Willow Master Development Plan

Appendix D.3B
Ice Bridge Plan

January 2023

2021 Willow Development Ocean Point Ice Bridge Crossing Update

2021 Summary Report – Ocean Point Discharge and Water Quality

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2021

WILLOW DEVELOPMENT OCEAN POINT ICE BRIDGE CROSSING UPDATE

Submitted to:

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Submitted by:

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August 6, 2021

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ABBREVIATIONS

ATM	Atmospheric Pressure
BPMSL	British Petroleum Mean Sea Level
CFDD	Cumulative Freezing Degree-Day
DS	Downstream
DS-2P	Drill Site 2P approximately 21.5 miles east of the proposed OPIB
ft	Feet
ft/sec	Feet per second
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
NAD83	North American Datum 1983
OPIB	Ocean Point Ice Bridge
psi	pounds per square inch
PT	Pressure Transducer
Q	Discharge (cubic feet per second)
SPMT	Self-Propelled Modular Transporter
STA	Survey Station (feet)
US	Upstream
WSE	Water Surface Elevation

DEFINITIONS

Hägglund	A low ground pressure rubber tracked articulated vehicle
Overflow	When water is present on the surface of the ice
Rolligon	An extremely low ground pressure pneumatic rubber tire all-terrain vehicle (as low as 4 psi) with an indirect drive that is approved for summer tundra travel

1 EXECUTIVE SUMMARY

A third winter investigation of the proposed Ocean Point Ice Bridge (OPIB) location was conducted in the winter of 2020-2021. For the first time a topographic survey along the alignment and across the river from bank-to-bank was conducted. With this new information the ice bridge design was updated. Prior to the topographic survey, the elevations of the river banks were estimated. The updated ice bridge design is included in Appendix D and the construction quantities are presented in Table 1.1. The ice bridge is designed 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.

TABLE 1.1: ICE CONSTRUCTION QUANTITIES OCEAN POINT ICE BRIDGE

Ocean Point Ice Bridge	Ice Quantity (yd^3)
****TOTAL =**	**64,700**

***The water equivalent quantity is 11.7 million gallons*

Observations from the winter of 2020 - 2021 have confirmed that the crossing has the potential to naturally ground. Overflow was not observed or reported to have occurred at the proposed crossing site.

Two direct discharge measurements were conducted by Michael Baker International (MBI). The first discharge of 13.8 ft^3/s (6,200 gpm) was measured on February 17, 2021. This had decreased to 0.7 ft^3/s (300 gpm) by March 10, 2021 (95% decrease). Discharge measurements were planned for March 23rd, April 7th, and 21st but they were not possible since the crossing had become naturally grounded. However, there was a possible trace amount of discharge through the crossing via the channel bottom and small pockets of water below the ice.

Future data collection efforts should be conducted at Ocean Point to better understand how the water discharge varies through the winter and the historical channel morphological data record. It is important to verify the frequency and magnitude of overflow events and the mechanisms that cause them. Continuing investigations should focus on the time period between mid-February to mid-April. This is the forecast timeframe for the construction and use of the OPIB (2024-2025) for the Willow module move.

2 INTRODUCTION

The objectives of the 2020-2021 investigation were to:

1. Determine the ice and hydrological conditions at the proposed OPIB location
2. Update the OPIB design pending any new discoveries

The following data was collected for this effort:

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

3 Suppositions

The following suppositions should be considered while reviewing this report.

1. The first year SPMTs moving with modules will occur during the winter of 2024-2025.
2. The module move is scheduled to take place between mid-February and mid-April.
3. The ice structure designs are subject to revision based on new information.
4. There is a potential for overflow at the proposed OPIB site (ICE 2020).
5. The proposed OPIB will not be a totally grounded ice bridge.
6. Loaded and unloaded SPMTs are capable of negotiating grades up to a maximum 5% longitudinal and with a maximum 1.5% lateral slope (side-to-side).
7. SPMTs are limited to a maximum grade change of +/-1.7% over 96.5 feet as measured along the travel surface.

4 Data and Observations

An area map of the proposed OPIB location is included in Appendix A. Five field investigations were made between February 17 and April 21, 2021. MBI engineers accompanied ICE engineers for each of the field visits. The seasonal timing of the field investigations was selection to coincide with the proposed Willow Module Move schedule. A Rolligon and Hägglund were used to access the project site from Drill Site 2P (DS-2P).

Ice profiles were conducted 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 WSE. 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 (Measured by MBI)

Pressure transducers (PT) were installed approximately 200 ft upstream (US) and downstream (DS) of the proposed OPIB centerline alignment (Appendix D). 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 15-minute intervals commencing on February 17th at noon and terminating on April 21st at noon.

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 (referenced to Fahrenheit degrees) has ranged from a high of 9,300 (2011-2012 winter season) to a low of 6,200 (2017-2018 winter season). The higher the CFDD the colder the winter. However, a higher CFDD doesn't necessarily equate to a longer winter. Figure 4.1 presents the historical CFDD from 2002 to 2021. The 2020-2021 winter was on the colder end of the data set spectrum.

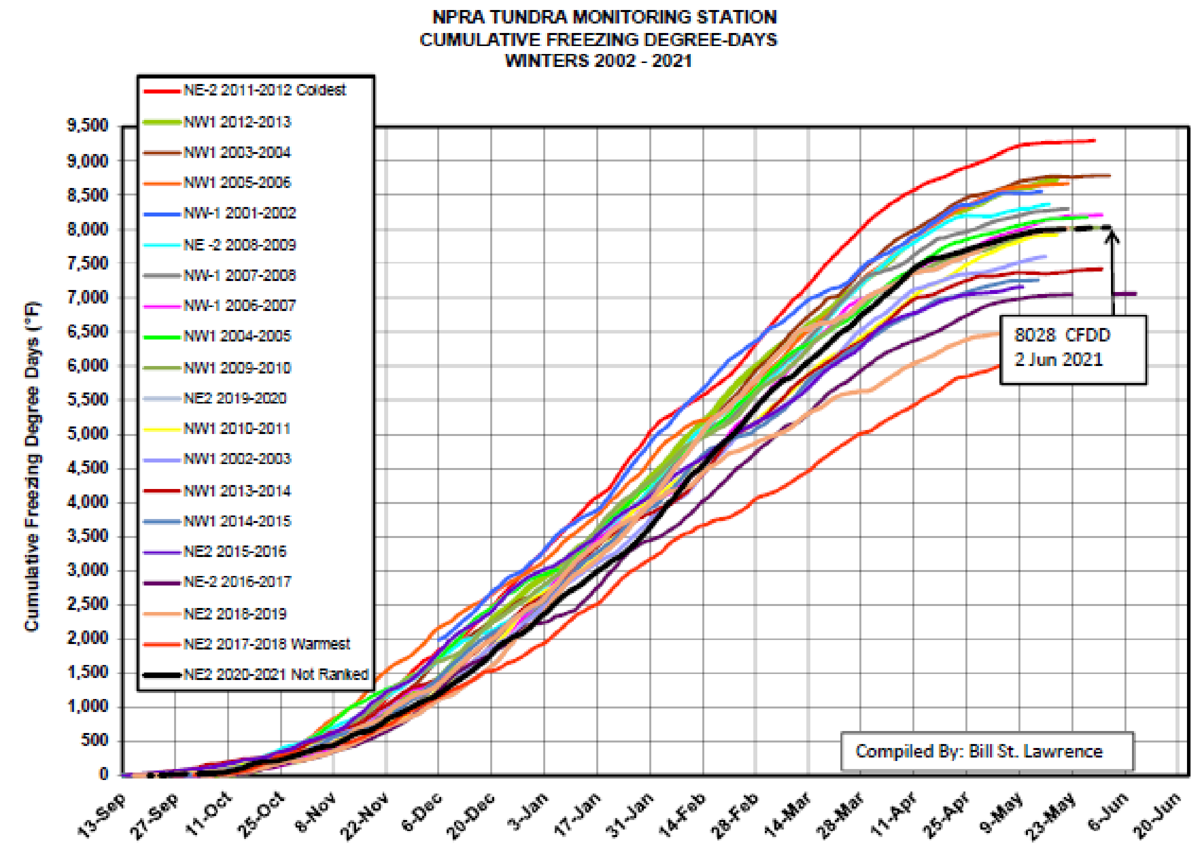


FIGURE 4.1: CUMULATIVE FREEZING DEGREE-DAYS 2002 - 2021

The air temperature CFDD index correlates with:

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 surface distance between the outer most edges of ice across a water body. The initial length of the span of ice at the proposed OPIB crossing location on February 17th was approximately 1,000 ft. It was difficult to establish the precise edges of the ice since the interfingering of ice and sediments made it difficult to establish the exact edge location. Generally, the river ice was blown clean and snow depths tended to be less than 0.1 ft.

4.3 Natural Ice Growth

Table 4.1 presents the ice natural ice thickness and ice growth rate at the proposed OPIB site over the course of the five field visits. The ice growth rate is not shown after March 23rd since the crossing became grounded. Natural river ice growth rates depend on air and water temperatures, water velocity, overflow, wind speed and direction, snow cover, and ice thickness. Historically, natural ice growth after mid-April is relatively low. This is primarily due to the increase in average daily temperatures and solar radiation. As a result, the reduction in natural ice growth may make ice bridge repairs and construction difficult during this timeframe.

TABLE 4.1: NATURAL ICE THICKNESS AND GROWTH RATE - 2021

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)
February 17th	4.5	0.028*	0.20*
March 10th	5.1	0.029	0.20
March 23rd	5.3	0.015	0.11
April 7th	†	†	†
April 21st	†	†	†

**Day 1 is set to the first day that CFDD > 1 (September 10, 2020)*

†Crossing is grounded

4.4 Span Of Free Water

The span of free water is the distance between the edges of water below the ice. Figure 4.2 provides an illustration of the span of free water.

Table 4.2 presents the length of the free water span during each of the five field visits. As the ice thickness increases the span of free water length and column thickness decreases.

By the time of the April 7th field visit, the natural ice had grounded across the alignment. It is possible that small pockets of flow were present under the ice but were not detected with the 50-foot ice profile intervals.

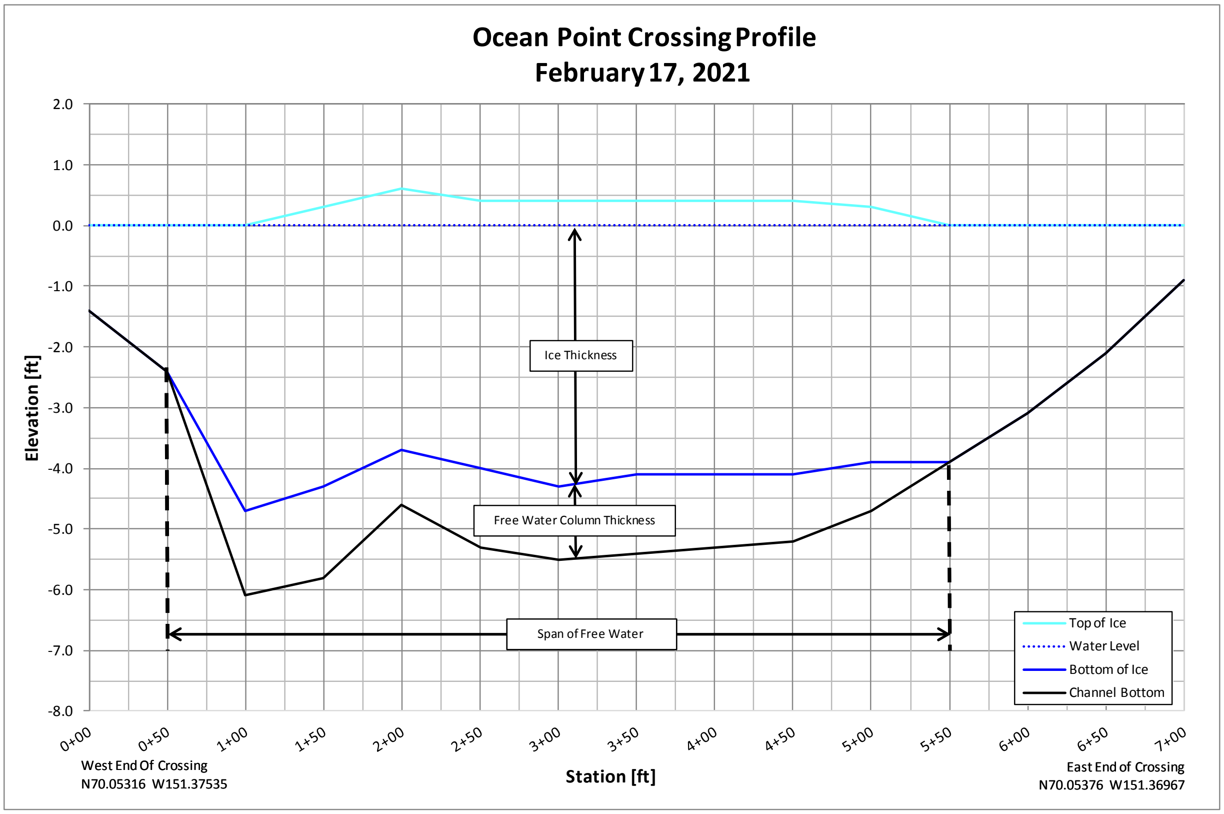


FIGURE 4.2: ICE PROFILE AND SPAN OF FREE WATER AREA

TABLE 4.2: SPAN OF FREE WATER

Field Visit Date	Span Of Free Water Length (feet)	Maximum Free Water Column Height (feet)
February 17th	500	1.5
March 10th	200	0.7
March 23rd	*100**	0.3
April 7th	†	†
April 21st	†	†

**Single location along ice profile was not grounded; additional ice profiles were conducted 200 feet upstream and downstream parallel to the alignment and were grounded*

†Crossing is grounded

ICE

4.5 Discharge Measurements

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

TABLE 4.3: MBI DISCHARGE MEASUREMENTS

Field Visit Date	Discharge (ft^3/s)	Discharge (gpm)	Average Velocity (ft/s)
February 17, 2021	13.8	6,200	0.03
March 10, 2021	0.7	300	0.01

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 groundwater and springs.

4.6 Winter Water Depths

Generally, water depth in a river decreases as the tributary discharge decreases with the onset of freeze-up. This was the case with Ocean Point location for the winter of 2020-2021. However, this was not the case during the winter of 2019-2020 (ICE 2020).

Figure 4.3 presents the water levels at the OPIB crossing as measured by the PTs. The water levels began to decrease about 4 days after the PT installation on February 17th. The US PT froze around March 17th and then thawed around April 13th. The data recorded during this timeframe is not representative of the water level but the pressure induced onto the PT by the expanding freezing water - ice. Similarly, the DS PT froze around April 2nd and was removed from the channel before it had a chance to thaw in-situ. The reason for the differences in freeze dates may be attributed to differences in water velocities, relative snow cover, water chemistry, and distribution of flow within the braided channel. Overall water depths measured by the PTs were less than 5.0 ft with the maximum 5.2 ft recorded during the installation of the PTs on February 17th.

Table 4.4 presents the maximum water depths at the OPIB location measured during the ice profiles. The maximum water depths decreased with each successive field visit. Once the ice became grounded water depths could not be measured. A study of all the possible water variations is beyond this report.

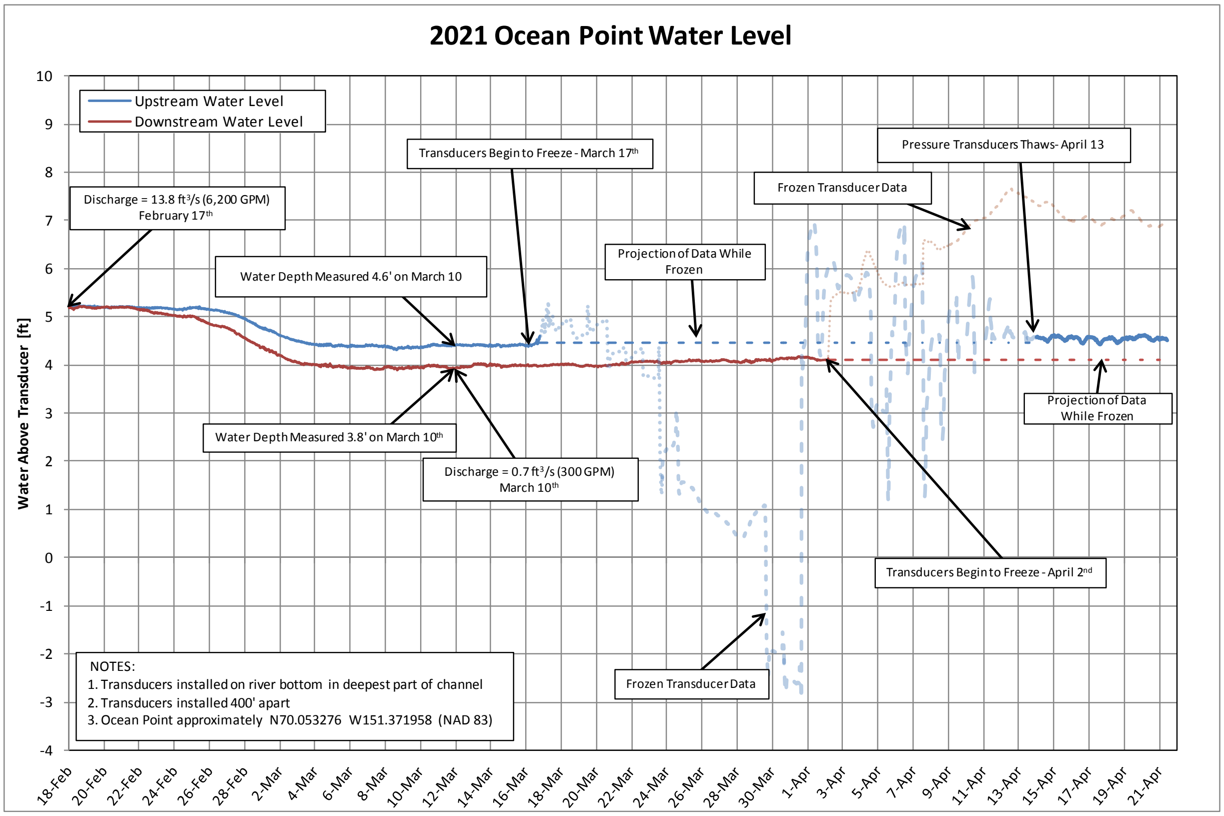


FIGURE 4.3: WATER DEPTHS AT THE PROPOSED OCEAN POINT CROSSING

TABLE 4.4: MAXIMUM WATER DEPTHS ALONG ICE PROFILE ALIGNMENT - 2021

Field Visit Date	Maximum Water Depth (feet)	Station	Notes
February 17th	6.1	1+00	9 locations along ice profile not grounded
March 10th	5.4	1+50	2 locations along ice profile not grounded
March 23rd	5.1	2+50	1 location along ice profile not grounded
April 7th	-	-	Crossing grounded
April 21st	-	-	Crossing grounded

4.7 Water And Air Temperatures

Water and air temperatures were recorded at Ocean Point. Figure 4.4 presents the river bottom water temperatures recorded at 15 minutes intervals. Figure 4.5 presents the average daily air temperature as recorded at the DS-2P weather station. The DS-2P weather station is located approximately 21.5 miles east of Ocean Point. What is noteworthy within the data set are the following:

1. The below freezing temperatures recorded by the transducers. This is consistent with the grounded ice profiles conducted after March 23rd.
2. The thermal drill created temperature spikes as a result of hot water being used to drill through the ice are evident on Figure 4.3.

3. Average daily air temperatures stayed below freezing between February 17th and April 21st.

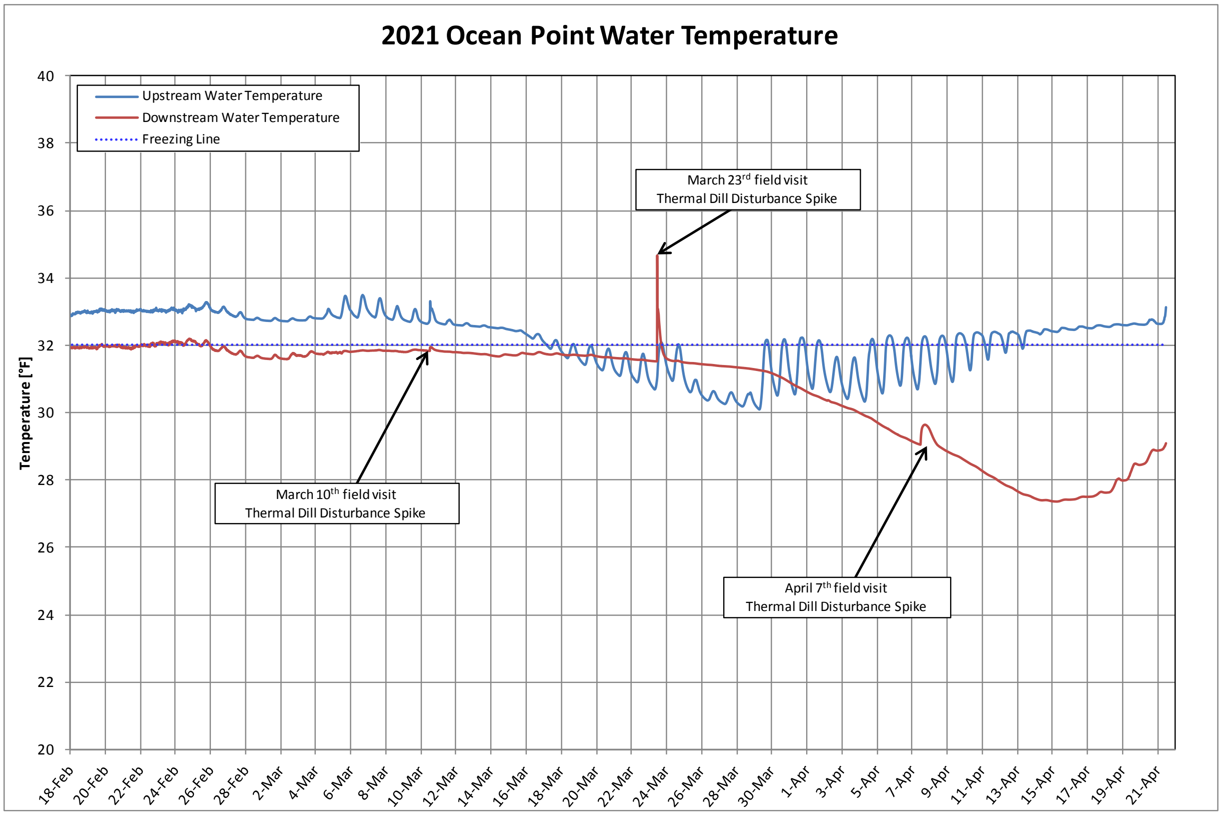


FIGURE 4.4: RIVER WATER AND ICE TEMPERATURES AT OCEAN POINT

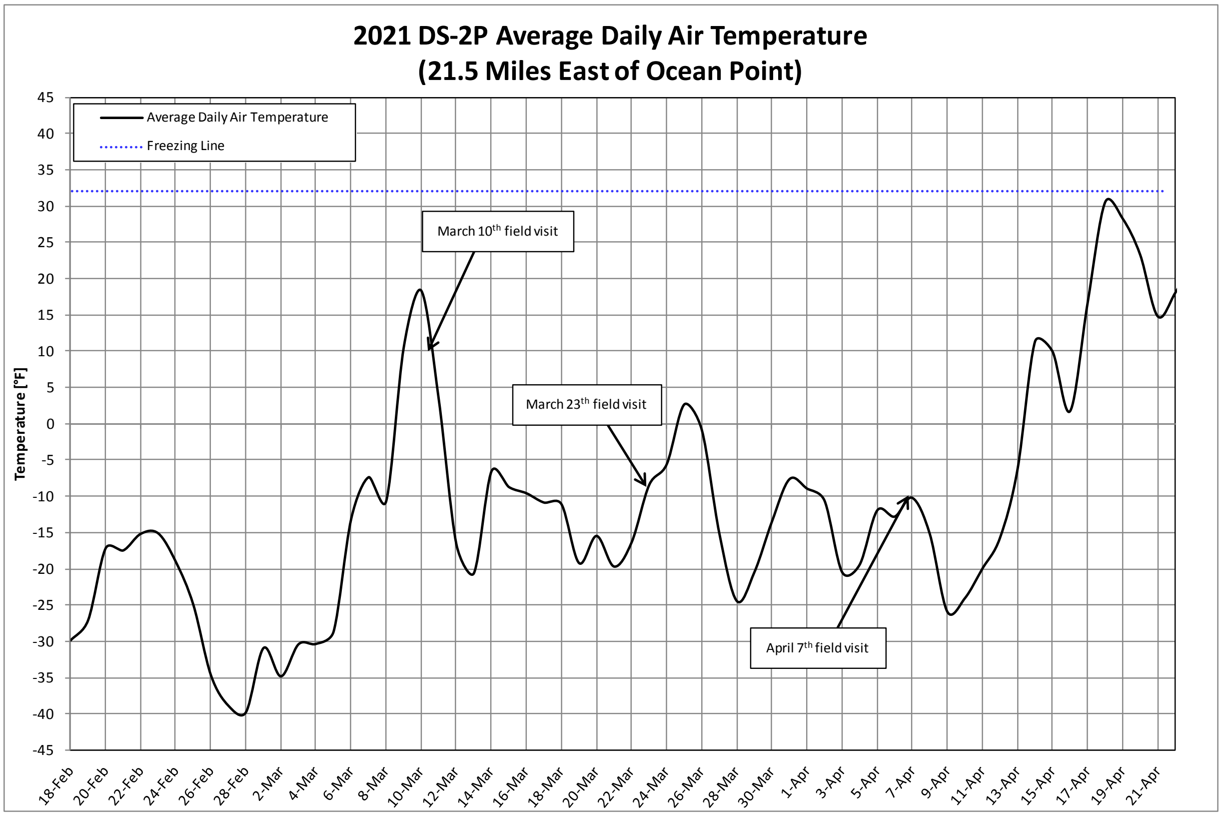


FIGURE 4.5: AVERAGE DAILY AIR TEMPERATURES DRILL SITE 2P WEATHER STATION

4.8 Overflow Considerations, Characteristics, and Observations

Unlike the 3 overflow events during the previous winter (ICE 2020), overflow events were not apparent within the PT data record (Figure 4.3). Furthermore, evidence of overflow events was not observed during the 5 field visits.

A unique design consideration for the proposed 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.

Generally, in 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 transition 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 increases in frequency and magnitude. The river ice becomes firmly grounded along the edges of the river and the cross-sectional area of free water is substantially reduced. 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 and warmer air temperatures. Overflow from snowmelt tends to result in ponding and minimal flow. Generally, there is no potential for runoff during this time period. The Colville River runoff normally occurs May.

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 2020–2021 investigation (Section 4) and the topographic survey conducted by Umiaq survey in August 2021. Future revisions will be issued as more information is obtained about the crossing. The revised ice bridge design (Appendix E) includes two main ramps into and out of the river floodplain.

5.1 ICE BRIDGE CONSTRUCTION QUANTITIES

Table 5.1 presents a summary of the in-place ice volume of the completed OPIB based on the most recent information. The ice quantities represent ice or water that must be mined, hauled, and placed for the completion of the ice bridge. The total takes in to account the typical natural ice thickness that will be present at the crossing at the commencement of construction. The average maximum natural floating ice thickness is expected to be between 4 and 5 ft by February 1st.

TABLE 5.1: SUMMARY OF OPIB ICE QUANTITIES

Ice Structure	Ice Quantity (yd^3)
West Ramp	15,100
East Ramp	23,200
Area Between East/West Ramps Including Buildup Ice Over River Channel	26,400
***TOTAL =**	**64,700**

**The water equivalent quantity is 11.7 million gallons*

The increase in construction quantities from the previous bridge design is driven primarily by the recently surveyed elevations of the tops of the east and west banks.

5.2 EMERGENCY BYPASS ROAD AND RAMPS

An emergency bypass road and ramps will be constructed on the downstream side of the ice bridge and ramps. These roads will provide emergency access around the SPMTs while they are crossing the OPIB. The emergency bypass roads are not designed for supply traffic or 'go-arounds' while the SPMTs are traversing the OPIB. Specific design details of the emergency bypass road 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 is needed regarding water discharge and water levels in the vicinity of the Ocean Point between the months of February and mid-April.
4. The crossing has the potential to naturally ground.

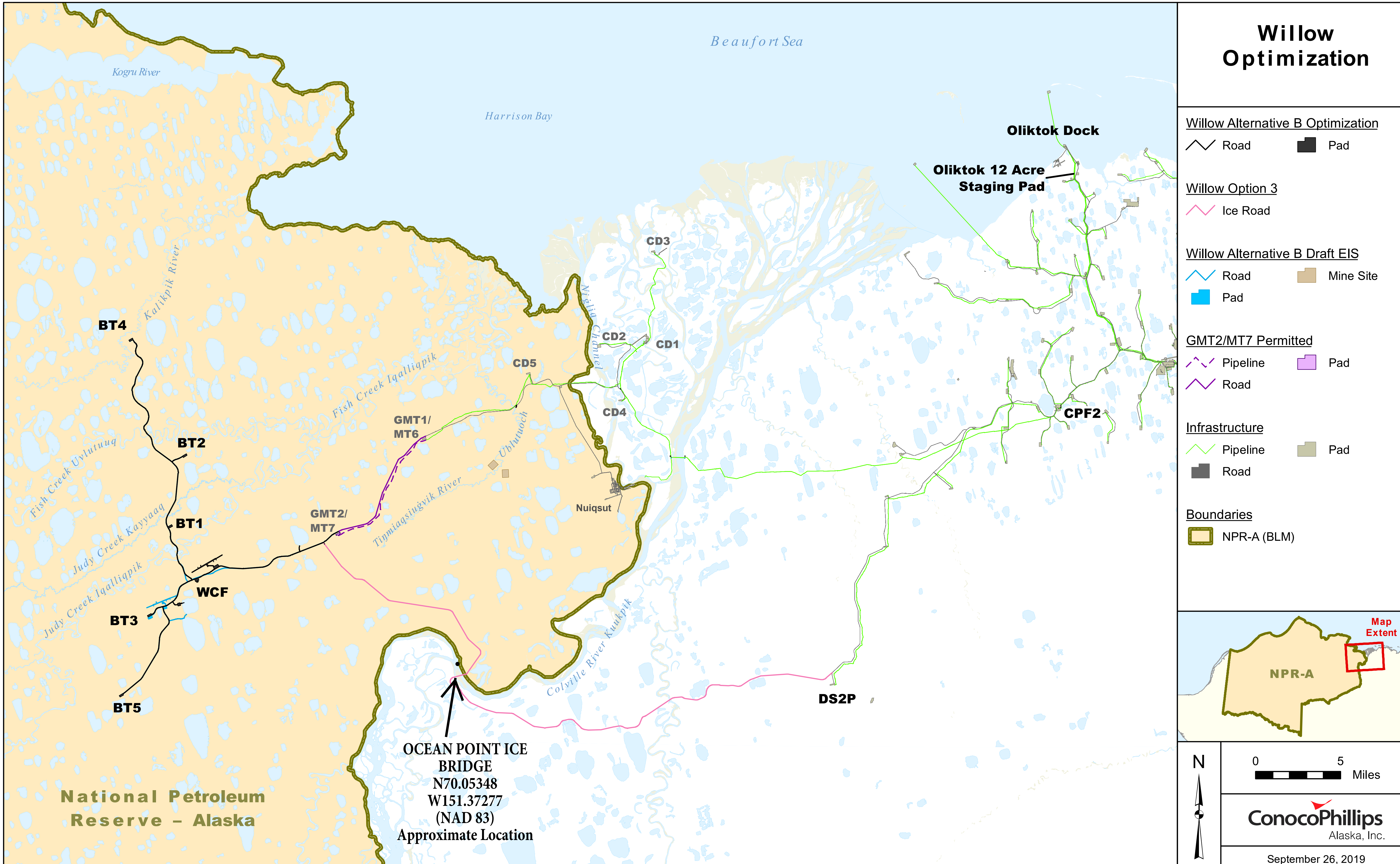
6.2 Recommendations

1. MBI should conduct weekly discharge measurements at the OPIB from mid-February to mid-April during the winter of 2021–2022.
2. Ice profiles should be conducted every two weeks at the OPIB from mid-February to mid-April during the winter of 2021-2022.
3. Delay any geotechnical investigation at the crossing until 2023-2024; this task may not be necessary.
4. Continue to install remote monitoring sites at the OPIB to collect water level, air temperature, and air pressure throughout the winter of 2021-2022.
5. Expand the topographic survey of the river banks US and DS of the proposed OPIB crossing alignment during the late fall of 2022 (early September).
6. Collect bathymetry at the OPIB during the late fall of 2022.

7 References

Innovative Civil Engineering, Design, Consult (ICE). 2020: *2019 – 2020 Willow Development Ocean Point Ice Bridge Revision*, Prepared for ConocoPhillips Alaska, Inc.

Appendix A
- Willow Optimization Option 3



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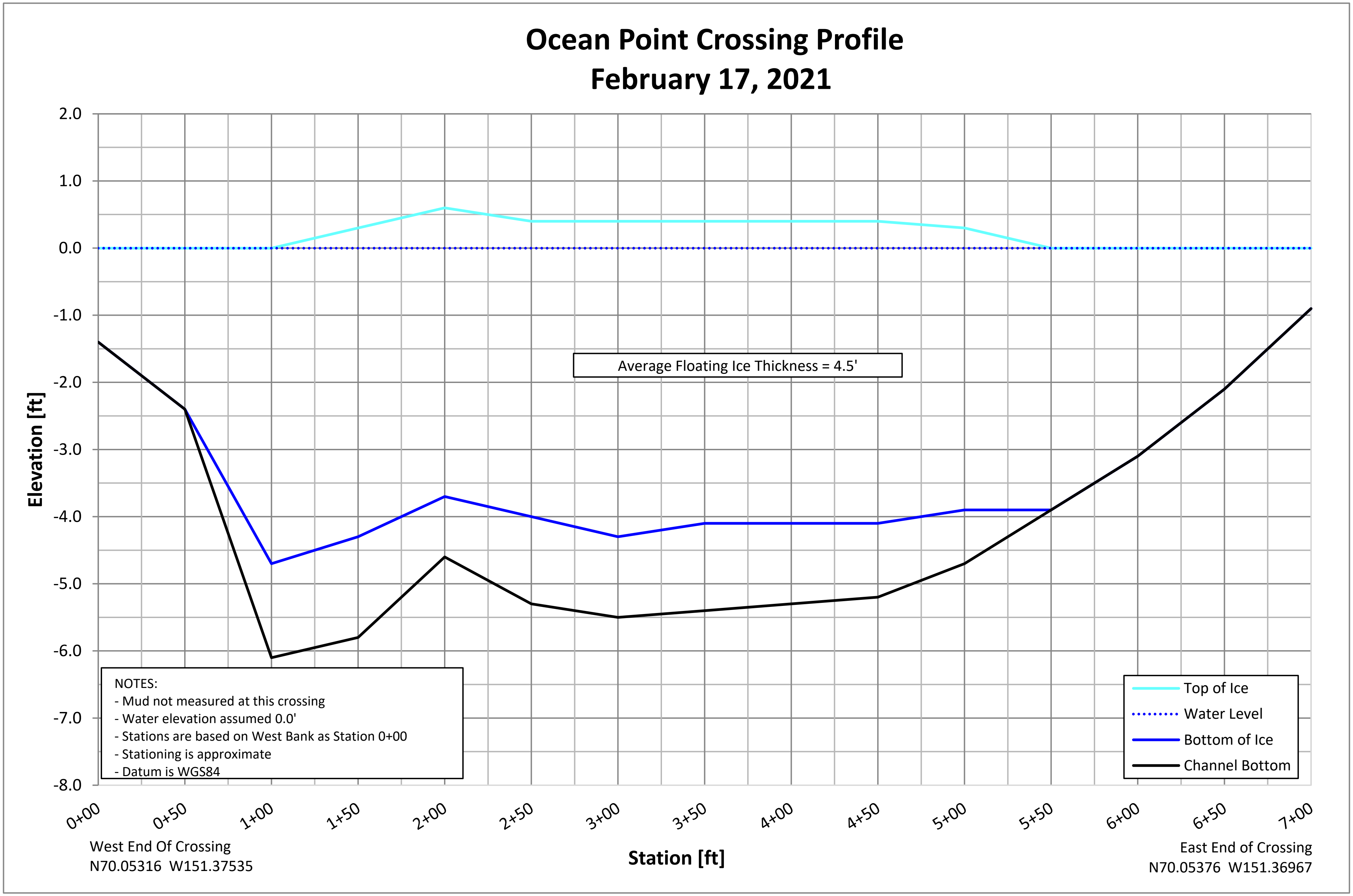
Appendix B
- ICE PROFILES

Submitted By: M. Hendee
Conducted By: ICE Design Group



Submitted By: M. Hendee
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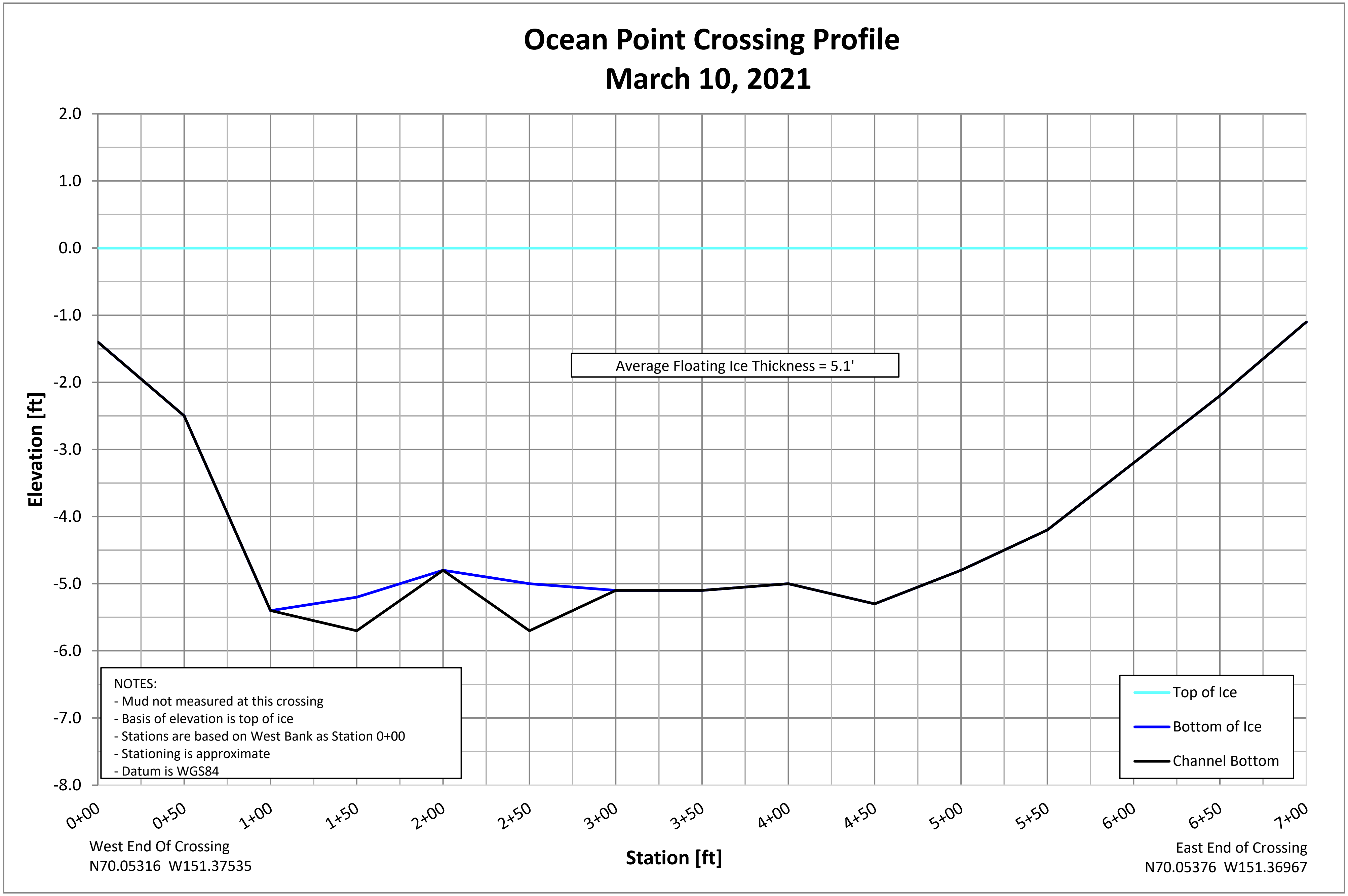

Submitted By: M. Hendee
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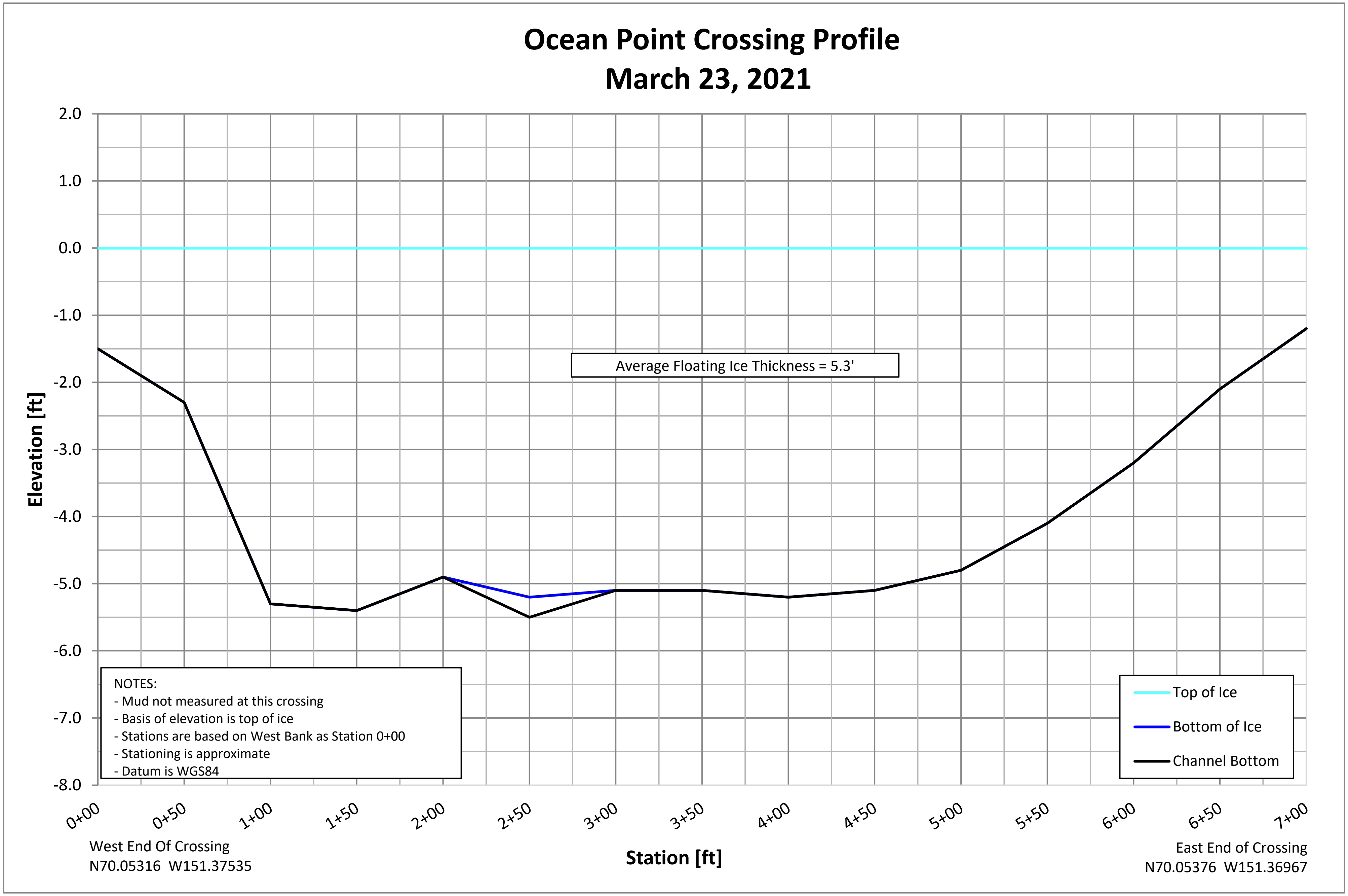
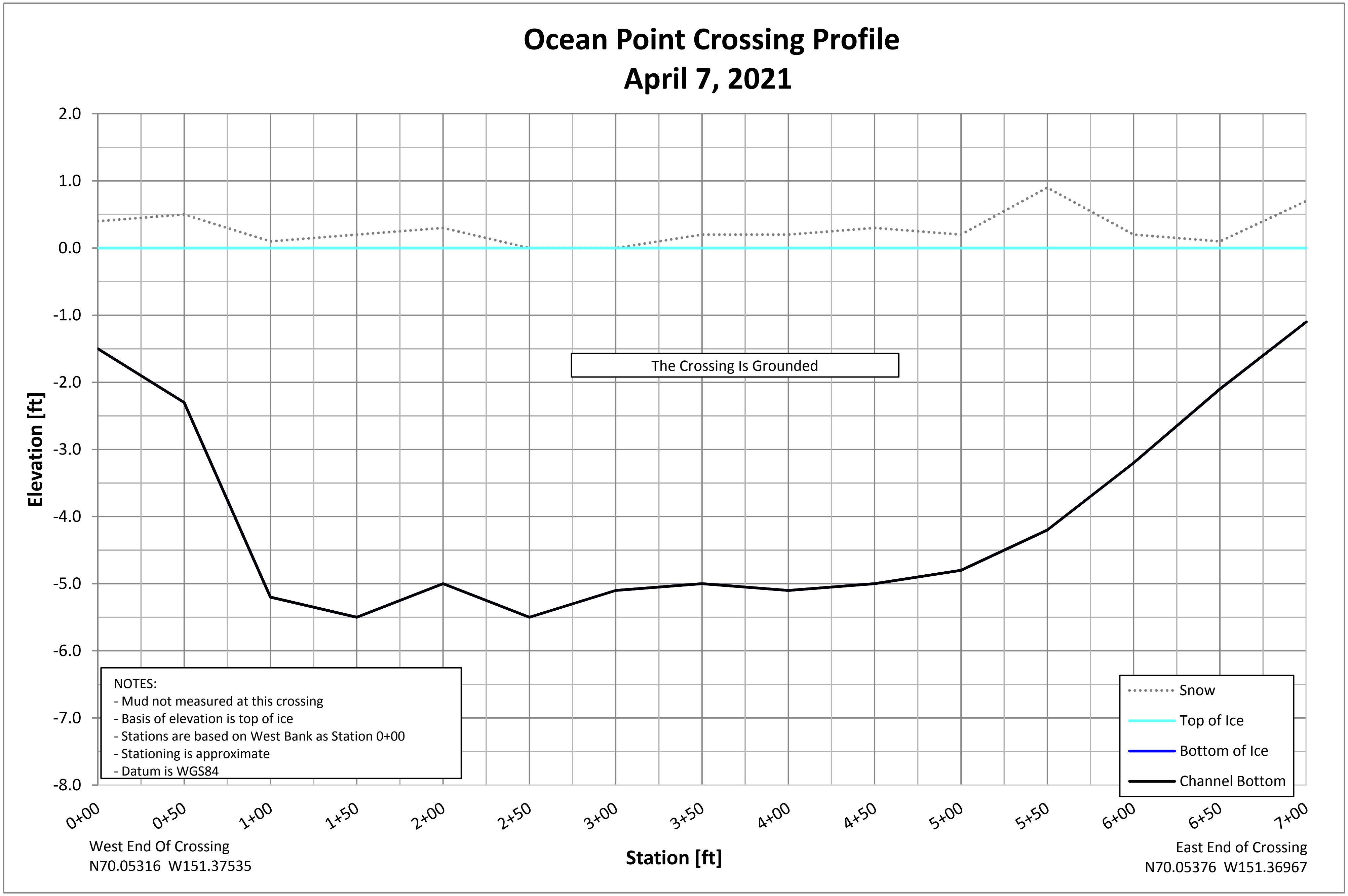
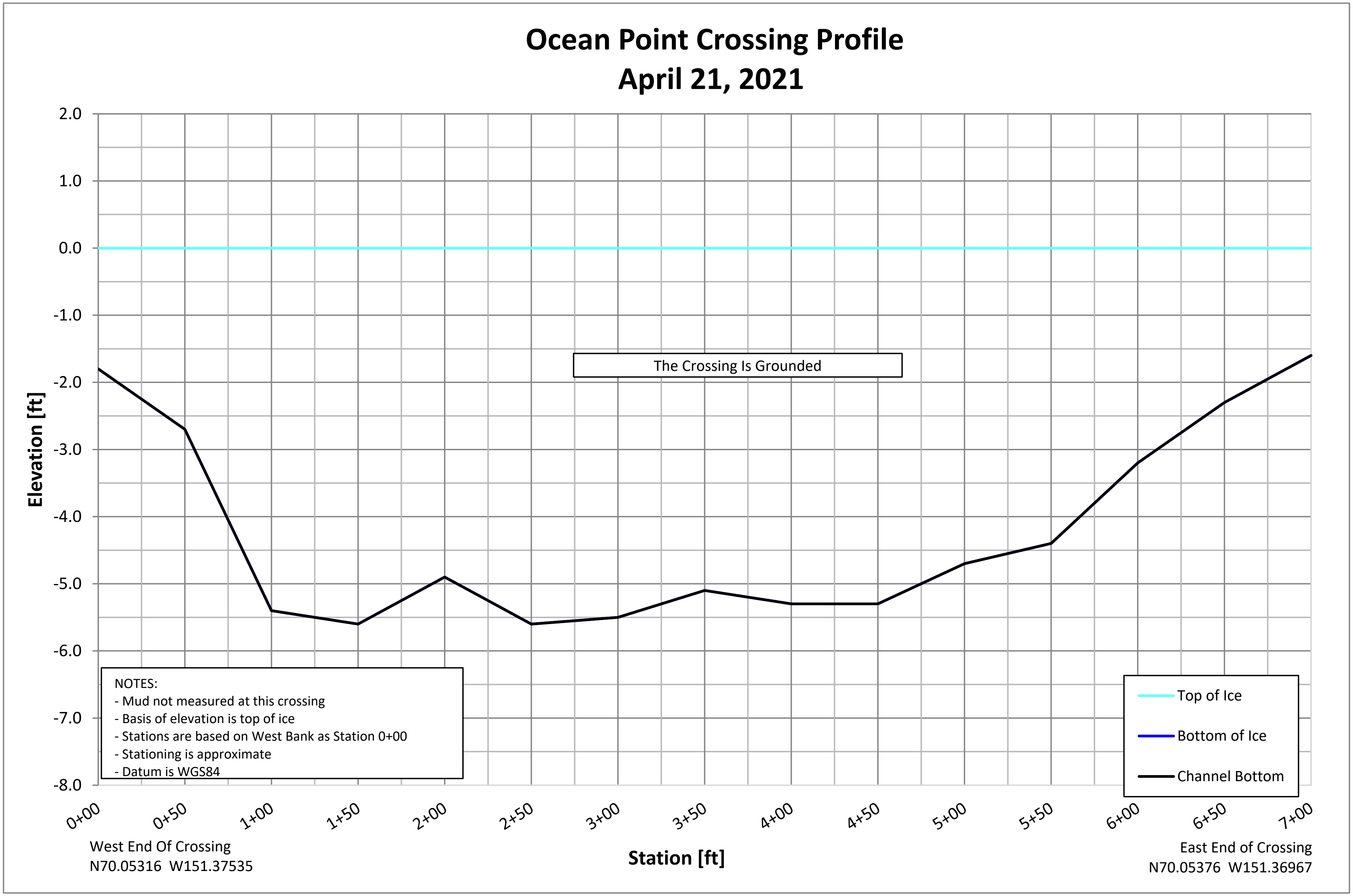


Submitted By: E. Keib
Conducted By: ICE Design Group



Submitted By: M. Hendee
Conducted By: ICE Design Group



Appendix C

- MBI Willow Ice Road – Ocean Point Water Resources Field Investigation

2021

Summary Report

Ocean Point
Discharge and Water Quality

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ACRONYMS & ABBREVIATIONS

% sat	percent saturation
°C	degrees Celsius
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
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
UMIAQ	UMIAQ, LLC
USGS	United States Geological Survey
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). The proposed ice road crossing of the Colville River was investigated at Ocean Point. During winter of 2021, data was collected in four field events. This report summarizes the methods and results of that effort.

ICE Design & Consult (ICE), Peak, and UMIAQ, LLC (UMIAQ) provided support during the field program and contributed to a safe and productive field season.

2.0 CROSSING LOCATION

The Ocean Point Upstream transect near Ocean Point was investigated this year and is shown in Figure 1. This transect was selected based on shallow water depths relative to the other transects investigated in previous years. Ocean Point Upstream (also historically referred to as “Transect #1”, the “Rolligon crossing”, the “west crossing”, the “upstream crossing”, “Ocean Point South”) is an historic ice and snow road crossing location. It was the location of a snow road during the 2018-2019 season and an ice road crossing for Cruz Construction during the 2020-21 season. This is the preferred proposed crossing location.

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

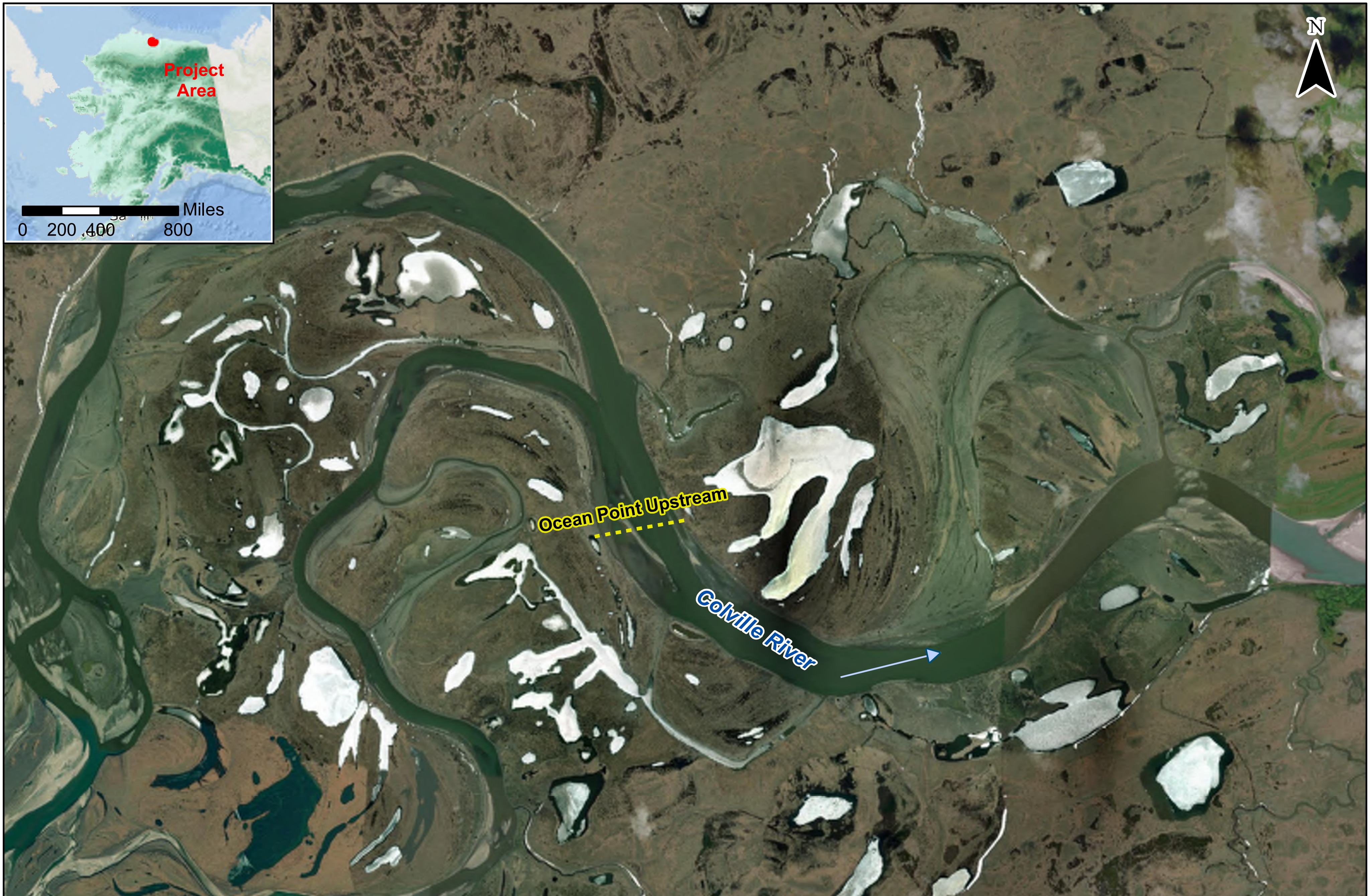
Table 1: Field Events

Data Collection	Ocean Point			
	2/17/2021	3/10/2021	4/8/2021	4/21/2021
discharge	✓[1]	✓	Grounded Channel Ice	Grounded Channel Ice
water quality		✓		
water surface elevation survey		✓		

1. Discharge estimated based on limited field measurements

Table 2: Data Collected

Data Collected		Units	
Discharge	water depth	feet	ft
	water depth, under ice	feet	ft
	ice thickness	feet	ft
	snow depth	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



ConocoPhillips Alaska

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Date:	8/31/2021	Scale:	1 Inch = 1 miles
Drawn:	DTR	Project:	183014
Checked:	ALS	File:	OceanPointUS&DS.mxd

Transect

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

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2021
Ocean Point Discharge Upstream & Downstream Transects

FIGURE 1

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 2020 Health, Safety, and Environment Plan (Michael Baker 2020a) and the 2020-2021 Winter Hydrology Programs – Job Safety Analysis (Michael Baker 2020b).

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 measurable cross-section since velocity measurements are limited to only where holes are drilled through the ice. It is assumed that the cross-sectional area is reasonably uniform upstream, downstream, 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.

Four field trips were performed to investigate the trend in discharge and water quality over the course of the ice-cover season. The ice-cover season typically initiates with freeze-up in mid-October and ends with spring breakup in mid-May. Ice-cover field events were one day apiece. The trips ranged from Mid-February to the end of April.

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

Thermal drill probing was performed by ICE to identify the extents of under-ice water bounded by ice grounded against the channel bed. Water measurements were facilitated by mechanically drilling through the river ice. 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. This was attached to a fixed rod and lowered to 0.6 the water depth below the ice. In-situ water quality measurements were collected at the deepest section. Field crew used a YSI ProSolo meter to collect temperature, conductivity, salinity, and dissolved oxygen. Measurements were taken at multiple depths throughout the water column, if possible.

Photo 3.1: Crew setting up GPS at Ocean Point; 2/17/21

Previously submitted ice cover season field data is provided in Attachment A.

4.0 RESULTS AND CONCLUSIONS

A summary of Colville River Ocean Point water resources information collected during the 2020-2021 winter field season is provided below. No overflow, aufeis, or evidence of any other notable hydraulic occurrence was observed at the transect during the ice-cover field events. Discharge decreased as the ice-cover season progressed.

4.1 DISCHARGE MEASUREMENTS

The first field event occurred on February 17. ICE profiled the crossing and Michael Baker measured velocity through 3 holes before both transport vehicles experienced mechanical issues in the cold temperatures. The trip was aborted before all data was collected. The average velocity was applied to the profile ICE collected to get an estimated discharge of 13.8 cfs.

The second trip occur on March 10th. The field crew was able to collect discharge and water quality measurements at the crossing. This included under-ice cross-sectional bathymetric profiles, discharge, velocity, water depth, ice thickness, water surface elevation, site conditions related to overflow, and in-situ water quality. The channel ice was grounded out in the middle of the channel creating 2 flow paths. The discharge was measured at 0.7 cfs.

On the third and fourth trip, April 8th and April 21st, the channel ice was completely grounded, leaving no liquid water. Colville River discharges measured at Ocean Point are provided in Table 3.

Table 3: Colville River Discharge Summary

Date	Ocean Point Upstream					
	Average Ice Thickness (ft)	Average Water Depth Under Ice (ft)	Effective Width (ft)	Average Velocity (ft/s)	Measured Discharge (cfs)	Rating
2/17/2021	4.6	1.1	450	0.03	13.8[1]	poor
3/10/2021	5.0	0.4	118	0.01	0.7	poor
4/8/2021	-[2]					
4/21/2021	-[2]					
Notes:						
1. Water velocity was averaged to estimate discharge.						
2. Channel was grounded out by ice.						

4.2 WATER QUALITY MEASUREMENTS

Water quality measurements were collected on March 10th. Slightly elevated salinity and conductivity measurements suggest this location may have had minor coastal influence this year. Though this year's values show an increase from 2019-2020 ice-cover seasons (average conductivity was 257 μS/cm), results are at the upper limits of freshwater. This year, the brackish water moved up the Colville River sooner than past years. The dissolved oxygen measurement was typical of water bodies under the influence of ice cover because ice prevents the introduction and mixing of atmospheric oxygen into the water.

Table 4: Colville River Ocean Point Water Quality Summary

Date	Ocean Point Water Quality						
	total depth (ft)	temperature (°C)	conductivity (µS/cm)	specific conductance (µS/cm)	dissolved oxygen (mg/L)	dissolved oxygen (%)	salinity (ppt)
2/17/2021	-[1]						
3/10/2021	4.6	-0.1	509	1,002	4.4	30.4	0.47
4/8/2021	-[2]						
4/21/2021	-[2]						

Notes:

1. Aborted measurement due to vehicle issues.
2. Channel ice was grounded out.

5.0 REFERENCES

Michael Baker International (Michael Baker). 2020a. North Slope Water Resources 2020 Health, Safety, and Environmental Plan. Prepared for ConocoPhillips Alaska, Inc.

——— 2020b. 2020-2021 Winter Hydrology Programs – Job Safety Analysis. Prepared for ConocoPhillips Alaska, Inc.

Miller, R.L., Bradford, W.L., & Peters, N.E. 1988. Specific Conductance: Theoretical Considerations and Application to Analytical Quality Control. United States Geological Survey. https://pubs.usgs.gov/wsp/2311/report.pdf

United States Geological Survey (USGS). 2006a. National Field Manual for the Collection of Water-Quality Data, Book 9 Handbooks for Water-Resources Investigations, Chapter A4 Collection of Water Samples. https://water.usgs.gov/owq/FieldManual/

——— 2010. Turnipseed, D.P., and Sauer, V.B., Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8, 87 p. (available online at http://pubs.usgs.gov/tm/tm3-a8/)

——— 2020. Gage USGS 15875000 COLVILLE R AT UMIAT AK discharge data. Website access May 6, 2020. https://waterdata.usgs.gov/nwis/uv?site_no=15875000.

YSI Incorporated. 2020a. YSI ProSolo User Manual. https://www.ysi.com/File%20Library/Documents/Manuals/ProDIGITAL-User-Manual-English.pdf

Attachment A Field Data

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Location Name: Colville River at Ocean Point - Transect #1 Date Collected: 2/17/2021

Field Party: S. Orizotti, Roy Baldwin (UMIAQ) Computed By: D. Roe Checked By: D. Roe

Start Time: 12:15 Finish Time: 14:30 Weather: winds 10 mph Temp: -34 °F

Channel Characteristics: Effective Width: 450 ft Average Velocity: 0.03 fps

Effective Area: 495 sq ft Discharge: 13.8 cfs

Measurement Details: Method: Midsection; 0.6 depth Number of Sections: 10

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

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: Ice grounded out from stations 0+00 to 0+50 and 5+50 to 7+00. Velocity measurements were taken at 1+00, 1+25, and 1+50 before vehicle issues halted work. Measurement was aborted and field crew left for safety. Ice design was able to profile the crossing before aborting. The average velocity of 0.03 was applied to the rest of crossing to estimate discharge. Survey was not completed due t vehicle issues.

Calculation Notes: Average velocity adjusted by coefficient of 0.92 to account for measurements collected at 0.6 feet of depth

Colville River at Ocean Point Transect #1
Date Collected: 02/17/2021

Distance from initial point (ft)	Total Depth (ft)	Ice Thickness (ft)	Freeboard (ft)	Measurement Depth Below Top of Ice (ft)	Effective Depth (ft)	Section Width (ft)	Effective Area (ft^2)	VELOCITY V1 (fps)	V2 (fps)	V3 (fps)	Average V (fps)	Adjusted Average V (fps)	Discharge (cfs)
0+00	1.4	1.4	grounded										
0+50	2.4	2.4	grounded										
1+00	5.3	4.7	0.1	5.1	0.6	37.5	22.5	0.02	0.02	0.00	0.01	*0.01*	**0.3**
1+25	6.5	5.0	0.2	5.9	1.5	25.0	37.5	0.04	0.05	0.03	0.04	*0.04*	**1.4**
1+50	5.9	4.7	0.2	5.4	1.2	37.5	45.0	0.03	0.04	0.03	0.03	*0.03*	**1.4**
2+00	5.2	4.3	-	4.8	0.9	50.0	45.0	-	-	-	0.03	*0.03*	**1.2**
2+50	5.7	4.4	-	5.2	1.3	50.0	65.0	-	-	-	0.03	*0.03*	**1.8**
3+00	5.9	4.7	-	5.4	1.2	50.0	60.0	-	-	-	0.03	*0.03*	**1.7**
3+50	5.8	4.5	-	5.3	1.3	50.0	65.0	-	-	-	0.03	*0.03*	**1.8**
4+00	5.7	4.5	-	5.2	1.2	50.0	60.0	-	-	-	0.03	*0.03*	**1.7**
4+50	5.6	4.5	-	5.2	1.1	50.0	55.0	-	-	-	0.03	*0.03*	**1.5**
5+00	5.0	4.2	-	4.7	0.8	50.0	40.0	-	-	-	0.03	*0.03*	**1.1**
5+50	3.9	3.9	grounded										
6+00	3.1	3.1	grounded										
6+50	2.1	2.1	grounded										
7+00	0.9	0.9	grounded										
									Total Estimated Discharge:				**13.8**

Project Name: Ocean Point Discharge
Project Number: 183014

Field Personnel: S. Orizotti
Date Collected: February 17, 2021

Velocity Measurement

Location: Colville River Transect #1 near Ocean Point
Weather: -34°F, 10 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	West/Right Bank; N70.053213 W151.375216	1.4	grounded	-
0+50	-	2.4	grounded	-
1+00	-	4.7	0.6	0.01
1+25	-	5	1.5	0.04
1+50	-	4.7	1.2	0.03
2+00	-	4.3	0.9	0.03*
2+50	-	4.4	1.3	0.03*
3+00	-	4.7	1.2	0.03*
3+50	-	4.5	1.3	0.03*
4+00	-	4.5	1.2	0.03*
4+50	-	4.5	1.1	0.03*
5+00	-	4.2	0.8	0.03*
5+50	-	3.9	grounded	-
6+00	-	3.1	grounded	-
6+50	-	2.1	grounded	-
7+00	East/Left Bank; N70.053813 W151.369598	0.9	grounded	-

Survey: Vehicle issues arose before survey could commence.

Notes: Velocities were taken at station 1+00, 1+25 and 1+50. The average velocity was 0.03 ft/sec in that section and was applied to the other stations to estimate the discharge.

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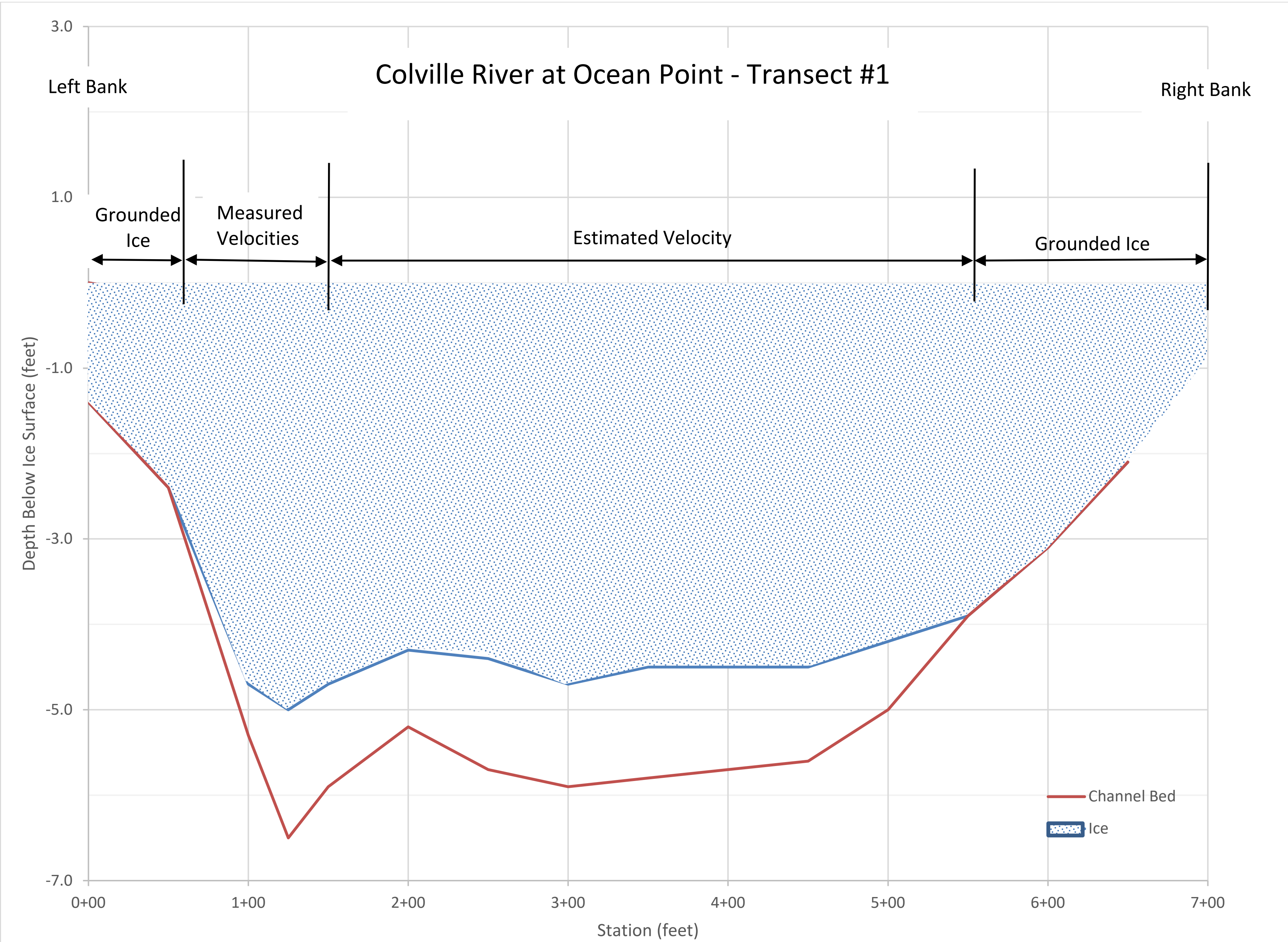

Colville River at Ocean Point - Transect #1
Left Bank
Right Bank
Grounded Ice
Measured Velocities
Estimated Velocity
Grounded Ice
3.0
1.0
-1.0
-3.0
-5.0
-7.0
Depth Below Ice Surface (feet)
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
Station (feet)
Channel Bed
Ice

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Location Name: Colville River at Ocean Point - Transect #1   Date Collected: 3/10/2021

Field Party: K. Braun, J. Varga (UMIAQ)   Computed By: S. Orizotti   Checked By: D. Roe

Start Time: 11:17   Finish Time: 13:00   Weather: winds 15 mph, Sunny   Temp: 20 °F

Channel Characteristics:

Effective Width: 118 ft   Average Velocity: 0.01 fps

Effective Area: 55 sq ft   Discharge: 0.7 cfs

Measurement Details:

Method: Midsection; 0.6 depth   Number of Sections: 6

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 1+00	4.18 ft NAVD88	-	RTK survey

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

Descriptions:

From Field Notes: Ice grounded out from stations 0+00 to 1+00 and 3+00 to 7+00. Ice was not grounded out at station 2+50. Freeboard ranged from 1.0 to 1.4 feet below the ice.

Calculation Notes: Average velocity adjusted by coefficient of 0.92 to account for measurements collected at 0.6 feet of depth

Colville River at Ocean Point Transect #1
Date Collected: 03/10/2021

Distance from initial point	Total Depth	Ice Thickness	Freeboard	Measurement Depth Below Top of Ice	Effective Depth	Section Width	Effective Area	VELOCITY					Discharge
								V1	V2	V3	Average V	Adjusted Average V	
(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft^2)	(fps)	(fps)	(fps)	(fps)	(fps)	(cfs)
0+00	1.4	1.4	grounded										
0+50	2.5	2.5	grounded										
0+75	-	-	grounded										
1+00	6.0	5.5	1.4	5.7	0.5	25.0	12.5	0.00	0.00	0.00	0.00	*0.00*	**0.0**
1+25	5.7	4.9	1.4	5.4	0.8	25.0	20.0	0.00	0.02	0.04	0.02	*0.02*	**0.4**
1+50	5.7	5.2	1.0	5.5	0.5	20.0	10.0	-0.01	0.00	0.02	0.00	*0.00*	**0.0**
1+65	4.9	4.5	1.1	4.7	0.4	12.5	5.0	0.01	0.02	0.01	0.01	*0.01*	**0.1**
1+75	4.8	4.6	1.4	4.7	0.2	10.0	2.0	0.01	0.02	0.02	0.02	*0.02*	**0.0**
1+85	-	-	grounded										
2+00	4.8	4.8	grounded										
2+25	4.8	4.8	grounded										
2+50	5.4	5.2	1.4	5.3	0.2	25.0	5.0	0.08	0.01	0.02	0.04	*0.03*	**0.2**
2+75	-	-	grounded										
3+00	5.1	5.1	grounded										
3+50	5.1	5.1	grounded										
4+00	5.0	5.0	grounded										
4+50	5.3	5.3	grounded										
5+00	4.8	4.8	grounded										
5+50	4.2	4.2	grounded										
6+00	3.2	3.2	grounded										
6+50	2.2	2.2	grounded										
7+00	1.1	1.1	grounded										

Project Name: Ocean Point Discharge
Project Number: 183014

Field Personnel: K. Braun
Date Collected: March 10, 2021

Velocity Measurement

Location: Colville River Transect #1 near Ocean Point
Weather: 20°F, 15 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	West/Right Bank; N70.053213 W151.375216	1.4	grounded	-
0+50	-	2.5	grounded	-
0+75		-	grounded	
1+00	-	5.5	0.5	0.00
1+25	-	4.9	0.8	0.02
1+50	-	5.2	0.5	0.00
1+65		4.5	0.4	0.01
1+75	-	4.6	0.2	0.02
1+85	-	-	grounded	-
2+00	-	4.8	grounded	-
2+25		4.8	grounded	-
2+50	-	5.2	0.2	0.03
2+75		-	grounded	
3+00	-	5.1	grounded	-
3+50	-	5.1	grounded	-
4+00	-	5	grounded	-
4+50	-	5.3	grounded	-
5+00	-	4.8	grounded	-
5+50	-	4.2	grounded	-
6+00	-	3.2	grounded	-
6+50	-	2.2	grounded	-
7+00	East/Left Bank; N70.053813 W151.369598	1.1	grounded	-

Survey: Water surface elevation surveyed at station 1+00 = 4.18 ft NAVD88. Average ice elevation was 5.4 ft and the average water surface elevation was 4.1 ft.

Notes: All water columns were less than 0.8 feet deep. Velocity measurements were collected with a Hach electromagnetic velocity meter. Postive freeboard occurred between stations 1+00 through 1+75 and at 2+50, averaging 1.3' below the ice surface. Water quality parameters were taken at Sta 1+00.

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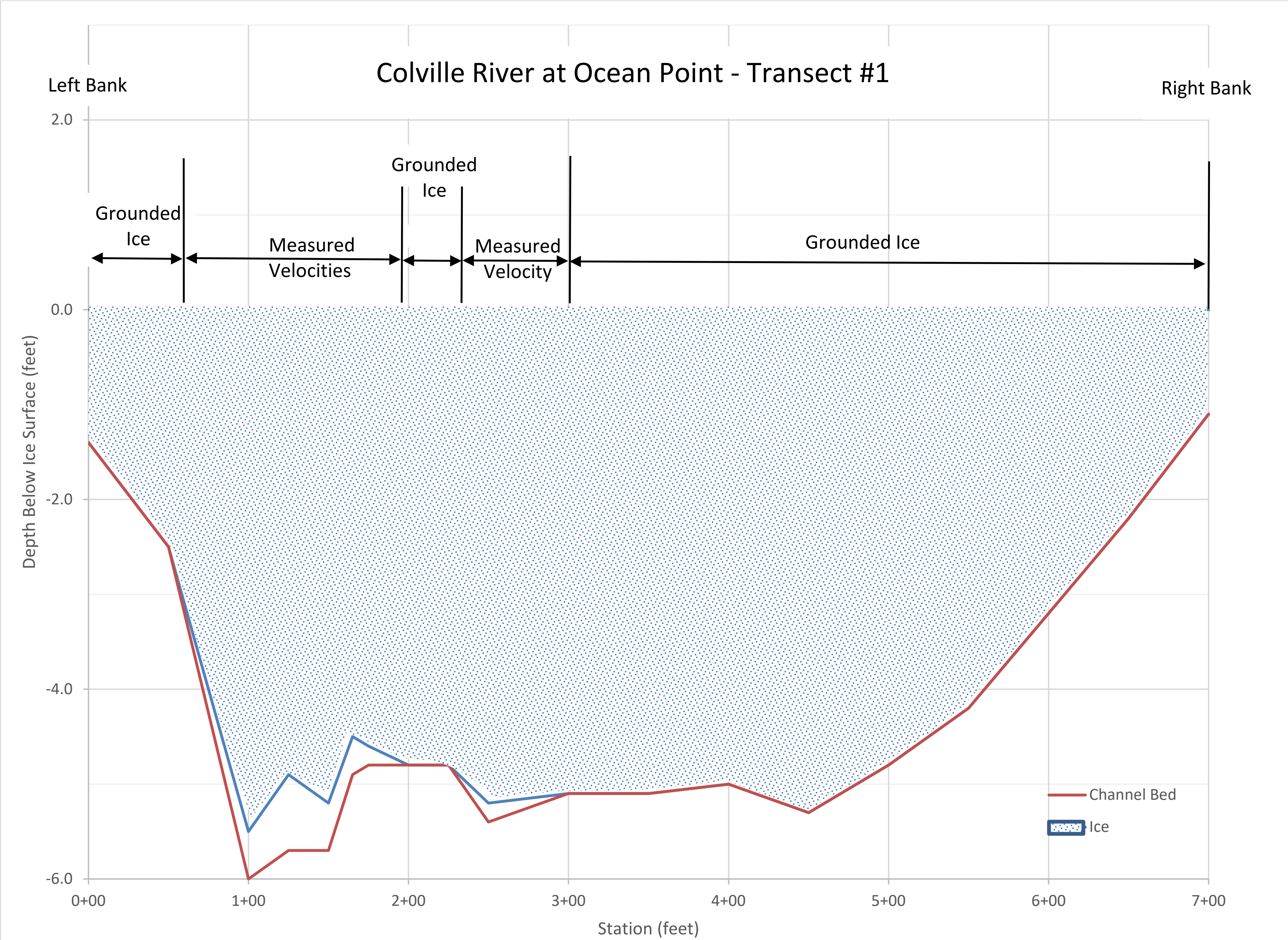
INTERNATIONAL


Colville River at Ocean Point - Transect #1
Left Bank
Right Bank
Grounded Ice
Measured Velocities
Grounded Ice
Measured Velocity
Grounded Ice
2.0
0.0
-2.0
-4.0
-6.0
Depth Below Ice Surface (feet)
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
Station (feet)
Channel Bed
Ice

Colville River at Ocean Point- Transect #1
Water Quality

Michael Baker INTERNATIONAL

Sample Date: **March 10, 2021**

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 1+00 N70.05329° W151.37445° 11:20 AM	4.6	5.5	1.4	4.0	-0.1	509	1,002	4.44	30.4	0.5

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, dissolved oxygen, and conductivity were measured using a YSI ProSolo meter.
(5) Specific conductance (referenced to 25°C) was obtained using a conversion coefficient of 0.0196 based on empirical data.
(6) Time shown indicates the start of the measurement.
(7) Temperature measurements have an accuracy of +/- 0.2ºC

4/7/21

Station	Ice	Depth	Effect depth	FB	Time	V_1	V_2	V_3	Notes
2+25	5.1	Ground							
~~[illegible]~~	4.5	ground							
2+25									
	~~Grounded~~								
2+60	5.3	Grounded							
~~[illegible]~~									
2+40	5.2	Grounded							

Grounded all the way across
drilled 4 extra holes where
water was last site visit
but grounded as well.

4/20/21

2005 ASRC Pit

Time collect	1235		
Time sample	1240		
Oily	sheen	yes	(NO)
Primary			
	Black	7.29	@ 0.8°C
	yellow	7.31	@ 0.6°C
Secondary			
	Black	7.2	@ 0.5°C
	yellow	7.5	@ 0.5°C

TDS

START	1645	
END	1745	
Result	0.0	mg/L

4/21/21

Prosolo		Cond	Temp	
	Pre	1286	17.2	
	cal	1413 (spc)		
	Post	1205	17.2	
		%	mg/L	Temp
	Pre	79.3	8.69	11.3
	cal	30.55 " hg		
	Post	78.1	8.68	10.7
BAKER		cond	temp	
	Pre	1285	17.7	
	cal	1413		
	Post	1215	17.7	
		%	mg/L	Temp
	Pre	82.6	8.80	12.6
	cal	30.55		
	Post	82.7	8.82	12.5

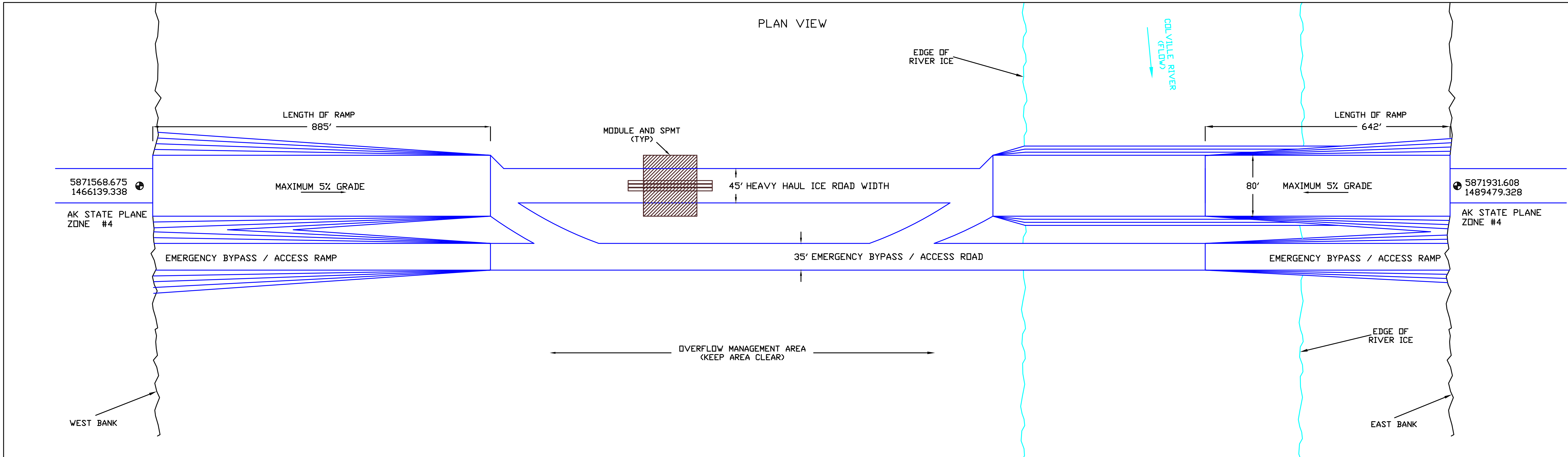
4/21/21

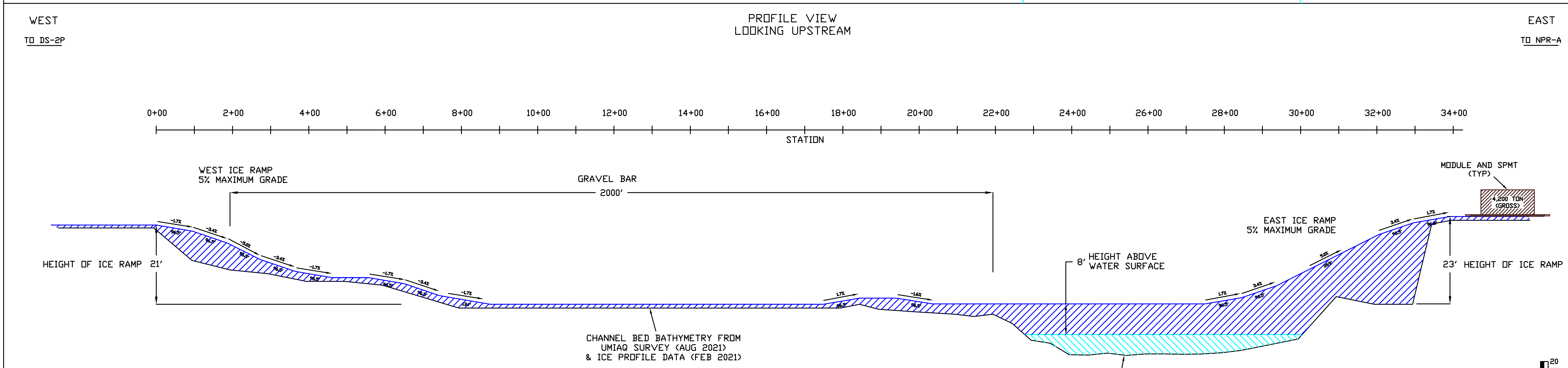
STA	Ice	Depth	Effect Depth	FB	Time	V_1	V_2	V_3	notes

Grounded @ all locations along crossing drilled by

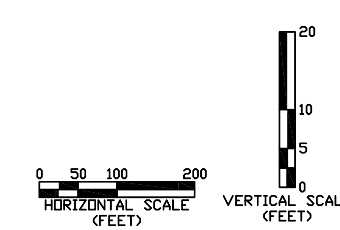
mike Hendee

Appendix D
- Ocean Point Ice Bridge Design Drawings





NOTES:
1. ALL DIMENSIONS AND STATIONING ARE APPROXIMATE
2. ICE BRIDGE CONSTRUCTION ASSUMED TO COMMENCE IN FEBRUARY
3. SPMT GRADE TRANSITIONS LIMITED TO A MAXIMUM OF 1.7% AND 96.5 FEET MEASURED HORIZONTALY; MAXIMUM ALLOWABLE GRADE OF 5%
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. BATHYMETRY BASED ON ICE PROFILE MARCH 10, 2021; TUNDRA ELEVATIONS BASED ON 2021 UMIAQ SURVEY 21-08-28-1W PROFILE.PDF
6. ACCESS ROADS AND RAMPS ARE INCLUDED FOR REFERENCE
7. THE HEAVY HAUL ICE BRIDGE WILL BE NON-GROUNDED; ESTIMATED AMOUNT OF FILL REQUIRED = 64.7K CU YDS (11.7 MGALS WATER EQUIVALENT)



PRELIMINARY

ICE DESIGN & CONSULT

PLAN / PROFILE
PROPOSED UPSTREAM SITE OCEAN POINT ICE BRIDGE
5% MAXIMUM GRADE
WILLOW DEVELOPMENT MODULES

DATE: 20200522	SCALE: AS SHOWN	REVISION: 2.0
DRAWN BY: EJK	SHEET SIZE: 11x17 LANDSCAPE	REVISION DATE: 20210909
CHECKED BY: WSTL; RIL; MKH	DRAWING NUMBER: PROPOSED UPSTREAM SITE OCEAN POINT ICE BRIDGE PLAN/PROFILE 5%	

DRAWING FOR: CPAI

PAGE: 1 OF 1