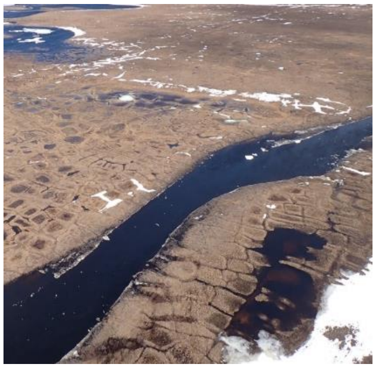
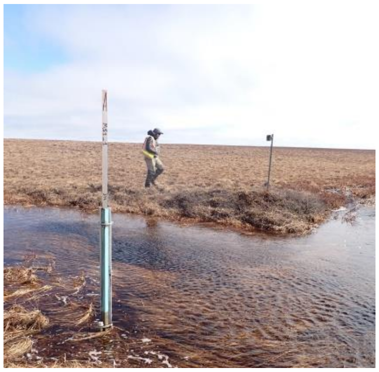
2020 Willow Spring Breakup and Summer Monitoring & Hydrological Assessment - Final





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Executive Summary

This report presents the results from the 2020 Willow Spring Breakup and Summer Monitoring and Hydrological Assessment conducted by Michael Baker International for ConocoPhillips Alaska. The monitoring and hydrological assessment supports the National Petroleum Reserve – Alaska Integrated Activity Plan by assessing the relative magnitude of spring breakup floodwater and summer hydrologic conditions. The analyses also provide data to support design and permitting.

Spring breakup typically occurs during a three-week period in May and June. The spring breakup event in larger rivers including Fish Creek, Judy Creek, and the Kalikpik River, historically produces flooding, and rapid rise and fall of stage can occur as the result of ice jam formation and release. Drifted snow that accumulates in the small incised streams and drainages during the winter has a large influence on water levels and discharge during spring breakup. Peak stage is often associated with elevated water levels from impeded flow through the snowpack and precedes peak discharge which occurs with increased conveyance as a channel is cut through the snowpack.

In general, the 2020 spring breakup flood event in the Willow study area was characterized as a low magnitude, event, preceded by above normal snowpack in the region, based on general observations. Spring breakup and summer hydrological conditions were monitored at various locations throughout Willow and were documented through visual observations and aerial and ground photography. Peak spring breakup conditions occurred between May 28 and June 4 across the monitoring area. During peak conditions, floodwater was generally confined within channels and swales. Stage was receding at all gage stations by June 6. Stage and discharge generally declined over the summer months, with occasional increases resulting from rainfall events. Summer peak conditions generally occurred between mid-August to the end of the summer monitoring period.

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Acronyms & Abbreviations

°F	degrees Fahrenheit
ADCP	Acoustic Doppler Current Profiler
Alcap	aluminum cap
Baro	barometric
BLM	Bureau of Land Management
BPMSL	British Petroleum Mean Sea Level
CFDD	Cumulative Freezing Degree Days
cfs	cubic-ft per second
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DGPS	differential global positioning system
FCB	Fish Creek Basin
fps	feet per second
gages	staff gages
GPS	global positioning system
H&H	Hydrologic and hydrology
HWM	high water mark
Michael Baker	Michael Baker International
NAD83	North American Datum of 1983
NPR-A	National Petroleum Reserve Alaska
PT	pressure transducer
RM	river mile
RTFM	Real-Time Flood Monitoring
Soloy	Soloy Helicopters, LLC
UMIAQ	Umiaq, LLC
USGS	U.S. Geological Survey

1. INTRODUCTION

The Willow Spring Breakup and Summer Monitoring and Hydrological Assessment supports ConocoPhillips Alaska, Inc. (CPAI) in meeting the National Petroleum Reserve–Alaska (NPRA) Integrated Activity Plan Record of Decision Requirement E-14 (BLM 2013). This document states "3 years of hydrologic data shall be collected by the lessee for any proposed crossing of a stream whose structure is designed to occur, wholly or partially, below the stream's ordinary high watermark. These data shall include, but are not limited to, the range of water levels (highest and lowest) at the location of the planned crossing."

Spring breakup is generally considered the largest annual flooding event on the North Slope and commences with the arrival of meltwater and progresses with a rapid rise in stage which facilitates the breakup and downstream movement of water and ice. Spring breakup typically occurs over a three-week period in May and June. Many areas on the North Slope of Alaska including the Colville River Delta (CRD) basin, the Fish Creek Basin (FCB), and the Kalikpik River Basin (Figure 1.1) share similar hydrologic and hydraulic (H&H) characteristics, common to the arctic climate. Spring breakup and summer monitoring is integral to understanding regional hydrology and ice effects, establishing baseline hydrological conditions to support permitting, and establishing appropriate design criteria for proposed facilities. Discharge generally declines over the summer months, with occasional increases resulting from precipitation events. After freeze-up, streamflow in Willow drainages rapidly declines and is mostly nonexistent throughout the winter (BLM 2012). During the winter, ice forms and becomes anchored to the banks and in shallow locations the entire water column freezes to the bed.

The 2020 Willow Spring Breakup and Summer Monitoring and Hydrological Assessment program included monitoring 34 existing gage stations. Gage J13.8C represents the longest record of H&H data in the Willow area. The H&H assessments at gage station J13.8C were conducted by URS in 2001 and 2002 (URS 2001, 2003). Spring breakup monitoring and hydrological assessments at gage station J13.8 were conducted annually by Michael Baker International (Michael Baker) from 2003 to 2006 and from 2017 to 2020 (Michael Baker 2003, 2005a, 2005b, 2007, 2017, 2018, 2019, 2020).

The 2020 field program took place from May 17 to September 10. Spring breakup setup began on May 17 and concluded on May 27. Spring breakup monitoring began on May 28 and concluded on June 9. Summer monitoring was broken up into two field programs. During the first program, June 29 through July 3, pressure transducers (PTs) and game cameras installed during spring breakup were downloaded and repositioned to capture low water conditions through the summer. During the second summer field program, September 6 through September 10, equipment was retrieved from the field and gages were rehabilitated and repositioned for the 2021 spring breakup monitoring program. Umiaq, LLC (UMIAQ), CPAI Alpine Field Environmental Coordinators, Alpine Helicopter Coordinators, and Soloy Helicopters, LLC (Soloy) provided support during the field programs and contributed to a safe and productive field season.

ConocoPhillips Alaska

0 25 50 Miles

Date:	11/20/2020
Drawn:	JEG
Checked:	GCY
Scale:	1 Inch = 25 Miles
Project:	178179
File:	Drainage_Basin_Overview.mxd

★ Place Name
Stream
Road
NPRA Boundary
Kalikpik River Basin
Fish Creek Basin
Colville River Basin

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Fish Creek
Kalikpik & Colville River
Drainage Basins

FIGURE: 1.1

1.1 Monitoring Objectives

The primary objective of the 2020 program was to monitor and estimate the magnitude of breakup flooding at select locations throughout the Willow project area. Monitoring and hydrological assessments included:

- Aerial and ground observations with photo and field notebook documentation;
- Spring breakup and summer stage measurements;
- Spring breakup discharge measurements;
- Spring breakup indirect discharge calculations; and
- Flood frequency analyses

1.2 Monitoring Locations, Gage Stations, & Tasks Per Location

Figure 1.2 presents the Willow monitoring locations and gage stations. Figure 1.3 and Figure 1.4 show a north and south detail of the locations and gage stations, respectively. Table 1.1 details the monitoring locations, gage stations, and tasks per location. Stage and discharge data were used to continue the historical hydrologic record at the Willow gage stations presented below.

Due to COVID-19 travel restrictions, spring breakup setup activities were postponed until mid-May. As a result, some of the small swales along the proposed alignment that have been monitored in the past were not monitored in 2020. These include the following sites:

- SW22
- SW23
- SW6
- SW3

ConocoPhillips Alaska

Miles
0 1 2 4

Date:	11/20/2020	Scale:	1 Inch = 2.25 Miles
Drawn:	JEG	Project:	178179
Checked:	GCY	File:	2020_Gage_Stations.mxd

Gage Location
Stream / River
Lake

Proposed
Bridge Location
Road
Facility

Existing
Pipeline
Road
Facility

Michael Baker INTERNATIONAL

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

2020 Willow Gage Stations

Proposed Roads & Facilities

FIGURE: 1.2

ConocoPhillips
Alaska

0 0.5 1 Miles

Date:	11/20/2020	Scale:	1 in = 0.5 miles
Drawn:	JEG	Project:	178179
Checked:	GCY	File:	Gage_Stations.mxd

Gage Location
Stream / River
Lake

Proposed
Bridge Location
Road
Facility

Michael Baker
INTERNATIONAL

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Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2020 Willow Gage Stations

North Detail

FIGURE: 1.3

ConocoPhillips Alaska	Miles: 0 0.5 1 2
Date: 11/20/2020	Scale: 1 Inch = 1.25 Miles
Drawn: JEG	Project: 178179
Checked: GCY	File: 2020_Gage_Stations.mxd

Gage Location

Stream / River

Lake

Proposed

Bridge Location

Road

Facility

Existing

Pipeline

Road

Facility

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2020 Willow Gage Stations

South Detail

FIGURE: 1.4

Table 1.1: Willow Monitoring Locations, Gage Stations, & Tasks Per Location

Location Type	Monitoring Location	Gage Station	Gage Station Description	No. of years of observations	Spring Breakup Stage - PT	Summer Stage - PT	Spring Breakup Measured Discharge	Real-Time Monitoring	Flood Frequency Analysis
Major Streams	Fish Creek	F55.5U	Proposed Fish Creek crossing, north bank, 55.5 miles upstream of mouth of Fish Creek	3	✓	✓	✓	✓	✓
		F55.5		3	✓	✓			
		F55.5D		3	✓	✓			
	Judy Creek	J13.8U	West bank, 13.8 river miles (RM) upstream of confluence with Fish Creek, downstream of Willow 2 tributary, upstream of Judy Creek Kayyaaq tributary	4	✓	--	✓	--	--
		J13.8C		9	✓	--			
		J13.8D		4	✓	--			
		J21.4	Proposed Judy Creek crossing, west bank, 21.4 RM upstream of confluence with Fish Creek, upstream of Willow 2 and Judy Creek Kayyaaq tributary	4	✓	✓	--	✓	--
	Kalikpik River	KAL1	Proposed Kalikpik River crossing, west bank	3	✓	✓	--	--	✓
Small Streams	Judy Creek Kayyaaq	UC2C	Proposed Judy Creek Kayyaaq crossing, east bank, approximately 13.0 RM upstream of Judy Creek	4	✓	✓	✓	--	✓
	Willow 1	W1S	Proposed Willow 1 crossing, in swale upstream of well-defined channel draining into Judy Creek	3	✓	--	--	--	--
	Willow 2	UC1B	Proposed Willow 2 crossing, east bank, approximately 4.5 RM upstream of Judy Creek	4	✓	✓	✓	--	✓
	Willow 3	W3S	Proposed Willow 3 crossing, west of the middle and lower Snowman Lakes	3	✓	✓	✓	--	--
	Willow 4	W4	On Willow 4 adjacent to proposed BT3/WCF pad, approximately 5.3 RM upstream of Judy Creek	3	✓	✓	--	--	--
		W_BS1	Proposed Willow 4 crossing, approximately 9 RM upstream of Judy Creek	3	✓	✓	✓	--	✓
	Willow 4a	W_S1	Proposed Willow 4A crossing,	3	--	✓	✓	--	--
	Willow 8	TBD_6	Proposed Willow 8 crossing, 1.7 RM upstream of Fish Creek, well defined channel	3	✓	✓	✓	--	--
		SW22	Proposed Willow 8 crossing, 3 RM upstream of Fish Creek, poorly defined channel	3	--	--	--	--	--
	TBD_5	TBD_5	Proposed crossing at TBD_5, a well-defined channel draining into the Kalikpik River	3	✓	--	--	--	--
Swales	Swale 1	SW1	Proposed crossing of Swale 1, a shallow swale with beads between two small unnamed lakes, conveys flow north into Judy Creek	4	✓	--	✓	--	--
	Swale 2	SW2	Proposed crossing of Swale 2, a low-lying area with occasional beads between Lake M0014 and Judy Creek	3	✓	✓	✓	--	--
	Swale 3	SW3	Proposed crossing of Swale 3, an area of channelized flow between paleolakes	2	--	--	--	--	--
	Swale 4	SW4	Proposed crossing of Swale 4, a polygon trough paleochannel of Judy Creek	4	✓	✓	--	--	--
	Swale 6	SW6	Proposed crossing of Swale 6, a swale depression at the outlet of a paleolake	2	--	--	--	--	--
	Swale 14	SW14	Proposed crossing of Swale 14, a low-lying area between Lake M0014 and Judy Creek	3	--	--	✓	--	--
	Swale 23	SW23	Proposed crossing of Swale 23, a beaded swale flowing from unnamed lake to the Kalikpik River	3	--	--	--	--	--
	Swale 24	SW24	Proposed crossing of Swale 24, a swale draining an unnamed lake into the W3S drainage area	2	--	✓	--	--	--
Minesite	Tinmiaqsiugvik River	UB14.5	On Tinmiaqsiugvik River at the proposed minesite	3	✓	--	--	--	--
		UB15.5	On Tinmiaqsiugvik River at the proposed minesite	3	✓	--	--	--	--
	Bills Creek	BC1	Beaded stream that boarders the proposed minesite to the east	3	✓	--	--	--	--
	MS1_1	MS1_1	Swale through proposed minesite	3	✓	--	--	--	--
Source Lakes	Lake M0015/R0056/R0056 (Middle Snowman Lake)	MSL	Northwest corner of middle Snowman Lake	3	✓	✓	✓	--	--
	Willow 3/Lake M0015/R0056/R0056 (Middle Snowman Lake) outlet	MSL_OUT	Lake outlet, approximately 75-ft west of MSL	3	✓	✓	--	--	--
	Lake R0064 (Lower Snowman Lake)	LSL	Northwest corner of lower Snowman Lake	3	✓	✓	--	--	--
	Willow 3/Lake R0064 (aka Lower Snowman Lake) outlet	LSL_OUT	Lake outlet, approximately 135-ft northwest of LSL	3	✓	✓	--	--	--

2. METHODS

2.1 Observations

Helicopter reconnaissance flights were conducted in the headwaters of the FCB to track the progression of floodwater. Field data collection and observations of breakup progression, ice events, and summer conditions were recorded in field notebooks. Photographic documentation of spring breakup and summer conditions was collected using digital cameras with integrated global positioning systems (GPS). Each photo was geotagged with the latitude and longitude, date, and time. The photo location is referenced to the North American Datum of 1983 horizontal datum (NAD83).

Due to COVID-19 travel restrictions, spring breakup setup activities were postponed until the helicopter was onsite. Soloy provided helicopter support beginning the second week of May to access gage stations during spring breakup and summer monitoring.

2.2 Water Surface Elevations

Water surface elevation (WSE) data was collected using hydrologic staff gages (gages) and pressure transducers (PTs) installed at monitoring locations. Gages were installed or rehabilitated, as needed, in the previous fall and re-surveyed prior to spring breakup using standard differential leveling techniques. Site visits were performed as needed and as conditions allowed. The field methodologies used to collect hydrologic data on the North Slope of Alaska are proven safe, efficient, and accurate for the conditions encountered.

Detailed gage and PT methods and site-specific data are presented in Appendix A. Locations where stage was measured during spring and summer monitoring events are shown in Table 1.1.

HYDROLOGIC GAGES

Gage stations consist of one or more gage assemblies positioned perpendicular to the waterbody. The number of gage assemblies per gage station was dependent upon site specific conditions: primarily slope of the channel bed, bank, and overbank. In locations where terrain elevation varied by more than 3-ft, multiple gages were installed linearly from the edge of the channel up to the overbank. Individual gage assemblies were identified with alphabetical designations beginning with 'A' representing the location nearest to the channel. Gage stations were also identified with alphabetical designations with 'U' or 'D' representing the furthest upstream or downstream gage station, respectively. Gage assemblies were installed at elevations overlapping by approximately one foot. One gage assembly per gage station was installed in each swale or small drainage and identified with an 'SW', sequential number (1 through 24), and alphabetical designation 'A'. The location of each gage assembly was recorded with a handheld GPS referenced to NAD83.

Gage readings were recorded from the gage faceplate and high water marks (HWMs) were measured by applying chalk on the angle iron gage supports and measuring the wash line.

PRESSURE TRANSDUCERS

The PTs were installed at most gage stations and supported with gage measurement readings to provide a continuous record of stage. They are designed to collect and store pressure and temperature data at discrete pre-set intervals of time. The PTs were programmed to collect data at 15-minute intervals beginning mid-May. Each PT was housed in a small perforated galvanized steel pipe and secured to the base of the gage assembly nearest to the channel via hose clamps. The PTs record the absolute pressure of the atmosphere and water column above the PT. Atmospheric pressure was accounted for by using a barometric pressure (Baro) PT installed at Judy Creek. The depth of water above the PT was calculated by subtracting the atmospheric pressure from the absolute pressure measured by the site PT. During data processing, the PT measurements were adjusted to WSE readings recorded at the gages.

GAME CAMERAS

Game cameras overlooking the gages were installed to photograph site conditions and record water levels at 15-minute intervals. Cameras were installed at select small swales and drainages where the range of water levels could be captured with a single gage and where photos would help determine if hydraulic connectivity is maintained during periods of low water. Capturing water levels with the game cameras helped reduce the number of NPR-A landings and helicopter time while providing continues stage observations.

VERTICAL CONTROL

Vertical control monuments are used to establish consistent reference points for water surface elevations at staff gage locations. Gage and PT elevations were surveyed to associated vertical control using standard differential leveling techniques. Two vertical control monuments were associated with each monitoring location. Each monument included an aluminum cap (Alcap) mounted on a piece of rebar driven into the ground. The top of the Alcap was stamped with an arbitrary naming convention. The location of each vertical control was recorded with a handheld GPS referenced to NAD83. Gage stations J13.8U, J13.8, and J13.8D had one existing vertical control with a known benchmark elevation installed in 2001 and referenced to British Petroleum Mean Sea Level (BPMSL); one additional vertical control was installed adjacent to the existing vertical control during the 2017 monitoring period and was also referenced to BPMSL. In July 2018 and August 2019, UMIAQ surveyors established elevations tied to the North American Vertical Datum of 1988 (NAVD88) at many of the spring breakup monitoring control monuments using Real-time Kinematic GPS.

REAL-TIME FLOOD MONITORING NETWORK

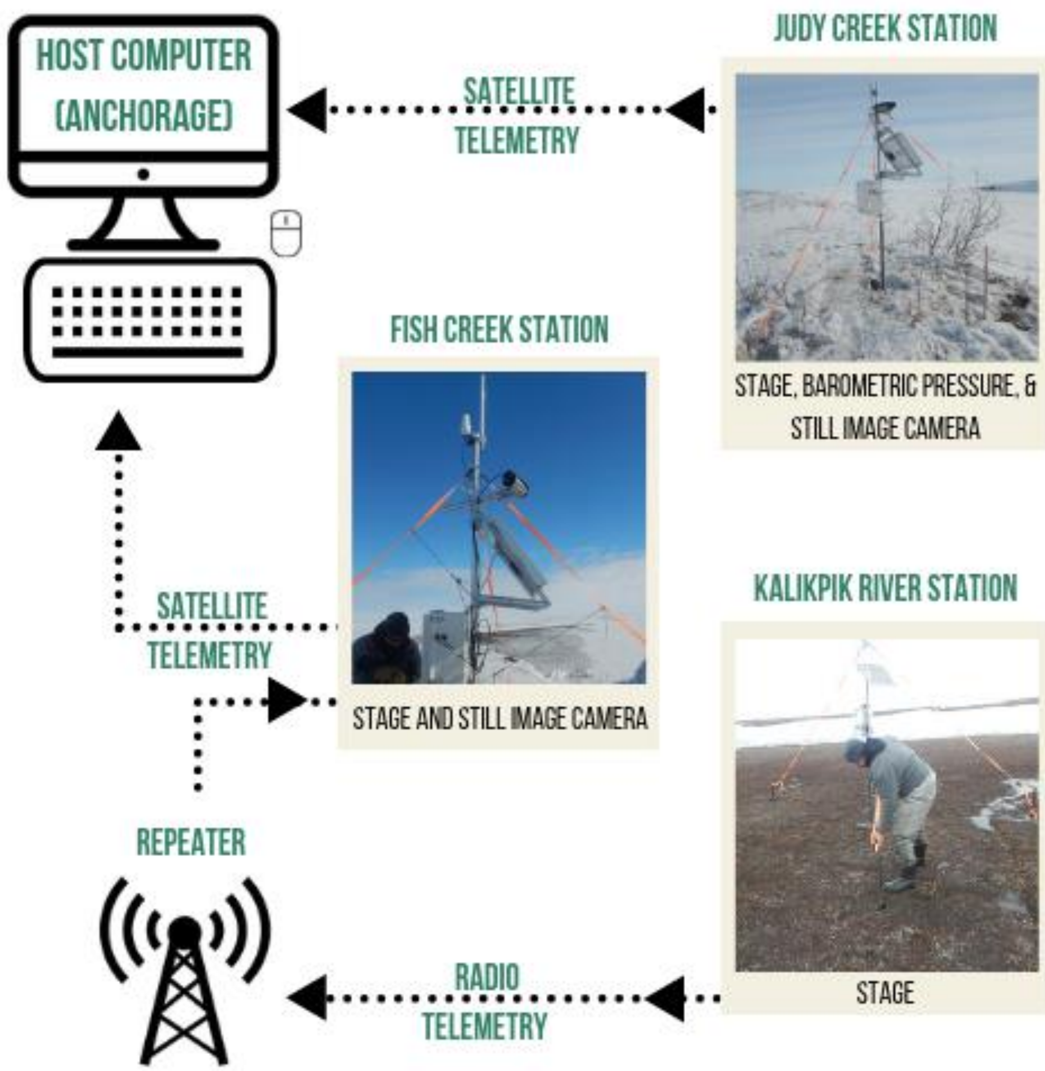
The ability to remotely monitor stage and river conditions helps reduce helicopter traffic, allows for round-the-clock monitoring of conditions, and allows for remote monitoring when helicopter travel is restricted due to weather or other circumstances. In addition, a network of real-time monitoring stations helps hydrologists deploy resources during peak conditions when critical measurements are required. One-way helicopter flight time to the Willow study area was approximately 35-45 minutes from Alpine. The remote monitoring capabilities installed for this effort drastically reduced the amount of helicopter travel by eliminating unnecessary site visits to assess conditions prior to spring flooding and during extended periods of unvarying conditions. Kalikpik station was not installed for the 2020 field season. Table presents the Real-Time Flood Monitoring (RTFM) Network locations and data collected at each location.

Table 2.1: Willow RTFM Network Stations

Monitoring Location (Gage Station)	Station	Real-Time Data
Judy Creek (J21.4)	Satellite	• Stage • Conditions via remote camera images • Barometric pressure
Fish Creek (F55.5)	Satellite	• Stage • Conditions via remote camera images
Kalikpik Rive (KAL1)	Satellite	• Stage • Conditions via remote camera images

The RTFM Network has the following components: remote cameras to monitor river conditions, PTs to monitor stage and barometric pressure, dataloggers and telemetry systems to collect and transmit data, and a host computer to receive the transmitted data (Figure 2.1). Onsite dataloggers were programmed to interface with the PTs. Data was uploaded to the datalogger via a data cable and stored internally. The dataloggers were programmed to interact with telemetry equipment to transmit data at set intervals. Real-time stage was processed using downloaded stage and barometric pressure data and was periodically compared with field-observed stage data for quality assurance. Real-time stage was plotted on graphs and updated in tables as data was received. Systems were powered with 12v DC batteries and charged with onsite solar panels.

Figure 2.1: Willow RTFM Network Schematic (Kalikpik River Station not installed in 2020)



The Fish Creek and Judy Creek stations consisted of a digital camera, barometric PT (at Judy Creek), stage PT, datalogger, and an Iridium satellite modem. The digital camera was used to remotely observe conditions and to help hydrologists determine when site visits were necessary. The camera was programmed to take high-resolution (5 Megapixel) pictures at 15-minute intervals and low-resolution (0.08 Megapixel) pictures at 4-hour intervals. The high-resolution pictures were stored on the camera and used for reviewing site conditions during data analysis after the camera was retrieved.

The remote station at the Kalikpik River typically consisted of stage PTs, dataloggers, and a spread spectrum radio that transmitted data to the Fish Creek station for satellite transmission to the host computer. Due to COVID-19 limitations, the Kalikpik River RTFM station was not installed in 2020.

2.3 Discharge

Discharge was measured and calculated at select locations across the Willow study area. Channel cross-section profiles were surveyed by Michael Baker during spring breakup discharge measurements. Site specific spring breakup and summer channel cross-section geometry is detailed in Appendix C.

MEASURED DISCHARGE

Detailed spring breakup and summer measured discharge methods are presented in Appendix B. Locations of spring breakup and summer measured discharge are detailed in Appendix C.

A. Spring Breakup

Spring breakup discharge (in cubic-ft per second [cfs]) was measured as close to observed spring breakup peak or highest recorded stage as possible at the following locations:

- Fish Creek at F55.5
- Judy Creek at J13.8
- Judy Creek Kayyaaq at UC2C
- Willow 2 at UC1B
- Willow 4 at W_BS1
- Willow 4a at W_S1
- Willow 8 at TBD_6
- Willow 3 at W3S
- Middle Snowman Lake outlet at MSL_OUT
- Small swales and drainages at SW1, SW2, and SW14

Discharge was measured at larger streams using an Acoustic Doppler Current Profiler (ADCP) mounted in a tethered trimaran using the methods outlined in the U.S. Geological Survey (USGS) *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (USGS 2005). Discharge was measured at the swales and other small streams using an electromagnetic velocity meter attached to a wading rod using the USGS midsection technique (USGS 1982).

CALCULATED DISCHARGE

A. Spring Breakup

Spring breakup discharge was calculated indirectly for Judy Creek at J13.8 and for Fish Creek at F55.5. When possible, the parameters used in the discharge calculation are calibrated with the respective direct measurement and measured stage. Under open channel conditions, peak discharge typically occurs at the same time as peak stage; however, in the Willow drainages, peak discharge is often affected by ice and snow which can temporarily increase stage and reduce velocity. This in turn yields a lower discharge than an equivalent stage under open water conditions.

Calculated discharge results are estimates based on conditions at the time of data collection. In the spring, these conditions are often influenced by ice, snow and bed movement, all of which are highly dynamic and challenging to quantify. Ice and snow conditions can affect channel geometry, roughness, energy gradient, and stage, which are used to calculate discharge indirectly. Bed material movement can also affect channel geometry and roughness, having additional influence on calculated discharge. In consideration of these conditions, calculations of discharge are presented with quality ratings, as described in Table . Detailed calculated discharge methods are presented in Appendix B.

Table 2.2: Discharge Quality Ratings

Quality Rating	Description
Good	Open channel/drainage structure free of ice and snow, no backwater effects from downstream ice jamming, uniform channel/drainage structure through reach. Cross-section geometry used in indirect calculations is representative of actual conditions.
Fair	Some ice floes and/or snow in the channel/drainage structure, some backwater effects, fairly uniform conditions through reach. Cross-section geometry is representative of actual conditions.
Poor	Significant quantities of ice and snow in the channel/drainage structure, significant backwater effects from downstream ice jamming, non-uniform conditions through channel/drainage structure reach. Discrepancies between cross-section geometry used in indirect calculations and actual conditions.

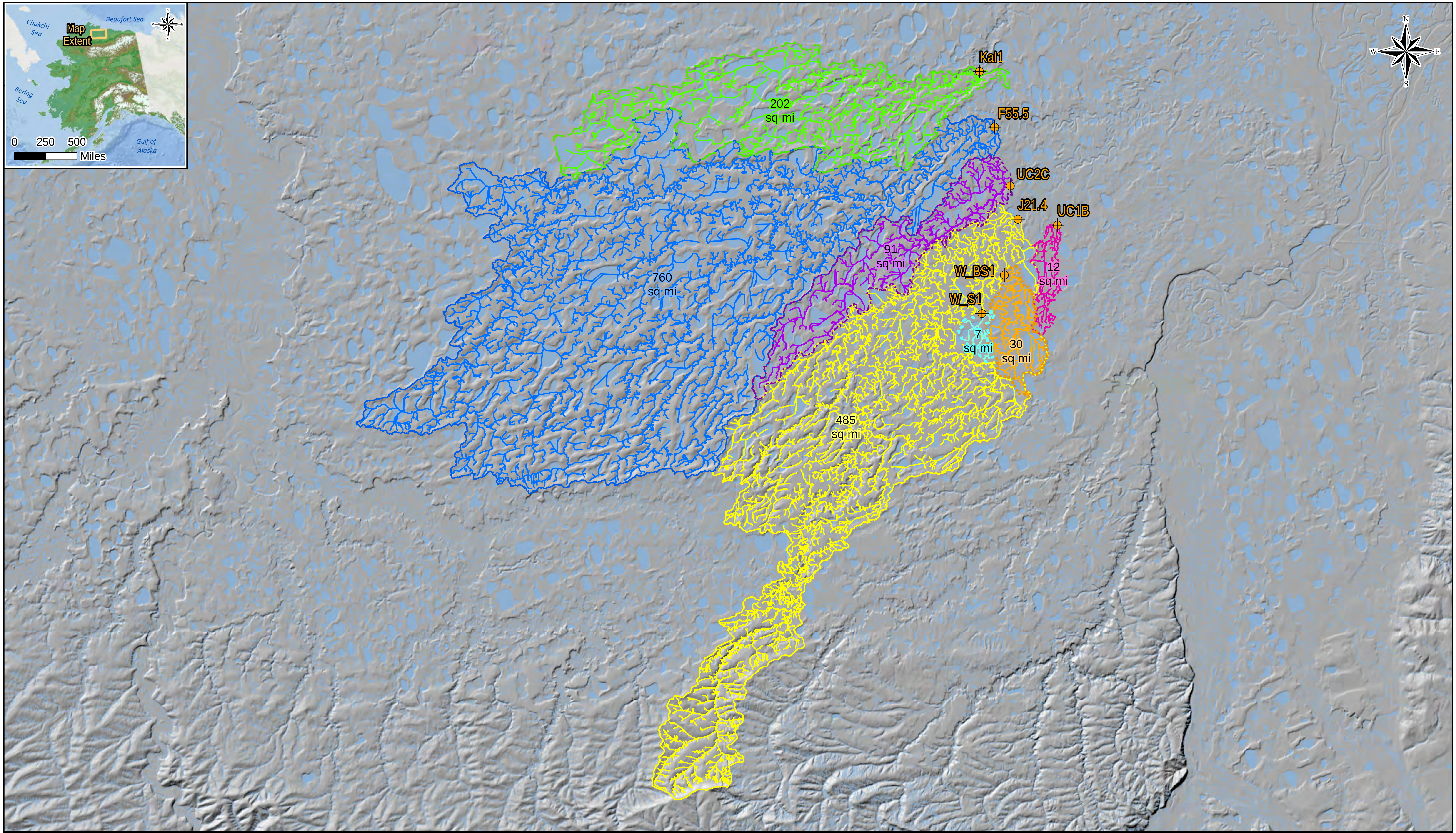
2.4 Flood Frequency Analysis

Estimates of the magnitude and frequency of peak discharge at Judy Creek at J21.4, Fish Creek at F55.5, Kalikpik River at KAL1, Willow 2 at UC1B, Judy Creek Kayyaaq at UC2C, and Willow 4 at W_BS1 were determined for the 2-, 10-, 25-, 50-, and 100-year recurrence intervals using the 2003 USGS peak discharge regional regression equations for Region 7 (USGS 2003). In addition, estimates of the magnitude and frequency of peak discharge at Judy Creek at J13.8 and Fish Creek at F55.5 were determined for the 2-, 10-, 25-, 50-, and 100-year recurrence intervals using the 2002 URS peak discharge regional regression equations for Judy Creek, Fish Creek, and the Tinmiaqsiugvik River (URS 2002). A recurrence interval was assigned to the peak or measured discharge value at each location based on the results of the regression analysis. The basin areas for all locations that were monitored are presented in Table 2.3 and Figure 2.2

Table 2.3: Willow Monitoring Location Basin Areas

Monitoring Location (Gage Station)	Basin Area (square miles)
Judy Creek at J21.4	485
Fish Creek at F55.5	760
Kalikpik River at KAL1	202
Willow 2 at UC1B	12
Judy Creek Kayyaaq at UC2	91
Willow 4 at W_BS1	30
Willow 4a at W_S1	7.0

Basin areas were delineated based on the USGS National Hydrography Dataset (USGS 2017), project imagery, and Digital Elevation Models generated from 2016 project LiDAR and publicly available NPR-A LiDAR data. Area calculations were performed in the NAD83 Alaska State Plane Zone 4 coordinate system and were manually adjusted to the respective gage station.



ConocoPhillips
Alaska

0 3.5 7 14 Miles

Date: 12/10/2020
Scale: 1 Inch = 7 Miles
Drawn: JEG
Project: 178179
Checked: KDB
File: Gage_Station_Basins.mxd

Streams & Basins

- Gage Location
- Waterbody
- Stream/River
- Kalikpik River (Kal1)
- Fish Creek (F55.5)
- Judy Creek Kayyaak (UC2C)
- Judy Creek (21.4)
- Willow 4 (W_BS1)
- Willow 4a (W_S1)
- Willow 2 (UC1B)

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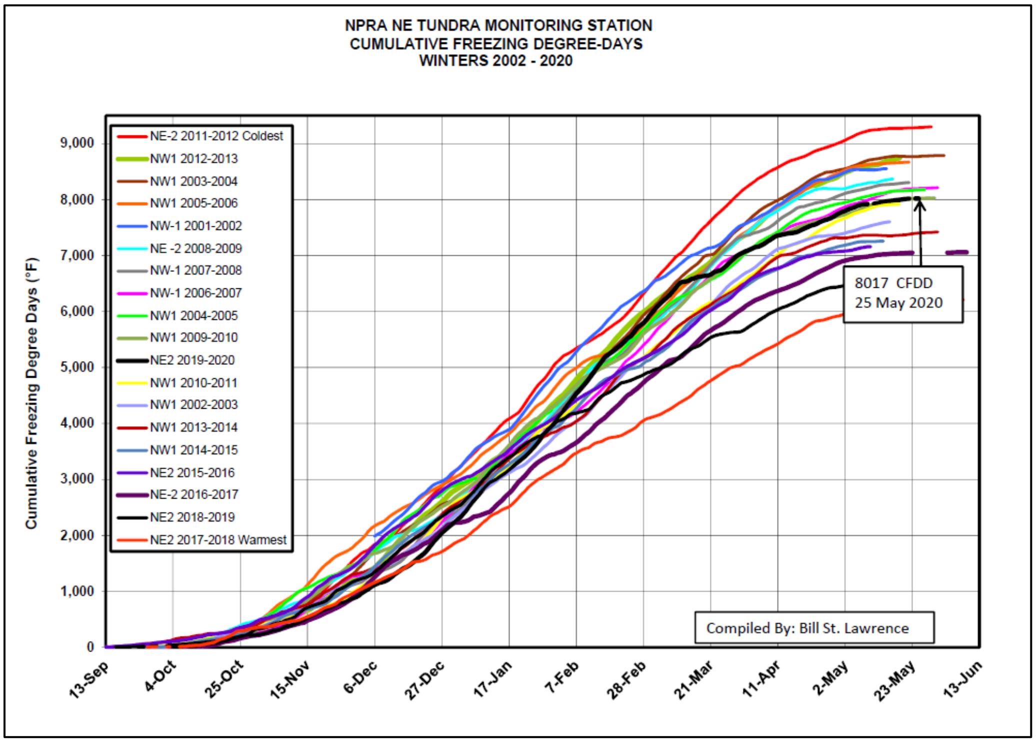
Willow Drainage Basins

FIGURE: 2.2

3. OBSERVATIONS

3.1 General Climatic Summary

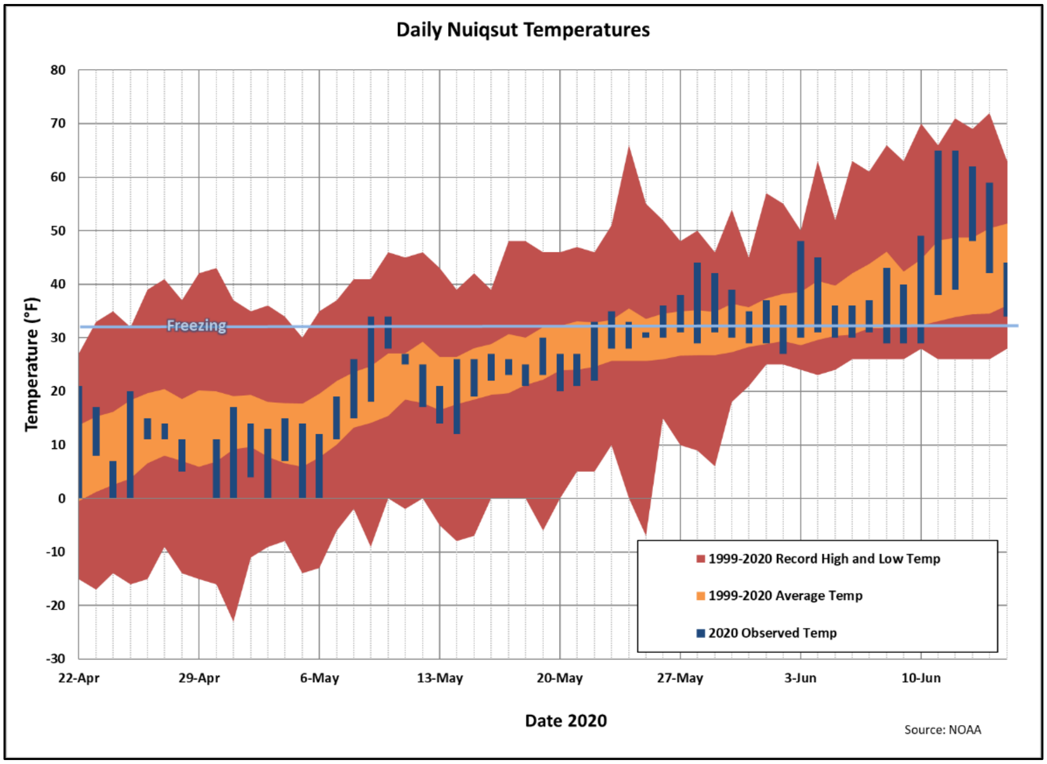
According to cumulative freezing degree-days (CFDD) measured at the National Petroleum Reserve Alaska (NPR-A) tundra monitoring station, the 2019-2020 (September – May) winter temperatures were within the normal range of the historical record for the past 18 years (Graph 3.1, ICE 2020).



Graph 3.1: NPR-A N. Tundra Monitoring Station, CFDD, Winters 2002-2020 (ICE 2020)

Snowpack data for the North Slope was not available for the 2019-2020 winter season through the Natural Resource Conservation Service, but general observations indicate snowpack was at or above normal levels in the lower Colville River drainage basin.

Air temperatures were generally average to lower than average throughout the Colville River drainage prior to the start of the spring breakup season. A warming trend in the Upper Colville River watershed (the Brooks Range foothills, as recorded at Umiat) started on May 9 and lasted until May 12. This event was followed by a 10-day period for where the daily highs at Umiat did not exceed freezing (NOAA, 2020). Temperatures at Umiat began to consistently exceed freezing around May 21 and daily minimum temperatures began to consistently exceed freezing after May 25. In the CRD, daily maximum temperatures consistently exceeded freezing on May 24 and continued through the breakup monitoring period. Daily minimum temperatures remained below freezing through the breakup period in the CRD. Graph 3.2 illustrates daily high and low ambient air temperatures recorded in Nuiqsut superimposed on the average and record daily highs and lows during the breakup monitoring period (NOAA, 2020).



Graph 3.2: Nuiqsut Daily High and Low Ambient Air Temperatures

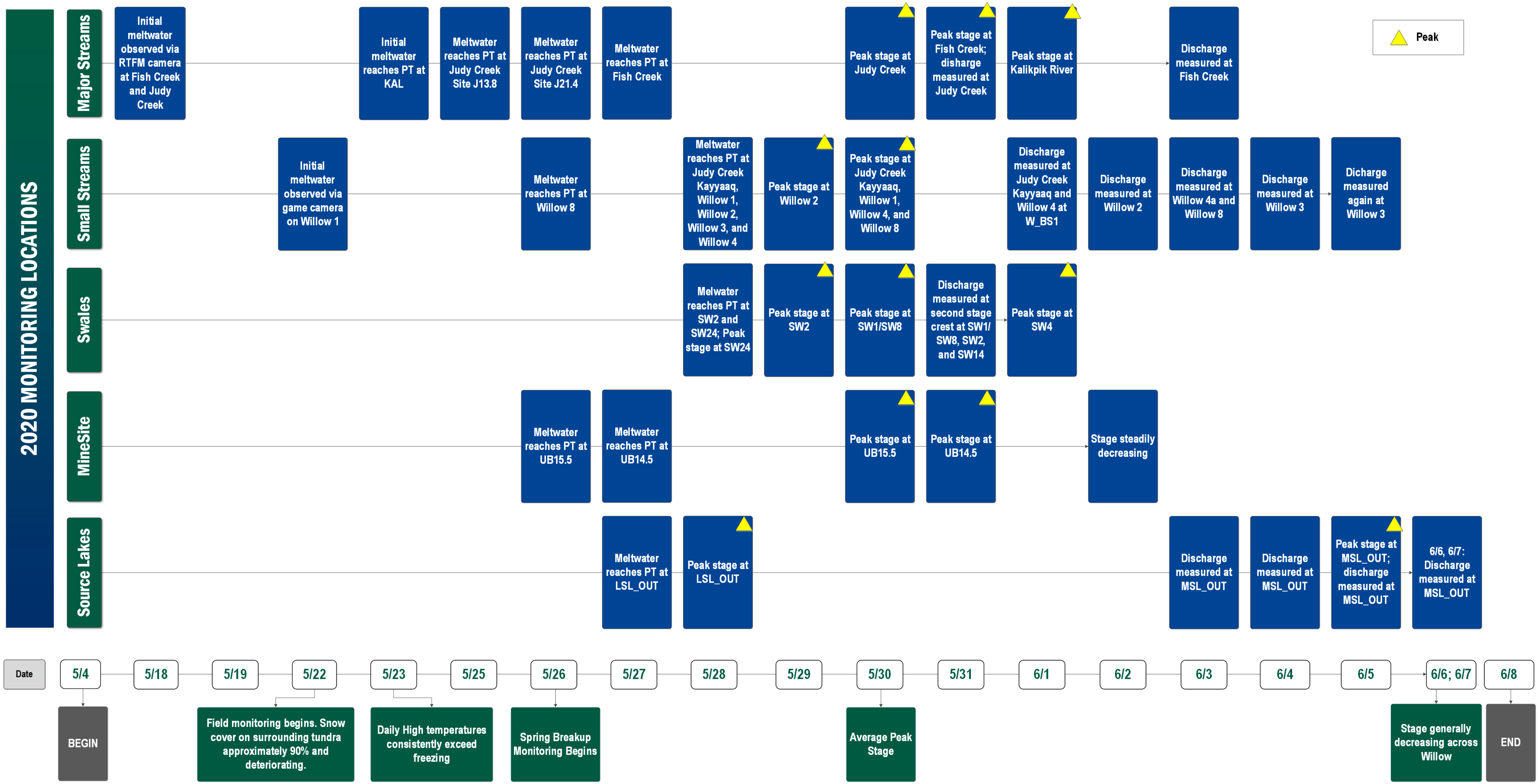
3.2 General Breakup Summary

Initial meltwater was first recorded in the Willow area on May 22 at Judy Creek Kayyaaq near its confluence with Fish Creek while snow cover was approximately 90% on the surrounding tundra. Stage increased in drainages throughout the Willow area from May 22 to May 30. By May 30, most streams in the Willow area were flowing at or above bankfull elevations with snow cover on the surrounding tundra at approximately 25%. Judy Creek Kayyaaq was flowing below bankfull while stage at Fish Creek had risen with aerial observations showing minor ice floes. Peak stage conditions generally occurred in the major Willow streams around May 31. During peak stage, snow and ice in the drainages confined meltwater and elevated stage. By June 2, most major drainages were free of ice and snow and stage was decreasing. Effects from ice jamming were minimal across the Willow area.

Peak stage was observed at small streams between May 30 and June 1 and was the result of elevated water levels associated with flow through snow-packed channels. By June 2, stage was receding at most Willow small stream monitoring locations. Snow was approximated at 10% coverage over surrounding tundra, but snow was still present in some stream banks and drifts along terrain features.

The summer monitoring period was defined by low, base flow conditions at all major and small streams. Most small swales were characterized as ponded water with no discernable flow, and many became disconnected. Periodic fluctuations in stage from either precipitation events or active layer contributions were recorded in PT data. Figure 3.1 provides a visual timeline summarizing the major spring breakup events.

Figure 3.1: Spring Breakup Hydrologic Timeline



4. STAGE & DISCHARGE

Table presents a summary of spring breakup peak or highest recorded stage, measured discharge, and peak discharge.

Table 4.1: Spring Breakup Stage & Discharge Summary

Monitoring Location	Gage Station	Spring Breakup Peak or Highest Recorded Stage		Spring Breakup Measured Discharge			Spring Breakup Peak Discharge		
		Stage (ft NAVD88)	Date & Time	Discharge (cfs)	Stage (ft NAVD88)	Date & Time	Discharge (cfs)	Stage (ft NAVD88)	Date & Time
Fish Creek	F55.5U	44.59	6/1 7:00 PM	1,700	43.28	6/2 2:45 PM	2,900	44.57	6/1 8:30 PM
	F55.5	44.50	6/1 6:45 PM		43.26			44.39	
	F55.5D	44.55	6/1 7:00 PM		43.19			44.47	
Judy Creek	J21.4	49.38	5/30 4:45 PM	--	--	--	--	--	--
	J13.8U [1]	35.08	5/30 11:30 PM	2,200	34.02	6/1 12:00 PM	3,500	35.06	5/30 12:45 PM
	J13.8 [1]	35.02	5/31 1:45 AM		33.90			34.85	
	J13.8D [1]	34.90	5/31 1:45 AM		33.48			34.63	
Kalikpik River	KAL1	49.72	5/31 11:45 PM	--	--	--	--	--	--
Judy Creek Kayyaaq	UC2C	54.18	5/30 4:45 PM	230	52.56	6/1 3:30 PM	--	--	--
Willow 1	W1S	79.34	5/30 8:30 AM	--	--	--	--	--	--
Willow 2	UC1B	82.12	5/29 7:15 PM	90	76.55	6/2 5:00 PM	--	--	--
Willow 3	W3S	88.00	5/28 4:15 PM	8	87.06	6/4 12:30 PM	--	--	--
Willow 4	W4 [6]	94.78	5/30 7:30 AM	--	--	--	--	--	--
	W_BS1	87.06	5/30 8:30 PM	185	85.40	6/1 4:30 PM	--	--	--
Willow 4a	W_S1	100.51 [5]	6/3 3:45 PM	185	100.50	6/3 4:00 PM	--	--	--
Willow 8	SW22	79.35	5/28 2:15 PM	--	--	--	--	--	--
	TBD_6	51.60	5/30 9:00 AM	40	50.82	6/3 1:00 PM	--	--	--
Swales	SW1	79.98	5/31 9:15 AM	23	79.90	5/31 1:00 PM	--	--	--
	SW2	83.27	5/29 12:30 PM	1.7	81.91	5/31 4:30 PM	--	--	--
	SW3 [2]	--	--	--	--	--	--	--	--
	SW4	55.93	6/1 4:45 AM	--	--	--	--	--	--
	SW6 [2]	--	--	--	--	--	--	--	--
	SW14 [2]	--	--	6.2	100.00 [6]	5/31 1:00 PM	--	--	--
	SW23 [2]	--	--	--	--	--	--	--	--
	SW24	85.23 [5]	5/28 2:45 PM	--	--	--	--	--	--

Monitoring Location	Gage Station	Spring Breakup Peak or Highest Recorded Stage		Spring Breakup Measured Discharge			Spring Breakup Peak Discharge		
		Stage (ft NAVD88)	Date & Time	Discharge (cfs)	Stage (ft NAVD88)	Date & Time	Discharge (cfs)	Stage (ft NAVD88)	Date & Time
Minesite	UB14.5	18.09	5/31 1:45 AM	--	--	--	--	--	--
	UB15.5	22.06	5/30 3:15 AM	--	--	--	--	--	--
	MS1_1	27.11	5/29 1:45 PM	--	--	--	--	--	--
	BC1	39.01	5/30 5:30 PM	--	--	--	--	--	--
Source Lakes	MSL[1]	89.26	6/5 2:30 AM	--[7]	--	--	--	--	--
	MSL_OUT[1]	89.21	6/5 4:45 AM	6.3 [7]	89.08	6/6 12:00 PM	--	--	--
	LSL	91.54	5/28 6:30 PM	--	--	--	--	--	--
	LSL_OUT	91.32	5/28 3:15 PM	--	--	--	--	--	--

Notes:
1. Stage elevations at MSL, MSL_OUT, J13.8U, J13.8, and J13.8D are ft BPMSL
2. Site setup not complete due to limitations associated with COVID-19
3. Highest recorded stage and timing values are accurately reported based on game camera images. No PT installed at the site.
5. Highest recorded stage and timing based on gage readings from site visit or HWMs.
6. Stage elevations are ft arbitrary.
7. Multiple discharge measurement taken at MSL/OUT.

Table presents a summary of summer peak stage, minimum stage, and measured discharge.

Table 4.2: Summer Stage Summary

Monitoring Location	Gage Station	Summer Peak Stage		Summer Minimum Stage	
		Stage (ft NAVD88)	Date & Time	Stage (ft NAVD88)	Date & Time
Fish Creek	F55.5D	40.60	6/30 5:00 PM	39.41	8/22 8:30 AM
Judy Creek	J21.4	44.46	8/8 2:30 AM	42.64	7/21 2:45 AM
Judy Creek Kayyaaq	UC2C	45.78	8/4 8:45 AM	44.75	9/5 3:30 PM
Willow 1	W1S	78.49	8/3 3:00 PM	78.33	9/6 12:15 AM
Willow 2	UC1B	73.59	8/3 11:00 PM	72.24	7/22 10:00 PM
Willow 3	W3S	86.73	7/27 8:45 AM	86.49	8/30 4:15 PM
Willow 4	W4 [1]	85.68	7/4 5:00 PM	84.40	9/6 2:45 PM
	W_BS1	82.23	8/4 10:45 PM	81.74	8/29 4:15 PM
Willow 4a	W_S1	98.45	7/3 4:00 AM	98.10	9/1 5:30 PM
Willow 8	TBD_6	49.19	8/4 1:15 PM	46.74	9/7 11:00 PM
Swales	SW2	81.52	8/3 9:00 PM	81.11	7/5 12:30 PM
	SW4	55.72	7/27 7:00 AM	55.47	7/22 8:00 PM
	SW14	83.83	8/27 4:45 PM	83.14	7/15 6:15 AM
	SW24	83.94	8/4 6:45 AM	83.74	8/24 4:30 PM
Minesite	BC1	37.91	7/13 4:15 PM	36.39	8/7 1:30 AM
Source Lakes	MSL [2]	89.15	7/3 11:15 AM	88.67	8/31 6:45 PM
	MSL_OUT [2]	89.08	7/2 5:15 PM	88.71	7/22 7:30 PM
	LSL	91.13	7/3 7:00 PM	90.63	9/7 11:45 PM
	LSL_OUT	91.16	7/2 5:30 PM	90.58	9/7 10:15 PM

Notes:
1. Stage elevations are ft arbitrary
2. Stage elevations are ft BPMSL

4.1 Major Streams

FISH CREEK

Fish Creek is a relatively low gradient, highly sinuous channel flowing generally northeast until its outlet into Harrison Bay. The Fish Creek drainage basin encompasses an area of approximately 1,850 square miles, with drainage contributions from the Tinmiaqsiugvik River, Judy Creek, and Inicok Creek. The proposed Willow alignment crosses Fish Creek at the F55.5 monitoring location. The F55.5U, F55.5, and F55.5D gage stations are located approximately 55.5 RM upstream from the mouth of Fish Creek. The monitoring site at RM 55.5 (F55.5) is located upstream of both the Tinmiaqsiugvik-Fish and Judy Creek-Fish Creek confluences. The channel bed and banks consist predominately of silt and sand. All Fish Creek monitoring locations experience a highly mobile channel bed during spring breakup when velocities are highest. The moving bed can make in-channel gages unstable and more susceptible to being knocked over from moving water and ice impacts. This is the third year of monitoring Fish Creek at F55.5.

Historical records are available for Fish Creek at locations further downstream of F55.5. Records from 2005 and 2006 (Michael Baker 2005 and 2006) present data at RM 0.7, 10.3, 25.1, and 32.4 along Fish Creek. Historical peak stage and discharge at F55.5 is presented in Table .

Table 4.3: Fish Creek at F55.5 Historical Peak Stage and Discharge

Year	F55.5				
	Peak Stage (ft NAVD88)	Date	Peak Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	44.50	6/1	2,900	6/1	44.39
2019	44.71	5/28	5,100	5/28	44.70
2018	46.25	6/23	4,400	6/23	46.03

A. Spring Breakup

Localized meltwater was first observed through RTFM camera images at F55.5 on May 21. On May 24, the leading edge of floodwater reached the F55.5 gage station. Stage remained below the PT elevation until May 27 when it began to steadily increase (Photo 4.1). Aerial observations on May 30 and May 31 showed elevated stage below bankfull, with periodic ice floes moving through the reach (Photo 4.2 & Photo 4.3). No intact channel ice was observed in the F55.5 reach at this time, though it is likely some was still grounded. Stage peaked in the evening on June 1 then steadily receded before rising again on June 4. During peak stage, minimal ice or snow remained in the channel and along the banks, observed in the RTFM images (Photo 4.4). Stage was below bankfull and no exposed sandbars were observed in the channel. On June 2, no stranded ice or other evidence of flooding was found above the banks, indicating no overbank flooding occurred at or near peak stage (Photo 4.5). Stage remained elevated through the end of the spring breakup monitoring period.

On June 2, crews conducted a reconnaissance flight toward the headwaters of Fish Creek to determine the likelihood that stage at F55.5 had already peaked, based on the quantity of remaining snowpack. Snow and ice persisted only on lakes and along steep terrain features. In most places, stage was below bankfull between F55.5 and the headwaters with minimal overbank flooding, and no significant ice jamming was observed (Photo 4.6). Most distributary streams and drainages appeared to have limited snowpack remaining.

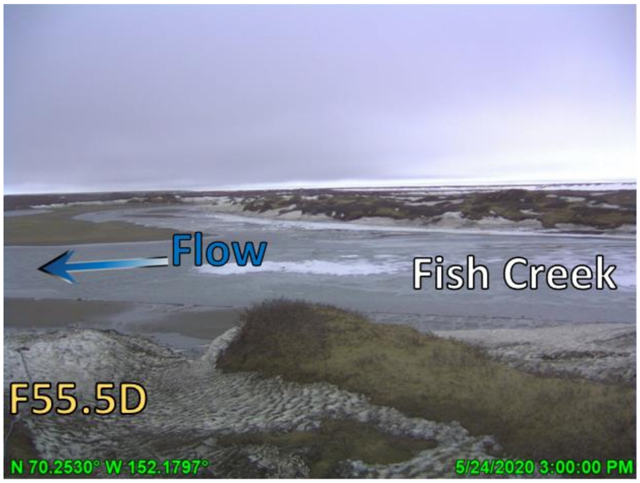


Photo 4.1: RTFM image of the leading edge of floodwater at F55.5D, looking east (downstream); May 24, 2020

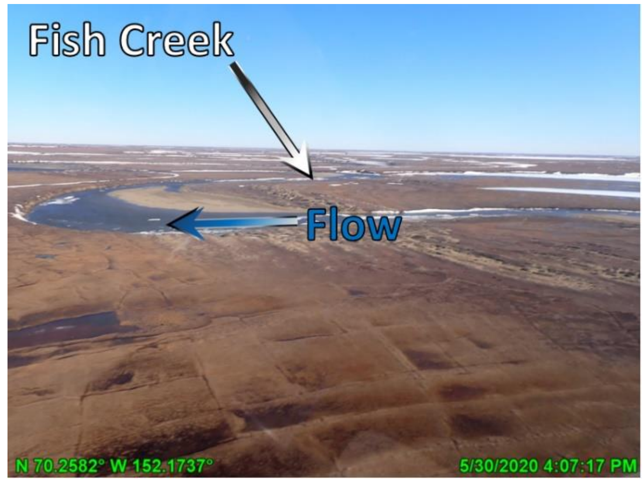


Photo 4.2: Fish Creek directly downstream from F55.5 gage stations, two days prior to peak stage, looking east (downstream); May 30, 2020

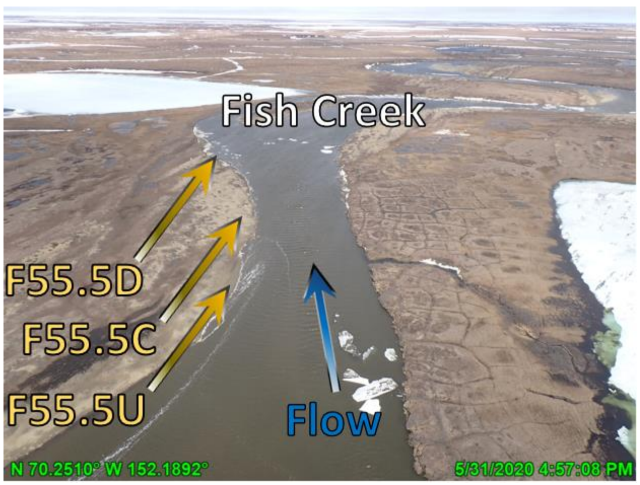


Photo 4.3: Elevated stage with periodic ice floes through F55.5 reach, looking northeast (downstream); May 31, 2020

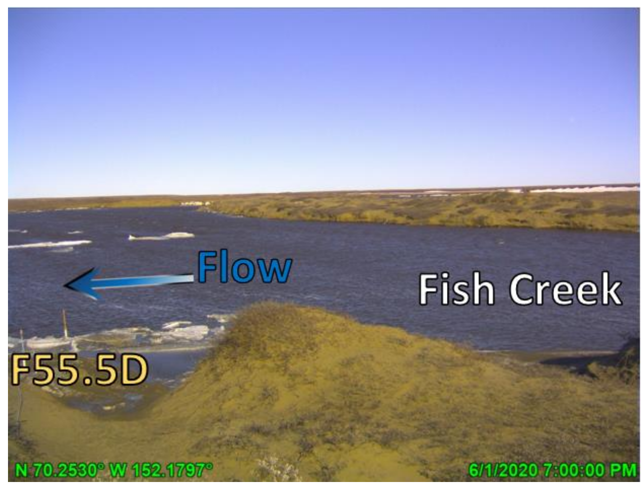


Photo 4.4: RTFM image of peak stage at F55.5, looking east (downstream); June 1, 2020

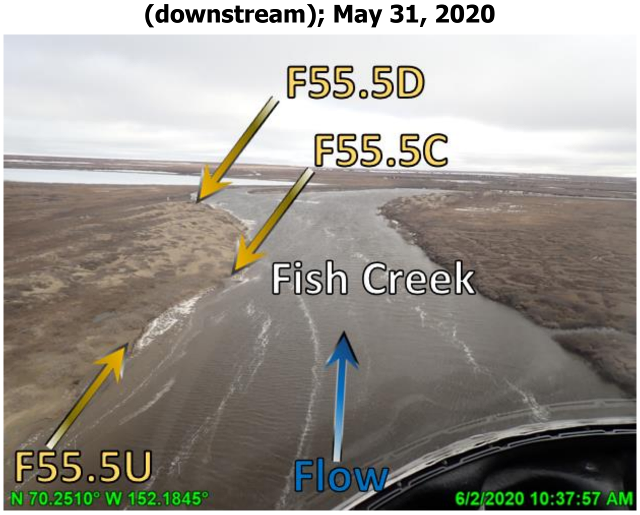


Photo 4.5: No evidence of overbank flooding after peak stage at F55.5, looking northeast (downstream); June 2, 2020

Photo 4.6: Minor overbank flooding near the headwaters of Fish Creek, looking west (upstream); June 2, 2020

Discharge was measured using a tethered ADCP at F55.5 on June 2 (Photo 4.7), approximately 1 day after peak stage occurred. During the measurement minimal snow was present along the banks and periodic ice floes were observed moving through the reach (Photo 4.8). The measurement was influenced by a moving bed, the effects of which were analyzed and applied as a correction to the discharge output. The quality of the discharge measurement was classified as good based on the conditions at the time of the measurement.

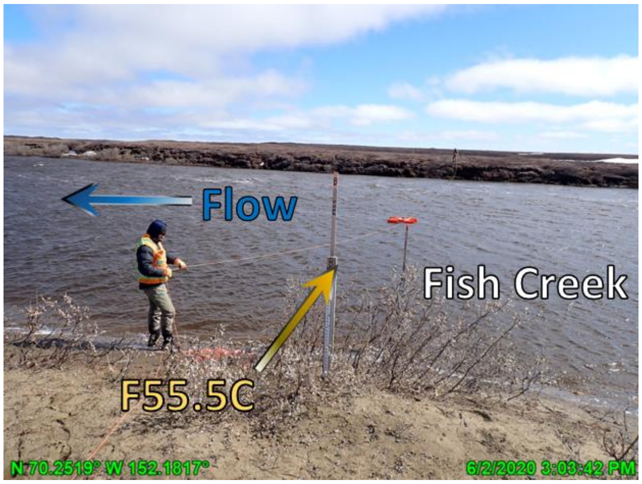


Photo 4.7: Crews measuring discharge at F55.5, looking northeast (downstream); June 2, 2020

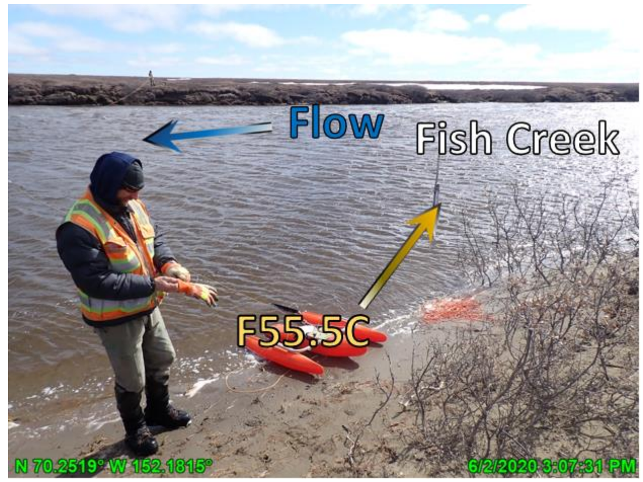
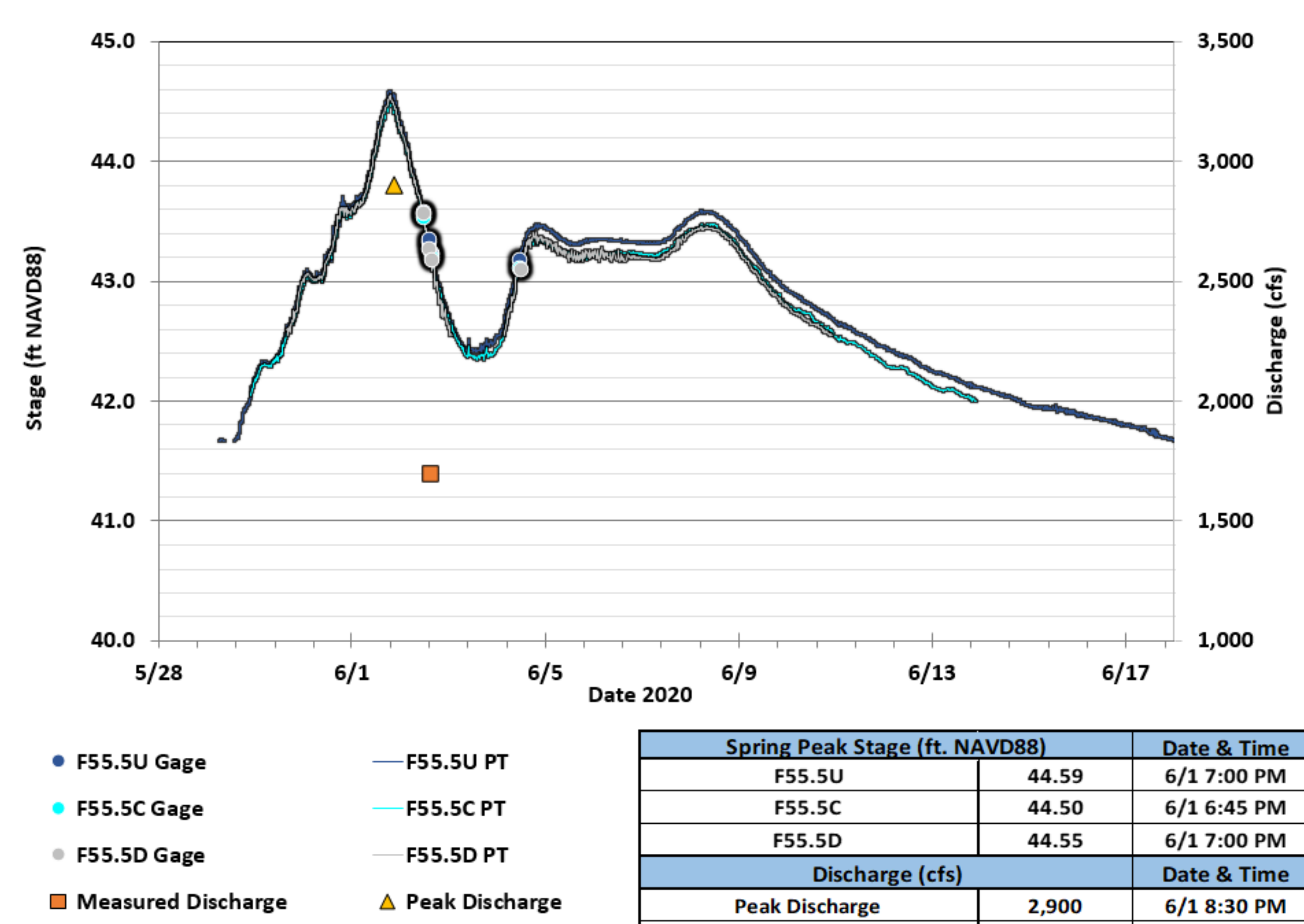


Photo 4.8: F55.5 reach clear of snow, looking east (upstream); June 2, 2020

Peak discharge was calculated indirectly based on stage and the differential stage levels between gage sites. The estimated date of peak discharge at F55.5 was June 1, coinciding with peak stage. The cross-section used to calculate peak discharge was determined from the direct discharge measurement on June 2, which may have been affected by snow and bottom-fast ice. The estimated peak discharge calculation was assigned a fair quality rating based on the potential presence of snow and ice within the cross section on June 2, and the uncertainty in channel geometry at the time of the peak discharge calculation.

Fish Creek F55.5 spring breakup stage and discharge data is provided in Graph 4.1. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.



Spring Peak Stage (ft. NAVD88)		Date & Time
F55.5U	44.59	6/1 7:00 PM
F55.5C	44.50	6/1 6:45 PM
F55.5D	44.55	6/1 7:00 PM
Discharge (cfs)		**Date & Time**
Peak Discharge	2,900	6/1 8:30 PM
Measured Discharge	1,700	6/2 2:45 PM

Graph 4.1: Fish Creek at F55.5 Spring Breakup Stage & Discharge

B. Summer

Summer stage was measured at F55.5D, just downstream of the proposed crossing location. Stage fluctuations associated with precipitation were recorded throughout the summer; water levels remained below peak spring stage (Photo 4.9). Summer stage at Fish Creek at F55.5 is presented in Graph 4.2.

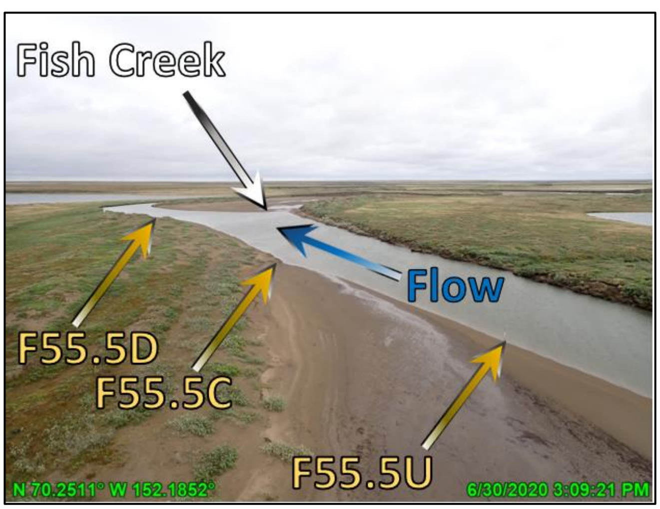
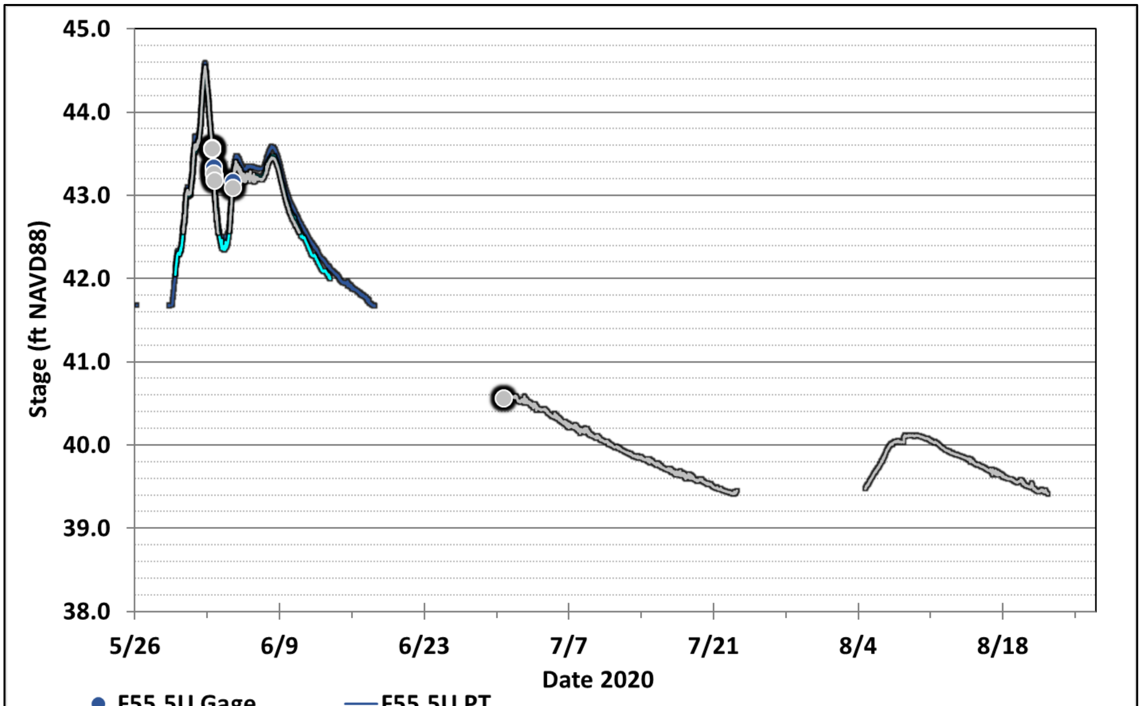


Photo 4.9: Low-flow summer conditions at F55.5, looking northeast (downstream); June 30, 2020



Summer Stage (ft. NAVD88)		Date & Time
F55.5 Highest Recorded Stage	40.60	6/30 5:00 PM
F55.5 Minimum Recorded Stage	39.41	8/22 8:30 AM

Graph 4.2: Fish Creek at F55.5 Spring and Summer Stage

JUDY CREEK

Judy Creek is a low gradient, highly sinuous channel flowing generally northeast into Fish Creek. The channel bed and banks consist of predominately silt and sand. ConocoPhillips' proposed Willow alignment crosses Judy Creek at the J21.4 monitoring location. The Judy Creek drainage basin at gage station J21.4 encompasses an area of approximately 485 square miles. The historical gage station J13.8 was also monitored in 2020 to build upon the historical record of stage and discharge. J13.8 is approximately 7.6 RMs downstream of J21.4 and has a drainage area of approximately 518 square miles. The J13.8 gage station was established in 2001, and 2020 represents the ninth year of stage monitoring.

The J21.4 gage station is 21.4 RMs upstream of the Judy Creek confluence with Fish Creek. The J21.4 gage station is upstream of the Willow 2 tributary and Judy Creek Kayyaaq tributary confluences. This gage site was established in 2017. The 2020 monitoring period represents the fourth year of monitoring activities at J21.4.

The J13.8U, 13.8, and J13.8D gage stations are 13.8 RMs upstream of the confluence with Fish Creek. The J13.8 gage stations are downstream of the Willow 2 tributary and upstream of the Judy Creek Kayyaaq tributary confluences. Historical peak stage at J13.8 and J21.4 is presented in Table .

Table 4.4: Judy Creek at J13.8 & J21.4 Historical Peak Stage and Peak Discharge

Year	J21.4		J13.8				
	Peak Stage (ft NAVD88)	Date	Peak Stage (ft BPMSL)	Date	Peak Discharge (cfs)	Date	Associated Stage (ft BPMSL)
2020	49.38	5/30	35.02	5/31	3,500	5/30	34.85
2019 [5]	49.80	5/27	35.81	5/27	4,600	5/27	35.64
2018 [4]	51.24	6/6	37.09	6/6	4,100	6/7	36.37
2017 [3]	48.56	6/4	34.68 [6]	6/4	3,900	6/3	34.66
2006 [2]	--		35.56	5/30	--		
2005 [2]	--		37.25	6/4	--		
2003 [2]	--		36.58	6/6	--		
2002 [1]	--		35.86	5/25	--		
2001 [1]	--		39.66	6/7	--		

Notes:
1. URS 2001-2003
2. Michael Baker 2002-2007
3. Michael Baker 2017
4. Michael Baker 2018
5. Michael Baker 2019
6. Stage interpolated between upstream and downstream gage stations

C. Spring Breakup

The leading edge of floodwater reached J21.4 on May 23, (Photo 4.10). Stage was not high enough to register on the J21.4 or J13.8 PTs until May 28. On May 24, lifted channel ice was observed near J21.4 (Photo 4.11). On May 28, J21.4 recorded a rapid stage rise of about 3 ft in 8 hours. As stage increased, RTFM images show ice floes moving through the channel (Photo 4.12). After this rapid rise, stage remained elevated and began rising again on May 30. Peak stage occurred at J21.4 in the afternoon on May 30 and at J13.8 about 8 hours later. Aerial observations on May 30, prior to peak stage, show the J13.8 reach generally clear of ice and snow, and stage below bankfull (Photo 4.13 and Photo 4.14).

No evidence of overbank flooding during peak stage was observed on June 1 (Photo 4.15). Saturated snow remained along the south bank and no ice was visible in the channel. Stage steadily decreased at all Judy creek monitoring stations after peak stage. The PT data and visual observations suggest minimal ice jamming effects at the monitoring stations. On June 3, stage continued to recede, and exposed sand bars were visible along sections of the banks near J21.4. Stage continued to recede through the end of the spring monitoring period.

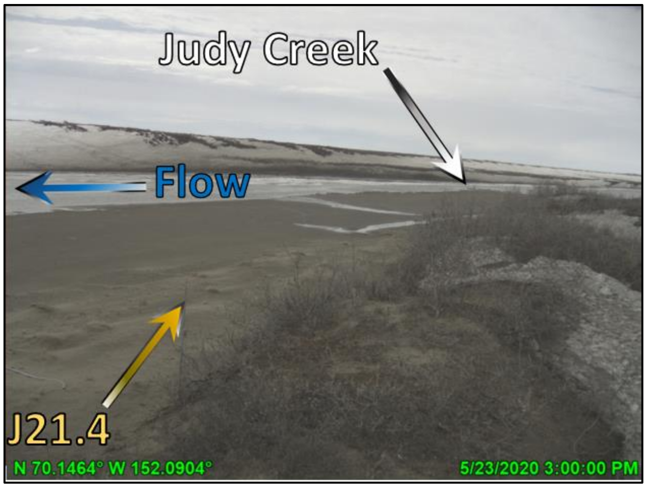


Photo 4.10: RTFM image of the leading edge of meltwater reaching J21.4, looking south (upstream); May 23, 2020

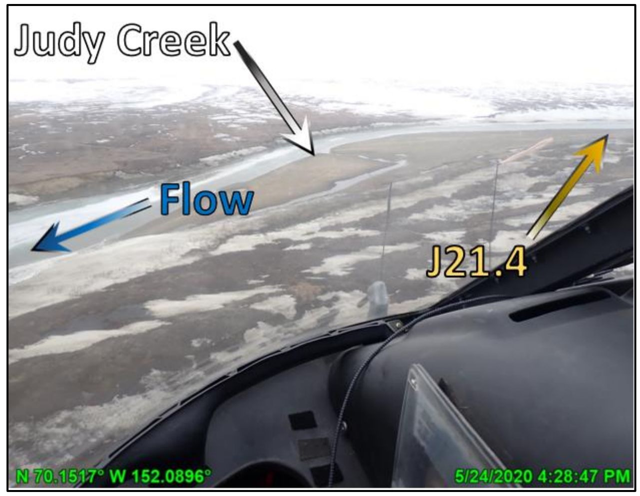


Photo 4.11: Lifted channel ice downstream of J21.4, looking southeast (upstream); May 24, 2020

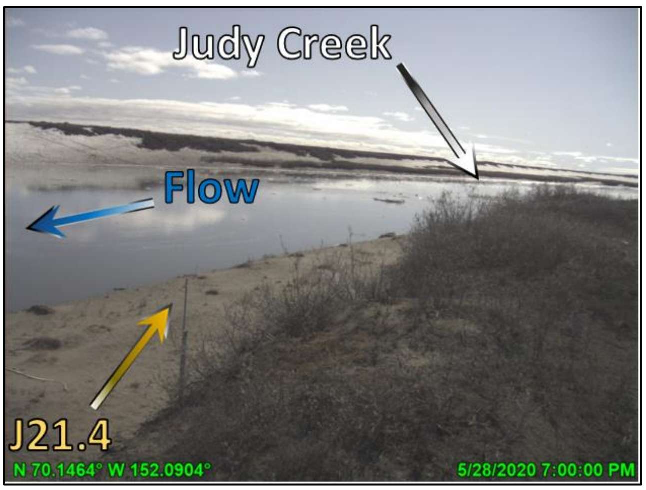


Photo 4.12: RTFM photo of ice moving through the J21.4 reach, looking south (upstream); May 28, 2020

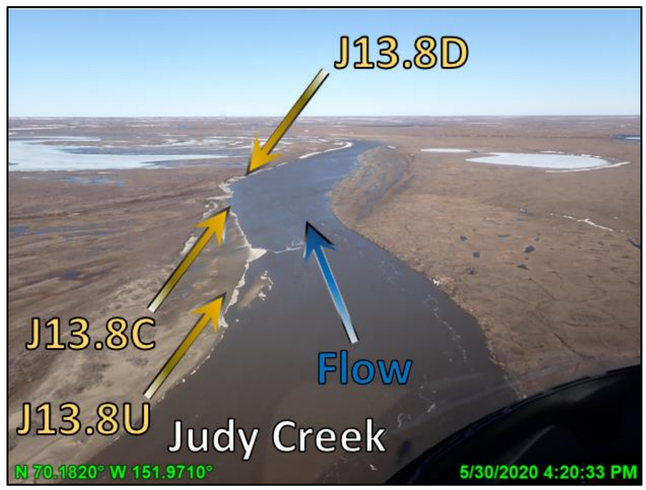


Photo 4.13: J13.8 on the day of peak stage, looking north (downstream); May 30, 2019

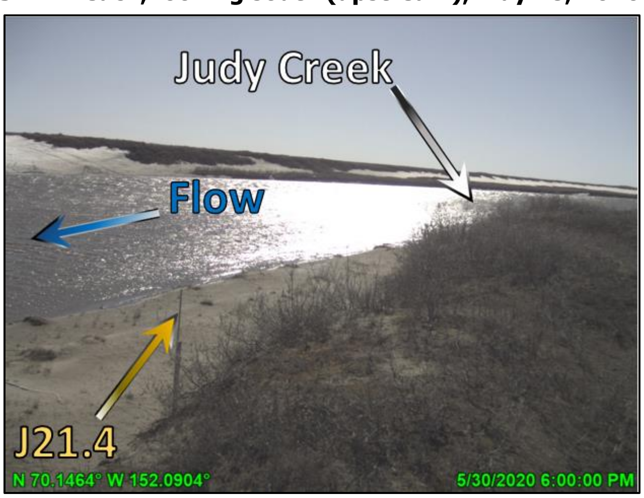


Photo 4.14: RTFM photo peak stage at J21.4, looking south (upstream); May 30, 2020

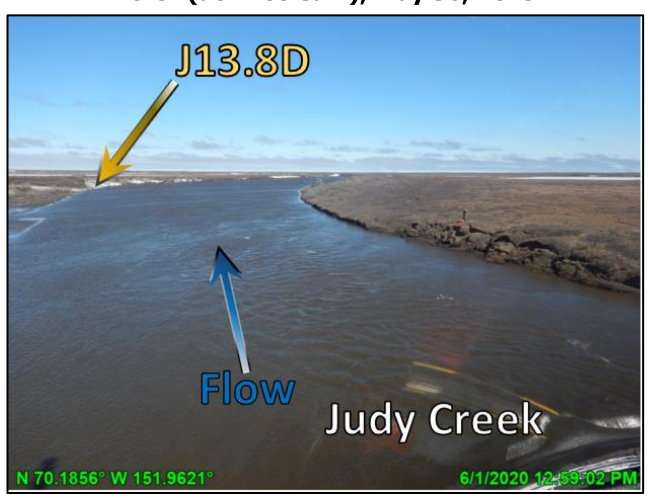


Photo 4.15: Judy creek at J13.8 2 days after peak stage, looking north (downstream); June 1, 2020

Discharge was measured using a tethered ADCP at J13.8 on June 1, approximately 2 days after peak stage. During the measurement, minimal ice floes were observed in the channel and no saturated snow was visible along the banks at the measurement cross section (Photo 4.16 and Photo 4.17). The measurement was influenced by a moving bed, the effects of which were analyzed and applied as a correction to the discharge output. The quality of the discharge measurement was classified as fair based on an equipment Bluetooth malfunction producing incomplete cross-sectional transect data.

Photo 4.16: Crews measuring discharge at J13.8, looking east (downstream); June 1, 2020

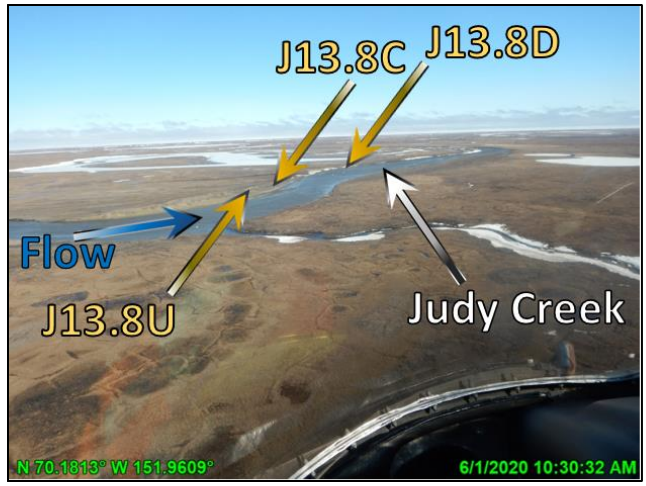
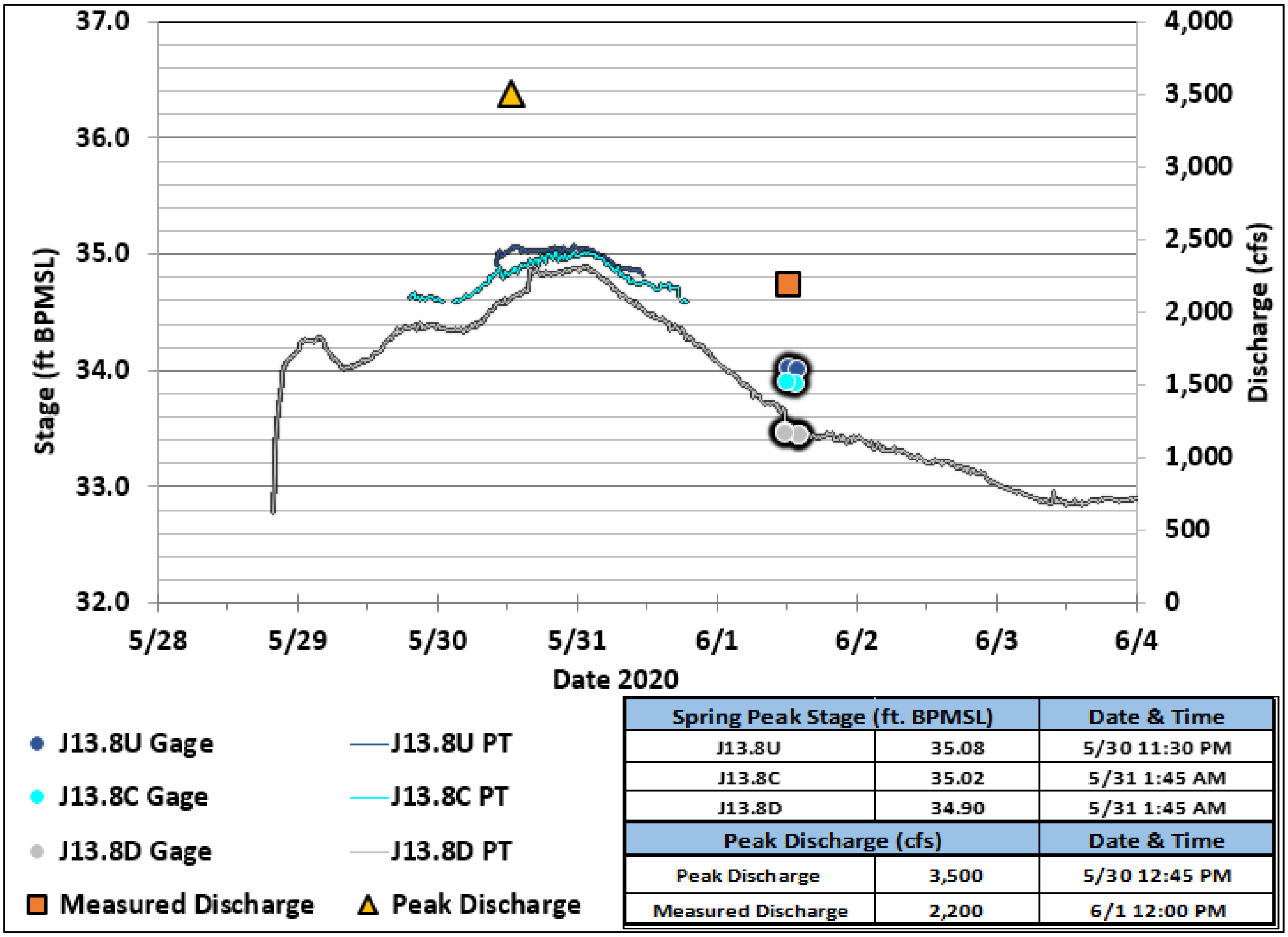


Photo 4.17: J13.8 reach on the day of the discharge measurement, looking south (upstream); June 1, 2020

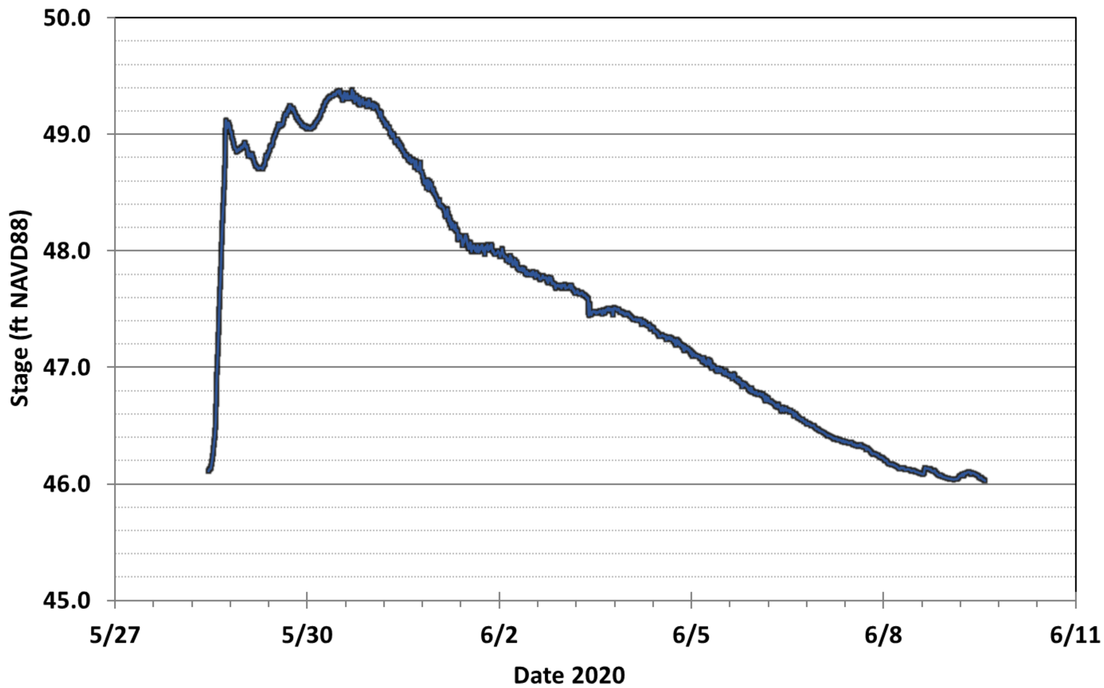
Peak discharge was calculated based on stage and stage differential between gage sites. The estimated date of peak discharge at J13.8 was May 30, coinciding with peak stage. The cross-section used to calculate peak discharge was determined from the direct discharge measurement on June 1. The estimated peak discharge was assigned a poor quality rating based on the uncertainty in channel geometry at the time of the peak discharge calculation.

Judy Creek J13.8 spring breakup stage and discharge data is provided in Graph 4.3. The J21.4 stage data is provided in Graph 4.4. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to BPMSL at J13.8, and NAVD88 at J21.4.



Spring Peak Stage (ft. BPMSL)		Date & Time
J13.8U	35.08	5/30 11:30 PM
J13.8C	35.02	5/31 1:45 AM
J13.8D	34.90	5/31 1:45 AM
Peak Discharge (cfs)		**Date & Time**
Peak Discharge	3,500	5/30 12:45 PM
Measured Discharge	2,200	6/1 12:00 PM

Graph 4.3: Judy Creek at J13.8U, J13.8, & J13.8D Spring Breakup Stage & Discharge



Spring Peak Stage (ft. NAVD88)		Date & Time
J21.4[1]	49.38	5/30 4:45 PM
1. Peak not confirmed by gage reading		

Graph 4.4: Judy Creek at J21.4 Spring Breakup Stage

D. Summer

Summer stage was measured at J21.4 near the proposed crossing location. Stage fluctuations associated with precipitation were recorded throughout the summer; water levels remained below peak spring stage (Photo 4.18). Summer stage at Judy Creek J21.4 is presented in Graph 4.5.

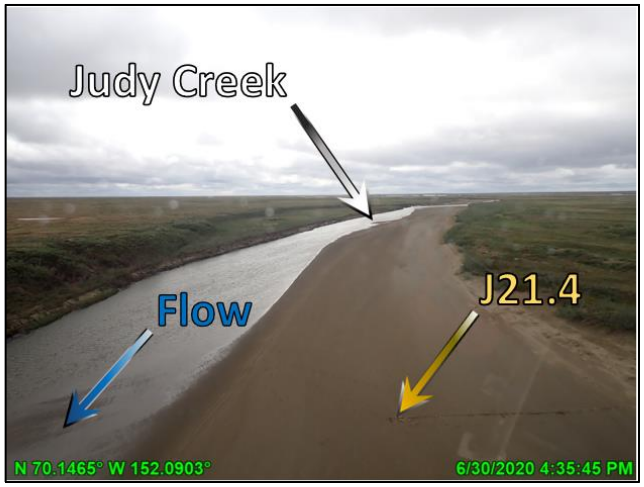
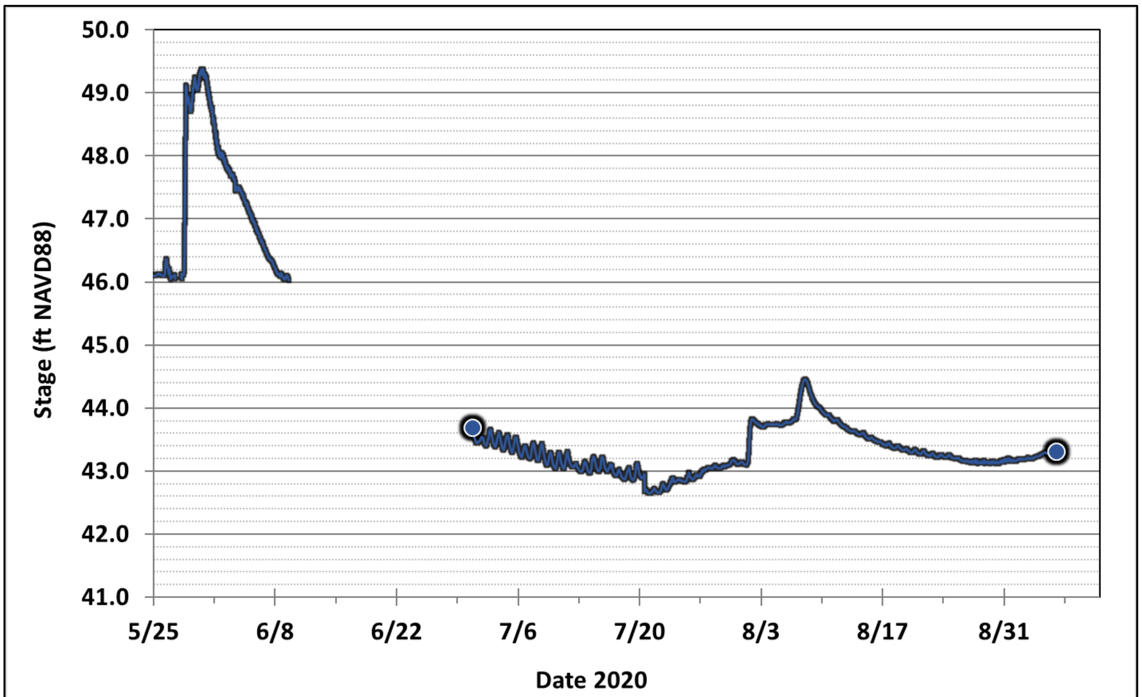


Photo 4.18: Summer conditions at J21.4, looking west (upstream); June 30, 2020



Summer Stage (ft. NAVD88)		Date & Time
J21.4 Highest Recorded Stage	44.46	8/8 2:30 AM
J21.4 Minimum Recorded Stage	42.64	7/21 2:45 AM

Graph 4.5: Judy Creek at J21.4 Summer Stage

KALIKPIK RIVER

The Kalikpik River drainage basin is a separate drainage basin that borders the FCB to the north. The Kalikpik River is a relatively low gradient, highly sinuous channel flowing generally northeast until its outlet into Harrison Bay. Like Judy Creek and Fish Creek, the channel bed and banks consist of predominately silt and sand. The headwaters of the Kalikpik River originate in a complex lake network approximately 15 miles south of Teshsepuk Lake. The Kalikpik River drainage basin encompasses an area of approximately 200 square miles. This is the third year of data collection and observations at the KAL1 monitoring location. Historical peak stage and measured discharge data at KAL1 is presented in Table .

Table 4.5: Kalikpik River at KAL1 Historical Peak Stage and Measured Discharge

Year	KAL1				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	49.72	5/31	Not Measured in 2020		
2019	49.44	5/26	245	5/30	48.94
2018 [1]	50.30	6/11	320	6/16	48.18

Notes:
1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

A. Spring Breakup

Meltwater was first recorded on the KAL1 PT on May 28. On May 30, meltwater appeared hydraulically connected through the area near the gage station, with significant quantities of ice and saturated snow remaining along the banks and in the channel (Photo 4.19). A site visit on May 31 revealed a small ice jam directly upstream of the gage. This ice jam appeared to hold minimal backwater as stage was below bankfull upstream of the ice jam (Photo 4.20). Stage remained elevated through May 31, with minor fluctuations producing peak stage late on May 31. Game camera images show saturated snow present along the banks during peak stage. After peaking, stage steadily receded, leaving ice floes stranded below the tops of each bank (Photo 4.21). Game camera images show open water conditions at KAL1 starting on June 4 (Photo 4.22). Discharge was not measured at KAL1 due to the persistent ice and snow effects days after peak stage.

Kalikpik River at KAL1 spring breakup stage and discharge data is provided in Graph 4.6. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.

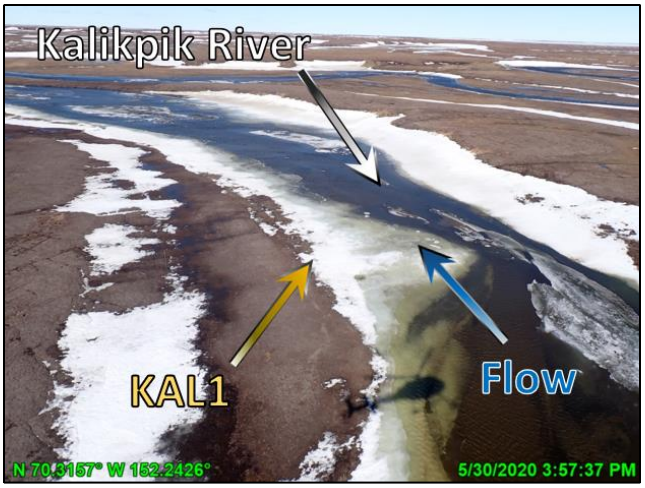


Photo 4.19: Connected meltwater with ice and saturated snow in the KAL1 reach, looking northeast; May 30, 2020

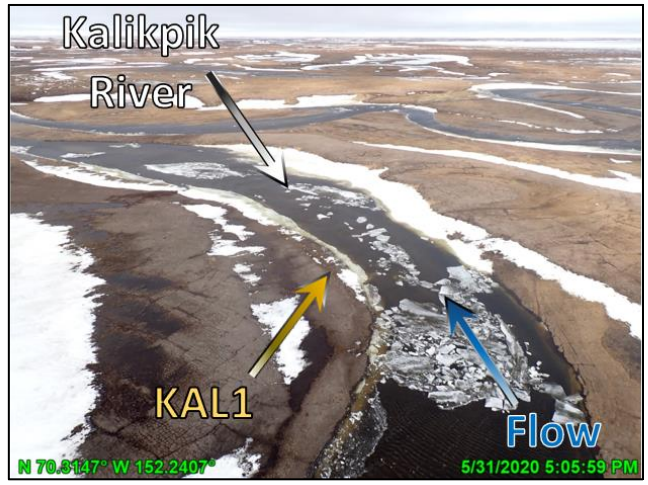


Photo 4.20: Minor ice jam directly upstream of KAL1 gage, looking northeast (downstream); May 31, 2020

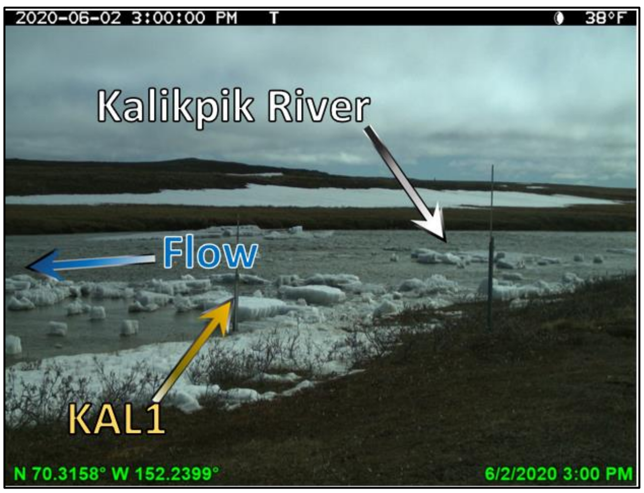


Photo 4.21: Stranded minor ice floes one day after peak stage, looking southeast; June 2, 2020

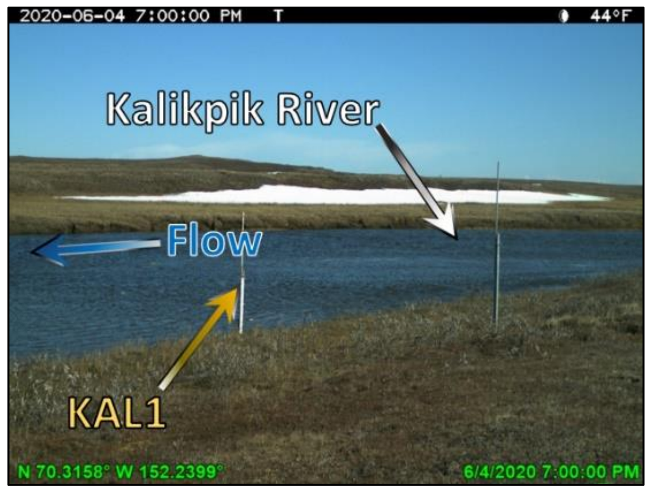
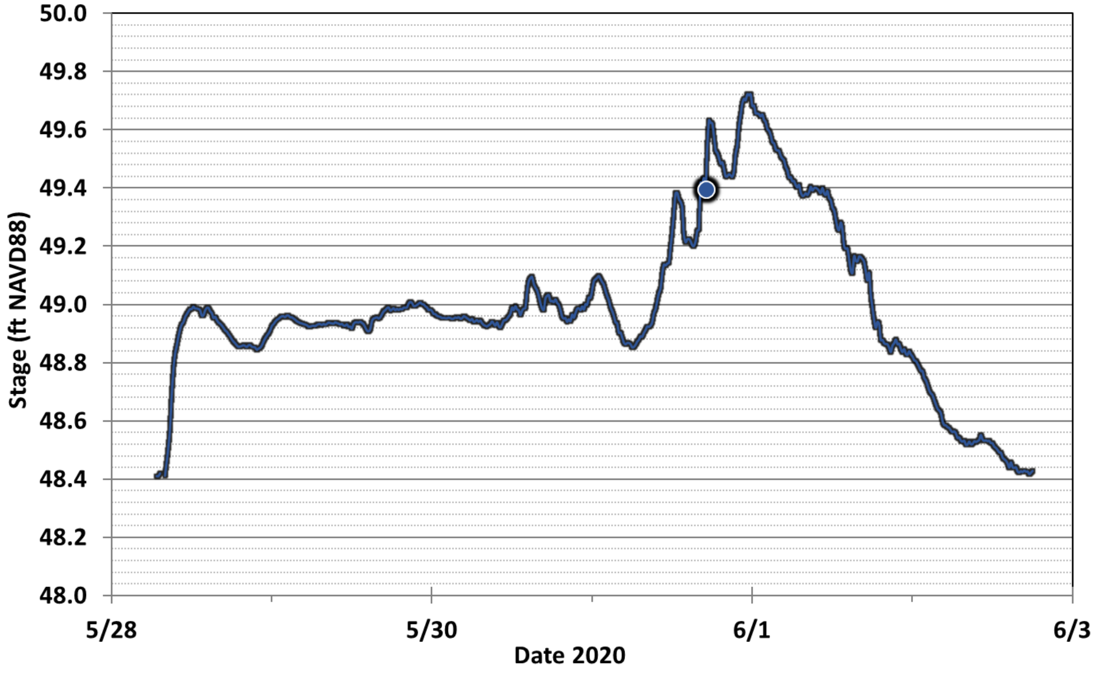


Photo 4.22: First sight of open water conditions at KAL1, approximately 3 days after peak; June 4, 2020



Spring Peak Stage (ft. NAVD88)		Date & Time
KAL1	49.72	5/31 11:45 PM

Graph 4.6: Kalikpik River at KAL1 Spring Breakup Stage & Discharge

4.2 Small Streams

JUDY CREEK KAYYAAQ

Judy Creek Kayyaaq is a meandering, incised channel (an average of over 8-ft from top of bank to creek bed; 30-ft typical channel width) flowing generally northeast into Judy Creek downstream of the J13.8 gage stations. The CPAI proposed Willow alignment crosses Judy Creek Kayyaaq at the UC2C monitoring location. The UC2C station is located in Judy Creek Kayyaaq approximately 13 RMs upstream of the confluence with Judy Creek. This is the fourth year of data collection and observations at the UC2C monitoring location. Historical peak stage and measured discharge data at UC2C is presented in Table .

Table 4.6: Judy Creek Kayyaaq at UC2C Historical Peak Stage and Measured Discharge

Year	UC2C				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	54.18	5/30	230	6/1	52.56
2019	54.06	5/27	270	5/30	52.33
2018 [2]	54.78	6/13	140	6/11	53.69
2017 [1,2]	54.38	5/30	190	6/3	--

Notes:
1. Discharge measured at historical site UC2A, 4.3 RM downstream of UC2C
2. 2017 and 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

A. Spring Breakup

Meltwater was first recorded at Judy Creek Kayyaaq at the UC2C gage on May 28. Stage rose steadily over the next day. On the evening of May 29, a sharp stage increase of 3.8 ft was recorded between 8 and 10 PM. Stage remained elevated through June 1 and reached peak on May 30. Aerial observations at peak stage on May 30 showed stage above bankfull (Photo 4.23). Overbank flooding was observed in low-lying areas near UC2C. Overbank floodwater filled tundra depressions and low lying area along the south bank at the crossing alignment. Minimal ice or saturated snow remained in the channel and along the banks during peak stage. Aerial observations from May 31 show stage had receded to back to bankfull levels (Photo 4.24). Stagnant pools of floodwater remained in low-lying areas near the banks at UC2C. Stage began to steadily decline on the morning of June 1 (Photo 4.25). Stage continued to recede through the rest of the spring monitoring period.

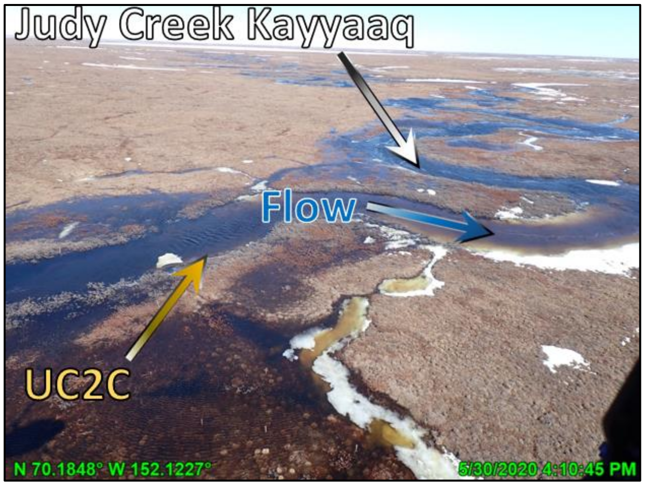


Photo 4.23: Stage above bankfull in Judy Creek Kayyaaq at UC2C, looking east (downstream); May 30, 2020

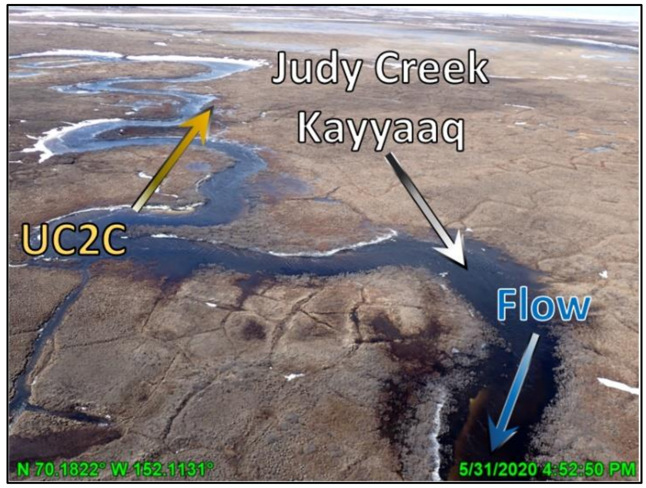


Photo 4.24: Bankfull stage near UC2C, looking northwest (upstream); May 31, 2020

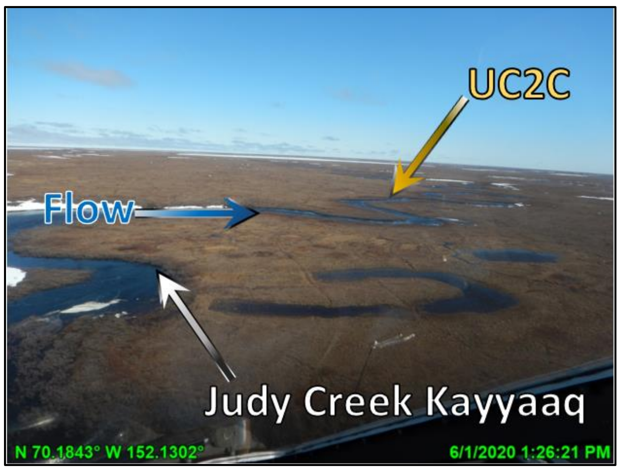


Photo 4.25: Receding stage at UC2C, looking northeast (downstream); June 1, 2020

Discharge during spring breakup was measured using a tethered ADCP at the UC2C gage station on June 1, approximately 2 days after peak stage. During the measurement, the channel was clear of snow and ice and flow was confined to within the channel banks (Photo 4.26 and Photo 4.27). The overall quality of the discharge measurement was classified as fair. The moving bed measurement associated with UC2C was negligible and not included as a correction to the overall measurement.

Judy Creek Kayyaaq UC2C spring breakup stage data is provided in Graph 4.7. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.

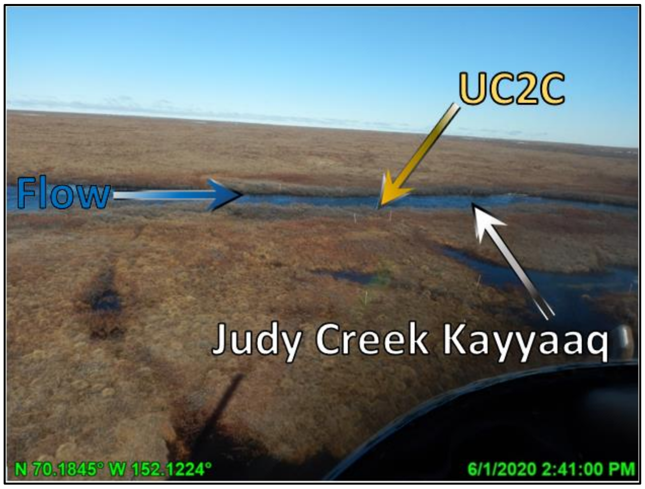
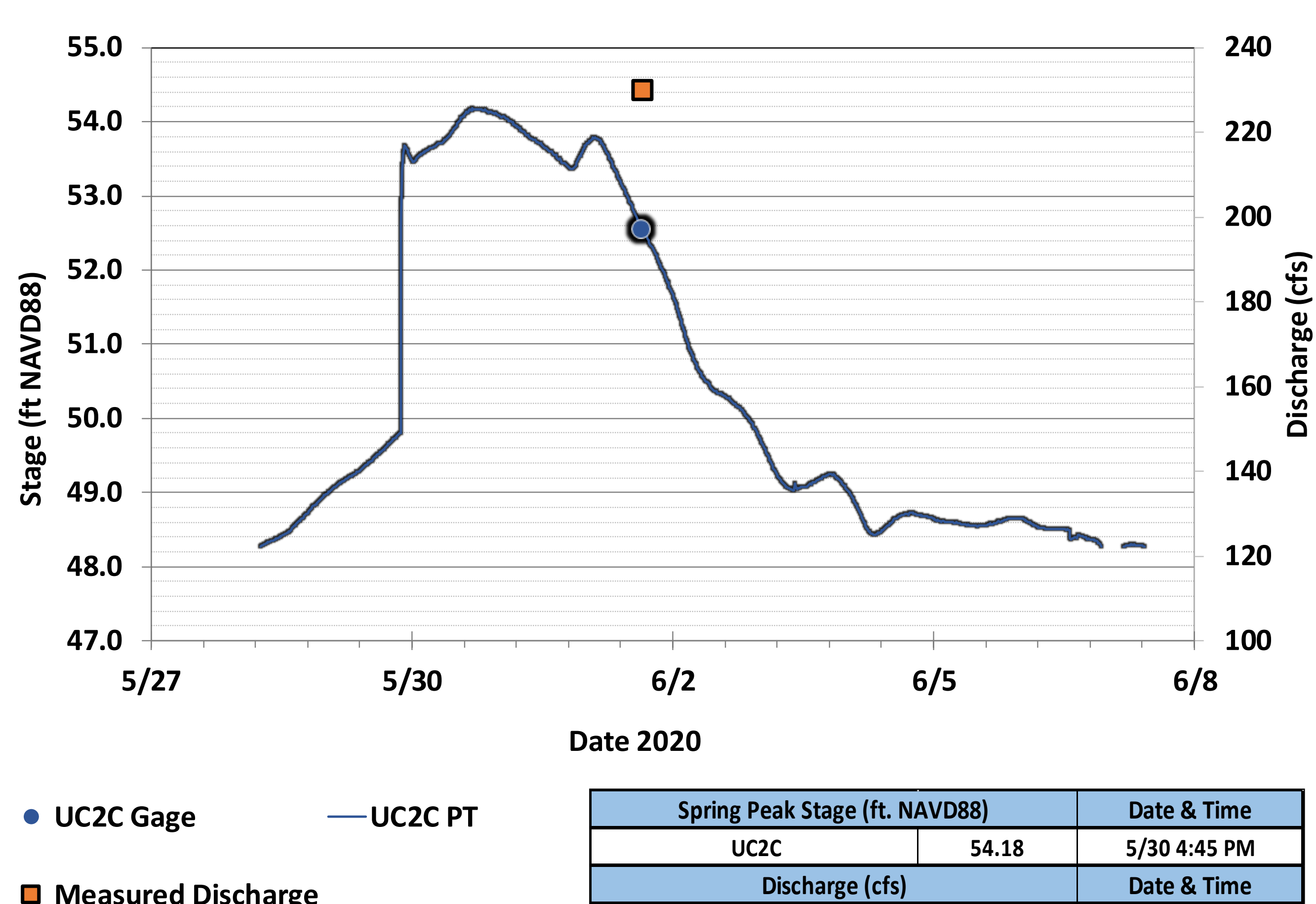


Photo 4.26: Clear channel conditions during the discharge measurement, looking north June 1, 2020

Photo 4.27: Crews measuring discharge at UC2C, looking north; June 1, 2020



Spring Peak Stage (ft. NAVD88)		Date & Time
UC2C	54.18	5/30 4:45 PM
Discharge (cfs)		**Date & Time**
UC2C Measured Discharge	230	6/1 3:30 PM

Graph 4.7: Judy Creek Kayyaaq at UC2C Spring Breakup Stage & Discharge

B. Summer

Small stage fluctuations associated with summer precipitation were recorded in the PT data; water levels remained below spring breakup peak stage (Photo 4.28). Summer stage in Judy Creek Kayyaaq at UC2C is presented in Graph 4.8.

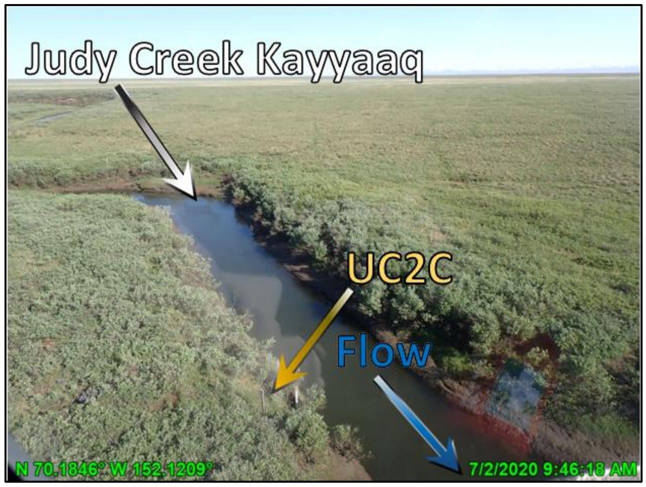
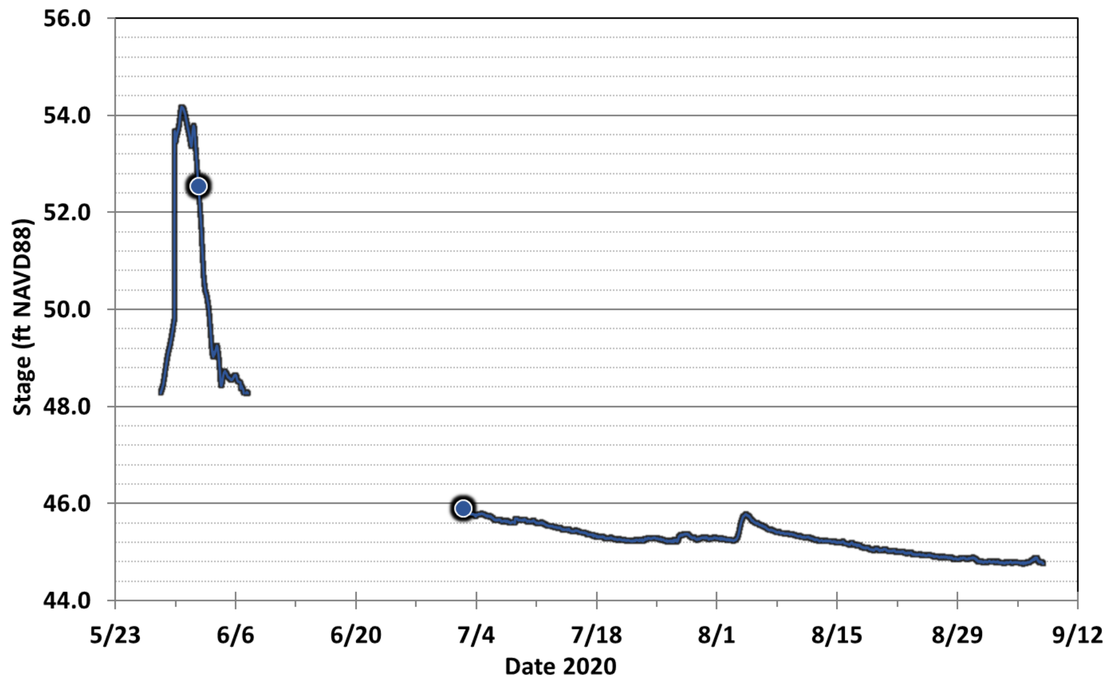


Photo 4.28: Summer conditions at UC2C, looking northwest (upstream); July 2, 2020



Summer Stage (ft. NAVD88)		Date & Time
UC2C Highest Recorded Stage	45.78	8/4 8:45 AM
UC2C Minimum Recorded Stage	44.75	9/5 3:30 PM

Graph 4.8: Judy Creek Kayyaaq at UC2C Spring and Summer Stage

WILLOW 1

The W1S gage station on Willow 1 is situated in a poorly defined low-lying area which conveys flow from Lake R0060 to Lake M0016. The CPAI proposed Willow alignment crosses Willow 1 at the W1S monitoring location. Meltwater from the Willow 1 drainage flows through lake M0016 before connecting with Willow 2 downstream of UC1B. This is the second year of monitoring at the W1S gage station. Historical peak stage and measured discharge data at W1S is presented in Table .

Table 4.7: Willow 1 at W1S Historical Peak Stage

Year	W1S	
	Peak Stage (ft NAVD88)	Date
2020	79.34	5/30
2019 [1]	79.25	5/28
2018 [1, 2]	79.16	6/6

Notes:
[1.] Peak stage reported based on game camera images of gage site. No PT deployed
[2.] 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

A. SPRING BREAKUP

Local melt was first observed through game camera images on May 28 (Photo 4.29). Stage increased until peaking on May 30. During peak, aerial observations show widespread meltwater in the low-lying areas of the drainage system (Photo 4.30). Bottomfast ice and saturated snow were observed in isolated portions of the drainage. The ice road crossing south of the gage station did not appear to impede flow. On May 31, a discharge measurement was attempted but could not be completed due to a lack of measurable flow paths. Direction of flow was south to north (Photo 4.31). After peaking, stage gradually receded. Snow cover on the surrounding tundra was estimated at 10%. By June 4, no flow was observed near the gage station, and local meltwater was confined to pools in low-lying areas (Photo 4.32). Other areas in the drainage not near the gage station appeared to still be hydraulically connected.

Willow 1 W1S spring breakup stage data is provided in Graph 4.9. Elevations are referenced to NAVD88.

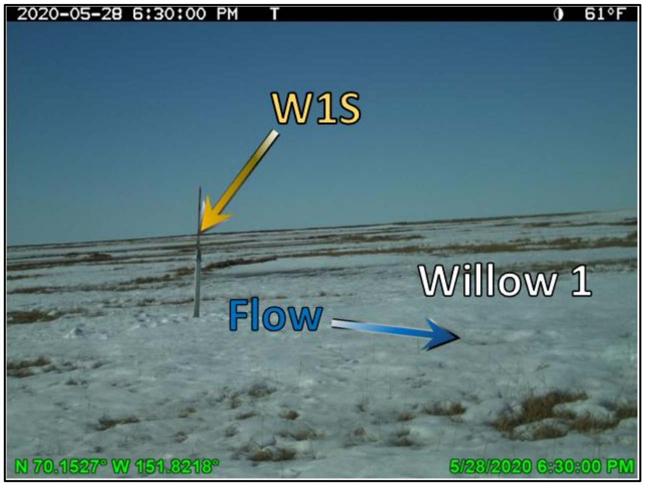


Photo 4.29: Initial meltwater at W1S, looking north; May 28, 2020

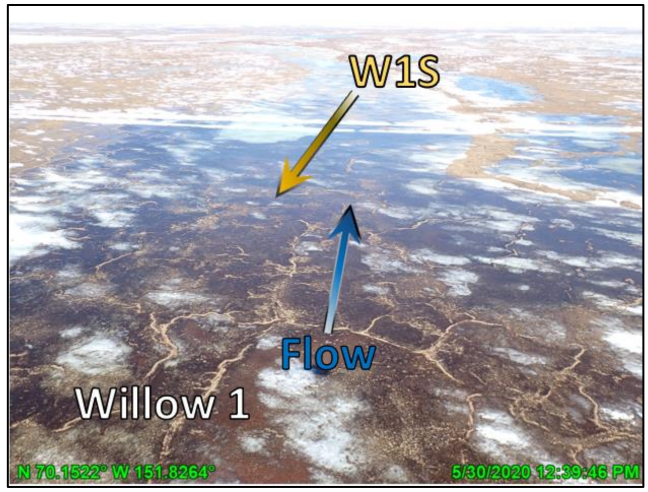


Photo 4.30: Widespread meltwater near peak stage at W1S, looking north; May 30, 2020

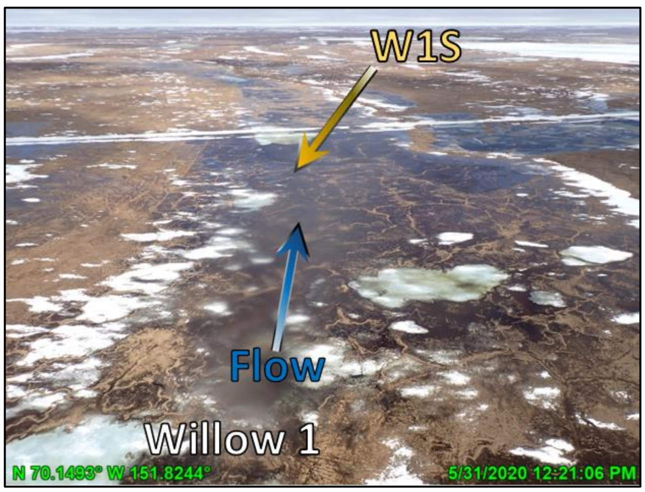


Photo 4.31: Receding stage at W1S, looking north (downstream); May 31, 2020

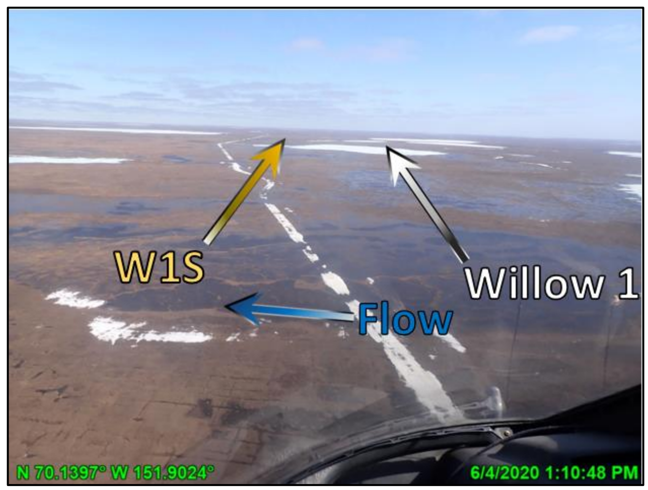
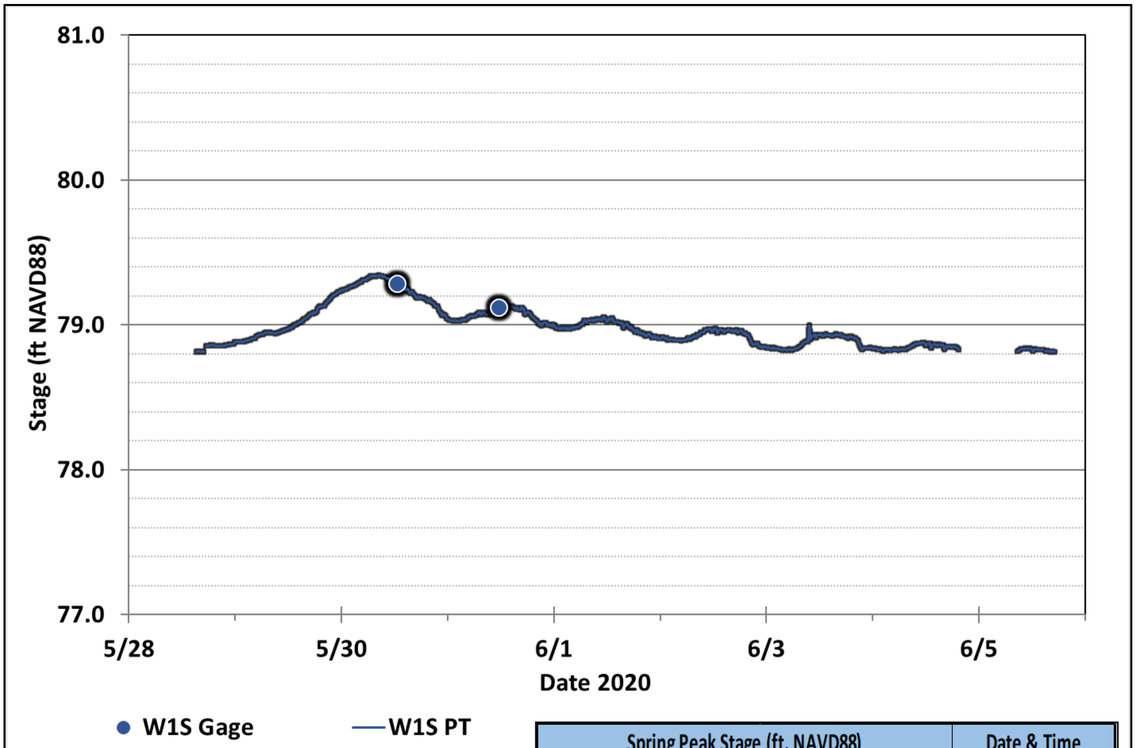


Photo 4.32: Late spring conditions at W1S, looking east; June 4, 2020



Spring Peak Stage (ft. NAVD88)		Date & Time
W1S	79.34	5/30 8:30 AM

Graph 4.9: Willow 1 at W1S Spring Breakup Stage

B. Summer

Summer stage was measured at W1S. Stage fluctuations associated with summer precipitation events were recorded in the PT data; water levels remained below spring breakup peak stage (Photo 4.33). Summer stage in Willow 1 at W1S is presented in Graph 4.10

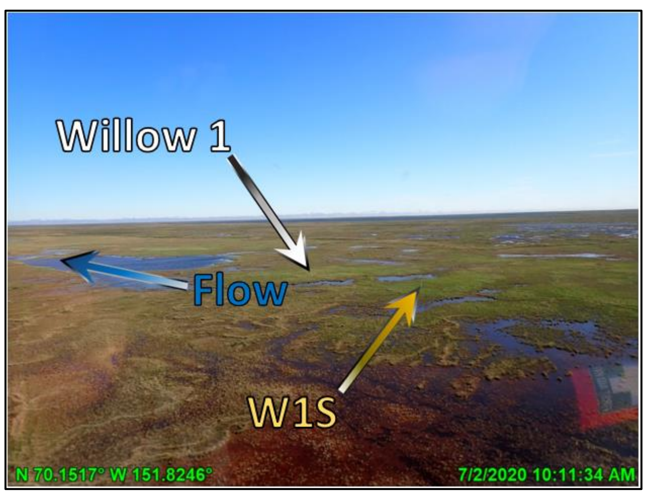
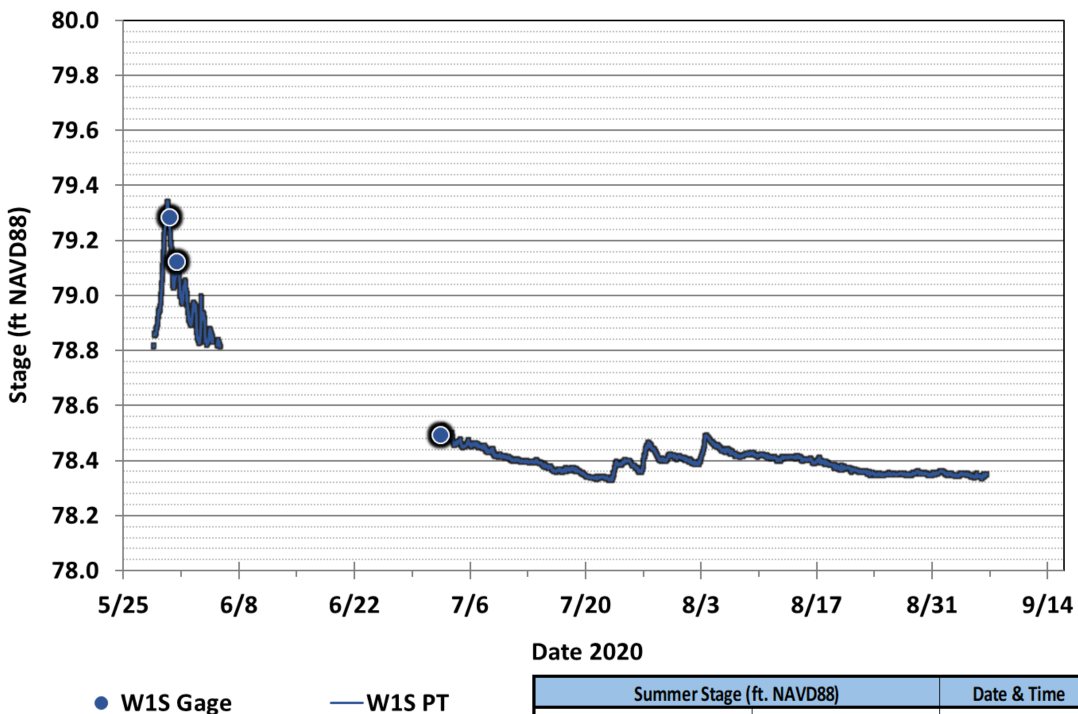


Photo 4.33: Summer conditions at W1S, looking northeast (downstream); July 2, 2020



Summer Stage (ft. NAVD88)		Date & Time
W1S Highest Recorded Stage	78.49	8/3/20 3:00 PM
W1S Minimum Recorded Stage	78.33	9/6/20 12:15 AM

Graph 4.10: Willow 1 at W1S Spring Breakup Stage

WILLOW 2

Willow 2 is a highly sinuous, deep and incised, beaded channel (over 10-ft from top of bank to creek bed; 20-ft typical channel width) flowing generally north into Judy Creek upstream of the J13.8 gage stations. The UC1B gage station is situated about 4.5 RM upstream of the Willow 2-Judy Creek confluence. The CPAI proposed Willow alignment crosses Willow 2 at the UC1B monitoring location. This is the fourth year the UC1B gage station has been monitored. Historical peak stage and measured discharge data at UC1B is presented in Table

Table 4.8: Willow 2 at UC1B Historical Peak Stage and Measured Discharge

Year	UC1B				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	82.12	5/29	90	6/2	76.55
2019	83.52	5/26	110	6/1	75.91
2018 [2]	84.42	6/10	120	6/13	81.17
2017 [1,2]	79.84	5/30	125	6/3	--

Notes:
1. Discharge measured at historical site UC1A, 3.5 RM downstream of UC1B
2. 2017 and 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

A. Spring Breakup

Willow 2 was filled with wind-driven snow at the onset of spring breakup. The leading edge of floodwater was observed through game camera images on May 29 as flow overtop of saturated snow (Photo 4.34). Peak stage quickly followed on May 29 as stage was elevated by saturated snow in the channel and along the banks. Stage remained elevated through May 30. Aerial observations from May 30 show stage below bankfull, and beginning to cut through the saturated snow pack. Snow cover on surrounding tundra was approximately 10% near the Willow 2 drainage (Photo 4.35). Stage began to steadily decline on May 31 as flow continued to cut through the snow pack. Aerial observations from May 31 show saturated snow remaining in the channel and on the banks near UC1B. No stranded ice or other evidence of overbank flooding was observed (Photo 4.36). Meltwater continued to cut through the snowpack in the channel through June 2 (Photo 4.37 and Photo 4.38). Stage receded through the rest of the spring monitoring period.

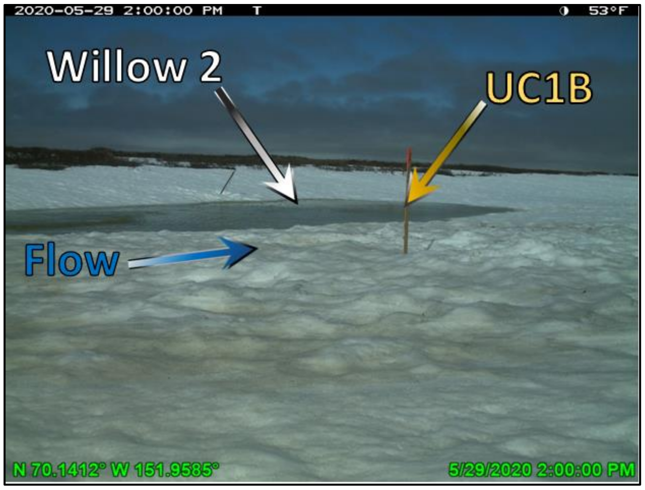


Photo 4.34: Leading edge of floodwater in Willow 2 at UC1B, looking north (downstream); May 29, 2020

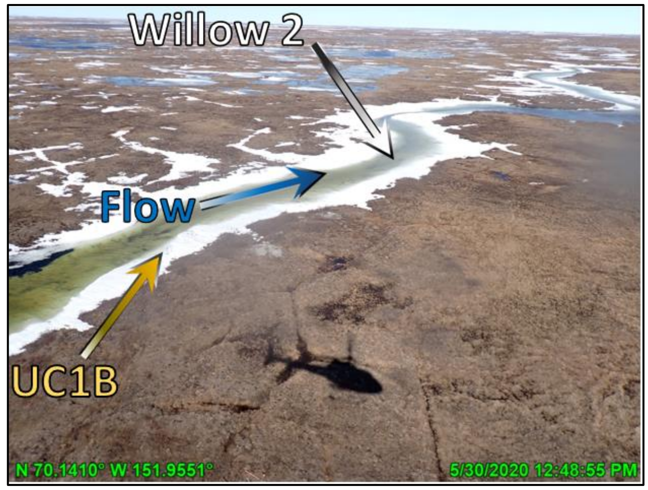


Photo 4.35: Floodwater and saturated snow in Willow 2 near UC1B, looking northwest (downstream); May 30, 2020

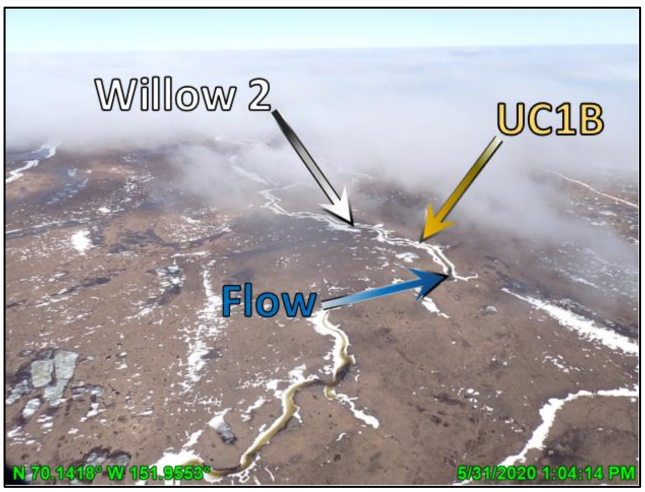


Photo 4.36: No evidence of overbank flooding after peak stage, looking north (stream); May 31, 2020.

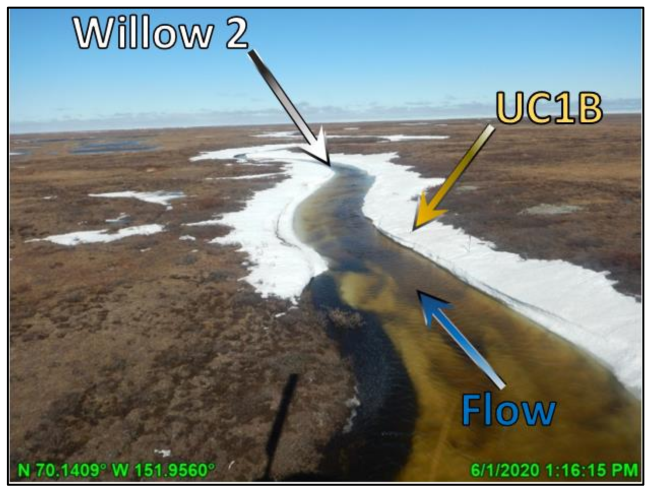
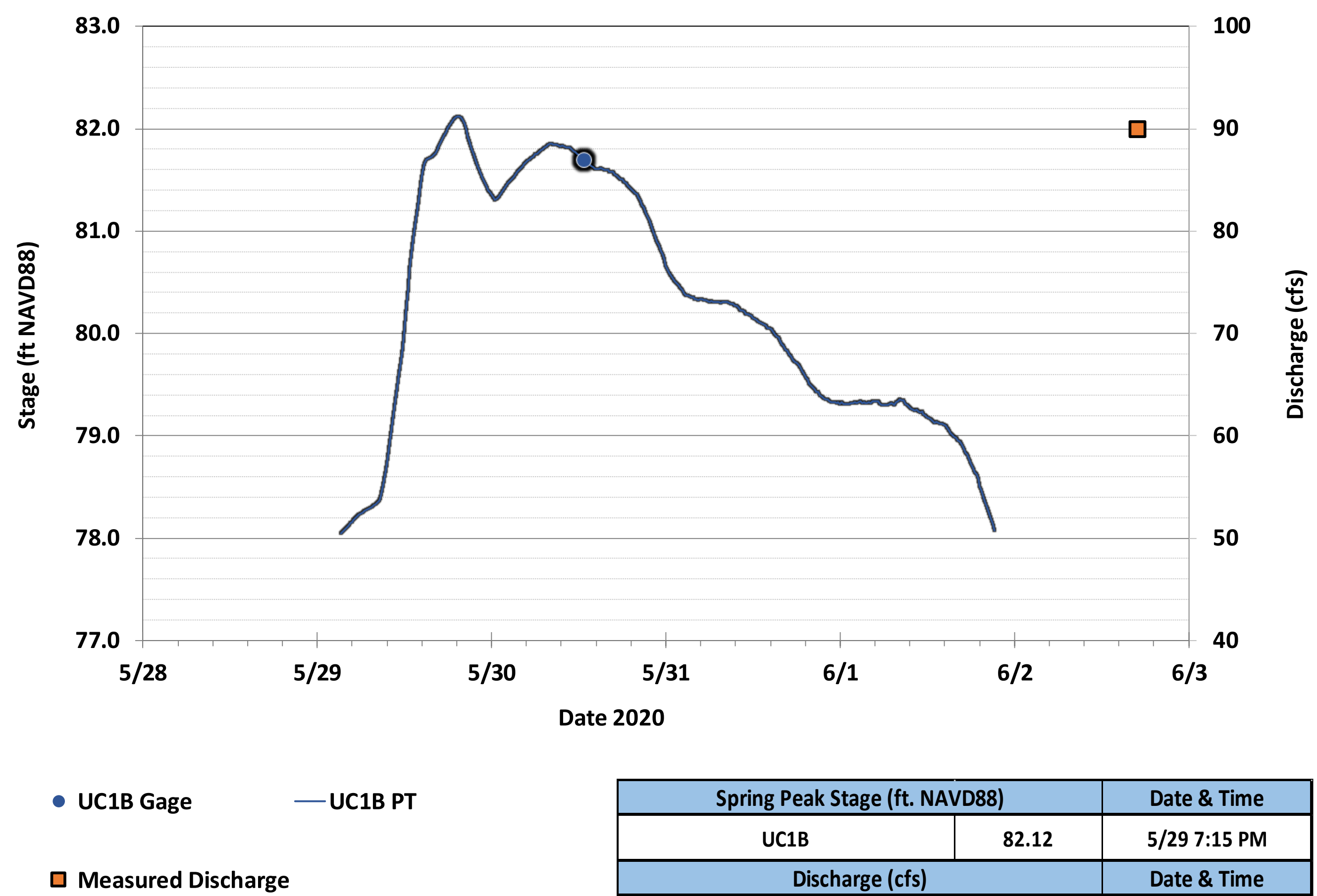


Photo 4.37: Snow-filled channel at UC1B, looking north (downstream); June 1, 2020

Photo 4.38: Conditions at UC1B on the day of the discharge measurement, looking north (downstream); June 2, 2020

Discharge was measured using a tethered ADCP at UC1B on June 2, approximately 4 days after peak stage. During the measurement, stage was far below bankfull and snow remained along the banks overhanging the channel. The overall quality of the discharge measurement was classified as poor due to the snow and ice in the channel. The moving bed measurement associated with UC1B was negligible and not included as a correction to the overall measurement.

Willow 2 at UC1B spring breakup stage and discharge data is provided in Graph 4.11. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.



Spring Peak Stage (ft. NAVD88)		Date & Time
UC1B	82.12	5/29 7:15 PM
Discharge (cfs)		**Date & Time**
UC1B Measured Discharge	90	6/2 5:00 PM

Graph 4.11: Willow 2 at UC1B Spring Breakup Stage & Discharge

B. Summer

Summer stage was measured at UC1B. Stage fluctuations associated with summer precipitation events were recorded in the PT data; water levels remained below spring breakup peak stage at all locations (Photo 4.39). Summer stage in Willow 2 at UC1B is presented in Graph 4.12.

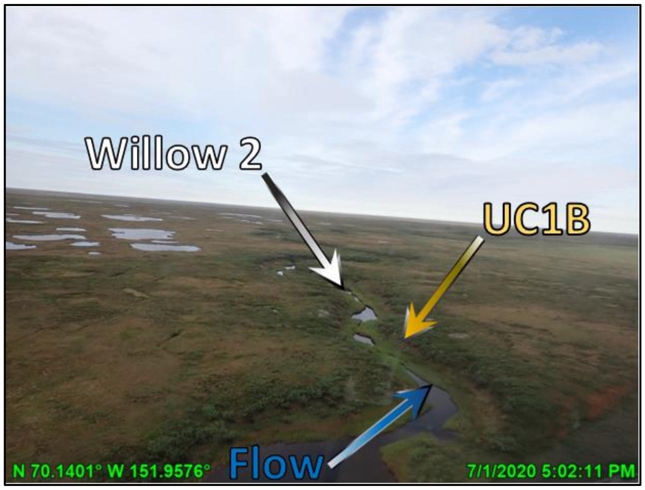
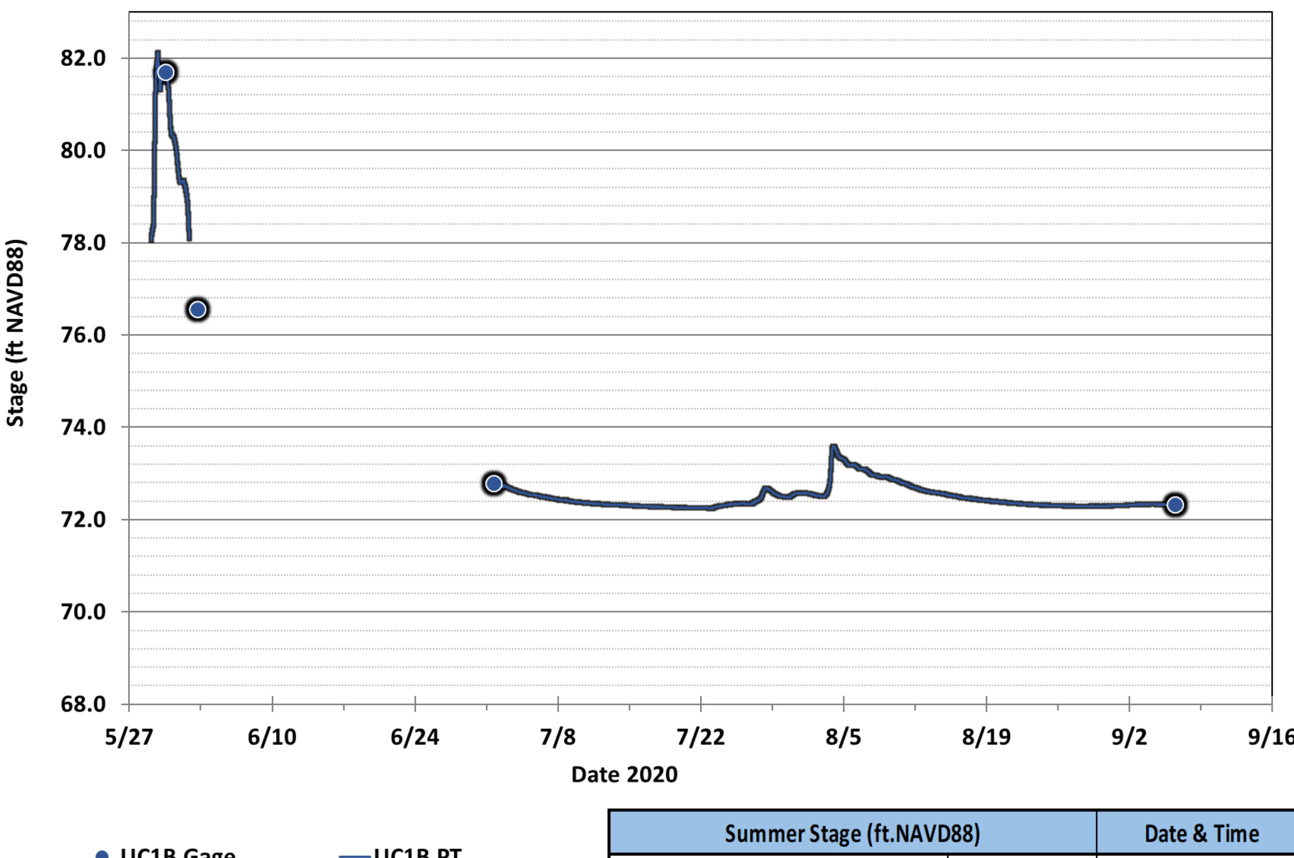


Photo 4.39: Summer conditions at UC1B, looking north (downstream); July 1, 2020



Summer Stage (ft.NAVD88)		Date & Time
UC1B Highest Recorded Stage	73.59	8/3 11:00 PM
UC1B Minimum Recorded Stage	72.24	7/22 10:00 PM

Graph 4.12: Willow 2 at UC1B Spring and Summer Stage

WILLOW 3 (W3S)

The W3S monitoring location is situated in a low-lying, poorly defined section of a swale connecting Lake M0015/R0056 to Lake R0055. The CPAI proposed Willow alignment crosses Willow 3 at the W3S monitoring location. The 2019 W3S monitoring station was moved 0.2 miles southeast from the 2018 location. This is the second year of data collection and observations at the 2019 W3S monitoring location, and the third year of monitoring the W3S drainage. Historical peak stage and measured discharge data at W3S is presented in Table .

Table 4.9: Willow 3 at W3S Historical Peak Stage and Measured Discharge

Year	W3S				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020 [1]	88.00	5/28	8	6/4	87.06
2019	88.49	6/2	5	5/30	88.22
			16	6/2	88.20
2018 [2,3]	84.13	6/4	--		

Notes:
1. Basis of elevation is the Game Camera Steel.
2. Peak stage reported based on game camera images of gage site. No PT deployed
3. Gage was located on a previous alignment 0.2 miles downstream on the Willow 3 drainage.

A. Spring Breakup

Local melt was first observed in the Willow 3 drainage at W3S on May 27 via game camera images. Peak stage occurred on May 28 and was the result of isolated local melt (Photo 4.40). Local melt increased until May 29 when game camera images suggest flow developed. A site visit on May 30 confirmed S-N flow overtop of saturated snow in the Willow 3 drainage. Aerial observations showed the poorly defined channel filled with saturated snow. Stagnant, local meltwater was accumulating in low-lying pools and polygon troughs near the channel (Photo 4.41). Snow cover on the surrounding tundra was estimated at 10%. On May 31, no flow from Lake M0015/R0056 into W3S was observed. Meltwater in the W3S drainage appeared to be entirely localized (Photo 4.42).

Aerial observations from June 2 show no integrated flow between Lake M0015/R0056 and Willow 3 at W3S (Photo 4.43). Localized meltwater persisted in the drainage until approximately June 3 when game camera images suggest integrated flow developed between Lake M0015/R0056 to Willow 3 at W3S. A site visit and aerial observations on June 4 confirmed that integrated flow was present (Photo 4.44). Stage levels after integrated flow were confirmed on June 4 and were significantly lower than the recorded peak stage due to localized melt. Discharge was measured using a HACH meter and wading rod at W3S on June 4 and June 5. During these measurements, flow was confined to the defined channel and minimal snow and ice remained in the channel and along the banks (Photo 4.45). The quality of the discharge measurements was rated as good based on these conditions. The PT data shows stage steadily decreasing throughout the rest of the spring monitoring period. The PTs recorded small short-term fluctuations in stage and notably minimal overall stage gain and loss over the monitoring period. This minimal overall stage fluctuation is characteristic of poorly defined drainages with multiple flow paths, as seen in Willow 3 at W3S and in Willow 1 at W1S.

The W3S stage data is presented in Graph 4.13. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.

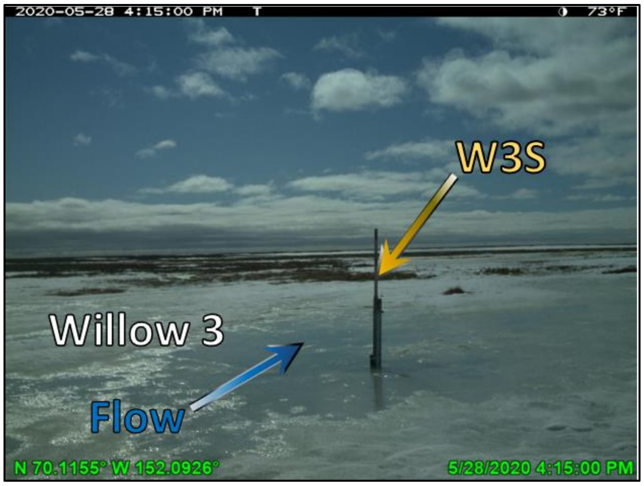


Photo 4.40: Game camera image of peak stage at W3S, looking northwest (downstream); May 28, 2020

Photo 4.41: Flow overtop of saturated snow at W3S, looking northwest (downstream); May 30, 2020

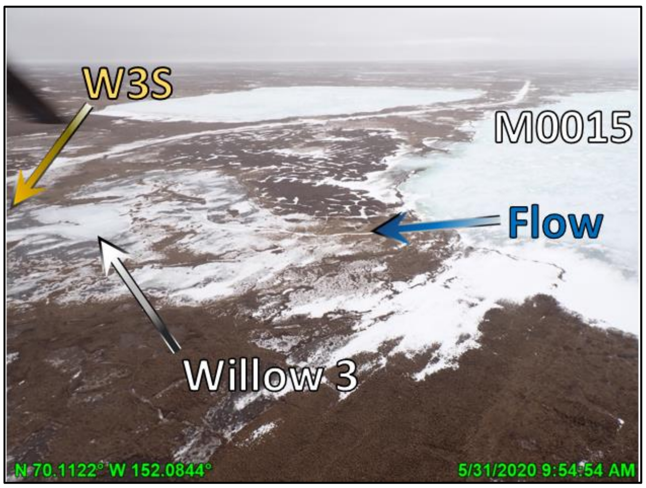


Photo 4.42: M0015 Lake outlet filled with snow, looking northeast (downstream); May 31, 2020

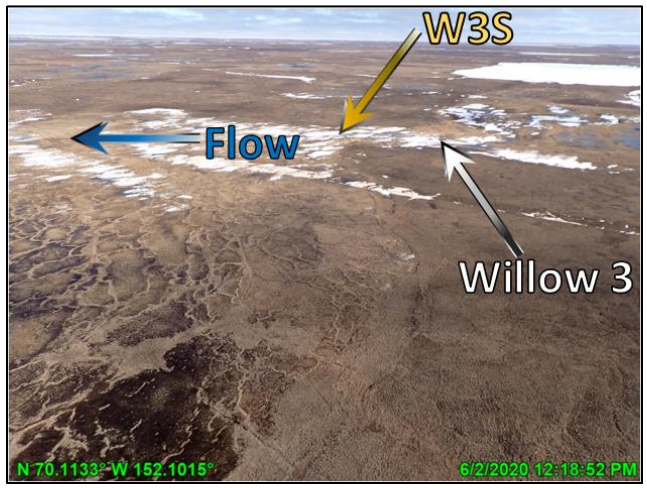


Photo 4.43: No evidence of integrated flow between M0015 and W3S; June 2, 2020

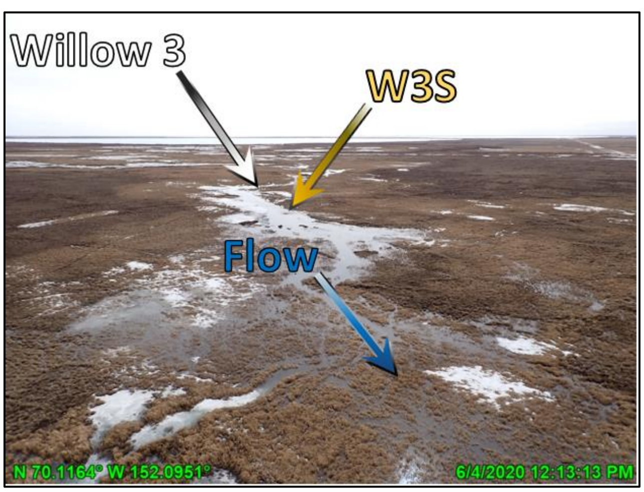


Photo 4.44: Integrated flow between Lake M0015/R0056 and W3S, looking south (upstream); June 4, 2020

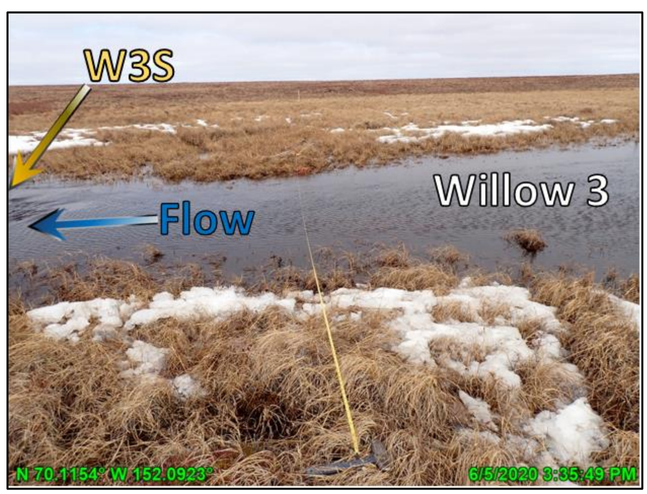
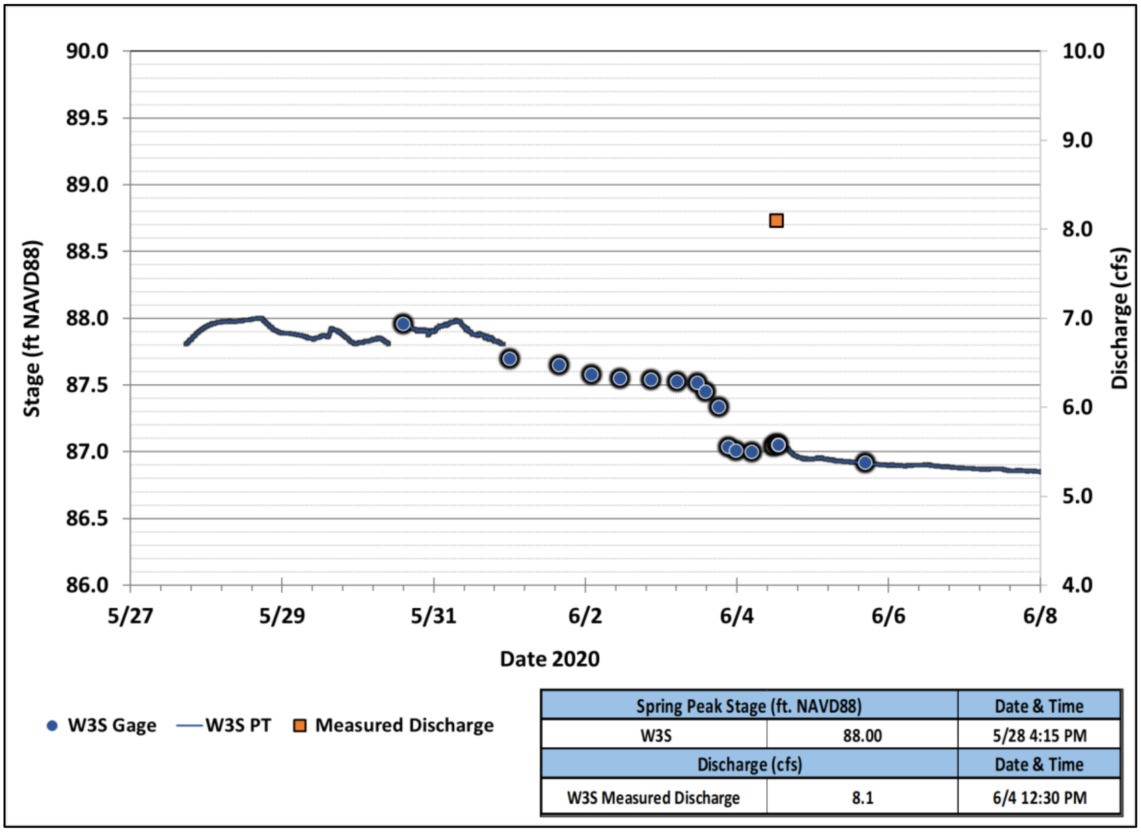


Photo 4.45: Conditions during the discharge measurement on W3S, looking west; June 5, 2020



Graph 4.13: Willow 3 at W3S Spring Breakup Stage and Discharge

B. SUMMER

Summer stage was measured at W3S. Minimal stage fluctuations associated with summer precipitation events were recorded in the PT data; water levels remained well below spring breakup peak stage (Photo 4.46). Low velocity flow through a poorly defined ephemeral channel was observed on July 1. Summer stage at W3S gage site is presented in Graph 4.14.

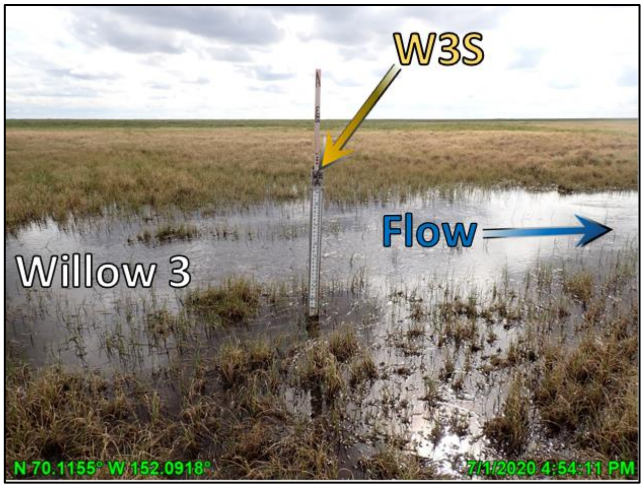
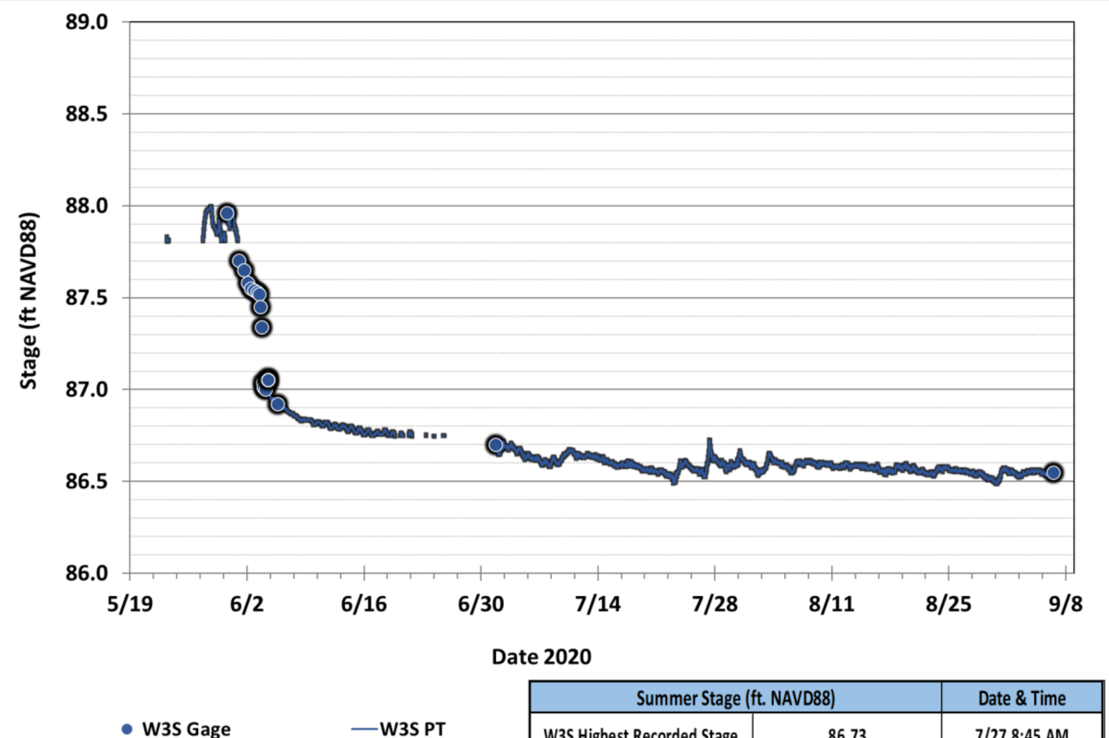


Photo 4.46: Summer conditions at W3S, looking east; July 1, 2020



Summer Stage (ft. NAVD88)		Date & Time
W3S Highest Recorded Stage	86.73	7/27 8:45 AM
W3S Minimum Recorded Stage	86.49	8/30 4:15 PM

Graph 4.14: Willow 3 At W3S Spring and Summer Stage

WILLOW 4 (W4, W_BS1)

Willow 4 is a meandering, incised channel with intermittent deep, beaded pools. Willow 4 generally flows north to the confluence with Judy Creek, approximately 4.3 RM upstream of the J21.4 gage stations. The CPAI proposed Willow alignment crosses Willow 4 at the W_BS1 monitoring location. The W4 monitoring location is situated on Willow 4 adjacent to the proposed BT3/WCF pad. The W4 and W_BS1 sites are situated approximately 5.2 and 9 RM upstream of the Judy Creek confluence, respectively. This is the third year of data collection and observations at the W4 and W_BS1 monitoring locations. The Willow 4a stream converges with the Willow 4 stream downstream of W_BS1 and upstream of W4. Historical peak stage and measured discharge data at W4 and W_BS1 is presented in Table and Table , respectively.

Table 4.10: Willow 4 at W4 Historical Peak Stage and Measured Discharge

Year	W4				
	Peak Stage (ft Arbitrary)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft Arbitrary)
2020 [1]	94.78	5/30	Not Measured in 2020		
2019 [1]	94.21	5/26	450	6/2	91.45
2018 [1]	96.38	6/7	600	6/11	95.12

Notes:
1. Arbitrary elevations referenced to local control point "MAD" (MBI 2018)

Table 4.11: Willow 4 at W_BS1 Historical Peak Stage and Measured Discharge

Year	W4				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	87.06	5/30	185	6/1	85.40
2019	87.38	5/26	350	5/28	86.91
2018 [1]	87.87	6/7	240	6/8	87.18

Notes:
1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

A. SPRING BREAKUP

Initial meltwater was first recorded on the Willow 4 PTs on May 28. At both monitoring locations Willow 4 PTs recorded steadily rising stage, elevated by saturated snow in the channel and along the banks. Following a slight stage decrease on May 29, stage rapidly increased on the night of May 29, rising 3 ft in 4 hours at W4, and 2 ft in 3 hours at W_BS1. Stage remained elevated at each site until reaching peak stage on May 30. Aerial observations at W_BS1 and W4 on May 30 show significant saturated snow along the banks and bottomfast ice in the channel (Photo 4.47 and Photo 4.48). Stage was near bankfull and meltwater flowed overtop of saturated snow and bottomfast ice in the channel. No evidence of overbank flooding was observed. The slotted ice road crossing at W4 was passing floodwater and no backwater was observed upstream. On May 31, stage had receded well below bankfull and snow and ice still remained in the channel at W4 (Photo 4.49). The PT data shows stage began steadily decreasing in Willow 4 early on May 31. Aerial observations on June 3 at W4 show saturated snow present along the banks and stage well below bankfull (Photo 4.50). Stage continued to decrease at both Willow 4 sites throughout the rest of the spring monitoring period.

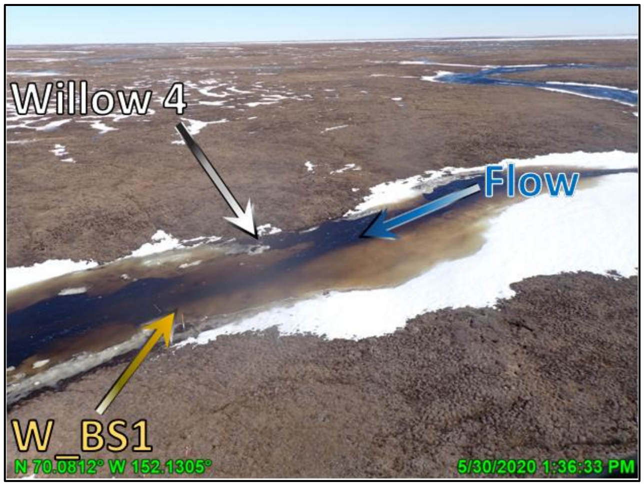


Photo 4.47: Drifted snow in the Willow 4 drainage near W_BS1 at peak stage, looking northeast (downstream); May 30, 2020

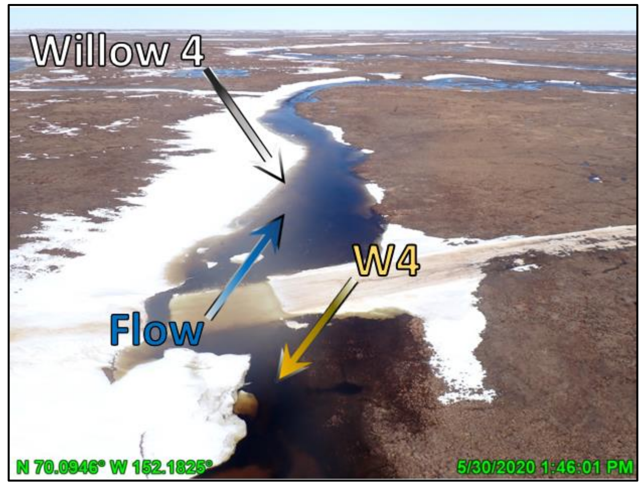


Photo 4.48: Slotted ice road crossing near W4 at peak stage, looking north (downstream); May 30, 2020

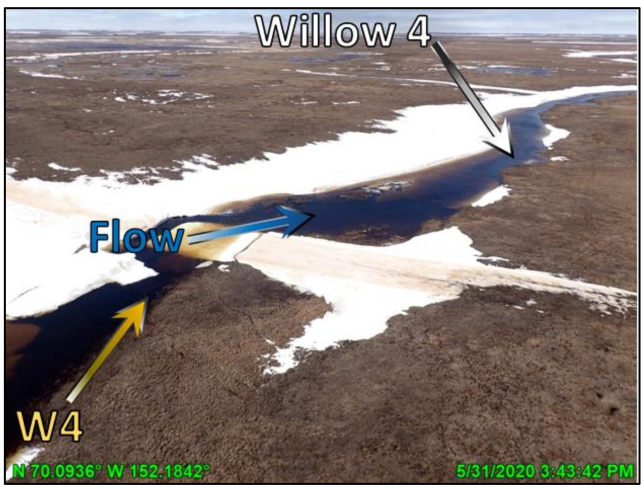


Photo 4.49: Receding stage in Willow 4 at W4, looking northwest (downstream); May 31, 2020.

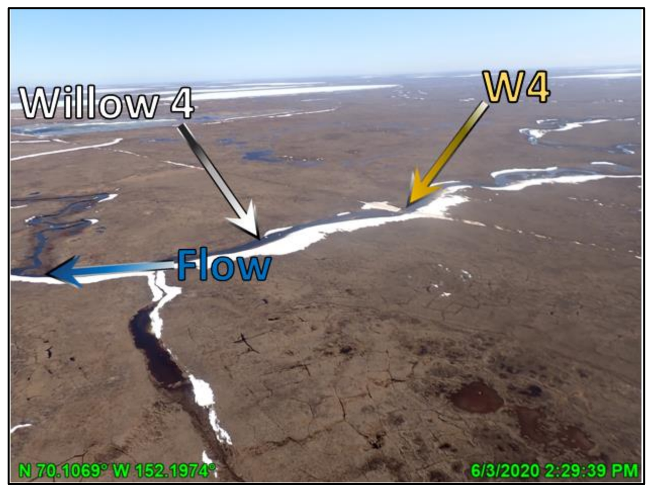


Photo 4.50: Conditions near W4 four days after peak stage, looking southeast (upstream); June 3, 2020

Discharge during spring breakup was measured at W_BS1 using a tethered ADCP on June 1. During the discharge measurement the channel was mostly clear of ice and snow, with saturated snow present along the banks (Photo 4.51 and Photo 4.52). Stage was below bankfull but still elevated relative to summer flow conditions. No visible bottomfast ice was observed. The quality of the discharge measurement was classified as fair based on the saturated snow along the channel banks. The moving bed measurement associated with W_BS1 was negligible and not included as a correction to the overall measurement.

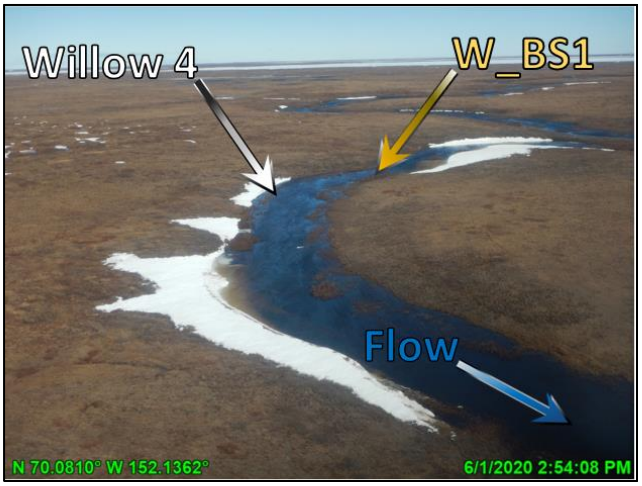


Photo 4.51: Conditions at W_BS1 the day of the discharge measurement, looking northeast (upstream); June 1, 2020

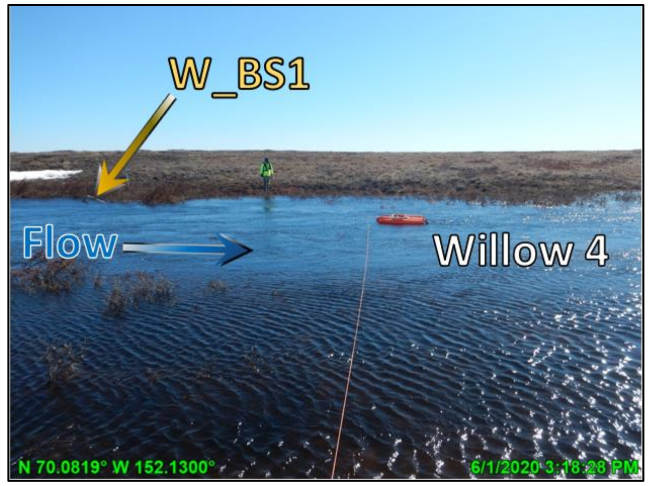
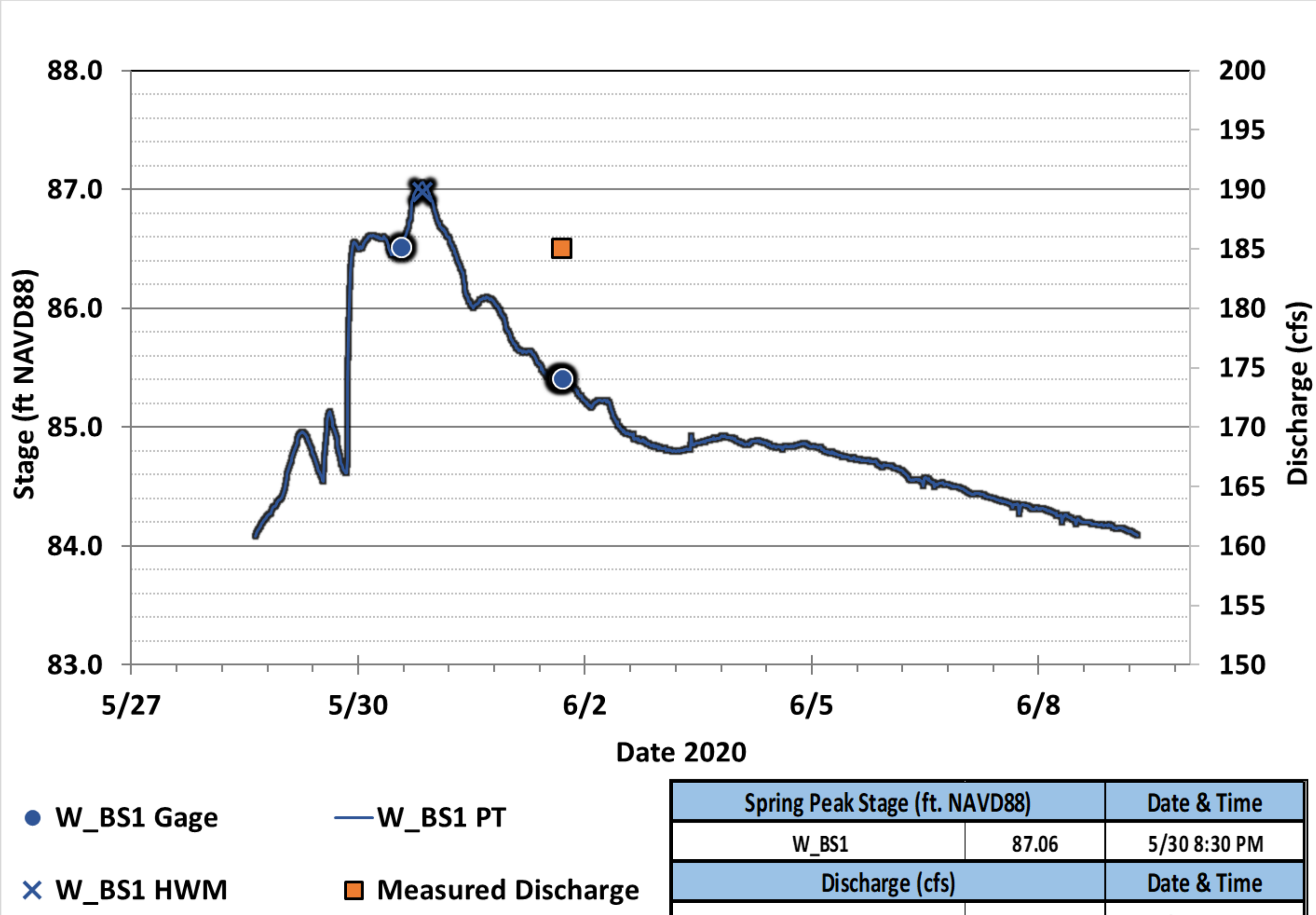


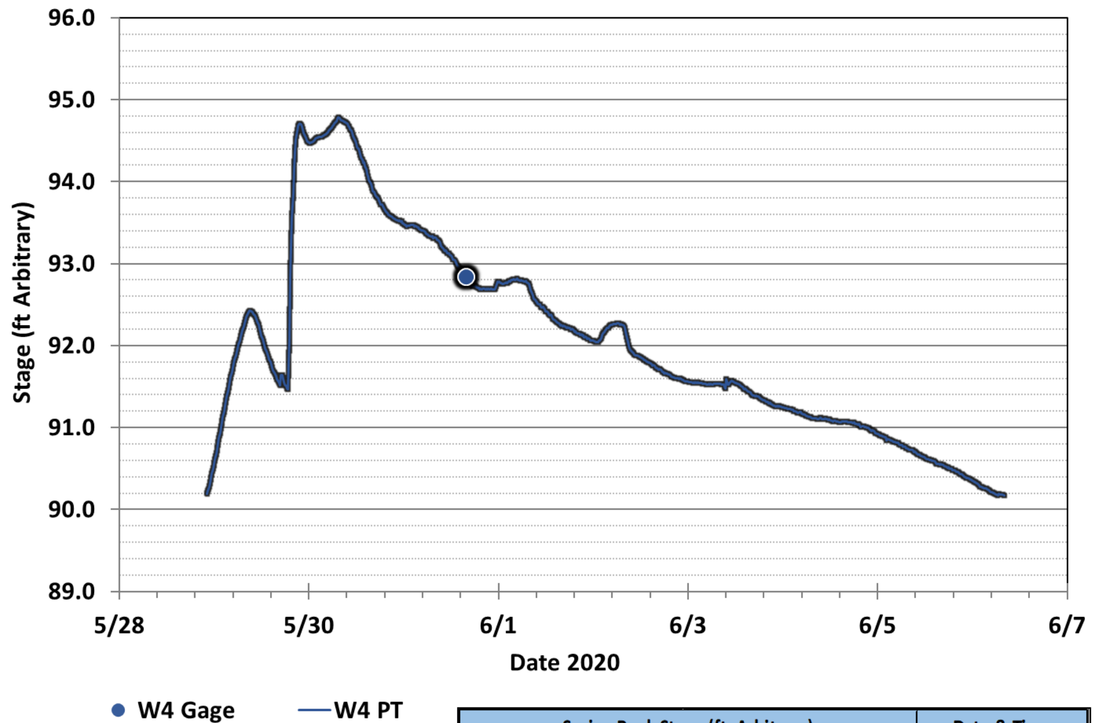
Photo 4.52: Crews measuring discharge in Willow 4 at W_BS1, looking north; June 1, 2020

The W_BS1 and W4 stage and measured discharge data are presented in Graph 4.15 and Graph 4.16, respectively. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations at W_BS1 are referenced to NAVD88. Elevations at W4 are referenced to an arbitrary datum based on a local control point.



Spring Peak Stage (ft. NAVD88)		Date & Time
W_BS1	87.06	5/30 8:30 PM
Discharge (cfs)		**Date & Time**
W_BS1 Measured Discharge	185	6/1 4:30 PM

Graph 4.15: Willow 4 At W_BS1 Spring Breakup Stage & Discharge



Spring Peak Stage (ft. Arbitrary)		Date & Time
W4	94.78	5/30 7:30 AM

Graph 4.16: Willow 4 At W4 Spring Breakup Stage & Discharge

B. Summer

Summer stage was measured at both W_BS1 and W_4. Stage fluctuations associated with summer precipitation events were recorded in the data at each monitoring station; water levels remained below spring breakup peak stage (Photo 4.53 and Photo 4.54). Summer stage at W_BS1 and W4 gage site is presented in Graph 4.17 and Graph 4.18, respectively.

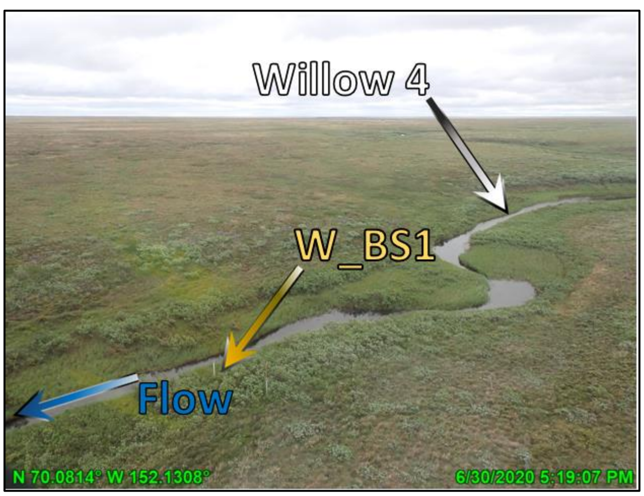


Photo 4.53: Summer conditions at W_BS1, looking east (upstream); June 30, 2020

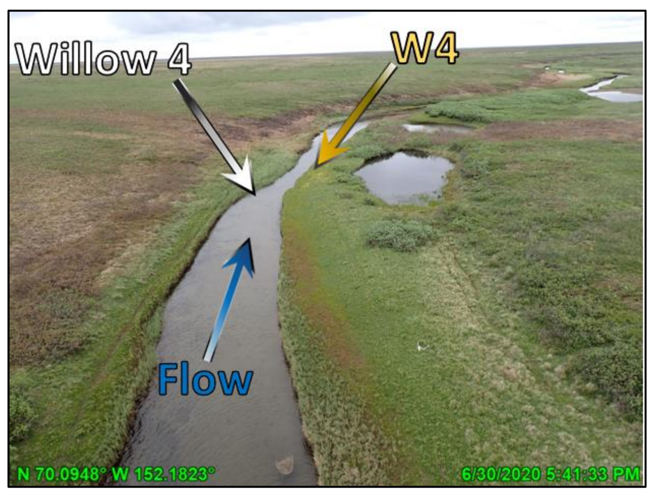
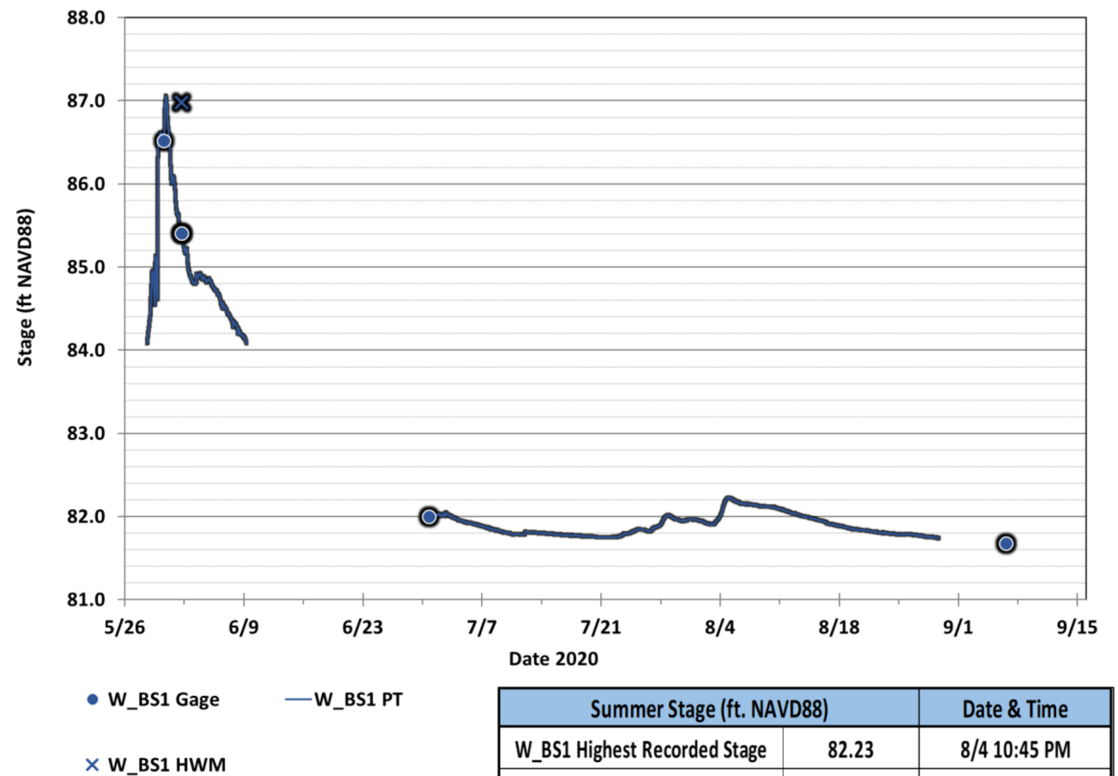
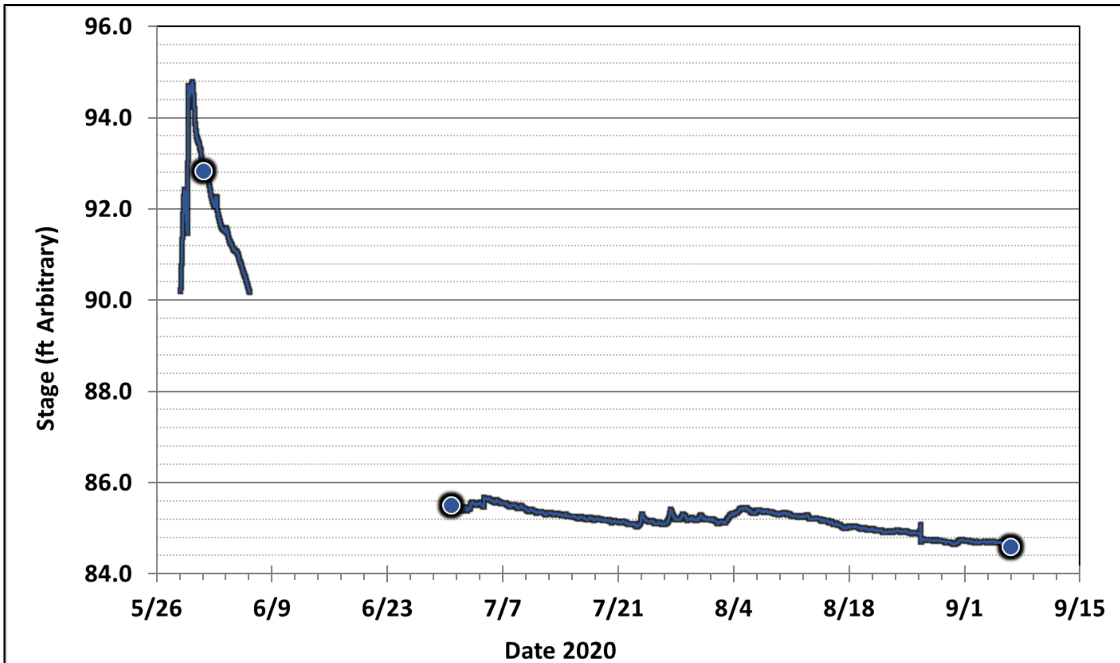


Photo 4.54: Summer conditions near W4, looking north (downstream); June 30, 2020



Summer Stage (ft. NAVD88)		Date & Time
W_BS1 Highest Recorded Stage	82.23	8/4 10:45 PM
W_BS1 Minimum Recorded Stage	81.74	8/29 4:15 PM

Graph 4.17: Willow 4 At W_BS1 Summer Stage



Summer Stage (ft. Arbitrary)		Date & Time
W4 Highest Recorded Stage	85.68	7/4 5:00 PM
W4 Minimum Recorded Stage	84.40	9/6 2:45 PM

Graph 4.18: Willow 4 At W4 Summer Stage

WILLOW 4A (W_S1)

Willow 4A, a tributary of Willow 4, is a small beaded stream that drains an interconnected lake network south of Judy Creek. Willow 4A converges with Willow 4 between the W_BS1 and W4 monitoring locations. The CPAI proposed alignment crosses Willow 4A at W_S1. This is the third year of data collection and observations at the W_S1 monitoring location. Historical peak stage and measured discharge data at W_S1 is presented in Table .

Table 4.12: Willow 4A at W_S1 Historical Peak Stage and Measured Discharge

Year	W_S1				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	100.51 [1]	6/3	185	6/3	100.50
2019	101.89	5/27	320	5/29	100.99
2018	101.93	6/8	40	6/13	99.77

Notes:
1. Highest reported stage reported. Not representative of peak stage.

A. SPRING BREAKUP

The progression of breakup at W_S1 was monitored starting June 3. Limitations due to COVID-19 prevented the MBI field teams from reaching W_S1 for set up and monitoring prior to this date. Observations and PT data trends suggest peak stage occurred prior to equipment deployment on June 3. On this day, Aerial observations revealed stage near bankfull, with minor overbank flooding observed in low-lying areas around the gage station (Photo 4.55). No snow was observed in the channel or along the banks. The presence of bottomfast ice in the channel was difficult to confirm due to the incised nature of the channel. PT data recorded a consistent stage decline from June 3 until the end of the spring monitoring period.

Discharge was measured at W_S1 using a tethered ADCP on June 3. During the measurement, the channel was clear of ice and snow (Photo 4.56 and Photo 4.57). The quality of the measurement was classified as good based on conditions at the time of the measurement. The moving bed measurement associated with W_S1 was negligible and not included as a correction to the overall measurement.

The W_S1 stage and measured discharge data are presented in Graph 4.19. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.

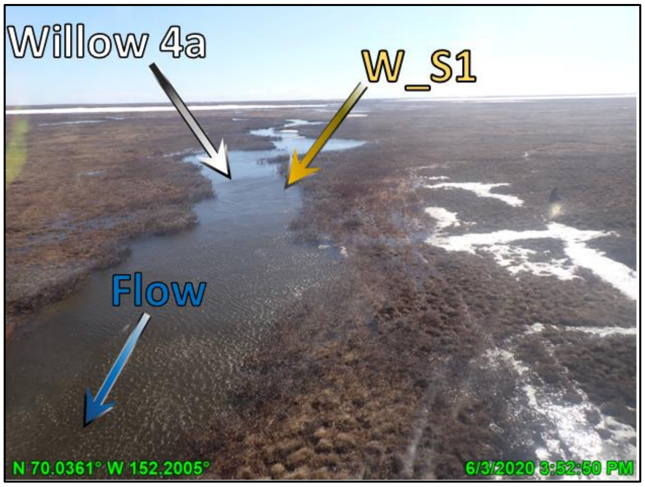


Photo 4.55: Stage near bankfull in the Willow 4a drainage near W_S1 looking south (upstream); June 3, 2020

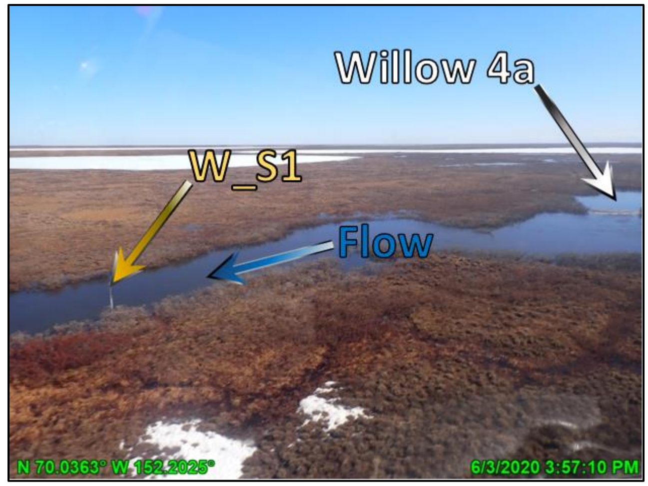


Photo 4.56: Ice free conditions in the W_S1 reach on the day of the discharge measurement, looking south (upstream); June 3, 2020

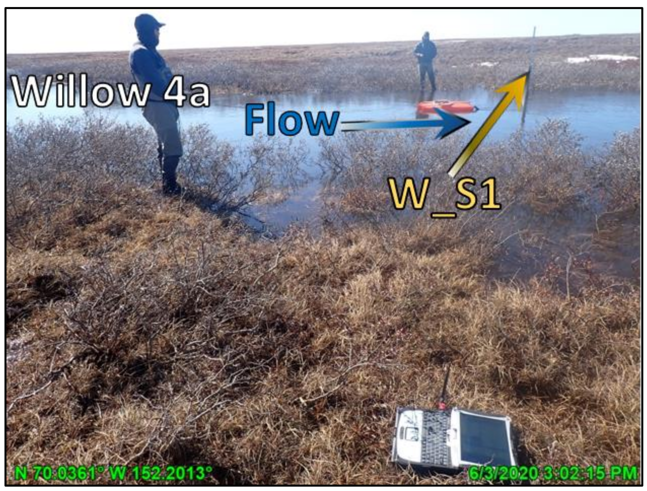
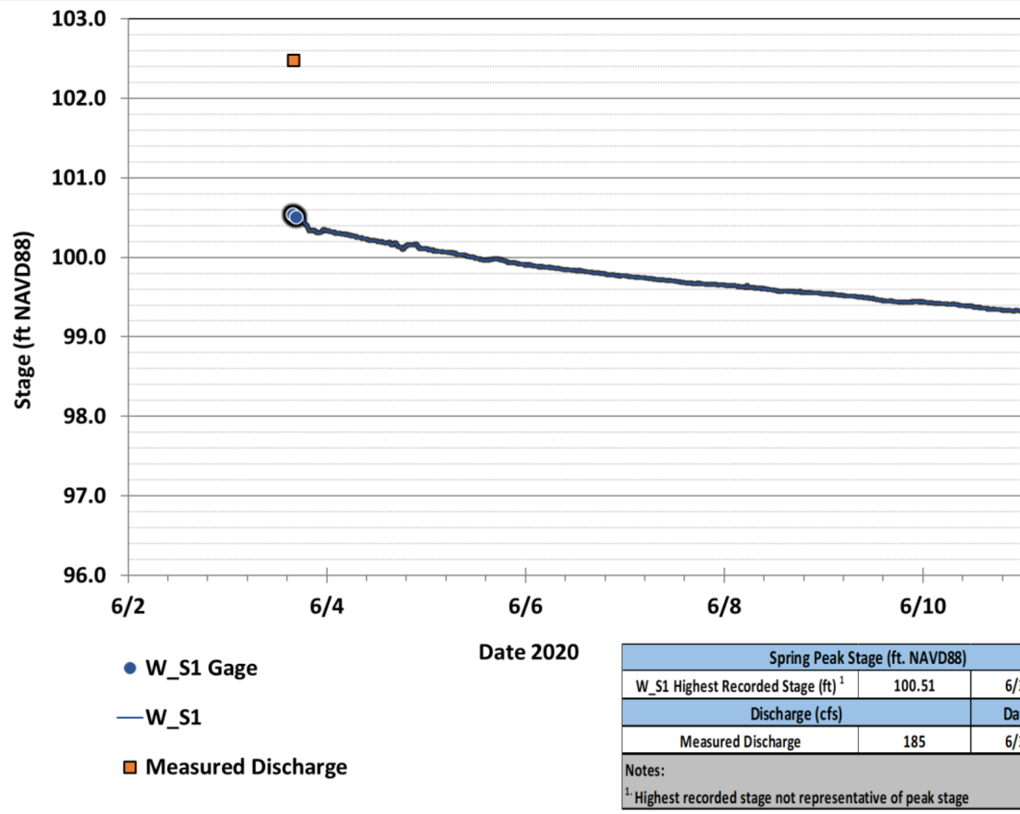


Photo 4.57: Crews measuring discharge at W_S1, looking west; June 3, 2020



Spring Peak Stage (ft. NAVD88)		
W_S1 Highest Recorded Stage (ft) [1]	100.51	6/3 3:45 PM
Discharge (cfs)		Date & Time
Measured Discharge	185	6/3 4:00 PM
Notes: [1] Highest recorded stage not representative of peak stage		

Graph 4.19: Willow 4a Stream W_S1 Spring Breakup Stage & Discharge

B. SUMMER

Summer stage was measured at W_S1. Stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained well below spring breakup peak stage (Photo 4.58). The stage increase at the end of the summer monitoring period is associated with a notable precipitation event. Summer stage at W_S1 gage site is presented in Graph 4.20.

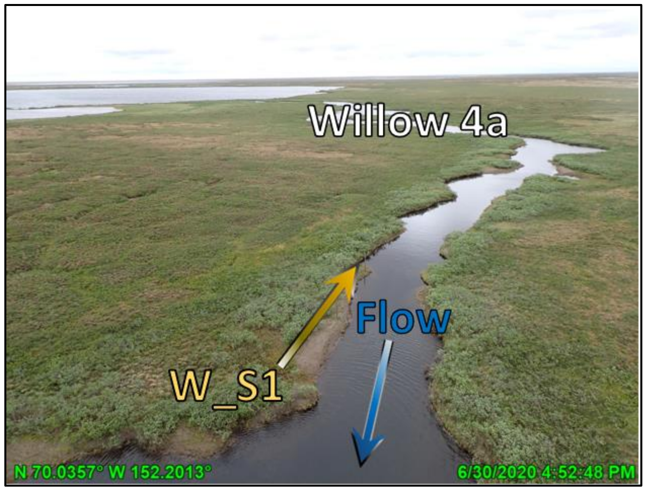
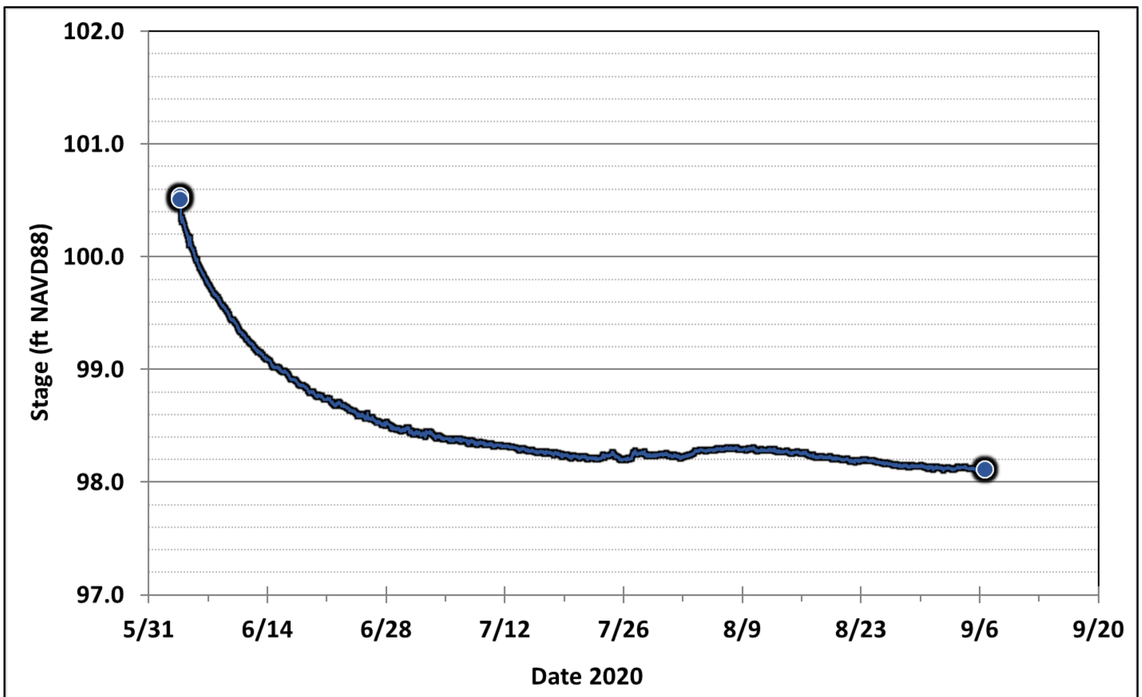


Photo 4.58: Summer conditions at W_S1, looking south (upstream); June 30, 2020



Summer Stage (ft. NAVD88)		Date & Time
W_S1 Highest Recorded Stage	100.51	6/3/20 4:30 PM
W_S1 Minimum Recorded Stage	98.12	9/6/20 1:30 PM

Graph 4.20: Willow 4a at W_S1 Spring and Summer Stage

WILLOW 8 (TBD_6, SW22)

Willow 8 is a meandering, incised channel with intermittent deep, beaded pools. Willow 8 generally flows southwest draining Lake M0305 into Fish Creek approximately 2.2 RM downstream of F55.5 gage station. The CPAI proposed alignment crosses Willow 8 at the TBD_6 and SW22 monitoring locations, approximately 1.7 and 3 RM upstream of the Fish Creek confluence, respectively. At the SW22 crossing, the Willow 8 drainage is a poorly defined channel in a low-lying area of polygon cracks flowing south, connecting Lake M0305 to an unnamed lake to the south. The Willow 8 drainage is a well-defined incised channel south of the unnamed lake where the alignment crosses at TBD_6. This is the third year of data collection and observations at the TBD_6. Limitations due to COVID-19 prevented the field teams from reaching SW22 for set up and monitoring during the 2020 monitoring season. Limited data from aerial observations near peak stage was collected and is reported below. Historical peak stage and measured discharge data at TBD_6 and SW22 is presented in Table and Table , respectively.

Table 4.13: Willow 8 at TBD_6 Historical Peak Stage and Measured Discharge

Year	TBD_6				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	51.60	5/30	40	6/3	50.82
2019 [1]	53.72	5/29	90	5/30	52.22
2018 [1]	52.71	6/13	65	6/15	51.36

Notes:
2. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

Table 4.14: Willow 8 at SW22 Historical Peak Stage and Measured Discharge

Year	SW22				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	Breakup data not collected in 2020				
2019	79.35	5/28	4	6/1	79.01
2018	No Recorded Water		--	--	--

A. Spring Breakup

Initial meltwater was recorded at TBD_6 on May 26. Stage steadily increased and crested on May 29. Elevated stage resulting from the drifted snowpack in the channel peaked on May 30. Aerial observations from May 30 show stage at bankfull with minor overbank flooding in low-lying areas near the banks (Photo 4.59). Minimal ponded water was observed further from the banks, indicating no widespread overbank flooding occurred during peak stage. Snow and ice were visible in the channel. Minimal snow remained along the banks. A slotted ice road crossing downstream from the gage did not appear to produce backwater as similar stage conditions were visually observed upstream and downstream of the crossing. Stage at TBD_6 quickly decreased after peaking but remained elevated through early June. Willow 8 at SW22 was filled with drifted snow on May 30 (Photo 4.60) and May 31, and any meltwater in the area was localized (Photo 4.62). On May 31, large amounts of saturated snow were observed in the channel through aerial observations (Photo 4.61). On June 2, areas of saturated snow and ice were still present in deep sections of the TBD_6 channel (Photo 4.63). Stage remained elevated at near bankfull and snow along the banks was isolated to small areas around stream bends. The TBD_6 PT data shows stage decreasing steadily after June 5.

Discharge was measured at TBD_6 using a tethered ADCP on June 3. During the measurement, snow and ice were present in the channel but clear from the banks, and stage was near bankfull (Photo 4.64). The quality rating of the discharge measurement was classified as poor based on the effects from and the saturated snow. The moving bed measurement associated with TBD_6 was negligible and not included as a correction to the overall measurement.

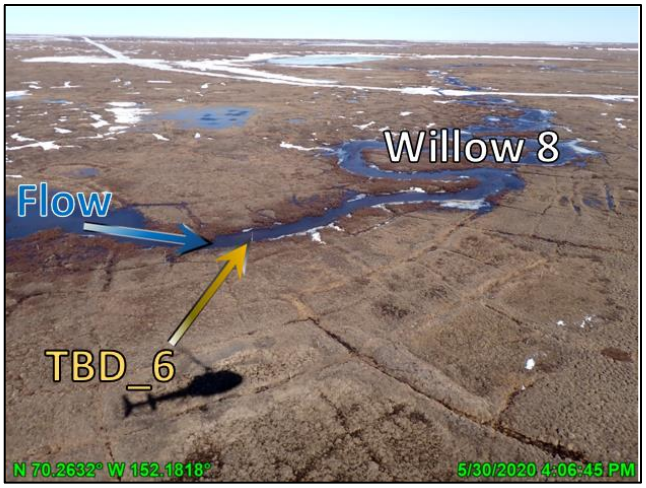


Photo 4.59: Peak stage in Willow 8 at TBD_6, looking northeast (downstream); May 30, 2020

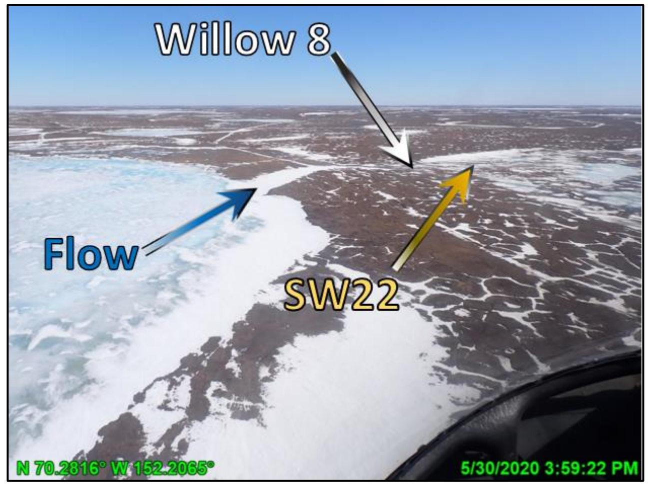


Photo 4.60: Willow 8 near SW22 filled with drifted snow, looking east (downstream); May 30, 2020

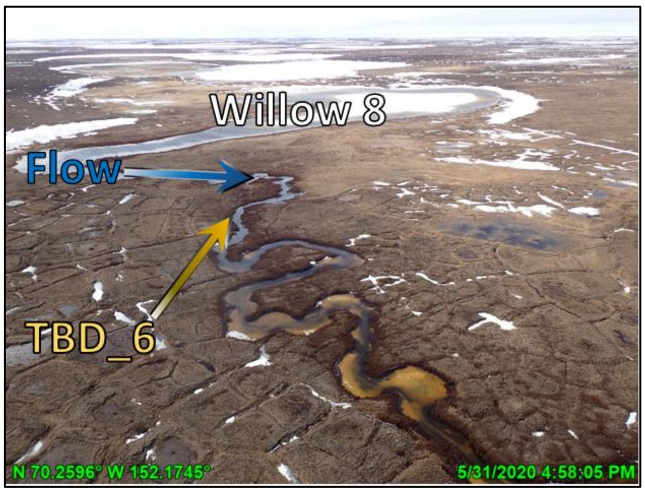


Photo 4.61: Visible snow and ice near TBD_6, looking west (upstream); May 31, 2020.

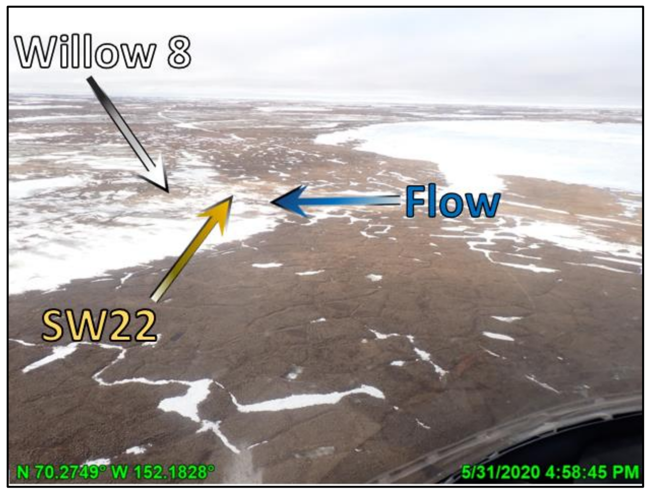


Photo 4.62: Increasing meltwater in Willow 8 near SW22, looking north (upstream); May 31, 2020

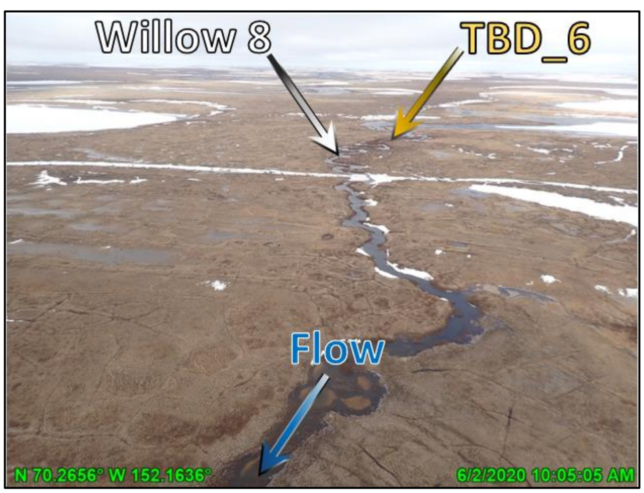


Photo 4.63: Receding stage in Willow 8 near TBD_6, looking east (downstream); June 2, 2020.

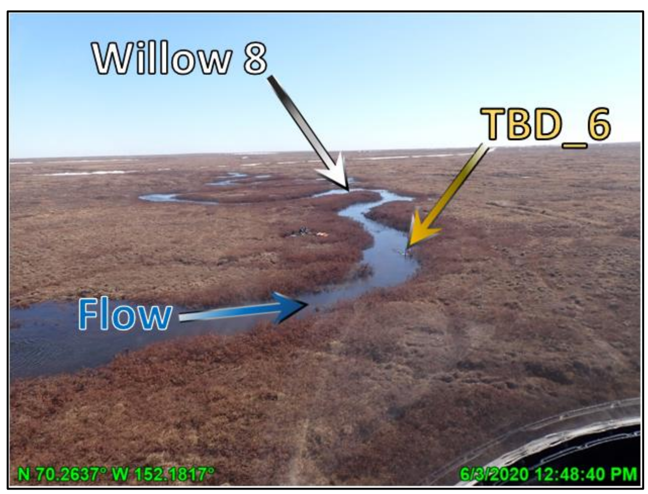
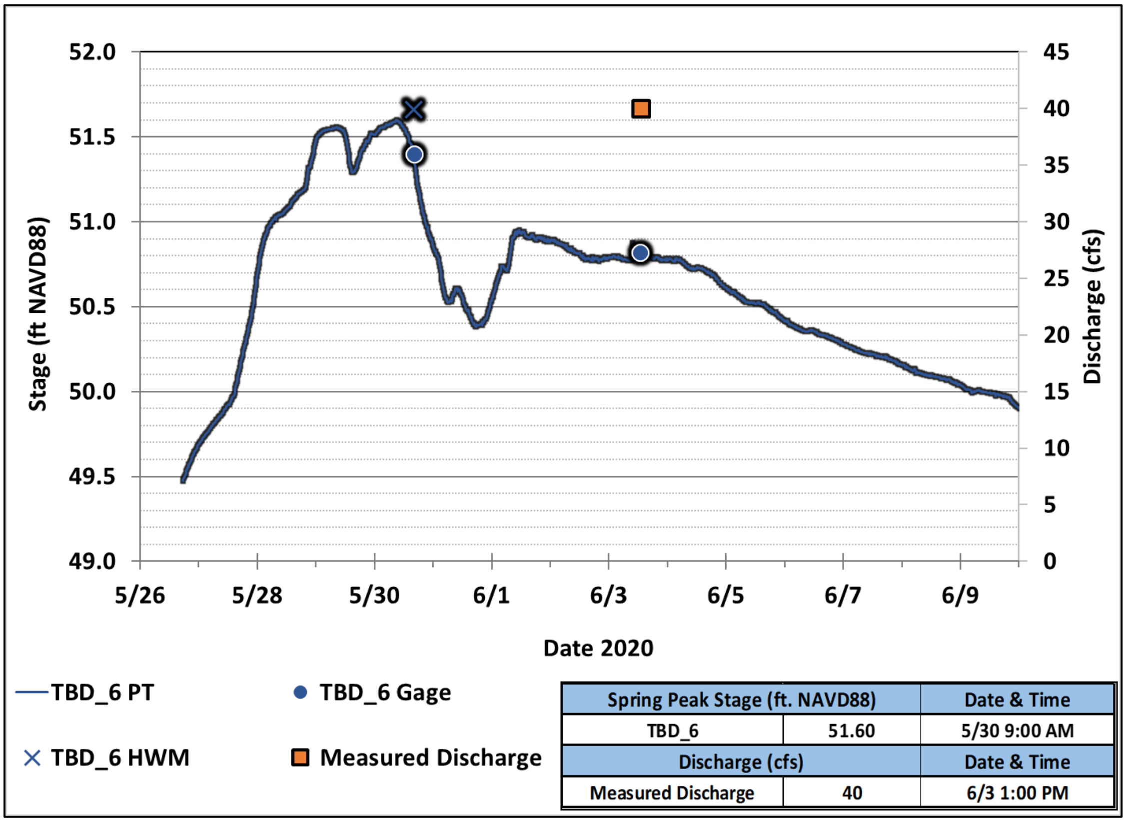


Photo 4.64: Willow 8 at TBD_6 on day of the discharge measurement, looking east (downstream); June 3, 2020

The TBD_6 stage and measured discharge data are presented in Graph 4.21. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Graph 4.21: Willow 8 at TBD_6 Spring Breakup Stage & Discharge

B. SUMMER

Summer stage was measured at TBD_6. Stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained well below spring breakup peak stage (Photo 4.65 and Photo 4.66). Summer stage at the TBD_6 gage site is presented in Graph 4.22.

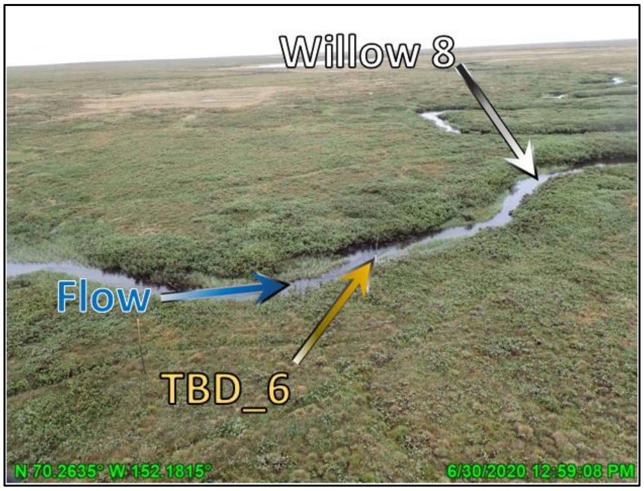


Photo 4.65: Summer conditions at TBD_6, looking northeast (downstream); June 30, 2020

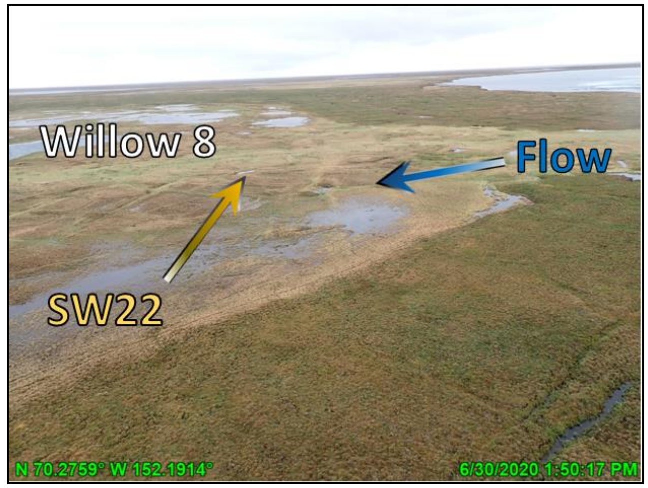
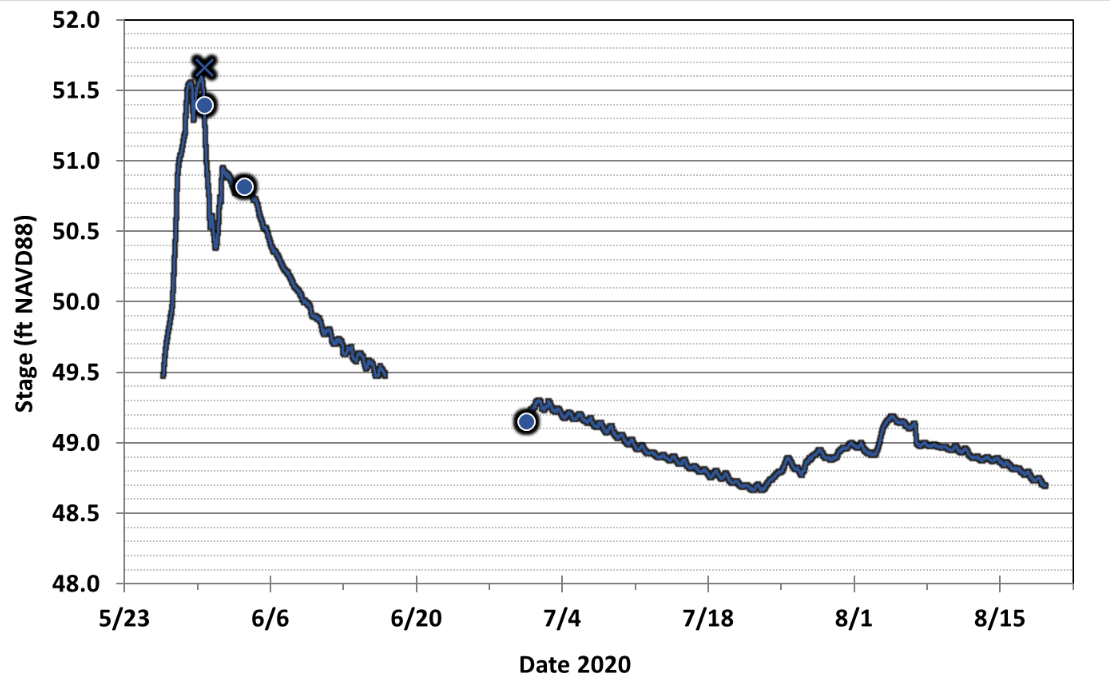


Photo 4.66: Summer Conditions in Willow 8 near SW22, looking north (upstream); June 30, 2020



Summer Stage (ft. NAVD88)		Date & Time
TBD_6 Highest Recorded Stage	49.19	8/4 1:15 PM
TBD_6 Minimum Recorded Stage	46.74	9/7 11:00 PM

Graph 4.22: Willow 8 at TBD_6 Spring and Summer Stage

4.3 Swales

Existing gage stations on swales 1, 2, and 4, 14, 23 (SW1, SW2, SW4, SW14, SW14) were established in 2017 and 2018. Swales 3, 6, and 24 (SW3, SW6 and SW24) were established in 2019 and this represents the second year of data collection and observations those monitoring locations.

SWALE 1 (SW1)

The CPAI proposed alignment crosses Swale 1 at the SW1 monitoring location. Gage station SW1 is situated in a poorly defined swale with occasional beads between two small unnamed lakes. This drainage conveys flow north through both a well-defined channel and low-relief paleolakes until emptying into Judy Creek upstream of gage station J13.8. This is the fourth year of monitoring at the SW1 monitoring station. The reported peak stage and timing values are based on gage readings from game camera images. Historical peak stage and measured discharge data at SW1 is presented in Table .

Table 4.15: SW1 Historical Peak Stage and Measured Discharge

Year	SW1				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	79.98	5/31	23	5/31	79.90
2019 [3]	80.20	5/26	13	5/29	79.96
2018 [1,3]	80.69	6/10	10	6/13	80.00
2017 [1,2]	79.83	6/3	6	6/3	79.83

Notes:
1. 2017 and 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019
2. Gage and PT installed after peak; peak stage not recorded; value presented is highest recorded stage
3. Highest recorded stage and timing values are accurately reported based on game camera images. No PT installed at the site

Water levels were first recorded on the PT beginning on May 26 at 2:00 pm (Photo 4.67). At that time, local meltwater was not present in the game camera photographs and snow cover remained at approximately 75%. The WSE increased steadily over the next five days until reaching the peak on May 31. Local melt was first observed near SW1 from game camera images on May 26 (Photo 4.67). Stage increased until peak stage conditions were observed on May 31. On May 27, site observations revealed hydraulically connected meltwater between the two unnamed lakes through the swale and the SW1 gage.

Widespread meltwater was observed in the overbanks of the swale near peak conditions (Photo 4.68). An area of channelized flow was present for about 150-ft upstream from the gage. Discharge was measured at SW1 on May 31 (Photo 4.69). Aerial observations revealed similar conditions to those observed on May 27. PT data indicates that stage had receded slightly. Saturated snow present on the eastern outer extent of both unnamed lakes did not appear to confine flow (Photo 4.69). Snow cover on the surrounding tundra was approximately 10% (Photo 4.70).

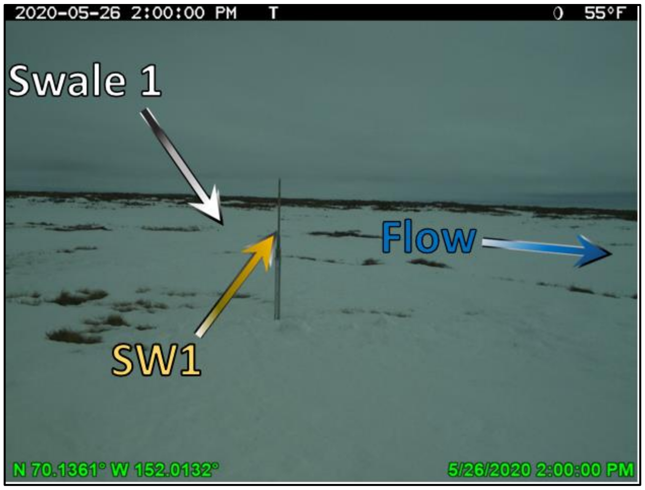


Photo 4.67: Game camera image of initial water recorded on the PT near SW1, looking east (upstream); May 26, 2020

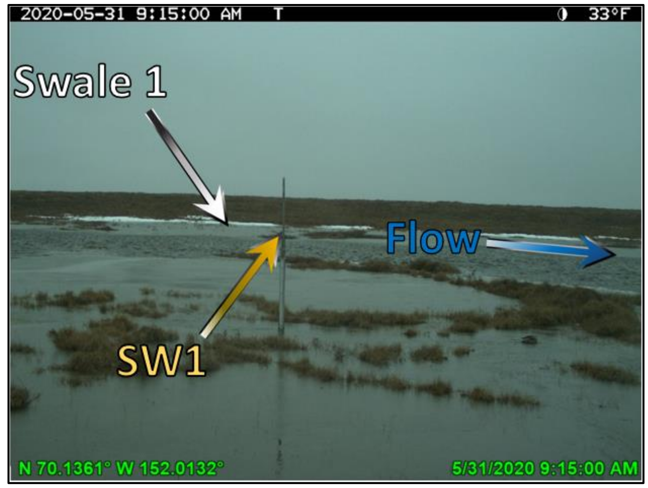


Photo 4.68: Game camera image of conditions at SW1 at peak WSE, looking east (upstream); May 31, 2020

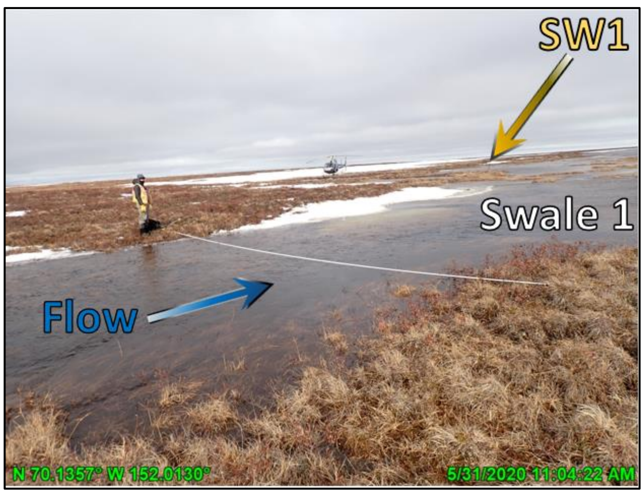


Photo 4.69: The SW1 drainage during discharge measurement near peak conditions, looking north (downstream), May 31,2020

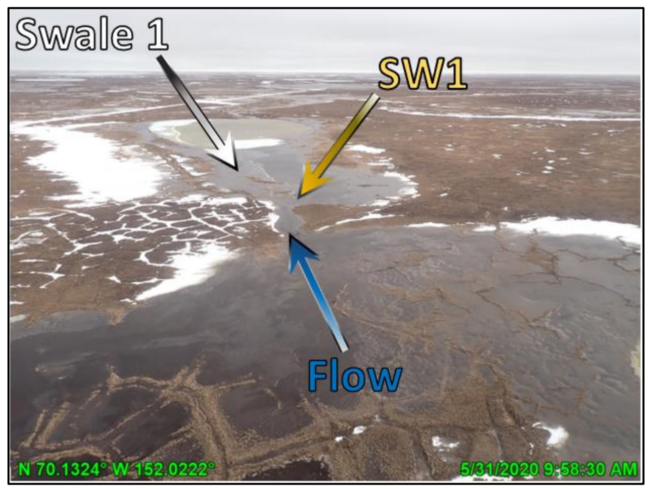
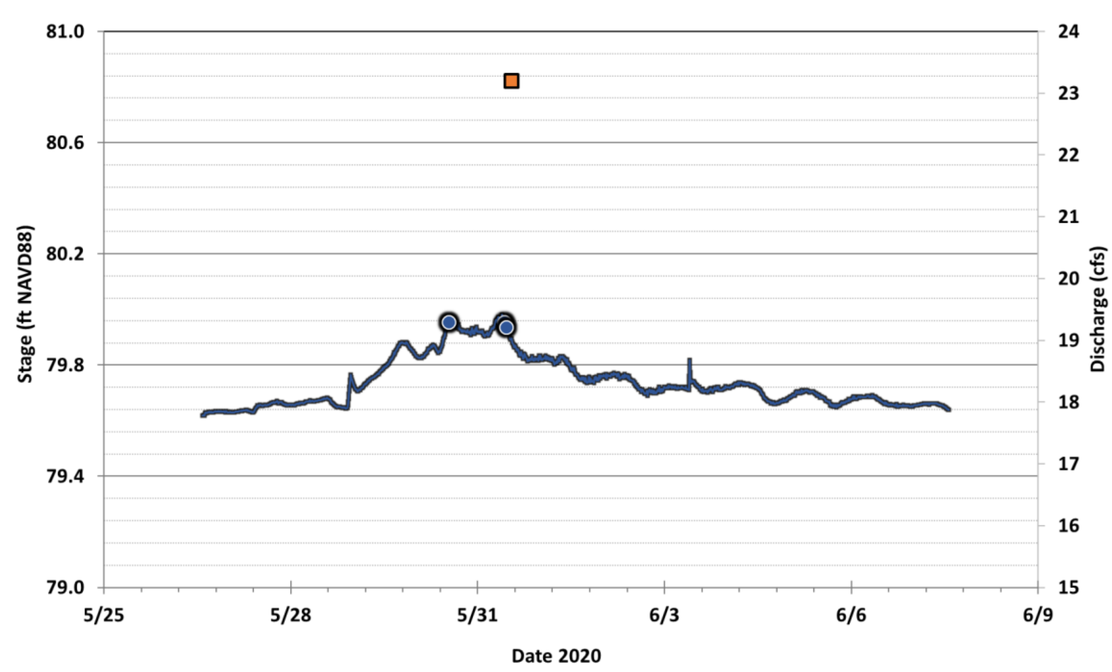


Photo 4.70: Peak stage in the SW1 drainage, looking northeast (downstream); May 31, 2020

Swale 1 at SW1 spring breakup stage and measured discharge data are presented in Graph 4.23. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring Peak Stage (ft.NAVD88)		Date & Time
SW1	79.98	5/31 9:15 AM
Discharge (cfs)		Date & Time
SW1 Measured Discharge	23	5/31 1:00 PM

Graph 4.23: Swale 1 Spring Breakup Stage & Discharge

SWALE 2 (SW2)

The CPAI proposed alignment crosses Swale 2 at the SW2 monitoring location. Gage station SW2 is situated in a swale conveying flow north from Lake M0014 to Judy Creek, downstream of the J21.4 gage station. This is the second year of monitoring at the SW2 monitoring station. Historical peak stage and measured discharge data at SW2 is presented in Table .

Table 4.16: SW2 Historical Peak Stage and Measured Discharge

Year	SW2				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	83.27	5/29	1.7	5/31	81.91
2019	81.98	5/27	1.5	5/30	81.16
2018 [1,2]	83.11	6/7	2.0	6/13	81.30

Notes:
1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019
2. Highest recorded stage and timing values are accurately reported based on game camera images. No PT installed at the site

C. Spring

Initial meltwater was first recorded on the SW2 PT on May 28. Stage increased until peak conditions were observed on May 29. Site observations from the following day revealed bankfull stage with flow over the top of saturated snow (Photo 4.71). On May 31, stage was still bankfull but less saturated snow was present in the channel (Photo 4.72). The PT data indicated that stage had receded about 0.47-ft from peak stage on May 31 when the swale discharge was measured. Snow cover on the surrounding tundra was estimated at 10%. Discharge was measured about 200-ft upstream of the gage station (Photo 4.72). During the discharge measurement, flow was confined to a single flow path and minimal snow remained in the swale and along the banks. As a result, the quality of the discharge measurement was classified as good. Swale 2 at SW2 spring breakup stage and measured discharge data are presented in Graph 4.24.

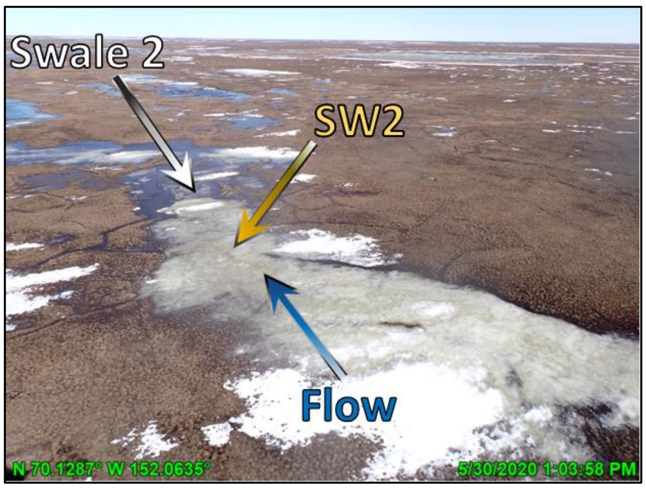


Photo 4.71: Near peak stage conditions at SW2, looking northeast (downstream); May 30, 2020

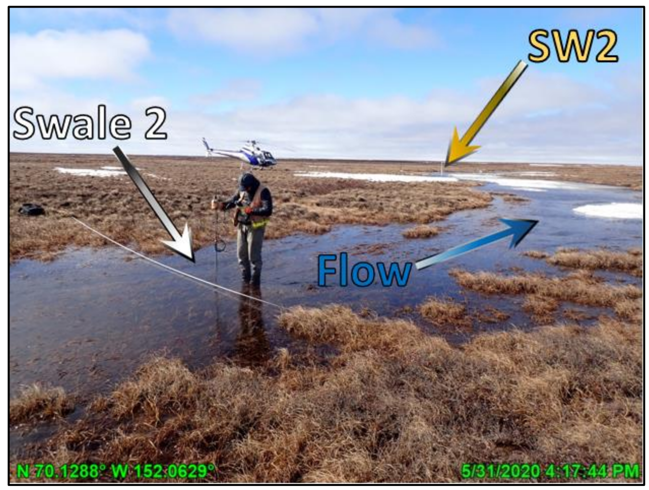
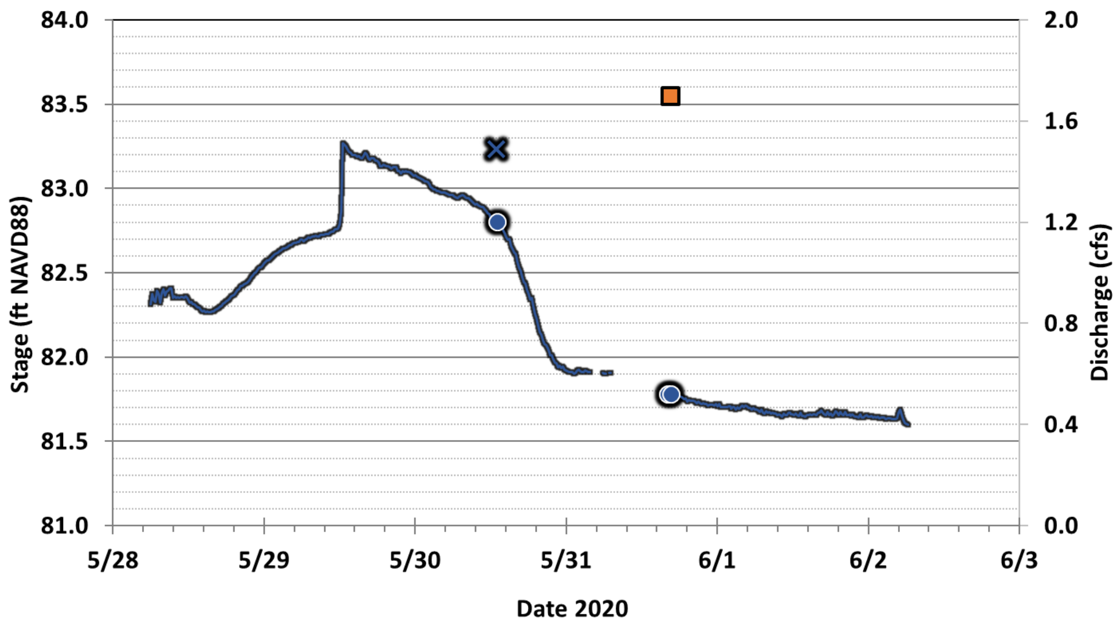


Photo 4.72: SW2 discharge measurement two days after peak stage, looking north (downstream); May 31, 2020

Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.

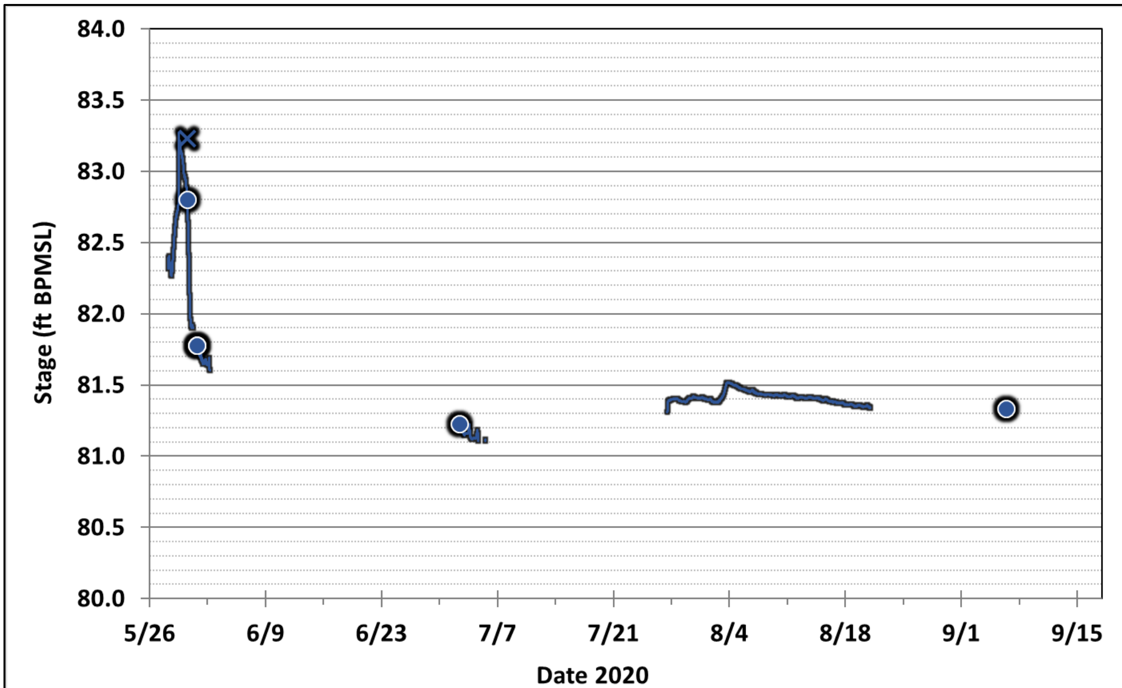
D. Summer

Stage fluctuations associated with summer precipitation were recorded in the PT data; water levels remained below spring breakup peak stage. There was little variation at the gage throughout the 2020 summer monitoring period. Summer stage in SW2 is presented in Graph 4.25.



Spring Peak Stage (ft. NAVD88)		Date & Time
SW2	83.27	5/29 12:30 PM
Discharge (cfs)		Date & Time
SW2 Measured Discharge	1.7	5/31 4:30 PM

Graph 4.24: Swale 2 Spring Breakup Stage & Discharge



Summer Stage (ft. NAVD88)		Date & Time
SW2 Highest Recorded Stage	81.52	8/3/20 9:00 PM
SW2 Minimum Recorded Stage	81.11	7/5/20 12:30 PM

Graph 4.25: Swale 2 Spring and Summer Stage

SWALE 3 (SW3)

The CPAI proposed alignment crosses Swale 3 at the SW3 monitoring location. Limitations due to COVID-19 prevented the MBI field teams from reaching SW3 for set up and monitoring during the 2020 monitoring season. An aerial photograph of the SW3 gage taken on May 30, 2020 indicates that water did reach the gage at 0.42 ft on the gage (Photo 4.73).

Photo 4.73: Gage SW3 (no PT) pictured with water on the gage, looking south (upstream) ; May 30, 2020

SWALE 4 (SW4)

Swale 4, consisting of interconnected polygon troughs, is a paleochannel of Judy Creek connecting Lakes M1523A, B, and C to Judy Creek downstream of gage station J21.4. The CPAI proposed alignment crosses Swale 4 at the SW4 monitoring location. This swale likely becomes hydraulically connected to Judy Creek during years of overbank flooding on Judy Creek. This is the fourth year of monitoring at the SW4 monitoring station. The reported peak stage and timing values are based on PT data and gage readings. Historical peak stage and measured discharge data at SW4 is presented in Table .

Table 4.17: SW4 Historical Peak Stage and Measured Discharge

Year	SW4				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	55.93	6/1	--	--	--
2019	55.98	5/24	1	6/1	55.75
2018	No Recorded Water		--	--	--
2017 [1]	55.65	6/6	--	--	--

Notes:
1. Gage and PT installed after peak; peak stage not recorded; value presented is highest recorded stage

A. Spring

Initial meltwater was first measured at the SW4 PT on May 30. Aerial observations at that time revealed some remaining snow present in the drainage, particularly along the higher-situated polygon troughs (Photo 4.74). Stage increased slightly until peak stage conditions were reached on May 31. Game camera images from this day show widespread ponded water in low-lying areas and polygon troughs around SW4 (Photo 4.76). The widespread nature of this drainage (Photo 4.77) creates ample conveyance with limited vertical rise in the water column. During breakup, minimal stage fluctuations were recorded with a maximum difference of 0.23 ft, and only local, disconnected meltwater was observed through aerial observations.

B. Summer

Summer observations at SW4 were limited to a site visit on June 30 when the low flow PT was installed (Photo 4.77). At that time, stagnant water was observed in low-lying areas around the poorly defined drainage. Gage height fluctuated a maximum of 0.3 ft in response to precipitation events through the summer monitoring period.

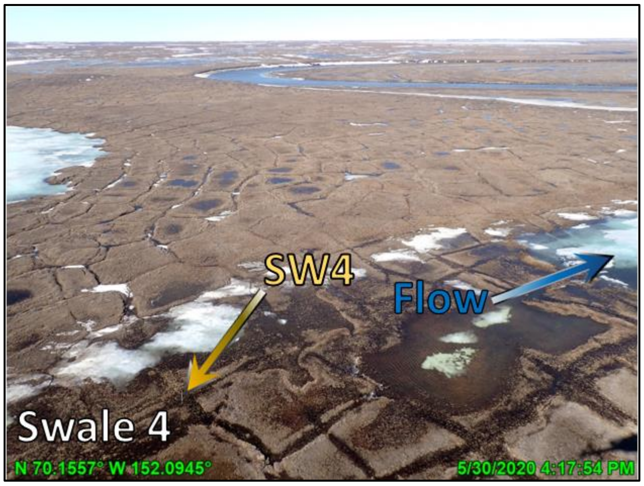


Photo 4.74: Limited meltwater in the SW4 drainage, looking north (downstream); May 30, 2020

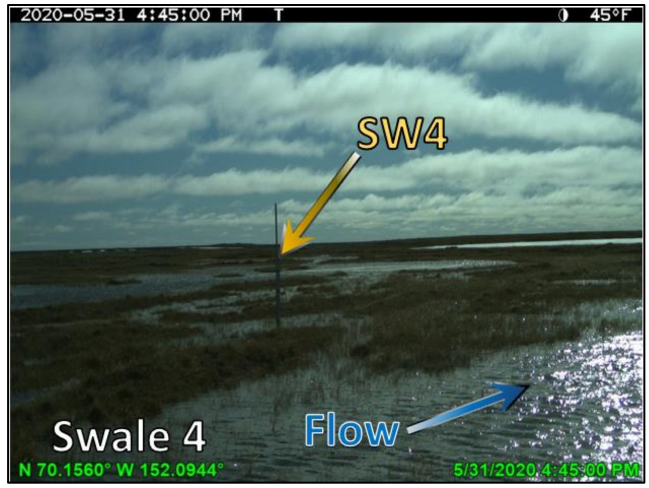


Photo 4.75: The SW4 gage at peak conditions; looking south (downstream); May 31, 2020

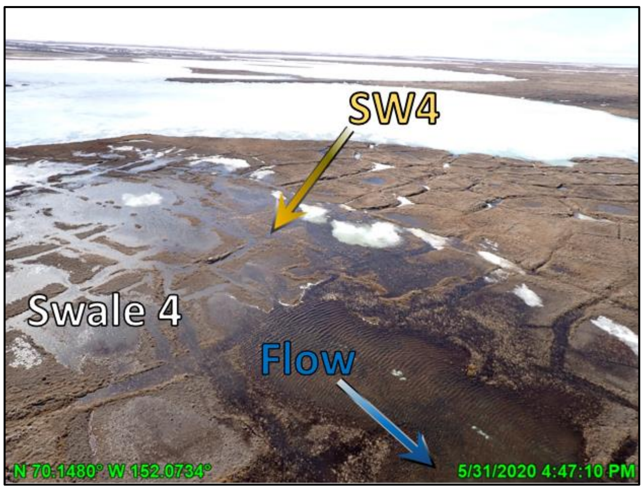


Photo 4.76: Conditions in the SW4 drainage during near peak stage, looking south (upstream); May 31, 2020

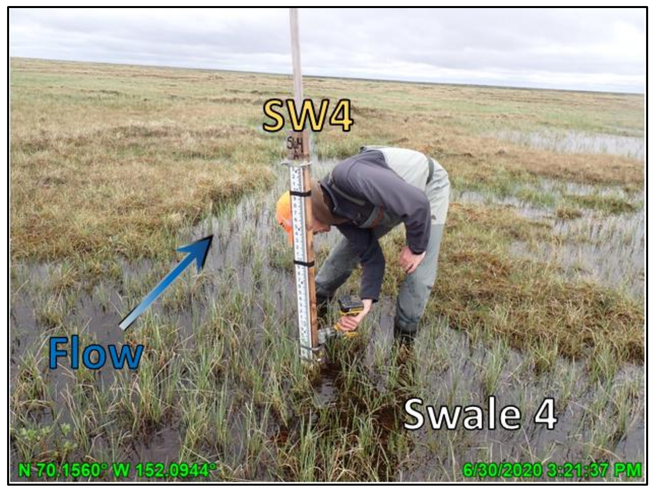
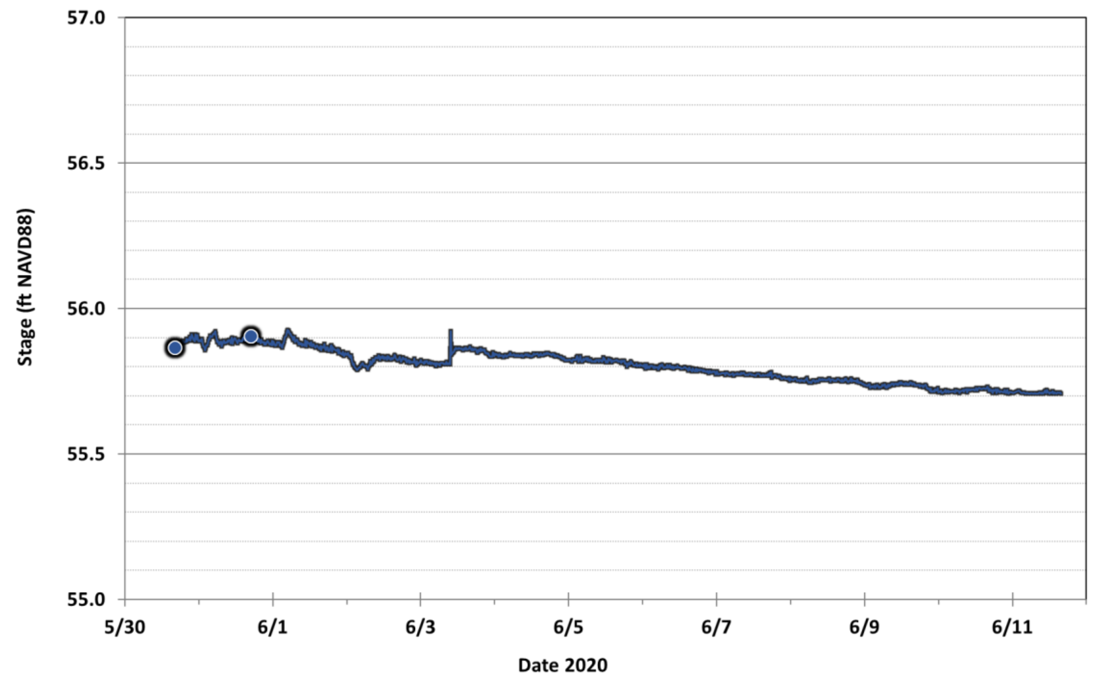


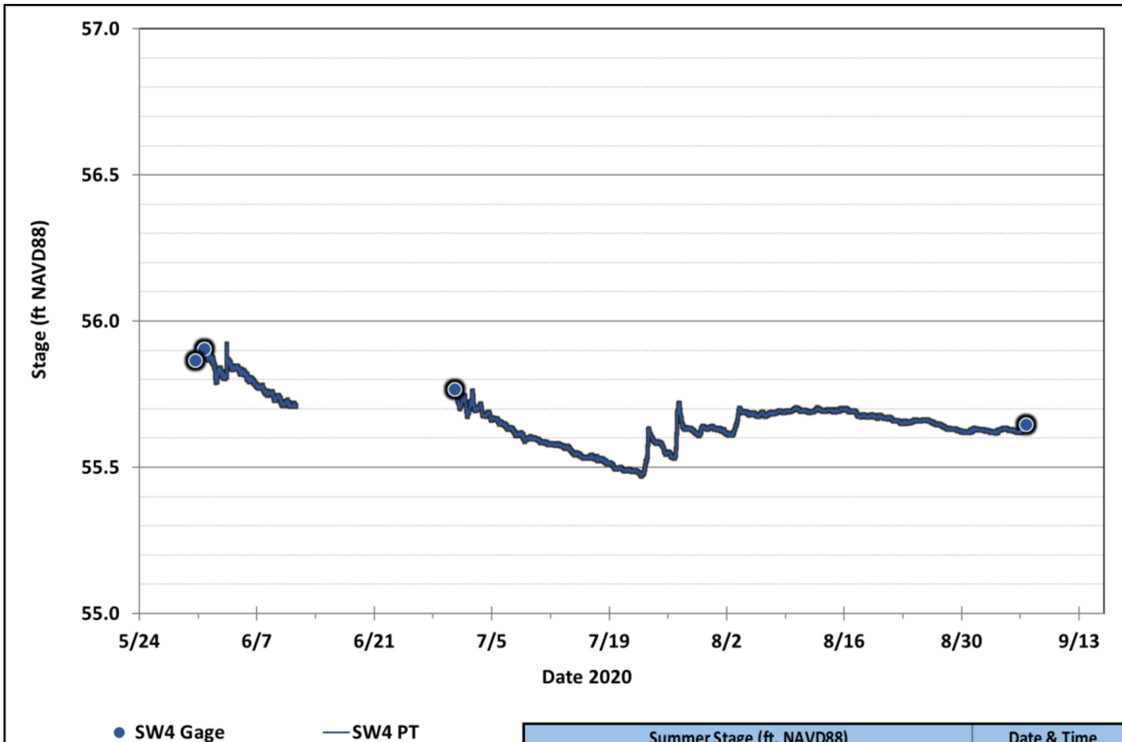
Photo 4.77: Installation of the low flow PT at the SW4 gage, June 30,2020

Swale 4 spring and summer breakup stage and measured discharge data are presented in Graph 4.26 and Graph 4.27, respectively. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring Peak Stage (ft. NAVD88)		Date & Time
SW4	55.93	6/1 4:45 AM

Graph 4.26: Swale 4 Spring Breakup Stage



Summer Stage (ft. NAVD88)		Date & Time
SW4 Highest Recorded Stage	55.72	7/27 7:00 AM
SW4 Minimum Recorded Stage	55.47	7/22 8:00 PM

Graph 4.27: Swale 4 at SW4 Spring and Summer Stage

SWALE 6 (SW6)

Swale 6 is a swale consisting of low-centered polygons connecting a series of paleolakes to Judy Creek Kayyaaq. Aerial imagery reveals two possible outlets for meltwater from this system. The first outlet is a beaded swale running south through the south end of the southern-most paleolake and into Judy Creek Kayyaaq, upstream of the UC2C gage station. The second outlet is a swale depression running east through the eastern end of the same paleolake and into Judy Creek Kayyaaq, downstream of the UC2C gage station. The SW6 monitoring station is situated in the eastern swale depression at its apparent outlet from the paleolake. 2019 was the first year of monitoring at the SW6 gage station. Limitations due to COVID-19 prevented the MBI field teams from reaching SW6 for set up and monitoring during the 2020 monitoring season. Aerial observation of the site on May 31 shows the low centered polygons with standing water and limited connectivity between (Photo 4.78).

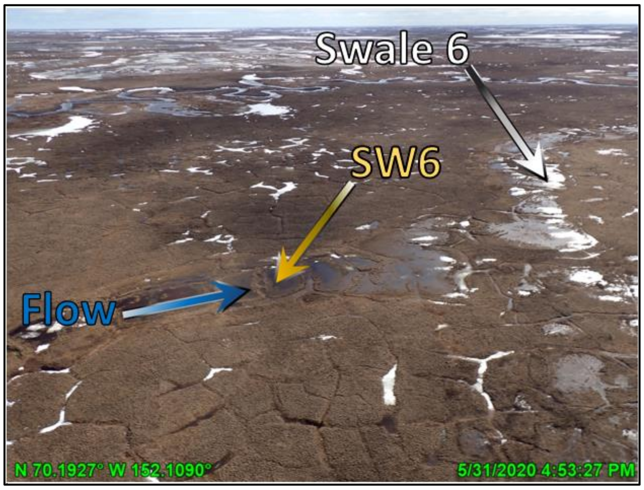


Photo 4.78: SW6 drainage near peak conditions, looking northwest (downstream); May 31, 2020

SWALE 14 (SW14)

Swale 14 connects Lake M0014 to Judy Creek, upstream of the J21.4 gage station. This swale is near and originates in the same lake as Swale 2. The CPAI proposed alignment crosses Swale 14 at the SW14 monitoring location, which is situated on a small, shallow beaded stream within the swale. Limitations due to COVID-19 prevented the MBI field teams from installing a pressure transducer and surveying the gages. However, aerial observations and a photograph of the gage indicate that this swale did flow during the 2020 breakup monitoring season. On May 31, SW14 channel appeared to be free of snow and bottomfast ice and was flowing, with a gage height of 0.2 ft (Photo 4.79). At that time approximately 10% of snow cover remained in the tundra (Photo 4.80). Discharge was measured the quality of the measurement was classified as "fair". By June 2, lakes remained frozen though most of the snow had melted on the tundra (Photo 4.81).

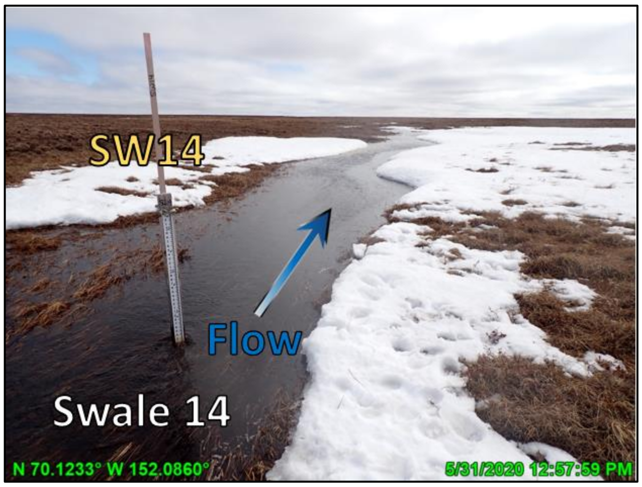


Photo 4.79: SW14 gage near peak conditions, looking west (upstream); May 31, 2020

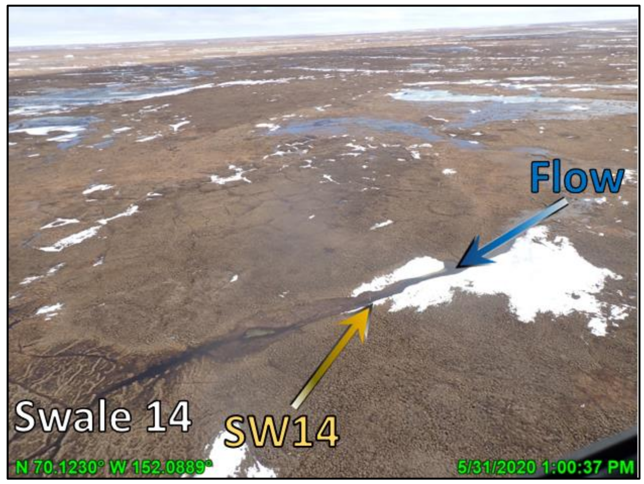


Photo 4.80: SW14 drainage near peak conditions, looking southeast (downstream); May 31, 2020

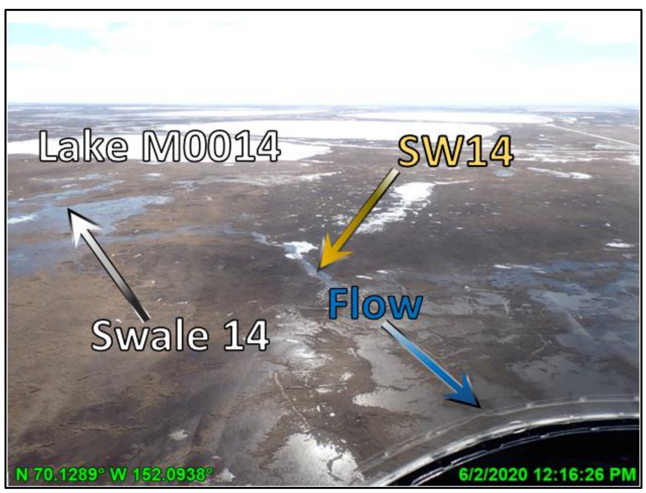


Photo 4.81: Receding stage near SW14, looking south (downstream); June 2, 2020

SWALE 23 (SW23)

Gage station SW23 is situated in a beaded swale flowing west from an unnamed lake to the Kalikpik River, upstream of the KAL1 gage station. Historical peak stage and measured discharge data at SW23 was collected in 2018 and 2019. Limitations due to COVID-19 prevented the field teams from reaching SW23 for set up and monitoring during the 2020 monitoring season. Aerial observations show the drainage on May 30 and May 31 (estimated peak) with approximately 10% snow pack and melt water in the swales (Photo 4.82 and Photo 4.83)

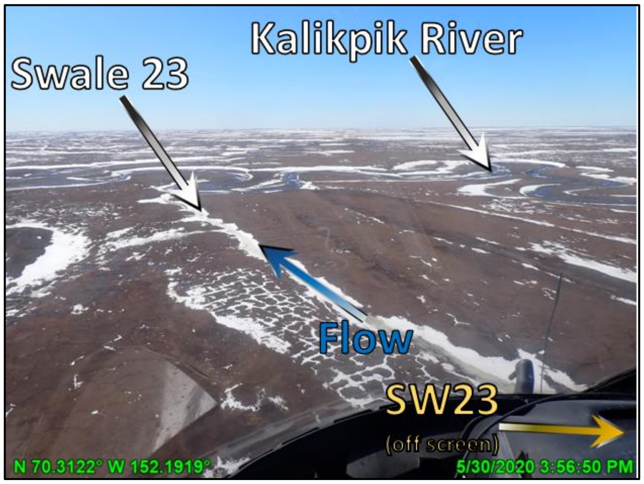


Photo 4.82: SW23 drainage conditions before peak, looking west (downstream); May 30, 2020

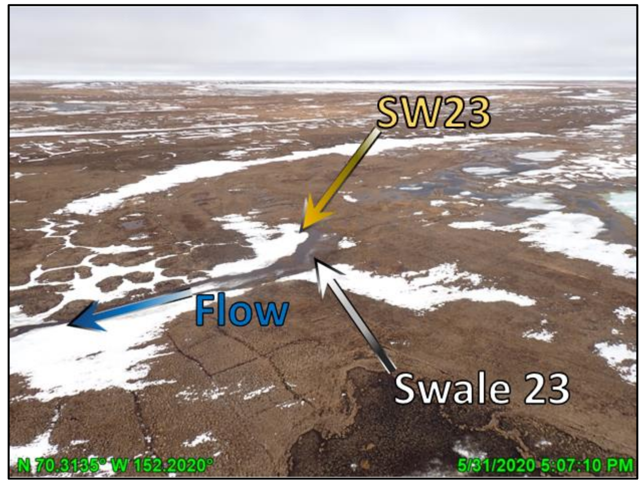


Photo 4.83: SW23 drainage near peak conditions, looking southeast (upstream); May 31, 2020

SWALE 24 (SW24)

C. SPRING

Gage station SW24 is situated in a swale draining east from an unnamed lake into the low-lying area associated with W3S and the outlet to Lake M0015/R0056. Gage SW24 is located near the outlet from the unnamed lake. The CPAI proposed Willow alignment crosses Swale 24 at the SW24 monitoring location. 2020 was the second year of monitoring at the SW24 monitoring station. Peak stage was estimated based on site observations and HWM readings.

On May 26 aerial site observations revealed 75% snow cover in the SW24 drainage (Photo 4.84 and Photo 4.85). By the early morning of May 28, meltwater flowing out of the unnamed lake reached the PT and peaked later that day. Aerial observations on May 30 show that snow and ice were present in the drainage, particularly on the unnamed lake, but the channel was clear (Photo 4.86). Stage appeared near bankfull. This section of the swale was predominantly shallow and wide with a grass-lined bottom. An HWM captured on May 28 recorded peak stage as 85.23 ft.

D. SUMMER

On July 2, a low flow PT was installed at the SW4 gage. At that time, water was noted as widespread and stagnant across the swale depression (Photo 4.87). Stage varied a maximum of 0.20 ft over the summer monitoring period in response to local precipitation events.

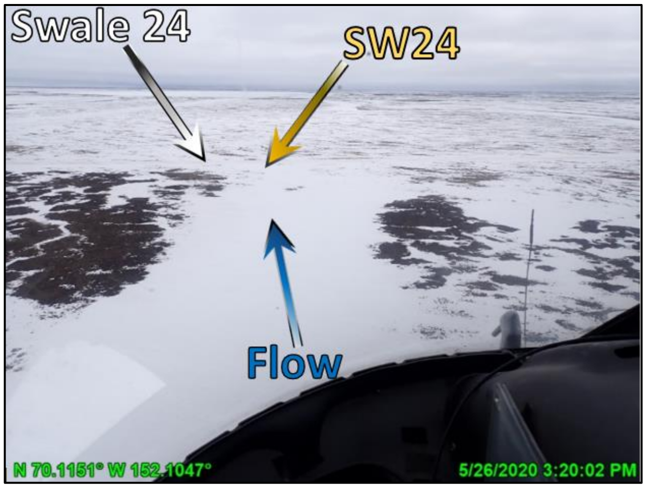


Photo 4.84: SW24 drainage two days before peak WSE, looking southwest (downstream); May 26, 2020

Photo 4.85: SW24 gage with installed PT, looking east; May 26, 2020

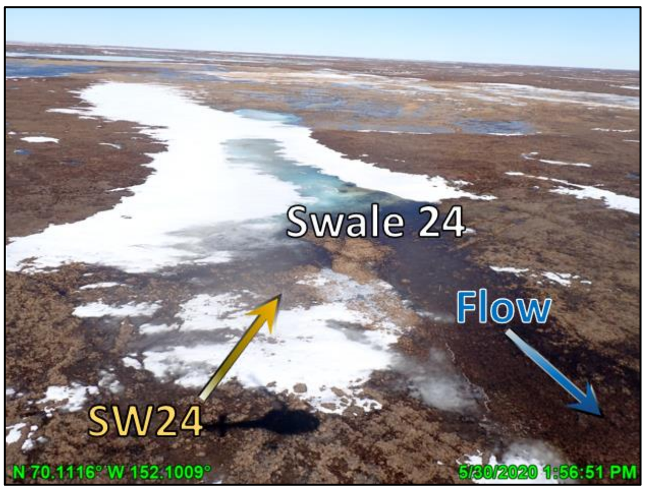


Photo 4.86: Near peak stage at SW24, looking northeast (upstream); May 30, 2020

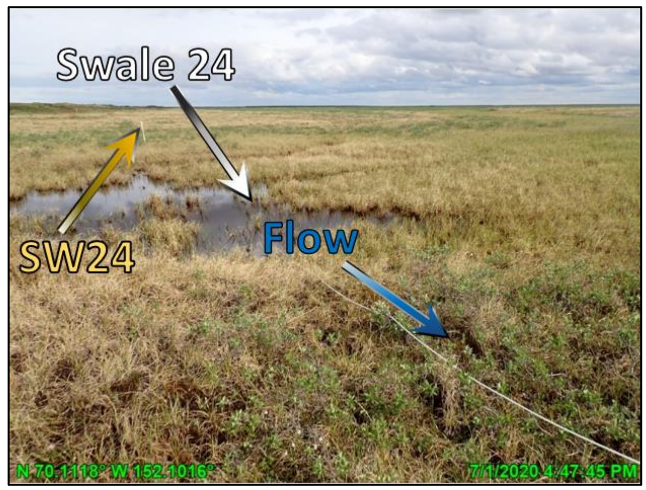
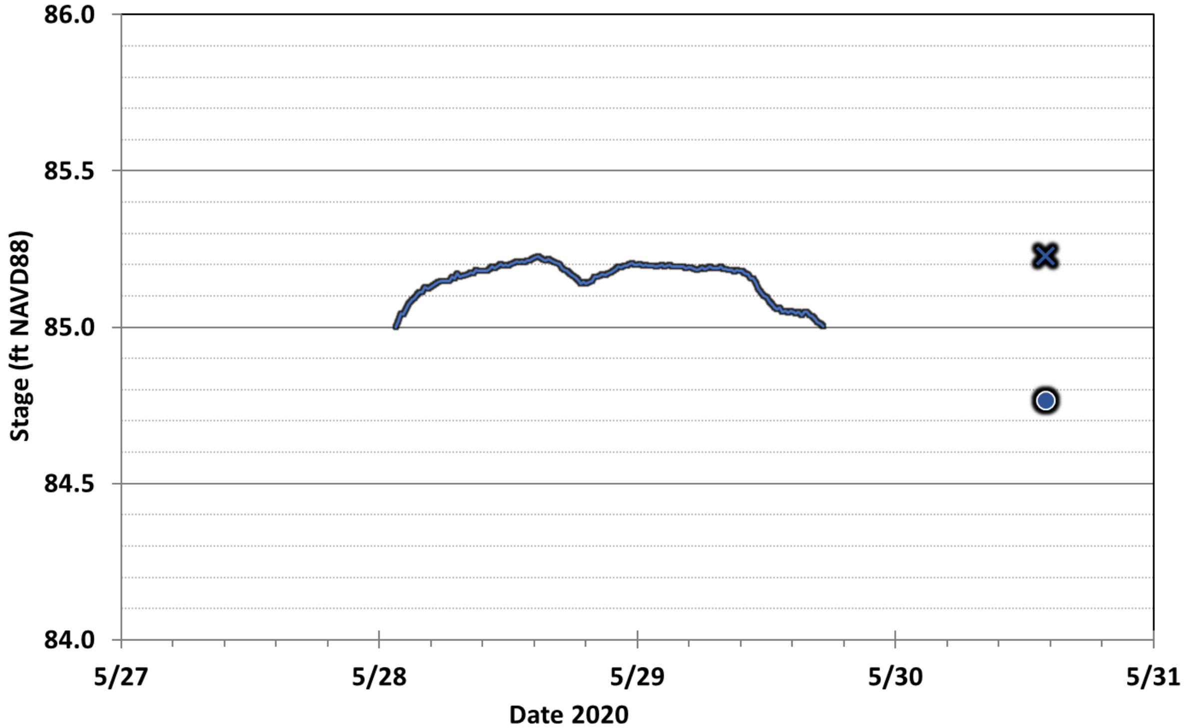


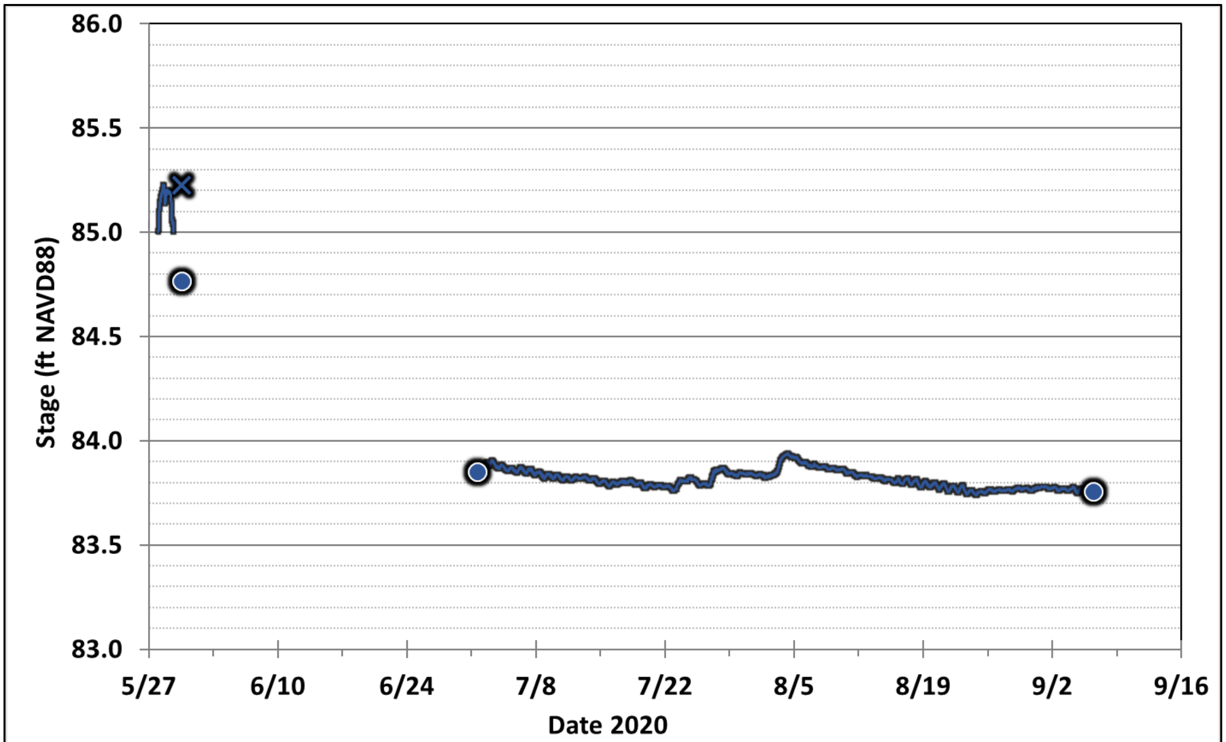
Photo 4.87: Summer conditions at SW24 looking east (upstream); July 1, 2020

Swale 24 spring and summer stage and measured discharge data are presented in Graph 4.28 and Graph 4.29, respectively. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring Peak Stage (ft. NAVD88)		Date & Time
SW24	85.23	5/28 2:45 PM

Graph 4.28: Swale 24 Spring Breakup Stage & Discharge



Summer Sage (ft. NAVD88)		Date & Time
SW24 Highest Recorded Stage	83.94	8/4 6:45 AM
SW24 Minimum Recorded Stage	83.74	8/24 4:30 PM

Graph 4.29: Swale 24 Spring and Summer Stage

4.4 Minesite

Four gage stations were established in 2018 to monitor stage and flood extents at the proposed minesite, located roughly 3 miles south of the GMT1 road near the Tinmiaqsiugvik River. Gage stations UB14.5 and UB15.5 are on the Tinmiaqsiugvik River and situated at low points along the bank where backwater from the Tinmiaqsiugvik River would encroach into the proposed minesite. The MS1_1 is a small swale that flows through the proposed minesite into the Tinmiaqsiugvik River at UB15.5. The BC1 is situated on Bill's Creek, a larger beaded stream that flows north into the Tinmiaqsiugvik River between gage stations UB15.5 and UB14.5 and bounds the proposed minesite to the northeast. This represents the third year of data collection and monitoring at these sites. The Tinmiaqsiugvik River at this location is a sinuous, deeply incised channel flowing north.

TINMIAQSIUGVIK RIVER (UB14.5, UB15.5)

Gage stations UB14.5 and UB15.5 are located on the Tinmiaqsiugvik River 14.5 and 15.5 RM upstream from its confluence with Judy Creek. Gage UB14.5 is downstream of the mouth of Bill's Creek (BC1) where it enters the Tinmiaqsiugvik River. Gage UB15.5 is located upstream and around a bend from UB14.5. The winter months fill the deep, incised channel with windblown snow. This is the third year of monitoring at the UB14.5 and UB15.5 monitoring stations. Historical peak stage and measured discharge data at UB14.5 and UB15.5 is presented in Table and Table , respectively.

Table 4.18: UB14.5 Historical Peak Stage and Measured Discharge

Year	UB14.5				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	18.09	5/31	--	--	--
2019	19.23 [3]	5/29	1000	6/2	14.30
2018 [1]	20.20	6/9	1200 [2]	6/10	--

Notes:
1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019
2. Discharge measured about 11 RM upstream of UB14.5 gage site
3. PT malfunction. Highest recorded stage. Peak timing at UB14.5 assumed to coincide with peak at UB15.5

Table 4.19: UB15.5 Historical Peak Stage and Measured Discharge

Year	UB15.5				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2020	22.06	5/30	--	--	--
2019	22.46	5/26	--	--	--
2018 [1]	23.49	6/8	--	--	--

Notes:
1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

Initial meltwater was first recorded on the UB15.5 PT on May 26, while the UB14.5 PT did not begin capturing the rising limb until May 29. Stage increased steadily at both gages until peak stage conditions occurred at UB15.5 on May 30. Peak at UB14.5 followed on May 31. Site observations on May 31 revealed bankfull stage at UB14.5, with minor overbank flooding in low-lying areas particularly along the west bank (Photo 4.88). The incised nature of the channel UB15.5 can be observed during summer conditions (Photo 4.89).

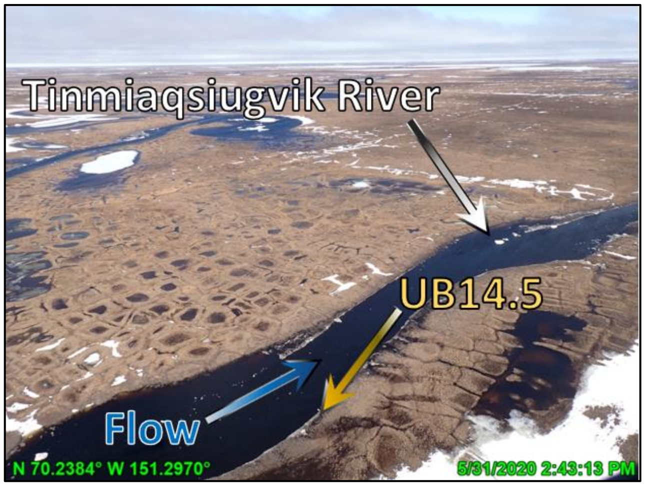


Photo 4.88: Bankfull conditions in the Tinmiaqsiugvik River near UB14.5, looking north (downstream); May 31, 2020

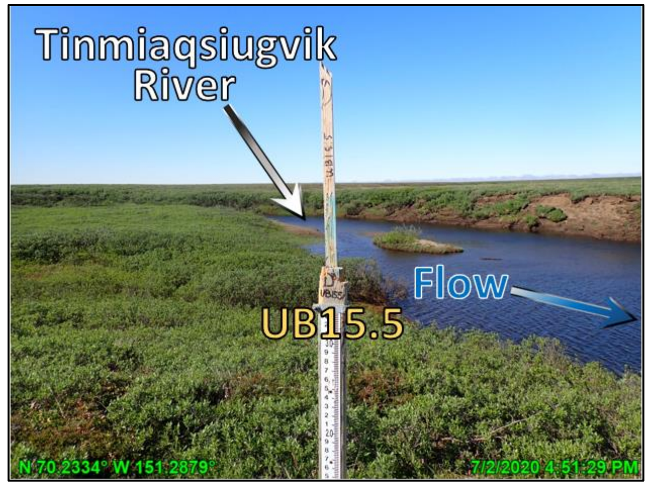
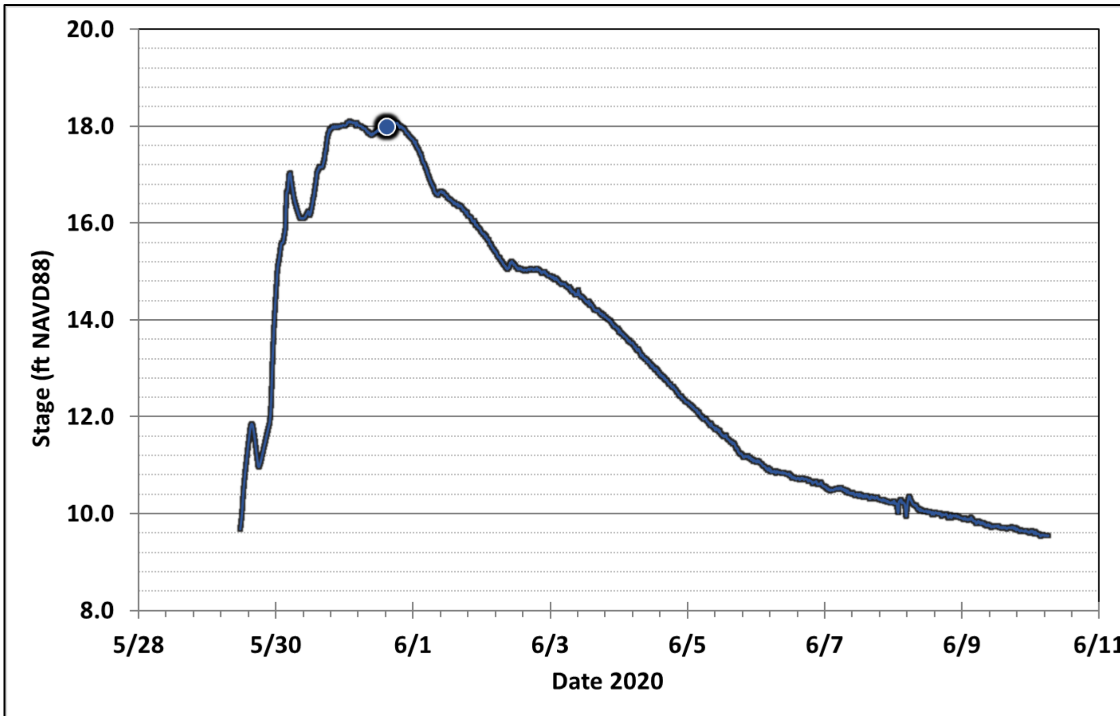


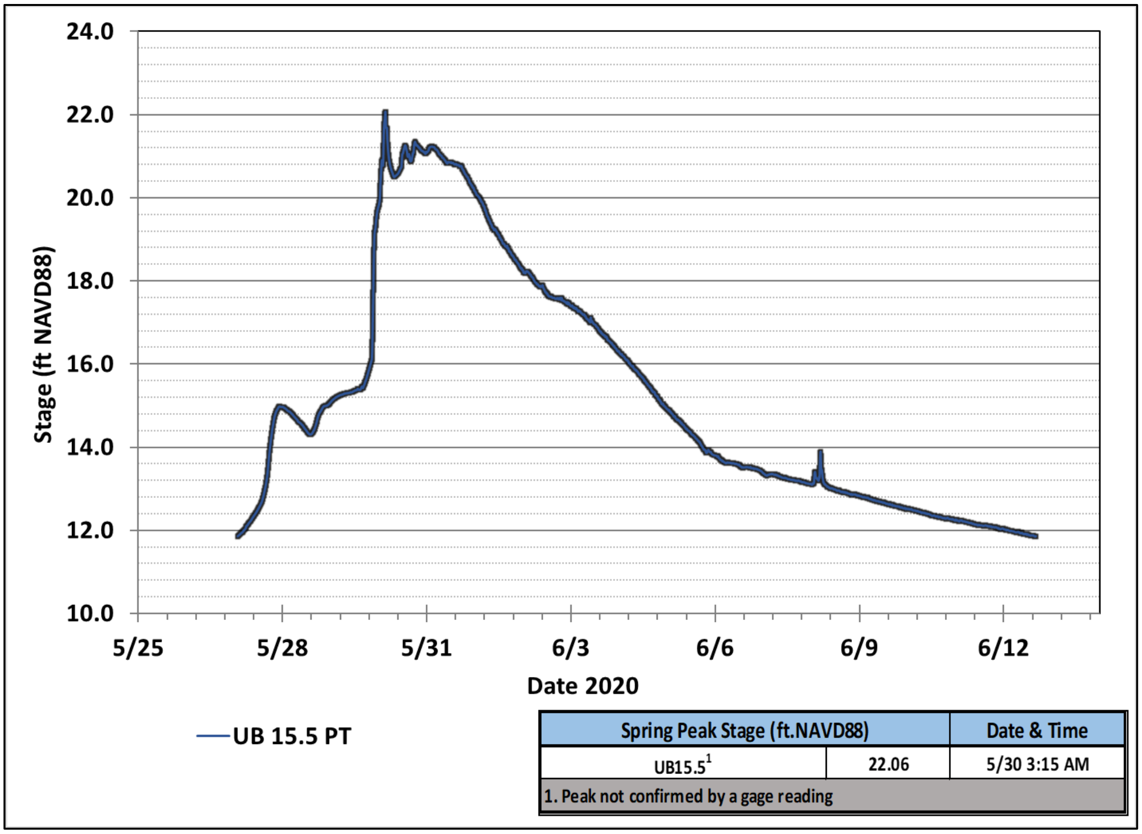
Photo 4.89: Summer conditions at UB15.5, looking upstream; July 2, 2020

The UB14.5 and UB15.5 stage are presented in Graph 4.30 and Graph 4.31, respectively. Plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring Peak Stage (ft.NAVD88)		Date & Time
UB14.5	18.09	5/31 1:45 AM

Graph 4.30: UB14.5 Spring Breakup Stage and Discharge



Graph 4.31: UB15.5 Spring Breakup Stage

MS1_1

Gage station MS1_1 is situated in a small beaded swale flowing north to the Tinmiaqsiugvik River adjacent to UB15.5. The MS1_1 swale drainage area is encompassed by the BC1 stream to the east, Lake L9816 to the south, and the Tinmiaqsiugvik River to the West. This is the third year of monitoring at the MS1_1 monitoring location. Historical peak stage and measured discharge data at MS1_1 is presented in Table .

Table 4.20: MS1_1 Historical Peak Stage and Measured Discharge

Year	MS1_1	
	Peak Stage (ft NAVD88)	Date
2020	27.11	5/29
2019	27.66	5/24
2018	27.57	6/5

Initial meltwater was first recorded on the MS1_1 PT on May 27 (Photo 4.90). Game camera images from this day shows the channel is snow covered with some ribbons of saturated snow downstream. Peak stage occurred early afternoon on May 29 and appeared to occur when saturated snow and bottomfast ice remained in the channel (Photo 4.91).

On May 31 the channel was free of snow and ice and flowing at bankfull conditions (Photo 4.92). By June 3, the WSE had returned to approximate base flow conditions.

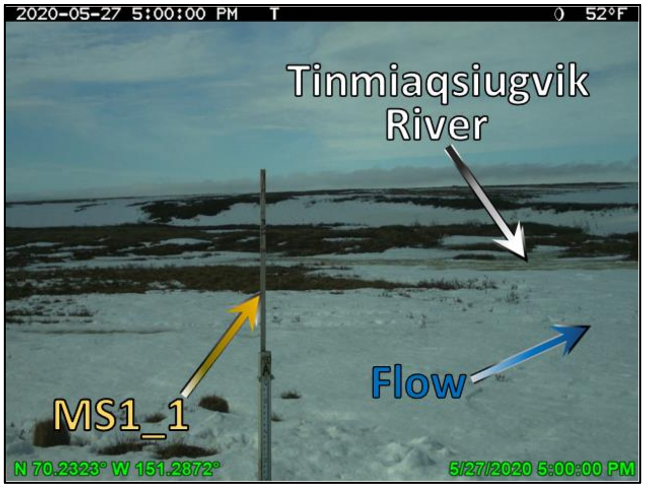


Photo 4.90: Game camera image of MS1-1 at the start of the rising limb, May 27, 2020

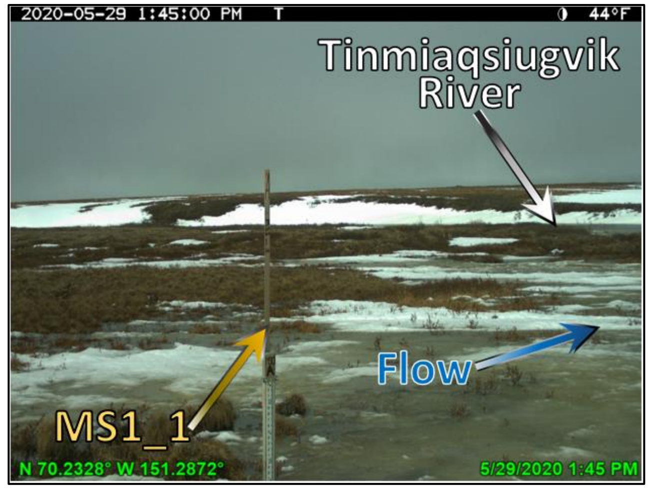


Photo 4.91: Game camera image of MS1_1 at peak conditions, meltwater over saturated snow and bottomfast ice, May 29, 2020

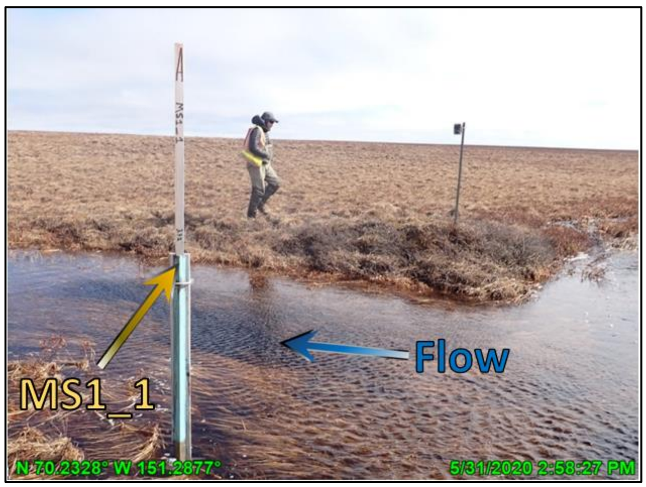
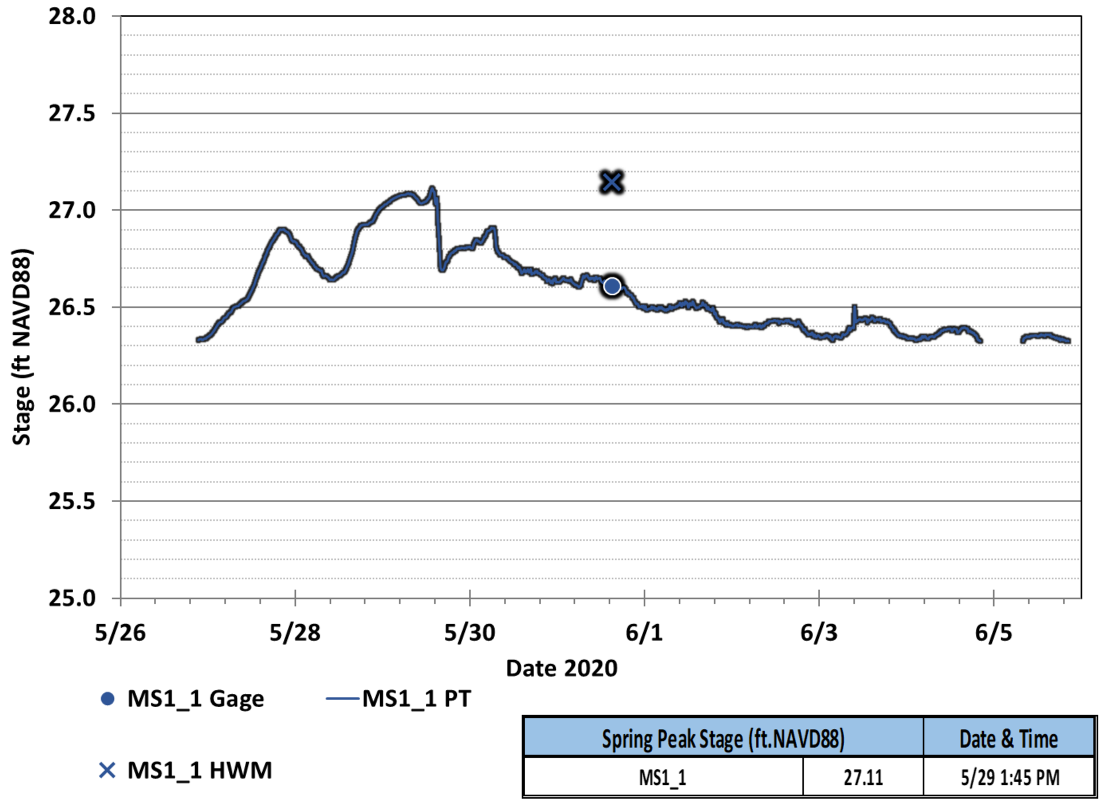


Photo 4.92: Bankfull flow at MS1_1, May 31,2020

MS1_1 stage data are presented in Graph 4.32. Elevations are referenced to NAVD88.



Spring Peak Stage (ft.NAVD88)		Date & Time
MS1_1	27.11	5/29 1:45 PM

Graph 4.32: MS1_1 Spring Breakup Stage

BC1

Gage station BC1 monitors a beaded stream flowing north from an area of small lakes. The BC1 drainage is broad, with long sloping banks bordering the east side of the proposed minesite location. The summer channel consists of large beads connected by deeply incised, narrow channels with long grass. Like many of the drainages, windblown snow filled much of the drainage during winter, and initial meltwater began by flowing over and through the snowpack. This is the third year of monitoring at the BC1 monitoring station. Historical peak stage data at BC1 is presented in Table .

Table 4.21: BC1 Historical Peak Stage

Year	BC1	
	Peak Stage (ft NAVD88)	Date
2020	39.01	5/30
2019	39.78	5/23
2018 [1]	41.85	6/11

Notes:

1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

Initial meltwater was first recorded at BC1 on May 28. Stage increased until peak conditions occurred on May 30. On May 31, site observations revealed meltwater flowing with high velocity overtop of drifted snow in the channel (Photo 4.93). No overbank flooding was noted as flow was confined to the defined channel. Snow cover on the surrounding tundra was approximately 5%. Stage decreased until the end of the spring monitoring period on June 4. On June 2, snow was present in the channel overbank and still appeared to confine meltwater (Photo 4.94).

The BC1 spring stage data are presented in Graph 4.33. Elevations are referenced to NAVD88.

Photo 4.93: Meltwater flowing over saturated snow near BC1, looking north (downstream); May 31, 2020

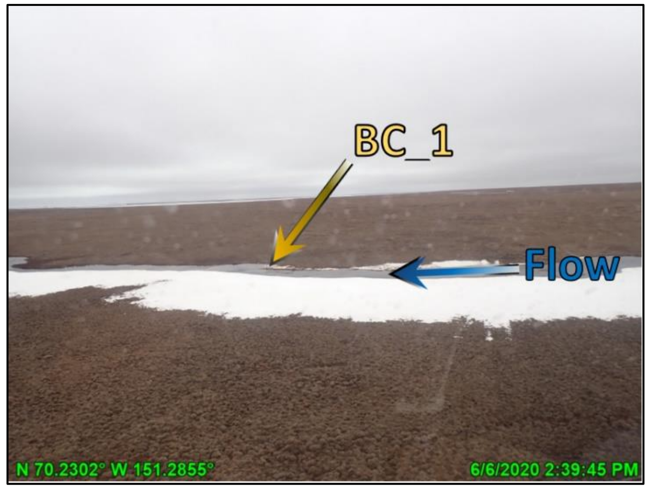
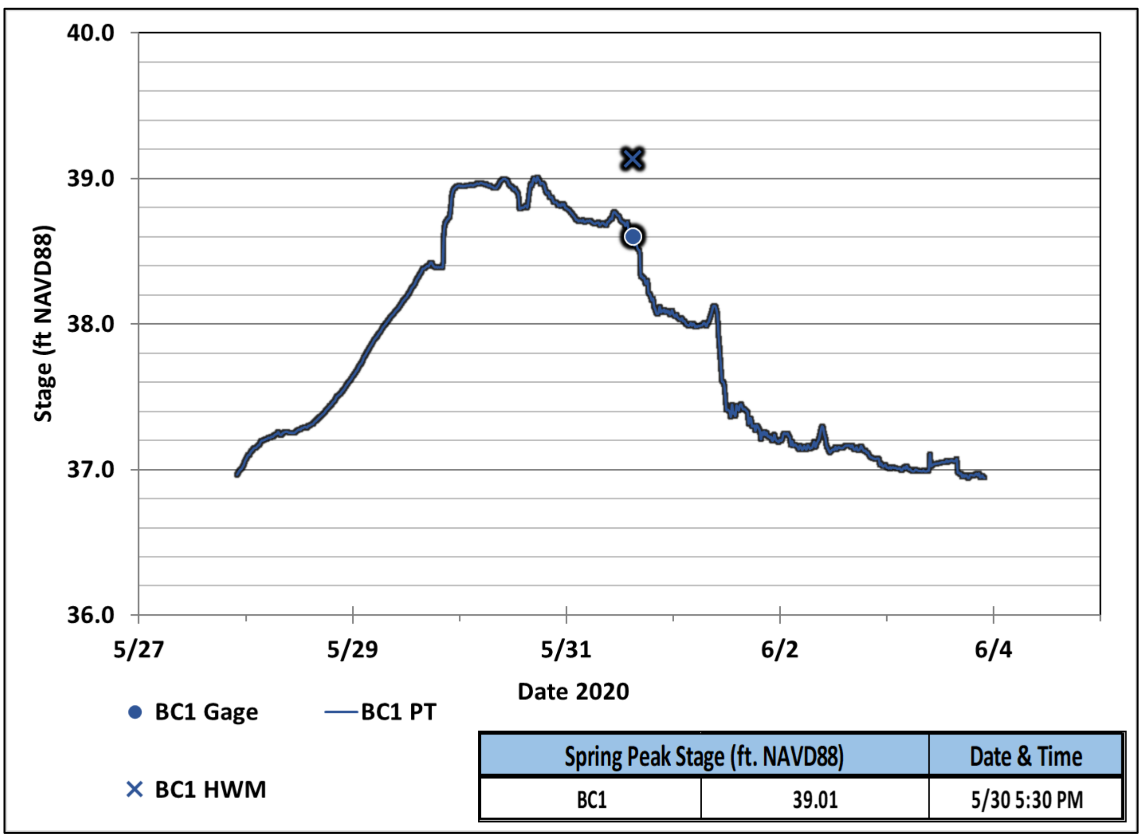


Photo 4.94: Receding stage at BC1, looking east (across the channel); June 2, 2020



Spring Peak Stage (ft. NAVD88)		Date & Time
BC1	39.01	5/30 5:30 PM

Graph 4.33: BC1 Spring Breakup Stage

4.5 Source Lakes

MIDDLE SNOWMAN LAKE AND OUTLET (MSL AND MSL_OUT)

Gage stations MSL and MSL_OUT monitor the proposed source Lake M0015/R0056, also known as Middle Snowman Lake. Gage station MSL is situated on the bank of the northwest corner of the lake near its outlet. Gage station MSL_OUT is situated in a well-defined, but very small (about 1-ft across) grass lined channel which bifurcated from the main channel about 30-ft to the north. This fork converges with the main channel about 100-ft downstream of MSL_OUT. From there, the channel is well-defined for another 200-ft, then opens into the poorly defined, low-relief drainage area associated with W3S. This is the third year of monitoring at this location. Historical peak stage data at MSL and MSL_OUT is presented in Table 4.22. A summary of all discharge measurements is presented in Table .

Table 4.22: MSL & MSL_OUT Historical Peak Stage

Year	MSL		MSL_OUT	
	Peak Stage (ft BPMSL)	Date	Peak Stage (ft BPMSL)	Date
2020	89.26	6/5	89.21	6/5
2019	89.51	5/30	89.45	5/30
2018	89.86	6/4	89.78	6/3

Notes:
1. 2018 and 2019 BPMSL datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to BPMSL in 2020

Table 4.23: Summary of Discharge measurements at MSL_OUT

Date	MSL	
	Stage (ft BPMSL)	Discharge (cfs)
6/4/2020	89.09	5.8
6/5/2020	89.09	5.8
6/6/2020	89.08	6.3
6/7/2020	89.07	5.3
6/8/2020	89.05	5.5
7/2/2020	88.93	3.7
9/16/2020	88.81	1.8

A. Spring Breakup

Localized meltwater was first observed through aerial observations on May 31. On this day, no flow was observed from Lake M0015/R0056 and the lake outlet remained filled with ice and saturated snow (Photo 4.95). On June 1, conditions in the drainage remained relatively unchanged. Snow cover on the surrounding tundra was approximately 5% and had decreased considerably from the previous day (Photo 4.96). On June 3, channelized flow through saturated snow was observed from Lake M0015/R0056 into the lake outlet (Photo 4.97). Discharge was measured downstream from gage station MSL_OUT starting every day from June 3 until June 8. Observations from June 3 show bottomfast ice in the channel along the reach from MSL to MSL_OUT (Photo 4.98). Ice cover was present on the majority of the lake surface except for along the banks on June 7 (Photo 4.99 and Photo 4.100).

Peak stage at MSL and MSL_OUT was recorded on June 5. During peak, stage fluctuation at each site was minimal. During peak stage, floodwater in the lake outlet slightly exceeded bankfull, with minor overbank flooding observed in low-lying areas around the channel. After peaking, stage gradually receded. Observations from June 5 show no ice or snow remaining in the drainage and Lake M0015/R0056 was still covered with ice. The PT data indicates stage began to level off around June 15.

Gage stations MSL and MSL_OUT stage and is presented in Graph 4.34. Elevations are referenced to BPMSL datum.

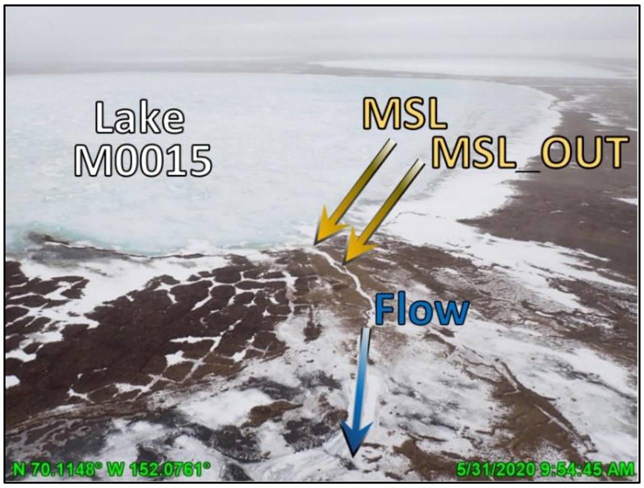


Photo 4.95: Snow in the MSL drainage, looking south (upstream); May 31, 2020

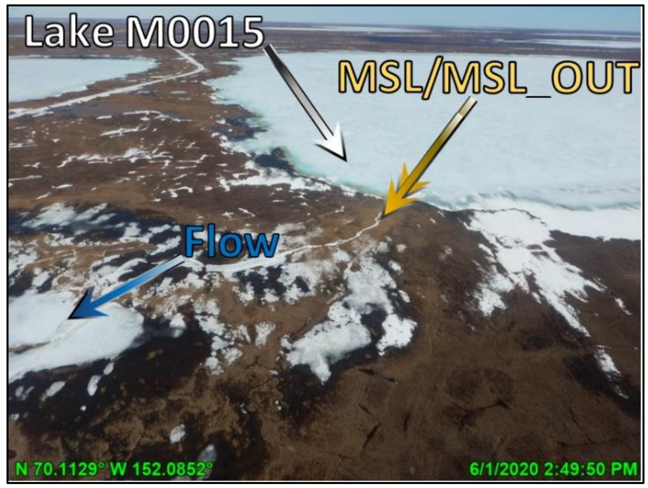


Photo 4.96: Conditions at MSL, looking east (upstream); June 1, 2020

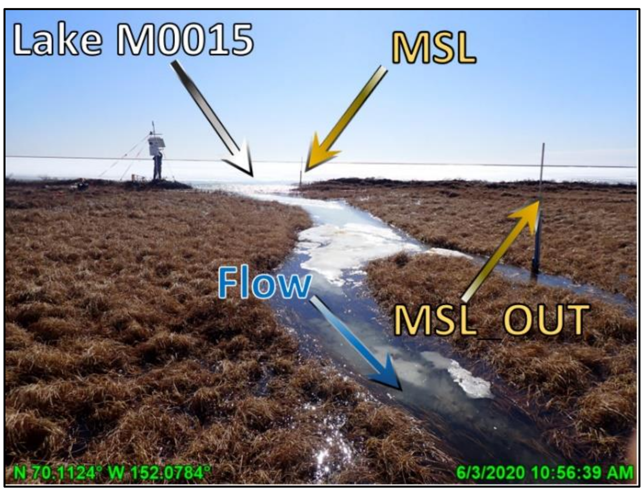


Photo 4.97: Channelized flow through MSL and MSL_OUT, looking south (upstream); June 3, 2020

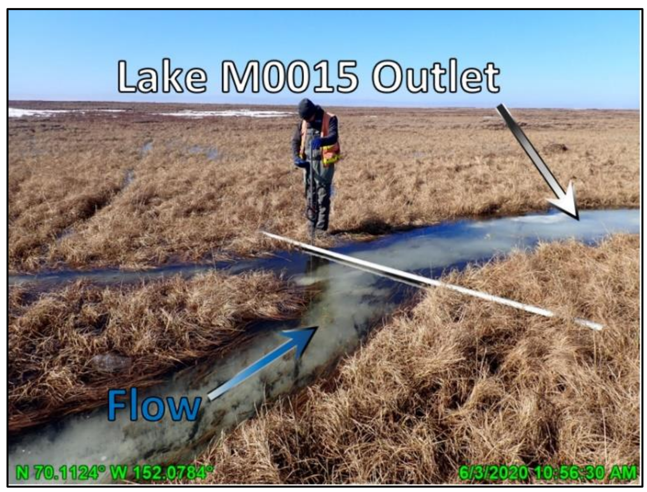


Photo 4.98: Crews measuring discharge at MSL_OUT, looking northwest (downstream); June 3, 2020

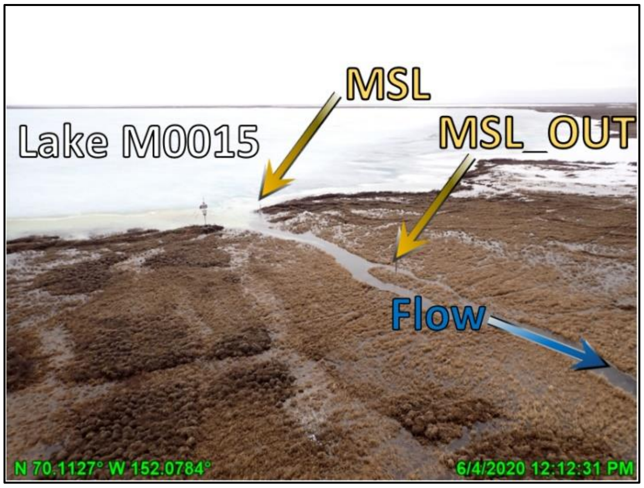


Photo 4.99: Minor overbank flooding at MSL and MSL_OUT near peak, looking southwest (upstream); June 4, 2020

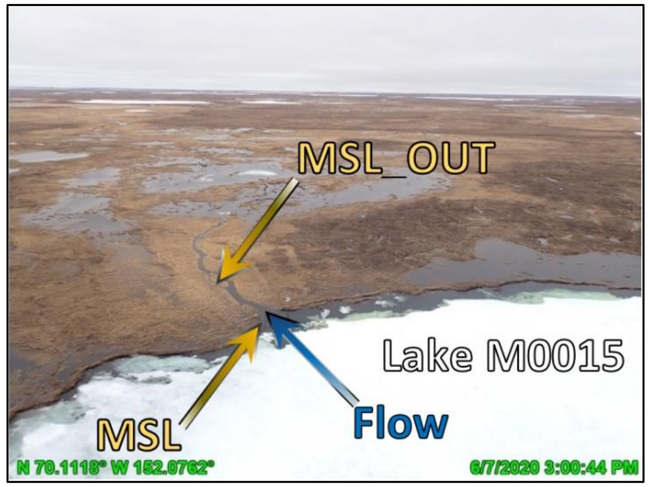
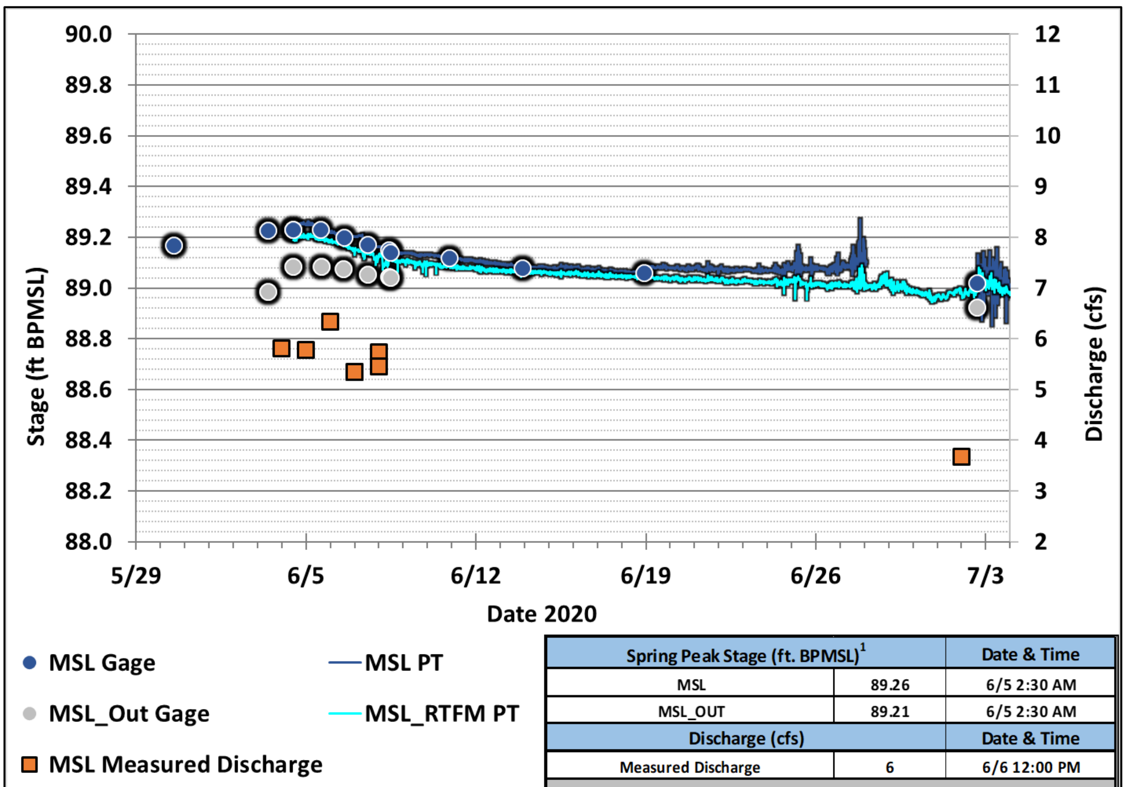


Photo 4.100: Late spring conditions at MSL and MSL_OUT, looking north (downstream); June 7, 2020



Spring Peak Stage (ft. BPMSL)[1]		Date & Time
MSL	89.26	6/5 2:30 AM
MSL_OUT	89.21	6/5 2:30 AM
Discharge (cfs)		**Date & Time**
Measured Discharge	6	6/6 12:00 PM

1. MSL_OUT peak stage not recorded directly at gage location.

Graph 4.34: Middle Snowman Lake at MSL & MSL_OUT Spring Breakup Stage

B. Summer

Summer stage was measured at both MSL and MSL_OUT. Small stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained below spring breakup peak spring stage (Photo 4.101). During the post-breakup observation period, discharge was measured on July 2 and September 16. Summer stage at MSL and MSL_OUT is presented in Graph 4.35.

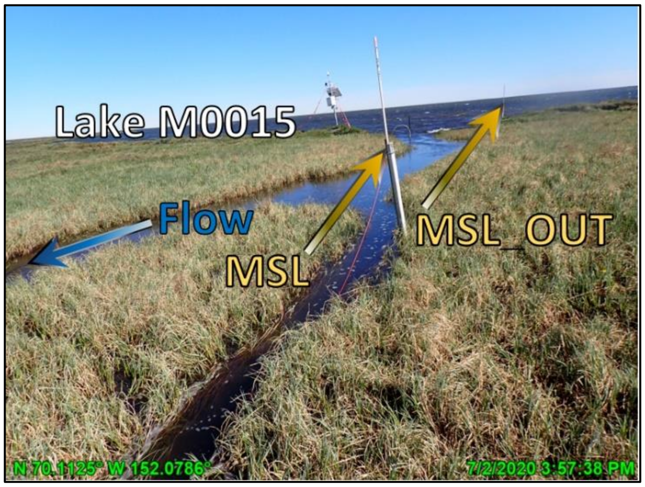
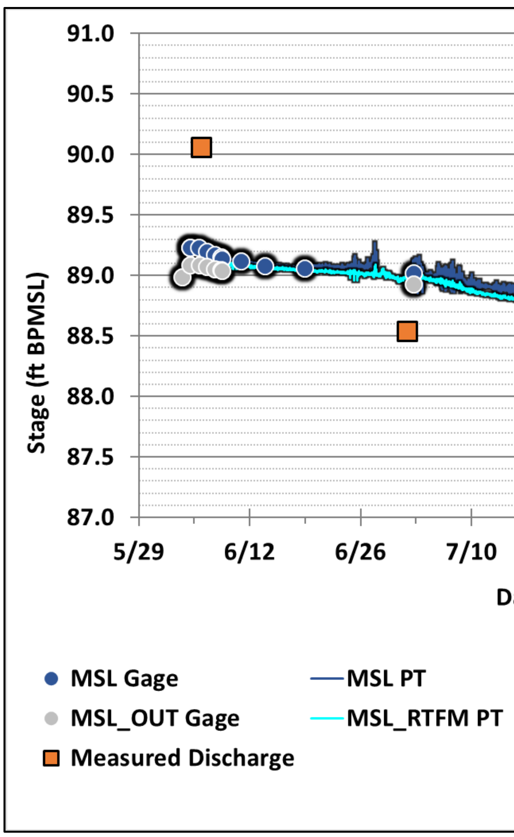


Photo 4.101: Summer conditions at MSL & MSL_OUT, looking south (upstream); July 2, 2020



Summer Stage (ft. BPMSL)		Date & Time
MSL Highest Recorded Stage	89.15	7/3 11:15AM
MSL_RTFM Highest Recorded Stage	89.08	7/2 5:15 PM
MSL Minimum Recorded Stage	88.67	8/31 6:45PM
MSL_RTFM Minimum Recorded Stage	88.71	7/22 7:30 PM

Graph 4.35: Middle Snowman Lake at MSL & MSL_OUT Summer Stage

LOWER SNOWMAN LAKE AND OUTLET (LSL & LSL_OUT)

Gage stations LSL and LSL_OUT monitor the proposed source Lake R0064, also known as Lower Snowman Lake. Gage station LSL is situated on the bank of the north corner of the lake near the lake's outlet while LSL_OUT is placed in the swale draining R0064, about 100 ft from the lake's outlet and gage station LSL. This is the third year that these gage stations have been monitored. Historical peak stage data at LSL and LSL_OUT is presented in Table .

Table 4.24: LSL & LSL_OUT Historical Peak Stage

Year	LSL		LSL_OUT	
	Peak Stage (ft NAVD88)	Date	Peak Stage (ft NAVD88)	Date
2020	91.54	5/28	91.32	5/28
2019	92.17	5/23	91.75	6/2
2018 [1]	92.58	6/26	92.41	6/15

Notes:
1. 2018 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby UMIAQ transect survey. The local control points associated with this site were surveyed and tied to NAVD88 in 2019

A. Spring Breakup

Meltwater was first recorded on the LSL PTs on May 27 and was the result of isolated local melt. Stage quickly peaked, then receded below the PT elevation by May 30. Aerial observations from May 31 show no visible flow with saturated snow in the lake outlet and ice cover on the entire lake surface (Photo 4.102). Disconnected local meltwater was present in low-lying areas on the surrounding tundra near the LSL outlet. Snow cover on the surrounding tundra was estimated at 10%. On June 1, meltwater was starting to enter the lake outlet (Photo 4.103). Game camera images show increasing localized meltwater at LSL through June 3. In the morning of June 4, the quantity of meltwater increased rapidly as meltwater entered Lake R0064 outlet (Photo 4.104). Game camera images suggest minimal fluctuation in stage throughout the rest of the spring breakup monitoring period.

On June 5, aerial observations show channelized flow out of Lake R0064 and into the low-lying area between Lake R0064 and M0015 (Photo 4.105). Hydraulic connection between the two lakes had likely occurred but could not be conclusively confirmed through aerial images. Stage was below bankfull with saturated snow remained in the channel. As observed in previous years, a bifurcation downstream of LSL_OUT produced two distinct channels each conveying flow into a low-lying area about 200-ft downstream of LSL_OUT.

LSL and LSL_OUT stage and is presented in Graph 4.36. Elevations are referenced to NAVD88.

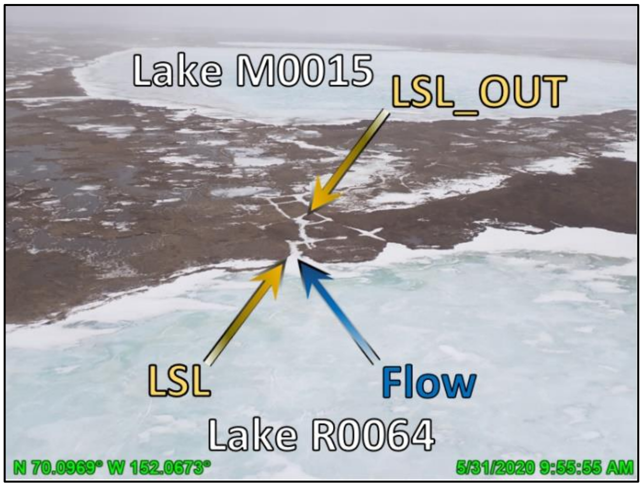


Photo 4.102: Snow-filled drainage near LSL & LSL_OUT, looking north (downstream); May 31, 2020

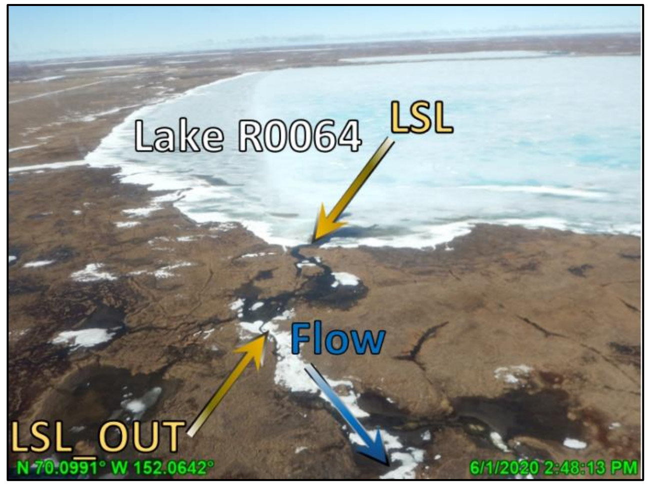


Photo 4.103: Meltwater near LSL and LSL_OUT, looking south (upstream); June 1, 2020

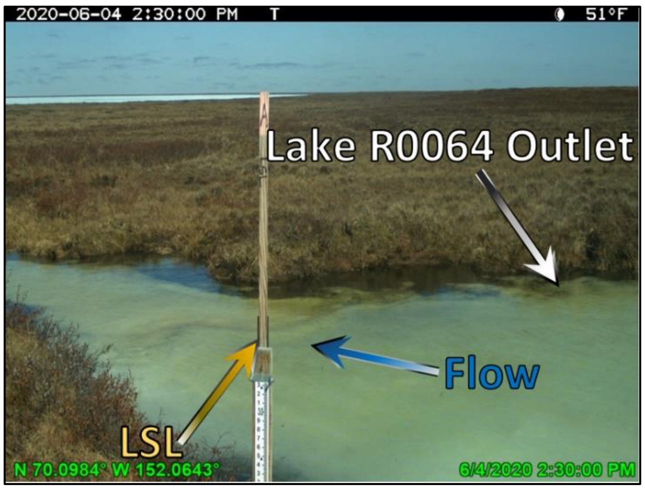


Photo 4.104: Game Camera image of LSL, looking northeast (downstream); June 4, 2020

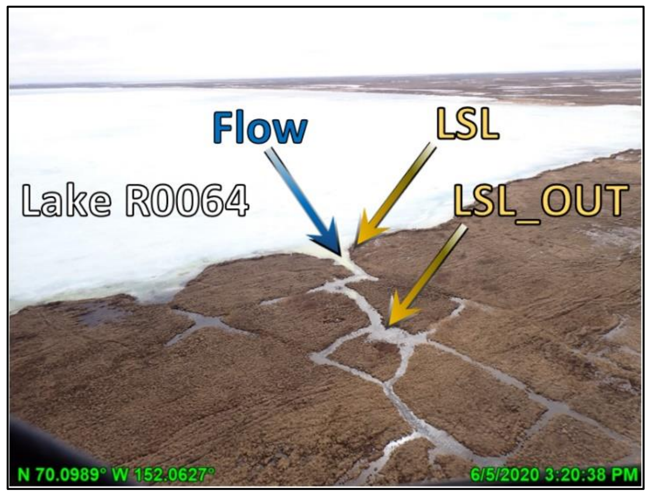
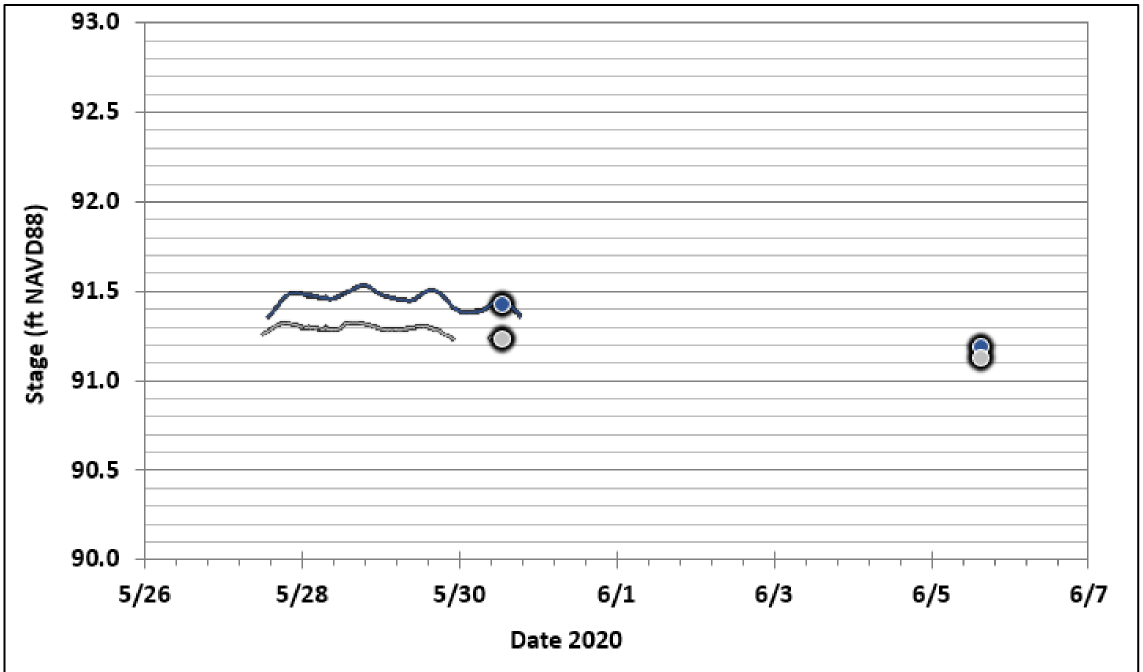


Photo 4.105: Confirmed flow through LSL and LSL_OUT, looking south (upstream); June 5, 2020



Spring Peak Stage (ft. NAVD88)		Date & Time
LSL	91.54	5/28 6:30 PM
LSL_OUT	91.32	5/28 3:15 PM

Graph 4.36: Lower Snowman Lake at LSL & LSL_OUT Spring Breakup Stage

B. Summer

Small stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained below spring breakup peak spring stage (Photo 4.106). During the summer observation period, no flow was present, although standing water around the gage was observed. Summer stage at LSL and LSL_OUT is presented in Graph 4.37.

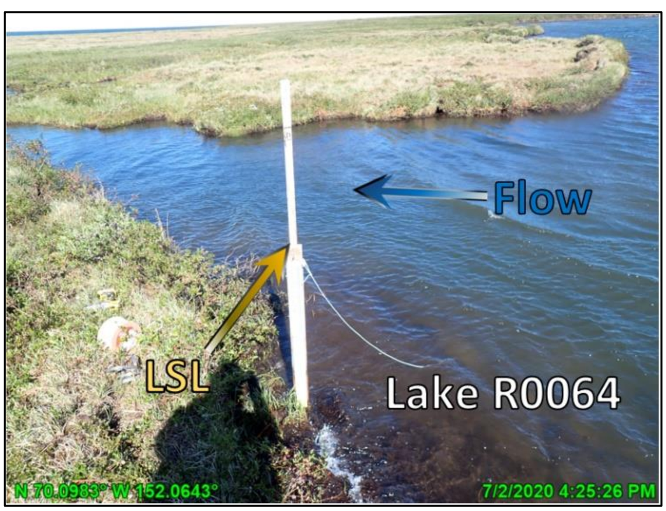
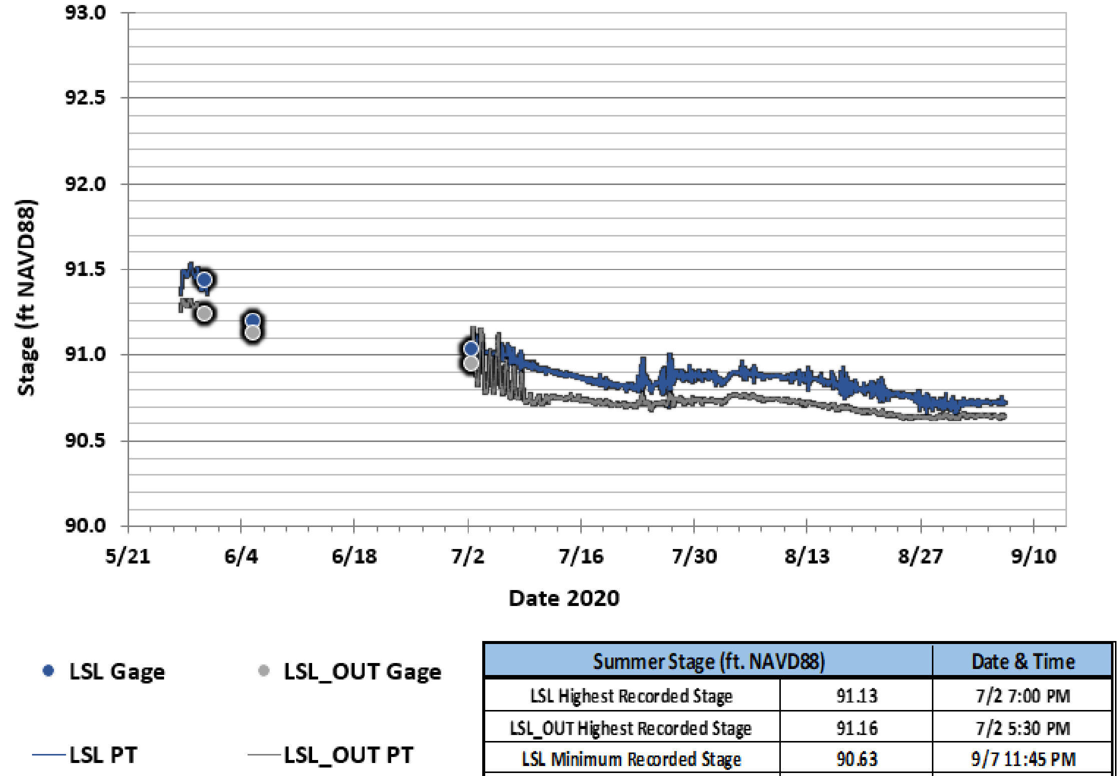


Photo 4.106: Summer conditions at LSL, looking east; July 2, 2020



Summer Stage (ft. NAVD88)		Date & Time
LSL Highest Recorded Stage	91.13	7/2 7:00 PM
LSL_OUT Highest Recorded Stage	91.16	7/2 5:30 PM
LSL Minimum Recorded Stage	90.63	9/7 11:45 PM
LSL_OUT Minimum Recorded Stage	90.58	9/7 10:15 PM

Graph 4.37: Lower Snowman at LSL & LSL_OUT Summer Stage

5. FLOOD FREQUENCY ANALYSIS

The flood frequency results and assigned recurrence intervals for 2020 peak discharge for Judy Creek, Fish Creek, Kalikpik River, Willow 2, Judy Creek Kayyaaq, and Willow 4 are presented below. Assigned recurrence intervals should be considered with respect to conditions at the time of peak discharge or measured discharge. Detailed USGS regression analysis results are provided in Appendix E.

Table presents the Judy Creek at J13.8 flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) and the URS peak discharge regional regression analysis (URS 2002). This year's J13.8 peak discharge of 3,800 cfs has a recurrence interval of less than 2 years.

Table 5.1: J13.8 Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]	URS Peak Discharge [2]
%	years	cfs	cfs
50	2	7,400	5,100
20	5	10,900	8,000
10	10	13,100	10,000
4	25	15,800	12,900
2	50	17,700	15,300
1	100	19,500	17,700

Notes:
[1.] USGS 2003
[2.] URS 2002

Table presents the Fish Creek at F55.5 flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) and the URS peak discharge regional regression analysis (URS 2002). This year's F55.5 peak discharge of 2,900 cfs has a recurrence interval of less than 2 years.

Table 5.2: F55.5 Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]	URS Peak Discharge [2]
%	years	cfs	cfs
50	2	10,400	7,400
20	5	15,200	11,500
10	10	18,200	14,300
4	25	21,800	18,300
2	50	24,400	21,500
1	100	26,900	24,700

Notes:
[1.] USGS 2003
[2.] URS 2002

Table presents the Willow 2 at UC1B flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) applied to the measured discharge value at UC1B. This year's UC1B measured discharge of 90 cfs has a recurrence interval of less than 2 years.

Table 5.3: UC1B Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]
%	years	cfs
50	2	300
20	5	400
10	10	500
4	25	700
2	50	800
1	100	900
Notes: [1.] USGS 2003		

Table presents the Judy Creek Kayyaaq at UC2C flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) applied to the measured discharge value at UC2C. This year's UC2C measured discharge of 230 cfs has a recurrence interval of less than 2 years.

Table 5.4: UC2C Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]
%	years	cfs
50	2	1,600
20	5	2,400
10	10	2,900
4	25	3,600
2	50	4,100
1	100	4,500
Notes: [1.] USGS 2003		

Table presents the Willow 4 at W_BS1 flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) applied to the measured discharge value at W_BS1. This year's W_BS1 measured discharge of 180 cfs has a recurrence interval of less than 2 years.

Table 5.5: W_BS1 Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]
%	years	cfs
50	2	600
20	5	900
10	10	1,100
4	25	1,400
2	50	1,600
1	100	1,800
Notes: [1.] USGS 2003		

Table presents the Willow 4 at W_S1 flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) applied to the measured discharge value at W_S1. This year's W_S1 measured discharge of 185 cfs has a recurrence interval of 3 years.

Table 5.6: W_S1 Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]
%	years	cfs
50	2	150
20	5	200
10	10	300
4	25	400
2	50	500
1	100	500

Notes:
[1.] USGS 2003

6. WILLOW ICE ROAD CROSSINGS BREAKUP

Ice roads are constructed annually for ground transportation of supplies and equipment to Willow and West Willow. Aerial surveys were conducted before, during, and after spring breakup at most locations to observe and document the ice deterioration at stream crossings. To expedite melt and facilitate flow through the crossings during breakup flooding, ice road crossings are mechanically slotted at the conclusion of the winter season.

In general, ice road crossings deteriorated at a similar rate as surrounding channel ice. Aerial surveys showed that slotting was completed, and floodwaters were passing through all ice road crossings. When flooding receded, the ice road crossings and channel ice had cleared at most locations. Photos of all monitored ice road crossings are presented in Appendix D.

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Appendix A Stage Methods & Site-Specific Data

A.1 STAGE METHODS

Gage Setup Methods

Each gage assembly included a standard USGS metal faceplate mounted on a wooden two-by-four. The two-by-four was attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground. The faceplate is graduated and indicates water levels every 100th of a foot between 0.00 to 3.33-ft.

PT Setup & Testing Methods

PTs measure the absolute pressure of the atmosphere and water, allowing the depth of water above the sensor to be calculated. Resulting data yield a comprehensive record of the fluctuations in stage. The reported pressure is the sum of the forces imparted by the water column and atmospheric conditions. Variations in local barometric pressure were taken into account using an In-Situ BaroTROLL® barometric pressure logger. A correction of barometric pressure was obtained from the BaroTROLL installed on the telemetry system at Fish Creek at F55.5.

The PTs were tested before field mobilization. The PTs were configured using Win-Situ® LT 5.6.21.0 (for the Level TROLL 500s) or Solinst Levelogger® v4.0.3 (for the Solinst Leveloggers) software prior to placement in the field. Absolute pressure was set to zero.

PT-based stage values were determined by adding the calculated water depth and the surveyed sensor elevation. PTs have the potential to drift and can be affected by ice and sediment. Gage stage readings were used to validate and adjust the data collected by the PTs. A standard conversion using the density of water at 0°C was used to calculate all water depths from adjusted gage pressures. Fluctuations in water temperature during the sampling period did not affect stage calculations because of the limited range in temperature and observed water depths.

A.2 SITE SPECIFIC DATA

Table A.1: Gage Locations & Associated Vertical Control

Location Type	Stream Name	Site Name	Site Location		Number of Gages	Associated Vertical Control	Vertical Control Location		Vertical Control Elevation (ft NAVD88)
			Latitude (WGS84)	Longitude (WGS84)			Latitude (WGS84)	Longitude (WGS84)	
Major Streams	Fish Creek	F55.5U	70.25140°	-152.18350°	4	BRECCIA SCORIA	70.25271° 70.25272°	152.18030° 152.18035°	64.526 65.124
		F55.5	70.25184°	-152.18152°	3				
		F55.5D	70.25301°	-152.17923°	3				
	Judy Creek[1]	J13.8U	70.18540°	-151.96231°	3	Line 4BW GILLY	70.18664° 70.18680°	151.96200° 151.96170°	40.880[2] 45.220[2]
		J13.8	70.18694°	-151.96094°	3				
		J13.8D	70.18920°	-151.95727°	3				
		J21.4	70.14645°	-152.09073°	3	OTIS LUCKY	70.14672° 70.14672°	152.09075° 152.09079°	58.083 58.334
	Kalikpik River	KAL1	70.31565°	-152.23961°	2	CHERT CHALK	70.31513° 70.31510°	152.24214° 152.24199°	63.293[4] 62.828[4]
Small Streams	Judy Creek Kayyaaq	UC2C	70.18479°	-152.12100°	2	ANAKIN VADER	70.18473° 70.18475°	152.12135° 152.12127°	54.506 55.031
	Willow 1	W1S	70.15256°	-151.82179°	1	ELORA DANAN	70.15323° 70.15323°	151.82312° 151.82316°	80.471 80.267
	Willow 2	UC1B	70.14127°	-151.95544°	1	LUKE LEIA	70.14097° 70.14126°	151.95462° 151.95486°	86.408 85.645
	Willow 3	W3S	70.11552°	-152.09244°	1	BLACK BLUE	70.11629° 70.11648°	152.09951° 152.09968°	85.366 85.286
	Willow 4	W4	70.09511°	-152.18296°	2	MAD MARTIGAN	70.09521° 70.09523°	152.18442° 152.18443°	100.000[3] 100.170[3]
		W_BS1	70.08163°	-152.13012°	2	SILVER COHO	70.08127° 70.08130°	152.12981° 152.12973°	94.625 94.307

Location Type	Stream Name	Site Name	Site Location: Latitude (WGS84)	Site Location: Longitude (WGS84)	Number of Gages	Associated Vertical Control	Vertical Control Location: Latitude (WGS84)	Vertical Control Location: Longitude (WGS84)	Vertical Control Elevation (ft NAVD88)
	Willow 4a	W_S1	70.03608°	-152.20164°	1	DOLLY VARDEN	70.03609° 70.03613°	152.20268° 152.20272°	104.662 [4] 104.852 [4]
	Willow 8	TBD_6	70.26351°	-152.18074°	1	KING CHINOOK	70.26334° 70.26333°	152.18127° 152.18117°	54.035 [4] 54.195 [4]
	Willow 8	SW22	70.27630°	-152.19270°	1	TWOFISH ONEFISH	70.27628° 70.27627°	152.19390° 152.19388°	79.971 80.123
Swales	SW1	SW1	70.13612°	-152.01333°	1	OBIWAN KENOBI	70.13573° 70.13574°	152.01193° 152.01192°	84.224 84.143
Swales	SW2	SW2	70.12888°	-152.06316°	1	ARCTICA GLAUCA	70.12869° 70.12870°	152.06450° 152.06438°	84.470 84.433
Swales	SW3	SW3	70.10583°	-152.13412°	1	COKE PEPSI	70.10557° 70.10557°	152.13543° 152.13552°	90.356 90.268
Swales	SW4	SW4	70.15596°	-152.09439°	1	BOBA FETT	70.15621° 70.15620°	152.09503° 152.09501°	58.306 58.279
Swales	SW6	SW6	70.19148°	-152.11165°	1	CP-18-13-21A CP-18-13-21B	70.19187° 70.19180°	152.11668° 152.11738°	64.030 60.350
Swales	SW14	SW14	70.12328°	-152.08699°	1	GREENEGGS ANDHAM	70.12303° 70.12313°	152.08729° 152.08727°	86.706 86.074
Swales	SW23	SW23	70.31504°	-152.19902°	1	PAPER SCISSORS	70.31493° 70.31493°	152.20025° 152.20023°	84.094 84.073
Swales	SW24	SW24	70.11166°	-152.10077°	1	DR PEPPER MR PIBB	70.11187° 70.11187°	152.10237° 152.10232°	90.165 90.137
Minesite	Tinmiaqsiugvik River	UB14.5	70.23904°	-151.29688°	5	PUMICE OBSIDIAN	70.23960° 70.24962°	151.29662° 151.29649°	21.929 21.229
Minesite	Tinmiaqsiugvik River	UB15.5	70.23373°	-151.28739°	4	LATITE ANDESITE	70.23325° 70.23323°	151.28595° 151.28585°	30.337 30.709
Minesite	MS1_1	MS1_1	70.23283°	-151.28757°	1	LATITE ANDESITE	70.23325° 70.23323°	151.28595° 151.28585°	30.337 30.709

Location Type	Stream Name	Site Name	Site Location		Number of Gages	Associated Vertical Control	Vertical Control Location		Vertical Control Elevation (ft NAVD88)
			Latitude (WGS84)	Longitude (WGS84)			Latitude (WGS84)	Longitude (WGS84)	
	Bills Creek	BC1	70.22840°	-151.26591°	1	GNEISS SCHIST	70.22859° 70.22860°	151.26833° 151.26800°	48.531 48.802
Source Lake	Lake M0015/R0056/R0056 aka Middle Snowman Lake	MSL	70.11227°	-152.07746°	1	PINK HUMPY	70.11280° 70.11279°	152.07728° 152.07744°	92.623 [2] 92.099 [2]
Source Lake	Willow 3/Lake M0015/R0056/R0056 (aka Middle Snowman Lake) outlet	MSL_Out	70.11237°	-152.07808°	1				
Source Lake	Lake R0064 (aka Lower Snowman Lake)	LSL	70.09833°	-152.06411°	1	RED SOCKEYE	70.09860° 70.09860°	152.06428° 152.06426°	94.318 93.832
Source Lake	Willow 3/Lake R0064 (aka Lower Snowman Lake) outlet	LSL_Out	70.09872°	-152.06414°	1				

Notes:
1. The current proposed Judy Creek crossing is at J21.4. The J13.8 reach is monitored to maintain the historical stage and discharge record
2. Control elevations are ft BPMSL
3. Control elevation is ft arbitrary
4. Control elevation was derived from concurrent WSE survey and pressure transducer reading

Table A.2: Gage & Spring PT Elevations

Gage Station	Gage Assembly	Gage Elevation Minimum (ft NAVD88)	Gage Elevation Maximum (ft NAVD88)	Spring PT Elevation (ft NAVD88) [2]
F55.5U	F55.5U-A F55.5U-B F55.5U-C	41.61	50.81	41.667
F55.5	F55.5-A F55.5-B F55.5-C	41.65	50.94	41.990
F55.5D	F55.5D-A F55.5D-B F55.5-C	42.47	50.49	42.540
J13.8U [1]	J13.8U-A J13.8U-B J13.8U-C	34.80	45.108	34.805
J13.8 [1]	J13.8-A J13.8-B J13.8-C	33.96	41.62	34.585
J13.8D [1]	J13.8D-A J13.8D-B J13.8D-C	32.30	40.91	32.360
J21.4	J21.4-A J21.4-B J21.4-C	46.08	56.18	46.023
KAL1 [4]	KAL1-A KAL1-B	47.77	54.23	48.403
UC2C	UC2C-A UC2C-B	46.94	53.93	48.271
W1S	W1S-A	78.20	82.42	78.812
UC1B	UC1B-B	78.00	81.72	78.048
W3S	W3S-A	89.49	93.40	89.616
W4 [3]	W4-A W4-B	86.92	92.22	87.000
W_BS1	W_BS1-A W_BS1-B	84.02	88.857	84.072
W_S1	W_S1-A	99.22	102.91	--
TBD_6	TBD_6-A	49.93	52.820	49.470
TBD_5 [3]	TBD_5-A TBD_5-B	92.83	99.45	--
SW1	SW1-A	79.33	83.61	79.614

Gage Station	Gage Assembly	Gage Elevation		Spring PT Elevation (ft NAVD88) [2]
		Minimum (ft NAVD88)	Maximum (ft NAVD88)	
SW2	SW2-A	81.29	84.98	80.580
SW3	SW3-A	87.13	90.71	--
SW4	SW4-A	55.52	59.30	55.706
SW6	SW6-A	60.97	64.71	--
SW14	SW14-A	83.35	87.08	--
SW22	SW22-A	78.23	82.51	--
SW23	SW23-A	79.50	83.40	--
SW24	SW24-A	84.83	88.67	84.997
UB14.5	UB14.5-A UB14.5-B UB14.5-C UB14.5-D UB14.5-E	9.39	20.36	9.524
UB15.5	UB15.5-A UB15.5-B UB15.5-C	11.16	25.17	11.857
MS1_1	MS1_1-A	26.25	30.04	26.320
BC1	BC1-A	36.34	39.98	36.936
MSL [1]	MSL-A	88.84	92.32	89.198
MSL_OUT [1]	MSL_OUT-A	88.59	92.37	89.090
LSL	LSL-A	91.00	95.02	91.352
LSL_OUT	LSL_OUT-A	90.89	93.85	91.232

Notes:
1. J13.8U, J13.8, J13.8D, MSL, and MSL_OUT elevations are-ft BPMSL
2. A dash "--" indicates spring PT was not installed
3. Gage and PT elevations are ft arbitrary
4. Gage and PT elevations were derived from concurrent WSE survey and pressure transducer reading

Appendix B Measured & Calculated Discharge Methods

B.1 MEASURED DISCHARGE METHODS

Standard USGS Midsection Techniques

Standard USGS midsection techniques (USGS 1982) were used to measure flow depth and velocity. Flow depth and velocity were measured using a HACH FH950 electromagnetic velocity meter attached to a wading rod. The accuracy of the meter is ± 2% of the reading, ± 0.05 ft/s between 0 ft/s and 10 ft/s, and ± 4% of the reading from between 10 ft/s and 16 ft/s. Discharge was calculated based on velocity, flow depth, and cross-section geometry.

ADCP Techniques

A RiverRay ADCP was used to measure discharge using the methods outlined in the USGS *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (USGS 2005) and USGS *Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat* (USGS 2013).

A. Hardware & Software

The RiverRay ADCP has a phased array, Janus four-beam transducer with a 20-degree beam angle. The ADCP was interfaced with a supporting laptop using a wireless Bluetooth connection. The ADCP was self-powered via internal batteries.

WinRiverII® v2.13 was used to perform pre-deployment tests, configure, initiate, and communicate with the ADCP while on the river. WinRiverII® was also used to review and evaluate collected discharge data.

B. Pre-Deployment Testing

Prior to deployment of the ADCP unit, a full suite of diagnostic tests were ran in accordance with the manufacturer's instructions. The tests confirmed the signal path and all major signal processing subsystems were functioning properly. Tests also confirmed accurate tilt and pitch readings. A beam continuity test was performed to verify the transducer beams were connected and operational. Pre-deployment tasks also included compass calibration and verification. Internal compass error was within the specified 5-degree limit.

C. Deployment & Data Collection

The RiverRay ADCP was housed in trimaran and tethered to a marked (1ft increments) Kevlar tag line across the channel. A minimum of four transects were completed the measured discharges varied by less than five percent of the mean. Cross-section end points were dependent on the retention of two vertical bins for accurate discharge extrapolation in the unmeasured edges. The position of the trimaran in the channel was determined using the bottom track function of the ADCP. Distances to the right and left edge of water from respective end points were measured using the tag line.

D. Background & Data Processing

An ADCP measures the velocity of particles in the water. Particles, on average, move at the same horizontal velocity of the water relative to the ADCP unit. The velocity of flow is then calculated relative to the earth, based on the simultaneous velocity and position of the trimaran. The velocity and position of the trimaran were recorded by tracking the bottom of the channel with the ADCP unit.

When using bottom tracking as a reference, a moving bed will tend to affect the accuracy of the results by biasing the velocity and discharge lower than actual values. This phenomenon can be eliminated with the use of either a differential global positioning system (DGPS) or accounted for by using a moving bed test. The loop method and stationary moving bed tests are techniques to determine whether a moving bed is present and, if present, to provide an approximate correction to the final discharge value. The USGS established guidance for the loop method by outlining procedures for mean correction and distributed correction (USGS 2006). Both procedures yield results within 2% of the actual discharge, as measured using a DGPS. The stationary moving bed test measures the moving bed velocity at discrete points and applies a proportional correction across the cross-section based on the near bed velocity.

B.2 CALCULATED DISCHARGE METHODS

The Normal Depth method (Chow 1959) was used to calculate discharge using channel cross-section geometry and stage differential between gage stations as an estimate for the energy grade line. Stage and energy grade line data were obtained from observations, gage data, and PT data.

Appendix C Site Specific Discharge Data, Plans, & Profiles

C.1 FISH CREEK AT F55.5

Spring Breakup Measured Discharge

Location: F55.5

Date & Time: June 2, 2020 2:45 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 1,700

Average Velocity (fps): 1.9

Measurement Rating: Good

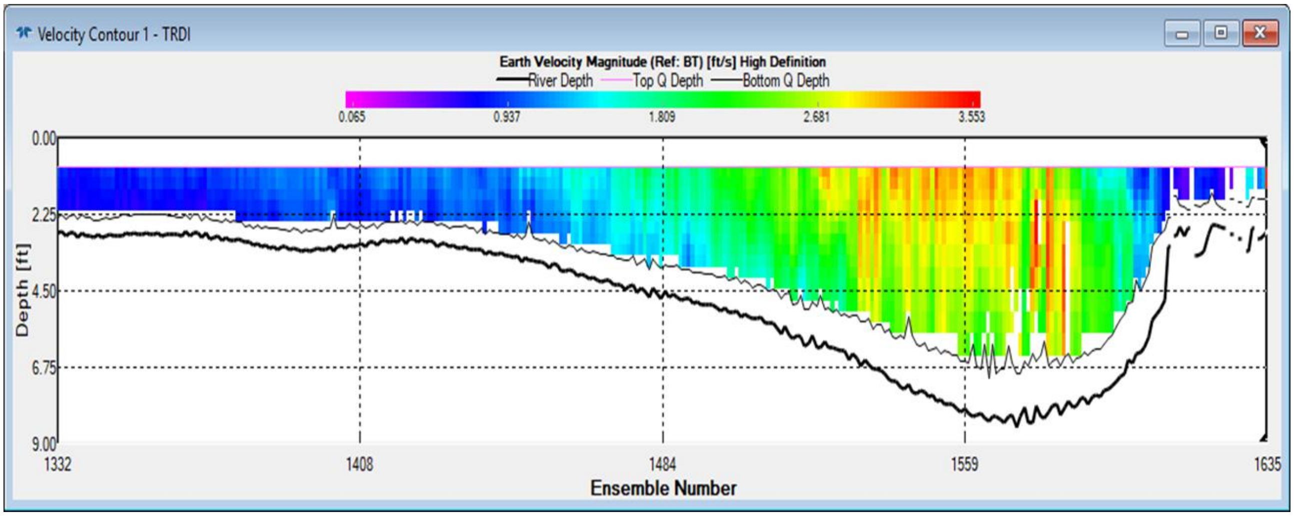
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from the loop test performed before measuring the five transects. Moving bed velocity estimated using the stationary moving bed test was 0.04 fps. The percentage of bad bottom track values (3.21%) was within the recommended maximum of 5%.

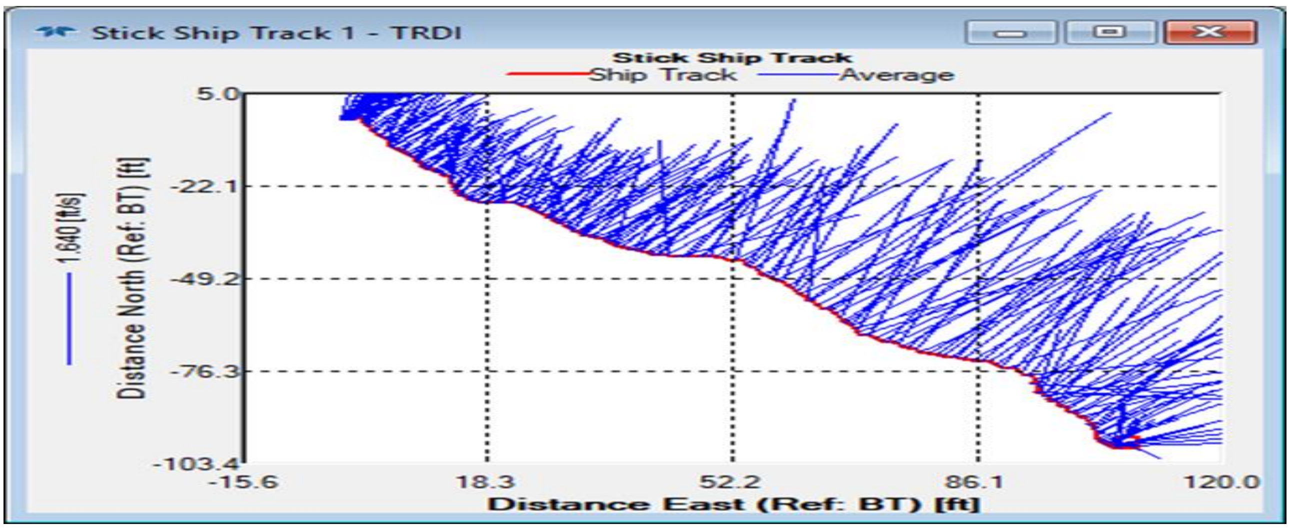
At the time of the measurement, open-channel conditions were present with periodic ice floes and minimal snow along the banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall quality of the discharge measurement is good considered based on conditions at the time of the measurement.

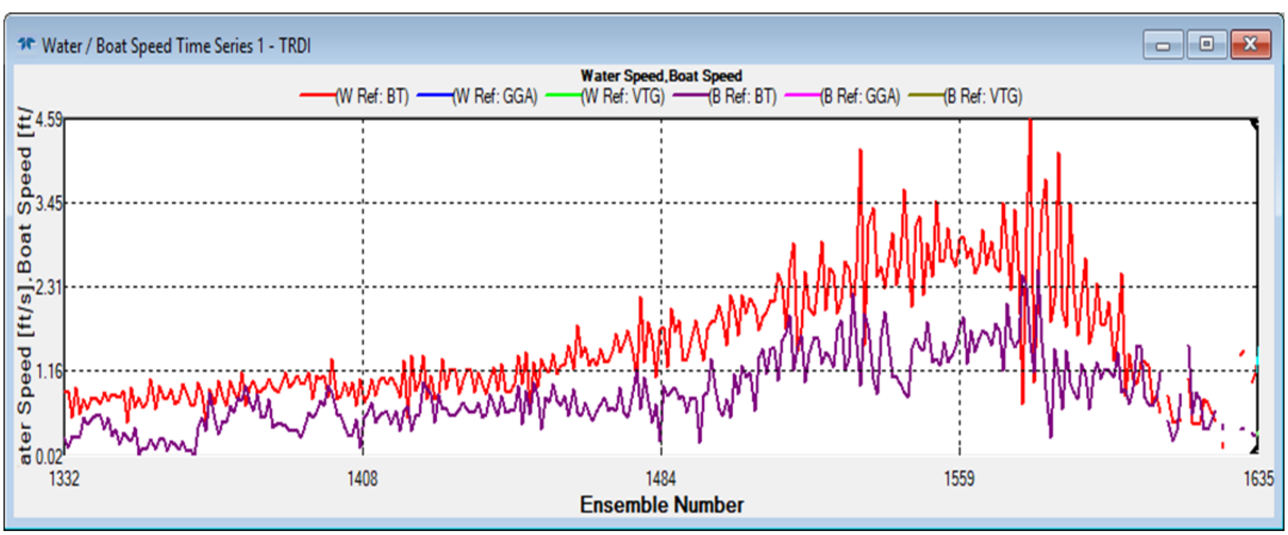
Table C.1: F55.5 June 2 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
F55.5C000	Left	1732	1.66%	1133	4.26	169	1001	852	2.03	1.73
F55.5C001	Right	1737	1.95%	1083	-0.35%	178	1004	925	1.88	1.73
F55.5C002	Left	1650	-3.15%	1052	-3.20%	164	897	833	1.98	1.84
F55.5C003	Right	1696	-0.45%	1079	-0.71%	175	980	903	1.88	1.73
Average		**1704**		**1087**		**172**		**878**	**1.94**	**1.76**

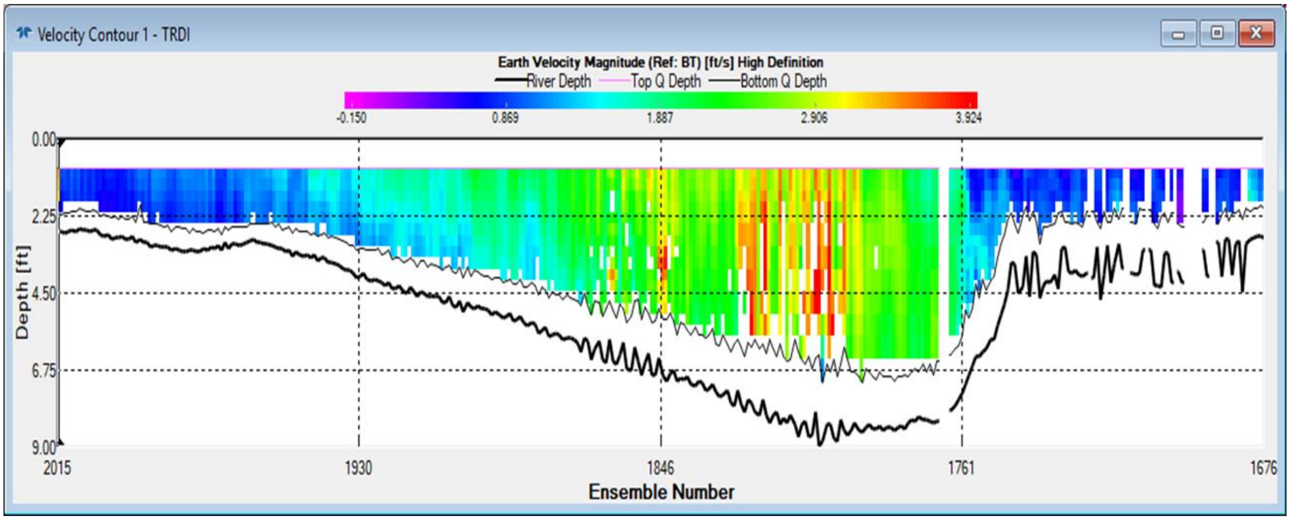
A. Transect F55.5-00 Raw Data Output

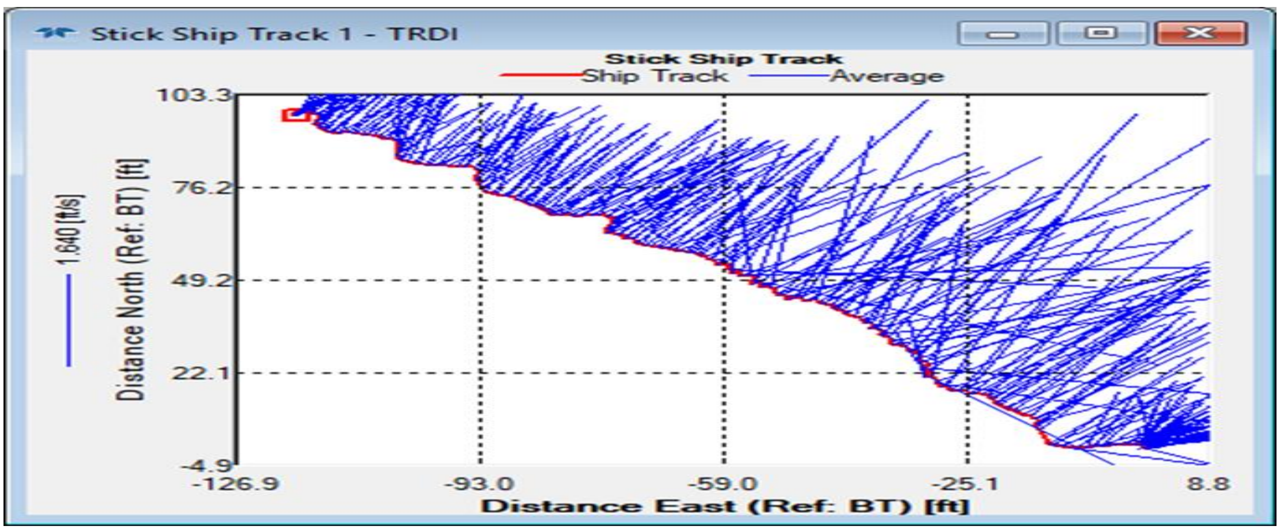


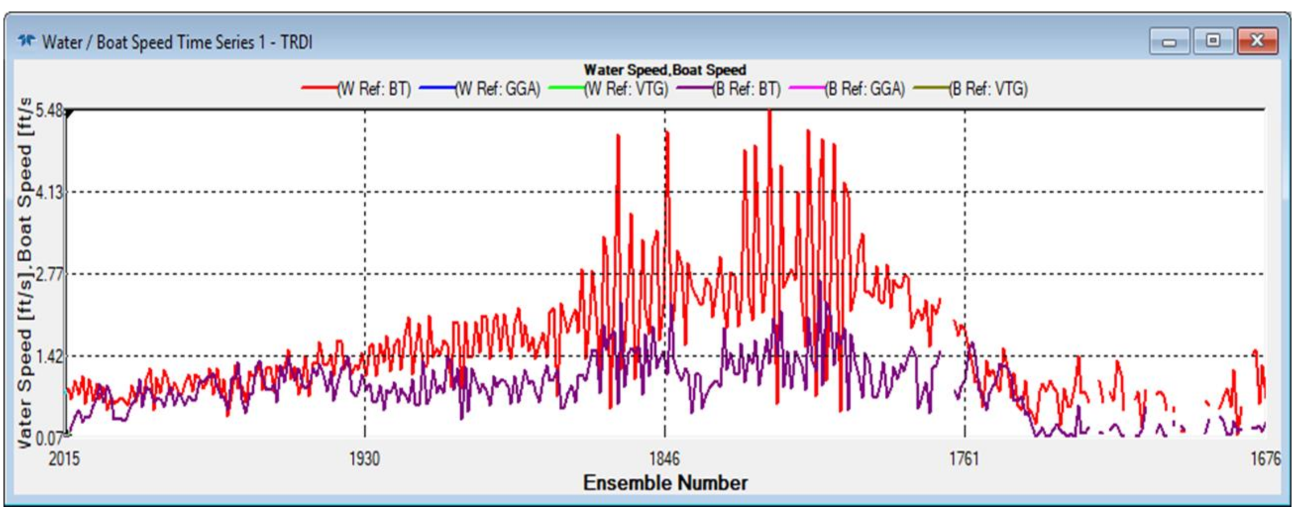




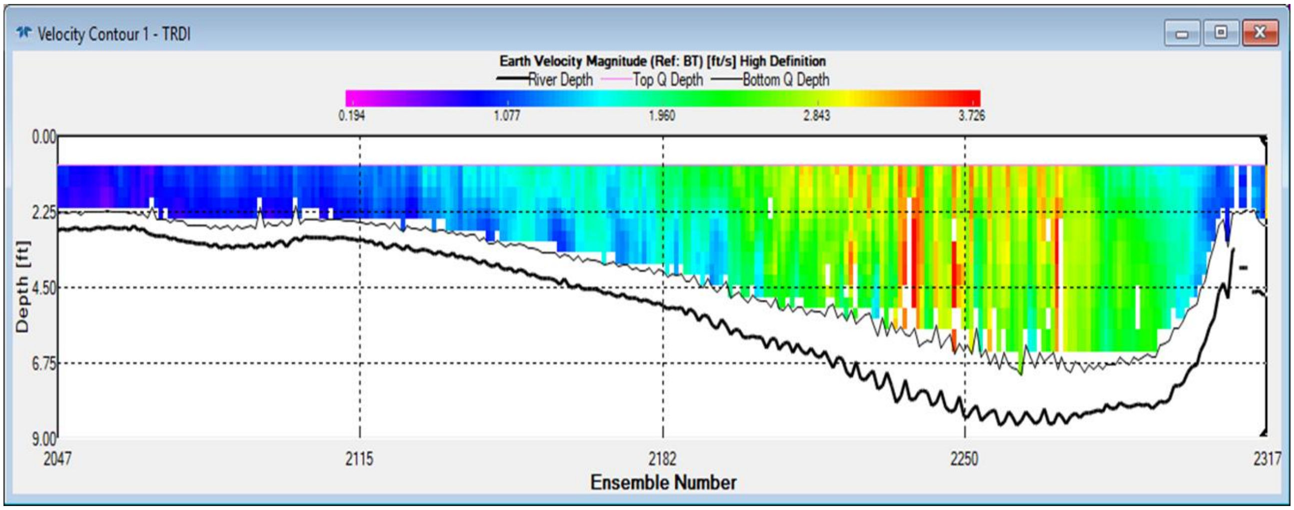
B. Transect F55.5-01 Raw Data Output

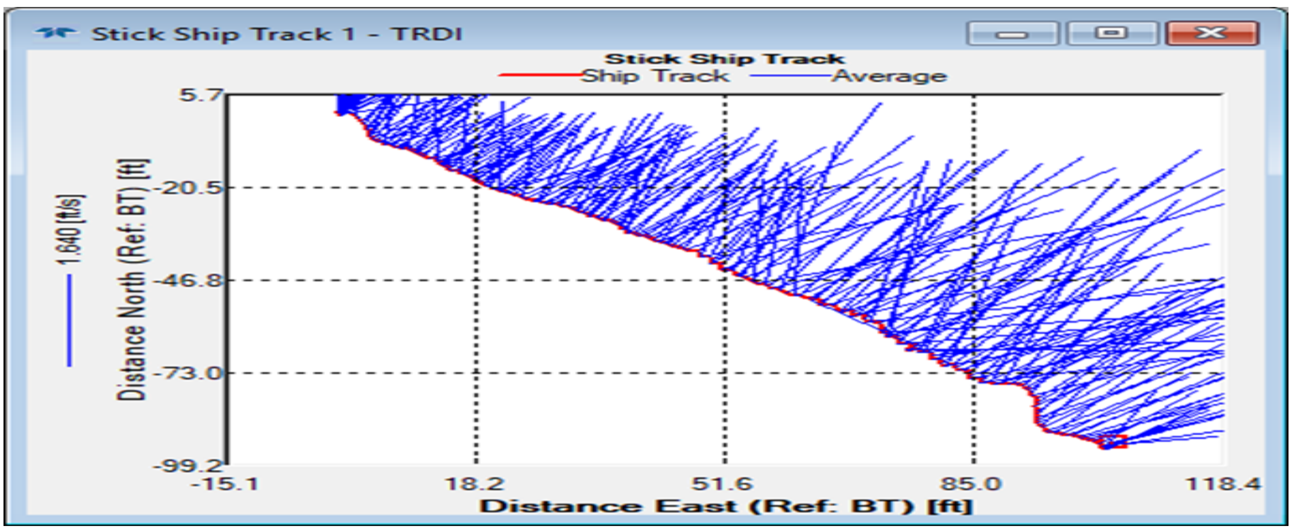


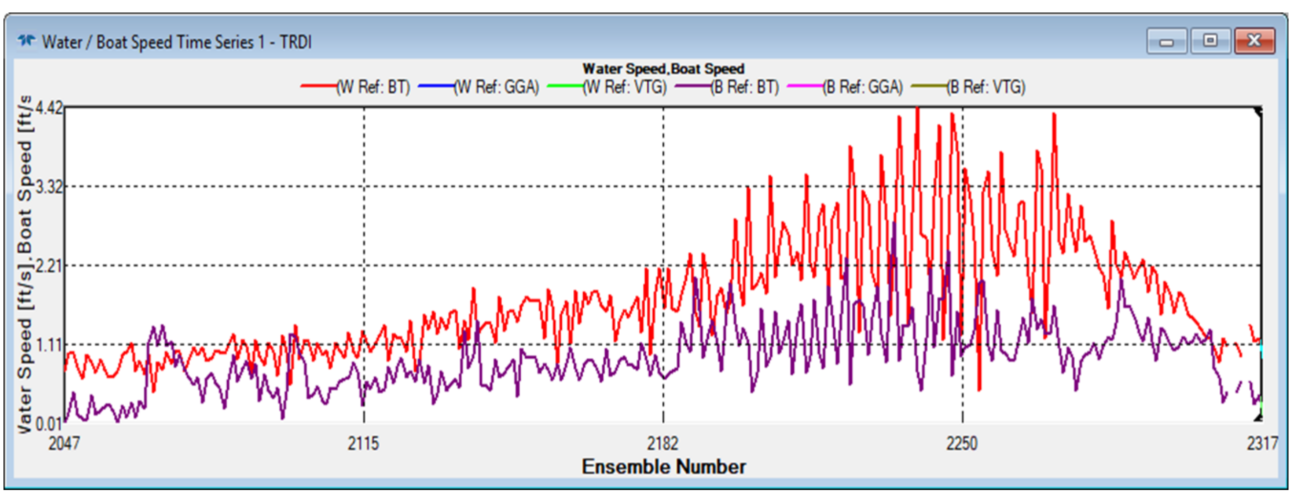




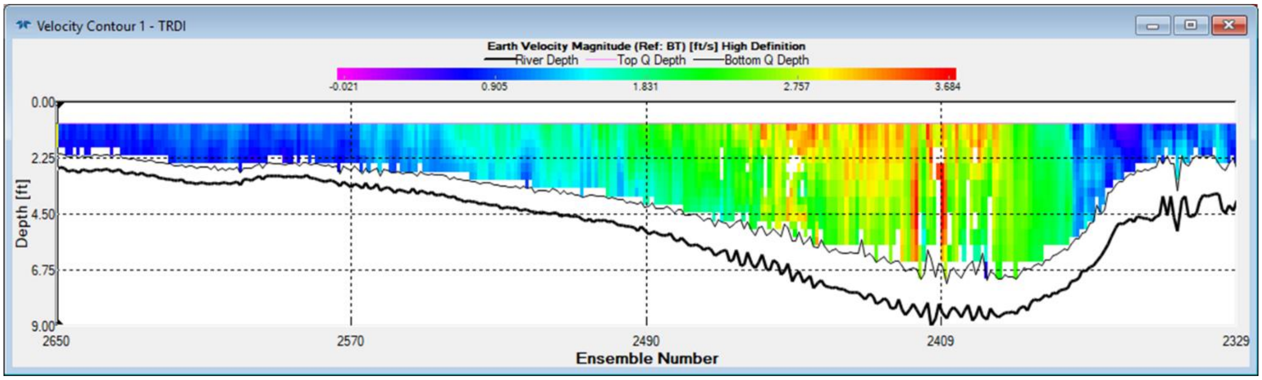
C. Transect F55.5-02 Raw Data Output

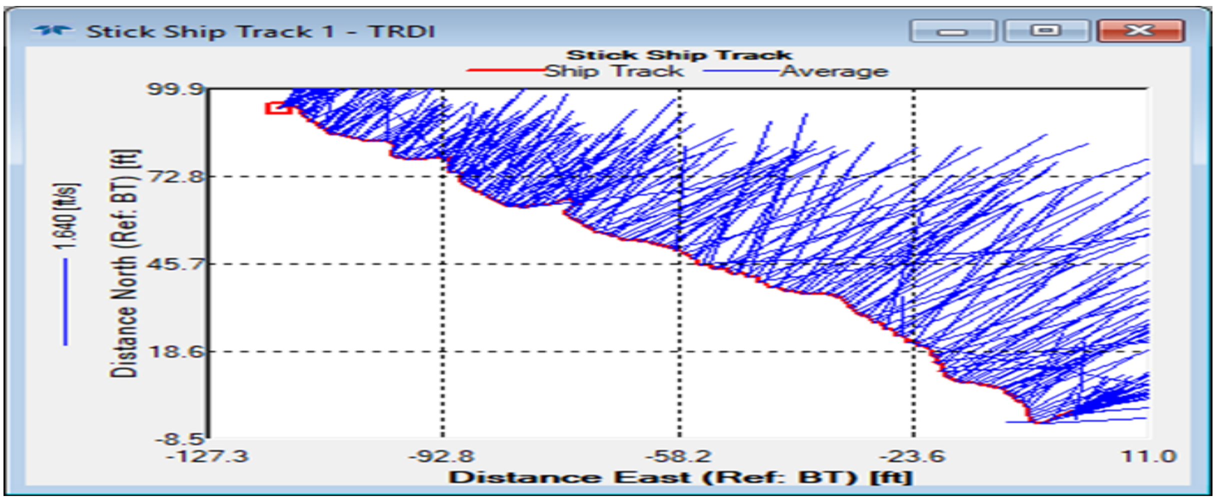


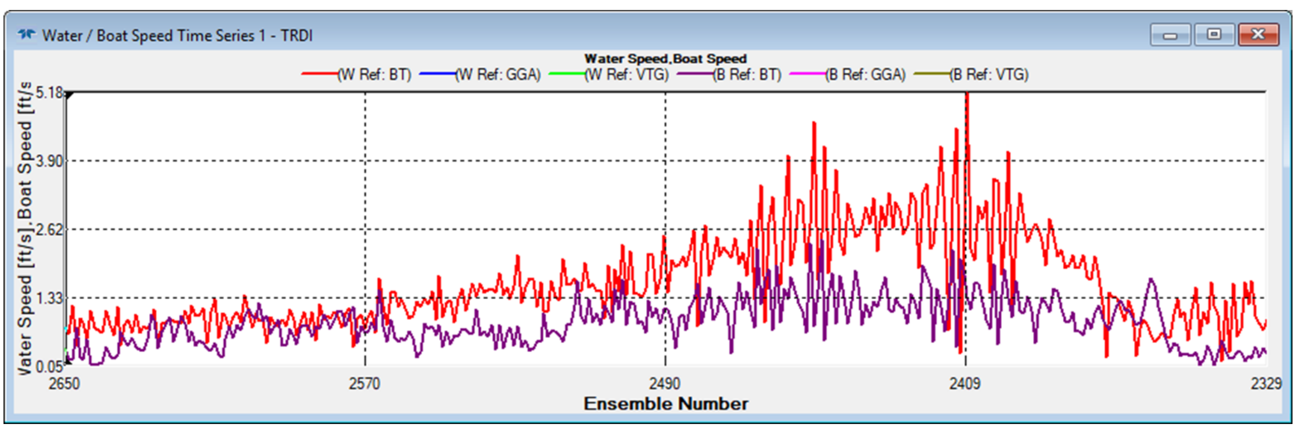




D. Transect F55.5-03 Raw Data Output







Spring Breakup Calculated Discharge

Discharge was calculated indirectly using the Normal Depth method. The cross-section was developed from the average of four cross-sections extracted from the F55.5 June 1, 2020 ADCP direct discharge measurement. The energy grade line was approximated by the average water surface slope between F55.5U and F55.5D. Manning's n values were selected from reference documents (URS 2001) and calibrated to the measured discharge values in 2017. The 2020 calculated discharge values were compared to the direct discharge for 2020 to verify Manning's n values from 2017 are still valid. The calibrated Manning's n values used in the calculations were 0.023 for the left overbank, 0.020 for the main channel, and 0.023 for the right overbank.

ConocoPhillips Alaska

Feet
0 600 1,200

Date:	12/10/2020	Scale:	1 Inch = 600 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C1_FishCreek.mxd

Gage Location
Flow Direction
Station
Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

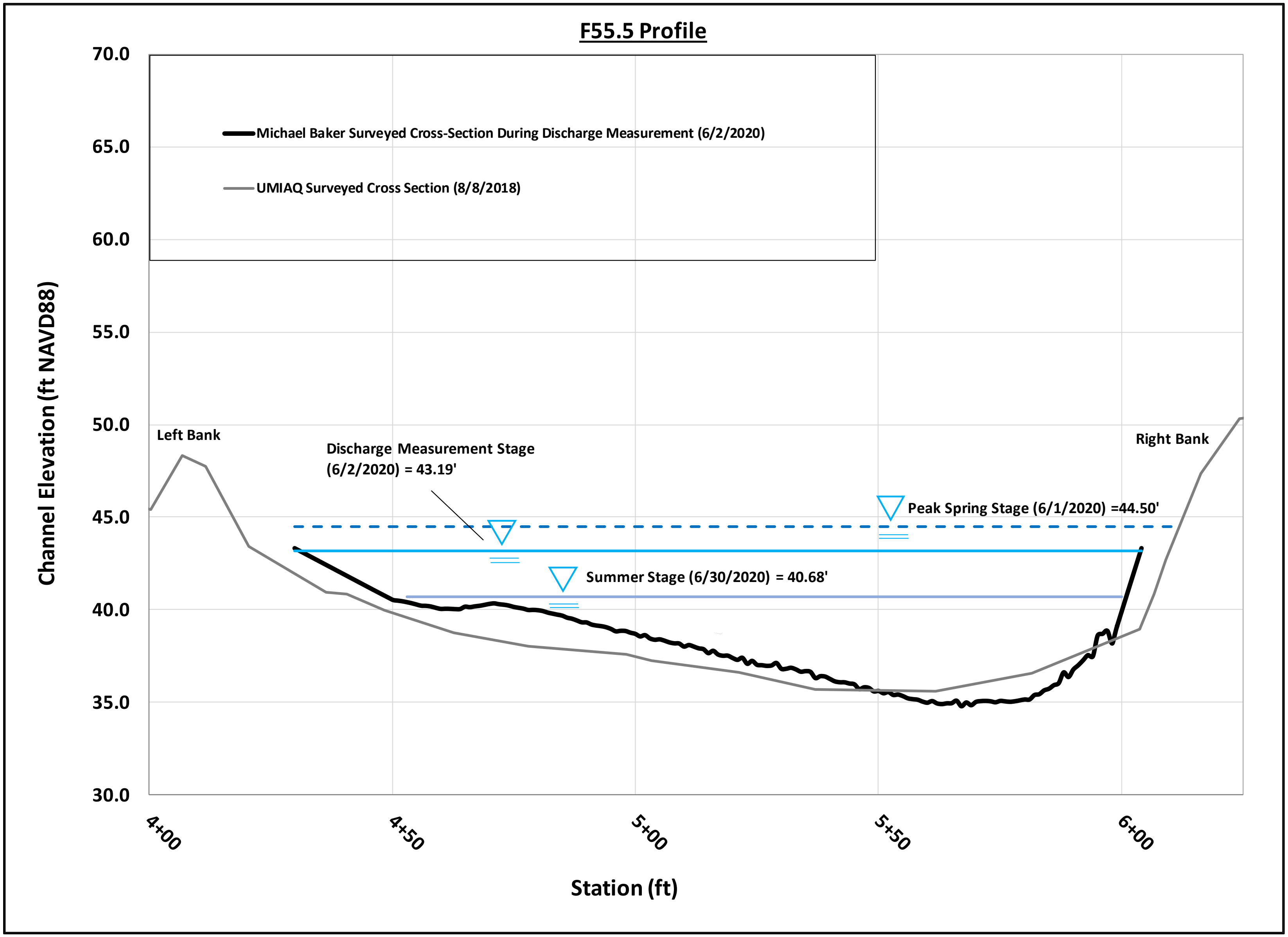
Michael Baker INTERNATIONAL

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

2020 Spring Breakup Fish Creek at F55.5 Plan

FIGURE C.1

Spring Breakup Cross-Section Profile



C.2 JUDY CREEK AT J13.8

Spring Breakup Measured Discharge

Location: J13.8

Date & Time: June 1, 2020 12:00 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 2,200

Average Velocity (fps): 2.29

Measurement Rating: Poor

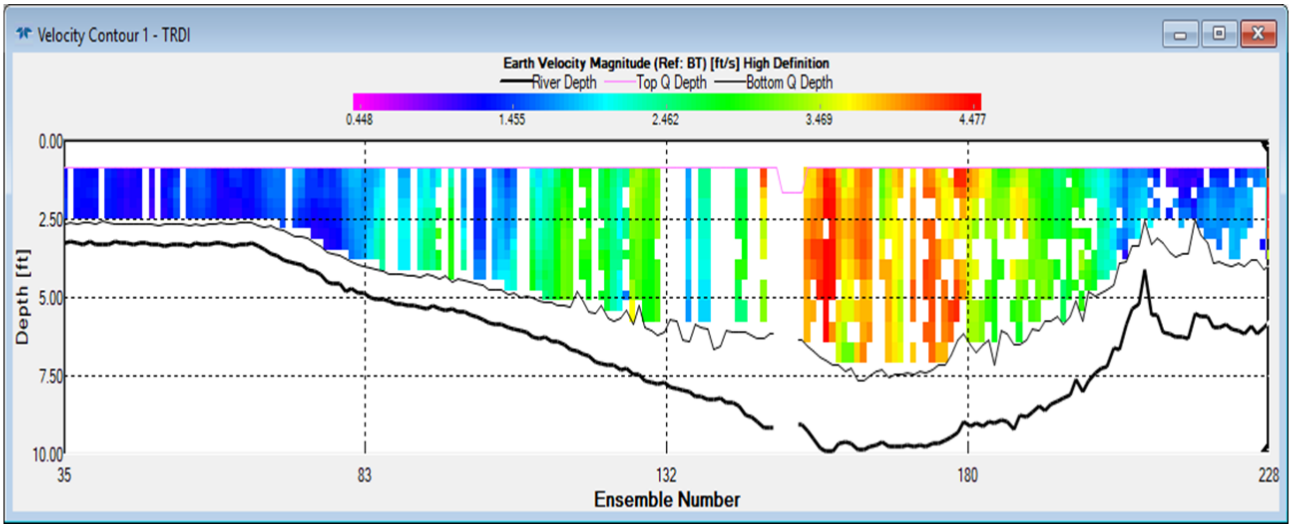
Measurement Notes: Moving bed conditions were identified, but discharge was not corrected for the moving bed using data acquired from the loop test because the percent bad bottom track (17%) exceeded the recommended threshold (5%).

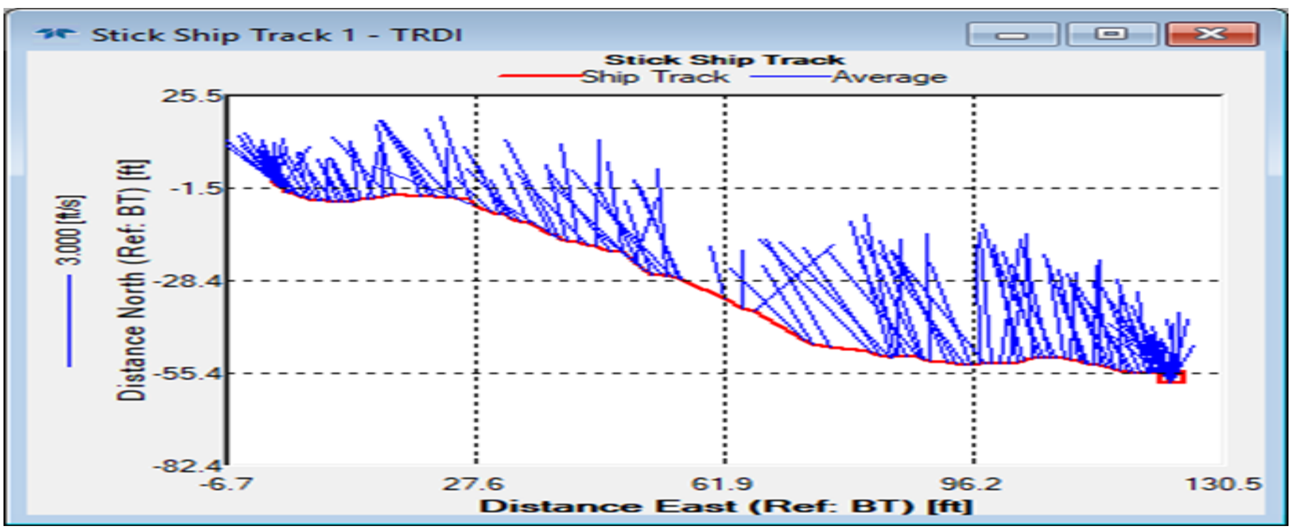
During the measurement, minimal ice floes were observed in the channel and no saturated snow was visible along the banks at the measurement cross section. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered poor based on the highly mobile bed detected at the time of measurements, the Bluetooth malfunction, and the moving bed having not been applied to the measurement.

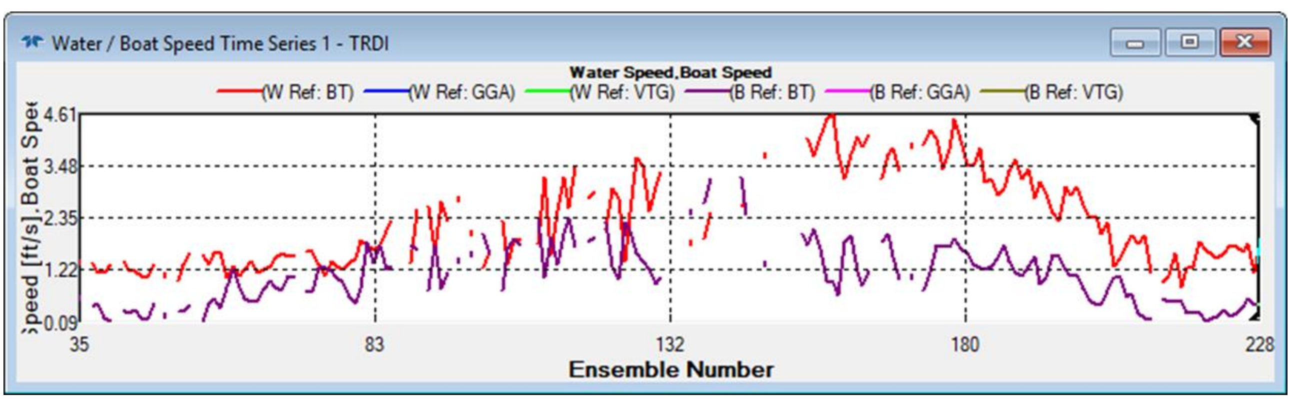
Table C.2: J13.8 June 1 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
000	Left	2134	-0.25%	1279	0.47%	165	885	1052	2.03	2.41
003	Left	2189	2.33%	1304	2.44%	159	842	1035	2.12	2.60
004	Right	2137	-0.11%	1254	-1.49%	154	838	911	2.35	2.55
006	Right	2097	-1.97%	1255	-1.41%	133	822	791	2.65	2.55
Average		**2139**		**1273**		**153**		**947**	**2.29**	**2.53**

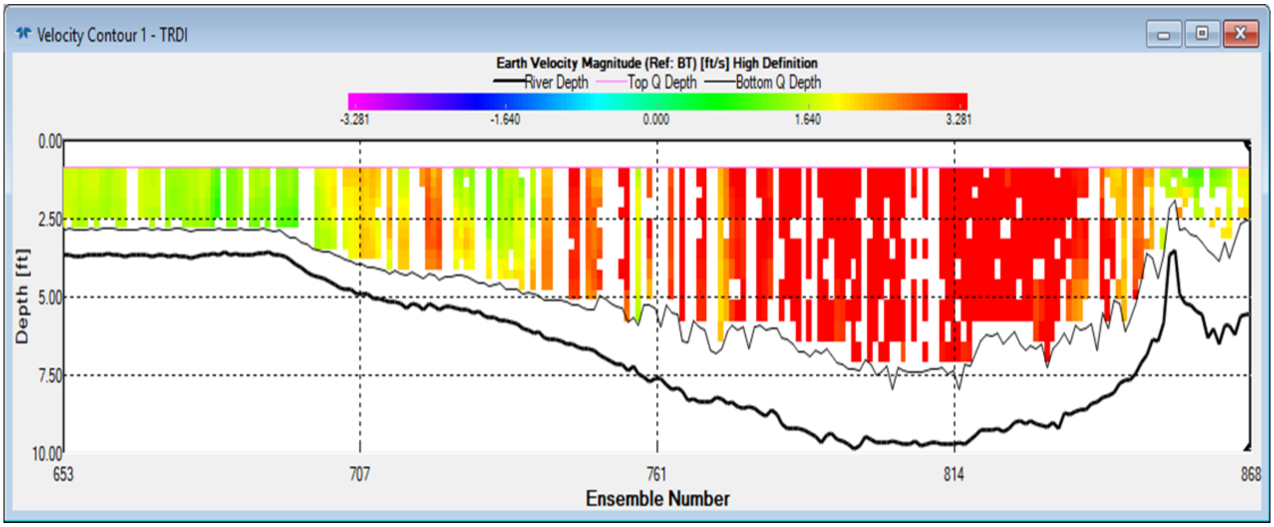
A. Transect J13.8-000 Raw Data Output

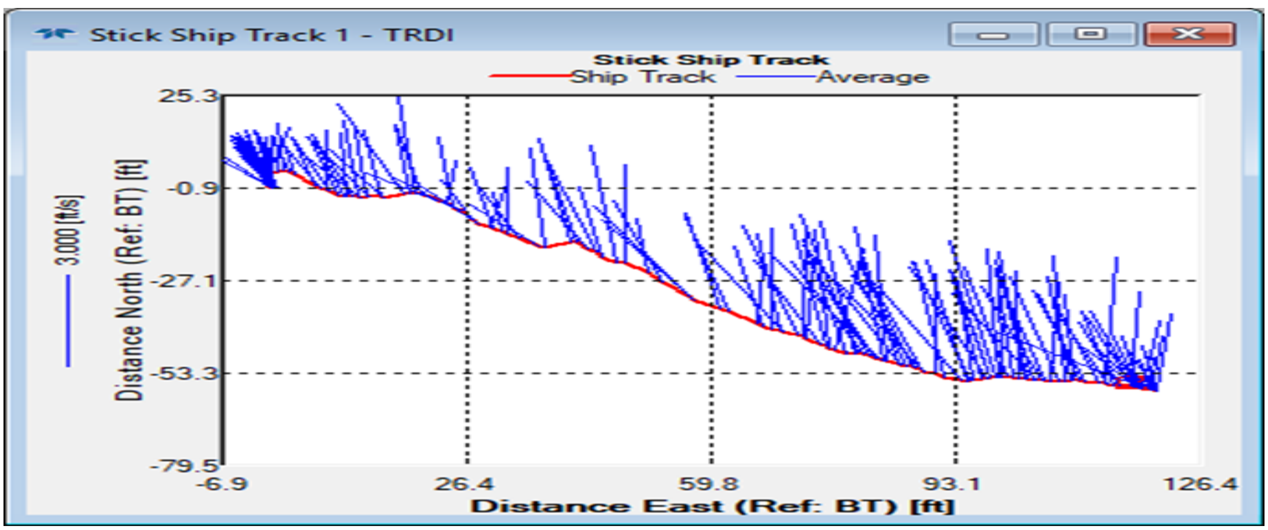


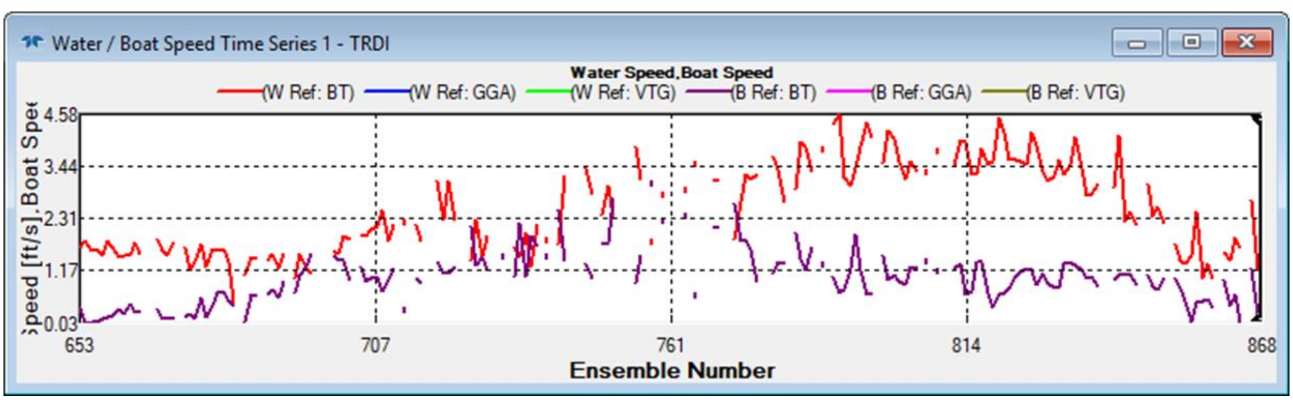




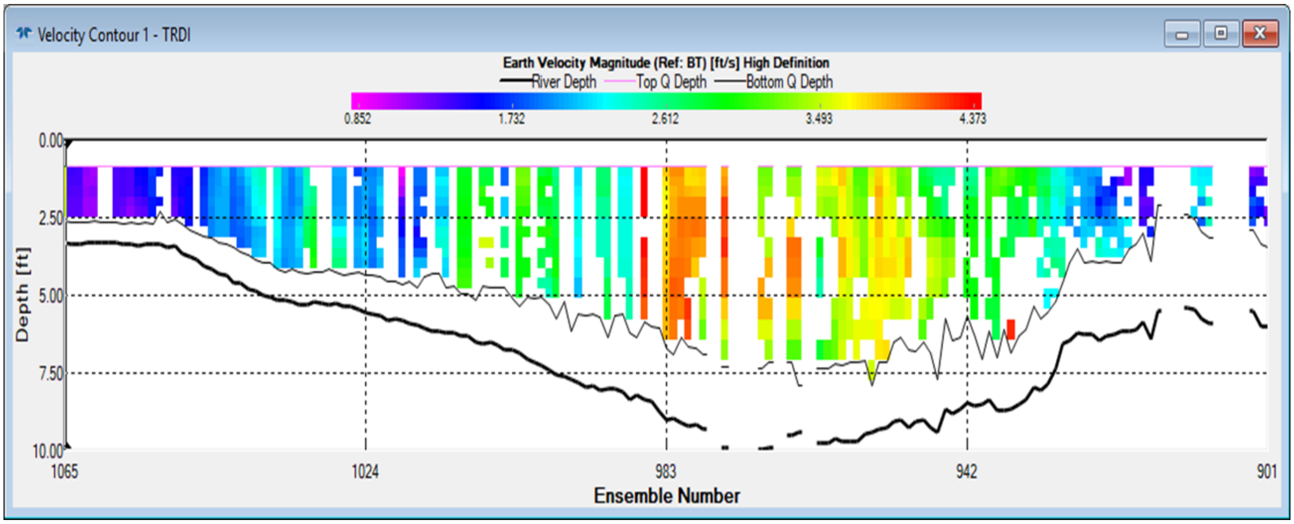
B. Transect J13.8-003 Raw Data Output

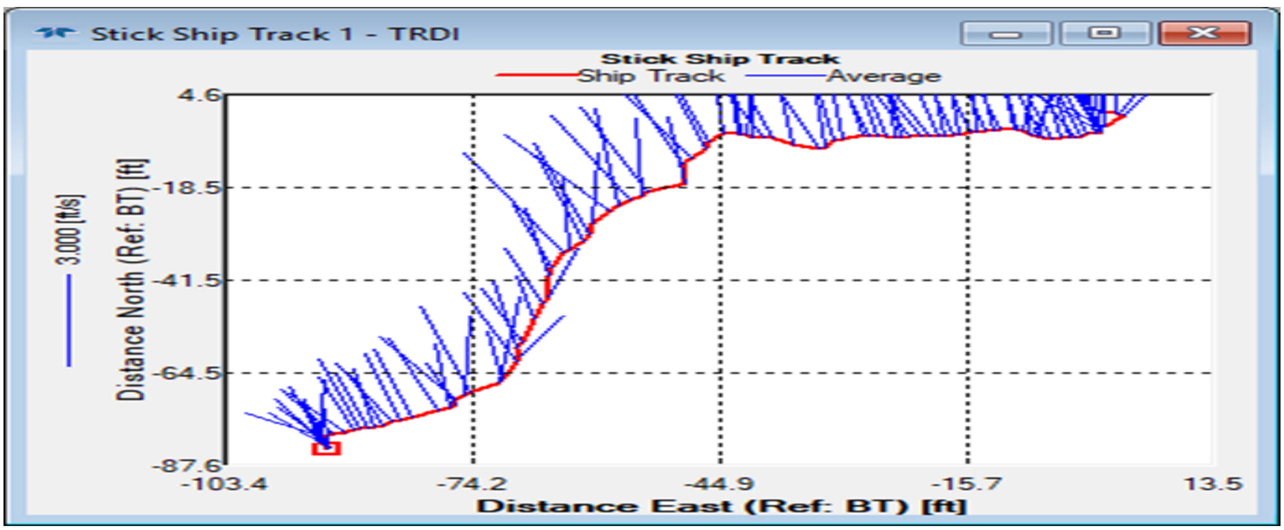


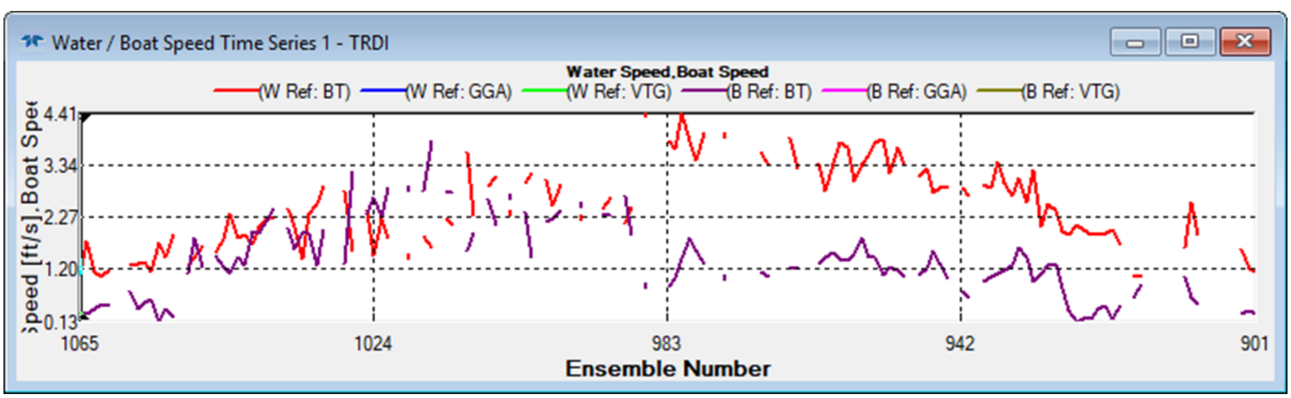




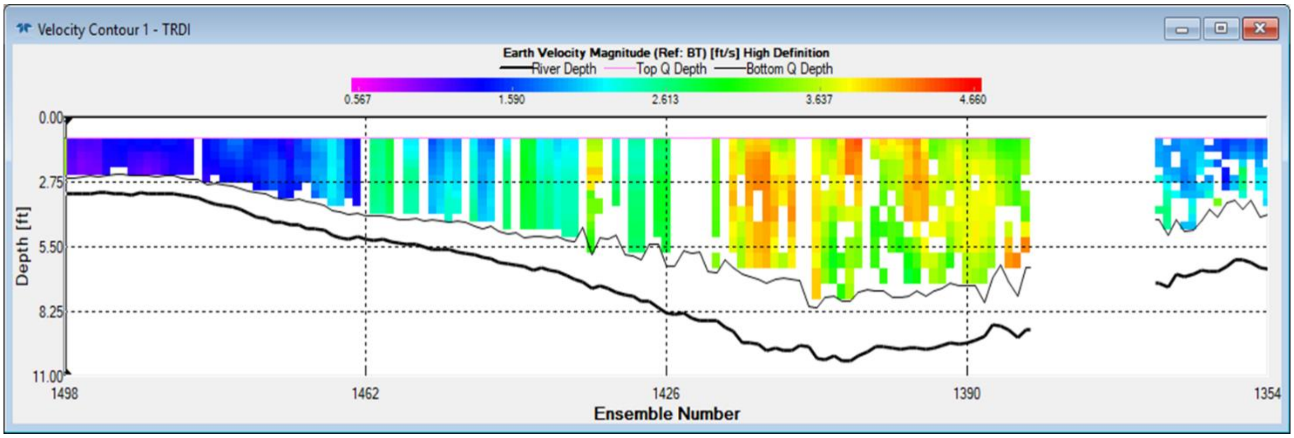
C. Transect J13.8-004 Raw Data Output

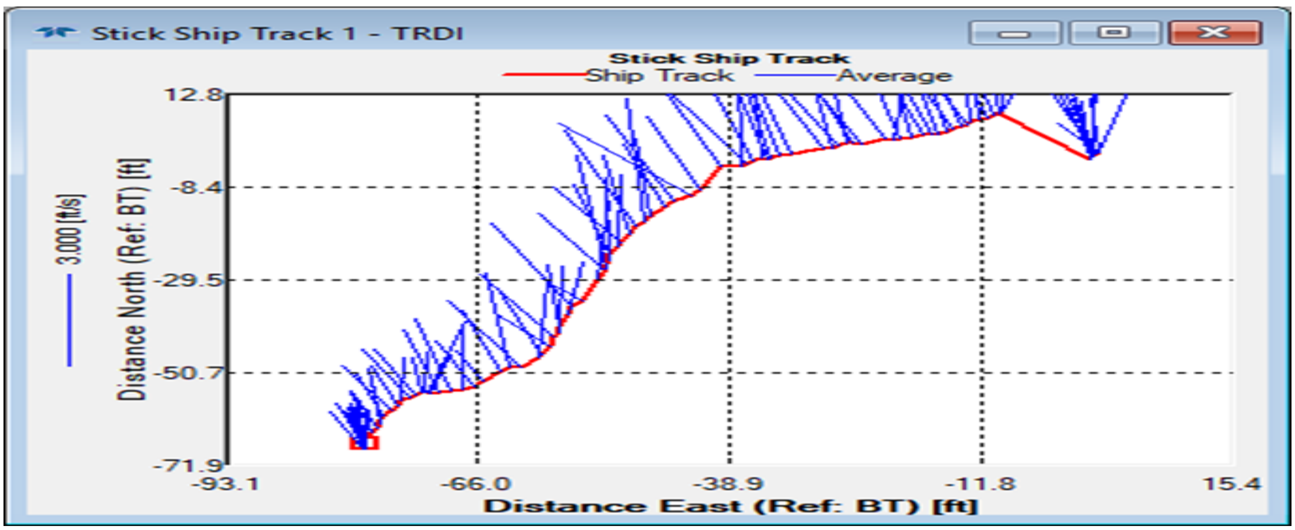


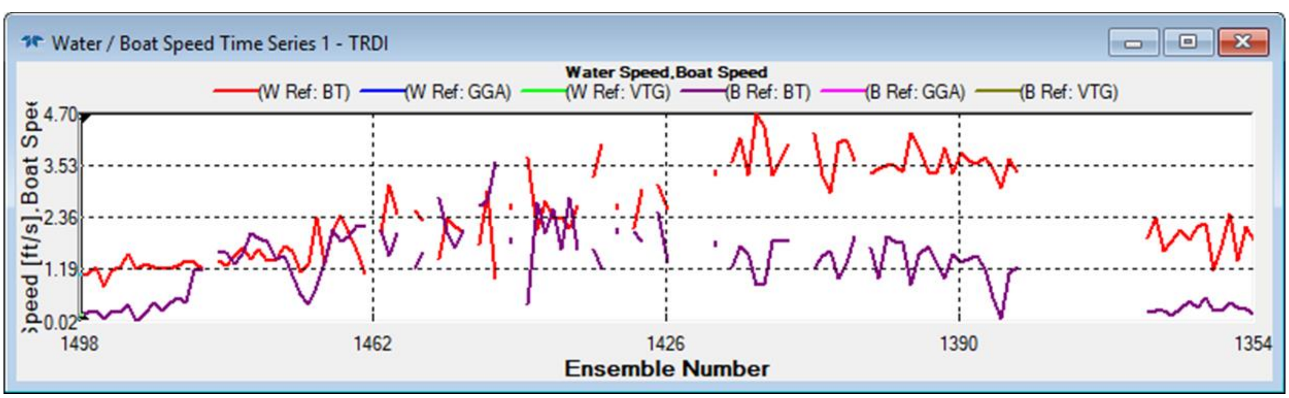




D. Transect J13.8-006 Raw Data Output







Spring Breakup Calculated Discharge

Discharge was calculated indirectly using the Normal Depth method. The cross-section was developed from the average of four cross-sections extracted from the J13.8 June 1, 2020 ADCP direct discharge measurement. The energy grade line was approximated by the average water surface slope between J13.8D, J13.8C and J13.8U. Stage at J13.8 was collected using PTs at the three gage locations (upstream, center, and down). The calibrated Manning's n values used in the calculations were 0.04 for the left overbank, 0.033 for the main channel, and 0.04 for the right overbank.

ConocoPhillips Alaska

Feet
0 600 1,200

Date:	12/10/2020	Project:	1 Inch = 600 Feet
Drawn:	JEG	File:	178179
Checked:	KDB	Scale:	C2_J13.8.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

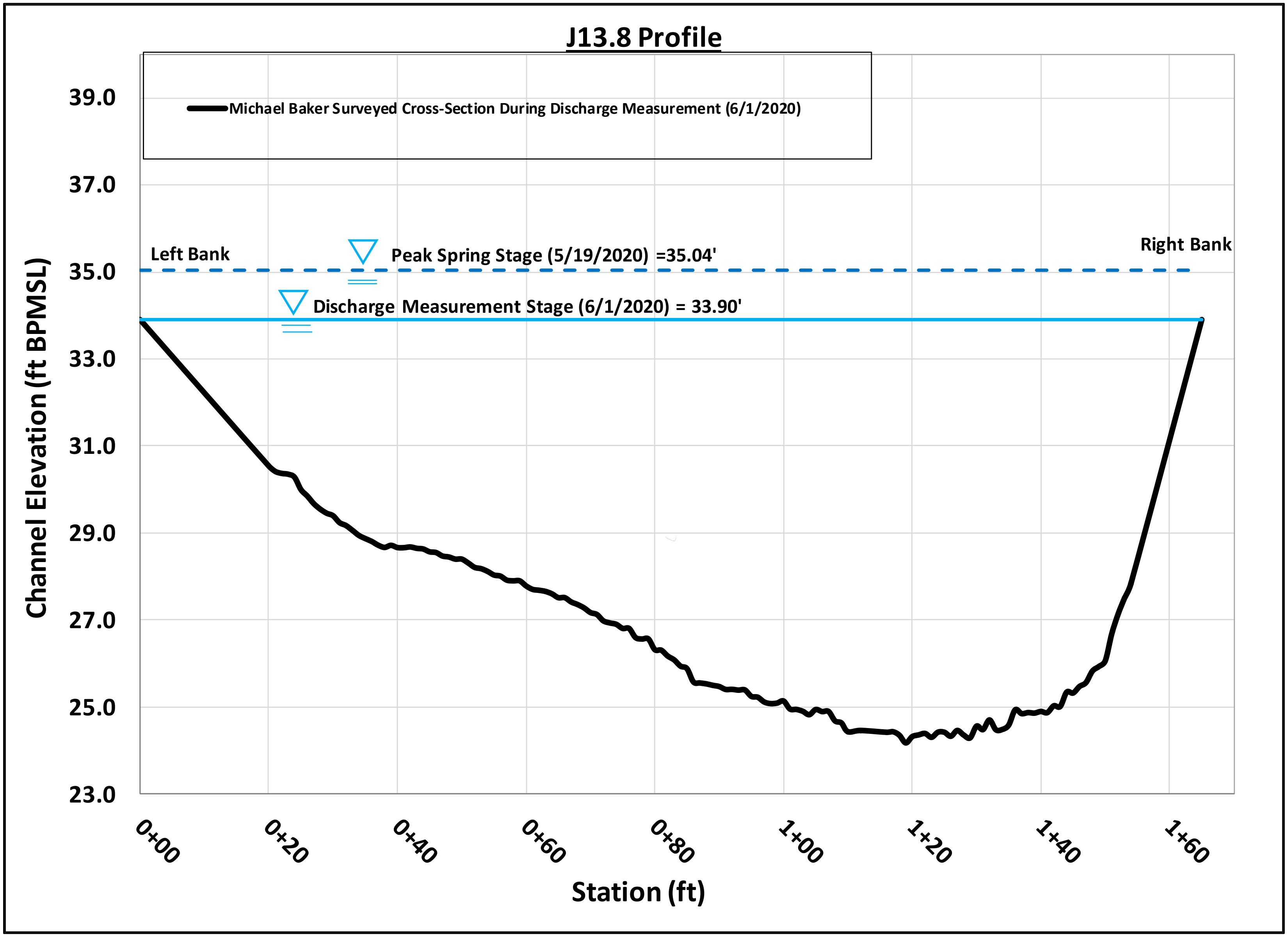
Michael Baker INTERNATIONAL

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

2020 Spring Breakup Judy Creek at J13.8 Plan

FIGURE C.2

Spring Breakup Cross-Section Profile



C.3 TBD_6

Spring Breakup Measured Discharge

Location: TBD_6

Date & Time: June 3, 2020 1:00 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 40

Average Velocity (fps): 0.85

Measurement Rating: Fair

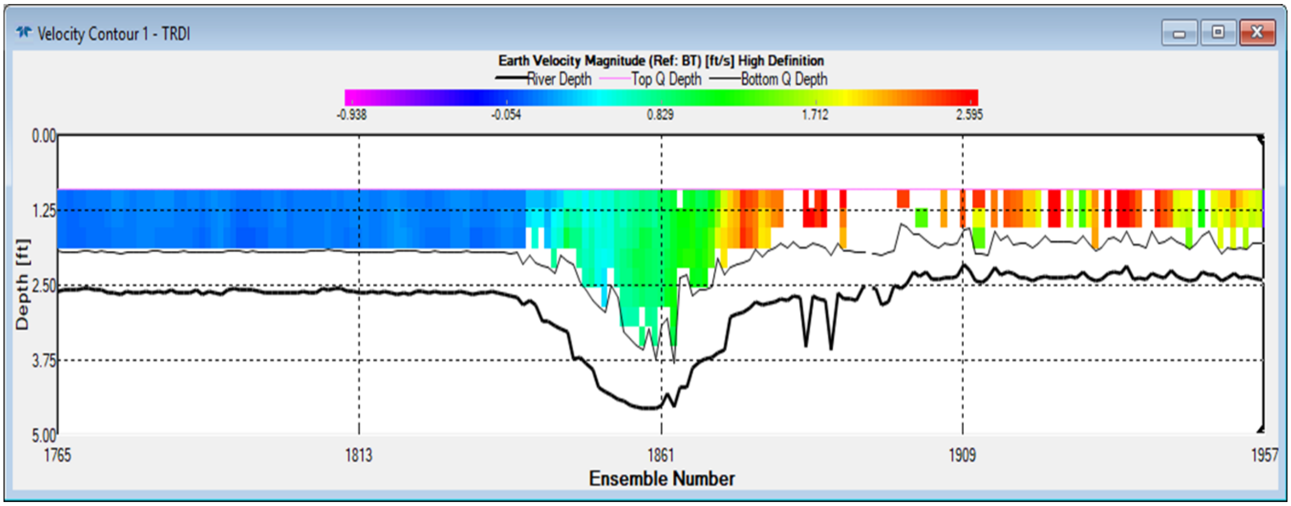
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.00%) was within the recommended maximum of 5%.

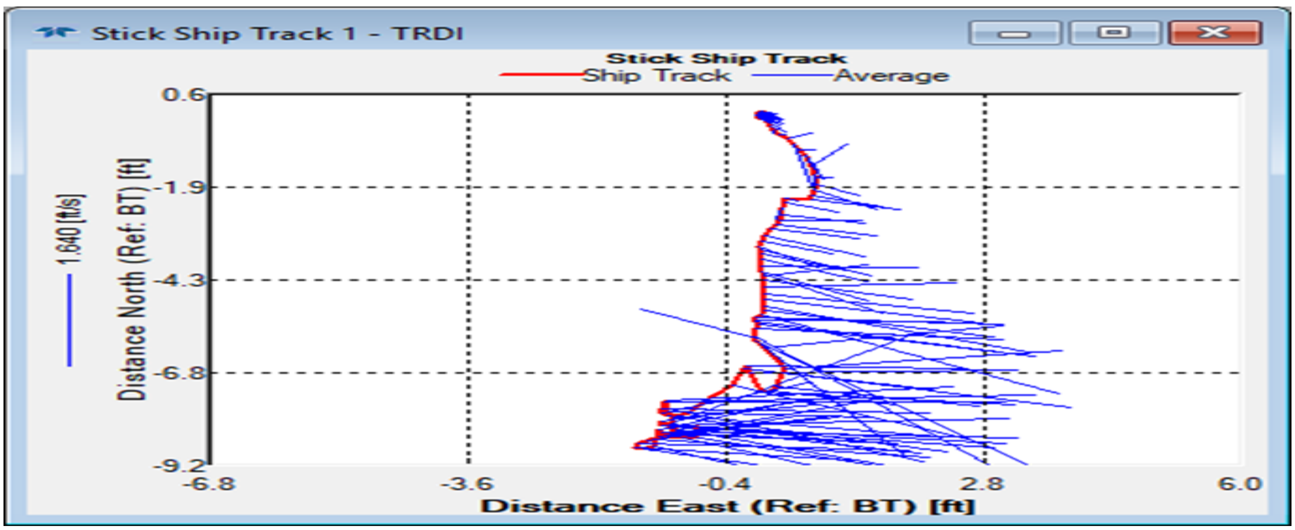
During the measurement, snow and ice were present in the channel but clear from the banks, and stage was near bankfull. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered poor based on the conditions at the time of the discharge measurement.

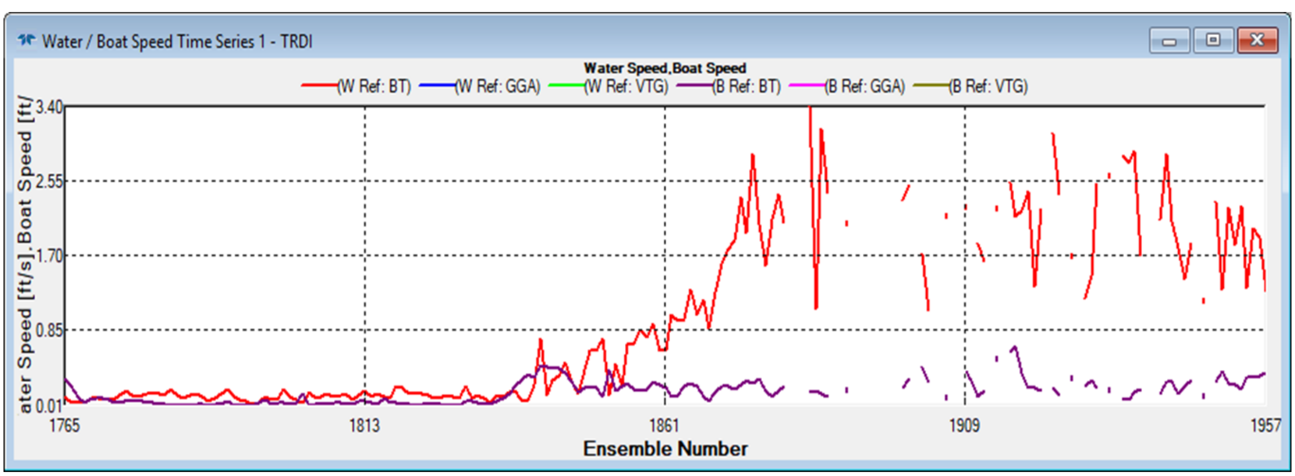
Table C.3: TBD_6 May 30 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
000	Left	43	1.78%	10	-9.09%	24	58	47	0.91	0.74
009	Right	41	-2.93%	11	0.00%	25	39	50	0.82	1.04
011	Right	43	1.78%	12	9.09%	26	40	50	0.85	1.07
013	Right	42	-0.59%	11	0.00%	26	44	51	0.82	0.96
Average		**42**		**11**		**25**		**50**	**0.85**	**0.95**

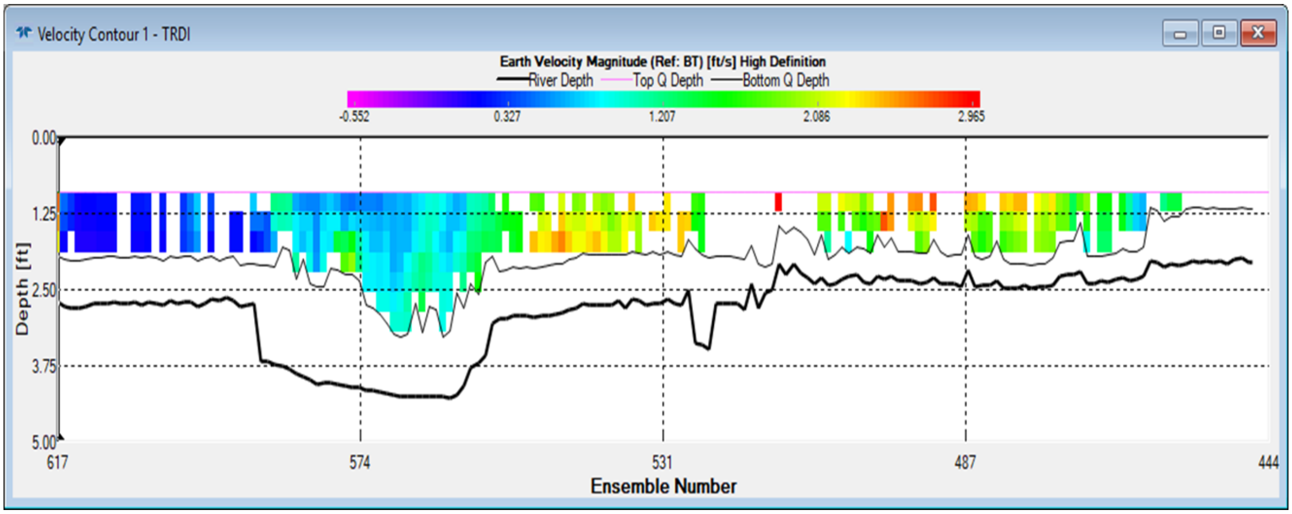
A. Transect TBD6-000 Raw Data Output

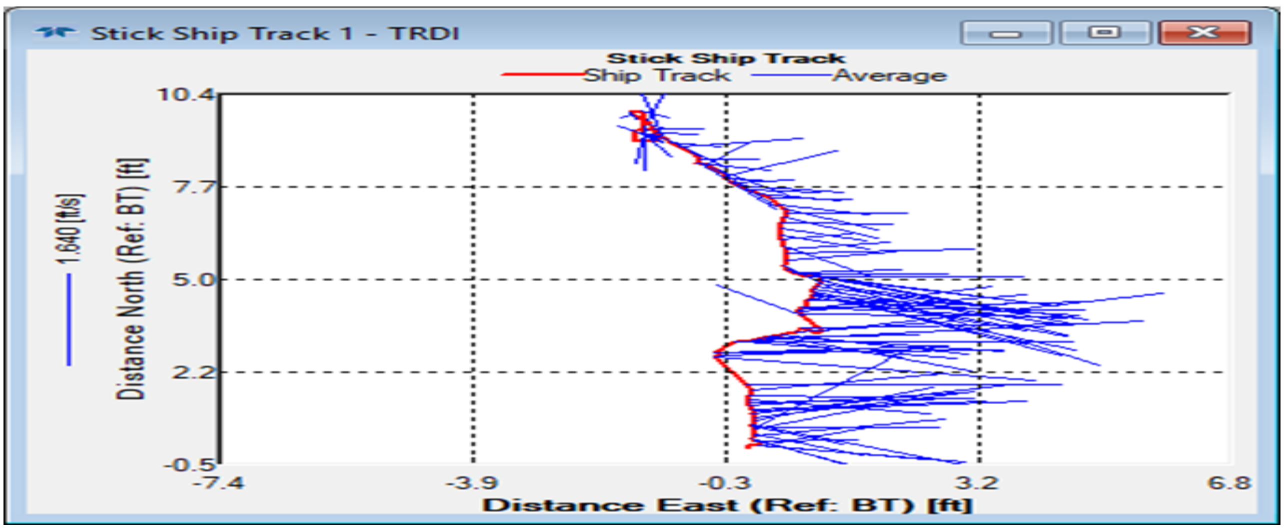


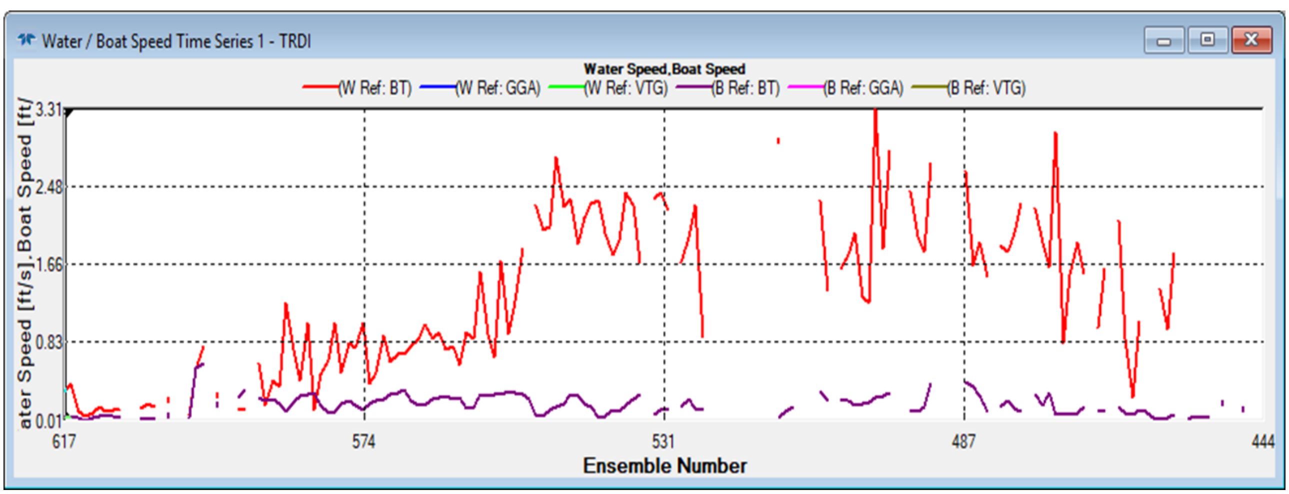




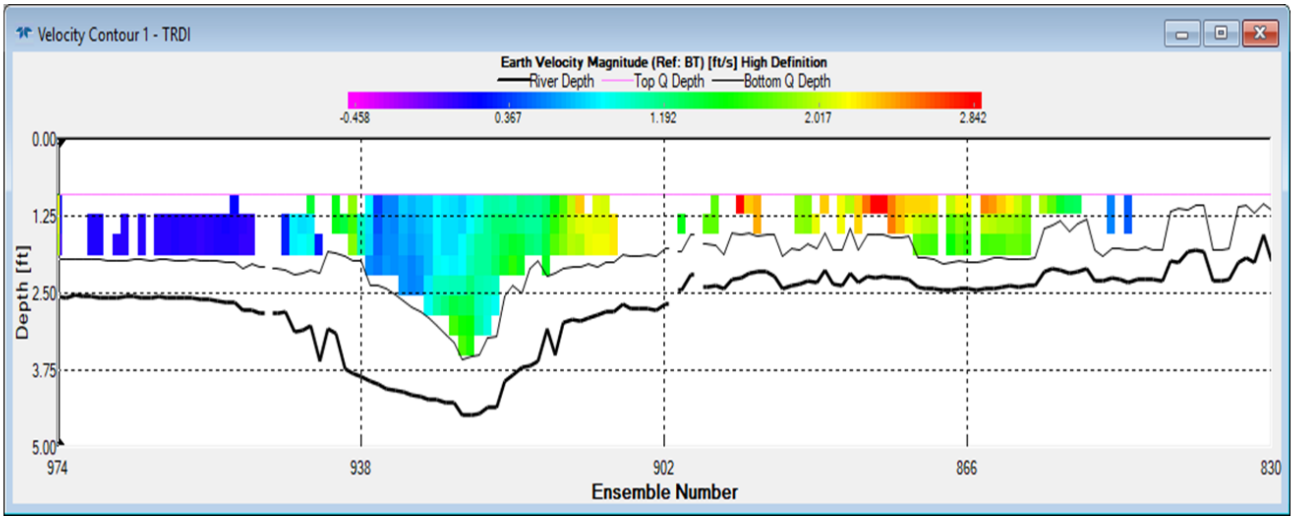
B. Transect TBD6-009 Raw Data Output

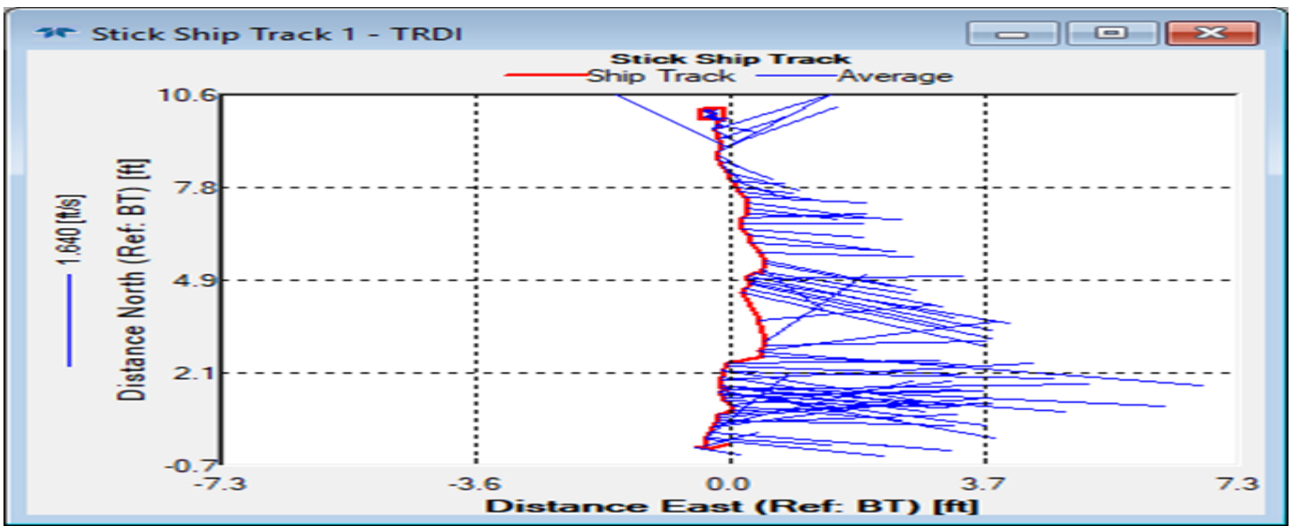




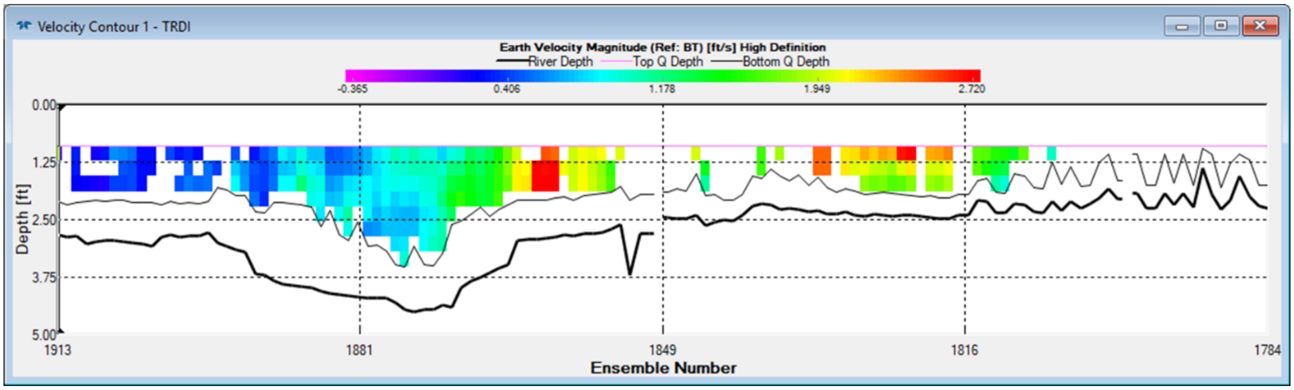


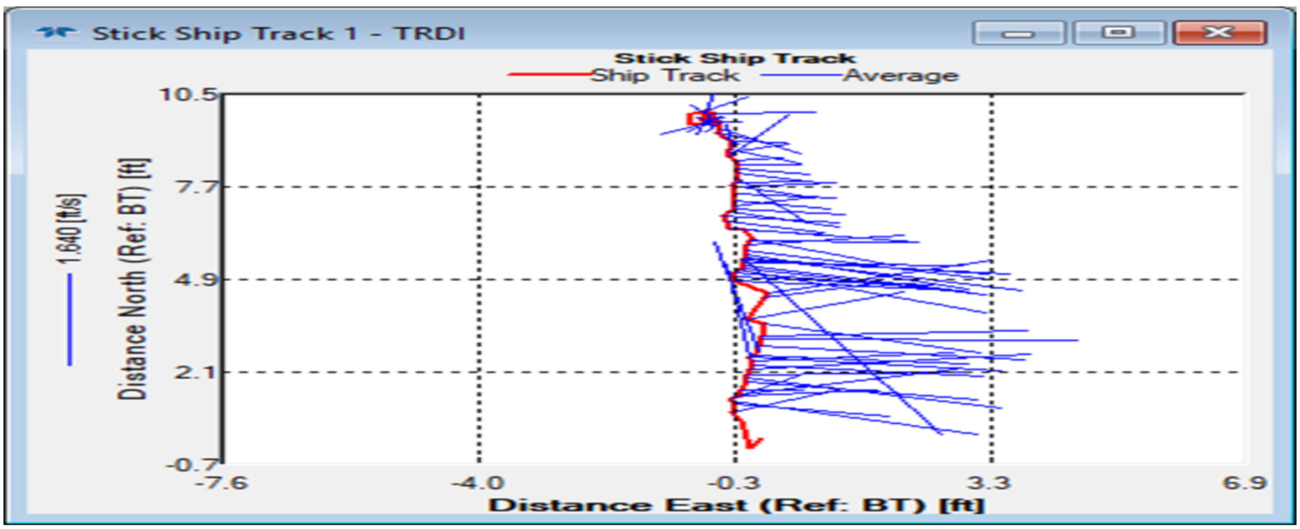
C. Transect TBD6-011 Raw Data Output

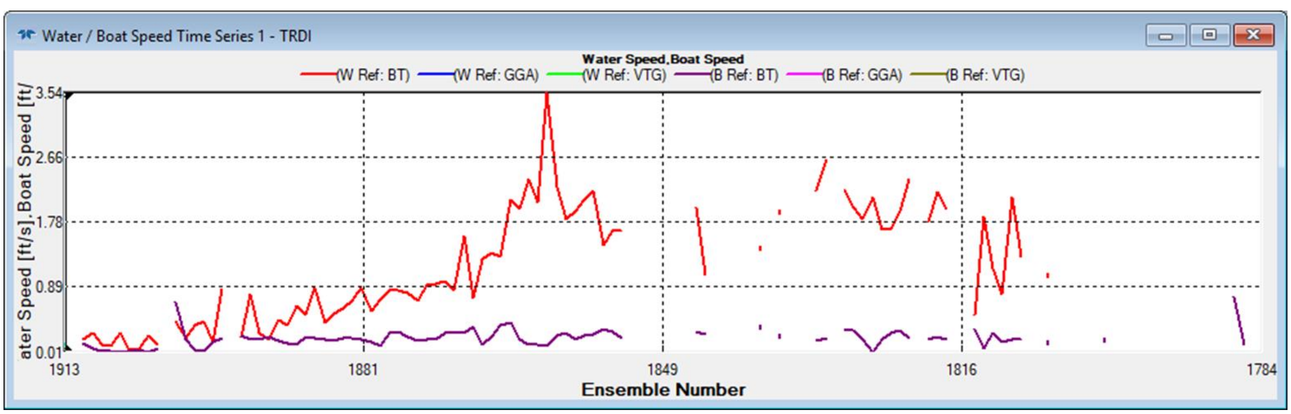




D. Transect TBD6-013 Raw Data Output







ConocoPhillips Alaska

0 200 400 Feet

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C3_TBD6.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

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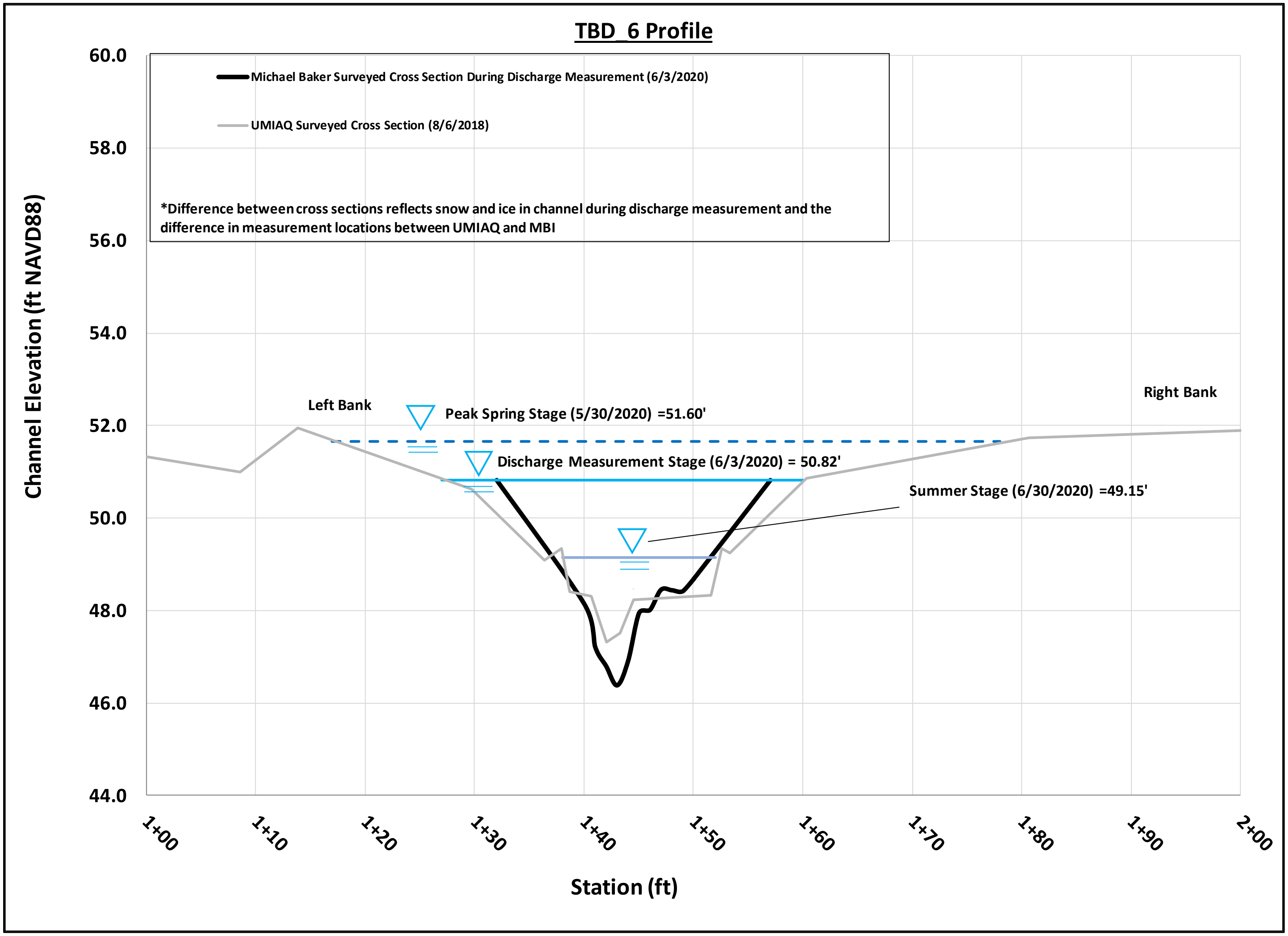
2020 Spring Breakup Willow 8 at TDB_6 Plan

FIGURE C.3

Spring Breakup Cross-Section Profile



C.4 WILLOW 2 AT UC1B

Spring Breakup Measured Discharge

Location: UC1B

Date & Time: June 2, 2020 5:00 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 90

Average Velocity (fps): 1.2

Measurement Rating: Poor

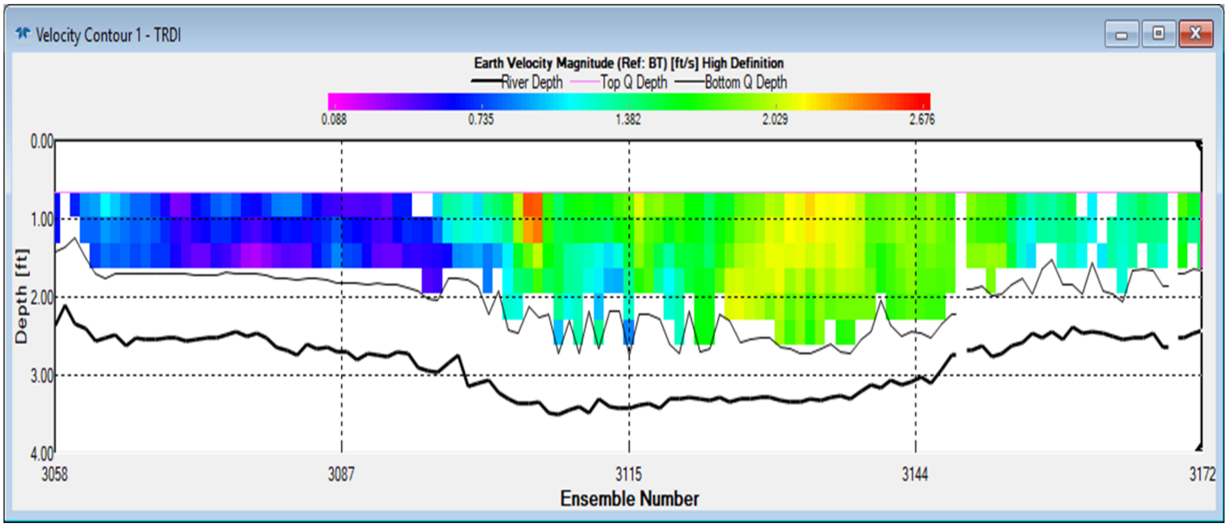
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.33%) was within the recommended maximum of 5%.

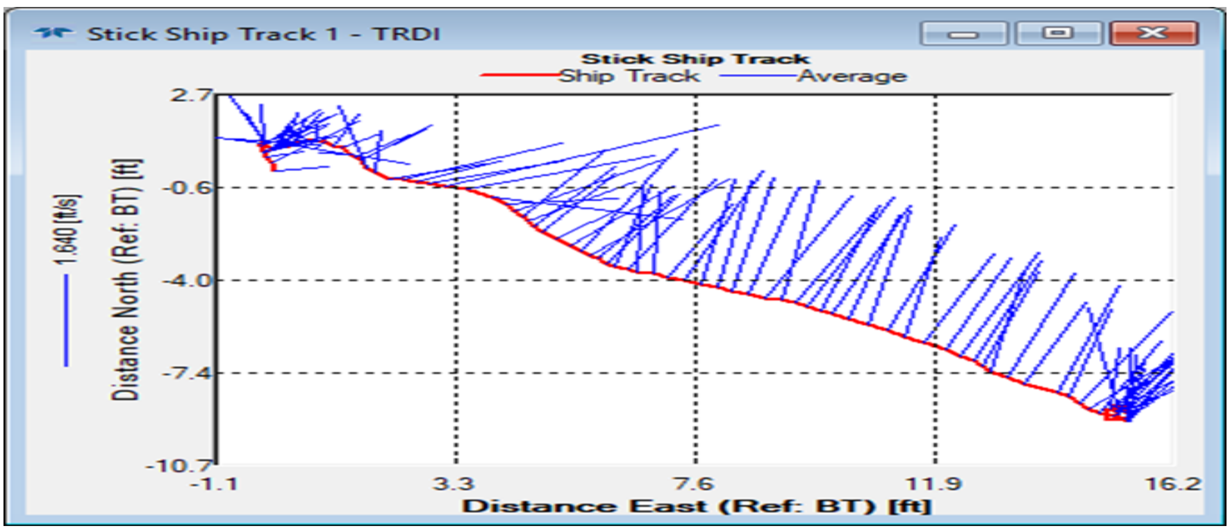
During the measurement, stage was far below bankfull and snow remained along the banks overhanging the channel. Bottomfast ice was visible in the channel. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered poor based on conditions at the time of measurement.

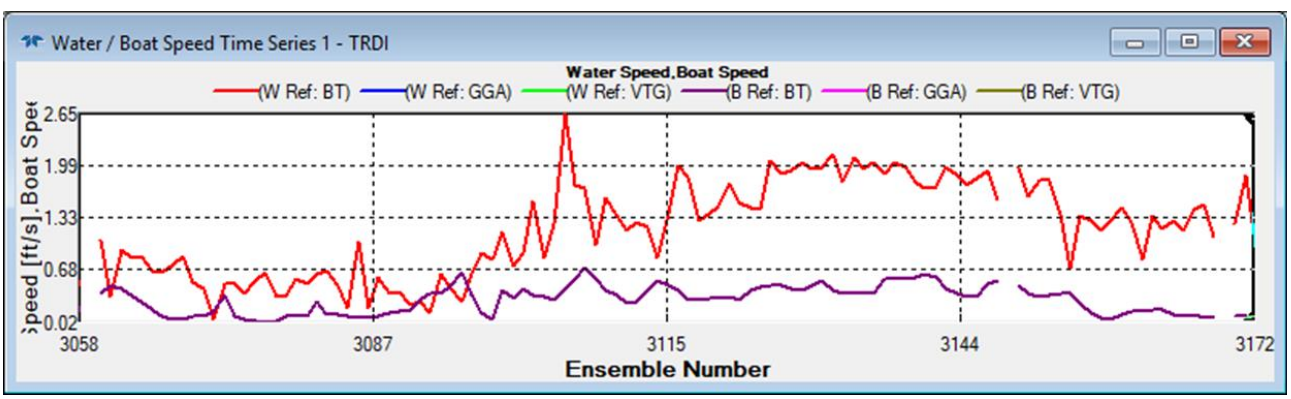
Table C.4: UC1B June 2 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
000	Left	89	0.85%	39	1.96%	34	75	76	1.18	1.19
001	Right	89	0.85%	38	-0.65%	34	70	78	1.13	1.27
002	Left	86	-2.55%	36	-5.88%	33	77	77	1.12	1.12
004	Left	89	0.85%	40	4.58%	33	68	75	1.19	1.30
Average		**88**		**38**		**34**		**77**	**1.16**	**1.22**

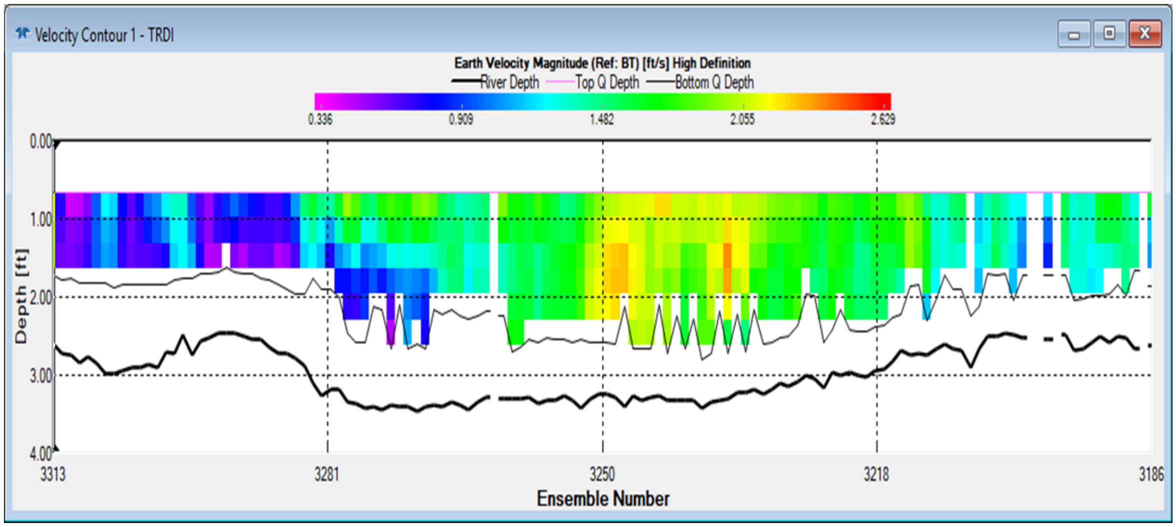
A. Transect UC1B-000 Raw Data Output

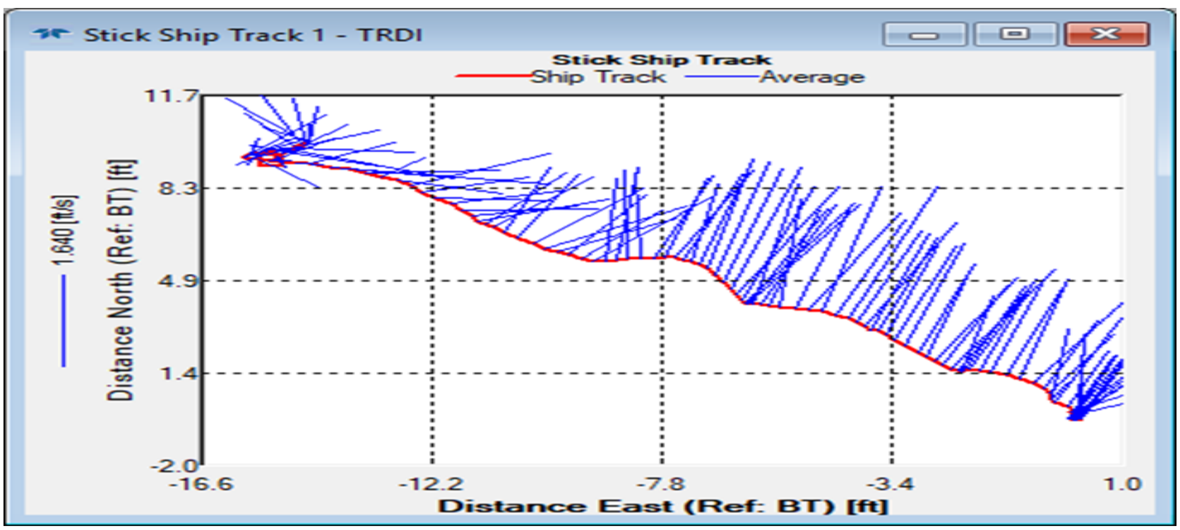


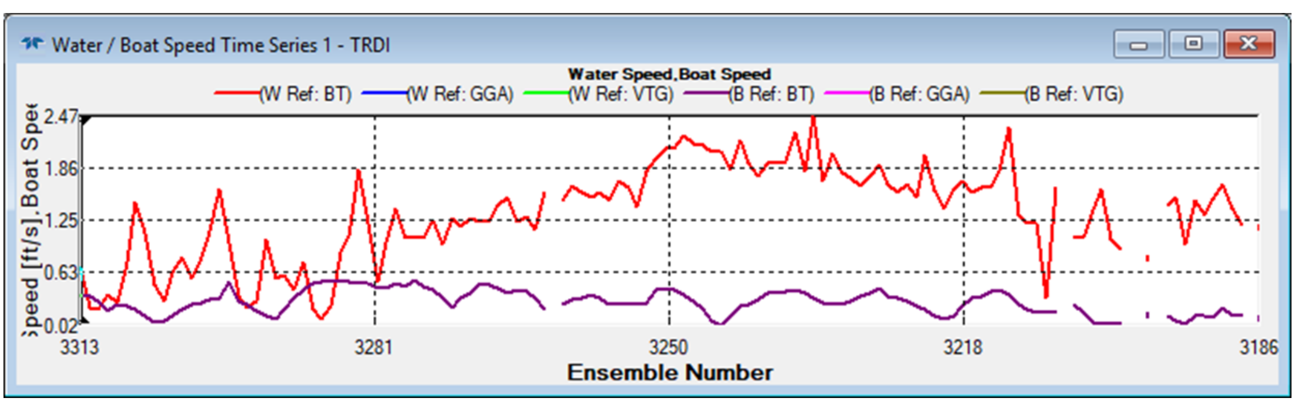




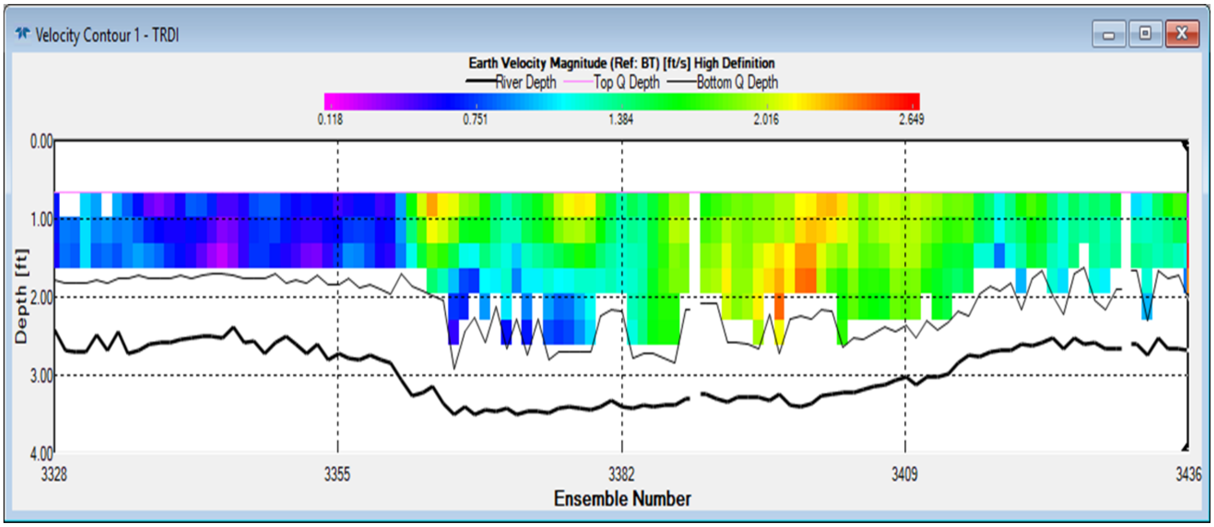
B. Transect UC1B-001 Raw Data Output

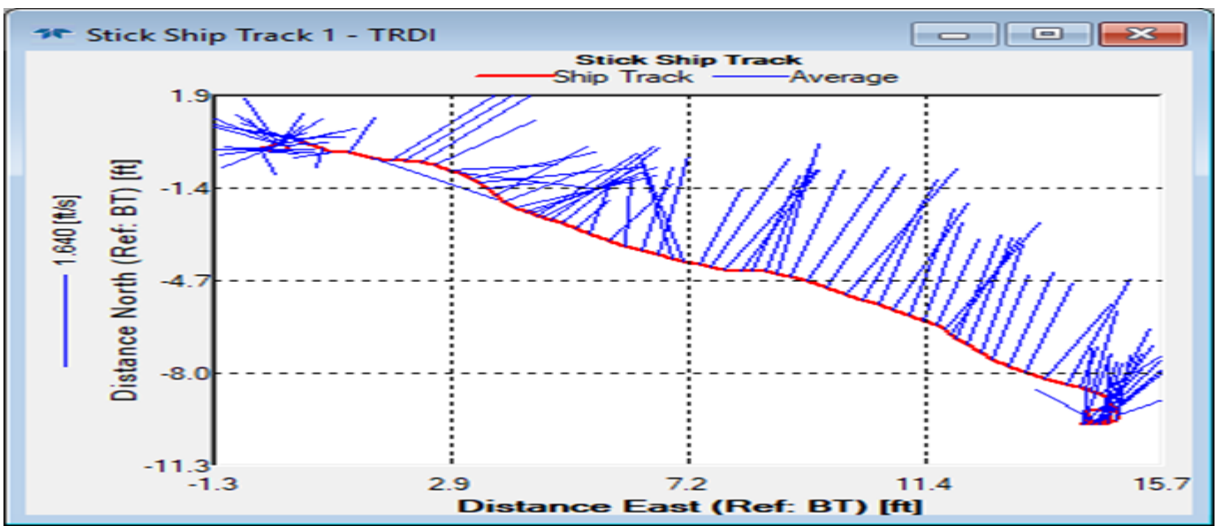


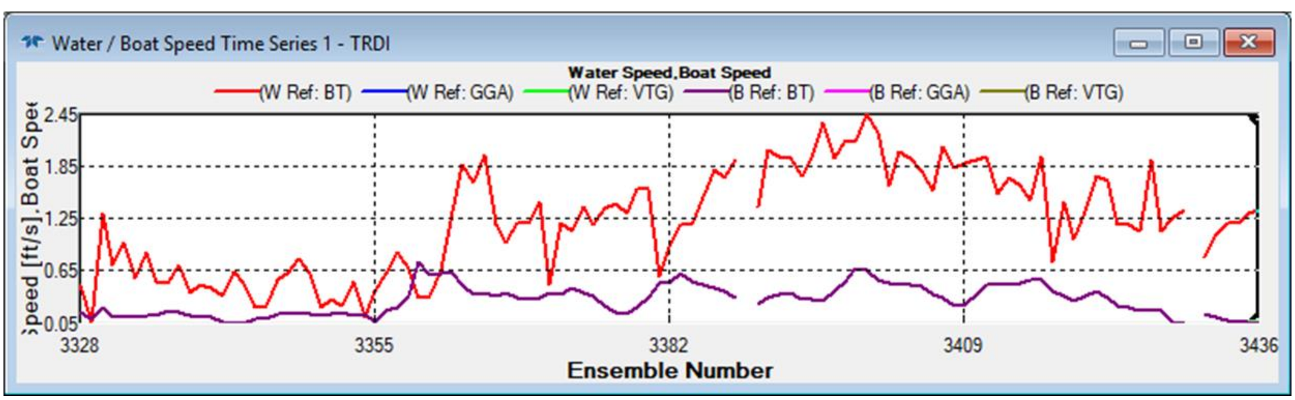




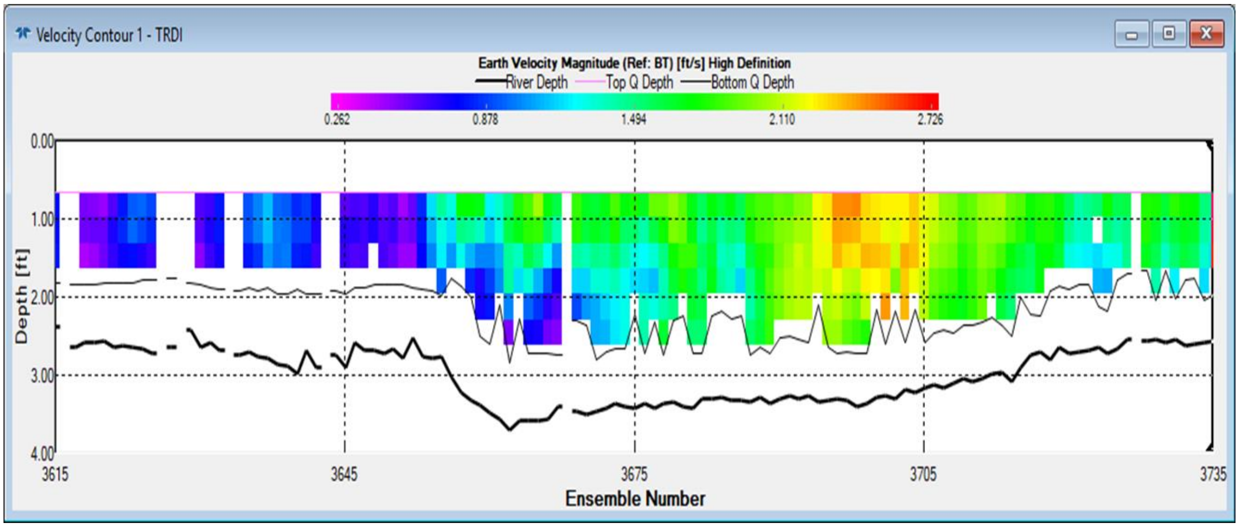
C. Transect UC1B-002 Raw Data Output

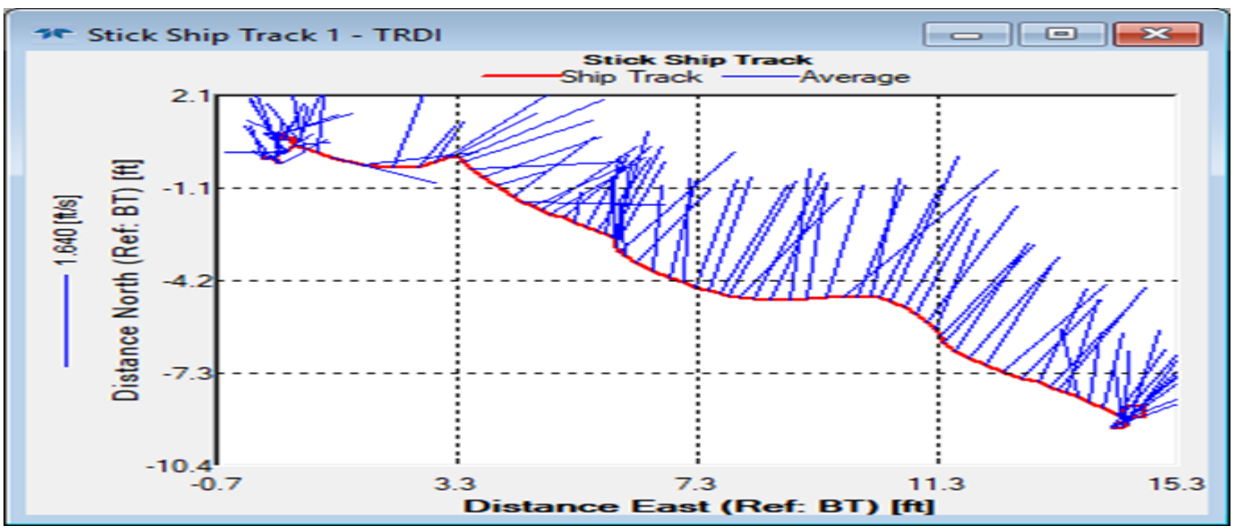


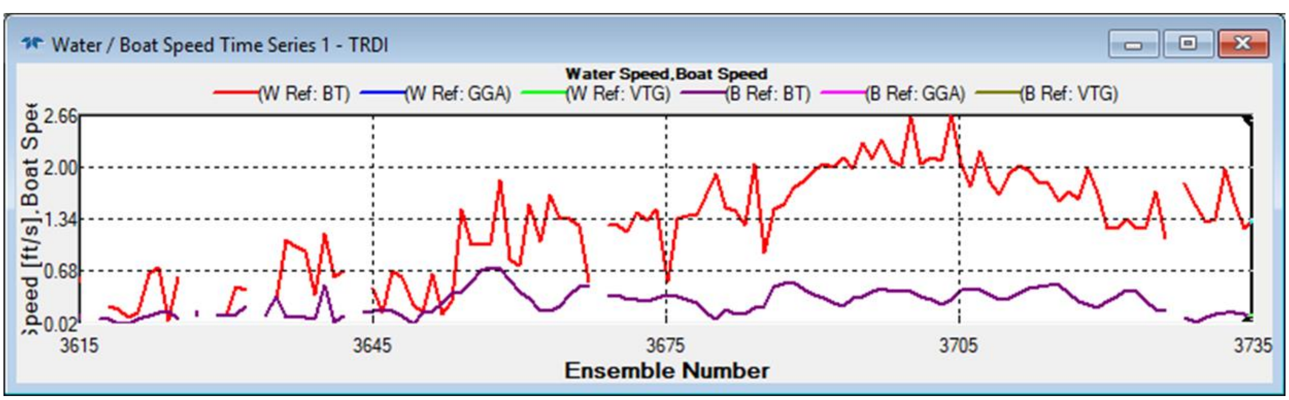




D. Transect UC1B-004 Raw Data Output







ConocoPhillips Alaska

Feet 0 200 400

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C4_UC1B.mxd

Gage Location

Station

Discharge Measurement Cross Section

Flow Direction

Imagery Source: CPAI, 2018

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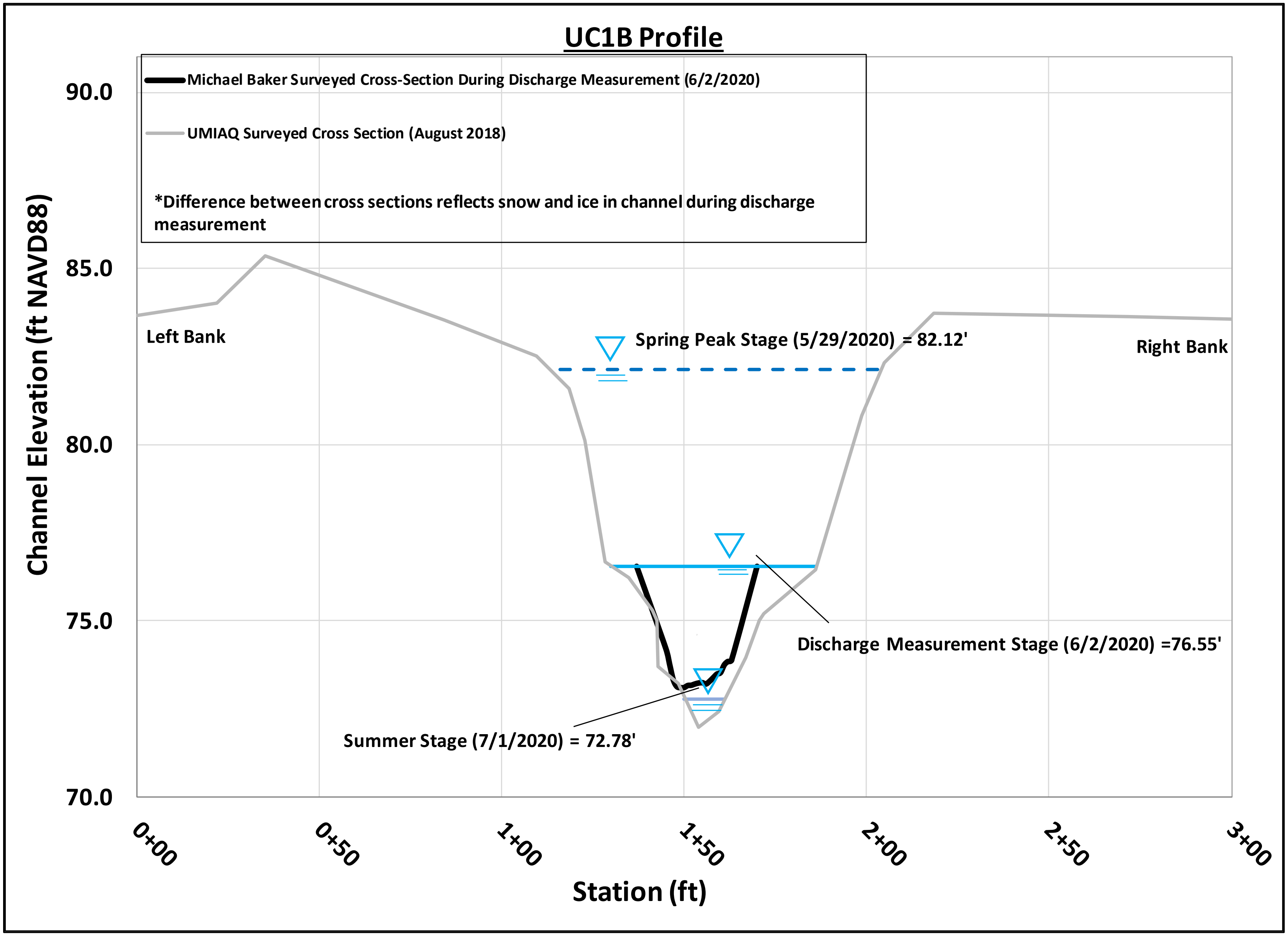
2020 Spring Breakup Willow 2 at UC1B Plan

FIGURE C.4

Spring Breakup Cross-Section Profile



C.5 JUDY CREEK KAYYAAQ AT UC2C

Spring Breakup Measured Discharge

Location: UC2C

Date & Time: June 1, 2020 3:30 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 230

Average Velocity (fps): 1.5

Measurement Rating: Fair

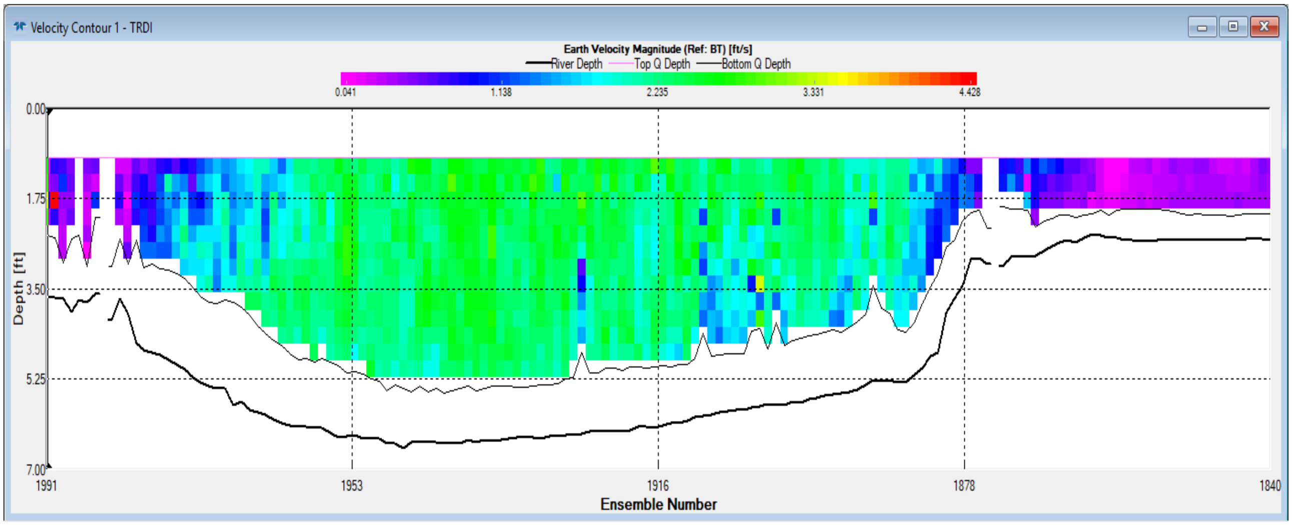
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.00%) was within the recommended maximum of 5%.

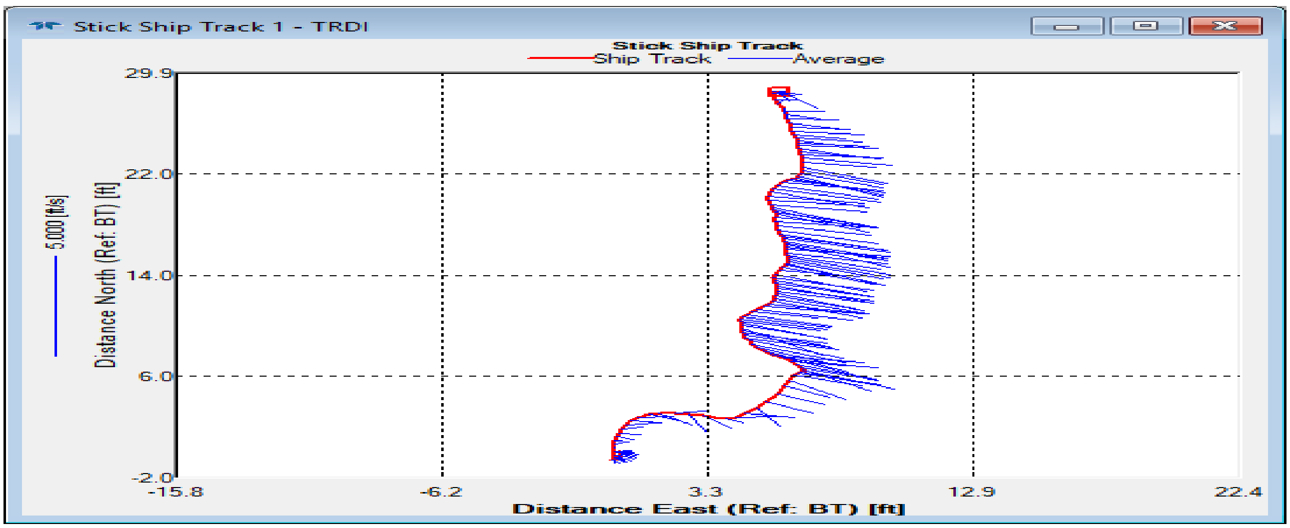
During the measurement, the channel was clear of snow and ice and flow was confined to within the channel banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on conditions at the time of measurement.

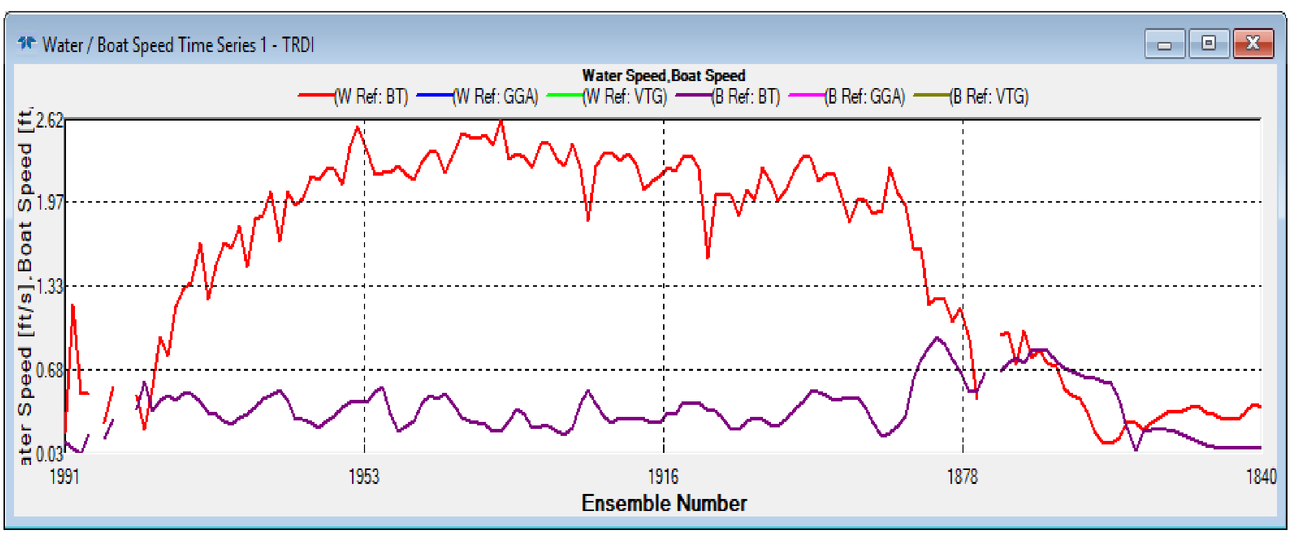
Table C.5: UC2C June 1 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
004	Left	231	1.20%	43	-4.44%	40	138	167	1.38	1.68
005	Right	226	-0.99%	49	8.89%	41	141	172	1.32	1.60
006	Left	224	-1.86%	43	-4.44%	39	140	161	1.39	1.60
008	Left	232	1.64%	45	0.00%	40	138	164	1.41	1.68
Average		**228**		**45**		**40**		**166**	**1.38**	**1.64**

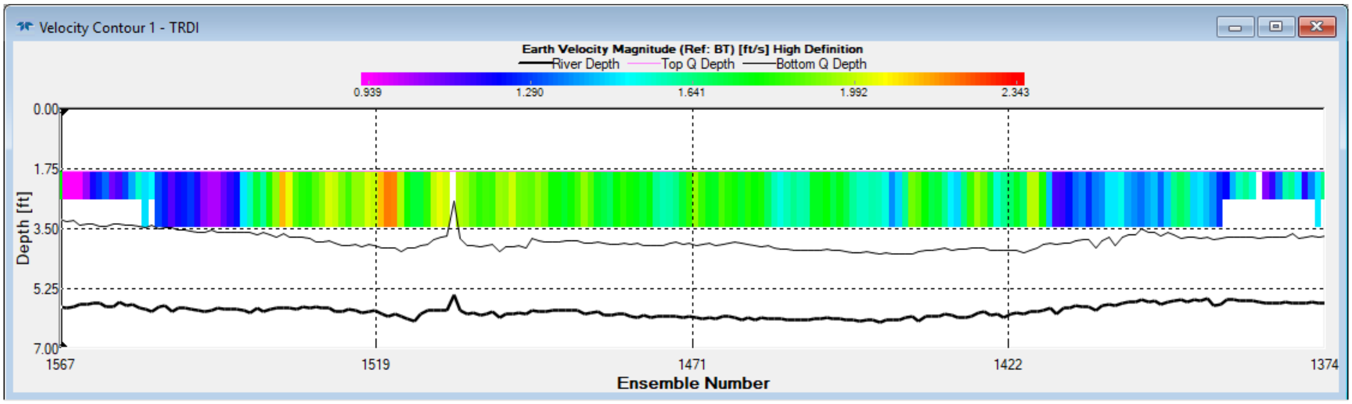
A. Transect UC2C-004 Raw Data Output

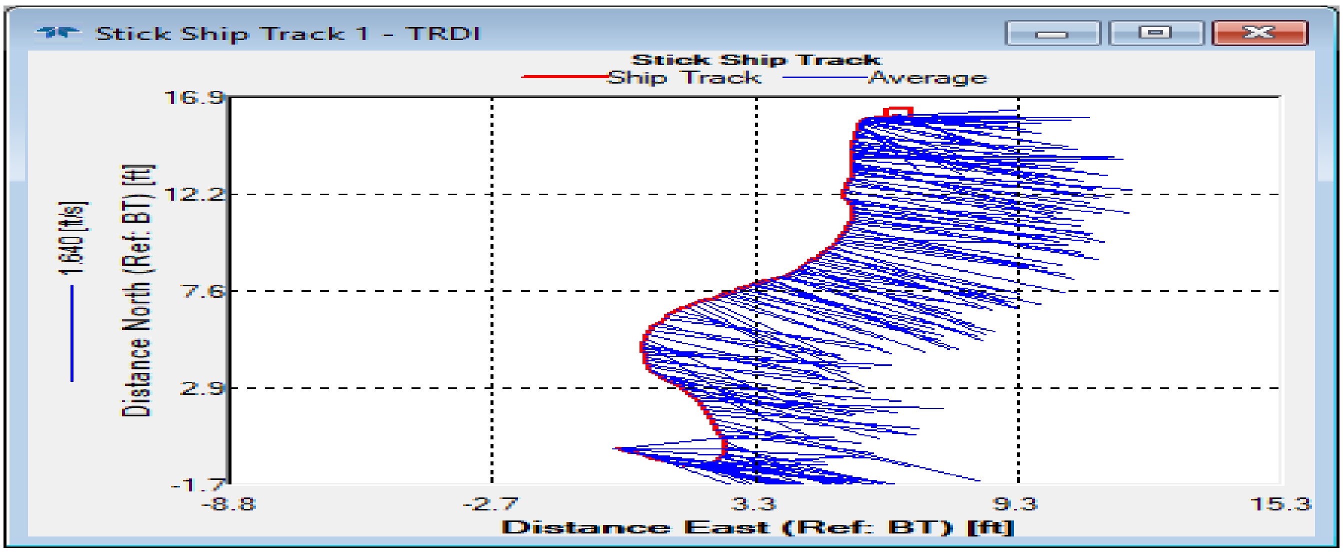


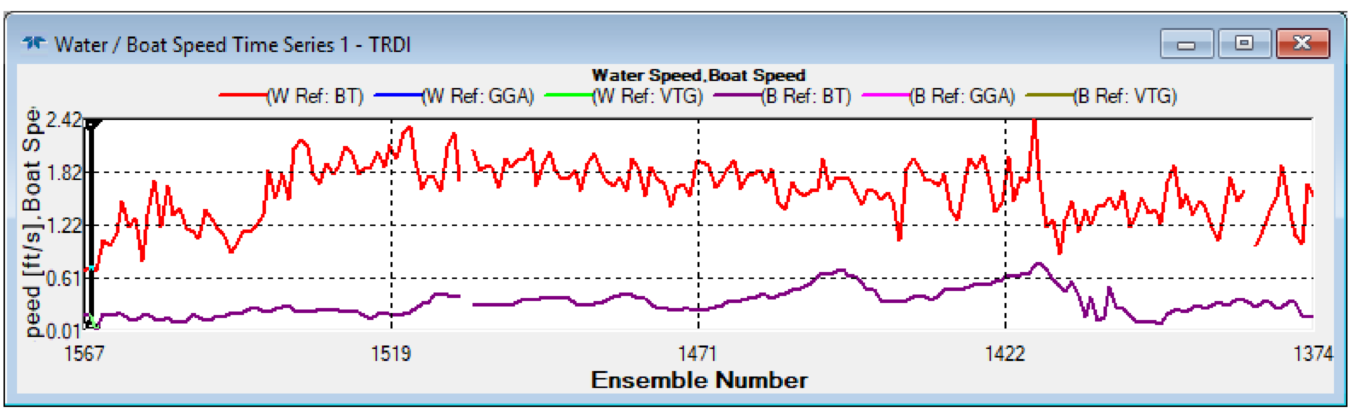




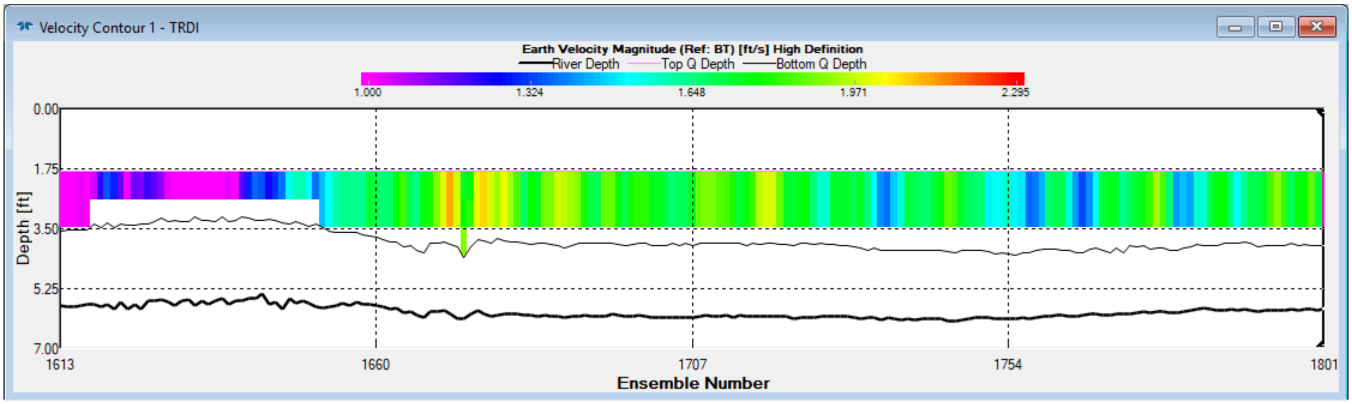
B. Transect UC2C-005 Raw Data Output

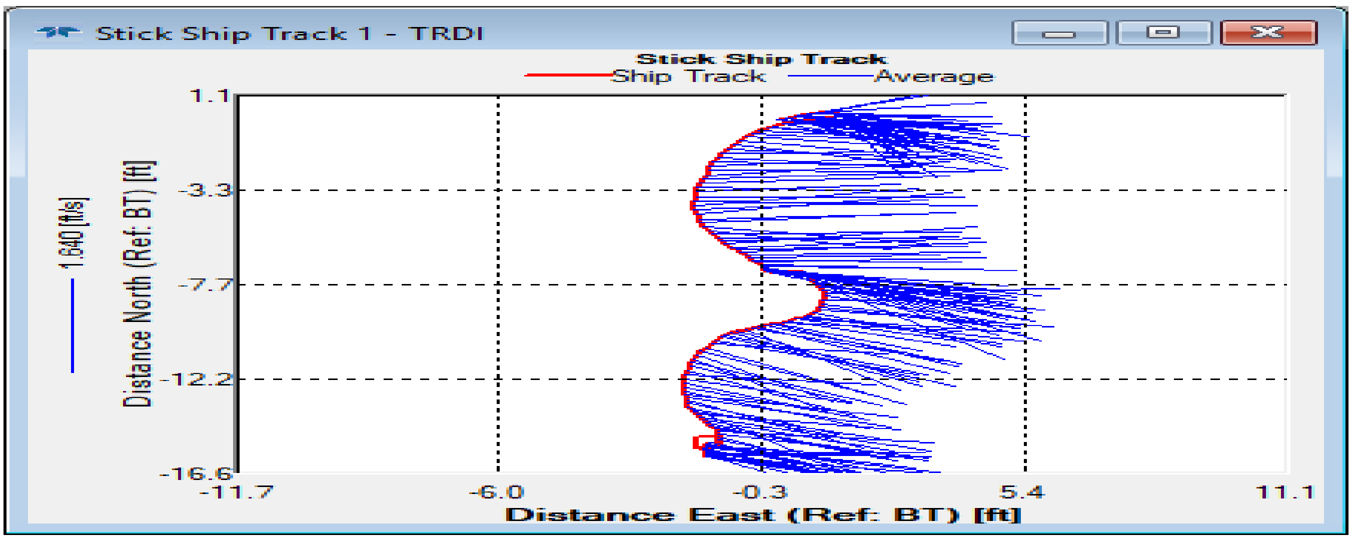


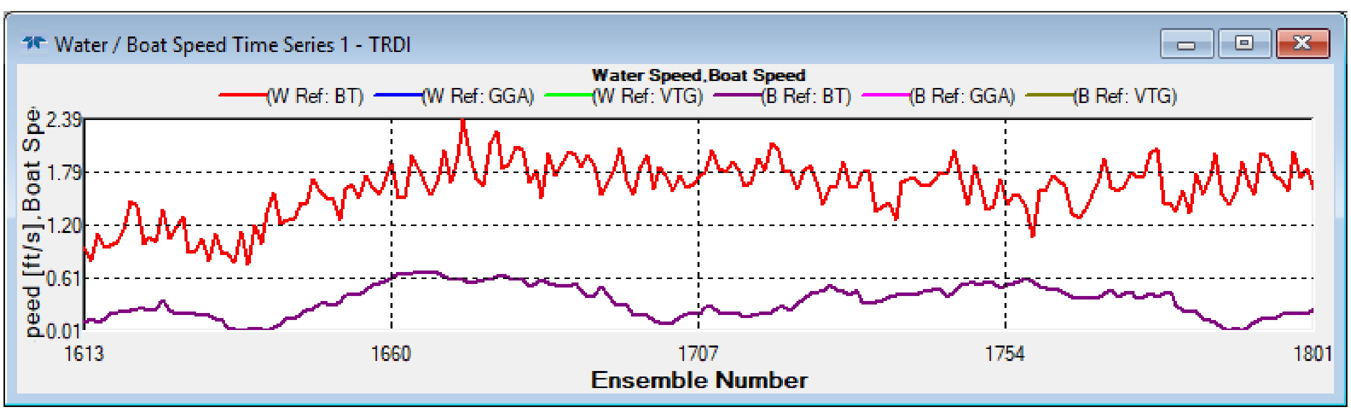




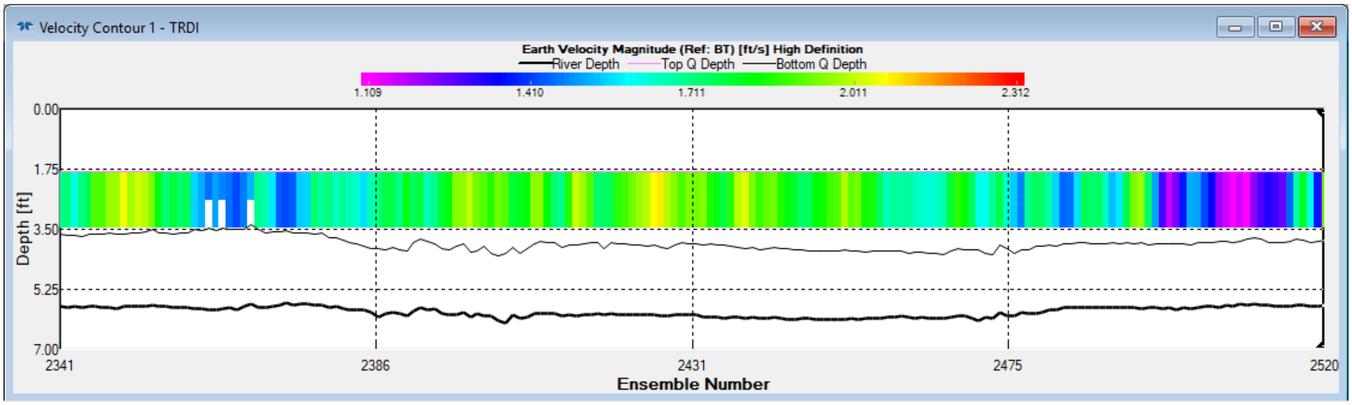
C. Transect UC2C-006 Raw Data Output

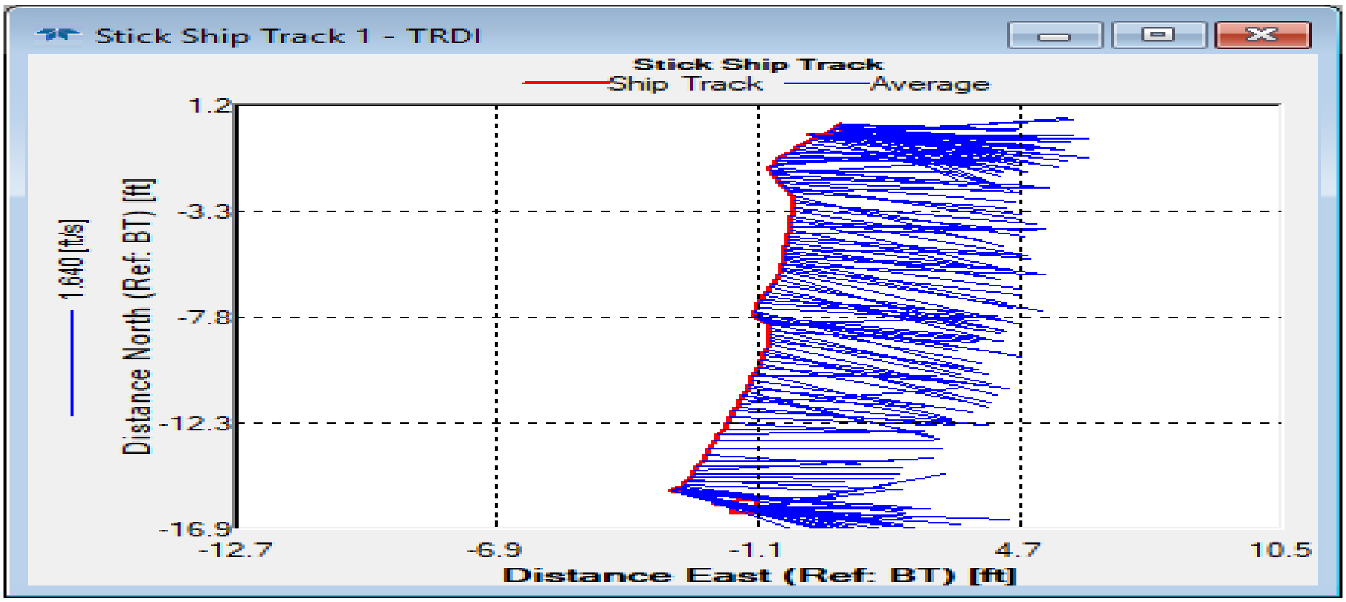


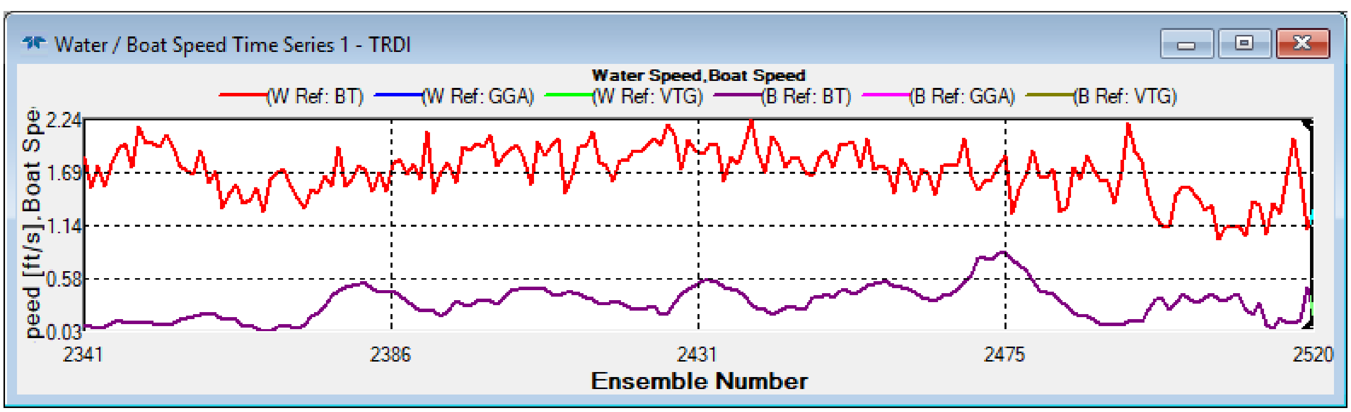


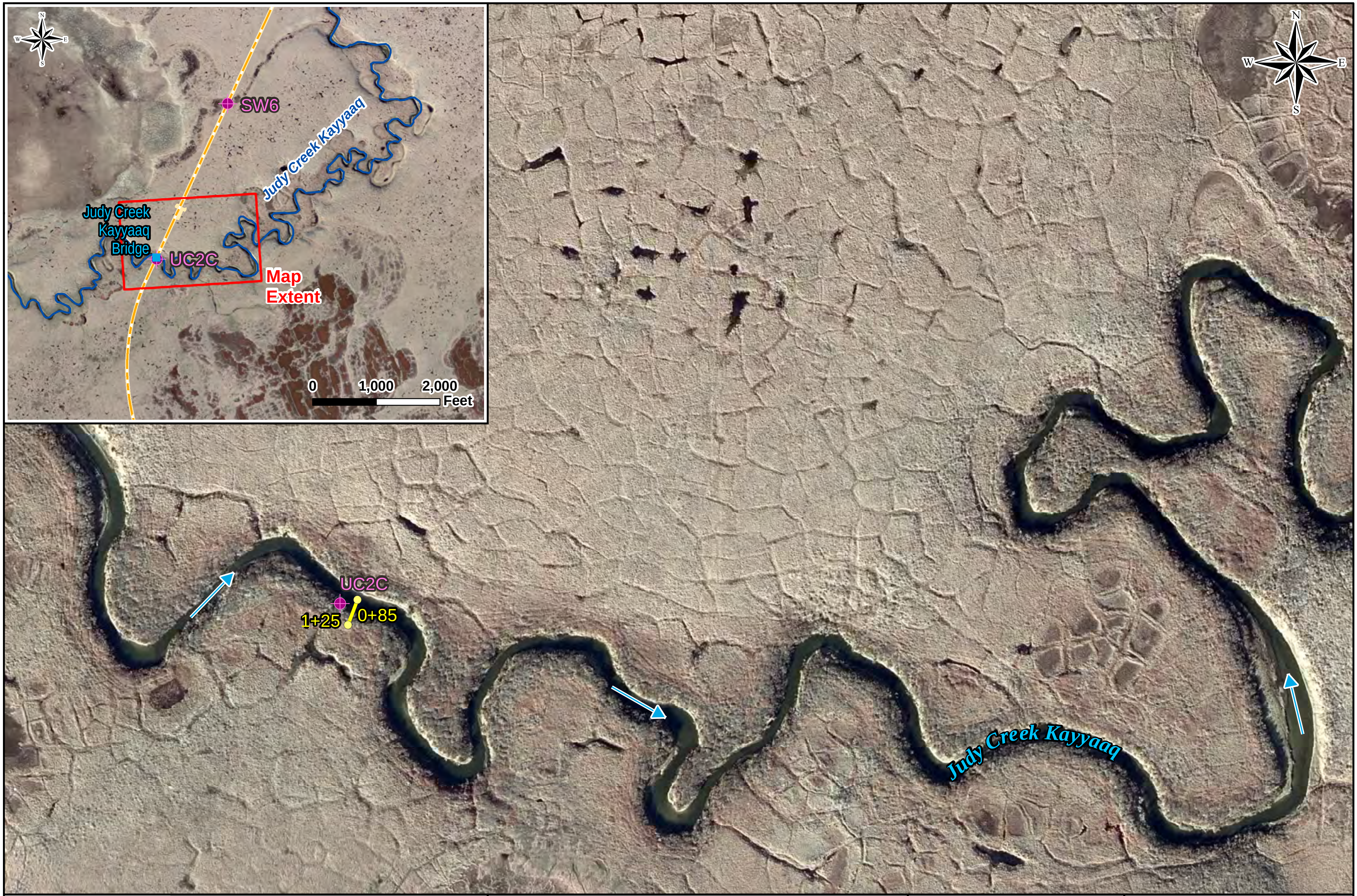


D. Transect UC2C-008 Raw Data Output









ConocoPhillips Alaska

0 200 400 Feet

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C5_UC2C.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

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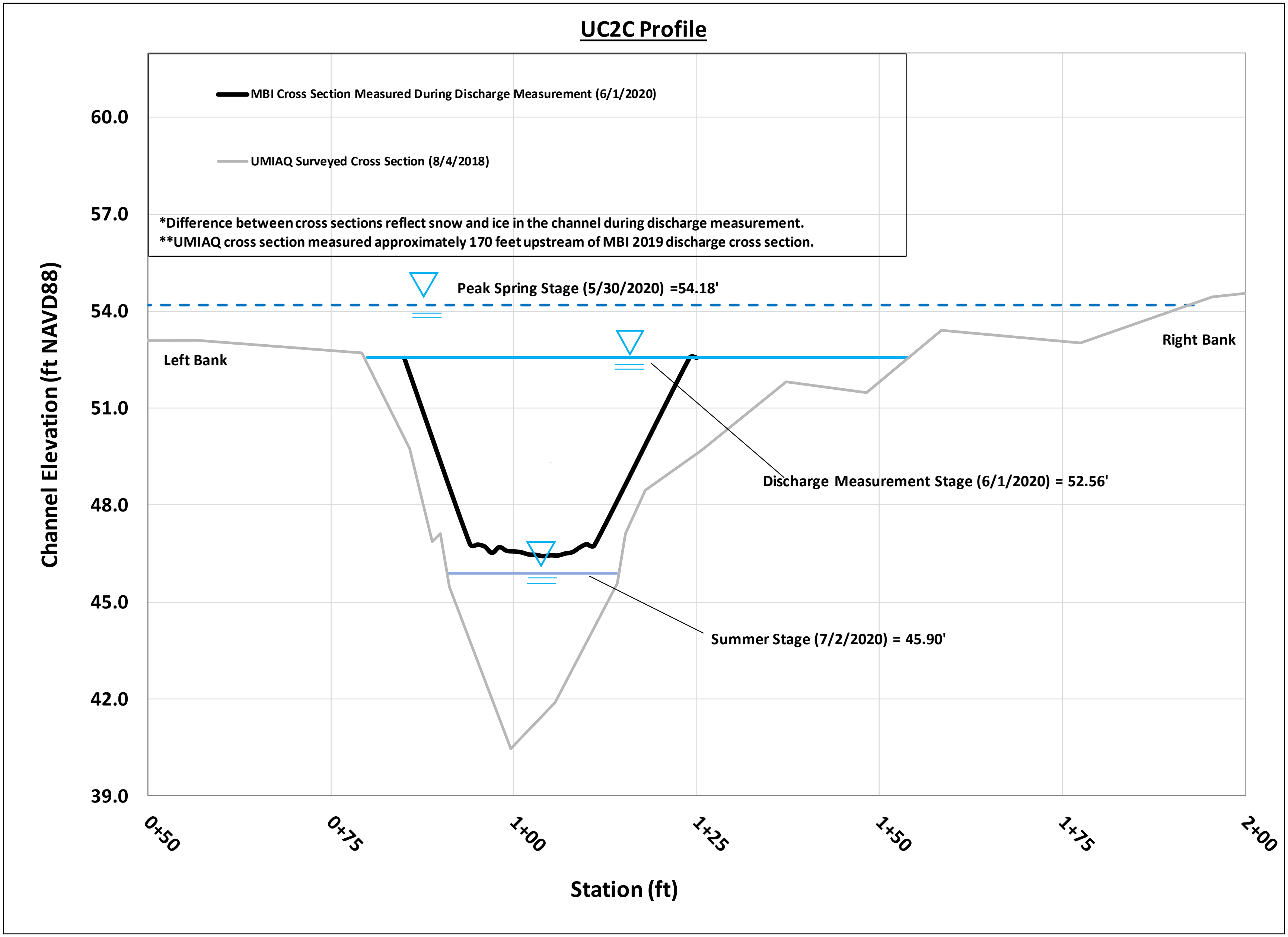
2020 Spring Breakup Judy Creek Kayyaaq at UC2C Plan

FIGURE C.5

Spring Breakup Cross-Section Profile



C.6 WILLOW 4 AT W_BS1

Spring Breakup Measured Discharge

Location: W_BS1

Date & Time: June 1, 4:30 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 185

Average Velocity (fps): 1.4

Measurement Rating: Fair

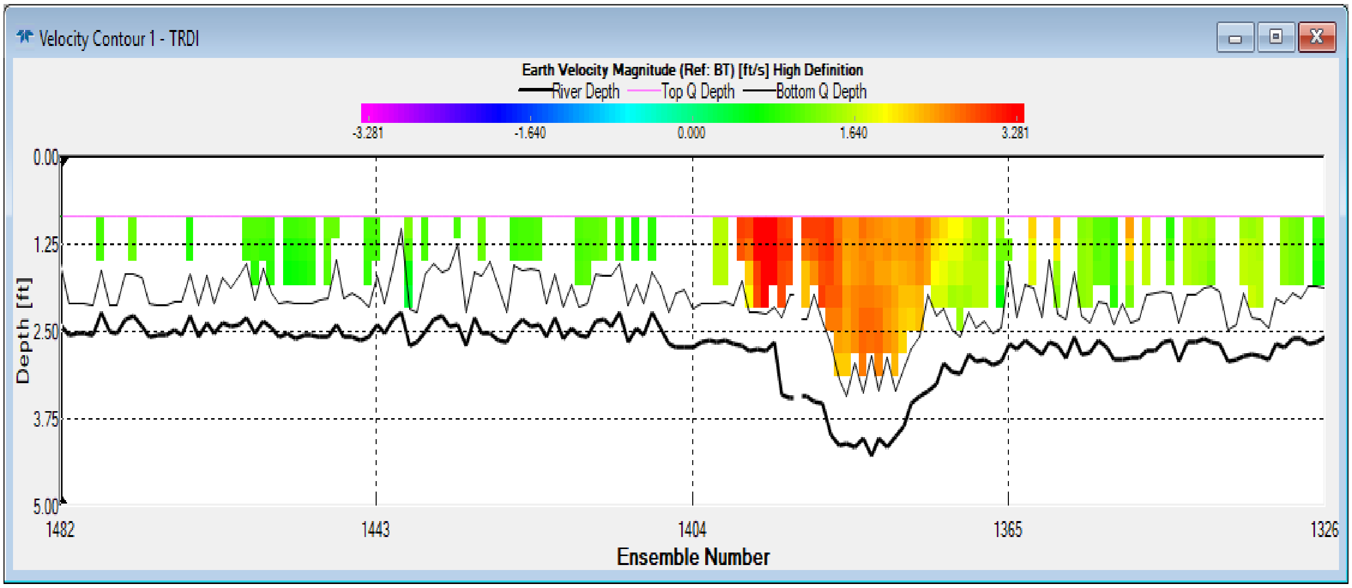
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.14%) did not exceed the recommended maximum of 5%.

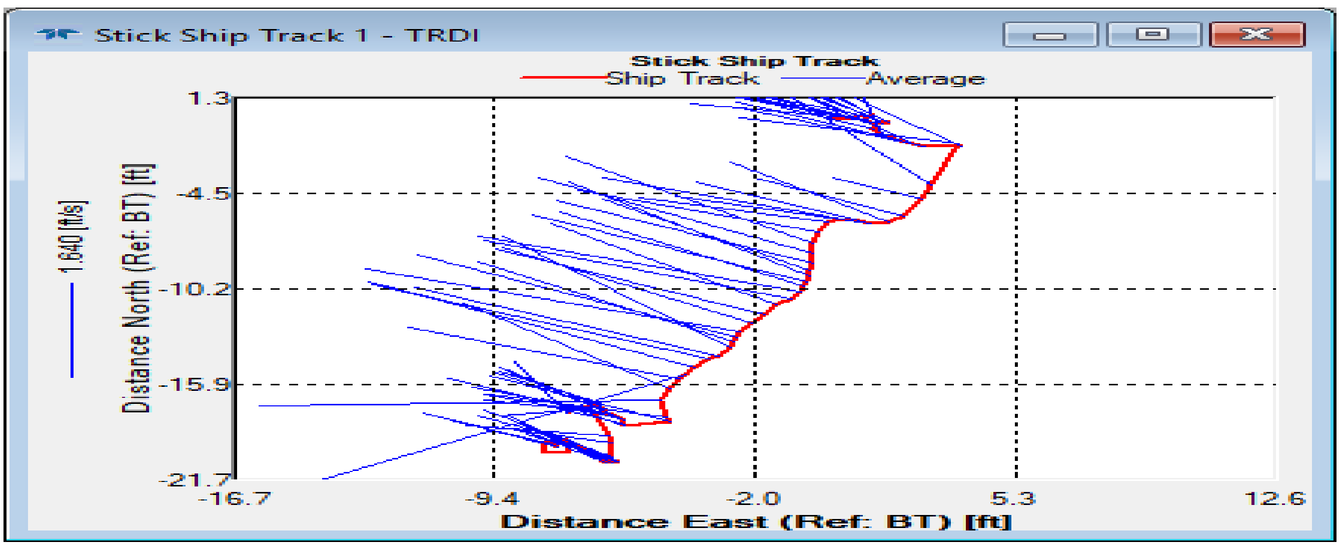
During the discharge measurement the channel was mostly clear of ice and snow, with saturated snow present along the banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on conditions at the time of the measurement.

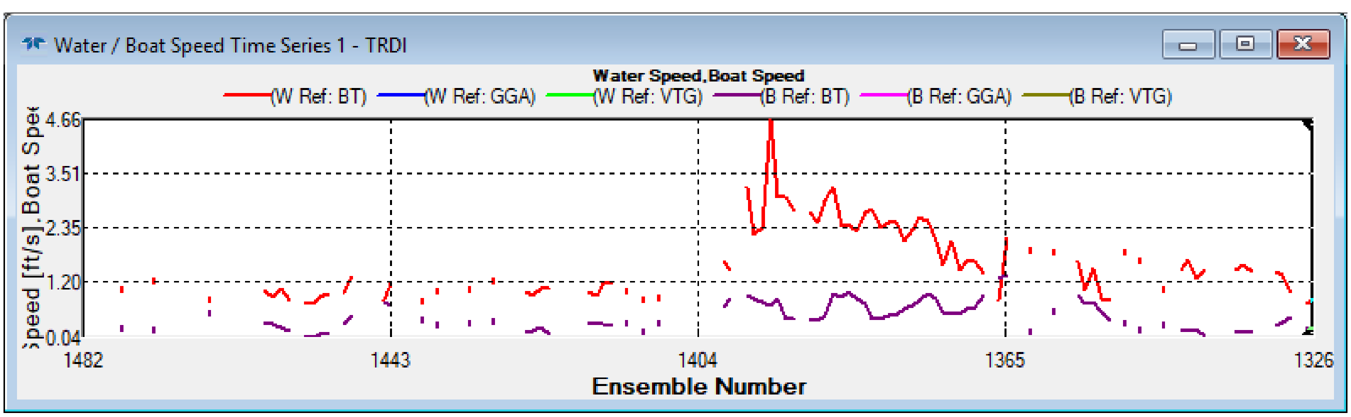
Table C.6: W_BS1 May 28 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
000	Right	181	-1.23%	53	-10.17%	71	105	131	1.38	1.72
002	Right	190	3.68%	62	5.08%	72	93	140	1.36	2.04
004	Right	180	-1.77%	60	1.69%	70	93	128	1.40	1.94
005	Left	182	-0.68%	61	3.39%	71	88	131	1.39	2.07
Average		**183**		**59**		**71**		**133**	**1.38**	**1.94**

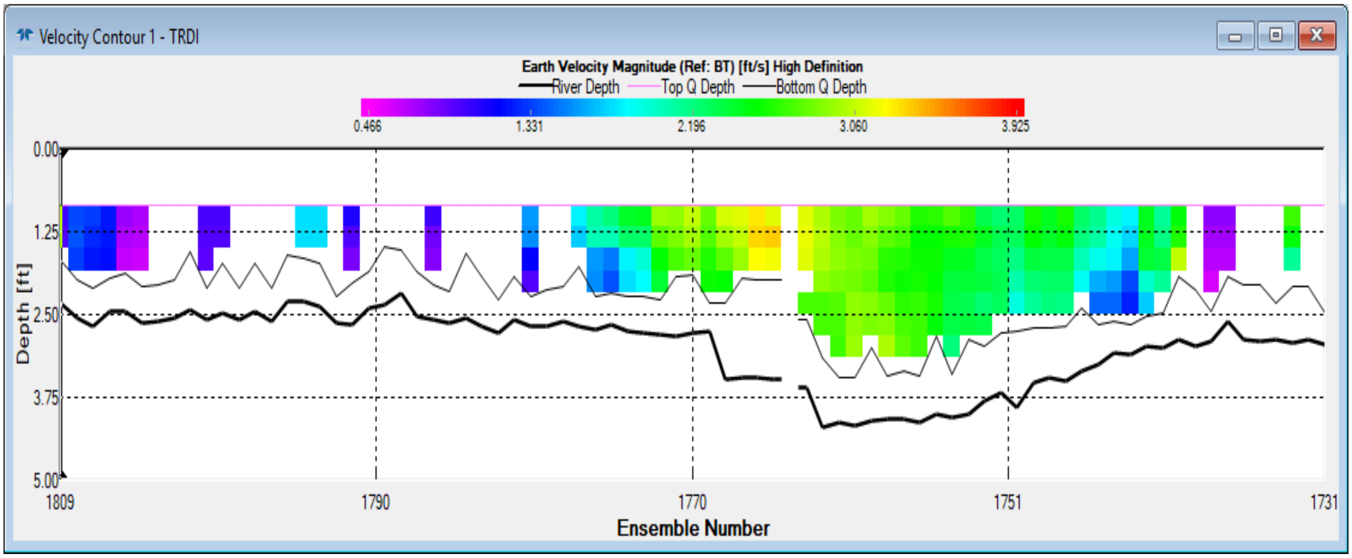
A. Transect W_BS1-000 Raw Data Output

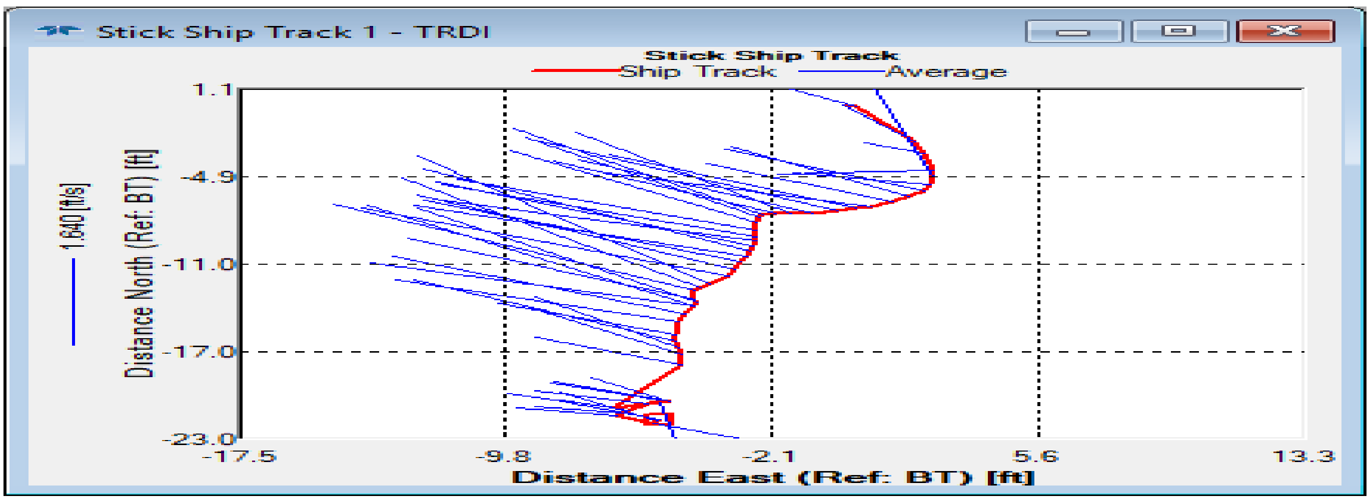


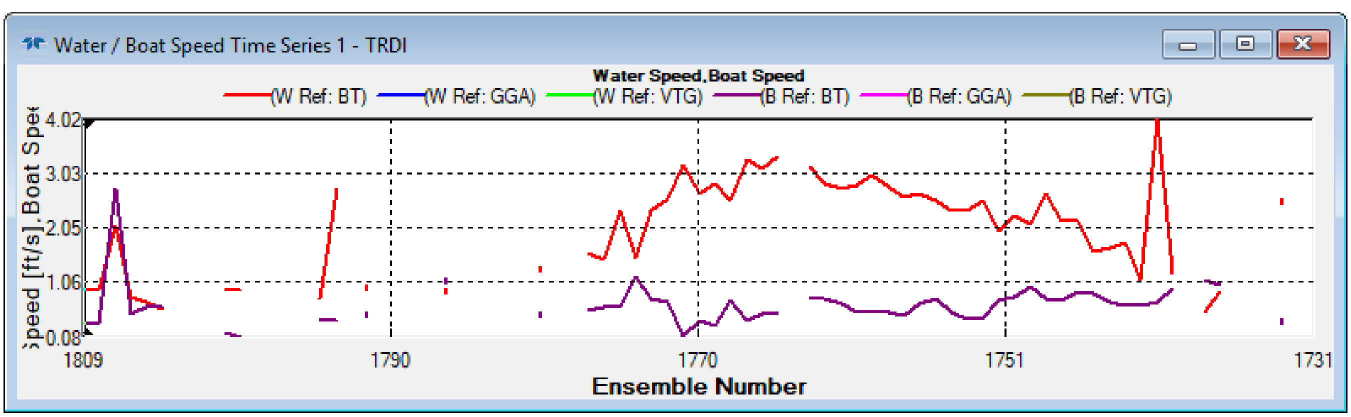




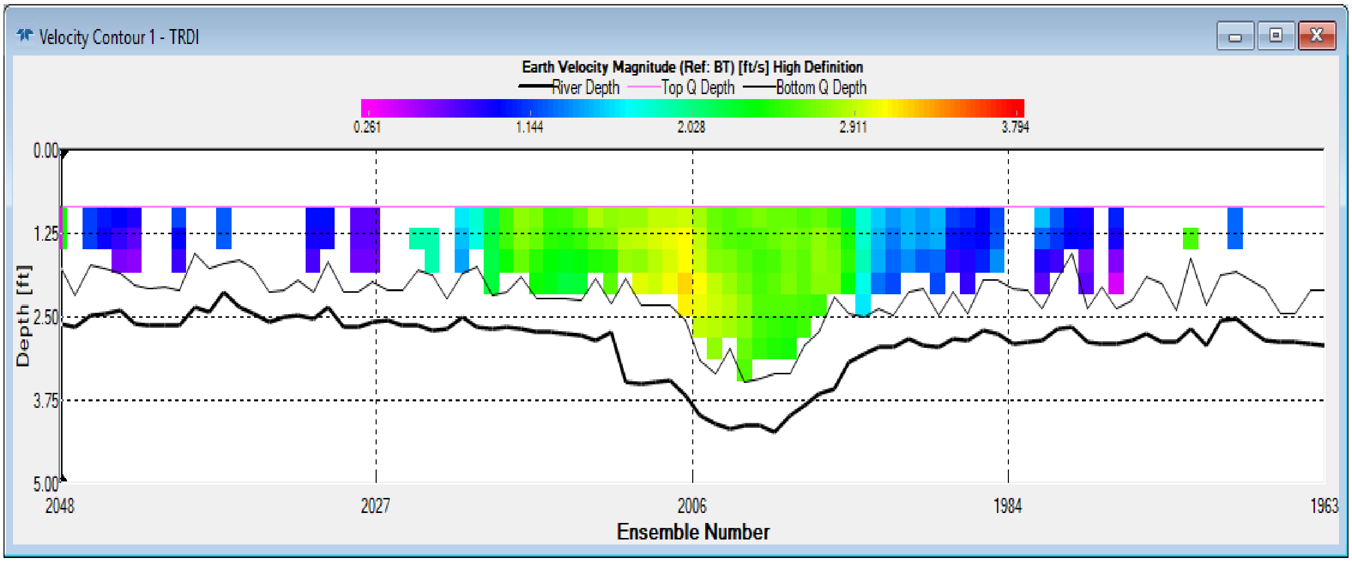
B. Transect W_BS1-002 Raw Data Output

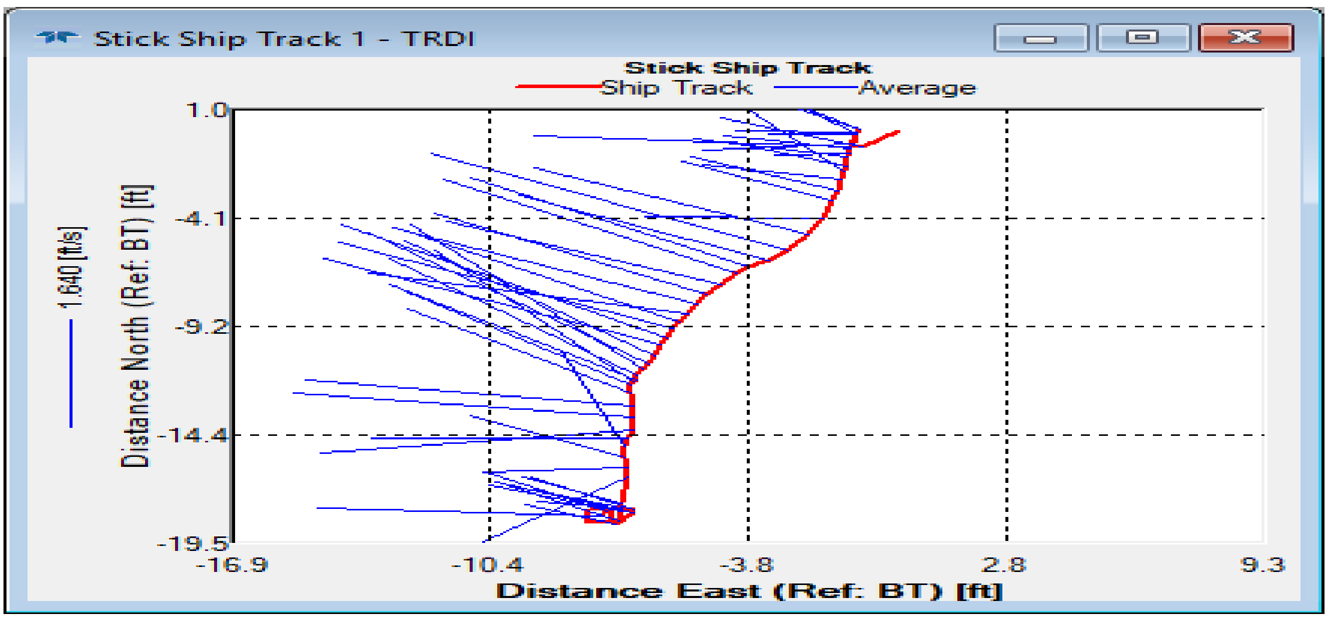


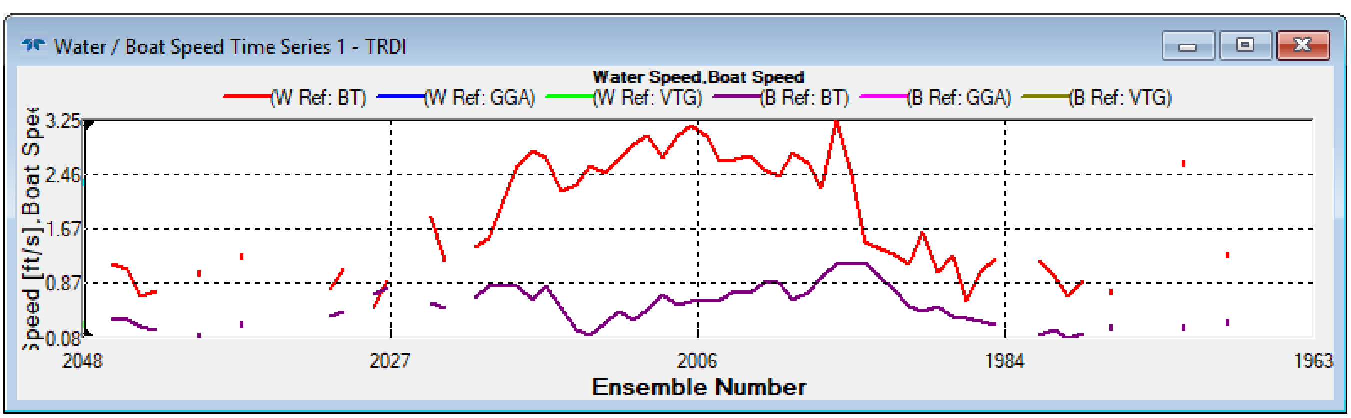




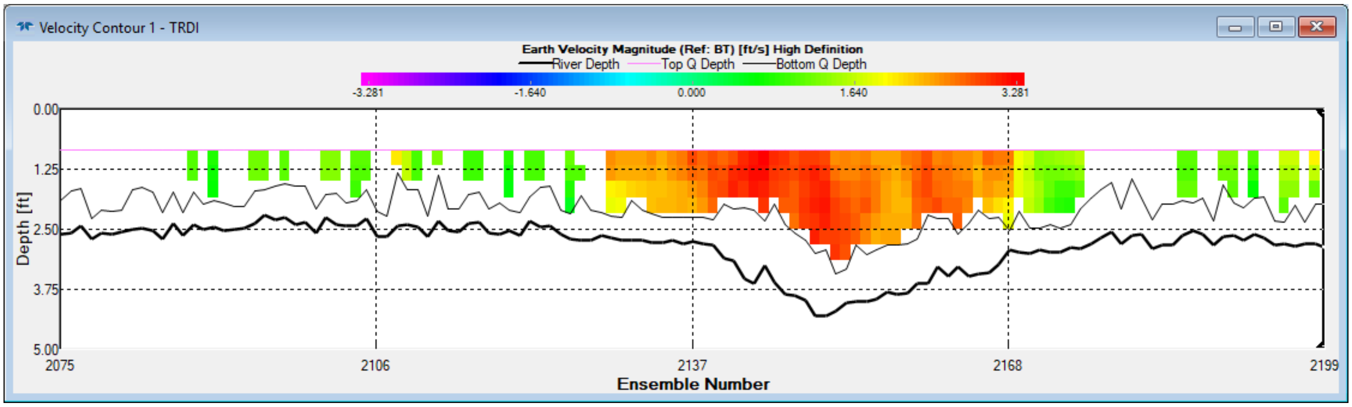
C. Transect W_BS1-004 Raw Data Output

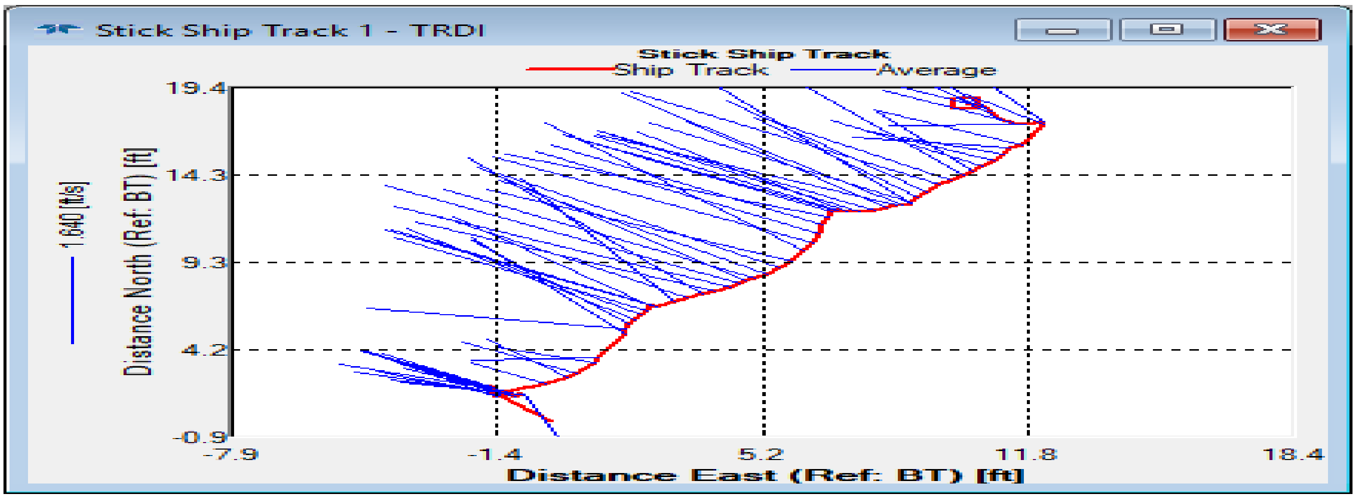


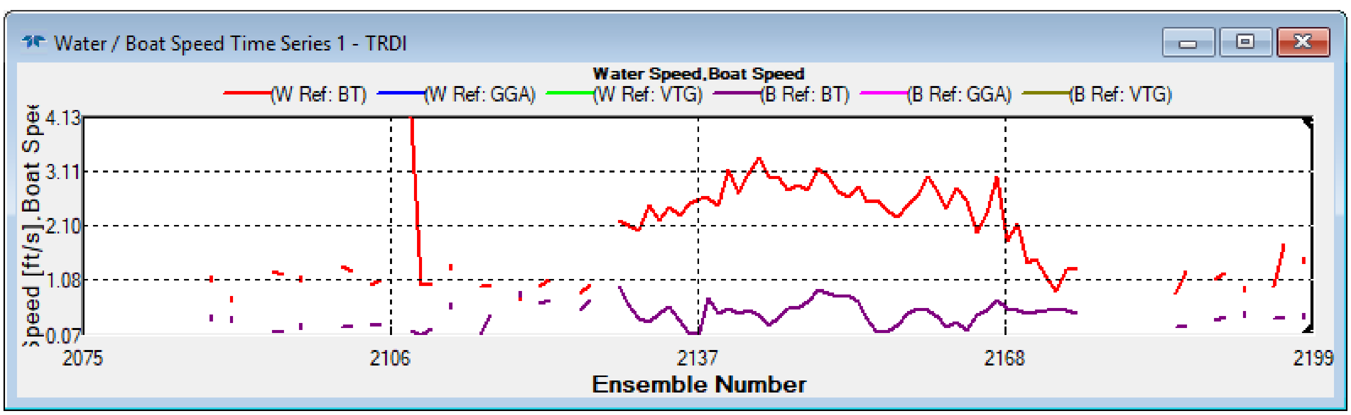




D. Transect W_BS1-005 Raw Data Output







ConocoPhillips Alaska

Feet
0 200 400

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C6_W_BS1.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

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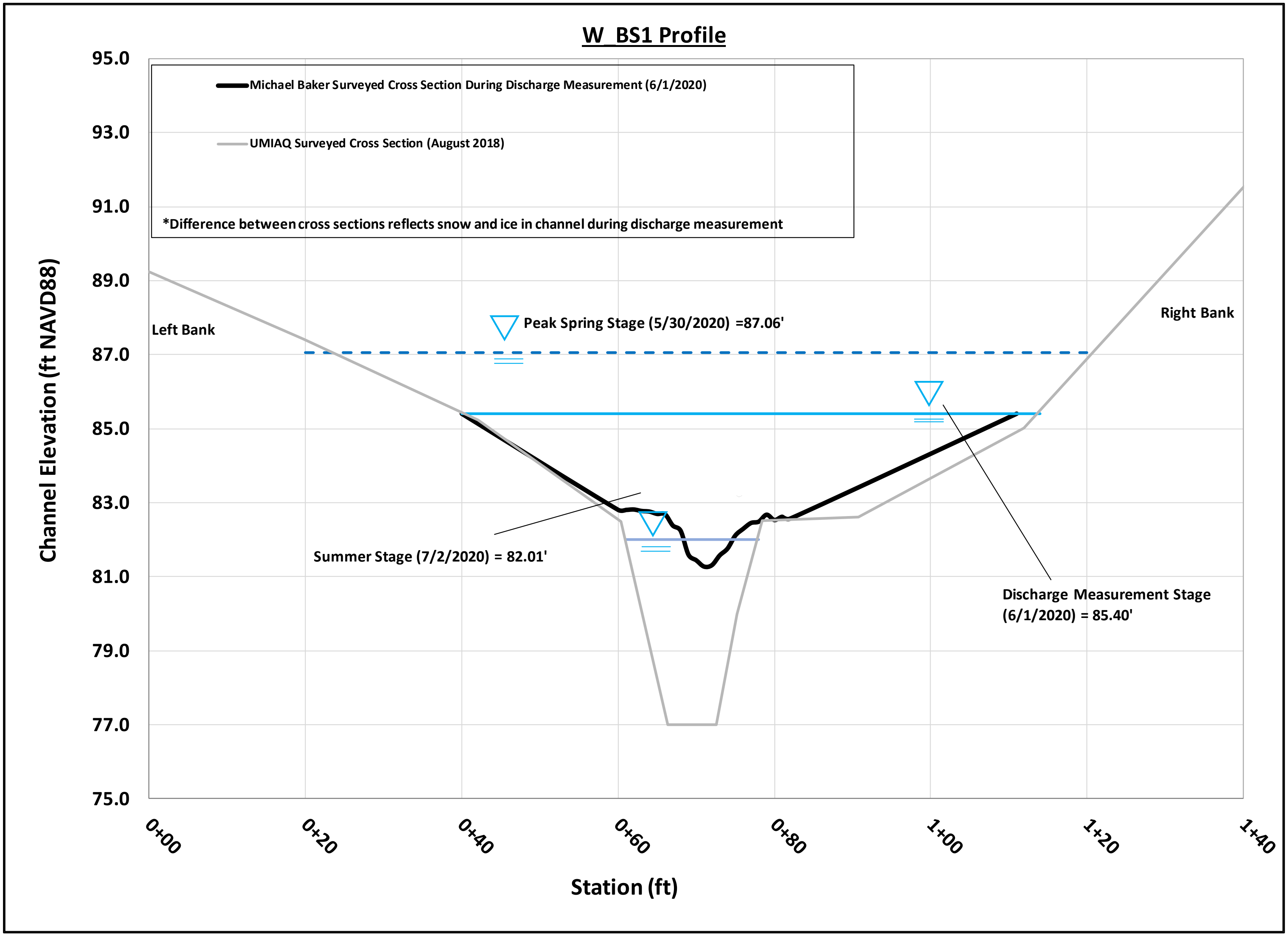
2020 Spring Breakup Willow 4 at W_BS1 Plan

FIGURE C.6

Spring Breakup Cross-Section Profile



C.7 WILLOW 4A AT W_S1

Spring Breakup Measured Discharge

Location: W_S1

Date & Time: June 3, 2020 4:00 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.

Final Discharge (cfs): 185

Average Velocity (fps): 2.1

Measurement Rating: Good

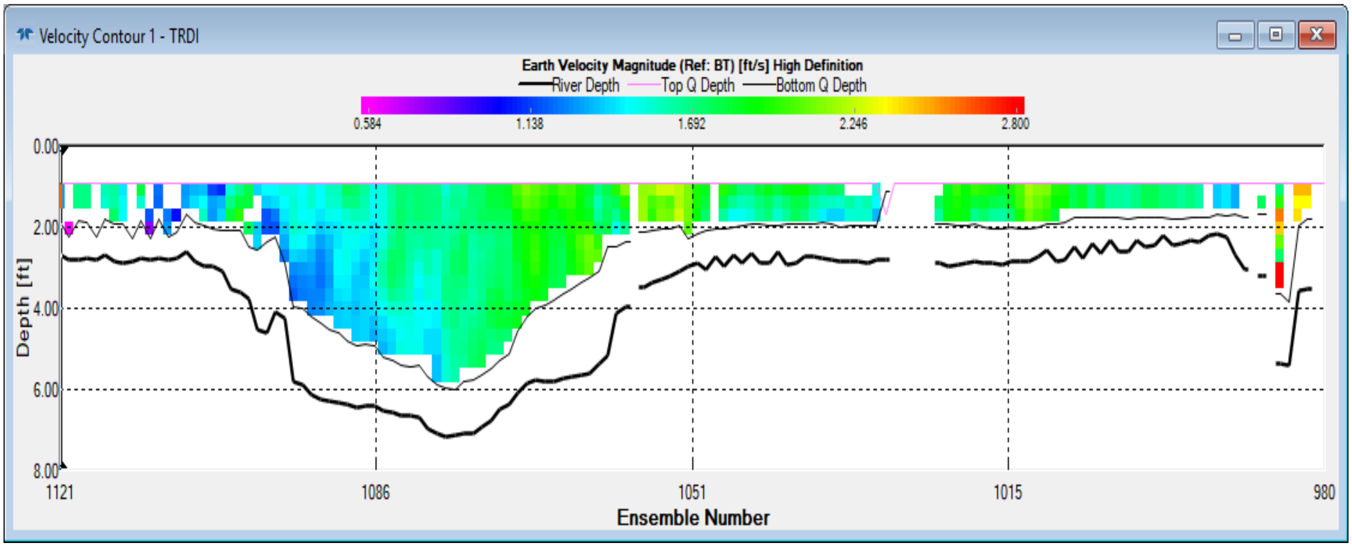
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.08%) did not exceed the recommended maximum of 5%.

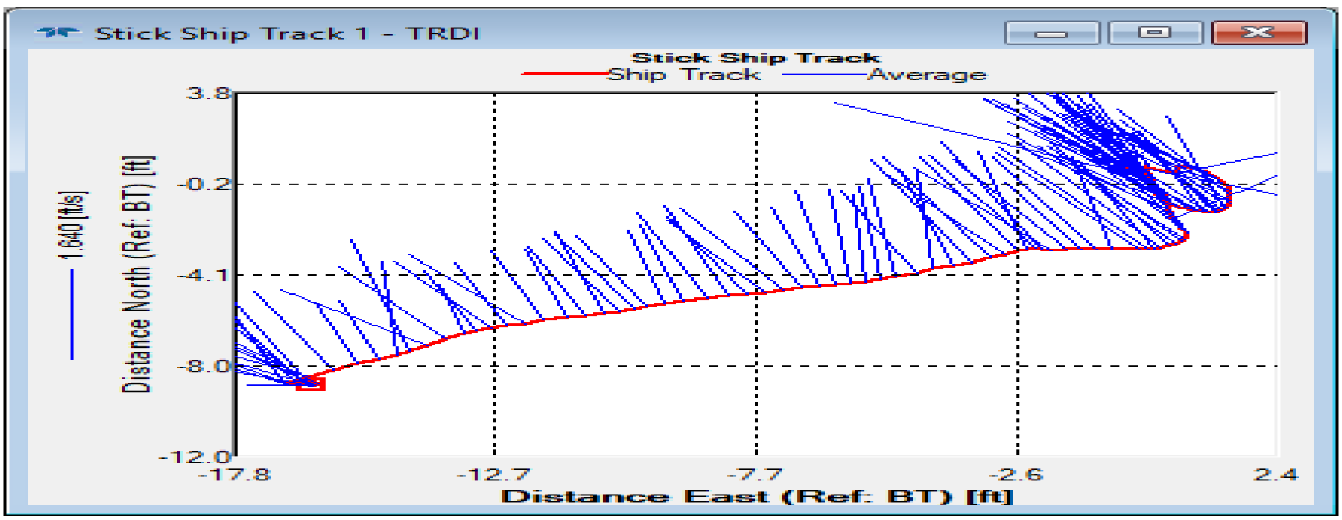
During the measurement, the channel was clear of ice and snow. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered good based on conditions at the time of the measurement.

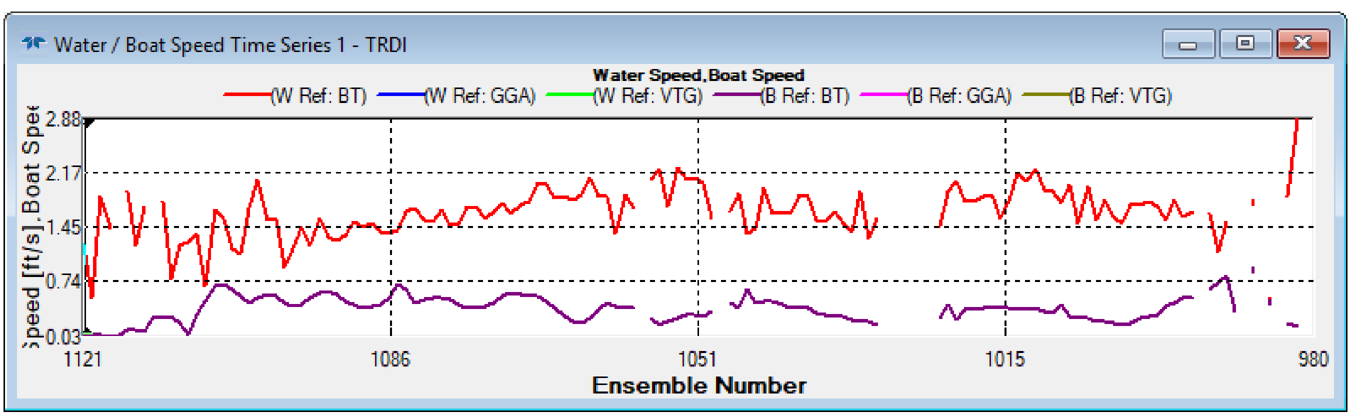
Table C.7: W_S1 June 3 Spring Breakup Measured Discharge Summary

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)	Q/A (ft/s)	Flow Speed (ft/s)
000	Right	183	-1.08%	84	3.70%	41	116	130	1.41	1.58
001	Left	188	1.62%	85	1.23%	41	118	130	1.44	1.60
002	Right	181	-2.16%	79	-2.47%	40	111	124	1.46	1.63
003	Left	188	1.62%	79	-2.47%	41	117	130	1.45	1.61
Average		**185**		**81**		**41**		**129**	**1.44**	**1.61**

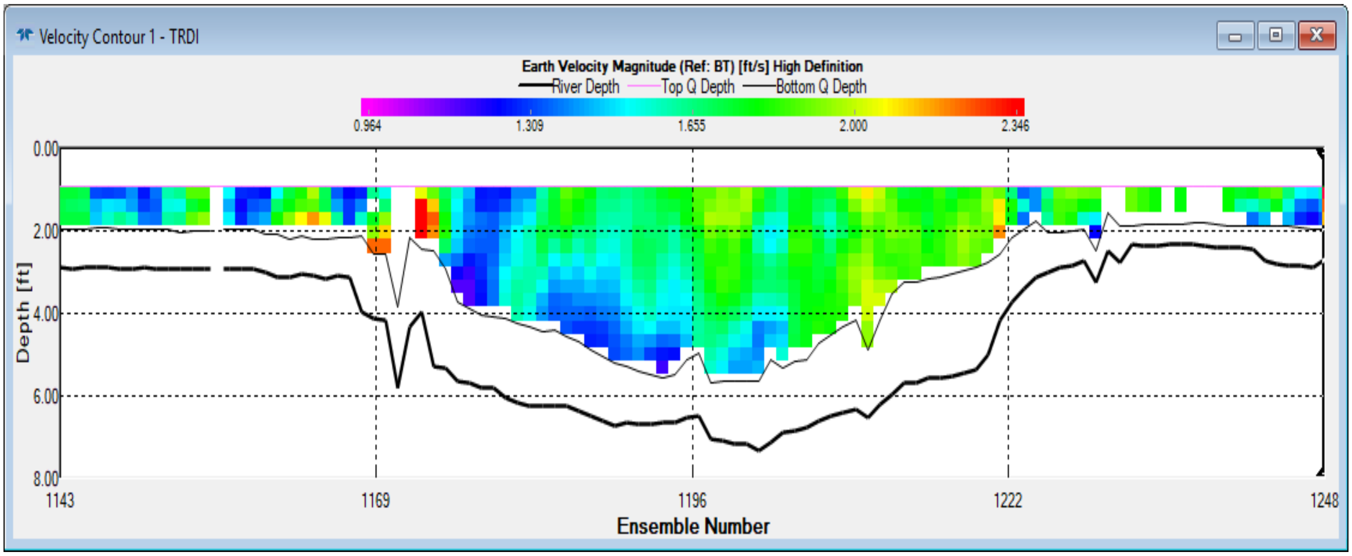
A. Transect W_S1-000 Raw Data Output

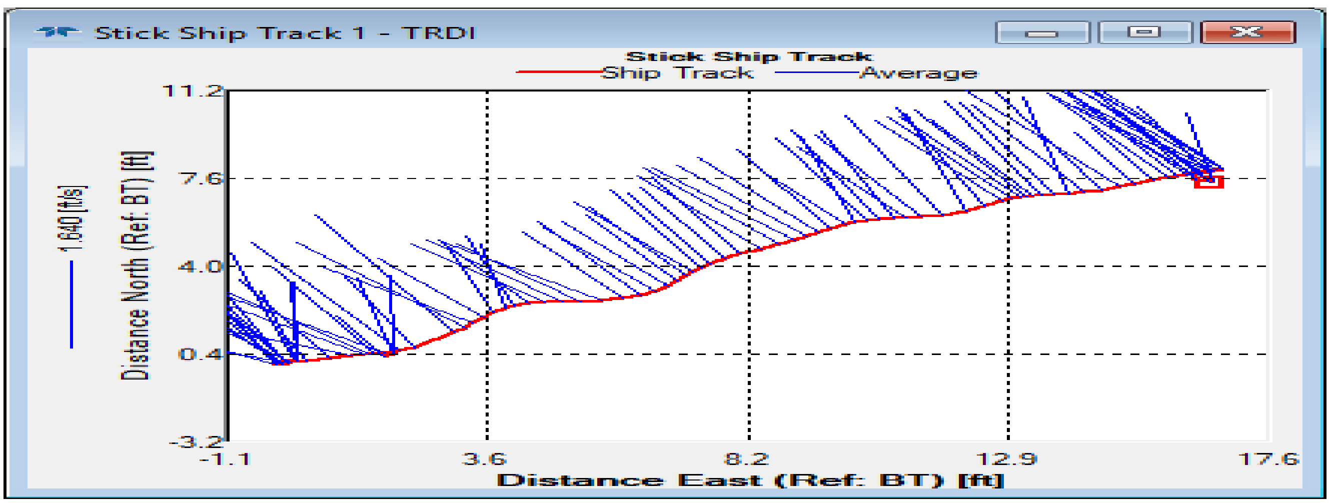


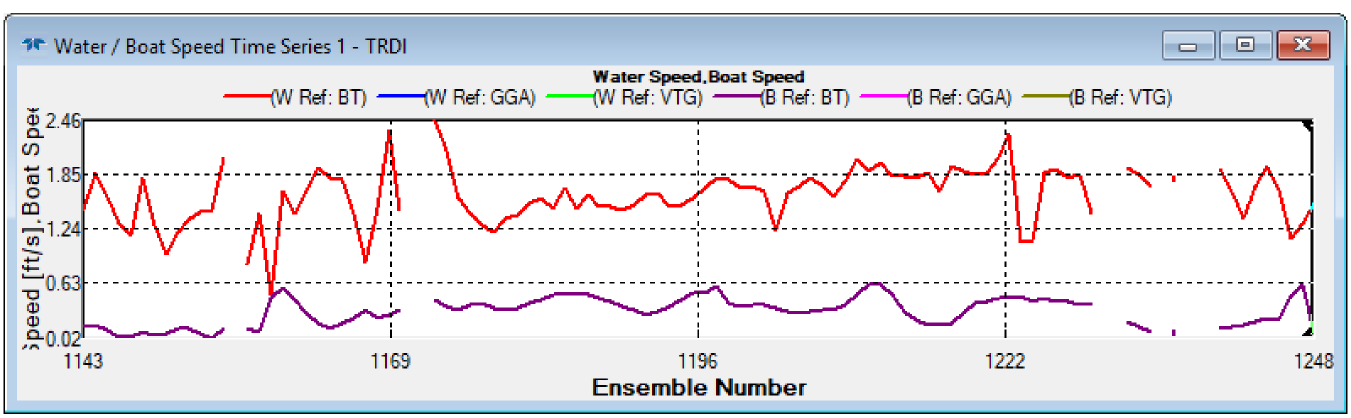




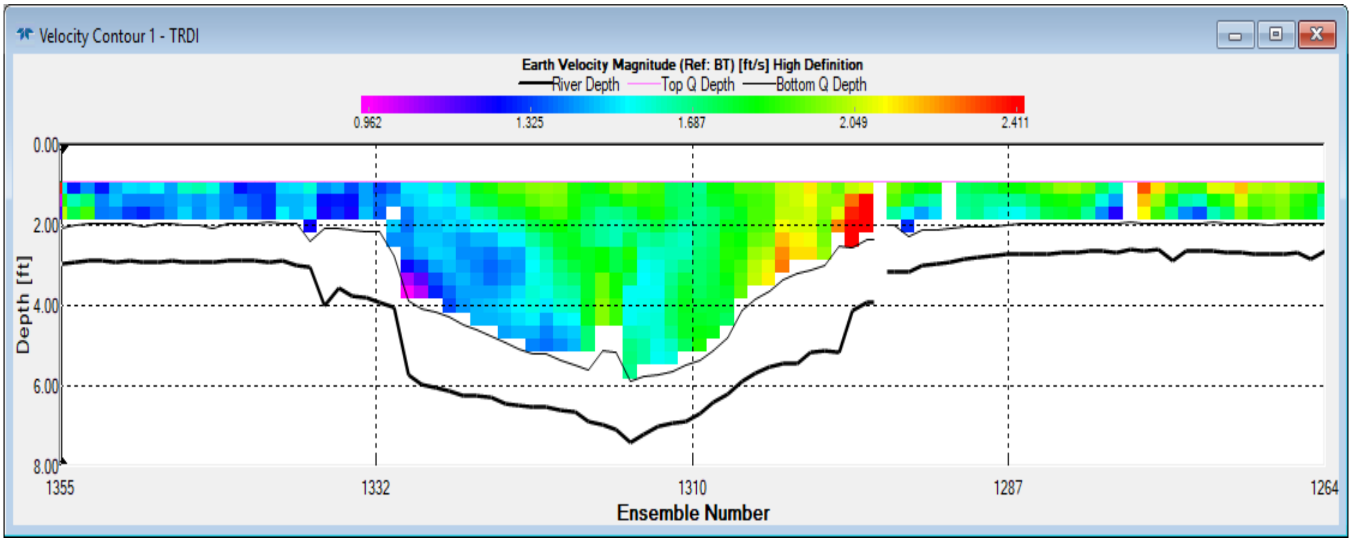
B. Transect W_S1-001 Raw Data Output

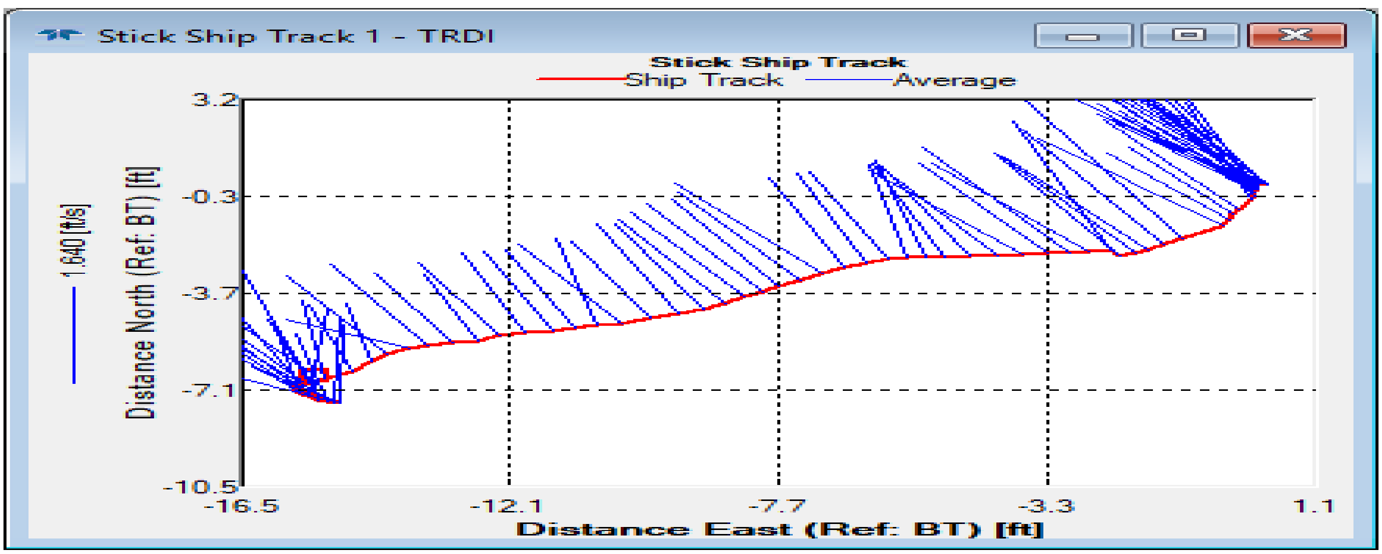


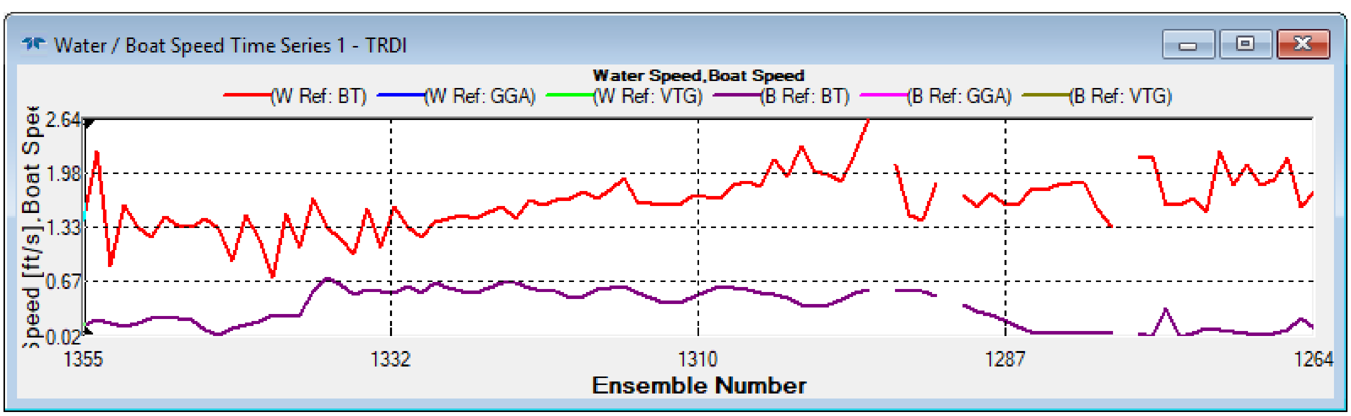




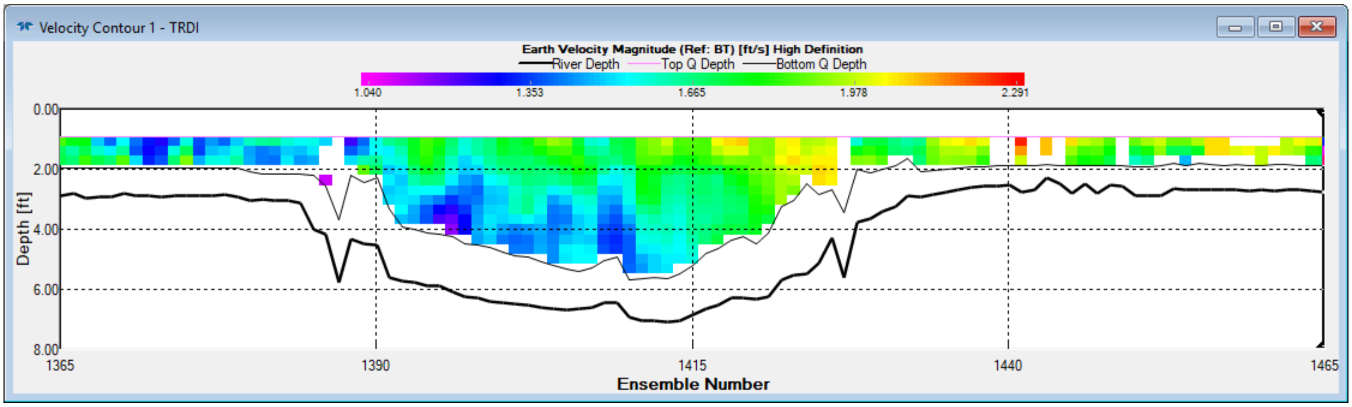
C. Transect W_S1-002 Raw Data Output

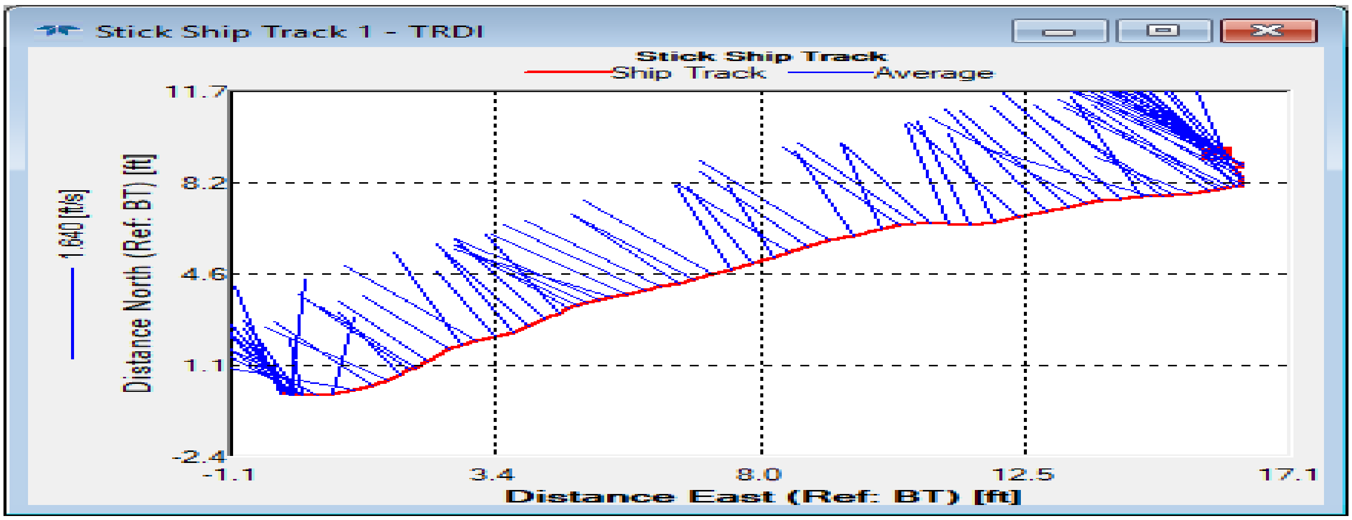


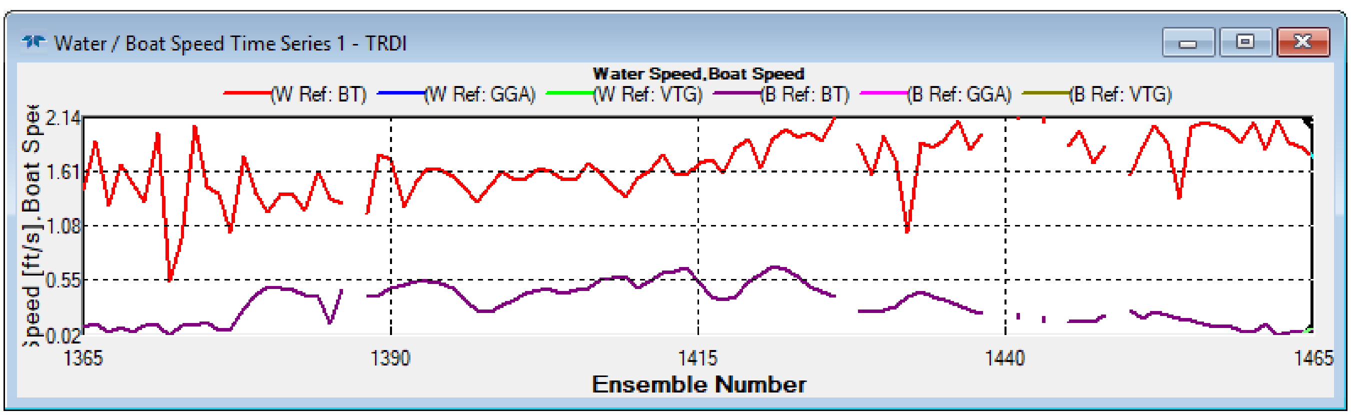




D. Transect W_S1-003 Raw Data Output







ConocoPhillips Alaska

0 200 400 Feet

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C7_W_S1.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

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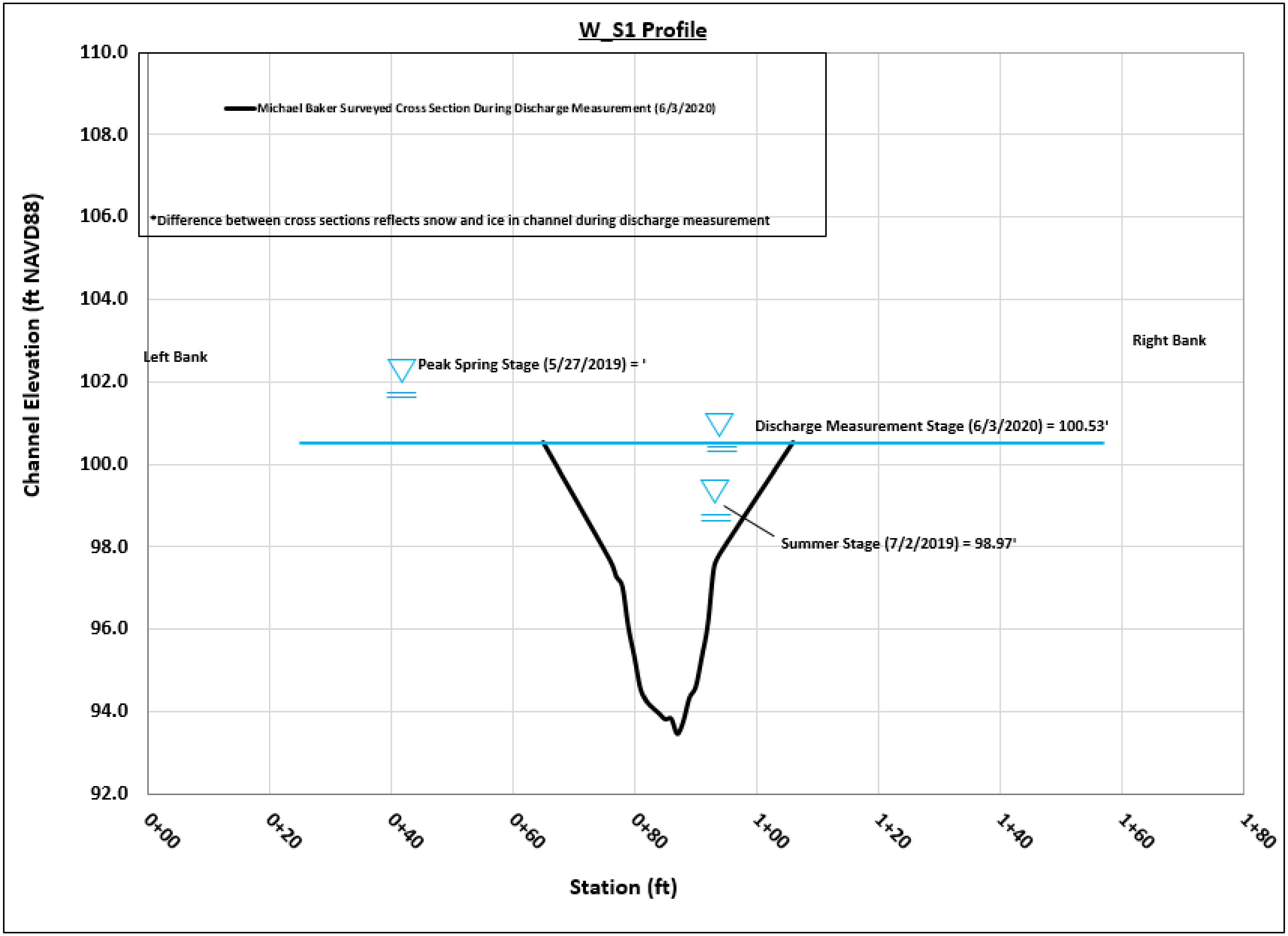
2020 Spring Breakup Willow 4a at W_S1 Plan

FIGURE C.7

Spring Breakup Cross-Section Profile



C.8 SWALE 1

Spring Breakup Measured Discharge

Table C.8: SW1 Spring Breakup Measured Discharge Summary

Date:	5/31/2020		**Time:**	1:00 PM	**Method:**	USGS Cross Section	
Location:	SW1		**Crew:**	KDB, SAO	**Depth:**	0.6 of measured depth	
Lat:	N 70.1361°		**Long:**	W 152.0133°	**Equipment:**	Hach Flow Meter	
Station (ft)	**Channel Elevation (ft NAVD88)**	**Measured Depth (ft)**	**Velocity (ft/s)**	**Section Width (ft)**	**Area (ft²)**	**Discharge (ft³/s)**	**Note**
0+05.0	79.94	0	-	-	-	-	RIGHT BANK
0+07.0	79.44	0.5	.25	1.5	0.75	0.19	Grass
0+09.0	78.94	1.0	0.81	1.0	1.0	0.81	Grass
0+10.0	78.74	1.2	1.36	1.0	1.20	1.63	Grass
0+11.0	78.94	1.0	1.70	1.0	1.0	1.70	Grass
0+12.0	78.94	1.0	1.72	1.0	1.0	1.72	Grass
0+13.0	79.04	0.90	1.98	1.0	0.90	1.78	Grass
0+14.0	79.14	0.80	1.85	1.0	0.80	1.48	Grass
0+15.0	79.04	0.90	1.54	1.0	0.90	1.38	Grass
0+16.0	79.04	0.90	1.50	1.0	0.90	1.35	Grass
0+17.0	78.94	1.0	1.15	1.0	1.0	1.15	Grass
0+18.0	79.04	0.90	1.33	1.0	0.90	1.2	Grass
0+19.0	79.14	0.80	0.46	1.0	0.80	0.37	Grass
0+20.0	79.14	0.80	1.77	1.0	0.80	1.42	Grass
0+21.0	79.24	0.70	1.36	1.0	0.70	0.95	Grass
0+22.0	79.24	0.70	1.47	1.0	0.70	1.03	Grass
0+23.0	79.34	0.60	0.84	1.0	0.60	0.51	Grass
0+24.0	79.04	0.90	1.01	1.0	0.90	0.91	Grass
0+25.0	78.94	1.0	0.65	1.0	1.0	0.65	Grass
0+26.0	79.14	0.80	1.49	1.0	0.80	1.19	Grass
0+27.0	79.14	0.80	0.32	1.0	0.80	0.25	Grass
0+28.0	79.14	0.80	0.84	1.0	0.80	0.67	Grass
0+29.0	79.14	0.80	0.24	1.0	0.80	0.19	Grass
0+30.0	79.24	0.70	0.31	1.0	0.70	0.22	Grass
0+31.0	79.44	0.50	0.42	1.0	0.50	0.21	Grass
0+32.0	79.54	0.4	0.21	1.0	0.40	0.08	Grass
0+33.0	79.94	0	-	-	-	-	LEFT BANK
Total Width (ft)	**Average Channel Elevation (ft NAVD88)**	**Average Depth (ft)**	**Average Velocity (ft/s)**	**-**	**Total Area (ft²)**	**Total Discharge (ft³/s)**	
28.0	79.20	0.80	1.03		21.2	23.2	

ConocoPhillips Alaska

Feet
0 200 400

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C8_SW1.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

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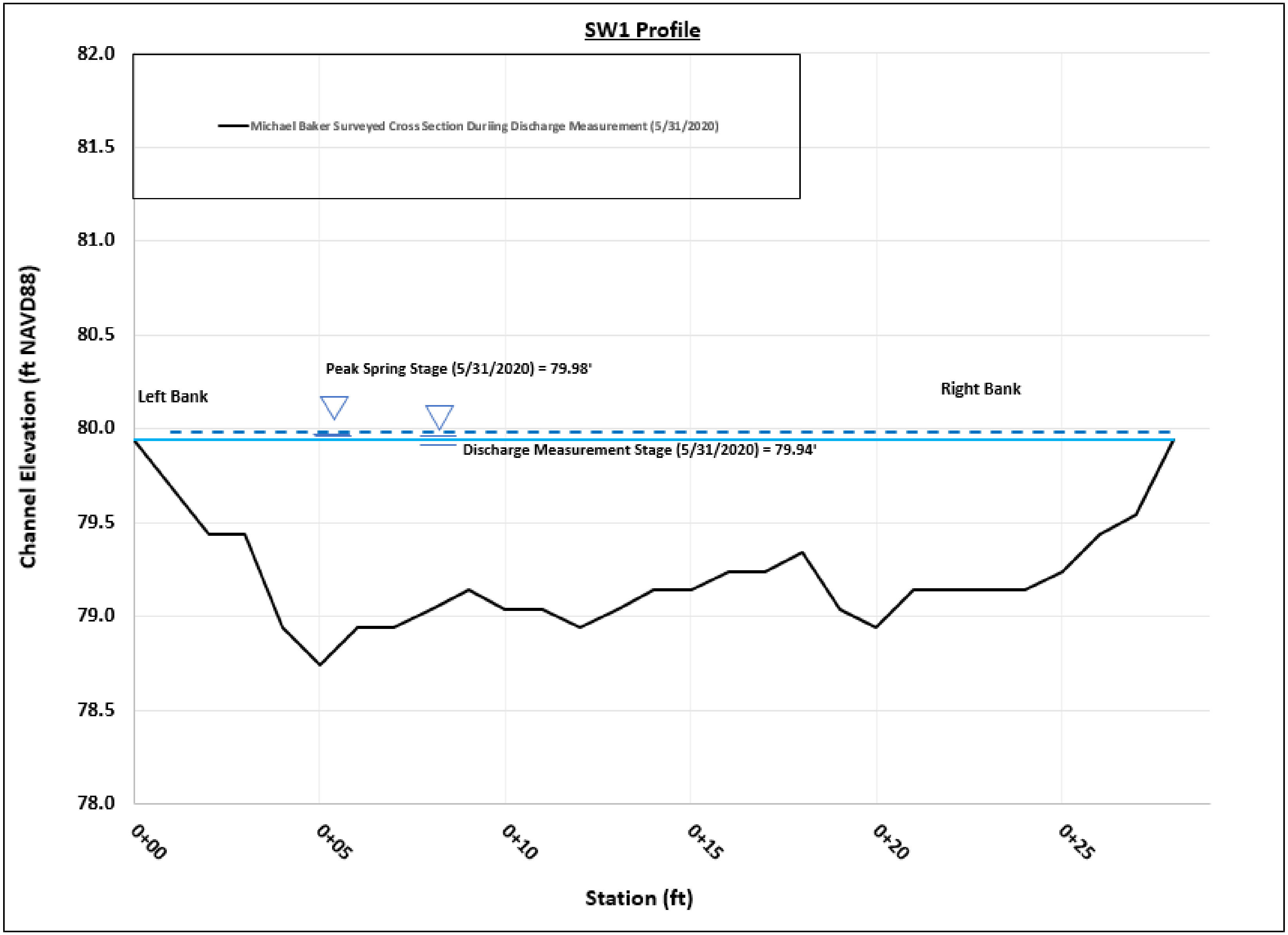
2020 Spring Breakup Swale 1 at SW1 Plan

FIGURE C.8

Spring Breakup Cross-Section Profile



C.9 SWALE 2

Spring Breakup Measured Discharge

Table C.9: SW2 Spring Breakup Measured Discharge Summary

Date:	5/31/2020		Time:	4:30 PM		Method:	USGS Cross Section
Location:	SW2		Crew:	KDB, SAO		Depth:	0.6 of measured depth
Lat:	N 70.1289°		Long:	W 152.0630°		Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft NAVD88)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+01.9	91.78	0	-	-	-	-	RIGHT BANK
0+02.0	81.68	0.1	0.16	0.55	0.06	0.01	Grass
0+03.0	81.58	0.2	0.33	1.0	0.20	0.07	Grass
0+04.0	81.58	0.2	0.27	1.0	0.20	0.05	Grass
0+05.0	81.58	0.2	0.31	1.0	0.20	0.06	Grass
0+06.0	81.38	0.4	0.26	1.0	0.40	0.10	Grass
0+07.0	81.28	0.5	0.34	1.0	0.50	0.17	Grass
0+08.0	81.28	0.5	0.27	1.0	0.50	0.14	Grass
0+09.0	81.28	0.5	0.40	1.0	0.50	0.20	Grass
0+10.0	81.38	0.4	0.18	1.0	0.40	0.07	Grass
0+11.0	81.28	0.5	0.45	0.75	0.38	0.17	Grass
0+11.5	81.08	0.7	0.79	0.5	0.35	0.28	Thalweg
0+12.0	81.28	0.5	0.20	0.75	0.38	0.07	Grass
0+13.0	81.38	0.4	0.14	1.0	0.40	0.06	Grass
0+14.0	81.28	0.5	0.32	1.0	0.50	0.16	Grass
0+15.0	81.38	0.4	0.04	1.0	0.40	0.02	Grass
0+16.0	81.38	0.4	0.12	1.0	0.40	0.05	Grass
0+17.0	81.58	0.2	0.02	1.0	0.20	0.00	Grass
0+18.0	81.58	0.2	0.06	1.0	0.20	0.01	Grass
0+19.0	81.48	0.3	0.03	1.0	0.30	0.01	Grass
0+20.0	81.68	0.1	0.03	1.25	0.13	0.00	Grass
0+21.5	81.78	0	-	-	-	-	LEFT BANK

Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
11.1	81.43	0.4	0.25	-	6.6	1.7

ConocoPhillips Alaska

0 200 400 Feet

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C9_SW2.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2018

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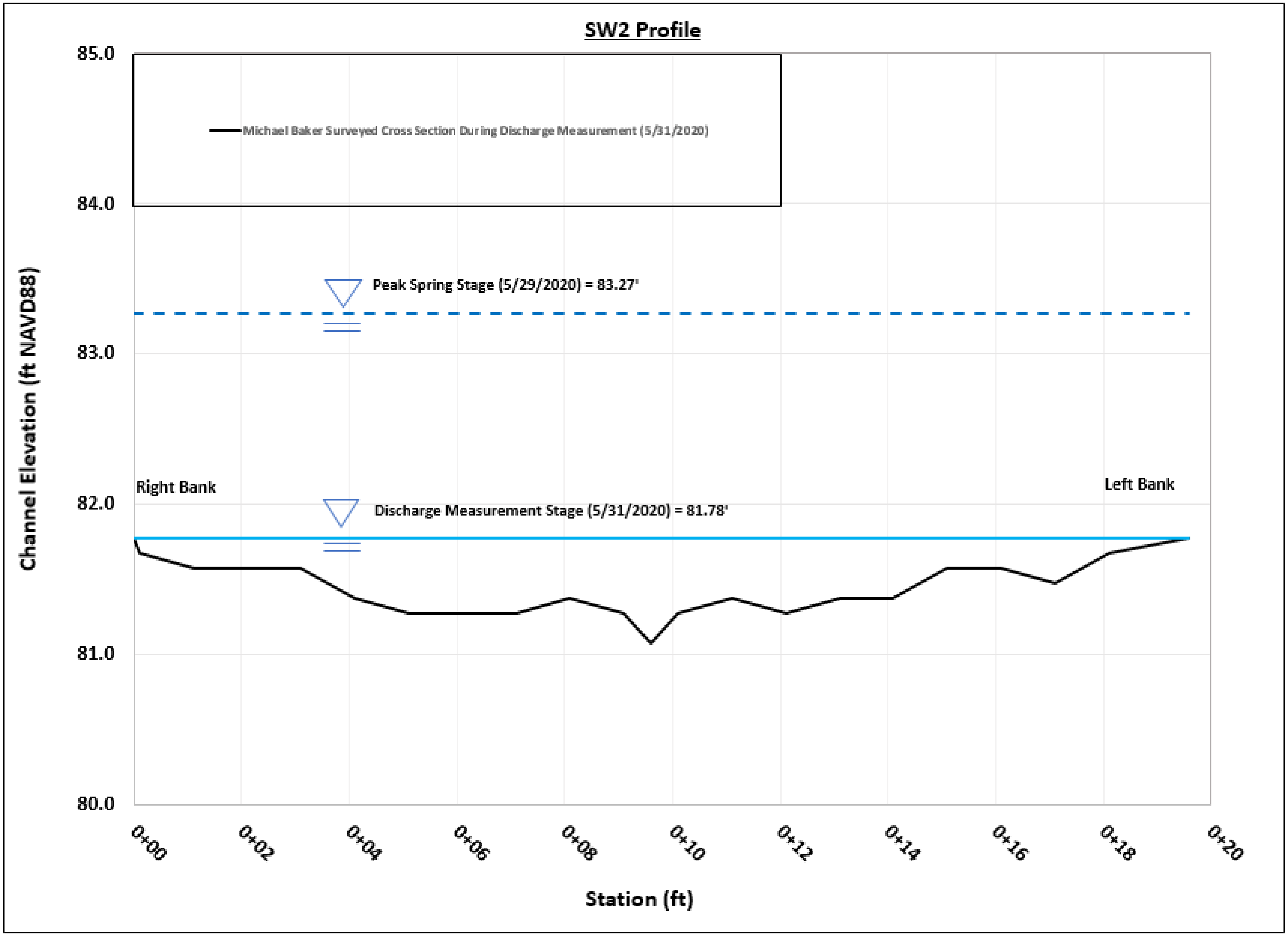
2020 Spring Breakup Swale 2 at SW2 Plan

FIGURE C.9

Spring Breakup Cross-Section Profile



C.10 SWALE 14

Spring Breakup Measured Discharge

Table C.10: SW14 Spring Breakup Measured Discharge Summary

Date:	5/31/2020		Time:	1:00 PM	Method:	USGS Cross Section	
Location:	SW14		Crew:	KDB, SAO	Depth:	0.6 of measured depth	
Lat:	N 70.1233°		Long:	W 152.0870°	Equipment:	Hach Flow Meter	
Station (ft)	Channel Elevation (ft NAVD88)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+02.0	83.75	0	-	-	-	-	LEFT BANK
0+01.0	83.45	0.30	0.23	1.0	0.30	0.07	Grass
0+02.0	83.45	0.30	0.30	1.0	0.30	0.09	Grass
0+03.0	83.30	0.45	0.32	1.0	0.45	0.15	Grass
0+04.0	83.35	0.40	0.35	1.0	0.40	0.14	Grass
0+05.0	82.85	0.90	0.19	0.75	0.68	0.13	Grass
0+05.5	82.75	1.00	0.94	0.5	0.50	0.47	Thalweg
0+06.0	82.65	1.10	1.24	0.5	0.55	0.68	Thalweg
0+06.5	82.65	1.10	1.12	0.5	0.55	0.61	Thalweg
0+07.0	82.50	1.25	0.59	0.75	0.94	0.56	Grass
0+08.0	82.55	1.20	0.96	1.0	1.20	1.15	Grass
0+09.0	82.65	1.10	0.90	1.0	1.10	0.99	Grass
0+10.0	82.75	1.00	0.66	1.0	1.00	0.66	Grass
0+11.0	82.85	0.90	0.37	1.0	0.90	0.33	Grass
0+12.0	83.15	0.60	0.11	1.0	0.60	0.07	Grass
0+13.0	83.25	0.50	0.08	1.0	0.50	0.04	Grass
0+14.0	83.35	0.40	0.09	1.0	0.40	0.04	Grass
0+15.0	83.50	0.25	0.08	1.0	0.25	0.02	Grass
0+16.0	83.75	0	-	-	-	-	RIGHT BANK
Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)	
16.0	83.00	0.8	0.50		10.6	6.2	

ConocoPhillips
Alaska

Feet
0 200 400

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C10_SW14.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2020

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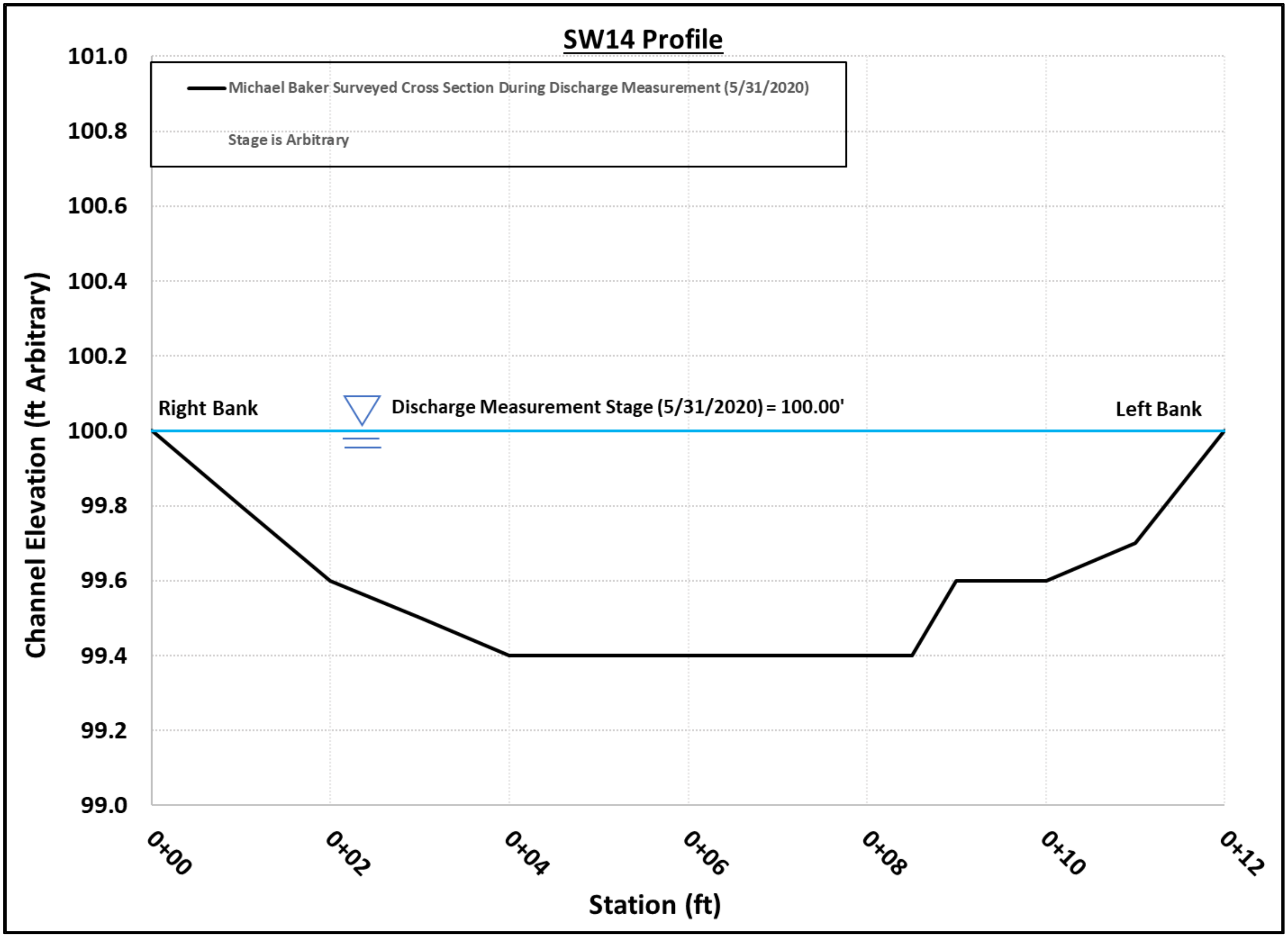
2020 Spring Breakup Swale 14 at SW14 Plan

FIGURE C.10

Spring Breakup Cross-Section Profile



C.11 MSL

Spring Breakup Measured Discharge

Table C.11: MSL Spring Breakup Measured Discharge Summaries

Date:	6/4/2020		Time:	10:45 AM	Method:	USGS Cross Section	
Location:	MSL Downstream		Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth	
Lat:	N 70.1125°		Long:	W 152.0785°	Equipment:	Hach Flow Meter	
Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+02.3	88.59	0.5	0.38	0.25	0.13	0.05	**Right Bank**
0+02.5	88.59	0.5	1.45	0.25	0.13	0.18	
0+02.8	88.49	0.6	2.05	0.25	0.15	0.31	
0+03.0	88.49	0.6	2.07	0.25	0.15	0.31	
0+03.3	88.39	0.7	2.30	0.25	0.18	0.40	
0+03.5	88.39	0.7	2.33	0.25	0.18	0.41	
0+03.8	88.34	0.75	2.17	0.25	0.19	0.41	
0+04.0	88.29	0.8	1.96	0.25	0.20	0.39	
0+04.3	88.19	0.9	1.72	0.25	0.23	0.39	
0+04.5	88.09	1	1.53	0.25	0.25	0.38	
0+04.8	87.99	1.1	1.20	0.25	0.28	0.33	
0+05.0	87.89	1.2	1.28	0.25	0.30	0.39	
0+05.3	87.99	1.1	0.91	0.25	0.28	0.25	
0+05.5	87.99	1.1	0.77	0.25	0.28	0.21	
0+05.8	87.99	1.1	1.07	0.25	0.28	0.29	
0+06.0	87.89	1.2	1.17	0.25	0.30	0.35	
0+06.3	87.89	1.2	0.99	0.25	0.30	0.30	
0+06.5	88.09	1	0.83	0.25	0.25	0.21	
0+06.8	88.19	0.9	0.72	0.25	0.23	0.16	
0+07.0	88.29	0.8	0.38	0.25	0.20	0.08	
0+07.3	88.39	0.7	0.08	0.25	0.18	0.01	Grass Interference
0+07.5	88.49	0.6	-	-	-	-	Grass Interference
0+07.8	88.79	0.3	-	-	-	-	Grass Interference
0+08.0	88.99	0.1	-	-	-	-	**Left Bank**
Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)	
5.8	88.3	0.8	1.33		4.6	5.8	

Date:	6/5/2020	Time:	1:00 PM	Method:	USGS Cross Section
Location:	MSL Downstream	Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth
Lat:	N 70.1125°	Long:	W 152.0785°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+03.3	88.89	0.2	0.30	0.25	0.05	0.01	**Right Bank**
0+03.5	88.59	0.5	0.33	0.25	0.13	0.04	
0+03.8	88.54	0.55	1.46	0.25	0.14	0.20	
0+04.0	88.49	0.6	1.98	0.25	0.15	0.30	
0+04.3	88.39	0.7	2.11	0.25	0.18	0.37	
0+04.5	88.39	0.7	2.25	0.25	0.18	0.39	
0+04.8	88.39	0.7	2.26	0.25	0.18	0.40	
0+05.0	88.29	0.8	2.22	0.25	0.20	0.44	
0+05.3	88.29	0.8	1.95	0.25	0.20	0.39	
0+05.0	88.19	0.9	1.68	0.25	0.23	0.38	
0+05.8	88.04	1.05	1.48	0.25	0.26	0.39	
0+06.0	87.89	1.2	1.40	0.25	0.30	0.42	
0+06.3	87.89	1.2	0.94	0.25	0.30	0.28	
0+06.5	87.94	1.15	0.81	0.25	0.29	0.23	
0+06.8	87.99	1.1	0.85	0.25	0.28	0.23	
0+07.0	87.94	1.15	1.02	0.25	0.29	0.29	
0+07.3	87.89	1.2	1.05	0.25	0.30	0.32	
0+07.5	87.99	1.1	0.90	0.25	0.28	0.25	
0+07.8	88.09	1	0.75	0.25	0.25	0.19	
0+08.0	88.19	0.9	0.69	0.25	0.23	0.15	
0+08.3	88.29	0.8	0.29	0.25	0.20	0.06	
0+08.5	88.39	0.7	0.16	0.25	0.18	0.03	
0+08.8	88.59	0.5	-	-	-	-	
0+09.0	88.79	0.3	-	-	-	-	**Left Bank**

Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
5.8	88.2	0.8	1.22		4.8	5.8

Date:	6/6/2020	Time:	1:00 PM	Method:	USGS Cross Section
Location:	MSL Upstream	Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth
Lat:	N 70.1124°	Long:	W 152.0780°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+01.5	89.08	0	-	-	-	-	**Right Edge of Water**
0+01.8	88.68	0.4	0.03	0.25	0.10	0.00	
0+02.0	88.48	0.6	0.06	0.25	0.15	0.01	
0+02.3	88.28	0.8	0.32	0.25	0.20	0.06	
0+02.5	88.18	0.9	0.48	0.25	0.23	0.11	
0+02.8	88.23	0.85	0.66	0.25	0.21	0.14	
0+03.0	88.23	0.85	0.82	0.25	0.21	0.17	
0+03.3	88.18	0.9	0.86	0.25	0.23	0.19	
0+03.5	88.13	0.95	0.88	0.25	0.24	0.21	
0+03.8	88.08	1	0.85	0.25	0.25	0.21	
0+04.0	88.03	1.05	0.89	0.25	0.26	0.23	
0+04.3	88.03	1.05	0.95	0.25	0.26	0.25	
0+04.5	88.18	0.9	1.33	0.25	0.23	0.30	
0+04.8	88.18	0.9	1.29	0.25	0.23	0.29	
0+05.0	88.18	0.9	1.37	0.25	0.23	0.31	
0+05.3	88.18	0.9	1.41	0.25	0.23	0.32	
0+05.5	88.18	0.9	1.45	0.25	0.23	0.33	
0+05.8	88.13	0.95	1.45	0.25	0.24	0.34	
0+06.0	88.08	1	1.52	0.25	0.25	0.38	
0+06.3	88.08	1	1.66	0.25	0.25	0.41	
0+06.5	88.08	1	1.59	0.25	0.25	0.40	
0+06.8	87.98	1.1	1.58	0.25	0.28	0.43	
0+07.0	87.88	1.2	1.44	0.25	0.30	0.43	
0+07.3	87.98	1.1	1.26	0.25	0.28	0.35	
0+07.5	87.98	1.1	0.94	0.25	0.28	0.26	
0+07.8	88.03	1.05	0.52	0.25	0.26	0.14	
0+08.0	88.08	1	0.15	0.25	0.25	0.04	Grass
0+08.3	88.13	0.95	0.07	0.25	0.24	0.02	Grass
0+08.5	88.38	0.7	-	-	-	-	Grass
0+08.8	88.58	0.5	-	-	-	-	Grass
0+09.0	89.08	0	-	-	-	-	**Left Edge of Water**

Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
7.3	88.1	0.9	0.99		6.2	6.3

Date:	6/7/2020		Time:	1:00 PM	Method:	USGS Cross Section	
Location:	MSL Upstream		Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth	
Lat:	N 70.1124°		Long:	W 152.0780°	Equipment:	Hach Flow Meter	
Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+03.0	89.06	0	-	-	-	-	**Right Edge of Water**
0+03.3	88.46	0.6	0.10	0.25	0.15	0.01	
0+03.5	88.26	0.8	0.26	0.25	0.20	0.05	
0+03.8	88.21	0.85	0.54	0.25	0.21	0.12	
0+04.0	88.21	0.85	0.66	0.25	0.21	0.14	
0+04.3	88.21	0.85	0.83	0.25	0.21	0.18	
0+04.5	88.16	0.9	0.89	0.25	0.23	0.20	
0+04.8	88.16	0.9	0.93	0.25	0.23	0.21	
0+05.0	88.06	1	0.83	0.25	0.25	0.21	
0+05.3	88.06	1	0.90	0.25	0.25	0.22	
0+05.5	88.06	1	0.97	0.25	0.25	0.24	
0+05.8	88.16	0.9	0.99	0.25	0.23	0.22	
0+06.0	88.16	0.9	1.10	0.25	0.23	0.25	
0+06.3	88.16	0.9	1.19	0.25	0.23	0.27	
0+06.5	88.16	0.9	1.31	0.25	0.23	0.30	
0+06.8	88.16	0.9	1.40	0.25	0.23	0.31	
0+07.0	88.11	0.95	1.49	0.25	0.24	0.35	
0+07.3	88.06	1	1.55	0.25	0.25	0.39	
0+07.5	88.06	1	1.55	0.25	0.25	0.39	
0+07.8	88.06	1	1.50	0.25	0.25	0.38	
0+08.0	88.01	1.05	1.35	0.25	0.26	0.35	
0+08.3	87.91	1.15	1.22	0.25	0.29	0.35	
0+08.5	87.91	1.15	1.11	0.25	0.29	0.32	
0+08.8	87.96	1.1	0.79	0.25	0.28	0.22	
0+09.0	88.06	1	0.48	0.25	0.25	0.12	
0+09.3	88.06	1	0.10	0.25	0.25	0.03	Grass
0+09.5	88.16	0.9	0.07	0.25	0.23	0.02	Grass
0+09.8	88.56	0.5	-	-	-	-	Grass
0+10.0	89.06	0	-	-	-	-	**Left Edge of Water**
Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)	
6.5	88.1	0.9	0.93		6.1	5.8	

Date:	6/7/2020	Time:	1:00 PM	Method:	USGS Cross Section
Location:	MSL Downstream	Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth
Lat:	N 70.1125°	Long:	W 152.0785°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+01.7	89.06	0	-	-	-	-	**Right Bank**
0+02.0	88.66	0.4	0.41	0.25	0.10	0.04	
0+02.3	88.56	0.5	0.31	0.25	0.13	0.04	
0+02.5	88.51	0.55	1.63	0.25	0.14	0.22	
0+02.8	88.41	0.65	2.15	0.25	0.16	0.35	
0+03.0	88.36	0.7	2.24	0.25	0.18	0.39	
0+03.3	88.36	0.7	2.26	0.25	0.18	0.40	
0+03.5	88.36	0.7	2.21	0.25	0.18	0.39	
0+03.8	88.26	0.8	2.02	0.25	0.20	0.40	
0+04.0	88.26	0.8	1.78	0.25	0.20	0.36	
0+04.3	88.16	0.9	1.68	0.25	0.23	0.38	
0+04.5	88.01	1.05	1.44	0.25	0.26	0.38	
0+04.8	87.91	1.15	1.25	0.25	0.29	0.36	
0+05.0	87.91	1.15	0.86	0.25	0.29	0.25	
0+05.3	87.96	1.1	0.72	0.25	0.28	0.20	
0+05.5	87.96	1.1	0.88	0.25	0.28	0.24	
0+05.8	87.91	1.15	1.06	0.25	0.29	0.30	
0+06.0	87.86	1.2	0.85	0.25	0.30	0.26	
0+06.3	88.01	1.05	0.60	0.25	0.26	0.16	
0+06.5	88.16	0.9	0.55	0.25	0.23	0.12	
0+06.8	88.26	0.8	0.47	0.25	0.20	0.09	
0+07.0	88.41	0.65	0.09	0.25	0.16	0.01	Grass
0+07.3	88.46	0.6	-	-	-	-	Grass
0+07.5	88.66	0.4	-	-	-	-	Grass
0+07.7	89.06	0	-	-	-	-	**Left Bank**

Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
5.8	88.2	0.8	1.21		4.5	5.3

Date:	6/8/2020	Time:	10:00 AM	Method:	USGS Cross Section
Location:	MSL Upstream	Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth
Lat:	N 70.1124°	Long:	W 152.0780°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+02.0	89.05	0	-	-	-	-	**Right Bank**
0+02.5	88.40	0.65	0.10	0.5	0.33	0.03	
0+03.0	88.20	0.85	0.54	0.375	0.32	0.17	
0+03.3	88.20	0.85	0.72	0.25	0.21	0.15	
0+03.5	88.20	0.85	0.83	0.25	0.21	0.18	
0+03.8	88.15	0.9	0.84	0.25	0.23	0.19	
0+04.0	88.15	0.9	0.84	0.25	0.23	0.19	
0+04.3	88.05	1	0.82	0.25	0.25	0.20	
0+04.5	88.05	1	0.94	0.25	0.25	0.24	
0+04.8	88.05	1	1.13	0.25	0.25	0.28	
0+05.0	88.15	0.9	1.15	0.25	0.23	0.26	
0+05.3	88.15	0.9	1.23	0.25	0.23	0.28	
0+05.5	88.15	0.9	1.29	0.25	0.23	0.29	
0+05.8	88.15	0.9	1.32	0.25	0.23	0.30	
0+06.0	88.15	0.9	1.42	0.25	0.23	0.32	
0+06.3	88.10	0.95	1.43	0.25	0.24	0.34	
0+06.5	88.10	0.95	1.44	0.25	0.24	0.34	
0+06.8	88.05	1	1.51	0.25	0.25	0.38	
0+07.0	88.05	1	1.48	0.25	0.25	0.37	
0+07.3	88.00	1.05	1.39	0.25	0.26	0.36	
0+07.5	87.95	1.1	1.14	0.25	0.28	0.31	
0+07.8	87.95	1.1	1.01	0.25	0.28	0.28	
0+08.0	88.05	1	0.56	0.375	0.38	0.21	Grass
0+08.5	88.15	0.9	0.15	0.5	0.45	0.07	Grass
0+09.0	89.05	0	-	-	-	-	**Left Bank**
Total Width (ft)	**Average Channel Elevation (ft NAVD88)**	**Average Depth (ft)**	**Average Velocity (ft/s)**	-	**Total Area (ft^2)**	**Total Discharge (ft^3/s)**	
6.5	88.1	0.9	1.07		6.0	5.7	

Date:	6/8/2020	Time:	11:30 AM	Method:	USGS Cross Section
Location:	MSL Downstream	Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth
Lat:	N 70.1125°	Long:	W 152.0785°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+03.8	89.041	0	-	-	-	-	**Right Edge of Water**
0+04.0	88.791	0.25	0.19	0.25	0.06	0.01	
0+04.3	88.541	0.5	0.42	0.25	0.13	0.05	
0+04.5	88.541	0.5	1.14	0.25	0.13	0.14	
0+04.8	88.441	0.6	1.93	0.25	0.15	0.29	
0+05.0	88.391	0.65	2.19	0.25	0.16	0.36	
0+05.3	88.391	0.65	2.35	0.25	0.16	0.38	
0+05.5	88.391	0.65	2.27	0.25	0.16	0.37	
0+05.8	88.341	0.7	2.17	0.25	0.18	0.38	
0+06.0	88.291	0.75	1.97	0.25	0.19	0.37	
0+06.3	88.191	0.85	1.75	0.25	0.21	0.37	
0+06.5	88.041	1	1.46	0.25	0.25	0.36	
0+06.8	87.941	1.1	1.26	0.25	0.28	0.35	
0+07.0	87.891	1.15	1.09	0.25	0.29	0.31	
0+07.3	87.941	1.1	0.84	0.25	0.28	0.23	
0+07.5	87.941	1.1	0.85	0.25	0.28	0.23	
0+07.8	87.891	1.15	1.08	0.25	0.29	0.31	
0+08.0	87.841	1.2	1.02	0.25	0.30	0.31	
0+08.3	87.941	1.1	0.82	0.25	0.28	0.23	
0+08.5	88.041	1	0.67	0.25	0.25	0.17	
0+08.8	88.141	0.9	0.69	0.25	0.23	0.16	
0+09.0	88.241	0.8	0.32	0.25	0.20	0.06	
0+09.3	88.341	0.7	0.03	0.25	0.18	0.01	Grass
0+09.5	88.541	0.5	-	-	-	-	Grass
0+10.0	87.941	1.1	-	-	-	-	**Left Edge of Water**

Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
6.3	88.2	0.8	1.21		4.4	5.5

Date:	7/2/2020	**Time:**	3:15 PM	**Method:**	USGS Cross Section
Location:	MSL Downstream	**Crew:**	SAO, UMIAQ	**Depth:**	0.6 of measured depth
Lat:	N 70.1125°	**Long:**	W 152.0785°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+03.0	88.93	0.35	-	-	-	-	**Right Edge of Water**
0+03.5	88.58	0.4	0.06	0.25	0.09	0.01	
0+03.8	88.53	0.5	0.72	0.25	0.10	0.07	
0+04.0	88.43	0.55	1.19	0.25	0.13	0.15	
0+04.3	88.38	0.6	1.65	0.25	0.14	0.23	
0+04.5	88.33	0.6	1.71	0.25	0.15	0.26	
0+04.8	88.33	0.65	1.72	0.25	0.15	0.26	
0+05.0	88.28	0.7	1.92	0.25	0.16	0.31	
0+05.3	88.23	0.8	1.41	0.25	0.18	0.25	
0+05.5	88.13	0.9	1.29	0.25	0.20	0.26	
0+05.8	88.03	1	1.20	0.25	0.23	0.27	
0+06.0	87.93	1	0.99	0.25	0.25	0.25	
0+06.3	87.93	1	0.84	0.25	0.25	0.21	
0+06.5	87.93	1	0.72	0.25	0.25	0.18	
0+06.8	87.93	1	0.69	0.25	0.25	0.17	
0+07.0	87.93	1	0.86	0.25	0.25	0.21	
0+07.3	87.93	0.95	0.78	0.25	0.25	0.20	
0+07.5	87.98	0.95	0.64	0.25	0.24	0.15	
0+07.8	87.98	0.8	0.51	0.25	0.24	0.12	
0+08.0	88.13	0.7	0.37	0.25	0.20	0.07	
0+08.3	88.23	0.6	0.22	0.25	0.18	0.04	
0+08.5	88.33	0	0.09	0.25	0.15	0.01	
0+09.0	88.93	0.35	-	-	-	-	**Left Edge of Water**

Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
6.0	88.2	0.7	0.93		4.0	3.7

Date:	9/16/2020	Time:	3:15 PM	Method:	USGS Cross Section
Location:	MSL Downstream	Crew:	SAO & KDB	Depth:	0.6 of measured depth
Lat:	N 70.1125°	Long:	W 152.0785°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft BPMSL)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+04.8	88.54	0.2	-	-	-	-	**Right Edge of Water**
0+05.0	88.34	0.4	0.15	0.25	0.10	0.02	
0+05.3	88.34	0.4	0.35	0.25	0.10	0.04	
0+05.5	88.34	0.4	0.61	0.25	0.10	0.06	
0+05.8	88.34	0.4	1.37	0.25	0.10	0.14	
0+06.0	88.34	0.4	1.42	0.25	0.10	0.14	
0+06.3	88.24	0.5	1.25	0.25	0.13	0.16	
0+06.5	88.24	0.5	1.21	0.25	0.13	0.15	
0+06.8	88.19	0.55	1.16	0.25	0.14	0.16	
0+07.0	88.14	0.6	1.12	0.25	0.15	0.17	
0+07.3	88.14	0.6	1.05	0.25	0.15	0.16	
0+07.5	88.14	0.6	0.64	0.25	0.15	0.10	
0+07.8	88.09	0.65	0.46	0.25	0.16	0.07	
0+08.0	88.09	0.65	0.09	0.25	0.16	0.01	
0+08.3	88.09	0.65	0.43	0.25	0.16	0.07	
0+08.5	88.04	0.7	0.47	0.25	0.18	0.08	
0+08.8	88.09	0.65	0.27	0.25	0.16	0.04	
0+09.0	88.14	0.6	0.44	0.25	0.15	0.07	
0+09.3	88.19	0.55	0.68	0.25	0.14	0.09	
0+09.5	88.24	0.5	0.26	0.25	0.13	0.03	
0+09.8	88.29	0.45	0.05	0.25	0.11	0.01	
0+10.0	88.34	0.4	0.01	0.25	0.10	0.00	
0+11.0	88.74	0	-	-	-	-	**Left Edge of Water**

Total Width (ft)	Average Channel Elevation (ft BPMSL)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
6.3	88.2	0.5	0.64		2.8	1.8

ConocoPhillips Alaska

Feet 0 200 400

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	PlanView_MSL.mxd

Gage Location

Station

Discharge Measurement Cross Section

Flow Direction

Imagery Source: CPAI, 2019

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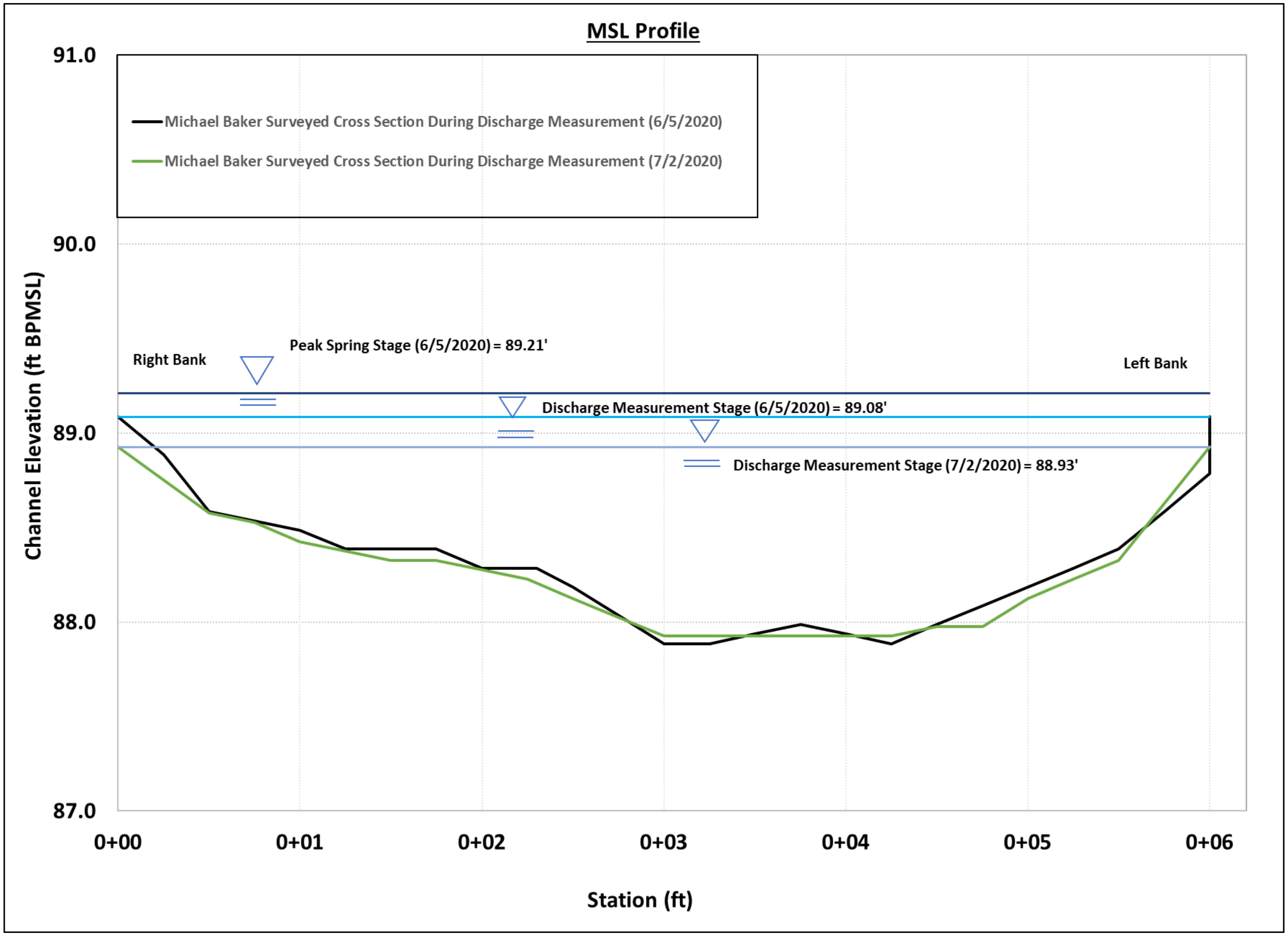
Fax: (907) 273-1699

2020 Spring Breakup Willow 3 MSL Plan

FIGURE C.11

Spring Breakup Cross-Section Profile



C.12 WILLOW 3 AT W3S

Spring Breakup Measured Discharge

Table C.12: W3S Spring Breakup Measured Discharge Summary

Date:	6/5/2020	Time:	3:45 PM	Method:	USGS Cross Section
Location:	W3S	Crew:	SAO, UMIAQ	Depth:	0.6 of measured depth
Lat:	N 70.1155°	Long:	W 152.0924°	Equipment:	Hach Flow Meter

Station (ft)	Channel Elevation (ft NAVD88)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+06.5	86.91	0	-	-	-	-	LEFT BANK
0+11.0	86.41	0.5	0.12	2.75	1.38	0.17	Grass
0+12.0	86.26	0.65	0.44	1.0	0.65	0.29	Grass
0+13.0	86.11	0.8	0.49	1.0	0.80	0.39	Grass
0+14.0	86.01	0.9	0.80	0.75	0.68	0.54	Grass
0+14.5	86.01	0.9	0.49	0.5	0.45	0.22	Grass
0+15.0	85.81	1.1	0.77	0.5	0.55	0.42	Grass
0+15.5	85.71	1.2	0.96	0.5	0.60	0.57	Grass
0+16.0	85.71	1.2	1.14	0.5	0.60	0.68	Grass
0+16.5	85.71	1.2	1.11	0.5	0.60	0.66	Grass
0+17.0	85.66	1.25	1.26	0.5	0.63	0.79	Grass
0+17.5	85.71	1.2	1.32	0.5	0.60	0.79	Grass
0+18.0	85.81	1.1	1.18	0.5	0.55	0.65	Grass
0+18.5	85.91	1.0	1.0	0.5	0.5	0.5	Grass
0+19.0	86.06	0.85	0.78	0.5	0.43	0.33	Grass
0+19.5	86.26	0.65	0.65	0.5	0.33	0.21	Grass
0+20.0	86.31	0.6	0.45	0.5	0.30	0.14	Grass
0+20.5	86.46	0.45	0.47	0.5	0.23	0.11	Grass
0+21.0	86.56	0.35	0.30	0.75	0.26	0.08	Grass
0+22.0	86.61	0.3	0.10	1.0	0.30	0.03	Grass
0+23.0	86.71	0.2	0.00	0.85	0.17	0.00	Grass
0+23.7	86.91	0	--	--	--	--	RIGHT BANK

Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
17.2	86.10	0.8	0.69		10.6	7.6

ConocoPhillips Alaska

Feet
0 200 400

Date:	12/10/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	178179
Checked:	KDB	File:	C12_W3S.mxd

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: CPAI, 2019

Michael Baker INTERNATIONAL

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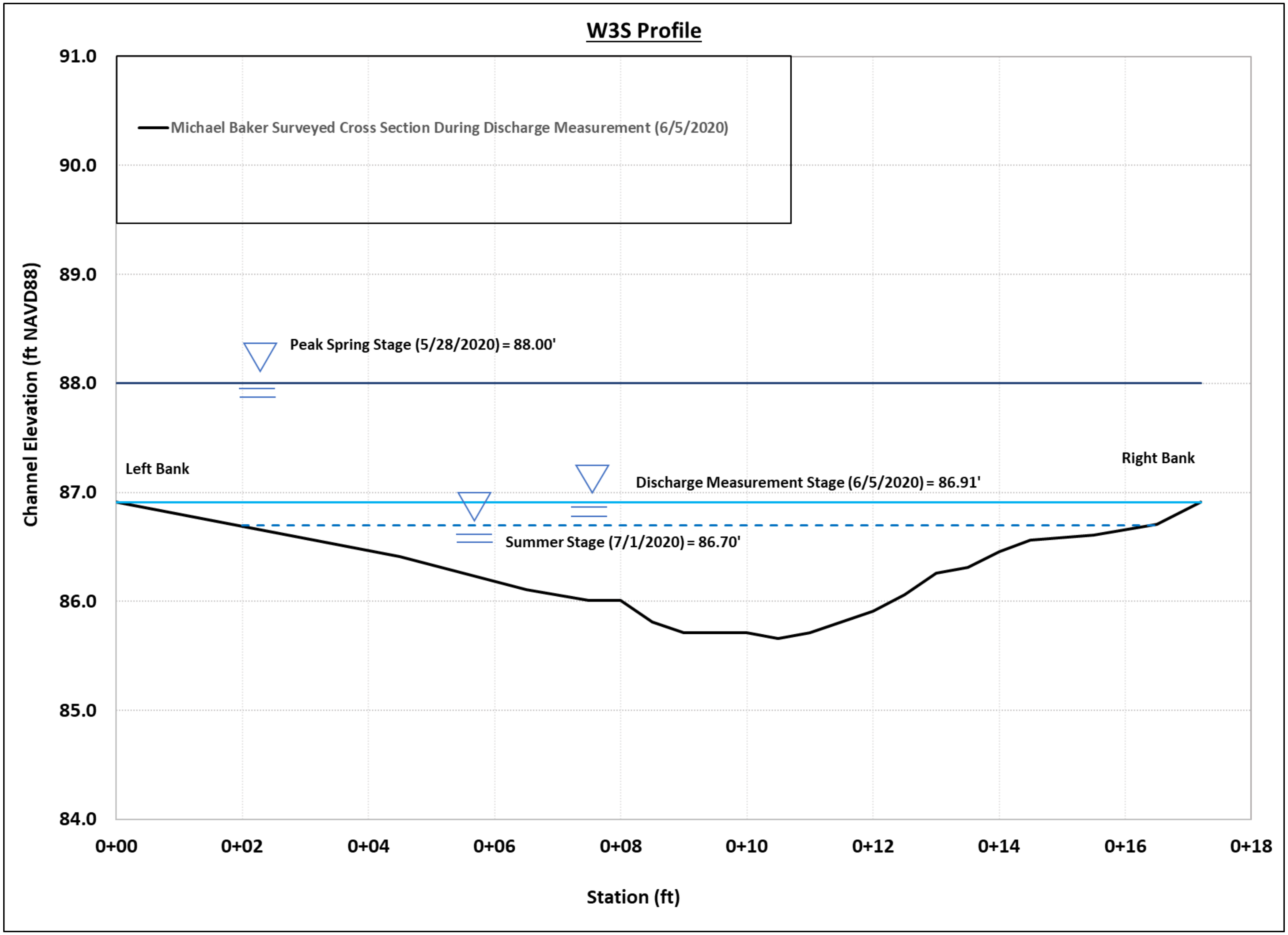
2020 Spring Breakup
Willow 3
W3S Plan

FIGURE C.12

Spring Breakup Cross-Section Profile



Appendix D Ice Road Crossings Breakup Photos

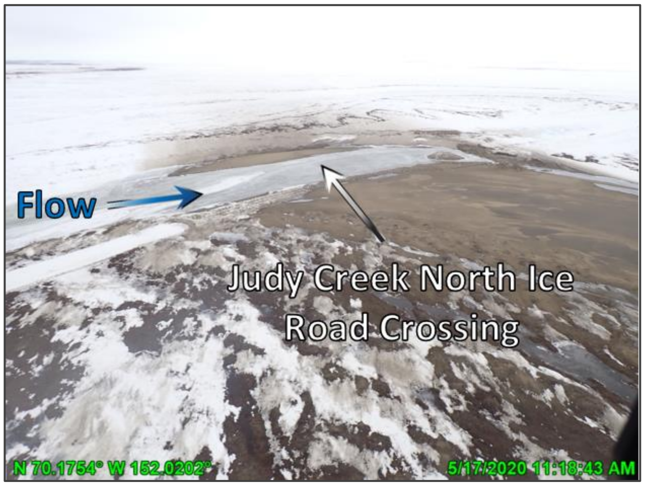


Photo D.1: Pre-breakup conditions at the slotted Judy Creek North ice road crossing, looking northwest; May 17, 2020

Photo D.2: Post-breakup conditions at the Judy Creek North ice road crossing, looking west; June 2, 2020

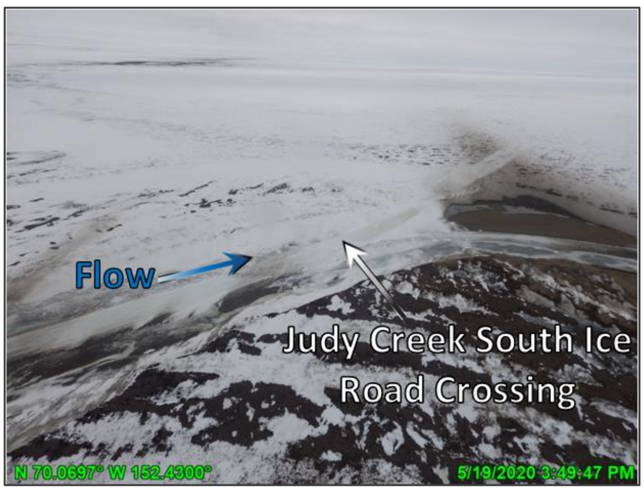


Photo D.3: Pre-breakup conditions at the Judy Creek South ice road crossing, looking west; May 19, 2020

Photo D.4: Peak stage at the Judy Creek South ice road crossing, looking west (downstream); May 31, 2020

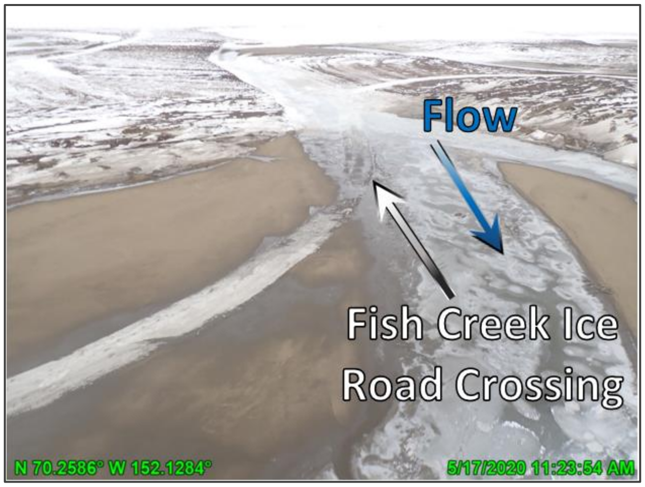


Photo D.5: Pre-breakup conditions at the slotted Fish Creek ice road crossing, looking southwest (upstream); May 17, 2020

Photo D.6: Post-breakup conditions at the Fish Creek ice road crossing, looking west; June 2, 2020

Photo D.7: Pre-breakup conditions at the slotted Kayyaaq Creek ice road crossing, looking southwest; May 17, 2020

Photo D.8: Post-breakup conditions at the Kayyaaq Creek ice road crossing, looking south (upstream); June 2, 2020

Photo D.9: Pre-breakup conditions at the slotted Willow 4 ice road crossing, looking north; May 29, 2020

Photo D.10: Peak stage at the Willow 4 ice road crossing, looking north (downstream); May 31, 2020

Photo D.11: Post-breakup conditions at the Willow 4 ice road crossing, looking east; June 3, 2020

Photo D.12: Pre-breakup conditions at the slotted No Name Creek #1 ice road crossing, looking southeast; May 19, 2020

Photo D.13: Breakup conditions at the No Name Creek #1 ice road crossing, looking north (downstream); May 31, 2020

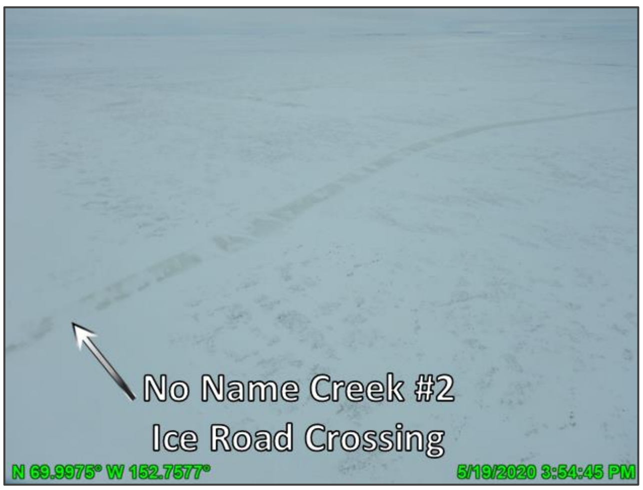


Photo D.14: Pre-breakup conditions at the slotted No Name Creek #2 ice road crossing, looking northeast; May 19, 2020

Photo D.15: Breakup conditions at the No Name Creek #2 ice road crossing, looking west (upstream); May 31, 2020

Photo D.16: Pre-breakup conditions at the slotted No Name Creek #3 ice road crossing, looking southeast; May 19, 2020

Photo D.17: Breakup conditions at the No Name Creek #3 ice road crossing, looking southwest (upstream); May 31, 2020

Photo D.18: Pre-breakup conditions at the slotted No Name Creek #4 ice road crossing, looking south; May 19, 2020

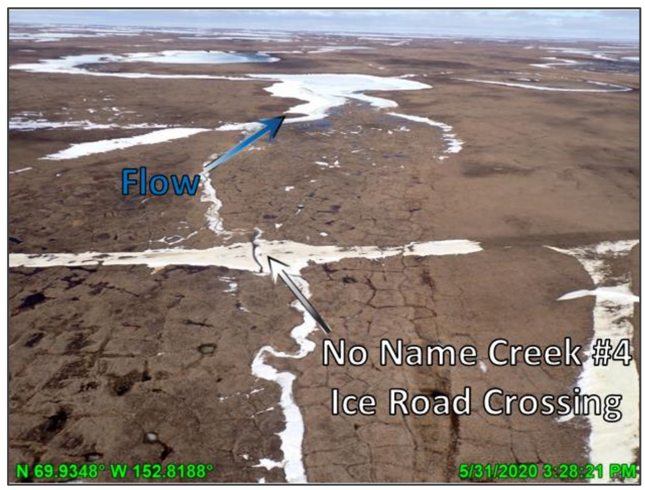


Photo D.19: Breakup conditions at the No Name Creek #4 ice road crossing, looking north (downstream); May 31, 2020

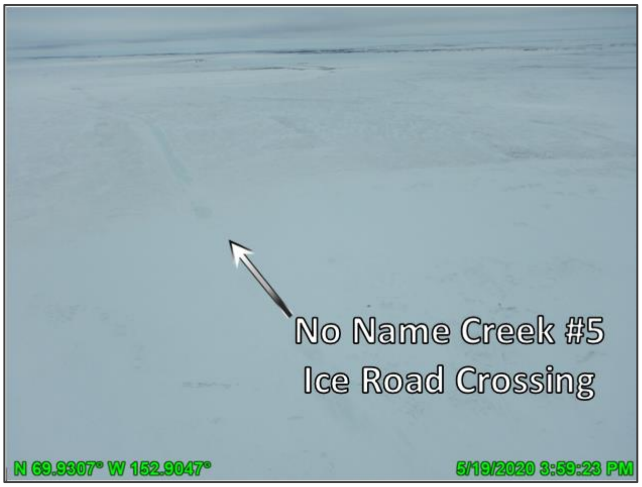


Photo D.20: Pre-breakup conditions at the slotted No Name Creek #5 ice road crossing, looking east; May 19, 2020

Photo D.21: Breakup conditions at the No Name Creek #5 ice road crossing, looking north (downstream); May 31, 2020

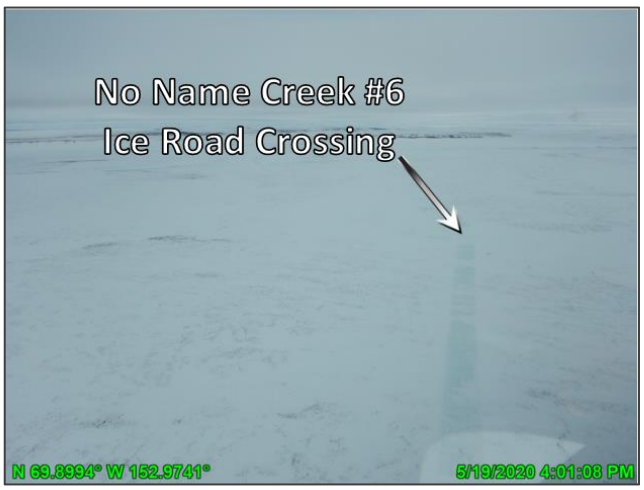


Photo D.22: Pre-breakup conditions at the slotted No Name Creek #6 ice road crossing, looking south; May 19, 2020

Photo D.23: Breakup conditions at the No Name Creek #6 ice road crossing, looking east; May 31, 2020

Photo D.24: Pre-breakup conditions at the slotted No Name Creek #7 ice road crossing, looking northwest; May 17, 2020

Photo D.25: Breakup progression at the No Name Creek #7 ice road crossing, looking northeast (downstream); May 30, 2020

Photo D.26: Post-breakup conditions at the No Name Creek #7 ice road crossing, looking west; June 2, 2020

Appendix E Flood Frequency Analysis

Table E.1 through Table E.5 present the peak discharge magnitude, frequency, standard error of prediction, confidence limits (prediction intervals) on the estimate of peak discharge magnitude, and equivalent years of record for J13.8, F55.5, UC1B, UC2C, and W_BS1. The results are determined using the USGS computer program which automates site-specific estimates of accuracy based on the USGS Water-Resources Investigations Report 03-4188. (USGS 2003).

Table E.1: Judy Creek at J13.8 Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	7,400	62.0	-38.3	3,300	16,500	0.9
20	5	10,900	59.0	-37.1	5,010	23,600	1.0
10	10	13,100	58.6	-36.9	6,050	28,200	1.3
4	25	15,800	59.2	-37.2	7,250	34,200	1.7
2	50	17,700	60.1	-37.6	8,040	38,800	2.0
1	100	19,500	61.5	-38.1	8,750	43,400	2.2
0.5	200	21,300	63.1	-38.7	9,380	48,100	2.4

Table E.2: Fish Creek at F55.5 Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	10,400	62.3	-38.4	4,630	23,300	0.9
20	5	15,200	59.3	-37.2	6,970	33,000	1.0
10	10	18,200	58.9	-37.1	8,390	39,400	1.3
4	25	21,800	59.5	-37.3	10,000	47,600	1.6
2	50	24,400	60.5	-37.7	11,100	53,700	1.9
1	100	26,900	61.8	-38.2	12,000	60,000	2.1
0.5	200	29,200	63.5	-38.8	12,900	66,500	2.3

Table E.3: Willow 2 at UC1B Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	300	61.9	-38.2	118	589	1.4
20	5	400	58.9	-37.1	194	913	1.6
10	10	500	58.6	-37.0	244	1,140	2.0
4	25	700	59.3	-37.2	303	1,430	2.6
2	50	800	60.3	-37.6	344	1,660	3.1
1	100	900	61.7	-38.2	382	1,900	3.4
0.5	200	900	63.4	-38.8	417	2,150	3.7

Table E.4: Judy Creek Kayyaaq at UC2C Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	1,600	61.3	-38.0	702	3,460	1.2
20	5	2,400	58.3	-36.8	1,110	5,130	1.3
10	10	2,900	57.9	-36.7	1,360	6,270	1.7
4	25	3,600	58.5	-36.9	1,660	7,730	2.1
2	50	4,100	59.5	-37.3	1,860	8,860	2.5
1	100	4,500	60.8	-37.8	2,050	10,000	2.8
0.5	200	5,000	62.5	-38.4	2,210	11,200	3.0

Table E.5: Willow 4 at W_BS1 Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record
%	years	cfs	+%	-%	5%	95%	
50	2	600	61.4	-38.1	258	1,280	1.3
20	5	900	58.5	-36.9	418	1,940	1.5
10	10	1,100	58.1	-36.8	520	2,400	1.9
4	25	1,400	58.7	-37.0	641	3,000	2.4
2	50	1,600	59.7	-37.4	724	3,460	2.8
1	100	1,800	61.1	-37.9	800	3,930	3.1
0.5	200	2,000	62.8	-38.6	869	4,420	3.4

2020 Willow Spring Breakup & Summer Monitoring & Hydrological Assessment