Appendix A Upper Liard 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.

A.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 Upper Liard.

A.1.1 POPULATION

Upper Liard has a population of 130 with 63 private dwellings according to 2021 census data (Statistics Canada 2023c). The population has increased by approximately 4% from 2016 when the population was 125 (Statistics Canada 2023c).

A.1.2 STUDY AREA

The Study Area in Figure A2 outlines the areas that are considered in this Project at Upper Liard. 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.

A.1.3 FIRST NATIONS

The Upper Liard area is within the Traditional Territories of the Liard First Nation (LFN). LFN has a parcel of Category A Settlement Lands in the Upper Liard area, along Liard River. The land claim selection is LFN R-70A. This means that LFN has surface and subsurface ownership of this parcel of land (Government of Yukon 2022). LFN also several community and fee simple parcels: C-112, C-107FS, C-105FS, and C-95 which are located along the Liard River in Upper Liard. Figure A2 illustrates the LFN settlement lands within the Study Area.

A.1.4 BATHYMETRY AND TOPOGRAPHY

Bathymetry data for the Liard River through Upper Liard 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 9 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 as per NRCan (2022b).

A.1.5 GEOLOGY

Based on the surficial geology mapping (Yukon Geological Survey 2020), the Study Area consists of poorly sorted gravel, sands, silts. The site deposits are of alluvial plain origin which are found near trunk valleys and at the confluence of tributary valleys. The assumed thickness of the deposits is between 10 and 100 m thick.

Permafrost may be present in the Upper Liard 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 sporadic discontinuous permafrost (20–30% 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.

A.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 alluvial deposits along the Liard River encompassing most of shoreline are likely to result in a groundwater table that would be highly dependant on the Liard River levels. 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 soil conditions in the area.

A.1.7 PAST FLOODING EVENTS AND RESPONSE

Upper Liard area has been subject to numerous flooding events dating back to 1960s. A summary of formally documented flood events are provided below. The flood events summarized below do no represent a comprehensive review of flooding history in the Study Area; rather, they are a summary of the flooding documentation provided to Stantec at the time of writing. Historical water surface elevations (WSEs) at Water Survey of Canada (WSC) Station 10AA001 (Liard River at Upper Crossing) are illustrated in Figure A1.

2005 Flood Event

Based on a Task Request / Approval Notification dated May 19, 2005, Upper Liard received approximately 3,000 sandbags from Government of Yukon, Emergency Measures Office (EMO). Wildland Fire Management (WFM) was in the community assisting with the supply of water pumps and helping where needed. Many volunteers were in the community helping with the construction of sandbag dikes. Throughout the flooding event, the local First Nation conducted well testing to confirm that they weren't contaminated. WSC Station 10AA001 (Liard River at Upper Crossing) reported a peak instantaneous discharge during the 2005 flood of 2,890 m^3/s on May 19, 2005 (GoC 2023). WSEs are only reported at WSC Station 10AA001 from 2011 – 2023 and are therefore not available for the 2005 flood event.

2007 Flood Event

The flood in 2007 took place between June 6 through 11. Numerous properties were affected on the east side of the river, north of the Alaska Highway. Wildland Fire Management (WFM) was onsite supporting homeowners. A local building inspector and WFM completed an inspection of all the buildings affected and recorded the extent of damage caused by the flooding. WSC Station 10AA001 (Liard River at Upper Crossing) reported a peak instantaneous discharge during the 2007 flood of 2,850 m^3/s on June 8, 2007 (GoC 2023). WSEs are only reported at WSC Station 10AA001 from 2011 – 2023 and are therefore not available for the 2007 flood event.

2012 Flood Event

The information summarized below is based on the After Action Review, Flood Operations from June 6 to 15, 2012 by Monterey Management Consulting. Pre-planning for the flood planning began in April 2012 when higher than normal snow pack conditions were published. The event started early June due to an extreme rainfall event over several days, coupled with increased and rapid snowmelt. WFM started by preparing a sandbag dike and berm in Upper Liard on June 5, 2012. When the dike failed, the local Incident Management Team (IMT) supported the residents with evacuation. The report noted that a flood response plan had previously been prepared but residences were not aware of the document. WSC Station 10AA001 (Liard River at Upper Crossing) reported a peak instantaneous discharge of 3,990 m^3/s and a peak instantaneous WSE of 610.47 m (at the WSC station) on June 10, 2012 (GoC 2023).

A $3.5 million flood assistance package was offered to owners of 11 properties on the east side of the Liard River, upstream of the Klondike Highway bridge, in the summer of 2012 (YG 2012). The flood assistance package offered to buy the properties, complete required environmental remediation, and identify the area as flood prone and not suitable for development (YG 2012). Anecdotal reports indicate that this assistance package was carried through, although formal documentation of this has not been provided to Stantec at the time of writing.

2022 Flood Event

High water conditions occurred in 2022, although there was no documentation of flood response actions provided to Stantec. WSC Station 10AA001 (Liard River at Upper Crossing) reported a peak instantaneous discharge of 3,010 m^3/s and a peak instantaneous WSE of 609.47 m (at the WSC station) on June 12, 2022 (GoC 2023).

A.1.8 EXISTING FLOOD MITIGATION INFRASTRUCTURE

Upper Liard currently has no existing permanent flood mitigation infrastructure documented within the Study Area. Erosion protection (stone installed on slope) has been identified on the outer (west) bank south of the bridge (although undocumented in available records).

A.1.9 WIND, WAVES, AND EROSION

While floodplain mapping and hydraulic modelling of the Design Flood Service Level (DFSL) has not been completed for Upper Liard to date, it is likely that flow velocities in the Liard River during flood conditions would require flood mitigations to include erosion mitigations. 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 impact flood mitigation design at Upper Liard.

A.1.10 HYDROLOGY

The Liard River is the major water feature at Upper Liard (Figure A2). The Liard River conveys snowmelt and rainfall induced runoff south into northern BC, then north into the Northwest Territories. Ultimately, the Liard River discharges into the Mackenzie River at Fort Simpson, NT.

WSC Station 10AA001 (Liard at Upper Crossing) is located on the west side of the Liard River, on the upstream side of the Alaska Highway bridge (Figure A2) and has a gross drainage area of approximately 32,600 km^2 (GoC 2023). The hydrology review considered WSEs that were recorded at WSC Station 10AA001.

Flood frequency analysis for WSEs was performed by both Morrison Hershfield (2022) and Yukon University (2022) for WSEs at WSC Station 10AA001. Table A1 summarizes the frequency results of these two studies for the 1:2-year event (50% Annual Exceedance Probability, or AEP), 1:20-year event (5% AEP), 1:100-year event (1% AEP), and 1:200-year event (0.5% AEP).

Table A1 Flood Frequency Analyses at WSC Station 10AA001 from Morrison Hershfield (2022) and Yukon University (2022)

	Morrison Hershfield (2022)	Yukon University (2022)
Years Included in Analysis	1990–2022 [a]	1972–2022
Number of Years	33	51
Selected Distribution	Log-Pearson Type 3	Lognormal 3
Water Surface Elevation (m) [1]		
1:2-year Event (50% AEP)	607.80	607.70
1:20 Event (5% AEP)	609.69	609.40
1:100 Event (1% AEP)	610.63	not provided
1:200 Event (0.5% AEP)	611.01	610.70

[a] Except for three breakup periods
[1] Elevations provided in CGVD2013 for WSC Station 10AA001

The Morrison Hershfield (2022) flood frequency analysis results were adopted for the Project because the 1:200-year event WSE was higher and would result in more conservative conceptual designs.

Figure A1 illustrates the recorded daily minimum, mean, and maximum WSEs, the WSE during the highest year on record (2012), and the WSEs for the 1:2-year and 1:200-year event at WSC Station 10AA001 from Morrison Hershfield (2022). While breakup ice jams are possible and could cause flooding at Upper Liard, past high-water events (1961, 1964, 1972, 2012, and 2022) have all occurred during open water conditions (Yukon University 2022). As illustrated in Figure A1, water levels at Upper Liard typically begin to rise in early May with the onset of freshet and increase until mid-June. Water levels typically decrease through the remainder of June and through July. Therefore, based on the available data and the documented flood processes at Upper Liard, flood conditions at Upper Liard may generally be expected to persist for 2–3 weeks sometime in the month of June.

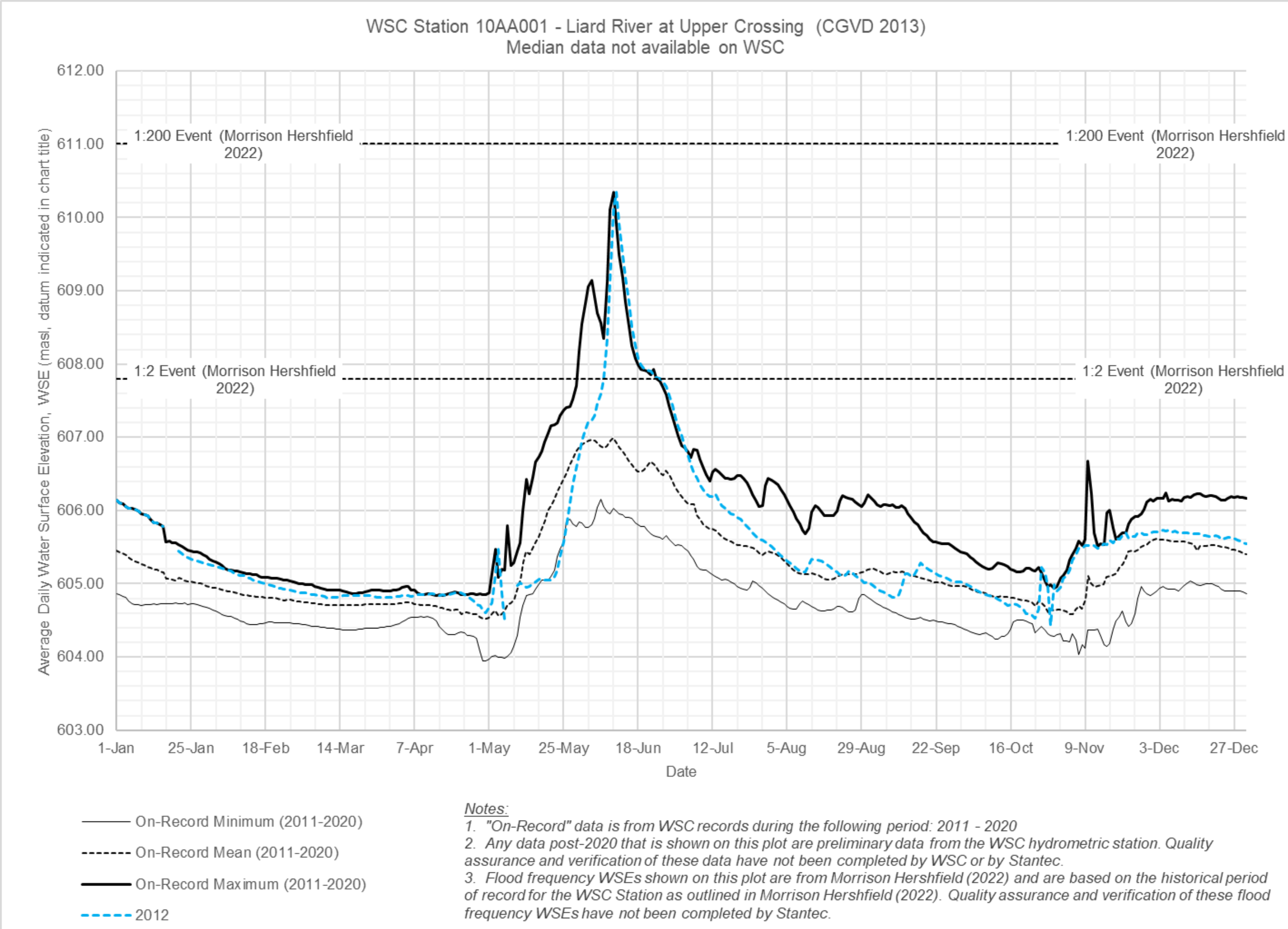


Figure A1 Historical Water Surface Elevations at WSC 10AA001 (Liard at Upper Crossing)

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.

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

In lieu of floodplain mapping, Stantec performed preliminary existing conditions (no mitigation) inundation analysis for Upper Liard using WSEs. This analysis considered the 1:200-year WSE (611.01 m) at WSC Station 10AA001 from Morrison Hershfield (2022) and an assumed WSE slope of 0.05% m/m (based on survey from Underhill 2022). The resulting water surface was overlain on the existing conditions topographic and bathymetric elevation data (GeoYukon 2023) and the limits of inundation were mapped (Figure A2). 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 Morrison Hershfield (2022). As stated in Section 3.6, the inundation/flood vulnerability of the Alaska Highway bridge is not in the scope of work of this Project. 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 inside of the meander bend at Upper Liard (east of river channel) has substantial areas that are inundated in this scenario although the impacted properties were reportedly purchased by YG following the 2012 flood (Section A.1.7). The preliminary analysis indicates that approximately 700 m of the Alaska highway on the east side of the Liard River would be inundated. For this 700 m distance, water would flow over the highway (from north to south) during flood conditions.

On the west side of the Liard River, the preliminary inundation covers private property and community infrastructure north of the Alaska Highway bridge, although the inundation does not extend as far from the river channel as it does on the east. An additional 4 individual private properties are inundated on the west side of the Liard River south of the Alaska Highway bridge.

The preliminary inundation analysis indicated an estimated 11 private properties and 1 community feature/parcel (approximately 700 m of the Alaska Highway) would have at least 25% of their area inundated (inundated parcels).

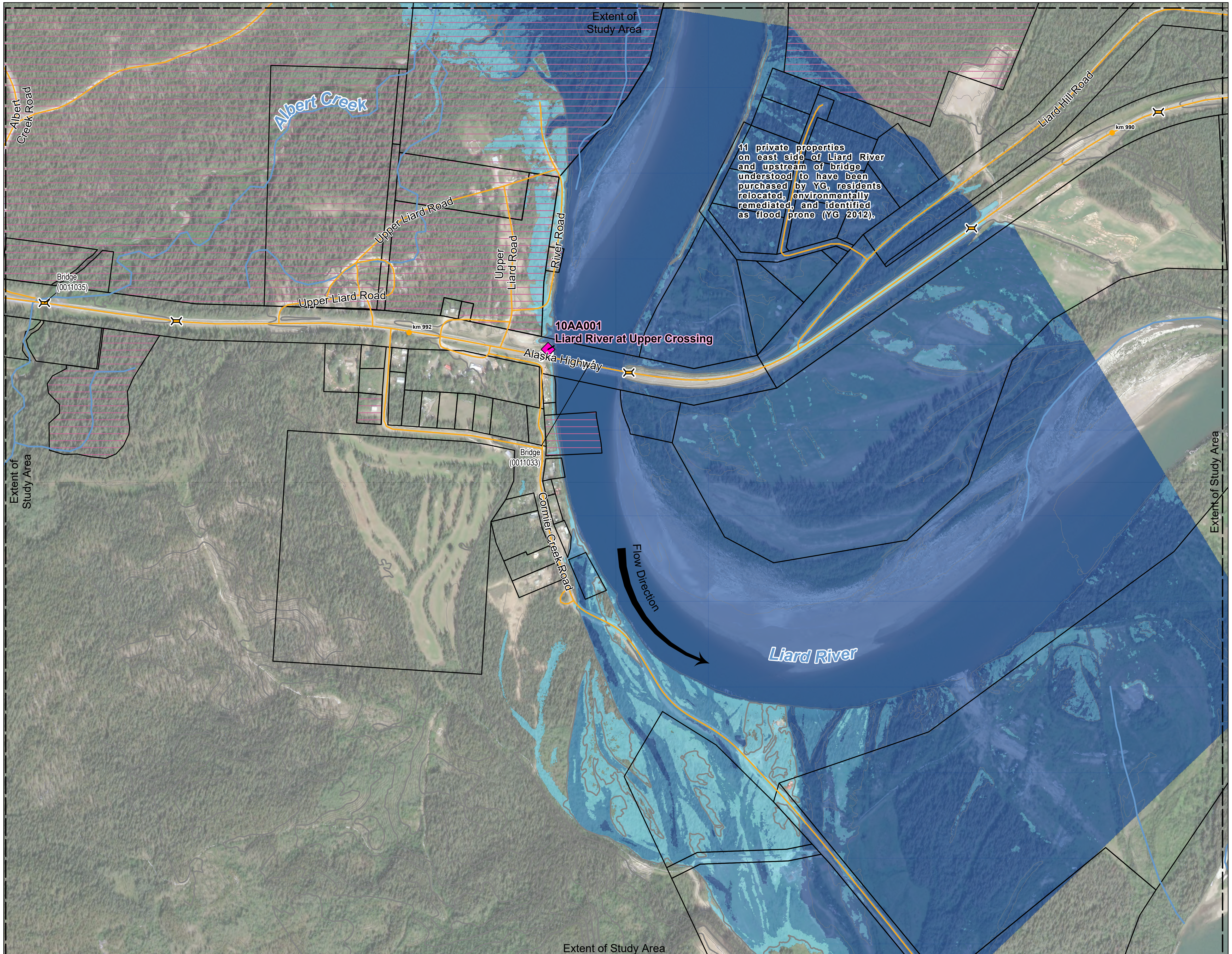


Figure No.
A2

Title
Existing Conditions and Preliminary Flood Inundation at Upper Liard

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

Project Location
Upper Liard,
Yukon

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

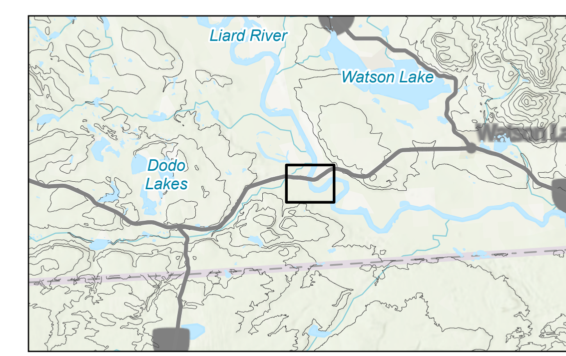
N

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

- WSC Station
- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - 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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A.2 Mitigation Options and Evaluation

The scope of this Project is to develop conceptual engineered flood mitigation options; these options for Upper Liard 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 flood mitigation options were developed for Upper Liard (Table A2) using combinations of the typical engineered flood mitigation designs from Section 3.3.2. Flood mitigations in the two options are provided for areas which are inundated under the 1:200-year WSE (611.01 m) in the preliminary inundation mapping (Figure A2). The top elevation of the flood mitigations is designed to reach the DFSL which in the case of Upper Liard (river site) is assumed to be 611.51 m (i.e., 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 A2 Summary of Conceptual Design Options

Location	Option 1 *lower capital costs, higher response/maintenance*	Option 2 *higher capital costs, lower response/maintenance*
Alaska Highway East of Liard River	Road used as Platform with Temporary Superbag Dike	Road Raising with Flood Conveyance Culverts
River Road on North Side of Alaska Highway	Platform with Temporary Superbag Dike	Road Raising
Four Individual Properties on Cormier Creek Road	Temporary Sandbag Dikes	

Section A2.1 and A2.2 provide a description, Class D OPC, and qualitative evaluation of the conceptual options specified in Table A2.

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

- Bridge span widening and/or highway culverts – The Alaska Highway bridge crossing Liard River likely acts as a hydraulic constriction during flood flows. Increasing hydraulic conveyance by widening bridge span or adding a substantial number of large culverts 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 complexity; as well as substantial environmental impacts.

A.2.1 OPTION 1

Description

The conceptual flood mitigations for Option 1 are illustrated in Figure A3.

On the east side of the Liard River, approximately 700 m of the Alaska Highway would be treated as a platform for temporary superbag dikes during flood conditions upstream side of the highway and (depending on water levels) potentially the downstream side of the highway in order to allow for vehicles to continue travelling on the highway. It is likely that substantial fortification of the superbag dikes (e.g., extra superbags on backside of dike) would be required in order to withstand hydraulic forces from river velocities flowing directly towards the temporary dikes on the upstream side of the highway. The temporary superbag dikes on either side of the road would likely restrict the number of traffic lanes from two to one, meaning traffic control would likely be required during flood conditions.

On the west side of Liard River (north of the Alaska Highway bridge), an approximately 650 m length of River Road would be used as a platform for the deployment of a temporary superbag dike to act as a flood barrier. This section of road is within 2 m of the DFSL and as such no road raising is required when coupled with the use of superbags. Of the approximately 650 m long platform, 30 m near the south end and 20 m near the north end would require a double superbag dike and the remaining 600 m would require a single superbag dike.

Four (4) individual properties at the south end of Cormier Creek Road would have temporary sandbag dikes around the individual homes to mitigate flood risk. The temporary sandbag dikes would range in height from approximately 0.5–2.0 m.

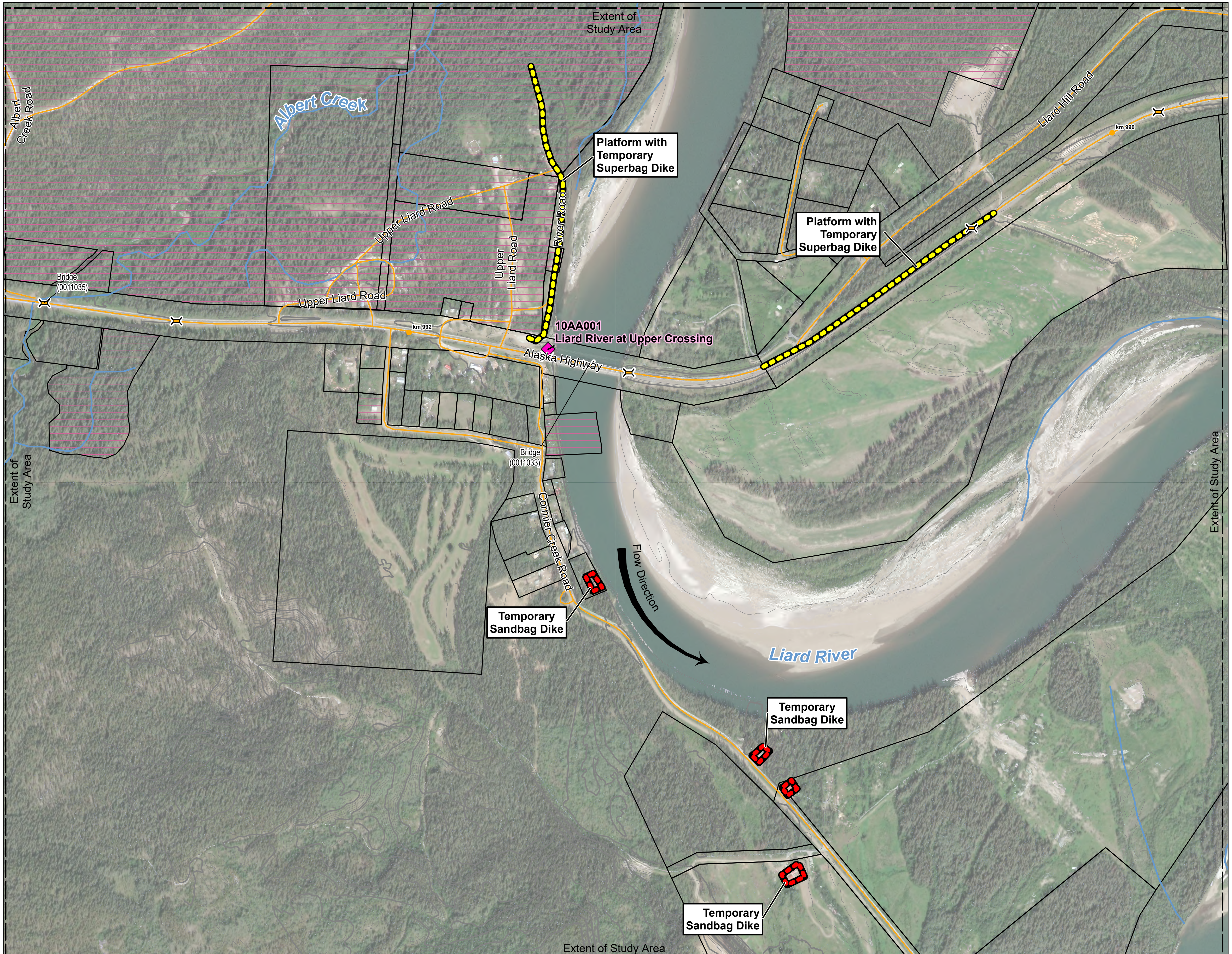


Figure No.

A3

Title

Upper Liard Conceptual Flood Mitigation - Option 1

Client/Project 144903232

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

Project Location
Upper Liard, Yukon

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

N

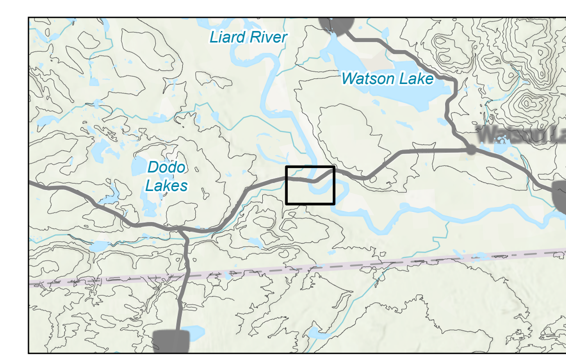
0 50 100 150 200 m
(At original document size of 11x17)
1:10,000

- WSC Station
- Culvert/ Bridge
- Highway Kilometre Post
- Road
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - 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
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Stantec Yukon

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table A3, considering the Class D level of accuracy (+/-50%). Table A3 also provides the Class D OPCs on a per-inundated property basis (from Section A.1.11).

Table A3 Option 1 Summary of Class D OPCs

	Class D OPC	Number of Inundated Properties (Section A.1.11)[1]	Class D OPC per Inundated Property
Capital Cost	No Capital Cost	11	No Capital Cost
Annual Cost (Flood Year)	\$ 1,991,500 - \$ 2,987,250		\$ 181,046 - \$ 271,569
Annual Cost (Non-Flood Year)	\$ 1,000 - \$ 1,500		\$ 91 - \$ 137

[1] As described in Section A.1.11, the inundated properties from the preliminary inundation analysis consists of 11 private properties and 1 community feature/parcel.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table A4 (annual cost, flood year), and Table A5 (annual cost, non-flood year).

Table A4 **Option 1 Annual Costs During a Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1A	**Option 1: Annual Costs, Flood Year**				
a)	Inspections	LS	1	$100,000.00	$100,000.00
b)	Minor Repairs	LS	1	$10,000.00	$10,000.00
c)	Storage of Superbags and Sandbags	LS	1	$500.00	$500.00
d)	Superbags c/w Sandfill (1.0 - 2.0m)	M	1350	$500.00	$675,000.00
e)	Sandbags c/w Sandfill (0.5 - 2.0m)	M	395	$464.00	$183,280.00
f)	Traffic Control	LS	1	$75,000.00	$75,000.00
				Total 1A	$1,043,780.00
				Contingency (20%)	$208,756.00
				Subtotal	$1,252,536.00
				Location Adjustment Factor (LCAF)	1.59
				Annual Cost, Flood Year Base Price	$1,991,500.00
				Annual Cost, Flood Year Upper Bound	$2,987,250.00

Table A5 **Option 1 Annual Costs During a Non-Flood Year Class D OPC**

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 1B	**Option 1: Annual Costs, Non-Flood Year**				
a)	Storage of Sandbags and Superbags	LS	1	$500.00	$500.00
				Total 1B	$500.00
				Contingency (20%)	$100.00
				Subtotal	$600.00
				Location Adjustment Factor (LCAF)	1.59
				Annual Cost, Non-Flood Year Base Price	$1,000.00
				Annual Cost, Non-Flood Year Upper Bound	$1,500.00

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 A6 summarizes the performance of Option 1 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table A6 Option 1 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	flooding duration is relatively short (on the scale of weeks not months); wind/wave impacts minimal; superbags susceptible to damage from high velocities and debris particularly at Alaska Highway; low likelihood of damage from ice because of typical timing of flood events; 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	medium regulatory risk; minimal baseline studies required; minimal property owner agreements required	Medium Performance
3	Capital Cost Per Inundated Property	No capital cost associated with this option.	High Performance
4	Maintenance and Storage	storage required for superbags and sandbags; no vegetation maintenance; no change to existing road inspection protocols	High Performance
5	Response and Activation	temporary superbag dikes require training, labour, and a timely response in a flood scenario to be effective; traffic control likely required on Alaska Highway due to restricted lanes; moderate length of temporary superbag dike; property-owner deployed temporary sandbag dikes	Low Performance
6	Aesthetics and Community Function	no change to existing landscape during non-flood conditions; temporary alteration of private/community function during flood conditions from temporary superbag and sandbag dikes	High 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	blockage of floodplain flow by establishment of superbag dike on Alaska Highway which is likely to increase WSEs upstream of Alaska Highway bridge and alter velocities and river processes through Upper Liard; no slope stabilization measures required	Low Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	high ROI considering that investments critical for maintaining access on the Alaska Highway	High Performance

A.2.2 OPTION 2

Description

The conceptual flood mitigations for Option 2 are illustrated in Figure A4.

On the east side of the Liard River, approximately 700 m of the Alaska Highway would be raised by approximately 1.0 – 1.5 m from the existing road surface to meet the DFSL. Floodplain culverts elevated in the road embankment would need to be installed along this section of road in order to maintain the existing flood-stage conveyance across the Alaska Highway. The number, sizes, configurations, and elevations of the floodplain culverts required to maintain the floodplain flows across the Alaska Highway would be determined through specific hydraulic analysis during the detailed design phase.

Approximately 600 m of River Road north of the Alaska Highway would be raised approximately 0.5–1.0 m such that the road functions as a dike. Raising of the River Road may require slope stabilization measures installed for approximately 400 m along the riverbank of the Liard River due to the added weight from the new fill for the raised road. Driveway entrances for 6 private residences may need to be upgraded to match the raised road.

Four (4) individual properties at the south end of Cormier Creek Road would have temporary sandbag dikes around the individual homes to mitigate flood risk. The temporary sandbag dikes would range in height from 0.5–2.0 m.

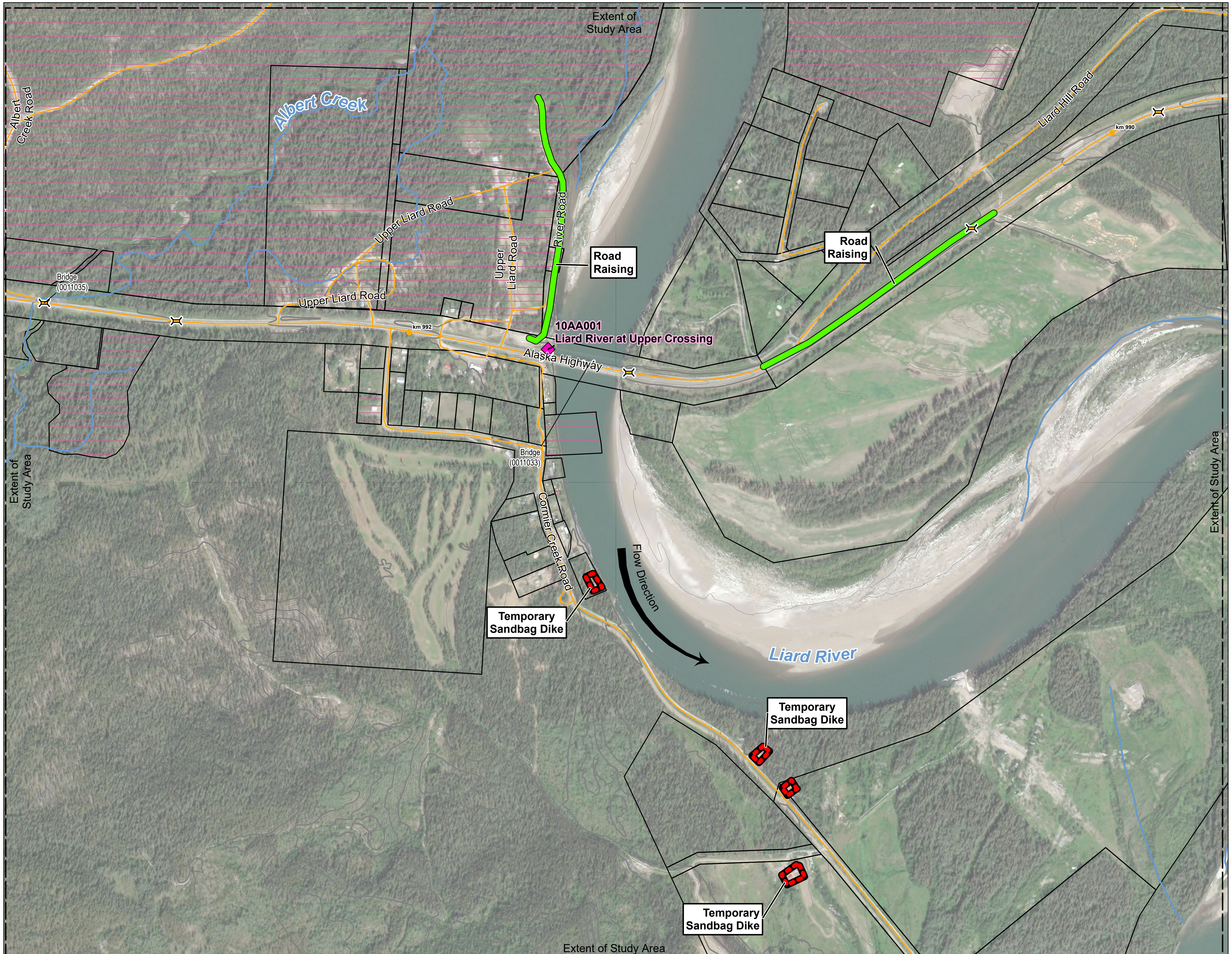

Figure No.

A4

Title

Upper Liard Conceptual Flood Mitigation - Option 2

Client/Project 144903232

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

Project Location
Upper Liard, 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
- Highway Kilometre Post
- Road
- Topographic Contour (10 m)
- Topographic Contour (2 m)
- Land Parcel - 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
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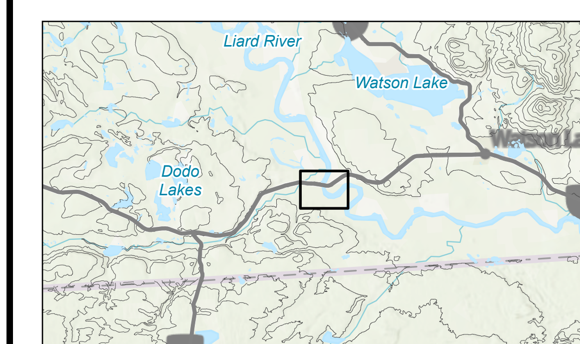

Notes
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Stantec Yukon

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Class D OPC

The Class D OPC's for capital and annual costs are summarized in Table A7 considering the Class D level of accuracy (+/-50%). Table A7 also provides the Class D OPCs on a per inundated property basis (from Section A.1.11).

Table A7 Option 2 Summary of Class D OPCs

	Class D OPC					Number of Inundated Properties (Section A.1.11)[1]	Class D OPC per Inundated Property				
Capital Cost	$	8,891,600	-	$	13,337,400	11	$	808,328	-	$	1,212,491
Annual Cost (Flood Year)	$	407,900	-	$	611,850		$	37,082	-	$	55,623
Annual Cost (Non-Flood Year)	$	20,000	-	$	30,000		$	1,819	-	$	2,728

[1] As described in Section A.1.11, the inundated properties from the preliminary inundation analysis consists of 11 private properties and 1 community feature/parcel.

The components, assumed unit costs, and estimated quantities which produce the Class D OPCs are detailed in Table A8 (capital costs), Table A9 (annual cost, flood year), and Table A10 (annual cost, non-flood year).

Table A8 Option 2 Capital Costs Class D OPC

Item No.		Description of Work	Units	Qty.	Unit Price	Amount
Section 2A		**Option 2: General Conditions**				
	a)	Mobilization/Demobilization	LS	1	$416,080.00	$416,080.00
	b)	Site Preparation/Restoration	LS	1	$83,300.00	$83,300.00
					Total 2A	$499,380.00
Section 2B		**Option 2: Road Raising (River Rd. & Alaska Hwy)**				
	a)	Rough Grading	M2	21260	$5.00	$106,300.00
	b)	Subgrade Preparation	M2	21260	$5.00	$106,300.00
	c)	80mm Minus Granular Subbase, Variable Depth	M3	24340	$40.00	$973,600.00
	d)	100mm Minus Granular Base, 100mm Depth	M3	2120	$50.00	$106,000.00
	e)	BST Surfacing	M2	10090	$50.00	$504,500.00
	f)	Rip Rap	MT	880	$141.00	$124,080.00
	g)	Slope Stabilization	M	580	$3,000.00	$1,740,000.00
	h)	Floodplain Culverts	LS	1	$500,000.00	$500,000.00
					Total 2B	$4,160,780.00
					Contingency (20%)	$932,032.00
					Subtotal	$5,592,192.00
					Location Adjustment Factor (LCAF)	1.59
					Capital Costs Base Price	$8,891,600.00
					Capital Costs Upper Bound	$13,337,400.00

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 A9 Option 2 Annual Costs During a Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2C	**Option 2: Annual Costs, Flood Year**				
a)	Inspections	LS	1	$25,000.00	$25,000.00
b)	Minor Repairs & Vegetation Management	LS	1	$5,000.00	$5,000.00
b)	Storage of Sandbags and Superbags	LS	1	$500.00	$500.00
c)	Sandbags c/w Sandfill (0.5 - 2.0m)	M	395	$464.00	$183,280.00
				Total 2C	$213,780.00
				Contingency (20%)	$42,756.00
				Subtotal	$256,536.00
				Location Adjustment Factor (LCAF)	1.59
				Annual Cost, Flood Year Base Price	$407,900.00
				Annual Cost, Flood Year Upper Bound	$611,850.00

Table A10 Option 2 Annual Costs During a Non-Flood Year Class D OPC

Item No.	Description of Work	Units	Qty.	Unit Price	Amount
Section 2D	**Option 2: Annual Costs, Non-Flood Year**				
a)	Inspections	LS	1	$10,000.00	$10,000.00
b)	Storage of Sandbags and Superbags	LS	1	$500.00	$500.00
				Total 2D	$10,500.00
				Contingency (20%)	$2,100.00
				Subtotal	$12,600.00
				Location Adjustment Factor (LCAF)	1.59
				Annual Cost, Non-Flood Year Base Price	$20,000.00
				Annual Cost, Non-Flood Year Upper Bound	$30,000.00

Qualitative Evaluation

Error! Reference source not found. summarizes the performance of Option 2 with respect to the evaluation criteria which were previously outlined in the main body of this Report.

Table A11 Option 2 Qualitative Evaluation

Criteria No.	Criteria Title	Evaluation	Anticipated Performance Rating
1	Viability and Reliability under Extreme Conditions	flooding duration is relatively short (on the scale of weeks not months); wind/wave impacts minimal; permanent infrastructure to withstand high velocities and debris although debris blockages of floodplain culverts may impact hydraulic function; low likelihood of damage from ice because of typical timing of flood events; seepage control measures likely required	Medium Performance
2	Time to Implementation	geotechnical investigations required including borehole drilling to address bank stability and construction requirements for road raising; hydraulic modelling and erosion mitigation design required; medium regulatory risk; minimal baseline studies required; minimal property owner agreements required	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 $808,328/property	Low Performance
4	Maintenance and Storage	no storage requirements; no vegetation maintenance; periodic road inspections likely required; floodbox maintenance may be required	High Performance
5	Response and Activation	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	moderate permanent alteration of existing landscape from existing by road raising (0.5 - 1.0 m in road elevation increase) which particularly on River Road may have aesthetic impacts; temporary alteration of private property function during floods from temporary sandbag dikes	Medium Performance
7	Future Adaptability	temporary superbag dike may be deployed on raised road in future for enhanced flood mitigation; additional sandbags may be provided for raising temporary sandbag dikes; permanent increases in height to road are 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	even with the inclusion of floodplain culverts, the raising of Alaska Highway may increase WSEs upstream of the Alaska Highway bridge and is likely to alter velocity patterns and river processes; debris blockages in culverts may exacerbate the impacts to existing hydraulics/river processes; slope stabilization measures may be required at both of the road raising locations	Low Performance
9	Disaster Mitigation and Adaptation Function (DMAF) Applicability	high ROI considering that investments critical for maintaining access on the Alaska Highway	High Performance

A.2.3 SUMMARY TABLES

Table A12 summarizes the Class D cost estimates for each of the conceptual design options.

Table A12 Summary of Class D Cost Estimates

	Option 1 Class D OPCs	Option 2 Class D OPCs
Capital Cost	No Capital Cost	$ 8,891,600 - $ 13,337,400
Annual Cost (Flood Year)	$ 1,991,500 - $ 2,987,250	$ 407,900 - $ 611,850
Annual Cost (Non-Flood Year)	$ 1,000 - $ 1,500	$ 20,000 - $ 30,000

Table A13 provides a summary of the evaluation of each of the conceptual design options.

Table A13 Summary of Qualitative Evaluation of Conceptual Options

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