Willow Master Development Plan

Appendix D.3A
Ice Bridge Plan

January 2023

2019 – 2020 Willow Development Ocean Point Ice Bridge Revision

2019 – 2020 Willow Ice Road – Ocean Point Water Resources Field Investigation

2019 Willow Ice Road Fall Field Trip Report

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2019 – 2020

WILLOW DEVELOPMENT

OCEAN POINT ICE BRIDGE REVISION

Submitted to:

ConocoPhillips Alaska, Inc.

Submitted by:

ICE Design & Consult

Innovative Civil Engineering, Design and Consult
PO Box 211846
Anchorage, Alaska 99521-1846

June 9, 2020

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ABBREVIATIONS

ATM	Atmospheric Pressure
BPMSL	British Petroleum Mean Sea Level
CFDD	Cumulative Freezing Degree-Day
COVID	Coronavirus
CRIB	Colville River Ice Bridge
CWAT	Community Winter Access Trail (approximately 300 miles of groomed snow roads connecting Utqiagvik, Atqasuk, Wainwright, and Nuiqsut, to gravel infrastructure)
DS	Downstream
ft	Feet
ft^2	Square Feet
ft^3/sec	Cubic Feet Per Second
GMT2	Greater Moose's Tooth Drill Site 2
GPM	Gallons Per Minute
ICE	Innovative Civil Engineering, Design, and Consult
MBI	Michael Baker International
MT7	Moose's Tooth 7 (occasionally used interchangeably with GMT2)
NAD83	North American Datum 1983
OPIB	Ocean Point Ice Bridge
PT	Pressure Transducer
Q	Discharge
SPMT	Self-Propelled Modular Transporter

STA	Survey Station (feet)
US	Upstream
WSE	Water Surface Elevation

DEFINITIONS

Albedo	A ratio of the reflected insolation to the incident insolation for any of the natural or manmade materials
Insolation	Exposure to the sun's rays
Overflow	When water is present on the surface of the ice

1 EXECUTIVE SUMMARY

An investigation of the proposed Ocean Point Ice Bridge (OPIB) was conducted in the winter of 2019-2020. An updated ice bridge design is included in Appendix E that is suitable to support the Willow Development maximum module net weight of 3,200 tons loaded on a Self-Propelled Modular Transport (SPMT) with maximum allowable gross weight of 4,200 tons. The construction quantities are presented in Table 1.1.

TABLE 1.1: ICE CONSTRUCTION QUANTITIES OCEAN POINT ICE BRIDGE

Ocean Point Ice Bridge	Ice Quantity (yd^3)
****TOTAL =**	**36,500**

***The water equivalent quantity is 6.6 million gallons*

Observations from the winter of 2019-2020 have confirmed that there is a significant potential for overflow at the OPIB. Furthermore, there is a decrease in water discharge throughout the course of the winter. These two factors were the reason for the revised OPIB design.

Three potential overflow events were documented at Ocean Point in the winter of 2019–2020 during January, February, and March. The overflow event in March temporarily closed the Community Winter Access Trail (CWAT). The average depth of the overflow was estimated to be less than 1 foot.

Two direct discharge measurements were conducted at Ocean Point by Michael Baker International (MBI). The first and discharge, 135 ft^3/s (60,000 GPM) was measured on December 31, 2019. This had decreased to 9 ft^3/s (4,000 GPM) by February 25, 2020 (93% decrease). A third direct discharge measurement was planned for April 14, 2020 but it was cancelled due to COVID travel related protective measures. The discharge probably continued to decrease through April and prior to runoff.

Future data collection efforts should be conducted at Ocean Point to better understand how the water discharge varies throughout the winter. It is important to verify the frequency and magnitude of overflow events and the mechanisms that create them. Investigations should focus on the period between mid-February to mid-April. This is the planned timeframe for construction and use of the OPIB (2024-2025).

2 INTRODUCTION

During the winter of 2018-2019 data were collected at 6 locations along an 8.2-mile reach of the Colville River in the vicinity of Ocean Point. The primary objective of this investigation was to identify potential locations across the Colville River where a heavy haul ice bridge could be constructed with a load capacity greater than the Colville River Ice Bridge (CRIB), and unlike the CRIB can be traversed by Self-Propelled Modular Transports (SPMT). Two potential locations were identified that met these criteria:

1. *Transect #1* – Henceforth known as the **Upstream Site**
2. *Transect #5 / #6* – Henceforth known as the **Downstream Site**

Figure 2.1 shows the approximate positions of the two locations overlaid on the 'Willow Optimization Option 3' that is presented in Appendix A. A follow-on study was planned for the winter of 2019-2020. The Upstream Site was selected for study because of its location on existing permitted routes and its ease of access.

The objectives for the 2019-2020 investigation were to determine the ice and hydrological conditions of the Upstream Site. The Downstream Site is assumed to have similar hydrological, bathymetric, and topographic characteristics as the Upstream Site - the details of which are contained within this report.

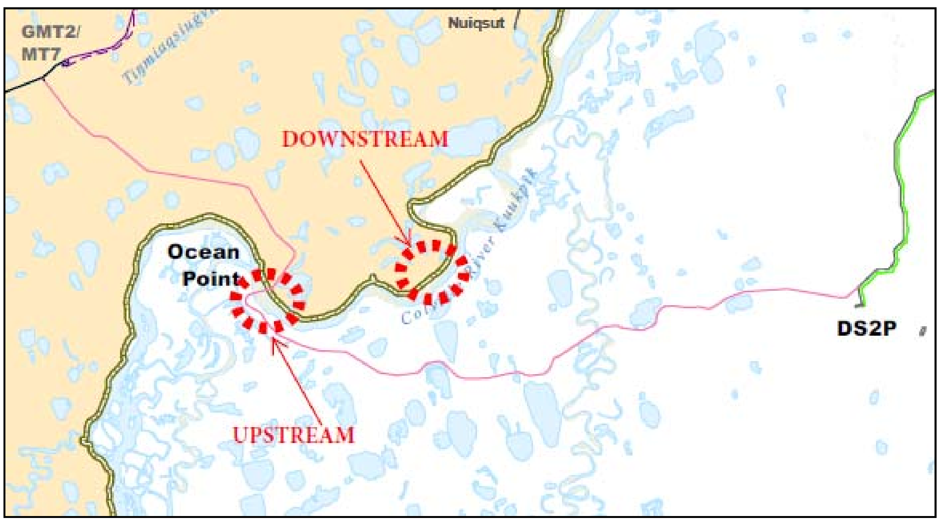


FIGURE 2.1: PROPOSED OCEAN POINT ICE BRIDGE CROSSINGS

2.1 PURPOSE OF 2019-2020 OCEAN POINT RECONNAISSANCE

The purpose of the 2019-2020 effort was to collect information about the Upstream Site for the Ocean Point Ice Bridge (OPIB). The data would be used to document and better understand how the crossing evolves throughout the course of the winter. Additionally, the new information has been used to revise the ice bridge design, construction quantities. To determine the maximum load capacity of the ice bridge the following data were collected:

1. Cumulative Freezing Degree-Days (CFDD)
2. Natural ice growth
3. Span of free water
4. Local weather observations
5. Water surface elevation (WSE)
6. Water Discharge (Q) (MBI 2020)
7. Overflow observations

The new information is presented in Section 4 and 5.

3 SUPPOSITIONS

The following suppositions should be considered while reviewing this report.

1. The first year of moving SPMTs with modules will likely be during the winter of 2024-2025.
2. The module move time span will be mid-February to mid-April.
3. The ice structures are subject to revision based on new information.
4. There is a potential for overflow at the proposed OPIB site.
5. This reports focus is limited to the Upstream Site for the OPIB. The Downstream Site is assumed to have similar physical characteristics (ice growth, water depths, discharge, construction volumes, topography, bathymetry, geometry, etc.).
6. The use of culverts is not addressed in this report and their potential usefulness has been published in the Innovative Civil Engineering, Design, and Consult (ICE) white paper: "20200602 – Culverts In Ice Bridges".
7. The proposed OPIB is not expected to be a grounded ice bridge and is not designed to be a grounded ice bridge.
8. Loaded and unloaded SPMTs are capable of traversing grades up to a maximum 5% longitudinal and a maximum of 1.5% transverse.

4 DATA AND OBSERVATIONS

The focus of the winter 2019-2020 data collection was at the proposed Upstream Site for the OPIB (N70.05348 W151.37277) (Figure 2.1). Three field investigations were made between December 31, 2019 and April 14, 2020. The timing of the field investigations was selection to coincide with early winter (December 31st), midwinter (February 25th), and prior the end of a typical ice road season (April 14th). Access to the Upstream Site was overland from GMT2/MT7 (Figure 2.1). A Rolligon and Hägglund were used on the first 2 visits and a Rolligon and Tucker on the last visit.

MBI engineers accompanied ICE engineers for the first two field visits (December 31st and February 25th). COVID related travel restrictions prohibited MBI from attending the last field visit (April 14th).

Ice profiles were surveyed during each field visit (Appendix B). The following data were recorded during each ice profile:

- - Span of ice
- - Ice thickness
- - Snow depth

- Span of free water under the ice
- Water depth

The surface of the ice was the basis of elevation for each of the ice profiles instead of British Petroleum Mean Sea Level (BPMSL). It is common practice to reference ice profiles to the water surface elevation. BPMSL ice elevations are not necessary during the early phases of ice bridge design.

The data collected from the ice profiles are necessary for calculating the following information:

1. Crossing Cross-sectional area
2. Construction Quantities
3. Direct Discharge (Calculated by MBI)

Figure 4.1 presents a sketch of the layout plan at the Upstream Site. In addition to ice profiles, pressure transducers (PT) were installed approximately 100 ft upstream (US) and downstream (DS) of the proposed Upstream Site centerline alignment. The PTs were installed on the channel bottom in the deepest part of the cross-section. The PTs measured absolute pressure which was translated into water depth by atmospheric (ATM) pressure corrections. The sample frequency of the PTs was set to 12-hour intervals (noon and midnight).

The CWAT was about 85 ft upstream and paralleled the ice profile alignments. The CWAT was not in place during the December 31st field visit.

ICE

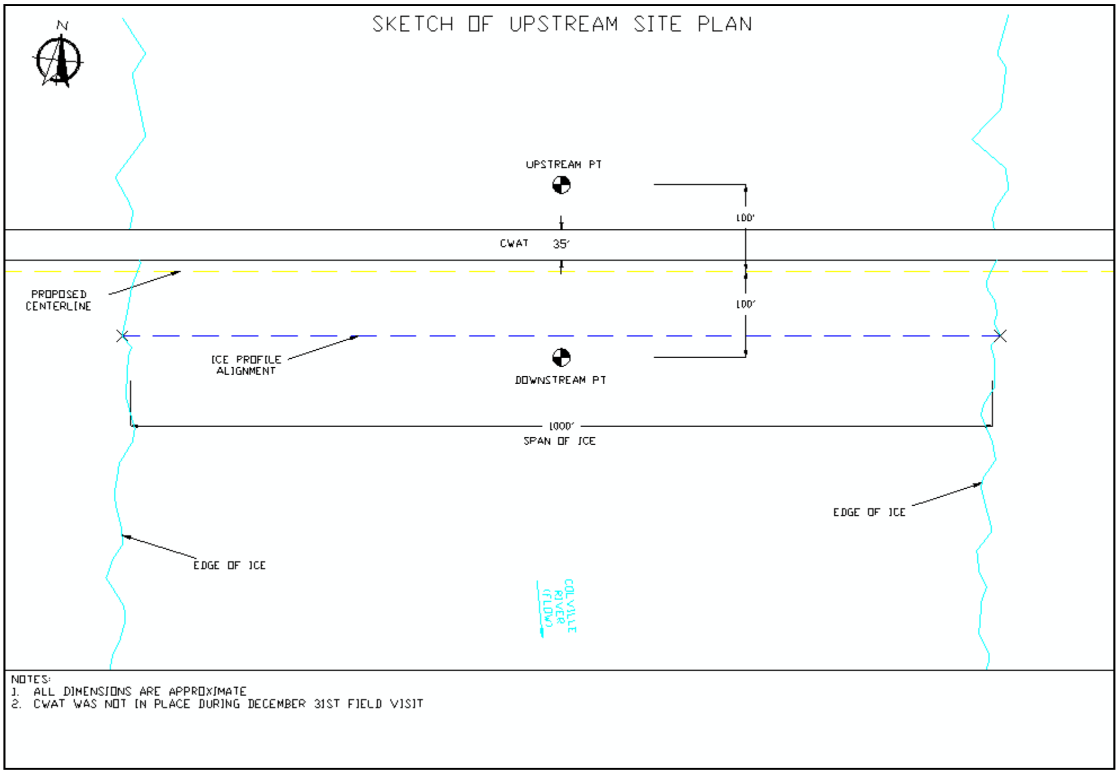


FIGURE 4.1: SKETCH OF UPSTREAM SITE PLAN

4.1 CUMULATIVE FREEZING DEGREE-DAYS

Cumulative Freezing Degree-Days (CFDD) are calculated as a sum of average daily degrees below freezing for a specified time period and are frequently used to measure and compare the coldness of winter from year to year. The annual CFDD has ranged from a high of 9,300°F (2011-2012 winter season) to a low of 6,200°F (2017-2018 winter season). Generally speaking, the higher the CFDD then the colder a winter was. However, a higher CFDD doesn't necessarily equate to a longer winter. Figure 4.2 presents the historical CFDD from 2002 to 2020.

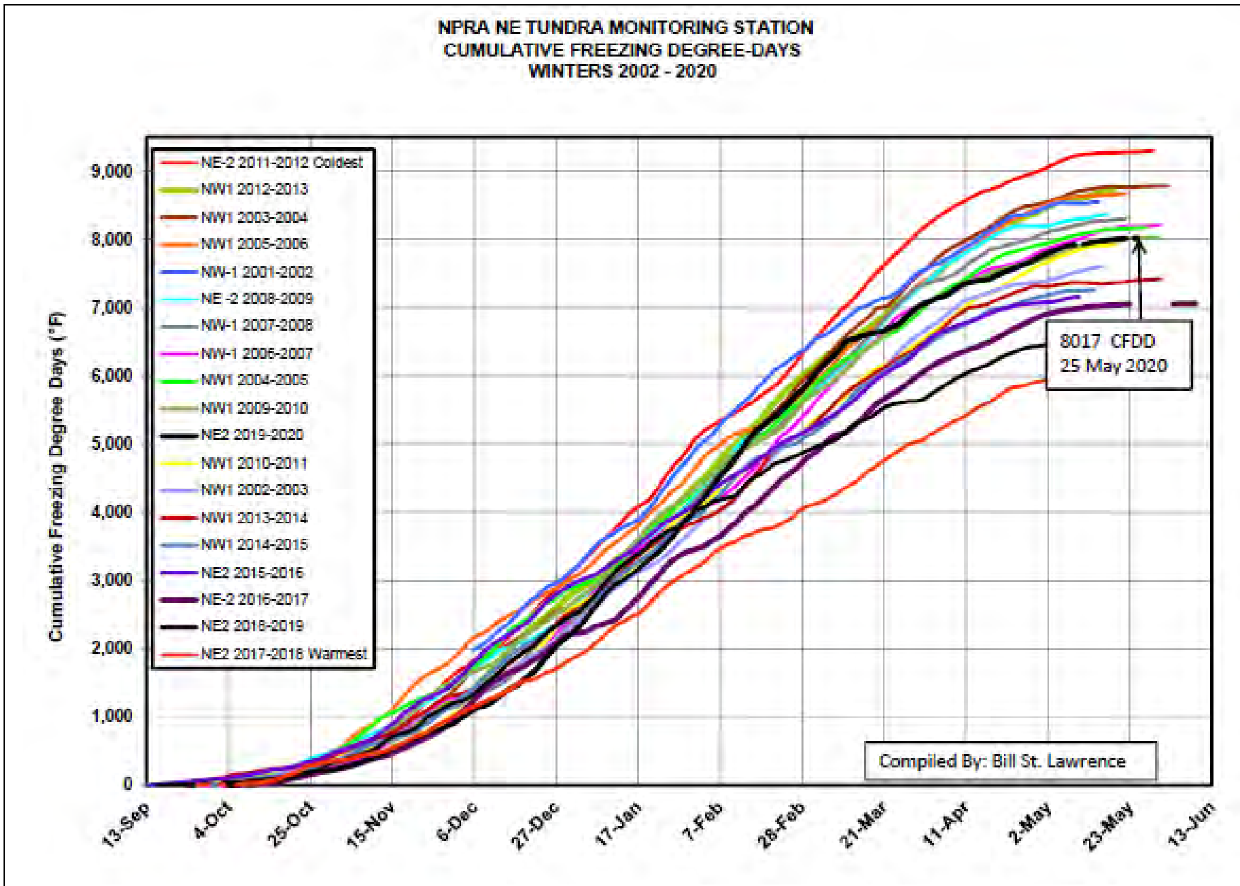


FIGURE 4.2: CUMULATIVE FREEZING DEGREE-DAYS 2002 - 2020

The air temperature CFDD index relates to:

1. Natural ice growth
2. Ice construction rates
3. Refreezing of seasonal thawed tundra

4.2 Span Of Ice

The span of ice is the distance between the two ice edges. The span of ice at the proposed Upstream Site crossing was approximately 1,000 ft (Figure 4.1). It was difficult to establish the precise edges of the ice the interfingering of ice and sediments made it difficult to establish the exact ice edge location. Generally, the river ice was blown clean of snowdrifts (snow depths <0.1 ft).

4.3 Natural Ice Growth

Table 4.1 presents the ice natural ice thickness at the proposed Upstream Site OPIB during the three field visits. Also presented is the ice growth rate. The ice growth rate was likely the highest between 25 February and 15 April. Historically, natural ice growth after mid-April is relatively low. This is due to the increase in average daily temperatures and the increase in daily solar radiation. The reduction in natural ice growth makes ice bridge repairs and construction difficult.

TABLE 4.1: NATURAL ICE THICKNESS AND GROWTH RATE

Field Visit Date	Average Floating Ice Thickness (feet)	Growth Rate From Previous Field Visit (feet per day)	Growth Rate From Previous Field Visit (feet per week)
December 31, 2019	2.7	0.027*	0.19*
February 25, 2020	4.6	0.034	0.24
April 14, 2020	5.6	0.020	0.14

**Day 1 is set to the day that CFDD > 1 (September 24, 2019)*

Natural river ice growth rates depend on air and water temperatures, water velocity, overflow, wind speeds and direction, ice snow cover, and ice thickness. Construction activities and techniques can modify ice growth to control production rates

4.4 Span Of Free Water

The span of free water under the ice at a given crossing is the distance measured between the edges of water below the ice. Figure 4.3 provides an illustration of how the span of free water is measured.

Table 4.2 presents the span of free water under the ice during each of the three field visits. Generally, as the ice thickness increases the span of free water and the maximum free water column height decreases.

During the April 14th field visit, the natural ice had come into contact with the river bottom about mid-way across the channel. This created two independent spans of free water measuring 117 ft and 94 ft wide (Appendix B – April 14, 2020 Ocean Point Crossing Profile).

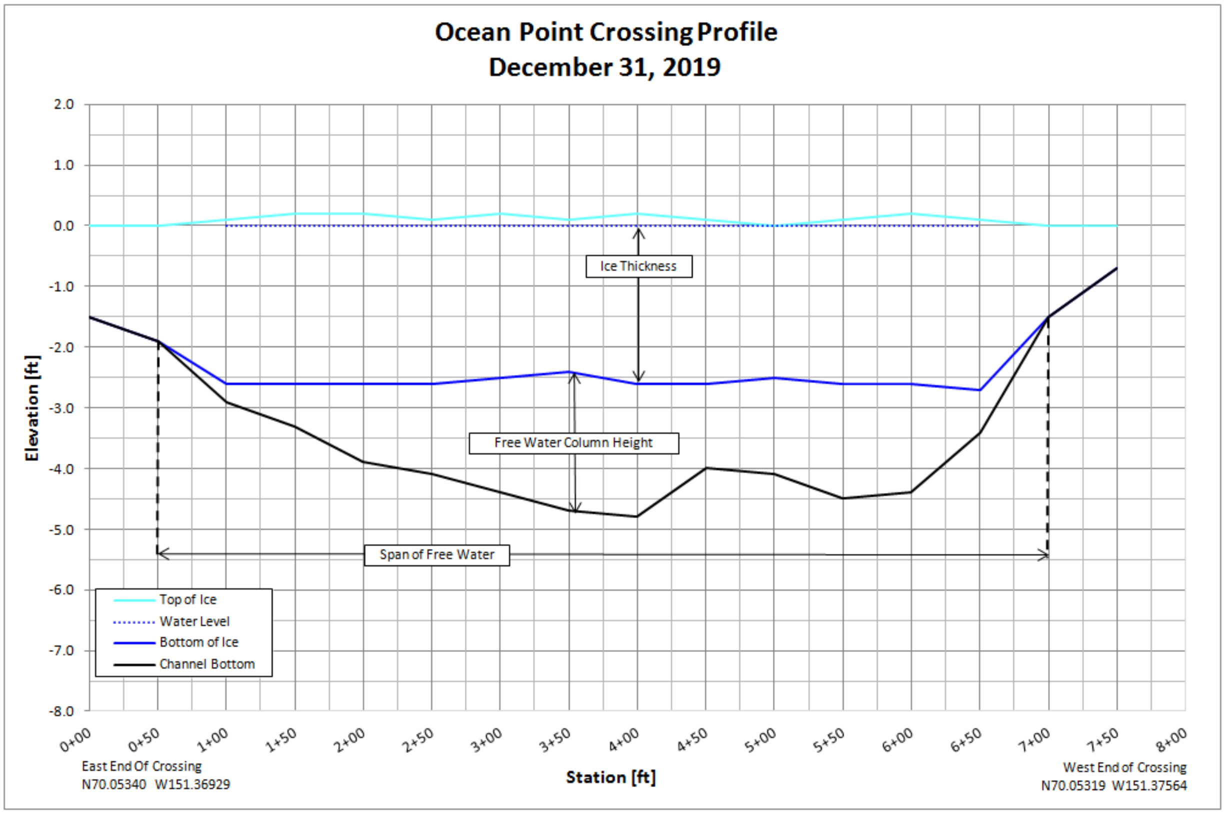


FIGURE 4.3: ICE PROFILE AND SPAN OF FREE WATER AREA

TABLE 4.2: SPAN OF FREE WATER

Field Visit Date	Span Of Free Water Under The Ice (feet)	Maximum Free Water Column Height Under Ice (feet)
December 31, 2019	650	3.0
February 25, 2020	400	1.2
April 14, 2020	*211**	0.9

**This is the combination of two independent spans of 117 ft and 94 ft that were separated by 94 ft of grounded ice*

4.5 Discharge Measurements

MBI conducted a direct discharge measurement during the first two field visits (Appendix C). A summary of the MBI discharge data are presented in Table 4.3 and Figure 4.4.

TABLE 4.3: MBI DISCHARGE MEASUREMENTS

Field Visit Date	Discharge (ft^3/s)	Discharge (GPM)	Average Velocity (ft/s)
December 31, 2019	135	60,600	0.15
February 25, 2020	9	4,000	0.04
April 14, 2020	**Data not obtained due to travel restrictions*		

The average water velocities and discharge decreased as winter progressed. Unlike the Mackenzie and Yukon Rivers, the Colville River is classified as an Arctic River. This means winter flow stops since the watershed is frozen. However, some flow continues from ground water as overflow.

4.6 WINTER WATER DEPTHS

Generally, water depth in a river decreases as the tributary discharge decreases with freeze-up. However, in the case of Ocean Point the overall water depth increased slightly as winter progressed.

Figure 4.4 illustrates the PT water levels and the atmospheric pressure. Potential overflow events were likely recorded by the pressure increases during February and early March (Section 4.8). The water levels increased by late March at a rate of about 0.2 ft in 30 days. Overall water depths were less than 5.0 ft with the maximum 5.6 ft in February.

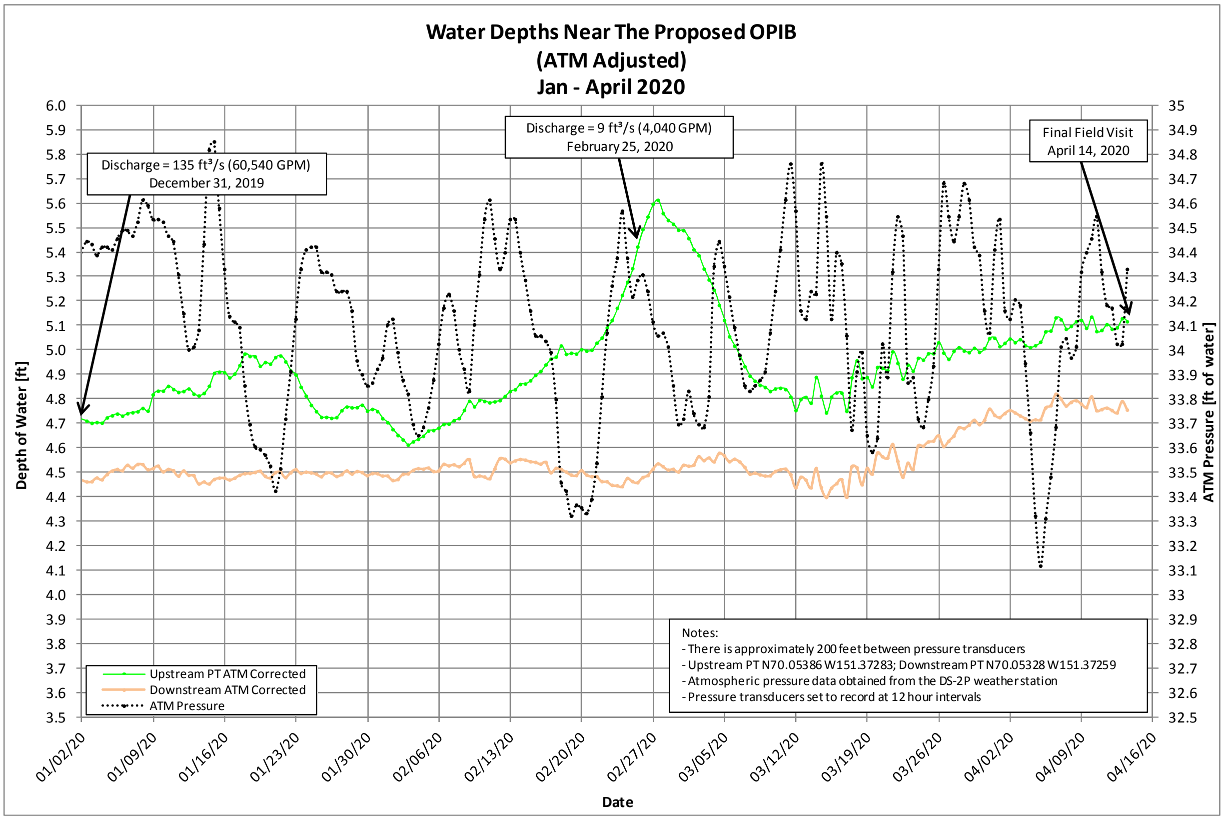


FIGURE 4.4: PT WATER DEPTHS NEAR THE PROPOSED OPIB

TABLE 4.4: MAXIMUM WATER DEPTHS

Field Visit Date	Maximum Water Depth (feet)
December 31, 2019	4.8
February 25, 2020	6.1
April 14, 2020	6.7

Possible explanations of the water depths whether rising or falling are a complex system of many unknown variables. A study of all the possible variations is beyond this report. Increasing ice thickness can constrict the flow and cause an increase in recorded pressure. During the coldest weeks of the winter, ground waters are emitted in larger volumes, but the waters freeze before moving far from the effluent. This makes the casual observations see what appears to be low flow.

4.7 Water Temperatures

In addition to pressure, water temperatures were recorded. Figure 4.5 presents the river bottom water temperatures and the average daily air temperature as recorded by the Drill Site 2P weather station (plotted on the right vertical axis). What is noteworthy in the data are the following:

1. There are spike-increases in the river bottom temperatures on February 28th and March 24th. These are likely related to overflow events and are discussed in further detail in Section 4.8.
2. For about 5 days starting on March 19th there was an event that caused the temperature to rise and fall -/+ 0.2°F at both PT locations. This is also likely related to an overflow event (Section 4.8) in addition to a potential phenomenon that is explained below in Section 4.7.3.
3. Daily temperature oscillations are visible in the data beginning on March 19th. These undulations are likely due to solar diurnal rhythms. The first annual sunrise at the OPIB latitude began on January 17th and by March 17th the daily sun exposure exceeded 12 hours per day.

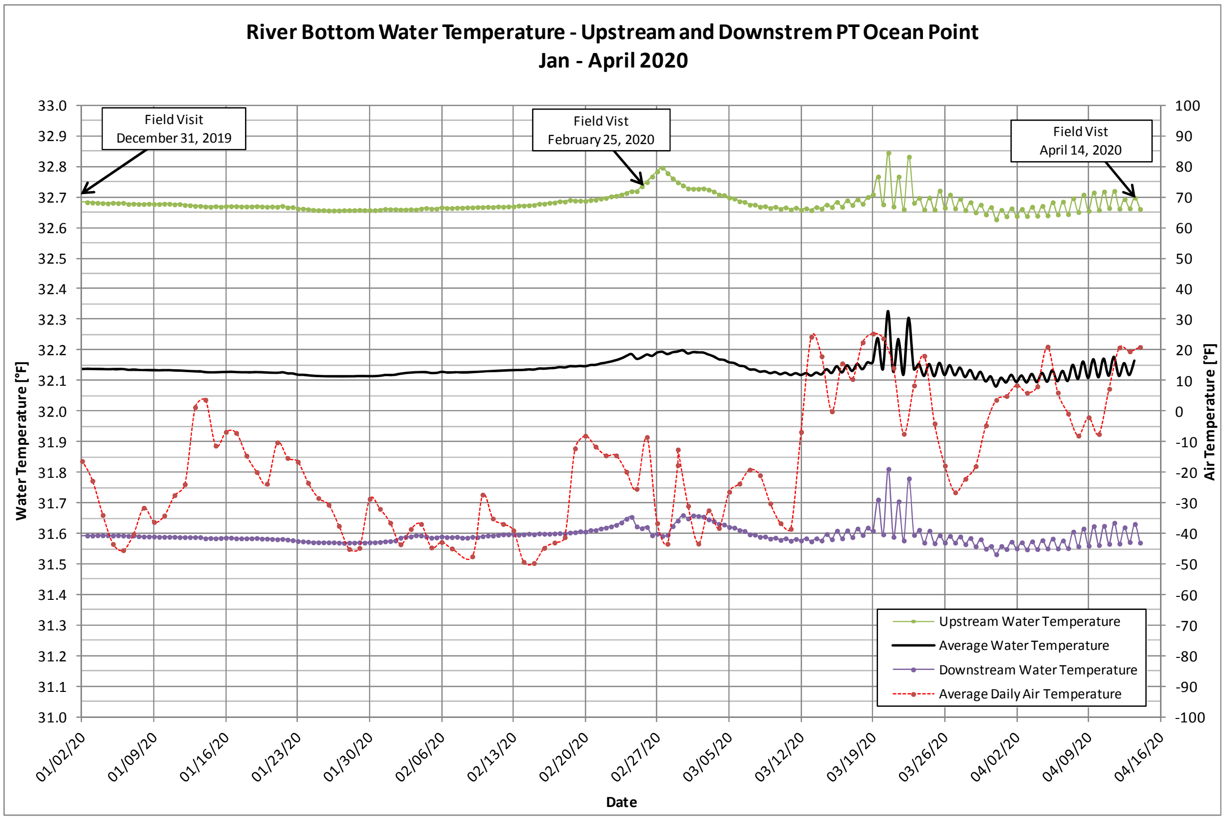


FIGURE 4.5: RIVER WATER TEMPERATURE – OCEAN POINT JANUARY TO APRIL 2020

4.8 Overflow Considerations, Characteristics, and Observations

A unique design consideration for the proposed Upstream Site OPIB is the potential for overflow. There is a high likelihood for overflow on the Colville River during any given winter. The frequency, location, triggers, and magnitude of overflow events can be difficult to predict and measure. Considerable attention was made during the data collection to record overflow events with instrumentation and observations. There were at least three potential overflow events during the winter of 2019-2020.

4.8.1 General Overflow Considerations At Ocean Point

Early in winter (November – December) overflow events are not typical. The thin ice (<2 ft) rises and falls with the changes in water levels. Discharge declines as the rains give water to snowfall and the watershed freezes. When overflow events do occur, they tend to be of lesser magnitude. Normally, when an overflow event occurs it breaches along the edges of the river where the ice has not become firmly grounded.

By the middle of winter (January – February) the potential for overflow events increase in frequency and magnitude. The river ice has become firmly grounded along the edges of the river and the cross-sectional area of free water is substantially reduced (80% reduction from the OPIB December 31st to the February 25th ice profile). This can lead to higher pressures, constrictions, and increased water velocity under the ice. Eventually the pressure becomes great enough to form cracks in the ice. The flowing water finds pathways through the cracks to the surface of the ice. The overflow from these events tends to flow in all directions on the surface of the river ice. These events can be difficult to observe if there is snow on the surface of the ice. Furthermore, the presence of snow can increase the amount of time required for the overflow to freeze.

Toward the end of winter (March – April), the potential for overflow is similar to that of the middle of winter with the additional contribution from increased solar radiation intensity and warmer air temperatures. Overflow from snowmelt due to solar radiation and warmer temperatures tend to result in ponding and minimal flow in any particular direction. Generally, there is little potential for runoff during this time period. However, runoff should be expected during the month of May.

4.8.2 Overflow Observations Summary

Table 4.5 summarizes the three potential overflow events recorded by the PTs. Figure 4.6 presents the relative water depth differential between the US and DS PTs. This difference is the DS PT water depth subtracted from the US water depth after each PT water level has been set to zero for its initial reading. Positive values on the graph indicate that the water levels were greater at the US PT than the DS PT. A water depth differential along the horizontal dashed line means that the water levels at the US and DS PTs are back to their initial (December 31, 2020) readings. Negative values on the graph indicate that the DS PT recorded water levels greater than the US PT.

TABLE 4.5: SUMMARY OF POTENTIAL OVERFLOW EVENTS

Approximate Date of Event	Notes
January 18, 2020	Evidence of this potential event was not observed during the February 25 field visit
February 28, 2020	The largest potential event recorded
March 24, 2020	CWAT reported event and travel suspended due to flooding

NOTE: The CWAT was located approximately 85 ft upstream of the ice profile centerline

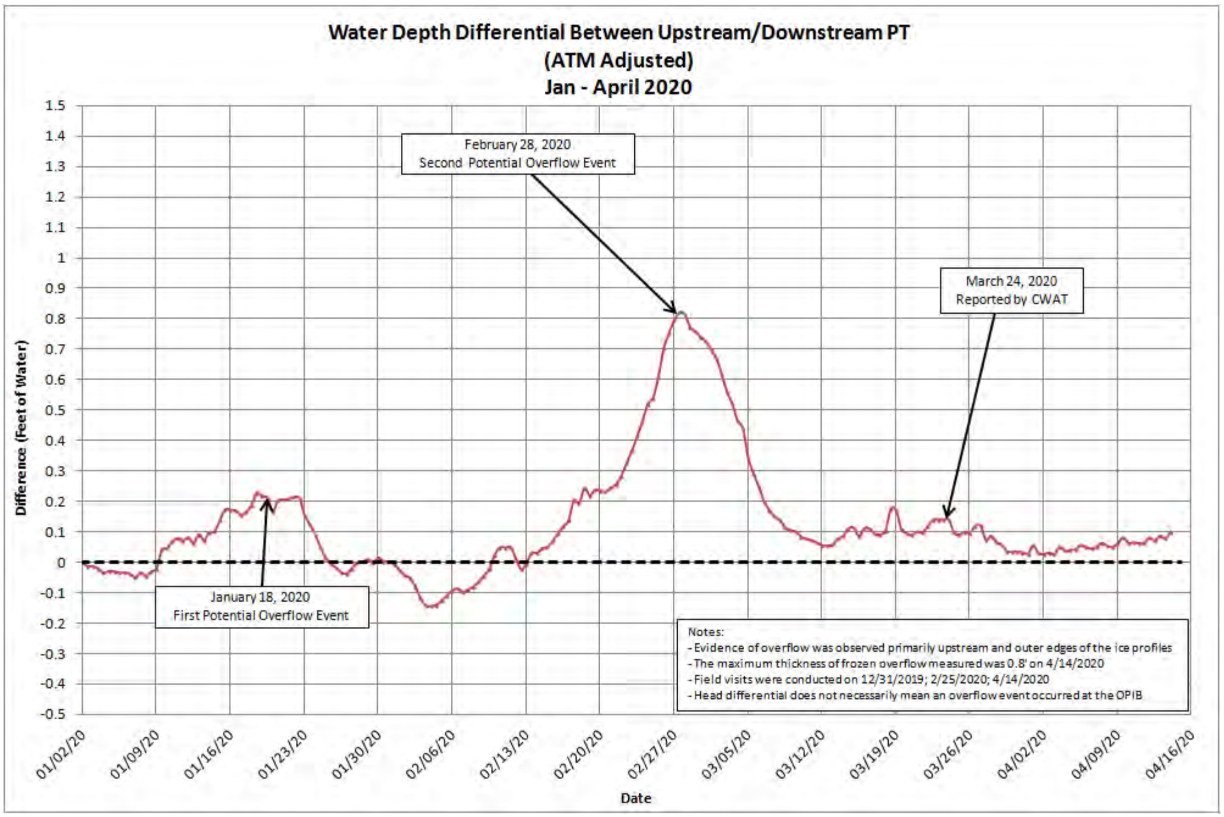


FIGURE 4.6: WATER DEPTH DIFFERENTIAL BETWEEN UPSTREAM AND DOWNSTREAM PTS

Once the potential February overflow event ended the water temperatures at the US and DS PTs returned to their typical differentials. It is likely that flow resumed under the ice. The overflow likely flowed toward the banks of the river and froze.

Evidence of this overflow event was observed during the April 14 field visit. While conducting the ice profile there was up to 0.8 ft of frozen overflow observed at the eastern and western edges of the profile. Frozen overflow is differentiated from natural ice in that it is opaque and rests atop natural ice that is clear. Frozen overflow was not observed between STA 3+00 and 6+00 of the ice profile.

An overflow event was observed and reported by CWAT users around March 24th. The CWAT snow bridge was located about 100 ft upstream from the ice profile centerline. The report stated that the snow bridge was flooded and deemed unsafe. This event was likely intensified by the warming air temperatures and the increased intensity of solar radiation. The overflow from this event was frozen by the time of the April 14 field visit.

4.9 Ocean Point Weather Station Installation

A weather station was installed on April 14, 2020 2.4 miles north of the proposed Upstream Site for the OPIB (N70.08730 W151.35590). Table 4.6 presents a summary of the parameters recorded by the Ocean Point weather station.

TABLE 4.6: OCEAN POINT WEATHER STATION INSTRUMENTATION

Wind Speed and Direction	Snow Depth
Solar Radiation	Atmospheric Pressure
Air Temperature	Ground Temperatures
Relative Humidity	*Soil Moisture Content**

**Planned installation for fall 2020*

The weather station summary report is included in Appendix D.

5 Ocean Point Ice Bridge Design

The OPIB design and construction quantities have been updated based on the data and observations from the winter of 2019–2020 investigation (Section 4). Further revisions will be issued as more information is obtained. The revised ice bridge design (Appendix E) includes new design features based on recent discoveries (overflow, ice profiles, etc.). The subsections below provide explanations for the updates and revisions of the OPIB design.

5.1 Overflow Monitoring

Any overflow, if it occurs, should be monitored beginning in December during the first year of heavy haul use (winter 2024-2025). Monitoring stations with remote capabilities would be installed prior to construction of the ice bridge and removed before breakup. Overflow monitoring will assist with mitigation management outlined in Section 5.2.

5.2 Overflow Mitigation Management

Overflow mitigation should be included in the OPIB design. Overflow events may impact the construction and use of the OPIB (Section 4.8).

Overflow mitigation actions can be classified into two broad categories; passive and active. Both mitigation requirements should be incorporated into any OPIB design.

5.2.1 Passive Overflow Mitigation

Passive overflow mitigation are preventative actions put into place to prevent overflow at an ice structure. Passive mitigation should not require constant attention and maintenance to remain effective; although routine maintenance may be required. Passive mitigation includes berms, passageways, and other diversion structures. Passive mitigation designs may require some cleanup and recovery depending on the impacts and magnitude of an overflow event.

5.2.2 Active Overflow Mitigation

Active overflow mitigation operates in combination with passive mitigation. Active overflow mitigation are preventative actions established if the passive mitigation systems become insufficient. Due to the likelihood of overflow events, active overflow mitigation will be necessary for the heavy haul ice bridge over the Colville at Ocean Point.

Two available forms of active mitigation are high-volumetric flow pumps and designated rapid response heavy equipment. The pumps would be staged at the site to move water from the upstream side of the ice structures to the downstream side if passive mitigation becomes insufficient. Rapid response heavy equipment would be used to clear new pathways for water to flow away from the ice structures. Furthermore, the heavy equipment would be utilized to repair, maintain, and restore passive mitigation structures.

All active mitigation measures must be readily available to assist with overflow management. A comprehensive 'overflow management plan' should be developed as more data is collected in the vicinity of the OPIB.

5.3 Ramp Designs

The revised ramp designs of the proposed OPIB have been modified to conform to the maximum design specification of 5%. The 3% grade of the central ramps will ensure that the ramps have overall lengths greater than that of the maximum specified SPMT length (220 ft) to avoid high-centering.

The ramps are 65 ft wide based on the maximum ice fill thickness. The east ramp width may increase depending upon the topographic survey of the east bank.

5.4 Ice Bridge Construction Quantities

Table 5.1 presents a summary of the ice material quantities required to construct the OPIB based on the most recent information. The average natural floating ice thickness is expected to be between 4 and 5 ft by February.

TABLE 5.1: SUMMARY OF MATERIAL QUANTITIES

Ice Structure	Ice Quantity (yd^3)
West Ramp	7,800
Central Ramps and Elevated Ice Bridge	16,100
East Ramp	11,200
Areas Between Elevated Ice Bridge and East/West Ramps	1,400
***TOTAL =**	**36,500**

**The water equivalent quantity is 6.6 million gallons*

Most of the construction material is required to build the ice ramps and the elevated ice bridge over the span of free water. In addition to supporting the loads, the elevated ice bridge performs other key functions, which include:

1. Elevate the driving surface away from the overflow zone.
2. Increase the maximum allowable width of the free water under the bridge by increasing the pressure area at the base of the ice sheet.
3. Reduce the amount of snow that accumulates on the driving surfaces.

5.5 Emergency Bypass / Access Road And Ramps

An emergency bypass/access roads and ramps should be constructed on the downstream side of the elevated ice bridge and ramps. These roads will provide access around the SPMTs while they are navigating ice structures when crossing the OPIB. Specific design details of the emergency bypass/access roads will be provided later.

6 Conclusions & Recommendations

Conclusions and recommendations are subject to change as new information becomes available.

6.1 Conclusions

1. The proposed Upstream Site OPIB will be a non-grounded ice bridge with a capacity that is suitable for the 3,200 ton module loaded onto a SPMT with a 4,200-ton allowable gross weight.
2. There is a high probability that at least one overflow event will occur in the vicinity of Ocean Point each winter.
3. More information regarding water discharge and water levels in the vicinity of the Ocean Point between the months of February and mid-April is needed. This is the timeframe of construction and heavy haul use.

6.2 Recommendations

1. MBI should conduct weekly discharge measurements at the OPIB from mid-February to mid-April during the winter of 2020–2021.
2. Ice profiles at the OPIB should be performed on a monthly basis during the winter of 2020-2021, with weekly ice profiles between mid-February to mid-April.
3. Delay any geotechnical investigation until 2023-2024; this task may not be necessary.
4. Install remote monitoring sites at the OPIB to collect water level, air temperature, and air pressure throughout the winter of 2020-2021.
5. Perform a topographic survey from the top of bank to the top of bank along the heavy haul ice road alignment at the Upstream Site during the winter of 2020-2021.

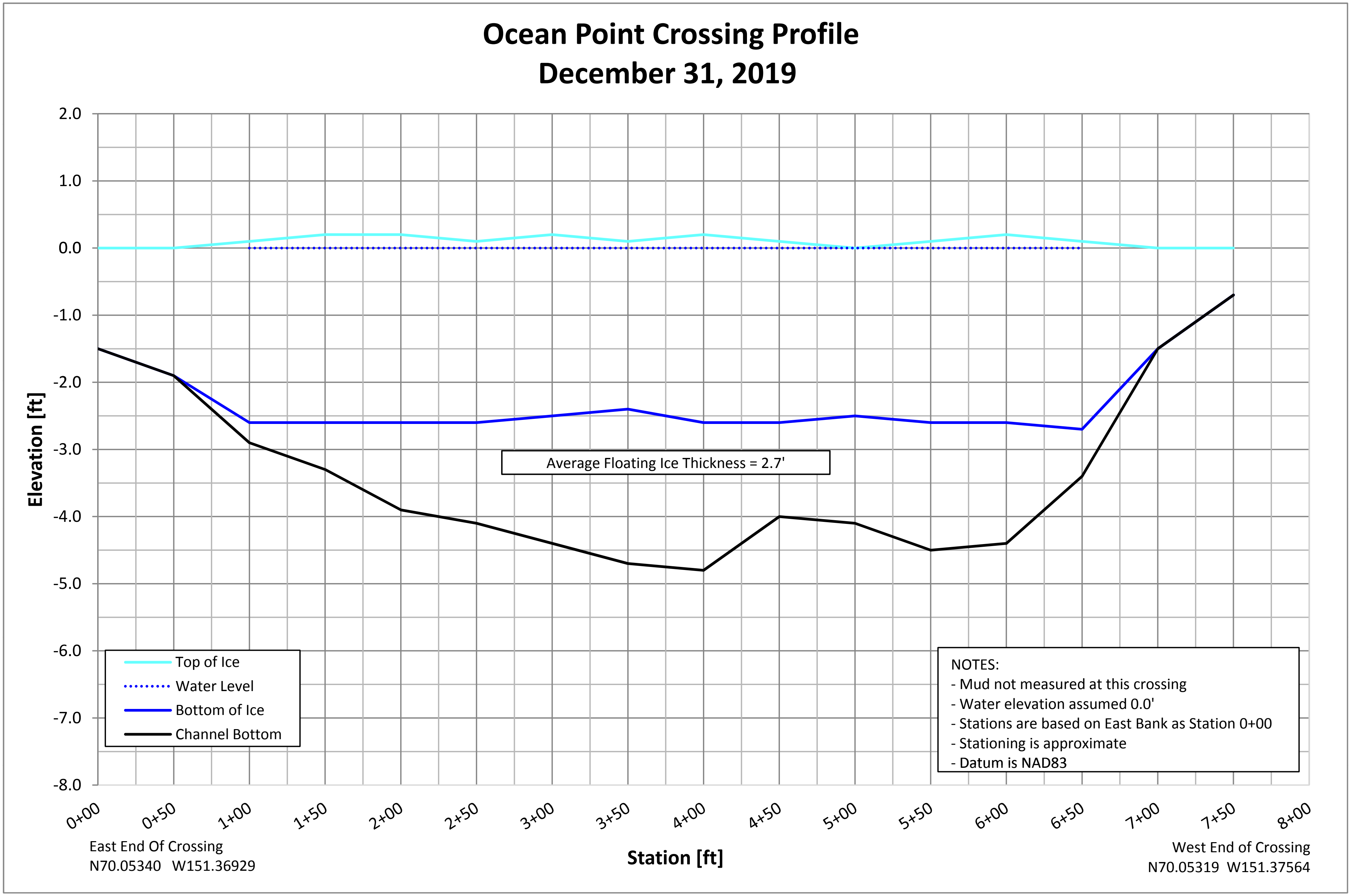
Appendix A
- WILLOW OPTIMIZATION OPTION 3

Willow Optimization
Willow Alternative B Optimization
Road
Pad
Willow Option 3
Ice Road
Willow Alternative B Draft EIS
Road
Mine Site
Pad
GMT2/MT7 Permitted
Pipeline
Pad
Road
Infrastructure
Pipeline
Pad
Road
Boundaries
NPR-A (BLM)
Map Extent
NPR-A
N
0
5
Miles
ConocoPhillips
Alaska, Inc.
September 26, 2019
Document Name: Willow_Optimization_Option3.mxd
Beaufort Sea
Harrison Bay
Kogru River
Oliktok Dock
Oliktok 12 Acre Staging Pad
CD3
CD2
CD1
CD5
CD4
CPF2
GMT1/ MT6
GMT2/ MT7
Nuiqsut
BT4
BT2
BT1
WCF
BT3
BT5
Ocean Point
DS2P
Kalikpik River
Fish Creek Iqalliqpik
Fish Creek Uvlutuuq
Judy Creek Kayyaaq
Judy Creek Iqalliqpik
Tinmiaqsiugvik River
Ublutuoch
Nigliq Channel
Colville River Kuukpik
National Petroleum Reserve – Alaska

Appendix B
- ICE PROFILES

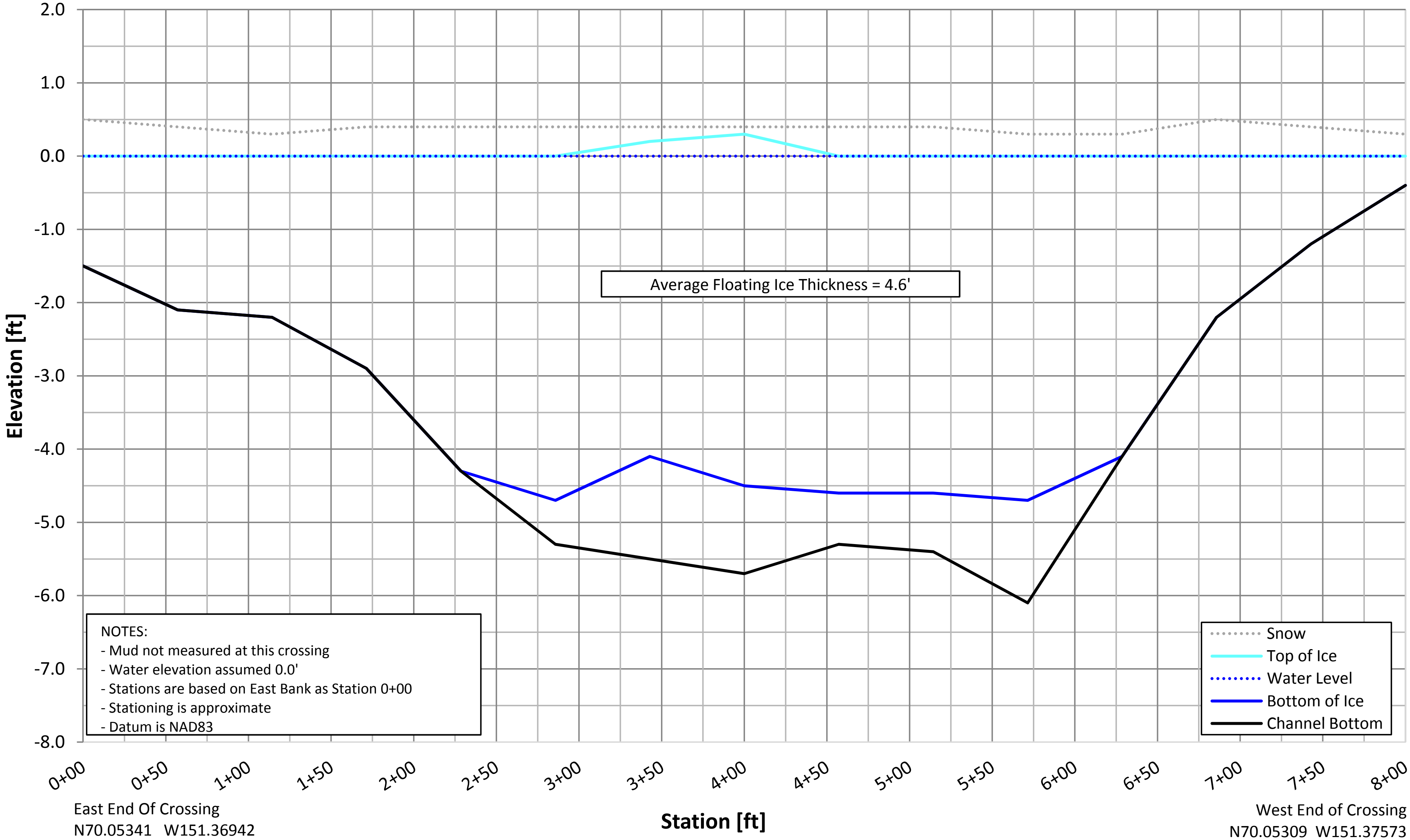
Submitted By: M. Hendee
Conducted By: M. Hendee

ICE DESIGN & CONSULT



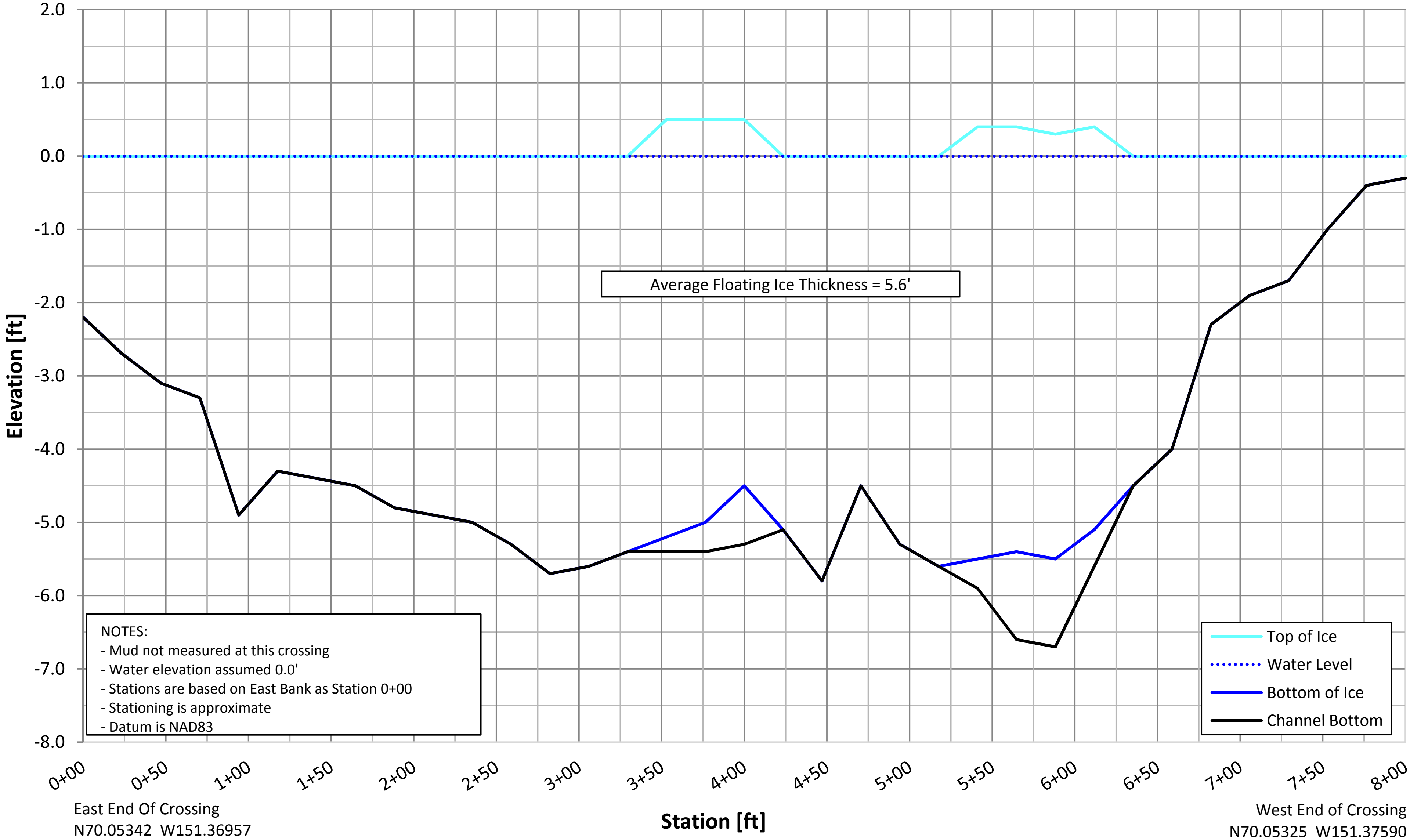
Submitted By: E. Keib
Conducted By: E. Keib

Ocean Point Crossing Profile
February 25, 2020



Submitted By: E. Keib
Conducted By: E. Keib

Ocean Point Crossing Profile (Looking Downstream)
April 14, 2020



Appendix C
- Michael Baker International
Willow Ice Road – Ocean Point
Water Resources Field Investigation

2019-2020

Summary Report

Willow Ice Road – Ocean Point Water Resources Field Investigation

PREPARED BY:
MICHAEL BAKER INTERNATIONAL
3900 C STREET SUITE 900
ANCHORAGE, AK 99503

PREPARED FOR:
ConocoPhillips Alaska

MSA Contract No. 2969377

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FIGURES

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CHARTS

PHOTOS

ACRONYMS & ABBREVIATIONS

% sat	percent saturation
°C	degrees Celsius
ADCP	acoustic doppler current profiler
cfs	cubic feet per second
COPA	ConocoPhillips Alaska, Inc.
DO	dissolved oxygen
ft	feet
ft/s	feet per second
ICE	ICE Design & Consult
µS/cm	microsiemens per centimeter
mg/L	milligrams per liter
Michael Baker	Michael Baker International
NAVD88	North American vertical datum of 1988
OPUS	Online Positioning User Service
Ocean Point Downstream	the North transect, Transect #6, the east crossing, the downstream crossing, Ocean Point North
Ocean Point Upstream	the South transect, Transect #1, the Rolligon crossing, the west crossing, the upstream crossing, Ocean Point South
Peak	Peak Oilfield Services Company
ppt	parts per thousand
Q	discharge
RM	river mile
UMIAQ	UMIAQ, LLC
USGS	United States Geological Survey
v	velocity
Willow	Willow Project
WSE	water surface elevation

1.0 INTRODUCTION

Michael Baker International (Michael Baker) collected water resources data for Conoco Phillips Alaska, Inc. (COPA) in support of the Willow Project (Willow). Two proposed crossings of the Colville River were investigated at Ocean Point. Data was collected during three field events occurring between Fall 2019 and Spring 2020. This report summarizes the methods and results of that effort.

ICE Design & Consult (ICE), UMIAQ, LLC (UMIAQ), Soloy Helicopters, Peak Oilfield Services Company (Peak) and CPAI Alpine Helicopter and Field Environmental Coordinators provided support during the field program and contributed to a safe and productive field season.

2.0 LOCATION

Two transects near Ocean Point were investigated: Ocean Point Downstream (Downstream) and Ocean Point Upstream (Upstream, Figure 1). These are two among six transects investigated during the 2018-2019 ice road season. The Downstream and Upstream transects were selected based on shallow water depths relative to the other transects investigated. Ocean Point Downstream is approximately 6.5 miles direct or 8.3 river miles (RM) downstream of Ocean Point Upstream. There is one minor tributary that enters the Colville River from the south between the two locations. This tributary is a meandering beaded stream that drains multiple lakes. There is also a tributary that enters the Colville River from the northwest at the Downstream transect. This tributary is a paleochannel which drains a series of lakes that formed in abandoned meanders after the reach of river between the Downstream and Upstream transects migrated south. This area is inundated during spring breakup-induced flooding.

Ocean Point Downstream (Figure 2, also historically referred to as “Transect #6”, the “east crossing”, the “downstream crossing”, or “Ocean Point North”) is the alternate proposed crossing location. Ocean Point Upstream (Figure 3, also historically referred to as “Transect #1”, the “Rolligon crossing”, the “west crossing”, the “upstream crossing”, “Ocean Point South”) is an historic crossing location. It was the location of a snow road during the 2018-2019 season and is the preferred proposed crossing location.

Table 1 provides a summary of dates and data collected at the locations investigated. Table 2 provides a summary of measurements collected.

Table 1: Field Events

Data Collection	OCEAN POINT DOWNSTREAM	9/5/2019	12/31/2019	2/25/2020	4/14/2020	OCEAN POINT UPSTREAM	9/5/2019	12/31/2019	2/25/2020	4/14/2020
Discharge		✓	-[1]	-[1]	-[1]		✓	✓	✓	-[2]
Water Quality		✓	-[1]	-[1]	-[1]		✓	✓	✓	-[2]
Water Surface Elevation Survey		✓	-[1]	-[1]	-[1]		✓		✓	-[2]
Bank Active Layer Investigation		✓	-[1]	-[1]	-[1]		✓			-[2]

Notes:
1. Crossing characterized as similar to Ocean Point Upstream so winter investigations were not performed.
2. Planned field event was cancelled.

Table 2: Data Collected

	Data Collected	Units	Units Abbreviations
Discharge	water depth	feet	ft
	water depth, under ice[1]	feet	ft
	ice thickness[1]	feet	ft
	snow depth[1]	feet	ft
	freeboard[1]	feet	ft
	flow width	feet	ft
	flow cross-sectional area	square feet	sqft
	velocity	feet per second	ft/s
	discharge	cubic feet per second	cfs
Water Quality	temperature	degrees Celsius	°C
	conductivity	microSiemens per centimeter	µS/cm
	specific conductance	microSiemens per centimeter	µS/cm
	salinity	parts per thousand	ppt
	dissolved oxygen	percent saturation	% sat
	dissolved oxygen	milligrams per liter	mg/L
Water Surface Elevation	water surface elevation	feet North American Vertical Datum of 1988	ft NAVD88
Bank Active Layer	thawed soil depth	feet	ft

Notes:
1. Data collected only in winter

ConocoPhillips Alaska

Miles
0 1 2

Date:	5/20/2020	Scale:	1 Inch = 5,280 Feet
Drawn:	HLR	Project:	174311
Checked:	ALS	File:	OceanPointUS&DS.mxd

Transect

- - - - (yellow dashed line)

Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Michael Baker INTERNATIONAL
Michael Baker International, Inc.
3900 C. Street Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019-2020
Willow Ice Road
Ocean Point H&H
Upstream & Downstream
Transects

FIGURE 1

ConocoPhillips Alaska

Feet
0 250 500 1,000

Date:	5/20/2020	Scale:	1 Inch = 528 Feet
Drawn:	HLR	Project:	174311
Checked:	ALS	File:	OceanPointDS.mxd

Transect

Measured Flow Width

2/25/2020 - not measured

12/31/2019 - not measured

9/5/2019

Active Layer

estimated

Photo

Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C. Street Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019-2020
Willow Ice Road
Ocean Point H&H
Downstream Transect

FIGURE 2

ConocoPhillips Alaska

Feet
0 250 500 1,000

Date:	5/20/2020	Scale:	1 Inch = 528 Feet
Drawn:	HLR	Project:	174311
Checked:	ALS	File:	OceanPointUS.mxd

Transect

Active Layer
estimated

Photo

Measured Flow Width
2/25/2020
12/31/2019
9/5/2019

Imagery Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Michael Baker
INTERNATIONAL
Michael Baker International, Inc.
3900 C. Street Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019-2020
Willow Ice Road
Ocean Point H&H
Upstream Transect

FIGURE 3

3.0 METHODS

Field sampling methods were based on United States Geological Survey (USGS 2006a and 2006b) methods. Safety precautions were followed using the North Slope Water Resources 2019 Health, Safety, and Environment Plan (Michael Baker 2019a) and the 2019-2020 Winter Hydrology Programs – Job Safety Analysis (Michael Baker 2019b).

3.1 OPEN WATER – FALL 2019

Open water tasks were completed over the course of multiple days during one field event and were timed to occur late in the fall season, prior to freeze up. Sites were accessed via helicopter and inflatable rafts with outboard motors. The effort was conducted by a three-person field crew. The data collected includes cross-sectional river bottom profiles, discharge, velocity, water depth, water surface elevation, site conditions, and in-situ water quality. Soil active layer depths were also investigated for both banks of each crossing.

Discharge, velocity, and cross-sectional river bottom profiles were measured using a RiverRay acoustic doppler current profiler (ADCP) (Photo 3.1). The ADCP was mounted in a trimaran. The trimaran was tethered via boom to the side of a 13-ft Achilles inflatable raft powered by outboard motor (Photo 3.2).

Water surface elevation (WSE) at the time of discharge and water quality measurements were determined using temporary benchmarks installed by UMIAQ surveyors and Michael Baker. UMIAQ benchmarks are aluminum cap survey control referenced to OPUS NAVD88 elevation. Michael Baker benchmarks are aluminum cap survey control tied by level loop technique to the UMIAQ control.

In-situ water quality parameters including temperature, conductivity (C), and salinity were recorded using the YSI ProPlus meter; dissolved oxygen (DO) was measured using the YSI ProODO meter. Specific conductance (SC) referenced to 25 degrees Celsius was calculated based on temperature, conductivity, and a conversion coefficient of 0.0196 based on empirical data. Measurements were collected at the deepest portion of each cross-section; two depths were investigated at each to confirm that parameters were consistent throughout the water column.

Photo 3.1: Discharge measurement at Ocean Point Upstream Transect; 9/5/19

Photo 3.2: In-situ water quality sampling at Ocean Point Downstream Transect; 9/5/19

Photo 3.3: Investigating soil active layer at Ocean Point Downstream Transect; right/east bank; 9/14/19

The soil active layer was investigated to characterize the depth of permafrost below the surface in the transition zones adjacent to the river. This investigation was performed on the right and left banks of each transect, perpendicular to the channel. Probing was performed using a 5-foot long T-bar probe driven by hand (Photo 3.3). Spacing was approximately 5-foot increments and at major grade breaks, between water's edge and the top of the riverbank. Results were provided directly to Golder as a separate deliverable and included in this report along with discharge and water quality in Attachment A.

3.2 ICE COVER – WINTER 2019 – 2020

Three field events were planned to investigate the trend in flow quantity and water quality over the course of the ice-cover season. Freeze-up typically initiates in mid-October and breakup typically initiates in mid-May. Ice cover field events were one day apiece. The first was performed early in the season, the second in the middle of the season, and a third was planned at the end of the season. The third field event was cancelled due to circumstances related to COVID-19 and changing project priorities. Data was collected at one transect, Ocean Point Upstream. This included under-ice cross-sectional river bottom profiles, discharge, velocity, water depth, ice thickness, water surface elevation, site conditions related to overflow, and in-situ water quality.

A one-person Michael Baker field crew conducted both events, supported by an ICE engineer who performed crossing profiling. UMIAQ and Peak provided transportation to the sampling locations and general field support. The sites were accessed by Hägglund and Rolligon.

Water measurements were facilitated by mechanically drilling through the river surface ice cover. Thermal drill probing was performed by ICE to identify the extents of under-ice water bounded at the left and right by ice grounded against the channel bed. Investigation of soils or groundwater within the channel bed was not performed. Discharge was determined using USGS mid-section techniques. Velocity was measured using a handheld Hach flow meter (Photo 3.4) and a handheld Sontek flow meter. These were attached to a fixed rod and lowered to 0.6 the water depth below the ice. In-situ water quality parameters investigated were the same as those in the fall. Measurements were collected at multiple depths from one location in the deepest portion of the cross-section.

Photo 3.4: Attaching Hach flow meter to fixed rod at Ocean Point Upstream; 2/25/20

Previously submitted ice cover season field data is provided in Attachment C and Attachment D.

4.0 RESULTS AND CONCLUSIONS

A summary of Colville River Ocean Point water resources information is provided below. Previously submitted trip reports and field data are provided in Attachment B through Attachment D.

4.1 TRANSECT LOCATIONS

The Ocean Point Downstream transect is located where a tributary enters the Colville River on the left/west bank. It is unknown what, if any, flow is contributed from this tributary during the ice-cover season. Bankfull width at this location is approximately 2,500 feet based on aerial imagery. This reach of the Colville River is relatively straight. Bars are exposed during low water. The low water channel lies approximately central to the cross section and the thalweg lies toward the left/west portion of the low water channel. Both banks are steep. The right/east bank is steeper than the left/west with sloughing and block failure; evidence of both thermal and mechanical erosion. The tops of both banks and overbanks are vegetated. Vegetation is present on the upper left/west bank below the top. Vegetation is present on the right/east bank.

The Ocean Point Upstream transect is located where the Colville River is conveyed within a single channel with a bankfull width of approximately 3,200 feet based on aerial imagery. The Colville River transitions from relatively straight to a wide bend at this location. The left/east bank is on the cut-bank inside of the bend and the right/west bank is on the point-bar outside of the bend. Bars are exposed during low water. The low water channel is located closer to the left/east bank and the thalweg lies toward the in the right/west portion of the low water channel. Both banks are steep. The left/east bank is steeper than the right/west bank. The tops of both banks and overbanks are vegetated. Vegetation is present on the upper left/east bank below the top. Vegetation is present on the right/west bank.

No springs were observed at the bank of either transect during the open water field event. No overflow, aufeis, or evidence of any other notable hydraulic occurrence was observed at Ocean Point Upstream during the ice-cover field events. Open water data collected at Ocean Point Downstream were compared against those collected at Ocean Point Upstream. With respect to discharge quantity and water quality parameters, values were similar between the two locations.

Photo 4.1: Field investigation at Ocean Point Upstream, looking toward the left/east bank; 2/25/20

Ice-cover investigation was performed only at Ocean Point Upstream (Photo 4.1). This was determined considering: the comparison of open water discharge quantity and water quality values, the better suitability of the Upstream transect to the Downstream transect based on the potential for undesirable geomorphological and hydraulic influences (i.e. actively eroding and sloughing bank and a tributary at Ocean Point Downstream), the remoteness of Ocean Point relative to facilities and the challenges of winter accessibility, the time available for investigation, and the historical use of the upstream transect.

4.2 BANK ACTIVE LAYER

The active layer was investigated in September, at the end of the thawing season. Elevations were not surveyed. Depths of thawed soil, as measured by probing to refusal, ranged from 1.75 feet to greater than 5 feet. Thaw depths were shallower at the tops of banks and deeper approaching the channel. A summary of thaw depths is provided in Table 3. Approximate locations probed are provided in Figure 2 and Figure 3.

Table 3: Colville River Ocean Point Bank Thaw Depth Summary

Bank Thaw Depth (ft)	Mean	Median
Ocean Point Downstream		
Left/West Bank	4.4	5.0
Right/East Bank	2.2	1.8
Ocean Point Upstream		
Left/West Bank	4.1	4.3
Right/East Bank	4.0	3.6

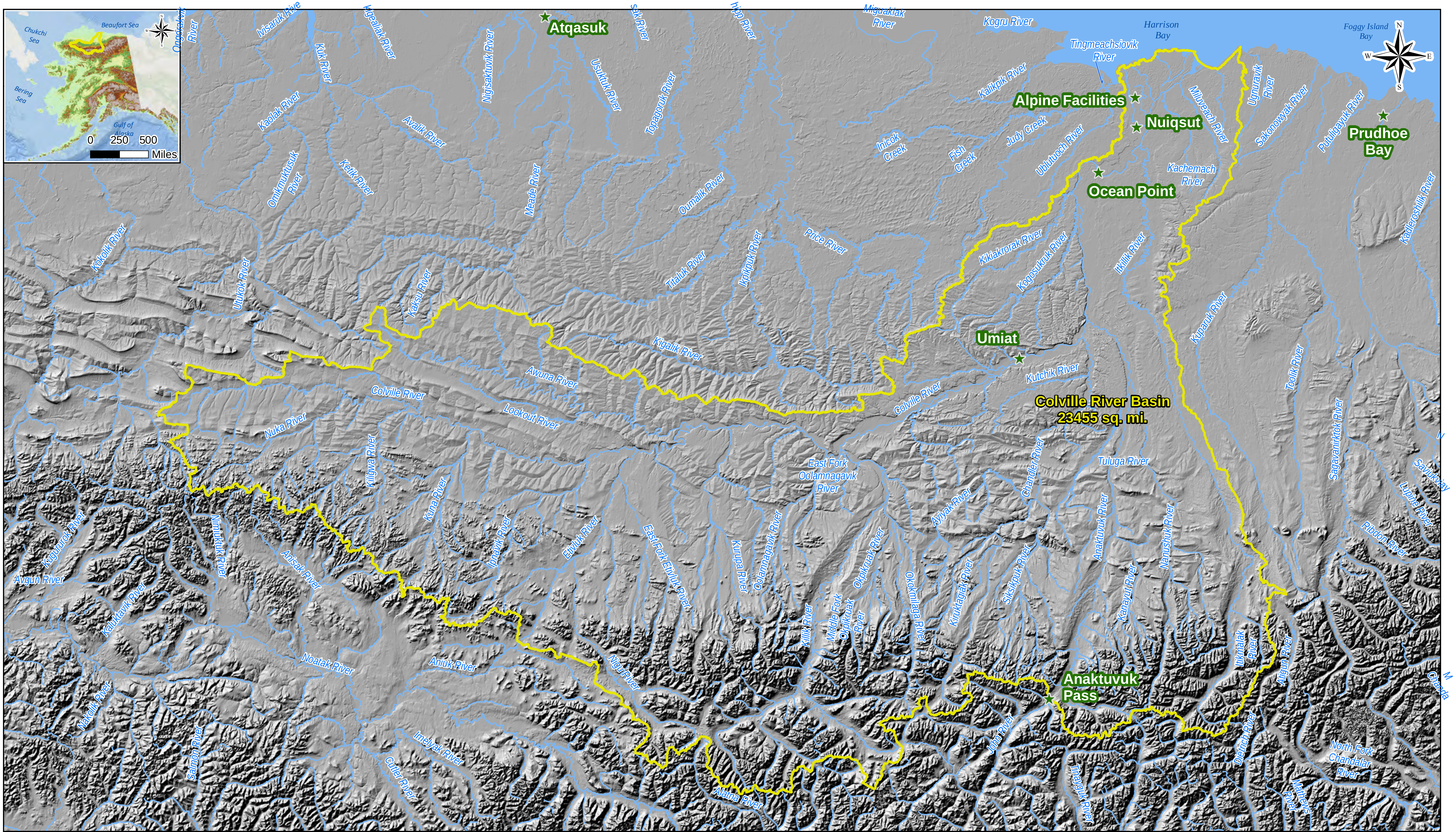
Notes:
Thaw depths of 5 feet indicated frozen ground was not encountered. These were assumed to be 5 feet for calculated averages though actual values are greater.

4.3 PHYSICAL WATER MEASUREMENTS

Colville River open water discharge measured at the Ocean Point Downstream transect was within 200 cfs, or 0.7% difference, of the discharge measured at the Ocean Point Upstream transect. The errors associated with each discharge measurement transect (two at the Downstream transect and four at the Upstream transect) were less than +/-1.5%. The total average error associated with discharge measured at each location was 0.0%, with a standard deviation of 0.3% at Ocean Point Downstream and 1.1% at Ocean Point Upstream.

Measuring discharge under ice cover is subject to limitations not applicable to open water measurements. Unlike open water where it is obvious where the edge of water exists, it is not possible to see the extents of the cross-sectional area of flow under the ice. Further, it is not possible to profile the entire cross- section. It is assumed that the cross-sectional area is relatively uniform upstream of, downstream of, and between measurement stations. However, the potential exists for “unseen” grounded or relatively shallow areas which would influence measured velocity direction and magnitude if occurring upstream or downstream of a measurement station. Grounded areas between measurement stations would reduce the estimated cross-sectional area of flow and resulting discharge. Colville River discharge measured at Ocean Point Upstream during the ice-cover season was significantly less than discharge measured during the open water season. Discharge decreased as the ice-cover season progressed.

This decreasing trend is also apparent in the Colville River at Umiat where a continuous gage station is operated by the USGS (USGS 2020). This location is approximately 70 RM upstream of Ocean Point (Figure 4). The drainage area between is expansive, including multiple large tributaries as well as an unknown quantity of groundwater springs. Despite this, general comparison regarding seasonal discharge trends can be made.



ConocoPhillips Alaska

Miles
0 25

Date:	5/14/2020	Scale:	1 Inch = 21.71 Miles
Drawn:	JEG	Project:	174311
Checked:	HLR	File:	ColvilleDrainage.mxd

Community
Stream
Colville River Drainage Basin

Michael Baker INTERNATIONAL

Michael Baker International, Inc.
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019-2020
Willow Ice Road
Ocean Point H&H
Colville River Basin

FIGURE 4

The USGS Colville River gage at Umiat (USGS 15875000 COLVILLE R AT UMIAT AK) was established in 1953. Hydrologic stage and discharge data are available from this site. Values provided are historical and current; they are alternatively measured, instantaneous, time-averaged, and statistical. Direct measurements validate calculated results. River hydraulics and environmental factors differ between the open water and ice-cover seasons, which necessitates different approaches to data collection and calculation during each.

During the open water season, instantaneous stage at Umiat is measured and provided. Instantaneous discharge is determined based on stage using a stage-discharge rating curve. The rating curve was developed by plotting measured stage events against measured concurrent discharge events. The accuracy of the rating curve is directly proportional to the accuracy and quantity of the measurements used to plot it. Numerous factors affect discharge measurements including temporal site conditions, equipment and technique used, and experience of the hydrologist (USGS 2010). USGS evaluates discharge measurements qualitatively by the ratings "excellent" (within 2%), "good" (within 5%), "fair" (within 8%), and "poor" (greater than 8%). Since 2002, 153 direct discharge measurements have been made by the USGS at the Umiat gage site. Of these, 102 have occurred during the open water season. Of those, 24% were rated "good", 61% were rated "fair", and 18% were rated "poor". None were rated "excellent" and one was not rated. Open water time-averaged and statistical values, i.e. daily means, mean of daily means, peaks, etc. for stage and discharge are determined based on instantaneous and measured values.

Instantaneous, time-averaged, and statistical stage values at Umiat are not provided during the ice-cover season. Time-averaged and statistical discharge values are provided, however. Measured stage and discharge values are also provided. There have been 37 direct measurements performed under the influence of surface ice cover. Of those, 5% were rated "good", 16% were rated "fair", and 76% were rated "poor". None were rated "excellent" and one was not rated. Daily mean discharge is determined not based on stage, but instead on storage depletion modeling based on time and using a low-flow value immediately prior to freeze-up as the controlling factor. Umiat daily mean discharges for the 2019-2020 ice-cover season have yet to be validated and made available. The mean of daily mean values, however, are available for comparison to measurements collected at Ocean Point. The period of record informing those is between October 1, 2001 and September 30, 2019.

Colville River discharges measured at Ocean Point are provided in Table 4. Colville River discharges at Umiat are provided for comparison.

Table 4: Colville River Discharge

Date	Ocean Point Downstream measured discharge (cfs)	Ocean Point Downstream rating	Ocean Point Upstream measured discharge (cfs)	Ocean Point Upstream rating	Umiat[1] mean discharge (cfs)	Percent difference[2] %
9/5/2019	28,900	fair	29,000	good	19,900[3]	46%
12/31/2019	-	-	135	poor	41[4]	229%
2/25/2020	-	-	9	fair	6.2[4]	45%
4/14/2020	-	-	-	-	2.9[4]	-

Notes:

1. USGS Gage 15875000 COLVILLE R AT UMIAT AK
2. Between Colville River Umiat and Ocean Point Upstream
3. Daily mean discharge record; mean of daily mean discharge is 20,100 cfs
4. No daily mean discharge record yet available for this date; value is mean of daily mean between 10/01/2001 and 9/30/2020

The lowest annual mean of daily mean discharges for the Colville River at Umiat is 2.9 cfs. This occurs between April 13 and April 21. Discharge is similarly low during the month of April and relatively low throughout the winter season. Discharge increases by orders of magnitude as breakup processes initiate in mid-May, peaking at the end of May. These data are provided in Table 5 and graphically in Chart 1 and Chart 2.

Table 5: Mean of Daily Mean Discharge Values for Colville River at Umiat

00060, Discharge, cubic feet per second,
Mean of daily mean values for each day for water year of record in, ft3/s (Calculation Period 2001-10-01 -> 2019-09-30)

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	40	13	5.5	3	15	90,400	17,700	15,300	20,100	5,950	676	157
2	39	13	5.4	3	39	83,600	17,800	19,400	21,700	5,900	641	149
3	36	12	5.2	3	121	79,100	17,600	18,700	22,700	6,730	610	144
4	35	12	5.1	3	215	78,100	20,600	19,200	22,500	9,670	574	133
5	34	11	5	3	151	79,200	17,800	22,700	20,100	8,710	549	129
6	34	11	4.8	3	133	76,000	15,500	21,600	18,200	6,620	517	123
7	32	11	4.7	3	121	75,800	14,100	19,400	17,400	5,610	501	113
8	30	11	4.6	3	110	69,300	12,800	19,200	17,400	4,830	475	109
9	29	10	4.3	3	105	62,100	12,200	18,300	16,400	4,170	448	104
10	28	10	4.3	3	111	58,700	13,100	16,700	15,800	3,630	422	99
11	27	9.4	4.2	3	100	56,700	15,500	15,500	15,400	3,120	405	95
12	26	9.2	4.1	2.9	101	51,300	16,200	15,300	13,900	2,800	378	90
13	25	9.1	4	2.9	105	43,900	15,100	17,100	13,300	2,610	364	87
14	24	9	4	2.9	2,140	38,000	14,000	22,100	12,800	2,420	346	82
15	24	8.6	3.8	2.9	4,740	33,700	13,600	26,600	13,300	2,070	327	79
16	23	8.5	3.7	2.9	4,110	31,600	14,800	24,700	13,700	1,890	313	75
17	22	8	3.7	2.9	7,270	29,400	13,700	22,100	13,600	1,720	301	73
18	21	7.8	3.6	2.9	14,200	27,200	13,800	24,100	12,700	1,580	278	70
19	20	7.5	3.5	2.9	20,000	25,600	15,000	27,000	12,000	1,450	271	68
20	19	7.5	3.5	2.9	23,700	25,100	17,600	24,300	11,200	1,370	257	64
21	19	7.2	3.3	2.9	29,600	24,200	20,100	21,600	10,500	1,280	249	63
22	18	7	3.3	3	36,300	24,300	19,500	20,800	10,200	1,200	231	59
23	18	6.6	3.3	3	45,100	24,000	18,900	21,600	10,400	1,120	224	57
24	17	6.5	3.2	3.1	57,000	25,900	19,900	22,500	9,890	1,060	210	56
25	17	6.2	3.2	3.1	59,300	23,400	18,700	22,300	9,040	990	204	53
26	16	6.1	3.2	3.2	65,900	21,600	16,400	22,300	8,470	944	196	51
27	15	5.9	3.2	3.2	66,600	22,000	16,200	21,100	7,730	894	187	49
28	15	5.8	3.2	3.3	65,500	23,300	15,600	22,100	7,190	844	178	47
29	14	3.5	3.2	3.5	73,000	22,400	13,900	21,400	6,600	797	172	45
30	14		3.2	6.5	89,200	19,500	12,400	20,200	6,250	755	164	43
31	14		3		94,700		12,500	19,900		708		41

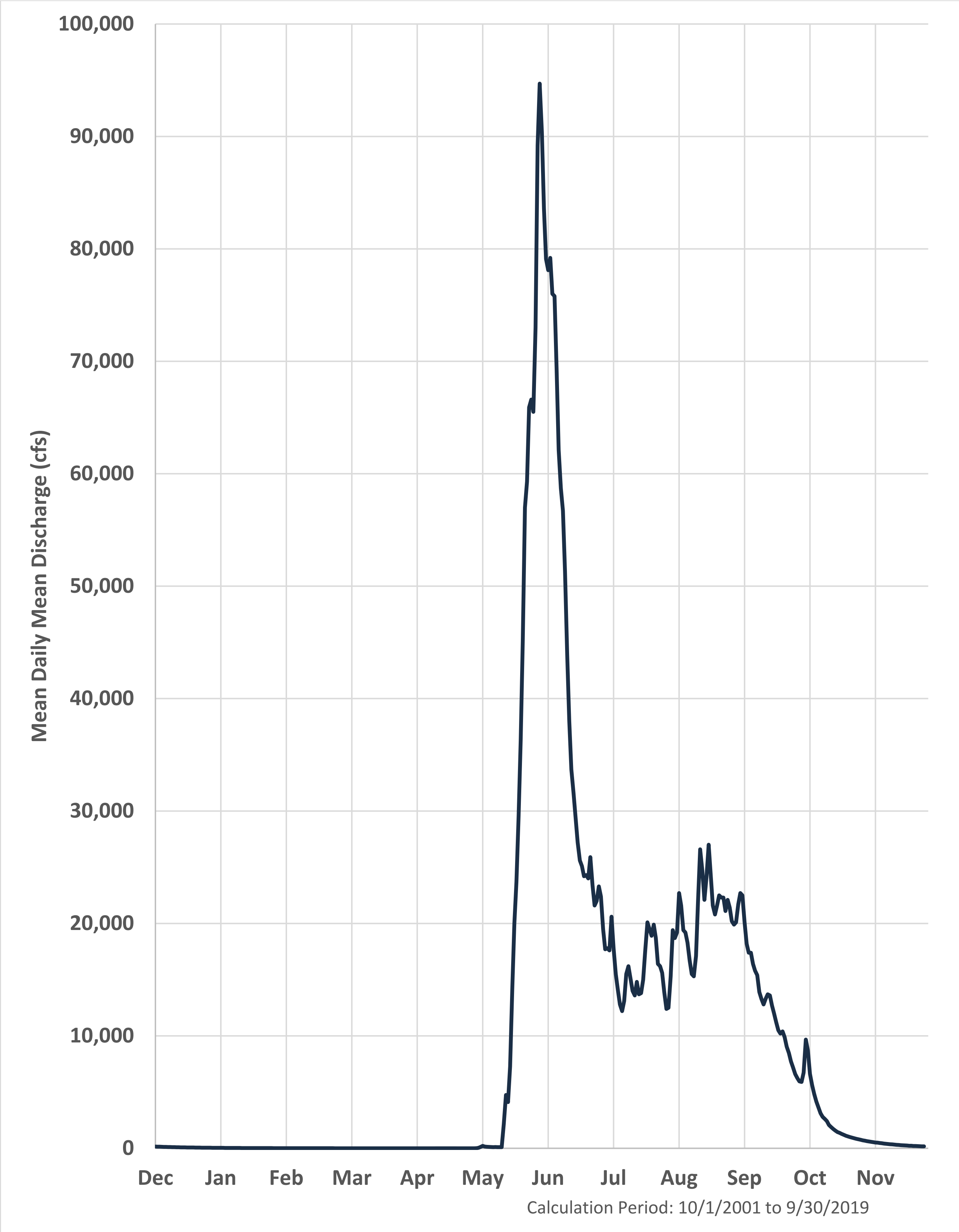


Chart 1: USGS Mean of Daily Mean Discharge Values for Colville River at Umiat - Annual

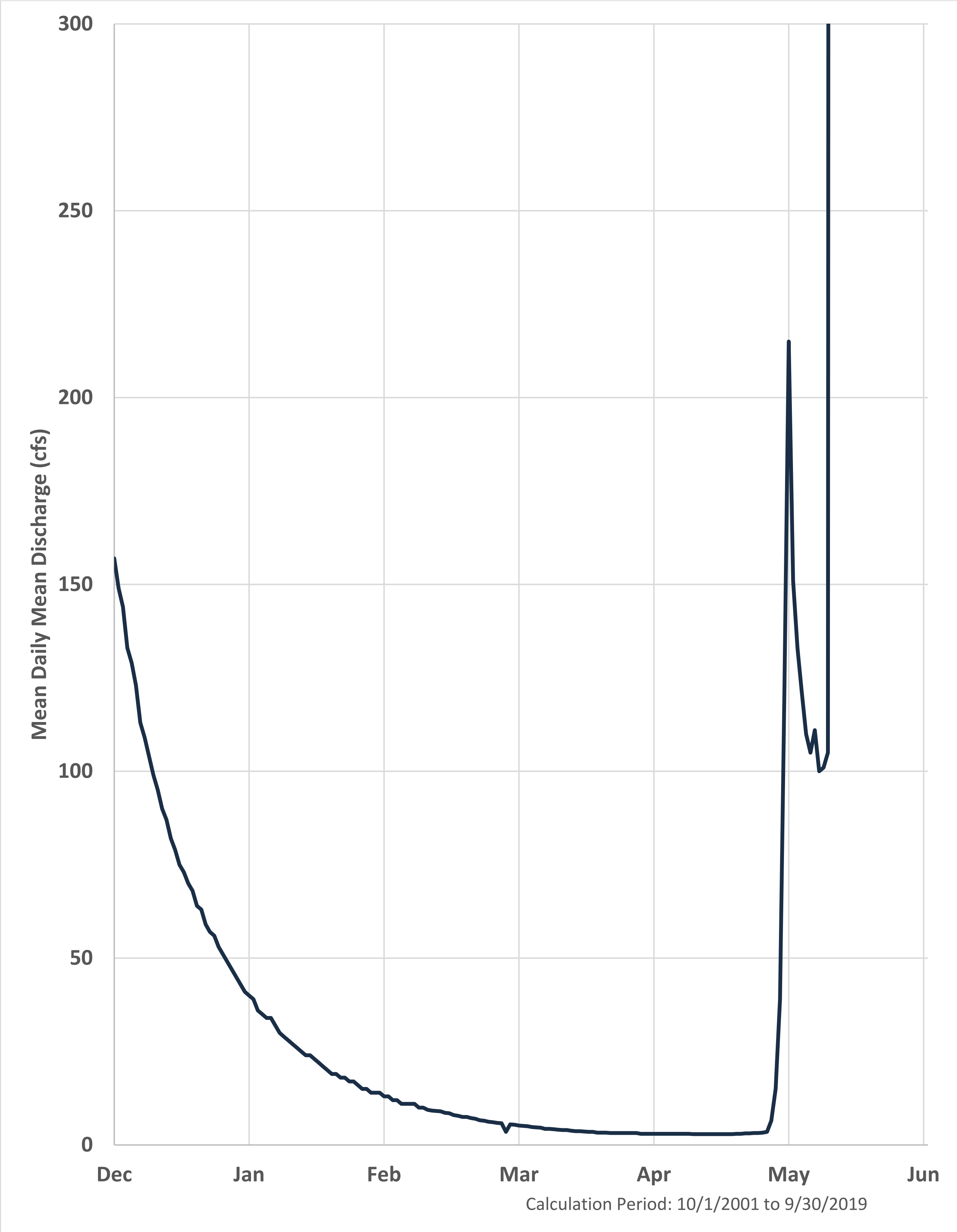


Chart 2: USGS Mean of Daily Mean Discharge Values for Colville River at Umiat – December through May

It is reasonable to assume that Colville River seasonal discharge trends at Ocean Point are similar to those at Umiat. Direct measurements at Ocean Point support this conclusion. Lacking evidence suggesting otherwise, it is further reasonable to assume that mid-April discharge at Ocean Point, had it been measured, would have been lower than the 9 cfs measured in February.

A summary of additional physical parameters measured during the project performance period are provided in Table 6 through Table 9.

Table 6: Colville River Ocean Point Discharge and Water Surface Elevation Summary

Date	Ocean Point Downstream measured discharge (cfs)	Ocean Point Downstream water surface elevation (ft NAVD88)	Ocean Point Upstream measured discharge (cfs)	Ocean Point Upstream water surface elevation (ft NAVD88)
9/5/2019	28,900	8.82	29,000	11.67
12/31/2019	-	-	135	-
2/25/2020	-	-	9	5.48

Table 7: Colville River Ocean Point Velocity Summary

Date	Ocean Point Downstream measured velocity (ft/s) maximum	Ocean Point Downstream measured velocity (ft/s) average	Ocean Point Upstream measured velocity (ft/s) maximum	Ocean Point Upstream measured velocity (ft/s) average
9/5/2019	9.1	2.8	10.5	3.0
12/31/2019	-	-	0.25	0.15
2/25/2020	-	-	0.11	0.04

Table 8: Colville River Ocean Point Water Depth Summary

Date	Ocean Point Downstream effective water depth (ft/s) maximum	Ocean Point Downstream effective water depth (ft/s) average	Ocean Point Upstream effective water depth (ft/s) maximum	Ocean Point Upstream effective water depth (ft/s) average
9/5/2019	13.2	5.5	12.0	5.0
12/31/2019	-	-	2.3	1.5
2/25/2020	-	-	1.3	0.8

Table 9: Colville River Ocean Point Flow Width Summary

Date	Ocean Point Downstream flow width (ft)	Ocean Point Upstream flow width (ft)
9/5/2019	1,803	1,270
12/31/2019	-	650
2/25/2020	-	304

4.4 Water Quality Measurements

Salinity and conductivity measurements throughout the monitoring period suggest this location is upstream of coastal influence. While values increased between the open water and ice-cover seasons, results are indicative of freshwater rather than a saline environment. Increases are likely attributable to concentration as a result of the freshwater freezing process, which readily excludes entrained materials. Temperature decreased between the open water and ice-cover season. Dissolved oxygen also decreased. This is typical of water bodies under the influence of ice cover, which prevents the introduction and mixing of atmospheric oxygen.

Table 10: Colville River Ocean Point Water Quality Summary

Date	total depth (ft)	temperature (°C)	conductivity (µS/cm)	specific conductance (µS/cm)	dissolved oxygen (mg/L)	dissolved oxygen (%)	salinity (ppt)
DOWNSTREAM							
9/5/2019	10.0	10.0	202	286	11.3	99.8	0.14
12/31/2019	-	-	-	-	-	-	-
2/25/2020	-	-	-	-	-	-	-
UPSTREAM							
9/5/2019	9.0	9.9	204	289	11.2	99.2	0.14
12/31/2019	5.0	0.1	225	440	5.7	39.5	0.20
2/25/2020	5.5	0.4	288	557	2.6	17.7	0.26

5.0 REFERENCES

Michael Baker International (Michael Baker). 2019a. North Slope Water Resources 2019 Health, Safety, and Environmental Plan. Prepared for ConocoPhillips Alaska, Inc.

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Attachment A Photos – Riverbanks

Note: Photo locations are provided in Figure 2 and Figure 3. Photo elevations are unknown.

Photo A.1: Ocean Point Downstream transect left/west bank, looking upstream/southwest toward tributary; 9/5/19

Photo A.2: Ocean Point Downstream transect right/east bank; looking upstream/southwest; 9/4/19

Photo A.3: Ocean Point Downstream transect right/east bank; looking toward channel/west; 9/4/19

Photo A.4: Ocean Point Downstream transect right/east bank; looking downstream/northeast; 9/4/19

Photo A.5: Ocean Point Upstream transect left/east bank exposed bar; looking upstream/northwest; 9/5/19

Photo A.6: Ocean Point Upstream transect left/east bank; looking downstream/southeast; 9/5/19

Photo A.7: Ocean Point Upstream transect right/west bank; looking upstream/northwest; 9/4/19

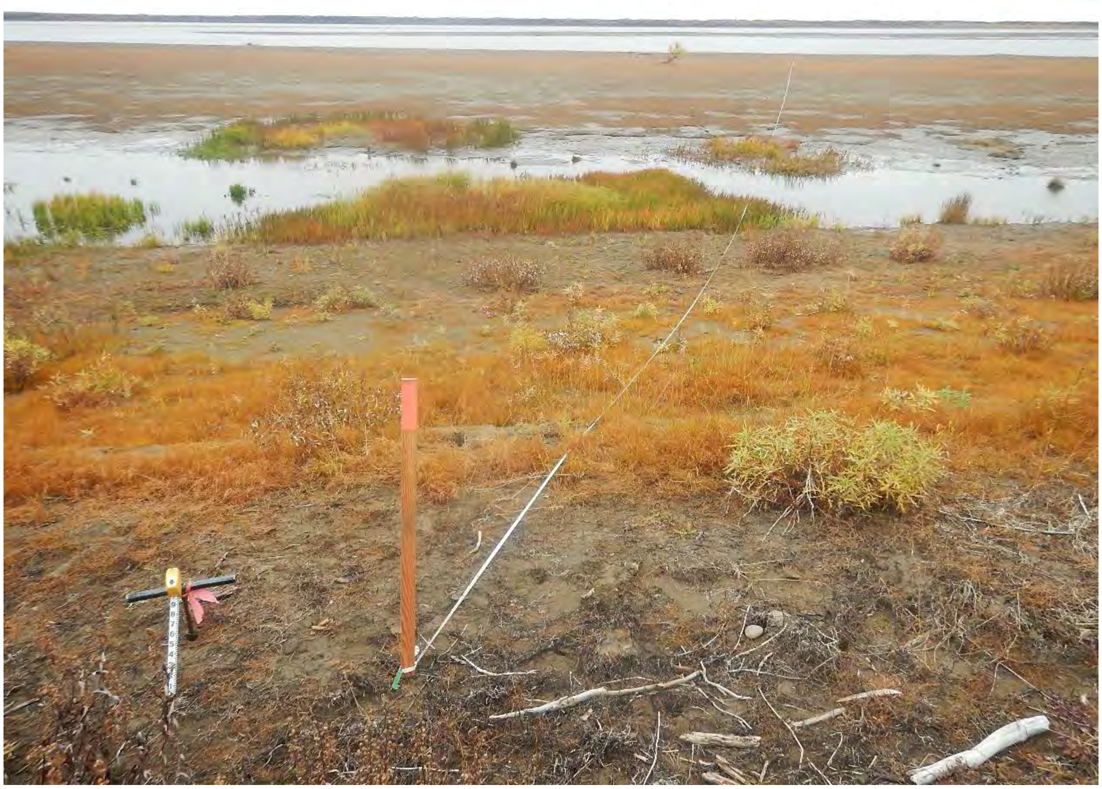

Photo A.8: Ocean Point Upstream transect right/west bank; looking toward channel/east; 9/4/19

Photo A.9: Ocean Point Upstream transect right/west bank exposed bar; looking upstream/northwest; 9/5/19

Attachment B Open Water – September 5, 2019 Field Report

2019 Willow Ice Road
Fall Field Trip Report

Michael Baker International
3900 C Street Suite 900
Anchorage, AK 99503

Prepared for:

ConocoPhillips Alaska

MSA Contract No. 296937

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Figures

Photos

Tables

Acronyms & Abbreviations

°C	degrees Celsius
ADCP	acoustic doppler current profiler
cfs	cubic feet per second
CPAI	ConocoPhillips Alaska, Inc.
fps	feet per second
ft	feet
µS/cm	microsiemens per centimeter
mg/L	milligrams per liter
Michael Baker	Michael Baker International
NAVD88	North American vertical datum of 1988
OPUS	Online Positioning User Service
ppt	parts per thousand
Q	discharge
v	velocity
WSE	water surface elevation

1. INTRODUCTION

Michael Baker International (Michael Baker) collected open water data for Conoco Phillips Alaska, Inc. (CPAI) for the Willow ice road project. This field event was the first of multiple trips between Fall 2019 and Spring 2020; it occurred between September 4 and September 6, 2019. These efforts are designed to support the characterization of two proposed ice road crossings of the Colville River near Ocean Point. This document presents a summary of this field effort and the preliminary results of the data collection.

2. LOCATIONS

Two transects near Ocean Point were investigated: Transect #1 and Transect #6 (Figure 1). These are two among six transects investigated during the 2018-2019 ice road season. Both were selected based on shallow water depths relative to the other areas. Transect #1 (also referred to as the “rolligon crossing”, the “west crossing”, or the “upstream crossing”) is an historic crossing location. It was the location of a snow road during the 2018-2019 season and is the preferred proposed heavy haul crossing location. Transect #6 (also referred to as the “east crossing” or the “downstream crossing”) is the alternate proposed crossing location.

ConocoPhillips Alaska	Miles 0 0.25 0.5 1		
Date:	07/26/2019	Project:	170782
Drawn:	BTG	File:	Figure 1
Checked:	HLR	Scale:	1 in = 1 miles

Legend

Transect

Michael Baker INTERNATIONAL

Michael Baker International
3900 C Street, Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019-2020
Alpine Ice Road H&H
Ocean Point

FIGURE: 1

(SHEET 1 of 1)

3. METHODS

Michael Baker collected field data at two proposed crossing locations across the Colville River near Ocean Point. Data included cross-sectional river bottom profiles, discharge, velocity, water depth, water surface elevation, site conditions, and general in-situ water quality parameters. Soil active layer depths were also investigated for both banks of each crossing.

Discharge, velocity, and cross-sectional river bottom profiles were measured using a RiverRay acoustic doppler current profiler (ADCP) (Photo 1). The ADCP was mounted in a trimaran. The trimaran was tethered via boom to the side of a Zodiac inflatable raft powered by outboard motor (Photo 2).

Photo 1. Discharge measurement in progress at Transect #1; Sept 5, 2019

In-situ water quality parameters including temperature, conductivity (C), and salinity were recorded using the YSI ProPlus meter; dissolved oxygen (DO) was measured using the YSI ProODO meter. Specific conductance (SC) referenced to 25 degrees Celsius was calculated based on temperature, conductivity, and a conversion coefficient of 0.0196 based on empirical data. Measurements were collected at the deepest portion of each cross-section; two depths were investigated at each to confirm that parameters were consistent throughout the water column.

Photo 2. In-situ water quality sampling at Transect #6; Sept 5, 2019

Water surface elevation (WSE) at the time of discharge and water quality measurements were determined using temporary benchmarks installed by UMIAQ surveyors and Michael Baker. UMIAQ benchmarks are aluminum cap survey control referenced to OPUS NAVD88 elevation. Michael Baker benchmarks are aluminum cap survey control tied by level loop technique to the UMIAQ control.

The soil active layer was investigated to characterize the depth of permafrost below the surface in the transition zones adjacent to the river. This investigation was performed on the right and left banks of each transect, perpendicular to the channel. Probing was performed using a 5-foot long T-bar probe driven by hand (Photo 3). Spacing was approximately 5-foot increments and at major grade breaks, between water's edge and the top of the riverbank. Results were provided directly to Golder as a separate deliverable and included in this report as Appendix A.

Photo 3. Investigating soil active layer at Transect #6; left bank. Sept 4, 2019

These tasks were completed over the course of multiple days during one field event and were timed to occur late in the fall season, prior to freeze up.

4. RESULTS

Results of the field effort are presented below.

4.1. Colville River Ocean Point Measured Discharge

TRANSECT #1

Location: Transect #1/Rolligon Route

Date & Time: September 5, 2019 2:50 PM

Equipment: RiverRay ADCP attached to the side of an inflatable raft with outboard motor

WSE (ft NAVD88): 11.67

Discharge ([Q] cfs): 29,000

Velocity ([v] fps): 2.7

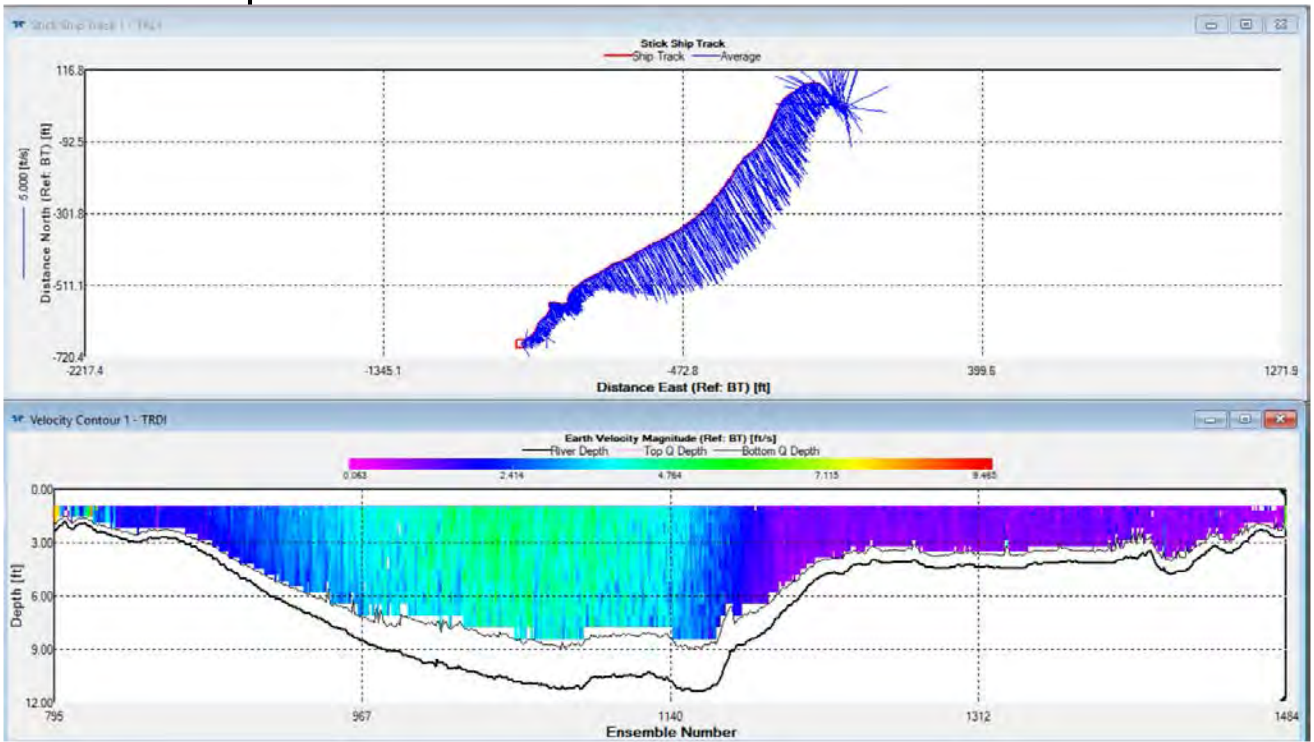
Measurement Rating: Good

Measurement Notes At the time of the measurement, open-channel conditions were present. Wind was negligible and surface waves were not present. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated.

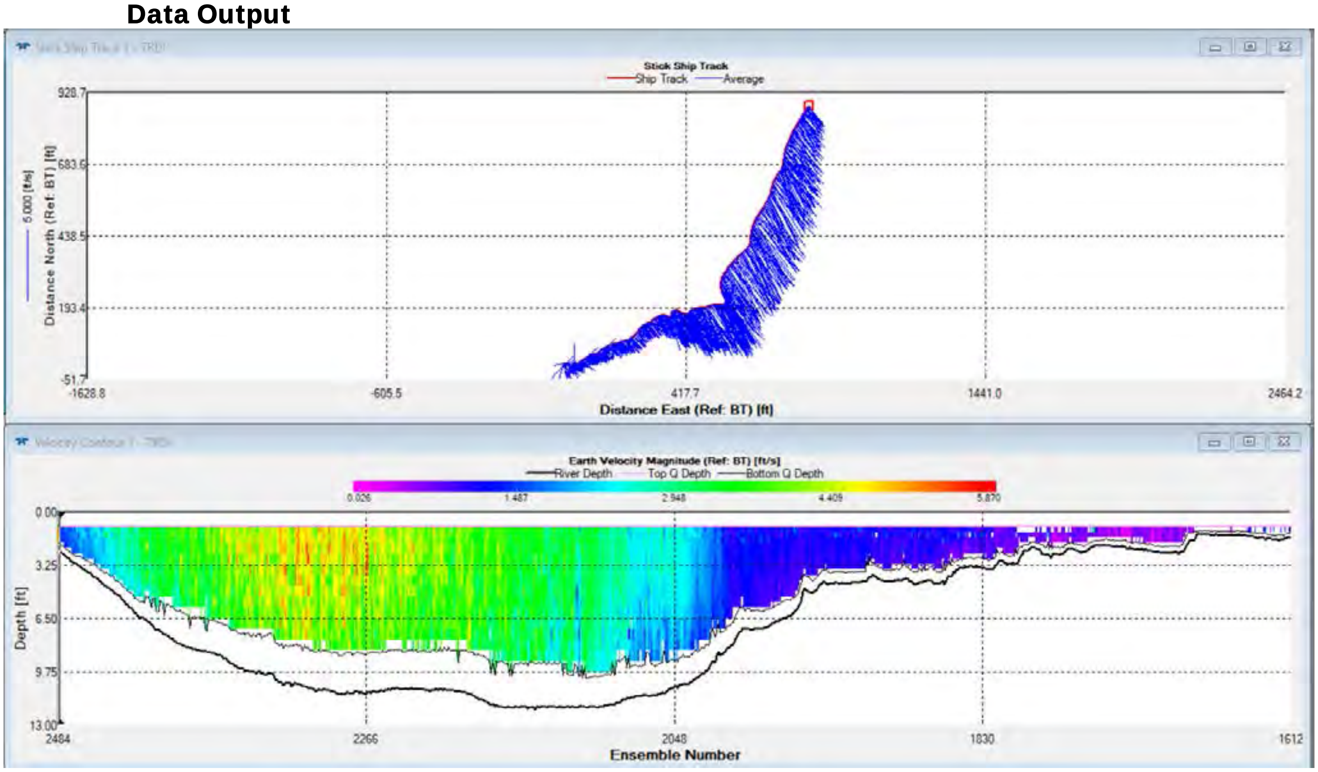
Table 1. Colville River Ocean Point Transect #1 Measured Discharge Summary

Measurement Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/v) (ft^2)	Total Area (ft^2)	Measured Velocity (ft/s)	Total Velocity (ft/s)
001	Left	28,811	-0.88%	20,083	-0.71%	1,256	8,056	9,468	2.49	3.04
002	Right	29,436	1.27%	20,470	1.20%	1,264	7,567	9,913	2.71	2.97
003	Left	29,228	0.55%	20,238	0.05%	1,258	7,551	9,666	2.68	3.02
004	Right	28,795	-0.94%	20,117	-0.54%	1,300	7,106	9,738	2.83	2.96
Average:		**29,068**		**20,227**		**1,270**	**7,570**	**9,696**	**2.68**	**3.00**

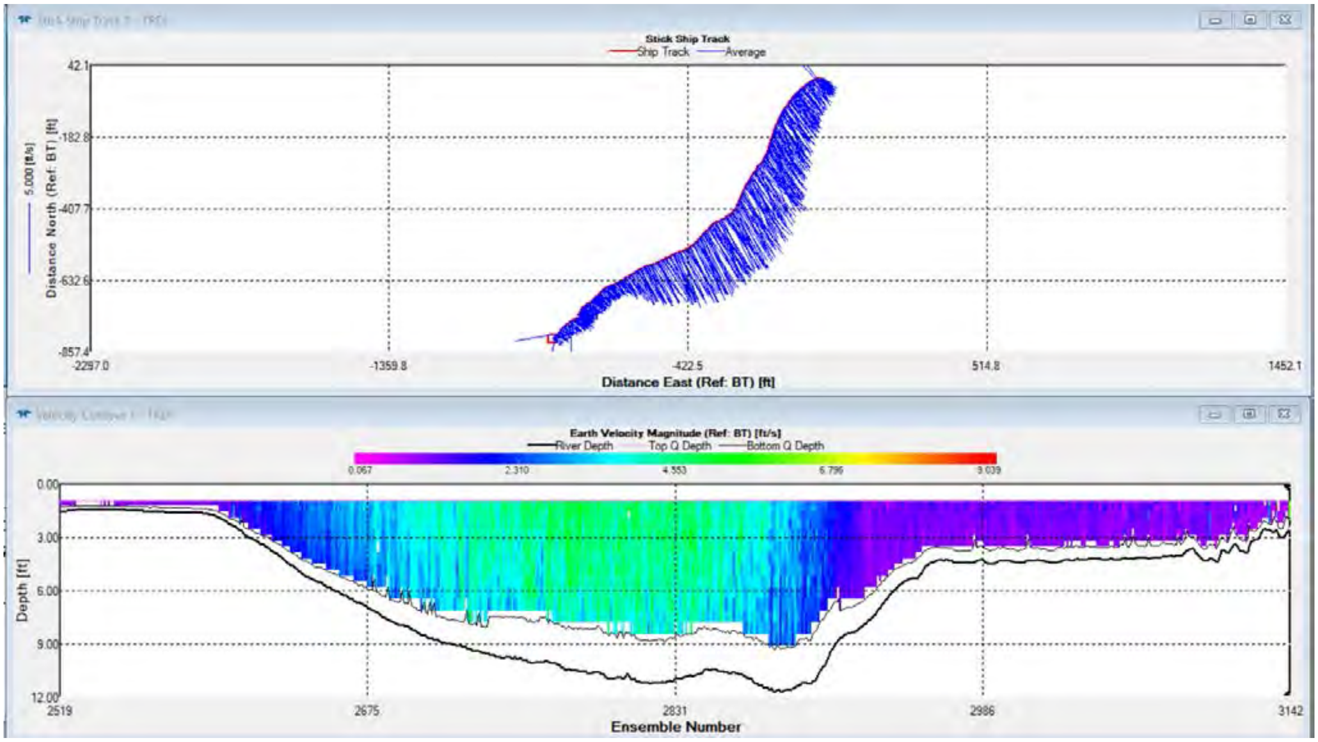
A. **Colville River Ocean Point Transect#1/Rolligon Route: Measurement Transect 001 Raw Data Output**



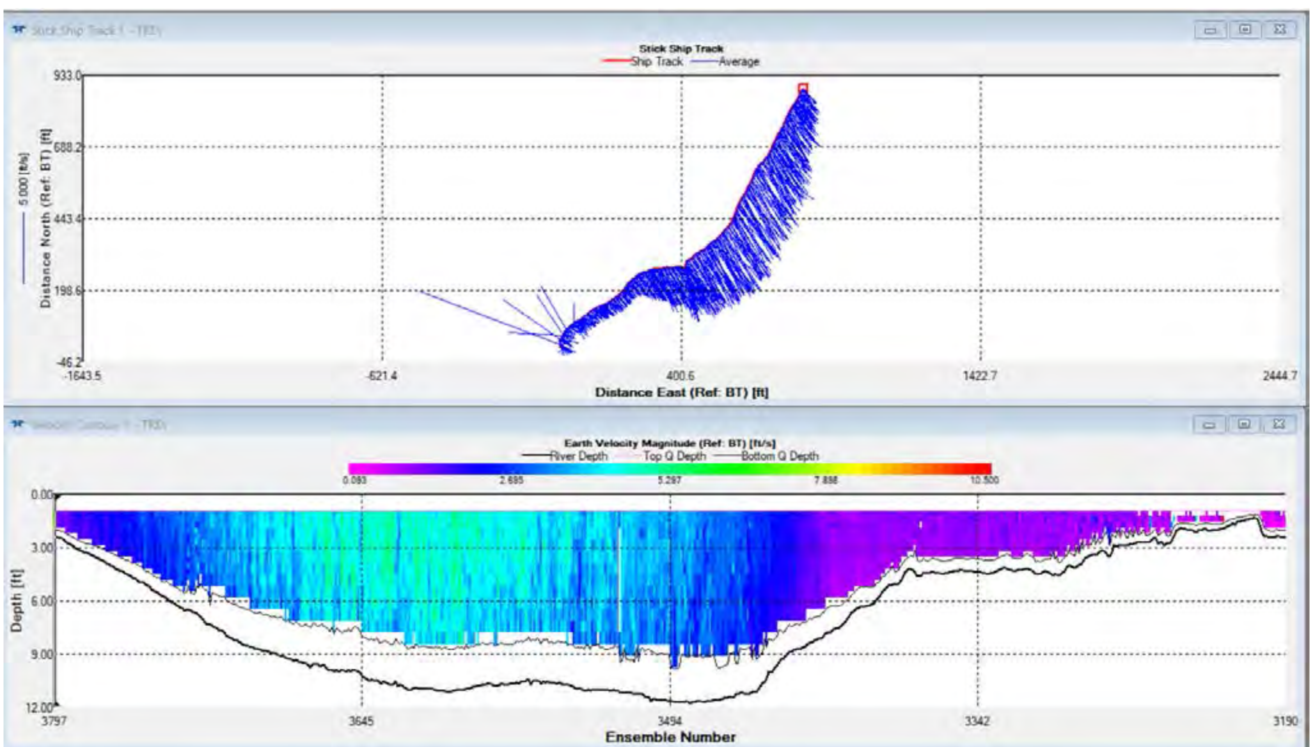
B. **Colville River Ocean Point Transect#1/Rolligon Route: Measurement Transect 002 Raw Data Output**



C. Colville River Ocean Point Transect#1/Rolligon Route: Measurement Transect 003 Raw Data Output



D. Colville River Ocean Point Transect#1/Rolligon Route: Measurement Transect 004 Raw Data Output



TRANSECT #6

Location: Transect #6

Date & Time: September 5, 2019 4:50 PM

Equipment: RiverRay ADCP attached to the side of an inflatable raft with outboard motor

WSE (ft NAVD88): 8.82

Discharge ([Q] cfs): 28,900

Velocity ([v] fps): 2.8

Measurement Rating: Fair

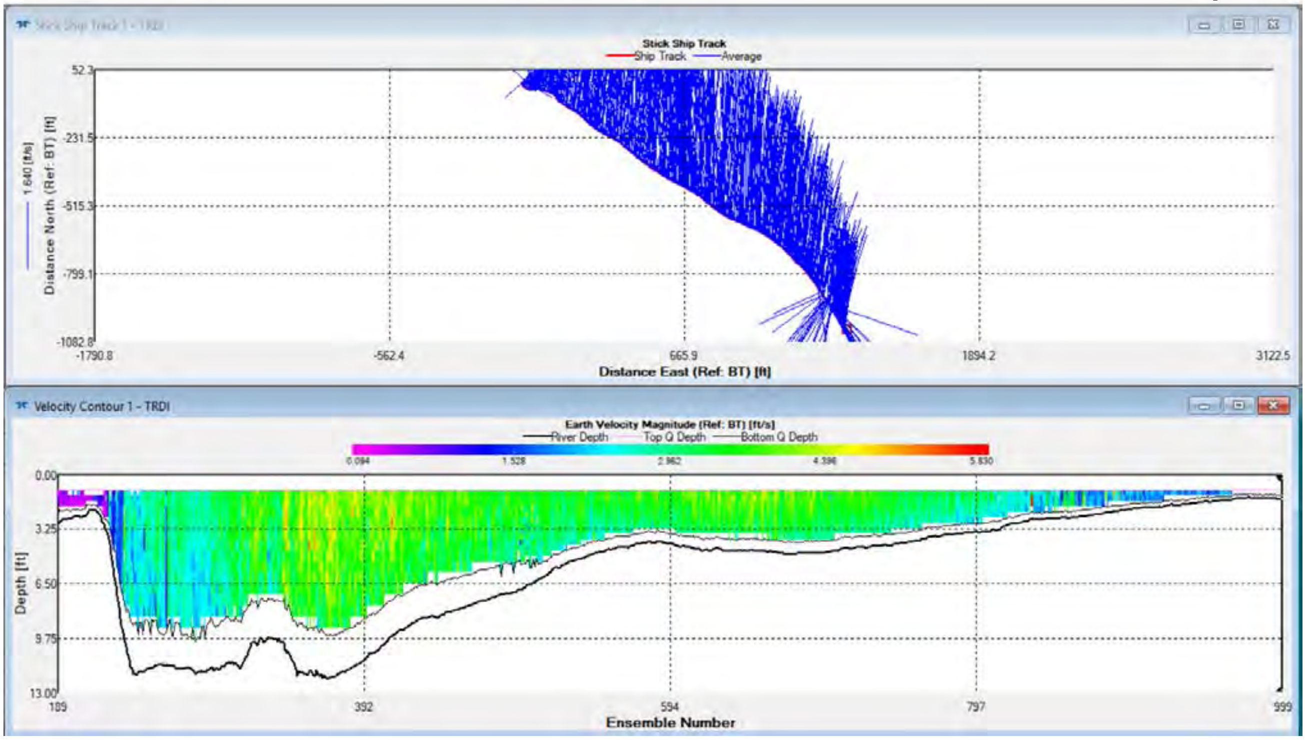
Measurement Notes: At the time of the measurement, open-channel conditions were present. Wind was negligible and surface waves were not present. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated.

A tributary enters the Colville River at this crossing location. Discharge was measured just downstream of the tributary. The deeper channel bathymetry influenced by this tributary is evident in the left bank side of the profile in the figures below.

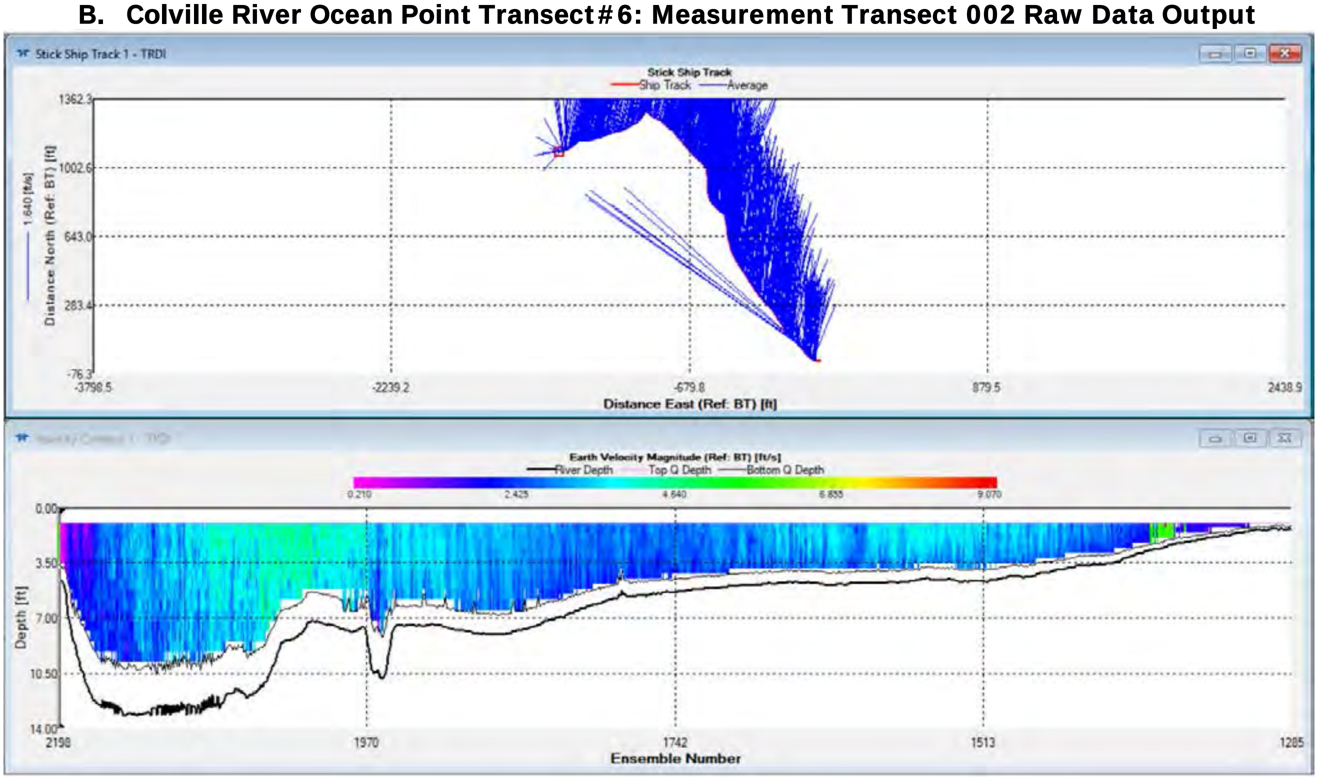
Table 2. Colville River Ocean Point Transect #6 Measured Discharge Summary

Measurement Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/v) (ft^2)	Total Area (ft^2)	Measured Velocity (ft/s)	Total Velocity (ft/s)
000	Left	28,809	-0.23%	18,864	-0.48%	1,771	6,163	10,313	3.06	2.79
002	Right	28,939	0.23%	19,046	0.48%	1,836	6,216	10,100	3.06	2.87
	Average:	**28,874**		**18,955**		**1,803**	**6,189**	**10,206**	**3.06**	**2.83**

A. Colville River Ocean Point Transect#6: Measurement Transect 000 Raw Data Output



B. Colville River Ocean Point Transect#6: Measurement Transect 002 Raw Data Output



4.2. Colville River Ocean Point Measured Water Quality

Table 3. Measured Water Quality Parameters

Location	Date & Time	Total Depth (ft)	Depth (ft)	Temp (°C)	Conductivity (µS/cm)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	Salinity (ppt)
Transect #1/ Rolligon Route N70.0513° W151.3705°	9/05/19 3:50pm	9	4	10	204	288	11.22	99.1	0.14
			8	9.8	203	290	11.23	99.2	0.14
Transect #6 N70.0652° W151.1012°	9/05/19 5:40pm	10	4	10	201	285	11.18	99.2	0.13
			8	9.9	202	287	11.32	100.3	0.14

Notes:
(1) Sample depth is measured from the water surface.
(2) Temperature, conductivity, and salinity were measured using a YSI ProPlus meter.
(3) Dissolved oxygen was measured using a YSI ProDO meter.
(4) Specific conductance (referenced to 25°C) was obtained using a conversion coefficient of 0.0196 based on empirical data.

Appendix A. Active Layer Investigation Results

Transect 1 - Right Bank					
Distance (ft)	Depth (ft)	Note	Distance (ft)	Depth (ft)	Note
-15	3.70	Top of bluff	150	3.50	
-10	5.00	Face of bluff	155	3.45	
0	4.35	Bottom of bluff	160	3.40	
5	4.50		165	3.25	
10	4.55		170	3.30	
15	5.00		175	3.30	
20	5.00		180	3.30	
25	5.00		185	3.30	
30	5.00		190	3.30	
35	5.00		195	3.30	
40	5.00		200	3.30	
45	5.00		205	3.20	
50	5.00		210	3.20	
55	5.00		215	3.20	
60	5.00		220	3.20	
65	5.00		225	3.20	
70	5.00		230	3.20	
75	5.00		235	3.20	
80	5.00		240	3.10	
85	5.00		245	3.10	
90	5.00		250	3.10	
95	5.00		255	3.10	
100	5.00		260	3.10	
105	5.00		265	3.10	
110	5.00		270	3.10	
115	4.80		275	3.10	
120	4.10		280	3.10	
125	3.90		285	3.10	
130	3.70		290	3.10	
135	3.65		295	3.10	
140	3.65		300	3.10	Edge of Water
145	3.60				

*Thaw depths of 5 feet indicate frozen ground was not encountered.

Transect 1 - Left Bank		
Distance (ft)	Depth (ft)	Note
-30	2.30	tundra behind bluff
-10	2.80	
0	3.25	Top of bluff
5	4.50	Top of bluff, out of willows
10	5.00	Face of bluff
15	5.00	Face of bluff
20	4.00	Bottom of bluff
25	4.10	
30	4.50	
35	5.00	Edge of Water

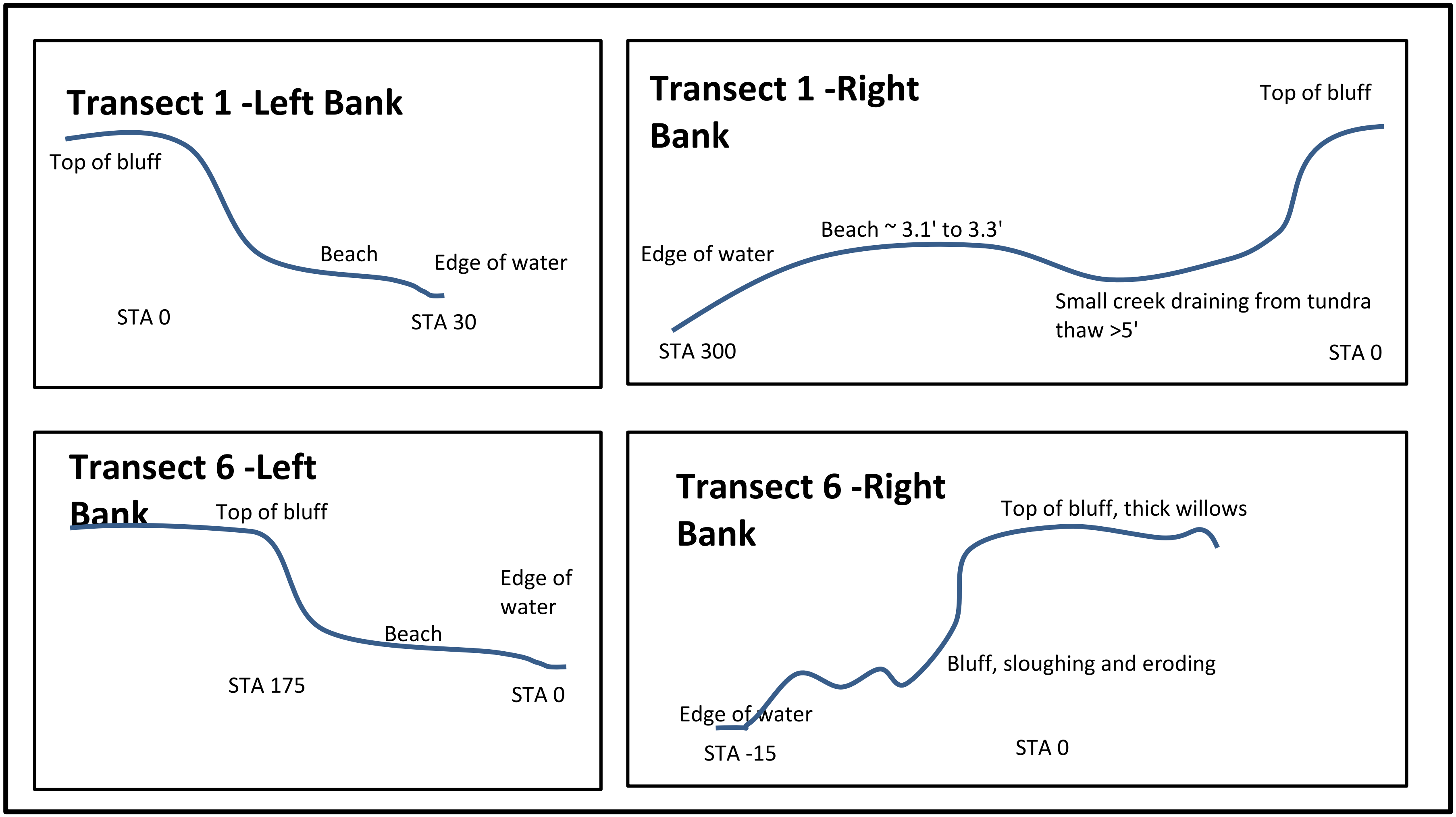
Notes:
Approximate locations of active layer probe transects are provided in Figure 2 and Figure 3 of main report.
Active layer bank elevations were not surveyed.

Transect 6 - Right Bank		
Distance (ft)	Depth (ft)	Note
-15	5.00	edge of water
-5	3.00	face of bluff
0	3.35	Top of bluff
5	1.75	tundra
10	1.75	tundra
15	1.75	tundra
20	1.75	tundra
25	1.75	tundra
30	1.75	tundra
35	1.75	tundra
40	1.75	tundra
45	1.75	tundra
50	1.75	tundra

*Thaw depths of 5 feet indicate frozen ground was not encountered.

Transect 6 - Left Bank		
Distance (ft)	Depth (ft)	Note
0	5.00	Edge of water
5	5.00	
10	5.00	
15	5.00	
20	5.00	
25	5.00	
30	5.00	
35	5.00	
40	5.00	
45	5.00	
50	5.00	
55	4.50	
60	4.00	
65	3.65	
70	3.75	
75	3.30	
80	2.95	
85	2.90	
90	3.50	ordinary high water/edge of beach
95	3.35	
100	3.75	
105	3.25	
110	3.50	
115	3.45	
120	4.10	
125	4.40	Beach to bluff transition
130	5.00	
135	5.00	
140	5.00	
145	5.00	
150	5.00	
155	5.00	
160	5.00	
165	5.00	
170	5.00	
175	4.50	top of bluff
180	2.90	tundra near bluff
195	3.50	

Notes:
Approximate locations of active layer probe transects are provided in Figure 2 and Figure 3 of main report.
Active layer bank elevations were not surveyed.



Notes:
Approximate locations of active layer probe transects are provided in Figure 2 and Figure 3 of main report.
Active layer bank elevations were not surveyed.

Attachment C Ice Cover – December 31, 2019 Field Data

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Location Name: Colville River at Ocean Point - South (Transect #1) Date Collected: 12/31/2019

Field Party: C. Lematta, M. Hendee (ICE) Computed By: G. Yager Checked By: H. Runa

Start Time: 11:20 Finish Time: 14:10 Weather: winds 7mph WNW, Partly Cloudy Temp: -20 °F

Channel Characteristics: Effective Width: 650 ft Average Velocity: 0.15 fps

Effective Area: 880 sq ft Discharge: 135 cfs

Measurement Details: Method: Midsection; 0.6 depth Number of Sections: 12

Crossing: Wading Cable **[Under Ice]** Boat Meter: HACH FH950

Side of bridge: Upstream Downstream **[N/A]** N/A ft above bottom of weight

GAGE READINGS			
Gage	Start	Finish	Change
N/A			

Weight: N/A lbs

Count: N/A

Spin Test: N/A revolutions

after N/A minutes

Measurement Rated: Excellent Good Fair **[Poor]** based on "Descriptions"

Descriptions:

From Field Notes:

All water columns were less than 2.5 ft. deep. Measurement began on the East/Left Edge of Water (Sta 0+00). Velocity measurements were inititally collected with a Sontek acoustic doppler velocity meter but results were inconsistent and unreliable. Measurements were then collected with a Hach electromagnetic velocity meter beginning at Sta 5+00 and remeasured at Sta 5+50 and 6+00. Large quantites of sediment encountered while drilling through ice results in dulling of all bits beyond ability for use at station 3+50. The thermal drill does not create holes large enough for velocity meter probes. Ice and water depths were measured between stations 3+50 and 0+00 and velocity at those stations is estimated.

Calculation Notes:

The average measured velocity was extrapolated to stations where velocity measurements were not acquired (Sta 3+50 to 0+00). This resulted in a computed discharge of 135 cfs. To provide a range of uncertainty, if the minimum velocity was extrapolated to these stations, the computed discharge would be 111 cfs, and if the maximum velocity was extrapolated, the computed discharge would be 176 cfs.

Colville River at Ocean Point Transect #1
Date Collected: 12/31/2019

Distance from initial point (ft)	Total Depth (ft)	Ice Thickness (ft)	Effective Depth (ft)	Section Width (ft)	Effective Area (ft^2)	Measurement Depth Below Ice (ft)	VELOCITY V1 (fps)	V2 (fps)	V3 (fps)	Average V (fps)	Discharge (cfs)
0	1.5	1.5	0.0	-	-	-	-	-	-	-	-
50	1.9	1.9	0.0	25.0	0.0	-	-	-	-	-	-
100	3.0	2.7	0.3	50.0	15.0	2.9	-	-	-	*0.15*	*2.3*
150	3.5	2.8	0.7	50.0	35.0	3.2	-	-	-	*0.15*	*5.4*
200	4.1	2.8	1.3	50.0	65.0	3.6	-	-	-	*0.15*	*10.1*
250	4.2	2.7	1.5	50.0	75.0	3.6	-	-	-	*0.15*	*11.6*
300	4.6	2.7	1.9	50.0	95.0	3.8	-	-	-	*0.15*	*14.7*
350	4.8	2.5	2.3	50.0	115.0	3.9	-	-	-	*0.15*	*17.8*
400	5.0	2.8	2.2	50.0	110.0	4.1	0.17	0.18	0.17	0.17	19.1
450	4.1	2.7	1.4	50.0	70.0	3.5	0.27	0.25	0.23	0.25	17.5
500	4.1	2.5	1.6	50.0	80.0	3.5	0.10	0.09	0.11	0.10	8.0
550	4.6	2.7	1.9	50.0	95.0	3.8	0.10	0.10	0.10	0.10	9.5
600	4.6	2.8	1.8	50.0	90.0	3.9	0.17	0.15	0.13	0.15	13.5
650	3.5	2.8	0.7	50.0	35.0	3.2	-	-	-	*0.15*	*5.4*
700	1.5	1.5	0.0	25.0	0.0	-	-	-	-	-	-
750	0.7	0.7	0.0	-	-	-	-	-	-	-	-

Shaded velocities were not measured because of equipment failure. These represent the average of the measured velocities.

Total Discharge: **134.8** cfs

Velocity Measurement

Location: Colville River Ocean Point South (Transect #1)
Weather: -20°F, 7 mph wind

Method: under ice; 0.6 depth
Meter: HACH FH950

Station	Location (NAD83)	Ice Thickness (ft)	Under Ice Water Depth (ft)	Velocity (ft/s)
0+00	East/Left Bank; N70.05340 W151.36929	1.5	grounded	-
0+50	-	1.9	grounded	-
1+00	N70.05338 W151.37006	2.7	0.3	0.15*
1+50	-	2.8	0.7	0.15*
2+00	N70.05331 W151.37088	2.8	1.3	0.15*
2+50	-	2.7	1.5	0.15*
3+00	N70.05330 W151.37166	2.7	1.9	0.15*
3+50	-	2.5	2.3	0.15*
4+00	N70.05330 W151.37262	2.8	2.2	0.17
4+50	N70.05326 W151.37303	2.7	1.4	0.25
5+00	N70.05325 W151.37349	2.5	1.6	0.10
5+50	N70.05324 W151.37389	2.7	1.9	0.10
6+00	N70.05322 W151.37436	2.8	1.8	0.15
6+50	-	2.8	0.7	0.15*
7+00	N70.05320 W151.37521	1.5	grounded	-
7+50	West/Right Bank; N70.05319 W151.37564	0.7	grounded	-

Notes: All water columns were less than 2.5 feet deep. Measurement began on the East/Left Edge of Water (Station 0+00).

Velocity measurements were initially collected with the Sontek acoustic doppler velocity meter, but results were inconsistent and unreliable. Measurements were then collected with a Hach electromagnetic velocity meter.

Large quantities of sediment encountered while drilling though ice results in dulling of all bits beyond ability for use between station 3+50 and 0+00. Thermal drill does not create holes large enough for velcity meter probes. Ice and water depths were measured between stations 3+50 and 0+00 and velocity is estimated for each station, indicated by an " * ".

Michael Baker
INTERNATIONAL

Submitted By: M. Hendee
Conducted By: M. Hendee

Ocean Point
Crossing Profile
December 31, 2019

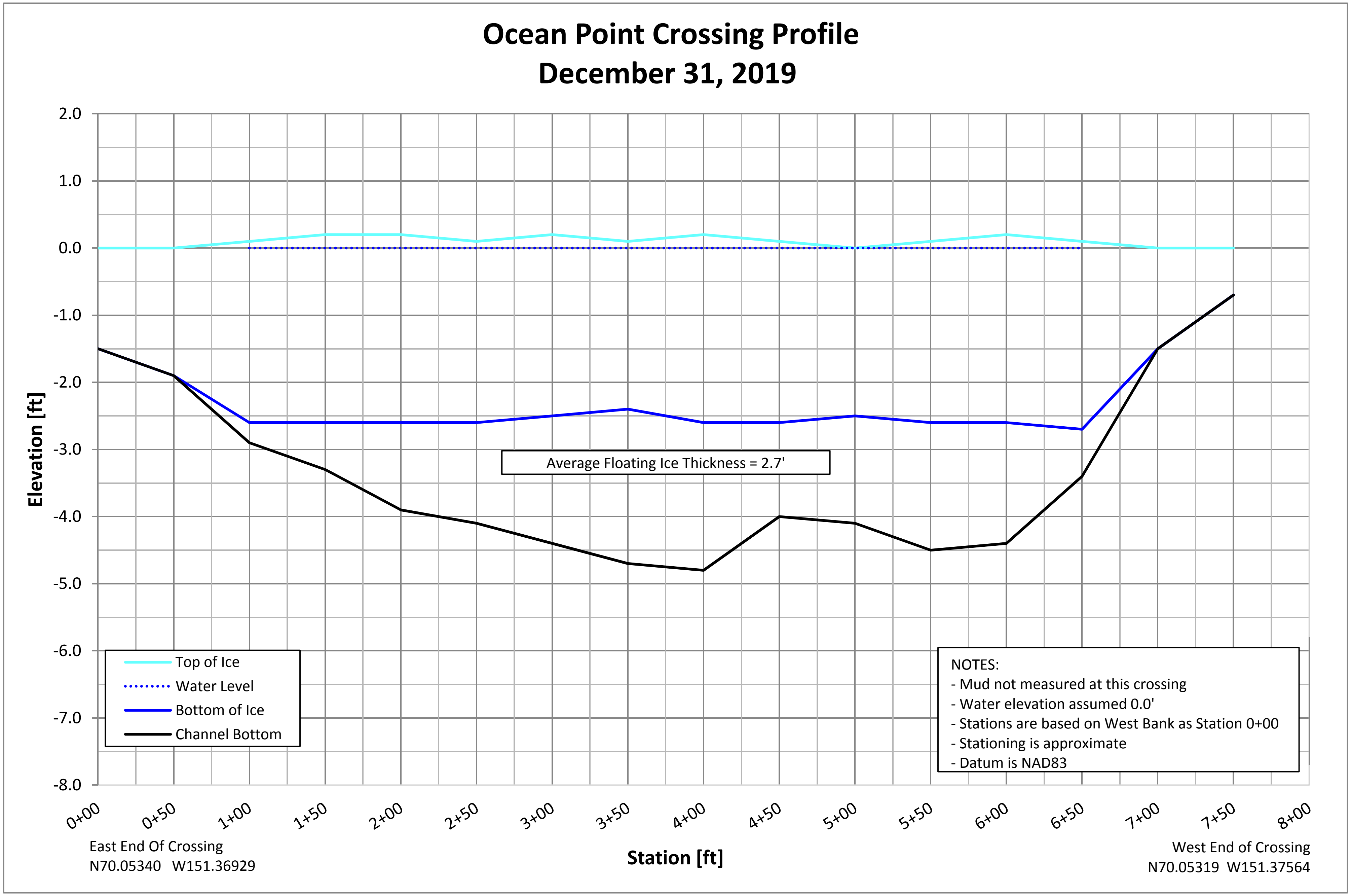
Waypoint	Station	Ice Thickness [ft]	Total Depth [ft]	Freeboard	Mud [ft]	Comments
003	0+00	1.5	1.5	Grounded		East Bank; N70.05340 W151.36929
	0+50	1.9	1.9	Grounded		
004	1+00	2.7	3.0	0.1		N70.05338 W151.37006
	1+50	2.8	3.5	0.2		
005	2+00	2.8	4.1	0.2		N70.05331 W151.37088
	2+50	2.7	4.2	0.1		
006	3+00	2.7	4.6	0.2		N70.05330 W151.37166
	3+50	2.5	4.8	0.1		
002	4+00	2.8	5.0	0.2		N70.05330 W151.37262
007	4+50	2.7	4.1	0.1		N70.05326 W151.37303
008	5+00	2.5	4.1	0.0		N70.05325 W151.37349
009	5+50	2.7	4.6	0.1		N70.05324 W151.37389
010	6+00	2.8	4.6	0.2		N70.05322 W151.37436
	6+50	2.8	3.5	0.1		
011	7+00	1.5	1.5	Grounded		N70.05320 W151.37521
012	7+50	0.7	0.7	Grounded		West Bank; N70.05319 W151.37564
Avg floating ice thickness =		2.7				

General Comments:

GPS coordinates given in NAD83. Mud not measured.

V1.0

Submitted By: M. Hendee
Conducted By: M. Hendee



Colville River at Ocean Point- Transect #1
Water Quality

Michael Baker INTERNATIONAL

Sample Date: December 31, 2019

Location & Time	Water Depth (ft)	Ice Thickness (ft)	Freeboard (ft)	Sample Depth (ft)	Temp (C)	Conductivity (µS/cm)	Specific Conductance (µS/cm)	DO (mg/L)	DO (% Saturation)	Salinity (ppt)
Sta 400+00 N70.05330° W151.37262° 2:20 PM	5.0	2.8	0.2	3.0	0.1	225	440	5.69	39.1	0.2
				3.5	0.1	225	440	5.74	39.4	0.2
				4.0	0.1	225	440	5.81	39.9	0.2

Notes:

(1) Sample location coordinates referenced to NAD83 datum.

(2) Freeboard is the distance from the top of ice to the water surface.

(3) Sample depth is measured from the water surface.

(4) Temperature, salinity, and conductivity were measured using a YSI Pro1030 meter.

(5) Specific conductance (referenced to 25°C) was obtained using a conversion coefficient of 0.0196 based on empirical data.

(6) Dissolved oxygen was measured using a YSI ProODO meter.

(7) Time shown indicates the start of the measurement.

(8) Temperature measurements have an accuracy of +/- 0.2ºC

Attachment D Ice Cover – February 25, 2020 Field Data

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Location Name: Colville River at Ocean Point - South (Transect #1) Date Collected: 2/25/2020

Field Party: D.Roe, J. Varga (UMIAQ) Computed By: D. Roe Checked By: H. Runa

Start Time: 13:25 Finish Time: 16:00 Weather: winds 5 mph, Sunny Temp: -5 °F

Channel Characteristics: Effective Width: 304 ft Average Velocity: 0.04 fps

Effective Area: 228 sq ft Discharge: 9 cfs

Measurement Details: Method: Midsection; 0.6 depth Number of Sections: 13

Crossing: Wading Cable **[Under Ice]** Boat Meter: HACH FH950

Side of bridge: Upstream Downstream **[N/A]** N/A ft above bottom of weight

Weight: N/A lbs

Count: N/A

Spin Test: N/A revolutions

after N/A minutes

GAGE READINGS			
Gage	Start	Finish	Change
Sta 2+85	5.48 ft NAVD88	-	RTK survey

Measurement Rated: Excellent Good **[Fair]** Poor based on "Descriptions"

Descriptions:

From Field Notes:

Negative freeboard occurred between Sta 5+12 and 5+72, averaging 0.2' above the top of ice surface. Positive occurred between Sta 2+85 and 4+52, averaging 0.2' below the ice surface. Ice was grounded in the middle of the channel from Sta 4+72 to 4+92. Depth of ice was not recorded at these locations but is estimated at approximately 5.0'. Discharge was measured beginning where water was encountered at Sta 5+72; observations were spaced every 20' using RTK GPS to where grounded ice was encountered at Sta 2+85.

Calculation Notes:

Colville River at Ocean Point Transect #1
Date Collected: 02/25/2020

Distance from initial point (ft)	Total Depth (ft)	Ice Thickness (ft)	Effective Depth (ft)	Section Width (ft)	Effective Area (ft^2)	Measurement Depth Below Ice (ft)	VELOCITY V1 (fps)	V2 (fps)	V3 (fps)	Average V (fps)	Discharge (cfs)
0+00	1.5	1.5									
0+57	2.1	2.1									
1+14	2.2	2.2									
1+71	2.9	2.9									
2+29	4.3	4.3									
2+85	5.1	4.9	0.2	41.5	8.3	5.0	0.04	0.03	0.05	0.04	*0.3*
3+12	5.3	4.9	0.4	23.5	9.4	5.1	0.03	0.04	0.06	0.04	*0.4*
3+32	5.5	4.8	0.7	20.0	14.0	5.2	0.06	0.06	0.06	0.06	*0.8*
3+52	5.7	4.8	0.9	20.0	18.0	5.3	0.04	0.05	0.06	0.05	*0.9*
3+72	5.8	4.6	1.2	20.0	24.0	5.3	0.05	0.10	0.19	0.11	*2.7*
3+92	5.8	4.9	0.9	20.0	18.0	5.4	0.05	0.04	0.08	0.06	*1.0*
4+12	5.5	4.9	0.6	20.0	12.0	5.3	-0.01	0.15	0.13	0.09	*1.1*
4+32	5.1	5.0	0.1	20.0	2.0	5.1	0.10	0.11	0.13	0.11	*0.2*
4+52	5.7	5.0	0.7	20.0	14.0	5.4	0.07	0.07	0.00	0.05	*0.7*
4+72	5.0	5.0									
4+92	5.0	5.0									
5+12	5.3	4.9	0.4	20.0	8.0	5.1	0.01	0.01	0.02	0.01	*0.1*
5+32	5.9	4.7	1.2	20.0	24.0	5.4	0.03	0.03	0.02	0.03	*0.6*
5+52	5.9	4.6	1.3	20.0	26.0	5.4	0.01	0.01	0.01	0.01	*0.3*
5+72	5.9	4.6	1.3	38.5	50.1	5.4	0.00	0.00	0.00	0.00	*0.0*
6+29	4.1	4.1									
6+86	2.2	2.2									
7+43	1.2	1.2									
8+00	0.4	0.4									

Total Discharge: **9.2** cfs

Project Name: Willow Ice Road Support
Project Number: 174311

Field Personnel: D. Roe
Date Collected: February 25, 2020

Velocity Measurement

Location: Colville River Ocean Point South (Transect #1)
Weather: -5°F, 5 mph wind

Method: under ice; 0.6 depth
Meter: HACH FH950

Station	Location (NAD83)	Ice Thickness (ft)	Under Ice Water Depth (ft)	Velocity (ft/s)
0+00	East/Left Bank; N70.053397 W151.369398	1.5	grounded	-
0+57	-	2.1	grounded	-
1+14	-	2.2	grounded	-
1+71	-	2.9	grounded	-
2+29	-	4.3	grounded	-
2+85	N70.053343 W151.371671 (see "Survey")	4.9	0.2	0.04
3+12	-	4.9	0.4	0.04
3+32	-	4.8	0.7	0.06
3+52	-	4.8	0.9	0.05
3+72	-	4.6	1.2	0.11
3+92	-	4.9	0.9	0.06
4+12	-	4.9	0.6	0.09
4+32	-	5	0.1	0.11
4+52	-	5	0.7	0.05
4+72	-	5	grounded	0.00
4+92	-	5	grounded	0.00
5+12	-	4.9	0.4	0.01
5+32	-	4.7	1.2	0.03
5+52	-	4.6	1.3	0.01
5+72	N70.053262 W151.373960	4.6	1.3	0.00
6+29	-	4.1	grounded	-
6+86	-	2.2	grounded	-
7+43	-	1.2	grounded	-
8+00	West/Right Bank; N70.053197 W151.375716	0.4	grounded	-

Survey: Water surface elevation surveyed at station 2+85 = 5.48 ft NAVD88.

Notes: All water columns were less than 1.3 feet deep. Measurement began on the East/Left Edge of Water (Station 0+00).

Velocity measurements were attempted using the Sontek acoustic doppler velocity meter, but results were inconsistent and unreliable. Measurements were then collected with a Hach electromagnetic velocity meter instead.

Negative freeboard occurred between station 5+12 and 5+72, averaging 0.2' above the top of ice surface. Postive freeboard occurred between stations 2+85 and 4+52, averaging 0.2' below the ice surface.

Michael Baker
INTERNATIONAL

Submitted By: E. Keib
Conducted By: E. Keib

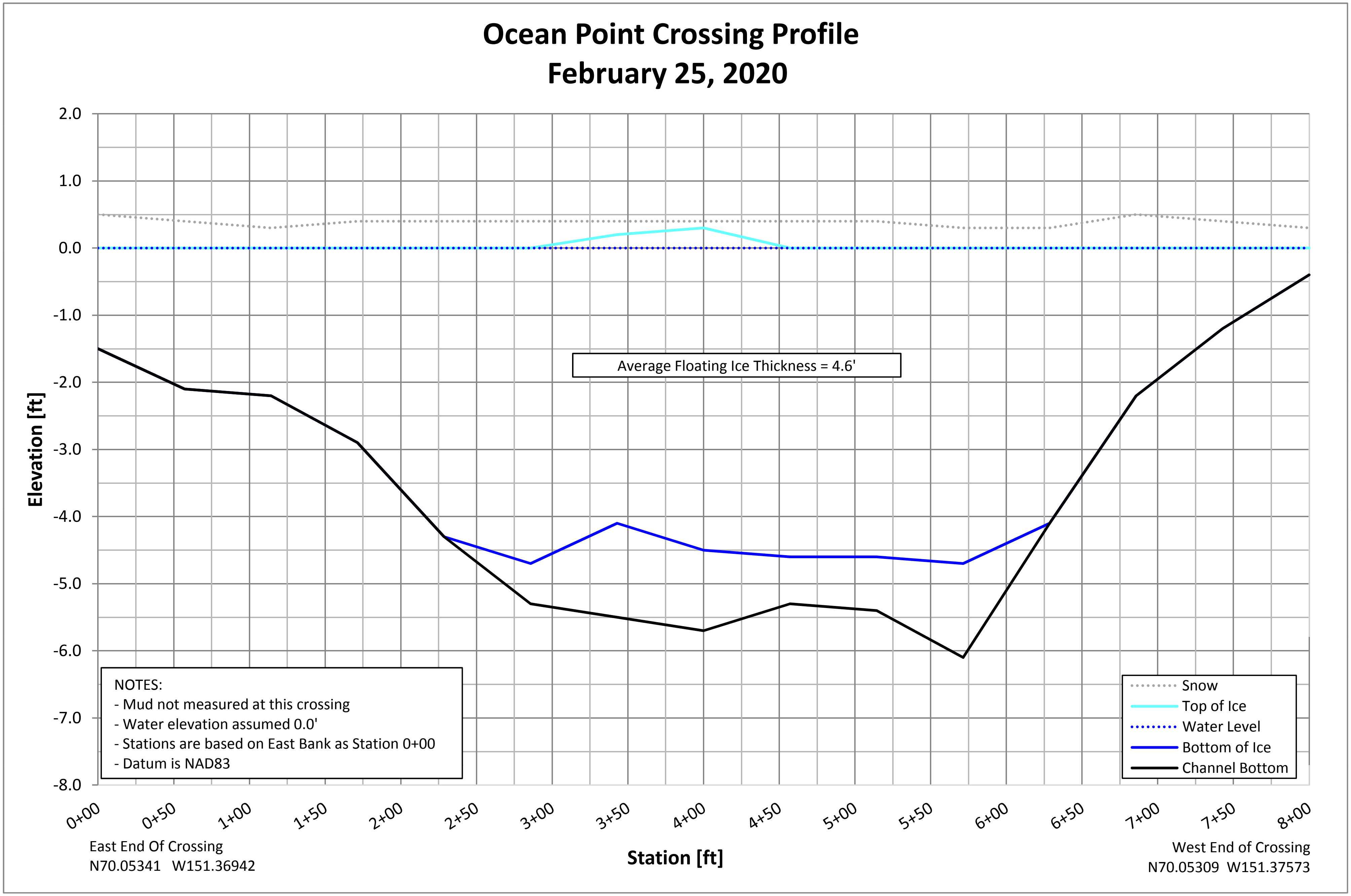
Ocean Point
Crossing Profile
February 25, 2020

Waypoint	Distance	Ice Thickness [ft]	Total Depth [ft]	Freeboard	Snow [ft]	Comments
055	0+00	1.5	1.5	Grounded	0.5	East Bank; N70.05341 W151.36942; Crossed Blue Tipped Lath Placed Here
	0+57	2.1	2.1	Grounded	0.4	
	1+14	2.2	2.2	Grounded	0.3	
	1+71	2.9	2.9	Grounded	0.4	
	2+29	4.3	4.3	Grounded	0.4	
	2+86	4.7	5.3	0.0	0.4	Single Blue Tip Lath Placed Here - Edge of Floating Ice
	3+43	4.3	5.7	0.2	0.4	
	4+00	4.8	6.0	0.3	0.4	
	4+57	4.6	5.3	0.0	0.4	
	5+14	4.6	5.4	+	0.4	
	5+71	4.7	6.1	+	0.3	Single Blue Tip Lath Placed Here - Edge of Floating Ice
	6+29	4.1	4.1	Grounded	0.3	
	6+86	2.2	2.2	Grounded	0.5	
	7+43	1.2	1.2	Grounded	0.4	
	8+00	0.4	0.4	Grounded	0.3	West Bank; N70.05309 W151.37573; Crossed Blue Tipped Lath Placed Here
Avg floating ice thickness =		4.6				

General Comments:

GPS coordinates given in NAD83. Mud not measured. Water depth at upstream transducer = 5.6'; Water depth at downstream transducer = 5.6'; the snow birdge has been installed between the transducers and upstream of the ice profile survey; RTK survey was conducted on the edge of ice, edge of water, transducer locatoins, and at each velocity measurement location.

Submitted By: E. Keib
Conducted By: E. Keib



Colville River at Ocean Point- Transect #1
Water Quality

Michael Baker INTERNATIONAL

Sample Date: February 25, 2020

Location & Time	Water Depth (ft)	Ice Thickness (ft)	Freeboard (ft)	Sample Depth (ft)	Temp (°C)	Conductivity (µS/cm)	Specific Conductance (µS/cm)	DO (mg/L)	DO (% Saturation)	Salinity (ppt)
Sta 400+00 N70.05330° W151.37262° 3:15 PM	5.5	4.6	0.2	4.5	0.0	288	565	2.48	17.0	0.3
				5.0	0.7	288	550	2.63	18.4	0.3

Notes:

(1) Sample location coordinates referenced to NAD83 datum.

(2) Freeboard is the distance from the top of ice to the water surface.

(3) Sample depth is measured from the water surface.

(4) Temperature, salinity, and conductivity were measured using a YSI Pro1030 meter.

(5) Specific conductance (referenced to 25°C) was obtained using a conversion coefficient of 0.0196 based on empirical data.

(6) Dissolved oxygen was measured using a YSI ProODO meter.

(7) Time shown indicates the start of the measurement.

(8) Temperature measurements have an accuracy of +/-0.2 degrees Celcius

Appendix D
- OCEAN POINT WEATHER STATION REPORT

OCEAN POINT WEATHER STATION

SYSTEM DESCRIPTION

14 APRIL 2020

Mike Hendee
ICE Design Consult
Mikal.Hendee@icedesignconsult.com
(907) 244-3807

Contents

OCEAN POINT WEATHER STATION

OVERVIEW

The Ocean Point weather station was installed on 14 April 2020 for the purpose of monitoring weather and climate parameters. The station is located 12 miles SW of Nuiqsut, Alaska on the north side of the Colville River where it bends to the south at Ocean Point. The vicinity map is shown in Figure 1. The geographical coordinates of the weather station are N70.08730, W151.35590. The site elevation is approximately 129 feet above mean sea level. The location map is shown in Figure 2.

The weather station monitors, in real-time, wind speed and direction, solar radiation, air temperature, relative humidity, snow depth, barometric pressure, and ground temperature.

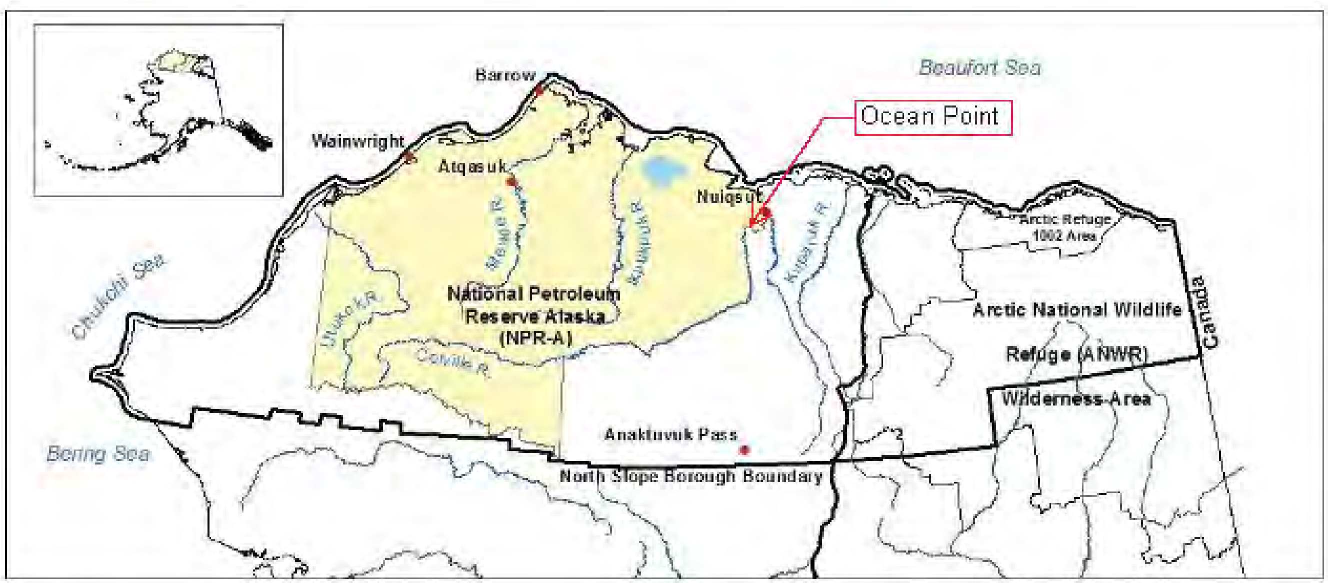


Figure 1 – Ocean Point Weather Station Vicinity Map

Figure 2 – Ocean Point Weather Station Location Map

The Ocean Point weather station is configured with the following instruments that are depicted in Figure 3:

1. Wind monitor (wind speed and direction)
2. Pyranometer (solar radiation)
3. Air temperature sensor
4. Relative humidity sensor
5. Snow depth sensor
6. Barometric pressure sensor
7. Ground temperature sensor array

The sensor information is processed by a CR1000X data processor and transmitted to a remote server via satellite modem. Power is supplied by a single 12-volt deep cycle battery that is recharged by a 50-watt solar panel.

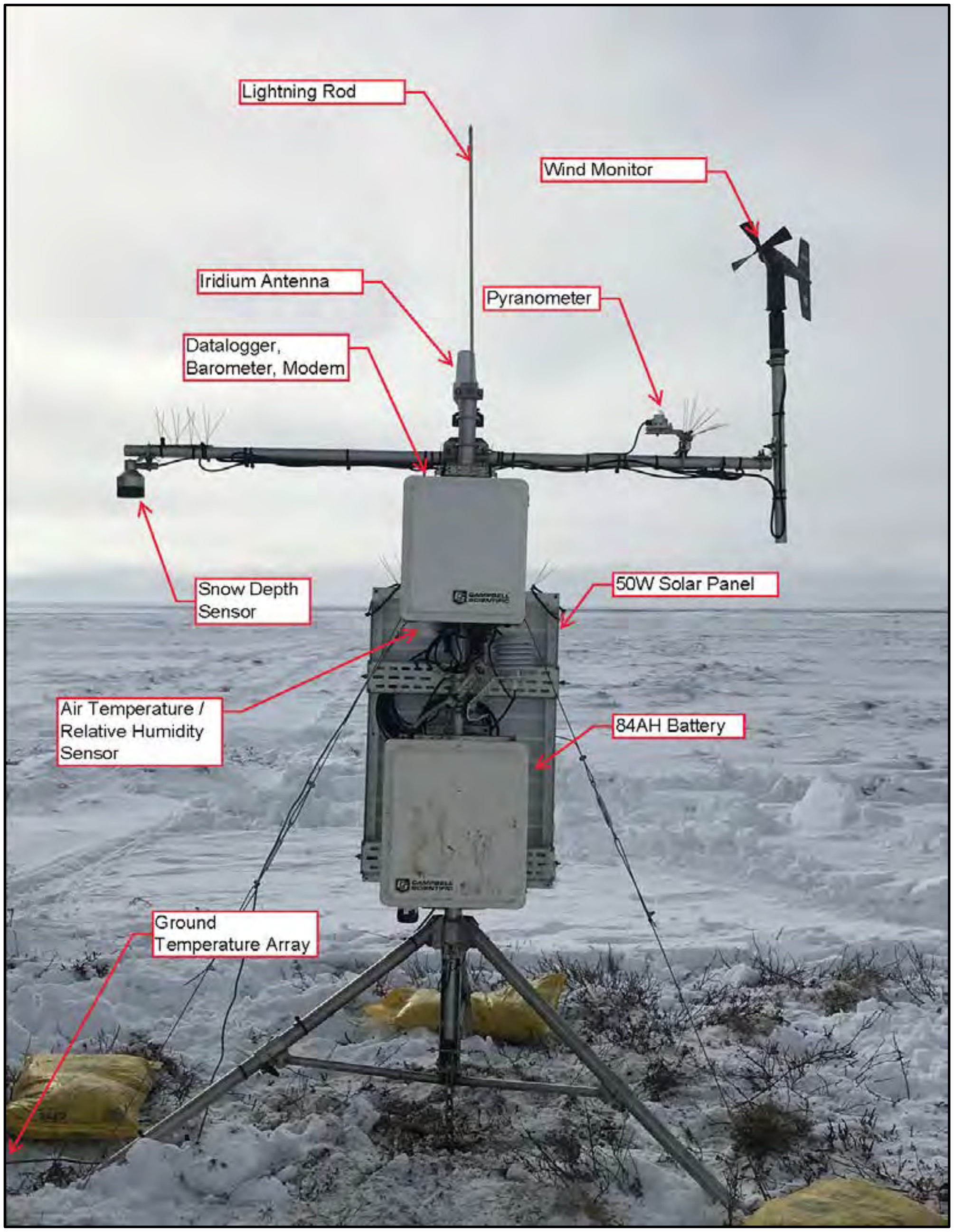


Figure 3 – Ocean Point Weather Station Configuration

INSTRUMENTATION SPECIFICATIONS

Data Processor

Campbell Scientific Inc. CR1000X
Serial number: 3236

Wind Monitor:

R. M. Young Model 05108-45 Alpine Version Wind Monitor
Serial number: WM164717
Operating temperature range: -50°C to +60°C
Wind speed range: 0 to 224 mph
Accuracy: +/- 0.6 mph or 1% of reading
Starting Threshold: 2.2 mph
Wind Direction Range: 0 to 360°
Accuracy: +/- 3°
The wind monitor is mounted at a height of 7 feet above the ground

Pyranometer

Hukseflux LP02
Serial number: 47571
Light spectrum waveband: 285 to 3000 nm
Maximum irradiance: 2000 W/m^2
Sensitivity (nominal): 15 μV/(W/m^2)
Operating temperature range: -40°C to +80°C
Temperature dependence: <0.15% per °C
ISO classification: Second class

Snow Depth Sensor

Campbell Scientific, Inc. SR50A Sonic Ranging Sensor
Serial number: 335867
Operating temperature range: -45°C to +50°C
Measurement range: 1.6 ft to 32.8 ft
Resolution: 0.01 in
Accuracy: +/- 0.4 in or 0.4% of distance to target (whichever is greater)
Height above ground (HAG) = 64.25 in

Air Temperature / Relative Humidity Sensor

HygroVUE5 Digital Temperature and Relative Humidity Sensor
Sensor element: SHT35
Temperature range: -40°C to +70°C
Tolerance: +/- 0.4°C (over -40°C to +70°C range)
Response time: 130s (wind speed of 1 m/s)
Resolution: 0.001°C
Long-term drift: < +/- 0.03°C per year
Humidity range: 0% to 100% RH
Accuracy (at 25°C): +/- 1.8% (over 0% to 80%), +/- 3% (over 80% to 100%)
Additional errors (-40°C to +60°C): +/- 1%
Short-term hysteresis: < 1%
Response time: 8s (wind speed of 1 m/s at +25°C)

Barometer

Setra CS100
Serial number: 7325117
Pressure range: 600 mBar to 1100 mBar
Accuracy: +/- 0.5 mBar (+20°C)
+/- 1.0 mBar (0°C to 40°C)
+/- 1.5 mBar (-20°C to +50°C)
+/- 2.0 mBar (-40°C to +60°C)
Linearity: +/- 0.4 mBar
Hysteresis: +/- 0.05 mBar
Repeatability: +/- 0.03 mBar

Modem

Iridium 9522B

Ground Temperature Array

BeadedStream Digital Acquisition Cable
Serial number: 3484
Operating temperature range: -55°C to +125°C
Sensor accuracy: +/- 0.1°C from -10°C to +30°C

DATA PROCESSING and TRANSMISSION

The following parameters are sampled at 30 second intervals:

- Wind speed and direction
- Solar radiation
- Air temperature

The following parameters are sampled at 10 minute intervals:

- Ground temperature

The following parameters are sampled hourly:

- Snow Depth
- Barometric Pressure

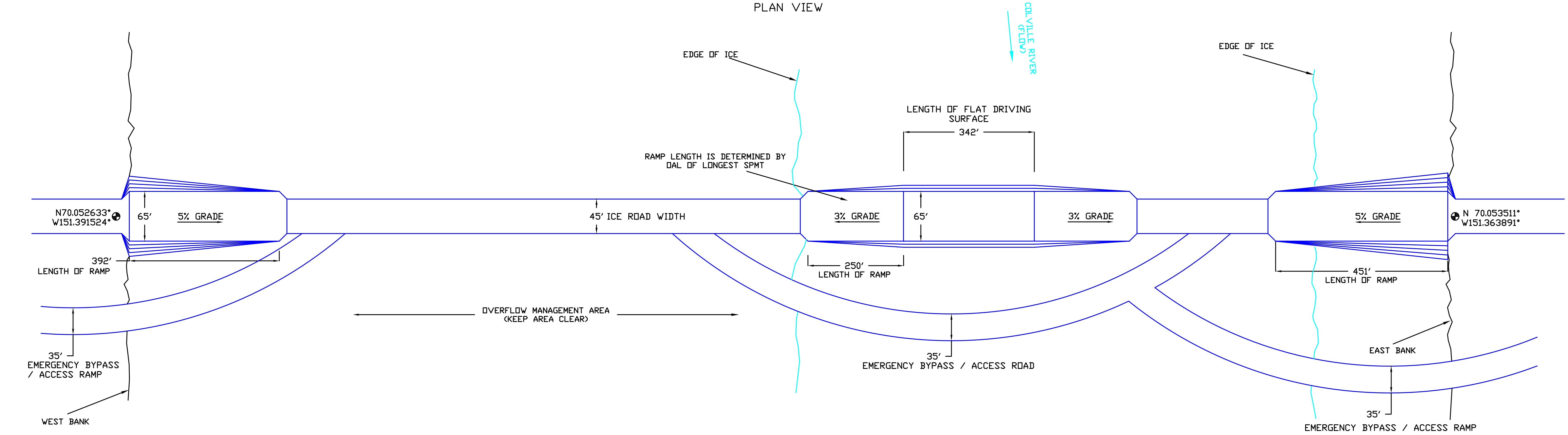
The parameters are transmitted hourly via the Iridium modem to a host computer operated by Polar Alpine Inc. The information is presented on a private web page.

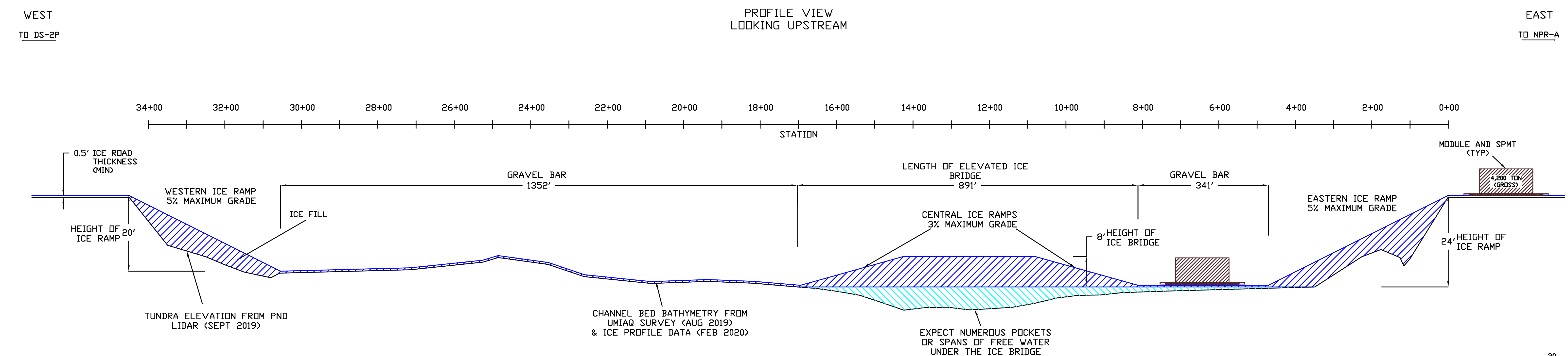
APPENDIX A – POWER SUPPLY INFORMATION

The Ocean Point weather station is powered by the following equipment:

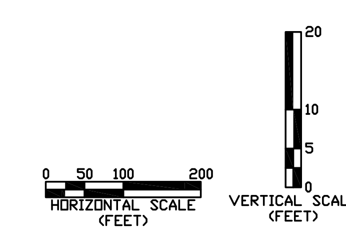
Sun Xtender® PVX-840T Solar Battery
Campbell Scientific, Inc. SP50 Solar Panel
Campbell Scientific, Inc. CH150 Charging Regulator

Appendix E
- Ocean Point Ice Bridge Design Drawings





NOTES:
1. ALL DIMENSIONS AND STATIONING ARE APPROXIMATE
2. ICE BRIDGE CONSTRUCTION ASSUMED TO BEGIN IN FEBRUARY
3. RAMP WIDTHS MAY INCREASE IF MORE THAN 8' OF FILL IS REQUIRED
4. ICE BRIDGE IS SUITABLE FOR 3,200 TON MODULE LOADED ONTO A SPMT WITH A MAXIMUM ALLOWABLE GROSS WEIGHT OF 4,200 TONS
5. OVERALL LENGTH OF CROSSING OBTAINED FROM GOOGLE EARTH (NAD83)
6. BATHYMETRY BASED ON ICE PROFILE FEB 25, 2020; TUNDRA ELEVATIONS BASED ON PND LIDAR DATA SEPT 2019
7. THE ICE BRIDGE WILL BE NON-GROUNDED; ESTIMATED AMOUNT OF FILL REQUIRED = 36.5K CU YDS (6.6 MGALS WATER EQUIVALENT)



PRELIMINARY

DATE: 20200522	SCALE: AS SHOWN	REVISION: 1.2
DRAWN BY: EJK	SHEET SIZE: 11x17 LANDSCAPE	REVISION DATE: 20200611
CHECKED BY: WSTL; RIL; MKH	DRAWING NUMBER: PROPOSED UPSTREAM SITE OCEAN PPOINT ICE BRIDGE PLAN/PROFILE	

ICE
DESIGN & CONSULT

PLAN / PROFILE
PROPOSED UPSTREAM SITE OCEAN POINT ICE BRIDGE
WILLOW DEVELOPMENT MODULES

DRAWING FOR: CPAI
PAGE: 1 OF 1