NUIQSUT REPAIR BRIDGE CROSSINGS

PROJECT ANALYSIS REPORT

CIP No. 68-041

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EXECUTIVE SUMMARY

The purpose of this study is to provide the North Slope Borough (Borough) with feasible alternatives and costs for the repair and/or replacement of three bridge and culvert crossings in Nuiqsut, Alaska. The three crossings at Sites 1, 2, and 3 have failed or require yearly reconstruction and maintenance.

The Lower Stream Crossing (Site 1) is a temporary culvert crossing approximately 300 feet from the Nigliq Channel. Currently, it provides the only access to the City's boat ramp and material source stockpile. This crossing requires complete reconstruction after the high water and ice jamming events every spring.

The Upper Stream Crossing (Site 2) consists of a 42-foot steel bridge constructed in 1974. This crossing originally provided access to the old airport, and now the village boat ramp and material source stockpile. Reports indicate it failed a couple of years ago. The lower stream crossing at Site 1 was built when the bridge failed.

The Tributary Stream Crossing (Site 3) is a culvert crossing approximately 6,200 feet upstream from the Nigliq Channel that provides the only access to the community's water source. This crossing was installed after a previous bridge failure and has required minimal maintenance with sandbags after seasonal flooding.

Alternatives for each of the crossings were analyzed. Our findings, recommendations and the costs of PAR alternatives are shown **Table EX-1** below.

FINDINGS

1. All three sites are in the flood plain of the Colville River and are subject to overtopping and ice jamming.

2. Little flood information exists for Nuiqsut and the Corps of Engineers has not established a flood datum for Nuiqsut.

3. A flood study and stream monitoring is needed to determine flood recurrence intervals and flood elevations.

4. Debris lines near Site 2 suggest seasonal floodwaters and ice floes overtop the bridge by approximately 2 feet annually and by approximately 8.5 feet during extreme flood events.

5. The Site 3 culverts are undersized and overtop annually but requires only minor sandbag repair after the high water recedes.

6. Debris lines near Site 3, suggests that the roadway overtops by approximately 4.5 feet during extreme high water events.

RECOMMENDATIONS

1. Conduct a flood study and stream monitoring study to determine flood recurrence intervals and flood elevations.
2. Conduct a geotechnical investigation to determine engineering and thermal properties of soils at the sites to allow for proper design.
3. At the Lower Stream Crossing (Site 1), remove the crossing after the Site 2 crossing is restored: **Alternative 1A – Remove Crossing and Salvage Useable Materials.**
4. At the Upper Stream Crossing (Site 2), remove the existing bridge and install three 120-inch culverts: **Alternative 2B – New Culverts, Minor Elevation Change.**
5. At the Tributary Stream Crossing (Site 3), install three new 72-inch culverts to provide all-season access to the water source lake: **Alternative 3B – Install New Circular Culverts, Elevate Roadway 3 Feet.**

Table EX-1 – Capital Cost Summary

Alternative	Capital Cost	Useful Life
1A. Remove Crossing and Salvage Useable Materials	$203,000	N/A
1B. Do Nothing	0	N/A
2A. New Bridge Crossing, Elevate Above Ordinary High Water	3,423,000	30 years
2B. New Culverts, Minor Elevation Change	3,216,000	30 years
2C. Do Nothing	406,000	N/A
3A. Armor Existing Culverts, No Elevation Change	1,502,000	15 years
3B. Install New Circular Culverts, Elevate Roadway 3 Feet	3,352,000	30 years
3C. Install New Arched Culvert, Elevate Roadway 4.5 Feet	3,932,000	30 years
3D. Do Nothing	0	N/A

1.0 INTRODUCTION

Hattenburg Dilley and Linnell, LLC (HDL) was retained by the North Slope Borough (Borough) Department of Capital Improvement Program Management (CIPM) to provide a Project Analysis Report (PAR) for the reconstruction of three drainage channel crossings at Nuiqsut, Alaska. The crossings include two culverts and one bridge crossing on the same unnamed drainage. Breakup flood events damage the structures, causing annual repairs and prevent access to the village water source, boat ramp, and material source stockpile.

1.1 Project Purpose and Objective

The purpose of this project is to provide the Borough with feasible solutions and costs for the reconstruction of the three drainage channel crossings at Nuiqsut.

1.2 Scope

The scope of this PAR includes analyzing the existing site conditions at each of the three sites, developing feasible bridge and culvert crossing alternatives, developing recommendations for repair and/or replacement, and developing a budgetary cost estimate for each alternative. The analysis of the alternatives considers cost, scheduling, phasing of work, material delivery, lead time, impacts on access, and other pertinent criteria determined during the study. HDL worked closely with the Borough and village public works staff to determine the history of failures and operational and maintenance issues.

1.3 Project Location

Figure 1: Project Location Map

The project sites are located on the village road system at Nuiqsut, Alaska. Nuiqsut is located 35 miles from the Beaufort Sea coast on the west bank of the Nigliq Channel near the Colville River Delta (CRD). The village is located at 70°13’00” North and 151°00’00” West. The climate is arctic and dominated by extreme temperatures, wind, long daylight hours in the summer and extended periods of darkness during the winter. Temperatures range from -56 to 78°F with the daily minimum temperature below freezing 297 days per year. Annual precipitation is minimal and averages around 5 inches with an annual snowfall of 20 inches.

This study evaluates three crossings - two culvert crossings and one failed bridge crossing located on an unnamed drainage channel. See **Figure 2.**

Figure 2: Site Location Map

The Lower Stream Crossing (Site 1) is a temporary culvert crossing approximately 300 feet from the Nigliq Channel. Currently, it provides the only access to the City's boat ramp and material source stockpile. This crossing requires complete reconstruction after the high water and ice jamming events every spring. The Upper Stream Crossing (Site 2) is a bridge constructed in 1974 approximately 1,550 feet upstream from Nigliq Channel.

This crossing originally provided access to the village boat ramp and material source stockpile, but has not been operational for the past couple of years. The lower stream crossing was established upon failure of this structure.

The Tributary Stream Crossing (Site 3) is a culvert crossing approximately 6,200 feet upstream from the Nigliq Channel that provides the only access to the community's water source.

1.4 Background

The Colville River is the largest river basin north of the Brooks Range draining nearly 23,500 square miles. (Baker, 2013 Colville River Delta Spring Breakup Monitoring & Hydrologic Assessment). Spring breakup on the Colville River is dominated by ice jams, glaciering, large ice floes, and high flow rates for an approximate 3 week period each spring. The three crossings are located on an unnamed stream channel adjacent to the Nigliq Channel. See **Figure 2.** The crossings are located in the flood plain of the Colville River.

ConocoPhillips has studied the timing and breakup of the CRD flooding since 2002, including the Nigliq Channel. ConocoPhillips has four stream monitoring stations (MON20, MON22, MON23 and MON28), on the Nigliq Channel downstream of Nuiqsut. Approximately 1.5 miles downstream from Nuiqsut the Nigliq Channel branches into another minor side channel, the Nigliagvik Channel. Peak discharge and water surface elevation in the Nigliq Channel has been monitored at the ice road crossing to CD5 between MON20 and MON23 since 2009. Peak annual discharges and water surface elevations (WSE) are shown in **Table 1**. The WSE is based on the British Petroleum Mean Sea Level (BPMSL) vertical datum. The scope of this study excluded any surveying, ties, or extrapolation to the BPMSL vertical datum.

Table 1: Nigliq Channel Historical Summary of Peak WSE CD5 Road

Year	Peak Indirect Discharge (cfs)	Peak WSE (ft BPMSL)
2014	66,000	9.38
2013	110000	12.42
2012	94,000	8.82
2011	141,000	9.89
2010	134,000	9.65
2009	57,000	7.91

Source Baker, 2013 CRD Spring Breakup Monitoring and Hydrologic Assessment

1.5 Crossing Evaluation

1.5.1 Lower Stream Crossing (Site 1)

The Lower Stream Crossing at Site 1 is a culvert crossing constructed after the upstream bridge failed. See **Figure 3**. The road was rerouted and culverts were installed approximately 1,250 feet downstream from the bridge to provide access to the boat ramp and village material source stockpile. The temporary culvert crossing is two 48-inch corrugated metal pipes (CMP) 42-feet in length. These pipes sit atop another series of five to seven buried steel pipes that are estimated to range in sizes from 18-inch to 24-inch. A 16-foot wide gravel roadway crosses the existing 48-inch diameter culverts. Due to the proximity of the lower stream crossing to the Nigliq Channel (approximately 300-feet) it is subjected to major damage during the spring breakup events and often times has to be reconstructed when the water levels recede.

Currently, it provides the only access to the community boat ramp and material source stockpile. This low profile road is approximately three feet above the surrounding terrain. This crossing is reported to fail almost every spring from overtopping, high flows and ice floes which erode the gravel embankment and scours around the culverts.

Figure 3: Site 1 Culverts

1.5.2 Upper Stream Crossing (Site 2)

The Upper Stream Crossing at Site 2 is a steel bridge constructed in 1974. This crossing originally provided the access to the old airport in the 1970s and then the village boat ramp and material source stockpile until its failure a few years ago. The bridge is a steel girder bridge supported by steel H-piles with abutments retained by timber lagging between piles. The bridge span length is 42 feet, measured from end of girder to end of girder. The bridge has a 14-foot wide overall deck width and decking consists of 2 x 8-inch treated timbers bolted together and attached to the steel girders. Railing consists of 12 x 12-inch timber posts and galvanized guardrail.

Figure 4: Failed Bridge at Site 2

The decking, girders and guardrail have failed. See **Figure 4**. Physical evidence from debris lines indicate that the Colville River spring flood waters overtop the bridge and the bridge elements have failed from the hydraulic pressures and/or impacts from ice floes. The steel pile and timber abutments have survived 40 years with only minor damage and displacement. See **Figure 5**. Steel elements show heavy surficial rust.

Figure 5: Bridge Abutments at Site 2

1.5.3 Tributary Stream Crossing (Site 3)

The Tributary Stream Crossing at Site 3 is a culvert crossing that provides access to the community's water supply - a fresh water lake located 1.2 miles south of the village. The 16-foot wide gravel roadway crosses the unnamed drainage that is estimated to be approximately 250 feet wide and 15 feet deep. The road profile sags approximately 11 feet at the culverts. Culverts were reportedly installed after a previous bridge failed.

The crossing consists of three 48-inch diameter by 40-foot long galvanized corrugated steel culverts. See **Figures 6 and 7**. Physical evidence of a debris line and anecdotal information indicate the roadway overtops yearly at spring breakup. To help protect the structure, the Borough has armored the inlets and outlets with sandbags. According to the Public Works Supervisor for Nuiqsut, the addition of sandbags has greatly extended the life of the structure. The condition of the sandbags is fair. The sandbags are easily accessible to vandalism. This crossing requires minimal maintenance and reconstruction after spring breakup, according to local public works staff.

The crossing appears to be in the floodplain of the Colville River, but primarily drains snowmelt in a basin defined later in this report south and west of Nuiqsut. The overtopping is likely caused by high spring breakup flows and undersized culverts.

Figure 6: Site 3 Crossing Looking South

Figure 7: Site 3 Culverts - Downstream Face

1.6 Flood and Stage Frequency

Since all of the crossings are located within the Colville River floodplain, flood and stage frequency depend heavily on Colville River hydrology. From 1992 to 2014, the measured peak flow ranged from 159,000 – 590,000 cfs, with an average peak discharge of 294,000 cfs. The peak stage varied between 12.20 – 20.69 feet (BPMSL), with an average historical peak of 16.79 feet (BPMSL). The earliest seasonal occurrence of peak flow was May 16, and the latest was June 11.

Colville River data collected for ConocoPhillips has limited applicability to Nuiqsut. Water surface elevations refer to a proprietary vertical datum, BPMSL, which prevented calibration of elevation data collected by HDL and others. Additionally the ConocoPhillips studies did not include a monitoring station immediately in the vicinity of Nuiqsut. Thus, there is no record of peak flow stage and discharge that accounts for isolated seasonal flow events caused by ice jams in the Nigliq Channel at Nuiqsut.

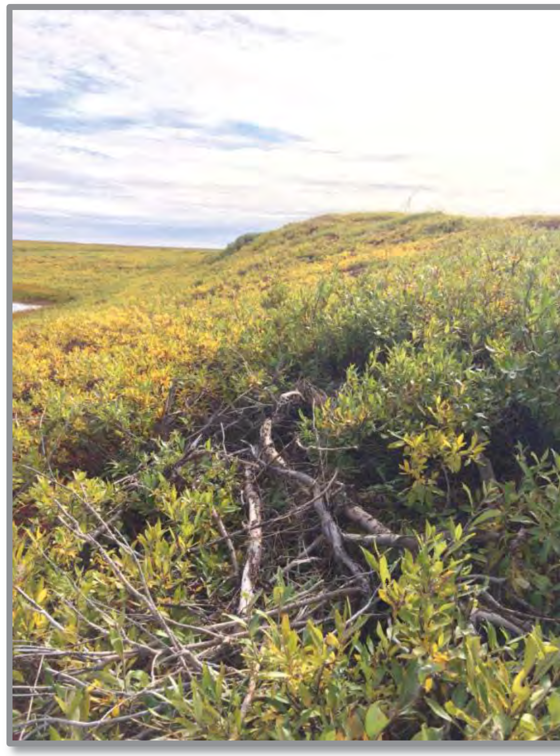

Figure 8: Upper Stream Crossing (Site 2), High Water Debris Line

For the crossings in this report, peak flood stage was determined by examining surrounding terrain for evidence of past high water events, such as woody debris deposited at a consistent elevation. See **Figure 8**. We found two locations with evidence of debris from high water events. We estimated that the lower of the two debris lines represented a normal high water event due to the large amount of debris in the area. The relative elevation of this debris line was approximately 2-feet higher than the centerline of the bridge deck. We estimated the higher of the debris lines represented an extreme high water event. This debris line was measured to be approximately 8.5-feet higher than the bridge deck.

For the comparison of alternatives, peak discharges, calculated by USGS regression equations, were used to estimate the preliminary bridge and culvert sizes. Determination of actual peak stage and discharge for design should include installation of stream gages at each of the crossings in question and the conduction of a flood study.

1.7 Drainage and Hydraulics

Sites 1 and 2 are located on an unnamed stream that meanders north from the drinking water supply to its outfall at the Nigliq channel. The drainage area upstream of the crossings is approximately 24.5 square miles. The hydraulic gradient of the channel is extremely mild at approximately 0.07%. The upstream watershed consists of flat, sparsely vegetated tundra with many permafrost lakes and ponds.

Site 3 drains an area of 9.5 square miles, and conveys snowmelt and permafrost thaw that collects in a series of kettle ponds south of the Nuiqsut airport runway. The tributary has a mild hydraulic gradient of 0.4%, and connects with the main channel of the unnamed stream approximately 500 feet downstream of the road crossing.

The hydraulics at each crossing are heavily influenced by the Colville River. As the Colville rises during spring breakup, a backwater effect can be created as culvert outlets become submerged or blocked by ice. The compromise in culvert capacity causes a rise in the headwater elevation, and in some cases, total inundation of the roadway.

Culvert design criteria should comply with the Alaska Highway Drainage Manual, Alaska DOT&PF, June 13, 2006.

Bridge hydraulic design criteria are provided in Sections 10.2 and 10.3 of the Alaska Highway Drainage Manual. The primary design constraint is maintaining a minimum of 3 feet of vertical clearance for passage of ice and debris at the design flow.

1.8 Soil Conditions

The project area is located in the Arctic Coastal Plain. The coastal plain is typically poorly drained and consequently marshy in the summer. Permafrost is known to exist from 800 - 1,000 feet below the ground surface. Soil conditions are unknown at these sites, but are generally assumed to be ice-rich, fine-grained soils with a thawed active layer of 1 to 3 feet in virgin undisturbed tundra, 6 to 10 feet in gravelly material, and deeper in the vicinity of stream channels where thaw bulbs are known to exist.

A geotechnical evaluation has not been performed as part of this contract, but should be performed prior to design and construction. A full geotechnical investigation should be conducted including a subsurface boring program to the depth of expected foundations with subsurface temperature measurements and laboratory testing. At a minimum, one boring should be performed per substructure and one boring per 50 linear feet of wingwall. Borings should include Standard Penetration Testing (SPT) in unfrozen soils and macro-coring, or equivalent sampling in frozen soils to retrieve samples of the frozen soil and ice. The subsurface temperature should be measured using thermistors to a depth of 10 feet below expected foundations. Laboratory testing should include grain size distribution analyses, moisture content, Atterberg limits (if applicable), and salinities. A grain size distribution analysis and proctor test should be performed on the anticipated fill material. In addition, samples of the stream bed materials should be collected to support evaluation of the scour potential.

1.9 Material Source

Gravel and riprap are the two main aggregate materials needed for the project.

1.9.1 Gravel

The Borough's material source stockpile is located approximately 0.5 miles east of the project areas on the south bank of the Nigliq Channel. See **Figure 2**. The stockpile contains approximately 150,000 cubic yards (CY) of sandy gravelly material and is suitable for constructing roadway embankments. The material was extracted 4.5 miles east of the project area on the east bank of the main channel of the Colville River. The Borough indicates the material was delivered to the stockpile in the winter of 2014/2015 for $40 per CY; 70,000 CY of this material is dedicated to the Colville River Access Road project. We understand the remaining 80,000 CY is available for Borough public works needs.

1.9.2 Riprap

There are no known local sources of rock for riprap. Most armor stone on the North Slope comes from Cape Nome or Dutch Harbor via ocean barge. The nearest upland source is Atigun Pass. Atigun Pass riprap would be mined and transported to Prudhoe Bay via the Dalton Highway and then to Nuiqsut via ice roads. The cost is estimated to be about $375 per CY in place - which is less than barged riprap.

1.10 Roadway Design Criteria

Roadway design Criteria are set forth in **Table 2**.

Table 2: Roadway Design Criteria

ELEMENT	VALUE	SOURCE
Construction Classification	Improvement of Existing Road	
Design Functional Classification	Very Low-Volume Local Road / Rural Minor Access Road	AASHTO GDVLVLR 2001
Design Year	2036	
AADT Construction Year (2016) Mid-Design Year (2025) Design Year (2035)	<400 <400 <400	
Design Hourly Volume (DHV)	<400	
Directional Split (%D)	50/50	
(%T)	50%	
Equiv. Single Axle Load (ESAL)	N/A	
Pavement Design Year	N/A	

Design Vehicle	N/A	
Design Speed (Terrain)	25 mph (Level)	
Stopping Sight Distance	250 (Assumed "Higher Risk" & doubled per p.52	AASHTO GDVLVLR 2001, p. 52 & Ex. 8, p.34
Maximum Allowable Grade Minimum Allowable Grade	7% 0.5%	AASHTO PGDHS 2011, Tbl. 5.2, pg. 5-3
Minimum Radius of Curvature	210 ft with Tc=0.4 (wet earth)	AASHTO GDVLVLR 2001, p. 51
Minimum K-Value for Vertical Curves	Crest = 29 Sag = 26	AASHTO GDVLVLR 2001, Ex. 12, pg. 39 AASHTO PGDHS 2011, Tbl. 5.3, pg. 5-4
Number of Roadways	1 lane	
Width of Traveled Way	16 ft	
Width of Shoulder	N/A	
Surface Treatment	N/A	
Side Slope Ratios	Fore: 2H:1V Back: 2H:1V	
Degree of Access Control	N/A	
Median Treatment	N/A	
Illumination:	N/A	
Curb Usage and Type	N/A	
Bicycle/ Pedestrian Provisions	N/A	

1.11 Design Standards and Guidelines

Design standards should comply with the following publications:

- Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400), American Association of State Highway and Transportation Officials (AASHTO), 2001.

- A Policy on Geometric Design of Highways and Streets (PGDHS or "Green Book"), AASHTO, 2001.

- Bridge LRFD Design Specifications, AASHTO, 2014.

- Alaska Highway Drainage Manual, Alaska Department of Transportation and Public Facilities (ADOT&PF).

2.0 ALTERNATIVES

The following feasible alternatives are considered.

Site 1

- Alternative 1A - Remove Crossing and Salvage Useable Materials
- Alternative 1B - Do Nothing

Site 2

- Alternative 2A - New Bridge Crossing, Elevate Above Ordinary High Water
- Alternative 2B - New Culverts, Minor Elevation Change
- Alternative 2C - Do Nothing

Site 3

- Alternative 3A - Armor Existing Culverts, No Elevation Change
- Alternative 3B - Install New Circular Culverts, Elevate Roadway 3 Feet
- Alternative 3C - Install New Arched Culvert, Elevate Roadway 4.5 Feet
- Alternative 3D - Do Nothing

2.1 Alternative 1A – Remove Crossing and Salvage Useable Materials

Alternative 1A consists of removing the lower stream crossing at Site 1 and salvaging the aggregate and two 48-inch culverts. The crossing is within 300 feet of the Nigliq Channel and is mostly affected by high flows in the Nigliq Channel. The crossing is reconstructed every spring. The banks of the stream and streambed would be reshaped and blended to match the existing contours to help facilitate the flow. Removing this crossing would eliminate a maintenance/reconstruction project every spring. Removing the crossing at Site 1 cannot occur until the crossing at Site 2 is reconstructed.

2.2 Alternative 1B - Do Nothing

Alternative 1B is to leave the lower stream crossing at Site 1 in place. If Alternative 1B is selected, the crossing will likely blow out within one year making the road to the boat ramp and material source stockpile impassible.

2.3 Alternative 2A – New Bridge Crossing, Elevate Above Ordinary High Water

This alternative consists of a one lane modular bridge on a steel pile foundation. The proposed superstructure would be a prefabricated modular bridge with an estimated deadload of 34-kips. The bridge would be designed to withstand loading conditions consistent with AASHTO's HL-93 loading condition, which is defined as lane load plus design truck load. In accordance with the Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) the recommended bridge width is 15 feet. This bridge would be constructed at the previous location and the span would remain unchanged at 42 feet. Prior to any new construction, the existing bridge would be removed and all salvageable materials delivered to the city landfill. The existing piles would be pulled using a vibratory hammer, and new piles driven at the same approximate location.

To allow passage of debris, the bottom chord of the new modular bridge would be elevated to a height of 3-feet above the ordinary high water mark per the recommendation of the Alaska Highway Drainage Manual. The deck height of the new bridge is estimated to be about 8 feet above that of the previous bridge. Based on the debris lines observed in the field, the additional height of this bridge would keep the structure from being impacted during ordinary high water events and spring ice jams, but not extreme flooding. Elevating the new structure would require reconstruction of the approaches.

According to the Alaska Highway Preconstruction Manual, bridge railings must comply with NCHRP 350 test level 2 or 3. To increase bridge rail performance the test level 3 railing should be considered.

Per the AASHTO Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400) the use of guardrails or other traffic barriers are not recommended and deemed impractical for use on roads with very low traffic volumes.

For the purposes of developing a cost estimate, we assumed an active layer of 8 to 10 feet and HP 14 x 117, grade 50, steel H-piles spaced at approximate 6 feet and driven to a depth of 50 feet below the ground surface. It is anticipated that the piles would be driven in the same general location as the existing piling. In permafrost, piles will likely require predrilling.

With an anticipated embankment height of 18 feet, abutments would consist of the H-piles, 8-inch x 8-inch treated timber lagging and horizontal steel rod tiebacks and deadmen to restrain lateral earth pressures. A steel pile cap would support the modular bridge and should be designed to resist the force of ice jams should the ordinary high water mark be exceeded. Riprap armoring would be installed on approach slopes and along the abutment toe to resist erosion and scour. See the concept drawings in **Appendix B**.

This alternative would elevate the bridge above the estimated ordinary high water mark, but could be expected to overtop occasionally and be damaged by extreme flood events on the Colville River. Approach slope armor may be displaced by large ice floes and would require maintenance. Stream gaging and flood study would be needed to estimate the recurrence interval and flood stages for a proper bridge design at Site 2. The roadway from the boat ramp to the village would intentionally not be elevated to allow flood waters and ice floes to pass around the bridge and approaches and avoid having the roadway act as a dam.

2.4 Alternative 2B – New Culverts, Minor Elevation Change

Alternative 2B consists of installing three 120-inch diameter galvanized steel culverts. Sheet piling should be considered under culverts at both ends to prevent piping around the bottom of culverts. Rigid insulation would be installed under culverts to avoid thaw settlements. Prior to any new construction, the existing bridge would be removed and all materials disposed of at the landfill. Existing piles would be pulled or cut off below grade.

A preliminary hydraulic analysis was performed to compare the existing condition to three 10-foot diameter culverts with headwalls. HEC-RAS modeling software was used to develop hydraulic models based on elevations recorded during the site visit. The complexity of the hydraulic processes associated with the ice jams in the Colville River Drainage limits the ability to validate the modeling, but it allows for a general comparison between the existing structure and a proposed structure.

Based on the Alaska Department of Transportation's listed design value for bridges in flood hazard areas, the 100-year peak flow was selected as the design flow. This flow was calculated using USGS regression equations. The model assumed that the bridges or culverts would have a 2-foot blockage due to icing. The results are depicted in **Table 3**.

Table 3: Upper Stream Crossing Model Results

	Existing Bridge	Proposed Condition 3 – 120" Culverts
Q_{10} Backwater Elevation (feet below low chord or top of pipe)	-1.3	+1.1
Flow Capacity	700 cfs	1,350 cfs

The results suggest that installing three 120-inch culverts would increase freeboard by 2.4 feet and nearly double the flow capacity.

This Alternative assumes there is no benefit to elevating the crossing because the roadways have flooded. Finished grade over the culverts would approximately match that of the existing bridge approaches with 2 feet of minimum cover over new culverts.

To prevent piping under the culverts, a sheet pile wall would be installed at the inlet and outlet ends to prevent piping under the culvert bottoms. The culverts would be bolted to a steel angle which is in turn secured to the sheet piling. The sheet piling wall shall be cut to accommodate the bottom of the culvert and driven to refusal at the permafrost interface.

The crossing would be armored with 32-inches of Class II riprap from the toe of the slope to the shoulder of the road. This armor toes should be keyed in at the bottoms and ends to prevent edge scour. A riprap apron should extend 15-feet in front of the inlet and outlet ends of the culverts.

Approach slope armor may be displaced by large ice floes and would require some maintenance but less than an elevated bridge. Stream gaging and flood study would be needed to estimate the flood recurrence intervals and stages for design. The roadways and crossings would flood more frequently than the Alternative 2A, the elevated bridge.

2.5 Alternative 2C – Do Nothing

Currently, half of the bridge decking is missing and a wooden barricade with a single warning sign is the only safety measure implemented. Leaving the site as-is is a potential hazard and liability for the Borough and therefore this alternative is not recommended. The bridge and abutments should be removed and the slopes graded to match the existing contours.

2.6 Alternative 3A – Armor Existing Structure, No Elevation Change

During HDL's site visit in August 2015, it was observed that very little flow was active through the culverts at Site 3. However, a high water debris line was discovered upstream of the crossing. This upstream debris line was measured at approximately 4.5 feet above the crest of the road at the culverts. Downstream of the crossing, a high water debris line was observed approximately 2 feet below the top of the road. Based on the debris lines, there appears to be a significant backwater buildup during peak flows resulting in roadway overtopping and erosion damage. This effect can be mitigated through hydraulic improvements at the crossing. This alternative, however, makes no improvement to the crossing's hydraulic issues but includes armoring the existing culverts and installing a minimum of 32 inches of Class II riprap. The embankment slopes would be armored and culvert ends armored 15 feet in front of the culvert ends to a width 4 feet on either side of the outside of the culvert. This alternative does not mitigate the backwater buildup during peak flows, but addresses erosion and damage sustained during these periods. Once the waters have receded there may still be a need for minor maintenance.

This alternative would be prone to flooding during breakup and would not provide all season access to the water source lake. This alternative is not recommended if all season access to the water source lake is required.

2.7 Alternative 3B – Install New Circular Culverts, Elevate Roadway 3 Feet

Alternative 3B consists of installing three 72-inch circular culverts at Site 3, raising road grade approximately 3 feet, and armoring slopes and aprons similar to Alternative 2B. Rigid insulation would be installed under culverts to reduce thaw settlements. To prevent piping under the culvert bottoms, a sheet pile wall would be installed at the inlet and outlet ends of the culverts. The culverts shall be bolted to an angle and secured to the sheet piling. The sheet piling would be trimmed to accommodate the shape of the culvert. Slopes and inlet and outlet aprons would be armored with 32-inches of Class II riprap. The aprons would extend 15 feet in front of the culverts.

A hydraulic analysis was performed to compare the existing conditions to the recommendation using HY-8 modeling software. It should be noted that the complexity of the hydraulic process associated with ice jams in the Colville River Drainage limits the ability to validate modeling results; however, a performance comparison between the existing and proposed condition is useful.

Based on the Alaska Department of Transportation's design value for low usage secondary highways, the 10-year peak flow was used as the design flow to analyze the tributary stream crossing. The results are depicted in **Table 4** below. USGS regression equations were used to calculate the flow and it was assumed that the culverts would have a 2-foot blockage due to icing.

Table 4: Tributary Culvert Model Results

	Existing Condition 3 – 48" Culverts	Proposed Condition 3 – 72" Culverts
Q_{10} Backwater Elevation (feet above roadway)	+1.7	-1.9
Overtopping Flow	199 cfs	552 cfs

The results suggest that upgrading to three 72-inch diameter circular culverts would reduce the backwater elevation by several feet and may significantly reduce the probability of overtopping.

The alternative would provide all season access to the water source lake. This alternative is recommended.

2.8 Alternative 3C – Install New Arched Culvert, Elevate Road 4.5 Feet

Alternative 3C consists of installing a single 100-inch by 154-inch arched culvert, rigid insulation, a sheet pile cutoff wall and slope and apron armoring. Similar to Alternatives 3A and 3B, the slopes and aprons would be armored with 32-inches of Class II riprap. The apron would measure approximately 15-feet by 27-feet in front of culvert inlets and outlets. To achieve the recommended minimum culvert cover of 2 feet, the existing roadway grade would have to be raised by 1.2 feet. In order to mitigate overtopping, similar to Alternative 3B (using the Q_{10} backwater information) the roadway should be raised 4.3 feet. Elevating the roadway would enable the road to be useable during spring breakup.

A preliminary hydraulic analysis was performed similar to Alternatives 3A and 3B. Based on the Alaska DOT's design value for low usage secondary highways, the 10-year peak flow was used as the design flow to analyze the tributary stream crossing. The results are depicted in **Table 5** below. USGS regression equations were used to calculate the flow and it was assumed that the culverts would have a 2-foot blockage due to icing.

Table 5: Tributary Culvert Model Results

	Existing Condition 3 – 48” Culverts	Proposed 100” x 154” Arched Culvert
Q_{10} Backwater Elevation (feet above roadway)	+1.7	-0.6
Overtopping Flow	199 cfs	557 cfs

The results suggest upgrading to a single 100-inch by 154-inch arched culvert would reduce the backwater elevation by a couple of feet and would reduce the occurrence of overtopping.

This alternative may be feasible, but its design should take special precautions to insulate the foundation under the arched culvert to prevent frost jacking. Arched culverts are susceptible to failure from frost jacking because of their flat bottom. Recently, a similar multiplate arched culvert in Buckland failed when the bottom jacked, while a circular multiplate structure alongside it performed satisfactorily. It is reported that an ice lense formed underneath, causing the bottom to buckle. For this reason, additional insulation should be added to prevent ice lenses from forming under the arch.

2.9 Alternative 3D – Do Nothing

Alternative 3D leaves the existing crossing as is. With minor spring time repairs this crossing may be useable for years, but will eventually fail due to damage sustained during high water events and ice jamming activities. If the Borough desires all season access to the water source lake, this option is not recommended.

2.10 Other Alternatives Considered

Other alternatives were considered, but deemed not feasible for technical or economic reasons.

2.10.1 Elevate Bridge at Site 2 Above Extreme High Water

Elevating the bridge at Site 2 above the extreme high water event was considered, but deemed not practical or feasible. This alternative would require extremely high, roughly 24.5–foot, abutment walls and extended approaches. Building abutments and approaches of this magnitude would require massive amounts of fill material and gravel, which would be expensive and complicated. Elevating the bridge to this extreme would pose no benefit to the community as the surrounding access roads would be inundated and the bridge would not be of any benefit to the general public. For cost estimate breakdown see **Page 10 of Appendix A.**

2.10.2 Precast Concrete Girders

A bulb-T prestressed concrete bridge was considered for Site 2, but deemed not economically feasible due to the short span. According to a local prestressed concrete manufacturer, a short 50-foot span with a 14 to 16 foot deck width, three 42-inch bulb-T prestressed concrete girders would not be competitive with modular steel bridges of an equivalent size. The concrete would also be more susceptible to ice damage because of the girder depth, and the bulbs lesser lateral strength when compared to a steel bridge.

2.10.3 Elevate the Entire Road to the Boat Ramp Above Extreme High Water

Elevating and armoring the 3200 feet of road to the boat ramp and bridge at Site 2 above extreme high water was considered, but the high cost, estimated to be $20M to $30M for the 28,800 CY of riprap and 92,800 CY of gravel fill was deemed not economically feasible. Elevating the entire road and bridge would hydraulically act as a dam for Colville River flood waters and would be prone to flood damage. The high cost compared to the benefit of providing access to the boat ramp and material source during flood events makes this concept not feasible.

3.0 CONSTRUCTION METHODS

The nature of the work and soils in the area lend itself to construction during multiple seasons. The mobilization/demobilization of materials and equipment on the ice road coupled with winter and summer construction activities will extend construction over the course of one year.

Construction access at Site 3 is governed by the need for access to the village's water source. The 3rd or 4th week of June the city begins pumping water from the lake and pumps continuously until the tanks are full, which is typically around the 1st week of September. The shutdown date varies according to weather. Freezing of the waterline ends the pumping season. During the pumping season, the water system operators require unrestricted access to service pumps and monitor the operation.

3.1 Construction Methods for Culverts

3.1.1 Site 2

The existing bridge should be removed and all salvageable materials shall be delivered to the Borough. The existing piles may be able to be pulled, salvaged, and returned to the City; otherwise, the piling should be cut two feet below grade. In late fall, the sheet pile walls should be installed when the active layer is at its maximum depth. These walls are to be driven through the active layer and to refusal in the permafrost layer below. The sheet pile walls should be left high, about to the spring line of the culverts. Under frozen ground conditions, the Contractor would excavate and install a layer of rigid insulation and install approximately 4-feet of sacrificial fill material to protect the crossing during spring runoff and breakup. After breakup, culverts would be installed and remaining thawed fill placed and compacted under low flow conditions. The sheet piles would be trimmed and attached to culverts using a double rolled angle. Fill slopes should be armored with Class II riprap 32-inches deep over a geotextile fabric with keyed edges. The culvert inlets would be armored with a riprap apron.

3.1.2 Site 3

Due to the average historical high water date of the Colville River on May 31st, and the need for access to the water source lake by the 3rd week in June, winter construction methods will need to be employed. In late fall, the existing culverts and fill would be removed and sheet pile walls installed similar to Site 2. Sheet piles would be cut to an elevation about 6 inches above the invert of the inlet and outlet of the culverts. Then under frozen ground conditions, excavation would occur to the bottom of insulation, insulation installed, then fill brought back up to the bedding depth of the culvert inverts. The culverts, fill, geotextile, and riprap could be placed under frozen ground conditions, if dry granular material could be properly placed and compacted; or the contractor could place temporary riprap to protect during breakup and complete the project under thawed conditions. The sheet piles would be trimmed and attached to culverts using a double rolled angle. Fill slopes should be armored with Class II riprap 32-inches deep over a geotextile fabric with keyed edges. The culvert inlets would be armored with a riprap apron.

3.2 Construction Methods for the Bridge

The removal of the existing bridge structure is needed to construct the bridge. The existing bridge should be removed and all salvageable materials shall be delivered to the Borough. The existing piles should be pulled, salvaged, and returned to the City, or the bridge offset to miss existing piles.

Gravel approaches would be removed to the extent required to drive piles and construct deadmen anchors. New H-piles would be predrilled with an undersized pilot hole and driven to depth. Near-water work should be avoided until spring breakup high flows have receded.

The abutments and wing walls, consisting of piles, treated-timber lagging and deadman anchors, would be constructed during thawing conditions to help ensure proper placement and compaction of fills. The pile caps, elastomeric bearing pads, backwall, bridge structure, and appurtenances would be installed when environmental conditions allow for proper welding and connection installation.

4.0 MAINTENANCE AND OPERATION

Yearly maintenance may be required at Sites 2 and 3 to ensure the longevity of the crossings. Erosion control and bank stabilization will need to be maintained and repaired in a timely manner to protect the structures in place. These structures will be subject to flooding and overtopping during extreme events and will need to be repaired and rearmored, if needed. If normal maintenance is not conducted in a timely fashion the structures may prematurely fail.

It is recommended to inspect culverts on an annual basis and after extreme events. The National Bridge Inspection Standards (NBIS) recommends that bridges should be inspected every two years and that the maximum interval between inspections should not exceed four years.

5.0 ENVIRONMENTAL CONSIDERATIONS AND PERMITTING REQUIREMENTS

HDL conducted preliminary environmental research using the most current available data from state and federal agencies to identify environmental resources in the vicinity of the proposed project. The purpose of the preliminary research was to assist in identifying permitting and regulatory requirements to ensure environmental considerations are adequately addressed in developing any of the "action" alternatives for the proposed project. Environmental categories with resources potentially present in the project area are discussed below.

National Environmental Policy Act (NEPA) Review

The funding source for the proposed project will dictate the type of environmental documentation necessary to satisfy state and federal requirements and/or authorizations.

Should federal funds be used, the federal agency appropriating the funds would likely assume the role of lead federal agency and would be responsible for development of appropriate NEPA documentation. NEPA documentation would outline potential impacts to the natural and man-made environment.

Should the project be entirely state funded, the NSB's primary environmental documentation will be the environmental review conducted for this PAR, which identifies potential environmental impacts and outlines permits and authorizations needed for the project. A NSB or state-funded project triggers the NEPA process when a federal permit is required, such as a U.S. Army Corps of Engineers (USACE) Section 404 permit for impacts to wetlands. This environmental review may be used by the USACE to streamline their NEPA documentation efforts and potentially decrease the amount of time necessary in receiving authorization.

Wetlands & Waters of the U.S.

A review of the U.S. Fish & Wildlife Service (USFWS) National Wetlands Inventory and recent satellite imagery indicates the project area contains wetlands under USACE jurisdiction. It is anticipated that the project will impact wetlands, and will require authorization under a Nationwide Permit and submittal of a Pre-Construction Notification to USACE. Should the project disturb more than 0.50 acre of wetlands, an Individual Permit application would be required.

Construction of the proposed project will involve the discharge of construction storm water into waters of the U.S. Should the project involve more than one acre of disturbed ground, coverage under the Alaska Department of Environmental Conservation's Alaska Pollutant Discharge Elimination Systems (APDES) Construction General Permit for stormwater discharges would be required.

Cultural, Historic, Pre-Historic, & Archaeological Resources

The likelihood of disturbing previously unknown cultural, historic, pre-historic, or archaeological resources within the project areas is low since the areas have been previously disturbed by construction of existing infrastructure. The project will require a Certificate of Traditional Land Use Inventory (TLUI) Clearance from the NSB Department of Inupiat History, Language, and Culture (IHLC).

Should the project receive state or federal funding, consultation with the Alaska Office of History and Archaeology under the Alaska Historic Preservation Act, or State Historic Preservation Officer (SHPO) under Section 106 of the National Historic Preservation Act, would be required.

Fish & Wildlife:

Threatened & Endangered Species

Initial project scoping conducted using USFWS's Information, Planning, and Conservation System tool indicates there is one species, the polar bear (Ursus maritimus), listed as threatened under the Endangered Species Act (ESA) that is known to inhabit the project area. There are no endangered or candidate species or designated critical habitats located in the project area. Consultation with the USFWS under Section 7 of the ESA would be required if federal funding is received for construction.

Migratory Birds

The project is located in areas that have been heavily disturbed; however, shrub and grass-vegetated areas are present. To avoid disturbance to migratory birds, USFWS recommends avoiding clearing from June 1st through August 10th.

Anadromous Fish Streams

A review of the Alaska Department of Fish and Game's (ADF&G) Anadromous Waters Catalog (AWC) indicates the project is located on the Nigliq Channel, a tributary of the Colville River, which is listed as supporting several species of anadromous fishes. Consultation with ADF&G during the design phase of the project is recommended to determine whether fish may be present in the project area and if a Fish Habitat Permit will be required.

Land Ownership

According the Alaska Division of Community and Regional Affairs' Community Map for Nuiqsut, the project would be located on a combination of lands owned by the Borough, City of Nuiqsut, and Kuukpik Corporation. The project will require easements or rights-of-way prior to construction.

Environmental Permitting Summary & Recommendations

Table 6 below summarizes environmental data and permit requirements for development.

Table 6: Recommended Regulatory and Permitting Tasks

NSB Land Management Regulations (LMR)	Development Permit. (fee waived for NSB projects).
Wetlands, Waters of the U.S, & Navigable Waters	Jurisdictional wetlands located within project areas. Section 404 Nationwide Permit/Pre-Construction Notification required. APDES Construction General required if disturbed area is 1 or more acre ($490 fee).

Cultural, Historic, Pre-Historic, & Archaeological Resources	Low potential to encounter historic sites; IHLC's Certificate of TLUI Clearance required (fee waived for NSB projects). Consultation with OHA/SHPO required depending on funding source.
Threatened & Endangered Species	Polar bear listed as Threatened under ESA. Consultation with USFWS required if federally funded.
Migratory Birds	No vegetation clearing between June 1st and August 10th recommended.
Anadromous Fish Streams	No AWC-listed anadromous fish habitat in project area; Nigliq Channel of Colville River is approximately 500 feet downstream of Site 1. Consultation with ADF&G recommended during design.
Land Ownership	Confirm existing or provide easements or rights-of-way for work on NSB, City of Nuiqsut, and Kuukpik Corporation lands.

6.0 ESTIMATE OF PROBABLE COSTS

6.1 Capital Cost

Capital costs for the three sites have been prepared based on the analysis provided herein for each of the sites, details of which are provided in **Appendix A** and summarized in **Table 7**. Capital cost estimates are based on the following general assumptions:

1. Work will be competitively bid.
2. Seasonal ice road between Prudhoe Bay and Nuiqsut will be available and constructed by industry.
3. Materials and equipment will mobilize and demobilize via ice road.
4. A site for material staging and equipment storage will be provided at no cost to the contractor.
5. The Borough stockpiled gravel will be available at no cost.
6. Piling will be predrilled in permafrost.
7. Sheet piling will be driven through the thawed active layer to refusal in the permafrost.