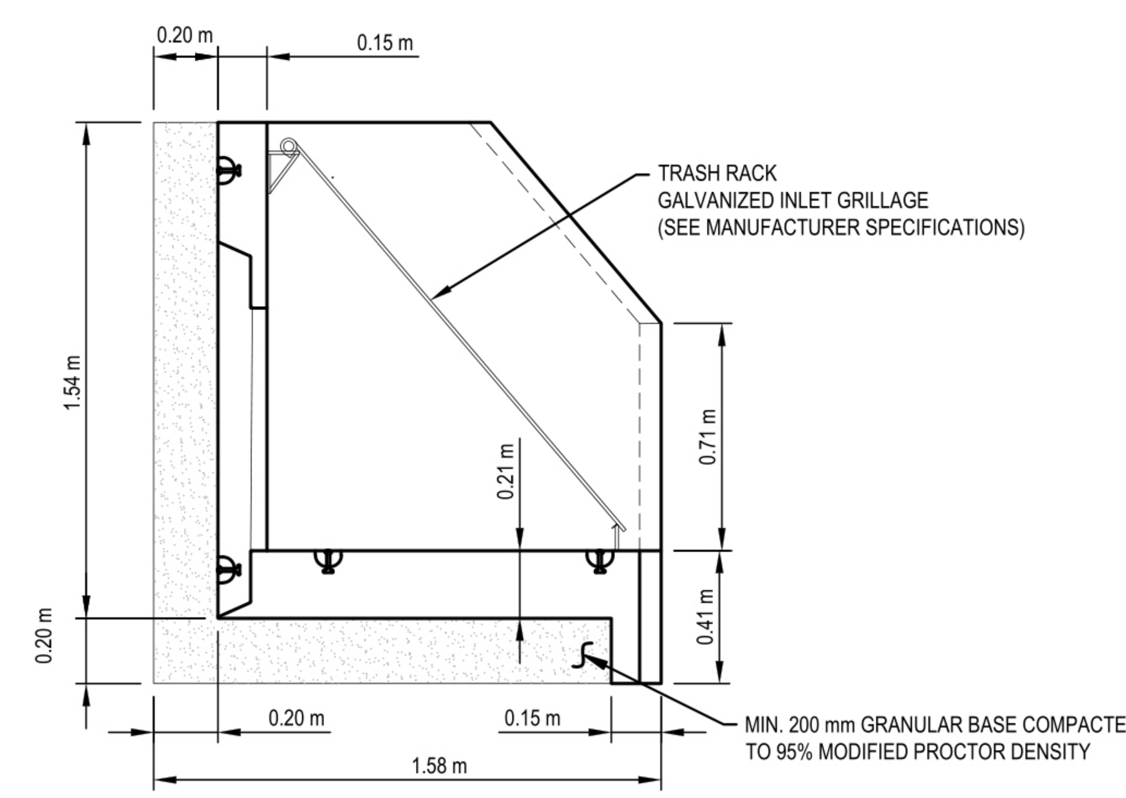
PLAN VIEW

SCALE 1:20



ELEVATION VIEW

SCALE 1:20



SIDE VIEW

SCALE 1:20

TYPICAL REFERENCE

LANGLEY CONCRETE GROUP 14-15 HEADWALL STRUCTURE

NOTES:

1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.
3. CONTOURS ARE INTERPOLATED FROM 2017 GEOBC LIDAR SURVEY.
4. UNIT SUPPLIED WITH ROUGH CORE FOR INLET/OUTLET AS SHOWN.
5. STRUCTURE SUPPLIED WITH EMBEDDED THREADED INSERTS FOR GRILLS AND HANDRAILS.
6. UNIT SUPPLIED WITH LIFTING INSERTS AS REQUIRED.
7. MINIMUM REBAR YIELD STRENGTH: 414 mPA.
8. MINIMUM CONCRETE STRENGTH: 30 mPA.

0m 0.2 0.4 0.6 0.8 1 — 1:20

0m 0.5 1 1.5 2 2.5 — 1:50

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PLAN AND PROFILE

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FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	2004

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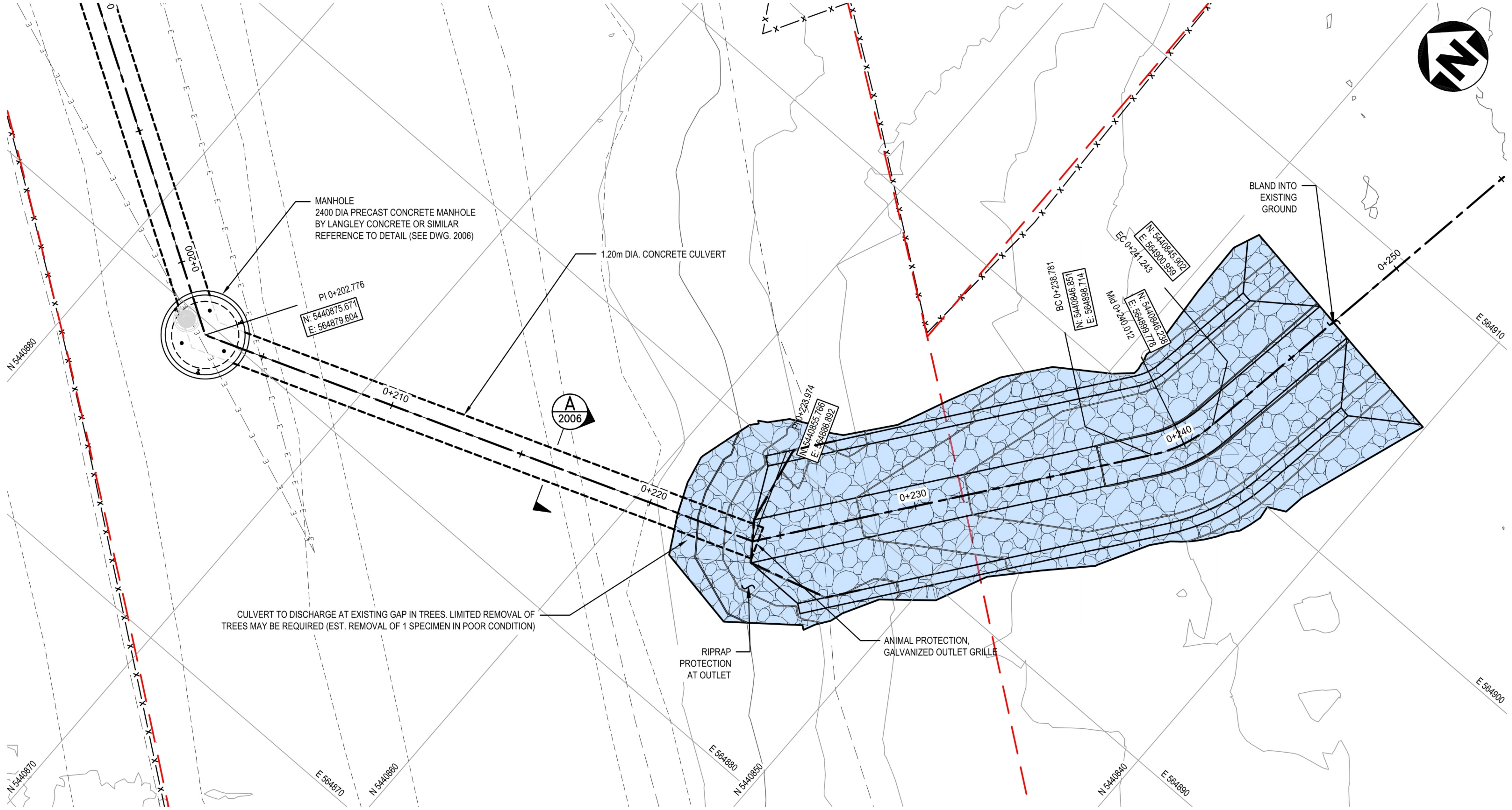
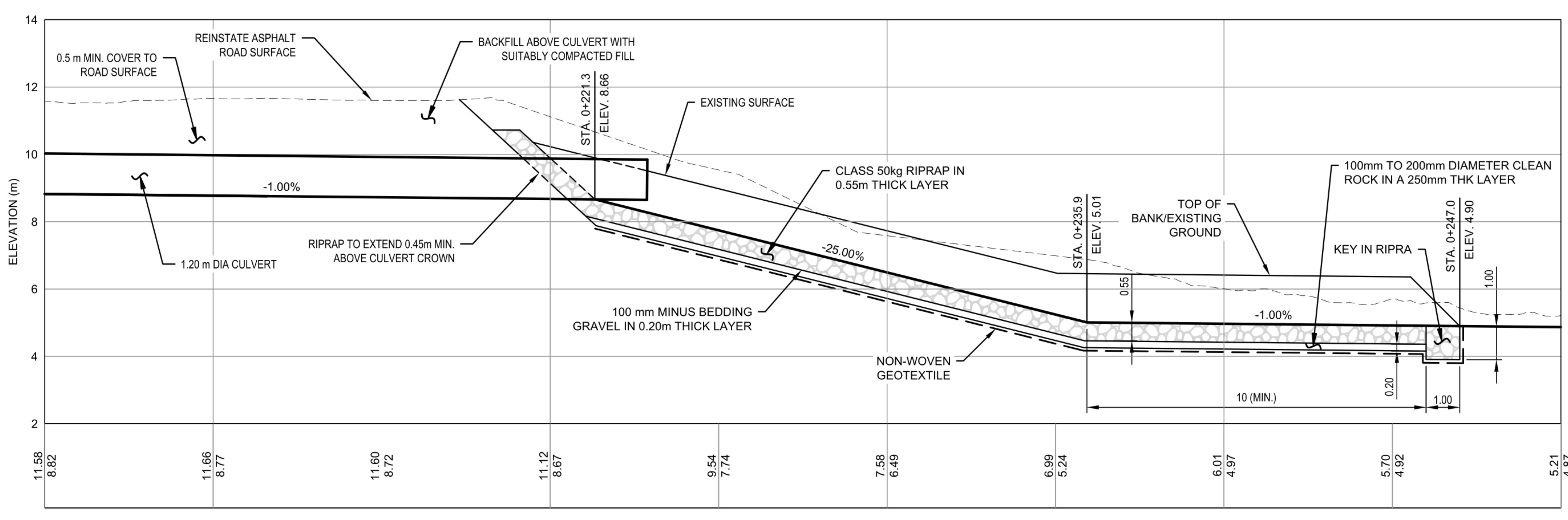
1. COORDINATES AND ELEVATIONS ARE IN METRES.
2. HORIZONTAL COORDINATES ARE UTM: DATUM WGS84, ZONE 10.
3. CONTOURS ARE INTERPOLATED FROM 2017 GEOBC LIDAR SURVEY.



PLAN

SCALE 1:100



PROFILE

SCALE 1:100

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0m 1 2 3 4 5
1:100

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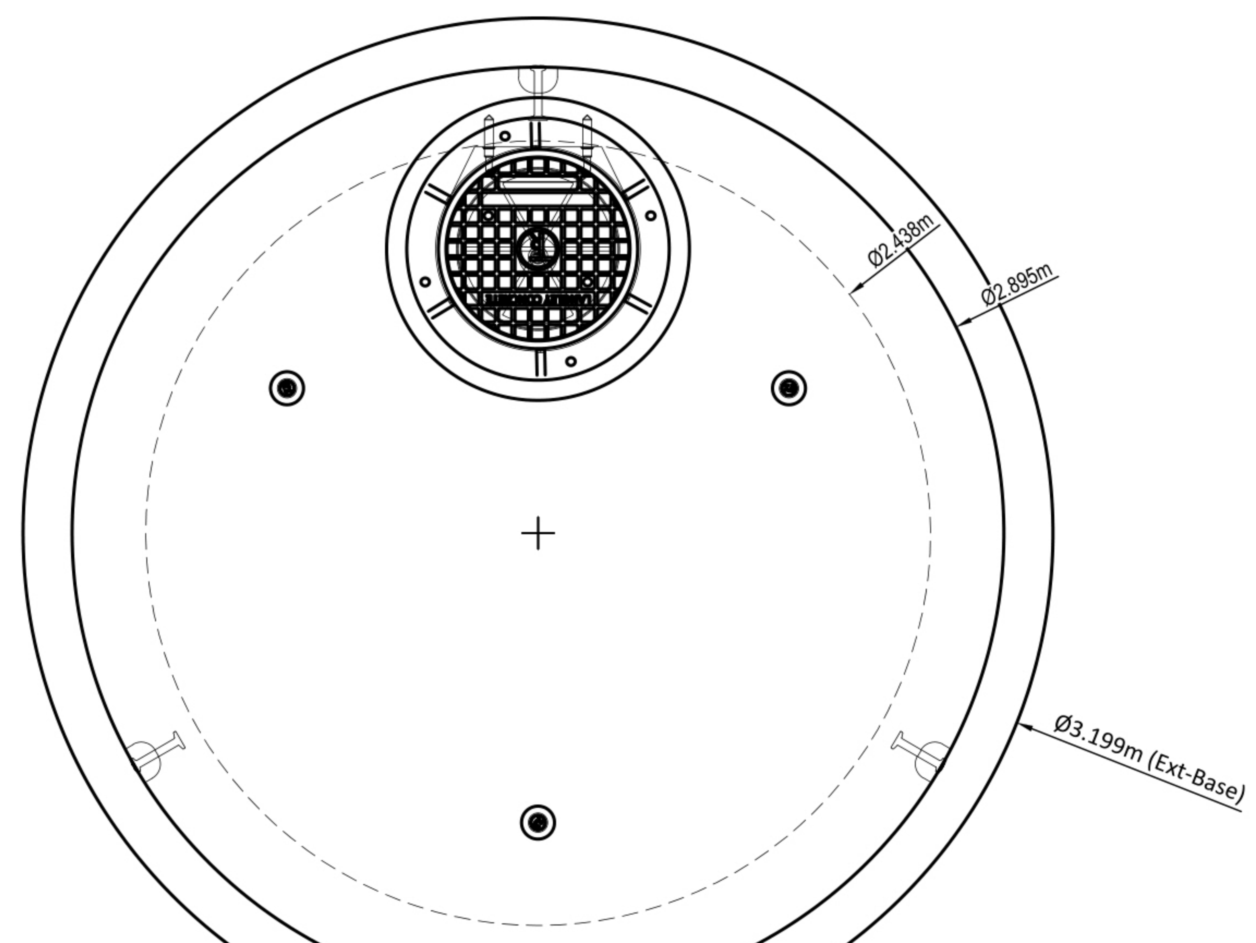
FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	2005

H-308-r1-c(03-07)

CANCEL PRINTS BEARING PREVIOUS LETTER

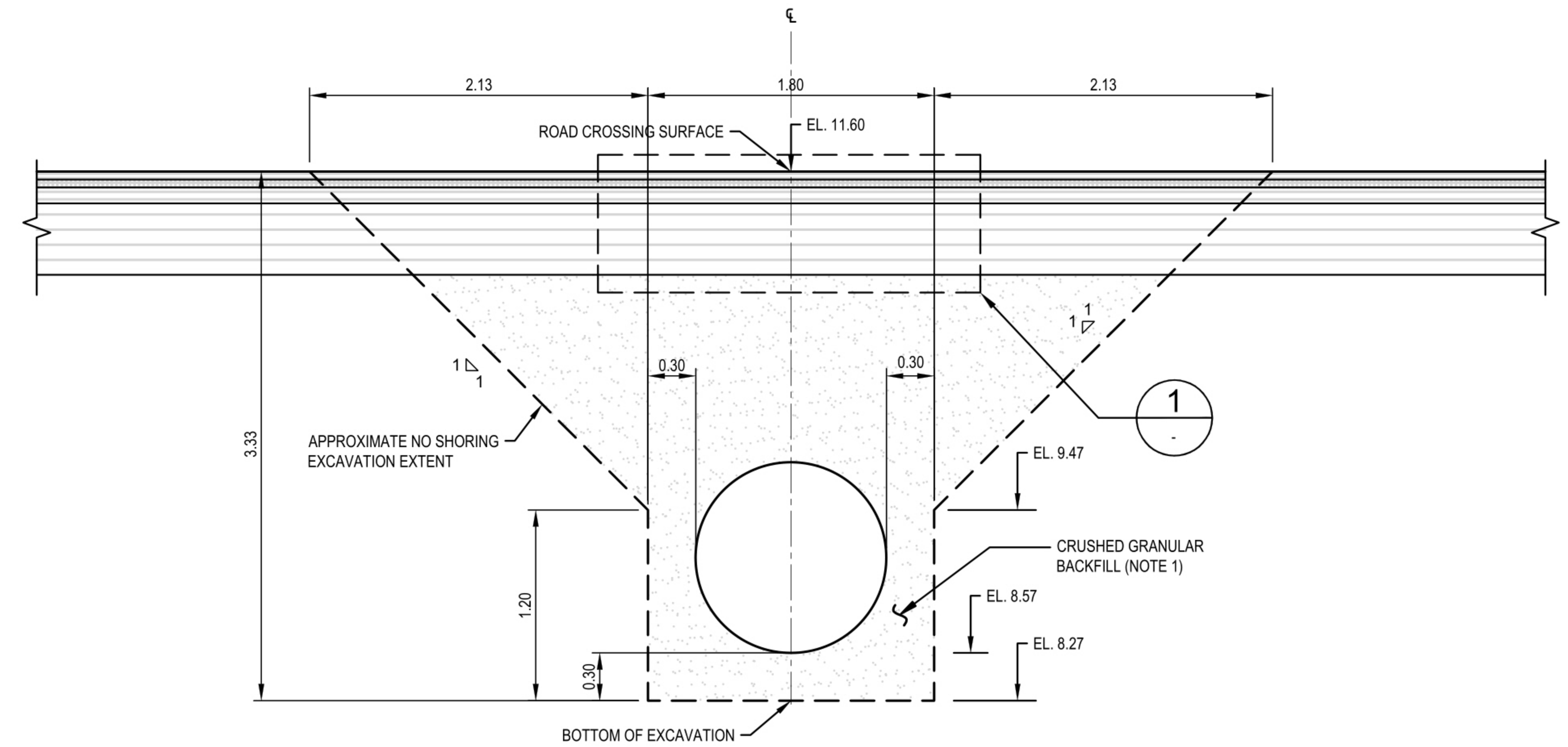
NOTES:

1. ALL COMPACTION TO BE IN MAX. 300 mm LIFTS TO 95% MODIFIED PROCTOR DENSITY.
2. ROAD CROSSING EXCAVATION TO BE SAW CUT AND RESTORED TO AN EVEN SURFACE WITH ASPHALT TO MATCH EXISTING.



MANHOLE - PLAN VIEW

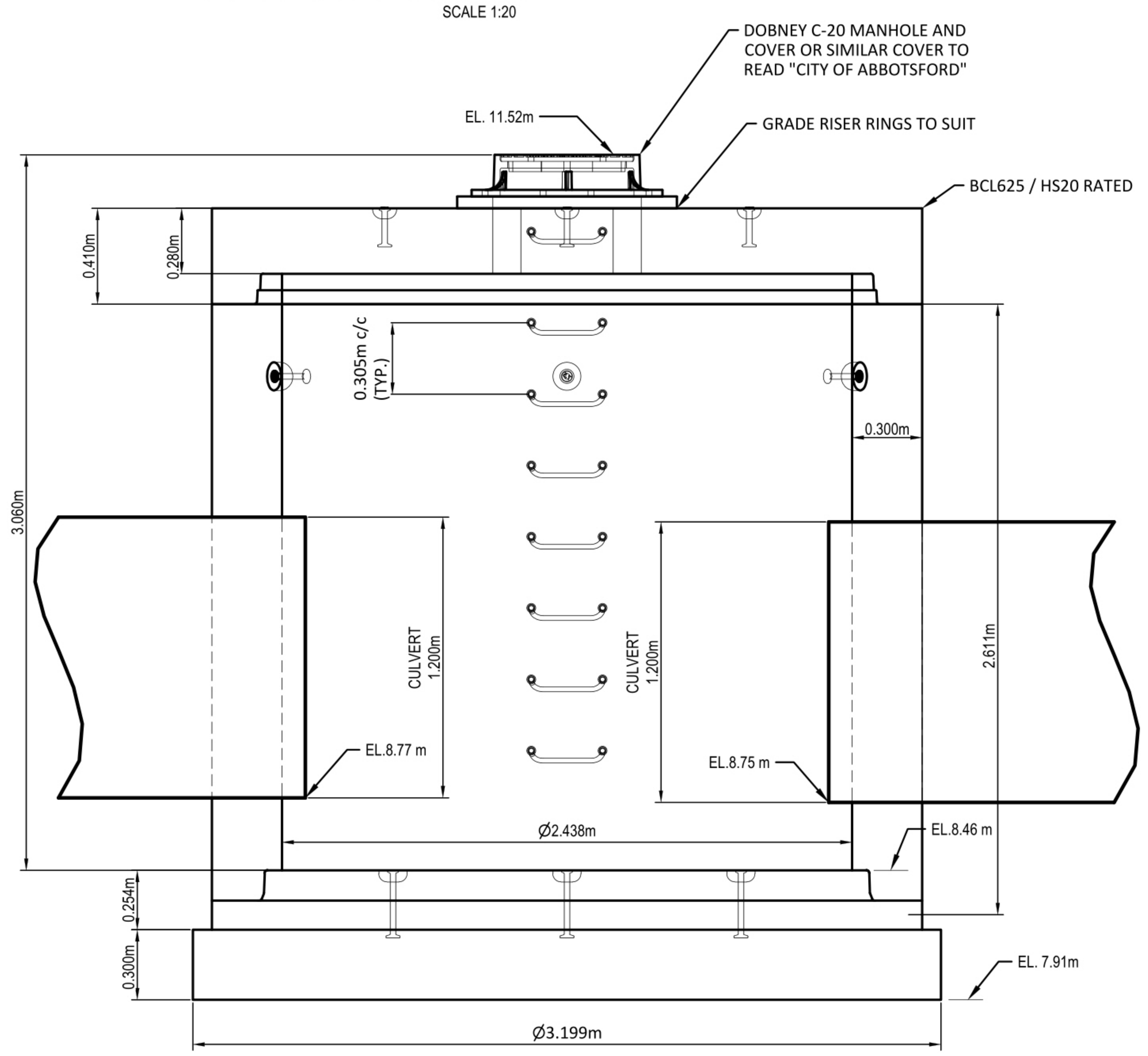
SCALE 1:20



CROSS SECTION SHOWING EXCAVATION WHERE TREES MAY BE IMPACTED

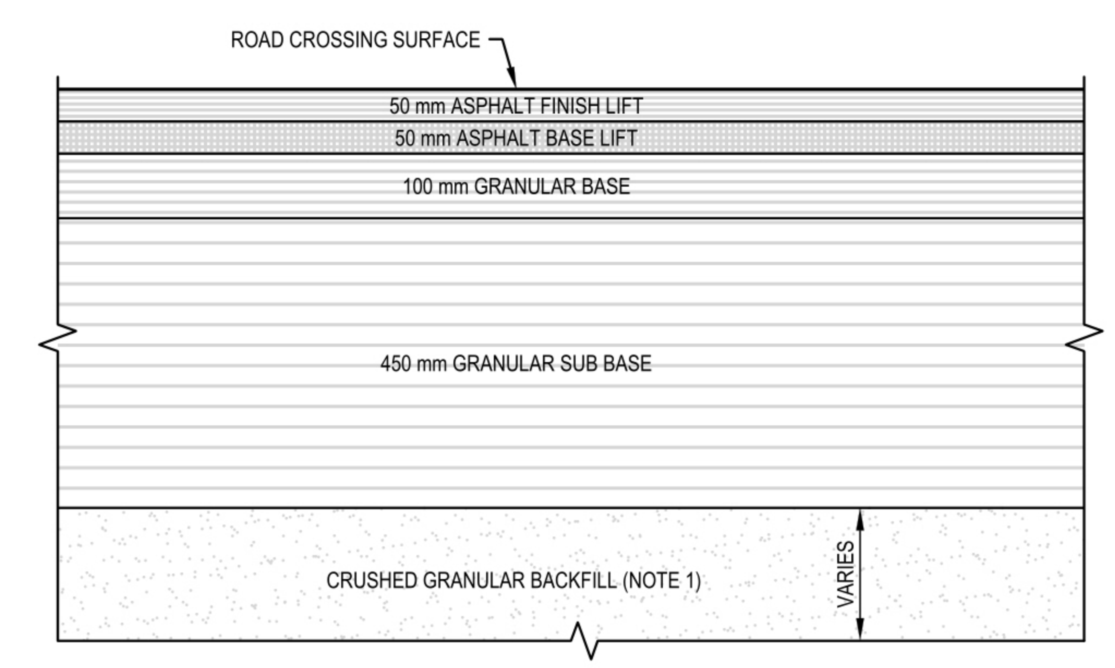
SECTION A 2005

SCALE 1:30



MANHOLE - ELEVATION VIEW

SCALE 1:20



DETAIL 1 ROAD CROSSING

SCALE 1:10

0m 0.1 0.2 0.3 0.4 0.5 — 1:10

0m 0.2 0.4 0.6 0.8 1 — 1:20

0m 0.3 0.6 0.9 1.2 1.5 — 1:30

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FILE No.	PROJECT No.	REG.	DRAWING No.
	VG07794.200	1	2006

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CANCEL PRINTS BEARING PREVIOUS LETTER

Appendix C

Site Shutdown Documents

WET WEATHER SHUTDOWN CRITERIA

BCTS-Seaward-tlasta Business Area

Environmental Management System

Discontinuing logging and road building activities during particularly intense storms can reduce landslide risk. If the total amount of rainfall over a specific time period (the intensity), exceeds the limits described below, at any time during the storm, then there is a high probability of failure based on empirical evidence.

To evaluate the potential for a landslide at a given site, it is essential to know the water balance (inputs minus outputs). The data below are required to obtain a water balance:

- A starting water balance, if known.
- The rainfall measurement taken once every 24 hours at the worksite, or from a reasonable location representing the worksite. Snowmelt is also to be added to the rain gauge measurement. Snowmelt is estimated at 2 mm of water equivalent per hour. If conditions dictate that snow is not melting, then reduce the time and associated snowmelt from the 24 hour period. During rain-on-snow conditions, the snow has a water equivalent approximately equal to 50% of the snow depth. Therefore, measuring the reduction in snow depth can give an estimate of snowmelt.
- The regional daily soil drainage rate for the worksite; 50 mm for the Seaward-tlasta Business Area.[1]

The shutdown limit for the Seaward-tlasta Business Area is a water balance of 80 mm.[2]

The following table demonstrates how the daily inputs and outputs would work.
Day 1: snowfall only (no melt)
Day 2: 40 mm of rainfall + a depth of 100mm of snow melted (use 50% as water)
Day 3: 80 mm of rainfall + a depth of 50mm of snow melted (use 50% as water)
Day 4: 130 mm of rainfall
Day 5: 40 mm of rainfall
Day 6: 10 mm of rainfall
Day 7: 0 mm of rainfall

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Previous Day's Water Balance	0 mm	0 mm	40 mm	95 mm	175 mm	165 mm	125 mm
Add Precipitation (rain plus snowmelt)	0 mm	90 mm	105 mm	130 mm	40 mm	10 mm	0 mm
Minus Regional Soil Drainage Rate	50 mm	50 mm	50 mm	50 mm	50 mm	50 mm	50 mm
Equals Current Water Balance	-50 mm = 0 mm	40 mm	95 mm = shutdown	175 mm= shutdown	165 mm= shutdown	125 mm= shutdown	75 mm= start-up

Should a landslide incident occur, complete and submit to BCTS an Incident Report Form (EMS-CHK-009), this record is a valuable component for due diligence.

[1] The Seaward-Tlasta Business Area has decided that all of its operating areas fall into the Wetter Hydrological Region referenced in the report "Precipitation Shutdown Guidelines for Worker Safety by Clayton Gillies, April 16, 2009"
[2] The 80mm shutdown limit referenced is taken from "Operational Shutdown Guidelines for Vancouver Island and the Lower Mainland", March 31, 1994.

Wet Weather Shutdown Record
BCTS Seaward tlasta Business Area

1	2	3	4	5	6	7
DATE	**Previous Day's Water Balance**	**Add Daily Precipatation**	**Minus Regional Soil Drainage Rate**	**Current Water Balance** (transfer column 5 to column 2)	**Results** (work or shutdown) if column 5 is >80mm shutdown	**Initials**
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
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	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		
	mm	+ mm	-50mm	= mm		

note: Add columns 2, 3 and 4.. Tranfser column 5 to column 2 for next day

WET WEATHER SHUTDOWN CRITERIA HARMONIZATION

BCTS Chinook and Strait of Georgia Business Areas

Project Number: 17-126
March 15, 2018

Client:
BC TIMBER SALES
Strait of Georgia Business Area
370 S Dogwood St, Campbell River, BC V9W 6Y7

Drew Brayshaw, Ph. D., P. Geo.
STATLU ENVIRONMENTAL CONSULTING LTD.
1-45950 Cheam Avenue
Chilliwack, BC V2P 1N6

www.statlu.ca

EARTH WATER LAND

EXECUTIVE SUMMARY

BC Timber Sales' Chinook and Strait of Georgia Business Units currently use separate procedures to determine whether or not environmental conditions warrant the shutdown of forestry work by their staff, licensees, and contractors.

This document consists of two components. The first is a detailed review of the existing procedures and of comparable procedures used by other units of BC Timber Sales and other licensees in the same geographic area, and a review of the relevant literature related to environmental shutdown procedures in southwestern British Columbia. The second component follows from the first and is a recommended shutdown procedure that updates, harmonizes, and streamlines the existing guidelines.

The second component has also been made into a stand-alone document circulated to contractors and licensees for their use in determining whether environmental conditions warrant shut down.

CONTENTS

1.0 INTRODUCTION

BC Timber Sales' (BCTS) Chinook (TCH) and Strait of Georgia (TSG) Business Units, acting together, retained Statlu Environmental Consulting Ltd. (Statlu) to recommend measures to harmonize their environmental shutdown criteria for forestry operations. The two business units currently use different criteria to determine whether forestry operations should shut down during wet and potentially hazardous weather. The criteria were developed at different times using differing rationales and methodology. A harmonized set of guidelines that provide consistent direction for BCTS staff and contractors as to whether forest operations should proceed or shut down in wet weather will increase safety and ease implementation across the combined business area.

2.0 THEORY OF ENVIRONMENTAL SHUTDOWN CRITERIA

Hazardous geotechnical processes are more likely to occur under some environmental conditions than others. Specifically, many mass movement processes, such as landslides and debris flows, occur when the ground is unusually wet because increased pore water pressure in surficial materials and fractured bedrock decreases cohesive forces, which increase slope instability. In Coastal British Columbia, decreased terrain stability most commonly occurs during or immediately after storms with intense precipitation or rain-on-snow precipitation, that are sometimes accompanied by high winds.

Environmental shutdown criteria are determined by defining conditions that are likely to result in mass movements. Typically, the criteria use the amount of precipitation over a period of time to set thresholds. When there is more precipitation than the threshold, field work is shut down, limiting worker exposure to precipitation-driven terrain hazards.

Climatic variation makes it difficult to define unusually wet conditions. A storm that is large enough to be significant and to cause landslides in dry parts of the province is neither unusual nor significant in wetter regions because landscapes adapt to the prevailing environmental conditions. Regions which are characteristically wetter, such as the west coasts of Vancouver Island and Haida Gwaii, require more precipitation than drier inland or sheltered areas such as Pemberton or Boston Bar, to trigger landslides.

A number of other factors complicate the issue and make it difficult to define simple, broadly applicable criteria for environmental shutdown. In addition to the climatic factors already identified, antecedent moisture conditions, the nature of surficial materials and bedrock present, the contribution to ground moisture from snowmelt and rainfall, the spatial variability of precipitation at different scales, the varying intensity of precipitation, and the varying timing of response of shallow and deep groundwater to climatic forcing all contribute to the likelihood of mass movement. Of these factors, antecedent moisture conditions are perhaps the hardest to adequately account for. Finally, climate stations in British Columbia are scattered in space and have discontinuous temporal records. They are usually located in low elevation valley bottoms and mostly absent from high elevation mountainous locales. Models and inferences must be used to refine uncertain estimates, especially in areas without measured climate values.

Environmental shutdown criteria are intended to reduce the risk to workers from unstable terrain. The mass movement events themselves do not create the risk, the potential exposure of workers and equipment to them do. If shutdown criteria are too stringent, work will be needlessly shut down, incurring an economic cost, and possibly making workers and managers less likely to follow shutdown procedures in future. Conversely, if shutdown criteria are too lenient workers, vehicles, and equipment will be at placed at unacceptable risk of injury or death, and damage or destruction respectively.

3.0 REVIEW OF RELEVANT RESEARCH AND APPLICATION

There has been considerable interest in using environmental shutdown criteria to manage risk, both in British Columbia, and internationally. Caine (1980) was one of the first to propose a simple criterion in the form of an equation relating intensity and duration of rainfall. Caine's proposed equation indicated that approximately 100 mm of rain over 24 hours was likely to cause landsliding or debris flows. The relationship was based on a wide range of climates and terrains, and consequently there was scatter in the data points from which the equation was derived. Church and Miles (1987) examined thresholds for debris flow initiation in British Columbia and found that, due to the unrepresentative nature of the climate station network, a threshold value of 50 mm of rainfall in 24 hours measured at a climate station was a predictor of landslides and debris flows in nearby mountainous terrain. Slaymaker (1990) criticized Caine's 100 mm/24 h value as being insensitive to climatic differences, as well as runoff generation mechanisms, and called for the development of different thresholds for different parts of BC. Howes (1987) noted that for the southern Coast Mountains near Norrish creek, estimated one-day and three-day precipitation totals for storms with an approximate one-in-ten year return period were respectively 93 and 123 mm, and that it was storms of approximately this frequency that typically triggered extensive landsliding and debris flows. This was an important early acknowledgement that storm frequency (return period) might be a better predictor of instability than storm magnitude (precipitation total). Crozier (1999) was one of the first to rigorously monitor and model antecedent moisture conditions and incorporate them into a 24-hour forecast model for landslide occurrence.

Chatterton (1984) was an early developer of rainfall shutdown thresholds for specific regions of BC, in this case Vancouver Island and the South Coast region. He used two zones, designating them as the "dry zone" and "wet zone", with shutdown values of 55 mm/24 h for the dry zone and 100 mm/24 h for the wet zone. These criteria were adopted by the BC Ministry of Forests in 1994.

Jakob and Weatherly (2003) developed a set of shutdown criteria for the District of North Vancouver that combined 4-week rainfall prior to a storm, 6-hour rainfall intensity during a storm, and reference to nearby stream gauges to identify two levels of landslide hazard. The first level is a warning threshold (landslides may occur – warnings are issued and personnel moved out of hazardous areas), while the second is a shutdown threshold. Jakob et al. (2006), building on earlier work by Hogan and Schwab (1991) and White and Schwab (2005) continued this analysis trend by developing shutdown criteria for forestry operations on the North Coast that incorporated wind speed, wind direction, differential air pressure at two elevations, and air temperature at elevation, as well as four-week antecedent precipitation and 24-hour rainfall intensity, to define low, moderate and high levels of landslide hazard. Low and moderate hazards correspond to local hazard shutdowns being possible and evaluated by on-site operators, while high hazards entail region-wide shutdowns.

Guthrie and Evans (2004) and Guthrie (2010) considered individual large storms that caused landslides on the mid-Coast (in 2001) and southern Vancouver Island (in 2006) respectively. Both studies found that local-scale effects (small storm cells, slope aspect and wind direction) played an important role in landslide initiation. The 2001 storm caused several significant clusters of landslides although overall precipitation recorded at nearby gauges was less than 50 mm/24 h. The 2006 storm had a wide range of precipitation intensities across Vancouver Island, and most landslides occurred when between 80 mm and 140 mm of total rainfall had fallen. Landslides did occur at a few locations when only about 50 mm to 75 mm of rain occurred, but landslides occurring at less than 80 mm of rainfall together comprised only 12% of the total number of landslides.

Sutton (2011) examined 27 years of debris flows in the Fraser Valley over a wide range of antecedent moisture conditions. She found that although high-intensity rainfall (>50 mm/24 hr) and seasonality of precipitation were the most significant variables in predicting debris flow initiation, overall predictive power of her model was low because of complex confounding factors including land use and sediment supply. Rain-on-snow precipitation events produced more debris flows than did pure rainfall-driven events.

4.0 CURRENT TCH AND TSG ENVIRONMENTAL SHUTDOWN CRITERIA

The present shutdown criteria used by the Chinook Business Area (TCH) and Strait of Georgia Business Area (TSG) are summarized below (Table 1). The TCH shutdown criteria were developed by Tom Millard, P. Geo. of the BC Ministry of Forests and Range in 2010. The TCH guidelines define four zones. Three of the zones are climate-based (very wet zone, wet zone, and dry zone) while the fourth zone is a site-specific case for areas where old, undeactivated, unstable road networks are located upslope of a work area. Shutdown criteria are presented for half-day (i.e. 12 hours to start of shift or shift end), 24-hour, 48-hour, and 72-hour intervals for each zone. Modifiers are presented to account for the effective precipitation derived from snowmelt for windy and sunny conditions, based on temperature and wind speed. After work is shut down, it remains shut down for a minimum of 24 hours, and may continue to be shut down for longer if ongoing precipitation inputs remain above the threshold criteria. No explicit assumptions concerning soil drainage rates are made.

The TSG shutdown criteria were developed by R.W. Askin, P. Eng., P. Geo. of Integrated Watersheds Ltd. in 2006. There are five zones based on mean annual precipitation, each with a different 24-hour rainfall intensity shutdown threshold. The zone-based threshold values are modified by surficial material type and slope steepness of local work areas to arrive at a specific shutdown threshold for a specific work site. Return to work after a shutdown depends on the slope position of the work site, with different elevations on the slope assumed to drain at different rates. Once total precipitation has been modified by drainage over time to be below shutdown threshold, work may recommence. Therefore, this method uses precipitation to guide shutdown but water balance to guide resumption of work.

In both cases, whether to shut down or not is determined locally (on or near the work site) based on readings of an on-site precipitation gauge or gauges. No additional information (such as weather forecasts, stream gauges, or measured conditions at locations other than the work site) is used, although the TCH guidelines note that using a base station and weather forecasts can help avoid having to travel to the site during shut down to determine if conditions are safe to restart.

Table 1: Comparison of 24-Hour Precipitation Shutdown Thresholds by Zone, Present TCH and TSG Guidelines

TCH Zone	Unmodified[1] Shutdown Threshold (mm)	TSG Zone	Unmodified[2] Shutdown Threshold (mm)
Very Wet (>2500 mm/yr)	100	>3500 mm/yr	90
		>3000 mm/yr	75
		>2500 mm/yr	60
Wet (1500-2500 mm/yr)	80	>1500 mm/yr	40
Dry (<1500 mm/yr)	50	>750 mm/yr	20

4.1 Other Relevant BC Timber Sales Operating Areas

For comparison purposes, I also evaluated BC Timber Sales' current Seaward-tlasta (TST) and Skeena (TSK) shutdown criteria. I did not want to directly compare their shutdown criteria thresholds to the TCH/TSK criteria, because the climate and local hydrology differ, but rather to compare and contrast their underlying methodology. The TST shutdown criteria are based on a water balance value, rather than a rainfall value, and are modified by estimates of rain-on-snow and snowmelt. The water balance is computed on a day-by-day basis based on total precipitation and snowmelt over the previous 24 hours modified by a single soil drainage rate of 50 mm/day. Work is shut down whenever the daily water balance exceeds 80 mm and resumes whenever the water balance drops below 80 mm.

The TSK criteria are the simplest of those I reviewed. The Skeena Business Unit is divided into three climate zones. Shutdown criteria are based on 24-hour precipitation, with values of 100 mm, 75 mm, and 50 mm respectively (from wettest zone to driest zone) resulting in

[1] If unstable upslope roads are present, the 24-hour shutdown threshold is 20 mm, regardless of zone.

[2] Slope gradient and surficial material type modify the listed threshold. The modified threshold may range from a high of 100% to a low of only 28% of the unmodified value.

shutdown. Operations may resume one day after shutdown conditions cease. There are no modifiers for snowmelt, slope position, soil drainage, or other factors.

4.2 Other Forest Licensee Shutdown Criteria

Rainfall shutdown criteria have not been standardized across BC, let alone in the Coastal region. WorkSafeBC prescribes that certain forestry operations, such as cable yarding of steep slopes, must have shutdown procedures in place, but does not specify the criteria for such shutdown. Currently, each forest licensee or contractor can use their own set of criteria, as long as such criteria are documented, are developed by a qualified professional using due diligence, and are provided to workers to guide shutdown of operations. For instance, Island Timberlands, a private forest land owner, has developed a Terrain Management Code of Practice that includes terrain vulnerability maps with defined regional rainfall criteria to guide operational shutdown (Higman and Horel, 2006).

In some cases, especially with smaller licensees, shutdown criteria developed for one area may later be reused in another area for which the developed criteria are inappropriate. Qualified professionals should always be consulted to determine if existing shutdown procedures are appropriate before the existing procedures are applied to new work areas, unless the existing procedures explicitly define the area(s) in which they should be applied.

4.3 Other Shutdown Criteria

Shutdown criteria are also used in other resource industries, and not just in the forest industry. Some of these contain detailed prescriptions for site-specific conditions. For instance, Pierre Friele, P. Geo of Cordilleran Geoscience (2012) developed shutdown criteria for the Upper Lillooet River run-of-river hydroelectric project that included specific shutdown criteria based on air temperature, because of the local hazard of very large landslides from the Mt Meager Volcanic Complex caused by glacial melt. Cordilleran (2013) has also provided recommendations to MoFLNRO's Squamish office for shut down criteria for users of the Squamish River FSR that incorporate air temperature, in this case because of frequent debris flows from the Mount Cayley volcanic complex.

4.4 Effectiveness of Existing Shutdown Criteria

There is evident variation in the nature of shutdown criteria applied across Coastal BC. Some sets of criteria are complex while others are simpler. Some account for factors such as wind speed and snow melt while others do not. For the same geographic area, two separate licensees may have two separate sets of shutdown criteria which use different methods and result in differing thresholds to determine if and when work should shut down, resulting in different acceptance of risk by workers.

Deaths or injuries due to landslides or debris flows are relatively rare events within the forest industry. Only one such event has occurred in the past decade in the TCH/TSG region, when a logging truck driver was killed by a debris flow in Emory Creek in November 2015. Case studies of such events can determine whether the shutdown criteria that were in place were followed or not, but the total number of events is too small to permit a statistically significant analysis of the comparative effectiveness of different shutdown criteria. Therefore, the design and implementation of new shutdown criteria cannot be entirely evidence-based, because the existing evidence is inadequate; they must incorporate professional knowledge and experience, as well as discussions of acceptable risk levels.

There are two measures of effectiveness (Table 2). When no shutdown is recommended and landslides do not happen, and when shutdown is recommended and landslides happen, the shutdown guidelines are functioning as designed. The possibility of landslides occurring when shutdown is not recommended, as discussed above, is an obvious potential failure of the shutdown guidelines, but occurs too rarely to be successfully analysed statistically to determine the comparative effectiveness of different shutdown thresholds.

Table 2: Success and Failure Matrix for Shutdown Guidelines

Shutdown Recommended?	**Landslides Happen?**	
	Yes	No
Yes	Success	Failure
No	Failure	Success

The last case to be considered is the failure of shutdown guidelines that happens when shutdown is recommended but no landslides occur. This incurs an economic cost that must be balanced against the decrease in safety incurred by less conservative shutdown guidelines. Although the sample size for deaths, injuries, and damage to equipment caused by lenient shutdown criteria is very small and thus difficult to analyze, it is relatively easy to evaluate the potential relative and absolute cost of any recommended shutdown criterion by comparing it to (measured or modelled) rainfall intensity and determining the return period of the shutdown criterion, i.e. a shutdown criterion that results in work being stopped, on average, for four days per year will be twice as expensive as one that results in work being shut down for only two days per year on average.

5.0 FEEDBACK ON EXISTING SHUTDOWN CRITERIA

BCTS staff from both TCH and TSG report that the existing procedures work, in that shutdown is not felt to idle workers too frequently, nor are workers exposed to unacceptable risk by criteria that indicate work should proceed when conditions are notably unsafe. They do report that clients and contractors sometimes find the calculations required to determine if shutting down operations is necessary, or if restart of operations is recommended, to be complex and require interpretation. Hence, a revised procedure using simpler calculations, with the potential to be developed into an app-based option for use on phones or tablets, is desirable.

The current system of using rainfall gauges at the work site provides accurate estimates of local precipitation, but BCTS staff suggested that advances and improvements in climate measurement, such as the new network of BC Wildfire Branch meteorological stations, might be able to improve on local-gauge-only calculations.

It is important to distinguish between environmental shutdown criteria designed for worker safety and environmental shutdown criteria designed for environmental management. From discussion with BCTS staff, shutdown criteria intended to manage worker safety have sometimes been used to manage for other values in the absence of more specific criteria. Typically, shutdown criteria designed to manage environmental values, such as to protect water quality in community watersheds, are much more stringent than criteria designed to protect worker safety, because safe work is still possible under environmental conditions where water quality may be adversely affected. Shutdown criteria for worker safety may be defined broadly (by climatic region) whereas shutdown criteria for environmental values would typically be best defined locally, depending on the environmental value(s) to be managed, through means such as watershed assessments or terrain stability and sedimentation hazard assessments.

6.0 RECOMMENDED HARMONIZED SHUTDOWN CRITERIA FOR TCH AND TSG BUSINESS AREAS

The combined TCH and TSG business area is very large, covering all of the BC South Coast from Boston Bar to the west coast of Vancouver Island, and including Haida Gwaii. Accordingly, the harmonized criteria must be capable of predicting when shutdown of operations is warranted over a wide range of environmental conditions from dry to wet, and over a similarly wide range of surficial geologies, flood generation processes, timings of runoff, and past histories of disturbance.

6.1 When to Use Shutdown Criteria

Workers are exposed to geotechnical hazards not only at the work site but also along access routes that reach the work site. Accordingly, shutdown criteria must apply to not only work sites such as cutblocks and roads under construction, but also roads used for access to and from these work sites.

Environment Canada provides forecasts and measurements of rainfall of varying accuracy for all of the areas of the TSG and TCH business areas. Where forecasts and measurements do not accurately reflect conditions at the work site, they typically underestimate, rather than overestimate, actual rainfall. Therefore, workers should check forecasts and reported rainfall totals before travelling to the work site. If predicted or recorded rainfall for the day exceeds the listed shutdown thresholds, it is likely unsafe to travel to the work site, and there is no need to expose workers to hazards while checking the rain gauge at the work site.

Otherwise, shutdown criteria should apply when work sites or access routes are located on, downslope of, or exposed to landslide-prone terrain. "Landslide prone terrain" includes, but is not limited to:

- areas with greater than 60% slope gradients (greater than 50% on Haida Gwaii),
- areas mapped as unstable or potentially unstable (U or P) on reconnaissance terrain stability mapping,
- areas mapped as Class III, IV, IVR, or V on detailed terrain stability mapping,
- areas identified as being subject to slope instability or where landslides would deposit in terrain stability field assessments,
- gullies or alluvial fans,
- areas where past instability has occurred.

Exceptions may be made where the nearest landslide-prone terrain is more than 300 m upslope of the work site or access route and the intervening terrain is low-gradient (i.e. with slope gradients of 30% or less throughout).

6.2 Basic Shutdown Criteria By Zone

Table 3 provides the recommended shutdown criteria based on rainfall for five climatic zones plus one "identified unstable conditions" zone, over four time intervals, combining the TSG and TCH methods. Climatic zones may be determined from maps showing the distribution of average annual precipitation or can be determined easily for a specific location from an online climate model such as ClimateBC (Wang et al, 2016). It is relatively simple for foresters, geoscientists or BCTS staff to use such models and specify the annual precipitation in a terrain report or project particulars for a proposed cutblock or road and thus to identify the appropriate zone for workers to use when evaluating shutdown criteria.

Table 3: Proposed Shutdown Criteria by Zone, Harmonized TSG and TCH Business Areas

		Time Period			
Zone	Zone (annual precipitation)	At start of or before end of shift (12-hr)	24-hr	48-hr	72-hr
1	Very wet (3000 mm to 4000 mm or more)	60 mm	100 mm	150 mm	200 mm
2	Wet (2500 mm to 3000 mm)	50 mm	80 mm	120 mm	160 mm
3	Average (1500 mm to 2500 mm)	40 mm	70 mm	100 mm	130 mm
4	Dry (750 mm to 1500 mm)	30 mm	50 mm	80 mm	110 mm
5	Very dry (less than 750 mm)	20 mm	30 mm	50 mm	80 mm
6	Identified Unstable Conditions	10 mm	20 mm	30 mm	40 mm

Table 3 assumes that rainfall will be measured in a gauge at the work site. It is expected that in some forestry settings, there may be a considerable elevation range between the elevation of the rainfall gauge and the highest elevation at which work is taking place, and that more rainfall may occur at higher elevations than is measured at the gauge; the shutdown criteria incorporate this assumption.

"Identified unstable conditions" refers to conditions where a qualified professional has identified and documented conditions at or upslope of the work site which require special precautions for safe work beyond those which are normally applicable. Identified unstable conditions can occur in any precipitation zone. This category might be used, for instance, to guide operations when attempting to determine if it is safe to rebuild a road across the deposit of a recent landslide. Examples of items from terrain stability field assessment reports that might indicate "identified unstable conditions" include old, undeactivated roads with tension cracks and drainage diversions upslope of a work site, landslide scars upslope of a work site, roads which cross gullies identified as experiencing debris flows, or terrain identified as having high or very high terrain stability hazard upslope of a work site.

6.3 Modifiers to Shutdown Criteria

Numerous factors other than direct rainfall can contribute to slope instability, including snow melt (either from rain-on-snow precipitation, high temperatures, or both), high winds, blocked drainage structures or diverted drainage upslope, long-term antecedent precipitation, earthquakes, and other less probable events. Unlike rainfall, these factors can be difficult for on-site workers to measure accurately; snow accumulation and snow melt are both more spatially variable than rainfall, and other factors like wind speed are even less amenable to simple measurement by workers. The variability of these factors with elevation can also be greater than the variability of rainfall with elevation.

To account for these factors without requiring multiple difficult and potentially inaccurate calculations, a simpler system is proposed. Potential additional risk factors beyond simple rainfall totals are listed below. The presence of one or more of these additional risk factors cause the zone number used to determine the shutdown criteria to change. Each risk factor present shifts the zone number up by one. For instance, a project is located in Zone 2 which has a 24-hr threshold of 80 mm. A storm brings 60 mm of rainfall in 24 hours, accompanied by warm temperatures with snow present (one factor) and rain-on-snow (one factor). Zone 2 is therefore shifted to Zone 4: 60 mm of rainfall is greater than the Zone 4 24-hr shutdown value of 50 mm, so work shuts down.

The additional risk factors beyond rainfall totals are:

- Rain falling on snow at the job site;
- Warm temperatures (greater than 5 °C at the gauge) with snow present on the ground at the job site;

For these two conditions, any snow, even small amounts of patchy snow, at the job site is counted as snow. Small amounts of snow at a job site indicate larger amounts of snow upslope.

- High winds (windspeed reported or predicted >60 km/h, or visibly breaking branches, or causing windthrow) at job site;
- Very wet conditions (defined as any period of 21 days or longer with precipitation recorded on every day). Periods longer than 21 days do not increase the very wet conditions hazard further;
- Visibly high stream flow (ditches full and overflowing onto roads, culverts discharging at capacity, culverts blocked by debris flow and diverting water to adjacent streams, floodwater present on adjacent highways, etc.)
- Earthquakes of magnitude 5.0 or greater within last week, reported with epicenter within 50 km of job site.

If the presence of additional risk factors increases the zone beyond Zone 6, i.e. beyond the "identified unstable conditions" zone, work should shut down regardless of whether or not the rainfall shutdown value has been exceeded, and should remain shut down until the additional risk factors are no longer present.

6.4 Other Shutdown Criteria

In addition to shutdowns resulting from the exceedance of rainfall criteria, workers and supervisors should remain aware of other indicators of geotechnical instability. These can include, but are not limited to:

- pulses of sediment-laden water in streams, especially in gullies,
- streams suddenly drying up when conditions are otherwise wet,
- constant small rock falls,
- cutslope slumps that block ditches and/or roads,
- tension cracks appearing in road fills or slopes,
- fresh avalanches, landslides, or debris flows or their deposits observed that were not present during the last shift,
- anchor stumps pulling out of wet ground during cable yarding,
- diverted streams with flow appearing in new stream courses that were previously dry.

If any of these indicators of instability are observed, work should shut down until a qualified professional can be brought in to determine if it is safe for work to proceed.

These shutdown criteria apply to landslides and debris flows that form the predominant geotechnical hazards to workers. Snow avalanches pose seasonal hazards to workers and exposure to snow avalanches should be managed by qualified professional avalanche technicians.

Rockfalls often pose an additional hazard to workers. Many rockfalls occur under the same environmental conditions that cause landslides and debris flows. In addition, freeze-thaw cycling, especially on clear days during winter with warm days and cold nights, can cause rockfall. If rockfall is an identified hazard that can affect a work site, workers should be aware of the potential for freeze-thaw conditions to trigger rockfall and take appropriate precautions. In most cases, freeze-thaw generated rockfall does not occur at scales necessitating complete shut down of work, and can be managed to reduce risk to tolerable levels by reducing worker exposure to areas in which rock fall is likely to occur.

6.5 Resumption of Work after Shut Down

Once shutdown criteria have been exceeded, work should remain shut down for at least 24 hours after the hazardous conditions end. In the case of 48-hour or 72-hour rainfall criteria being exceeded, work should remain shut down for at least two days (48 hours) after shutdown criteria have been exceeded. If workers and supervisors believe it is safe for work to resume before the recommended 24- or 48-hour period is over, they should consult a qualified professional to confirm and document this before resuming work.

7.0 LIMITATIONS

WorkSafeBC Section 20.78 (Excavations) requires written instructions by a qualified professional that specifies the influence of changing weather conditions on the stability of an excavation. This procedure does not waive or take precedence over the requirements of WorkSafeBC Section 20.78.

The recommendations provided in this report are based on observations made by Statlu and are supported by information Statlu gathered. Observations are inherently imprecise. Conditions other than those indicated above may exist. If such conditions are observed or if additional information becomes available, Statlu should be contacted so that this report may be reviewed and amended accordingly.

This report was prepared considering circumstances applying specifically to the client. It is intended only for internal use by the client for the purposes for which it was commissioned and for use by government agencies regulating the specific activities to which it pertains. It is not reasonable for other parties to rely on the observations or conclusions contained herein.

Statlu prepared the report in a manner consistent with current provincial standards and on par or better than the level of care normally exercised by Professional Geoscientists currently practicing in the area under similar conditions and budgetary constraints. Statlu offers no other warranties, either expressed or implied.

8.0 CLOSURE

Please contact me should you have any questions or if you require further clarification.

Prepared by:

Statlu Environmental Consulting Ltd.

Reviewed by:

Drew Brayshaw, Ph. D., P. Geo.
Senior Hydrologist and Geoscientist

Eryne Croquet, M. Sc., P. Ag., P. Geo
Agrologist and Geoscientist

REFERENCES

BC Timber Sales, 2006. Wet Weather Shutdown Guidelines, Strait of Georgia Business Area.

BC Timber Sales, 2009. Wet Weather Shutdown Criteria, Seaward-tlasta Business Area.

BC Timber Sales, 2010. Wet weather safety shutdown guidelines (WWSSG) (rainfall and snowmelt), Chinook Business Area.

BC Timber Sales, 2012. Standard operating procedures, Heavy Rainfall Shutdown, Skeena Business Area

Cordilleran Geoscience Ltd., 2012. Volcanic landslide risk management, Lillooet River valley, BC: start of North and South FSRs to Meager Confluence. Unpublished technical report for MoFLNRO.

Cordilleran Geoscience Ltd., 2013. Weather thresholds and operational safety planning, Turbid Creek, Mount Cayley, Squamish River Valley, BC. Unpublished technical report for MoFLNRO.

BGC Engineering Inc., 2005. Hydro-meteorological thresholds for landslide initiation and forest operations shutdowns in the Kalum and North Coast forest districts. Forest Sciences Program, File # 17010-30/FR05RNI004.

Caine, N. 1980. The rainfall intensity-duration control of shallow landslides and debris flows. Geografiska Annaler Series, A62, 23-27.

Chatterton, A., 1984. Operational shutdown guidelines for Vancouver Island and the Lower Mainland. Government of Canada.

Church, M and M. Miles, 1987. Meteorological antecedents to debris flow in southwestern British Columbia. In JE Costa and GF Wieczorek, eds, Debris flows and Avalanches, Geological Society Review Engineering Geology, VII.

Crozier, M. 1999. Prediction of rainfall-triggered landslides: a test of the antecedent water status model. Earth Surface Processes and Landforms, 24, 9, 825-833.

Egginton, V., J. Clague, and P. Jackson, 2007. Using weather imagery to identify potential landslide triggers in northern British Columbia. Streamline Watershed Management Bulletin, 11, 1, Fall 2007.

Hogan D. and J. Schwab, 1991. Meteorological controls associated with hillslope failures on the Queen Charlotte Islands. BC MOF Land Management Report 73.

Horel, G, and S. Higman, 2006. Terrain management code of practice. Streamline Watershed Management Bulletin, 9, 2, Spring 2006.

Guthrie, R. and S. Evans, 2004. Magnitude and frequency of landslides triggered by a storm event, Loughborough Inlet, British Columbia. Natural Hazards and Earth System Sciences, 4, 475-483

Guthrie, R., S. Mitchell, N. Lanquaye-Opoku, and S. Evans, 2010. Extreme weather and landslide initiation in coastal British Columbia. Quarterly Journal of Engineering Geology and Hydrogeology, 43, 417-428

Jakob, M., K. Holm., O. Lange, and J. Schwab, 2006. Hydrometeorological thresholds for landslide initiation and forest operation shutdowns on the north coast of British Columbia. Landslides DOI 10.1007/s10346-006-0044-1

Jakob, M. and H Weatherly, 2003. A hydroclimatic threshold for landslide initiation on the North Shore Mountains of Vancouver, British Columbia. Geomorphology 54, 137-156.

Millard, T., M. Geertsma, J. Clague, P. Bobrowsky, A. Hasler and M. Sakals, 2012. Landslides on Haida Gwaii during and after the earthquake. Risky Ground 2012, SFU, Winter Edition.

Ministry of Forests, Lands and Natural Resource Operations, 2013. Review of landslide management in BC.

Slaymaker, O. 1990. Debris torrent hazard in the Eastern Fraser and Coquihalla Valleys. Western Geography 1, 1.

Sutton, E., 2011. Influence of hydrometeorological controls on debris flows near Chilliwack, British Columbia. Master's Thesis, School of Resource and Environmental Management, SFU.

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA - High-Resolution Spatial Climate Data for Western North America. Journal of Applied Meteorology and Climatology 51: 16-29. [http://climatemodels.forestry.ubc.ca/climatewna/]

White R., and J. Schwab, 2005. Precipitation shutdown guidelines; a strategy for their identification in the North Coast Forest District. BC MOF, unpublished technical report.

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 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 are 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, guaranty, 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 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, mould 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.

17. **Sample Disposal:** Wood will dispose of all uncontaminated soil and rock samples after 30 days following the release of the final geotechnical report. Should the Client request that the samples be retained for a longer time, the Client will be billed for such storage at an agreed upon rate. Contaminated samples of soil, rock or groundwater are the property of the Client, and the Client will be responsible for the proper disposal of these samples, unless previously arranged for with Wood or a third party.