Appendix Q Deep Creek 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.

Q.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 Deep Creek.

Q.1.1 POPULATION

Census data specific to the Deep Creek was not available. Based on available aerial imagery, there are approximately 38 properties with structures on them within the Study Area.

Q.1.2 STUDY AREA

The Study Area in Figure Q2 outlines the areas that flood mitigations are being designed in this Project at Deep Creek. The boundaries of the Study Area are based on Stantec's understanding that the flood mitigations are to be considered for communities, and that individual properties outside of the main community consolidation are not included.

Q.1.3 FIRST NATIONS

The Deep Creek 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 B Settlement Lands and Fee Simple lands near Deep Creek, along Lake Laberge. The land claim selections are C-39FS/D and S-73B1. This means that TKC has surface ownership of these parcels of land (Government of Yukon 2022). Figure Q2 illustrates the TKC and KDFN settlement lands within the Study Area.

Q.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).

Q.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Study Area likely consists of a veneer of glacial deposits (Till), deposited directly by glacier ice without modification by any other agent of transportation. The till deposits are estimated to be between 10 cm to 1 m in thickness and are underlain by Pre-Quaternary Bedrock. The mineralogical, textural, structural, and topographic characteristics of till deposits are highly variable and depend upon both the source of material incorporated by the glacier and the mode of deposition. In general, till at the Study Area likely consists of well compacted to noncompacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, commonly in a matrix of sand, silt, and clay. The underlying bedrock consists of volcanic, volcaniclastic, clastic and carbonate rocks of the Lewes River Group (Upper Triassic); volcaniclastic, clastic and coal of the Laberge Group (Lower-Middle Jurassic); and clastics and coal of the Tantalus Formation (Upper-Lower Cretaceous; Wheeler, 1961; Lowey, 2005).

Based on the Permafrost Probability Model (Bonnaventure et al. 2012), the Study Area is located within a region of extensive discontinuous permafrost (80-90% of land area underlain by permafrost). The Canada Permafrost Map (National Atlas of Canada 1995) also indicates the Study Area is in a region of extensive discontinuous permafrost (50-90% of land area underlain by permafrost) with a low to medium (<10-20% by volume of visible ice) ground ice content in the upper 10-20 m of the ground.

Q.1.6 HYDROGEOLOGY

The veneer of till deposits with a matrix of sand, silt and clay and the underlying bedrock encountered within the Study Area are likely to result in relatively fast rates of groundwater flow. The deposits encompassing most of the shoreline are likely to result in a groundwater table that would be highly dependant 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.

Q.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 Q1.

2021 Flood Event

In 2021, Deep Creek 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 organizations provided the community with sand and sandbags to protect their private properties. Property owners also installed their own sump and pumping system. Many of the properties along Deep Creek were also affected by the high groundwater levels – flooding basements and causing slopes in their properties to fail. WSC Station 09AB010 reported a peak instantaneous WSE of 628.00 m (at the WSC station) on July 15, 2021 (GoC 2023).

Q.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

Deep Creek currently has no existing permanent flood mitigation infrastructure documented within the Study Area.

Q.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 at Deep Creek flood mitigations, because the extreme flooding at Deep Creek occurs from backwater from Lake Laberge and not river flows in Deep Creek itself.

While Deep Creek is generally considered part of the Lake Laberge communities, the properties at Deep Creek are along the creek itself and not on the main lake. Wind and waves are not anticipated to pose substantial erosion hazards to the flood mitigations at Deep Creek.

Q.1.10 HYDROLOGY

Deep Creek flows through the Deep Creek community, and discharges into Lake Laberge (Figure Q2). Although the Deep Creek watercourse may cause elevated water levels during runoff events, it is understood that elevated Lake Laberge WSEs result in more severe flood hazards than Deep Creek itself.

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 Q1). 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 Q1 summarizes the frequency results of these two studies.

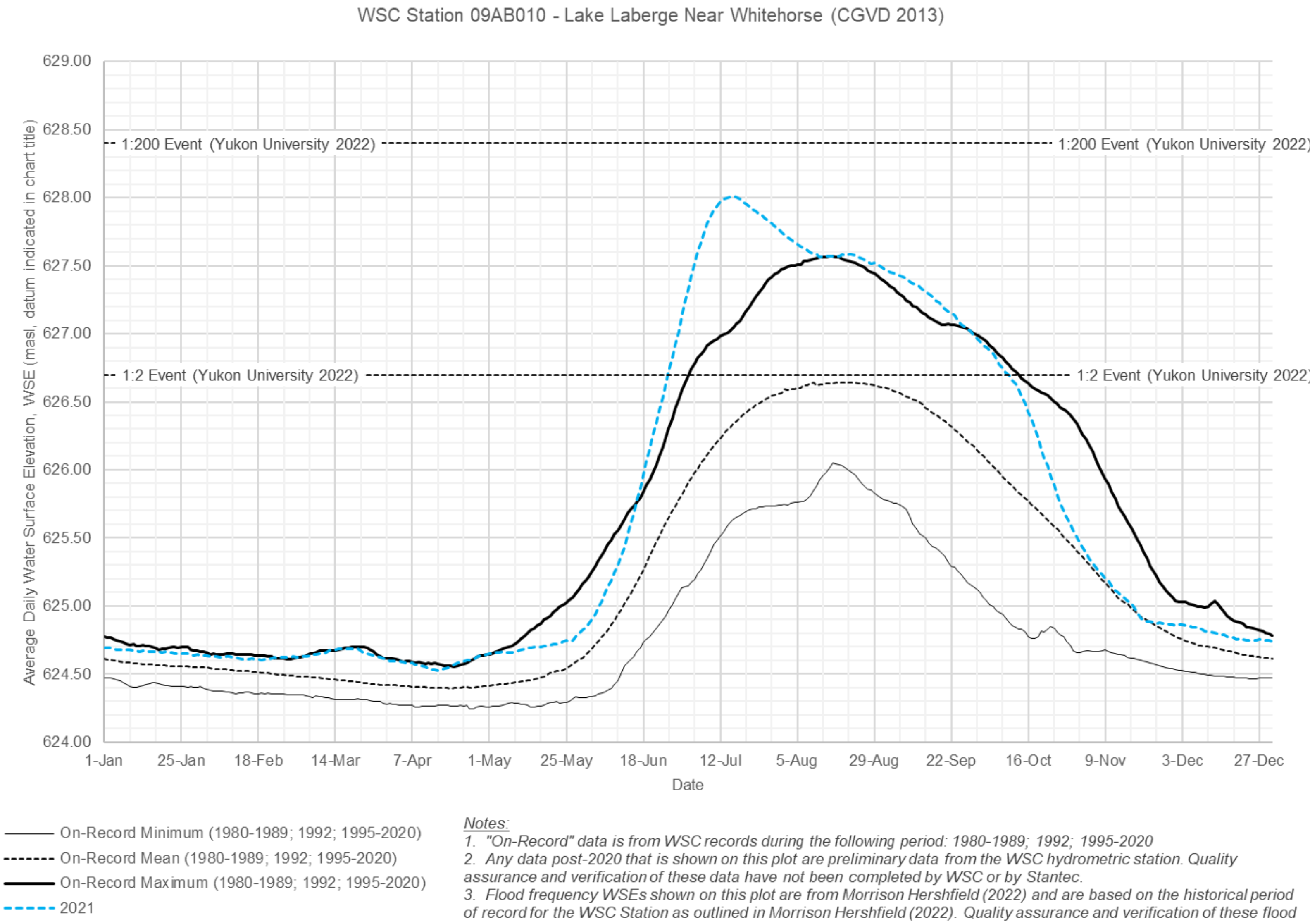
Table Q1 Flood Frequency Analyses at WSC Station 09AB010 from Morrison Hershfield (2022) and Yukon University (2022)

	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
[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 Q1 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). The mentioned water levels 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 50-year return period, the Takhini River supplied about 25% of the total Lake Laberge inflow; this ratio was 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 Q1 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.

Q.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 Deep Creek using WSEs from Lake Laberge. 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 Q2). 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.

Within the Study Area, the preliminary inundation results illustrates that approximately 15 private properties along Deep Creek South Road and Deep Creek Road would have inundated properties. A portion of Deep Creek South Road is also inundated (total of 16 inundated properties).

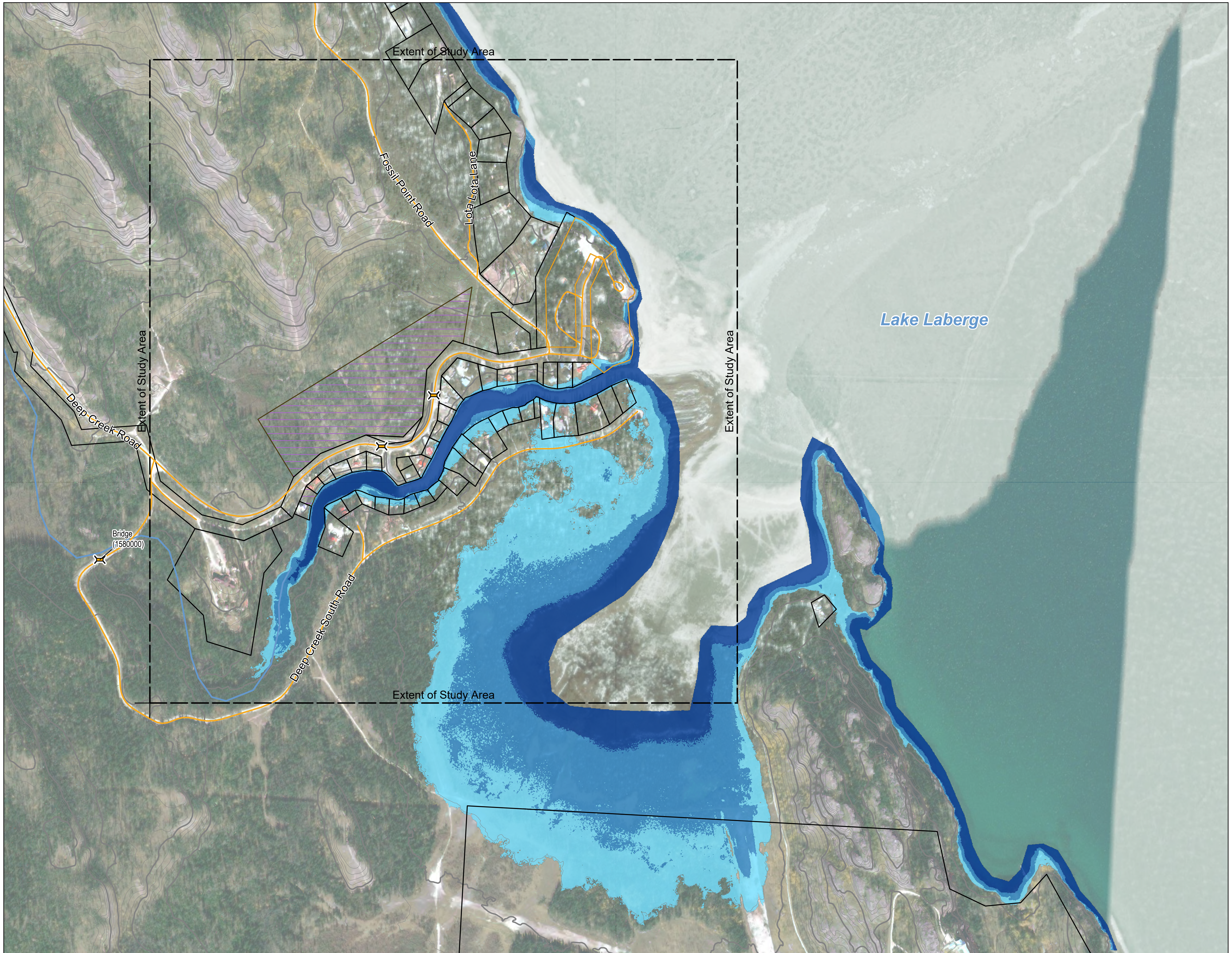


Figure No.

Q2

Title

Existing Conditions and Preliminary Flood Inundation at Deep Creek

Client/Project 144903232

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

Project Location
Deep Creek,
Yukon

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

N

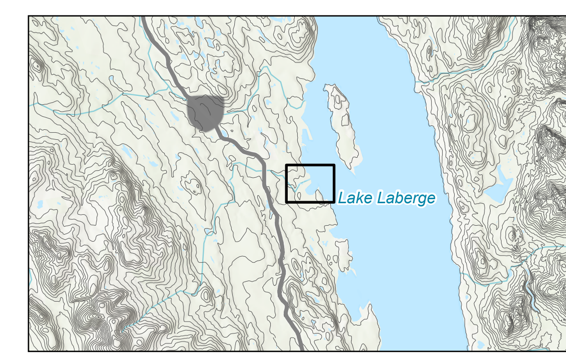
0 50 100 150 200 m
(At original document size of 11x17)
1:8,000

- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- 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

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Q.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Deep Creek 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, three flood mitigation options were developed for Deep Creek (Table P2) using typical engineered flood mitigation designs from Section 3.3.2. Flood mitigations in the options are provided for areas which are inundated under the 1:200-year WSE (628.40 m) in the preliminary inundation mapping (Figure P2). The top elevation of the flood mitigations is designed to reach the DFSL. In the case of Deep Creek, the DFSL is assumed to be 628.90 m (i.e., 0.5 m above the 1:200-year WSE as outlined for river sites in Section 3.2) because the community itself is located along a creek and wind/wave effects are anticipated to be minimal (as outlined in Section Q.1.9).

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 Q2 Summary of Conceptual Design Options

Location	Option 1 *lower capital costs, higher response/maintenance*	Option 2 *moderate capital cost, moderate response/maintenance*	Option 3 *higher capital costs, lower response/maintenance*
Private Properties on Deep Creek Road	Temporary Sandbag Dikes		
Private Properties on Deep Creek South Road	Temporary Sandbag Dikes		
Group of Private Properties on Deep Creek South Road	Temporary Sandbag Dike	Platform with Temporary Superbag Dike	Structural Dike
Deep Creek South Road	Platform with Temporary Superbag Dike	Road Raising	Road Raising

Sections Q.2.1, Q.2.2, and Q2.3 provide a description, Class D OPC, and qualitative evaluation of conceptual options specified in Table Q2.

Q.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure Q3.

There are 4 private properties along Deep Creek Road and 11 private properties along Deep Creek South Road that are located within area inundated under the preliminary analysis and would require a temporary sandbag dike around the structures during flood conditions. The depth of flooding around these properties is less than 1 m and as such can be protected with the construction of sandbag dikes. The temporary sandbags would be up to 1.5 m high to meet the DFSL with a total length of approximately 885 m.

As illustrated in the inundation mapping, approximately 180 m of the east end of Deep Creek South Road is inundated and requires flood mitigations. In order to reach the DFSL, a temporary double superbag dike would be constructed on the lake side of Deep Creek South Road. This would serve two purposes: i) to maintain access to properties along Deep Creek Road South and ii) act as a dike, preventing water from entering properties only the south property line. The creek side of the road may also need temporary superbag dikes in specific locations.

Figure No.

Q3

Title

Deep Creek 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
Deep Creek,
Yukon

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

N

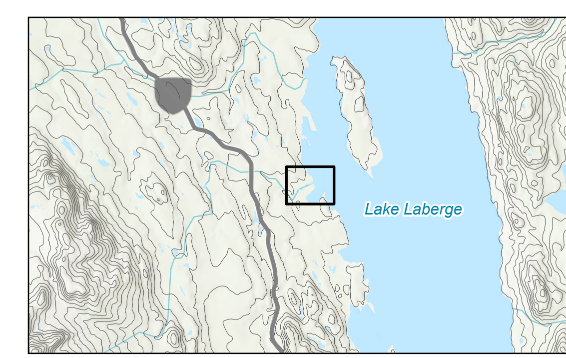
0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- 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
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3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table Q3, considering the Class D level of accuracy (+/-50%). Table Q3 also provides the Class D OPCs on a per inundated property basis (from Section Q.1.11).

Table Q3 Option 1 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section Q.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	None	16	None
Annual Cost (Flood Year)	$ 713,200 - $ 1,069,800		$ 44,575 - $ 66,863
Annual Cost (Non-Flood Year)	$ 700 - $ 1,050		$ 44 - $ 66

[1]As described in Section Q.1.11, the inundated properties from the preliminary inundation analysis consists of 15 private properties and a portion of Deep Creek Road.

The components assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table Q4 (annual cost, flood year) and Table Q5 (annual cost, non-flood year).

Table Q4 **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)	Inspections	LS	1	$50,000.00	$50,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$5,000.00	$5,000.00
c)	Storage of Sandbags and Superbags	LS	1	$500.00	$500.00
d)	Sandbags c/w Sandfill (1.0m - 2.0m)	M	830	$464.00	$385,120.00
e)	Superbags c/w Sandfill (1.0m - 2.0m)	M	180	$500.00	$90,000.00
				Total 1A	$530,620.00
				Contingency (20%)	$106,124.00
				Subtotal	$636,744.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost Flood Year Base Price	$713,200.00
				Annual Cost, Flood Year Upper Bound	$1,069,800.00

Table Q5 **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**				
a)	Storage of Sandbags and Superbags	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	$700.00
				Annual Cost, Non-Flood Year Upper Bound	$1,050.00

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 Q6 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table Q6 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	moderate anticipated construction effort; no design or regulatory efforts required for sandbag dikes on private properties;	High Performance
3	Capital Cost Per Inundated Property	No capital cost associated with this option.	High Performance
4	Maintenance and Storage	minimal storage requirements (sandbags and superbags for low number of temporary dikes);	Medium Performance
5	Response and Activation	organization to construct the superbag dike; organization to provide sandbags and earthen material for private property owners; 15 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; superbag dike will not affect aesthetics and community function	High Performance
7	Future Adaptability	additional sandbags may be provided for raising temporary sandbag dikes; demountables could be added to the road in the future, if needed	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	no anticipated alterations to existing hydraulics, erosion/sedimentation, ice processes and slope stability	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	low return on investment (ROI) given the private properties and access routes within the community that would be mitigated from flooding as a result of improvements	Low Performance

Q.2.2 OPTION 2

Description

The conceptual flood mitigations for Option 2 are illustrated in Figure Q4.

There are 4 private properties along Deep Creek Road and 3 private properties along Deep Creek South Road that are located within areas inundated under the preliminary analysis and would require a temporary sandbag dike around the structures during flood conditions. The depth of flooding around these properties is less than 1 m and as such can be protected with the construction of sandbag dikes. The temporary sandbags would be up to 1.5 m high to meet the DFSL with a total length of approximately 560 m.

There is a group of 8 private properties along Deep Creek South Road that are located within areas inundated under the preliminary analysis and would require flood mitigation around the structures. An platform with a temporary double superbag dike on the creek side of the properties would act as a flood barrier. The platform would be approximately 200 m long.

As illustrated on the inundation mapping, approximately 180 m of the east end of Deep Creek South Road is inundated and requires flood mitigations. In order to reach the DFSL, the road would need to be raised 1.0 – 2.0 m from existing to act as a flood barrier. This would serve two purposes, i) to maintain access to properties along Deep Creek Road South and ii) act as a dike for the properties at the south property line. Raising of Deep Creek South Road may require slope stabilization measures installed lakeside due to the added weight from the new material for the raised road. The footprint of the road widening would be approximately 15 m and does not extent onto private properties with all work anticipated to be above the OHWM.

Figure No.

Q4

Title

Deep Creek Conceptual Flood Mitigation Design - Option 2

Client/Project 144903232

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

Project Location
Deep Creek,
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)
1:10,000

- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- 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
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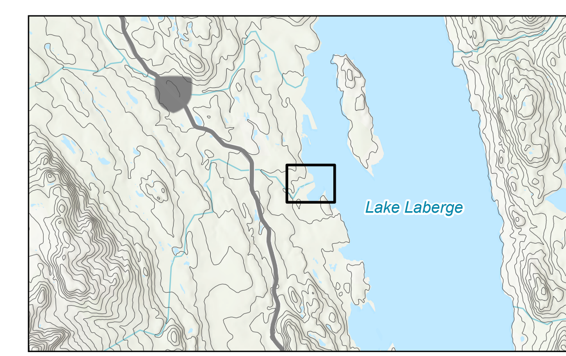

Notes
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2. Data Sources: Government of Yukon; Government of Canada
3. Imagery Government of Yukon Geomatics Yukon; ESRI World Imagery

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table Q7, considering the Class D level of accuracy (+/-50%). Table Q7 also provides the Class D OPCs on a per inundated property basis (from Section Q.1.11).

Table Q7 Option 2 Summary of Class D OPCs

	Class D OPC					Number of Inundated Properties (Section Q.1.11)[1]	Class D OPC per Inundated Property				
Capital Cost	$	4,664,300	-	$	6,996,450	16	$	291,519	-	$	437,279
Annual Cost (Flood Year)	$	577,700	-	$	866,550		$	36,107	-	$	54,160
Annual Cost (Non-Flood Year)	$	700	-	$	1,050		$	44	-	$	66

[1]As described in Section Q.1.11, the inundated properties from the preliminary inundation analysis consists of 15 private properties and a portion of Deep Creek Road.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table Q8 (capital costs), Table Q9 (annual cost, flood year), and Table Q10 (annual cost, non-flood year).

Table Q8 **Option 2 Capital Costs Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2A	**Option 2: General Conditions**				
a)	Mobilization/Demobilization	LS	1	$309,860.00	$309,860.00
b)	Site Preparation/Restoration	LS	1	$62,000.00	$62,000.00
				Total 2A	$371,860.00
Section 2B	**Option 2: Road Raising**				
a)	Rough Grading	M2	1310	$5.00	$6,550.00
b)	Subgrade Preparation	M2	1310	$5.00	$6,550.00
c)	80mm Minus Granular Subbase, Variable Depth	M3	550	$40.00	$22,000.00
d)	100mm Minus Granular Base, 100mm Depth	M3	120	$50.00	$6,000.00
e)	BST Surfacing	M2	780	$50.00	$39,000.00
				Total 2B	$80,100.00
Section 2C	**Option 2: Structural Platform**				
a)	Clearing and Grubbing	M2	2800	$10.00	$28,000.00
b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	850	$25.00	$21,250.00
c)	Platform Topsoil	M2	990	$20.00	$19,800.00
d)	Platform Seeding	M2	990	$5.00	$4,950.00
e)	Embankment Fill, Clay Core	M3	1320	$50.00	$66,000.00
f)	Embankment Fill, Granular Shell	M3	740	$100.00	$74,000.00
g)	Sheet Pile Wall	M2	680	$1,700.00	$1,156,000.00
h)	Concrete Lock-Block Retaining Wall	M2	340	$1,000.00	$340,000.00
i)	Handrail	M2	330	$140.00	$46,200.00
j)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	330	$300.00	$99,000.00
k)	Slope Stabilization	M	330	$3,000.00	$990,000.00
				Total 2C	$2,845,200.00
Section 2D	**Option 2: Floodboxes, Structural Platform**				
a)	Reinforced Concrete Pipe	M	40	$1,000.00	$40,000.00
b)	Gatewell Manhole c/w Sluice Gate	EA	4	$17,500.00	$70,000.00
c)	Concrete Headwall	EA	8	$5,000.00	$40,000.00
d)	Slide Gate	EA	4	$3,000.00	$12,000.00
e)	Riprap	MT	80	$141.00	$11,280.00
				Total 2D	$173,280.00
				Contingency (20%)	$694,088.00

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.

Subtotal	$4,164,528.00
Location Adjustment Factor (LCAF)	1.12
Capital Costs Base Price	$4,664,300.00
Capital Costs Upper Bound	$6,996,450.00

Table Q9 Option 2 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2E	**Option 2: Annual Costs, Flood Year**				
a)	Inspections	LS	1	$25,000.00	$25,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$5,000.00	$5,000.00
c)	Storage of Sandbags and Superbags	LS	1	$500.00	$500.00
d)	Sandbags c/w Sandfill (1.0m - 2.0m)	M	505	$464.00	$234,320.00
e)	Superbags c/w Sandfill (1.0m - 2.0m)	M	330	$500.00	$165,000.00
				Total 2E	$429,820.00
				Contingency (20%)	$85,964.00
				Subtotal	$515,784.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost Flood Year Base Price	$577,700.00
				Annual Cost, Flood Year Upper Bound	$866,550.00

Table Q10 Option 2 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2F	**Option 2: Annual Costs, Non-Flood Year**				
a)	Storage of Sandbags and Superbags	LS	1	$500.00	$500.00
				Total 2F	$500.00
				Contingency (20%)	$100.00
				Subtotal	$600.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost, Non-Flood Year Base Price	$700.00
				Annual Cost, Non-Flood Year Upper Bound	$1,050.00

Qualitative Evaluation

Table Q11 summarizes the performance of Option 2 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table Q11 Option 2 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	moderate anticipated construction effort; no design or regulatory efforts required for sandbag dikes on private properties; minor design and regulatory efforts may be required for the platform; geotechnical investigations required including borehole drilling to address bank stability and construction requirements for road raising; work is not anticipated below the OHWM meaning reduced regulatory requirements;	Medium Performance
3	Capital Cost Per Inundated Property	moderate capital costs for raising the road and development of platform for superbag dike; per-inundated-property capital cost is $291,519/property	High Performance
4	Maintenance and Storage	minimal storage requirements (sandbags and superbags for low number of temporary dikes); minor maintenance requirements for road raising; vegetation clearing of platform	Medium Performance
5	Response and Activation	organization to construct the superbag dike on platform; organization to provide sandbags and earthen material for private property owners; 15 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; temporary superbag dike will not affect aesthetics and community function	High Performance
7	Future Adaptability	additional sandbags may be provided for raising temporary sandbag dikes; demountables could be added to the road in the future, if needed	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	no anticipated alterations to existing hydraulics, erosion/sedimentation, ice processes and slope stability	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	low return on investment (ROI) given the private properties and access routes within the community that would be mitigated from flooding as a result of improvements	Low Performance

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Q.2.3 OPTION 3

Description

The conceptual flood mitigations for Option 3 are illustrated in Figure Q5.

The 4 private properties along Deep Creek Road and 3 private properties along Deep Creek South Road would have temporary sandbag dikes around the structures during flood conditions as outlined in Option 2. The approximately 180 m of Deep Creek South Road would be raised as outlined in Option 2.

There is a group of 8 private properties along Deep Creek South Road that are located within areas inundated under the preliminary analysis and would require flood mitigation around the structures during flood conditions. A structural dike, approximately 2.0 m high on the creek side of the properties, would act as a flood barrier. The structural dike would be approximately 200 m long.

Figure No.

Q5

Title

Deep Creek Conceptual Flood Mitigation Design - Option 3

Client/Project 144903232

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

Project Location
Deep Creek,
Yukon

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

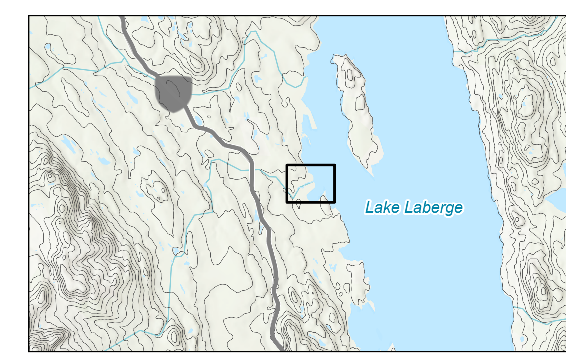
N

0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Parks Campgrounds Surveyed
- 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

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

Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table Q12, considering the Class D level of accuracy (+/-50%). Table Q12 also provides the Class D OPCs on a per inundated property basis (from Section Q.1.11).

Table Q12 Option 3 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section Q.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	$ 7,056,000 - $ 10,584,000	16	$ 441,000 - $ 661,500
Annual Cost (Flood Year)	$ 384,000 - $ 576,000		$ 24,000 - $ 36,000
Annual Cost (Non-Flood Year)	$ 700 - $ 1,050		$ 44 - $ 66
[1]As described in Section Q.1.11, the inundated properties from the preliminary inundation analysis consists of 15 private properties and a portion of Deep Creek Road.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table Q13 (capital costs), Table Q14 (annual cost, flood year), and Table Q15 (annual cost, non-flood year).

Table Q13 Option 3 Capital Costs Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 3A	**Option 3: General Conditions**				
a)	Mobilization/Demobilization	LS	1	$468,750.00	$468,750.00
b)	Site Preparation/Restoration	LS	1	$93,800.00	$93,800.00
				Total 2A	$562,550.00
Section 3B	**Option 3: Road Raising**				
a)	Rough Grading	M2	1310	$5.00	$6,550.00
b)	Subgrade Preparation	M2	1310	$5.00	$6,550.00
c)	80mm Minus Granular Subbase, Variable Depth	M3	550	$40.00	$22,000.00
d)	100mm Minus Granular Base, 100mm Depth	M3	120	$50.00	$6,000.00
e)	BST Surfacing	M2	780	$50.00	$39,000.00
				Total 2B	$80,100.00
Section 3C	**Option 3: Structural Dike**				
a)	Clearing and Grubbing	M2	2960	$10.00	$29,600.00
b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	890	$25.00	$22,250.00
c)	Platform Topsoil	M2	990	$20.00	$19,800.00
d)	Platform Seeding	M2	990	$5.00	$4,950.00
e)	Embankment Fill, Clay Core	M3	1320	$50.00	$66,000.00
f)	Embankment Fill, Granular Shell	M3	1643	$100.00	$164,300.00
g)	Sheet Pile Wall	M2	1360	$1,700.00	$2,312,000.00
h)	Concrete Lock-Block Retaining Wall	M2	680	$1,000.00	$680,000.00
i)	Handrail	M2	330	$140.00	$46,200.00
j)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	330	$300.00	$99,000.00
k)	Slope Stabilization	M	330	$3,000.00	$990,000.00
				Total 2C	$4,434,100.00
Section 3D	**Option 3: Floodboxes, Structural Dike**				
a)	Reinforced Concrete Pipe	M	40	$1,000.00	$40,000.00
b)	Gatewell Manhole c/w Sluice Gate	EA	4	$17,500.00	$70,000.00
c)	Concrete Headwall	EA	8	$5,000.00	$40,000.00
d)	Slide Gate	EA	4	$3,000.00	$12,000.00
e)	Riprap	MT	80	$141.00	$11,280.00
				Total 2D	$173,280.00
				Contingency (20%)	$1,050,006.00

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Subtotal	$6,300,036.00
Location Adjustment Factor (LCAF)	1.12
Capital Costs Base Price	$7,056,000.00
Capital Costs Upper Bound	$10,584,000.00

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.

Table Q14 Option 3 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 3E	**Option 3: Annual Costs, Flood Year**				
a)	Inspections	LS	1	$25,000.00	$25,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$5,000.00	$5,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
d)	Sandbags c/w Sandfill (1.0m - 2.0m)	M	550	$464.00	$255,200.00
				Total 2E	$285,700.00
				Contingency (20%)	$57,140.00
				Subtotal	$342,840.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost Flood Year Base Price	$384,000.00
				Annual Cost, Flood Year Upper Bound	$576,000.00

Table Q15 Option 3 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 3F	**Option 3: Annual Costs, Non-Flood Year**				
a)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 2F	$500.00
				Contingency (20%)	$100.00
				Subtotal	$600.00
				Location Adjustment Factor (LCAF)	1.12
				Annual Cost, Non-Flood Year Base Price	$700.00
				Annual Cost, Non-Flood Year Upper Bound	$1,050.00

Qualitative Evaluation

Table Q16 summarizes the performance of Option 3 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table Q16 Option 3 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	moderate anticipated construction effort; no design or regulatory efforts required for sandbag dikes on private properties; moderate design and regulatory efforts may be required for the structural dike; geotechnical investigations required including borehole drilling to address bank stability and construction requirements for structural dike and road raising; work is not anticipated below the OHWM meaning reduced regulatory requirements;	Low Performance
3	Capital Cost Per Inundated Property	moderate capital costs for raising the road and construction of structural dike; per-inundated-property capital cost is $441,000/property	Medium Performance
4	Maintenance and Storage	minimal storage requirements (sandbags and superbags for low number of temporary dikes); minor maintenance requirements for road raising; vegetation clearing of structural dike slopes.	Medium Performance
5	Response and Activation	Organization to provide sandbags and earthen material for private property owners; 15 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; structural dike will affect aesthetics and community function for 8 private properties	Medium Performance
7	Future Adaptability	additional sandbags may be provided for raising temporary sandbag dikes; demountables could be added to the structural dike and road in the future, if needed	Medium Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	no anticipated alterations to existing hydraulics, erosion/sedimentation, ice processes and slope stability	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	low return on investment (ROI) given the private properties and access routes within the community that would be mitigated from flooding as a result of improvements	Low Performance

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Q.2.4 SUMMARY TABLES

Table Q17 summarizes the Class D OPC for each of the conceptual design options.

Table Q17 Summary of Class D OPCs

	Option 1 Class D OPCs	Option 2 Class D OPCs	Option 3 Class D OPCs
Capital Cost	None	$4,664,300 - $6,996,450	$7,056,000 - $10,584,000
Annual Cost (Flood Year)	$ 713,200 - $1,069,800	$ 577,700 - $ 866,550	$ 384,000 - $ 576,000
Annual Cost (Non-Flood Year)	$ 700 - $ 1,050	$ 700 - $ 1,050	$ 700 - $ 1,050

Table Q18 provides a summary of the evaluation of each of the conceptual design options.

Table Q18 Summary of Qualitative Evaluation of Conceptual Options

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