Appendix C Carcross 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.

C.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 Carcross.

C.1.1 POPULATION

Carcross has a population of 354 with 245 private dwellings according to 2021 census data (Statistics Canada 2023c). The population has increased by approximately 5% from 2016 when the population was 336 (Statistics Canada 2023c).

C.1.2 STUDY AREA

The Study Area in Figure C2 outlines the areas that are considered in this Project at Carcross. 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.

C.1.3 FIRST NATIONS

The Carcross Study Area is within the Traditional Territories of the Carcross / Tagish First Nation (C/TFN). C/TFN has parcels of Category B Settlement Lands and Fee Simple Lands around Carcross, along the Bennett Lake and Nares Lake shores. The land claim selections are C-3FS, C-13FS, C-15B, C-17B, C-31FS, C-35B, and C-38B. This means that C/TFN has surface and private property ownership of these parcel of land (Government of Yukon 2022). Figure C2 illustrates the C/TFN settlement lands within the Study Area.

C.1.4 BATHYMETRY AND TOPOGRAPHY

Bathymetry data for Bennett Lake and Nares Lake at Carcross were not provided to Stantec.

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

- 2014 LiDAR derivative 1m horizontal resolution Digital Elevation Model (DEM), UTM Zone 8 CSRS NAD1983, CGVD1928 (Government of Yukon 2022d)

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).

C.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Study Area likely consists of Eolian sand along the portion of the site north of the Nares River and Morainal till materials consisting of gravel, sand, silt, and clay along the portion of the site south of the Nares River. The Eolian sand was deposited in forms of rolling blankets in thickness greater than 1 m. The Morainal till was deposited in forms of veneers and blankets ranging in thickness between 0.1 m and greater than 1 m.

Based on borehole and testpit data provided in the Yukon Permafrost Database (Government of Yukon 2022b), the soil conditions in the flooding areas within the Carcross area are likely to consist of intermixed layers of silt, sand and gravel overlying sand and silt tills to depths exceeding 14 m. Based on the borehole and testpit data reviewed from the Yukon Permafrost Database (Government of Yukon 2022b) permafrost was not encountered, however permafrost may be present in the Carcross area based on the Permafrost Probability Model (Yukon Geological Survey 2020) and the Canada Permafrost Map (The National Atlas of Canada, 1995). The Permafrost Probability Model suggests the Study Area is located within a region of isolated patches (1–10% of land underlain by permafrost). The Canada Permafrost Map 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. If permafrost is present in the foundational material for the flood mitigation options, differential settlements of the proposed flood mitigation options may occur and should be further investigated and evaluated in preliminary and detailed designs.

C.1.6 HYDROGEOLOGY

The gravels, sands, and silt encountered within the Study Area are likely to result in relatively fast rates of groundwater flow. The deposits encompassing most of shoreline are likely to result in a groundwater table that would be highly dependent on the Bennett Lake and Nares River 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 designs.

C.1.7 PAST FLOODING EVENTS AND RESPONSE

A summary of documented flood events are provided below. 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.

2007 Flood Event

The Southern Lakes region – including Carcross – experienced flooding during the summer of 2007 due to a “perfect storm” of heavy snowpack, warm temperatures resulting in substantial snow and glacier melt, and record rainfall (Sierra 2008). Limited documentation of the flooding has been provided to Stantec however records indicate that emergency response actions were undertaken and sandbag dike operations were completed at Carcross (Sierra 2008). WSC Station 09AA004 (Bennett Lake at Carcross) reported a peak instantaneous WSE of 657.86 m during the 2007 flood event at Carcross on August 12, 2007 (GoC 2023).

2021 Flood Event

The Southern Lakes region—including Carcross—experienced flooding again during the summer of 2021. The flooding was largely due to record snowpack in the winter of 2020–2021 and warm temperatures in late June of 2021. Emergency flood response actions were undertaken included temporary earthen fill dikes along the Waterfront Drive (both east and west of the Klondike Highway bridge) and temporary superbag dikes along the north shore of the Carcross narrows. The pedestrian bridge and the rail bridge were both closed to the public during the flooding for safety reasons. WSC Station 09AA004 (Bennett Lake at Carcross) indicates that the peak instantaneous WSE during the 2021 flood event at Carcross was recorded at 658.03 m (at the WSC station) on July 12, 2021 (GoC 2023).

C.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

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

C.1.9 WIND, WAVES, AND EROSION

The current knowledge of the Southern Lakes systems suggests that flow velocities through the narrows between Bennett Lake and Nares Lake are low during high water conditions. This is because during high water conditions, water in the Southern Lakes is backwatered outflow restrictions (control structures, Miles Canyon) such that the Southern Lakes trend towards a single WSE and behave as a single large basin. If the Bennett Lake basin were to have a localized flood event and backwatered conditions did not exist in the Southern Lakes basin, flow velocities may be high through the Carcross narrows and the flood mitigations may require erosion mitigation measures.

As a lake community, Carcross is affected by beach processes and 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 (especially along Bennet Lake) should be studied and considered in preliminary and detailed design phases of flood mitigations.

C.1.10 HYDROLOGY

Bennett 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 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.

Water flows from Bennett Lake to Nares Lake through the Carcross narrows. WSC Station 09AA004 (Bennett Lake at Carcross) is located at the upstream end of the narrows, on the southwest side of the community (Figure C2). Gross drainage area to the WSC station is not reported by GoC (2023). Flood frequency analysis was performed by Morrison Hershfield (2022) at WSC Station 09AA004 (Bennett Lake at Carcross) and Yukon University (2022) at WSC Station 09AB004 (Marsh Lake near Whitehorse, located farther downstream) with moderate and storage peaks excluded from the analysis. Yukon University (2022) then added 0.2 m to Marsh Lake flood frequency WSEs (based on observed difference in peak event WSEs between the two locations; B. Turcotte, personal communication, 11 November 2022) to produce estimates of flood frequency WSEs at Carcross. Table C1 summarizes the frequency results of these two studies.

Table C1 Flood Frequency Analyses at WSC Station 09AA004 (Morrison Hershfield 2022) and WSC Station 09AB004 (Yukon University 2022) for Tagish

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1985-2022	1970-2022
Number of Years	38	53
Selected Distribution	Log-Pearson Type 3	Gumbel
Water Surface Elevation (m) [1]		
1:2-year Event (50% AEP)	656.96	656.90
1:20-year Event (5% AEP)	657.66	657.80
1:100-year Event (1% AEP)	658.02	not provided
1:200-year Event (0.5% AEP)	658.17	658.50
[1] Elevations provided in CGVD2013 for WSC Station 09AA004 (by Morrison Hershfield 2022) and Station 09AB004+0.2m (by Yukon University 2022)		

The Yukon University (2022) flood frequency analysis results were adopted for the Project because there is greater certainty in the reliability of the datum used for their analysis and the 1:200-year event WSE was higher (which would result a more conservative conceptual design).

Figure C1 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 Carcross from Yukon University (2022). Past high-water events at Carcross (2007, 1981, 1961) have all occurred during open water conditions, and are likely to be correlated to high snowpack conditions in the preceding winter. As illustrated in Figure C1, water levels at Carcross typically begin to rise in mid May with the onset of freshet and increase through June. Water levels typically reach a prolonged peak through the months of July and August, before decreasing in September and October. The pattern of several week-long flood conditions at Carcross are typical in the Southern Lakes region, as outflows from the large lakes are restricted by Miles Canyon. Therefore, based on the available data and the documented flood processes at Carcross, flood conditions at Carcross may generally be expected to persist for several weeks in July and August.

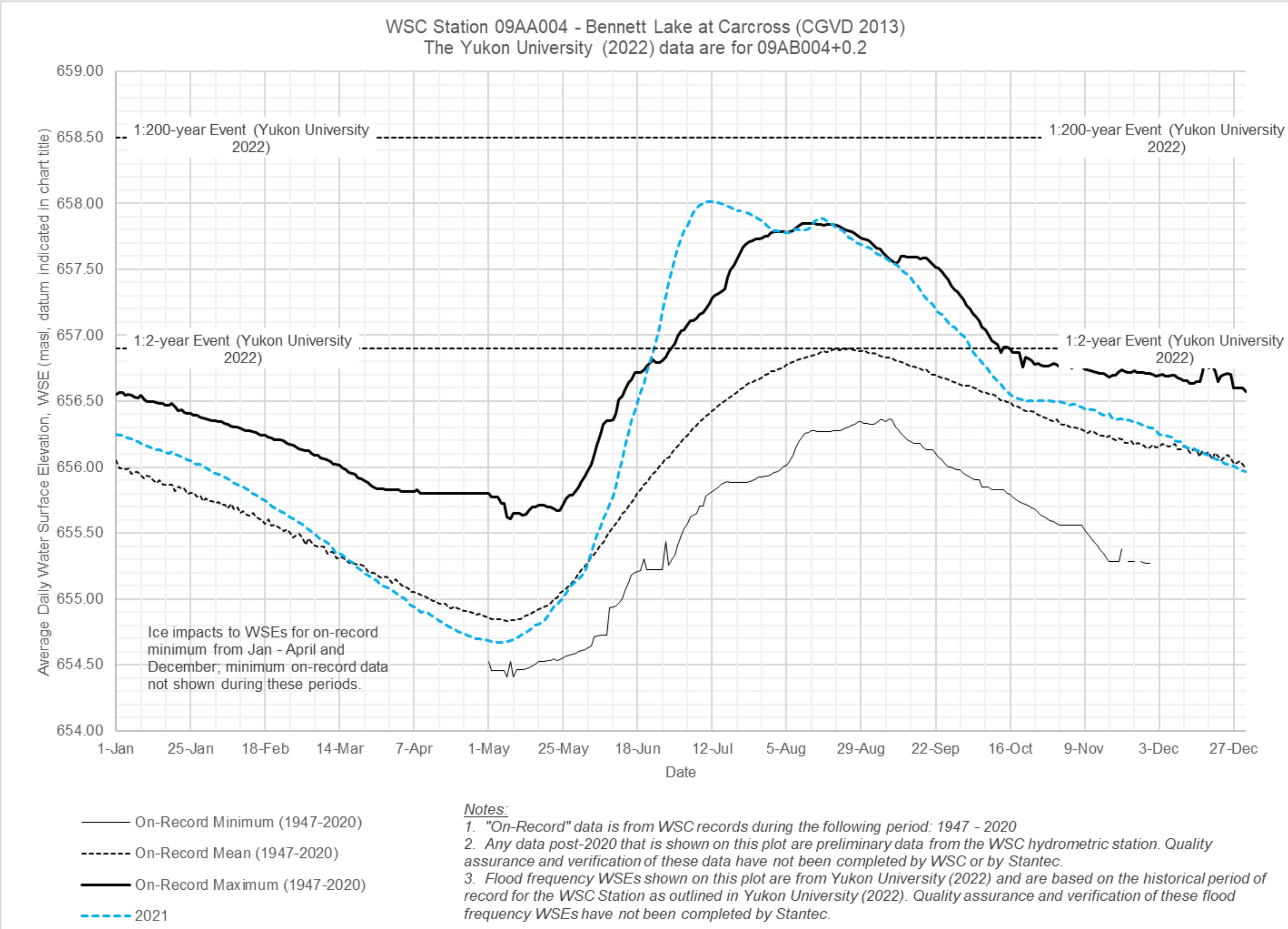


Figure C1 Historical Water Surface Elevations at WSC 09AA004 (Bennett Lake at Carcross

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.

C.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 flood mapping has 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 Carcross using WSEs. This analysis considered the 1:200-year WSE (658.50 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 C2). 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.

The north and south side of the narrows between Nares Lake and Bennett Lake have substantial areas that are inundated in preliminary inundation mapping. On the north side of the narrows, the inundation encroaches on private residential properties and community infrastructure east of the railway bridge crossing. On the south side of the narrows, the inundation extends along the full length of Waterfront Drive. At the north side of the community along Grayling Bay, an individual property and the airport runway are inundated in this preliminary inundation.

Although the inundation/flood vulnerability of the pedestrian bridge, railway bridge, and Klondike Highway across the Carcross narrows are not in the scope of work of this Project (Section 3.6), we note that the pedestrian bridge and railway bridge were closed to the public in the 2021 flood and the preliminary inundation analysis considers a WSE that is 0.49 m higher than 2021. Therefore it is likely that these features would be susceptible to flood damage under the preliminary flood inundation scenario.

The preliminary inundation analysis indicated that an estimated 23 private residence properties and 11 major community features/properties (Waterfront Drive, approximately 6 buildings in the Carcross Commons, boat launch, 2 heritage features (S.S. Tutshi and building) on the north shore of the narrows, and the airport runway) would have at least 25% of their area inundated (inundated properties).

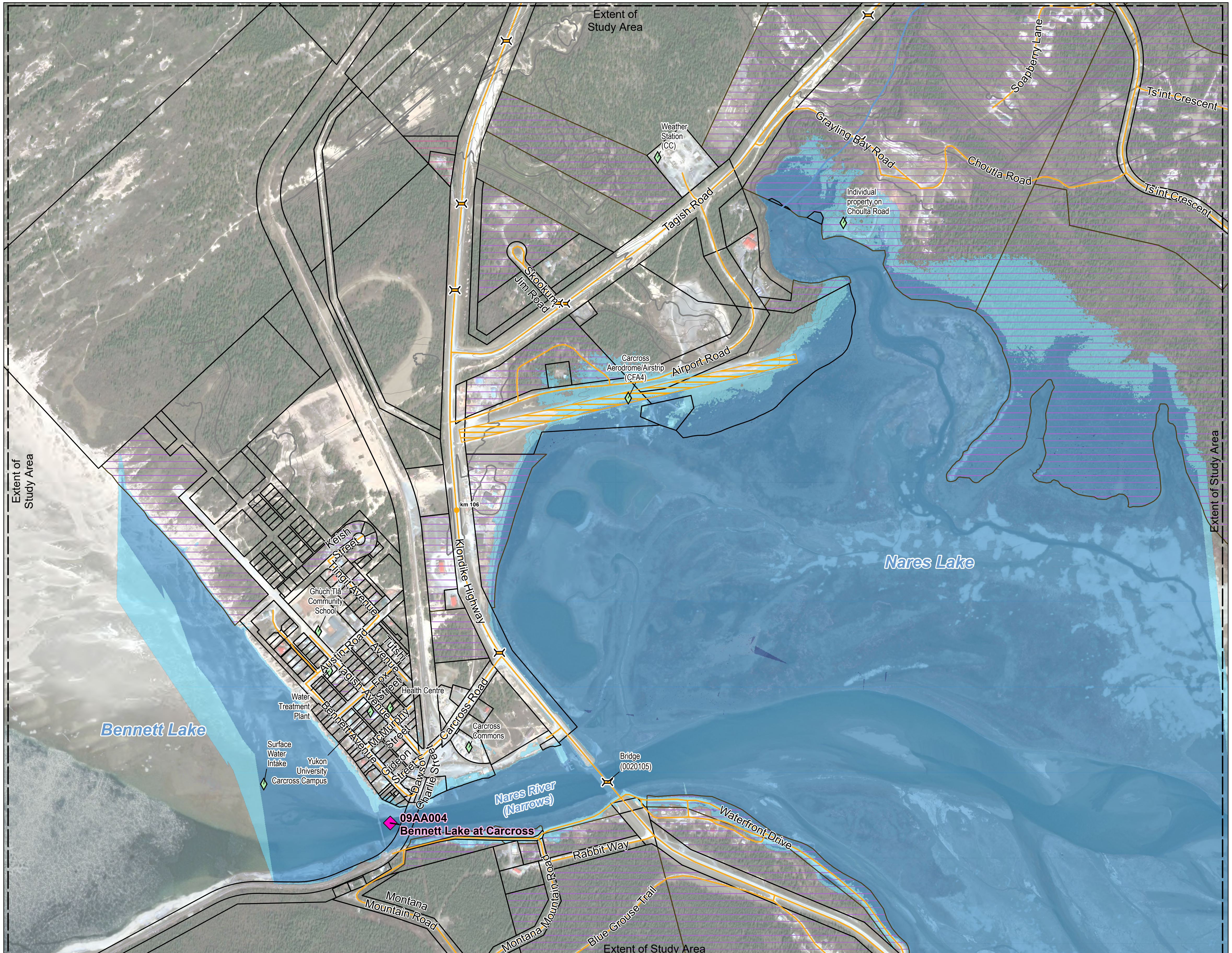
Figure No.
C2

Title
Existing Conditions and Preliminary Flood Inundation at Carcross

Client/Project 144903232
Government of Yukon
Community Services | Infrastructure Development Branch
Yukon Territory Flood Mitigation Conceptual Design Options

Project Location
Carcross,
Yukon

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



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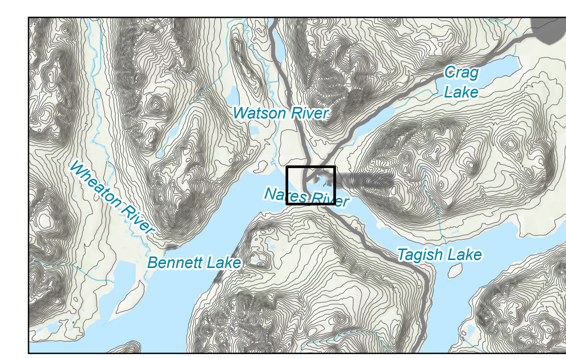
0 50 100 150 200
m
(At original document size of 11x17)
1:10,000

- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Runway
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed

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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C.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Carcross 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 Carcross (Table C2) using combinations of the typical engineered flood mitigation designs from Section 3.3.2. Flood mitigations in the three options are provided for areas which are inundated under the 1:200-year WSE (658.50 m) in the preliminary inundation mapping (Figure C2). The top elevation of the flood mitigations is designed to reach the DFSL which in the case of Carcross (lake site) is assumed to be 660.50 m (i.e., 2 m above the 1:200-year WSE as outlined for lake sites in Section 3.2).

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

As noted in Section C.1.11, it is likely that the pedestrian bridge and railway bridge are susceptible to damage due to flooding. Flood mitigations for bridges is outside the scope of this Project and should be investigated under a separate scope of work.

Table C2 Summary of Conceptual Design Options

Location	Option 1	Option 2	Option 3
	lower capital costs, higher response/maintenance	*higher capital costs, lower response/maintenance - scenario A*	*higher capital costs, lower response/maintenance - scenario B*
North Side of Narrows	Platform with Temporary Superbag Dike	East of Railway Bridge: Structural Dike	East of Railway Bridge: Structural Dike
		West of Railway Bridge: Earthen Dike	West of Railway Bridge: Earthen Dike
South Side of Narrows	East of Klondike Highway: Road Raising as Platform	East of Klondike Highway: Road Raising	East of Klondike Highway: Road Raising
	West of Klondike Highway: Platform with Temporary Superbag Dike	West of Klondike highway: Structural Dike	West of Klondike Highway: Structural Dike
Airport	Platform with Temporary Superbag Dike	Earthen Dike	Raise Runway, Temporary Sandbag Dikes at Airport Buildings
Individual Property on Choulta Road	Temporary Sandbag Dike		

Sections C.2.1, C.2.2 and C.2.3 provide a description, Class D cost estimate, and qualitative evaluation of conceptual options specified in Table C2.

Other engineered flood mitigation approaches that may have merit but were not advanced to conceptual design in this Project include:

- Alterations to any of the three bridges (pedestrian bridge, railway bridge, Klondike Highway bridge) as flood mitigation of the transportation network (including bridges within communities) is outside the scope of this Project (Assumption 4, Section 3.6)

The sandy geology and long duration of flooding at Carcross may pose above-average threats to the stability of the foundational material beneath the flood mitigations at Carcross. Geotechnical and hydrogeological studies to evaluate the foundational risk to the flood mitigations at Carcross should be performed prior to advancement of flood mitigation design.

C.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure C3.

On the south side of the narrows and west of the Klondike Highway bridge, an approximate 530 m long platform would be constructed on the lake side of Waterfront Drive to mitigate flooding for properties along Waterfront Drive. The platform would be approximately 1.5 m higher than existing ground for its full length and would require a double temporary superbag dike to reach DFSL during flood conditions. The platform wet side slope may encroach into wetted areas of the narrows. East of the Klondike Highway, approximately 830 m of the existing road would be raised 1.5–2.5 m and be used as a platform. The raised road/platform would require a double temporary superbag dike to reach DFSL during flood conditions. The width of the raised road is anticipated to be sufficient for a double superbag dike and single-lane vehicle traffic (if required for property access in the area). The lake side of the raised road would be lined with rip rap to mitigate erosion risk from waves.

On the north side of the narrows, an approximate 580 m long platform would extend along the narrows from 108 Bennett Ave and terminate 600 m to the east at the Klondike Highway. The platform would be 0.5–1.5 m higher than existing ground for its length and would replace the boardwalk along the narrows between the railway bridge and the Klondike Highway bridge. The platform footprint would encroach into the building along the water near the railway bridge; either this building would need to be removed, or a small section of structural slope stabilization would be needed to narrow the footprint of the platform (to be determined during detailed design). The platform would require a double temporary superbag dike to reach DFSL during flood conditions.

Along the south side of the airport runway, an approximate 800 m long platform would provide flood mitigation for the runway, hangar buildings, and single private residence. The platform would be 1.5–2.0 m higher than existing ground for its length and would require a double temporary superbag dike to reach DFSL during flood conditions.

Raising of the ground surface along the length of the platforms may require slope stabilization measures to be installed along the banks of the narrows between Bennett Lake and Nares Lake and along the shores of Nares Lake near the airport and Waterfront Drive.

One property located in the floodplain of Grayling Bay at the southwest corner of Choulta would require a temporary sandbag dike around the structure during flood conditions. The temporary sandbag dike would need to be approximately 2.5 m high to meet the DFSL. The depth of flooding around this property is estimated to be less than 1 m and as such can be protected with the construction of a sandbag dike with a perimeter length of approximately 200 m. The protection of this property with sandbags is constant through all mitigation options.

Figure No.

C3

Title

Carcross 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
Carcross, Yukon

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

N

0 50 100 150 200 m

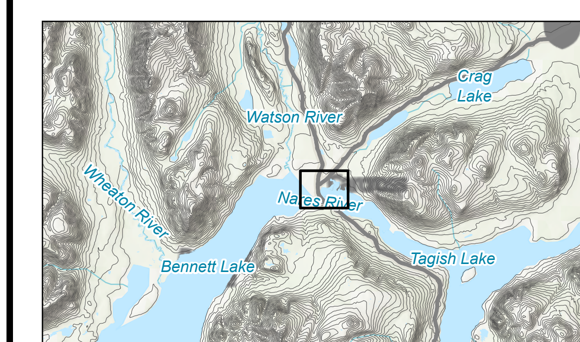
(At original document size of 11x17)
1:10,000

- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Runway
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed

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

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table C3, considering the Class D level of accuracy (+/-50%). Table C3 also provides the Class D OPCs on a per inundated property basis (from Section C.1.11).

Table C3 Option 1 Summary of Class D OPCs

	Class D OPC			Number of Inundated Properties (Section C.1.11)[1]	Class D OPC per Inundated Property		
Capital Cost	$ 26,532,500	-	$ 39,798,750	34	$ 780,368	-	$1,170,552
Annual Cost (Flood Year)	$ 2,437,700	-	$ 3,656,550		$ 71,698	-	$ 107,546
Annual Cost (Non-Flood Year)	$ 23,800	-	$ 35,700		$ 700	-	$ 1,050

[1]As described in Section C.1.11, the inundated properties from the preliminary inundation analysis consists of 23 private residences and 11 major community features/properties.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table C4 (capital costs), Table C5 (annual cost, flood year), and Table C6 (annual cost, non-flood year).

Table C4 Option 1 Capital Costs Class D Cost Estimate

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1A	**Option 1: General Conditions**				
a)	Mobilization/Demobilization	LS	1	$1,542,300.00	$1,542,300.00
b)	Site Preparation/Restoration	LS	1	$308,500.00	$308,500.00
				Total 1A	$1,850,800.00
Section 1B	**Option 1: Earthworks & Landscaping, Platform**				
a)	Clearing and Grubbing	M2	24810	$10.00	$248,100.00
b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	7450	$25.00	$186,250.00
c)	Platform Topsoil	M2	21310	$20.00	$426,200.00
d)	Platform Seeding	M2	21310	$5.00	$106,550.00
e)	Geotextile Fabric	M2	7610	$10.00	$76,100.00
f)	Embankment Fill, Clay Core	M3	9290	$100.00	$929,000.00
g)	Embankment Fill, Granular Shell	M3	19050	$50.00	$952,500.00
h)	Riprap	MT	8900	$141.00	$1,254,900.00
i)	Seepage Cutoff Wall-Clay, 1m Width	M3	7610	$100.00	$761,000.00
j)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	1920	$300.00	$576,000.00
k)	Slope Stabilization	M	1920	$3,000.00	$5,760,000.00
				Total 1B	$11,276,600.00
Section 1C	**Option 1: Floodboxes, Platform**				
a)	600mm Dia. Concrete Culvert	M	400	$750.00	$300,000.00
b)	Flatback Drainage Gate, 600mm Dia.	EA	20	$3,000.00	$60,000.00
c)	Type II Concrete Headwall, 600mm Dia.	EA	20	$5,000.00	$100,000.00
d)	Canal Gate, 600mm Dia.	EA	20	$3,000.00	$60,000.00
				Total 1C	$520,000.00
Section 1D	**Option 1: Road Raising, Platform (Waterfront Dr.)**				
a)	Rough Grading	M2	10820	$5.00	$54,100.00
b)	Subgrade Preparation	M2	10820	$5.00	$54,100.00
c)	80mm Minus Granular Subbase, Variable Depth	M3	8400	$40.00	$336,000.00
d)	100mm Minus Granular Base, 100mm Depth	M3	680	$50.00	$34,000.00
e)	BST Surfacing	M2	5070	$50.00	$253,500.00
f)	Riprap	MT	2870	$141.00	$404,670.00
g)	Slope Stabilization	M	830	$3,000.00	$2,490,000.00
				Total 1D	$3,626,370.00

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.

Contingency (20%)	$3,454,754.00
Subtotal	$20,728,524.00
Location Adjustment Factor (LCAF)	1.28
Capital Costs Base Price	$26,532,500.00
Capital Costs Upper Bound	$39,798,750.00

Table C5 Option 1 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1E	**Option 1: Annual Cost, Flood Year**				
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 Sandbags and Superbags	LS	1	$500.00	$500.00
d)	Superbags c/w Sandfill (2.0m)	M	2750	$500.00	$1,375,000.00
e)	Sandbags c/w Sandfill (2.0m)	M	180	$564.00	$101,520.00
				Total 1E	$1,587,020.00
				Contingency (20%)	$317,404.00
				Subtotal	$1,904,424.00
				Location Adjustment Factor (LCAF)	1.28
				Annual Cost, Flood Year Base Price	$2,437,700.00
				Annual Cost, Flood Year Upper Bound	$3,656,550.00

Table C6 Option 1 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1F	**Option 1: Annual Cost, Non-Flood Year**				
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 Sandbags and Superbags	LS	1	$500.00	$500.00
				Total 1F	$15,500.00
				Contingency (20%)	$3,100.00
				Subtotal	$18,600.00
				Location Adjustment Factor (LCAF)	1.28
				Annual Cost, Non-Flood Year Base Price	$23,800.00
				Annual Cost, Non-Flood Year Upper Bound	$35,700.00

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 C7 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table C7 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 given underlying soils and long duration of flooding	Low Performance
2	Time to Implementation	geotechnical investigations including borehole drilling for bank stability and construction requirements; design will need to consider underlying sand geology and potentially increased seepage rates and impacts on stability; hydraulic modelling, wind/wave analysis, aerodrome studies, beach processes studies, and erosion mitigation design required; medium regulatory risk; moderate anticipated design effort; property owner agreements required; moderate anticipated construction effort	Medium 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 and 3); per-inundated-property capital cost is $780,368/property	Medium Performance
4	Maintenance and Storage	storage required for substantial number of superbags and sandbags; stockpiling of material required for superbags/sandbags; numerous platforms will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required	Low Performance
5	Response and Activation	numerous temporary superbag dikes require training, labour, equipment, and a timely response in a flood scenario to be effective; property-owner deployed temporary sandbag dikes; floodbox slide gates need to be manually closed prior to arrival of flood	Low Performance
6	Aesthetics and Community Function	alterations to existing landscape during non-flood conditions however the platforms may be used as a community feature (e.g., walking path) if the community members are supportive; temporary alteration of private/community function and view during flood conditions from temporary superbag and sandbag dikes	Medium Performance
7	Future Adaptability	three-high temporary superbag dikes or additional raising of road may be completed in future for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height to platform structure are likely possible without additional widening of structure but will require engineering study	High Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	minor intrusions into Bennett Lake, Nares Lake, and narrows; portions of mitigations on beach areas may impact natural beach processes and morphodynamics but are not anticipated to substantially disrupt existing lake and river processes; slope stabilization measures may be required over an approximate length of 2.7 km	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	high return on investment (ROI) given the eleven major community features (including heritage features) that would be mitigated from flooding as a result of improvements	High Performance

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.

C.2.2 OPTION 2

Description

The conceptual flood mitigations for Option 2 are illustrated in Figure C4. The main difference between Option 1 and Option 2 is that Option 2 includes permanent flood mitigations to the DFSL which do not require construction of temporary dikes in the event of a flood.

On the south side of the narrows and west of the Klondike Highway bridge, a structural dike with an approximate height of 3.5 m greater than the existing ground would be installed over an approximate length of 530 m. The structural dike would be on the lake side of Waterfront Drive. The footprint of the dike is not expected to extend below the OHWM. East of the Klondike Highway bridge, approximately 930 m of Waterfront Drive would be raised by approximately 3.0 – 3.5 m (compared to existing ground). The footprint of the road widening would be approximately 25 m and may extend into private properties and below the OHWM.

On the north side of the narrows and west of the pedestrian bridge, an approximate 200 m long earthen dike would be installed along the shore of Bennett Lake. The earthen dike crest would be approximately 2.5 – 3.5 m greater than the existing ground. The lake side of the earthen dike would be lined with rip rap to mitigate erosion risk from waves. East of the pedestrian bridge, the earthen dike would transition to a structural dike along the north side of the narrows, east of the railway bridge. The structural dike would extend to the Klondike Highway bridge (approximately 380 m) along the current alignment of the existing boardwalk. Allowances/modifications to dike design would be required to maintain the boat launch on the west side of the highway bridge. The crest of the structural dike would be 2.5 – 3.5 m higher than existing ground.

Along the south side of the airport runway, an approximate 800 m long earthen dike would enclose the airport, hangars, and the single private property to the south of the runway. The earthen dike would have approximate height of 3.5 – 4.0 m. The earthen dike footprint would be approximately 30 m wide, which is likely to extend both onto the single private property and below the OHWM. The lake side of the earthen dike would be lined with rip rap to mitigate erosion risk from waves.

As with Option 1, the property located in the floodplain of Grayling Bay is proposed to be protected with a temporary sandbag dike with a height of up to 2.5 m.

The installation of the dikes and raising of Waterfront Drive may require slope stabilization measures to be installed along the banks of the narrows between Bennett Lake and Nares Lake and along the shores of Nares Lake near the airport and Waterfront Drive.

Figure No.

C4

Title

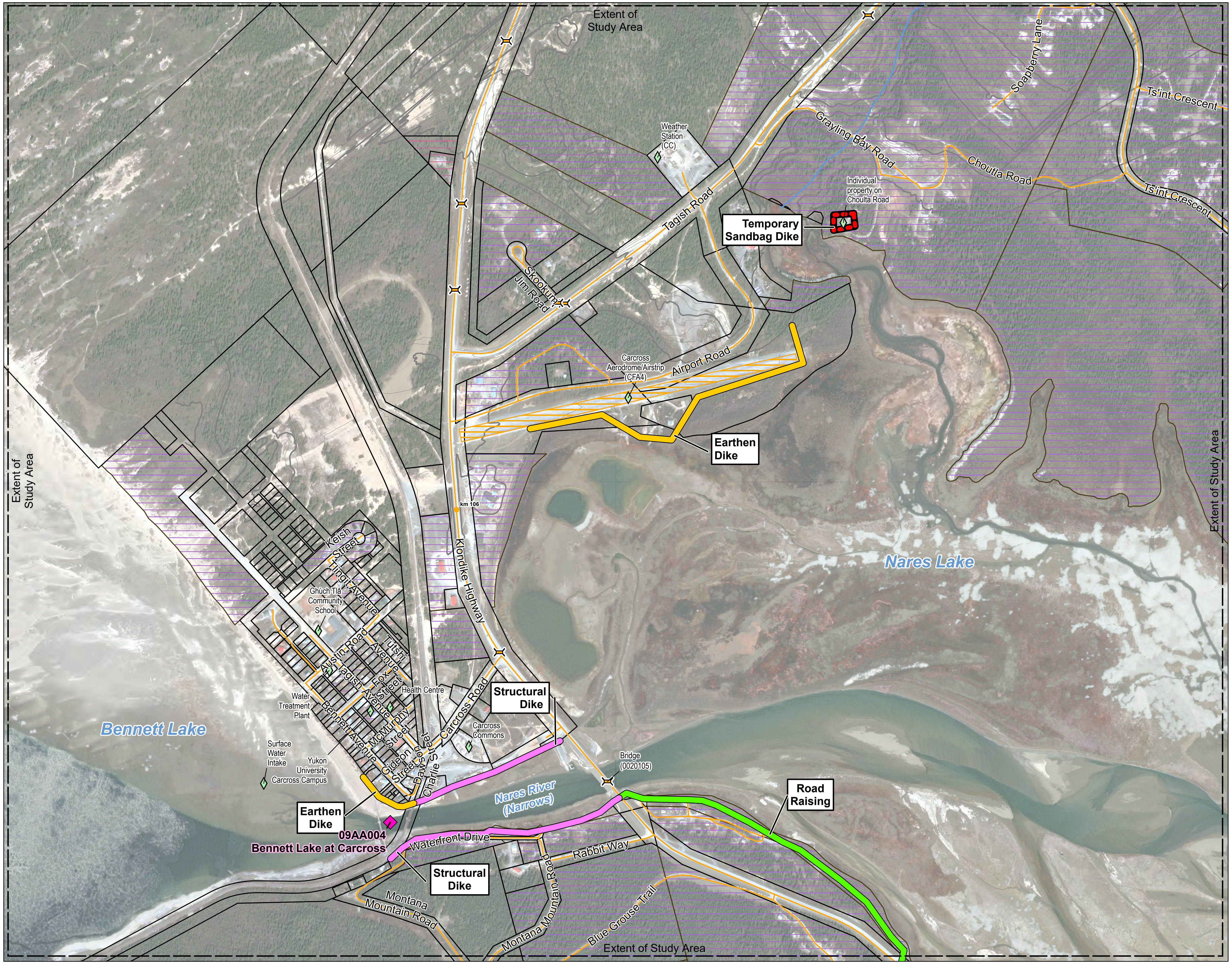
Carcross Conceptual Flood Mitigation Design - Option 2

Client/Project 144903232

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

Project Location
Carcross,
Yukon

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



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0 50 100 150 200 m

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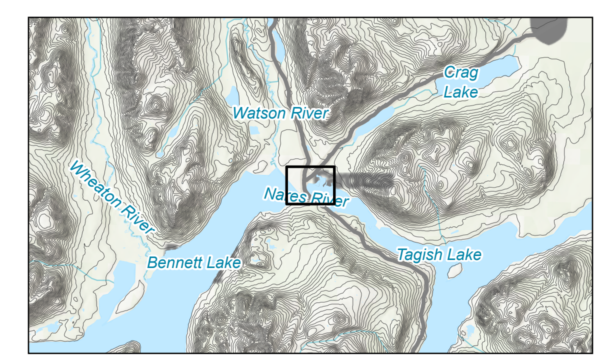
- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Runway
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed

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

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table C8, considering the Class D level of accuracy (+/-50%). Table C8 also provides the Class D OPCs on a per inundated property basis (from Section C.1.11).

Table C8 Option 2 Summary of Class D OPCs

	Class D OPC					Number of Inundated Properties (Section C.1.11)[1]	Class D OPC per Inundated Property				
Capital Cost	$	72,260,100	-	$	108,390,150	34	$	2,125,298	-	$	3,187,946
Annual Cost (Flood Year)	$	271,903	-	$	407,854		$	7,998	-	$	11,996
Annual Cost (Non-Flood Year)	$	92,928	-	$	139,392		$	2,734	-	$	4,100

[1]As described in Section C.1.11, the inundated properties from the preliminary inundation analysis consists of 23 private residences and 11 major community features/properties.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table C9 (capital costs), Table C10 (annual cost, flood year), and Table C11 (annual cost, non-flood year).

Table C9 Option 2 Capital Costs Class D Cost Estimate

Item No.		Description of Work	Units	Qty.	Unit Price	Amount
Section 2A		**Option 2: General Conditions**				
	a)	Mobilization/Demobilization	LS	1	$4,200,390.00	$4,200,390.00
	b)	Site Preparation/Restoration	LS	1	$840,100.00	$840,100.00
					Total 2A	$5,040,490.00
Section 2B		**Option 2: Earthworks & Landscaping, Earthen Dike (Airport)**				
	a)	Clearing and Grubbing	M2	26450	$10.00	$264,500.00
	b)	Cut and Re-use Onsite - Native Material	M3	3340	$15.00	$50,100.00
	c)	Cut and Dispose Offsite - Native Material	M3	23850	$30.00	$715,500.00
	d)	Import and Place Fill - Native Material	M3	3340	$15.00	$50,100.00
	e)	Embankment Fill, Clay Core	M3	13300	$100.00	$1,330,000.00
	f)	Embankment Fill, Granular Shell	M3	46870	$50.00	$2,343,500.00
	g)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	1940	$25.00	$48,500.00
	h)	Riprap	MT	13500	$141.00	$1,903,500.00
	i)	Geotextile Fabric	M2	11540	$10.00	$115,400.00
	j)	Embankment Seeding	M2	10900	$5.00	$54,500.00
	k)	Embankment Topsoil	M2	10900	$20.00	$218,000.00
	l)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	800	$300.00	$240,000.00
	m)	Slope Stabilization	M	800	$3,000.00	$2,400,000.00
					Total 2B	$9,733,600.00
Section 2C		**Option 2: Earthworks & Landscaping, Structural Dike (North and South)**				
	a)	Clearing and Grubbing	M2	5280	$10.00	$52,800.00
	b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	1590	$25.00	$39,750.00
	c)	Dike Topsoil	M2	3360	$20.00	$67,200.00
	d)	Dike Seeding	M2	3360	$5.00	$16,800.00
	e)	Dike Fill	M3	15120	$100.00	$1,512,000.00
	f)	Sheet Pile Wall	M2	8070	$1,700.00	$13,719,000.00
	g)	Modular Block Wall	M2	7040	$900.00	$6,336,000.00
	h)	Handrails	M	2240	$140.00	$313,600.00
	i)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	1120	$300.00	$336,000.00
	j)	Slope Stabilization	M	1120	$3,000.00	$3,360,000.00
					Total 2C	$25,753,150.00
Section 2D		**Option 2: Floodboxes, Structural Dike & Earthen Berm**				

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.

	a)	600mm Dia. Concrete Culvert	M	400	$750.00	$300,000.00
	b)	Flatback Drainage Gate, 600mm Dia.	EA	20	$3,000.00	$60,000.00
	c)	Type II Concrete Headwall, 600mm Dia.	EA	20	$5,000.00	$100,000.00
	d)	Canal Gate, 600mm Dia.	EA	20	$3,000.00	$60,000.00
					Total 2D	$520,000.00
Section 2E		**Option 2: Road Raising, (Waterfront Dr.)**				
	a)	Rough Grading	M2	21270	$5.00	$106,350.00
	b)	Subgrade Preparation	M2	21270	$5.00	$106,350.00
	c)	80mm Minus Granular Subbase, Variable Depth	M3	40281	$40.00	$1,611,240.00
	d)	100mm Minus Granular Base, 100mm Depth	M3	690	$50.00	$34,500.00
	e)	BST Surfacing	M2	5140	$50.00	$257,000.00
	f)	Riprap	MT	9870	$141.00	$1,391,670.00
	g)	Slope Stabilization	M	830	$3,000.00	$2,490,000.00
					Total 2E	$5,997,110.00
					Contingency (20%)	$9,408,870.00
					Subtotal	$56,453,220.00
					Location Adjustment Factor (LCAF)	1.28
					Capital Costs Base Price	$72,260,100.00
					Capital Costs Upper Bound	$108,390,150.00

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 C10 Option 2 Annual Costs During a Flood Year Class D Cost Estimate

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2F	**Option 2: Annual Cost, Flood Year**				
a)	Inspections	LS	1	$25,000.00	$25,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$50,000.00	$50,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
d)	Sandbags c/w Sandfill (2.0m)	M	180	$564.00	$101,520.00
				Total 2F	$177,020.00
				Contingency (20%)	$35,404.00
				Subtotal	$212,424.00
				Location Adjustment Factor (LCAF)	1.28
				Annual Cost, Flood Year Base Price	$271,902.72
				Annual Cost, Flood Year Upper Bound	$407,854.08

Table C11 Option 2 Annual Costs During a Non-Flood Year Class D Cost Estimate

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2G	**Option 2: Annual Cost, Non-Flood Year**				
a)	Inspections	LS	1	$10,000.00	$10,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$50,000.00	$50,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 2G	$60,500.00
				Contingency (20%)	$12,100.00
				Subtotal	$72,600.00
				Location Adjustment Factor (LCAF)	1.28
				Annual Cost, Non-Flood Year Base Price	$92,928.00
				Annual Cost, Non-Flood Year Upper Bound	$139,392.00

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 C12 summarizes the performance of Option 2 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table C12 Option 2 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	permanent structures would withstand long duration of flooding (several weeks or months); wind/wave impacts and damage risks from ice/debris would be mitigated by elevated DFSL and erosion mitigation measures; low number of temporary sandbag dikes vulnerable to damage from ice/debris and waves; 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 bank stability and construction requirements for dikes; design will need to consider underlying sand geology and potentially increased seepage rates and impacts on stability; hydraulic modelling, wind/wave analysis, aerodrome studies, beach processes studies, and erosion mitigation design required; high regulatory risk; high anticipated design effort; property owner agreements required; substantial anticipated construction effort	Low 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 $2,125,295/property	Low Performance
4	Maintenance and Storage	minimal storage requirements (sandbags for low number of temporary sandbag dikes); numerous large dikes will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required	High Performance
5	Response and Activation	1 property-owner deployed temporary sandbag dike; floodbox slide gates need to be manually closed prior to arrival of flood and opened following abatement of the flood	High Performance
6	Aesthetics and Community Function	substantial permanent alteration of existing landscape and lake views by earthen dike, structural dike, and raised road construction (2.5 - 4.0 m in height); dike crests may be established as community features (e.g., walking paths) if the community members are supportive; temporary alteration of private property function during flood conditions from temporary sandbag dikes	Low Performance
7	Future Adaptability	temporary superbag dike may be deployed on earthen and structural dike crest and raised roads in future for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height to dike and road are possible but will require engineering study and are likely to require widening of structure	Medium Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Bennett Lake, Nares Lake, and narrows; portions of mitigations on beach areas may impact natural beach processes and morphodynamics but are not anticipated to substantially disrupt existing lake and river processes; slope stabilization measures may be required over an approximate length of 2.7 km	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	high return on investment (ROI) given the eleven major community features (including heritage features) that would be mitigated from flooding as a result of improvements	High Performance

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.

C.2.3 OPTION 3

Description

The conceptual flood mitigations for Option 3 are illustrated in Figure C5. Option 3 is identical to Option 2, with the exception of an altered approach at the airport: instead of an earthen dike surrounding the airport and private property, the airport runway would be raised and a temporary sandbag dike would be constructed at the private property.

The airport runway would be raised by approximately 2.0–3.0 m over the 900 m approximate length of the runway. The width of the raised runway would be approximately 20 m (same as under existing conditions). Embankment side slopes would typically be 3H:1V. The footprint of the runway raising would be approximately 40 m.

The airport buildings south of the runway would be protected with a temporary sandbag dike which would be approximately 3.5 m high to reach the DFSL.

As with Option 2, the installation of the dikes and raising of Waterfront Drive may require slope stabilization measures to be installed along the banks of the narrows between Bennett Lake and Nares Lake.

Figure No.

C5

Title

Carcross 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
Carcross,
Yukon

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

N

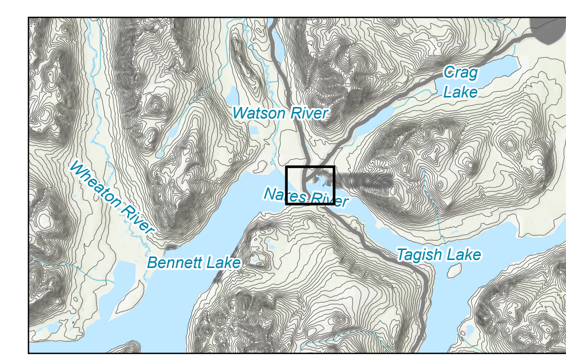
0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- WSC Station
- Culvert/ Bridge
- Community Infrastructure and Points of Interest
- Highway Kilometre Post
- Road
- Runway
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - Surveyed
- First Nation Settlement Lands - Surveyed
- First Nation Settlement Lands - Unsurveyed

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

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table C13, considering the Class D level of accuracy (+/-50%). Table C13 also provides the Class D OPCs on a per inundated property basis (from Section C.1.11).

Table C13 Option 3 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section C.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	$ 61,548,600 - $ 92,322,900	34	$ 1,810,253 - $ 2,715,380
Annual Cost (Flood Year)	$ 419,174 - $ 628,762		$ 12,329 - $ 18,493
Annual Cost (Non-Flood Year)	$ 92,928 - $ 139,392		$ 2,734 - $ 4,100
[1]As described in Section C.1.11, the inundated properties from the preliminary inundation analysis consists of 23 private residences and 11 major community features/properties.			

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table C14 (capital costs), Table C15 (annual cost, flood year), and Table C16 (annual cost, non-flood year).

Table C14 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	$3,577,740.00	$3,577,740.00
	b)	Site Preparation/Restoration	LS	1	$715,600.00	$715,600.00
					Total 3A	$4,293,340.00
Section 3B		**Option 3: Airport Raise (Carcross Aerodrome CFA4)**				
	a)	Rough Grading	M2	21270	$5.00	$106,350.00
	b)	Subgrade Preparation	M2	21270	$5.00	$106,350.00
	c)	80mm Minus Granular Subbase, Variable Depth	M3	40281	$40.00	$1,611,240.00
	d)	100mm Minus Granular Base, 100mm Depth	M3	690	$50.00	$34,500.00
	e)	BST Surfacing	M2	5140	$50.00	$257,000.00
	f)	Riprap	MT	9870	$141.00	$1,391,670.00
					Total 3B	$3,507,110.00
Section 3C		**Option 3: Earthworks & Landscaping, Structural Dike (North and South)**				
	a)	Clearing and Grubbing	M2	5280	$10.00	$52,800.00
	b)	Topsoil Stripping and Stockpiling, 300mm Depth	M3	1590	$25.00	$39,750.00
	c)	Dike Topsoil	M2	3360	$20.00	$67,200.00
	d)	Dike Seeding	M2	3360	$5.00	$16,800.00
	e)	Dike Fill	M3	15120	$100.00	$1,512,000.00
	f)	Sheet Pile Wall	M2	8070	$1,700.00	$13,719,000.00
	g)	Modular Block Wall	M2	7040	$900.00	$6,336,000.00
	h)	Handrails	M	2240	$140.00	$313,600.00
	i)	Toe Drain: Perforated Pipe, Geotextile and Drain Rock	M	1120	$300.00	$336,000.00
	j)	Slope Stabilization	M	1120	$3,000.00	$3,360,000.00
					Total 3C	$25,753,150.00
Section 3D		**Option 3: Floodboxes, Structural Dike & Earthen Dike**				
	a)	600mm Dia. Concrete Culvert	M	400	$750.00	$300,000.00
	b)	Flatback Drainage Gate, 600mm Dia.	EA	20	$3,000.00	$60,000.00
	c)	Type II Concrete Headwall, 600mm Dia.	EA	20	$5,000.00	$100,000.00
	d)	Canal Gate, 600mm Dia.	EA	20	$3,000.00	$60,000.00
					Total 3D	$520,000.00
Section 3E		**Option 3: Road Raising, (Waterfront Dr.)**				

a)	Rough Grading	M2	21270	$5.00	$106,350.00
b)	Subgrade Preparation	M2	21270	$5.00	$106,350.00
c)	80mm Minus Granular Subbase, Variable Depth	M3	40281	$40.00	$1,611,240.00
d)	100mm Minus Granular Base, 100mm Depth	M3	690	$50.00	$34,500.00
e)	BST Surfacing	M2	5140	$50.00	$257,000.00
f)	Riprap	MT	9870	$141.00	$1,391,670.00
g)	Slope Stabilization	M	830	$3,000.00	$2,490,000.00
				Total 3E	$5,997,110.00
				Contingency (20%)	$8,014,142.00
				Subtotal	$48,084,852.00
				Location Adjustment Factor (LCAF)	1.28
				Capital Costs Base Price	$61,548,600.00
				Capital Costs Upper Bound	$92,322,900.00

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.

Table C15 Option 3 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 3F	**Option 3: Annual Cost, Flood Year**				
a)	Inspections	LS	1	$25,000.00	$25,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$50,000.00	$50,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
d)	Sandbags c/w Sandfill (2.0m)	M	350	$564.00	$197,400.00
				Total 3F	$272,900.00
				Contingency (20%)	$54,580.00
				Subtotal	$327,480.00
				Location Adjustment Factor (LCAF)	1.28
				Annual Cost, Flood Year Base Price	$419,174.40
				Annual Cost, Flood Year Upper Bound	$628,761.60

Table C16 Option 3 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 3G	**Option 3: Annual Cost, Non-Flood Year**				
a)	Inspections	LS	1	$10,000.00	$10,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$50,000.00	$50,000.00
c)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 3G	$60,500.00
				Contingency (20%)	$12,100.00
				Subtotal	$72,600.00
				Location Adjustment Factor (LCAF)	1.28
				Annual Cost, Non-Flood Year Base Price	$92,928.00
				Annual Cost, Non-Flood Year Upper Bound	$139,392.00

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 C17 summarizes the performance of Option 3 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table C17 Option 3 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	permanent structures would withstand long duration of flooding (several weeks or months); wind/wave impacts and damage risks from ice/debris would be mitigated by elevated DFSL and erosion mitigation measures; 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 bank stability and construction requirements for dikes; design will need to consider underlying sand geology and potentially increased seepage rates and impacts on stability; hydraulic modelling, wind/wave analysis, aerodrome studies, beach processes studies, and erosion mitigation design required; high regulatory risk; high anticipated design effort; property owner agreements required; substantial anticipated construction effort	Low 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 $1,810,253/property	Low Performance
4	Maintenance and Storage	no storage requirements; numerous large dikes will require inspections, maintenance, and vegetation clearing; floodbox maintenance will be required	Medium Performance
5	Response and Activation	two property-owner deployed temporary sandbag dikes; 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	substantial permanent alteration of existing landscape and lake views by earthen dike, structural dike, raised road, and raised runway construction (2.5 - 4.0 m in height); dike crests may be established as community features (e.g., walking paths) if the community members are supportive; temporary alteration of private property function during flood conditions from temporary sandbag dikes	Low Performance
7	Future Adaptability	temporary superbag dike may be deployed on earthen and structural dike crest and raised roads/runway in future for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height to dike and road are possible but will require engineering study and are likely to require widening of structure	Medium Performance
8	Alteration of Existing Hydraulics, Erosion/ Sedimentation, Ice Processes, and Slope Stability	intrusions into Bennett Lake, Nares Lake, and narrows; portions of mitigations on beach areas may impact natural beach processes and morphodynamics but are not anticipated to substantially disrupt existing lake and river processes; slope stabilization measures may be required over an approximate length of 2.0 km	High Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	high return on investment (ROI) given the eleven major community features (including heritage features) that would be mitigated from flooding as a result of improvements	High Performance

C.2.4 SUMMARY TABLES

Table C18 summarizes the Class D cost estimates for each of the conceptual design options.

Table C18 Summary of Class D OPCs

	Option 1 Class D OPCs	Option 2 Class D OPCs	Option 3 Class D OPCs
Capital Cost	$26,532,500 - $39,798,750	$72,260,100 - $108,390,150	$61,548,600 - $92,322,900
Annual Cost (Flood Year)	$ 2,437,700 - $ 3,656,550	$ 271,903 - $ 407,854	$ 419,174 - $ 628,762
Annual Cost (Non-Flood Year)	$ 23,800 - $ 35,700	$ 92,928 - $ 139,392	$ 92,928 - $ 139,392

Table C19 provides a summary of the evaluation of each of the conceptual design options.

Table C19 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	High Performance	High Performance
2	Time to Implementation	Medium Performance	Low Performance	Low Performance
3	Capital Cost Per Inundated Property	Medium Performance	Low Performance	Low Performance
4	Maintenance and Storage	Low Performance	High Performance	Medium Performance
5	Response and Activation	Low Performance	High Performance	High Performance
6	Aesthetics and Community Function	Medium Performance	Low Performance	Low Performance
7	Future Adaptability	High Performance	Medium 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	High Performance	High Performance	High Performance