Appendix O Shallow Bay Conceptual Flood Mitigation Design Options

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

O.1 Existing Conditions

The existing conditions presented in this section provide a brief summary of characteristics of the Study Area that are pertinent to the development of mitigation options and their evaluation. The contents of this section are not a comprehensive review of all existing conditions for Shallow Bay.

O.1.1 POPULATION

Census data specific to Shallow Bay was not available.

O.1.2 STUDY AREA

The Study Area in Figure O2 outlines the areas that are being considered in this Project at Shallow Bay. The boundaries of the Study Area are based on Stantec's understanding that the flood mitigations are to be designed for communities, and that individual properties outside of the main community consolidation are not included.

O.1.3 FIRST NATIONS

The Shallow Bay area is within the Traditional Territories of the Ta'an Kwäch'än Council (TKC) and Kwanlin Dün First Nation (KDFN). The TKC has parcels of Category A and B Settlement Lands in the Shallow Bay area, along Lake Laberge. The land claim selection is R-12A, R-23B, and S-187 B1. This means that TKC has surface and subsurface ownership of the Category A parcels and surface ownership of the Category B parcels of land (Government of Yukon 2022). Figure O2 illustrates the TKC and KDFN settlement lands within the Study Area.

O.1.4 BATHYMETRY AND TOPOGRAPHY

The following data sources were provided to or obtained by Stantec:

- 2022 LiDAR LAS files UTM Zone 8 CSRS NAD1983, CGVD2013 (McElhanney Ltd, GeoYukon 2023) and interpolated into a derivative 1m horizontal resolution Digital Elevation Model (DEM) (Government of Yukon 2022e).

All elevations are reported in CGVD2013. The LiDAR accuracy is assumed to be sufficient for the preliminary flood inundation analysis and conceptual design presented in this Report. There is insufficient metadata to determine whether the LiDAR meets the base requirement in terms of accuracy or precision for flood mapping per NRCan (2022b).

O.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Study Area likely consists of undivided pre-quaternary glaciolacustrine deposits. Glaciolacustrine sediments likely found in the Study Area likely consist of lakebed sediments of stratified fine sand, silt and/or clay and moderately sorted to well sorted sand and coarser beach sediment that were transported and deposited by wave action along the margins of the glacial lake. Slump structures and associated hummocky, kettled and irregular terrain, such as that seen at Shallow Bay, is common in and along the margins of a glacially fed lake and are caused by the collapse of material due to melting ice.

Based on the Permafrost Probability Model (Bonnaventure et al. 2012), the Study Area is located within a region of sporadic discontinuous permafrost (20-30% of land underlain by permafrost). The Canada Permafrost Map (National Atlas of Canada 1995) also indicates the Study Area is in a region of sporadic discontinuous permafrost (20-30% of land underlain by permafrost) with a low (<10% by volume of visible ice) ground ice content in the upper 10-20 m of the ground.

O.1.6 HYDROGEOLOGY

The sand, silt and/or clay and sorted sand and beach gravel encountered within the Study Area are likely to result in relatively medium to fast rates of groundwater flow. The deposits encompassing most of the shoreline are likely to result in a groundwater table that would be highly dependent on the Lake Laberge water levels. During flooding, the high-water levels would result in high groundwater levels and after flood waters recede, it is likely that the groundwater levels would recede relatively quickly based on the permeability of the soil conditions in the area.

Based on the anticipated soils at this site, the need for seepage control measures (i.e., seepage cut-off below flood mitigation option, toe drains, sump pits and pumping, etc.) may be required for the proposed flood mitigation options and should be further evaluated in preliminary and detailed design.

O.1.7 PAST FLOODING EVENTS AND RESPONSE

A summary of formally documented flood events are provided below. The flood events summarized below do no represent a comprehensive review of flooding history in the Study Area; rather, they are a summary of the flooding documentation provided to Stantec at the time of writing. Historical water surface elevations (WSEs) at Water Survey of Canada 09AB010 (Lake Laberge near Whitehorse) are illustrated in Figure O1.

2021 Flood Event

In 2021, Shallow Bay on Lake Laberge experienced high lake levels that affected shoreline properties. The summer peak was caused by high flows from the Southern Lakes and Kusawa Lake, through the Takhini River. During the flood in 2021, the local government organization provided the community with sand and sandbags to protect their private properties. Property owners also installed their own sump and pumping systems. WSC Station 09AB010 reported a peak instantaneous WSE of 628.00 m (at the WSC station) on July 15, 2021 (GoC 2023).

O.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

Shallow Bay currently has no existing permanent flood mitigation infrastructure documented within the Study Area.

O.1.9 WIND, WAVES, AND EROSION

The low flow velocities at Lake Laberge are not expected to introduce erosion risks to flood mitigations. Erosion protection from riverine flow velocities is not anticipated to be required as Shallow Bay flood mitigations.

As a lake community, Shallow Bay is affected by erosion due to wind and waves. Flood mitigations would need to be capable of withstanding not only the erosion potential from wind and waves, but higher WSEs due to wave runup and potential lake seiche.

O.1.10 HYDROLOGY

Lake Laberge is the major water feature at Shallow Bay (Figure O2), and is the waterbody which causes flooding in this community. Lake Laberge is a widening of the Yukon River located approximately 25 km north (downstream) of Whitehorse. The Takhini River discharges into the Yukon River between Whitehorse and Lake Laberge. This means water levels in Lake Laberge are influenced by Yukon River flows through Whitehorse (controlled by the Whitehorse Dam and/or Miles Canyon) and flows in the Takhini River.

WSC Station 09AB010 Lake Laberge near Whitehorse is located on the west of Lake Laberge and Richthofen Island (Figure O2). Gross drainage area to WSC Station 09AB010 is not reported by GoC (2023). The hydrology review considered WSEs at WSC Station 09AB010. Flood frequency analysis for WSEs was performed by both Morrison Hershfield (2022) and Yukon University (2022) for WSEs at WSC Station 09AB010. Table O1 summarizes the frequency results of these two studies.

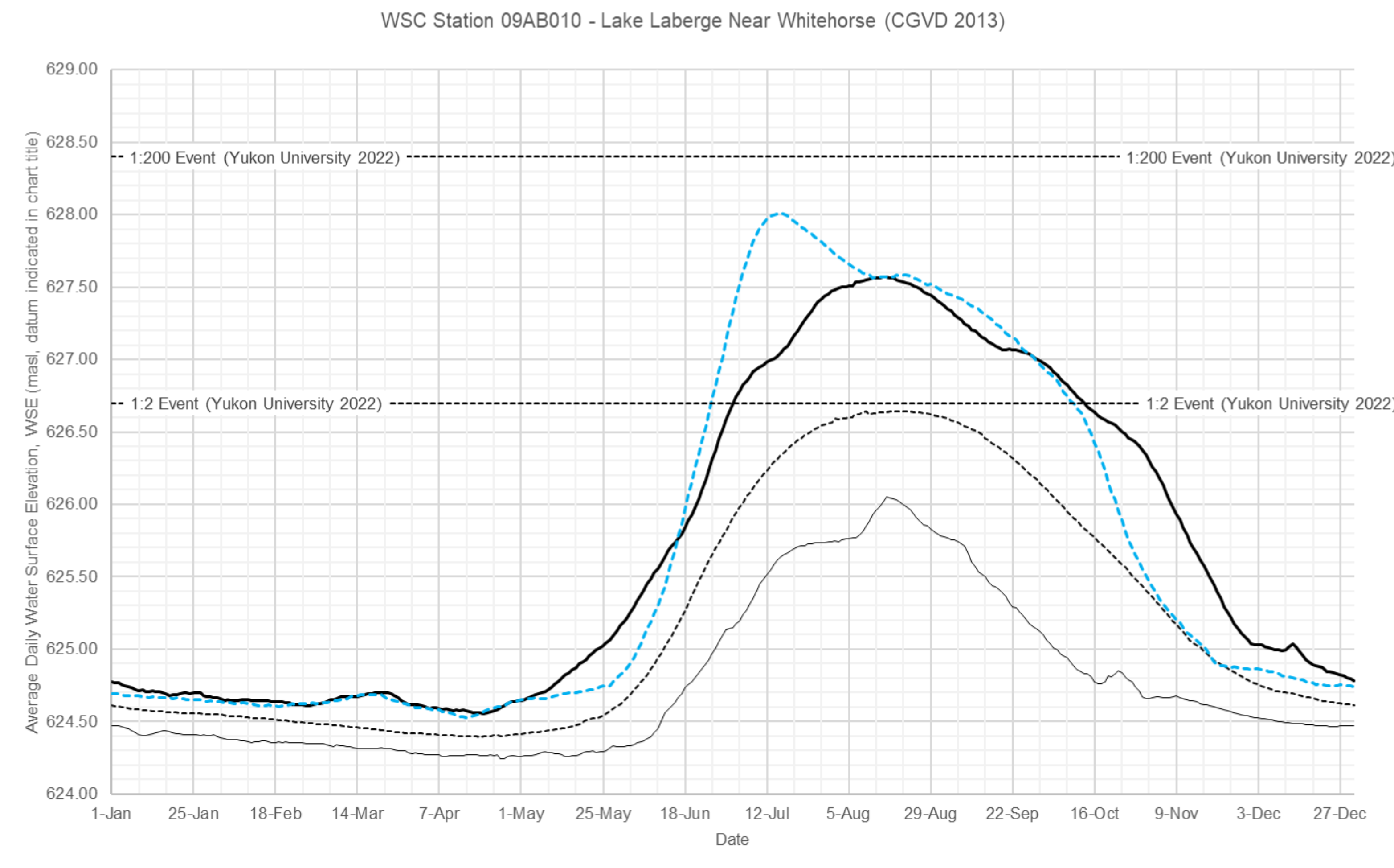
Table O1 Flood Frequency Analyses at WSC Station 09AB010 from Morrison Hershfield (2022) and Yukon University (2022)

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1980-2022	1970-2022
Number of Years	43	53
Selected Distribution	GEV	Gumbel
Water Surface Elevation (m) [1]		
1:2 Event (50% AEP)	626.70	626.70
1:20 Event (5% AEP)	627.51	627.60
1:100 Event (1% AEP)	627.96	not provided
1:200 Event (0.5% AEP)	628.14	628.40

Note:
[1] Elevations provided in CGVD2013 for WSC Station 09AB010

The Yukon University (2022) flood frequency analysis results were adopted for the Project because the 1:200-year event WSE was higher and would yield more conservative designs.

Figure O1 illustrates the on-record daily minimum, mean, and maximum WSEs, the WSE during the highest year on record (2021), and the WSEs for the 1:2-year and 1:200-year event at WSC Station 09AB010 from Yukon University (2022). WSEs do not include wave runup which could be affected by wind, its direction, intensity, duration, and the beach profile. Normally, high outflows from Marsh Lake and Kusawa Lake (through the Takhini River) cause the summer peaks. During the peak water level in 2021, associated with a 1:50-year return period, the Takhini River supplied about 25% of the total Lake Laberge inflow; this ratio was suspected to be even higher in 2022 (Yukon University 2022).



Notes:
1. *"On-Record" data is from WSC records during the following period: 1980-1989; 1992; 1995-2020*
2. *Any data post-2020 that is shown on this plot are preliminary data from the WSC hydrometric station. Quality assurance and verification of these data have not been completed by WSC or by Stantec.*
3. *Flood frequency WSEs shown on this plot are from Morrison Hershfield (2022) and are based on the historical period of record for the WSC Station as outlined in Morrison Hershfield (2022). Quality assurance and verification of these flood frequency WSEs have not been completed by Stantec.*

Figure O1 Historical Water Surface Elevations at WSC 09AB010 (Lake Laberge near Whitehorse)

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

O.1.11 PRELIMINARY INUNDATION MAPPING

Floodplain mapping and the associated flood policy is ultimately what is required for design and implementation of flood mitigations at communities. Wind/wave analysis and floodplain mapping have not been completed to date for the Study Area and is beyond the scope of this Project. However, an understanding of inundation extents under the 1:200-year event is required for conceptual design of flood mitigations.

In lieu of floodplain mapping, Stantec performed preliminary existing conditions (no mitigation) inundation analysis for Shallow Bay using WSEs. This analysis considered the 1:200-year WSE (628.40 m) developed by Yukon University (2022) in a flat-water inundation scenario. The resulting water surface was overlain on the existing conditions topographic/bathymetric elevation data (GeoYukon 2023) and the limits of inundation were mapped (Figure O2). The inundation analysis performed herein is provided for information only and is considered a high-level estimate of the flood inundation under the 1:200-year WSE from Yukon University (2022). The preliminary inundation analysis does not take into account flow pathways and blockages. That is, if the land in a given location is below the 1:200 WSE surface, it presents as inundated whether or not there is an overland flow path for the water to arrive there.

Three properties along Shallow Bay Road are inundated in the preliminary inundation mapping. The inundation encroaches on private residential properly solely along Shallow Bay Road.

Figure No.

O2

Title

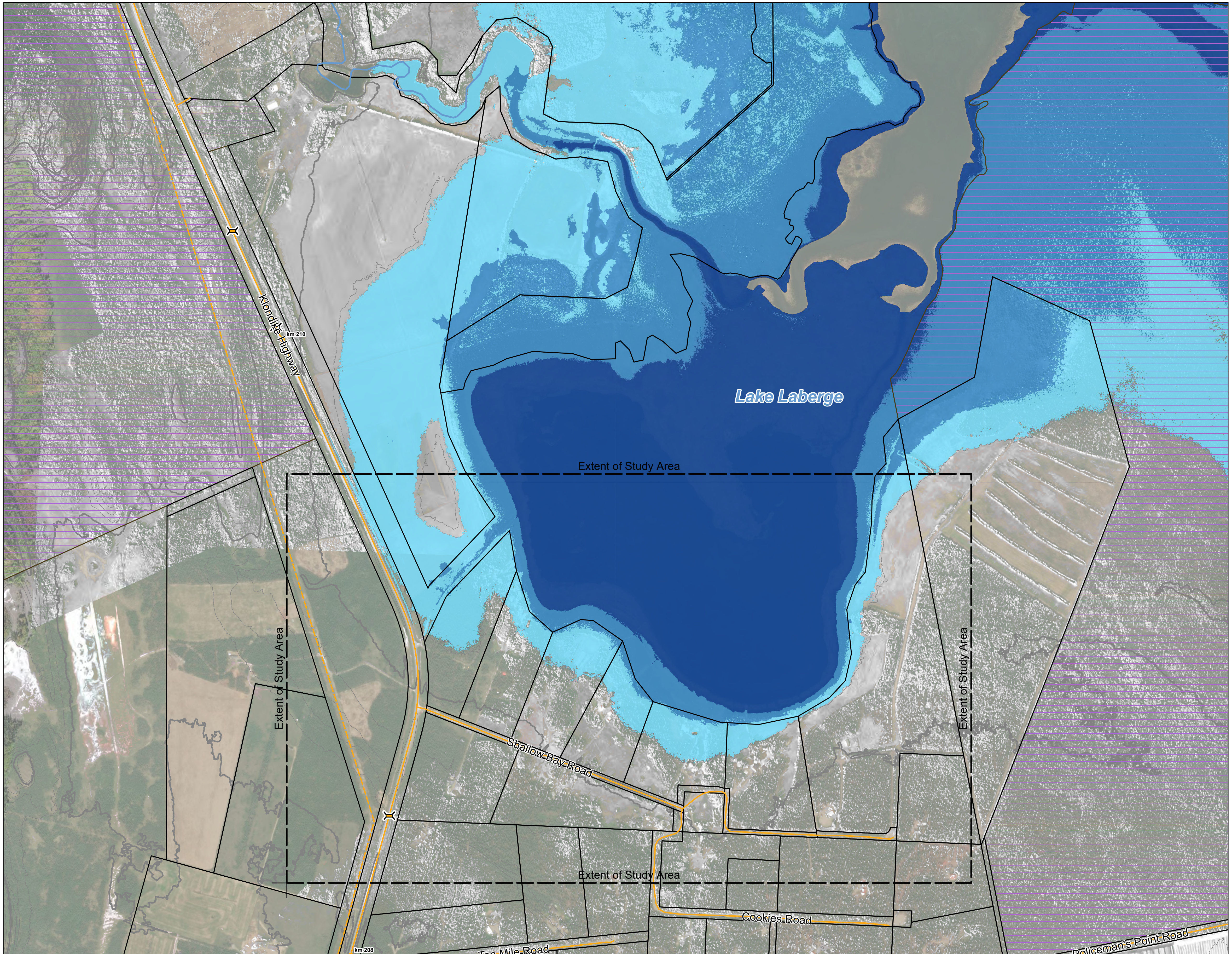
Existing Conditions and Preliminary Flood Inundation at Shallow Bay

Client/Project 144903232

Government of Yukon
Community Services | Infrastructure Development Branch
Yukon Territory Flood Mitigation Conceptual Design Options

Project Location
Shallow Bay,
Yukon

Prepared by LLT on 2023-05-08
TR by JD on 2023-05-08



N

0 50 100 150 200 m

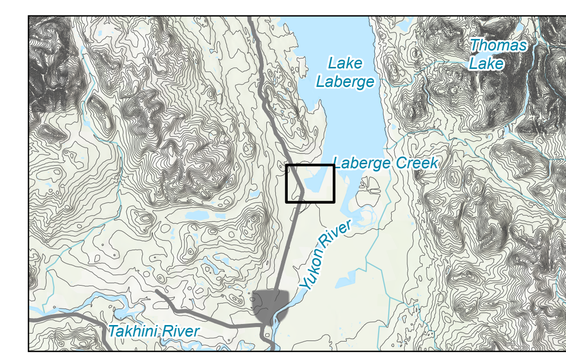
(At original document size of 11x17)
1:12,000

- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Powerline
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed

Water Depth at 1:200 WSE Inundation (m)

- 0 - 1
- 1 - 2
- > 2

The preliminary inundation analysis does not take into account flow pathways and blockages. That is, if the land in a given location is below the 1:200 WSE surface, it presents as inundated whether or not there is an overland flow path for the water to arrive there.



Notes

1. Coordinate System: NAD 1983 Yukon Albers
2. Data Sources: Government of Yukon; Government of Canada
3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

S:\1232\projects\144903232\figures\reports\YukonWide\YukonWideFigures.aprx Revised: 2023-07-04 By: LTrudell

O.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Shallow Bay are presented in this section. Non-engineered options presented in Section 3.3.1 of the main body of this Report (emergency response-based, mitigation funding to property owners, land purchase/exchange, regulation of flow, management of ice, nature-based approaches) should be considered as part of a comprehensive approach to flood mitigation in the Yukon.

Based on the objectives and assumptions presented in the main body of this Report, one flood mitigation option was developed for Shallow Bay (Table O2) using a typical engineered flood mitigation design from Section 3.3.2. Flood mitigations in the option are provided for areas which are inundated under the 1:200-year WSE (628.40 m) in the preliminary inundation mapping (Figure O2). The top elevation of the flood mitigations is designed to reach the DFSL which in the case of Shallow Bay (lake site) is assumed to be 630.40 m (i.e., 2.0 m above the 1:200-year WSE as outlined for lake sites in Section 3.2).

Areas which are above the 1:200-year WSE in the preliminary inundation analysis but below the DFSL are not included in this Project. These areas may need to be included in future design advancements depending on the requirements of future territorial flood policy.

Table O2 Summary of Conceptual Design Options

Location	Option 1 *lower capital costs, higher response/maintenance*
Private Properties on Shallow Bay Road	Temporary Sandbag Dikes

Section O.2.1 provides a description, Class D cost estimate, and qualitative evaluation of conceptual options specified in Table O2.

Other engineered flood mitigation approaches may have merit but would require additional study and design efforts.

O.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure O3 Shallow Bay Conceptual Flood Mitigation Design – Option 1

There are three (3) private properties along Shallow Bay Road that have structures which are inundated under the preliminary analysis. These three properties would require temporary sandbag dikes around the structures during flood conditions. The depth of flooding around these properties is less than 1 m meaning the temporary sandbags would be up to 3 m high to meet the DFSL. The total length of temporary sandbag dikes would be approximately 720 m.

Figure No.

O3

Title

Shallow Bay Conceptual Flood Mitigation Design - Option 1

Client/Project 144903232

Government of Yukon
Community Services | Infrastructure Development Branch
Yukon Territory Flood Mitigation Conceptual Design Options

Project Location
Shallow Bay,
Yukon

Prepared by LLT on 2023-04-11
TR by JM on 2023-04-11

N

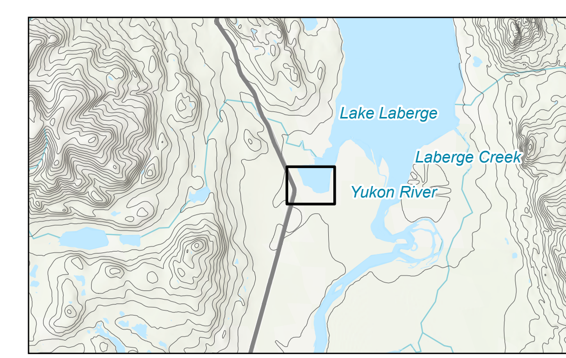
0 50 100 150 200 m
(At original document size of 11x17)
1:30,000

- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Powerline
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed

Proposed Mitigation Feature

- Earthen Dike
- Platform with Temporary Superbag Dike
- Road Raising
- Structural Dike
- Temporary Sandbag Dike

CONCEPTUAL DESIGN
This document is for general information only and is not for permits, tendering, or construction.



Notes
1. Coordinate System: NAD 1983 Yukon Albers
2. Data Sources: Government of Yukon; Government of Canada
3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

Stantec Yukon

Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table O3, considering the Class D level of accuracy (+/-50%). Table O3 also provides the Class D OPCs on a per inundated property basis (from Section O.1.11).

Table O3 Option 1 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section O.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	None	3	None
Annual Cost (Flood Year)	\$ 677,880 - \$ 1,016,820		\$ 225,960 - \$ 338,940
Annual Cost (Non-Flood Year)	\$ 672 - \$ 1,008		\$ 224 - \$ 336
[1] As described in Section O.1.11, the inundated properties from the preliminary inundation analysis consists of 3 private residential properties.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table O4 (annual cost, flood year) and Table O5 (annual cost, non-flood year)

Table O4 Option 1 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1A	**Option 1: Annual Costs, Flood Year**				
a)	Storage of Sandbags	LS	1	$500.00	$500.00
b)	Sandbags c/w Sandfill (2.0m - 3.0m)	M	725	$695.00	$503,875.00
				Total 1A	$504,375.00
				Contingency (20%)	$100,875.00
				Subtotal	$605,250.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost Flood Year Base Price	$677,880.00
				Annual Cost, Flood Year Upper Bound	$1,016,820.00

Table O5 Option 1 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1B	**Option 1: Annual Costs, Non-Flood Year**				
b)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 1B	$500.00
				Contingency (20%)	$100.00
				Subtotal	$600.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost, Non-Flood Year Base Price	$672.00
				Annual Cost, Non-Flood Year Upper Bound	$1,008.00

The contents of this appendix are subject to the project objectives, methods, assumptions, and limitations outlined in the main body of the Yukon Territory Flood Mitigation Conceptual Design Options report and in Appendix T.

Qualitative Evaluation

Table O6 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table O6 Option 1 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	temporary dikes may degrade under long duration of flooding (several weeks or months); wind/wave impacts would be mitigated by elevated DFSL and erosion mitigation measures however ice/debris damage from wave action is a risk for temporary superbag dikes; risk of vandalism and degradation risk increases with duration that the temporary dikes are deployed; seepage control measures likely required	Low Performance
2	Time to Implementation	no design or regulatory efforts required; minor effort required by organization to supply sandbags and earthen material to a central location; highly dependent on individual property owners to take on the responsibility of constructing the sandbag dikes on their private properties	High Performance
3	Capital Cost Per Inundated Property	No capital cost associated with this option.	High Performance
4	Maintenance and Storage	storage required for sandbags; stockpiling of material required for sandbags; maintenance needs for the sandbag dikes to be completed by private property owner	High Performance
5	Response and Activation	organization to provide sandbags and earthen material for private properties owners; property-owner deployed temporary sandbag dikes; temporary sandbag dikes require proper installation and a timely response in a flood scenario to be effective	Medium Performance
6	Aesthetics and Community Function	temporary alteration of private function and view during flood conditions from temporary sandbag dikes	Medium Performance
7	Future Adaptability	additional sandbags may be provided for raising temporary sandbag dikes;	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Lake Laberge are not anticipated to disrupt existing lake processes	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	low return on investment (ROI) for Option 1 given the number of affected properties and low capital cost	Low Performance

O.2.2 SUMMARY TABLES

Table O7 summarizes the Class D OPC for each of the conceptual design options.

Table O7 Summary of Class D OPCs

	Option 1 Class D OPCs
Capital Cost	None
Annual Cost (Flood Year)	$677,880 - $1,016,820
Annual Cost (Non-Flood Year)	$672 - $1,008

Table O8 provides a summary of the evaluation of each of the conceptual design options.

Table O8 Summary of Qualitative Evaluation of Conceptual Options

Criteria No.	Criteria Title	Option 1
1	Viability and Reliability under Extreme Conditions	Low Performance
2	Time to Implementation	High Performance
3	Capital Cost Per Inundated Property	High Performance
4	Maintenance and Storage	High Performance
5	Response and Activation	Medium Performance
6	Aesthetics and Community Function	Medium Performance
7	Future Adaptability	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	Low Performance