BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

FRASER BASIN COUNCIL

THOMPSON RIVER WATERSHED GEOHAZARD RISK PRIORITIZATION

DRAFT SCOPING STUDY

PROJECT NO.: 0511-002 DATE: July 15, 2018

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY
Suite 500 - 980 Howe Street
Vancouver, BC Canada V6Z 0C8
Telephone (604) 684-5900
Fax (604) 684-5909

July 15, 2018
Project No.: 0511-002

Mike Simpson, Senior Regional Manager
Fraser Basin Council
200A – 1383 McGill Road
Kamloops, BC V2C 6K7

Dear Mr. Simpson,

Re: Thompson River Watershed Geohazard Risk Prioritization Scoping Study - DRAFT

Please find enclosed BGC Engineering Inc.'s (BGC) draft scoping study report, as part of our flood risk prioritization study for the Thompson River Watershed. The purpose of this draft scoping study report is to provide Fraser Basin Council (FBC) with an update on BGC's progress towards the project objectives and an opportunity to comment on the results of the work completed to date.

We appreciate having the opportunity to work on such an interesting project.

Yours sincerely,

BGC ENGINEERING INC.
per:

Kris Holm, M.Sc., P.Geo.
Senior Geoscientist

EXECUTIVE SUMMARY

This study will provide a clear-water flood, debris-flood, debris-flow, and landslide-dam flood geohazard risk prioritization for the Thompson River Watershed (TRW). The TRW includes remote wilderness, rural development, and urban centers. The project focuses on areas of existing rural or urban development, particularly improved properties, subject to these geohazards.

This scoping report is an intermediate deliverable of the study. It is a work in progress, and all material provided in this report is subject to change for the Draft and Final reports. Note that some of the report wording is in the past tense, anticipating its completion for the Draft report, but still represents work in progress. BGC has inserted italicized comments and placeholders where project elements are not yet complete.

The following project elements are included in the main body of this scoping report:

Introduction (Section 1.0). This section describes project objectives and the scope of work, and defines the geohazard types assessed. It also clarifies geographic areas and geohazard types within the TRW that are outside the scope of assessment. This section is approaching draft status.

Background (Section 2.0). This section will describe the project setting in terms of geology, climate, hydrology, flood history, and existing policies and bylaws related to flood hazard management. This section is incomplete and is provided as a placeholder.

Risk Prioritization Framework, Geohazard Exposure, Geohazard Identification, and Risk Prioritization (Sections 3.0 to 5.0). These sections describe methods to identify the geohazard areas to be assessed, and to combine ratings for geohazards and potential consequences into a priority rating for each area. These sections are approaching draft status.

Results (Section 6.0). As an intermediate deliverable of the study, this scoping report does not include prioritized geohazard areas.

Climate Change (Section 7.0). This section is not included with the Scoping Study, and will be completed for the Draft and Final Reports.

Conclusions and Further Considerations (Section 8.0). Conclusions are not included with this scoping report.

Appendices to the report describe terminology, data sources, previous work, and analysis methods as follows:

Terminology (Appendix A). This appendix defines geohazard-related terms used throughout the report and compares them to terminology used in flood-related policy documents.

Data Sources (Appendix B). This appendix tabulates previous work within the TRW that is to be referenced in this project.

Clear-water Flood, Steep-Creek, and Landslide Geohazard Assessment Methods (Appendices C through E). These appendices describe methods to identify geohazard areas and determine geohazard ratings. The Steep-Creek methods appendix is included with this report, and the clear-water and landslide-dam flood appendices will be provided for the Draft and Final reports.

Web Maps

Much of this study's background information and results exist as complex geospatial data that would be difficult to display using conventional, "static" maps and tables. At completion, BGC will present the study results on an interactive, searchable online map titled *Cambio™ Communities* that will show the jurisdictional boundaries, building and infrastructure assets, geohazard inventory, and geohazard areas prioritized in this assessment.

The final format web map is in preparation and is not included in this scoping level report. In the interim, BGC is publishing geospatial information on a password-protected, ArcGIS Online web map that will eventually be transferred to the final web map. Access requires an ESRI user account. The web address and access information will be provided separately.

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LIMITATIONS

BGC Engineering Inc. (BGC) prepared this document for the account of Fraser Basin Council. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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1.0 INTRODUCTION

1.1. Objectives

A geohazard risk prioritization initiative for the entire Thompson River Watershed (TRW) was launched in February 2018 at a Community-to-Community Forum in Kamloops, coordinated by Fraser Basin Council (FBC) with participation of local governments and First Nations.

FBC retained BGC Engineering Inc. (BGC) to carry out the work with the support of Kerr Wood Leidal Associates (KWL), with funding provided by Emergency Management BC (EMBC) and Public Safety Canada under Stream 1 of the Natural Disaster Mitigation Program (NDMP, 2018). This work is being carried out under the terms of an agreement between FBC and BGC dated April 2, 2018. The scope of work was described in BGC Engineering Inc.'s (BGC) March 9, 2018 proposal titled "Thompson Watershed Flood and Debris Flow Risk Assessment". The work was authorized in an April 2, 2018 contract between FBC and BGC.

The primary objective of this initiative is to characterize and prioritize flood, debris-flood, debris-flow and landslide hazards in the TRW that might impact developed properties. The long-term goal is to support decisions that prevent or minimize injury or loss of life, environmental damage, and economic loss due to geohazard events. Completion of this risk prioritization study is the foundational step towards this goal.

This study provides the following outcomes across the TRW:

- A consistent approach to manage information related to geohazards and elements at risk, for the types and areas of geohazards assessed
- A consistent methodology to characterize and prioritize geohazard areas and manage geospatial information associated with these areas
- A web map displaying prioritized geohazard areas and supporting information
- Identification of gaps and areas where existing information is outdated or unreliable.

These outcomes support the foundational basis for:

- Geohazard risk-informed development planning, bylaw enforcement, and emergency response planning
- A framework for additional steps of geohazard risk management, including detailed hazard mapping, risk assessment, and mitigation planning
- The basis to apply for funding to undertake additional work related to geohazard risk management within the TRW.

The work is consistent with the Engineers and Geoscientists BC (EGBC) Professional Practice guidelines for Legislated Flood Assessments in a Changing Climate in BC, as well as the Draft Alberta Guidelines for Steep Creek Risk Assessments[1] (BGC, March 31, 2017).

[1] No equivalent guidelines have yet been prepared by the Engineers and Geoscientists BC or the Province of BC.

1.2. Scope of Work

BGC's scope of work was described in a proposal dated March 9, 2018. The work is based on collating previous assessments and collection of additional field and desktop-based hazard information. Sections 1.3 to 1.3.3 define the assessment framework, geohazard types and mechanisms for damage included in the BGC/KWL assessment. Data sources are listed in Appendix B.

Scoping Report Note: Appendix B is a work-in-progress that will be completed for the Draft and Final Reports.

Table 1-1 summarizes tasks for each project stage, as well as the current status of each task. The table presents the same scope described in the Contract, updated to reflect the work flow of the assessment. The assessment was based on the existing elements at risk. Proposed or future development scenarios were not examined.

This study focuses on 'settled' urban and rural areas within the TRW. The boundary between settled areas and wilderness is not always sharp, so defining the areas assessed can be challenging. Prioritized geohazard areas typically include buildings improvements and adjacent development (i.e., transportation infrastructure, utilities, and agriculture). Although infrastructure in otherwise undeveloped areas (e.g., roads pipelines, transmission lines, and highways) could be impacted by geohazards, these were outside the core focus of the study and therefore not included.

Table 1-1. Overview of project tasks.

Activities	Tasks	Status Comment (Scoping Report)
Project Initiation	Define the study objectives, scope of work and study area.	Draft completed.
	Define the roles of the parties involved in the project.	
	Identify the geohazard types and damage mechanisms to be assessed.	
Background	Compile information on study area physiography, climate, hydrology, and flood history.	In progress; some report sections to be completed for Draft Report issue; geospatial data compilation in progress; existing data are displayed on ArcGIS Online Map.
	Review floodplain management policies and bylaws, and define data sources.	
	Compile and organize existing basemap and geohazard data in geospatial format.	
Prioritizing Framework	Define over-arching study framework.	Draft completed.
Elements at Risk	Identify and characterize elements at risk for vulnerability assessment.	In progress; some report sections to be completed for Draft Report issue.
Geohazard Identification	Identify and characterize geohazards to be assessed. Define geohazard areas to be prioritized.	In progress; some report sections to be completed for Draft Report issue.
Geohazard Prioritization	Identify elements considered vulnerable to geohazard impact. Assign geohazard, consequence and priority ratings for the relative likelihood that geohazards will occur and reach elements at risk vulnerable to some level of consequence. For areas subject to funding applications for further study, categorize ratings in terms of NDMP inputs, including confidence ratings and the Risk Assessment Information Template (RAIT).	Methodology completed in draft. Results will follow completion of preceding project elements.
Climate Change Assessment	Identify climate change considerations (inputs). Determine characterize key mechanisms for hazard change due to climate change.	In progress; report sections to be completed for Draft Report issue.
Conclusions	Summary of findings and considerations for further work. Web-based application.	In progress; report sections to be completed for Draft or Final report issue.

1.3. Geohazards Assessed

1.3.1. Terminology

Jurisdictions within the TRW have legal definitions for common terms that are used throughout this study. For example, these include *watercourse, flood construction levels (FCLs)* and *development setbacks*. Some of these terms were adapted from those used by the BC Ministry of Water, Land and Air Protection (MWLAP, 2004) or from provincial legislation (e.g., those related to land title).

These legal definitions are not necessarily identical to technical definitions, or there may be nuances that require clarification to ensure terms are properly applied. Appendix A defines flood-related terms referenced in this project and clarifies differences between their use in technical work versus policy.

1.3.2. Geohazard Types

The term "geohazards" describes all geophysical processes with the potential to result in some type of undesirable outcome, including floods and other types of geohazards.

The NDMP broadly defines the following terms:

Flood: The overflow of natural drainage channels, natural shorelines and/or human-made facsimiles leading to partial or complete inundation from the overflow of inland or tidal waters, and/or the accumulation or runoff of surface waters from any source.

Flood mapping: The delineation of flood lines and elevations on a base map, typically taking the form of flood lines on a map that show the area that will be covered by water, or the elevation that water would reach during a flood event. The data shown on the maps, for more complex scenarios, may also include flow velocities, depth, other hazard parameters, and vulnerabilities.

The following geohazards are included in the scope of work[2].

Clear-water flooding:

This study evaluates riverine and lake flooding resulting from inundation. Herein we define inundation as: flooding resulting from an excess of clear-water discharge in a watercourse or body of water such that land outside the natural or artificial banks which is not normally under water, is submerged or inundated.

Triggering mechanisms for riverine flooding and flooding along a lake or shoreline included in this scope of work focused on natural runoff (from rainfall, snowmelt and glacial melt).

Debris flows and debris floods (steep creek geohazards):

[2] Definitions adapted from NDMP Application Guidelines and BGC.

Both processes are characterized by the rapid flow of water and debris in a steep channel[3]. These are collectively referred to as "steep creek geohazards" in this document. Triggering mechanisms for debris flows and debris floods included in this scope of work are natural runoff (from rainfall and snowmelt) and landslides. Steep creek processes fall on a spectrum, where the type of process can be classified in terms of sediment concentration, slope, velocity and planform appearance (Figure 1-1).

Landslide-dam flooding:

This study evaluates the potential for floods caused when landslides impact and temporarily dam major water courses. Flooding due to landslide dams can occur both upstream from water impoundment, and downstream when dam failure results in the sudden discharge of impounded water. Landslide-dam flooding is considered as a type of clear-water flood mechanism requiring separate assessment from conventional riverine flooding, due to the different source of hazard. Note that it is the flood hazard area, not the landslide, that is ultimately prioritized in this study.

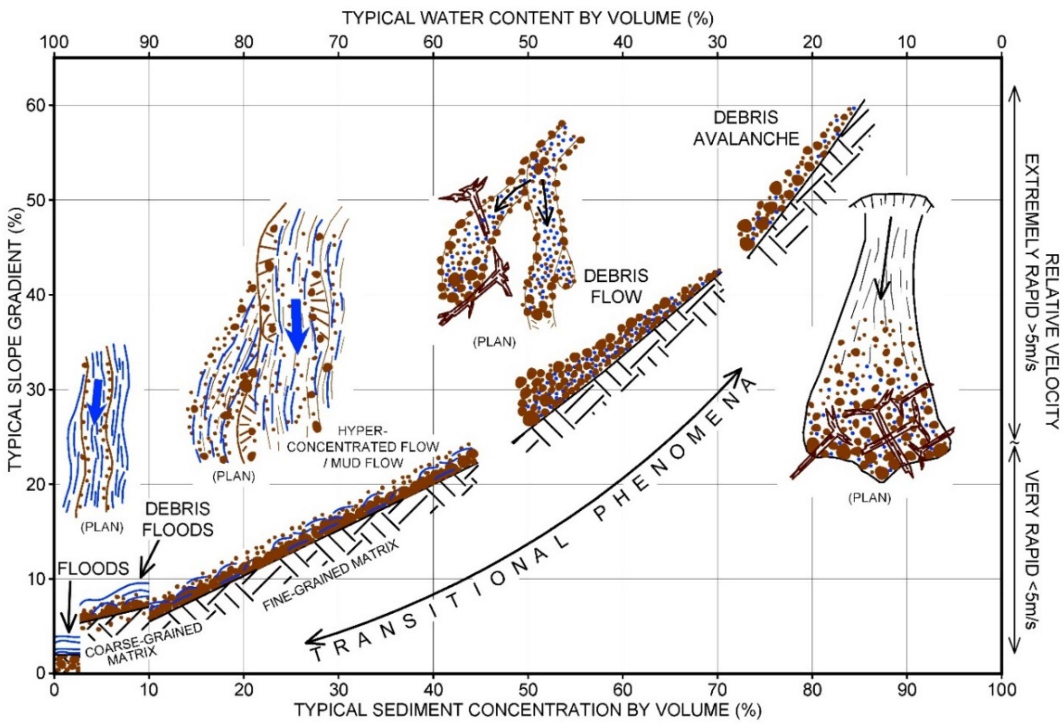

Figure 1-1. Steep creek process classification by sediment concentration, slope, velocity and planform appearance. Source: generated by BGC.

3 Debris flows occur in relatively steeper channels and have higher volumetric sediment concentrations than debris floods. These processes can have peak discharges up to 100 times higher than clear-water riverine floods at comparable return periods and can pose greater risk to life. Historically, more fatalities have occurred in British Columbia due to debris flows and debris floods than clear-water floods.

1.3.3. Geohazard Mechanisms

Viewing different types of flood geohazards from the perspective of their mechanisms for damage, which are common across geohazard types, provides a way to simplify how they are considered in risk prioritization and policy.

The geohazard types included in this study can damage elements at risk through the following processes, either separately or in combination:

- Directly through either the presence water or debris or by the physical force of their movement through an affected area
- Secondary geomorphic processes such as channel avulsion, aggradation or scour, bank erosion, channel encroachment, or landslides
- Secondary interaction with infrastructure, such as culvert blockage resulting in avulsion, or debris impact causing building damage leading to loss of life to building occupants.

These processes can be further simplified to three geohazard mechanisms with different forms of destructive potential: flood inundation, debris impact, and ground instability (e.g., erosion, encroachment, or scour). These mechanisms for damage can occur separately or in combination, although it is usually possible to identify the dominant mechanism for damage. These hazard mechanisms underpin the basic subdivision of hazard areas for prioritization in this study.

Scoping report note: a schematic illustration will be added here to show the three geohazard mechanisms: flood inundation, debris impact, and ground instability.

While all three geohazard mechanisms are important, the risk prioritization completed in this study is based primarily on the first two mechanisms (flood inundation and debris impact). Detailed assessments of high priority sites, where completed, may consider a greater number of processes, geohazard mechanisms, and consequence types than this study.

1.3.4. Limitations

It is important to recognize that there are other types of geohazards that are not covered by NDMP funding and are outside the scope of work, but may also pose a hazard within the TRW. Geohazards specifically excluded from this assessment include:

- Channel encroachment due to bank erosion during high or low flows
- Shoreline erosion
- Wind-generated or landslide-generated waves in lakes/reservoirs
- Dam and dike/levee failure[4]

[4] A dynamic and rapid release of stored water due to the full or partial failure of a dam, dike, levee or other water retaining or diversion structure. The resulting floodwave may generate peak flows and velocities many orders of magnitude greater than typical design values. Consideration of these hazards requires detailed hazard scenario modelling. Under BC's Dam Safety Regulation, owners of select classes of dams are required to conduct dam failure hazard scenario modelling.

- Overland urban flooding[5]
- Sewer-related flooding[6]
- Ice jam flooding
- Landslides other than those considered as part of steep creek or landslide-dam flood geohazards assessments
- Landslide-dam floods other than those caused when landslides impact and temporarily dam major water courses (e.g., moraine-dam failures, glacial lake outburst floods, tailings dam or other human-caused dam failures, or secondary landslide/flood hazards such as landslide-triggered flood waves)
- Geohazards other than those listed as being assessed (e.g., fire, seismic, volcanic, etc.).

1.4. Risk Prioritization Framework

This section describes a framework to prioritize geohazard areas across the TRW. The prioritization framework is consistent across the range of geohazards assessed, where methods to estimate input values are specific to each hazard type.

The prioritization framework used in this study is based on the following principles:

- Application of a prioritization approach that supports decision making without being overly prescriptive, recognizing that the FBC and stakeholders must also consider additional factors for risk management decision making that are outside the scope of this assessment (e.g., community stakeholder input).
- Definition of the broad spectrum of geohazard types included in this study in terms of three fundamental mechanisms of damage: water inundation, debris impact, and ground instability. This approach allows different hazard types to be included in the same ranking system without altering the prioritization approach.
- Use of a single geohazard scenario with credible potential to result in consequences to prioritize sites recognizing that geohazards behave according to a frequency-magnitude relationship. Development of geohazard frequency-magnitude relationships would still be required to complete more detailed hazard and risk analyses in support of mitigation design.
- Development of a baseline prioritization that assumes existing conditions (current level of geohazards and exposure of elements at risk to these geohazards). Additional risk mitigation (including resiliency) and non-stationarity of geohazard levels (e.g., climate change) would be considered after baseline ratings are established.
- Use of the principles of quantitative risk assessment, but with results expressed in qualitative terms that reflect the quality of available data, give flexibility in decision support and how inputs are estimated, and that are feasible to incorporate into policy.

[5] Due to drainage infrastructure such as storm sewers, catch basins, and stormwater management ponds being overwhelmed by a volume and rate of natural runoff that is greater than the infrastructure's capacity. Natural runoff can be triggered by hydro-meteorological events such as rainfall, snowmelt, freezing rain, etc.

[6] Flooding within buildings due to sewer backups, issues related to sump pumps, sewer capacity reductions (tree roots, infiltration/inflow, etc.).

- Application of a method that allows future refinement of parameter estimates as methods and data quality improve, without fundamentally altering the prioritization approach.
- An approach that could potentially allow optimization of capital expenditures by comparing risk reduction benefits to the capital cost of mitigation works, either qualitatively or quantitatively. Benefit-cost analysis is not included in the current scope of work.

Figure 1-2 illustrates the three components of the risk prioritization framework used in this study: hazard, exposure, and vulnerability. The combination of exposure and vulnerability represents consequences, and all three components together represent risk. Each of these components is estimated separately and combined to form a priority rating for a given site.

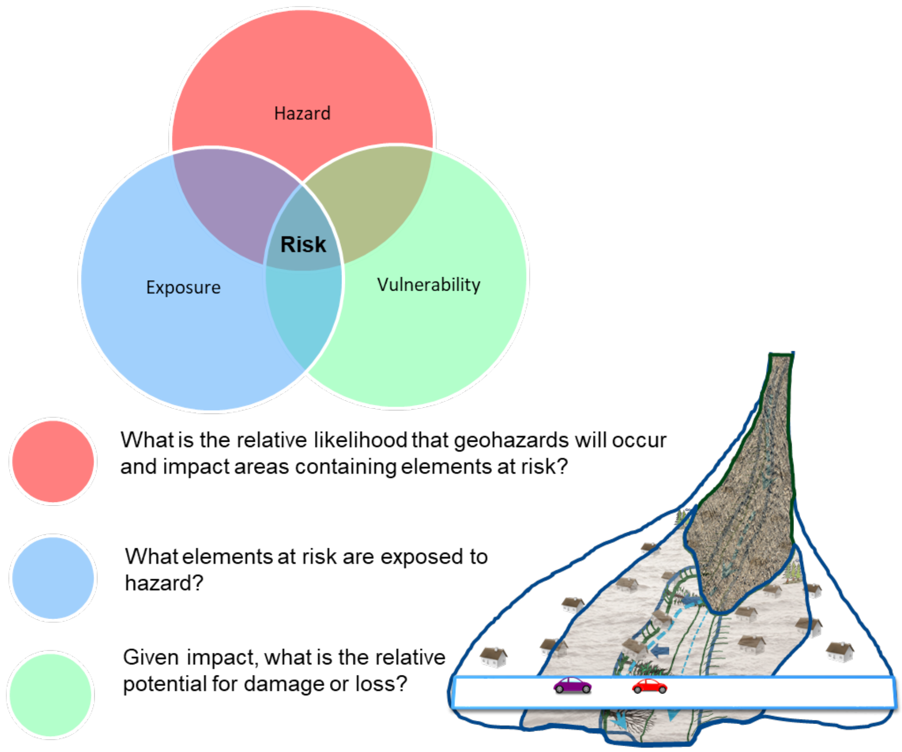

Figure 1-2. Elements of the prioritization approach.

The approach is based on qualitative ratings of hazard, consequence and risk-based priority. Specifically, the ratings are defined as follows:

- Geohazard rating (Section 5.1). This rating estimates the relative likelihood a geohazard will occur and reach elements a risk.
- Consequence rating (Section 5.2). This rating estimates the relative consequences given impact by a geohazard, based on proxies for the value of elements at risk and their vulnerability to damage or loss.
- Priority rating (Section 5.3). This rating combines the geohazard and consequence ratings, to estimate the relative likelihood that geohazards could occur and result in a certain level of consequences.

BGC notes that the prioritization approach is a simplification in that it considers a single geohazard scenario for each hazard area, as opposed to the cumulative (total) risk of a spectrum of event magnitudes and frequencies that could occur at a given geohazard site. This simplification is considered reasonable given the study objective to compare relative risk at regional scale. Section 4.0 describes how geohazard scenarios were identified for a given hazard type.

BGC notes that risk is formally defined as a measure of the probability and severity of an adverse effect to health, property or the environment, estimated by the product of hazard probability (or likelihood) and consequences (Canadian Standards Association (CSA), 1997). This study is risk-based in that it considers the potential for events to occur and result in undesirable consequences. However, it should not be considered as a formal, quantitative risk assessment. On its own, the level of detail of assessment is not sufficient to develop detailed geohazard mitigation plans.

Sections 3.0 to 5.0 describe the steps used to characterize elements at risk, define geohazard areas and determine geohazard, consequence, and priority ratings for each area. Appendices C, D and E provide more detailed description of methods to determine geohazard ratings for clear-water, steep creek and landslide geohazard areas, respectively.

Scoping report note: only Appendix D (steep creek hazard assessment methods) is included with this scoping report. Appendices D and E will be included with the Draft and Final reports.

2.0 BACKGROUND

This section provides an overview description of the study area.

2.1. General

The TRW covers approximately 56,000 km^2, approximately 6% of the area of British Columbia. The basin covers diverse physiographic area, encompassing highlands, a dissected plateau, and mountain ranges (Holland, 1976). As defined by DeMarchi (2011), the TRW encompasses 6 ecoregions, which are areas of major physiographic[7] and minor climatic variation. Table 2-1 outlines the characteristics of each ecoregion and associated ecosection. The largest ecoregion is the Thompson-Okanagan Plateau (TOP), an upland flat to rolling plateau that has been dissected by the largest river systems in the basin: North Thompson, South Thompson, Thompson, and Nicola Rivers. These rivers flow west into the Fraser River at Lytton. East of the TOP lies the Columbia Highlands, a rolling to mountainous highland intersected by steep-sided valleys and large lakes, such as Shuswap, Mara, and Adams lakes. A section of the Fraser Plateau within the TRW is north of the TOP, and comprises a rolling plateau with numerous small lakes and wetlands. On the western margin of the TOP, the plateau transitions to the mountainous Interior Transition Ranges and Northern Cascade Ranges, which are influenced by the rain shadow from the Cascade Range further south. The Columbia Highlands transition eastward into the rugged Northern Columbia Mountains.

Due to the dissection of the plateau and highlands ecoregions by streams and rivers, many of the watersheds in TRW display “gentle over steep” topography: their upland catchments are in broad areas of little elevation relief, whereas their lower reaches flow down steep valley sides to large rivers or lakes. This topographic setting influences the distribution of hydrogeomorphic hazards: the upper portion of the watershed is subject mainly to floods, whereas the lower portion can experience steep creek hazards. Additionally, steep creek hazards can be generated in the mountainous regions of the TRW.

Scoping report note: a schematic illustration or map may replace much of the above text for the Draft and Final report.

[7] Referring to landforms and geology

Table 2-1. Ecoregions and Ecosections of the Thompson River Watershed (as defined by Demarchi, 2011).

Ecoregion	Ecosection	Area Within TRW (km^2)	Physiography	Climate	Major Watersheds	Vegetation
Northern Columbia Mountains	Northern Kootenay Mountains	2,095	High, rugged mountains. Sedimentary, volcanic, quartzite, and limestone rocks.	Summer – warm, potentially intense rainfall Winter – cold, potentially intense snowfall	Mud, upper Adams, upper Seymour, Crazy.	Interior Cedar-Hemlock, moist Engelmann Spruce.
	Cariboo Mountains	5,277	Rugged mountains and narrow valleys. Sedimentary, metamorphosed sedimentary, granitic rocks.	Summer – wet and humid, rainfall Winter – cold, potentially intense snow	Upper North Thompson, Lampiere, Blue, upper Murtle, Azure, Hobson, upper Clearwater.	Sub-Boreal Spruce, wet Interior Cedar-Hemlock, moist Engelmann Spruce.
	Central Columbia Mountains	727	High ridges and mountains, narrow valleys and trenches. Sedimentary, metamorphic, gneiss, granitic rocks.	Summer – high humidity, rainfall Winter – cold, deep snow	Sugar.	Interior Cedar-Hemlock, moist Engelmann Spruce-Subalpine Fir.
Columbia Highlands	Quesnel Highland	2,147	Transitional highland from plateau to mountainous. Sedimentary, volcanic, limestone, and quartz rocks	Intense precipitation common from fall to early spring Summer – warm, rainfall Winter – potentially intense cold, snowfall	Molybdenite, Canim, Spanish.	Wet Interior Cedar-Hemlock, Engelmann Spruce-Subalpine Fir.
	Northern Shuswap Highland	10,131	Gentle to moderately sloping highland, transitioning from plateau in the west to mountains on the east, steep valley sides. Metamorphic, intrusive, and sedimentary rocks.	Intense precipitation common from fall to early spring Summer – warm, potentially significant rainfall Winter – cold, potentially significant snowfall	Lower Clearwater, North Thompson, upper Adams, lower Seymour, lower Eagle, Raft, Mud, Barriere, Cayenne, Kwikoit.	Interior Cedar-Hemlock, Engelmann-Spruce Subalpine Fir.
	Shuswap River Highland	4,559	Steep-sided, gentle or moderate rolling uplands and ridges dissected by large rivers and lakes. Metamorphic and sedimentary rocks.	Intense precipitation common from fall to early spring Summer – warm, potentially heavy rainfall Winter – cold, potentially heavy snowfall	Eagle, lower Shuswap, Sicamous, Kingfisher, Tsuis.	Wet Interior Cedar-Hemlock, cold Engelmann Spruce-Subalpine Fir.
Fraser Plateau	Cariboo Basin	2,731	Rolling upland. Volcanic rocks.	Subcontinental climate Summer – warm, dry Winter – cool, moist.	Bonaparte, Deadman.	Interior Douglas Fir, Trembling Aspen, lodgepole pine.
	Cariboo Plateau	4,758	Rolling upland. Volcanic rocks.	Subcontinental climate Summer – warm, moist Winter – cool, moist.	Upper Bonaparte.	Sub-Boreal Pine-Spruce, lodgepole pine, trembling aspen, Sub-Boreal Spruce, white spruce, subalpine fir, lodgepole pine.
Thompson Okanagan Plateau	Tranquille Upland	2,9823	Rolling upland with plateau-front and steep sides. Volcanic rocks and extensive glacial deposits.	Summer – warm, dry Winter – cool, moist	Upper Deadman, upper Tranquille, Criss, Watching, Jamieson, Whitewood, Peterson.	Interior Douglas-fir, Montane Spruce, Engelmann Spruce-Subalpine Fir, lodgepole pine.
	Northern Thompson Upland	2,690	Rolling upland dissected by North Thompson River, steep valley sides. Metamorphic, sedimentary, and intrusive rocks.	Transitional climate (continental to upland) Summers – warm, dry Winter – cool, wet with relatively high snowfall	North Thompson, McGillvray, Lewis, Nisconlith, Sinmax, Barrier, Chu Chua, Joseph.	Ponderosa Pine, meadow-steppe, Lodgepole Pine, Engelmann Spruce-Subalpine Fir.
	Shuswap Basin	2,660	Rolling plateau uplands, steep sided plateau walls, large inter-plateau lowlands. Metamorphic, sedimentary, and intrusive rocks.	Summer – warm, dry Winter – cool, moist	Salmon, Little Shuswap, upper Deep, Chase, upper Monte.	Sagebrush-steppe, Ponderosa Pine, meadow-steppe, Lodgepole Pine, Engelmann Spruce-Subalpine Fir.

Ecoregion	Ecosection	Area Within TRW (km^2)	Physiography	Climate	Major Watersheds	Vegetation
	Thompson Basin	3,107	Broad, low elevation basin. Extensive glacial deposits and volcanic rocks.	Summer – hot, dry Winter – cool, dry	North Thompson, South Thompson, Thompson, lower Bonaparte, lower Deadman, lower Venables, lower Carbine, lower Durrand, lower Tranquille, lower Cherry, lower Peterson, lower Heffley, lower Knouff, lower Monte.	Bunchgrass-steppe, sagbrush-steppe, meadow-steppe, Ponderosa Pine, Douglas Fir.
	Guichon Upland	2,866	Plateau with steep sides and rolling upland. Granitic and volcanic rocks.	Affected by rain shadow of Cascade Mountains. Summer – Hot, dry Winter – potentially cold Arctic air influence	Thompson, Durrand, Nicola, Droppingmore, Moore, Clapperton, Guichon, Skuhun.	Bunchgrass-steppe, Ponderosa Pine, montane and subalpine forests.
	Nicola Basin	3,736	Basin, valley, uplands. Volcanic rocks and extensive glacial lake deposits.	Affected by rain shadow of Cascade Mountains. Summer – Hot, dry Winter – Cool, dry	Nicola, Campbell, Stumplake, Wasley, Quilchena, Coldwater.	Sagebrush-steppe, bunchgrass-steppe, meadow-steppe, dry ponderosa pine, Douglas-fir.
	Northern Okanagan Basin	175	Wide trench and foothills between the Thompson Plateau and the Okanagan Highlands. Extensive glacial deposits.	Affected by the rain shadow of the Thompson Plateau. Summer – hot, dry Winter – cool, potential Arctic air influence	Deep.	Sagebrush-steppe, bunchgrass-steppe, meadow-steppe, dry ponderosa pine, Douglas-fir.
	Northern Okanagan Highland	613	Rolling upland. Gneiss rock.	Summer – warm, dry to moist Winter – cool, moist	Lawson, Creighton.	Douglas-fir, Montane Spruce, lodgepole pine, Engelmann-Spruce-Subalpine Fir, moist Interior Cedar-Hemlock.
	Western Okanagan Upland	1,070	Rounded upland. Granitic and volcanic rocks.	Summer – hot, dry Winter – cool, moist, potentially affected by cold Arctic air.	Upper Nicola, Quilchena, Pothole.	Douglas fir, Montane Spruce, Engelmann Spruce-Subalpine Fir, Interior Cedar-Hemlock.
Interior Transition Ranges	Pavilion Ranges	2,407	Mountainous upland. Limestone, volcanic, and metamorphosed sedimentary rocks.	Affected by rain shadow of Cascade Mountains. Summer – hot, dry Winter – cold, dry.	Thompson, Pavilion, Twaal.	Sagebursh-steppe, ponderosa pine, Interior Douglas-fir, Montane Spruce.
Northern Cascade Ranges	Hozameen Range	859	Rugged mountains. Metamorphosed sedimentary, volcanic, granitic rocks.	Transitional climate, affected by rain shadow of Cascade Mountains. Summer – dry and warm Winter – potentially high snowfall towards Coquihalla Summit	Coldwater, Prospect	Moist Douglas-fir, western Hemlock

2.2. Geological History

The TRW lies within the Canadian Cordilleran Orogen, which contains distinct regions of different rock types. Much of what is now present as rock in the TRW began its geological history as islands, volcanoes, shallow oceans, and small continents in the Pacific Ocean. Between 200 to 60 million years ago, these terranes[8] were accreted onto the western margin of the North American continent. Each successive terrane accretion deformed and uplifted older terranes already joined onto North America. In places, accreted terranes were also intruded by magma, shown for example in the volcanic rocks of Wells Grey Provincial Park. Because of these different geological processes, the geological map of the Thompson River Basin resembles a patchwork of distinct units (Figure 2-1), with high variability in the spatial distribution of different rock types. This differs, for instance, from the Canadian Rockies, where rock types tend to be more consistent, due to its geologic origins as a large inland ocean. In general, the rocks in the Thompson River basin are oldest and most deformed in the eastern portion of the watershed, and youngest and less deformed in the western portion of the watershed.

Figure -1 shows the distribution of the following rock types:

- Sedimentary rocks, common throughout all ecoregions
- Volcanic rocks, extensive within Wells Grey Provincial Park, the Fraser Plateau ecoregion, and surrounding the Nicola River Basin
- Metamorphic rocks, extensive in the Columbia Highlands ecoregion and scattered throughout other ecoregions
- Intrusive rocks, common throughout all ecoregions.

Scoping report note: a schematic map will be added for the Draft and Final Reports.

Figure 2-1. Bedrock geology of the Thompson River Watershed. Digital mapping and bedrock classes from Cui et al. (2015).

Scoping report note: further description of glacial history may be added for the Draft and Final Reports.

2.3. Climate

Scoping report note: This section is a work-in-progress that will be completed for the Draft and Final Reports.

2.3.1. General

- *To be completed for the Draft and Final Reports.*

[8] Terranes are regions of distinct rock formations that are typically bounded by fault structures.

2.3.2. Projected Climate Change

- *To be completed for the Draft and Final Reports.*

2.4. Hydrology

2.4.1. Physiographic Characterization of Watercourses

We define three general categories of watercourses that are differentiated by scale and physiography:

- Major valley systems
- Minor valley systems
- Tributary creeks.

Example characteristics and example watersheds are shown in Table 2-2, while each is described in the sections which follow.

Table 2-2. Physiographic characterization of watercourses.

Category	Watershed Area Range	Strahler Order[1]	Example Watersheds
Major Valley Systems	3,000 km^2 and up	6+	Bonaparte River, Nicola River, North Thompson River, South Thompson River, Thompson River
Minor Valley Systems	500 - 1000 km^2	4 to 6	Clearwater River, Guichon Creek, Louis Creek, Mud Creek, Scotch Creek
Tributary Creeks	200 km^2 and less	1 to 3	Finn Creek, Heffley Creek, Hummingbird Creek, Silver Creek

Note:

1. Strahler stream order classification system (Strahler, 1952) was applied to all the stream reaches within the Thompson River Watershed. The stream order hierarchy is a method to define the relative size of a perennial stream with a stream network. A first order stream corresponds to the headwaters, while a higher order stream indicates a larger channel.

Major Valley Systems (Rivers and Lakes):

Major valley bottoms are characterized by wide, U-shaped valley bottoms, which feature large rivers and lakes that are the backbone of the region's physical and human geographies. Catchment areas are in excess of 3,000 km^2. These areas are where most people live and work, and where transportation and linear infrastructure is generally located.

Minor Valley Systems (Rivers and Lakes):

Minor valley bottoms are characterized by U-shaped valley bottoms that form major tributaries to the major valleys. They typically bisect mountain ranges and have catchment areas around 500-1,000 km^2.

These areas contain farms and lower density residential development, and provide access to forestry operations. Transportation and linear infrastructure follow some of the larger valleys as they connect major valley bottoms. Where minor valleys terminate in a fan, these fans are typically more densely populated with urban development.

Tributary Creeks

- Tributary creeks are typically mountain streams that have headwaters at high elevation and follow a less circuitous path down the mountainside. They are typically in V-shaped valleys with Strahler stream order between 1 and 3. Catchment areas are typically less than 100 km^2 with many of the tributary creeks terminating at fans where they enter larger and lower-gradient valley bottoms.

Many tributary creeks are subject to steep creek processes (debris floods and debris flows). Methods to identify creeks subject to steep creek processes are provided in Section 4.1.

2.5. Dams

- *To be completed for the Draft and Final Reports.*

2.6. Historical Hydrology

- *To be completed for the Draft and Final Reports.*

2.7. Historical Event Inventory

BGC reviewed several data sources to compile a historical flood, steep creek, and landslide dam inventory across the watershed. Data bias is typically inherent in historical accounts of past events due to gaps in recorded storms or geohazard events, because media reports tend to generalize effects of large region-wide events (e.g., 1948 region-wide floods) rather than smaller and more localized impacts, and because reported data can be inaccurate or outdated (e.g., stream names, locations, names of historical residences).

Somewhat unique to the TRW, in comparison to other large watersheds in BC, is the historical accounts of large landslide dams and associated flooding on the Thompson River near Ashcroft and Spences Bridge in the late 1800s and early 1900s (Clague and Evans, 2003). These landslides have either fully or partially dammed the Thompson River for several hours, resulting in widespread upstream flooding prior to dam overtopping and incision. Some of these dams required human intervention to create a spillway through the dam to lessen the flooding effects. During the 1905 Spences Bridge event, at least 15 people were killed because of the landslide and flooding.

Large region-wide data sources of historical events include:

- A text compilation of media reports of flooding, landslide, and avalanche events from 1808 to 2006 (Septer, 2007).
- Historical DriveBC numbered highway incident database, which includes incidents and closures related to flooding, “mudslides” and washouts (typically debris flows and debris floods), rockslides, and debris on road (MOTI, n.d.).
- The Canadian Disaster Database (Public Safety Canada, n.d.).

- Media and social media reports of freshet-related flooding and landslides across the watershed, compiled by BGC from March to May 2018.
- Reports from the Water Stewardship Information Sources database for the Thompson-Okanagan area (MFLRNO, n.d.).

This historical event inventory is assumed to be incomplete, but the information contained within it can be used to identify the location of past geohazards events and associated consequences of these events. BGC digitized the locations of historical events from the Septer (2007), DriveBC (MOTI, n.d.), and 2018 freshet-related floods and landslides. These locations were referenced during geohazard identification (Section 4.0).

Scoping report note: This section and the relevant data compilation associated with it is a work-in-progress that will be completed for the Draft and Final Reports.

3.0 ELEMENTS AT RISK

3.1. Introduction

Elements at risk are objects of value that could be exposed to damage or loss due to geohazard impact (geohazard exposure). This study assessed areas that both contained elements at risk and that were subject to geohazards. As such, identifying elements at risk was required to both define the areas to be assessed, and to assign consequence ratings as part of risk prioritization (Section 4.0).

Table 3-1 lists the elements at risk assessed in this study. Of these, elements at risk within settled areas were considered in the scope of work, as described in Section 1.2. Sections 3.2 to 3.7 describe methods to compile and organize these data and lists gaps and uncertainties. Appendix B lists data sources.

Scoping Report Note: Appendix B is a work-in-progress that will be completed for the Draft and Final Reports.

Table 3-1. Elements at risk.

Type	Description
Buildings	Cadastral Parcels and Attributes (e.g., building improvements)
	Building Locations (footprints or points)
	Critical Facilities
Businesses	Business activity
Agriculture	Active Agricultural Areas
Life Lines	Roads
	Railway
	Petroleum Infrastructure
	Electrical Infrastructure
	Communication Infrastructure
	Water Infrastructure
Environmental Values	Fisheries
	Species and Ecosystems at risk

The elements at risk identified in this study do not include all elements within the study area. For example, the utilities inventory is not exhaustive, and elements where loss can be intangible, such as objects of cultural value, were not included. The objective is to identify key elements that can be identified systematically and used for risk prioritization. In addition, this inventory of elements at risk can help support detailed hazard and risk assessments if completed in future.

BGC notes that estimating the number of people potentially exposed to geohazards, as would be required for safety risk assessment, was outside the scope of work. However, characterization of buildings infrastructure provides a proxy for areas likely to have higher populations, and thus gives a way to implicitly consider population in the prioritization.

Scoping report note: Elements at risk listed in Table 3-1 represent a work in progress, as BGC is still in the process of signing data sharing agreements with stakeholders. As such, this list is subject to re-structuring and potential changes for the Draft and Final Reports.

3.2. Buildings

Scoping report note: cadastral and BC Assessment data required to complete the buildings inventory have not yet been provided to BGC. This text is based on BGC's previous experience working with similar data, and will be updated once BGC has compiled and reviewed data within the TRW.

BGC compiled information on building improvements based on cadastral and municipal assessment data. Cadastral data shows the spatial location of parcels (land title areas), where each parcel is assigned a unique identifier (Parcel ID).

BC Assessment data are provided in tabular format, with a unique identifier included for each property (folio number). Linked to cadastral polygons, 2018 BC Assessment data were used to determine the type and total value of improvements for a given property.

Table 3-2 lists assessment data attributes used in the analysis, and Table 3-3 summarizes building improvement values within each jurisdiction.

BGC spatially joined the assessment and cadastral data to geohazard areas. This allowed BGC to summarize the types and assessed values of buildings potentially exposed to geohazards. All of the data for individual parcels were retained in the database for more detailed analyses, if and when required in future.

Building location data were obtained as point locations where available. However, the assessment was completed at a parcel level of detail, and individual buildings were not assessed in this study. In these cases, building data were aggregated by parcel.

Table 3-2. BC Assessment data used in analyses.

Data	BC Assessment Class	Description
Property and Building Type	Actual Use Value Description and Actual Use Code	The actual use of the property. Used to identify critical facilities.
Folio	Folio Number	Reference number for each taxable entity in the municipal assessment data. Parcels may contain more than one folio number in the case of multiple unit properties (e.g., strata development). Conversely, a single folio may correspond to more than one Parcel ID (PID) (e.g., small parcels such as old mining claims). The provincial cadastral data includes both PID and folio number for linking to municipal assessment data. BGC developed tables to address these one-to-many and many-to-one relationships when linking folio and parcel data.
Land Value	General Land Gross	Assessed land value as of 2018. Includes land and all buildings and accessory buildings associated with a single roll number (property reference number).
Building Value	General Improvement Gross	Assessed value as of 2018. Includes all buildings and accessory buildings associated with a single roll number (property reference number).
Parcel	Parcel ID (PID)	Reference number for each parcel within the provincial cadaster.

Table 3-3. Summary of building improvement values in each jurisdiction.

Jurisdiction	Total Improvement Value of Parcels Intersecting Hazard Areas		
	Residential Parcels	Non-Residential Parcels	Total

Scoping report note: Table 3-3 is a placeholder to be filled out for the Draft and Final report.

Uncertainties exist in the data used to characterize improved parcels across the TRW, as described further below.

Assessed versus replacement value: Improvement values used as proxies for the 'importance' of buildings within a geohazard area describe the taxable value. This does not necessarily reflect the current market or replacement value of a building, and does not include building contents. The assessed value may be much lower than replacement value, and the improvement value should thus be considered a minimum.

Minimum bound on improved parcels: BGC excluded cadastral parcels from the risk prioritization where the assessed improvement values were less than $50,000 and the parcel size was larger than X m^2. This threshold was applied to remove large parcels containing only minor outbuildings or cabins, typically in remote areas.

Cadastral Data Gaps: Settlement areas not defined by the provincial cadastre (e.g., not under provincial tax jurisdiction) are subject to higher uncertainty when characterizing the value of the built environment. The completeness of assessment data for Federal cadastral parcels is not known.

Missing buildings: Residential buildings can exist on parcels that were not included in the assessment data, such as unpermitted development. This can result in under-estimation of the value of development potentially subject to geohazards.

Active Use Code (Building Use): BGC classified parcels based on the predominant Active Use Code in the assessment data. Multiple use buildings or parcels may have usages – and corresponding building, content, or commercial value – not reflected in the code. This uncertainty may affect summaries of parcel types. However, it does not affect geohazard area priority levels, which were based only on assessed value. It will affect the certainty of damage cost estimation as part of more detailed risk assessments if completed in future.

Parcels partially intersecting geohazard areas: Assessment of building improvements was completed at a parcel level of detail. As such, improvements located anywhere on parcels that partially intersect geohazard areas were conservatively assumed to be subject to those geohazards, because exact building locations within a parcel were generally not known. This assumption should be subject to verification if more a detailed assessment is completed in the future.

3.3. Critical Facilities

Critical facilities are defined as facilities that:

- Provide vital services in saving and avoiding loss of human life
- Accommodate and support activities important to rescue and treatment operations
- Are required for the maintenance of public order
- House substantial populations
- Confine activities or products that, if disturbed or damaged, could be hazardous to the region
- Contain irreplaceable artifacts and historical documents.

For the purpose of prioritization, BGC distinguishes between “critical facilities” and “lifelines”, where the latter includes transportation networks and utility systems. While both may be critical in an emergency, the distinction was made because lifelines are linear infrastructure extending through geohazard areas.

A total of XX critical facilities within the study area were identified by XX and include the facilities listed in Table 3-4. These facilities were defined at a parcel level of detail and identified using BC Assessment actual use codes and input from stakeholders. BGC notes that the completeness of the critical facilities inventory depends on data contributions from stakeholders. The inventory is not exhaustive.

Table 3-4. TRW critical facility descriptions.

Category	Actual Use Value Description[1]
Emergency Response Services	Emergency Operations Center, Government Buildings (Offices, Fire Stations, Ambulance Stations, Police Stations).
Emergency Response Resources	Asphalt Plants, Concrete Mixing, Oil & Gas Pumping & Compressor Station, Oil & Gas Transportation Pipelines, Petroleum Bulk Plants, Works Yards.
Utilities	Electrical Power Systems, Gas Distribution Systems, Water Distribution Systems, Hydrocarbon Storage.
Communication	Telecommunications.
Medical Facilities	Hospitals, Group Home, Seniors Independent & Assisted Living, Seniors Licenses Care.
Transportation	Airports, Heliports, Marine & Navigational Facilities, Marine Facilities (Marina), Service Station.
Environmental[2]	Garbage Dumps, Sanitary Fills, Sewer Lagoons, Liquid Gas Storage Plants, Pulp & Paper Mills.
Community	Government Buildings, Hall (Community, Lodge, Club, Etc.), Recreational & Cultural Buildings, Schools & Universities, College or Technical Schools.

Notes:

1. From BC Assessment Data
2. Includes facilities with environmental hazards. Environmental consequences are addressed in Section 3.6

Scoping report note: compilation of critical facilities is a work-in-progress. Text within this section and categories listed in Table 3-4 are subject to revision *for for the Draft and Final reports.*

3.4. Lifelines

Lifelines considered in this assessment are shown on the web map and include roads, railways, petroleum infrastructure, electrical infrastructure, communications infrastructure, and water infrastructure. Pipeline utility systems were identified at a right-of-way (ROW) level of detail. BGC obtained traffic frequency data from BC Ministry of Transportation and Infrastructure (MoTI), which were used to assign relative weights to different road networks as part of the prioritization scheme (Section 5.1).

Lifelines infrastructure compiled for this study should not be considered complete. As noted in Section 3.1, the objective is to identify key infrastructure that can be identified systematically and used for prioritization. Detailed studies, if completed in future, would include more detailed characterization of lifelines systems.

As noted in Section 1.2, this study focuses on ‘settled’ urban and rural areas within the TRW. Geohazards exist within the TRW that could impact lifelines infrastructure in otherwise undeveloped areas (e.g., roads pipelines, transmission lines, and highways) that are outside the scope of assessment and were not identified or prioritized in this study.

3.5. Business Activity

Business activity considered in this assessment includes public and private employers with their primary address located in the risk assessment area. Business data are based on information compiled by the commercial information provider Dun and Bradstreet (D&B) (Hoovers, 2018). Business data are not shown on the web map but can be provided on request.

The business data used in the assessment are subject to uncertainties associated with both the data itself and how it is assigned to particular parcels. Table 3-5 summarizes uncertainties associated with the data. Business activity impacts listed in this report are likely underestimated due to the uncertainties in the business data.

Scoping report note: BGC is in the process of obtaining an updated quote for the purchase of Dun and Bradstreet data, and the completeness of these data is subject to review for the Draft and Final Reports. The text in this section and uncertainties listed are based on our previous experience working with the data; we expect the uncertainties to be similar in the TRW.

In addition to the uncertainties listed in Table 3-5, business activity estimates do not include individuals working at home for businesses located elsewhere or businesses that are located elsewhere but that depend on lifelines within the study area.

Table 3-5. Business data uncertainties.

Type	Description
Geocoding	A total of XX out of XX businesses were successfully linked to parcels. The remaining businesses could not be linked due to incomplete or no address information and improper formatting of addresses.
Revenue data	Missing for XX businesses of the XX businesses that were successfully linked to parcels (not available from D&B).
D&B data quality	BGC has not reviewed the accuracy of business data obtained for this assessment.
Worker location	Whether the employee primarily works at the office or some other location is not known. The estimates also do not include individuals working at home for businesses located elsewhere.
Source of revenue	Whether a business' source of revenue is geographically tied to its physical location (e.g., a retail store with inventory, versus an office space with revenue generated elsewhere) is not known.

3.6. Agriculture

BGC identified agricultural areas based on the Agricultural Land Use Inventory (ALUI) completed by the BC Ministry of Agriculture in 2016 (Ministry of Agriculture, 2016). Table 3-6 provides a simplified description of agricultural classes used in the inventory. For simplicity at the regional scale of study, BGC's assessment was limited to identifying areas classed as "actively farmed".

Table 3-6. List of agricultural use classifications.

Scoping report note: BGC has not yet obtained agricultural land use inventory data. This section is subject to revision for the Draft and Final Reports.

3.7. Environmental Values

BGC included stream networks classed as fish bearing and areas classed as sensitive habitat in the risk prioritization.

In the case of fish, the BC Ministry of Environment (MOE) maintains a spatial database of historical fish distribution in streams based on the Fisheries Information Summary System (FISS) (MOE, 2012). The data includes point locations and zones (river segments) where fish species have been observed, the extent of their upstream migration, and where activities such as spawning, rearing and holding are known to occur. As a preliminary step and because fisheries values are of regulatory concern for structural flood mitigation works, FISS data was used to identify fan and flood hazard areas that intersect known fish habitat. Hazard areas were conservatively identified as intersecting fish habitat irrespective of the proportion intersected (e.g., entire hazard areas were flagged as potentially fish bearing where one or more fish habitat points or river segments were identified within the hazard zone), so these results should be interpreted as potential only.

For endangered species and ecosystems, the BC Conservation Data Centre (BC CDC) maintains a spatial data set of known confidential locations of endangered species and ecosystems, with a masked version available for public viewing and download (BC CDC, 2018).

BGC emphasizes that the information used to identify areas containing environmental values is highly incomplete, and estimation of vulnerability is highly complex. More detailed identification of habitat values in areas subject to flood geohazards starts with an Environmental Scoping Study (ESS), typically based on a review of existing information, preliminary field investigations, and consultation with local stakeholders and environmental agencies.

BGC also notes that environmental values are distinct from the other elements at risk considered in this section in that flood mitigation, not necessarily flooding itself, has the potential to result in the greatest level of negative impact. For example, flood management activities, particularly structural protection measures (e.g., dikes), have the potential to cause profound changes to the ecology of floodplain areas. The construction of dikes and dams eliminates flooding as an agent of disturbance and driver of ecosystem health, potentially leading to substantial changes to species composition and overall floodplain ecosystem function.

Within rivers, fish access to diverse habitats necessary to sustain various life stages has the potential to be reduced due to floodplain reclamation for agricultural use and wildlife management, restricting fisheries values to the mainstem of the river. Riparian shoreline vegetation also provides important wildlife habitat, and itself may include plants of cultural significance to First Nations peoples. On the floodplains, reduction in wetland habitat may impact waterfowl, other waterbirds, migratory waterbirds, and associated wetland species such as amphibians.

The ecological impacts of dike repair and maintenance activities can also be severe. Dike repairs often result in the removal of riparian vegetation compromising critical fisheries and wildlife habitat values. The removal of undercut banks and overstream (bank) vegetation results in a lack of cover for fish and interrupts long term large woody debris (LWD) recruitment processes and riparian function. Alternative flood mitigation approaches could include setback dikes from the river, providing a narrow floodplain riparian area on the river side of the dike, and vegetating the dikes with non-woody plants so that inspections may be performed and the dike integrity is not compromised. Such approaches may prevent conflicting interests between the *Fisheries Act* and *Dike Maintenance Act*.

Lastly, BGC notes that increased impact to fish habitat may result where land use changes (e.g., logging, forest fires) have increased debris flow activity and the delivery of fine sediments to fish bearing streams.

4.0 GEOHAZARD IDENTIFICATION

This section describes how BGC defined the geohazard extents prioritized in this study. Areas of the TRW that were included in the risk prioritization contained both elements at risk and were subject to applicable geohazards, which include clear-water floods, debris floods or debris flows, and landslide dam-related floods.

4.1. Clear-water Floods

Table 4-1 lists the approaches used to identify clear-water flood geohazards including process-type identification, floodplain mapping, floodplain extent predication and a review of historical flood events compiled for the TRW. Appendix D provides further details on the methods used to identify clear-water flood hazards and associated limitations.

Table 4-1. Summary of clear-water flood identification approaches.

Approach	Area of TRW Assessed	Application
Process type identification	All creeks	Classification of creeks as dominantly subject to clear-water floods, debris floods, or debris flows.
Floodplain mapping	All creeks prone to clear-water flooding	Identification of floodplain extents from publicly available mapping historical and 3rd party data sources.
Floodplain extent predication	All creeks without existing floodplain mapping and a Strahler stream order of 4 or greater	Identification of low-lying areas adjacent to streams and lakes using a topographic elevation offset applied to Strahler stream order of 4 or greater creeks.
Historical flood event inventory review	All creeks prone to clear-water flooding	Identification of creeks and rivers with historical precedent for flooding.

4.1.1. Process Type Identification

Every stream segment in the TRW was assigned a predicted process type based on statistical analysis of Melton Ratio[9] and watershed length[10]. The typical watershed characteristics that differentiate the primary geohazard for each creek are shown in Table 4-2.

These terrain factors are a useful screening-level indicator of the propensity of a creek to produce primarily floods, debris floods or debris flows (Holm et al., 2016). The web map displays every stream segment in the TRW and its associated predicted steep creek geohazard process type (clear-water flood, debris flood or debris flow).

[9] Melton ratio is watershed relief divided by the square root of watershed area (Melton 1957).
[10] Stream network length is the total channel length upstream of a given stream segment to the stream segment farthest from the fan apex.

Table 4-2. Class boundaries using Melton ratio and total stream network length.

Process	Melton Ratio	Stream Length (km)
Clear-water flood	< 0.2	all
Debris flood	0.2 to 0.5	all
	> 0.5	> 3
Debris flow	> 0.5	≤ 3

The advantage of statistically based classification is that it can be applied to large regions. Limitations include:

- Reduced reliability of interpretations from a single line of evidence, as compared to combining statistical, remote-sensed, and field observation data.
- A flood process type assignment that may not preclude significant bedload transport.
- That there is a continuum between clear-water floods and steep creek process types (i.e., Figure 1-1).

Process type identification outside the prioritized study creeks were not validated by other means and should be considered a screening level assessment.

4.1.2. Floodplain Mapping

4.1.2.1. Historical Mapping Sources

The BC government provides publicly-available information on the location of floodplains, floodplain maps and supporting data (Government of BC, 2016; MFLNRO, 2016;). Inundation (or flood extent) mapping was conducted between 1976 to 1996. A limited portion of the watershed was mapped during this time and was generally focused on major rivers as summarized in Table 4-2. While the maps are now outdated, their use is promoted by the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) as often representing the best floodplain mapping information available (EGBC, 2017). The historical floodplain maps are based on the designated flood as represented by the 200-year return period event. Flood levels associated with the 200-year event have been used to establish design elevations for flood mitigation works and to inform local floodplain management policy and emergency preparedness.

Table 4-3. Summary of historical floodplain mapping within the TRW.

Watercourse	Major Watershed	District	Mapping Year
Bonaparte River	Bonaparte	TNRD	1996
Eagle River	South Thompson	CSRD	1979
Nicola/Coldwater Rivers	Nicola	TNRD	1989
North Thompson River (Vavenby to Kamloops)	North Thompson	TNRD	1982
Salmon River (Falkland to Salmon Arm)	South Thompson	CSRD	1991/1992
Seymour River at Seymour Arm[1]	South Thompson	CSRD	1991
Shuswap River	South Thompson	RDNO	1980, 1998
Spius Creek	Nicola	TNRD	1989
Thompson River (Kamloops)	Thompson	TNRD	1976

Note:

1. Floodplain map indicated as withdrawn from Government of BC website [accessed July 11, 2018]

4.1.2.2. Third-party Mapping Sources

While additional third-party floodplain mapping has occurred in the watershed (e.g., FBC, 2018), only existing spatial floodplain mapping data that could be incorporated into the ArcGIS Online Map were used in the clear-water flood assessment.

Scoping report note: This section and the relevant data compilation associated with it is a work-in-progress that will be completed for the Draft and Final Reports.

4.1.3. Floodplain Extent Prediction

A GIS-based modelling approach was used to identify geographical low-lying areas adjacent to mapped watercourses including lakes within the TRW to represent potential flood inundation extents for watercourses without existing historical floodplain or 3rd party mapping information. This approach was applied to each watercourse with a Strahler stream order classification of 4 or greater (Strahler, 1952). For this study, Strahler order 4 and greater streams are considered potential clear-water flood hazards, while Strahler order 3 and fewer streams are typically headwater streams prone to steep-creek flood processes as described in Section 4.2.

The surrounding valley topography for each watercourse was represented using a watershed-wide 1:20,000 scale digital elevation model (DEM; NRCan, 2016). An offset of 4.0 m was applied to the base stream elevation for each mapped watercourse in order to represent an elevated stream surface relative to the surrounding topography (Figure 4-1). In the absence of existing floodplain mapping, this surface represents a “high-water level” estimate used to define topographic low-lying areas adjacent to watercourses that are potentially subject to flood inundation. A 4.0 m offset was selected by comparing automated results to floodplain extents generated from previous hydraulic modelling conducted within the watershed (e.g., City of Salmon Arm, 2011) as shown in Appendix D.

This approach can be used to inform hydraulic modelling extents and additional data collection initiatives such as LiDAR acquisition within the watershed but is not intended to replace hydraulic modelling or detailed floodplain mapping.

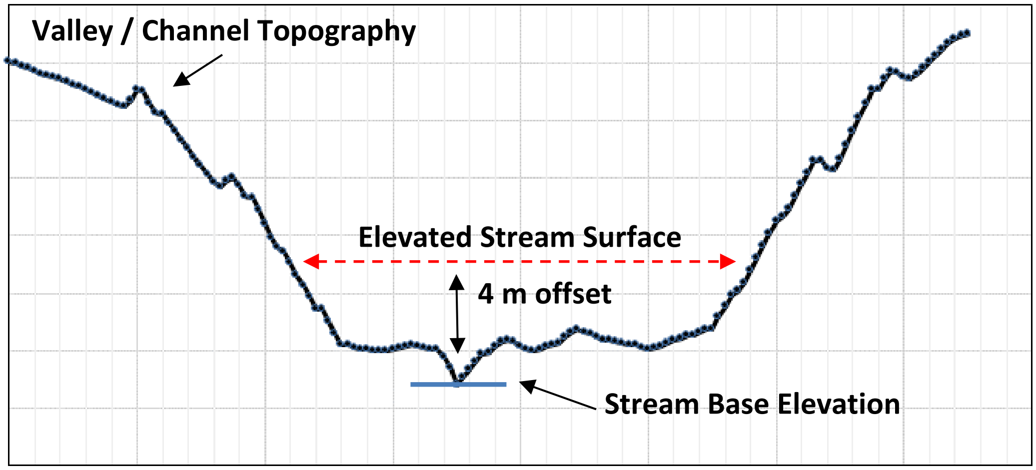

Figure 4-1. Topographic offset modelling conceptual sketch.

4.1.4. Historical Flood Event Inventory

Historical flood events as summarized in Section 2.7 were used to confirm flood-prone low-lying terrain outside of the historical floodplain maps.

4.2. Steep Creek Geohazards

Table 4-3 lists the three approaches used to identify steep creek geohazards: process type identification, steep creek susceptibility mapping, and the alluvial fan inventory. Appendix E provides further details on the methods used to complete these approaches and associated limitations.

Geohazard process types were identified for every stream segment in the study area, and susceptibility mapping was completed for creeks subject to debris flows and debris floods. The alluvial fan inventory was completed for prioritized study creeks, where the fan boundaries define the areas that were prioritized, based upon the presence of both a steep creek geohazard and elements at risk (existing building development).

Table 4-4. Summary of steep creek geohazard identification approaches.

Approach	Area of TRW Assessed	Application
Process type identification	All creeks	Classification of creeks as dominantly subject to clear-water floods, debris floods, or debris flows.
Susceptibility mapping	All steep creeks prone to debris flows or debris floods	Screening level identification of geohazard susceptibility for all steep creeks; basis to assign geohazard ratings to prioritized study creeks.
Alluvial fan Inventory	Prioritized study creeks	Delineation of alluvial fans to be prioritized; interpretation of terrain characteristics used to assign geohazard ratings.

4.2.1. Process Type Identification

Two methods were used to interpret the dominant geohazard process type on a stream including the process type identification method described in Section 4.1.1 and terrain analysis for streams that intersect an alluvial fan.

Terrain analysis was used to interpret the dominant geohazard process entering prioritized alluvial fans[11]. The analysis included review of airphoto or satellite imagery, and review of historical records if available. In the case of disagreement between the terrain analysis and statistically-based classifications, the terrain-based classification was used.

4.2.2. Impact Likelihood

Regional risk prioritization requires estimation of the relative, spatial likelihood that debris flows or debris floods will reach elements at risk, given occurrence of a geohazard. Appendix E provides further description of methods to estimate spatial impact likelihood, and describes limitations and uncertainties. In summary, BGC used two methods to estimate impact likelihood for debris floods and debris flows at a fan level of detail: numerical susceptibility modelling and terrain analysis.

BGC used the Flow-R model[12] developed by Horton *et al*. (2008, 2013) to model debris flow or debris flood susceptibility on every mapped creek within the TRW. The term "susceptibility" was modified from Fell *et al*. (2008), who described it as "a quantitative or qualitative assessment of the classification, volume (or area), and spatial distribution of landslides which exist or potentially may occur in an area". In this assessment, the term is generalized to include steep creek processes, and the modelling was applied to identify areas potentially susceptible to geohazard impact.

Numerical susceptibility modelling has the advantage that it can be applied to much larger regions than are feasible to manually assess. Limitations include (see Appendix E):

[11] Note that many creeks with debris floods entering the fan apex also contain debris flow channels in their upper basins.
[12] "Flow-R" refers to "Flow path assessment of gravitational hazards at a Regional scale". See http://www.flow-r.org

- Susceptibility mapping has highest confidence when it is based on multiple lines of evidence.
- Mapping outside the prioritized study creeks was not validated by other means and should be considered a screening level assessment.
- Because debris flows can also initiate outside of mapped channels, additional debris flow hazard areas exist within the TRW that were not mapped.

Regional scale debris flow and debris flood susceptibility modelling results are displayed as a layer on the web map.

Terrain analysis was completed at prioritized study creeks to interpret the relative likelihood that steep creek events could result in uncontrolled flows that could impact elements at risk.

For the prioritized study creeks, susceptibility analysis was used in combination with hazard likelihood estimates developed from the terrain analysis to assign geohazard ratings to each prioritized fan (Section 5.0). For creeks other than those prioritized, susceptibility mapping is presented as a screening level tool to identify potential geohazard areas.

4.2.3. Alluvial Fan Inventory

The boundary of alluvial fans represents the steep creek geohazard areas prioritized in this study. BGC mapped a total of XXXX fans, based on the interpretation of available aerial and satellite imagery, LiDAR Digital Elevation Models (DEM), review of previous fan mapping (e.g., Lau, 2017), and limited field checking. The web map provided with this report identifies the fans that were field checked. Geobase terrain models and satellite imagery available within the ESRI web map were used for terrain interpretations where LiDAR was not available.

Scoping report note: a schematic figure will be added here to show example alluvial fan boundaries.

BGC notes that it is not possible to rule out the potential for steep creek geohazards to extend beyond the limit of the fan boundary in some cases. Most of the alluvial fans mapped in this study represent the accumulation of sediment over the Holocene period (since about 11,000 years BP). The fan boundary approximates the extent of sediment deposition since the beginning of fan formation. Geohazards can potentially extend beyond the fan boundary due to localized flooding, where the fan is truncated by a lake or river, in young landscapes where fans are actively forming (e.g., recently deglaciated areas) or where large landslides (e.g., rock avalanches) trigger steep creek events larger than any previously occurring. Assessment of such scenarios could form part of more detailed study. The limits of geohazard areas identified in this assessment (the alluvial fan boundary) should be treated as transitions, not exact boundaries.

4.3. Landslide-Dam Floods

This section describes the approach used to identify and evaluate landslide-dam flooding geohazards within the TWR. Flooding caused by a landslide is possible when a landslide blocks a water course and forms a dam. Flooding can occur upstream from a landslide dam due to water impoundment, and downstream when dam failure results in the sudden discharge of impounded water. Well-known examples in the TRW include a 1905 landslide that dammed the Thompson River, resulting in the loss of 15 lives and flooding at Spences Bridge, and 1880 landslide dam south of Ashcroft that created a lake on the Thompson River nearly 14 km long (Clague and Evans 2003). For the purposes of this assessment, the flood area is the hazard and landslides are the source of the hazard. Additional details about the methodology used to complete this evaluation is provided in Appendix E [*Scoping report note: Appendix E will be forthcoming for the Draft and Final Report]*.

BGC notes that the TRW contains many landslides adjacent to waterways, of which only some have credible potential to form a landslide dam or cause landslide-dam flood impact to elements at risk. BGC used a multi-step process to identify potential landslide-dam flood geohazard areas that could impact elements at risk.

The landslide dam geohazard evaluation process included four sequenced steps that are shown in Table X-X. The first step included narrowing the analysis from the entire TWR to a study area focusing on major stream and river valleys where landslide-dam floods could impact elements at risk. "Major" stream and river valleys include those where Strahler order > 4 (Section 4.1). Landslide dams in smaller, upper watersheds (Strahler order =< 4) are considered potential debris flow sources in this study.

Next, existing LiDAR and interferometric synthetic-aperture radar (InSAR) data were used to delineate potential landslides sources and style of deformation. Then, the study area was subdivided into landslide dam source areas based on common geologic and geomorphic characteristics, and elements at risk. The source areas were also informed by LiDAR and InSAR mapping and the landslide inventory (Section 2.7).

Scoping report note: the Draft and Final report will further describe InSAR data and how it was used.

The final step in the geohazard evaluation of landslide dam source areas was to evaluate the likelihood of landslide dam formation and flooding events.

Scoping report note: additional details on landslide-dam floods assessment methodology, and the above-noted "Table X-X", will be included in as part of the Draft and Final reports.

5.0 GEOHAZARD RISK PRIORITIZATION

This section describes methods to assign ratings of hazard, consequence and risk-based priority to each geohazard area. The ratings are defined in three parts as follows:

- Geohazard rating (Section 5.1). This rating estimates the relative likelihood a geohazard will occur and reach elements a risk.
- Consequence rating (Section 5.2). This rating estimates the relative consequences given impact by a geohazard, based on proxies for the value of elements at risk and their vulnerability to damage or loss.
- Priority rating (Section 5.3). This rating combines the geohazard and consequence ratings, to estimate the relative likelihood that geohazards could occur and result in a certain level of consequences.

5.1. Geohazard Rating

Table 5-1 presents the qualitative geohazard rating system used in this study. It combines hazard and impact likelihood ratings to provide a relative estimate of the potential for events to occur and impact elements at risk.

Table 5-1. Geohazard rating.

Geohazard Likelihood	**Geohazard Rating**				
Very High	M	H	H	VH	VH
High	L	M	H	H	VH
Moderate	L	L	M	H	H
Low	VL	L	L	M	H
Very Low	VL	VL	L	L	M
Impact Likelihood	Very Low	Low	Moderate	High	Very High

Geohazard ratings assume that elements at risk are present within the hazard zone at the time of impact, as would be expected for buildings, lifelines, critical facilities, and other immobile features that are the subject of this study.

While the principles are similar, some differences exist between how hazard likelihood and impact likelihood are defined and assigned for each geohazard type. Table 5-2 describes how hazard and impact likelihood were defined. Appendices C through E provide analysis methodologies.

Table 5-2. Definitions of hazard likelihood and impact likelihood for the geohazard types assessed.

Factor	Geohazard Type	Definition
Hazard likelihood	Steep creeks	Likelihood of a steep-creek event large enough to impact elements at risk on an alluvial fan.
	Clear-water floods	0.XX annual probability (XXX-year) flood[1]
	Landslide-dam floods	Likelihood of a landslide occurring, damming a watercourse, and retaining sufficient water volumes to create a credible threat to downstream (outburst flood) or upstream (impoundment flood) elements at risk.
Impact likelihood	Steep creeks	Estimated likelihood of an uncontrolled flow reaching elements at risk, given that a steep-creek event occurs.
	Clear-water floods	Assumed impact likelihood of High (Table 5-1) within the flood extent, given occurrence of the 0.XX annual probability (XXX-year flood.
	Landslide-dam floods	Assumed impact likelihood of High (Table 5-1) within the flood extent, given occurrence of the landslide-dam flood.

Note:

1. BGC is still considering what flood return period we recommend should be used for clear-water flood risk prioritization. BGC also notes that choosing a single flood return period to prioritize flood geohazard areas, which is a simplification, pre-defines the clear-water flood geohazard rating with fixed categories for hazard and impact likelihood. Thus, the prioritization is based on a comparison of potential consequences. Appendix C considers advantages and limitations of this approach.

Table 5-3 defines approximate frequency and return period ranges for the hazard likelihood categories shown in Table 5-1[13].

Scoping report note: the long-term annual frequency and return period ranges shown in Table 5-3 are most suited for recurring geohazards (floods and steep creek geohazards). Further clarification will be provided in the Draft and Final report for the definition of "geohazard likelihood" as it applies to landslide-dam source areas.

Table 5-3. Relative hazard likelihood and approximate frequency and return period categories.

Geohazard Likelihood	Long-term Annual Frequency Range	Approximate Return Period Range (years)	Representative Return Period (years)
Very High	1 – 0.1	1-10	5
High	0.1 – 0.03	10-30	20
Moderate	0.03 – 0.01	30-100	50
Low	0.01 – 0.003	100-300	200
Very Low	0.003 – 0.001	300-1000	500

[13] Note that geohazard events outside the ranges shown are possible, but are not included as they are unlikely to influence decision making given the objectives of this study and types of geohazards assessed.

5.2. Consequence Rating

In quantitative risk analysis, consequence combines the value of the element at risk with its vulnerability to damage or loss, given impact by that hazard. It is the conditional probability that elements at risk will suffer some severity of damage or loss, given geohazard impact with a certain severity.

Quantitative consequence estimation for regional risk prioritization requires detailed scenario modelling, but the same principles apply to qualitative approaches. In this assessment, ratings for relative consequence consider the presence of elements at risk within the hazard area, and their potential vulnerability given impact by geohazards at a certain level of destructive potential. The ratings should not be considered estimates of probability of loss given impact.

Specifically, BGC assigned consequence ratings that considered the following questions:

- What is the exposure of elements at risk to geohazards (Section 5.2.1)?
- What is the destructive potential of uncontrolled flows that could impact elements at risk (Section 5.2.2)?

5.2.1. Geohazard Exposure (Elements at Risk)

Table 5-3 lists weightings applied to elements at risk (Section 3.0) that intersect or are contained within geohazard areas. These weightings represent relative "importance" of elements at risk, and are not meant as units of quantitative consequence. Table 5-4 assigns summed geohazard exposure ratings to Low, Moderate, or High exposure rating classes.

BGC recognizes that weightings and exposure rating classes are subjective, and will vary depending on stakeholder perspective. Exposure rating classes presented in Table 5-4 are oriented towards those tasked with making risk management decisions that must balance competing priorities across multiple elements at risk within a given jurisdiction.

Scoping Report note: the weightings shown in Table 5-3 *require review once spatial analysis relating geohazards to elements at risk is completed. They are subject to change for the Draft and Final Report.*

Table 5-4. Relative geohazard exposure weightings.

Element at Risk Intersecting Hazard Zone		Weighting
Building Improvements (BC Assessment)	<$100k[1]	1
	$100k - $1M	10
	$1M - $10M	20
	$10M - $50M	40
	$50M - $100M	80
	>$100M	160

Element at Risk Intersecting Hazard Zone		Weighting
Business Activity[2]	<$100k annual revenue or <2 businesses	1
	$100k - $1M annual revenue or 2-5 businesses	10
	$1M - $10M annual revenue or 5-10 businesses	20
	$10M - $50M annual revenue or 10-25 businesses	40
	$50M - $100M annual revenue or >25 businesses	80
Critical Facilities	High Importance	10
	Moderate Importance	8
	Low Importance	6
Roads[3]	0-10 vehicles/day (Class 7)	1
	10-100 vehicles/day (Class 6)	2
	100-500 vehicles/day (Class 5)	4
	500-1000 vehicles/day (Class 4)	8
	> 1000 cars/day (Class <4)	16
Transmission Lines	Presence of	10
Railway	Presence of	2
Pipeline	Presence of	2
Environmental Values	Fish-Bearing Areas	16
	Species and Ecosystems at Risk	16

Note:

1. Cadastral parcels with an assessed improvement (i.e., building) value less than $50,000 and a parcel size larger than X m^2 were excluded from the analysis. This threshold was applied to remove large parcels, typically in remote areas, with only minor outbuildings or cabins.

Table 5-5. Geohazard exposure classification.

Total Weighting	Elements at Risk Exposure Rating
-	Very Low
-	Low
-	Moderate
-	High
-	Very High

Scoping report note: Table 5-4 will be completed for the Draft and Final reports.

5.2.2. Geohazard Destructive Potential (Intensity)

The vulnerability of elements at risk to damage or loss depends on the destructive potential of an event (hazard intensity), and the ability of the element at risk to resist damage or loss given impact. In this assessment, relative ratings for destructive potential were used as a proxy to assign relative vulnerability ratings for direct economic loss. No differentiation was made between the vulnerability of different types of elements at risk, which would be considered as part of more detailed consequence modelling and risk analyses. This simplification is considered reasonable given the level of detail of study and the objective to prioritize relative risk.

BGC used an index of flow “intensity” to differentiate between areas subject to higher velocity impact by water and debris, versus lower velocity flood inundation. Jakob et al. (2011) describes an intensity index as follows:

$$I_{DF} = v^2 * d \qquad \text{[Eq. 5-1]}$$

where v is flow velocity and d is flow depth.

Areas where $I_{DF} > 1$ were considered potentially subject to impact by higher velocity water and debris, for example by debris flows, debris floods, or areas of high velocity clear-water flow. Areas where $I_{DF} < 1$ were considered subject to lower velocity clear-water flood inundation.

Table 5-5 describes four flow intensity categories that were assigned as measures of destructive potential after Jakob *et al.* (2011). These measures were used for steep creek geohazard areas.

Table 5-6 lists depth thresholds used to assign intensity ratings to clear-water flood and landslide-dam flood inundation areas ($I_{DF} < 1$). The flood depth thresholds shown in Table 5-6 are not equivalent to flood stage-damage curves used in detailed flood consequence estimation (e.g., FEMA, 2017, IBI Group, 2015).

Table 5-6. Relative ratings for destructive potential (intensity) based on flow intensity ranges.

Hazard Zone	Vulnerability Rating	I_{DF} range	Hazard Zone Characteristics
Impact	Very High	>100	Very fast flowing and deep water and debris. High likelihood of severe building structure damage and severe sediment and water damage. Extremely dangerous to people in buildings, on foot or in vehicles.
	High	10-100	Fast flowing and deep water and debris. High likelihood of moderate building structure damage and severe sediment and water damage. Very dangerous to people in buildings, on foot or in vehicles.
	Moderate	1-10	Potentially fast flowing but mostly shallow water and debris. Moderate likelihood of building structure damage and high likelihood of major sediment and/or water damage. Potentially dangerous to people on the first floor or in the basement of buildings, on foot or in vehicles.
Inundation	N/A, See Table 5-6	<1	Slow flowing shallow and deep water with little or no debris. High likelihood of water damage. Potentially dangerous to people in buildings, on foot or vehicles in areas with higher water depths. Can be supplemented by water depth maps for ponding water where flow velocities are zero.

Note: I_{DF} stands for debris flow intensity index (after Jakob *et al*., 2011)

Table 5-7. Relative flood intensity criteria for elements at risk where $I_{DF} < 1$.

Estimated Max Flood Depth above ground surface (m)	Vulnerability
< 0.1	Very Low
0.1 – 0.3[1]	Low
0.3 - 1.5[1]	Moderate
1.5 – 3	High
> 3	Very High

Note:

1. 0.3 m and 1.5 m correspond to the default assumed first-floor elevation of a concrete slab foundation residential building, and a residential building with a sub-grade basement, respectively (FEMA, 2017). These thresholds assume a step-increase in flood damages once flood depths exceed first-floor elevation, but do not replace the use of stage-damage curves as would be required for detailed flood scenario and consequence modelling.

5.2.3. Consequence Rating

Table 5-7 presents a qualitative consequence rating assigned to each hazard area, based on ratings for hazard exposure and destructive potential. It combines the asset exposure and flow intensity ratings (Table 5-5), and provides a relative estimate of the potential for damage to assets given impact by a geohazard.

Table 5-8. Relative consequence rating.

Hazard Exposure	Relative Consequence Rating				
Very High	M	H	H	VH	VH
High	L	M	H	H	VH
Moderate	L	L	M	H	H
Low	VL	L	L	M	H
Very Low	VL	VL	L	L	M
Destructive Potential	Very Low	Low	Moderate	High	Very High

5.3. Priority Rating

Table 5-8 displays a matrix used to prioritize each geohazard area based on the geohazard (Table 5-1) and consequence (Table 5-7) ratings. It provides a basis to prioritize geohazard areas by relative risk and supports decisions and requirements for land use planning and policy making. The alphanumeric priority codes shown in the matrix indicate the basis for the rating (for example to clarify whether a "high" priority is due to high hazard or high vulnerability, or both).

Table 5-9. Prioritization matrix (assets).

Geohazard Rating	Priority Rating (Elements at Risk)				
VH (1)	1a	1b	1c	1d	1e
H (2)	2a	2b	2c	2d	2e
M (3)	3a	3b	3c	3d	3e
L (4)	4a	4b	4c	4d	4e
VL (5)	5a	5b	5c	5d	5e
Consequence Rating	**VL (a)**	**L (b)**	**M (c)**	**H (d)**	**VH (e)**

6.0 PRIORITIZATION RESULTS

6.1. Introduction

Scoping report note: placeholder for text to be included in the Draft or Final reports.

6.2. Summary of Geohazard Areas

Scoping report note: placeholder for text to be included in the Draft or Final reports.

6.3. Priority Ratings

Scoping report note: placeholder for text to be included in the Draft or Final reports.

6.4. Risk Assessment Information Template (RAIT)

Appendix XX provides RAIT forms prepared based on the results of this assessment. Hazard areas requiring RAIT form preparation were selected by FBC as sites where funding is desired to support the completion of more detailed assessments (e.g., detailed floodplain or steep creek hazard mapping). The RAIT forms were filled out based on judgement with reference to the geohazard, consequence, and priority ratings systematically assigned to geohazard areas.

Scoping report note: the above represents placeholder text, for inclusion of RAIT forms once prepared. RAIT forms are not a deliverable of this scoping report, but will be prepared as required for BGC's support of NDMP Stream 2 funding applications in August 2018.

6.5. Confidence Rating

Table 5-9 lists the confidence level categories prescribed by NDMP. BGC applied these confidence ratings using judgement, based on our review of the data available and methods of analysis. The ratings were applied to areas where RAIT forms were prepared in support of NDMP Stream 2 funding application submission.

Scoping report note: confidence ratings will be applied as required during BGC's support of NDMP Stream 2 applications in August 2018.

Table 5-1. NDMP confidence ratings.

Confidence Level	Definition
A	Very high degree of confidence. Risk assessment used to inform the risk assessment information template was evidence-based on a thorough knowledge of the natural hazard risk event; leveraged a significant quantity of high-quality data that was quantitative and qualitative in nature; leveraged a wide variety of data and information including from historical records, geospatial and other information sources; and the risk assessment and analysis processes were completed by a multidisciplinary team with subject matter experts (i.e., a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences). Assessment of impacts considered a significant number of existing/known mitigation measures.
B	High degree of confidence. Risk assessment used to inform the risk assessment information template was evidence-based on a thorough knowledge of the natural hazard risk event; leveraged a significant quantity of data that was quantitative and qualitative in nature; leveraged a wide variety of data and information including from historical records, geospatial and other information sources; and the risk assessment and analysis processes were completed by a multidisciplinary team with some subject matter expertise (i.e., a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences). Assessment of impacts considered a significant number of potential mitigation measures.
C	Moderate confidence. Risk assessment used to inform the risk assessment information template was moderately evidence-based from a considerable amount of knowledge of the natural hazard risk event; leveraged a considerable quantity of data that was quantitative and/or qualitative in nature; leveraged a considerable amount of data and information including from historical records, geospatial and other information sources; and the risk assessment and analysis processes were completed by a moderately sized multidisciplinary team, incorporating some subject matter experts (i.e., a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences).Assessment of impacts considered a large number of potential mitigation measures.
D	Low confidence. Risk assessment used to inform the risk assessment information template was based on a relatively small amount of knowledge of the natural hazard risk event; leveraged a relatively small quantity of quantitative and/or qualitative data that was largely historical in nature; may have leveraged some geospatial information or information from other sources (i.e., databases, key risk and resilience methodologies); and the risk assessment and analysis processes were completed by a small team that may or may not have incorporated subject matter experts (i.e., did not include a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences). Assessment of impacts considered a relatively small number of potential mitigation measures.
E	Very low confidence. Risk assessment used to inform the risk assessment information template was not evidence-based; leveraged a small quantity of information and/or data relating to the natural risk hazard and risk event; primary qualitative information used with little to no quantitative data or information; and the risk assessment and analysis processes were completed by an individual or small group of individuals little subject matter expertise (i.e., did not include a wide array of experts and knowledgeable individuals on the specific natural hazard and its consequences). Assessment of impacts did not consider existing or potential mitigation measures.

7.0 CLIMATE CHANGE

Scoping report note: placeholder for text to be included in the Draft or Final reports.

8.0 CONCLUSIONS AND FURTHER CONSIDERATIONS

Scoping report note: placeholder for text to be included in the Draft or Final reports.

9.0 CLOSURE

We trust the above satisfies your requirements at this time. Should you have any questions or comments, please do not hesitate to contact us.

Yours sincerely,

BGC ENGINEERING INC.
per:

Kris Holm, M.Sc., P.Geo.
Senior Geoscientist and Project Manager

Marty Zaleski, M.Sc., P.Geo.
Engineering Geologist

Reviewed by:

Hamish Weatherly, M.Sc., P.Geo.
Principal Hydrologist

Matthias Jakob, Ph.D., P.Geo.
Principal Geoscientist

KH/HW-MJ/sf/mm

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TABLES

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APPENDIX A
TERMINOLOGY

A 1. INTRODUCTION

Jurisdictions within the Thompson River Watershed (TRW) have legal definitions for common terms that are used throughout this study. For example, these include *watercourse, flood construction levels (FCLs)* and *development setbacks*. Some of these terms were adapted for use from the BC Ministry of Water, Land and Air Protection (MWLAP, 2004) or from provincial legislation. As a result, legal definitions are not necessarily identical to technical definitions, or there may be nuances that require clarification to ensure terms are properly applied. This appendix defines geohazard-related terms referenced in this project and clarifies differences between their use in technical work versus policy.

Table A-1 summarizes available policy and local bylaws within the TRW that were considered in this assessment. This assessment uses, as much as possible, terms consistent with these documents along with provincial and federal guidelines (e.g., MWLAP, 2004; NRCan, 2017) and professional practice guidelines (e.g., EGBC, 2017). Section A2 through A5 lists and in some cases comments on the cited terms used in this assessment.

Table A-1. Summary of related floodplain management policy documents in the TRW

Document	Year	District	Zoning Bylaw #	Content
Village of Chase, B.C.	2006	TNRD	683	Floodplain Management Provisions

Scoping report note: Table A-1 is a placeholder to be filled out for the Draft and Final report.

A 2. CLEAR-WATER FLOOD TERMINOLOGY

The following sections list terminology related to flood, floodplain and watercourse, lakes and wetlands that were considered as part of the TRW assessment for clear-water flood geohazards.

A.2.1. Flood and Floodplain

Designated Flood: a flood, which may occur in any given year, of such magnitude as to equal a flood having a 200-year recurrence interval, based on a frequency analysis of unregulated historic flood records or by regional analysis where there is inadequate stream flow data available. Where the flow of a large watercourse is controlled by a major dam, the designated flood shall be set on a site-specific basis.

Flood fringe: the portion of the floodplain not in the floodway to which floodproofing requirements apply.

Flood level: the calculated elevation of the designated flood, including an allowance for uncertainty (freeboard) based on site specific conditions.

Flood: the overflow of natural drainage channels, natural shorelines and/or human-made facsimiles leading to partial or complete inundation from the overflow of inland or tidal waters, and/or the accumulation or runoff of surface waters from any source.

Floodplain: an area that is susceptible to flooding from a watercourse, lake, or other body of water and for administrative purposes is taken to be that area submerged by the Designated Flood plus freeboard.

Floodway: The channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge a design flood without cumulatively increasing the water surface elevation more than a designated height. It is typically the portion of a floodplain where flood depths are greatest and flow velocities are highest.

Freeboard: a vertical distance added to the actual calculated flood level to accommodate uncertainties (hydraulic and hydrologic variables), potential for waves, surges, and other natural phenomena.

Geomorphic floodplain: the area overlain by fluvial deposits. This area represents the long-term accumulation of fluvial sediments and is not associated with any particular flood return period.

Inundation: flooding resulting from an excess of clear-water discharge in a watercourse or body of water such that land outside the natural or artificial banks which is not normally under water, is submerged or inundated.

Natural boundary: the visible high watermark of any lake, river, watercourse, or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, watercourse, or other body of water a character distinct from that of the banks thereof, in respect to vegetation, as well as in respect to the nature of the soil itself. In addition, the natural boundary includes the best estimate of the edge of dormant or old side channels and marsh areas.

Setback: a distance which an undertaking or landfill must be set back from a natural boundary or other reference line to maintain a floodway and allow for erosion. A minimum required setback is required from the natural boundary.

A.2.2. Watercourse

Watercourse: any natural or man-made depression with well-defined banks and a bed 0.6 metres (2.0 feet) or more below the surrounding land serving to give direction to a current of water at least six months of the year and/or having a drainage area of two square kilometres (0.8 square miles) or more upstream of the point of consideration.

Comments:

- Watercourse is defined in terms of level of channel confinement (minimum 0.6 m), seasonality of flow (minimum 6 months), and minimum drainage area (2 km^2).

However, stream channels exist in the TRW that are unconfined, contain flows for less than 6 months per year, or that have watershed areas less than 2 km^2, that represent a hazard but would not be defined as a watercourse. Examples include debris flow fans at the outlet of small (e.g., <2 km^2) watersheds, alluvial fans where water flow is below-grade for much of the year, and relic channels that may be active during low frequency (high return period) floods.

- The TRW assessment uses the National Hydrology Network (NHN) stream network in addition to stream segments that were digitized by BGC using aerial imagery. Unmapped, natural and human-made water courses exist within the TRW that would fit this definition, including watercourses in developed areas, that are were not considered in this assessment. For example, these may include small streams, ditches, canals, and field drains.
- Differences may exist between local stream names and those officially defined by the NHN. This can result in inconsistent channel naming conventions between different assessment reports. BGC maintains a detailed stream network with unique identifiers assigned to individual stream segments.
- The NHN stream network is defined according to the channel thalweg, but often bylaw requirements and definitions are relative to the high-water mark, which is not contained in NHN data. Channel thalwegs also change over time and the current position may be different than mapped in NHN.

A.2.3. Watercourse Characteristics

Top of Bank: the point at which the upward ground level becomes less than one (1.0) vertical to four (4.0) horizontal, and refers to the crest of the bank or bluff where the slope clearly changes into the natural upland bench; or as otherwise designated from time to time by the authority having jurisdiction.

Natural ground: the undisturbed ground elevation prior to site preparation.

Figure A-1 and provides a cross-section of a typical floodplain for illustrative purposes. Figure A-2 illustrates additional definitions of watercourse characteristics that were used in the assessment.

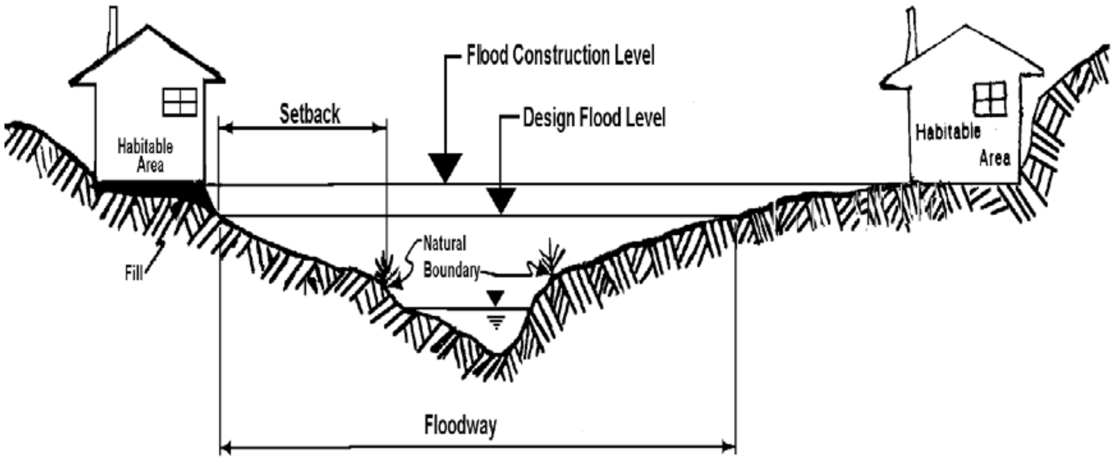

Figure A-1. Cross Section of a typical floodplain. Source: BC Ministry of Environment.

Active floodplain width: the fluvial-affected area inundated during a 10-year flood; where there is evidence of previous flow occupation (i.e., lower succession vegetation and side channels)

Bankfull width: channel width during a 2-year flood (water + exposed bed material = bankfull width).

Floodplain width: the fluvial-affected area during a 200-year flood.

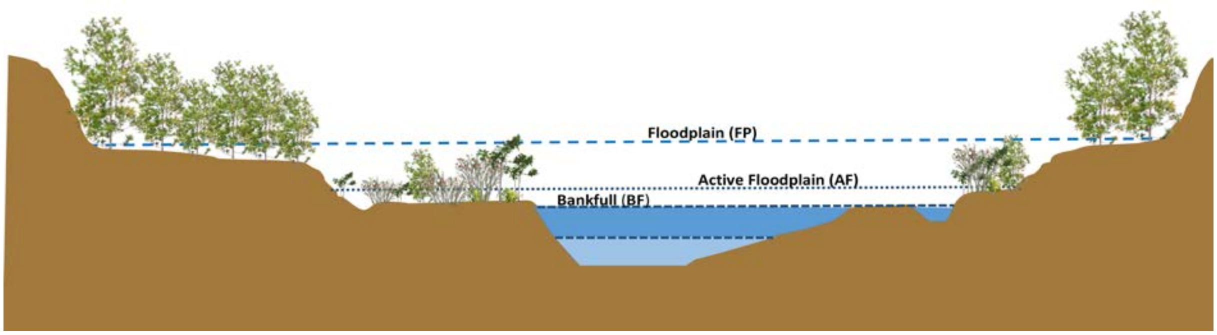

Figure A-2. Conceptual sketch illustrating Bankfull, Active Floodplain, and Floodplain definitions used in this assessment.

Bankfull (BF), active floodplain (AF), and floodplain (FP) widths vary with the watercourse configuration (Figure A-3).

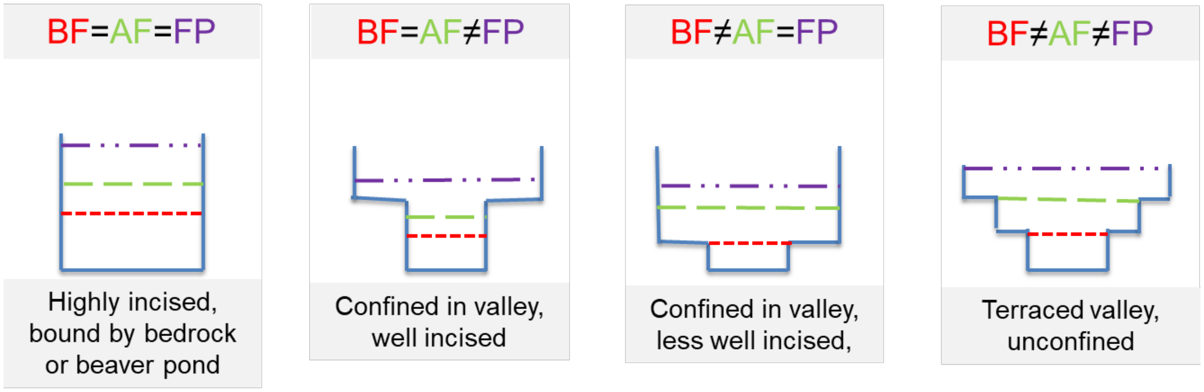

Figure A-3. Illustration of cases with different bankfull, active floodplain, and floodplain widths.

A.2.4. Lakes and Wetlands

Lakes: defined as those over 15 kilometres in length, or any pond, backwater, slough, swamp or marsh area affected by the lake. Any area of year-round open water covering a minimum of 1.0 hectares (2.47 acres) of area and possessing a maximum depth of at least 2.0 metres. Smaller and shallower areas of open water may be considered to meet the criteria of a wetland.

Small Lakes: defined as those lakes less than 15 kilometres in length and where there is no history of severe flooding or concern for shoreline erosion, and for ponds, swamps or marsh areas.

Wetland: land seasonally or permanently covered by water and dominated by water tolerant vegetation. Wetlands include swamps, marshes, bogs and fens but do not include lands periodically flooded for agricultural purposes."

Comments:

- The TRW contains thousands of water bodies that fit the definition of small lakes and wetlands. These water bodies may be subject to flood hazard that was not included in this assessment.

A 3. STEEP-CREEK TERMINOLOGY

Alluvial fan: A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or wherever a constriction in a valley abruptly ceases or the gradient of stream suddenly decreases.

Active alluvial fan: The portion of the fan surface which may be exposed to contemporary hydrogeomorphic or avulsion hazards (Kellerhals and Church, 1990).

Avulsion: Lateral displacement of a stream from its main channel into a new course across its fan or floodplain.

Clast supported: Deposits that contain a higher proportion of clasts than matrix.

Colluvial: Applied to weathered rock debris that has moved down a hillslope by creep or by surface wash.

Debris: A mixture of sand, gravel, cobbles and boulders, often with varying proportions of silt and clay.

Debris flood: A very rapid (0.5-5 m/s velocity) flow of water that is heavily charged with debris in a steep channel (Hungr et al., 2014).

Debris flow: A very to extremely rapid (0.5-50 m/s velocity) surging flow of saturated debris in a steep channel (Hungr et al., 2014).

Distal fan: The zone on the alluvial fan closest to the fan toe.

Fan apex: The highest point on an alluvial fan, generally where the stream emerges from the mountain front.

Fan toe: The downslope end of an alluvial fan.

"Gentle over steep": Steep or potentially unstable slopes below gently-sloping terrain.

Hydrogeomorphology: The interdisciplinary science that focuses on the interaction and linkage of hydrologic processes with landforms or earth materials

Inactive alluvial fan: Portions of the fan that are removed from active hydrogeomorphic or avulsion processes by severe fan erosion, also termed fan entrenchment (Kellerhals and Church, 1990).

Levée: Steep-sided ridges that can be up to several metres in height. They lie outside and above the sides of a pre-existing stream channel, and can extend for many tens of metres along a channel.

LiDAR: Stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses - combined with other data recorded by the airborne system - generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Lobe: Debris deposited over an aerial portion of the debris fan. They are often characterized by a number of arms, each ending in a "snout".

Matrix-supported: Deposits that contain a higher proportion of matrix than clasts. As a consequence, clasts tend to not be in contact with one another.

Melton ratio: The ruggedness of the basin can be characterized by the dimensionless ratio, $H/\sqrt{A}$ (H is the watershed relief in km, and A is watershed area in km^2), which indicates how rugged the basin was at the time of maximum fan development (Melton, 1965).

Paraglacial fan: Alluvial fans that were constructed under environments conditioned by glaciation, or occurring in the transition from one environment to another (e.g. glaciated to unglaciated) (Church and Ryder, 1972).

Proximal fan: The zone on the alluvial fan closest to the fan apex.

Scour: The powerful and concentrated clearing and digging action of flowing air or water, especially the downward erosion by stream water in sweeping away mud and silt on the outside curve of a bend, or during a time of flood.

Comments:

- Geohazards on alluvial fans do not necessarily end at the boundary of the alluvial fan. For example, a debris flow or debris flood could also result in flooding that extends beyond the fan boundary. As such, it may sometimes be important to delineate hazard zones that extend beyond the alluvial fan boundary.
- It is important to recognize that alluvial fans can be formed from the deposits of different types of geohazards, such as debris flows, debris floods, and floods. Distinguishing between these process types is important because it influences the characteristics of the fan landform, methods to assess hazard and risk, and the determination of appropriate risk reduction measures.

A 4. LANDSLIDE-DAM TERMINOLOGY

Scoping report note: landslide-dam terminology may be included here as part of the Draft and Final reports.

A 5. GEOHAZARD RISK TERMINOLOGY

Table A-2 provides defines terms that are commonly used in geohazard risk assessment. BGC notes that the definitions provided are commonly used, but international consensus on geohazards does not fully exist.

Table A-2. Geohazard risk terminology

Term	Definition	Source
Acceptable Risk	A risk within a range that society accepts to secure certain net benefits. In countries governed under Napoleonic Law (e.g., the Netherlands), it is a range of risk below which no further risk reduction is required. In countries governed under the framework of British Common Law (e.g., Canada, not including Quebec), the term **tolerable risk** is preferred, and represents a starting point beyond which further risk reduction occurs according to the ALARP Principle.	AGS (2007), Ale (2005)
Action [component of the geohazard risk management framework]	As part of the **Geohazard Risk Management Framework**, includes the implementation of chosen risk control options, and defining and documenting ongoing monitoring and maintenance requirements	VanDine (2012), BGC

Term	Definition	Source
Annual Exceedance Probability (P_H)	The estimated probability that an event will occur exceeding a specified magnitude in any year.	Fell et al. 2005
As Low As Reasonably Practicable (ALARP)	ALARP compares a quantum of risk against the effort (financial, time, or other sacrifice) required to reduce the risk. If it is shown that one is in gross disproportion to the other, e.g., that the effort required to reduce risk is grossly disproportionate to the additional level of risk reduction achieved, then the risk is ALARP and there should be no additional burden placed to reduce the risk.	HSE (1988)
As Low As Reasonably Practicable (ALARP) zone on F-N curve	Region of an F-N curve, where risk should be reduced to As Low As Reasonably Practicable (ALARP).	GEO (1998)
Asset Management	Strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on both engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the life cycle of the assets at minimum practicable cost.	U.S. Highways Administration (unaltered legal definition)
Broadly Acceptable zone on F-N curve	Region of an **F-N curve** where risk is considered acceptable and no further risk reduction is required.	GEO (1998)
Consequence (C)	In relation to risk analysis, the outcome or result of a geohazard being realised. Consequence is a product of **vulnerability** (V) and a measure of the **elements at risk** (E)	AGS (2007), BGC, Fell et al. (2005).
Consultation Zone	The Consultation Zone (CZ) includes all proposed and existing development in a geographic zone defined by the approving authority that contains the largest credible area affected by **geohazards**, and where damage or loss arising from one or more simultaneously occurring geohazards would be viewed as a single catastrophic loss.	Porter et al. (2009)
Cumulative Frequency (F)	Sum of the class and all classes below it in a frequency distribution. For example, the cumulative frequency (F) of at least N fatalities is the summed frequency of one *or more* fatalities, and thus describes the cumulative risk of all **geohazard risk scenarios**. The 1:100 cumulative annual frequency of a debris flow is the probability of the 1:100-year debris flow *or larger*.	BGC Discussion

Term	Definition	Source
Elements at Risk (E)	This term is used in two ways: a) To describe things of value (e.g., people, infrastructure, environment) that could potentially suffer damage or loss due to a geohazard. b) For risk analysis, as a measure of the value of the elements that could potentially suffer damage or loss (e.g., number of persons, value of infrastructure, value of loss of function, or level of environmental loss).	BGC Discussion
Encounter Probability	This term is used in two ways: a) Probability that an event will occur and impact an element at risk when the element at risk is present in the geohazard zone. b) For quantitative analyses, the probability of facilities or vehicles being hit at least once when exposed for a finite time period L, with events having a return period T at a location. In this usage, it is assumed that the events are rare, independent, and discrete, with arrival according to a statistical distribution (e.g., binomial or Bernoulli distribution or a Poisson process).	BGC Discussion
F-N Curve	Cumulative frequency, F, of all conceivable **geohazard scenarios** that each lead to N or more **consequences** (e.g., fatalities or economic loss). The data are graphed as a continuous curve against logarithmic axes for both F and N. This allows comparison with thresholds for intolerable, ALARP, broadly acceptable, and “intense scrutiny” levels of risk.	GEO (1998), BGC
F-N Pair	Cumulative frequency, F, of all conceivable **geohazard scenarios** that each lead to N or more **consequences** (e.g., fatalities or economic loss). F-N pairs are constructed by ranking f-N pairs for all geohazard scenarios from lowest N to highest N, and accumulated into F-N pairs, where each F value is the sum of all f values associated with N or more fatalities. F-N pairs are used to construct an **F-N curve**.	BGC Discussion
f-N Pair	Estimate of the frequency of a **geohazard scenario** of a given magnitude per year, f, and the associated number of fatalities, N, for each identified geohazard event and its possible outcome. The resulting data are expressed as f-N pairs. Note the use of the lower case “f” to distinguish it from an **F-N pair**, which is a cumulative frequency calculated from f-N pairs.	GEO (1998), BGC

Term	Definition	Source
Frequency (f)	Estimate of the number of events per time interval (e.g., a year) or in a given number of trials. Inverse of the **recurrence interval** (return period) of the geohazard per unit time. Recurring geohazards typically follow a frequency-magnitude (F-M) relationship, which describes a spectrum of possible geohazard magnitudes where larger (more severe) events are less likely. For example, annual frequency is an estimate of the number of events per year, for a given geohazard event magnitude. In contrast, annual probability of exceedance is an estimate of the likelihood of one or more events in a specified time interval (e.g., a year). When the expected frequency of an event is much lower than the interval used to measure probability (e.g., frequency much less than annual), frequency and probability take on similar numerical values and can be used interchangeably. When frequency approaches or exceeds 1, defining a relationship between probability and frequency is needed to convert between the two. The main document provides a longer discussion on frequency versus probability.	Fell et al. (2005), BGC Discussion
Geohazard	Geophysical process that is the source of potential harm, or that represents a situation with a potential for causing harm. Note that this definition is equivalent to Fell et al. (2005)'s definition of Danger (threat), defined as an existing or potential natural phenomenon that could lead to damage, described in terms of its geometry, mechanical and other characteristics. Fell et al. (2005)'s definition of danger or threat does not include forecasting, and they differentiate Danger from Hazard. The latter is defined as the probability that a particular danger (threat) occurs within a given period of time.	CSA (1997), BGC discussion, Fell et al. (2005).
Geohazard Analysis	Procedure to: identify the geohazard process; characterize the geohazard in terms of factors such as mechanism, causal factors, and trigger factors; estimate frequency and magnitude; develop geohazard scenarios; and estimate extent and intensity of geohazard scenarios.	

Term	Definition	Source
Geohazard Assessment	Combination of **geohazard analysis** and evaluation of results against a **hazard tolerance standard** (if existing). Geohazard assessment includes the following steps: a. Geohazard analysis: identify the geohazard process, characterize the geohazard in terms of factors such as mechanism, causal factors, and trigger factors; estimate frequency and magnitude; develop geohazard scenarios; and estimate extent and intensity of geohazard scenarios. b. Comparison of estimated hazards with a hazard tolerance standard (if existing)	AGS (2007), BGC discussion
Geohazard Event	Occurrence of a **geohazard**. May also be defined in reverse as a non- occurrence of a geohazard (when something doesn't happen that could have happened).	ISO 31000, BGC discussion
Geohazard Intensity	A set of parameters related to the destructive power of a geohazard (e.g., depth, velocity, discharge, impact pressure, etc.)	BGC discussion
Geohazard Inventory	Recognition of existing **geohazards.** These may be identified in geospatial (GIS) format, in a list or table of attributes, and/or listed in a **risk register**.	CSA (1997), BGC discussion
Geohazard Magnitude	Size-related characteristics of a **geohazard**. May be described quantitatively or qualitatively. Parameters may include volume, discharge, distance (e.g., displacement, encroachment, scour depth), or acceleration. In general, it is recommended to use specific terms describing various size-related characteristics rather than the general term magnitude. Snow avalanche magnitude is defined differently, in classes that define destructive potential.	BGC discussion, CAA (2016)
Geohazard Risk	Measure of the probability and severity of an adverse effect to health, property the environment, or other things of value, resulting from a geophysical process. Estimated by the product of geohazard probability and consequence.	CSA (1997), BGC discussion
Geohazard Risk Analysis [component of the geohazard risk management framework]	Combination of steps to estimate the level of **geohazard risk.** Includes the **scope definition**, **geohazard analysis**, **elements at risk analysis**, and **risk estimation** components of the **geohazard risk management framework**.	BGC discussion, CSA (1997), Fell et al. (2005)
Geohazard Risk Assessment (GRA)	Combination of **risk analysis** and **risk evaluation**. Includes the following steps of the **geohazard risk management framework: scope definition, hazard analysis, elements at risk analysis, risk estimation, and risk evaluation**.	AGS (2007), BGC discussion

Term	Definition	Source
Geohazard Risk Control (Mitigation) [component of the geohazard risk management framework]	The implementation and enforcement of actions to control geohazard risk, and the periodic re-evaluation of the effectiveness of these actions. Steps of geohazard risk control include: a. Identify options to reduce risks to levels considered tolerable by the client or governing jurisdiction b. Select option(s) fulfilling risk control objectives, as well as other objectives that may have bearing on the selection process (e.g., economic cost, social, environmental and political considerations). c. Estimate residual risk for preferred option(s)	Fell et al. (2007)
Geohazard Risk Evaluation [component of the geohazard risk management framework]	The stage at which values and judgement enter the decision process, explicitly or implicitly, by comparing risk estimates to levels of risk tolerance. Steps of geohazard risk evaluation include: a. Compare the estimated risk against local or other acceptance or tolerance criteria b. Prioritize risks for risk control and monitoring	Fell et al. (2007), BGC discussion.
Geohazard Risk Identification [component of the geohazard risk management framework]	Combination of **geohazard analysis** and **elements at risk analysis**.	BGC discussion
Geohazard Risk Management	Systematic application of physical measures, management policies, procedures, and practices to the tasks of analyzing, evaluating, controlling, and communicating about geohazard risk issues.	CSA (1997), Fell et al. (2005)
Geohazard Risk Register	Document and/or table describing the results of **geohazard risk identification** and, where completed, the input parameters and results of qualitative or quantitative geohazard risk analysis.	Public Safety Canada, CSA (1997), BGC discussion.
Geohazard Scenario	Defined sequences of events describing a **geohazard** occurrence. Geohazard scenarios characterize parameters required to estimate risk such **geohazard extent or runout exceedance probability,** and **intensity.** Geohazard scenarios (as opposed to geohazard risk scenarios) typically consider the chain of events up to the point of impact with an element at risk, but do not include the chain of events following impact (the consequences).	BGC discussion, Fell et al. (2005)
Geohazard Risk Scenario	Defined sequences of events where a **geohazard scenario** occurs and reaches the geohazard zone while the element at risk is present, and results in consequences. Geohazard scenarios consider both the chain of events up to the point of impact with an element at risk, and the chain of events that follows impact (e.g., the entire sequence of events for which risk is being estimated).	BGC discussion, Fell et al. (2005)

Term	Definition	Source
Geohazard Tolerance Standard	Standard for geohazard reduction defined by a certain geohazard exceedance probability, without consideration of consequences. An example is legislative requirements for 1:200-year flood protection (irrespective of the consequences of flood impact).	BGC Discussion
Individual Risk (Safety)	Risk of fatality or injury to a particular individual due to a geohazard.	AGS (2007), BGC discussion
Individual Risk to Life	The increment of risk imposed on a particular individual by the existence of a geohazard. This increment of risk is an addition to the background risk to life, which the person would live with on a daily basis.	Fell et al. (2005)
Intense Scrutiny zone on F-N curve	Region on an F-N curve defined as very high potential loss of life (>1000 persons). The risk tolerance threshold for the Intense Scrutiny Zone is vertical, implying near-zero risk tolerance for such high loss of life.	BGC discussion, GEO (1998)
Intolerable zone on F-N curve	Region on an **F-N curve** where risks are not considered tolerable.	GEO (1998)
Likelihood	Conditional probability of an outcome given a set of data, assumptions and information. Also used as a qualitative description of probability and frequency.	Fell et al. (2005)
Partial Risk	Risk associated with one of several **geohazard scenarios** that must be summed to determine total risk. This term is also used synonymously with encounter probability, but this usage is discouraged (better to just use the term **encounter probability**, which itself has dual meanings!).	BGC discussion

Term	Definition	Source
Probability	A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty) and must refer to a set like occurrence of an event in a certain period of time, or the outcome of a specific event. It is an estimate of the likelihood of the magnitude of the uncertain quantity, or the likelihood of the occurrence of the uncertain future event. There are two main interpretations: i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an “objective” or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment. ii) Subjective (or Bayesian) probability (degree of belief) – Quantified measure of belief, judgement, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly, and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgement regarding an evaluation, or the quality and quantity of information. It may change over time as the state of knowledge changes.	Fell et al. (2005)
Probability of Death of an Individual (PDI)	Estimated annual probability of loss of life for an individual.	GEO (1998), BGC discussion
Project Initiation [component of a geohazard risk management framework]	First phase of the **geohazard risk management framework**, including recognition of a potential geohazard, defining the study area and level of effort, defining project team roles, and identifying ‘key’ consequences to be considered for risk estimation.	BGC discussion
Qualitative Geohazard Risk Analysis	Geohazard risk analysis based on word form, descriptive or numeric rating scales of probability, vulnerability and consequences, and that results in a non-numerical value of the risk.	AGS (2007), BGC discussion
Quantitative Geohazard Risk Analysis (QRA)	Geohazard risk analysis based on numerical values of the probability, **vulnerability** and **consequences**, and that results in a numerical value of the risk.	AGS (2007), BGC discussion
Residual Risk	The risk remaining after all **risk control** strategies have been applied.	BGC discussion
Return Period (Recurrence Interval)	Estimated time interval between events of a similar size or intensity. Return period and recurrence interval are equivalent terms. Inverse of **frequency**.	BGC discussion

Term	Definition	Source
Risk-based geohazards assessments	Geohazards assessments that consider more than one, but not all, parameters in the quantitative risk equation. Risk-based methods can be quantitative, semi-quantitative, or qualitative. Many geohazards assessments completed by BGC, if not the majority, fall in this category.	BGC discussion
Semi-Quantitative Risk Analysis	A risk analysis based on a combination of numerical and word form, descriptive or numerical parameters. For example, many geohazard risk matrices combine numerical **geohazard** probability estimates with word form, descriptive or numeric rating scales to describe the magnitude of potential consequences.	BGC discussion
Societal (Group) Safety Risk	Measure of the overall risk to life associated with a **geohazard** event. It accounts for the likely impact of all geohazard events on all individuals who may be exposed to the risk, and it reflects the number of people exposed. For geohazard risk assessment, group safety risk is usually represented on an **F-N curve**.	GEO (1998), BGC discussion
Spatial Probability ($P_{S,H}$)	Conditional probability ($P_{S:H}$) that the **geohazard**, should it occur, impacts the location of the element at risk.	BGC discussion
Temporal Probability ($P_{T,H}$)	Conditional probability ($P_{T:H}$) that the **element at risk** would be in the impact zone at the time of impact.	BGC discussion
Tolerable Risk	A risk within a range that society accepts as tolerable to secure certain net benefits. In countries governed under the framework of British Common Law, tolerable risk is a range of risk regarded as non-negligible, and is a starting point for further risk reduction according to the ALARP Principle.	AGS (2007), Ale (2005)

Term	Definition	Source
Uncertainty	Indeterminacy of possible outcomes. Two types of uncertainty are commonly defined: a) Aleatory uncertainty includes natural variability and is the result of the variability observed in known populations. It can be measured by statistical methods, and reflects uncertainties in the data resulting from factors such as random nature in space and time, small sample size, inconsistency, low representativeness (in samples), or poor data management. b) Epistemic uncertainty is model or parameter uncertainty reflecting a lack of knowledge or a subjective or internal uncertainty. It includes uncertainty regarding the veracity of a used scientific theory, or a belief about the occurrence of an event. It is subjective and may vary from one person to another.	
Vulnerability (V)	Probability that **elements at risk** will suffer **consequences (N)** given geohazard impact with a certain severity. For example, **vulnerability** for persons can be defined as the likelihood of fatality given **geohazard** impact, or likelihood of some level of injury. For buildings, it could be defined as the level of damage, measured as a proportion of the building replacement cost or as an absolute cost. May also be defined as the degree of loss to a given element or set of elements.	AGS (2007), BGC discussion

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APPENDIX B
DATA SOURCES

Location				Project			Hazard Type			Reference
Name	**River Basin**	**District**	**NTS ID**	**Project Title**	**Report? (Y/N)**	**Spatial information?**	**Flooding?**	**Landslide?**	**Steep Creek?**	**Citation**
Camp Creek	South Thompson	CSRD	082L15	Camp Creek Slide	Y	N			Y	Department of Highways, 1968. Camp Creek Slide. Report M2-486. 3 pages.
Creighton Valley	South Thompson	RDNO	082L02	Creighton Valley Terrain Stability Mapping	Y	Y - See Terrain Mapping		Y	Y	Golder Associates Ltd., 1998, Creighton Valley Terrain Stability Mapping - FRBC Project #TO96198T, Project No. 972-3104. 18 pages.
Hunters Range	South Thompson	RDNO	082L	Landslide susceptibility from watershed and fan characteristics	Y	N			Y	Eichel, A. and Fuller, T., 2002. Landslide susceptibility from watershed and fan characteristics, Salmon Arm and Vernon Forest Districts. Terrain Stability and Forest Management in the Interior of British Columbia. Technical Report 003. Nelson, BC.
Hunters Range/Eagle River	South Thompson	RDNO/CSRD	082L	N/A	Y	N			Y	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.
Hummingbird Creek	South Thompson	CSRD	082L14	An unusually large debris flow at Hummingbird Creek, Mara Lake, British Columbia	Y	N			Y	Jakob, M., Anderson, D., Fuller, T., Hungr, O., and Ayotte, D. 2000. An unusually large debris flow at Hummingbird Creek, Mara Lake, British Columbia. Canadian Geotechnical Journal 37: 1109-1125.
Fall Creek	South Thompson	RDNO	082L10	Landslide Risk Analysis of Historic Forest Development in the Interior of British Columbia—Challenges Encountered at Fall Creek	Y	N		Y	Y	Smith, F.R., and Vanbuskirk, C.D., 2002. Landslide Risk Analysis of Historic Forest Development in the Interior of British Columbia—Challenges Encountered at Fall Creek. In Terrain Stability and Forest Management in the Interior of British Columbia: Workshop Proceedings: May 23-25, 2001 Nelson, British Columbia, Canada.
Hummingbird Creek	South Thompson	CSRD	082L14	Sediment Coring at Swansea Point Fan Delta, Mara Lake, British Columbia	Y	N			Y	Fuller, T., 2002. Sediment Coring at Swansea Point Fan Delta, Mara Lake, British Columbia—Application of a Coring Method to Determine Historical Debris Flow Events. In Terrain Stability and Forest Management in the Interior of British Columbia: Workshop Proceedings: May 23-25, 2001 Nelson, British Columbia, Canada.
South Thompson	South Thompson	TNRD		South Thompson Settlement Strategy - Map 09 Natural Hazards	Y	N	Y	Y	Y	Thompson Nicola Regional District, 2011. South Thompson Settlement Strategy - Map 09 Natural Hazards. Schedule "A" of Bylaw No. 1888.
McIntyre Creek	South Thompson	CSRD	082L14	2014 McIntyre Creek Debris Flow	Y	N			Y	Westrek Geotechnical Services Ltd., 2015. 2014 McIntyre Creek Debris Flow Emergency Response and Investigation Findings. File 014-024.
Robinson Creek	South Thompson	CSRD	082L14	2017 Robinson Creek Debris Flow	Y	N			Y	Westrek Geotechnical Services Ltd., 2017. Summary of Emergency Response Activities and Intitial Geotechnical Assessment of the 2017 Robinson Creek Debris Flow. File 017-053.
Paraglacial fans I	Thompson	TNRD	092L	Some aspects of the morphology of paraglacial alluvial fans in South-Central British Columbia	Y	N			Y	Ryder, J. 1971. Some aspects of the morphology of paraglacial alluvial fans in South-Central British Columbia. Canadian Journal of Earth Sciences 8: 1252-1264.
Paraglacial fans II	Thompson	TNRD	092L	The stratigraphy and morphology of paraglacial alluvial fans in British Columbia	Y	N			Y	Ryder, J. 1971. SThe stratigraphy and morphology of paraglacial alluvial fans in British Columbia. Canadian Journal of Earth Sciences 8: 279-298.
Eagle River Valley	South Thompson	CSRD	082L	Debris torrent hazards along Highway 1 Sicamous to Revelstoke	Y	N			Y	Thurber Consultants Ltd. 1987. Debris torrent hazards along Highway 1 Sicamous to Revelstoke. File 15-3-51.
Sicamous Creek	South Thompson	Sicamous	082L15	Detailed terrain mapping of the Sicamous Creek Community Watershed	Y	Y - See Terrain Mapping			Y	Terratech Consulting Ltd. 1998, Detailed terrain mapping (TSIL C) of the Sicamous Creek Community Watershed. File 425-8
Silver Creek	South Thompson	CSRD	082L11	The Silver Creek Fire Watershed Hazards Assessment	Y	N			Y	Winkler, R., Giles, T., Turner, K., Hope, G., Bird, S., Schwab, K., Hogan, D., and Anderson, D., 1998. The Silver Creek Fire Watershed Hazards Assessment.
Loon Lake	Bonaparte	TNRD	092P03	Post-wildfire geohazard risk assessment: Elephant Hill Fire	Y	Y			Y	BGC Engineering Inc., 2017. Post-wildfire geohazard risk assessment: Elephant Hill Fire, BC. Project 1114012
Loon Lake	Bonaparte	TNRD	092P03	Detailed Post-Wildfire Natural Hazard Risk Assessment	Y	N			Y	Westrek Geotechnical Services Ltd. 2018. Detailed Post-Wildfire Natural Hazard Risk Assessment. Properties along the Northwest Side of Loon Lake Within the Elephant Hills Fire (K20637) Perimeter Loon Lake, BC. File No. 017-240.
Nicoamen Village	Thompson	TNRD	092I06	Nicoamen Forest Service Road	Y	N	Y		Y	BGC
Nicoamen Village	Thompson	TNRD	092I06	Nicoamen Village	Y	N	Y		Y	BGC

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Silver Creek	South Thompson	CSRD	082L11	Silver Creek Detailed Terrain Mapping	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Consultants Ltd., 1999. Detailed terrain mapping with interpretations for terrain stability, surface erosion potential, landslide induced stream sedimentation, and sediment delivery potential. Salmon Arm Forest District.
Deadman River	Thompson	TNRD	092I15	Deadman River Channel Stability Analysis	Y	N				Miles, M., 1995. Deadman River Channel Stability Analysis. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 2310.
Cornwall Creek	Thompson	TNRD	092I14	Cornwall Creek Community Watershed	Y	N	Y			Integrated Woods Services Ltd. 1997, Cornwall Creek Community Watershed Level 1 Interior Watershed Assessment Procedure.
Criss Creek	Thompson	TNRD	092I14	Lower Criss Creek Sub-basin, Reconnaissance Channel Assessment Procedure	Y	N	Y			Integrated Woods Services Ltd., 2000. Lower Criss Creek Sub-basin, Reconnaissance Channel Assessment Procedure.
Durand Creek	Thompson	TNRD	092I10	Durand Creek Watershed	Y	N	Y			Integrated Woods Services Ltd., 1998. Durand Creek Watershed. Level 1 Interior Watershed Assessment Procedure.
East Murray/Twaal Creek	Thompson	TNRD	092I	East Murray Sub-Basin and Twaal Creek Watershed	Y	N	Y			Integrated Woods Services Ltd. 2001. East Murray Sub-Basin and Twaal Creek Watershed. Channel conditions and prescriptions assessment/watershed assessment update.
Jimmies Creek	Thompson	TNRD	092I	Jimmies Creek Community Watershed	Y	N	Y			Integrated Woods Services Ltd. 1997, Jimmies Creek Community Watershed Level 1 Interior Watershed Assessment Procedure.
Debris Flow Bibliography	All	All	All	Bibliography Canadian Subaerial Channelized Debris Flows	Y	N			Y	VanDine, D.F., 2000. Bibliography Canadian Subaerial Channelized Debris Flows.
Murrary Creek/Twaal Creek	Thompson	TNRD	092I	Murrary Creek Community Watershed and Twaal Creek Watershed	Y	N	Y			Integrated Woods Services Ltd., 1999. Overview Channel Conditions and Prescriptions Assesssment in the Murrary Creek Community Watershed and Twaal Creek Watershed
Tranquille River	Thompson	TNRD	092I	Watershed Risk Analysis for Tranquille River.	Y	N	Y			M.J. Milne & Associates Ltd., 2009. Watershed Risk Analysis for Tranquille River.
Nicoamen River	Thompson	TNRD	092I03	Nicoamen River Watershed, Hydrologic Review	Y	N	Y			Integrated Woods Services Ltd., 2000. Nicoamen River Watershed, Hydrologic Review.
Ross Creek	South Thompson	CSRD	082L14	Channel and Debris Flow Risk Assesment of Ross Creek	Y	N	Y		Y	M.J. Milne & Associates Ltd., and Grainger and Associates Consulting Ltd., 2002. Channel and debris flow risk assessment of Ross Creek.
Finn Creek	North Thompson	TNRD	082M	Interior Watershed Assessment for the Finn Creek Watershed.	Y	N	Y			Dobson Engineering Ltd., 1997. Interior Watershed Assessment for the Finn Creek Watershed.
Wylie Creek	North Thompson	TNRD	092P09	Reconnaissance watershed assessment of Wylie Creek Study Area	Y	N	Y			Summit Environmental Consultants Ltd., 2000. Reconnaissance waterhsed assessment of Wylie Creek Study Area. Project #770.3
Tranquille River/Peterson River	Thompson/North Thompson	TNRD	092I15/092P(	Tranquille-Watching and Peterson-Rosen Community Watersheds.	y	Y - See Terrain Mapping			Y	Denny Maynard & Associates Ltd., 2002. Upgrade of terrain classification, terrain stability, surface erosion potential, and sediment delivery potential of Tranquille-Watching and Peterson-Rosen Community Watersheds.
Eakin Creek/Lemieux Creek	North Thompson	TNRD	092P	Eakin Creek and Lemieux Creek Detailed Terrain Stability Mapping	Y	Y - See Terrain Mapping			Y	AMEC Earth and Environmental Ltd., 2001. Eakin Creek and Lemieux Creek Detailed Terrain Stability Mapping Kamloops Forest District. Job No. KX12459
Sicamous Creek	South Thompson	Sicamous	082L15	Interior Watershed Assessment for the Sicamous Creek Watershed	Y	N			Y	Dobson Engineering Ltd., 1998. Interior Watershed Assesment for the Sicamous Creek Watershed.
Cooke Creek	South Thompson	RDNO	082L10	Maintenance of the Cooke Creek Forest Service Road near Enerby	Y	N			Y	Forest Practices Board, 2016. Maintenance of the Cooke Creek Forest Service Road near Enerby. Complaint Investigation #15083.
Cedar Hills	South Thompson	CSRD	082L11	Post-wildfire landslides in Southern British Columbia	Y	N			Y	Jordan, P., 2012. Post-wildfire landslides in Southern British Columbia. In 11th Internation & 2nd North American Symposium on Landslides, Banff, Alberta, Canada, June 3-8, 2012.
Chase Creek	South Thompson	CSRD	082L12	Investigations of 22 landslides in Upper Chase Creek, B.C.	Y	N		Y	Y	Grainger, B., 2002. Investigations of 22 landslides in Upper Chase Creek, B.C.
Mile 5.5	Thompson	TNRD	092I03	5.5 Mile Debris Fence	Y	N			Y	Bichler, A., Yonin, D., Stelzer, G., N.D. Flexible debris flow mitigation: introducting the 5.5 Mile Debris Fence.
Hummingbird Creek	South Thompson	CSRD	082L14	Community of Swansea Point, Sicamous, British Columbia.	Y	N			Y	Singh, N., 2004. Quantitative Analysis of Partial Risk from Debris Flows and Debris Floods: Community of Swansea Point, Sicamous, British Columbia. In Landslide Management Handbook 56. Landslide Risk Case Studies in Forest Development Planning and Operations.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Bonaparte River	Bonaparte	TNRD	092I14	Floodplain Mapping Bonaparte River at Cache Creek	Y	Y - See Floodplain Mapping	Y			KPA Engineering, 1996. Floodplain Mapping Bonaparte River at Cache Creek. Design Brief. File 5739 008 00 02
Bonaparte River	Bonaparte	TNRD	092I	Lower Bonaparte River Watershed	Y	N	Y			Integrated Woods Services Ltd., 1998. Lower Bonaparte River Watershed Level 1 Interior Watershed Assessement Procedure.
Chase Creek	South Thompson	CSRD	082L12	Chase Creek Hydrologic Assessment	Y	N	Y			Dobson Engineering Inc. 2004. Chase Creek Hydrologic Assessment Impact of Mountain Pine Beetle Infestations on Peak Flows
Charcoal Creek	South Thompson	CSRD	082L12	Charcoal Creek Detailed Terrain Stability Mapping	Y	Y - See Terrain Mapping	Y		Y	EBA Engineering Consultants Ltd., 2000. Charcoal Creek Detailed Terrain Stability Mapping (TSIL C). EBA Project No. 0801-99-81086
Chase Creek	South Thompson	CSRD	082L12	Hydrology of the Chase Creek watershed	Y	N	Y			Dobson Engineering Inc. 2005. Hydrology of the Chase Creek watershed. FIA Activity 2029021
Bonaparte River	Bonaparte	TNRD	092I	Bonaparte River Interior Watershed Assessment	Y	N	Y			Bioterra Consulting, 1997. Bonaparte River Interior Watershed Assessment
Cedar Hills	South Thompson	CSRD	082L11	Post-wildfire landslides in southern British Columbia	Y	N			Y	Jordan, P., 2012. Post-wildfire landslides in southern British Columbia. 11th International & 2nd North American Symposium on Landslides, Banff, Alberta, Canada, 3-8 June, 2012.
Cedar Hills	South Thompson	CSRD	082L11	Developing a risk analysis procedure for post-wildfire mass movement and flooding in British Columbia.	Y	N			Y	Jordan, P., Turner, K., Nicol, D., Boyer, D. 2006. Developing a risk analysis procedure for post-wildfire mass movement and flooding in British Columbia. 1st Specialty Conference on Disaster Mitigation. Calgary, Alberta, Canada. May 23-26, 2006.
Cedar Hills	South Thompson	CSRD	082L11	Debris flows and floods following the 2003 wildfires in Southern British Columbia.	Y	N			Y	Jordan, P., and Covert, S.A., 2009. Debris flows and floods following the 2003 wildfires in Southern British Columbia. Environmental & Engineering Geoscience 15 (4): 217-234.
Thompson	Thompson	TNRD	092I	Quaternary stratigraphy and geomorphology of the Lower Thompson Valley, British Columbia.	Y	N				Anderton, L. J., 1970. Quaternary stratigraphy and geomorphology of the Lower Thompson Valley, British Columbia. Unpublished MSc. Thesis, University of British Columbia.
Mabel Lake	South Thompson	RDNO	082L	Mabel Lake Tributaries Interior Watershed Assessment	Y	N	Y			Wildstone Group, N.D., Mabel Lake Tributaries Interior Watershed Assessment
Thompson River	Thompson	TNRD	092I	South Thompson River (Kamloops to Chase) Floodplain Mapping.	Y	Y - See Floodplain Mapping	Y			BC Water Surveys Unit and Canada-BC Floodplain Mapping Program. 1976. South Thompson River (Kamloops to Chase) Floodplain Mapping. BC Ministry of Environment.
Hunters Range	South Thompson	CSRD	082L	Hunters Range (Kingfisher)	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd., 2001. Detailed Terrain Stability Mapping (TSIL C) Hunters Range (Kingfisher). File 425-13
Upper Momich	South Thompson	TNRD	082M	Upper Momich Drainage	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd., 1999. Detailed Terrain Stability Mapping (TSIL C) of Upper Momich Drainage
Pisima Face	South Thompson	TNRD	082M	Pisima Face Area Within Forest License A18693	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd., 1999. Detailed Terrain Stability Mapping (TSIL C) of Pisima Face Area within Forest License A18693
Hummingbird Creek/Mara Creek	South Thompson	CSRD/RDNO	082L	Hummingbird Creek and Mara Creek Watersheds	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd., 1999. Detailed Terrain Stability Mapping (TSIL C) Hummingbird Creek and Mara Creek Watersheds
Brash Creek/Siddle Creek/Ashton Creek	South Thompson	RDNO	082L	Detailed Terrain Mapping Brash, Siddle, and Ashton Creeks	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd. 1998. Detailed Terrain Mapping with Interpretations for Slope Stability, Erosion Potential, and Sediment Transfer - Brash, Siddle, and Ashton Creeks. File 425-7
Hiuihill Creek	South Thompson	TNRD	082M	Watershed Assessment of Hiuihill Creek Watershed.	Y	N	Y			Summit Environmental Consultants Ltd., 2002. Watershed Assessment of Hiuihill Creek Watershed. File 037-13.00
Upper Momich	South Thompson	TNRD	082M	Reconnaissance watershed assessment of Upper Momich River Watershed	Y	N	Y			Summit Environmental Consultants Ltd. 1999. Reconnaissance waterhsed assessment of Upper Momich River Watershed. Project 802
Corning Creek	South Thompson	CSRD	082L13	Interior Watershed Assessment for the Corning Creek Watershed	Y	N	Y		Y	Silvatech Consulting Ltd. 2000. Interior Watershed Assessment for the Corning Creek Watershed.
Tumtum Lake	South Thompson	TNRD	082M14	Reconnaissance Channel Assessments of East Facing Tributaries of Tumtum Lake.	Y	N	Y			Silvatech Consulting Ltd. 2000. Interior Watershed Assessment for the Corning Creek Watershed.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Sinmax Creek	South Thompson	TNRD	082M04	Sinmax Creek Watershed	Y	N	Y			Silvatech Consulting Ltd. 1999. Interior Watershed Assessment Procedure for the Sinmax Creek Watershed.
Kingfisher Creek/Cooke Creek/Noisy Creek	South Thompson	RDNO	082L10	Kingfisher, Cooke, and Noisy Creek Watersheds.	Y	N	Y			Silvatech Consulting Ltd. 1998. Interior Watershed Assessment Procedure for the Kingfisher, Cooke, and Noisy Creek Watersheds.
Spapilem Creek	South Thompson	TNRD	082M04	Spapilem Operating Area.	Y	N	Y			Silvatech Consulting Ltd. 1998. Channel Assesment Procedure for the Spapilem Operating Area.
Momich River/Cayenne Creek	South Thompson	TNRD	082M06	Momich River/Cayenne Creek Watershed	Y	N	Y			Silvatech Consulting Ltd. 1996. Bell Pole Co. Ltd. Level 1 IWAP Overview Conditions Assessments for the Momich River/Cayenne Creek Watershed.
Fisher Creek	South Thompson	TNRD	082M06	Fisher Creek Operating Area.	Y	Y - See Terrain Mapping		Y	Y	Redding, T., and Giles, T., 1999. Detailed Terrain Stability Mapping of the Fisher Creek Operating Area.
Monashee Creek/Yeoward Creek	South Thompson	RDNO	082L01	Monashee/Yeoward Creeks Terrain Stability Report.	Y	Y - See Terrain Mapping		Y	Y	Quaterra Environmental Consulting Ltd. 2001. Monashee/Yeoward Creeks Terrain Stability Report.
Hidden Lake/Sowsap Creek	South Thompson	RDNO	082L10	Hidden Lake/Sowsap Creek Area Terrain Stability Report.	Y	Y - See Terrain Mapping		Y	Y	Quaterra Environmental Consulting Ltd. 2000. Hidden Lake/Sowsap Creek Area Terrain Stability Report.
Trinity Creek	South Thompson	RDNO	082L	Trinity Operating Area Terrain Stability Report	Y	Y - See Terrain Mapping		Y	Y	Quaterra Environmental Consulting Ltd. 1999. Trinity Operating Area Terrain Stability Report
Salmon River	South Thompson	CSRD		Salmon River Tributaries Terrain Stablity Report.	Y	Y - See Terrain Mapping		Y	Y	Quaterra Environmental Consulting Ltd. 1999. Trinity Operating Area Terrain Stability Report
Flood Protection Works - Appurtenant Structures	All	All	N/A	Flood Protection Works - Appurtenant Structures	N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2017. Flood Protection Works - Appurtenant Structures. Digital Dataset. https://catalogue.data.gov.bc.ca/dataset/flood-protection-works-appurtenant-structures
Flood Protection Works - Structural Works	All	All	N/A	Flood Protection Works - Structural Works	N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2017. Flood Protection Works - Structural Works. Digital Dataset. https://catalogue.data.gov.bc.ca/dataset/flood-protection-works-appurtenant-structures
Mapped Floodplains in BC (Historical).	All	All	N/A	Mapped Floodplains in BC (Historical).	N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2017. Mapped Floodplains in BC (Historical). Digital Dataset. https://catalogue.data.gov.bc.ca/dataset/mapped-floodplains-in-bc-historical
Alluvial fans - Lau	All	All	N/A	Channel scour on temperate alluvial fans on British Columbia.	Y	Y			Y	Lau, C.A., 2017. Channel scour on temperate alluvial fans on British Columbia. Unpublished M.Sc. Thesis, Simon Fraser University.
Historical Floods and Landslides	All	All	N/A	Flooding and Landslide Events Southern British Columbia	Y	BGC to Digitize Locations			Y	Septer, D. 2007. Flooding and Landslide Events Southern British Columbia 1808-2006. Ministry of the Environment
Terrain Mapping	All	All	N/A	Terrain Mapping	N	Y		Y	Y	Ministry of Environment and Climate Change Strategy, 2016. Digital Dataset dated 16 Sep 2016. http://www.env.gov.bc.ca/esd/distdata/ecosystems/TEI/TEI_Data/
All	All	All	N/A	Historical DriveBC Events	N	Y				Ministry of Transportation and Infrastructure, 2018. Historical DriveBC Events. Digital Data Source. https://catalogue.data.gov.bc.ca/dataset/historical-drivebc-events
Mabel Lake	South Thompson	RDNO	082L	Mabel Lake Reconnaissance Terrain Stability Report	Y	Y - See Terrain Mapping		Y	Y	Quaterra Environmental Consulting Ltd., 1998. Mabel Lake Reconnaissance Terrain Stability Report.
Bessette Creek	South Thompson	RDNO	082L	Bessette Creek Basin Storage Study	Y	N	Y			Government of British Columbia. 1977. Bessette Creek Basin Storage Study
Johnson Lake	South Thompson	TNRD	082M04	Johnson Creek Hydrology	Y	N	Y			Department of Lands, Forests, and Water Resources, 1975. Johnson Creek Hydrology
Shuswap River	South Thompson	RDNO	082L11	Shuswap River Flood Plain Mapping	Y	Y - See Floodplain Mapping	Y			Province of British Columbia, N.D., Shuswap River Flood Plain Mapping

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Shuswap River/Bessette Creek/Duteau Creek	South Thompson	RDNO	082L	Floodplain Mapping Program, Shuswap River, Bessette and Duteau Creeks Design Brief	Y	Y - See Floodplain Mapping	Y			Klohn-Cripper Consultants Ltd. 1998. Floodplain Mapping Program, Shuswap River, Bessette and Duteau Creeks Design Brief.
Fortune Creek	South Thompson	RDNO	082L	Fortune Creek Hydrology Study	Y	Y - See Floodplain Mapping	Y			Ministry of Environment. 1978. Fortune Creek Hydrology Study
Duteau Creek	South Thompson	RDNO	082L03	Duteau Creek Hydrology Division Report	Y	N	Y			British Columbia Water Resources Service. 1974. Duteau Creek Hydrology Division Report.
Salmon River	South Thompson	CSRD	082L11	Floodplain Mapping Program, Salmon River Shuswap Lake to Spa Creek Design Brief	Y	Y - See Floodplain Mapping	Y			Crippen Consultants. 1990. Floodplain Mapping Program, Salmon River Shuswap Lake to Spa Creek Design Brief
Scotch Creek	South Thompson	CSRD	082M03	Channel Assessment Procedure for Scotch Creek	Y	N	Y			Dobson Engineering Inc., 1997. Channel Assessment Procedure for Scotch Creek.
Harris Creek	South Thompson	RDNO	082L02	Interior Watershed Assessment for the Harris Creek Watershed	Y	N	Y			Dobson Engineering Inc., 1997. Interior Watershed Assessment for the Harris Creek Watershed
Duteau Creek	South Thompson	RDNO	082L03	Interior Watershed Assessment for the Duteau Creek Watershed	Y	N	Y			Dobson Engineering Ltd., 1999. Interior Watershed Assessment for the Duteau Creek Watershed.
Scotch Creek	South Thompson	CSRD	082M03	Results of the Interior Watershed Assessment Procedure for the Scotch Creek Watershed	Y	N	Y			Dobson Engineering Ltd., 1999. Results of the Interior Watershed Assessment Procedure for the Scotch Creek Watershed
Cherry Creek	Thompson	TNRD	092I	Hydrologic Assessment of the Cherry Creek Watershed	Y	N	Y			Dobson Engineering Ltd., 2000. Hydrologic Assessment of the Cherry Creek Watershed
Wap Creek	South Thompson	RDNO	082L	Results of the Interior Watershed Assessment Procedure for the Wap Creek Watershed	Y	N	Y			Dobson Engineering Ltd. 2000. Results of the Interior Watershed Assessment Procedure for the Wap Creek Watershed.
Twig Creek	South Thompson	TNRD	082L05	Watershed Condition Report for Twig Creek	Y	N	Y			Dobson Engineering Ltd. 2001. Watershed Condition Report for Twig Creek.
Weyman Creek	South Thompson	TNRD	082L05	Watershed Condition Report for Weyman Creek	Y	N	Y			Dobson Engineering Ltd. 2001. Watershed Condition Report for Weyman Creek.
Nikwikwaia Creek	South Thompson	CSRD	082L04	Terrain Stability and Hydrology of the Nikwikwaia Creek Watershed	Y	Y - See Terrain Mapping	Y	Y	Y	Dobson Engineering Ltd. N.D. Terrain Stability and Hydrology of the Nikwikwaia Creek Watershed
Celista Creek/Sim Creek/Pickett/Syphon/Palmer Creek	South Thompson	CSRD	082M	Celista Creek-Humamilt Lake, Sim Creek, and Pickett-Syphon-Palmer Creek Watersheds	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc. 1997, Reconnaissance Terrain Stability Mapping (TSIL D) for the Celista Creek-Humamilt Lake, Sim Creek, and Pickett-Syphon-Palmer Creek Watersheds
Sugar Lake	South Thompson	CSRD	082L	Sugar Lake, Vernon Forest District, British Columbia.	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 1998. Detailed Terrain Stability Mapping, Sugar Lake, Vernon Forest District, British Columbia. File 0806-97-87495
Sugar Lake/Gates Creek	South Thompson	CSRD	082L	Sugar Lake and Gates Creek Areas, British Columbia.	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 1999. Detailed and Reconnaissance Terrain Mapping with Interpretation of Terrain Stability, Erosion Potential and Potential Fine Sediment Transfer, Sugar Lake and Gates Creek Areas, British Columbia. Project No. 0801-98-87752.
Creighton Creek/Ferry Creek	South Thompson	CSRD	082L	Upper Creighton Creek and Ferry Creek	Y	N	Y			EBA Engineering Inc., 1999. Interim Interior Watershed Assessment Procedure Upper Creighton Creek and Ferry Creek
Creighton Creek/Bonneau Creek/Ferry Creek	South Thompson	CSRD	082L	Upper Creighton Creek, Bonneau Creek, Ferry Creek	Y	N	Y			EBA Engineering Inc., 1999. Reconnaissance Channel Assessment Procedure (ReCAP) As Part of the Interior Watershed Assessment Procedure for Upper Creighton Creek, Bonneau Creek, Ferry Creek.
Scotch Creek/Kwikoit Creek/Corning Creek	South Thompson	CSRD	082M03	Scotch Creek, Kwikoit Creek, Corning Creek	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 1999. Detailed and Reconnaissance Terrain Mapping with Interpretation of Terrain Stability, Erosion Potential and Sediment Transfer Potential

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Blueberry Creek/Skimikin Lake	South Thompson	CSRD	082M/082L	Blueberry Creek and Skimikin Lake Terrain Stability Mapping	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 2000. Salmon Arm Forest District Federated Co-operatives Limited Operating Area (Blueberry Creek and Skimikin Lake) Terrain Stability Mapping
Squilax Creek/ Broderick Creek/ Reinecker Creek	South Thompson	CSRD	082L	Squilax, Broderick Creek, Reinecker Creek, TFL 33.	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 2001. Salmon Arm Forest District Federated Co-operatives Limited Detailed Terrain Stability Mapping Squilax, Broderick Creek, Reinecker Creek, TFL 33. EBA Project No. 0801-00-81153
Reiter Creek/Holstein Creek	South Thompson	CSRD	082L	Reiter and Holstein Creeks Bobbie Burns Mountain	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 2002 Detailed Terrain Stability Mapping Reiter and Holstein Creeks Bobbie Burns Mountain
Wap Creek	South Thompson	RDNO	082L15	Detailed Terrain Stability Mapping Wap Creek	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Inc., 2002. Detailed Terrain Stability Mapping Wap Creek.
Shuswap Lake and Mara Lake	South Thompson	CSRD	082L	Shuswap Watershed Mapping Project	Y	N	Y			Ecoscape Environmental Consultants Ltd., 2009. Shuswap Watershed Mapping Project - Foreshore Inventory and Mapping
Anstey River/Eagle River	South Thompson	CSRD	082L/082M	Anstey and Eagle River Watersheds	Y	N	Y			Forsite Forest Management Consultants, 1998. Anstey and Eagle River Watersheds Level 1 Interior Watershed Assessment and Report
Celista Creek	South Thompson	CSRD	082M06	Celista Creek (Humamilt Lake)	Y	N	Y			Forsite Forest Management Consultants, 1998. Celista Creek (Humamilt Lake) Watershed Channel Assessment Procedure (CAP)
Salmon River	South Thompson	CSRD	082L	The stability of stream channels within the Salmon River Watershed	Y	N	Y			Forsite Forest Management Consultants, 1998. The stability of stream channels within the Salmon River Watershed
Adams River	South Thompson	TNRD	082M	Upper Adams Watershed Risk Analysis	Y	N	Y		Y	Forsite Forest Management Specialists, 2005. Upper Adams Watershed Risk Analysis
Hiuhill Creek	South Thompson	TNRD	082M	Hui Hill Level 1 Interior Watershed Assessment British Columbia	Y	N	Y			Golder Associates Ltd. 1996. Hui Hill Level 1 Interior Watershed Assessment British Columbia
Onyx Creek	South Thompson	CSRD	082L14	Onyx Creek Watershed Salmon Arm, B.C.	Y	N	Y			Golder Associates Ltd. 1996. Level 1 - Interior Watershed Assessment Onyx Creek Watershed Salmon Arm, B.C.
Brash Creek	South Thompson	RDNO	082L	Brash Creek Watershed.	Y	N	Y			Dobson Engineering Inc., 1998. Interior Watershed Assessment for the Brash Creek Watershed.
Robert Creek	South Thompson	TNRD	082M12	Robert Creek Watershed Assessment	Y	N	Y			Integrated Woods Services Ltd. 2000. Robert Creek Watershed Assessment
Duteau Creek	South Thompson	RDNO	082L03	Duteau Creek Watershed Assessment	Y	N	Y			Kerr Wood Leidal and Dobson Engineering Ltd., 2008. Duteau Creek Watershed Assessment & Recommendations for Source Protection.
Seymour Arm	South Thompson	CSRD	082M	Soil and Terrain of the Seymour Arm Area	Y	N			Y	Kowall, R.C., 1980. Soil and Terrain of the Seymour Arm Area (N.T.S. Map 82M)
Salmon River	South Thompson	CSRD	082L	Floodplain Mapping Program Salmon River Spa Creek to Falkland	Y	Y - See Floodplain Mapping	Y			KPA Engineering Ltd., 1991. Floodplain Mapping Program Salmon River Spa Creek to Falkland.
Hiuhill Creek	South Thompson	TNRD	082M	Channel Stability Mapping Hiuihill Creek	Y	N	Y			M. Miles and Associates, 1995. Channel Stability Mapping Hiuihill Creek Between Km 0 and Km 25
Salmon River	South Thompson	CSRD	082L	Salmon River Channel Stability Analysis	Y	N	Y			M. Miles and Associates, 1995. Salmon River Channel Stability Analysis
Harris Creek	South Thompson	RDNO	082L02	Watershed Risk Assessment for Harris Creek	Y	N	Y			M.J. Milne & Associates, 2010. Watershed Risk Assessment for Harris Creek
Eagle-Perry Area	South Thompson	CSRD	082M	Detailed Terrain Stabiltiy Report Eagle-Perry Area	Y	N		Y	Y	R.T. Banting Engineering Ltd., 2001. Detailed Terrain Stabiltiy Report TSIL "C" Eagle-Perry Area.
Adams Lake	South Thompson	TNRD	082M	Adams Lake TSIL D Reconnaissance Slope Stability	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd. 1998. FL A18693 - Adams Lake Kamloops and Clearwater Forest Districts TSIL D Reconnaissance Slope Stability
Campbell Creek	South Thompson	TNRD	092I	Campbell Creek Watershed	Y	N	Y			Ministry of Environment, 1989. Campbell Creek Watershed
Hummingbird Creek	South Thompson	CSRD	082L	Forest Practices and the Hummingbird Creek Debris Flow	Y	N			Y	Forest Practices Board, 2001. Forest Practices and the Hummingbird Creek Debris Flow
Fishtrap Creek	North Thompson	TNRD	092P01	Short term morphodynamics of Fishtrap Creek following wildfire	Y	N	Y			Christie, A., 2010. A stream in transition : short term morphodynamics of Fishtrap Creek following wildfire. Unpublished M.Sc. Thesis, University of British Columbia.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Thompson River	Thompson	TNRD	092I	Thompson and North Thompson Rivers (Kamloops Area) Floodplain Mapping	Y	Y - See Floodplain Mapping	Y			BC Water Surveys Unit and Canada-BC Floodplain Mapping Program. 1976. Thompson and North Thompson Rivers (Kamloops Area) Floodplain Mapping and BC Water Surveys Data. BC Ministry of Environment.
Thompson River	Thompson	TNRD	092I	Thompson River Data	Y	N	Y			Barr, L. 1989. Thompson River Data (Thompson, North Thompson, South Thompson Rivers). BC Ministry of Environment.
Deception Creek/Spanish Creek	North Thompson	CRD	092P01	Deception/Spanish Creek Watershed.	Y	N	Y			AIM Environmental Consultants Ltd. 1997. Results of the Interior Watershed Assessment Procedure for the Deception/Spanish Creek Watershed. Prepared for Weldwood Canada Ltd.
Hellroar Creek	North Thompson	TNRD	083D03	Interior Watershed Assessment for the Hellroar Creek Watershed.	Y	N	Y			Dobson Engineering Ltd. 1997. Interior Watershed Assessment for the Hellroar Creek Watershed. Prepared for Weyerhauser Canada Ltd.
Jamieson Creek	North Thompson	TNRD	092I	Level 1 Channel Assessment for the Jamieson Creek Watershed: Final Report	Y	N	Y			Dobson Engineering Ltd. 1999. Level 1 Channel Assessment for the Jamieson Creek Watershed: Final Report. Prepared for Weyerhauser Canada Ltd.
Louis Creek/Vavenby	North Thompson	TNRD	082M	North Thompson River Flood Hazard Risk Assessment	Y	N	Y			Doyle Engineering. 2006. Priority sites for improved flood protection on the North Thompson River from Exlou to Vavenby. Prepared for Thompson-Nicola Regional District
Fishtrap Creek	North Thompson	TNRD	092P01	Wildfire, morphologic change and bed material transport at Fishtrap Creek, British Columbia.	Y	N	Y			Eaton, B, Andrews, A, Giles, T and Phillips, J. 2010. Wildfire, morphologic change and bed material transport at Fishtrap Creek, British Columbia. Geomorphology 118:409-424.
Fishtrap Creek	North Thompson	TNRD	092P01	Fishtrap Creek Watershed Project.	Y	N	Y			Eaton, B, Giles, T, Heise, B, Moore, RD, Owens, P and Petticrew, E. 2010. Fishtrap Creek Watershed Project. Streamline Watershed Management Bulletin. 14(1):12-13.
Fishtrap Creek	North Thompson	TNRD	092P01	Forest fire, bank strength and channel instability: the 'unusual" response o fFishtrap Creek, British Columbia.	Y	N	Y			Eaton, B, Moore, RD and Giles, T. 2010. Forest fire, bank strength and channel instability: the 'unusual" response o fFishtrap Creek, British Columbia. Earth Surface Processes and Landforms 35:1167-1183.
Fishtrap Creek	North Thompson	TNRD	092P01	The broader significance of the morphologic life cycle - Watershed Response to the McLure Forest Fire	Y	N	Y			Eaton, B. 2008. Channel morphology, aquatic habitat, and disturbance: The broader significance of the morphologic life cycle - Watershed Response to the McLure Forest Fire. Streamline Watershed Management Bulletin 12(1):10-11.
Fishtrap Creek	North Thompson	TNRD	092P01	Predicting the range of potential morphologic changes - Watershed Response to the McLure Forest Fire.	Y	N	Y			Eaton, B. 2008. UBC Regime Model: Predicting the range of potential morphologic changes - Watershed Response to the McLure Forest Fire. Streamline Watershed Management Bulletin 12(1):10.
Fishtrap Creek	North Thompson	TNRD	092P01	Fishtrap Creek Workshop: Watershed Response to the MacLure Forest Fire.	Y	N	Y			Eaton, B. 2008. Workshop Handbook: Fishtrap Creek Workshop: Watershed Response to the MacLure Forest Fire. FORREX and UBC
North Thompson River	North Thompson	TNRD	092P01	North Thompson River (Kamloops to Vavenby) Floodplain Mapping (including Barriere and Clearwater Rivers)	Y	Y - See Floodplain Mapping	Y			BC Water Surveys Unit and Canada-BC Floodplain Mapping Program. 1982. North Thompson River (Kamloops to Vavenby) Floodplain Mapping (including Barriere and Clearwater Rivers). BC Ministry of Environment.
TMEP	All	TNRD	N/A	Trans Mountain Pipeline Expansion Project: Route Physiography and Hydrology.	Y	N	Y			BGC Engineering Inc. 2013. Trans Mountain Pipeline Expansion Project: Route Physiography and Hydrology. Prepared for Trans Mountain Pipeline ULC.
TMEP	All	TNRD	N/A	Trans Mountain Pipeline Expansion Project: Terrain Mapping and Geohazard Inventory	Y	Y		Y	Y	BGC Engineering Inc. 2013. Trans Mountain Pipeline Expansion Project: Terrain Mapping and Geohazard Inventory. Prepared for Trans Mountain Pipeline ULC.
Shannon Creek	North Thompson	TNRD	082M14	Waterpower project scope for the Shannon Creek Waterpower Project.	Y	N	Y			Bieber, W. 2011. Waterpower project scope for the Shannon Creek Waterpower Project. Prepared for Soler Logging Ltd.
Raft Creek	North Thompson	TNRD	082M	West Raft & Raft Residual TSIL D Terrain Stability Mapping (BAPID 4674).	Y	Y - See Terrain Mapping		Y	Y	Bruce Geotechnical Services Ltd. 1999. West Raft & Raft Residual TSIL D Terrain Stability Mapping (BAPID 4674). Prepared for Slocan Forest Products Ltd.
Fishtrap Creek	North Thompson	TNRD	092P01	Interception Loss - Watershed Response to the McLure Forest Fire	Y	N	Y			Carlyle-Moses, D. 2008. Interception Loss - Watershed Response to the McLure Forest Fire. Streamline Watershed Management Bulletin 12(1):3.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Deception Creek/Spanish Creek	North Thompson	CRD	092P01	Deception/Spanish Watershed Integrated Resrource Restoration Plan.	Y	N	Y			Carr Environmental Consultants Ltd. 1998. Deception/Spanish Watershed Integrated Resrource Restoration Plan. Prepared for Weldwood Canada Ltd.
North Thompson River	North Thompson	TNRD	N/A	List of creeks and rivers in the North Thompson River Watershed	Y	N	Y			Chan, B. 1974. List of creeks and rivers in the North Thompson River Watershed. BC Ministry of Environment
Fadear Mountain	North Thompson	TNRD	082M	Fadear Mountain - Moose Meadows Operating Area,	Y	Y - See Terrain Mapping		Y	Y	Denton, J and Giles, T. 1999. Detailed Terrain Stability Mapping of the Fadear Mountain - Moose Meadows Operating Area, BAPID 4945. BC Ministry of Forests and Range.
Fishtrap Creek	North Thompson	TNRD	092P01	Detection of runoff timing changes in pluvial, nival, and glacial rivers of western Canada.	Y	N	Y			Dery, S, Stahl, K, Moore, RD, Whitfield, P, Menounos, B and Burford, JE. 2009. Detection of runoff timing changes in pluvial, nival, and glacial rivers of western Canada. Water Resources Research 45: doi:10.1029/2008WR006975
Foam Creek	North Thompson	TNRD	082M14	Interior Watershed Assessment Procedure Foam Creek.	Y	N	Y			EBA Engineering Consultants Ltd. 2000. Interior Watershed Assessment Procedure Foam Creek. Prepared for Weyerhauser Canada Ltd.
Thompson Plateau	North Thompson	TNRD	092P	Thompson Plateau Risk Analysis.	Y	N	Y		Y	Forsite Consultants Ltd. 2005. Thompson Plateau Risk Analysis. Prepared for Wyerhauser Canada Ltd.
Yellowhead/ Hellroar Creek/Mud Creek/Peddie Creek/Wilkens Creek/Foghorn Creek	North Thompson	TNRD	083M/083D	Risk Assessment for Selected Watersheds in the Headwaters Forest District	Y	N	Y		Y	Forsite Consultants Ltd. 2007. Risk Assessment for Selected Watersheds in the Headwaters Forest District. Prepared for BC Timber Sales.
North Thompson River	North Thompson	TNRD	083D03	Detailed Terrain Stability Mapping of the Upper North Thompson River Area	Y	Y - See Terrain Mapping		Y	Y	Giles, T. 1999. Detailed Terrain Stability Mapping of the Upper North Thompson River Area. BC Ministry of Forests.
Fishtrap Creek	North Thompson	TNRD	092P01	Channel Morphology - Watershed Response to the McLure Forest Fire.	Y	N	Y			Giles, T. 2008. Channel Morphology - Watershed Response to the McLure Forest Fire. Streamline Watershed Management Bulletin 12(1):5.
North Thompson River	North Thompson	TNRD	082M12	Clearwater-Vavenby Community Watersheds Terrain Stability Mapping	Y	Y - See Terrain Mapping		Y	Y	Golder Associates Ltd. 1998. Clearwater-Vavenby Community Watersheds Terrain Stability Mapping (BAPID 4932). Prepared for Slocan Forest Products Ltd.
Leonie Creek/Skowootum Creek/Cayoosh Creek	North Thompson	TNRD	092P01	Leonie and Skowootum Cayoosh Creek Watershed: Overview Assessment	Y	N	Y			Integrated ProAction Corp. 2006. Leonie and Skowootum Cayoosh Creek Watershed: Overview Assessment. Tolko Industries Ltd.
Raft River	North Thompson	TNRD	082M	Raft River Watershed Channel Assessment.	Y	N	Y			Integrated Woods Services Ltd. 2002. Raft River Watershed Channel Assessment. Prepared for Slocal Forest Products Ltd.
Raft River	North Thompson	TNRD	082M	Raft River Level 1 Watershed Assessment.	Y	N	Y			Integrated Woods Services Ltd. 1996. Raft River Level 1 Watershed Assessment. Prepared for Slocal Forest Products Ltd.
Barriere River	North Thompson	TNRD	082M	Barriere River Level 1 Interior Watershed Assessment Procedure	Y	N	Y			Integrated Woods Services Ltd. 1997. Barriere River Level 1 Interior Watershed Assessment Procedure. Prepared for Tolko Industries Ltd.
Lopex Creek	Thompson	TNRD	092I14	Lopex Creek Community Watershed	Y	N	Y			Integrated Woods Services Ltd. 1997. Lopex Creek Community Watershed Level 1 Interior Watershed Assessment Procedure. Prepared for Ainsworth Lumber Co.
Mann Creek	North Thompson	TNRD	092P09	Mann Creek Watershed Assessment Procedure.	Y	N	Y			Integrated Woods Services Ltd. 1997. Mann Creek Watershed Assessment Procedure. Prepared for Slocan Forest Products Ltd.
Birk Creek	North Thompson	TNRD	082M	Birk Creek Channel Conditions and Prescription Assessment.	Y	N	Y			Integrated Woods Services Ltd. 1998. Birk Creek Channel Conditions and Prescription Assessment. Prepared for Tolko Industries Ltd.
Leonie Creek	North Thompson	TNRD	082M	Leonie Creek Community Watershed Channel Conditions and Prescription Assessment.	Y	N	Y			Integrated Woods Services Ltd. 1998. Leonie Creek Community Watershed Channel Conditions and Prescription Assessment. Prepared for Tolko Industries Ltd.
Skowootum Creek	North Thompson	TNRD	082M	Skowootum Creek Community Watershed Channel Conditions and Prescription Assessment.	Y	N	Y			Integrated Woods Services Ltd. 1998. Skowootum Creek Community Watershed Channel Conditions and Prescription Assessment. Prepared for Tolko Industries Ltd.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Barriere River	North Thompson	TNRD	082M	Barriere River Watershed Residual Sub-basin Channel Assessment Procedure.	Y	N	Y			Integrated Woods Services Ltd. 1999. Barriere River Watershed Residual Sub-basin Channel Assessment Procedure. Prepared for Tolko Industries Ltd.
Mann Creek	North Thompson	TNRD	092P09	Final Report: Mann Creek Watershed Assessment Procedure.	Y	N	Y			Integrated Woods Services Ltd. 1999. Final Report: Mann Creek Watershed Assessment Procedure. Prepared for Slocan Forest Products Ltd.
Heffley Creek	North Thompson	TNRD	092I16	Heffley Creek Watershed Assessment Procedure	Y	N	Y			Integrated Woods Services Ltd. 1999. Heffley Creek Watershed Assessment Procedure. Prepared for Tolko Industries Ltd.
Canimred Creek	Bonaparte	CRD	092P15	Level 2 Watershed Assessment for the Canimred Creek Sub-basin	Y	N	Y			Integrated Woods Services Ltd. 1999. Level 2 Watershed Assessment for the Canimred Creek Sub-basin. Slocan Forest Products
Brookfield Creek	North Thompson	TNRD	092P09	Level 2 Watershed Assessment: Brookfield Creek Watershed.	Y	N	Y			Integrated Woods Services Ltd. 1999. Level 2 Watershed Assessment: Brookfield Creek Watershed. Prepared for BC Ministry of Forests.
Louis Creek	North Thompson	TNRD	092P01/092I1	Louis Creek Watershed Assessment Procedure.	Y	N	Y			Integrated Woods Services Ltd. 1999. Louis Creek Watershed Assessment Procedure. Prepared for Tolko Industries Ltd.
Albreda River	North Thompson	TNRD	083D11	Albreda River Watershed Channel Conditions and Prescriptions Assessment.	Y	N	Y			Integrated Woods Services Ltd. 2000. Albreda River Watershed Channel Conditions and Prescriptions Assessment. Prepared for Slocan Forest Products Ltd.
Spahats Creek	North Thompson	TNRD	082M	Spahats Creek Watershed Assessment.	Y	N	Y			Integrated Woods Services Ltd. 2000. Draft: Spahats Creek Watershed Assessment. Prepared for Slocan Group.
Aver Creek/Foghorn Creek/Two Mile Creek	North Thompson	TNRD	082M12	Aver, Foghorn, and Two Mile Creek Watershed Assessments	Y	N	Y			Integrated Woods Services Ltd. 2000. Final Report: Aver, Foghorn, and Two Mile Creek Watershed Assessments. Prepared for Slocal Forest Products Ltd.
Paul Lake	North Thompson	TNRD	092I	Paul Lake Community Watershed Integrated Watershed Restoration Plan and Updated Watershed Assessement	Y	N	Y			Integrated Woods Services Ltd. 2000. Final Report: Paul Lake Community Watershed Integrated Watershed Restoration Plan and Updated Watershed Assessement. Prepared for Weyerhauser Canada Ltd.
East Bone	North Thompson	TNRD	083D03	Review of road and channel conditions for the East Bone Creek Residual Sub-Basin.	Y	N	Y		Y	Integrated Woods Services Ltd. 2000. Review of road and channel conditions for the East Bone Creek Residual Sub-Basin. Prepared for BC Ministry of Forests.
Russell/Haschaek/ McDougal Creek	North Thompson	TNRD	092P09/082M	Watershed Assessment of Russell, Hascheak, and McDougall Creek Community Watersheds.	Y	N	Y			Integrated Woods Services Ltd. 2001. Watershed Assessment of Russell, Hascheak, and McDougall Creek Community Watersheds. Prepared for Weyerhauser Canada Ltd.
Fishtrap Creek	North Thompson	TNRD	092P01	TFL 35 Fishtrap Creek Watershed Detailed Terrain Stability Mapping.	Y	Y - See Terrain Mapping		Y	Y	JM Ryder and Associates Ltd. 1999. TFL 35 Fishtrap Creek Watershed Detailed Terrain Stability Mapping. Prepared for Weyerhauser Canada Ltd.
Blue River	North Thompson	TNRD	083D03	Detailed and Reconnaissance Terrain Stability Mapping of Cedar- Cook-Whitewater, Blue River, Finn Creek and Foam Creek areas (Vavenby)	Y	Y - See Terrain Mapping		Y	Y	JM Ryder and Associates. 1999. Detailed and Reconnaissance Terrain Stability Mapping of Cedar- Cook-Whitewater, Blue River, Finn Creek and Foam Creek areas (Vavenby) BAPID 4772, 4773, 4930, 4774. Prepared for Weyerhauser Canada Ltd.
Avola	North Thompson	TNRD	082M11	Wallace-Loyst-Anderson and Shannon-Wirecache Areas (Vavenby): Detailed and Reconnaissance Terrain Stability Mapping	Y	Y - See Terrain Mapping		Y	Y	JM Ryder and Associates. 1999. Wallace-Loyst-Anderson and Shannon-Wirecache Areas (Vavenby): Detailed and Reconnaissance Terrain Stability Mapping. Prepared for Weyerhauser Canada Ltd.
Brookfield Creek	North Thompson	TNRD	092P09	Canfo - Vavenby Division, Forest Road Risk Management, Risk Evaluation Report.	Y	N			Y	Keystone Environmental Ltd. 2005. Canfo - Vavenby Division, Forest Road Risk Management, Risk Evaluation Report. Prepared for Canfor.
Albreda River/Avola	North Thompson	TNRD	082M14/083D	Terrain classification and terrain stability mapping: Albreda and Messiter Project Areas.	Y	Y - See Terrain Mapping		Y	Y	Madrone Environmental Services Ltd. 2007. Terrain classification and terrain stability mapping: Albreda and Messiter Project Areas. Prepared for BC Timber Sales.
Louis Creek	North Thompson	TNRD	092P01/092I1	Hydrotechnical assessment: Louis Creek Watershed	Y	N	Y		Y	Miles, M and Associates Ltd. 1996. Hydrotechnical assessment: Louis Creek Watershed. Prepared for BC Ministry of Environment

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Russell/Haschaek/ McDougal Creek	North Thompson	TNRD	092P09/082N	Watershed Risk Analysis and Forest Development Suitability Report for Russell, Hascheak and MacDougal Creeks	Y	N	Y			MJ Milne and Associates Ltd. 2010. Watershed Risk Analysis and Forest Development Suitability Report for Russell, Hascheak and MacDougal Creeks. Prepared for Wells Gray Community Forest Corporation.
Fishtrap Creek	North Thompson	TNRD	092P01	Introduction to the Fishtrap Creek Study - Watershed Response to the McLure Forest Fire.	Y	N	Y			Moore, RD. 2008. Introduction to the Fishtrap Creek Study - Watershed Response to the McLure Forest Fire. Streamline Watershed Management Bulletin 12(1):1-2.
South Thompson River	South Thompson	City of Kamlo	092I09	South Thompson River Watershed Management Study	Y	N	Y			Northwest Hydraulic Consultants Ltd and Urban Systems Ltd. 1996. South Thompson River Watershed Management Study: Draft Final Report. South Thompson/Chase Creek Turbidity Task Force, City of Kamloops.
Fishtrap Creek/Jamieson Creek	North Thompson	TNRD	092P01	Changes in sediment sources following wildfire in mountainous terrain: A paired catchment approach	Y	N	Y			Owens, P, Blake, W and Petticrew, E. 2006. Changes in sediment sources following wildfire in mountainous terrain: A paired catchment approach, British Columbia, Canada. Water, Air and Soil Pollution 6:637-645.
Fishtrap Creek	North Thompson	TNRD	092P01	Post-fire determination of fine-grained sediment sources - Watershed Response to the McLure Forest Fire.	Y	N	Y			Owens, P, Petticrew, E, Blake, WH, Giles, TR and Moore, RD. 2008. Post-fire determination of fine-grained sediment sources - Watershed Response to the McLure Forest Fire. Streamline Watershed Management Bulletin 12(1):6-7.
Fishtrap Creek	North Thompson	TNRD	092P01	Techniques for monitoring channel disturbance: A case study of Fishtrap Creek, British Columbia	Y	N	Y			Phillips, J and Eaton, B. 2008. Techniques for monitoring channel disturbance: A case study of Fishtrap Creek, British Columbia. Streamline Watershed Management Bulletin 12(1):16-21.
Fishtrap Creek	North Thompson	TNRD	092P01	Detecting the timing of morphologic change using stage-discharge regressions: A case study at Fishtrap Creek, British Columbia, Canada.	Y	N	Y			Phillips, J and Eaton, B. 2009. Detecting the timing of morphologic change using stage-discharge regressions: A case study at Fishtrap Creek, British Columbia, Canada. Canadian Water Resources Journal 34: DOI:10.4296/cwrj3403285
North Thompson River	North Thompson	TNRD	082M12	Detailed terrain stability mapping of the upper North Thompson Watershed: Lebher Creek - Miledge Creek	Y	Y - See Terrain Mapping		Y	Y	Quaterra Environmental Consulting Ltd. 2000. Detailed terrain stability mapping of the upper North Thompson Watershed: Lebher Creek - Miledge Creek (BAPID 4675). Prepared for Tolko Industries Ltd.
Mayson Lake	North Thompson	TNRD	092P01	Mayson Lake Study Examines Hydrological Processes.	Y	N	Y			Redding, T, Winkler, R, Carlyle-Moses, D and Spittlehouse, D. 2007. Mayson Lake Study Examines Hydrological Processes. LINK 9(2): 10-11.
Fishtrap Creek	North Thompson	TNRD	092P01	Fishtrap Creek: Studying the Effects of Wildfire on Watersheds.	Y	N	Y			Redding, T. 2008. Fishtrap Creek: Studying the Effects of Wildfire on Watersheds. LINK 10(1): 1-2.
Berry Creek	North Thompson	TNRD	082M14	Interior Watershed Assessment for Berry Creek	Y	N	Y			Silvatech. 2001. Interior Watershed Assessment for Berry Creek. Prepared for Weyerhauser Canada Ltd.
Peddie Creek	North Thompson	TNRD	083D03	Interior Watershed Assessment for the Peddie Creek Study Are	Y	N	Y			Silvatech. 2001. Interior Watershed Assessment for the Peddie Creek Study Area. Prepared for Weyerhauser Canada Ltd and Gilbert Smith Forest Products Ltd.
White River	North Thompson	TNRD	083D03	Interior Watershed Assessment for the White River Watershed.	Y	N	Y			Silvatech. 2001. Interior Watershed Assessment for the White River Watershed. Prepared for Gilbert Smith Forest Products Ltd.
Clanwilliam Landslide	Eagle River	CSRD	082L	The 1999 Clanwilliam Landslide: A preliminary Analysis of Potential Failure Mechanisms	Y	N		Y		Brideau, M-A., Stead, D., Couture, R. 2008, The 1999 Clanwilliam Landslide: A preliminary Analysis of Potential Failure Mechanisms *In* J. Locat, D., Perret, D., Turmel, D. Demers, et S. Leroueil, (2008). Comptes rendus de la 4e Conférence canadienne sur les géorisques: des causes à la gestion. Proceedings of the 4th Canadian Conference on Geohazards : From Causes to Management.Presse de l'Université Laval, Québec, 594 p
McAuley Creek Landslide	Paradise Creek	NORD	082L	Three-dimensional distinct element modelling and dynamic runout analysis of a landslide in gneiss rock	Y	N		Y		Brideau, M-A., McDougall, S., Stead, D., Evans, S.G., Couture, R., Turner, K. 2012, Three-dimensional distinct element modelling and dynamic runout analysis of a landslide in gneiss rock, British Columbia, Canada, Bull Eng Geol. Environ 71: 467-486
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	2003 Geologic Framework of Large Historic Landslides in Thompson River Valley	Y	N		Y		Clague, J.J., Evans, S.G., 2003 Geologic Framework of Large Historic Landslides in Thompson River Valley, British Columbia, Environmental & Engineering Geoscience, Vol IX, No. 3, August 2003, pp.201-212.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Complex Earth Slides in the Thompson River Valley, Ashcroft, British Columbia	Y	N		Y		Eshraghian, A., Martin, C.D., Cruden, D.M. 2007, Complex Earth Slides in the Thompson River Valley, Ashcroft, British Columbia, Environmental & Engineering Geoscience, Vol. XIII, No. 2, May 2007, pp. 161-181.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Hazard Analysis of an active slide in the Thompson River Valley, Aschroft, British Columbia	Y	N		Y		Eshraghian, A., Martin, C.D., and Morgenstern, N.R., 2008. Hazard Analysis of an active slide in the Thompson River Valley, Aschroft, British Columbia, Canada, Can. Geotech J. v.45, pp.297-313 (2008).
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Movement triggers and mechanisms of two earth slides in the Thompson River Valley, Aschroft, British Columbia	Y	N		Y		Eshraghian, A., Martin, C.D., and Morgenstern, N.R., 2008. Movement triggers and mechanisms of two earth slides in the Thompson River Valley, Aschroft, British Columbia, Canada, Can. Geotech J. v.45, pp.1189-1209 (2008).
South Central BC Landslides	Many	TNRD, NORD	092P, 092I, 0	Landslides in layers of volcanic successions with particular reference to the Tertiary rocks of south central British Columbia	Y	N		Y		Evans, S.G., 1983. Landslides in layers of volcanic successions with particular reference to the Tertiary rocks of south central British Columbia, University of Alberta Thesis, Department of Geology, Fall 1983
South Central BC Landslides	Many	TNRD, NORD	092P, 092I, 0	Landslides in the Kamloops Group in South-Central British Columbia, A Progress Report, Scientific and Technical Notes in Current Research	Y	N		Y		Evans, S. and Cruden, D.M.. 1981, Landslides in the Kamloops Group in South-Central British Columbia, A Progress Report, Scientific and Technical Notes in Current Research, Part B; Geol. Surv. Can. Paper 81-1b.
Spence's Bridge	Thompson River	TNRD	092I	Landslides and surficial deposits in urban areas of British Columbia	Y	N		Y		Evans, S.G. 1982, Landslides and surficial deposits in urban areas of British Columbia: A Review, Can. Geotech J. v. 19, pp. 269-288.
Ripley Slide (Ashcroft Area)	Thompson River	TNRD	092I	Effects of Thompson River elevation on velocity and instability of Ripley Slide	Y	N		Y		Hendry, M.T., Macciotta, R., Martin, C.D., Reich, B.. 2014, Effects of Thompson River elevation on velocity and instability of Ripley Slide, NRC Research Press, Can. Geotech. J., v52, pp. 257-267
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Measuring displacements of the Thompson River valley landslides, south of Ashcroft, BC, Canada, using satellite InSAR	Y	N		Y		Journault, J., Macciotta, R., Hendry, M.T., Charbonneau, F., Huntley, D., Bobrowsky, P.T.. 2017, Measuring displacements of the Thompson River valley landslides, south of Ashcroft, BC, Canada, using satellite InSAR, Landslides, DOI 10.1007/s10346-017-0900-1, Published online: 23 September 2017.
Blais Creek DsGSD	Blais Creek	TNRD	083D	Blais Creek DsGSD (Monashee Mountains, BC, Canada).	Y	N		Y		Moretti, D., Giardino, M., Stead, D., Clague, J., Gibson, D., Ghirotti, M., Perotti, L., 2013. Multidisciplinary approach (geology, geomorphology, geomechanics, geomatics) for the characterization of the Blais Creek DsGSD (Monashee Mountains, BC, Canada), Geophysical Research Abstracts, Vol. 15, EGU2013-7522-1.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Characterization of a landslide-prone glaciolacustrine clay from the Thompson River Valley near Ashcroft, British Columbia	Y	N		Y		Le Meil, G. 2017, Characterization of a landslide-prone glaciolacustrine clay from the Thompson River Valley near Ashcroft, British Columbia, University of Alberta Master's Thesis, Department of Civil and Environmental Engineering.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Climatic influences on the Ashcroft Thompson River Landslides, British Columbia	Y	N		Y		Tappenden, K.M. 2014b. Climatic influences on the Ashcroft Thompson River Landslides, British Columbia, Canada. *In* Proceedings of the 6th Canadian Geohazards Conference, 15-17 June 2014. Kingston, Ontario, Canada.
Drynoch Landslide	Thompson River	TNRD	092I	Drynoch Landslide, British Columbia – a history	Y	N		Y		VanDine, D.F. 1983, Drynoch Landslide, British Columbia – a history, Can. Geotech J., v20 pp.82-103.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Geotechnics and hydrology of landslides in Thompson River Valley, near Ashcroft, British Columbia	Y	N		Y		Bishop, N.F., 2008. Geotechnics and hydrology of landslides in Thompson River Valley, near Ashcroft, British Columbia, University of Waterloo Masters thesis.
Southwestern BC	Thompson River	TNRD	092I	Risk Analysis of Landslides Affecting Major Transportation Corridors in Southwestern British Columbia	Y	N		Y		Hazzard, J., 1998. Risk Analysis of Landslides Affecting Major Transportation Corridors in Southwestern British Columbia, University of British Columbia Masters Thesis.
Harris Creek	Harris Creek	NORD	082L	The relations between false gold anomalies, sedimentological process and landslides in Harris Creek, British Columbia	Y	N		Y		Hou, Z., and Fletcher, W.K., 1996. The relations between false gold anomalies, sedimentological process and landslides in Harris Creek, British Columbia, Canada, Journal of Geochemical Exploration, Vol. 57, pp. 21-30.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Little Chief Slide	former Columbia R.	CSRD	083D	Movement behavior of the Little Chief Slide	Y	N		Y		Mansour, M.F., Martin, C.D., and Morgenstern, N.R., 2011. Movement behavior of the Little Chief Slide, Can. Geotech J., Vol., 48, pp.655-670.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	High Magnitude-Low Frequency Catastrophic Landslides in British Columbia	Y	N		Y		Evans, S.G., 1991. High Magnitude-Low Frequency Catastrophic Landslides in British Columbia in Bobrowsky, P., 1992. Geologic Hazards in British Columbia Proceedings in the Geologic Hazards '91 Workshop February 20-21, 1992, Victoria, BC, British Columbia Geological Survey Branch Open File 1992-15.
South Central BC Landslides	Multiple	CRD, TNRD	092P	Landslide susceptibility and element at risk assessment – web mapping and mobile solution	Y	N		Y		Ramesh, A., 2015. Landslide susceptibility and element at risk assessment – web mapping and mobile solution, GeoBC Decision Support Section, preliminary presentation November 17, 2015.
	Multiple	CRD, TNRD,	Multiple	Review of Landslide Management in British Columbia	Y	N	Y	Y	Y	Symonds, B. and Zandbergen, J., 2013. Review of Landslide Management in British Columbia, Ministry of Forests, Lands and Natural Resource Operations, Provence of BC.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Landslide Risk to Railway Operations and Resilience in the Thompson River Valley near Ashcroft, British Columbia	Y	N		Y		Tappenden, K.M., 2017. Landslide Risk to Railway Operations and Resilience in the Thompson River Valley near Ashcroft, British Columbia, University of Alberta Masters Thesis.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Landslide Risk and Resilience for Rail Operations in the Thompson River Valley near Ashcroft	Y	N		Y		Tappenden, K.M., and Martin, C.D., 2015. Landslide Risk and Resilience for Rail Operations in the Thompson River Valley near Ashcroft, British Columbia, Canadian Rail Research Laboratory, Research Update, December 2015.
Thompson River valley landslides south of Aschroft	Thompson River	TNRD	092I	Formation and Failure of Natural Dams in the Canadian Cordillera	Y	N		Y		Clague, J., and Evans, S.G., 1994. Formation and Failure of Natural Dams in the Canadian Cordillera, Geological Survey of Canada Bulletin 464.
	Multiple	Multiple	Multiple	Landslide Susceptibility Map of Canada	N	Y		Y		Bobrowsky, P.T., Dominguez, M.J., Landslide Susceptibility Map of Canada, Geological Survey of Canada, Open-File 7228, 2012, 1 sheet
Candle Creek	Thompson River	TNRD	092P	Candle Creek Watershed Assessment	Y	N	Y			Silvatech. 2002. Candle Creek Watershed Assessment. Prepared for Slocan Forest Products Ltd.
Cahilty Creek	Thompson River	TNRD	082L13	Cahilty Creek Channel Assessment.	Y	N	Y			Summit Environmental Consultants Ltd. 1996. Final Report: Cahilty Creek Channel Assessment. Prepared for Tolko Industries Ltd.
Finn Creek	Thompson River	TNRD	082M14	Finn Creek Integrated Watershed Restoration Plan, Sediment Source Survey, Channel Assessment Procedure, and Access Management Strategy.	Y	N	Y		Y	Summit Environmental Consultants Ltd. 1998. Final Report: Finn Creek Integrated Watershed Restoration Plan, Sediment Source Survey, Channel Assessment Procedure, and Access Management Strategy. Prepared for Weyerhauser Canada Ltd.
Otter Creek	Thompson River	TNRD	082M11	Otter Creek Watershed Assessment.	Y	N	Y			Summit Environmental Consultants Ltd. 1998. Final Report: Otter Creek Watershed Assessment. Prepared for Weyerhauser Canada Ltd..
Otter Creek/Hellroar Creek/Finn Creek	Thompson River	TNRD	082M	Otter, Hellroar and Finn Creeks Channel Assessment.	Y	N	Y			Summit Environmental Consultants Ltd. 1998. Final Report: Otter, Hellroar and Finn Creeks Channel Assessment. Prepared for Weyerhauser Canada Ltd.
Blue River	Thompson River	TNRD	083D	Blue/Macrae (Blue River) Watershed Assessment.	Y	N	Y			Summit Environmental Consultants Ltd. 1999. Final Report: Blue/Macrae (Blue River) Watershed Assessment. Prepared for Weyerhauser Canada Ltd.
Leonie/Bottrel/Chip Creeks	Thompson River	TNRD	092P01	Hydrological Review: Leonie/Bottrel/Chip Creeks.	Y	N	Y			Summit Environmental Consultants Ltd. 1999. Hydrological Review: Leonie/Bottrel/Chip Creeks. Tolko Industries Ltd.
Lemieux Creek	Thompson River	TNRD	092P	Reconnaissance Watershed Assessment of Lemieux Creek Watershed	Y	N	Y			Summit Environmental Consultants Ltd. 2000. Reconnaissance Watershed Assessment of Lemieux Creek Watershed. Prepared for Tolko Industries Ltd.
Barriere River	North Thompson	TNRD	082M	Reconnaissance Watershed Assessment of Barrierre River Watershed	Y	N	Y			Summit Environmental Consultants Ltd. 2001. Final Report: Reconnaissance Watershed Assessment of Barrierre River Watershed. Prepared for Tolko Industries Ltd.
Newhykulston Creek	North Thompson	TNRD	092P08	Reconnaissance Watershed Assessment of Newhykulston Creek Watershed	Y	N	Y			Summit Environmental Consultants Ltd. 2001. Final Report: Reconnaissance Watershed Assessment of Newhykulston Creek Watershed. Prepared for Tolko Industries Ltd.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Barriere River	North Thompson	TNRD	082M	Barriere River Watershed TSIL D Reconnaissance Terrain Stability Mapping	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd. 1999. Barriere River Watershed TSIL D Reconnaissance Terrain Stability Mapping. Prepared for Tolko Industries Ltd.
Leonie/Skowootum Creek	Thompson River	TNRD	092P01	Detailed Terrain Stability Mapping (TSIL C) of the Leonie and Skowootum Creek Community Watershed	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd. 1999. Detailed Terrain Stability Mapping (TSIL C) of the Leonie and Skowootum Creek Community Watershed (BAPID 4947). Prepared for Tolko Industries Ltd.
Tyner Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment of the Tyner Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of the Tyner Creek Sub-basin. Prepared for Aspen Planers Ltd.
Stumbles Creek	Nicola	TNRD	092I02	Overview Hydrological Assessment for the Stumbles Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Stumbles Creek Sub-basin. Prepared for Aspen Planers Ltd.
Steffens Creek	Nicola	TNRD	092I	Overview Hydrological Assessment for the Steffens Creek Sub-basin.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Steffens Creek Sub-basin. Prepared for Aspen Planers Ltd.
Spius Creek	Nicola	TNRD	092I03	Overview Hydrological Assessment for the Spius Creek Watershed.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Spius Creek Watershed. Prepared for Aspen Planers Ltd.
Shuta Creek	Nicola	TNRD	092I	Overview Hydrological Assessment for the Shuta Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Shuta Creek Sub-basin. Prepared for Aspen Planers Ltd.
Rey Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Rey Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Rey Creek Sub-basin. Prepared for Aspen Planers Ltd.
Quilchena Creek	Nicola	TNRD	092I01	Overview Assessment for the Quilchena Creek above Wasley Creek Watershed.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Assessment for the Quilchena Creek above Wasley Creek Watershed. Prepared for Weyerhauser Canada Ltd.
Pothole Creek	Nicola	TNRD	092H15	Overview Assessment for the Pothole Creek Sub-basins	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Assessment for the Pothole Creek Sub-basins #139. Prepared for Weyerhauser Canada Ltd.
Pennask Creek	Nicola	TNRD	092H16	Channel condition and prescription assessment and riparian assessment and prescription procedure for the Pennask Creek	Y	N	Y			Dobson Engineering Ltd. 1999. Channel condition and prescription assessment and riparian assessment and prescription procedure for the Pennask Creek: Final Report. Prepared for Pennask Lake Fish and Game Club.
Nicola River	Nicola	TNRD	092I	Nicola River: Spences Bridge to Nicola Lake Floodplain Mapping	Y	Y - See Floodplain Mapping	Y			BC Water Surveys Unit and Canada-BC Floodplain Mapping Program. 1989. Nicola River: Spences Bridge to Nicola Lake Floodplain Mapping (Including Coldwater River and Spius Creek). BC Ministry of Environment.
Gordon Creek	Nicola	TNRD	092I03	Overview Hydrological Assessment of the Gordon Creek Residual Area	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of the Gordon Creek Residual Area. Prepared for Aspen Planers Ltd.
Gordon Creek	Nicola	TNRD	092I06	Overview Hydrological Assessment of the Gordon Creek Sub-basin.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of the Gordon Creek Sub-basin. Prepared for Aspen Planers Ltd.
Guichon Creek	Nicola	TNRD	092I	Overview Hydrological Assessment of the Guichon Creek Residual Area	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of the Guichon Creek Residual Area. Prepared for Aspen Planers Ltd.
Guichon Creek	Nicola	TNRD	092I	Guichon Creek Community Watershed, Level 1 Interior Watershed Assessment Procedure.	Y	N	Y			Integrated Woods Services Ltd. 1997. Guichon Creek Community Watershed, Level 1 Interior Watershed Assessment Procedure. Ainsworth Lumber Company Ltd.
Guichon Creek	Nicola	TNRD	092I	Hydrology Section Report: Guichon Creek	Y	N	Y			Obedkoff, W. 1987. Hydrology Section Report: Guichon Creek. BC Ministry of Environment
Hector Creek	Nicola	TNRD	092I02	Overview Hydrological Assessment for the Hector Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Hector Creek Sub-basin. Prepared for Aspen Planers Ltd.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Jesse Creek	Nicola	TNRD	092I02	Overview Hydrological Assessment for the Jesse Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Jesse Creek Sub-basin. Prepared for Aspen Planers Ltd.
Juliet Creek	Nicola	TNRD	092H11	Overview Hydrological Assessment of Juliet Creek Watershed	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of Juliet Creek Watershed. Prepared forTolko Industries Ltd.
July Creek	Nicola	TNRD	092H11	Reconnaissance Channel Assessment and Detailed CAP of July Creek	Y	N	Y			Klohn-Crippen Consultants Ltd. 1999. Reconnaissance Channel Assessment and Detailed CAP of July Creek. Prepared for BC Ministry of Forests.
Kwinshatin/Skuagam Creek	Nicola	TNRD	092I02	Interior Watershed Assessment of Kwinshatin and Skuagam Creeks.	Y	N	Y			Henderson Environmental Consulting Ltd. 2002. Interior Watershed Assessment of Kwinshatin and Skuagam Creeks. Prepared for Tolko Industries Ltd.
Lauder Creek	Nicola	TNRD	092I01	Lauder Creek Watershed Yield	Y	N	Y			Obedkoff, W. 1979. Lauder Creek Watershed Yield. BC Ministry of Environment.
Meadow Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Meadow Creek Face Unit	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Meadow Creek Face Unit. Prepared for Weyerhauser Canada Ltd.
Moore Creek	Nicola	TNRD	092I08	Moore Creek - Water Supply - Freshet Runoff Estimates	Y	N	Y			Obedkoff, W. 1989. Moore Creek - Water Supply - Freshet Runoff Estimates. BC Ministry of Environment
Nicola Lake	Nicola	TNRD	092I	Nicola Lake Inflow Forecasting Model Review	Y	N	Y			Costerton, RW. 1993. Nicola Lake Inflow Forecasting Model Review. BC Ministry of Environment.
Nicola Lake	Nicola	TNRD	092I	Nicola Lake Foreshore Inventory and Mapping.	Y	N	Y			Ecoscape Environmental Consultants Ltd. 2012. Nicola Lake Foreshore Inventory and Mapping. Prepared for Thompson-Nicola Regional District and Fisheries and Oceans Canada.
Nicola Lake	Nicola	TNRD	092I	Overview Hydrological Assessment of the Nicola Lake Sub-basin (	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of the Nicola Lake Sub-basin (#191). Prepared for Aspen Planers Ltd.
Nicola River	Nicola	TNRD	092I	A design brief on the floodplain mapping study of the Nicola River	Y	Y - See Floodplain Mapping	Y			Nichols, RW. 1988. A design brief on the floodplain mapping study of the Nicola River: An overview of the study undertaken to produce floodplain mapping for the Nicola River from Spences Bridge to Nicola Lake. BC Ministry of Enviroment.
Abbot Creek	Nicola	TNRD	092I06	Overview Hydrological Assessment of the Abbot Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment of the Abbot Creek Sub-basin. Prepared for Aspen Planers Ltd.
Beak Creek	Nicola	TNRD	082L04	Beak Creek Watershed: Hydrologic Assessment and ECA Evaluation.	Y	N	Y			Dobson Engineering Ltd. 2005. Beak Creek Watershed: Hydrologic Assessment and ECA Evaluation. Prepared for Riverside Forest Products Ltd.
Spius Creek	Nicola	TNRD	092I03	Spius Creek Reconnaissance Terrain Stability Mapping	Y	Y - See Terrain Mapping		Y	Y	EBA Engineering Consultants Ltd. 1999. Spius Creek Reconnaissance Terrain Stability Mapping. Prepared for Weyerhauser Canada Ltd.
Brook Creek	Nicola	TNRD	092H15	Interior Watershed Assessment of Brook Creek.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Interior Watershed Assessment of Brook Creek. Prepared for Tolko Industries Ltd.
Brook Creek	Nicola	TNRD	092H15	Detailed Terrain Stability Mapping (TSIL C) Brook Creek Watershed	Y	Y - See Terrain Mapping		Y	Y	Terratech Consulting Ltd. 2002. Detailed Terrain Stability Mapping (TSIL C) Brook Creek Watershed (BAPID 4882). Prepared for Tolko Industries.
Broom Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Broom Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Broom Creek Sub-basin. Prepared for Aspen Planers Ltd.
Chataway Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Chataway Creek Watershed	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Chataway Creek Watershed. Prepared for Aspen Planers Ltd.
Chataway Creek	Nicola	TNRD	092I07	Three-year (2000,2002) Results of Channel Monitoring in Chataway Creek	Y	N	Y			Henderson Environmental Consulting Ltd.2003. Three-year (2000,2002) Results of Channel Monitoring in Chataway Creek - Final Report. Prepared for Aspen Planers Ltd.
Clapperton Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Clapperton Creek Residual Area.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Clapperton Creek Residual Area. Prepared for Aspen Planers Ltd.

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Clapperton Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Clapperton Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Clapperton Creek Sub-basin. Prepared for Aspen Planers Ltd.
Clapperton Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Clapperton Creek West of Helmer Lake Sub-basin.	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Clapperton Creek West of Helmer Lake Sub-basin. Prepared for Aspen Planers Ltd.
Coldwater River	Nicola	TNRD	092H	Coldwater Watershed Level 1 - IWAP Assessment	Y	N	Y			Borrett Engineering Ltd. 1998. Coldwater Watershed Level 1 - IWAP Assessment. Prepared for Tolko Industries.
Coldwater River	Nicola	TNRD	092H	Coldwater River Study	Y	N	Y			McPhail, JD. 1980. Coldwater River Study. BC Ministry of Environment.
Coldwater River	Nicola	TNRD	092H	Bank vegetation, bank strength, and application of the university of British Columbia regime model to stream restoration	Y	N	Y			Millar, RG and Eaton, BC. 2011. Bank vegetation, bank strength, and application of the university of British Columbia regime model to stream restoration. In: Stream restoration indynamic fluvial systems: Scientific approaches, analyses and tools. Geophysical Monographs Series 194. American Geophysical Union.
Coldwater River	Nicola	TNRD	092H	Coldwater River Encroachment/Confinement Assessment: Kingsvale to Juliet Draft Report	Y	N	Y			Northwest Hydraulic Consultants Ltd. 2002. Coldwater River Encroachment/Confinement Assessment: Kingsvale to Juliet Draft Report. Prepared for Pacific Salmon Foundation.
Dupuis Creek	Nicola	TNRD	092I07	Overview Hydrological Assessment for the Dupuis Creek Sub-basin	Y	N	Y			Henderson Environmental Consulting Ltd. 1999. Overview Hydrological Assessment for the Dupuis Creek Sub-basin. Prepared for Aspen Planers Ltd.
Logan Lake	Nicola	TNRD	092I10	Logan Lake Community Forest Road Risk Analysis	Y	N			Y	Forsite Consultants Ltd. 2010. Logan Lake Community Forest Road Risk Analysis. Foresite Consutants Ltd.
Nicola River	Nicola	TNRD		2015 Nicola River Flood Mitigation and Erosion Control Assessment for Nooaitch Indian Band	Y	Y	Y			Kerr Wood Leidal
Whispering Pines	Bonaparte	TNRD		Urgent Flood Mitigation and Erosion Inspection - Southwest/East Region Whispering Pines/Clinton Band	Y	N	Y			Kerr Wood Leidal
Bonaparte	Bonaparte	TNRD		Contruction of 2007 Emergency Flood Protection Works - Skeetchestn Indian Band	Y	Y	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD	092I	2007 Emergency Flood Works - Kamloops	Y	Y	Y			Kerr Wood Leidal
Camin Lake	North Thompson	TNRD		Flood and Erosion Mitigation Plan - Camin Lake Band / Lytton First Nation	Y	Y	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		Flood and Erosion Mitigation Plan - Lytton First Nation	Y	Y	Y			Kerr Wood Leidal
Mara Lake	South Thompson	CSRD		Sicamous Hyrdological Connectivity Report	Y	Y	Y			Kerr Wood Leidal
Shuswap, Bessette, Duteau Creeks	South Thompson	CSRD		Village of Lumby Floodplain Mapping Update & Creek Banks and Earthworks Assessment	Y	Y	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		ACRS Flood and Erosion Inspections for 2005-2006 - Kamloops Indian Band	Y	N	Y			Kerr Wood Leidal
North Thompson	North Thompson	TNRD		ACRS Flood and Erosion Inspections for 2005-2006 - Simpcw FN	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		ACRS Flood and Erosion Inspections for 2005-2006 - Oregon Jack Creek Band	Y	N	Y			Kerr Wood Leidal

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
North Thompson	North Thompson	TNRD		ACRS Flood and Erosion Inspections for 2005-2006 - Whispering Pines/Clinton Indian Band	Y	N	Y			Kerr Wood Leidal
North Thompson	North Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Simpcw FN	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Bonaparte Indian Band	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Cook's Ferry Band	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Kamloops Indian Band	Y	N	Y			Kerr Wood Leidal
Nicola River / Lake	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Shackan Indian Band	Y	N	Y			Kerr Wood Leidal
Shuswap Lake	South Thompson	CSRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Little Shuswap Lake Indian Band	Y	N	Y			Kerr Wood Leidal
Nicola River / Lake	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Nooaitch Indian Band	Y	N	Y			Kerr Wood Leidal
Nicola Lake	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Upper Nicola Indian Band	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Skeetchestn Indian Band	Y	N	Y			Kerr Wood Leidal
Mara Lake	South Thompson	CSRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Spallumcheen Band	Y	N	Y			Kerr Wood Leidal
Whispering Pines	Bonaparte	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Whispering Pines / Clinton Indian Band	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Oregon Jack Creek Band	Y	N	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Ashnola, Bonaparte, Chopaka, Cook's Ferry, Kamloops, Little Shuswap Lake, Lower Similkameen, Nooaitch, Okanagan, Oregon Jack Creek, Osoyoos, Penticton, Simpcw, Skeetchestn, Spallumcheen, Upper Nicola, Whispering Pines	Y	Y	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Kamloops	Y	Y	Y			Kerr Wood Leidal

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Kamloops	Y	Y	Y			Kerr Wood Leidal
Bonaparte	Bonaparte	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Bonaparte	Y	Y	Y			Kerr Wood Leidal
Bonaparte	Bonaparte	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Bonaparte	Y	Y	Y			Kerr Wood Leidal
Nicola River / Lake	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Nooaitch	Y	Y	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Oregon Jack Creek	Y	Y	Y			Kerr Wood Leidal
Nicola River / Lake	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Shackan	Y	Y	Y			Kerr Wood Leidal
North Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Simpcw	Y	Y	Y			Kerr Wood Leidal
North Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Simpcw	Y	Y	Y			Kerr Wood Leidal
Thompson	Thompson	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Skeetchetn	Y	Y	Y			Kerr Wood Leidal
Upper Nicola	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Upper Nicola	Y	Y	Y			Kerr Wood Leidal
Upper Nicola	Nicola River	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Upper Nicola	Y	Y	Y			Kerr Wood Leidal
Whispering Pines	Bonaparte	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Whispering Pines / Clinton Indian Band	Y	Y	Y			Kerr Wood Leidal
Whispering Pines	Bonaparte	TNRD		2008-2009 ACRS Inspection Final Report Flood and Erosion Assets - Whispering Pines / Clinton Indian Band	Y	Y	Y			Kerr Wood Leidal
TRIM Water Points	All	All	N/A		N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, 2017. TRIM Water Points. Online data source. https://catalogue.data.gov.bc.ca/dataset/trim-water-points
Hydrometric Stations - Active and Discontinued	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2018. Hydrometric Stations - Active and Discontinued. Online Data Source. https://catalogue.data.gov.bc.ca/dataset/hydrometric-stations-active-and-discontinued
BC Points of Diversion with Water Licence Information	All	All	N/A		N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, 2017. BC Points of Diversion with Water Licence Information. Online resource. https://catalogue.data.gov.bc.ca/dataset/bc-points-of-diversion-with-water-licence-information

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Ground Water Aquifers	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2017. Ground Water Aquifers. Online Resource. https://catalogue.data.gov.bc.ca/dataset/ground-water-aquifers
Water Resource Management Streams	All	All	N/A		N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, 2017. Water Resource Management Streams. Online resource. https://catalogue.data.gov.bc.ca/dataset/water-resource-management-streams
Bathymetric Maps	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2017. Bathymetric Maps. Online Resource. https://catalogue.data.gov.bc.ca/dataset/bathymetric-maps
Surface Water Monitoring Sites	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2018. Surface Water Monitoring Sites. Online Resource. https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=0ecd608e27ec45cd923bdcfeefba00a7
PSCIS Assessments	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2017. PSCIS Assessments. Online Resource. https://catalogue.data.gov.bc.ca/dataset/7ecfafa6-5e18-48cd-8d9b-eae5b5ea2881
PSCIS Habitat Confirmations	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2017. PSCIS Habitat Confirmations. Online Resource. https://catalogue.data.gov.bc.ca/dataset/572595ab-0a25-452a-a857-1b6bb9c30495
PSCIS Remediation	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2017. PSCIS Remediation. Online Resource. https://catalogue.data.gov.bc.ca/dataset/1596afbf-f427-4f26-9bca-d78bceddf485
PSCIS Design Proposal	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2017. PSCIS Design Proposal. Online Resource. https://catalogue.data.gov.bc.ca/dataset/0c9df95f-a2da-4a7d-b9cb-fea3e8926661
BC Dams	All	All	N/A		N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, 2017. B.C. Dams. Online resource. https://catalogue.data.gov.bc.ca/dataset/b-c-dams
Reservoirs - Permits over Crown Land	All	All	N/A		N	Y	Y			Ministry of Forests, Lands, Natural Resource Operations, and Rural Development, 2017. Reservoir Permits Over Crown Land. Online resource. https://catalogue.data.gov.bc.ca/dataset/reservoir-permits-over-crown-land
Soil Survey Spatial View	All	All	N/A		N	Y	Y			Ministry of Environment and Climate Change Strategy, 2018. Soil Survey Spatial View. Online Resource. https://catalogue.data.gov.bc.ca/dataset/soil-survey-spatial-view
Flood Protection Works Inspection Guide	N/A	N/A	N/A	Flood Protection Works Inspection Guide	Y	N	Y			Minstiry of Environment Lands and Parks, 2000. Flood Protection Works Inspection Guide. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/integrated-flood-hazard-mgmt/fld_prot_insp_gd.pdf
EGBC Professional Practice Guidelines for Flood Mapping in BC	N/A	N/A	N/A	Flood Mapping in BC - APEGBC Professional Practice Guidelines V1.0	Y	N	Y			Engineers and Geoscientists of British Columbia, 2017. Flood Mapping in BC - APEGBC Professional Practice Guidelines V1.0. https://www.egbc.ca/getmedia/8748e1cf-3a80-458d-8f73-94d6460f310f/APEGBC-Guidelines-for-Flood-Mapping-in-BC.pdf.aspx

Location				Project			Hazard Type			Reference
Name	River Basin	District	NTS ID	Project Title	Report? (Y/N)	Spatial information?	Flooding?	Landslide?	Steep Creek?	Citation
Professional Practice Guidelines for Legislated Flood Assessments in a Changing Climate in BC	N/A	N/A	N/A	Legislated Flood Assessments in a Changing Climate in BC	Y	N	Y			Engineers and Geoscientists of British Columbia, 2012. Legislated Flood Assessments in a Changing Climate in BC. https://www.egbc.ca/getmedia/18e44281-fb4b-410a-96e9-cb3ea74683c3/APEGBC-Legislated-Flood-Assessments.pdf.aspx
Professional Practice Guidelines for Landslide Assessments	N/A	N/A	N/A	Landslide Assessments for Proposed Residential Developments in BC	Y	N	Y			Engineers and Geoscientists of British Columbia, 2010. Landslide Assessments for Proposed Residential Developments in BC. https://www.egbc.ca/getmedia/5d8f3362-7ba7-4cf4-a5b6-e8252b2ed76c/APEGBC-Guidelines-for-Legislated-Landslide-Assessments.pdf.aspx
Global Landslide Catalogue	N/A	N/A	N/A	Global Landslide Catalogue	N	Y		Y	Y	NASA Global Landslide Catalogue, 2018. Online Resource. https://maps.nccs.nasa.gov/arcgis/apps/webappviewer/index.html?id=824ea5864ec8423fb985b33ee6bc05b7
Ministry of Transportation (MOT) Road Structures	All	All	N/A	Ministry of Transportation (MOT) Road Structures	N	Y				Ministry of Transportation and Infrastructure, 2017. Ministry of Transportation (MOT) Road Structures. Online resource. https://catalogue.data.gov.bc.ca/dataset/ministry-of-transportation-mot-road-structures
Ministry of Transportation (MOT) Culverts	All	All	N/A	Ministry of Transportation (MOT) Culverts	N	Y				Ministry of Transportation and Infrastructure 2017. Ministry of Transportation (MOT) Culverts. Online resource. https://catalogue.data.gov.bc.ca/dataset/ministry-of-transportation-mot-culverts
Ministry of Transportation (MOT) Road Features Inventory (RFI)	All	All	N/A	Ministry of Transportation (MOT) Road Features Inventory (RFI)	N	Y				Ministry of Transportation and Infrastructure, 2017. Ministry of Transportation (MOT) Road Features Inventory (RFI). Online resource. https://catalogue.data.gov.bc.ca/dataset/ministry-of-transportation-mot-road-features-inventory-rfi

APPENDIX C
HAZARD ASSESSMENT METHODOLOGY: CLEAR-WATER FLOODS

APPENDIX D
HAZARD ASSESSMENT METHODOLOGY: STEEP CREEKS

D.1. INTRODUCTION

This appendix describes methods used by BGC to identify and characterize steep creek geohazards within the study area. The results formed the basis to assign geohazard ratings to each study area.

This appendix is organized as follows:

- Section D.2 provides background information and key terminology
- Section D.2.2 describes methods used to identify steep creek geohazard areas
- Section D.4 describes methods used to assign geohazard ratings.

Appendix F provides a detailed list of the attributes compiled for each geohazard area that form the basis for geohazard, consequence, and priority ratings. The main report describes how geohazard and consequence ratings were combined to prioritize each geohazard area.

D.2. STEEP CREEK PROCESSES

D.2.1. Overview

A steep creek watershed consists of hillslopes, small feeder channels, a principal channel (Figure D-1) and a fan composed of deposited sediments at the lower end of the watershed. Every watershed is unique in the type and intensity of mass movement and fluvial processes, and the hazard and risk profile associated with such processes. Figure D-1 schematically illustrates two fans side by side. The steeper one on the left is dominated by debris flows and perhaps rock fall near the fan apex, whereas the one on the right with the lower gradient is likely dominated by debris floods.

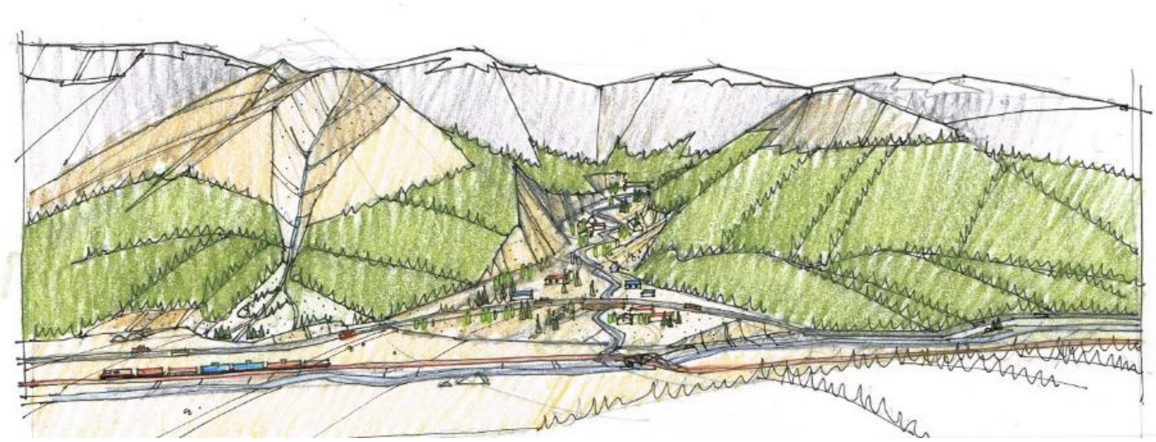

Figure D-1. Typical steep and low-gradient fans feeding into a broader floodplain. On the left a small watershed prone to debris flows has created a steep fan that may also be subject to rock fall processes. On the right a larger watershed prone to debris floods has created a lower gradient fan. Development and infrastructure are shown to illustrate their interaction with steep creek hazard events. Artwork: Derrill Shuttleworth.

Steep creeks are defined by their gradient and geomorphic processes. The principal hazards on steep creeks are debris impact and water inundation along the steep creek channel and on the creek fans. Water inundation can also be associated with bank erosion along the main channel, particularly on the fan. Photograph D-1 provides a typical example of a steep creek in the Thompson River Watershed (TRW).

Photograph D-1. A typical steep creek watershed and fan (Hummingbird Creek) in the Thompson River Watershed, located near Sicamous. Photo: BGC taken on October 4, 2012.

In steep basins, most mass movements on hillslopes directly or indirectly feed into steep mountain channels from where they begin their journey downstream. Viewed at the scale of the catchment and over geologic time, distinct zones of sediment production, transfer and deposition may be identified within a drainage basin (Church, 2002), see Figure D-2.

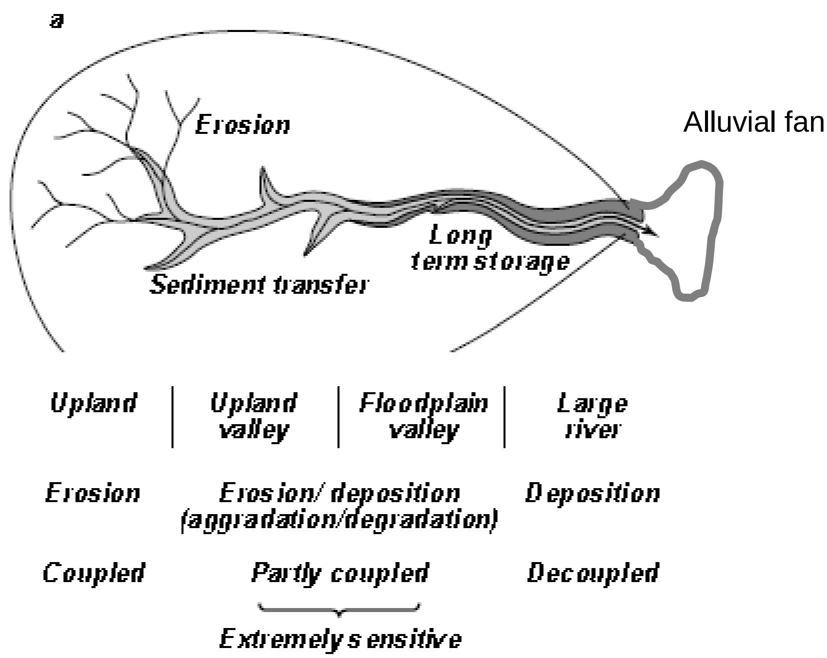

Figure D-2. Schematic diagram of a drainage basin that shows the principal zones of distinctive sediment behaviour. The alluvial fan is thought of as the long-term storage landform with a time scale of thousands to tens of thousands of years. Concept by Schumm (1977).

There is a continuum between clear-water floods, debris floods and debris flows in space and time. Figure D-3 summarizes the different steep creek processes by their appearance in plan form, velocity and sediment concentration. The distinction between these processes is important, as they differ in flow mechanics and potential consequences.

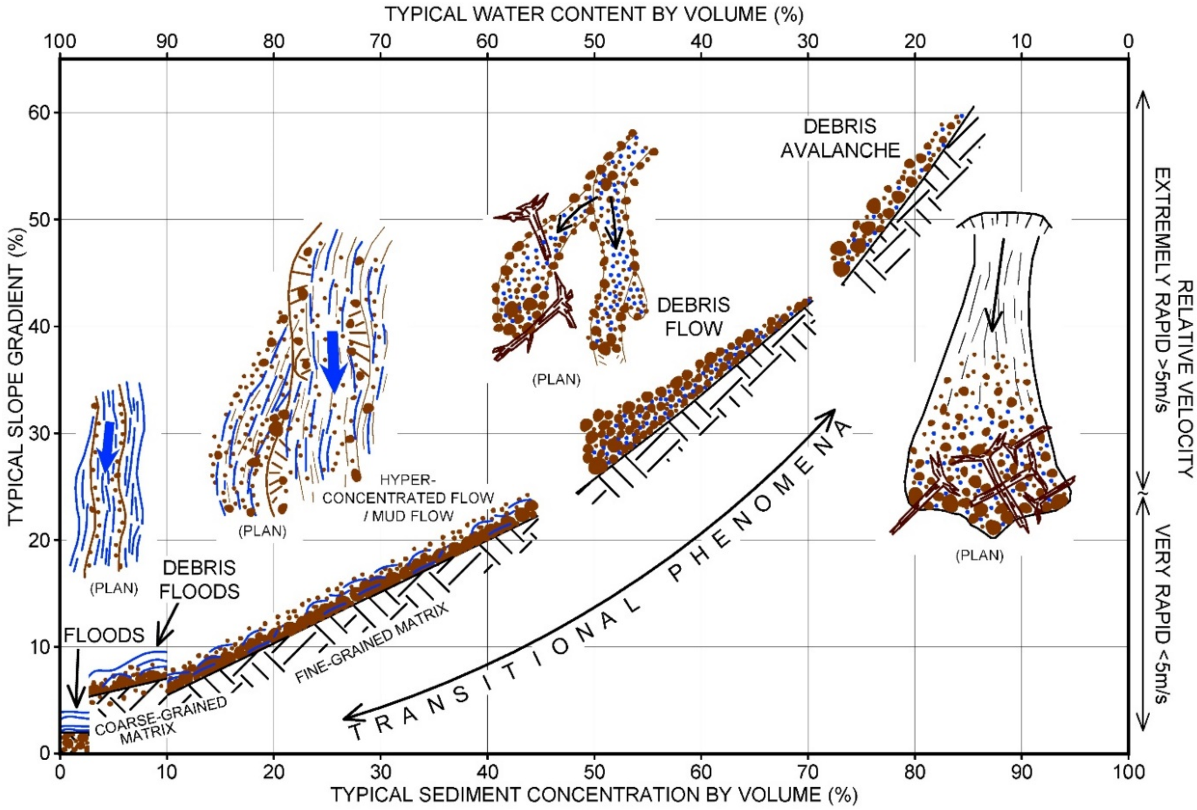

Figure D-3. Steep creek process classification by sediment concentration, slope, velocity and planform appearance.

D.2.2. Terminology

This appendix refers to the following key definitions:

Alluvial fan: Depositional landform that accumulates at the outlet of a steep creek. This landform is properly called a colluvial fan when formed by debris flows, but for simplicity the term alluvial fan is used herein irrespective of geohazard type. “Classic” alluvial fans are triangular in planform, but most fans have irregular shapes influenced by the surrounding topography.

Debris flow: Debris flows are very rapid to extremely rapid surging flow of saturated, non-plastic debris in a steep channel (Hungr et al., 2014). Debris flows originate from single or multiple source areas in colluvium, till or other surficial sediments, mobilized by the influx of ground- or surface water. Typical debris flows require a channel gradient of at least 27% (15°) for transport over significant distances and have volumetric sediment concentrations in excess of 50%. Due to their high flow velocities, peak discharges can be at least an order of magnitude larger than those of comparable return-period floods.

Debris flood: Very rapid surging flow of water heavily charged with debris in a steep channel (Hungr et al., 2014). Transitions from water flows to debris floods occur at minimum volumetric sediment concentrations of 3 to 10%, the exact value depending on the particle size distribution of the entrained sediment and the ability to acquire yield strength. Because debris floods are characterized by heavy bedload transport, rather than by a more homogenous mixture of suspended sediments typical of hyperconcentrated flows (Pierson, 2005), the exact definition of sediment concentration depends on how sediment is transported in the water column. Debris floods typically occur on creeks with channel gradients between 5 and 30% (3 to 17^{o}). Debris flows can also transition into debris floods when lower stream channel gradients are encountered in lower reaches.

D.3. STEEP CREEK GEOHAZARD IDENTIFICATION

The steep creek geohazard identification involved two methods: steep creek process identification and the alluvial fan inventory. Details on these methods are provided below.

D.3.1. Geohazard Process Type

Steep creeks are subject to hydrogeomorphic processes whose dominant driver is water with varying sediment concentrations; these include clear-water flood, debris-flood, and debris-flow process types. The process type assignment does not specifically contribute to the fan prioritization rating. However, it is important for more detailed assessment of flow magnitude and behavior, the choice of parameters for numerical modeling of flows, criteria used to estimate vulnerability and associated risk, and the design of risk reduction measures.

BGC used two methods to assign geohazard processes: morphometric statistics and terrain interpretations. The statistically predicted process was applied to every stream segment in the entire study area, including both developed and undeveloped areas. These process types were considered alongside terrain interpretations to assign a dominant process type to each fan, as described below.

D.3.1.1. Morphometric Statistics

BGC applied the following approach to predict steep creek process type for all segments of every mapped creek within the study area, based on morphometric statistics:

1. Collect statistics on Melton Ratio[1] and watershed length[2] for each segment of each creek. These terrain factors are a good screening level indicator of the propensity of a creek to dominantly produce floods, debris floods or debris flows (Holm et al., 2016).
2. Use Analysis of Variance (ANOVA) to determine class boundaries that best predict process types for fans where the process type is well understood based on previous study.
3. Apply class boundaries to predict process types for all stream segments in the study area, regardless of whether they intersect fans.

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[1] Melton ratio is watershed relief divided by the square root of watershed area (Melton 1957).

[2] Stream network length is the total channel length upstream of a given stream segment to the stream segment farthest from the fan apex.

Figure D-4 plots the prioritized study creeks with respect to Melton Ratio and watershed length[3]. Although there is overlap, creeks with the highest Melton ratio and shortest watershed stream length are mostly prone to debris flows, and those with the lowest Melton ratio and longest watershed stream lengths are mostly prone to floods. Debris floods fall between these types. Table D-1 lists class boundaries used to define process types on each segment of each creek within the TRW. The results are shown on the web map as a layer coloring each stream by predicted process type.

Scoping Report Note: Below is an example figure. An updated figure showing classified prioritized study sites by Melton ratio will be added for the Draft and Final Reports.

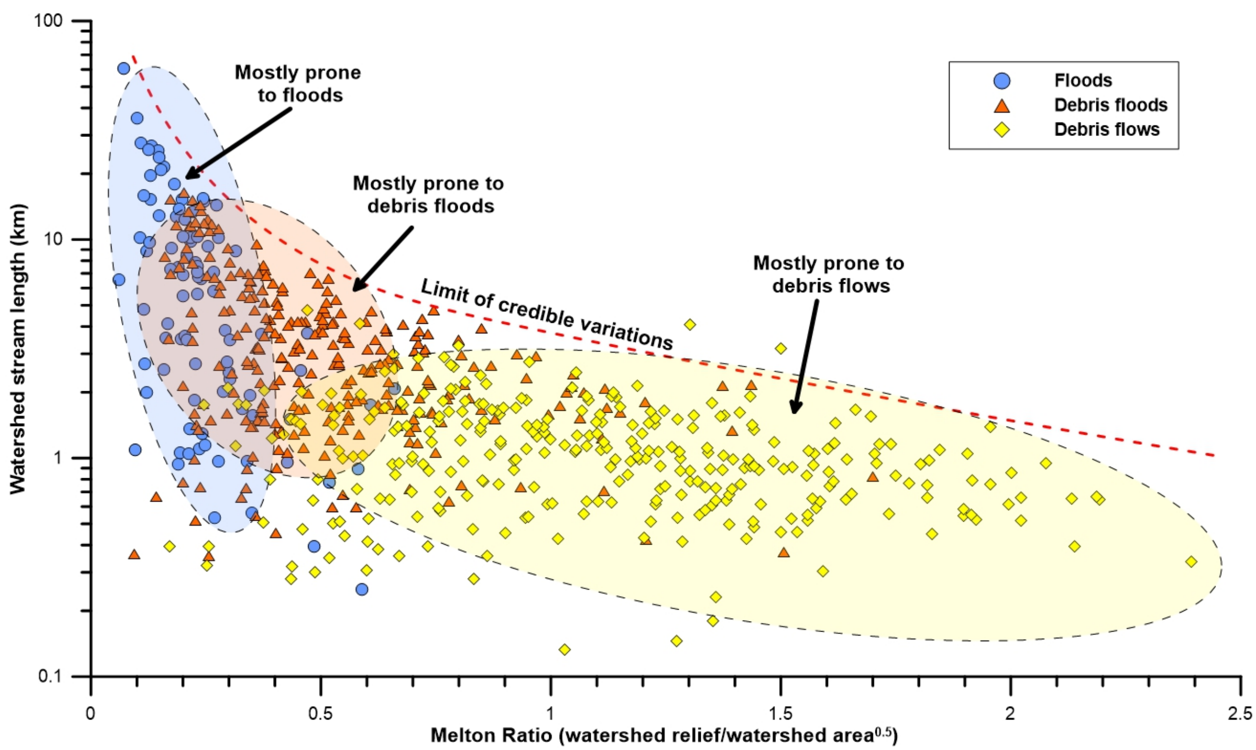

Figure D-4. Steep creek processes as a function of Melton Ratio and stream length. Steep creeks within the study area are shown in color. Additional creeks from previous studies in the Alberta Rocky Mountains and in Southwest British Columbia are also shown for reference (Holm et el., 2016, BGC Engineering, June 2018).

3 The process type shown in the figure represents the process at the location of the fan apex. Many creeks subject to debris floods are also subject to debris flows on steeper creeks higher in the basin.

Table D-1. Class boundaries using Melton ratio and total stream network length.

Process	Melton Ratio	Stream Length (km)
Floods	< 0.2	all
Debris floods	0.2 to 0.5	all
	> 0.5	> 3
Debris flows	> 0.5	≤ 3

Scoping Report Note: The class boundaries are a work-in-progress and will be finalized and changed, if necessary, for the Draft and Final Reports.

Steep creek process types predicted from watershed morphometry are subject to limitations. Creeks at the transition between debris flows and debris floods may generate either type of process and do not fall clearly into one category or another. The classification describes the potential dominant process type, but does not consider the geomorphic or hydroclimatic conditions needed to trigger events. As such, channels may be classified as "debris flow" or "debris flood" without evidence for previous events. Some streams subject to lower frequency debris floods will be subject to higher frequency clear-water floods.

Watershed conditions that affect hydrogeomorphic process types cannot be considered using a purely statistical approach. For example, a fan could be located at the outlet of a gentle valley, but where a debris-flow tributary enters near the fan apex. In this situation, debris flows could run out onto a fan that is otherwise subject to floods or debris floods from the main tributary. Other exceptions include hanging valleys, where the lower channel sharply steepens below a gentle upper basin. It should further be understood that there is a continuum between each of the geohazard processes. As an example, a steep creek could have an event that has characteristics that fall between a debris flood and debris flow (i.e., the hyperconcentrated flow of Figure D-3).

In summary, the major advantage of statistically based methods is that they can be applied to much larger regions than would be feasible to manually assess. However, interpretation of steep creek process types from multiple lines of evidence (statistical, remote-sensed, field observation) would result in higher confidence. Therefore, BGC also manually interpreted the dominant fan-forming process types for the prioritized study sites (where both a steep creek hazard and element(s) at risk were present).

D.3.1.2. Terrain Interpretations

BGC manually interpreted the dominant fan-forming process types for the prioritized study sites from the following information sources:

- The geomorphology of fans and their associated watersheds observed in available imagery
- Field observations, where available

- Records of previous events
- Review of statistically predicted process type for channel(s) intersecting the fan (Section D.3.1.1).

While a single process type was assigned to a given fan, many fans are subject to more than one process type. Fans classified as subject to debris flows are also subject to floods though rarely debris floods. Those classified as debris flood fans are also subject to floods, as a debris flood is simply a flood in which the stream power allows full surface bed entrainment. Those classified as subject to clear-water floods were interpreted as not subject to debris floods or debris flows.

D.3.2. Alluvial Fan Inventory

Steep creek geohazard identification at prioritized steep creek sites focused on the delineation of alluvial fans, as these are the landforms commonly occupied by elements at risk. The boundaries of alluvial fans[4] define the steep creek geohazard areas prioritized in this study. Upstream watersheds were assessed to identify geohazard processes and determine geohazard ratings, but were not mapped.

Alluvial fan extents were interpreted in an ESRI ArcGIS Online web map based on aerial imagery, hillshade images built from LiDAR Digital Elevation Models (DEM), and review of previous fan mapping (e.g., Lau, 2017). As noted in the scope of work (Main Report Section 5.1), the fan mapping focused on areas that contain existing buildings. Geobase terrain models (approx. 20 m resolution) and satellite imagery available within the ESRI web map were used for terrain interpretations where LiDAR was not available. Drawing XX displays LiDAR coverage and sources. The web map provided with this report links to geotechnical reports for a given fan, where existing.

Scoping Report Note: Drawing XX is a work-in-progress that will be completed for the Draft and Final Reports.

The accuracy of each fan's boundary and hazard rating depends, in part, on the resolution of the available terrain data. LiDAR terrain models, where available, provide 1 m or better resolution (e.g., Figure D-5). Fan boundaries are approximate, but contain higher uncertainty where LiDAR coverage was not available. Specific site investigations could alter the locations of fan boundaries.

Scoping Report Note: An annotated figure showing alluvial fan boundaries on a LiDAR hillshade image will be added for the Draft and Final Reports.

Figure D-5. Example of LiDAR hillshade showing XXX fans.

BGC mapped a total of XXXX prioritized study site fans, of which XXX were field checked. The primary objectives of field assessment include surface observations to calibrate remote-sensed interpretations and identify channels with evidence for recent events. Subsurface investigations, channel hikes, or upper basin inspections were not completed.

[4] Defined in Appendix A (Section A.2.4)

Scoping Report Note: The total number of delineated and field-checked fans will be added for the Draft and Final Reports.

D.4. GEOHAZARD RATING

BGC assigned geohazard ratings to the prioritized steep creek sites that considered the following two factors:

- Geohazard likelihood: What is the likelihood of steep creek geohazard events large enough to potentially impact elements at risk (Section D.4.1)?
- Impact Susceptibility: Given a geohazard event occurs, how susceptible is the hazard area to uncontrolled flows that could impact elements at risk (Section D.4.2)?

This section describes methods to estimate both factors and combine them to arrive at a geohazard rating.

D.4.1. Geohazard Likelihood

Frequency analysis estimates how often geohazard events occur, on average. Frequency can be expressed either as a return period or an annual probability of occurrence. For example, if five debris floods have occurred within a 100-year period, the average return period is 20 years and the annual probability is the inverse, so 0.05, or a 5% chance that a debris flood may occur in any given year. The magnitude of a geohazard event refers to the volume of sediment deposited on a fan, peak discharge, or both.

BGC assigned a geohazard likelihood rating to each fan based on terrain analysis, with reference to recorded events and past assessments. While a single geohazard likelihood rating was assigned for prioritization, BGC notes that events of different frequencies and magnitudes can occur on any given steep creek. Frequency and magnitude (volume and peak discharge) of steep creek geohazards are inversely related. The higher the frequency, the lower the magnitude and vice versa. In short, the rarer an event, the larger it will be. A frequency analysis alone does not inform on the relation between magnitudes and frequencies. Thus, BGC also used a morphometric statistical approach to establish preliminary frequency-magnitude (F-M) relationships for each study creek with a mapped fan. Although a F-M relationship was directly used in the regional prioritization, the analysis supported the study in the following ways:

- Determining a representative range of event magnitudes and associated frequencies that could occur on a given creek, as information supporting future study.
- Checking the consistency of single ratings for relative frequency and destructive potential applied to each creek.

Methods and criteria to estimate steep creek frequency and magnitude based on terrain interpretation and morphometric statistics are discussed further below.

D.4.1.1. Terrain Interpretations

The terrain analysis approach assigns a single, “typical” event frequency to each fan based on surface evidence for previous events, recorded events, and reference to previous work.

Professional experience and judgement was applied to estimate the most frequent event of sufficient magnitude to have credible potential for consequences.

Table D-2 lists the relative hazard likelihood ratings and corresponding annual frequency and return period ranges assigned to each fan. Note that frequency is the inverse of return period (higher frequency events have a smaller return period). Event magnitude was not quantified, but the rating is intended to allow relative comparison of hazard levels between fans.

Table D-2. Relative hazard likelihood and approximate frequency and return period categories for rivers and lakes.

Relative Hazard Likelihood	Long-term Annual Frequency Range	Approximate Return Period Range (years)	Representative Return Period (years)
Very High	1 – 0.1	1-10	5
High	0.1 – 0.03	10-30	20
Moderate	0.03 – 0.01	30-100	50
Low	0.01 – 0.003	100-300	200
Very Low	0.003 – 0.001	300-1000	500

Examples of surface evidence for geomorphic activity within the basin and fan are shown in Figure D-6 and Figure D-7. Both examples correspond to events large enough to produce visible surface evidence. Dense tree cover, for example, could obscure small events that would not be detected at the scale of study. Accordingly, the ratings are relative measures.

Scoping report note: these and other photos will be annotated in more detail for the Draft and Final Reports, as required for clarity.

Figure D-6. Example of evidence for recent landslide and debris flow activity within the basin of Hart Creek, east of Paradise Point.

Figure D-7. Example of evidence (red arrows) for recent (early 2000s) debris flow deposit on an unnamed fan north of Avola.

Table D-3 shows the basin and fan activity characteristics used to assign a relative hazard likelihood rating for each prioritized study site.

Table D-3. Relative hazard likelihood criteria for steep creek fans.

			Typical Basin Activity Characteristics									
			Very Low		Low		Moderate		High		Very High	
			Debris Flood Creek	Debris Flow Creeks	Debris Flood Creek	Debris Flow Creeks	Debris Flood Creeks	Debris Flow Creeks	Debris Flood Creeks	Debris Flow Creeks	Debris Flood Creeks	Debris Flow Creeks
			Small watershed with no identifiable source areas. Dominantly a bedrock-controlled main channel. Supply limited watershed	No identifiable source areas; absence of fresh landslide scars or channel deposits; low AAR[2]; supply-limited watershed.	Few tributaries with few identifiable sediment sources; little or no sediment sources along main channel; supply limited watershed; mostly bedrock-controlled main channel with little alluvium; mature tree growth to margin of active channel; tree line close to watershed peak elevations.	Poorly defined source areas; absence of fresh landslide scars or channel deposits; low AAR[2]; supply-limited watershed.	Some tributaries with identifiable sediment sources; deciduous tree bordering active channel; 1/3 of watershed above treeline; some active sediment sources along main channel; variable channel width; partially bedrock-partially alluvial channel; supply unlimited watershed.	Well-defined source areas; presence of some fresh landslide scars in soil or rock and some channel deposits; moderate active-area-ratio (AAR[2]); usually supply-limited watershed.	Many tributaries with abundant identifiable sediment sources in tributaries; deciduous tree bordering active channel; 2/3 of watershed above treeline; numerous highly active sediment sources along main channel (i.e., debris slides, debris avalanches, raveling in lacustrine, glaciofluvial, or morainal sediments); wide and debris-rich alluvial channel; supply unlimited watershed.	Numerous, well-defined, actively producing source areas in tributaries and along main channel; channel choked with debris; abundant fresh landslide scars in soils and rock; fresh channel deposits; high active area ration (AAR[2]); supply-unlimited watershed.	Most tributaries with abundant identifiable sediment sources in tributaries; deciduous tree bordering active channel; 2/3 of watershed above treeline; numerous highly active sediment sources along main channel (i.e., debris slides, debris avalanches, raveling in lacustrine, glaciofluvial, or morainal sediments); wide and debris-rich alluvial channel; supply unlimited watershed.	Numerous, well-defined, actively producing source areas in tributaries and along main channel; easily entrained materials along incised channels (e.g., talus, glacial deposits, volcanics); channel choked with debris; abundant fresh landslide scars in soils and rock; fresh channel deposits; high active area ratio (AAR[2]); supply-unlimited watershed.
Fan Activity Characteristics	Very High	Obvious fresh deposits in mainstem; channels, lobes or levees of previous events easily discernible; swaths of bare sediment or low (<2 yr) pioneer vegetation, multiple active channels	n/a[1]		n/a[1]		High		Very High		Very High	
	High	Obvious fresh deposits in mainstem; channels, lobes or levees of previous events easily discernible; swaths of bare sediment or low (<2 yr) pioneer vegetation	n/a[1]		n/a[1]		High		High		Very High	
	Moderate	Partially vegetated mainstem; channels, lobes or levees of previous events well visible; swaths of young (<50 yr) deciduous or coniferous vegetation on fan.	Low		Low		Moderate		High		High	
	Low	Vegetated mainstem; channels, lobes or levees of previous events difficult to discern; mature (>50 yr) vegetation on fan.	Very Low		Low		Low		Moderate		Moderate	
	Very Low	Raised paleo fans. Vegetated fan with no clear channels.	Very Low		Very Low		Low		Low		Moderate	

Note:

1. A combination of higher fan activity and lower basin activity is considered unlikely. [2]AAR stands for "Active Area Ratio" and is a ratio of the total area of sediment sources to the total basin area (Jakob, 1996). It provides a measure of degree of instability, normalized by basin area. A high AAR value implies abundant sediment sources which in turn results in a higher frequency of debris flows as those watersheds will produce debris flows whenever a critical hydroclimatic threshold is exceeded. AAR were not quantified for this assignment, but were assessed qualitatively during terrain analysis.

Geomorphic evidence for "activity" within each basin (e.g., erosion, landslides, sediment transport) was rated as Very Low, Low, Moderate, High, or Very High based on the freshness of channel deposits and whether basin sediment supply is limited or unlimited. Supply-unlimited basins typically contain erodible deposits and/or landslides that continuously charge the channel with sediment and debris; these will trigger an event every time a hydroclimatic threshold is exceeded. Supply-limited basins are typically rocky or heavily vegetated and with a lower drainage density, with fewer sediment and debris sources for the main channel; these require time to accumulate debris before a rainfall and/or snowmelt event can trigger a debris flow. To support sediment supply classification, BGC plotted the fan area / watershed area ratio for all fans. Basins with a high fan to basin area ratio are typically sediment supply-unlimited.

Geomorphic evidence for activity on each fan (e.g., evidence for recent events) was rated based on freshness and visibility of recent sediment deposits, sediment sources and the estimated age of vegetation (pioneer (<2 year), young (<50 year), or mature (> 50 year)). The rating considered evidence for geomorphic activity anywhere on the fan surface and along the mainstem channel.

Landslide Dam Outbreak Floods

Some watersheds are prone to landslide dam outbreak floods (LDOFs), which can significantly increase the magnitude of steep creek geohazards. Potential for LDOFs on streams with a Strahler order greater than XX (generally subject to "clear-water" flood processes) were assessed separately as part of the landslide-induced flooding prioritization in the TRW (Main Report Section 5.4). Table D-4 lists criteria used to estimate the potential for LDOFs in steep creek upper basins at a screening level of detail. Ratings were assigned as Very High, High, Moderate, Low or Very Low based on evidence of past landslide dams, presence of large landslide scars with the potential to travel to the valley floor and presence of channel sections potentially susceptible to blockage (e.g., channel constrictions). LDOF potential was implicitly considered in basin and fan activity that formed part of hazard likelihood criteria (Table D-3); as such it was not separately included in the hazard rating. However, LDOFs are a distinct population of events from "conventional" debris flows and debris floods. This rating serves as a flag for consideration in detailed frequency-magnitude analysis, should such analysis be completed in the future.

Table D-4. Landslide dam outbreak flood potential criteria.

Relative Frequency	Landslide Dam Outbreak Flood Potential
Very High	Extensive evidence of past landslide dams, presence of large landslide scars with the potential to travel to the valley floor, channel sections potentially susceptible to blockage (e.g., channel constrictions)
High	Evidence of past landslide dams, presence of large landslide scars with the potential to travel to the valley floor, channel sections potentially susceptible to blockage (e.g., channel constrictions)
Moderate	Minimal evidence of previous landslide dams, presence of potential landslides with the potential to travel to the valley floor, presence of channel sections potentially susceptible to blockage (e.g., channel constrictions)
Low	No evidence of previous landslide dams, presence of potential landslides with the potential to travel to the valley floor, presence of channel sections potentially susceptible to blockage (e.g., channel constrictions)
Very Low	Absence of evidence of larger landslides reaching the valley floor, no evidence of previous landslide dams

Evidence for LDOF potential was gathered from LiDAR and satellite imagery. Figure D-8 shows an example of a potential landslide dam location in XX basin. Note that actual landslide dams are not visible at the resolution of Figure D-8; the interpretation is based on the combination of characteristics noted above. However, these basins are identified on the web application and in results for consideration in future more detailed assessment.

Scoping Report Note: An annotated figure showing an example of a landslide dam in a steep creek basin will be added for the Draft and Final Reports.

Figure D-8. Example of evidence for landslide dam outbreak flood potential in XX basin.

D.4.1.2. Morphometric Statistics

Scoping report note: the below is placeholder text based on our experience with these methods elsewhere. While it is written with the assumption that the analysis is possible with the data available, we will re-evaluate that once the inventory has been completed.

Steep creeks are subject to debris flows and debris floods that follow a frequency-magnitude (F-M) relationship, where larger events occur more rarely. While a single, representative frequency may be used in prioritization studies, defining an F-M relationship is essential for more detailed geohazard scenario modelling, risk estimation and the design of risk control measures.

F-M relationships of debris flows and debris floods are difficult to compile because of the scarceness of direct observations, the discontinuous nature of event occurrence, and the obfuscation of field evidence due to progressive erosion or debris inundation. Detailed F-M analyses involve a high level of effort for each creek and are outside of the present scope of work.

However, when a number of reliable F-M curves have been assembled in a specific region, regional relations can be developed. These relations can then can be applied to watersheds for which detailed studies are unavailable, unaffordable or impractical due to lack of dateable field evidence. The number of watersheds with this level of detailed information is increasing, but at present is still limited.

In this assessment, BGC used F-M curves developed by Jakob et al. (2016) from creeks in southwestern British Columbia and Bow Valley, Alberta that have received detailed geohazard investigations (where the magnitude refers to sediment volume rather than peak discharge) (Holm et al., 2018). Individual F-M curves were normalized by dividing sediment volume by fan area and then plotted collectively versus return period. A logarithmic best-fit curve was then fit to the data, Figure D-9 and Figure D-10 show the resulting F-M curves for debris flows and debris floods in southwestern British Columbia and the Bow Valley, Alberta, respectively.

BGC cautions against the indiscriminate use of regionally based F-M curves, especially in watersheds where multiple geomorphic upland processes are suspected, or where drastic changes (mining, major landslides) have occurred in the watershed that change event frequency compared to that in the past. These site-specific factors could result in data population distributions that violate underlying statistical assumptions in the regional F-M curves. Although no comparably detailed assessments have been completed within the TRW, BGC completed a preliminary validation of the curves based on the relatively 'best studied' fans within the study area (Table D-5).

Table D-5. Fans within the Thompson River Watershed that have previously received relatively more detailed geohazards assessments.

Fan ID	Name	Dominant Process	Sources

Scoping Report Note: Table D-5 *will be updated with applicable studies for the Draft and Final Reports. Results of the preliminary validation of the regional curves will be completed for the Draft and Final Reports.*

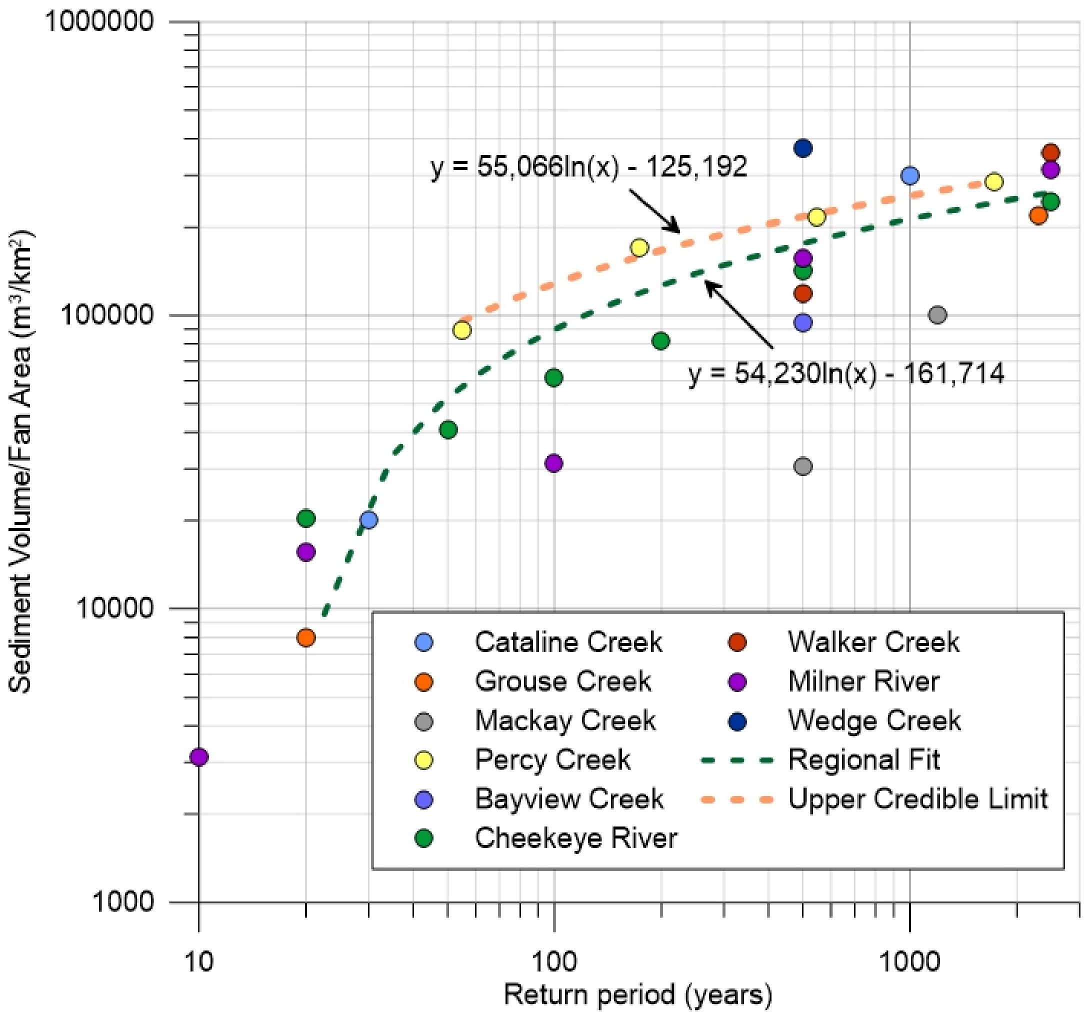

Figure D-9. F-M curve for debris flows in southwestern British Columbia using data from nine study creeks. Curves are truncated at the 30-year return period (smallest period considered in this study) (data from Jakob et al., 2016).

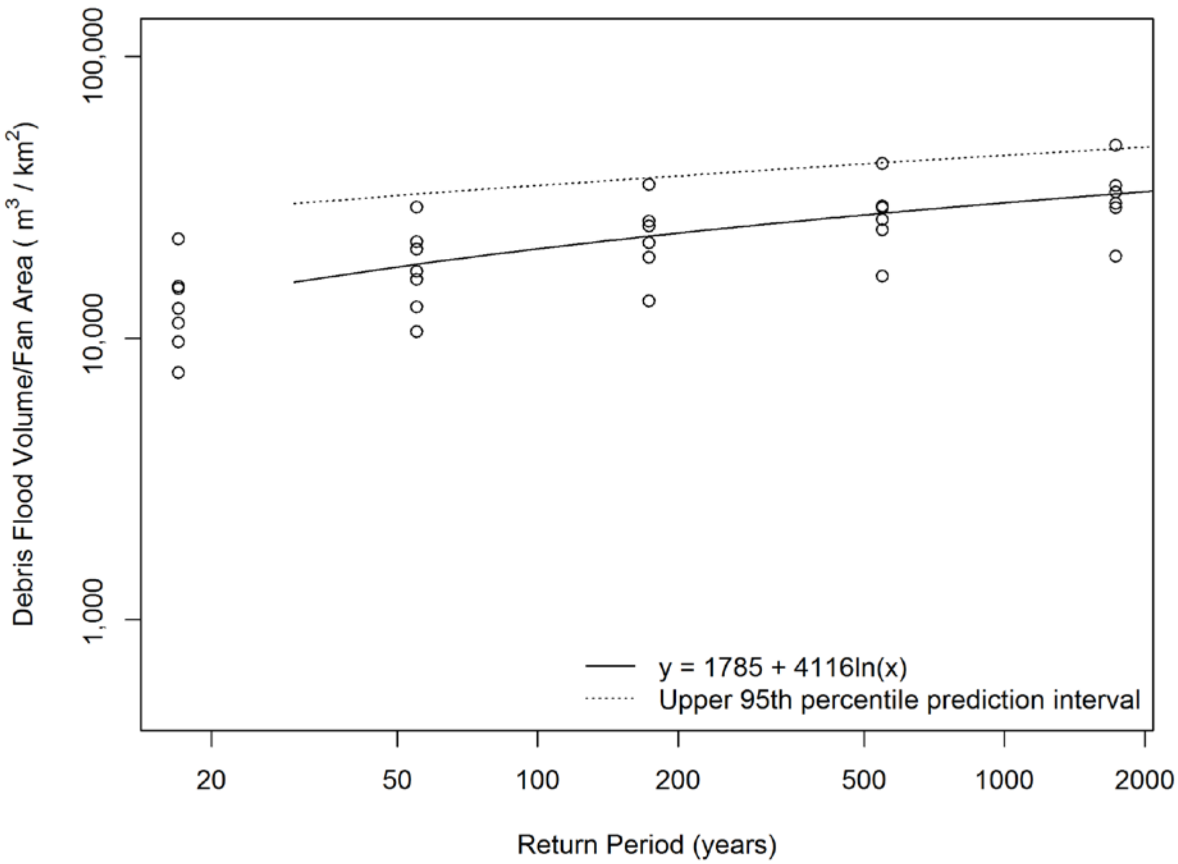

Figure D-10. F-M curve for debris floods in the Bow Valley, Alberta. Curves are truncated at the 30-year return period (smallest period considered in this study) (data from Jakob et al., 2016).

Scoping report note: the above graph would be updated for the draft and final reports.

The regional relations below predict the sediment volume (V_S) in m^3 generated in various return period (T) events and normalized by fan area (A_f) in km^2. These relations have been established by BGC through detailed dendrochronological and/or radiocarbon dating methods paired with expert judgement. Each relation is applicable for return period events ranging from 10 to 2,500 years.

The regional debris-flow relation (Equation D-1) was developed by Jakob et al. (2016) from the detailed study[5] of nine creeks in southwestern BC and has a coefficient of determination (R^2) of 0.65, which indicates goodness of curve fit.

$$V_S = A_f[54{,}230\ln(\mathrm{T}) - 161{,}714] \quad \text{[Eq. D-1]}$$

5 BGC 2015a, 2014b, 2013, and 2008; Cordilleran Geoscience 2015 and 2008; and Michael Cullen Geotechnical Ltd. and Cordilleran Geoscience 2015.

The regional debris-flood relation (Equation D-2) was developed by Jakob et al. (2016) from the detailed study[6] of seven creeks in the Bow Valley, near Canmore, Alberta and has an R^2 of 0.51.

$$V_S = A_f[4116\ln(\mathrm{T}) + 1786] \quad \text{[Eq. D-2]}$$

BGC predicted sediment volumes for each prioritized study creek based on the upper end of the return period range. Best estimates are based on the best fit line for the regional F-M curve, and maximum estimates are based on the upper 95% prediction limit.

Having determined sediment volume, three published empirical relations for granular debris flows were considered to estimate peak flow (or discharge) on each study creek interpreted as dominantly subject to debris flows. These relations are as follows:

$M = 13 * Q^{1.33}$ (Mizuyama et al., 1992) [Eq. D-3]

$M = 28 * Q^{1.11}$ (Jakob and Bovis, 1996) [Eq. D-4]

$M = (10 * Q)^{6/5}$ (Rickenmann, 1999) [Eq. D-5]

where M is the debris flow volume in m^3 and Q is peak discharge in m^3/s. The above equations were solved iteratively for Q using the sediment volumes (M) derived using Equation D-1. The average of the above peak flow relations is reported for each creek in the tables in their respective section below, where applicable.

D.4.2. Impact Likelihood

BGC assigned an impact likelihood rating to each fan that considered the relative spatial likelihood that geohazard events, given they occur, result in uncontrolled flows that could impact elements at risk. This rating is assigned as an average for the fan. It is not an estimate of spatial probability of impact for specific elements at risk, which would vary depending on their location. This section describes methods to determine this rating.

BGC used two methods to estimate impact likelihood: quantitative geohazard susceptibility modelling for all streams identified as being subject to steep creek hazards (Section D.3.1.1) and terrain interpretations for prioritized study sites. Both were combined in criteria to assign impact susceptibility ratings. The methods described in this section are applicable for regional scale assessment but do not replace quantitative estimates of spatial probability of impact to specific elements at risk, as would be completed for detailed risk analysis.

D.4.2.1. Susceptibility Modelling

Debris flow or debris flood susceptibility mapping based on terrain analysis is limited by the availability of surface evidence for past events, which may be hidden by development or

[6] BGC 2015b-f, 2014b, c.

obscured by progressive erosion or debris inundation. BGC used the Flow-R model[7] developed by Horton *et al*. (2008, 2013) to model debris flow and debris flood susceptibility within the study area, including both developed and undeveloped areas. Others that have modelled debris flow susceptibility using comparable approaches include Blahut et al., (2010), Baumann et al., (2011), and Blaise-Stevens and Behnia (2016).

Flow-R propagates landslides through a digital elevation model (DEM). Sections of the freely available Canadian Digital Elevation Model (CDEM) at 20 m resolution were used in the current project; the analysis did not rely on LiDAR data. Flow-R simulates flow propagation based on both spreading algorithms and simple frictional laws. As explained in Sections D.3.1.1, the source areas were identified as stream segments associated with debris flow or debris flood processes.

BGC used the following steps to complete debris flow/flood susceptibility modelling for all creeks in the TRW identified as potentially subject to debris floods or debris flows (Section D.3.1.1):

- For model calibration purposes, BGC first completed susceptibility modelling at several steep creeks outside the study area, in the Town of Canmore. Steep creeks in this area have been previously assessed by BGC at a higher level of detail than any creeks within the Thompson River Watershed (Holm et al, 2016). As such, the Canmore-area creeks provided a good starting point to calibrate the model.
- BGC then applied the calibrated model to a selected number of creeks with reported historical events (Hummingbird Creek, and compared the results to terrain analyses and mapped extents (e.g., Figure D-11.)
- Finally, BGC applied the model to map debris flow and debris flood susceptibility on all creeks in the stream network within the TRW.

Table D-6 and Table D-7 show the calibrated debris flow and debris flood parameters, respectively.

Scoping report note: Draft and Final report will include additional notes here on calibration.

Table D-6. Calibrated debris flow parameters used in Flow-R.

Selection	Flow-R Parameter	Value
Directions algorithm	Holmgren (1994) modified	dh = 2 exponent = 1
Inertial algorithm	Weights	Gamma (2000)
Friction loss function	travel angle	5°
Energy limitation	Velocity	< 15 m/s

[7] "Flow-R" refers to "Flow path assessment of gravitational hazards at a Regional scale". See http://www.flow-r.org

Table D-7. Calibrated debris flood parameters used in Flow-R.

Selection	Flow-R Parameter	Value
Directions algorithm	Holmgren (1994) modified	dh = 2 exponent = 1
Inertial algorithm	weights	Cosinus
Friction loss function	travel angle	4°
Energy limitation	velocity	< 15 m/s

Flow-R can generate the maximum susceptibility that passes through each cell of the DEM, or the sum of all susceptibilities passing through each cell. The former is calculated in Flow-R using the “quick” calculation method and is used to identify the area susceptible to landslide processes. The “quick” method propagates the highest source areas, and iteratively checks the remaining source areas to determine if a higher energy or susceptibility value will be modelled. The latter is calculated in Flow-R using the “complete” method and can be used to identify areas of highest relative regional susceptibility. The complete method triggers propagation from every cell in the source segments.

For this study, the sum of susceptibilities using the “complete” method was calculated once the final model parameters had been chosen. The sum of susceptibilities has no physical meaning, rather it was used as a regional comparison between sites to determine higher hazard potential. The debris flow and debris flood scenarios were modelled separately.

The summed susceptibility values were classified into areas of low, moderate, and high susceptibility according to the distribution of all susceptibility values of the study area. Areas of “low” regional susceptibility were within one standard distribution, “moderate” susceptibility between one and two standard distributions, and “high” susceptibility greater than two standard distributions. A threshold value, corresponding to the __ percentile was defined for areas with extremely low susceptibility.

Scoping Report Note: This section under development and values may be changed for the Draft and Final Reports.

This procedure allows direct comparison of the relative debris flow/debris flood susceptibility for fans within the study area. Areas of higher relative regional susceptibility in a susceptibility zone account for both more source zones (increasing the number of potential debris flows/floods that reach a susceptibility zone), as well as increased susceptibility due to topographic effects (incised channels or avulsion paths).

Appendix XX provides a more detailed description of the modelling methodology

Scoping Report Note: Appendix XX is under development and will be completed and appended to the Draft and Final Reports.

Scoping Report Note: An annotated figure showing the results of the susceptibility modelling compared to the mapped extents of historical events will be provided for the Draft and Final Reports.

Figure D-11. Comparison of susceptibility modelling results with mapped extents of historical events at ___ fan.

Debris flow and debris flood susceptibility model results for each creek are displayed on the web map. Three ratings are shown, corresponding to High, Moderate and Low relative susceptibility.

Flow-R results generally corresponded well to the extent of known debris flow or debris flood events within the study area, but regional scale modelling contains uncertainties and should be interpreted with caution. Susceptibility modelling is not suited for detailed risk analyses or risk control design, which require modelling of flow extent, depth and velocity for specific hazard scenarios. BGC highlights the followings specific limitations:

- Susceptibility modelling on creeks without mapped fans contain much higher uncertainty.
- Some areas mapped as susceptible to debris flows or debris floods may not have credible potential for events due to factors not considered in screening level modelling, such as lack of sediment supply.
- Modelling was only completed for creeks within the mapped stream network. Because debris flows can also initiate in areas without mapped streams, additional debris flow hazard areas exist that were not mapped.
- Debris flow and debris flood susceptibility model calibration was optimized for flow propagation on the fan. Susceptibility modelling in the upper basin should be considered a proxy for debris sources, not necessarily an accurate representation of actual source areas.

D.4.2.2. Terrain Interpretations

BGC used terrain interpretations of channel avulsion as a proxy to assign debris flood or debris flow impact susceptibility ratings, where uncontrolled flow outside the active channel is assumed to have higher potential to impact elements at risk. Avulsion refers to a sudden change in stream channel position on a fan due to partial or complete blockage of the existing channel by debris or due to exceedance of bankfull conditions. During an event, part or all of a flow may avulse out of the existing channel and travel across a different portion of the fan. Table D-6 lists criteria used to rate avulsion potential as Very High, High, Moderate, Low, or Very Low, based on channel confinement and surface evidence for previous avulsions. Fans with previously recorded avulsions were assigned a “Very High” or “High” rating. BGC notes that fan-deltas (fans that form in standing water bodies, such as large lakes) have an inherently higher avulsion potential than terrestrial (land-based) alluvial fans due to channel back-filling effects from the stream-water body interface. As such, these fans were assigned a “Very High” or “High” rating, as long as the channel was not entrenched (highly dissected) into the fan. A single representative rating is applied for an event magnitude corresponding to the hazard frequency (likelihood) rating.

Channel confinement level was based on estimated bank height and the presence of locations where confinement could be reduced during an event (e.g., channel bends, changes in channel gradient, channel constrictions at road crossings).

Surface evidence for previous avulsions included vegetation and the presence of relict channels, lobes and deposits on the fan surface (e.g., Figure D-13). These features are readily detectable on LiDAR hillshades; interpretations are less certain for areas without LiDAR coverage.

BGG acknowledges that some overlap exists in the criteria used to assess hazard likelihood and avulsion potential, because channels with high avulsion potential are more likely to have obvious evidence for debris flows or debris floods. More conservative hazard susceptibility ratings were assigned to fans with evidence for both recent events and channel avulsions.

Figure D-12. Example of evidence for higher avulsion potential on Miledge Creek, located north of Blue River.

Table D-8. Avulsion potential criteria.

			Channel Confinement[1]				
			Very High	**High**	**Moderate**	**Low**	**Very Low**
			Deeply incised, straight channel; no obvious locations where confinement could be reduced during an event (e.g., channel bends, changes in channel gradient, channel constrictions).	Obvious (likely >15 m high) channel banks on LiDAR hillshade; no obvious locations where confinement could be reduced during an event (e.g., channel bends, changes in channel gradient, channel constrictions).	Obvious (likely 5-15 m high) channel banks on LiDAR hillshade; some presence of locations where confinement could be reduced during an event (e.g., channel bends, changes in channel gradient, channel constrictions or areas of potential blockage).	Minor or transient channel banks visible on LiDAR hillshade (likely < 5 m high), or obvious presence of locations where confinement could be reduced during an event (e.g., channel bends, changes in channel gradient, channel constrictions).	Multiple channels visible on LiDAR hillshade. Minor or transient channel banks visible on LiDAR hillshade (likely < 5 m high), or obvious presence of locations where confinement could be reduced during an event (e.g., channel bends, changes in channel gradient, channel constrictions).
Surface Evidence of Previous Avulsions[2]	**Very strong**	Multiple obvious fresh avulsion paths exist. swaths of bare sediment or low (<2 yr) pioneer vegetation exist on previous avulsion paths.	n/a[3]	n/a[3]	n/a[3]	Very High	Very High
	Strong	Obvious fresh avulsion paths exist. swaths of bare sediment or low (<2 yr) pioneer vegetation exist on previous avulsion paths.	n/a[3]	n/a[3]	High	High	Very High
	Moderate	Relict channels on fan surface are well visible; swaths of young (<50 yr) deciduous or coniferous vegetation exist in previous avulsion paths.	n/a[3]	n/a[3]	Moderate	High	Very High
	Poor	Relict channels on fan surface exist but are vegetated and difficult to discern.	n/a[3]	Low	Low	Moderate	High
	Very Poor	No clear relict channels can be identified.	Very Low	Very Low	Low	Low	Moderate

Notes:
1 Channel confinement is a rating applied at the fan level of detail that primarily considers the natural channel. Channel constrictions at road crossings were identified as potential avulsion mechanisms (where existing). However, quantitative analysis of channel conveyance at bridge and culvert crossings was outside the scope of work.
2 Fans with no surface evidence or record of previous avulsions were assigned to the "Low" avulsion susceptibility category. Fans with recorded previous avulsion events were assigned to the "High" category.
3 A combination of high channel confinement and higher or moderate evidence of avulsion is considered unlikely.

D.4.2.3. Impact Susceptibility Rating

Table D-7 lists criteria used to assign an impact susceptibility rating to each fan. The ratings are based on terrain criteria and the proportion of the fan modelled as low, moderate, or highly susceptible to debris flows or debris floods. For example, a fan with more abundant evidence for previous flow avulsions and a greater area with high debris flow/flood susceptibility would be assigned a higher rating.

Table D-9. Impact susceptibility criteria.

Impact Susceptibility Rating	Terrain Criteria	Susceptibility Modelling
Very Low	Very low avulsion potential; susceptibility modelling results suggest that avulsions, if occurring, have very low potential to result in uncontrolled flows that could impact areas containing existing elements at risk.	<5% of fan area is rated Moderate or High susceptibility; areas rated as High susceptibility are generally confined to the active channel.
Low	Low avulsion potential; susceptibility modelling results suggest that avulsions, if occurring, have low potential to result in uncontrolled flows that could impact areas containing existing elements at risk.	<10% of fan area is rated Moderate or High Susceptibility; areas rated as High susceptibility are mostly confined to the active channel.
Moderate	Moderate avulsion potential; susceptibility modelling results suggest that avulsions, if occurring, have moderate potential to result in uncontrolled flows that could impact areas containing existing elements at risk.	10-30% of fan area is rated as Moderate or High Susceptibility
High	High avulsion potential; susceptibility modelling results suggest that avulsions, if occurring, have high potential to result in uncontrolled flows that could impact areas containing existing elements at risk.	30-60% of the fan area is rated as Moderate or High susceptibility
Very High	Very High avulsion potential; susceptibility modelling results suggest that avulsions, if occurring, have very high potential to result in uncontrolled flows that could impact areas containing existing elements at risk.	>60% of the fan area is rated as Moderate or High susceptibility.

Scoping Report Note: The specified extent values in the susceptibility modeling results are under development and may change based on the outcomes of the Flow-R modelling. This table may be updated for the Draft and Final Reports.

D.4.3. Geohazard Rating

Table D-8 presents a qualitative geohazard rating assigned to each alluvial fan at the prioritized steep creek study sites. It combines the hazard likelihood (Table D-3) and susceptibility ratings (Table D-7) for each alluvial fan, and provides a relative regionalized estimate of the likelihood for events to occur and result in flows outside the main channel. For example, a fan estimated to have a high likelihood of events that could result in consequences, and where large proportions of the fan are highly susceptible to impact, would be assigned a high geohazard rating.

Table D-10. Geohazard rating.

Geohazard Likelihood	Geohazard Rating				
Very High	M	H	H	VH	VH
High	L	M	H	H	VH
Moderate	L	L	M	H	H
Low	VL	L	L	M	H
Very Low	VL	VL	L	L	M
Impact Susceptibility	Very Low	Low	Moderate	High	Very High

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APPENDIX E
HAZARD ASSESSMENT METHODOLOGY: LANDSLIDE DAMS

DRAWINGS