REPORT TO:	Council	FOR:	Regular Council Meeting
REPORT FROM:	Community Planning, Community Development		
PRESENTED:	April 1, 2025		
SUBJECT:	Garibaldi Estates Neighbourhood Plan – Official Community Plan Bylaw Update Second Reading		

Recommendation:

THAT

District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 be given second reading.

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1. Objective:

To present the Official Community Plan (OCP) Bylaw amendment related to the Garibaldi Estates Neighbourhood Planning Process (GENPP; Process) to Council for second reading of the Bylaw.

2. Background:

The 2021 Planning Department work plan prioritized the Garibaldi Estates Neighbourhood Plan (GENP; Plan) with Staff resources to engage in the project. At the June 8, 2021 Committee of the Whole meeting, Staff presented a proposed Garibaldi Estates Neighbourhood Planning and Engagement Process overview to Council.

A detailed background of the Process can be found in the January 10, 2023 Stage 3 Update Report to Council. Stage 3 of the Process concluded on May 9, 2023 with a presentation of the Stage 3 Engagement Summary to the Committee of the Whole. Stage 4 of the Process concluded on September 24, 2024 with a presentation of the draft Plan to the Committee of the Whole. At the September 24, 2024 meeting, the Committee recommended Staff prepare a final Garibaldi Neighbourhood Plan based on comments received at that meeting, and bring the plan to Council for first and second readings.

The Plan was presented to Council on December 17, 2024 for consideration of readings. At that meeting Council passed the following motions:

THAT:

1. *For the purpose of section 475 of the Local Government Act, consultation for District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 be satisfied by referral of the Bylaws to the Squamish Nation and* Tsleil-Waututh Nation *for comment prior to first reading and that consultation not be ongoing after first reading.*

2. *For the purpose of section 475 (2)(b) of the Local Government Act, no consultation is required for District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 with the board of the Squamish-Lillooet Regional District, any adjacent Regional District or neighbour municipalities, any boards of education, greater boards, improvement district boards, the Provincial or Federal governments or their agencies, or any first nations except to the extent that consultation has occurred during the neighbourhood planning process.*
3. *District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 is considered to be consistent with the District of Squamish Financial Plan and Waste Management Plans, pursuant to Section 477 of the Local Government Act.*

THAT:

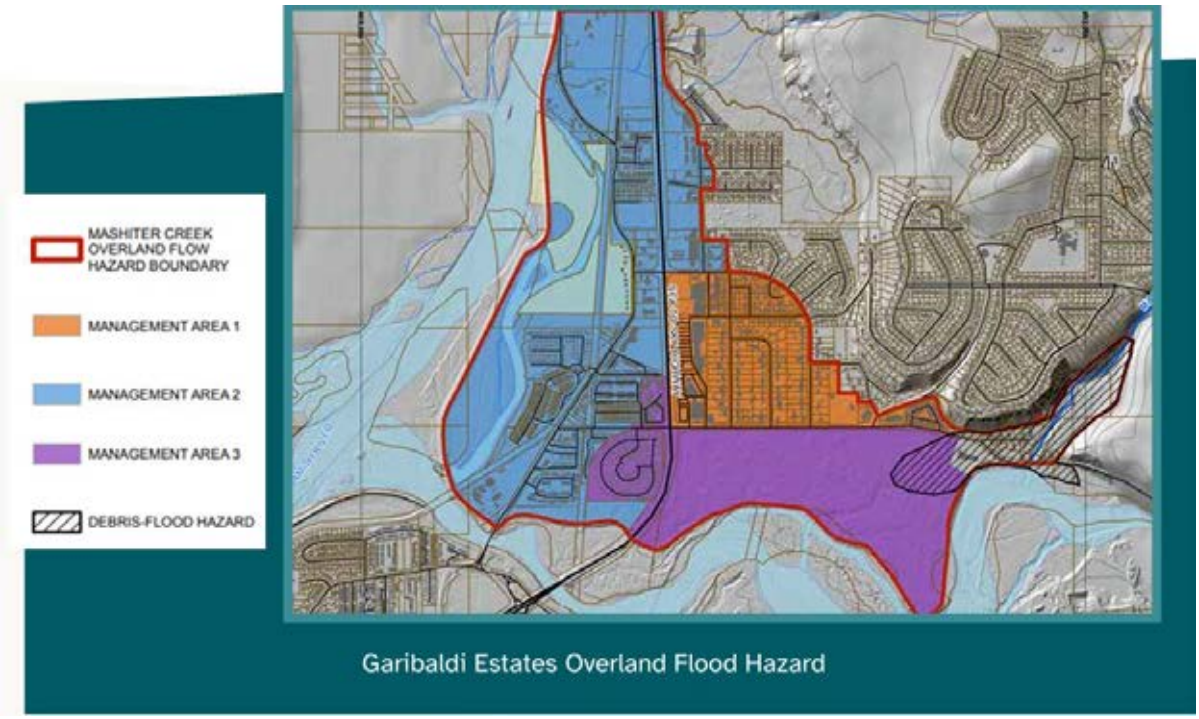
1. *District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 be given first reading. 2. Council direct Staff to receive the Mashiter Creek Hazard Assessment results and include the outcomes of the assessment in the Garibaldi Estate Neighbourhood Plan prior to Council consideration of second reading.*

3. Project Information:

Following the December 17, 2024 Council meeting, Staff worked with BGC Engineering on finalization of the Mashiter Creek Overland Flow Hazard Assessment. That study was completed in January 2025.

The study identifies three separate management areas which are shown in the Overland Flow Hazard Management Figure below.

- In Management Area 1, which covers most of the Garibaldi Estates Neighbourhood Plan area, a Flood Construction Level of 0.3 m above the crown of the adjacent road is recommended. When a parcel in Management Area 1 borders two roads, the crown of the upslope road should govern.
- In Management Area 2, which covers the northwest portion of the Garibaldi Estates Neighbourhood Plan area, the recommended management approach is to retain the existing Flood Construction Levels associated with dike breach modelling completed by KWL (2017b) for the Squamish River and Mamquam River, as part of the Integrated Flood Hazard Management Plan.
- Management Area 3 is outside the Garibaldi Estates Neighbourhood Plan area.
- The northeast portion of the Garibaldi Estates Neighbourhood Plan area is not subject to overland flow hazard; consequently, no flood construction level is required for most properties in this area.



Based on the results of the study, Staff updated policies within the GENP to reflect the identified flood construction levels. This work included a review of road cross sections in areas where mixed-use buildings will feature retail spaces at ground level, to identify the connection between the road and retail frontage. Analysis of street cross sections has shown that the necessary flood construction levels can be accommodated in the public realm between the curb and retail frontage through gradation across sidewalks, landscaped boulevards, bike lanes and outdoor seating areas.

The following additional edits were made to the GENP to address the findings of the Mashiter Creek Overland Flow Hazard Assessment:

- Policies regarding connections between the Commercial Core and residential areas to the east were clarified to reflect the design of adjacent roads, given the Flood Construction Level and anticipated road cross sections.
- The rendering of potential mixed-use development along Diamond Head Road south of Diamond Road has been updated to reflect the updated flood hazard information. Specifically, the depiction of a 1 m Flood Construction Level with accessibility ramps and a 10 m setback was replaced with a depiction of 0.3 m Flood Construction Level and a 5.5 m setback. The updated rendering is included below:

Possible Mixed-Use Frontage Along Diamond Head Road

- Policies in the Mixed Use Residential A section were updated to reflect the updated flood hazard information.
    - For buildings on the west side of Diamond Head Road north of Diamond Road, a front setback of 0.5 m, to be used as an active transportation setback, is identified.
    - For Diamond Head Road south of Diamond Road a front setback of 5.5 m is identified. Of this setback, the 2.5 m adjacent to the road is intended as an active transportation setback. The 3.0 m portion of the setback adjacent to the building is intended as an activated pedestrian realm with opportunities for outdoor seating, outdoor dining and/or landscaping. Above the ground level, cantilevered buildings are supported to project 3.0 m over the setback above the activated pedestrian realm.
    - For Tantalus Road south of Garibaldi Way, a front setback of 2.0 m is identified, to be used as an active transportation setback.
- Road cross section images have been updated to reflect the updated flood hazard information for the following roads (with two options for Diamond Head Road North of Diamond Road, and Tantalus Road South of Garibaldi Way, to reflect different potential routes of frequent transit):
    - Garibaldi Way
    - Mamquam Road
    - Diamond Road
    - Diamond Head Road north of Diamond Road
    - Diamond Head Road south of Diamond Road
    - Tantalus Road south of Garibaldi Way

- Policies related to the implementation of the Mashiter Creek Overland Flow Hazard Assessment were updated to reflect completion of the study.

4. Implications:

a. Budget:

Moving forward, the following items have been budgeted as implementation steps for the Plan:

- Water and Sanitary Sewer Servicing Review - $35,000.
- Stormwater Servicing Review and preliminary Streetscape Design – approximately $70,000.

In the 2024 budget, $35,000 is allocated to neighbourhood planning. These funds are being supplemented by funding from the Housing Accelerator Fund to cover the costs of implementation activities. Funds from the 2024 budget will be carried forward to the 2025 budget.

District-led rezonings are proposed as short-term implementation actions for many properties in the Plan area. There is the potential for one large development property along Mamquam Road, in the southeast portion of the Plan area, to provide a neighbourhood park, which will necessitate consideration of future District operational costs. For parklands proposed and secured through future rezonings, Staff will identify expected park maintenance costs and necessary staffing capacity to maintain the park for Council before the rezoning bylaw proceeds to initial readings.

b. Cross department collaboration:

Development of the Plan has required dedicated senior planner involvement to facilitate and lead background research, engagement, policy development and land use planning.

Ongoing support from other Departments has been critical for this project including Engineering, Communications, Environment, Economic Development, GIS, Public Works, and Emergency Services.

c. Bylaws:

✓ Official Community Plan Bylaw 2500, 2017

5. Strategic Plan

Connected and Livable Community

The Plan process aligns with the following specific 2023-2026 goal:

Increase the diversity of housing forms and tenure types year over year to promote affordable and attainable housing for people living in Squamish.

Prepared for the Future

Given the potential for an increase in retail and office space within the Garibaldi Estates neighbourhood in mixed use developments, the Process offers an opportunity to address the following strategic goals:

Create a net increase of employment lands and spaces both on land and marine by September 2026.

6. Engagement:

Engagement in this planning process is intended to occur at the "Involve" level of the IAP2 Spectrum of Public Participation. Staff work directly with the public throughout the process to ensure public concerns and aspirations are consistently understood and considered, and provided to Council.

Specific engagement activities from various stages of the Process, and the results of that engagement, are outlined in detail in engagement summaries available on the LetsTalkSquamish page.

7. Next Implementation Steps:

If Council gives Bylaw No. 3135 second reading, the bylaw will proceed to public hearing, which is anticipated to occur in May 2025.

Additional implementation steps currently underway include a water and sanitary sewer serving review, and a Garibaldi Estates stormwater and street design review to determine infrastructure requirements for proposed land uses within the neighbourhood.

If the Plan is adopted as currently drafted, a number of bylaw amendments are proposed as implementation actions, including the following:

- Repeal District of Squamish Veterans Land Act (VLA) Bylaw No. 211, 1966 to allow reconfiguration of property boundaries in alignment with policies in the Plan.
- Amend the District of Squamish Zoning Bylaw to permit Accessory Commercial Units on residential properties within the Garibaldi Estates Neighbourhood.
- Amend the District of Squamish Zoning Bylaw to provide zoning for apartment uses in the Mixed-Use Residential A and Mixed-Use Residential B areas at 0.7 FAR.
- Amend the District of Squamish Zoning Bylaw to provide zoning for townhouse uses for most properties in the Ground Oriented Residential Area at 0.6 FAR.
- Update the Subdivision and Development Control Bylaw to enable the Engineering Department to secure needed rights-of-way, and utility and access easements through the development process.

These implementation amendments are aligned with the Provincial directive of prezoning lands for long term housing supply. They will be brought forward following the District's adoption of the Amenity Cost Charges later this year to ensure that developments are contributing towards community amenities without a rezoning process.

8. Attachments:

1. Garibaldi Estates Neighbourhood Plan
2. Mashiter Creek Overland Flow Hazard Assessment

9. Alternatives to Staff Recommendation:

THAT District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 be given second reading with the following amendments:

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10. Staff Review

Prepared By:

Matt Gunn, Planner

Reviewed By:

Jonas Velaniskis, Senior Director of Community Development

Bill Stoner, General Manager, Community Development

Melissa von Bloedau, Corporate Officer

CAO Recommendation:

That the recommendation of Community Development be approved.

Linda Glenday, CAO

District of Squamish
BYLAW NO. 3135, 2024

A bylaw to amend District of Squamish Official Community Plan Bylaw No. 2500, 2017

WHEREAS the District of Squamish deems it necessary and appropriate to amend District of Squamish Official Community Plan Bylaw No. 2500, 2017.

The Council of the District of Squamish, in open meeting assembled, enacts as follows:

1. CITATION

1.1. This bylaw may be cited as "District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024."

2. AMENDMENTS

2.1. District of Squamish Official Community Plan Bylaw No. 2500, 2017 is amended as follows:

a. Schedule "A" of this bylaw, titled "Garibaldi Estates Neighbourhood Plan" is to be attached and designated as Schedule "R".

b. Schedule "B" of the District of Squamish Official Community Plan Bylaw No. 2500, 2017, is amended to delete Residential Neighbourhood; Mixed Use Commercial; and Parks, Greenway Corridors and Recreation land use designations for the area outlined in Schedule "B" of this bylaw, titled "Garibaldi Estate Neighbourhood Plan Land Use Area".

c. Schedule "B" of District of Squamish Official Community Plan Bylaw No. 2500, 2017 is amended by redesignating the area outlined in Schedule "B" of this bylaw, titled "Garibaldi Estate Neighbourhood Plan Land Use Area" as "Adopted Sub Area Plans", with a notation indicating "Schedule R – Garibaldi Estates Neighbourhood.

READ A FIRST TIME this 17 day of December, 2024.

READ A SECOND TIME this day of , .

Local Government Act, **NOTICE WAS ADVERTISED ON** and day of , .

PUBLIC HEARING HELD on this day of , .

READ A THIRD TIME this day of , .

ADOPTED this day of , .

_____
Armand Hurford, Mayor

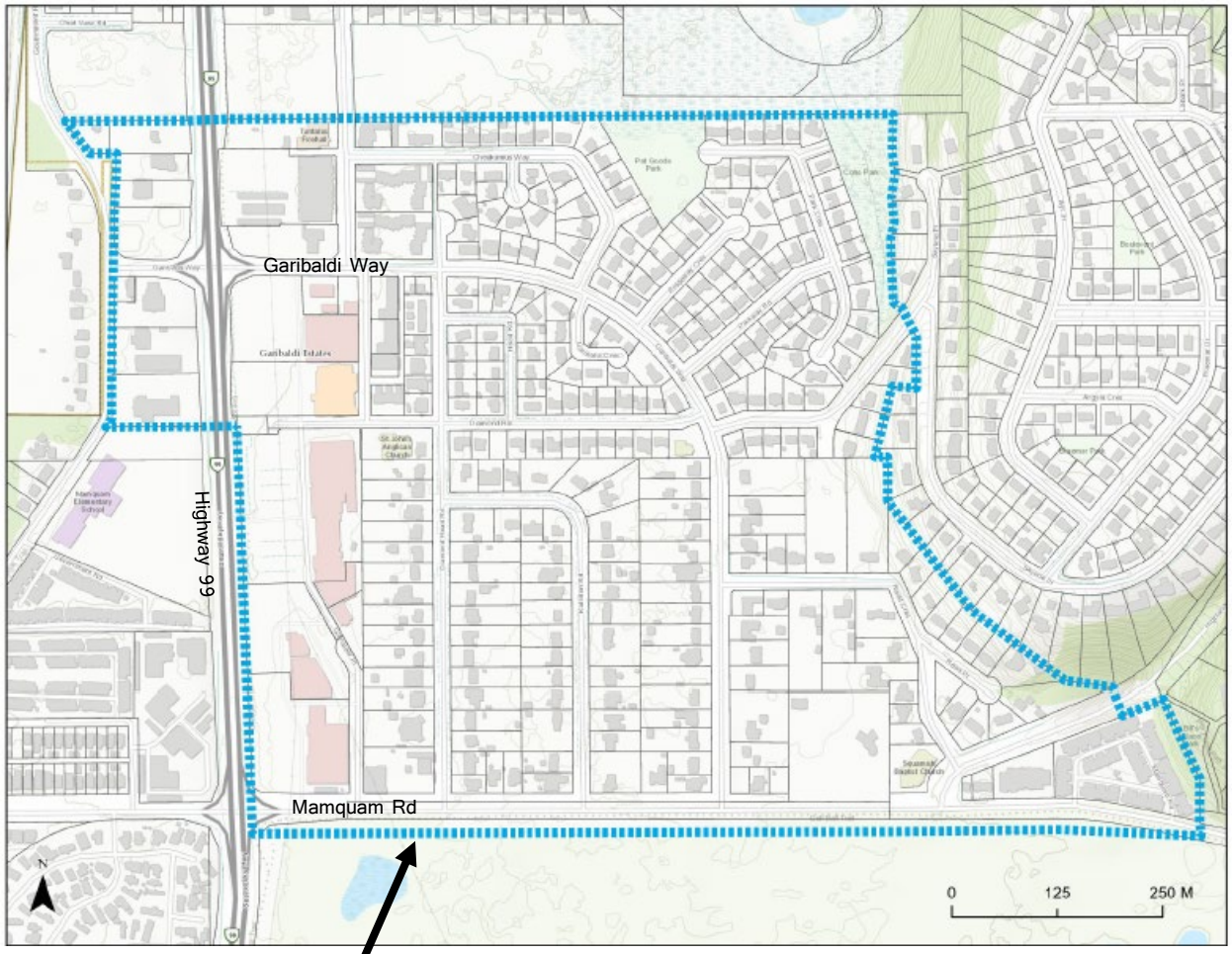
_____
Melissa Von Bloedau, Corporate Officer

Schedule “A” to District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024

(Full Neighbourhood Plan to be designated Schedule “R” to District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024

Schedule "B" to District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024

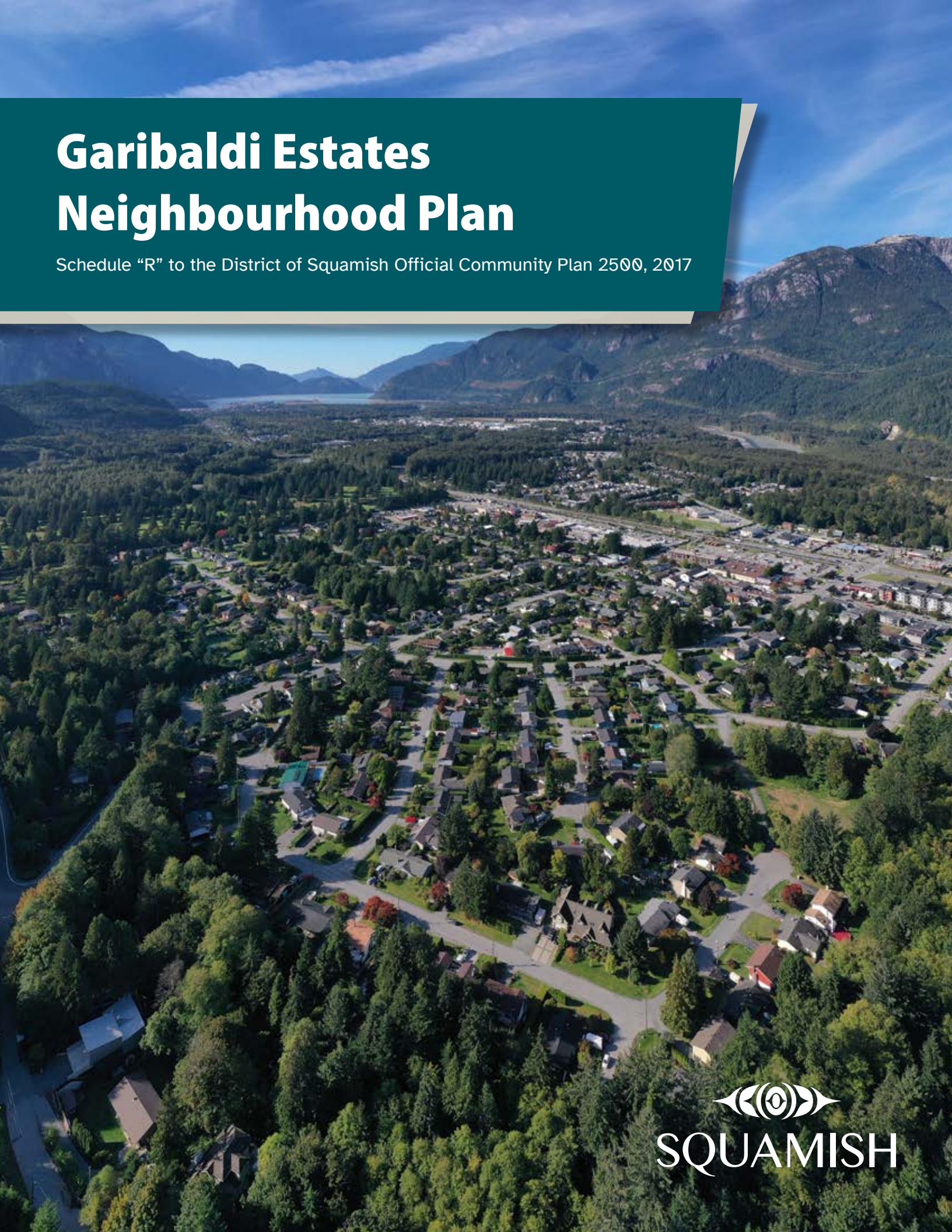
Garibaldi Estate Neighbourhood Plan Land Use Area



Area to be redesignated to "**Adopted Sub Area Plan**" (Schedule R – Garibaldi Estates Neighbourhood Plan Area)

Garibaldi Estates Neighbourhood Plan

Schedule “R” to the District of Squamish Official Community Plan 2500, 2017



SQUAMISH

CONTENTS

The District of Squamish is located within the unceded traditional territory and homelands of the Sḵwx̱wú7mesh Úxwumixw (Squamish Nation). Sḵwx̱wú7mesh people have rich and diverse links to the lands and waters that embrace all of Howe Sound, including settlements and villages, resource sites, spiritual and ritual places, and cultural management areas. The closest Sḵwx̱wú7mesh village and reserve to the Neighbourhood Plan Area is Kewtín (Kowtain), located west of Highway 99. The District acknowledges the Nation's governing laws, policies, customs and land use plans for the lands and waters within the traditional territory.

On the 100-year anniversary of the Amalgamation of the Sḵwx̱wú7mesh Úxwumixw, in 2023 the Nation and District of Squamish signed a new protocol agreement Wa Iyi̓m ta Sḵwx̱wú7mesh (Squamish Strong).

1. INTRODUCTION

1.1 Plan Area

The Garibaldi Estates Neighbourhood Plan area encompasses the land north of Mamquam Road, south of the Pat Goode and Coho Park's north boundary, west of the slope leading to the Garibaldi Highlands, and east of Highway 99, plus commercial properties west of the highway near Garibaldi Way. The plan is meant to guide future growth where there is additional capacity for future housing and employment space in the area.

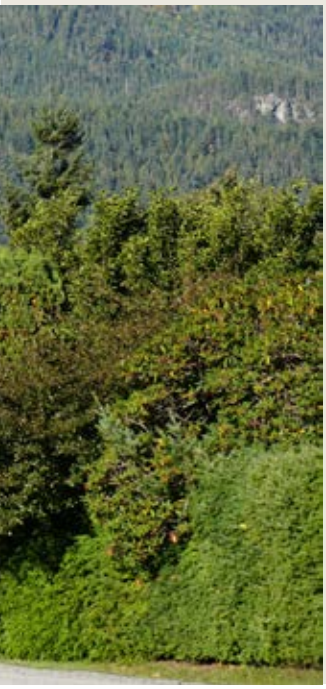
The Garibaldi Estates is a centrally located neighbourhood within the District of Squamish. Residents of the Garibaldi Estates appreciate many aspects of the existing neighbourhood. The neighbourhood encompasses friendly streets, mature trees, access to excellent parks, connections to trails and bike paths, and numerous walkable commercial services and employment opportunities. A range of existing housing forms contribute to housing diversity; however, the area has limited dedicated rental buildings. These attributes make the neighbourhood an excellent place to live.

The large ‘VLA’ lots are a unique aspect of the neighbourhood. These lots were created as a soldier settlement program under the Veterans Land Administration, a branch of the Department of Veterans Affairs. The Veterans Land Act was developed during WW II and the Korean War, following a Canadian tradition dating from the 17th century of settling returned and ex-soldiers. One goal of the program was to ensure stability for the returning veterans. To enable this, agricultural activities were supported on the VLA lots so that veterans could earn additional income off the land. Municipal zoning guide land use on VLA lots rather than Federal regulations; historically, subdivision has been controlled by the District of Squamish V.L.A. Subdivision Bylaw 211, 1966.

The VLA lots represent an important opportunity to accommodate diverse housing options within the neighbourhood given their large size, central location, low flood hazard, access to amenities, and proximity to transportation options. Many of these characteristics apply to residential areas across the Garibaldi Estates neighbourhood. In recognition of this, the Official Community Plan (OCP) includes policy direction to provide opportunities for increased housing diversity and density within the Garibaldi Estates, and to initiate a public process to repeal the ‘District of Squamish V.L.A. Subdivision Bylaw 211, 1966’ to support infill development near the Garibaldi Village commercial area. This direction is well aligned with the 2023 Squamish Housing Needs Report, which indicates that a significant amount of new housing is needed within the horizon of this neighbourhood plan.

1.2 Plan Purpose

The Garibaldi Estates is a centrally located neighbourhood well connected to community services and infrastructure; the neighbourhood is identified in the OCP as a key neighbourhood to accommodate some of the expected growth in Squamish. This Neighbourhood Plan is intended to provide coordinated direction for land use, housing and employment space supply, transportation, infrastructure, recreation, and service provision in the neighbourhood. The Plan helps to manage change and inform how the community vision and needs may be achieved over a 20-year horizon (2044). Because it is expected to meet evolving needs, the Neighbourhood Plan may require multiple updates and amendments during its life. The plan is meant to be a flexible and living document.



1.3 Public Input

Community engagement has been conducted throughout the Estates Planning Process with a focus on engaging the current residents of the area, as well as with the broader community and community organizations. Engagement activities for the planning process are outlined below:

Stage 1 - Project Initiation

- Project kick-off, Council approval of engagement initiation.

Stage 2 - Engagement Kick-Off

- Launch of *Let's Talk Squamish* page.
- Initial survey, idea sharing, mapping, and open houses.

Stage 3 - Future Neighbourhood Scenarios

- Small-group discussions
- Future possible land-use scenarios presented to the community for consideration.

Stage 4 - Proposed Land Use and Policy Plan

- Open houses and online engagement regarding the draft land use and policy plan.

Stage 5 – Bylaw Adoption

- Public Hearing process and Council consideration.

Stage 2 Engagement Activities

Let's Talk Squamish was used as the primary hub for engagement activities in Stage 2 of the Garibaldi Estates Planning Process. The platform hosted multiple activities including surveys, an opportunity to ask questions, a mapping exercise, and a vision & ideas activity. The engagement platform saw considerable use over the course of Stage 2.

Two open house events were held in October 2021. Two virtual open houses were also held in October 2021.

In support of the Garibaldi Estates Neighbourhood Planning Process, Squamish Climate Action Network, a local non-profit organization involved in local food systems policy, hosted a Garibaldi Estates Agriculture and Food Assets Workshop with the Squamish Food Policy Council. The workshop focused on several questions related to food production and opportunities to integrate food assets within the neighbourhood plan.

Early engagement with First Nations was initiated at the start of the planning process. Both the Squamish Nation and the Tsleil-Waututh Nation were contacted by staff by email and the Squamish Nation online referral platform. An Archaeological Overview Assessment was completed at the request of the Squamish Nation. The two Nations have been kept up to date on progress in the planning process via email and the online referral system.

Stage 3 Engagement Activities

For Stage 3 of the planning process, future land use scenarios were developed for the Garibaldi Estates Neighbourhood; these scenarios presented options for how to manage change in the Garibaldi Estates in the coming years as the neighbourhood evolves together with other Squamish neighbourhoods.

Community engagement regarding land use scenarios was initiated in February 2023 and focused on small group meetings. The intended discussion format for the meetings was to provide an opportunity for questions and discussion regarding land use scenarios and emerging ideas. Feedback from these sessions informed the development of the draft Plan.

Squamish Nation Staff met with District of Squamish staff regarding the neighbourhood planning process in April 2023. Squamish Nation members suggested opportunities for reconciliation that could be considered, these suggestions have been integrated into policy development.

OurSquamish, a Squamish placemaking organization, provided input into the Garibaldi Estates Planning Process regarding placemaking and activating public spaces. Staff integrated the input into policies within the draft plan.

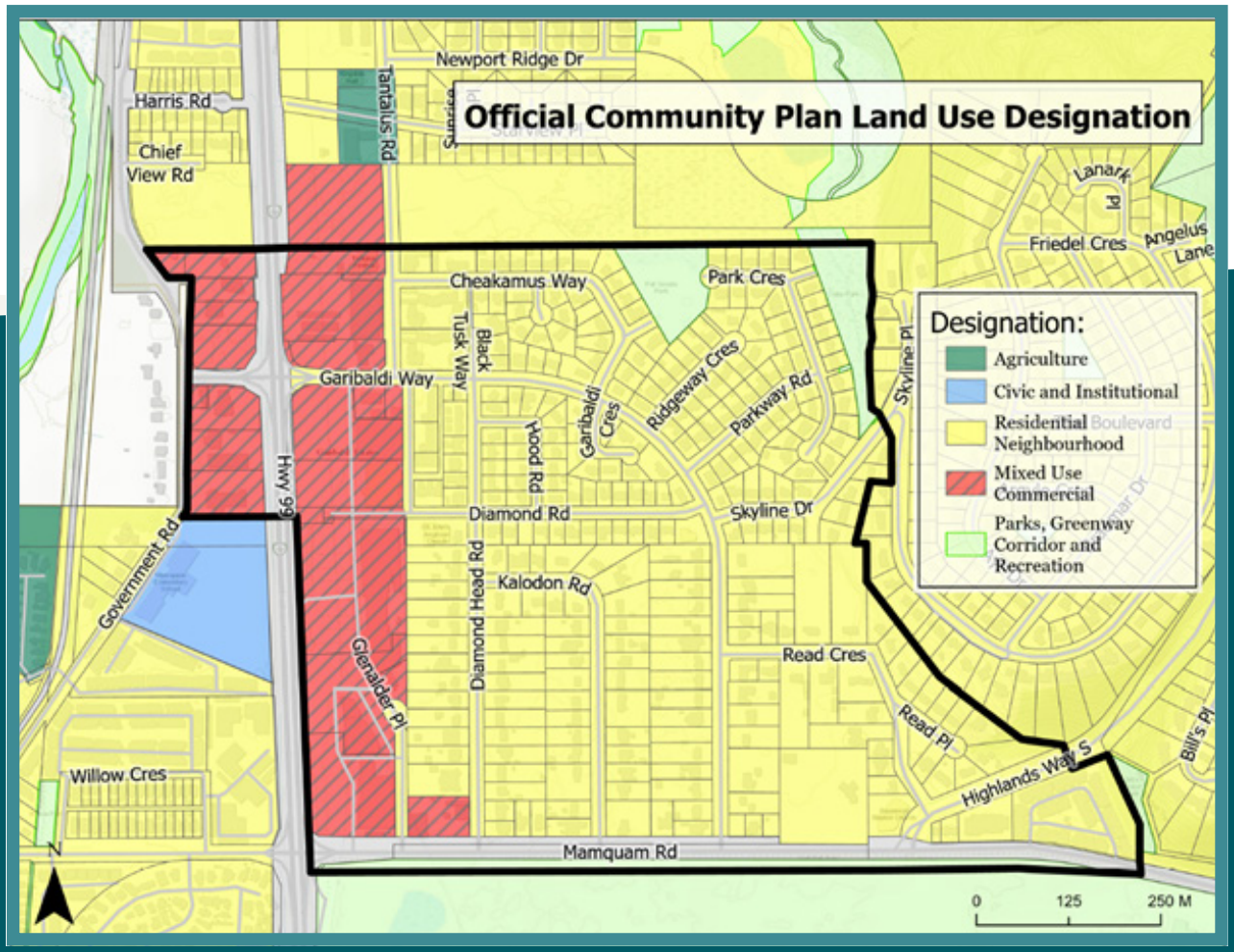
The Squamish Community Housing Society (SCHS) provided input into the Garibaldi Estates Planning Process regarding the delivery of housing in Squamish to support a diverse and vibrant population. The input recommended that the plan support additional height and density for projects that deliver critical housing priorities. These include 100% non-market rental or co-op housing, 100% secured market rental housing, below-market rental units transferred to the SCHS, redevelopment of rental buildings as 100% secured rental housing with a share of Perpetually Affordable Housing units to preserve existing affordability and housing, and housing developed by or in partnership with the Squamish First Nation. In addition, the SCHS input recommended the plan support additional height and density for the redevelopment of existing churches, daycares or other institutional uses.

2. BACKGROUND

2.1 Current Planning Policy

2.1.1 Official Community Plan

The Garibaldi Neighbourhood Plan is drafted as a schedule within the OCP that provides greater direction on land uses and policies specific to the neighbourhood. Prior to the adoption of the Neighbourhood Plan, the OCP land use designations (Schedule B) for the Garibaldi Estates Neighbourhood include **Residential Neighbourhood** across most of the plan area, **Mixed Use Commercial** along the highway, and two parcels designated **Parks, Greenway Corridors and Recreation**.



Official Community Plan Designations

Residential Neighbourhood is intended to accommodate residential growth for Squamish through a diverse mix of housing and employment forms. The intent for these lands is to support complete neighbourhoods; mixed residential and commercial land uses are allowed within these areas. OCP policies support increasing the range of attached multifamily housing types to create compact neighbourhoods and maximize the efficient use of municipal infrastructure and transportation.

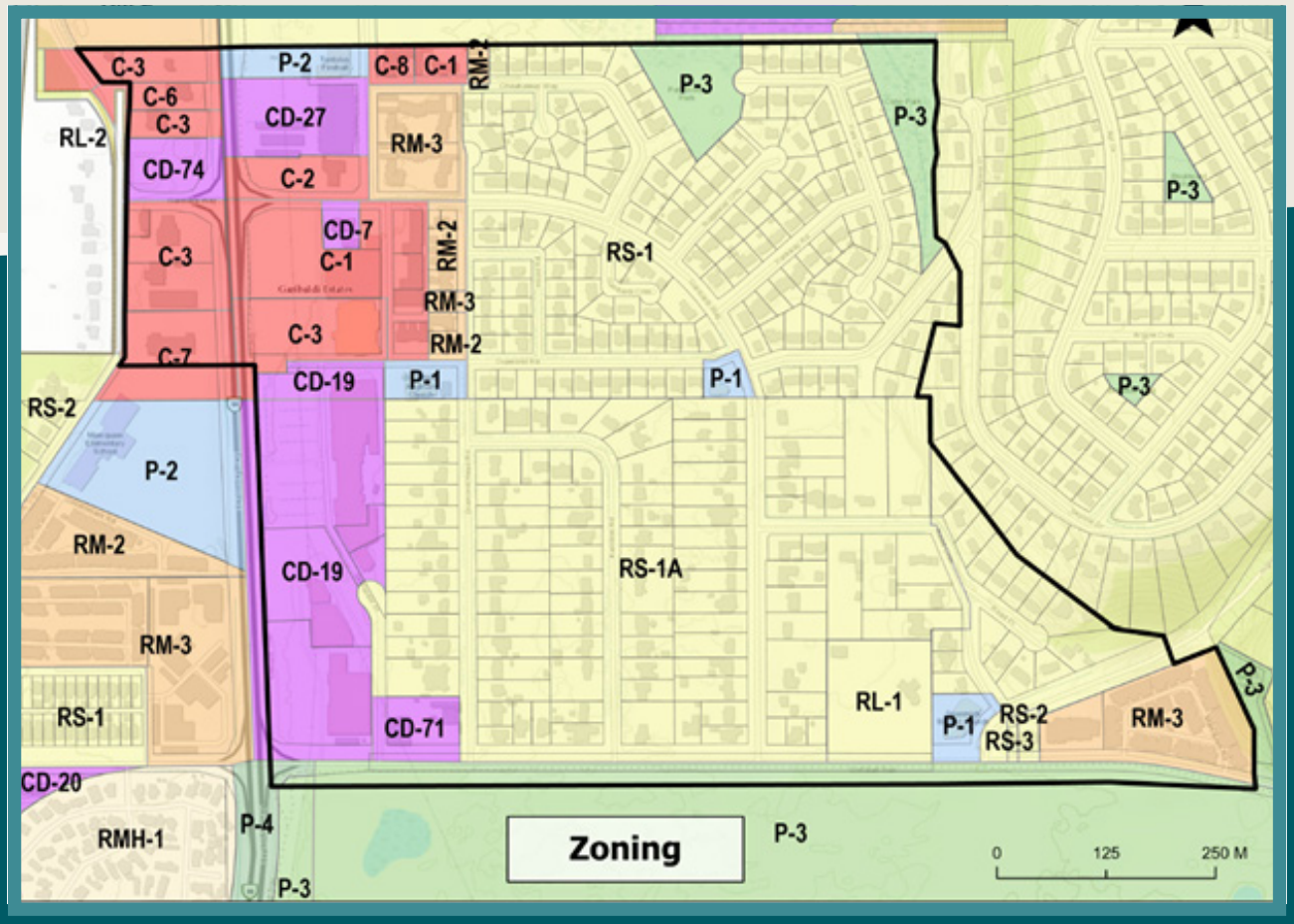
Mixed-Use Commercial is intended to support ground level-commercial uses with complementary office, professional services and/or residential uses allowed above the first floor.

Parks, Greenway Corridors and Recreation applies to lands permanently set aside for provincial, regional, and municipal parks; major recreational areas and natural greenways.

2.1.2 Zoning

Current Zoning

Existing zoning in the Garibaldi Estates includes a range of commercial and residential zones. The commercial area along Highway 99 includes C-1 Local Commercial, C-2 Vehicle Fueling Station, C-3 Tourist Commercial, C-6 Liquor Primary Establishment Commercial, C-7 Highway Commercial, and C-8 Crematorium Commercial. This area also includes several comprehensive development zones including CD-7, CD-19, CD-27, CD-71, and CD-74. Most of the residential properties in the neighbourhood are zoned RS-1A Residential 1, which permits single-unit dwellings as well as secondary suites and accessory dwelling units. Other residential zones found within the area include RL-1 Rural Residential 1, RM-2 Multiple Unit Residential 2 and RM-3 Multiple Unit Residential 3. Three properties which are current or former churches are zoned P-1 Neighbourhood Civic; the District firehall is zoned P-2 Assembly District.



Current Zoning

2.2 Land Use and Population

Current Land Use

The Garibaldi Estates Neighbourhood Plan area is 77.7 hectares in size, representing 3.2% of the land within the Squamish Growth Management Boundary. The following characteristics of the neighbourhood were identified through a review of District of Squamish zoning data and BC Assessment data.

- The Estates area is comprised predominantly of low-density residential land use, with single-unit dwellings occupying over 60% of the land (excluding road dedication). According to BC Assessment data, 19% of these properties include legal secondary suites or accessory dwelling units (carriage houses). Almost all these properties are zoned Residential 1. One larger property is zoned RL-1.
- Just under 24% of the land (excluding road dedication) is occupied by commercial land uses, primarily retail businesses on commercially zoned land.
- Approximately 6% of the land (excluding road dedication) is occupied by multi-unit residential, including plexes, apartments, and townhouses; most of these properties are zoned RM-2 and RM-3.
- Just over 3.5% of the land (excluding road dedication) is used for public parks.

Garibaldi Estates Land Use (Excluding Road Dedication)	Zones	%	Dwelling Units	Dwelling Units/ha
Commercial and Comprehensive Development	C, CD	23.91%		
Civic and Assembly	P-1, P2	2.07%		
Park	P-3	3.65%		
Residential - Single-unit (including 54 with suites)	RS-1	61.38%	338	9.1
Residential - Two-unit dwelling and Small Lot	RS-1/2/3	0.59%	6	16.8
Multiple Unit Residential	RM	5.83%	168	47.4
Rural	RL	2.56%	1	0.6
Total			**513**	

Dwelling Units by Zoning (BC Assessment and District of Squamish Data)

2021 Census Results

In 2021, Stats Canada conducted a national census of the population; the District of Squamish had Stats Canada organize the census results by neighbourhood boundaries. The results of this work provide a snapshot of the population living within the Garibaldi Estates Neighbourhood during the planning process. Dwelling unit totals in the Stats Canada information are significantly below those identified through BC Assessment Data. This likely reflects unoccupied dwelling units such as suites, dwelling units and secondary suites which were not included in the census data.

Garibaldi Estates Population	#	%
Men	615	51.5%
Women	575	48.1%
Total	1195	
Residents 0 to 14 years old		16.3%
Residents 15 to 54 years old		69%
Residents 65 years old and over		14.2%
Total	**1195**	

(Stats Canada 2021 Census – 100% Data)

Languages Spoken Most Often at Home in Garibaldi Estates	#	%
English	1020	85.4%
French	15	1.3%
Official Language Not Specified	5	0.4%
Cebuano	10	0.8%
Tagalog (Pilipino, Filipino)	30	2.5%
Other Austronesian	5	0.4%
Punjabi (Panjabi)	55	4.6%
Other Indo-Iranian	10	0.8%
Spanish	10	0.8%
Japanese	5	0.4%
English and a non-official language	30	2.5%
Total	**1195**	

(Stats Canada 2021 Census – 100% Data)

Occupied private dwellings by type in Garibaldi Estates	Total	%
Single-detached house	270	64%
Semi-detached house	15	4%
Row house	10	2%
Apartment or flat in a two-unit dwelling	20	5%
Apartment in a building that has fewer than five storeys	100	24%
Other single-attached house	10	2%
Total	**425**	

(Stats Canada 2021 Census – 100% Data)

Shelter-cost-to-income ratio for owner and tenant households in Garibaldi Estates	#	%
Spending less than 30% of income on shelter costs	320	74%
Spending 30% or more of income on shelter costs	115	26%
Total	**435**	

(Stats Canada 2021 Census – 25% Data)

Private households by tenure in Garibaldi Estates	#	%
Owner	255	59%
Renter	175	40%
Total	**435**	

(Stats Canada 2021 Census – 25% Data)

2.3 Rental Housing

The Garibaldi Estates has limited dedicated rental buildings. These include:

- Sixty-four apartment units at Garibaldi Garden Court at 1951 Garibaldi Way.
- 6 townhouse units at 40351-40361 Diamond Head Road.
- 6 apartment units at 1917-1927 Diamond Head Road.

Zoning on the 3 properties above is restricted to residential rental tenure for a minimum of the current housing units. This ensures that any redevelopment of the property will include the replacement of the existing rental units.

In addition, within the RS-1 properties, BC Assessment data indicates that fifty-four properties have suites. These properties could include secondary suites or separate accessory dwelling units, also referred to as carriage or laneway homes. Generally, these types of dwelling units are considered part of the rental housing stock.

2.4 Archaeological Resources Potential

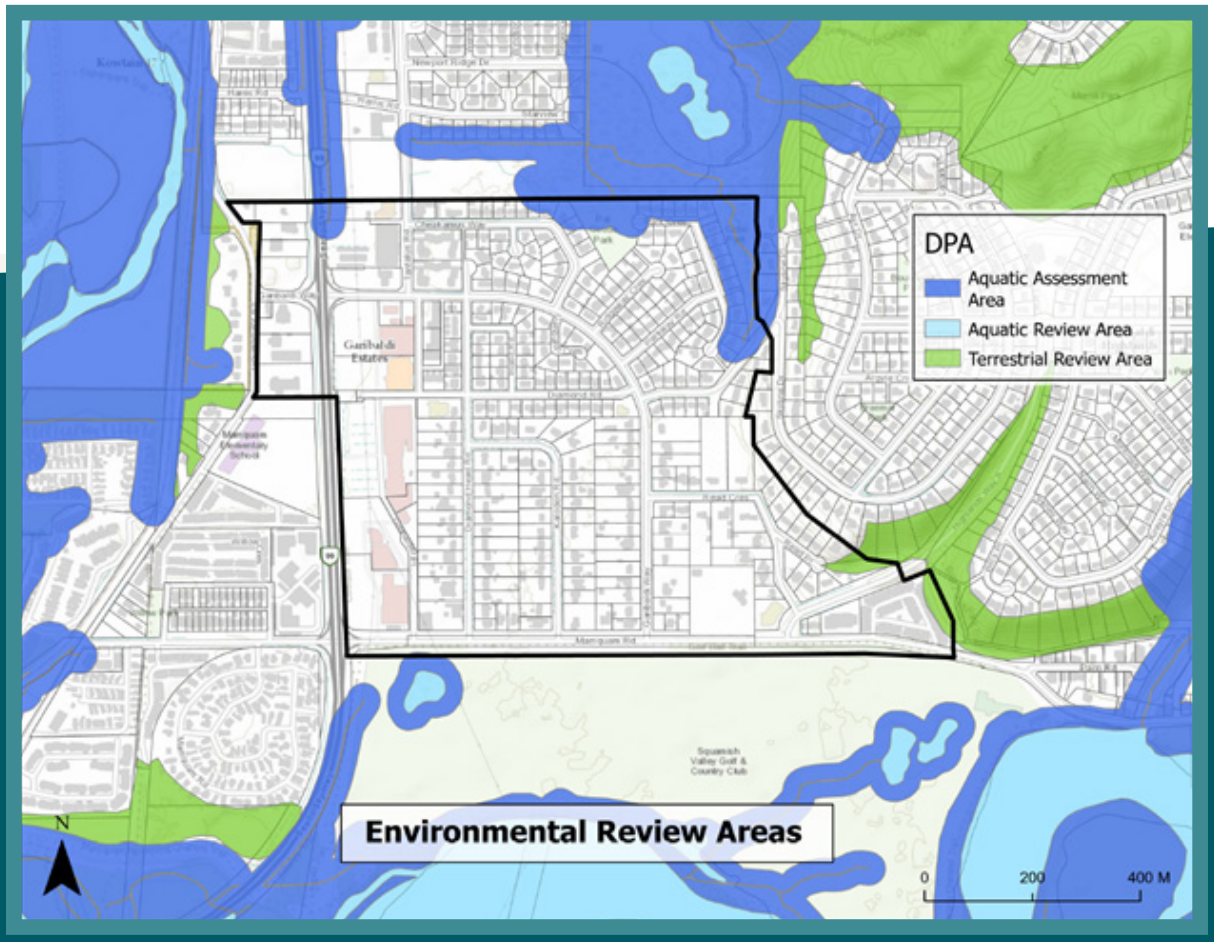
Archaeological resources and sites are critically important to First Nations' communities and are protected in B.C. for their historical, cultural, scientific and educational value.

In the initial stages of the planning process, an Archaeological Overview Assessment (AOA) was conducted for the plan area. AOAs compile existing knowledge about recorded archaeological site locations, First Nations' traditional land use, along with cultural and environmental constants or changes in the area. Their purpose is to identify and assess the potential of an area for as-yet unrecorded archaeological sites to ensure First Nation cultural heritage resources are conserved and development impacts are mitigated. Overall, most of the Garibaldi Estates Neighbourhood area is assessed as having low potential for the presence of archaeological material and/or deposits due to the generally flat topography, likely seasonally inundated in the past, and lacking significant features or watercourses, aside from the eastern periphery abutting the Garibaldi escarpment. This low potential rating is informed by prior land clearing, logging, road construction, and residential and infrastructure developments that have taken place in the past within the plan area which may have resulted in the destruction and/or removal of any other archaeological sites or materials that may have been present in the area prior to development activities. Two areas of moderate to high potential were identified, including a previously identified archaeological site and its immediate surrounding area, and a second area which is comprised of a large flat bench located adjacent to the Garibaldi escarpment that appears to be largely undisturbed by previous development activities.

2.5 Environment

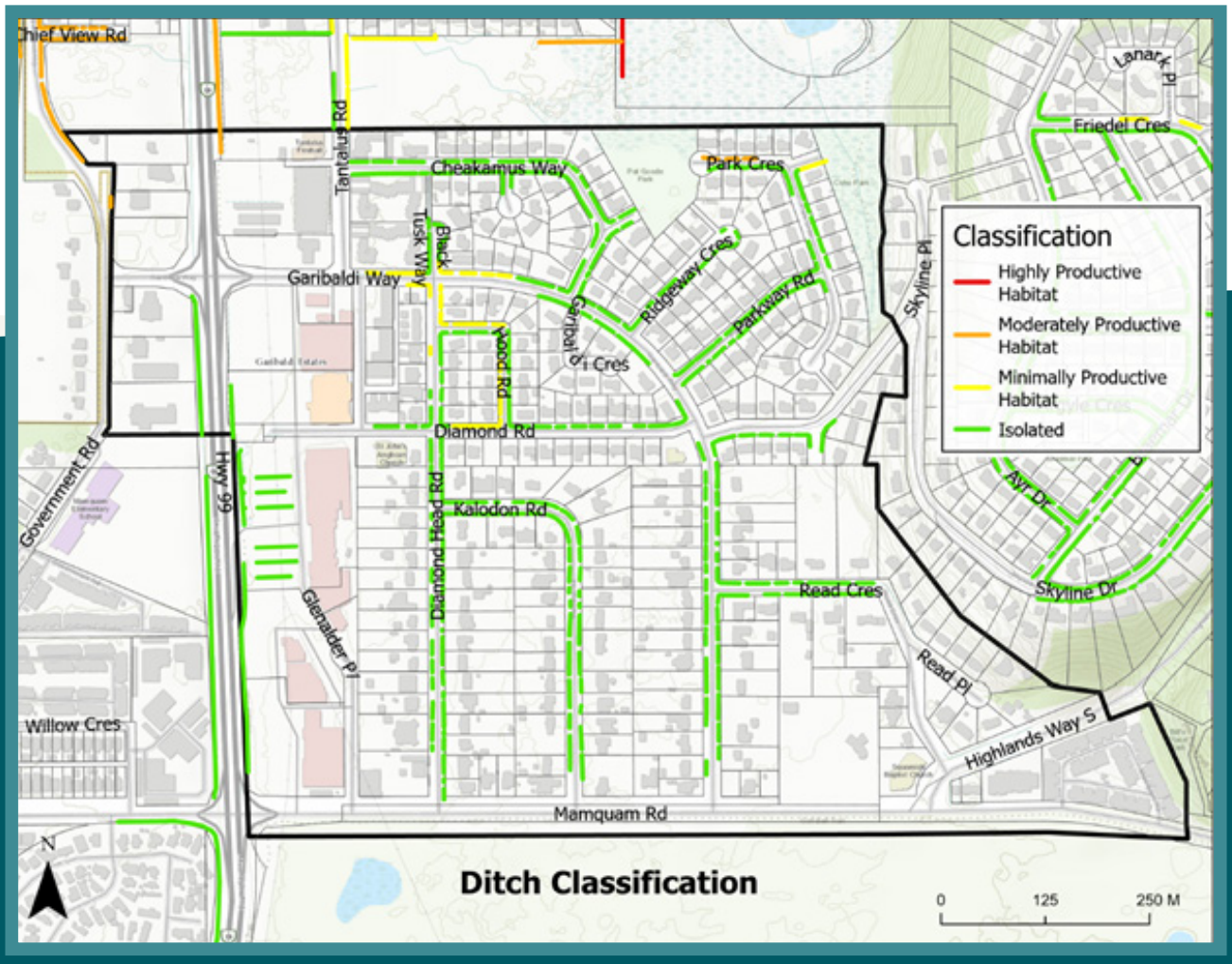
The OCP designates Environmental Review Areas on Schedule K-1. These review areas are identified as either Terrestrial Review Areas, Aquatic Review Areas, or Aquatic Assessment Review Areas. This mapping has been informed by Environmentally Sensitive Areas (ESA) mapping in the "District of Squamish Sensitive Ecosystems Inventory (SEI) and Environmentally Sensitive Areas Mapping" report (January 2016), and the "District of Squamish Wetlands Inventory and Mapping and Watercourse Mapping" report (December 2016).

Within the Neighbourhood Plan area, Aquatic Assessment Areas are primarily found in the northeast corner of the plan area along riparian areas within Coho Park and Pat Goode Park, as well as a section of the Corridor Trail in the northwest corner of the plan area. In addition, a limited extent of the Terrestrial Review Area can be found in the southeast corner of the plan area, adjacent to Mamquam Road.



Environmental Review Areas 1. OCP Schedule K-1

The OCP also designates the habitat productivity of ditches within the community in Schedule K-2. Ditches are classified as either isolated, minimally productive habitat, moderately productive habitat, or highly productive habitat. Within the Garibaldi Estates, a significant majority of ditches are classified as isolated. A limited number of ditches are classified as minimally productive habitat, specifically near the Garibaldi Way and Diamond Head Road intersection and adjacent to Park Crescent. In addition, there are moderately productive ditches at the NE corner of the neighbourhood, at the end of Park Crescent.



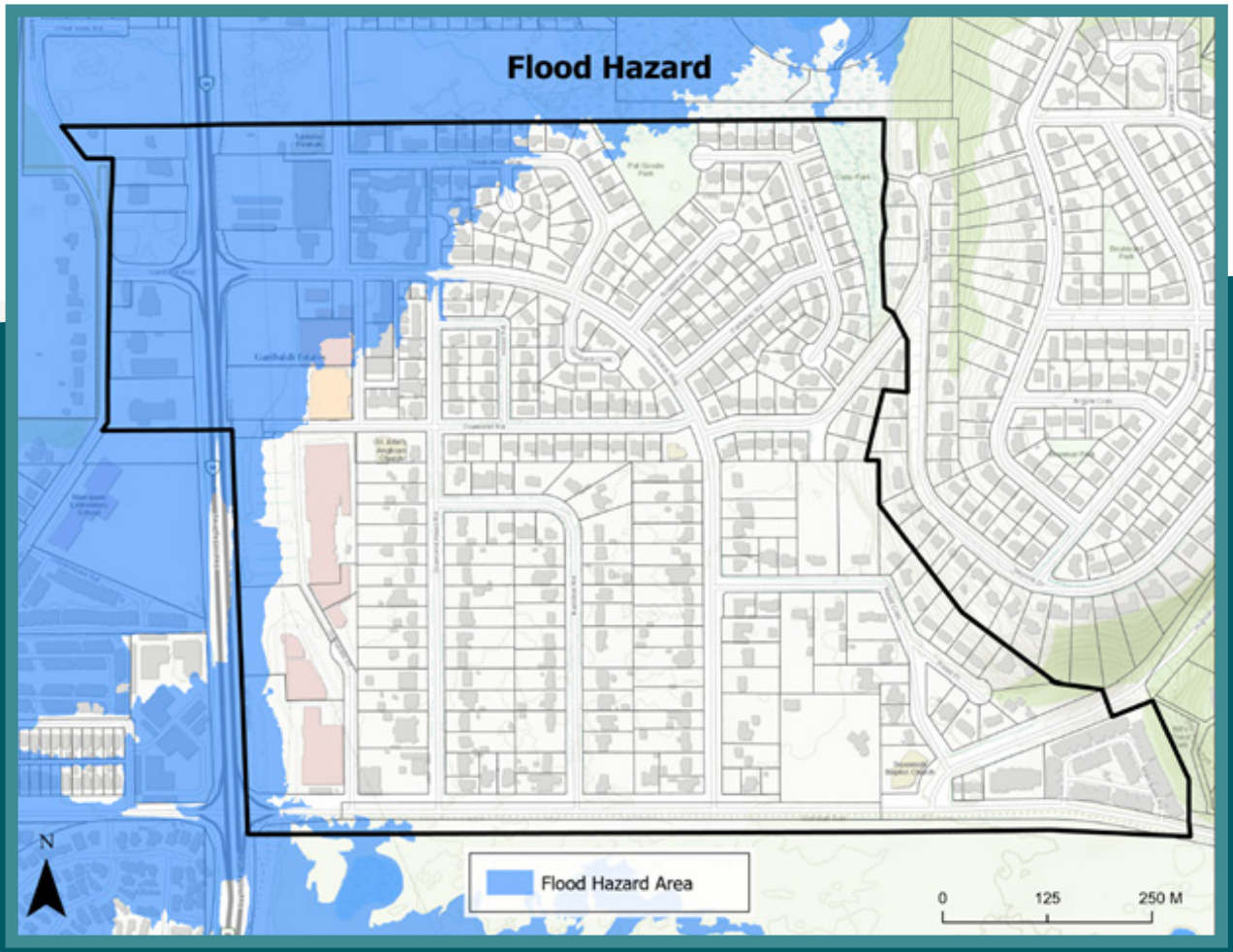
Ditch Classification – Habitat Productivity OCP Schedule K-2

Applications for development within the District of Squamish are subject to Development Permit Area (DPA) 1 guidelines. Terrestrial guidelines in DPA 1 apply to Terrestrial Review Areas as shown on Schedule K-1. Watercourses and Wetlands guidelines apply to aquatic review areas and aquatic assessment areas as shown on Schedule K-1 and ditches as shown on Schedule K-2.

2.6 Flood Hazard

The District of Squamish has evaluated flood hazards comprehensively throughout the community as part of the Integrated Flood Hazard Management Plan (IFHMP).

While the Garibaldi Estates is within a designated floodplain, most areas of the neighbourhood are outside of flood hazard areas identified as part of the Squamish and Mamquam River floodplains. Areas that are encompassed by these flood hazard areas are primarily a limited number of commercial properties in the northwest corner of the plan area, adjacent to Highway 99, and a limited number of nearby residential properties.



Garibaldi Estates Flood Hazard Area

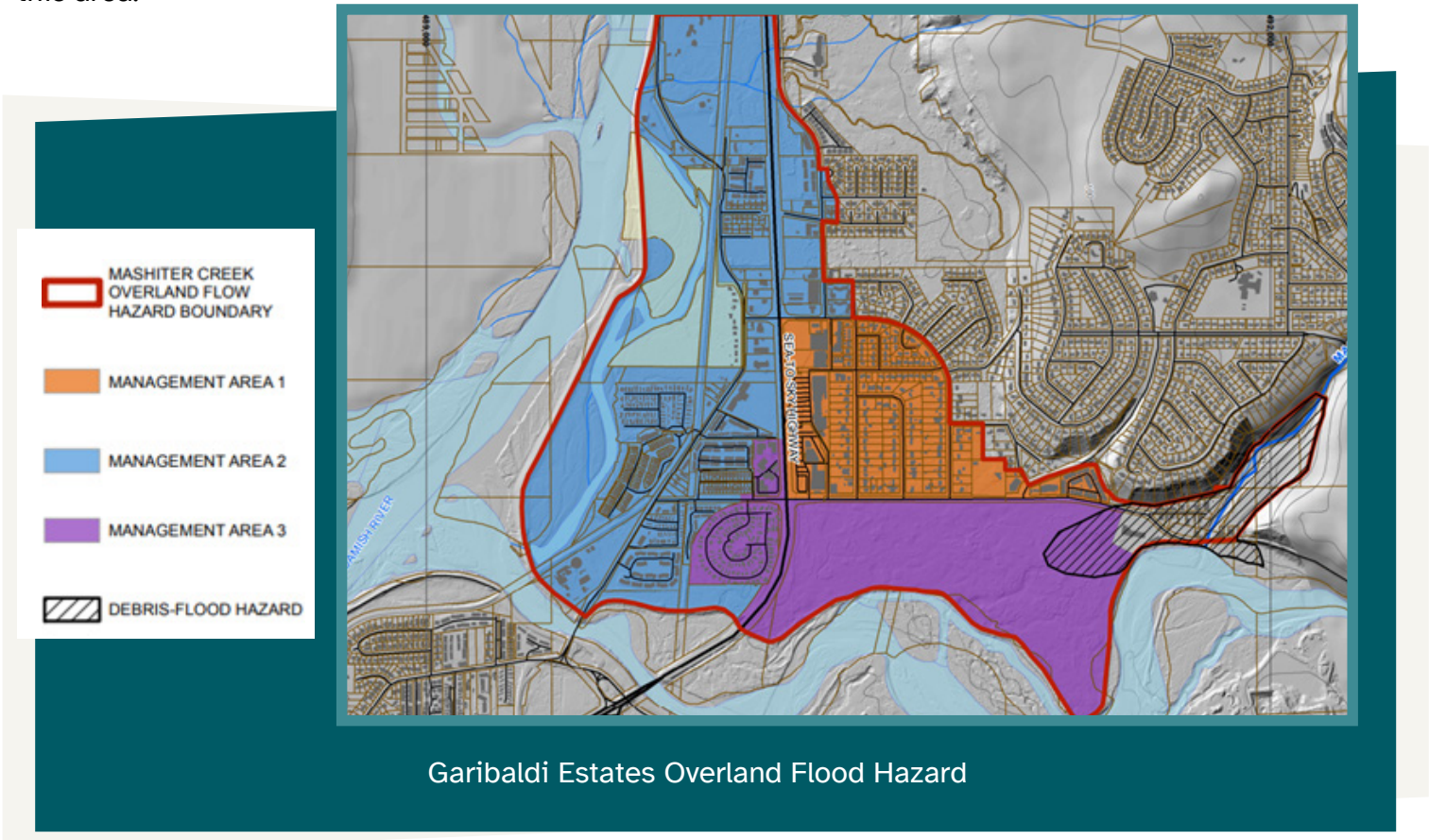
A portion of the Garibaldi Estates is an Overland Flow Hazard Area due to the potential of Mashiter Creek 'avulsing' (overflowing its banks). An Overland Flow Hazard Area is an area where shallow water may flow during a flood event, but where water is not expected to rise to a significant depth. In the Overland Flow Hazard Area, future development will be governed by recommendations included in the Mashiter Creek Overland Flow Hazard Assessment (BGC Engineering, 2025). The study identifies three separate management areas which are shown in the Overland Flow Hazard Management Figure below.

In Management Area 1, which covers most of the Garibaldi Estates Neighbourhood Plan area, a Flood Construction Level of 0.3 m above the crown of the adjacent road is recommended. When a parcel in Management Area 1 borders two roads, the crown of the upslope road should govern.

In Management Area 2, which covers the northwest portion of the Garibaldi Estates Neighbourhood Plan area, the recommended management approach is to retain the existing Flood Construction Levels associated with dike breach modelling completed by KWL (2017b) for the Squamish River and Mamquam River as part of the Integrated Flood Hazard Management Plan.

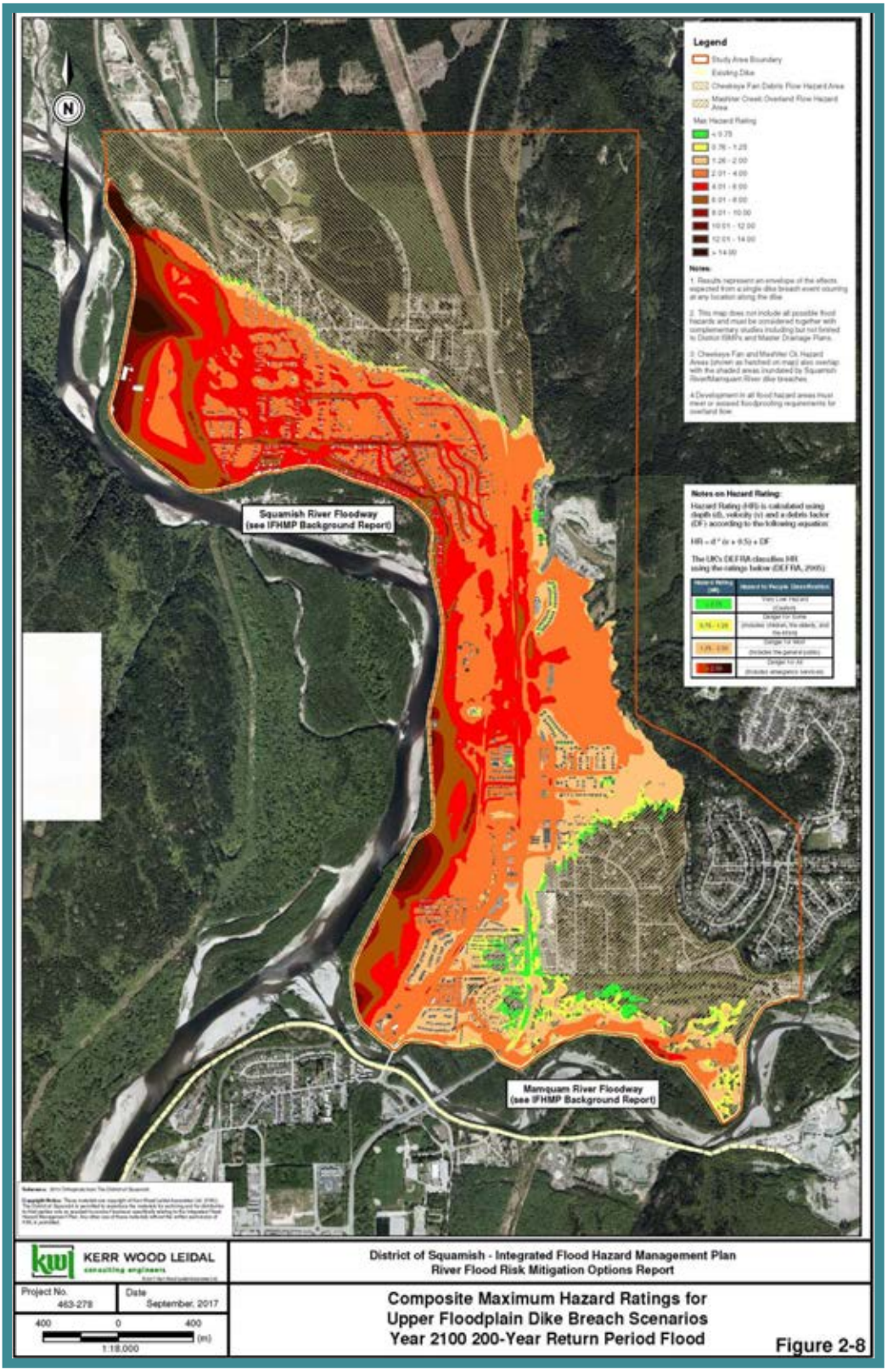
Management Area 3 is outside the Garibaldi Estates Neighbourhood Plan area.

The northeast portion of the Garibaldi Estates Neighbourhood Plan area is not subject to overland flow hazard; consequently, no flood construction level is required in this area for most properties in this area.



Garibaldi Estates Overland Flood Hazard

Overall, the Garibaldi Estates is considered one of the lowest-hazard floodplain areas in the community. This is illustrated in the floodplain mapping contained with the IFHMP. This is illustrated in Figures 2-5, 2-6, 2-7 and 2-8 of the River Flood Risk Mitigation Options. The maximum hazard rating (Figure 2-8) for the northern portion of the community is included below.

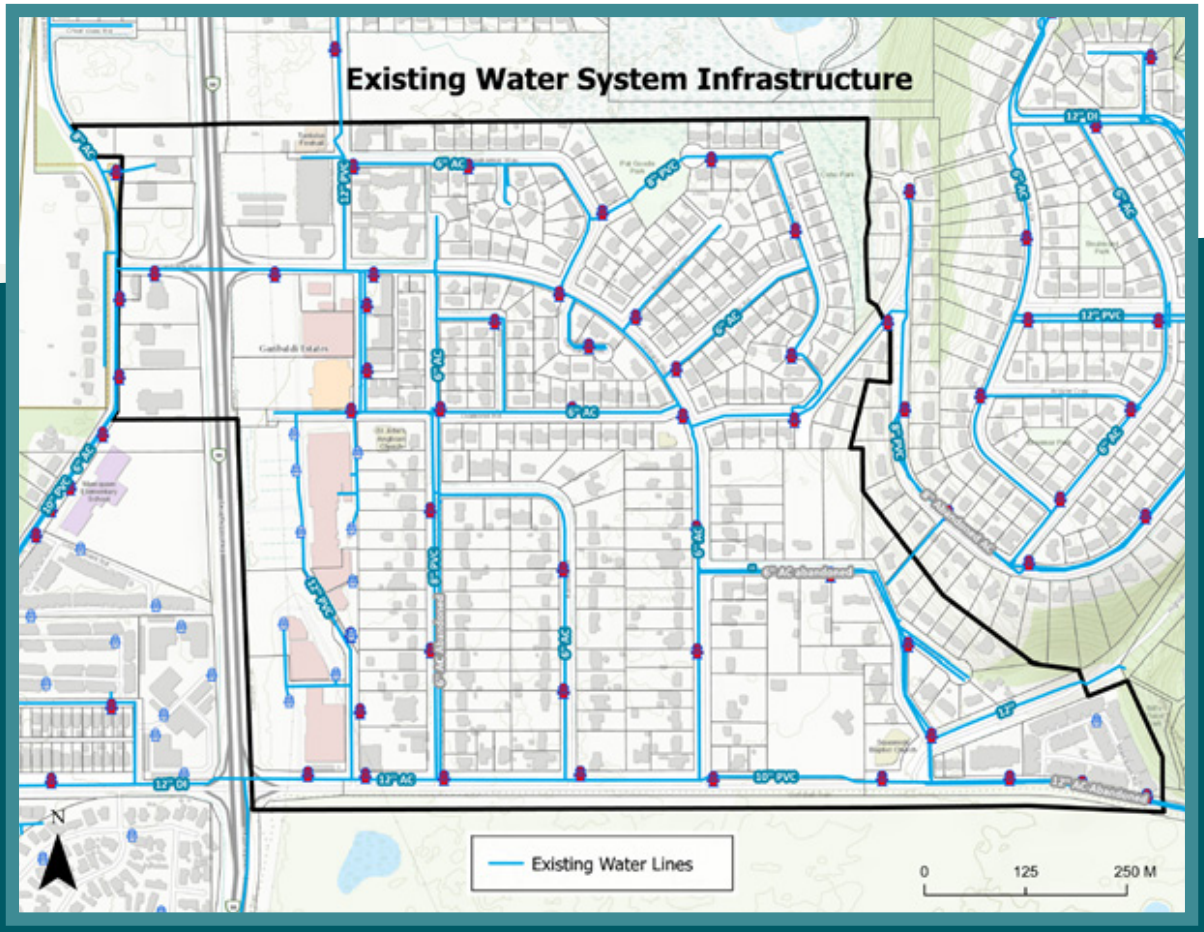


2.7 Servicing Infrastructure

Generally, water and sanitary servicing throughout the Garibaldi Estates Neighborhood is connected to larger infrastructure running north-south through the Garibaldi Village Commercial area and east-west along Mamquam Road. The bulk of stormwater management currently occurs through a system of ditches along roads in the residential areas of the neighbourhoods. The neighbourhood's existing water and sanitary sewer systems are described in more detail below.

2.7.1 Water System

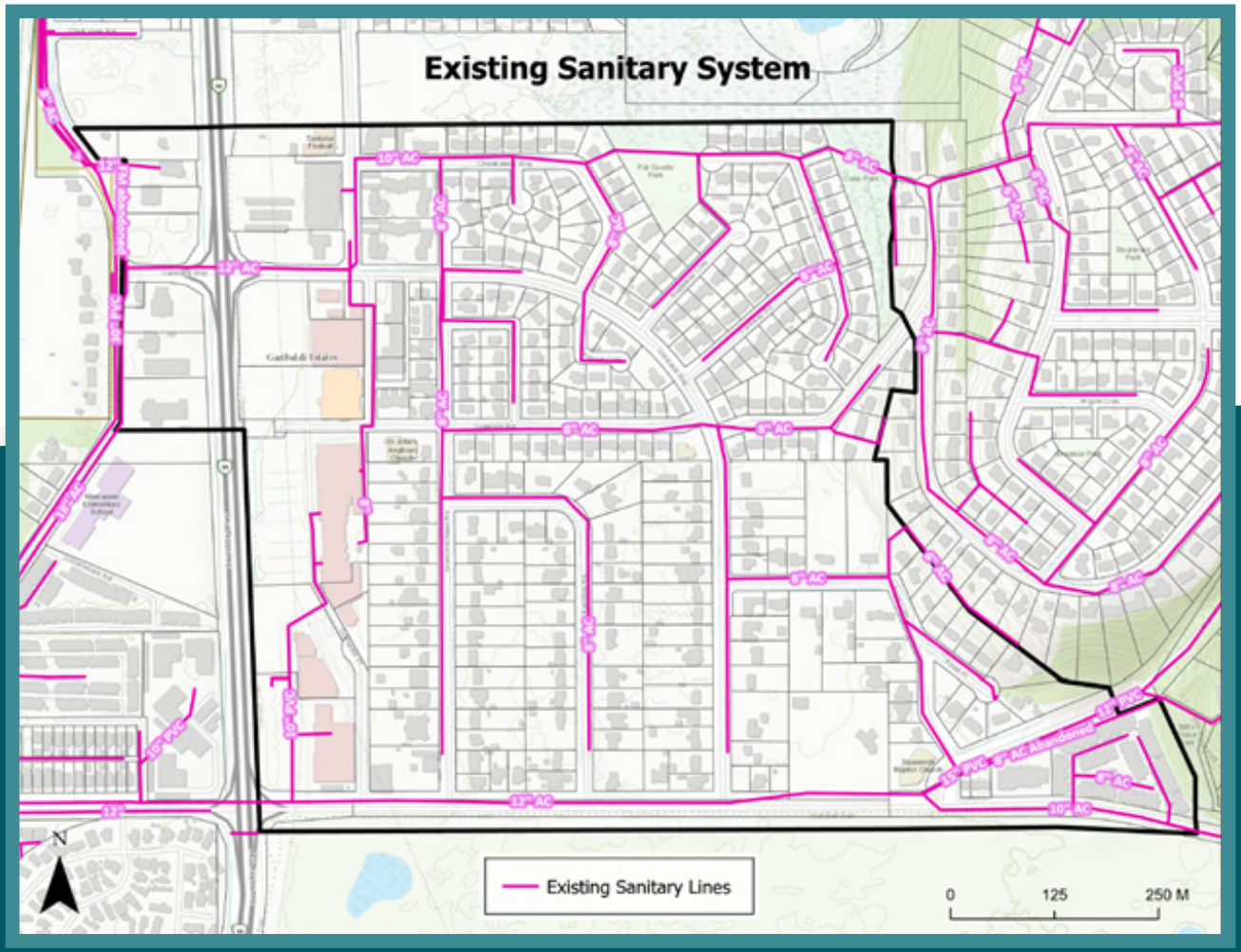
The existing water distribution network consists largely of a mix of newer PVC water mains and older asbestos-cement (AC) water mains, with the majority being AC. 12” water mains are located along Garibaldi Way from Highway 99 to Diamond Head Rd, along Tantalus Road and Glenalder Way, along Mamquam Road from Highway 99 to Diamond Head Rd and east of Highlands Way S. A section of 10” water main can be found along Mamquam Road between Diamond Head Road and Highlands Way South. Sections of 8” water main can be found along Diamond Head Road, through Pat Goode Park, and up Skyline Dr. Most other lines in the neighbourhood are 6” water mains. A number of these water mains located within the neighbourhood also service large areas of the community, including areas of significant future growth, and provide critical connections to maintain adequate fire flows throughout Squamish.



Existing Water Infrastructure

2.7.2 Sanitary Sewer System

The majority of the existing sanitary sewer system consists of older AC sewer lines, with a few short sections of newer PVC lines. 12" sanitary lines are located along Mamquam Road and up Highlands Way South, Tantalus Road between Garibaldi Way and Cheakamus Way, and Garibaldi Way west of Tantalus Road. A short section of 15" line can be found on Highlands Way South. 10" sanitary lines can be found on Mamquam Road east of Highlands Way South, through the southern portion of Garibaldi Village, and the west end of Cheakamus Way. The remainder of the network is predominantly composed of 8" sanitary lines, with a few limited sections of 6" lines. Similarly to the existing water main infrastructure, some of the sewer lines located within the neighbourhood transmit flow from adjacent areas of the community, and in the case of the main along Mamquam Road, transmit flows from areas of significant future growth.

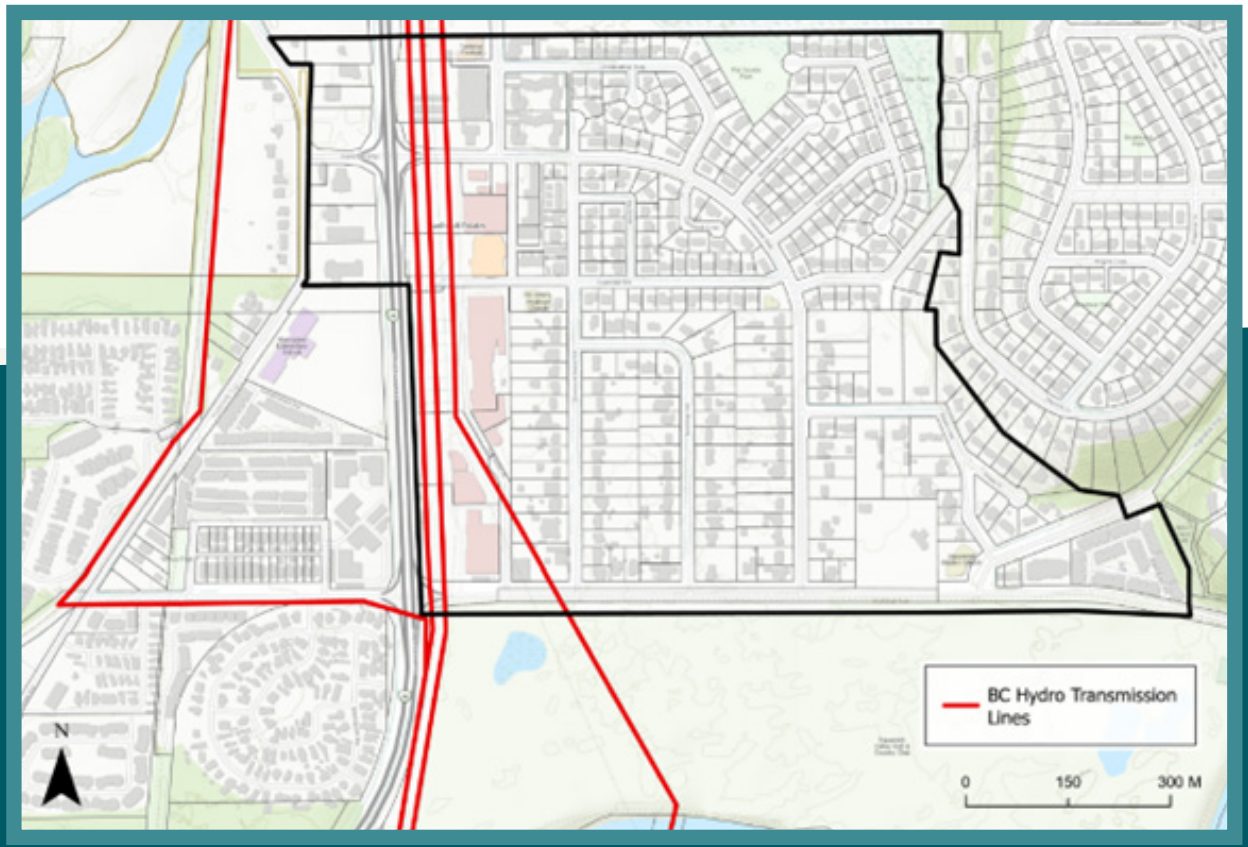


Existing Sanitary Infrastructure

2.8 Major Utilities

A significant BC Hydro transmission line corridor runs north-south through commercial properties on the western edge of the neighbourhood plan area. In the southern half of the plan area, two BC Hydro transmission lines converge north of Mamquam Road; moving north the two lines run parallel adjacent to Highway 99 occupying a corridor approximately 82 metres wide. These hydro lines impact the potential use of the subject properties. Within this corridor, buildings are not permitted; compatible uses such as trails, gardens or parking may be allowed (subject to BC Hydro approval). Currently, parking is the predominant use within this area.

As part of the planning process, staff met with BC Hydro to discuss options for expanding development opportunities within the transmission corridor. Moving the transmission lines underground is possible; in such a move, it may be possible to slightly reduce the overall width of the corridor. However, the cost of such an investment is very significant. In addition, once underground, the transmission lines must remain accessible for maintenance; as such, structures are not permitted above buried transmission lines. Given the limited benefit from such a change, it is unlikely that such an investment would be financially feasible or warranted.



Existing Transmission Lines

2.9 Transportation Background

The Garibaldi Estates is served by one arterial road (Highway 99), two major collectors (Mamquam Road and Garibaldi Way), and one minor collector (Tantalus Road). Most of these roads have transit stops, and street parking is generally informal, if not limited. Most roads in the Estates lack pedestrian functionality.

2.9.1 Active Transportation

Streets in the Garibaldi Estates include blocks up to 450 metres long, cul-de-sacs, limited sidewalks, and a lack of neighbourhood connections. Because of this, many walks to services (parks, grocery, etc.) are upwards of 1,000m – or more than 10 minutes of walking. Limited north-south sidewalk opportunities exist. This results in limited opportunities for safe walking. Garibaldi Way, Mamquam Road, and Diamond Head Road are identified as locations for pedestrian improvements in the medium term in the District's Active Transportation Plan.

The Garibaldi Estates is partially served by bicycle infrastructure in the form of on-street bike lanes on portions of Garibaldi Way, the Corridor Trail, Tantalus Road North, and Mamquam Road. The District's Active Transportation Plan identifies Garibaldi Way, Mamquam Road, Diamond Road and Diamond Head Road as priority areas for improved bicycle infrastructure.

2.9.2 Transit

The Garibaldi Estates are served by four bus routes: Route 1 Brackendale, Route 2 Highlands, Route 9 University and Route 4 Garibaldi. Routes 9 and 4 currently only operate on weekdays, and Route 4 has limited trips.

Staff have engaged with BC Transit to discuss land use planning options that would support enhanced bus service and increased ridership (also known as transit mode share). A key result from these discussions was the importance of developing a frequent transit route that provides 15-minute frequency. One of the critical metrics to achieve this level of service is the density of jobs and residents within a 400-metre walk of the bus stops along the core transit network. A density of 3,500 residents and jobs/km^2 is considered by BC Transit to be an appropriate minimum density to support service with a 15-minute frequency. Resident and job density above this threshold further supports the viability of frequent transit.

Squamish Transit Network
Squamish Transit Future Action Plan 2022

The Squamish Transit Future Action Plan 2022 outlines priorities for improvements to the Squamish transit network. A sub-priority outlined for implementation in 2027 is to add additional frequency to the Frequent Transit Network to work towards 15-minute service between 7:00 AM and 7:00 PM during the week. The current Frequent Transit Network passes through the Garibaldi Estates, running along Diamond Head Road.

2.9.3 Provincial Housing Regulations and Frequent Transit

With the introduction of Bill 44 by the Provincial government in November of 2023, proximity to a Frequent Transit Network has become an important consideration when determining future land uses. The new Provincial legislation prescribes land use and zoning regulation direction for areas within 400 metres and 800 metres of bus stops with scheduled stops that are, on average, every 15 minutes. Notably, under Bill 44, local governments are now prohibited from setting off-street parking requirements for small-scale multi-unit residential uses on properties over 281 m^2 that are within 400 metres of a frequent transit bus stop. Recognizing the priorities outlined in the Squamish Transit Future Action Plan 2022, it is likely that many properties will meet these criteria within the projected timeframe of this neighbourhood plan. To account for this new Provincial guidance, parking requirements below previous standards should be considered along the Frequent Transit Network where a 15-minute transit service is expected; this is particularly relevant to the Diamond Head Road area.

3. NEIGHBOURHOOD VISION

3.1 Guiding Principles

Livability

Retain and enhance the livability of the Garibaldi Estates neighbourhood.

Housing Options

Provide a diverse range of housing forms and tenures suitable for a broad range of District of Squamish residents. Support the provision of attainable housing and rental options in the neighbourhood.

Guiding Principles

Connectivity

Support pedestrian and cycling connections within the neighbourhood and to adjacent areas. Improve transportation infrastructure for the safety and convenience of residents and visitors.

Food Production

Provide enhanced opportunities for gardening, food production and agriculture to support local food access and the wider regional food system.

Employment

Preserve dedicated commercial areas as employment lands and consider options to integrate additional commercial opportunities into the neighbourhood through mixed uses.

Parks, Greenspace and Public Outdoor Space

Improve and expand existing parks and outdoor public spaces to meet the needs of residents and foster a sense of community for all members. Preserve the canopy of mature trees that enhances the character of the neighbourhood and supports environmental values.

Services and Amenities

Ensure access to day-to-day services and amenities for neighbourhood residents. Build on the role of the neighbourhood as a service hub for the broader community.

Neighbourhood Design

Ensure new residential and commercial development supports a safe, inclusive, and accessible environment with visual appeal.

Respond to Climate Change

Reduce greenhouse gas emissions (GHG) and eliminate non-renewable energy use associated with new growth. Ensure resilience to interface wildfire hazards.

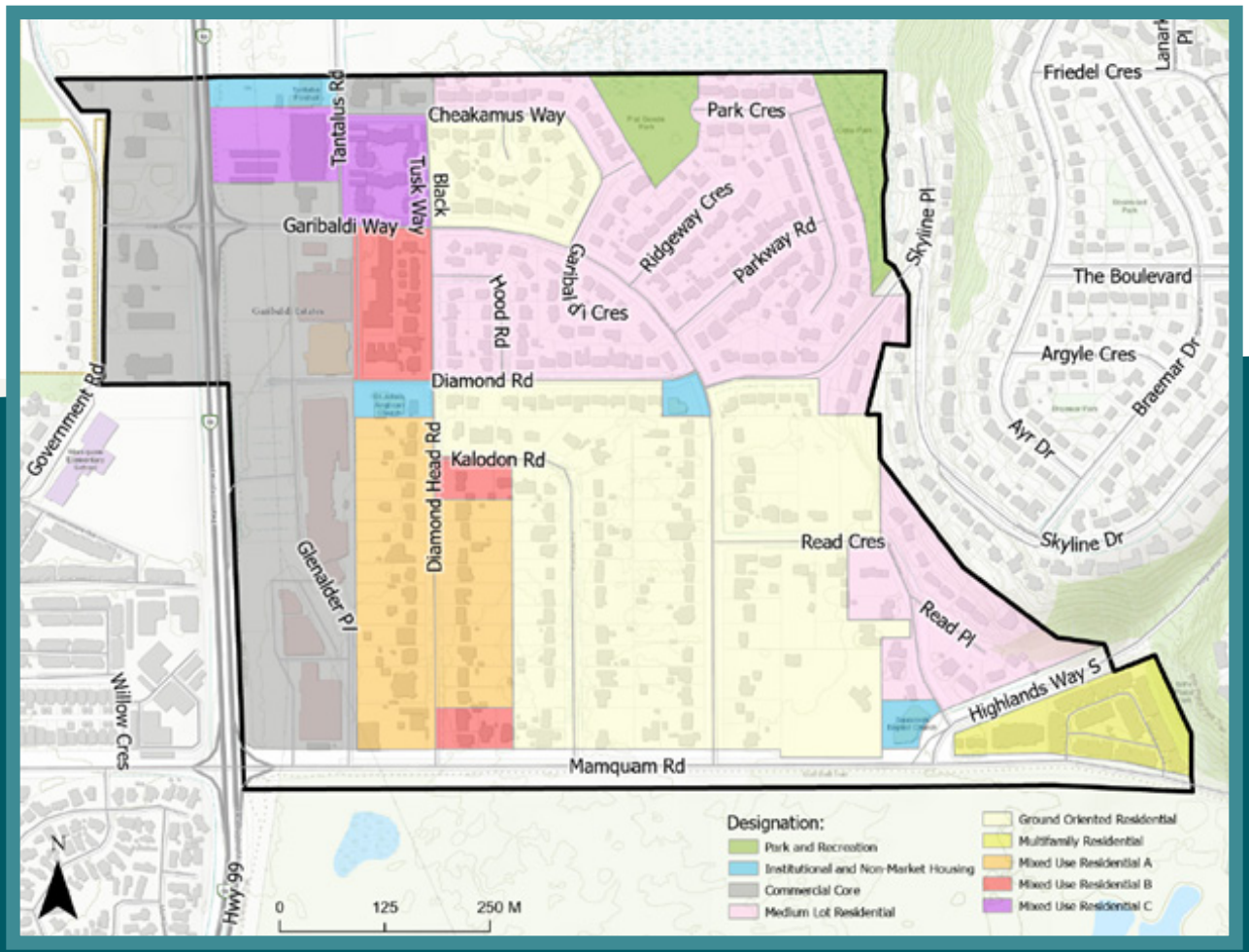
Infrastructure

Plan for appropriate water, sanitary, transportation and green infrastructure services to support the neighbourhood as it continues to mature. Share costs of infrastructure upgrades across the range of development activities in the neighbourhood.

4. LAND USE PLAN

4.1 Schedule A Land Use Plan

The Garibaldi Estates Land Use Plan provides a long-term vision intended to direct the evolution of different land uses (residential, commercial, institutional, parks, etc.) within the neighbourhood. The District of Squamish Zoning Bylaw includes specific regulations that govern land use and development in the District. These regulations address permitted uses such as specific housing forms (e.g. two-unit dwelling or townhouse) or specific commercial businesses (e.g. retail store, office, gas station). The Zoning bylaw also includes detailed development requirements such as building height, setbacks, and densities. Any changes to zoning bylaw regulations through rezoning applications or District-led bylaw changes are required to align with the policies in this Plan. The Garibaldi Estates Future Land Use Plan is included on the following page as Schedule A. This section also includes descriptions for each land use designation.

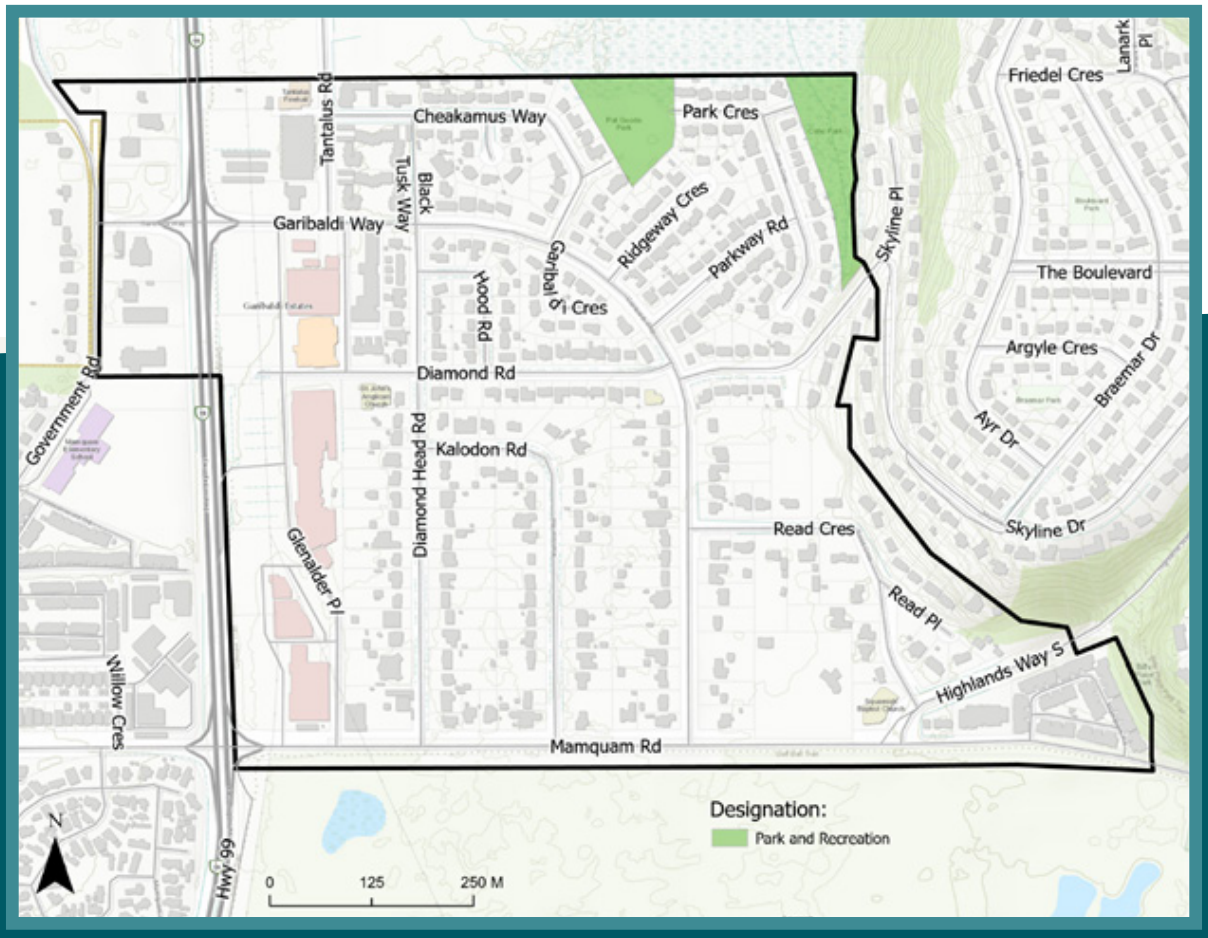


5. LAND USE DESIGNATIONS

Diamond Head Road Pedestrian Oriented High Street – Long-term vision

5.1 Parks and Recreation

5.1.1. Area



Parks and Recreation Land Use Designations

5.1.2 Intent

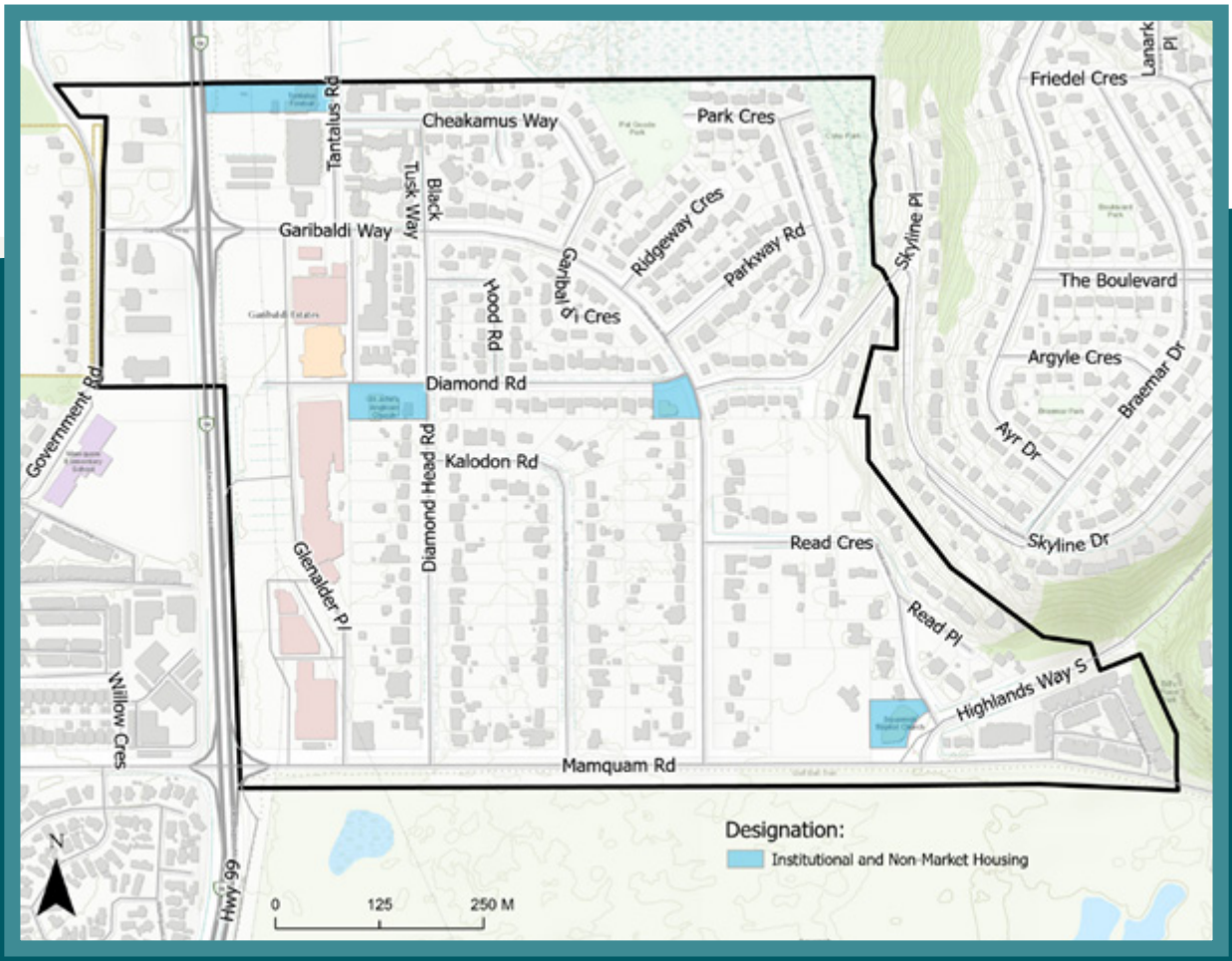
To support neighbourhood parks, trails, and recreation facilities. To provide sufficient usable active park space. To protect and enhance natural areas such as watercourses, riparian corridors and habitats. To support fish and wildlife populations.

5.1.3 Supported Land Uses

- Neighbourhood parks
- Protected environmentally sensitive areas

5.2 Institutional

5.2.1 Area



Institutional Land Use Designations

5.2.2 Intent

To support a variety of institutional uses that serve the residents of Garibaldi Estates and the broader community. To support the creation of affordable housing units that complement institutional land uses.

5.2.3 Supported Land Uses

- Institutional buildings such as schools, churches, daycares and community facilities.
- Public and civic designed to serve a residential neighbourhood.
- Essential government, administrative, recreation and cultural services which serve the entire District.
- Mixed-use buildings that combine institutional uses and publicly funded non-market rental apartment dwellings.
- Rental housing that is secured mainly at non-market rates.

5.2.4 Institutional Policies

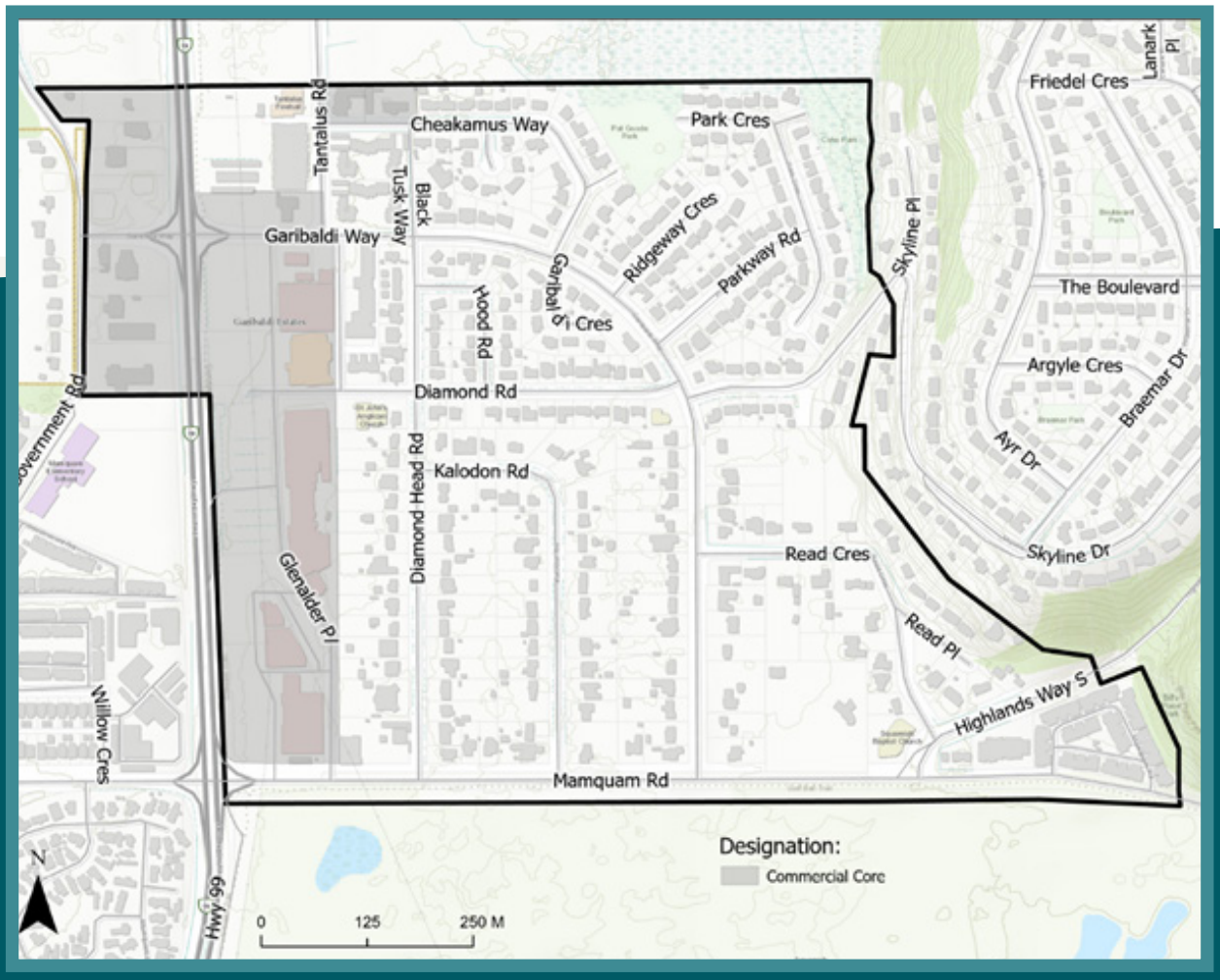
1. Zoning regulations related to siting, lot coverage, gross floor area and the number of permitted principal buildings do not apply to public service land uses owned by the District of Squamish, Provincial or Federal government agencies, or for affordable housing delivered by a government agency or non-profit organization.

2. Affordable housing delivered by a government agency or non-profit organization is not subject to a maximum building height, in alignment with the Zoning Bylaw.

3. Support rezonings to increase height and density for redevelopment of existing churches, daycare or other institutional uses.

5.3 Commercial Core

5.3.1 Area



Commercial Core Residential Land Use Designations

5.3.2. Intent

To function as a vibrant commercial centre in the north half of Squamish, supporting a range of commercial services for residents of the Garibaldi Estates neighbourhood and the broader community. To host significant employment opportunities in both retail and office space.

5.3.3 Supported Land Uses

- A broad range of commercial land uses
- Multi-story mixed-use buildings with retail at grade and offices above
- Large format retail stores
- Multi- and single-tenant retail buildings

5.3.4 Maximum Building Height

Area	Maximum Height
Properties West of Highway 99	6 Storeys
Properties East of Highway 99	4 Storeys

5.3.5 Commercial Core Policies

1. On the west side of Highway 99, support commercial buildings with increased height, up to 6 stories, to ensure project viability, given the high flood construction level and small lot size.

2. Redevelopment of commercial properties east of Highway 99 must incorporate site planning that establishes a safe pedestrian realm along the commercial frontage. Vehicular access and travel corridors should be directed away from the pedestrian realm to minimize exposure of pedestrians to vehicle traffic when moving to and from parking areas.

3. Residential land uses are not supported within the Commercial Core area.

4. Connect the Commercial Core area located east of Highway 99 to Garibaldi Estates residential areas to the east using the following development design strategies:

    - Include mid-block connections through larger commercial developments;
    - Include customer entrances to some retail spaces from the east, between Diamond Road and Mamquam Road; and
    - Include sections of retail frontage facing east onto Tantalus Road, between Diamond Road and Garibaldi Way.

5. Rezoning applications within the Commercial Core area east of Highway 99 should integrate connections between the Corridor Trail and the retail frontages; and consider opportunities to establish a north-south cycling route through the development adjacent to the retail frontage that can connect with neighbouring commercial properties.

6. For properties 2.0 hectares in size or larger within the Commercial Core area at the time this plan is adopted, rezoning applications to expand the gross floor area, floor area ratio, or height beyond what is permitted under existing zoning must address the following considerations in development design:

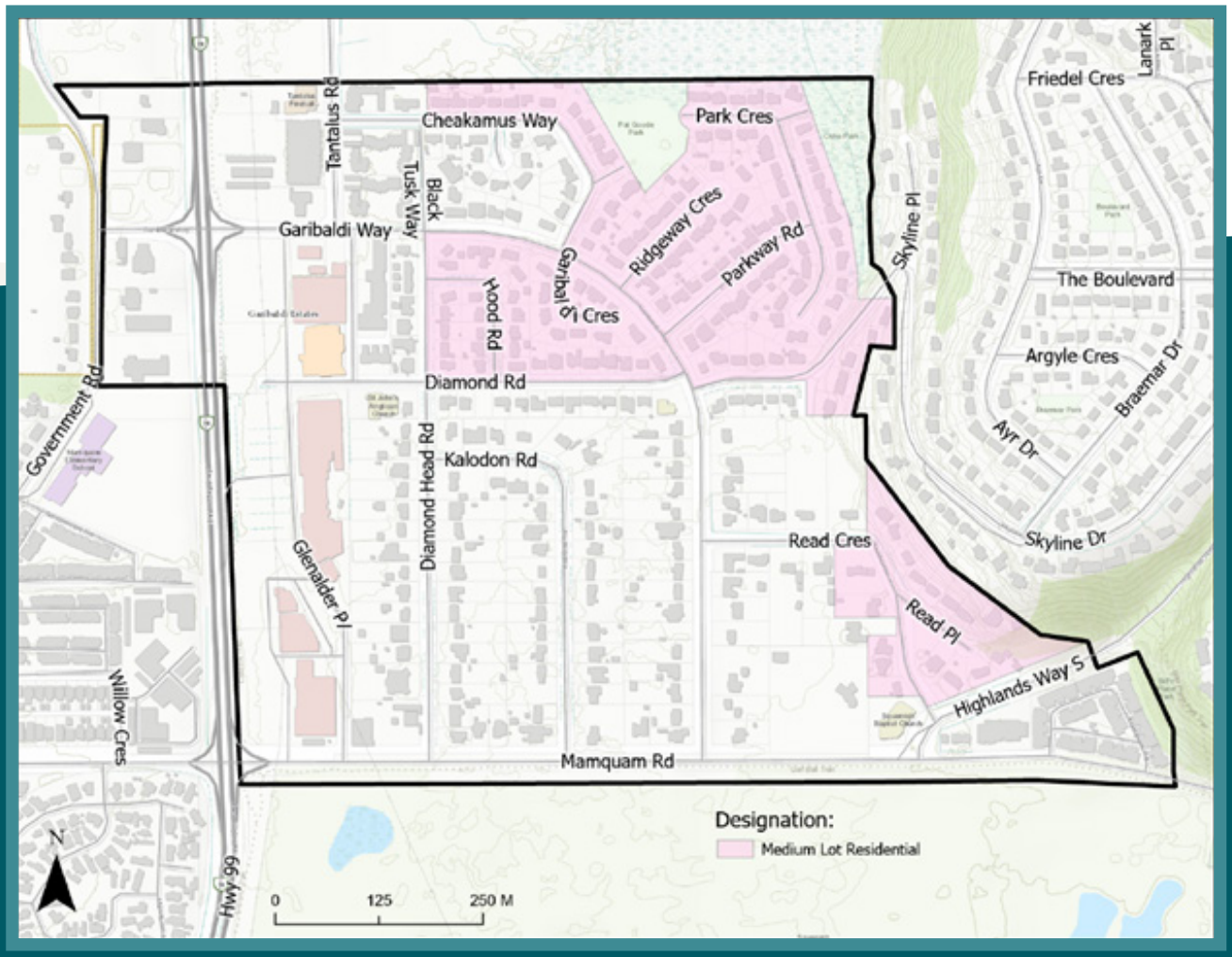
    - Ensure building design has a maximum north-south dimension of 65 m.
    - Should multiple buildings be proposed, site design must ensure buildings are separated by a minimum of 35 metres from one another. This 35-metre separation is intended to function as a pedestrian realm plaza located at ground level for use by employees and customers of all ages and abilities and to provide east-west connectivity through the built form for customers.
    - Provide direct access to an accessible washroom facility from the plaza.
    - Establish a significant landscaping buffer to provide visual screening separating the parking area from the plaza and commercial development.
    - Provide significant electric vehicle and e-bike charging stations close to the plaza.
    - Provide parking spaces for use by a car-share operation close to the plaza.


BCLIQUOR
Firehill Pets


Chevron
TECHRON
ON the RUN.

5.4 Medium Lot Residential

5.4.1 Area



Medium Lot Residential Land Use Designations

5.4.2 Intent

To support a range of small-scale multi-unit housing options, in an established residential neighbourhood within walkable distance to various neighbourhood services and amenities.

5.4.3 Supported Land Uses

- Single-unit dwelling
- Two-unit dwelling
- Multiple Dwelling Residential

5.4.4 Maximum Building Height

Use	Maximum Height
Single-unit Dwelling Two-unit dwelling Multiple Dwelling Residential	Align with District of Squamish R-1 Zoning

5.4.5 Maximum Floor Area Ratio

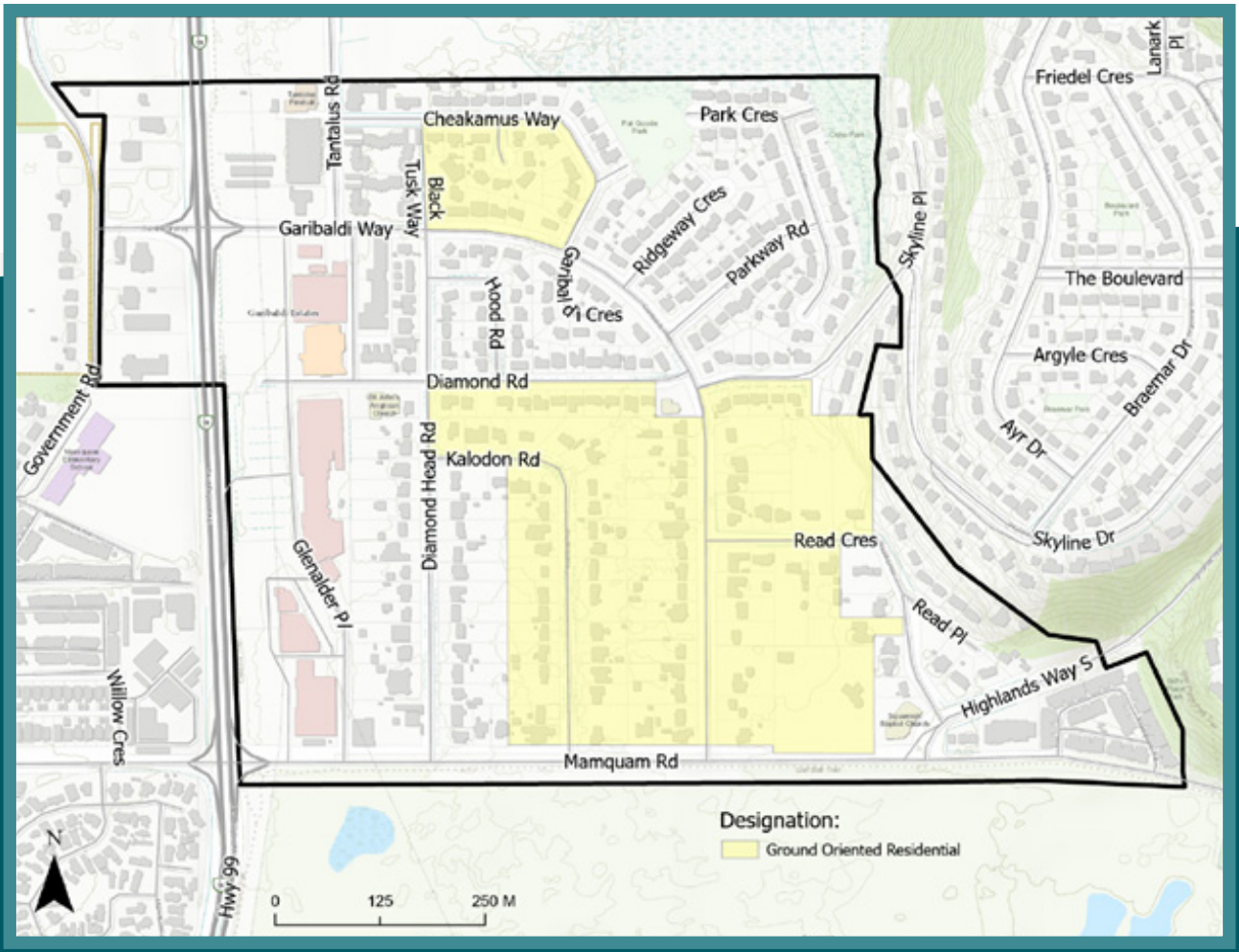
Use	Maximum Floor Area Ratio
Single-unit dwelling Two-unit dwelling Multiple Dwelling Residential	Align with District of Squamish R-1 Zoning

5.4.6 Medium Lot Residential Policies

1. Support the delivery of a diverse range of housing forms in alignment with Provincial guidance on small-scale multi-unit housing.
2. Support accessory commercial units on residential properties to increase access to walkable services throughout neighbourhoods.

5.5 Ground-Oriented Residential

5.5.1 Area



Ground Oriented Residential Land Use Designations

5.5.2 Intent

To support a range of ground-oriented missing-middle housing options, including small-scale multi-unit housing and townhouses, in an established residential neighbourhood within walkable distance to various services and amenities.

5.5.3 Supported Land Uses

- Single-unit dwelling
- Two-unit dwelling
- Multiple Dwelling Residential
- Townhouse on properties a minimum of 0.3 hectares in size

5.5.4 Maximum Building Height

Use	Maximum Height
Single-unit dwelling Two-unit dwelling	Align with District of Squamish R-1 Zoning
Multiple Dwelling Residential Townhouse	3 Storeys

5.5.5 Maximum Floor Area Ratio

Use	Maximum Floor Area Ratio
Single-unit dwelling Two-unit dwelling Multiple Dwelling Residential	Align with District of Squamish R-1 Zoning
Townhouse	0.6 - 0.8

5.5.6 Ground-Oriented Residential Area Policies

1. Support the establishment of a diverse range of housing forms in alignment with Provincial guidance on small-scale multi-unit housing.

2. Support accessory commercial units on residential properties to increase access to walkable services throughout neighbourhoods.

3. Initiate a District-led rezoning of 2163 Mamquam (PID: 014698561) which supports a maximum townhouse FAR of 0.7 with the provision of 27.5% of contiguous land adjacent to a public road as a publicly accessible, activated park secured through a tool such as a land development agreement, before adoption of the rezoning.

4. Site planning and design for any proposed redevelopment of 2163 Mamquam Road (PID: 014698561) should support the connection of the proposed Mamquam Greenway (see Parks and Public Open Space Section) to the active transportation network on Read Crescent to the north and Highlands Way S to the east.

Townhouse Minimum Lot Size and Dimensions

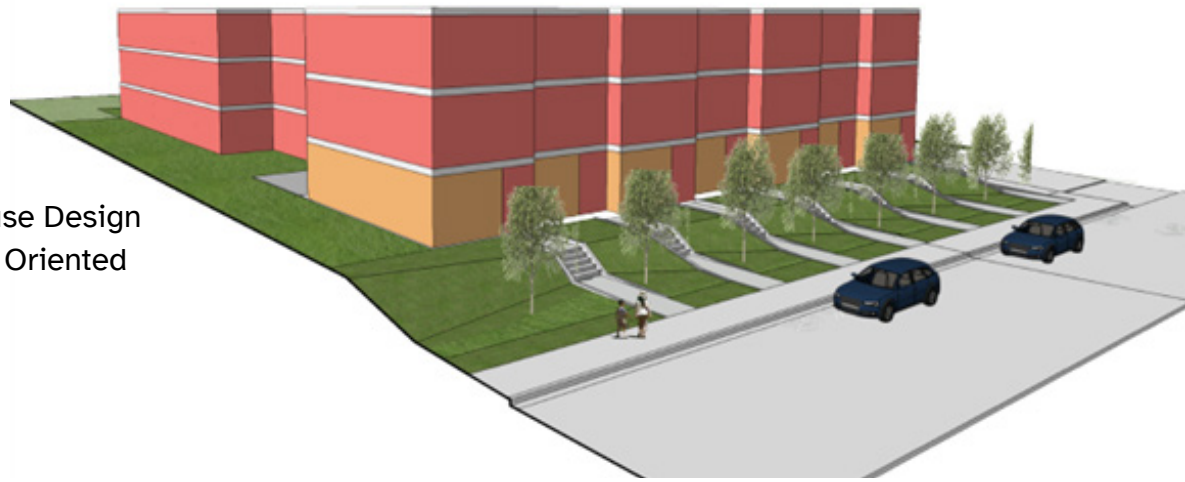
5. Ensure townhouse development properties are an appropriate size to enable efficient land use, maximize usable open space, and minimize allocation of land to driveways. Townhouse developments are only supported on properties with the following characteristics:
   - A minimum lot size of 0.3 ha, and
   - A minimum frontage of 40 m.

Townhouse Density

6. The maximum floor area ratio range is intended to reflect the difference between anticipated by-right (pre-zoned) density, and density that might be achievable through a rezoning process:
   - Following the adoption of this plan, amend the Zoning Bylaw to permit mixed-use development at a floor area ratio of 0.6 by right.
   - Applications for townhouse development at higher densities, up to a floor area ratio of 0.8, may be considered to support improved project viability. To be supported, projects should demonstrate at the rezoning stage strong alignment with the policies of this neighbourhood plan, the OCP, and Zoning Bylaw requirements, including specific considerations for:
     - Ground-oriented residential area policies in this section.
     - Open space requirements and policies, including tree canopy considerations.
     - Access and transportation considerations.
     - Flood construction level.
     - Waste and diversion room regulations.

Townhouse Design

7. Support up to 3.0 metres in addition to the maximum height for principal buildings to enable:
    - rooftop access to a maximum of 12 m^2 gross floor area; and
    - trellises or shade sails.
8. Align setbacks with those of the R-1 zoning, including a reduced font setback, to provide additional opportunity for common open space at the rear of properties.
9. For townhouse units located adjacent to the street:
    - Building entries should be oriented with the long axis of the buildings facing the street, building entries are not supported to face the interior lot line;
    - Pedestrian access should be provided from the sidewalk to the front doors of each unit; and
    - Front yards should be provided as private usable open space in the front setbacks.
10. Townhouse unit design should locate garages and parking spaces in such a way as to minimize visibility from the fronting public street.
11. A minimum distance between buildings of 8.0 metres should be required to enable the provision of drive-isles and walkways, or landscape strips.
12. Provide landscaping strips at entrances and around drive aisles. Landscaping strips should be a minimum of 0.75 metres in width to facilitate healthy plant growth.
13. Pedestrian walkways are encouraged in the following locations, particularly within developments on parcels over 0.45 hectares in size:
    - along strata roads;
    - in common usable open space within the development; and
    - connecting to adjacent sidewalks.
14. Solid waste storage should not face the street and should be accessed by laneways where possible.
15. The use of underground or semi-submerged parking is encouraged where feasible, to maximize contiguous open space adjacent to dwelling units.



Potential Townhouse Design within the Ground Oriented Residential Area.

Townhouse Open Space

16. For properties fronting Garibaldi Way and Kalodon Road, common usable open space in townhouse developments should be consolidated and directed to the rear of properties to maximize tree canopy within the neighbourhood. The tree canopy can be maximized through the preservation of existing mature trees, which are found at the rear of many properties, or by establishing contiguous areas between parcels that back onto one another where new trees can be planted. New trees should be fire-resistant and should not be animal attractants.

17. Encourage the connection of private usable open space located at grade to common usable open space, where possible.

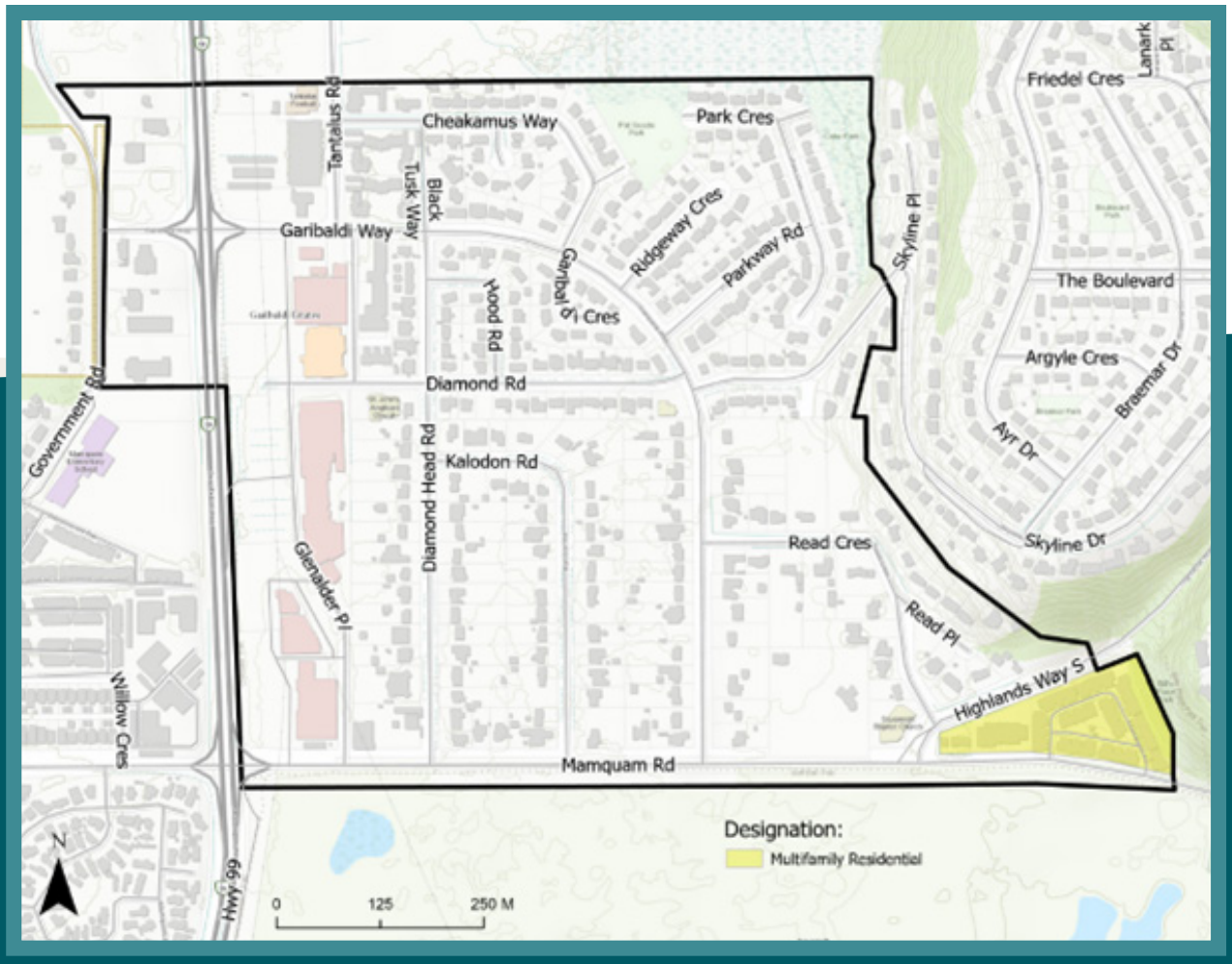
18. For townhouse developments adjacent to Mamquam Road, where frontage improvements are aligned with a District of Squamish design for the Mamquam Greenway, consider support for densities up to 0.8 FAR and reductions in common open space requirements.

Townhouse Community Amenity Contributions

19. Townhouse development projects are expected to provide Community Amenity Contributions (CACs) in line with targets included in the District of Squamish Community Amenity Contribution Policy. For developments on properties over 0.5 hectares in size, CAC contributions can be offset through the dedication of 30% of land to agriculture/greenspace/park.

5.6 Multifamily Residential

5.6.1 Area



Multifamily Residential Land Use Designations

5.6.2 Intent

To support a range of multifamily housing, including apartments and townhouses, which provide diverse housing options for Squamish residents.

5.6.3 Supported Land Uses

- Townhouse
- Apartment

On the two westernmost parcels (PID 030095492 and PID 030095506) the following land uses are supported:

- Single-unit dwellings
- Two-unit dwelling
- Multiple Dwelling Residential

5.6.4 Maximum Building Height

Use	Maximum Height
Single-unit dwelling Two-unit dwelling	Align with District of Squamish R-1 Zoning
Multiple Dwelling Residential Townhouse	3 Storeys
Apartment	15.0 m

5.6.5 Maximum Floor Area Ratio

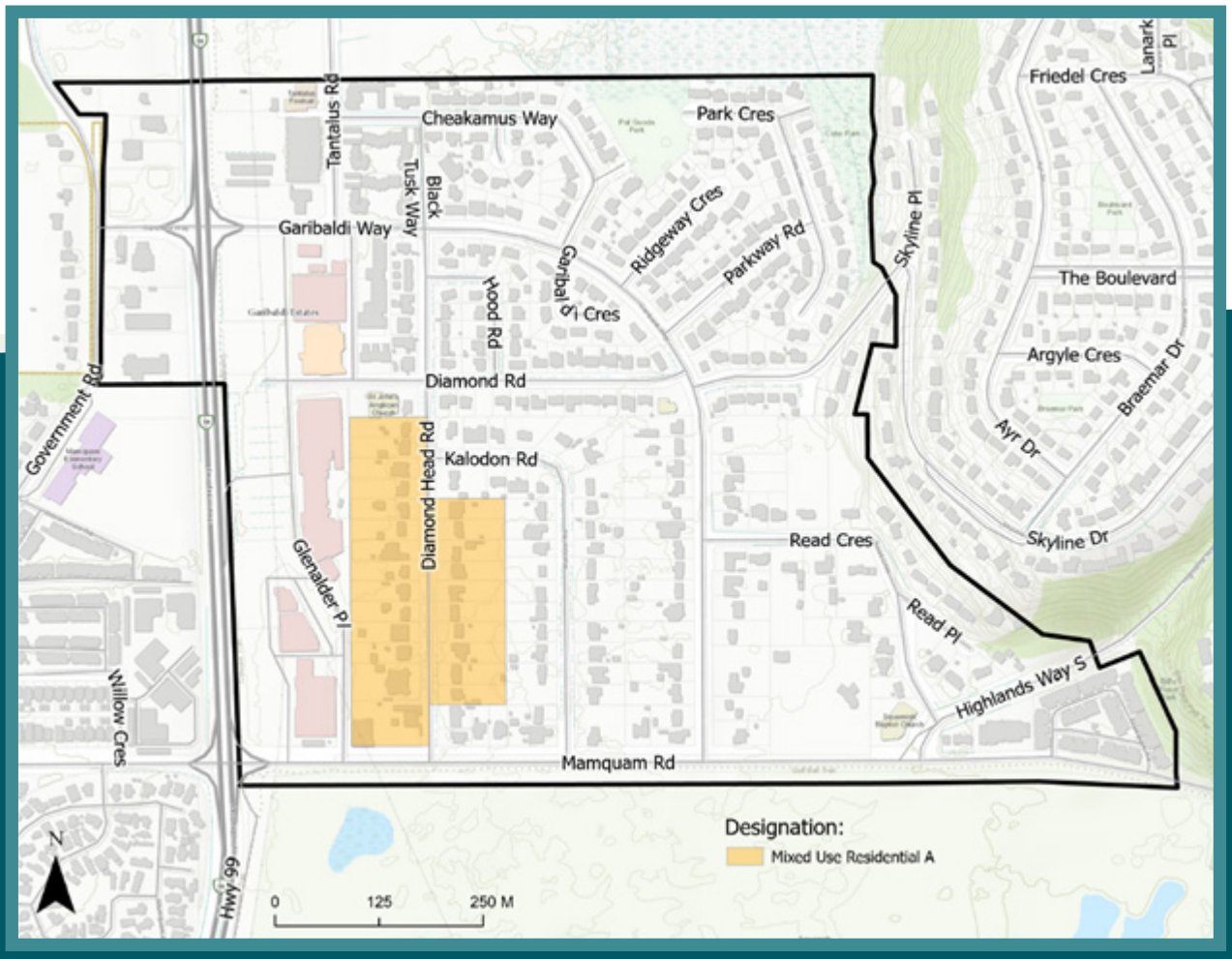
Use	Maximum Floor Area Ratio
Single-unit dwelling Two-unit dwelling Multiple Dwelling Residential	Align with District of Squamish R-1 Zoning
Townhouse Apartment	1.0

5.6.6 Multifamily Residential Policies

Support the establishment of a diverse range of housing forms in alignment with Provincial guidance on small-scale multi-unit housing.

5.7 Mixed-Use Residential A

5.7.1 Area



Mixed-Use Residential A Land Use Designations

5.7.2 Intent

To support mixed-use buildings on large properties along Diamond Head Road with apartments above vibrant retail uses that offer walkable services to the neighbourhood.

Backgrounder: Anticipated Frequent Transit Network Land Uses

As outlined in the Squamish Transit Future Action Plan 2022, service along Diamond Head Road with a 15-minute frequency is a transit goal within the timeframe of this neighbourhood plan. Once at the level of frequent transit service, Provincial small-scale multi-unit legislation tabled in late 2023 will apply to the entire area within the Garibaldi Estates designated Mixed-Use Residential A. Under that provincial legislation, the establishment of any off-street parking requirements for small-scale multi-unit residential uses for properties within the Mixed-Use Residential A area will not be permitted.

In addition, the Transit Future Action Plan anticipates a transit exchange within the vicinity of Garibaldi Village; at that time Provincial legislation pertaining to Transit-Oriented Areas, also tabled in late 2023, is expected to be applicable to a considerable proportion of the Diamond Head Road area. That legislation also prohibits local governments from establishing requirements for off-street residential parking other than for use by persons with disabilities.

Given Provincial legislation related to frequent transit networks and transit-oriented areas, the timelines associated with the development process, and the vision for this area to transition to mixed-use apartments with retail at the street level, consideration of alternative parking standards is appropriate. Parking requirements should reflect the anticipated transit network infrastructure guidance and support transportation goals outlined in the OCP that prioritizes walking, cycling and transit as a hierarchy of transportation modes. Along Diamond Head Road, minimum parking requirements should align with R-1 regulations until 15-minute transit service is established, at which time parking requirements should be removed, in alignment with Provincial requirements.

5.7.3 Supported Land Uses

Mixed-use buildings with retail or institutional uses on the first storey, and residential apartments above

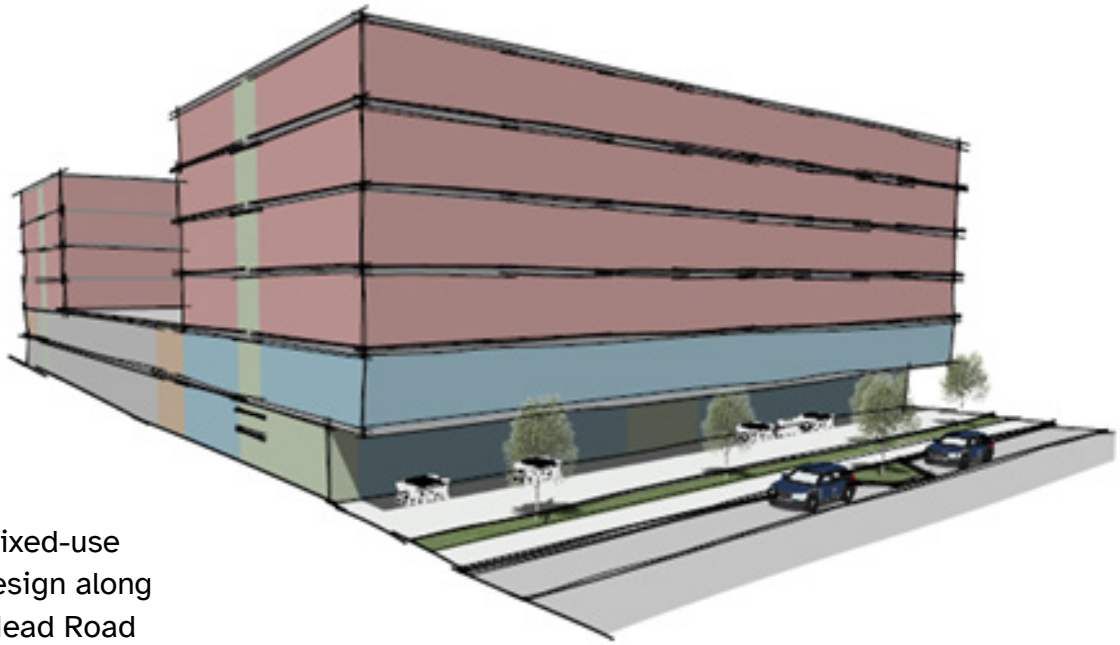
5.7.4 Target Maximum Floor Area Ratio

Use	Maximum Floor Area Ratio
Single-unit dwelling	Align with District of Squamish R-1 Zoning
Mixed-Use Retail/Apartment	0.7 – 2.0

5.7.5 Maximum Building Height

Use	Maximum Height
Use	Maximum Height
Single-unit dwelling	Align with District of Squamish R-1 Zoning
Mixed-Use Retail Apartment	6 Storeys

5.7.6 Mixed-Use Residential A Area Policies



Possible mixed-use frontage design along Diamond Head Road

Mixed-Use Density and Height

1. The maximum floor area ratio range is intended to reflect the difference between anticipated by-right (pre-zoned) density, and density that might be achievable through a rezoning process.

2. Following the adoption of this plan, initiate a District-led amendment to the Zoning Bylaw to permit mixed-use development at a floor area ratio of 0.7. Consider the inclusion of a bonus for 100% rental housing projects to achieve a 6-storey height and a 0.9 floor area ratio.

3. Applications for mixed-use development at higher densities, up to a floor area ratio of 2.0, may be considered. Due to lot configuration, and the need to establish lane access to the rear of properties for parking and solid waste collection, higher densities may be difficult to achieve without consolidation of multiple properties and/or underground parking. Consolidation of multiple properties is supported to address these challenges.

    - To support project viability, the following may be considered through a rezoning application:
        - reduction of common open space requirements, and
        - reduction of employment space requirements, provided the design includes viable retail uses along Diamond Head Road.

    - To be supported, projects should demonstrate strong alignment with the policies of this neighbourhood plan, the OCP, and the District of Squamish zoning bylaw requirements, including specific considerations for:
        - Mixed-Use Residential A area policies in this section.
        - Open space requirements.
        - Bike parking requirements.
        - Driveway access.
        - Flood construction level.
        - Waste and diversion rooms.

Flood Construction Level and Setbacks

4. Development south of Diamond Road is intended to front Diamond Head Road. Retail space should be established at a Flood Construction Level of 0.3 meters above the crown of road, in alignment with the Mashiter Creek Overland Flow Hazard Assessment (BCG 2025). The Flood Construction level is intended to be achieved between the road and building frontage through beveled curbs and gradients across the sidewalks, parking, bikes lanes, landscaped boulevards and open space pedestrian realm adjacent to retail spaces.

5. A front setback of 5.5 meters for mixed-use buildings along Diamond Head Road, south of Diamond Road, should be established in the District of Squamish Zoning Bylaw. Of this setback, the 2.5 meters adjacent to the road should be used as an active transportation setback. The 3.0 meters portion of the setback adjacent to the building should be used as an activated pedestrian realm with opportunities for outdoor seating, outdoor dining and/or landscaping.
6. Above the ground level, cantilevered buildings are supported to project 3.0 m into the setback above the activated pedestrian realm to provide additional opportunities for building floor area, as well as to provide rain shelter for the pedestrian realm.
7. For buildings south of Diamond Road, a rear setback of 9.0 metres should be considered to accommodate the establishment of a 6.0 wide lane for parking and servicing access.
8. Interior side lot line setbacks for mixed-use buildings along Diamond Head Road should be 0.0 metres to support a continuous pedestrian realm along the retail frontage. A larger setback may be appropriate in limited locations where mid-block connections are appropriate.

Mixed-Use Design

9. Support up to 3.0 metres in addition to the maximum height for principal buildings to enable:
    - Stairs and elevator providing rooftop access to common open space; and
    - trellises or shade sails.

10. Solid waste collection should be within a dedicated waste and diversion room, preferably at the rear of the property, accessed through the rear laneway.

Mixed-Use Commercial Floor Area

11. In mixed-use buildings along Diamond Head Road, 20% of the gross floor area should be considered for commercial employment space.

Mixed-Use Parking Requirements

12. The Zoning Bylaw should be amended to establish or eliminate minimum parking requirements for the Mixed-Use Residential A that consider Provincial legislation related to frequent transit networks.
    - Following the adoption of the neighbourhood plan, specific minimum parking requirements for residential uses should reflect the requirements of the R-1 zone.
    - Once frequent transit that meets Provincial criteria is established, parking requirements should be removed, in alignment with Provincial legislation.

13. Consider permitting shared use of visitor and commercial parking spaces for mixed-use buildings. For development applications at the upper end of the supported FAR, consider support for the elimination of visitor and commercial parking requirements to increase development viability.

Mixed-Use Parking and Servicing Access

14. Parking and solid waste collection for mixed-use buildings should be accessed from the rear of the properties using a north-south lane where possible.

15. In tandem with the redevelopment process, establish north-south, 6-metre-wide, public lanes along the rear lot line of properties utilizing a variety of land acquisition strategies to provide public access to the rear lot line.

16. Prior to the completion of the north-south lanes, development applications will need to establish access to the rear of properties to support parking and servicing. This is expected to necessitate a development design that includes public, east-west access easements between Diamond Head Road and the anticipated north-south lane locations. Consolidation of multiple properties to establish frontages of at least 70 m is expected to be necessary to ensure sufficient space for the dedication of these east-west easements, which should provide connectivity for adjacent development opportunities. Once the complete north-south lanes have been established, the east-west easements should be considered for discharge and conversion to mid-block active transportation connections; mechanisms to support this transition should be considered during the development application process.

17. Redevelopment of properties designated Mixed-Use Residential B along Mamquam Road and Kalodon Road is supported to establish the initial sections of a north-south lane. Incremental additions to the lane are encouraged through successive development on adjacent properties.

Overland Flow Hazard

18. Ensure new development aligns with recommendations of the Mashiter Creek Overland Flood Hazard Assessment.

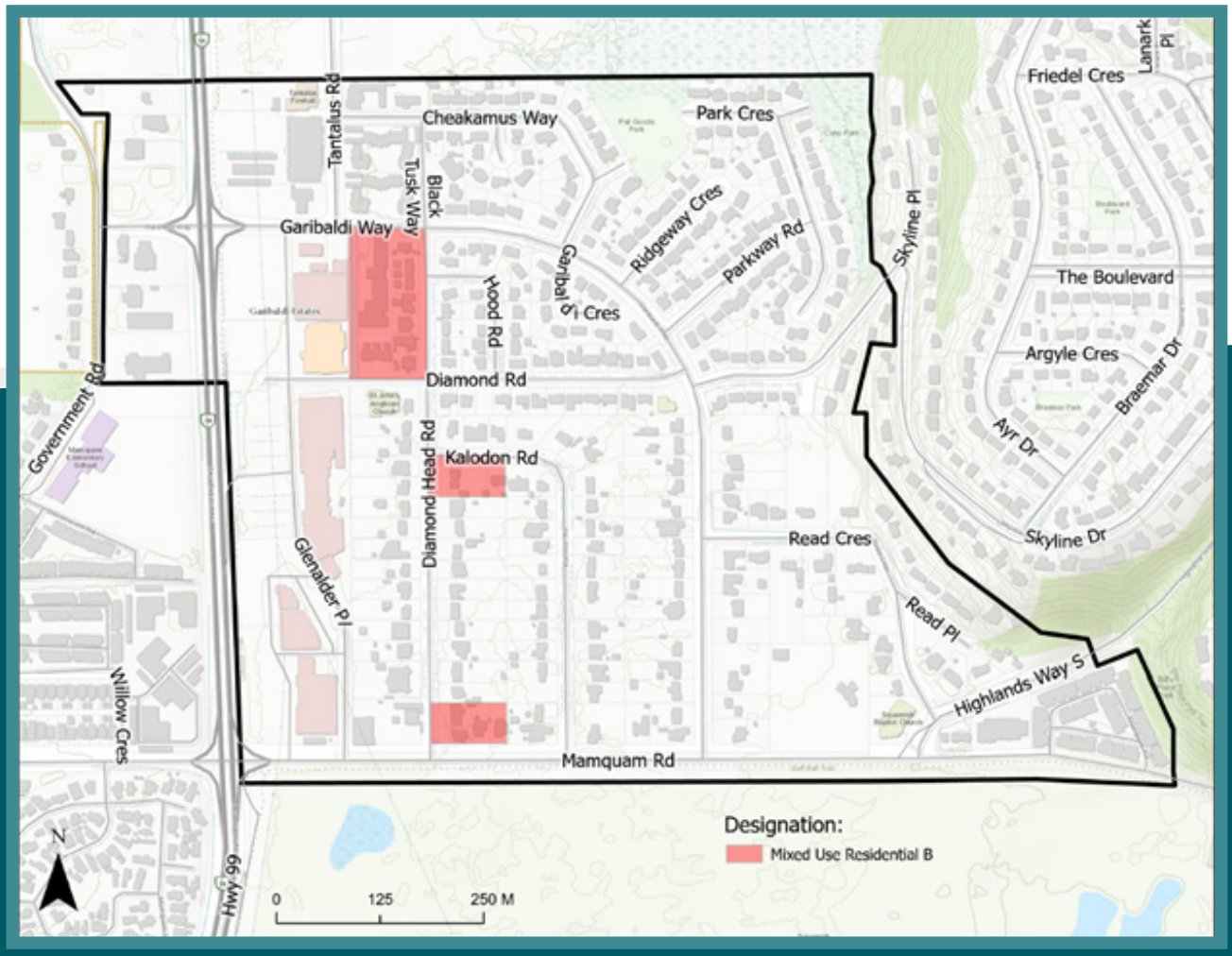
Backgrounder: Anticipated Frequent Transit Network Land Uses

As outlined in the Squamish Transit Future Action Plan 2022, service along Diamond Head Road with a 15-minute frequency is a transit goal within the timeframe of this neighbourhood plan. Once at the level of frequent transit service, Provincial small-scale multi-unit legislation tabled in late 2023 will apply to the entire area within the Garibaldi Estates designated Mixed-Use Residential A. Under that provincial legislation, the establishment of any off-street parking requirements for small-scale multi-unit residential uses within the Mixed-Use Residential A area will not be permitted.

In addition, the Transit Future Action Plan anticipates a transit exchange within the vicinity of Garibaldi Village; at that time Provincial legislation for Transit-Oriented Areas, also tabled in late 2023, is expected to apply to a considerable proportion of the Diamond Head Road area. That legislation also prohibits local governments from establishing requirements for off-street residential parking other than for use by persons with disabilities.

Given Provincial legislation related to frequent transit networks and transit-oriented areas, the timelines associated with the development process, and the vision for this area to transition to mixed-use apartments with retail at the street level, consideration of alternative parking standards is appropriate. Parking requirements should reflect the anticipated transit network infrastructure guidance and support transportation goals outlined in the OCP that prioritizes walking, cycling and transit as a hierarchy of transportation modes. Along Diamond Head Road, minimum parking requirements should align with R-1 regulations until 15-minute transit service is established, at which time parking requirements should be removed, in alignment with Provincial requirements.

5.8 Mixed-Use Residential B



Mixed-Use Residential B Land Use Designations

5.8.1 Intent

To support housing diversity in mixed-use buildings and apartments on smaller properties near Diamond Head Road with apartments above vibrant retail uses that offer walkable services to the neighbourhood.

To recognize the challenges for mixed-use development on smaller parcels and parcels which may benefit from consolidation, and to encourage redevelopment of parcels that could support important transportation connections in the Diamond Head Road area.

5.8.2 Supported Land Uses

- Mixed-use building with retail or institutional uses on the first storey, and residential apartments above.
- Residential apartments on the following parcels:
  - PID 007-161-182 (40261 KALODON RD)
  - PID 007-191-987 (1959 MAMQUAM RD)
  - PID 007-191-979 (1949 MAMQUAM RD) if consolidated with PID 007-191-987 (1959 MAMQUAM RD)
- Two-unit dwelling and Multiple Dwelling Residential along Diamond Head Road north of Diamond Road.

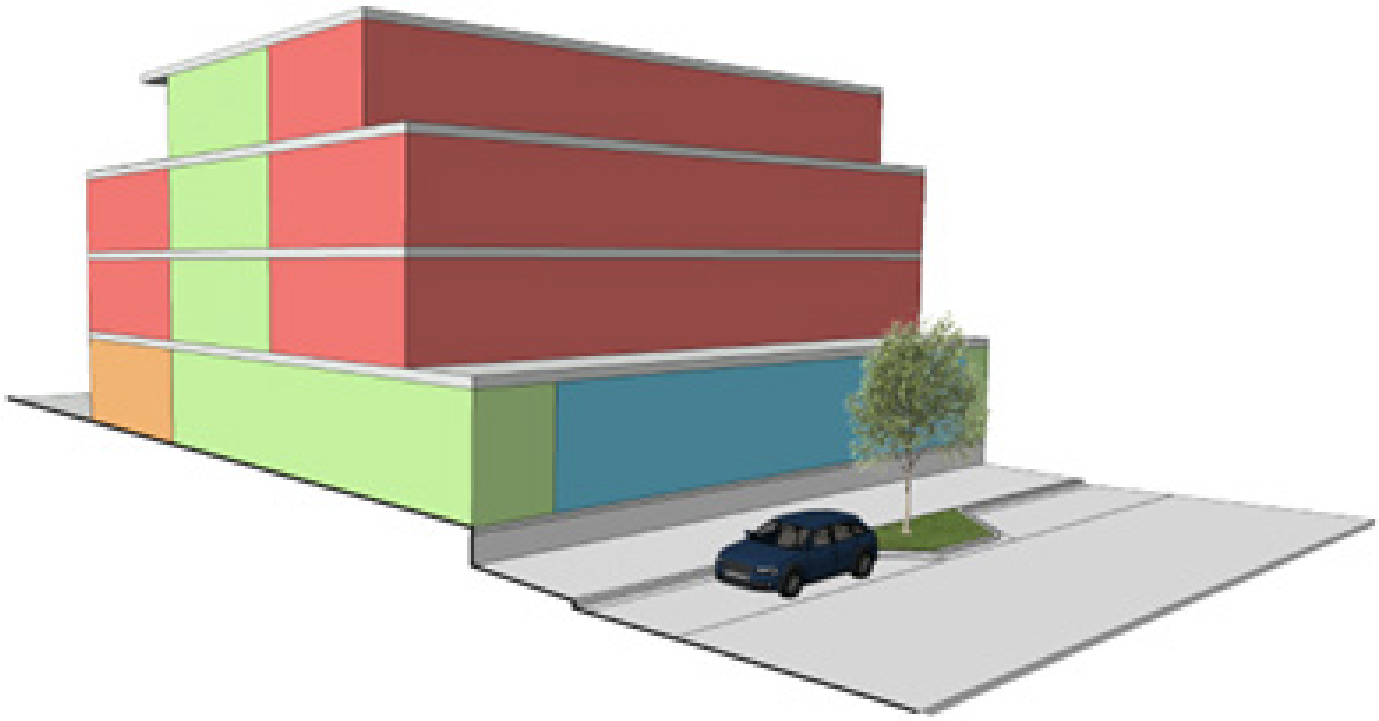
5.8.3 Maximum Building Height

Use	Maximum Height
Single-unit dwelling Two-unit dwelling Multiple Dwelling Residential	Align with District of Squamish R-1 Zoning
Mixed-Use Retail Apartment	6 Storeys

5.8.4 Maximum Floor Area Ratio

Use	Maximum Floor Area Ratio
Single-unit dwelling Two-unit dwelling Multiple Dwelling Residential	Align with District of Squamish R-1 Zoning
Mixed-Use Retail/Apartment	1.3 - 1.6 North of Diamond Rd 1.3 - 2.0 South of Diamond Rd
Apartment	1.3 - 2.0

5.8.5 Mixed-Use Residential B Policies



Possible mixed-use design fronting Diamond Head Road north of Diamond Road

Mixed-Use and Apartment Density

1. The maximum floor area ratio range is intended to reflect the difference between anticipated by-right (pre-zoned) density, and density that might be achievable through a rezoning process.
2. Following the adoption of this plan, initiate a District-led amendment to the Zoning Bylaw to permit mixed-use development at a floor area ratio of 1.3.
3. Applications for mixed-use development at higher densities, up to a floor area ratio of 1.6, may be considered. Due to lot configuration and the need to ensure lane access to the rear of properties for parking and solid waste collection, higher densities may be difficult to achieve without consolidation of multiple properties and/or underground parking. Consolidation of multiple properties is supported to address these challenges.
    - To support project viability, the following may be considered through a rezoning application:
        - reduction of common open space requirements, and
        - reduction of employment space requirements, provided the design includes viable retail uses along fronting roads.

- To be supported, projects should demonstrate strong alignment with the policies of this neighbourhood plan, the OCP, and the District of Squamish zoning bylaw requirements, including specific considerations for:
  - Mixed-Use Residential B area policies in this section.
  - Open space requirements.
  - Bike parking requirements.
  - Driveway access.
  - Flood construction level.
  - Waste and diversion room guidelines.

Flood Construction Level and Setbacks - Diamond Head Road North of Diamond Road

4. Along Diamond Head Road north of Diamond Road, the plan supports mixed use development with retail at the ground level fronting Diamond Head Road, and residential uses above. Retail space should be established at a Flood Construction Level of 0.3 meters above the crown of road, in alignment with the Mashiter Creek Overland Flow Hazard Assessment (BCG 2025). The Flood Construction level is intended to be achieved between the road and building frontage through beveled curbs and gradients across landscaped boulevards, sidewalks, bikes lanes and/or parking.

5. A front setback of 0.5 meters for buildings along the west side of Diamond Head Road north of Diamond Road, should be established in the District of Squamish Zoning Bylaw. This setback should be used as an active transportation setback.

6. Interior side lot line setbacks along Diamond Head Road north of Diamond Road should be 0.0 metres to support a continuous pedestrian realm along the retail frontage.

Flood Construction Level and Setbacks - Diamond Head Road South of Diamond Road

7. Along Diamond Head Road south of Diamond Road, the plan supports mixed use development with retail at the ground level fronting Diamond Head Road, and residential uses above. Retail space should be established at a Flood Construction Level of 0.3 meters above the crown of road, in alignment with the Mashiter Creek Overland Flow Hazard Assessment (BCG 2025). The Flood Construction level is intended to be achieved between the road and building frontage through beveled curbs and gradients across the sidewalks, parking, bikes lanes, landscaped boulevards and open space pedestrian realm adjacent to retail spaces.

8. A front setback of 5.5 meters for buildings along Diamond Head Road, south of Diamond Road, should be established in the District of Squamish Zoning Bylaw. Of this setback, the 2.5 meters adjacent to the road should be used as an active transportation setback. The 3.0 meter portion of the setback adjacent to the building should be used as an activated pedestrian realm with opportunities for outdoor seating, outdoor dining and/or landscaping.

9. For mixed-use buildings along Diamond Head Road south of Diamond Road, above the ground level, cantilevered buildings are permitted to project 3.0 m over the setback above the activated pedestrian realm to provide additional opportunities for building floor area, as well as to provide rain shelter for the pedestrian realm.

10. For buildings south of Diamond Road, along the proposed alignment of a rear north-south lane between Mamquam Road and Kalodon road, a setback should be considered to accommodate the establishment of a 6.0 wide lane for parking and servicing access.

Flood Construction Level and Setbacks – Tantalus Road South of Garibaldi Way

11. Along Tantalus Road south of Garibaldi Way, the plan supports mixed use development with retail at the ground level fronting Tantalus Road, and residential uses above. Retail space should be established at a Flood Construction Level of 0.3 meters above the crown of road, in alignment with the Mashiter Creek Overland Flow Hazard Assessment (BCG 2025). The Flood Construction level is intended to be achieved between the road and building frontage through beveled curbs and gradients across the sidewalks, landscaped boulevards and possibly bike lanes.

12. A front setback of 2.0 meters for buildings along Tantalus Road, south of Garibaldi Way, should be established in the District of Squamish Zoning Bylaw. This setback should be used as an active transportation setback.

13. Interior side lot line setbacks along Tantalus Road south of Garibaldi Way should be 0.0 metres to support a continuous pedestrian realm along the retail frontage.

Mixed-Use Commercial Floor Area

14. In mixed-use buildings along Diamond Head Road, a minimum of 20% of gross floor area should be considered for commercial employment space.

Design

15. Support up to 3.0 metres in addition to the maximum height for principal buildings to enable features such as:

    - Stairs and elevator providing rooftop access to common open space; and
    - trellises or shade sails.

16. Solid waste collection should be within a dedicated waste and diversion room, preferably at the rear of the property, accessed through the rear laneway.

17. Innovative solutions should be encouraged to provide social spaces across multiple levels through building mass, variation, and integration to meet common usable open space

requirements.

Parking Requirements

18. The Zoning Bylaw should be amended to establish or eliminate minimum parking requirements for the Mixed-Use Residential B that consider Provincial legislation related to frequent transit networks.

    - Following the adoption of the neighbourhood plan, specific minimum parking requirements for residential uses should reflect requirements of the R-1 zone or the general zoning regulations/practices applicable across the community.
    - Once frequent transit that meets Provincial criteria is established, parking requirements should be removed, in alignment with Provincial legislation.

19. Consider permitting shared use of visitor and commercial parking spaces for mixed-use buildings. For development applications at the upper end of the supported FAR, consider support for the elimination of visitor and commercial parking requirements to increase development viability.

Parking and Servicing Access

20. For properties north of Diamond Road and West Diamond Head Road, where possible, access to parking and solid waste facilities for mixed-use buildings and apartments should be from the established rear lane to support the development of a continuous pedestrian realm along retail frontages.

21. For properties east of Diamond Head Road and south of Diamond Road:

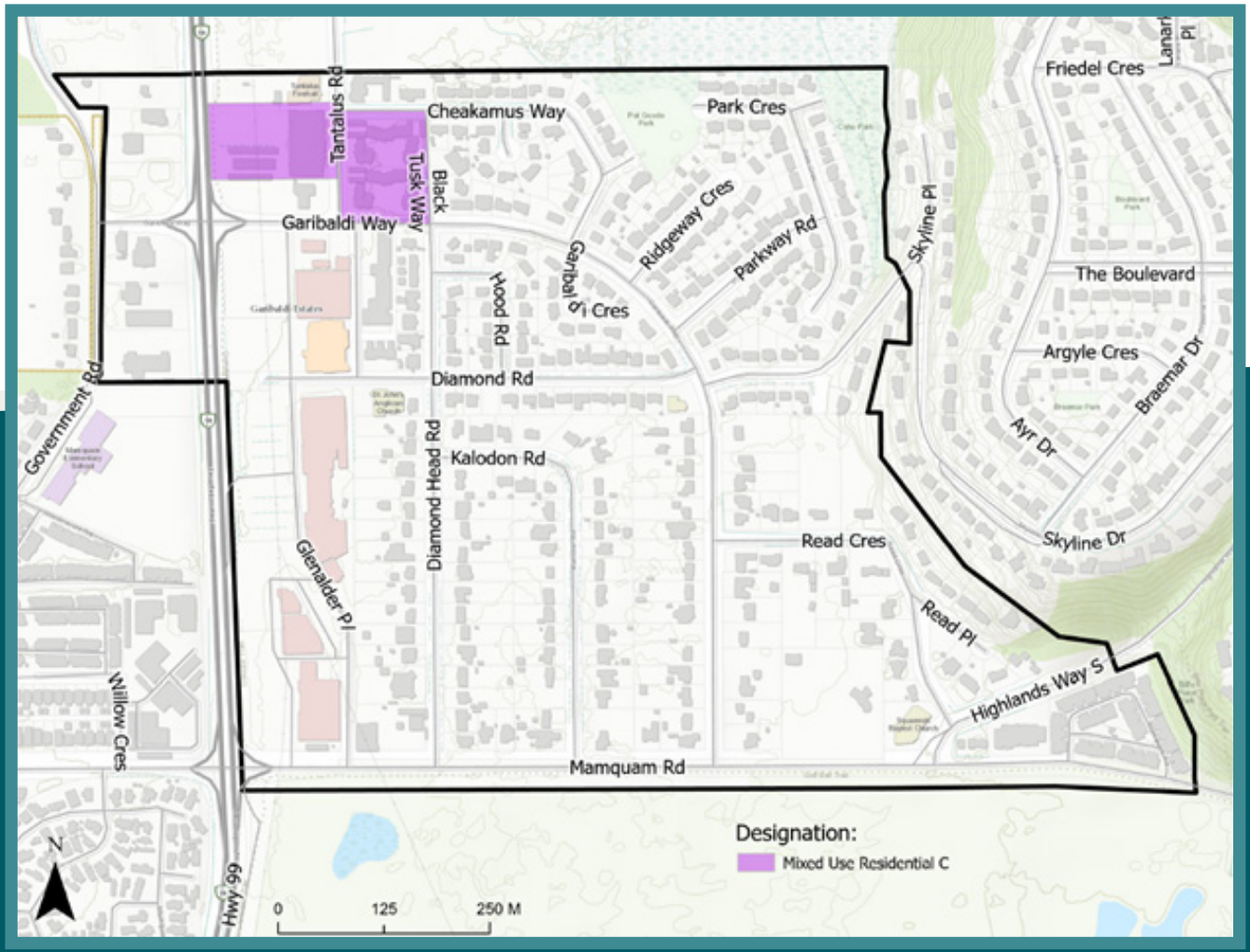
    - Development applications should support the establishment of a public access lane connecting Kalodon Road at the north end and Mamquam Road at the south end, utilizing a variety of land acquisition strategies by the District of Squamish.
    - Where possible, parking and solid waste collection for mixed-use or apartment buildings should be accessed from the public access lane on the eastern side.
    - Consolidation of properties along Mamquam Road is encouraged to support practical access points from a public access lane.
    - Consider supporting an increase in height and density to enable viable development projects where consolidation of multiple lots is beneficial to the establishment of a public access lane and achieving the intended development pattern with mixed-use buildings and a pedestrian realm along Diamond Head Road.
    - Residential development without a mixed-use retail component is supported for the following three specific properties to increase project viability and facilitate the establishment of a public access lane connecting Kalodon Road at the north end and Mamquam Road at the south end:

        - PID 007-161-182 (40261 KALODON RD)
        - PID 007-191-987 (1959 MAMQUAM RD)
        - PID 007-191-979 (1949 MAMQUAM RD) if consolidated with PID 007-191-987 (1959

MAMQUAM RD)

5.9 Mixed-Use Residential C

5.9.1 Area



5.9.2 Intent

To support housing diversity within the Garibaldi Estates, including mixed-use apartments and rental

tenure units, in combination with retail space that offers walkable services to the neighbourhood.

5.9.3 Supported Land Uses

Mixed-use buildings with retail commercial on the first storey, and residential apartments above.

5.9.4 Maximum Building Height

Use	Maximum Height
Mixed-Use Retail Apartment	6 Storeys

5.9.5 Maximum Floor Area Ratio

Use	Maximum Floor Area Ratio
Mixed-Use Retail/Apartment	2.0

5.9.6 Mixed-Use Residential C Policies

1. Development applications should support improvements to existing transportation infrastructure including the intersection at Garibaldi Way and Tantalus Road.
2. Development applications along Tantalus Road and Mamquam Road should include pedestrian-oriented retail development at the ground level that supports a vibrant public realm and activated street frontage.
3. In mixed-use buildings, a minimum of 20% of gross floor area should be used for commercial employment space.
4. The provision and integration of childcare space is strongly encouraged. The Mixed-Use Residential C area represents one of the most important opportunities to establish a larger childcare facility within the plan area.
5. The use of underground or semi-submerged parking is encouraged where feasible, to maximize contiguous open space.
6. The design of developments along Black Tusk Way and the lane that continues north from Black Tusk Way should consider opportunities to address the height discrepancy between the adjacent land uses. Lower building heights or upper-storey setbacks for buildings west of Black Tusk Way should be considered in this area to reduce the impact on properties east of Black

Tusk Way.

6. POLICIES

6.1 Housing

Diverse Housing Proposed on Garibaldi Way — Long-term vision

6.1.1 Background

Residential areas in the Garibaldi Estates are close to a diverse range of services, amenities, parks, greenspace, and transportation opportunities. These characteristics make the neighbourhood a desirable place to live and provide an important opportunity within the District of Squamish to support missing middle housing forms. The Garibaldi Estates Neighborhood Planning Process is intended to consider this opportunity.

In November 2023, partway through the Garibaldi Estates Planning Process, the Province of British Columbia announced changes to the Local Government Act as part of the Homes for People Plan. These changes are intended to support housing diversity within municipalities. These changes include mandatory zoning for small-scale multi-unit housing and reduced parking requirements for properties within specific distances of transit stops on frequent transit networks.

Residential policies within this plan have been drafted to address the results of the Garibaldi Estates planning process, as well as new Provincial requirements under the Homes for People Plan.

Garibaldi Estates Dwelling Unit Projections

To understand infill growth potential within the Garibaldi Estates under the land use designations included within this plan, the existing land uses were compared to a theoretical potential, as well as a high and low growth land use scenario for the year 2044.

The Existing scenario reflects current land uses. In 2024, the total number of existing dwelling units within the Garibaldi Estates is 546 dwellings, with single-unit dwellings forming the largest proportion, followed by apartments and then townhouses.

Scenario	Single Unit Dwellings & Suites	Duplexes & Multiple Dwelling Residential	Townhouse Dwellings	Apartment Units	Total Dwelling Units
Existing	301	16	63	166	546
Plan Maximum	0	985	644	1168	2797
2044 High	206	200	358	756	1520
2044 Low	269	68	163	367	867

2024 Existing and Projected Dwelling Units in the Garibaldi Estates

The Plan Maximum scenario reflects an assumption that every property in the Garibaldi Estates Neighbourhood transitions to the maximum density option supported within the plan. This scenario would result in approximately 2,800 total homes with apartments making up the largest proportion, followed by multiple-dwelling residential and townhouses. However, given the magnitude of change the scenario reflects, this scenario does not represent a possible future reality.

A more nuanced scenario for the year 2044 is represented in the 2044 High scenario. This scenario represents a high growth estimate over the coming decades based on past trends and expectations. This 2044 High scenario would result in 1,520 total dwelling units by 2044, with apartments making up the largest proportion, followed by townhouses and then a roughly equal split between single-unit dwellings and multiple dwelling residential units. Approximately 80 existing single-unit dwellings would be replaced with new housing forms, resulting in a total of approximately 1,000 new dwelling units in the neighbourhood.

The 2044 Low scenario has been calibrated against the expected growth rate for the community and the total development potential. In this scenario, approximately 320 new dwelling units could be expected to be completed in the Garibaldi Estates by 2044 for a total of 867 dwelling units. In

this scenario, apartments make up the largest proportion of dwelling units, followed by single-unit dwellings, then townhouses and finally multiple-dwelling residential units. Approximately 30 existing single-unit dwellings would be replaced with new housing forms, resulting in a total of approximately 320 new dwelling units in the neighbourhood.

It is important to note that housing projections in the 2044 Low Scenario are significantly below the 2023 District of Squamish Housing Needs Report, which projected that, under a high growth scenario, 6,840 new homes are needed by 2031.

The most likely outcome is that the total number of residential units in the Garibaldi Estates in 2044 will be somewhere between the 2044 Low scenario at 867 dwelling units and the 2044 High scenario at 1,520 units. The true rate of growth will depend on a broad range of economic, demographic, and political trends which are challenging to accurately predict.

The scenarios depicted above are dependent on numerous assumptions, which are outlined in Appendix A.

6.1.2 Objectives

1. To support a diverse mix of housing options in the Garibaldi Estates that meet the needs of current and future residents.
2. To support the establishment of a cohousing development within the Garibaldi Estates.

6.1.3 Policies

Diverse Housing

1. Encourage and support a mix of unit sizes, housing types, and tenure across the neighbourhood, including apartments, townhouses, multiple dwelling residential, secondary suites and accessory dwelling units, two-unit dwellings and single-unit dwellings.
2. Support senior housing facilities within proximity of services and amenities.
3. Support the use of tiny homes in the Garibaldi Estates, provided they align with provincial and municipal regulatory requirements.
4. The implementation of policy recommendations included in the District of Squamish Deconstruction & Demolition Report 2021 is encouraged to mitigate deconstruction and demolition impacts associated with infill development.

Affordable Housing

5. Support non-market housing throughout the neighbourhood on all properties where residential land uses are permitted.
6. Support increases to height and density beyond policies outlined in the land use designations for development projects aligned with the following critical housing priorities:
    - 100% secured market rental housing;
    - 100% non-market co-op housing (member-owned and controlled residential development);
    - housing developed by or in partnership with the Squamish Nation.
7. For redevelopment of existing purpose-built rental buildings, support additional height and density, beyond policies outlined in the Garibaldi Estates Neighborhood Plan land use designations, provided the proposed development includes dedicated rental units in alignment with the Perpetually Affordable Housing Policy or comparable District of Squamish policy. The number and size of proposed rental dwelling units should meet or exceed the number and size of existing rental dwelling units.
8. Affordable housing projects owned by a government agency or non-profit organization are not subject to a maximum building height or gross floor area restrictions, in alignment with the District of Squamish Zoning Bylaw.
9. Encourage the development of affordable housing projects on land designated Institutional within the Garibaldi Estates.

Parking Requirements

10. For townhouse developments utilizing tandem parking, consider locating one of the required parking spaces in an unenclosed carport to maximize the use of the space for parking.
11. Enclosed parking spaces in townhouse developments may include garage entrances and sizes that are suitable for large vehicles frequently owned by Squamish residents.

Backgrounder: Cohousing

Cohousing typically refers to residential developments with the following characteristics:

- Cohousing is neither a specific ownership structure nor tenure. Cohousing can take form as a stratified, co-op structure or take place in a single unit dwelling.
- Cohousing projects can support intergenerational housing through the inclusion of accessible ground-oriented units in combination with larger, family-oriented units.
- Cohousing developments can include affordable housing units rented at below-market rates.
- Cohousing units can be structured to face inwards towards a central shared space.
- Increased common areas in cohousing developments allow homes with smaller private spaces.
- Cohousing in multi-unit form can operate optimally in size between 25-35 units.
- Support the creation of an intentional, collaborative community of private homes clustered around shared space.
- Address alienation found in modern housing developments where few people know their neighbours and there is little sense of community.
- Support the combination of autonomous compact self-contained private dwellings with the benefits of shared, spacious community amenities within individual residential developments.

12. To qualify for the cohousing zoning exceptions, development projects should have the following cohousing characteristics: Indoor amenity space that supports spontaneous connections and may include meeting spaces and nooks with seating, gathering spaces, community workshops, guest bedrooms, and children's playrooms. Consider a target of 7% of the project's gross floor area for indoor amenity space.

    - A communal kitchen and dining area equipped with facilities for heating food and baking. Consider a target of accommodating 65% of projected residents. Commercial-grade cooking facilities are not required.
    - Common usable open space with amenities that facilitate spontaneous connection such as garden allotments, children's play areas, gathering spaces, or central pedestrian common areas. A communal kitchen and dining area equipped with facilities for heating food and baking. Consider a target of accommodating 65% of projected residents. Commercial-grade cooking facilities are not required.

13. Projects that meet the identified cohousing characteristics may be eligible for the following cohousing zoning exceptions:

    - Exemption from, or reduction of, the standard employment space requirements in the Mixed-Use Residential A area.
    - Exemption of indoor amenity space beyond requirements in the District of Squamish Zoning Bylaw from gross floor area calculations.

14. Increased by-right (pre-zoned) maximum floor area ratio of up to 0.8, rather than 0.7 as identified in the Multi-Family Residential A area.

6.2 Parks and Public Open Space

6.2.1 Background

Parks and open space are an essential part of the Garibaldi Estates Neighborhood. These assets allow residents to access nature, and participate in recreation opportunities, and outdoor gatherings.

As the Garibaldi Estates neighbourhood grows and accommodates more residents, it is important to ensure residents are well served by parks and open spaces. These amenities should be accessible to all residents and provide options for recreation and play within the community.

Engagement activities for the Garibaldi Estates Neighbourhood Planning Process highlighted that residents would like access to a range of public open space options. Examples of these amenities include more park space, communal outdoor space such as pocket parks, additional benches and seating areas, covered spaces that can be used year-round, elements that appeal to a range of ages, including structures geared to older kids, a dog park, activated places for more mature residents, facilities and spaces designed for teens, public washrooms at parks and trailheads, and public art.

6.2.2 Objectives

1. To ensure sufficient and well-located park space that provides active and passive recreational opportunities to meet the diverse needs of the neighbourhood.
2. To create a vibrant, resilient, and healthy neighbourhood with unique public spaces that support public gatherings and connection.

6.2.3 Policies

New Neighbourhood Park

1. Establish a new Neighbourhood Park in the Garibaldi Estates Neighbourhood, in alignment with the 2012 District of Squamish Parks and Recreation Master Plan (PRMP), which identifies the neighbourhood location as a Potential Underserved Area.
2. The new neighbourhood park should be of sufficient size. Consider the PRMP's Park Acquisition Guidelines.

3. The new neighbourhood park should meet the active and passive recreation needs of the neighbourhood. It should include a playground (with high play value equipment to meet the needs of 0-5 years and 5-12 years), multi-use sports court(s), public washroom, open grass area for playing sports, paths, seating, area for teens to be social, planting beds, trees and site furnishings (e.g. waste receptacles, lights, bike racks, benches).

4. The creation of a new municipal park will depend on factors such as available land parcels, development opportunities and funding options. Some options that can be used to establish a new park could include:

    - Acquisition of a portion of a property under consideration for development as part of a rezoning process. Consider a variance to common usable open space requirements, for larger developments that consolidate properties and offer land for a Neighbourhood Park as part of a community amenity contribution.
    - Purchase of property funded in part by development cost charges or amenity cost charges.
    - Utilization of existing municipal land.

5. The design of new neighbourhood parks should include thoughtfully designed gathering spaces and sports/play areas.

Public Open Space

6. Develop high-quality public open space throughout the Garibaldi Estates. Public open space can be located in parks, on District of Squamish-owned land, along multi-modal paths, on boulevards, within front setbacks, on or near trails, and incorporate existing natural areas and existing trees.

7. Public open spaces to be considered include the following:

    - Pocket parks, sidewalk extension that provides more space and amenities for people using the street, and corner plazas.
    - Public park spaces created through multi-family developments.
    - Areas with multiple seating options in a variety of locations including sheltered/shaded areas, commercial patios with public use Rights-of-Way, and transit stops.
    - Landscaping, planters, and murals.
    - Community gardens.
    - Public washroom.
    - All-weather covered spaces.
    - Bike shelters.
    - Public art (pedestrian infrastructure, lit gathering spaces, indigenous works).

Enhance Amenities at Existing Parks

8. Incorporate high quality, high play value, low maintenance, CSA standard play structures that fit Squamish aesthetic to existing child play areas.
9. Install accessible, covered seating in parks to encourage gathering and year-round use.
10. Incorporate “foyer” style entrances at the gate of parks for gathering and opportunity for information about the space or activation opportunities.
11. Ensure active transportation infrastructure along road access to District parks.
12. Provide facilities in parks to support cycling such as covered bike racks.
13. Incorporate wayfinding to Coho Park along access roads.
14. Enhance Pat Goode Park by adding some of the following amenities:
    - A covered space that can be used year-round.
    - Elements that are intended for older kids (i.e. pump track, features that facilitate youth hanging out, etc.).
    - Elements for mature residents such as a fitness circuit, chess tables or picnic areas.
    - Improved public parking.

Mamquam Greenway

15. Develop District of Squamish-owned land along the north side of Mamquam Road as a greenway incorporating a variety of public amenities such as:
    - Clearly marked, separated bike lanes, pedestrian routes and/or multi-use paths with safe road crossings and linkages.
    - Food gardens.
    - Green infrastructure.
    - Shade trees with accessible benches & seating including covered seating.
    - Small plazas and pocket parks.
    - Covered public kiosks.
    - Public art.
    - Portable washrooms and waste receptacles.
    - Colourful crosswalks.
    - Pedestrian and bike-level lighting.

16. Consider bioswales along Mamquam Road to reduce flooding while activating the area, particularly surrounding active transportation infrastructure.

District Land along Mamquam Road Identified in Yellow

Commercial Core Area

17. Consider opportunities to enhance and activate outdoor amenity spaces within the public realm through redevelopment activities, or on District land, using the following approaches:

- Through redevelopment, require public open space of sufficient size to meet the needs of the public to gather, have space for children to play, and to include trees and plantings. It can be strata-maintained but must be publicly accessible with public Rights-of-Way.
- Design open spaces to be animated, inviting and accessible for all, with shelter from elements for year-round use.
- Invest in enhancements of current public spaces such as the small Diamond Road park (a small area with a 'Neighbourhood Nook' covered space, table and bench).

- Incorporate public plaza space into the design of future commercial development, particularly in areas offering significant employment opportunities.
- Design public spaces for pedestrian users with strong linkages to active transportation routes.
- Consider establishing a food truck plaza in larger parking spaces or open spaces, near active commercial areas. A food truck plaza should include lighting and sufficient trees and plantings to make it a pleasant space with shade.

Ground Oriented Residential Area

18. Support the installation of murals on electrical boxes along pathways.
19. Create public street corners with dedicated public space and the addition of landscaping and benches to street corner design, particularly in proximity to Mamquam Road where pedestrian traffic may be higher.
20. Create the following placemaking opportunities during the design of townhouse developments:
    - Pocket parks and small activation features such as accessible seating areas with natural placemaking features, and community gathering spaces.
    - Larger community gathering spaces, where feasible, in large-scale development projects.
21. Encourage vibrant streetscape activation with smaller projects such as:
    - Traffic circles or boulevard gardens where street design permits.
    - Seating at wider street corners with adequate lighting.
    - “Local libraries”.
    - Art installations.
    - Community gardens.
22. Increase boulevard width on streetscapes to improve tree canopy and enhance natural streetscape opportunities.

6.3 Transportation & Connectivity

6.3.1 Background

The Squamish Official Community Plan, Active Transportation Plan, Community Climate Action Plan, and other District policies strongly support well-connected, walkable neighbourhoods and actively shifting away from dependency on car travel. This theme is expected to be reflected in the Transportation Master Plan, currently being developed. Three main active transportation routes connect the Garibaldi Estates to other neighbourhoods. These include bike routes leading to the Garibaldi Highlands via Garibaldi Way/Skyline Drive and Mamquam Road/ South Highlands Way, and the north-south Corridor Trail adjacent to Highway 99. Most of the roads in the neighbourhood are built with ditches rather than sidewalks and will require upgrades to establish sidewalk pedestrian connections.

6.3.2 Objectives

1. To encourage active transportation as a primary transportation mode in the neighbourhood.
2. To promote a well-connected neighbourhood by establishing formal walking and cycling routes that meet accessibility needs within the neighbourhood and to areas beyond.
3. To support the development of a convenient and efficient transit system.
4. To support the establishment of mid-block connections to improve pedestrian and cycling connectivity.
5. To incorporate active transportation as part of road upgrades.
6. To anticipate and support upgrades to road infrastructure that accommodate growth expected in the neighbourhood over time.

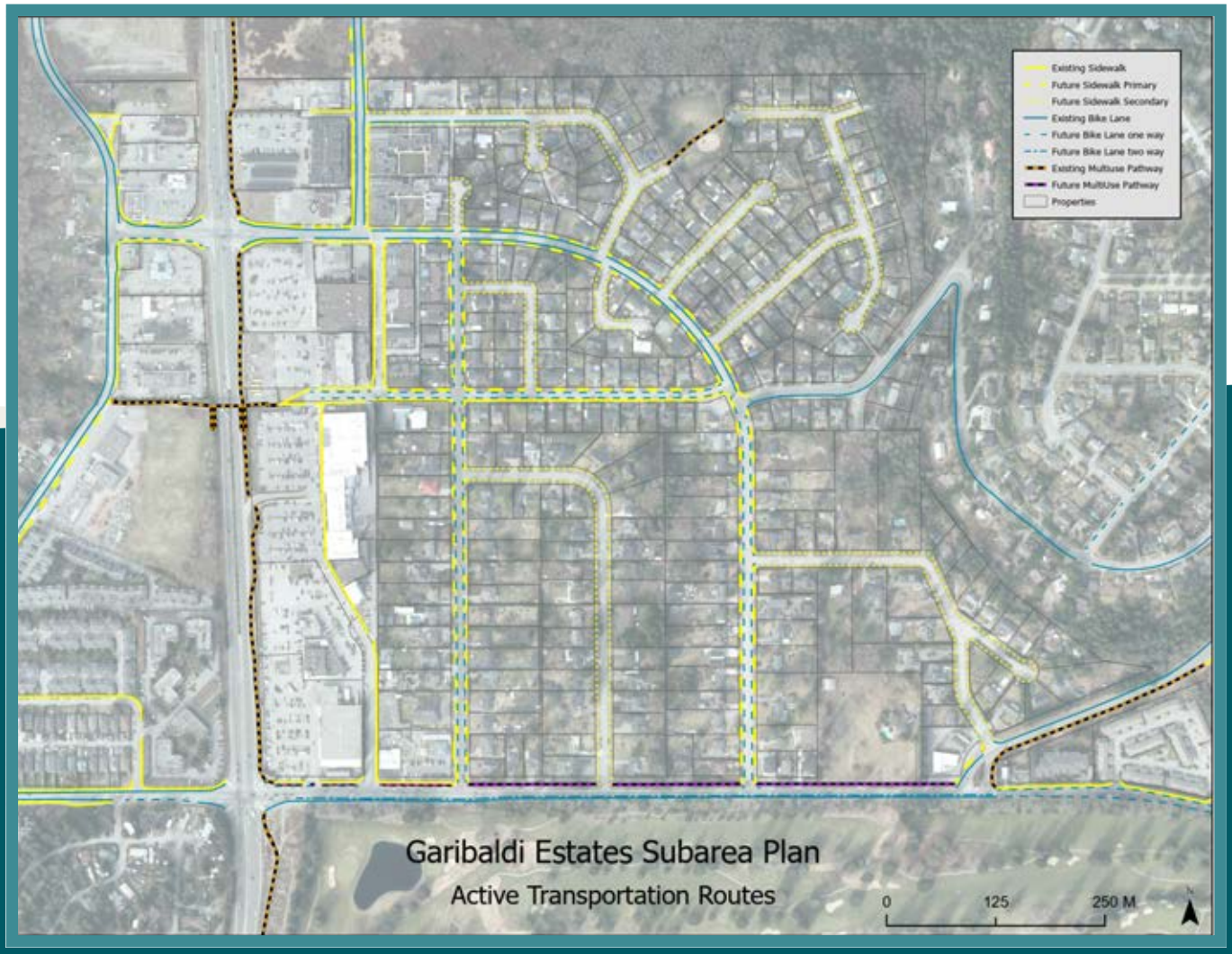
6.3.3 Policies

Street Design

1. Following completion of the District of Squamish Transportation Master Plan, identify appropriate and functional designs for roads within the Garibaldi Estates Neighbourhood, in consideration of policies in this subsection.
2. Ensure streetscape standards that include large tree species to support the enhancement of the neighbourhood tree canopy.

Active Transportation Routes

3. Proposed active transportation routes for the Garibaldi Estates Neighbourhood include existing and future sidewalks and bike lanes. Roads noted as Future Sidewalk Primary will be the initial focus for sidewalk construction, however as opportunities arise on roads noted as Future Sidewalk Secondary, sidewalks will need to be constructed there also.



Existing and Future Garibaldi Estates Active Transportation Routes

4. New development will be required to address upgrades to fronting roads as per the District of Squamish Subdivision and Development Control Bylaw.

5. New and upgraded active transportation routes within the Garibaldi Estates will be sought through development applications in alignment with street designs identified by the District of Squamish.

6. Establish an additional north-south bike route through Garibaldi Estates to improve cycling connectivity. Consider Diamond Head Road for this route, provided there is sufficient space in the right-of-way.

7. Proposed attributes of priority active transportation routes are outlined below. The exact configurations may be determined through a District's design process and may not be exactly as shown. Along transit routes, some variation may be required to accommodate bus stops.

Garibaldi Road

- On Garibaldi Way, establish sidewalks and protected bike lanes along the entire length of Garibaldi Way.

Garibaldi Way Road Cross Section

Mamquam Road

- On Mamquam Road, establish a multi-use path and park area on the north side and a bidirectional bike path on the south side.

Mamquam Road Cross Section

Diamond Road

- On Diamond Road establish protected bike lanes on both sides of Diamond Road, maintain a sidewalk along the south side, and establish a new sidewalk on the north side.

Diamond Road Cross Section

Diamond Head Road North of Diamond Road

On Diamond Head Road, north of Diamond Road, provide a pedestrian realm with potential outdoor seating areas, street parking and street trees. In addition, accommodate transit vehicles and stops where necessary.

- A protected bike lane is anticipated on either Diamond Head Road or Tantalus Road, depending on the routing of frequent transit through the neighbourhood, as determined by work underway at the time this plan was developed. Consequently, road cross sections included below depict two options, one with a focus on transit, another with a focus on biking. The anticipated width of the right-of-way is 18.0 m.

Diamond Head Road Cross Section (North of Diamond Road) – Transit Focus

Diamond Head Road Cross Section (North of Diamond Road) – Bike Focus

Diamond Head Road South of Diamond Road

- On Diamond Head Road, south of Diamond Road, provide a pedestrian realm with potential outdoor seating areas, protected bike lanes, street parking and street trees. In addition, accommodate transit vehicles and stops where necessary. The anticipated width of the right-of-way is 25.0 m.

Diamond Head Road Cross Section (South of Diamond Road)

Tantalus Road

- On Tantalus Road, south of Garibaldi Way, provide a pedestrian realm with street trees.
- A protected bike lane is anticipated on either Diamond Head Road or Tantalus Road, depending on the routing of frequent transit through the neighbourhood, as determined by work underway at the time this plan was developed. Consequently, road cross sections included below depict two options, one with a focus on parking, another with a focus on biking. The anticipated width of the right-of-way is 19.0 m.

Tantalus Road Cross Section (South of Garibaldi Way) – Parking Focus

Tantalus Road Cross Section (South of Garibaldi Way) – Bike Focus

- A strong focus on pedestrian active transportation along Diamond Head Road should be supported by incorporating public realm improvements that create an activated pedestrian experience. Improvements to consider include:
  - Natural aspects, shade.
  - Plazas and gathering spaces.
  - Boulevard gardens.
  - Landscaping and bioswales (landscape features that collect stormwater runoff, soak it into the ground, and filter out pollution).
  - Road narrowing at crosswalks to slow vehicle traffic.
  - Streets with soft features (gardens, tree canopy) to slow traffic.

Kalodon Road

- On Kalodon Road consider a street design that includes wider sidewalks, boulevards, landscaping design elements, traffic calming features, and increased tree canopy to improve aesthetics, promote safety, expand the tree canopy, and encourage active transportation.

Active Transportation Facilities

8. As part of significant residential or commercial redevelopment projects, consider opportunities to establish publicly accessible “bike hubs” with covered gathering areas, bike repair tools, and waste disposal, particularly for areas with significant existing or expected active transportation use.
9. Ensure residential developments provide sufficient covered bike parking for residents with facilities for e-bikes, cargo bikes, and bike trailers.

10. Consider and support opportunities for bike share facilities within the neighbourhood.

Mid Block Connections

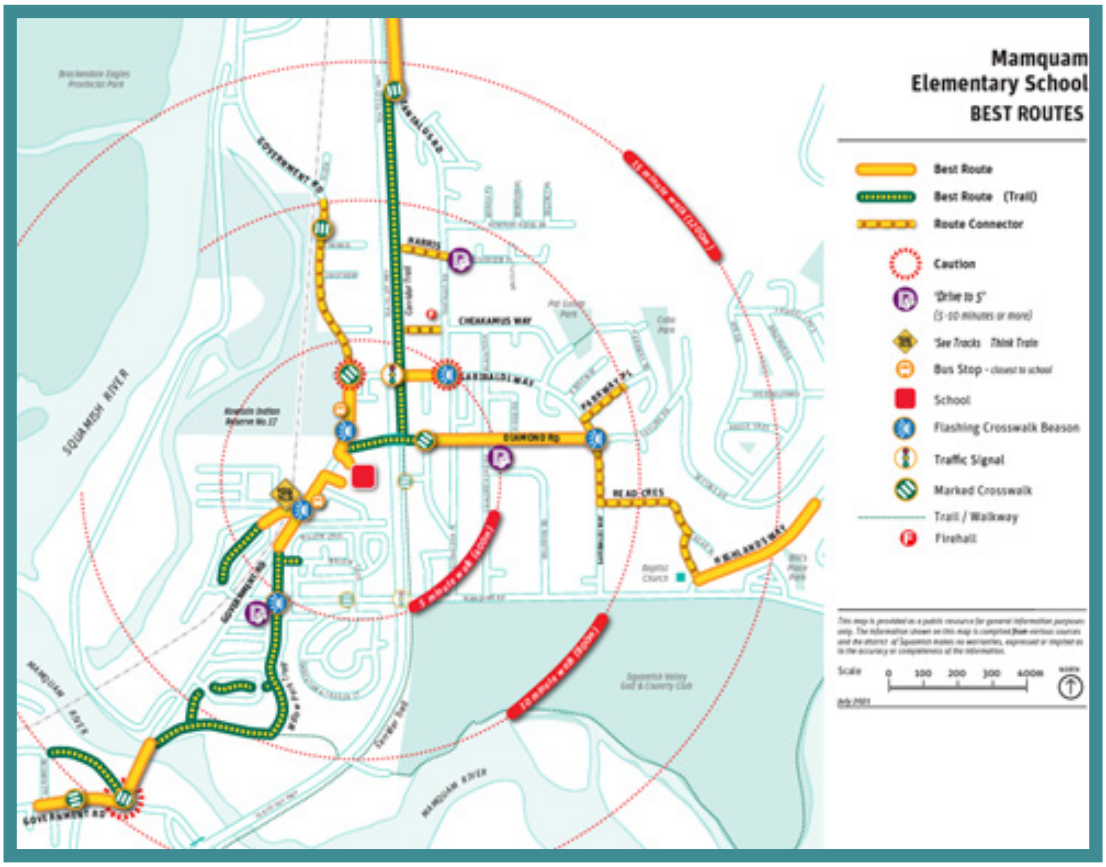
Backgrounder: Mid-Block Connections

Mid-block connections are outdoor public pedestrian routes that provide a connection or short-cuts through blocks. This mid-block connection offers pedestrians an opportunity to break down the scale of long blocks and to create easy connections between residential streets and nearby destinations such as shops and services.

11. An east-west mid-block connection for pedestrian and cyclist movement is supported between Garibaldi Way (near Read Crescent) and the Garibaldi Village commercial area to improve the convenience of active transportation routes between residences and services at Garibaldi Village given the layout of long north-south blocks.
12. Consider a variety of land, or right-of-way, acquisition strategies to establish the mid-block connection, including opportunities through redevelopment.
13. Mid-block connections between Diamond Head Road and the Commercial Core area to the east are particularly important to link intended pedestrian-oriented retail areas and local spaces for gathering.
14. The design of the mid-block connection should consider the following characteristics which are intended to improve functionality:
    - A width of 4 metres to allow for a path oriented towards pedestrian traffic.
    - Incorporate seating and landscaping, where suitable.
    - Place lighting at regular intervals.
    - Support a height of 4 stories for developments alongside the path.
    - Where appropriate, situate building entrances and windows in facades facing the mid-block connection to activate the streetscape, increase pedestrian activity, and increase the overlook of the space.
    - Establish the following setbacks on properties adjacent to mid-block connections to minimize impacts of lateral obstructions, such as lane delineators, street trees, landscaping, railing, fences, and curbs:
        - 0.2 metre for lateral obstructions 100-750 mm in height.
        - 0.5 metre for lateral obstructions >750 mm in height.
    - Incorporate creative and interactive programming such as public art displays to animate the spaces, create more inviting spaces, and increase a sense of safety.

Safe Routes to School

15. Elementary school students living in the Garibaldi Estates Neighbourhood Plan area are within the Mamquam Elementary catchment area. Middle school grades 7 to 9 attend Don Ross Middle School and secondary grades 10-12 attend Howe Sound Secondary School, with students bussed from stops in the Garibaldi Estates Neighbourhood. The primary safe route to Mamquam Elementary is along Diamond Road and across Highway 99 via the pedestrian overpass. Some residents may opt for an out-of-catchment transfer to Garibaldi Highlands Elementary School, accessing safe routes via Diamond Road, Garibaldi Way, Read Crescent and Highlands Way South, The Boulevard, and Highlands Way North. Road and frontage upgrades have the potential to significantly improve many of the current routes and may enable new safe route options. Maps for the current routes are shown in this section; mapping should be updated periodically to reflect changes.

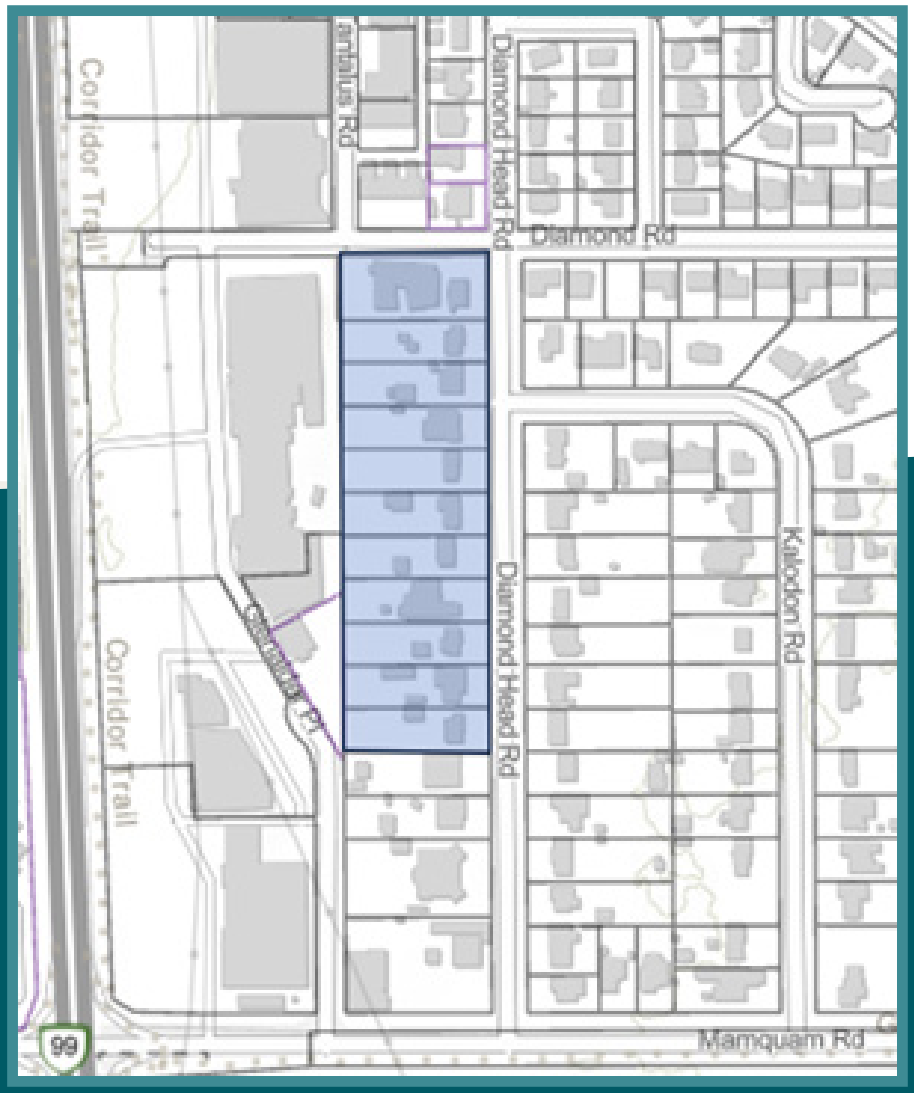


Mamquam Elementary School Safe Routes

Garibaldi Highlands Elementary School Safe Routes

Diamond Head Road Laneways

16. Consider a variety of land, or right-of-way, acquisition strategies to establish a vehicle laneway along the west side of properties between Glenalder Place and Diamond Head Road, to provide opportunities for vehicle access and solid waste service.



Properties Proposed for Laneway Access from the West.

17. Consider a variety of land, or right-of-way, acquisition strategies to establish a vehicle laneway along the west side of properties between Mamquam Road and Kalodon Road, to provide opportunities for vehicle access and solid waste service.

Properties Proposed for Laneway Access from the East.

18. The laneways are intended to establish opportunities for servicing and residential access while facilitating opportunities along Diamond Head Road to enhance the public realm, improve pedestrian safety, and support alternative transportation options with reduced interruption by driveways.

19. If a north-south laneway is established along the west side of properties between Glenalder Place and Diamond Head Road, consider the following:

    - Encourage reduced vehicle traffic speed in the lane.
    - Future development along the lane should include characteristics that invite pedestrian use of the lane including the following.
        - Establish a landscaping strip on private property along both sides of the lane.
        - Ensure the form and character of any buildings along the lane include design elements that address the lane, rather than large, blank surfaces.
    - Redevelopment of commercial properties west of the lane should consider incorporating the following elements:
        - Mid-block connections through to the pedestrian realm on the west side of the commercial properties.
        - Connectivity to the retail environment directly from the lane.
        - Lit pedestrian pathways adjacent to the lane.

Commercial Core Area

20. For significant vehicle entrances that exist within the Commercial Core area, including connections to Tantalus Way and Mamquam Road, follow best practice guidelines such as the BC Active Transportation Design Guidelines. This may include elements such as continuous sidewalks or bike lanes, appropriate traffic control, good sightlines, and adequate lighting.

Tantalus Road and Garibaldi Way

21. Address existing and future congestion at the Garibaldi Way and Tantalus Road intersection through implementation of the following improvements:

    - Convert the Tantalus Road / Garibaldi Way intersection to a signalized intersection, with no right-turn-on-red at all approaches to minimize vehicle vs pedestrian/bike conflicts.
    - Convert the Garibaldi Way / Plaza parking access to a right-in right-out with a centre median.
    - Establish new sidewalks and protected bike lanes on Garibaldi Way and Tantalus Road north of Garibaldi Way.
    - Review the westbound left turn to Tantalus Way South.

Transit

22. Support future transit expansion to establish a 15-minute Frequent Transit Network through the Garibaldi Estates Neighbourhood along Diamond Head Road.

23. To support future ridership increases on the District of Squamish transit system, establish a transit exchange near the Garibaldi Village area that:

    - Acts as a centralized location for connecting multiple transit lines and allows riders to transfer between routes; and
    - Offers customers and bus operators enhanced convenience, comfort, and safety during travel on transit.

24. Support the establishment of car share parking near the future transit exchange.

25. Support the establishment of pocket parks near transit stops with accessible seating.

Carshare

26. Support carshare parking throughout the neighbourhood, including on-street parking spaces.

Access to Highway 99

27. Support and advocate for improvements to Highway 99 to address present and future congestion, as identified in the 2022 Garibaldi Estates Transportation Study.

28. Road network changes that are supported as options for addressing increased traffic volume due to future development and improving access between the Garibaldi Estates and Highway 99, include the following:

    - Encourage the Ministry of Transportation and Infrastructure to establish a 70 km/hour Speed Limit along Highway 99 extending north of Dowad Drive.
    - Pursue the establishment of a new Newport Ridge Drive Connection between Highway 99 and Tantalus Road as resources allow.
    - Pursue establishment of right-in-right-out access from Highway 99 onto Dowad Drive and a westbound left turn for access from Dowad Drive onto Highway 99.
    - Pursue establishment of a non-signalized intersection at Newport Ridge Drive and Highway 99 with right-in-right-out from northbound Highway 99 and southbound left turn in off Highway 99 onto Newport Ridge Drive.
    - Maintain a single westbound left turn from Garibaldi Way to Highway 99.
    - Maintain a 3-lane cross-section on Garibaldi Way on both sides of the Highway.
    - Pursue the establishment of a third northbound lane on Highway 99 starting south of

Garibaldi Way and extending north to Newport Ridge Drive.

- Pursue the establishment of a dual westbound left turn from Mamquam Road onto Highway 99.
- Pursue the establishment of a third northbound lane on Highway 99, starting south of Mamquam Road and extending north to the Garibaldi Village right turn-in.

29. Identify a mechanism to ensure incremental infill development across the Garibaldi Estates neighbourhood contributes to a fund for anticipated road network improvements to ensure equitable cost-sharing of infrastructure upgrades.

6.4 Employment Space

6.4.1 Background

The Garibaldi Estates neighbourhood includes one of the primary commercial centres within the District of Squamish, providing over 27,000 m^2 of retail and office space. This space, which is located along Highway 99 between Mamquam Road and Garibaldi Way, makes an important contribution to employment in our community while providing numerous shops and services to community members. As part of the neighbourhood planning process, it is important to consider options for future employment space and associated job opportunities, to meet the needs of future residents.

The most significant opportunity to create new employment space is through mixed-use commercial buildings in the Commercial Core area along Highway 99. Currently, this area is largely retail, with limited second-storey office/employment space. Multi-storey office and other employment-use buildings with retail at the ground floor are supported in this plan.

Throughout the Mixed-Use Residential areas, mixed-use buildings at the ground floor provide opportunities for an expansion of employment space, shops, and services to residents of the Garibaldi Estates.

6.4.2 Objectives

1. To support the Garibaldi Village area as one of Squamish's core commercial areas offering significant retail and service opportunities for residents of the neighbourhood, the community, the region, and visitors to the Sea to Sky Corridor.
2. To support a diverse range of local employment opportunities in the Garibaldi Estates neighbourhood that provide jobs for neighbourhood residents as well as members of the wider community.
3. To establish an attractive pedestrian-oriented commercial environment along Diamond Head Road that enables residents to socialize, and to meet day-to-day needs within walking distance of home.
4. To preserve dedicated commercial land for the possibility of future employment opportunities that support high employee density.
5. To increase access to small-scale retail and service opportunities throughout the neighbourhood that improve community connection and create spaces for local gatherings.

6.4.3 Policies

Commercial Core Area

The Garibaldi Estates Neighbourhood plan supports the development of a significant amount of employment space within the plan area. Within the Commercial Core Area, up to 43,000 m^2 of commercial space could be developed. This amount of office space has the potential to support up to 2,300 employees.

1. Support commercial uses that generate varied and increased local employment opportunities for Squamish residents.
2. Encourage the development of dedicated multi-storey commercial buildings throughout the Commercial Core with retail use on the ground floor.
3. Residential uses are not supported within the Garibaldi Village Commercial Core to preserve existing and future opportunities for commercial land uses such as retail and office.
4. Increased building heights are supported in the Commercial Core area east of Highway 99 to facilitate redevelopment viability given limited parcel sizes and flood construction levels.
5. Ensure that the prominence of street corner locations capitalizes on opportunities for retail or commercial activity.

Mixed-Use Residential Area

Mixed-use buildings along the length of Diamond Head Road south of Diamond Road are envisioned to establish a new pedestrian-oriented commercial area and contribute a considerable amount of new commercial space within the neighbourhood. Along Diamond Head Road and Tantalus Road up to 10,500 m^2 of commercial space could be developed, which has the potential to support up to 300 employees. Place-making opportunities in mixed-use areas can help draw patrons, create a sense of community, and provide space for employees and neighbours to gather.

6. Encourage the development of mixed-use buildings with ground-level commercial space that supports the needs of retail tenants in Squamish, including the following characteristics:
    - Smaller unit sizes to maximize efficient utilization of space in high-cost locations.
    - High ceilings, supportive of high-quality retail space.
7. Utilize front setbacks along Diamond Head Road to support potential requirements for grade transitions between the road and the flood construction level, as informed by a Hydrotechnical Hazard Assessment of Mashiter Creek.

8. Consider setbacks for mixed-use buildings to provide adequate frontage area for:

    - Outdoor patios with food & beverage businesses.
    - Public spaces with seating, encompassing hard features and landscaping, to enable gathering for patrons of businesses and residents of the area.
    - Opportunities to accommodate sidewalk extensions that provide more space and amenities for people using the street, and small plaza-type public spaces, including accessible seating, lighting, and all-weather use areas.

9. Use the prominence of street corners to create buildings that define the surrounding area and reinforce the adjacent public space through their overall form and façade. Building elements that emphasize the corner include:

    - reduced setbacks.
    - architectural elements including corner pediments, parapets, and awnings or verandas that wrap the corner.
    - extra height at the corner; and
    - entrances to ground floor commercial/retail space placed in the most prominent position at the corner, with entrances to upper residential spaces placed along the façade on either street.

Accessory Commercial Units

Backgrounder: Accessory Commercial Units

Accessory Commercial Units (ACUs) are small structures built on residential properties that host businesses. The intent is to enable walkable services throughout neighbourhoods without the impact of building larger commercial structures. Like Accessory Dwelling Units (ADUs) ACUs are intended to be smaller in scale than the principal residential building on the property. However, while ADUs are typically located in the backyard, ACUs are often located in the front yard, often within the front setback.

ACUs typically support minimal impact, small-scale, homeowner-driven passion projects which cater primarily to neighbourhood clients. ACUs offer opportunities for gathering and access to commercial services away from busy commercial areas. For homeowners interested in starting a business, ACUs can dramatically reduce the incremental cost in comparison to leasing a separate space. Typically, ACUs are located within an accessory building; however, they can be located within the principal building, thereby reducing barriers and increasing affordable commercial space.

Examples of businesses that might be located in an ACU include coffee shops, artisan retail, massage therapists, yoga studios, barbershop/salons, bicycle repair, or tech/ software offices.

10. Amend the District of Squamish Zoning Bylaw to allow ACUs within existing Garibaldi Estates neighbourhood residential zones to increase access to walkable services.

11. Consider the following regulations for ACUs when amending the Zoning Bylaw:

    - ACUs can be located within an accessory building or the principal building.
    - ACUs can be located within the front setback, up to the front lot line,
    - ACUs can occupy a maximum floor area of 75 m^2.
    - Parking is not required for ACUs.
    - ACUs may be identified using one non-illuminated sign.
    - For ACUs where people may gather for commercial uses, ensure waste management, and encourage accessible seating options, either on the property or nearby, such as a small seating area on a nearby corner.

12. Encourage local growers to collaborate with owners of ACUs for the sale of farm goods in market-type settings.

6.5 First Nations

6.5.1 Background

The District is committed to a long-term journey toward Truth, Healing, and Reconciliation in Squamish. The District supports Reconciliation and healing efforts, engagement, and partnerships to build strong relationships with First Nations founded in respect and recognition of Aboriginal rights and title, culture, and heritage.

6.5.2 Objectives

1. To respect, honour and promote expressions of local First Nations culture and heritage within the Garibaldi Estates.
2. To honour and respect First Nations potential archaeological and burial sites within the neighbourhood.

6.5.3 Policies

1. Integrate First Nation's place names into neighbourhood locations and streets.
2. Integrate cultural signage where appropriate within the Garibaldi Estates Neighbourhood, including:
    - extent of the traditional territory of First Nations;
    - the harvesting and use of native plant species by First Nations;
    - Indigenous animal species; and
    - First Nations place names.
3. Support the establishment of services within the Garibaldi Estates Core Commercial area aligned with the needs of Squamish Nation residents that are not conveniently accessible north of the Downtown commercial area.
4. In collaboration with Skwxwu7mesh Uxwumixw (Squamish Nation), recognize specific sites and locations of cultural importance within the Garibaldi Estates Neighbourhood if identified.

Archaeological Resource Protection Considerations

5. For areas within the Garibaldi Estates Neighbourhood Plan not identified as Archaeological Areas of Potential before the adoption of this plan, proposed development should proceed under a development-specific Chance Finds Procedure (CFP). Chance Find procedures and guidelines outline appropriate responses to the discovery of known or suspected archaeological materials, including human remains, that are unexpectedly encountered during construction activities.

6. For private property identified before the adoption of this plan as an Archaeological Area of Potential, it is recommended that proposed future developments be redesigned to avoid the property. If the property cannot be avoided due to engineering concerns, it is recommended that a site alteration permit be obtained and that future ground-altering developments within and adjacent to the site be subject to monitoring by a professional archaeologist and trained First Nations representatives under the provisions of the appropriate First Nations permits.

7. Within Coho Park, an Archaeological Impact Assessment (AIA), involving Skwxwú7mesh Úxwumixw (Squamish Nation), and səlilwətaɬ (Tsleil-Waututh Nation) community representatives, should be conducted for any contemplated future development.

6.6 Environment

6.6.1 Background

There are important natural features within the Garibaldi Estates Neighbourhood. Coho Park and Pat Goode Park encompass riparian areas, greenspace, and mature trees that contribute to the neighbourhood's identity and character, serving as both natural and recreational amenities. These natural features also contribute habitat for species that inhabit the area. As the neighbourhood continues to evolve, deliberate protection of these natural features will support the long-term health of the neighbourhood's ecosystems.

During community engagement for the Garibaldi Estates Neighbourhood Plan, several residents highlighted the importance of mature trees located on private properties within the neighbourhood. Residents highlighted the contribution these trees made to the character of the Garibaldi Estates, as well as their environmental benefits. During the drafting of the plan, several approaches were considered to support the preservation of these trees: a District-wide urban forest management plan, planting of new street trees along public roads through upgrades that accompany infill development, and Development Permit Area Guidelines or zoning provisions specific to the retention of existing mature trees or planting of new trees along rear property lines, particularly on large properties south of Diamond Road.

6.6.2 Objectives

1. To protect and enhance the ecological values of the Garibaldi Estates neighbourhood.
2. To recognize the value of natural assets as part of municipal infrastructure.
3. To encourage stewardship of trees and green spaces and achieve a mature tree canopy, carbon sequestration, and habitat benefits.
4. To encourage retention of mature trees and natural vegetation on private property where possible during re-development.
5. To encourage the incorporation of native vegetation and pollinator-friendly species in landscaping, and the removal of invasive plants.
6. To encourage the planting of shade trees where appropriate, using species that are best suited for changing climate conditions.

6.6.3 Policies

Development Guidelines

1. New development in the Garibaldi Estates should follow guidelines and recommendations outlined in Environmental Best Management Practices for Urban and Rural Land Development (BC MOE, 2014). This includes best management practices for stormwater, pollution prevention, wildlife, and ecosystem management.
2. Protect riparian areas along watercourses to provide habitat for aquatic and terrestrial species, facilitate stormwater management, and contribute to the neighbourhood's greenspace and urban tree resources.
3. All Streamside Protection and Enhancement Areas (SPEAs) should be viewed as significant habitats and protected; riparian buffers adjacent to watercourses will also protect wildlife use of water features.
4. Minimize the impact of exterior lighting from developments on nearby habitat areas.
5. Bear-safe design should be provided for any garbage/composting facilities and landscaping.
6. Pursue opportunities, as part of ongoing road improvement projects, to add street trees, rain gardens, landscaped bump outs, and additional greening along street frontages, to support stormwater management, provide shade for pedestrians, and improve connections between habitat areas.

Tree Canopy

7. Prioritize a tree canopy analysis for the Garibaldi Estates and establish canopy targets for the neighbourhood within the District's Urban Forest Management Plan in the future.
8. Develop street design standards for roads within the neighbourhood to ensure street trees are included in future street designs throughout the neighbourhood.
9. Consider the use of soil cells to ensure the long-term health of street trees along public roads.
10. Encourage the preservation of existing mature trees and the planting of new large-canopy trees adjacent to the rear property line in the Ground Oriented Residential area. In the properties between Diamond Head Road and Read Crescent, opportunities for the retention or enhancement of the tree canopy along rear property boundaries should be identified during redevelopment. New development should be designed to preferentially retain existing mature trees, and new trees should be planted to provide buffering from adjacent properties. Required open space should be consolidated at the rear of the properties to ensure adequate space for tree health.

6.7 Arts, Culture and Heritage

6.7.1 Background

The establishment of the Garibaldi Estates Neighbourhood, as it is now known, began in the mid-1900s. At that time, the unorganized mid-Squamish Valley area came to be known as Mamquam with the establishment of the Mamquam utility boards that provided water and sewer services. These services enabled the acquisition of a large tract of second-growth forest land for the development of the Garibaldi Estates subdivision by a developer Pat Goode, along with a Veteran's Land Act (VLA) subdivision in the 1970s. The area was marketed as 'Sunny Garibaldi Estates' for its south-facing slopes. More details about the history of the Garibaldi Estates can be found in the District of Squamish Garibaldi Estates Historical Context Statement.

At present there are no dedicated venues for arts and culture in the neighbourhood; however, both the St John the Divine Anglican Church and the Squamish Baptist Church have served as venues for performing arts. More recently, a limited number of public art pieces have been installed in public areas. These include 'Squamish Wings 2.0", a mural by Liesl Petersen, located in the commercial development at 1861 Mamquam Road, and 'Salmon', a sculpture by Christina Nick, located at 1870 Diamond Road in Garibaldi Village. Wood sculptures of an orca and a salmon can be found in the Squamish Valley Golf Club, near the neighbourhood. As the neighbourhood evolves, there is an opportunity to cultivate and look for space for gathering, arts, and culture.

6.7.2 Objectives

1. To support the space needs of the creative community within the District of Squamish.
2. To facilitate opportunities for public art within the Garibaldi Estates Neighbourhood.
3. To support the conservation of Garibaldi Estates heritage values.

6.7.3 Policies

Arts Venues

1. Encourage the establishment of venues within the neighbourhood that support the arts and culture communities of both the Garibaldi Estates and the broader District of Squamish, including:

    - Venues capable of hosting community events.
    - Small specialty maker spaces with their own galleries.
    - Small dedicated gallery spaces.

2. Support the continued use of existing institutional spaces as hubs and venues for performing arts, including the St John the Divine Anglican Church and the Squamish Baptist Church.

Public Art

3. Encourage the integration of art with recreation opportunities in the District of Squamish parks within the Garibaldi Estates neighbourhood.

4. In areas with mixed-use retail/apartment development in the Commercial Core area, encourage public art installations as part of redevelopment projects to improve vibrancy.

5. Implement the District of Squamish Public Art Policy for new development within the neighbourhood.

    - Work with local artists/schools/community groups in commissioning art to increase community connectivity.
    - Consider locations where public art is visible from the highway and adjacent areas.
    - Consider art on the crosswalk off Mamquam Road adjacent to the Commercial Core area.

Heritage Conservation

6. Acknowledge and protect Indigenous heritage within the neighbourhood.

    - Work with the Squamish Nation community to protect and celebrate cultural heritage and resources.
    - Integrate Indigenous placenames, artwork, and other cultural expressions to share Indigenous values and perspectives in the landscape and built and natural environment.
    - Contribute to a broader program of local cultural revitalization of the Squamish Nation.

7. Heritage conservation and design

    - Provide heritage information about the neighbourhood to property owners including residents and developers.
    - Consider the neighbourhood qualities outlined in the District of Squamish Garibaldi Estates Historical Context Statement when making decisions about new infill or development.
    - Retain the curvilinear subdivision pattern and the significant relationships between the neighbourhood's major qualities.
    - Consider the integration of native plant material to increase biodiversity while retaining the character of the planted landscape.

6.8 Future Infrastructure and Risk Mitigation

6.8.1 Background

Generally, water and sanitary servicing throughout the Garibaldi Estates Neighborhood is connected to larger infrastructure running north-south through the Garibaldi Village Commercial Area and east-west along Mamquam Road. The bulk of stormwater management currently occurs through a system of ditches along roads in the residential areas of the neighbourhood. It is anticipated that the neighbourhood will require upgrades to the water, sanitary sewer, and drainage infrastructure to accommodate growth.

The District of Squamish Integrated Flood Hazard Management Plan (IFHMP) identifies flood hazards throughout the community. Much of the Garibaldi Estates neighbourhood is outside of the modelled Squamish/Mamquam River floodplain; however, portions of the neighbourhood are subject to overland flow hazard from Mashiter Creek. A detailed assessment for this hazard was conducted through the Mashiter Creek Overland Flow Hazard Assessment (BGC Engineering, 2025).

6.8.2 Objectives

1. To provide adequate infrastructure to serve the long-term needs of the Garibaldi Estates neighbourhood and lands beyond.
2. To protect new development from flood risk.
3. To ensure new development does not increase stormwater flows or drainage issues.

6.8.3 Policies

Infrastructure

1. To inform new development opportunities identified in the Schedule A Land Use Plan, the District of Squamish should complete a servicing model study for stormwater, water, and sanitary sewer infrastructure. The intent of the study is to identify the scope of upgrades required to accommodate infill potential in the Garibaldi Estates Neighbourhood, in addition to anticipated development in adjacent neighbourhoods and lands beyond.
2. Based on results of the water and sanitary sewer servicing model study, identify an approach to equitably share the cost of required upgrades across anticipated growth in the neighbourhood and beyond.

3. All new development is required to provide road, water, sanitary sewer, and stormwater infrastructure, etc. as required by, and to the standards set forth in, the District of Squamish Subdivision and Development Control, unless otherwise varied by the District.
4. All new development is required to provide frontage upgrades which include the Future Sidewalk Primary and Future Bike Lanes identified in the Garibaldi Estates Neighbourhood Plan Active Transportation map and policies unless otherwise varied by the District.
5. Mixed-use commercial/apartment development is anticipated along the east side of Diamond Head Road between Kalodon Road and Mamquam Road. New servicing infrastructure is anticipated to be sited in a new lane established at the rear of these properties connecting to established infrastructure on Kalodon Road and Mamquam Road. Infrastructure installed in this lane should be sized to accommodate projected mixed-use buildings on Diamond Head Road.

Drainage and Stormwater

6. Stormwater management practices shall minimize negative impacts on water quality, water quantity, and ecosystem health in accordance with the following principles:
    - Reduce or avoid any impacts on public infrastructure and the environment.
    - Maximize the use of landscape-based solutions to meet both storage and water quality treatment requirements.
    - Maintain and enhance natural assets and riparian forest integrity by maximizing tree canopy on each lot through tree retention and replanting/restoration of vegetation where possible.
    - Minimize total impervious area (TIA) and minimize the EIA (effective impervious area, or the area that drains directly to a watercourse or municipal systems) through development practices such as pervious paving and unpaved parking and access routes outside of accessible design requirements. The EIA can be achieved through techniques such as disconnecting roof leaders from the municipal system and drainage to an aboveground or subsurface storage tank.
7. New development should be required to:
    - Provide a site-specific stormwater management plan that meets District requirements.
    - Mitigate impacts of development on water quality and water quantity through on-site stormwater controls.
    - Source controls may be required to treat potential pollutant loading in runoff and to protect watercourses.
    - Provide sufficient land area for on-site detention of stormwater which may be in the form of detention ponds, above-ground, or below-ground storage facilities.
    - Provide a lot grading template in addition to flood construction levels to ensure buildings are appropriately placed to avoid nuisance flooding during normal saturated conditions and catastrophic flooding during a design event.
    - Strata developments with stormwater detention, storage, and/or water treatment infrastructure/facilities should be required to establish a program for monitoring and maintenance of stormwater facilities.

Rights-of-Way

8. Major roads and engineering services, including stormwater, water, sanitary sewer, detention ponds, road dedications, widenings, and rights-of-way should be provided and extended (at no cost to the District) to accommodate the proposed development. Various means of recovering servicing costs, such as Latecomer Agreements, Development Cost Charges credits, and Development Cost Charges Frontender Agreements may be considered, where applicable, to the acceptance of the District.

9. All new streets, extensions, and realignments are expected to be dedicated as public rights-of-way.

Flood & Wildfire Hazard

10. Any new construction must meet flood construction levels in accordance with District Floodplain Management Bylaw requirements unless varied by the District.

11. Ensure new development aligns with recommendations of the Mashiter Creek Overland Flow Hazard Assessment (BGC Engineering, 2025). Update the District of Squamish Floodplain Management Bylaw to align with findings of the Mashiter Creek Overland Flow Hazard Assessment. Recommendations of the Mashiter Creek Overland Flow Hazard Assessment are supported for use to inform interim exemptions for new development prior to an update of the District of Squamish Floodplain Management Bylaw.

12. Ensure new construction and landscaping meet the guidelines of the Protection from Wildfire Hazard Development Permit Area and the Wildfire Landscaping Management Bylaw.

6.9 Energy & Climate Change

6.9.1 Background

In 2020, Squamish adopted the Community Climate Action Plan, which aims to reduce emissions by at least 45% below 2010 levels by 2030 with strategies and actions that account for 38% of emissions reductions.

In 2021 Council adopted a Low Carbon Incentive Program. This program is intended to minimize the environmental impact of housing development in Squamish by discouraging the use of high-carbon energy sources in residential construction.

In May 2023, the BC Building Code was revised, allowing municipalities to implement the Zero Carbon Step Code which regulates building operating emissions rather than efficiency. This update will provide new opportunities to address greenhouse gas emissions and provides an alternative to the Low Carbon Incentive Program.

Policies included in the Garibaldi Estates Neighbourhood Plan aim to reduce reliance on non-renewable energy and reduce community emissions.

6.9.2 Objectives

1. To prioritize/incentivize the use of low-carbon energy systems and highly efficient construction techniques in the built environment.
2. To ensure that as the neighbourhood grows, development patterns support active transportation options as alternatives to car-dependent development.

6.9.3 Policies

1. For development projects subject to rezoning application, ensure low-carbon energy sources are incorporated as the exclusive energy source, to limit the production of greenhouse gases associated with ongoing operations of those buildings.
2. Support the development and implementation of District of Squamish policy to address embodied carbon in new construction.
3. Encourage developments to use wood-based building materials or other carbon-storing materials beyond business-as-usual practices.
4. Encourage site layout and connectivity that is highly integrated with active transportation and recreational networks.

6.10 Food and Agriculture

6.10.1 Background

Throughout the planning process, residents expressed an appreciation of food production opportunities in the Garibaldi Estates Neighbourhood. Respondents enjoyed the opportunity to garden for personal reasons and highlighted the opportunity for these properties to support urban agricultural activities among young farmers. This local food production was highlighted as a sustainable practice that involved lower GHG emissions than commercially produced food. Food security was also identified as a benefit of food production on these properties.

The Squamish Climate Action Network Food Policy Council completed a report to inform the Garibaldi Estates Neighbourhood planning process. The report provided an overview of what small-scale farming could look like in the Garibaldi Estates and included policy recommendations to advance a holistic sustainable food system. The report identified seven existing food assets in or near the neighbourhood, which included: Garibaldi CAN Grow Community Garden, Mamquam Edible Schoolyard, Mamquam Elementary School, Independent Grocer, Kitchen Quickies, and Plant X.

6.10.2 Objectives

1. Support small-scale farming within the Garibaldi Estates Neighbourhood.
2. Support the creation of a regional farm hub, including a commissary kitchen and market, in the Garibaldi Estates.

6.10.3 Policies

1. Consider the establishment of a Community Agriculture Fund to support continued operations and maintenance of small-scale farming within the Garibaldi Estates Neighbourhood.
2. Encourage the establishment of a community farm within a larger development located in the eastern portion of the Ground Oriented Residential area. The community farm is envisioned to encompass the following characteristics:
    - Approximately 70% of the land is dedicated to farm business and 30% of the land is dedicated to community gardens.
    - Covenant dedication of areas proposed for food agricultural uses requiring continuous agricultural use by an approved community group, land trust, agricultural operator, or strata.

3. Encourage the establishment of a regional farm hub in the Mixed-Use Residential A area. The regional farm hub is envisioned to encompass the following characteristics:

    - A commissary kitchen and market.
    - Support for farmers to conduct ongoing and year-round sales to complement farmers' existing operations (CSA, farmers market, relationships with restaurants).

4. Encourage land-sharing opportunities for front or rear yards on larger properties to support food production. Consider a demonstration project to encourage uptake.

6.11 Neighbourhood Amenities

6.11.1 Background

The Garibaldi Estates Neighbourhood is served by two parks and three childcare facilities. New development will need to address the need for community amenities, such as additional public gathering spaces and childcare facilities, to accommodate population growth within the neighbourhood.

Child Care

The Squamish Child Care Needs Assessment identifies accessible, affordable, and high-quality child care as a critical need in the community, relevant to the overall affordability situation for families, and a meaningful contributor to social and economic development. An initial "reach" target rate of 30% for access to care (30 spaces per 100 children) has been used in the past; however, this goal is now recognized as low, a childcare access rate of 40% is recommended in this plan as a community-wide reach target.

Currently, there are three childcare facilities within the Garibaldi Estates neighbourhood:

- Discovery Kids Childcare, located at 2120 Diamond Road, is a facility that provides care for children between the age of 0-5 and currently can accommodate 25 children.
- Les Petits Aventuriers, located at 2178 Skyline Dr, is a family child care facility that provides care for children aged 2 to 5 years old and currently can accommodate 7 children.
- Kamp Sonshine Day Care, located at 2262 Read Crescent, is a licensed before- and after-school care program in the Squamish Baptist Church and currently can accommodate 20 children.

Together, these three facilities offer a total of 52 childcare spaces within the Garibaldi Estates. Stats Canada Data from the 2021 Census indicates that 195 children are living in the Garibaldi Estates ages 0-14. The current childcare access rate for children within the Garibaldi Estates is 27%. In addition, afterschool childcare is offered at Mamquam Elementary adjacent to the plan area.

Within the Garibaldi Estates, there are a limited number of opportunities for new childcare

facilities that could be developed under land use scenarios supported in the neighbourhood plan. Development projects that align with policies in the Community Amenity Contribution Policy are anticipated to contribute to the overall childcare needs; other opportunities to meet the overall needs include small-scale residential childcare facilities in homes throughout the neighbourhood. Development projects that could support childcare needs include:

- Redevelopment of the civic zoned St. Anglican's Church property at 40285 Diamond Head Rd, as a civic building with expanded uses.
- A mixed-use redevelopment of Garibaldi Garden Courts at 1951 Garibaldi Way.
- Mixed-use development along Diamond Head Road.
- An amenity provided as part of a larger townhouse redevelopment in the Ground Oriented Residential Area. However, the feasibility of securing a childcare amenity will depend on other community amenities negotiated as part of those developments. For example, scenarios, where 30% of land is dedicated to agriculture/greenspace or park, will have limited opportunities for contributions to child care.

The 2044 High Scenario and 2044 Low Scenarios for future dwelling unit numbers outlined in the housing policy section of this plan were used to estimate the child populations. Under the 2044 High Scenario, an estimated 518 children would reside in the Garibaldi Estates; 207 childcare spaces would be required to achieve an access rate of 40%. To enable this access rate, 155 new childcare spaces would be required beyond the existing 52 spaces.

Under the 2044 Low Scenario, an estimated 322 children would reside in the Garibaldi Estates; 129 childcare spaces would be required to achieve an access rate of 40%. To enable this access rate, 77 new childcare spaces would be required beyond the existing 52 spaces.

2044 High Scenario					
Scenario	Single Unit Dwellings & Suites	Duplexes & Multiple Dwelling Residential	Townhouse Dwellings	Apartment Units	Total
Dwelling Units	206	200	358	756	1520
Estimated Child Population	111	110	168	129	518
Child Care Spaces to Achieve 40% Access	44	44	67	51	207

2044 Low Scenario					
Scenario	Single Unit Dwellings & Suites	Duplexes & Multiple Dwelling Residential	Townhouse Dwellings	Apartment Units	Total
Dwelling Units	269	68	163	367	867
Estimated Child Population	145	37	77	62	322
Child Care Spaces to Achieve 40% Access	58	15	31	25	129

6.11.2 Objectives

1. To ensure community benefits that meet the needs of the neighbourhood are provided with any new development.

6.11.3 Policies

Community Amenity Contributions

1. All new developments seeking rezoning for additional density should meet targets set out in the District's Community Amenity Contributions policy. Any onsite amenities should provide direct benefit to the wider neighbourhood.
2. Priorities for community benefits in the Garibaldi Estates neighbourhood (beyond standard bylaw requirements) are:

- Secured affordable rental housing.
- Child care facilities.
- Neighbourhood park/open space that provides an opportunity for public playground.
- Pocket parks on the parcel frontage and/or adjacent to trail connections to create gathering spaces that are open to all residents.
- Mid-block connections that provide an opportunity for east-west pedestrian connections through the neighbourhood, as described in the transportation policy section of this plan.
- Arts venues identified in the Arts, Culture and Heritage section of this plan, which are publicly owned or owned by a not-for-profit organization.
- Commercial space dedicated to a regional farm hub, which incorporates a commissary kitchen and market, intended to support farmers to conduct ongoing and year-round sales to complement farmers' existing operations (CSA, farmers market, relationships with restaurants).
- Specific to parcels over 0.3 hectares in the Ground Oriented Residential Area, either:
- Dedication of 30% of parcel area to agriculture, greenspace, or park or,
- Contributions to secured affordable rental housing.
- Contributions to a Community Agriculture Fund to support continued operations and maintenance of small-scale farming in the neighbourhood.

New Neighbourhood Parks

3. The design of development projects within the southwest area of the neighbourhood should consider opportunities to establish a neighbourhood park in alignment with the needs outlined in the Parks and Recreation Master Plan.

4. The design of larger developments in the Ground Oriented Residential Area should consider opportunities to dedicate significant greenspace or agriculture amenities to serve the needs of residents within the neighbourhood area where feasible.

Child Care and Institutional Uses

5. Prioritize the development of childcare facilities within the Garibaldi Estates Neighbourhood in alignment with the Community Amenity Contribution Policy.

6. Develop childcare centres in the Mixed-Use Residential, Multifamily Residential and Ground Oriented Residential areas in combination with larger redevelopment projects, in line with targets from the Community Amenity Contribution Policy.

7. Support inclusion of smaller purpose-built multi-age family-based childcare operations throughout all residential areas.

8. Ensure areas with significant child populations or services such as daycares, activity centres and parks have designated pick up/drop off zones with clearly painted directions on roads and signage and design to safely accommodate pick up and drop off by bicycle.

7. IMPLEMENTATION

Implementation actions identify key steps that will be necessary to move the Garibaldi Estates Neighbourhood Plan from policy to action.

The Schedule A Future Land Use Plan outlines the future land uses for the Garibaldi Estates neighbourhood. Land use changes from current uses will require rezoning and, in some cases, Development Permits, in accordance with Official Community Plan (OCP) policies.

7.1 General Implementation Steps

1. The Garibaldi Estates Neighbourhood Plan will be adopted as a Schedule to the OCP Bylaw at which time, an OCP amendment bylaw should revise the OCP land use designations to those shown on the Schedule A Land Use Plan.
2. The Garibaldi Estates Neighbourhood Plan is intended to supplement the broader policies of the OCP. In case of any discrepancy with the OCP, the more detailed policies of the Neighbourhood Plan will prevail.
3. New development applications may be required to address the policies of this plan at the time of rezoning, subdivision and/or development permit application.
4. The District may initiate a rezoning process that brings the current zoning closer in line with Plan policies to avoid development outcomes not aligned with the Plan.

7.2 Development Guidance Policies

1. Complete guiding policies concerning the following matters:
    - A water and sanitary servicing review for the Garibaldi Estates Neighbourhood, reflecting potential development opportunities, to identify future infrastructure needs.
    - Street design with cross sections for key roads within the Garibaldi Estates, including Garibaldi Way, Diamond Head Road, Diamond Road, and Mamquam Road.
    - An integrated stormwater management plan or other neighbourhood-level drainage plan that applies to the Garibaldi Estates Neighbourhood, to inform stormwater infrastructure needs and policies.
    - A Mashiter Creek Hydrotechnical Hazard Assessment to determine an appropriate flood construction level for the overland flow hazard within the neighbourhood.
    - A design for the Mamquam Greenway.

7.3 District of Squamish Bylaw Updates

Veterans Land Act (VLA) Bylaw

1. Repeal District of Squamish Veterans Land Act (VLA) Bylaw No. 211, 1966 to allow reconfiguration of property boundaries in alignment with policies in this plan.

Zoning Bylaw

2. Amend the District of Squamish Zoning Bylaw to permit Accessory Commercial Units on residential properties within the Garibaldi Estates Neighbourhood.
3. Amend the District of Squamish Zoning Bylaw to provide zoning for apartment uses in the Mixed-Use Residential A and Mixed-Use Residential B areas.
4. Amend the District of Squamish Zoning Bylaw to provide zoning for townhouse uses for most properties in the Ground Oriented Residential Area.
5. Amend the District of Squamish Zoning Bylaw to provide zoning for townhouse uses on 2163 Mamquam (PID: 014698561), with the provision of an activated park, secured through the rezoning process.
6. Amend the District of Squamish Zoning Bylaw to support cohousing opportunities within the Mixed-Use Residential A area.

Subdivision and Development Control Bylaw

7. Update the Subdivision and Development Control Bylaw to enable the Engineering Department to secure needed rights-of-way, and utility and access easements through the development process.

7.4 On Street Parking Management

1. Consider the implementation of a Resident Exempt Zone to manage on-street parking along Diamond Head Road and adjacent roads impacted by visitation to the proposed retail land uses. A resident-exempt zone consists of a geographic area where residents may choose to register their vehicles to an address within the zone. Registered vehicles are exempt from existing on-street parking restrictions. Non-residents are permitted to park within the Resident Exempt zone provided they observe identified time restrictions.

8. APPENDIX A

Garibaldi Estates Projections Assumptions

To understand infill growth potential within the Garibaldi Estates under the land use designations included within this plan, the existing land uses were compared to a theoretical potential, as well as a high and low growth land use scenario for the year 2044.

Scenario	Single Unit Dwellings & Suites	Duplexes & Multiple Dwelling Residential	Townhouse Dwellings	Apartment Units	Total Dwelling Units
Existing	301	16	63	166	546
Plan Maximum	0	985	644	1168	2797
2044 High	206	200	358	756	1520
2044 Low	269	68	163	367	867

2024 Existing and Projected Dwelling Units in the Garibaldi Estates

Assumptions in these scenarios are outlined below.

The Plan Maximum scenario reflects an assumption that every property in the Garibaldi Estates Neighbourhood transitions to the maximum density option supported within the plan.

The 2044 High scenario represents a high growth estimate over the coming decades based on past trends and expectations. The scenario is dependent on numerous assumptions, which are outlined below.

- **Multiple Dwelling Residential:** The 2044 High scenario assumes two redevelopments per year within the plan area from single-unit dwellings to multiple dwelling residential with four strata lots and one secondary suite, as permitted under the R-1 zoning. Over 20 years, this would result in 40 single-unit dwellings being replaced by 200 new strata and secondary suite units,
  - Assumption basis: Currently the District of Squamish includes over 1,100 properties zoned RS-2, which allows two-unit dwellings, also known as duplexes. Over the past 10 years, the average number of new duplex developments on RS-2 properties across the entire community is just under two per year. In the last four years that average has climbed to 3.5 projects per year. Two such developments per year in the Garibaldi Estates represent a significant increase in the development of this housing form.

- **Large Lot Townhouses:** Completion of townhouse projects on all six larger properties in the eastern plan area, resulting in approximately 170 new strata townhouse units.
- **Single Unit Dwelling to Townhouse:** Conversion of 15 large single-unit dwelling properties in the Ground Oriented Residential Area to townhouse developments, representing 30% of 51 possible properties, resulting in approximately 125 new townhouse units.
- **Single Unit Dwelling to Apartment:** Conversion of 19 single unit dwelling properties to apartments along Diamond Head Road and Tantalus Road, representing 50% of 38 potential properties, plus redevelopment of an older apartment property on Garibaldi Way, resulting in approximately 590 new apartment units.

The 2044 Low scenario calibrates growth in the Garibaldi Estates against the expected growth rate for Squamish and the total development potential across the community. Estimates of new dwelling unit potential across the remainder of the District of Squamish indicate a plausible capacity of approximately 11,000 new dwellings (including single dwelling units, multiple dwelling residential, townhouses, and apartments) over the next 20 years. Combined with the Garibaldi Estates capacity identified in the 2044 High scenario, the total plausible capacity across the community is roughly 12,000 new dwelling units. However, BC Stats population projections for Squamish indicate 10,759 new residents between 2024 and 2044, resulting in a total population of 36,256. At an average of 2.6 residents per dwelling unit, this projection suggests a total of 4,136 new dwelling units across the community in the next 20 years, or 34% of the plausible capacity across the community. Because these expected dwelling units will be distributed across the entire community; the 2044 Low scenario assumes that only 34% of the plausible neighbourhood development capacity will be completed over the next 20 years, to align with the Provincial population projections. This suggests that approximately 320 new dwelling units could be expected to be completed in the Garibaldi Estates by 2044 for a total of 867 dwelling units.

Census data indicates that the Provincial population projections have underestimated growth in Squamish, particularly in recent years. Consequently, the most likely outcome is that the total number of new residential units in the Garibaldi Estates in 2044 will be somewhere between the 2044 Low scenario and the 2044 High scenario. The true rate of growth will depend on a broad range of economic, demographic, and political trends which are challenging to accurately predict.

District of Squamish
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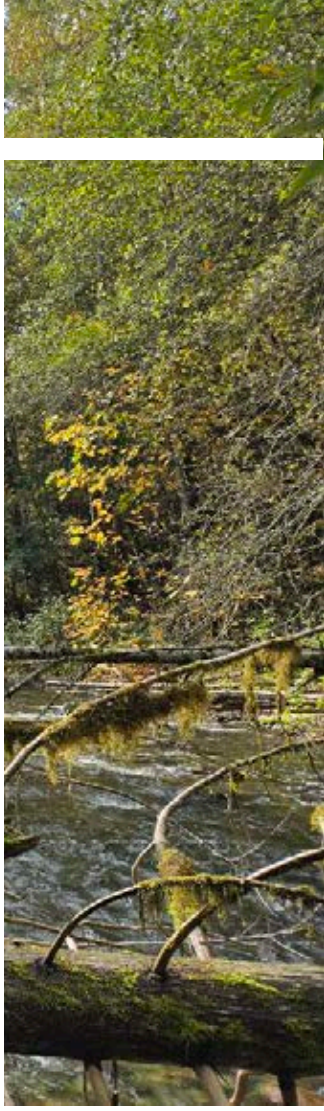

Mashiter Creek

Overland Flow Hazard Assessment

Prepared by BGC Engineering Inc. for:

SQUAMISH

February 5, 2025

Project 1348005/Rev 0

BGC

February 5, 2025 Project 1348005/Rev 0

District of Squamish
37955 Second Avenue
Squamish, BC V8B 0A3

Attention: Matt Gunn, MRM, RPP, Planner

Mashiter Creek Overland Flow Hazard Assessment

Please find the draft report attached. We appreciate the opportunity to collaborate with the District of Squamish on this challenging and interesting project.

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

Yours sincerely,

BGC Engineering Inc.
per:

Kathleen Horita, M.Sc., P.Eng.
Hydrotechnical Engineer

SUMMARY

Introduction

The District of Squamish (DoS) is currently completing a Sub-Area Plan for Garibaldi Estates East. One area of the neighbourhood, along Diamond Head Road, is proposed to develop from existing single family homes, to a 'high street' with retail stores and a wide pedestrian sidewalk at the ground floor, and apartments above. A 2017 Integrated Flood Hazard Management Plan (IFHMP) study (Kerr Wood Leidal (KWL), September, 2017b) identified Garibaldi Estates as an Overland Flow Hazard Area (Drawing 02) based on the potential for a debris flow or debris flood to cause an avulsion in the lower reaches of Mashiter Creek with floodwaters subsequently entering the neighbourhood.

The DoS identified that the Flood Construction Level (FCL) requirements for an Overland Flow Hazard Area in the DoS' Floodplain Management Bylaw (2022) may be conservative for the Garibaldi Estates East neighbourhood and retained BGC Engineering Inc. (BGC) to conduct a detailed study of the overland flow hazard from Mashiter Creek.

BGC's scope of service is to:

1. Provide the DoS with an understanding of the flood extents, and flood depths and velocities for the overland flow hazard from Mashiter Creek in the Garibaldi Estates East neighbourhood (extents shown in Drawing 02).
2. Recommend flood mitigation within the Garibaldi Estates neighbourhood (if required).
3. Recommend updates to the DoS's Floodplain Bylaw, if appropriate.

Background

Mashiter Creek was first identified as subject to steep creek geohazards in 1987 by Squamish-based engineer Frank Baumann (Septer, 2007). Following this assessment, Mashiter Creek was subject to significant floods events in November 1990 and August 1991 that caused considerable damage to the water intake on Mashiter Creek (Septer, 2007). The 2017 (a,b) IFHMP study by KWL did not include Mashiter Creek but identified it as an "Overland Flow Hazard Area" and recommendations for management were provided to DoS that were integrated into the DoS' flood management bylaw. A flood, debris-flood, or debris-flow assessment was recommended for Mashiter Creek and other steep creeks to integrate with the results of the IFHMP.

Mashiter Creek is an approximately 40 km^2 watershed that is susceptible to floods, Type 1 debris floods, and Type 2 debris floods:

- BGC and Cordilleran Geoscience (Cordilleran) completed field work on September 24 and October 9, 2024. BGC and Cordilleran found an eroded bank approximately 380 m upstream of the Mamquam River that exposed four distinct depositional layers. A log that was deeply embedded in the bank was used to date the top of the fourth layer back to approximately 550 years ago. The four depositional layers included three Type 2 debris flood deposits and one layer of flood deposits. These observations demonstrate

that there have been at least three Type 2 debris floods that have reached the lower 500 m of Mashiter Creek between 80 and 550 years ago.

- Floods and Type 1 debris floods have been recorded within living memory, most notable the 1990 and 1991 events (Septer, 2007). The 1990 and 1991 sediment deposits are visible throughout the channel in the 1994 air photo (Appendix B).
- The watershed morphometrics (its size, average gradient, ruggedness) suggest that Mashiter Creek is susceptible to floods and debris floods. Mashiter Creek does not have a sufficiently steep gradient to sustain a debris flow.

A Type 2 debris flood is caused by a debris flow that dilutes into a debris flood as additional water is added from tributaries or contributing watershed area and/or sediment deposition.

Overland Flow Hazard Scenarios for Mashiter Creek

BGC estimated the process type, approximate size, and frequency of floods and debris floods on Mashiter Creek to inform the selection of overland flow scenarios for numerical modelling. BGC assessed the climate-adjusted 200-year, 500-year, 1,000-year, and 2,500-year return period events. BGC defined overland flow scenarios using a variety of methods informed by evidence from past geohazard events, air photos, field observations, and topographic data and are shown in Table S-1.

The overland flow scenarios assume that the triggering event for each scenario is a multi-day storm bringing a period of heavy rain over 2.5 days to Squamish, BC. BGC estimated peak discharge and storm hydrographs (i.e., distribution of the flow over a storm duration) for all scenarios using a rainfall-runoff model of Mashiter Creek and climate-adjusted precipitation estimates to the year 2100. The peak discharge shown in Table S-1 reflects the peak runoff from Mashiter Creek during this storm.

The overland flow scenarios are Type 2 debris floods for all return periods greater than or equal to 200 years. The sediment associated with each scenario is anticipated to deposit primarily within the Mashiter Creek channel and impact the immediate overbank area including parcels within the Debris-Flood Hazard Area outlined in Drawing 05. One of two terrain modification options were applied to the base terrain of the numerical model for each model scenario to account for potential morphological changes within Mashiter Creek during a debris flood. The two terrain modifications assessed were (i) blocking the Mamquam Road bridge over the Mashiter Creek channel and (ii) full aggradation of the Mashiter Creek channel within the model domain.

BGC estimates that the lower 500 m of Reach 1 of Mashiter Creek has the capacity to store approximately 10,000 to 20,000 m^3 of sediment. Based on the BGC's estimates of sediment volumes associated with the 200-year event (Section 4.6), it is considered likely that the Mamquam Road bridge over Mashiter Creek is blocked for the 200-year return period scenario. For all scenarios with return periods greater than 200 years, it was assumed that the channel

was filled with sediment up to bankfull for return periods greater than 200 years within the model domain.

Table S-1 Overland flow scenarios used for numerical modelling of the overland flow hazard in Mashiter Creek.

Representative Return Period (years)	Process Type	Peak Discharge (m^3/s)	Terrain Modifications
200	Type 2 debris flood	220	The bridge over Mashiter Creek at Mamquam Road is fully blocked during the debris flood (Figure 5-3).
500	Type 2 debris flood	245	The Mashiter Creek channel is fully aggraded. (1)
1,000	Type 2 debris flood	260	The Mashiter Creek channel is fully aggraded. (1)
2,500	Type 2 debris flood	280	The Mashiter Creek channel is fully aggraded. (1)

Notes:

1. Full aggradation of the channel within the model domain included filling the channel up to bankfull (approximately 4 m of depth) for the full 350 m of the Mashiter Creek channel within the numerical modelling domain. Illustration of the changes made to the terrain of the numerical model to represent channel aggradation are shown in Figure 5-4)

Overland Flow Modelling

BGC used a two-dimensional (2D) hydraulic model to estimate the overland flooding extents, along with the modelled depths and velocities within the study area. The modelling showed that Mashiter Creek avulses from its main channel to the west flowing down Paco Road and then Mamquam Road along the general path of the historical channel of Mashiter Creek (Drawing 02 and 03). As the discharge increases, a second avulsion occurs towards the west along Mamquam Road. The avulsions occur in all overland flow scenarios modelled, including the 200-year climate-adjusted scenario.

Once Mashiter Creek avulses, most of the avulsed flow floods the lands of the Squamish Valley Golf Club with a small amount of flow (< 1 m^3/s) that continues west down Mamquam Road then flows north to enter the study area. Modelled flow velocities were less than 0.5 m/s within the study area for all scenarios modelled. Flow depths were less than 0.15 m on the roads within the study area for the 200-year climate-adjusted scenario with the exception of ponded depths up to 0.45 m on the west side of the Canadian Tire parking lot and the southern portion of Glenalder Place behind Canadian Tire.

The flows that flood the Squamish Valley Golf Club lands split into two flow paths. The first follows the historical channel towards the Mamquam River dike and overtops the Mamquam River dike. The discharge overtopping the dike was estimated to be 45 m^3/s at its peak for the 200-year climate-adjusted scenario. The duration of time the dike is being overtopped during a debris flood on Mashiter Creek could exceed 24 hours. The remaining flow generally continues west and overtops the Sea-to-Sky Highway to enter the Garibaldi Estates West neighbourhood

where it is eventually reaches the Squamish River dike and begins to pond. At the Sea-to-Sky Highway, some flow heads south to enter the Mamquam River.

The diking network along the Mamquam River and the Squamish River results in a 'bathtub effect' for the overland flows from Mashiter Creek. The dikes prevent Mashiter Creek from exiting developed land north of the Mamquam River.

Recommendations

BGC met with the DoS on November 28, 2024 and January 7, 2025 to discuss options to manage the overland flow hazard from Mashiter Creek within the study area, and the following was decided:

- The 200-year climate-adjusted debris-flood scenario results were selected to guide the management recommendations.
- The DoS requested that BGC comment on updated management recommendations for the Overland Flow Hazard Area for Mashiter Creek outlined during the IFHMP study (KWL, 2017a) and shown in Drawing 02.

BGC re-delineated the overland flow hazard boundary for Mashiter Creek based on the results of this study and then divided that boundary into three management areas with recommendations as shown in Drawing 05. The refined overland flow hazard boundary now excludes several parcels in the northwest portion of Garibaldi Estates East, northwest of Garibaldi Way.

Table S-2 outlines the updated FCL recommendations for each management area within the overland flow hazard area for Mashiter Creek (Drawing 05). An FCL means the required elevation of the underside of a wooden floor system or top of pad to be used as Habitable Areas as defined in the DoS Floodplain Management Bylaw (DoS, 2022). The general FCL exemptions listed in the DoS Floodplain Management Bylaw (DoS, 2022) apply, including basements that do not include habitable space, and parking.

Table S-2. Management area recommendations for the overland flow hazard from Mashiter Creek (Drawing 05).

Management Area	Overland Flood Description	Recommendations
Management Area 1	Overland flooding from Mashiter Creek is anticipated to be mostly standing water in ditches and in low-lying areas. Roads have flow depths up to 0.15 m throughout most of the neighbourhood with the exception of the western portion of the Canadian Tire parking lot and the southern portion of Glenalder Place that show ponded depths up to 0.45 m.	BGC recommends that the FCL is 0.3 m above the crown of the adjacent road aligning with freeboard recommendations in EGBC (2018). When a parcel borders two roads, the crown of the upslope road should govern.
Management Area 2	Management Area 2 includes most of the area west of the Sea-to-Sky Highway and north of Garibaldi Way within the delineated overland flow hazard boundary in Drawing 05. Modelled water surface elevations from Mashiter Creek are less than the existing FCLs for this area by 0.5 m or more.	BGC recommends that the existing FCL govern within this area. The existing FCLs are associated with dike breach modelling completed by KWL (2017b) for the Squamish River and Mamquam River.
Management Area 3	Management Area 3 includes the Squamish Valley Golf Club land and portions of the Garibaldi Estates west of the Sea-to-Sky Highway as shown in Drawing 05. The modelled water surface elevations from Mashiter Creek are within 0.5 m of the existing FCLs within this area.	BGC recommends that the Overland Flow Hazard Area as identified in the IFHMP (KWL, 2017a) continues to govern. In areas of existing development, the freeboard may be reduced following further study to evaluate the probability and inundation extents of one or more dike breaches on the Squamish River and/or Mamquam River coinciding with a debris flood on Mashiter Creek along with additional modelling, as required. In advance of any topographical changes within the Squamish Valley Golf Club lands, BGC recommends further study. Topographical changes within the lands of the Squamish Valley Golf Club are expected to have impacts on the floodways and overland flow management recommendations for all three areas.

The overland flow management recommendations are based on the existing topography. The DoS should not modify the topography within the Squamish Valley Golf Club lands, nor on Mamquam Road between Paco Road and Highland Way South without additional study on how this will impact existing floodway and the overland flow management recommendations.

Additional Recommendations

- The debris-flood hazard and risk from Mashiter Creek was not quantified in this study for parcels adjacent to Mashiter Creek (approximate delineated Debris-Flood Hazard Area in Drawing 05). In the event of a debris flood on Mashiter Creek, this area is likely exposed to bank erosion and may be exposed to impact forces that may cause structural damage and possible loss of life. The geomorphic and F-M assessment completed herein is likely adequate to develop credible geohazard scenarios; however, a bank erosion assessment and detailed runout modelling would be required to quantify the debris-flood hazard and associated risks in this area. BGC recommends that a hazard and risk assessment is completed for the debris-flood hazard area in Drawing 05.
- There are two locations on the Mamquam River dike that are overtopped for all geohazard scenarios modelled including the 200-year climate-adjusted scenario (Figure 5-2). Overtopping is a possible failure mechanism for a dike. BGC recommends that the DoS consider placing erosion protection on the Mamquam River side of the dike to reduce the likelihood of failure due to overtopping flows from Mashiter Creek.

TABLE OF REVISIONS

Date	Revision	Remarks
January 23, 2025	A	Draft issued for client review
February 5, 2025	0	Final Issue

CREDITS AND ACKNOWLEDGEMENTS

BGC Engineering Inc. (BGC) would like to acknowledge the support of the District of Squamish (DoS) team including Matt Gunn, David Roulston, and Jessica Gagne in providing project background information and discussion on hazard management within the context of Squamish, BC.

The analysis and report herein were developed through the contributions of many individuals on the BGC and Cordilleran Geoscience (Cordilleran) team (Table CA 1-1):

Table CA 1-1 Study team. Professional designations are for practice in British Columbia.

Project Role	Subject Area	Team Member
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Technical Lead		Kathleen Horita, M.Sc., P.Eng.
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Technical Reviewers	Frequency-Magnitude Assessment	Pierre Friele, M.Sc., P.Geo., P.L.Eng. (Cordilleran)
	Overall	Lauren Hutchinson, M.Sc., P.Eng.
	Corporate	Michael Porter, M.Eng., P.Eng.
Project Support	Project Engineer/ Geoscientist	Andrew Funk, B.A.Sc., EIT
	GIS Analyst	Kevin Carpenter, B.Sc.

This work was completed by BGC and Cordilleran employees who live and work in Squamish and in Vancouver, British Columbia, situated on the unceded traditional territories of the xʷməθkʷəy̓ əm (Musqueam Indian Band), Sḵwx̱wú7mesh Úxwumixw (Squamish Nation), and səlilwətaɬ (Tsleil-Waututh Nation).

BGC acknowledges that the project study area is within the unceded traditional territory of the Sḵwx̱wú7mesh Úxwumixw (Squamish Nation).

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1.0 INTRODUCTION

The District of Squamish (DoS) is currently completing a Sub-Area Plan for Garibaldi Estates. One area of the neighbourhood, along Diamond Head Road, is proposed to develop from existing single family homes, to a 'high street' with retail stores and a wide pedestrian sidewalk at the ground floor, and apartments above. A 2017 Integrated Flood Hazard Management Plan (IFHMP) study (Kerr Wood Leidal (KWL), September, 2017b) identified Garibaldi Estates as an Overland Flow Hazard Area (Drawing 02) based on the potential for a debris flow or debris flood to cause an avulsion in the lower reaches of Mashiter Creek with floodwaters subsequently entering the neighbourhood.

Based on the DoS's Floodplain Bylaw (DoS, January 4, 2022), the Flood Construction Level (FCL) requirement within Overland Flow Hazard Areas is the higher elevation of:

1. 1.5 m above the Natural Boundary of any adjacent Watercourse, lake, pond, marsh or reservoir, whether natural or constructed.
2. 0.6 m above the crest of any downstream road or embankment or other feature that could result in a backwater condition, but specifically excluding the effect of downstream Standard Dikes and Sea Dikes.
3. 1.0 m above the finished grade around the building.

The DoS identified that these FCL mitigation requirements may be conservative for the Garibaldi Estates neighbourhood and retained BGC Engineering Inc. (BGC) to conduct a detailed study of the overland flood hazard from Mashiter Creek.

1.1 Scope of Services

BGC's scope of service is to:

1. Provide the DoS with an understanding of the flood extents, and flood depths and velocities for the overland flow hazard from Mashiter Creek in the Garibaldi Estates East neighbourhood (extents shown in Drawing 02).
2. Recommend flood mitigation within the Garibaldi Estates neighbourhood (if required).
3. Recommend updates to the DoS's Floodplain Bylaw, if appropriate.

The scope of service includes:

- Geologic and geomorphic assessment of the Mashiter Creek watershed including geomorphic mapping, air photo and satellite imagery review, compilation of historical events, and confirmation of the dominant geohazard process for Mashiter Creek.
- Frequency-magnitude (F-M) assessment including a flood-frequency analysis with a climate-change adjustment to the year 2100, as well as estimates of sediment volumes to define credible overland flow scenarios for numerical modelling. The return periods evaluated align with a Class 3 debris-flood hazard assessment (EGBC, August 28, 2018), with the addition of the 500-year return period at the request of the DoS.
- Two-dimensional (2D) hydraulic modelling of the overland flood hazard from Mashiter Creek for the selected credible overland flow scenarios.
- Flood maps illustrating the extent and characteristics of the overland flow hazard from Mashiter Creek.

- Recommendations on:
  - FCL requirements within the study area (Drawing 02);
  - Measures that may be taken to meet FCL requirements;
  - Other considerations for the future planning of Garibaldi Estates including risk transfer; and
  - Updates to the Floodplain Management Bylaw, if applicable.

BGC's scope of service does not include:

- A detailed hazard assessment of the steep creek hazard from Mashiter Creek to existing or future development on the banks directly adjacent to Mashiter Creek (debris-flood hazard area delineated in Drawing 05).
- Detailed modelling of the timing of and interaction of flooding from Mashiter Creek with flooding on the Mamquam River or Squamish River, or flooding associated with dike breach scenarios outlined in the 2017 IFHMP (KWL, 2017b).
- Flood maps for the overland flow hazard from Mashiter Creek in the areas outside of the study area extents shown in Drawing 02.

1.2 Terms of Reference

This report was prepared for the DoS to provide recommendations to mitigate the overland flow hazard from Mashiter Creek within the study area extents shown in Drawing 02. The services were completed under Form of Agreement R24-32 between BGC and the DoS signed August 21, 2024.

Cordilleran Geoscience (Cordilleran) supported the field work and provided external review for the frequency-magnitude assessment of Mashiter Creek under a Professional Services Agreement with BGC signed October 1, 2024.

2.0 STEEP CREEK PROCESSES BACKGROUND

2.1 Introduction

A geohazard is a geophysical process that is a source of potential harm, or that represents a situation with a potential for causing harm. There are many different types of geohazards (e.g., Figure 2-1, Figure 2-2). The dominant geohazard process type for a stream is related to its watershed characteristics, channel gradient, and the sediment volumes it can transport.

Geohazards are generally classified by their sediment concentration, velocity, and speed (Figure 2-1). On the left side of the figure, floods (sometimes also called “clearwater” floods) generally contain very little sediment and flow more slowly relative to the other geohazards. These hazards can cover large areas (e.g., Squamish River or Mamquam River) and can persist over long durations (e.g., flooding over days). On the right side of the diagram are landslides, which contain mostly sediment and can have the widest range of slope movement, from nearly imperceptible to faster than highway vehicles. Landslides can be very sudden and create intense damage (e.g., catastrophic house damage). They are generally localized compared with floods that can affect wide areas. In the middle of the diagram are “steep creek” hazards, which contain a mixture of water and sediment and are those most relevant to this study. Steep creek hazards typically occur on streams with small watersheds (usually less than 100 km^2). These hazards can cause community-scale damage to houses and infrastructure (e.g., Cheekeye River debris-flow hazard).

The following subsections describe steep creek geohazards relevant to the study area in more detail.

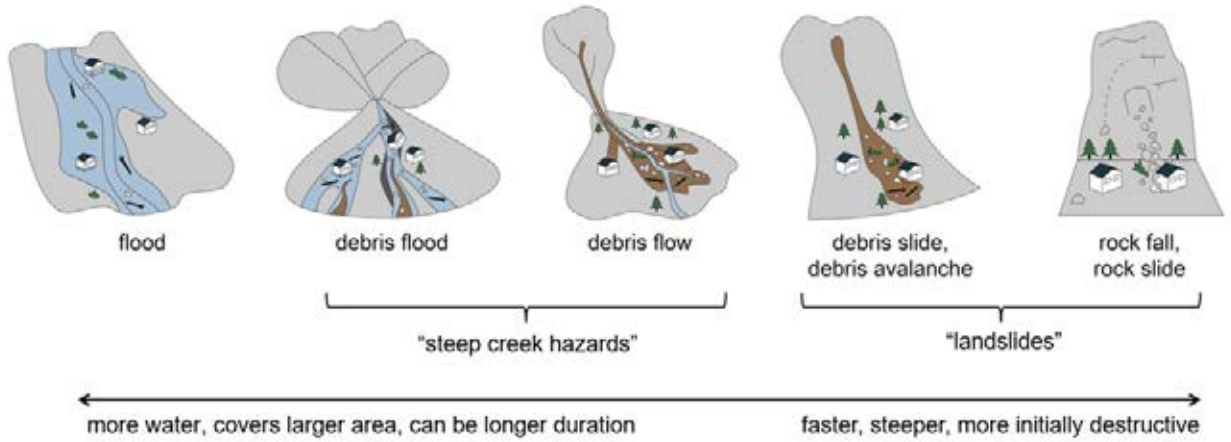


Figure 2-1 Example of geohazard types.

Figure 2-2 Photos of relevant geohazards that have occurred near the project area or in BC. a) 2012 debris flood on Sicamous Creek in the BC interior, photo from YouTube. b) 2015 debris flow near Birken approximately 25 km northeast of Pemberton, photo by Mike McAurthur/CBC. c) 1997 Gowan Creek debris avalanche that initiated as a road fill failure approximately 80 km southeast of Pemberton, photo from Collins (2007). d) 2008 rock slide/rock fall on the Sea-to-Sky Highway near Porteau Cove, photo from the Canadian Press/Jonathan Hayward. e) 2019 Joffre Peak rock avalanche 25 km east of Pemberton, photo by Wilfried Braun/X.

2.2 Debris Floods

Debris floods are a case of flooding with extreme sediment transport where much of the streambed becomes mobile and is actively rolling and sliding along the stream bed, and is occasionally suspended in the fluid flow. This is referred to as “full bed mobilization” where the entire bed becomes mobile except perhaps the largest clasts (Church & Jakob, 2020). Debris floods can occur on all sizes of gravel to cobble-bed rivers with channel gradients less than 30% (17º).

Debris floods have higher sediment concentrations compared to clearwater floods, but much less than debris flows, making them an intermediate process between the two. Debris floods can cause extensive scour, bank erosion, and channel aggradation. There are different types of debris floods based on their triggering mechanisms (Figure 2-3). A “Type 1” debris flood is caused by heavy rain or snowmelt leading to full mobilization of the channel bed, a “Type 2” debris flood is caused by a debris flow that dilutes into a debris flood by adding water or depositing sediment, and a “Type 3” debris flood is an outbreak flood caused by a dam failure

(human-made or natural, such as a landslide dam) causing a rapid release of water (Church & Jakob, 2020).

The type of debris flood is relevant as it impacts the sediment concentration the debris flood may carry, the fluid density of the debris flood, and the magnitude of both the sediment volume transported and the peak discharge. Type 1 and Type 2 debris floods are both relevant to Mashiter Creek.

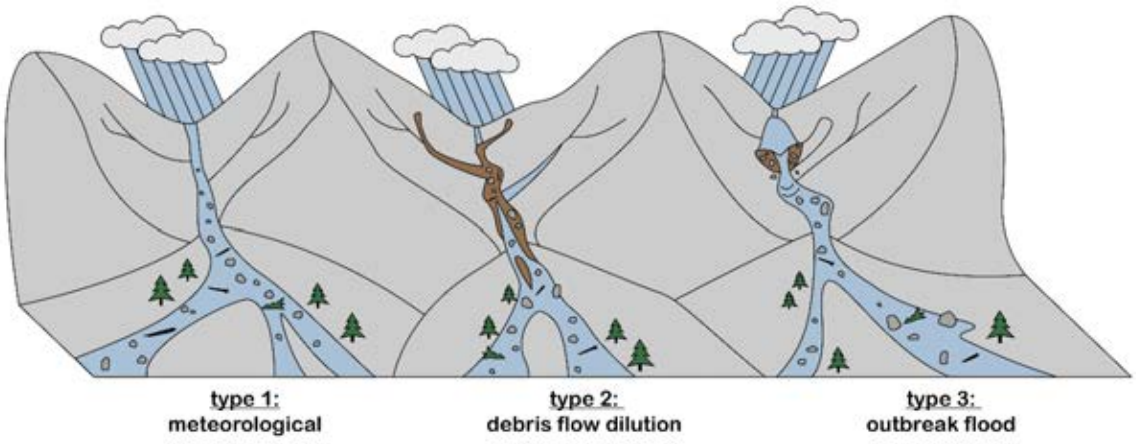


Figure 2-3 Debris flood types based on triggering mechanisms. Schematic based on descriptions from Church & Jakob (2020).

2.3 Debris Flows

A debris flow is a fast-flowing mixture of water and debris (rock, soil, organics) travelling down a steep channel (Hungr et al., 2014). Their consistency can be like wet concrete as they typically have about a 50% water concentration (by volume). They usually come down in pulses and accumulate volume as they entrain material along their path. Debris flows can be triggered by heavy bursts of rain, rapid snow melt, or a landslide (e.g., rock slide, debris avalanche) that enters a channel and transitions into a debris flow. They can occur with little warning and typically have short durations (minutes to hours). Debris flows can be extremely destructive because of their high velocities[2], sediment concentrations, and ability to move large boulders and trees. Debris flows can generate impact pressures large enough to destroy buildings. Wildfires and logging in the watershed can increase the frequency and magnitude of debris flows due to removal of vegetation and drainage disturbances which increase and concentrate runoff that trigger debris flows.

[2] Velocities can reach up to about 70 km/hour in the steep channels of the watershed, up to 40 km/hour at the outlet of the channel (fan apex), and down to a few km/hour (jogging speed) further down the fan once flows spread out across gentler terrain.

3.0 STUDY AREA

3.1 Squamish, BC

Squamish, BC is located on the unceded traditional territory of the Squamish (Sḵwx̱wú7mesh) Nation. The City of Squamish was initially incorporated in 1914 then became the Village of Squamish in 1948. On December 15, 1964, the Village of Squamish, Brackendale, and Mamquam amalgamated to become the new District of Squamish.

3.2 Physical Setting

3.2.1 Physiography and Geology

Mashiter Creek is situated on the southern slopes of Mount Garibaldi (Nch'ka̓y̓) with headwaters originating at its sub-peak, Diamond Head. The watershed crosses two primary geological groups and drains southwest into Mamquam River (Drawing 03). Bedrock materials along Mashiter Creek are comprised of the two major geological units, with the headwaters and upper 500 m of Mashiter Creek flowing within the Garibaldi Group (basaltic volcanic rocks). The lower 70% of Mashiter Creek flows through more competent intrusive dioritic bedrock. A portion of the upper southeast corner of the watershed is within the Gambier Group, comprising less competent marine sedimentary and volcanic rocks. However, the mainstem channel does not flow through Gambier Group bedrock, and limited sediment contributions to Mashiter Creek are estimated to be derived from this unit given the spatial separation and limited evidence of sediment sources identified from the area. A summary of geological units and description of characteristics are outlined in Table 3-1.

Table 3-1 Geological units within the Mashiter Creek watershed.

Geological Unit	Spatial Extent	Description
Garibaldi Group	Upper reaches of the Mashiter Creek watershed	Late Glacial to Early Post Glacial: olivine basalt flows, basaltic andesite flows and pyroclastic cones, rhyolite, dacite and andesite flows and domes; polymictic breccias and pyroclastics, minor intercalated sediments
Granodioritic Intrusive	Lower and middle reaches of the Mashiter Creek watershed	Quartz diorite; includes Cloudburst, Ashlu Creek and Ward Point Plutons
Gambier Group	Two isolated areas in upper watershed and transport reaches of the Mashiter Creek watershed – disconnected from primary drainage	Undifferentiated Gambier Group volcanic and sedimentary rocks include thick bedded basaltic andesite, dacitic and rhyolitic tuffs, flows and volcanic breccia, greenstone, pillowed basalt, argillite, greywacke, shale, siltstone, basal conglomerate

The Mashiter Creek watershed is characterized by steep hillslopes throughout the upper sections of the channel. Soil veneers of typically less than 3 m thick consisting of colluvium, till, and reworked glacial deposits form the majority of surface materials throughout the watershed (Blais-Stevens, 2008). Slope angles in the upper watershed range from 25°-35°, with localized areas exceeding 45°.

The headwaters of Mashiter Creek border the south side of the Cheekeye watershed, which has produced numerous high hazard debris floods and debris flows, the sediment of which is typically composed of tuff-breccias derived from Garibaldi Group bedrock and volcanic deposits in the steep (<45°) upper watershed (Mathews, 1952). Much of the sediment available for transport by the Cheekeye River is derived from the western flank of Mount Garibaldi, which collapsed during deglaciation about 13,000 to 11,300 years ago (Clague, Friele, & Hutchison, 2003) and deposited sediment across the Cheekeye basin, Mashiter Creek, and Hop Ranch Creek (Mathews, 1952). Topography-based assessments of landslide and debris-flow susceptibility (Blais-Stevens & Kung, 2009) along Mashiter Creek identify steep slopes capable of producing landsliding high on the hillslopes around Mashiter Creek, as well as moderate to high debris-flow susceptibility through the middle and lower portions of Mashiter Creek.

3.2.2 Watershed and Channel Geomorphology

Mashiter Creek is an approximately 40 km^2 watershed that originates on the south slopes of Mount Garibaldi at Diamond Head and the Gargoyles (Drawing 01). From its headwaters at an approximate elevation of 1920 m, the creek flows to the south for about 4 km before turning west for an additional 4 km. The creek then turns to the south-southwest for 7 km, eventually discharging into the Mamquam River immediately upstream of the Squamish Valley Golf Club. In its lower reach, the creek is crossed by Mamquam Road (100 m upstream of the Mamquam River) and The Boulevard (1 km above Mamquam Road) (Drawing 02).

The watershed morphometrics at a desktop-level suggests that the dominant geomorphic process types for Mashiter Creek at its fan apex (beginning of Reach 1 in Drawing 03) are floods and debris floods (Figure 3-1) and this has been confirmed through field investigation (Section 4.4). A summary of watershed geomorphic characteristics is provided in Table 3-2.

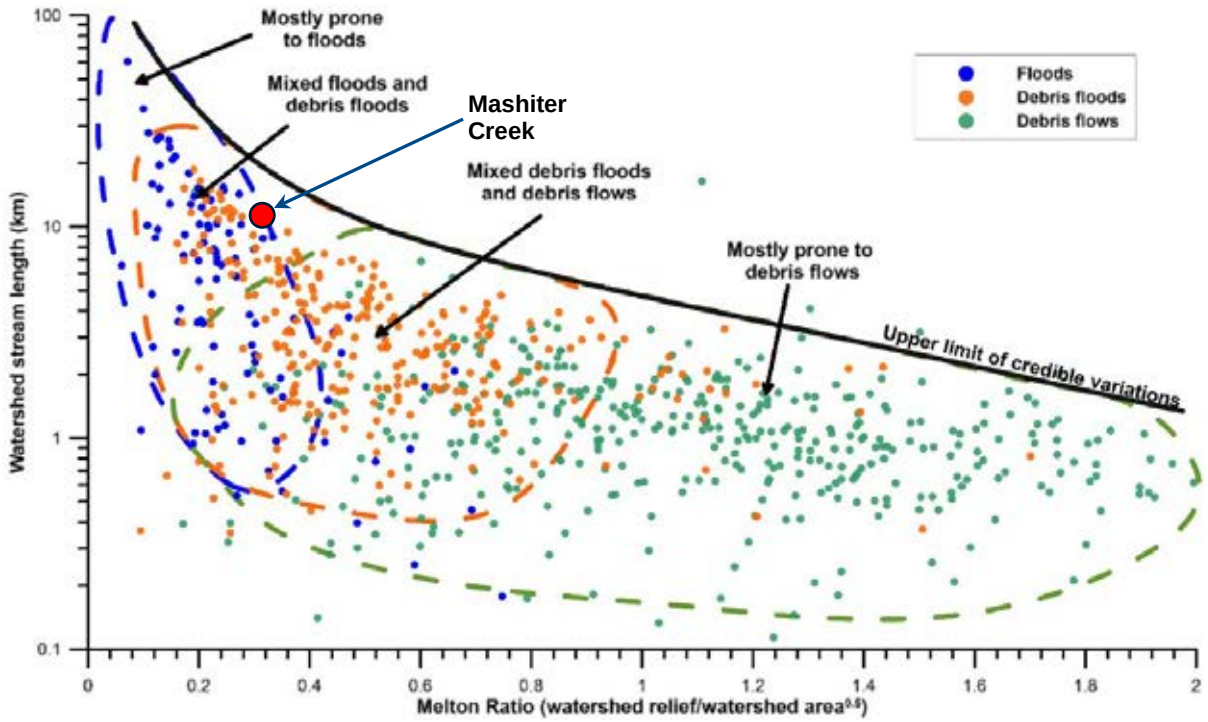


Figure 3-1 Steep creek processes as a function of Melton ratio and stream lengths (from Jakob et al., 2022).

Table 3-2 Summary of geomorphic measurements and interpretations for Mashiter Creek watershed.

Measurement	Mashiter Creek
Watershed Area	40 km^2
Maximum Watershed Elevation	1920 m
Minimum Watershed Elevation	30 m
Watershed Relief	1890 m
Watershed Length	12.4 km
Melton Ratio (1)	0.3
Watershed Mainstem Channel Length	14.1 km
Average Mainstem Channel Gradient	11.3%
Fan Area	Unknown (2)
Average Fan Gradient (%)	2%
Dominant Geomorphic Process Type	Floods and Debris Floods

Note:

1. Melton ratio (index) is a measure of the ruggedness of a watershed and is often used at a screening level to evaluate the dominant geomorphic process type for a watershed (Wilford et al., 2004). Melton ratio is calculated as the watershed relief divided by the square root of the watershed area.
2. The fan of Mashiter Creek originates at its fan apex (upstream end of Reach 1) and extends downstream intermingling with the alluvial fan of the Mamquam River. It is not possible to accurately separate the fan of Mashiter Creek from the alluvial fan of the Mamquam River, therefore the fan area for Mashiter Creek was not estimated.

Table 3-3 Channel characteristics for each reach of Mashiter Creek listed from upstream to downstream.

Reach	Average Channel Width	Floodplain Width	Average Channel Gradient	Bedrock Geology
5 (1,2)	Unknown	Unknown	15 to 20%	Garibaldi Group of volcanics
4 (3)	10 to 20 m	none	10 to 15%	Dioritic Intrusive
3 (3,4)	20 to 25 m	~100 m in the upper portions and reducing to ~10 m near the downstream end	5 to 7%	
2 (2,4)	4 to 6 m	None	~ 15%	
1 (4)	15 to 20 m	80 to 100 m	1 to 2%	

Notes:
1. No lidar was available for Reach 5 and there are no field observations of Reach 5 to support channel size estimates.
2. The channel gradient was estimated from the MRDEM dataset which is a 30 m resolution digital terrain model available from the Government of Canada.
3. Dimensions in this reach are based on field observations (Section 4.4).
4. Dimensions in this reach are based on lidar collected in 2018 (Section 4.2.2).

BGC has separated Mashiter Creek into five reaches for the purposes of this study. The reaches are numbered from downstream to upstream and are separated based on their channel characteristics. The extent of each reach is shown in Drawing 03, and a summary of the defining channel characteristics is provided in Table 3-3.

- Reach 5 originates in the upper watershed of Mashiter Creek within the boundary of Garibaldi Provincial Park. Its bedrock geology is the Garibaldi Group of volcanic rocks. It has numerous bare side slopes and debris-flow tributaries that act as sediment sources to the main channel.
- Reach 4 is predominantly a canyon with steep bedrock walls composed of granite blocks with occasional bedrock outcrops along the channel bed. The granite sidewalls have produced rockfalls that have resulted in numerous waterfall and step-pool like features along the channel (Photo 1 and 2, Appendix A). The north and south hillslopes of Reach 4 were heavily logged in the 1950s to 1970s (Drawing 04).
- Reach 3 is characterized by a deeply incised channel with a wide floodplain on the order of 100 m in its upstream half that transitions to steeper bedrock side walls and a minimal floodplain width (on the order of approximately 10 m) in its lower half. Debris flows from Reaches 5 & 4 are deposited/stored along this reach.
- Reach 2 is deeply incised into bedrock with predominantly bedrock banks. It is a short reach that begins at the Boulevard bridge crossing where the channel transitions to a steep bedrock-lined cascading waterfall with a gradient of approximately 15% (Photo 10, Appendix A).
- Reach 1 represents the lower 750 m of Mashiter Creek before it joins the Mamquam River. The floodplain of Reach 1 is well-vegetated with mature forest, is 80 to 100 m wide, and is approximately three to five meters above the main channel of Mashiter

Creek. Only flood and debris-flood sediments were noted by BGC in bank exposures within this reach.

3.2.3 Forestry and Wildfires

The Mashiter Creek watershed is forested. The mid-part of the watershed was heavily logged right to the creek banks through the 1950s, 1960s, and 1970s (Drawing 04). The lower watershed was logged in the 2000s to present day and there are logging roads that parallel the slopes upslope of the Mashiter Creek channel (Drawing 04) (Forest Analysis and Inventory Branch, 2023). In January 2020, there was a fill slope failure that triggered a landslide on Branch 02 of the Ring Creek Forest Service Road (FSR) and this triggered a road-related landslide hazard/risk assessment by the Ministry of Forests (MoF). The assessment identified both Branch 02 and Spur H to be high hazard roads that have experienced post-logging landslides (Cordilleran Geoscience, September 26, 2021). These forestry spur roads run parallel to the slope and are located upslope of the Mashiter Creek channel in Reach 3 and Reach 4 (Drawing 04).

There were small wildfires in the Mashiter Creek watershed in 1929 and 1946 (Drawing 04) (BC Wildfire Service, 2023). There is no other record of wildfire within the watershed. Burn probability mapping[3] provided by the BC Wildfire Service used in BGC's (April 24, 2023) regional geohazard risk assessment for the Squamish-Lillooet Regional District shows a probability of less than 5% per year across the study area. Given hotter, drier summers anticipated with climate change (Section 3.3), wildfires may increase in the future. The impact of logging activities and wildfires on the frequency and magnitude of geohazards is discussed in Section 4.6.4.

3.2.4 Mamquam River Alluvial Fan

While the focus of this study is on the overland flow hazard posed by Mashiter Creek on the Garibaldi Estates neighbourhood east of the Sea-to-Sky Highway, it should be recognized that this neighbourhood has been built on the larger alluvial fan complex of the Mamquam River. Just downstream of Ring Creek, the Mamquam River has developed a large alluvial fan complex that eventually interfingers with the floodplain sediments of the Squamish River to the west. The approximate extent of the Mamquam River alluvial fan is delineated on Drawing 02.

The Mamquam River alluvial fan formed through sediment transport and deposition on the Mamquam River (watershed area ~ 380 km^2), although it is also partially formed by steep creek processes from Mashiter Creek.

3.3 Regional Climate and Climate Trends

Squamish lies within the southern portion of the Coast Mountain ranges of British Columbia. The major climatic process bringing precipitation to the Coast Mountains are atmospheric rivers

[3] Burn probability mapping is created using the Burn-P3 software using inputs such as fuel characterization (e.g., vegetation), topography, weather, and patterns of fire ignitions throughout BC.

which come from the Pacific Ocean to the west. Atmospheric rivers tend to carry warmer air and heavy precipitation which can fall as rain or snow within the project area. Atmospheric rivers are most common between October and March. Cold arctic air can also build up over the interior of the province and overflow south through the Coast Mountain ranges resulting in short periods of extreme cold and snow. Convective rainstorms occur predominantly in the summer months, typically cover a relatively small (10s of km^2 in area or less) spatial scale, and are shorter in duration (<24 hours). If convective rainstorms are localized over a small watershed such as those covered in this report, they can generate high runoff (e.g., the August 30, 1991 debris flood on Mashiter Creek).

Climate normals are 30-year averages of observed climate data from stations that have high-quality records. They are used to summarize general climatic data at a particular location. Figure 3-2 shows the modelled monthly mean daily temperature and precipitation climate normals for Squamish historically (1981 to 2010), currently (2011 to 2040), and in the future (2071 to 2100)[4] from ClimateBC[5].

Table 3-4 tabulates the historic, current, and future climate and precipitation values by season. Historically, approximately two-thirds of the precipitation occurred during fall and winter with the remaining third in spring and summer. With climate change, annual precipitation is expected to increase overall in the future, with wetter winters and drier summers.

[4] Note these are modelled climate normals and may not match the historical observed climate normals for Squamish, BC. It is recommended that the reader looks at the projected changes in the climate variables rather than the precise values for each variable within each 30-year period estimated by the models. Historical models are calibrated to observations, but they are not a replacement for observational data.

[5] ClimateBC (Wang et al., 2016; Mahony et al., 2022) is a repository of downscaled gridded (800 m x 800 m) climate data for the Province of British Columbia. Climate data for historical and future climates come from 13 General Circulation Models (GCMs) of the Coupled Model Intercomparison Project (CMIP6) assuming Shared Socioeconomic Pathway (SSP) 5/8.5. SSP5/8.5 is the upper-bound or worst-case climate scenario available and is a “business as usual” scenario assuming very little climate adaptation and emission reductions are achieved by 2100.

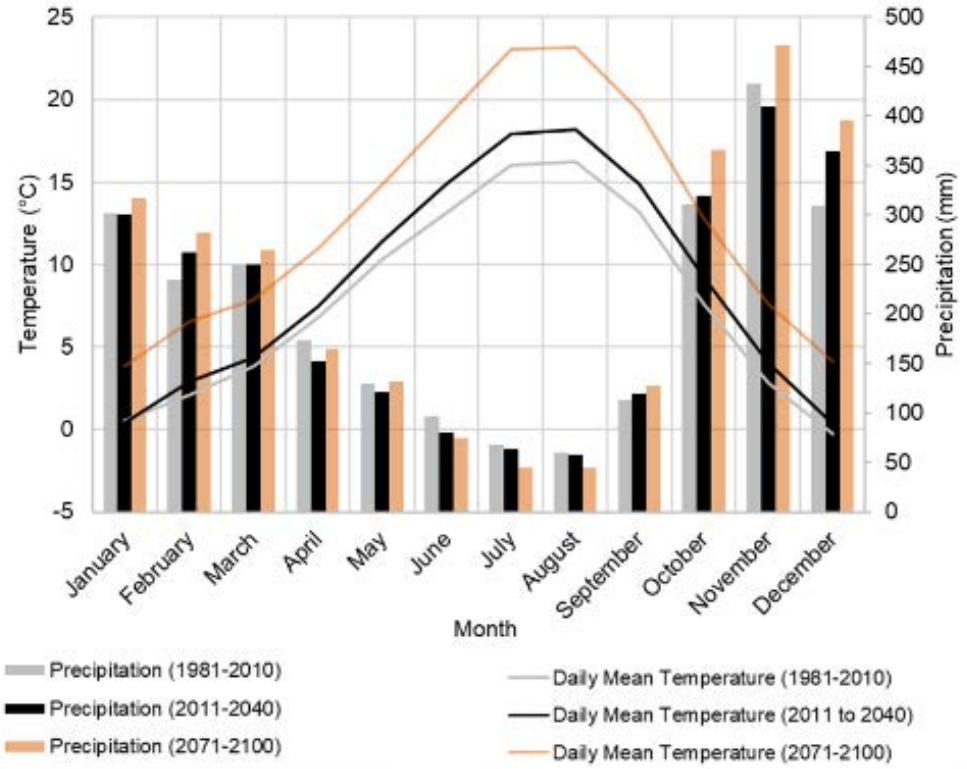


Figure 3-2 Climate normal (30-year average) for the DoS historically (1961 to 1990), current (2011 to 2040), and future (2071 to 2100). Data is from ClimateBC (Wang et al., 2016; Mahony et al., 2022) under CMIP6 and the SSP5/8.5 emissions scenario.

Table 3-4 Average seasonal and annual temperature and precipitation for the DoS for a historical 30-year period (1961 to 1990), current period (2011 to 2040), and future period (2071 to 2100). Change from the 1961 to 1990 to the period of interest is shown in brackets. Data is from ClimateBC (Wang et al., 2016; Mahony et al., 2022) under CMIP6 and the SSP5/8.5 emissions scenario.

Climate Parameter	Period	Winter (Dec to Feb)	Spring (Mar to May)	Summer (Jun to Aug)	Fall (Sept to Nov)	Annual
Mean Temperature (°C)	1981 to 2010	0.8	7.0	15.1	7.9	7.7
	2011 to 2040	1.2 (+0.4)	7.8 (+0.8)	17.0 (+1.9)	9.4 (+1.5)	8.8 (+1.1)
	2071 to 2100	4.8 (+4.0)	11.2 (+4.2)	21.7 (+6.6)	13.2 (+5.3)	12.7 (+5.0)
Precipitation (mm)	1981 to 2010	845	554	223	856	2479
	2011 to 2040	928 (+10%)	523 (-6%)	201 (-10%)	848 (-1%)	2500 (+1%)
	2071 to 2100	996 (+18%)	561 (+1%)	164 (-26%)	966 (+13%)	2687 (+8%)
Precipitation as snow (mm)	1981 to 2010	174	40	1	71	287
	2011 to 2040	167 (-4%)	26 (-35%)	0 (N/A)	42 (-41%)	236 (-18%)
	2071 to 2100	44 (-75%)	3 (-93%)	0 (N/A)	12 (-83%)	59 (-79%)

The proportion of precipitation that falls as snow has historically been approximately 15% of the total annual precipitation. Within the current time period (2011 to 2040), the proportion of precipitation falling as snow has reduced to approximately 10% of the total annual precipitation. By 2071 to 2100, snow is expected to be approximately 2% of the total annual precipitation.

Historical daily average temperatures ranged from -0.8 °C in the winter to 15.1°C in the summer. Temperatures are expected to increase in all months of the year with the greatest increase expected in the summer and autumn. By 2071 to 2100, the summer mean daily temperature is expected to be 21.7°C and the winter mean daily temperature is expected to be 4.8°C (Table 3-4).

The modelled data is generalized and provides trends in the mean behaviour of the climate in the Squamish area. The decrease in snowpack combined with an increase in winter precipitation suggests there will be more rain-on-snow flood events in the short-term and the rainfall-induced flood season will become more common in the winter months of December, January, and February. Snowmelt-induced and glacier melt-induced floods will likely shift to earlier in the year. Hotter and drier summers may increase the likelihood of wildfires within forested watersheds such as Mashiter Creek.

3.4 Development

BGC reviewed historical air photos from 1946 to 1994 (Section 4.2.3 and Appendix B) and developed an approximate timeline of development of the Garibaldi Estates neighbourhood and land-use changes adjacent to Reach 1 of Mashiter Creek.

1946 air photo – Mamquam Road is visible crossing the lower 500 m of Mashiter Creek. There is evidence of lots being partitioned, some roads, and a few buildings within the Garibaldi Estates neighbourhood. There is no development visible within the Garibaldi Highlands neighbourhood nor in Reach 1 of Mashiter Creek. The Mashiter Creek centerline alignment flows along the present-day location of Paco Road and through land that would become the Squamish Valley Golf Club before discharging into the Mamquam River (Figure B-02, Appendix B).

1966 air photo – The Squamish Valley Golf Course is under construction, and Mashiter Creek has been straightened (unknown whether natural or anthropogenic cause), no longer flowing through the golf course. There is a bridge over Mashiter Creek on Mamquam Road. Development has started in Garibaldi Highlands and in the lower 500 m of Mashiter Creek (Figure B-02, Appendix B).

1982 air photo – The land adjacent to the lower 500 m Mashiter Creek has been developed to an extent comparable to present day. Paco Road is visible along with multiple buildings on both sides of the creek. The Garibaldi Highlands and Garibaldi Estates neighbourhoods are both developed to an extent comparable to present day (Figure B-03, Appendix B).

3.5 Flood Protection Infrastructure

The DoS manages multiple structural flood protection works to mitigate the flood hazard within the municipal boundary. These structural flood protection works include dikes, erosion revetments (e.g., riprap), and other ancillary structures (e.g., pump stations). The structural flood protection relevant to this study includes the dike system along the Squamish and Mamquam Rivers that was constructed in the early 1980s (KWL, 2017a). The centerline alignments of these dikes are shown in Drawing 02.

The DoS also owns and maintains the Mashiter Creek surface water intake that is part of the municipal water system. The intake structure was originally constructed in 1990, and consists of a diversion channel, head pond, intake weir, and an overflow weir. The Mashiter Creek intake is located in the upstream half of Reach 3 as shown in Drawing 03.

4.0 GEOHAZARD ASSESSMENT

4.1 Introduction

The purpose of the geohazard assessment is to estimate the magnitude and frequency of potential geohazard events on Mashiter Creek to inform the selection of credible overland flow scenarios for modelling that will characterize the overland flow hazard from Mashiter Creek within the study area. The assessment included:

- Compilation of available data (e.g., lidar, air photos, previous studies) (Section 4.2)
- Confirmation of the geohazard process characterization through a field assessment and dating of geohazard deposits (Section 4.4)
- Compilation and characterization of historical geohazard events on Mashiter Creek (Section 4.5)
- Estimation of the frequency and magnitude of geohazard processes from Mashiter Creek including an assessment of climate change impacts on precipitation volume to the year 2100 for the return periods of interest (Section 4.6).

4.2 Data Acquisition

4.2.1 Previous Documents and Studies

Below is a summary of related documents and/or studies on Mashiter Creek and its watershed that provide a brief history of the assessments completed on Mashiter Creek and the recorded history of geohazard events on Mashiter Creek.

1987

Mashiter Creek was first identified as subject to steep creek geohazards in 1987 by Squamish-based engineer Frank Baumann (Septer, 2007). In a letter to the Ministry of Municipal Affairs in December 1987, Mr. Baumann noted:

> "Mashiter Creek drains a basin that has been heavily logged. Its upper reaches are underlain by unstable volcanic debris from Mount Garibaldi that has produced numerous mud flows in the past and is likely to produce more slides in the future."

1990 and 1991 Flood Events

Following this assessment, Mashiter Creek was subject to significant floods events in November 1990 and August 1991. As reported by Septer (2007):

> "The Squamish area was hit by 165 mm of rain on the morning of November 10 and 69 mm on the evening of **November 11, 1990**. An additional 71 mm were recorded the next morning. Late on the afternoon of November 10, high water caused the Mashiter Creek rock dam that diverts water to the cement intake structure to break. Adjacent to the new intake structure, a 15 m rock dam was ripped out. The hole in the dam allowed water to divert away from the intake and reopen the original creek bed. When the dam broke, a "tremendous pulse" of water, gravel and logs was sent down the creek. Damage was extensive and the Fisheries intake on the diversion structure was completely buried in gravel. Although a section of the diversion weir washed out and

sediment was deposited, there was no apparent damage to the gates, screens, or concrete of the diversion structure."

"Extremely heavy rainfall between **August 27-31, 1991** resulted in flooding or near-flooding situations in the Squamish area. On August 30, Squamish recorded its greatest one-day rainfall with 103 mm. On August 31, the Mashiter Creek dam was taken out after a debris jam formed in the Mashiter Creek water intake. On August 30, rocks and debris had filled the dam solid and rendered it inoperable. An estimated 20,000-50,000 tons of debris clogged the Mashiter. The overall damage seemed worse than the previous year."

The water intake structure on Mashiter Creek was reconfigured following the 1991 event to allow the majority of Mashiter Creek to bypass the intake (Cascade Environmental, May 12, 2017) (Drawing 01).

1991

Following the 1990 and 1991 floods, a Howe Sound Environmental Science workshop was held in October 1991. That workshop included a presentation by Peter Jordan, a research geomorphologist with the BC Ministry of Forests. The title of his paper was "Mass Movement and Sediment Yield in the Howe Sound Drainage Basin: the Significance of Industrial Development" and includes the observation that Mashiter Creek displays some evidence of an increase in sediment yield following logging, and a subsequent decrease a few decades later.

1994 Flood Hazard Management Plan (FHMP)

A 1994 FHMP for the District of Squamish by Klohn-Leonoff identified several creeks within the DoS boundary as potentially debris-flow prone. The analysis was conducted at a screening-level using channel gradients. The North Fork and South Fork of Mashiter Creek (both located in the upper watershed) were identified as potentially prone to debris flows, with the North Fork having a low potential and the South Fork having a moderately high potential (KWL, 2017a).

1997 NHC Study

In 1997 Northwest Hydraulics Consultants (NHC) conducted a flood hazard study of Mashiter Creek for Rostrum Development Corporation. The focus of that study was the proposed development of a lot on the east side of Mashiter Creek in its lower 500 m. The report includes a flood hazard assessment based on 1D hydraulic modelling and a qualitative assessment of potential bank erosion. The report notes that Mashiter Creek used to flow west through the golf course before being diverted into its current alignment and identifies this path as a potential avulsion hazard for lower Mashiter Creek (Drawing 03).

2017

The head pond of the Mashiter Creek intake was cleaned out as it was full of approximately 1500 m^3 of gravel. Following the 2017 cleanout, a large rock berm was placed at the entrance to the intake channel and there has been a reduction of gravel deposited into the headwater pond during high flow events since (pers. comm. David Roulston, email, September 10, 2024).

2017 Integrated Flood Hazard Management Plan (IFHMP)

The 2017a,b IFHMP for Squamish was completed by KWL. Mashiter Creek was not included in that assessment, as steep creek flood hazards were out-of-scope. However, KWL did identify a flood hazard area for Mashiter Creek which was labeled as an “Overland Flow Hazard Area” and recommendations for management were provided to DoS that were integrated into the DoS’ flood management bylaw. A flood, debris-flood, or debris-flow assessment was recommended for Mashiter Creek and other steep creeks to integrate with the results of the IFHMP.

4.2.2 Lidar and Ortho Photos

The lidar available for use in this study was collected in 2018 by McElhanney Inc. (McElhanney) and included most of the overland flow area to the west of Mashiter Creek including the Garibaldi Estates neighbourhood, but did not include most of the Mashiter Creek channel or watershed. BGC contacted McElhanney to ask if more lidar was available, and there was additional lidar from the same 2018 flight available for purchase. McElhanney processed the additional lidar in October 2024 which increased the available lidar coverage to include a section of the channel between the Boulevard Road and Ring Creek FSR, and the lower 500 m of the Mashiter Creek channel.

The lidar was used to support the hydraulic modelling (Section 5.0) and some sediment transport estimates (Appendix D). Lidar can be used effectively to map landslides, bedrock, and other geological features to support geomorphic mapping; however, there was not adequate coverage of the watershed to support detailed geomorphic mapping of the full watershed (Section 4.3).

Ortho photos collected in 2024 were provided by the DoS with coverage within the municipal boundary. The ortho photos did not include the Mashiter Creek watershed outside of the municipal boundary.

4.2.3 Air Photos and Satellite Imagery

BGC purchased and reviewed high-resolution digital air photos from the Province of British Columbia (GeoBC) and National Air Photo Library with dates ranging from 1946 to 1994 (Appendix B). BGC reviewed air photo stereopairs and georeferenced select images for geomorphic mapping and to document changes in the landscape (Drawing 03; Figures B-01 to B-08 in Appendix B). A list of the reviewed air photos, air photo observations, and select annotated air photos where changes were observed are provided in Appendix B. BGC also reviewed Google Earth™ satellite imagery from 2009 and 2022.

Below is a summary of observations relevant to this study in the air photo record:

- In 1946, the lower 500 m of the main channel of Mashiter Creek used to flow to the west through undeveloped forest (present-day Paco Road) taking a longer path (through present-day Squamish Valley Golf Club) before flowing into the Mamquam River. By 1966, the main channel had been straightened to flow in its present-day location.

- There was extensive logging in the watershed upstream of the Ring Creek FSR in the 1950s, 1960s, and 1970s that is visible in the 1966 and 1982 air photos. The hillslopes were logged up to the creek banks in the 1950s and 1960s (Drawing 04; Figure B-06) with no riparian buffer. There are numerous logging roads in the hillslopes above the Mashiter Creek channel. The 1994 air photo showed two road fill slope failures originating from logging roads on the hillslope north of the Mashiter Creek channel.
- The 1982 air photo showed nine discrete slope failures on the north side of the channel upstream of the Ring Creek FSR. The channel is brightly toned and filled with sediment immediately downstream and for a short distance downstream of the Ring Creek FSR. There were no signs of sediment further downstream.
- The 1994 air photo showed multiple (10 to 15) tributaries to the Mashiter Creek channel in the upper watershed within Garibaldi Provincial Park as brightly toned suggesting the tributaries were recently active. The channel of Mashiter Creek is brightly toned and is wider than in previous images with multiple sediment deposits throughout the channel from the Ring Creek FSR downstream to the mouth (with some exceptions in locations where the channel is bedrock-confined). These sediment deposits are interpreted to be from the debris-flood events on Mashiter Creek in 1990 and 1991 (Section 4.5).

The historical channel in the 1946 air photo and the longer path it used to take through present-day Squamish Valley Golf Club before flowing into the Mamquam River suggests the Mashiter Creek channel was several meters higher in elevation in 1946 compared to current conditions. By 1966, the main channel had been straightened to flow in its present-day location. Whether this straightening was natural or the result of human intervention, the effect was the formation of a shorter and steeper Reach 1.

4.3 Geomorphic Mapping

Geomorphic mapping of the Mashiter Creek watershed is shown in Drawing 03 and is based on interpretation of air photos reviewed in stereopair and satellite imagery (Appendix B), lidar where it was available, and field observations (Section 4.4). The sediment within Mashiter Creek is primarily sourced from debris-flow and rockfall tributaries within the upper watershed, and through entrainment of bed material and bank erosion through the middle channel reaches of Mashiter Creek.

4.4 Field Work

BGC and Cordilleran completed field work to characterize geohazards, date geohazard deposits, and support geomorphic mapping, summarized in Table 4-1. Select field photos are provided in Appendix A.

Table 4-1 Summary of field activities.

Date	Field Personnel	Field Activities
September 24, 2024	Kathleen Horita, P.Eng. (BGC) Hamish Weatherly, P.Geo. (BGC) Andrew Funk, EIT (BGC)	Ground traverse of Mashiter Creek, Wolman counts
October 9, 2024	Kathleen Horita, P.Eng. (BGC) Pierre Friele, P.Geo., P.L.Eng. (Cordilleran)	Ground traverse of Mashiter Creek; Sample collected for radiocarbon dating (Appendix C)

Below is a summary of field observations listed from upstream to downstream:

- Reach 4 (Drawing 03) upstream of the Ring Creek FSR crossing is a bedrock-lined canyon with steep sidewalls composed of fractured granite blocks. There is evidence of multiple rockfalls into the channel that have formed large step pools (Photo 1 and 2, Appendix A).
- Reach 3 (Drawing 03) downstream of the Ring Creek FSR is well-incised and has a wide floodplain (~100 m).
- The Mashiter Creek intake is located in the upper 1/3 of Reach 3 and there is an intake channel that is separate from the main channel of Mashiter Creek. The entrance to the intake channel is protected by several large (> 1 m) boulders (Photo 4, Appendix A).
- Terrace deposits were observed throughout Reach 3 with vegetation growing on the deposits of various ages. Several of the lower terraces were vegetated with hemlock trees estimated to be 20 to 30 years old, which suggests these may be deposits from the 1990 and 1991 events (Photos 5 and 11). There was also evidence of channel degradation around older deposits vegetated with cedar trees estimated to be 300 to 500 years old (Photo 8).
- Approximately 380 m upstream of the Mamquam River in Reach 1, the left bank of the channel was eroded by approximately 6 to 7 horizontal meters. Full grown trees from the top of the bank had fallen into the channel. In review of Google Earth™ imagery, the bank erosion occurred sometime after August of 2021.
- The bank erosion in Reach 1 exposed the upper 2.6 m of the floodplain of Reach 1 (total floodplain height above main channel bed is approximately 5 m in this location). The bank exposure showed four distinct depositional layers. Three of the depositional layers had characteristics consistent with a Type 2 debris flood (i.e., a debris flow that transitions into a debris flood) (Appendix C). A log was found embedded within the fourth layer[6] and a sample was collected for dating (see below).

Data collected in the field included Wolman count samples from Reach 3 and Reach 1, and a wood sample from within the bank exposure in Reach 1.

[6] Layers are counted starting with Layer 1 at the ground surface with the layer number increasing for layers at greater depths.

- The Wolman count samples were used to support sediment transport estimates (Section 4.6.3; Appendix D). The Wolman count sample locations are shown in Drawing 03.
- The wood sample was collected from within the bank exposure found in Reach 1 (Drawing 03) and was submitted for radiocarbon dating. Radiocarbon dating is a technique used to assign approximate dates to stratigraphic layers. The radiocarbon dating sampling methods, processing, and results are documented in Appendix C. The estimated age of the log sample within layer four was dated to between 1474 and 1638 AD (Appendix C).

4.5 Historical Geohazard Events

Table 4-2 summarizes the historical geohazard events on Mashiter Creek that have been compiled by BGC. The geohazard process of each event was inferred by field observations of the deposit or by recorded accounts following the event. The 1990 and 1991 debris floods were well-documented and are referenced in Septer (2007) as well as other consultant reports and newspaper articles. The deposits from these events were visible in the field within Reach 3 (Section 4.4) and in the 1994 air photos (Appendix B).

The process type and age of older geohazard events were inferred based on the composition and number of stratigraphic layers found in the exposed bank within Reach 1, and the estimated age of the log found within layer four of the bank exposure (Appendix C). The ages of layers one and three of the bank exposure were estimated based on field observations of deposits (Section 4.4), and the lack of evidence of geohazard events observed in the earliest air photo (1946).

Table 4-2 Summary of historical geohazard events on Mashiter Creek.

Approximate Date	Inferred Geohazard Process	Source
August 1991	Type 1 debris flood	Septer, 2007; air photos (Figure C-05); field observations (Photos 5 and 11, Appendix A)
November 1990	Type 1 debris flood	Septer, 2007; air photos; field observations (Photos 5 and 11, Appendix A)
(1638 to 1750) [(1)] to 1946	Type 2 debris flood	Radiocarbon dating (Layer 1); air photos (Appendix B)
1638 to 1750	Type 2 debris flood	Radiocarbon dating (Layer 3); field observations (Photo 8, Appendix A)
1474 to 1638 AD	Type 2 debris flood	Radiocarbon dating (Layer 4)

Note:
1. The approximate date of the Layer 1 deposit from the exposure in the floodplain of Reach 1 must be after the approximate date of layer three chronologically.

4.6 Frequency-Magnitude Assessment

4.6.1 Introduction

BGC completed an F-M assessment to inform the selection of geohazard scenarios for numerical modelling of the overland flow hazard from Mashiter Creek. In this study, frequency is expressed by return periods and magnitude is expressed by peak discharge and by sediment volume. The sediment volume is the estimated volume of sediment or other debris (e.g., wood) that may be transported by Mashiter Creek and reach the upstream extent of Reach 1. The F-M assessment methods are described in detail in Appendix D.

4.6.2 Process Type

Mashiter Creek is susceptible to floods, Type 1 debris floods, and Type 2 debris floods.

- Field observations identified a minimum of three Type 2 debris floods with runout deposits within Reach 1 suggesting three such events in the last 80 years (no event visible in the oldest air photo from 1946) to up to 550 years ago (maximum estimated age of the radiocarbon sample; Appendix C).
- Floods and Type 1 debris floods have been reported to have occurred within living memory (e.g., Septer, 2007; Section 4.5).
- The watershed morphometrics presented in Section 3.2.2 suggest that Mashiter Creek does not have a sufficiently steep gradient to maintain the momentum of a debris flow to affect Reach 1.

The Type 2 debris flood deposits found within Reach 1 of Mashiter Creek (Section 4.4; Appendix C) contained both volcanics and plutonics (e.g., granite) which suggests the initiating debris flows for these deposits originated within the Garibaldi Group of volcanics in the upper watershed of Mashiter Creek and entrained the plutonics within the channel as the flow travelled through Reach 4. The debris flow is then diluted through accumulation of water volume and deposition of sediment throughout Reach 3 becoming a Type 2 debris flood by the time the flow arrives within Reach 1 of Mashiter Creek. Type 2 debris floods on Mashiter Creek likely have sediment concentrations between 5 and 30% by volume (Jakob et al., 2022).

4.6.3 F-M Results Summary

The F-M results for Mashiter Creek are summarized in Table 4-3. Figure 4-1 is a graphical summary of the sediment volume F-M estimates. The process type transition point from Type 1 debris floods to Type 2 debris floods is unknown but is estimated to between the 100-year and 200-year return period. The sediment volumes and their associated return period were estimated using several empirical methods, published yield rates (Hungr et al., 1984), sediment transport equations, and absolute dating methods (e.g., radiocarbon sample described in Appendix C). There was not sufficient information to constrain the volume estimates for return periods greater than or equal to 200 years and instead an interpreted best-estimate range of volumes is provided. For return periods greater than 500 years, the only information on sediment volumes available were the results of empirical relationships (regional FM and rainfall-

sediment in Figure 4-1) which provides a narrow range of sediment volume estimates. However, these methods are not precise and BGC has assumed the true FM range is greater and is represented by the grey box with a dashed outline within the figure.

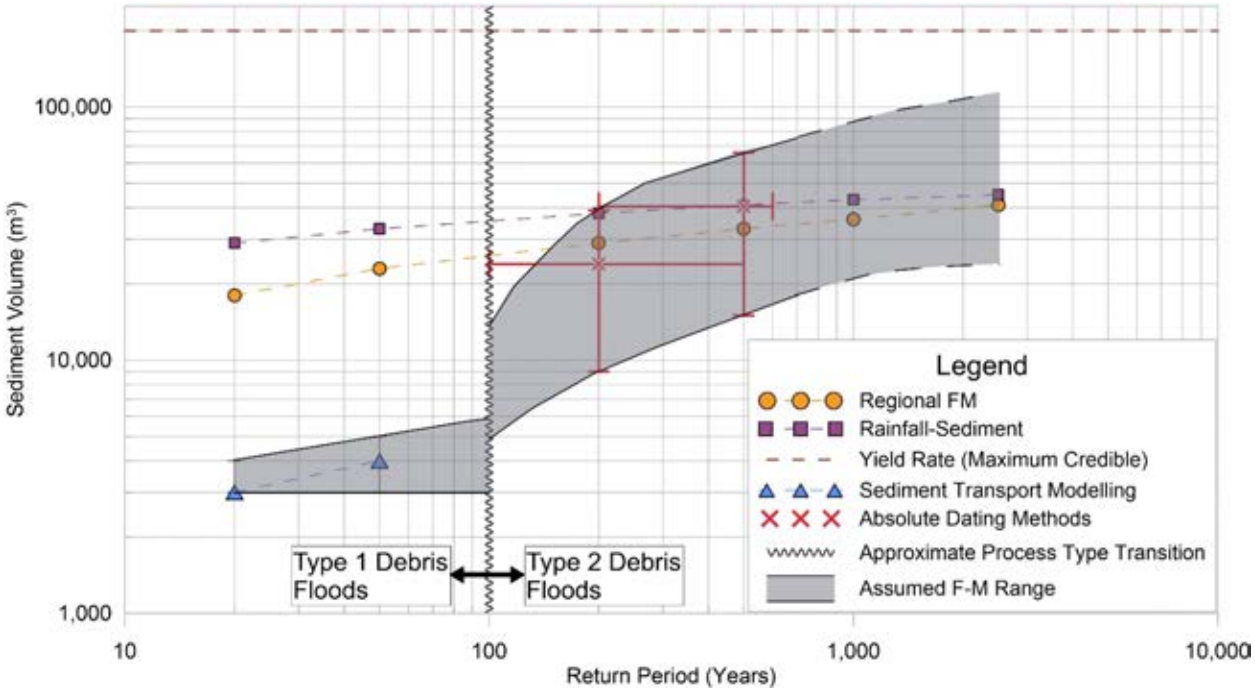


Figure 4-1. Graphical summary of the sediment volume F-M for Mashiter Creek. Dashed lines were used where the delineated values are unknown.

The peak discharges selected to inform the numerical modelling were the climate-adjusted clearwater flow estimates with no debris bulking factor. It is anticipated that there will be debris within the flow for return periods ≥ 50 years that is between 5% and 30% by volume (Jakob et al., 2022); however, it is anticipated that the debris will deposit primarily within the Mashiter Creek channel and impact the immediate overbank area including parcels within the Debris-Flood Hazard Area outlined in Drawing 05. BGC completed a sensitivity analysis to evaluate the sensitivity of the model results to the assumed peak discharge and found that it did not affect the outcome of this study (Section 5.2.2).

Table 4-3 Summary of F-M results. Detailed methods and rationale are provided in Appendix D.

Representative Return Period (years)	Process Type	Peak Discharge (m^3/s) (1)	Sediment Volume (m^3) (2)
20	Flood	165	3,000 to 5,000
50	Type 1 Debris Flood	190	3,000 to 5,000
200	Type 2 Debris Flood	220	9,000 to 39,000
500	Type 2 Debris Flood	245	15,000 to 66,000
1,000	Type 2 Debris Flood	260	21,000 to 90,000 (3)
2,500	Type 2 Debris Flood	280	25,000 to 105,000 (3)

Note:

1. The peak discharge shown is the climate-adjusted clearwater peak discharge. No bulking factor was applied to account for the sediment within the flow. BGC instead made terrain modifications to the numerical model to account for the influence of sediment on the overland flow hazard.
2. The sediment volumes provided are an interpreted best estimate range compiled from various methods and informed by BGC's judgement.
3. The interpreted best estimate range for the 1,000-year and 2,500-year return period is based on the empirical relationships used and the judgement and experience of BGC working on steep creeks.

4.7 Factors Contributing to Changes in Geohazard Frequency and/or Magnitude

Climate change, forestry, wildfires, and other land-use changes can influence the frequency and magnitude of geohazards. Brief summaries of these cumulative pressures and how they may apply to Mashiter Creek are provided below.

Climate change will increase the average temperature within the study area (Section 3.3). Increasing temperatures change when, where, and how much precipitation falls. Rainstorms are projected to increase in intensity, resulting in changes to steep creek and landslide processes (Jakob, 2021). An analysis of landslides within the North Shore Mountains in Vancouver, BC projected an increase of up to 300% in the frequency of shallow landslides (e.g., debris flows) until the end of century (Jakob & Owen, 2021). Climate change is included in the F-M analysis by applying scaling factors to precipitation inputs. Other climate-change effects that may impact geohazard scenario F-M, such as changes in triggering conditions of rock slope stability or sediment supply, are not explicitly accounted for.

Logging and resource road construction influence flood and landslide activity within watersheds. Generally, removing vegetation increases the amount of precipitation and surface flow that is transferred to streams (Winkler et al., 2010). Additionally, resource road construction and clearcut logging can increase the frequency of landslides if these risks are not managed and accounted for during planning (Jakob, 2000; Jordan, 2001). The most common failure mechanisms are debris slides and debris flows initiating from road fill failures. In the road-related landslide hazard/risk assessment for MoF completed for FSRs within the southern portion of the Mashiter Creek watershed, both Branch 02 and Spur H were categorized as high

hazard roads that have experienced post-logging landslides (Cordilleran Geoscience, September 26, 2021). Post-logging landslides are a potential triggering mechanism for Type 2 debris floods on Mashiter Creek.

Wildfires impact the hydrology and stability of a slope through loss of vegetation and modification of soil properties. Figure 4-1 outlines some of the effects of wildfires on slope hydrology and stability, including loss of evapotranspiration and root strength, and excessive runoff and sediment mobilization. As a result, burned slopes are often more susceptible to debris flows, debris floods, floods, and other slope hazards.

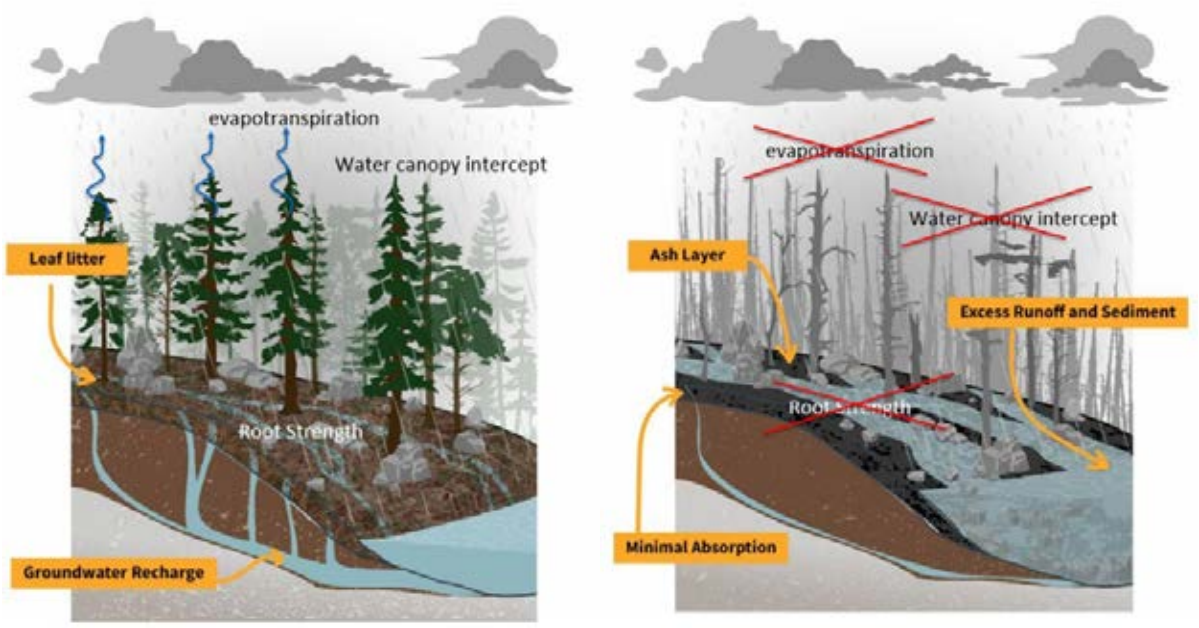


Figure 4-2 Schematic showing hydrology on a slope in unburned conditions (left) and the potential effects of wildfires on slope hydrology, which influences slope stability (right). Figure adapted from United States Geological Survey (2020).

The radiocarbon sample collected within Reach 1 of Mashiter Creek dated back to 1474 to 1638 AD which coincides with the Little Ice Age around 1350 to 1850 AD. One could argue that the three Type 2 debris-flood deposits observed within Reach 1 of Mashiter Creek were the result of a climate anomaly associated with the Little Ice Age and that events of this size are not likely to re-occur in the future. BGC and Cordilleran could not find any definitive evidence that this is the case and has assumed similar-scale events are possible in the future given the sediment availability in the upper watershed and the cumulative pressures discussed in this section.

4.8 Channel Aggradation in Reach 1 of Mashiter Creek

Aggradation within Reach 1 could conceivably occur over a period of decades to centuries or rapidly during a single large event, resulting in a loss of channel capacity. The observation of Type 2 debris-flood deposits in Reach 1 are evidence of rapid aggradation events.

In Section 4.2.3, it was noted that, in 1946, the Mashiter Creek channel used to flow to the west taking a longer path through present-day Squamish Valley Golf Club before flowing into the Mamquam River suggesting that the Creek had to have been several meters higher in elevation in 1946 compared to current conditions. By 1966, the main channel had been straightened to flow in its present-day location. The natural response of a river to such a disturbance is incision (Weatherly & Jakob, 2014), which has created the current relatively incised conditions. However, this present level of incision protection is not assured to persist into the future. Mashiter Creek could slowly start to aggrade, which would be a natural response, as the geomorphic response to the mid-20th century straightening should have run its course.

Mashiter Creek bed levels in Reach 1 will be affected by the bed levels in the Mamquam River at the confluence. During the 1980s, significant volumes of gravel were removed from the fan reaches of the Mamquam River[7] that were about 5.5 times larger than the estimated rate of gravel supply (Sutek & Kellerhals, 1989). These removals resulted in modest net degradation between 1995 and 2008 (KWL, 2017a). However, it was expected that once the Mamquam River fully recovered from the large removals in the 1980s, it would return to a net depositional regime again and the channel bed would start to rise more uniformly (KWL, 2017a). Channel aggradation in the Mamquam River would cause the bed levels of Mashiter Creek bed levels to increase as well.

4.9 Overland Flow Scenarios

The overland flow scenarios outlined in Table 4-4 were selected to align with the return periods for a Class 3 debris-flood hazard assessment (EGBC, 2018). The 500-year return period was added at the request of the DoS.

The overland flow scenarios assume that the triggering event for each scenario is a multi-day storm bringing a period of heavy rain over 2.5 days to Squamish, BC. The peak discharge shown in Table 4-4 reflects the peak runoff from Mashiter Creek during this storm. Further discussion on the storm duration and its selection is in Section 5.2.2 and Appendix D.

The overland flow scenarios are Type 2 debris floods for all return periods modelled. The sediment associated with each scenario is anticipated to deposit primarily within the Mashiter Creek channel and impact the immediate overbank area including parcels within the Debris-Flood Hazard Area outlined in Drawing 05. One of two terrain modification options were applied to the base terrain of the numerical model (Section 5.2) for each model scenario to account for potential morphological changes within Mashiter Creek during a debris flood. The two terrain modifications assessed were (i) blocking the Mamquam Road bridge over the Mashiter Creek channel and (ii) full aggradation of the Mashiter Creek channel within the model domain.

BGC estimates that the lower 500 m of Reach 1 of Mashiter Creek has the capacity to store approximately 10,000 to 20,000 m^3 of sediment. Based on the F-M results presented in Table 4-3, it is considered likely that the Mamquam Road bridge over Mashiter Creek is blocked for

[7] The Mamquam River fan extends from just upstream with the confluence of Mashiter Creek to the Squamish River.

the 200-year return period scenario. For all scenarios with return periods greater than 200 years, it was assumed that the channel was filled with sediment up to bankfull for return periods greater than 200 years. BGC completed a sensitivity analysis on this assumption which is discussed further in Section 5.2.2.

Table 4-4 Overland flow scenarios used for numerical modelling of the overland flow hazard in Mashiter Creek.

Representative Return Period (years)	Process Type	Peak Discharge (m^3/s)	Terrain Modifications
200	Type 2 debris flood	220	The bridge over Mashiter Creek at Mamquam Road is fully blocked during the debris flood (Figure 5-3).
500	Type 2 debris flood	245	The Mashiter Creek channel is fully aggraded. (1)
1,000	Type 2 debris flood	260	The Mashiter Creek channel is fully aggraded. (1)
2,500	Type 2 debris flood	280	The Mashiter Creek channel is fully aggraded. (1)

Notes:

1. Full aggradation of the channel within the model domain included filling the channel up to bankfull (approximately 4 m of depth) for the full 350 m of the Mashiter Creek channel within the numerical modelling domain. Illustration of the changes made to the terrain of the numerical model to represent channel aggradation are shown in Figure 5-4)

5.0 OVERLAND FLOW MODELLING

5.1 Introduction

The purpose of the overland flow modelling is to estimate the overland flood extents, modelled flow depths, and velocities within the study area. The model results are then interpreted to inform the management recommendations presented in Section 6.0. The numerical modelling methods are described in detail in Appendix E with a brief summary provided herein.

5.2 Numerical Modelling Methods

5.2.1 Model Software and Domain

BGC used Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 6.6 modelling software. BGC developed a 0.5 m x 0.5 m Digital Elevation Model (DEM) grid based on the 2018 lidar McElhanney Inc. (McElhanney). Buildings were incorporated into the terrain surface by extruding the building footprints within the model extent to 4 m above the surrounding ground (Figure 5-1). The model domain, overland flooding study area, and the model boundary conditions are shown in Figure 5-1.

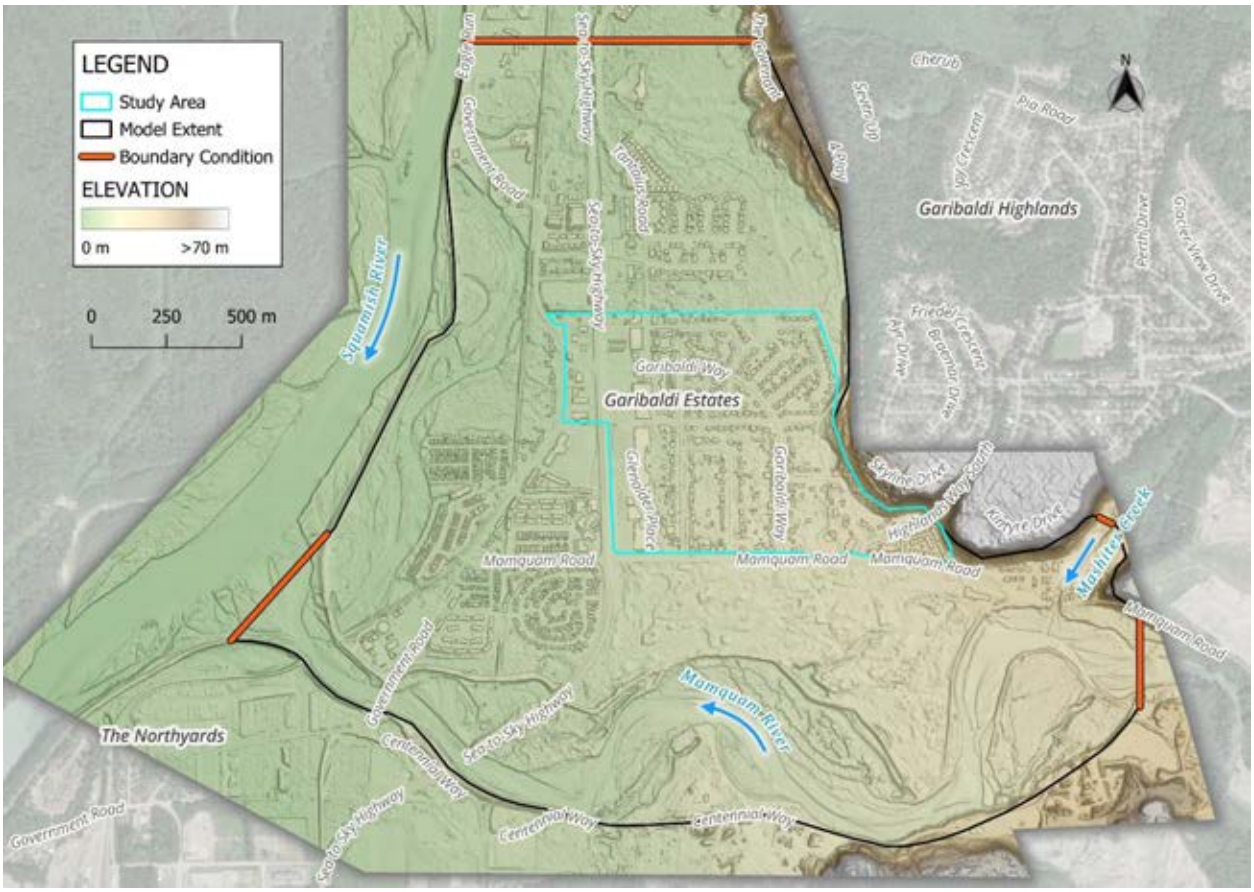


Figure 5-1. Model domain, model terrain (including available lidar extents), and model boundary conditions.

5.2.2 Model Inputs

The overall model development and selection of inputs is discussed in Appendix E. The discussion in this section is limited to model inputs that (i) affect the outcome of the overland flood assessment, and (ii) informed the development of the overland flow scenarios described in Section 4.6.5.

Inflow Hydrograph

The upstream boundary condition for Mashiter Creek was defined as a flow hydrograph corresponding to each of the return periods of interest (Figure 5-2). A flow hydrograph provides the discharge from Mashiter Creek at a regular time step (in this case, hourly) over a specified duration. BGC developed the flow hydrographs based on the results of rainfall-runoff modelling which is described in detail in Appendix D. The flow hydrograph was based on a six-day storm that had two peaks over a 52-hour window (~2.5 days). The model was run over this 52-hour period between hours 56 and 108 to capture the peak activity of the storm hydrograph. The flow hydrograph is scaled to the climate-adjusted peak discharges estimated for Mashiter Creek (Table 4-3).

BGC did a sensitivity analysis on the assumed peak discharge, comparing the inundation extents and modelled flow depths within the study area for the climate-adjusted 200-year and 2,500-year return period flow hydrographs which represents an increase in peak discharge of +30% (Appendix E). Increasing the peak discharge by 30% resulted in a larger inundation extent (an 8% increase) and an increase in modelled depths within the study area of up to 0.05 m. These sensitivity analysis results demonstrate that the uncertainty in the estimation of the peak discharge value does not have a significant impact on the outcome of this study.

The duration of the flow hydrograph does have an impact on the overall inundation extents and modelled flow depths within the study area, though impacts are greatest for areas west of the Sea-to-Sky highway. Squamish, BC is known to experience multi-day storms, commonly known as atmospheric rivers, that carry heavy rain and often last two to six days. BGC considers a 6-day storm with a more intense period of heavy rainfall over 2.5 days to be credible.

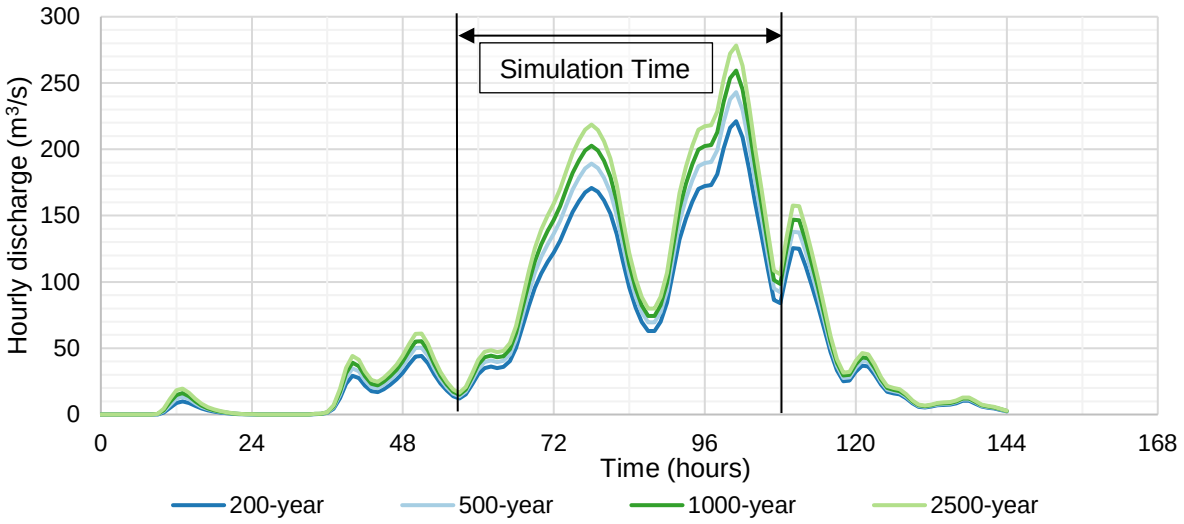


Figure 5-2 Mashiter Creek inflow hydrographs.

Assumed Morphological Changes

The affect of sediment accumulation in Reach 1 of Mashiter Creek on the overland flow hazard within the study area was unknown. Therefore, BGC did a sensitivity analysis comparing the modelled inundation extent results for the climate-adjusted 200-year flow for three morphological scenarios:

1. The Mashiter Creek channel maintains its current capacity and the Mamquam Road bridge is clear of debris (e.g., no bridge blockage);
2. The bridge over Mashiter Creek at Mamquam Road is completely blocked (Figure 5-3); and
3. The Mashiter Creek channel is fully aggraded within the model domain (Figure 5-4).

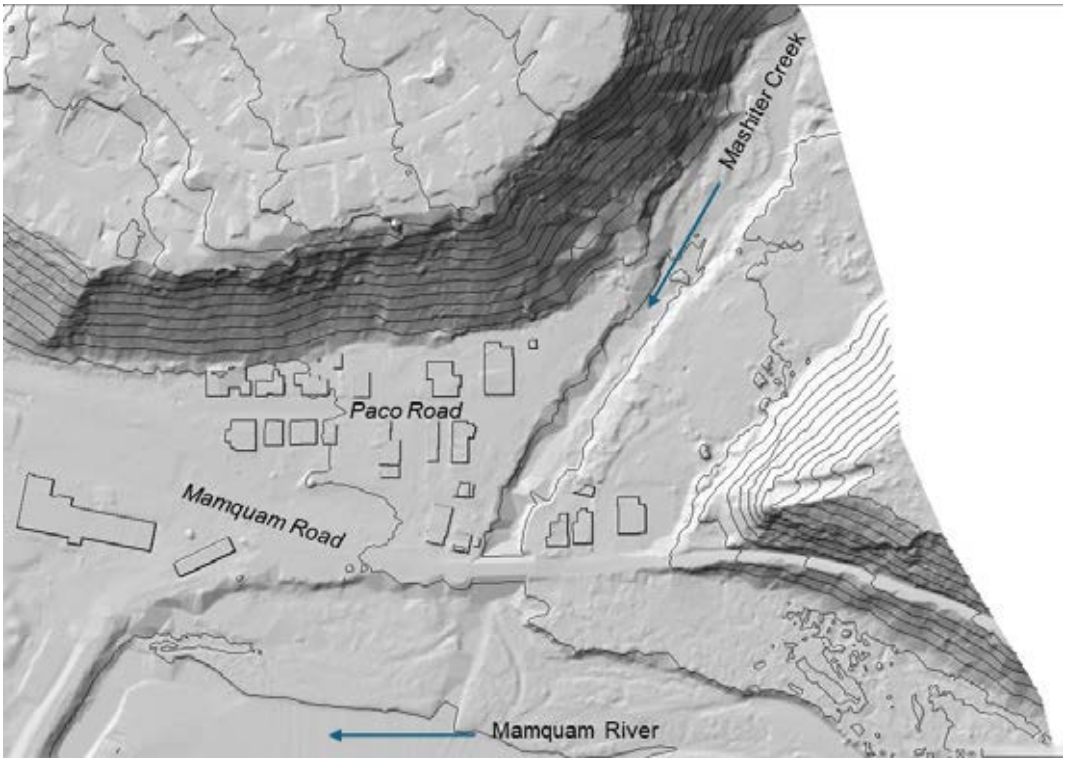


Figure 5-3. Illustration showing the terrain modifications to the 2018 lidar to represent a blockage of the Mamquam Road bridge over Mashiter Creek. Contour interval is 5 m.

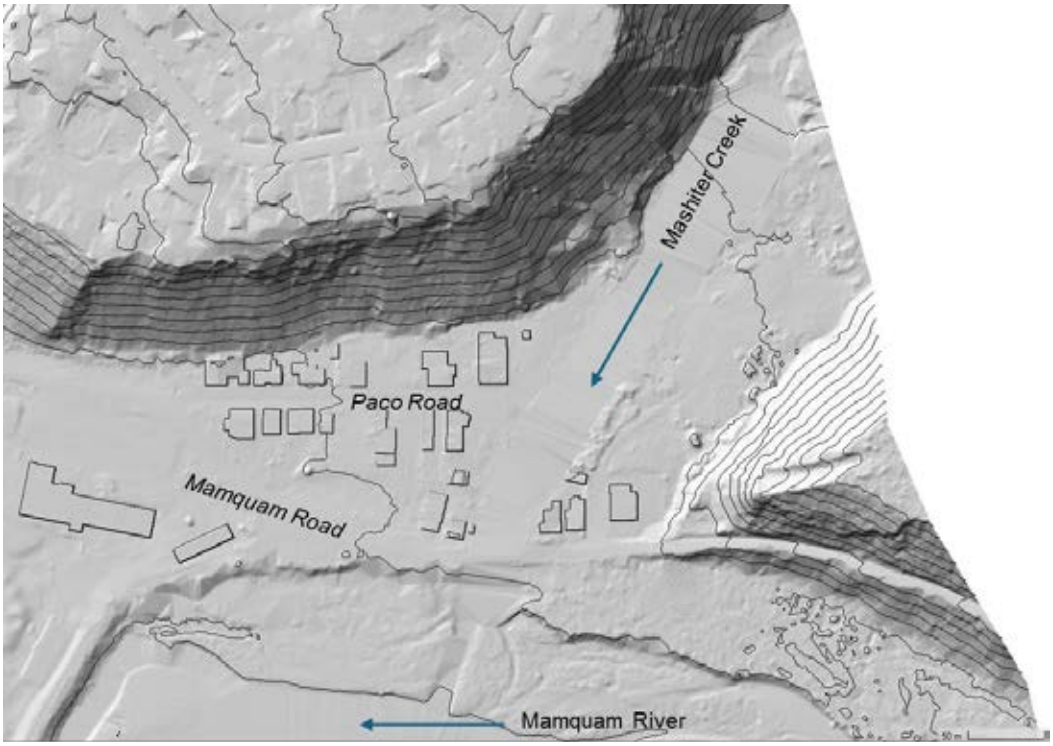


Figure 5-4. Illustration showing the terrain modifications to the 2018 lidar to represent full aggradation of the Mashiter Creek channel. Contour interval is 5 m.

The no bridge blockage run resulted in a smaller inundation extent compared to the blocked bridge run, showing a 40% decrease. Little to no difference in the inundation extent was observed within the study area for the bridge blockage and full aggradation models runs

The sensitivity analysis results demonstrate that it was important in the development of overland flow scenarios to be confident in deciding when the bridge may become blocked, but it was not important to resolve the extents (depth and area) of channel aggradation that may occur. BGC blocked the bridge for the 200-year return period model scenario because the channel capacity of Reach 1 of Mashiter Creek is estimated to be on the order of 10,000 to 20,000 m^3. The 200-year sediment volumes are estimated to range from 9,000 to 39,000 m^3 which suggests that the bridge is likely to be blocked for the 200-year return period event. BGC aggraded the channel for all return periods exceeding the 200-year event assuming the channel is fully aggraded rather than spending additional time refining the depth and extents of channel aggradation for each overland flow scenario.

5.3 Numerical Modelling Results

Figures showing the modelled depths and velocities for each geohazard scenario are provided in Appendix E. Below is a summary of observations from the modelling which should be reviewed in conjunction with Figure 5-5 for additional clarity on the flow direction and points of interest:

- Mashiter Creek avulses from the main channel and flows west down Paco Road and Mamquam Road along the general path of the historical channel of Mashiter Creek (Drawing 03). This avulsion occurs once the discharge in the Mashiter Creek channel exceeds ~110 m^3/s assuming the Mamquam Road bridge is not blocked. If the bridge is blocked or the Mashiter Creek channel is filled with sediment, an avulsion can be expected to occur at discharges < 110 m^3/s. As the discharge increases, a second avulsion occurs towards the west along Mamquam Road. The avulsions occur in all overland flow scenarios modelled including the 200-year climate-adjusted scenario.
- Once Mashiter Creek avulses, most of the avulsed flow floods the lands of the Squamish Valley Golf Club with a small amount of flow (< 1 m^3/s) that continues west down Mamquam Road then flows north to enter the study area.
    - Modelled flow velocities were less than 0.5 m/s within the study area for all scenarios modelled.
    - Flow depths were less than 0.15 m on the roads within the study area for the 200-year climate-adjusted scenario with the exception of ponded depths up to 0.45 m on the west side of the Canadian Tire parking lot and the southern portion of Glenalder Place behind Canadian Tire.
    - The flow depths for the 2,500-year climate-adjusted scenario are up to 0.05 m greater than for the 200-year climate-adjusted scenario within the study area.
- The flows that flood the Squamish Valley Golf Club lands split into two flow paths.
    - The first follows the historical channel towards the Mamquam River dike and overtops the Mamquam River dike. The discharge overtopping the dike is modelled to be 45 m^3/s at its peak for the 200-year climate-adjusted scenario.

The duration of time the dike is being overtopped during a debris flood on Mashiter Creek could exceed 24 hours.

- The remaining flow generally continues west and overtops the Sea-to-Sky Highway to enter the Garibaldi Estates West neighbourhood where it eventually reaches the Squamish River dike and begins to pond. At the Sea-to-Sky Highway, some flow heads south to enter the Mamquam River.

- The diking network along the Mamquam River and the Squamish River cause a bathtub effect for the overland flows from Mashiter Creek. The dikes prevent Mashiter Creek from exiting developed land north of the Mamquam River.
- There are three locations where Mashiter Creek re-enters the Mamquam River: (i) Mashiter Creek itself, (ii) the overtopping flow over the Mamquam River dike in the Squamish Valley Golf Club lands, and (iii) at the Highway 99 bridge over Mamquam River where there is a gap in the existing dike system.

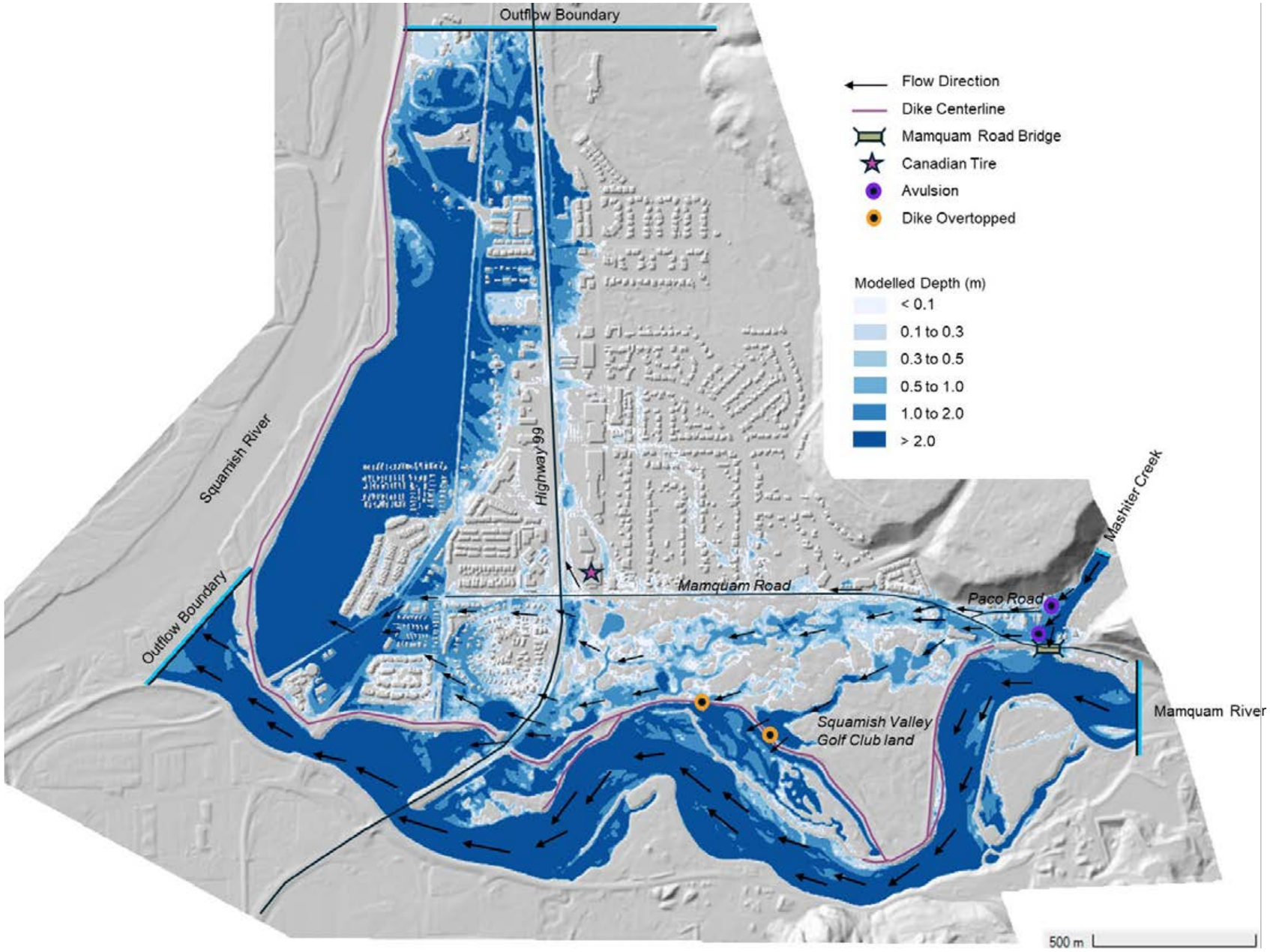


Figure 5-5 **Modelled depths from the 200-year climate-adjusted scenario with the Mamquam Road Bridge blocked. The figure is provided to show the locations discussed in the text and the flow direction that was generally seen in all modelled geohazard scenarios**

5.4 Model Limitations

Models are useful tools, but they do not provide a precise or exact prediction of real events. Model results require additional interpretation and judgement for their intended purpose. At Mashiter Creek, BGC developed the model for the purpose of characterizing the overland flow hazard within the study area from Mashiter Creek.

A summary of model uncertainties and limitations are:

- The lidar-derived topography from 2018 is a “snapshot in time”. Future modification of the landscape (e.g., mitigation structures, road construction, erosion, channel migration, landslide deposits) will influence model results. Specific topographical changes expected to alter the outcome of this assessment include any activities that direct flow away from the Squamish Valley Golf Club toward Garibaldi Estates including but not limited to: change in the topography within the Squamish Valley Golf Club lands; and changes in the topography of Mamquam Road between Highland Way South and Mashiter Creek.
- The stormwater system was not included in the model. The ditches within the Garibaldi Estates were represented in the terrain, but the culverts (where they exist) connecting ditches were not included. The overland flow path within Garibaldi Estates is likely to vary from that modelled as the flow direction will depend on the ditch and culvert capacity throughout the neighbourhood.
- BGC did not evaluate the probability of coincident flooding on the Squamish River and/or Mamquam River with overland flooding on Mashiter Creek, not did BGC consider any dike breach scenarios because these were not included in the current scope of service. Coincident flooding on the Mamquam River and/or Squamish River will impact the net water surface elevation and flow behaviour in the Squamish Valley Golf Club, and west of Sea-to-Sky Highway (Garibaldi Estates West).
- There was not sufficient lidar to model the initiating landslide mass for a Type 2 debris flood. As such, morphological changes that were evaluated through a sensitivity analysis were assumed within Reach 1 for the purposes of evaluating the overland flow hazard.
- HEC-RAS 2D was run as a fixed bed model, therefore channel aggradation was not computed, nor was the potential for bank erosion in Reach 1.
- HEC-RAS 2D assumes a homogeneous fluid meaning that the water and sediments of a debris flood are treated as a single fluid. The model results require interpretation to judge where the flow may have more debris (e.g., sediment, boulders, large woody debris) and where it may be more clearwater in nature.

6.0 RECOMMENDATIONS

6.1 Overland Flow Management Recommendations

BGC met with the DoS on November 28, 2024 and January 7, 2025 to discuss options to manage the overland flow hazard from Mashiter Creek within the study area, and the following was decided:

- The 200-year climate-adjusted debris-flood scenario results were selected to guide the management recommendations.
- The DoS requested that BGC comment on updated management recommendations for the Overland Flow Hazard Area for Mashiter Creek outlined during the IFHMP study (KWL, 2017a) and shown in Drawing 02.

BGC re-delineated the overland flow hazard boundary for Mashiter Creek based on the results of this study and then divided that boundary into three management areas with recommendations as shown in Drawing 05. The refined overland flow hazard boundary now excludes several parcels in the northwest portion of Garibaldi Estates East, northwest of Garibaldi Way including parcels on Skyline Drive, Parkway Road, Park Crescent, Ridgeway Crescent, and select parcels on Cheakamus Way and Blacktusk Way.

Currently, the governing Flood Construction Level (FCL) requirement within the Overland Flow Hazard Area for Mashiter Creek outlined in the IFHMP (KWL, 2017a) is the greater of the existing Upper Floodplain FCL[8] or the Overland Flow Hazard Area requirement. The Flood Construction Level (FCL) requirement within Overland Flow Hazard Areas is the higher elevation of:

1. 1.5 m above the Natural Boundary of any adjacent Watercourse, lake, pond, marsh or reservoir, whether natural or constructed.
2. 0.6 m above the crest of any downstream road or embankment or other feature that could result in a backwater condition, but specifically excluding the effect of downstream Standard Dikes and Sea Dikes.
3. 1.0 m above the finished grade around the building.

Table 6-1 outlines the updated FCL recommendations for each management area within the overland flow hazard area for Mashiter Creek (Drawing 05). An FCL means the required elevation of the underside of a wooden floor system or top of pad to be used as Habitable Areas as defined in the DoS Floodplain Management Bylaw (DoS, 2022). The general FCL exemptions listed in the DoS Floodplain Management Bylaw (DoS, 2022) apply, including basements that do not include habitable space, and parking.

[8] The Upper Floodplain FCL is based on maximum water surface elevations extracted from dike breach modelling on both the Squamish River and Mamquam River by KWL (2017b) for areas in Squamish located north of the Mamquam River.

Table 6-1. Management area recommendations for the overland flow hazard from Mashiter Creek (Drawing 05).

Management Area	Overland Flood Description	Recommendations
Management Area 1	Overland flooding from Mashiter Creek is anticipated to be mostly standing water in ditches and in low-lying areas. Roads have flow depths up to 0.15 m throughout most of the neighbourhood with the exception of the western portion of the Canadian Tire parking lot and the southern portion of Glenalder Place that show ponded depths up to 0.45 m.	BGC recommends that the FCL is 0.3 m above the crown of the adjacent road aligning with freeboard recommendations in EGBC (2018). When a parcel borders two roads, the crown of the upslope road should govern.
Management Area 2	Management Area 2 includes most of the area west of the Sea-to-Sky Highway and north of Garibaldi Way within the delineated overland flow hazard boundary in Drawing 05. Modelled water surface elevations from Mashiter Creek are less than the existing FCLs for this area by 0.5 m or more.	BGC recommends that the existing FCL govern within this area. The existing FCLs are associated with dike breach modelling completed by KWL (2017b) for the Squamish River and Mamquam River.
Management Area 3	Management Area 3 includes the Squamish Valley Golf Club land and portions of the Garibaldi Estates west of the Sea-toSky Highway as shown in Drawing 05. The modelled water surface elevations from Mashiter Creek are within 0.5 m of the existing FCLs within this area.	BGC recommends that the Overland Flow Hazard Area as identified in the IFHMP (KWL, 2017a) continues to govern. In areas of existing development, the freeboard may be reduced following further study to evaluate the probability and inundation extents of one or more dike breaches on the Squamish River and/or Mamquam River coinciding with a debris flood on Mashiter Creek along with additional modelling, as required. In advance of any topographical changes within the Squamish Valley Golf Club lands, BGC recommends further study. Topographical changes within the lands of the Squamish Valley Golf Club are expected to have impacts on the floodways and overland flow management recommendations for all three areas.

The overland flow management recommendations are based on the existing topography. The DoS should not modify the topography within the Squamish Valley Golf Club lands, nor on Mamquam Road between Paco Road and Highland Way South without additional study on how this will impact existing floodway and the overland flow management recommendations.

6.2 Application of the FCL in Management Area 1

In the meeting between BGC and DoS on January 7, 2025, DoS requested that BGC comment on methods that the DoS may use to accommodate the FCL recommendation in Management Area 1. BGC understand that the Sub-Area Plan for Garibaldi Estates includes a proposal to develop a ‘high street’ with retail stores and a wide pedestrian sidewalk at the ground floor, and apartments above, along Diamond Head Road.

The intention of the overland flow management recommendation in the study area is to have sidewalks and development at higher elevations than the road such that the road is maintained as the floodway during a flood or debris flood. In a road cross-section, the crown of road is the highest elevation point along the cross-section and the road then slopes away from the crown at a gradient of approximately -0.02 m/m to allow the road to drain. The crown of road is typically at the centerline of city streets to encourage drainage towards stormwater gutters, ditches, or catchments located at both edges of the road.

The DoS provided a concept of the Diamond Head Road layout by email on December 2, 2024. BGC has used the horizontal dimensions and layout within the sketch and adapted it to show the approximate slope on the road and how the 0.3 m is measured from the crown of road to set the height of the curb (Figure 6-1).

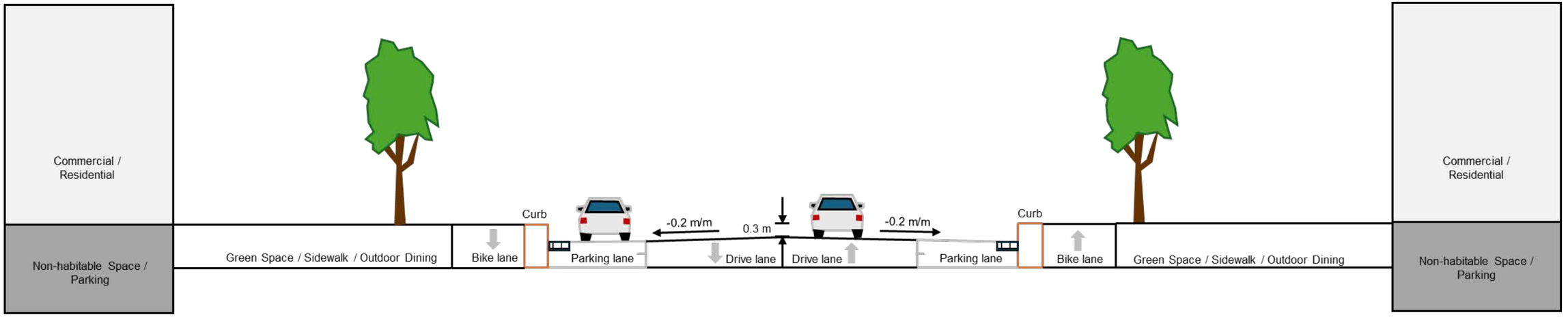


Figure 6-1 Conceptual layout of the Diamond Head Road adapted from a Streetmix layout provided by the DoS on December 2, 2024. The horizontal and vertical scale of the sketch is 1 cm = 1 m.

6.3 Additional Recommendations

The debris-flood hazard and risk from Mashiter Creek was not quantified in this study for parcels adjacent to Mashiter Creek (approximate delineated Debris-Flood Hazard Area in Drawing 05). In the event of a debris flood on Mashiter Creek, this area is likely exposed to bank erosion and may be exposed to impact forces that may cause structural damage and possible loss of life. The geomorphic and F-M assessment completed herein is likely adequate to develop credible geohazard scenarios; however, a bank erosion assessment and detailed runout modelling would be required to quantify the debris-flood hazard and associated risks in this area. BGC recommends that a hazard and risk assessment is completed for the debris-flood hazard area in Drawing 05.

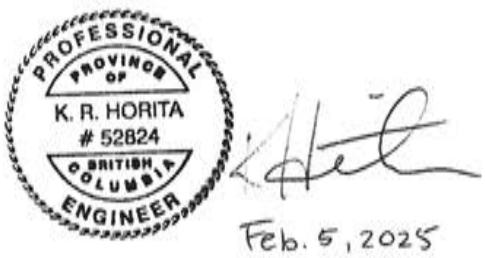
There are two locations on the Mamquam River dike that are overtopped for all geohazard scenarios modelled including the 200-year climate-adjusted scenario (Figure 5-2). Overtopping is a possible failure mechanism for a dike. BGC recommends that the DoS consider placing erosion protection on the Mamquam River side of the dike to reduce the likelihood of failure due to overtopping flows from Mashiter Creek.

7.0 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:



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Senior Geotechnical Engineer

EGBC Permit to Practice, BGC Engineering Inc. 1000944

KRH/LCH/mjp/mm

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DRAWINGS

N

SCALE 1:50,000

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METRES

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

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DIAMOND HEAD

THE GARGOYLES

COLUMNAR PEAK

ROUND MOUNTAIN

GARIBALDI PROVINCIAL PARK

ALICE LAKE PROVINCIAL PARK

CHEAKAMUS RIVER

CHEEKYE RIVER

SQUAMISH RIVER

MASHITER CREEK

SEA-TO-SKY HIGHWAY

DISTRICT OF SQUAMISH

RING CREEK

MAMQUAM RIVER

INSET MAP

PROJECT LOCATION

Kilometres

LEGEND

STUDY AREA (NOTE 5)

HYDROLOGY

WATERCOURSE

MASHITER CREEK

WATERBODY

MASHITER CREEK WATERSHED

INFRASTRUCTURE

HIGHWAY

ROAD

FOREST SERVICE ROAD

ADMINISTRATIVE

FIRST NATION RESERVE

PROVINCIAL PARK

MUNICIPAL BOUNDARY

NOTES:

1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUCTION WITH BGC'S REPORT TITLED "MASHITER CREEK, OVERLAND FLOW HAZARD ASSESSMENT", AND DATED FEBRUARY 2025.
3. BASE TOPOGRAPHIC DATA IS DERIVED FROM 2018 LIDAR PROVIDED BY THE DISTRICT OF SQUAMISH AND PURCHASED FROM MCELHANNEY. TOPOGRAPHIC DATA IN THE NORTHWEST CORNER IS BASED ON LIDAR DEM PROVIDED BY THE GOVERNMENT OF BC OPEN DATA PORTAL AND IS DATED 2018. LOW RESOLUTION TOPOGRAPHIC DATA IN THE REMAINING AREA IS BASED ON MRDEM DATA, PROVIDED BY THE GOVERNMENT OF CANADA OPEN DATA. CONTOUR INTERVAL IS 20 m.
4. PROJECTION IS NAD 83 UTM ZONE 10N. VERTICAL DATUM IS CGVD2013.
5. THE "STUDY AREA" BOUNDARY IS THE APPROXIMATE POLYGON FOR THE SUB-AREA PLAN FOR GARIBALDI ESTATES AND IS THE STUDY AREA IDENTIFIED WITHIN BGC'S SCOPE OF SERVICES.
6. ROADS WERE RETRIEVED FROM OPENSTREETMAP.
7. 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.

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DATE:	FEB 2025
DRAWN:	KJC
CHECKED:	LCH
APPROVED:	KRH

CLIENT: SQUAMISH

BGC

PROJECT: **MASHITER CREEK OVERLAND FLOW HAZARD ASSESSMENT**

TITLE: **WATERSHED OVERVIEW**

PROJECT No.:	DWG No.:
1348005	01

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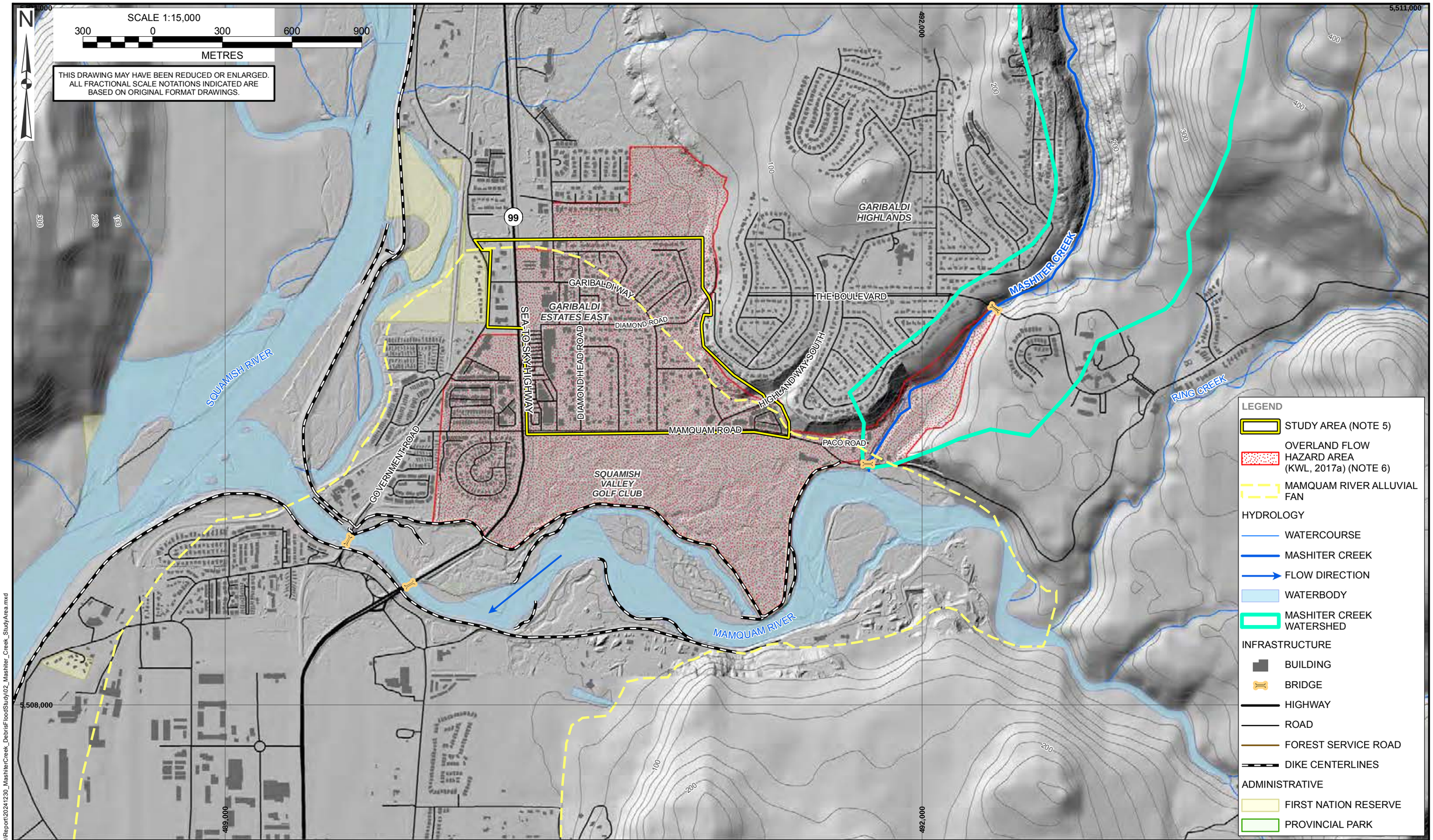

NOTES:
1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUCTION WITH BGC'S REPORT TITLED "MASHITER CREEK, OVERLAND FLOW HAZARD ASSESSMENT", AND DATED FEBRUARY 2025.
3. BASE TOPOGRAPHIC DATA IS DERIVED FROM 2018 LIDAR PROVIDED BY THE DISTRICT OF SQUAMISH AND PURCHASED FROM MCELHANNEY. LOW RESOLUTION TOPOGRAPHIC DATA IN THE REMAINING AREA IS BASED ON MRDEM DATA, PROVIDED BY THE GOVERNMENT OF CANADA OPEN DATA. CONTOUR INTERVAL IS 20 m.
4. PROJECTION IS NAD 83 UTM ZONE 10N. VERTICAL DATUM IS CGVD2013.
5. THE "STUDY AREA" BOUNDARY IS THE APPROXIMATE POLYGON FOR THE SUB-AREA PLAN FOR GARIBALDI ESTATES AND IS THE STUDY AREA IDENTIFIED WITHIN BGC'S SCOPE OF SERVICES.
6. THE OVERLAND FLOW HAZARD AREA SHOWN WAS PROVIDED BY THE DISTRICT OF SQUAMISH AND IS THE OVERLAND FLOW HAZARD AREA FROM MASHITER CREEK ONLY (KWL,2017a).
7. THE MAMQUAM RIVER HAS AN ALLUVIAL FAN COMPLEX THAT JOINS THE ALLUVIAL FAN SEDIMENTS OF THE SQUAMISH RIVER. THE MAMQUAM RIVER ALLUVIAL FAN DELINEATION IS APPROXIMATE.
8. ROADS AND BUILDING FOOTPRINTS WERE RETRIEVED FROM OPENSTREETMAP.
9. 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.

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DRAWN:	KJC
CHECKED:	LCH
APPROVED:	KRH

CLIENT: SQUAMISH

BGC

PROJECT: **MASHITER CREEK OVERLAND FLOW HAZARD ASSESSMENT**

TITLE: **STUDY AREA**

PROJECT No.: **1348005**

DWG No.: **02**

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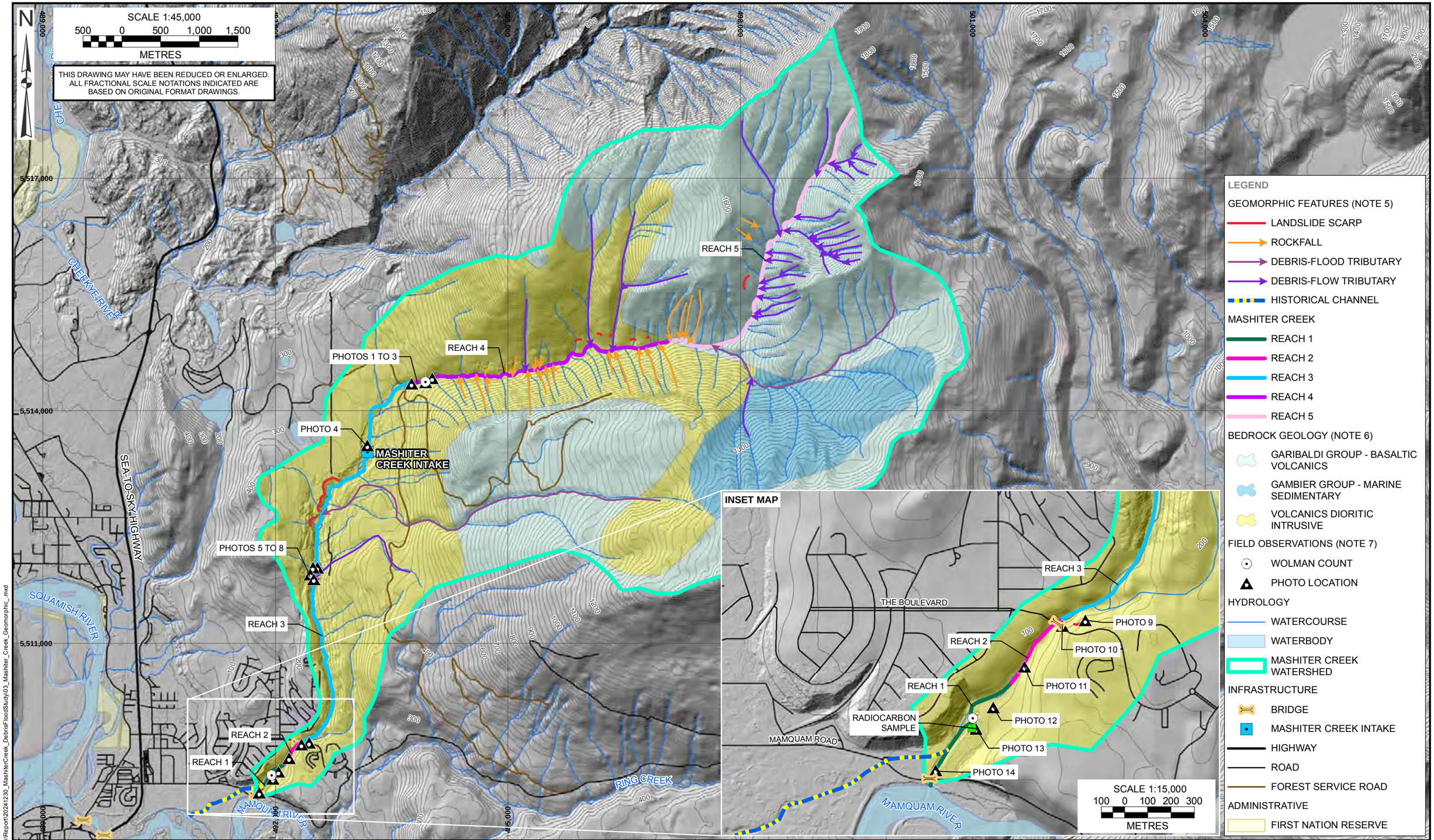

LEGEND

GEOMORPHIC FEATURES (NOTE 5)
- LANDSLIDE SCARP
- ROCKFALL
- DEBRIS-FLOOD TRIBUTARY
- DEBRIS-FLOW TRIBUTARY
- HISTORICAL CHANNEL

MASHITER CREEK
- REACH 1
- REACH 2
- REACH 3
- REACH 4
- REACH 5

BEDROCK GEOLOGY (NOTE 6)
- GARIBALDI GROUP - BASALTIC VOLCANICS
- GAMBIER GROUP - MARINE SEDIMENTARY
- VOLCANICS DIORITIC INTRUSIVE

FIELD OBSERVATIONS (NOTE 7)
- WOLMAN COUNT
- PHOTO LOCATION

HYDROLOGY
- WATERCOURSE
- WATERBODY
- MASHITER CREEK WATERSHED

INFRASTRUCTURE
- BRIDGE
- MASHITER CREEK INTAKE
- HIGHWAY
- ROAD
- FOREST SERVICE ROAD

ADMINISTRATIVE
- FIRST NATION RESERVE

NOTES:
1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUCTION WITH BGC'S REPORT TITLED "MASHITER CREEK, OVERLAND FLOW HAZARD ASSESSMENT", AND DATED FEBRUARY 2025.
3. BASE TOPOGRAPHIC DATA IS DERIVED FROM 2018 LIDAR PROVIDED BY THE DISTRICT OF SQUAMISH AND PURCHASED FROM MCELHANNEY. TOPOGRAPHIC DATA IN THE NORTHWEST CORNER IS BASED ON LIDAR DEM PROVIDED BY THE GOVERNMENT OF BC OPEN DATA PORTAL AND IS DATED 2018. LOW RESOLUTION TOPOGRAPHIC DATA IN THE REMAINING AREA IS BASED ON MRDEM DATA, PROVIDED BY THE GOVERNMENT OF CANADA OPEN DATA. CONTOUR INTERVAL IS 20 m.
4. PROJECTION IS NAD 83 UTM ZONE 10N. VERTICAL DATUM IS CGVD2013.
5. THE GEOMORPHIC FEATURES WERE MAPPED BASED ON AIR PHOTOS, AVAILABLE LIDAR, AND FIELD OBSERVATIONS. THE DEBRIS-FLOOD AND DEBRIS-FLOW TRIBUTARIES WERE DIFFERENTIATED BASED ON THEIR MELTON RATIO INDEX ACCORDING TO WILFORD ET AL., (2004).
6. THE BEDROCK GEOLOGY POLYGONS ARE FROM THE BC GEOLOGICAL SURVEY (MASSEY ET AL., 2005).
7. FIELD OBSERVATIONS AND PHOTOS WERE COLLECTED BY BGC AND CORDILLERAN ON SEPTEMBER 24 AND OCTOBER 9, 2024.
8. ROADS WERE RETRIEVED FROM OPENSTREETMAP.
9. 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:	1:45,000
DATE:	FEB 2025
DRAWN:	KJC
CHECKED:	LCH
APPROVED:	KRH

CLIENT: SQUAMISH

PROJECT: **MASHITER CREEK OVERLAND FLOW HAZARD ASSESSMENT**

TITLE: **WATERSHED GEOMORPHOLOGY**

PROJECT No.: **1348005**

DWG No.: **03**

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SCALE 1:50,000

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METRES

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

RING CREEK FSR CROSSING

MASHITER CREEK

CHEAKAMUS RIVER

CHEEKYE RIVER

SQUAMISH RIVER

SEA-TO-SKY HIGHWAY

SPUR H FSR

RING CREEK FSR

BRANCH 02 FSR

RING CREEK

MAMQUAM RIVER

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LEGEND

- RING CREEK FSR CROSSING
- HISTORICAL WILDFIRE EXTENTS (WITH FIRE YEAR)

BC CUTBLOCKS

- 1930s
- 1940s
- 1950s
- 1960s
- 1970s
- 1980s
- 1990s
- POST-2000

INFRASTRUCTURE

- HIGHWAY
- ROAD
- FOREST SERVICE ROAD

HYDROLOGY

- WATERCOURSE
- WATERBODY
- MASHITER CREEK WATERSHED

ADMINISTRATIVE

- FIRST NATION RESERVE

NOTES:

1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUCTION WITH BGC'S REPORT TITLED "MASHITER CREEK, OVERLAND FLOW HAZARD ASSESSMENT", AND DATED FEBRUARY 2025.
3. BASE TOPOGRAPHIC DATA IS DERIVED FROM 2018 LIDAR PROVIDED BY THE DISTRICT OF SQUAMISH AND PURCHASED FROM MCELHANNEY. TOPOGRAPHIC DATA IN THE NORTHWEST CORNER IS BASED ON LIDAR DEM PROVIDED BY THE GOVERNMENT OF BC OPEN DATA PORTAL AND IS DATED 2018. LOW RESOLUTION TOPOGRAPHIC DATA IN THE REMAINING AREA IS BASED ON MRDEM DATA, PROVIDED BY THE GOVERNMENT OF CANADA OPEN DATA. CONTOUR INTERVAL IS 20 m.
4. PROJECTION IS NAD 83 UTM ZONE 10N. VERTICAL DATUM IS CGVD2013.
5. BC CUTBLOCK HISTORY AND BC WILDFIRE HISTORY DATASETS PROVIDED BY THE GOVERNMENT OF BC OPEN DATA PORTAL PUBLISHED BY THE FOREST ANALYSIS AND INVENTORY BRANCH (2023) AND THE BC WILDFIRE SERVICE (2023).
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.

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DATE:	FEB 2025
DRAWN:	KJC
CHECKED:	LCH
APPROVED:	KRH

CLIENT: SQUAMISH

BGC

PROJECT: **MASHITER CREEK OVERLAND FLOW HAZARD ASSESSMENT**

TITLE: **LOGGING AND WILDFIRE HISTORY**

PROJECT No.:	DWG No.:
1348005	04

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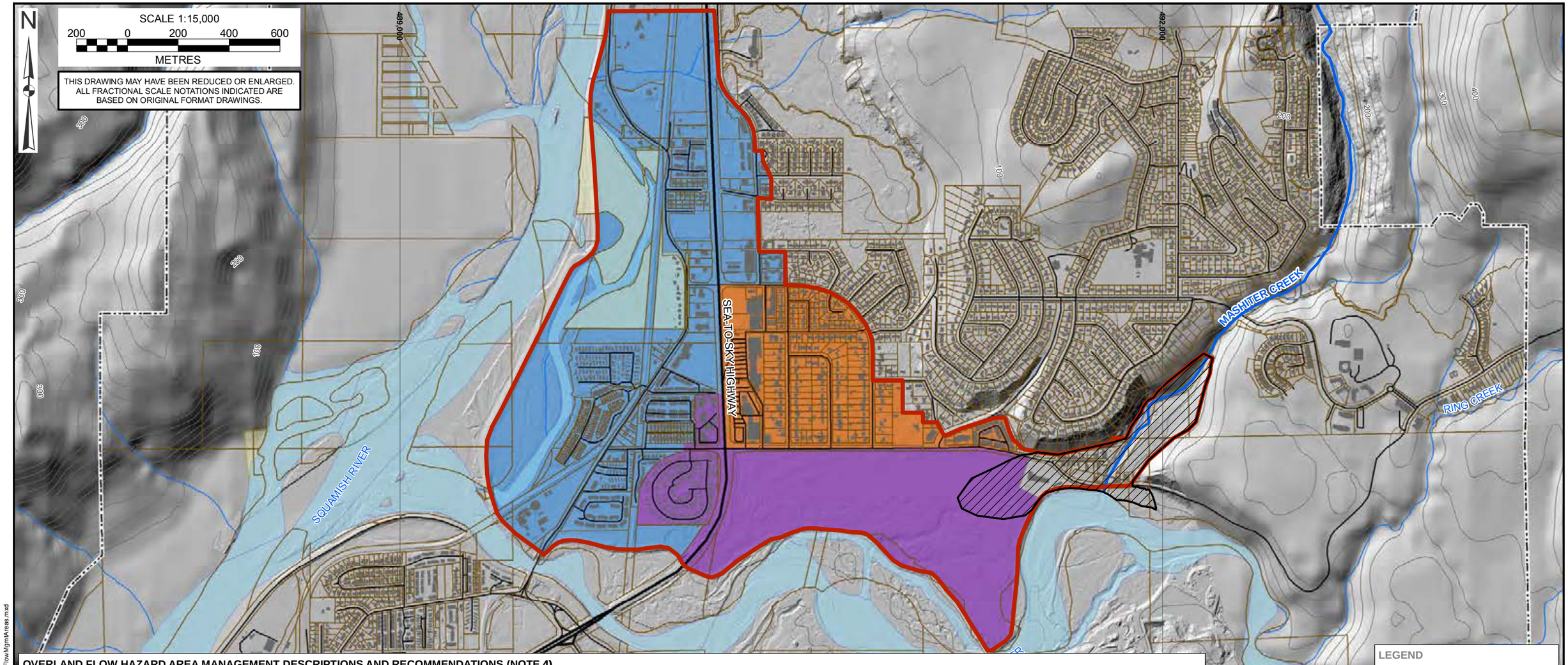


OVERLAND FLOW HAZARD AREA MANAGEMENT DESCRIPTIONS AND RECOMMENDATIONS (NOTE 4)

MASHITER CREEK OVERLAND FLOW HAZARD BOUNDARY	THIS BOUNDARY INCLUDES THE OVERLAND FLOW HAZARD BOUNDARY FROM MASHITER CREEK. THE BOUNDARY IS LIMITED TO THE NORTH BY THE MODEL EXTENTS USED IN THIS STUDY.
MANAGEMENT AREA 1	OVERLAND FLOODING IN THIS AREA IS ANTICIPATED TO BE MOSTLY STANDING WATER IN DITCHES AND IN LOW-LYING AREAS. ROADS HAVE FLOW DEPTHS UP TO 0.15 m THROUGHOUT MOST OF THE NEIGHBOURHOOD WITH THE EXCEPTION OF THE WESTERN PORTION OF THE CANADIAN TIRE PARKING LOT AND THE SOUTHERN PORTION OF GLENALDER PLACE THAT SHOW DEPTHS UP TO 0.45 m. THE MANAGEMENT RECOMMENDATION IS THAT THE FCL IS FOR THIS AREA IS 0.30 m ABOVE THE CROWN OF THE ROAD ADJACENT TO THE PARCEL (IF THE PARCEL BORDERS TWO ROADS, THE CROWN OF THE MORE UPSLOPE ROAD SHOULD GOVERN). EXCEPTIONS FOR ITEMS BELOW THE FCL MAY INCLUDE BASEMENTS THAT DO NOT INCLUDE HABITABLE SPACE, AND PARKING. ALL HABITABLE SPACE AND ELECTRICAL MUST BE ABOVE THE FCL.
MANAGEMENT AREA 2	MODELLED WATER SURFACE ELEVATIONS FROM MASHITER CREEK ARE LESS THAN THE EXISTING FCL BY 0.5 m OR MORE. THE MANAGEMENT RECOMMENDATION WITHIN THIS AREA IS THAT THE EXISTING FCL SHOULD GOVERN.
MANAGEMENT AREA 3	THERE IS OVERLAND FLOW FROM MASHITER CREEK WITHIN THIS AREA AND THE WATER SURFACE ELEVATIONS ARE WITHIN 0.5 m OF THE EXISTING FCL. IN ADVANCE OF FURTHER DEVELOPMENT, FURTHER STUDY IS RECOMMENDED TO EVALUATE THE PROBABILITY OF ONE OR MORE DIKE BREACHES ON THE SQUAMISH RIVER AND/OR MAMQUAM RIVER COINCIDING WITH A DEBRIS FLOOD ON MASHITER CREEK, AND ADDITIONAL MODELLING TO UPDATE THE FCL IN THIS AREA. THE MANAGEMENT RECOMMENDATION IS THAT THE OVERLAND FLOW HAZARD CONTINUE TO GOVERN WITHIN THIS AREA.
DEBRIS-FLOOD HAZARD	THE DEBRIS-FLOOD HAZARD AREA IS AN APPROXIMATE BOUNDARY OF THE POSSIBLE RUNOUT EXTENTS FROM A DEBRIS FLOOD ON MASHITER CREEK. IN THE EVENT OF A DEBRIS FLOOD, THIS AREA MAY BE EXPOSED TO BANK EROSION AND IMPACT FORCES THAT MAY CAUSE STRUCTURAL DAMAGE AND MAY POSE A LIFE LOSS RISK. THE DEBRIS-FLOOD HAZARD HAS NOT BEEN QUANTIFIED AS PART OF THIS STUDY. ADDITIONAL ANALYSIS AND ADDITIONAL RUNOUT MODELLING WOULD BE REQUIRED TO QUANTIFY THE HAZARD.

LEGEND

HYDROLOGY
- WATERCOURSE
- MASHITER CREEK
- WATERBODY

INFRASTRUCTURE
- BUILDING
- HIGHWAY
- ROAD
- MUNICIPAL BOUNDARY

ADMINISTRATIVE
- FIRST NATION RESERVE
- PARCEL BOUNDARIES

NOTES:
1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE NOTED.
2. THIS DRAWING MUST BE READ IN CONJUCTION WITH BGC'S REPORT TITLED "MASHITER CREEK, OVERLAND FLOW HAZARD ASSESSMENT", AND DATED FEBRUARY 2025.
3. BASE TOPOGRAPHIC DATA IS DERIVED FROM 2018 LIDAR PROVIDED BY THE DISTRICT OF SQUAMISH AND PURCHASED FROM MCELHANNEY. LOW RESOLUTION TOPOGRAPHIC DATA IN THE REMAINING AREA IS BASED ON MRDEM DATA, PROVIDED BY THE GOVERNMENT OF CANADA OPEN DATA. CONTOUR INTERVAL IS 20 m.
4. THE OVERLAND FLOW MANAGEMENT RECOMMENDATIONS ARE BASED ON THE LIDAR-DERIVED TOPOGRAPHY FROM 2018. TOPOGRAPHICAL CHANGES CAN RESULT IN CHANGES TO THE FLOODWAY AND TO THE OVERLAND FLOW MANAGEMENT RECOMMENDATIONS. THE DISTRICT OF SQUAMISH SHOULD NOT MODIFY THE TOPOGRAPHY WITHIN THE SQUAMISH VALLEY GOLF CLUB LANDS, NOR THE TOPOGRAPHY OF MAMQUAM ROAD BETWEEN PACO ROAD AND HIGHLAND WAY SOUTH WITHOUT ADDITIONAL STUDY ON THE IMPACTS TO EXISTING FLOODWAYS AND TO THE OVERLAND FLOW MANAGEMENT RECOMMENDATIONS.
5. PROJECTION IS NAD 83 UTM ZONE 10N. VERTICAL DATUM IS CGVD2013.
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:	1:15,000
DATE:	FEB 2025
DRAWN:	KJC
CHECKED:	LCH
APPROVED:	KRH

CLIENT: SQUAMISH

BGC

PROJECT: **MASHITER CREEK OVERLAND FLOW HAZARD ASSESSMENT**

TITLE: **MASHITER CREEK OVERLAND FLOW MANAGEMENT RECOMMENDATIONS**

PROJECT No.: **1348005**

DWG No.: **05**

X:\Projects\1348\005\Production\Report\20241230_MashiterCreek_DebrisFloodStudy\05_Mashiter_Creek_OverlandFlowMgmtAreas.mxd

APPENDIX A
PHOTOGRAPHS

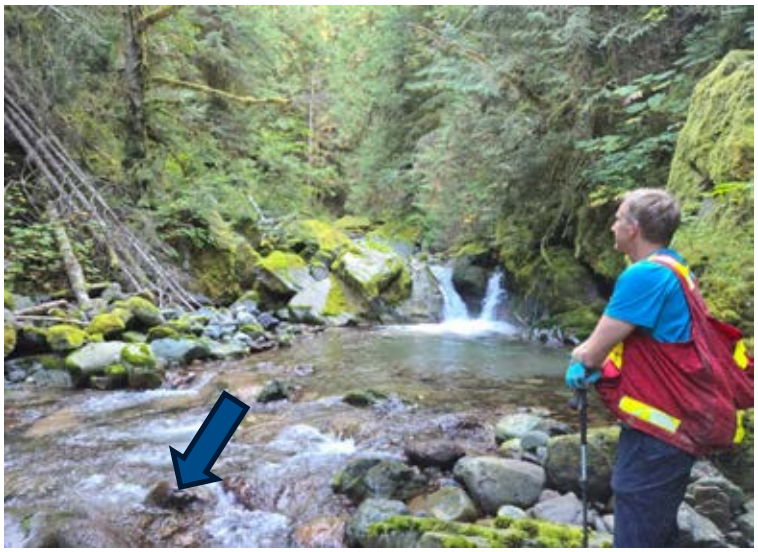


Photo 1

Looking upstream at a representative portion of channel within Reach 4 of Mashiter Creek.

The channel in Reach 4 has a typical gradient of 10 to 15% and varies in width from 10 to 20 m. The banks consist of steep bedrock that is fractured and is the likely source of large boulders within the channel. The channel morphology is step pool with multiple waterfalls built out of large (>2 m) granite boulders. BGC photo September 24, 2024.

Photo 2

Looking upstream in Reach 4 near the collection site of Wolman Count #1.

BGC photo September 24, 2024.

Photo 3

Looking at the right (north) bank immediately upstream of the Ring Creek FSR at levelogger and instrumentation within the creek.

It is unknown whether the instrumentation is active or what it is used for. It was not used to inform the assessment. BGC photo September 24, 2024.

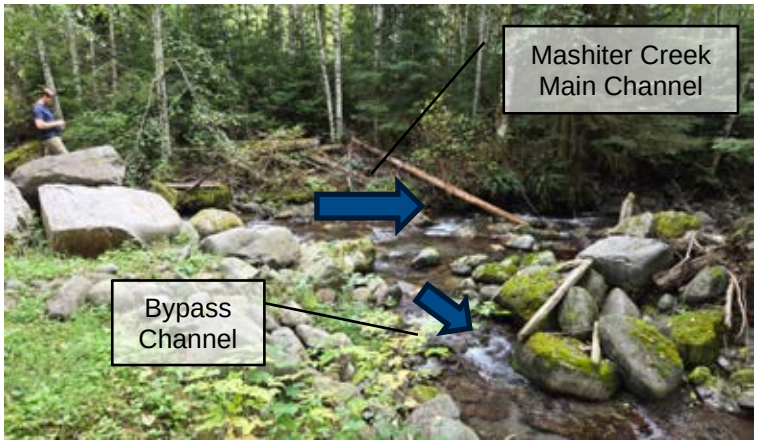


Photo 4

Looking east towards the entrance of the bypass channel leading to the Mashiter Creek headpond.

The boulders on the right (west) bank of the channel near the entrance were placed in 2017. BGC photo September 24, 2024.

Photo 5

Terrace on left (east) bank of Mashiter Creek with hemlock trees approximately 20 to 30 years old. It is presumed that the terrace is a deposit from the 1990/91 events.

The channel in Reach 3 is generally wider than Reach 4 (20 to 25 m wide channel with 100 m wide floodplain) and has a gradient of 3 to 7%.

BGC photo October 9, 2024.

Photo 6

High water mark on the right (west) bank on top of another terrace deposit (unknown age).

High water mark was 1.4 to 1.7 m above the existing channel bed elevation. BGC photo October 9, 2024.

Photo 7

Paraglacial rock avalanche or debris-flow deposit on the right (west bank). The deposit is matrix-supported silts, sands, and cobbles.

BGC photo October 9, 2024.

Photo 8

Deposit located mid to left (east) side of the channel approximately 2.5 m above the channel bed. Three cedar trees approximately 300 to 400 years old grew out of the deposit (as opposed to being buried in the deposit).

BGC photo October 9, 2024.

Photo 9

Landslide on left (east) bank ~20 m upstream of the Boulevard Bridge. The landslide scarp is approximately 25 m wide.

BGC photo October 9, 2024.

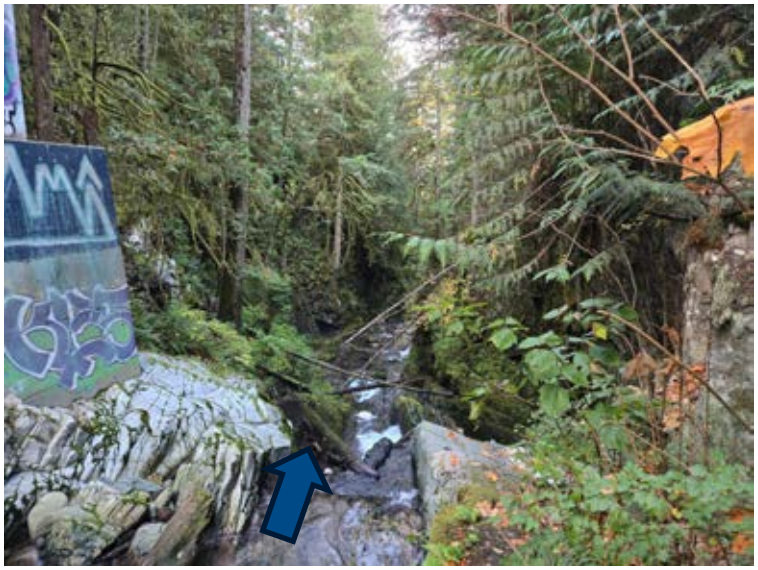


Photo 10

Looking downstream at the channel at the Boulevard Bridge. The pier on the left bank is the sole substructure element in the flow. Lack of abrasion on the abutment suggests it is rarely impacted by debris.

Immediately downstream of the Boulevard Bridge is a cascading waterfall that leads into the start of Reach 1.

BGC photo October 9, 2024.

Photo 11

Looking downstream at the start of Reach 1. The mid-channel bar has vegetation ~20 years old and could be a deposit from the 1990/91 events.

BGC photo October 9, 2024.

Photo 12

Constructed berm or dike structure found in the left (east) bank floodplain. Its extents and purpose are unknown.

BGC photo October 9, 2024.

Photo 13

Looking at the bank erosion on the left (east) bank.

The log used for radiocarbon dating was found within the exposed bank. See Appendix E for more information.

BGC photo October 9, 2024.

Photo 14

Looking downstream at the Mamquam Road Bridge over Mashiter Creek.

BGC photo October 9, 2024.

APPENDIX B
AIR PHOTOS

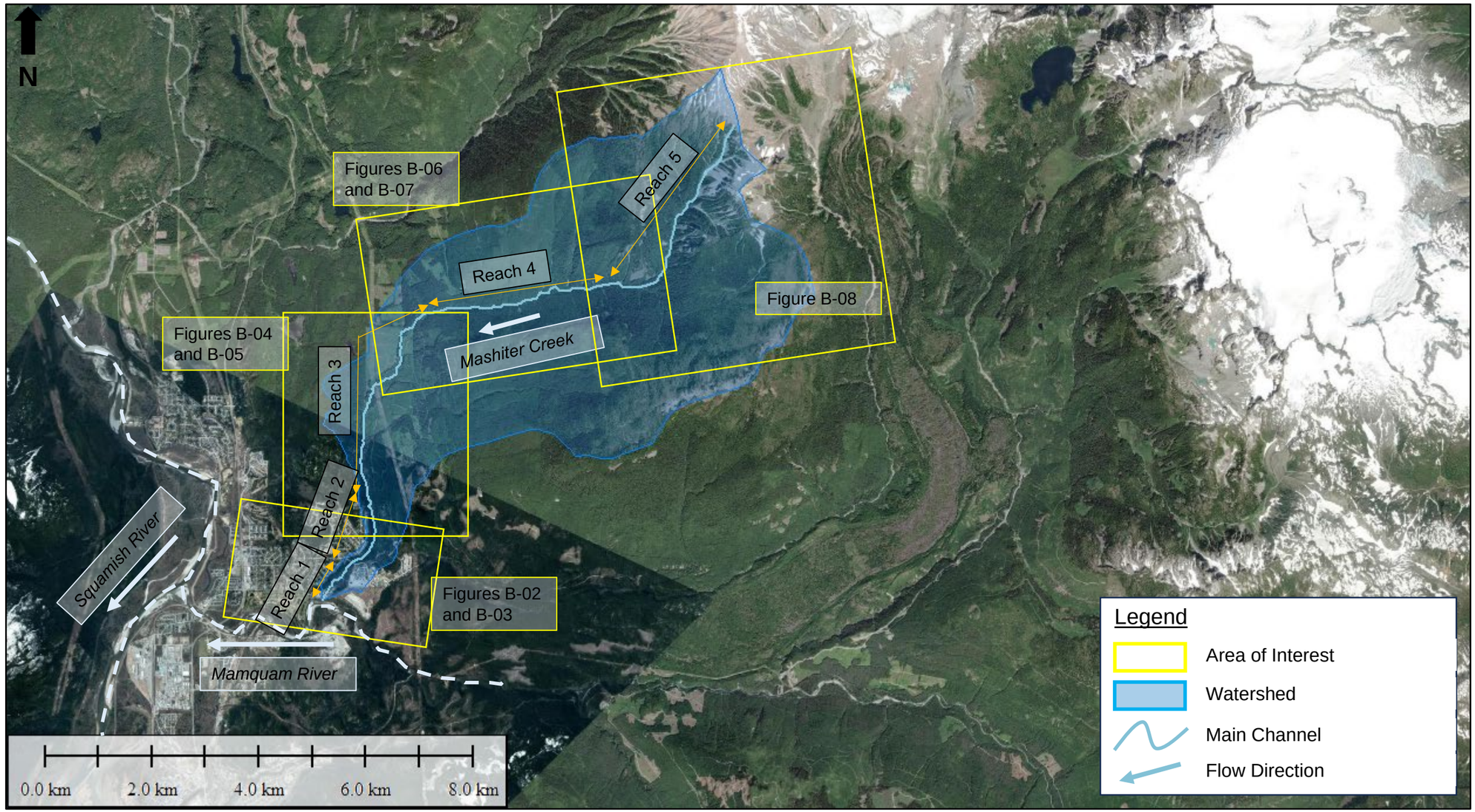
B-1 INTRODUCTION

Air photos and satellite imagery reviewed to support the geohazard assessment of Mashiter Creek are documented in Table B-1. Observations are generally ordered from downstream (Mamquam River and Mashiter Creek confluence) to upstream (Garibaldi Provincial Park and Mashiter Creek headwaters). Select air photos are annotated in Figures B-02 to B-08. An overview of the reaches of Mashiter Creek and organization of the air photo annotations is shown in Figure B-01.

Table B-1 Air photos reviewed.

Year	Source	Approximate Scale	Coverage	Roll/Photo Number	Summary of Observations
1946	NAPL	1:20,000	Lower Mashiter Creek channel and confluence with Mamquam River	A10362: 78, 79, 82, 83	The Mashiter Creek channel flows to the west along the present-day location of Paco Road and through the golf course before joining the Mamquam River. This suggests that the modern bed elevation of Mashiter Creek today is lower than it was in 1946 (Figure B-02). The lower watershed connected to Reach 3 between Ring Creek FSR and the Boulevard (both not yet constructed) appears to have been logged leaving a minimal riparian buffer of trees adjacent to the Creek (Figure B-04).
1951	NAPL	1:70,000	Full watershed of Mashiter Creek	A13250: 98, 99	Both the Mashiter Creek channel and its watershed appear in comparable condition to 1946. The watershed upstream of the Ring Creek FSR crossing (Reaches 4 and 5) is forested with limited evidence of logging. The channel is bounded by steep hillslopes in Reach 4. There are incised gully features leading to the channel that are all vegetated in 1951. There are several exposed sediment sources visible in the upper watershed in Reach 5.
1966	NAPL	1:60,000	Full watershed of Mashiter Creek	A19426: 29, 30, 125, 126	The lower 250 m of Reach 1 of Mashiter Creek has straightened (unknown if natural or anthropogenic) and is flowing in its present-day location. The channel appears to be wider than in previous images with sediment bars within the channel. The bridge crossing Mashiter Creek at Mamquam Road has been constructed. The Squamish Valley Golf Course is under construction (Figure B-02). The lower watershed in Reach 3 between Ring Creek FSR and the Boulevard is largely revegetated with trees. There are logging roads visible upslope and parallel to the Mashiter Creek channel. The watershed upstream of the Ring Creek FSR (Reach 4) has been logged upstream to the Garibaldi Park Boundary (Figure B-06). The hillslopes were logged immediately adjacent to the channel of Reach 4 and there are numerous logging roads visible along the hillslopes, as well some fill slope failures. Tributaries to the Mashiter Creek channel show bright tones suggesting they were recently active.
1982	GeoBC	1:20,000	Full watershed of Mashiter Creek	BC82057: 38, 39, 112, 113 BC82060: 28, 29, 30, 31, 88	There is development on both banks of Mashiter Creek in the lower 500 m of Reach 1. Dike construction is visible along the Mamquam River along the boundary of the Squamish Valley Golf Course. The Garibaldi Highlands and Garibaldi Estates neighborhood have been developed. The University lands and the bridge at the Boulevard have not yet been developed (Figure B-03). The watershed adjacent to Reaches 2 and 3 appears similar to 1966. The upper portion of Reach 3 near Ring Creek FSR shows some brighter tones and evidence of sediment deposition. A right-of-way for the BC Hydro transmission line is visible that has a northwest-southeast orientation (Figure B-04). The watershed upstream of the Ring Creek FSR shows partial revegetation following the logging in the 1950s and 1960s. A new cutblock is visible on the north side of the channel and there are nine discrete hillslope failures visible on the north side of Reach 4. The Mashiter Creek channel downstream of the failures within Reach 4 is brightly toned and filled with sediment (Figure B-07).
1994	GeoBC	1:15,000	Full watershed of Mashiter Creek	BCC94121: 137, 153, 154, 155, 156, 181, 182 BCC94122: 28, 29, 55, 56	Around the Boulevard crossing (not yet constructed) in Reach 2, there is limited sediment visible in the channel. Downstream of the Boulevard and the cascading waterfall (Photo 10, Appendix A) in Reach 1, the channel is straight and there is sediment visible along the channel until it flows into the Mamquam River (Figure B-03).

Year	Source	Approximate Scale	Coverage	Roll/Photo Number	Summary of Observations
					In Reach 3 between Ring Creek FSR and the Boulevard, the channel is brightly toned, wider than in previous images, and multiple sediment deposits are visible throughout the channel. Bank erosion is visible throughout the channel. It is interpreted that the sediment in the channel are deposits from the 1990/91 events (Figure B-05). The watershed upstream of the Ring Creek FSR along Reach 4 that had been previously logged showed activation of five tributaries on the southern hillslope and reactivation of three tributaries on the northern hillslope. There is a logging road fill slope failure visible on the northern hillslope into one of the tributaries. The Mashiter Creek channel is brightly toned with sediment within Reach 4 and Reach 3 (Figure B-07). The upper watershed of Mashiter Creek within the Garibaldi Park boundary shows bright tones within several (10 to 15) tributaries providing sediment to Mashiter Creek. Two of these tributaries appeared more active in 1994 compared to previous imagery (Figure B-08). Reach 5 of Mashiter Creek is brightly toned with sediment.
2009	Satellite Imagery	N/A	Full watershed of Mashiter Creek	N/A	The University Lands neighborhood and the Boulevard bridge crossing Mashiter Creek have been developed. Sediment bars within Reach 3 that were visible in the 1994 images are partially vegetated. Tributaries in the upper watershed connected to Reach 4 and Reach 5 show signs of revegetation.
2022	Satellite Imagery	N/A	Full watershed of Mashiter Creek	N/A	Sediment bars within Reach 3 and 4 that were visible in the 1994 images are re-vegetated. Tributaries in the upper watershed connected to Reach 4 and 5 are re-vegetated with secondary growth except for a small handful of tributaries in the upper watershed.



NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
2. Background imagery is Esri imagery captured on July 27, 2021.
3. Extents for subsequent figures and the air photos presented are approximate and are intended to guide the reader on the approximate location of the images. The actual image extents vary by the photo selected for annotation.

PREPARED BY: KRH	FIGURE TITLE: Overview		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-01

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1946
A10362/082

1966
A19429/125

NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.

PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 1 – 1946 and 1966		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-02

0 5 10 mm in ANSI B sized paper

BGC Engineering

1982
BC82060/028

1994
BCC94122/028

NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.

PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 1 – 1982 and 1994		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-03

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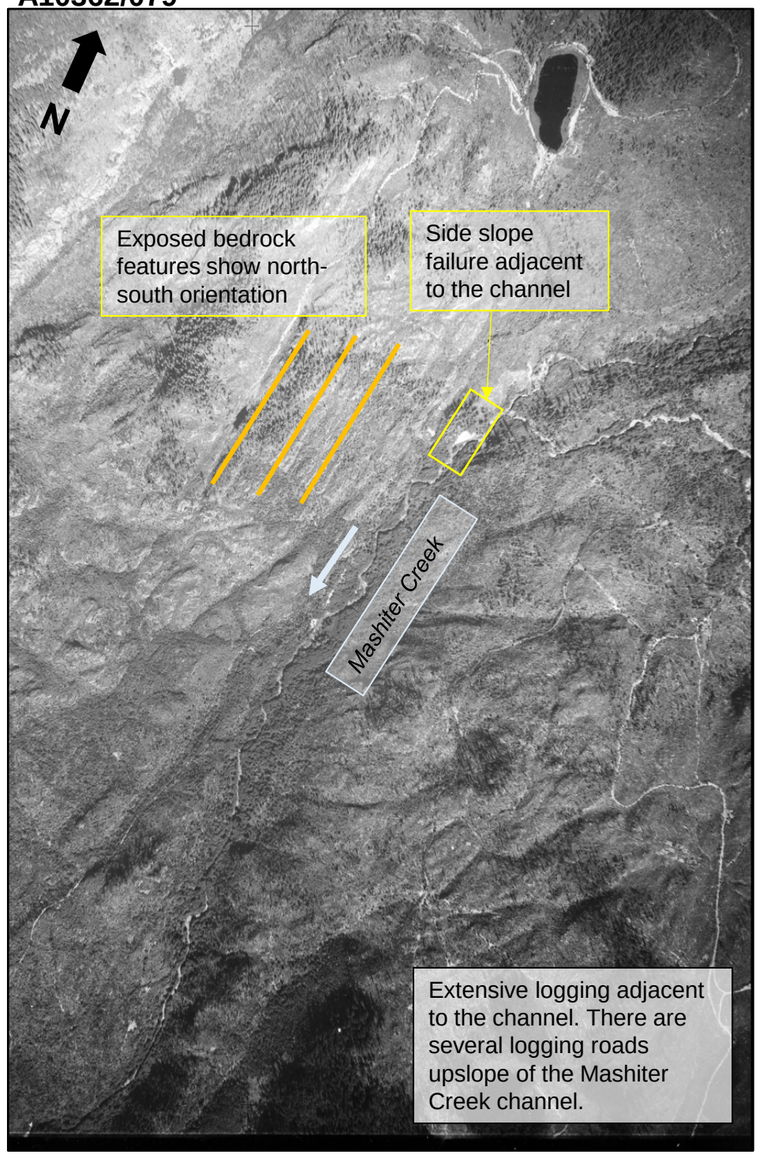
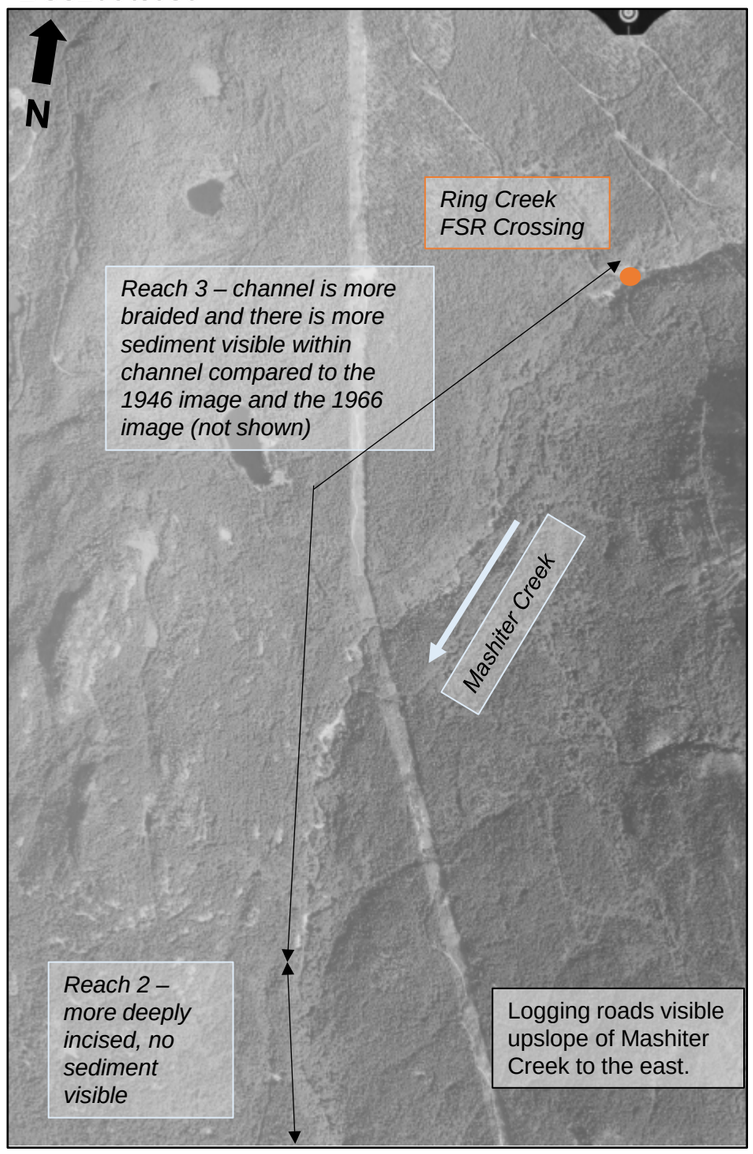
BGC Engineering

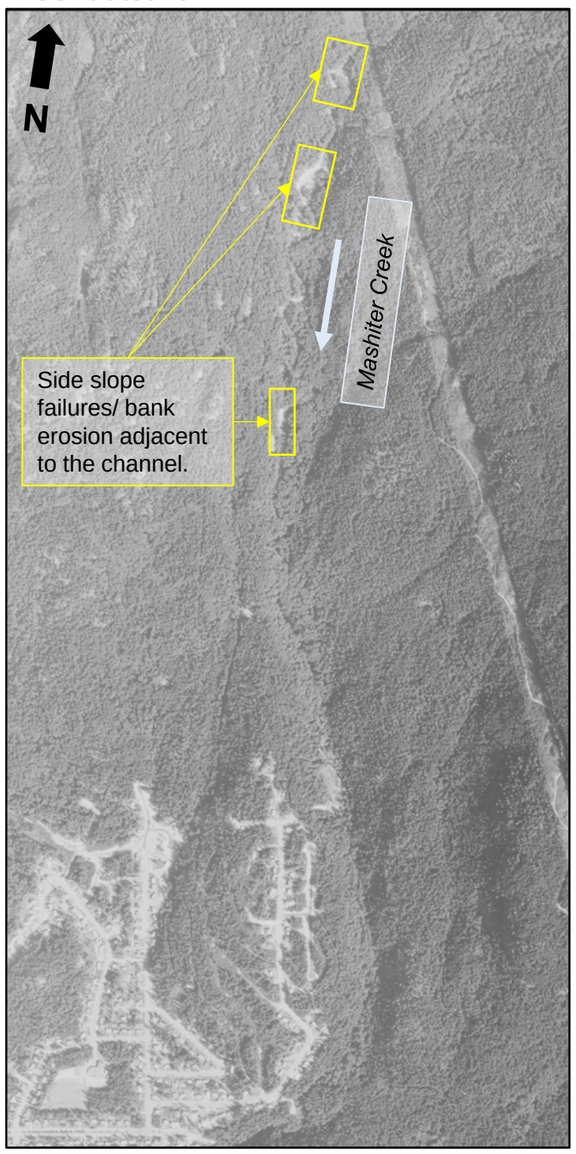
1946
A10362/079



1982
BC82060/030



1982
BC82060/029



NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.

PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 2/3 – 1946 and 1982		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-04

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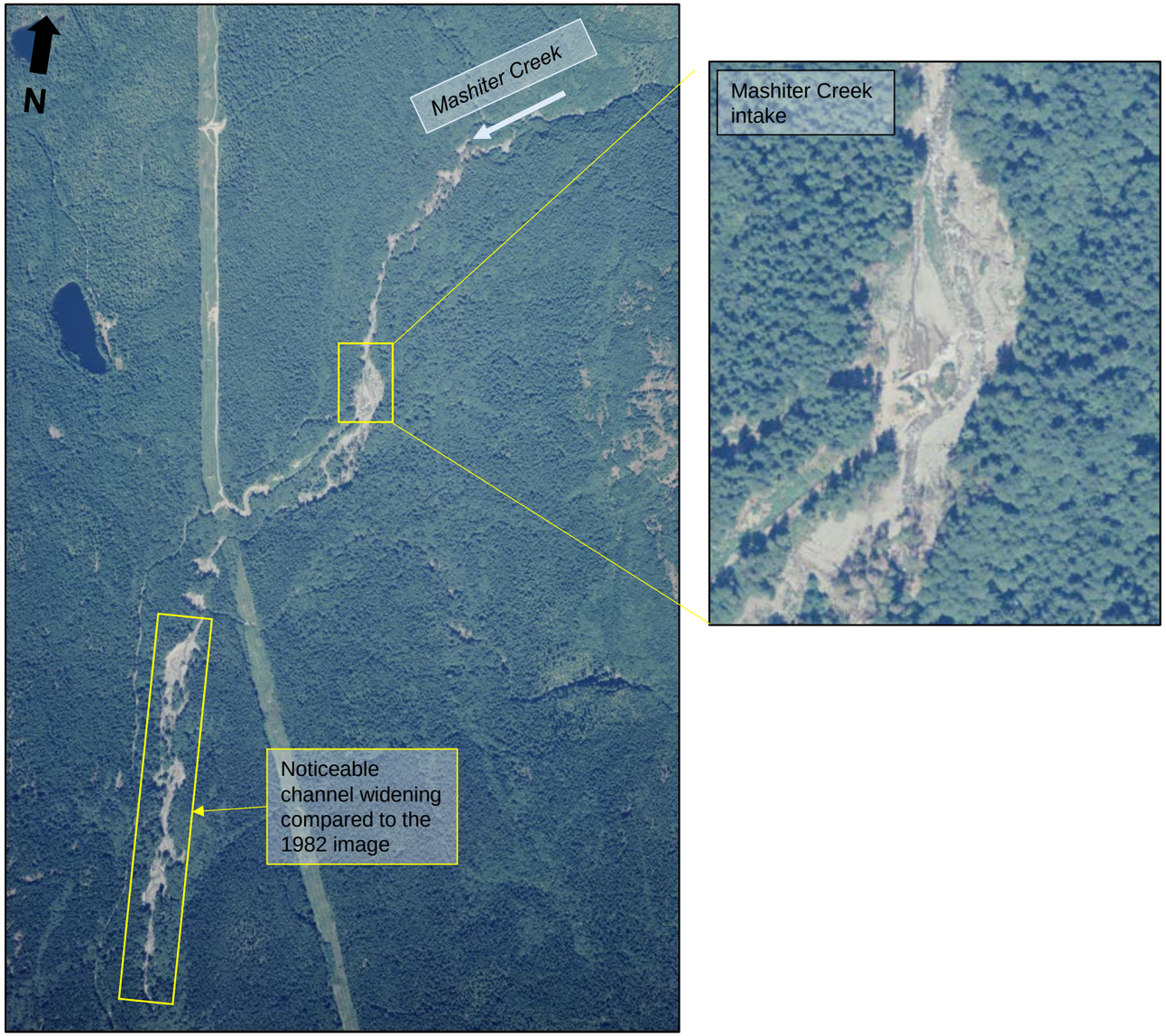
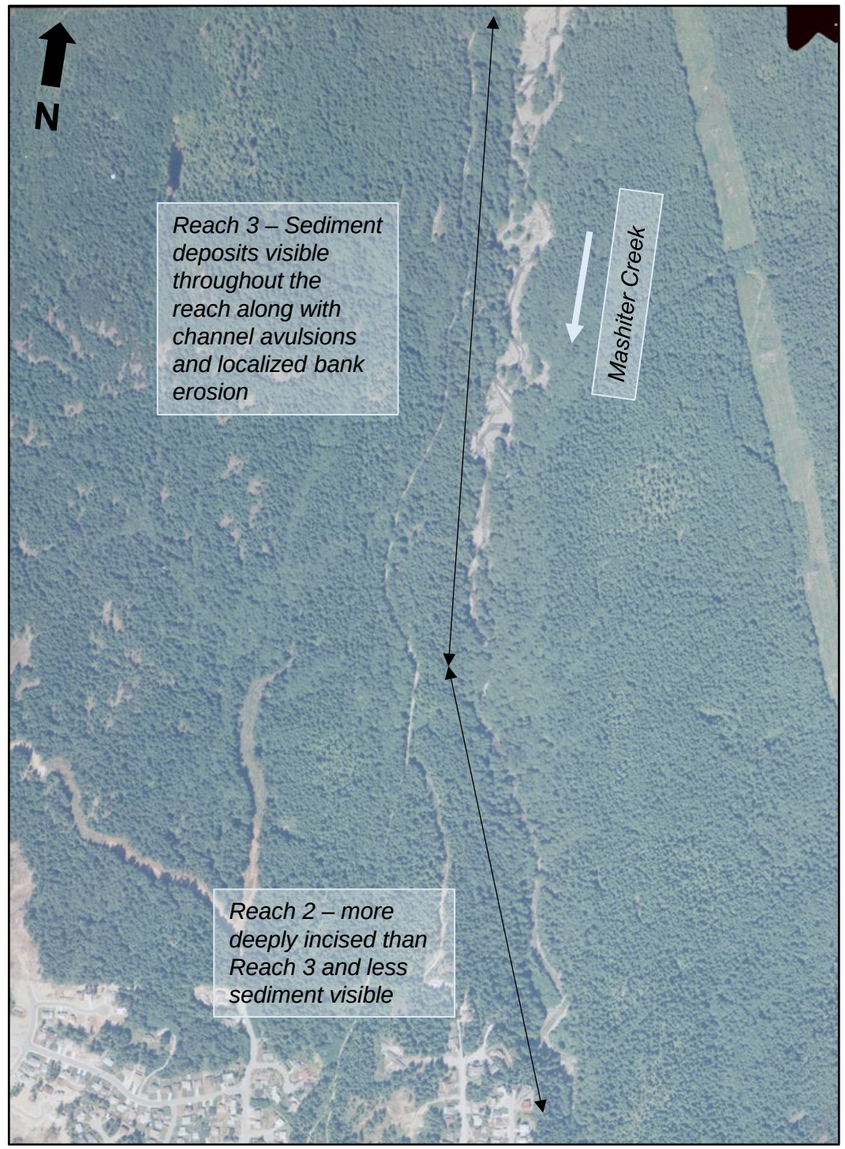
1994
BCC94122/028



1994
BC94122/028



NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.

PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 2/3 – 1994		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-05

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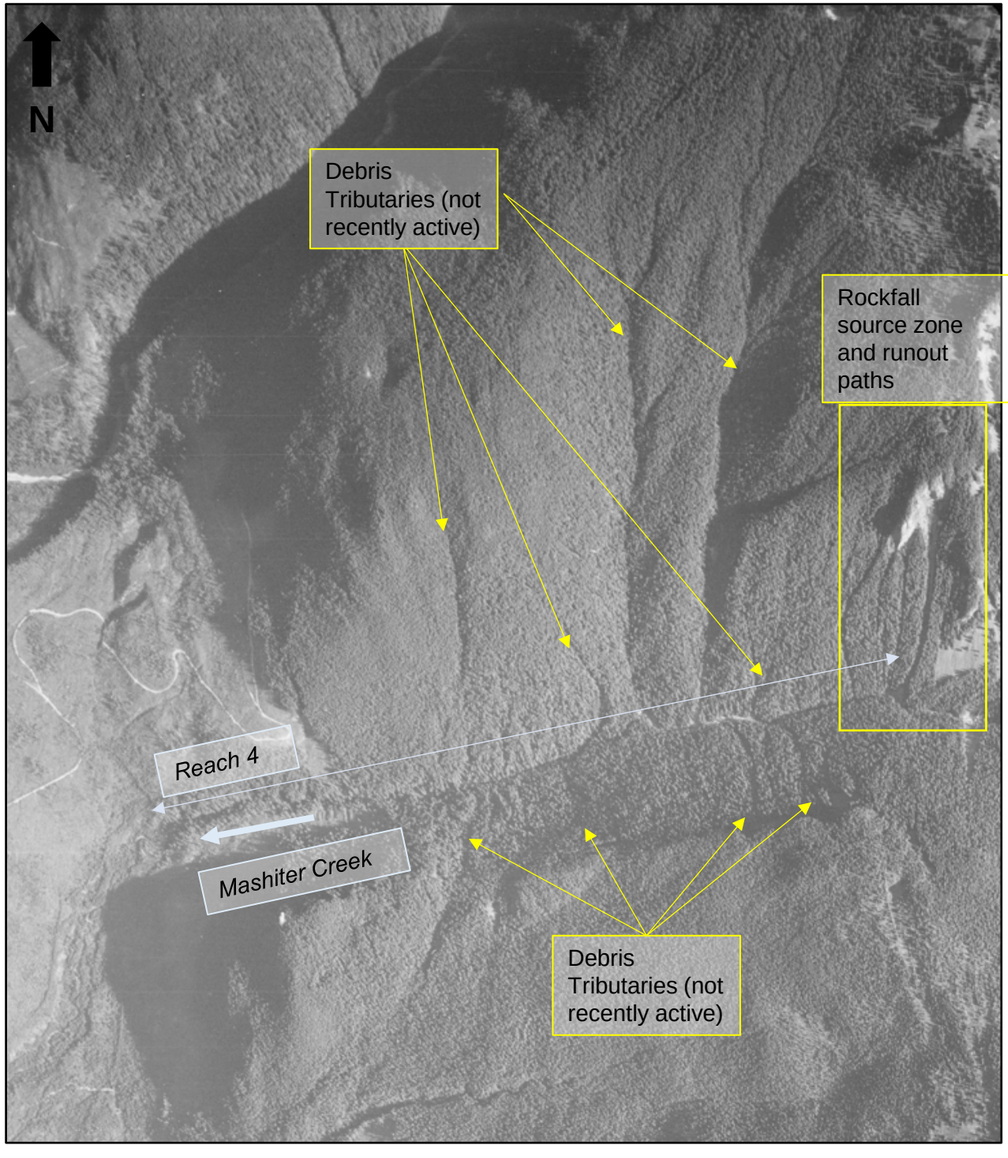
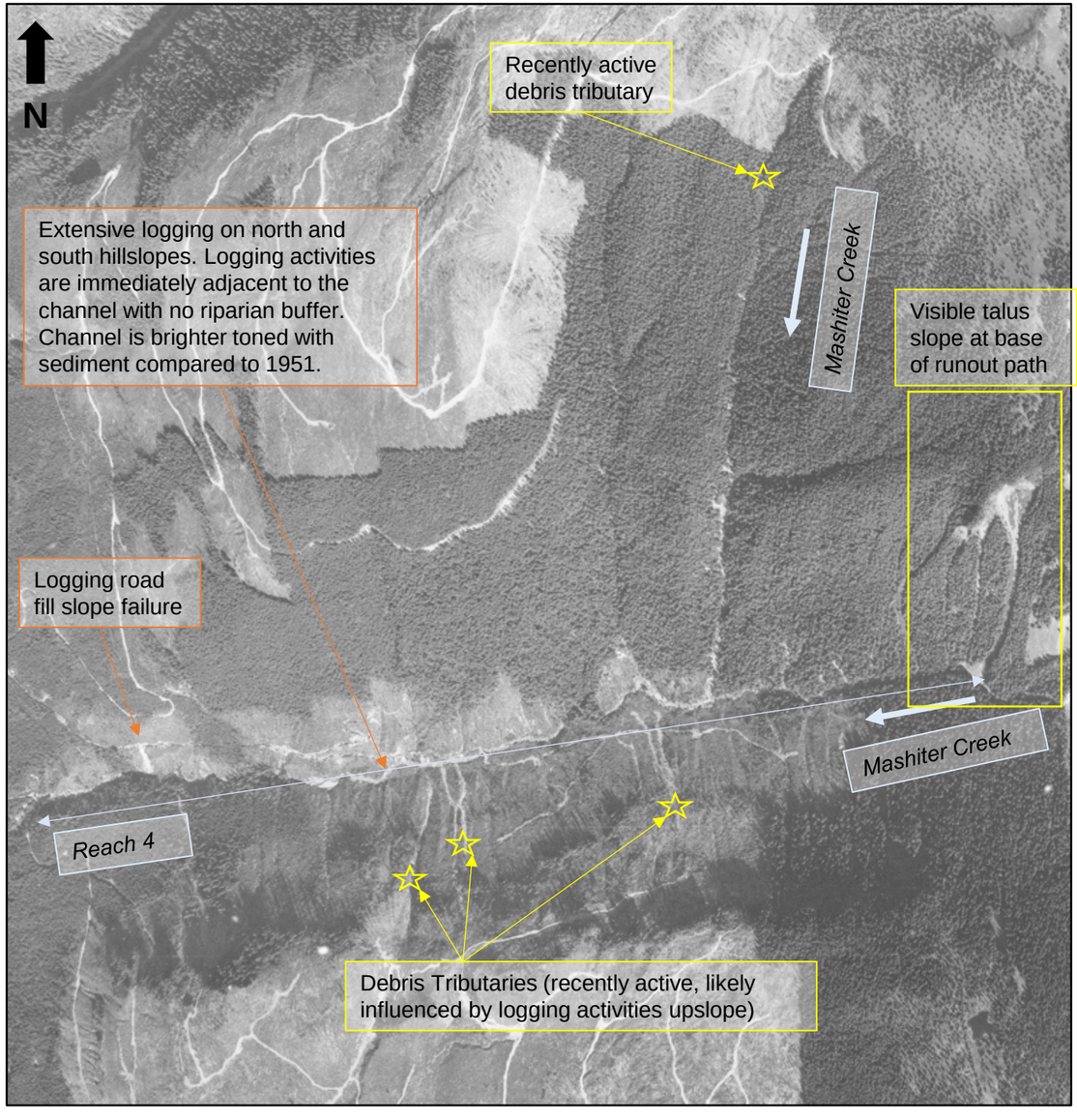
1951
A13250/099



1966
A19429/030



NOTES:

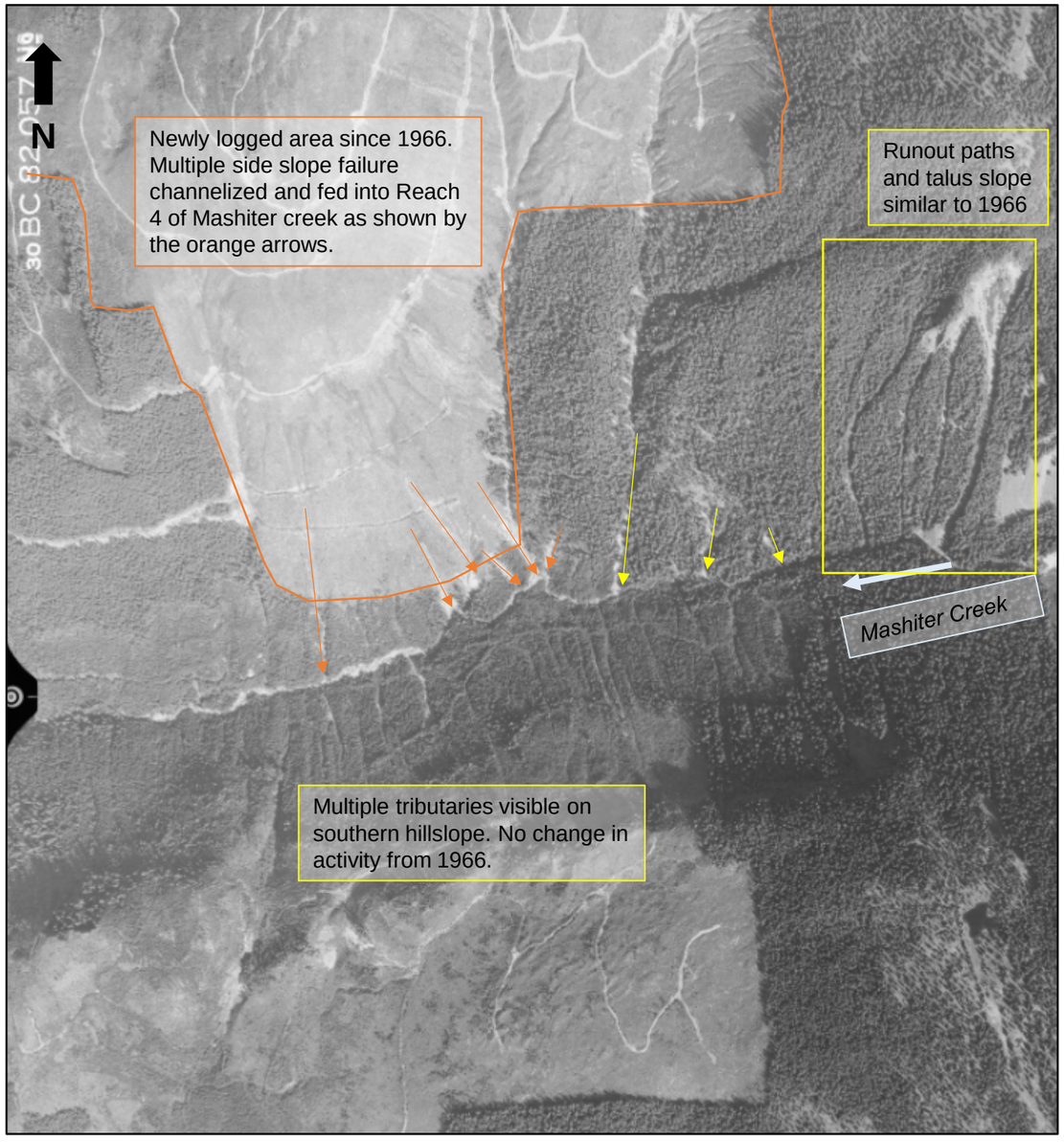
1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.

PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 4 – 1951 and 1966		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-06

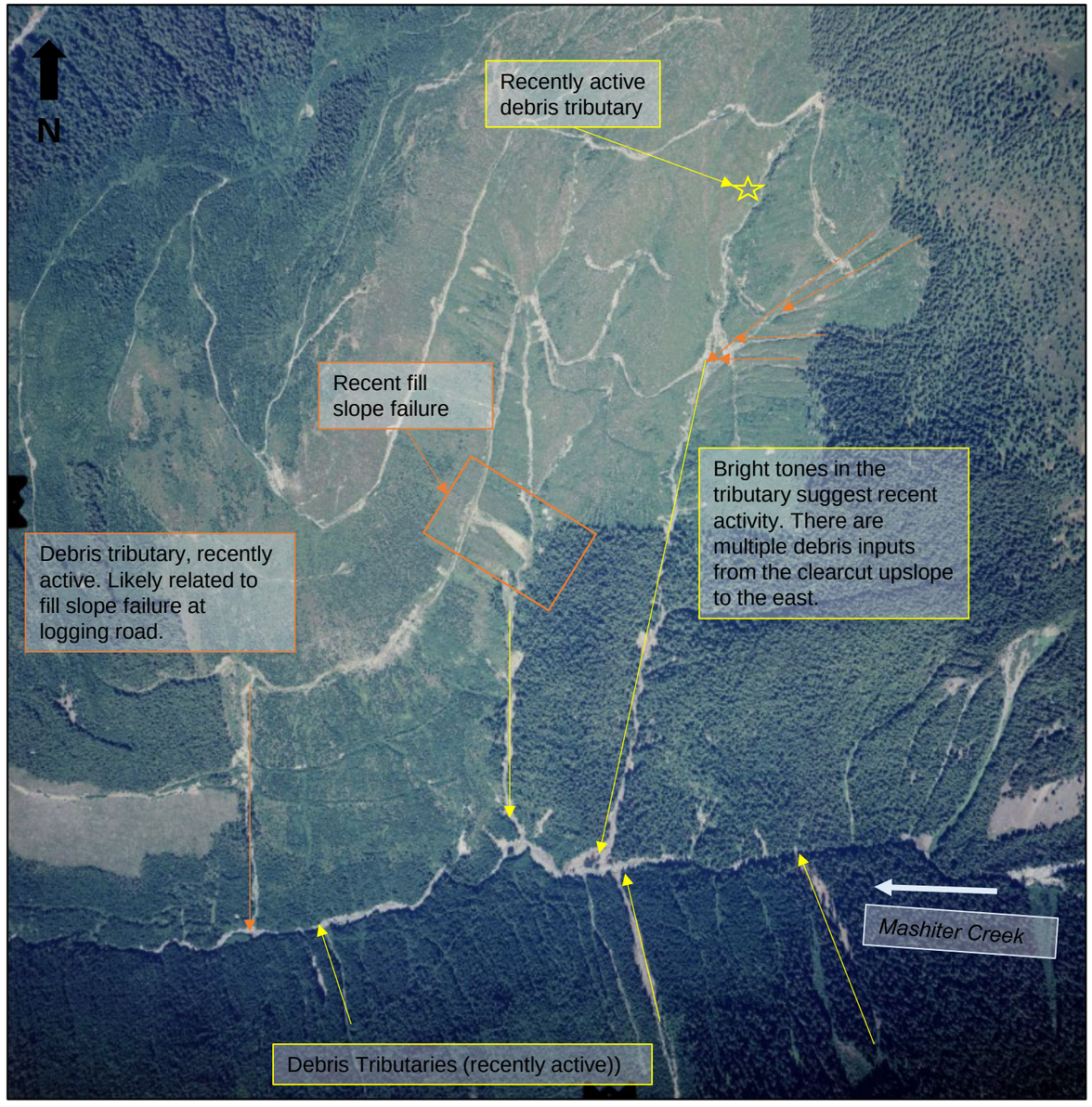
0 5 10 mm in ANSI B sized paper

BGC Engineering

1982
A82057/113



1994
BCC94121/155



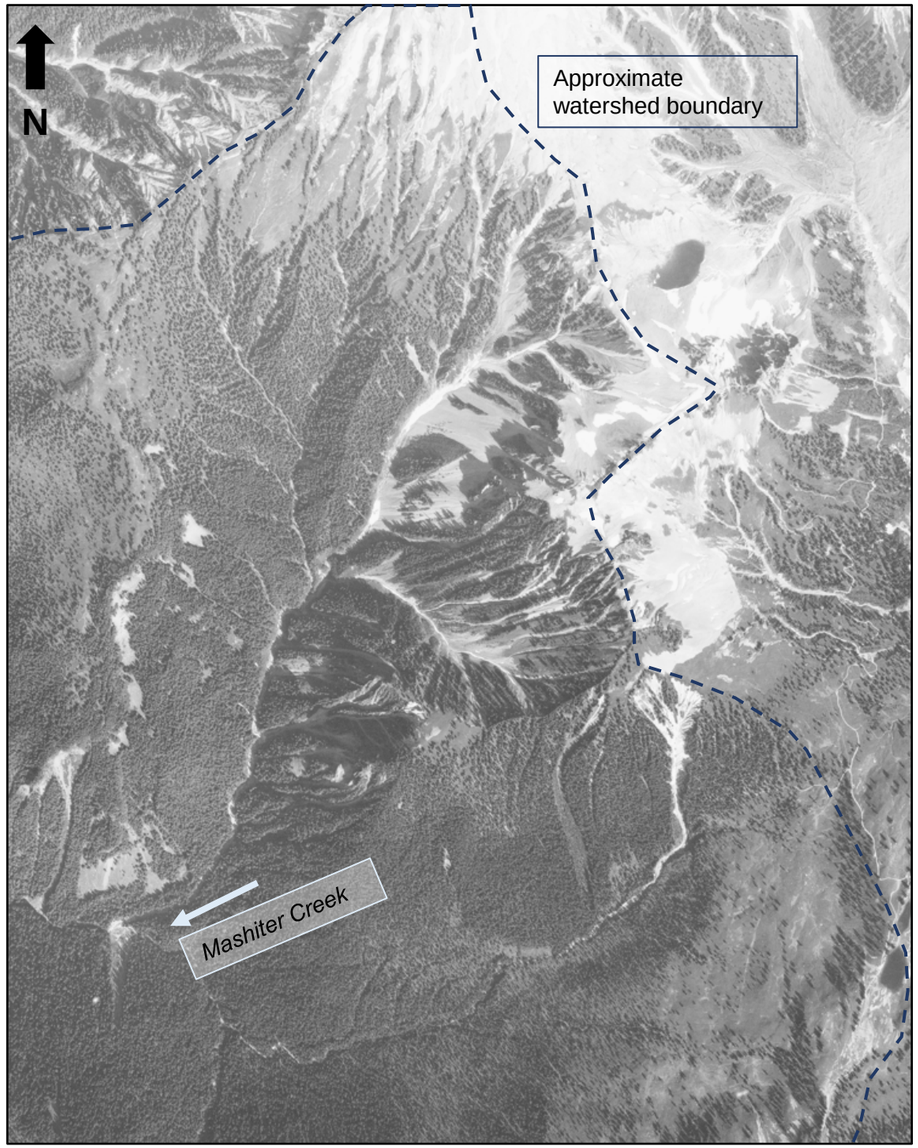
NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.

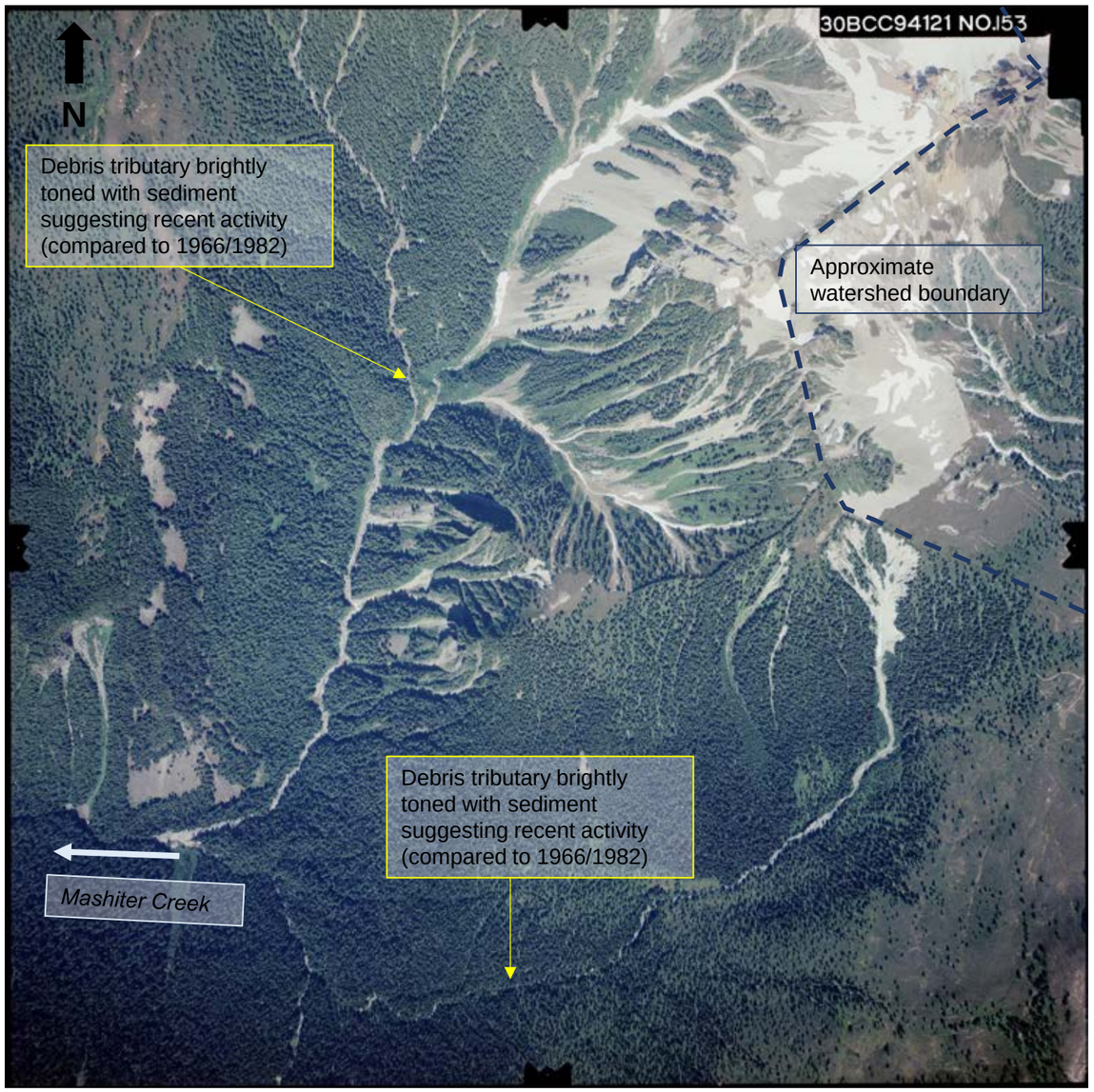
PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 4 – 1982 and 1994		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-07

0 5 10 mm in ANSI B sized paper

1966
A19429/030



1994
BCC94121/153



NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
2. There are multiple debris tributaries to Reach 5 of Mashiter Creek (located within Garibaldi Provincial Park) as can be seen in both the 1966 and 1994 images. Only debris tributaries that show a change in activity between images have been highlighted.

PREPARED BY: KRH	FIGURE TITLE: Mashiter Creek Reach 5 – 1951 and 1966		
CHECKED BY: AJF	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: N/A	PROJECT NO: 1348005	FIGURE NO: B-08

0 5 10 mm in ANSI B sized paper

APPENDIX C
RADIOCARBON DATING

C-1 INTRODUCTION

Radiocarbon dating is a technique used to assign approximate dates to stratigraphic layers and can be used to constrain the timing of fan evolution. There was no test pitting program completed on the Mashiter Creek fan and therefore not sufficient data to form a full understanding of the fan evolution.

However, during the field visit on October 9, 2024, Pierre Friele (Cordilleran) and Kathleen Horita (BGC) observed bank erosion on the left (east) bank of Mashiter Creek approximately 380 m upstream of the Mamquam River (Photo 13, Appendix A). In review of Google Earth™ imagery, the bank erosion occurred sometime after August of 2021. The magnitude of bank that had eroded was approximately 6 to 7 horizontal meters of bank material. Full grown trees from the top of the bank had fallen into the channel. The bank erosion exposed the upper 2.55 m of the Mashiter Creek fan and there was a log buried at a depth of 2.55 m below existing ground. Cordilleran and BGC dug into the bank to establish the log was buried between layers of sediment rather than pushed into the bank by the Mashiter Creek flow. A sample of the outermost three rings of the log was sent in for radiocarbon dating and the layers of the bank erosion exposure were examined to determine the flow process type for each layer, the sediment composition, and the layer thickness.

This appendix describes dating techniques, presents the findings from the bank exposure, and the interpretation of the results.

C-2 DATING TECHNIQUES

C-2.1 Radiocarbon Dating

The radiocarbon (^{14}C) method dates the death age of an organic sample. The ^{14}C dating does not directly date what is of interest, the sediment layer. Rather, it provides maximum or minimum bracketing ages, depending on whether the sample was within or below (maximum age) or above (minimum age) the unit of interest. The bracketing may not provide a tight age constraint on the unit of interest: with further dating for instance, one may find that for a maximum age context (^{14}C sample within or below the unit of interest) the age range of multiple samples may span centuries, and the youngest of the maximum ages will be the closest bracket; conversely, for a minimum age context (^{14}C sample above a unit of interest), the oldest of the ages will be the closest minimum age.

When a tight bracketing age is desired, running more samples or being very specific with what is being dated is required; for example, one must find a buried tree with bark attached, convince yourself the tree was killed by a landslide (landslide age and tree death age are the same), then use a band saw to remove only the last ring and date that, then the lab error will be the only error. Often the sampling errors are not known, and this introduces the need for judgement in the interpretation process.

The reported conventional age error (i.e., ±30 years) refers to lab error only. It is good to have it small, and ±20 to ±30 years is typical. Note though, as discussed above, the sample error is the

uncertainty in the association between what is being dated and what we are interested in. The sample error (potentially centuries) is much greater than the lab error (typically decades) and is typically unknown.

There are two reported ages, conventional radiocarbon ages (Yr BP ^{14}C), and calibrated ages (Yr BP). Since the production of radioactive carbon in the atmosphere is not constant in time, raw conventional ages need to be calibrated to calendric time.

C-2.2 Soil Development and Relative Dating

In the region, the so-called zonal soil is referred to as a podzol (Valentine et al., 1978). Podzols are characteristic of wet temperate climates, and are the product of chemical weathering, leaching of minerals from the upper soil levels and translocation of oxidants to deeper soil depths. A well-developed podzol may have an organic forest floor horizon (Duff, or Ah), a leached mineral zone (Ae), and a B horizon enriched by humus (Bh) and by ferrous oxides (Bf). A well-developed podzol B-horizon typically has an orange to red colour. Based on local experience and on published literature (Protz et al., 1984; Sanborn et al., 2011), it takes at least 1,000 years to begin to see an oxidized B-horizon. Deeply oxidized B-horizons will be several millennia in age. Thus, the presence and degree of podzolisation can aid interpretation of deposit age, at least in relative terms.

C-3 RESULTS

C-3.1 Exposure Description

The bank erosion exposure was 2.55 m deep as measured from the ground surface. Four stratigraphic layers were visible within the exposure (Photo C-1). The log used for radiocarbon dating was within layer 4 and at 2.55 m depth.

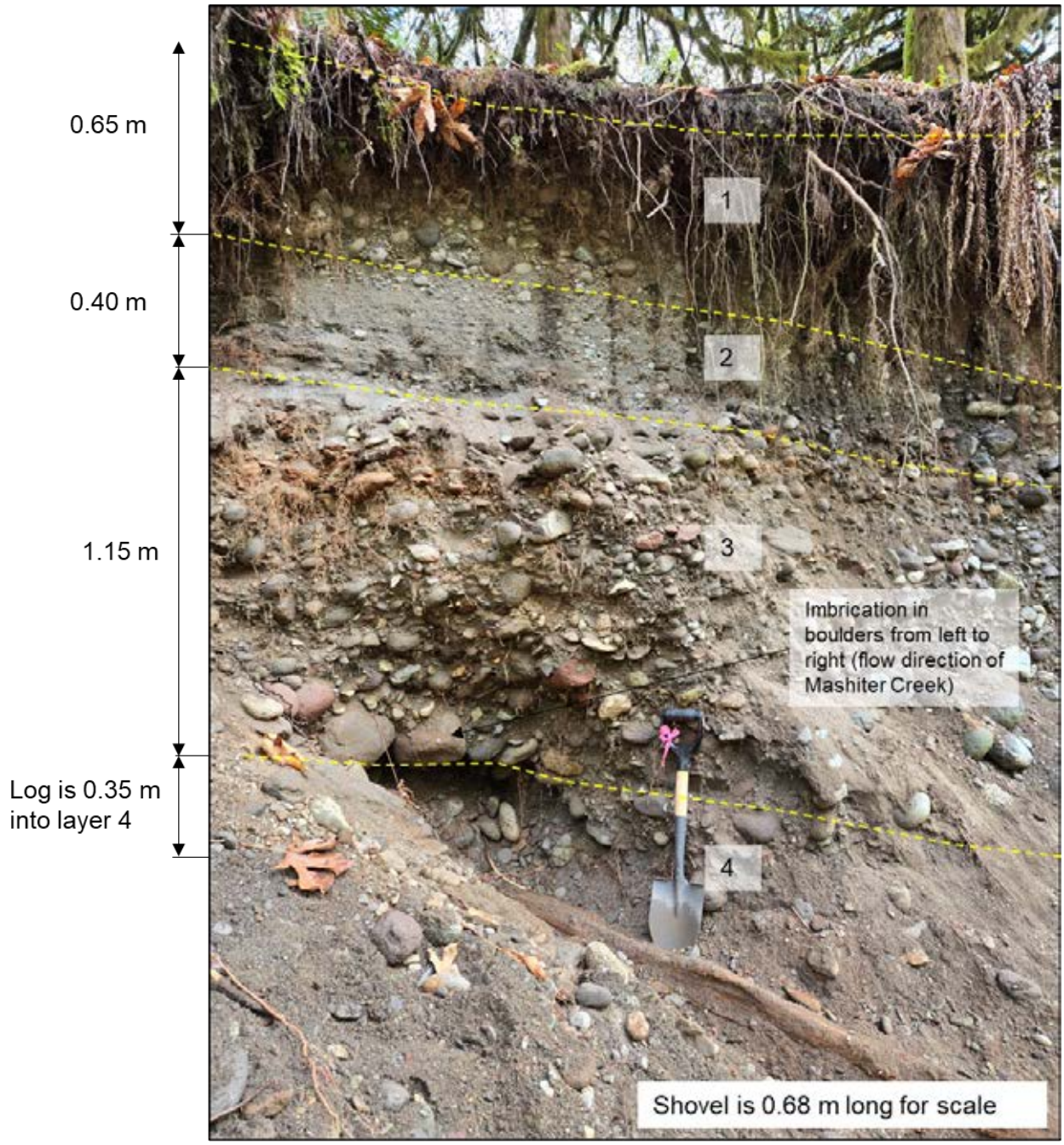


Photo C-1 Exposure on left bank approximately 380 m upstream of the Mamquam River.

C-3.2 Stratigraphic Layers

Stratigraphic layers in the exposed bank are described in Table C-1. No podzol development was visible between layers nor on the surface.

Table C-1 Stratigraphic layer descriptions.

Layer	Start Depth (m)	End Depth (m)	Description
1	0	0.65	Clast to matrix-supported, sand, fine to coarse gravel, pebbles, some cobbles, no stratification (massive structure), rounded with some angular, polymictic (volcanics with some plutonics).
2	0.65	1.05	Sand, fine to coarse gravel, horizontal stratification with layer thicknesses from 5 to 50 mm, polymictic (volcanics and plutonics)
3	1.05	2.20	Clast to matrix-supported, cobble and gravel, some sand, trace silt and boulders, no stratification (massive structure), imbrication in direction of flow for Mashiter Creek, rounded with some angular, polymictic (volcanics with some plutonics). Oxidation visible in upper 200 mm of layer.
4	2.20	unknown	Clast to matrix-supported, cobble and gravel, some sand, trace silt and boulders, no stratification (massive structure), rounded with some angular, polymictic (volcanics with some plutonics). Log used for radiocarbon dating at depth of 2.55 m.

C-3.3 Radiocarbon Dating

Cordilleran submitted one carbon sample collected from the bank exposure to Beta Radiocarbon Laboratories in Florida for radiocarbon age determination. The three outermost rings of the sample were sent for dating; however, it is unknown how many more outer rings there may have been on the log. Therefore, the age of the sample is the maximum age of the deposit; the deposit could be younger. The results are provided in Table C-2 and indicate the age of the log buried in Layer 4 is from 1474 to 1638 AD, coinciding with the Little Ice Age around 1350-1850 AD.

Table C-2 Radiocarbon sample metadata and results from Beta Laboratories.

Sample	BETA ID	Material	Yr BP ^{14}C	Calendar Year
1	716016	Wood	340 +/- 30	1474 to 1638 AD

C-4 INTERPRETATION

Layers 1, 3, and 4 of the bank exposure have properties that are characteristic of both debris flows and debris floods. They are clast- to matrix-supported deposits and have a typically massive structure with some signs of imbrication. These layers also contain both volcanics and plutonics (e.g., granite) which suggests the initiation of the flow most likely originated within the Garibaldi Group of volcanics in the upper watershed of Mashiter Creek and entrained the plutonics within the channel as the flow travelled downstream. The morphometric indicators of Mashiter Creek (channel and fan gradient, Melton ratio; Section 2.2.2 of Main Report) suggest

that Mashiter Creek is prone to floods and debris floods. It is likely that the flow process type of Layers 1, 3, and 4 were Type 2 debris floods, which are debris flows that are diluted as they move downstream. These types of flows typically have characteristics of both debris flows and debris floods.

Layer 2 consists of several layers of sands and gravel deposits that are horizontally stratified. Layer 2 likely originated from overland flow deposits from a flood or several floods on Mashiter Creek.

The log was within Layer 4 and was dated to be from 1474 to 1638 AD, so approximately 400 to 550 years old. This implies there have been two to three Type 2 debris floods within the last ~500 years. This suggests an annual exceedance probability of 0.55% to 0.75% or a return period of 130 to 180 years per event.

The volume associated with each Type 2 debris-flood event is unknown. The exposure was located 380 m upstream of the Mamquam River near the upper end of the Mashiter Creek fan. It is unknown how much further each deposit would have runout on the fan or how thick it would have been. As such, only vague estimates of a minimum and maximum volume can be estimated by assuming approximate runout extents and average depths of the deposit.

The last unknown is: were these events the results of a climate anomaly associated with the little Ice Age? It is possible, yet BGC and Cordilleran could not find any definitive evidence that this is the case and has assumed similar events are possible in the future given the sediment availability in the upper watershed, the logging roads crossing upslope of the channel, and the potential for increased climate variability and intensity in the future.

A summary of BGC and Cordilleran's interpretations used to inform the frequency-magnitude assessment is provided in Table C-3.

Table C-3 Summary of interpretations for the exposed bank and dated log.

Layer	Process Type	Volume Estimate (m^3) (1)			Estimated Return Period (years)
		Min	Max	Average	
1	Type 2 debris flood	9,000	39,000	24,000	100 to 500 years
2	Type 2 debris flood	15,000	66,000	40,500	100 to 500 years
3	Multiple floods	N/A	N/A	N/A	N/A
4	Type 2 debris flood (2)	N/A	N/A	N/A	100 to 500 years

Note:

1. The minimum and maximum volume estimates are based on estimating a minimum and maximum runout area (the channel extents and the full fan, respectively) and a minimum and maximum deposit depth. The maximum deposit depth is assumed to be equal to what was measured at the exposure.
2. The thickness of Layer 4 is unknown and therefore no volume estimate was made.

APPENDIX D
FREQUENCY-MAGNITUDE ASSESSMENT METHODS

D-1 INTRODUCTION

This appendix details the methods and results for assessing the frequency and magnitude of geohazard events on Mashiter Creek. The objective of a frequency-magnitude (F-M) assessment is to develop a relationship between the frequency ("how often") of the hazard and its magnitude ("how big"). The frequency-magnitude assessment is supported by data collected during the desktop study phase and during field work (Sections 4.2, 4.4, and 4.5 of Main Report; Appendix B; and Appendix C).

BGC estimated magnitudes (peak discharge, sediment volumes) associated with each representative return period (Table D-1). The return periods selected for this study align with the return periods recommended for a Class 3 debris-flood hazard assessment in EGBC's Professional Practice Guidelines, *Legislated Flood Assessments in a Changing Climate in BC* (2018). The methods used in the F-M assessment generally follow those outlined in *Debris-Flood Hazard Assessments in Steep Streams* by Jakob et al. (2022).

F-M relationships are dependent on the dominant steep creek process type(s) for each stream. Streams may be subject to a continuum of processes over different return periods. Mashiter Creek is subject to floods, Type 1 debris floods, and Type 2 debris floods.

Table D-1 Return periods included in the frequency-magnitude assessment on Mashiter Creek.

Representative Return period (years)	Annual Exceedance Probability (AEP)	The Probability of an Individual Experiencing such an Event at least Once in an 80-year Lifespan
200	0.5%	33%.
500	0.2%	15%.
1000	0.1%	8%.
2500	0.04%	3%.

D-2 PEAK DISCHARGE ESTIMATES

The peak discharges on Mashiter Creek were estimated using a rainfall-runoff model. A rainfall-runoff model approximates the relationship between precipitation and how the watershed responds to that precipitation. Outputs from the rainfall-runoff model include clearwater peak flows and storm hydrographs (discharge over time). The following subsections detail BGC's approach.

D-2.1 24-hour Rainfall and Storm Hyetograph

BGC estimated 24-hour rainfall depths for a point near the middle of the Mashiter Creek watershed using the web-interface MetPortal v2.2.3 (DTN & MGS Engineering, 2020). The MetPortal web-interface was developed by DTN and MGS Engineering (2020) for the Water Management Branch (WMB) of the BC Ministry of Forest (MoF) to increase the information on extreme hydrometeorological events available in BC and improve the design of flow conveyance

and storage infrastructure. The software provides gridded point precipitation-frequency estimates, probable maximum precipitation (PMP) estimates, and scaled historical storm events on an hourly time step at any location throughout BC. The 24-hour point depths and PMP estimates for Mashiter Creek are listed in Table D-2.

The historical storm events provided in the MetPortal for Squamish, BC are mid-latitude cyclone storm events (e.g., atmospheric rivers) that have a duration of 144 hours or six days. The storms are scaled within the software to the 24-hour rainfall depth allowing for one day of particularly intense rain during a longer duration storm event. The historical storm event selected from the MetPortal was a backloaded (24-hour intensity is near the end of the storm) mid-latitude cyclone from October 1950. The scaled storm hyetographs for the 200-year, 1000-year, and 2500-year rainfall events are shown in Figure D-1.

Table D-2 Historical 24-hour rainfall estimates used in the rainfall-runoff model for Mashiter Creek.

Return Period (years)	24-hour Rainfall Depth (mm)
20	180
50	210
200	240
500	265
1000	280
2500	300
PMP	410

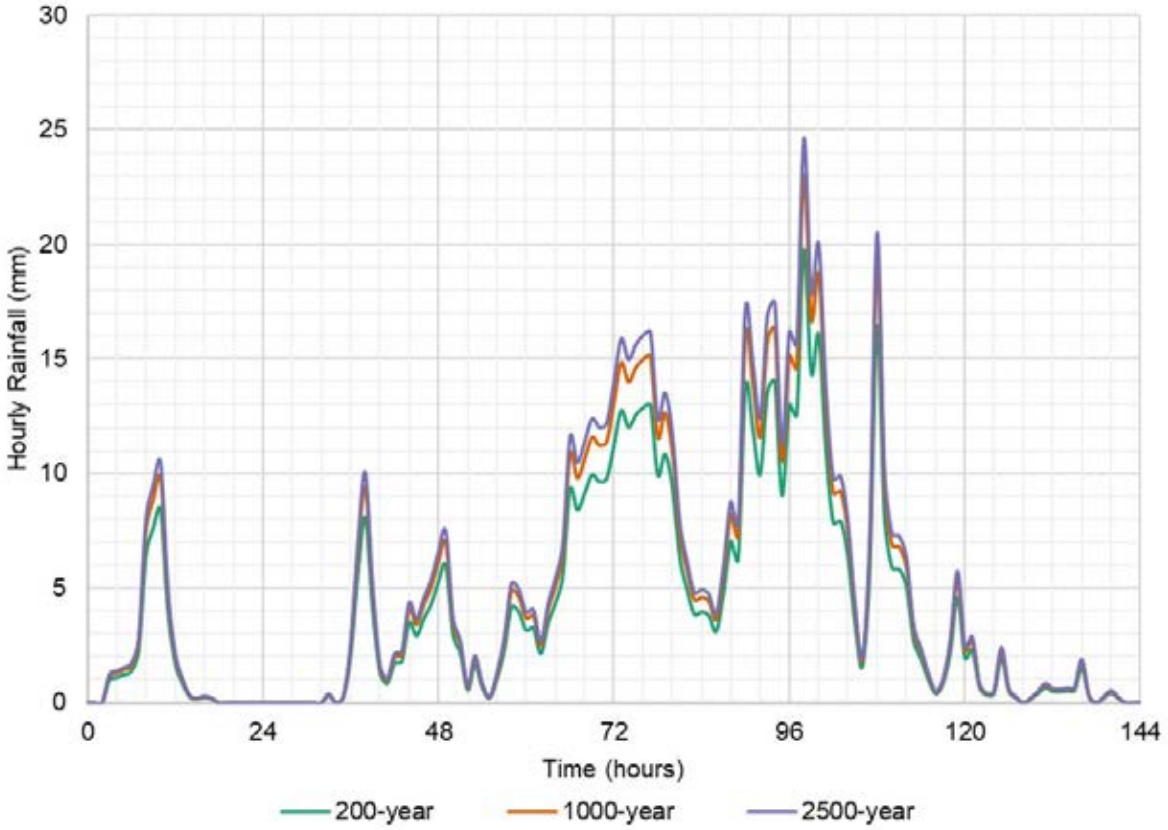


Figure D-1 October 1950 storm from the MetPortal scaled to the 200-year, 1000-year, and 2500-year 24-hour rainfall depths.

D-2.2 Rainfall-Runoff Model

BGC used the Soil Conservation Service (SCS) unit hydrograph method with hydraulic modelling software HEC-HMS (Version 4.12) developed by the United States Army Corps of Engineers (USACE) for the rainfall-runoff model. This method is widely used to derive synthetic unit hydrographs, applying a design storm event and physical watershed characteristics to predict peak discharges. A rainfall-runoff model requires the following inputs:

- The storm event hyetograph (i.e., Figure D-1).
- A curve number (CN), which is an empirically derived relationship between soil type, land use, antecedent conditions, and runoff used to establish initial soil moisture conditions and infiltration response.
- The lag time is a measurement of the speed that the watershed responds to rainfall and produces runoff.

Watershed parameters selected for the rainfall-runoff model are summarized in Table D-3.

Table D-3 Watershed characteristics used in the rainfall-runoff model for Mashiter Creek.

Parameters	Mashiter Creek
Watershed Area (km^2)	40
SCS Curve Number (CN II)[1]	68
Lag time (min)[2]	154

Notes:
1. Calculated from a global gridded dataset (Jaafar et al., 2019) of CN values. The value shown assumes average antecedent moisture conditions.
2. SCS Lag Time method (USDA, 2008).

D-2.3 Regional Flood Frequency Analysis

A regional FFA identifies hydrometric gauges recording discharge on watersheds within the region of interest that share similar hydrologic regimes, land uses, flood processes, watershed sizes, and geographic zones to the watershed of interest. Flood quantiles are generated from each regional gauge based on the historical peak instantaneous discharge records of these regional gauges. The flood quantiles are then transferred to the watershed of interest using a regression analysis.

There was no calibration or validation data available for the rainfall-runoff model. Therefore, a regional FFA was completed to validate the rainfall-runoff model for lower return periods. Regional FFAs are only as good as the data that is available to support them. The regional gauges had peak discharge records ranging from 19 years to 52 years in length, therefore, the regional FFA was considered reasonable up to the 50-year return period. The regional Water Survey of Canada (WSC) gauges used in the analysis are listed in Table D-4.

Table D-4 Regional WSC gauges used in the FFA for Mashiter Creek.

Number	Station Name	Watershed Area (km^2)	Complete Years of Data on Record	200-year Flood Quantile (m^3/s)
08GA076	Stawamus River at Highway No. 99	53	19	160
08GB013	Clowhom River near Clowhom Lake	147	27	640
08GA077	Seymour River below Orchid Creek	63	22	220
08MH141	Coquitlam River above Coquitlam Lake	53	38	240
08MG001	Chehalis River near Harrison Mills	383	29	990
08MH058	Salloomt River near Hagensborg	159	52	350

The regional FFA was not used to estimate the peak flows for all return periods because the gauge records are not long enough nor reliable enough to provide reasonable estimates of peak flows for events with return periods that are more than double the period of record.

Gauge records in smaller, and particularly steeper watersheds (< 100 km^2) are typically short (< 30 years) and often have missing data at the time of peak discharges due to sedimentation or damage to the gauge. For example, the WSC operated station *Mashiter Creek near Squamish* (08GA057) between 1966 and 1981. While this station should provide valuable data for this study, hand-written records provided by the WCS frequently note that the discharge on Mashiter Creek was estimated by pro-rating to the discharge measured nearby on the Mamquam River. The rationale for this was often ice effects, but burial of the orifice for the station was also recorded on December 26, 1980. As a result, BGC did not consider this gauge in the FFA.

D-2.4 Climate Change

BGC completed a climate change analysis to obtain adjustment factors to the end of century (2100) to apply to the rainfall depths in Table D-2. BGC used three methods to estimate the adjustment factor and the average value was used to adjust the rainfall-runoff model inputs. The Shared Socio-economic Pathway (SSP) assumed for the analysis is SSP5/8.5[1].

1. The University of Western Ontario's IDF_CC Tool Version 7.5 (Simonovic et al., 2015) that provides projected changes in 24-hour precipitation using bias-corrected downscaled CMIP6 climate models the Pacific Climate Impacts Consortium (PCIC).
2. PCIC's Design Value Explorer which provides projected changes for several design variables (PCIC, 2025). The tool was created to support engineers in determining climatic design values, particularly for the design of buildings and infrastructure.
3. The scientific literature has estimated that precipitation intensities are expected to increase at ~7% per degree Celsius of warming according to the Clausius-Clapeyron relationship (Prein et al., 2017). However, there have been observations of temperature scaling rates greater than 7% in some cases (Martel et al., 2021) and up to 12% per degree warming for SSP5/8.5 in some models. A scaling rate of both 7% and 12% per degree Celsius of warming was reviewed assuming an increase in temperature, on average, of 5°C by 2100 in Squamish (Section 2.3 of Main Report).

The adjustment factors estimated using each method and the value selected are summarized in Table D-5. Assuming an average adjustment factor of 1.4, the adjusted 24-hour rainfall depths are provided in Table D-6 rounded to the nearest 5 mm.

[1] CMIP6 stands for Coupled Model Intercomparison Project 6th Phase and it is a working group for developing and reviewing coupled climate models. CMIP6 is the most recent phase of General Circulation Models (GCMs) available for use in climate change analyses. To develop these climate models, different greenhouse gas emission scenarios are considered that are termed Shared Socioeconomic Pathways (SSP). SSP5/85 is the upper-bound or worst-case climate scenario available and is a "business as usual" scenario assuming very little climate adaptation and emission reductions are achieved by 2100.

Table D-5 Summary of estimated climate-adjustment factors to be used to adjust the 24-hour rainfall depths.

Method	Adjustment Factor
IDF_CC Tool	1.2 to 1.3 (1)
Design Value Explorer	1.4
Clausius-Clapeyron	1.4 to 1.7
Selected Value	1.4

Notes:

1. The percent increase in the 24-hour rainfall predicted by the IFC_CC tool varied based on the return period between +20% and +30%.

Table D-6 Climate-adjusted 24-hour rainfall depths.

Return Period (years)	24-hour Rainfall Depth (mm)
20	250
50	285
200	330
500	365
1000	385
2500	415
PMP	565

D-2.5 Clearwater Flood Results

The clearwater peak discharge estimates for Mashiter Creek including climate adjustments are summarized in Table D-7. The climate-adjusted storm hydrographs produced in the rainfall-runoff model for the 200-, 500-, 1000-, and 2,500-year return periods are shown in Figure D-2.

Table D-7 Summary of peak discharge estimates for Mashiter Creek.

Return Period (years)	Rainfall-Runoff Model	Regional FFA	Rainfall-Runoff Model with Climate Adjustment
	Peak Discharge (m^3/s)		
20	115	120	165
50	130	135	190
200	160		220
500	175		245
1000	185		260
2,500	200		280
Probable Maximum Flood (PMF)	275		380

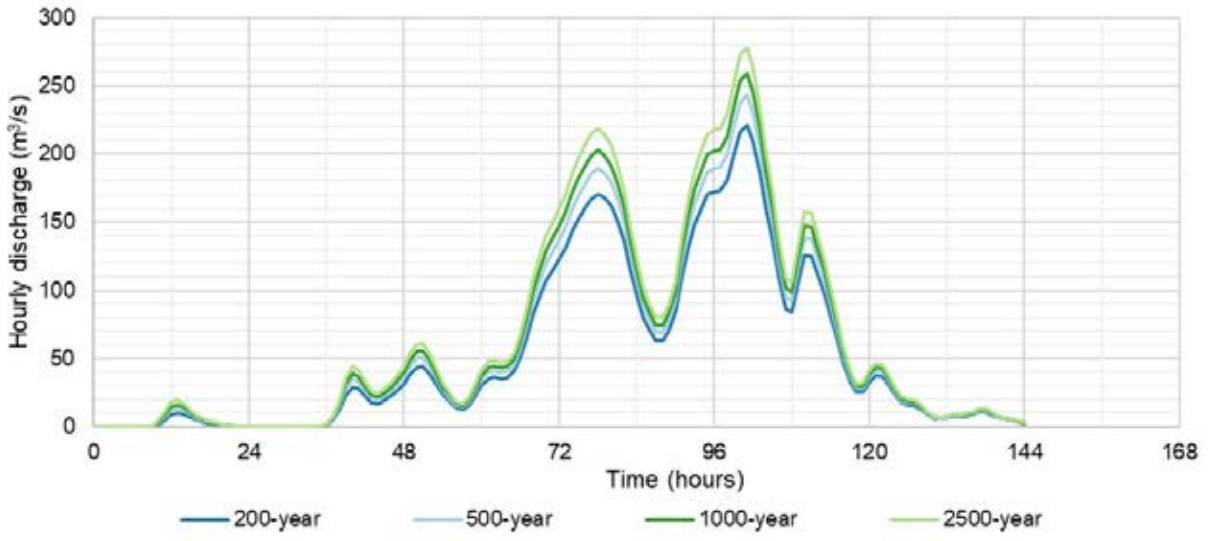


Figure D-2 Climate-adjusted storm hydrographs for clearwater flooding on Mashiter Creek.

D-3 SEDIMENT VOLUMES

BGC used several methods to estimate the sediment volumes that may be transported to the Mashiter Creek fan (Reach 1 of Mashiter Creek). The following subsections describe each method and their applicability to Mashiter Creek, followed by the results.

D-3.1 Empirical Regional F-M Relationships

Jakob et al. (2020) developed regional F-M relations based on detailed site-specific F-M relationships for debris flows and debris floods in Southern BC and in the Bow River valley near Canmore, Alberta. These site-specific F-M relationships are from detailed absolute dating methods, stratigraphic analysis, and analytical tools. The regional relations provide a means to estimate sediment volumes at different return periods normalized by fan or watershed area. The regional equation can be adjusted by selecting steep creeks of similar size and geology. BGC used Equation D-1 for debris-flood sediment volumes on Mashiter Creek based on data from debris-flood creeks in Southern BC, mainly near Lillooet, BC:

$$V_s = A_w[114.76\ ln(T) + -113.45] \quad \text{[Eq. D-1]}$$

where V_S is the sediment volume (m^3), A_w is the watershed area (km^2), and T is the return period (years). The watershed area was used rather than the fan area because it is not possible to distinguish the Mashiter Creek fan from the alluvial fan of the Mamquam River. The fan area of Mashiter Creek is unknown.

D-3.2 Empirical Rainfall-Sediment Relationship

Rickenmann and Koschni (2010) compiled rainfall volume and sediment volumes associated with numerous floods, debris floods, and debris flows that occurred during a storm in August

2005 in Switzerland and developed an upper envelope curve for estimating sediment volumes. Jakob et al. (2022) refined the dataset further with a multivariate regression analysis to produce Equation D-2.

$$V_s = 10^{(0.019S-1.55)V_R{}^{0.877}} \quad \text{[Eq. D-2]}$$

where V_S is the sediment volume (m^3), V_R is the total rainfall (m^3), and S is the channel gradient. The total rainfall was estimated using the 24-hour rainfall depths presented in Table D-6 and assuming that depth falls over the entire Mashiter Creek watershed.

The empirical rainfall-sediment relation is a method intended to provide an order of magnitude estimate of sediment volumes.

D-3.3 Yield Rates

Total debris volume can be approximated by summing the available sediment along debris-flow and debris-flood channels in a catchment and estimates of point-source volumes, such as landslides or potential rock-slide detachments. Channel sediment availability is described by a yield rate (m^3/m), which is the available sediment volume per meter length of channel that could be entrained by a debris flow. Yield rates can be measured in the field during a channel traverse or approximated from ranges provided by Hungr et al. (1984) (Table D-8). Steep, challenging terrain and time constraints precluded a traverse of the entire mainstem channel by foot, so instead BGC mapped channel segments and point sources from satellite imagery (Figure D-3). Yield rates were approximated for each mapped channel segment based on measured channel widths and estimates of erodible sediment depth, using typical yield rates from Table D-8. Average yield rates ranged from 0 to 15 m^3/m for Mashiter Creek. No point source volumes were mapped that would contribute to the yield rate estimate.

Table D-8 General yield rate estimates for typical stream channels of the southern coast ranges (Hungr et al., 1984).

Channel Type	Typical Gradient (°)	Bed Material	Side Slopes	Stability Prior to Debris Flow	Channel Yield Rate (m^3/m)
A	20-35	Bedrock	Non-erodible	Stable, practically bare of soil cover	0-5
B	10-20	Thin debris or loose soil over bedrock	Non-erodible (bedrock)	Stable	5-10
C	10-20	Deep talus or moraine	Less than 5 m high	Stable	10-15
D	10-20	Deep talus or moraine	Talus, over 5 m high	Side slopes at repose	15-30
E	10-20	Deep talus or moraine	Talus, over 20 m high	Side slopes potentially unstable (landslide area)	Up to 200 (consider as point source)

The yield rate approach provides an indication of how big the next debris flow or debris flood could be based on material availability, but judgement is required to assign a relative likelihood to various volume estimates. On Mashiter Creek, much of the sediment yield is in the upper watershed and it is considered unlikely that all the sediment would be mobilized to Reach 1.BGC interprets that it is likely some of the volume would deposit and be stored within Reach 3, similar to what happened in 1990/91 as can be seen in the 1994 air photo (Appendix B).

BGC used the yield rate method to estimate the maximum credible volume of sediment that could be produced by the Mashiter Creek watershed. This estimate assumes the entire channel network is fully cleared of sediment during a debris flow with no in-channel deposition, which is a relatively unlikely scenario and is considered an upper-bound estimate.

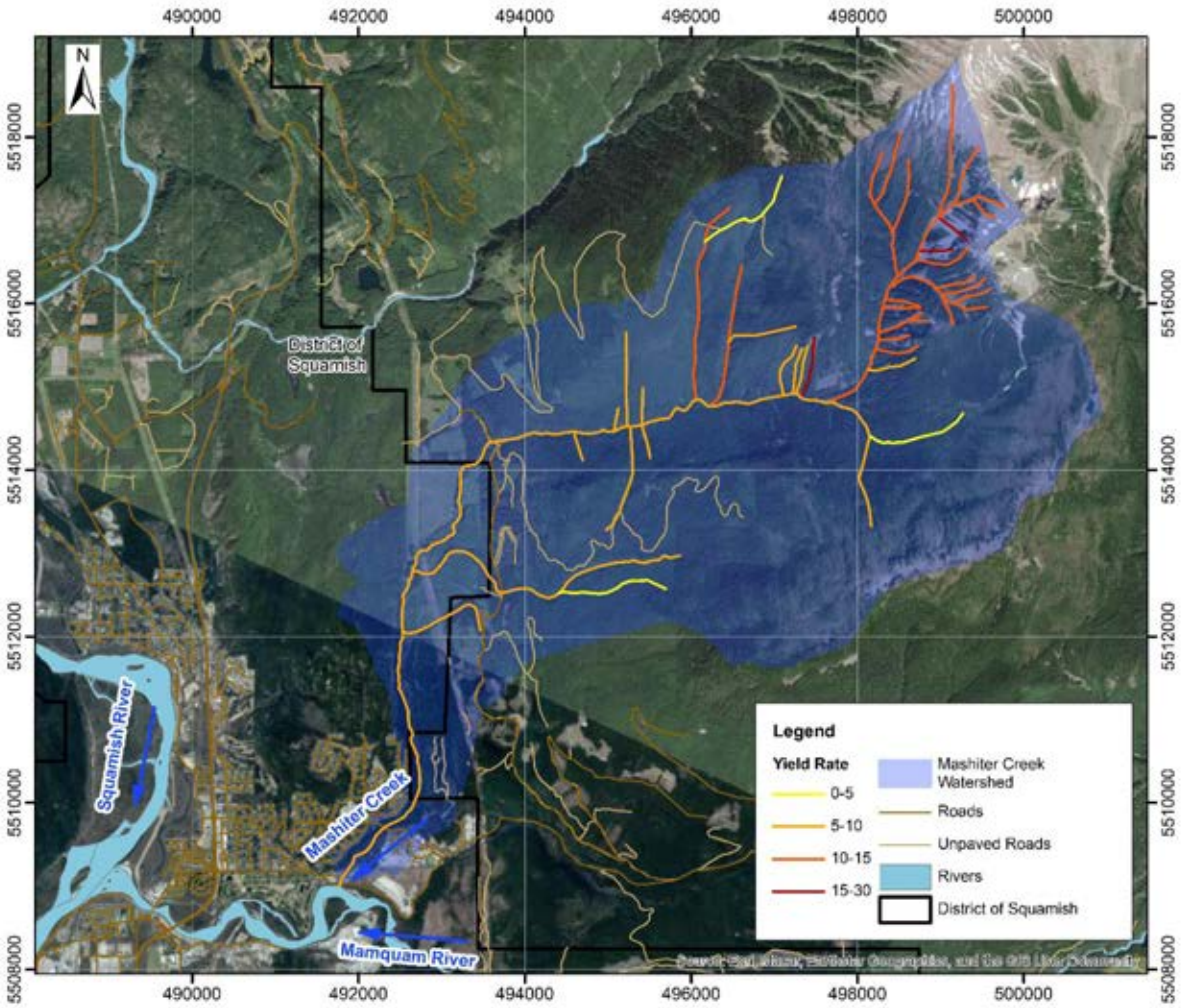


Figure D-3 Mapped channel segments for estimating sediment volumes using the yield-rate approach Yield rates are in units of m^3/m. Background imagery used for mapping is Esri imagery captured in 2022.

D-3.4 Sediment Transport Modelling

BGC developed a sediment transport model in the R programming language used to estimate transported sediment volumes for creeks and rivers for flood processes that include sediment transport and Type 1 debris floods. The model is not applicable for Type 2 debris floods. The program inputs include:

- Cross sections: Cross sections were sampled from the lidar, where available, at approximately 100 m intervals along Mashiter Creek from the Rink Creek FSR crossing downstream to the Mamquam River confluence. One-dimensional (1D) (i.e., average) channel hydraulics were calculated from the sampled cross sections.
- Long profile: A channel centerline was drawn along the lidar from which the long profile could be extracted. The local slope of each cross section was calculated from the long profile averaged for the 100 m interval.
- Grain size estimates (locations shown in Drawing 03).
- A flow hydrograph: The flow hydrographs output from the climate-adjusted rainfall-runoff model in Section D-2.5 were used.

The sediment transport model uses five sediment transport equations to calculate the sediment transport rate and the transported volume at each time step of the hydrograph. Sediment transport equations have a physical basis but are all empirical formulae developed from data collected in either the lab (flume experiments) or in the field, and each have their own uncertainty. The use of an ensemble helps to capture some of that uncertainty.

The equations in the model were Eaton & Church (2010), Einstein-Brown (1950) (Einstein, 1942; Brown, 1950), Wong & Parker (2006), Recking (2013), and Yalin (1963). Both Recking (2013) and Yalin (1963) were not used by BGC to estimate the sediment transport capacity at Mashiter Creek. Recking (2013) was developed based on field data which included data from supply-limited streams and BGC considered its estimates to be too low. Yalin (1963) was developed for steady flow over uniform bed material and was not considered relevant for Mashiter Creek.

The model outputs include the transported volume and transport rate over the hydrograph duration at each cross section sampled. An example a graphical output of the model with the 200-year sediment transport volumes is shown in Figure D-4. The sediment volumes are calculated as the difference in transport capacity between reaches. For example, the expected deposited volume in Reach 1 is the transport capacity in Reach 3 less the transport capacity in Reach 1.

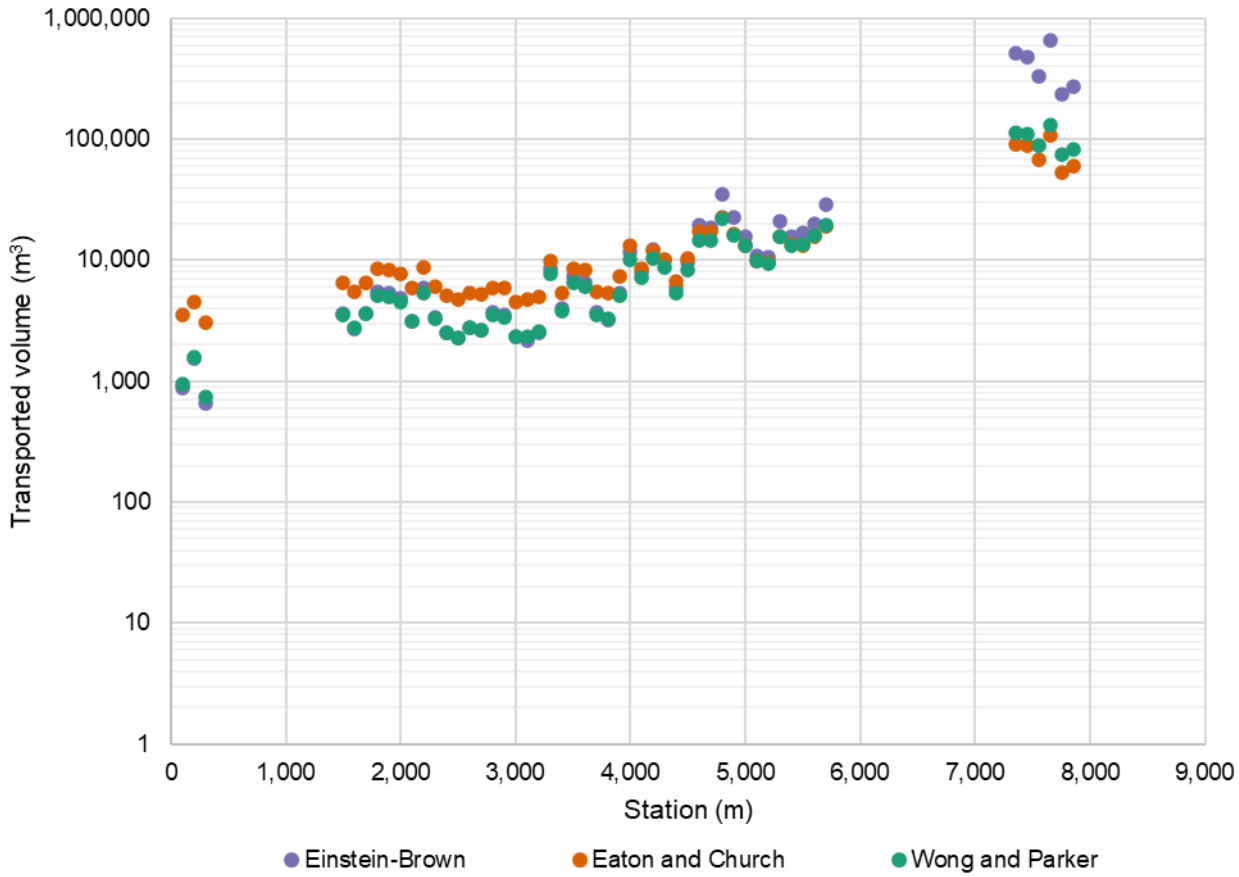


Figure D-4 Example output from the sediment transport model in R for the climate-adjusted 200-year return period. Station is measured from downstream to upstream where Station 0 m is the confluence of Mashiter Creek and Mamquam River.

D-3.5 Absolute Dating Methods

There was an exposure found in the left bank of Mashiter Creek within Reach 1, and it showed multiple depositional layers from past debris-flood events. A radiocarbon sample was taken from the upper portion of Layer 4, and it was dated to approximately 1474 to 1638 AD. Additional details on the sample collection, sample processing, and its interpretation are provided in Appendix C.

Very approximate sediment volumes and frequencies can be estimated from the debris-flood deposits resting above Layer 4; Layers 1 and 3[2]. BGC's estimates are summarized in Table D-9 with the rationale for the assumed frequency and magnitude estimates provided below:

- The log was within Layer 4 and was dated to be from 1474 to 1638 AD, so approximately 400 to 550 years old. This implies there have been two to three Type 2 debris floods within the last ~500 years. The frequency of the Type 2 debris floods can be interpreted assuming each deposit has the same AEP which suggests an annual

[2] Layer 2 was a sediment deposit resulting from multiple clearwater floods and does not provide any additional information on debris-flood magnitude or frequency.

exceedance probability of 0.55% to 0.75% or a return period of 130 to 180 years per event. However, there is uncertainty in this estimate and BGC has assumed a possible return period range of 100 to 500 years for each of these deposits.

- The thicknesses of debris-flood deposit layers 1 and 3 were measured at the location of the exposure 380 m upstream of the Mamquam River, however, it is unknown how thick the deposit would be over its runout area, and it is unknown how great the runout area may have been. BGC made rough minimum and maximum runout area estimates, as well as minimum and maximum deposit depths throughout the runout area to inform volume estimates. It was assumed that the measured deposit thickness was a maximum deposit depth as it was located near the fan apex of Mashiter Creek.

Table D-9 Summary of debris-flood deposit estimates based on field observations and absolute dating methods on Mashiter Creek. These are order of magnitude estimates and should not be considered precise.

	Runout Area (m^2)		Deposit Depth (m)		Sediment Volume (m^3)	
Layer	Min	Max	Min	Max (1)	Min	Max
1	30,000	60,000	0.3	0.65	9,000	39,000
3	30,000	60,000	0.5	1.1	15,000	66,000

Notes:

1. The maximum deposit depth was assumed to be equal to the measured deposit thickness as the exposure was located near the fan apex of Mashiter Creek.

D-4 F-M RESULTS

Figure D-5 is a graphical summary of the sediment volume F-M estimates. The process type transition point from Type 1 debris floods to Type 2 debris floods is unknown but is estimated to between the 100-year and 200-year return period. Table D-10 summarizes volume and peak discharge estimates from the various methods described in this Appendix. There was not sufficient information to constrain the volume estimates for return periods greater than or equal to 200 years and instead a range of volumes is provided. For return periods greater than 500 years, the only information on sediment volumes available were the results of empirical relationships (regional FM and rainfall-sediment in Figure 4-1) which provides a narrow range of sediment volume estimates. However, these methods are not precise and BGC has assumed the true FM range is greater and is represented by the grey box with a dashed outline.

The selected process type for each return period is based on the morphometric characteristics of the watershed and its geological setting (Section 3.2 Main Report), the historical geohazard event record (Section 4.5 Main Report), and field observations (Section 4.4 Main Report).

The peak discharges selected to inform the numerical modelling were the climate-adjusted clearwater flow estimates with no debris bulking factor. It is anticipated that there will be debris within the flow for return periods ≥ 50 years that is between 5% and 30% by volume; however, it is anticipated that the debris will deposit primarily within the Mashiter Creek channel and impact the immediate overbank area including parcels within the Debris-Flood Hazard Area outlined in Drawing 05.

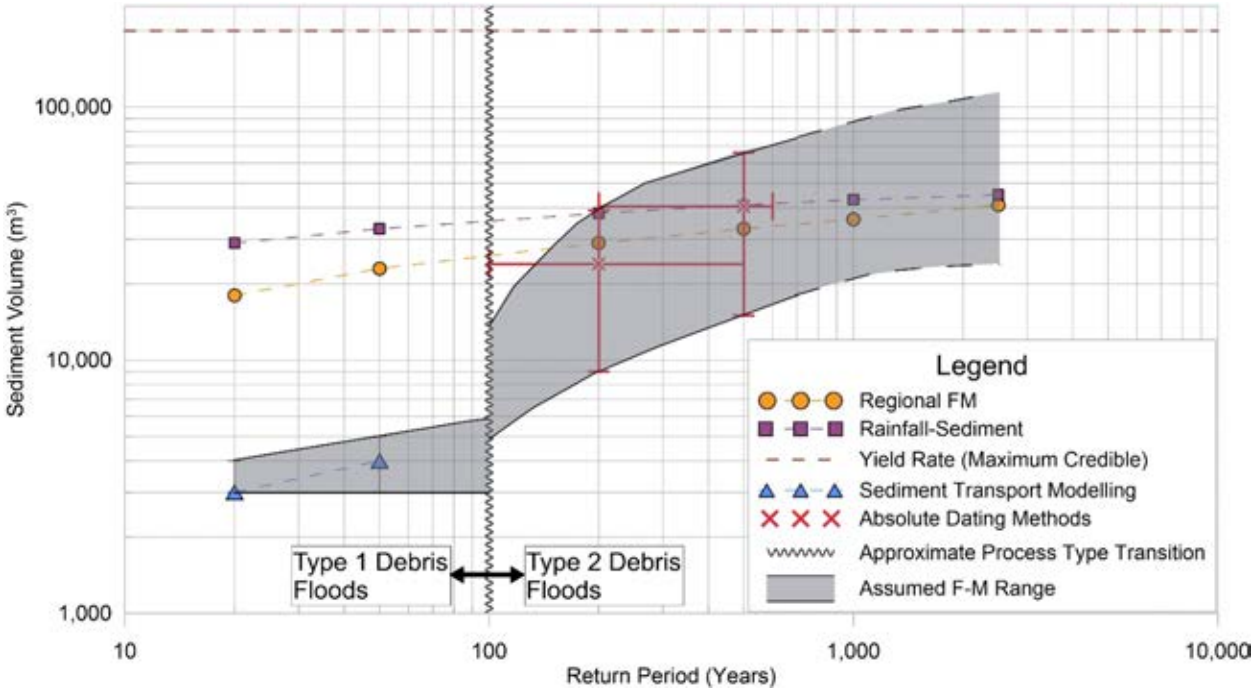


Figure D-5 Graphical summary of the sediment volume F-M for Mashiter Creek. Dashed lines are used where the delineated values are unknown.

Table D-10. Summary of geohazard frequency-magnitude estimates from various methods described in this appendix. Volumes are rounded to the nearest 1000 m^3 and peak discharges to the nearest 5 m^3/s.

Representative Return Period (years)	Process	Peak Discharge (m^3/s)	Sediment Volume (m^3)					
		Climate-Adjusted Rainfall-Runoff Model (Clearwater) (2)	Regional F-M	Rainfall-Sediment	Yield Rate (Maximum Credible Volume)	Sediment Transport Modelling	Absolute Dating Method	Interpreted Best Estimate Range
20	Flood	165	18,000	29,000	-	3,000	-	3,000 to 5,000
50	Type 1 Debris Flood	190	23,000	33,000	-	4,000	-	3,000 to 5,000
200	Type 2 Debris Flood	220	29,000	38,000	-	-	9,000 to 39,000	9,000 to 39,000
500	Type 2 Debris Flood	245	33,000	41,000	-	-	15,000 to 66,000	15,000 to 66,000
1,000	Type 2 Debris Flood	260	36,000	43,000	-	-	-	21,000 to 90,000 (3)
2,500	Type 2 Debris Flood	280	40,000	45,000	-	-	-	25,000 to 105,000 (3)
Probable Maximum	Type 2 Debris Flood	380 (2)	-	-	200,000	-	-	N/A

Note:

1. Values presented in this table are for the purposes of runout assessment for overland flow modelling.
2. The peak discharges used for modelling were the clearwater values estimated using the climate-adjusted rainfall-runoff model. The Probable Maximum is shown for comparison but was not modelled.
3. The interpreted best estimate range for the 1,000-year and 2,500-year return period is based on the empirical relationships used and the judgement and experience of BGC working on steep creeks.

D-5 UNCERTAINTIES AND LIMITATIONS

Uncertainties with the F-M analysis that are pertinent to this study are listed below.

- Frequencies are not precise, and a range of frequencies have been provided in the F-M analysis to convey this uncertainty.
- Reports from the 1990/91 debris floods that damaged the Mashiter Creek water intake reported sediment volumes on the order of 20,000 to 50,000 m^3 (Septer, 2007) with no reporting on where this sediment was deposited. The 1994 air photo showed most sediment deposited within Reach 3 which is also where the water intake is located (Appendix B). This suggests that much of the sediment was deposited within Reach 3 and that Reach 3 may have a large storage capacity. It is unknown how much of the estimated sediment volumes may deposit in Reach 3 of Mashiter Creek, thereby reducing the estimated sediment volume that gets to Reach 1.
- Empirical methods are based on records of past events from different geologic, geomorphic and climatic settings. Although these may be useful analogues for the study catchment, estimates are uncertain and are order of magnitude estimates.
- Climate change is included in the F-M analysis by applying scaling factors to precipitation inputs. Other climate-change effects that may impact geohazard scenario F-M, such as changes in triggering conditions of rock slope stability or sediment supply, are not explicitly accounted for.

APPENDIX E
NUMERICAL MODELLING METHODS

E-1 INTRODUCTION

A two-dimensional (2D) hydraulic model was developed for Mashiter Creek to assess the overland flow hazard in the Garibaldi Estates neighborhood of Squamish, BC. This appendix describes the model development, model assumptions, and model uncertainties and limitations.

E-2 MODEL DEVELOPMENT

E-2.1 Modelling Software

BGC used Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 6.6 modelling software. HEC-RAS is a public domain hydraulic modelling program developed and supported by the United States Army Corps of Engineers (USACE).

E-2.2 Model Terrain

BGC developed a 0.5 m x 0.5 m Digital Elevation Model (DEM) grid based on the lidar bare-earth point cloud data collected by McElhanney Inc. (McElhanney) in 2018. Buildings were incorporated into the terrain surface by extruding the building footprints within the model extent to 4 m above the surrounding ground (Figure E-1). The building footprints were retrieved from OpenStreetMap.

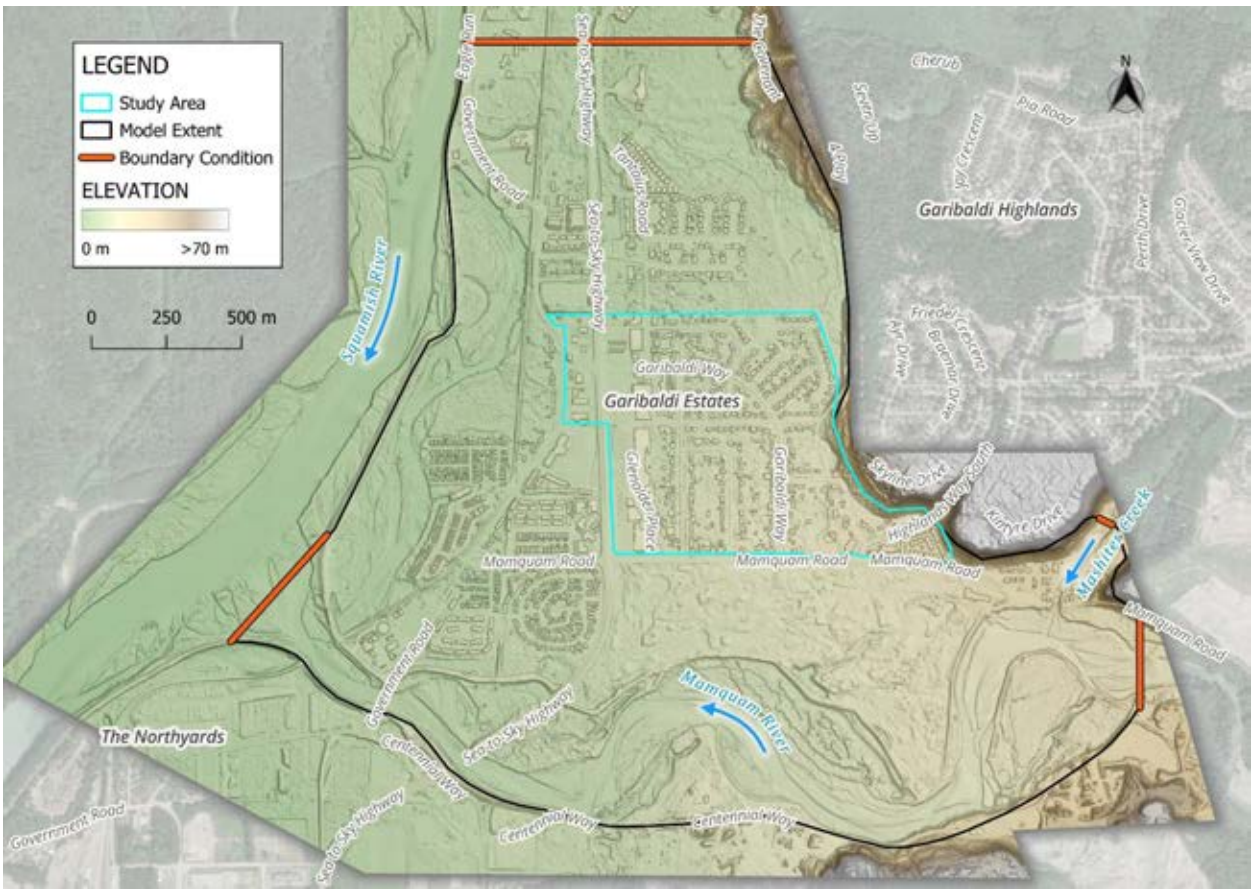


Figure E-1 Study area, model extent, and digital elevation model.

E-2.3 Model Domain and Boundary Conditions

The model domain includes the neighbourhood of Garibaldi Estates, located north of Mamquam Road and east of the Sea-to-Sky Highway (Figure E-1). It also encompasses a section of Mashiter Creek, extending approximately 350 m upstream (northeast) from its confluence with the Mamquam River, as well as a 3.8 km segment of the Mamquam River, starting from its confluence with the Squamish River and ending approximately 350 m east of Mashiter Creek. Modelling this segment of the Mamquam River allows for a single outlet boundary condition at its confluence with the Squamish River, rather than multiple outlet boundary conditions at locations where water from Mashiter Creek is presumed to escape the model domain. The Mamquam River also provides flow conditions at its confluence with Mashiter Creek.

The upstream boundary condition for Mashiter Creek was defined as a flow hydrograph corresponding to the return periods of interest (Figure E-2). The model was run over a 52-hour period between hours 56 and 108 to capture the peak activity of the storm hydrograph. The inflow hydrographs for Mashiter Creek were generated using a rainfall-runoff model for its watershed (a detailed discussion on the return periods and flow hydrograph estimation is provided in Appendix D). In contrast, the Mamquam River inflow was set at a constant rate of 500 m^3/s for all simulations based on peak flows estimated by Kerr Wood Leidal Associates Ltd. (KWL, 2017a)[1].

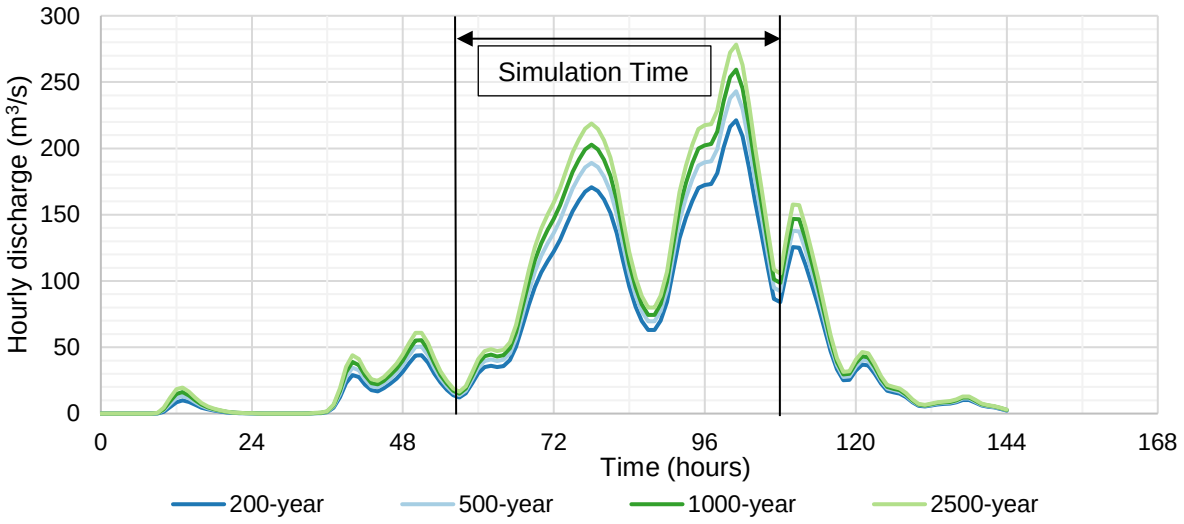


Figure E-2 Mashiter Creek inflow hydrographs.

[1] KWL (2017a) estimated the 200-year peak instantaneous flow on the Mamquam River to be 1000 m^3/s under climate-adjusted conditions and this estimate includes the contributions expected from Mashiter Creek. BGC modelled the Mamquam River at a peak instantaneous flow less than the 200-year estimate assuming the timing of peak flows on the Mamquam River and Mashiter Creek are not coincident.

A normal depth condition was applied to both the downstream boundary of the Mamquam River and the northern edge of the model extent. Friction slopes were set to 0.3% (0.003 m/m) for the Mamquam River and 0.5% (0.005 m/m) for the northern edge, as measured from the lidar data.

E-2.4 Model Meshing

HEC-RAS uses a numerical mesh (or grid) to discretize the area of interest into a series of discrete areas (i.e., computational cells) that are considerably smaller than the area of interest. The idea being, that as the size of the computational cells tend towards being infinitesimally small then they will better capture the hydraulic processes driving flooding. Using infinitesimally small cells would require infinitely large computing resources. As such, the objective of mesh development is to use the coarsest mesh possible to reduce model runtime, while preserving the desired level of accuracy in the hydraulic results.

Within HEC-RAS, a 2D mesh was generated based on:

- Model domain
- Refinement areas to define sub-domains where the mesh properties (e.g., mesh resolution) are adjusted
- Breaklines to align the mesh with terrain features which influence the flow such as dikes, ditches, terraces, and embankments. HEC-RAS provides options to adjust the mesh resolution along breaklines.

From these inputs, HEC-RAS generates the mesh consisting of interconnected grid cells with computational points at the cell centroids and along the faces of the cells (i.e., along the cell sides).

To balance accuracy and model runtimes, a base mesh resolution of 10 m was selected. A refinement region at a resolution of 5 m was added for the study area for better representation of the flood extent. Breaklines were placed iteratively along the channel centrelines (CL) to build a curvilinear mesh aligned with the main channel flows with a resolution of 10 m for the Mamquam River and 5 m for Mashiter Creek. Breaklines were also placed along terrain features such as road and railroad embankments, and dikes or flood protection/mitigation structures. The final mesh consisted of over 98,000 computational cells with an average cell face length of 7 m and an average cell area of 47 m^2.

E-2.5 Roughness

Like many hydraulic models, HEC-RAS 2D uses the Manning's roughness coefficient (Manning's n) to represent hydraulic flow resistance. BGC divided the model domain into five classes based on ESRI satellite aerial imagery, and Manning's n values were assigned according to Chow (1959) (Figure E-3). The sensitivity of the model results to the selected roughness values was assessed and is presented in Section E-4.

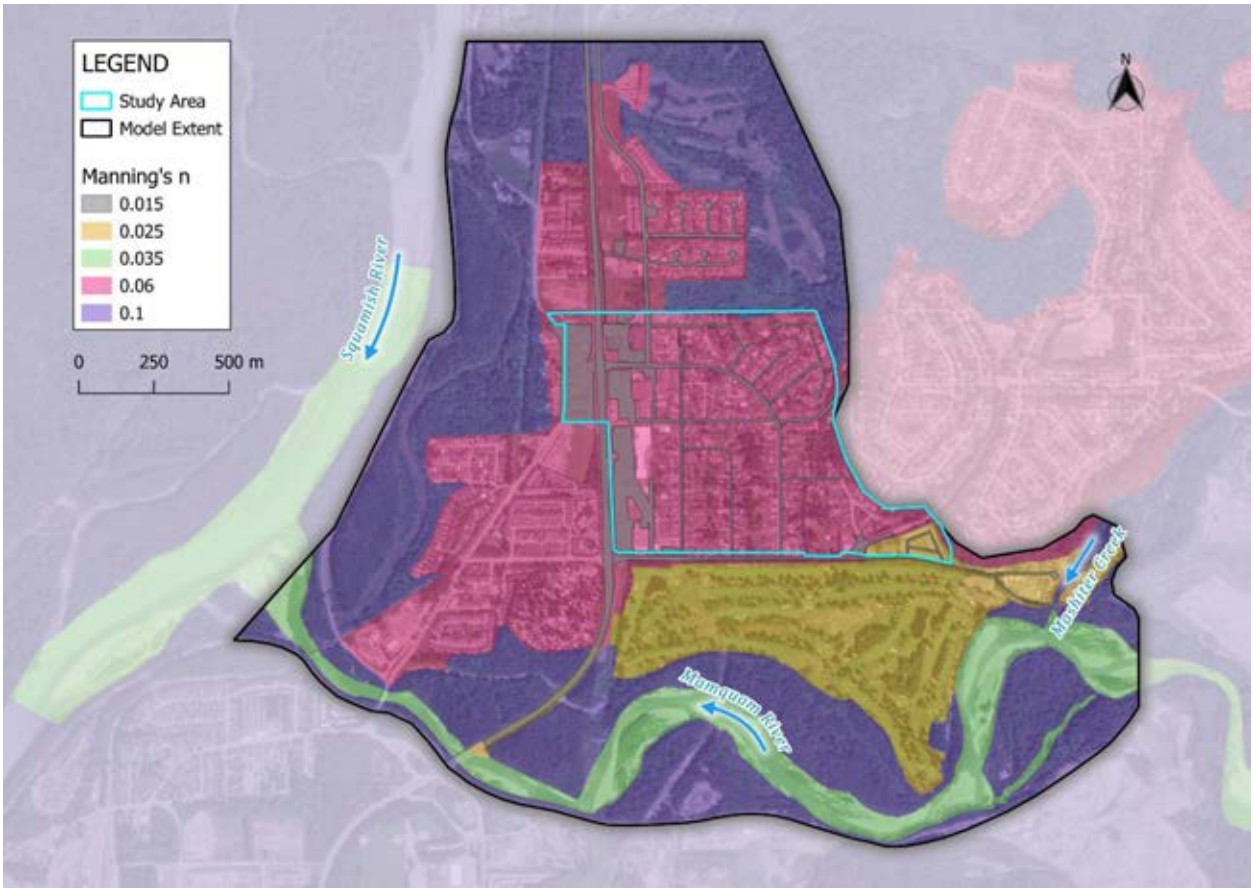


Figure E-3 Manning's roughness layer defined for the model.

E-2.6 Simulation Settings

The HEC-RAS 2D model was run using shallow water equations with a Courant controlled time step[2]. The shallow water equations generally provide an accurate representation of flow dynamics, especially in areas with sharp constrictions, expansions, or changes in flow direction (e.g., meander bends, bridges, etc.). The maximum Courant number was 2. The initial condition was set to 2 hours to gradually raise the water surface from a dry condition to a wet condition and to establish the flow throughout the model domain. The model was then run to simulate a 52-hour period, between hours 56 and 108 (Figure E-2). The water surface tolerance[3] was set to 0.003 m and the maximum number of iterations was set to 20 (default values).

[2] The Courant number is the product of the velocity and the time step divided by the distance step. For a Courant controlled time step, the time step will be halved if the Courant number for any cell exceeds the maximum Courant number set by the user.

[3] Used to compare the water surface elevation difference between two consecutives iterations at each time step. If the difference is greater than the tolerance, the program continues to iterate for the current time step up to the maximum number of iterations

E-3 MODEL SCENARIOS

Scenarios were run for the climate-adjusted 200-year (0.5% AEP[4]), 500-year (0.2% AEP), 1,000-year (0.1% AEP), and 2,500-year (0.04% AEP) debris-flood events. Model results figures are presented in Figures E-8 to E-12.

One of two terrain modification options were applied to the base terrain model described in Section E-2.2 for each model scenario to account for potential morphological changes within Mashiter Creek during a debris flood. The two terrain modifications assessed were (i) blocking the Mamquam Road bridge over the Mashiter Creek channel and (ii) full aggradation of the Mashiter Creek channel within the model domain[5].

The selection of terrain modification for each model scenario was based on the volume of sediment assumed to be transported to and deposited within Reach 1 of Mashiter Creek (i.e., the lower 750 m of Mashiter Creek before it joins the Mamquam River) for that scenario. The channel capacity of Reach 1 of Mashiter Creek is estimated to be on the order of 10,000 to 20,000 m^3. At the 200-year return period, BGC assessed it is likely that a bridge blockage or similar channel blockage would occur. For all events greater than the 200-year return period, the channel was assumed to be fully aggraded.

The model scenarios are listed in Table E-1.

Table E-1 Summary of model scenarios including terrain modification assumptions.

Representative Return Period (years)	Process Type	Peak Discharge (m^3/s)	Scenario Assumptions	Figure No.
200	Type 2 debris flood	220	The bridge over Mashiter Creek at Mamquam Road is fully blocked during the debris flood.	E-8 and E-9
500	Type 2 debris flood	245	The Mashiter Creek channel is fully aggraded.	E-10
1000	Type 2 debris flood	260	The Mashiter Creek channel is fully aggraded.	E-11
2500	Type 2 debris flood	280	The Mashiter Creek channel is fully aggraded.	E-12

[4] Annual Exceedance Probability (AEP) is the estimated probability that an event will exceed a specified magnitude in any year. For example, a flood with a 0.5% AEP has a one in two hundred chance of being reached or exceeded in any year. AEP is used alongside of 'return period' to describe flood recurrence intervals in this study.

[5] Full aggradation of the channel within the model domain included filling the channel up to bankfull (approximately 4 m of depth) for the full 350 m of the Mashiter Creek channel within the model domain.

E-4 MODEL SENSITIVITY ANALYSIS AND PARAMETRIZATION

Ideally a model is calibrated and validated using observational data from past known events. However, no observational data was available from past flood events on Mashiter Creek. In lieu of observational data, a sensitivity analysis can be used to evaluate the model's sensitivity to different input parameters and to assess the impact of an input parameter on the modelled results. The uncertain parameters of the model include, but is not limited to:

- The roughness coefficient, Manning's n.
- The peak discharge.
- The effects of morphological changes within the channel (e.g., channel aggradation, bridge blockage).

All sensitivity scenarios were performed on the climate-adjusted 200-year (0.5% AEP) debris-flood event to evaluate the impact these input parameters could have on inundation extent within the study area outlined in Figure E-1.

E-4.1 Roughness Coefficient

BGC assessed the sensitivity of the model to the roughness coefficient (Manning's n) through applying a 20% decrease and a 20% increase to the roughness coefficients defined in the combined Manning's layer for the climate-adjusted 200-year debris flood. Little to no difference was found within the study area, except for the region located west of the Sea-to-Sky Highway and south of Garibaldi Way (Figure E-4). Higher roughness values resulted in a larger inundation extent, varying from -4% to 3% compared to the base case. The model results are not considered sensitive to the above change in roughness.

BGC ran an additional scenario, discretizing paved surfaces such as roads and parking lots and assigning a Manning's value of 0.015 to those areas. This scenario resulted in a larger inundation extent, particularly in the region south of Diamond Road, west of Kamloops Road, and east of Glenalder Road (Figure E-5).

Figure E-4 Comparison of flood extent among the base case, a 20% decrease in roughness, and a 20% increase in roughness.

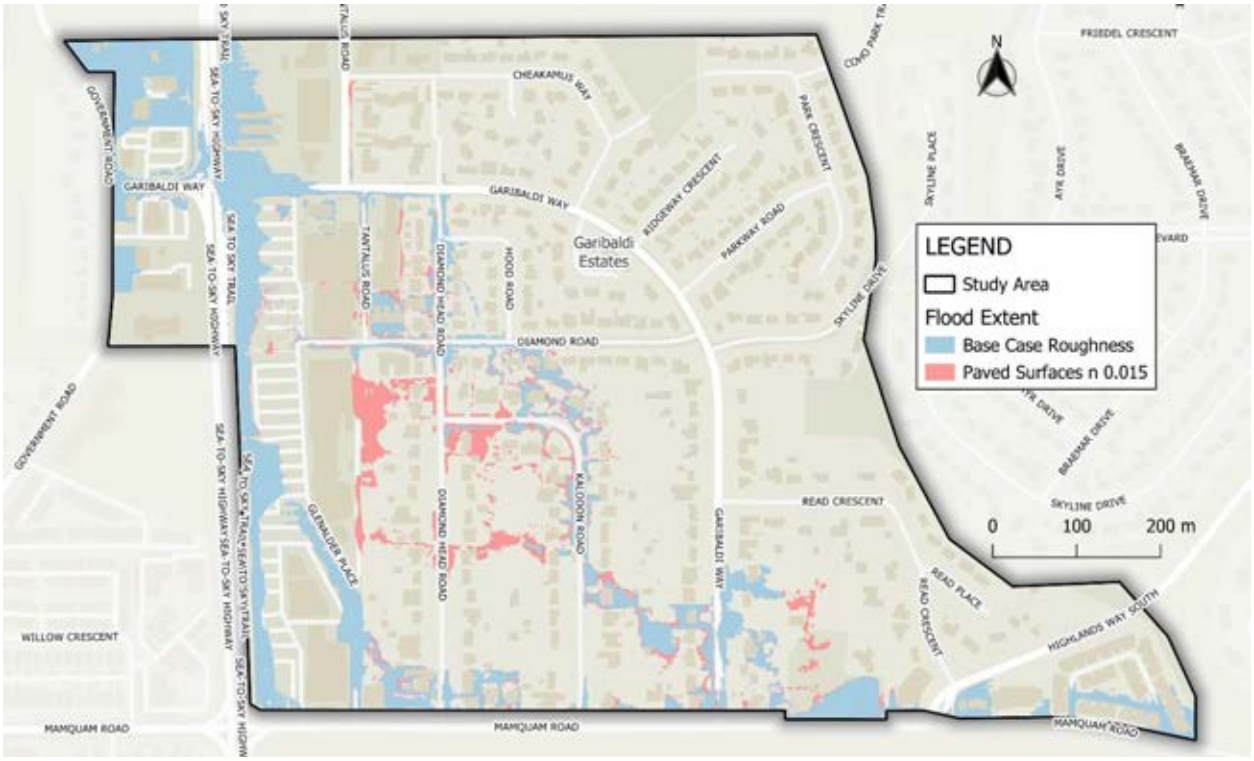


Figure E-5 Comparison of flood extent between urbanized areas using a uniform roughness value (base case) and a scenario that reduces the roughness value to 0.015 for roads and parking lots.

E-4.2 Peak Discharge

BGC examined the sensitivity of the model results to peak discharge by comparing the inundation extent using the climate-adjusted 200-year (base case) and the climate-adjusted 2,500-year inflow hydrographs (which represent approximately a 30% increase in peak discharge). The higher peak discharge resulted in a larger inundation extent (an 8% increase) and an increase in modelled depths within the study area of up to 0.05 m. The increase in inundation extents is limited primarily to the region west of the Sea-to-Sky Highway and south of Garibaldi Way (Figure E-6). The model is mildly sensitive to fairly large increases in peak discharge.

Figure E-6 Comparison of flood extent between the base case and a scenario with approximately a 30% increase in peak discharge.

E-4.3 Assumed Morphological Changes within Mashiter Creek

To assess the sensitivity of the assumed morphological changes within Mashiter Creek channel, BGC compared the modelled inundation extent results for the following climate-adjusted 200-year flood events: blocking the Mamquam Road bridge over the Mashiter Creek channel (base case), no bridge blockage, and full aggradation of the Mashiter Creek channel within the model domain.

Little to no difference in the inundation extent was observed within the study area for the bridge blockage and full aggradation models runs, except for the region west of the Sea-to-Sky Highway and south of Garibaldi Way (Figure E-7). The full aggradation run resulted in a larger inundation extent compared to the bridge blockage run, with an 8% increase. Therefore, BGC

considered the model results to be slightly sensitive to the morphological channel changes mentioned.

The no bridge blockage run resulted in a smaller inundation extent compared to the blocked bridge run, showing a 40% decrease. This reduction was particularly noticeable in two areas: the housing complex south of Highlands Way South (in the southeast corner of the study area) and the area west of the Sea-to-Sky Highway (Figure E-7).

The reduced extent in the housing complex is due to less water being diverted along Mamquam Road in the no bridge blockage scenario. Flooding in the area west of the Sea-to-Sky Highway, observed during the bridge blockage and full aggradation runs, is primarily caused by water from the low-lying area west of Government Road (Figure E-1) flowing eastward into the study area. In the no bridge blockage run, this low-lying area was not fully filled by the end of the simulation, as a larger proportion of water from Mashiter Creek was discharged into the Mamquam River through the bridge location.

Figure E-7 Comparison of flood extent for the assumed morphological changes.

E-4.4 Interpretation of Sensitivity Analysis

BGC used the results of the sensitivity analysis to inform the selection of the roughness coefficients to use in the hydraulic model, and to inform the development of the model scenarios.

Roughness Coefficient

Although the modelled inundation extent was moderately sensitive to the discretization of Manning's layer for roads and parking lots (20% larger than the base case), the recommendations outlined in Section 6.0 in the main body report remain unchanged.

Peak Discharge

Increasing the peak discharge by 30% resulted in a larger inundation extent (an 8% increase) and an increase in modelled depths within the study area of up to 0.05 m. This is considered within the error of the model and does not impact the recommendations presented in Section 6.0 of the main report.

The sensitivity analysis results demonstrate that the uncertainty in the estimation of the peak discharge value does not have an impact on the outcome of this study.

Morphological Changes

The no bridge blockage run resulted in a smaller inundation extent compared to the blocked bridge run, showing a 40% decrease. Little to no difference in the inundation extent was observed within the study area for the bridge blockage and full aggradation models runs

The sensitivity analysis results demonstrated that it was important in the development of model scenarios to be confident in deciding when the bridge may become blocked, but it was not important to resolve the extents (depth and area) of channel aggradation that may occur. BGC blocked the bridge for the 200-year return period model scenario because the results of the F-M assessment and estimates of the channel capacity in the lower 750 m of Mashiter Creek suggest that the bridge is likely to be blocked for the 200-year return period event. BGC aggraded the channel for all return periods exceeding the 200-year event but did not spend additional time refining the depth and extents of channel aggradation between each modelled scenario.

E-5 MODEL UNCERTAINTIES AND LIMITATIONS

Models are useful tools, but they do not provide a precise or exact prediction of real events. Model results require additional interpretation and judgement for their intended purpose(s). At Mashiter Creek, BGC developed the model for the purpose of characterizing the overland flood hazard within the study area from Mashiter Creek.

Uncertainties and Limitations of the model are:

Natural Processes

- Steep creek hazards are natural processes with complex behavioural feedback mechanisms associated with meteorological, orographic, and topographic factors. Such interactions are complicated by future change associated with a changing climate and natural or man-made modifications to the landscape. Given this, there is a stochastic or unpredictable nature to these process types that lead to inherent uncertainty and limitations to the accuracy of numerical models.

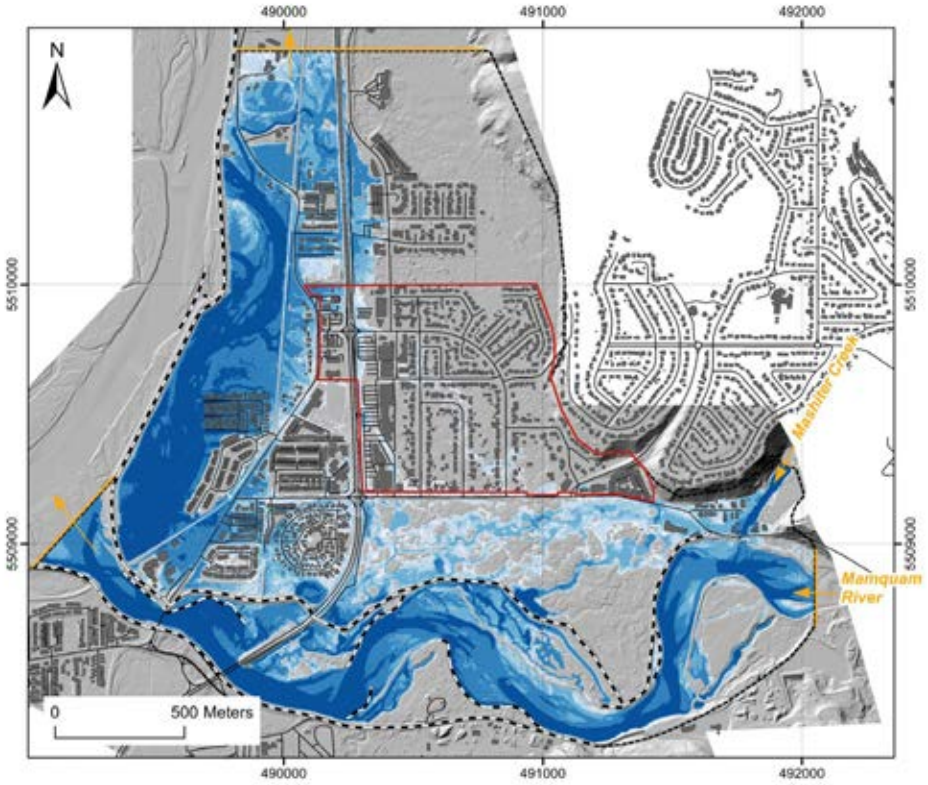
Model Inputs

- The lidar-derived topography from 2018 is a “snapshot in time”. Future modification of the landscape (e.g., mitigation structures, road construction, erosion, channel migration, landslide deposits) will influence model results. Specific topographical changes expected to alter the outcome of this assessment include any activities that direct flow away from the Squamish Valley Golf Club toward Garibaldi Estates including but not limited to: change in the topography within the Squamish Valley Golf Club lands; and changes in the topography of Mamquam Road between Highland Way South and Mashiter Creek.
- The stormwater system was not included in the model. The ditches within the Garibaldi Estates were represented in the terrain, but the culverts (where they exist) connecting ditches were not included. The overland flow path within Garibaldi Estates is likely to vary from that modelled as the flow direction will depend on the ditch and culvert capacity throughout the neighbourhood.
- There was not sufficient lidar to model the initiating landslide mass for a Type 2 debris flood. As such, morphological changes that were evaluated through a sensitivity analysis were assumed within Reach 1 for the purposes of evaluating the overland flood hazard.

Model/Method Limitations

- HEC-RAS 2D was run as a fixed bed model, therefore channel aggradation was not computed. HEC-RAS 2D does not compute bank erosion or avulsion. A sensitivity analysis was performed to select appropriate terrain modifications to apply to the model scenarios, but these are not precise.
- HEC-RAS 2D assumes a homogeneous fluid meaning that the water and sediments of a debris flood are treated as a single fluid. The model results require interpretation to judge where the flow may have more debris (e.g., sediment, boulders, large woody debris) and where it may be more clearwater in nature.

Model Extents



Study Area

Representative Return Period:	200-year
Peak Discharge:	220 m^3/s
Terrain Modifications:	Mamquam Road bridge blocked
Mamquam River Discharge:	500 m^3/s
Rheology:	Newtonian

Road
Building
Model Extents
Model Boundary Condition
Study Area
Dike Centerline

Max. Depth (m)
< 0.1
0.1 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0

NOTES:

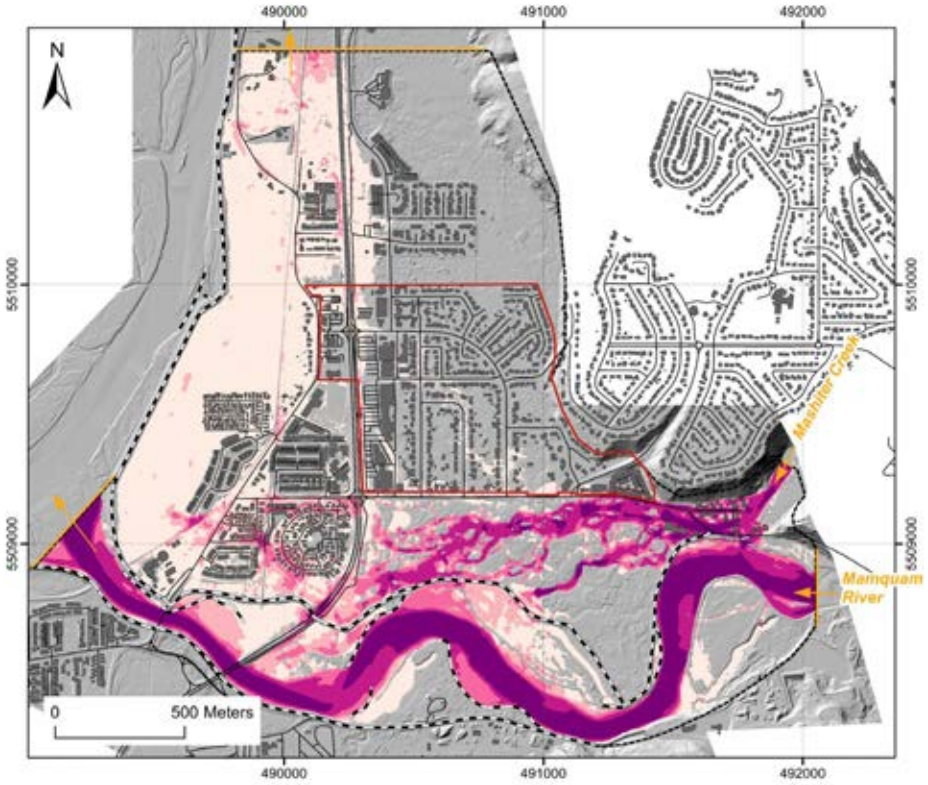
1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
2. Numerical modelling methods and assumptions in Appendix E.
3. Model results are based on the maximum depth and velocity modelled by BGC with HEC-RAS 2D.
4. Topographic data based on lidar provided by District of Squamish and McElhanney, dated 2018.
5. Dike centerlines were downloaded from the District of Squamish open data hub. Building footprints and roads were retrieved from OpenStreetMap.
6. Model results represent current topography only. Changes to topography, such as addition of mitigation structures, roads, and changes in deposition or channelization, may influence flow behaviour. Model results should be reviewed and revisited after any significant change.

PREPARED BY: KRH	FIGURE TITLE: 200-year discharge with bridge blockage: Maximum Depth		
CHECKED BY: LCH	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: As shown	PROJECT NO: 1348005	FIGURE NO: E-8

0 5 10 mm in ANSI A sized paper

BGC Engineering

Model Extents



Study Area

Representative Return Period:	200-year
Peak Discharge:	220 m^3/s
Terrain Modifications:	Mamquam Road bridge blocked
Mamquam River Discharge:	500 m^3/s
Rheology:	Newtonian

Road
Building
Model Extents
Model Boundary Condition
Study Area
Dike Centerline

Max. Velocity (m/s)
< 0.25
0.25 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0

NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
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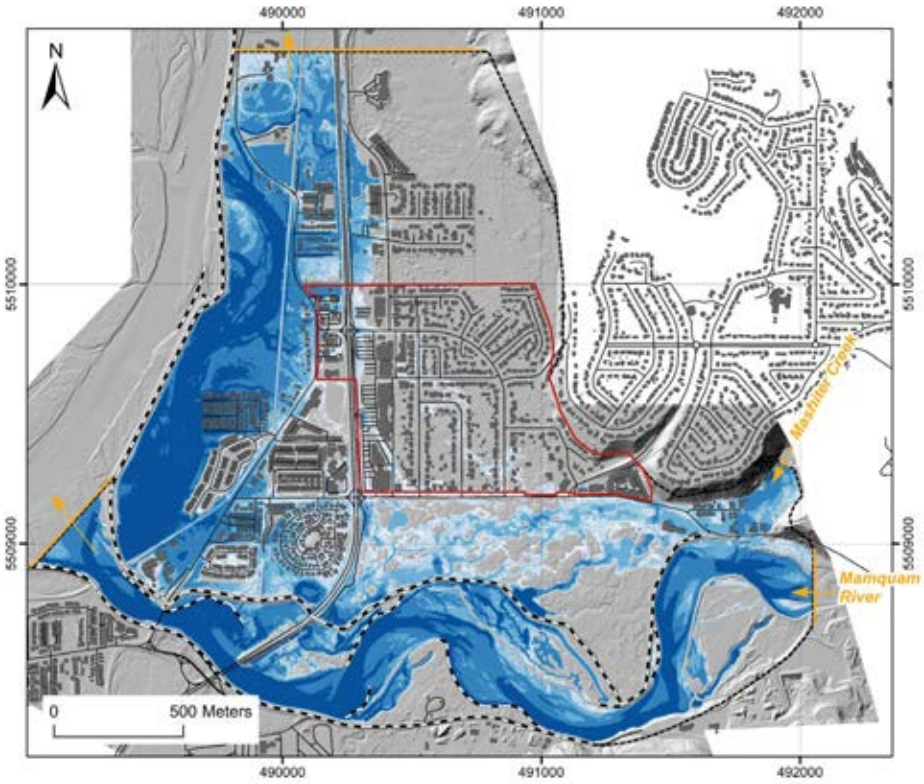
5. Dike centerlines were downloaded from the District of Squamish open data hub. Building footprints and roads were retrieved from OpenStreetMap.
6. Model results represent current topography only. Changes to topography, such as addition of mitigation structures, roads, and changes in deposition or channelization, may influence flow behaviour. Model results should be reviewed and revisited after any significant change.

PREPARED BY:	FIGURE TITLE:		
KRH	200-year discharge with bridge blockage: Maximum Velocity		
CHECKED BY:	CLIENT:		
LCH	District of Squamish		
APPROVED BY:	SCALE:	PROJECT NO:	FIGURE NO:
KRH	As shown	1348005	E-9

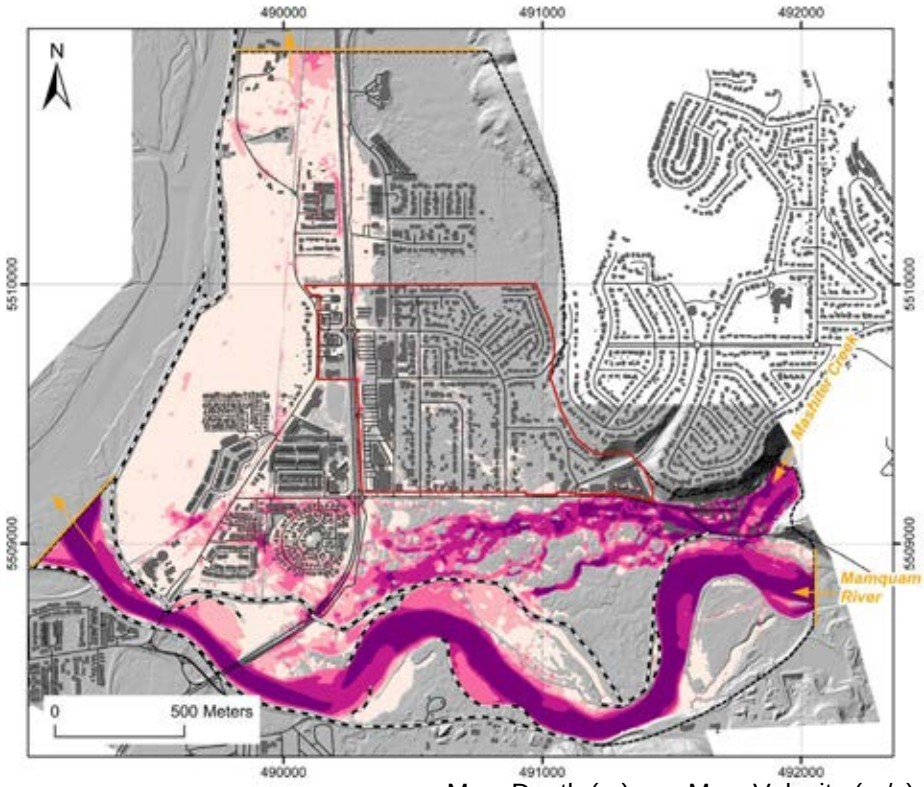
0 5 10 mm in ANSI A sized paper

BGC Engineering

Maximum Depth



Maximum Velocity



Representative Return Period:	500-year
Peak Discharge:	245 m^3/s
Terrain Modifications:	Reach 1 of Mashiter Creek is aggraded with sediment
Mamquam River Discharge:	500 m^3/s
Rheology:	Newtonian

- Road
- Building
- Model Extents
- Model Boundary Condition
- Study Area
- Dike Centerline

Max. Depth (m)	Max. Velocity (m/s)
< 0.1	< 0.25
0.1 to 0.3	0.25 to 0.5
0.3 to 0.5	0.5 to 1.0
0.5 to 1.0	1.0 to 2.0
1.0 to 2.0	> 2.0
> 2.0	

NOTES:

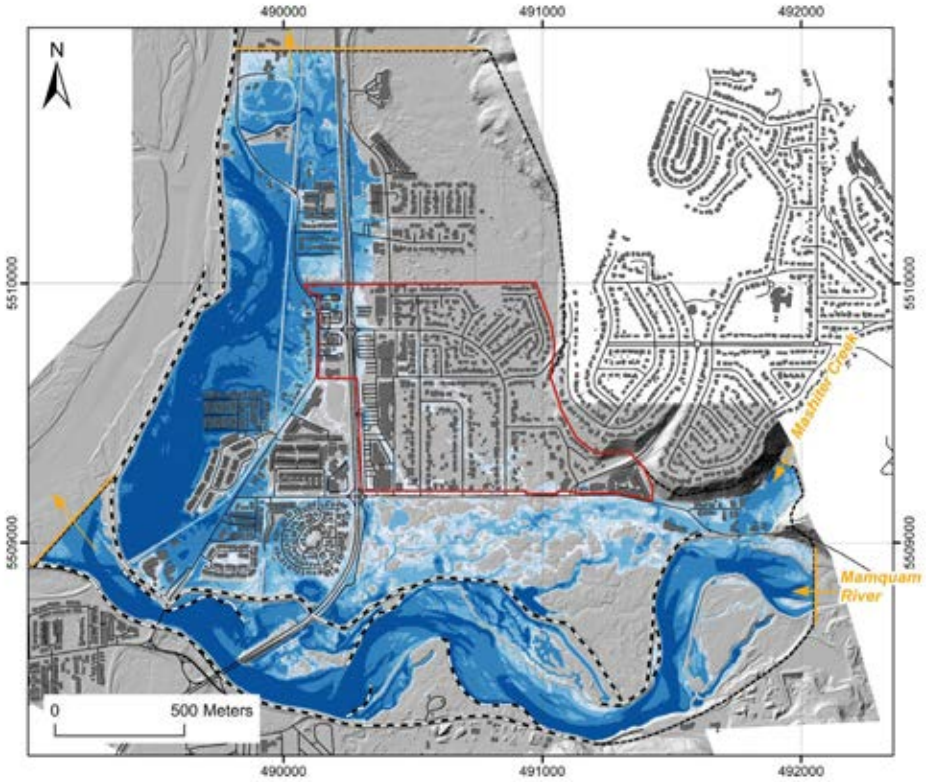
1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
2. Numerical modelling methods and assumptions in Appendix E.
3. Model results are based on the maximum depth and velocity modelled by BGC with HEC-RAS 2D.
4. Topographic data based on lidar provided by District of Squamish and McElhanney, dated 2018.
5. Dike centerlines were downloaded from the District of Squamish open data hub. Building footprints and roads were retrieved from OpenStreetMap.
6. Model results represent current topography only. Changes to topography, such as addition of mitigation structures, roads, and changes in deposition or channelization, may influence flow behaviour. Model results should be reviewed and revisited after any significant change.

PREPARED BY: KRH	FIGURE TITLE: 500-year discharge with Reach 1 aggradation		
CHECKED BY: LCH	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: As shown	PROJECT NO: 1348005	FIGURE NO: E-10

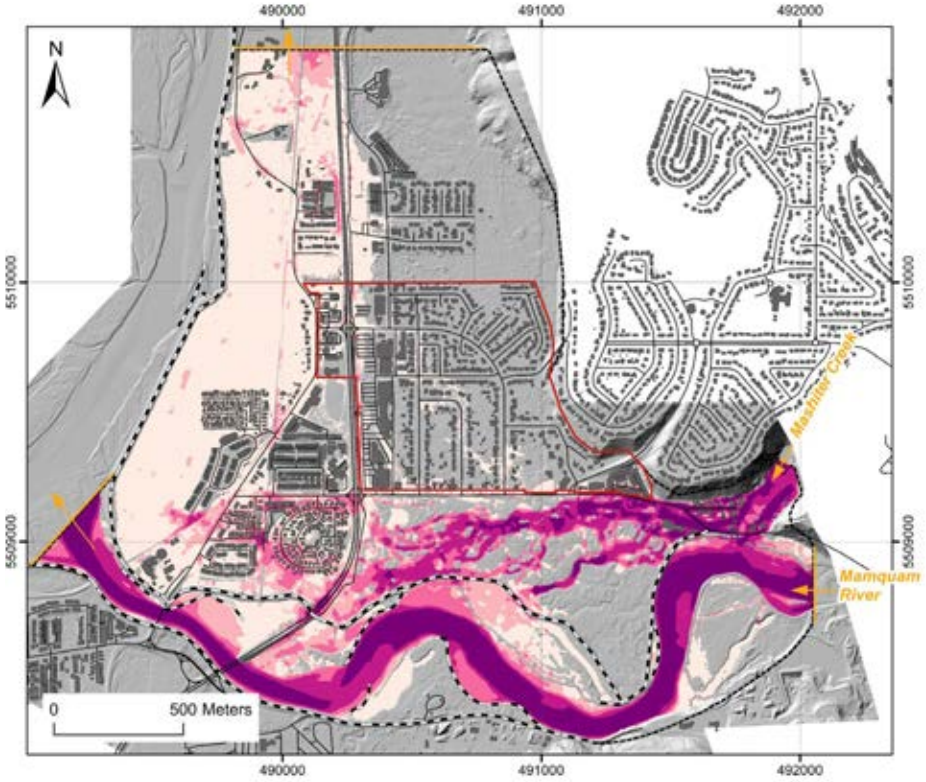
0 5 10 mm in ANSI A sized paper

BGC Engineering

Maximum Depth



Maximum Velocity



Representative Return Period:	1000-year
Peak Discharge:	260 m^3/s
Terrain Modifications:	Reach 1 of Mashiter Creek is aggraded with sediment
Mamquam River Discharge:	500 m^3/s
Rheology:	Newtonian

- Road
- Building
- Model Extents
- Model Boundary Condition
- Study Area
- Dike Centerline

Max. Depth (m)	Max. Velocity (m/s)
< 0.1	< 0.25
0.1 to 0.3	0.25 to 0.5
0.3 to 0.5	0.5 to 1.0
0.5 to 1.0	1.0 to 2.0
1.0 to 2.0	> 2.0
> 2.0	

NOTES:

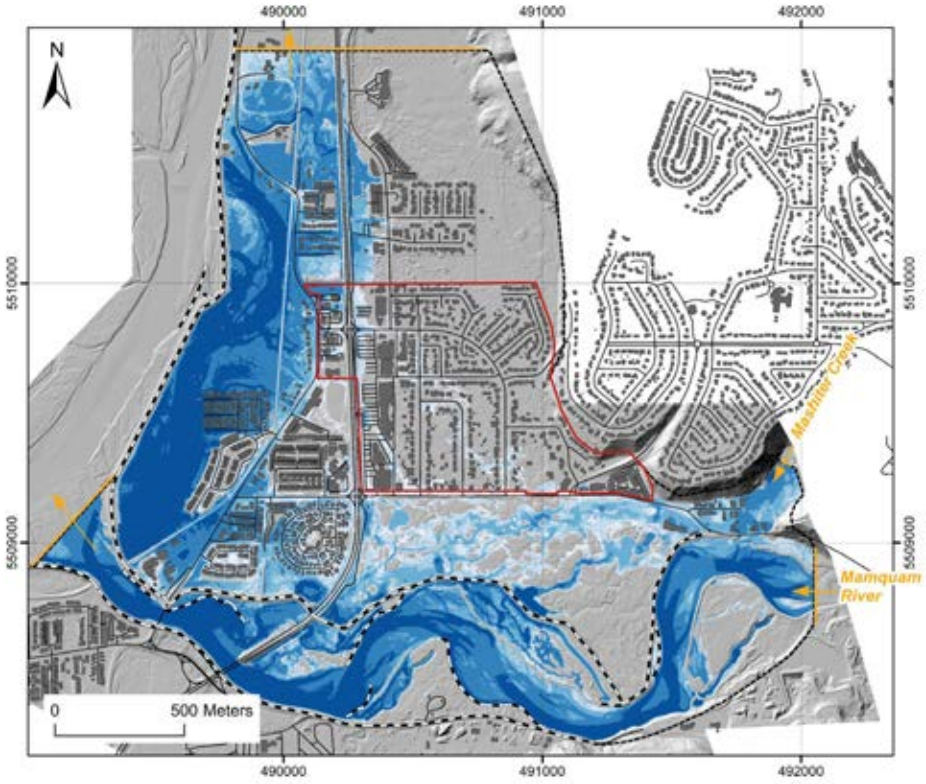
1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
2. Numerical modelling methods and assumptions in Appendix E.
3. Model results are based on the maximum depth and velocity modelled by BGC with HEC-RAS 2D.
4. Topographic data based on lidar provided by District of Squamish and McElhanney, dated 2018.
5. Dike centerlines were downloaded from the District of Squamish open data hub. Building footprints and roads were retrieved from OpenStreetMap.
6. Model results represent current topography only. Changes to topography, such as addition of mitigation structures, roads, and changes in deposition or channelization, may influence flow behaviour. Model results should be reviewed and revisited after any significant change.

PREPARED BY: KRH	FIGURE TITLE: 1000-year discharge with Reach 1 aggradation		
CHECKED BY: LCH	CLIENT: District of Squamish		
APPROVED BY: KRH	SCALE: As shown	PROJECT NO: 1348005	FIGURE NO: E-11

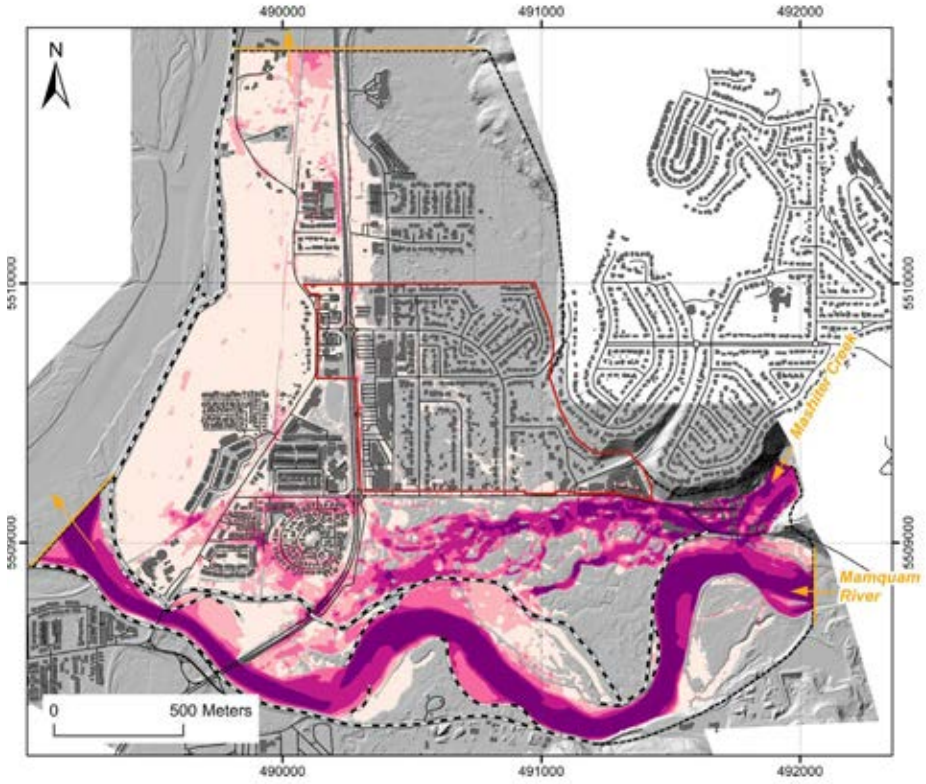
0 5 10 mm in ANSI A sized paper

BGC Engineering

Maximum Depth



Maximum Velocity



Representative Return Period:	2500-year
Peak Discharge:	280 m^3/s
Terrain Modifications:	Reach 1 of Mashiter Creek is aggraded with sediment
Mamquam River Discharge:	500 m^3/s
Rheology:	Newtonian

- Road
- Building
- Model Extents
- Model Boundary Condition
- Study Area
- Dike Centerline

Max. Depth (m)	Max. Velocity (m/s)
< 0.1	< 0.25
0.1 to 0.3	0.25 to 0.5
0.3 to 0.5	0.5 to 1.0
0.5 to 1.0	1.0 to 2.0
1.0 to 2.0	> 2.0
> 2.0	

NOTES:

1. This Figure should be read in conjunction with BGC's report title "Mashiter Creek, Overland Flow Hazard Assessment", and dated February 2025.
2. Numerical modelling methods and assumptions in Appendix E.
3. Model results are based on the maximum depth and velocity modelled by BGC with HEC-RAS 2D.
4. Topographic data based on lidar provided by District of Squamish and McElhanney, dated 2018.
5. Dike centerlines were downloaded from the District of Squamish open data hub. Building footprints and roads were retrieved from OpenStreetMap.
6. Model results represent current topography only. Changes to topography, such as addition of mitigation structures, roads, and changes in deposition or channelization, may influence flow behaviour. Model results should be reviewed and revisited after any significant change.

PREPARED BY:	FIGURE TITLE:		
KRH	2500-year discharge with Reach 1 aggradation		
CHECKED BY:	CLIENT:		
LCH	District of Squamish		
APPROVED BY:	SCALE:	PROJECT NO:	FIGURE NO:
KRH	As shown	1348005	E-12

0 5 10 mm in ANSI A sized paper

BGC Engineering

Garibaldi Estates Neighbourhood Plan

Second Reading

April 1, 2025

SQUAMISH

Background

- Planning process initiated in 2021
- Land uses and policy directions identified in Stage 3
- Draft Plan presented to Community in Stage 4
- Draft plan considered by Committee of the Whole September 2024
- 1st Reading December 17, 2024
  - Include outcomes of Mashiter Creek Hazard Assessment in plan

SQUAMISH

Guiding Principles

Livability
Retain and enhance the livability of the Garibaldi Estates neighbourhood.

Connectivity
Support pedestrian and cycling connections within the neighbourhood and to adjacent areas. Improve transportation infrastructure for the safety and convenience of residents and visitors.

Food Production
Provide enhanced opportunities for gardening, food production and agriculture to support local food access and the wider regional food system.

Services and Amenities
Ensure access to day-to-day services and amenities for neighbourhood residents. Build on the role of the neighbourhood as a service hub for the broader community.

Neighbourhood Design
Ensure new residential and commercial development supports a safe, inclusive, and accessible environment with visual appeal.

Housing Options
Provide a diverse range of housing forms and tenures suitable for a broad range of District of Squamish residents. Support the provision of attainable housing and rental options in the neighbourhood.

Employment
Preserve dedicated commercial areas as employment lands and consider options to integrate additional commercial opportunities into the neighbourhood through mixed uses.

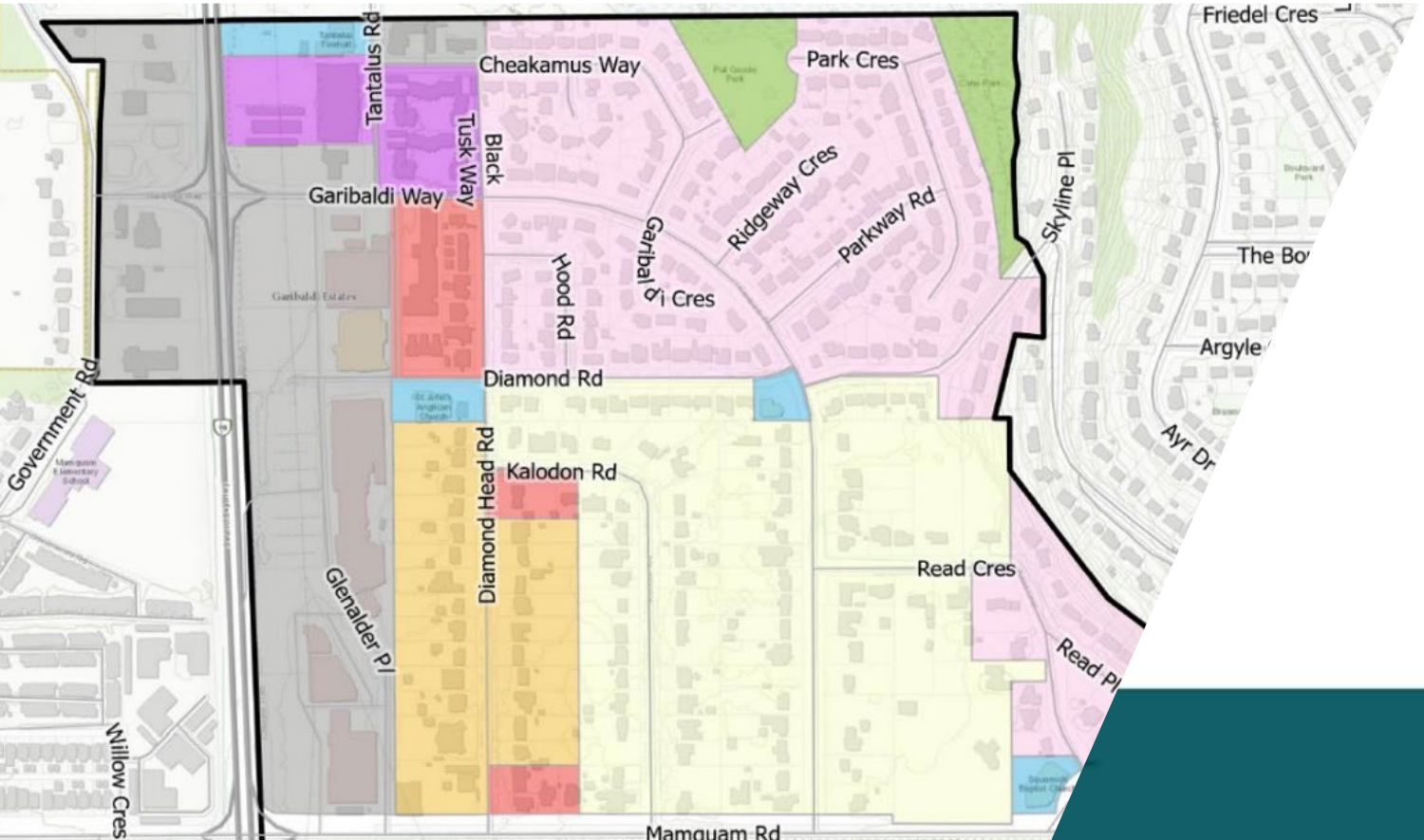
Parks, Greenspace and Public Outdoor Space
Improve and expand existing parks and outdoor public spaces to meet the needs of residents and foster a sense of community for all members. Preserve the canopy of mature trees that enhances the character of the neighbourhood and supports environmental values.

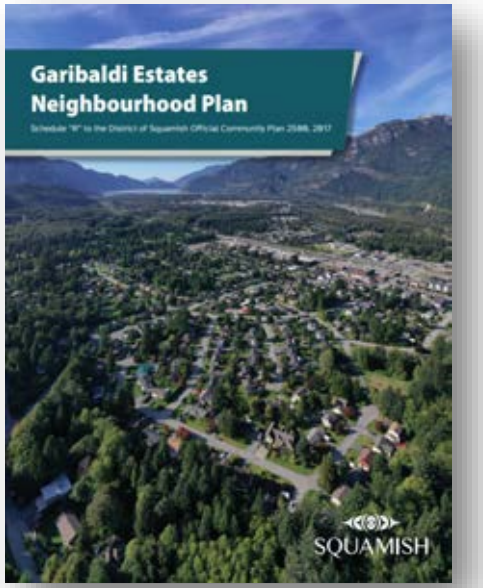
Respond to Climate Change
Reduce greenhouse gas emissions (GHG) and eliminate non-renewable energy use associated with new growth. Ensure resilience to interface wildfire hazards.

Infrastructure
Plan for appropriate water, sanitary, transportation and green infrastructure services to support the neighbourhood as it continues to mature. Share costs of infrastructure upgrades across the range of development activities in the neighbourhood.

SQUAMISH


Coho Park
SQUAMISH
euphoria
2 KINGLANDS

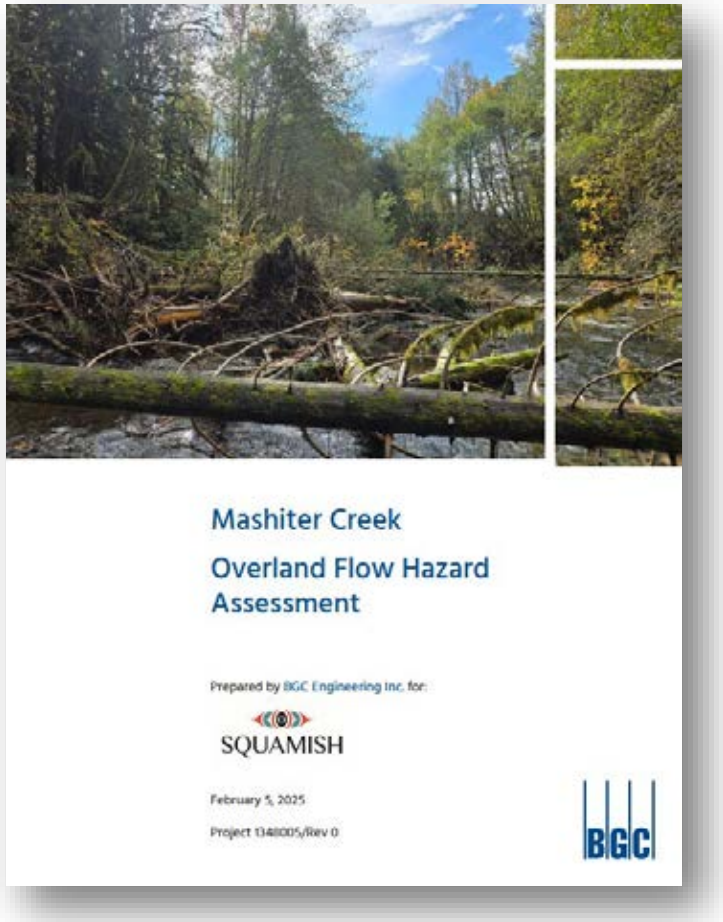

Tantalus Rd
Cheakamus Way
Park Cres
Friedel Cres
Tusk Way
Black
Garibaldi Way
Ridgeway Cres
Parkway Rd
Skyline Pl
Hood Rd
Garibaldi Cres
The Bo
Argyle
Diamond Rd
Government Rd
Kalodon Rd
Diamond Head Rd
Ayr Dr
Read Cres
Glenalder Pl
Read Pl
Willow Cres
Mamquam Rd

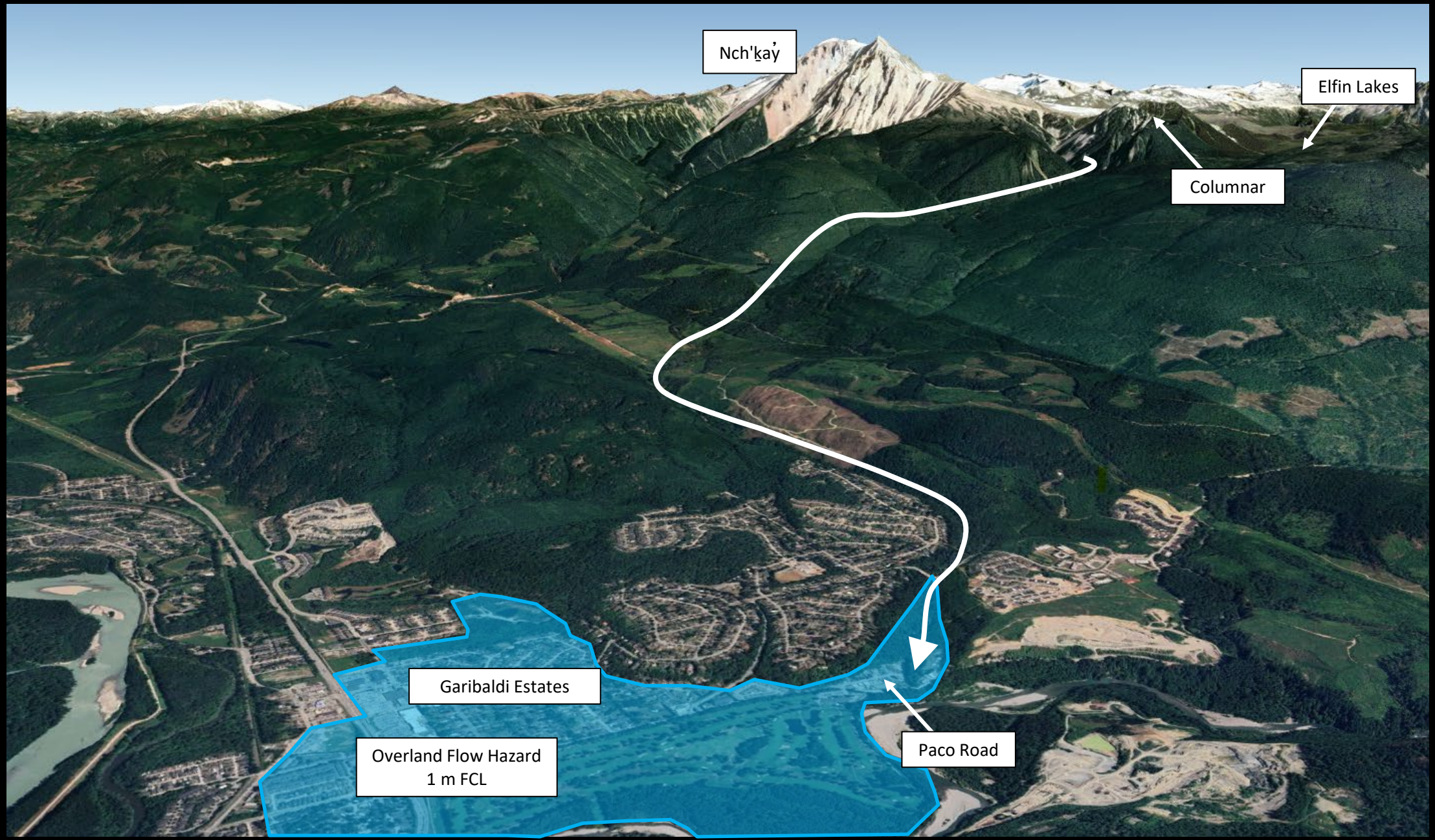

Garibaldi Estates
Neighbourhood Plan
SQUAMISH

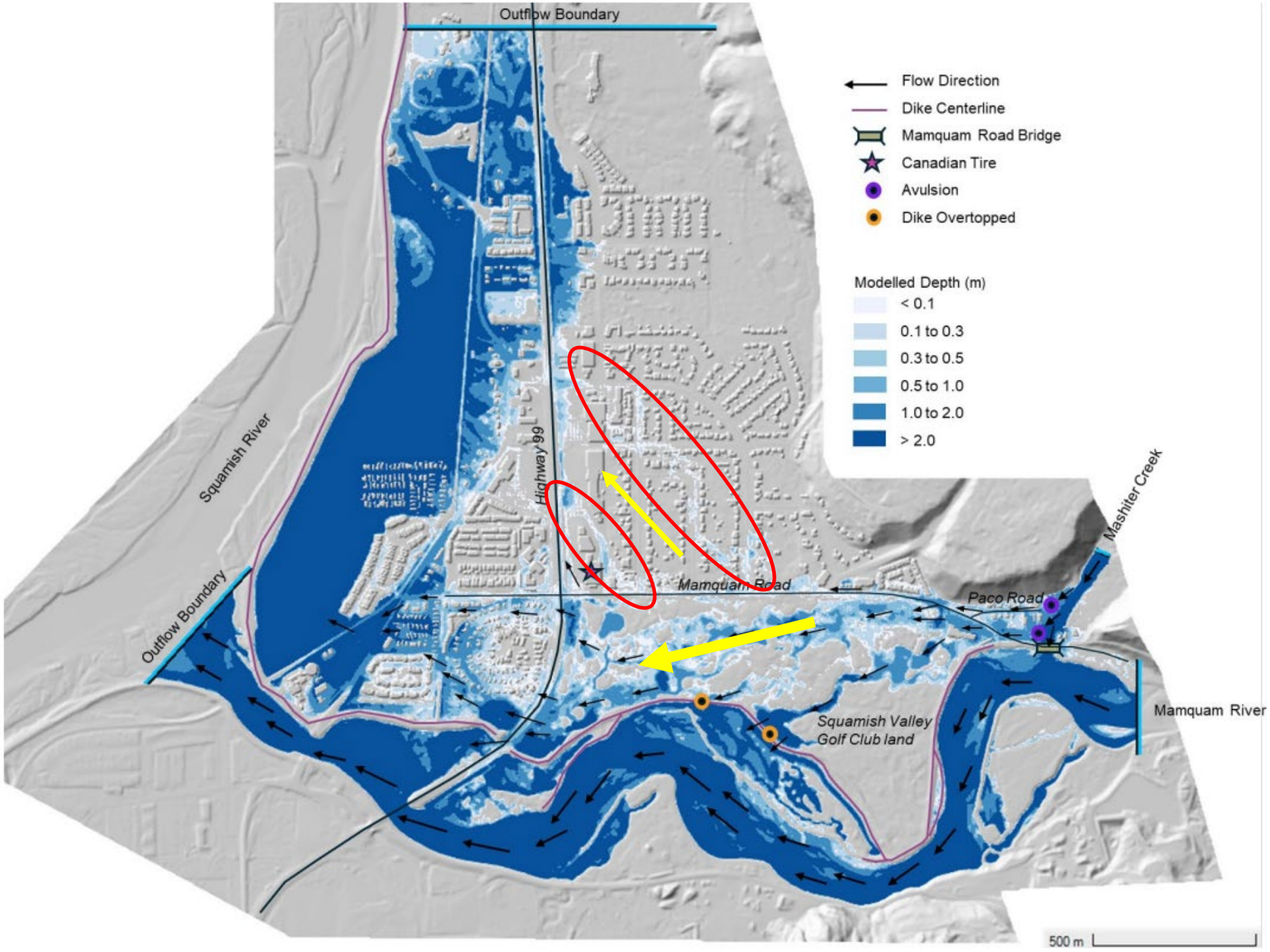
SQUAMISH

Mashiter Creek Overland Flow Hazard Assessment

- Study completed in February 2025

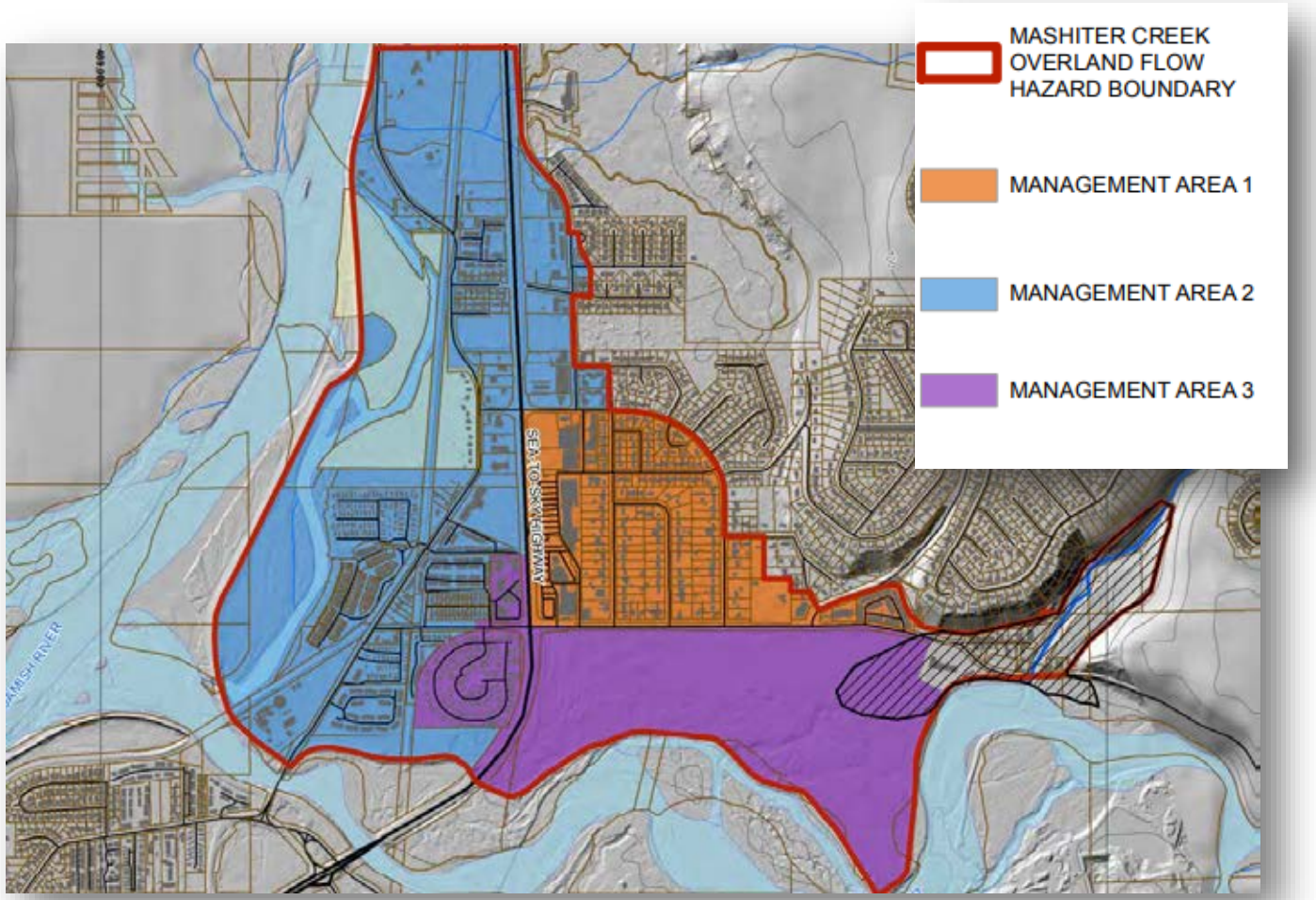



Nch'ka'y
Elfin Lakes
Columnar
Garibaldi Estates
Overland Flow Hazard
1 m FCL
Paco Road


Outflow Boundary
Flow Direction
Dike Centerline
Mamquam Road Bridge
Canadian Tire
Avulsion
Dike Overtopped
Modelled Depth (m)
< 0.1
0.1 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0
Squamish River
Highway 99
Mashiter Creek
Outflow Boundary
Mamquam Road
Paco Road
Squamish Valley
Golf Club land
Mamquam River
500 m

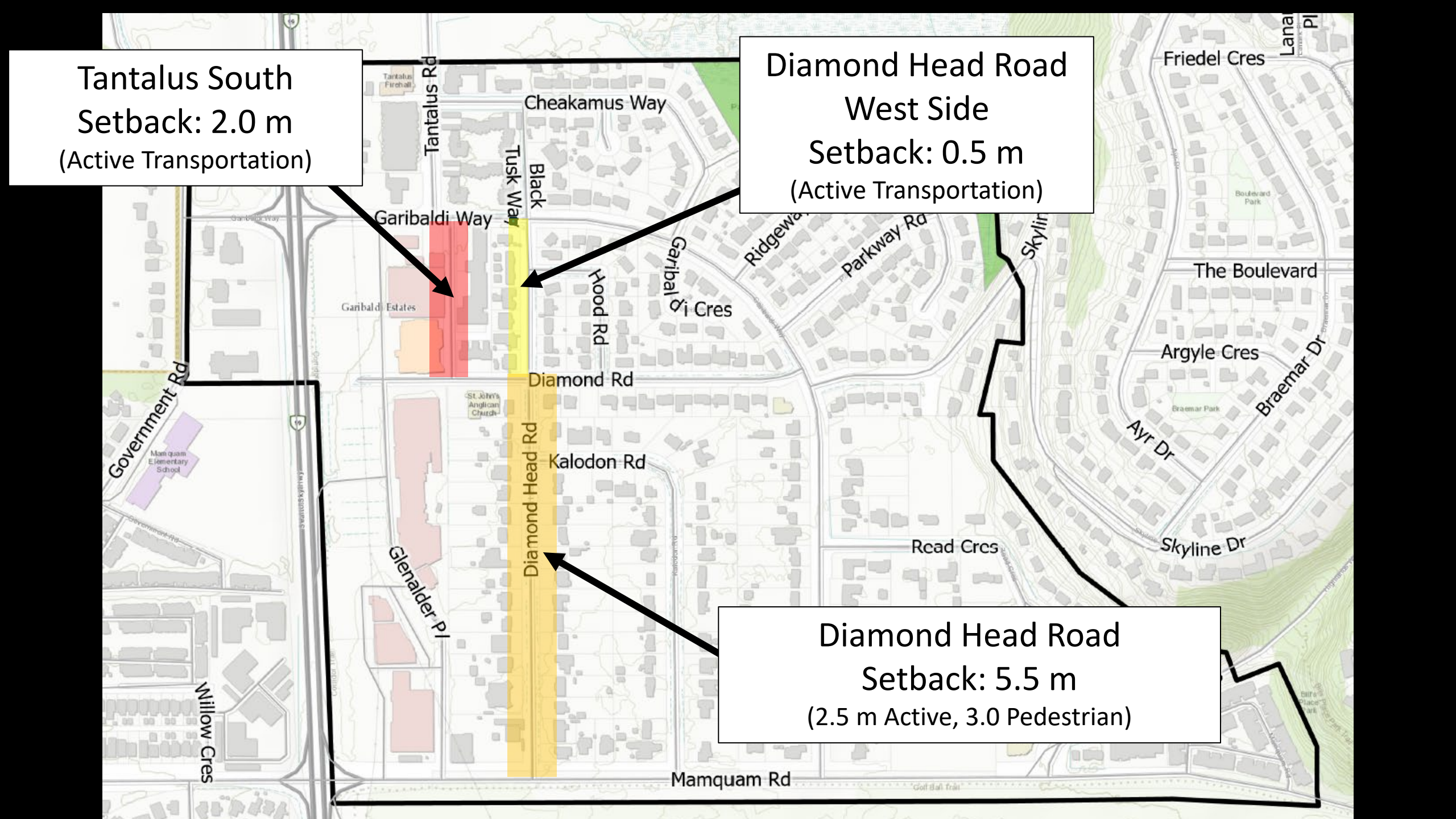
Management Recommendations

- Area 1
  - 0.3 m FCL
- Area 2
  - Existing FCLs (IFHMP) to govern
- Area 3
  - Overland Flow Hazard FCL (1.0 m) to govern



Road Cross Sections

Diamond Head Road Cross Section (South of Diamond Road)


Tantalus South
Setback: 2.0 m
(Active Transportation)
Diamond Head Road
West Side
Setback: 0.5 m
(Active Transportation)
Diamond Head Road
Setback: 5.5 m
(2.5 m Active, 3.0 Pedestrian)
Tantalus Rd
Cheakamus Way
Tusk Way
Black
Garibaldi Way
Garibaldi Estates
Hood Rd
Parkway Rd
Friedel Cres
The Boulevard
Argyle Cres
Braemar Dr
Ayr Dr
Skyline Dr
Government Rd
Mamquam Elementary School
St John's Anglican Church
Diamond Head Rd
Kalodon Rd
Glenalder Pl
Willow Cres
Mamquam Rd

Possible Mixed-Use Frontage

Diamond Head Road

- Diamond Head Road rendering
  - 0.3 m FCL
  - 5.5 m setback

Correction

- Error in anticipated right-of way width
  - Was noted as 1m
  - Changed to 25.0 m

Diamond Head Road South of Diamond Road

- On Diamond Head Road, south of Diamond Road, provide a pedestrian realm with potential outdoor seating areas, protected bike lanes, street parking and street trees. In addition, accommodate transit vehicles and stops where necessary. The anticipated width of the right-of-way is 25.0 m.

Diamond Head Road Cross Section (South of Diamond Road)

Next Steps

- Flowing Second reading
  - Public Hearing
    - May 27th, 2025
    - Brennan Park
  - Notification
    - Squamish Chief
    - LetsTalkSquamish mailing list

Recommendations

THAT:

District of Squamish Official Community Plan Bylaw No. 2500, 2017, Amendment Bylaw (Garibaldi Estates Neighbourhood Plan) No. 3135, 2024 be given second reading.