



THURBER ENGINEERING LTD.

MEMORANDUM

To: Claire Dewar – Senior Planner
Squamish Lillooet Regional District

Date: June 8, 2021

Cc: Kevin Healy, P.Eng.
CREUS Engineering Ltd.

From: Jason Pellett, P.Eng. / P.Geo.
(Reviewed by David Regehr, P.Eng.)

File: 21452.100

NATURAL HAZARD DEVELOPMENT PERMIT AREAS - FURRY CREEK LANDS FURRY CREEK, BC

Thurber Engineering Ltd. (Thurber) and Kerr Wood Leidal Associates Ltd. (KWL) have been retained to develop natural hazard Development Permit Areas (DPAs) for the community of Furry Creek. Thurber is responsible for geotechnical hazards, such as slope stability and rockfall, while KWL's focus is on the creek and coastal flood hazards. For debris flow and debris flood aspects (creek hazards), Thurber and KWL are collaborating.

Per your request, an updated working draft of the natural hazard DPAs for Furry Creek is provided herein for further review and discussion. The study area limits are shown on Figure 1.

This memo should be read in conjunction with the following background documents in the context of DPA determination:

- Kerr Wood Leidal Associates Ltd. 2021. Furry Creek Area Flood Hazard DPAs. Technical memorandum to CREUS dated May 26, 2021. **(Copy attached)**.
- Thurber Engineering Ltd. 2020. Overview Geohazard Assessment - Furry Creek Lands - Review of Updated Neighbourhood Plans, Furry Creek, BC. Technical Memorandum to Fine Peace Holdings Ltd. dated July 9, 2020.
- Thurber Engineering Ltd. 2019. Overview Geohazard Assessment - Furry Creek Lands - Furry Creek, BC. Report to Fine Peace Holdings Ltd. dated June 14, 2019.

It is a condition of this memo that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

1. DEVELOPMENT PERMIT AREAS

DPAs are used to vary or supplement the bylaws of the Regional District, thereby providing the flexibility to adjust regulations to meet certain requirements or objectives within specific areas.



Five (5) DPAs, herein referred to as DP-NH-01 to DP-NH-05, are established for the protection of development from natural hazards at Furry Creek. In the context of natural hazards, the main objectives of the DPAs are:

1. To limit development within or near hazardous areas.
2. To allow for land use suitable under hazardous conditions, in accordance with geotechnical and hydrotechnical studies and SLRD policy as it exists at the time.
3. To obtain assurance from Qualified Professionals that the development satisfies the appropriate EGBC Professional Practice Guidelines and Standards.
4. To ensure adequate professional evaluation of natural hazards and associated mitigation works.
5. To minimize the potential that new developments and alterations of land will increase hazards to adjacent lands and existing developments at Furry Creek, both upslope and downslope.

Details of DP-NH-01 to DP-NH-05 are provided below and on the attached Figures 2 and 3.

2. DP-NH-01: LANDSLIDE HAZARDS

Background and Justification:

- The Furry Creek area is subject to high volumes of precipitation and runoff driven by winter storm activity, which in combination with the steep terrain gives rise to various mass-wasting hazards (landslide hazards) that have the potential to affect the community. Landslide hazards may originate in bedrock or soil and exhibit various modes of movement including falls, slides and flows.
- The overview geohazard study completed by Thurber (2019) delineates areas affected by landslide hazards based on an annual probability of occurrence of 10% in 50 years (1:475 annual probability), which provides a basis for locating the boundaries of Development Permit Area DP-NH-01.

Applies to:

- Any development within the DP-NH-01 polygons per the attached Figure 2.

Development Permit Required for:

- Alteration or disturbance of land
- Subdivision of land
- Construction of, addition to, or alteration of a building or structure
- Exemptions may be granted for the following circumstances:
 - Additions to buildings or structures up to 25% of the existing ground floor area
 - Buildings or structures with footprint of 20 m² or less, not intended for residential occupancy

- Removal of hazard trees by Certified Arborist or professional forester
- Riparian enhancement
- Subdivision to facilitate a lot consolidation or a boundary adjustment, provided that no additional parcels are created
- Lots/subdivisions with an existing registered covenant or proposed covenant
- Parks for local and regional facilities
- Emergency response
- Flood management
- Public utilities and infrastructure
- Forestry activities on Crown Land

Guidelines/Requirements:

- Where possible, development should be sited to avoid hazards. Where impossible or impractical to avoid hazards, mitigation measures may be required.
- Applications for land alteration/disturbance, subdivision, or building permits shall include a site-specific report from a qualified Professional Engineer or Professional Geoscientist that considers all relevant potential landslide hazards including, but not limited to, debris slides/slumps, rock falls, and rock slides.
- The report shall include the following information, as applicable to the development:
 - Slope profiles with documentation of the limits of slope instability shall be provided. Consideration shall be given to the limits and types of instability and changes in stability that may be induced by site clearing, road building, climate change, timber harvesting, and future development both upslope and downslope of the subject property.
 - Recommended wet weather shutdown criteria for worker safety during site clearing, road building, and building construction.
 - Appropriate land use recommendations such as restrictions on tree cutting, surface drainage, filling and excavation.
 - A detailed stability assessment indicating potential failure modes, limiting factors of safety, and stability during seismic events. Geotechnical analytical techniques for evaluating seismic slope stability should follow the procedures described EGBC's Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in British Columbia (May 2010 or current version).
 - A recommendation of required building setbacks from the crests and/or toes of steep slopes, and a demonstration of suitability for the proposed use.
 - An assessment of shallow groundwater conditions and the anticipated effects of septic systems, footing drains, etc. on local slope stability.

- If required, definition of the site-specific rock fall shadow area, including an indication of the appropriate buffer zone and required protective works.
- Development Permits shall be in accordance with the recommendations of the applicable natural hazard report or reports, including required mitigative measures.
- Natural hazard reports submitted in support of a development permit applications shall meet the requirements outlined in the appropriate EGBC Professional Practice Guidelines and Standards.
- Where development also falls within Environmental/Creek Hazard/Coastal Hazard/other DPA(s), the report shall be coordinated with other Qualified Professionals to create a comprehensive development permit application.
- Property owners are cautioned that the following activities may exacerbate hazards and contribute to slope failure, and should generally be avoided:
 - Alterations to natural drainage patterns or vegetation
 - Excavation on steep slopes or at the base of slopes
 - Constructing swimming pools, ponds, or other water features along or near the crest of slopes, where these features are not founded on competent bedrock
 - Placing fill, organic wastes, and debris along or near the crest of slopes
 - Dumping of significant quantities of plowed snow on or near the crest of slopes
 - Discharge of surface or ground water on or near the crest of slopes
 - Cutting trees or removing other vegetation on or near the crest of slopes, except where required for emergency works.

3. DP-NH-02: EXCAVATED ROCK AND FOUNDATION STABILITY HAZARDS

Background and Justification:

- Some of the proposed future developments at Furry Creek are located on or near steep bedrock slopes. Within these areas, further, site-specific geotechnical assessments will be required to confirm the siting of individual buildings and associated foundation design and construction requirements related to bedrock.
- In some areas of the site, such as the Northwest neighbourhood, additional restrictions on development may also be imposed by CN Rail or other stakeholders with respect to building setbacks and specific construction practices such as rock blasting.
- Where buildings cannot be adequately set back from the crest of steep bedrock slopes, it may be necessary to construct buildings with specially designed foundations, using carefully excavated platforms and rock anchors. These buildings will need to be very carefully sited and the building, its access and landscaping designed with input from both geotechnical and structural engineering disciplines. Protective measures may also be required at these locations to mitigate risks from rock fall.



Applies to:

- Any development within the DP-NH-02 polygons per the attached Figure 2.

Development Permit Required for:

- Alteration or disturbance of land
- Subdivision of land
- Construction of, addition to, or alteration of a building or structure
- Exemptions may be granted for the following circumstances:
 - Additions to buildings or structures up to 25% of the existing ground floor area
 - Buildings or structures with footprint of 20 m² or less, not intended for residential occupancy
 - Removal of hazard trees by Certified Arborist or professional forester
 - Riparian enhancement
 - Subdivision to facilitate a lot consolidation or a boundary adjustment, provided that no additional parcels are created
 - Lots/subdivisions with an existing registered covenant or proposed covenant
 - Parks for local and regional facilities
 - Emergency response
 - Flood management
 - Public utilities and infrastructure
 - Forestry activities on Crown Land

Guidelines/Requirements:

- Where possible, development should be sited to avoid hazards. Where impossible or impractical to avoid hazards, mitigation measures may be required.
- Applications for land alteration/disturbance, subdivision, or building permit shall include a site-specific report from a qualified Professional Engineer or Professional Geoscientist that considers all relevant potential hazards related to rock excavation, foundation construction, and foundation stability in bedrock.
- The report shall include the following information, as applicable:
 - Slope profiles with documentation of the limits of slope instability shall be provided. Consideration shall be given to the limits and types of instability and changes in stability that may be induced by rock excavation and foundation construction. The impacts of rock excavation and foundation construction both upslope and downslope shall also be considered.
 - A detailed stability assessment indicating potential failure modes, limiting factors of safety, and stability during seismic events. For strong rock masses which are

structurally controlled, kinematic stability analyses as well as limit equilibrium stability analyses on dominant, kinematically possible failure modes should be carried out.

- A recommendation of required building setbacks / foundation setbacks from the crest of steep rock slopes, and a demonstration of suitability for the proposed use.
 - Recommended rock excavation methods (e.g. blasting, ripping, non-explosive splitting, machine excavation, or other) based on the anticipated rock mass conditions and foundation design and construction requirements, including anticipated measures that may be required to contain flyrock and dislodged boulders such as blast mats, berms, barriers, or catchment fences.
 - Anticipated rock slope stabilization measures such as shotcrete and rock bolts which may be required for both temporary and permanent stability.
 - Recommendations and key issues that should be considered for blast design such as ground vibration thresholds and associated monitoring requirements. Additional requirements may apply where blasting will be required near fish-bearing waters or near other infrastructure such as high-pressure gas lines or the CN Rail tunnel.
- Development Permits shall be in accordance with the recommendations of the applicable natural hazard report or reports, including required mitigative measures.
 - Natural hazard reports submitted in support of a development permit applications shall meet the requirements outlined in the appropriate EGBC Professional Practice Guidelines and Standards.
 - Where development also falls within Environmental/Creek Hazard/Coastal Hazard/other DPA(s), the report shall be coordinated with other Qualified Professionals to create a comprehensive development permit application.

4. DP-NH-03: SEISMIC LIQUEFACTION AND FAN STABILITY HAZARDS

Background and Justification:

- The alluvial sediments forming the fan of Furry Creek are potentially liquefiable under strong earthquake shaking. The potential consequences of liquefaction include differential vertical settlement, horizontal displacement (lateral spreading), and associated damage to buildings and buried facilities. Previous seismic analyses completed by Thurber indicate that liquefaction hazards on the Furry Creek fan are localized, rather than widespread; however, these hazards will need to be assessed on a site-specific basis per the 2018 BC Building Code (BCBC 2018).
- Submarine slides unrelated to seismic activity have also been documented in Howe Sound on other fans/deltas. In August 1955, a major slump of the delta slope at the mouth of Woodfibre Creek triggered by an extreme low tide damaged warehouses and wharf constructed on the delta. At the head of the slump, water depths increased by about 10 m and the disturbed part of the delta front apparently extended to about 150 m below sea level (Eisbacher 1983). The collapse of the wharf and three warehouses into Howe Sound forced the closure of the Woodfibre pulp mill. In June 1957, a submarine slump at Britannia



Beach washed out an approximately 50 m long section of the BC rail line shortly after the grade was constructed (Septer 2007).

Seismic slope stability and soil liquefaction hazards may require specific consideration in development approvals. BCBC 2018 requires that the:

- Design of some buildings, notably buildings for assembly and institutional uses and buildings in excess of 600 m² in building area or exceeding three stories in height ("Part 3 Buildings") address seismic liquefaction hazards.
- Consideration of potential for slope instability and its consequences at a building site is an explicit requirement in designs of structures and their foundations.
- Seismic hazard probability level to be used in the assessment of seismic slope stability is the 1:2475 year event (2% probability of exceedance in 50 years).

Applies to:

- Any development within the DP-NH-03 polygon per the attached Figure 2.

Development Permit Required for:

- Construction of, addition to, or alteration of a building or structure
- Exemptions may be granted for the following circumstances:
 - Alteration or disturbance of land
 - Subdivision of land
 - Minor alterations or additions up to 25% of the existing ground floor area
 - Buildings or structures with footprint of 20 m² or less, not intended for residential occupancy
 - Removal of hazard trees by Certified Arborist or professional forester
 - Riparian Enhancement
 - Parks for local and regional facilities
 - Emergency Response
 - Flood management
 - Public utilities and infrastructure
 - Forestry activities on Crown Land

Guidelines/Requirements:

- Applications for building permits in DP-NH-03 shall include a site-specific report from a qualified Professional Engineer that considers seismic liquefaction and related geotechnical hazards (e.g., submarine landslides, flow slides, lateral spreading, subsidence), as applicable to the proposed building per BCBC (2018 or current version).
- The report shall include the following information, as applicable to the development:

- Seismic liquefaction triggering assessments, conducted in general accordance with the procedures recommended by Idriss and Boulanger (2008) and Boulanger and Idriss (2014), which are the current standard of practice in British Columbia.
- A detailed global stability assessment of the proposed building site indicating potential failure modes, limiting factors of safety, and stability under both static and seismic loading. Geotechnical analytical techniques for evaluating seismic slope stability should follow the procedures described EGBC's Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in British Columbia (May 2010 or current version). Consideration shall also be given to limits or potential changes in stability that may be induced by non-seismic factors including site grading and foundation loads, extreme low tides, and sea level rise.
- Assessment of liquefaction and its consequences, including recommendations for ground improvement and foundation design, should reference the Greater Vancouver Liquefaction Task Force Report, Geotechnical Design Guidelines for Buildings on Liquefiable Sites in Accordance with NBC 2005 for Greater Vancouver Region (May 2007 or current version), as applicable.
- Recommended geotechnical building setbacks from the natural boundary of Howe Sound, and a demonstration of suitability for the proposed use.
- Recommended mitigative measures to limit potential impacts to the building site and adjacent developments from construction-related disturbances including, as applicable, the stockpiling of soil, excavation shoring, dewatering, ground improvement, and pile driving.
- Development Permits shall be in accordance with the recommendations of the applicable natural hazard report or reports, including required mitigative measures.
- Natural hazard reports submitted in support of a development permit applications shall meet the requirements outlined in the appropriate EGBC Professional Practice Guidelines and Standards.
- Where development also falls within Environmental/Creek Hazard/Coastal Hazard/other DPA(s), the report shall be coordinated with other Qualified Professionals to create a comprehensive development permit application.

5. DP-NH-04: COASTAL HAZARDS

Details are provided in Figure 3 and in the attached memorandum from KWL.

6. DP-NH-05: CREEK HAZARDS

Details are provided in Figure 3 and in the attached memorandum from KWL.



7. OTHER CONSIDERATIONS

For further discussion with SLRD, the following policy tools could be considered in addition to the DPA guidelines provided herein:

- Requiring property owners to obtain a Site Alteration Permit, similar to that required by the Resort Municipality of Whistler, for initial land use activities such as clearing, grubbing, road grading and site servicing.
- Requiring property owners to register a “save harmless” covenant on the title of the property where their development is located within the mapped DPAs, as required in neighbouring jurisdictions such as the Sunshine Coast Regional District.
- Preparing brochures to inform property owners of natural hazards at Furry Creek and best practices for residential development, creek management and slope management in accordance with these guidelines.

8. CLOSURE

We trust the above provides the information you require at this time. If you have any questions regarding this memo, please contact either of the undersigned.

Yours truly,
Thurber Engineering Ltd.
David Regehr, M.Eng., P.Eng.
Review Principal

Jason Pellett, M.Eng., P.Eng./P.Geo.
Geotechnical Engineer

Attachments:

- Statement of Limitations and Conditions
- Figures 1 to 3
- Kerr Wood Leidal Associates Ltd. 2021. Furry Creek Area Flood Hazard DPAs. Technical memorandum to CREUS dated May 26, 2021



STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

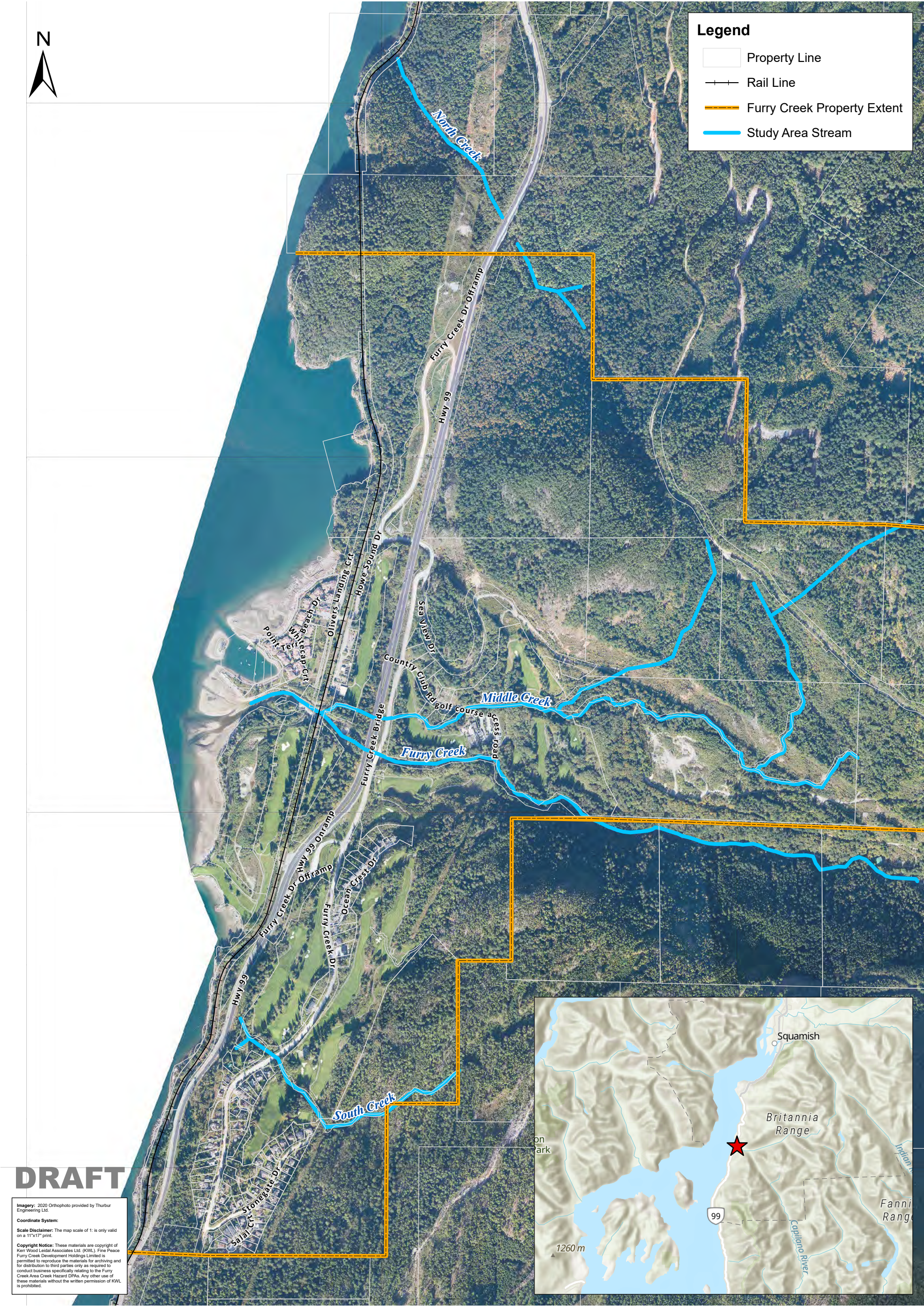
- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

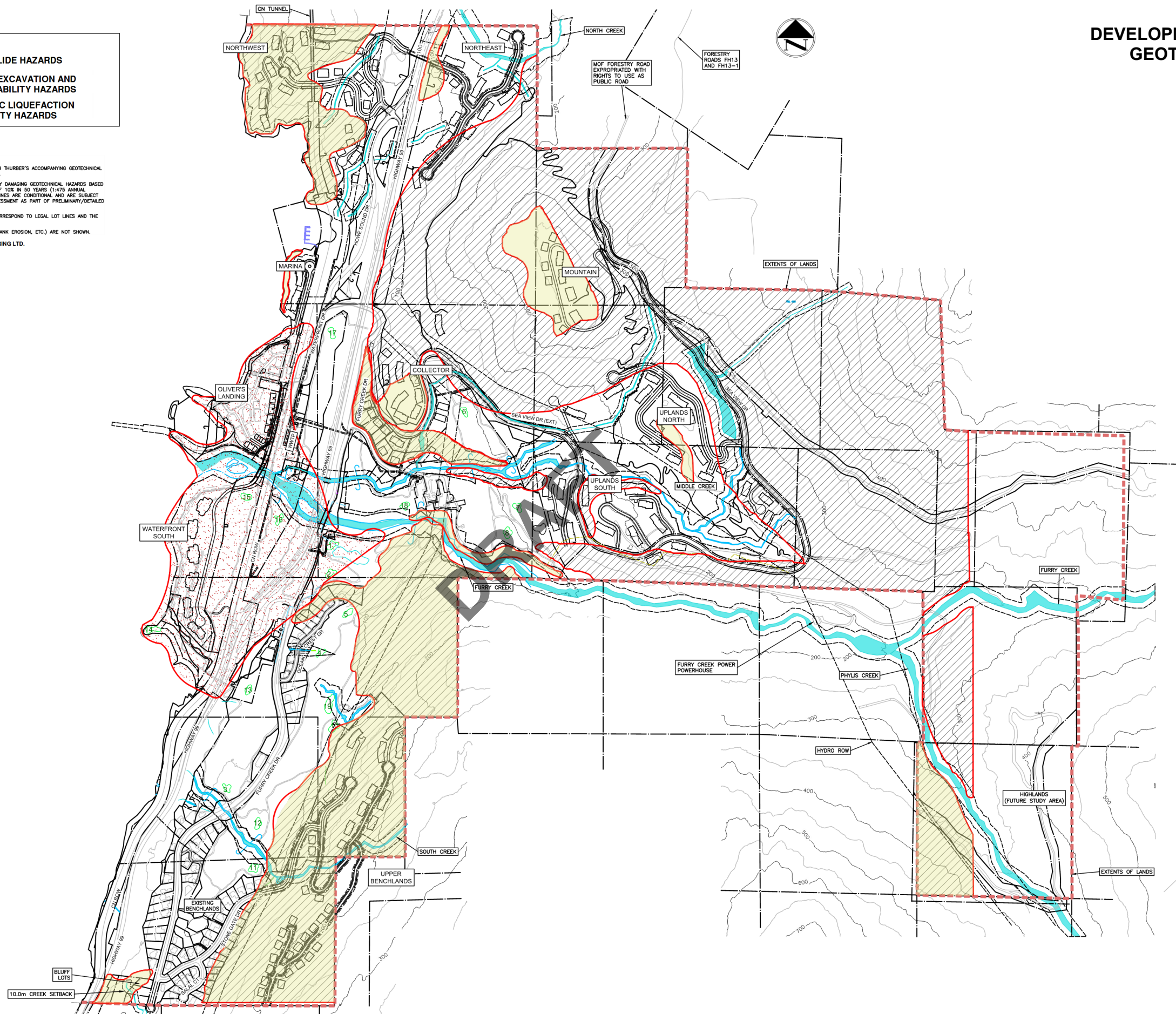




LEGEND

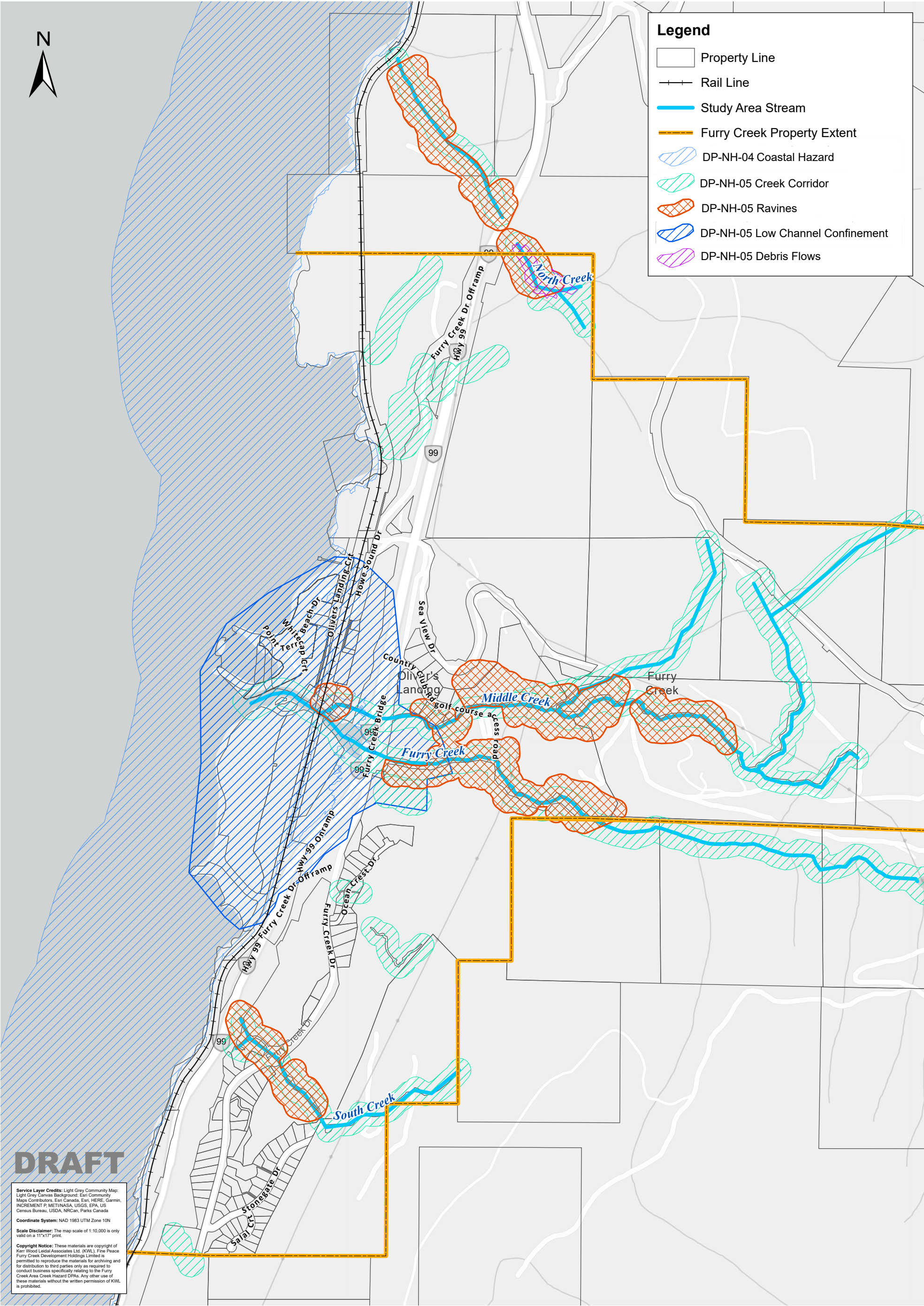
	DP-NH-01 LANDSLIDE HAZARDS
	DP-NH-02 ROCK EXCAVATION AND FOUNDATION STABILITY HAZARDS
	DP-NH-03 SEISMIC LIQUEFACTION AND FAN STABILITY HAZARDS

- NOTES:**
1. THIS FIGURE IS TO BE USED IN CONJUNCTION WITH THURBER'S ACCOMPANYING GEOTECHNICAL REPORT (PROJECT #21452) DATED JUNE 14, 2019.
 2. HAZARD LINES DENOTE THE EXTENT OF POTENTIALLY DAMAGING GEOTECHNICAL HAZARDS BASED ON AN ESTIMATED PROBABILITY OF OCCURRENCE OF 10% IN 50 YEARS (1:475 ANNUAL PROBABILITY), MAPPED AT 1:5,000 SCALE. THESE LINES ARE CONDITIONAL AND ARE SUBJECT TO CHANGE PENDING FURTHER GEOTECHNICAL ASSESSMENT AS PART OF PRELIMINARY/DETAILED DESIGN.
 3. THE BOUNDARIES OF THE GEOHAZARD MAPPING CORRESPOND TO LEGAL LOT LINES AND THE EXTENT OF THE AVAILABLE LIDAR DATA.
 4. FLUVIAL AND COASTAL HAZARD LINES (FLOODING, BANK EROSION, ETC.) ARE NOT SHOWN.
 5. BASE PLAN PROVIDED BY CREUS ENGINEERING LTD.



**DEVELOPMENT PERMIT AREAS
GEOTECHNICAL HAZARDS
FURRY CREEK, BC**

FIGURE 2



Technical Memorandum

DATE: May 26, 2021

TO: Kevin Healy, Creus Engineering
Fine Peace Furry Creek Development Holdings Ltd.

CC: Jason Pellett, Thurber Engineering Ltd.

FROM: Mike Currie and Chad Davey, KWL

RE: **FURRY CREEK AREA**
Flood Hazard DPAs
Our File 4015.002-300

1. Introduction

1.1 Scope of Work

Kerr Wood Leidal Associates Ltd. (KWL) and Thurber Engineering Ltd. (Thurber) have been retained to develop natural hazard Development Permit Areas (DPAs) for the Fine Peace development area at Furry Creek. Thurber is responsible for geotechnical hazards, such as slope stability and rockfall, while KWL's focus is on the creek and coastal flood hazards. For debris flow and debris flood aspects, KWL and Thurber are collaborating.

The following project tasks were completed:

- development of creek hazard DPA map;
- development of coastal flood DPA map; and
- preparation of this technical memorandum to document the project work.

This technical memorandum should be read in conjunction with Thurber's project report to provide overall documentation for the DPA determination. This will be submitted to the Squamish-Lillooet Regional District (SLRD) for consideration with respect to its natural hazards management programs.

1.2 Study Area

The Furry Creek study area is shown in the attached Figure 1. In terms of flood hazards, the study area generally includes Furry Creek, North Creek, Middle Creek, South Creek, and some Howe Sound shoreline.



2. Methodology

This section describes the methods used to delineate the DPA's, including: air photo review, GIS mapping, and hazard categorization.

2.1 Air Photo Review

Hard copy air photographs were obtained from the UBC air photo library and reviewed (Table 1).

Table 1: Summary of Air Photographs Reviewed

Date	Roll/Photo Number	Scale
1994	30BCC94122 #193-197, 003-007, 050-053	~1:20,000
1940	BC200 #3-6, 24-27	~1:40,000
1939	BC135 #57-60	~1:40,000

In general, the relatively small size of the creeks in combination with the forest canopy cover prevented detailed observations of the channels. Thus, air photos were mainly used for:

- geographic reference;
- confirmation of previously identified hazards;
- noting land-use changes over time; and
- general confinement noted for the creeks except in select locations.

2.2 GIS Mapping

GIS data were obtained from Creus Engineering and Thurber, including:

- topographic data:
 - o 1 m contours and LiDAR (x, y, z);
- creeks and rivers (ground survey by Bennet Survey);
- administrative data:
 - o development boundary (legal survey performed by Bennet Survey);
 - o parcels;
 - o existing slope hazard DPA areas;
- roads; and
- orthophotos (2009).

The GIS data was used to delineate the coastal and creek hazards described in the following sections.



2.3 Hazard Categorization and Assessment Criteria

The Furry Creek area is subject to a number of geohazards resulting from steep terrain and a maritime climate. For the purpose of this project, hazards are grouped into three main categories:

1. coastal hazards: coastal flooding and erosion;
2. creek hazards: ravines, low channel confinement, creek corridors (e.g., flooding, erosion, etc.), and debris floods/flows; and
3. Slope related hazards (e.g., rockfall, landslides, etc.).

Information on debris flow hazards was provided by Thurber for inclusion on KWL's creek hazard map. Information on slope related hazards is included in a separate report by Thurber.

Figure 2 presents the general topography for the Furry Creek area. This was used to perform the initial hazard analysis for each hazard category.

Coastal Hazard DPA Criteria

Coastal hazards include flooding (from high sea level, waves, and tsunami) and erosion. It is worth noting that the flood and erosion hazards posed by the sea are likely to be non-stationary, given that sea level is rising and is anticipated to rise at an increasingly rapid rate in the future. Coastal flooding can arise from the combination of a number of elements, including:

- astronomic tide;
- atmospheric (storm) surge;
- wind and wave setup;
- wave runup; and
- sea level rise.

Tidal Condition

The higher high water large tide condition is most applicable (HHWLT).

Storm Surge

Storm surge magnitude varies depending on the severity of the design condition. For the Fraser River delta, the suggested design annual exceedance probability (AEP) is 1 in 500 years (Table 6-1, Ausenco Sandwell, 2011a). This criteria would also be considered appropriate for Howe Sound.

Wind and Wave Setup

Wind setup is a rise of the water surface above the water level on the open coast due to the local action of wind stress on the water surface. This process acts to raise the overall water surface and is not the same as wave setup. Wave setup is a shorter duration and more local raising of the water surface similar to wind setup, but not associated with individual waves.

Wave Runup

Wave runup is the vertical component of the total distance that the wave travels once meeting the shoreline. An appropriate setback (horizontal) should be applied to address wave runup on a site-specific basis to avoid flooding and limit damage from spray.



Sea Level Rise

Global sea level rise (SLR) allowances are suggested for the Year 2100 and 2200 planning horizons (+1.0 m and +2.0 m, respectively, compared to the Year 2000 baseline). Since DPA's serve to guide long-term land development, and are a screening tool, a conservative allowance of 2 m SLR is used for this project.

Tsunami

Tsunami poses an additional hazard that is superimposed on tidal and possibly storm effects.

Hamilton and Wigen (1987) suggested that slumping of the Fraser delta could induce a tsunami of perhaps several metres height in Georgia Strait. However, Clague and Bobrowsky (1994) concluded that within low-lying coastal wetland settings around Georgia Strait there is no evidence of tsunami deposits; therefore, had they occurred, the wave(s) would have been less than about 1 m in height.

Coastal Flood Level

Table 2 summarizes the various elements of coastal flooding considered for this assessment and provides a preliminary coastal flood level at Furry Creek.

Table 2: Coastal Flood Hazard at Furry Creek

Component	Elevation
high tide still water level	2.05 m
storm surge	1.3 m
allowance for local effects (residual, datum offset, wind setup and subsidence)	0.3 m
allowance for sea level rise to year 2200 as per BC guidelines	2.0 m
allowance for wave runup	1.2 m
freeboard allowance	0.6 m
Preliminary Coastal Flood Level (geodetic datum)	7.45 m

To delineate the potential area of impact for DPA of coastal flooding, a conservative elevation of 8 m CGD is proposed, which encompasses areas subject to flood hazard from both tsunami and rising sea levels. An elevation of 8 m was also used for coastal flooding hazard assessments conducted for Lions Bay (Cordilleran Geoscience, 2018), and the Sunshine Coast (KWL, 2013)

Creek Hazards DPA Criteria

In most cases, the Furry Creek watercourses are confined within incised channels and ravines, and potential hazards are restricted to the immediate creek or river corridor. Areas without good confinement are usually floodplain areas or fans. In these areas, flood hazards can be more extensive and unpredictable channel relocation (avulsion) is possible due to debris blockages or sediment deposition.

The following creek hazards were considered for this assessment:

- creek corridor;
- ravines;
- low channel confinement (including fans); and
- debris floods/flows.



Creek Corridors

Creek corridor hazards include localized flooding and erosion that can occur in the vicinity of the creek. The DPA for creek corridors has been delineated using a buffer width of 30 m on all creeks shown in the GIS mapping. On the ground, the DPA for creek corridors should be interpreted as extending 30 m from the natural boundary, consistent with the Riparian Areas Regulation definitions.

Ravines

Ravines are landforms associated with creeks that have become incised into thick deposits of surficial material. Typically there is an abrupt slope break from adjacent terrain onto a steep erosional slope. At the toe of slope, there may or may not be a floodplain between the toe and the natural boundary of the creek.

Ravine crests were mapped in the GIS-based on slope (by including areas of 30% or steeper terrain within the ravine) and also using slope breaks identified on the contour maps. Since creeks may or may not be incised in ravines, ravine crests are not necessarily continuous along creeks.

Identified ravine crest lines are shown in Figure 2. Based on consideration of stable angles of repose and the typical terrain seen in the Furry Creek area, the following approach has been adopted:

- A 30 m setback from ravine crests defines the area that falls within the Ravine DPA.
- An engineering report from an appropriately qualified professional will be required to reduce the setback from 30 m.

Low Channel Confinement

Flood hazards and channel avulsion occur in areas of low channel freeboard where the channel is not well confined by high ground on either side (i.e. floodplains and fan areas). LiDAR contour data (1 m contour interval) were reviewed to identify potential areas of low channel confinement, or fans, based on judgement.

The available air photographs and contour mapping have been used to identify potential areas of low channel confinement, which are included in low channel confinement DPA.

Debris Floods/Flows

Steep mountain creeks may be subject to a spectrum of events, ranging from clear water floods to debris flows. Creek events are typically categorized by sediment concentration, with clear water floods having the lowest concentrations of sediment, debris floods having intermediate concentrations and debris flows having the highest concentration.

Debris floods and debris flows are very rapid flows of water and debris along a steep channel (Hung et al., 2001). Debris flows are differentiated from debris floods by their significant entrainment of water and material from the flow path, higher destructive potential, and widely different strategies that must be used to design protective structures (Hung et al., 2014). The sediment may be transported in the form of massive surges. These events leave lobes, levees, and sheets of poorly sorted debris ranging from sand to large boulders. Significant quantities of coarse woody debris (logs and stumps) may also be entrained in the deposits. The peak discharge (flow rate) of debris floods is commonly 2 to 5 times higher than that of equivalent "clear water" floods (Jakob and Jordan, 2001). Debris flows, however, can have peak discharges up to 40 times that of a flood due to the strong surging behaviour of these events (VanDine 1996).



TECHNICAL MEMORANDUM

Flood Hazard DPAs
May 26, 2021

These types of events would be expected to initiate higher in the watershed, along open slopes or within channels, and be conveyed along confined channels. As the channel gradient drops and/or the channel becomes less confined, debris is deposited. Repeated deposition forms alluvial fans, but deposition may also occur at road crossings or other human modifications in the landscape, especially where transport capacity has been reduced by encroachment.

Potential for debris flood and debris flow is primarily dictated by the basin characteristics, including gradient, watershed size, channel length, and the underlying geology/lithology of the area. Smaller, steeper watersheds may be debris flow prone; whereas larger, gentler watersheds may only be vulnerable to flooding.

KWL and Thurber collaborated on defining a DPA for debris flows. Thurber used a Melton ratio¹ (Millard et al., 2006) to screen individual creeks within the Furry Creek area for the potential for flood, debris floods, and debris flows. The results of the Melton ratio screening tool revealed that North Creek has the potential for debris flows to occur. A hypothetical debris flow lobe and flooding event was simulated for North Creek to help define the extents of a debris flow DPA. A 5 m thick debris flow lobe (10,000 m³ total volume) with an associated 6 m deep flood was simulated for North Creek using GIS software. This hypothetical event is not tied to a specific probability of occurrence (return period); rather, it is a subjective upper-bound estimate of debris flow and flooding potential in the creek, solely for the purposes of DPA mapping. As such, these parameters are not intended to be used for detailed design studies.

¹ The Melton Ratio is defined as the ratio of total watershed relief to the square root of the drainage area; it is a proxy for basin ruggedness.



3. Results: DPA Hazard Areas

3.1 DPA Maps

Proposed revised DPA zones are presented in Figure 3 based on the approach presented above.

The goal of the DPA boundary delineation is to apply a uniform screening criterion for potential hazards. The likelihood of magnitude of possible hazards is not explicitly estimated.

In determining the DPA boundaries for the hazard categories, it is recognized that there is inherent uncertainty in the spatial data upon which the DPA categories have been based, as well as uncertainty in the extent of influence of possible hazards. Therefore site specific surveys may be used to confirm or refine the DPA boundaries on a site specific basis (e.g. setbacks).

3.2 Future Land Use Considerations

The primary purpose of this assessment is to provide a planning tool for future development. It is acknowledged that some existing development is located within DPA areas identified in this assessment, as approved under applicable previous guidelines and regulations.

Within each DPA, future development applications will need to give further site-specific consideration to the hazards and develop appropriate mitigation plans. This section provides some guidance in this respect, in consideration of the following:

- BC Flood Hazard Area Land Use Management Guidelines (2018); and
- Engineers and Geoscientists BC Guidelines for Flood Assessments in a Changing Climate in BC (2018).

It is noted that subdivision of lands within SLRD requires consent of the provincial Approving Officer (Ministry of Transportation and Infrastructure). Therefore, projects that may involve future subdivisions will need to specifically consider provincial requirements at such future time.

DPA: Ocean Hazards

Site-Specific Analysis

Development applications should involve a refined assessment of the coastal flood level (compared to the general analysis undertaken for this project) by an appropriately qualified professional engineer or geoscientist, with particular emphasis on highly variable wave effects. Some considerations for such assessments are noted below.

- If any area on the property is below 8 m (GSC), a coastal flood hazard assessment should be required, that would include: estimation of a site-specific coastal flood level, consideration of future sea level rise and allowance for wave runup as outlined in the Provincial Guidelines.
- Areas subject to coastal flooding should require the definition of an appropriate flood construction level (FCL) that reflects the foreseeable coastal flood levels for the life of the development, in view of pertinent guidelines and SLRD provisions.



Considerations for Mitigation Plan

Some considerations for a coastal flood hazard mitigation plan are noted below.

- The preferred approach is to avoid development within the coastal flood hazard area.
- In some situations, it may be appropriate to consider the need for a sea dike, with an appropriate setback from the shoreline.
- As dikes are subject to approval by the Inspector of Dikes (IOD) pursuant to the Dike Maintenance Act, it is important that any dike design is performed in consideration of IOD standard dike criteria. This includes provision for any constructed dikes to be under the maintenance authority of SLRD. The design criteria would include appropriate allowances for sea level rise and wave effects, and provision for long-term upgrading of dikes for additional sea level rise.
- In the absence of a sea dike, an appropriate coastal setback should be provided. In general, the setback should be sufficient to preclude development being affected by shoreline erosion without the need for shore protection works.
- Development should meet applicable setback provisions from the landside dike toe and any internal watercourses.
- The FCL should be achieved by landfill to the FCL. Any construction of basements or other habitable areas below the FCL would require justification and variance.
- The mitigation plan should consider appropriate protection of infrastructure associated with the proposed development.
- Integration with mitigation plans for other hazards may be required.

DPA: Creek Hazards

Site-Specific Analyses

Development applications should involve a refined assessment of the creek hazards (compared to the general analysis undertaken for this project) by an appropriately qualified professional engineer or geoscientist. Some considerations for such an assessment are noted below.

- Potential creek-related hazards should be assessed in terms of frequency and magnitude, and potential area of impact. The hazard assessment should cover the entire land parcel being considered for development, with a focus on the hazard areas identified in this report. The hazard assessment should reasonably consider the potential for upstream resource development activity (such as forestry) and land development in adjacent areas. The hazard assessment should also consider the potential for future climate change.
- Creek corridors upstream and on the property should be subject to detailed assessment, including survey to establish the natural boundary location and provide information regarding the channel geometry (including cross-sections).
- The proposed development design should endeavour to avoid the area of potential creek hazard impact. Where development is proposed within an area of potential creek hazard, an appropriate mitigation plan should be prepared.
- The need for a setback from the crest and/or toe of a ravine, and the natural boundary of a creek, should be considered.



TECHNICAL MEMORANDUM

Flood Hazard DPAs
May 26, 2021

- Debris flow and debris flood hazards may require consideration of channel and slope characteristics upstream from the subject property. Associated data may include stream and ravine bank profiles, bank stability assessment, and run out limits of debris within the creeks.
- The degree of hazard assessment work may be tailored to suit the proposed scale of development, as provided in the EGBC guidelines for flood assessments.

Considerations for Mitigation Plan

Some considerations for a flood hazard mitigation plan are noted below.

- The preferred approach is to avoid development within creek hazard areas.
- In some situations, it may be appropriate to consider the need for a flood protection dike, with an appropriate setback from the creek.
- As dikes are subject to approval of the IOD under the Dike Maintenance Act, it is important that any dike design is performed in consideration of IOD standard dike criteria. This includes provision for any constructed dikes to be under the maintenance authority of SLRD.
- Development should meet applicable setback provisions from the natural boundary of the creek or the landside dike toe.
- A flood construction level (FCL) should be developed in consideration of the design flood level and other design considerations as noted herein.
- The FCL should be achieved by landfill to the FCL. Any construction of basements or other habitable areas below the FCL would require justification and variance.
- The mitigation plan should consider appropriate protection of infrastructure associated with the proposed development.
- The mitigation plan should include documentation that it will not result in a transfer of risk to other properties, or otherwise mitigate such impacts.
- Integration with mitigation plans for other hazards may be required. Integration with any pertinent stormwater management plans may also be required.



Report Submission

KERR WOOD LEIDAL ASSOCIATES LTD.

Prepared by:

Reviewed by:

Chad Davey, M.Sc., R.P.Bio
Project Geomorphologist

Mike V. Currie, M.Eng., P.Eng., FEC
Senior Water Resources Engineer

CD/MVC

Enclosures: Figure 1: Furry Creek Study Area
Figure 2: Furry Creek Hazard Screen Map
Figure 3: Proposed DPAs for Furry Creek Study Area

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of the intended recipient. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

Copyright Notice

These materials (text, tables, figures, and drawings included herein) are copyright of Kerr Wood Leidal Associates Ltd. (KWL). Fine Peace Furry Creek Development Holdings Ltd. is permitted to reproduce the materials for archiving and for distribution to third parties only as required to conduct business specifically relating to the Flood Hazard DPAs. Any other use of these materials without the written permission of KWL is prohibited.

Revision History

Revision #	Date	Status	Revision Description	Author
A	April 15, 2021	Draft		CD
B	April 30, 2021	Draft	Minor revision to text as recommended by Thurber, addition of Figure 1	CD
C	May 14, 2021	Draft	Updated text in section 3	CD
D	May 26, 2021	Draft	Updated text in sections 2 and 3	CD





References

- Ausenco Sandwell. 2011a. Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Use – Sea Dikes Guidelines. Report prepared for Ministry of the Environment. 19 pp + appendices
- British Columbia Ministry of Forests, Land and Natural Resource Operations (FLNR). (2018). Flood Hazard Area Land Use Management Guidelines.
- Clague, J., and J., Bobrowsky, 1994. Evidence for large earthquake and tsunami 100-400 years ago on western Vancouver Island, British Columbia. Canadian Journal of Earth Sciences, v 41, p. 176-184.
- Cordilleran Geoscience. 2018. The Village of Lions Bay, Natural hazards development permit strategy: Coastal, Creek and Hillslope Hazards. Final V4 January 18, 2018.
- Engineers and Geoscientists of British Columbia. 2018. Legislated flood assessments in a changing climate in BC. Professional Practise Guidelines; Natural Hazards. Version 2.1.
- Hamilton, T.S., and Wigen, S.O. 1987. The foreslope hills of the Fraser Delta: implications to tsunamis in Georgia Strait. Science of Tsunami Hazards, 5: 15-33.
- Hungr, O., S.G., Evans, and M., Bovis., 2001. Review of the classification of landslides of the flow type. Environmental and Engineering Geoscience 7(3):221-238.
- Jakob, M. and Jordan, P. 2001. Design flood estimates in mountain streams - the need for a geomorphic approach. Canadian Journal of Civil Engineering, 28: 425-439.
- Kerr Wood Leidal. 2013. Geotechnical hazard report: Roberts Creek. Submitted to Sunshine Coast Regional District. KWL file: 724.022
- Millard, T.H., D.J. Wilford and M.E. Oden. 2006. Coastal fan destabilization and forest management. Res. Sec., Coast For. Reg., BC Min. For., Nanaimo, BC. Technical Report TR-034/2006.
- VanDine, D. F. 1996. Debris flow control structures for forest engineering. Res. Br., B.C. Min. For., Victoria, B.C., Work. Pap. 08/1996

