

## Appendix F Whitehorse 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.*

## **F.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 Whitehorse.

### **F.1.1 POPULATION**

Whitehorse has a population of 28,201 with 11,970 private dwellings according to the 2021 census data (Statistics Canada 2023c). The population has increased by approximately 12.4% from 2016 when the population was 25,085 (Statistics Canada 2023c).

### **F.1.2 STUDY AREA**

The Study Area in Figure F3 outlines the areas that flood mitigations are considered in this Project at Whitehorse. 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.

### **F.1.3 FIRST NATIONS**

The Whitehorse area is within the Traditional Territories of the Kwanlin Dün First Nation (KDFN) and the Ta'an Kwä'nch'än Council (TKC). The KSFN and TKC have numerous parcels of B Settlement Lands along the Yukon River through the Whitehorse corridor. KDFN's land claim selections include: C-77B/D, C-85FS, C-70FS, C-192B, C-195B, C-42B, C-196B, C-43B, C-140B and S-367B1/D. TKC's land claim selections include: C-64B/D, C-85FC, C-96B/D, C-77B, S-200B1, and C-86B. This means that KDFN and TKC have surface ownership of these parcels of land (Government of Yukon 2022).

### **F.1.4 BATHYMETRY AND TOPOGRAPHY**

Bathymetry data for the Yukon River through Whitehorse were not provided to Stantec.

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

- 2019 LiDAR derivative 1 m horizontal resolution Digital Elevation Model (DEM), UTM Zone 8 CSRS NAD1983, CGVD1928 (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).

### **F.1.5 GEOLOGY**

The geology of the Whitehorse area can be broadly grouped into three main geological components: Triassic to Jurassic (approx. 200 Million years) aged sedimentary rocks along the upland areas in the East and West of the city, young Quaternary (approx. 2.6 Million years) aged Glaciolacustrine and Alluvial Sediment within the trough and low lying areas near the Yukon River, and Cretaceous to Tertiary (approx. *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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145 to 2.6 million years) aged igneous and metamorphic rocks along the Western foothills of the upland areas (Bond et al., 2005). The Whitehorse area underwent regional tectonism and rapid exhumation during the Late Triassic to Early Jurassic (van Drecht et al., 2017). This exhumation exposed older limestone and mudstone sedimentary rocks of the Eastern and Western uplands (van Drecht et al., 2017). This event was followed by volcanic activity and localized faulting along the foothills of the upland areas during the Cretaceous. Plutonic Granodiorites and Granite rocks, formed of coarse-grained light and

Surficial geology mapping (Yukon Geological Survey 2020) indicates that the low-lying areas of the Study Area likely consists of level to gently sloping fluvial deposits made up of gravel, sand, and silt. The gravel is typically rounded and contains interstitial sand. The sediment is generally moderately to well-sorted and stratified. Sediments along the Yukon River typically have a sandy texture due to the abundance of reworked glaciolacustrine sediment. The fluvial deposits are underlain by glaciolacustrine deposits consisting of silt and fine sand. The glaciolacustrine deposits have been previously found from 6 to 55 metres below ground surface.

Based on the Permafrost Probability Model (Bonnaventure et al. 2012), the Study Area is located within a region of sporadic discontinuous permafrost (10-20% 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 (10-50% 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.

### **F.1.6 HYDROGEOLOGY**

Alluvial deposits along the Yukon River encompassing most of active floodplain are likely to result in a groundwater table that is highly dependant on the Yukon River levels. A surface layer of alluvium overlying permeable gravel in the Marwell area in northern Whitehorse has been documented by Oreclin, (1980) and Janowicz (1983), resulting in high hydraulic connectivity between the Yukon River and the floodplain. During flooding, the high river 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 surficial materials 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.

### **F.1.7 PAST FLOODING EVENTS AND RESPONSE**

Flooding has historically occurred in early winter at Marwell, located approximately 6 km downstream of the present-day Whitehorse Rapids Generating Station (WRGS) (Orecklin 1980, Janowicz 1983). A decrease in channel cross-section combined with freeze-up ice jams have historically been the cause of this flooding. Backwater from the hydraulic constriction and ice jams vary depending on meteorological and hydrologic inputs, but has extended to upstream of the Robert Campbell Bridge in the past (Janowicz 1983). Flow regulation operations (limiting both flow and ice production) by the WRGS have largely reduced the frequency and extent of freeze-up ice jam flooding in Whitehorse (Janowicz 1983).

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Following commencement of operations at the WRGS, three flood events of note have been documented. The flood events summarized below do not 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.

### **Winter 1963-1964 and 1964-1965**

This event was described in Orecklin (1980) as the worst natural flooding since completion of the WRGS. No details were provided in Orecklin (1980) on the factors that led to the flooding.

### **Winter 1978**

An advancing ice front froze to a spoil pile left on the bank of the Yukon River following in-channel works (Orecklin 1980). The accumulation of ice at the spoil pile reduced the channel capacity and the constricted flow eroded approximately 100 feet of bank. Bank overflow flooded nearby properties and froze.

### **Winter 2000-2001**

Anecdotal reports and CBC (2001) indicate that flooding at Marwell occurred in the winter of 2000/2001 due to a freeze-up ice jam in the downstream portion of the Whitehorse Study Area.

## **F.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE**

Freeze-up ice jam occurrences and severity on the Yukon River through Whitehorse have been lessened through the construction of the WRGS and implementation of various flow regulation approaches, including ice-setting protocols in the early winter of each year.

Riprap has been installed on the banks of the Yukon River for erosion mitigation in various locations through Whitehorse.

Janowicz (1983) documents discussions between the Yukon Territorial Government, City of Whitehorse, and Department of Indian Affairs and Northern Development regarding dike construction or property buyouts for residences in the Marwell area considering a flood level of 2075 feet above sea level (approximately equivalent to 632.12 m in CGVD2013). Property buyouts at market price were documented as the preferred option in Janowicz (1983) due to seepage concerns; documentation of completion of the buyouts are not available at the time of writing.

No other documentation of flood mitigation infrastructure was available at the time of writing. Anecdotally, there are berms and dikes along the banks of the Yukon River in several locations (e.g., west bank at Marwell upstream of the Water Survey of Canada (WSC) Station 09AB001 (Yukon River at Whitehorse)).

## **F.1.9 WIND, WAVES, AND EROSION**

While floodplain mapping and associated hydraulic modelling of the DFSL has not been completed for Whitehorse to date, it is likely that flow velocities in the Yukon River during flood conditions would require any flood mitigations to include erosion protection. In addition, bank erosion and river migration should be studied and considered in preliminary and detailed design phases of flood mitigations.

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Wind and wave effects are not anticipated to occur at a scale which would require additional flood mitigation design at Whitehorse.

### **F.1.10 HYDROLOGY**

Flows in the Yukon River through Whitehorse drain the Southern Lakes, which are located south of Whitehorse (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 flood conditions and when the YEC control structures are fully open, Miles Canyon is the main hydraulic constriction that limits flow exiting the Southern Lakes and therefore controls the flood-stage WSEs in the Southern Lakes and flow in the Yukon River through Whitehorse. During non-flood conditions, the two YEC control structures regulate flow in the Yukon River through Whitehorse. Downstream of Whitehorse, the Yukon River flows north through the Yukon and west through Alaska, eventually discharging to the Bering Sea.

WSC Station 09AB001 (Yukon River at Whitehorse) is located on the west side of the Yukon River near Marwell (Figure F3). WSC Station 09AB001 has a gross drainage area of 19,600 km<sup>2</sup> (GoC 2023). The Probable Maximum Flood (PMF) for the Yukon River at the WRGS is estimated to be 1,350 m<sup>3</sup>/s (Acres 1995), which is less than the spillway capacity of the WRGS at full supply level (1,760 m<sup>3</sup>/s, per KGS Group 2012a). One-dimensional hydraulic modelling of the Yukon River through Whitehorse (simulating WSEs from flow and river geometry using HEC-RAS modelling software) has been completed by KGS Group (2012a) as part of a dam breach study for the WRGS. The hydraulic model was not made available to Stantec and development of a new hydraulic model is beyond the scope of this Project. Therefore, hydrology review for the Yukon River considered WSEs but not the discharges at WSC Station 09AH001.

Flood frequency analysis for WSEs was performed by Morrison Hershfield (2022) for WSEs at WSC Station 09AB001 (Table F1). YEC operates the WRGS within the requirements of their regulatory permits and operation protocols are subject to change. These protocols have a substantial influence on the WSEs that the flood frequency analysis statistics at WSC Station 09AB001 are based on. The flood frequency analysis results should be interpreted with the understanding that changes to the operation protocols and technical issues at the WRGS have the potential to produce WSEs that exceed those provided in the flood frequency analysis that are relied upon for this Project (Table F1).

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**Table F1 Flood Frequency Analyses at WSC Station 09AB001 from Morrison Hershfield (2022)**

	Morrison Hershfield (2022)
Years Included in Analysis	1976 - 2022 <sup>a</sup>
Number of Years	47
Selected Distribution	Log-Pearson Type 3
Water Surface Elevation (m) <sup>1</sup>	
1:2-year Event (50% AEP)	631.20
1:20-year Event (5% AEP)	631.79
1:100-year Event (1% AEP)	632.12
1:200-year Event (0.5% AEP)	632.25
<sup>a</sup> Freeze up peak water elevations (with many gaps)	
<sup>1</sup> Elevations provided in CGVD2013 for WSC Station 09AB001	

As discussed previously in this section, freeze-up jams in the Yukon River are understood to have been largely mitigated by WRGS operating protocols, although detailed studies regarding ice jam risks for the Study Area were not available to Stantec at the time of writing. Flows in the Yukon River during open-water flood conditions are largely attenuated by the storage effects of the Southern Lakes and the upstream hydraulic controls (YEC control structures when gates not fully open, Miles Canyon). As a result, open-water flood flows are generally slow to recede and can remain elevated in the Yukon River for several weeks or months.

#### F.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. Floodplain mapping has not been completed to date at Whitehorse and is not within 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 Whitehorse using the 1:200 WSE from Morrison Hershfield (2022) and hydraulic modelling results from KGS Group (2012a). 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.

As part of their dam breach study for YEC, KGS Group (2012a) performed hydraulic modelling for no breach scenario during the open-water PMF flow of 1,350 m<sup>3</sup>/s (estimated by Acres 1995). The resulting WSE profile does not have a consistent slope; WSE slope is steepest at the upstream end and decreases in the downstream direction (Figure F1).

WSC Station 09AB001 is located approximately 6 km downstream of the WRGS. At this location, the 1:200-year event WSE from Morrison Hershfield (2022) (632.25 m) is 0.95 m below the WSE that was modelled for the PMF from KGS Group (2012a) (633.20 m). For the purposes of this preliminary inundation analysis, the 1:200-year open-water WSE profile in Figure F1 is therefore estimated to be the 0.95 m below the open-water PMF WSE profile at all stations.

Ice jam flood inundation scenarios may result in a different WSE profile through Whitehorse than is illustrated in Figure F1. No recent ice jam studies (under the current WRGS operating protocol) for

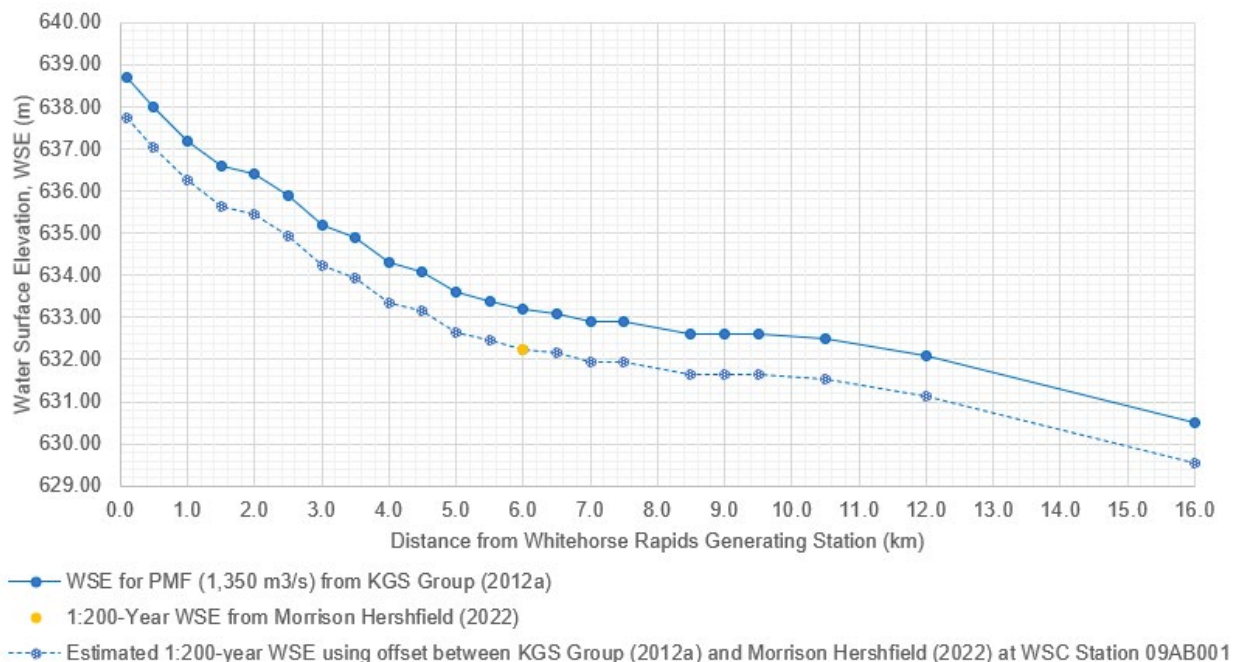
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Whitehorse were available to Stantec at the time of writing. Ice jam flooding is therefore not included in the preliminary inundation analysis (open-water only), but should be a part of floodplain mapping studies in the future.



**Figure F1 Open-Water WSE Profile for the PMF (KGS Group 2012a) and Estimated Open-Water 1:200-year Event Preliminary Inundation Profile Using 1:200-year WSE from Morrison Hershfield (2022)**

The preliminary inundation analysis considers the estimated 1:200-year open-water WSE profile in Figure F1. The resulting water surface was overlain on the existing conditions topographic/bathymetric elevation data (Underhill 2022) and the limits of inundation were mapped (Figure F2). The inundation analysis performed herein is provided for information only and is considered a high-level estimate of the open-water flood inundation under the 1:200-year WSE from Morrison Hershfield (2022).

The preliminary inundation in Figure F2 indicates that flood water would enter Whitehorse at the north end of Shipyards Park, approximately 4.5 km downstream of the WRGS. The flood waters would inundate areas surrounding 2<sup>nd</sup> and 3<sup>rd</sup> Avenue. The preliminary inundation also indicates that flood waters at Marwell would enter the industrial site south of Industrial Road, through a narrow low spot in the west bank.

The preliminary inundation analysis indicates that an estimated 10 commercial/industrial properties would have at least 25% of their area inundated (inundated properties). The inundated properties include grocery stores, government buildings, restaurants, and fuel stations.

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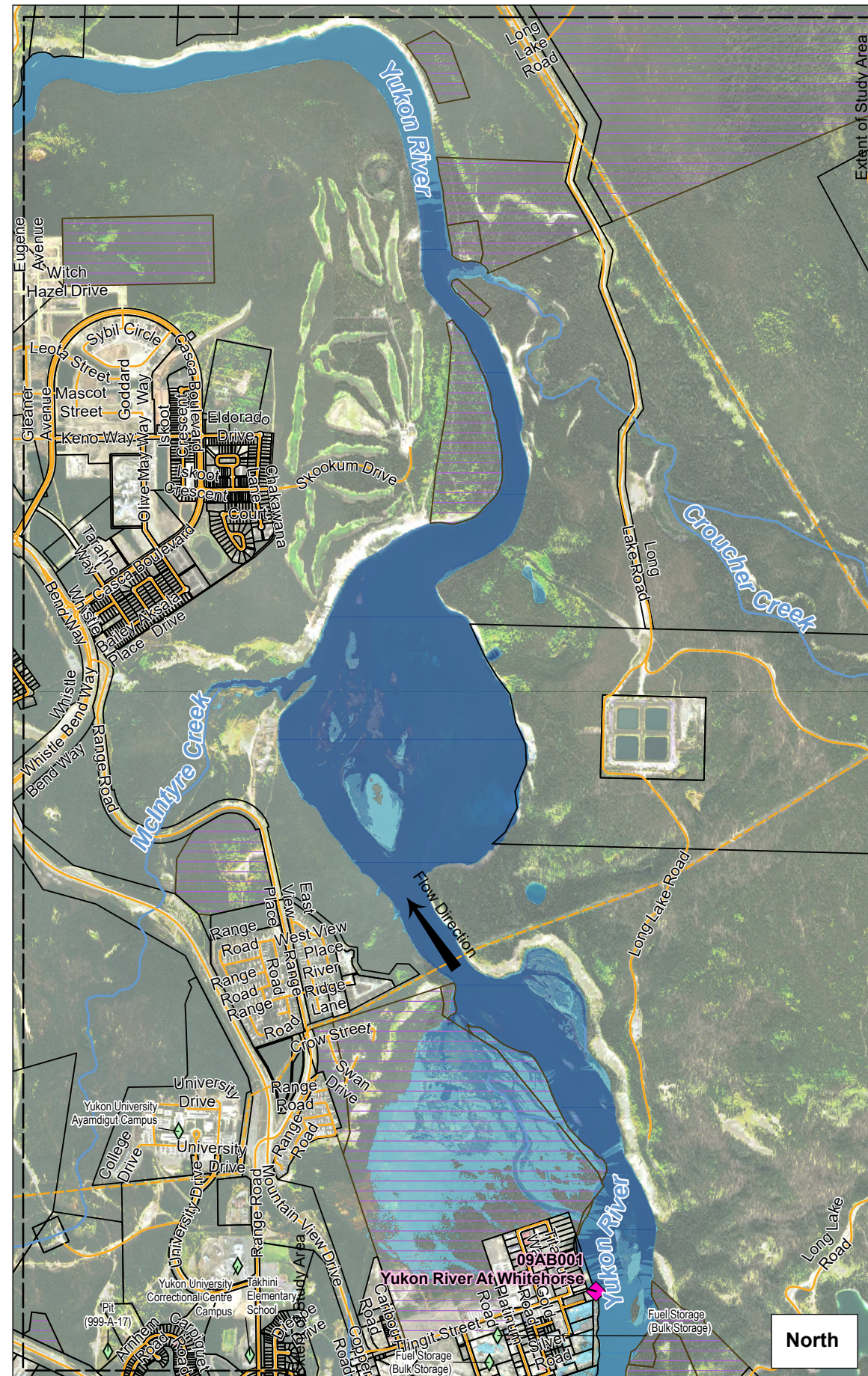
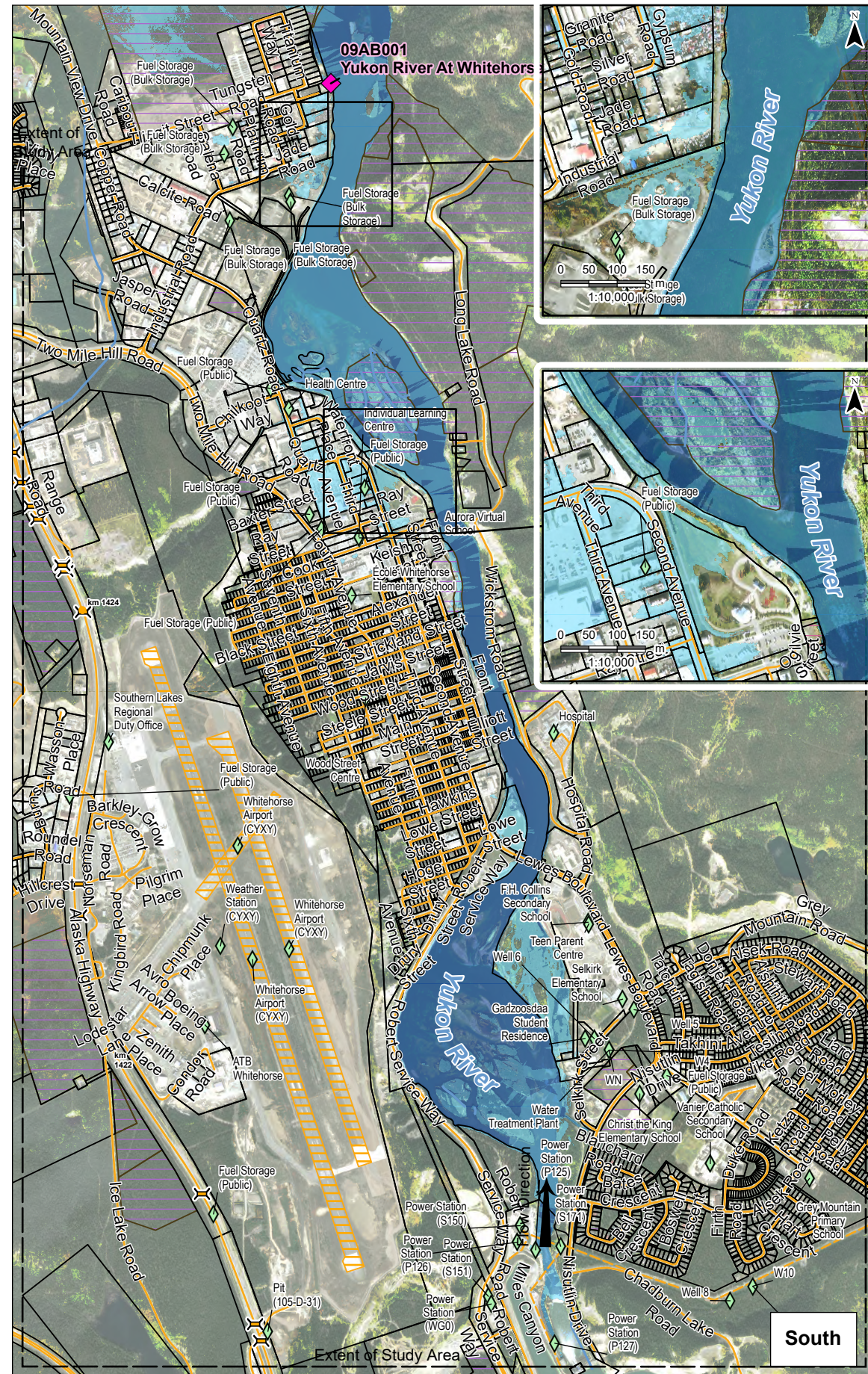


Figure No. **F2**  
**Title**  
**Existing Conditions and Preliminary Flood Inundation at Whitehorse**  
 Client/Project 144903232  
 Government of Yukon  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location Whitehorse, Yukon Prepared by LLT on 2023-05-08 TR by JM on 2023-05-08

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- ◆ WSC Station
- ◆ Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- - - Powerline
- 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



## F.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Whitehorse 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, two conceptual flood mitigation options were developed for Whitehorse (Table F2) using combinations of the typical engineered flood mitigation designs from Section 3.3.2. Flood mitigations in the two options were provided for areas which are inundated under the estimated 1:200-year WSE (Figure F1) in the open-water preliminary inundation mapping (Figure F2). The top elevation of the flood mitigations is designed to reach the DFSL which in the case of Whitehorse (river site) is assumed to consider 0.5 m of freeboard above the 1:200-year WSE as outlined for river 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 F2 Summary of Conceptual Design Options**

Location	Option 1	Option 2
	<i>lower capital costs, higher response/maintenance</i>	<i>higher capital costs, lower response/maintenance</i>
Shipyards Park	Platform with Temporary Superbag Dike	Earthen Dike
Marwell	Platform with Temporary Superbag Dike	Earthen Dike

Section F2.1 and F2.2 provide a description, Class D OPC, and qualitative evaluation of the conceptual options specified in Table F2.

### F.2.1 OPTION 1

#### Description

The conceptual flood mitigations for Option 1 are illustrated in Figure F3.

At Shipyards Park, approximately 240 m of the existing pathway would be used as a platform for a temporary double superbag dike during flood conditions. The temporary superbag dike would be required to cross over the White Pass & Yukon Railway and connect with the parking lot to the west.

At Marwell, an approximately 80 m long platform would be constructed across the existing low point in the west bank. A temporary double superbag dike deployed during flood conditions to meet the DFSL. The existing low point is a ditch/drainage outlet to the Yukon River, meaning a floodbox would be required in the platform. Riprap would be required on the river side of the platform to mitigate erosion. The platform crest could be established as a pathway if zoning allows and community support exists. Slope stabilization measures may be required.

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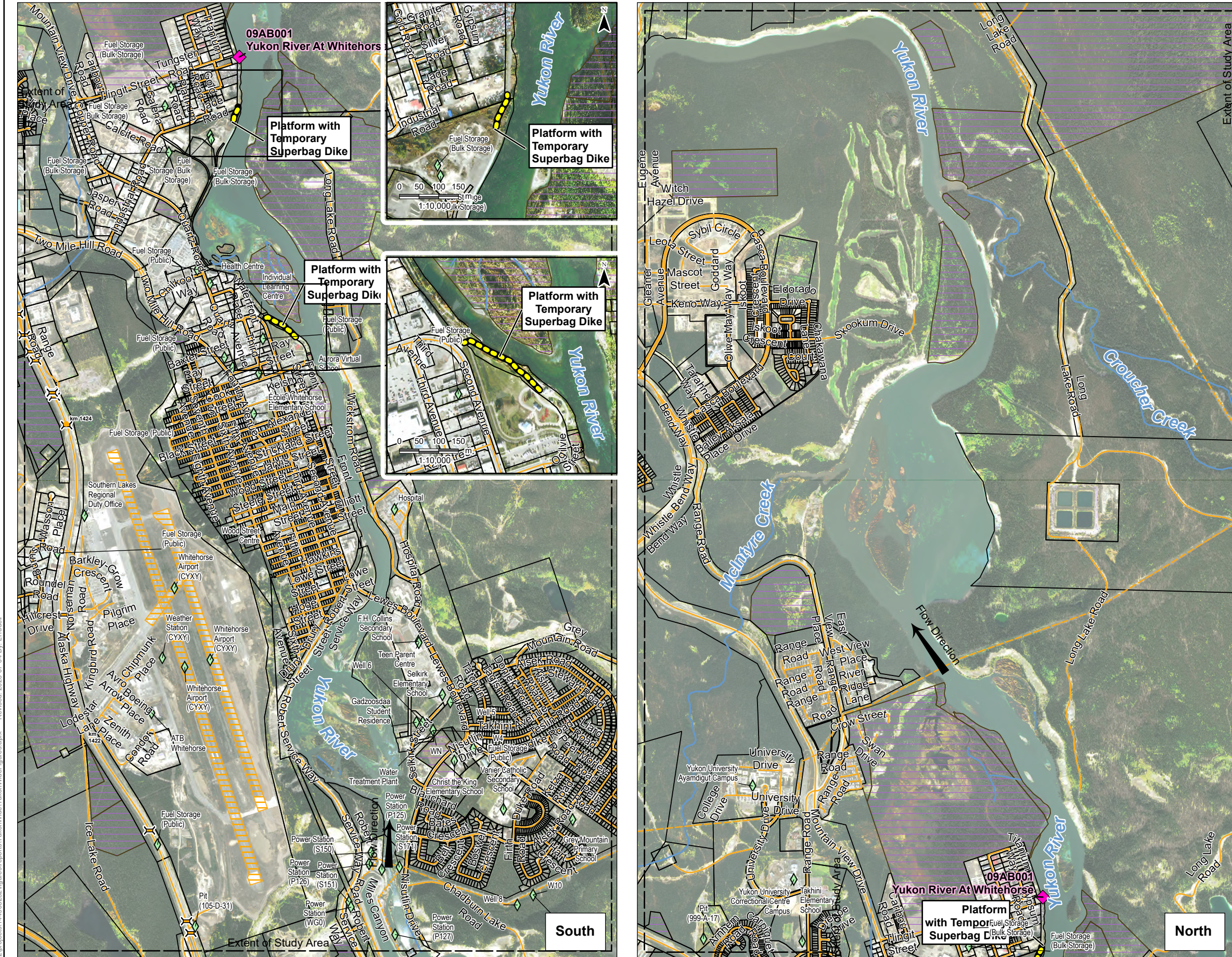
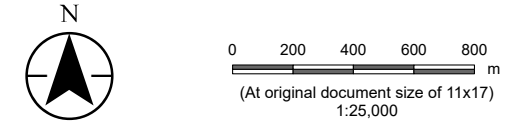


Figure No. **F3**  
 Title **Whitehorse Conceptual Flood Mitigation Design - Option 1**  
 Client/Project 144903232  
 Government of Yukon  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location Whitehorse, Yukon  
 Prepared by LLT on 2023-05-08  
 TR by JM on 2023-05-08



- ◆ WSC Station
- ◆ Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- - - Powerline
- 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



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**Class D OPC**

The Class D OPC's for capital and annual costs are summarized in Table F3, considering the Class D level of accuracy (+/-50%). Table F3 also provides the Class D OPCs on a per inundated property basis (from Section F.1.11).

**Table F3 Option 1 Summary of Class D OPCs**

	Class D OPC	Number of Inundated Properties (Section F.1.11) <sup>1</sup>	Class D OPC per Inundated Property
Capital Cost	\$ 1,032,700 - \$ 1,549,050	10	\$ 103,270 - \$ 154,905
Annual Cost (Flood Year)	\$ 330,600 - \$ 495,900		\$ 33,060 - \$ 49,590
Annual Cost (Non-Flood Year)	\$ 18,600 - \$ 27,900		\$ 1,860 - \$ 2,790

<sup>1</sup>As described in Section F.1.11, the inundated properties from the preliminary inundation analysis consists of 10 industrial/commercial properties.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table F4 (capital costs), Table F5 (annual cost, flood year), and Table F6 (annual cost, non-flood year).

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**Table F4 Option 1 Capital Costs Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 1A Option 1: General Conditions</b>					
a)	Mobilization/Demobilization	LS	1	\$76,840.00	\$76,840.00
b)	Site Preparation/Restoration	LS	1	\$15,400.00	\$15,400.00
<i>Total 1A</i>					\$92,240.00
<b>Section 1B Option 1: Earthworks &amp; Landscaping, Platform (Marwell)</b>					
a)	Clearing and Grubbing	M2	1530	\$10.00	\$15,300.00
b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	460	\$25.00	\$11,500.00
c)	Platform Topsoil	M2	1020	\$20.00	\$20,400.00
d)	Platform Seeding	M2	1020	\$5.00	\$5,100.00
e)	Geotextile Fabric	M2	570	\$10.00	\$5,700.00
f)	Embankment Fill, Clay Core	M3	660	\$100.00	\$66,000.00
g)	Embankment Fill, Granular Shell	M3	1320	\$50.00	\$66,000.00
h)	Riprap	MT	350	\$141.00	\$49,350.00
i)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	330	\$300.00	\$99,000.00
j)	Slope Stabilization	M	90	\$3,000.00	\$270,000.00
<i>Total 1B</i>					\$608,350.00
<b>Section 1C Option 1: Floodboxes, Platform (Marwell &amp; Downtown)</b>					
a)	Reinforced Concrete Pipe	M	60	\$1,000.00	\$60,000.00
b)	Gateway Manhole c/w Sluice Gate	EA	3	\$17,500.00	\$52,500.00
c)	Concrete Headwall	EA	6	\$5,000.00	\$30,000.00
d)	Flap Gate	EA	3	\$3,000.00	\$9,000.00
e)	Riprap	MT	60	\$141.00	\$8,460.00
<i>Total 1C</i>					\$159,960.00
<i>Contingency (20%)</i>					\$172,110.00
<i>Subtotal</i>					\$1,032,660.00
<i>Location Adjustment Factor (LCAF)</i>					1.00
<b>Capital Costs Base Price</b>					\$1,032,700.00
<b>Capital Costs Upper Bound</b>					\$1,549,050.00

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**Table F5 Option 1 Annual Costs During a Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 1D</b>	<b>Option 1: Annual Costs, Flood Year</b>				
a)	Inspections	LS	1	\$100,000.00	\$100,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
c)	Storage of Superbags	LS	1	\$500.00	\$500.00
d)	Superbags c/w Sandfill (1.0m – 2.0m)	M	330	\$500.00	\$165,000.00
				<i>Total 1D</i>	\$275,500.00
				<i>Contingency (20%)</i>	\$55,100.00
				<i>Subtotal</i>	\$330,600.00
				<i>Location Adjustment Factor (LCAF)</i>	1.00
				<b>Annual Cost, Flood Year Base Price</b>	\$330,600.00
				<b>Annual Cost, Flood Year Upper Bound</b>	\$495,900.00

**Table F6 Option 1 Annual Costs During a Non-Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 1E</b>	<b>Option 1: Annual Costs, Non-Flood Year</b>				
a)	Inspections	LS	1	\$5,000.00	\$5,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
c)	Storage of Superbags	LS	1	\$500.00	\$500.00
				<i>Total 1E</i>	\$15,500.00
				<i>Contingency (20%)</i>	\$3,100.00
				<i>Subtotal</i>	\$18,600.00
				<i>Location Adjustment Factor (LCAF)</i>	1.00
				<b>Annual Cost, Non-Flood Year Base Price</b>	\$18,600.00
				<b>Annual Cost, Non-Flood Year Upper Bound</b>	\$27,900.00

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.

## **Yukon Territory Flood Mitigation Conceptual Design Options**

### **Whitehorse Conceptual Flood Mitigation Design Options**

July 2023

#### **Qualitative Evaluation**

Table F7 summarizes the performance of Option 1 with respect to the evaluation criteria which was previously outlined in the main body of this Report.

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**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Whitehorse Conceptual Flood Mitigation Design Options**  
 July 2023

**Table F7 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); ice/debris damage poses 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 given underlying soils and long duration of flooding	Low Performance
2	Time to Implementation	geotechnical investigations required including borehole drilling to address shoreline stability and construction requirements for platforms; hydraulic modelling (including ice jam modelling), and erosion mitigation design required; low regulatory risk; generally low anticipated design effort; low anticipated construction effort	High Performance
3	Capital Cost Per Inundated Property	reduced capital costs in exchange for increased operational and maintenance costs when compared to permanent flood mitigation infrastructure (Option 2); per-inundated-property capital cost is \$103,270/property	High Performance
4	Maintenance and Storage	storage required for relatively small quantity of superbags; stockpiling of material required for superbags; inspections, maintenance, and vegetation clearing required; floodbox maintenance will be required	Medium Performance
5	Response and Activation	temporary superbag dikes require training, labour, and a timely response in a flood scenario to be effective - this is likely assisted by Whitehorse being a central hub of services and staff; floodbox slide gates would need to be manually closed prior to arrival of flood and opened following abatement of the flood	Medium Performance
6	Aesthetics and Community Function	existing pathways would be maintained and additional pathways may be established if zoning allows and community is supportive; temporary and small impact to community use and aesthetics during flood conditions	High Performance
7	Future Adaptability	three-high temporary superbag dikes are possible; additional raising of platforms is possible but will require engineering study and are likely to require widening of structure	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	mitigations are unlikely to impact flood conveyance or other river processes in the Yukon River	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	relatively strong ROI given industrial/commercial properties important to the community that would have flooding mitigated under this option	High Performance

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## **Yukon Territory Flood Mitigation Conceptual Design Options**

### **Whitehorse Conceptual Flood Mitigation Design Options**

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#### **F.2.2 OPTION 2**

##### **Description**

The conceptual flood mitigations for Option 2 are illustrated in Figure F4.

At Shipyards Park, approximately 240 m of the existing pathway would be raised by 1.0 – 1.5 m, to create an earthen dike meeting the DFSL with the pathway established on the top of the dike. A gap in the earthen dike may be required at the White Pass railway which would be filled with superbags during flood conditions.

At Marwell, an approximately 80 m long earthen dike would be constructed across the existing low point in the west bank. The earthen dike crest would be 2.0 – 2.5 m higher than the existing ground. The existing low point is a ditch/drainage outlet to the Yukon River, meaning a floodbox would be required in the earthen dike. Riprap would be required on the river side of the dike to mitigate erosion. The earthen dike crest could be established as a pathway if zoning allows and community support exists. Slope stabilization measures may be required.

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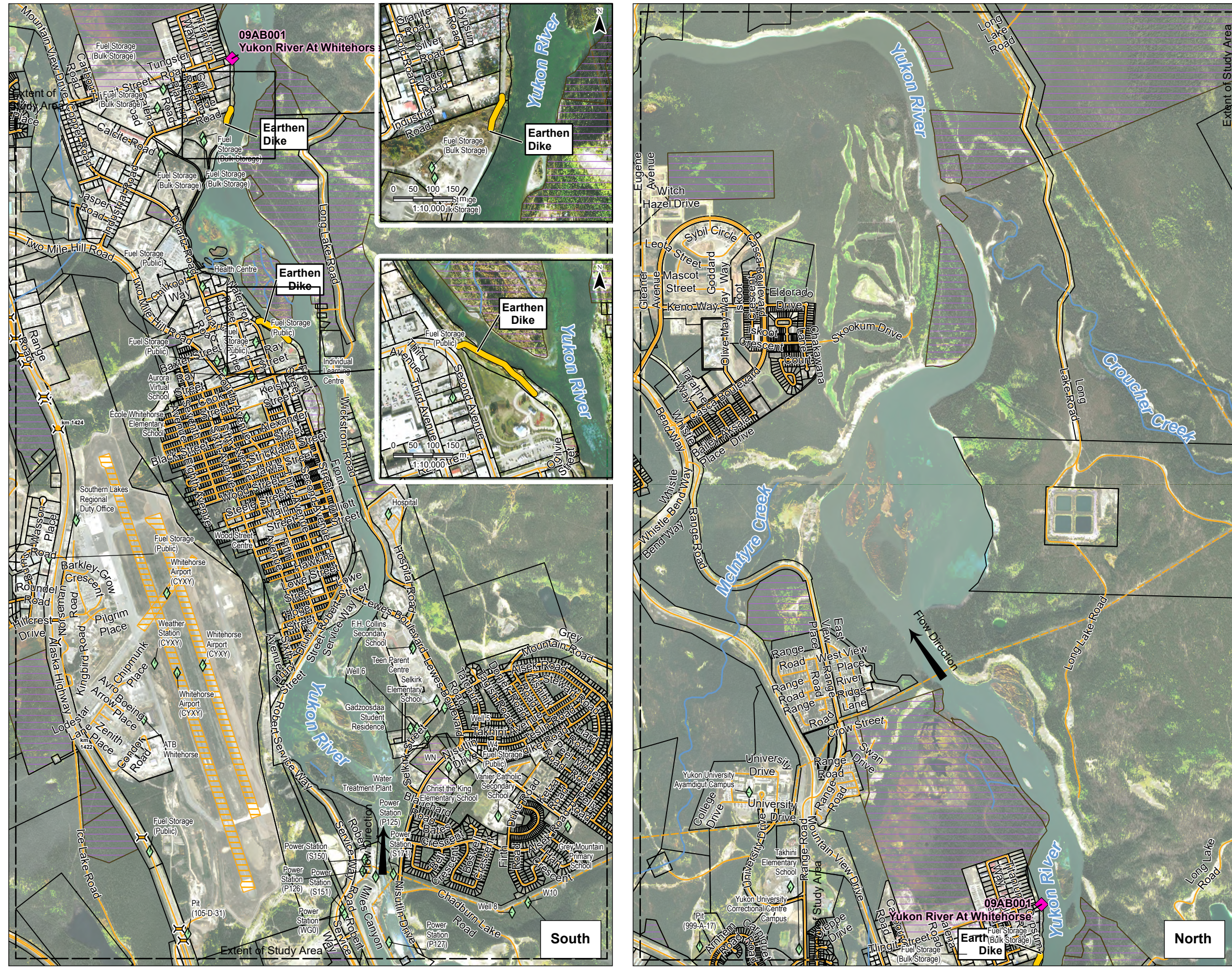


Figure No. **F4**  
**Title**  
**Whitehorse Conceptual Flood Mitigation Design - Option 2**  
 Client/Project 144903232  
 Government of Yukon  
 Community Services | Infrastructure Development Branch  
 Yukon Territory Flood Mitigation Conceptual Design Options  
 Project Location Whitehorse, Yukon  
 Prepared by LLT on 2023-05-08  
 TR by JM on 2023-05-08

N

0 200 400 600 800 m  
 (At original document size of 11x17)  
 1:25,000

- ◆ WSC Station
- ◆ Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- - - Powerline
- 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



**Yukon Territory Flood Mitigation Conceptual Design Options**

**Whitehorse Conceptual Flood Mitigation Design Options**

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**Class D OPC**

The Class D OPC's for capital and annual costs are summarized in Table F3, considering the Class D level of accuracy (+/-50%). Table F3 also provides the Class D OPCs on a per inundated property basis (from Section F.1.11).

**Table F8 Option 2 Summary of Class D OPCs**

	Class D OPC	Number of Inundated Properties (Section F.1.11) <sup>1</sup>	Class D OPC per Inundated Property
Capital Cost	\$ 3,329,400 - \$ 4,994,100	10	\$ 332,940 - \$ 499,410
Annual Cost (Flood Year)	\$ 132,000 - \$ 198,000		\$ 13,200 - \$ 19,800
Annual Cost (Non-Flood Year)	\$ 18,000 - \$ 27,000		\$ 1,800 - \$ 2,700

<sup>1</sup>As described in Section F.1.11, the inundated properties from the preliminary inundation analysis consists of 10 industrial/commercial properties.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table F9 (capital costs), Table F10 (annual cost, flood year), and Table F11 (annual cost, non-flood year).

**Yukon Territory Flood Mitigation Conceptual Design Options**  
**Whitehorse Conceptual Flood Mitigation Design Options**  
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**Table F9 Option 2 Capital Costs Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 2A Option 2: General Conditions</b>					
a)	Mobilization/Demobilization	LS	1	\$247,720.00	\$247,720.00
b)	Site Preparation/Restoration	LS	1	\$49,600.00	\$49,600.00
				<i>Total 2A</i>	\$297,320.00
<b>Section 2B Option 2: Earthworks &amp; Landscaping, Earthen Dike (Marwell &amp; Downtown)</b>					
a)	Clearing and Grubbing	M2	4950	\$10.00	\$49,500.00
b)	Cut and Re-use Onsite - Native Material	M3	1980	\$15.00	\$29,700.00
c)	Cut and Dispose Offsite - Native Material	M3	3960	\$30.00	\$118,800.00
d)	Import and Place Fill - Native Material	M3	990	\$15.00	\$14,850.00
e)	Embankment Fill, Clay Core	M3	1980	\$100.00	\$198,000.00
f)	Embankment Fill, Granular Shell	M3	3960	\$50.00	\$198,000.00
g)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	4950	\$25.00	\$123,750.00
h)	Riprap	MT	2450	\$141.00	\$345,450.00
i)	Geotextile Fabric	M2	2090	\$10.00	\$20,900.00
j)	Embankment Seeding	M2	5170	\$5.00	\$25,850.00
k)	Embankment Topsoil	M2	5170	\$20.00	\$103,400.00
l)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	330	\$300.00	\$99,000.00
m)	Slope Stabilization	M	330	\$3,000.00	\$990,000.00
				<i>Total 2B</i>	\$2,317,200.00
<b>Section 2C Option 2: Floodboxes, Earthen Berm (Marwell &amp; Downtown)</b>					
a)	Reinforced Concrete Pipe	M	60	\$1,000.00	\$60,000.00
b)	Gatewell Manhole c/w Sluice Gate	EA	3	\$17,500.00	\$52,500.00
c)	Concrete Headwall	EA	6	\$5,000.00	\$30,000.00
d)	Flap Gate	EA	3	\$3,000.00	\$9,000.00
e)	Riprap	MT	60	\$141.00	\$8,460.00
				<i>Total 2C</i>	\$159,960.00
				<i>Contingency (20%)</i>	\$554,896.00
				<i>Subtotal</i>	\$3,329,376.00
				<i>Location Adjustment Factor (LCAF)</i>	1.00
				<b>Capital Costs Base Price</b>	\$3,329,400.00
				<b>Capital Costs Upper Bound</b>	\$4,994,100.00

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Yukon Territory Flood Mitigation Conceptual Design Options  
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**Table F10 Option 2 Annual Costs During a Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 2D</b>	<b>Option 2: Annual Costs, Flood Year</b>				
a)	Inspections	LS	1	\$100,000.00	\$100,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
				<i>Total 2D</i>	\$110,000.00
				<i>Contingency (20%)</i>	\$22,000.00
				<i>Subtotal</i>	\$132,000.00
				<i>Location Adjustment Factor (LCAF)</i>	1.00
				<b>Annual Cost Flood Year Base Price</b>	\$132,000.00
				<b>Annual Cost, Flood Year Upper Bound</b>	\$198,000.00

**Table F11 Option 2 Annual Costs During a Non-Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
<b>Section 2E</b>	<b>Option 2: Annual Costs, Non-Flood Year</b>				
a)	Inspections	LS	1	\$5,000.00	\$5,000.00
b)	Minor Repairs & Vegetation Management	LS	1	\$10,000.00	\$10,000.00
				<i>Total 2E</i>	\$15,000.00
				<i>Contingency (20%)</i>	\$3,000.00
				<i>Subtotal</i>	\$18,000.00
				<i>Location Adjustment Factor (LCAF)</i>	1.00
				<b>Annual Cost, Non-Flood Year Base Price</b>	\$18,000.00
				<b>Annual Cost, Non-Flood Year Upper Bound</b>	\$27,000.00

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## **Yukon Territory Flood Mitigation Conceptual Design Options Whitehorse Conceptual Flood Mitigation Design Options**

### **Qualitative Evaluation**

Table F12 summarizes the performance of Option 2 with respect to the evaluation criteria which was previously outlined in the main body of this Report.

**Yukon Territory Flood Mitigation Conceptual Design Options  
Whitehorse Conceptual Flood Mitigation Design Options**

**Table F12 Option 2 Qualitative Evaluation**

<b>Criteria No.</b>	<b>Criteria Title</b>	<b>Evaluation</b>	<b>Anticipated Performance Rating</b>
1	Viability and Reliability under Extreme Conditions	permanent structures would withstand long duration of flooding (several weeks or months); erosion and damage risks from ice/debris would be mitigated by riprap on river side of dikes; seepage control measures likely required given underlying soils and long duration of flooding	High Performance
2	Time to Implementation	geotechnical investigations required including borehole drilling to address shoreline stability and construction requirements for platforms; hydraulic modelling (including ice jam modelling), and erosion mitigation design required; low regulatory risk; generally low anticipated design effort; low anticipated construction effort	Medium Performance
3	Capital Cost Per Inundated Property	increased capital costs in exchange for decreased operational and maintenance costs when compared to options requiring substantial temporary deployments (Option 1); per-inundated-property capital cost is \$332,940/property	High Performance
4	Maintenance and Storage	no storage requirements; relatively short lengths of earthen dikes will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required	High Performance
5	Response and Activation	floodbox slide gates would need to be manually closed prior to arrival of flood and opened following abatement of the flood	High Performance
6	Aesthetics and Community Function	existing pathways would be maintained and additional pathways may be established if zoning allows and community is supportive; temporary and small impact to community use and aesthetics during flood conditions	High Performance
7	Future Adaptability	temporary superbag dike may be deployed on earthen dike crest for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height possible but will require engineering study and are likely to require widening of structure	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	mitigations are unlikely to impact flood conveyance or other river processes in the Yukon River	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	relatively strong ROI given industrial/commercial properties important to the community that would have flooding mitigated under this option	High Performance

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**Yukon Territory Flood Mitigation Conceptual Design Options  
Whitehorse Conceptual Flood Mitigation Design Options**

**F.2.3 SUMMARY TABLES**

Table F13 summarizes the Class D cost estimates for the three conceptual design options.

**Table F13 Summary of Class D Cost Estimates**

	Option 1 Class D OPCs	Option 2 Class D OPCs
Capital Cost	\$1,032,700 - \$1,549,050	\$3,329,400 - \$4,994,100
Annual Cost (Flood Year)	\$330,600 - \$495,900	\$132,000 - \$198,000
Annual Cost (Non-Flood Year)	\$18,600 - \$27,900	\$18,000 - \$27,000

Table F14 provides a summary of the evaluation of each of the conceptual design options.

**Table F14 Summary of Costs and Evaluation of Conceptual Options**

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

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