

Appendix M Marsh Lake East Shore 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.

M.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 Marsh Lake East Shore.

M.1.1 POPULATION

Marsh Lake has a population of 746 with 527 private dwellings according to the 2021 census data (Statistics Canada 2023c). The population has increased by approximately 7% from 2016 when the population was 696 (Statistics Canada 2023c). Census data specific to the Marsh Lake East Shore communities were not available. Based on available aerial imagery, there are approximately 298 private properties with structures on them within the Study Area.

M.1.2 STUDY AREA

The Study Area in Figure M2 outlines the areas that flood mitigations are being considered in this Project at Marsh Lake East Shore. 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.

M.1.3 FIRST NATIONS

The Marsh Lake East Shore area is within the Traditional Territories of the Kwanlin Dün First Nation (KDFN) and the Carcross/Tagish First Nation (C/TFN). The KDFN and CTFN have parcels of Category A and B Settlement Lands along the east shore of Marsh Lake. This means that KDFN and CTFN have surface and subsurface ownership of the parcels of land (Government of Yukon 2022c). Other First Nation's with Traditional Territories near the Study Area, such as the Ta'an Kwäch'än Council, should also be considered when engaging with local stakeholders. Figure M2 illustrates the KDFN, C/TFN, and TKC settlement lands within the Study Area.

M.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 CGVD2013. The LiDAR accuracy is assumed to be sufficient for the preliminary flood inundation analysis and conceptual design presented in this Report. The LiDAR dataset meets the Canadian Quality Level 1 minimum requirements for flood mapping as per NRCan Federal Guidelines for Airborne LiDAR Acquisition (2022b).

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M.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Study Area likely consists of glaciolacustrine deposits overlying pre-Quaternary bedrock. The glaciolacustrine deposits are made up of two sediment types: lakebed sediments of stratified fine sand, silt, clay, and ice-rafted stones; and beach sediments made up of sorted to well sorted stratified sand and coarser material transported and deposited by wave action along the margins of a glacial lake. The topographic expression in the area likely consists of hummocky, kettled, and irregular terrain formed during the collapse of material from the melting of overlying ice.

The Permafrost Probability Model (Bonnaventure et al. 2020) suggests the Study Area is located within a region of sporadic discontinuous permafrost (10-20% 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 sporadic discontinuous permafrost (10-50% of land area underlain by permafrost) with a low (<10% by volume of visible ice) ground ice content in the upper 10-20 m of the ground.

M.1.6 HYDROGEOLOGY

The sand, silt, clay, and ice-rafted stones encountered within the Study Area are likely to result in relatively slow 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 Marsh Lake 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 slowly 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 designs.

M.1.7 PAST FLOODING EVENTS AND RESPONSE

2021 Flood Event

In 2021, the Southern Lakes region (including Marsh Lake East Shore) experienced flooding due to high snowpack in the previous winter and warm early summer conditions. Property owners constructed small earthen dikes, sandbag dikes, and installed sump and pumping systems on their properties. YG provided the sandbags and material for these temporary flood mitigation measures.

M.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

There is no community-wide flood mitigation infrastructure at Marsh Lake East Shore, although some individual property owners have implemented certain flood mitigations on their property.

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M.1.9 WIND, WAVES, AND EROSION

The flow velocities at Marsh Lake are not expected to introduce erosion risks to flood mitigations. Erosion protection from riverine flow velocities is not anticipated to be required at Marsh Lake East Shore flood mitigations.

As a lake community, Marsh Lake East Shore 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. Natural beach processes and morphodynamics should be studied and considered in preliminary and detailed design phases of flood mitigations.

M.1.10 HYDROLOGY

Marsh Lake is part of the Southern Lakes system (Tutshi Lake, Bennett Lake, Windy Arm, Nares Lake, Tagish Lake, Marsh Lake). Water supply to the Southern Lakes consists of snowmelt, runoff from precipitation events, and glacier melt. The Southern Lakes drain north, eventually conveying flow out of Marsh Lake and into the Yukon River. Water levels in the Southern Lakes are regulated by two control structures maintained by the Yukon Energy Corporation (YEC): the Marsh Lake/Lewes controls structure and the Whitehorse dam. A natural hydraulic constriction (Miles Canyon) on the Yukon River is located between the Marsh Lake/Lewes control structure and the Whitehorse dam. During high water conditions and when the YEC control structures are fully open, Miles Canyon is the feature that limits flow exiting the Southern Lakes and therefore controls the flood-stage WSEs in the Southern Lakes. During these flood conditions, the Miles Canyon flow restriction produces a backwater effect such that the Southern Lakes trend towards acting as a single large basin with a common WSE.

Marsh Lake is the most downstream lake in the Southern Lakes system. The Marsh Lake East Shore community is located along the midpoint of the east shore of Marsh Lake.

WSC Station 09AB004 (Marsh Lake near Whitehorse) is located on the northwest side of the Marsh Lake. Gross drainage area to the WSC station is not reported by GoC (2023). The hydrology review considered WSEs at WSC Station 09AB004. Flood frequency analysis for WSEs was performed by both Morrison Hershfield (2022) and Yukon University (2022) for WSEs at WSC Station 09AB004. Table M1 summarizes the frequency results of these two studies.

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Table M1 Flood Frequency Analyses at WSC Station 09AB004 from Morrison Hershfield (2022) and Yukon University (2022)

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1985-2022	1970- 2021
Number of Years	38	52
Selected Distribution	Log-Pearson Type 3	Gumbel
Water Surface Elevation (m) ¹		
1:2 Event (50% AEP)	656.70	656.70
1:20 Event (5% AEP)	657.45	657.60
1:100 Event (1% AEP)	657.83	not provided
1:200 Event (0.5% AEP)	657.98	658.30
Note: ¹ Elevations provided in CGVD2013 for WSC Station 09AB004		

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 M1 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 09AB004 from Yukon University (2022). The WSEs do not include wave runup which could be affected by wind, its direction, intensity, duration, and the beach profile.

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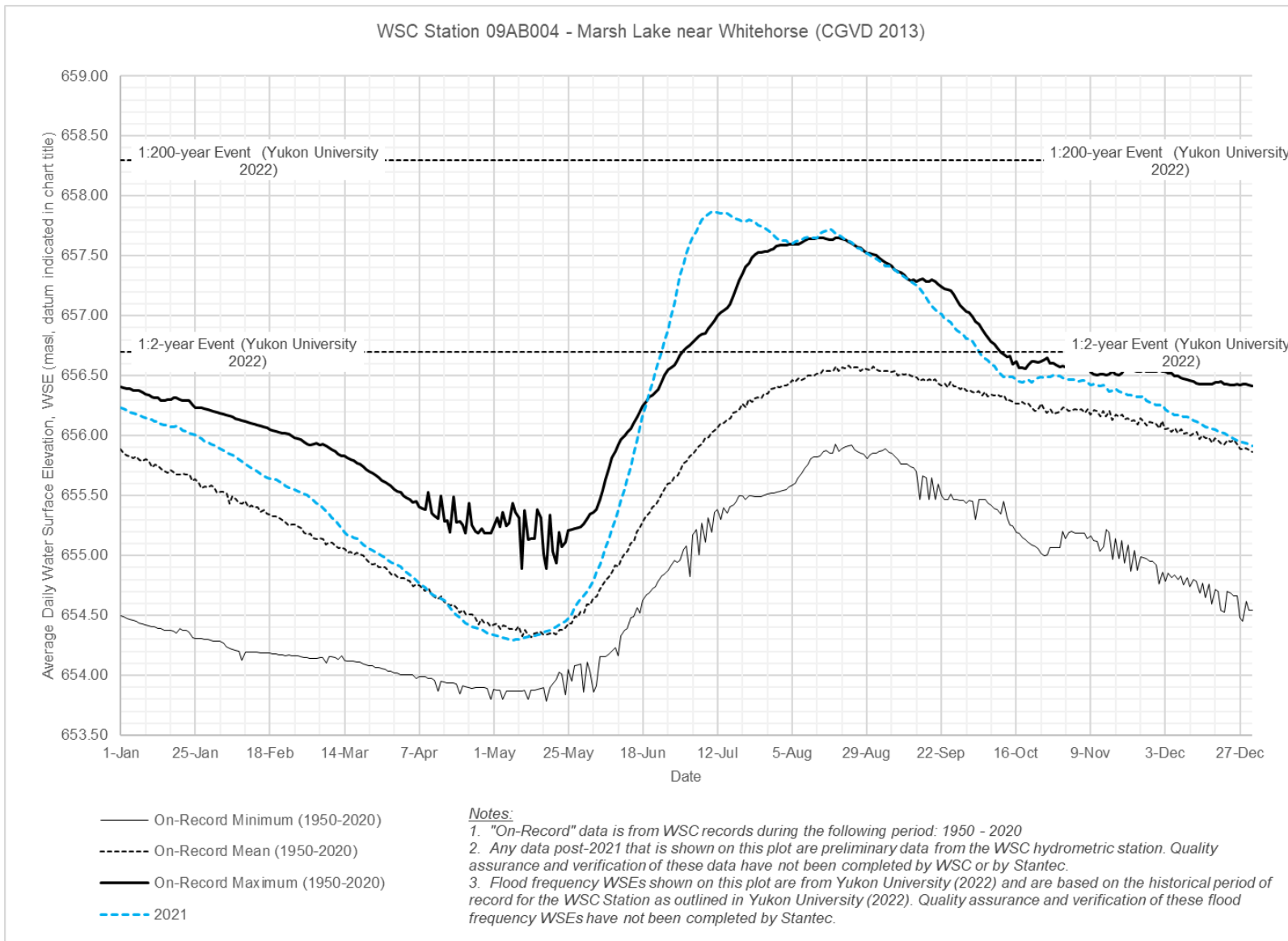


Figure M1 Historical Water Surface Elevations at WSC 09AB004 (Marsh Lake near Whitehorse)

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M.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 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 Marsh Lake East shore using WSEs. This analysis considered the 1:200-year WSE (658.30 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 (McElhanney Ltd., GeoYukon 2023) and the limits of inundation were mapped (Figure M2). 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.

Relatively small areas of Marsh Lake East Shore are inundated in the preliminary inundation mapping. The inundation encroaches on private residential properties at various locations along the east shore. Areas impacted include Grayling Place, Nolan Road, Burnt Road, Scout Bay Road, Judas Creek Drive, and a property directly connected to the Alaska Highway.

The preliminary inundation analysis indicated that approximately 10 private properties would be inundated at Marsh Lake East Shore.

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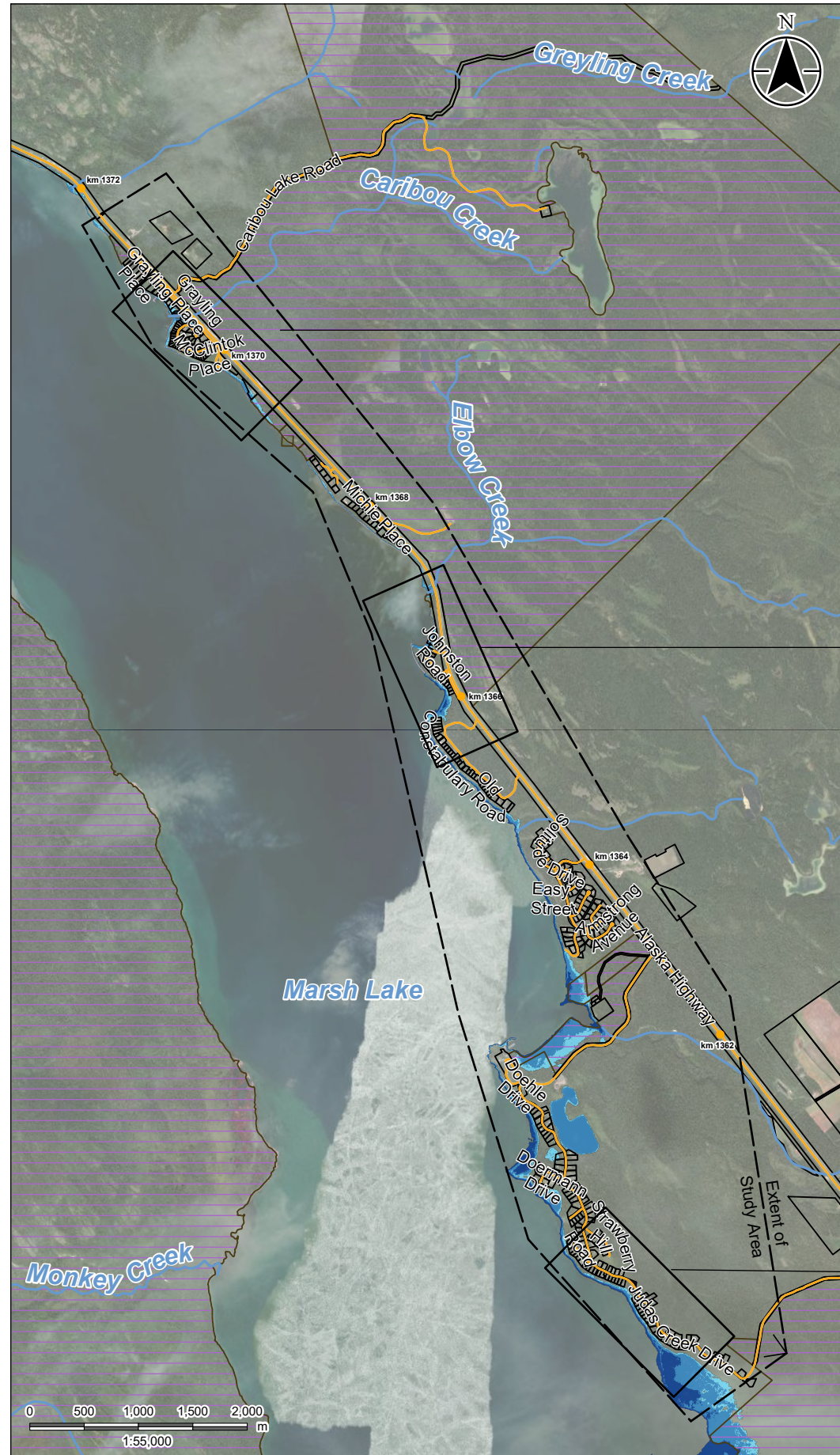
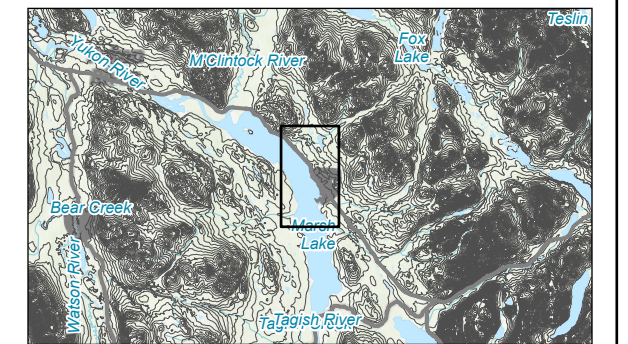


Figure No. **M3**
Marsh Lake East Conceptual Flood Mitigation Design - Option 1
 Client/Project: Government of Yukon 144903232
 Community Services | Infrastructure Development Branch
 Yukon Territory Flood Mitigation Conceptual Design Options
 Project Location: Marsh Lake East Shore, Yukon
 Prepared by LLT on 2023-05-08
 TR by JD on 2023-05-08

- Culvert/ Bridge
 - Highway Kilometre Post
 - Road
 - Topographic Contour (10 m)
 - Topographic Contour (2 m)
 - Land Parcel - Surveyed
 - First Nation Settlement Lands - Surveyed
 - First Nation Heritage Site
- Water Depth at 1:200 WSE Inundation (m)
- 0 - 1
 - 1 - 2
 - > 2 m depth color swatch"/> > 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**
- Coordinate System: NAD 1983 Yukon Albers
 - Data Sources: Government of Yukon; Government of Canada
 - Imagery: Government of Yukon Geomatics Yukon; ESRI World Imagery



M.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Marsh Lake East Shore 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 conceptual flood mitigation option was developed for Marsh Lake East Shore (Table M2) using one typical engineered flood mitigation design from Section 3.3.2.

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.

Flood mitigations in the option were provided for areas which are inundated under the 1:200-year WSE (658.30 m) in the preliminary inundation mapping (Figure M2). The top elevation of the flood mitigations is described to reach the DFSL which in the case of Marsh Lake East Shore (lake site) is assumed to be 660.30 m (i.e., 2.0 m of free board above the 1:200-year WSE as outlined for lake sites in Section 3.2).

Table M2 Summary of Conceptual Design Options

Location	Option 1
	<i>lower capital costs, higher response/maintenance</i>
Private Properties on Grayling Place	Temporary Sandbag Dike
Private Property on Nolan Road	Temporary Sandbag Dike
Private Properties on Burnt Road	Temporary Sandbag Dike
Private Property on Scout Bay Road	Temporary Sandbag Dike
Private Property on Judas Creek Drive	Temporary Sandbag Dike
Private Property on Alaska Highway	Temporary Sandbag Dike

Section M.2.1 provides a description, Class D OPC, and qualitative evaluation of conceptual options specified in Table M2.

M.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure M3.

There are 10 private properties along the Marsh Lake East shore that would be 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. *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.*

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with the construction of sandbag dikes. The temporary sandbag dikes would be up to 3 m high to meet the DFSL with a total length of approximately 960 m.

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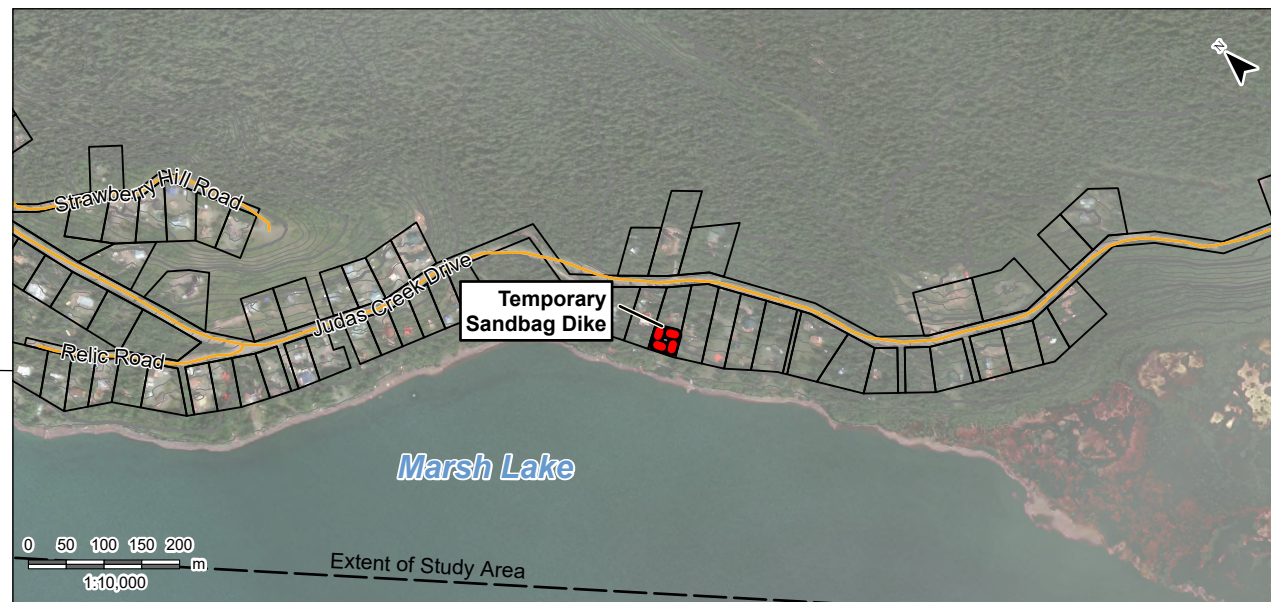
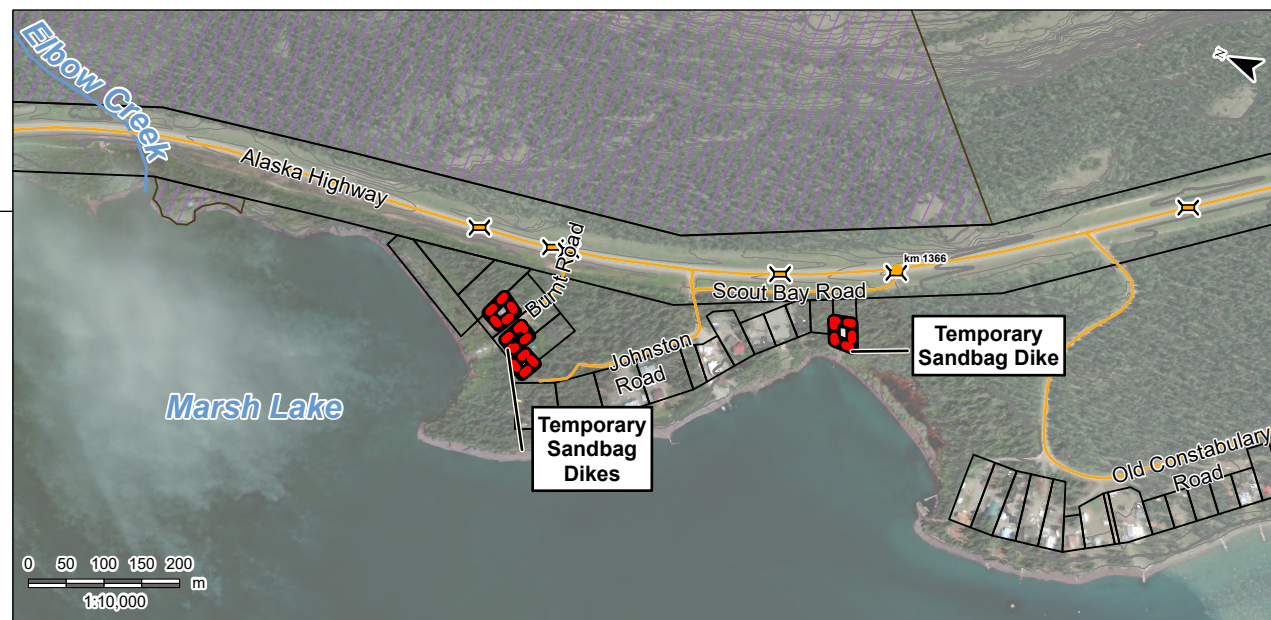
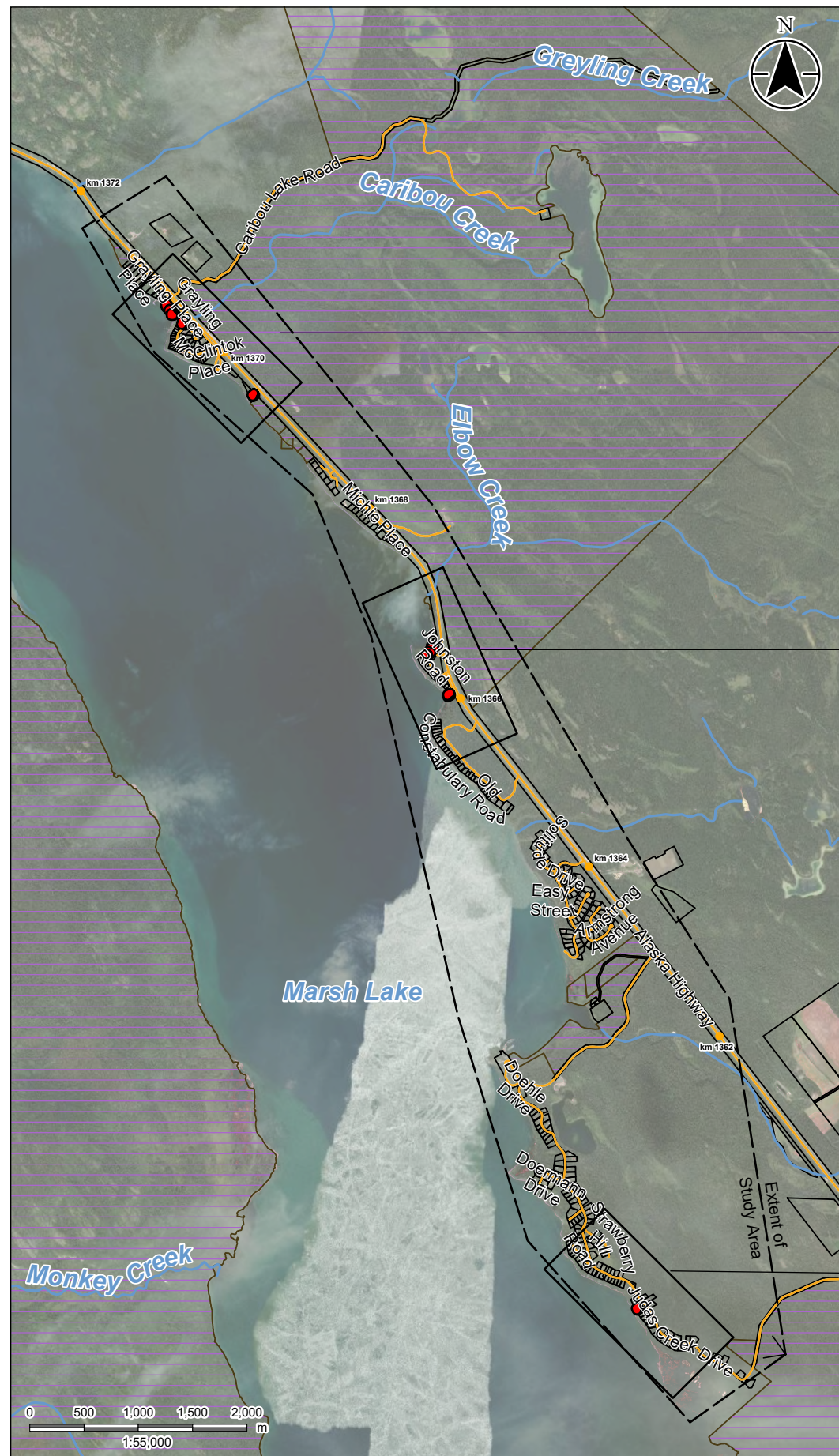


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 Project Location: Marsh Lake East Shore, Yukon
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- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Heritage Site
- 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



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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table M3, considering the Class D level of accuracy (+/-50%). Table M3 also provides the Class D OPCs on a per inundated property basis (from Section M.1.11).

Table M3 Option 1 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section M.1.11) ¹	Class D OPC per Inundated Property
Capital Cost	None	10	None
Annual Cost (Flood Year)	\$ 1,001,600 - \$ 1,502,400		\$ 100,160 - \$ 150,240
Annual Cost (Non-Flood Year)	\$ 800 - \$ 1,200		\$ 80 - \$ 120
¹ As described in Section M.1.11, the inundated properties from the preliminary inundation analysis consists of 10 private properties.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table M4 (annual cost, flood year), and Table M5 (annual cost, non-flood year).

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Table M4 Option 1 Annual Costs During 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	960	\$695.00	\$667,200.00
				<i>Total 1D</i>	\$667,700.00
				<i>Contingency (20%)</i>	\$133,540.00
				<i>Subtotal</i>	\$801,240.00
				<i>Location Adjustment Factor (LCAF)</i>	1.25
				Annual Cost, Flood Year Base Price	\$1,001,600.00
				Annual Cost, Flood Year Upper Bound	\$1,502,400.00

Table M5 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	LS	1	\$500.00	\$500.00
				<i>Total 1F</i>	\$500.00
				<i>Contingency (20%)</i>	\$100.00
				<i>Subtotal</i>	\$600.00
				<i>Location Adjustment Factor (LCAF)</i>	1.25
				Annual Cost, Non-Flood Year Base Price	\$800.00
				Annual Cost, Non-Flood Year Upper Bound	\$1,200.00

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Qualitative Evaluation

Table M6 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

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Table M6 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 sandbag 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 Marsh Lake 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 low number of private properties which are impacted	Low Performance

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M.2.2 SUMMARY TABLES

Table M7 summarizes the Class D OPC for the conceptual design option.

Table M7 Summary of Class D OPCs

	Option 1 Class D OPCs
Capital Cost	None
Annual Cost (Flood Year)	\$1,001,600 - \$1,502,400
Annual Cost (Non-Flood Year)	\$800 - \$1,200

Table M8 provides a summary of the evaluation of the conceptual design option.

Table M8 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

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