Electoral Area A

Preliminary Steep Creek Hazard Assessment

Prepared by BGC Engineering Inc. for:

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION

November 3, 2023

Project 0431038

Pioneering responsible solutions to complex earth science challenges

November 3, 2023 Project 0431038

Metro Vancouver
4515 Central Boulevard
Burnaby, BC V5H 0C6

Attention: Tom Pearce, RPP, MCIP

Electoral Area A - Preliminary Steep Creek Hazard Assessment

BGC Engineering Inc. (BGC) is pleased to provide this report documenting the preliminary characterization of steep creek hazards in select sections of Metro Vancouver's Electoral Area A.

We appreciate the opportunity to work for Metro Vancouver on this interesting project.

Should you have any questions, please do not hesitate to contact the undersigned.

Yours sincerely,

BGC Engineering Inc.
per:

Marc-André Brideau, Ph.D., P.Geo.
Senior Engineering Geologist

TABLE OF REVISIONS

Date	Revision	Remarks
June 9, 2023	DRAFT	Issued for comments
November 3, 2023	0	Incorporates comments from Metro Vancouver and updates modelling using the 2022 lidar

CREDITS AND ACKNOWLEDGEMENTS

BGC would like to acknowledge the following contributors to this report:

- Julia Kimball, M.A.Sc., Geological Engineer-in-Training
- Hazel Wong, M.Eng., P.Geo., Engineering Geologist
- Betsy Waddington, M.Sc., P.Geo., Principal Geoscientist

LIMITATIONS

BGC Engineering Inc. (“BGC”) prepared this document[1] for the exclusive use of Metro Vancouver (the “Client”). This document is only intended for the Client’s use for the specific purpose or project identified herein. This document may not be used for any other purpose, modified, or published (either on the Internet, through open-source artificial intelligence (AI) tools, or through any other form of print or electronic media) without BGC’s express written consent. BGC is not liable for any loss, injury, or damages arising from any unapproved use or unauthorized modification of this document.

No third party may use or rely on this document unless BGC provides express written consent. Any use or reliance which a third party makes of this document is the responsibility of the third party and is at such third party’s own risk. BGC accepts no responsibility for damages, if any, suffered by any third parties as a result of their use of this document.

This document contains BGC’s professional opinions on the specific issues identified herein, based on the information available to BGC when BGC prepared this document. While preparing this document, BGC relied on information BGC received from the Client or other sources. Unless otherwise stated in this document, BGC did not independently verify such information, and BGC assumed that such information is accurate, complete, and reliable. BGC is not responsible for any deficiency, misstatement, or inaccuracy in this document due to errors or omissions in information provided by the Client or third parties.

This document may include or rely upon estimates, forecasts, or modeling analyses (e.g., results or outputs of numerical modeling) that are based on available data. Such estimates, forecasts, or modeling analyses do not provide definitive or certain results. The Client is solely responsible for deciding what action (if any) to take based on any estimates, forecasts, or modeling analyses.

BGC prepared this document in accordance with generally accepted practices for similar services in the applicable jurisdiction. BGC makes no warranty (either express or implied) related to this document. BGC is not responsible for any independent conclusions, interpretations, extrapolations, or decisions made by the Client or any third party based on this document. The record copy of this document in BGC’s files takes precedence over any other copy or reproduction of this document.

[1] References in these Limitations to the “document” include the document to which these Limitations are attached, any content contained in this document, and any content referenced in this document but located in one of BGC’s proprietary software applications (e.g., Cambio).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF DRAWINGS

1.0 INTRODUCTION

BGC Engineering Inc. (BGC) was retained by Metro Vancouver to characterize steep creek hazards in select sections of the Electoral Area A (Figure 1-1). BGC (March 30, 2022) synthesized previous geohazard studies in a spatial database (geographical information system – GIS), supplemented by terrain analyses to confirm, refine, or add to previously developed landslide, snow avalanche, riverine and coastal flooding hazard inventories. The purpose of the previous and current studies is to inform Metro Vancouver's review process of building permit (primarily) and land development permit (secondary) applications in Electoral Area A. The work was approved by Metro Vancouver on January 19, 2023 (PO 766797) and is performed under Metro Vancouver's Consulting and Professional Services Agreement with the limit of liability and insurance coverage outlined in Document 49096723, RFSQ No 21-364, and approved on November 16, 2021. Addendum to the contract on July 25, 2023 and September 26, 2023 were issued to cover a presentation to the committee and model updates using the newly available 2022 lidar for the study area.

1.1 Scope

The scope of this project is to use the Tier 1 level geohazard assessment (see Section 1.2 for definition of assessment levels) prepared in the first phase of work (BGC, March 30, 2022) and develop a Tier 2 level assessment for the debris flood and debris flow steep creek geohazards identified in the project area (Figure 1-1). This report includes:

- A summary of source materials consulted, and methodology applied.
- An inventory of the identified debris flood and debris flow steep creek hazard areas (fans) with associated attributes and ratings assigned to the hazard areas. Including:
    - Estimation of prioritization-level steep creek hazard for each fan.
    - Estimation of preliminary magnitude-frequency curve for each fan based on regional empirical relationships between watershed area and debris volumes available in literature.
    - Sensitivity analysis using potential effects of climate change on debris volume.
- Maps containing steep creek hazard susceptibility results (numerical modelling outputs).

Additionally, digital GIS files of the study results are provided to Metro Vancouver with this report.

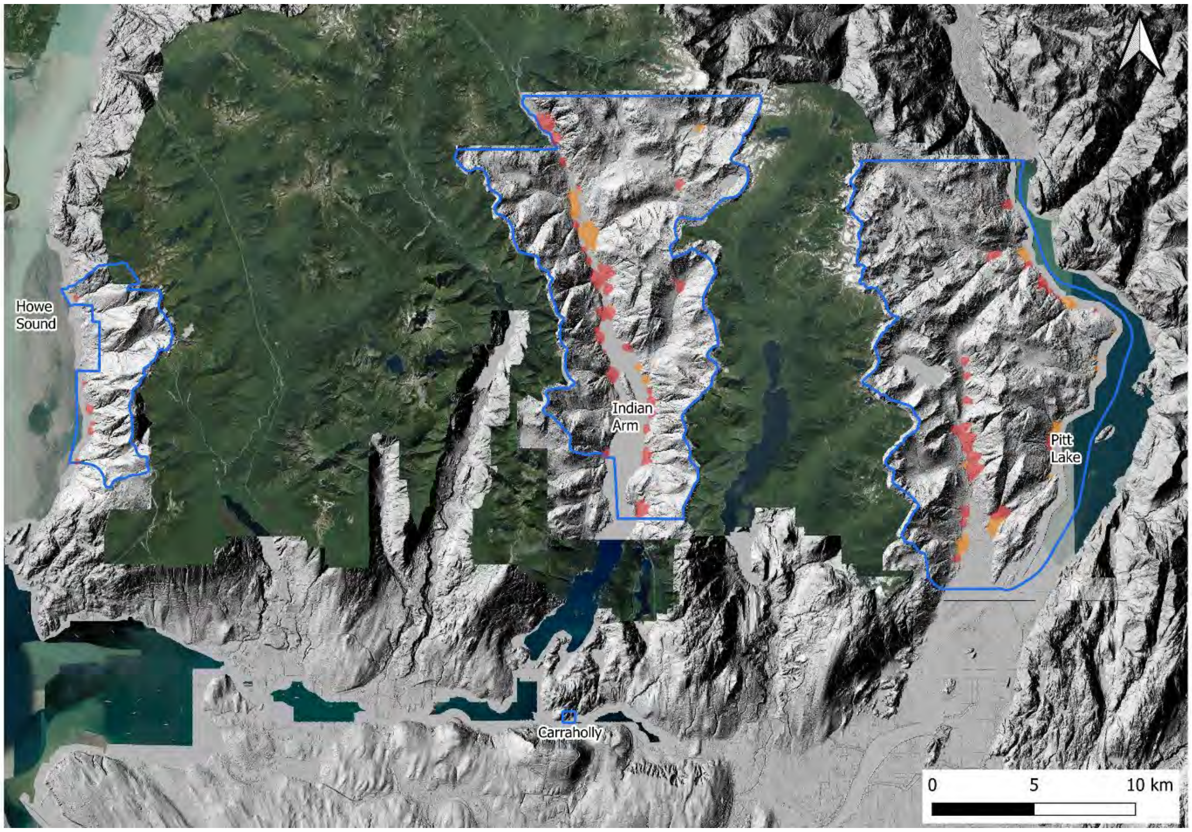


Figure 1-1 Project area (blue) for the steep creek hazards characterization in select sections of Metro Vancouver's Electoral Area A. Also shown are previously mapped, by BGC, debris flow (red) and debris flood (orange) fans. Lidar hillshade from NRCan High Resolution Digital Elevation Model Mosaic and 2022 lidar hillshade from Metro Vancouver for the project area.

1.2 Level of Detail

Geohazard assessments can be prepared at different levels of detail depending on the intended use, geographic scale of the project area, and available budget. While the Engineers and Geoscientist of British Columbia landslide assessment guidelines (EGBC, 2023) mention regional scale studies, their level of effort guidelines are focused on project-specific cases (e.g., single family development, subdivision, town). As the current project is regional in scale and not specific to a development, the three tiers of level of detail based on a draft of the BC floodplain mapping guidelines (Table 1-1) was used to provide context for the current work.

Table 1-1 Summary descriptions of Tiers 1 through 3 mapping. This study was completed at Tier 2 level of detail.

	Tier 1	Tier 2	Tier 3
Tier	**1: Hazard Identification Mapping**	**2: Base Level Hazard Assessment Mapping**	**3: Detailed Hazard Assessment Mapping**
Level of Detail	**Low**	**Medium**	**High**
Relative Cost	$	$$	$$$$
Target Use	Emergency response planning Prioritization Insurance.	Some land use planning (e.g., to delineate the area subject to regulation and/or additional review) Input to most risk assessments Emergency response planning.	Engineering design Building control bylaws Detailed regulatory land use planning Site level assessments.
Limitations to Use	Not appropriate for engineering design Not appropriate for site level assessments Not appropriate for most land use planning	Not appropriate for engineering design Not appropriate for site level assessments.	Appropriate for some engineering design purposes (e.g., conceptual design), but additional site-level detail may still be required for detailed design.
Accuracy and Uncertainty	These types of maps are indicative only and have significant uncertainty.	These types of maps can be broadly accurate over large areas but have significant uncertainty at a site level related to the model and mapping inputs. Climate change and other drivers of change will create additional uncertainty.	Generally considered the most accurate mapping. There will still be uncertainty related to data availability and modelling accuracy. Further climate change and other drivers of change will create uncertainty.
Hazard Scenarios	These types of mapping projects will include a small number of generalised hazard scenarios (e.g., a frequent and a rare event).	These types of mapping projects will include a range of hazard scenarios including consideration for future changes.	These types of mapping projects will include a full range of quantifiable hazard scenarios (e.g., 10% through 0.2% AEPs) and future changes.
Geographic Scale	Generally applied over large areas (e.g., larger watersheds, provincial-scale, etc.).	Generally applied over smaller regional areas (e.g., within a regional district, within a medium watershed).	Local area (e.g., within a single municipality, a single geomorphic reach, or a small watershed).

1.3 Other Considerations

The project limitations and exclusions outlined below were used to complete the project within the available timeframe and budget. They also limit the current geographical extent of the analysis. The current scope excludes:

- Site-specific magnitude-frequency (how large and how often) characterization of steep creek hazards, and their intensity (velocity, depth, erosion potential, impact forces)
- Geohazard risk assessment (i.e., inclusion of geohazard consequences)
- Characterization of debris flood and debris flow hazards initiating within the project area and impacting infrastructure or people outside Electoral Area A
- Existing geohazard mitigation strategies
- Characterization of geohazards including landslide hazards other than debris flows and debris floods
- Assessment of potential impact of recent and legacy resource road on landslide hazard and surface water drainage
- Detailed assessment of the potential effects of wildfire, insect infestations or climate change on geohazards.

The completed first phase of work (BGC, March 30, 2022) describes the limitations of the hazard mapping completed in the study area. The debris flood and debris flow hazards identified and mapped in the first phase of work have been carried forward to this study. This study refines the mapped debris flood and debris flow hazard areas identified in the first phase of work; however, it is still limited by variable mapping scale and other limitations described in the first phase of work (BGC, March 30, 2022). Figure 1-1 outlines the publicly available LiDAR (e.g., topographic data at a scale finer than the 1:20,000 scale data available region-wide) used to refine the mapped debris flood and debris flow hazards in the study area. Appendix A documents source material referenced for this second phase study. Past or present-day field observations can be used to update the geohazard mapping and characterization once they become available.

BGC notes that empirical classification of steep creek geohazard types (i.e., clear-water flood, debris-flood, or debris-flow hazards) were used in the first phase of work because it can be applied to large regions (BGC, March 30, 2022). This level of detail was considered reasonable for a Tier 1 assessment. Empirical classification reliability is lower than for Tiers 2 and 3, which typically combine multiple lines of evidence such as statistical, remote-sensed, and field observation data. Assigning each fan with one of three likely steep creek process types also does not recognize that there is a continuum between clear-water floods and steep-creek processes that is not accounted for in morphometrics. Similarly, many creeks are prone to a specific hazard up to a certain return period, above which another process dominates.

The geohazard ratings, susceptibility mapping and 200-year debris flow volume estimates provided as results from this study do not substitute detailed site-specific characterization and should be superseded by any detailed (e.g., Tier 3) site studies in the future. The results presented in this report are at the Tier 2 level which is not sufficient to support mitigation planning, selection, and design.

2.0 STUDY AREA

The select sections of Electoral Area A that are part of the project include a range of physiographic regions from rugged steep mountains of the Coast Mountain Range, to rocky islands and a low-lying island of surficial material (Holland, 1976; Armstrong & Hickock, 1980; Blais-Stevens, 2008). While the climate of the low-lying area differs from the high elevation peaks, they typically all receive significant amounts of precipitation (rain or snow) in the winter (Figure 2-1). The project area is also within the zone of influence of the Cascadia Subduction zone which represents a high seismic hazard (Figure 2-2).

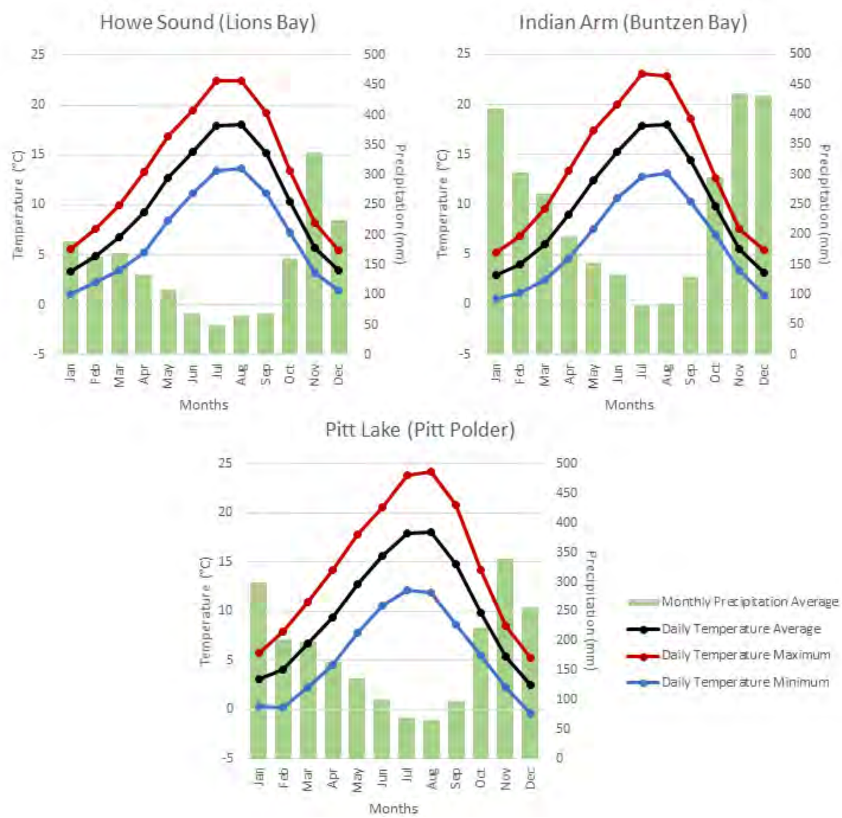


Figure 2-1 Climate Normals for three weather stations at or near sea level (data from PCIC, 2021).

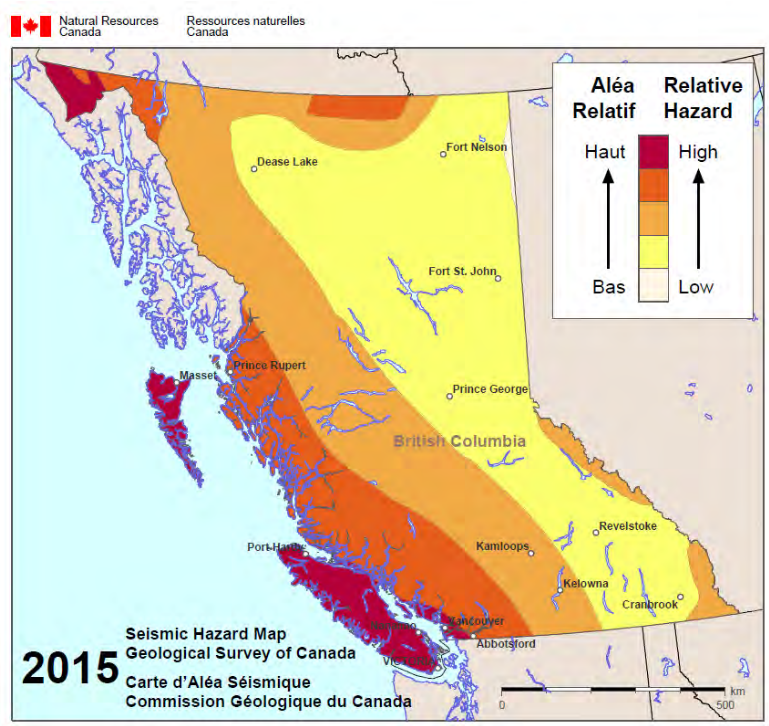


Figure 2-2 Simplified seismic hazard map for British Columbia (Natural Resources Canada, 2015).

3.0 METHODOLOGY

This section summarizes the approach used to characterize steep creek hazards in select areas of Metro Vancouver's Electoral Area A at a Tier 2 level of detail. Appendix B provides further details about geohazard characterization methods. This methodology has been developed by BGC over the last nine years based on regional steep creek risk assessments in southern Alberta and British Columbia. At the current level of detail, the geohazard characterization mapping unit is the fan. This means that the estimated geohazard rating is assumed to be consistent within a given fan. A more detailed assessment (Tier 3) would be needed to subdivide the hazard and risk within a fan.

Figure 3-1 illustrates the key components of regional geohazard risk assessment: hazard, exposure (e.g., people and assets), and vulnerability (likelihood of damage or loss). The combination of exposure and vulnerability represents consequences, and all three components together represent risk. In a regional risk assessment, each of these components is estimated separately and combined to provide a relative rating for each hazard area. This study considers the hazard component of risk. Exposure and vulnerability are not assessed but could be included as part of a future study.

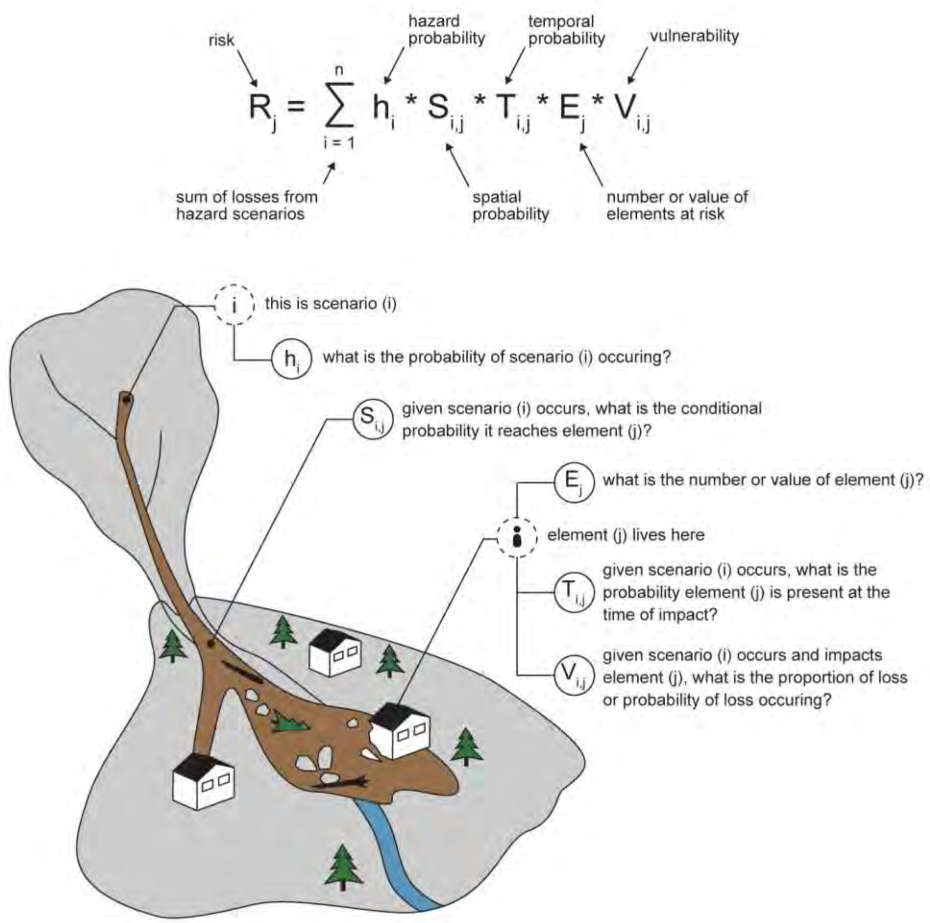


Figure 3-1 Elements of the regional steep creek risk prioritization approach. The hazard component of the equation is being assessed in this report.

3.1 Hazard Assessment

The parameters used to rank steep creek geohazard areas are:

- Hazard likelihood (probability a steep creek hazard initiates)
- Impact likelihood (probability that if a steep creek hazard initiates, it reaches the area of interest).

Together, these parameters reflect an estimated likelihood that a geohazard process occurs and reaches areas with elements at risk with a certain level of intensity. This likelihood is presented in the form of a geohazard rating.

3.1.1 Geohazard Rating

Table 3-1 describes the application of hazard likelihood and impact likelihood whereas Table 3-2 presents the qualitative geohazard rating system used in this study. It combines hazard and impact likelihood ratings to rate the potential for events to occur and – if they occur – impact potential elements at risk on the fan. The ratings assume that potential 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. BGC notes that all steep creek hazard areas are subject to hazard scenarios of different frequencies and magnitudes, where larger events occur more rarely. To compare hazard areas, BGC applied a rating that represents a single, “typical” event frequency assigned to each fan and watershed based on surface evidence for previous events, recorded events, and reference to previous work. The typical event corresponds to an event of sufficient magnitude to have credible potential for consequences.

Table 3-1 Description of the applications for the hazard and impact likelihood.

Parameters	Area Assessed	Application
Hazard likelihood	Alluvial fans	Benchmark estimate of geohazard likelihood for all alluvial fans; basis for assign geohazard ratings to alluvial fan
Impact likelihood	Alluvial fans	Benchmark, relative estimate of impact likelihood for all prioritized geohazard areas, basis to assign geohazard rating to all alluvial fans.

Table 3-2 Geohazard rating.

Hazard 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

3.1.2 Hazard Likelihood Estimation

Hazard likelihood was estimated based on terrain interpretation considering both basin and fan activity. Basin activity considered parameters such as identifiable source areas, the nature of channels, and whether watersheds are sediment supply-limited or unlimited. Fan activity focused on evidence of fresh deposits and lobes on the fan, and the type of vegetation. Basin and fan activity criteria were combined in a matrix to estimate hazard likelihood rating. Appendix B provides further description of methods to estimate geohazard likelihood and describes limitations and uncertainties.

3.1.3 Impact Likelihood Estimation

BGC estimated the relative likelihood that debris flows or debris floods will result in avulsions on fans, given the occurrence of a geohazard. Impact likelihood is estimated based on a combination of susceptibility modelling and terrain mapping of avulsion activity (informed by previous assessments and event records where available) and landslide dam outburst flood (LDOF) potential.

Susceptibility modelling generates spatial information on an area’s propensity for steep creek hazards. The modelling does not represent a specific event but provides a range of possible runout events. Relative to susceptibility values across a modelled area, areas of higher susceptibility are areas which are more likely to be impacted by hazard events.

In the susceptibility modelling method applied in this study, BGC used classified stream segments, and the Flow-R model[2] developed by Horton et al. (2013) to identify debris-flow or debris-flood susceptibility and model their runout susceptibility.

Appendix B provides further description of methods to estimate impact likelihood and describes limitations and uncertainties. The results of susceptibility modelling are shown for debris flows and debris floods in Drawing Set A and Drawing Set B, respectively.

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

3.1.4 Climate Change Considerations

Climate change will affect the frequency of steep creek hazards (see further details in Appendix B). Fan activity ratings were artificially increased to generate hazard likelihood ratings adjusted for the anticipated increase in steep creek hazard occurrences. These climate change adjusted likelihood ratings were applied to generate climate change adjusted geohazard ratings. Details on this process are presented in Appendix B.

3.2 Frequency Magnitude Relationship

Jakob et al. (2020) compiled a series of detailed steep creek investigations in southern British Columbia and Alberta. For each of these projects, a Frequency Magnitude (F-M) curve had been established using a variety of methods. Jakob et al. (2020) normalized the individual F-M curves by fan area or watershed area and plotted them on the same graph. A best-fit line was plotted, and a predictive equation extracted. This equation can be used as a preliminary estimate of debris-flow and debris-flood F-M curve at other sites, where detailed field investigations have not been completed.

BGC developed an F-M equation for the study area using debris-flood and debris-flow prone creeks from the Jakob et al. (2020) study with similar characteristics to the study creeks (watershed area, fan areas). This F-M relationship was used to predict the 200-year event debris flow sediment volumes for each identified fan within the study area. Details on the development of the F-M relationship are provided in Appendix B.

For the Metro Vancouver Electoral Area A study area many fans are subaqueous or partially subaqueous (i.e., part of the fan is underwater in Howe Sound, Indian Arm, Pitt Lake). The extent of these fans is obstructed in aerial imagery and LiDAR and therefore the fan areas could not be reliably obtained. For this reason, watershed area is the parameter used in this study to generate an approximate Frequency-Magnitude (F-M) curve for each fan.

3.2.1 Climate Changes Considerations

Steep creek hazards will be affected by climate change. These affects will differ based on sediment availability in watersheds. Supply limited fans, fans with limited debris available for transport, once sediment depleted, will have lesser magnitude events regardless of hydro-climatic triggers. Supply-unlimited fans, fans with unlimited debris availability for transport, will have event magnitudes corresponding to the severity of the hydro-climatic triggers. An overview of climate change affects on steep creek hazard is provided in Appendix B.

Jakob and Owen (2021) completed a predictive climate change study on the landslide occurrence in the North Shore Mountains of Vancouver, BC. The study included watersheds between and adjacent to this report study area. Landslide event frequency increases of 130-380% and volume increases of 20-50% are expected between the 2050s and 2080s based on this work. This volume increase has been applied to the predicted 200-year event debris flow sediment volumes, generated for the study area, to provide a range of possible event sediment volumes expected in the future due to climate change. All fans in the study area were conservatively assumed to be supply unlimited for these climate change predictions. Further details on this climate change adjustment process can be found in Appendix B.

It should be noted that other climate change effects, such as post-wildfire conditions, have not been considered in the current geohazard assessment.

4.0 RESULTS

BGC assessed the steep-creek hazard for a total of 86 fans in Metro Vancouver's Electoral A study areas encompassing about 413 km^2 of the Metro Vancouver Regional District. The study area consisted of three primary sections referred to in this report as Howe Sound, Indian Arm and Pitt Lake (See Drawing Set A and Drawing Set B). Mapped fan areas range from 1,700 m^2 to 760,000 m^2.

4.1 Summary of Steep Creek Fan Inventory

Appendix C contains an inventory of all fans assessed in the study area with the steep creek hazard characterization results of this study. Table 4-1 summarizes the impact likelihood ratings and hazard likelihood ratings generated across the project.

Notes: Percent of fans may not add to 100% due to rounding of values.

Table 4-2 summarizes the geohazard ratings assigned to the fans within the study area. A total of six fans impact likelihood and hazard likelihood ratings generated a "Very High" geohazard rating. Most fans fall within the "Low" to "High" geohazard rating range. Fans geohazard ratings are illustrated in Drawings Set A and Drawing Set B.

Table 4-1 Summary table of impact likelihood and hazard likelihood ratings assigned to study area fans.

Rating	Impact Likelihood		Hazard Likelihood	
	Number of Fans	Percent of Fans in Study Area	Number of Fans	Percent of Fans in Study Area
Very Low	1	1%	1	1%
Low	18	21%	36	42%
Moderate	40	47%	21	24%
High	22	26%	21	24%
Very High	5	6%	7	8%

Notes: Percent of fans may not add to 100% due to rounding of values.

Table 4-2 Summary table of geohazard ratings assigned to study area fans.

Geohazard Rating	Number of Fans	Percent of Fans in Study Area
Very Low	2	2%
Low	35	41%
Moderate	17	20%
High	26	30%
Very High	6	7%

4.1.1 Adjusted Climate Change Ratings

Appendix C contains the adjusted climate change hazard likelihood and geohazard ratings for each fan within the study area. Table 4-3 summarizes the impact likelihood ratings and hazard likelihood ratings generated across the project for the climate change scenario. Notes: Percent of fans may not add to 100% due to rounding of values.

Table 4-4 summarizes the climate change scenario geohazard ratings assigned to the fans within the study area. A total of 11 fans impact likelihood and hazard likelihood ratings generated a “Very High” geohazard rating. Fans geohazard ratings are illustrated in Drawings Set A and Drawing Set B.

Table 4-3 Summary table of impact likelihood and climate change adjusted hazard likelihood ratings assigned to study area fans.

Rating	Impact Likelihood		Hazard Likelihood	
	Number of Fans	Percent of Fans in Study Area	Number of Fans	Percent of Fans in Study Area
Very Low	1	1%	1	1%
Low	18	21%	15	17%
Moderate	40	47%	21	24%
High	22	26%	33	38%
Very High	5	6%	16	19%

Notes: Percent of fans may not add to 100% due to rounding of values.

Table 4-4 Summary table of climate change adjusted geohazard ratings assigned to study area fans.

Geohazard Rating	Number of Fans	Percent of Fans in Study Area
Very Low	1	1%
Low	19	22%
Moderate	21	24%
High	34	40%
Very High	11	13%

4.2 Predicted Frequency-Magnitude Relationship

A frequency-magnitude relationship was derived for steep creek events in the Metro Vancouver Electoral Area A based on data from previous studies. For each assessed fan, sediment volumes for the 200-year return events are presented in Appendix C. The climate change adjusted 200-year event sediment volumes are also recorded in Appendix C. For all inventoried fans entering water bodies (e.g., along Indian Arm), BGC notes that the visible fan is only part of the landform, which also extends beneath the water surface. As the total landform is not visible, BGC's regional (statistically based) estimates of steep creek frequency-magnitude are largely based on watershed characteristics.

4.3 Susceptibility Mapping

Debris flood and debris flow susceptibility maps are contained within Drawing Set A and Drawing Set B, respectively. As described in Appendix B areas of moderate and high susceptibility were accounted for in the estimation of Impact Likelihood.

While the geohazard hazard attribution methodology provides a rating at the fan level of detail (as explained in Section 3.0), the susceptibility map shown in Drawing Sets A and B can be read at a sub-fan level (meaning that areas within fans can be compared).

As such, moderate and high susceptibility area on the fans mapped in Drawing Set A and Drawing Set B represent the areas within fans that are relatively more likely to be impacted by steep creek events occurring in the respective watersheds. BGC emphasizes that susceptibility mapping provides a relative measure of impact likelihood. The analyses are limited to the topographic resolution used in the model and the current channel conditions. For example, a higher resolution topographic model will provide more localized modelled susceptibility, but channel conditions frequently change due to erosion and deposition which will impact debris flow or debris flood susceptibility. Such that a higher resolution model can give an impression of accuracy that is not representative of the dynamic nature of alluvial fans. The 10 m DEM used in this study is a compromise between accurately capturing the terrain but keeping the topography general enough to account for potential change in channel geometry. Subject to detailed assessment that considers specific hazard scenarios, the potential for hazard impact anywhere within a mapped fan cannot be ruled out.

4.4 GIS Compilation

The steep creek fan mapping and susceptibility model outputs are provided as ESRI shapefiles. The shapefiles use NAD 83 UTM Zone 10N projection. The geohazard mapping was completed in GIS software and Google Earth during the first phase of work (BGC, March 30, 2022), with some boundary refinement applied during this study, and is subject to the exclusions and limitations outlined in Section 1.2 and those described in the first phase of work.

Table 4-5 Provided GIS files inventory and details.

File Name (data type)	Description
MVRD_SteepCreekFansInventory_20230809.shp (polygon)	Represents debris flood and debris flow fans from (BGC, March 30, 2022) modified for newly available 2022 lidar for Indian Arm. Additional fan characterization info, assigned in this second phase of study, are included as polygon attributes in the shapefile.
DfldSus_Norm_Reclass.shp (polygon)	Represents susceptibility modelling outputs for debris floods in Metro Vancouver Electoral Area A. Polygon values correspond to debris flood susceptibility ratings as follows: 2 = very low, 3= low, 4 = moderate and 5 = high.
DflwSus_Norm_Reclass.shp (polygon)	Represents susceptibility modelling outputs for debris flows in Metro Vancouver Electoral Area A. Polygon values correspond to debris flow susceptibility ratings as follows: 2 = very low, 3 = low, 4 = moderate and 5 = high.

5.0 RECOMMENDATIONS

BGC makes the following recommendations for consideration by Metro Vancouver for geohazard risk management in Electoral Area A:

- Field confirmation of desktop-based steep creek hazard interpretations. Along with additional factors Metro Vancouver may consider, such as hazard exposure and land use planning, the hazard ratings provided with this study could inform fieldwork priorities.
- Update the results of this study to reflect more detailed assessments when completed in future, maintaining an up-to-date source of knowledge for regional scale understanding of geohazards within the study area. BGC notes a distinction between document management to maintain report access and this recommendation, which is for continued maintenance and refinement of the hazard mapping as new knowledge becomes available.
- Build on the results of this steep creek hazard study to consider regional risk, with added consideration of exposure and relative vulnerability. Whether an ancillary structure, seasonally occupied structure, year-round residence, or multi-family development could influence the permit approval or planning process, and consideration of exposure may inform future resource allocation (e.g., towards greater focus on hazard areas with a combination of both higher hazard and loss potential).
- When applying the results of this study in decision making processes, reviewing the intended use of a Tier 2 hazard study to check if it meets the requirements of the applicable Provincial Guidelines.

6.0 CLOSURE

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

Yours sincerely,

BGC Engineering Inc.
per:

PROFESSIONAL
PROVINCE OF
Dr. M. BRIDEAU
42325
BRITISH COLUMBIA
GEOSCIENTIST

Nov. 3 2023

Marc-André Brideau, Ph.D., P.Geo.
Senior Engineering Geologist

Matthieu Sturzenegger, Ph.D., P.Geo.
Senior Engineering Geologist

Reviewed by:

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

EGBC Permit to Practice, BGC Engineering Inc. 1000944

MAB/KH/sf/th

REFERENCES

Armstrong, J.E., & Hicock, S.R. (1980). Surficial geology, New Westminster, West of Sixth Meridian, British Columbia. Geological Survey of Canada. Map 1484A.

BGC Engineering Inc. (2022, March 30). *Electoral Area A – Geohazard Mapping (Phase 1)* [Report]. Prepared for Metro Vancouver.

Blais-Stevens, A. (2008). Surficial geology and landslide inventory of the lower Sea to Sky corridor, British Columbia; Geological Survey of Canada, Open File 5322, scale 1:50,000.

Holland, S.S. (1976). Landforms of British Columbia – A physiographic outline. Bulletin 48.

Jakob, M., Moase, E., McDougall, S., Friele, P., Lau, C-A., & Bale, S. (2020). Regional debris-flow frequency-magnitude curves. Submitted to *Earth Surface Processes and Landforms*.

Jakob, M., & Owen, T. (2021). *Projected effects of climate change on shallow landslides, North Shore Mountains, Vancouver, Canada.* [Journal] Geomorphology 392; 107921.

Natural Research Canada (NRCan). (2015). Simplified seismic hazard map for Canada, the provinces and territories, **https://seismescanada.rncan.gc.ca/hazard-alea/simphaz-en.php**. Accessed December 2021.

Pacific Climate Impact Consortium (PCIC). (2021). **https://data.pacificclimate.org/portal/pcds/map/**, retrieved December 16, 2021.

APPENDIX A
MATERIAL CONSULTED

A-1 MATERIAL CONSULTED

Table A-1: Aerial photographs consulted.

Year	Flight line	Photograph	Project area
1952	BC 1632	26 to 35	Indian Arm
1952	BC 1632	47 to 55	Indian Arm
1952	BC 1632	102 and 103	Indian Arm
1952	BC 1633	40 to 43	Indian Arm
1952	BC 1634	59 to 64	Howe Sound
1953	BC 1806	68 to 78	Pitt Lake
1953	BC 1806	107 to 109	Pitt Lake
1953	BC 1807	1 and 2	Pitt Lake
1953	BC 1816	102 to 106	Pitt Lake
1957	BC 2326	69 to 74	Pitt Lake
1957	BC 2326	108 to 114	Pitt Lake
1957	BC 2327	1 to 5	Pitt Lake
1957	BC 2327	35 to 49	Pitt Lake
1957	BC 2336	79 to 98	Pitt Lake
1957	BC 2337	17 to 37	Pitt Lake
1957	BC 2337	103 to 108	Pitt Lake
1957	BC 2338	1 to 7	Pitt Lake
1957	BC 2338	63 to 65	Indian Arm
1957	BC 2339	75 to 89	Indian Arm
1957	BC 2340	30 to 48	Indian Arm
1957	BC 2341	45 to 47	Indian Arm
1957	BC 2341	63 to 81	Indian Arm
1957	BC 2345	93 to 107	Indian Arm
1957	BC 2346	61 to 75	Indian Arm
1957	BC 2347	20 to 27	Indian Arm
1957	BC 2347	80 to 82	Indian Arm
1957	BC 2348	75 to 84	Howe Sound
1957	BC 2349	18 to 29	Howe Sound
1957	BC 2349	49 to 53	Howe Sound
1992	BCB92018	136 and 137	Indian Arm
1992	BCB92018	45	Belcarra
1984	BC84016	77 and 78	Belcarra

Table A-2: Publicly available lidar consulting for this project.

Tile	Source	Year	Resolution
bc_092g017_xl1m_utm10_170714	BC Government	2016	1 m
bc_092g026_xl1m_utm10_170713	BC Government	2016	1 m
bc_092g027_xl1m_utm10_170713	BC Government	2016	1 m
bc_092g034_xl1m_utm10_2019	BC Government	2019	1 m
bc_092g036_xl1m_utm10_170713	BC Government	2016	1 m
bc_092g044_xl1m_utm10_2019	BC Government	2019	1 m
bc_092g045_xl1m_utm10_170713	BC Government	2016	1 m
bc_092g046_xl1m_utm10_170713	BC Government	2016	1 m
dtm_1m_utm10_e_1_146	Natural Resource Canada	2016	1m
dtm_1m_utm10_e_2_146	Natural Resource Canada	2019	1m
dtm_1m_utm10_e_2_147	Natural Resource Canada	2019	1m
dtm_1m_utm10_e_2_147	Natural Resource Canada	2020	1m
dtm_1m_utm10_e_2_148	Natural Resource Canada	2019	1m
dtm_1m_utm10_e_2_148	Natural Resource Canada	2020	1m
dtm_1m_utm10_e_3_146	Natural Resource Canada	2019	1m
dtm_1m_utm10_e_3_147	Natural Resource Canada	2019	1m
dtm_1m_utm10_e_3_148	Natural Resource Canada	2019	1m
481500_5481000	Metro Vancouver	2022	1m
481500_5479500	Metro Vancouver	2022	1m
481500_5478000	Metro Vancouver	2022	1m
481500_5476500	Metro Vancouver	2022	1m
481500_5475000	Metro Vancouver	2022	1m
481500_5473500	Metro Vancouver	2022	1m
481500_5472000	Metro Vancouver	2022	1m
481500_5470500	Metro Vancouver	2022	1m
483000_5481000	Metro Vancouver	2022	1m
483000_5479500	Metro Vancouver	2022	1m
483000_5478000	Metro Vancouver	2022	1m
483000_5476500	Metro Vancouver	2022	1m
483000_5475000	Metro Vancouver	2022	1m
483000_5473500	Metro Vancouver	2022	1m
483000_5472000	Metro Vancouver	2022	1m
483000_5470500	Metro Vancouver	2022	1m
484500_5472000	Metro Vancouver	2022	1m
484500_5470500	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
510000_5479500	Metro Vancouver	2022	1m
510000_5478000	Metro Vancouver	2022	1m
510000_5476500	Metro Vancouver	2022	1m
505500_5472000	Metro Vancouver	2022	1m
505500_5470500	Metro Vancouver	2022	1m
505500_5469000	Metro Vancouver	2022	1m
507000_5479500	Metro Vancouver	2022	1m
507000_5478000	Metro Vancouver	2022	1m
507000_5476500	Metro Vancouver	2022	1m
507000_5475000	Metro Vancouver	2022	1m
507000_5473500	Metro Vancouver	2022	1m
507000_5472000	Metro Vancouver	2022	1m
507000_5470500	Metro Vancouver	2022	1m
507000_5469000	Metro Vancouver	2022	1m
508500_5479500	Metro Vancouver	2022	1m
508500_5478000	Metro Vancouver	2022	1m
508500_5476500	Metro Vancouver	2022	1m
508500_5475000	Metro Vancouver	2022	1m
508500_5473500	Metro Vancouver	2022	1m
508500_5472000	Metro Vancouver	2022	1m
508500_5470500	Metro Vancouver	2022	1m
508500_5469000	Metro Vancouver	2022	1m
510000_5475000	Metro Vancouver	2022	1m
510000_5473500	Metro Vancouver	2022	1m
510000_5472000	Metro Vancouver	2022	1m
510000_5470500	Metro Vancouver	2022	1m
510000_5469000	Metro Vancouver	2022	1m
511500_5472000	Metro Vancouver	2022	1m
511500_5470500	Metro Vancouver	2022	1m
511500_5469000	Metro Vancouver	2022	1m
522000_5466000	Metro Vancouver	2022	1m
523500_5469000	Metro Vancouver	2022	1m
523500_5467500	Metro Vancouver	2022	1m
523500_5466000	Metro Vancouver	2022	1m
525000_5469000	Metro Vancouver	2022	1m
525000_5467500	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
525000_5466000	Metro Vancouver	2022	1m
526500_5487000	Metro Vancouver	2022	1m
526500_5485500	Metro Vancouver	2022	1m
526500_5484000	Metro Vancouver	2022	1m
526500_5482500	Metro Vancouver	2022	1m
526500_5481000	Metro Vancouver	2022	1m
526500_5479500	Metro Vancouver	2022	1m
526500_5469000	Metro Vancouver	2022	1m
526500_5467500	Metro Vancouver	2022	1m
526500_5466000	Metro Vancouver	2022	1m
528000_5487000	Metro Vancouver	2022	1m
528000_5485500	Metro Vancouver	2022	1m
528000_5484000	Metro Vancouver	2022	1m
528000_5482500	Metro Vancouver	2022	1m
528000_5481000	Metro Vancouver	2022	1m
528000_5479500	Metro Vancouver	2022	1m
528000_5478000	Metro Vancouver	2022	1m
528000_5475000	Metro Vancouver	2022	1m
528000_5473500	Metro Vancouver	2022	1m
528000_5472000	Metro Vancouver	2022	1m
528000_5470500	Metro Vancouver	2022	1m
528000_5469000	Metro Vancouver	2022	1m
528000_5467500	Metro Vancouver	2022	1m
528000_5466000	Metro Vancouver	2022	1m
529500_5481000	Metro Vancouver	2022	1m
529500_5479500	Metro Vancouver	2022	1m
529500_5478000	Metro Vancouver	2022	1m
529500_5475000	Metro Vancouver	2022	1m
529500_5473500	Metro Vancouver	2022	1m
529500_5472000	Metro Vancouver	2022	1m
529500_5470500	Metro Vancouver	2022	1m
529500_5469000	Metro Vancouver	2022	1m
529500_5467500	Metro Vancouver	2022	1m
522000_5467500	Metro Vancouver	2022	1m
522000_5469000	Metro Vancouver	2022	1m
531000_5479500	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
531000_5478000	Metro Vancouver	2022	1m
531000_5476500	Metro Vancouver	2022	1m
531000_5475000	Metro Vancouver	2022	1m
532500_5479500	Metro Vancouver	2022	1m
532500_5478000	Metro Vancouver	2022	1m
532500_5476500	Metro Vancouver	2022	1m
529500_5476500	Metro Vancouver	2022	1m
528000_5476500	Metro Vancouver	2022	1m
516000_5490000	Metro Vancouver	2022	1m
514500_5485500	Metro Vancouver	2022	1m
514500_5490000	Metro Vancouver	2022	1m
514500_5488500	Metro Vancouver	2022	1m
526500_5478000	Metro Vancouver	2022	1m
526500_5475000	Metro Vancouver	2022	1m
526500_5473500	Metro Vancouver	2022	1m
526500_5476500	Metro Vancouver	2022	1m
526500_5472000	Metro Vancouver	2022	1m
526500_5470500	Metro Vancouver	2022	1m
525000_5470500	Metro Vancouver	2022	1m
525000_5472000	Metro Vancouver	2022	1m
523500_5472000	Metro Vancouver	2022	1m
523500_5470500	Metro Vancouver	2022	1m
522000_5470500	Metro Vancouver	2022	1m
522000_5472000	Metro Vancouver	2022	1m
511500_5479500	Metro Vancouver	2022	1m
511500_5478000	Metro Vancouver	2022	1m
511500_5476500	Metro Vancouver	2022	1m
511500_5475000	Metro Vancouver	2022	1m
511500_5473500	Metro Vancouver	2022	1m
513000_5475000	Metro Vancouver	2022	1m
513000_5476500	Metro Vancouver	2022	1m
513000_5478000	Metro Vancouver	2022	1m
513000_5479500	Metro Vancouver	2022	1m
520500_5479500	Metro Vancouver	2022	1m
520500_5478000	Metro Vancouver	2022	1m
520500_5476500	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
522000_5473500	Metro Vancouver	2022	1m
522000_5475000	Metro Vancouver	2022	1m
522000_5476500	Metro Vancouver	2022	1m
522000_5478000	Metro Vancouver	2022	1m
522000_5479500	Metro Vancouver	2022	1m
523500_5479500	Metro Vancouver	2022	1m
523500_5478000	Metro Vancouver	2022	1m
523500_5476500	Metro Vancouver	2022	1m
523500_5475000	Metro Vancouver	2022	1m
523500_5473500	Metro Vancouver	2022	1m
525000_5473500	Metro Vancouver	2022	1m
525000_5475000	Metro Vancouver	2022	1m
525000_5476500	Metro Vancouver	2022	1m
525000_5478000	Metro Vancouver	2022	1m
525000_5479500	Metro Vancouver	2022	1m
505500_5479500	Metro Vancouver	2022	1m
505500_5478000	Metro Vancouver	2022	1m
505500_5476500	Metro Vancouver	2022	1m
505500_5475000	Metro Vancouver	2022	1m
505500_5473500	Metro Vancouver	2022	1m
504000_5473500	Metro Vancouver	2022	1m
504000_5475000	Metro Vancouver	2022	1m
486000_5476500	Metro Vancouver	2022	1m
486000_5478000	Metro Vancouver	2022	1m
486000_5479500	Metro Vancouver	2022	1m
484500_5479500	Metro Vancouver	2022	1m
484500_5478000	Metro Vancouver	2022	1m
484500_5473500	Metro Vancouver	2022	1m
484500_5475000	Metro Vancouver	2022	1m
484500_5476500	Metro Vancouver	2022	1m
525000_5487000	Metro Vancouver	2022	1m
525000_5485500	Metro Vancouver	2022	1m
525000_5484000	Metro Vancouver	2022	1m
525000_5482500	Metro Vancouver	2022	1m
525000_5481000	Metro Vancouver	2022	1m
523500_5485500	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
523500_5487000	Metro Vancouver	2022	1m
523500_5484000	Metro Vancouver	2022	1m
523500_5481000	Metro Vancouver	2022	1m
523500_5482500	Metro Vancouver	2022	1m
522000_5487000	Metro Vancouver	2022	1m
522000_5485500	Metro Vancouver	2022	1m
522000_5484000	Metro Vancouver	2022	1m
522000_5482500	Metro Vancouver	2022	1m
522000_5481000	Metro Vancouver	2022	1m
520500_5484000	Metro Vancouver	2022	1m
520500_5485500	Metro Vancouver	2022	1m
520500_5481000	Metro Vancouver	2022	1m
520500_5482500	Metro Vancouver	2022	1m
519000_5485500	Metro Vancouver	2022	1m
519000_5484000	Metro Vancouver	2022	1m
520500_5487000	Metro Vancouver	2022	1m
514500_5487000	Metro Vancouver	2022	1m
513000_5482500	Metro Vancouver	2022	1m
513000_5481000	Metro Vancouver	2022	1m
513000_5485500	Metro Vancouver	2022	1m
513000_5484000	Metro Vancouver	2022	1m
513000_5487000	Metro Vancouver	2022	1m
513000_5488500	Metro Vancouver	2022	1m
513000_5490000	Metro Vancouver	2022	1m
511500_5484000	Metro Vancouver	2022	1m
511500_5485500	Metro Vancouver	2022	1m
511500_5481000	Metro Vancouver	2022	1m
511500_5482500	Metro Vancouver	2022	1m
511500_5490000	Metro Vancouver	2022	1m
511500_5488500	Metro Vancouver	2022	1m
511500_5487000	Metro Vancouver	2022	1m
510000_5482500	Metro Vancouver	2022	1m
510000_5481000	Metro Vancouver	2022	1m
510000_5485500	Metro Vancouver	2022	1m
510000_5484000	Metro Vancouver	2022	1m
508500_5484000	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
508500_5485500	Metro Vancouver	2022	1m
508500_5481000	Metro Vancouver	2022	1m
508500_5482500	Metro Vancouver	2022	1m
510000_5487000	Metro Vancouver	2022	1m
510000_5488500	Metro Vancouver	2022	1m
510000_5490000	Metro Vancouver	2022	1m
508500_5490000	Metro Vancouver	2022	1m
508500_5488500	Metro Vancouver	2022	1m
508500_5487000	Metro Vancouver	2022	1m
507000_5482500	Metro Vancouver	2022	1m
507000_5481000	Metro Vancouver	2022	1m
507000_5485500	Metro Vancouver	2022	1m
507000_5484000	Metro Vancouver	2022	1m
507000_5487000	Metro Vancouver	2022	1m
507000_5488500	Metro Vancouver	2022	1m
507000_5490000	Metro Vancouver	2022	1m
505500_5484000	Metro Vancouver	2022	1m
505500_5485500	Metro Vancouver	2022	1m
505500_5481000	Metro Vancouver	2022	1m
505500_5482500	Metro Vancouver	2022	1m
504000_5482500	Metro Vancouver	2022	1m
504000_5481000	Metro Vancouver	2022	1m
504000_5485500	Metro Vancouver	2022	1m
504000_5484000	Metro Vancouver	2022	1m
505500_5490000	Metro Vancouver	2022	1m
505500_5488500	Metro Vancouver	2022	1m
505500_5487000	Metro Vancouver	2022	1m
504000_5487000	Metro Vancouver	2022	1m
504000_5488500	Metro Vancouver	2022	1m
504000_5490000	Metro Vancouver	2022	1m
502500_5484000	Metro Vancouver	2022	1m
502500_5485500	Metro Vancouver	2022	1m
502500_5482500	Metro Vancouver	2022	1m
501000_5485500	Metro Vancouver	2022	1m
502500_5487000	Metro Vancouver	2022	1m
501000_5487000	Metro Vancouver	2022	1m

Tile	Source	Year	Resolution
499500_5487000	Metro Vancouver	2022	1m
486000_5481000	Metro Vancouver	2022	1m
484500_5481000	Metro Vancouver	2022	1m

APPENDIX B
STEEP CREEK HAZARD ASSESSMENT METHODOLOGY

B-1 INTRODUCTION

This appendix describes methods used by BGC to identify and characterize steep creek geohazards within the study area. This appendix is organized as follows:

- Section B-1 provides background information and key terminology on steep creek geohazards, high level introduction to climate change effects on steep creek geohazards, and the work used to prioritize steep creek geohazard areas.
- Section B-2 describes methods and criteria used to identify steep creek geohazard areas.
- Section B-3 describes methods and criteria used to assign geohazard ratings.
- Section B-4 describes the method used to define steep creek frequency-magnitude relationship.

Section 4.0 of the main report describes how study results are delivered, including geohazard ratings and supporting information.

B-1.1 What Are Steep Creek Geohazards?

Steep creek or hydrogeomorphic hazards are natural hazards that involve a mixture of water and debris or sediment (Figure B-1). These hazards typically occur on creeks and steep rivers with small watersheds (usually less than 100 km^2) in mountainous terrain, usually after intense or long rainfall events, sometimes aided by snowmelt and worsened by forest fires.

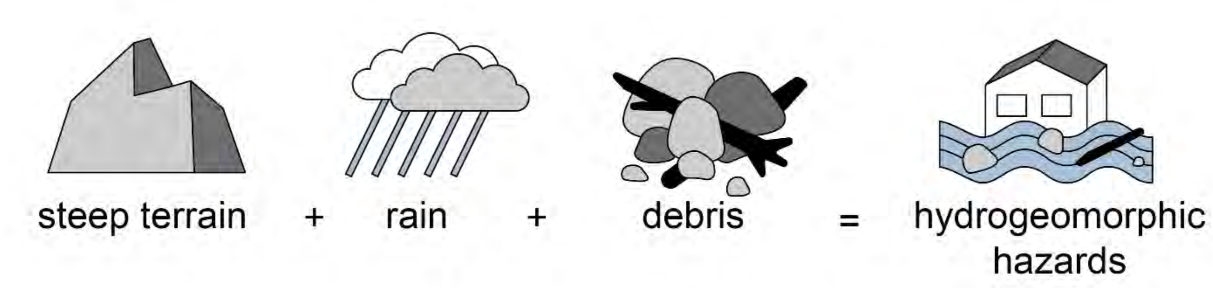


Figure B-1 Illustration of steep creek hazards.

Steep creek hazards span a continuum of processes from clear-water floods (flood) to debris flows (Figure B-2). Debris floods and debris flows are described further in the following sections.

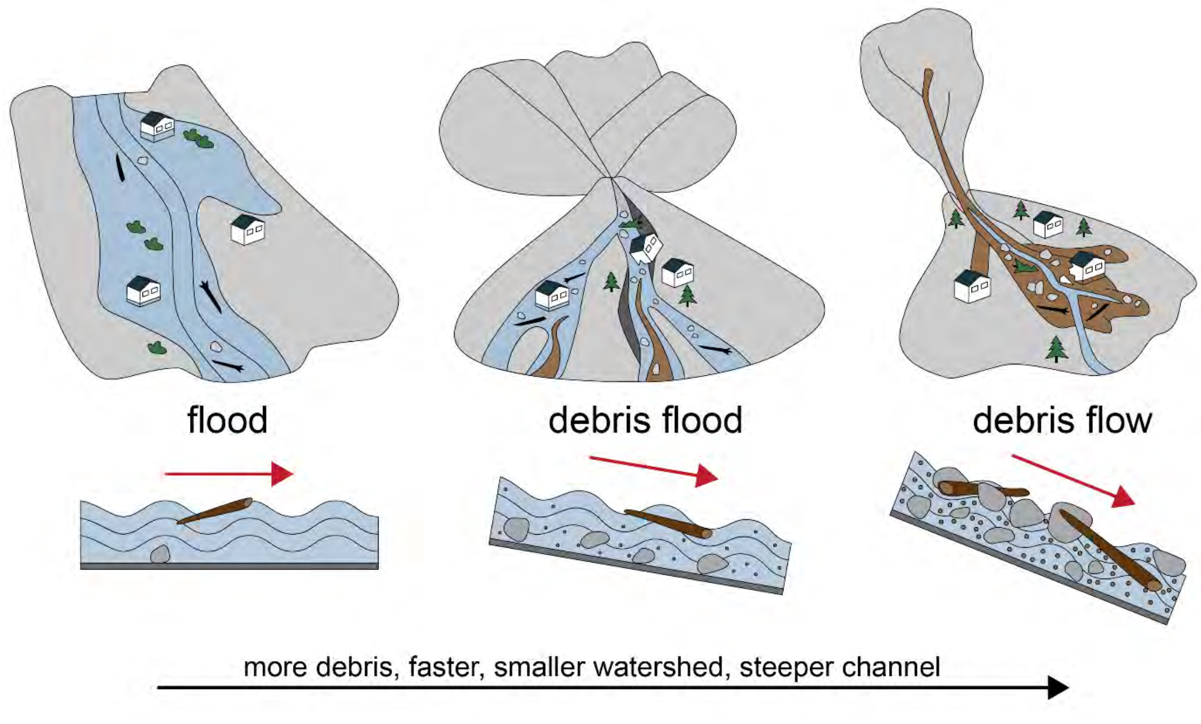


Figure B-2 Continuum of steep creek hazards.

B-1.1.1 Steep Creek Watersheds and Fans

A steep creek watershed consists of hillslopes, small feeder channels, a principal channel, and an alluvial fan composed of deposited sediments at the lower end of the watershed. Figure B-3 provides a typical example of steep creeks in the Electoral Area A. Every watershed and fan are unique in the type and intensity of mass movement and fluvial processes, and the hazard and risk profile associated with such processes. Figure B-4 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.

In steep creek basins (or watersheds), most mass movements on hillslopes directly or indirectly feed into steep mountain channels from which they begin their journey downstream. Viewed at the scale of the catchment and over geologic time, distinct zones of sediment production, transfer, erosion, deposition, and avulsions may be identified within a drainage basin (Figure B-4 and Figure B-5).

Steep mountain slopes deliver sediment and debris to the upper channels by rock fall, rock slides, debris avalanches, debris flows, slumps and raveling. Debris flows and debris floods characteristically gain momentum and sediments as they move downstream and spread across an alluvial fan where the channel enters the main valley floor. Landslides may also create temporary dams that pond water, which can fail catastrophically. In these scenarios, a landslide dam outburst flood (LDOF) may be initiated in the channel that can travel further than other steep creek processes.

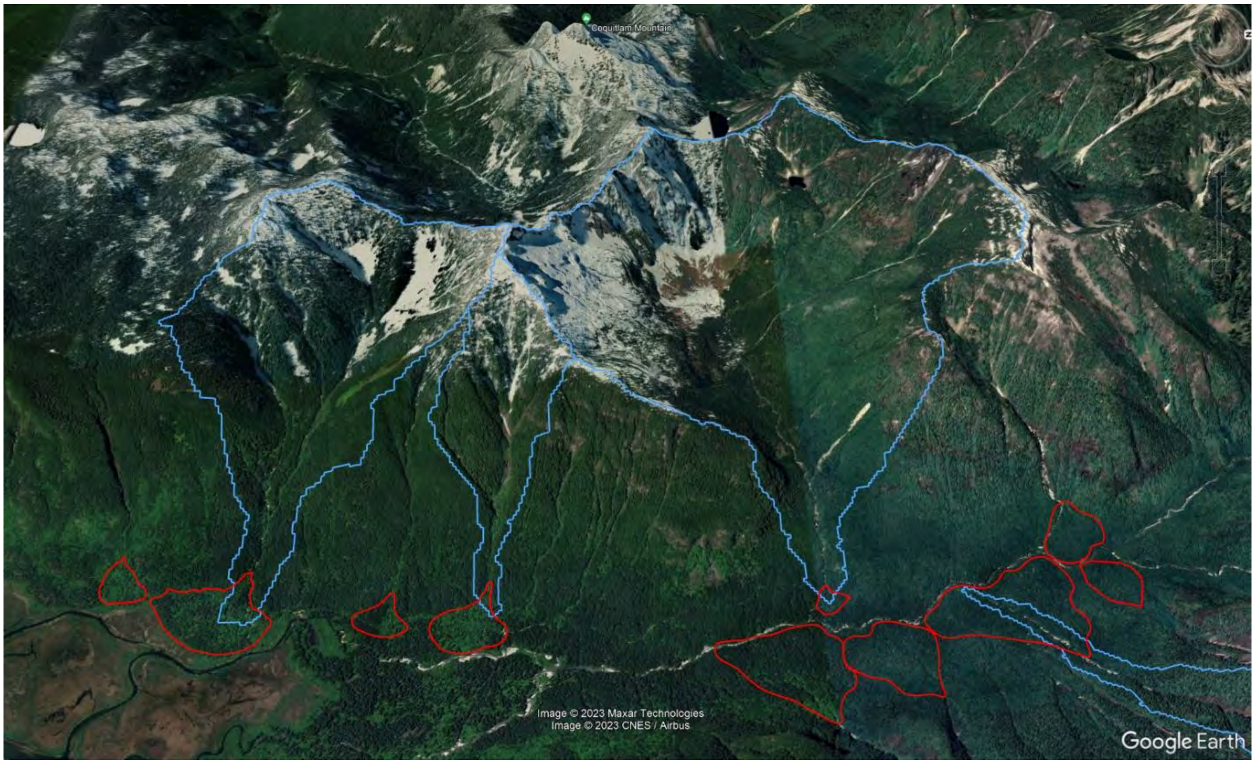


Figure B-3 **Typical steep creek watersheds in Electoral Area A. Example above shows drainages in the Widgeon Valley. The approximate watershed boundaries are outlined in blue and fans are outlined in red. Google Earth May and July 2021 imagery.**

Figure B-4 **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 geohazard events. Artwork: Derrill Shuttleworth.**

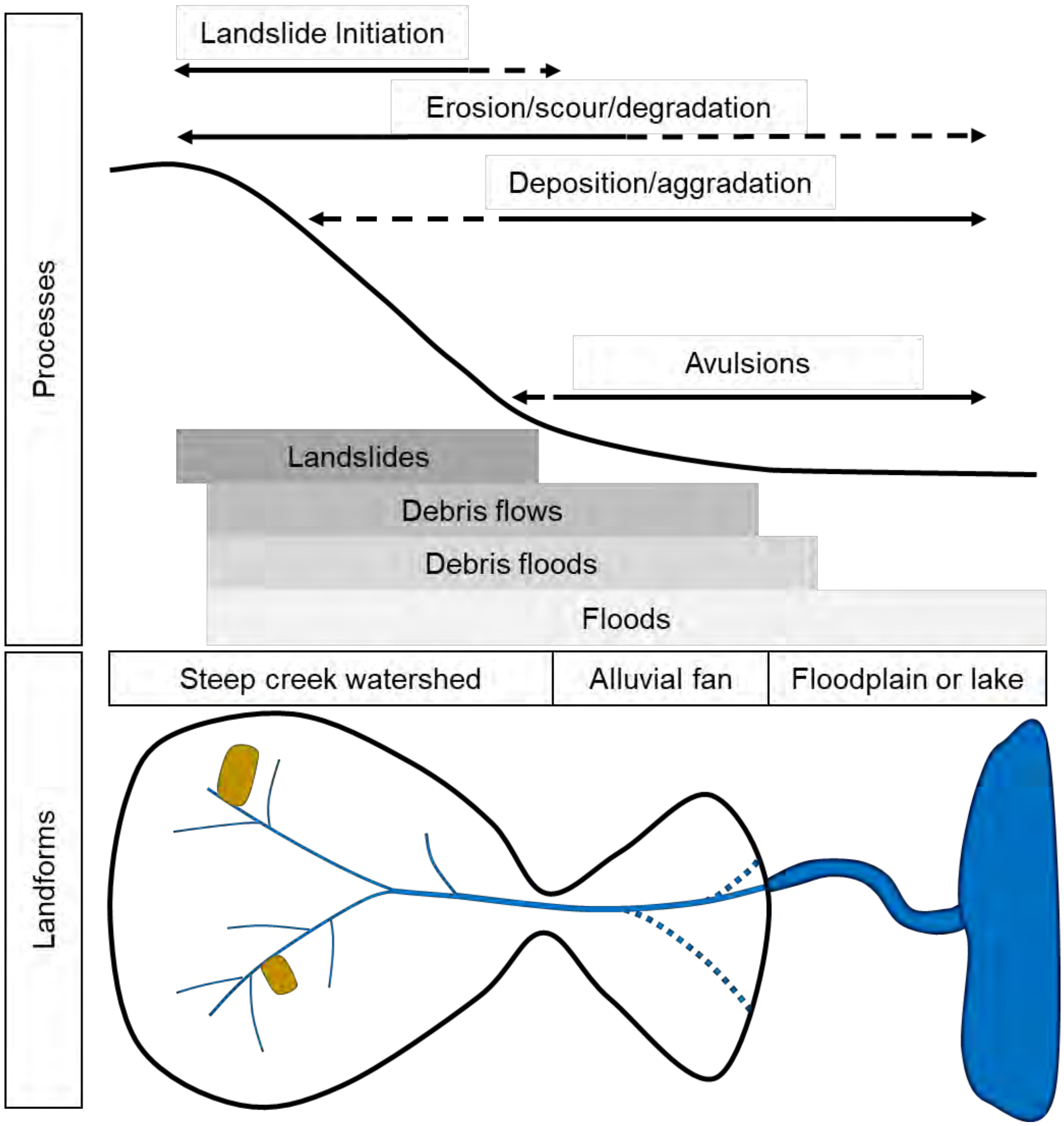


Figure B-5 Schematic diagram of a steep creek watershed system that shows the principal zones of distinctive processes and sediment behaviour. Landslides are shown in brown. The alluvial fan is thought of as the long-term storage landform with a time scale of thousands to tens of thousands of years. Sketch developed by BGC from concepts produced by Schumm (1977), Montgomery & Buffington (1997), and Church (2022).

The alluvial fan represents a mostly depositional landform at the outlet of a steep creek watershed. Alluvial fans are dynamic and potentially very dangerous (hazardous) landforms that represent the approximate extent of past and future hydrogeomorphic processes. This landform is more correctly called a colluvial fan when formed by debris flows because debris flows are classified as a landslide process, and an alluvial fan when formed by clear-water floods (those which do not carry substantial bedload or suspended load) or debris floods. For simplicity the term alluvial fan is used herein irrespective of geohazard type. “Classic” alluvial fans are roughly triangular in planform, but most fans have irregular shapes influenced by the surrounding topography. Redistribution of sediments from the upper steeper fan to the lower flatter fan, primarily through bank erosion and channel scour, is common (Lau, 2017).

Stream channels on the fan are prone to avulsions, which are rapid changes in channel location, due to natural cycles in alluvial fan development and from the loss of channel confinement during hydrogeomorphic events (e.g., Kellerhals & Church, 1990; van Dijk et al., 2009; van Dijk et al., 2012; de Haas et al., 2017; de Haas et al., 2019; Zubrycky et al., 2021). If the alluvial fan is formed on the margin of a still water body (lake, reservoir, ocean), the alluvial fan is termed a fan-delta. These landforms differ from alluvial fans in that sediment deposition at the margin of the landform occurs in still water, which invites in-channel sediment aggradation due to a pronounced morphodynamic backwater effect. This can increase the frequency and possibly severity of avulsions (van Dijk et al., 2009; van Dijk et al., 2012).

The term “paleofan” is used to describe portions of fans interpreted as no longer active (under present climate and geomorphic/geological setting) and entirely removed from the channel processes described previously (i.e., with negligible potential for channel avulsion and flow propagation) due to deep channel incision (Kellerhals & Church, 1990). Paleofans were identified in the Indian River Valley portion of the study area.

B-1.1.2 Debris Flows

‘Debris flow’, as defined by Hungr et al. (2014), is a very rapid, channelized flow of saturated debris containing fine grained sediment (i.e., sand and finer fractions) with a plasticity index of less than 5%. Debris flows originate from a single or distributed source area(s) from sediment mobilized by the influx of ground or surface water. Post-fire debris flows are a special case where the lack of vegetation can lead to abundant rilling and gullying that delivers sediment to the main channel and the formation of debris flows. In those cases, no single source is required to initiate or maintain debris-flow mechanics.

Debris flows travel in confined channels bordered by steep slopes. In confined channels, the flow volume, peak discharge, and flow depth increase, and the debris becomes sorted along the flow path. Flow velocities typically range from 1 to 10 m/s, although very large debris flows from volcanic edifices, often containing substantial fines, can travel at more than 20 m/s along much of their path (Major et al., 2005). The front of the rapidly advancing flow is steep and commonly followed by several secondary surges that form due to particle segregation and upwards or outwards migration of boulders. Hence, one of the distinguishing characteristics of coarse granular debris flows is vertical inverse grading, in which larger particles are concentrated at the top of the deposit. This characteristic behaviour leads to the formation of lateral levees along the channel that become part of the debris-flow depositional legacy. Similarly, depositional lobes are formed where frictional resistance from unsaturated coarse-grained or large organic debris-rich fronts is high enough to slow and eventually stop the motion of the trailing liquefied debris.

Due to their high flow velocities, peak discharges during debris flows are at least an order of magnitude larger than those of comparable return period floods and can be 50 times larger or more (Jakob & Jordan, 2001; Jakob et al., 2016). Channel banks can be severely eroded during debris flows, although lateral erosion is often associated with the trailing flow characterized by lower volumetric sediment concentrations. The most severe damage results from direct impact of large clasts or coarse woody debris against structures that are not designed for the impact forces (Jakob et al., 2012). Similarly, linear infrastructure such as roads, and railways are subject to damage from debris flows either from direct impact or erosion. Buried infrastructure can be damaged by debris flows if it is exposed by erosion and then impacted by boulders or woody debris.

Avulsions are likely in poorly confined channel sections and on the outside of channel bends where debris flows tend to superelevate. A sudden loss of confinement and decrease in channel slope cause debris flows to decelerate and slow the advancing bouldery front, which blocks the channel. Further flows are often deflected by the slowing front, leading to secondary avulsions and the creation of distributary channels on the fan. Because debris flows often display surging behaviour, in which bouldery fronts alternate with hyperconcentrated afterflows, the cycle of coarse bouldery lobe and levee formation and afterflow deflection can be repeated several times during a single event (Iverson, 2014).

B-1.1.3 Debris Floods

Church and Jakob (2020) define debris floods as “floods during which the entire bed, barring the very largest clasts, becomes mobile for at least a few minutes and over a length of at least 10 times the channel width”. Accordingly, debris floods represent flood flows with high transport of gravel to boulder size material. Debris floods typically occur on creeks with channel gradients between 5 and 30% (3 and 17º) but can also occur on lower gradient gravel bed rivers.

Due to their initially relatively low sediment concentration, debris floods can be more erosive along low-gradient alluvial channel banks than debris flows. Bank erosion and excessive amounts of bedload introduce large amounts of sediment to the fan where they accumulate (aggrade) in channel sections with decreased slope. Debris floods can also be initiated on the fan itself through rapid bed erosion and entrainment of bank materials, as long as the stream power is high enough to transport clasts larger than the D_{50}. Because typical long-duration storm hydrographs fluctuate several times over the course of the storm, several cycles of aggradation and remobilization of deposited sediments on channel and fan reaches can be expected during the same event (Jakob et al., 2016). Similarly, debris floods triggered by outbreak floods may lead to single or multiple surges irrespective of hydrograph fluctuations that can lead to cycles of bank erosion, scour and infill. This is important for interpretations of field observations as only the final deposition or scour can be measured.

Church and Jakob (2020) developed a three-fold typology for debris floods (Table B-1). Identifying the correct debris-flood type is key in preparing for numerical modelling and hazard assessments. Type 2 is the typical debris-flood type referred to in this study. Type 1 is the result of a flow with sufficient magnitude and shear stress to mobilize the channel bed. Type 3 is considered in the landslide dam outbreak flood (LDOF) parameter presented in Section B-3.2.4.

Table B-1 Debris-flood classification based on Church and Jakob (2020).

Term	Definition	Typical sediment concentration by volume (%)	Typical Q_{max} factor compared to calc. clear-water	Physical characteristics	Typical impacts	Typical return period range (years)
Type 1	Rainfall/snowmelt generated through exceedance of critical shear stress threshold when most of the surface bed grains are being mobilized	< 5	1.05 (or higher should there be multiple side slope landslides expected or large organic debris)	Steep fans (1% to 10%), shallow but wide active floodplain, widespread boulder carpets, clast to matrix-supported sediment facies, poorly sorted, subrounded to rounded stones, imbrication of elongate clasts, occasional crossbedding, disturbed riparian vegetation, frequent avulsions on fan	Widespread bank instability, avulsions, alternating reaches of bed aggradation and degradation, blocked culverts, scoured bridge abutments, damaged buried infrastructure particularly in channel reaches u/s of fans	>2
Type 2	Transitional as a consequence of debris flows. Substantially higher sediment concentration compared to a Type 1 debris flood and accordingly greater facility to transport larger volumes of sediment. All grain calibers mobilized, except from lag deposits(big glacial or rock fall boulders)	< 50	2–5 (but possibly larger at the transition zone)	As for Type 1 but rarely clast-supported and with higher matrix sediment concentration, unsorted, inverse grading near debris flow tributary. Stones subangular to angular, boulder carpets on fans often display abrupt sediment deposit edges	Widespread bank instability, avulsions, substantial bed aggradation particularly on fans, blocked culverts, scoured bridge abutments, damaged and buried infrastructure on fans	>50
Type 3	Type 3 (outbreak floods) (artificial-, landslide-, glacial-, moraine-, beaver, o-log jam outbreaks)	<10 (except immediately downstream of the outbreak where it can reach greater than30%)	2 to 100 depending on size of dam and distance to dam failure	High matrix fines content especially in volcanic sources or fine-grained soil (e.g., loess), sometimes inverse grading near outbreak flood source, unsorted near source. Increasing sorting and stratification with downstream distance, erosion and fill structures	Extreme bank erosion, avulsions, substantial bed degradation along channels and aggradation on fans, destroyed culverts, outflanked or overwhelmed bridges, damaged and buried infrastructure on channels and fans	>100 (can be singular event in the case of a moraine dam or glacial breach)

B-1.2 Climate Change

This section outlines some of the climate change affects specifically related to steep creek hazards. Climate change is expected to impact steep creek geohazards both directly and indirectly through complex feedback mechanisms. Given that hydrological and mass movement processes are higher order effects of air temperature increases, their prediction is highly complex and often site-specific.

B-1.2.1 Hydro-Climatic Effect

Jakob (2022) provides a general overview of how climate change will affect steep creek hazards based on sediment availability:

- Supply-limited: meaning that debris available for transport is a limiting factor on the magnitude and frequency of steep creek events. In other words, once debris in the source zone and transport zone has been depleted by a debris flow or debris flood, another event even with the same hydro-climatic trigger will be of lesser magnitude.
- Supply-unlimited: meaning that debris available for transport is not a limiting factor on the magnitude and frequency of steep creek events, and another factor (such as precipitation frequency/magnitude) is the limiting factor. In other words, there is always an abundance of debris along a channel and in source areas so that whenever a critical hydro-climatic threshold is exceeded, an event will occur. The more severe the hydro-climatic event, the higher the resulting magnitude of the debris flow or debris flood.

Further subdivisions into channel supply-limited and unlimited and basin supply-limited and unlimited are possible but not considered herein.

Climate change is expected to increase the short-duration rainfall intensity in the Metro Vancouver Regional District (Prein et al., 2017; Crévolin et al., 2023). The sensitivity of the two basic types of basins to increases in rainfall (intensity and frequency increases) differ (Figure B-6):

- Supply-limited basins would likely see a decrease in individual geohazard event magnitude, but an increase in their frequency as smaller amounts of debris that remains in the channel are easily mobilized (i.e., more, but smaller events).
- Supply-unlimited basins would likely see an increase in hazard magnitude and a greater increase in frequency (i.e., significantly more, and larger events).

Supply-limited basins can transition into supply-unlimited due to landscape changes. For example, sediment supply could be increased by wildfires, landslide occurrence, or human activity (e.g., related to road building or resource extraction).

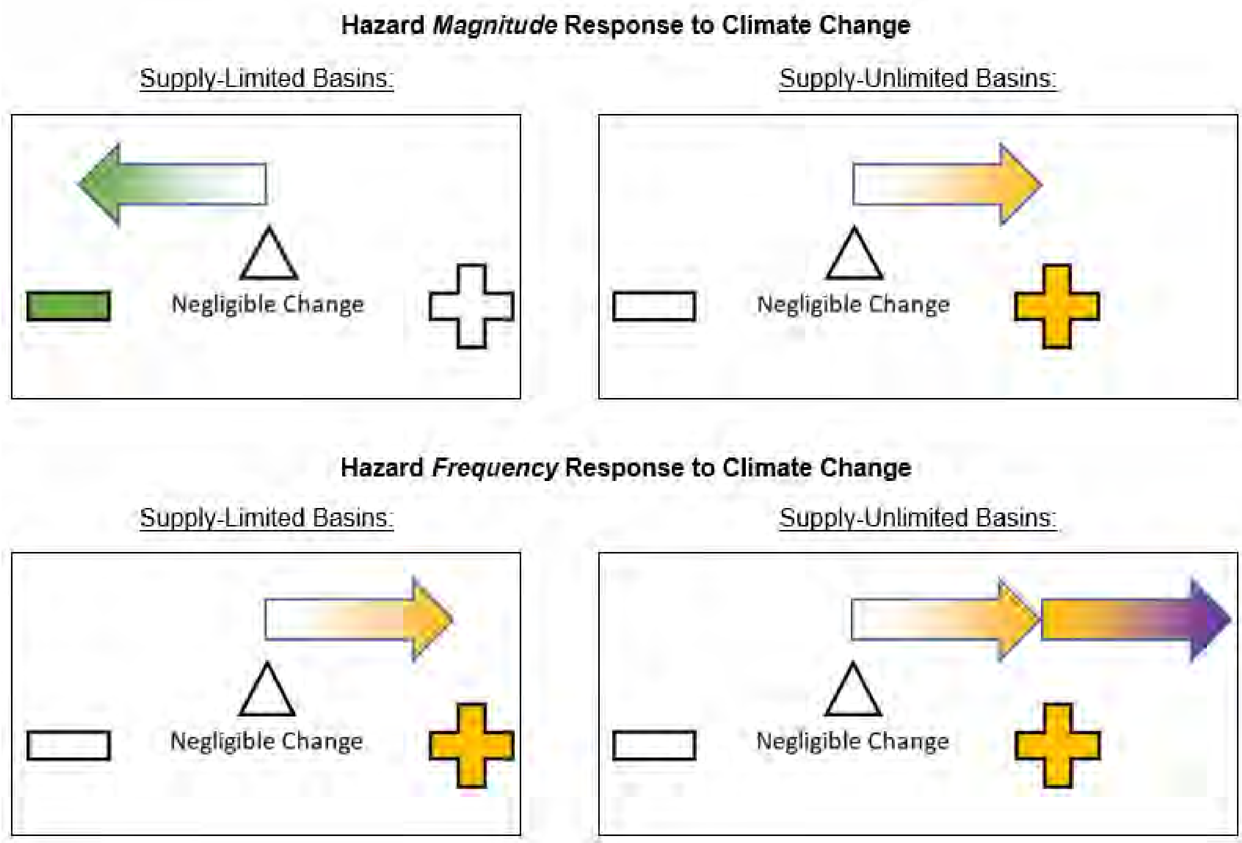


Figure B-6 Steep creek hazard sensitivity to climate change – supply-limited and supply unlimited basins.

B-1.2.2 Post Wildfire Conditions

Climate change is projected to increase the conditions for extreme fire weather (high temperature, low humidity, and high winds) and lengthen the fire season resulting in increased fire sizes (Utzig et al., 2011; Haider et al. 2019). In addition to larger fires, changes to short duration (one hour and less) rainfall intensities are particularly relevant for post-fire situations. Debris-flows can be triggered within the year to a few years after a wildfire from short duration and high intensity rainfall that previously would not trigger debris flows or debris floods in the same watershed. Wildfires are known to both increase the sediment supply and lower the precipitation threshold for steep creek events to occur.

B-1.2.3 Study Area Specific Climate Change Considerations

Jakob and Owen (2021) completed a climate change study on shallow landslides in the North Shore Mountains of Vancouver. This study included the watersheds of Capilano River, Seymour River, Lynn Creek, and Coquitlam River which are watersheds adjacent and between the ones considered in this report. The study examined possible landslide occurrence and magnitude trends under the conditions of Relative Concentration Path (RCP) 4.5 and RCP 8.5 using a multivariate regression analysis. Projections achieved for RCP 4.5 and 8.5 anticipate an increase in the number of landslides by the 2050s and the 2080s to be 140-280% and

130-380%, respectively. Landslide volume increases of 20% to 50% are expected for RCP 4.5 and 8.5, in the 2050s and 2080s respectively.

B-1.3 Workflow

The workflow for the steep creek geohazard assessment and risk prioritization includes three main phases: hazard identification, geohazard rating, and consequence rating. Figure B-7 summarizes the parameters used in each phase. BGC previously completed hazard identification for the study area (BGC, March 30, 2022). Geohazard rating for the study area was completed for this report. Consequence rating has not been assessed for the study area and therefore risk prioritization has not been completed to date. The steep creek geohazard assessment reflects the observed conditions of watershed and fan at the time of this study.

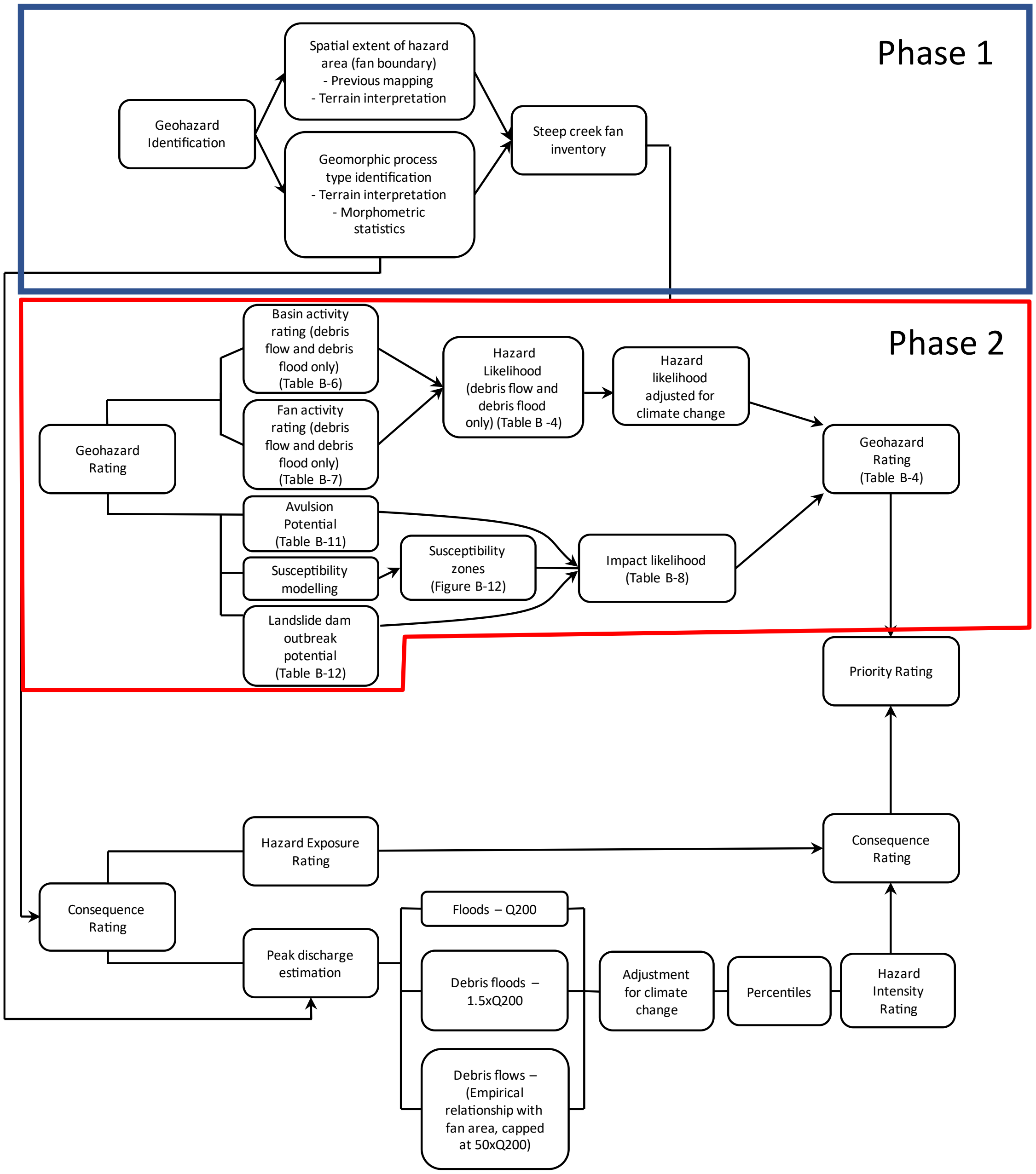


Figure B-7 Workflow for steep creek geohazard assessment and risk prioritization. Geohazard rating procedure completed by this study is outlined in red; geohazard identification and steep creek fan inventory (outlined in blue) completed in BGC (March 30, 2022)

B-2 STEEP CREEK GEOHAZARD IDENTIFICATION

Tier 1 steep creek geohazard identification (see Section 1.2 of main report) occurred in Phase 1 of this work (BGC, March 30, 2022). It focused on the delineation of alluvial fans, the boundary of which define the steep creek geohazard areas. The streams of the entire study area were delineated, classified, and used for susceptibility modelling (impact likelihood rating, in Section B-3.2.2).

B-2.1 Fan Inventory

A steep creek fan inventory was generated for Phase 1 of this work (BGC, March 30, 2022). Details of the fan delineation methodology and geohazard identification are contained within the Phase 1 report.

While the presence of a fan indicates past geohazard occurrence, the lack of a fan on a steep creek does not necessarily rule out the potential for future geohazard occurrence. As such, the fan inventory presented in this study should not be considered exhaustive. In addition, in some cases, BGC does not rule out the potential for steep creek geohazards to extend beyond the limit of the mapped fan boundary. 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 river or extends into a water body, 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.

B-2.2 Stream Network

The streams of the entire Electoral Area A were extracted from BGC's River Network Tools™ (RNT). RNT is a web-based application developed by BGC for analysis of hydrotechnical geohazards associated with rivers and streams. The basis for RNT is a digital stream network that is used to evaluate catchment hydrology, including delineating catchment areas and analyzing flood frequencies over large geographical areas. RNT incorporates hydrographic data with national coverage from Natural Resources Canada's (NRCan's) National Hydro Network (NHN) at a resolution of 1:50,000 (NRCan, January 25, 2016). The publicly available stream network is enhanced by algorithms within the RNT database to ensure the proper connectivity of the stream segments even through complex braided sections. Modifications to the stream network within RNT are made as necessary based on review of satellite imagery (e.g., Google Earth™) at approximately 1:10,000 scale.

In the RNT, the stream network is represented as a series of individual segments that includes hydraulic information such as:

- A water flow direction
- The upstream and downstream stream segment connections
- A local upstream catchment area for each stream segment (used to calculate total catchment area)
- A Strahler stream order classification (Strahler, 1952)
- A local channel gradient, which is determined using a topographic dataset to assess the elevation differential between the upstream and downstream limit of the segment.

Strahler stream order is used to classify stream segments by its branching complexity within a drainage system and is an indication of the significance in size and water conveying capacity at points along a river (Strahler, 1952). Strahler order 4 and higher streams are typically larger streams and rivers (e.g., DeBeck Creek), while Strahler order 3 and lower streams are typically smaller, headwater streams (e.g., Bishop Creek). An illustration of Strahler stream order classification is shown in Figure B-8 and described conceptually for the study area in Table B-2.

BGC supplements these data with 1:50,000-scale CanVec digital watercourse linework to represent lakes and reservoirs and 1:20,000 scale GeoBase digital elevation models (DEMs; NRCan, January 25, 2016) to generate catchment areas and a local stream gradient for each segment in RNT.

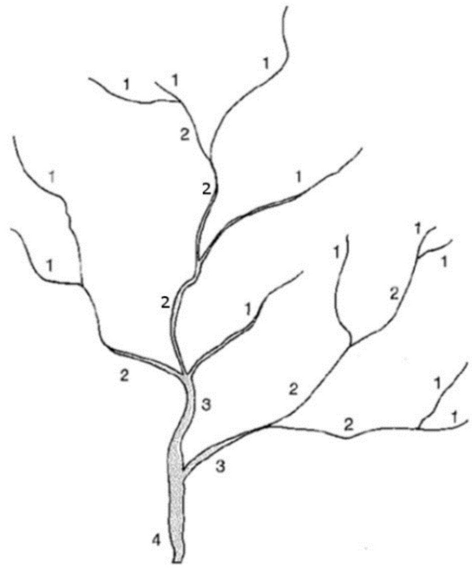


Figure B-8 Illustration showing Strahler stream order (Montgomery, 1990).

Table B-2. Strahler order summary for the Metro Vancouver Electoral Area A stream network.

Strahler Order	Description	% of Stream Segments	Metro Vancouver Examples
1 – 3	Small, headwater streams generally on steeper slopes and typically subject to steep-creek processes (debris floods/ flows). Channel may be dry for a portion of the year. They are tributaries to larger streams and are typically unnamed.	91	*Bishop Creek, Clegg Creek, Newman Creek*
4 – 6	Medium stream or river. Generally, less steep and lower flow velocity than headwater streams.	9	*DeBeck Creek, Hanging Creek, Hixon Creek*
7+	Large river. Larger volumes of runoff and potentially debris conveyed then from smaller waterways.	NA	*NA*

B-2.3 Geohazard Process Type Identification

Details of the geohazard process type identification for the inventoried fans are contained within the Phase 1 report.

For this study, RNT stream segments within the study area were classified as either debris flow, debris flood or clear-water flood segments. A morphometric statistical approach was applied to every stream segment in the entire study area, including both developed and undeveloped areas. Sections below outline these approaches.

B-2.3.1 Morphometric Statistics

BGC applied the following morphometric statistical approach to predict steep creek process type for all stream segments of every mapped creek within the study area:

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 flow (Holm et al., 2016).
2. Apply class boundaries to predict process types for all stream segments in the study area, regardless of whether they intersect fans.

Figure B-9 plots sample data from BC and Alberta 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 clear-water floods. Debris floods fall between these types. Table B-3 lists class boundaries used to define process types on each segment of each creek within the Metro Vancouver Electoral Area A, based on recommendations from previous studies in BC (Holm et al., 2016).

[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.
[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.

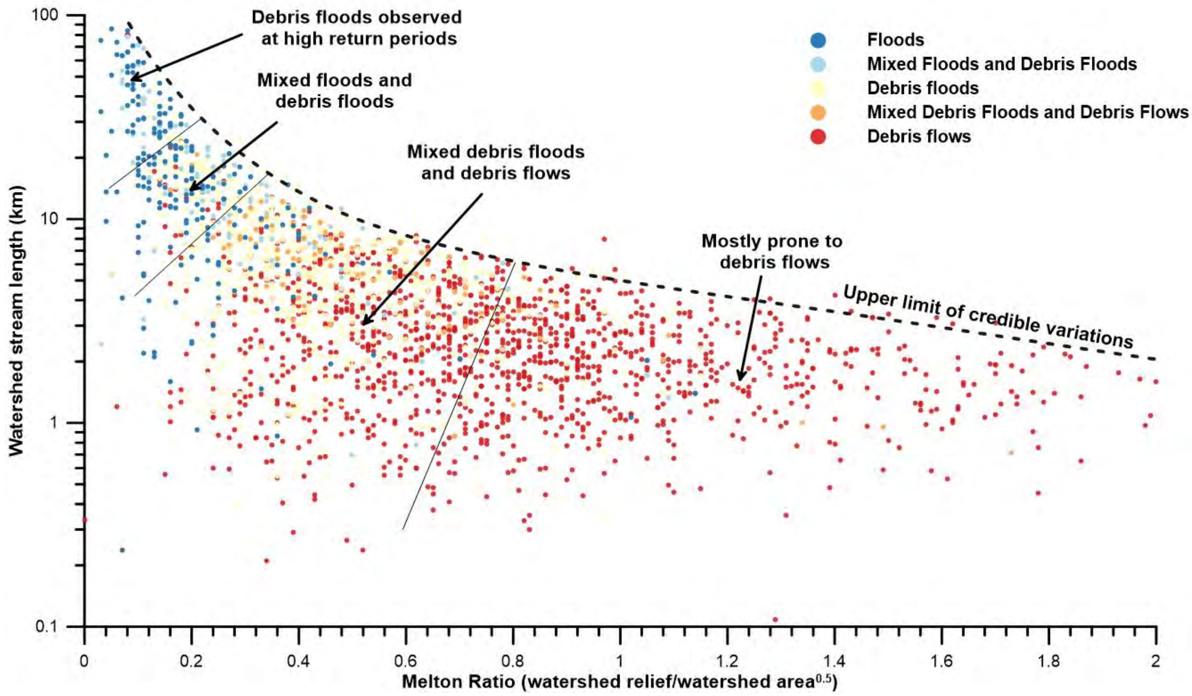


Figure B-9 Steep creek processes in BC and Alberta as a function of Melton Ratio and stream length with process boundaries derived (Holm et el., 2016; Lau, 2017).

Table B-3 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

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. In rare occasions, channels may be classified as “debris flow” or “debris flood” without evidence for previous such events. Some streams subject to debris floods are subject to clear-water floods at lower return periods.
- 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 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.
- The morphometric statistical approach may be appropriate for hanging valleys, where the lower channel sharply steepens below a gentle upper basin.

- Finally, as explained in Section B-1.1, there is a continuum between each of the geohazard processes and consequently, a steep creek could have an event that has characteristics that fall between a debris flood and debris flow. Similarly, not every debris flood shows the same characteristics (see Section B-1.1.3).

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.

B-3 GEOHAZARD RATING

The geohazard ratings are a function of:

1. Geohazard likelihood: What is the likelihood of steep creek geohazard events large enough to potentially impact elements at risk[4] (Section B-3.1)?
2. Geohazard impact likelihood: Given a geohazard event occurs, how susceptible is the hazard area to flows that could impact elements at risk (Section B-3.2)?

These two factors were combined in the qualitative geohazard rating matrix shown in Table B-4 to prioritize each geohazard area. Sections B-3.1 and B-3.2 describe methods and criteria used to estimate geohazard likelihood and impact likelihood, respectively. In these methods, terrain interpretation was based on a combination of lidar, air photos, satellite imagery and recorded events.

Table B-4 Geohazard rating matrix.

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

4 Elements at risk are defined as assets exposed to potential consequences of geohazard events.

B-3.1 Geohazard Likelihood Rating

BGC assigned a geohazard likelihood rating to each fan based on terrain analysis. The geohazard likelihood rating represents a single, "typical" event frequency assigned to each fan and watershed based on surface evidence for previous events, recorded events, and reference to previous work. The typical event corresponds to an event of sufficient magnitude to have credible potential for consequences[5].

Geohazard likelihood ratings were estimated based on surface evidence for geomorphic activity within the basin and fan. The relative ***basin activity*** and relative ***fan activity*** ratings were combined to generate a geohazard likelihood rating (Table B-5) for each prioritized geohazard area, as discussed in the section below.

Table B-5 Geohazard likelihood hazard rating matrix.

		Typical Basin Activity Characteristics				
		Very Low	**Low**	**Moderate**	**High**	**Very High**
Fan Activity Characteristics	**Very High**	Moderate	Moderate	High	Very High	Very High
	High	Low	Moderate	High	High	Very High
	Moderate	Low	Low	Moderate	High	High
	Low	Very Low	Low	Low	Moderate	Moderate
	Very Low	Very Low	Very Low	Low	Low	Moderate

Table B-6 and Table B-7 summarize the criteria used to rate basin activity and fan activity, respectively. Figure B-10 and Figure B-11 show examples of events large enough to produce visible surface evidence of activity. It should be noted that dense tree cover could obscure small events that would not be detected at the scale of this study. Accordingly, the ratings are relative measures and can be subject to the limitations of available records and datasets. Specifically, terrain interpretation on less vegetated fans can be biased in favour of relatively smaller, more frequent events that would not have been visible under tree cover. All ratings are potentially subject to revision following future more detailed study.

5 While a single geohazard likelihood rating was assigned for prioritization (i.e., to compare areas in relative terms), BGC notes that events of different frequencies and magnitudes (volume of sediment deposited on a fan, peak discharge) can occur on any given steep creek.

Table B-6 Relative basin activity for steep creeks organized by dominant process type.

Basin Activity	Description	Characteristic Observations	
		Debris-flood dominated steep creeks	**Debris-flow dominated steep creeks**
Very Low	• Minimal sediment sources. • Supply limited watershed.	• Negligible sediment sources in or along channel or in tributaries.	• Absence of landslide scars or erodible terrain. • Basin is treed. • Several rounded slopes.
Low	• Identifiable sediment sources, but most show limited evidence of activity or connectivity. • Supply limited watershed	• Minimal sediment sources in or along channel and any existing channel material is not easily mobilized (e.g., dense till, partially bedrock controlled).	• Some exposed soil or rock occurs. • Absence of fresh landslide scars or debris below exposed terrain. • Absence of channel deposits. • Basin and channel are mostly treed
Moderate	• Active sediment sources, but the material is not easily mobilized AND is not connected to the main channel or fan. • Supply limited or unlimited watershed.	• Sediment sources are present in or along channel. • Channel material is not easily mobilized (e.g., dense till, partially bedrock controlled) • Tributaries with identifiable sediment sources (e.g., debris-flow tributaries) typically stall before reaching main channel. • Main channel often has variable width.	• Sediment sources are present on slopes (e.g., presence of landslide scars in soil or rock). • Source material or in channel deposits are not easily mobilized (e.g., coarse, angular colluvium, dense till, or partially bedrock controlled). • Landslide deposits typically stall before the main channel.
High	• Active sediment sources, but the material is either not easily mobilized, or not clearly connected to the main channel or fan. • Supply unlimited watershed	• Numerous, actively producing source areas along main channel and tributaries (i.e., debris slides, debris avalanches, raveling in lacustrine, glaciofluvial, or morainal sediments); • Evidence of temporary sediment storage along main channel.	• Numerous, actively producing source areas on slopes or in channel. • Channel is choked with debris, but the material is not easily entrained (e.g., coarse angular colluvium) • Source material could be easily entrained (e.g., talus, loose glacial deposits, volcanic), but there is no clear connection between the sources and main channel (e.g., hanging valley).
Very High	• Active sediment sources that could be easily mobilized and are well connected to the main channel or fan. • Supply unlimited watershed.	• Numerous, actively producing source areas along main channel and tributaries (i.e., debris slides, debris avalanches, raveling in lacustrine, glaciofluvial, or morainal sediments); • Source material could be easily entrained. • Tributaries with identifiable sediment sources (e.g., debris-flow tributaries) deposit straight into main channel.	• Numerous, actively producing source areas on slopes or in channel. • Channel choked with debris. • Easily entrained source materials along channels (e.g., talus, glacial deposits, volcanics)

Table B-7 Relative fan activity for steep creeks organized by dominant process type. Fan activity refers to the frequency of steep creek events reaching the fan.

Fan Activity[1,2]	Return Period	Number of Recorded Events[4]	Fan Observations: Debris-flood dominated creeks	Fan Observations: Debris-flow dominated creeks
Very Low	500-year	None	• Vegetated mainstem. • No distinguishable debris-flood related landforms. • Uniform tree canopy of mature forest.	• No observable mainstem. • No distinguishable debris-flow related landforms. • Uniform tree canopy of mature forest.
Low[3]	200-year	None	• Partially vegetated mainstem. • Muted channels or over bank deposits (most likely only visible in lidar). • Uniform tree canopy of mature forest.	• Vegetated mainstem. • Muted channels, lobes or levees (most likely only visible in lidar). • Uniform tree canopy of mature forest.
Moderate	50-year	0 to 1	• Unvegetated mainstem. • Channels and over bank deposits are visible in lidar, but potentially not in imagery. • Persistently includes swaths of mixed deciduous or conifer trees in riparian zone.	• Partially vegetated mainstem; • Channels, lobes or levees are visible in lidar, but potentially not in imagery. • Persistently includes swaths of mixed deciduous or coniferous trees associated with debris-flow landforms.
High	20-year	1 to 2	• Unvegetated mainstem; • Channels and over bank deposits are visible in imagery and lidar. • Persistently includes variable tree stand ages in riparian zone. • Regenerative vegetation and exposed sediment along channel. • Undersized channel in comparison with active floodplain width. • Partially vegetated bank erosion scars.	• Partially vegetated mainstem. • Channels, lobes or levees are visible in imagery and lidar. • Persistently includes swaths of regenerative (<10 year) or immature (<50 year) forest, potential areas of bare sediment.
Very High	5-year	8 (or at least two in the past 10 years where records are not available over a longer period)	• Unvegetated mainstem; • Channels and over bank deposits are visible in imagery and lidar. • Persistently includes areas of pioneer vegetation in riparian zone. • Fresh deposits are visible. • Undersized channel in comparison with active floodplain width. • Fresh bank erosion scars along mainstem.	• Fresh deposits are visible. • Channels, lobes or levees are visible in imagery and lidar. • Persistently includes swaths of bare sediment or low (<2 year) pioneer vegetation.
Cannot determine[3]	n/a	n/a	• Anthropogenic modifications across most of fan, and no evidence of past events in air photo record.	

Notes:

1. In cases where fan activity cannot be determined from available data, the basin activity rating was applied as the likelihood rating.
2. Very low vs. low classification cannot reliably be determined without lidar. A classification of low is conservatively applied in such cases.
3. For the purposes of this assessment, BGC defined the record event span to be 1980 to present, for which there are readily and freely available air photo and recorded event records in the study area. The true number of recorded events at each geohazard area depends on the length and quality of air photo, imagery, and media records.

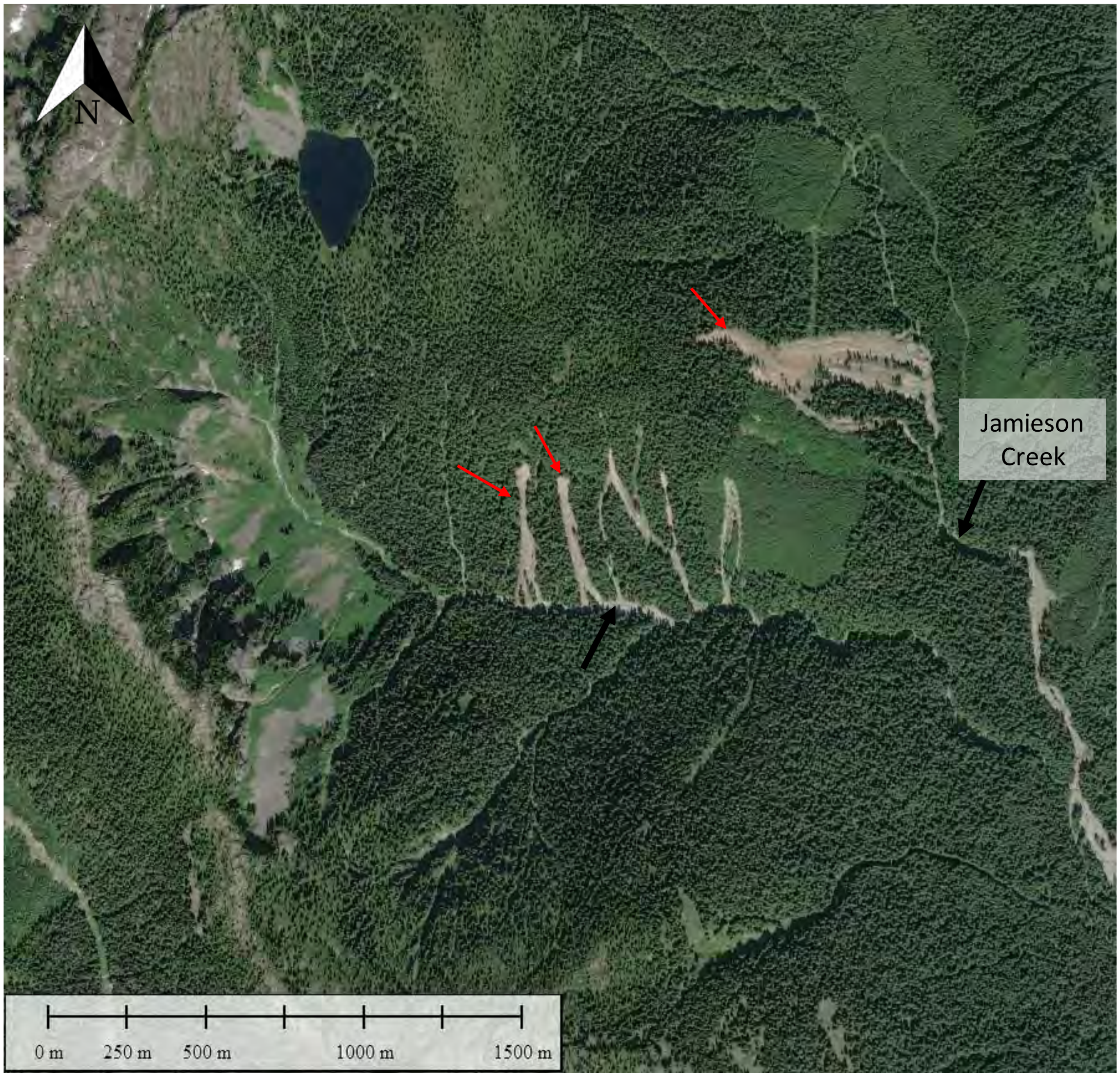


Figure B-10 **Example of evidence for recent landslide or in-channel debris-flow initiation (red arrows) within the basin of Aaron and Jamieson Creek, located approximately 3.5 km west of the Indian Arm section of the study area.**

Figure B-11 Example of evidence (red arrows) for a recent debris-flow deposit on Unnamed Creek 31912, located in the east portion of the Indian Arm section of the study area. The approximate alluvial fan boundary is shown in red.

B-3.1.1 Geohazard Likelihood Adjusted for Climate Change

Geohazard likelihood ratings were adjusted for climate change by increasing fan activity ratings by one order of magnitude. This increase in fan activity accounts for the increase frequency of debris flow and debris floods anticipated with climate change (Section B-1.2).

B-3.2 Geohazard Impact Likelihood

BGC assigned an impact likelihood rating to each fan that considered the relative spatial likelihood that geohazard events result in flows that could impact elements at risk. Given the study objective of regional risk prioritization, the geohazard impact likelihood rating was 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 the methods used to determine this geohazard impact likelihood rating.

Geohazard impact likelihood is predominantly concerned with avulsions. 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 of or all of a flow may avulse from the existing channel and travel across a different fan portion.

B-3.2.1 Impact Likelihood Rating

BGC estimated geohazard impact likelihood based on a combination of susceptibility modelling and terrain interpretations. The results of the susceptibility model provided an initial estimate of impact likelihood (Section B-3.2.2), which was then complemented by observations on avulsion activity (Section B-3.2.3) and the potential for an LDOF (Section B-3.2.4). Previous assessments and event records were referenced where available. The methods described in this section are applicable for regional-scale assessment.

An initial impact likelihood rating was first calculated as the proportion of “moderate” and/or “high” modelled susceptibility classes included within the area of each fan (Table B-8). This initial estimate of impact likelihood was then adjusted based on the other factors (avulsion activity and LDOF potential) as follows:

- The initial impact likelihood rating was increased by a factor of 1 if the evidence for previous avulsion rating (see Section B-3.2.3) was “moderate”; and by a factor of 2 if it was “high’ or “very high”.
- The initial impact likelihood rating was further increased by a factor of 1 if (i) the LDOF potential rating was “high’ or “very high” (Section B-3.2.4); or (ii) there was evidence of steep-creek mixed processes. This adjustment serves to flag fans where there is a possibility of major flooding events associated with potential LDOF events.

Table B-8 Summary of criteria used for impact likelihood rating for debris flows and debris floods in the Electoral Area A region.

Impact Likelihood Rating[1]	Criteria
Very Low	Fan area is rated Very Low susceptibility; no evidence of previous avulsion
Low	Less than 5% of fan area is rated Moderate or High susceptibility; none to poor evidence of previous avulsion.
Moderate	Poor evidence of previous avulsion where more than 5% of fan area is rated Moderate or High susceptibility but less than 40% of the fan area is rated High susceptibility; OR moderate evidence of previous avulsion where less than 5% of fan area is rated Moderate or High susceptibility
High	Poor evidence for previous avulsion where more than 40% of fan area is rated High susceptibility; OR moderate evidence of previous avulsion where more than 5% of fan area is rated Moderate or High susceptibility but less than 40% of the fan area is rated High susceptibility; OR strong or very strong evidence of previous avulsion where less than 5% of the fan is rated Moderate or High susceptibility
Very High	Moderate or stronger evidence of previous avulsion where more than 40% of fan area is rated High susceptibility; strong or very strong evidence of previous avulsion where more than 5% of fan area is rated Moderate or High susceptibility but less than 40% of the fan area is rated High susceptibility

Note:

1. The impact likelihood rating was increased by a factor of 1 if (i) the LDOF potential criteria are "high' or "very high"; or (ii) there is evidence of steep-creek mixed processes.

B-3.2.2 Debris-Flow- and Debris-Flood Susceptibility Modelling

Debris-flow or debris-flood hazard assessment based on terrain interpretation alone is limited by the availability of surface evidence for previous events, which may be hidden by development or obscured by progressive erosion or debris inundation. To address this limitation, BGC used a semi-automated approach based on the stream channel morphometric statistics (Section B-2.2), and the Flow-R model[6] developed by Horton et al. (2008; 2013) to identify potential debris-flow or debris-flood hazards and model their runout susceptibility. Others that have modelled debris-flow susceptibility using comparable approaches include Blahut et al. (2010), Baumann et al. (2011), Blais-Stevens & Behnia (2016), Sturzenegger et al. (2021). This approach allowed estimation of potential debris-flow or debris-flood hazard extent within the entire study area, including both developed and undeveloped areas. The results were used as an initial impact likelihood rating to each fan, as described in Section B-3.2.1.

Flow-R propagates landslides across a surface defined by a DEM. A 10 m pixel down-sampled version of Metro Vancouver's 2022 lidar was used in the current project. Flow-R simulates flow

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

propagation based on both spreading algorithms and simple frictional laws. The source areas are identified as stream segments associated with debris-flow or debris-flood processes, based on the stream network and morphometric statistics presented in Sections B-2.2. Both spreading algorithms and friction parameters need to be calibrated by back-analysis of past events or using geomorphological observations.

Flow-R calculates the sum of all susceptibilities passing through each cell. This method is used to identify areas of highest relative regional susceptibility. Flow-R triggers propagation from every cell in the source segments.

Although the absolute value of susceptibility at a given location has no physical meaning, areas of higher relative regional susceptibility account for both larger source zones (increased the number of potential debris flows or debris floods that reach a susceptibility zone), as well as increased control of topographic features (i.e., incised channels or avulsion paths within alluvial fans).

BGC used the following steps to complete debris-flow/flood susceptibility modelling using Flow-R:

- As an initial step, Flow-R parameters were assigned based on calibration with assessments completed at a higher level of detail. As described by Sturzenegger et al. (2021), BGC chose detailed assessments completed for several steep creeks near Canmore, Alberta, as a calibration starting point.
- BGC then calibrated the Flow-R model parameters by attempting to reproduce the extent of fans at selected locations within and nearby the Electoral Area A including Percy Creek where a detailed frequency-magnitude analysis has been completed by BGC as part of a study completed for the District of North Vancouver (BGC, May 31, 2017).
- Finally, BGC applied the model to map debris-flow and debris-flood susceptibility on all creeks in the stream network, within the Electoral Area A. The results were further compared to terrain analyses.

Table B-9 and Table B-10 show Flow-R calibrated parameters for debris flows and debris floods, respectively. The debris-flow and debris-flood scenarios are modelled separately.

Table B-9 Calibrated debris-flow parameters used in Flow-R.

Selection	Flow-R Parameter	Value
Directions algorithm	Holmgren (1994) modified	dh = 2 exponent = 2
Inertial algorithm	Weights	Default
Friction loss function	Travel angle	9°
Energy limitation	Velocity	< 15 m/s

Table B-10 Calibrated debris-flood parameters used in Flow-R.

Selection	Flow-R Parameter	Value
Directions algorithm	Holmgren (1994) modified	dh = 2 exponent = 2
Inertial algorithm	Weights	Default
Friction loss function	Travel angle	4°
Energy limitation	Velocity	< 15 m/s

Debris-flow/flood susceptibility results are displayed in Drawing Set A and Drawing Set B and generally correspond well to the extent of known debris-flow or debris-flood events and fan boundaries within the study area (Figure B-12). The summed susceptibility values throughout the study area follow a negative exponential distribution. Zones of the DEM with summed susceptibility values lower than a threshold corresponding to the 70th percentile were attributed 'very low' regional susceptibility (i.e., 'very low' susceptibility include the majority of areas covered by Flow-R simulations). Zones of 'low' regional susceptibility were defined between the 70th and 85th percentile (the 85th percentile corresponding approximately to the mean susceptibility value); 'moderate' and 'high' susceptibility were defined between the 85th and 95th percentile, and greater than the 95th percentile, respectively. Portions of alluvial fans not encompassed by susceptibility modelling were interpreted as having 'very low' regional susceptibility, where modern fan morphometry encourages flow away from the unaffected area.

BGC notes that regional scale susceptibility modelling contains uncertainties and should be interpreted with caution. BGC highlights the following specific limitations:

- Susceptibility modelling on creeks without mapped fans contains much higher uncertainty.
- Susceptibility modelling does not imply any specific hazard likelihood. Some areas mapped as susceptible to debris flows or debris floods may not have credible potential for events due to factors not considered in regional scale modelling, such as lack of sediment supply.
- Susceptibility modelling is 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 are not mapped.

- Debris-flow and debris-flood susceptibility model calibration was optimized for flow propagation on the fan. Susceptibility in the upper basin should be considered a proxy for debris sources, not necessarily an accurate representation of actual source areas.
- Flow-R propagation was simulated using parameters calibrated at regional scale. It is not applicable for detailed runout simulations, risk analyses and risk control design at specific sites. In addition, the model is not physics-based (it is an empirical model) and not attached to any specific return period. Thus, it cannot inform on return period-specific runout distance, nor does it provide flow depths and velocity estimates which are necessary to calculate debris-flow intensities.
- Susceptibility mapping does not replicate specific scenarios undertaken as part of detailed hazard and risk assessment, e.g., modelled avulsions of the Cheekeye debris flow in BGC (August 30, 2019).

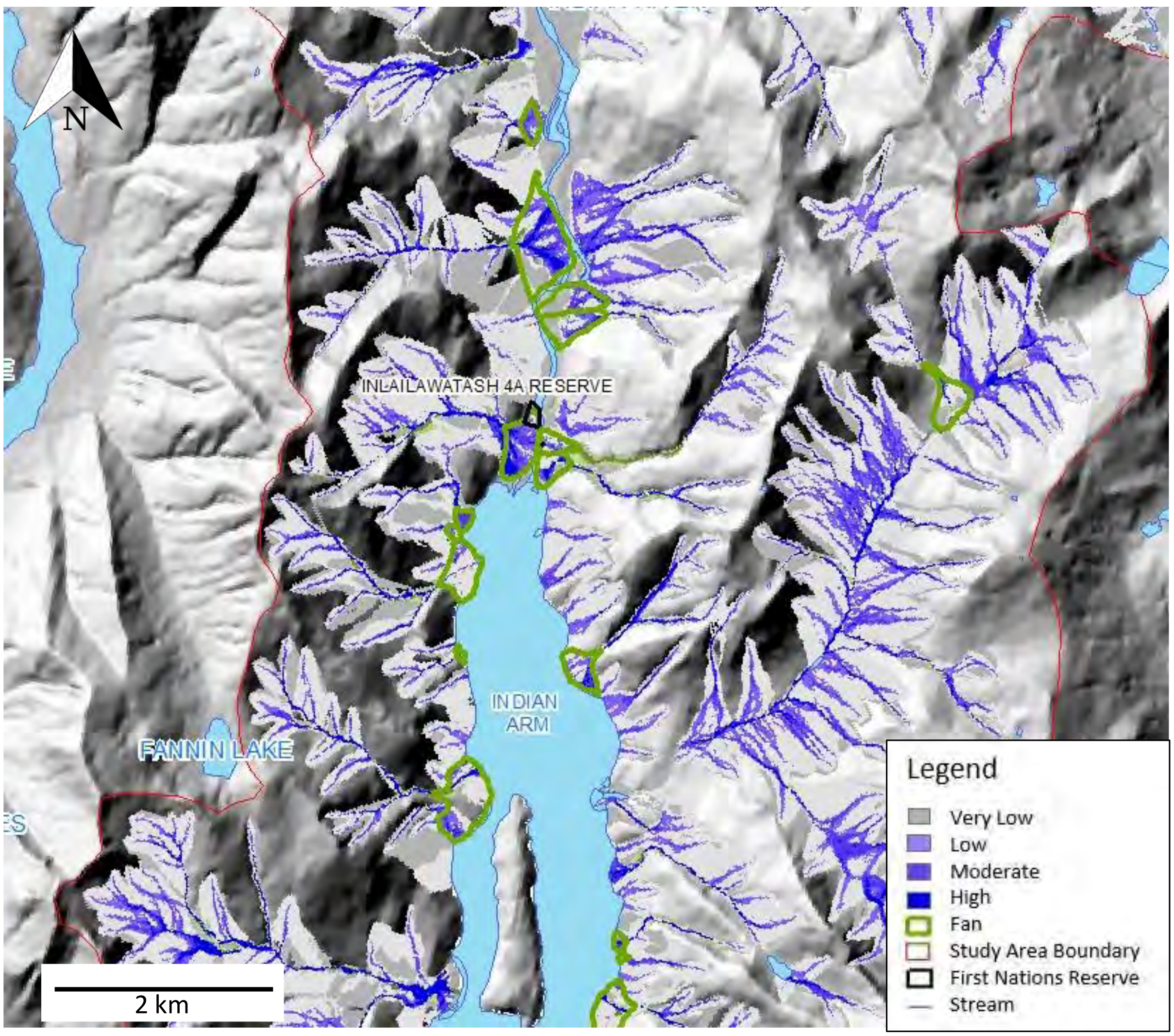


Figure B-12 Debris-flow susceptibility map for a section of the study area showing the spatial distribution of the four different susceptibility classes and outlines of study area debris-flow fans.

B-3.2.3 Avulsion Activity

BGC used terrain interpretations of evidence of previous avulsions and description of potential avulsion mechanisms to assess the potential for avulsion to impact elements at risk at each fan. Surface evidence for previous avulsions includes pioneer vegetation on gravel deposits and the presence of relict channels, lobes, and deposits on the fan surface or along the channel (Table B-11; Figure B-13). These features are usually detectable on lidar hillshades and high-resolution satellite images; interpretations are less certain for areas without lidar or satellite image coverage. The rating is subject to greater uncertainty where development has obscured previous evidence for flow avulsions (e.g., channel modification or highly developed fans) or where avulsions deposits are removed by emergency works.

Fan-deltas (fans that form in standing water bodies, such as lakes, oceans and reservoirs) typically have a higher potential for avulsion than terrestrial (land-based) alluvial fans due to channel back-filling effects from the stream-lake/reservoir interface. As such, these fans typically exhibit characteristics of a "Very High" or "High" avulsion evidence rating, if the channel is not entrenched (highly incised) into the fan and the water level at any time of the year is well below the fan surface. Fan deltas with steeper gradients are less influenced by lake level and their avulsion rating remains unchanged.

The potential for avulsion can be variable along a channel due to relative confinement of the channel within the fan landform. For example, flows can more easily fill and overtop a channel that has low channel banks, rather than a deeply incised channel. In addition, structures such as bridges and culverts can become blocked during hydrogeomorphic events and encourage avulsion upstream.

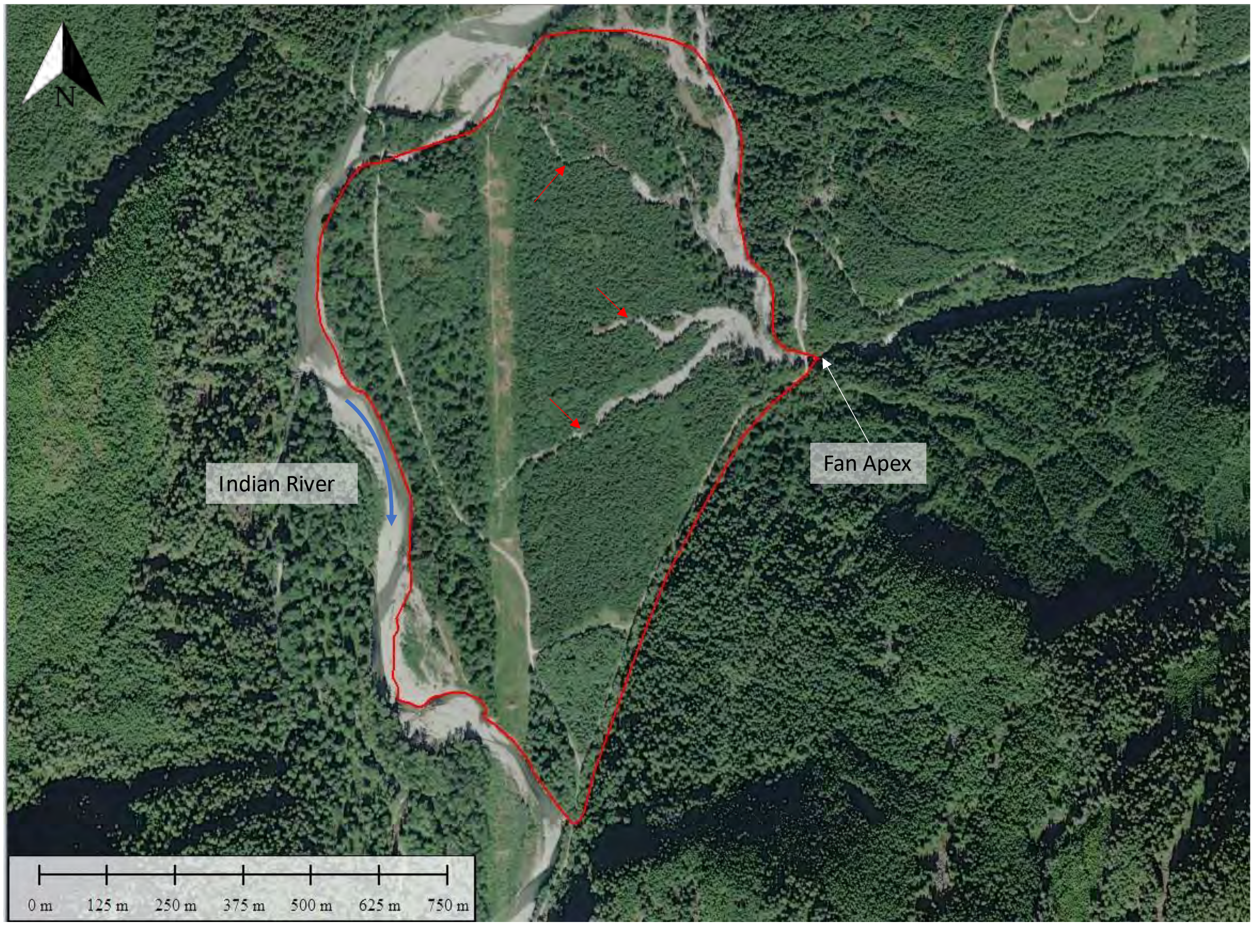


Figure B-13 **Example of high evidence for previous avulsion on Hixon Creek, located North of Indian Arm. The approximate fan boundary is shown as a red polygon and avulsions are noted by red arrows.**

Table B-11 Evidence of previous avulsions criteria. These criteria refer to the frequency of events avulsing on the fan, as opposed to Table B-7, which refers to the frequency of events reaching the fan regardless of avulsing or not.

Surface Evidence of Previous Avulsions[1]	Representative Return Period (years)	Number of Recorded Events[2]	Description	Characteristic Observations[3]
Very Low	500	None	Active or historical channels cannot be identified in lidar or imagery.	Vegetated fan with consistent, mature tree stand age. No avulsion channels visible in lidar if available.
Low[1]	200	None	Historical channels visible with lidar or air photographs, but they are muted and vegetated and not discernable on satellite imagery.	Vegetated fan with consistent, mature stand age. Muted historical channels visible in lidar if available.
Moderate	50	0 to 1	Historical channels on fan surface are visible in lidar, air photo and satellite imagery.	Swaths of young (<50 year) deciduous or coniferous vegetation exist in previous avulsion paths. Relict channels clear in lidar. Channels have similar characteristic geomorphic observations (e.g., debris-flow levees) as described in the fan activity rating.
High	20	1 to 2	An avulsion path is visible.	Swaths of bare sediment or low (<20 year) pioneer vegetation exist on previous avulsion path. Channels have similar characteristic geomorphic observations (e.g., boulder levees) as described in the fan activity rating.
Very High	5	8 (or at least two in the past 10 years where records are not available over a longer period)	At least one fresh avulsion path exists.	Swaths of bare sediment or low (<2 year) pioneer vegetation exist on previous avulsion paths. Channels have similar characteristic geomorphic observations (e.g., debris-flow levees) as described in the fan activity rating.

Notes:

1. Very low vs. low classification cannot reliably be determined without lidar. A classification of low is conservatively applied in such cases.
2. For the purposes of this assessment, BGC defined the record event span to be 1980 to present, for which there are readily and freely available air photo and recorded event records in the study area. The true number of recorded events at each geohazard area depends on the length and quality of air photo, imagery, and media records.
3. Fans classified as being a flood geohazard type are assessed according to these characteristics, but smaller flood events can be difficult to discern in air photos or satellite imagery. lidar, historical records and judgement is used where applicable. A low classification is conservatively applied as the lowest option for flood type fans.

B-3.2.4 Landslide Dam Outbreak Flood (LDOF) Potential

Some steep creek watersheds are prone to LDOFs, which could trigger flooding, debris floods, or debris flows with larger magnitudes than "typical" hazards. An example of this hazard is landslides in the Mount Meager volcanic complex, which have generated several landslide dams along Meager Creek and Lillooet River in British Columbia (Figure B-14; Bovis & Jakob, 2000; Guthrie et al., 2012). In this assessment, LDOF potential is expected to be a factor potentially increasing the potential for avulsion; therefore, it is considered in the impact likelihood rating (see Section B-3.2.1). However, LDOFs are a distinct population of events from the "typical" debris flows and debris floods defined in Section B-1.1. Therefore, this rating serves as a flag for consideration of more specific analyses to address this type of geohazard.

Figure B-14 Landslide dam on Meager Creek from the August 6, 2010 rockslide-debris flow from Capricorn Creek. The dam impounded Meager Creek for some time. Photo by D. Steers.

Table B-12 lists terrain criteria used to estimate LDOF potential. Ratings are assigned based on evidence of past landslide dams, presence of large landslides with the potential to travel to the valley floor, and presence of channel sections potentially susceptible to blockage (e.g., channel constrictions).

Table B-12 Landslide dam outbreak flood potential criteria.

Relative Frequency	LDOF Potential
Very High	Presence of active landslides that are potentially large enough to reach the valley floor and block the typically confined stream channel. Historical evidence of several landslide dams in the main channel. Main stem channel is entrenched and confined within a steep sided and narrow valley, resulting in multiple constriction points (e.g., bedrock canyon).
High	Evidence of historical landslides that are potentially large enough to reach the valley floor and block the river channel. Historical evidence of at least one landslide dam in the main channel. Main stem channel is entrenched and confined within a narrow valley and may have constrictions (e.g., bedrock canyon).
Moderate	Evidence of historical landslides that are potentially large enough to reach the valley floor and block the river channel. Landslide damming is considered possible. No evidence of historical landslide dams in the main channel. Main stem channel has moderately steep valley walls and is partially confined (e.g., U-shaped valleys, glacial deposits, river terraces).
Low	No evidence of historical landslides potentially large enough to reach the valley floor and block the river channel. Landslide damming is improbable. No evidence of historical landslide dams in the main channel. Main stem channel is broad, with low angle to flat valley floor (e.g., floodplain).
Very Low	No evidence of historical landslides in the watershed. Main stem channel is broad and flat (e.g., floodplain). Landslide damming is impossible.

B-4 FREQUENCY MAGNITUDE RELATIONSHIP

A regional frequency-magnitude (F-M) relationship was developed for steep creek events in the study area, to provide an estimate of expected 200-year event debris flood and debris flow volumes. This study primarily considers debris flows and Type 2 debris floods. The F-M relationship was developed to be applicable to both debris flows and Type 2 debris flows, considered in this study, given the similarities between the two process types (Section B-1.1 and Table B-1). The developed F-M relationship, herein referred to as the 200-year debris flow event F-M relationship, is not valid for Type 1 and Type 3 debris floods.

B-4.1 Debris Flows

The 200-year event debris flow volume was estimated using the following procedure:

- A regional frequency-magnitude (F-M) relationship was developed for debris flows (and Type 2 debris floods) in the study area, based on data from previous studies.
- A hypothetical site-specific F-M was developed based on watershed area for each debris flow and debris flood fan within the study area.
- The hypothetical sediment volume of a 200-year return period debris-flow event was calculated from the site-specific F-M.

Typically, F-M relationships for debris flows are challenging 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 that is outside the current scope of work. However, where several reliable F-M curves have been assembled, regional relations can be developed (Jakob et al., 2020). These relations can then 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 detailed F-M analyses is increasing, but at present is still limited.

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 are not yet fully responded to by the fan area. These site-specific factors could result in data population distributions that violate underlying statistical assumptions in the regional F-M curves.

In this assessment, BGC used F-M curves outlined in BGC (April 6, 2018) and Jakob et al. (2020) from detailed studies of 13 creeks in southwestern Alberta and British Columbia, which has similar climate and geology to the study area. Individual F-M curves were normalized by dividing sediment volume by watershed area and then plotted collectively versus return period. A logarithmic best-fit curve was then fit to the data. Figure B-15 shows the resulting normalized F-M curve for debris flows in the study area.

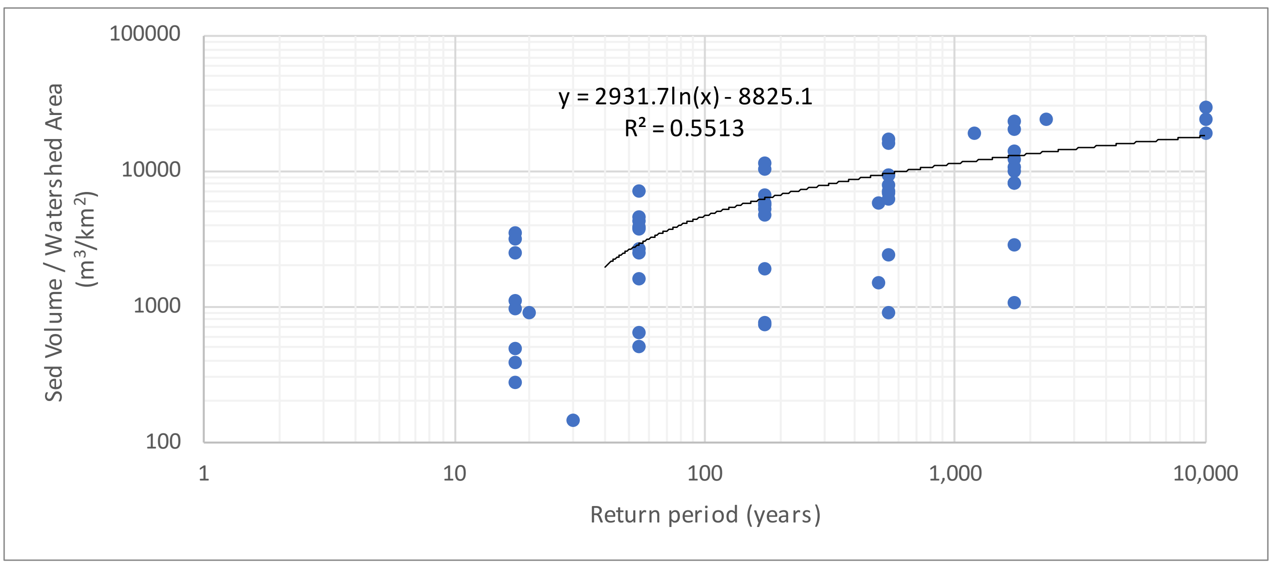


Figure B-15 F-M curve for debris flows in southwestern British Columbia using data from 13 study creeks.

The regional F-M relationship (Equation F-7), based on the best-fit line from Figure B-15 for the detailed study[7] of 13 creeks in southwestern Alberta and British Columbia, is then derived:

$$V_S = A_{WS}[2931.7\ln(\mathrm{T}) - 8825.1] \qquad \text{[Eq. F-1]}$$

Using this equation, BGC predicted sediment volumes (V_s) for each prioritized geohazard area within the MVRD Electoral Area A study area using the watershed area (A_{WS}) and an average return period (T) of 200 years.

B-4.2 Climate Change Adjustment

For debris flows and debris floods, climate change was considered in this study by applying the predicted volume increases, described in Section B-1.2.3, to the 200-year event sediment volumes estimated in Section B-4.1. Climate adjusted 200-year event sediment volumes for the study area are reported in Appendix C.

[7] BGC (January 16, 2015), BGC (April 10, 2015), BGC (November 23, 2015), BGC (May 31, 2017), BGC (April 6, 2018), BGC (September 25, 2018), BGC (December 21, 2018), BGC (December 28, 2018).

REFERENCES

Baumann, V., Wick, E., Horton P., & Jaboyedoff, M. (2011). Debris-flow susceptibility mapping at a regional scale along the National Road N7, Argentina. In: Proceedings of the 14th Pan-American Conference on Soil Mechanics and Geotechnical Engineering, 2-6 October 2011, Toronto, Ontario, Canada.

BGC Engineering Inc. (2015, January 16). *Stone Creek Debris-Flow Hazard Assessment* [Report]. Prepared for Town of Canmore.

BGC Engineering Inc. (2015, April 10). *Stoneworks Creek Debris-Flow Hazard Assessment* [Report]. Prepared for Town of Canmore.

BGC Engineering Inc. (2015, November 23). *Steve's Canyon Creek Debris-Flow and Debris-Flood Assessment* [Report]. Prepared for Municipal District of Bighorn.

BGC Engineering Inc. (2017, May 31). *Debris Geohazard Risk and Risk Control Assessment* [Report]. Prepared for District of North Vancouver.

BGC Engineering Inc. (2018, April 6). *Seton Portage Area Integrated Hydrogeomorphic Risk Assessment* [Report]. Prepared for Squamish-Lillooet Regional District.

BGC Engineering Inc. (2018, September 25). *Steep Creek Hazard and Risk Assessment: X, Y and Z Creeks* [Draft Report]. Prepared for Town of Canmore.

BGC Engineering Inc. (2018, December 21). *Steep Creek Hazard and Risk Assessment: Echo Canyon Creek* [Report]. Prepared for Town of Canmore.

BGC Engineering Inc. (2019, August 30). *Cheekeye Fan Debris-Flow Mitigation Baseline Risk Assessment* (Rev.0) [Report]. Prepared for Squamish Sea to Sky Developments LP.

BGC Engineering Inc. (2022, March 30). *Electoral Area A – Geohazard Mapping (Phase 1)* [Report]. Prepared for Metro Vancouver.

Blahut, J., Horton, P., Sterlacchini, S., & Jaboyedoff, M. (2010). Debris-flow hazard modelling on medium scale: Valtellina di Tirano, Italy. *Natural Hazards Earth System Science, 10,* 2379–2390. https://doi.org/10.5194/nhess-10-2379-2010

Blais-Stevens, A., & Behnia, P. (2016). Debris-flow susceptibility mapping using qualitative heuristic method and Flow-R along the Yukon Alaska Highway Corridor, Canada. *Natural Hazards Earth System Science, 16***,** 449-462. https:/doi.org/10.5194/nhess-16-449-2016

Bovis, J., & Jakob, M. (2000). The July 29, 1998, debris flow and landslide dam at Capricorn Creek, Mount Meager Volcanic Complex, southern Coast Mountains, British Columbia. *Canadian Journal of Earth Sciences, 37(10),* 1321-1334.

Church, M. (2022). Steep headwater channels. Chapter 6.39 in: Shroder, J.F. (ed.) Treatise on Geomorphology, Fluvial Geomorphology. Elsevier 841-864.

Church, M., & Jakob, M. (2020). What is a debris flood? *Water Resources Research*. 56; Paper e2020WR027144.

Crévolin, V., Hassanzadeh, E., & Bourdeau-Goulet, S-C. (2023). Updating the intensity-duration-frequency curves in major Canadian cities under changing climate using CMIP5 and CMIP6 projections. *Sustainable Cities and Society* 92: Paper 104473.

de Haas, T., Densmore, A.L., Stoffel, M., Suwa, H., Imaizumi, F., Ballesteros-Cánovas, J.A., & Wasklewicz, T. (2017). Avulsions and the spatio-temporal evolution of debris-flow fans. *Earth-Science Reviews, 177*, 53-75.

de Haas, T., Densmore, A.L., den Hond, T., Cox, N.J. (2019) Fan-surface evidence for debris-flow avulsion controls and probabilities, Saline Valley, California. Journal Geophysical Research Earth Surface 124: 1118-1138.

Guthrie, R.H., Friele, P., Allstadt, K., Roberts, N., Evans, S. G., Delaney, K.B., Roche, D., Clague, J. J., & Jakob, M. (2012). The 6 August 2010 Mount Meager rock slide-debris flow, Coast Mountains, British Columbia: characteristics, dynamics, and implications for hazard and risk assessment. *Natural Hazards Earth System Sciences, 12*, 1277–1294. https://doi.org/10.5194/nhess-12-1277-2012

Haider, W., Knowler, D., Trenholm, R., Moore, J., Bradshaw, P., & Lertzman, K. (2019) Climate change, increasing forest fire incidence, and the value of visibility: evidence from British Columbia, Canada. Canadian Journal of Forest Research 49: 1242-1255.

Holm, K., Jakob, M., and Scordo, S. (2016). An inventory and risk-based prioritization of steep creek fans in Alberta. 3rd European Conference on Flood Risk Management: Innovation, Implementation, Integration.

Holmgren, P. (1994). Multiple flow direction algorithms for runoff modelling in grid-based elevation models: an empirical evaluation. Hydrological Processes, 8, 327-334.

Horton, P., Jaboyedoff, M., & Bardou, E. (2008). Debris-flow susceptibility mapping at a regional scale. In: Proceedings of the 4th Canadian Conference on Geohazards, edited by: Locat, J., Perret, D., Turmel, D., Demers, D., and Leroueil, S., Qu´ebec, Canada, 20-24 May 2008, 339–406.

Horton, P., Jaboyedoff, M., Rudaz, B., & Zimmermann, M. (2013). Flow-R, a model for susceptibility mapping of debris flows and other gravitational hazards at regional scale. *Natural Hazards and Earth System Sciences, 13*, 869-885. https://doi.org/10.5194/nhess-13-869-2013

Hungr, O., Leroueil, S., & Picarelli, L. (2014). Varnes classification of landslide types, an update. *Landslides*, 11, 167-194.

Iverson, R.M. (2014). Debris flows: behaviour and hazard assessment. *Geology Today, 30(1)*, 15-20. **https://doi.org/10.1111/gto.12037**

Jakob, M., & Jordan, P. (2001). Design flood estimates in mountain streams – the need for a geomorphic approach. *Canadian Journal of Civil Engineering, 28*, 425-239. https://doi.org/10.1139/l01-010.

Jakob, M., Stein, D., & Ulmi, M. (2012). Vulnerability of buildings to debris-flow impact. *Natural Hazards, 60(2)*, 241-261.

Jakob, M., Clague, J., & Church, M. (2016). Rare and dangerous: recognizing extra-ordinary events in stream channels. *Canadian Water Resources Journal*. 41: 161-173.

Jakob, M., Moase, E., McDougall, S., Friele, P., Lau, C-A., & Bale, S. (2020). Regional debris-flow frequency-magnitude curves. Submitted to *Earth Surface Processes and Landforms*.

Jakob, M., & Owen, T. (2021). Projected effects of climate change on shallow landslides, North Shore Mountains, Vancouver, Canada. *Geomorphology 392*; Paper 107921.

Jakob, M. (2022). Landslides in a changing climate. In Davies, T., Rosser, N., Shroder, J.E. (eds.) *Landslide Hazards, Risks, and Disasters*. Elsevier. pp. 505-579.

Kellerhals, R., & Church, M. (1990). Hazard management on fans, with examples from British Columbia. In: Rachocki, A.H. & Church, M. (Eds.), *Alluvial fans: a field approach* (pp. 335-354). John Wiley & Sons, Chichester, UK.

Lau, C.A. (2017). *Channel scour on temperate alluvial fans in British Columbia* (Master's thesis). Simon Fraser University, Burnaby, British Columbia. Retrieved from http://summit.sfu.ca/system/files/iritems1/17564/etd10198_CLau.pdf

Major, J., Pierson, T., & Scott, K. (2005). Debris flows at Mount St. Helens, Washington, USA. In M. Jakob, O. Hungr (Eds), *Debris-flow Hazards and Related Phenomena* (pp. 685-731). Springer, Berlin Heidelberg.

Montgomery, C.W. (1990). *Physical Geology, 2nd edition*. WCB Publishers, Dubuque, IA, USA.

Montgomery, D.R., & Buffington, J.M. (1997). Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin, 109*, 596-611.

Natural Resources Canada (NRCan). (2016, January 25). National hydro network [GIS data]. Retrieved from http://open.canada.ca/data/en/dataset/a4b190fe-e090-4e6d-881e-b87956c07977.

Prein, A.F., Rasmussen, R.M., Ikeda, K., Liu, C., Clark, M.P., & Holland, G.J. (2017). The future intensification of hourly precipitation extremes. *Nature Climate Change, 7*, 48-52.

Schumm, S.A. (1977). *The fluvial system*. Wiley, New York, 338 p.

Strahler, A.N. (1952). Hypsometric (area-altitude) analysis of erosional topography. *Bulletin Geological Society of America*, 63, 1117-1142.

Sturzenegger, M., Holm, K., Lau, C-A., & Jakob, M. (2021). Debris-flow and debris-flood susceptibility mapping for geohazard risk prioritization. *Environmental and Engineering Geoscience* 27 (2): 179-194.

Utzig, G., Ag., P., Boulanger, J., Bio, R.P., & Holt, R.F. (2011). Climate change and area burned: Projections for the West Kootenays. Unpublished Report #4 from the *West*

Kootenay Climate Vulnerability and Resilience Project. Retrieved from www.kootenayresilience.org

van Dijk, M., Kleihans, M.G., & Postma, G. (2009). Autocyclic behaviour of fan deltas: an analogue experimental study. *Sedimentology,* 56(5), 1569-1589. https://doi.org/10.1111/j.1365-3091.2008.01047.x

van Dijk, M., Kleihans, M.G., Postma, G., & Kraal, E. (2012). Contrasting morphodynamics in alluvial fans and fan deltas: effects of the downstream boundary. *Sedimentology, 59(7)*, 2125-2145. https://doi.org/10.1111/j.1365-3091.2012.01337.x

Zubrycky, S., Mitchell, A., McDougall, S., Strouth, A., Clague, J.J., & Menounos, B. (2021). Exploring new methods to analyze spatial impact distributions on debris-flow fans using data from south-western British Columbia. Earth Surface Processes and Landforms 46: 2395-2413.

APPENDIX C
STEEP CREEK INVENTORY

Table C-1 Steep Creek Fan Inventory

Creek Name	Dominant Geohazard Process Type	Basin Type	Watershed Area (km^2)	Basin Activity	Fan Activity	Avulsion Evidence	Channel Confinement	Outbreak Flood Susceptibility	Hazard Likelihood Rating	Climate Change Adjusted Likelihood Rating	Impact Likelihood Rating	Geohazard Rating	Climate Change Adjusted Geohazard Rating	Estimated 200-Year Event Sediment Volume (m^3)	Estimated 200-Year Event Sediment Volume Climate Change Range (m^3)
Clegg Creek	Debris Flow	Supply Unlimited	0.97	High	Moderate	Poor	Moderate	Moderate	High	High	Moderate	High	High	6,500	7,800 - 9,800
Newman	Debris Flow	Supply Unlimited	2.00	Moderate	Moderate	Poor	High	Low	Moderate	High	Low	Low	Moderate	13,400	16,100 - 20,100
Montizambert Creek	Debris Flow	Supply Unlimited	3.93	Low	Low	Poor	Moderate	Moderate	Low	Low	Moderate	Low	Low	26,400	31,700 - 39,600
M/Yahoo Creek	Debris Flow	Supply Unlimited	3.52	Moderate	Moderate	Very Poor	High	Moderate	Moderate	High	Moderate	Moderate	High	23,600	28,300 - 35,400
Lone Tree Creek	Debris Flow	Supply Unlimited	1.66	Low	Moderate	Very Poor	Moderate	Moderate	Low	Moderate	Moderate	Low	Moderate	11,200	13,400 - 16,800
Turpin Creek	Debris Flow	Supply Limited	0.48	Low	Low	Poor	Low	Low	Low	Low	Moderate	Low	Low	3,200	3,800 - 4,800
Charles Creek	Debris Flow	Supply Unlimited	1.79	Very High	Very High	Poor	High	Moderate	Very High	Very High	Low	High	High	12,000	14,400 - 18,000
Unnamed Creek 31887	Debris Flow	Supply Unlimited	1.70	Moderate	Moderate	Poor	Low	Moderate	Moderate	High	Moderate	Moderate	High	11,400	13,700 - 17,100
Forestry Creek	Debris Flood	Supply Unlimited	12.25	High	Low	Poor	Low	Low	Moderate	High	Moderate	Moderate	High	82,200	98,600 - 123,300
Unnamed Creek 31888	Debris Flow	Supply Limited	0.76	High	High	High	Low	Low	High	High	Moderate	High	High	5,100	6,100-7,700
Unnamed Creek 31889	Debris Flow	Supply Limited	0.60	Moderate	High	Poor	Low	Low	High	Very High	Moderate	High	High	4,000	4,800 - 6,000
Unnamed Creek 31890	Debris Flow	Supply Limited	0.81	High	High	Poor	Low	Moderate	Moderate	High	Low	Low	Moderate	5,500	6,600 - 8,300
Unnamed Creek 31891	Debris Flow	Supply Unlimited	1.93	Moderate	Moderate	Poor	Low	Moderate	Very Low	Very Low	Low	Very Low	Very Low	12,900	15,500 - 19,400
Unnamed Creek 31892	Debris Flood	Supply Limited	0.35	Very Low	Very Low	Very Poor	Low	Very Low	Low	Moderate	Moderate	Low	Moderate	2,400	2,900 - 3,600
Unnamed Creek 31893	Debris Flow	Supply Limited	0.38	Moderate	Low	Poor	Low	Low	Moderate	High	Very High	High	Very High	2,500	3,000 - 3,800
Unnamed Creek 31894	Debris Flow	Supply Unlimited	1.50	Moderate	Low	Low	Low	Low	High	High	Moderate	High	High	10,000	12,000-15,000
Unnamed Creek 31895	Debris Flow	Suply Limited	0.50	Moderate	Low	Moderate	Low	Low	Moderate	High	Low	Low	Moderate	3,400	4,100-5,100
Unnamed Creek 31896	Debris Flow	Suply Limited	0.48	Moderate	Moderate	Moderate	Low	Low	Low	Low	Moderate	Low	Low	3,200	3,800-4,800
Unnamed Creek 31897	Debris Flow	Supply Unlimited	1.45	Moderate	Low	Low	Low	Low	High	Very High	Very High	Very High	Very High	9,700	11,500-14,400
Bishop Creek	Debris Flood	Supply Unlimited	0.38	Moderate	Moderate	Strong	Low	Moderate	Low	Low	Low	Low	Low	2,500	3,000 - 3,800
Unnamed Creek 31914	Debris Flow	Supply Unlimited	2.17	High	Moderate	Poor	Moderate	Moderate	Low	Low	Moderate	Low	Low	14,600	17,500 - 21,900
Wigwam Creek	Debris Flow	Supply Unlimited	1.43	Moderate	Moderate	Poor	Moderate	Moderate	Low	Low	Moderate	Low	Low	9,600	11,500 - 14,400

Table C-1 Steep Creek Fan Inventory

Creek Name	Dominant Geohazard Process Type	Basin Type	Watershed Area (km^2)	Basin Activity	Fan Activity	Avulsion Evidence	Channel Confinement	Outbreak Flood Susceptibility	Hazard Likelihood Rating	Climate Change Adjusted Likelihood Rating	Impact Likelihood Rating	Geohazard Rating	Climate Change Adjusted Geohazard Rating	Estimated 200-Year Event Sediment Volume (m^3)	Estimated 200-Year Event Sediment Volume Climate Change Range (m^3)
Unnamed Creek 31898	Debris Flow	Supply Limited	0.29	Low	Low	Poor	Low	Low	Low	Low	Moderate	Low	Low	1,900	2,300 - 2,900
Unnamed Creek 31899	Debris Flood	Supply Unlimited	20.05	High	High	Strong	Very Low	Low	Low	Moderate	High	Moderate	High	134,500	161,400 - 201,800
Unnamed Creek 31900	Debris Flood	Supply Unlimited	1.57	Low	Low	Poor	Low	Moderate	Low	Moderate	High	Moderate	High	10,500	12,600 - 15,800
Unnamed Creek 31901	Debris Flow	Supply Limited	0.33	Low	Low	Poor	Low	Low	High	High	High	High	High	2,200	2,600 - 3,300
Unnamed Creek 31902	Debris Flow	Supply Limited	0.14	Low	Low	Poor	Low	Very Low	Moderate	High	Low	Low	Moderate	900	1,100 - 1,400
Unnamed Creek 31903	Debris Flow	Supply Limited	0.83	Low	Low	Poor	Low	Moderate	Low	Moderate	Low	Low	Low	5,600	6,700 - 8,400
Unnamed Creek 31904	Debris Flow	Supply Limited	0.86	Low	Moderate	Moderate	Low	Moderate	Low	Moderate	Moderate	Low	Moderate	5,800	7,000 - 8,700
Unnamed Creek 31905	Debris Flow	Supply Unlimited	2.62	Moderate	Low	Moderate	Low	Moderate	Moderate	High	High	High	High	17,600	21,100 - 26,400
Unnamed Creek 31906	Debris Flood	Supply Unlimited	9.10	High	Moderate	Moderate	Low	Low	Low	Moderate	Moderate	Low	Moderate	61,000	73,200 - 91,500
Unnamed Creek 31907	Debris Flow	Supply Limited	0.69	Moderate	Moderate	Poor	Moderate	Moderate	High	High	Low	Moderate	Moderate	4,600	5,500 - 6,900
Unnamed Creek 31908	Debris Flow	Supply Unlimited	1.32	Moderate	Low	Poor	Low	Moderate	Moderate	High	High	High	High	8,800	10,600 - 13,200
Unnamed Creek 31909	Debris Flow	Supply Limited	1.02	Moderate	Low	Poor	Moderate	Moderate	Very High	Very High	High	Very High	Very High	6,800	8,200 - 10,200
Unnamed Creek 31910	Debris Flow	Supply Unlimited	1.81	Moderate	Moderate	Moderate	Low	Low	Low	Low	Moderate	Low	Low	12,100	14,500 - 18,200
Unnamed Creek 31911	Debris Flow	Supply Limited	0.41	Moderate	Low	Poor	Low	Low	Moderate	High	Low	Low	Moderate	2,800	3,400 - 4,200
Unnamed Creek 31912	Debris Flow	Supply Unlimited	2.36	Moderate	High	Poor	Low	Low	Low	Low	Moderate	Low	Low	15,800	19,000 - 23,700
Unnamed Creek 31913	Debris Flow	Supply Limited	1.28	Moderate	Moderate	Moderate	Low	Low	High	High	Moderate	High	High	8,600	10,300 - 12,900
Hixon Creek	Debris Flood	Supply Unlimited	35.90	High	Very High	Very Strong	Very Low	Low	Low	Moderate	High	Moderate	High	240,800	289,000 - 361,200
Unnamed Creek 31915	Debris Flow	Supply Unlimited	2.31	Low	Low	Poor	Low	Low	Low	Low	Moderate	Low	Low	15,500	18,600 - 23,300
Unnamed Creek 31916	Debris Flow	Supply Limited	0.15	Moderate	Moderate	Poor	Low	Low	Low	Moderate	Very Low	Very Low	Low	1,000	1,200 - 1,500
Unnamed Creek 31917	Debris Flow	Supply Limited	0.49	Low	Low	Poor	Low	Moderate	Low	Low	Moderate	Low	Low	3,300	4,000 - 5,000
Unnamed Creek 31918	Debris Flow	Supply Limited	0.66	Moderate	Moderate	Low	Moderate	Low	Low	Moderate	High	Moderate	High	4,400	5,300-6,600
Unnamed Creek 31919	Debris Flow	Supply Limited	0.21	Low	Low	Low	Low	Low	Low	Moderate	High	Moderate	High	1,400	1,700-2,100

Table C-1 Steep Creek Fan Inventory

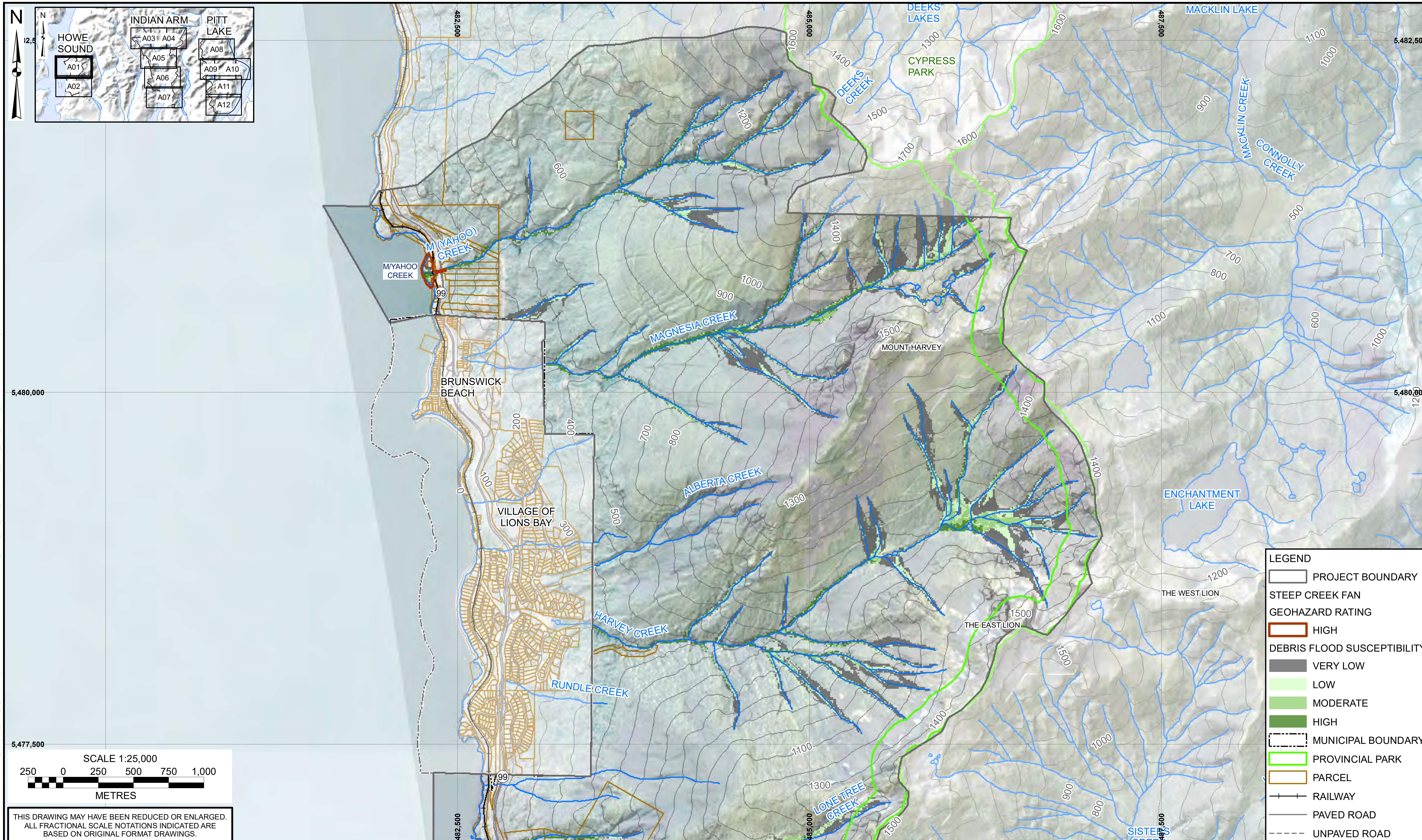
Creek Name	Dominant Geohazard Process Type	Basin Type	Watershed Area (km^2)	Basin Activity	Fan Activity	Avulsion Evidence	Channel Confinement	Outbreak Flood Susceptibility	Hazard Likelihood Rating	Climate Change Adjusted Likelihood Rating	Impact Likelihood Rating	Geohazard Rating	Climate Change Adjusted Geohazard Rating	Estimated 200-Year Event Sediment Volume (m^3)	Estimated 200-Year Event Sediment Volume Climate Change Range (m^3)
Unnamed Creek 31920	Debris Flow	Supply Unlimited	0.67	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	Low	Low	Low	4,500	5,400-6,800
Unnamed Creek 31921	Debris Flood	Supply Unlimited	16.88	Moderate	Moderate	Low	Low	Moderate	High	High	Moderate	High	High	113,000	136,000-170,000
Unnamed Creek 31922	Debris Flow	Supply Limited	0.75	Moderate	Low	Low	Low	Low	Low	Moderate	High	Moderate	High	5,000	6,000-7,500
Unnamed Creek 31923	Debris Flow	Supply Unlimited	0.85	High	Moderate	Moderate	Moderate	Moderate	High	Very High	Moderate	High	High	5,700	6,800 - 8,600
Unnamed Creek 31924	Debris Flow	Supply Limited	0.46	Low	Moderate	Moderate	Moderate	Low	High	Very High	Moderate	High	High	3,100	3,700 - 4,700
Unnamed Creek 31925	Debris Flow	Supply Limited	0.59	Low	Low	Poor	Moderate	Very Low	High	Very High	High	High	Very High	3,900	4,700 - 5,900
Unnamed Creek 31926	Debris Flow	Supply Unlimited	0.35	Low	Moderate	Poor	Very Low	Very Low	High	High	Low	Moderate	Moderate	2,400	2,900 - 3,600
Unnamed Creek 31927	Debris Flood	Supply Limited	1.25	Low	Low	Poor	Low	Low	Very High	Very High	Very High	Very High	Very High	8,400	10,100 - 12,600
Unnamed Creek 31929	Debris Flow	Supply Unlimited	0.33	Low	Moderate	Moderate	Low	Moderate	High	Very High	High	High	Very High	2,200	2,600 - 3,300
Unnamed Creek 31930	Debris Flow	Supply Limited	0.48	Low	Moderate	Moderate	Low	Moderate	Very High	Very High	Moderate	High	High	3,200	3,800 - 4,800
Unnamed Creek 31931	Debris Flow	Supply Limited	0.18	Low	Low	Poor	Very Low	Low	High	Very High	High	High	Very High	1,200	1,400 - 1,800
Unnamed Creek 31932	Debris Flow	Supply Unlimited	3.47	High	Moderate	Moderate	Low	Moderate	Low	Moderate	Moderate	Low	Moderate	23,300	28,000 - 35,000
Unnamed Creek 31933	Debris Flow	Supply Limited	0.44	Low	Moderate	Moderate	Very Low	Moderate	Moderate	High	High	High	High	3,000	3,600 - 4,500
Unnamed Creek 31934	Debris Flow	Supply Unlimited	0.33	High	High	Moderate	Very Low	Moderate	Low	Moderate	Moderate	Low	Moderate	2,200	2,600 - 3,300
Unnamed Creek 31935	Debris Flood	Supply Unlimited	6.62	High	High	Moderate	Low	Moderate	Very High	Very High	Very High	Very High	Very High	44,400	53,300 - 66,600
Unnamed Creek 31936	Debris Flow	Supply Limited	0.57	Moderate	Moderate	Moderate	Moderate	Low	High	Very High	High	High	Very High	3,800	4,600-5,700
Hanging Creek	Debris Flood	Supply Unlimited	7.09	High	High	Moderate	Low	Very Low	Low	Low	High	Moderate	Moderate	47,500	57,000 - 71,300
Unnamed Creek 31937	Debris Flow	Supply Limited	0.31	High	Moderate	Poor	Very Low	Very Low	Moderate	High	Moderate	Moderate	High	2,100	2,500 - 3,200
Unnamed Creek 31938	Debris Flow	Supply Unlimited	5.75	Very High	Very High	Very Strong	Low	Moderate	High	High	Moderate	High	High	38,600	46,300 - 57,900
Unnamed Creek 31939	Debris Flow	Supply Limited	0.95	High	High	Strong	Low	Moderate	Very High	Very High	High	Very High	Very High	6,400	7,700 - 9,600
Unnamed Creek 31940	Debris Flow	Supply Limited	0.30	Very High	Very High	Moderate	Very Low	Moderate	Very High	Very High	Moderate	High	High	2,000	2,400 - 3,000
Unnamed Creek 31941	Debris Flow	Supply Limited	0.15	Low	Low	Low	Low	Low	High	High	Moderate	High	High	1,000	1,200-1,500

Table C-1 Steep Creek Fan Inventory

Creek Name	Dominant Geohazard Process Type	Basin Type	Watershed Area (km^2)	Basin Activity	Fan Activity	Avulsion Evidence	Channel Confinement	Outbreak Flood Susceptibility	Hazard Likelihood Rating	Climate Change Adjusted Likelihood Rating	Impact Likelihood Rating	Geohazard Rating	Climate Change Adjusted Geohazard Rating	Estimated 200-Year Event Sediment Volume (m^3)	Estimated 200-Year Event Sediment Volume Climate Change Range (m^3)
Ashby Creek	Debris Flood	Supply Unlimited	2.97	High	High	Moderate	Low	High	Moderate	High	Low	Low	Moderate	19,900	23,900 - 29,900
Unnamed Creek 31942	Debris Flow	Supply Limited	0.52	Low	Moderate	Moderate	Moderate	Low	Low	Moderate	Low	Low	Low	3,500	4,200 - 5,300
Unnamed Creek 31943	Debris Flood	Supply Unlimited	3.14	Moderate	Moderate	Moderate	Low	Low	Moderate	High	Low	Low	Moderate	21,000	25,200 - 31,500
Unnamed Creek 31944	Debris Flood	Supply Unlimited	0.29	Low	Moderate	Moderate	Low	Low	High	High	High	High	High	1,900	2,300 - 2,900
Dark Creek	Debris Flood	Supply Unlimited	4.79	Very High	High	Strong	Low	High	Moderate	High	Low	Low	Moderate	32,100	38,500 - 48,200
Unnamed Creek 31946	Debris Flow	Supply Limited	0.12	High	High	Moderate	Low	Very Low	High	High	High	High	High	800	1,000 - 1,200
Unnamed Creek 31947	Debris Flow	Supply Limited	0.85	Low	Low	Moderate	Low	Moderate	Low	Moderate	Low	Low	Low	5,700	6,800 - 8,600
Unnamed Creek 31948	Debris Flow	Supply Limited	0.42	Moderate	Moderate	Moderate	Low	Moderate	Low	Moderate	Moderate	Low	Moderate	2,800	3,400 - 4,200
Unnamed Creek 31949	Debris Flow	Supply Unlimited	0.74	Moderate	High	Moderate	Low	Moderate	High	Very High	Very High	Very High	Very High	5,000	6,000 - 7,500
Unnamed Creek 31950	Debris Flow	Supply Unlimited	1.02	High	Very High	Very Strong	Low	Moderate	Low	Moderate	Moderate	Low	Moderate	6,800	8,200 - 10,200
Unnamed Creek 31951	Debris Flow	Supply Unlimited	1.10	Very High	High	Moderate	Low	Moderate	Low	Moderate	High	Moderate	High	7,400	8,900 - 11,100
Unnamed Creek 31952	Debris Flood	Supply Unlimited	1.37	Moderate	High	Moderate	Low	Low	Low	Moderate	Moderate	Low	Moderate	9,200	11,000 - 13,800
Defrauder Creek	Debris Flood	Supply Unlimited	6.03	Moderate	Moderate	Poor	Low	Low	High	High	Low	Moderate	Moderate	40,400	48,500 - 60,600
Unnamed Creek 31954	Debris Flood	Supply Unlimited	1.45	Low	Moderate	Poor	Low	Low	Moderate	High	Moderate	Moderate	High	9,800	11,800 - 14,700
Unnamed Creek 31955	Debris Flow	Supply Limited	0.32	Moderate	Moderate	Poor	Low	Very Low	Low	Low	Moderate	Low	Low	2,100	2,500 - 3,200
Unnamed Creek 31956	Debris Flow	Supply Unlimited	3.49	High	Moderate	Moderate	Low	Moderate	Moderate	High	High	High	High	23,400	28,100 - 35,100
DeBeck Creek	Debris Flood	Supply Unlimited	39.27	Moderate	Moderate	Poor	Moderate	Moderate	Moderate	High	Moderate	Moderate	High	263,400	316,100 - 395,100
Unnamed Creek 34572	Debris Flood	Supply Unlimited	3.19	High	Moderate	Moderate	Low	Moderate	Low	Moderate	Low	Low	Low	21,400	25,700 - 32,100
Unnamed Creek 34573	Debris Flow	Supply Limited	0.36	Moderate	Low	Poor	Low	Low	Moderate	High	High	High	High	2,400	2,900 - 3,600
Unnamed Creek 34575	Debris Flow	Supply Limited	0.80	Low	Moderate	Poor	Low	Low	Low	Low	Moderate	Low	Low	5,300	6,400 - 8,000

Note:
1. Watershed Area was delinated for all fans was automatically in BGCs RNT (see Appendix B) with the expection of Unamed Creek 31926, 31928 and 31931 which were manually delinated.

DRAWINGS



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

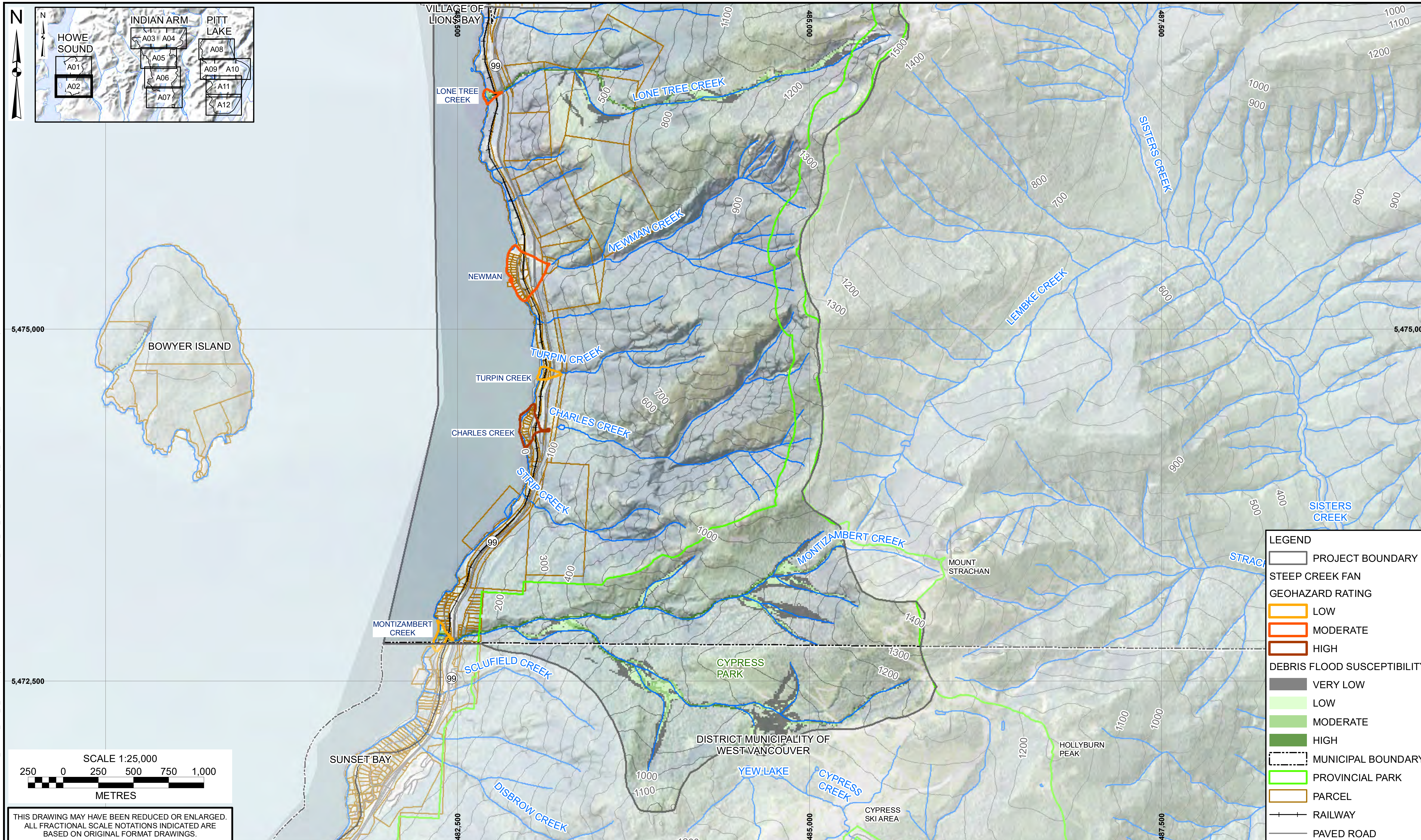
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY HOWE SOUND

PROJECT No.: 0431038

DWG No: A01

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:43 AM



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

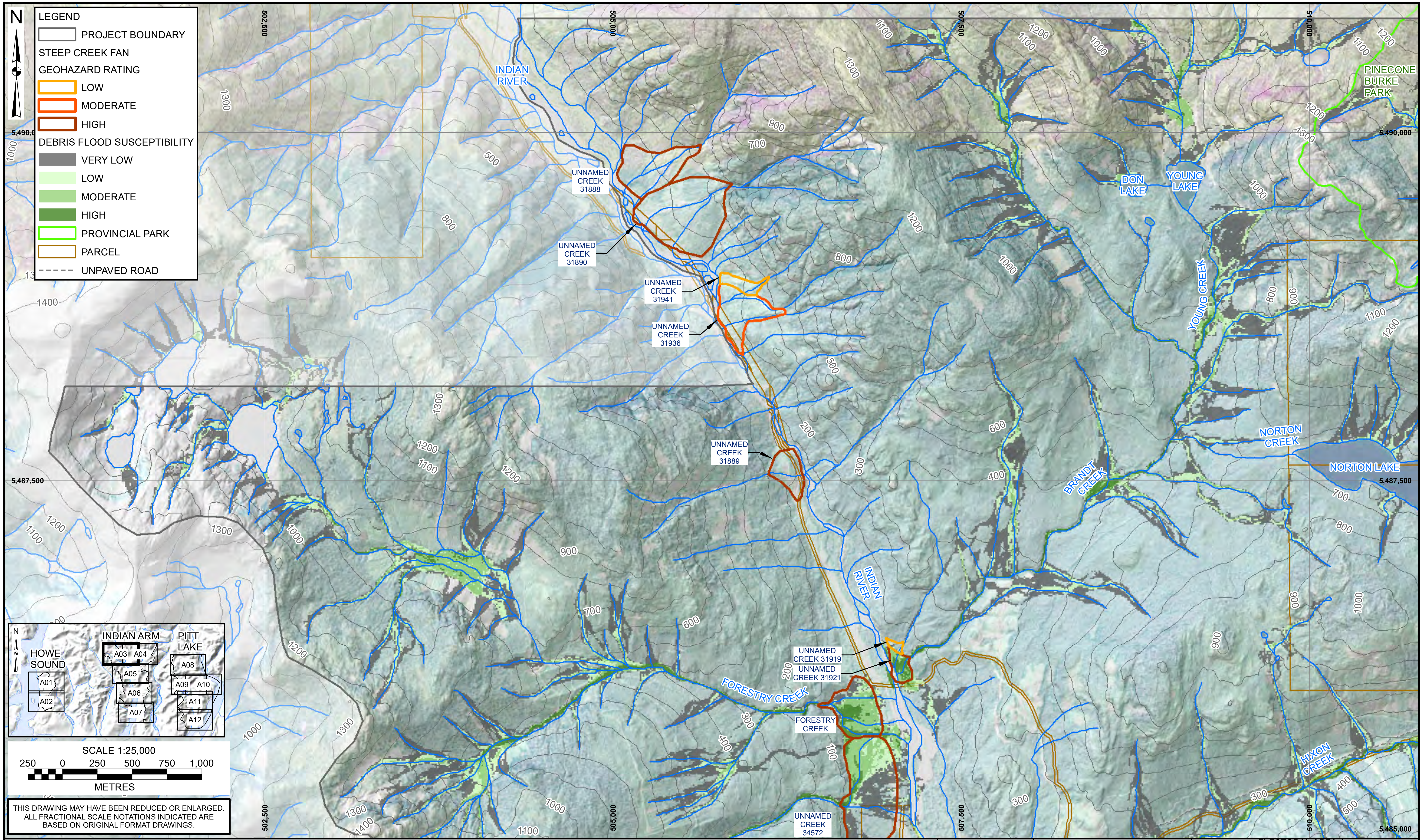
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY HOWE SOUND

PROJECT No.: 0431038

DWG No: A02

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:49 AM



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:52 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

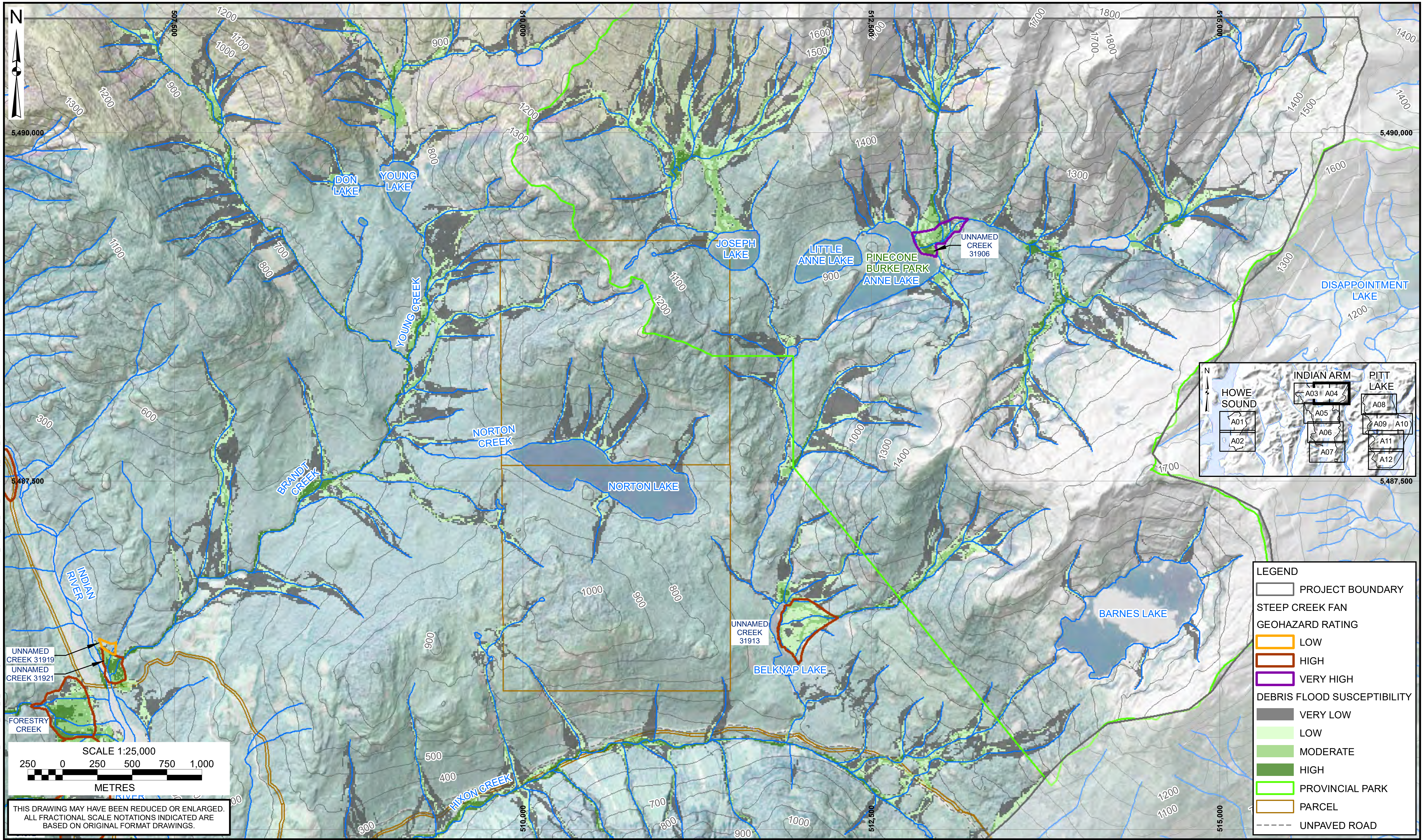
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: A03



THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

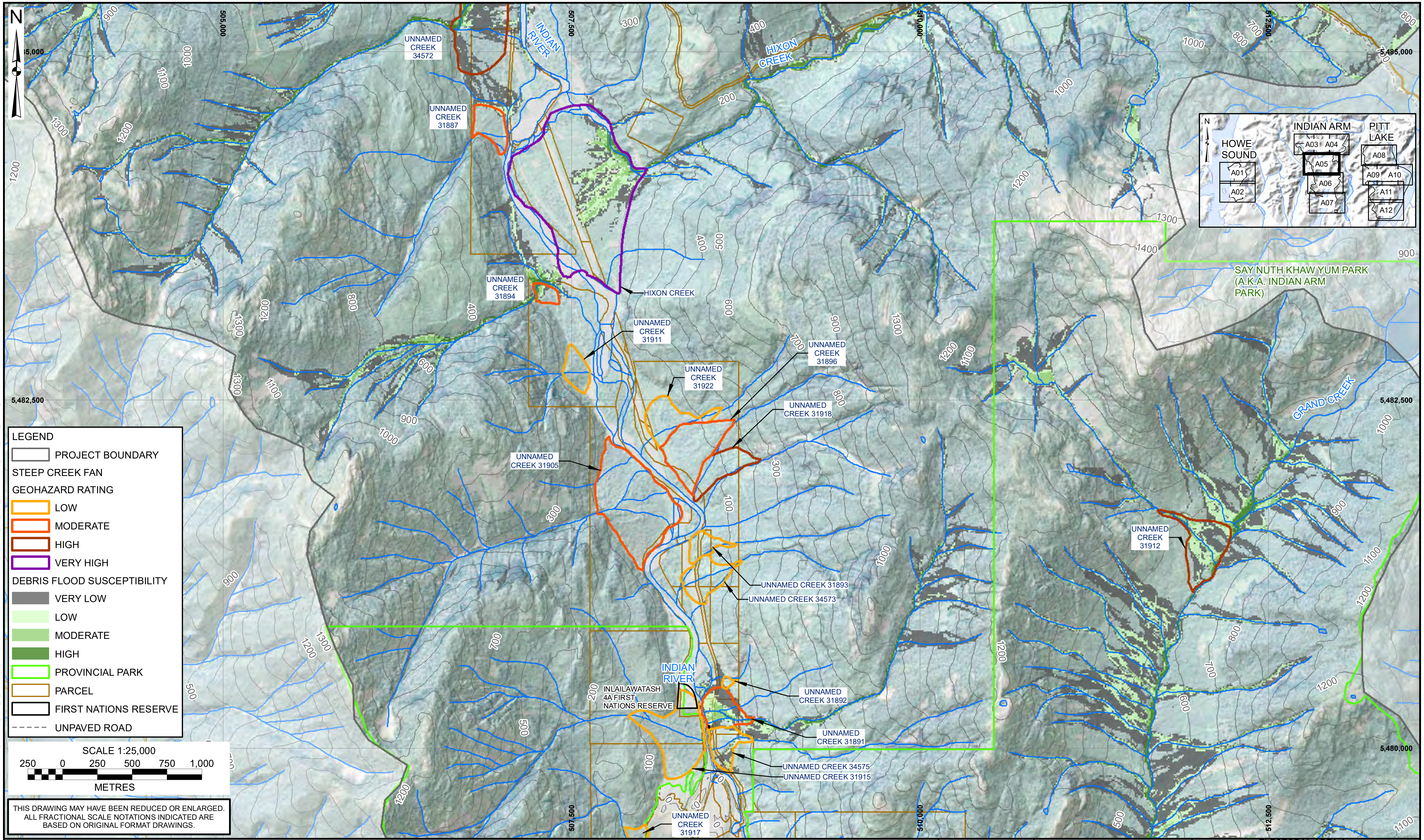
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: A04

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:55 AM



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

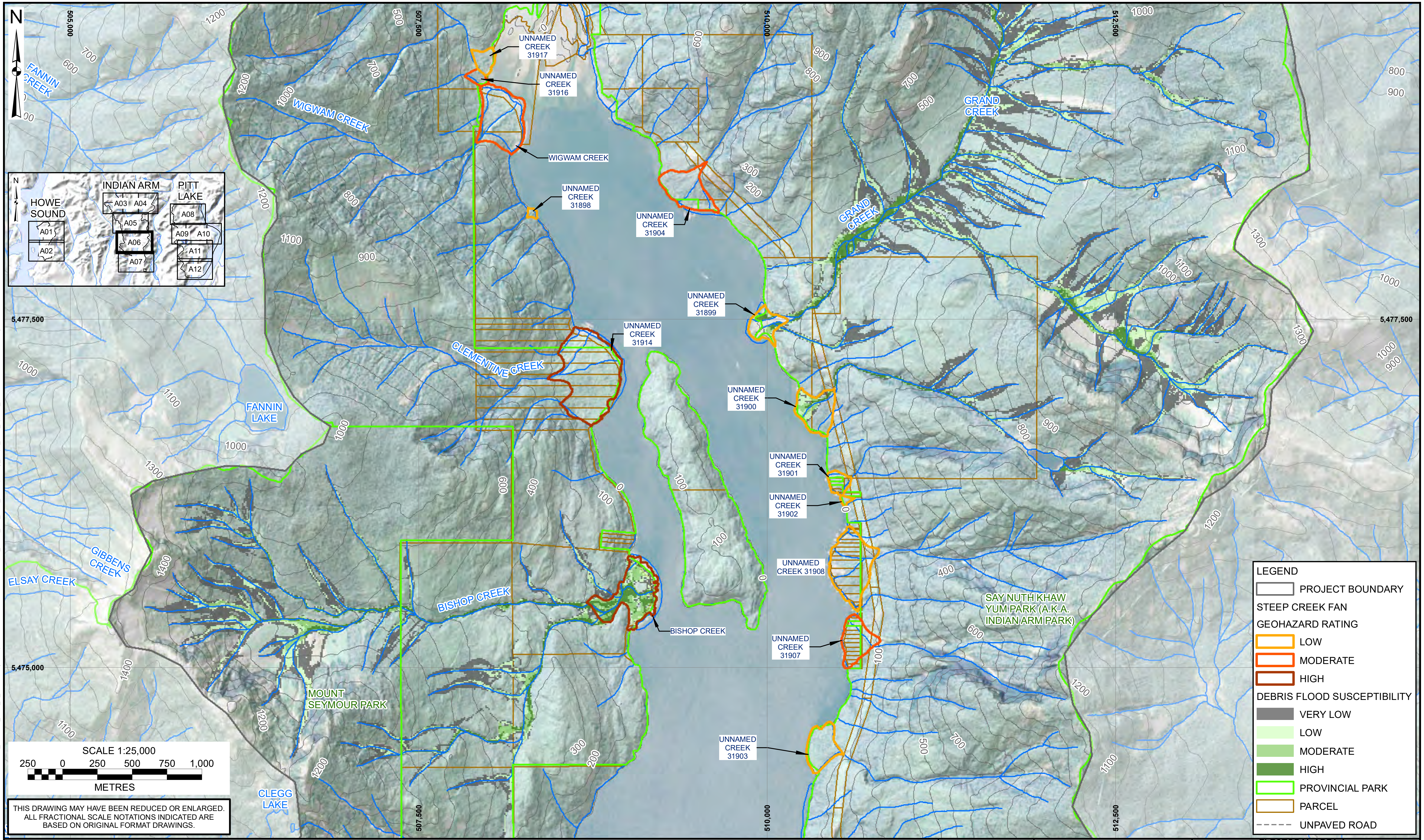
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: A05

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:58 AM



THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:58 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

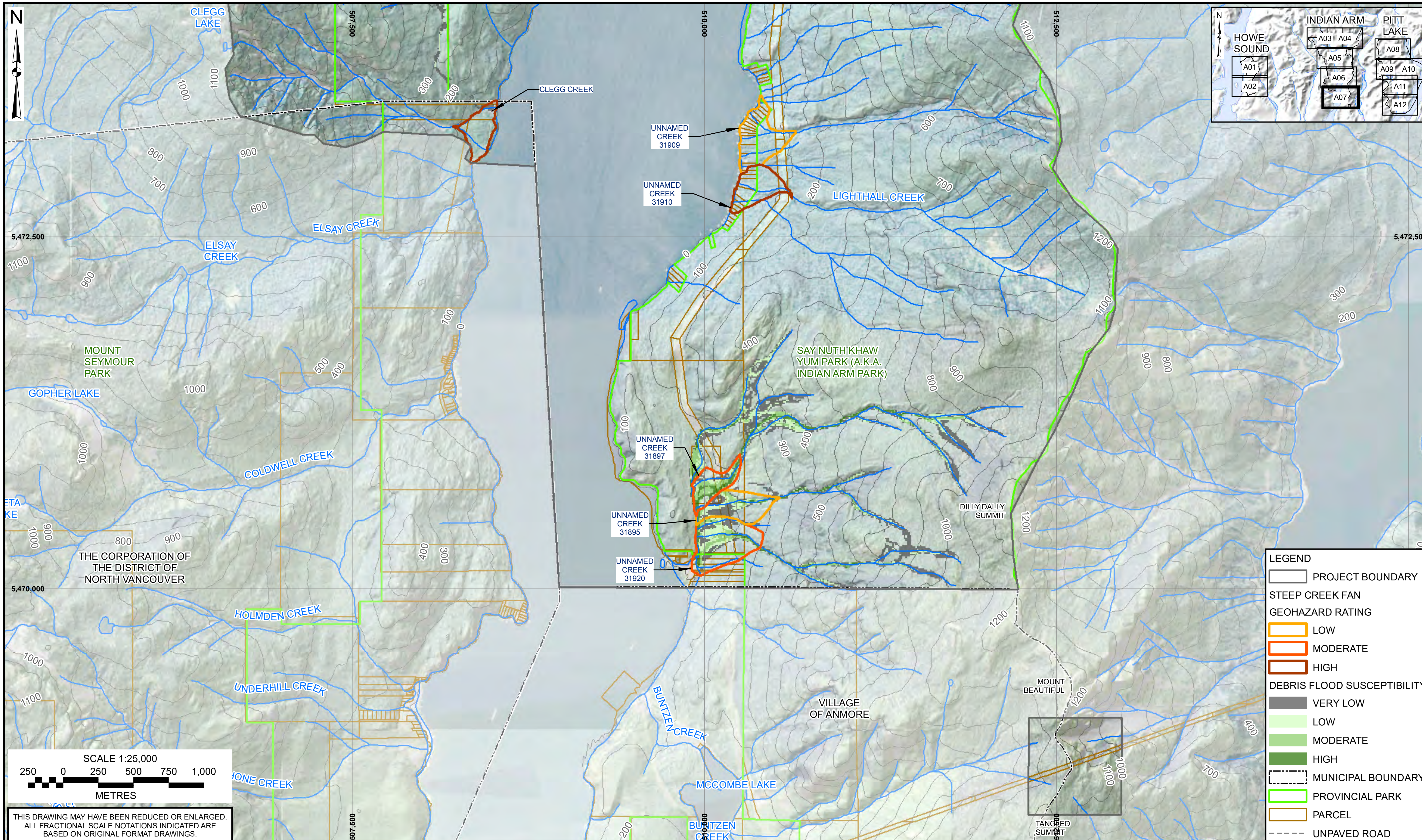
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: A06



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

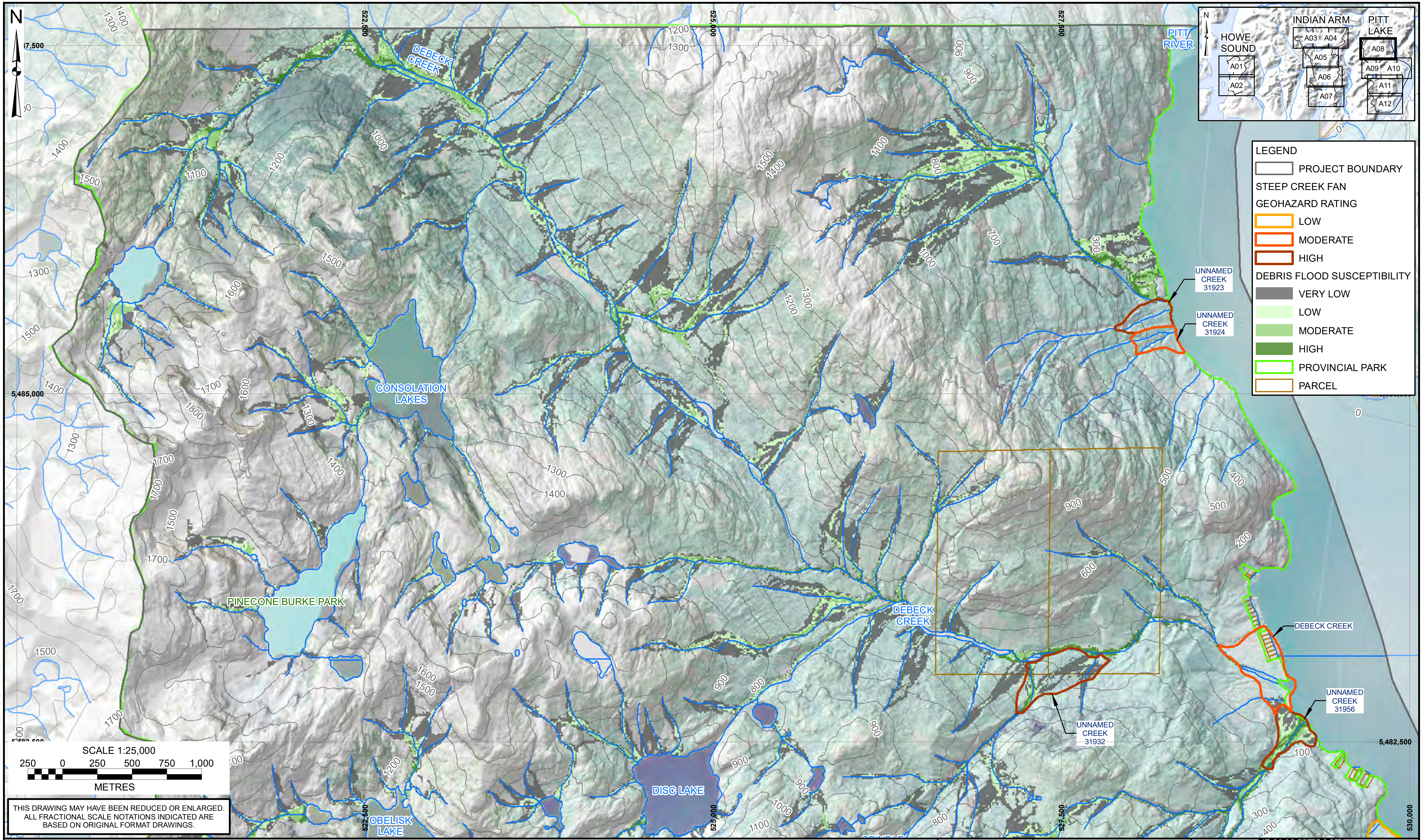
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: A07

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 12:00 PM



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:55 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

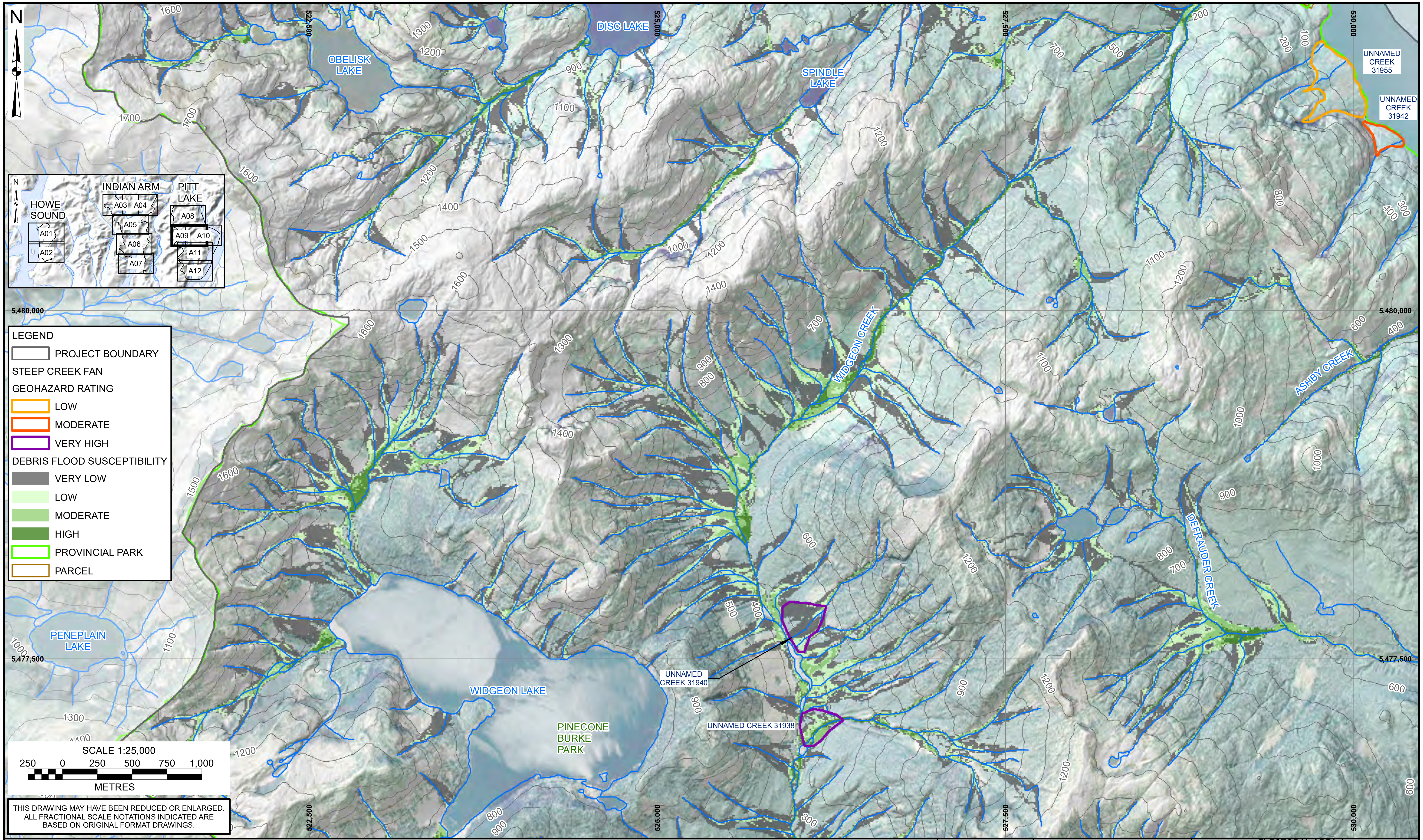
CLIENT: metro vancouver

BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY PITT LAKE

PROJECT No.:	DWG No:
0431038	A08



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

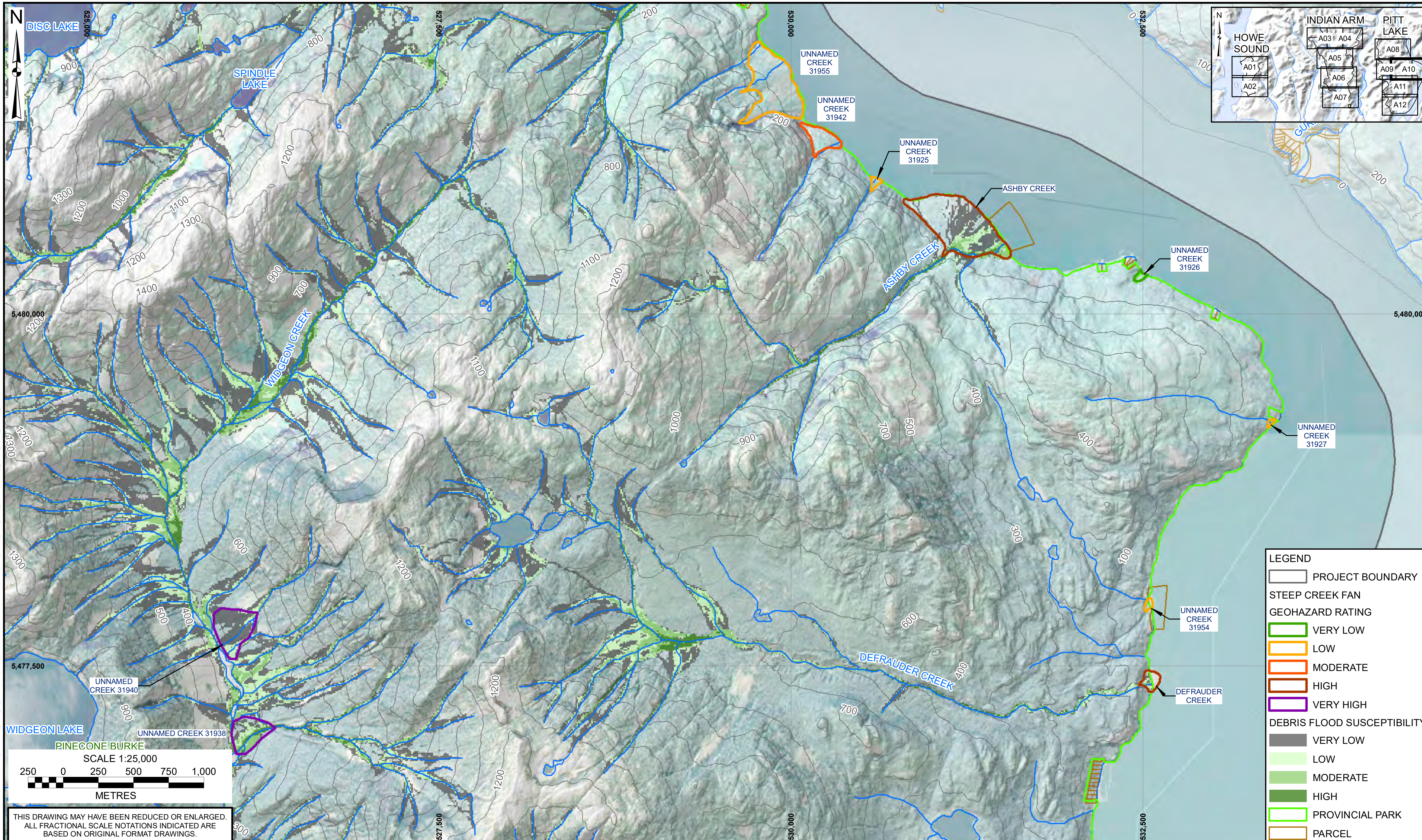
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY PITT LAKE

PROJECT No.: 0431038

DWG No: A09

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:53 AM



THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

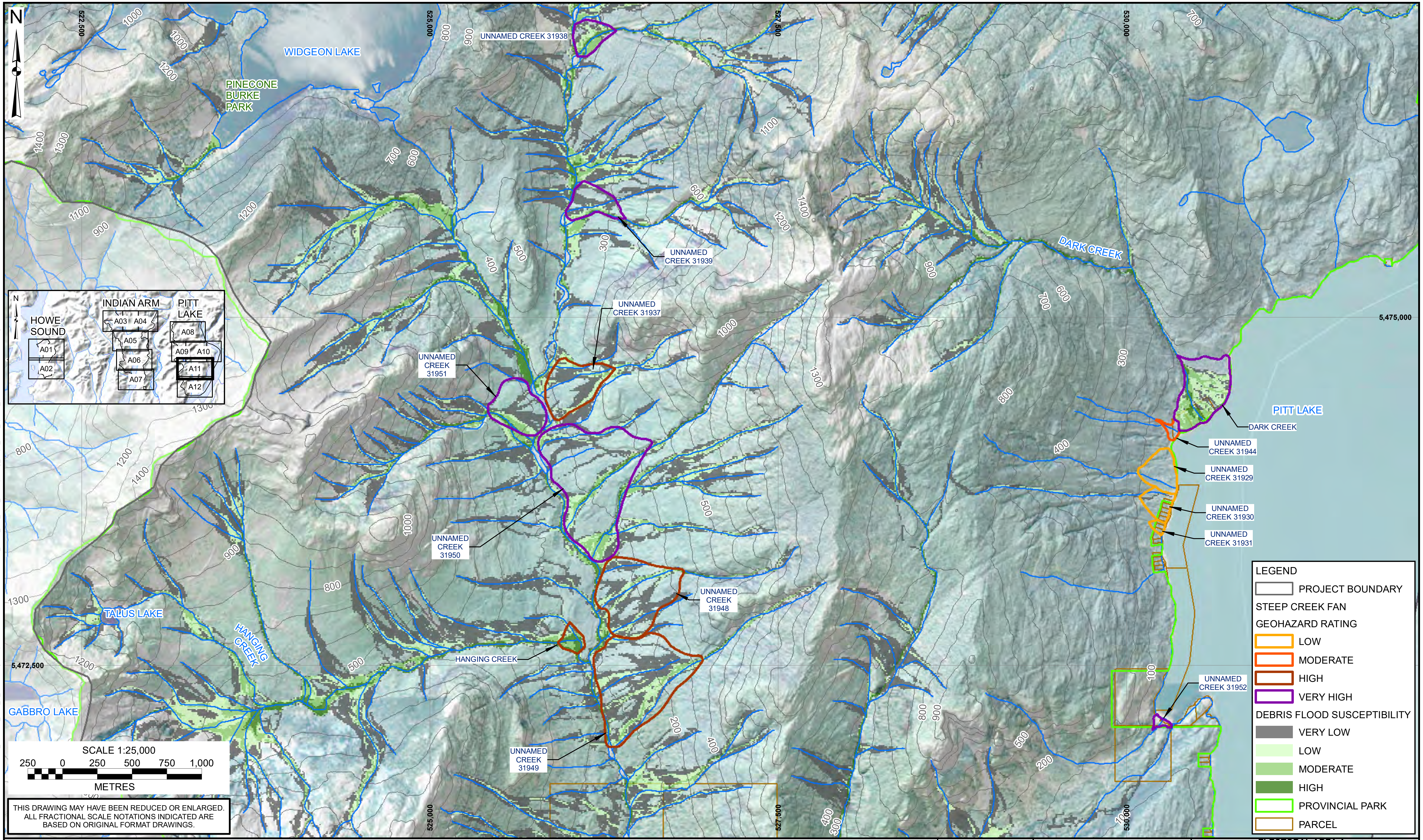
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY PITT LAKE

PROJECT No.: 0431038

DWG No: A10

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:50 AM



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

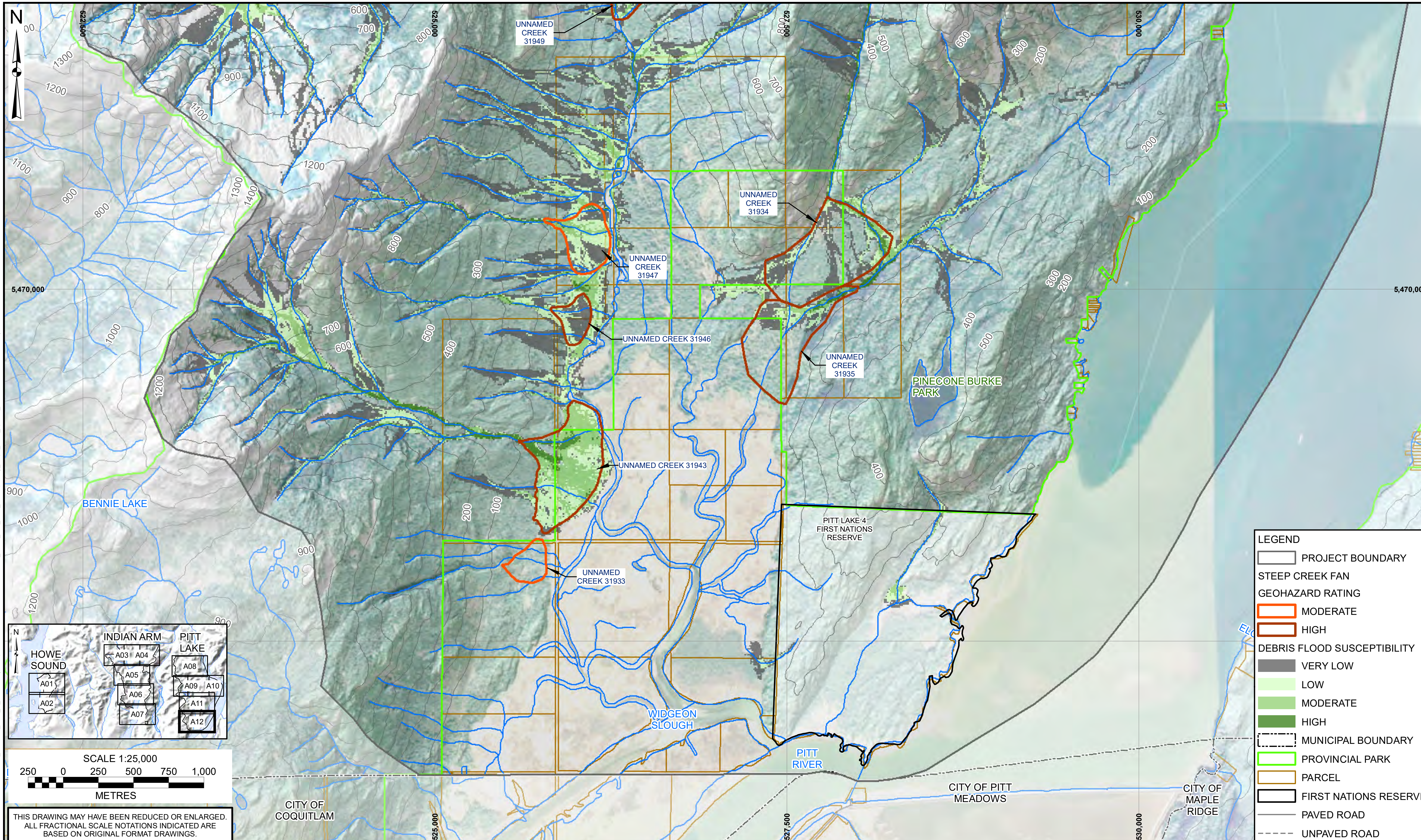
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY PITT LAKE

PROJECT No.:	DWG No:
0431038	A11

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:43 AM



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

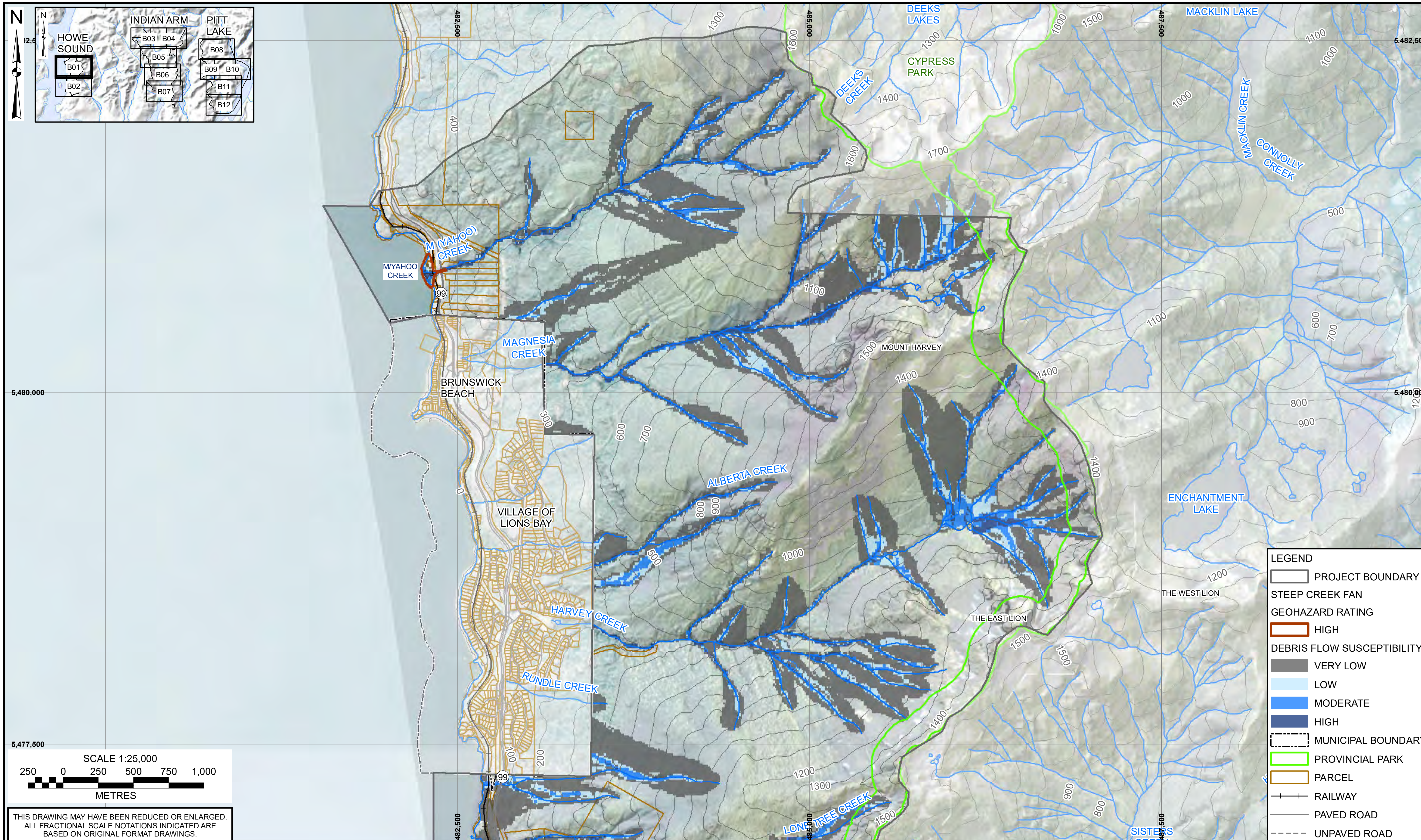
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOOD SUSCEPTIBILITY PITT LAKE

PROJECT No.:	DWG No:
0431038	A12

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: Friday, October 27, 2023 Time: 11:47 AM



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 11:48 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

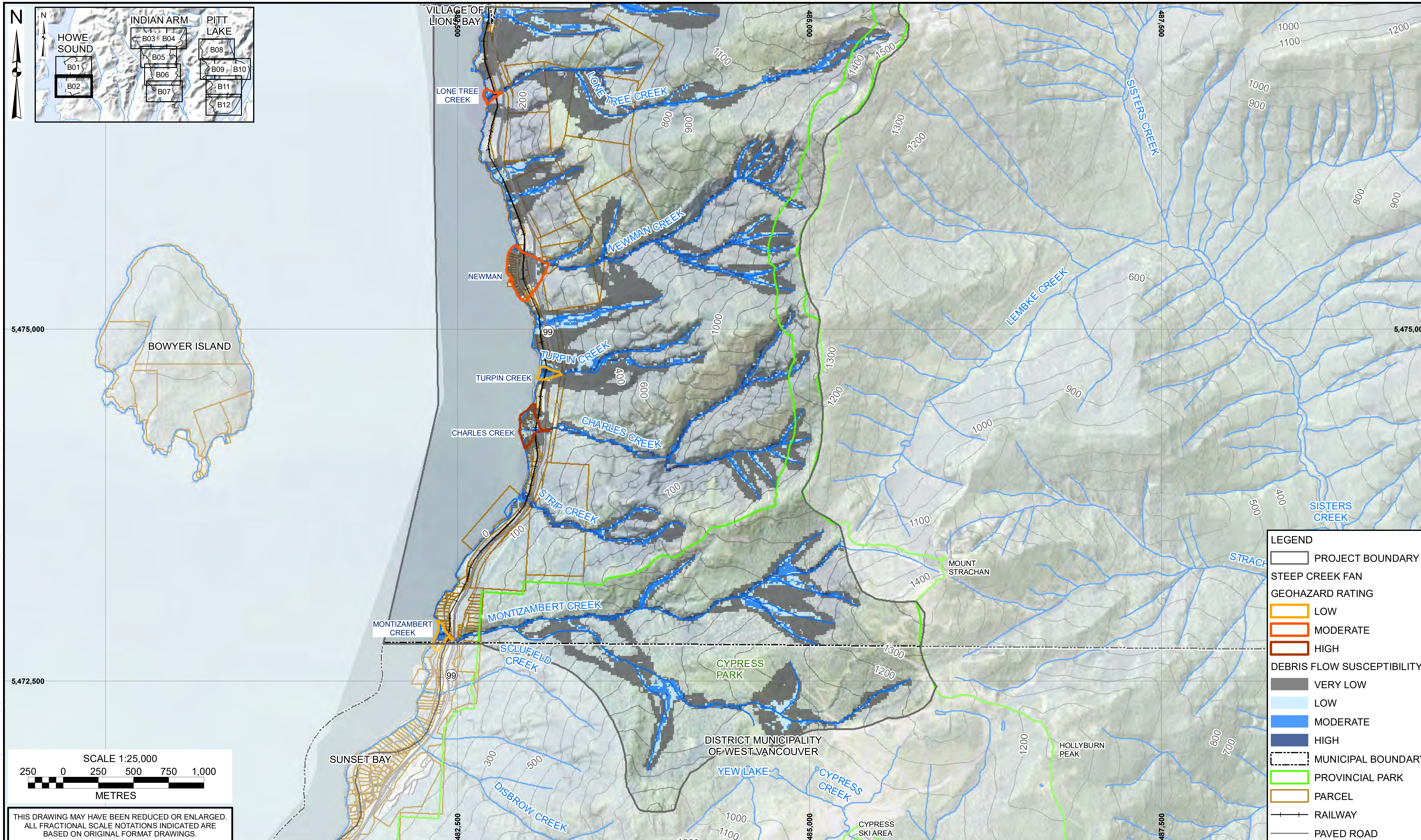
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY HOWE SOUND

PROJECT No.: 0431038

DWG No: B01



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 11:53 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

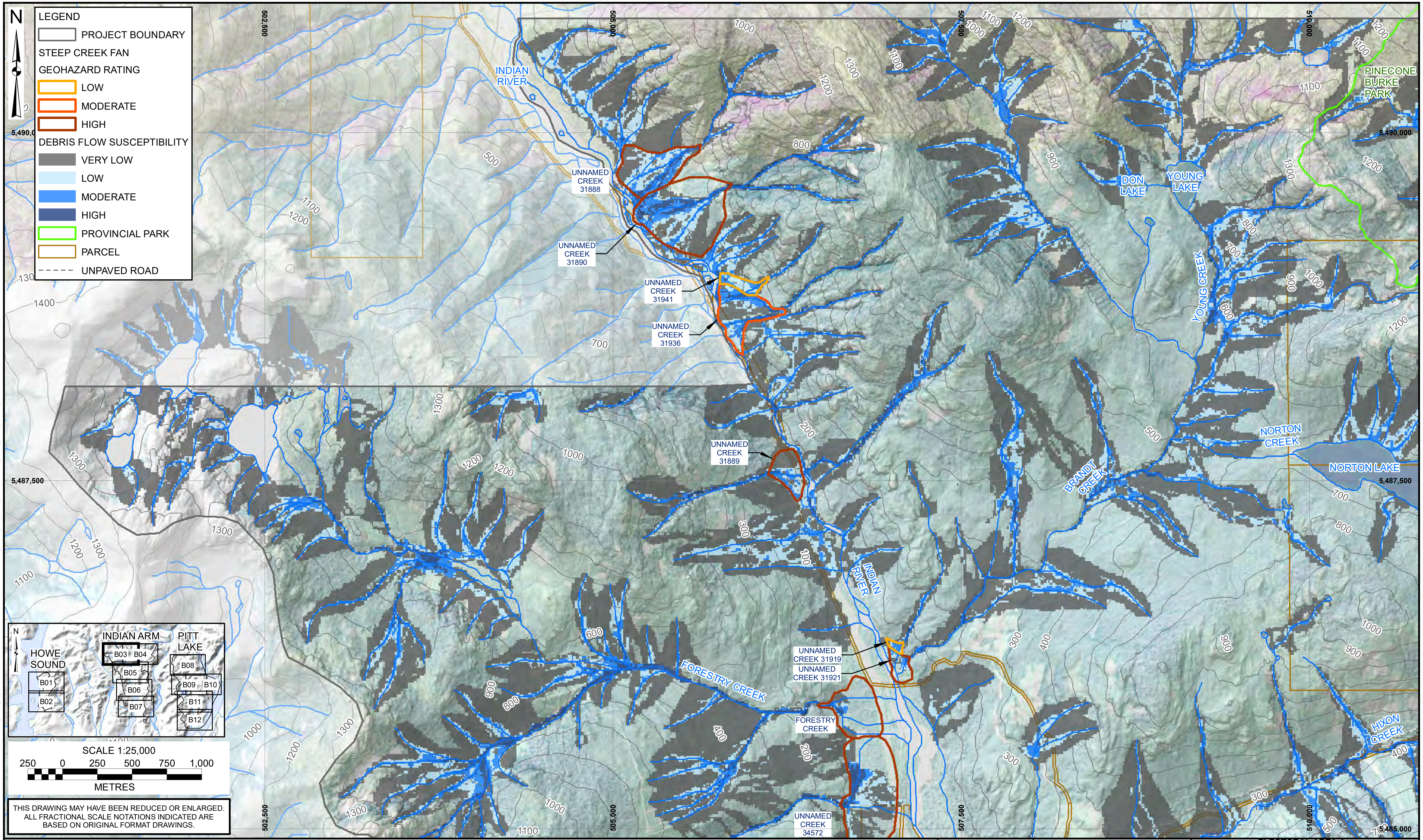
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY HOWE SOUND

PROJECT No.: 0431038

DWG No: B02



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 11:56 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

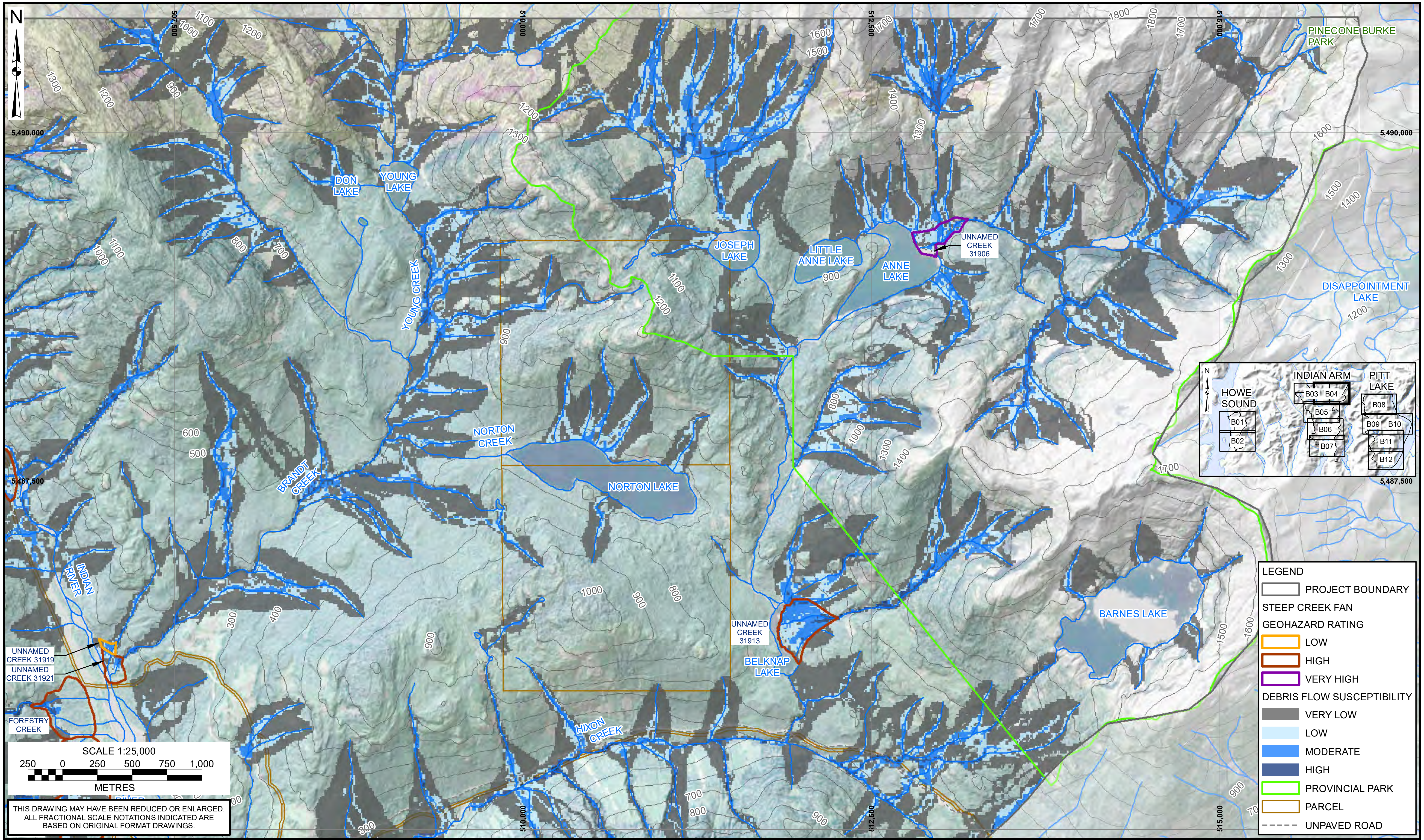
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: B03



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 11:59 AM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

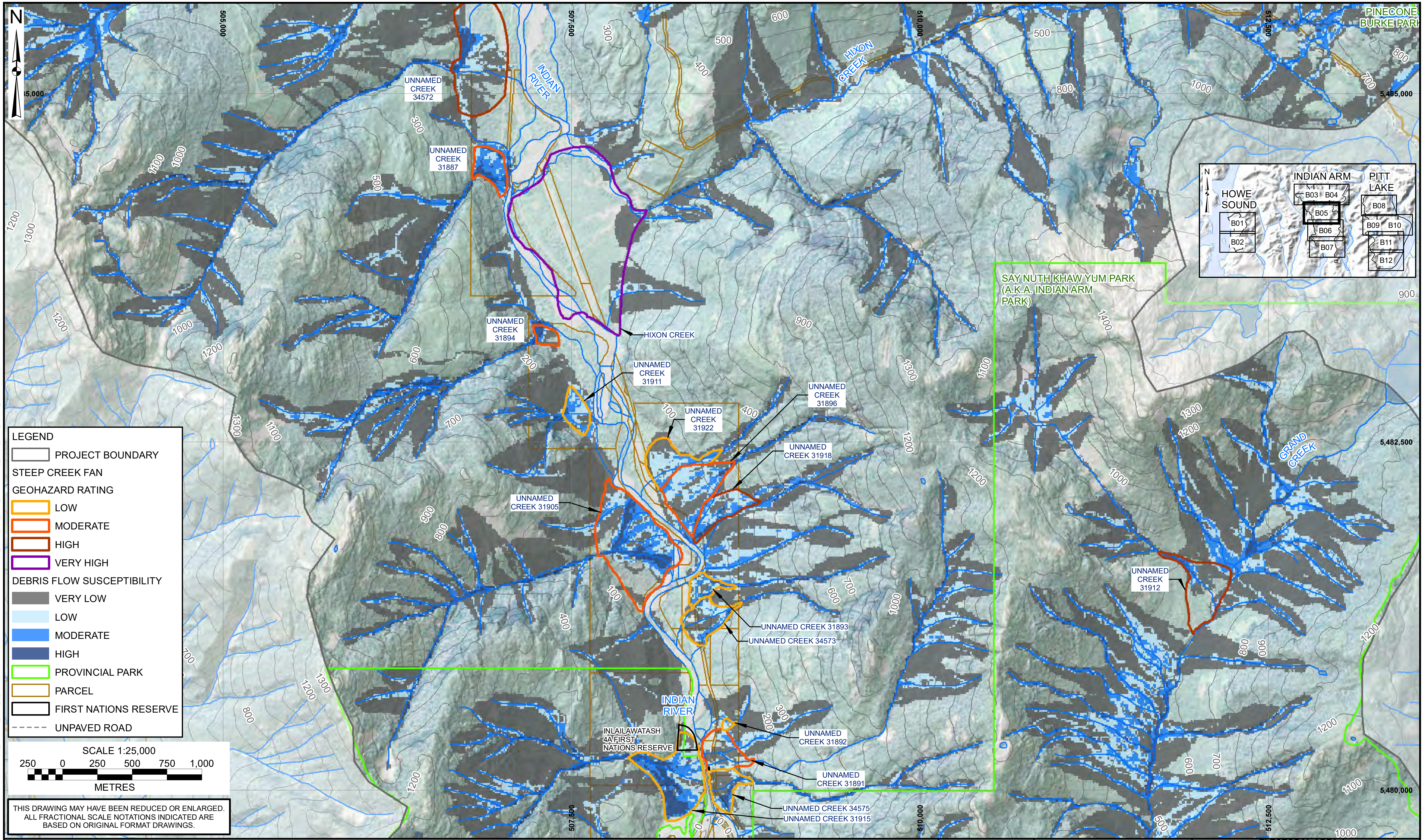
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: B04



LEGEND

PROJECT BOUNDARY

STEEP CREEK FAN

GEOHAZARD RATING

- LOW
- MODERATE
- HIGH
- VERY HIGH

DEBRIS FLOW SUSCEPTIBILITY

- VERY LOW
- LOW
- MODERATE
- HIGH

PROVINCIAL PARK

PARCEL

FIRST NATIONS RESERVE

UNPAVED ROAD

SCALE 1:25,000

250 0 250 500 750 1,000

METRES

THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 12:04 PM

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

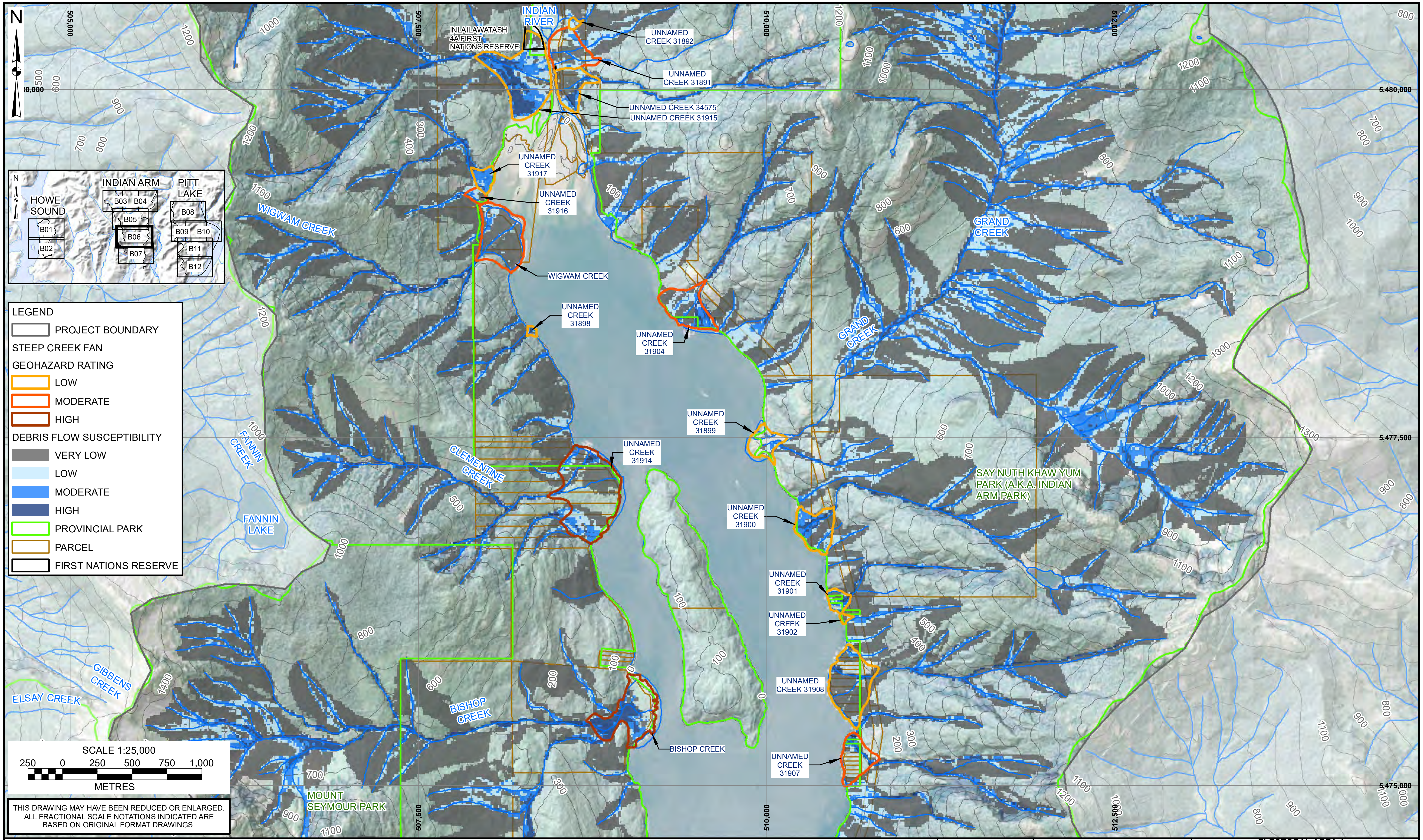
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: B05



THIS DRAWING MAY HAVE BEEN REDUCED OR ENLARGED. ALL FRACTIONAL SCALE NOTATIONS INDICATED ARE BASED ON ORIGINAL FORMAT DRAWINGS.

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

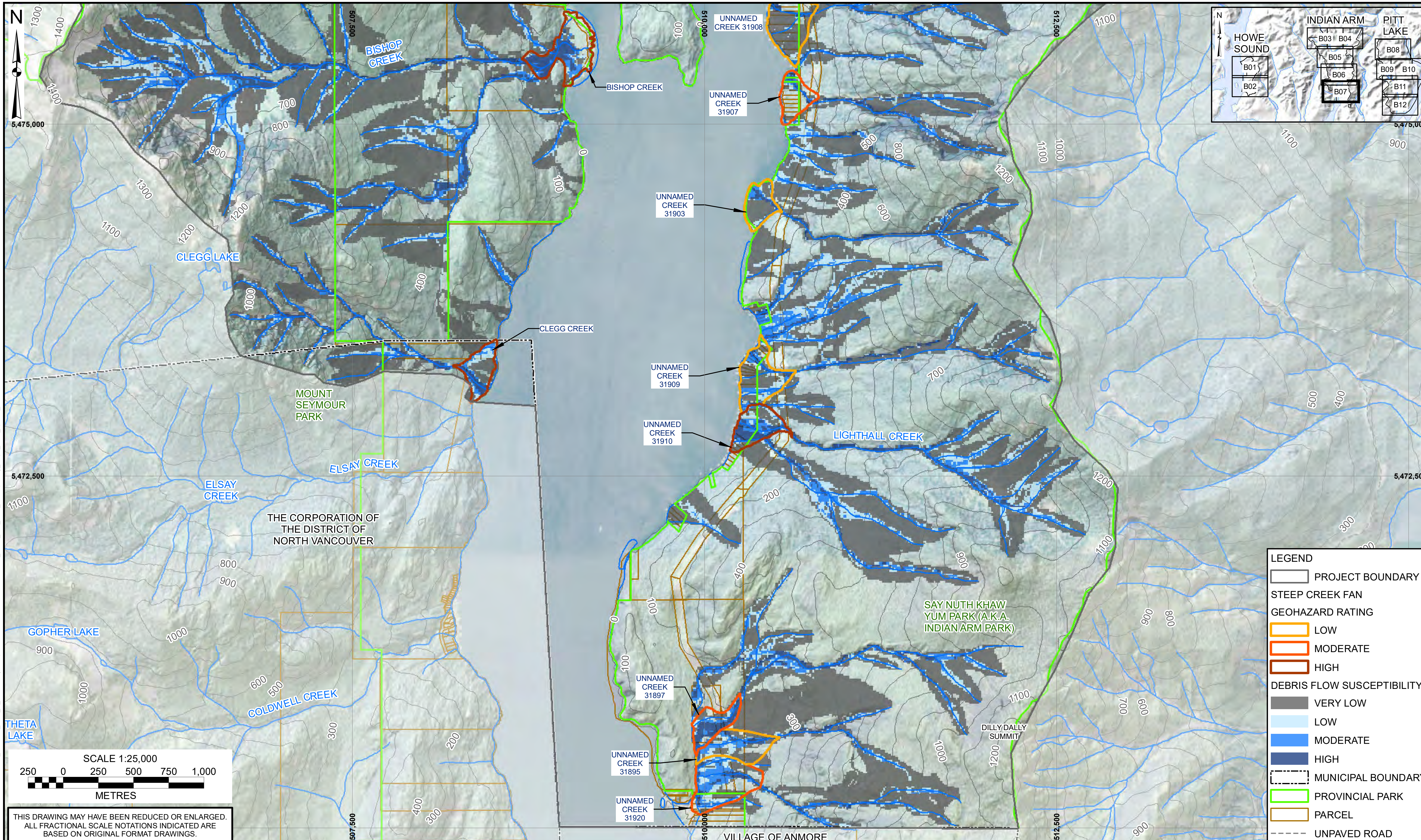
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: B06



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

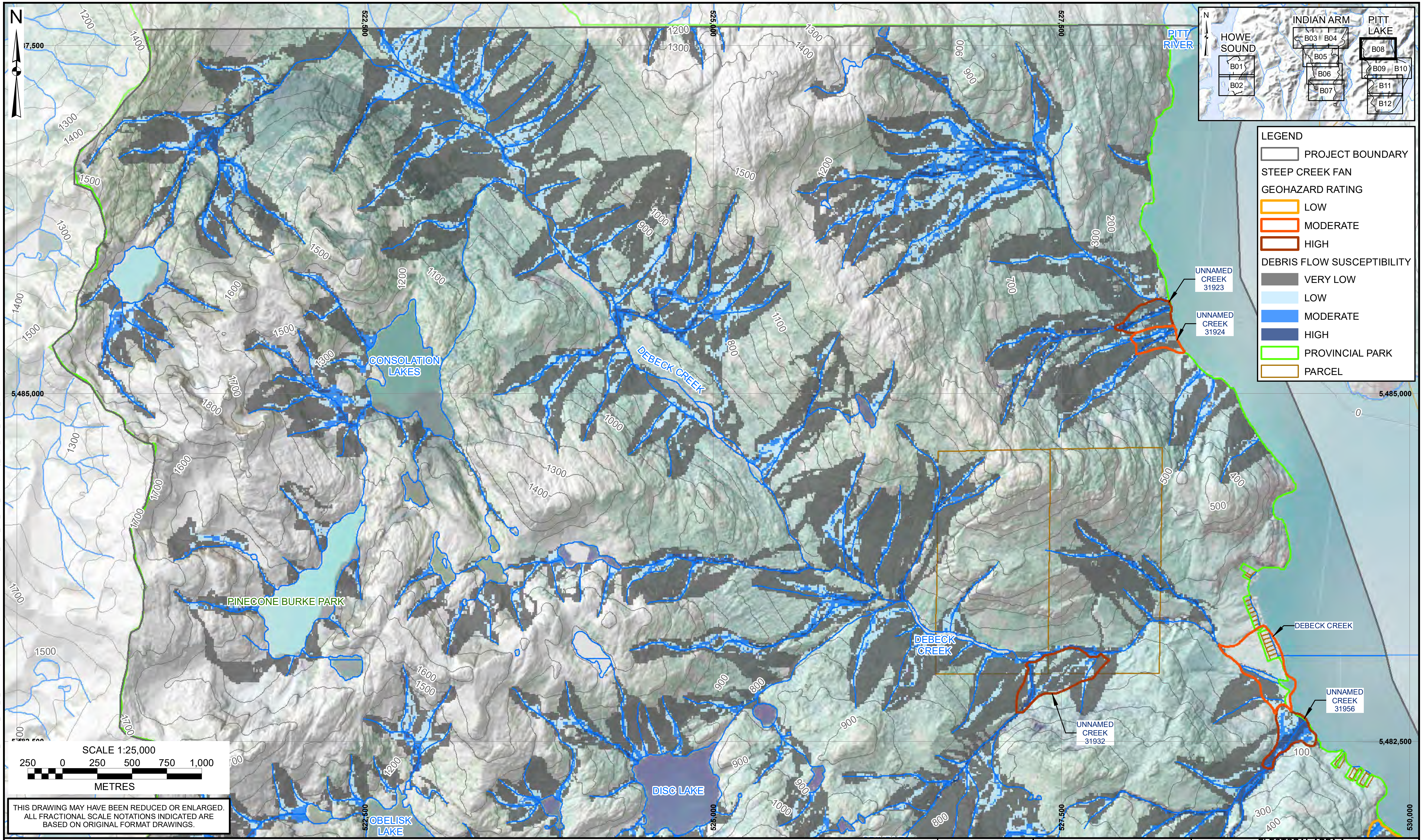
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY INDIAN ARM

PROJECT No.: 0431038

DWG No: B07

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 12:08 PM



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 12:09 PM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

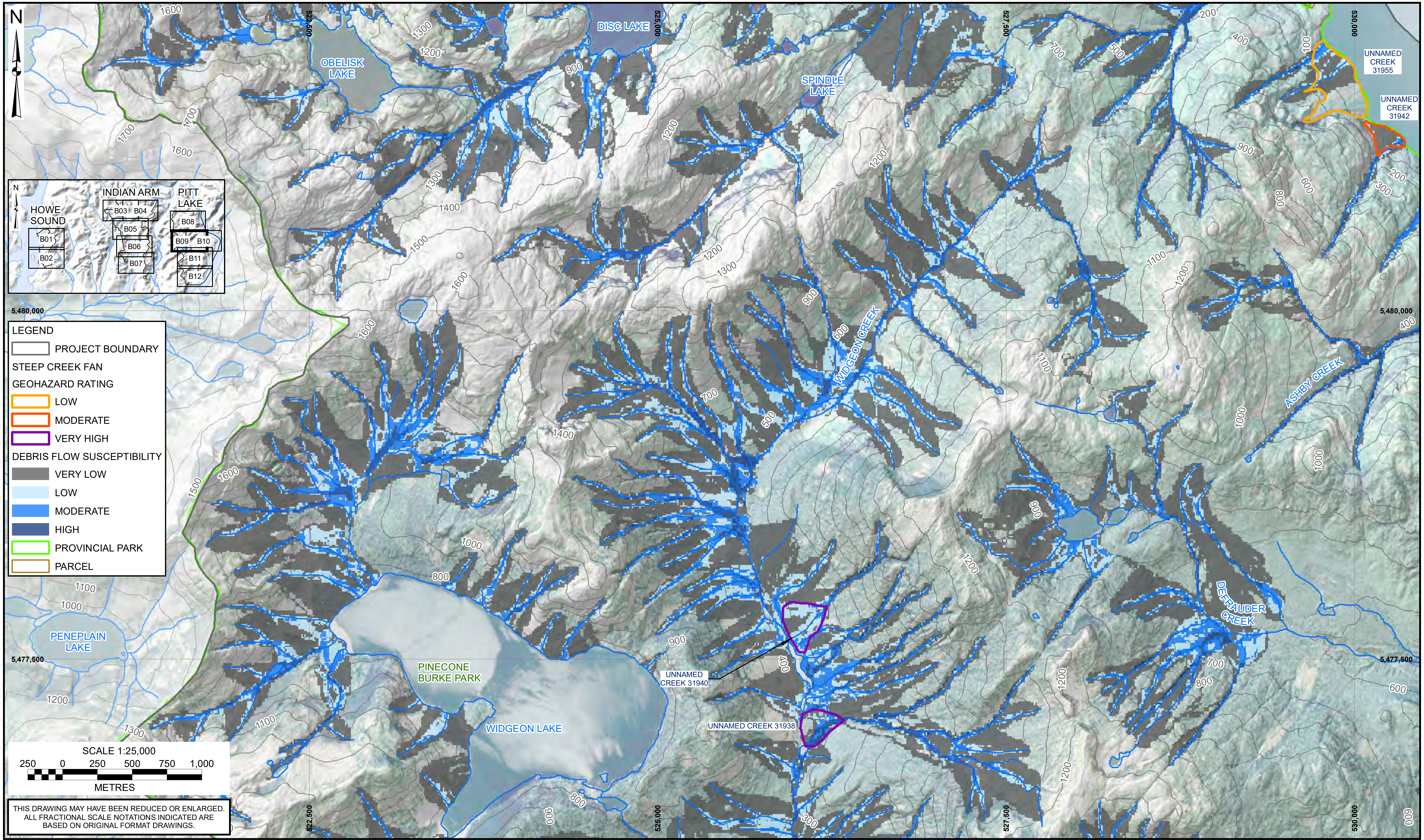
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY PITT LAKE

PROJECT No.: 0431038

DWG No: B08



X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 12:07 PM

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY PITT LAKE

PROJECT No.: 0431038

DWG No: B09

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

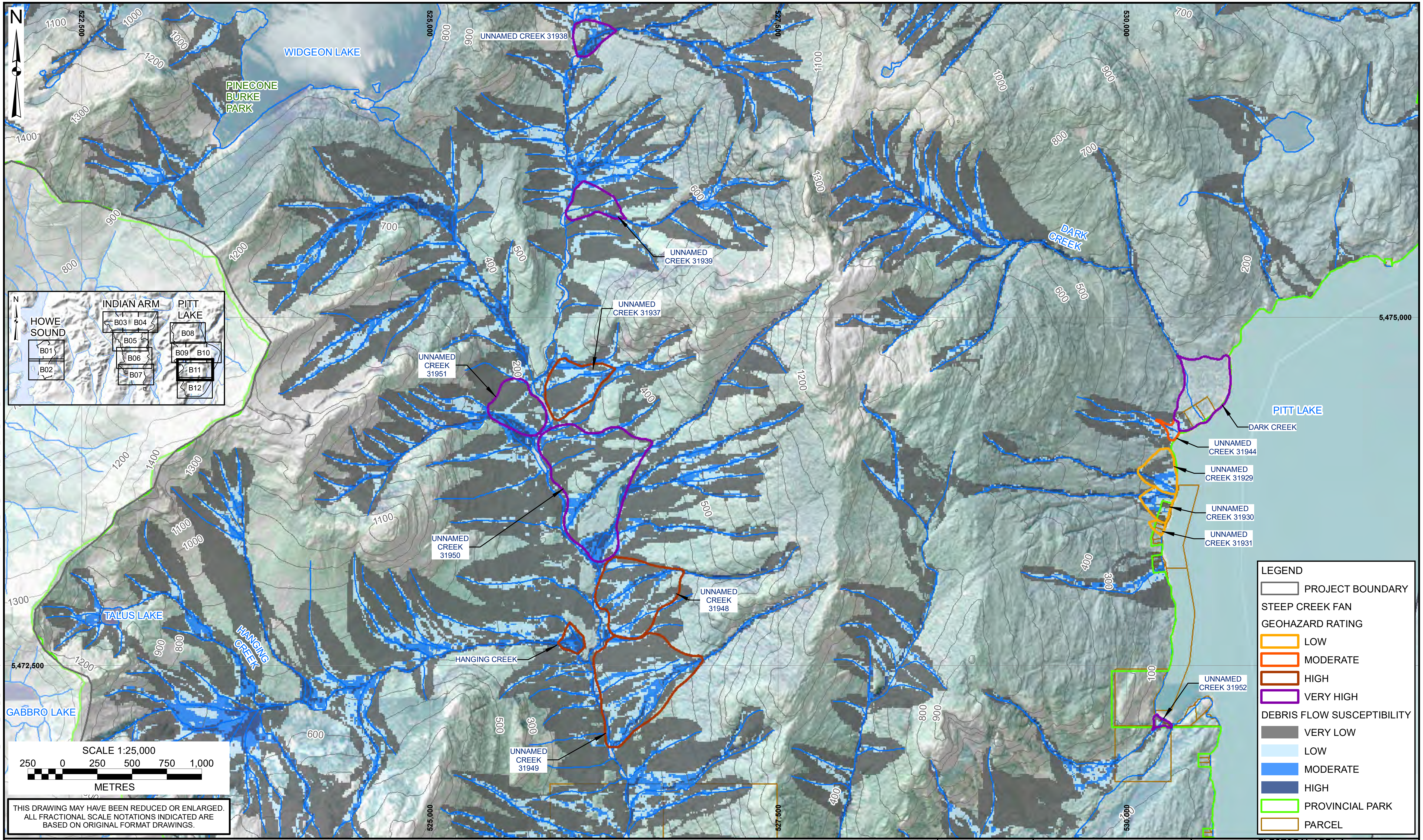
BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY PITT LAKE

PROJECT No.:	DWG No:
0431038	B10

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 12:00 PM



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

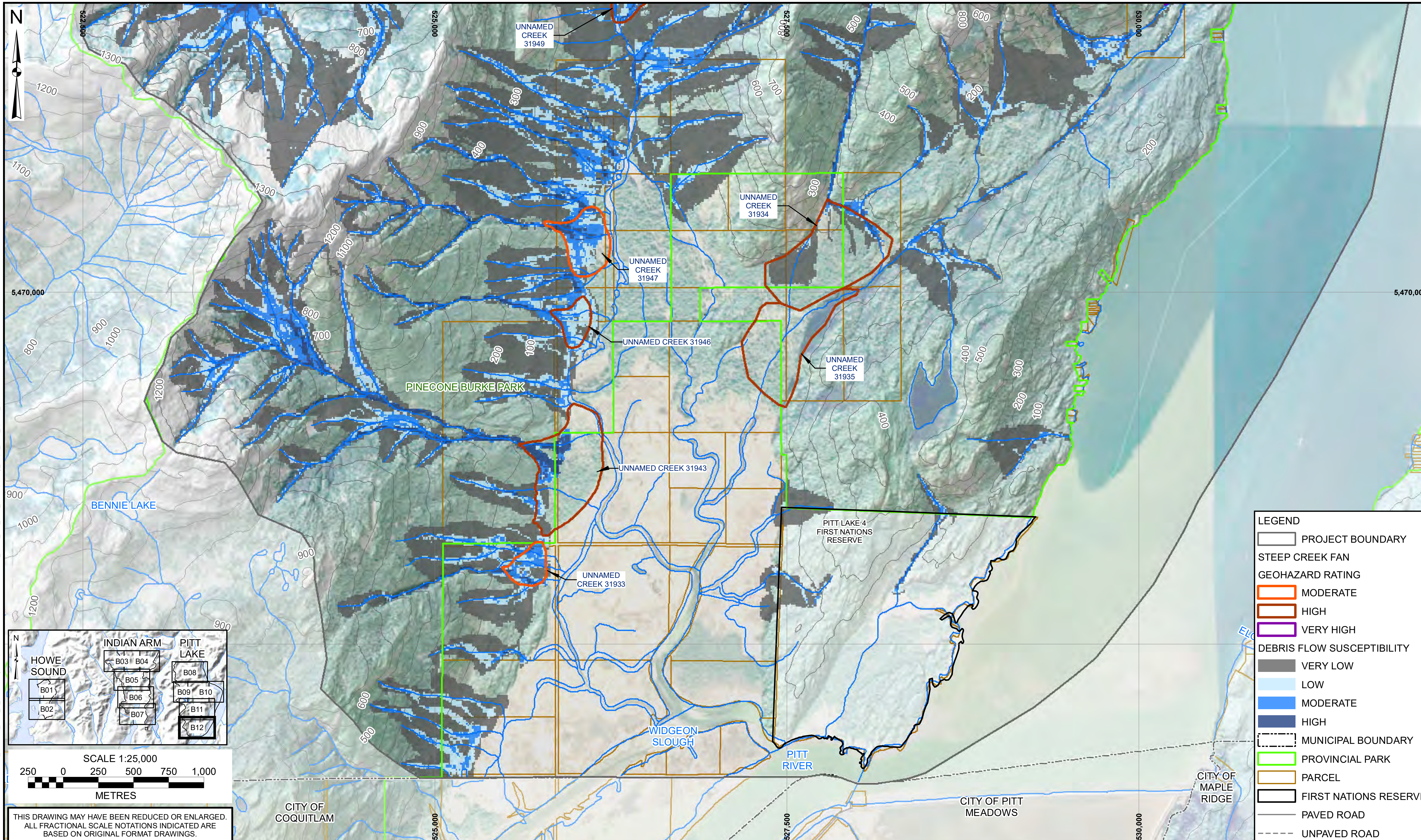
PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY PITT LAKE

PROJECT No.: 0431038

DWG No: B11

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 11:57 AM



NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUNCTION WITH BGC'S REPORT TITLED "ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT", AND DATED NOVEMBER 2023.
3. BASE TOPOGRAPHIC DATA BASED ON COMPILATION OF DIGITAL ELEVATION MODELS FROM BC GOVERNMENT AND NATURAL RESOURCES CANADA. SEE APPENDIX A FOR DETAILS. CONTOUR INTERVAL IS 100 m.
4. STREAM AND ROAD DATA FROM CANVEC.
5. COORDINATE SYSTEM IS NAD 1983 UTM ZONE 10N. VERTICAL DATUM IS UNKNOWN.
6. BGC PREPARED THIS DRAWING FOR THE EXCLUSIVE USE OF BGC'S CLIENT IDENTIFIED ON THIS DRAWING. UNLESS BGC AGREES OTHERWISE IN WRITING, THIS DRAWING MUST NOT BE MODIFIED OR USED FOR ANY PURPOSE OTHER THAN THE SPECIFIC PURPOSE FOR WHICH BGC GENERATED IT. BGC SHALL HAVE NO LIABILITY FOR ANY DAMAGES, INJURY, OR LOSS ARISING FROM ANY UNAUTHORIZED USE OR MODIFICATION OF THIS DRAWING. THIRD PARTIES USE OR RELY UPON THIS DRAWING AT THEIR OWN RISK.

SCALE:	1:25,000
DATE:	NOV 2023
DRAWN:	LL
REVIEW:	JK
APPROVED:	MAB

CLIENT: metro vancouver

BGC

PROJECT: ELECTORAL AREA A - PRELIMINARY STEEP CREEK HAZARD ASSESSMENT

TITLE: DEBRIS FLOW SUSCEPTIBILITY PITT LAKE

PROJECT No.: 0431038

DWG No: B12

X:\Projects\0431 MetroVancouver\038\GIS\Production\20230407_Electoral_Area_A_Preliminary Steep Creek Hazard Assessment\Debris_Flood_and_Flow_Susceptibility_Maps_DDP_update_Nov2023.mxd Date: October 27, 2023 Time: 12:04 PM