Appendix I Pelly Crossing 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.

I.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 Pelly Crossing.

I.1.1 POPULATION

Pelly Crossing has a population of 316 with 527 private dwellings according to the 2021 census data (Statistics Canada 2023c). The population has decreased by approximately 10% from 2016 when the population was 353 (Statistics Canada 2023c).

I.1.2 STUDY AREA

The Study Area in Figure I1 outlines the areas that flood mitigations are being designed in this Project at Pelly Crossing. The boundaries of the Study Area are based on Stantec's understanding that the flood mitigations are to be considered for communities, and that individual properties outside of the main community consolidation are not included.

I.1.3 FIRST NATIONS

The Pelly Crossing area is within the Traditional Territory of the Selkirk First Nation (SFN) and First Nation of Na-cho Nyäk Dun (FNNND). The SFN have parcels of Category B Settlement Lands along the Pelly River in Pelly Crossing. The land claim selection is SFN C-1B, C-5B, C-6B, C-7B, C-9B, C-17B, C-11FS, and C-12FS. This means that SFN has surface and fee simple ownership of these parcels of land (Government of Yukon 2022). Other First Nation's with Traditional Territories near the Study Area, such as the FNNND, should also be considered when engaging with local stakeholders. Figure I2 illustrates the SFN settlement lands within the Study Area.

I.1.4 BATHYMETRY AND TOPOGRAPHY

The following 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 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 as per NRCan (2022b).

I.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey, 2020), the Study Area likely consists of alluvial terrace sediments along the Pelly River shoreline overlain by glaciofluvial plain sediments within the Town of Pelly Crossing. The alluvial sediments are made up of gravel, cobble to pebble, with a sandy matrix, massive to thick bedding, capped by sands and silts. Sediments are of floodplain origin now isolated from flooding by stream incisions. The alluvial sediment thickness ranges between 1 m to 10 m. The glaciofluvial sediments are made up of pebble to cobble gravel with massive to thick bedding, incised into flights of terraces by glacial streams. The glaciofluvial sediment thickness ranges between 1 m to 10 m.

Based on the Permafrost Probability Model (Bonnaventure et al. 2012), the Study Area is located within a region of extensive discontinuous permafrost (50-60% of land area underlain by permafrost). The Canada Permafrost Map (National Atlas of Canada 1995) also indicates the Study Area is in a region of extensive discontinuous permafrost (50-90% of land area underlain by permafrost) with a low to medium (<10-20% by volume of visible ice) ground ice content in the upper 10-20 m of the ground.

I.1.6 HYDROGEOLOGY

The alluvial sediments are made up of gravel, cobble to pebble, with a sandy matrix, 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 Pelly River water levels. During flooding, the high-water levels would result in high groundwater levels and after flood waters recede, it is likely that the groundwater levels would recede relatively quickly based on the permeability of the soil conditions in the area.

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

I.1.7 PAST FLOODING EVENTS AND RESPONSE

No background documentation was provided to Stantec on past flood events and their associated responses in the Study Area at the time of writing.

Stantec observed elevated water levels in Mica Creek (outside of the Study Area) in June of 2022, to the point where water was hitting the Mica Creek bridge soffit and debris was accumulating on the upstream side. It is not known if private residences or other infrastructure requiring access/egress exist to the east of the bridge.

I.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

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

I.1.9 WIND, WAVES, AND EROSION

While floodplain mapping and associated hydraulic modelling of the DFSL has not been completed for Pelly Crossing to date, it is likely that flow velocities in the Pelly River during flood conditions would likely 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.

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

I.1.10 HYDROLOGY

The Pelly River is the major water feature at Pelly Crossing community (Figure I1). The Pelly River rises on the western slopes of Selwyn Mountains, feeding mainly on glacier water melt. It flows south, and west passing the Pelly Lakes, and there turns to the west. It then assumes a northwesterly course, and merges with the Yukon River near old Fort Selkirk. The Pelly River passes the communities of Ross River, Faro and Pelly Crossing on its course.

WSC Station 09BC001 (Pelly River at Pelly Crossing) is located on the north side of the Pelly River (river's right bank), and on the upstream side of the Klondike HWY bridge (Figure I1). WSC Station 09BC001 has a gross drainage area of 48,900 km^2 (GoC 2023). The hydrology review considered WSEs at WSC Station 09BC001. Flood frequency analysis for WSEs was performed by both Morrison Hershfield (2022) and Yukon University (2022) for WSEs at WSC Station 09BC001. Table I1 summarizes the frequency results of these two studies.

Table I1 Flood Frequency Analyses at WSC Station 09BC001 from Morrison Hershfield (2022) and Yukon University (2022)

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1980 - 2022 [a]	1970 - 2022
Number of Years	43	53
Selected Distribution	Lognormal 3	Log-Pearson Type 3 (open water freshet data), Gumble (breakup ice jams) and GEV (freeze-up jams)
Water Surface Elevation (m) [1]		
1:2- Year Event (50% AEP)	462.51	462.70
1:20- Year Event (5% AEP)	463.81	463.90
1:100- Year Event (1% AEP)	464.43	not provided
1:200- Year Event (0.5% AEP)	464.67	465.00

Notes:
[a] Except for three breakup peaks
[1] Elevations provided in CGVD2013 for WSC Station 09BC001

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

Figure I1 illustrates the on-record daily minimum, mean, and maximum WSEs, the WSE during the highest year on record (2013), and the WSEs for the 1:2-year and 1:200-year event at WSC Station 09BC001 from Yukon University (2022). Recent Highest water levels (2022, 2013, 1972, and 1964) have been generated by open water freshet flows. However, breakup ice jams (e.g., 1991) have the potential to cause even higher water levels.

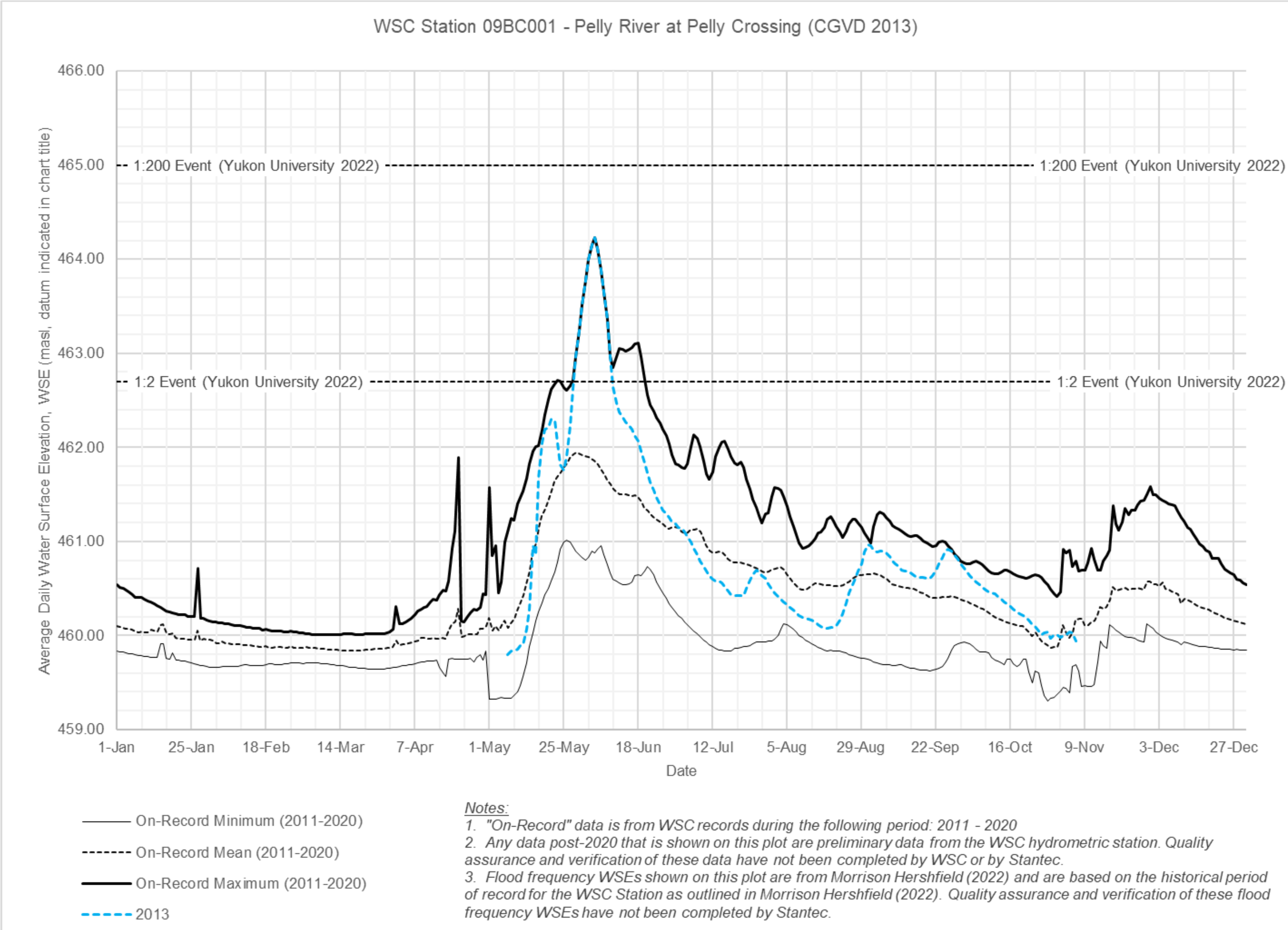


Figure I1 Historical Water Surface Elevations at WSC 09BC001 (Pelly River at Pelly Crossing)

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.

I.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. Hydraulic modelling and floodplain mapping have not been completed to date for the Study Area and is beyond the scope of this Project. However, an understanding of inundation extents under 1:200-year event is required for conceptual design of flood mitigations.

In lieu of floodplain mapping, Stantec performed preliminary existing conditions (no mitigation) inundation analysis for Pelly Crossing using WSEs. This analysis considered the 1:200-year event WSE (465.00 m) developed by Yukon University (2022) with an assumed WSE slope of 0.06% m/m (based on survey from Underhill 2022). The resulting water surface was overlain on the existing conditions topographic and bathymetric elevation data (McElhanney Ltd., GeoYukon 2023) and the limits of inundation were mapped (Figure I2). 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 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).

Relatively small areas of Pelly Crossing are inundated in the preliminary inundation mapping. The inundation encroaches on the campground on the southwest side of the bridge, owned and operated by Selkirk First Nation. It also encroaches on another property occupied by the First Nation on the northwest side of the bridge that has a number of mobile camp trailers.

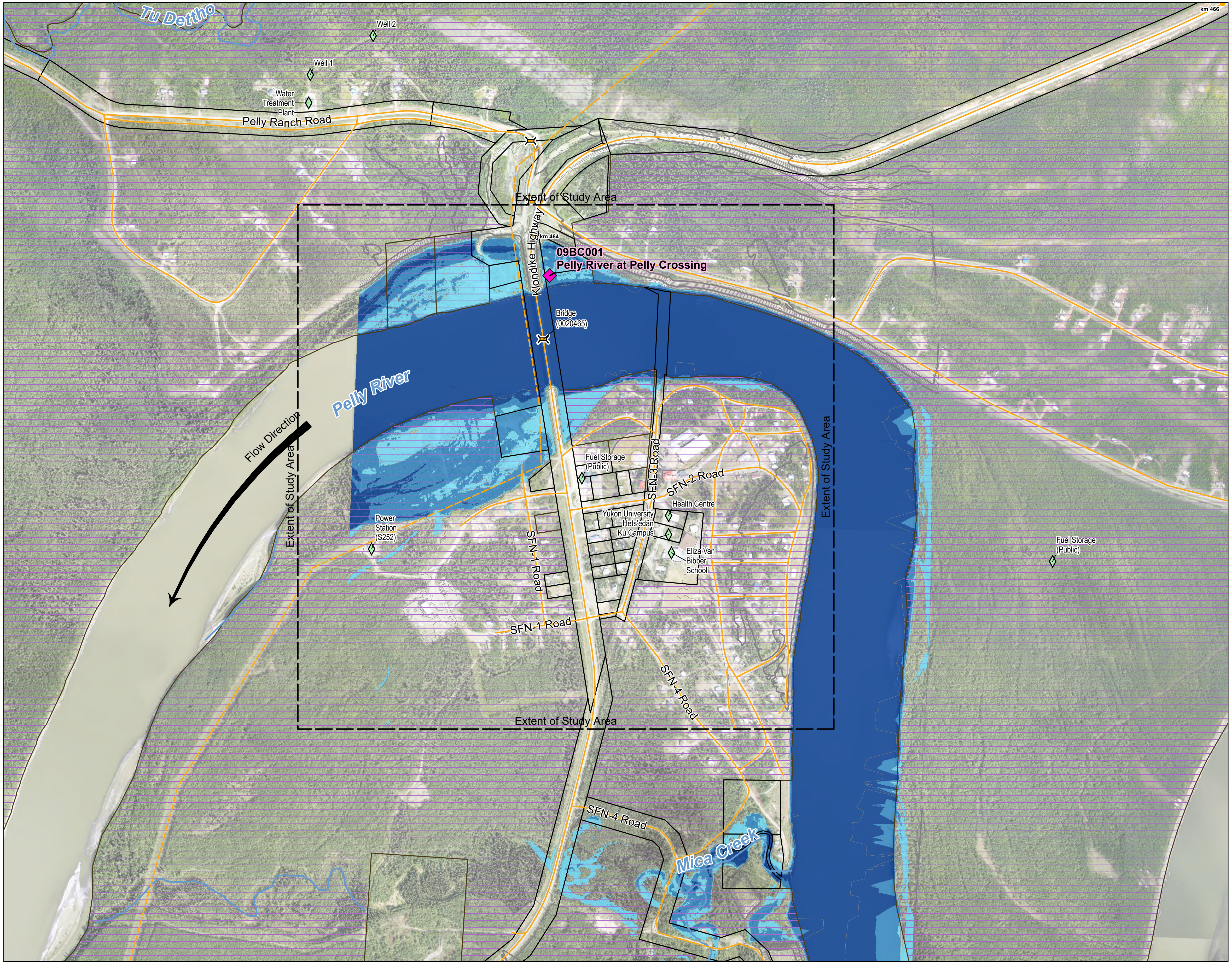


Figure No.

I2

Title

Existing Conditions and Preliminary Flood Inundation at Pelly Crossing

Client/Project 144903232

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

Project Location
Pelly Crossing,
Yukon

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

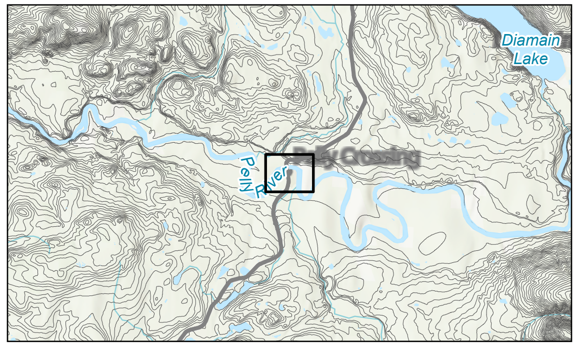
N

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

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

Water Depth at 1:200 WSE Inundation (m)
- 0 - 1
- 1 - 2
- > 2

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



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

Stantec Yukon

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I.2 Mitigation Options and Evaluation

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

Based on the objectives and assumptions presented in the main body of this Report, one conceptual flood mitigation option was developed for Pelly Crossing (Table I2) using one typical engineered flood mitigation design from Section 3.3.2. Flood mitigations in the option were provided for areas which are inundated under the 1:200-year WSE (465.00) in the preliminary inundation mapping (Figure I2). The top elevation of the flood mitigations is described to reach the DFSL which in the case of Pelly Crossing (river site) is assumed to be 465.50 m (i.e., 0.5 m of free board 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 I2 Summary of Conceptual Design Options

Location	Option 1 *lower capital costs, higher response/maintenance*
Northwest Side of the Bridge	Temporary Sandbag Dike
Southwest Side of the Bridge	Temporary Sandbag Dike

Section I.2.1 provides a description, Class D OPC, and qualitative evaluation of conceptual options specified in Table I2.

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

- Bridge widening – The Klondike Highway bridge crossing the Pelly River likely acts as a hydraulic constriction during flood flows. Increasing bridge span to increase hydraulic capacity may reduce flood risk, but was not considered due to significant economic cost.
- River cut-off – Re-routing the river channel to by-pass the community was not considered due to significant economic cost and design complexity; as well as substantial environmental impacts.

I.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure I1.

The area on the southwest side of the bridge in Pelly Crossing, known locally as the campground, has various structures (e.g., several cabins occupied year round, outhouses) that are inundated under the preliminary analysis and would require a temporary sandbag dike around the structures during flood conditions. The depth of flooding around these properties is 1 -2 m and as such can be protected with the construction of sandbag dikes. The temporary sandbag dikes would be up to 2.5 m high to meet the DFSL with a total length of approximately 300 m.

The area on the northwest side of the bridge in Pelly Crossing, the Wildland Fire Management camp, has various structures, including mobile camp trailers, that are inundated under the preliminary analysis and would require a temporary sandbag dike around the structures during flood conditions. The depth of flooding around these properties is less than 1 m and as such can be protected with the construction of sandbag dikes. The temporary sandbag dikes would be up to 1.5 m high to meet the DFSL with a total length of approximately 150 m.

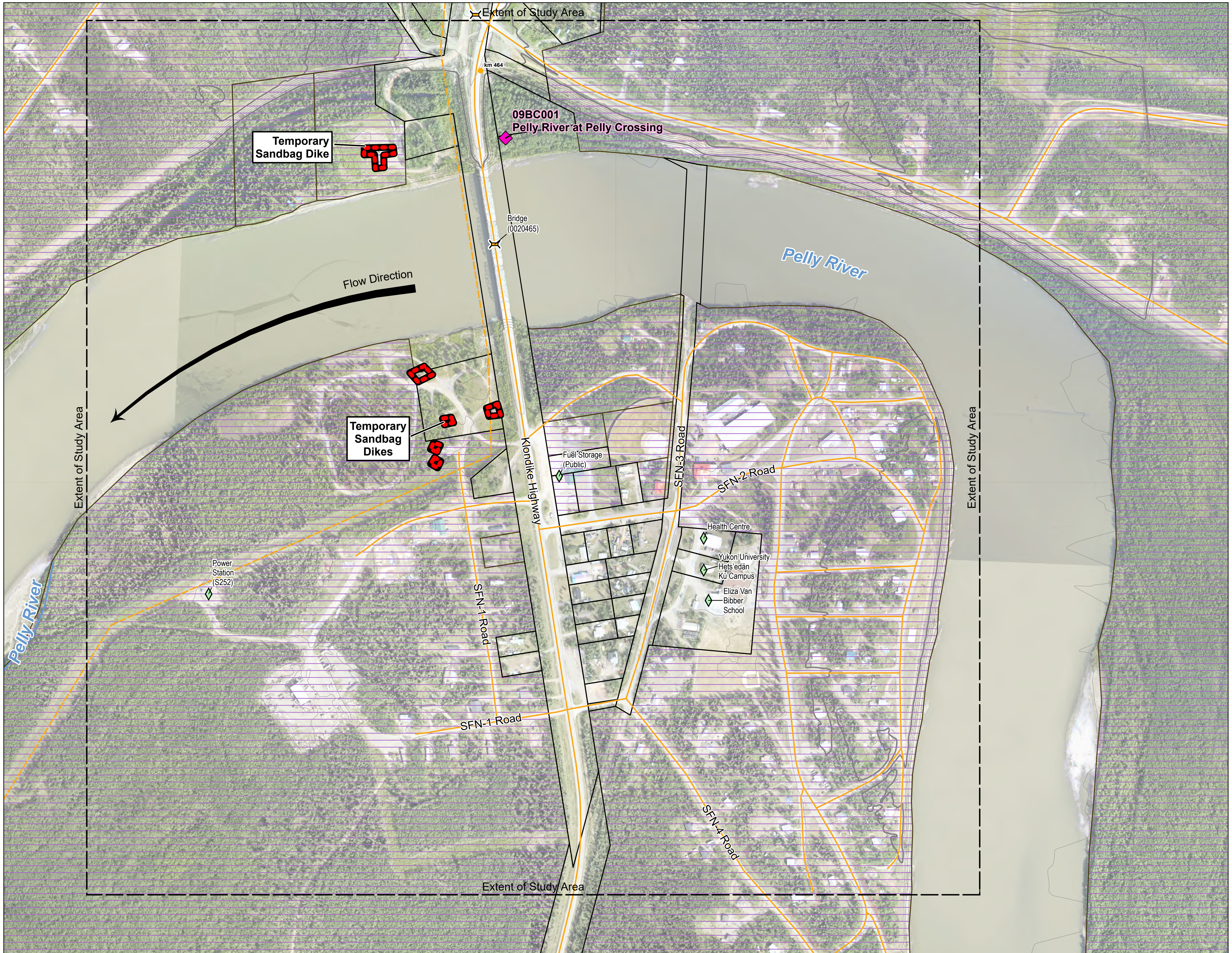


Figure No.
I3

Title
Pelly Crossing 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
Pelly Crossing,
Yukon

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

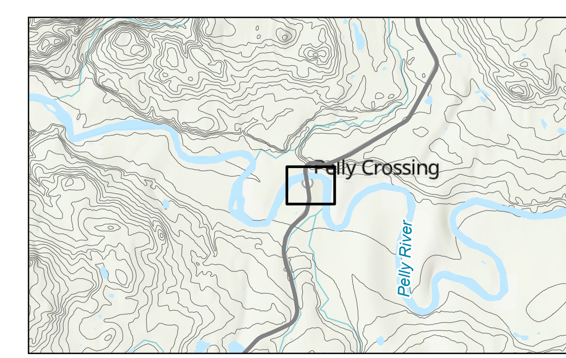
N

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

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

Proposed Mitigation Feature
- Earthen Dike
- Platform with Temporary Superbag Dike
- Road Raising
- Structural Dike
- Temporary Sandbag Dike

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



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

Stantec Yukon

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table I3, considering the Class D level of accuracy (+/-50%). Table I3 also provides the Class D OPCs on a per inundated property basis (from Section I.1.11).

Table I3 Option 1 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section I.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	None	6	None
Annual Cost (Flood Year)	$ 509,200 - $ 763,800		$ 84,867 - $ 127,300
Annual Cost (Non-Flood Year)	$ 1,200 - $ 1,800		$ 200 - $ 300

[1]As described in Section I.1.11, the inundated properties from the preliminary inundation analysis consists of a campground and another property with a number of mobile camp trailers.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table I4 (annual cost, flood year) and Table I5 (annual cost, non-flood year).

Table I4 Option 1 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1A	**Option 1: Annual Costs, Flood Year**				
a)	Storage of Sandbags	LS	1	$500.00	$500.00
b)	Sandbags c/w Sandfill (1.0m - 2.0m)	M	445	$464.00	$206,480.00
				Total 1A	$206,980.00
				Contingency (20%)	$41,396.00
				Subtotal	$248,376.00
				Location Adjustment Factor (LCAF)	2.05
				Annual Cost, Flood Year Base Price	$509,200.00
				Annual Cost, Flood Year Upper Bound	$763,800.00

Table I5 Option 1 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1B	**Option 1: Annual Costs, Non-Flood Year**				
a)	Storage of Sandbags	LS	1	$500.00	$500.00
				Total 1B	$500.00
				Contingency (20%)	$100.00
				Subtotal	$600.00
				Location Adjustment Factor (LCAF)	2.05
				Annual Cost, Non-Flood Year Base Price	$1,200.00
				Annual Cost, Non-Flood Year Upper Bound	$1,800.00

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 I6 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table I6 Option 1 Qualitative Evaluation

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

I.2.2 SUMMARY TABLES

Table I7 summarizes the Class D OPC for the conceptual design option.

Table I7 Summary of Class D Cost Estimates

	Option 1 Class D OPCs
Capital Cost	None
Annual Cost (Flood Year)	$509,200 - $763,800
Annual Cost (Non-Flood Year)	$1,200 - $1,800

Table I8 provides a summary of the evaluation the conceptual design option.

Table I8 Summary of Costs and Evaluation of Conceptual Options

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