GEO-HAZARD ASSESSMENT

30420 Trans-Canada Highway, Yale BC

FOR:

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BY:

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Synopsis

1. Parts of the property are subject to localized landslip and inundation by flooding. We recommend the following for the main residential structure:

    - We estimate an annual probability of localized landslip to be 1:200 to 1:10,000 and recommend a 10 m setback from the crest of Slope 2.
    - The subject property is within the Fraser River 60 m setback. Based on our geohazard assessment, we believe that a setback of 45 m is reasonable and safe for use intended.
    - The annual probability of flooding from Fraser River is greater than 1:200 below Terrace 2, and less than 1:200 at and above Terrace 2. A Flood Construction Level of 55.35 m elevation for the property is prescribed by Bylaw No. 0681.

2. The surrounding area is subject to large catastrophic landslides (1:1,000 to 1:10,000), mountain stream avulsion (<1:500), and rockfalls (<1:10,000), however, the annual return frequency of these evidence are acceptable for Approval without conditions related to the hazard. Gordon Creek is subject to debris flows (1:500 to 1:10,000), however, the risk of affecting the property decreases with its distance (130+ m) from the property. There is no evidence of these hazards directly affecting the property in the past and recommend approval.

3. In our professional opinion, the land on the subject site is safe for the intended use of single family dwelling provided that the recommendations of this report are adopted.

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GEO-HAZARD ASSESSMENT

30420 Trans-Canada Highway, Yale BC

1 Introduction

As requested by Mr. Mike Cook (the 'Client'), Madrone Environmental Services Ltd. ('Madrone') performed a geo-hazard assessment of 30420 Trans-Canada Highway, Yale, B.C. (the 'Land' or 'Property' or 'Site'), PID 024651320.

The Land is situated within the Fraser Valley Regional District (FVRD) Electoral Area B, and subject to the Official Community Plan (OCP) Bylaw, 1998, No. 0150[1] and the Floodplain Management Bylaw 0681, 2005[2]. Geological Hazards Development Permit Areas (DPA) is designated according to Section 488 of the Local Government Act to protect development from hazardous conditions. Among other things, FVRD wishes to protect existing and future development from natural hazards such as flooding, debris torrents, channel bank erosion, and potential instability of adjacent slopes.

The provincial Community Charter (Section 56) requires that any new development on property subject to or likely to be subject to geotechnical hazards requires a geotechnical hazard assessment to characterize the hazards, estimate their probability of occurrence, and provide a professional opinion that development is safe for the use intended if mitigation measures are incorporated.

We prepared this report in accordance with the guidelines for geotechnical hazard assessments as described in:

[1] Fraser Valley Regional District Electoral Area 'B' Official Community Plan (OCP) Bylaw, 1998, No. 0150 file://fs4/users_profiles$/robertaa/Desktop/Area%20B%20-%20OCP%20Bylaw%200150%20-%20Yale,%20Emory%20Creek,%20Dogwood%20Valley%20and%20Choate.pdf

[2] Fraser Valley Regional District Floodplain Management Bylaw No. 0681, 2005 http://www.fvrd.ca/assets/Government/Documents/Bylaws/Planning~and~Land~Use/Floodplain%20Management%20Bylaw%200681,%202005.pdf

1. FVRD Electoral Area B Official Community Plain, No. 0150, 1998, and FVRD Floodplain Management Bylaw 0681, 2005;
2. Hazard acceptability thresholds for development approvals by local government (Cave, 1993); and
3. Guidelines for legislated landslide assessments for proposed residential developments in BC (APEGBC, 2010).

We have collected and reviewed appropriate background information, conducted field work on and beyond the Property, and considered changed conditions (i.e. climate and land use). For geo-hazard analysis, we have reviewed, characterized, and estimated geo-hazards that may affect the Property, namely, possible slope instability above and below the proposed dwelling location. We have described the method of geo-hazard analysis used, referred to an appropriate and identified regional guideline for levels of geo-hazard safety, compared this guideline with the findings of our investigation, made a finding on the levels of safety on the Property based on the comparison, and made recommendations to reduce geo-hazards.

1.1 Scope and Objectives

We understand that the proposed development consists of one single-family dwelling or mobile home unit and a workshop, and as such a building permit is being sought. The Property is not designated as being within the DPA 1 B Geological Hazard Development Permit Area within the 1998 OCP Bylaw, however, multiple studies commissioned by the FVRD have identified this area as such, and therefore the FVRD utilizes these studies in lieu of an updated OCP. The scope of work includes a geotechnical hazard assessment for the property, which includes modeling slope performance during seismic events if applicable, and a proposed building envelope. At the time of this assessment, the exact locations of the buildings had not been finalized.

The objective of this assessment, therefore, is, as required by the Local Government Act (Sections 488(1) and 491) for a building permit, to assist the local government in determining what conditions or requirements it will impose in the permit.

This geotechnical hazard assessment is limited to the property at 30420 Trans-Canada Highway, Yale, B.C. The scope of this report does not extend to other properties; however, we considered the potential for landslides from adjacent areas to affect the subject property.

1.2 Background Information

For this assessment, we collected and reviewed:

- iMapBC[3]
- FVRD Electoral Area B Official Community Plan Bylaw 1998, No. 0150;
- FVRD Webmap[4]
- Climate data[5]
- Previous reports
- Air photos

1.2.1 Air Photo Analysis

Air photo analysis allows us to observed changes in the landscape over time, as well as finds features that may not be clearly visible during field assessments. However, short-term events such as flooding are not always captured in air photos; we can only see them when the damage is extensive and long lasting. We know that Gordon Creek flooded in 1949 and 1980, and Fraser River flooded in 1948. The 1948 air photos were taken July 16, 1948, whereas the river flooded June 8, 1948 and non-destructive evidence of flooding is difficult to observe.

TABLE 1: AIR PHOTO ANALYSIS FOR AREA SURROUNDING 30420 TRANS-CANADA HIGHWAY, YALE BC

Photo Number(s)	Year Taken	Interpretation
A289:39	1928	Most of the property has been stripped of vegetation with the exception of the northern portion near the River backchannel. Railway and roads already exist.
BC614:52-51	1948	The second largest flood in historical time for the lower Fraser Valley occurred a month before this photo was taken. Unfortunately, the quality of the

[3] Government of British Columbia. (updated 2015, September 3). *iMapBC 2.0*. Retrieved October 2017, from http://maps.gov.bc.ca/ess/sv/imapbc/

[4] FVRD. *Regional Webmap*. Retrieved October 2017 from http://leo.fvrd.bc.ca/RIM_Public/?tempest_wi_sessionid=649650875334624400

[5] Environment Canada. (modified January 25, 2017). *1981 – 2010 Climate Normals and Averages – Normals Laidlaw.* Retrieved October 2017 from http://climate.weather.gc.ca/climate_normals/index_e.html

Photo Number(s)	Year Taken	Interpretation
		photo makes flood evidence hard to discern. Water levels are high and the backchannel is full, infrastructure routes appear to be open.
S69-R4:18-19	1951	Driveway/trail on property with small shed/building at the eastern most edge of upper terrace. Neighbour to south has building. Gordon Creek to south has large discharge evident that has cleared vegetation near creek east of railway.
BC1686:109	1954	NN
BC4018:8-9	1961	Logging road northwest of site, switchbacks up mountain and logged.
BC5327:56-55	1969	Neighbour property developed.
BC7468:90-89	1974	Transmission lines installed north of property.
BC79140:93	1979	Driveway cleared
BC83019:35-36	1983	Gordon creek widened at highway, possibly for channelization.
BC88096:114-115	1988	NN
BCB92112:104-105	1992	NN
BCC96125:192-193	1996	Building in NW corner of property built
BCC02032:112-111	2002	NN

1.2.2 Review of Existing Reports

We retained previous geotechnical reports from the FVRD Cloud Server[6] that may affect the Property and found the following reports. Other reports may have been completed in the area, but these were the only ones available at time of this report.

1. Overview of Geological Hazards in the Yale-Dogwood Valley Areas. Thurber Consultants Ltd., 1987; FVRD # (80) 1987 09 22*.

    - This report was commissioned by the Regional District of Fraser Cheam in 1987 as an overview of the geological hazards for the Yale and Dogwood Valley areas. The work consisted of a map and aerial photo study, review of information, and field work. The result was an area description and geological overview as well as a map outlining preliminary "safelines" and

[6] https://cloud.fvrd.ca/s/tPwSftwPiTifniR

highlighting areas of concern. In general fault movements, earthquakes, rockfall, rockslide, debris avalanche, catastrophic erosion of deposits, snow avalanches, and floods were all determined to be natural hazards relevant to the study area. A detailed assessment was recommended, and a map was made for reference. However, this map was not included in the background information provided by the FVRD.

2. Yale South Slope Stability Assessment. Thurber Consultants Ltd., 1990; FVRD # (125) 1990 01 04*.

    - This slope stability assessment was commissioned by the Regional District of Fraser Cheam in 1990. An overview of the study area was completed and focus was spent on the west slopes, Princess and All Hallows, All Hallows and Graveyard creeks, and South Yale. This report revised the safeline locations originally defined in the 1987 report. A map was provided with this report; however, it did not extend to the property.

3. Geologic Hazards and Risk Assessment, Yale, BC. Cordilleran Geoscience, 2010; FVRD # (677) 2010 03 09.

    - This study addresses the recommendation for a review and update of the geologic hazards and risk management policies for Yale by the FVRD. Ultimately this study is to be used to adopt a geological risk management for the Village of Yale Official Community Plan. As of this report, the OCP has not been updated since 1998. This report was a compilation of existing data and site-specific fieldwork. The report outlined multiple geologic hazards within the area as well as recommending changes for the OCP hazard mapping. This is the most comprehensive mapping done of the area in recent years. Like the previous reports, the map accompanying this report does not extend towards the subject property. However, relevant background information for larger geohazard features is applicable.

4. Flooding and Landslide Events Southern British Columbia 1808 to 2006. Ministry of Environment, 2006.

    - This report attempts to assemble and catalog landslides, snow avalanches, and flooding events that have had impacts on property and human life since the early 19th century. This report is chronological and covers the southern part of British Columbia. Flooding events that are expanded upon in detail in this report.

* Report and assessments were carried out before APEGBC's Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC (2010) and the Legislated Flood Assessments in a Changing Climate in BC (2012)

2 Physical Setting and Observations

The subject Property is situated along the western shore of the Fraser River, approximately 1.5 km southwest of Yale town centre (Figure 1). Yale is the southern extent of the Fraser Canyon, a gorge cut by the Fraser River through the Coast Mountains, which widens to approximately 1 km south of Yale. Gordon Creek runs west to east into the Fraser River, approximately 140 m south of the property. The bedrock geology of the area has been mapped as Cretaceous to Tertiary, which locally consists of metamorphic rock. The bedrock underlying the subject property is mapped as the Custer Gneiss[7], a granitic gneiss with abundant pegmatite dikes, schist and amphibolite. No bedrock was exposed on site, however, this is consistent with the local geotechnical reports. The Hope Fault runs north-northeast approximately 900 m west of the property, and is believed to be inactive.

FIGURE 1: OVERVIEW OF YALE REGION. PROPERTY OUTLINED IN RED, GORDON CREEK IN BLUE. FROM GOOGLE EARTH PRO.

South of Yale where the property is located, the lower elevations in the river valley consist of terraces, alluvial fans, and floodplains. The upper sections of the valley walls consist of morainal mantles an colluvium deposits overlying bedrock slopes. The property itself is underlain by fluvial sediments consisting of sands and gravels. There is no published

[7] Bellefontaine, K., Alldrick, D. and Desjardins, P.J., 1994: Mid Coast (all or parts of 92F, G, J, K, L, M, N; 93D; 102P; 103A), Ministry of Energy, Mines and Petroleum Resources, Open File 1994-17.

surficial geology map for the Yale region; however, the fluvial sediments are consistent with the geomorphology, glacial history, and observations from other reports.

The property ranges in elevation between approximately 42.63 and 62.67 m.a.s.l..

FIGURE 2: TOPOGRAPHIC TERRAIN OF AREA, RED STAR IS PROPERTY. FROM GOOGLE MAPS TERRAIN VIEW.

Climatic conditions at the Property are likely very similar to those recorded at the nearest Environment Canada weather station (i.e. 'Laidlaw', at 37 m elevation). During the period 1981-2010, the mean annual precipitation was 2186.8 mm including a mean annual snowfall of 78.2 cm, while extreme daily precipitation was 131.6 mm on February 21, 2002. Snow accumulation will be higher due to the elevation difference between the station and the property. In addition, the prevalence of cold air drainage in the winter depress temperatures and are responsible for a greater proportion of total precipitation falling as snow. Peak flows in streams flowing into the Fraser are likely to result from rain-on-snow events.

2.1 Field Assessment

On September 19th, 2017, the Property was ground traversed by Ms. Roberta Adams, M.Sc., G.I.T. of Madrone, at a detailed intensity level –slopes were measured with clinometer and tape and compass, surficial soil was classified, and GPS placemarks were added to a handheld device. The property is bound to the north by a Fraser River back channel, Fraser River to the east, and train tracks to the west.

I walked transects of the property and flagged three lines to be surveyed: 1- 5 year high water mark of the Fraser River, 2- crest of Slope 1, and 3- crest of Slope 2 (see Figure 3). Slope 1 runs up from the river and crests at an elevation between 52 and 56 m. Slope 1 is 30-35% for 10 m from the river, then 60-65% for 10-12 m, where it then crests at a natural terrace (Terrace 1) that has been altered into a trail and large flat area used for recreation. Slope 2 is between Terrace 1 area and the upper terrace (Terrace 2) of the property, the crest of which is marked by line 3. Slope 2 is 55-70% and 2 to 3 m high. Terrace 2 is flat and slopes very gently towards the train tracks, just beyond the western property boundary.

There are some rounded boulders on the property and do not appear to be recently deposited. They vary in size from 30 cm to 2 m in diameter.

The northern property boundary is just outside of the transmission line corridor, faces a backchannel of the Fraser River. Air photos show this backchannel does fill completely during high water events.

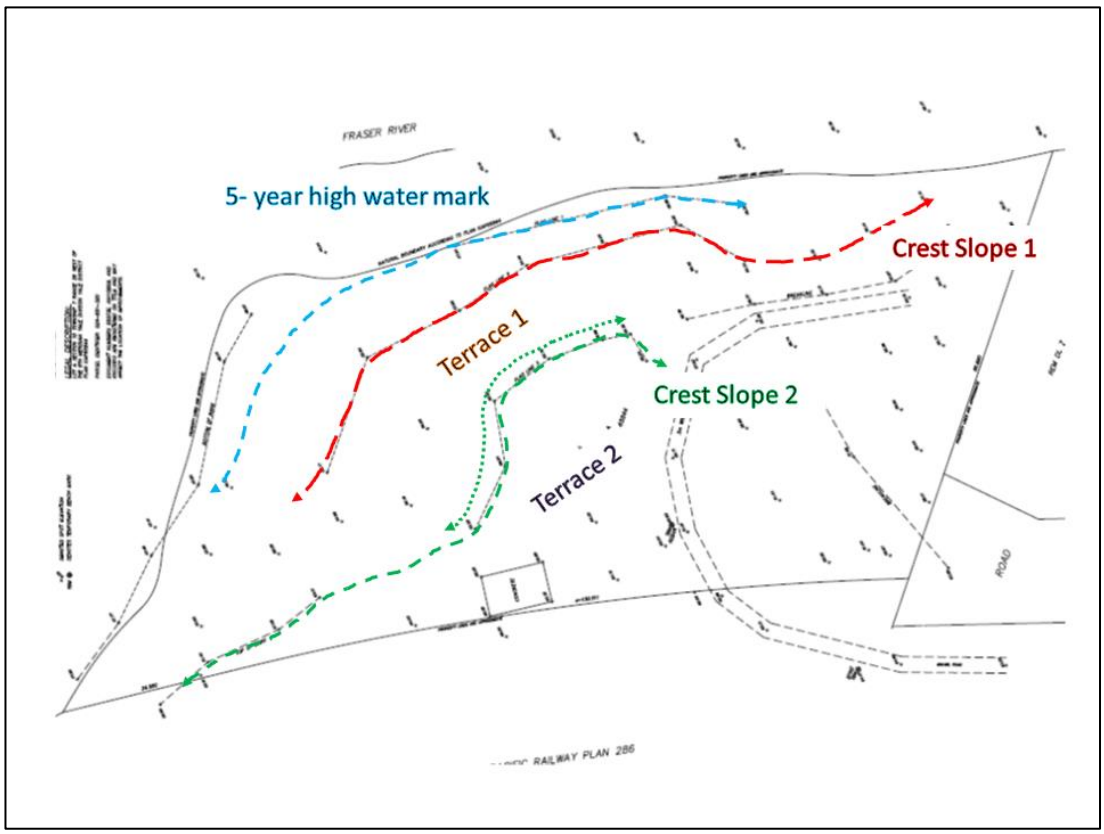

FIGURE 3: PROPERTY OVERVIEW, FOR DEMONSTRATION PURPOSES ONLY.

PHOTO 1: BACK CHANNEL FOR THE FRASER RIVER, NOT FULL AT TIME OF PHOTO, ALONG THE NORTHERN PROPERTY BOUNDARY.

3 Geo-Hazard Analyses

Our geo-hazard analysis involved the review and characterization of the geo-hazards that may affect the Property, followed by a subjective quantitative estimate (e.g. range of annual probability of occurrence) of the geo-hazards. These estimated ranges are then compared to the safety thresholds presented in the revised 1993 report[8] by Dr. Peter Cave, which have been developed and adopted by the Fraser Valley Regional District. We consider the Cave (1993) criteria to be an appropriate guideline for risk acceptability in this assessment.

Cave (1993) distinguished geo-hazards based on their effects. Seven types of developments are ranked in order of increasing intensity of land use, from a minor building repair to a major rezoning. Combined with its probability of occurrence, each type of geo-hazard forms a matrix with at least five levels of acceptability implied by the regulatory responses ranging from outright refusal to unconditional acceptance (Table 1). The client plans on building a single family residence which is categorized by Cave (1993) as a New Building.

[8] Cave, P. W. (1993). Hazard Acceptability Thresholds for Development Approvals by Local Government. *British Columbia Geologic Hazards Workshop, February 20 & 21, 1991.*

Table 2: Hazard acceptability thresholds [adapted from Cave (1993)]

		Hazard-Related Responses to Building Approval Applications				
		Not approvable	Approval, but with a covenant including "save harmless" conditions as well as siting conditions, protective works or both	Approval, but with siting requirements to avoid the hazard, or with requirements for protective works to mitigate the hazard	Approval without siting conditions or protective works, but with a covenant including "save harmless" conditions	Approval without conditions relating to hazards
New Building	TYPE OF HAZARD	Annual Return Frequencies				
	Inundation by Flood Waters	N/A	>1:40	1:40 – 1:200	N/A	< 1:200
	Mountain Stream Erosion or Avulsion	>1:100	1:100 – 1:200	N/A	1:200 – 1:500	< 1:500
	Debris Flood	N/A	>1:50	1:200 - 1:500	N/A	1:500 – 1:10,000
	Debris Flow / Debris Torrent	> 1:200	1:200 – 1:500	1:500 – 1:10,000	N/A	<1:10,000
	Localized Landslip	> 1:50	1:50 – 1:500	1:500 – 1:10,000	N/A	< 1:10,000
	Snow Avalanche	> 1:30	1:30 – 1:10,000	N/A	N/A	< 1:10,000
	Rock Fall	> 1:100	1:100 – 1:1,000	N/A	N/A	< 1:1,000
	Catastrophic Landslide	> 1:1,000	N/A	N/A	N/A	< 1:1,000

After assessing the property, we believe the property contains hazards associated with small-scale landslip, which may occur during seismic loading, and inundation by floodwaters. The surrounding area is subject to stream erosion and avulsion, debris flow, rock fall and catastrophic landslides. It should be noted that the Hope fault and adjacent faults are believed to be inactive, and earthquakes associated with fault rupture are not considered potential landslide triggers.

In the assessed area and under reasonably foreseeable conditions (including climate change and seismic events), it is our opinion that the property is not subject to Snow Avalanche or Debris Flood hazards listed in the table and they are therefore not analyzed further in this report.

3.1 Catastrophic Landslide, Rock Fall, and Localized Land Slip

Large catastrophic failures are documented in the area surrounding Yale, though these events are not specifically above the subject property. We believe that the frequency of these large events was higher in early post-glacial time when rebound and pressure release forces affected the valley. Probability of reactivation of previous events or activation of new events is analyzed on a case-by-case basis when applicable.

The Graveyard Creek Landslide is located to the northwest of the property. It is on the east flank of the Gordon- Yale Creek divide and is moderately steep and underlain by schist and granodiorite. The slope is approximately 2.2 km wide has 900 m of vertical relief. The site has been described as an ancient post-glacial landslide where the southern half may have failed catastrophically blocking the Fraser River. Numerous field reconnaissance investigations by other parties have traversed the site and determined that the landslide consists of fragmental bedrock debris. No landslide deposit has been found below 110 elevation, and could indicate that the debris either did not travel farther than that location or the toe has been removed by Fraser River erosion. We estimate the annual probability of reactivation of failure as 1:1,000 to 1:10,000.

FIGURE 4: PERSPECTIVE VIEW OF AREA; YELLOW LINE IS APPROXIMATE LOCATION OF THE GRAVEYARD CREEK LANDSLIDE HEAD SCARP. FROM GOOGLE EARTH PRO.

The Kuthlath landslide is on the east side of the river, upstream of Yale. It is approximately 2 km wide and the headscarp is over 1,000 m in elevation. The landslide

scar has been described as the shape of an amphitheater, and is filled with debris cones from 400 m elevation to the river level, and consists of locally derived bedrock. It is postulated that the landslide was a small rock fall and debris flow[9]. The potential for the head scarp reactivation where fresh angular rocks may create a fragmental rock fall is still unknown. Due to the location and shape of the landform we do not believe a reactivation would directly affect the property, while indirect effects would consist of blocking the Fraser River.

The South Yale block field extends south of Yale towards Hills Bar, on the west side of the river. It is approximately 500 m wide and is characterized by 2 to 5 m wide sub rounded boulders and 5 to 15 m wide angular blocks. The block field has been channeled by the Fraser River, and is believed to have occurred at least 5,000 years ago, although the origin is not agreed upon. It is postulated that the block field is the result of the large debris flow that evolved from a rock avalanche upstream due to the surface morphology of the deposit. It is possible that the source is the Kuthlath due to the gneiss from the head scarp found in the block field. If this to be correct, the Fraser River would have removed all the material from the landslide along its floodplain[10]. It is unclear if the subject property would be affected by a reactivation if the Kuthlath area was the south of material, however any events that change the hydrology of the river are expected to affect all riverside properties.

The Spirit Cave Steep Lands, also referred to as the Spirit Cave Bluff, is approximately 300 m wide and 150 m tall at an elevation ranging between 350 to 500 m. The steep slopes base consists of rockfall colluvium meeting the outwash terrace below. Thurber (1987) and Golder (2008) have mapped the rockfall hazard and indicate there is moderate rockfall potential. A trench in the outwash at the toe of the slope appears to be natural and has acted as a rockfall catchment. Carbon dating has indicated that there has been no large rock fall in the area for approximately 10,000 years, only minor fragmental rock falls. Given that there is no evidence of extensive rock fall deposits on the property or beyond the toe of the slope, we estimate the probability of fragmental rock fall to be 1:5,000. This event is unlikely to affect the subject property due to its location. Small fragmental

[9] Geologic Hazards and Risk Assessment, Yale, BC. Cordilleran Geoscience, 2010; FVRD # (677) 2010 03 09, https://www.for.gov.bc.ca/ftp/DCK/external/!publish/Stewardship/FSP/Hydrology_Terrain%20Stability/Yale/Geologic%20Hazards%20and%20Risk%20Assessment%20Mar%202010.pdf

[10] Geologic Hazards and Risk Assessment, Yale, BC. Cordilleran Geoscience, 2010.

rockfalls from the cut slopes on the west side of Trans-Canada Highway are estimated to be less than 1:1,000.

From the field assessment, we conclude that there is no evidence of a large failure affecting the property; however, small failures in the sands and gravels that make up the property may have occurred over 300 years ago that would no longer be recognizable. We completed air photo interpretation of the area using stereo-pairs of photos (Table 1) of different ages dating back to 1928 and we saw no evidence of large landslides within the property boundaries or within the immediate surrounding area (outside of those mentioned above). Nothing 10 m or less would have been visible at the resolution of the photos. Therefore, we estimate the annual probability of localized land slip (i.e. small earth slumps) due to instability to be moderate (1:200 to 1:10,000).

FIGURE 5: LARGE FAILURES IN THE AREA. SOUTH YALE BLOCKFIELD AND SPIRIT CAVES BLUFFS ARE OFF THE IMAGE BUT GENERAL DIRECTION IS INDICATED. PROPERTY LOCATED AR RED STAR IN CENTER OF IMAGE. ALL LOCATIONS ARE APPROXIMATE.

3.2 Debris flow and Mountain Stream Erosion of Gordon Creek

Gordon Creek is approximately 130 m south of the property. Records indicate that rain and/or rain-on- snow events have triggered debris flows that blocked or covered the road and railway at Gordon Creek at least twice in the past 75 years (1949 and 1980, possibly 1977). Air photos indicate that the 1949 event cleared vegetation from its fan at the Fraser River, suggesting that material moved down the creek during that event. The creek at the road and rail confluence appears to have been channelized, and potentially widened, after

1979 and before 1983, possibly after the 1980 event. There is no evidence that the creek's orientation was altered, it continued to flow east-southeast from the highway.

Drainage basin ruggedness has been used as a potential indicator of sediment flow and debris flow activity[11]. Gordon Creek has an intermediate ruggedness of 40 to 50% and may be affected by flood activity. Taking into account the topography surrounding Gordon Creek and the potential unstable terrain near the channel upslope, landslides may directly impact the creek upstream causing temporary blockage and therefore the potential for a debris flow downstream; this activity may reach as far as the fan of the creek which enters into the Fraser River. Gordon Creek's fall/winter peak flood is estimated to be 36 m^3/s with a 13.3 km^2 catchment area[12]

[11] Geologic Hazards and Risk Assessment, Yale, BC. Cordilleran Geoscience, 2010.

[12] Adapted from Water Survey Canada *in* Geologic Hazards and Risk Assessment, Yale, BC. Cordilleran Geoscience, 2010.

PHOTO 2: GORDON CREEK AT TRANS CANADA HIGHWAY, LOOKING DOWNSTREAM.

Stream avulsion may occur upstream, where Gordon Creek runs through unconsolidated sediments, however, just above the highway and towards the Fraser River, the creek runs through bedrock before being channelized to the river, minimizing the potential for avulsion.

Through field and air photo analysis, there appears to be no possibility for avulsion to affect the subject property. There has been no major change in the alluvial fan location since 1928, it remains approximately 150 m south of the property. However, the large discharge event in 1949 appears to have cleared vegetation along the alluvial fan's edges, but did not extend to the property. Approximate minimum distance from property is 100 m. If material blocks the channel downstream of the railway bridge, the flow of the channel will most likely be diverted to the southeast due to the topography, and not towards the subject property. Any debris flow event large enough to impact the subject property would not be able to pass under the first bridge at the highway.

I estimate the annual probability of a debris flow as 1:500-1:10,000 and stream avulsion as <1:500.

PHOTO 3: GORDON CREEK, LOOKING UPSTREAM, CUTS THROUGH BEDROCK BEFORE ENTERING CHANNELIZED PORTION.

3.3 Inundation by Fraser River floodwaters

In their comprehensive review of the Fraser River Flooding at Hope in 2008, northwest hydraulics (nhc) concluded that the appropriate design flood flow at Yale should be 15,200 m^2/s given the 1894 (500 year event) and 1948 freshet values (200 year event). Historical records from 1866 indicate that the flood on record was 15 meters above the high-water mark in Yale. However, the definition of the high-water mark with relation to the natural boundary and our current high water mark, is unknown. The property lies on post glacial deposits and straddles the 200 year flood limit, and as such is subject to the Flood Construction Level prescribed in the FVRD Bylaw No. 0681. Specifically, the following portions of the bylaw apply to the property:

Section 6: Floodplain Specifications

a.) Flood Construction Levels : The following elevations are specified as Flood Construction Levels, except where more than one Flood Construction Level is applicable, the higher elevation shall be the Flood Construction Level:

i. The Flood Construction Level for a specific property, as determined by interpolation from those Flood Construction Levels shown on Schedule A. Or where the Flood Construction Level is not shown on Schedule A the following shall apply

ii. 6.0 metres above the Natural Boundary of the Fraser River.

b.) Floodplain Setbacks: The following distances are specified as Floodplain Setbacks, except that where more than one Floodplain Setback is applicable, the greater setback shall be the Floodplain Setback:

i. Where the Floodplain Setback line is shown on Schedule A the distance shall be scaled from the map. or, where the Floodplain Setback is not shown on Schedule A the following shall apply:

ii. 60.0 metres from the Natural Boundary of Cascade Creek, Chilliwack River (downstream of Slesse Creek to the Floodplain Setback line), Deroche Creek, Norrish Creek, Pattison Creek, Slesse Creek and from any flood channels.

iii. 30.0 metres from the Natural Boundary of Anderson Creek, Anderson River, Carratt Creek, Chehalis River, Chilliwack River (upstream of Slesse Creek), Clayburn Creek, Coquihalla River, Emory Creek, Eng Creek, Frosst Creek, Gourlay Creek, Harrison River, Herford Creek, Hunter Creek, Jones Creek (Wahleach Creek), Legace Creek, Lillooet River, Liumchen Creek, Lost Creek, Lorenzetta Creek, McNab Creek, Nahatlatch River, Nicolum Creek, Paleface Creek, Pitt River, Pye Creek, Ryder Creek, Sakwi Creek, Scuzzy Creek, Siddle Creek, Silverhope Creek, Slesse Creek, Squakum Creek, Stave River, Stulkawhits Creek, Sumallo River, Sweltzer Creek, Tamihi River, Yale Creek, Vedder River, Weaver Creek, Wingfield Creek and from any flood channels.

iv. 15.0 metres from the Natural Boundary of any other watercourse.

During the field reconnaissance, we marked out the five-year high water mark, which is slightly higher in elevation than the approximate natural boundary of the river. The elevation was at a minimum 49.35 m. In order to meet ByLaw No. 0681, all habitable portions of the property must be built at least 6 m above this value, giving an elevation of 55.35 m (minimum). In addition, recommendations from Cordilleran Geoscience (2010),

an FCL 6 m above high water is reasonable for this area. The client intends to build a house on the upper terrace, Terrace 2. Terrace 2 minimum elevation is 59.68 (4.33 m above the minimum), and slopes up to the west 10 m over the high water mark.

The required setback from the Fraser River is outlined in Schedule A as 60 m from the natural boundary of the Fraser River. Most of the property is within this setback. When applied to the property, 60 m setback would limit the buildable area to a small portion of the southwest corner of the property.

A site-specific exemption and covenant with the district will be sought after personal communication with Mr. Graham Daneluz, Deputy Director of Planning and Development at the FVRD in November 2017. We recommend the setback be reduced to 45 m; the property elevation, specifically the buildable area on Terrace 2, exceeds the required FCL, and there is no evidence of flooding on the property since before 1929. The 45 m setback is applied from the 5-year high-water mark as there is no defined top of (western) bank for the Fraser River in this area. The 5-year high-water line was marked in the field and is delineated on the land survey as Line 1 (and in blue in Figure 3). We estimate a probability of less than 1:200 annual occurrence of Fraser River flooding Terrace 2 based on mapping a conservative buffer above past estimates of maximum flood level elevations. We believe the property is safe for the use intended when the flood construction levels are adhered to.

4 Conclusions and Recommendations

We have identified that the Land is subject to localized land slip, inundation by floodwaters, and debris flows. We compared these findings with the levels of safety (i.e. regulatory responses) described by Cave (1993), and provide our recommendations for avoidance and protective measures.

Hazard	Annual Return Frequency	Response to Building Approval Application	Recommendations
Inundation by Flood Waters	See response.	Below Terrace 2 and the FCL: Approval, but with siting requirements to avoid the hazard, or with requirements for protective works to mitigate the hazard. Annual return frequency >1:200,	All habitable buildings must be built at an elevation greater than 55.35 m. The elevation of the proposed building site is over 59 m, on Terrace 2. We recommend an exception to the 60 m setback from ByLaw No. 0681, and recommend a 45 m setback from the Fraser River as safe for the use intended.
		For Terrace 2 and above: Approval without conditions relating to hazards. Annual return frequency <1:200.	
Mountain Stream Erosion or Avulsion	<1:500	Approval without conditions relating to hazards	
Debris Flow / Debris Torrent	1:500 to 1:10,000	Approval, but with siting requirements to avoid the hazard, or with requirements for protective works to mitigate the hazard	There is no evidence of debris flow from Gordon Creek ever encroaching on the property, and we recommend approval based on the distance from Gordon Creek exceeding the setback of 15 m by an additional 115 m.

Localized Landslip	1:500 to 1:10,000	Approval, but with siting requirements to avoid the hazard, or with requirements for protective works to mitigate the hazard	Due to the steepness of Slope 2 we recommend a 10 m setback from the crest of the slope for all habitable buildings. This setback falls within the recommended 45 m setback from Fraser River.
Rock Fall	<1:1,000	Approval without conditions relating to hazards	
Catastrophic Landslide	1:1,000 to 1:10,000	Approval without conditions relating to hazards	

5 Closure

We trust that this report meets the applicable requirements. We grant permission to the Fraser Valley Regional District to use this report in determining what conditions or requirements it will impose in the development permit. Please contact us if you require further information or services.

Prepared by:

Roberta Adams, M.Sc., G.I.T.
Geoscientist

Prepared and Reviewed by:

PROFESSIONAL ENGINEER
PROVINCE OF BRITISH COLUMBIA
G. BUTT
GEOSCIENTIST
Dec 18 2017.

Gordon Butt, M.Sc., P.Geo.
Senior Geoscientist

MADRONE ENVIRONMENTAL SERVICES LTD.

6 Limitations

To properly understand the recommendations and opinions contained in this report, its limitations, and Madrone's rights and responsibilities, reference must be made to entire report, including, without limitation, all appendices, drawings, and figures.

A geo-hazard site investigation can reduce, but not wholly eliminate uncertainty regarding the natural hazards at a site, given reasonable limits of time and cost. Madrone Environmental Services Ltd. (Madrone) has conducted this investigation and prepared this report in a manner consistent with the level of care normally exercised by qualified professionals currently practicing in the area under similar conditions and budgetary constraints. No other warranties, either expressed or implied, are made. If unexpected environmental conditions are encountered on the site, Madrone must be notified in order that we may determine if modifications to our findings are necessary.

Madrone has made reasonable efforts to investigate the extent and properties of soil, rock and water at locations that are representative of conditions in the relevant portions of the project site. However, due to the nature of geotechnical engineering, there is an inherent risk that some conditions were not detected, and that actual subsurface conditions may vary considerably from the investigation points and with the passage of time. You are responsible for ensuring that any other party making use of any documents prepared by Madrone regarding the project also acknowledges and accepts this risk.

Madrone has prepared this report for the exclusive use of its client. This report is intended to assist the client in a rezoning, subdivision, and building permit process. This report was prepared considering circumstances applying specifically to the client and applies only to the specific property identified in the report. 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.

Where practical, Madrone has attempted to verify the information provided to us by you or other individuals or organizations. However, Madrone does not accept any responsibility for any inaccuracies, deficiencies, or omissions resulting from receipt of incorrect or fraudulent information.

Madrone's investigation and findings specifically does not address regulatory compliance of your subject property per requirements of the B.C. *Environmental Management Act* and its subordinate regulations including, but not limited to, the *Contaminated Sites Regulation*.

Any verbal advice provided by Madrone, though given in good faith, may be subject to misinterpretation. Consequently Madrone does not accept responsibility for any verbal advice unless the advice is confirmed in writing. Madrone will not be responsible for any project

decisions you, your agents or contractors make if the decisions were made without Madrone's advice or are inconsistent with Madrone's advice.

6.1 Limitations on Liability

The total amount of all claims you may have against Madrone or any present or former partner; executive officer, director, stockholder, employee or agent thereof under this engagement, including but not limited to claims for negligence, negligent misrepresentation and breach of contract, are strictly limited to the amount of any professional liability insurance that Madrone may have available for such claims.

Madrone is not liable for any consequential loss, injury or damages you suffer, including but not limited to loss of use, earnings and business interruption.

No claim may be brought against Madrone in contract or tort more than two (2) years after Madrone's involvement in the project.

6.2 Intellectual Property

Copyright in this report and associated documents prepared by Madrone, including those prepared at your request or direction, remain the property of Madrone. We hereby grant you alone a non-transferable license to use documents in connection with the particular project for which the documents were prepared. This license does *not* apply to any draft version of any document. You will not use the documents in connection with any other work, or project without the prior written approval by Madrone. If you are in breach of any obligation to make payment to Madrone, Madrone may revoke the licence referred to above and you will cause to be returned to Madrone all the documents and all copies thereof and you will remove from your computer systems any electronic copies of any of the documents. Field notes and technical documents used by and/or produced by Madrone are not subject to distribution.

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APPENDIX A

FIELD PHOTO

PHOTO 4: VIEW OF FRASER RIVER FROM TERRACE 2, FACING EAST.

PHOTO 5: VIEW FROM TERRACE 1 UP TO TERRACE 2, FACING WEST. SLOPE IN FOREFRONT IS SLOPE 2.

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APPENDIX B

Overview Maps

FIGURE 6: OVERVIEW OF SUBJECT PROPERTY RELATIVE TO FRASER RIVER AND YALE, OUTLINED IN YELLOW.

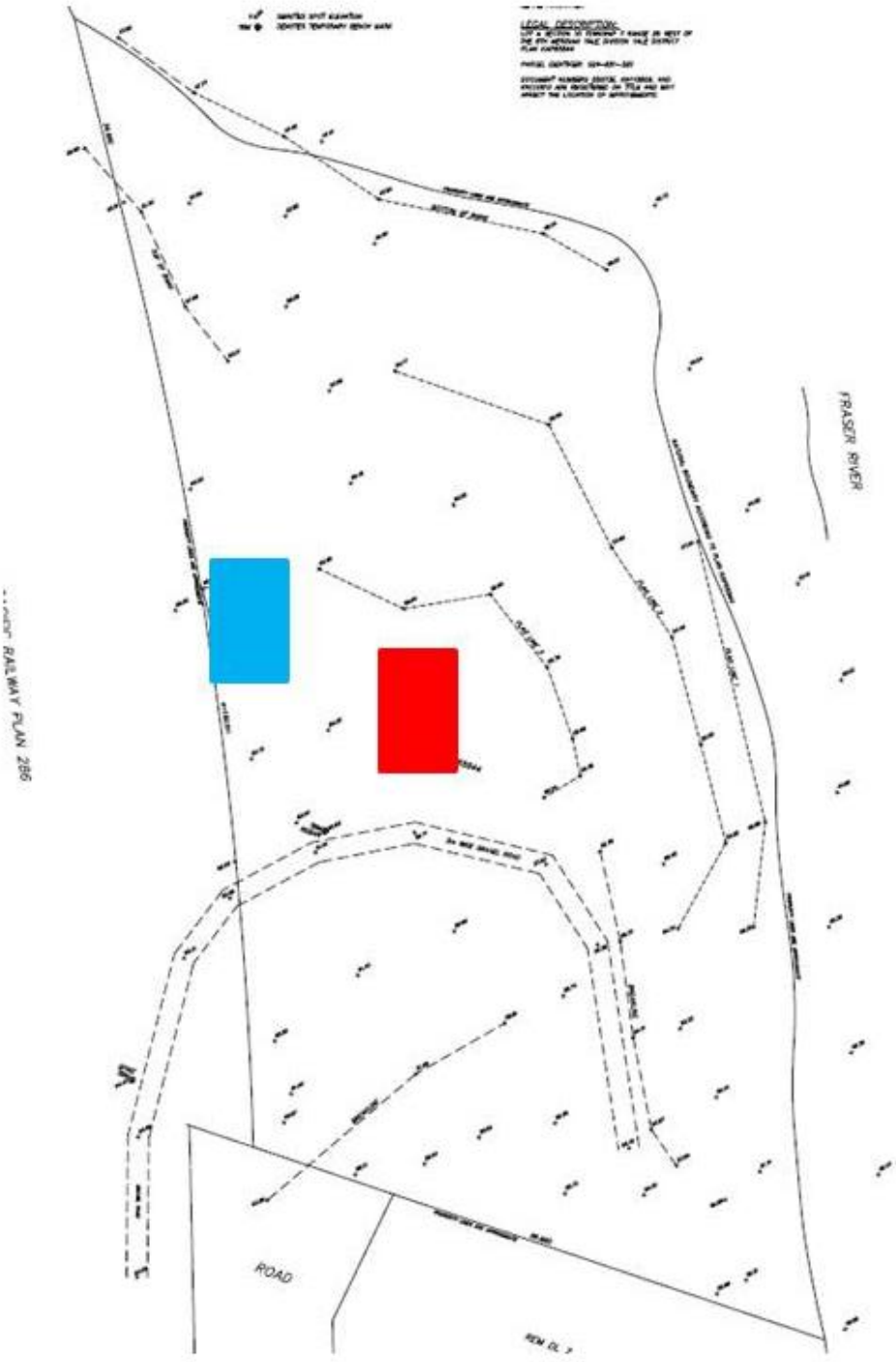


FIGURE 7: APPROXIMATE SITE PLAN WORKSHOP (BLUE) AND DWELLING (RED). LOCATIONS NOT FINALIZED AT TIME OF THIS REPORT.

APPENDIX C

ASSESSMENT ASSURANCE STATEMENT

Geo-Hazard Assurance Statement
for Development Approvals

A. Project Information

Date: December 18, 2017 FVRD File No.:

Property Information

Project Name & Description:

Legal Description:

Site Address: 30420 Trans Canada Highway, Yale BC PID: 024651320

Client Information

Name: Mike Cook

Role: ☑ Property Owner ☐ Developer ☐ Other

Client Address: 1138 East Georgia St, Vancouver BC

Qualified Professional Information

Name: Gordon Butt

APEGBC Designation: ☐ P.Eng. ☑ P. Geo. ☐ Eng.L ☐ Geo.L

Company Name: Madrone Environmental Services Ltd

Mailing Address: 202-2790 Gladwin Rd, Abbotsford BC V2T 4S7

Email Address: gordon.butt@madrone.ca Phone #: 604-504-1972

Geo-Hazard Report Reference

Title: 17.0333 Geo-hazard Assessment 30420 Trans-Canada Highway, Yale BC Date: November 14, 2017

Personal information on this form is being collected in accordance with Section 27 of the Freedom of Information and Protection of Privacy Act, RSBC 1996 Ch. 165; Part 9, Division 1 [Building Regulation] and Part 14 [Planning and Land Use Management] of the Local Government Act, RSBC 2015 Ch. 1; and Section 56 of the Community Charter, SBC 2003 Ch. 26 and will only be collected, used and disclosed for the purpose of administering geo-technical hazard reviews and assurance statements related to development approvals. Questions? Contact FVRD Privacy Officer at 45950 Cheam Avenue, Chilliwack, BC V2P 1N6; 604-702-5000 or 1-800-528-0061; or FOI@fvrd.ca.

B. Assurance

Based on the contents of this Assurance Statement and the Report, I hereby give assurance that:
(check as applicable)

☐	Development Permit	The Report will "assist the local government in determining what conditions or requirements under it will impose in the permit", as required by the *Local Government Act* (Division 7)
☑	Building Permit ☑ Community Charter	"The land may be used safely for the use intended", as required by the *Community Charter* (Section 56)
	☐ Seismic Slope	The Report addresses the requirements of the BC Building Code 2006, 4.1.8.1.6 (8) and 9.4.4.4 (2), as detailed in the BC Building & Safety Policy Branch Information Bulletin B10-01, Jan 18, 2010
☑	Floodplain Management Bylaw Exemption	"The land may be used safely for the use intended", as required by the *Local Government Act*. (Section 524)
☐	Subdivision	"The land may be used safely for the use intended", as required by the *Land Title Act* (Section 86).
☐	Other *(e.g. Zoning Bylaw Amendment, Official Community Plan Amendment, Temporary Use Permit, etc.)*	<Insert statement as appropriate>

C. APEGBC Professional Practice Guidelines

The Report and this Assurance Statement should be completed in accordance with the current version of one or both of the following Professional Engineers and Geoscientists of BC (APEGBC).

- *Legislated Flood Assessments in a Changing Climate in BC*
- *Legislated Landslide Assessments for Proposed Residential Development in British Columbia, ("APEGBC Landslide Guidelines").*

These two documents are collectively referred to as the "APEGBC Guidelines". The italicized words in this Assurance Statement are defined in the APEGBC Guidelines.

The Report has been prepared pursuant to the following APEGBC Guidelines *(check one or both as applicable)*.

☑ APEGBC Flood Guidelines

☑ APEGBC Landslide Guidelines

If the Report is **not** prepared pursuant to either of the APEGBC Guidelines, please explain.

D. Background Information

Qualified Professionals **must** confirm and check that each item is included in the Report.

☑ 1. Property location map — 8.5 x 11 size

☑ 2. Development proposal site plan — 8.5 x 11 size. *If a subdivision, show the parent parcel and all lots to be created, including any remainder.*

☑ 3. Description of the proposed development project (including building use) to the extent this is known at the time of Report preparation.

- ☑ residential
- ☐ industrial
- ☐ commercial
- ☐ institutional
- ☐ other _____

E. Technical Requirements

Qualified Professionals **must** review, confirm and check completed items (as applicable).

Report Content

- [x] 4. Relevant information pertaining to the Property and pertinent potential hazards from appropriate background sources, including the FVRD online library.
- [ ] 5. Time limitation or condition statement to describe extent the FVRD may rely on the Assurance Statement and Report for development approvals, and when resubmittal is recommended.
- [x] 6. Maps, illustrations and diagrams to illustrate areas referred to in the Report.
- [x] 7. Description of field work conducted on and, if required, beyond the Property.
- [x] 8. Contact and consultation with the Fraser Valley Regional District. Provide name and title of contact.

  Mr. Graham Daneluz, Deputy Director of Planning and Development at the FVRD
- [x] 9. Review of relevant FVRD bylaws and other statutory requirements.
- [ ] 10. Restrictive covenants registered against the Property title that pertain to geo-hazards (if registered, the Report provides relevant information about the covenants).
- [x] 11. Notation of any visibly apparent natural hazards or other hazards identified in background reports, which are not identified and addressed in this Report. If yes, provide details in Section H: Geo-Hazard Summary Table.

  ○ Yes
  ◉ No
- [x] 12. Does the report rely on one or more supporting reports, each of which is independently reviewed, signed and sealed. If yes, provide details in Section H: Geo-Hazard Summary Table.

  ○ Yes
  ◉ No
- [ ] 13. For subdivision approval, the Report addresses natural hazards for:

  ☐ the parent parcel prior to subdivision
  ☐ any lots to be created (including any remainder)

Geo-hazard Assessment, Risk Acceptability and Risk Transfer

☑ 14. In considering the above-noted potential hazards that may affect the property, I have:

- ☑ reviewed and characterized the potential hazard(s)
- ☑ estimated the potential frequency and magnitude of the potential hazard(s)
- ☑ relied on supporting reports as noted above
- ☑ relied on a pre-existing assessment of hazard frequency and magnitude
- ☑ considered the potential effects of climate change in the context identified in the Report
- ☑ considered the potential effects of changed future conditions (upstream watershed changes, forestry activity, land use changes, sea level rise, etc.) in the context identified in the Report

☑ 15. This Assurance Statement pertains to all geo-hazards that are assessed in the Report and any supporting reports, and accurately reflects the contents of those documents.

☑ 16. The FVRD has adopted "Hazard Acceptability Thresholds for Development Approvals by Local Government", which provides a specific level of hazard or risk tolerance. I have included a Hazard Summary Table which:

- ☑ lists all the potential hazards addressed by the Report and any supporting reports
- ☑ provides an annual return frequency and acceptability threshold classification for the unmitigated condition
- ☑ proposes mitigative measures to appropriately reduce the geo-hazard risk
- ☑ provides an annual return frequency and acceptability threshold classification for the mitigated condition

☑ 17. The Report describes the potential transfer of natural hazard risk to other properties or infrastructure as a result of the proposed project (including any proposed *mitigation works*) and

- ☐ considered the potential for transfer of natural hazard risk
- ☑ concludes that there is no significant transfer of natural hazard risk
- ☐ identifies the potential transfer of natural hazard risk and proposes measures to offset such transfer of risk

Mitigation and Design Recommendations (if recommended)

The Report contains the following items:

☐ 18. Implementation steps for the identified structural mitigation works (in terms of design, construction and approval).

☑ 19. Clearly identified safe locations for building(s), ancillary structures, and onsite utility services (as applicable, such as a septic field) out of the natural hazard area as a preferred development alternative.

☐ 20. Commentary on the effectiveness of proposed structural mitigation works in terms of ability to reduce the potential hazard impact, and identification of any residual risk that would remain.

☑ 21. Proposed Flood Construction Level (FCL) for future development and including specification of an appropriate method of achieving the FCL.

☑ 22. Proposed watercourse setback, which is clearly referenced from the natural boundary, top of bank or another suitable basis.

☐ 23. Proposed operation and maintenance actions that will be necessary in order for the level of safety to be maintained in the future, with indications of who should be responsible for those actions and when.

Riparian Area Regulation (if applicable)

☐ 24. QP must review RAR assessment report to avoid conflict with Geo-Hazard Report recommendations.

F. FVRD Supplemental Requirements

The following points are understood by the Qualified Professional when submitting a Report:

☑ 25. Permission is granted to the FVRD to use the Report in considering approval of the proposed development on the property, provided that such permission is limited only to the proposed development project for which the Report was prepared.

☑ 26. Methodology used in the Report is described in sufficient detail to facilitate a professional review of the study by the FVRD when necessary.

☑ 27. Professional liability insurance coverage of at least $1 million per claim is carried by the QP.

☑ 28. Third party review or supplemental information may be required by the FVRD where complex development proposals warrant.

☑ 29. Permission is granted to the FVRD to include the Report in the online FVRD geo-hazard report library (as background information, not for other parties to rely).

G. Qualified Professional (QP)

Prepared by: (QP of Record)

Name Roberta Adams, G.I.T.

Designation ☐ P.Eng. ☐ P. Geo. ☐ Eng.L ☐ Geo.L

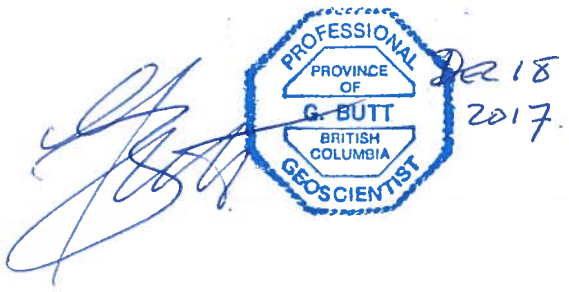
Reviewed by:

Name Gordon Butt

Designation ☐ P.Eng. ☑ P. Geo.

The Report has received appropriate technical review which is consistent with both the APEGBC Professional Practice Guidelines, and APGBC Quality Management Guidelines. The name of the reviewer is noted in the Report and below.

Professional Seal, Signature and Date:



Gordon Butt, M.Sc., P.Ag., P.Geo.

☑ I am a Qualified Professional as defined in the APEGBC Guidelines, and I fulfill the education, training and experience requirements as outlined in the APEGBC Guidelines

☑ I have signed, sealed, dated and thereby certify, this Assurance Statement and the attached report.

H. Geo-Hazard Summary Table

The geo-hazard report and/or any supporting reports addresses the following hazard types.

Geo-Hazard Type #1 Fraser River and tributaries flooding	Geo-Hazard Type #2 Fraser River and tributaries flooding
Annual Return Frequency (Unmitigated) >1:200	Annual Return Frequency (Unmitigated) <1:200
Acceptability Threshold Classification: 3	Acceptability Threshold Classification: 1
MITIGATION (if necessary)	
Proposed Mitigation Measures: Yes ○ No ●	Proposed Mitigation Measures: Yes ○ No ●
Annual Return Frequency (Mitigated) >1:200, mitigation is to avoid this area	Annual Return Frequency (Mitigated)
Acceptability Threshold Classification:	Acceptability Threshold Classification:
Comments This is for areas below "Terrace 2" and the FCL.	Comments This is for "Terrace 2" and above.
SUPPORTING REPORT	
Was this report prepared by others? Yes ○ No ●	Was this report prepared by others? Yes ○ No ●
If yes, list report name, date and author.	If yes, list report name, date and author.

Geo-Hazard Type #3 Debris Flow and Debris Torrent	Geo-Hazard Type #4 Small Scale Localized Landslip
Annual Return Frequency (Unmitigated) 1:500 to 1:10,000	Annual Return Frequency (Unmitigated) 1:500 to 1:10,000
Acceptability Threshold Classification: 3	Acceptability Threshold Classification: 3
MITIGATION (if necessary)	
Proposed Mitigation Measures: Yes ○ No ●	Proposed Mitigation Measures: Yes ○ No ●
Annual Return Frequency (Mitigated)	Annual Return Frequency (Mitigated) 1:500 to 1:10,000
Acceptability Threshold Classification:	Acceptability Threshold Classification: 3
Comments Hazard 130m south of property, no evidence of encroachment	Comments 10 m setback from "Slope 2" recommended.
SUPPORTING REPORT	
Was this report prepared by others? Yes ○ No ●	Was this report prepared by others? Yes ○ No ●
If yes, list report name, date and author.	If yes, list report name, date and author.

Indicate which hazards were **NOT** reviewed:

- [x] Chilliwack River Valley Erosion or Avulsion
- [ ] Debris Flow and Debris Torrent
- [ ] Debris Flood
- [ ] Fraser River & tributaries flooding
- [ ] Mountain Stream Erosion or Avulsion
- [ ] Major Catastrophic Landslide
- [x] Seismic Effects/Liquefaction
- [ ] Rockfall - Small Scale Detachment
- [ ] Slope Stability
- [ ] Small Scale Localized Landslide
- [x] Snow Avalanche
- [x] Tsunami

Hazard Acceptability Thresholds Classification, as per Hazard Acceptability Thresholds for Development Approvals by Local Government dated November 1993 by Dr. Peter Cave.

1 Approval with conditions relating to hazards.
2 Approval, without siting conditions or protective works conditions, but with a covenant including "save harmless" conditions.
3 Approval, but with siting requirements to avoid the hazard, or with requirements for protective works to mitigate the hazard.
4 Approval as (3) above, but with a covenant including "save harmless" conditions as well as siting conditions, protective works or both.
5 Not approvable.

Additional Comments