Stantec Consulting Ltd.
500-4515 Central Boulevard
Burnaby BC V5H 0C6

August 9, 2024

Project/File: 111700815

Mark Phillips - Director of Protective Services
1350 Aster Street,
Pemberton, BC, V0N 2L1

Dear Mark Phillips - Director of Protective Services,

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

1 Introduction

On Sunday, July 21st, a sudden and large volume of water flowed from Place Glacier into Place Creek, within the Squamish-Lillooet Regional District (SLRD). The event is likely attributable to the rapid outflow of glacial meltwater from the Place Glacier into Place Creek, in what is typically referred to as a glacial lake outburst flood. The event caused flooding and deposition of sediment and debris at the valley bottom near 9118-9126 Pemberton Portage Rd, and SLRD was advised by residents of localized flooding on Monday, July 22 (the Event).

Stantec's Graeme Vass, P.Eng., visited the area with representatives from the Pemberton Valley Dyking District (PVDD) for an initial assessment of flood conditions on Tuesday July 23rd, and provided hydrotechnical engineering input to help alleviate immediate flood concerns.

Prior to the Event, Place Creek flowed west into Poole Creek. However, the deposition of sediment and debris that occurred during the Event caused Place Creek to form a distributary channel, such that the majority of flow now drains east into an unnamed channel and onwards to Gates Lake, rather than west into Poole Creek (Figure 1). The SLRD retained Stantec Consulting Ltd. to assess the new alignment of Place Creek and determine whether it poses geohazard, flood and debris flood hazards to the general public and structures situated along Gates Lake and immediately downstream of the lake along Gates River.

Following the Event, overland flooding from the new Place Creek alignment has persisted and Gates Lake water levels have remained at or above the previous natural boundary level of the lake. SLRD has requested Stantec conduct an immediate, preliminary hazard assessment (qualitative) of hydrotechnical (flood and debris flood) and geohazard (landslide, debris flood) elements to determine whether an immediate hazard is posed to the local population prior to conducting a more fulsome, quantitative hazard assessment that aligns with Engineering and Geoscientists of British Columbia (EGBC) legislated flood and landside assessment guidelines. This memorandum (memo) details the preliminary hazard assessments and recommended actions to mitigate these hazards (the Assessment).

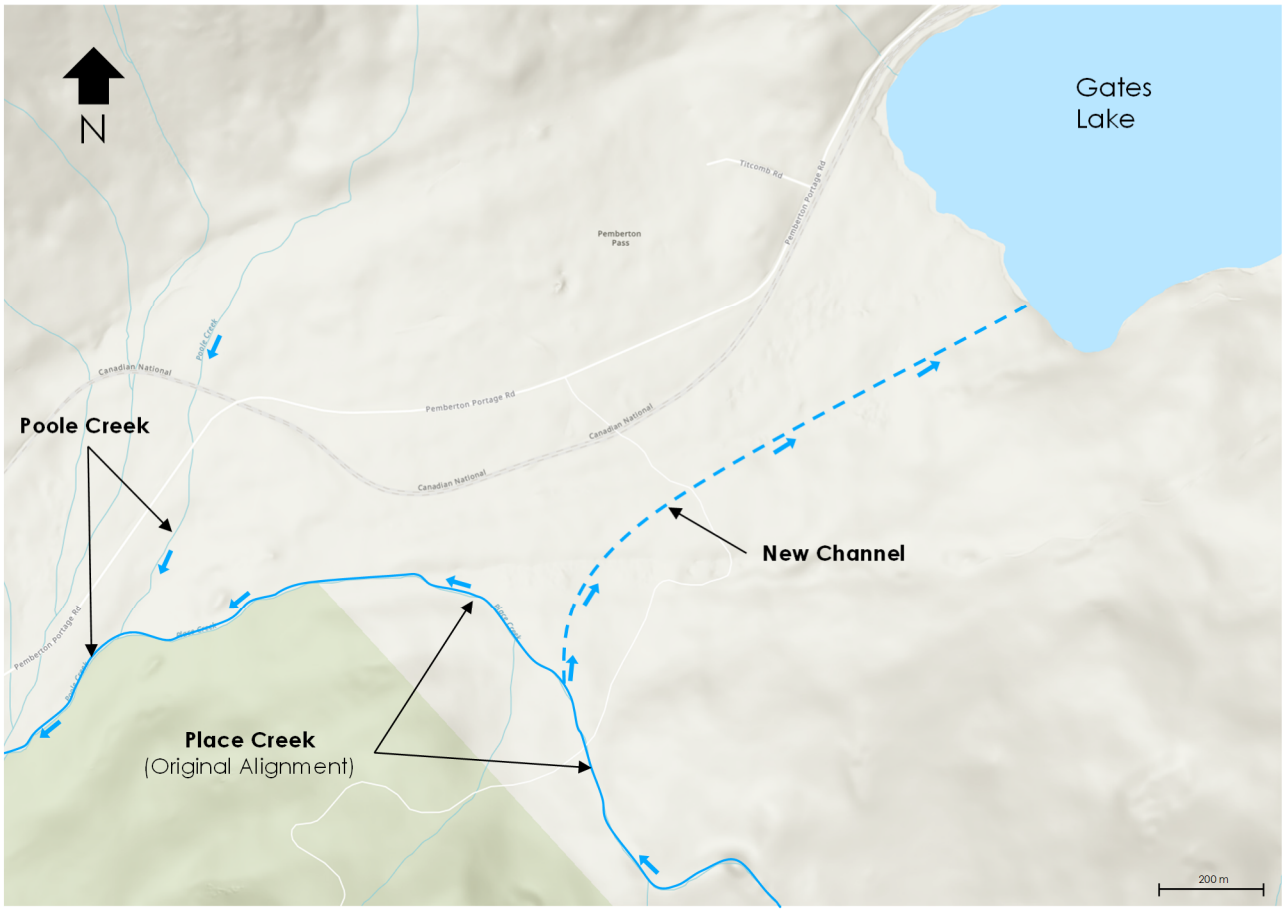


Figure 1: Map Sketch Illustrating Relevant Flow Paths Pre and Post Event

1.1 Information Sources

The Assessment was completed based on the following digital resources provided by the SLRD, Stantec's internal team, and publicly available:

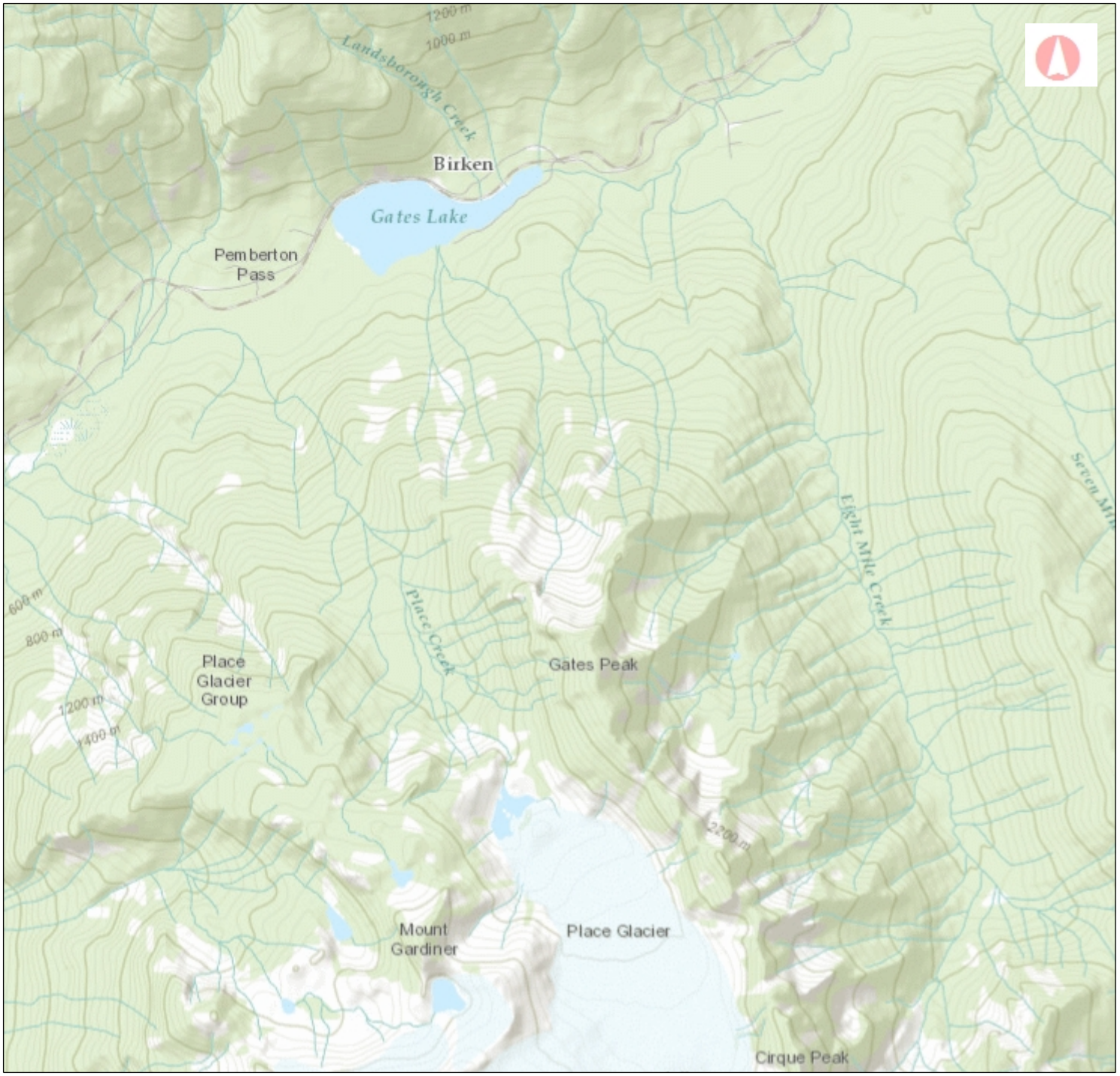
- McElhanney, 2023. Topographic Survey Plan of Part of REM District Lot 1251 Lillooet District Gates Lake, BC.
- Baumann Engineering, 2000. Geologic and Hydrologic Hazard Assessment of District Lot 1251 Near Birken, B.C.

- Kontur Geotechnical Consultants, 2023. Flood Construction Level, Single Family Residential, 9102 Pemberton Portage Road, Briken, BC.
- Kontur Geotechnical Consultants, 2022. Geotechnical Assessment, Single Family Residential, 9102 Pemberton Portage Road, Briken, BC.
- City of Vancouver, 1914. Plan Showing Pacific Great Eastern Railway Right of Way Through Dist. Lots 1251, 1577, 1252, 1171, 1253, 2685, 1250, 1548, 1162, 1249, 553, 2762TL, 2763 P.R.1800 & Crown Lands Lillooet District.
- SLRD, 2004. Plan from 2004 Subdivision File.
- BC Freshwater Atlas

2 Background

2.1 Pre-Event Location

The Gates Lake area is underlain by two major rock types: metamorphic rock (mainly argillite and phyllite) belonging to the upper Triassic age (200 million year old), Hurley Formation, and Cretaceous-aged (70 million year old) grantie rock of the Mt. Rohr formation, part of the Coast Plutonic Complex. The metamorphic rock predominates in the valley bottom along the Gates River and the slopes of Birkenhead Peak to the north; whereas, Gates Peak to the south is composed of both metamorphic and some granite rock. In prehistoric times at least one large rock avalanche came down to the valley floor from Gates Peak and formed the natural dam behind which Gates Lake now lies (Baumenn Engineering, 2000).



BRITISH COLUMBIA

iMapBC Mapping

Legend

0 1.47 2.94 km

1: 72,224

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CAUTION: Maps obtained using this site are not designed to assist in navigation. These maps may be generalized and may not reflect current conditions. Uncharted hazards may exist. DO NOT USE THESE MAPS FOR NAVIGATIONAL PURPOSES.

Datum: NAD83

Projection: WGS_1984_Web_Mercator_Auxiliary_Sphere

Key Map of British Columbia

Place Creek watershed is bounded by Cirque Peak, Mt. Olds, Mt Oleg, and Gates Peak with a north-east aspect and peak elevation of approximately 2520 m. Place Creek originates from several glacial lakes within Place Glacier, situated in a hanging valley between the peaks detailed above. The channel then extends down the mountainous slope through steep, incised gulleys before transitioning to meandering planform along an alluvial fan located on the shallower valley bottom slope referred to as Pemberton Pass. The Pemberton Pass is the divide between the Lillooet River watershed (containing Poole Creek) and the Fraser River watershed (containing Gates Creek). A historical map from 1914 (City of Vancouver, 1914) indicates that a portion of Place Creek (referred to as Summit Creek) flowed northeast and outletted into Gates Lake (referred to as Summit Lake). Subdivision drawings from 2004 (SLRD, 2004), a geotechnical report (Kontur, 2023), and regional maps (BC Freshwater Atlas) indicate that Place Creek flowed to the southwest outletting into Poole Creek (Figure 2). It is unknown when Place Creek established the pre-Event alignment (i.e. flowing into Poole Creek); however, based on conversations with local Gates Lake and Poole Creek residents, Líl̓wat Nation members, and the SLRD this pre-Event alignment has existing in living memory and was the basis for developments along Poole Creek, Gates Lake, and Gates River.

Several residential properties are located along the south-west end of Gates Lake (9126, 9122, 9118, 9102 Pemberton Portage Rd) along with two BC Hydro high voltage power line right of way (ROW). Two constructed drainage ditches (approximately 1 m deep) cut across the BC Hydro ROW, 9102 and 9122 Pemberton Portage Rd properties outletting into Gates Lake (Figure 3 - Kontur, 2022).

The natural boundary[1] of Gates Lake was situated at 478.6 m (Kontur, 2023).

Figure 3 - Drainage Ditch through 9102 Pemberton Portage Road Prior to Event (Kontur, 2022)

[1] The visible high watermark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river, stream or other body of water a character distinct from that of the banks thereof (Land Act, Section 1).

McElhanney ANSI D - 2017-05-29

LOT 3
PLAN KAP31674

LOT B
STRATA PLAN EPS5693

LOT C
STRATA PLAN EPS5693

COMMON PROPERTY
(ACCESS ROAD)

COVENANT
Plan EPP90495

GATES LAKE

REM LOT 4
PLAN KAP71081

PEMBERTON PORTAGE RD

RAILWAY PLAN A8

RAIL TRACKS

EDGE OF PAVEMENT

WOOD SHED

HOUSE

DECK

GARAGE

BARN

BUILDING WITH
2 OPEN SIDES

COVENANT
PLAN KAP71082

TOP OF BANK
ENVIRONMENTAL
SETBACKS

DRIVEWAY CENTERLINE

Culvert Outlet 600D CSP
INV ELEV=480.49

Culvert Inlet 600D CSP
INV ELEV=480.44

TOP OF BANK
(ENVIRONMENTAL SETBACKS)

ENVIRONMENTAL SETBACK

REM DL 1251

FENCE

OLD WOODEN SHACK

GUEST HOUSE

WOOD SHED

COTTAGE

DOCK

INTERIOR BOUNDARY BETWEEN
DL 5526 & REM DL 1251 TO BE EXTINGUISHED
CURRENTLY UNDER SURVEY JAN 25, 2023

PRESENT NATURAL BOUNDARY

DL 5526

BLK B
DL 8582

BLK A
DL 8582

ROAD

BLK A
DL 8582

HYDRO TOWER

HYDRO TOWER

HYDRO TOWER

BC HYDRO RIGHT OF WAY PLAN KAP3366B

REM DL 5146

LE

- CULVERT
- GUY WIRE
- POLE - HYDRO
- TREE - CONIFEROUS
- TREE - DECIDUOUS

NOTES:

1. THE GRID COORDINATES ARE UTM ZONE 10, NAD83 (CSRS) AND ARE DERIVED FROM DUAL FREQUENCY GPS DIFFERENTIAL CARRIER PHASE OBSERVATIONS.
2. ELEVATIONS ARE IN METRES AND ARE REFERRED TO GEODETIC DATUM CVD28.
3. THIS PLAN REPRESENTS FIELD SURVEY CONDUCTED ON MAY 17TH, 2022.
4. THIS PLAN SHALL NOT BE USED TO DEFINE PROPERTY LINES OR PROPERTY CORNERS.
5. CONTOUR INTERVAL IS 1.0m.

Rev	Date	Description	Drawn	Design	App'd
1	2023-01-25	EXTINGUISHED PROPERTY LINE NOTE	TB	N/A	TB
0	2022-05-19	INITIAL SUBMISSION	CW	ES	TB

0 1:1,250 50

ORIGINAL DWG SIZE: ANSI D (22" x 34")

McElhanney
Suite 205
1055 Millar Creek Road
Whistler BC
Canada V0N 0K7
T 604 932 5426

Approved Sealed

TM BUILDERS
115B - 1330 ALPHA LAKE RD, WHISTLER, BC V0N 1B1

TOPOGRAPHIC SURVEY PLAN OF PART OF REM DISTRICT LOT 1251 LILLOOET DISTRICT GATES LAKE, BC

Drawing No.
V-01

Project Number	Rev.
2113-04297-00	1

DESTROY ALL PRINTS BEARING PREVIOUS REVISION

2.2 The Event

On July 21st, 2024 a sudden and large volume of water flowed from Place Glacier into Place Creek. Based on available satellite imagery from before and after July 21st (Figure 5), a glacial lake appears to have fully drained (outburst). This sudden outburst of water entrained sediment and debris as it flowed down Place Creek precipitating in a debris flood event that deposited large volumes of sediment within Place Creek and along the Pemberton Pass (Figure 6). An avulsion[2] of the Place Creek channel occurred in response to the debris flood with the new alignment now conveying the majority of Place Creek flow into the existing constructed drainage ditches and into Gates Lake (Figure 6, Figure 7).

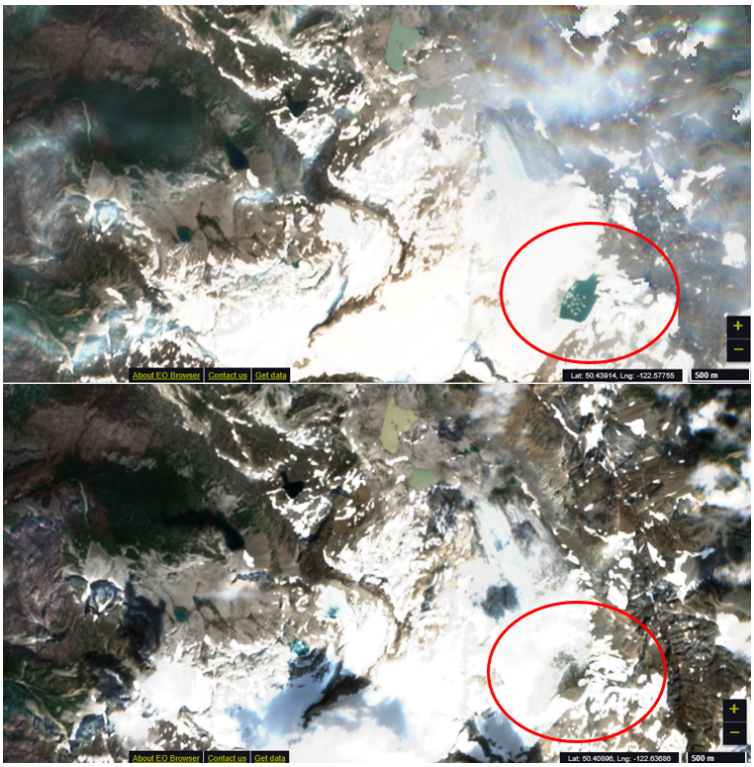


Figure 5 - Satellite Imagery of Glacial Lake within Place Glacier (Top Image July 17, 2024; Bottom Image July 23, 2024 - provided by Sentinel Hub EO)

[2] A rapid abandonment of a river channel and the formation of a new river channel.

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Figure 6 - Place Creek Post-Event (Solid Line) and Pre-Event (Dashed Line) Alignments (Stantec, July 24, 2024)

Reference: **Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment**

Figure 7 - Post Event Place Creek Flow Conveyed Through Man-Made Drainage Ditches (Red and Green Solid Lines - Stantec, July 24, 2024)

Following the outburst and realignment of Place Creek, Gates Lake water level rose and overtopped the natural boundary (Figure 8, Figure 9).

Figure 8 - Gates Lake Water Level Post-Event (Stantec, July 23, 2024)

Figure 9 - Flooded Overbank Above Natural Boundary (Stantec, July 24, 2024)

3 Hazard Assessment

On July 23, 2024 Stantec was retained by the SLRD to provide emergency response services and conduct geohazard, flood, and debris flood hazard assessments associated with post-Event Place Creek and Gates Lake conditions. The following site visits were conducted:

- July 23, 2024 – Graeme Vass, P.Eng. – Emergency response services to alleviate immediate overland flood hazards to 9102, 9118, 9122, and 9129 Pemberton Portage Rd.
- July 24, 26, 28, 2024 – Graeme Vass, P.Eng. – Emergency response services to assess conditions of Place Creek and Gates Lake water level.
- July 30, 2024 – Graeme Vass, P.Eng, Duncan McTaggart – Assessment of flood and debris flood hazards along new and previous Place Creek alignments.
- August 1, 2024 – Graham Knibbs, P.Geo, - Assessment of geohazards along new and previous Place Creek alginments.
- August 1-3 and 6-8, 2024 – Duncan McTaggart – Direct implementation of emergency flood mitigation measures.

The following sections detail geohazard and hydrotechnical hazards observed as part of these site visits.

3.1 Hydrotechnical Hazard Assessment

Debris flood hazards and flood hazards associated with the new alignment of Place Creek and Gates Lake water level were assessed by Stantec via. comparison of the visual observations collected by Stantec during the site visits detailed in Section 3. Quantitative assessments of flows, water levels, and flood hydraulics as a result of the Event have not been conducted at this time.

3.1.1 Debris Flood Hazard

On July 30, 2024 Stantec walked the new and previous alignments of Place Creek to assess for debris flood hazards (Figure 10).

3.1.1.1 Upstream of Avulsion Location

Upstream of the avulsion location the channel is steep exiting a confined gully reach comprised of erodible, near vertical banks comprised of unconsolidated colluvium. The portion of the channel conveying flow is poorly defined within the active channel width but was observed to be incised into the deposited debris flood material, comprised of well graded cobbles and boulders with large woody debris (Figure 11). The

channel has a boulder step planform and based on observations, is expected to be prone to lateral migration in its current state.

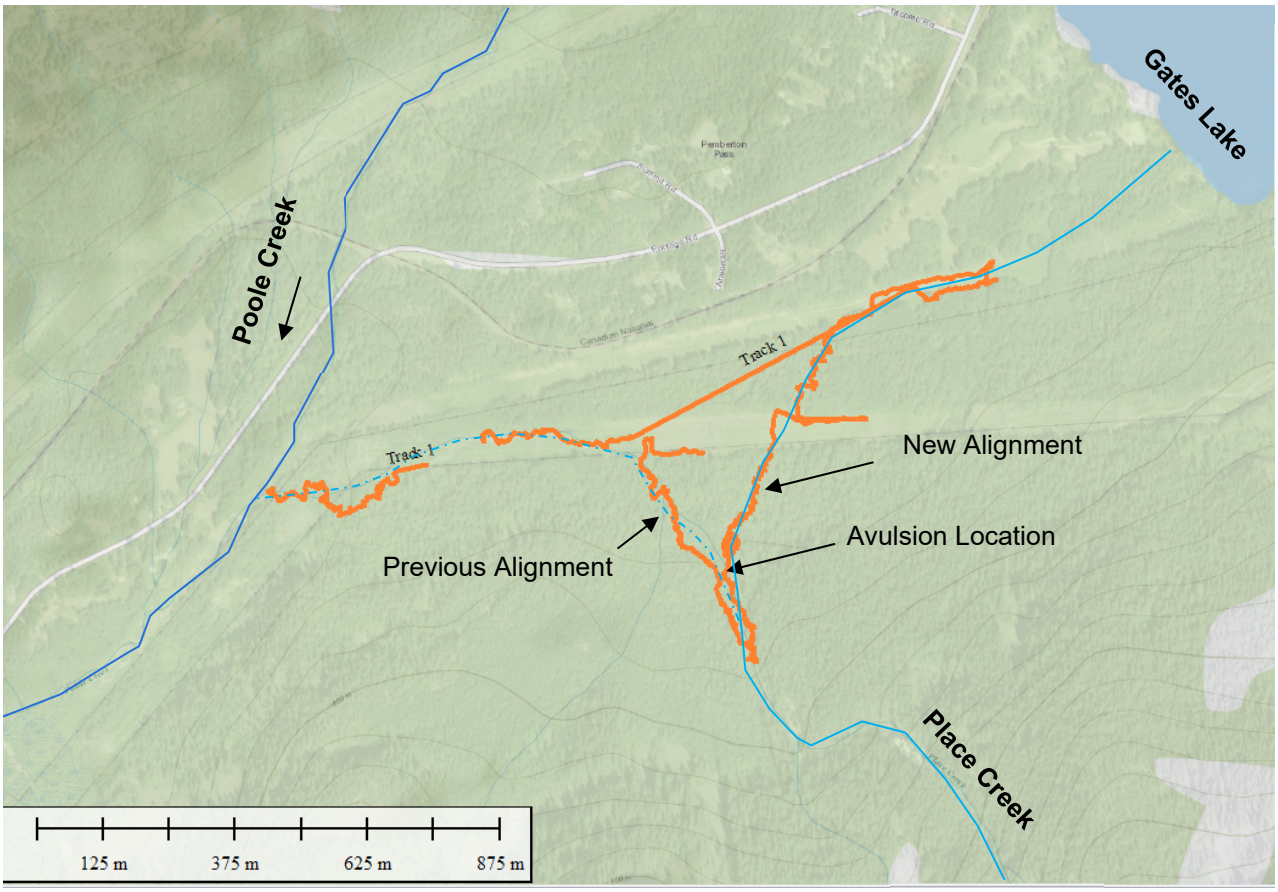


Figure 10 - Track Lines from Stantec Visual Assessment (Orange Solid Line) - July 30, 2024

There are two locations approximately 20 m and 50 m upstream of the current avulsion location where the right[3] bank is low and poorly defined. The potential for a further avulsion and reconfiguration of the channel at these locations is high in response to higher flows or lateral migration of the channel (Figure 12).

[3] Right and left are with respect to viewing downstream along the channel.

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Figure 11 – Looking Upstream Along Place Creek from Avulsion Location

Figure 12 – Looking Downstream at Low Right Bank Upstream from Avulsion Location

3.1.1.2 Avulsion Location

At the avulsion location approximately 10% to 20% of flow is being conveyed by the previous Place Creek alignment while 80% to 90% of flow is being conveyed by the new alignment (Figure 12). Based on conversations with local Gates Lake and Poole Creek residents, Líl̓wat Nation members, and the SLRD all pre-Event Place Creek flow was conveyed by the previous alignment. The previous Place Creek channel alignment is perched above the new Place Creek alignment. Further lowering of the new Place Creek alignment may result in the majority of flow being conveyed through the new alignment.

Figure 13 – Looking Downstream At New (Right) and Previous (Left) Place Creek Alignments

3.1.1.3 New Place Creek Alignment Downstream of Avulsion Location

The portion of the new channel extending approximately 20 m downstream of the avulsion has similar geometry and characteristics to the upstream portion. At this location the channel grade abruptly lowers by 2 m (Figure 14) and transitions to a well defined, incised channel approximately 2 to 3 m wide and 1 to 1.5 m deep with near vertical banks (Figure 15). The location of the grade change (also referred to as a “headcut”) is being temporarily held in place by tree roots and boulders – if these tree roots were to fail the grade change will continue to retrograde upstream to the avulsion point. Once it reaches this point the previous Place Creek alignment will become fully perched and no longer convey flow.

Figure 14 – Looking Downstream Towards the Grade Change Within the New Place Creek Alignment

Figure 15 – Looking Downstream at the Incised Channel Downstream of the Grade Change

This incised channel continues downstream until the grade flattens out where it transitions to a braided, multi-thread, poorly defined channel through the finer sediments deposited by the Event (Figure 16). It is uncertain whether the incised channel has reached a quasi-equilibrium state; however, as more of Place Creek flow may eventually be conveyed through this channel and the channel has not experienced a mean annual flow it is likely that further incising and widening/bank slumping is anticipated.

Figure 16 – Looking Downstream from Incised Channel Reach Towards Braided Reach.

3.1.1.4 Previous Place Creek Alignment Downstream of Avulsion Location

Downstream of the avulsion location the previous Place Creek alignment is poorly defined as it incises down into the deposited debris flood boulder, cobbles, and gravel material (Figure 17). The channel transitions from a single thread to a double thread channel sporadically along this mountainous reach. As the channel approaches the BC Hydro ROW the slope flattens out and the channel becomes less defined (Figure 18) for approximately 100 m before reforming into a single channel, approximately 7 to 10 m wide with 1 to 2 m high steep banks within the defined active width of the previous Place Creek Alignment (Figure 19). These channel characteristics are maintained for a further 400 m – the channel then transitions to a steep, cascading section along bedrock before flattening out and flowing into Poole Creek. Just upstream of the cascade section two large woody debris (LWD) jams, approximately 1 to 2 m high and 10 m wide are located within the channel – flow is currently conveyed below the LWD jams but higher flow would be obstructed (Figure 20).

Reference: **Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment**

Figure 17 – Looking Upstream Along Previous Place Creek Alignment Downstream of Avulsion Location

Figure 18 – Looking Upstream Towards Poorly Defined Channel Reach of Previous Place Creek Alignment

Figure 19 – Looking Downstream Along Channelized Portion of Previous Place Creek Alignment Through BC Hydro ROW

Figure 20 – Looking Downstream at LWD Jams

3.1.1.5 Summary of Debris Flood Hazards

The following is a summary of the debris flood hazards observed during the site visits:

- **Low right bank upstream of avulsion point**. Channel susceptible to further avulsions and realignment which may mobilise sediment and debris.

- **Grade change along new alignment**. Further retrograding of grade change upstream towards avulsion would perch old alignment resulting in all Place Creek flow conveyed through new alignment. This may also mobilise sediment and debris

- **LWD jams in old alignment**. During higher flow events LWD jam will obstruct flow, increasing water levels upstream and potentially resulting in avulsion of channel which may mobilise sediment and debris.

3.1.2 Flood Hazard

3.1.2.1 New Place Creek Alignment

As flow transitions from the steep mountainous slope to the flatter slopes along the BC Hydro ROW it changes from being channelized within a defined channel to a braided planform within poorly defined, highly mobile channels. Flow is conveyed northeast along the BC Hydro ROW and into two constructed drainage ditches that convey flow across 9102 and 9118 Pemberton Portage Road. These ditches did not have sufficient capacity to convey Place Creek flow, as a result they either:

- Incised further down and eroded the banks creating a deeper and wider channel (Figure 21); or

- Overtopped with a portion of flow being conveyed overland adjacent to the ditch (Figure 22).

Both responses pose immediate flood hazards to 9102 and 9118 Pemberton Portage Rd. The Gates Lake area experienced a rainfall event on July 29, 2024 with a total accumulation of 0.6 mm [4]. This resulted in an appreciable amount of flow overtopping the drainage ditches and being conveyed through 9102 and 9118 Pemberton Portage Rd. properties encroaching upon structures and flooding crawl spaces. To address this immediate flood hazard, emergency response works were implemented (technical input provided by Stantec) from Aug 1 to Aug 8 that incorporated a system of ditches and gabion bulk bags to reroute flow into the larger of the two ditches with an alignment that was confined to 9102 Pemberton Portage Rd., set-back from structures and conveyed flow into Gates Lake (Figure 23). These emergency works are only intended for short term use (i.e. prior to the extreme rainfall events that generally occur in the fall) – for

[4] Rainfall data sourced from Canadian HRDPS model.

context a 2-year return period, 24 hour rainfall event total accumulation for the Gates Lake area is estimated to be 38.75 mm.

On Aug 4/5th, 2024 the Gates Lake area experienced a more sever rainfall event with a total accumulation of 12.86 mm. The braided channels within the BC Hydro ROW laterally migrated across the width ROW; however, the emergency works functioned as intended and conveyed the flow to Gates Lake within the constructed ditch system (Figure 24).

Along Gates River overland flooding was noted within the agricultural fields of 9234 Pemberton Portage Rd. The extents of the flooding appear to be stable with the property owner noting slight fluctuations in response to the July 29 and Agu 4/5 rainfall events (Figure 25).

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Figure 21 – Looking Downstream Along Previous Constructed Ditch now Incised Upstream of New Place Creek Outlet into Gates Lake

Figure 22 – Overland Flooding Due to Undersized Constructed Ditch Conveying Place Creek Flow

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Figure 23 – Emergency Flood Mitigation Works Plan Implemented from Aug 1 to 8th

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Figure 24 – Overland Flow Along New Place Creek Alignment Through BC Hydro ROW Following Aug 4/5 Rainfall Event.

Figure 25 – Overland Flooding of 9234 Pemberton Portage Road Downstream of Gates Lake

3.1.2.2 Gates Lake

In response to the Event the water level within Gates Lake increased by approximately 0.3 m to 0.5 m (per conversation with owner of 9118 Pemberton Portage Rd) overtopping the existing natural boundary. On July 23rd, 2024 Stantec noted that the water level was still at or slightly above the natural boundary – a wooden monitoring stake was installed at the observed Gates Lake edge of water (Figure 26) to assess the change in water levels between each site visit.

- Between July 23 and July 26 the water level lowered approximately 5 cm; however no change was observed between July 26 and July 28.

- Following the rainfall event on July 29 the water level increased a negligible amount; however, following the August 4th/5th rainfall event the water level was observed to have raised back to or slightly above the level observed on July 23.

The owner of 9118 Pemberton Portage Rd noted to Stantec (pers. email Aug 8, 2024) that the increase in lake water level following the Augst 4/5th rainfall event caused the crawl space below their home to flood. They also noted that wave action is now flooding their property and causing erosion along their shoreline.

The hazard of increased shoreline erosion due to wave action at a higher lake level will impact all properties fronting Gates Lake that do not have adequately sized foreshore erosion protection.

The outlet of Gates Lake in Gates River is naturally regulated by LWD (Figure 27) that has collected within the outlet. A sudden failure of the LWD may cause a pulse of water to be conveyed downstream exacerbating ongoing flood conditions and erosion potential. Condition of the LWD blockage and relationship between lake storage and flow within Gates River associated with the outlet is unknown.

3.1.2.3 Summary of Flood Hazards

The following is a summary of the flood hazards observed during the site visits and conveyed to Stantec via. conversation and emails from property owners:

- **Overland Flooding.** Overland flow through the BC Hydro ROW has erratic flow paths that are susceptible to lateral migration. The existing ditch system was not designed to convey the entire Place Creek Flow. Emergency works were implemented to alleviate the immediate risk; however, these structures should not be relied upon to mitigate flood hazards posed to property owner's by greater magnitude rainfall events (anticipated to occur during the fall) and high Gates Lake water levels. Increased flow conveyed by the new Place Creek alignment will exacerbate flood hazards.

- **Gates Lake Water Level.** Gates Lake water level remains at or above the existing natural boundary. The lake level fluctuates in response to rainfall events with magnitudes below the 2-year return period magnitude (equivalent to the mean annual flood) estimated for the Gates Lake area. Wave action with the current water level is causing shoreline erosion. Failure of the outlet LWD blockage may exacerbate ongoing flooding and bank erosion adjacent to Gates River.

Reference: **Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment**

Figure 26 - Gate Lake Edge of Water with Monitoring Stake (July 24, 2023)

Figure 27 - LWD (Black Circle) Naturally Regulating Outlet Flow from Gates Lake (July 24, 2023).

3.2 Geohazard Assessment

On August 2, 2024, Stantec completed an aerial geohazard assessment of the affected area from the eastern extent of Gates Lake to confluence of Poole Creek and the Birkenhead River. The intent of the assessment was to identify residual geohazards that may pose a threat to public safety. Geohazards reviewed for this assessment were limited to glacial hazards and landslides (i.e., rockfall, debris flow and debris slides).

The assessment was completed by Graham Knibbs (P.Geo.). On the day of the assessment, Mr. Knibbs was accompanied by members of the SLRD, Líl̓wat Nation and N'Quatqua in the helicopter. The weather was clear, with ultimately unlimited visibility and flight access to the upper elevations of the Place Glacier and lower elevation areas. During the flight, Mr. Knibbs recorded video and photos of pertinent locations on a GPS enabled camera device. Photos and GPS point locations were later shared with the SLRD and accompanying members of Líl̓wat Nation and N'Quatqua.

3.2.1 Glacial Hazards

During the flight, the upper elevations of the glacier were flown. As visible in satellite imagery presented in Figure 5, there were two discernable lakes in the cirque prior to the Event. Based on the imagery it was inferred that the upper lake had drained rapidly causing the outburst and flood event to occur in the lower lake.

During the aerial assessment, collapsed cavity openings along the basal ice surface in the dried upper lakebed were observed. No evidence of overland flow along the ice surface was observed. Based on these observations, in conjunction with the satellite imagery, it was inferred that the lake drained along the basal surface of the ice to the lower lake causing the outburst event. At the time of the inspection, no flow into the dried upper lakebed was observed (i.e., the lake was not visibly recharging). The lower lake in the cirque was full relative to levels identified in Figure 5. Based on the extent and volume of ice remaining on the Place Glacier, it is possible for the upper lake to impound water again over time.

Figure 28. Photo taken of the drained remnant of the upper glacial lake. Blocks of ice (formerly icebergs) can be seen on the glacier surface in this image.

In the lower cirque lake, remnants of a broken cement weir were identified at the mouth of Place Creek and unobstructed flow from the lake was entering stream. Evidence of imminent glacial calving (i.e., large fractures in the ice, or ice overhangs) into the lower lake was not observed.

Some evidence of mass wasting along the steep slopes of the cirque, including rockfall and rockslides, were observed upslope of the lower lake. Most observed mass wasting events appeared to be low volume rockslides and fall events which deposit on well established talus deposits – no large colluvial blocks were observed in the area. Based on these observations, no immediate landslide threat that could trigger wave runup in the lower lake was observed. Figure 29 shows pertinent features in the lower lake.

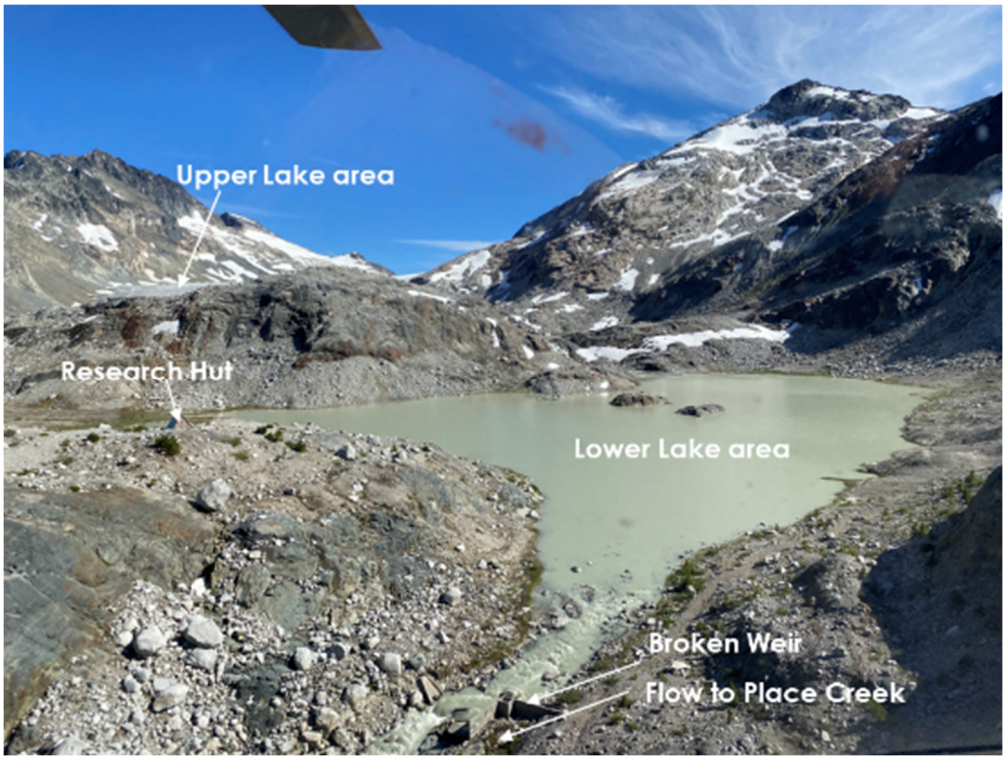


Figure 29. Viewing the lower glacial lake, where uncontrolled flow to Place Creek through the broken weir was observed.

Based on observations made during the aerial assessment, there are suitable conditions that may lead to a similar outburst event in the future. However, since flow is freely exiting the lower lake at this time and the upper lake would take some time to re-establish, Stantec infers that glacial hazards pose a low hazard to public safety at the time of the assessment and are likely to pose a low threat in the immediate future. Periods of sustained high temperatures, rapid snow melt, or rainfall, are likely to cause increased flows to Place Creek. This may acutely affect flooding and landslide hazard downstream.

3.2.2 Landslide Hazards

Steep slopes, susceptible to landslides, along in the upper to mid slope position along the Place Creek gully and the adjacent face slopes were identified during the flight. Stream flow along the confined reaches of the upper Place Creek stream was observed to be actively under cutting unconsolidated stream and gully banks. Consequently, ravelling and channel side wall failures are expected to occur frequently until the stream returns to a stable flow – this time frame is unknown. This is likely to result in consistent sediment inputs into the stream, and pulses of more sediment laden flows during sustained melt or rainfall events, resulting in increased debris flood and landslide (debris flow) hazard.

Figure 30. Looking upslope at the bedrock lip of the Place Glacier cirque, where flow from Place Creek begins. Debris and colluvial deposits from the Event, and prior events, are visible down slope.

Figure 31. Bank undercutting along the upper reaches of Place Creek. Levees along the adjacent slopes are visible in this image from other historic mass wasting events.

Based on observations of sediment inputs and steep slopes, debris flows[5] are likely to occur through Place Creek. However, low gradient depositional slopes, up-gradient of private property in the area were identified. Based on observations of deposition from the Event, particularly along the upper BC Hydro right-of-way, it is anticipated that a debris flow initiating along Place Creek, or the flanking face slopes, would deposit in this area. Debris deposits may further be transported through flood processes if this occurs, much like what occurred during the Event.

[5] Debris flows are a form of landslides that carry entrained saturated debris and sediment rapidly down mountain sides Often these events can travel long distances from their initiation location.

Reference: **Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment**

Figure 32. Viewing the steep slopes in the mid-slope position of Place Creek. Deposition from mass wasting events is anticipated to occur along the fan deposit indicated in this image.

Figure 33. Viewing flood deposits along the upper BC Hydro right-of-way. Landslides occurring upslope of this area are anticipated to deposit along or upslope of the BC Hydro right-of-way (right); however deposits may transport further through flood processes.

Based on observations made during the aerial assessment, the threat to the public's safety from a direct landslide impact is relatively low. However, landslide frequency is likely increased from pre-Event conditions due to stream bank undercutting that is actively occurring. Landslide deposits are anticipated to contribute further to debris flood hazard downstream.

Further debris flow modelling is required to quantify the frequency and runout susceptibility of landslides in the area. Recommendations to address long-term landslide threats are provided in Section 4 below.

4 Summary and Recommendations

Following the Event that occurred on July 21, 2024 the new Place Creek alignment now conveys flow into Gates Lake rather than the pre-Event alignment towards Poole Creek. Properties around Gates Lake and along Gates River downstream of Gates Lake experienced overland flooding and shoreline erosion in the immediate response to the Event. Immediate overland flooding from Place Creek within properties along the south-west end of Gates Lake has been temporarily mitigated by the implementation of emergency works; however, flooding still persists at 9234 Pemberton Portage Rd and the drainage ditch conveying all of the Place Creek flow is at capacity.

The Gates Lake water level remains high and has fluctuated in response to low magnitude rainfall events, exacerbating shoreline erosion from waves and flooding crawl spaces within homes.

The potential for further avulsions along the new alignment of Place Creek increases the potential for further debris flood events to occur and further retrograding of the grade change within the channel up to the avulsion location threatens to leave the previous Place Creek alignment perched and no longer conveying any portion of flow.

The emergency works implemented along 9102 Pemberton Portage Rd. is a temporary structure with the sole purpose of alleviating immediate overland flooding hazards. It is not intended to be relied upon for longer term purposes (i.e. peak flows that generally occur in the fall) and has not been designed based on quantitative engineering analyses.

Based on these considerations, imminent more extreme rainfall events, and the absence of quantitative hazard analysis associated with how water levels within the new Place Creek channel, Gates Lake, and Gates River will respond to larger magnitude rainfall or glacier meltwater events, a sufficient flood hazard is posed to the properties around Gates Lake to warrant immediate mitigative actions be taken.

4.1 Mitigative Actions

4.1.1 Stream Alignment and Flood Hazard

One mitigative action that can be taken immediately is to realign Place Creek back into the previous, pre-Event alignment. This could be completed by implementing the following actions:

1. Clear an access route up the mountainous portion of the previous alignment from the BC Hydro ROW up to the avulsion point and divert all flow into the new alignment to allow further works within the previous alignment to proceed in the dry. If a qualified environmental professional would prefer some flow be maintained within the previous alignment while further work proceeds, the diversion of flow could be forgone.

2. Excavate a suitably sized channel along the previous alignment to convey the mean annual flow from the avulsion point down the mountainous slope and along the BC Hydro ROW to the location where flow is currently channelized.

3. Remove a sufficient volume of material from the LWD jams along the previous Place Creek alignment to mitigate the potential for obstructed flow to result in avulsions of the channel.

4. Divert all flow back into the enhanced, previous alignment and re-establish the pre-Event right channel embankment with available, onsite material to reduce the potential for further avulsions at this location.

To mitigate the imminent flood and debris flood hazards a formal engineering design will not be developed; rather, an accelerated, field-based channel modification based on a rudimentary hydrologic and channel capacity analyses will be developed. All works would need to be supervised by a qualified hydrotechnical engineer and monitored by a qualified environmental professional. When diverting flow back into the enhanced, previous alignment a gradual ramping of flow should be implemented to mitigate sediment releases into Poole Creek. Figure 34 presents a plan view and typical section of the proposed mitigative actions.

4.1.2 Geohazards

While glacial hazards posed a low threat to public safety at the time of this assessment, Stantec identified that glacial and landslide hazards have increased from pre-Event levels. Further investigation is recommended to quantify glacial hazards:

1. In the long term, flow monitor stations should be installed at the mouth of the lower glacial lake to monitor outflow to Place Creek. This will support flood mitigation and action response for future events.

2. Annual inspections of the Place Glacier should be completed regularly. The intent of this monitoring would be to ensure unobstructed flow at the mouth of the lower lake and to identify impounded waters that may result in future outbreaks (as experienced during this event).

3. If obstructions or impounding water levels change from current conditions, further assessment of threat levels to public safety should be completed by a qualified professional.

4. Model landslide (debris flow) runout scenarios from slopes above residential structures affected by the Event.

4.1.3 Budget and Schedule

The following schedule is proposed to complete the suggested mitigative actions for stream alignment and flood hazard. The schedule and budget are based on consultation with the Active Mountain Contracting Ltd. (contractor that completed the emergency works, Aug 1 to 8).

- Receive permission to proceed from SLRD.
- 5 days to complete further assessment to determine mean annual flow, size excavation channel, and develop design drawings sufficient for the contractor to complete the works under supervision by a qualified hydrotechnical engineer.
- 1 day to clear the access route up to the avulsion location.
- 5 days to excavate the channel through the mountainous slope.
- 2 day to excavate the channel through the BC Hydro ROW.
- 2 days to re-establish the pre-Event embankment at avulsion location.
- 1 day to remove LWD jams.
- 2 days to deactivate access route.
- 2 days for equipment breakdowns or unforeseen delays.

This schedule assumes one 21 Tonnes and one 30 Tonnes excavators are conducting the works. Activities associated with contractor mobilisation of equipment and clearing of the access route can proceed while the design drawings are being developed.

The budget to complete the rudimentary hydrotechnical analyses and develop a typical section to be used for excavation of the channel and re-establishment of the pre-Event embankment is $29,945 (exclusive of applicable taxes) – a detailed breakdown is presented in Appendix A. This budget does not include hydraulic modelling, collection of survey, environmental services associated with the development or application of required environmental permits. It is assumed that all non-hydrotechnical engineering services will be coordinated by SLRD.

The Class D (+-50%) opinion of probable cost to complete the construction activities (including engineering and environmental monitoring) is $265,500 (exclusive of applicable taxes) – a detailed breakdown is presented in Appendix A. Hourly rates for excavation and labourers was provided by Active Mountain Contracting Ltd. Hourly rates to complete environmental monitoring were provided by Cascade Environmental Resource Group.

The provided budget and opinion of probable cost are for information and planning purposes – they do not form a formal contract and may be subject to change. It is assume that construction administration tasks will be coordinated by SLRD.

5 Limitations

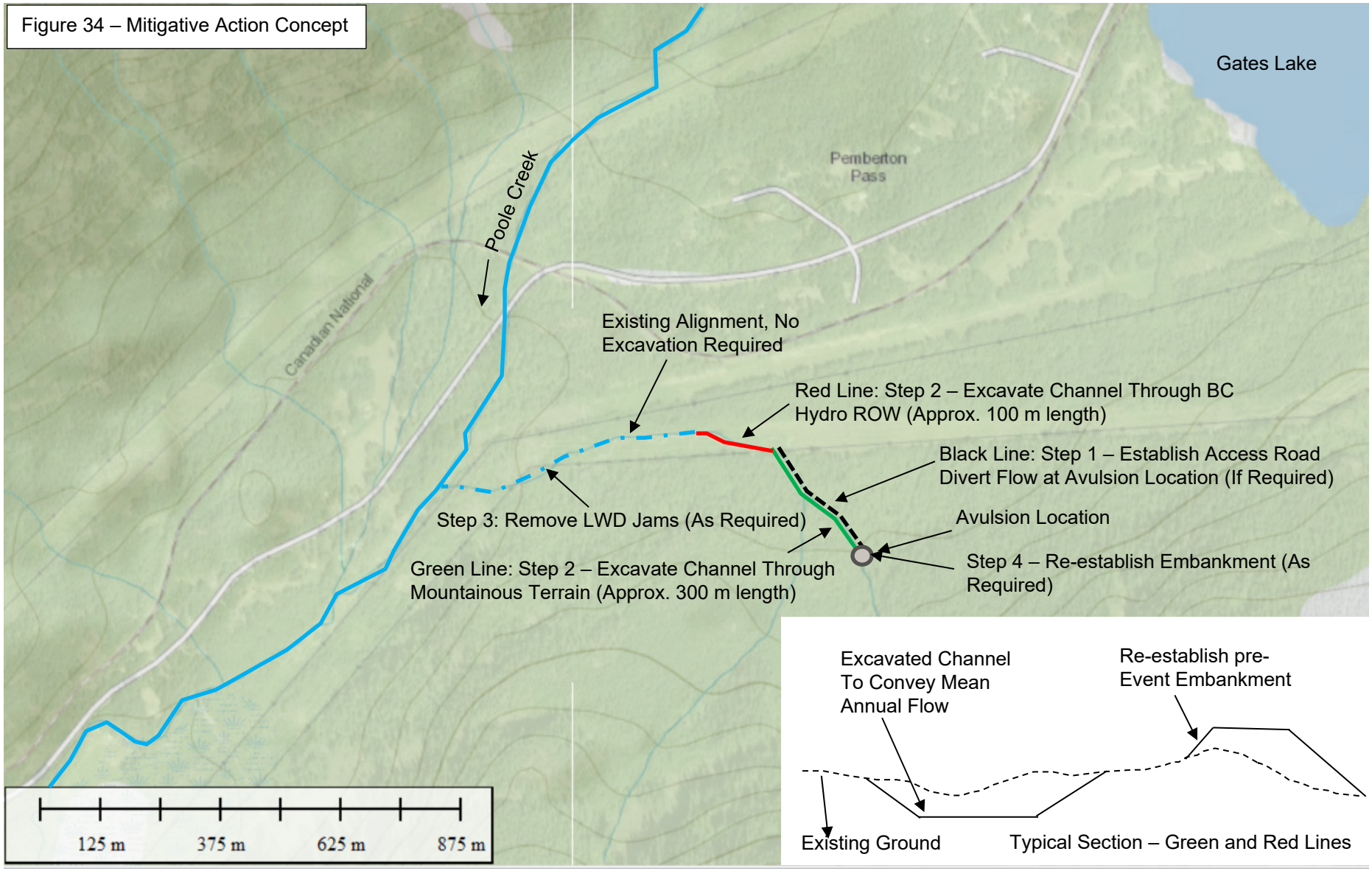
The assessment of flood and debris flood hazards presented in this memo are based solely on visual observations collected during various site visits conducted by Stantec – they form a qualitative assessment of hazards posed to properties within the subject area detailed within the body of this memo. No quantitative analyses or assessments of flood and debris flood hazards have been completed to form the basis of the findings, recommendations, and suggested mitigative actions detailed within the memo.

The geohazard assessment described in this report is largely constrained by observations made from the helicopter survey and supplementing information available to the assessor. It is possible for conditions to rapidly change from the time of the inspection, ultimately leading to varied hazard conditions. As well, visibility of some geologic features may be obscured during the aerial assessments, such as tree canopy cover or flight elevation constraints. Stantec takes these considerations into account when assigning hazard and threat levels, however, it is possible that re-evaluation of threat levels is required if new conditions arise or evidence is presented.

The intent of the suggested mitigative action provided in this memo is to alleviate the immediate debris flood and flood hazards posed to the properties around Gates Lake and portion of Gates River immediately downstream of Gates Lake prior to the imminent extreme rainfall events generally experienced in the fall. The concept incorporates re-establishing the pre-Event embankment – the purpose of this is to reduce the potential for another avulsion event to occur in the immediate future. Due to the location, physiography, and geography Place Creek will likely continue to be prone to avulsion and lateral migration, if left unmitigated. Implementing a engineer designed structure could provide long-term protection from similar events. Detailed monitoring of Place Creek conditions and evaluating potential frequency and associated risk further outbursts from the glacial lake perched on Place Glacier poses to the public is recommended.

Reference: **Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment**

Figure 34 – Mitigative Action Concept



Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

6 Closure

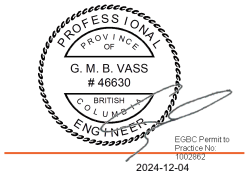
This report was prepared for the exclusive use of the Squamish-Lillooet Regional District for specific application to the Gates Lake Debris Flood and Flood Preliminary Hazard Assessment project. Use of this report is subject to the Statement of General Conditions included in Appendix B. It is the responsibility of Squamish-Lillooet Regional District, who is identified as “the Client” within the Statement of General Conditions, to review the conditions and notify Stantec should any of them not be satisfied.

The majority of this report was prepared by Graeme Vass (Peng.), supported by Ducan McTaggart (M.Sc.). Section 3.2 and accompanying geohazard recommendations in Section 4.1.2 were completed by Graham Knibbs (P.Geo.). This report was reviewed by Jeff Muirhead (P.Eng.) and Richard Guthrie (Ph.D., P.Geo.).

We trust that this report meets your present requirements. If you have any questions or require additional information, please contact the undersigned.

Regards,

STANTEC CONSULTING LTD.



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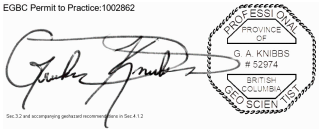

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Attachment: Appendix A

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Appendix A

Detailed Breakdown of Budget and Opinion of Probable Cost

FEE ESTIMATE - Gates Lake Mitigative Actions Analyses Typical Section

Name	FRD (Percentage)	PM and Hydrotechnical Lead	Senior Review - Geomorphology	Hydrotechnal Support	Geoscientist	Hydrotechnical Senior Review	GIS	CAD	Admin Support
Project Billing Rate (T&M)	6.00%	$211.00	$247.00	$169.00	$194.00	$211.00	$158.00	$169.00	$163.00
Total Units (T&M)	154.00	34.00	8.00	60.00	8.00	2.00	8.00	30.00	4.00
Fee (T&M)	$1,695.00	$7,174.00	$1,976.00	$10,140.00	$1,552.00	$422.00	$1,264.00	$5,070.00	$652.00

Summary			
Hours	**Labour**	**FRD**	**Total**
154	$28,250.00	$1,695.00	**$29,945.00**

WBS Code	Task Name	Units								Hours	Labour	FRD	Total
1	**Project Management**									**20**	**$4,028.00**	**$241.68**	**$4,269.68**
1.1	Meetings	6	6							6	$1,266.00	$75.96	$1,341.96
1.2	Administration	14	10						4	14	$2,762.00	$165.72	$2,927.72
2	**Mitigative Action Design**									**134**	**$24,222.00**	**$1,453.32**	**$25,675.32**
2.1	Hydrologic Analysis	24		4	20					24	$4,368.00	$262.08	$4,630.08
2.2	Channel Capacity Analysis and Typical Section	78	10	4	20	4	2	8	30	78	$14,010.00	$840.60	$14,850.60
2.3	Reporting	32	8		20	4				32	$5,844.00	$350.64	$6,194.64

Opinion of Probable Cost Breakdown

SLRD - Gates Lake Flood Mitigative Works

Class D Opinion of Probable Cost

Schedule of Approximate Quantities and Unit Prices

Project No: 111700815

Project Name: SLRD - Gates Lake Flood Mitigative Works

TOTAL CONSTRUCTION AND ENGINEERING AND ENVIRONMENTAL SUPERVISION COST ESTIMATES

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
0	**PART A - CONSTRUCTION COST ESTIMATE**				
01	**SECTION 1 - GENERAL**				
01.01	Mobilization	L.S.	1	$1,200	$1,200
01.02	Establish Access Route - 1 x 210, 1 x 300 Excavator and 1 labourer	Hour(s)	10	$565	$5,650
01.03	Engineering Construction Supervision	Hour(s)	10	$195	$1,950
01.04	Environmental Monitor	Hour(s)	540	$33	$17,820
				SubTotal	**$26,600**
02	**SECTION 2 - EXCAVATION OF CHANNEL (GREEN LINE)**				
02.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	50	$565	$28,250
02.02	Labourer	Hour(s)	50	$75	$3,750
02.03	Engineering Construction Supervision	Hour(s)	50	$195	$9,750
02.04	Environmental Monitor	Hour(s)	50	$150	$7,500
				SubTotal	**$49,300**
03	**SECTION 3 - EXCAVATION OF CHANNEL (RED LINE)**				
03.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	20	$565	$11,300
	Labourer	Hour(s)	20	$75	$1,500
03.02	Engineering Construction Supervision	Hour(s)	20	$195	$3,900
03.03	Environmental Monitor	Hour(s)	20	$150	$3,000
				SubTotal	**$19,700**
04	**SECTION 4 - CLEAR LWD JAMS**				
04.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	10	$565	$5,650
	Labourer	Hour(s)	10	$75	$750
04.02	Engineering Construction Supervision	Hour(s)	10	$195	$1,950
04.03	Environmental Monitor	Hour(s)	10	$150	$1,500
				SubTotal	**$9,900**
05	**SECTION 5 - RE-ESTABLISH EMBANKMENT**				
05.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	20	$565	$11,300
	Labourer	Hour(s)	20	$75	$1,500
05.02	Engineering Construction Supervision	Hour(s)	20	$195	$3,900
05.03	Environmental Monitor	Hour(s)	20	$150	$3,000
				SubTotal	**$19,700**
06	**SECTION 6 - SITE CLOSURE**				
06.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	20	$565	$11,300
60.02	Labourer	Hour(s)	20	$75	$1,500
06.03	Engineering Construction Supervision	Hour(s)	20	$195	$3,900
06.04	Environmental Monitor	Hour(s)	20	$150	$3,000
				SubTotal	**$19,700**
07	**SECTION 7 - ADDITIONAL DAYS FOR EQUIPMENT BREAKDOWN UNFORSEEN ISSUES**				
07.01	Excavate - 1 x 210, 1 x 300 Excavator	Hour(s)	20	$565	$11,300
07.02	Labourer	Hour(s)	20	$75	$1,500
07.03	Engineering Construction Supervision	Hour(s)	20	$195	$3,900
07.04	Environmental Monitor	Hour(s)	20	$150	$3,000
SubTotal					**$19,700**
				Part A - SubTotal	**$164,600**
	PART B - Enginering and Environmental Expenses				
08	**SECTTION 8 - EXPENSES**				
17.01	Mileage	Each	5100	$0.70	$3,570
17.02	Hotel - Pemberton Valley Inn	Each	14	$300.00	$4,200
17.03	Per Diem	Each	15	$50.00	$750
17.04	Record Survey	L.S.	1	L.S.	$20,000
17.05	Completion Report	L.S.	1	L.S.	$5,000
				SubTotal	**$33,500**

Item#	Description of Work	Unit of Measure	Approx. Quantity	Unit Price	Extended Amount
18.02	Construction Cost Estimate Including Environmental and Engineering Supervision	L.S.	1	L.S.	$164,600
18.03	Engineering and Environemtnal Expenses (Part B)	L.S.	1	L.S.	$33,500
				SubTotal	**$198,100**
	PART C - CONTINGENCY				
	Class D (+50%)				**$99,050**
				Total Construction Cost (Part A+ Part B + Part C)	**$297,150**

Reference: Gates Lake Flood, Debris Flood, and Geohazard Preliminary Hazard Assessment

Appendix B

Statement of General Conditions

Stantec

STATEMENT OF GENERAL CONDITIONS

USE OF THIS REPORT: This professional work product ("hereinafter referred to as the Report") has been prepared for the sole benefit of the Client in accordance with Stantec's contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance, or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

BASIS OF THIS REPORT: This Report relates solely to the site-specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The information, opinions, conclusions and/or recommendations made in this Report are in accordance with Stantec's present understanding of the site-specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time the scope of work was conducted and do not take into account any subsequent changes. If the proposed site-specific project differs or is modified from what is described in this Report or if the site conditions are altered, this Report is no longer valid unless Stantec is requested by the Client to review and revise the Report to reflect the differing or modified project specifics and/or the altered site conditions. This Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose or site, and any unauthorized use or reliance is at the recipient's own risk.

STANDARD OF CARE: Preparation of this Report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

PROVIDED INFORMATION: Stantec has assumed all information received from the Client and third parties in the preparation of this Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this Report are based on site conditions encountered by Stantec at the time of the scope of work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behaviour. Extrapolation of in-situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this Report or encountered at the test and/or sample locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the Report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or subsurface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec geotechnical engineers, sufficiently ahead of initiating the next project stage (e.g., property acquisition, tender, construction, etc.), to confirm that this Report completely addresses the elaborated project specifics and that the contents of this Report have been properly interpreted. Specialty quality assurance services (e.g., field observations and testing) during construction are a necessary part of the evaluation of subsurface conditions and site work. Site work relating to the recommendations included in this Report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.