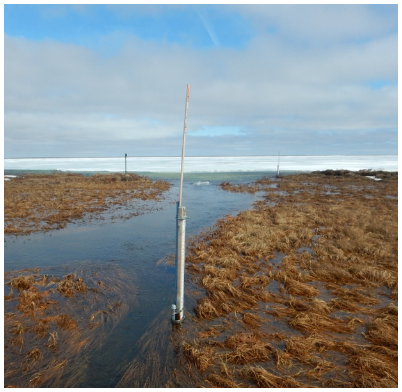
2019 Willow Spring Breakup & Summer Monitoring & Hydrological Assessment



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Prepared for:

ConocoPhillips
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MSA Contract No. 296937

Executive Summary

This report presents the results from the 2019 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 2019 spring breakup flood event in the Willow study area was characterized as a low magnitude, short duration event. 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 22 and June 3 across the monitoring area. During peak conditions, floodwater was generally confined within channels and swales. Stage was receding at all gage stations by June 7. 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 feet 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

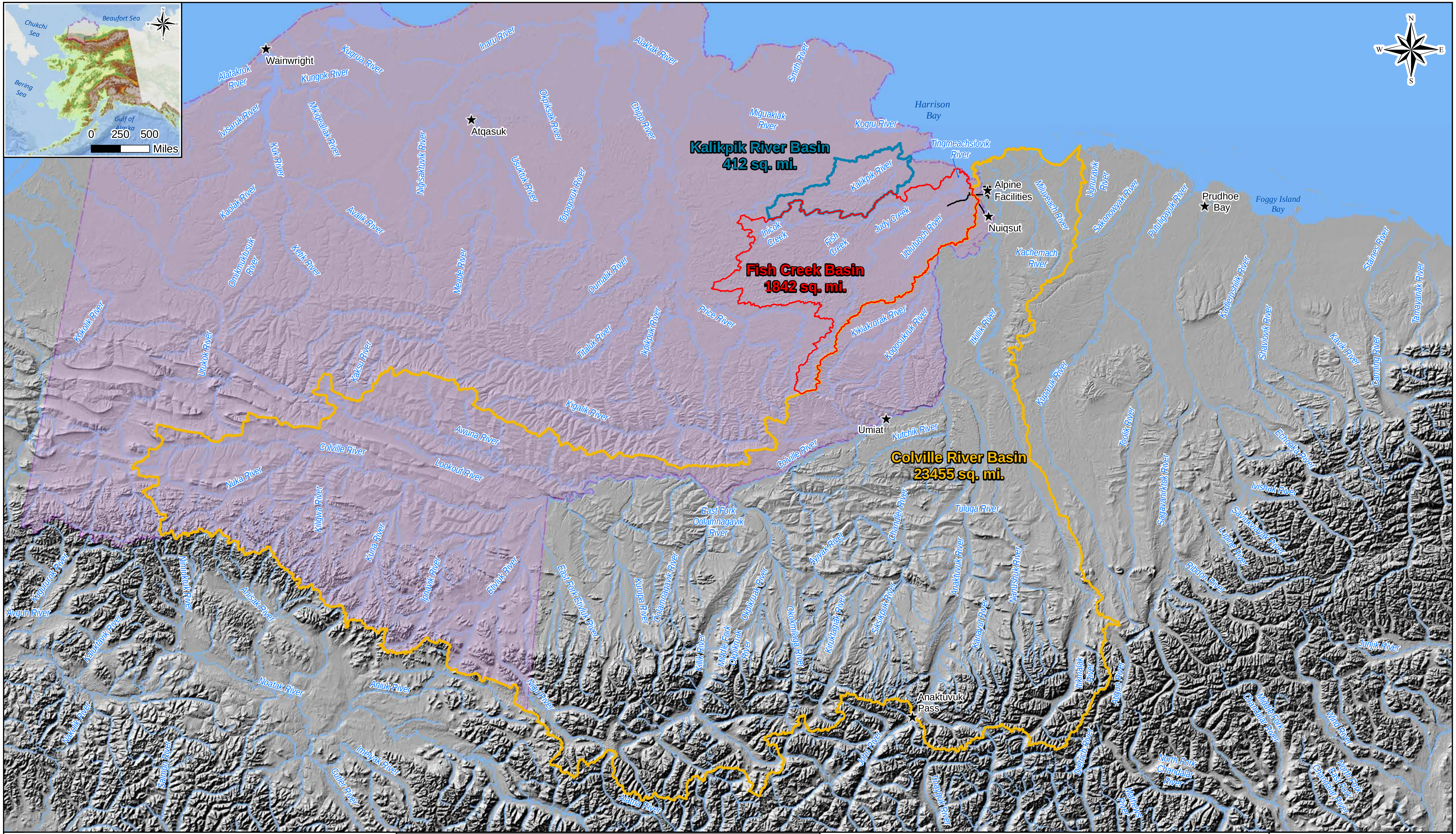
1. INTRODUCTION

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 in 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 becomes anchored to the bed and in shallow locations the entire water column freezes.

The 2019 Willow Spring Breakup and Summer Monitoring and Hydrological Assessment program included monitoring three new gage stations and 31 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 again in 2017 to 2019 (Michael Baker 2003, 2005a, 2005b, 2007, 2017, 2018, 2019).

The 2019 field program took place from April 19 to September 10. Spring breakup setup began on April 19 and concluded on May 6. Spring breakup monitoring began on May 9 and concluded on June 4. Summer monitoring was broken up into two field programs. During the first program, July 1 through July 4, 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 2020 spring breakup monitoring. 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.



★	Place Name
〰	Stream
—	Road
▨	NPRA Boundary
▢	Kalikpik River Basin
▢	Fish Creek Basin
▢	Colville River Basin

ConocoPhillips
Alaska

Miles
0 25 50

Date:	10/18/2019	Scale:	1 Inch = 25 Miles
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	Drainage_Basin_Overview.mxd

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Fish Creek
Kalikpik & Colville River
Drainage Basins

FIGURE: 1.1

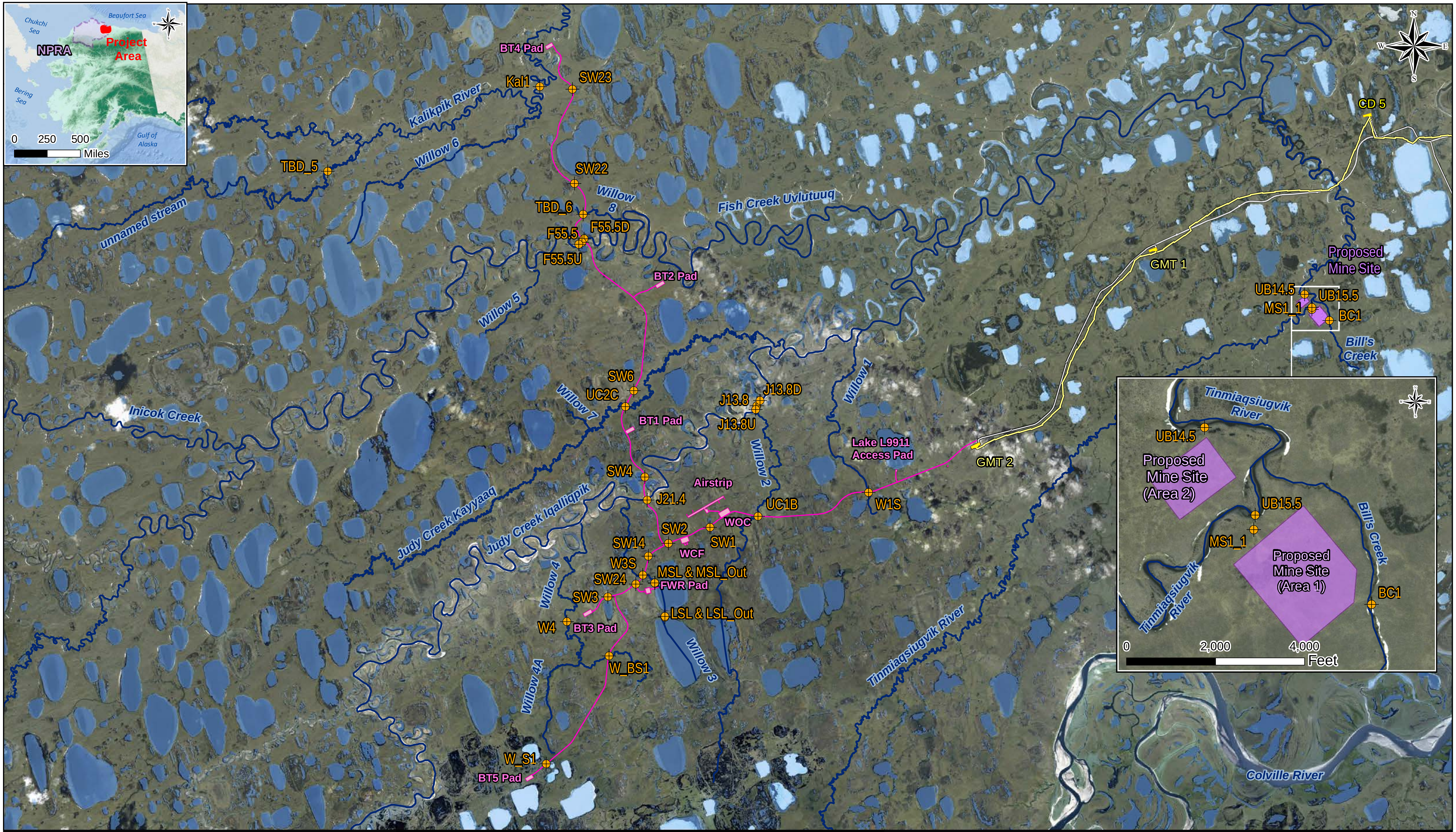
1.1 Monitoring Objectives

The primary objective of the 2019 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 either begin or continue the historical hydrologic record at the Willow gage stations presented below.



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0 1.25 2.5 5 Miles

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⌖ Gage Location

〰 Stream / River

Lake

Willow Alternative B

Proposed Road

Proposed Facility

Pipeline

Road

Facility

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2019 Willow
Gage Stations

Proposed Roads & Facilities

FIGURE: 1.2

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Miles
0 0.5 1 2

Date:	10/18/2019	Scale:	1 Inch = 1 Mile
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Checked:	GCY	File:	Gage_Stations_&_Roads_N.mxd

⌖ Gage Location
Stream / River
Lake

Willow Alternative B
Proposed Road
Proposed Pipeline

Proposed Facility

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2019 Willow
Gage Stations
North Detail

Proposed Roads & Facilities

FIGURE: 1.3

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Alaska

0 0.75 1.5 3
Miles

Date: 10/18/2019
Scale: 1 Inch = 1.5 Miles
Drawn: JEG
Project: 172339
Checked: GCY
File: Gage_Stations_&_Roads_S.mxd

⊕ Gage Location
〰 Stream / River
● Lake

Willow Alternative B
— Proposed Road
═ Proposed Pipeline
▨ Proposed Facility

═ GMT2 Road
═ Pipeline
🟨 Facility

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2019 Willow
Gage Stations
South Detail

Proposed Roads & Facilities

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	2	✓	✓	✓	✓	✓
		F55.5		2	✓	✓			
		F55.5D		2	✓	✓			
	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	3	✓	--	✓	--	--
		J13.8C		8	✓	--			
		J13.8D		3	✓	--			
		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	3	✓	✓	--	✓	--
	Kalikpik River	Kal1	Proposed Kalikpik River crossing, west bank	2	✓	✓	✓	✓	✓
Small Streams	Judy Creek Kayyaaq	UC2C	Proposed Judy Creek Kayyaaq crossing, east bank, approximately 13.0 RM upstream of Judy Creek	3	✓	✓	✓	--	✓
	Willow 1	W1S	Proposed Willow 1 crossing, in swale upstream of well-defined channel draining into Judy Creek	2	--	--	--	--	--
	Willow 2	UC1B	Proposed Willow 2 crossing, east bank, approximately 4.5 RM upstream of Judy Creek	3	✓	✓	✓	--	✓
	Willow 3	W3S	Proposed Willow 3 crossing, west of the middle and lower Snowman Lakes	2	✓	✓	✓	--	--
	Willow 4	W4	On Willow 4 adjacent to proposed BT3/WCF pad, approximately 5.3 RM upstream of Judy Creek	2	✓	✓	✓	--	--
		W_BS1	Proposed Willow 4 crossing, approximately 9 RM upstream of Judy Creek	2	✓	✓	✓	--	✓
	Willow 4a	W_S1	Proposed Willow 4A crossing,	2	✓	✓	✓	--	--
	Willow 8	TBD_6	Proposed Willow 8 crossing, 1.7 RM upstream of Fish Creek, well defined channel	2	✓	✓	✓	--	--
		SW22	Proposed Willow 8 crossing, 3 RM upstream of Fish Creek, poorly defined channel	2	✓	✓	✓	--	--
	TBD_5	TBD_5	Proposed crossing at TBD_5, a well-defined channel draining into the Kalikpik River	2	✓	✓	✓	--	--
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	3	--	--	✓	--	--
	Swale 2	SW2	Proposed crossing of Swale 2, a low-lying area with occasional beads between Lake M0014 and Judy Creek	2	✓	--	✓	--	--
	Swale 3	SW3	Proposed crossing of Swale 3, an area of channelized flow between paleolakes	1	--	✓	✓	--	--
	Swale 4	SW4	Proposed crossing of Swale 4, a polygon trough paleochannel of Judy Creek	3	--	--	✓	--	--
	Swale 6	SW6	Proposed crossing of Swale 6, a swale depression at the outlet of a paleolake	1	--	--	--	--	--
	Swale 14	SW14	Proposed crossing of Swale 14, a low-lying area between Lake M0014 and Judy Creek	2	✓	✓	✓	--	--
	Swale 23	SW23	Proposed crossing of Swale 23, a beaded swale flowing from unnamed lake to the Kalikpik River	2	--	--	✓	--	--
	Swale 24	SW24	Proposed crossing of Swale 24, a swale draining an unnamed lake into the W3S drainage area	1	--	--	✓	--	--
Minesite	Tinmiaqsiugvik River	UB14.5	On Tinmiaqsiugvik River at the proposed minesite	2	✓	--	✓	--	--
	Tinmiaqsiugvik River	UB15.5	On Tinmiaqsiugvik River at the proposed minesite	2	✓	--	--	--	--
	Bills Creek	BC1	Beaded stream that boarders the proposed minesite to the east	2	✓	✓	--	--	--
	MS1_1	MS1_1	Swale through proposed minesite	2	✓	--	--	--	--
Source Lakes	Lake M0015/R0056 (Middle Snowman Lake)	MSL	Northwest corner of middle Snowman Lake	2	✓	✓	--	--	--
	Willow 3/Lake M0015/R0056 (Middle Snowman Lake) outlet	MSL_OUT	Lake outlet, approximately 75 feet west of MSL	2	✓	✓	--	--	--
	Lake R0064 (Lower Snowman Lake)	LSL	Northwest corner of lower Snowman Lake	2	✓	✓	--	--	--
	Willow 3/Lake R0064 (aka Lower Snowman Lake) outlet	LSL_OUT	Lake outlet, approximately 135 feet northwest of LSL	2	✓	✓	--	--	--

2. METHODS

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.

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).

UMIAQ provided Hägglund track vehicle support to access gage stations during spring breakup setup before a helicopter was onsite for the late spring and summer season. Soloy provided helicopter support beginning the second week of May to access gage stations during spring breakup and summer monitoring.

2.2 Stage

Stage data was collected using hydrologic staff gages (gages) and PTs designed to measure stage. 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 feet, 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 23), 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

Primary PTs were installed at most gage stations and supported with gage measurement readings to provide a continuous record of stage. The PTs are designed to collect and store pressure and temperature data at discrete pre-set intervals of time; all PTs were programmed to collect data at 15-minute intervals. Each PT was housed in a small perforated galvanized steel pipe and secured to the base of the gage assembly. By sensing the absolute pressure of the atmosphere and water column above the PT, the depth of water above the sensor was calculated. Absolute pressure was accounted for using a barometric pressure sensor (Baro PT) at Judy Creek. During data processing, the PT measurements were adjusted to stage 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 installed at 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 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 GPS. At locations where UMIAQ did not directly survey the local control points, NAVD88 elevations were derived by correlating WSE data recorded from the PT, to *edge of water* values determined from UMIAQ's survey. Arbitrary elevations were retained at some of the swales, where survey data tied to NAVD88 was not collected.

REAL-TIME FLOOD MONITORING NETWORK

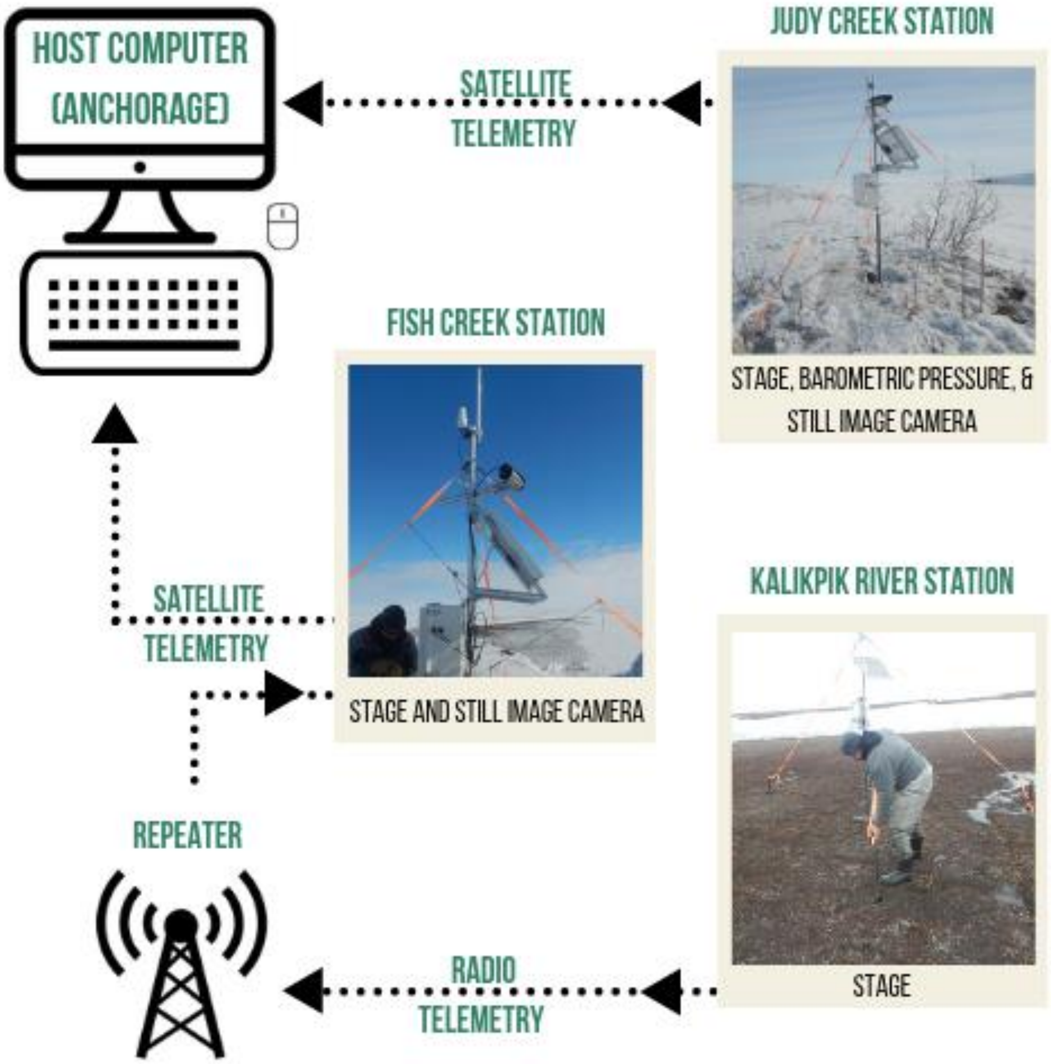
The ability to remotely monitor stage and river conditions helps reduce helicopter traffic, allows for round-the-clock monitoring of conditions, and allows for remote monitoring when helicopter travel is restricted due to weather or other circumstances. In addition, a network of real-time monitoring 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. Table 2.1 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 River (Kal1)	Radio link relayed through a repeater to Fish Creek station	• Stage

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



The Fish Creek and Judy Creek stations consisted of a digital camera, barometric PT (at Judy Creek), stage PT, datalogger, radio, 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.

A spread spectrum radio was connected to the datalogger for communicating with remote stations at the Kalikpik River. Low-resolution camera images, stage, and barometric pressure were stored on the datalogger and uploaded to the host computer every 4 hours via an Iridium satellite connection.

The remote station at the Kalikpik River 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.

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 feet 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 W4 and W_BS1
- Minesite at UB14.5
- Willow 4a at W_S1
- Willow 8 at TBD_6 and SW22
- Kalikpik River at Kal1
- Willow 3 at W3S
- Small swales and drainages at SW1, SW2, SW3, SW4, SW14, SW23, TBD_5, and SW24

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 at Judy Creek at J13.8 and 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, peak discharge can be 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.

Discharge results are estimates based on conditions at the time of data collection. In the spring, these conditions often include ice and snow effects and bed movement, which are highly dynamic and challenging to quantify. Ice and snow conditions can affect channel geometry, roughness, energy gradient, and stage, all of 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 2.2. 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.

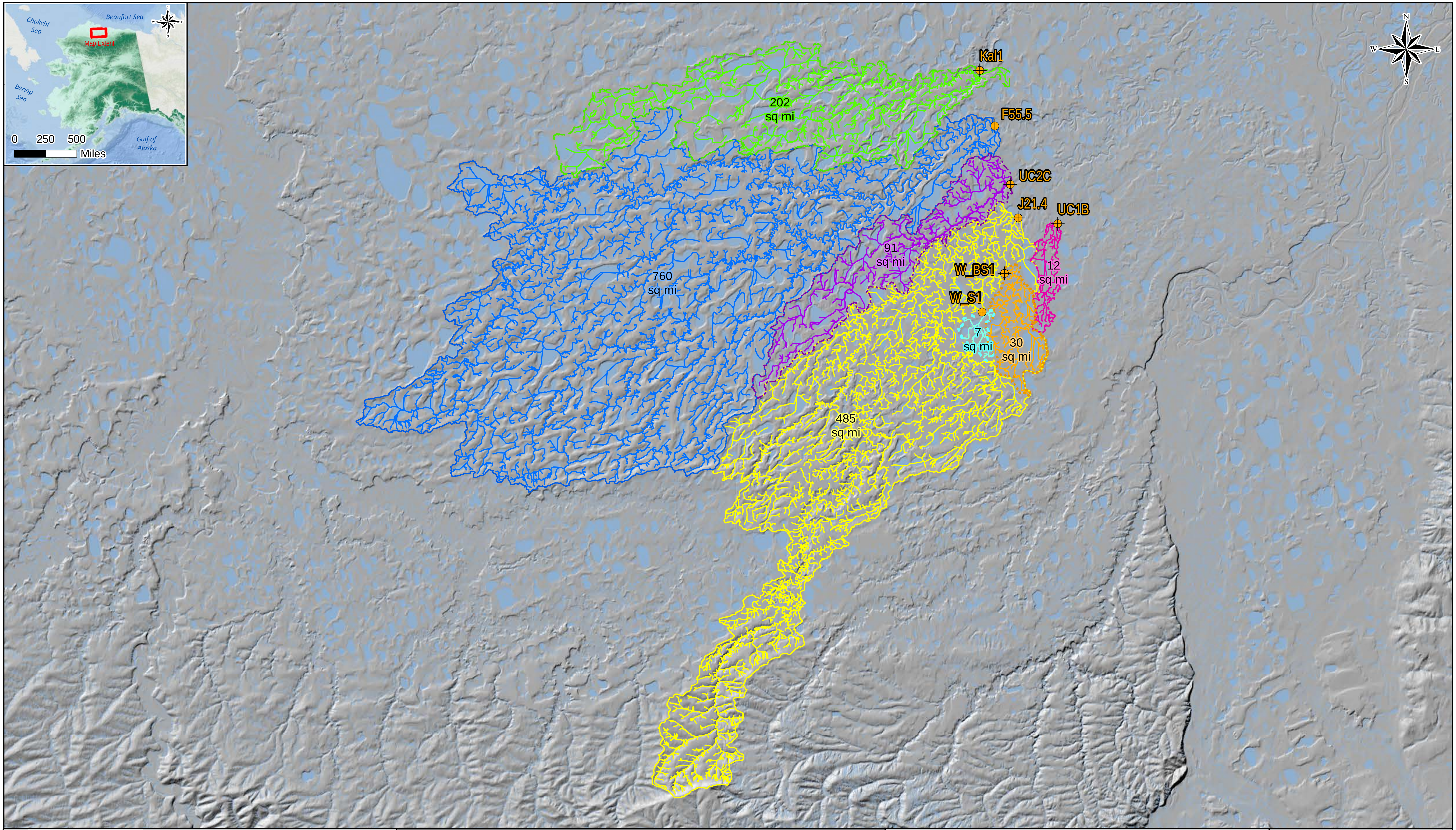
2.4 Flood Frequency Analysis

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 NAD83 Alaska State Plane Zone 4 and were manually adjusted to the respective gage station.



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Alaska

0 3.5 7 14 Miles

Date: 10/18/2019
Scale: 1 Inch = 7 Miles
Drawn: JEG
Project: 172339
Checked: GCY
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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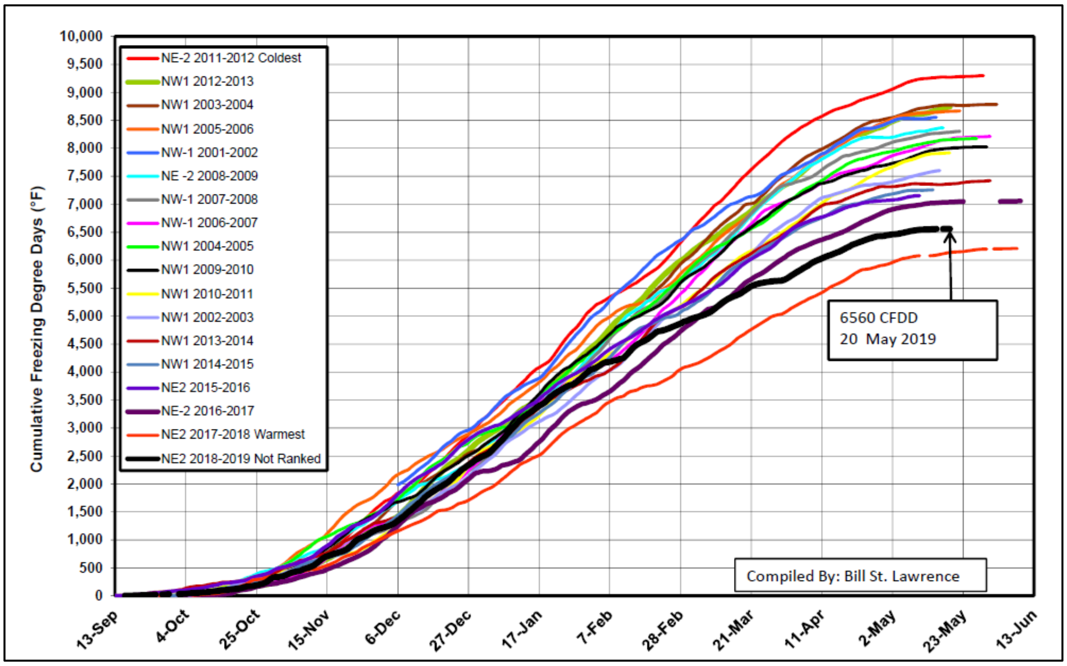
**Willow
Drainage
Basins**

FIGURE: 2.2

3. OBSERVATIONS

3.1 General Climatic Summary

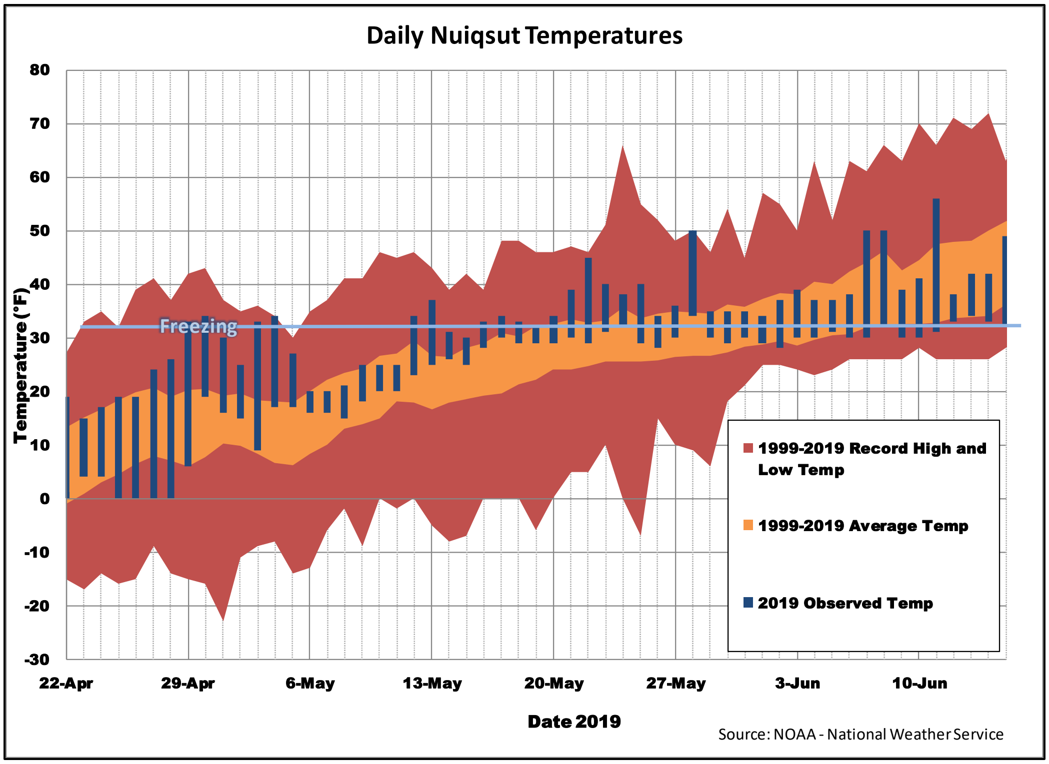
According to cumulative freezing degree-days (CFDD) measured at the National Petroleum Reserve Alaska (NPR-A) tundra monitoring station, the 2018-2019 (September – May) winter was the second warmest on record for the past 18 years, as shown in Graph 3.1 (ICE 2019).



Graph 3.1: NPR-A N. Tundra Monitoring Station, CFDD, Winters 2002-2019 (ICE 2019)

There is no NRCS North Slope snowpack data currently available for the 2018-2019 winter season, but general observations indicate snowpack was at or above normal levels in the Willow study area.

A warming trend in the Upper Colville River watershed (the Brooks Range foothills, as recorded at Umiat) started on April 23 (USGS 2019). Daily maximum temperatures began to exceed freezing on May 12 and daily minimum temperatures began to exceed freezing on May 21. In the CRD, daily maximum temperatures began to exceed freezing from April 29 to May 4, followed by a cooler period with sub-freezing temperatures (Weather Underground 2019). Daily high temperatures consistently exceeded freezing on May 16 and continued through the breakup monitoring period. Daily minimum temperatures remained below freezing through the breakup monitoring period. 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: NWS, 2019).



Source: NOAA - National Weather Service

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 20 at Judy Creek Kayyaaq. Stage increased throughout Willow from May 20 to May 27. Peak stage conditions generally occurred in the major Willow streams near May 27. During peak stage, snow and ice in the drainages confined meltwater and elevated stage. By June 4, most major drainages were free of ice and snow and stage was decreasing (Photo 3.1). Effects from ice jamming was minimal across the Willow area.

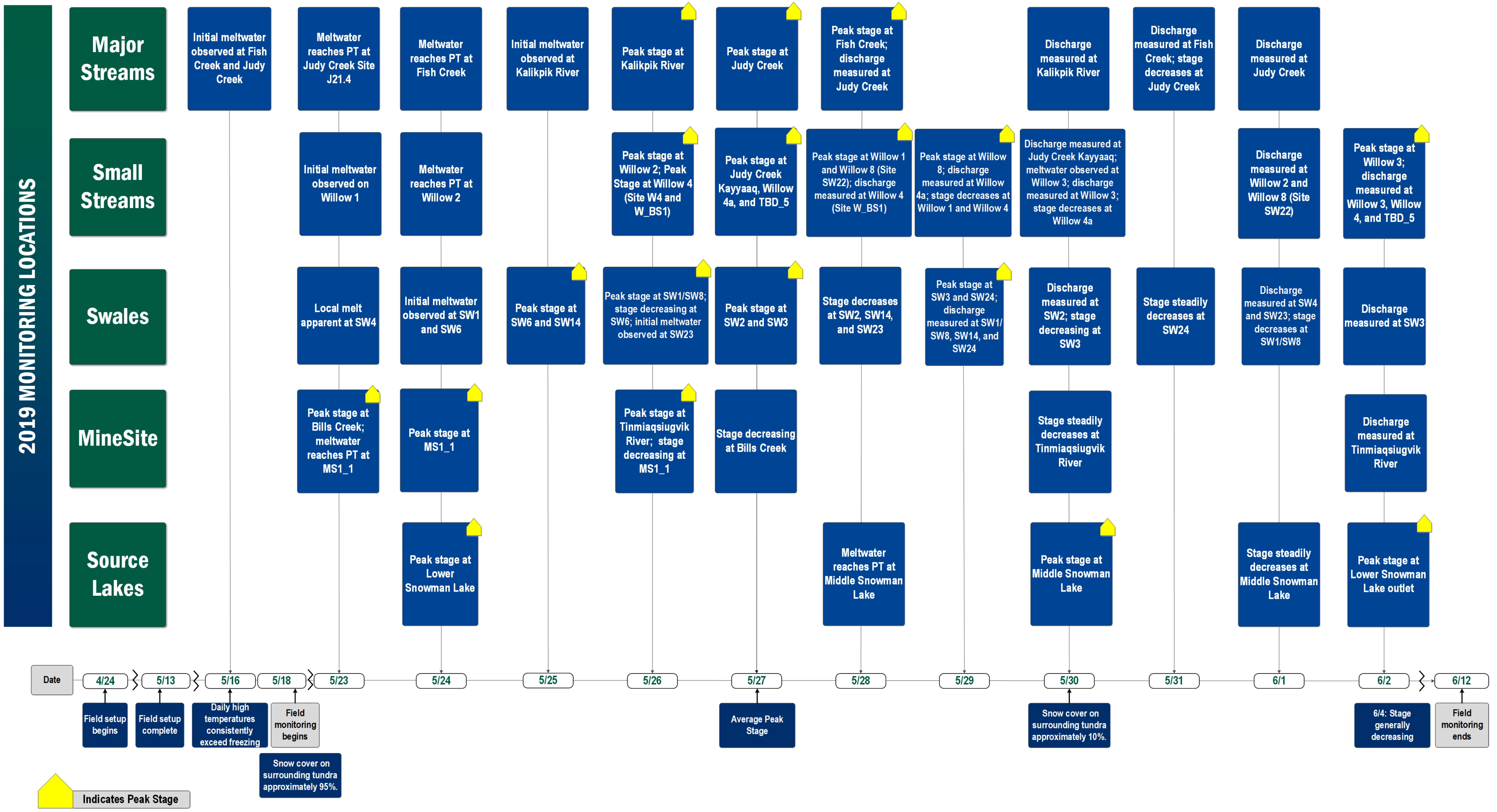
Peak stage was observed at small streams between May 25 and May 29 and was the result of elevated water levels associated with flow through snow-packed channels. By May 30, stage was receding at most Willow small stream monitoring locations. Snow was approximated at 10 percent coverage over surrounding tundra, but snow was still present in channels and along river banks (Photo 3.2). All swales, except SW2, peaked May 25 while SW2 peaked on May 27, and most were hydraulically connected by May 27.

The summer monitoring period was defined by low, base flow conditions at all major and small streams. Most small swales and drainages 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. A late summer precipitation event with 1.25 inches of rain recorded at Nuiqsut between August 24 and August 27 produced a notable late summer increase in stage at many monitoring locations. Figure 3.1 provides a visual timeline summarizing the major spring breakup events.

Photo 3.1 Fish creek near F55.5, looking northeast (downstream); June 4, 2019

Photo 3.2: Willow 4 near W_BS1, looking east (upstream); May 30, 2019

Figure 3.1: Spring Breakup Hydrologic Timeline



2019 MONITORING LOCATIONS

Date	Major Streams	Small Streams	Swales	MineSite	Source Lakes	
4/24						Field setup begins
5/13						Field setup complete
5/16	Initial meltwater observed at Fish Creek and Judy Creek					Daily high temperatures consistently exceed freezing
5/18						Field monitoring begins Snow cover on surrounding tundra approximately 95%.
5/23	Meltwater reaches PT at Judy Creek Site J21.4	Initial meltwater observed on Willow 1	Local melt apparent at SW4	⬟ Peak stage at Bills Creek; meltwater reaches PT at MS1_1		
5/24	Meltwater reaches PT at Fish Creek	Meltwater reaches PT at Willow 2	Initial meltwater observed at SW1 and SW6	⬟ Peak stage at MS1_1	⬟ Peak stage at Lower Snowman Lake	
5/25	Initial meltwater observed at Kalikpik River		⬟ Peak stage at SW6 and SW14			
5/26	⬟ Peak stage at Kalikpik River	⬟ Peak stage at Willow 2; Peak Stage at Willow 4 (Site W4 and W_BS1)	⬟ Peak stage at SW1/SW8; stage decreasing at SW6; initial meltwater observed at SW23	⬟ Peak stage at Tinmiaqsiugvik River; stage decreasing at MS1_1		
5/27	⬟ Peak stage at Judy Creek	⬟ Peak stage at Judy Creek Kayyaaq, Willow 4a, and TBD_5	⬟ Peak stage at SW2 and SW3	Stage decreasing at Bills Creek		Average Peak Stage
5/28	⬟ Peak stage at Fish Creek; discharge measured at Judy Creek	⬟ Peak stage at Willow 1 and Willow 8 (Site SW22); discharge measured at Willow 4 (Site W_BS1)	Stage decreases at SW2, SW14, and SW23		Meltwater reaches PT at Middle Snowman Lake	
5/29		⬟ Peak stage at Willow 8; discharge measured at Willow 4a; stage decreases at Willow 1 and Willow 4	⬟ Peak stage at SW3 and SW24; discharge measured at SW1/SW8, SW14, and SW24			
5/30	Discharge measured at Kalikpik River	Discharge measured at Judy Creek Kayyaaq; meltwater observed at Willow 3; discharge measured at Willow 3; stage decreases at Willow 4a	Discharge measured at SW2; stage decreasing at SW3	Stage steadily decreases at Tinmiaqsiugvik River	⬟ Peak stage at Middle Snowman Lake	Snow cover on surrounding tundra approximately 10%.
5/31	Discharge measured at Fish Creek; stage decreases at Judy Creek		Stage steadily decreases at SW24			
6/1	Discharge measured at Judy Creek	Discharge measured at Willow 2 and Willow 8 (Site SW22)	Discharge measured at SW4 and SW23; stage decreases at SW1/SW8		Stage steadily decreases at Middle Snowman Lake	
6/2		⬟ Peak stage at Willow 3; discharge measured at Willow 3, Willow 4, and TBD_5	Discharge measured at SW3	Discharge measured at Tinmiaqsiugvik River	⬟ Peak stage at Lower Snowman Lake outlet	6/4: Stage generally decreasing
6/12						Field monitoring ends

⬟ Indicates Peak Stage

4. STAGE & DISCHARGE

Table 4.1 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	44.78	5/28 8:30 PM	2,875	44.26	5/31 3:15 PM	5,100	44.70	5/28 8:30 PM
	F55.5	44.71	5/28 8:45 PM						
	F55.5D	44.61	5/28 8:45 PM						
Judy Creek	J21.4	49.80	5/27 8:15 AM	--	--	--	--	--	--
	J13.8U [1]	35.94	5/27 8:45 PM	3,400	35.38	5/28 12:00 PM	4,600	35.64	5/27 8:00 PM
	J13.8 [1]	35.81	5/27 8:45 PM						
	J13.8D [1]	35.66	5/28 1:45 AM	2,900	33.90	6/1 12:15 PM			
Kalikpik River	Kal1	49.44	5/26 3:00 PM	245	48.94	5/30 12:00 PM	--	--	--
Judy Creek Kayyaaq	UC2C	54.06	5/27 7:45 PM	270	52.33	5/30 2:30 PM	--	--	--
Willow 1	W1S [3]	79.25	5/28 2:15 PM	--	--	--	--	--	--
Willow 2	UC1B	83.52	5/26 1:45 PM	110	75.91	6/1 4:00 PM	--	--	--
Willow 3	W3S	88.49	6/2 7:30 AM	5	88.22	5/30 1:00 PM	--	--	--
				16	88.20	6/2 3:30 PM			
Willow 4	W4 [6]	94.21	5/26 10:15 AM	450	91.45	6/2 2:45 PM	--	--	--
	W_BS1	87.38	5/26 11:30 PM	350	86.91	5/28 3:30 PM	--	--	--
Willow 4a	W_S1	101.89	5/27 10:45 AM	320	100.99	5/29 5:00 PM	--	--	--
Willow 8	SW22	79.35	5/28 2:15 PM	4	79.01	6/1 1:15 PM	--	--	--
	TBD_6	53.72	5/29 10:00 AM	90	52.22	5/30 4:00 PM	--	--	--
Willow 9	TBD_5 [6]	97.77	5/27 6:15 PM	135	97.11	6/2 12:00 PM	--	--	--
Swales	SW1 [3]	80.20	5/26 1:30 PM	13	79.96	5/29 2:00 PM	--	--	--
	SW2	81.98	5/27 10:30 AM	1.5	81.16	5/30 3:30 PM	--	--	--
	SW3 [2]	87.25	5/29 10:45 AM	3.5	86.84	6/2 2:30 PM	--	--	--
	SW4 [3]	55.98	5/24 3:30 PM	1	55.75	6/1 3:00 PM	--	--	--
	SW6 [3]	62.55	5/25 7:30 AM	--	--	--	--	--	--
	SW14	84.62	5/25 11:30 PM	6	83.75	5/29 1:00 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
	SW23 [2]	81.02	5/27 1:00 AM	1	79.37	6/1 12:30 PM	--	--	--
	SW24 [5]	84.98	5/29 10:30 AM	3.7	84.98	5/29 11:30 AM	--	--	--
Minesite	**UB14.5** [4]	19.23	5/29 3:45 AM	1000	14.30	6/2 4:45 PM	--	--	
	UB15.5	22.46	5/26 10:30 PM	--	--	--	--	--	--
	MS1_1	27.66	5/24 12:45 AM	--	--	--	--	--	--
	BC1	39.78	5/23 6:00 AM	--	--	--	--	--	--
Source Lakes	**MSL** [6]	96.34	5/30 10:00 AM	--	--	--	--	--	--
	MSL_OUT [6]	96.28	5/30 9:00 AM	--	--	--	--	--	--
	LSL	92.17	5/23 8:15 PM	--	--	--	--	--	--
	LSL_OUT	91.75	6/2 6:15 AM	--	--	--	--	--	--

Notes:

[1] Stage elevations at J13.8U, J13.8, and J13.8D are feet BPMSL

[2] Highest recorded stage and timing are estimated based on game camera images. No PT installed at the site.

[3] Highest recorded stage and timing values are accurately reported based on game camera images. No PT installed at the site.

[4] PT malfunction at UB14.5. Peak timing at UB14.5 assumed equal to peak timing at UB15.5

[5] Highest recorded stage and timing based on gage readings from site visit.

[6] Stage elevations are ft arbitrary.

Table 4.2 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**	42.59	8/29 6:45 PM	40.08	7/20 5:15 AM
Judy Creek	**J21.4**	48.14	8/29 8:15 AM	43.40	7/20 4:45 AM
Kalikpik River	**KAL1**	47.91	8/28 12:45 AM	47.10	8/8 7:15 AM
Judy Creek Kayyaaq	**UC2C**	49.42	8/28 5:45 PM	45.87	8/8 7:15 AM
Willow 2	**UC1B**	75.20	9/1 8:45 PM	72.83	7/16 2:15 AM
Willow 3	**W3S**	87.78	7/2 2:15 PM	87.24	8/13 5:00 PM
Willow 4	**W4** [1]	86.47	7/4 5:15 PM	84.99	7/19 11:15 AM
	W_BS1	85.46	8/28 7:30 AM	82.29	7/20 4:45 AM
Willow 4a	**W_S1**	99.68	8/29 6:45 PM	98.77	7/18 1:30 PM
Willow 8	**TBD_6**	50.96	8/28 4:00 PM	49.07	7/30 8:30 PM
	SW22	78.48	8/27 1:15 PM	78.17	7/30 7:15 PM
TBD_5	**TBD_5** [1]	94.89	8/31 11:00 PM	92.99	8/8 7:00 AM
Swales	**SW3**	86.42	7/2 2:15 PM	85.95	8/7 7:00 PM
	SW14	83.83	8/27 4:45 PM	83.14	7/15 6:15 AM
Minesite	**BC1**	37.91	7/13 4:15 PM	36.39	8/7 1:30 AM
Source Lakes	**MSL** [1]	96.25	7/2 8:00 PM	95.65	8/8 2:45 AM
	MSL_OUT [1]	96.01	7/2 8:15 PM	95.73	8/1 8:15 PM
	LSL	92.00	7/3 8:15 PM	91.51	7/20 11:30 AM
	LSL_OUT	91.74	7/3 10:30 PM	91.46	8/3 10:45 PM

Notes:

[1] Stage elevations are ft arbitrary

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, capturing drainage 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 Tinmiaqsuigvik-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 second 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 4.3.

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)
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

On May 24, initial meltwater was first recorded at F55.5, and stage began to steadily rise (Photo 4.1). On-site visual observations of F55.5 on May 27 showed elevated stage below bankfull, with periodic ice floes in the channel (Photo 4.2). Minimal channel ice was observed in the F55.5 reach at this time, though it is likely some was still grounded. PT data reveals the May 27 observations occurred during a sharp, steady rise in the stage hydrograph. Stage crested in the morning on May 28 and dropped before a sharp spike in stage was recorded in the evening, likely resulting from and upstream ice jam and associated backwater release. Peak stage occurred in the evening on May 28 and stage remained elevated through the next week (Photo 4.3).

On May 31 visual observations revealed minimal snow along the banks and stage below bankfull height. No overbank flooding was observed, and no evidence was found to suggest overbank flooding occurred at or near peak stage on May 28. Stranded ice was observed partially submerged in the outer reaches of the channel, particularly around the downstream gage, suggesting stage had peaked and was receding. Minimal change to these conditions were noted during observations on June 1 (Photo 4.4).

After peak stage on May 28, stage remained elevated and eventually crested again on June 6, reaching 0.1 feet lower than the prior peak stage value. After this crest, stage receded to low-flow summer conditions.

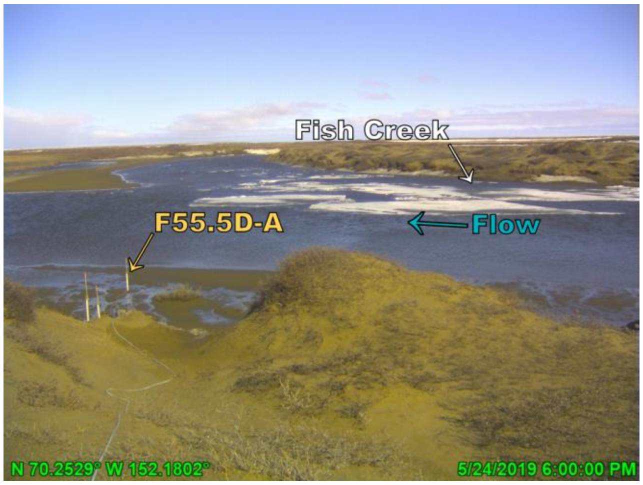


Photo 4.1: RTFM photo of meltwater first reaching F55.5D-A gage, looking east; May 24, 2019

Photo 4.2: F55.5 before peak stage, looking east (downstream); May 27, 2019

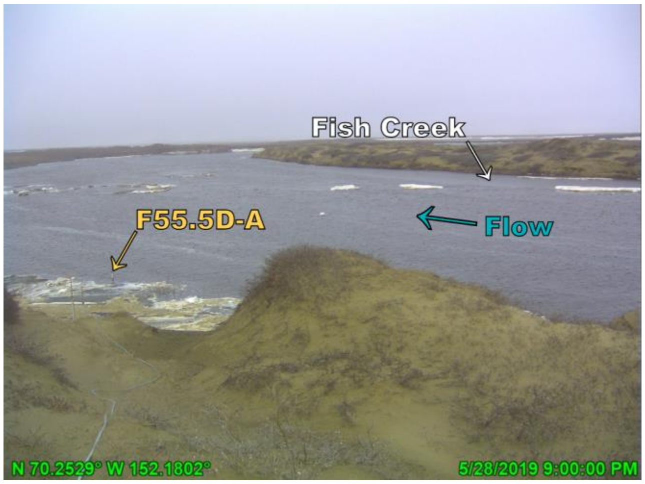


Photo 4.3: RTFM photo of peak stage conditions at F55.5D, looking east; May 28, 2019

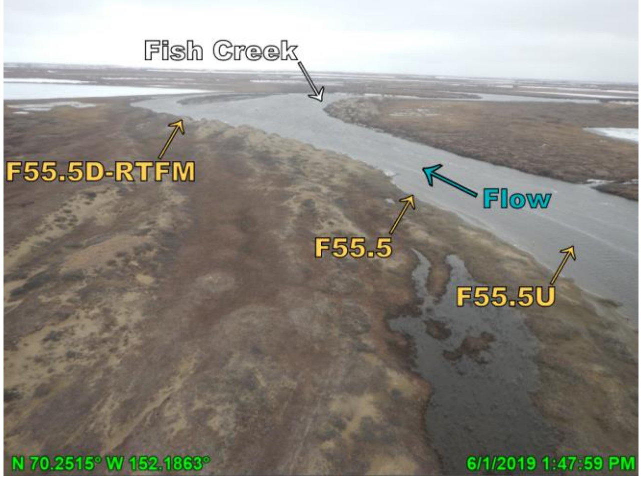


Photo 4.4: F55.5 reach after peak stage, looking northeast (downstream); June 1, 2019

Discharge was measured using a tethered ADCP at F55.5 on May 31, approximately 3 days after peak stage conditions occurred (Photo 4.5). During the measurement, ice floes were observed moving down the reach, but minimal snow remained in the channel and along the banks (Photo 4.6). The measurement was influenced by a moving bed, which was analyzed and applied as a correction to the discharge data. The overall quality of the discharge measurement was classified as fair, based on the uncertainty associated with a highly mobile channel bed, and the ice in the channel.

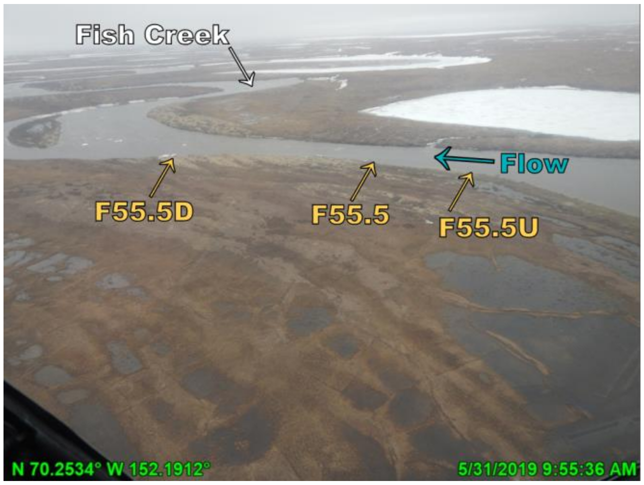


Photo 4.5: F55.5 reach on the day of the discharge measurement, looking northeast (downstream); May 31, 2019

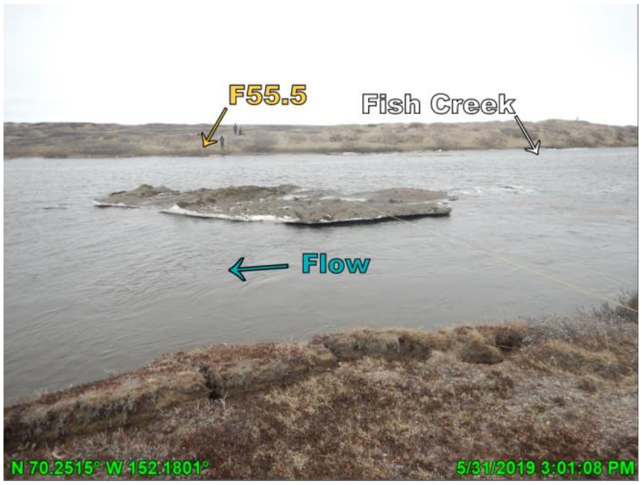
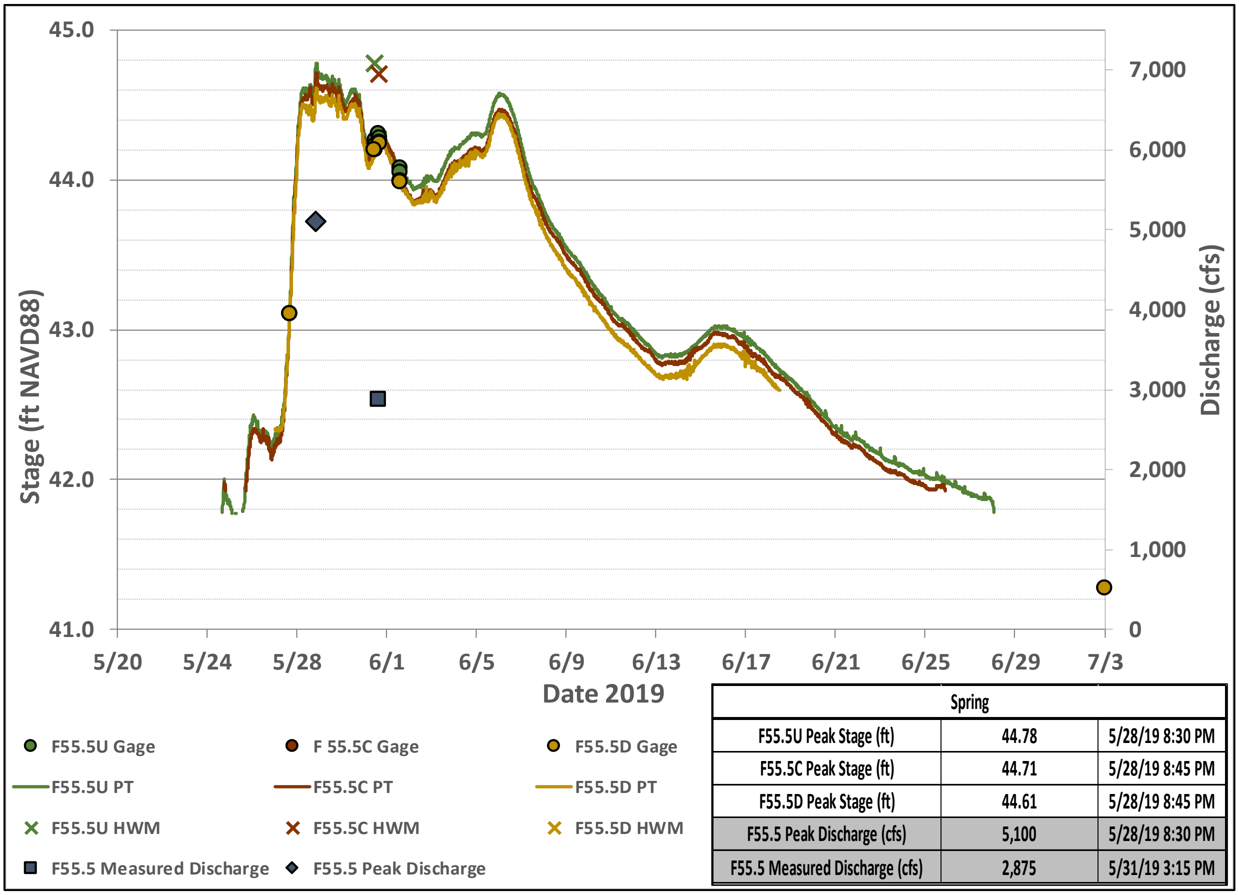


Photo 4.6: Ice pan passing through discharge measurement cross section, looking northwest (upstream); May 31, 2019

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 May 28, coinciding with peak stage. The cross-section used to calculate peak discharge was determined from the direct discharge measurement on May 31, which may have been affected by snow and bottom-fast ice. The estimated peak discharge calculation was assigned a poor quality rating based on the presence of snow and ice within the cross section on May 28, 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		
F55.5U Peak Stage (ft)	44.78	5/28/19 8:30 PM
F55.5C Peak Stage (ft)	44.71	5/28/19 8:45 PM
F55.5D Peak Stage (ft)	44.61	5/28/19 8:45 PM
F55.5 Peak Discharge (cfs)	5,100	5/28/19 8:30 PM
F55.5 Measured Discharge (cfs)	2,875	5/31/19 3:15 PM

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

B. SUMMER

Summer stage was measured at F55.5C, just upstream of the proposed crossing location. Stage fluctuations associated with precipitation were recorded throughout the summer; water levels remained below peak spring stage (Photo 4.7). During a late summer precipitation event, stage crested at levels observed near the end of spring breakup. Summer stage at Fish Creek at F55.5 is presented in Graph 4.2.

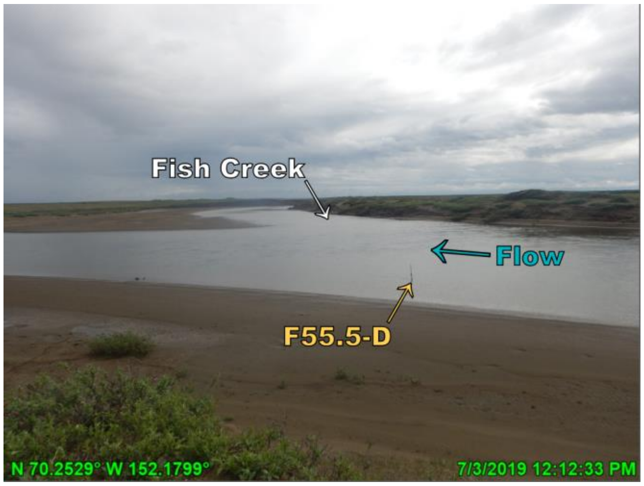
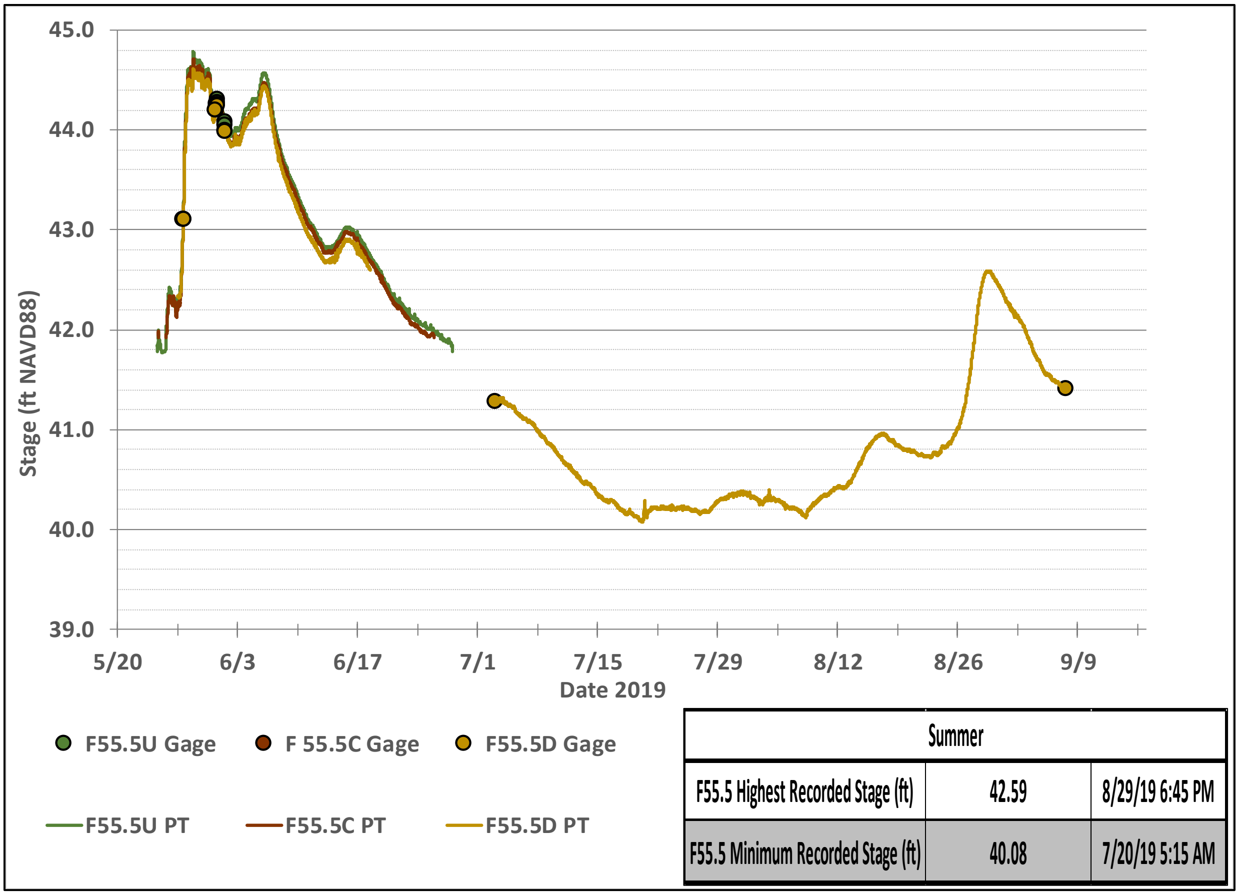


Photo 4.7: Low-flow summer conditions at F55.5D, looking southeast (downstream); July 3, 2019



Summer		
F55.5 Highest Recorded Stage (ft)	42.59	8/29/19 6:45 PM
F55.5 Minimum Recorded Stage (ft)	40.08	7/20/19 5:15 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. CPAI's 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 2019 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 2019 represents the eighth 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 2019 monitoring period represents the third 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 4.4.

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)
2019	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 [5]	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] Stage interpolated between upstream and downstream gage stations

A. SPRING BREAKUP

On May 18, aerial observations revealed the leading edge of meltwater to be slightly downstream of J21.4 (Photo 4.8), although stage was not high enough to register on the J21.4 PT until May 23. At J13.8, meltwater was first recorded at the downstream PT on May 24. Visual observations on May 27 show the J13.8 reach generally clear of ice and snow, although saturated snow was observed near the banks of the channel, particularly around bends. Stage at all Judy Creek monitoring stations was below bankfull on May 27, except in an area where minor flooding was observed in low-lying land near the Willow 2 and Judy Creek confluence (Photo 4.9). Peak stage occurred at J21.4 on the morning of May 27 (Photo 4.10).

Following three days of steadily increasing stage at J13.8, PT data on May 27 recorded a stage drop followed by a spike of 0.3 feet in about 3 hours, culminating in peak stage at all three J13.8 monitoring locations. Another similar spike in stage occurred at J13.8 early on May 28, after which stage slowly decreased but remained elevated at near peak levels. The gradual drop in stage, followed by spikes are indicative of ice jams and associated backwater releases upstream of the J13.8 reach.

Following another stage spike to near peak conditions at J13.8 on May 29, visual observations on May 30 revealed stage had noticeably receded at all Judy creek monitoring locations. No evidence of overbank flooding from peak stage was observed. Minor flooding near the Willow 2 and Judy Creek confluence persisted (Photo 4.11). The channel was free of ice while saturated snow was observed along the banks. By June 1, stage had receded to near low-flow summer conditions at J13.8 and J21.4 monitoring locations.

Photo 4.8: The leading edge of meltwater downstream of J21.4, looking northwest (upstream); May 18, 2019

Photo 4.9: Minor flooding near Willow 2 – Judy Creek confluence, looking north (downstream); May 27, 2019

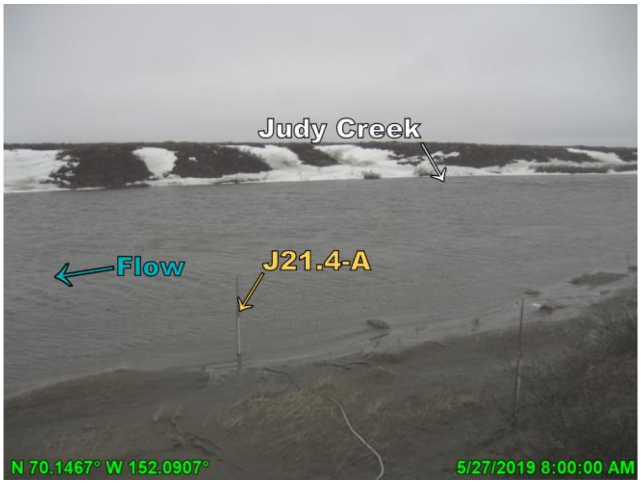


Photo 4.10: RTFM photo of peak stage at J21.4, looking southwest (upstream); May 27, 2019

Photo 4.11: Minor flooding near Willow 2 – Judy Creek confluence, looking north (downstream); May 30, 2019

Discharge was measured twice using a tethered ADCP at J13.8, once on May 28, and again on June 1. During the first measurement on May 28, minimal ice floes were observed in the channel and some saturated snow was present along the banks (Photo 4.12 and Photo 4.13). Similar conditions were observed during the second measurement on June 1 (Photo 4.14). No bottom-fast ice was observed during either discharge measurement. Both measurements were influenced by moving bed conditions, the effects of which were analyzed and applied as corrections to both measurements. A moving bed velocity averaging 0.37 foot per second (fps) was observed during the ADCP discharge measurements. The quality of the first measurement was classified as poor due to the equipment Bluetooth malfunction producing incomplete cross-sectional transect data. The quality of the second measurement was classified as fair due to the remaining snowpack along the banks and moving bed conditions.

Photo 4.12: J21.4 reach on the day of the first discharge measurement at J13.8, looking east (downstream); May 28, 2019

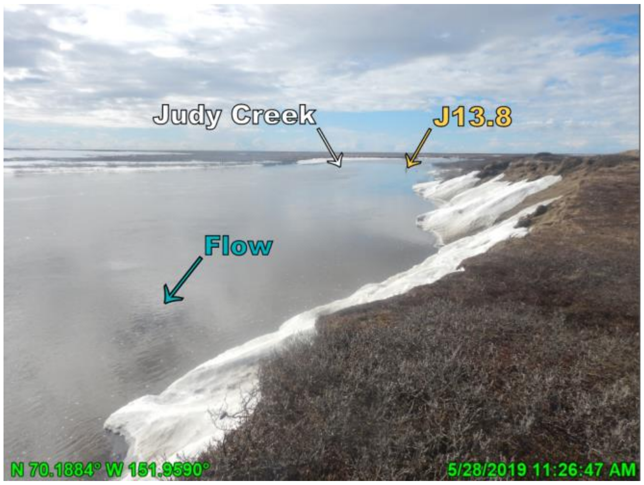
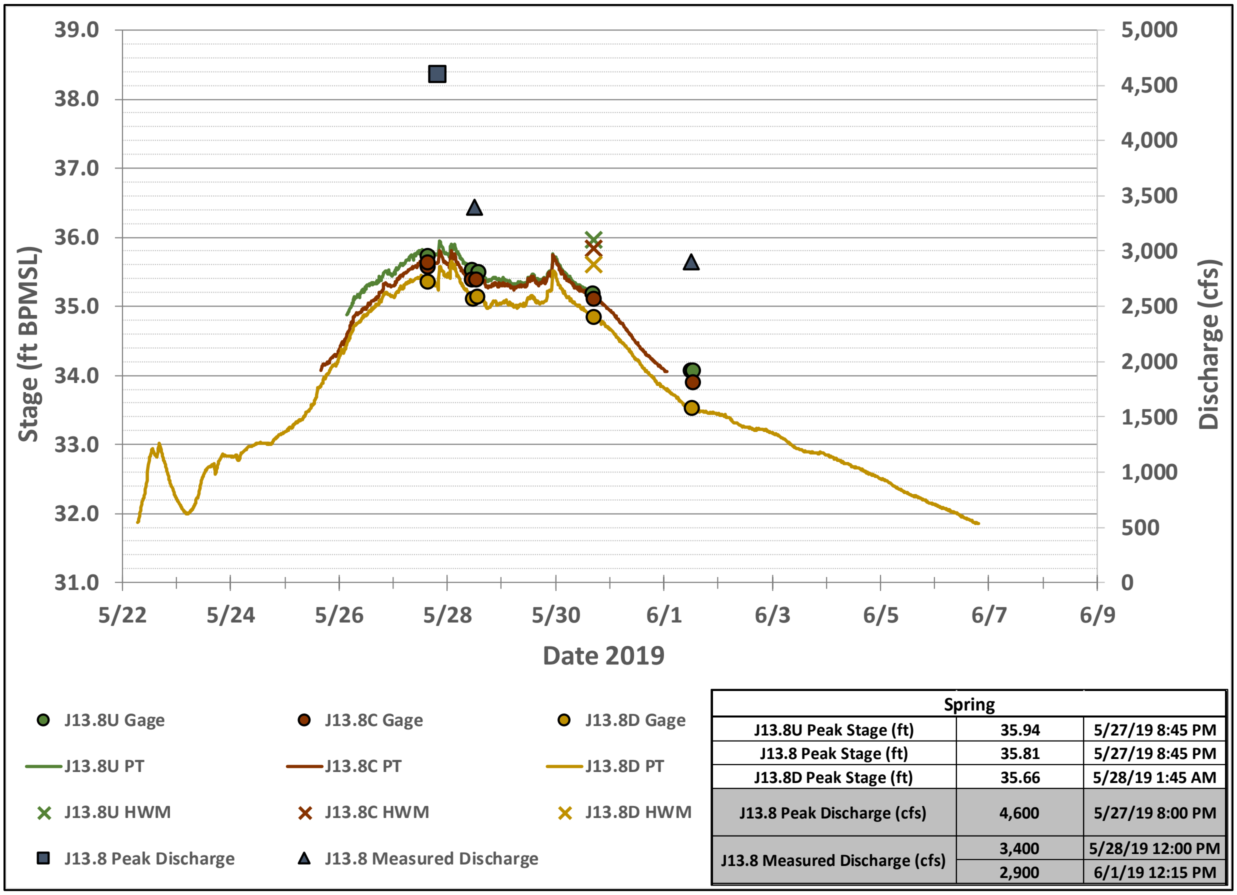


Photo 4.13: J13.8 reach on the day of the first discharge measurement, looking south (upstream); May 28, 2018

Photo 4.14: Conditions at J13.8 during the second discharge measurement, looking east (downstream); June 1, 2019

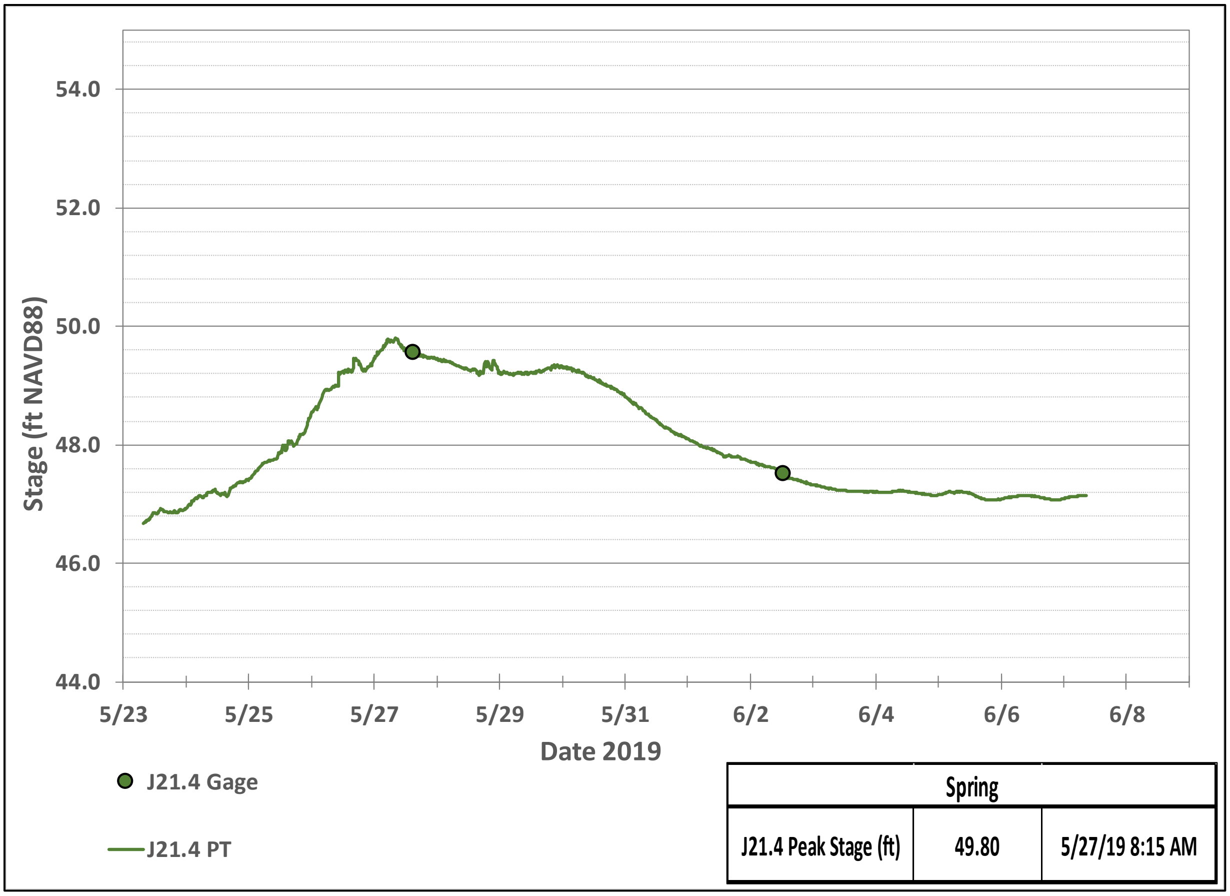
Peak discharge was calculated based on stage and stage differential between gage sites. The estimated date of peak discharge at J13.8 was May 27 and was attributed to an upstream ice jam release. The cross-section used to calculate peak discharge was determined from the direct measurement on June 1. The estimated peak discharge was assigned a poor quality rating based on the presence of snow along the banks during the cross section on June 1, and 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		
J13.8U Peak Stage (ft)	35.94	5/27/19 8:45 PM
J13.8 Peak Stage (ft)	35.81	5/27/19 8:45 PM
J13.8D Peak Stage (ft)	35.66	5/28/19 1:45 AM
J13.8 Peak Discharge (cfs)	4,600	5/27/19 8:00 PM
J13.8 Measured Discharge (cfs)	3,400	5/28/19 12:00 PM
	2,900	6/1/19 12:15 PM

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



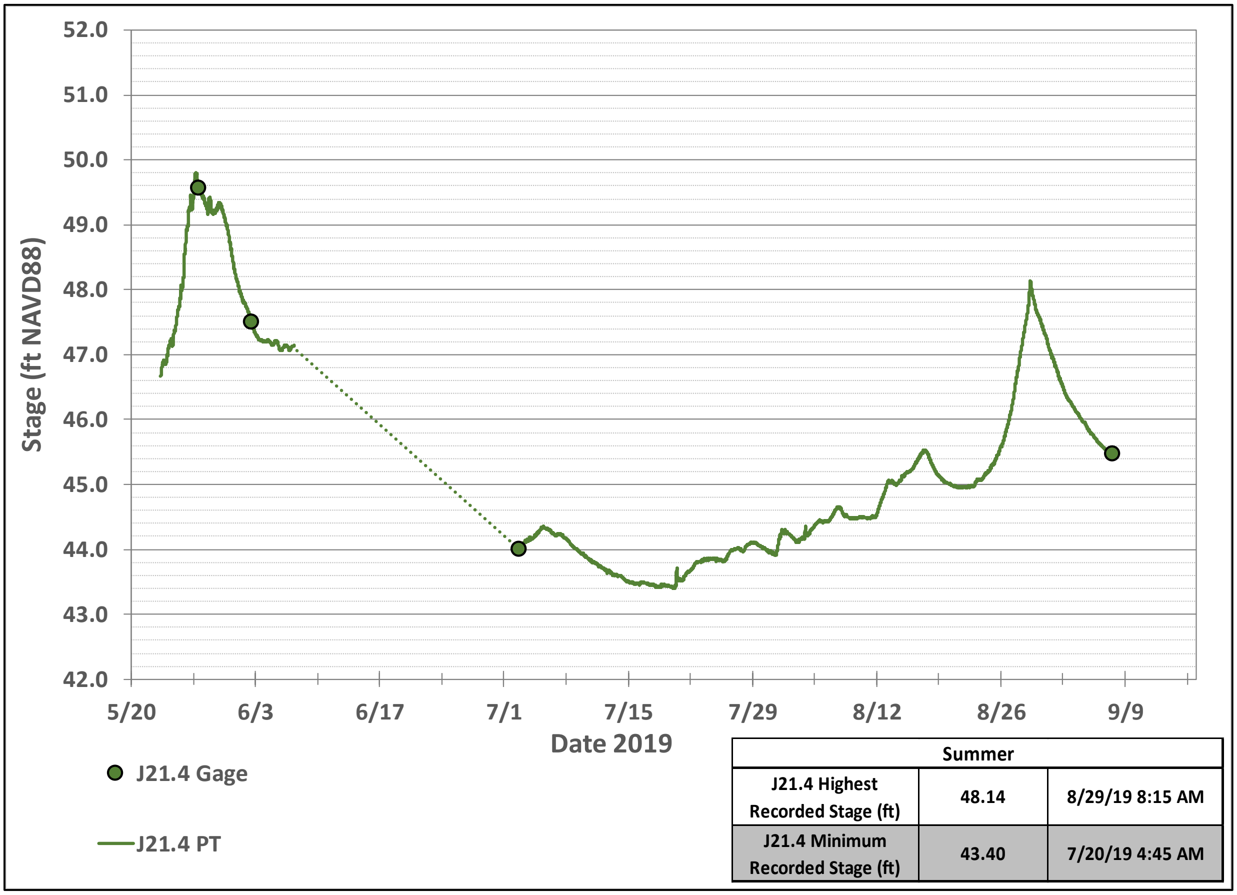
Spring		
J21.4 Peak Stage (ft)	49.80	5/27/19 8:15 AM

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

B. 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 4.15). During a late summer precipitation event, stage crested at levels observed near the end of spring breakup. Summer stage at Judy Creek J21.4 is presented in Graph 4.5.

Photo 4.15: Summer conditions at J21.4, looking west (upstream); July 2, 2019



Summer		
J21.4 Highest Recorded Stage (ft)	48.14	8/29/19 8:15 AM
J21.4 Minimum Recorded Stage (ft)	43.40	7/20/19 4:45 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 Teshekpuk Lake. The Kalikpik River drainage basin encompasses an area of approximately 200 square miles. This is the second year of data collection and observations at the Kal1 monitoring location. Historical peak stage and measured discharge data at Kal1 is presented in Table 4.5.

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)
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

The leading edge of meltwater arrived at the Kal1 monitoring station on May 25, based on game camera images. Peak stage conditions quickly followed on May 26, likely elevated by large quantities of saturated snow and bottom-fast channel ice. A site visit performed on May 27 confirmed the influence of ice and snow on peak stage. On that day, the channel width was mostly filled with saturated snow, and meltwater appeared to flow overtop of bottom-fast ice (Photo 4.16). Stranded ice was observed in the channel near the gage station, indicating stage had crested and was now receding (Photo 4.17). Beyond the channel banks, no stranded ice or other evidence of overbank flooding was observed.

The PT data indicated that stage fluctuated, but generally receded, after May 27. Visual observations from May 30 revealed similar conditions to those observed on May 27. The extent of saturated snow and bottom-fast ice had diminished slightly, and a small ice jam had formed on a bend just upstream of Kal1 (Photo 4.18). By June 1, stage had receded to near low-flow summer conditions and significant snow remained in the channel and on the banks (Photo 4.19).

Photo 4.16: Saturated snow in the Kal1 reach, the day after peak stage, looking east; May 27, 2019

Photo 4.17: Stranded ice near the Kal1 gage, looking northeast (downstream); May 27, 2019

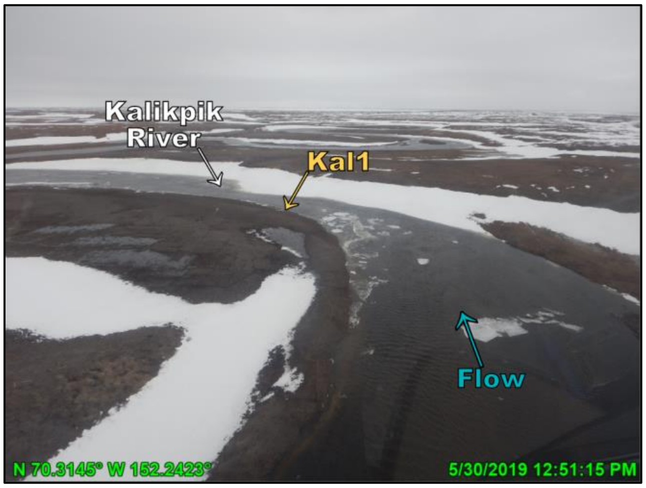


Photo 4.18: Small ice jam upstream of Kal1 gage, looking north (downstream); May 30, 2019

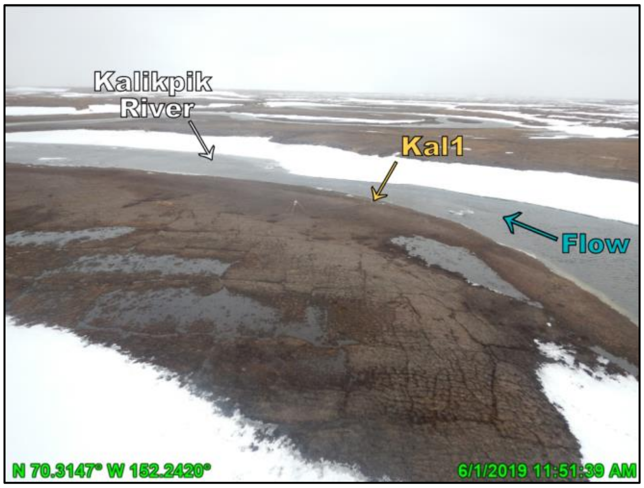
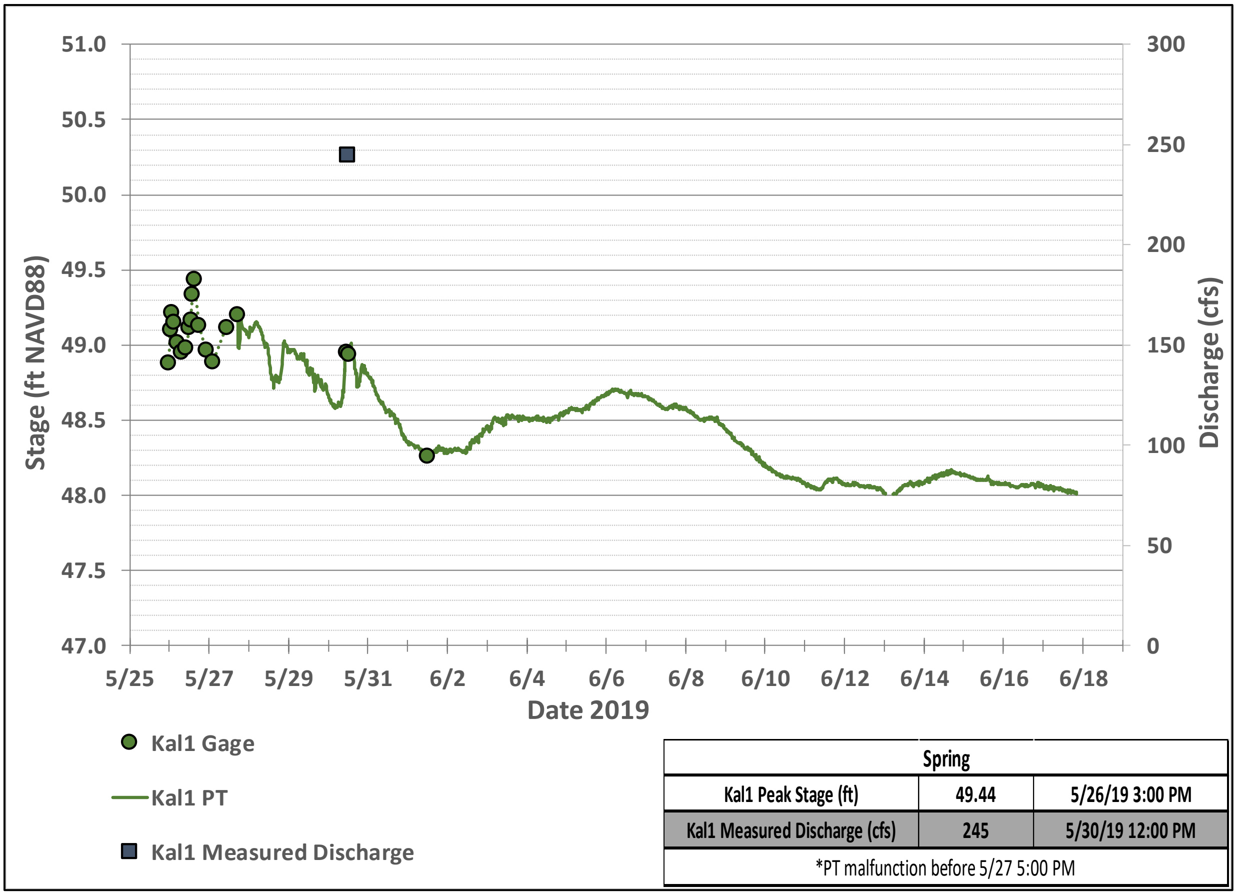


Photo 4.19: Kal1, about a week after peak stage, looking north (downstream); June 1, 2019

Discharge was measured using a tethered ADCP at Kal1 on May 30. During the measurement, stage was below bankfull and a small ice jam had formed just upstream of the discharge cross section. In the channel, saturated snow remained along the south bank and bottom-fast ice was observed (Photo 4.20). These factors resulted in a discharge measurement with a quality classification of poor.

Kalikpik River 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 4.20: Kal1 on the day of the discharge measurement, looking south (upstream); May 30, 2019



Spring		
Kal1 Peak Stage (ft)	49.44	5/26/19 3:00 PM
Kal1 Measured Discharge (cfs)	245	5/30/19 12:00 PM
*PT malfunction before 5/27 5:00 PM		

Graph 4.6: Kalikpik River at Kal1 Spring Breakup Stage & Discharge

B. SUMMER

Stage fluctuations associated with summer precipitation were recorded in the summer stage data; water levels remained below spring breakup peak stage (Photo 4.21). The stage increase at the end of the summer monitoring period is associated with a late precipitation event. Summer stage at Kal1 gage site is presented in Graph 4.7.

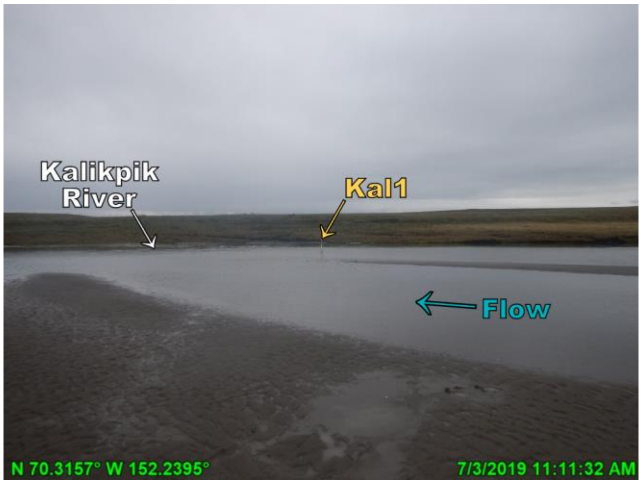
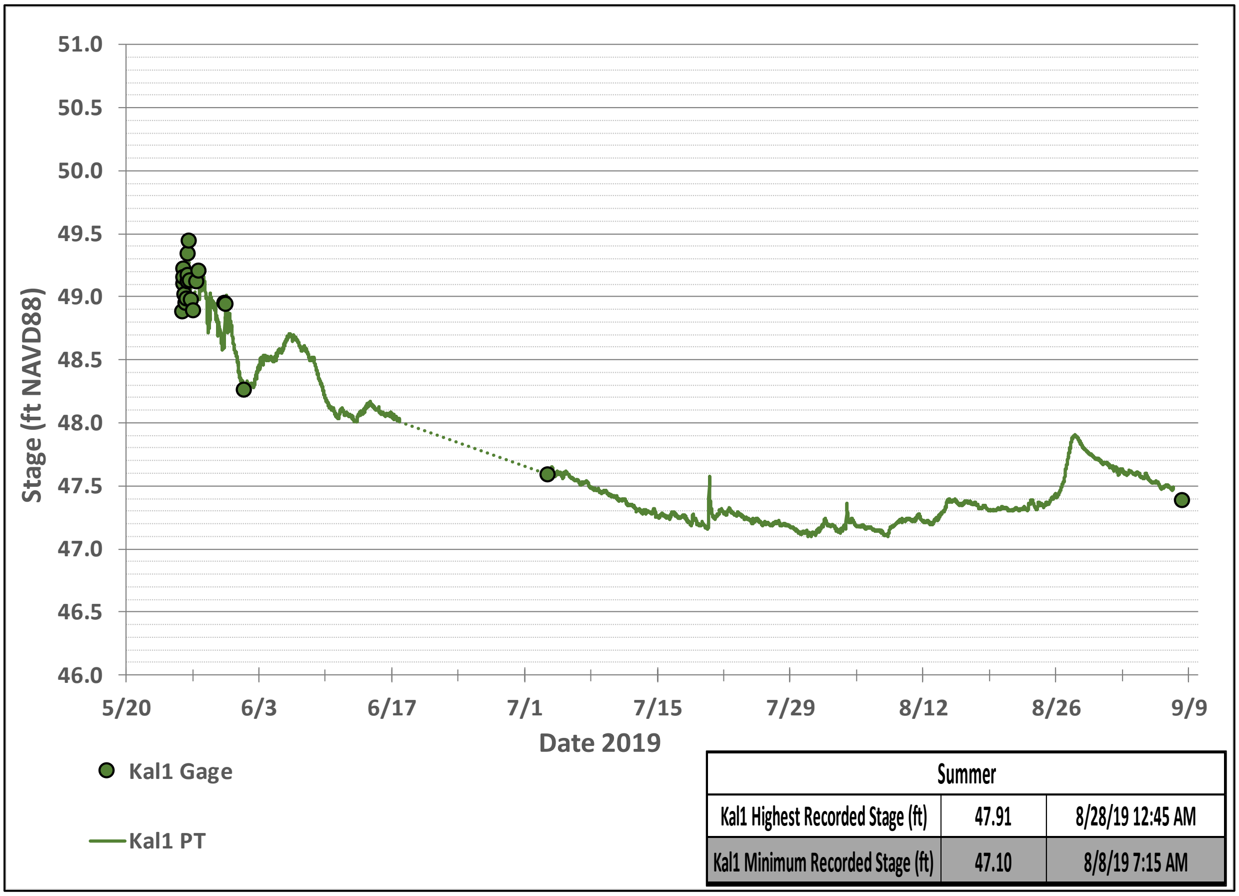


Photo 4.21: Summuer conditions near Kal1, looking north (downstream); July 3, 2019



Summer		
Kal1 Highest Recorded Stage (ft)	47.91	8/28/19 12:45 AM
Kal1 Minimum Recorded Stage (ft)	47.10	8/8/19 7:15 AM

Graph 4.7: Kalikpik River at Kal1 Spring and Summer Stage

4.2 Small Streams

JUDY CREEK KAYYAAQ

Judy Creek Kayyaaq is a meandering, incised channel (over 8 feet from top of bank to creek bed; 30 feet 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 third year of data collection and observations at the UC2C monitoring location. Historical peak stage and measured discharge data at UC2C is presented in Table 4.6.

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)
2019	54.06	5/27	270	5/30	52.33
2018 [2]	54.78	6/13	140	6/11	53.69
2017 [1,2]	53.84	5/30	190	6/3	50.47

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 on Judy Creek Kayyaaq at UC2C on May 20. Stage rise over the next week was characterized by cyclical periods of rapidly increasing stage, followed by prolonged periods of slight stage recession. Three such cycles accounted for the nearly 7-foot stage increase at UC2C from May 20 to May 27. Peak stage occurred on May 27, following a period of 1.5-foot stage increase over 6 hours. Aerial observations from May 27 revealed bankfull stage at UC2C, with minor overbank flooding in low-lying areas (Photo 4.22). Minimal snow was observed on the surrounding tundra, but submerged snow was present in the channel and along the banks (Photo 4.23). The appearance of bottom-fast channel ice was noted, but difficult to confirm due to the deep, incised channel. An ice road crossing on Judy Creek Kayyaaq downstream of UC2C was slotted and observed conveying flow (Photo 4.24).

Following peak stage on May 27, stage began to steadily recede at UC2C. On May 30, aerial observations show stage below bankfull and submerged snow present in the outer reaches of the channel (Photo 4.25). By June 1, stage had receded further and the snow coverage on the surrounding tundra was approximately 5 percent (Photo 4.26).

Photo 4.22: Minor overbank flooding at UC2C, looking north; May 27, 2019

Photo 4.23: Saturated snow near the banks of Judy Creek Kayyaaq, looking southeast (upstream); May 27, 2019

Photo 4.24: Slotted ice road near UC2C; looking southeast (upstream); May 27, 2019

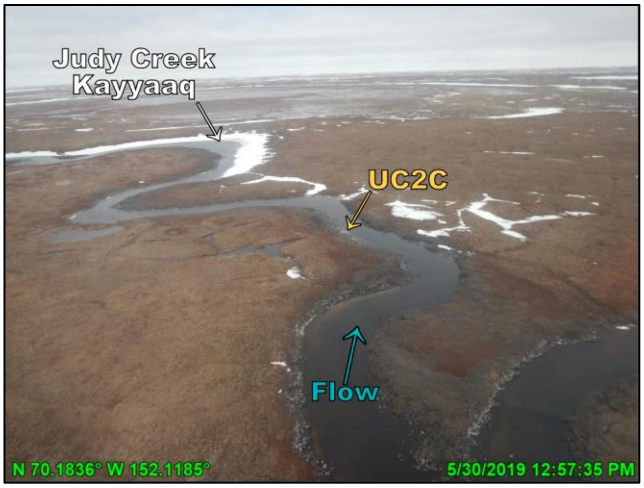


Photo 4.25: Conditions at UC2C after peak stage, looking northwest (downstream); May 30, 2019

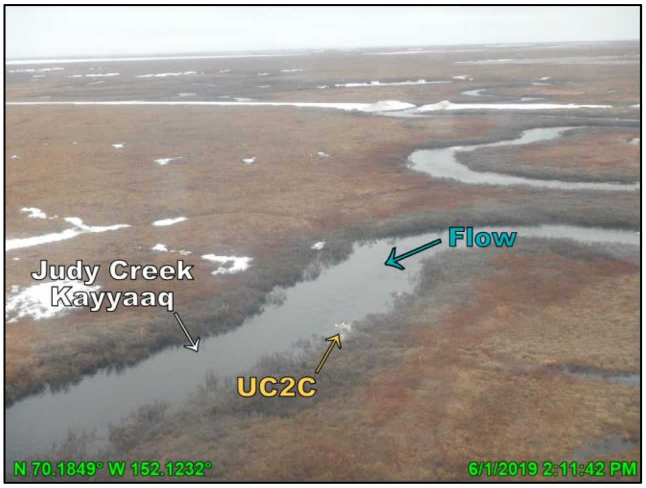
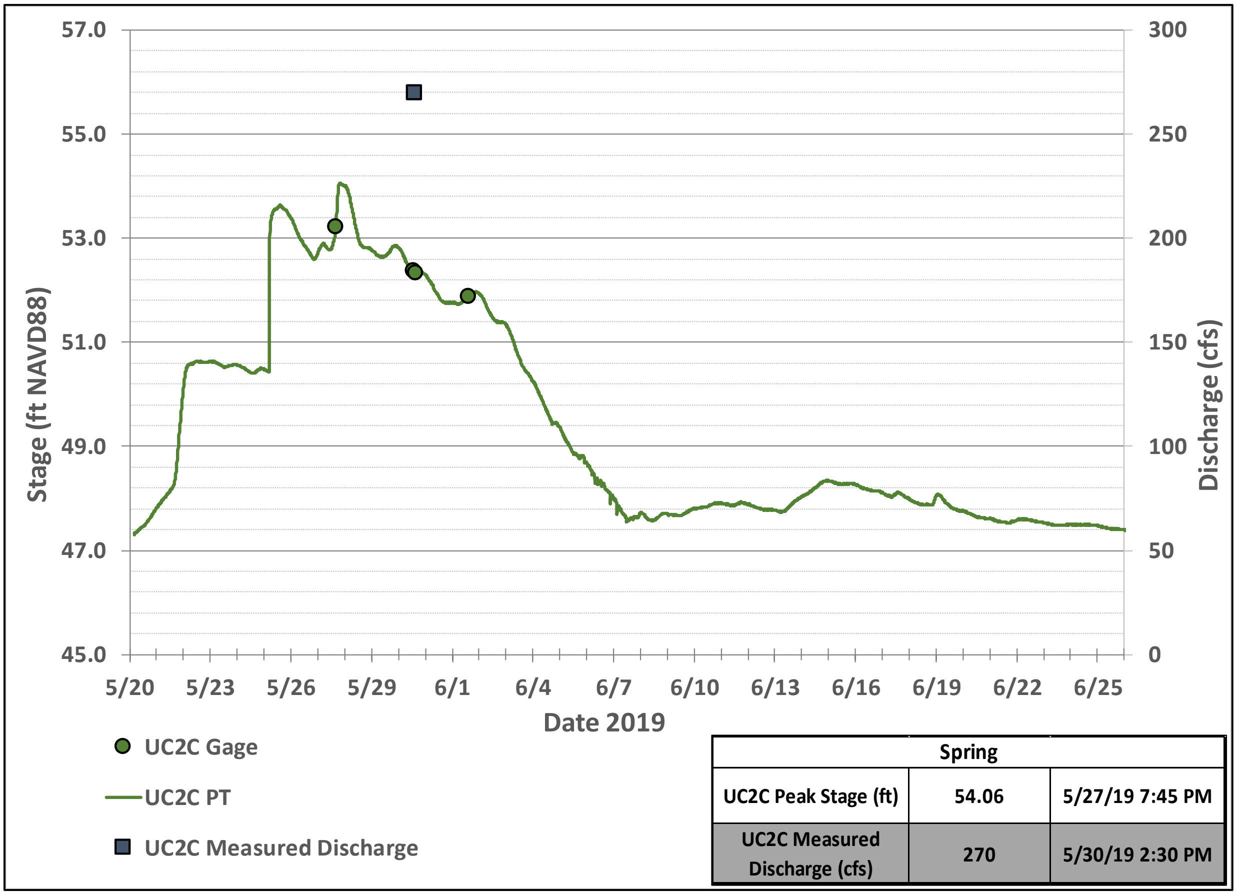


Photo 4.26: Receding stage at UC2C, looking east (upstream); June 1, 2019

Discharge during spring breakup was measured using a tethered ADCP at the UC2C gage station on May 30, three days after peak stage. During the measurement, no ice was observed moving down the channel and flow was confined to the defined channel (Photo 4.25). The overall quality of the discharge measurement was classified as good. The moving bed measurement associated with UC2C was minimal and not included as a correction to the overall measurement.

Judy Creek Kayyaaq UC2C spring breakup stage data is provided in Graph 4.8. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.



	Spring	
UC2C Peak Stage (ft)	54.06	5/27/19 7:45 PM
UC2C Measured Discharge (cfs)	270	5/30/19 2:30 PM

Graph 4.8: Judy Creek Kayyaaq at UC2C Spring Breakup Stage & Discharge

B. SUMMER

Stage fluctuations associated with summer precipitation were recorded in the PT data; water levels remained below spring breakup peak stage (Photo 4.27). The stage increase at the end of the summer monitoring period is associated with a late summer precipitation event. Summer stage in Judy Creek Kayyaaq at UC2C is presented in Graph 4.9.

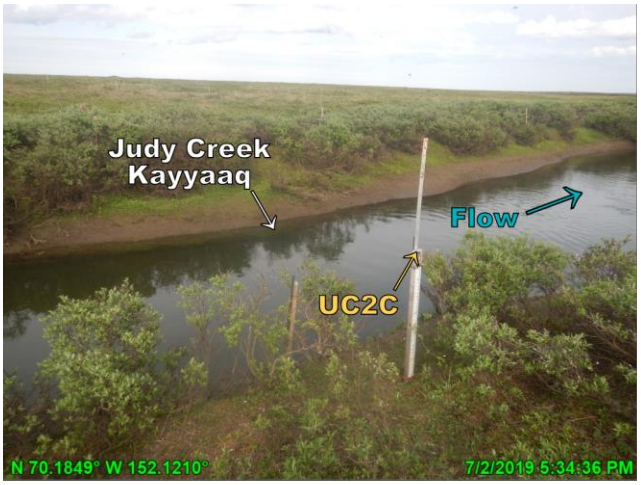
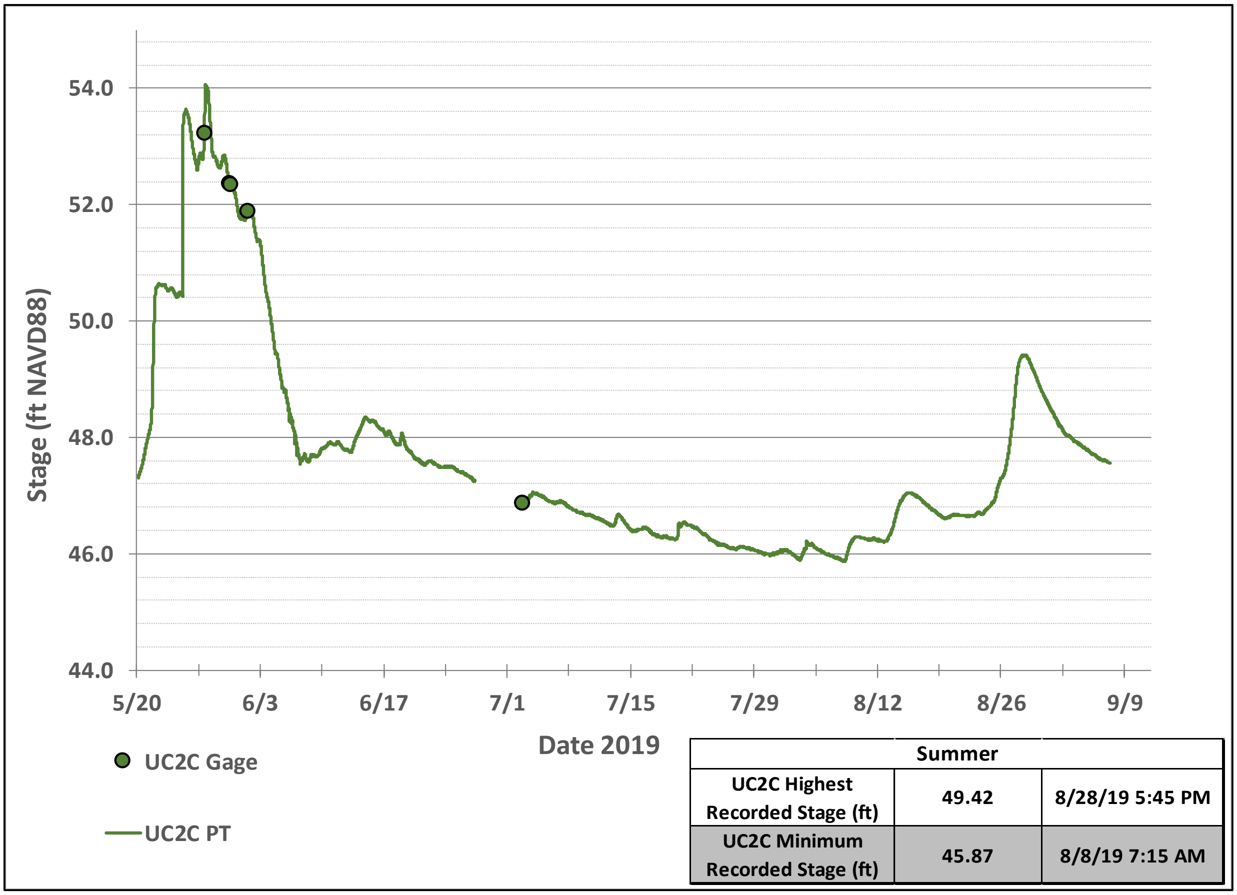


Photo 4.27: Summer conditions at UC2C, looking north (downstream); July 2, 2019



	Summer	
UC2C Highest Recorded Stage (ft)	49.42	8/28/19 5:45 PM
UC2C Minimum Recorded Stage (ft)	45.87	8/8/19 7:15 AM

Graph 4.9: 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. The reported peak stage and timing values are based on gage readings from game camera images. Historical peak stage and measured discharge data at W1S is presented in Table 4.7.

Table 4.7: Willow 1 at W1S Historical Peak Stage and Measured Discharge

Year	W1S				
	Peak Stage (ft NAVD88)	Date	Measured Discharge [3] (cfs)	Date	Associated Stage (ft NAVD88)
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

[3] Discharge not measured at W1S within the reported monitoring record

A. SPRING BREAKUP

Aerial observations from May 22 show small, isolated pockets of meltwater in the Willow 1 drainage (Photo 4.28). Local meltwater was first observed ponding at the W1S gage station on May 25. Game camera footage from the following days show increasing meltwater and rising stage. Aerial observations from May 27 reveal widespread meltwater across the drainage area with no apparent channel or flow path (Photo 4.29). Saturated snow was present across the drainage, particularly around the gage station. Within the poorly defined drainage network, approximately 95 percent of the tundra was covered with meltwater or saturated snow, with only the highest portion of polygon crests remaining above water level.

Peak stage conditions occurred on May 28, based on measurements from game camera images. At peak stage, meltwater and saturated snow were still widespread across the drainage area (Photo 4.30). After peak, stage receded throughout the rest of the monitoring period. On May 30, widespread meltwater was still present in the drainage, but minimal saturated snow remained (Photo 4.31). Approximately 80 percent of the tundra was covered with meltwater. By June 3, game camera footage revealed no remaining saturated snow, and meltwater still ponding in low-lying areas.

Willow 1 at W1S spring breakup stage data is provided in Graph 4.10. Elevations are referenced to NAVD88.

Photo 4.28: Initial meltwater at W1S, looking south; May 22, 2019

Photo 4.29: Widespread meltwater at W1S, looking east; May 27, 2019

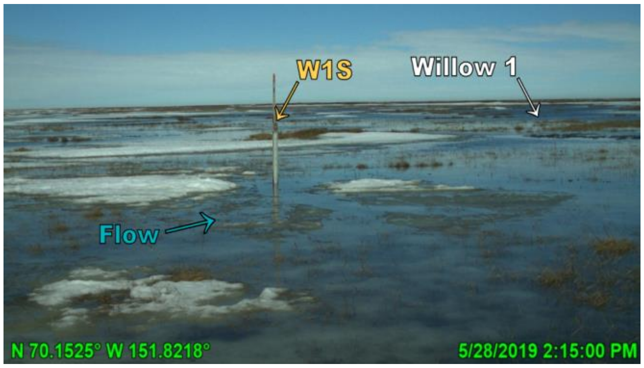
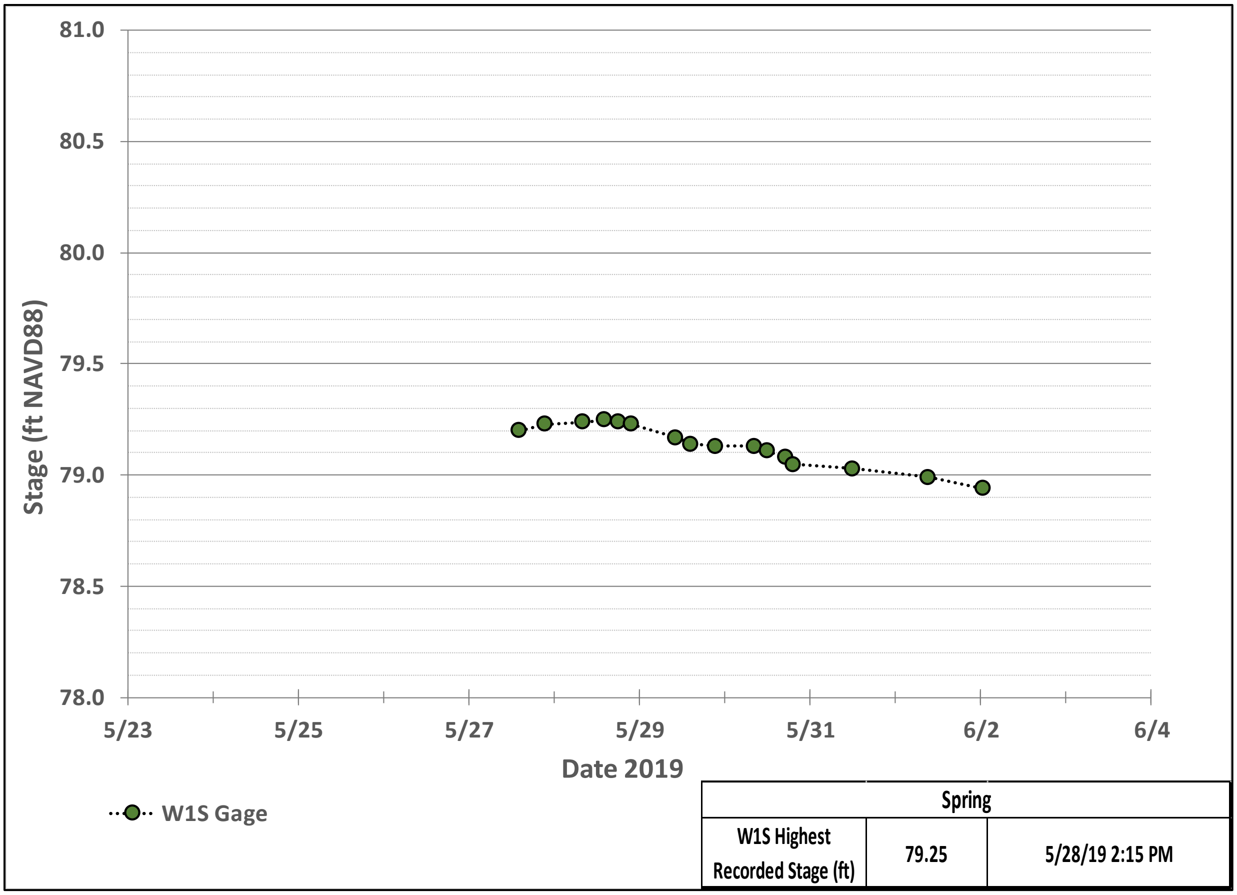


Photo 4.30: Game camera image of peak stage at W1S; May 28, 2019

Photo 4.31: Widespread meltwater at W1S, two days after peak stage, looking north; May 30, 2019



	Spring	
W1S Highest Recorded Stage (ft)	79.25	5/28/19 2:15 PM

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 feet from top of bank to creek bed; 20 feet 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 third year the UC1B gage station has been monitored. Historical peak stage and measured discharge data at UC1B is presented in Table 4.8.

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)
2019	83.52	5/26	110	6/1	75.91
2018 [2]	84.42	6/10	120	6/13	81.17
2017 [1,2]	83.28	5/30	125	6/3	75.71

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. On May 22, isolated pockets of local melt were observed along the snow-filled channel. Snow cover on surrounding tundra was approximately 80 percent near the west bank of the Willow 2 drainage (Photo 4.32). The PT data indicates that stage increased approximately 6 feet in 48 hours from May 24 to May 26, elevated by saturated snow in the channel. Peak stage conditions were observed on May 26 at UC1B.

Aerial observations from May 27 show saturated snow in the channel and on the banks near UC1B. Meltwater was flowing over top of saturated snow, but stage remained below bankfull (Photo 4.33). The snow cover on the surrounding tundra was approximately 25 percent. No stranded ice or other evidence of overbank flooding was observed. After peak, stage receded quickly and dropped below the PT elevation on May 31. On June 1, observations revealed stage far below bankfull, with snow remaining along the banks overhanging the channel (Photo 4.34). Observations on June 2 revealed similar conditions to June 1 (Photo 4.35).

After the spring breakup monitoring period ended, the UC1B PT recorded another comparable rise in stage. Starting on June 5, stage increased nearly linearly at about 1 foot every 24 hours until cresting on June 10. Once stage crested, the PT recorded a sharp stage recession, with water dropping below the PT on June 13. There is uncertainty in this data since no site observations or gage readings were performed during this time, and this trend was not recoded at any other site. It is possible the overhanging snow along the banks had collapsed and blocked the channel downstream of the gage station, resulting in backwater at UCIB. After this late spring event, low-flow summer conditions prevailed in Willow 2.

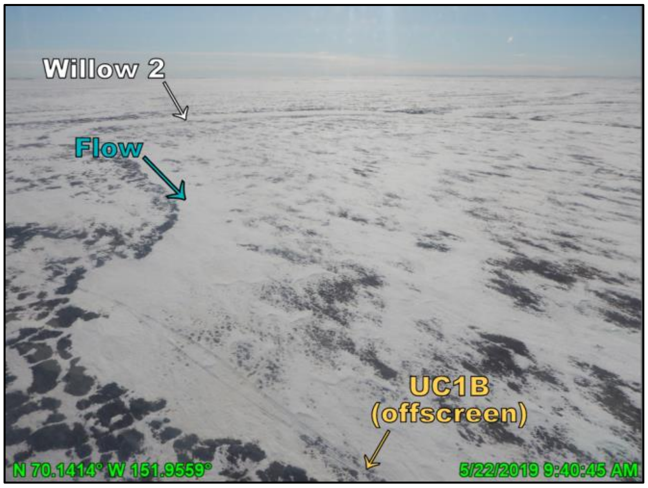


Photo 4.32: Drifted snow in the Willow 2 drainage, looking south (upstream); May 22, 2019

Photo 4.33: Meltwater and saturated snow in Willow 2 near UC1B, looking northeast (downstream); May 27, 2019

Photo 4.34: Overhanging snow near UC1B, looking north (downstream); June 1, 2019

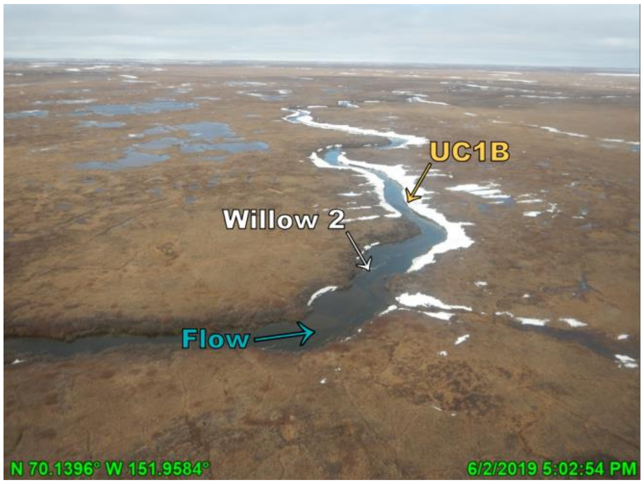


Photo 4.35: UC1B nearly a week after peak stage, looking north (downstream); June 2, 2019

Discharge was measured using a tethered ADCP near the UC1B gage station on June 1. During the measurement, saturated snow was present on the banks of the channel, and minimal snow remained in the channel (Photo 4.36). The quality of the measurement was classified as fair based on these conditions. This measurement coincided with a period of low stage. The moving bed measurement associated with UC1B was minimal and not included as a correction to the overall measurement.

Willow 2 at UC1B spring breakup stage 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.

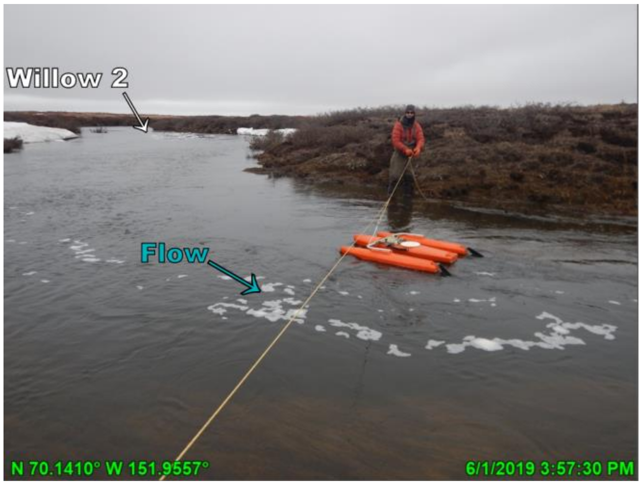
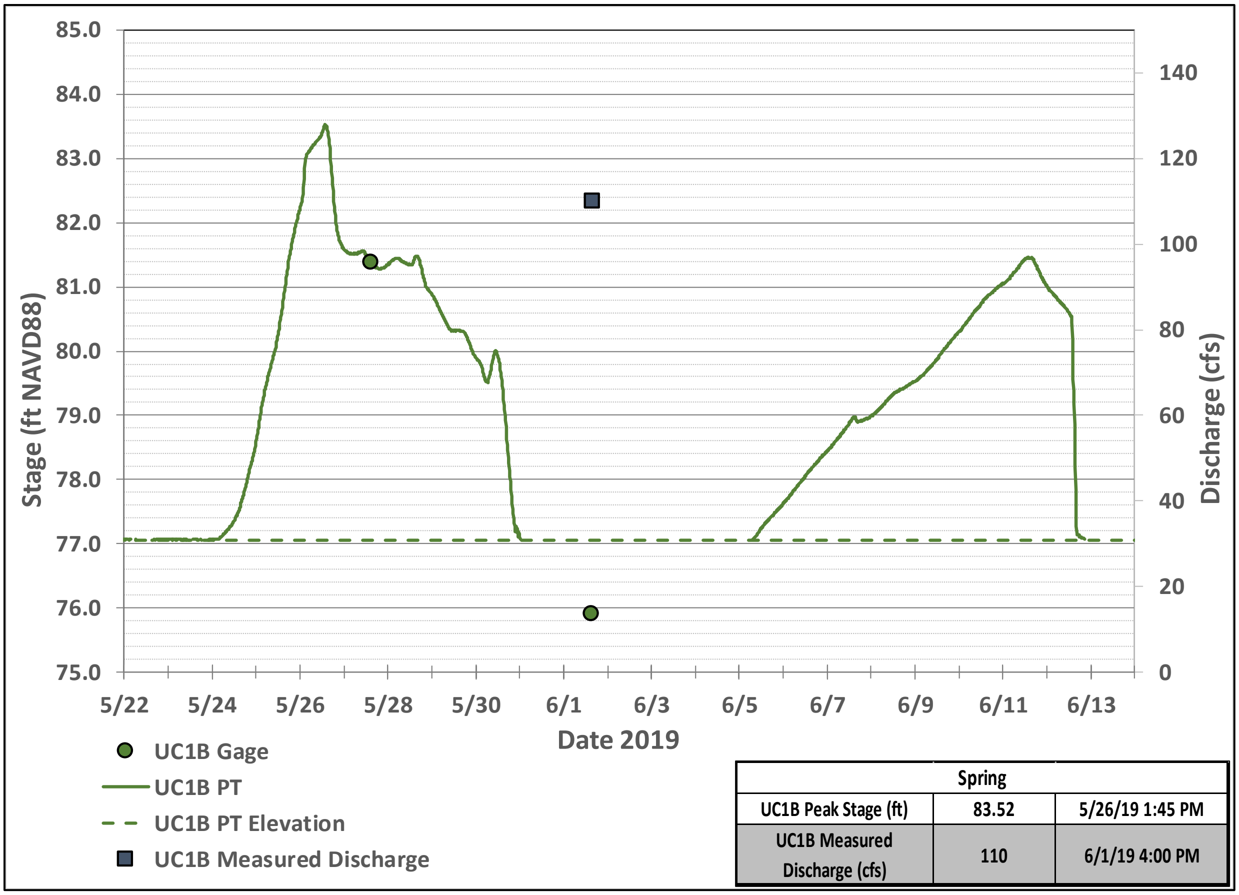


Photo 4.36: Crew conducting discharge measurements on Willow 2 near UC1B, looking south (upstream); June 1, 2019



	Spring	
UC1B Peak Stage (ft)	83.52	5/26/19 1:45 PM
UC1B Measured Discharge (cfs)	110	6/1/19 4:00 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 4.37). Summer stage in Willow 2 at UC1B is presented in Graph 4.12.

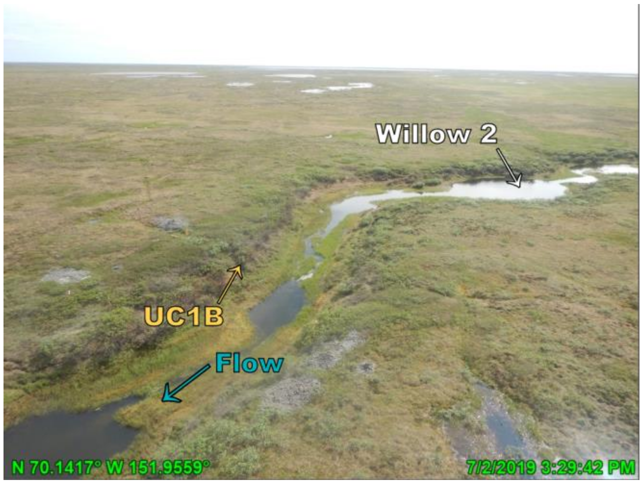
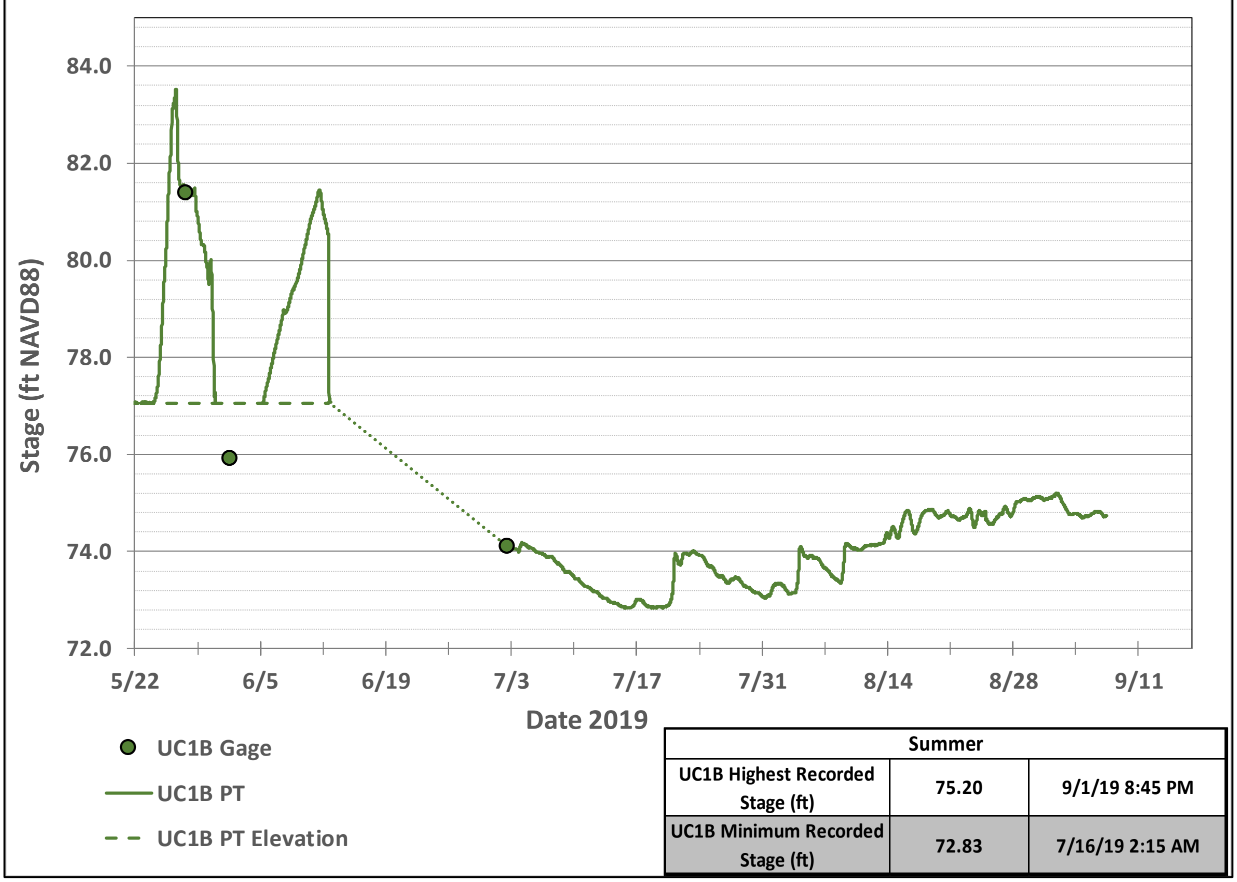


Photo 4.37: Summer conditions at UC1B, looking south (upstream); July 2, 2019



Summer		
UC1B Highest Recorded Stage (ft)	75.20	9/1/19 8:45 PM
UC1B Minimum Recorded Stage (ft)	72.83	7/16/19 2:15 AM

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 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 first year of data collection and observations at the 2019 W3S monitoring location, and the second year of monitoring the W3S drainage. Historical peak stage and measured discharge data at W3S is presented in Table 4.9.

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)
2019 [2]	88.49	6/2	5	88.22	5/30
			16	88.20	6/2
2018 [1,2]	84.13	6/4	--		

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

A. SPRING BREAKUP

Local melt was first observed in the Willow 3 drainage on May 29. On this day, the PT was repositioned to better capture water levels at W3S. Aerial observations revealed widespread meltwater and saturated snow across the Willow 3 drainage. No defined drainage channel was apparent (Photo 4.38). Snow cover on the surrounding tundra was approximately 20 percent. Observations from May 30 revealed minimal change from conditions observed on May 29 (Photo 4.39). The PT data 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 in the region, as seen in Willow 3 at W3S and in Willow 1 at W1S.

Peak stage at W3S occurred on June 2. Peak stage resulted from a short-duration stage increase of 0.3 feet in 4 hours, followed by a short-duration stage recession. Observations from June 2, after stage had receded from peak, revealed widespread meltwater persisting across the drainage. Snow cover on the surrounding tundra was approximately 5 percent.

Discharge during spring breakup was measured twice at W3S using a HACH velocity meter attached to a wading rod. During the first measurement on May 30, snow and ice was present underneath flowing meltwater (Photo 4.40). The quality of the May 30 measurement was classified as poor based on the influence of ice and snow in the channel. The measurement on June 2 occurred after water had receded from peak stage and multiple flow paths had been established through the remaining snow. Some ice and snow remained in the flow paths and on the higher-situated tundra surrounding the flow paths (Photo 4.41). The quality of the measurement on June 2 was classified as fair based on these conditions.

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.

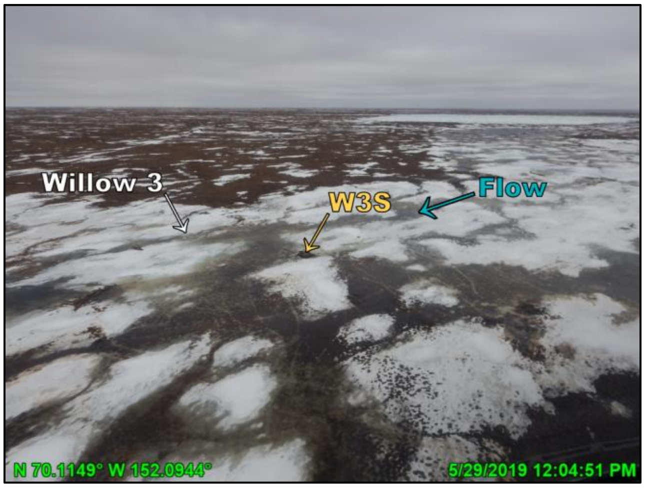


Photo 4.38: W3S drainage before peak stage, looking north (upstream); May 29, 2019

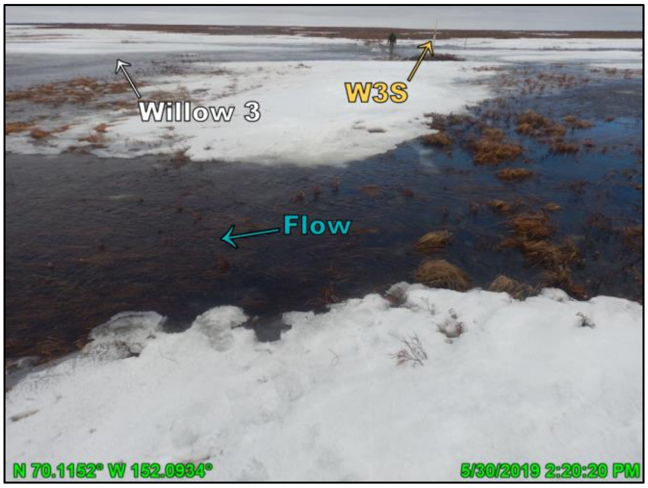


Photo 4.39: Meltwater at W3S, looking east; May 30, 2019

Photo 4.40: Snow in drainage during first discharge measurement on W3S, looking south (upstream); May 30, 2019

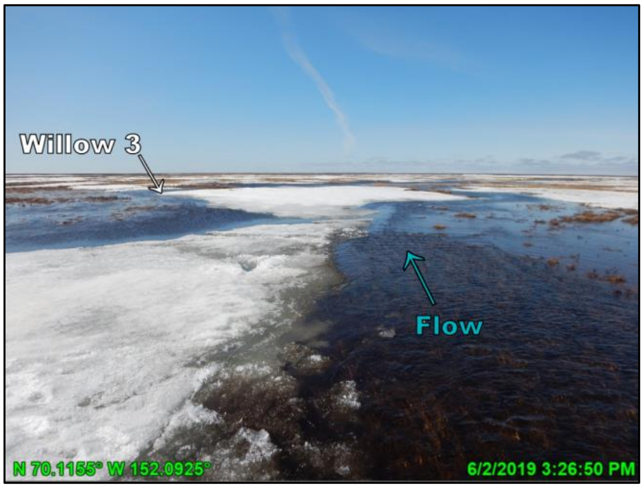
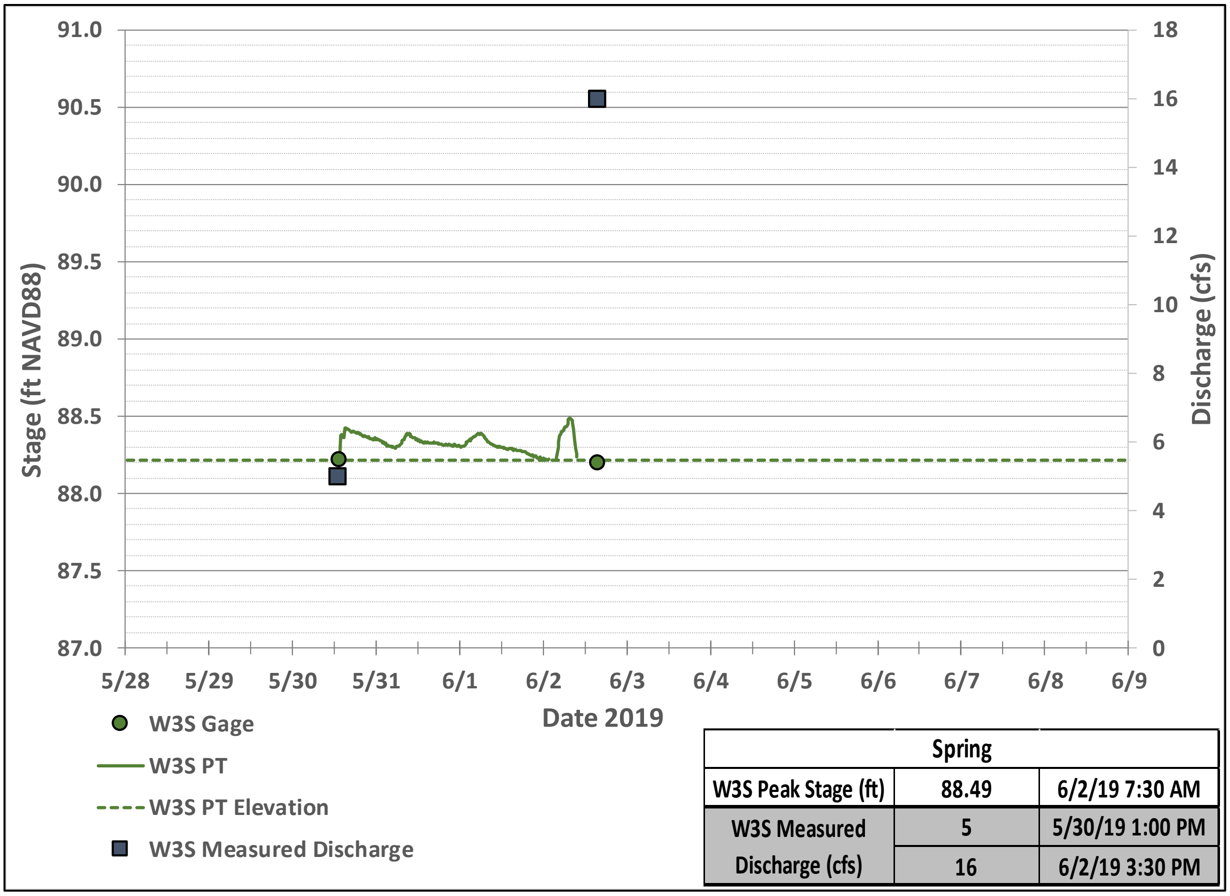


Photo 4.41: Conditions during the second discharge measurement on W3S, looking south (downstream); June 2, 2019



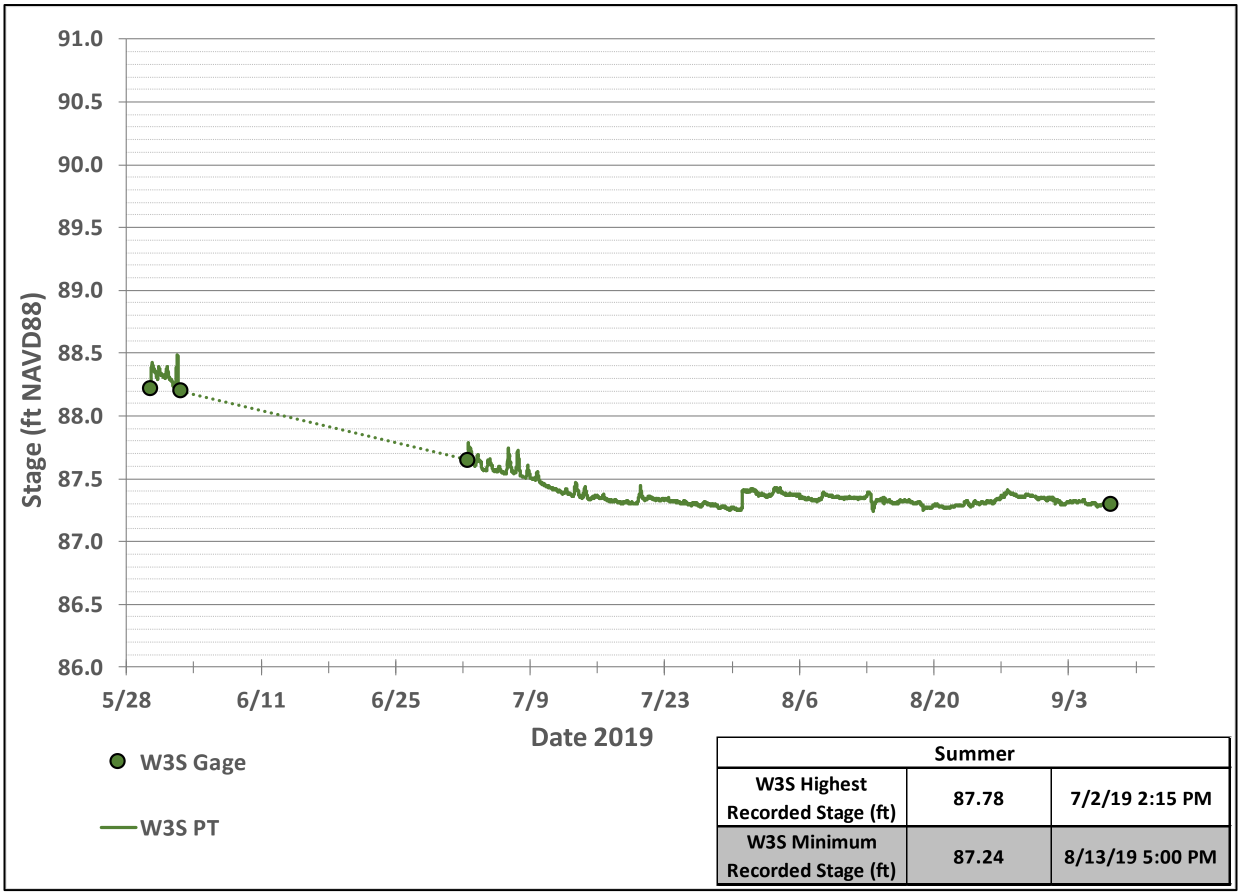
Spring		
W3S Peak Stage (ft)	88.49	6/2/19 7:30 AM
W3S Measured Discharge (cfs)	5	5/30/19 1:00 PM
	16	6/2/19 3:30 PM

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 4.42). Low velocity flow through a poorly defined ephemeral channel was observed on July 2. Summer stage at W3S gage site is presented in Graph 4.14.

Photo 4.42: Summer conditions at W3S, looking north; July 2, 2019



Summer		
W3S Highest Recorded Stage (ft)	87.78	7/2/19 2:15 PM
W3S Minimum Recorded Stage (ft)	87.24	8/13/19 5:00 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 second 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 4.10 and Table 4.11, respectively.

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

Year	W4				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
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)
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 21. Stage rose from May 21 to May 27 and was elevated by saturated snow in the channel and along the banks. Peak stage occurred at both Willow 4 monitoring locations on May 27. The upstream gage, W_BS1, recorded peak stage about 3 hours prior to peak stage at the downstream gage, W4. Aerial observations from May 28 at W4 show meltwater flowing over the top of saturated snow in the channel and confined by drifted snow along the banks (Photo 4.43). At W_BS1, the channel appeared clear of ice and snow, with drifted snow observed primarily along the north bank (Photo 4.44). Stage at both monitoring locations was below bankfull, and no evidence of overbank flooding from peak stage was observed.

On May 29, observations at W4 revealed minimal change from conditions observed on May 28. Saturated snow was observed underneath meltwater across the entire channel with deep, drifted snow present along each bank (Photo 4.45). At W_BS1, observations from May 30 show stage had decreased slightly from peak conditions, with snow still present along the east bank (Photo 4.46). By June 2, saturated snow had cleared from the channel at W4. Snow cover on the surrounding tundra was approximately 5 percent. Stage at each location decreased from peak conditions on May 29 to near low-flow summer conditions by June 12, based on PT data.

Photo 4.43: Drifted snow in the Willow 4 drainage near W4, looking south (upstream); May 28, 2019

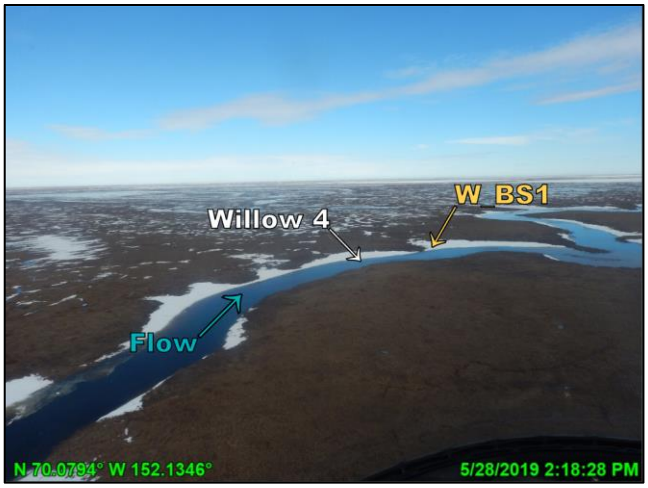


Photo 4.44: Aerial observations of the Willow 4 drainage near W_BS1, looking north (downstream); May 28, 2019

Photo 4.45: Drifted snow remains in drainage near W4, looking north (downstream); May 29, 2019

Photo 4.46: Conditions near W_BS1 four days after peak stage, looking east (upstream); May 30, 2019

Discharge during spring breakup was measured at both W4 and W_BS1 using a tethered ADCP. Discharge at W_BS1 was measured one day after peak stage on May 28 as the channel was mostly clear of ice and snow, with drifted snow present along the east bank (Photo 4.47). As a result, the quality of the May 28 measurement at W_BS1 was classified as fair. Discharge was measured at W4 on June 2. By this day, stage had receded nearly 2 feet from peak conditions and saturated snow was present along each bank (Photo 4.48). As a result, the quality of the June 2 measurement at W4 was also classified as fair. Discharge at W_BS1 will naturally be lower than W4 since it is upstream of the Willow 4A confluence.

Photo 4.47: Conditions at W_BS1 during the discharge measurement, looking north; May 28, 2019

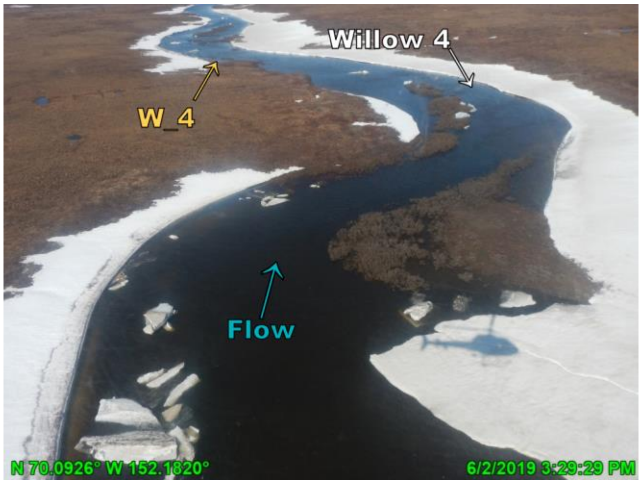
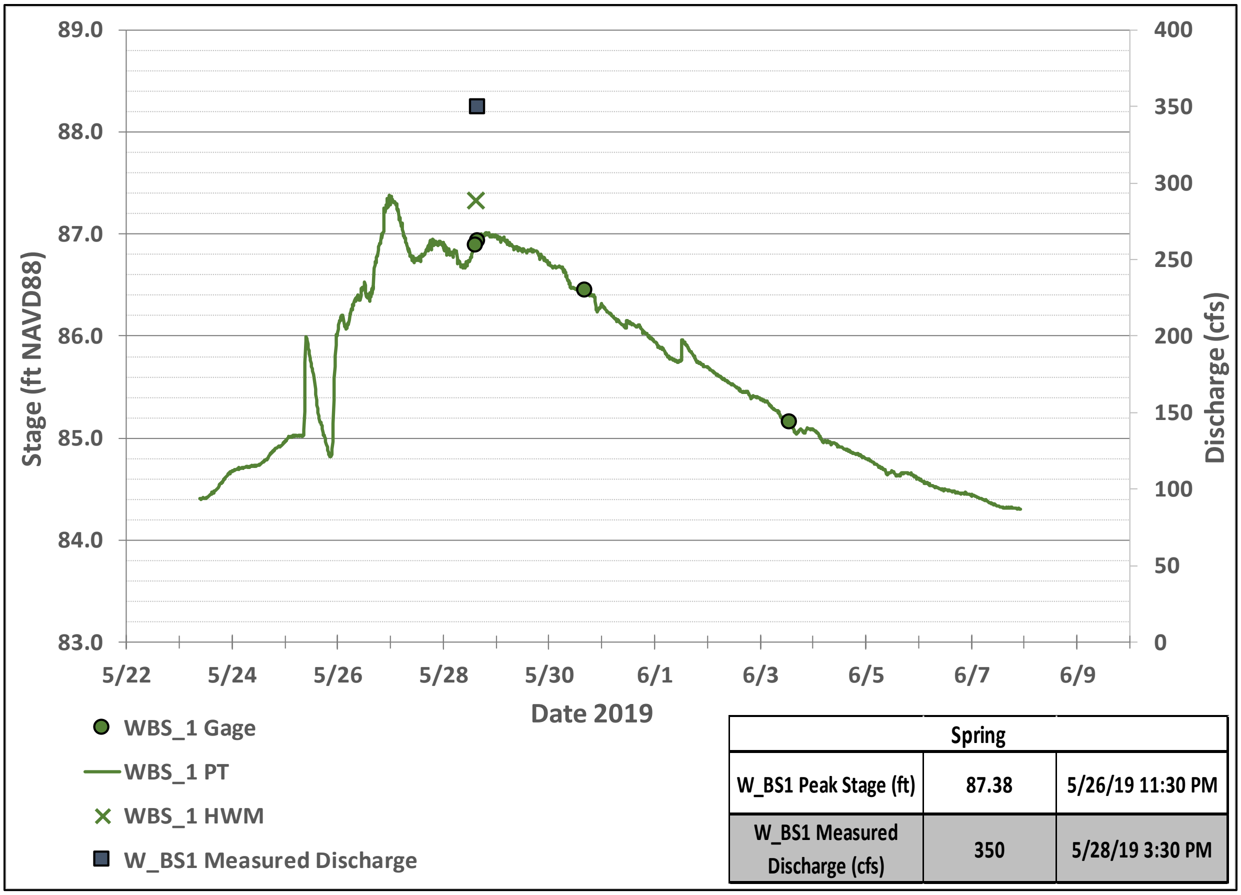


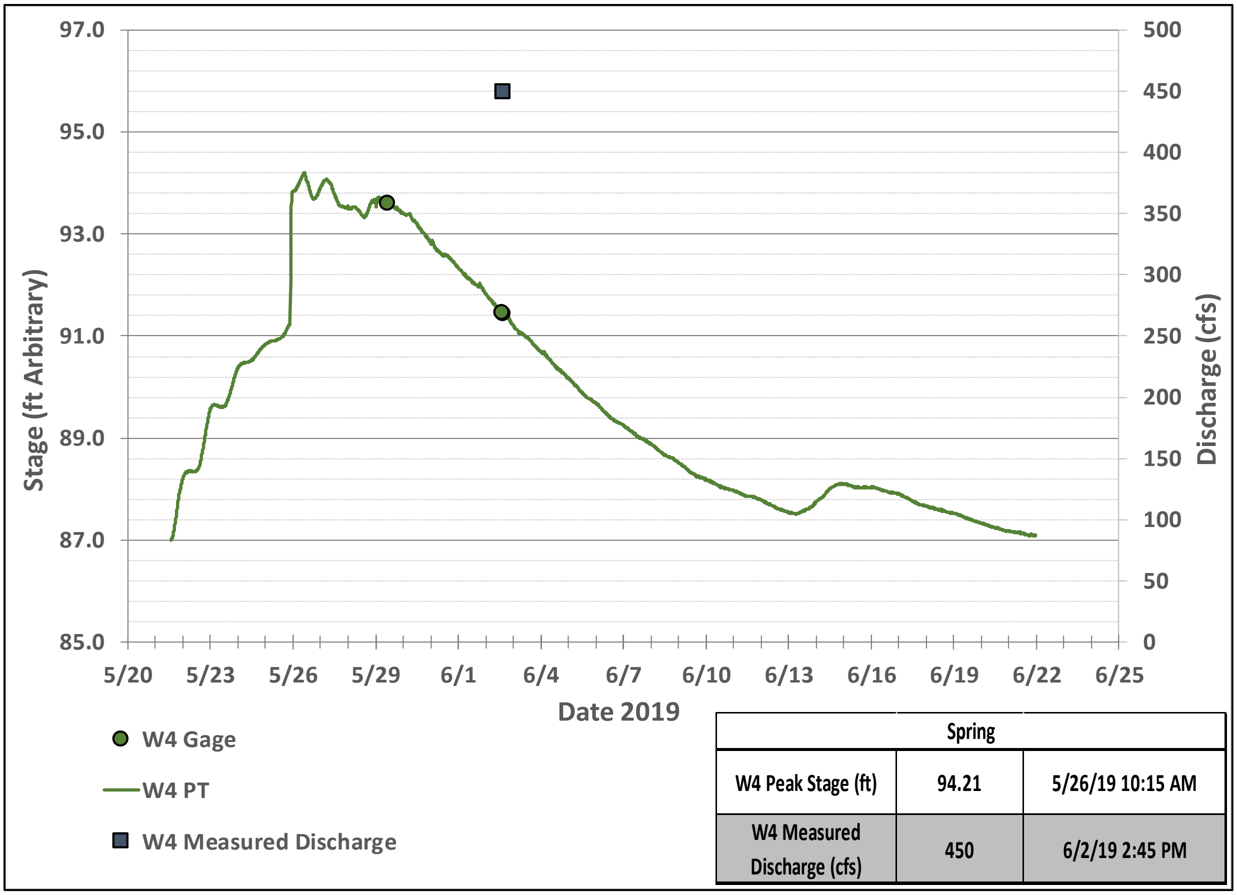
Photo 4.48: Conditions at W4 during the discharge measurement, looking north (downstream); June 2, 2019

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 are referenced to an arbitrary datum based on a local control point.



Spring		
W_BS1 Peak Stage (ft)	87.38	5/26/19 11:30 PM
W_BS1 Measured Discharge (cfs)	350	5/28/19 3:30 PM

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



Spring		
W4 Peak Stage (ft)	94.21	5/26/19 10:15 AM
W4 Measured Discharge (cfs)	450	6/2/19 2:45 PM

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 4.49 and Photo 4.50). The PT at W4 malfunctioned after July 31. During a late summer precipitation event, the W_BS1 PT recorded a stage crest comparable to water levels observed near the end of spring breakup. Summer stage at W_BS1 and W4 gage site is presented in Graph 4.17 and Graph 4.18, respectively.

Photo 4.49: Summer conditions at W4, looking south (upstream); July 2, 2019

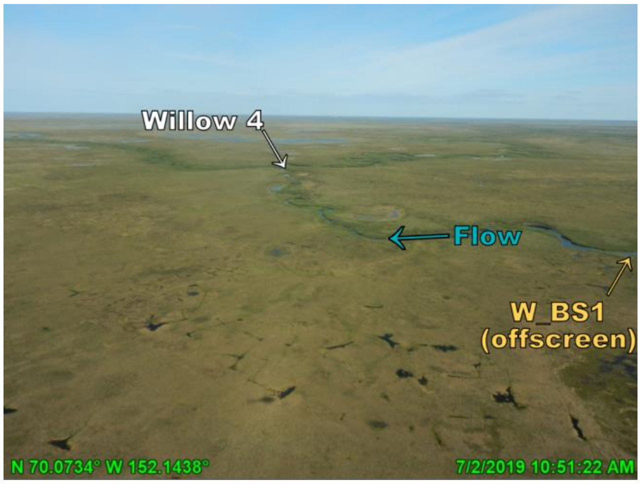
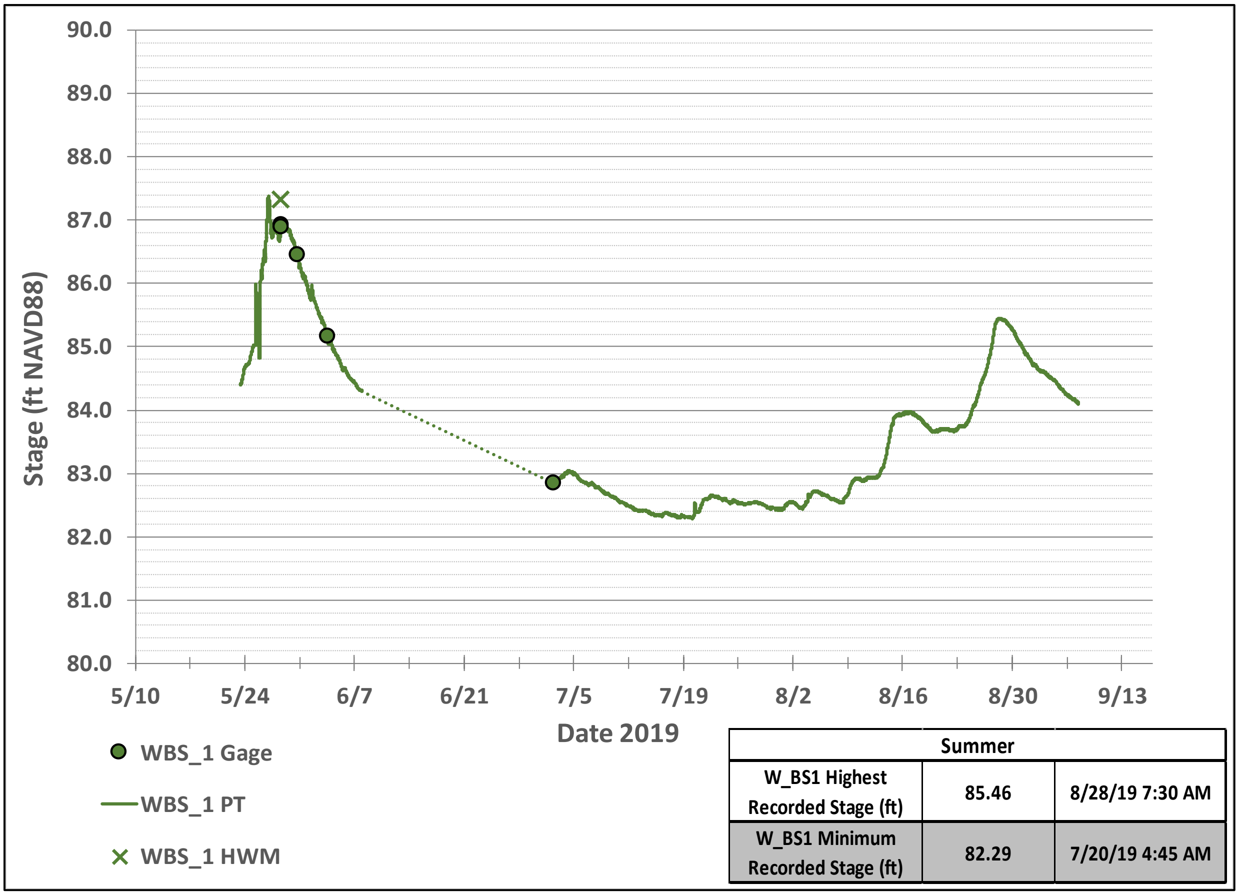
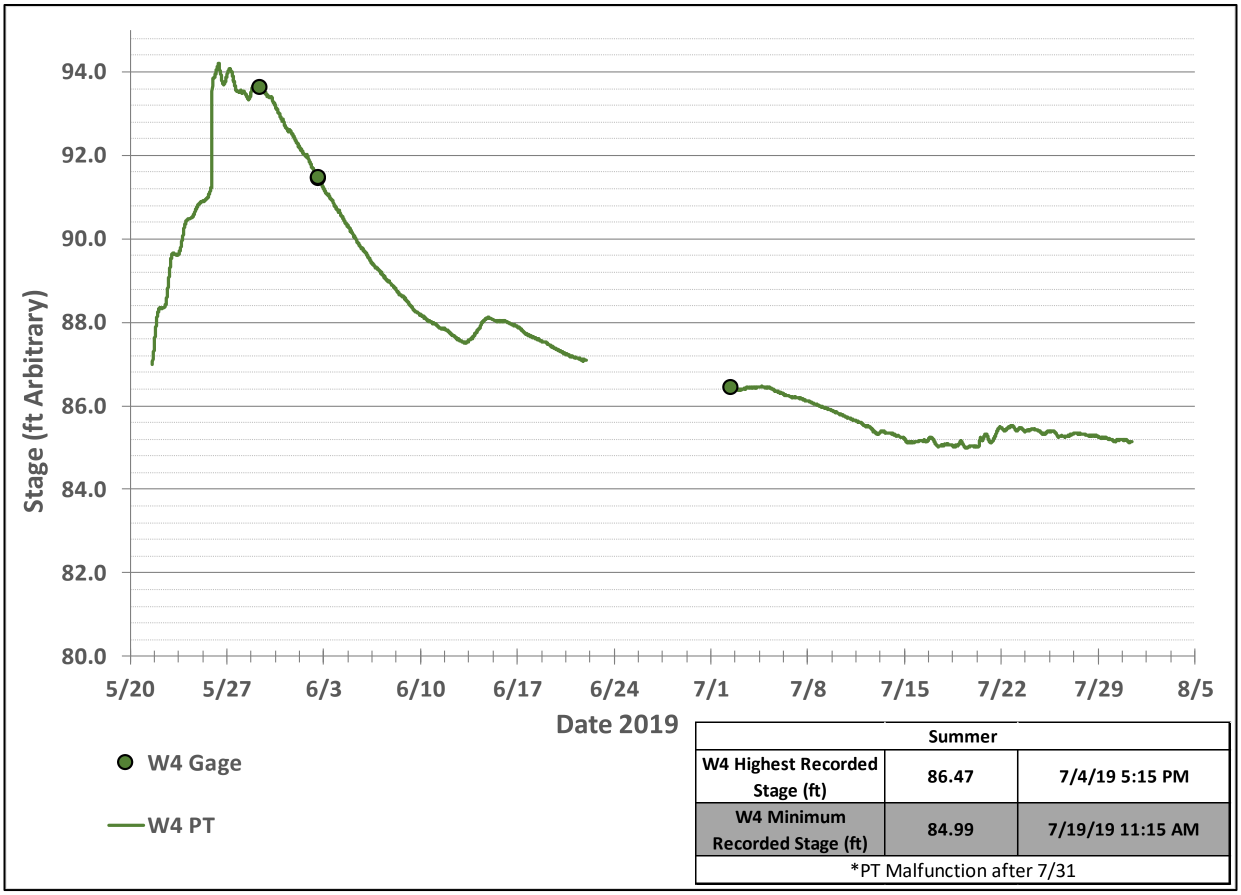


Photo 4.50: Summer conditions near W_BS1, looking north (downstream); July 2, 2019



	Summer	
W_BS1 Highest Recorded Stage (ft)	85.46	8/28/19 7:30 AM
W_BS1 Minimum Recorded Stage (ft)	82.29	7/20/19 4:45 AM

Graph 4.17: Willow 4 At W_BS1 Summer Stage



Summer		
W4 Highest Recorded Stage (ft)	86.47	7/4/19 5:15 PM
W4 Minimum Recorded Stage (ft)	84.99	7/19/19 11:15 AM
*PT Malfunction after 7/31		

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 second 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 4.12.

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)
2019	101.89	5/27	320	5/29	100.99
2018 [1]	101.93	6/8	40	6/13	99.77

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 at W_S1 was recorded on May 22. PT data indicates stage rose until peak stage on May 27. Visual observations were first conducted on May 29, when stage had receded nearly 1-ft from peak stage. On May 29, aerial observations revealed stage above bankfull, with minor overbank flooding in low-lying areas and adjacent polygon troughs (Photo 4.51). Stranded ice was also noted above the reach of the bank (Photo 4.52). An ice jam had formed upstream of W_S1 but did not appear to significantly impede flow through the area. Aerial photos suggest the presence of bottom-fast ice or saturated snow at the channel bottom.

After peak stage on May 27, PT data indicated that stage receded but remained elevated to near bankfull levels through the end of the monitoring period. On June 3, stage was observed to be near bankfull, with minimal snow remaining in the channel and along the banks (Photo 4.53). Snow cover on the surrounding tundra was approximately 5%.

Photo 4.51: Willow 4A drainage near W_S1 two days after peak stage; looking east; May 29, 2019

Photo 4.52: Ice jam and stranded ice upstream of W_S1, looking north (downstream); May 29, 2019

Photo 4.53: Receding stage at W_S1, looking north (downstream); June 3, 2019

Discharge was measured using a tethered ADCP at W_S1 on May 29, two days after peak stage. Overbank flooding was observed during the measurement, but most of the flow (over 95 percent) was confined to the channel (Photo 4.54). An ice jam located approximately 100-ft upstream of the discharge cross-section would periodically release ice through the measurement reach. The presence of bottom-fast ice was likely but ultimately inconclusive. Based on these factors, the overall quality of the discharge measurement was classified as fair.

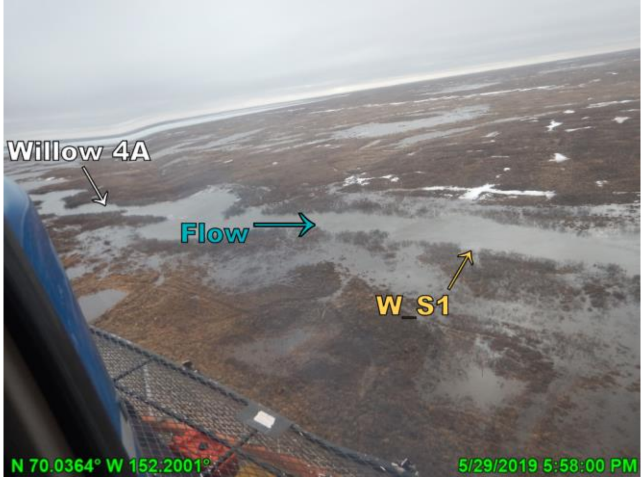
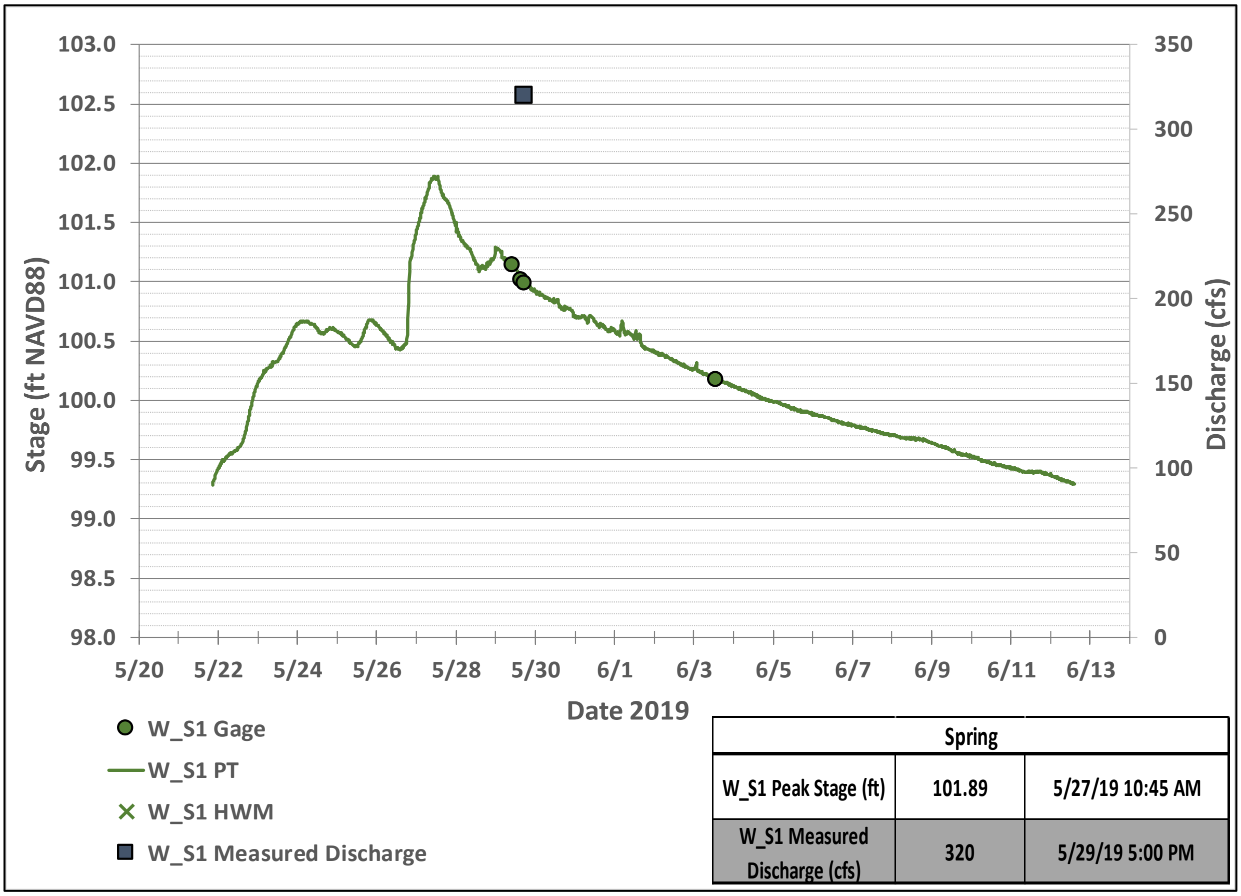


Photo 4.54: Discharge cross-section in Willow 4a near W_S1, looking southwest (upstream); May 29, 2019

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.



	Spring	
W_S1 Peak Stage (ft)	101.89	5/27/19 10:45 AM
W_S1 Measured Discharge (cfs)	320	5/29/19 5:00 PM

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 4.55). 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.

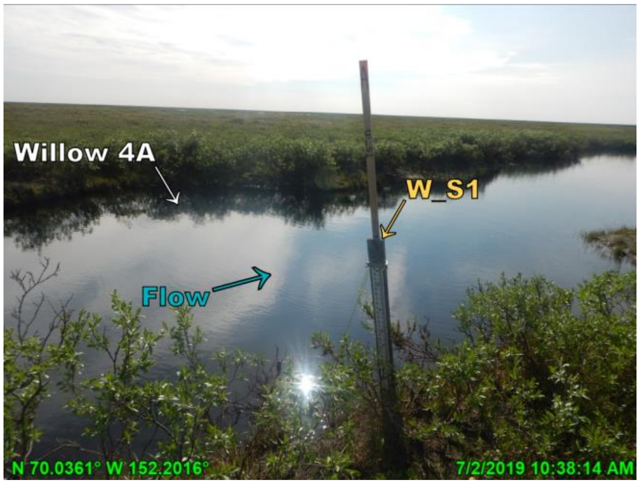
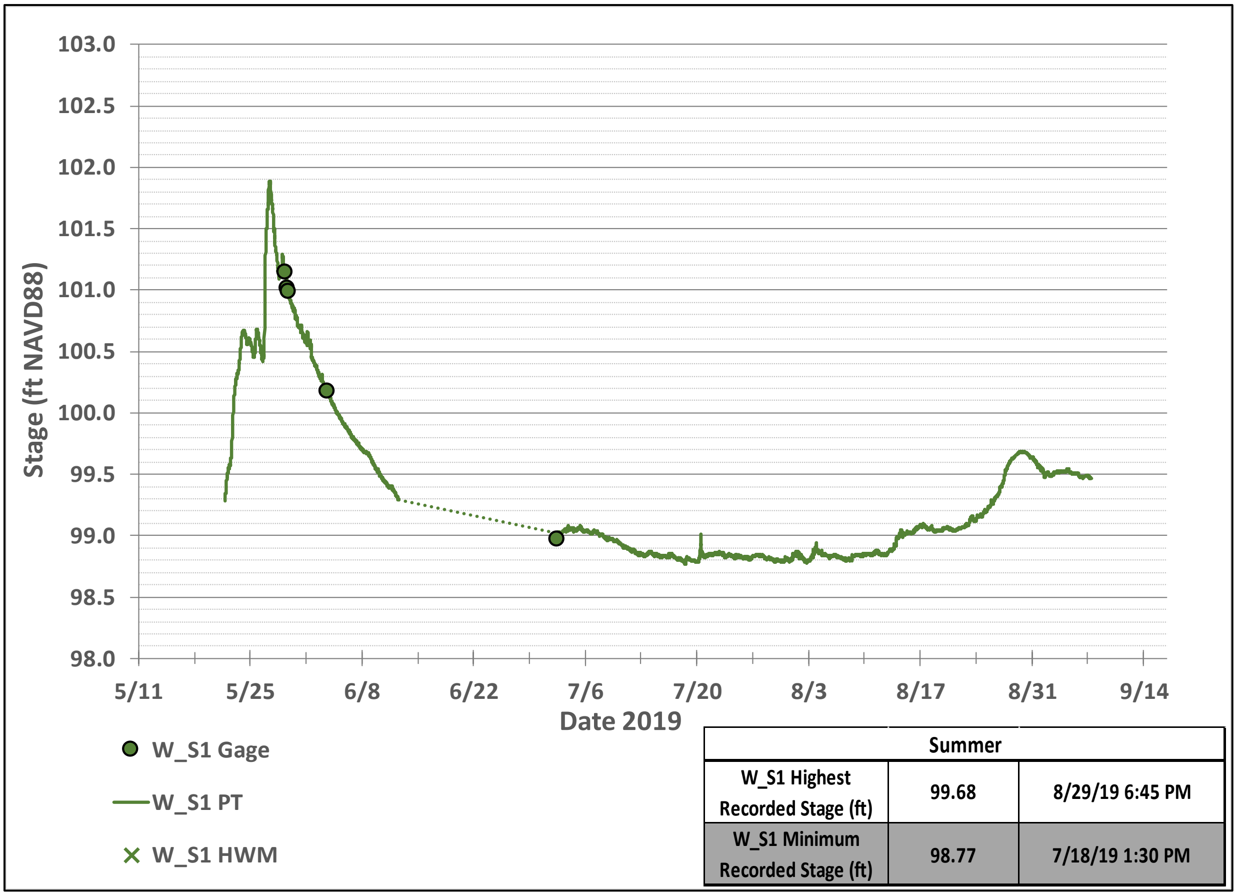


Photo 4.55: Summer conditions at W_S1, looking east (downstream); July 2, 2019



	Summer	
W_S1 Highest Recorded Stage (ft)	99.68	8/29/19 6:45 PM
W_S1 Minimum Recorded Stage (ft)	98.77	7/18/19 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 second year of data collection and observations at the TBD_6 and SW22 monitoring locations. Historical peak stage and measured discharge data at TBD_6 and SW22 is presented in Table 4.13 and Table 4.14, respectively.

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

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

Notes:
[1.] 2018 and 2019 NAVD88 datum derived by correlating PT data with the reported edge of water from a nearby 2018 UMIAQ transect survey

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)
2019	79.35	5/28	4	6/1	79.01
2018	No Recorded Water		--	--	--

A. SPRING BREAKUP

Initial meltwater was recorded on both Willow 8 site PTs on May 22. At SW22, game camera images suggest this meltwater was localized and stage was elevated by drifted, saturated snow. As stage increased at SW22, images from the game camera show the area remained covered with snow. Any flow paths developed during this time were cut underneath drifted snow, and no visible flow was observed (Photo 4.56). Game camera images show this condition was maintained until June 7, when snow melt exposed flow paths previously concealed underneath drifted snow (Photo 4.57). It is noted that Willow 8 near SW22 has a wide area of possible flow paths due to low relief in the drainage, so data collected from the gage and game camera at SW22 may not capture the entirety of flow behavior through the reach.

On May 27, aerial observations from SW22 show significant drifted snow remaining in the drainage area. A poorly defined flow path was visible from the air based on areas of dark, saturated snow (Photo 4.58). Minimal visible flow was observed as flow paths were cut underneath drifted snow. On June 1, conditions were similar to those observed on May 27 (Photo 4.59). An area of visible flow in Willow 8 was observed further upstream from SW22, but any flow around SW22 was confined underneath snow.

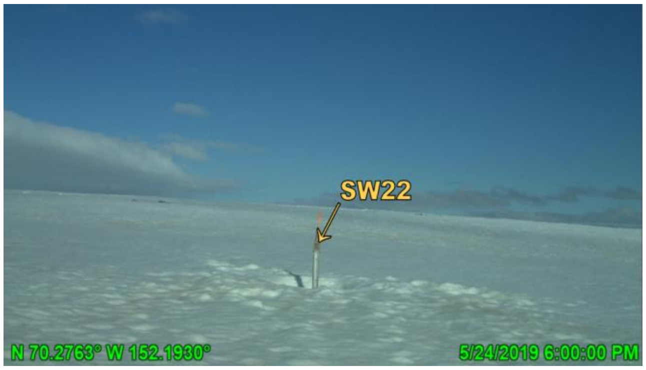


Photo 4.56: Game camera image of Willow 8 at SW22, looking west; May 24, 2019

Photo 4.57: Game camera image of Willow 8 at SW22 as first flow paths are revealed, looking north; June 7, 2019

Photo 4.58: Saturated snow in the Willow 8 drainage near SW22, looking southeast (upstream); May 27, 2019

Photo 4.59: Increasing meltwater in Willow 8 near SW22, looking north (upstream); June 1, 2019

At TBD_6, stage increased from May 22 to May 27. On May 27, aerial observations revealed meltwater flowing over the top of saturated snow and bottom-fast ice (Photo 4.60). Stage was near bankfull, elevated by saturated snow in the channel and along the banks. A slotted ice road intersecting Willow 8 about 0.25 RMs downstream of TBD_6 appeared to impede meltwater. Minor overbank flooding was observed upstream of this ice road, including near TBD_6, and no overbank flooding was noted downstream of the road (Photo 4.61).

The PT data at TBD_6 indicates a general leveling of stage on May 27 and May 28, followed by a spike of nearly 1.5-ft in under 24 hours, culminating in peak stage conditions on May 29. After peaking, stage decreased at a rate of nearly 1-ft per day until June 1. This rapid stage recession is likely attributed to the disintegration of the nearby ice road, allowing meltwater to pass with decreasing impedance. On May 30, aerial observations show overbank flooding in low-lying areas upstream of the ice road, and bankfull conditions downstream of the ice road (Photo 4.62). Saturated snow and bottom-fast ice were observed in the channel near the ice road (Photo 4.63). By June 1, stage had receded to bankfull at TBD_6, and the natural drainage path was now unimpeded from the disintegrating ice road. The snow cover on the surrounding tundra was approximately 5 percent (Photo 4.64).

Photo 4.60: Willow 8 drainage near TBD_6, two days before peak stage, looking west (downstream); May 27, 2019

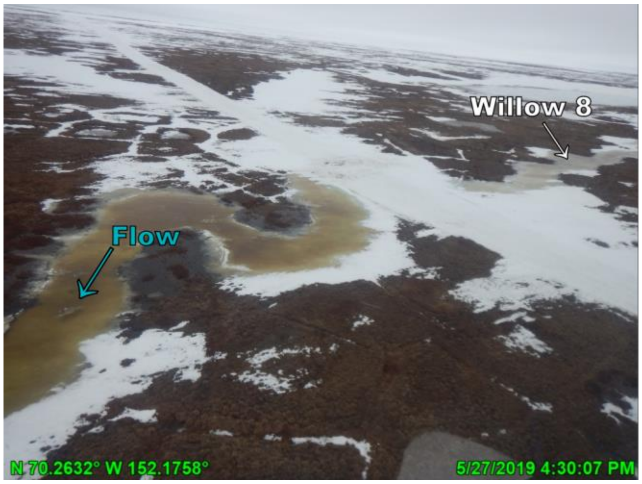


Photo 4.61: Ice road across Willow 8 downstream of TBD_6, looking northeast (upstream); May 27, 2019

Photo 4.62: Bankfull stage in Willow 8, downstream of TBD_6; looking northeast (upstream); May 30, 2019

Photo 4.63: Ice road crossing in Willow 8, looking north; May 30, 2019

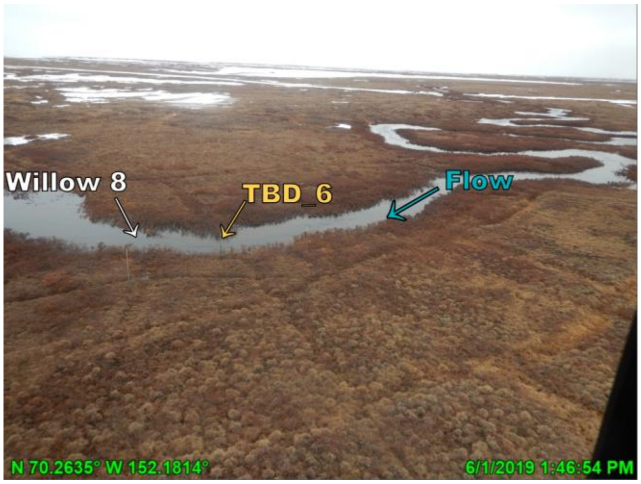


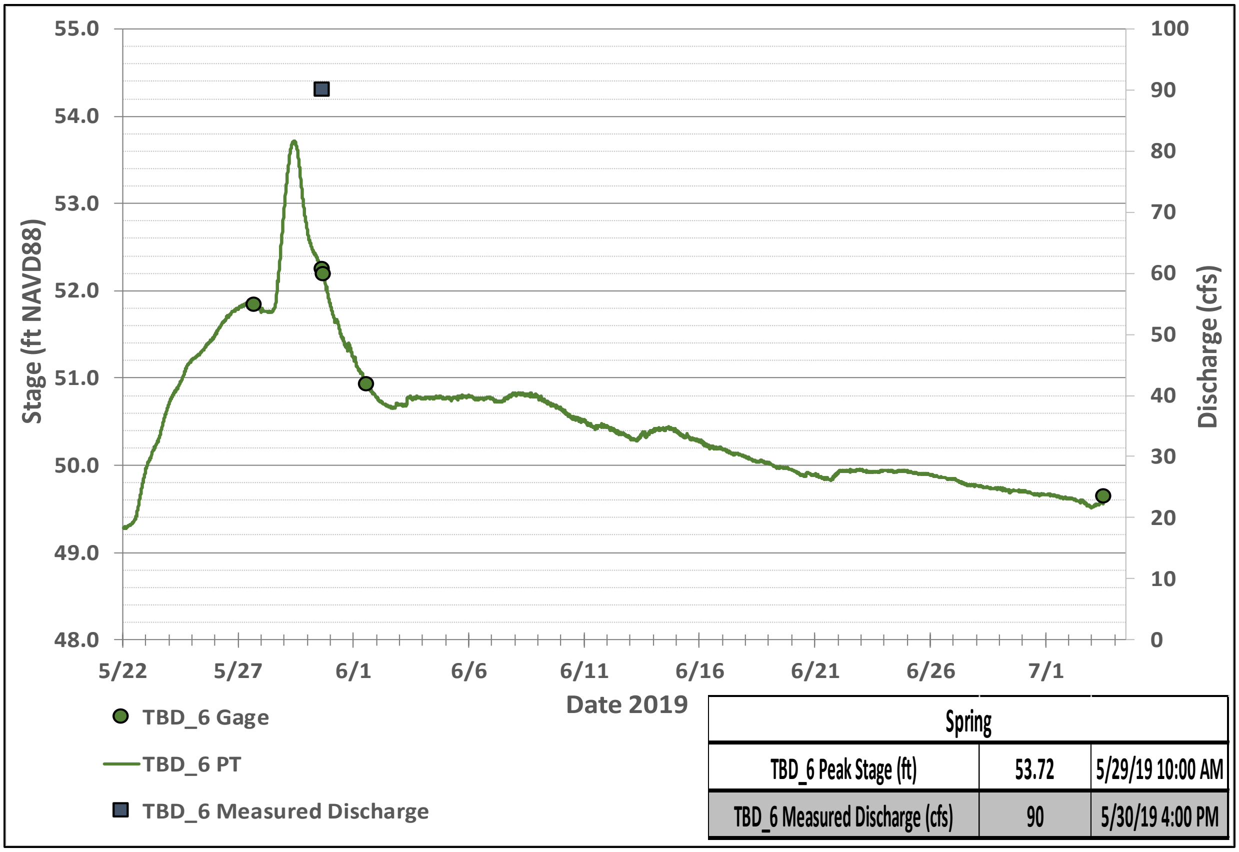
Photo 4.64: Open channel conditions at TBD_6, looking northeast (upstream); June 1, 2019

Discharge was measured using a tethered ADCP at TBD_6 on May 30 and using a HACH velocity meter attached to a wading rod at SW22 on June 1. At SW22, an exposed flow path, surrounded by drifted snow, was observed and measured upstream of the gage site (Photo 4.65). The topography of the area suggests this flow path did not capture the entirety of flow through Willow 8 as the presence of additional flow paths underneath drifted snow was likely. The quality of the measurement was classified as poor based on the inherent uncertainty of drainage patterns at this location. At TBD_6, discharge was measured about 0.4 RM downstream of the gage station, directly downstream of the degrading ice road, as minimal snow remained in the channel and along the banks at this location. Minor overbank flooding was noted during the measurement and the reach was clear of ice (Photo 4.66). The quality of the measurement was classified as fair based primarily on the minor overbank flooding.

Photo 4.65: Discharge cross-section in Willow 8 near SW22, looking south (downstream); June 1, 2019

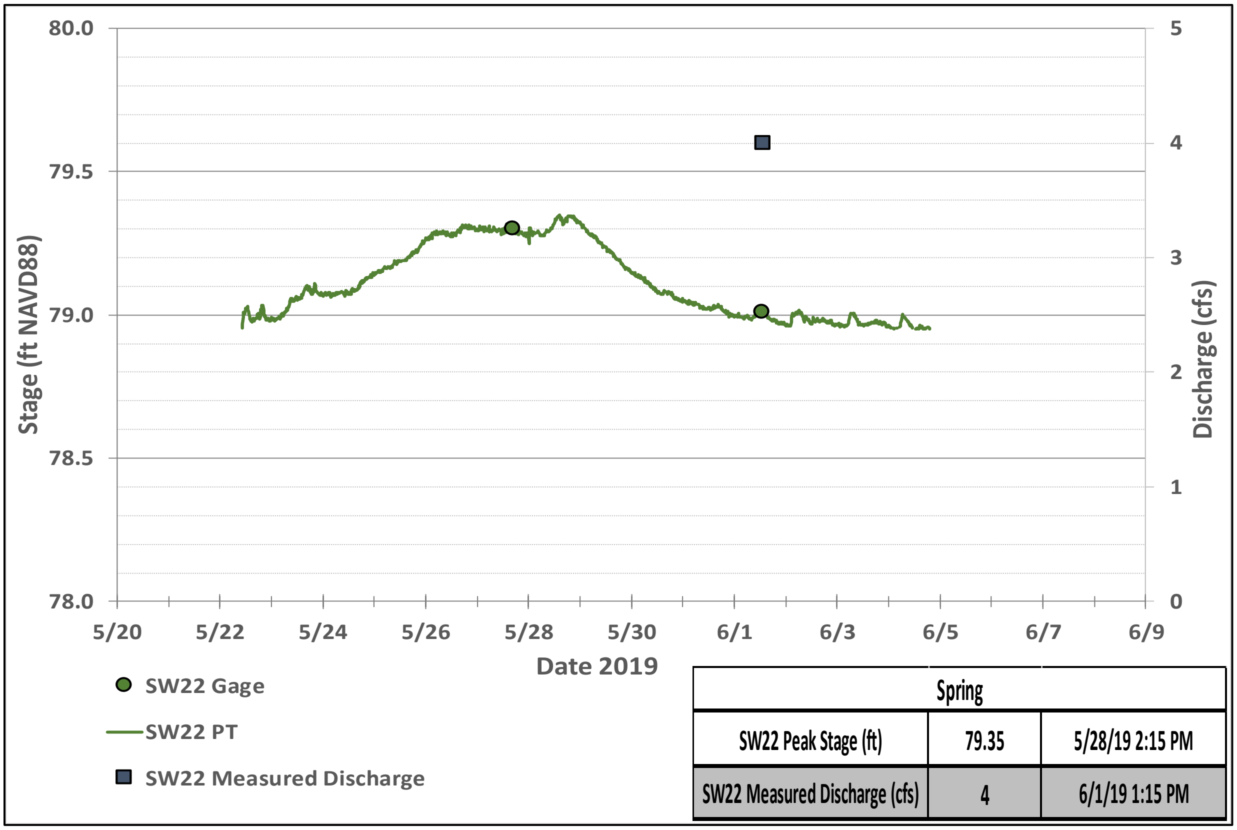
Photo 4.66: Discharge cross-section in Willow 8 near TBD_6, looking northeast (upstream); May 30, 2019

The TBD_6 and SW22 stage and measured discharge data are presented in Graph 4.21 and Graph 4.22. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring		
TBD_6 Peak Stage (ft)	53.72	5/29/19 10:00 AM
TBD_6 Measured Discharge (cfs)	90	5/30/19 4:00 PM

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



Spring		
SW22 Peak Stage (ft)	79.35	5/28/19 2:15 PM
SW22 Measured Discharge (cfs)	4	6/1/19 1:15 PM

Graph 4.22: Willow 8 at SW22 Spring Breakup Stage & Discharge

B. SUMMER

Summer stage was measured at both SW22 and TBD6. Stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained well below spring breakup peak stage at all locations (Photo 4.67and Photo 4.68). The stage increase at the end of the summer monitoring period is associated with a notable precipitation event. Summer stage at the TBD_6 and SW22 gage sites are presented in Graph 4.23 and Graph 4.24, respectively.

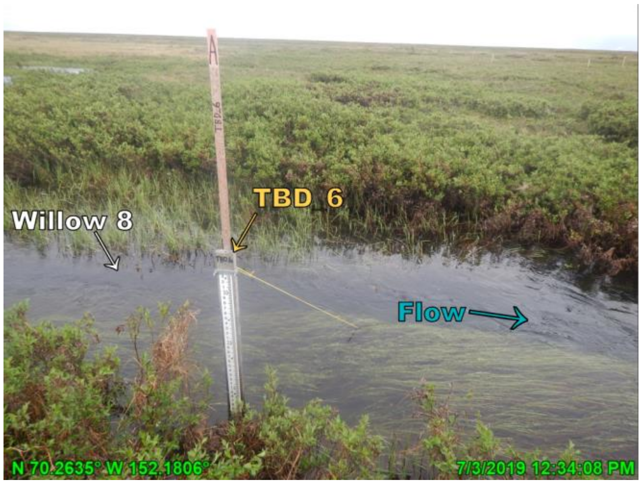


Photo 4.67: Summer conditions at TBD_6, looking north; July 3, 2019

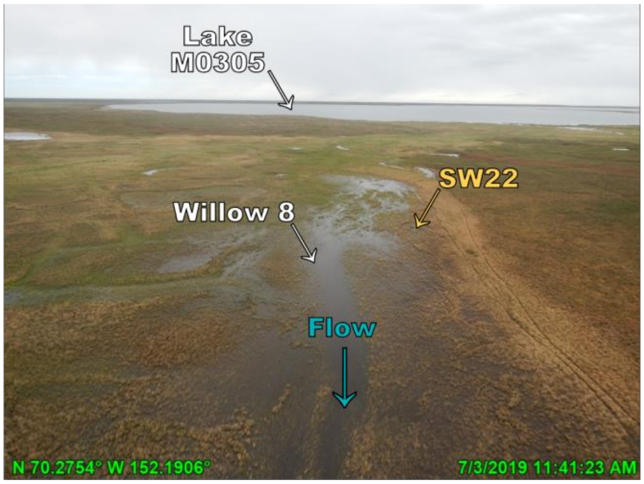
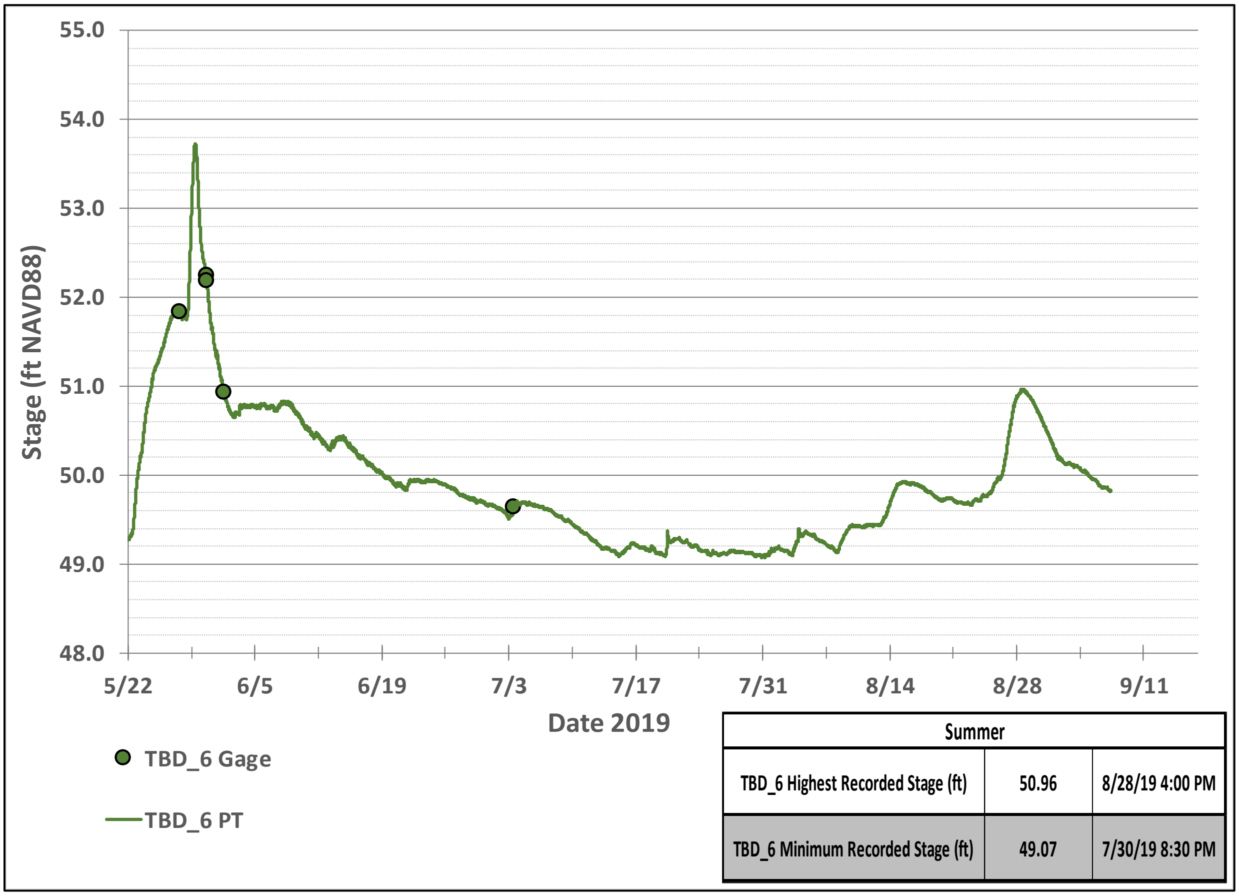
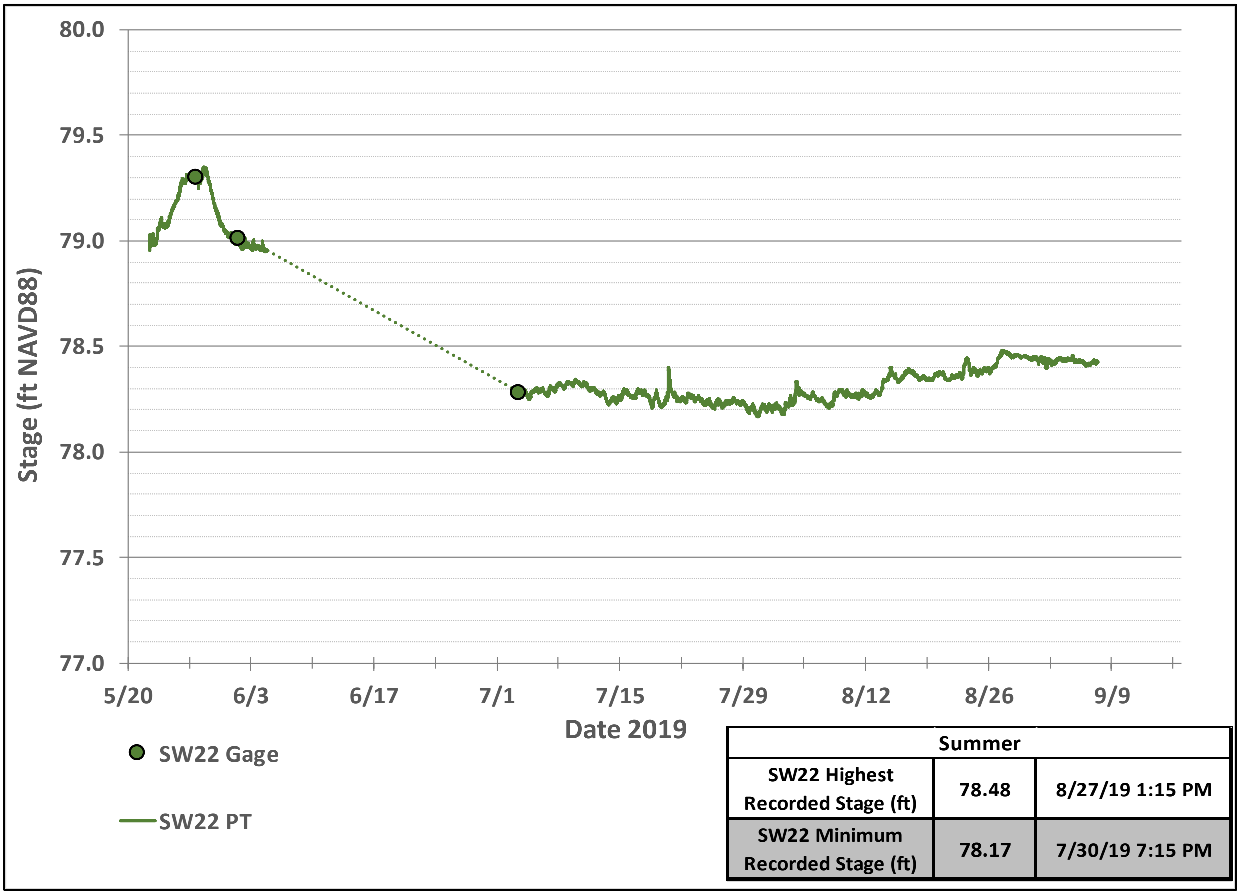


Photo 4.68: Summer Conditions in Willow 8 near SW22, looking north (upstream); July 3, 2019



Summer		
TBD_6 Highest Recorded Stage (ft)	50.96	8/28/19 4:00 PM
TBD_6 Minimum Recorded Stage (ft)	49.07	7/30/19 8:30 PM

Graph 4.23: Willow 8 at TBD_6 Spring and Summer Stage



Summer		
SW22 Highest Recorded Stage (ft)	78.48	8/27/19 1:15 PM
SW22 Minimum Recorded Stage (ft)	78.17	7/30/19 7:15 PM

Graph 4.24: Willow 8 at SW22 Spring and Summer Stage

TBD_5

Gage station TBD_5 is situated in a deep, incised channel draining into the Kalikpik River west of Willow 6. This stream is located southwest of the CPAI proposed alignment. This is the second year of data collection and observations at the TBD_5 monitoring location. Historical peak stage and measured discharge data at TBD_5 is presented in Table 4.15.

Table 4.15: TBD_5 Historical Peak Stage and Measured Discharge

Year	TBD_5				
	Peak Stage (ft Arbitrary) [1]	Date	Measured Discharge (cfs)	Date	Associated Stage (ft Arbitrary) [1]
2019	97.77	5/27	135	6/2	97.11
2018	98.42	6/11	250	6/18	98.08

Notes:
[1] Arbitrary elevations referenced to local control point "REDFISH" (MBI 2018)

A. SPRING BREAKUP

The TBD_5 drainage was filled with wind-driven snow at the onset of spring breakup. Initial meltwater was recorded on the site PT on May 21. Stage increased at a relatively consistent pace until peak stage occurred on May 27. Site observations first occurred on May 27, coincidently one hour before peak stage. On this day, large quantities of drifted snow were observed in the channel and along the banks. Stage was elevated by saturated snow, and overbank flooding was present in low-lying areas. Snow and bottom-fast ice were observed across the entire width of the channel near TBD_5 (Photo 4.69). A slotted ice road intersecting the drainage and located approximately 1 RM downstream of TBD_5 appeared to not inhibit the passage of meltwater (Photo 4.70).

On May 30, aerial observations revealed saturated snow present in the channel and along the banks. Stage was still elevated above bankfull, and flooding was observed in low-lying areas (Photo 4.71). The condition of the slotted remained relatively unchanged from May 27. The snow cover on the surrounding tundra was approximately 10 percent. On June 1, stage had receded but was still above bankfull. Bottom-fast ice was present in the channel and saturated snow remained along the banks (Photo 4.72). PT data indicates that stage remained elevated after peak and did not begin to recede below elevated breakup stage levels until June 6.

Photo 4.69: Bottom-fast ice and saturated snow near TBD_5, looking northeast (downstream); May 27, 2019

Photo 4.70: Slotted ice road near TBD_5, looking west (upstream); May 27, 2019

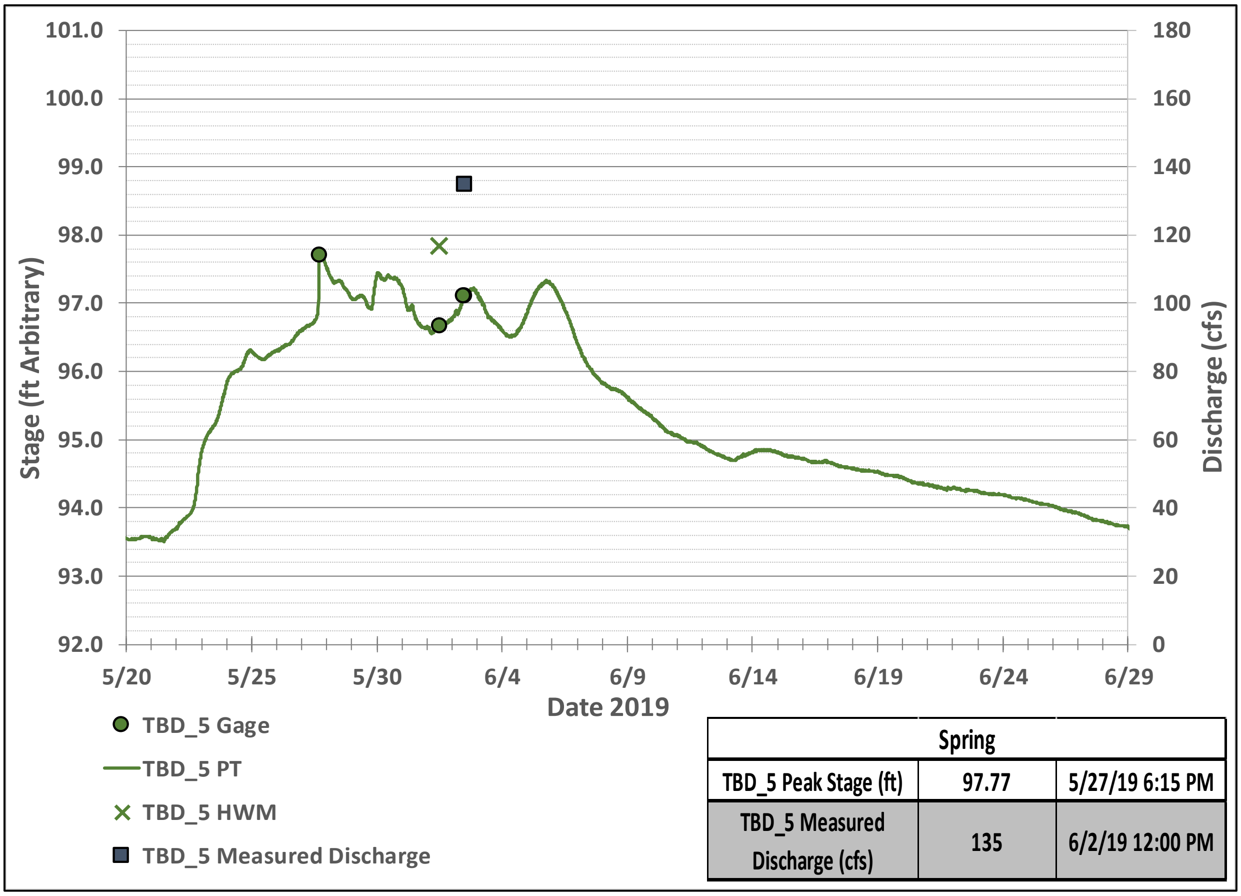
Photo 4.71: Overbank flooding near TBD_5, looking northeast (downstream); May 30, 2019.

Photo 4.72: TBD_5 drainage five days after peak stage, looking northeast (downstream); June 1, 2019

Discharge was measured using a tethered ADCP at TBD_5 on June 2 as stage was about 0.5-ft below recorded peak stage on May 27. Conditions at the time of measurement included overbank flooding, saturated snow along the banks, and bottom-fast ice across nearly the entire width of the channel (Photo 4.73). Discharge was measured in an area where flow was generally well-confined to the channel. Based on conditions at the time of the measurement, the overall quality of the discharge measurement was considered fair.

Photo 4.73: Conditions during TBD_5 discharge measurement, looking north (downstream); June 2, 2019

The TBD_5 spring breakup stage and measured discharge data are presented in Graph 4.25. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are arbitrary.



	Spring	
TBD_5 Peak Stage (ft)	97.77	5/27/19 6:15 PM
TBD_5 Measured Discharge (cfs)	135	6/2/19 12:00 PM

Graph 4.25: TBD_5 Spring Breakup Stage & Discharge

B. SUMMER

Summer stage was measured at TBD_5. Stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained well below spring breakup peak stage (Photo 4.74). During a late summer precipitation event, stage crested at levels observed near the end of spring breakup. Summer stage at TBD_5 gage site is presented in Graph 4.26.

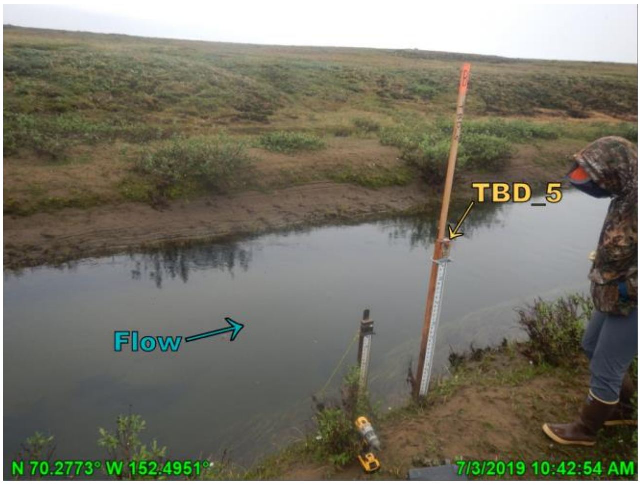
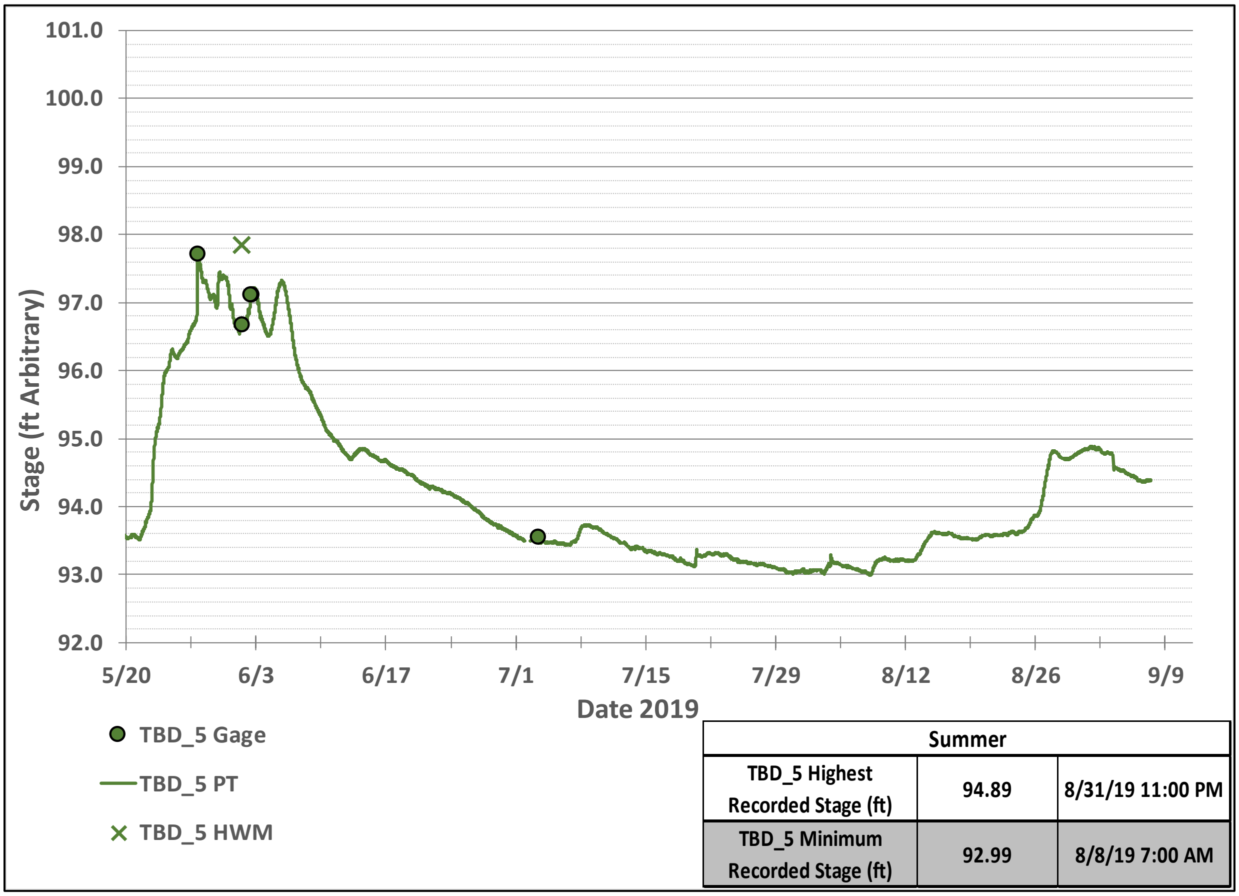


Photo 4.74: Summer conditions at TBD_5, looking north (downstream); July 3, 2019



Summer		
TBD_5 Highest Recorded Stage (ft)	94.89	8/31/19 11:00 PM
TBD_5 Minimum Recorded Stage (ft)	92.99	8/8/19 7:00 AM

Graph 4.26: Willow 8 TBD_5 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 first year of data collection and observations. Snow cover during spring breakup setup masked the subtle topographic features defining the swales and small drainages, making it challenging to accurately determine the flow path and optimal location for new gage station installations.

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 third 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 4.16.

Table 4.16: SW1 Historical Peak Stage and Measured Discharge

Year	SW1				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
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]	79.92	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

Local melt was first observed near SW1 from game camera images on May 23 (Photo 4.75). Stage increased until peak stage conditions were observed on May 26. 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 near the low-relief areas associated with the two unnamed lakes on either end of the swale (Photo 4.76). An area of channelized flow was present for about 150 feet between these areas of widespread meltwater. Discharge was measured at SW1 on May 29. 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 4.77). Snow cover on the surrounding tundra was approximately 10 percent. On June 2, widespread meltwater persisted across the low-relief areas and ice still covered each unnamed lake (Photo 4.78). By early July, water was confined to beads within the drainage path, adjacent low-lying areas were dry, and no flow was observed (Photo 4.79).

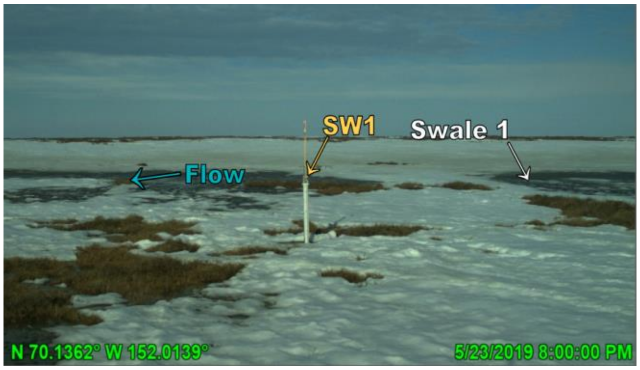


Photo 4.75: Game camera image of initial meltwater near SW1, looking east; May 23, 2019

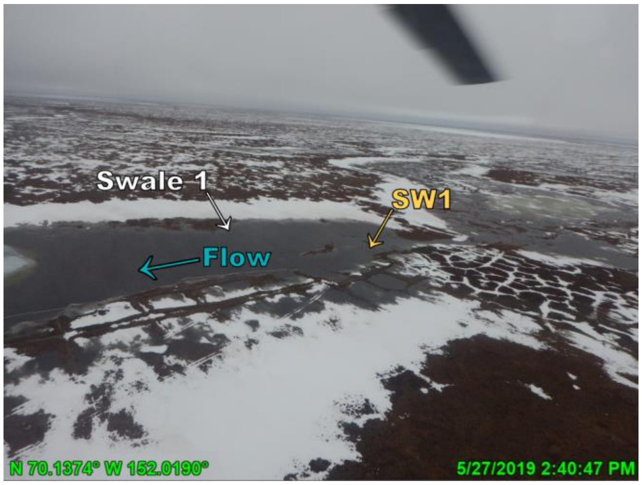


Photo 4.76: Widespread meltwater in the SW1 drainage the day after peak stage, looking southeast (upstream); May 27, 2019

Photo 4.77: The SW1 drainage three days after peak stage; looking northeast (downstream); May 29, 2019

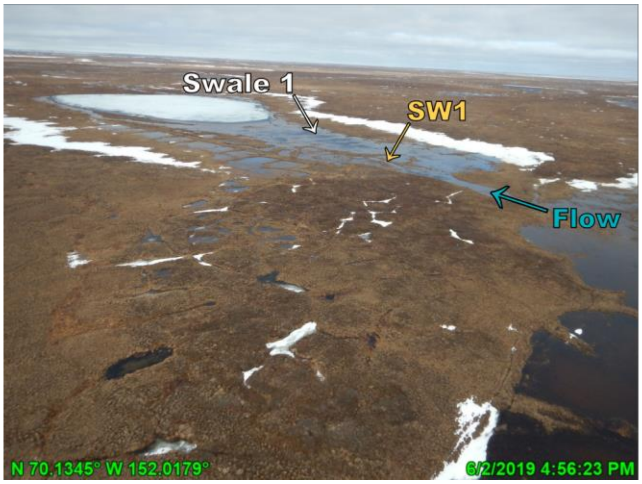


Photo 4.78: Receding stage in the SW1 drainage, looking northeast (downstream); June 2, 2019

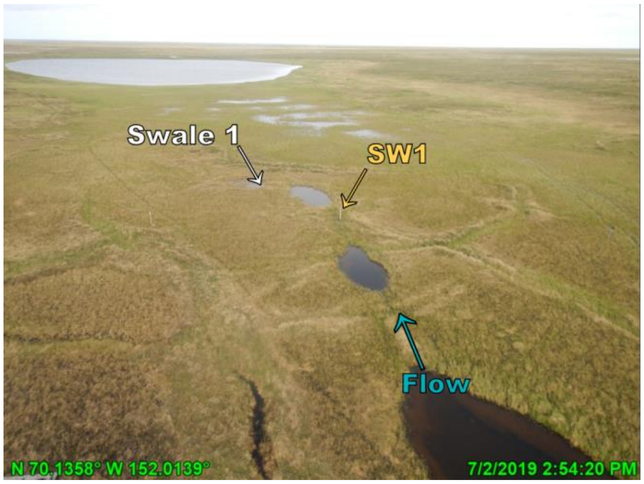
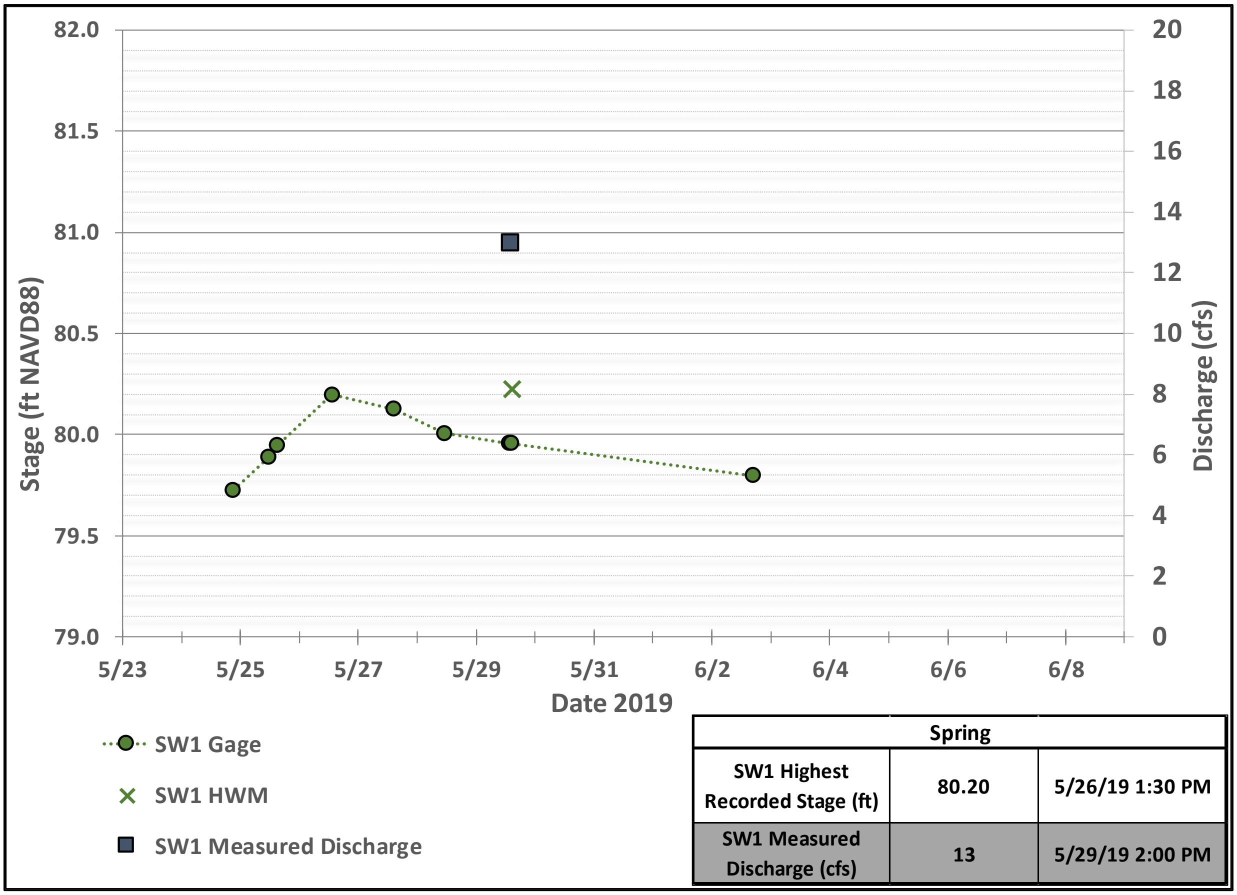


Photo 4.79: Summer conditions in the SW1 drainage, looking north (downstream); July 2, 2019

Swale 1 at SW1 spring breakup stage and measured discharge data are presented in Graph 4.27. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



	Spring	
SW1 Highest Recorded Stage (ft)	80.20	5/26/19 1:30 PM
SW1 Measured Discharge (cfs)	13	5/29/19 2:00 PM

Graph 4.27: 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 4.17.

Table 4.17: SW2 Historical Peak Stage and Measured Discharge

Year	SW2				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2019	81.98	5/27	1.5	5/30	81.16
2018 [1,2]	83.11	6/7	2	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

Initial meltwater was first recorded on the SW2 PT on May 22. Stage increased until peak stage conditions were observed on May 27. Site observations from this day coincided with peak stage and revealed bankfull stage with flow over the top of saturated snow (Photo 4.80). On May 29, stage was still bankfull but less saturated snow was present in the channel (Photo 4.81). The PT data indicated that stage had receded about 0.7-ft from peak stage. Snow cover on the surrounding tundra was estimated at 10 percent. Discharge was measured on May 30 at a location about 200 feet upstream of the gage station (Photo 4.82). 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. By June 3, stage continued to recede, and minimal snow remained in the drainage area (Photo 4.83).

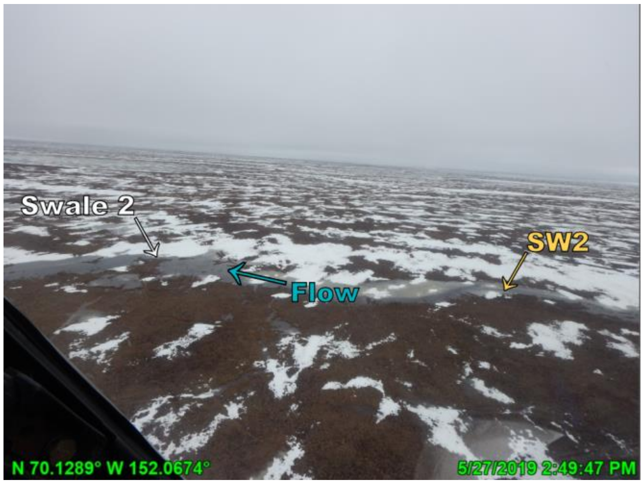


Photo 4.80: Peak stage conditions at SW2, looking east; May 27, 2019

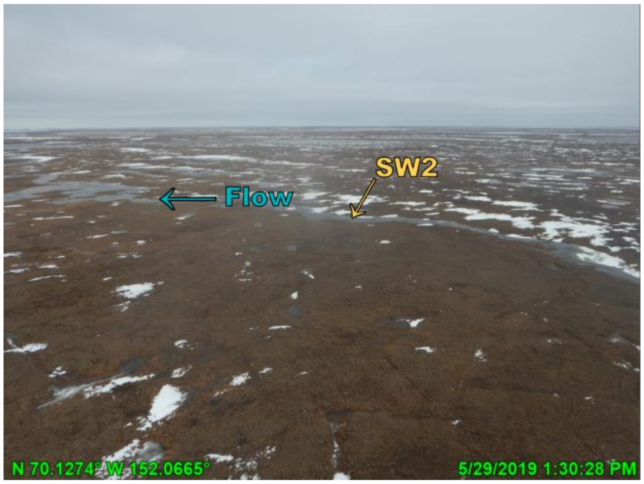


Photo 4.81: SW2 drainage two days after peak stage, looking northeast (downstream); May 29, 2019

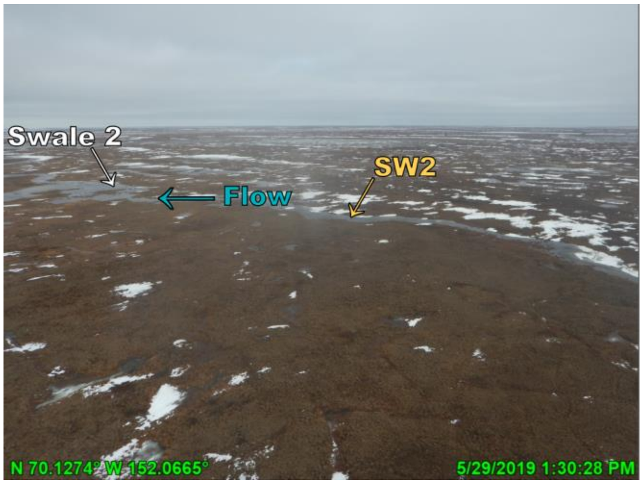


Photo 4.82: SW2 drainage the day of the discharge measurement, looking northeast (downstream); May 30, 2019.

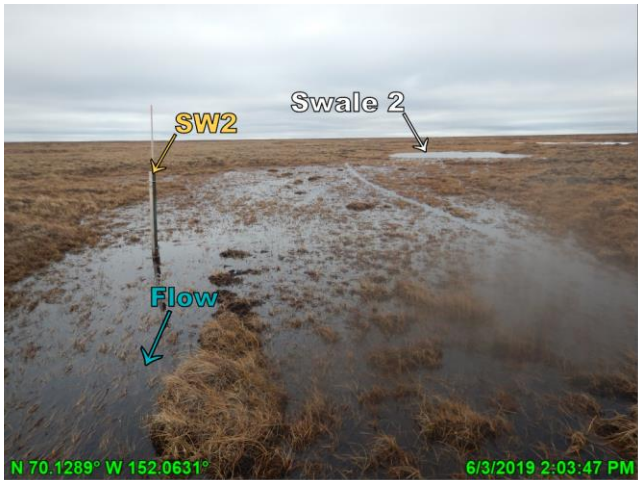
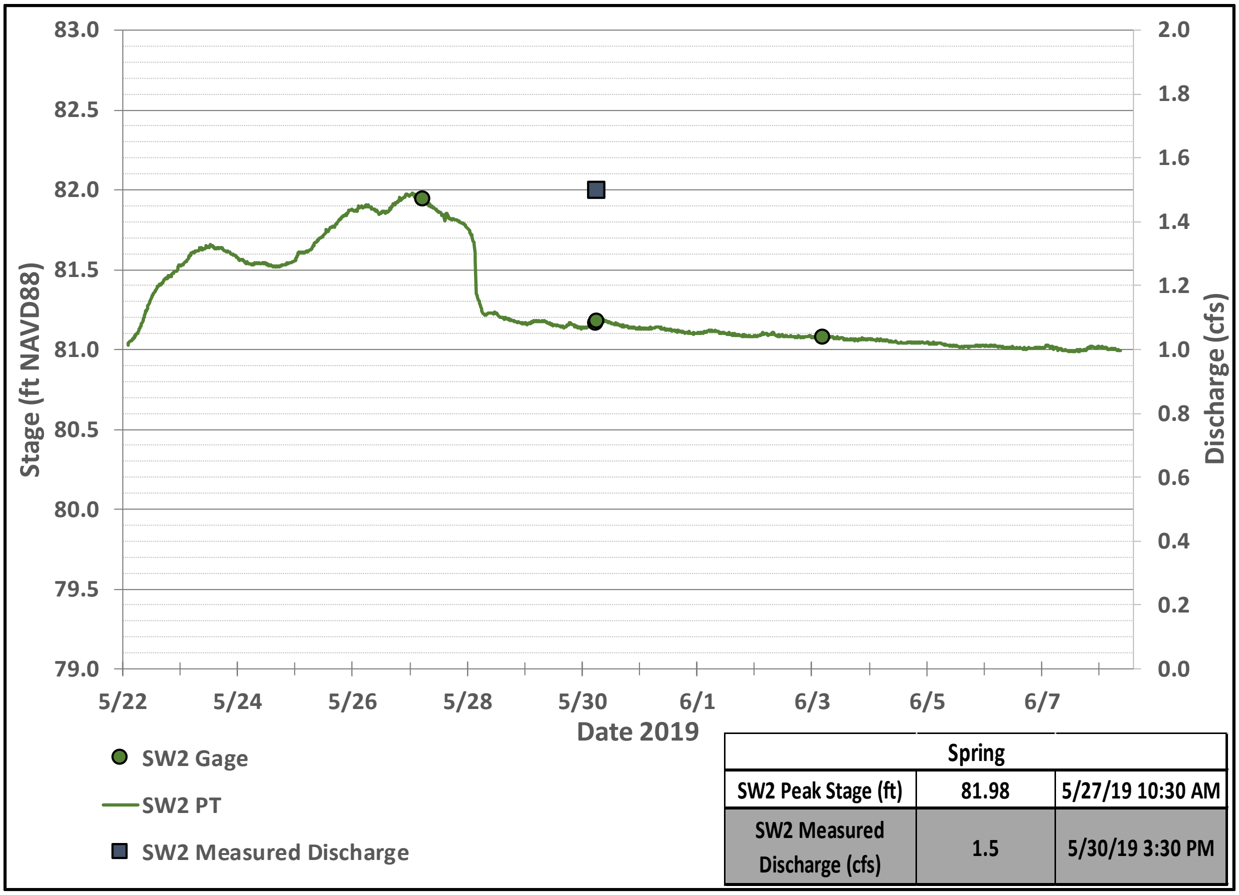


Photo 4.83: Receding stage near SW2, looking south (upstream); June 3, 2019

Swale 2 spring breakup stage and measured discharge data are presented in Graph 4.28. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring		
SW2 Peak Stage (ft)	81.98	5/27/19 10:30 AM
SW2 Measured Discharge (cfs)	1.5	5/30/19 3:30 PM

Graph 4.28: Swale 2 Spring Breakup Stage & Discharge

SWALE 3 (SW3)

The CPAI proposed alignment crosses Swale 3 at the SW3 monitoring location. Gage station SW3 is situated near the outlet of lake M0017 in a swale draining meltwater north from Lake M0017 to Lake R0055. While SW3 is situated in an area of channelized flow, this drainage system is otherwise mostly comprised of low-relief paleolakes until its outlet into Judy creek upstream of the J21.4 monitoring location. This is the first year of monitoring at the SW3 monitoring station. The reported peak stage and timing values are estimated based on gage readings and site observations.

Site observations from May 29 reveal meltwater flowing north through saturated snow at SW3. Aerial observations show the Swale 3 drainage filled with bottom-fast ice and snow (Photo 4.84). Snow cover on the surrounding tundra was approximately 20%. Peak stage is estimated to have occurred near this time, based on site observations of bankfull stage and the presence of ice and snow in the channel. Discharge was measured at SW3 on June 2 as most of the snow and ice had cleared the channel (Photo 4.85). Aerial photos from June 2 reveal multiple flow paths associated with this drainage (Photo 4.86). A bifurcation was noted upstream of the gage station and discharge cross-section; however, this reach of the swale was still noted as the best location for measuring the largest proportion of flow. As a result of the multiple flow paths, the quality of the discharge measurement was classified as poor.

Summer stage was measured at SW3. Stage fluctuations associated with summer precipitation events were recorded in the data; water levels remained well below spring breakup peak stage (Photo 4.87). The stage increase at the end of the summer monitoring period is associated with a significant precipitation event. Swale 3 spring breakup stage and measured discharge, and summer stage data are presented in Graph 4.29. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.

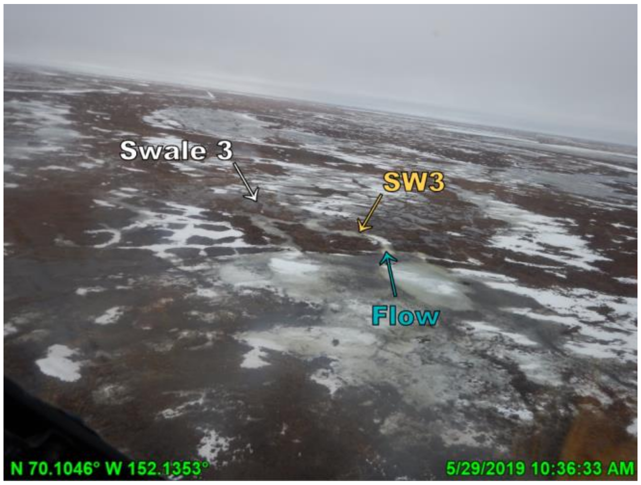


Photo 4.84: Snow-filled channel of the SW3 drainage, looking northeast (downstream); May 29, 2019

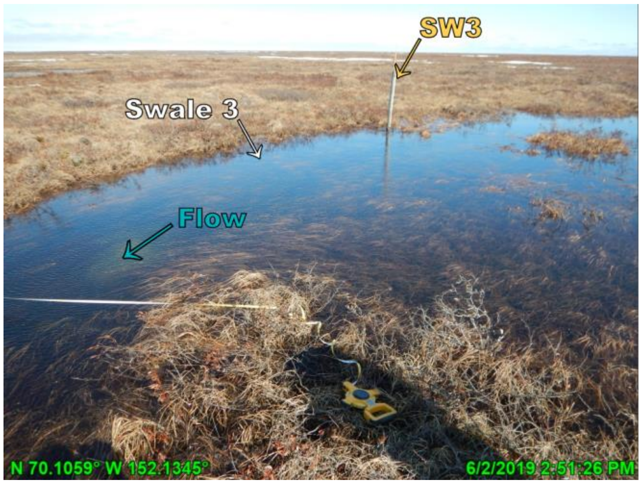


Photo 4.85: Discharge cross-section at SW3, looking east (upstream); June 2, 2019

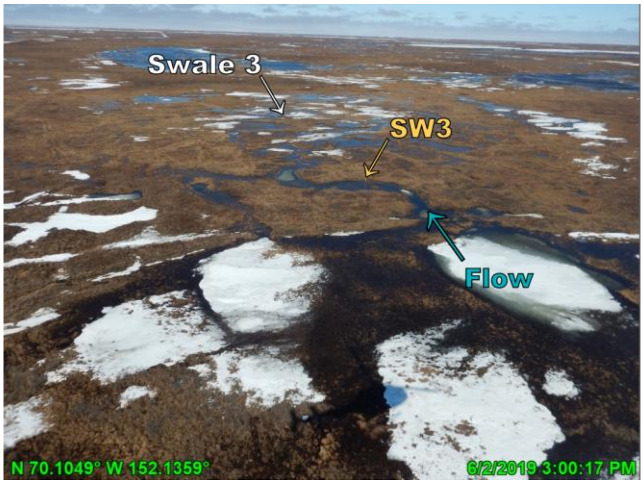
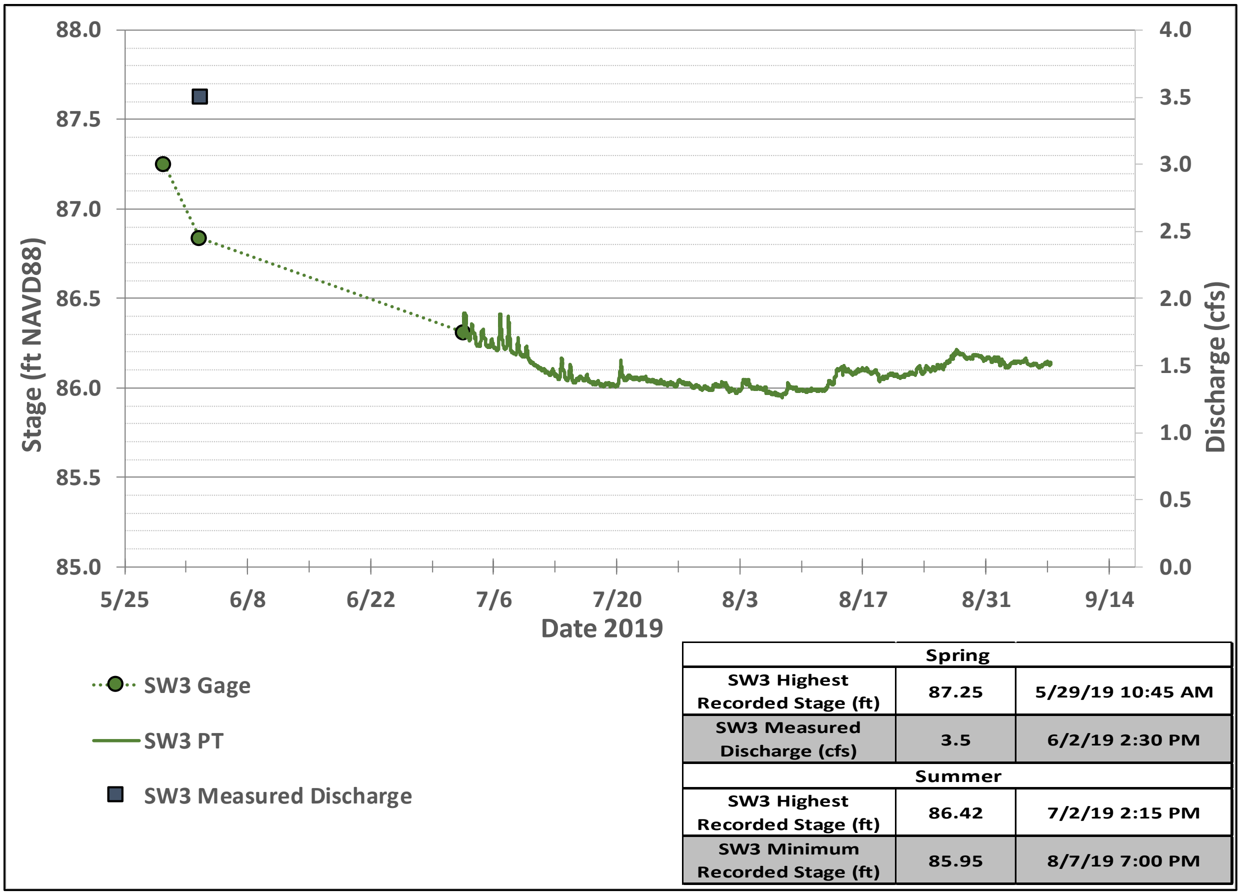


Photo 4.86: Aerial photo of SW3 the day of the discharge measurement, looking north (downstream); June 2, 2019

Photo 4.87: Summer conditions at SW3, looking south (upstream); July 2, 2019



Spring		
SW3 Highest Recorded Stage (ft)	87.25	5/29/19 10:45 AM
SW3 Measured Discharge (cfs)	3.5	6/2/19 2:30 PM
Summer		
SW3 Highest Recorded Stage (ft)	86.42	7/2/19 2:15 PM
SW3 Minimum Recorded Stage (ft)	85.95	8/7/19 7:00 PM

Graph 4.29: Swale 3 Spring Breakup Stage and Discharge, and Summer Stage

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 third year of monitoring at the SW4 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 SW4 is presented in Table 4.18.

Table 4.18: SW4 Historical Peak Stage and Measured Discharge

Year	SW4				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2019	55.98	5/24	1	6/1	55.75
2018	No Recorded Water		--	--	--
2017 [1,2]	55.66	6/6	--	--	--

Notes:

[1] 2017 peak stage elevation adjusted after NAVD88 datum elevation was established in 2019

[2] Gage and PT installed after peak; peak stage not recorded; value presented is highest recorded stage

Initial meltwater was first measured at SW4 on May 23 through game camera images. Stage increased until peak stage conditions were reached on May 24. Game camera images from this day show widespread ponded water in low-lying areas and polygon troughs around SW4 (Photo 4.88). On May 27, a site visit revealed meltwater in the Swale 4 drainage was hydraulically disconnected from Judy Creek. Aerial observations revealed saturated snow present in the drainage, particularly along the higher-situated polygon troughs (Photo 4.89). On May 30, stage in the SW4 drainage had receded and meltwater was still disconnected from Judy Creek, although it did appear to be connected to Lake M1523 to the west (Photo 4.90). By June 1, stage continued to decrease, and minimal snow remained in the drainage. Discharge was measured on June 1 in a narrow area of channelized flow through a polygon trough in an otherwise slow-moving, dispersed drainage pattern (Photo 4.91). The widespread nature of this drainage creates challenges in measuring discharge, and the resulting quality classification was rated as poor. During breakup, minimal stage fluctuations were recorded, and only local, disconnected meltwater was observed through aerial observations.

Summer observations at SW4 were limited to a site visit on July 2. At this time, stagnant water was observed in low-lying areas around the poorly defined drainage and no flow was observed (Photo 4.92).

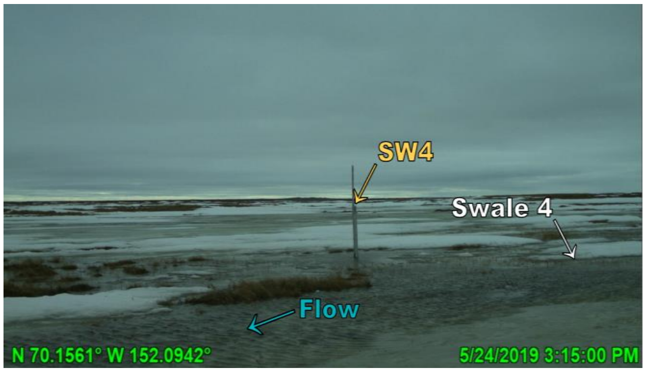


Photo 4.88: Game camera image of peak stage at SW4, looking south (upstream); May 24, 2019

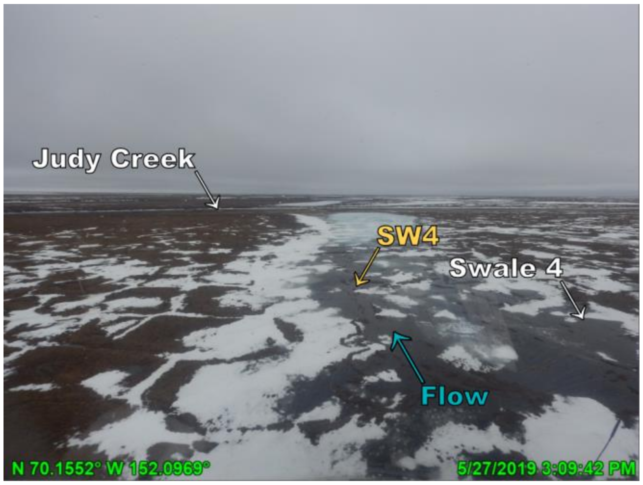


Photo 4.89: Widespread meltwater in the SW4 drainage, looking northeast (downstream); May 27, 2019

Photo 4.90: The SW4 drainage one week after peak stage; looking south (downstream); May 30, 2019

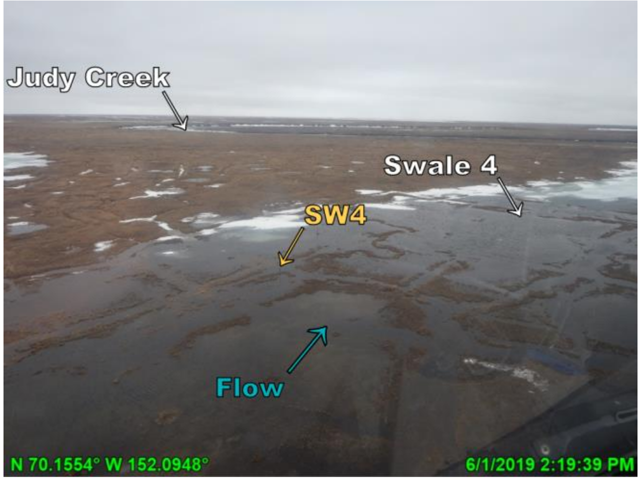


Photo 4.91: Conditions in the SW4 drainage during the discharge measurement, looking north (downstream); June 1, 2019

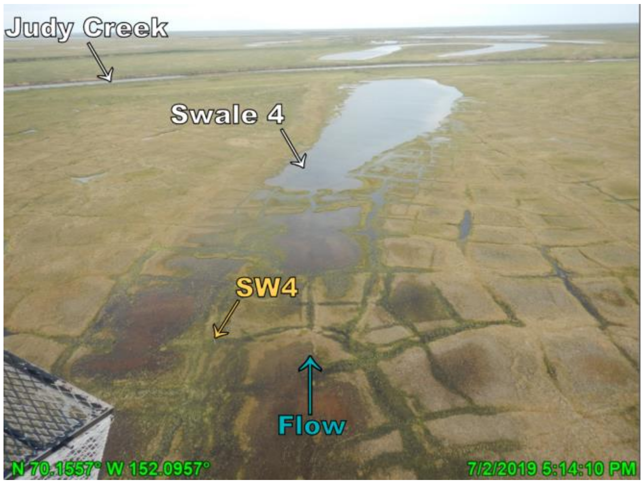
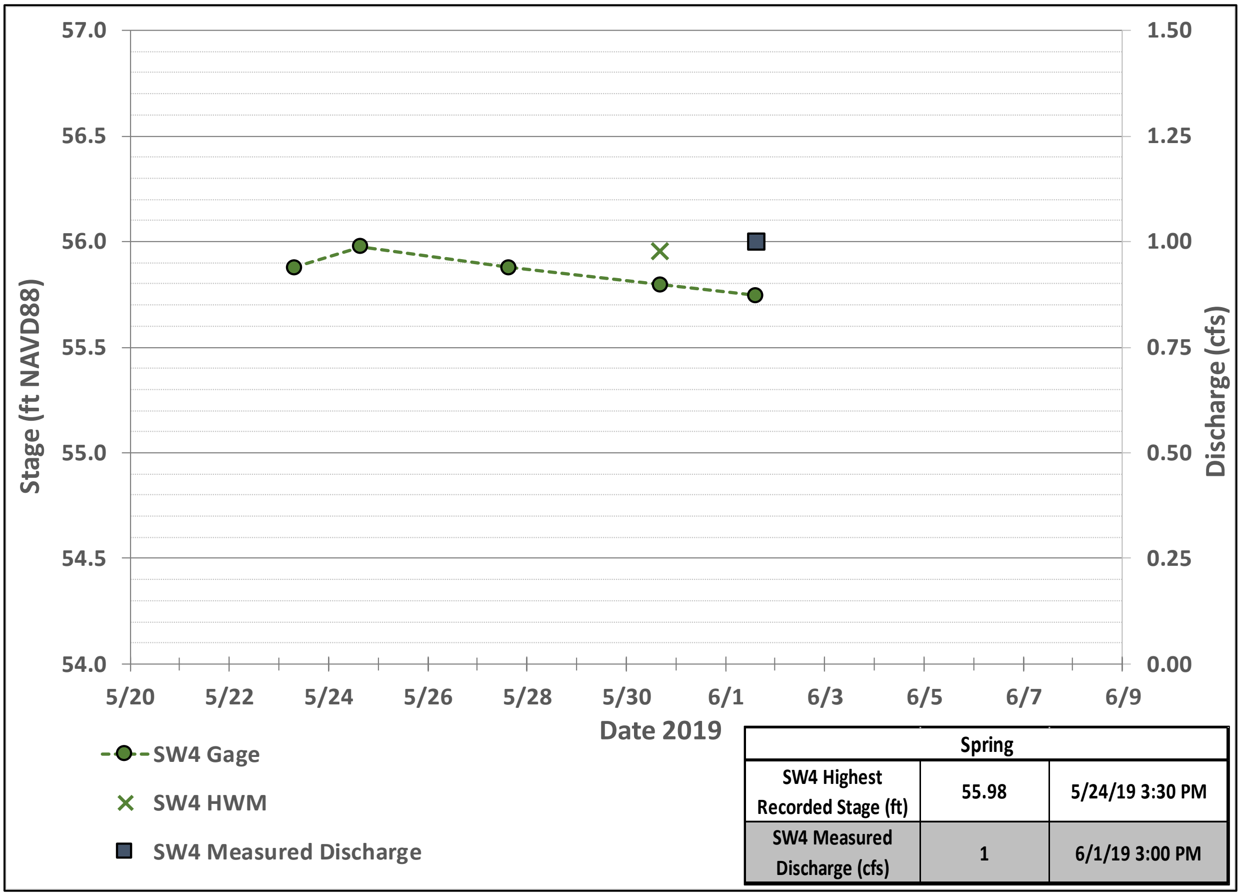


Photo 4.92: Summer conditions in the SW4 drainage, looking northeast (downstream); July 2, 2019

Swale 4 spring breakup stage and measured discharge data are presented in Graph 4.30. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring		
SW4 Highest Recorded Stage (ft)	55.98	5/24/19 3:30 PM
SW4 Measured Discharge (cfs)	1	6/1/19 3:00 PM

Graph 4.30: Swale 4 Spring Breakup Stage & Discharge

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. This is the first year of monitoring at the SW6 gage station. The reported peak stage and timing values are based on gage readings from game camera images.

Initial meltwater was first observed from the SW6 game camera on May 23. Stage increased until peak stage conditions were reached on the morning of May 25. During peak stage, game camera images revealed apparent stagnant meltwater overtopping polygon crests around the SW6 gage station (Photo 4.93). After peak, stage rapidly decreased, and polygon crests were again visible by the afternoon on May 25. On May 27, aerial observations revealed meltwater in low-lying areas and polygon troughs in the swale depression (Photo 4.94). Meltwater had cut a path through a nearby ice road downstream of the gage station. By June 1, stage continued to recede and meltwater within polygon troughs was becoming disconnected from other troughs (Photo 4.95). Summer observations from July 2 show stagnant, disconnected meltwater in a series of polygon troughs and low-centered polygon depressions (Photo 4.96).

Photo 4.93: Game camera image of peak stage at SW6, looking northwest (upstream); May 25, 2019

Photo 4.94: Meltwater in polygon troughs near SW6, looking northeast (downstream); May 27, 2019

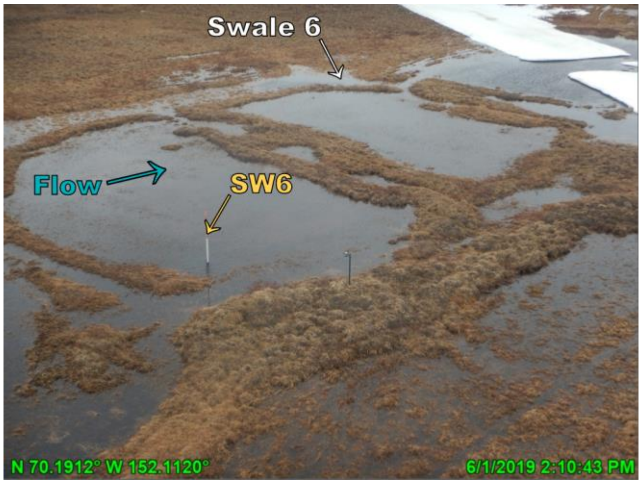


Photo 4.95: Receding stage at SW6, looking northeast (downstream); June 1, 2019

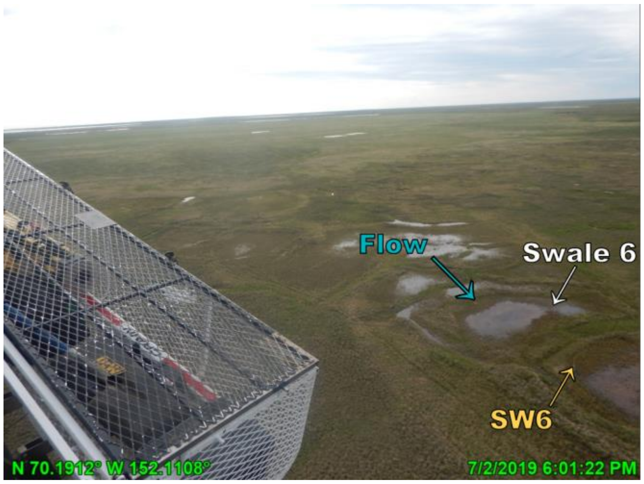
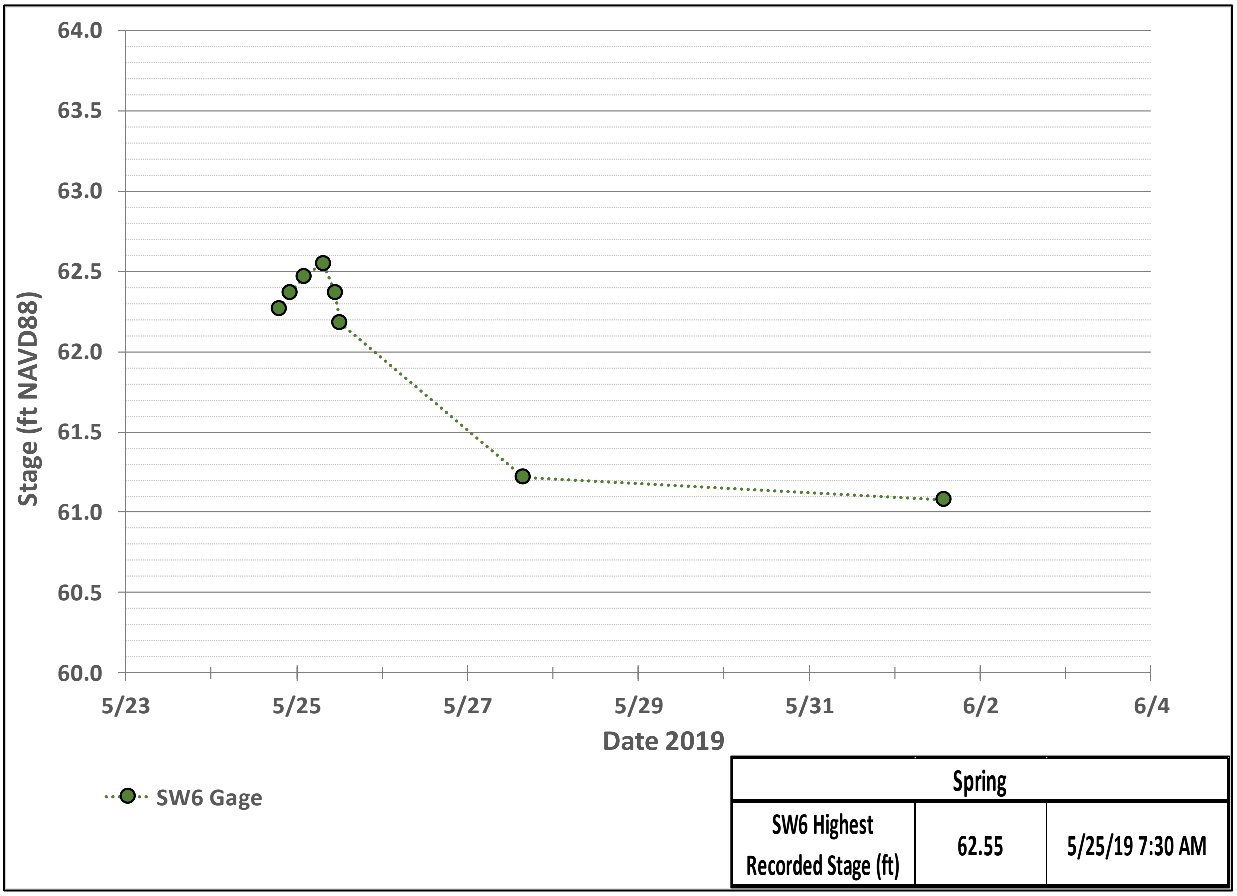


Photo 4.96: Summer conditions near SW6, looking northwest (upstream); July 2, 2019

Swale 6 spring breakup stage data is presented in Graph 4.31. Elevations are referenced to NAVD88.



	Spring	
SW6 Highest Recorded Stage (ft)	62.55	5/25/19 7:30 AM

Graph 4.31: Swale 6 Spring Breakup Stage

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. This is the second year of monitoring at the SW14 monitoring location. Historical peak stage and measured discharge data at SW14 is presented in Table 4.19.

Table 4.19: SW14 Historical Peak Stage and Measured Discharge

Year	SW14				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2019	84.62	5/25	6	5/29	83.75
2018 [1,2]	78.30	6/5	7	6/7	76.75

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 are estimated based on game camera images. No PT installed at the site.

Initial meltwater was recorded at SW14 on May 22. Stage peaked on May 25 and remained elevated at peak levels until May 28. Site observations from May 29 reveal stage below bankfull at SW14 (Photo 4.97). Snow and ice had cleared from the swale while some saturated snow was noted along the bank. No overbank flooding was observed. Discharge was measured about 20 feet downstream of SW14 on May 29 (Photo 4.98). The quality of the discharge measurement was classified as good based on the conditions described above. On June 2, aerial observations revealed minimal saturated snow along the banks. The stage condition was similar to that noted on May 29 (Photo 4.99). Snow cover on the surrounding tundra was approximately 5 percent. By July 2, flow was confined to the narrow, shallow, grass-lined beaded stream near SW14 (Photo 4.100).

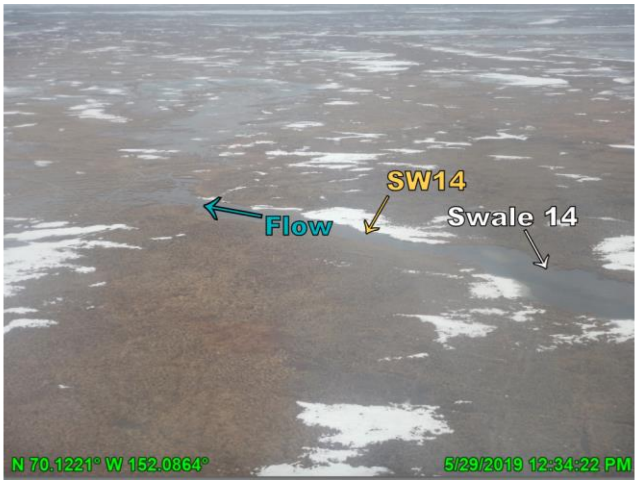


Photo 4.97: SW14 drainage four days after peak stage, looking northwest (downstream); May 29, 2019

Photo 4.98: Measuring discharge near SW14, looking south (upstream); May 29, 2019

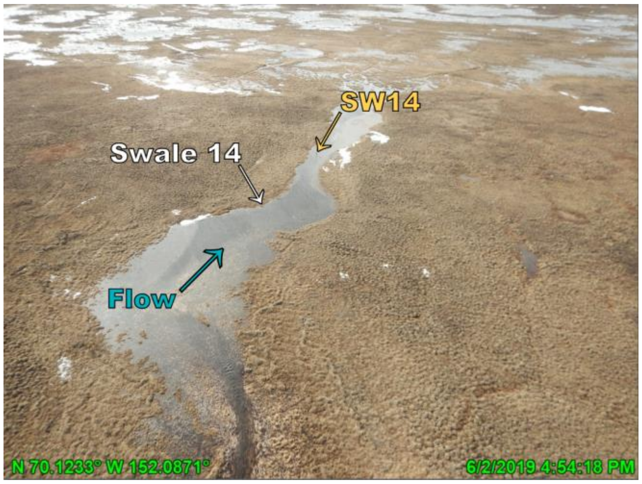


Photo 4.99: Receding stage near SW14, looking east (downstream); June 2, 2019

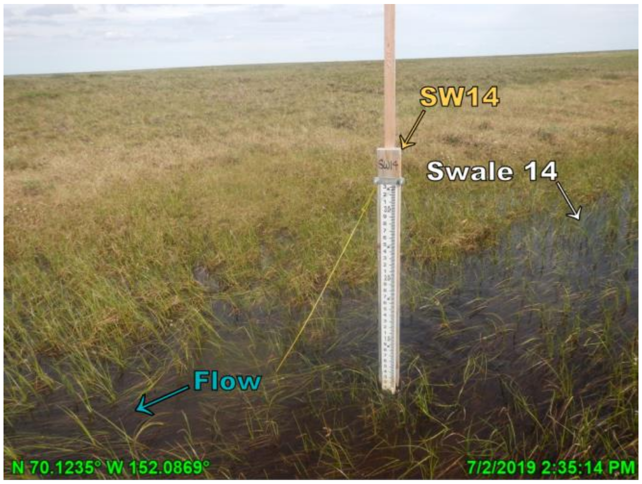
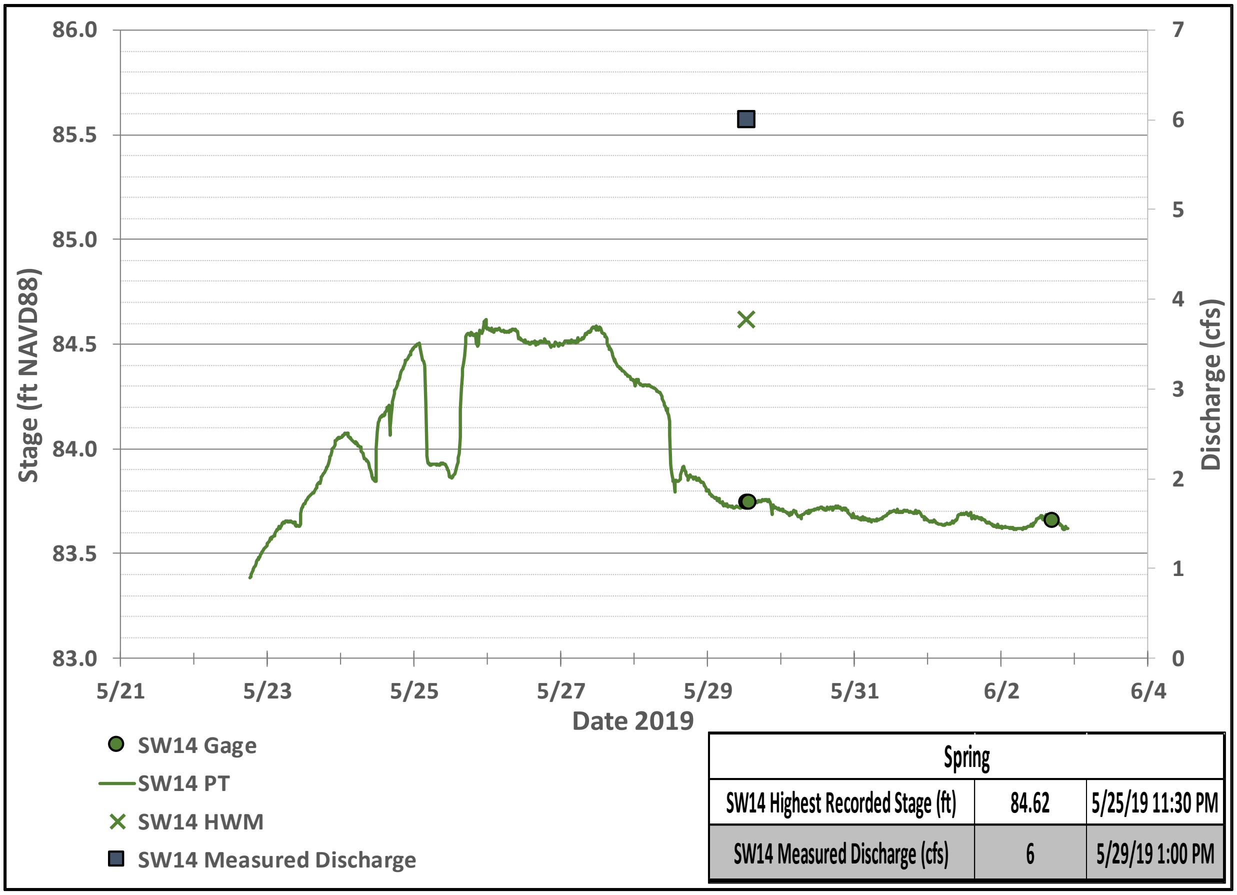


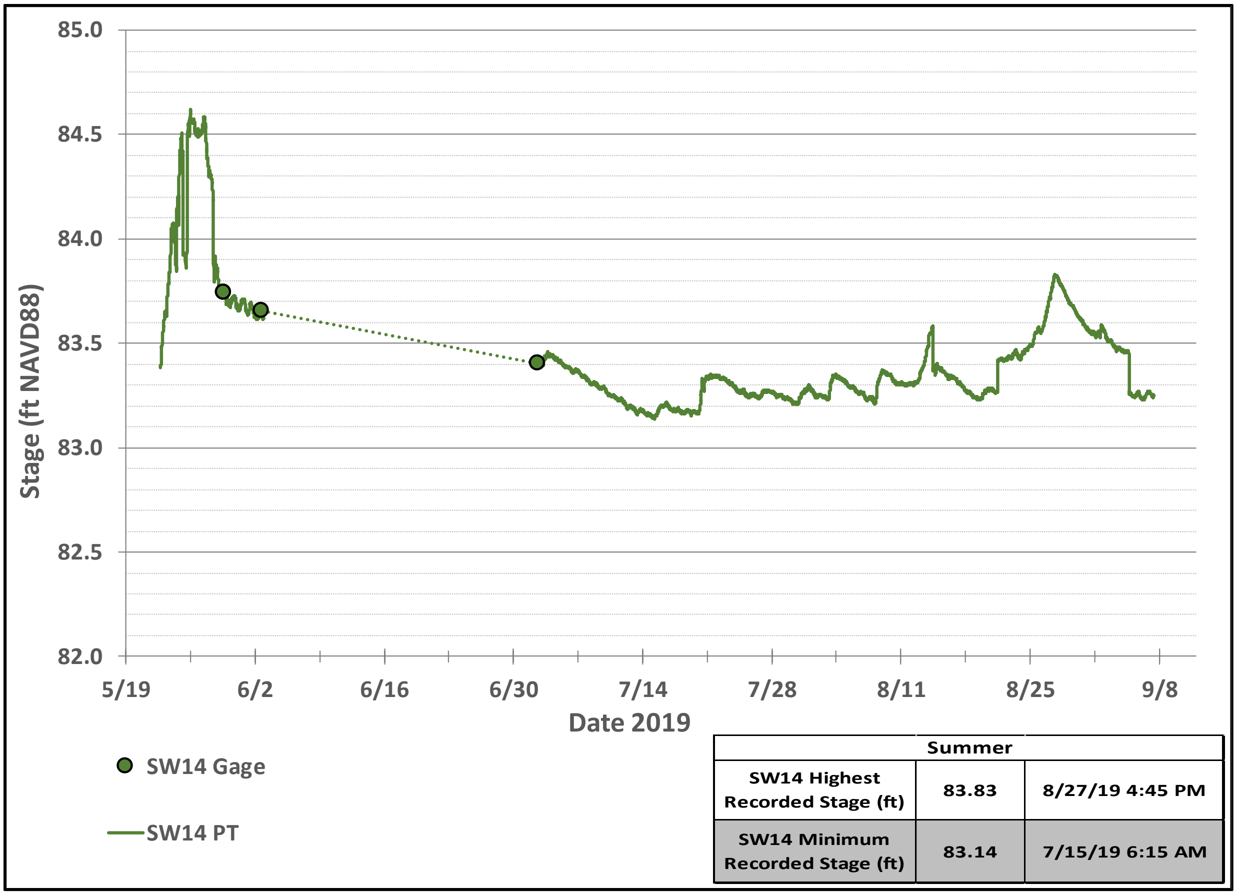
Photo 4.100: Summer conditions at SW14, looking northwest; July 2, 2019

Swale 14 spring stage and measured discharge data are presented in Graph 4.32. The SW14 summer stage data is presented in Graph 4.33. Measured discharge details and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



Spring		
SW14 Highest Recorded Stage (ft)	84.62	5/25/19 11:30 PM
SW14 Measured Discharge (cfs)	6	5/29/19 1:00 PM

Graph 4.32: Swale 14 Spring Breakup Stage & Discharge



Summer		
SW14 Highest Recorded Stage (ft)	83.83	8/27/19 4:45 PM
SW14 Minimum Recorded Stage (ft)	83.14	7/15/19 6:15 AM

Graph 4.33: Swale 14 Spring and Summer Stage

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. This is the second year of monitoring at the SW23 monitoring location. The game camera was positioned such that the gage could not be read from the camera image. Reported peak stage was from an HWM, and timing was based on water levels visible in the game camera images. Historical peak stage and measured discharge data at SW23 is presented in Table 4.20.

Table 4.20: SW23 Historical Peak Stage and Measured Discharge

Year	SW23				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2019 [1]	81.02	5/27	1	6/1	79.37
2018 [1,2]	91.86	6/12	4	6/18	90.14

Notes:

[1] Highest recorded stage and timing based on gage readings from site visits. Game camera footage suggests peak stage occurred close to reported time. No PT installed at the site.

[2] Arbitrary elevations referenced to local control point “PAPER” (MBI 2018). This site was active only for 2018 as the gage location was moved prior to the 2019 monitoring period.

Ponded local meltwater first appeared in Swale 23 at SW23 on May 26, based on game camera footage. Peak stage conditions occurred on May 27 (Photo 4.101). Stage remained near peak levels until a sudden drop was observed on May 28 around 3:00 PM. After this drop, stage remained below levels observed on May 26 through May 28. Game camera footage suggests meltwater was stagnant during the period of elevated stage from May 26 to May 28, then began to flow as stage dropped. Aerial observations from May 27 reveal meltwater in the main channel through Swale 23, based on the coloration of dark saturated snow (Photo 4.102). Site observations on May 27 confirm that meltwater near SW23 was stagnant. Aerial observations on May 31 show flowing meltwater had cut a path through snow. Minor overbank flowing was observed in low-lying areas around SW23 (Photo 4.103). Snow cover on the surrounding tundra was approximately 25 percent.

Discharge was measured on Swale 23 upstream of gage station SW23, near the swale's outlet from an unnamed lake, on June 1. At this location, flow was confined to a single flow path through saturated snow along the banks. Snow and ice were present in the channel (Photo 4.104). The overall quality of the discharge measurement was classified as fair based on the presence of saturated snow along the banks. By July 3, water was confined to small, disconnected pools within the swale (Photo 4.105).

Photo 4.101: Game camera image of peak stage at SW23, looking west (downstream); May 27, 2019

Photo 4.102: Saturated snow in the SW23 drainage, looking west (downstream); May 27, 2019

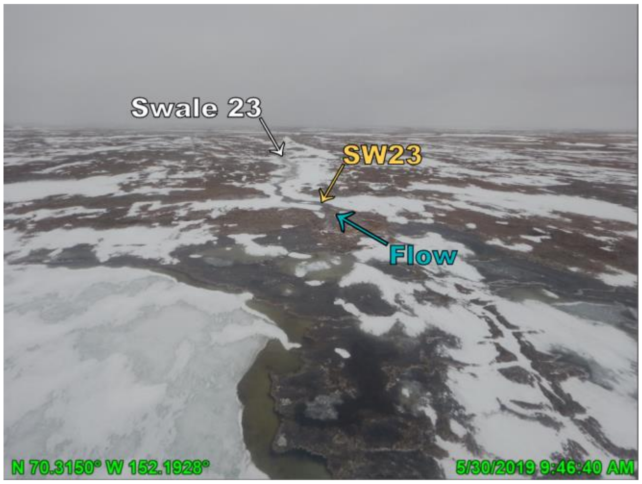


Photo 4.103: Meltwater in the SW23 drainage; looking west (downstream); May 30, 2019

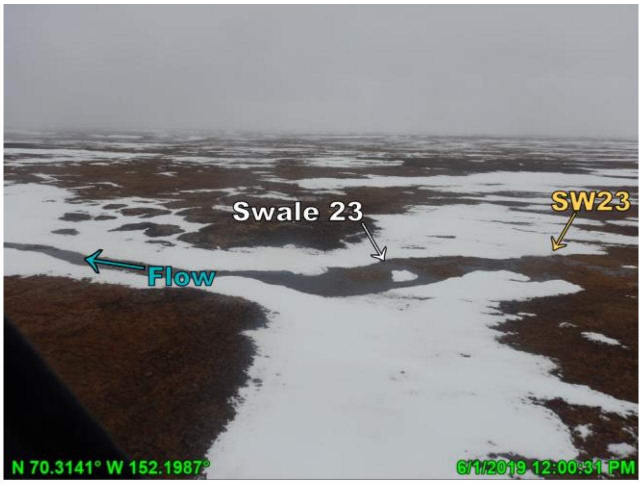


Photo 4.104: Conditions in the SW23 drainage during the discharge measurement, looking north; June 1, 2019

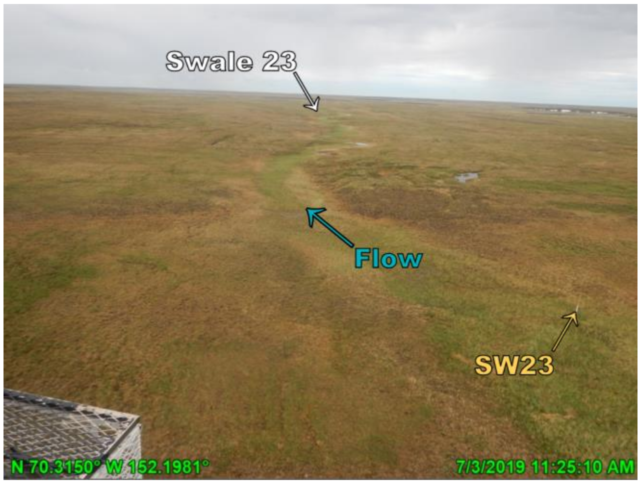
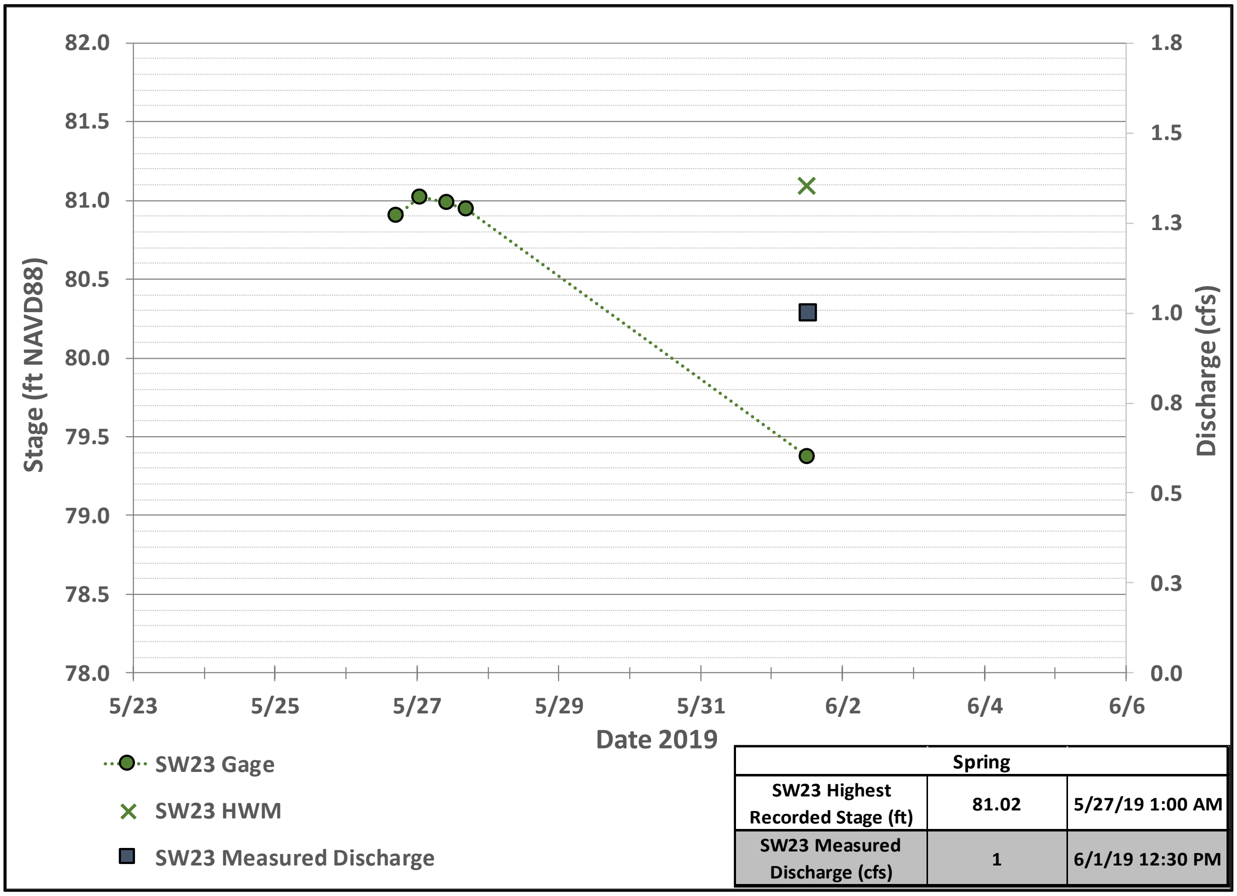


Photo 4.105: Summer conditions in the SW23 drainage, looking west (downstream); July 3, 2019

Swale 23 spring stage and measured discharge data are presented in Graph 4.34. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



	Spring	
SW23 Highest Recorded Stage (ft)	81.02	5/27/19 1:00 AM
SW23 Measured Discharge (cfs)	1	6/1/19 12:30 PM

Graph 4.34: Swale 23 Spring Breakup Stage & Discharge

SWALE 24 (SW24)

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. SW24 is located near the outlet from the unnamed lake. The CPAI proposed Willow alignment crosses Swale 24 at the SW24 monitoring location. This is the first year of monitoring at the SW24 monitoring station. Peak stage was estimated based on site observations and HWM readings.

On May 29 site observations revealed meltwater flowing out of the unnamed lake past SW24. Snow and ice were present in the drainage, particularly on the unnamed lake, but the channel was clear (Photo 4.106). Stage appeared near bankfull. This section of the swale was predominantly shallow and wide with a grass-lined bottom. Discharge was measured near SW24 on May 29 (Photo 4.107). The overall quality of the discharge measurement was classified as good based on the open-channel conditions present. An HWM captured on May 29 recorded peak stage as 85.35 ft.

Aerial observations from June 3 show bankfull stage and minimal snow in the channel and along the banks (Photo 4.108). The unnamed lake was still covered with ice. Snow cover on the surrounding tundra was approximately 5 percent. By July 2, water was noted as widespread and stagnant across the swale depression (Photo 4.109).

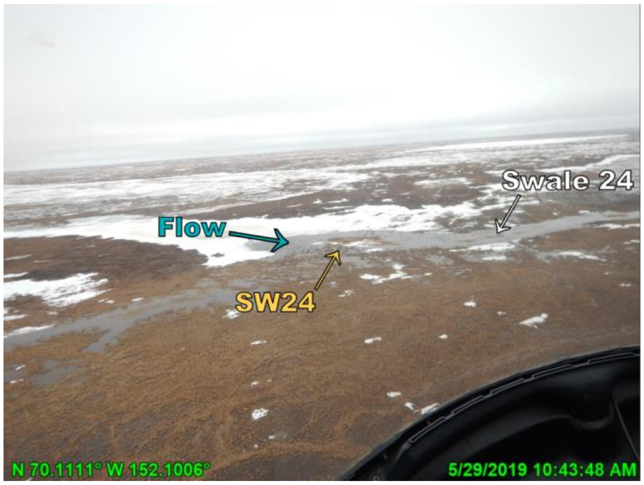


Photo 4.106: Meltwater in the SW24 drainage, looking northeast (upstream); May 29, 2019

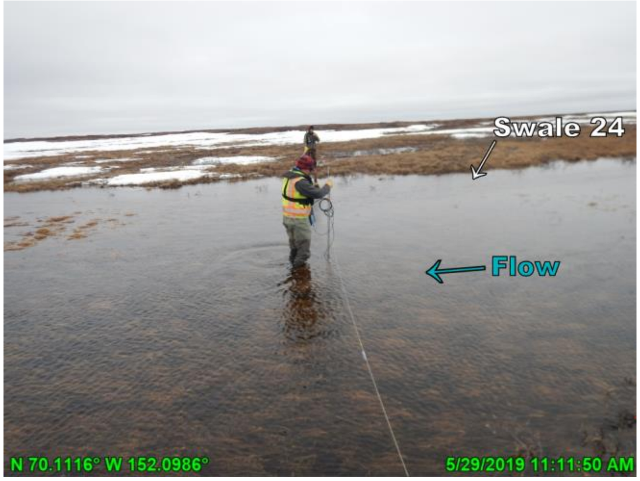


Photo 4.107: Measuring discharge near SW24, looking south; May 29, 2019

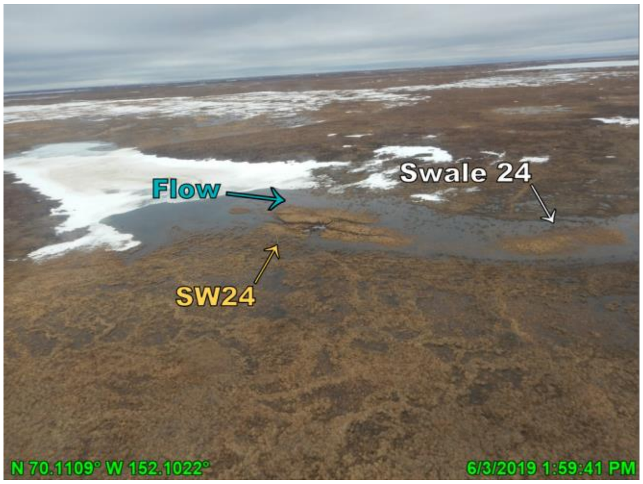


Photo 4.108: Receding stage near SW24, looking northeast (upstream); June 3, 2019

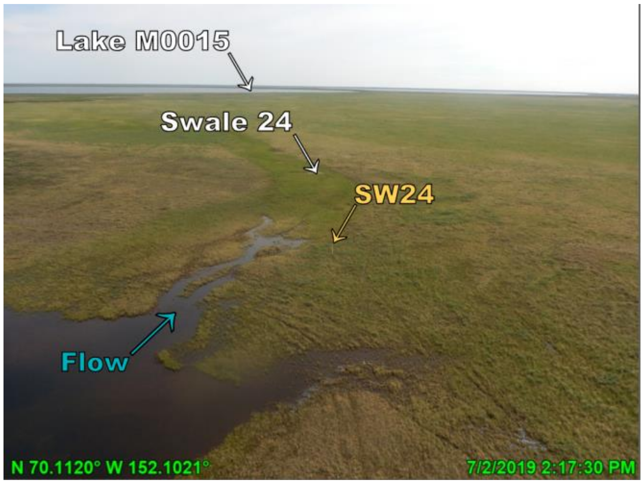
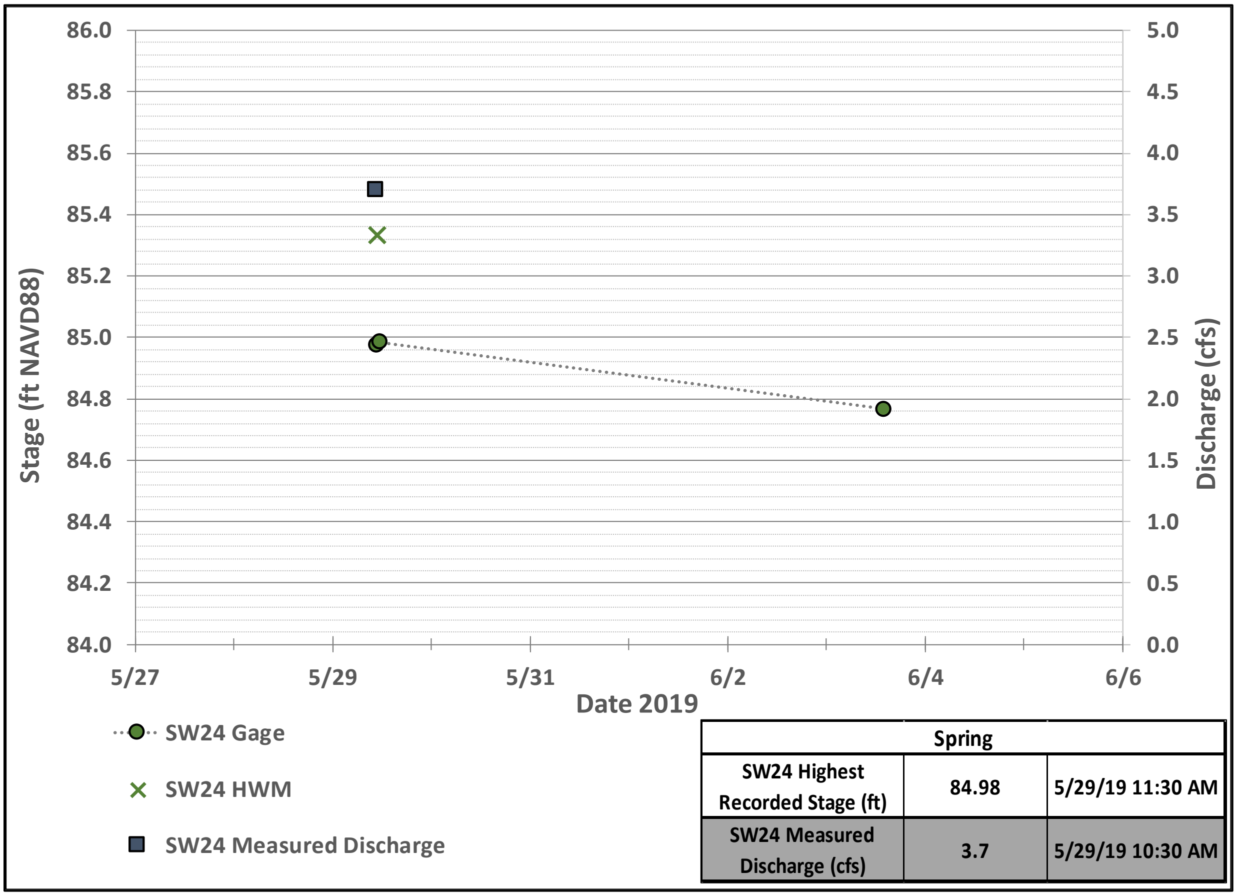


Photo 4.109: Summer conditions at SW24, looking south (downstream); July 2, 2019

Swale 24 stage and measured discharge data are presented in Graph 4.35. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



	Spring	
SW24 Highest Recorded Stage (ft)	84.98	5/29/19 11:30 AM
SW24 Measured Discharge (cfs)	3.7	5/29/19 10:30 AM

Graph 4.35: Swale 24 Spring Breakup Stage & Discharge

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/MT6 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 adjacent to the proposed minesite. MS1_1 is situated on 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 second 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. 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 second 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 4.21 and Table 4.22, respectively.

Table 4.21: UB14.5 Historical Peak Stage and Measured Discharge

Year	UB14.5				
	Peak Stage (ft NAVD88)	Date	Measured Discharge (cfs)	Date	Associated Stage (ft NAVD88)
2019	19.23 [3]	5/29	1000	6/2	14.30
2018 [1]	20.20	6/9	1200 [2]	6/10	19.88

Notes:
[1] 2018 peak stage elevation adjusted after NAVD88 datum elevation was established 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 4.22: UB15.5 Historical Peak Stage and Measured Discharge

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

Notes:
[1] Elevations arbitrary; referenced to local control point “PUMICE” (MBI 2018)

Initial meltwater was first recorded on PTs at both sites on May 22. Stage increased until peak stage conditions occurred at UB15.5 on May 26. Peak at UB14.5 also likely occurred on May 26, but a PT malfunction at this site prevented a conclusive determination of peak stage magnitude and timing. Site observations on May 28 reveal stage above bankfull at UB14.5, with minor overbank flooding in low-lying areas particularly along the west bank (Photo 4.110). Stranded ice was observed along the channel banks and overbanks near UB14.5, suggesting peak stage had exceeded bankfull and was now decreasing (Photo 4.111). At UB15.5, overbank flooding was observed near the low-lying area near the gage station (Photo 4.112). Drifted snow was observed in the MS1_1 swale. Stranded ice was also observed near UB15.5.

On June 2, discharge was measured using a tethered ADCP, slightly upstream of the UB14.5 gage station. At the time of the discharge measurement, stage had receded nearly 5 feet from peak conditions and was below bankfull. Stranded ice and wood debris were observed in the overbank in various locations within the monitoring reach (Photo 4.113). Ice floes were observed periodically flowing through the reach during the discharge measurement, but the channel was otherwise clear of ice and snow. The overall quality of the discharge measurement was classified as good based on these conditions. By June 3, stage had receded to below bankfull at UB15.5 (Photo 4.114). Drifted snow was observed along the banks and snow cover on the surrounding tundra was approximately 5%.

Photo 4.110: Bankfull conditions in the Tinmiaqsiugvik River near UB14.5, looking north (downstream); May 28, 2019

Photo 4.111: Stranded ice near UB14.5, looking west (downstream); May 28, 2019

Photo 4.112: Overbank flooding near UB15.5; looking east (downstream); May 28, 2019

Photo 4.113: Discharge cross-section in the Tinmiaqsiugvik River near UB14.5, looking north (downstream); June 2, 2019

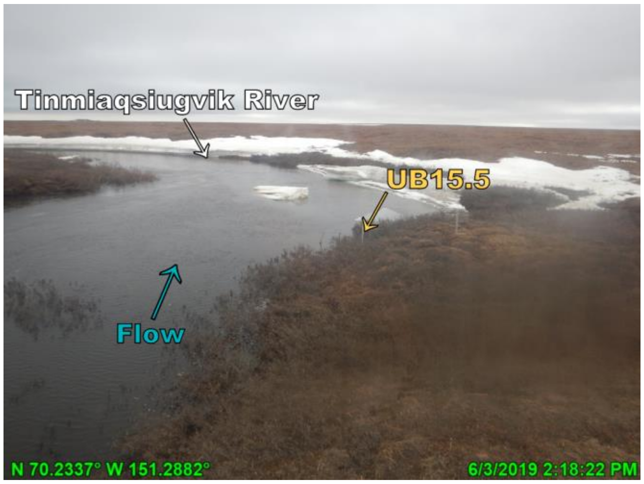
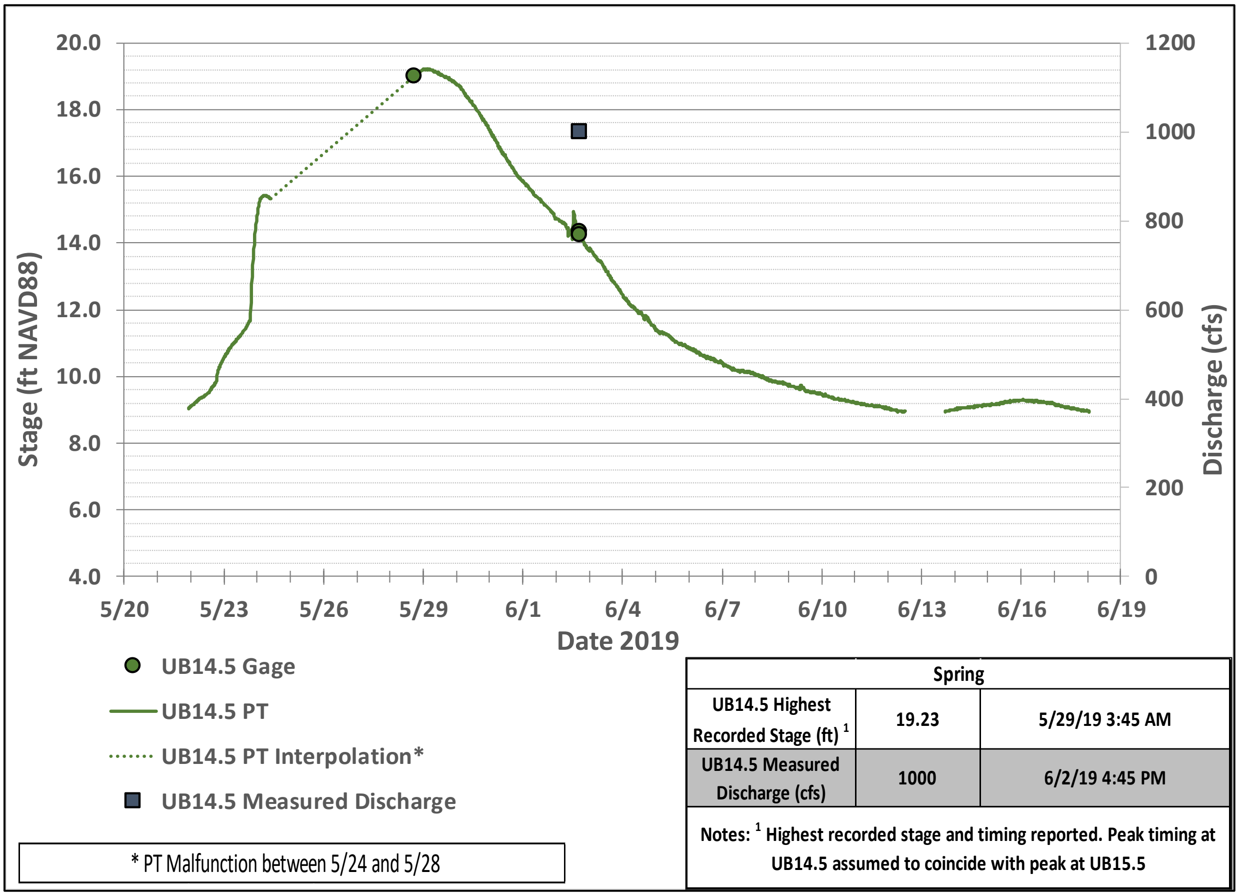


Photo 4.114: Receding stage in the Tinmiaqsiugvik river, looking east (downstream); June 3, 2019

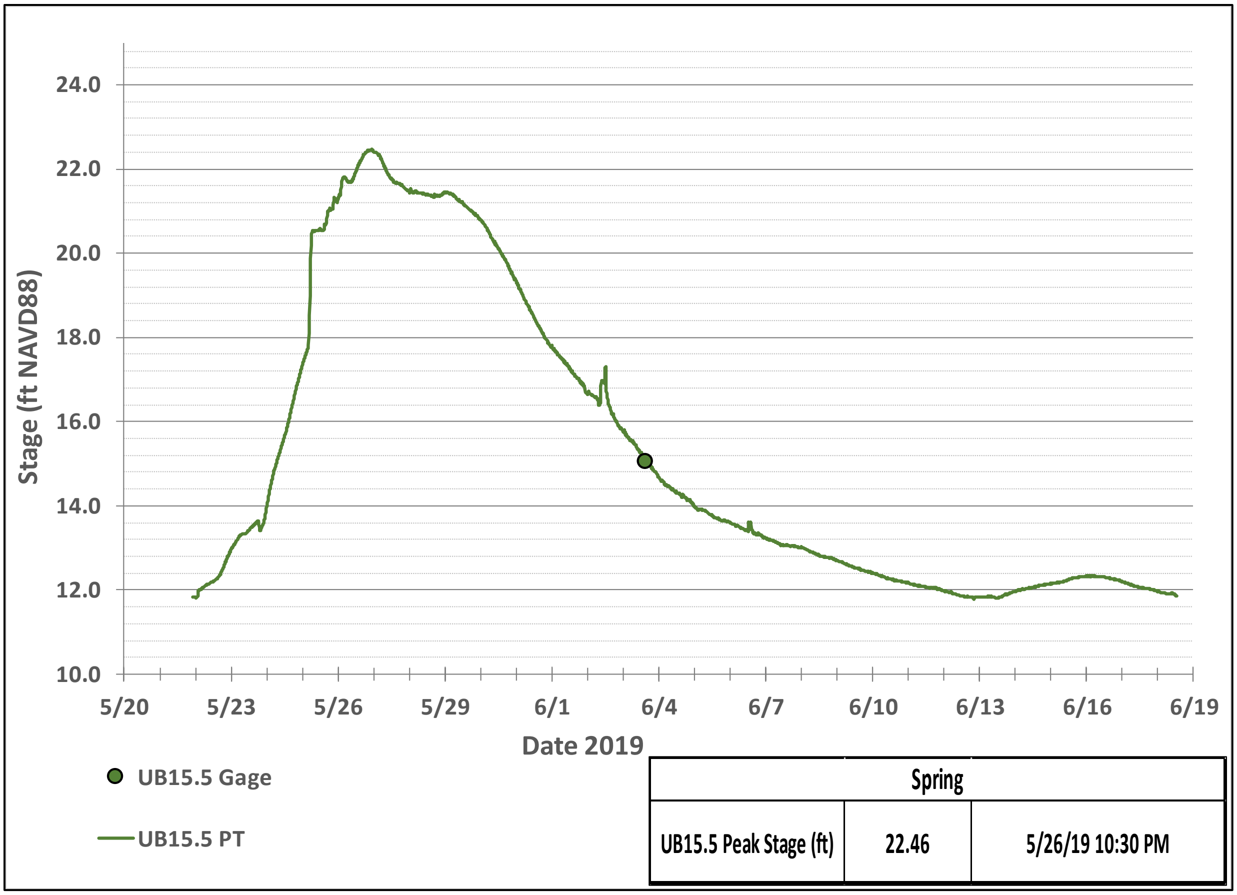
The UB14.5 and UB15.5 stage and measured discharge data are presented in Graph 4.36 and Graph 4.37, respectively. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.



	Spring	
UB14.5 Highest Recorded Stage (ft) [1]	19.23	5/29/19 3:45 AM
UB14.5 Measured Discharge (cfs)	1000	6/2/19 4:45 PM

Notes: [1] Highest recorded stage and timing reported. Peak timing at UB14.5 assumed to coincide with peak at UB15.5

Graph 4.36: UB14.5 Spring Breakup Stage and Discharge



Spring		
UB15.5 Peak Stage (ft)	22.46	5/26/19 10:30 PM

Graph 4.37: 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 second year of monitoring at the MS1_1 monitoring location. Historical peak stage and measured discharge data at MS1_1 is presented in Table 4.23.

Table 4.23: MS1_1 Historical Peak Stage and Measured Discharge

Year	MS1_1	
	Peak Stage (ft NAVD88)	Date
2019	27.66	5/24
2018 [1]	27.57	6/5

Notes:
[1] 2018 peak stage elevation adjusted after NAVD88 datum elevation was established in 2019

Initial meltwater was first recorded on the MS1_1 PT on May 23. Game camera images from this day show meltwater, confined by saturated snow, accumulating around the gage station. Peak stage occurred early morning on May 24 and was likely the result of disconnected local melt (Photo 4.115). Meltwater appeared to break through the saturated snow and connect with the Tinmiaqsiugvik River in the afternoon of May 24, corresponding with a sharp drop in stage. On the afternoon of May 25, increasing localized meltwater was observed at MS1_1 through game camera images. Peak stage on the Tinmiaqsiugvik River at UB15.5 occurred on May 26 (Photo 4.116).

Backwater from the Tinmiaqsiugvik River did not reach the MS1_1 gage station during the spring breakup monitoring period.

On May 28, site observations at MS1_1 reveal meltwater flowing over exposed tundra and into the Tinmiaqsiugvik River. Snow present along the east bank of the swale did not appear to confine flow. Multiple flow paths within polygon troughs were noted around the gage site (Photo 4.117). Snow cover on the surrounding tundra was approximately 5 percent, not including drifted snow within the swale drainage. Overbank flooding was still seen at the nearby UB15.5 gage station. By June 3, stage had receded to near summer levels and minimal snow remained in the MS1_1 drainage (Photo 4.118). Summer stage did not reach the spring PT elevation during summer monitoring.

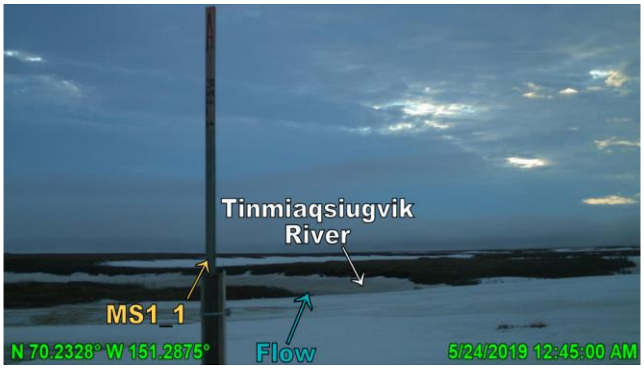


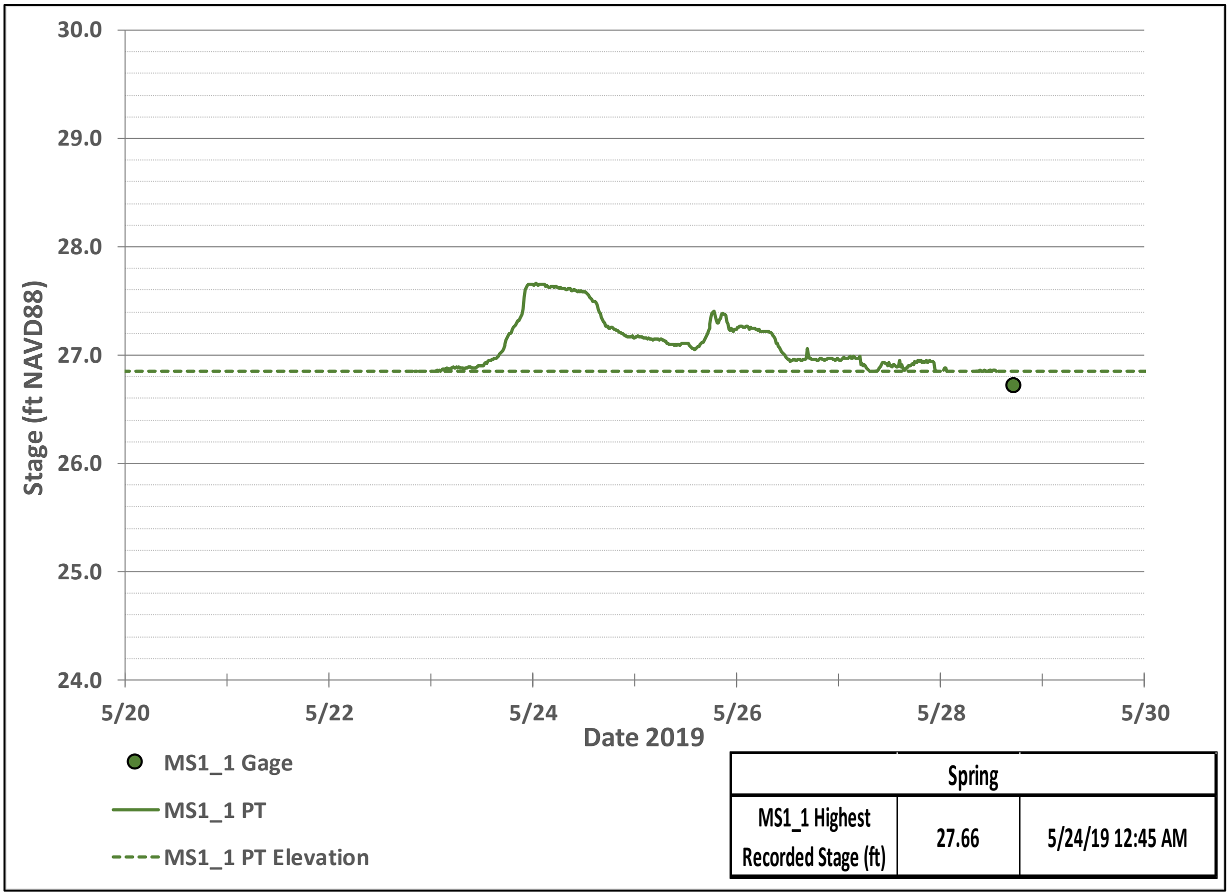
Photo 4.115: Game camera image of peak stage at MS1_1, looking northwest (downstream); May 24, 2019

Photo 4.116: Game camera image of peak stage at UB15.5 from the MS1_1 gage, looking northwest (downstream); May 26, 2019

Photo 4.117: Meltwater flowing over exposed tundra near MS1_1, looking north (downstream); May 28, 2019

Photo 4.118: Receding stage in the Tinmiaqsiugvik River near MS_1, looking east (downstream); June 3, 2019

MS1_1 stage data are presented in Graph 4.38. Elevations are referenced to NAVD88.



Graph 4.38: 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 second year of monitoring at the BC1 monitoring station. Historical peak stage data at BC1 is presented in Table 4.24.

Table 4.24: BC1 Historical Peak Stage

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

Notes:

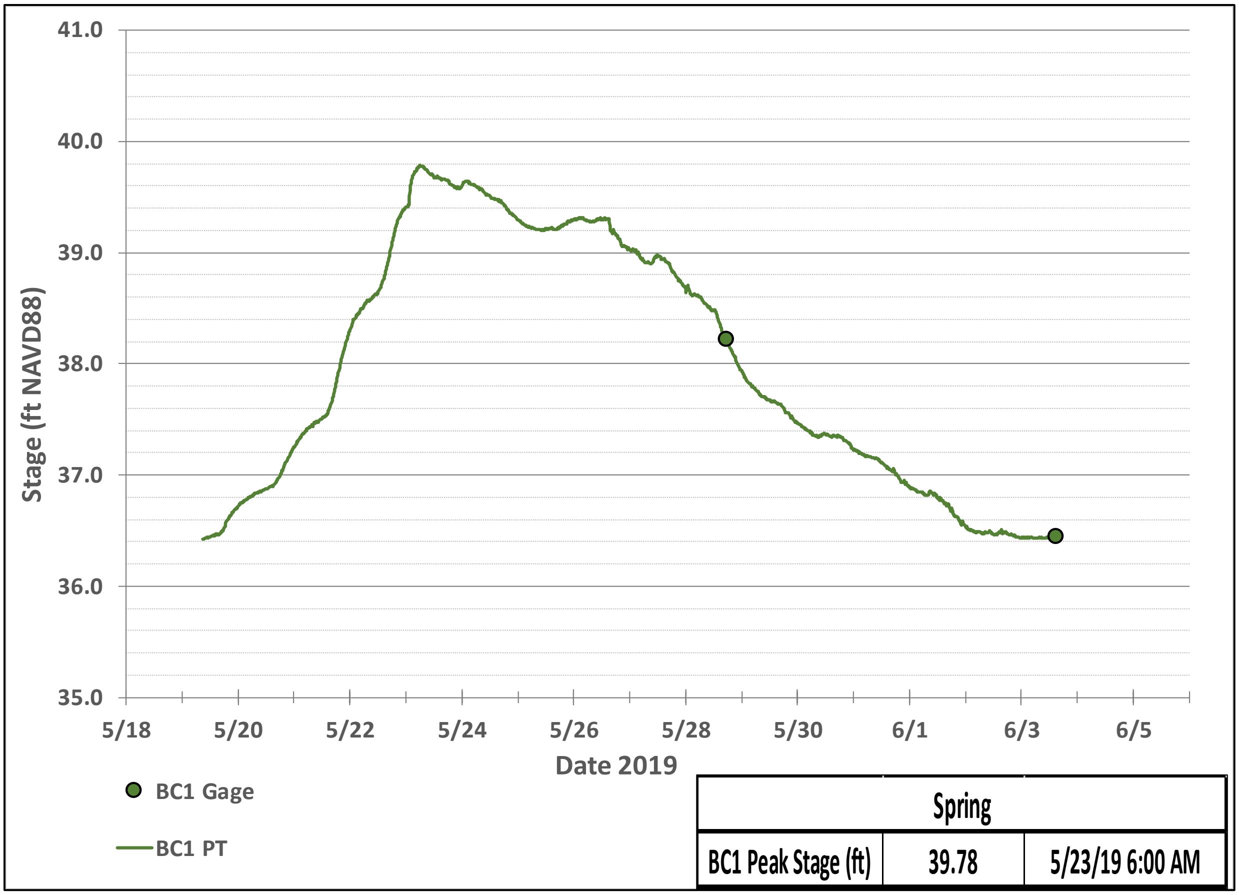
[1] 2018 peak stage elevation adjusted after NAVD88 datum elevation was established in 2019

Initial meltwater was first recorded at BC1 on May 19. Stage increased until peak conditions occurred on May 23. On May 28, site observations revealed meltwater flowing with high velocity overtop of drifted snow in the channel (Photo 4.119). No overbank flooding was noted as flow was confined to the defined channel. Snow cover on the surrounding tundra was approximately 5 percent. Stage decreased until the end of the spring monitoring period on June 3. On June 3, snow was present in the drainage and still appeared to confine meltwater (Photo 4.120).

The BC1 spring stage data are presented in Graph 4.39. Elevations are referenced to NAVD88.

Photo 4.119: Meltwater flowing over saturated snow near BC1, looking north (downstream); May 28, 2019

Photo 4.120: Receding stage at BC1, looking west; June 3, 2019



	Spring	
BC1 Peak Stage (ft)	39.78	5/23/19 6:00 AM

Graph 4.39: 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, also known as Middle Snowman Lake. Gage station MSL is situated on the bank of the northwest corner of the lake near its outlet while MSL_OUT is placed in the swale draining M0015, about 100 feet from the lake's outlet and gage station MSL. This is the second year of monitoring at this location. Historical peak stage data at MSL and MSL_OUT is presented in Table 4.25.

Table 4.25: MSL & MSL_OUT Historical Peak Stage

Year	MSL		MSL_OUT	
	Peak Stage (ft Arbitrary) [1]	Date	Peak Stage (ft Arbitrary) [1]	Date
2019	96.34	5/30	96.28	5/30
2018	97.24	6/4	97.15	6/3

Notes:

[1] Elevations arbitrary; referenced to local control point "PINK" (MBI 2018)

A. SPRING BREAKUP

Meltwater was initially recorded on the MSL PT on May 28. On May 29, stage at MSL and MSL_OUT began to rise concurrently, culminating in peak stage conditions at each site on May 30. Site observations conducted on May 29 show an open water lead near MSL, and saturated snow with minor overbank flooding near MSL_OUT. Aerial photographs show integrated flow was confirmed as meltwater was seen extending from M0015 to the W3S reach (Photo 4.121). At both MSL and MSL_OUT, overbank flooding was observed, and the main outlet channel was difficult to identify.

On June 2, site observations revealed channelized flow between MSL and MSL_OUT with stage slightly exceeding bankfull. Minor overbank flooding was observed in low-lying areas around the channel. Gage 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 feet to the north (Photo 4.122). This fork converges with the main channel about 100 feet downstream of MSL_OUT. From there, the channel is well-defined for another 200 feet, then opens into the poorly defined, low-relief drainage area associated with W3S. No saturated snow was observed in the drainage near the MSL and MSL_OUT gage station and lake M0015 was still covered with ice. The PT data indicates that stage leveled off at both sites around June 10.

Gage stations MSL and MSL_OUT stage and is presented in Graph 4.40. Elevations are referenced to an arbitrary datum based on a local control point.

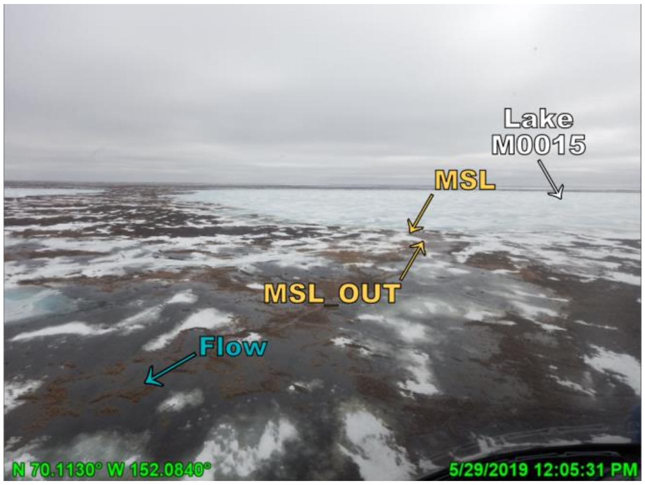
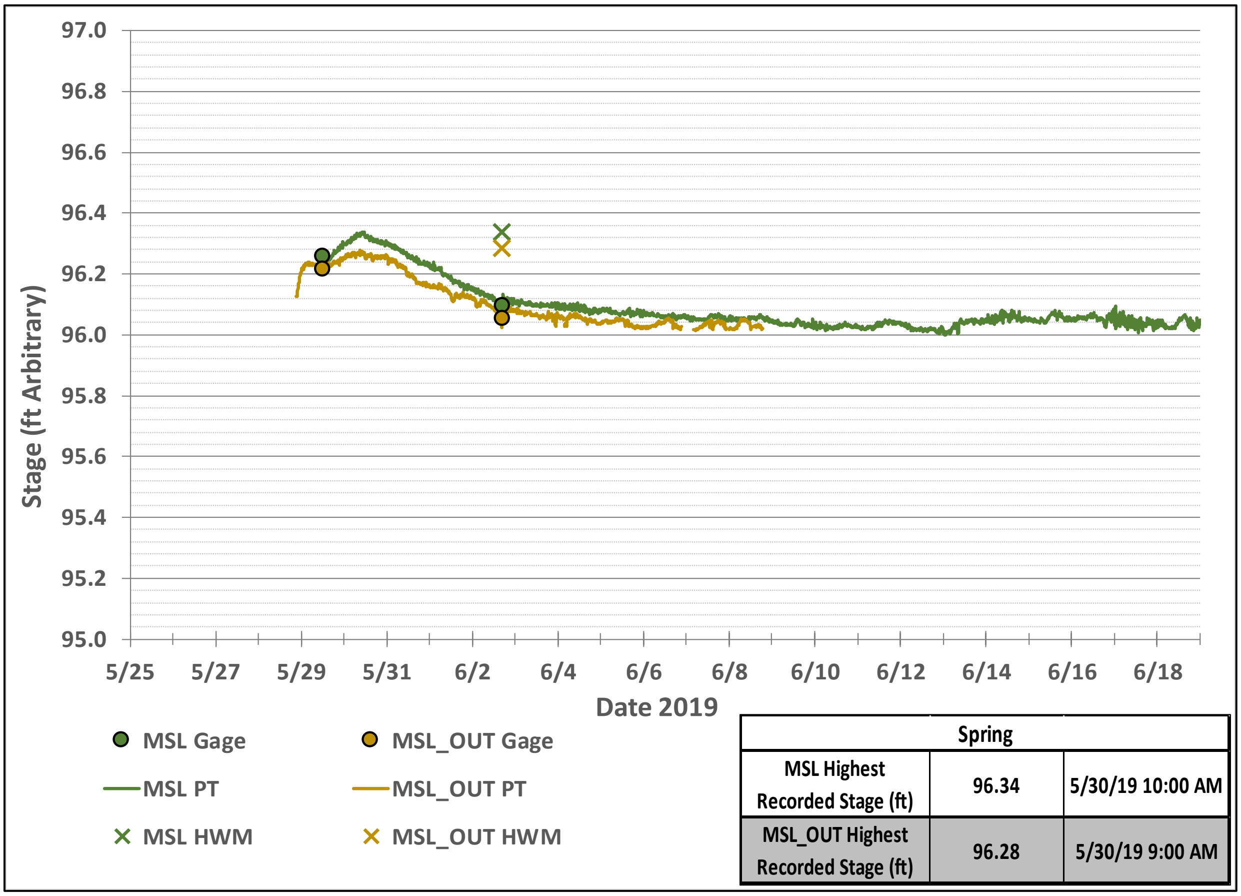


Photo 4.121: MSL drainage one day prior to peak stage, looking southeast (upstream); May 29, 2019

Photo 4.122: Meltwater near MSL & MSL_OUT, looking southeast (upstream); June 2, 2019



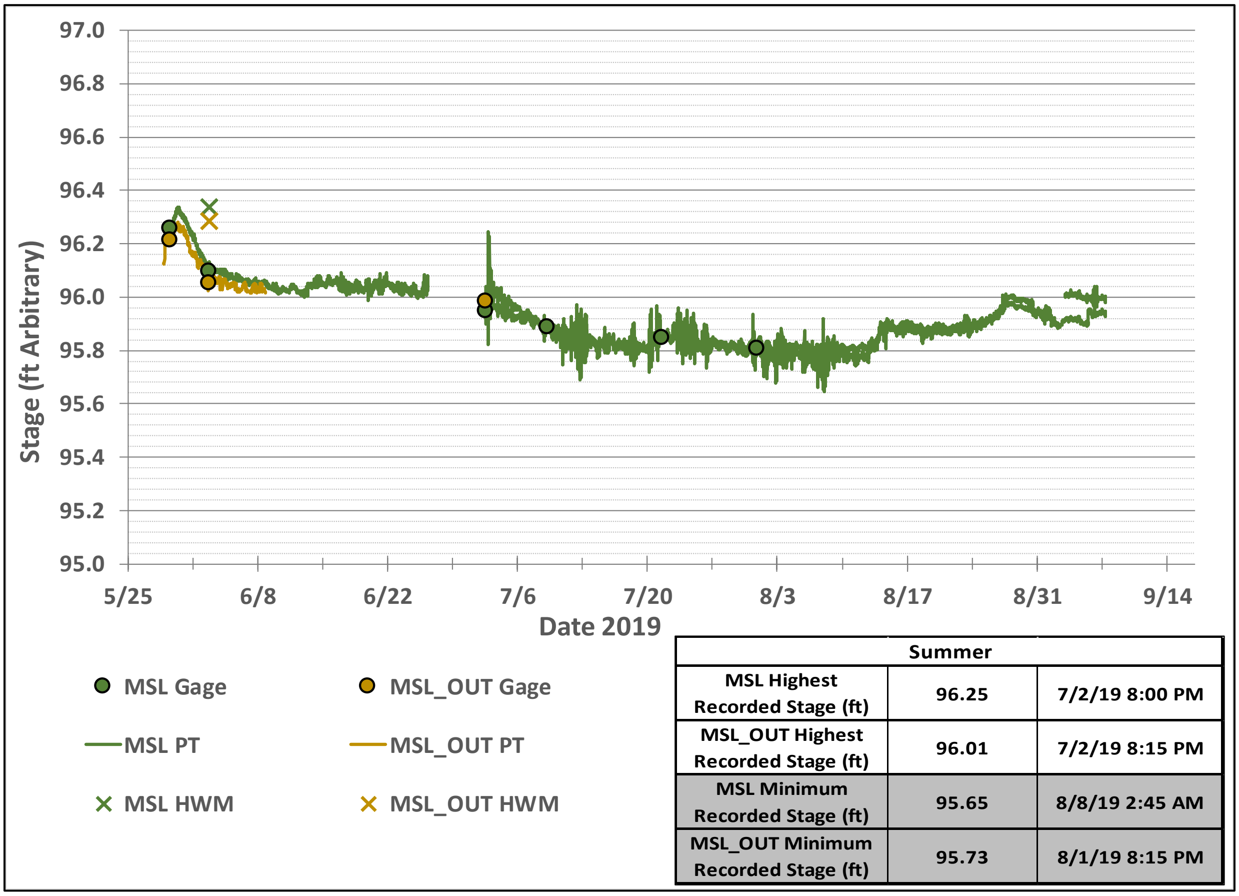
Spring		
MSL Highest Recorded Stage (ft)	96.34	5/30/19 10:00 AM
MSL_OUT Highest Recorded Stage (ft)	96.28	5/30/19 9:00 AM

Graph 4.40: 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 4.123). During the summer observation period, no flow was present, although standing water around the gage was observed. Summer stage at MSL and MSL_OUT is presented in Graph 4.41.

Photo 4.123: Summer conditions at MSL & MSL_OUT, looking north (downstream); July 2, 2019



Summer		
MSL Highest Recorded Stage (ft)	96.25	7/2/19 8:00 PM
MSL_OUT Highest Recorded Stage (ft)	96.01	7/2/19 8:15 PM
MSL Minimum Recorded Stage (ft)	95.65	8/8/19 2:45 AM
MSL_OUT Minimum Recorded Stage (ft)	95.73	8/1/19 8:15 PM

Graph 4.41: 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 feet from the lake's outlet and gage station LSL. This is the second year that these gage stations have been monitored. Historical peak stage data at LSL and LSL_OUT is presented in Table 4.26.

Table 4.26: LSL & LSL_OUT Historical Peak Stage

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

Notes:
[1]. 2018 peak stage elevations adjusted after NAVD88 datum elevation was established in 2019

A. SPRING BREAKUP

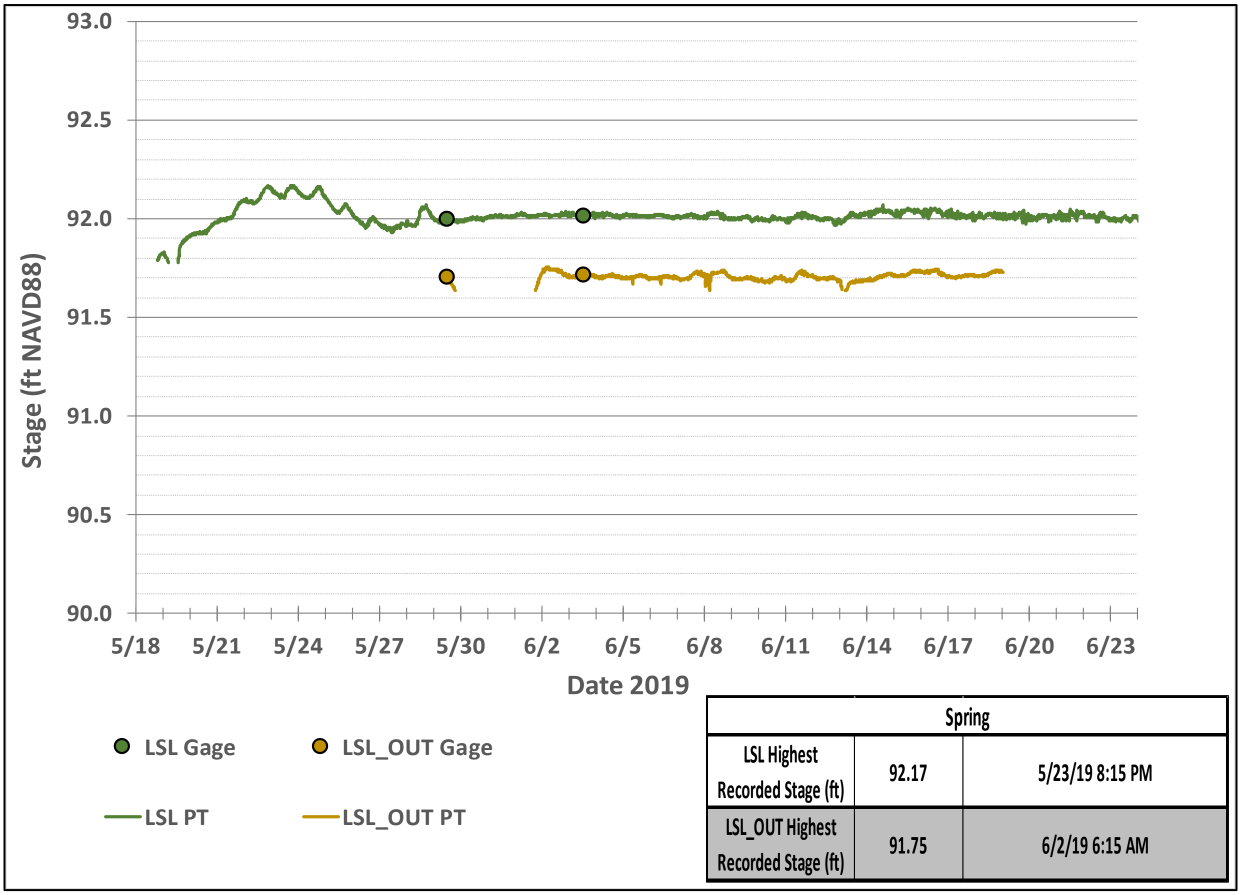
Meltwater was first recorded on the LSL PT on May 19 and was likely the result of isolated local melt. From May 19 to May 29, the LSL PT recorded the largest daily stage fluctuations in the monitoring period. After May 29, stage remained steady with fluctuations less than 0.1-ft. The LSL_OUT PT recorded stage following a similar, steady trend after water reached the PT on June 1. Site observations at LSL and LSL_OUT on May 29 showed local meltwater from lake R0064 reaching LSL but not LSL_OUT. Aerial observations on this day confirmed that integrated flow had not yet developed as the swale was filled with snow (Photo 4.124). Disconnected local meltwater was present in low-lying areas to the west of the LSL outlet.

By June 3, aerial observations showed a well-defined channel conveying flow from Lake R0064 north, past the LSL and LSL_OUT gage stations, then across a poorly defined low-lying area, and eventually emptying into the south end of Middle Snowman Lake (Lake M0015) (Photo 4.125). Minimal snow remained in the area on this day. The flow-path observed upstream of the gage was well-defined with multiple 90-degree bends along polygon features. A bifurcation was observed at gage station LSL_OUT, with two distinct channels each conveying flow into a low-lying area about 200 feet downstream of LSL_OUT. Overbank flooding was observed in the low-lying areas closer to M0015, while flow was confined to the defined channels around the gage sites where bankfull conditions were observed. The lake was still covered with ice on June 3.

LSL and LSL_OUT stage and is presented in Graph 4.42. Elevations are referenced to NAVD88.

Photo 4.124: Snow-filled drainage near LSL & LSL_OUT, looking east; May 29, 2019

Photo 4.125: Meltwater between R0064 and M0015, looking northeast (downstream); June 3, 2019



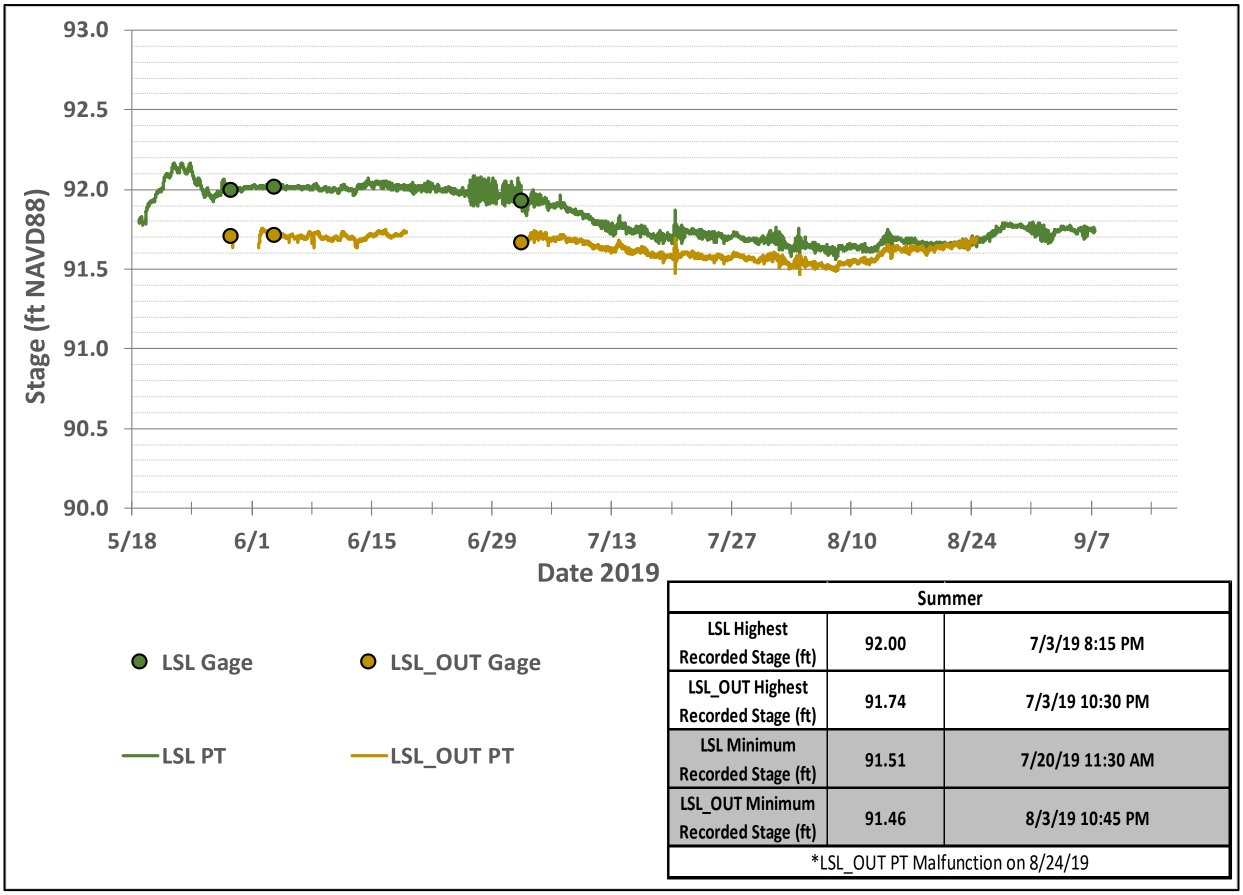
	Spring	
LSL Highest Recorded Stage (ft)	92.17	5/23/19 8:15 PM
LSL_OUT Highest Recorded Stage (ft)	91.75	6/2/19 6:15 AM

Graph 4.42: 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 4.126). 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 4.43.

Photo 4.126: Summer conditions at LSL_OUT, looking north (downstream); July 2, 2019



Summer		
LSL Highest Recorded Stage (ft)	92.00	7/3/19 8:15 PM
LSL_OUT Highest Recorded Stage (ft)	91.74	7/3/19 10:30 PM
LSL Minimum Recorded Stage (ft)	91.51	7/20/19 11:30 AM
LSL_OUT Minimum Recorded Stage (ft)	91.46	8/3/19 10:45 PM

*LSL_OUT PT Malfunction on 8/24/19

Graph 4.43: Lower Snowman at LSL & LSL_OUT Summer Stage

5. FLOOD FREQUENCY ANALYSIS

The flood frequency results and assigned recurrence intervals for 2019 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 D.

Table 5.1 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 4,600 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 5.2 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 5,100 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 5.3 presents the Kalikpik River at Kal1 flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003) applied to the measured discharge value at Kal1. This year's Kal1 measured discharge of 245 cfs has a recurrence interval of less than 2 years.

Table 5.3: Kal1 Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]
%	years	cfs
50	2	3,200
20	5	4,800
10	10	5,800
4	25	7,100
2	50	8,000
1	100	8,900
Notes: 1. USGS 2003		

Table 5.4 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 110 cfs has a recurrence interval of less than 2 years.

Table 5.4: 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 5.5 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 270 cfs has a recurrence interval of less than 2 years.

Table 5.5: 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 5.6 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 350 cfs has a recurrence interval of less than 2 years.

Table 5.6: 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 5.7 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 320 cfs has a recurrence interval of 11 years.

Table 5.7: W_S1 Flood Frequency Analysis Results

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

Notes:
[1] USGS 2003

6. REFERENCES

Chow, V.T., 1959, Open-Channel Hydraulics, New York, McGraw-Hill, p. 138.

ICE Consult and Design (ICE). NPR-A North Tundra Monitoring Station. Cumulative Freezing Degree Days. Winters 2002-2018 Coldest to Warmest Year. June 2018. Prepared for ConocoPhillips Alaska, Inc.

Michael Baker International (Michael Baker). 2003. Alpine Satellite Development Plan 2003 Spring Breakup and Hydrologic Assessment. December 2003. Prepared for ConocoPhillips Alaska, Inc.

———2005a. Alpine Satellite Development Plan 2004 Spring Breakup and Hydrologic Assessment. March 2005. Prepared for ConocoPhillips Alaska, Inc.

———2005b. Colville River Delta and Fish Creek Basin 2005 Spring Breakup and Hydrological Assessment. December 2005. Prepared for ConocoPhillips Alaska, Inc.

———2007. 2006 Colville River Delta and Fish Creek Basin 2006 Spring Breakup and Hydrological Assessment. January 2007. Prepared for ConocoPhillips Alaska, Inc.

———2017. 2017 Willow Spring Breakup and Summer Monitoring and Hydrological Assessment. November 2017. Prepared for ConocoPhillips Alaska, Inc.

———2018. 2018 Willow Spring Breakup and Summer Monitoring and Hydrological Assessment. November 2018. Prepared for ConocoPhillips Alaska, Inc.

Natural Resource Conservation Service. 2018. Alaska Snow Survey Report. April 2018. United States Department of Agriculture (USDA).

National Oceanic and Atmospheric Administration: National Weather Service. Weather.gov. Retrieved from Nuiqsut weather observations: https://w1.weather.gov/data. Accessed September 2019.

U.S. Department of the Interior Bureau of Land Management (BLM). 2012. National Petroleum Reserve-Alaska Integrated Activity Environmental Impact Statement. November 2012.

———2013. National Petroleum Reserve-Alaska Integrated Activity Plan Record of Decision. February 2013.

URS. 2001. 2001 Hydrologic Assessment. Fish Creek, Judy Creek and the Ublutuoch River North Slope, Alaska. Prepared for ConocoPhillips Alaska, Inc. December 2001.

———2002. 2001 Water Surface Profiles for Selected Flood Peak Discharges on Fish Creek, Judy Creek and the Ublutuoch River North Slope, Alaska. Prepared for ConocoPhillips Alaska, Inc. March 2002.

———2003. 2002 Hydrologic and Hydraulic Assessment. Fish Creek, Judy Creek and the Ublutuoch River North Slope, Alaska. Prepared for ConocoPhillips Alaska. January 2003.

U.S. Geological Survey (USGS). 1967. Benson, M. A. and Tate Dalrymple. General Field and Office Procedures for Indirect Discharge Measurements: Techniques of Water-Resources Investigations of the United States Geological Survey. USGS-TWRI Book 3, Chapter A1. United States Government Printing Office, Washington, DC. USGS. 1967.

———1982. Bodhaine G. L. Measurement and Computation of Streamflow, Vols. 1 and 2. S.E. Rantz and others. Water Supply Paper 2175.

———2003. Curran, Janet H., David F. Meyer, and Gary D. Tasker. Estimating the Magnitude and Frequency of Peak Streamflows for Ungaged Sites on Streams in Alaska and Conterminous Basins in Canada. U.S. Geological Survey Water-Resources Investigation Report 03-4188. Alaska: Alaska Department of Transportation and Public Facilities. Available online at http://pubs.usgs.gov/wri/wri034188/.

———2005. Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers. Lipscomb, Steven W., Scientific Investigations Report 2005-5183.

———2006. Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport. Scientific Investigations Report 2006-5079.

———2013. Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat. Chapter 22 of Section A, Surface-Water Techniques, Book 3, Applications of Hydraulics.

Weather Underground. Website access August 2019. (http://www.wunderground.com).

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 feet.

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		Number of Gages	Associated Vertical Control	Vertical Control Location		Vertical Control Elevation (ft NAVD88)
			Latitude (WGS84)	Longitude (WGS84)			Latitude (WGS84)	Longitude (WGS84)	
	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]
		SW22	70.27630°	-152.19270°	1	TWOFISH ONEFISH	70.27628° 70.27627°	-152.19390° -152.19388°	79.971 80.123
	TBD_5	TBD_5	70.27726°	-152.49517°	2	REDFISH BLUEFISH	70.27707° 70.27707°	-152.49462° -152.49453°	100.000 [3] 99.930 [3]
Swales	SW1	SW1	70.13612°	-152.01333°	1	OBIWAN KENOBI	70.13573° 70.13574°	-152.01193° -152.01192°	84.224 84.143
	SW2	SW2	70.12888°	-152.06316°	1	ARCTICA GLAUCA	70.12869° 70.12870°	-152.06450° -152.06438°	84.470 84.433
	SW3	SW3	70.10583°	-152.13412°	1	COKE PEPSI	70.10557° 70.10557°	-152.13543° -152.13552°	90.356 90.268
	SW4	SW4	70.15596°	-152.09439°	1	BOBA FETT	70.15621° 70.15620°	-152.09503° -152.09501°	58.306 58.279
	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
	SW14	SW14	70.12328°	-152.08699°	1	GREENEGGS ANDHAM	70.12303° 70.12313°	-152.08729° -152.08727°	86.706 86.074
	SW23	SW23	70.31504°	-152.19902°	1	PAPER SCISSORS	70.31493° 70.31493°	-152.20025° -152.20023°	84.094 84.073
	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
		UB15.5	70.23373°	-151.28739°	4				

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)	
	MS1_1	**MS1_1**	70.23283°	-151.28757°	1	LATITE ANDESITE	70.23325° 70.23323°	-151.28595° -151.28585°	30.337 30.709
	Bills Creek	**BC1**	70.22840°	-151.26591°	1	GNEISS SCHIST	70.22859° 70.22860°	-151.26833° -151.26800°	48.531 40.802
Source Lake	Lake M0015/R0056 aka Middle Snowman Lake	**MSL**	70.11227°	-152.07746°	1	PINK HUMPY	70.11280° 70.11279°	-152.07728° -152.07744°	100.000 [3] 99.450 [3]
	Willow 3/Lake M0015/R0056 (aka Middle Snowman Lake) outlet	**MSL_Out**	70.11237°	-152.07808°	1				
	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
	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. Line 4BW and GILLY 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		Spring PT Elevation (ft NAVD88) [2]
		Minimum (ft NAVD88)	Maximum (ft NAVD88)	
F55.5U	F55.5U-A	41.69	50.81	41.770
	F55.5U-B			
	F55.5U-C			
F55.5	F55.5-A	41.82	50.94	41.920
	F55.5-B			
	F55.5-C			
F55.5D	F55.5D-A	42.07	50.47	42.285
	F55.5D-B			
	F55.5-C			
J13.8U [1]	J13.8U-A	34.85	45.12	34.860
	J13.8U-B			
	J13.8U-C			
J13.8 [1]	J13.8-A	34.00	41.64	34.050
	J13.8-B			
	J13.8-C			
J13.8D [1]	J13.8D-A	31.79	40.96	31.850
	J13.8D-B			
	J13.8D-C			
J21.4	J21.4-A	46.57	56.20	46.664
	J21.4-B			
	J21.4-C			
Kal1 [4]	KAL1-A	47.92	54.28	48.010
	KAL1-B			
UC2C	UC2C-A	47.19	53.95	47.246
	UC2C-B			
W1S	W1S-A	78.52	82.71	--
UC1B	UC1B-B	76.98	80.98	77.061
W3S	W3S-A	88.15	93.40	88.216
W4 [3]	W4-A	86.92	92.22	87.000
	W4-B			
W_BS1	W_BS1-A	84.23	89.13	84.302
	W_BS1-B			
W_S1	W_S1-A	99.23	102.97	99.282
TBD_6	TBD_6-A	49.19	53.10	49.268
TBD_5 [3]	TBD_5-A	92.83	99.45	93.500
	TBD_5-B			
SW1	SW1-A	79.44	83.72	--

Gage Station	Gage Assembly	Gage Elevation		Spring PT Elevation (ft NAVD88) [2]
		Minimum (ft NAVD88)	Maximum (ft NAVD88)	
SW2	SW2-A	80.93	84.63	80.983
SW3	SW3-A	87.13	90.71	--
SW4	SW4-A	55.42	59.30	--
SW6	SW6-A	60.97	64.71	--
SW14	SW14-A	83.35	87.08	83.381
SW22	SW22-A	78.23	82.51	78.951
SW23	SW23-A	79.50	83.40	--
SW24	SW24-A	84.92	88.76	--
UB14.5	UB14.5-A	8.71	20.52	8.939
	UB14.5-B			
	UB14.5-C			
	UB14.5-D			
	UB14.5-E			
UB15.5	UB15.5-A	11.80	20.27	11.789
	UB15.5-B			
	UB15.5-C			
MS1_1	MS1_1-A	26.50	30.29	26.847
BC1	BC1-A	36.44	40.07	36.372
MSL [3]	MSL-A	94.86	98.35	95.833
MSL_OUT [3]	MSL_OUT-A	95.72	99.54	96.015
LSL	LSL-A	91.64	95.64	91.775
LSL_OUT	LSL_OUT-A	91.56	95.19	91.632

Notes:
1. J13.8U, J13.8, and J13.8D elevations are feet 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 percent 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: May 31, 2019 3:15 PM

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

Final Discharge (cfs): 2,875

Average Velocity (fps): 2.5

Measurement Rating: Fair

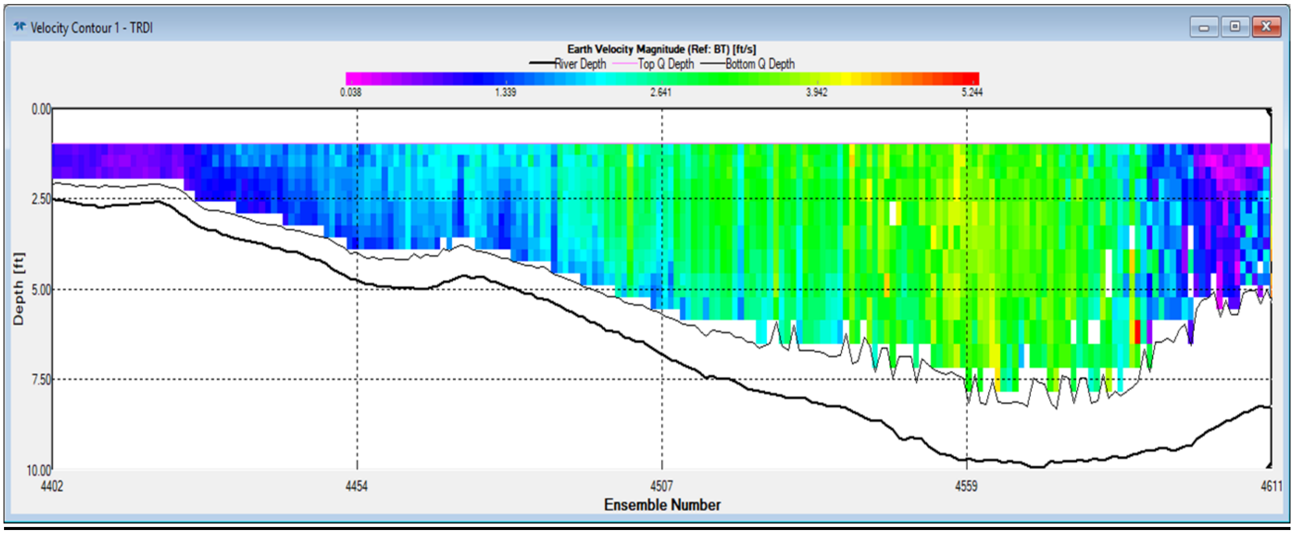
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from the loop test performed before measuring the five transects. Moving bed velocity estimated using the stationary moving bed test was 0.23 fps. The percentage of bad bottom track values (1.09%) was within the recommended maximum of 5%.

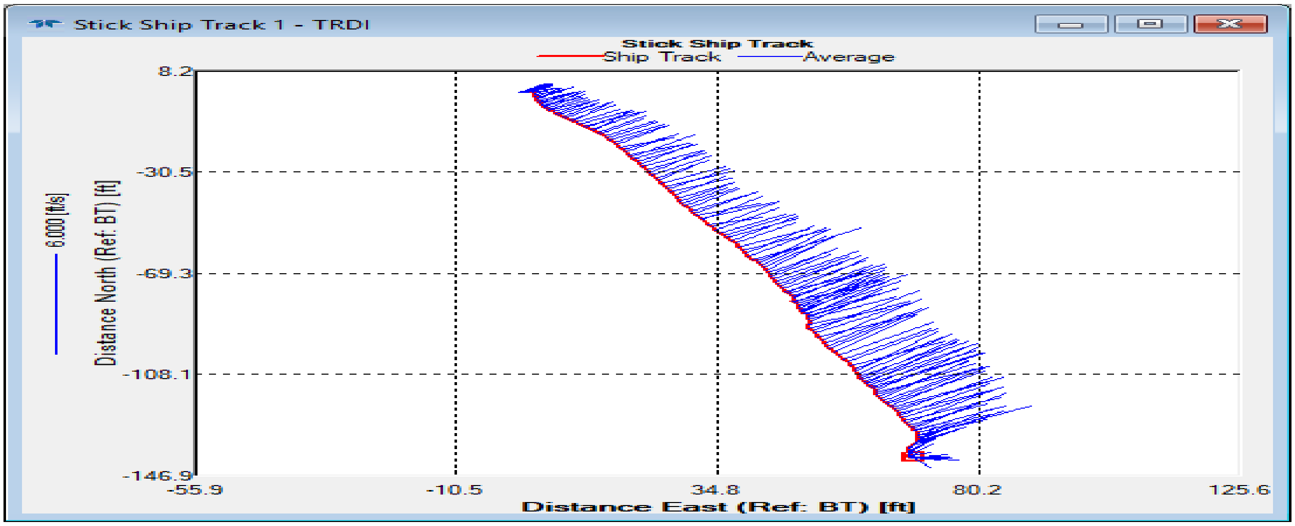
At the time of the measurement, open-channel conditions were present with intermittent ice floes and snow along the banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall quality of the discharge measurement is fair considered based on conditions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

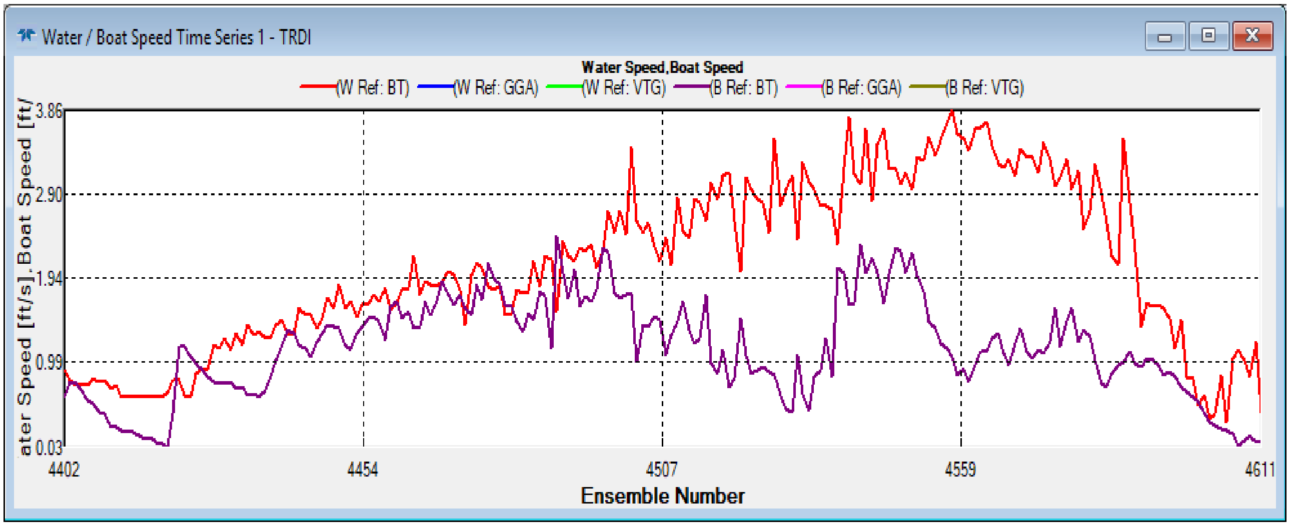
Table C.1: F55.5 May 31 Spring Breakup Measured Discharge Summary

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)
F55.5C002	Left	2833	-1.45%	1882	-0.71%	183	1257	1,140	2.49	2.25
F55.5C003	Right	2793	-2.85%	1839	-2.94%	179	1291	1,115	2.50	2.16
F55.5C004	Left	2858	-0.57%	1915	1.04%	185	1248	1,146	2.50	2.29
F55.5C006	Right	2877	0.06%	1865	-1.58%	183	1221	1,149	2.50	2.36
Average		**2875**		**1895**		**182**		**1,140**	**2.52**	**2.28**

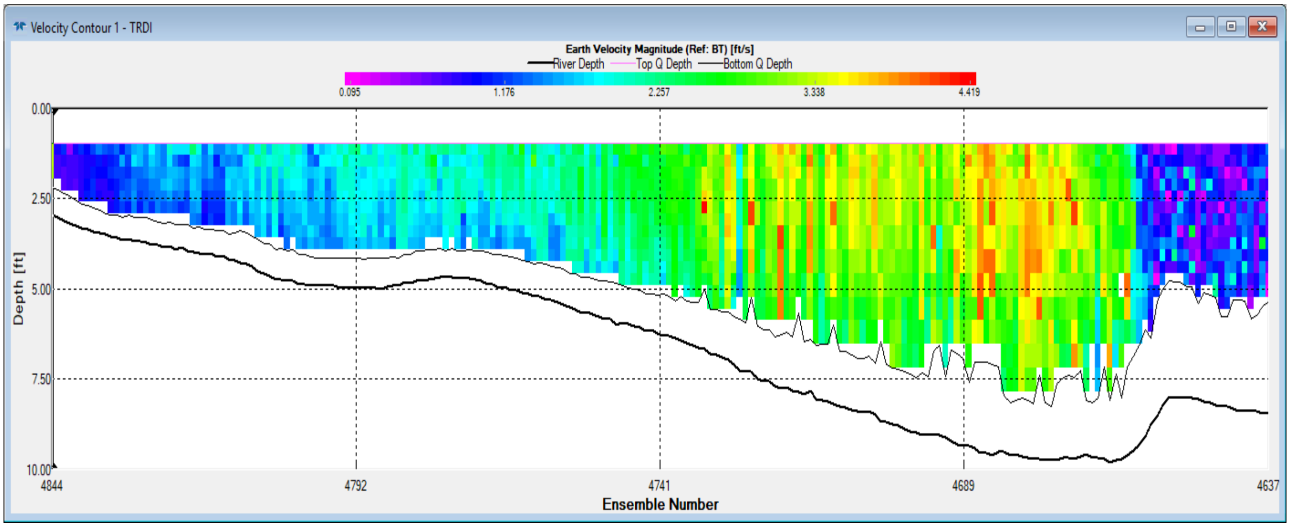
A. Transect F55.5-02 Raw Data Output

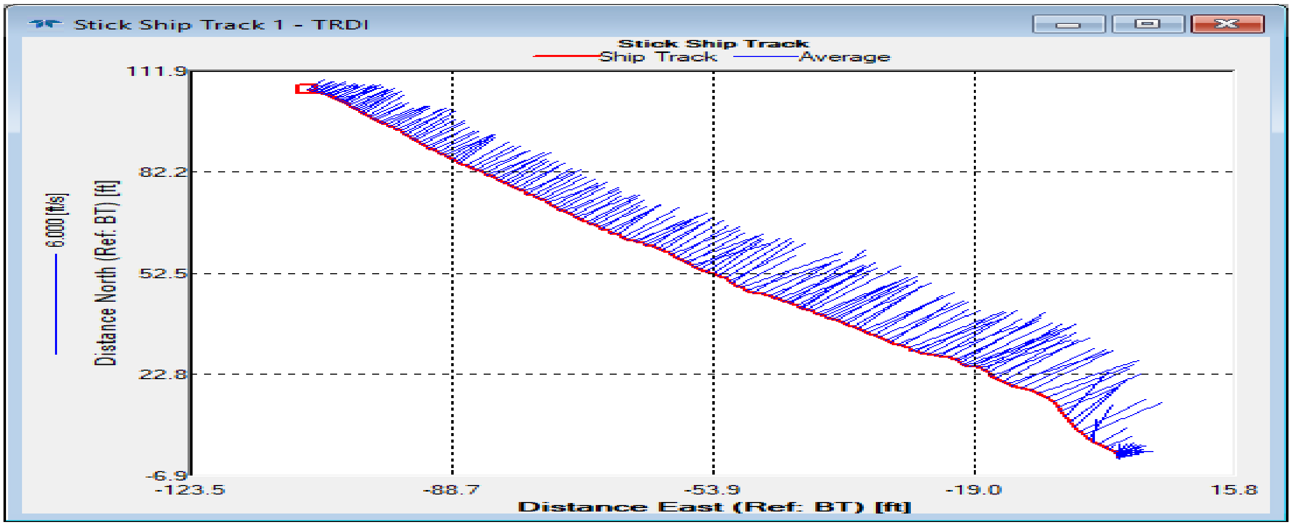


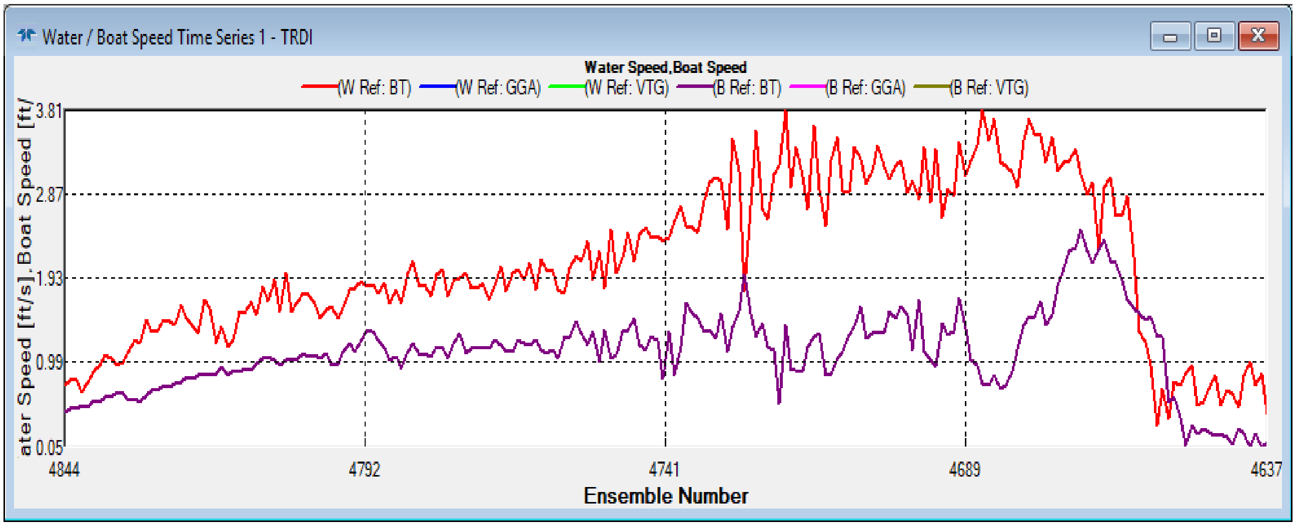




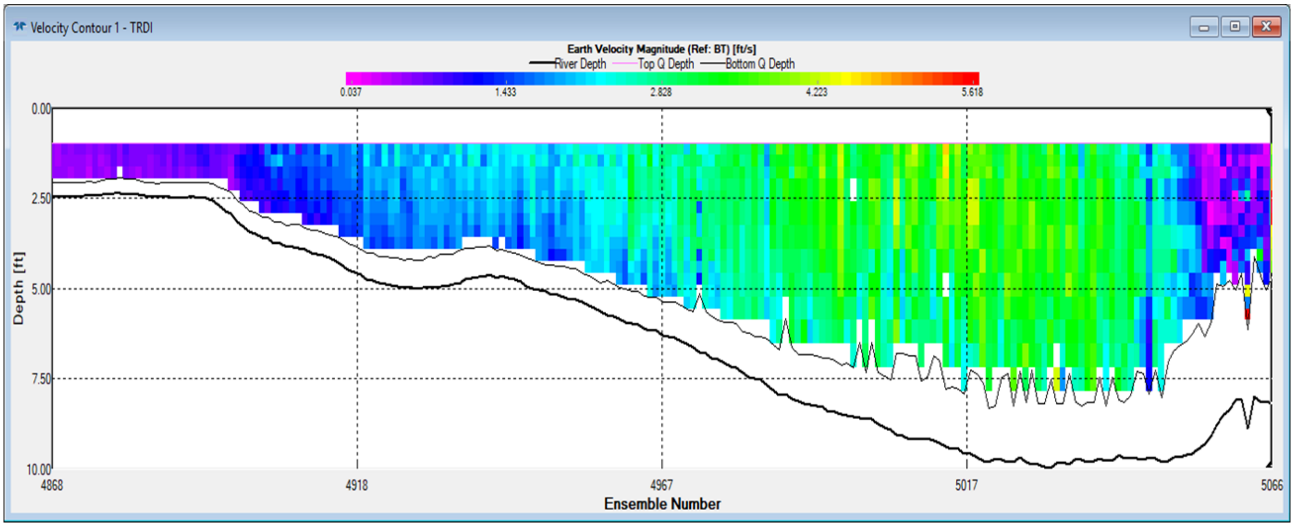
B. Transect F55.5-03 Raw Data Output

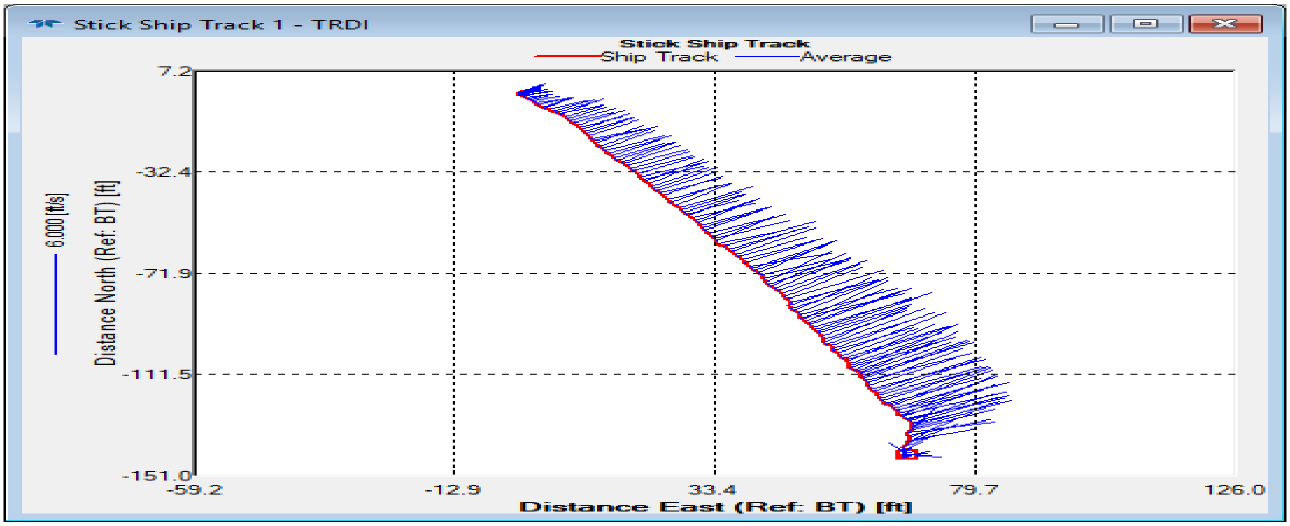


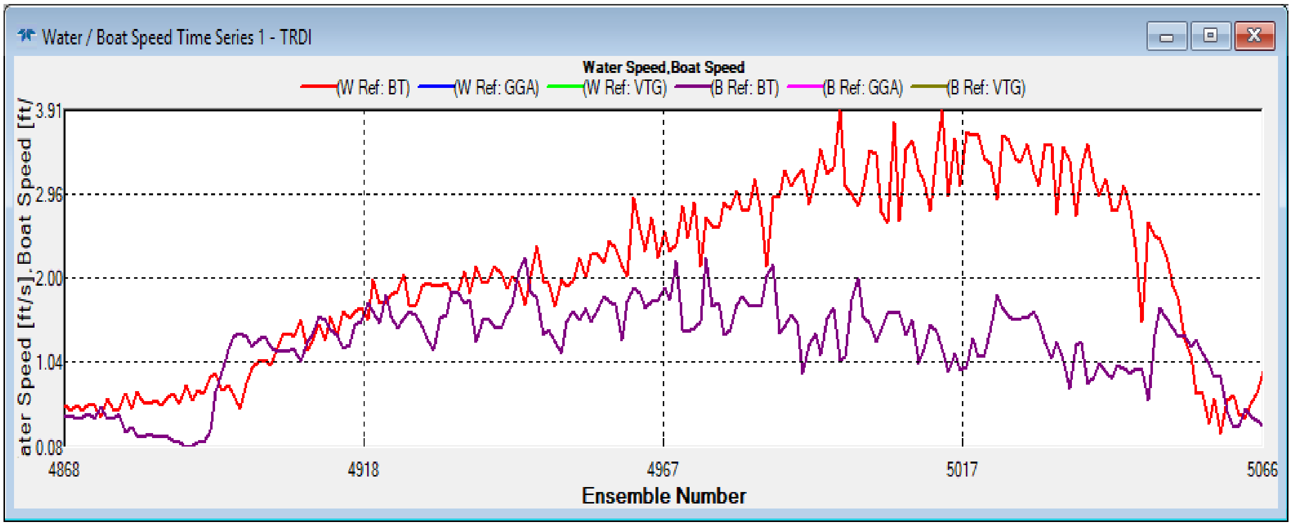




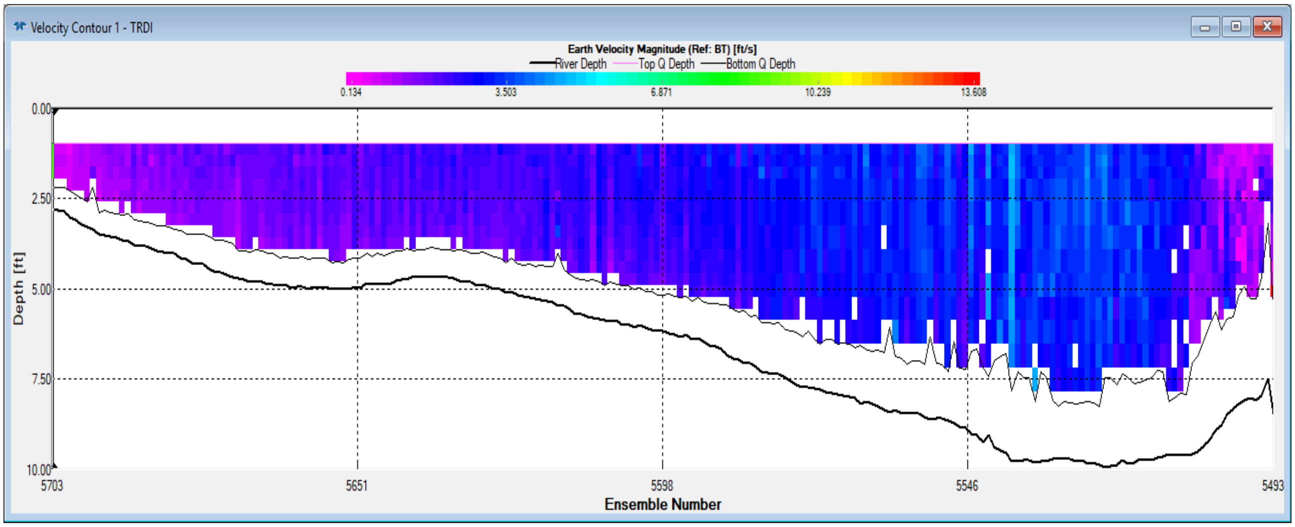
C. Transect F55.5-04 Raw Data Output

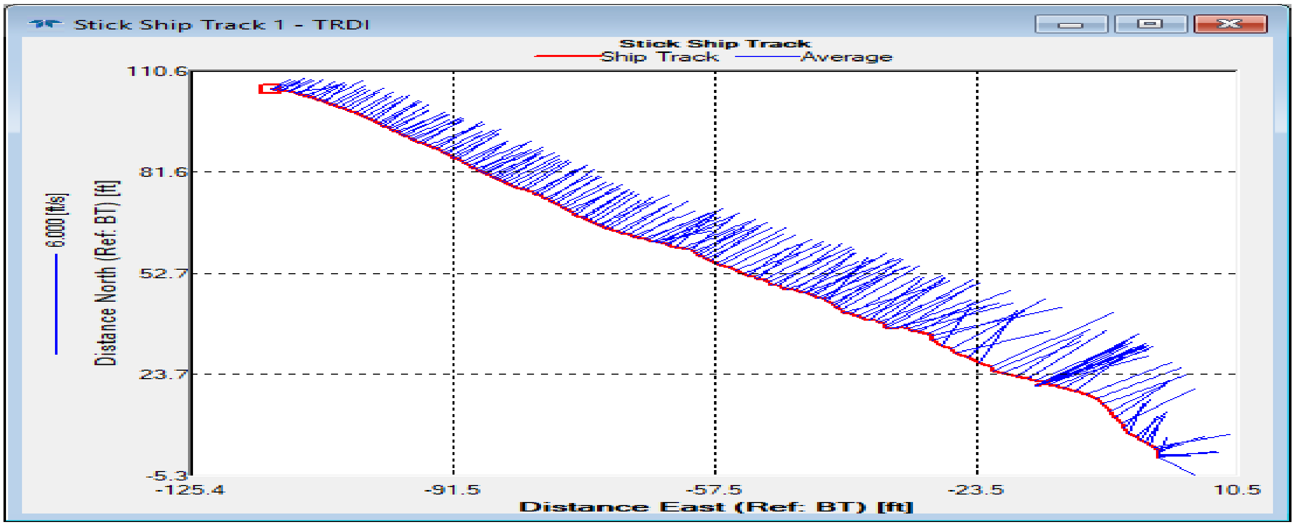


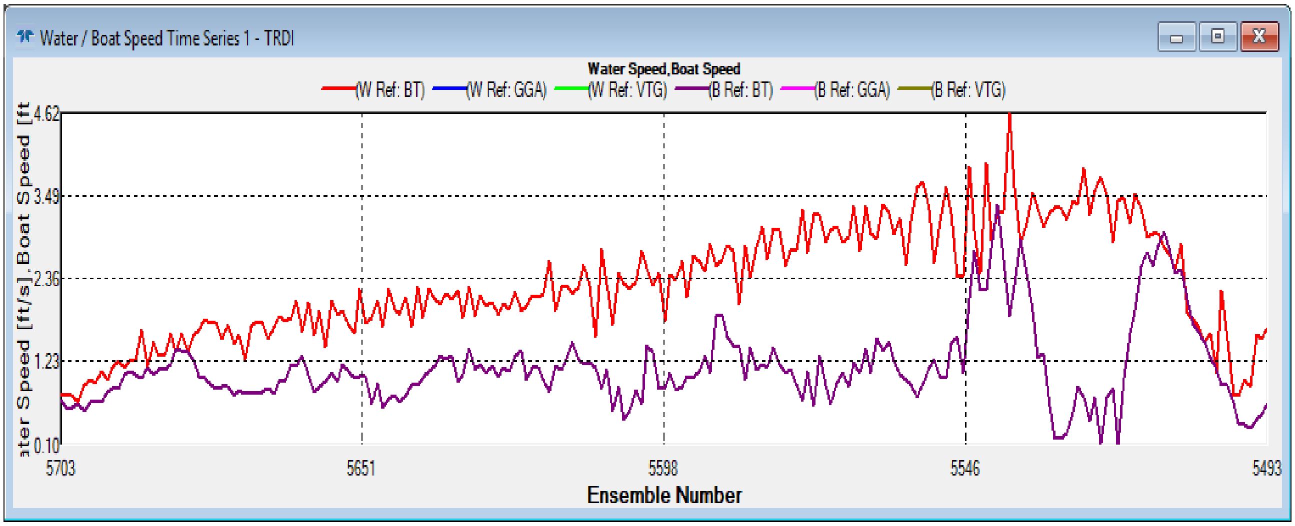




D. Transect F55.5-06 Raw Data Output







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 May 31, 2019 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 2019 calculated discharge values were compared to the direct discharge for 2019 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

0 600 1,200 Feet

Date:	10/18/2019	Scale:	1 Inch = 600 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_F55.5.mxd

● Station

→ Flow Direction

⊕ Gage Location

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

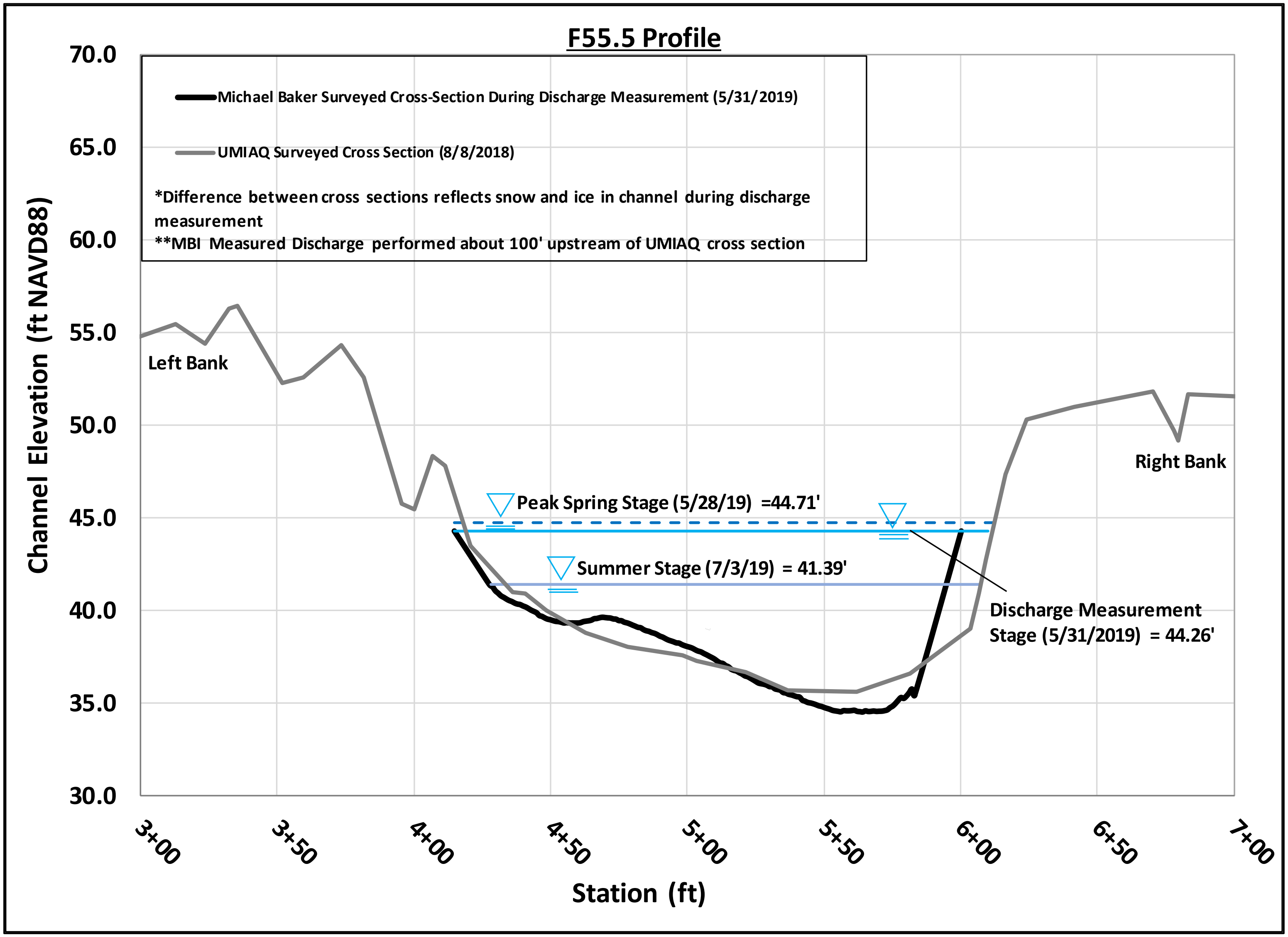
Michael Baker
INTERNATIONAL

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

2019 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: May 28, 2019 12:00 PM

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

Final Discharge (cfs): 3,400

Average Velocity (fps): 2.3

Measurement Rating: Poor

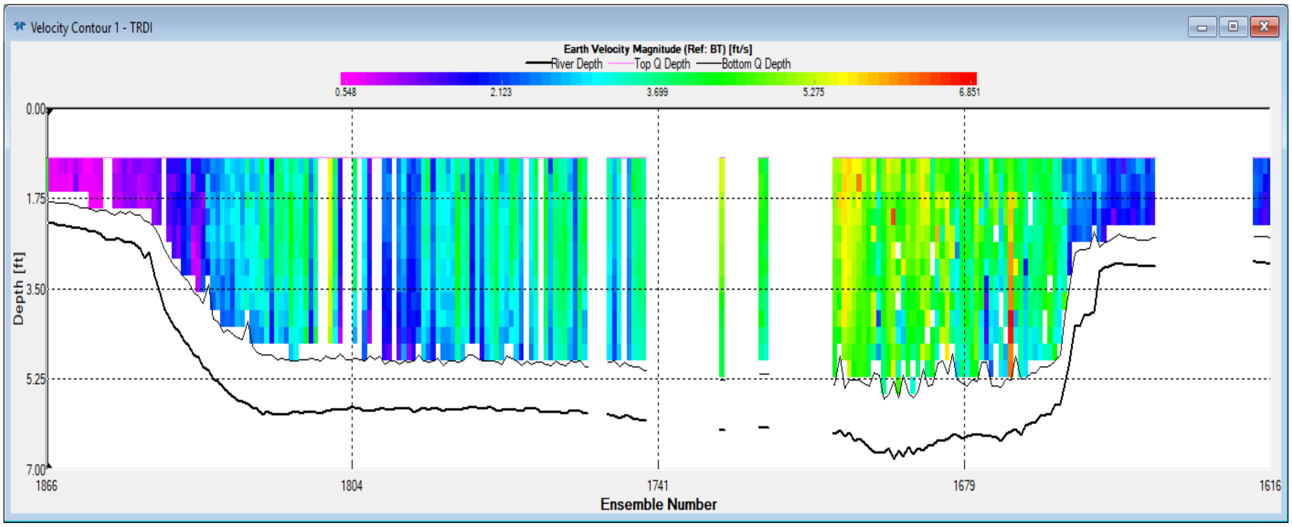
Measurement Notes: Moving bed conditions were identified, but discharge was not corrected for the moving bed using data acquired from the loop test because the percent bad bottom track (25%) exceeded the recommended threshold (5%).

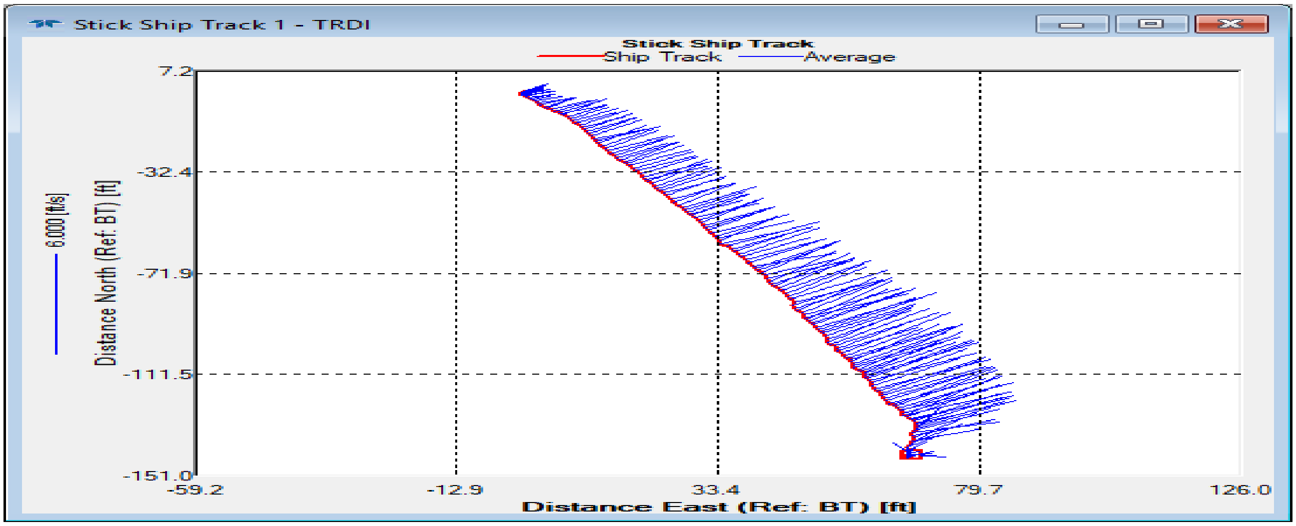
At the time of the measurement, the river was mostly clear of snow and ice with intermittent ice floes and saturated snow along the banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered poor based on the highly 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 May 28 Spring Breakup Measured Discharge Summary

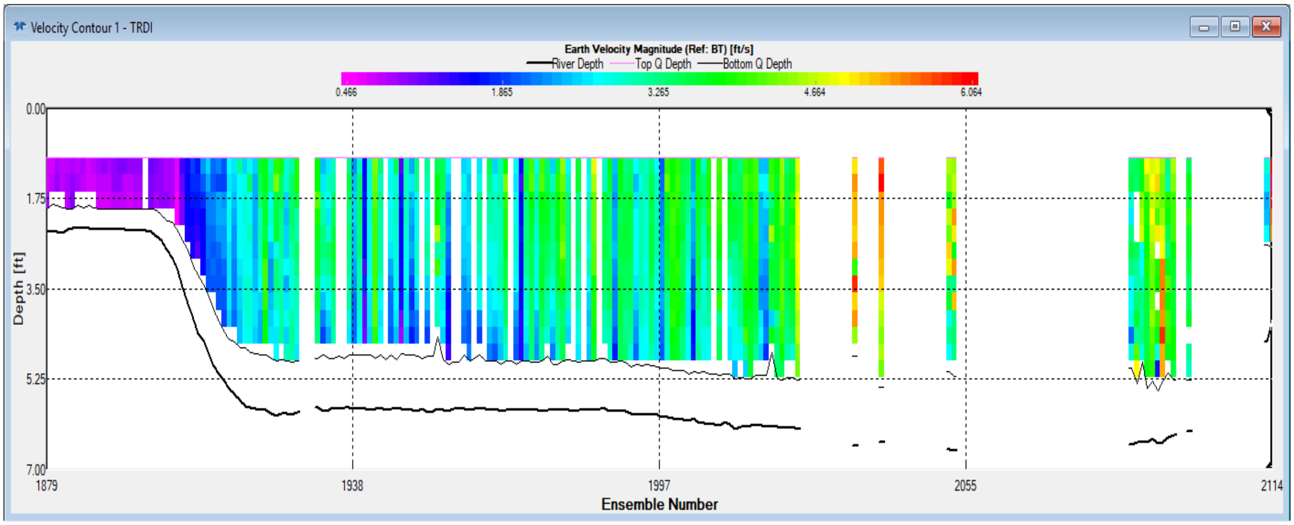
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
001	Right	4224	23.29%	2804	26.07%	255	1299	1,486	2.84	3.25
002	Left	2886	-15.77%	1811	-18.59%	237	985	1,403	2.06	2.93
003	Right	3222	-5.94%	2115	-4.91%	282	1013	1,667	1.93	3.18
005	Left	2871	-16.20%	1826	-17.92%	245	814	1,470	1.95	3.53
007	Left	3704	8.12%	2359	6.07%	277	1079	1,625	2.28	3.43
008	Right	4060	18.51%	2681	20.53%	264	1293	1,555	2.61	3.14
010	Left	3015	-12.00%	1974	-11.24%	235	936	1,394	2.16	3.22
Average		**3426**		**2224**		**256**		**1,514**	**2.26**	**3.24**

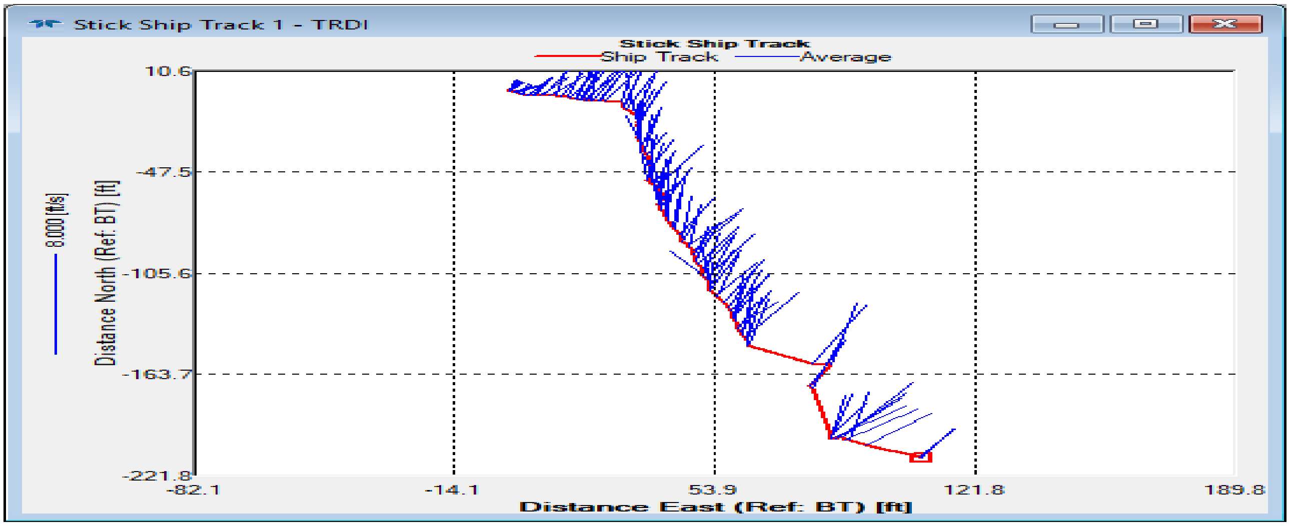
A. Transect J13.8-001 Raw Data Output

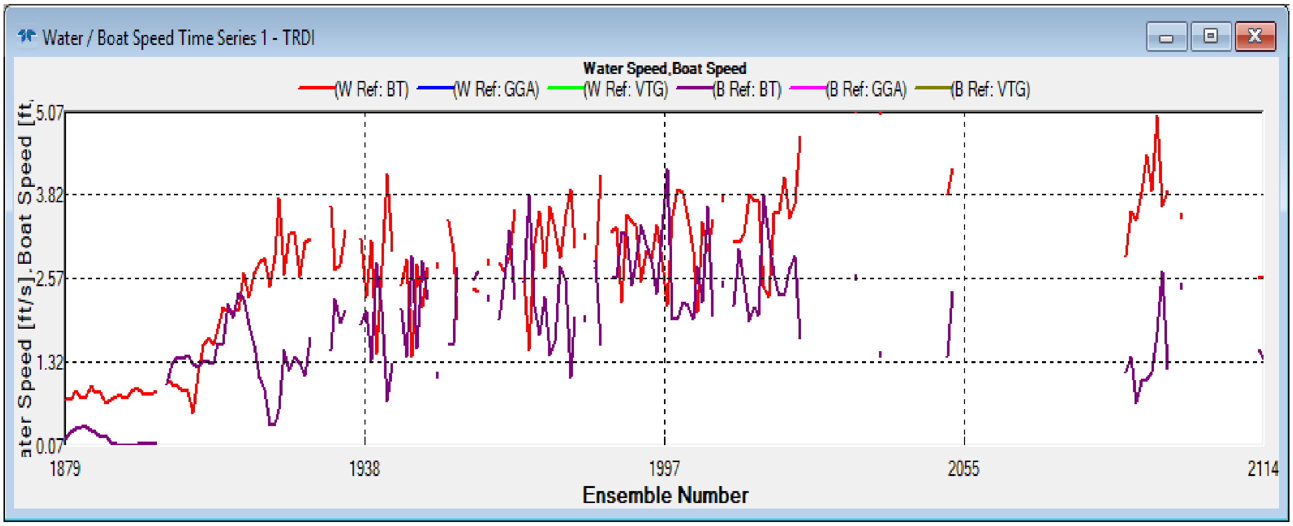




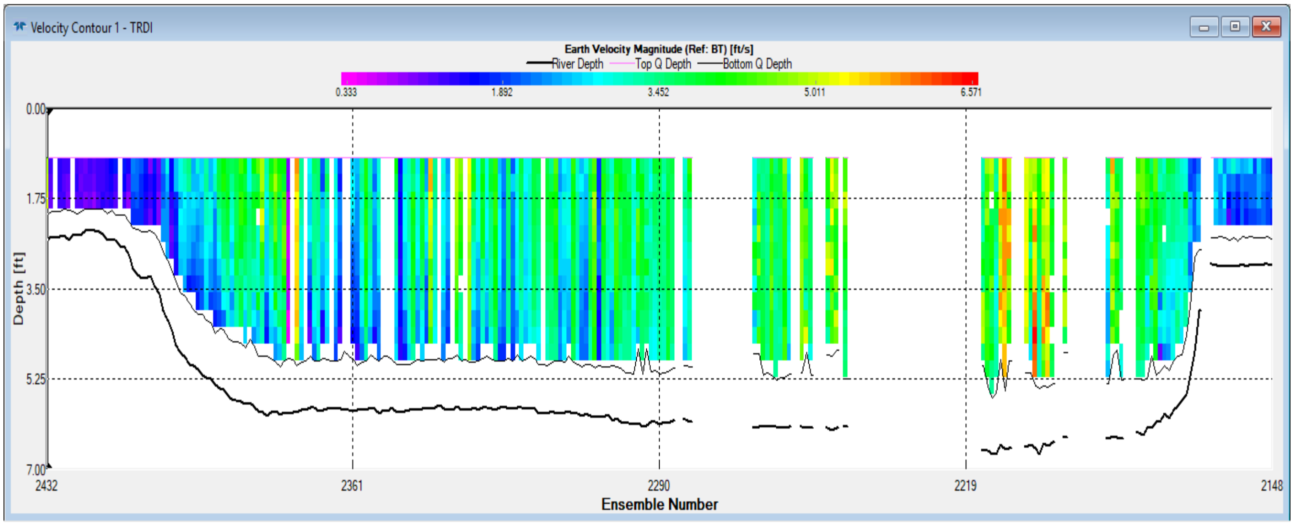
B. Transect J13.8-002 Raw Data Output

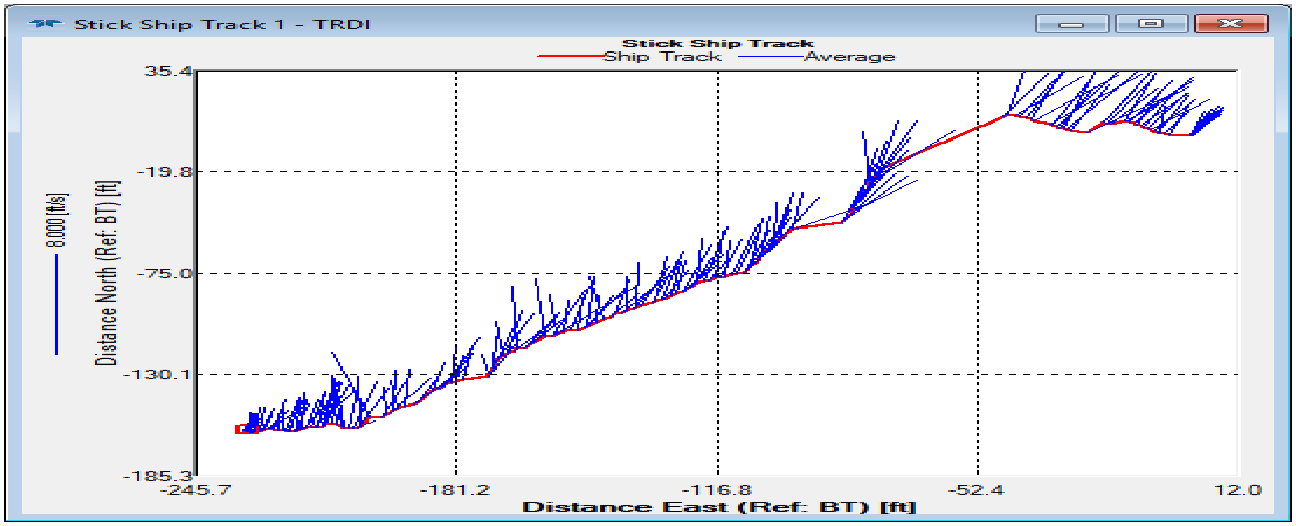


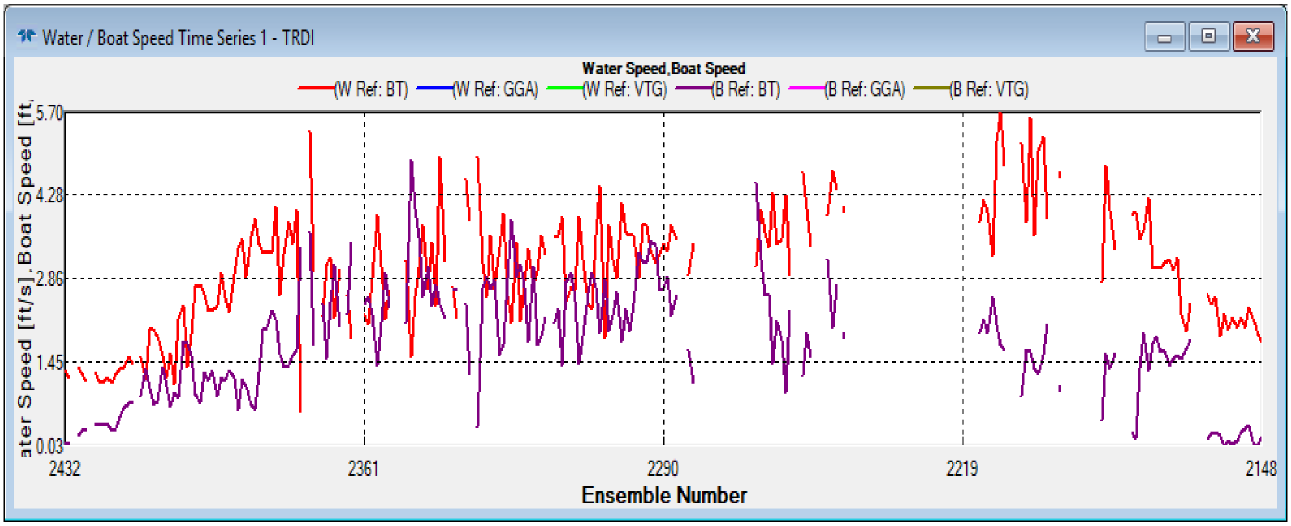




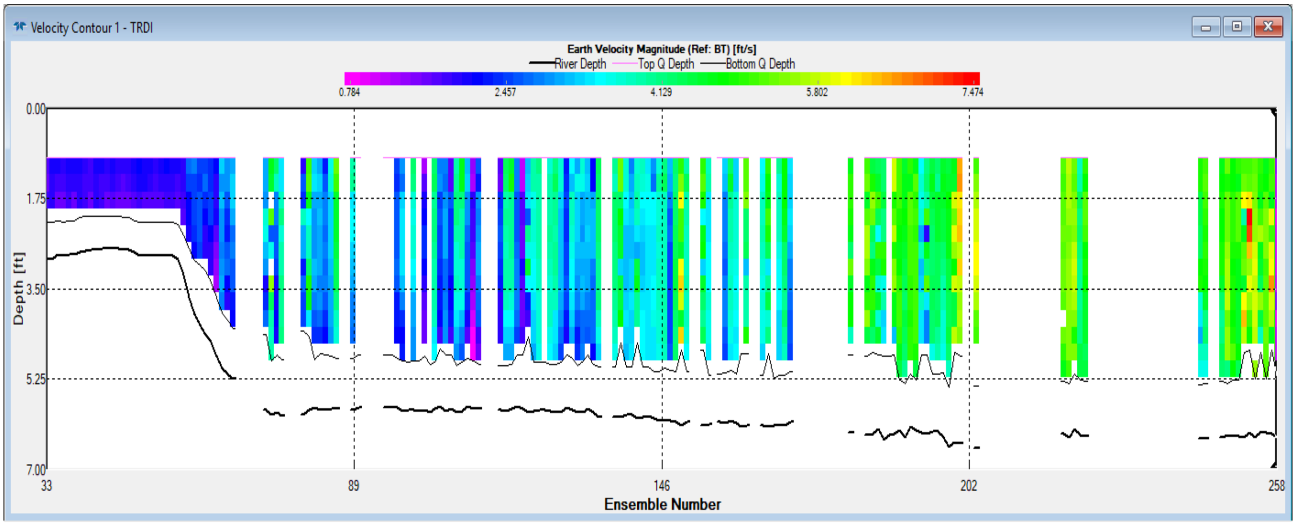
C. Transect J13.8-003 Raw Data Output

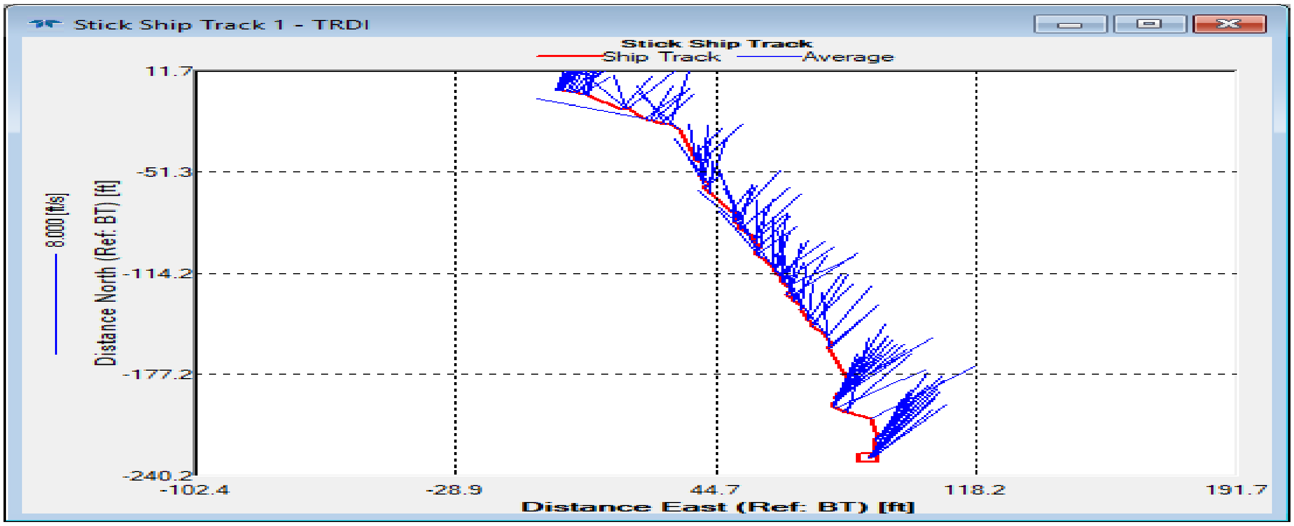


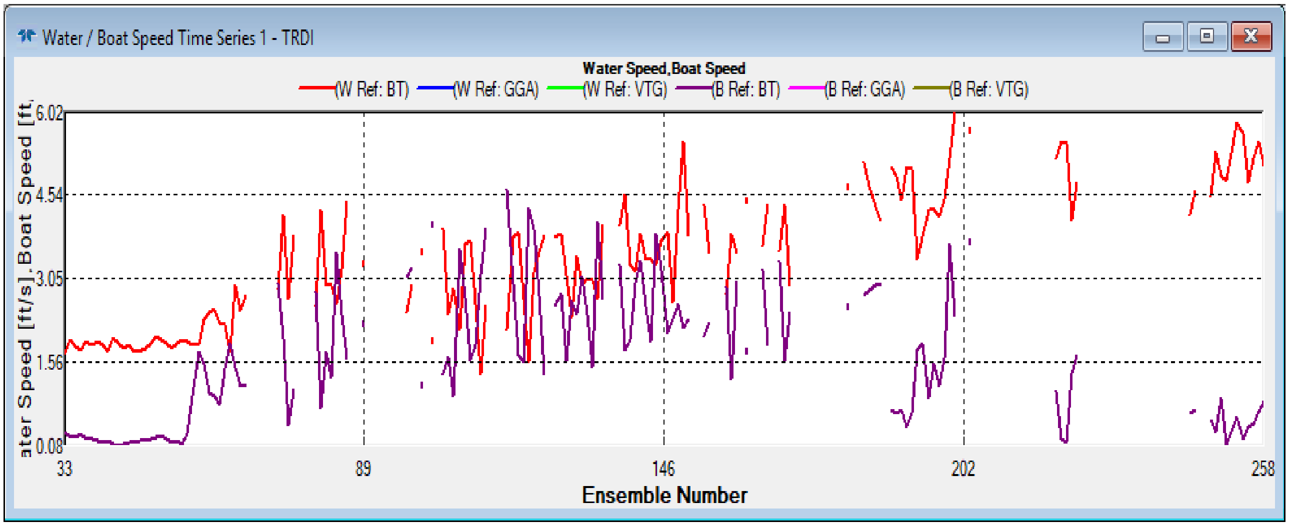




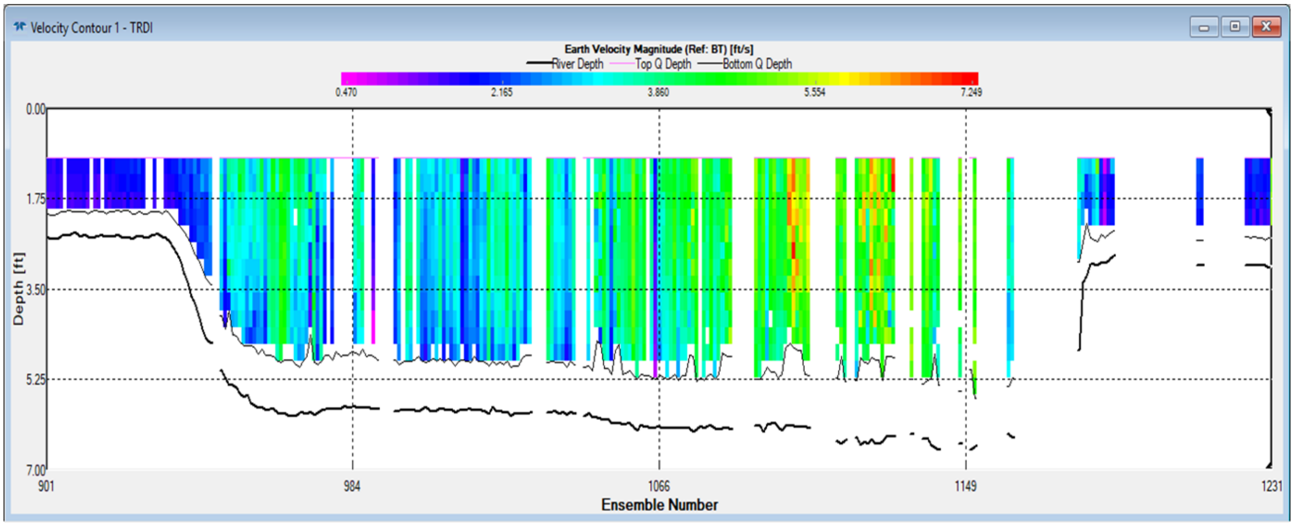
D. Transect J13.8-005 Raw Data Output

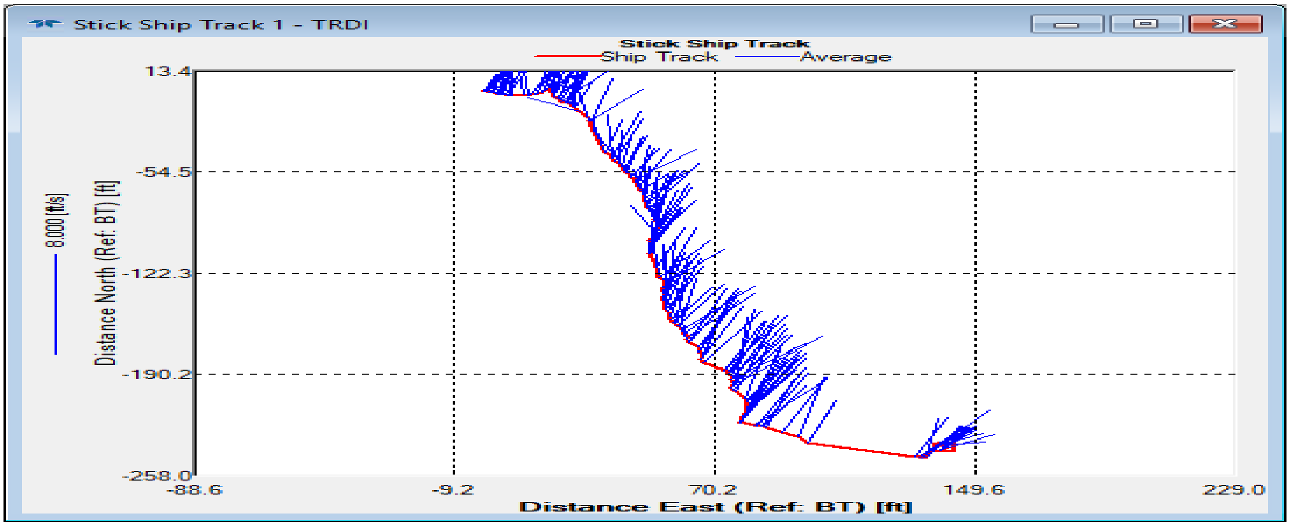


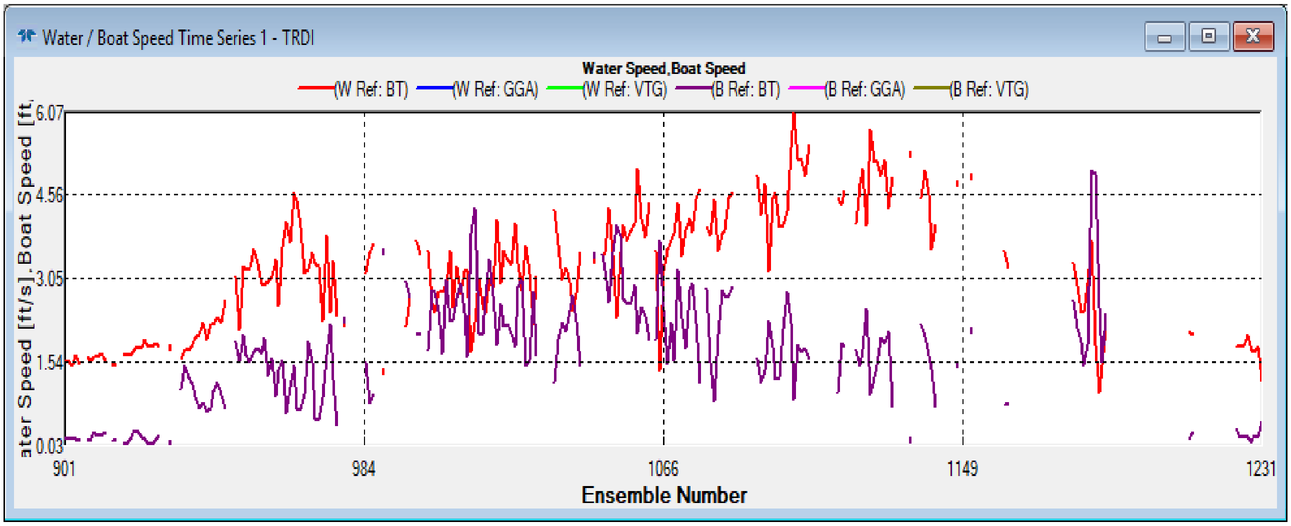




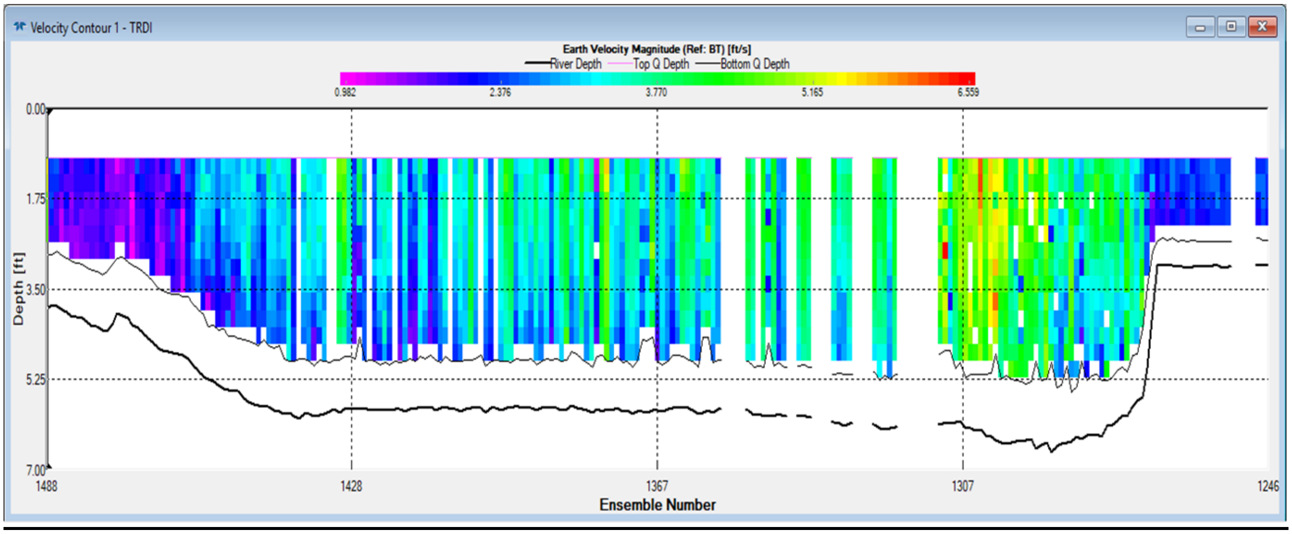
E. Transect J13.8-007 Raw Data Output

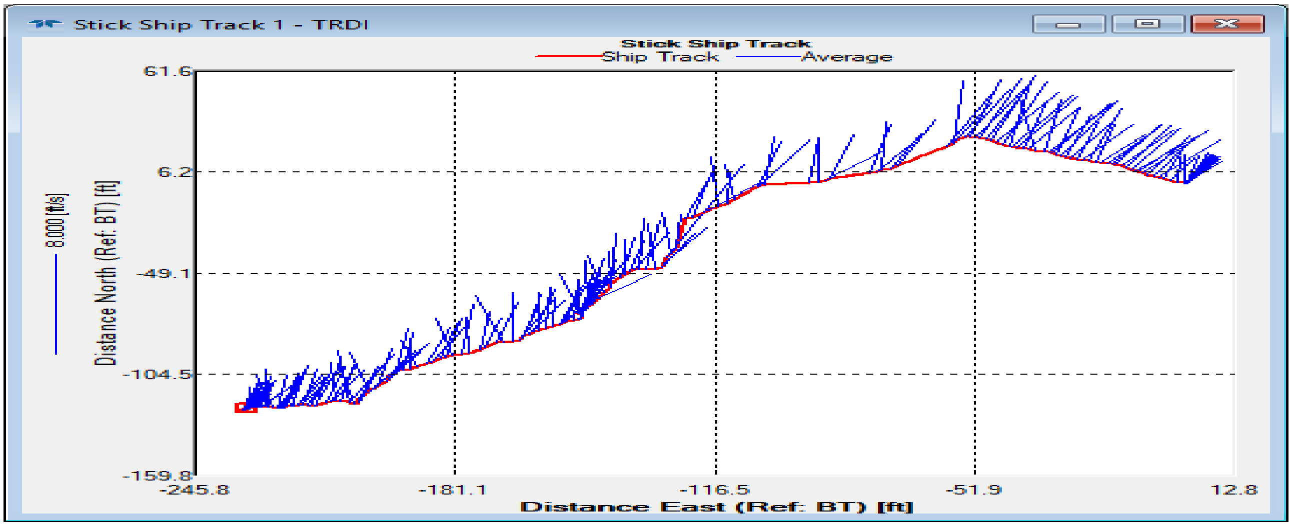


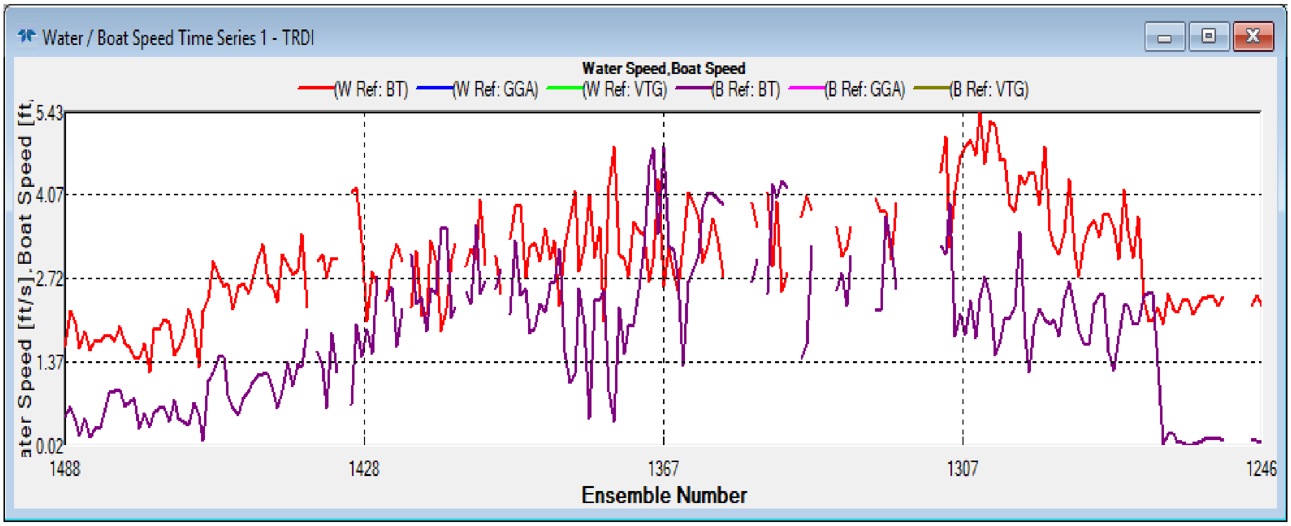




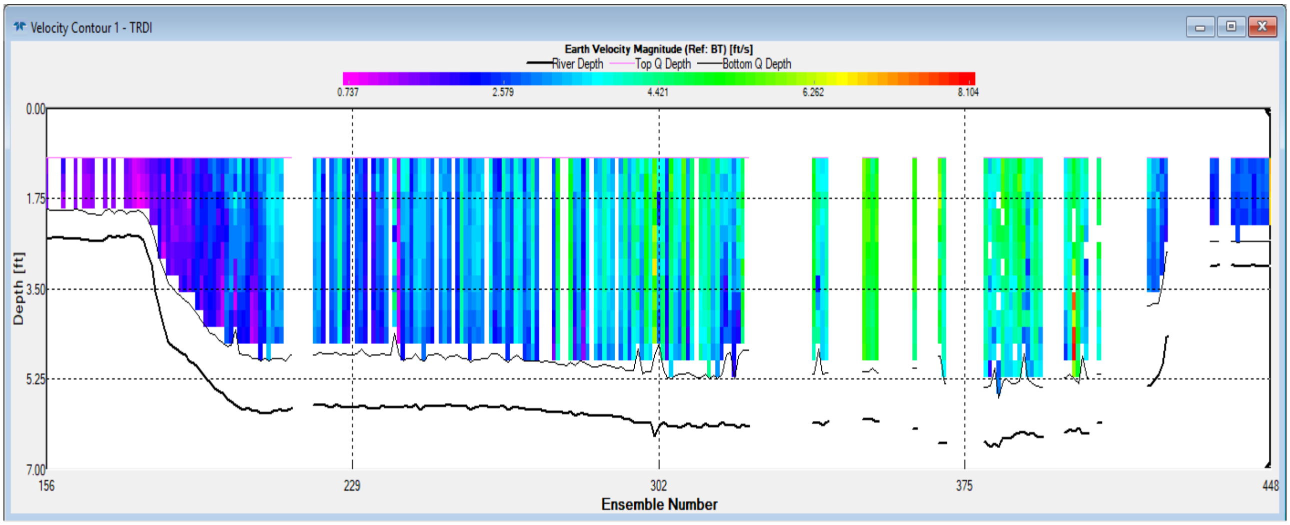
F. Transect J13.8-008 Raw Data Output

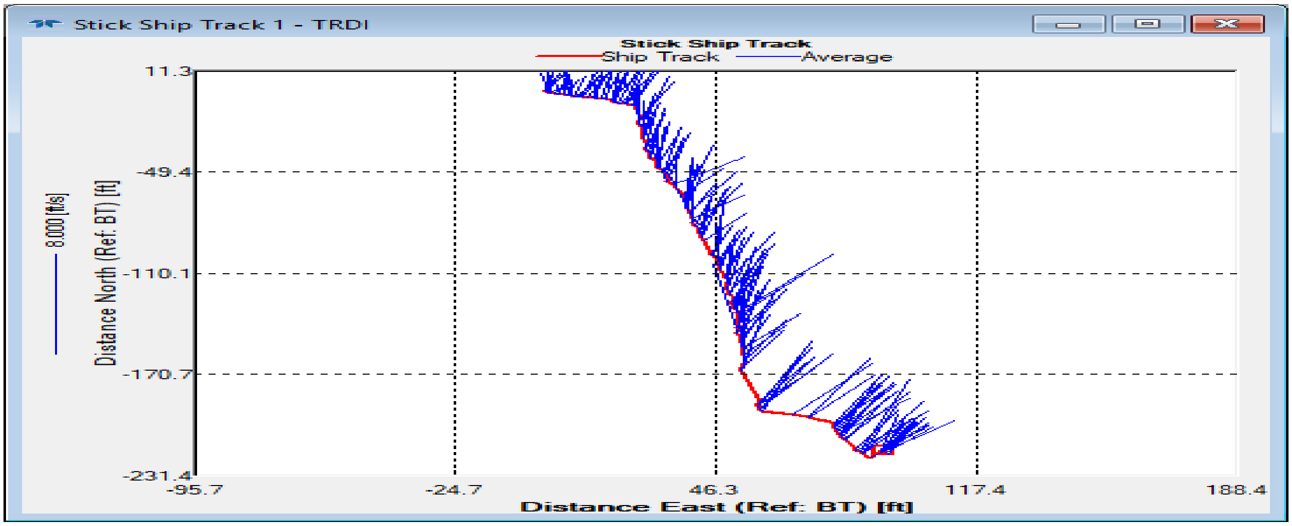


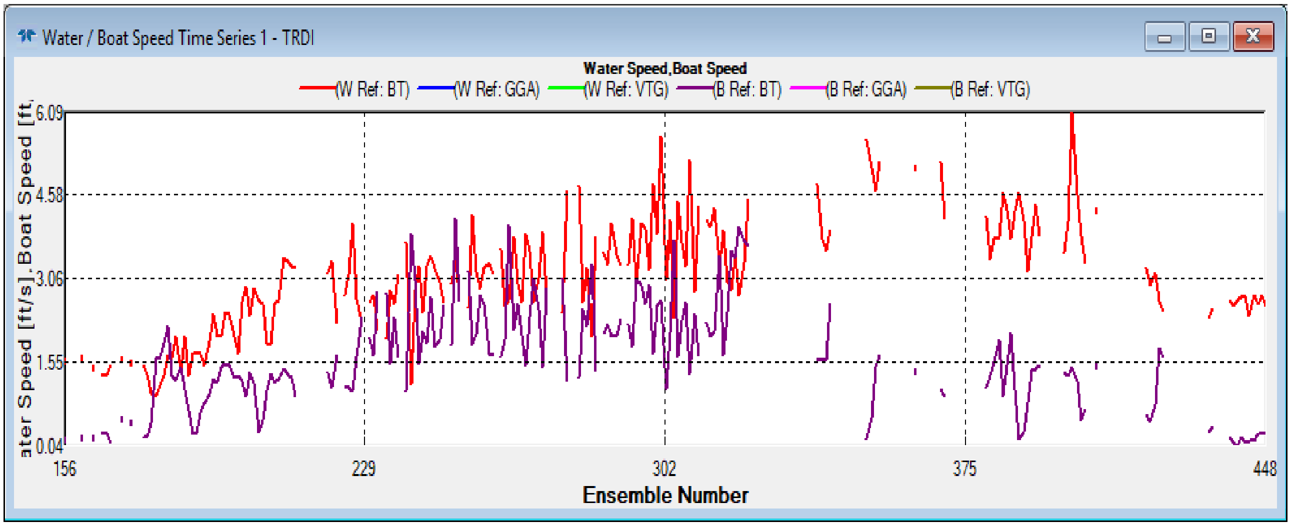




G. Transect J13.8-010 Raw Data Output







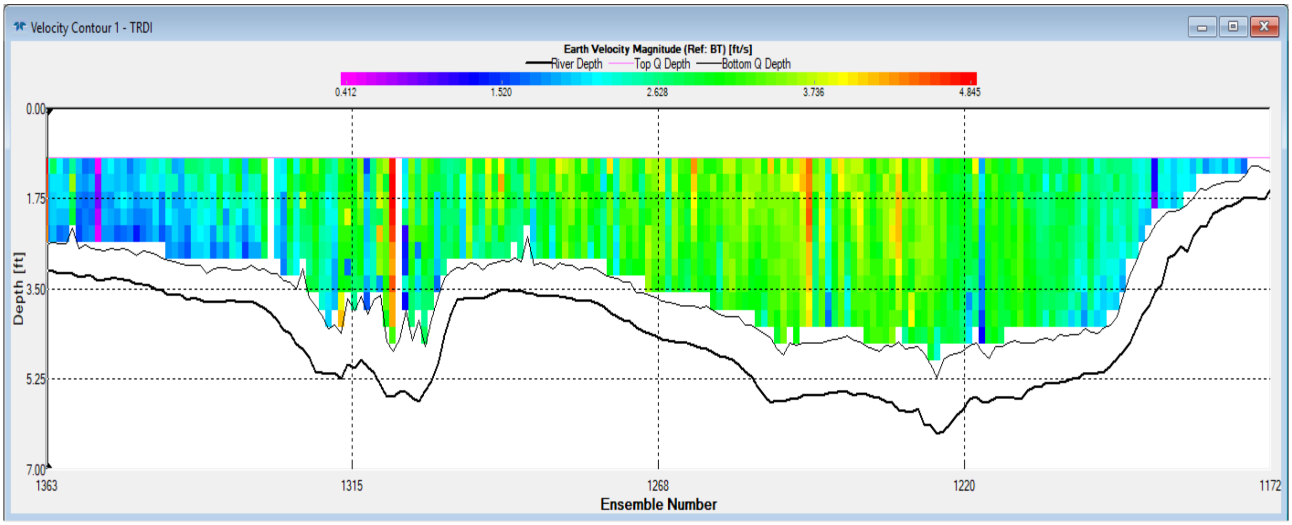
Spring Breakup Measured Discharge

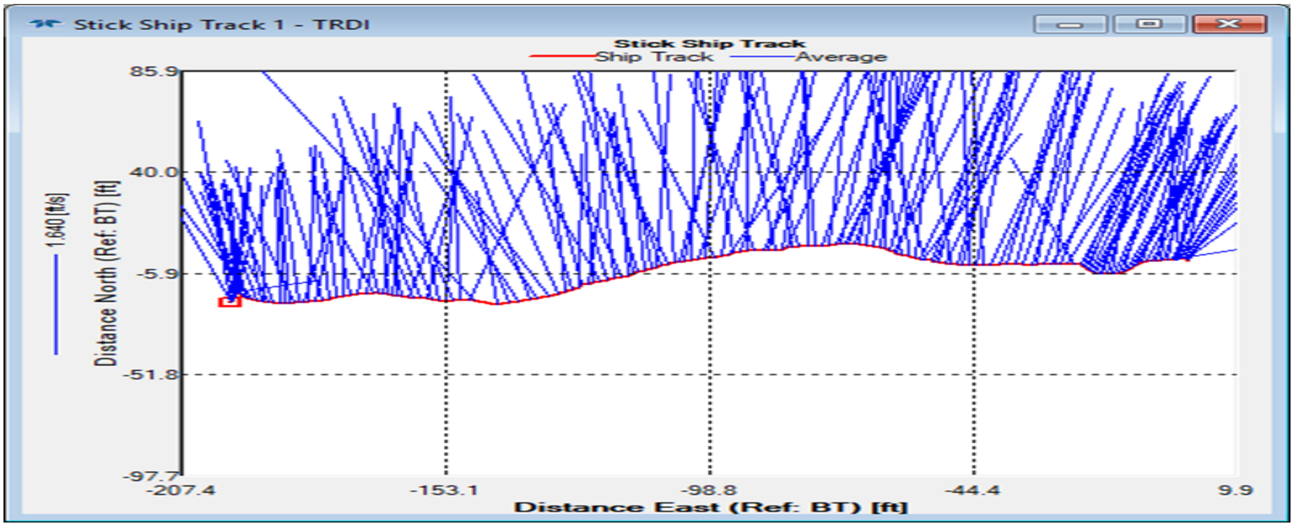
Location:	J13.8
Date & Time:	June 1, 2019 12:15 PM
Equipment:	RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.
Final Discharge (cfs):	2,900
Average Velocity (fps):	3.1
Measurement Rating:	Fair
Measurement Notes:	Moving bed conditions were identified and the discharge was corrected for moving bed using data acquired from the moving bed loop test performed before the six measured transects. Moving bed velocity estimated using the stationary moving bed test was 0.37 fps. The percentage of bad bottom track values (1.08%) was within the recommended maximum of 5%. At the time of the measurement, the river was mostly clear of snow and ice. Some snow remained along the both banks but were outside the channel and did not affect flow in the channel. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on the highly mobile bed detected at the time of measurements.

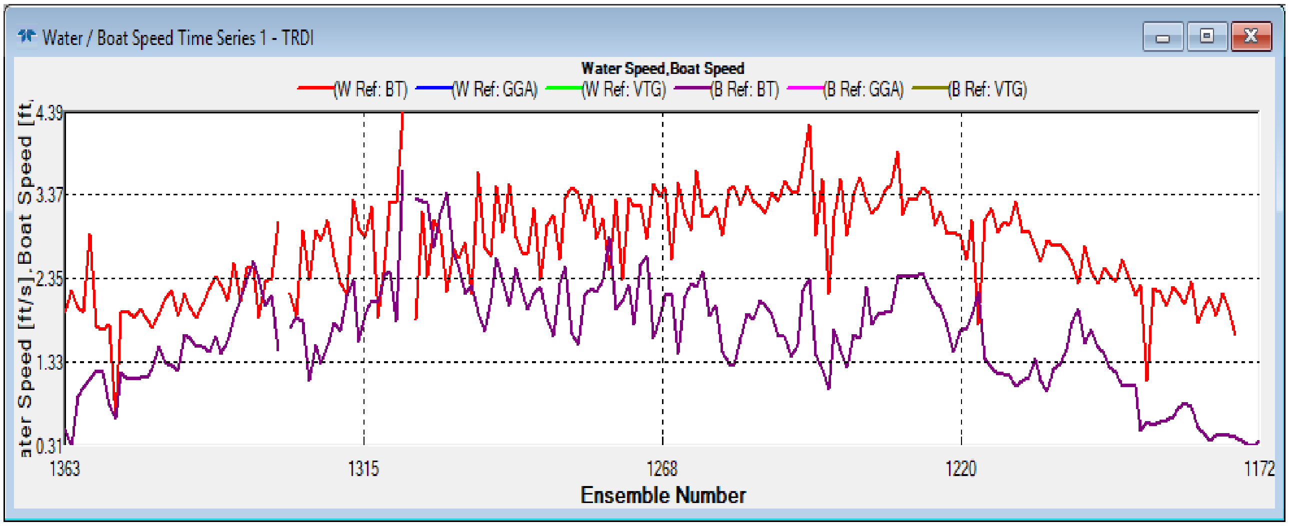
Table C.3: June 1 Spring Breakup Measured Discharge Summary

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)
001	Right	2991	-3.62%	1760	-3.85%	208	1060	942	3.18	2.82
002	Left	2942	1.90%	1742	2.80%	209	1072	936	3.14	2.74
003	Right	2812	-2.58%	1673	-1.27%	214	1051	954	2.95	2.68
004	Left	2957	2.44%	1722	1.61%	212	1073	941	3.14	2.76
005	Right	2770	-4.05%	1612	-4.86%	208	1020	908	3.05	2.72
006	Left	2848	-1.33%	1659	-2.13%	216	1035	925	3.08	2.75
Average		**2887**		**1695**		**211**		**934**	**3.09**	**2.74**

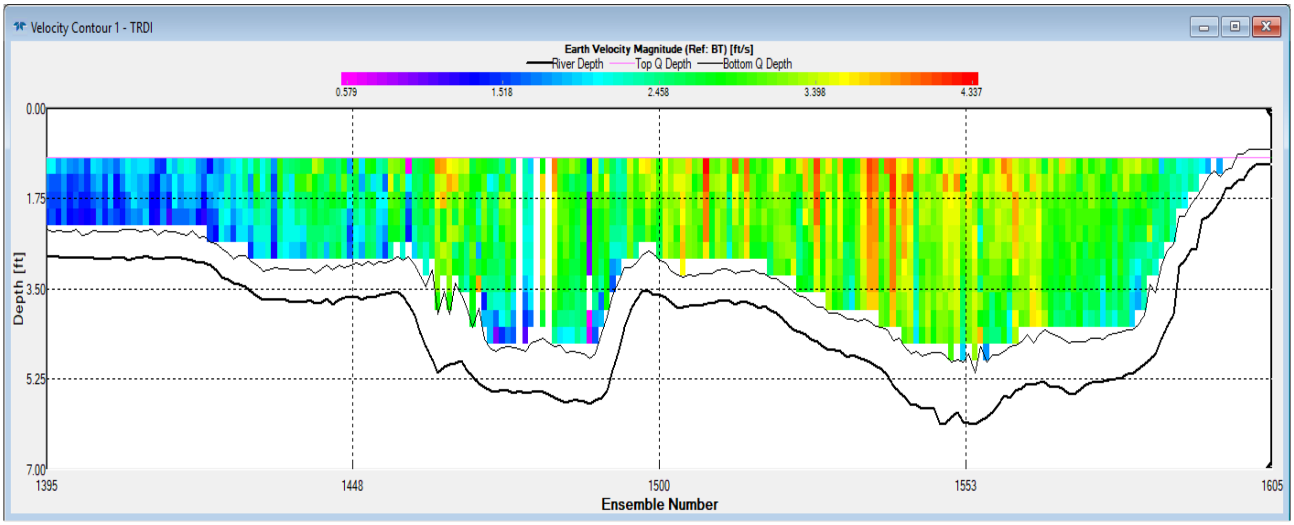
A. Transect J13.8-001 Raw Data Output

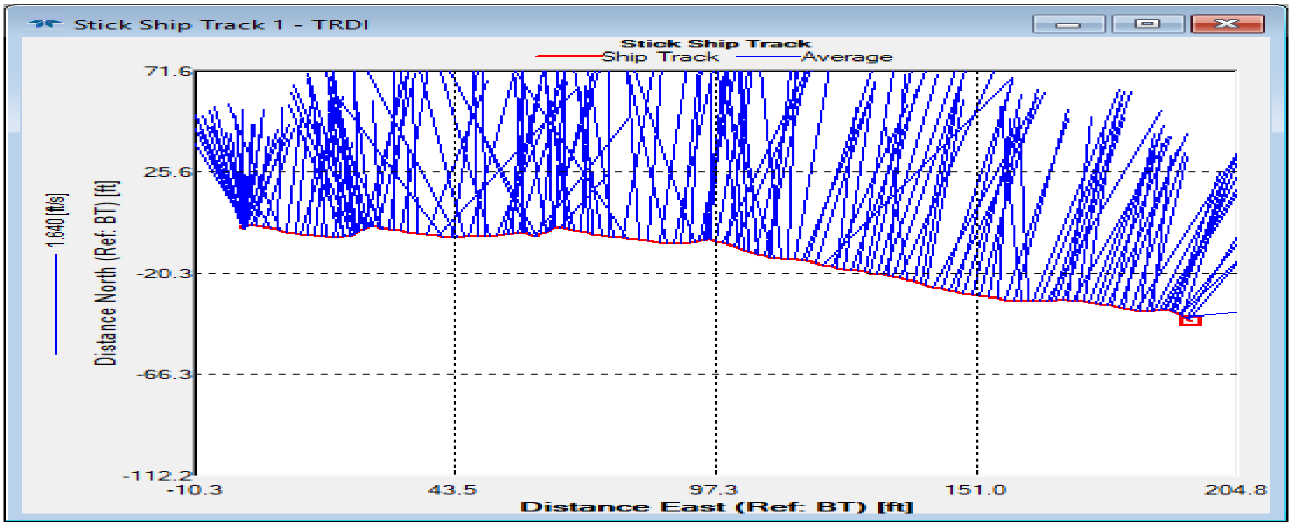


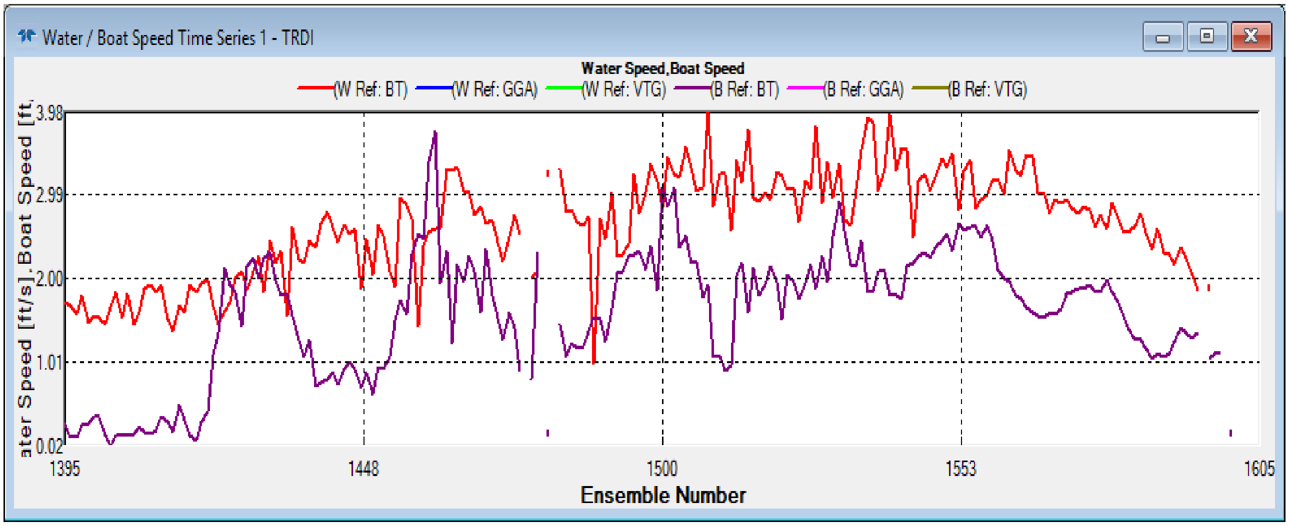




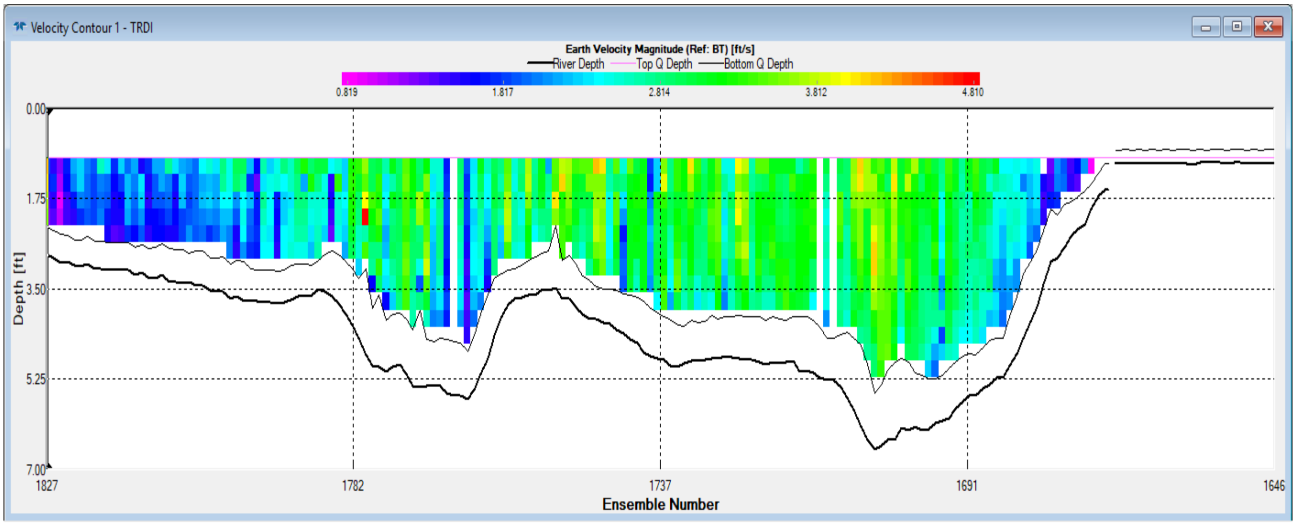
B. Transect J13.8-002 Raw Data Output

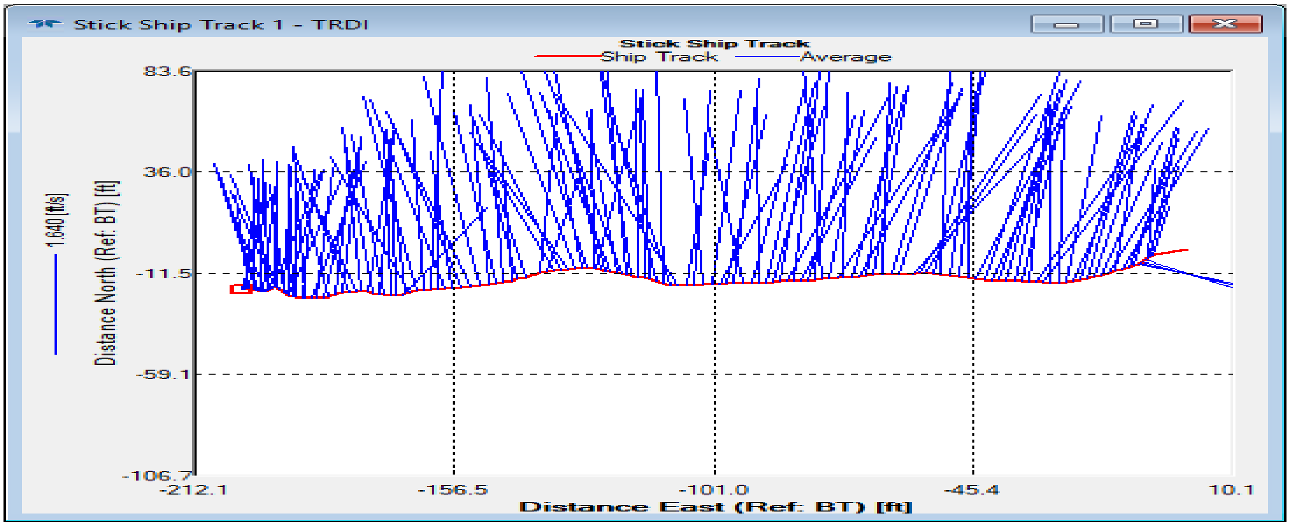


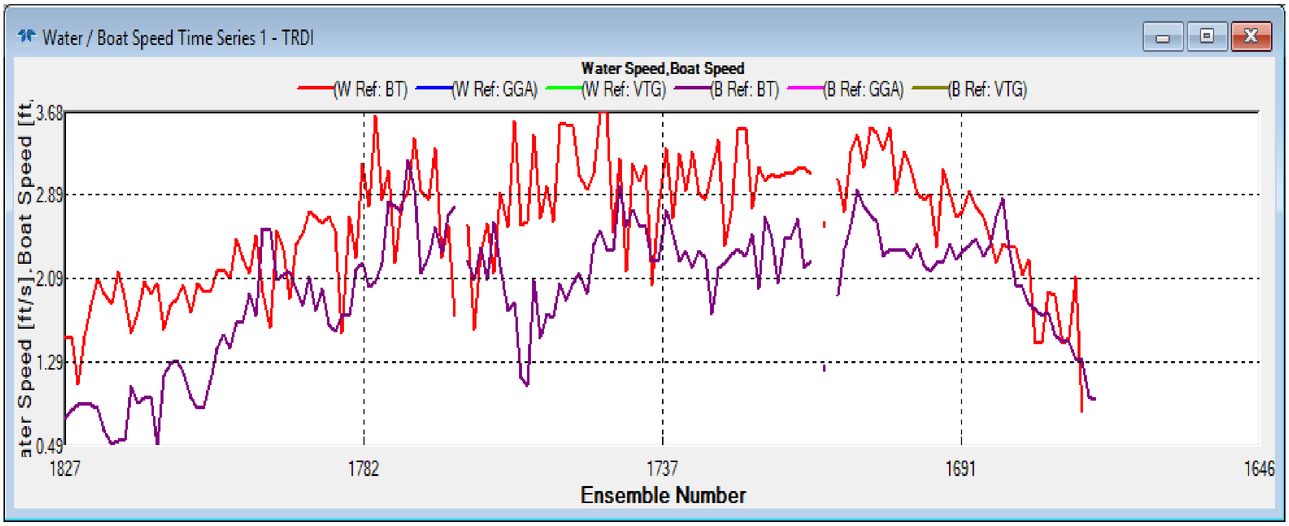




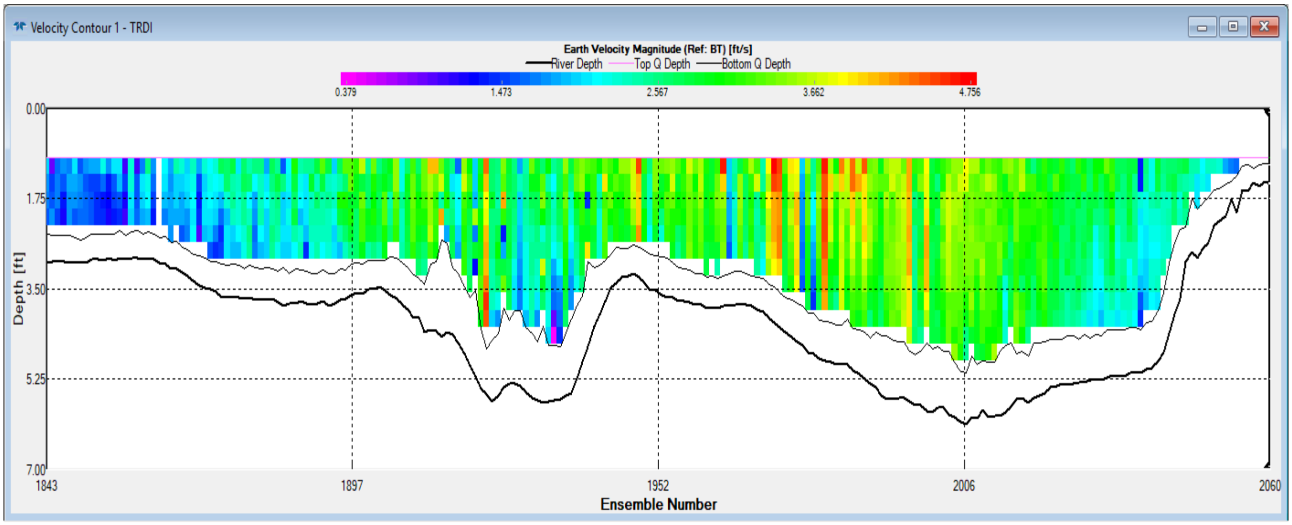
C. Transect J13.8-003 Raw Data Output

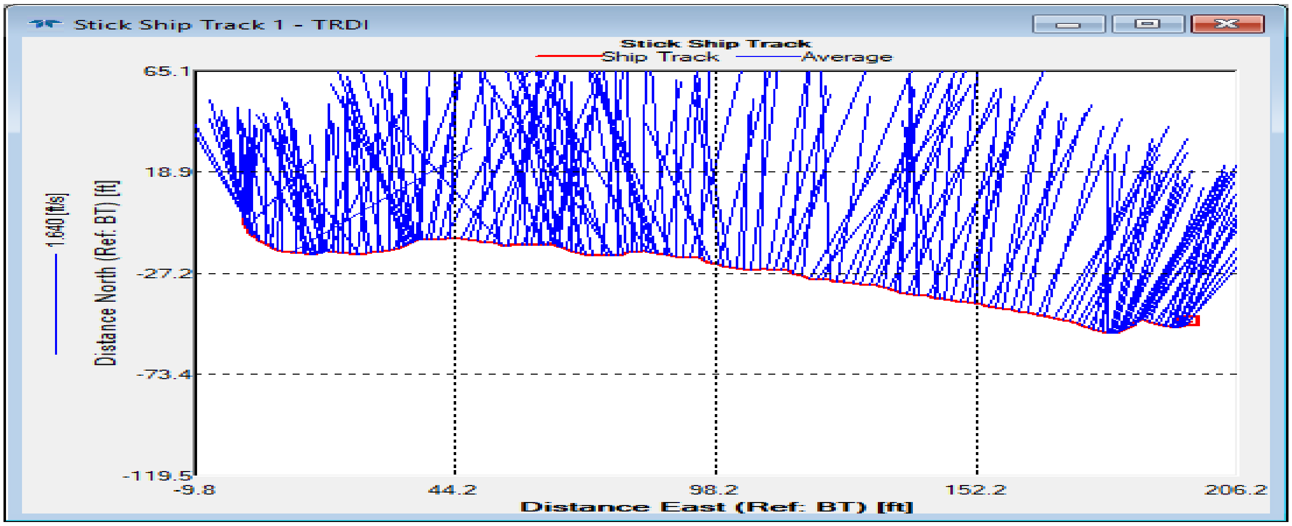


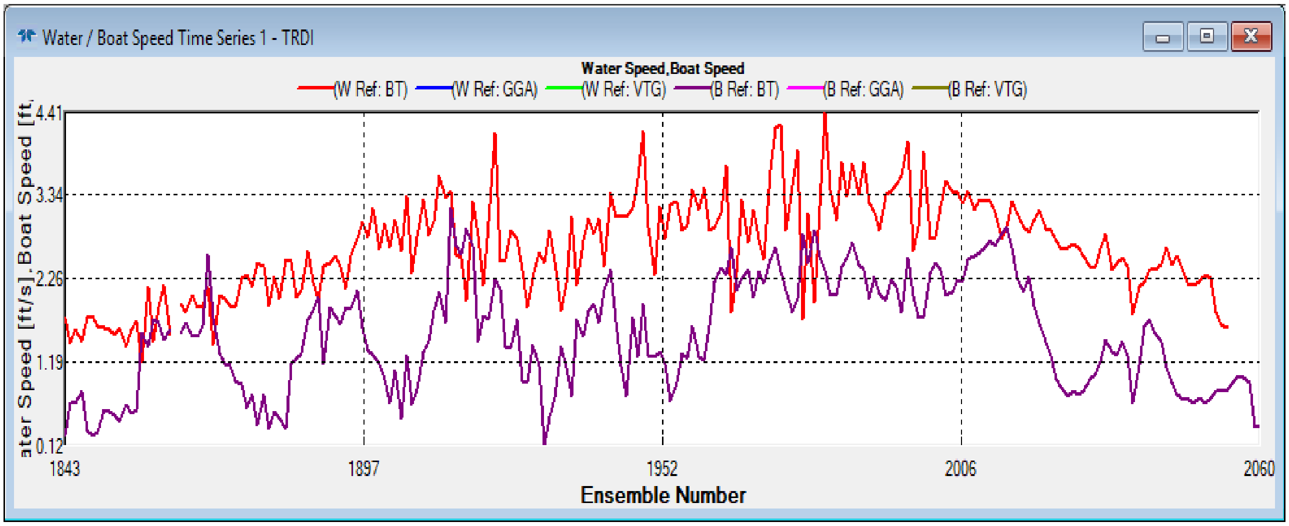




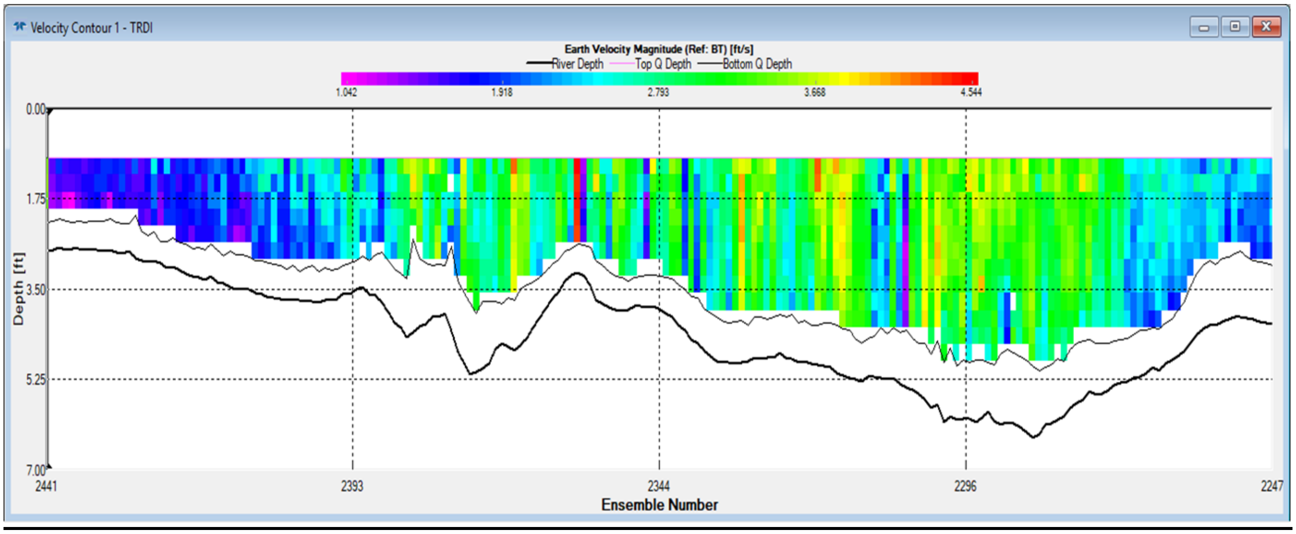
D. Transect J13.8-004 Raw Data Output

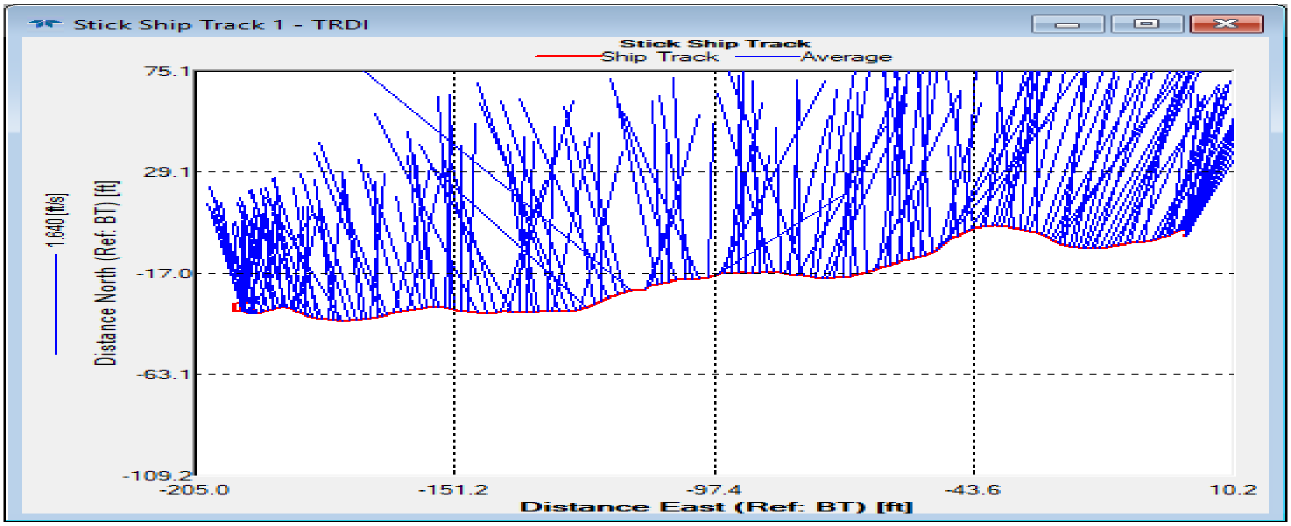


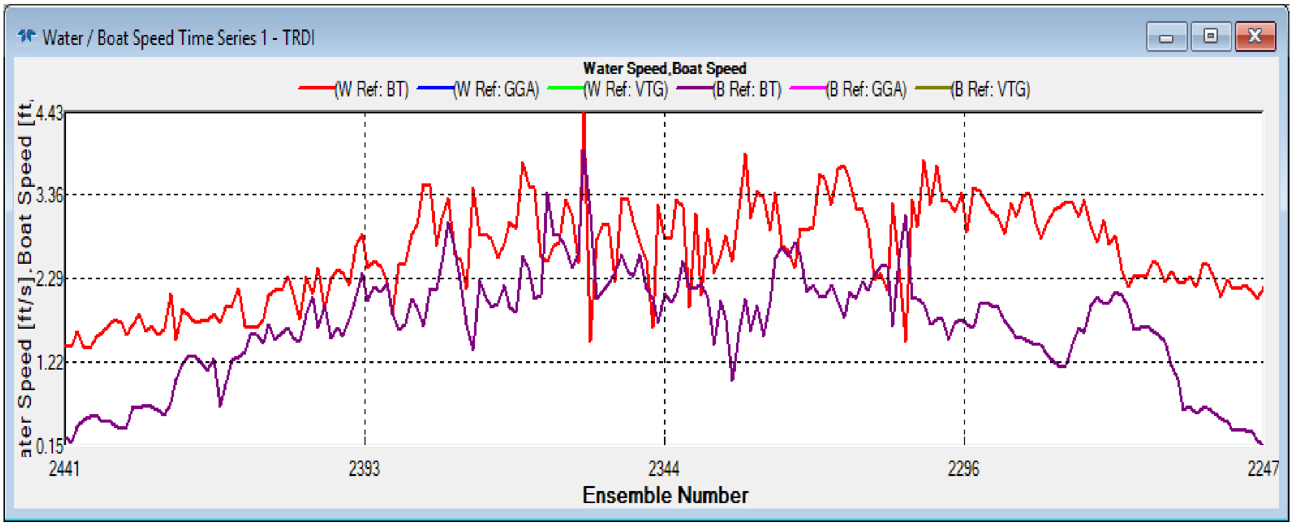




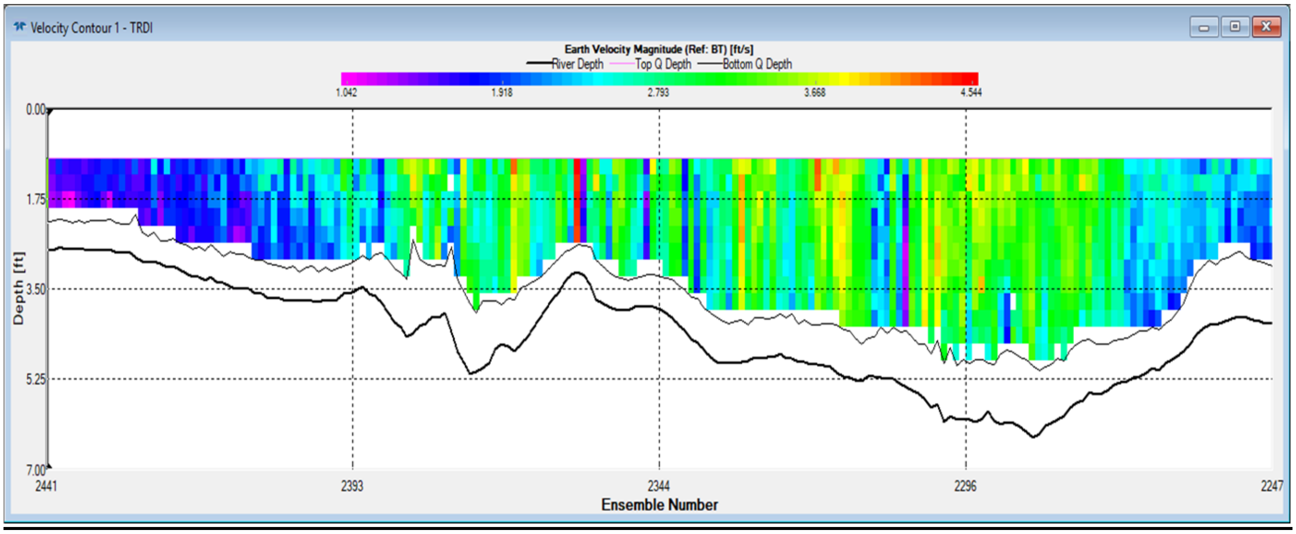
E. Transect J13.8-005 Raw Data Output

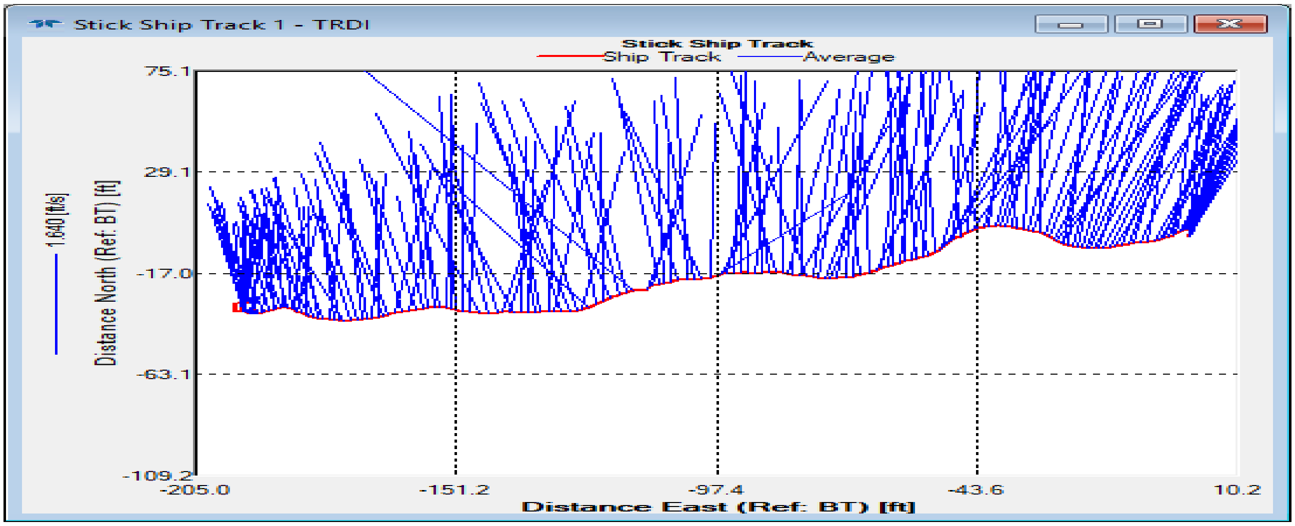


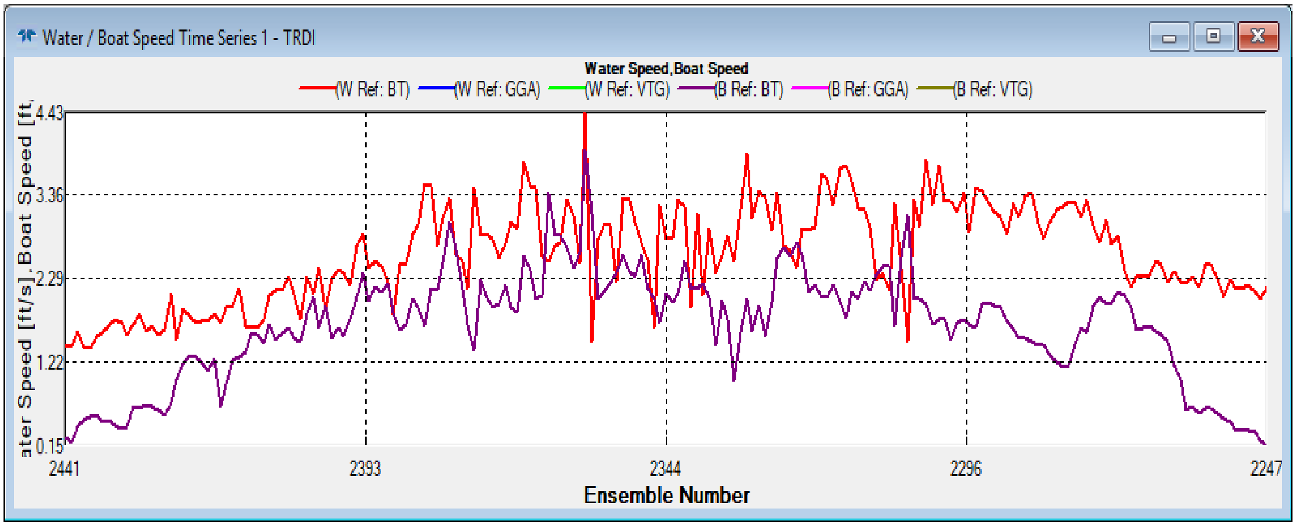




F. Transect J13.8-006 Raw Data Output







Spring Breakup Calculated Discharge

Discharge was calculated indirectly using the Normal Depth method. The cross-section was developed from the average of six cross-sections extracted from the J13.8 June 1, 2019 ADCP direct discharge measurement. The energy grade line was approximated by the average water surface slope between J13.8D and J13.8C. Stage at J13.8 was collected using PTs at the three gage locations (upstream, center, and down). Manning's n values were selected from reference documents (URS 2001) and calibrated to the measured discharge values. The calibrated Manning's n values used in the calculations were 0.035 for the left overbank, 0.022 for the main channel, and 0.035 for the right overbank.

ConocoPhillips
Alaska

Feet
0 600 1,200

Date:	10/18/2019	Project:	1 Inch = 600 Feet
Drawn:	JEG	File:	172339
Checked:	GCY	Scale:	PlanView_J13.8.mxd

● Station

→ Flow Direction

⊕ Gage Location

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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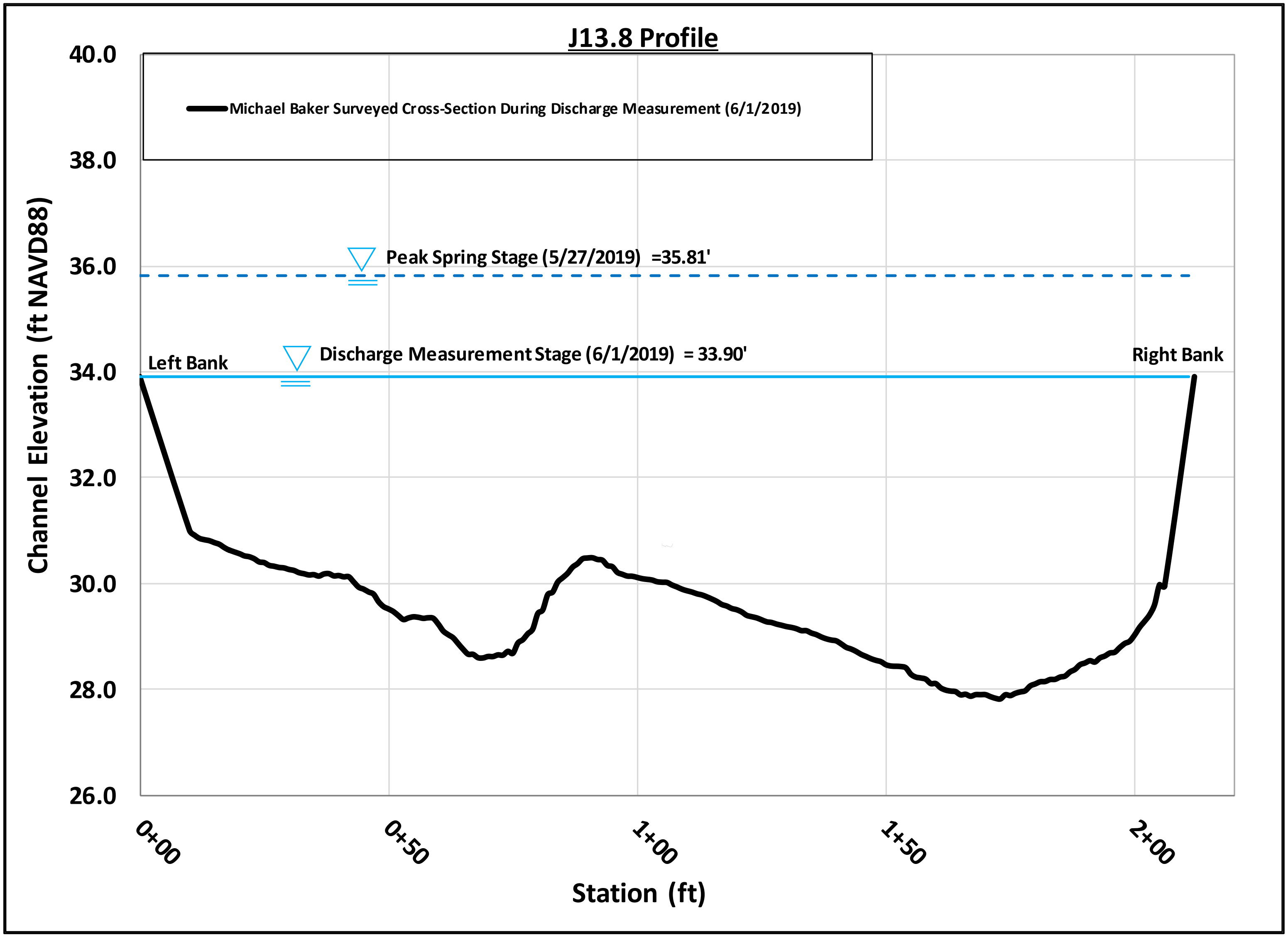
2019 Spring Breakup Judy Creek at J13.8 Plan

FIGURE C.2

Spring Breakup Cross-Section Profile



C.3 KALIKPIK RIVER AT KAL1

Spring Breakup Measured Discharge

Location: KAL1

Date & Time: May 30, 2019 12:00 PM

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

Final Discharge (cfs): 245

Average Velocity (fps): 1.5

Measurement Rating: Poor

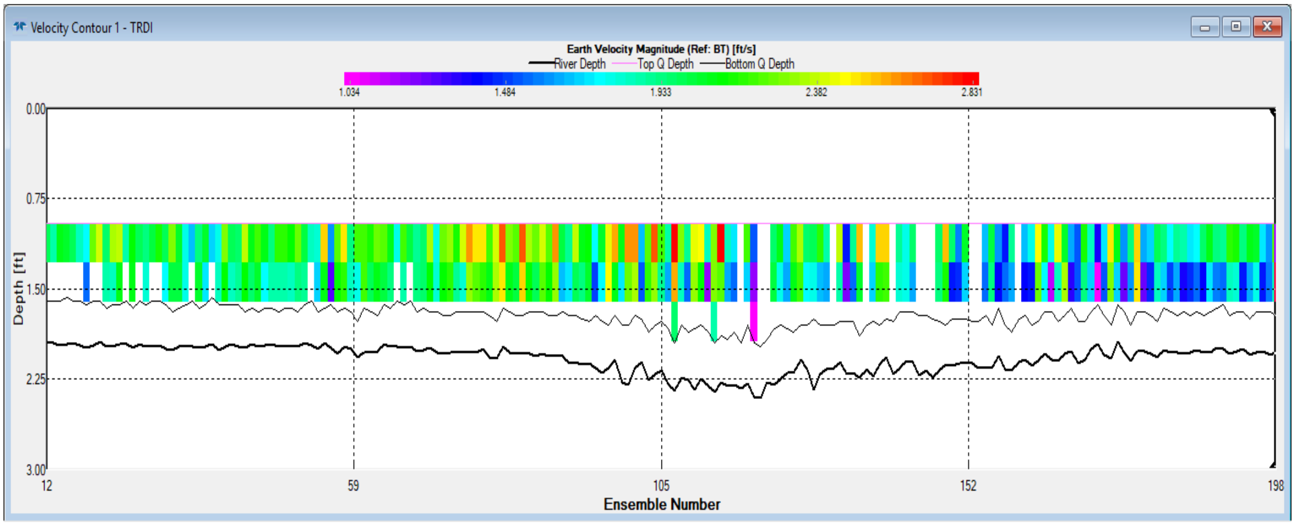
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (-0.72%) was within the recommended maximum of 5%.

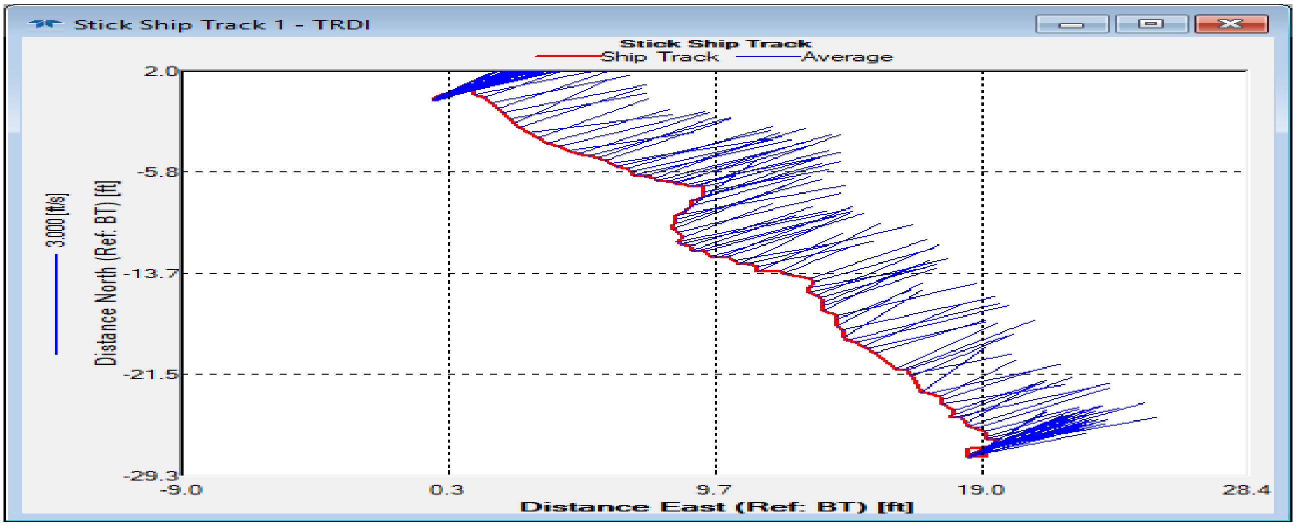
At the time of the measurement, stage was below bankfull and a small ice jam was present upstream of the measurement cross-section. Along the banks, large snowdrift remained and confined flow. Intermittent ice floes and some snow were observed during the measurement. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered poor based on the channel conditions at the time of measurement.

Table C.4: Kal1 May 30 Spring Breakup Measured Discharge Summary

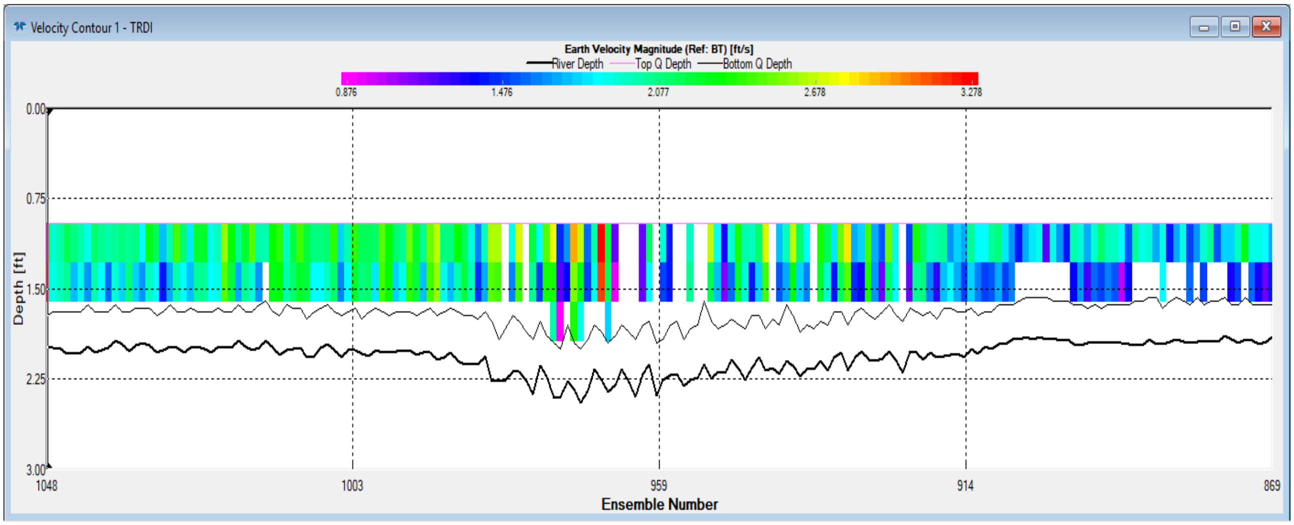
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
001	Left	261	5.97%	42	6.87%	129	134	167	1.55	1.95
004	Right	246	-0.34%	40	3.32%	130	130	164	1.50	1.89
005	Left	244	-0.90%	38	-2.67%	125	126	160	1.53	1.94
006	Right	242	-1.78%	37	-4.02%	127	127	162	1.49	1.90
007	Left	239	-2.95%	38	-3.50%	125	125	158	1.51	1.91
Average		**245**		**39**		**127**		**162**	**1.52**	**1.92**

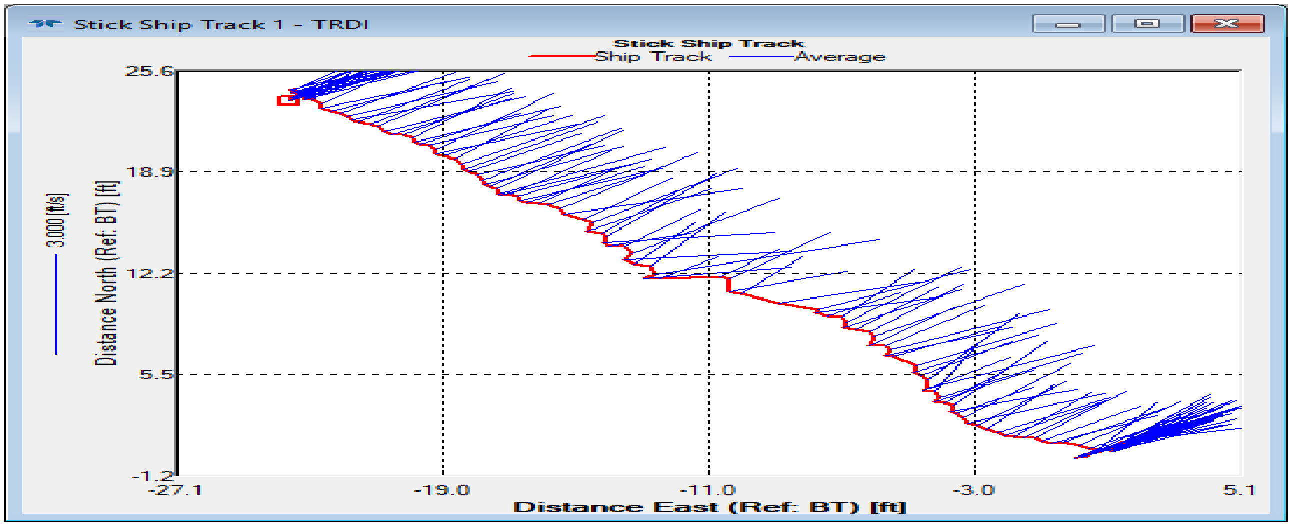
A. Transect KAL1-001 Raw Data Output

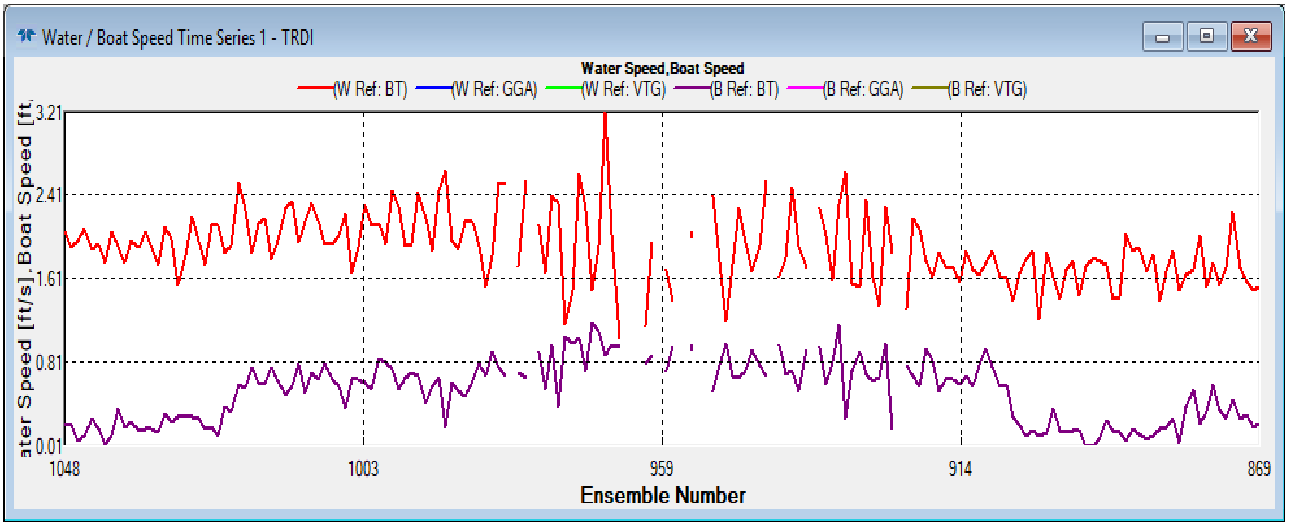




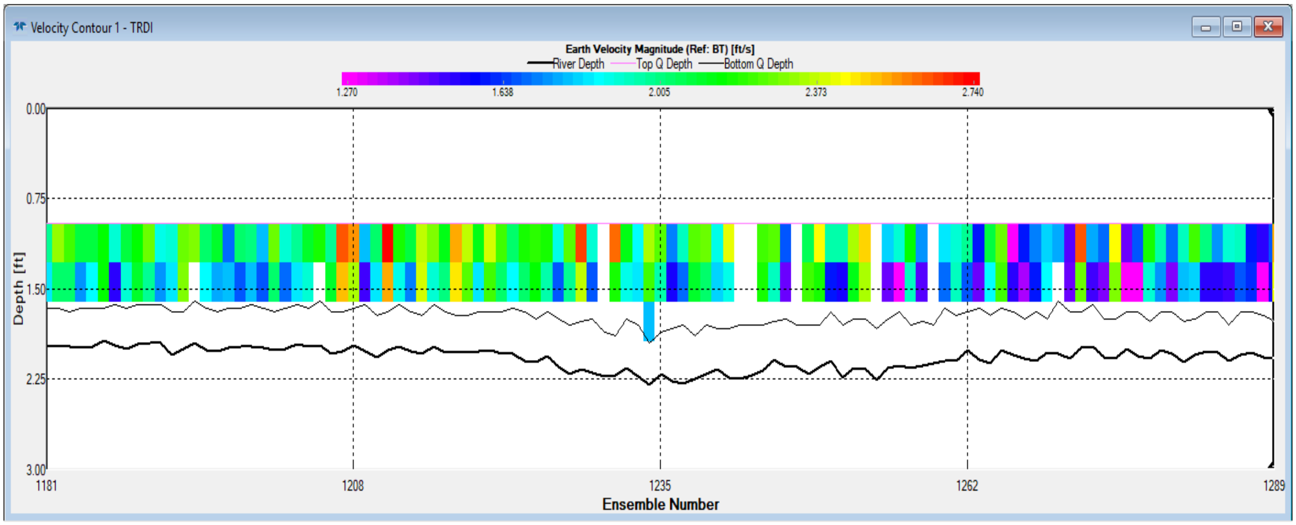
B. Transect KAL1-004 Raw Data Output

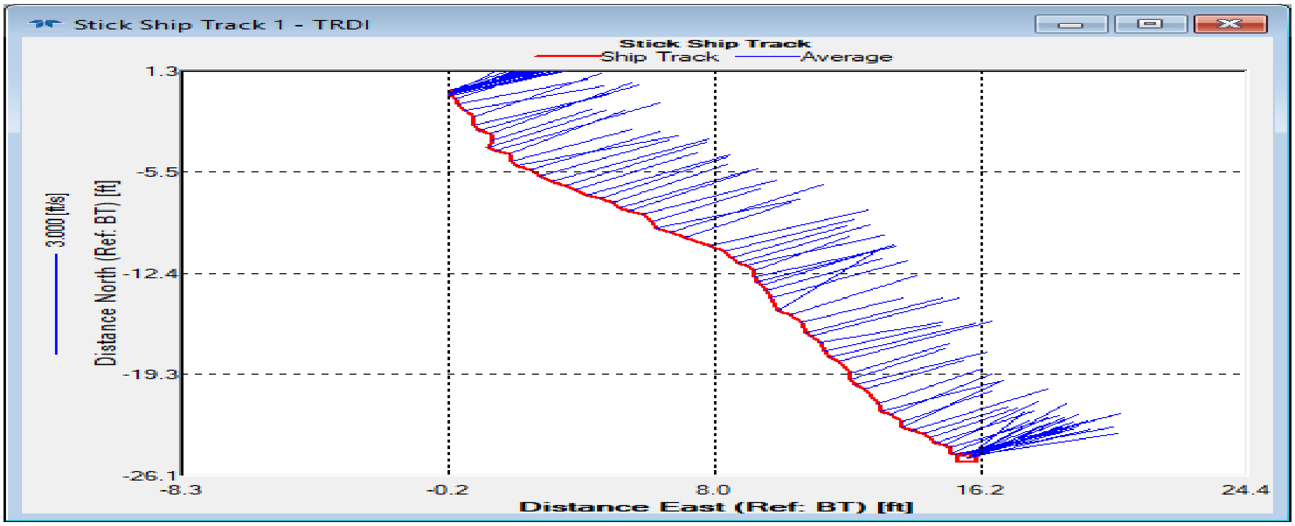


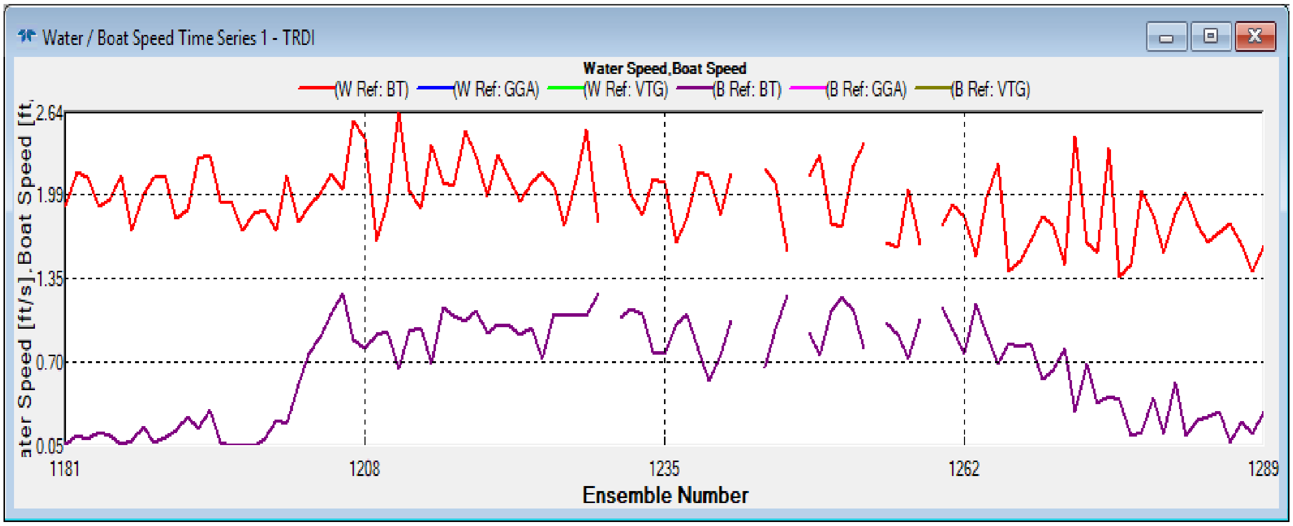




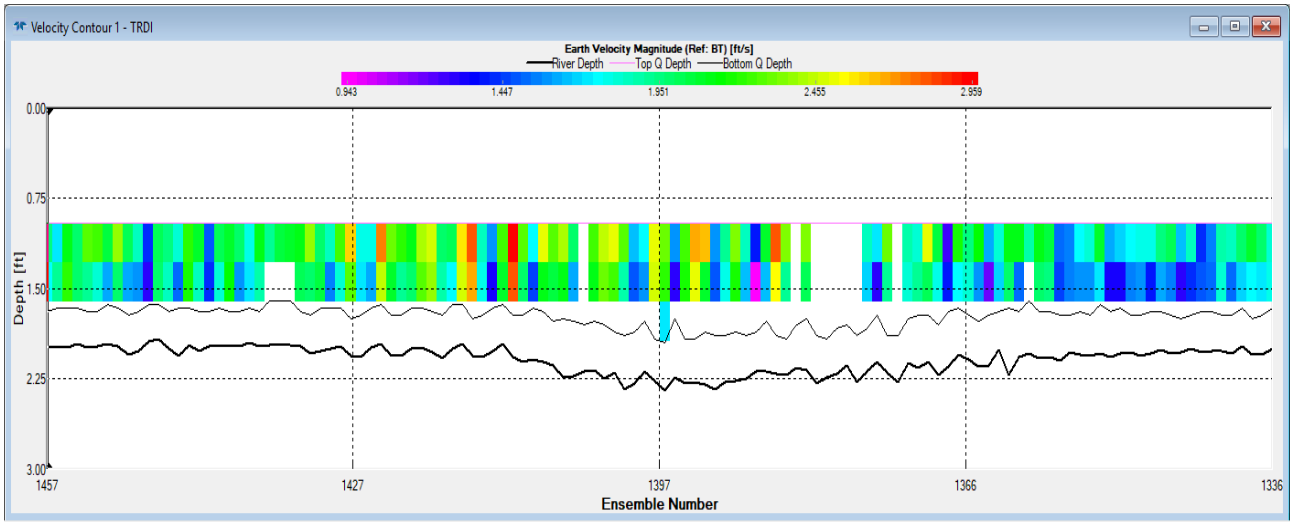
A. Transect KAL1-005 Raw Data Output

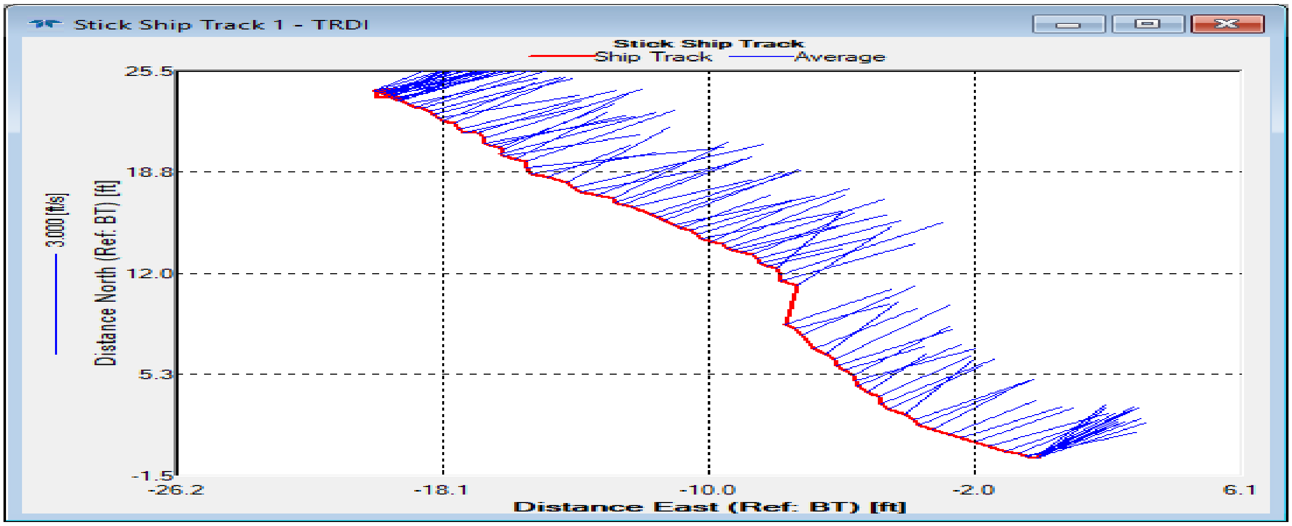


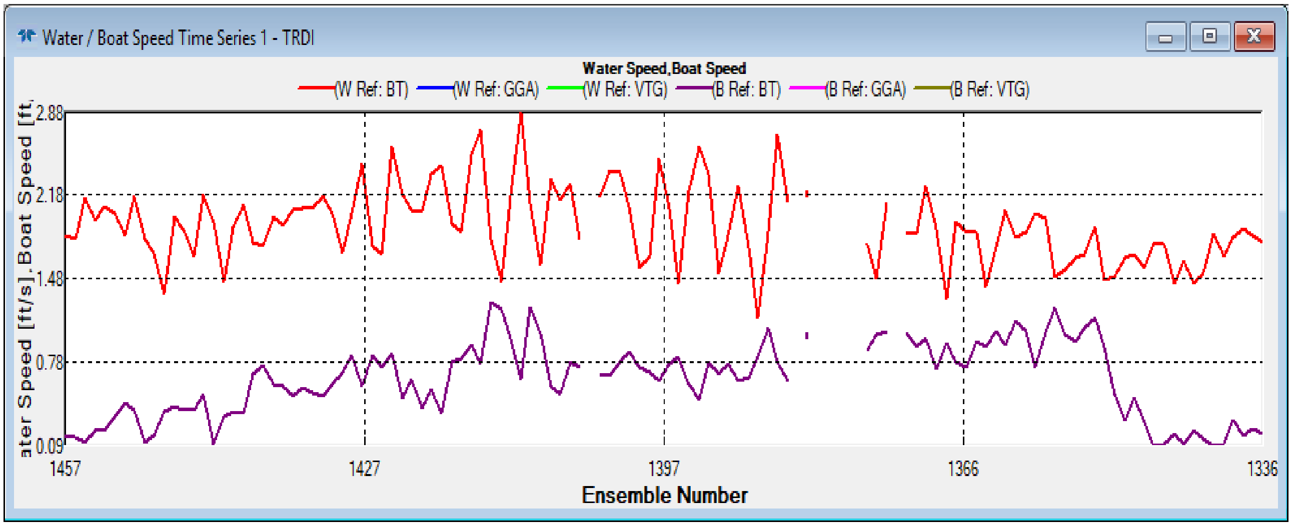




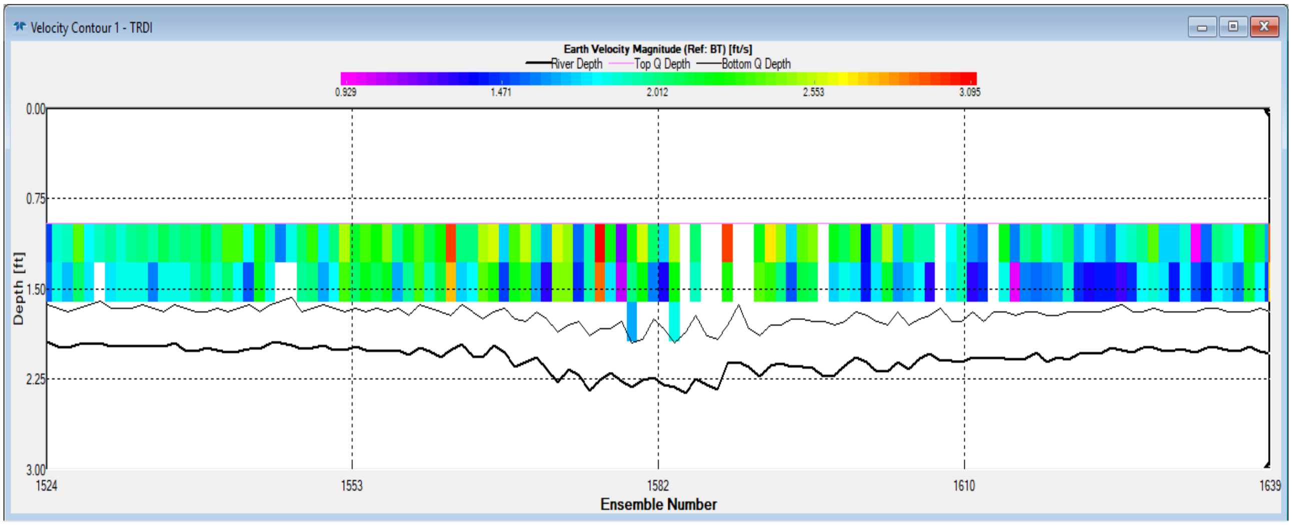
B. Transect KAL1-006 Raw Data Output

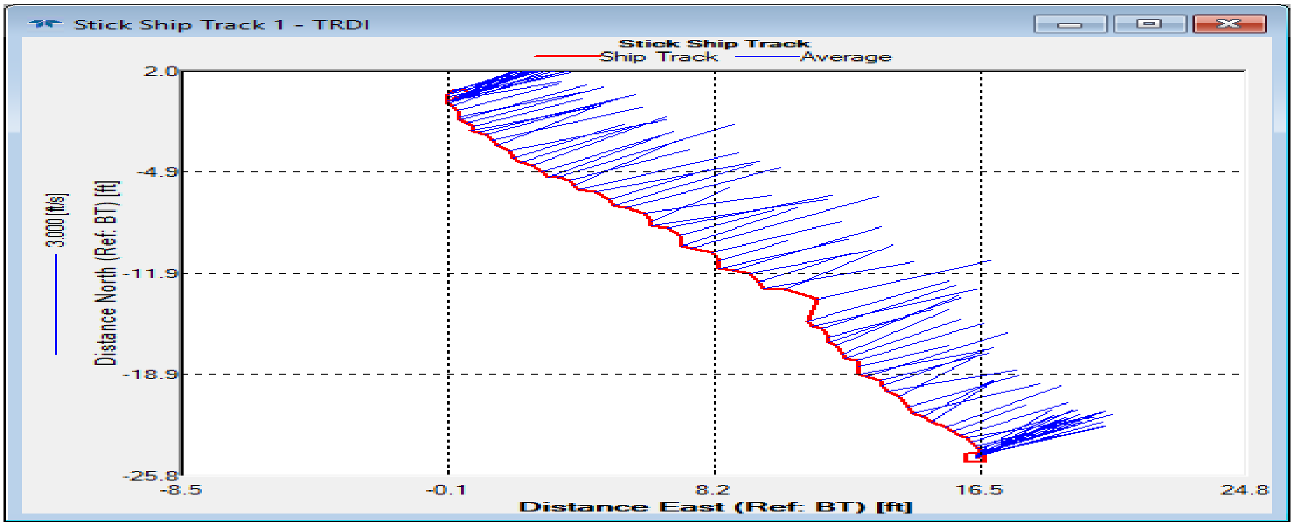


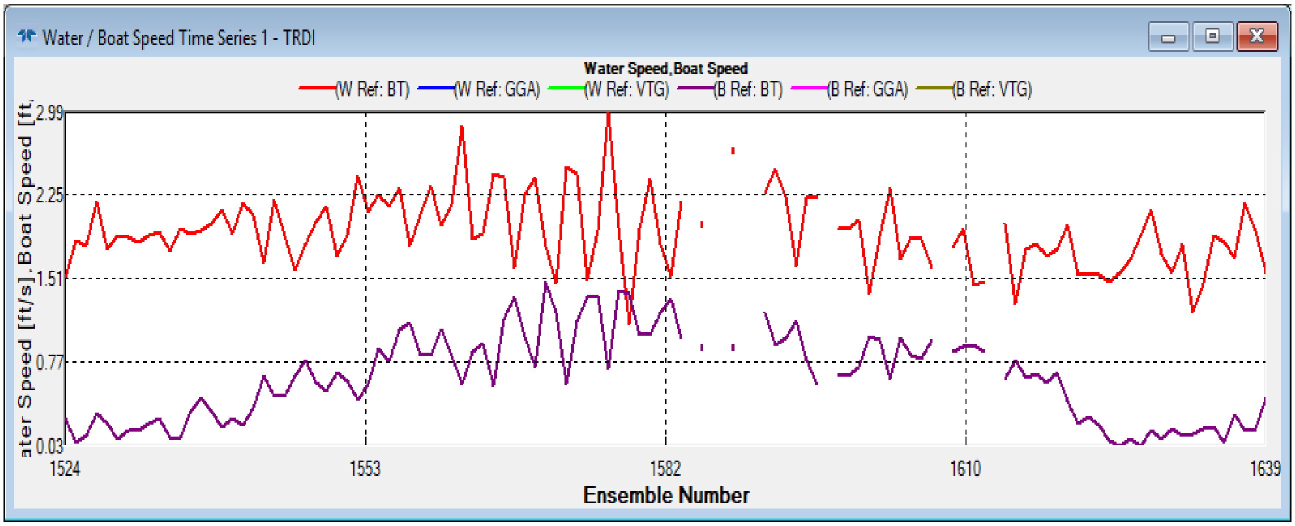




C. Transect KAL1-007 Raw Data Output







ConocoPhillips
Alaska

0 200 400 600 800 Feet

Date:	10/19/2019	Scale:	1 Inch = 400 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_Kal1.mxd

- ⊕ Gage Location
- → Flow Direction
- ● Station
- — Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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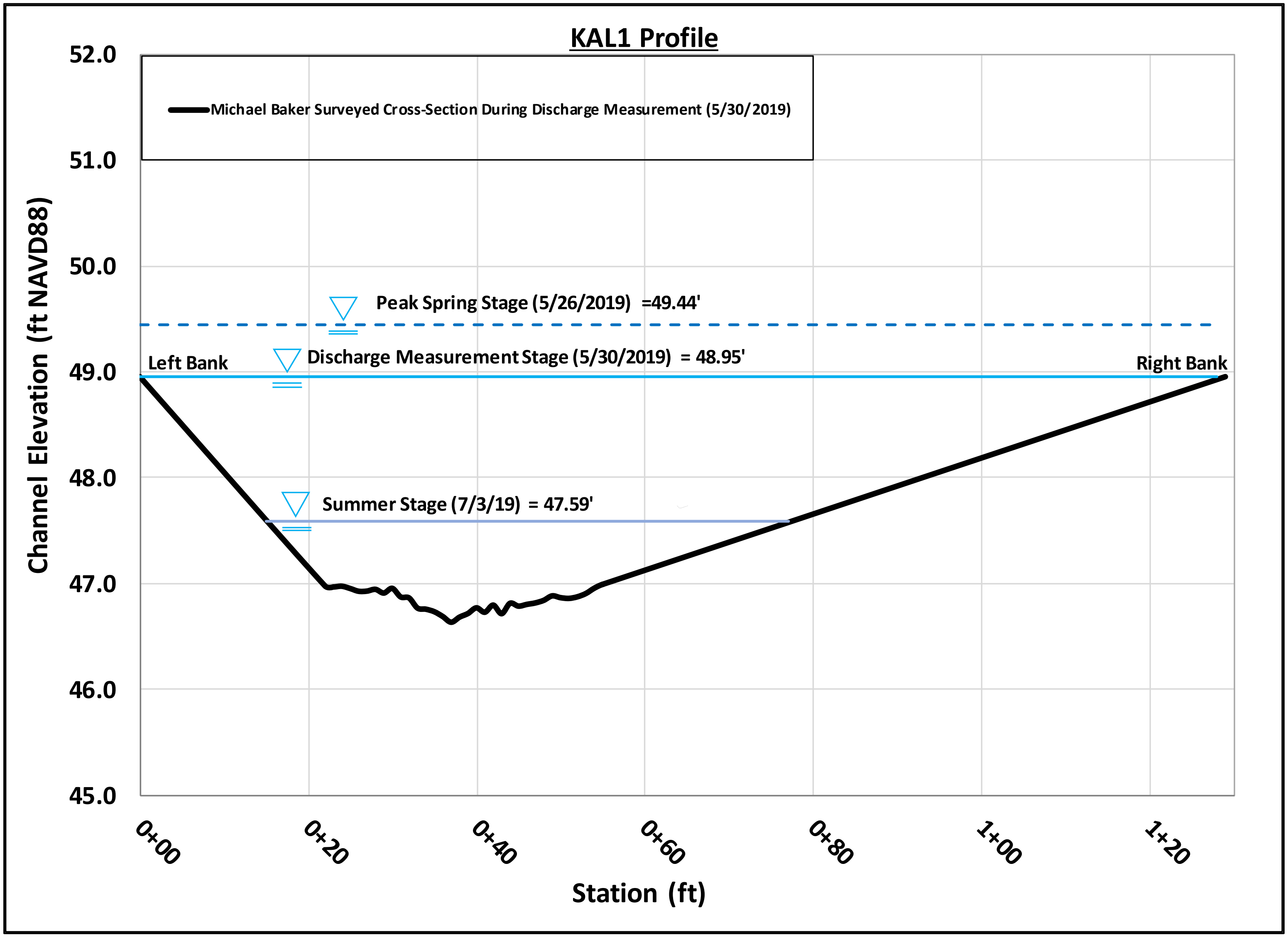
Fax: (907) 273-1699

2019 Spring Breakup Kalikpik River at Kal1 Plan

FIGURE C.3

Spring Breakup Cross-Section Profile



C.4 TBD_5

Spring Breakup Measured Discharge

Location: TBD_5

Date & Time: June 2, 2019 12:00 PM

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

Final Discharge (cfs): 135

Average Velocity (fps): 2.3

Measurement Rating: Fair

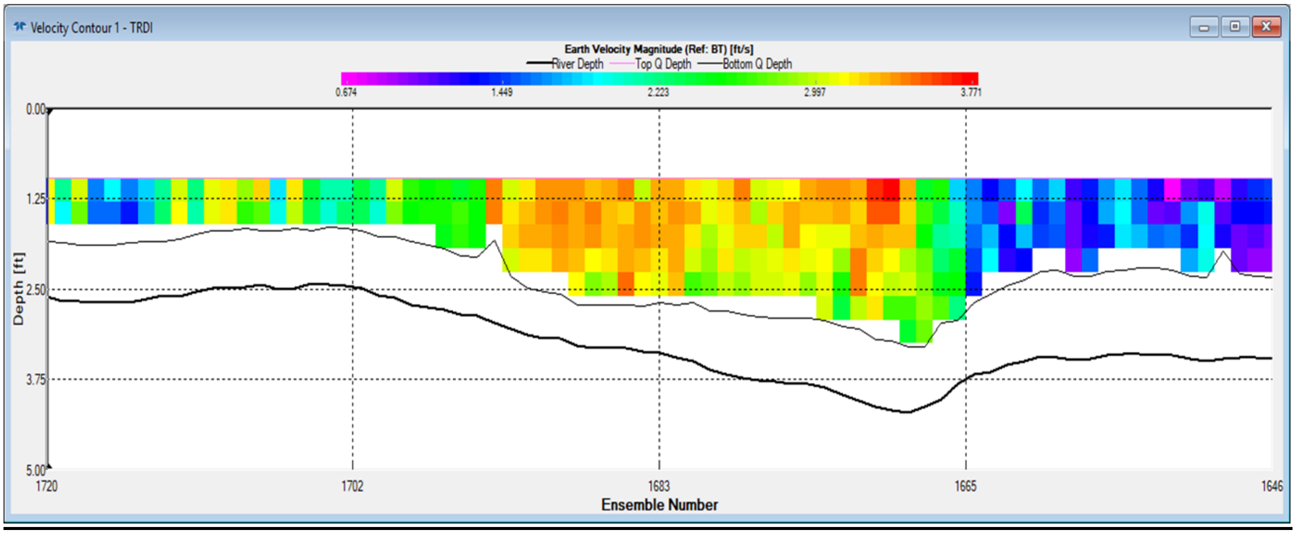
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.92%) was within the recommended maximum of 5%.

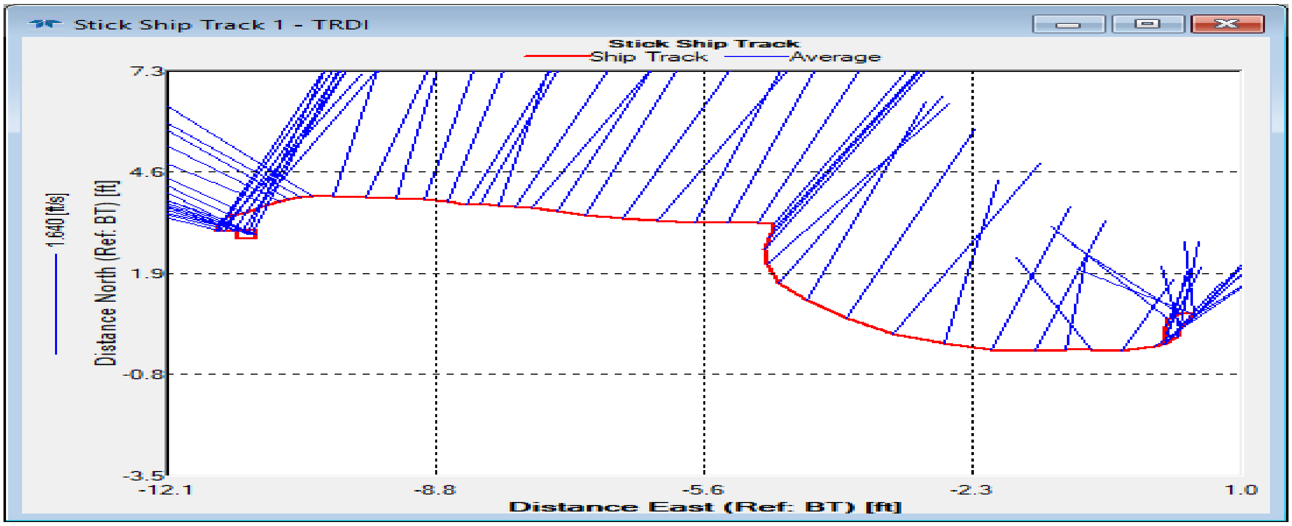
At the time of the measurement, bottom-fast ice was noted, and saturated snow remained along each bank. Minor overbank flooding was observed downstream of the discharge cross-section. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered go based on the fair based on the conditions at the time of the measurement.

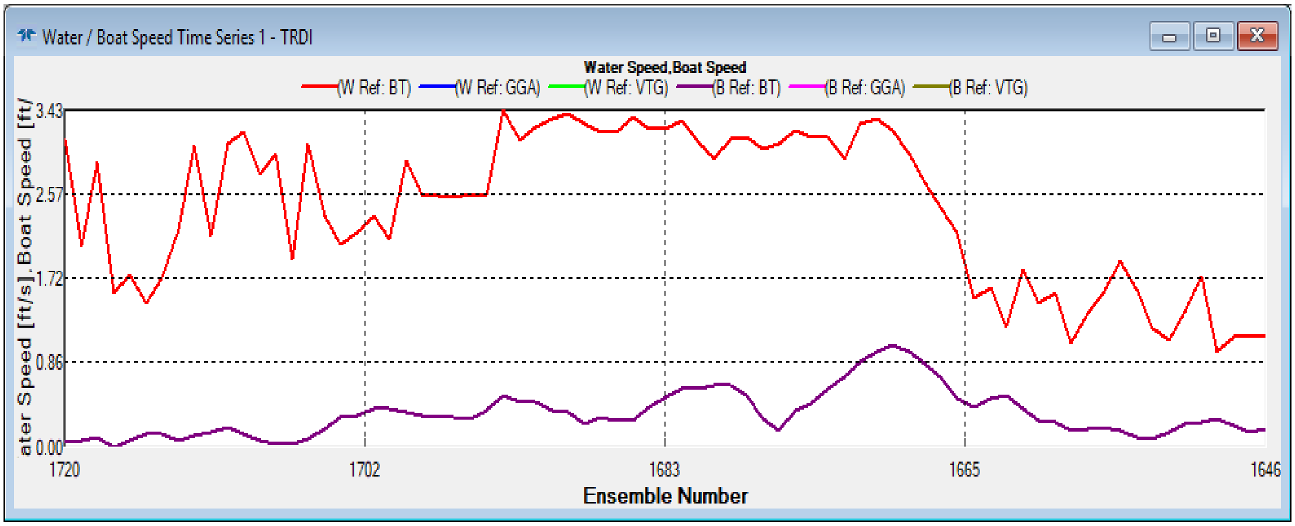
Table C.5: TBD_5 June 2 Spring Breakup Measured Discharge Summary

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)
001	Right	137	2.59%	57	2.08%	22	59	58	2.37	2.34
002	Left	136	2.14%	58	2.68%	22	56	59	2.32	2.41
003	Right	132	-1.21%	55	-2.05%	22	59	58	2.27	2.24
004	Left	129	-3.52%	55	-2.71%	21	55	56	2.28	2.35
Average		**133**		**56**		**22**		**58**	**2.31**	**2.33**

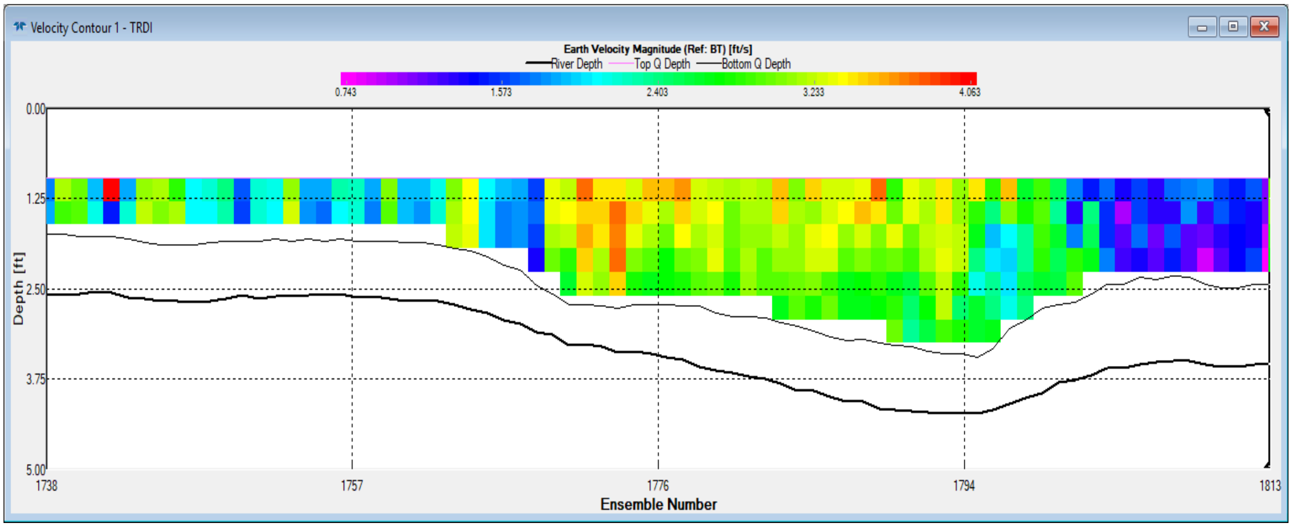
A. Transect TBD5-001 Raw Data Output

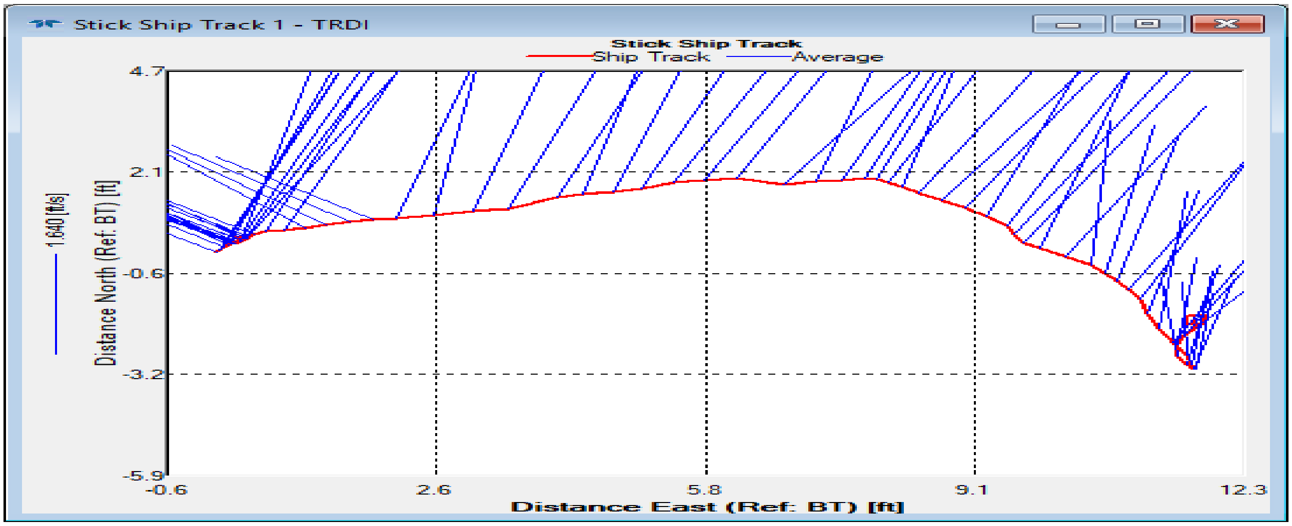


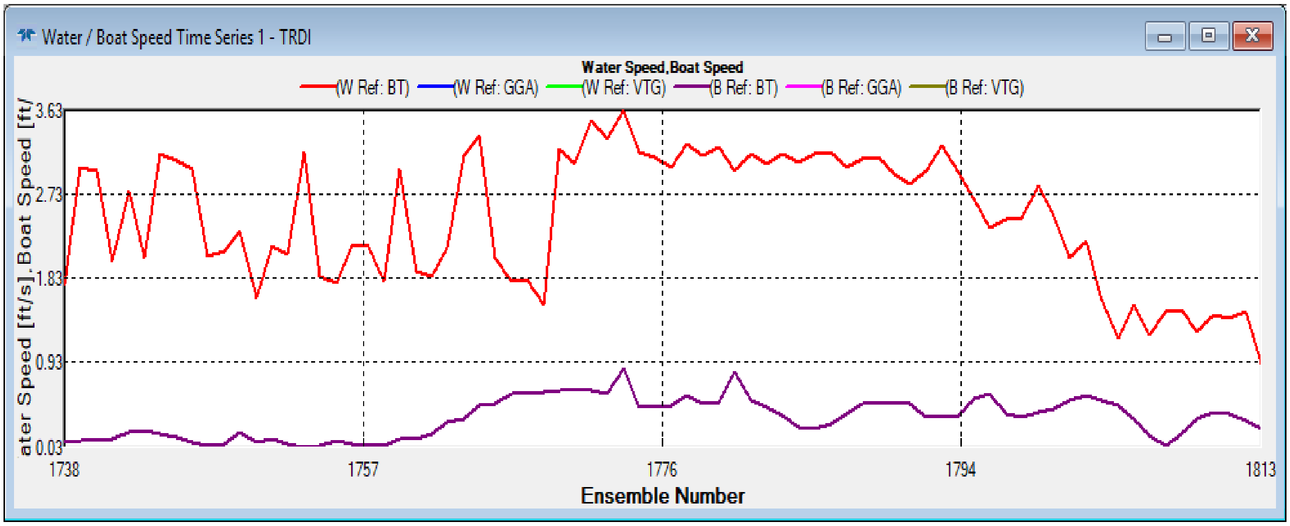




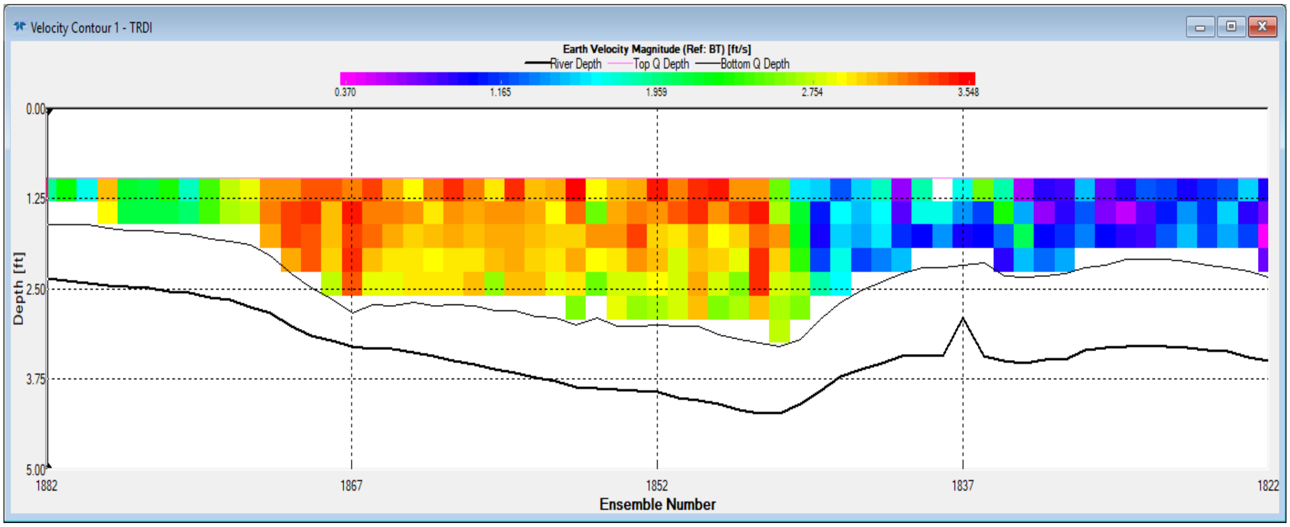
B. Transect TBD5-002 Raw Data Output

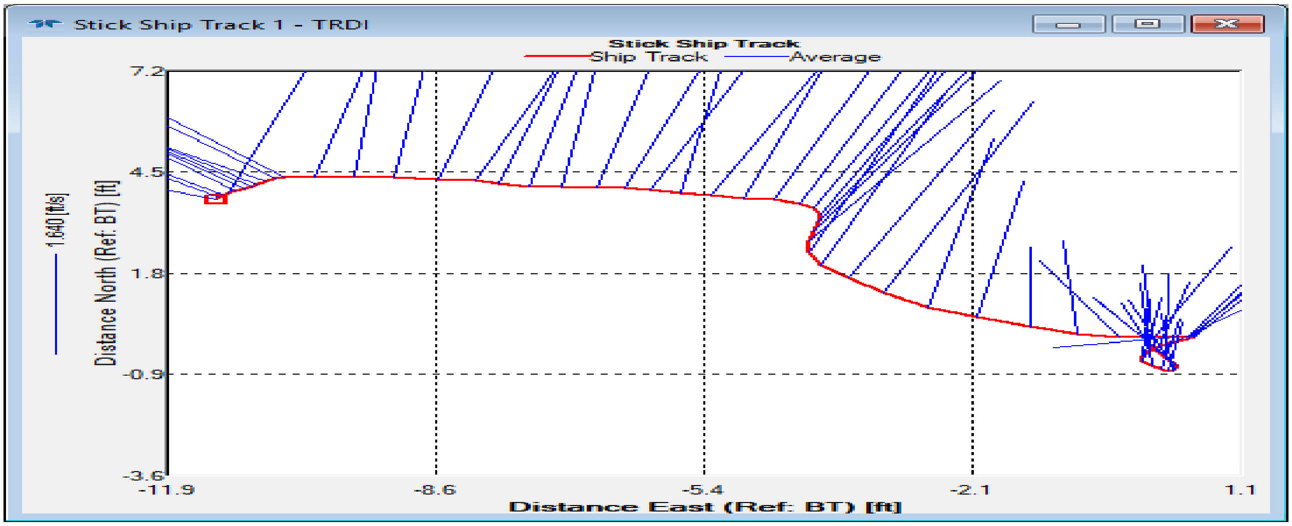


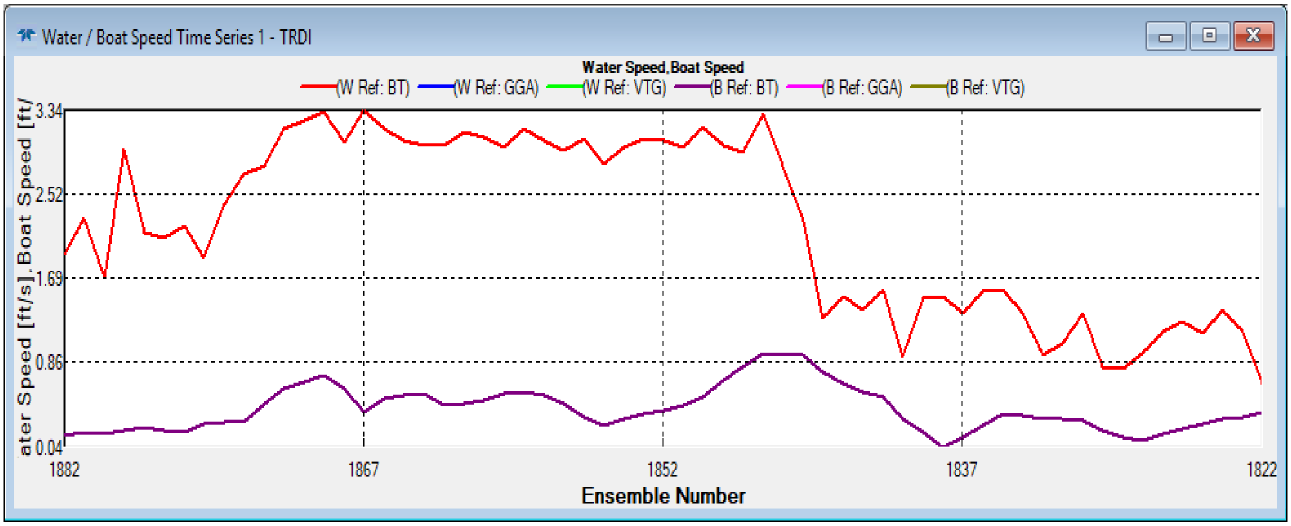




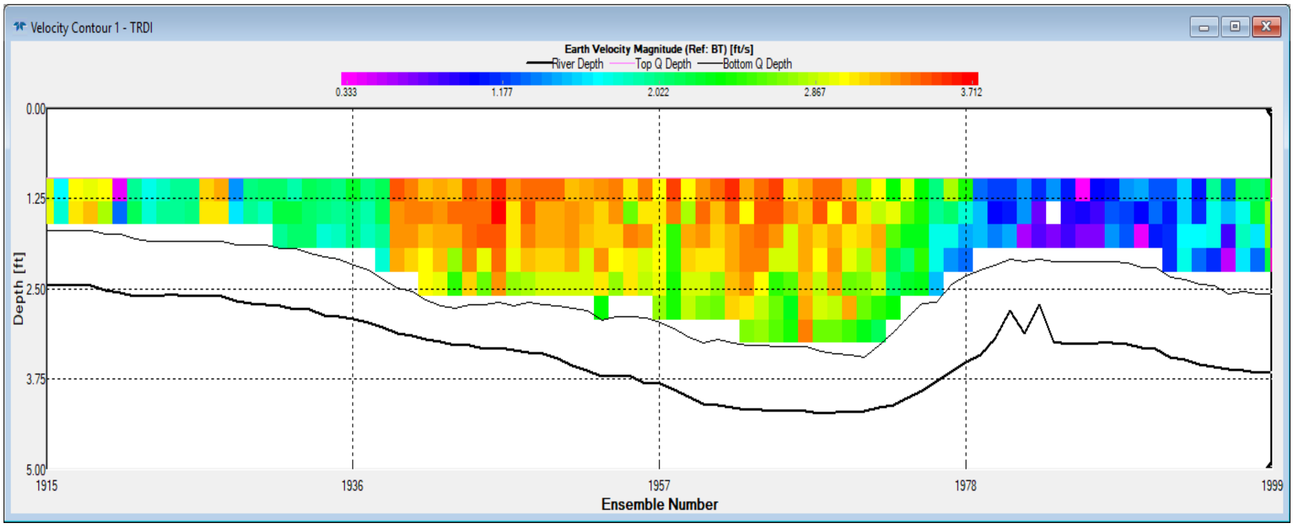
C. Transect TBD5-003 Raw Data Output

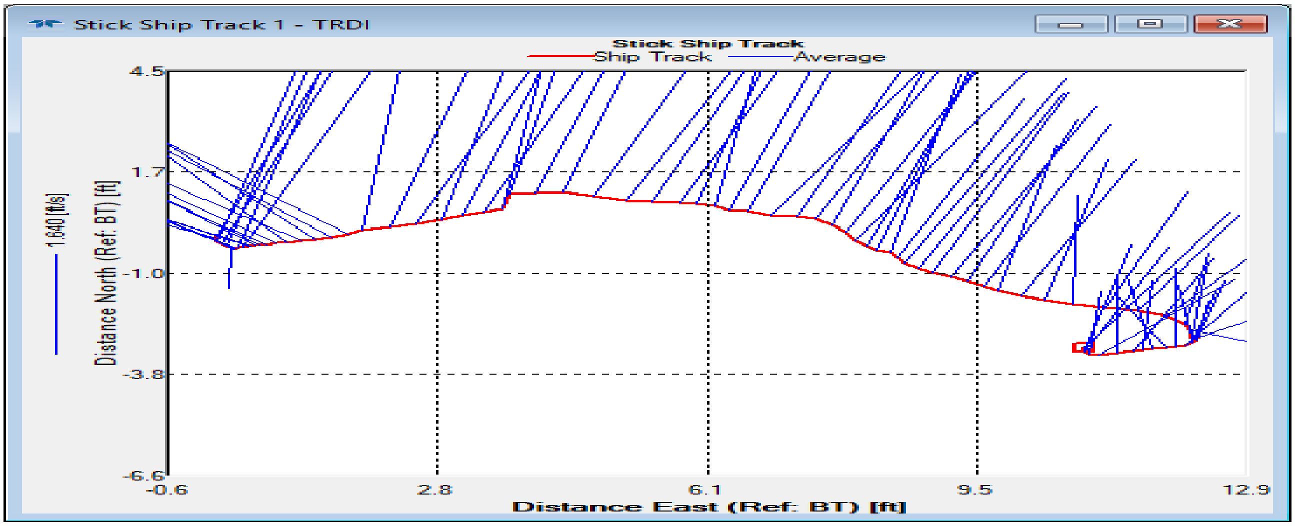


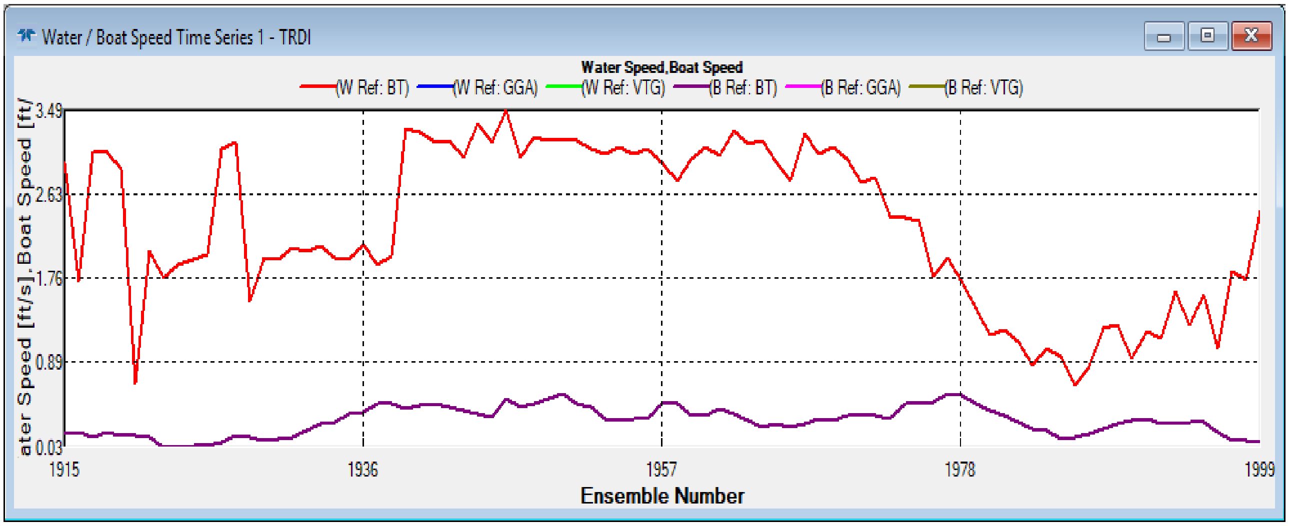




D. Transect TBD5-004 Raw Data Output







ConocoPhillips
Alaska

Feet
0 200 400

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_TBD5.mxd

● Station

⌖ Gage Location

Discharge Measurement Cross Section

→ Flow Direction

Imagery Source: Willow Aerial (COPA), 2018

Michael Baker
INTERNATIONAL

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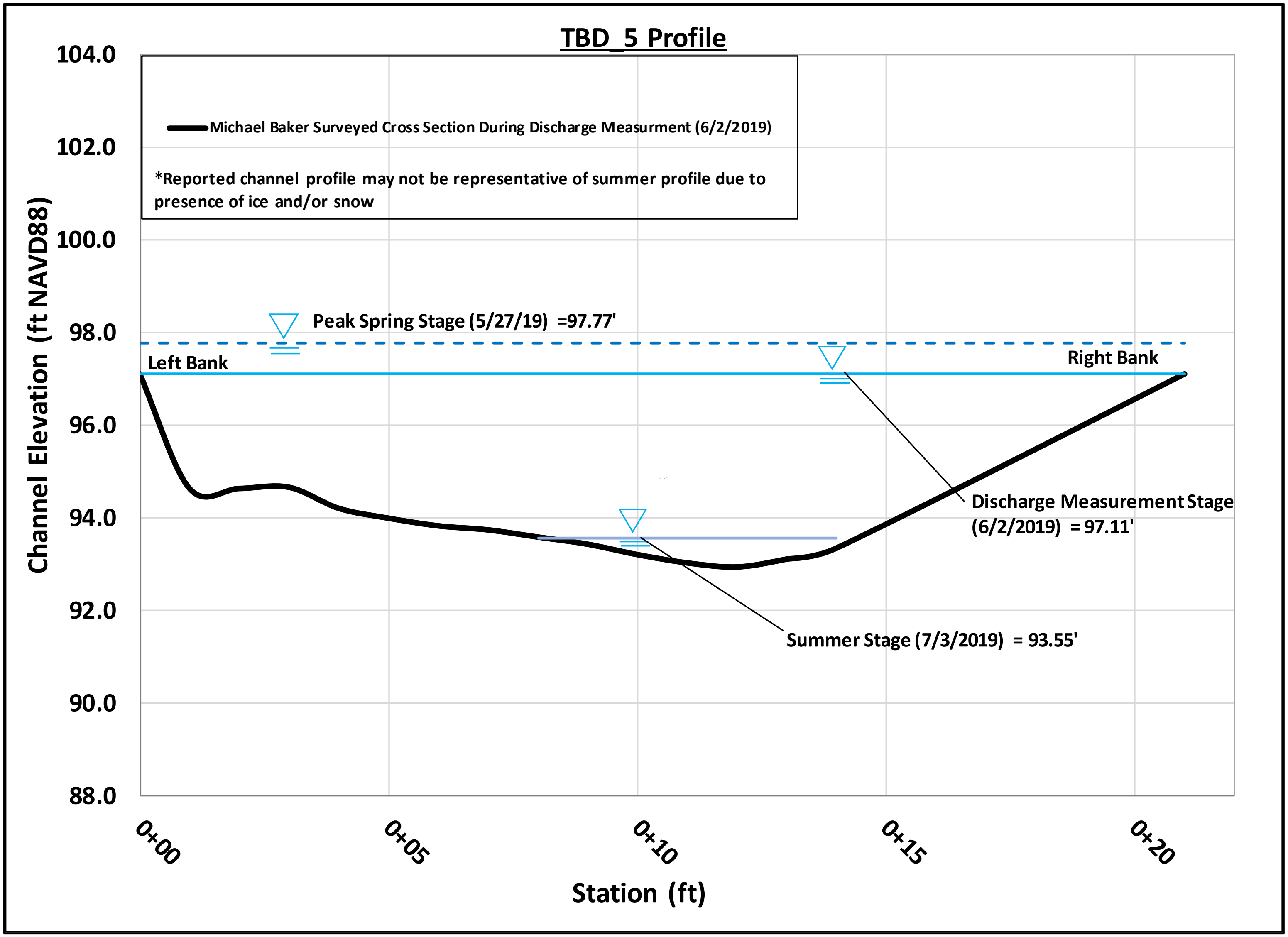
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019 Spring Breakup unnamed stream at TDB_5 Plan

FIGURE C.4

Spring Breakup Cross-Section Profile



C.5 TBD_6

Spring Breakup Measured Discharge

Location: TBD_6

Date & Time: May 30, 4:00 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: Fair

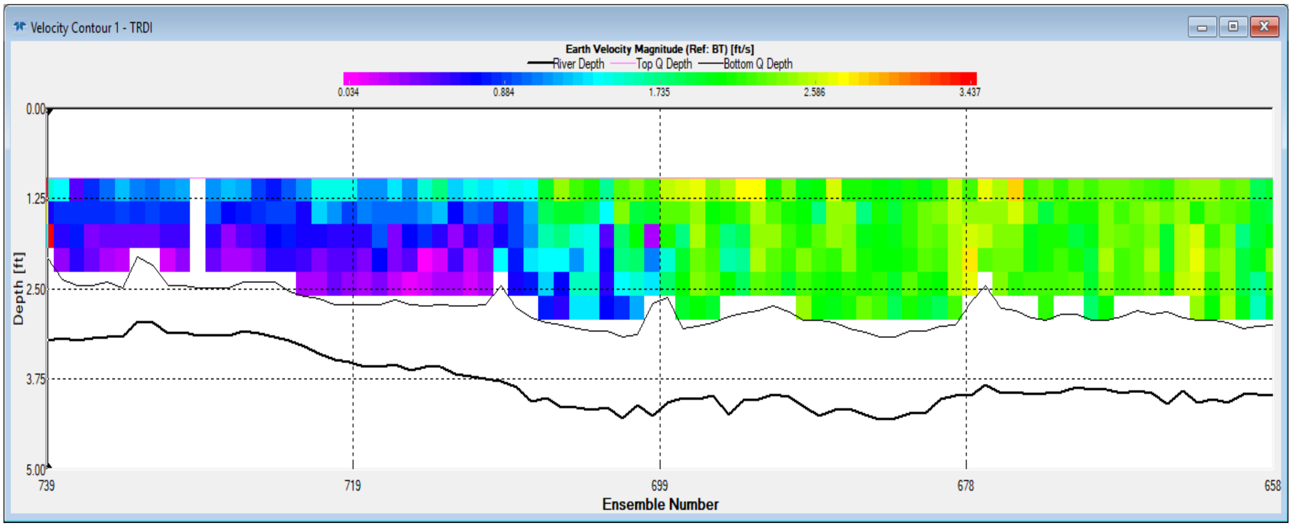
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (0.00%) was within the recommended maximum of 5%.

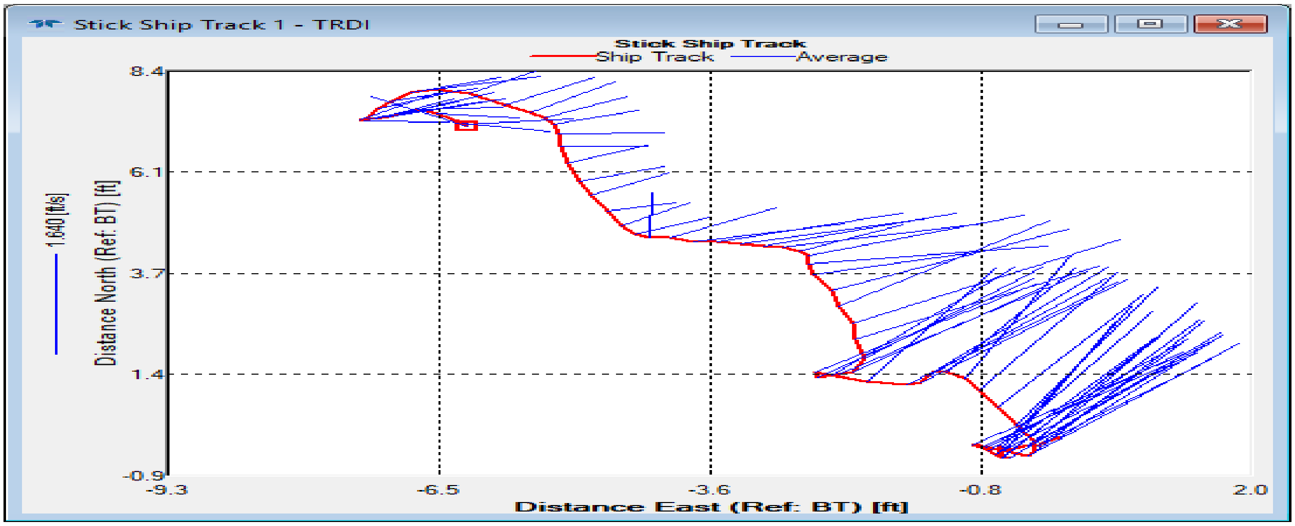
At the time of the measurement, the river was clear of snow and ice. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on the conditions at the time of the discharge measurement.

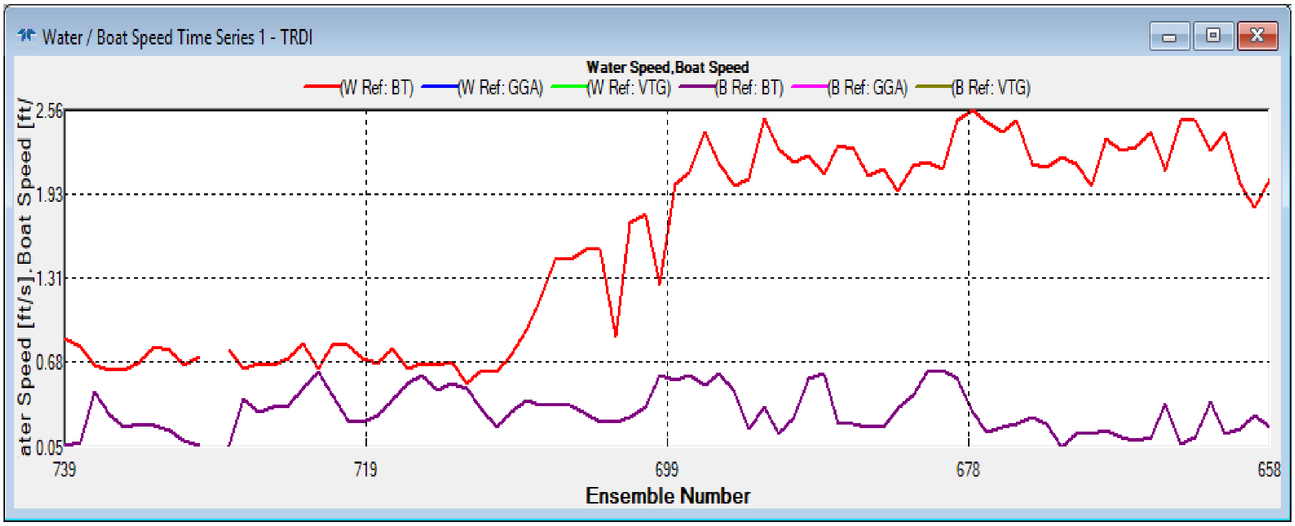
Table C.6: TBD_6 May 30 Spring Breakup Measured Discharge Summary

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	Right	89	3.42%	26	14.25%	27	58	69	1.29	1.55
001	Left	84	-2.84%	21	-6.39%	27	54	67	1.25	1.57
002	Right	88	1.49%	23	-1.08%	28	60	71	1.24	1.47
004	Right	85	-2.07%	21	-6.78%	28	60	71	1.24	1.41
Average		**86**		**23**		**28**		**70**	**1.24**	**1.50**

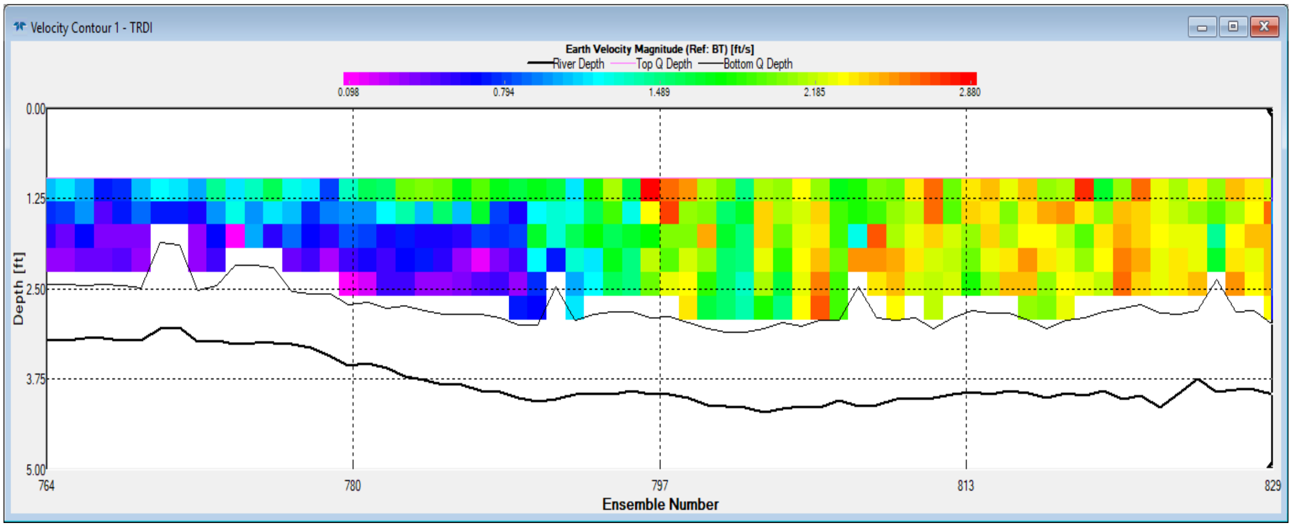
A. Transect TBD6-000 Raw Data Output

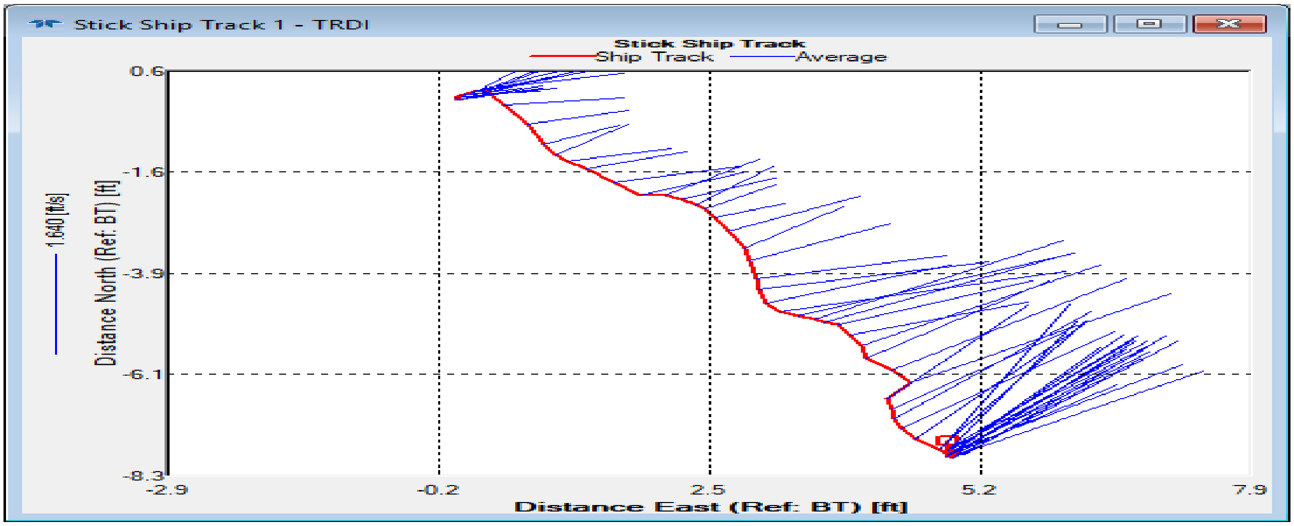


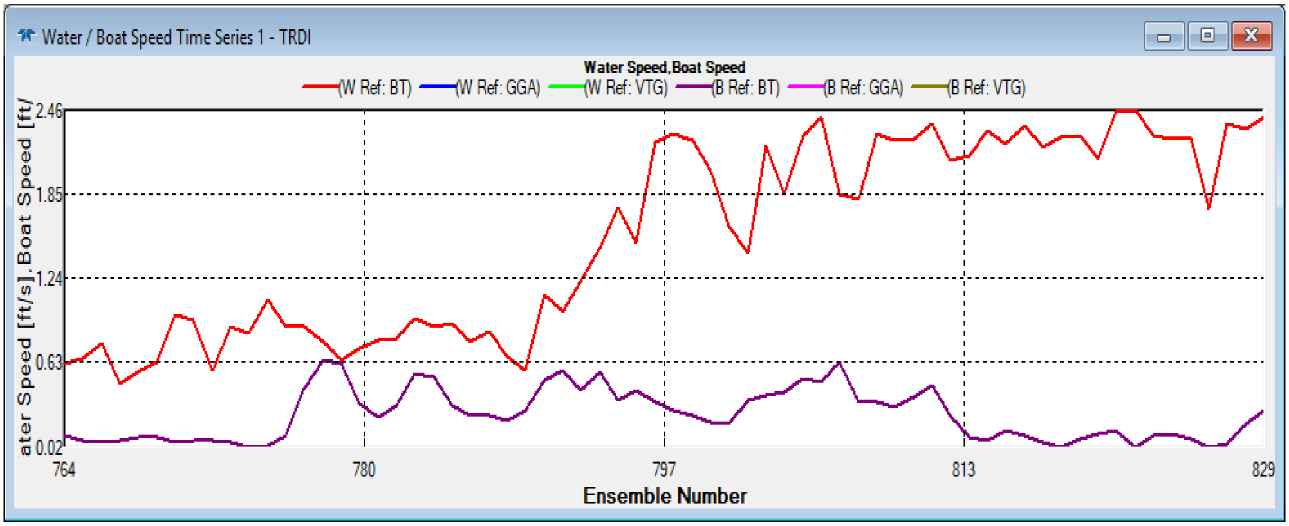




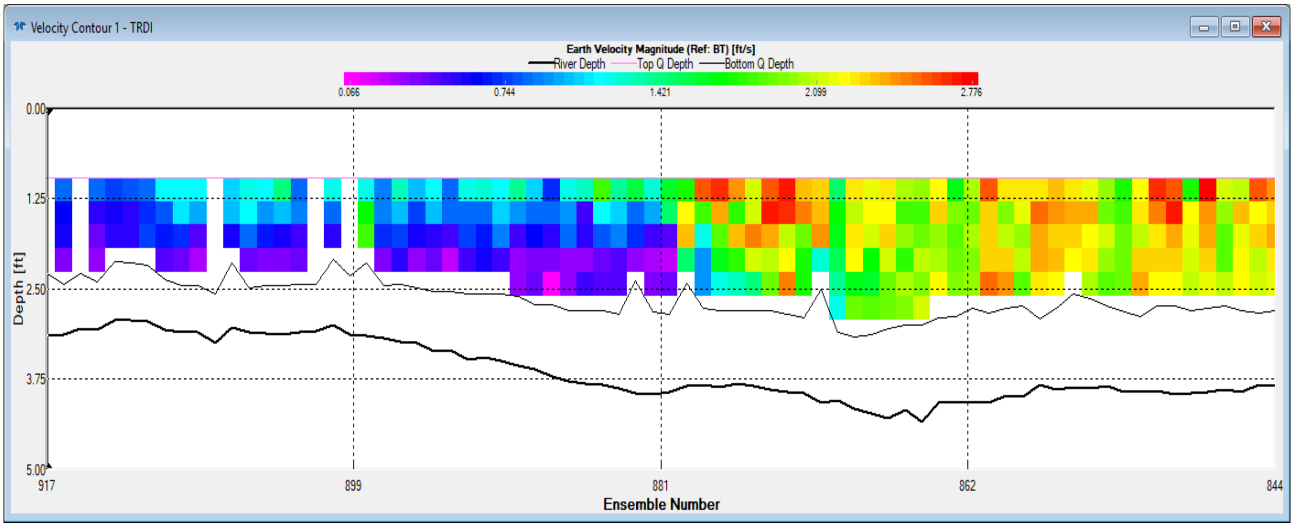
B. Transect TBD6-001 Raw Data Output

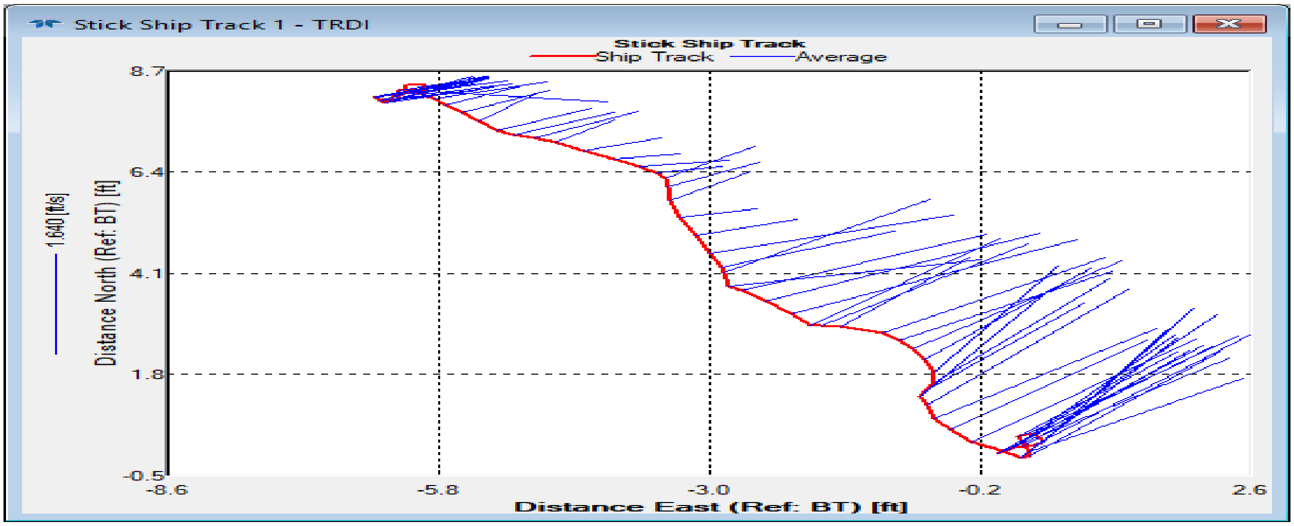


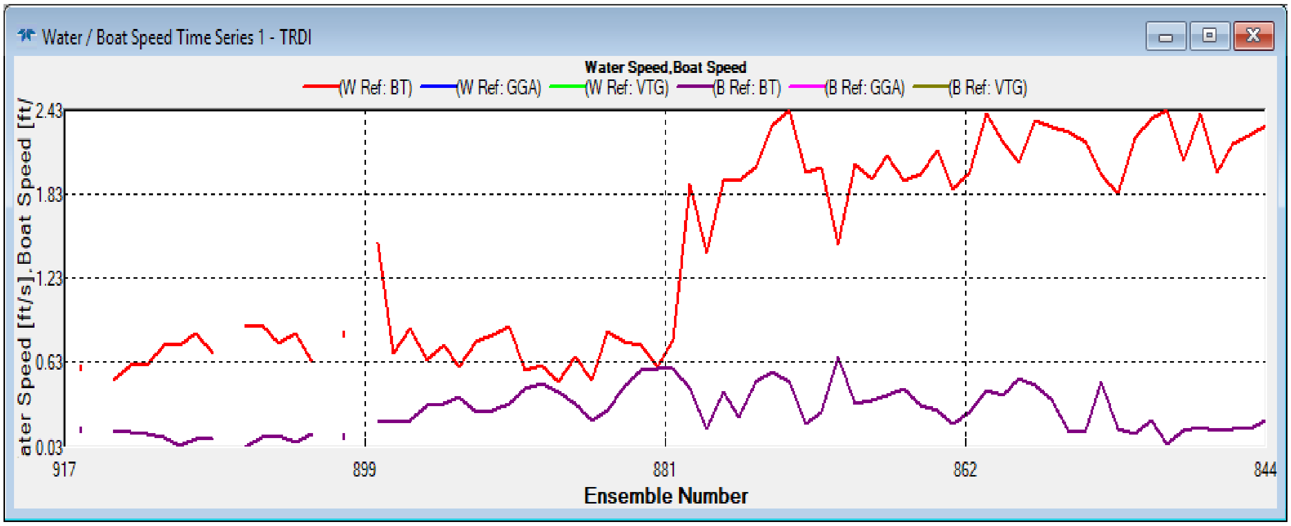




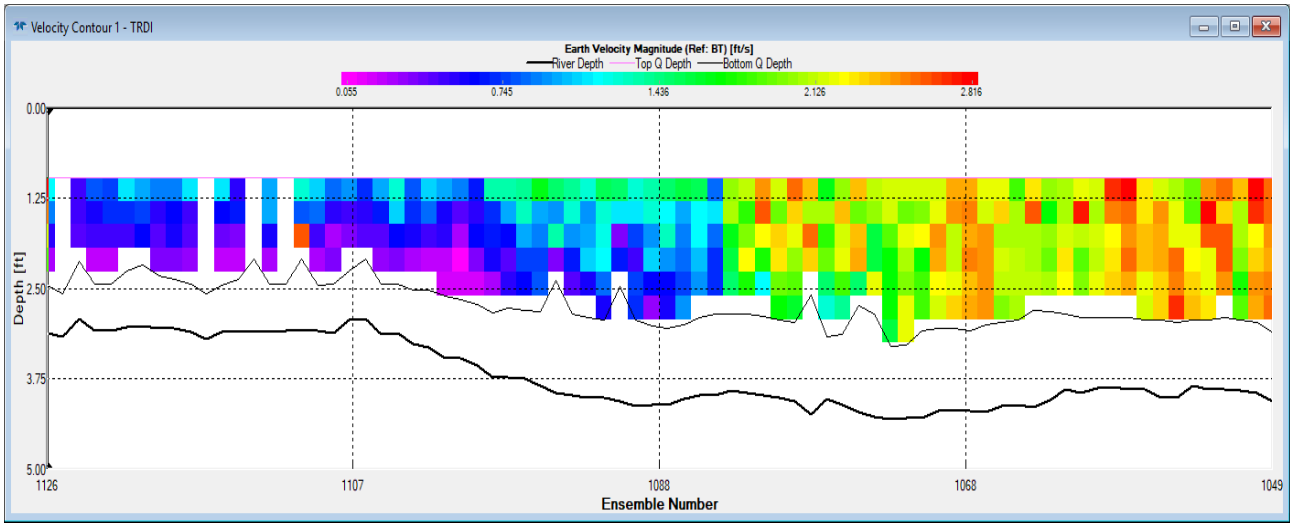
C. Transect TBD6-002 Raw Data Output

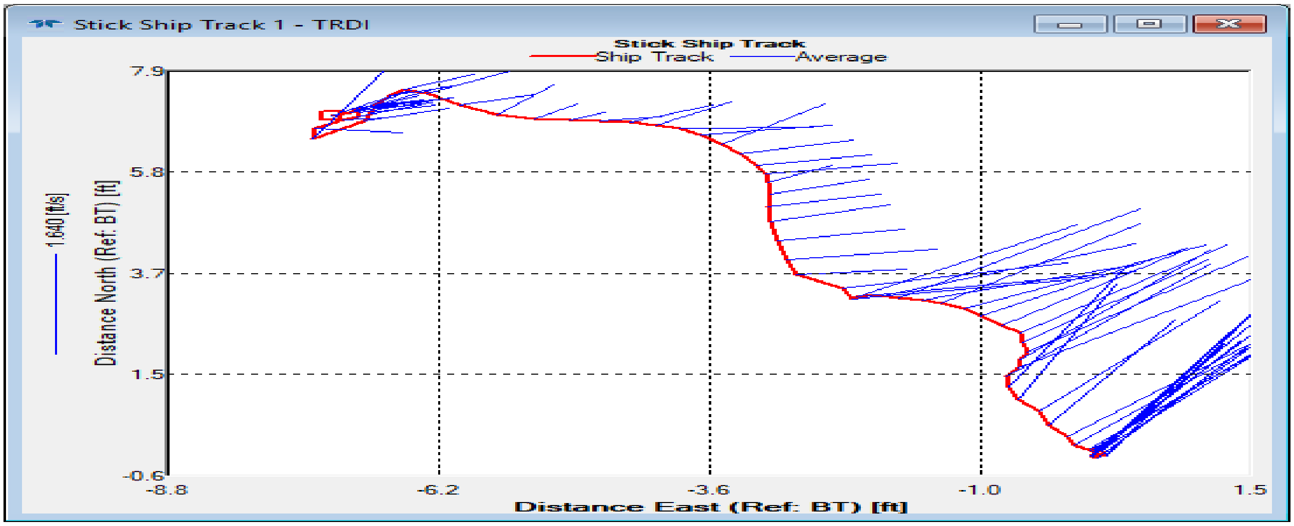


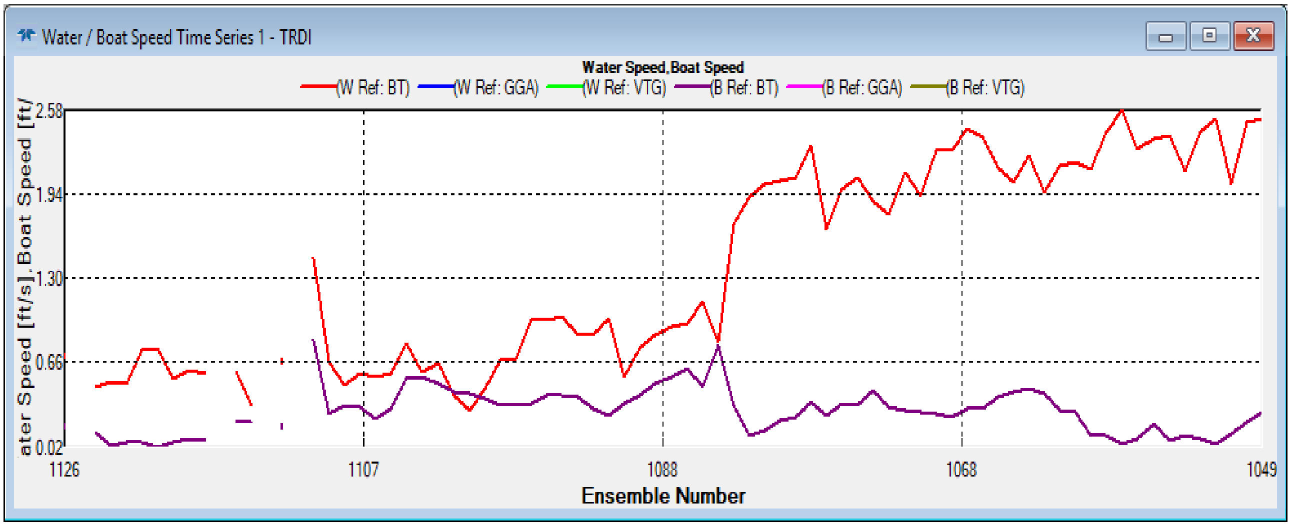




D. Transect TBD6-004 Raw Data Output







ConocoPhillips
Alaska

0 200 400 Feet

Date:	01/24/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_TBD6.mxd

● Station

⌖ Gage Location

— Discharge Measurement Cross Section

→ Flow Direction

Imagery Source: Willow Aerial (COPA), 2018

Michael Baker
INTERNATIONAL

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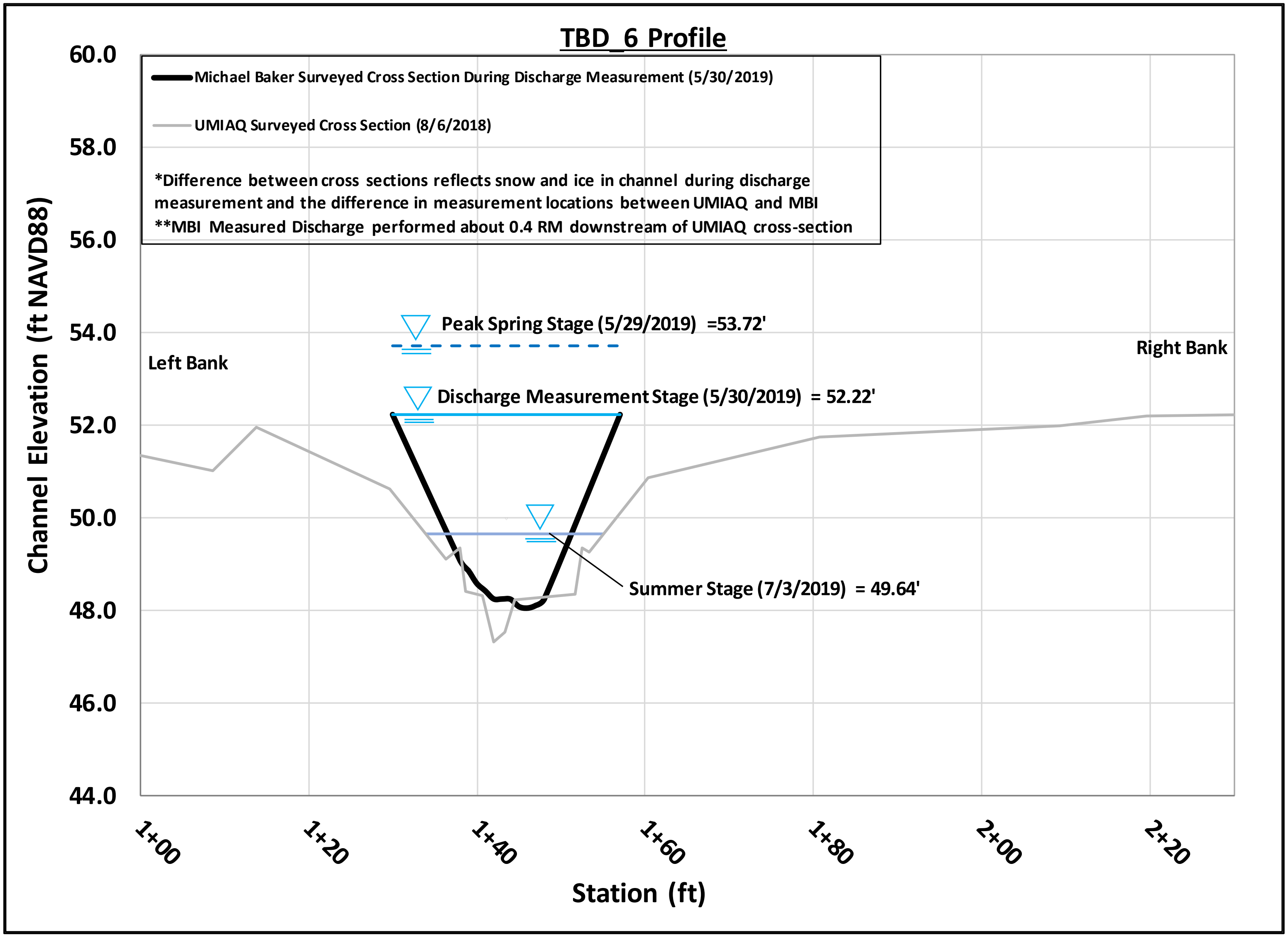
3900 C. Street Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019 Spring Breakup Willow 8 at TDB_6 Plan

FIGURE C.5

Spring Breakup Cross-Section Profile



C.6 WILLOW 2 AT UC1B

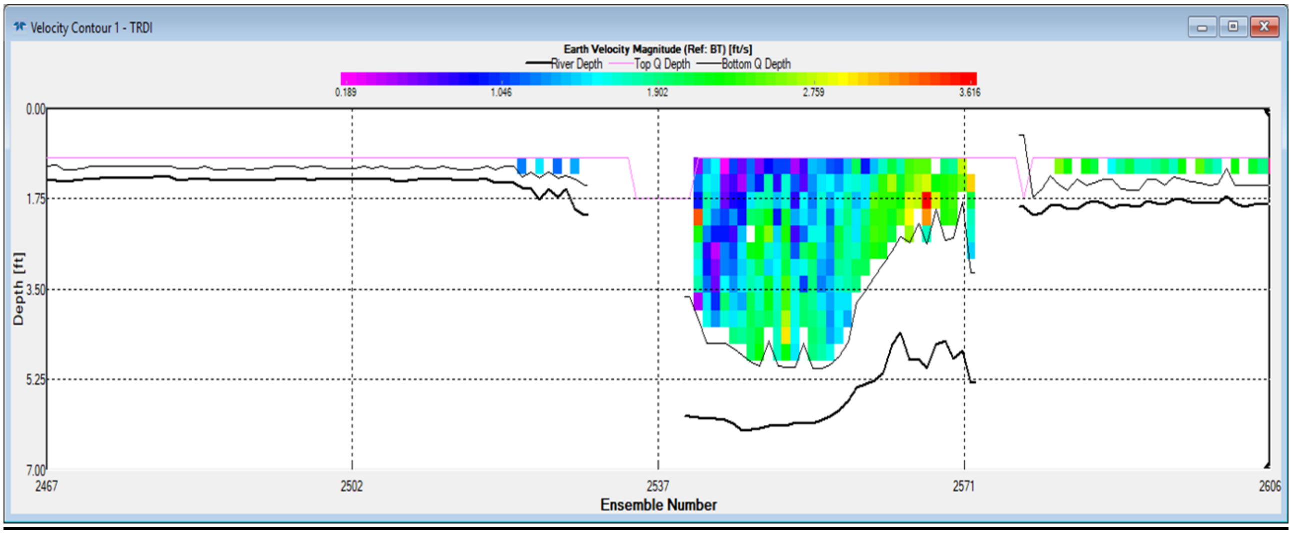
Spring Breakup Measured Discharge

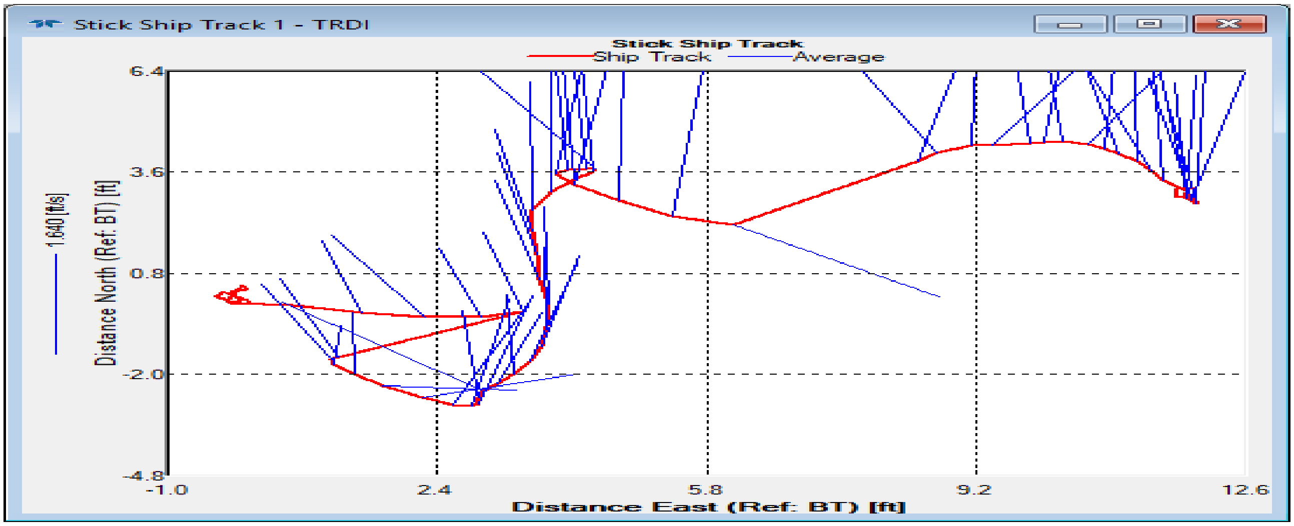
Location:	UC1B
Date & Time:	June 1, 2019 4:00 PM
Equipment:	RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.
Final Discharge (cfs):	110
Average Velocity (fps):	1.6
Measurement Rating:	Fair
Measurement Notes:	Moving bed conditions were identified; discharge was 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 0.11 fps. The percentage of bad bottom track values (60.96%) exceeded the recommended maximum of 5%. At the time of the discharge measurement, saturated snow remained 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 measurement.

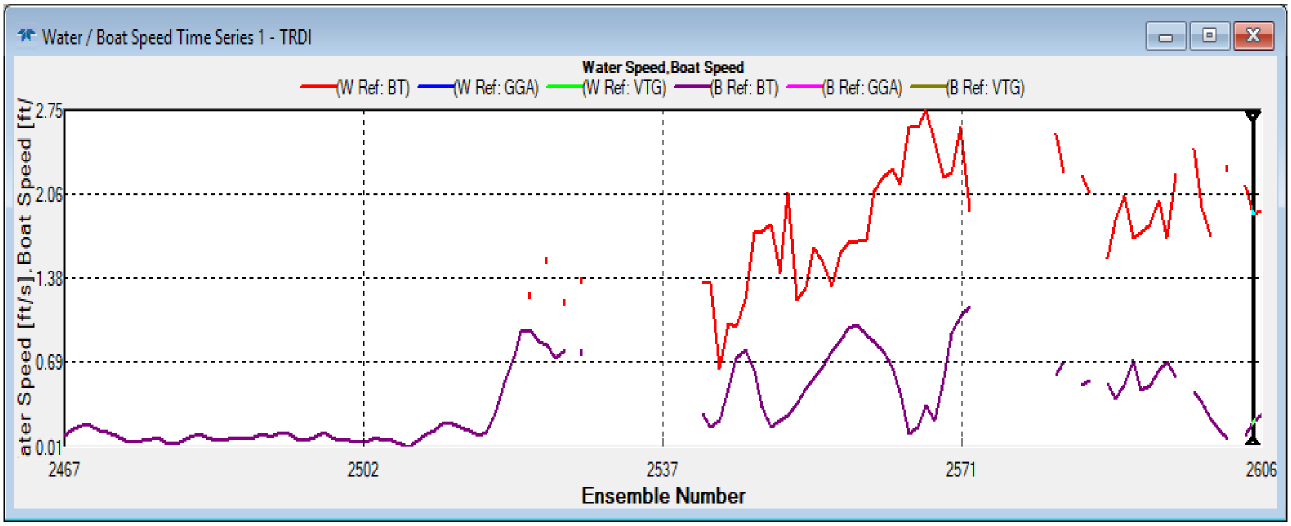
Table C.7: UC1B June 1 Spring Breakup Measured Discharge Summary

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)
001	Left	109	-2.84%	23	-21.74%	44	75	80	1.37	1.46
004	Right	107	-4.77%	46	54.71%	27	93	82	1.30	1.15
005	Left	115	2.58%	25	-14.75%	37	70	76	1.51	1.64
008	Right	114	1.95%	30	3.43%	24	55	58	1.97	2.08
010	Right	116	3.08%	23	-21.65%	27	55	63	1.83	2.10
Average		**112**		**29**		**32**		**72**	**1.60**	**1.68**

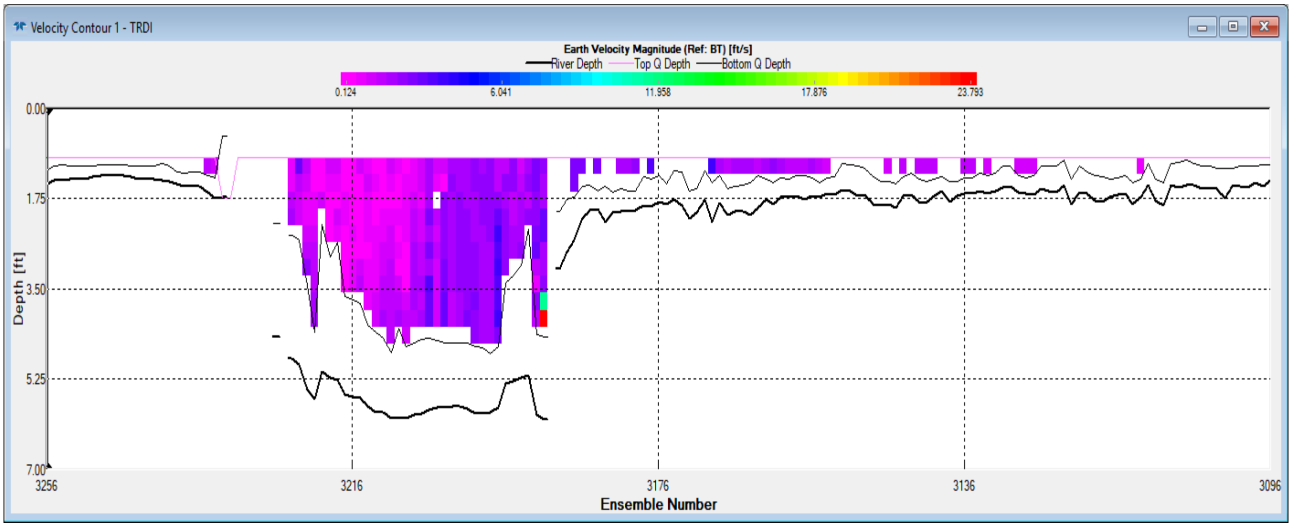
A. Transect UC1B-001 Raw Data Output

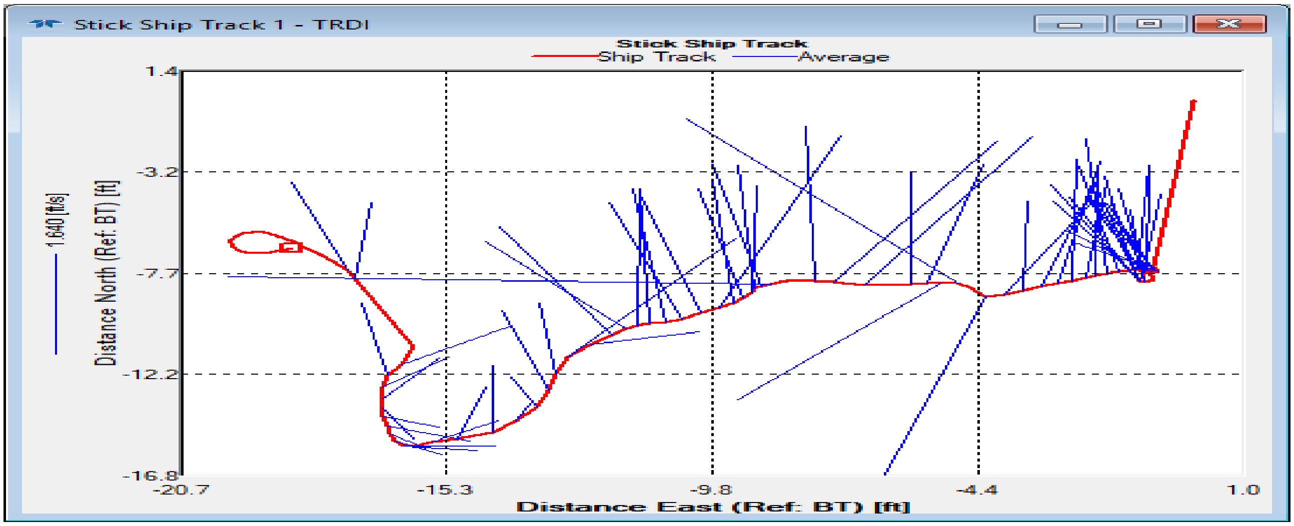




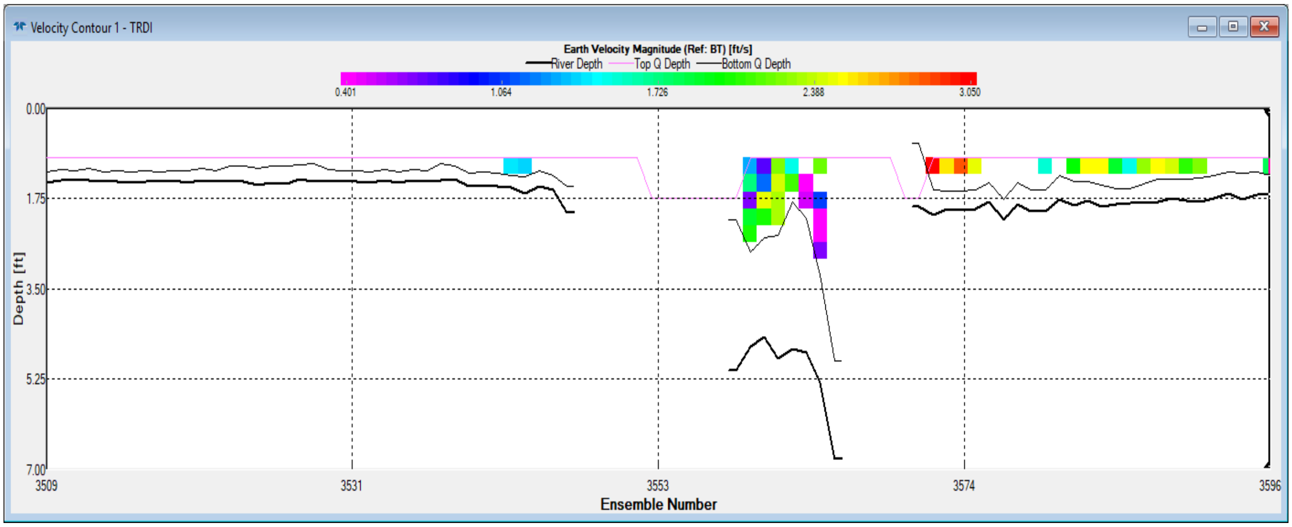


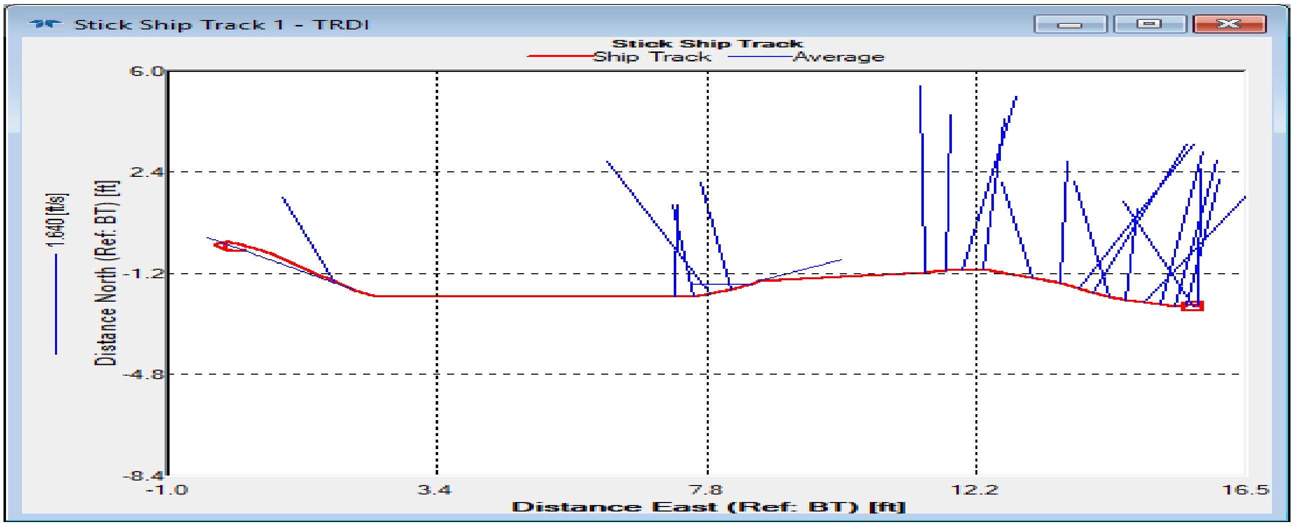
B. Transect UC1B-004 Raw Data Output

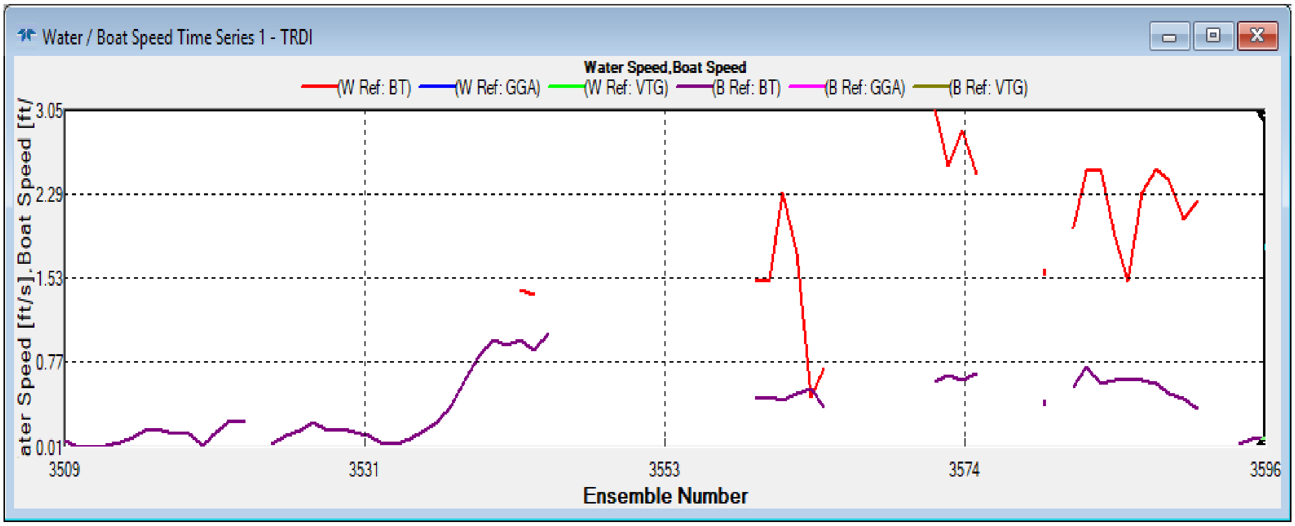




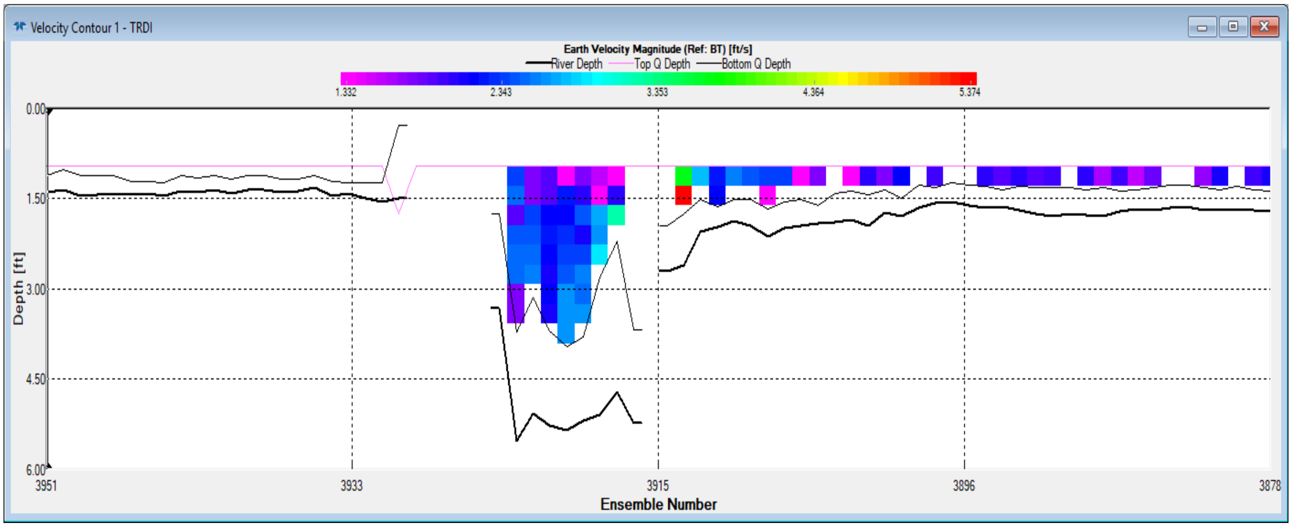
C. Transect UC1B-005 Raw Data Output

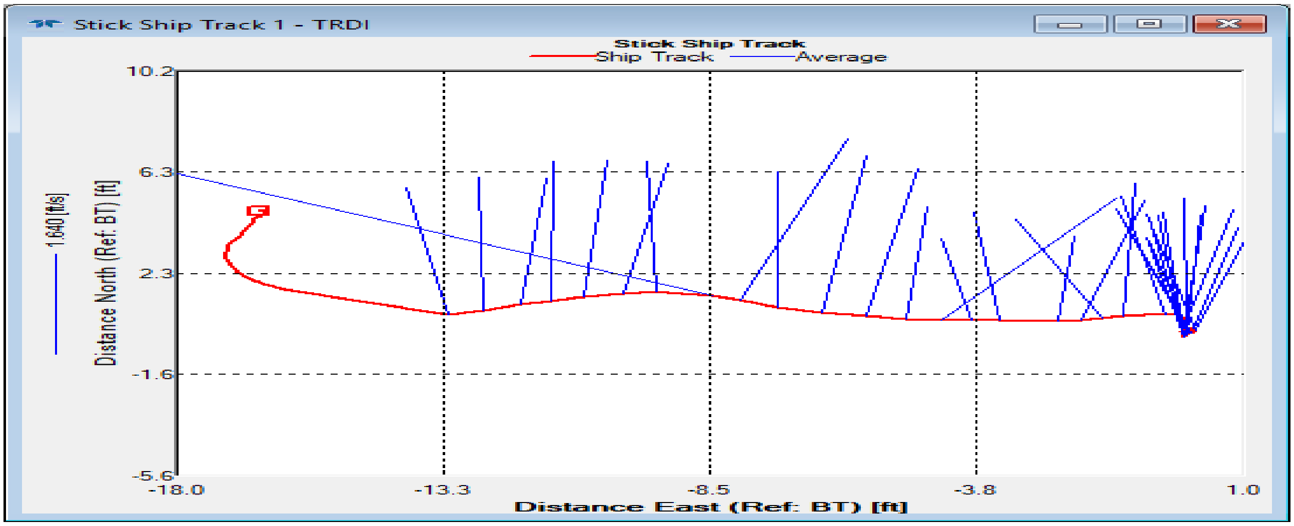




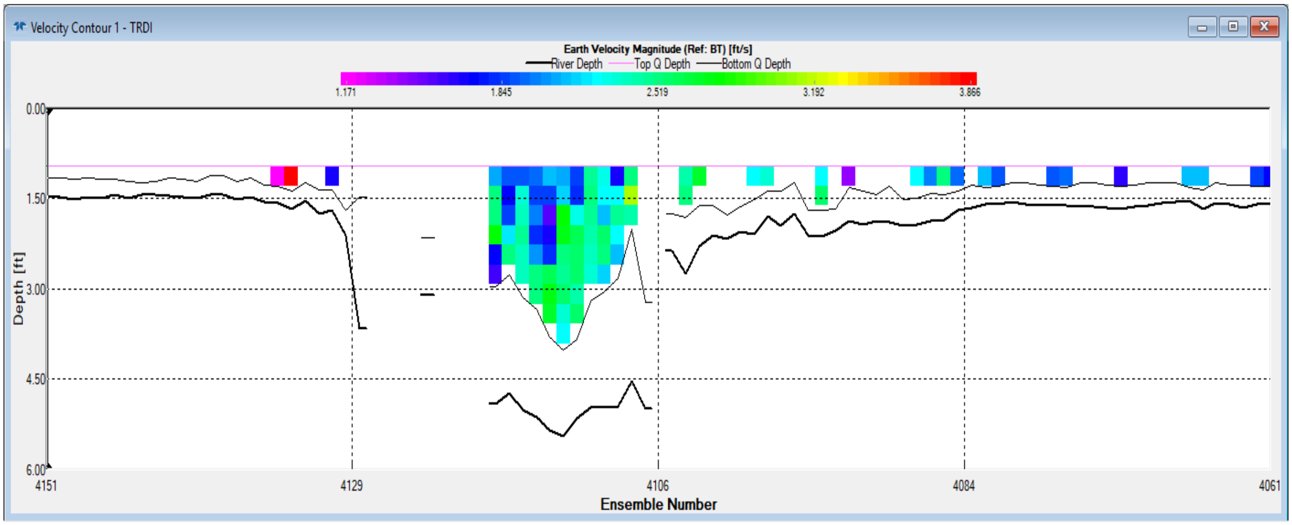


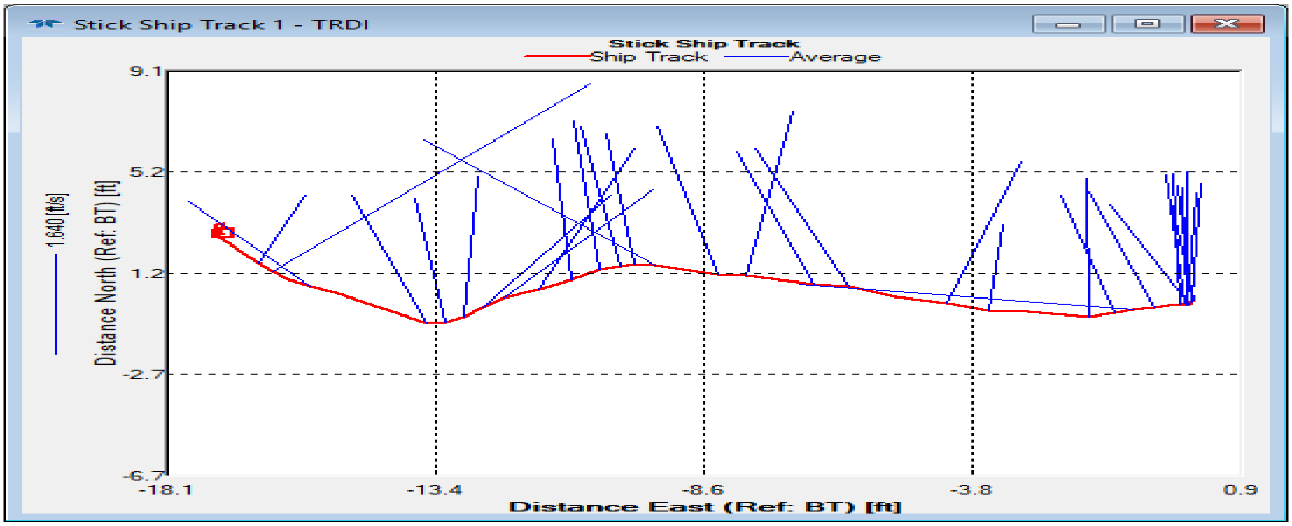
D. Transect UC1B-008 Raw Data Output

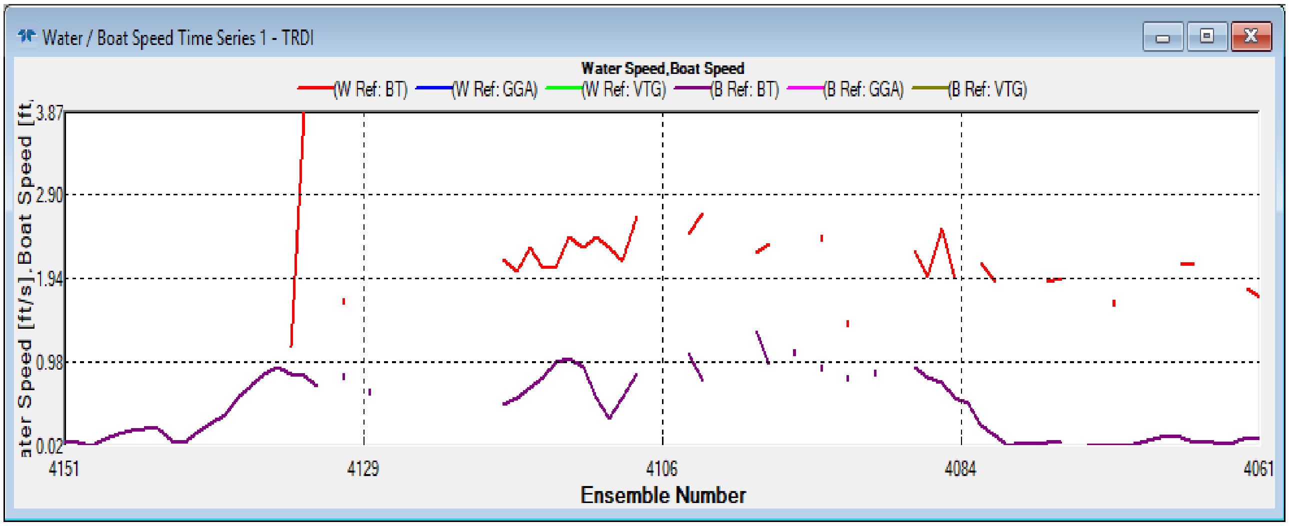


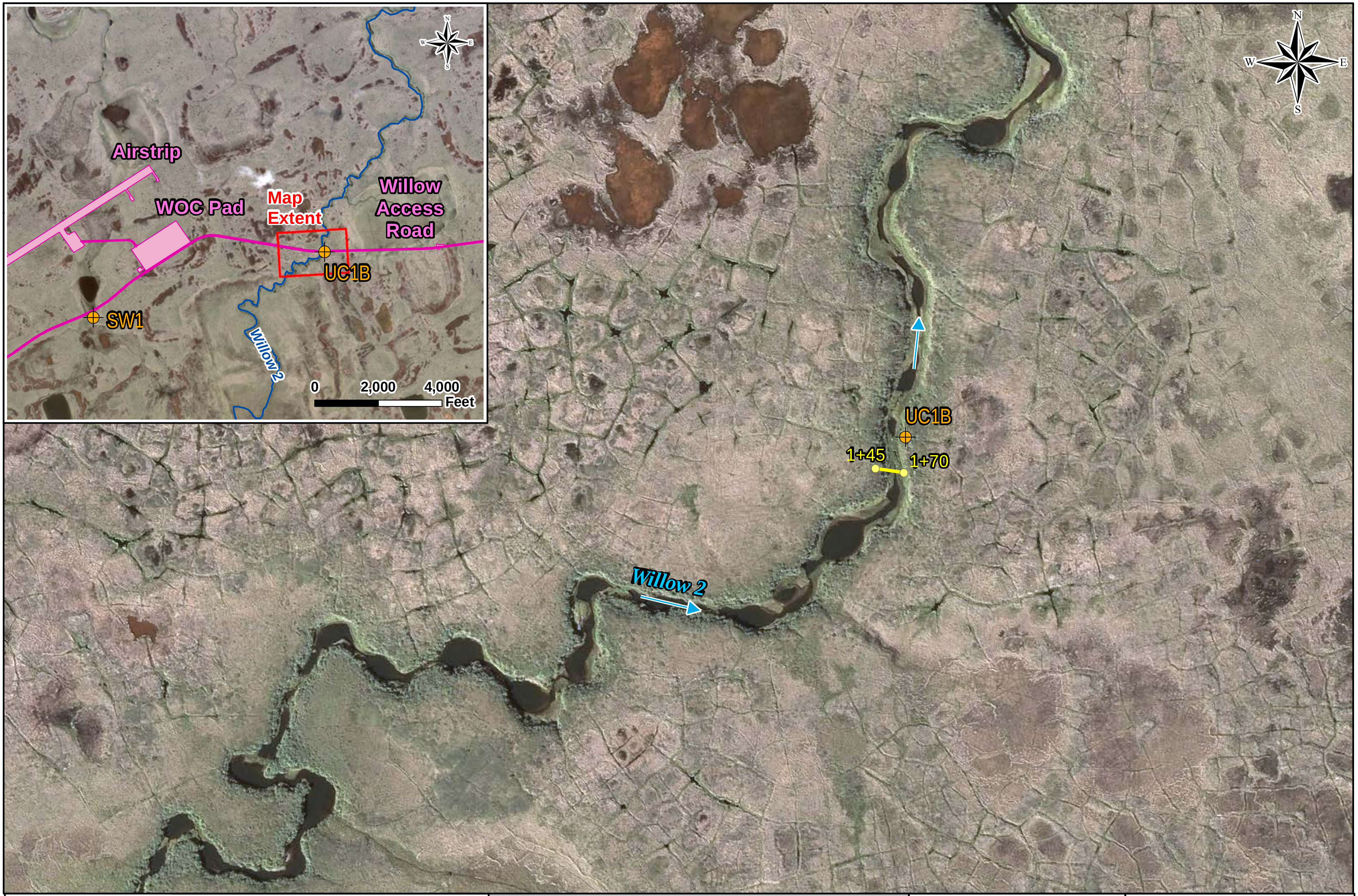


E. Transect UC1B-010 Raw Data Output









ConocoPhillips
Alaska

0 200 400 Feet

Date: 10/18/2019
Scale: 1 Inch = 200 Feet
Drawn: JEG
Project: 172339
Checked: GCY
File: PlanView_UC1B.mxd

● Station

→ Flow Direction

⊕ Gage Location

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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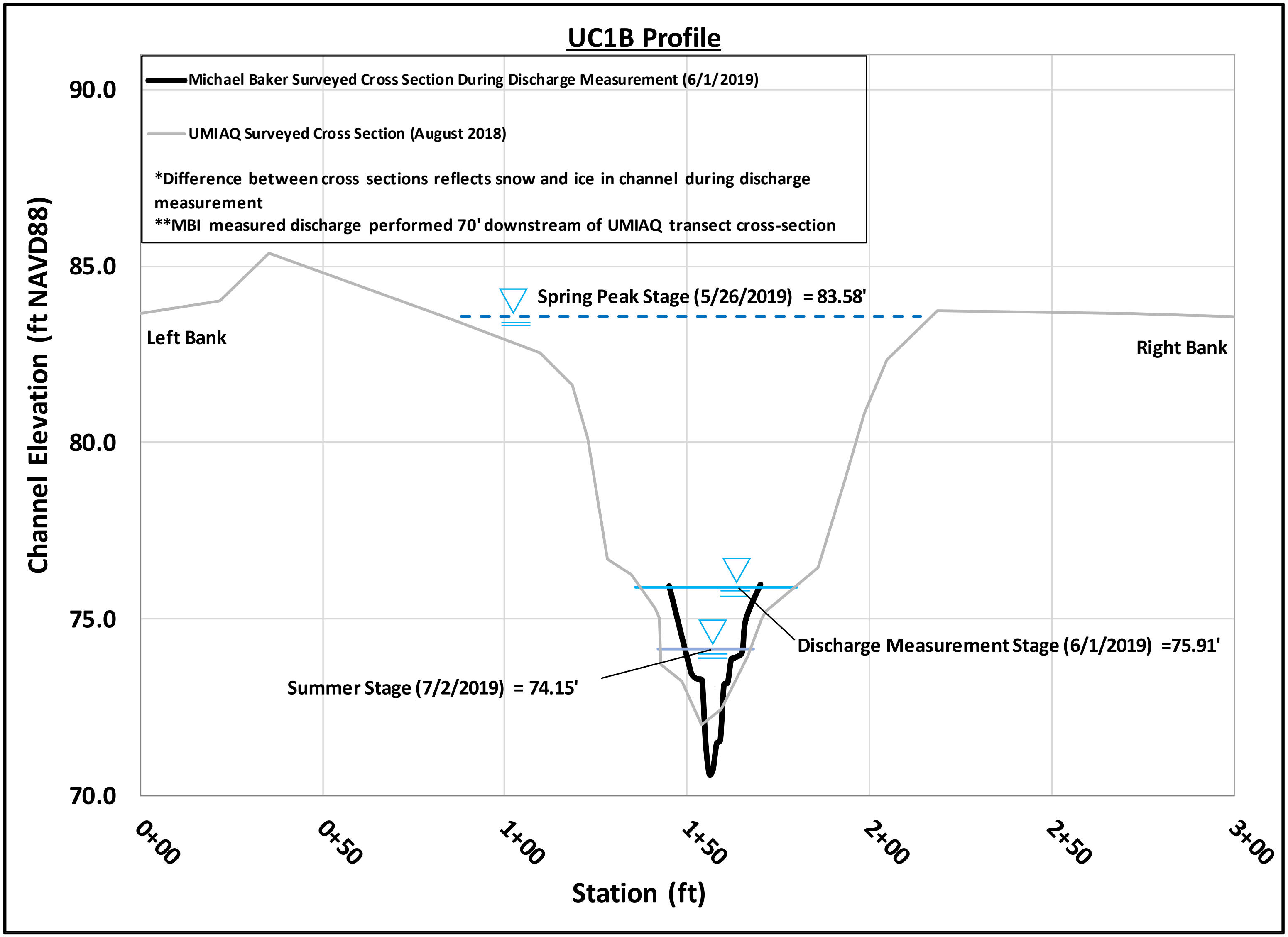
2019 Spring Breakup Willow 2 at UC1B Plan

FIGURE C.6

Spring Breakup Cross-Section Profile



C.7 JUDY CREEK KAYYAAQ AT UC2C

Spring Breakup Measured Discharge

Location: UC2C

Date & Time: May 30, 2019 2:30 PM

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

Final Discharge (cfs): 270

Average Velocity (fps): 1.5

Measurement Rating: Good

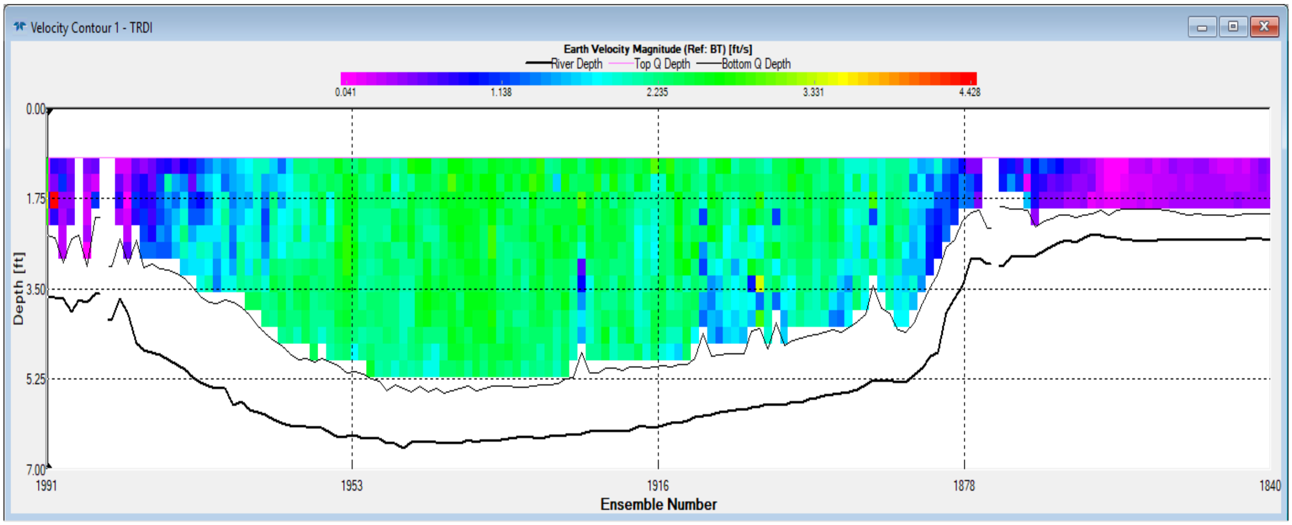
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (1.27%) was within the recommended maximum of 5%.

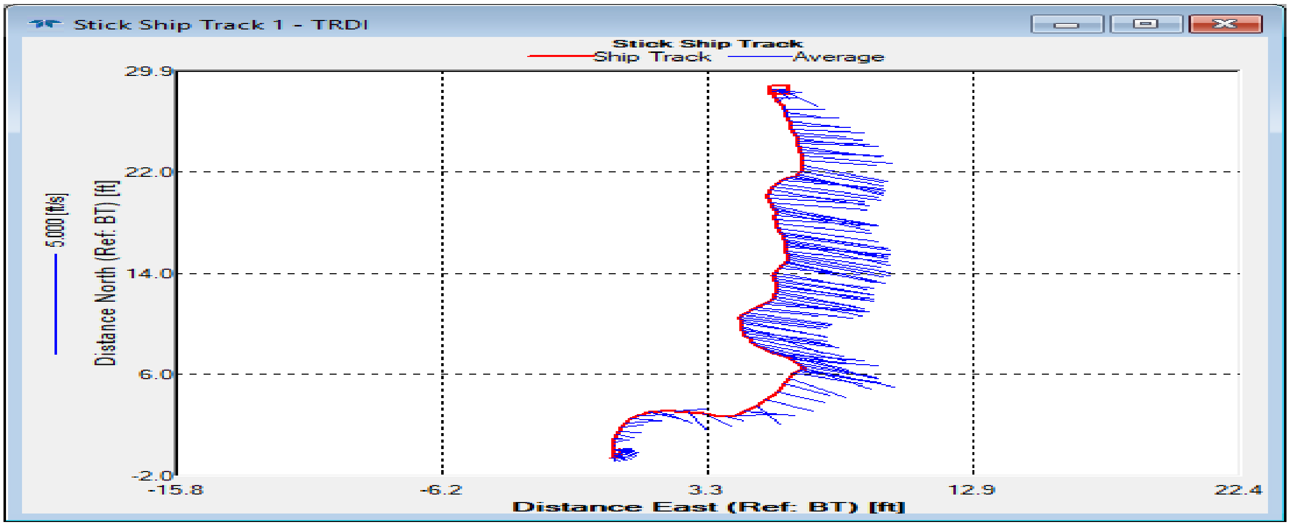
At the time of the discharge measurement, minimal saturated snow remained along the banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered good based on conditions at the time of measurement.

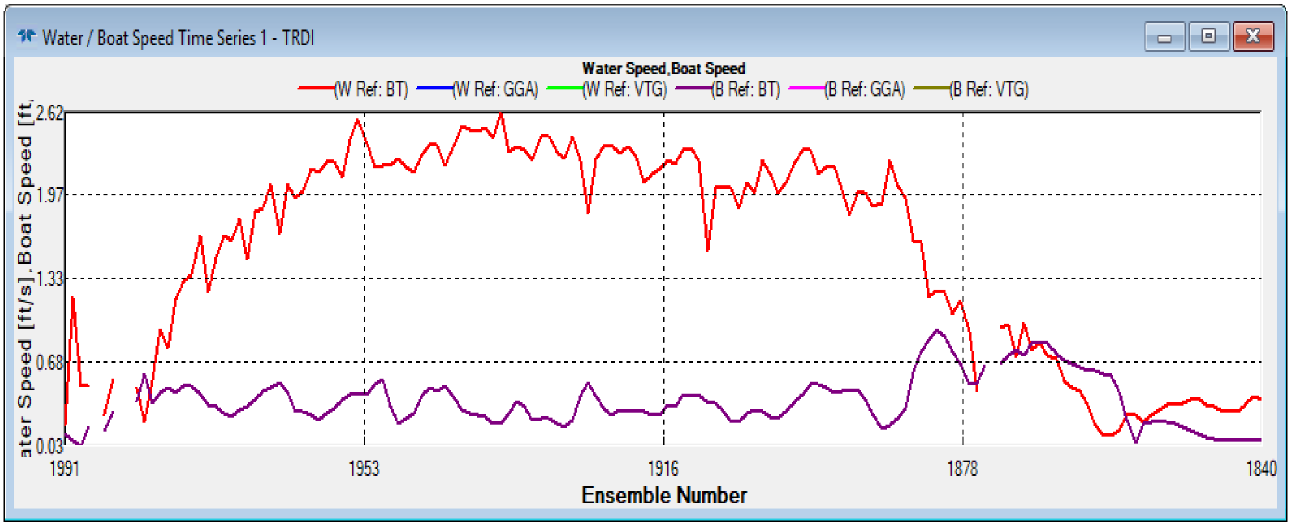
Table C.8: UC2C May 30 Spring Breakup Measured Discharge Summary

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)
004	Right	272	1.22%	162	0.52%	43	143	176	1.54	1.90
005	Left	279	3.67%	166	3.44%	43	146	176	1.58	1.91
006	Right	258	-4.17%	154	-4.28%	46	149	189	1.36	1.74
007	Left	267	-0.72%	161	0.32%	44	154	179	1.49	1.74
Average		**269**		**161**		**44**		**180**	**1.50**	**1.82**

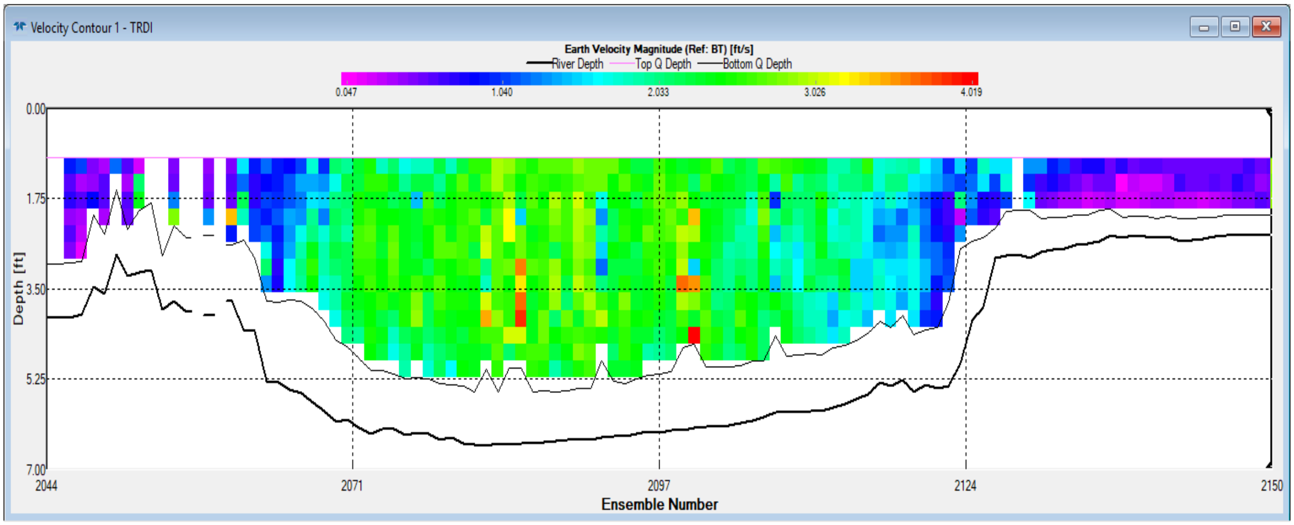
A. Transect UC2C-004 Raw Data Output

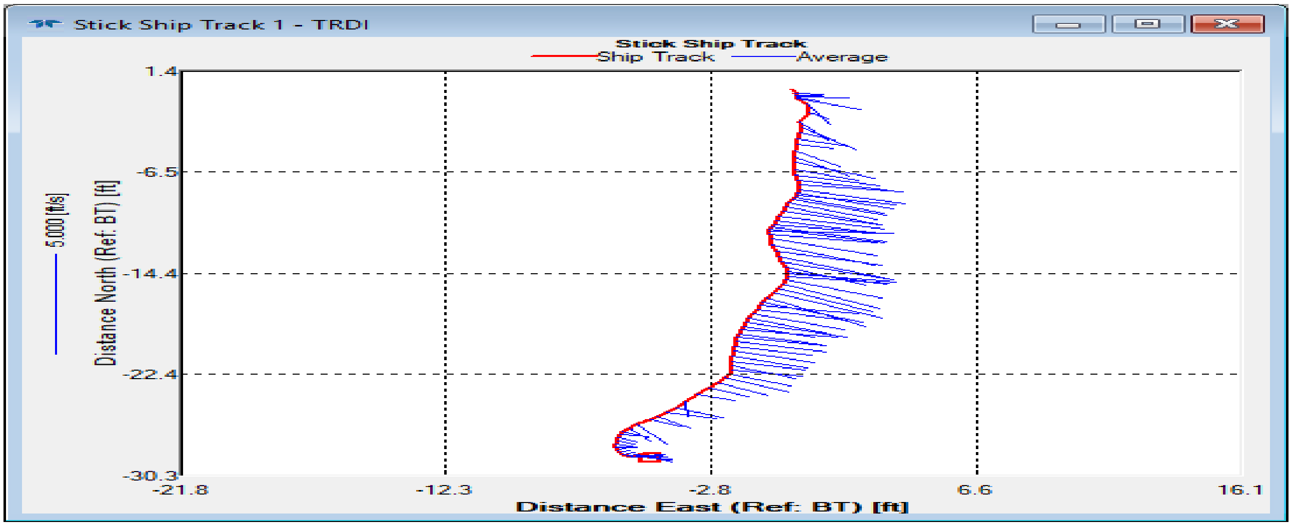


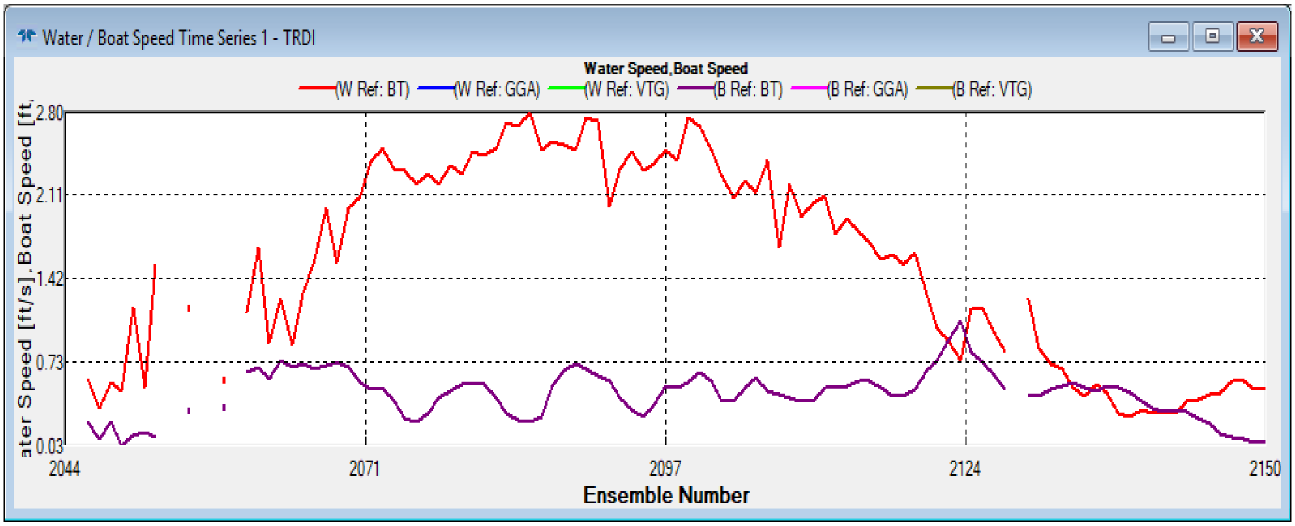




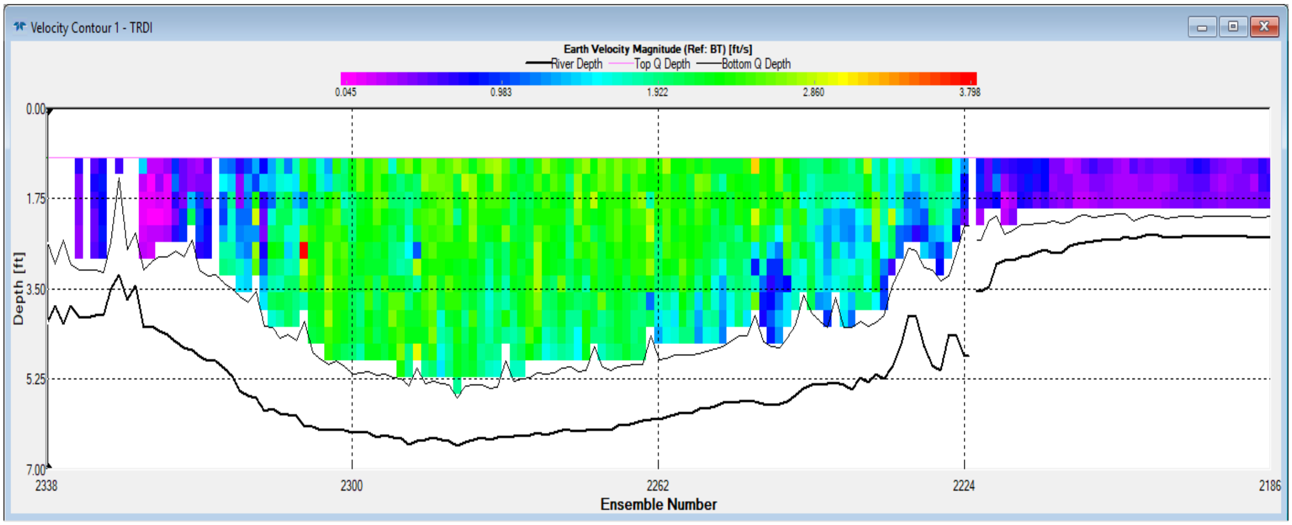
B. Transect UC2C-005 Raw Data Output

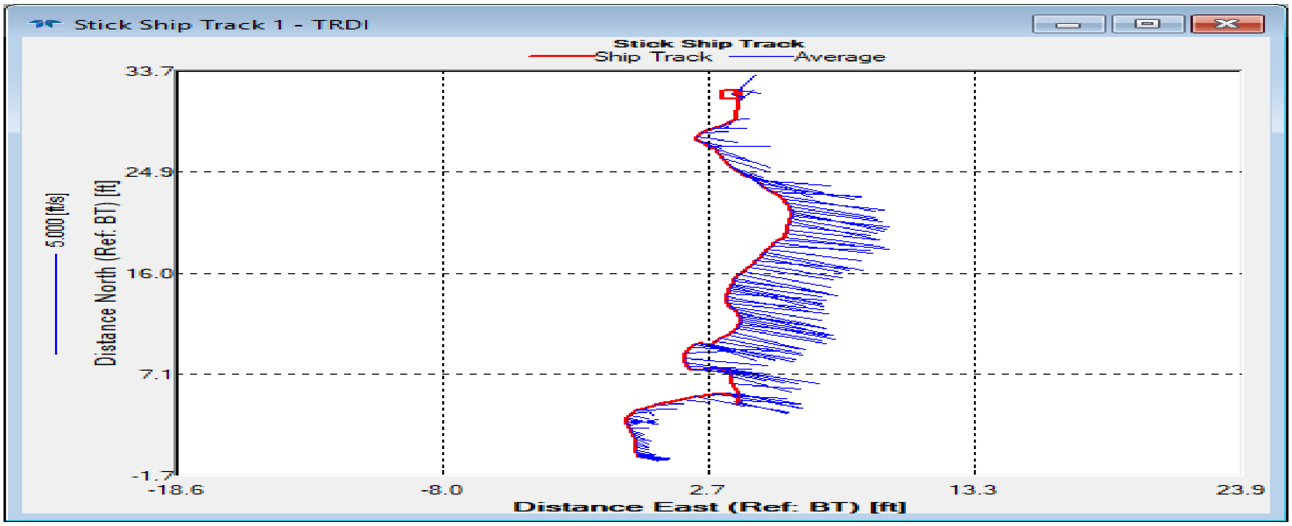


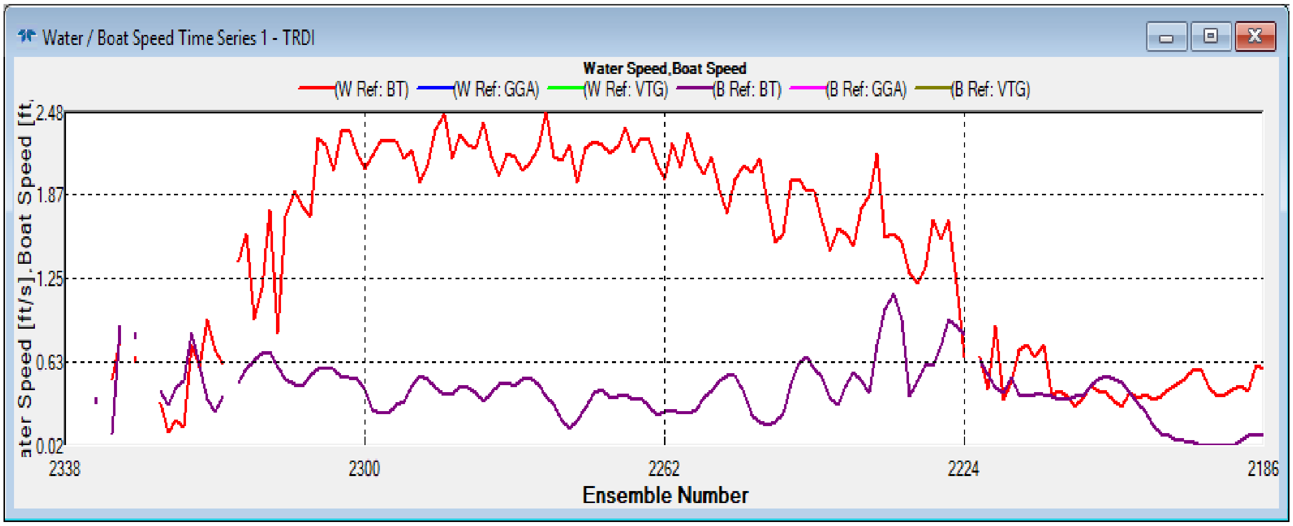




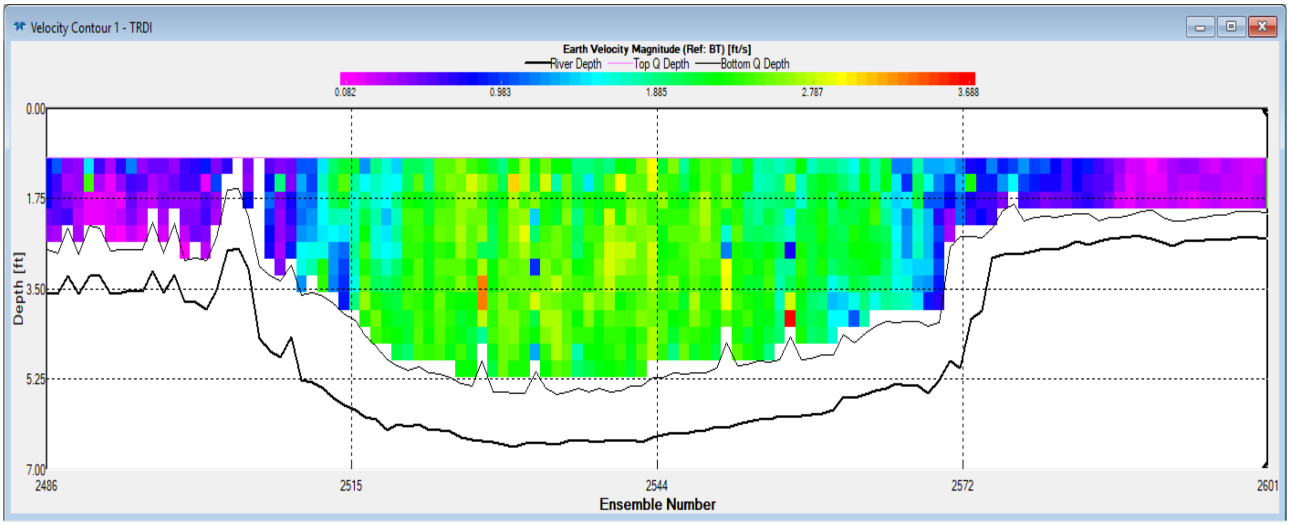
C. Transect UC2C-006 Raw Data Output

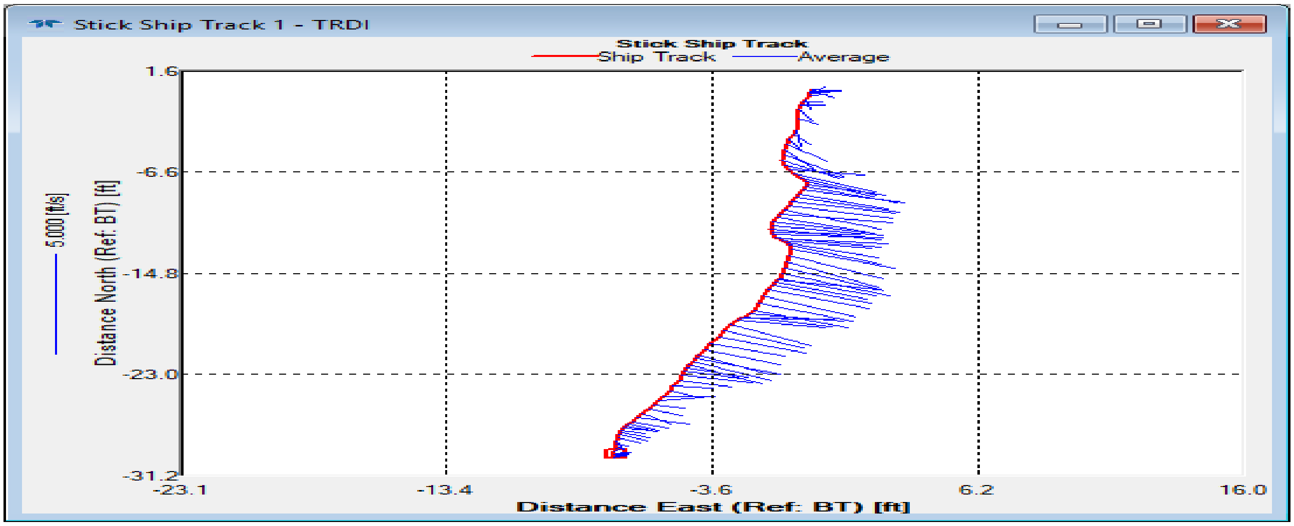


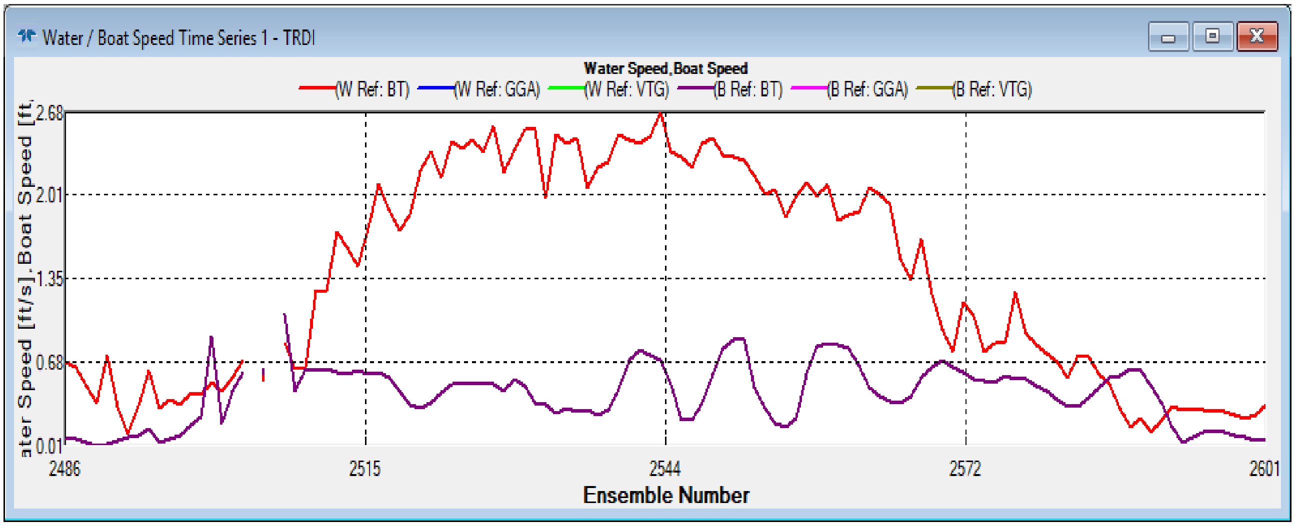


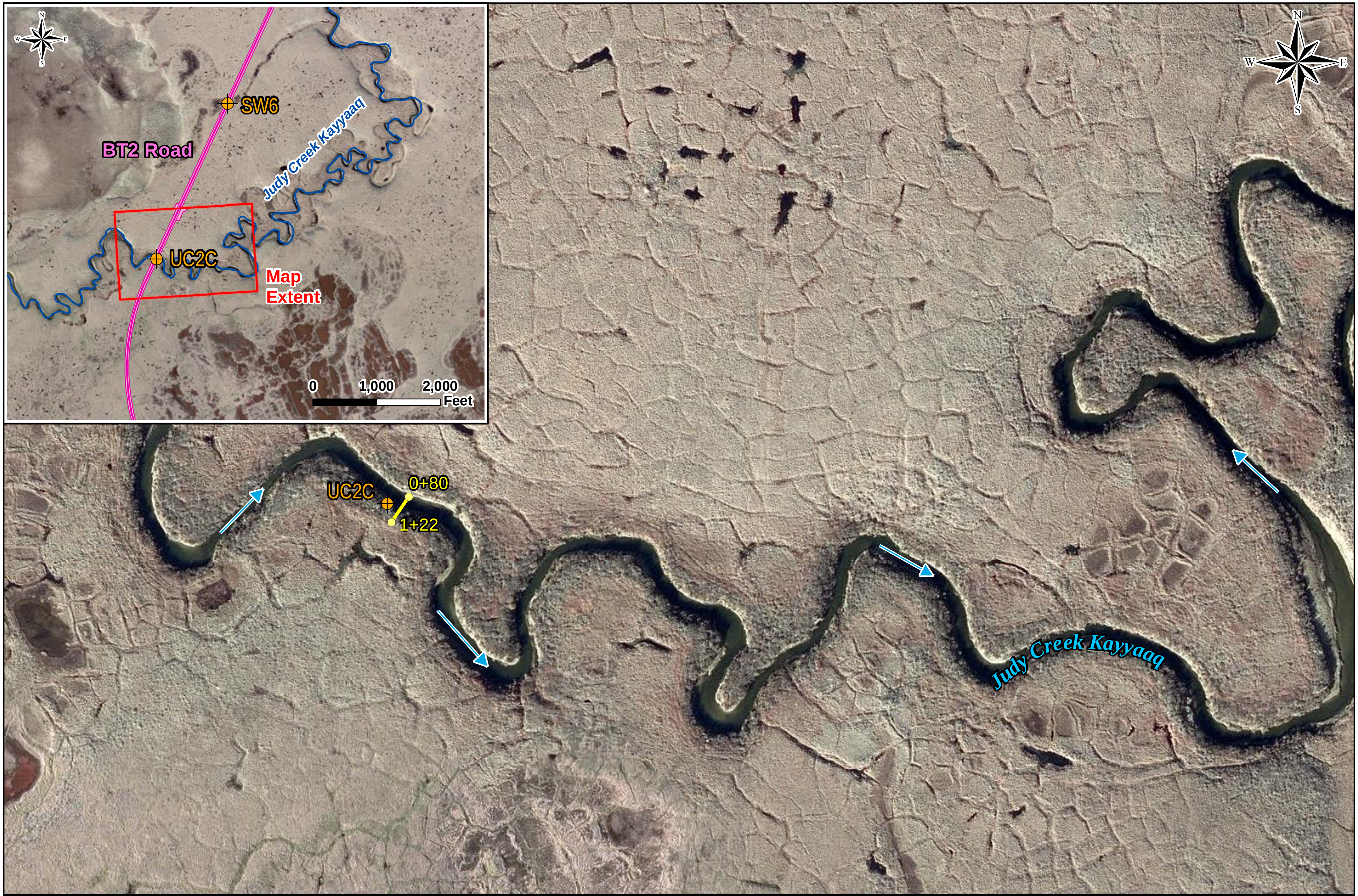


D. Transect UC2C-007 Raw Data Output









ConocoPhillips
Alaska

Feet
0 200 400

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_UC2C.mxd

● Station

→ Flow Direction

⊕ Gage Location

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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Phone: (907) 273-1600
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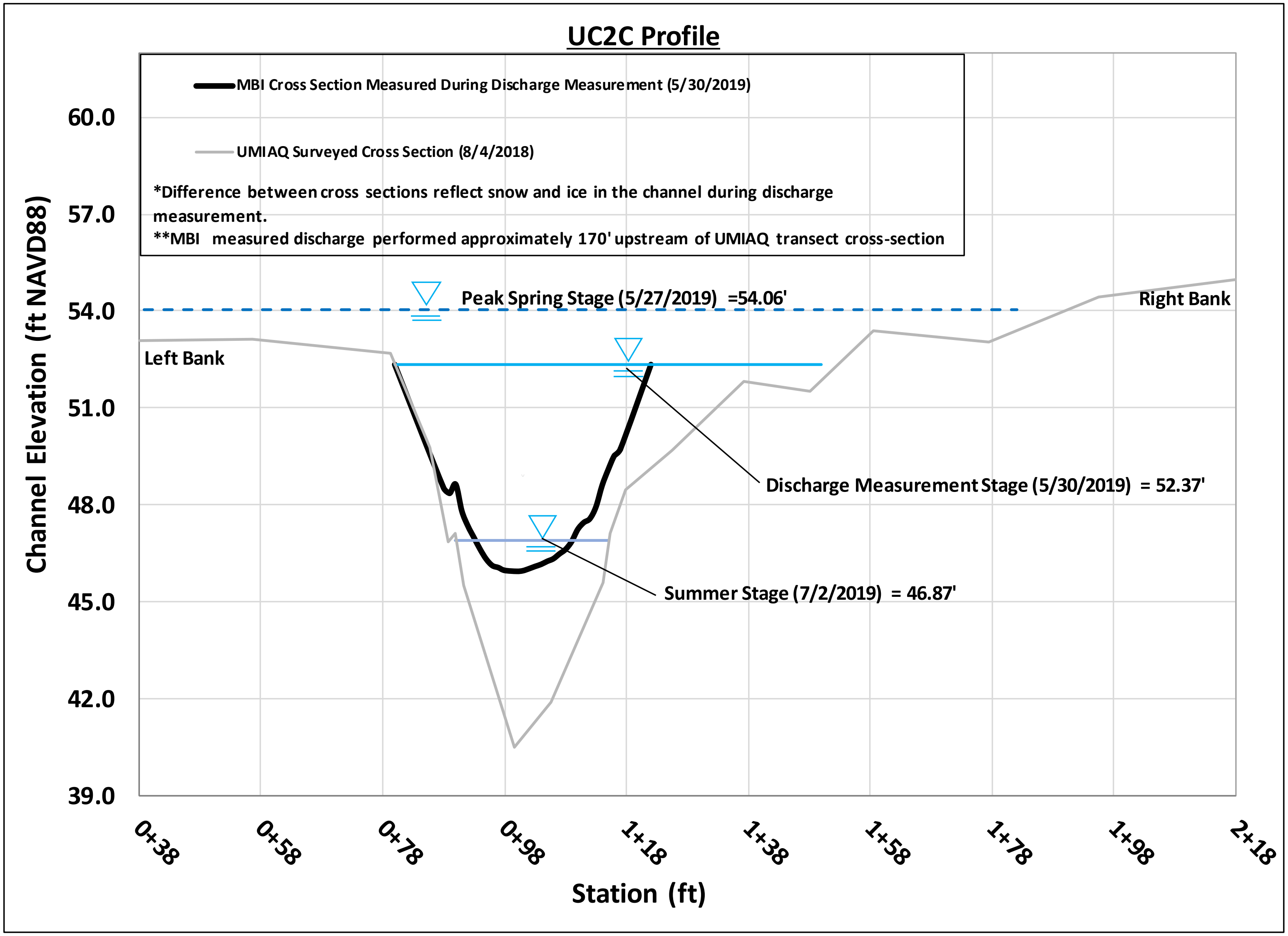
2019 Spring Breakup Judy Creek Kayyaaq at UC2C Plan

FIGURE C.7

Spring Breakup Cross-Section Profile



C.8 WILLOW 4 AT W_BS1

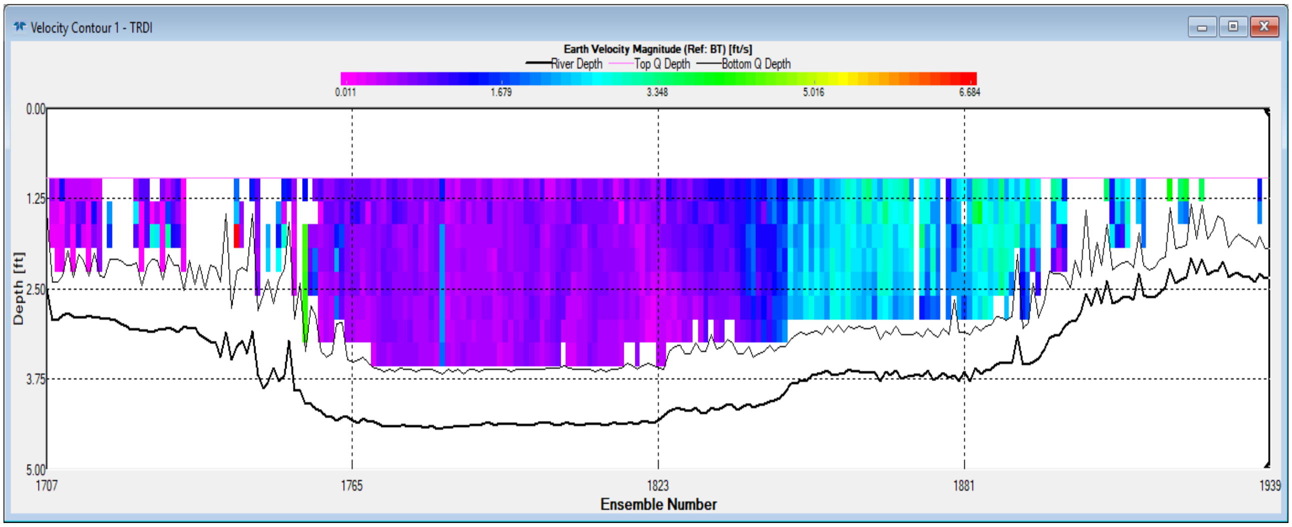
Spring Breakup Measured Discharge

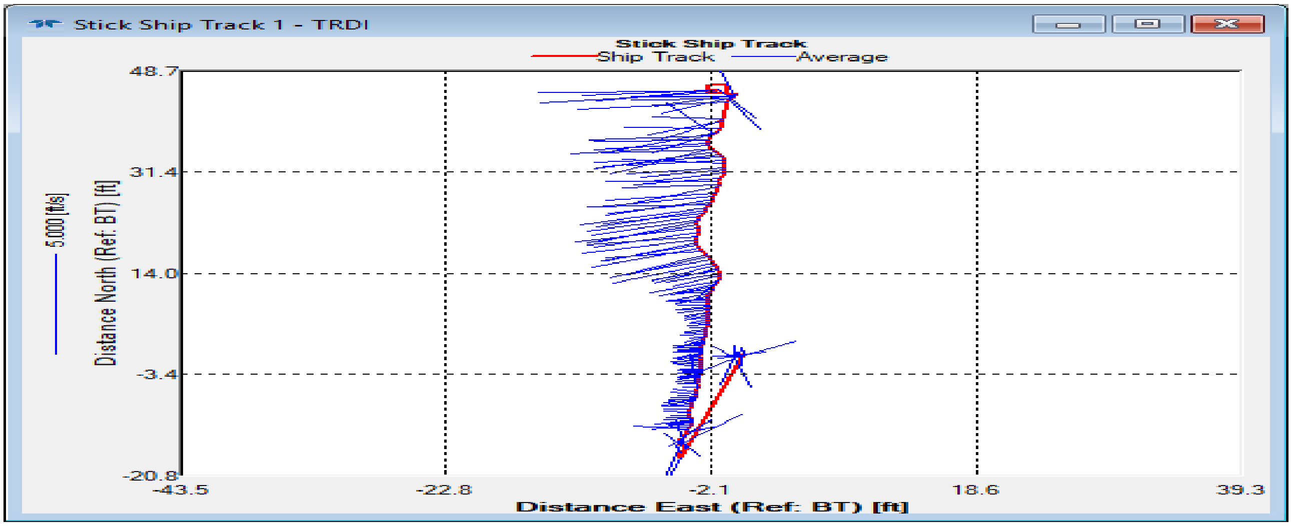
Location:	W_BS1
Date & Time:	May 28, 3:30 PM
Equipment:	RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.
Final Discharge (cfs):	350
Average Velocity (fps):	1.4
Measurement Rating:	Fair
Measurement Notes:	Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (20%) exceeded the recommended maximum of 5%. At the time of the measurement, the river was mostly clear of snow and ice with some snow 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.

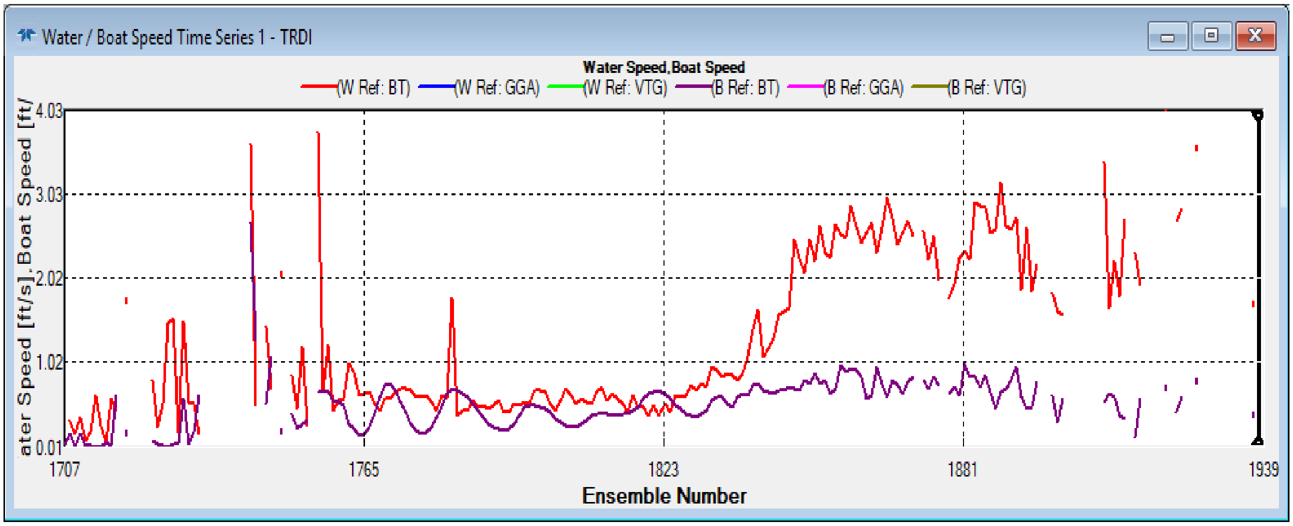
Table C.9: W_BS1 May 28 Spring Breakup Measured Discharge Summary

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	Left	342	-3.12%	162	-2.24%	75	317	223	1.54	1.08
001	Right	363	2.58	163	-1.99%	93	266	280	1.30	1.36
002	Left	344	-2.66%	168	1.21%	95	291	291	1.19	1.18
003	Right	365	3.20%	171	3.03%	88	268	266	1.37	1.36
Average		354		166		88		165	1.35	1.25

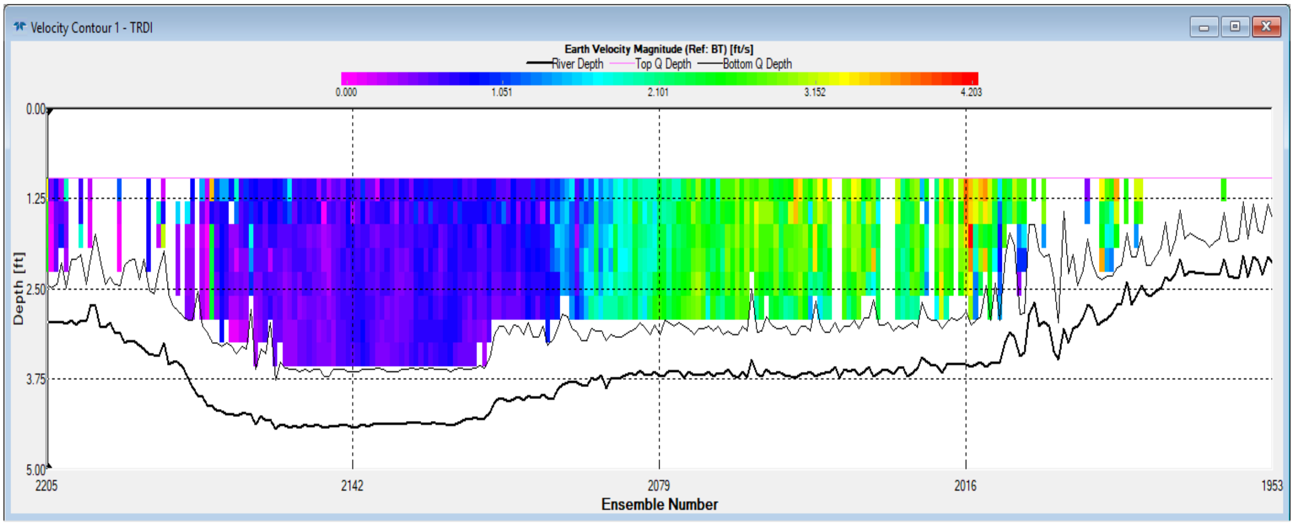
A. Transect W_BS1-000 Raw Data Output

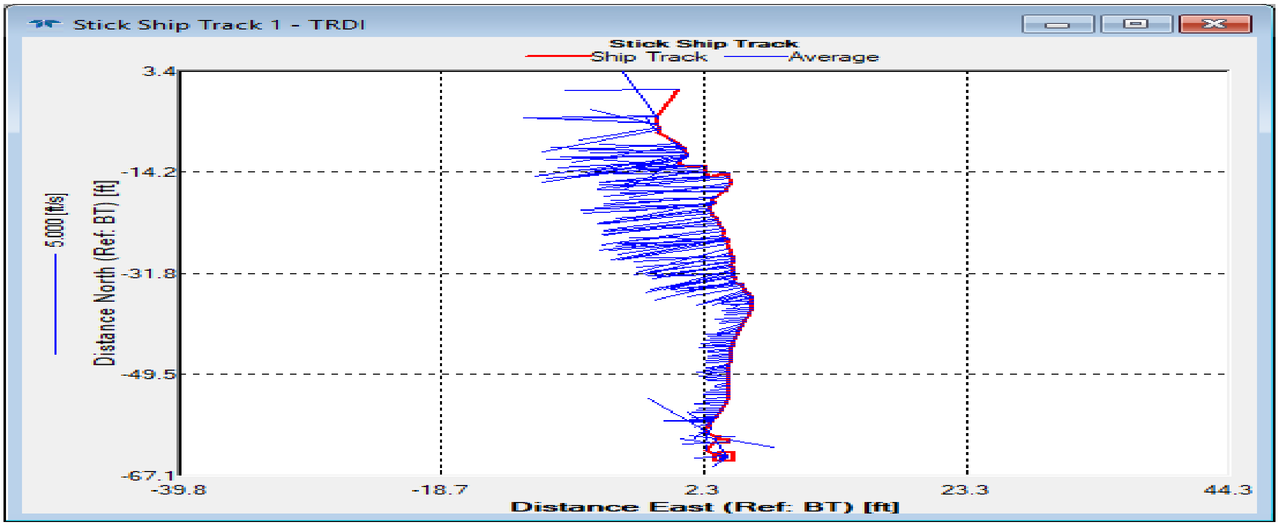


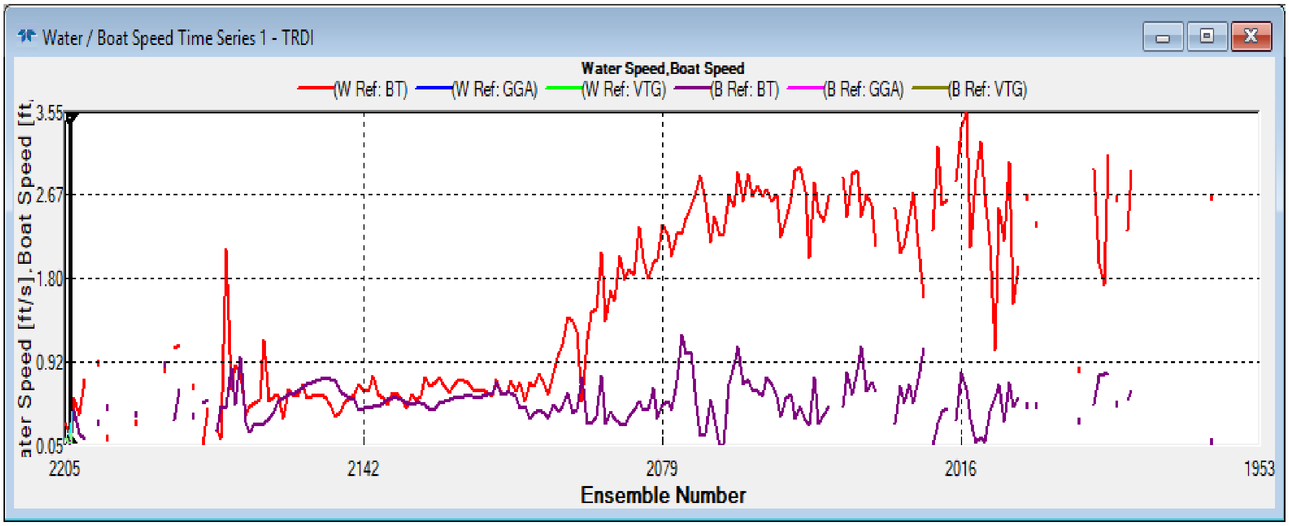




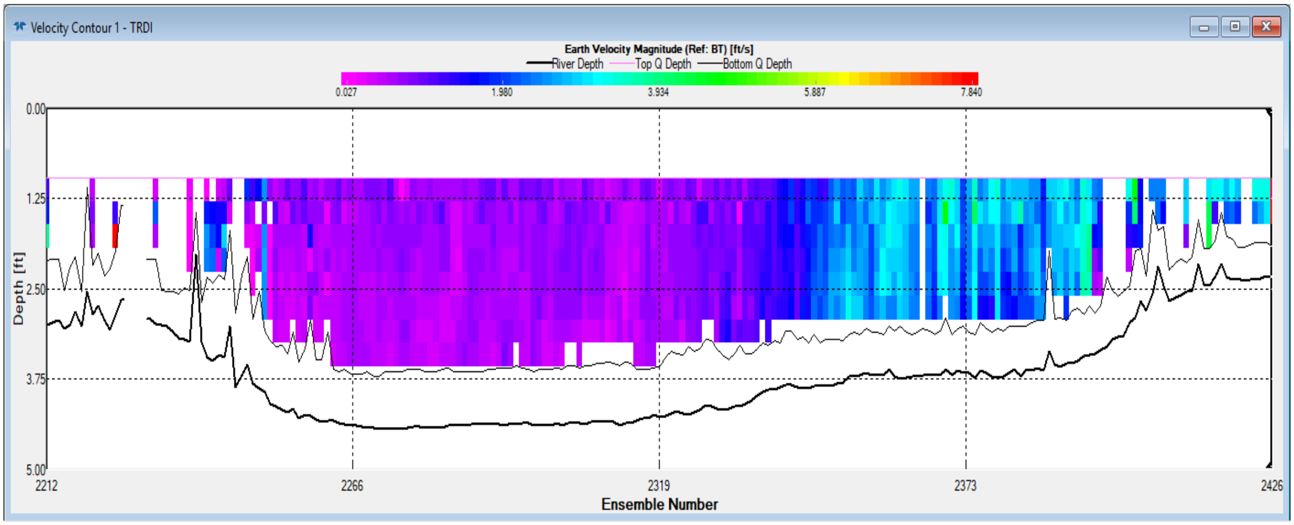
B. Transect W_BS1-001 Raw Data Output

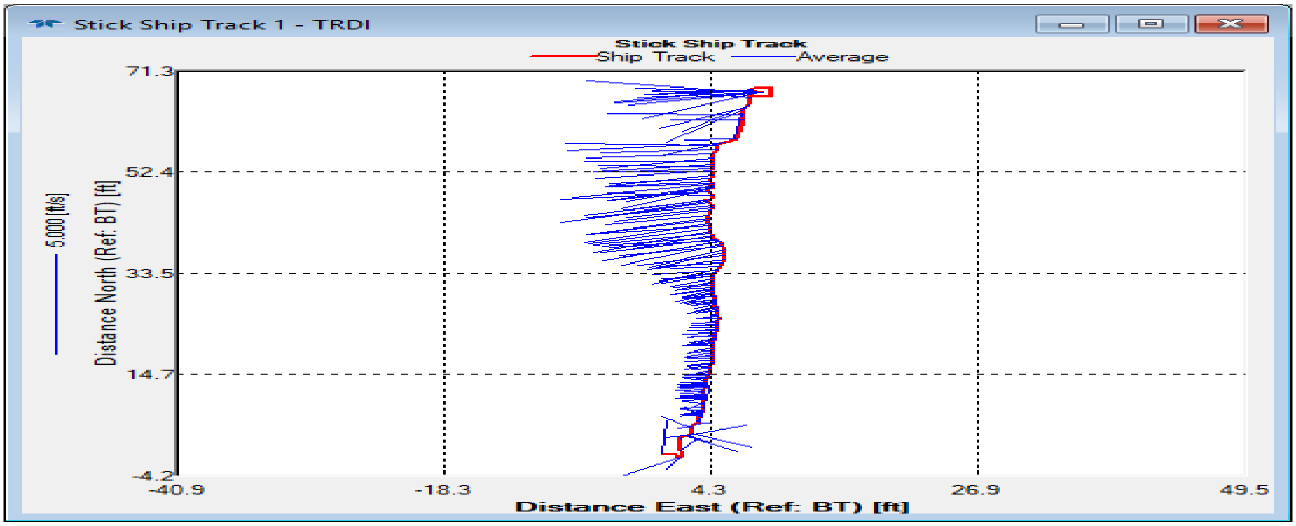


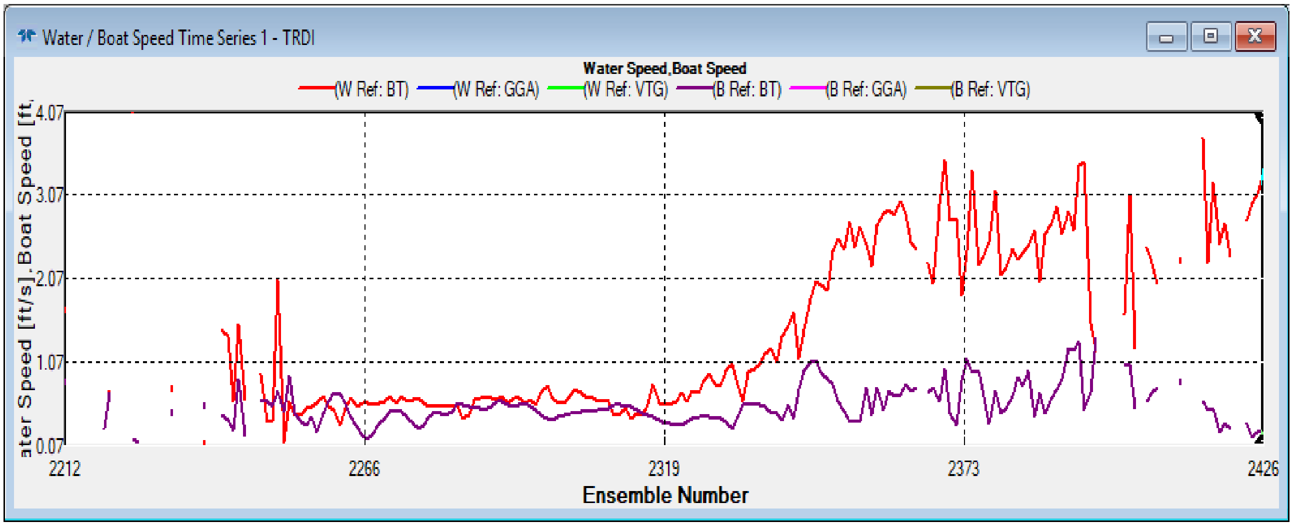




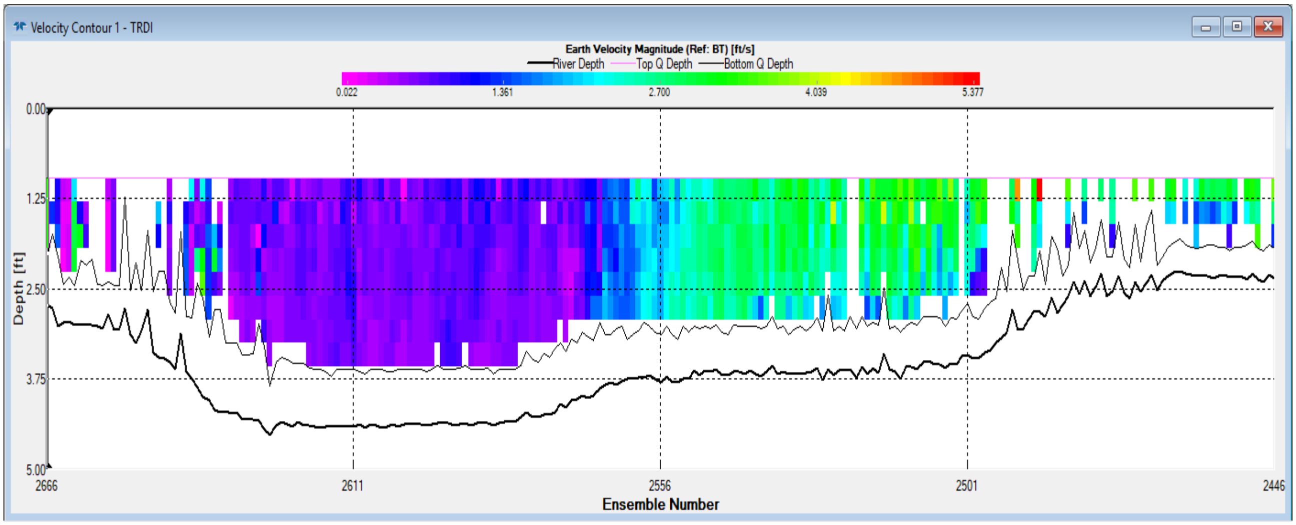
C. Transect W_BS1-002 Raw Data Output

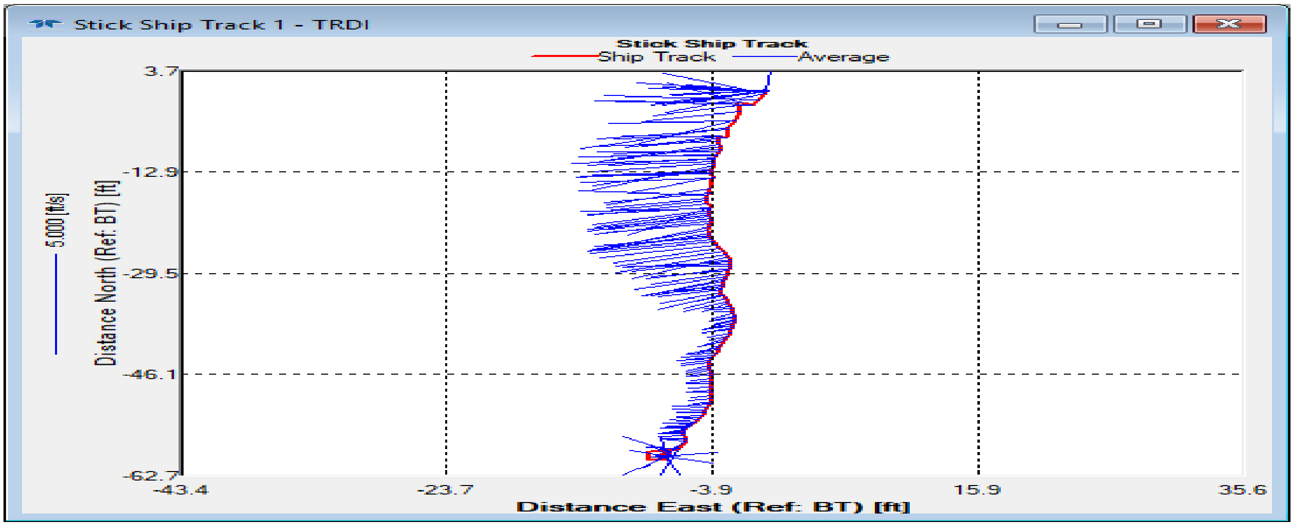


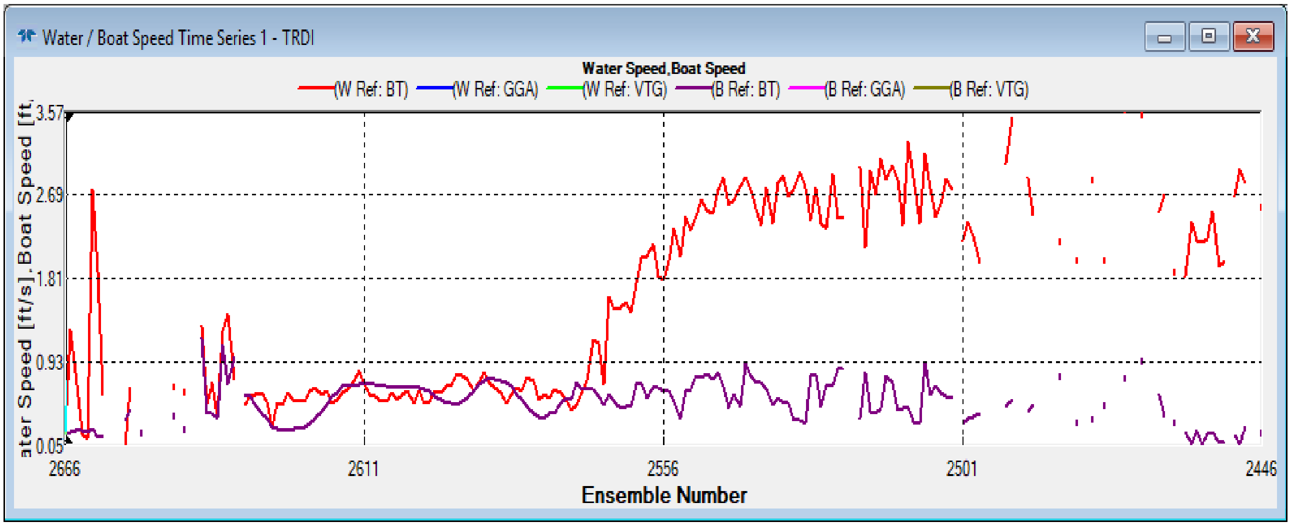




D. Transect W_BS1-003 Raw Data Output







ConocoPhillips
Alaska

Feet
0 200 400

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_W_BS1.mxd

⊕	Gage Location
→	Flow Direction
●	Station
—	Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

Michael Baker
INTERNATIONAL

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Anchorage, AK 99503
Phone: (907) 273-1600
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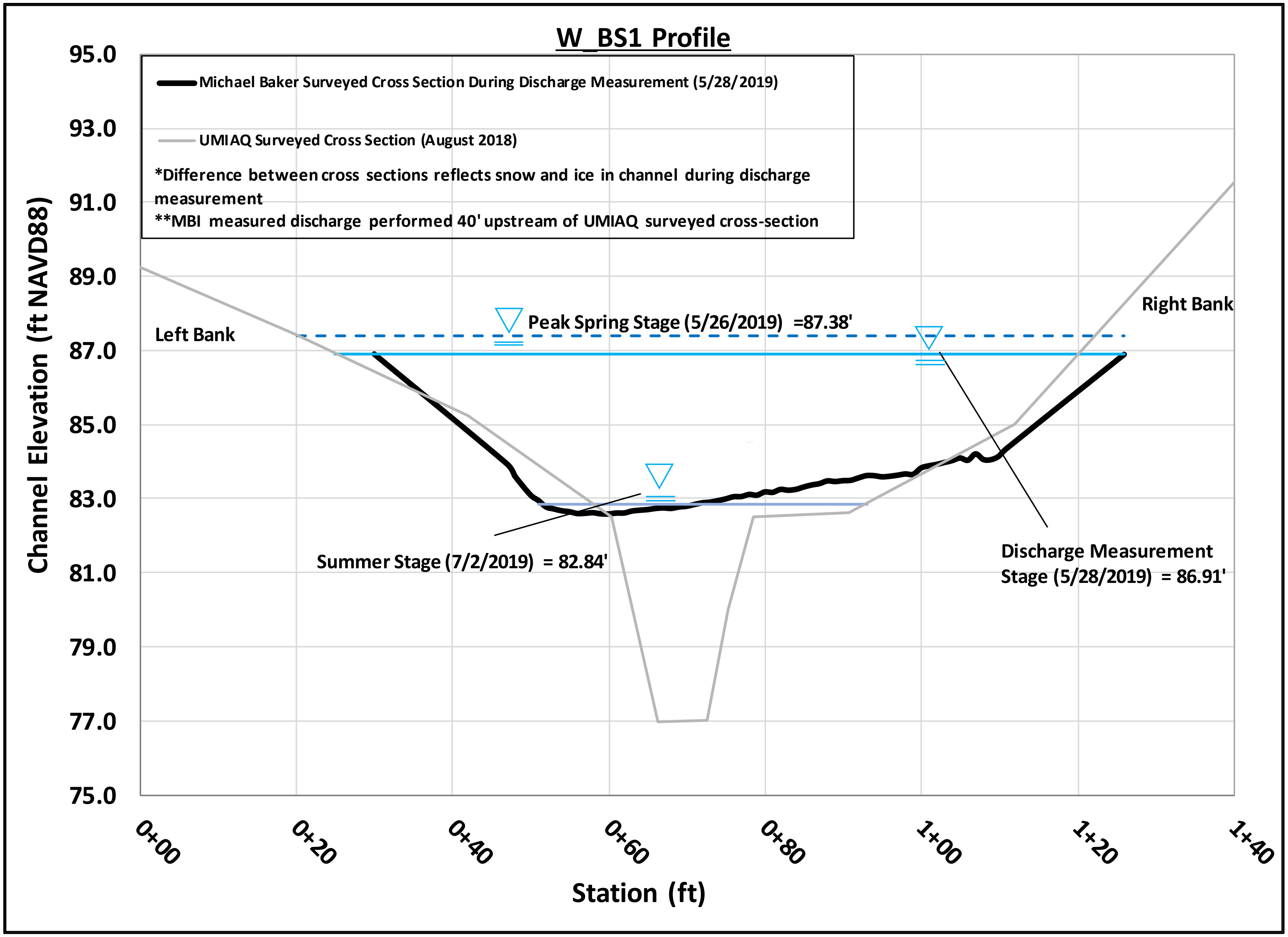
2019 Spring Breakup Willow 4 at W_BS1 Plan

FIGURE C.8

Spring Breakup Cross-Section Profile



C.9 WILLOW 4 AT W4

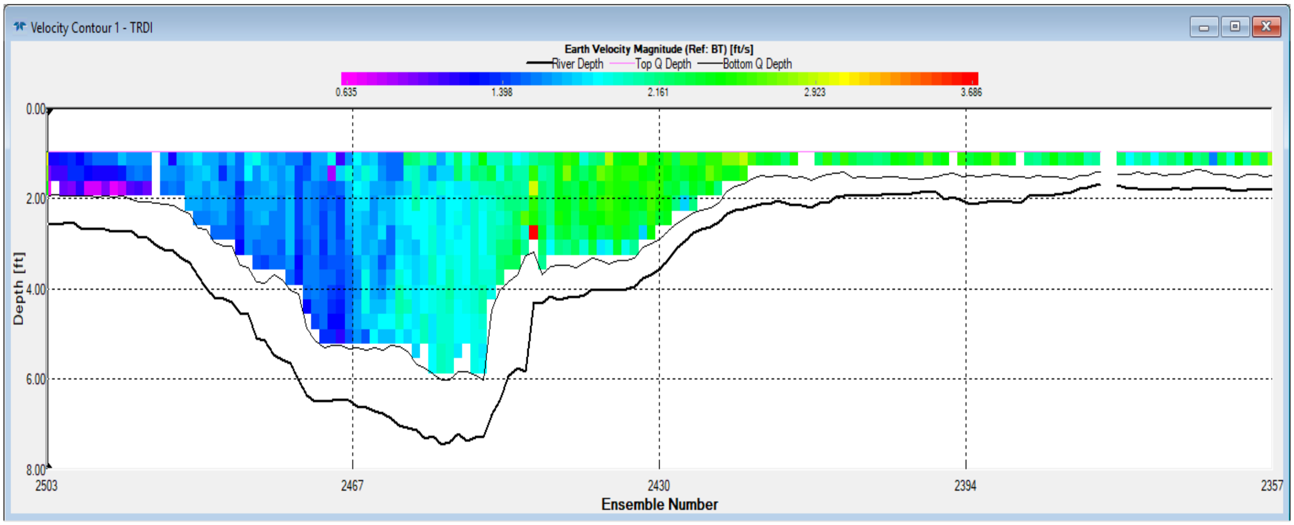
Spring Breakup Measured Discharge

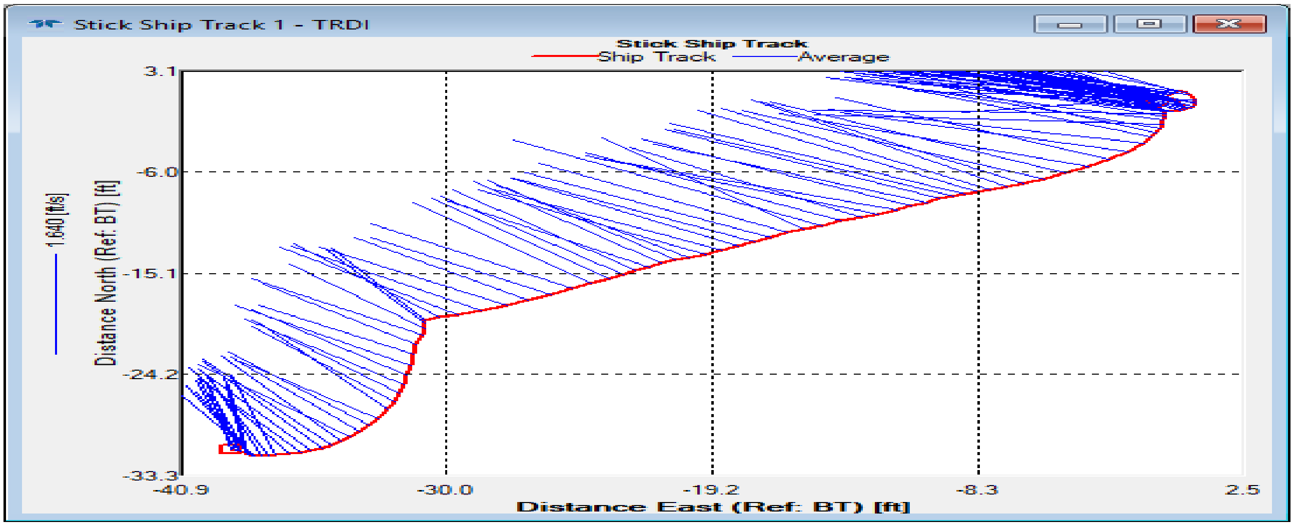
Location:	W4
Date & Time:	June 2, 2:45 PM
Equipment:	RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel.
Final Discharge (cfs):	450
Average Velocity (fps):	1.6
Measurement Rating:	Fair
Measurement Notes:	Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (10%) exceeded the recommended maximum of 5%. At the time of the measurement, the river was mostly clear of snow and ice with some snow 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.

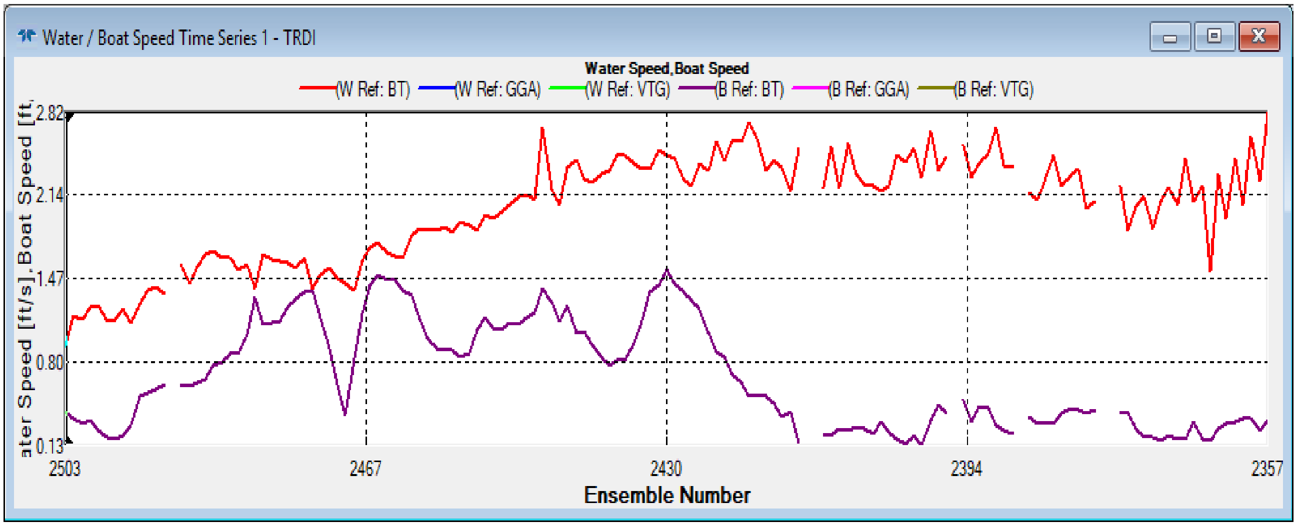
Table C.10: W_4 May 28 Spring Breakup Measured Discharge Summary

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)
001	Right	475	3.99%	244	3.73%	85	258	290	1.64	1.84
002	Right	459	0.41%	236	0.28%	85	253	287	1.60	1.81
003	Left	441	-3.44%	228	-3.08%	83	257	278	1.59	1.71
004	Right	458	0.36%	239	1.47%	84	253	288	1.59	1.81
005	Left	446	-2.28%	229	-2.39%	86	262	282	1.58	1.70
006	Right	461	0.97%	235	0.00%	83	265	293	1.57	1.74
Average		**457**		**235**		**84**		**286**	**1.59**	**1.77**

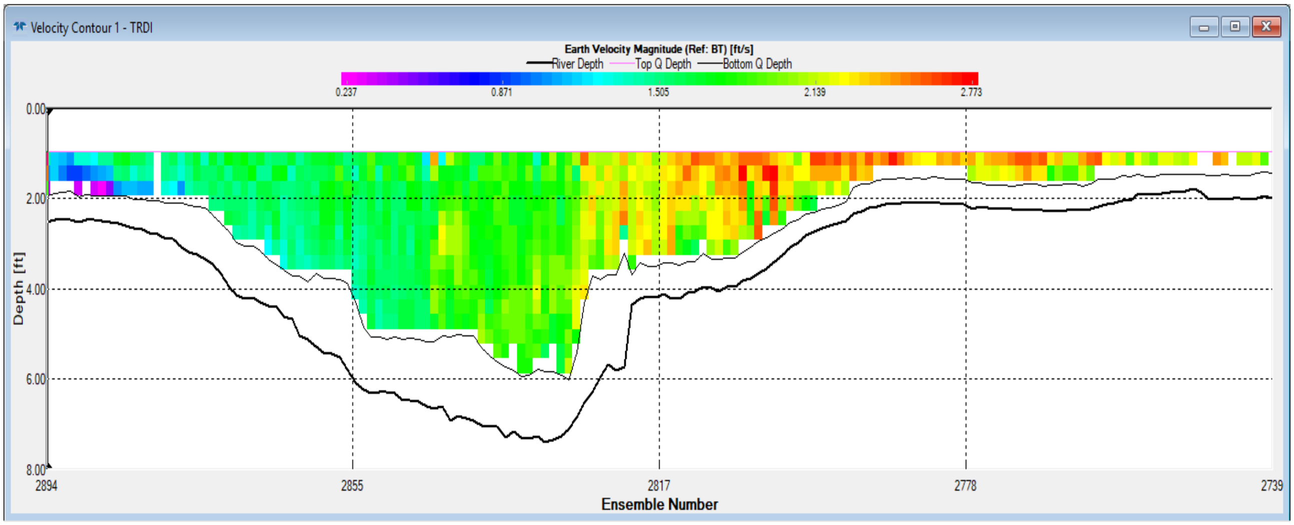
A. Transect W4-001 Raw Data Output

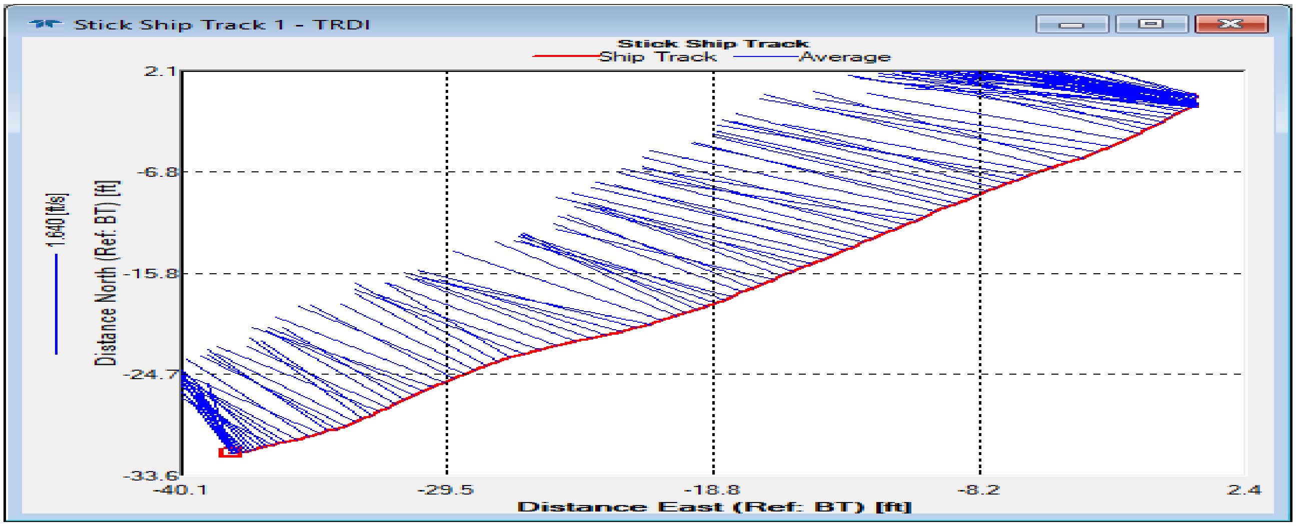


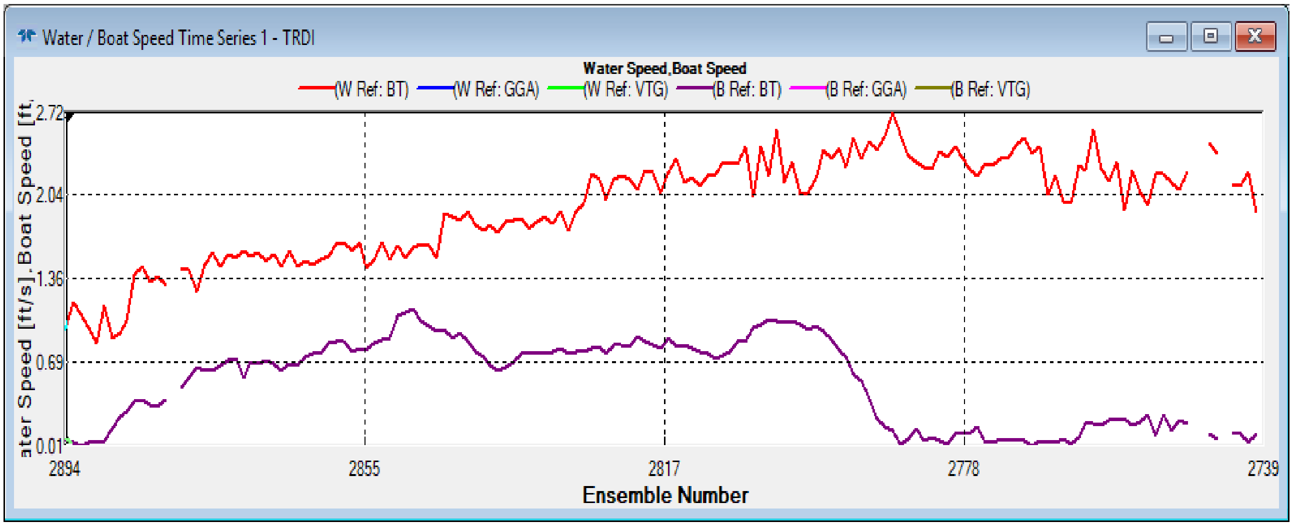




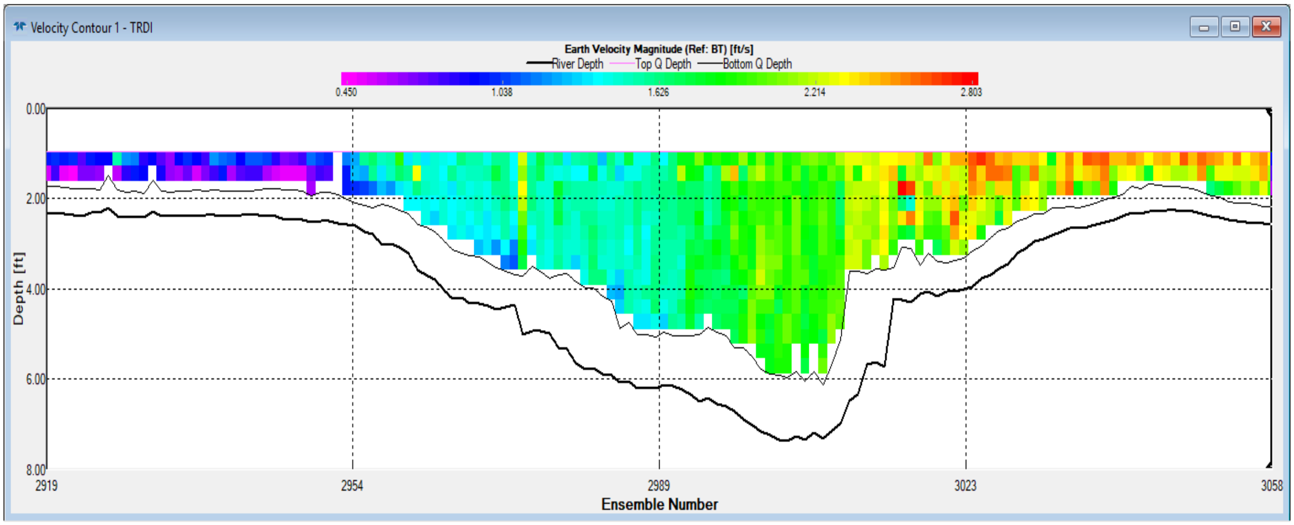
B. Transect W4-002 Raw Data Output

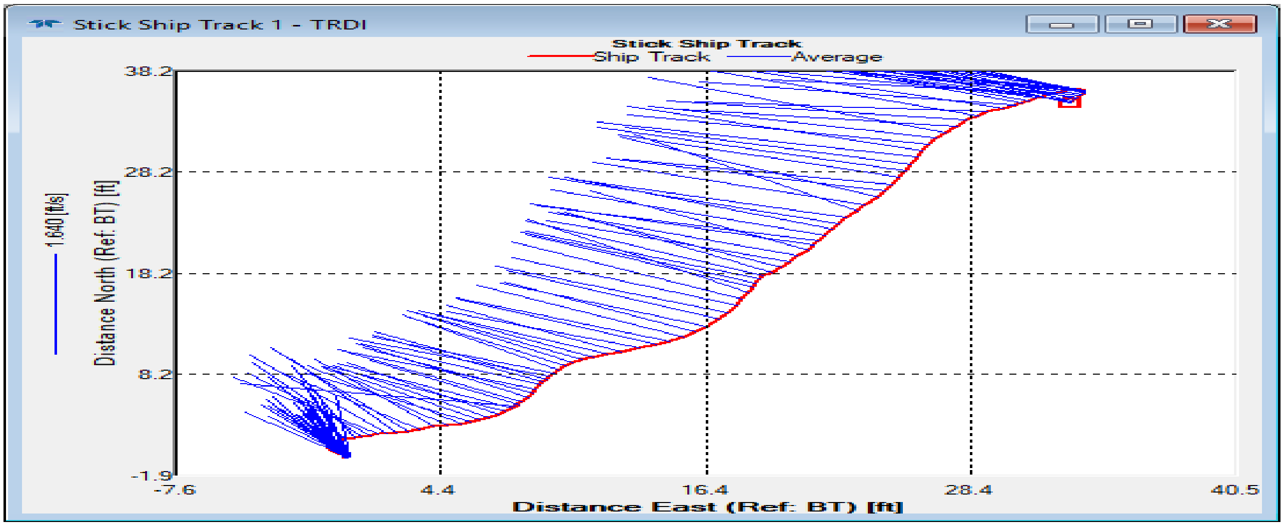


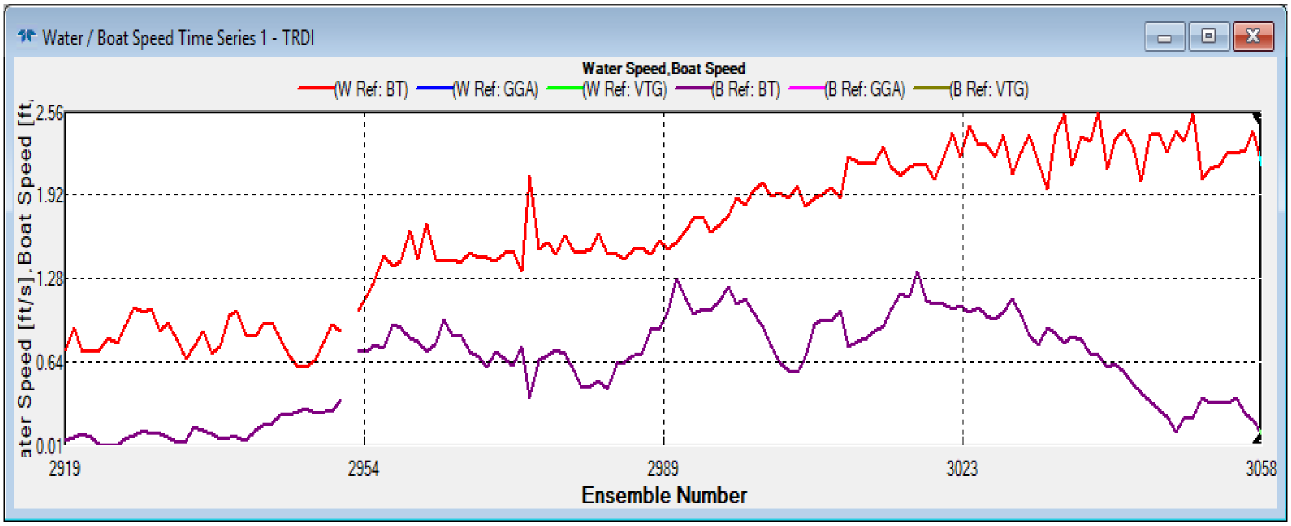




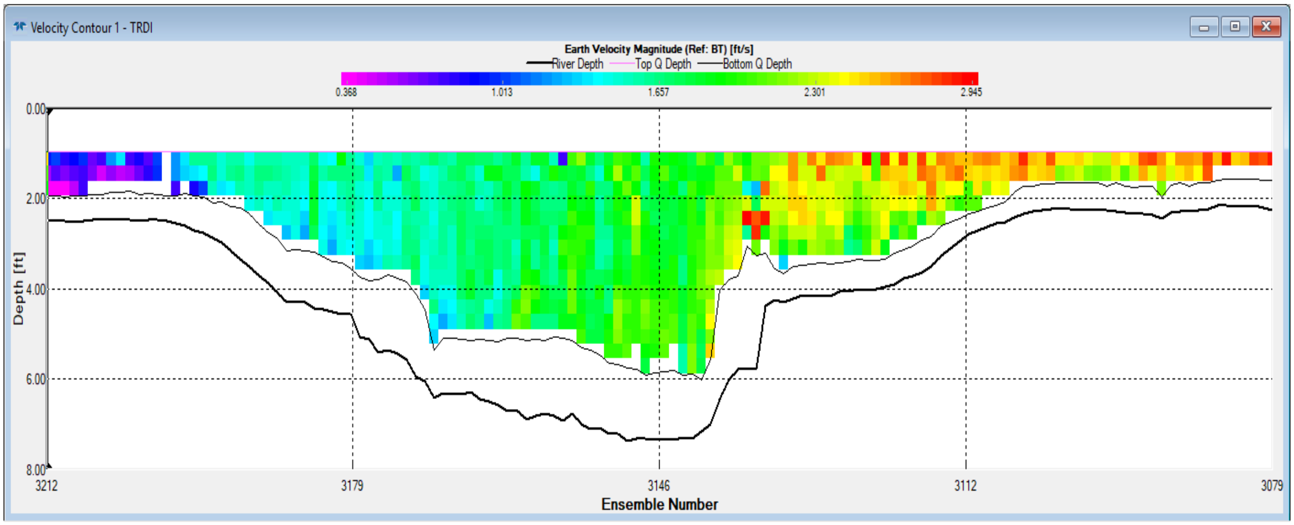
C. Transect W4-003 Raw Data Output

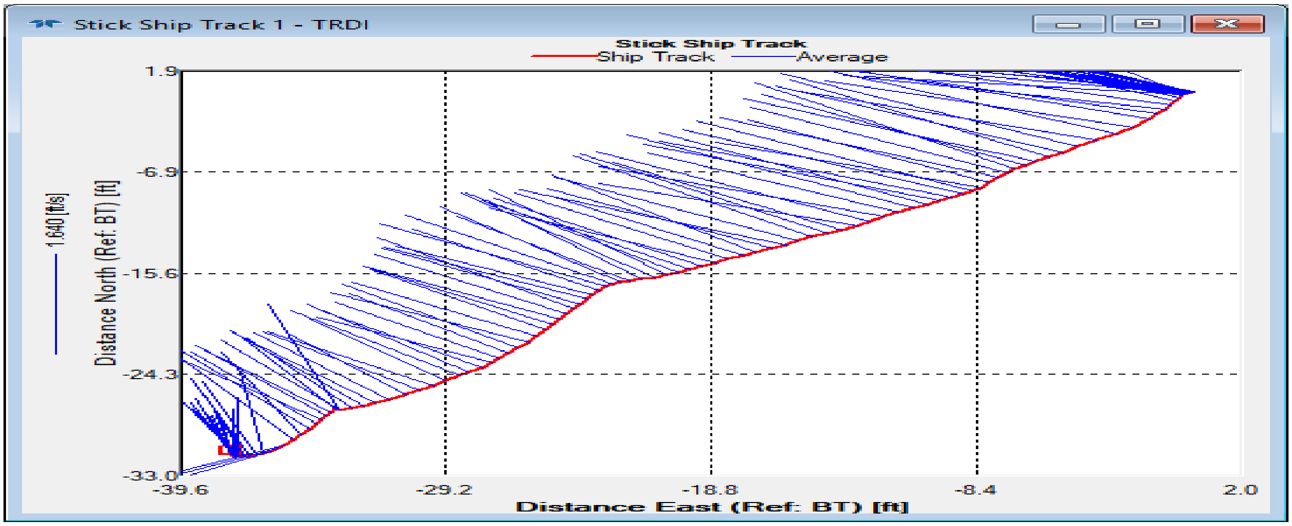


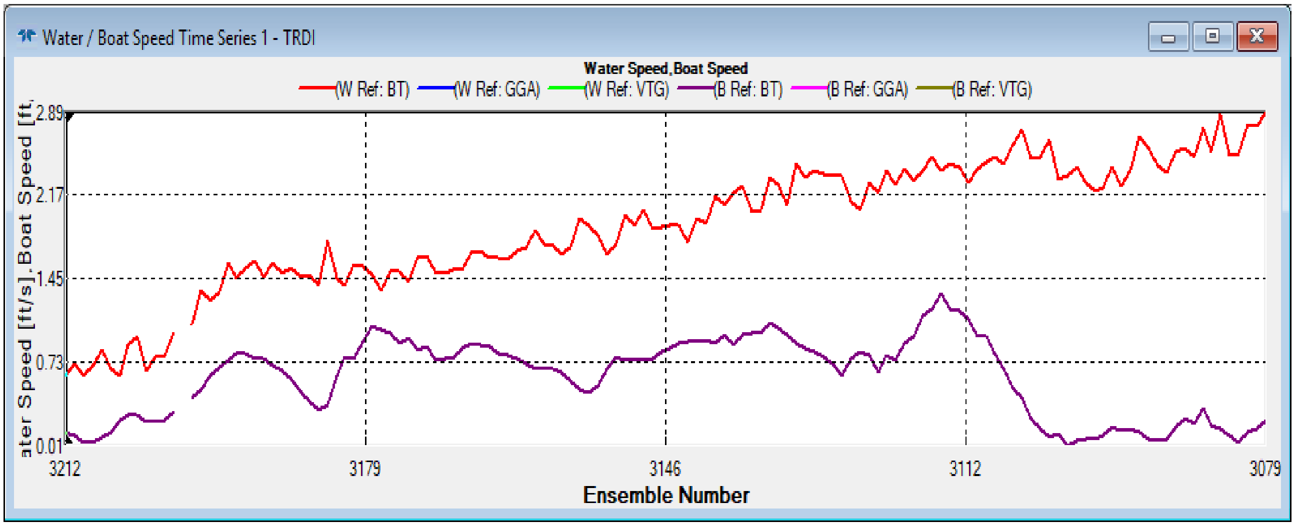




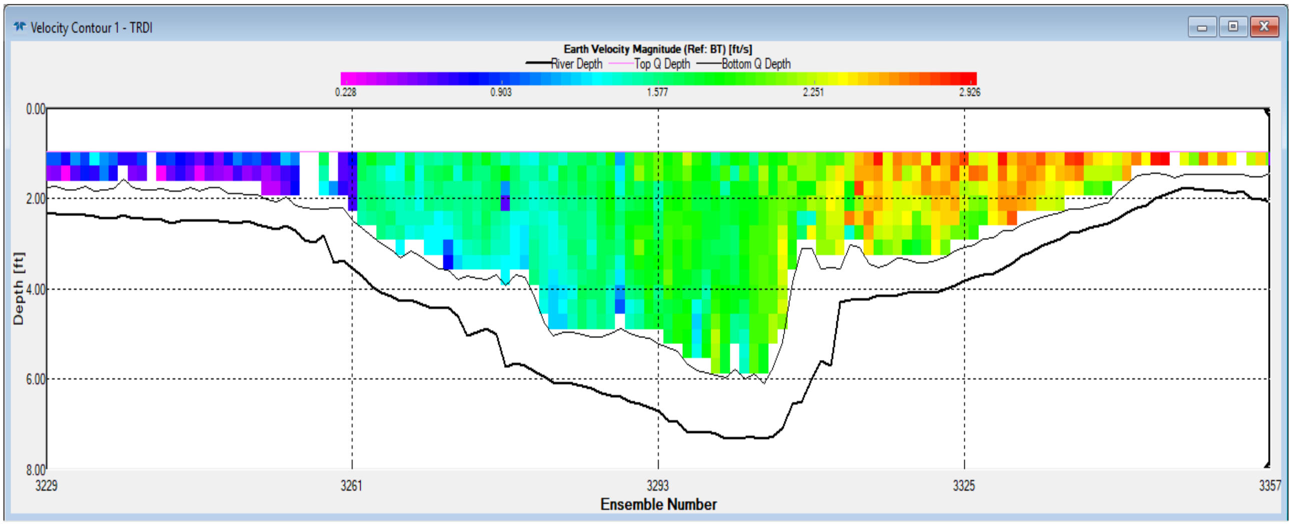
D. Transect W4-004 Raw Data Output

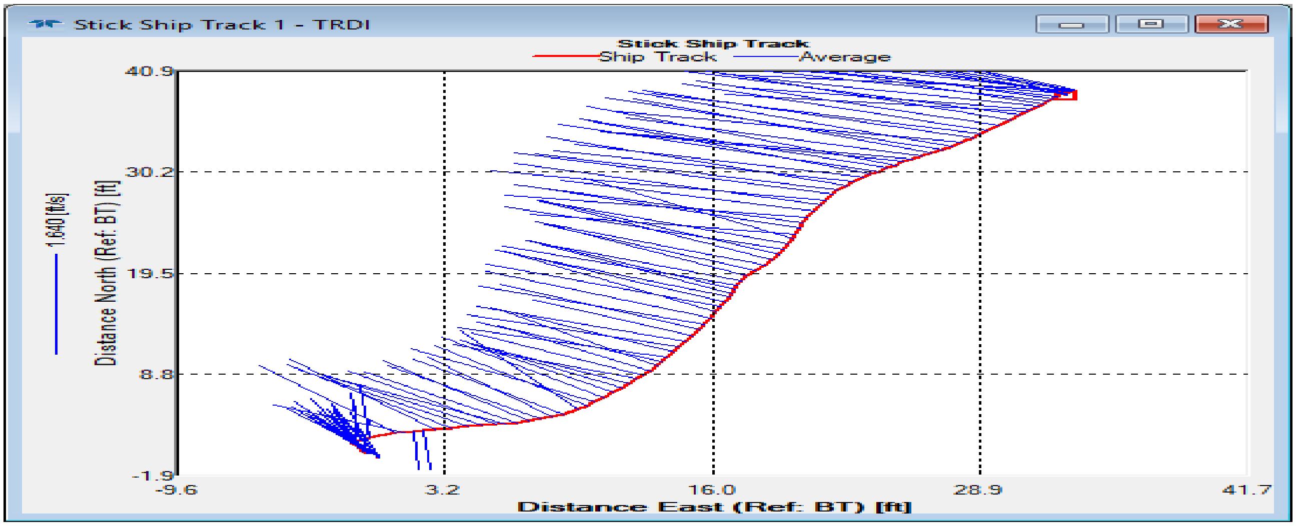


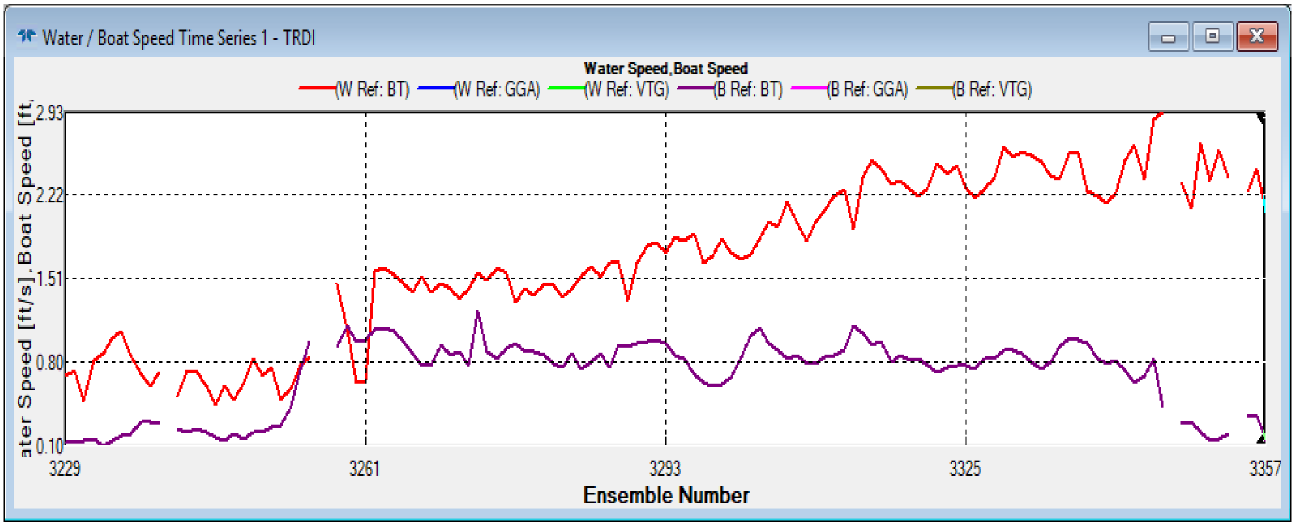




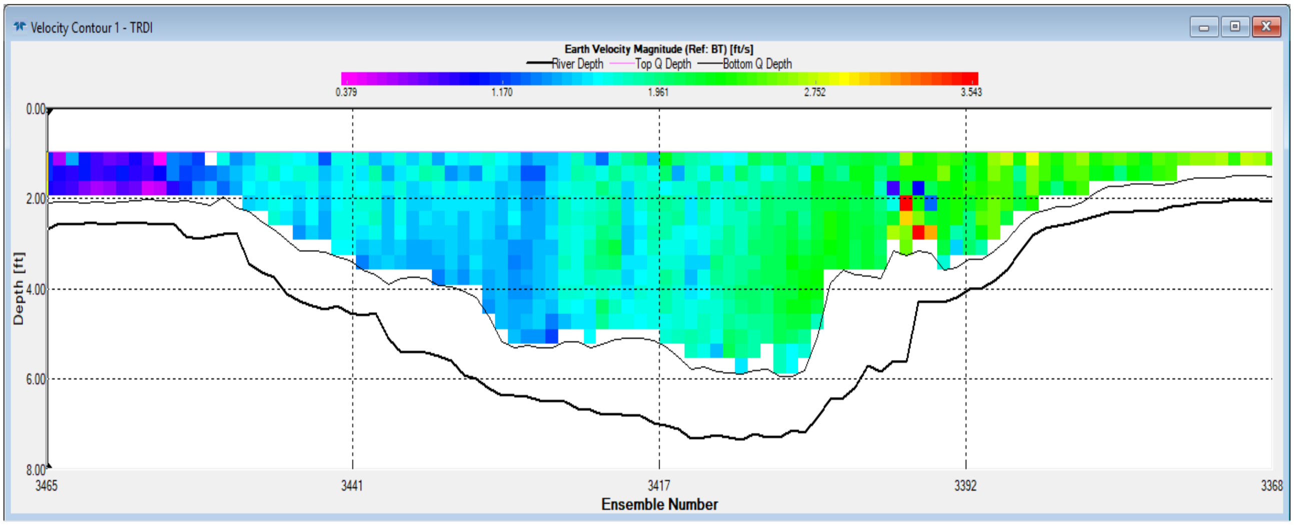
E. Transect W4-005 Raw Data Output

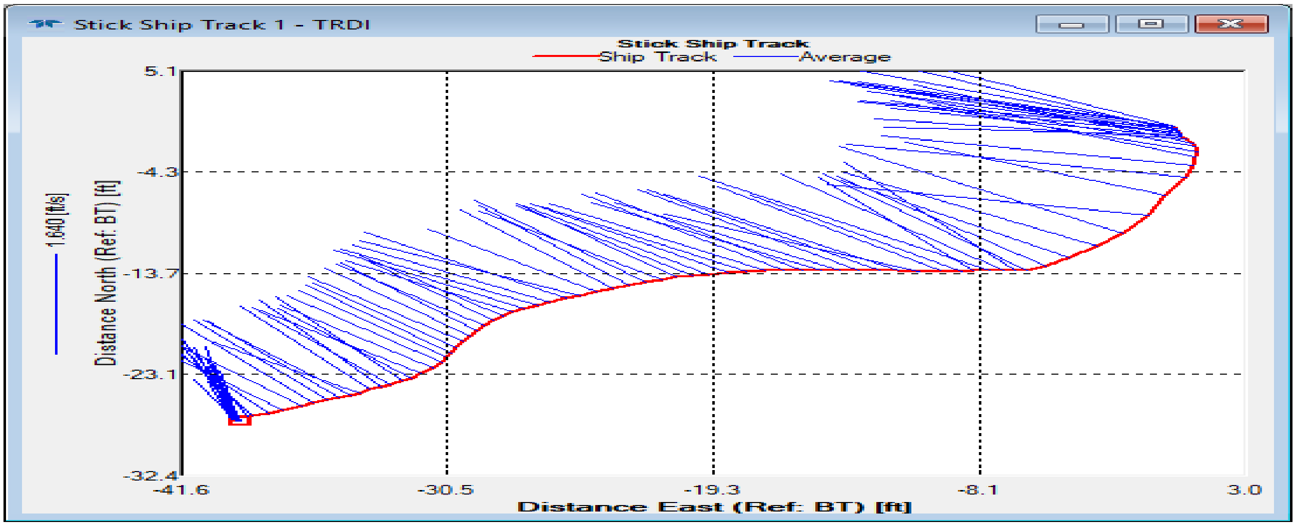


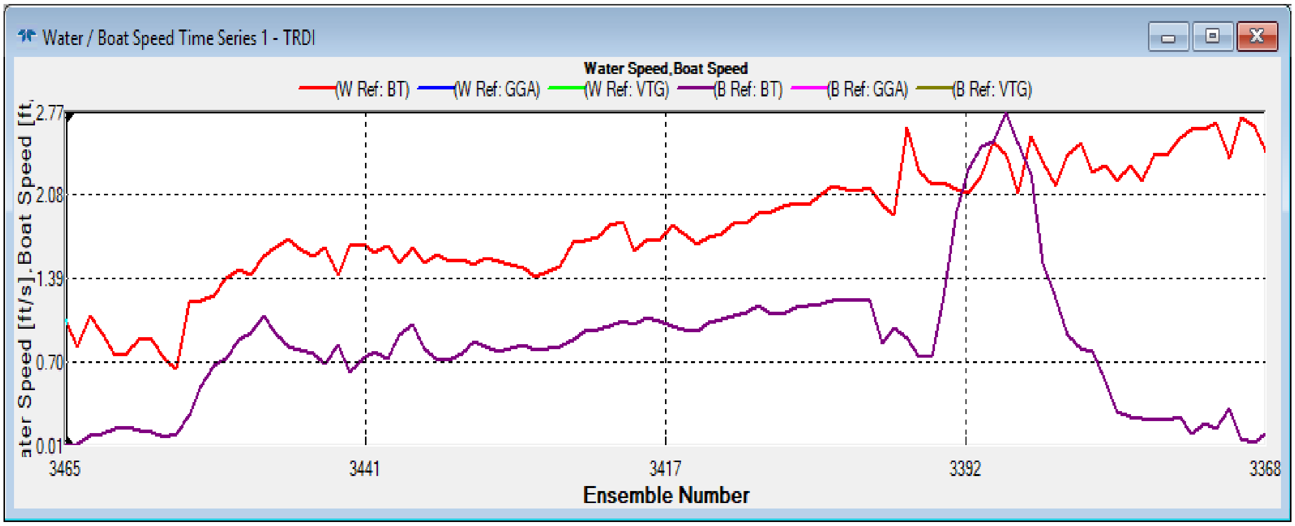




F. Transect W4-006 Raw Data Output







ConocoPhillips
Alaska

Feet
0 200 400 600

Date:	10/18/2019	Scale:	1 Inch = 400 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_W4.mxd

⊕ Gage Location

→ Flow Direction

● Station

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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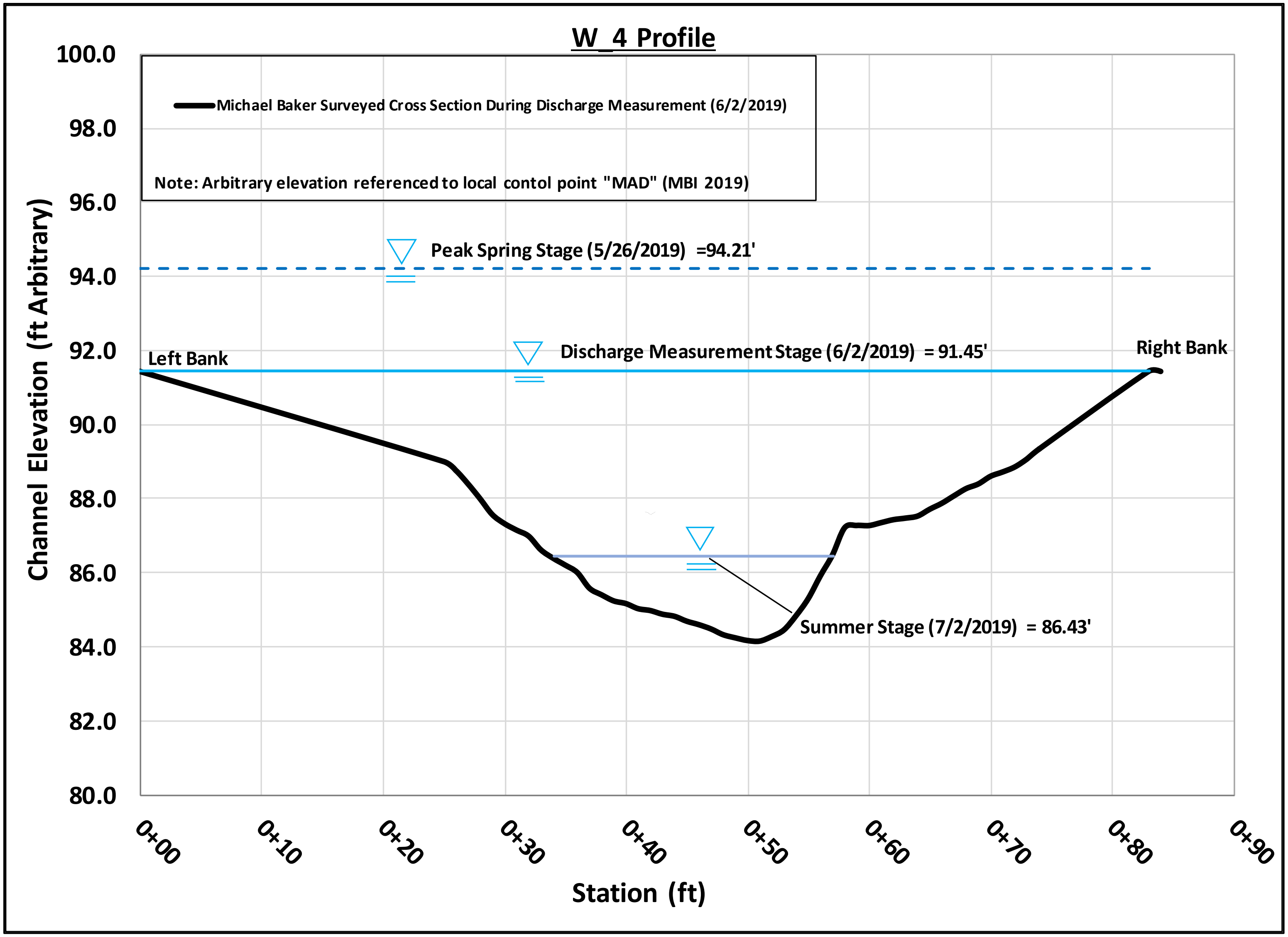
2019 Spring Breakup Willow 4 at W4 Plan

FIGURE C.9

Spring Breakup Cross-Section Profile



C.10 WILLOW 4A AT W_S1

Spring Breakup Measured Discharge

Location: W_S1

Date & Time: May 29, 5:00 PM

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

Final Discharge (cfs): 320

Average Velocity (fps): 2.1

Measurement Rating: Fair

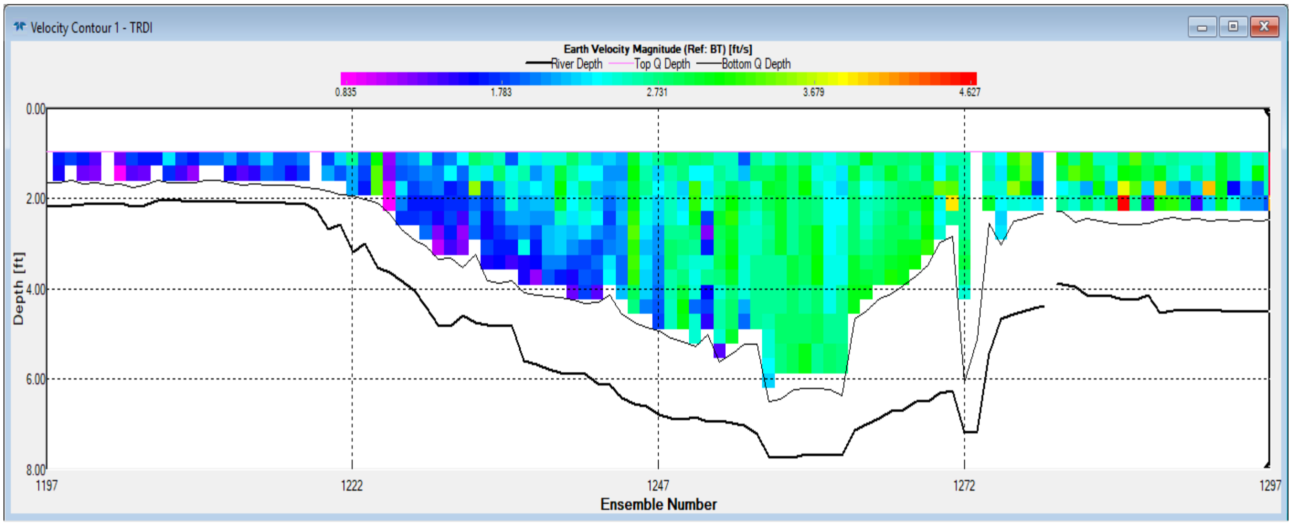
Measurement Notes: Moving bed conditions were measured as minimal and not applied to the total discharge. The percentage of bad bottom track values (10%) exceeded the recommended maximum of 5%.

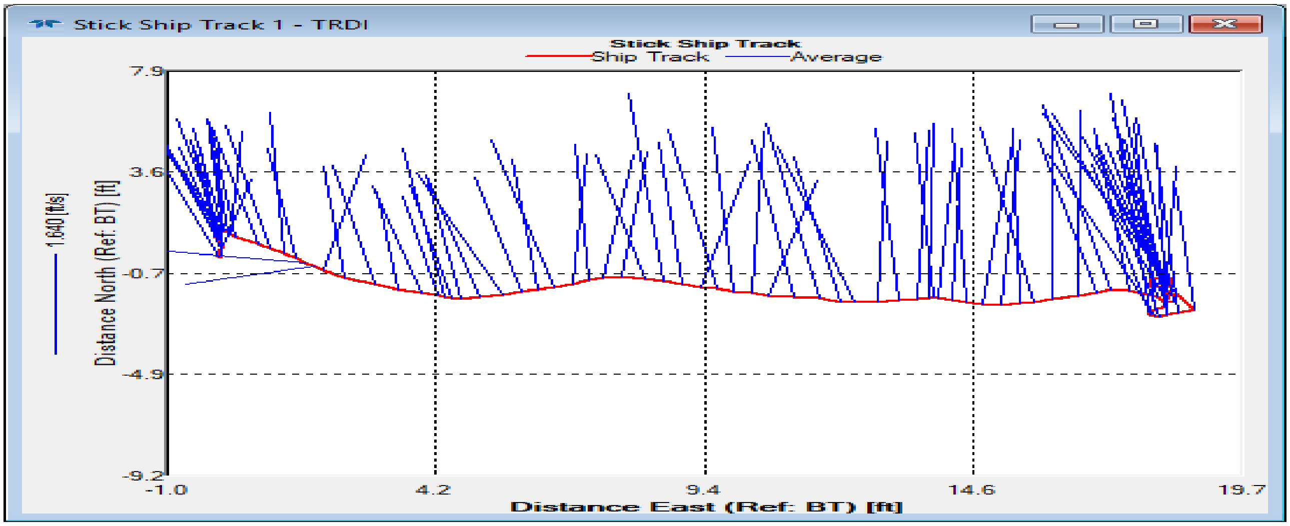
At the time of the measurement, the river was mostly clear of snow and ice. There was a small ice jam present just upstream of the discharge cross section. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on conditions at the time of the measurement.

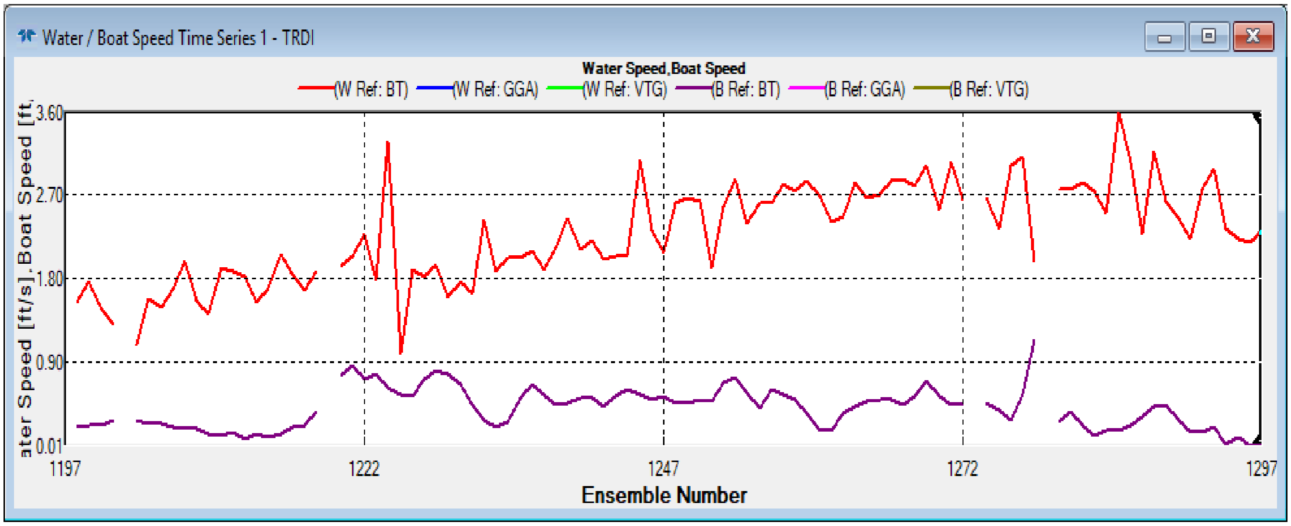
Table C.11: W_S1 May 29 Spring Breakup Measured Discharge Summary

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)
002	Left	304	-4.79%	131	-3.47%	39	128	145	2.09	2.37
003	Right	328	2.93%	140	3.17%	40	128	148	2.23	2.56
005	Left	313	-1.74%	134	-1.49%	40	130	144	2.17	2.42
006	Right	330	3.60%	138	1.80%	46	143	163	2.03	2.31
Average		**319**		**136**		**41**		**150**	**2.13**	**2.41**

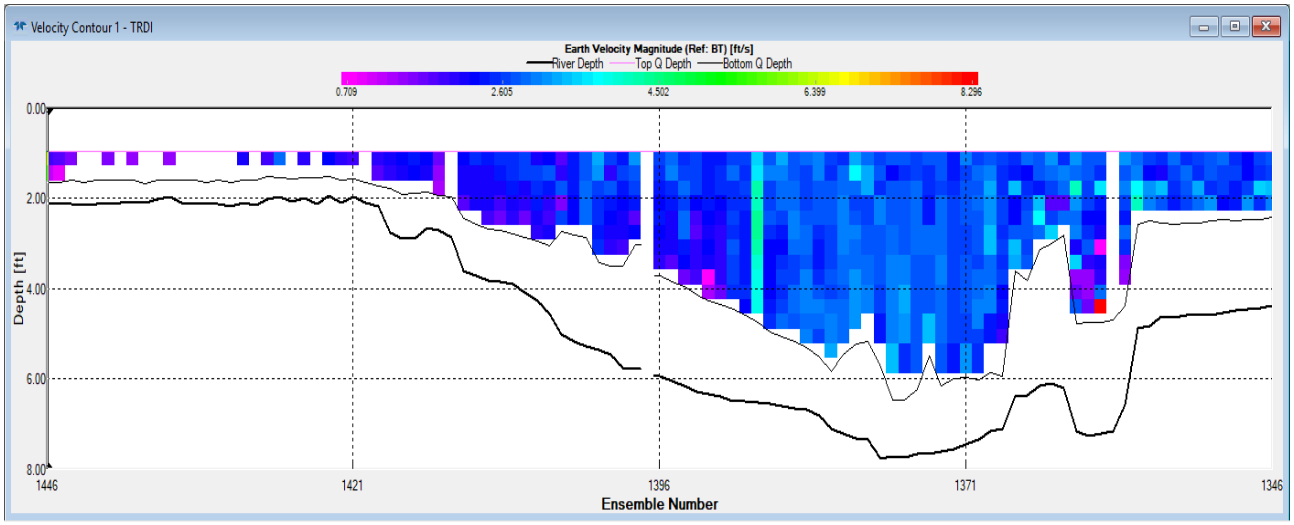
A. Transect W_S1-002 Raw Data Output

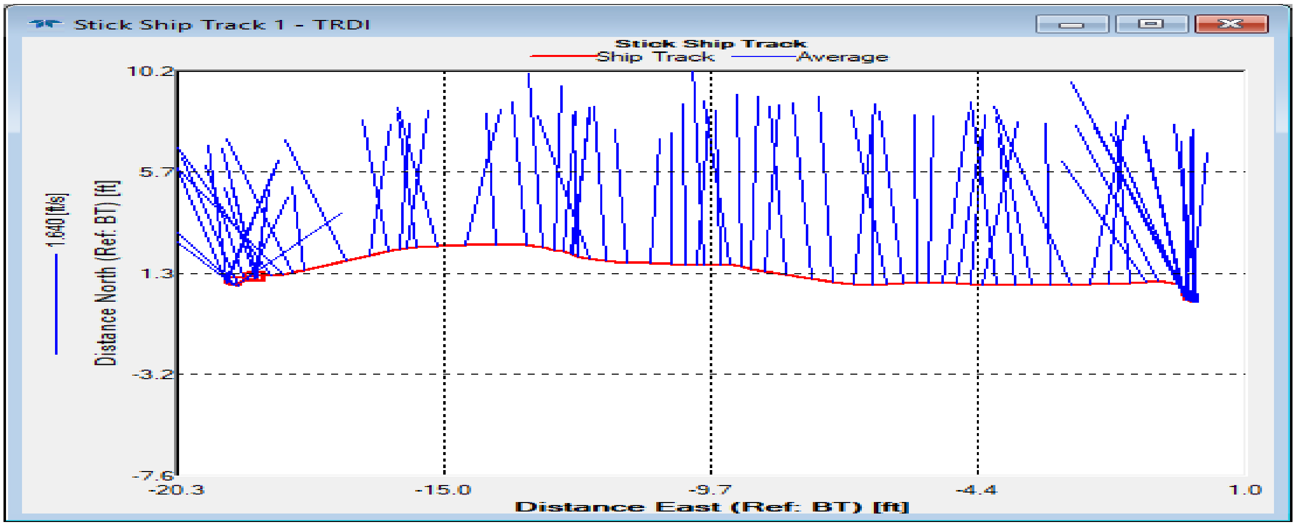


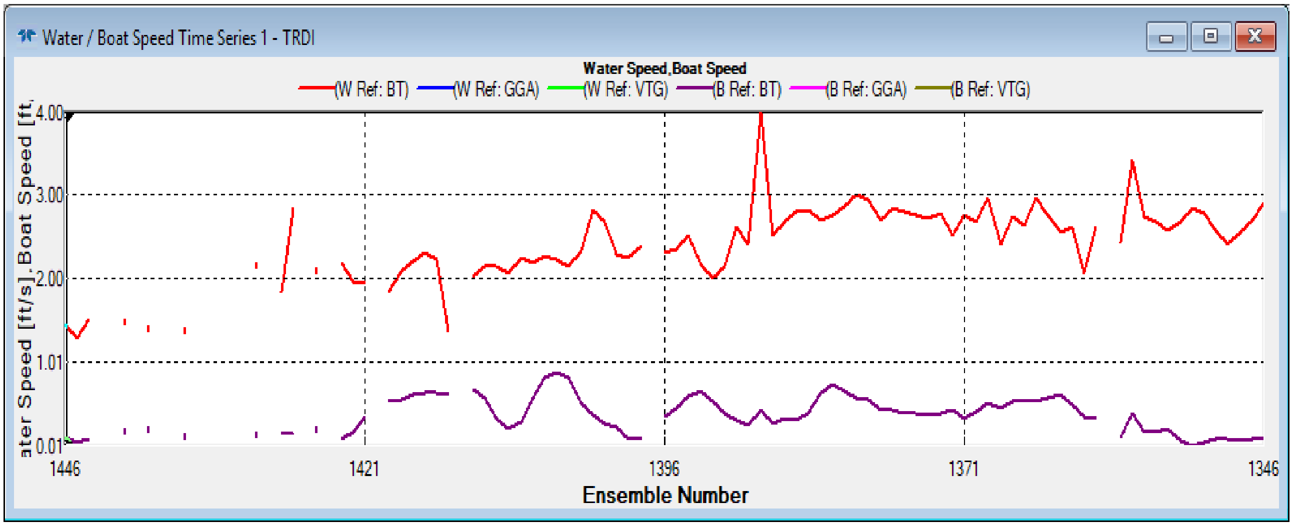




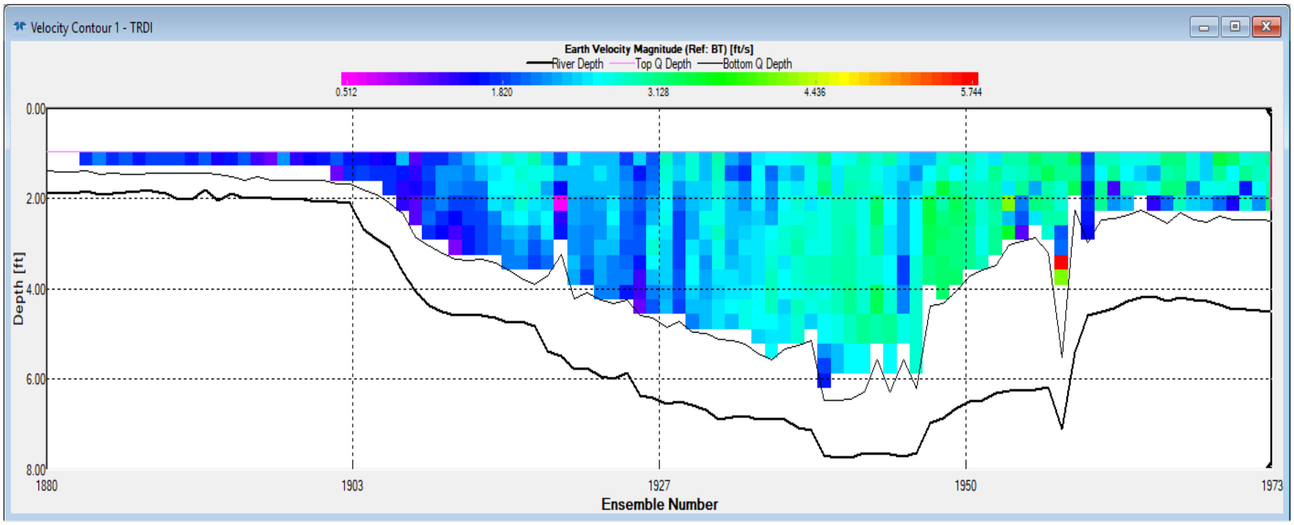
B. Transect W_S1-003 Raw Data Output

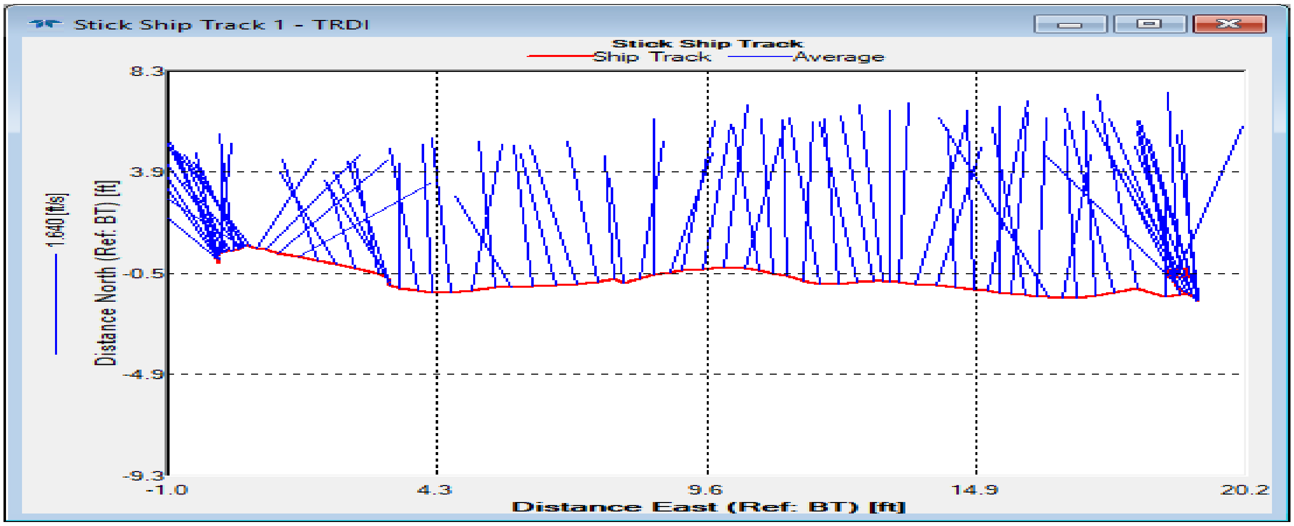


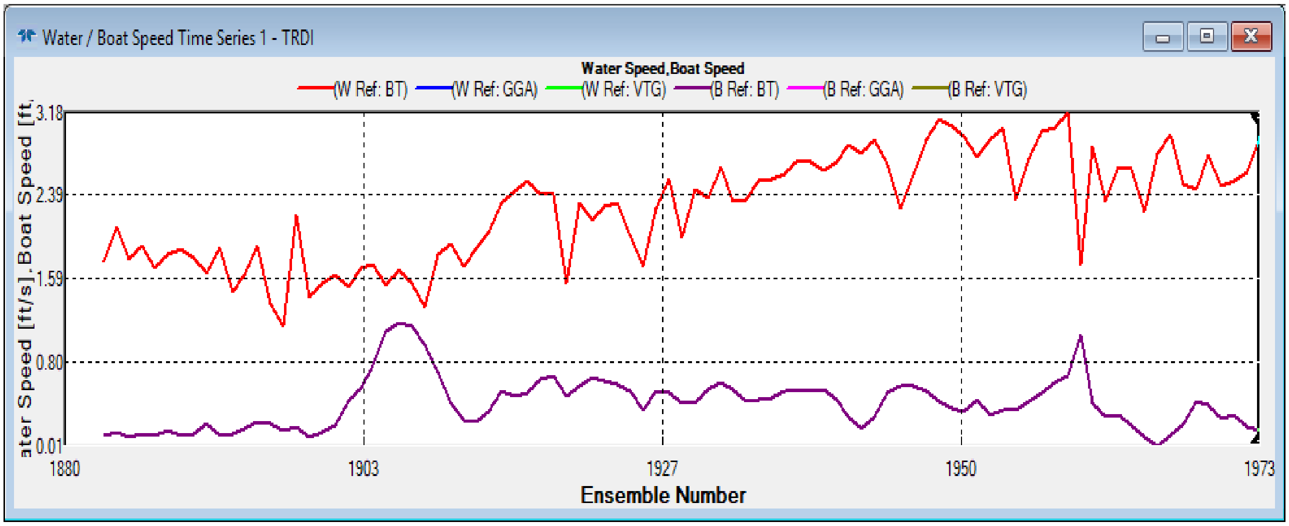




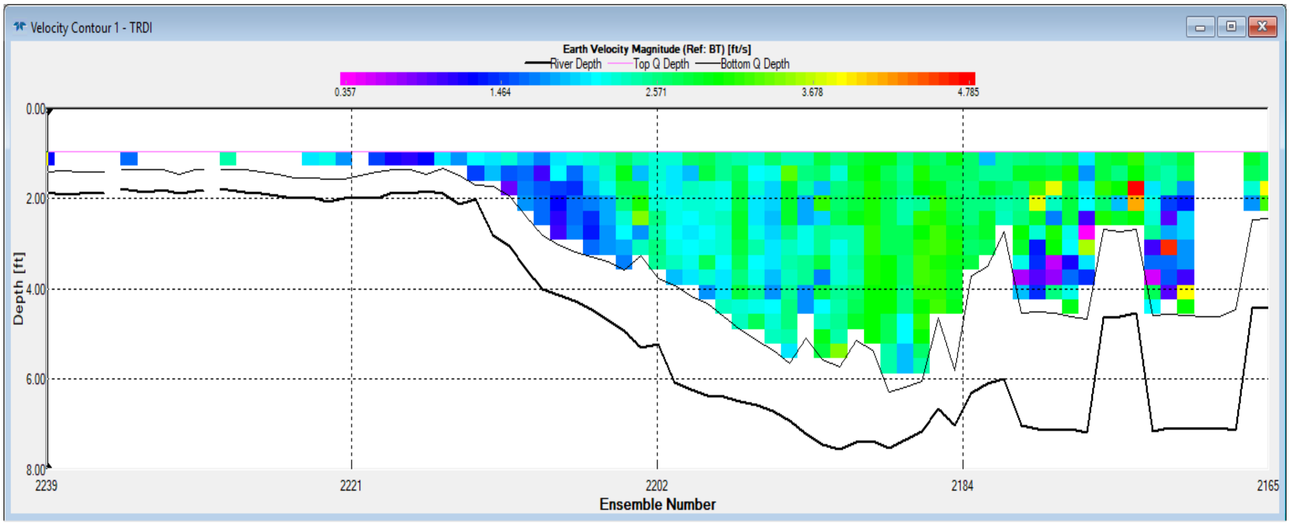
C. Transect W_S1-005 Raw Data Output

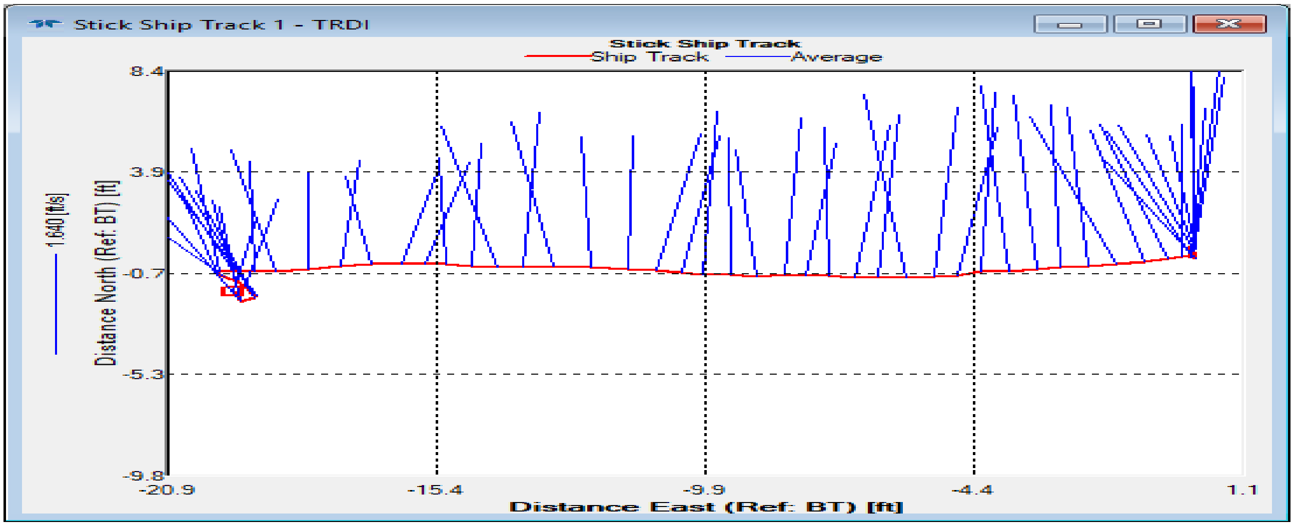


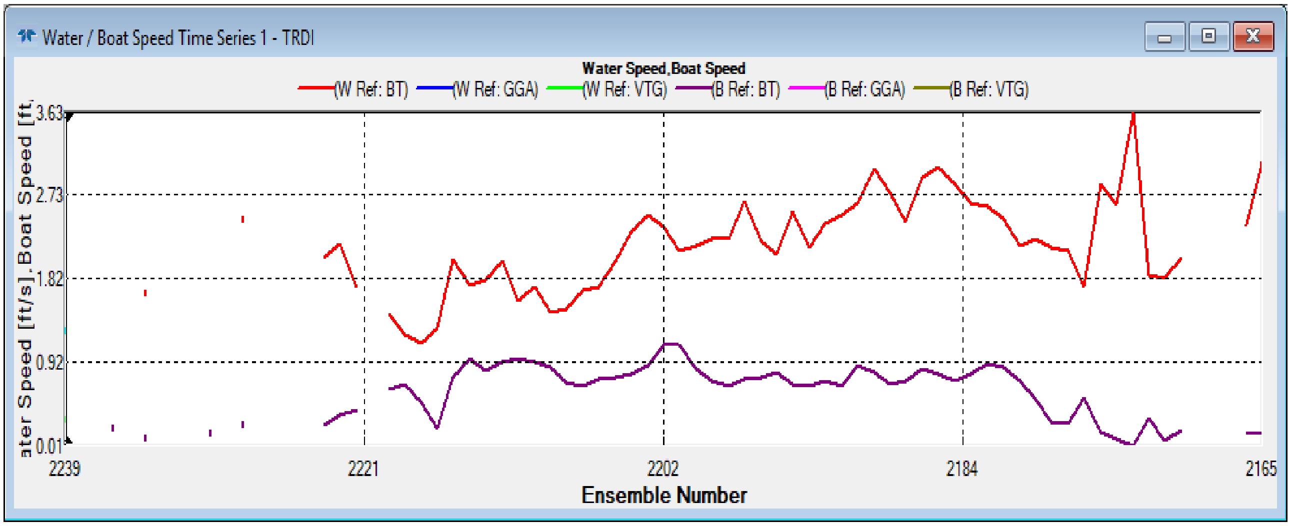


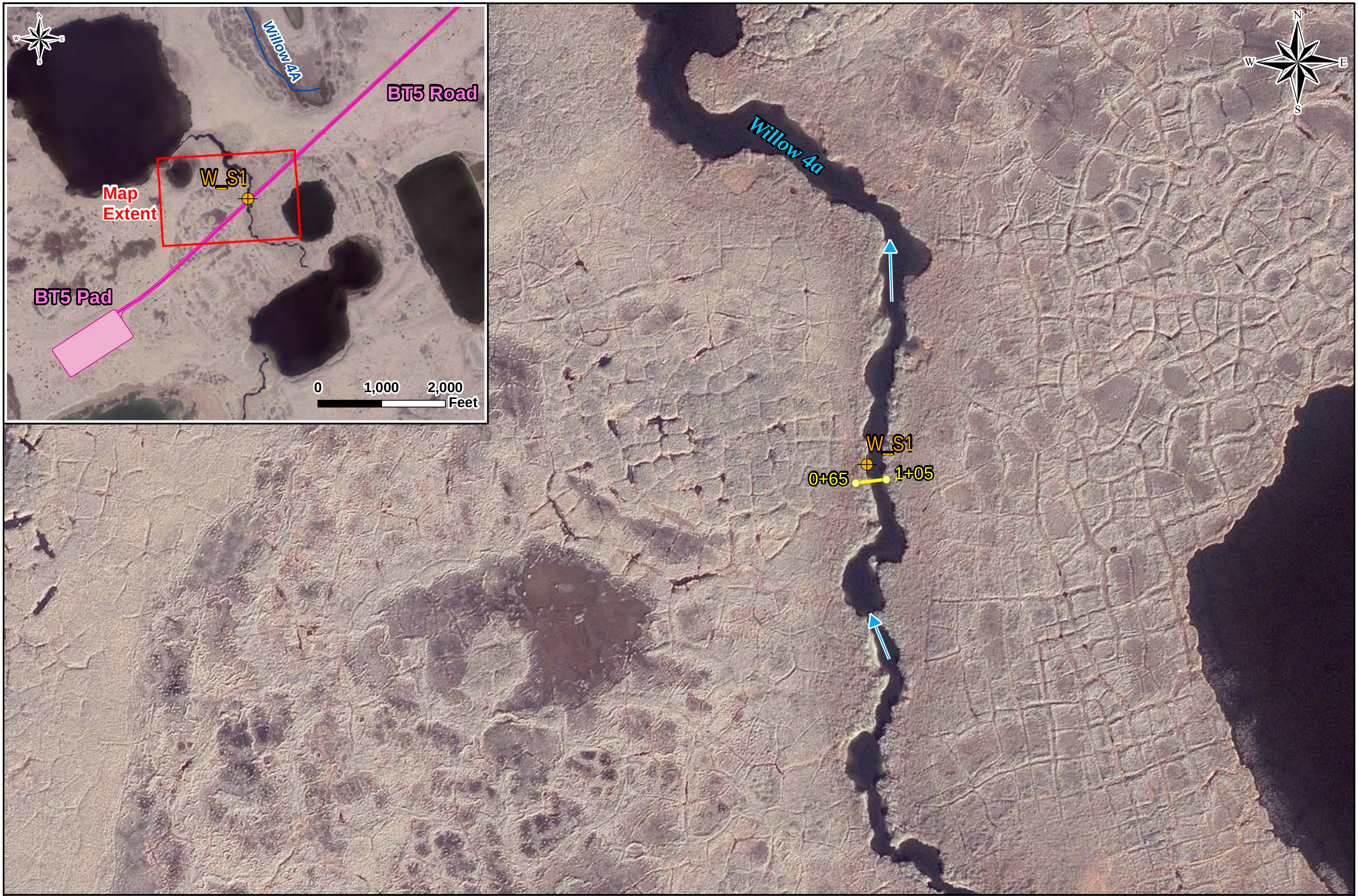


D. Transect W_S1-006 Raw Data Output









ConocoPhillips
Alaska

Feet
0 200 400

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_W_S1.mxd

⊕ Gage Location

→ Flow Direction

● Station

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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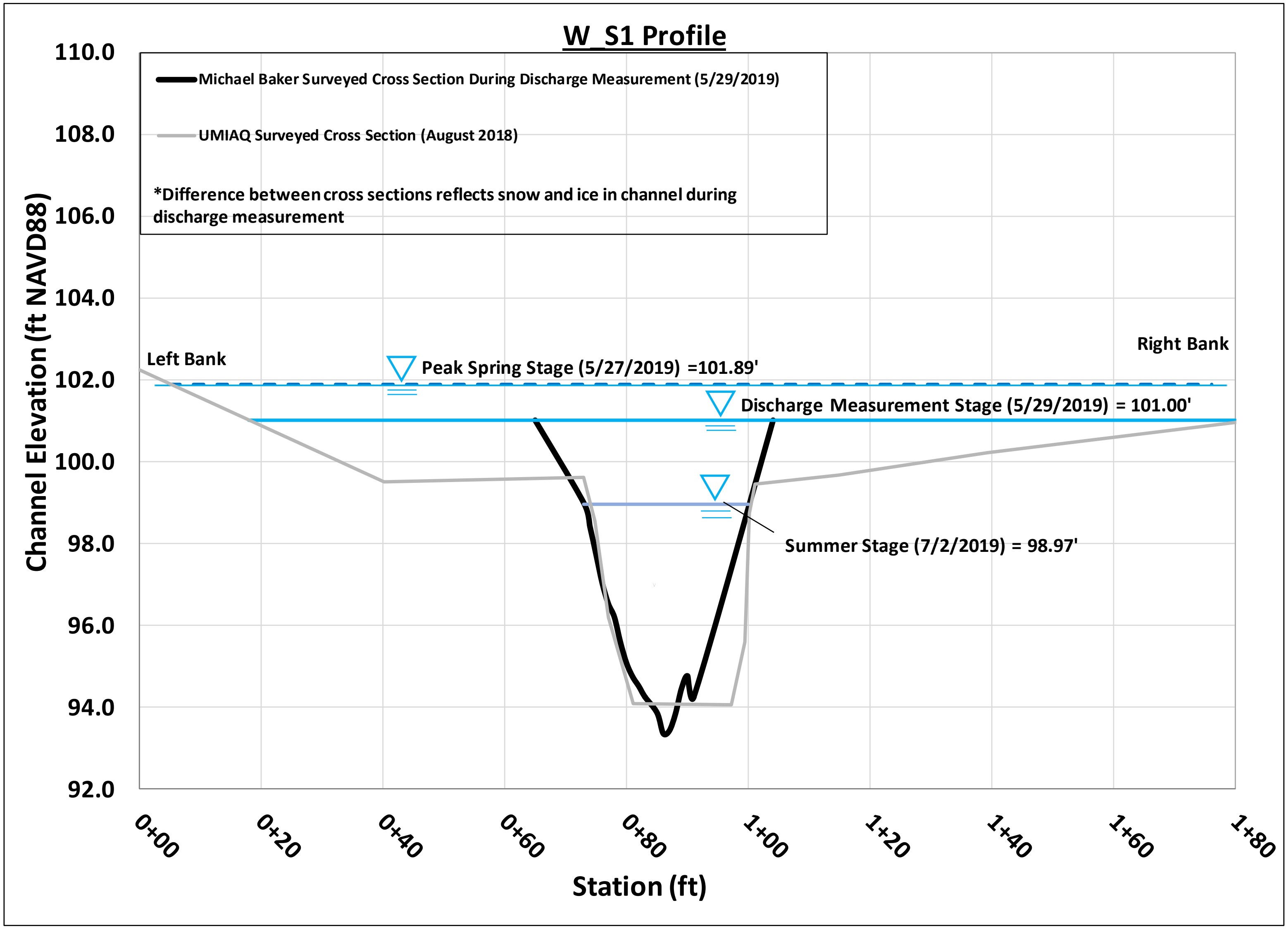
2019 Spring Breakup Willow 4a at W_S1 Plan

FIGURE C.10

Spring Breakup Cross-Section Profile



C.11 MINESITE AT UB14.5

Spring Breakup Measured Discharge

Location: UB14.5

Date & Time: June 2, 2019 4:45 PM

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

Final Discharge (cfs): 1000

Average Velocity (fps): 3.1

Measurement Rating: Good

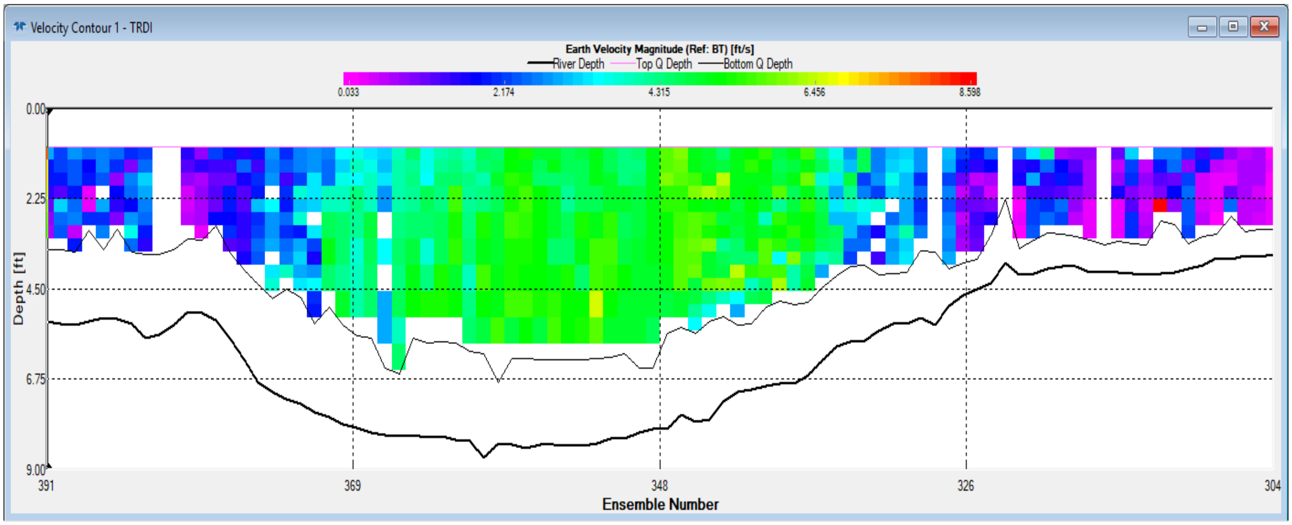
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from the loop test performed before measuring the four transects. Moving bed velocity estimated using the stationary moving bed test was 0.06 fps. The percentage of bad bottom track values (2.07%) was within the recommended maximum of 5%.

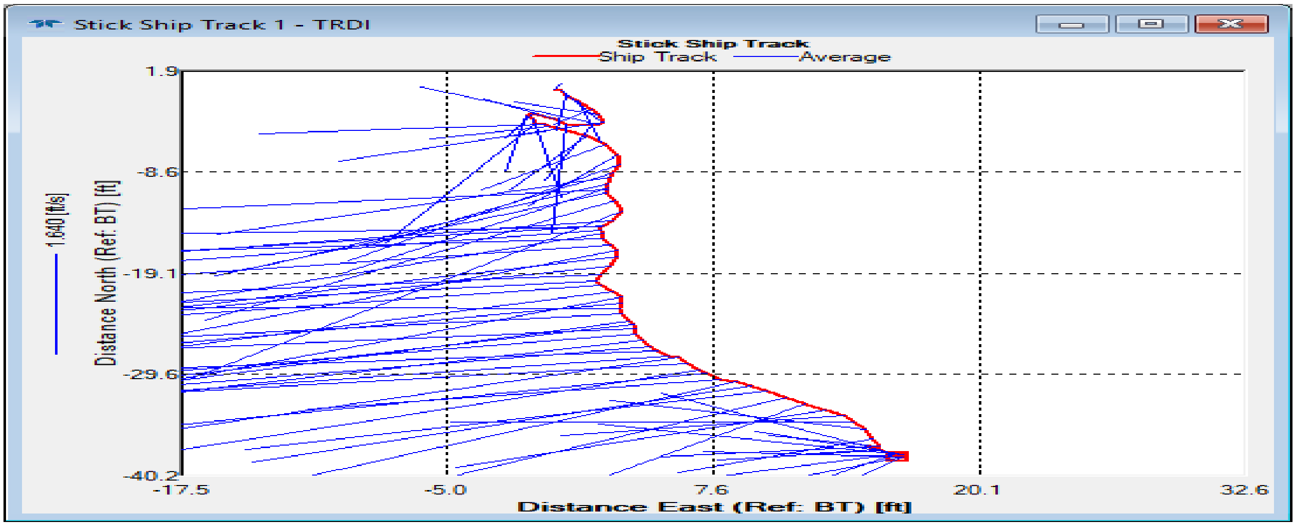
At the time of the measurement, the creek was mostly clear of snow and ice. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered good based on the conditions at the time of the measurement.

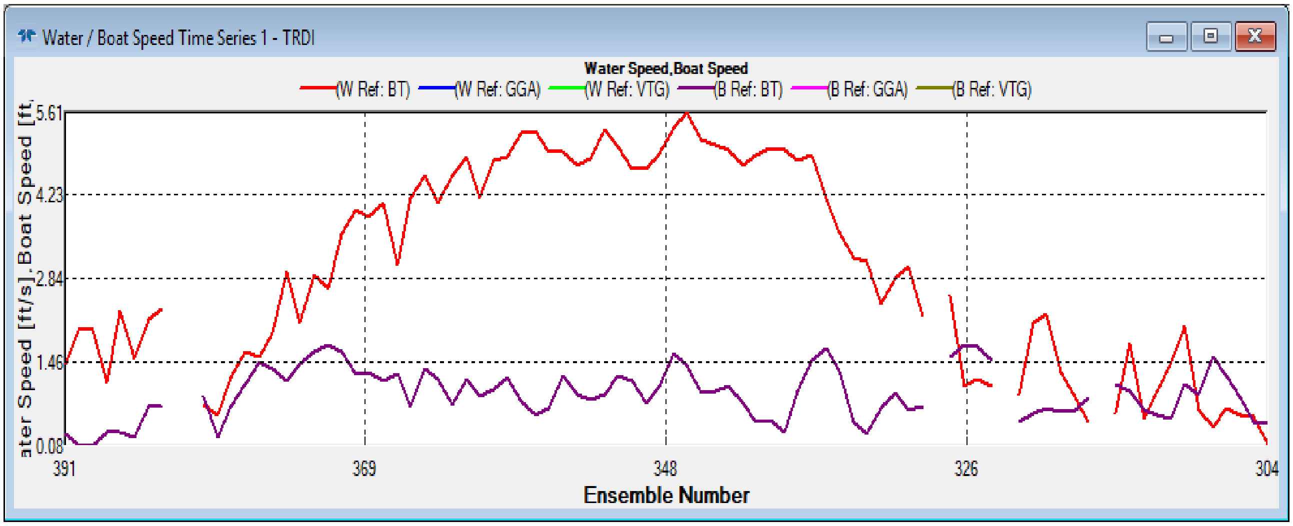
Table C.12: UB14.5 June 2 Spring Breakup Measured Discharge Summary

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)
000	Right	1036	2.77%	588	1.72%	64	331	329	3.15	3.13
002	Left	996	-1.16%	579	0.14%	67	370	343	2.91	2.69
003	Right	990	-1.78%	576	-0.39%	63	340	317	3.12	2.91
004	Left	1010	0.18%	570	-1.47%	66	321	328	3.08	3.14
Average		**1008**		**578**		**65**		**329**	**3.06**	**2.97**

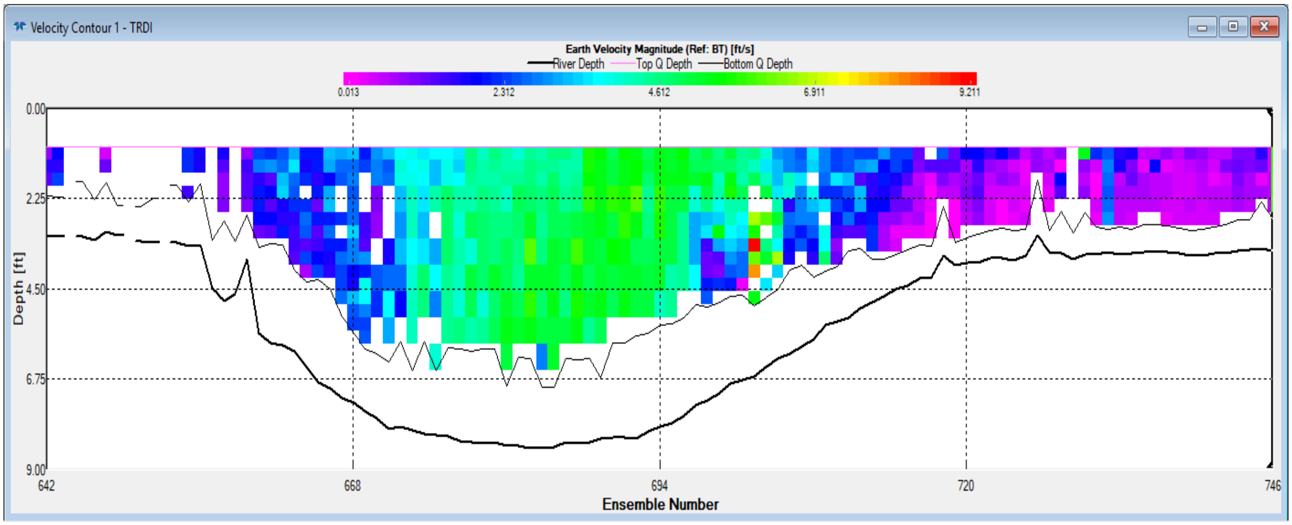
A. Transect UB14.5-000 Raw Data Output

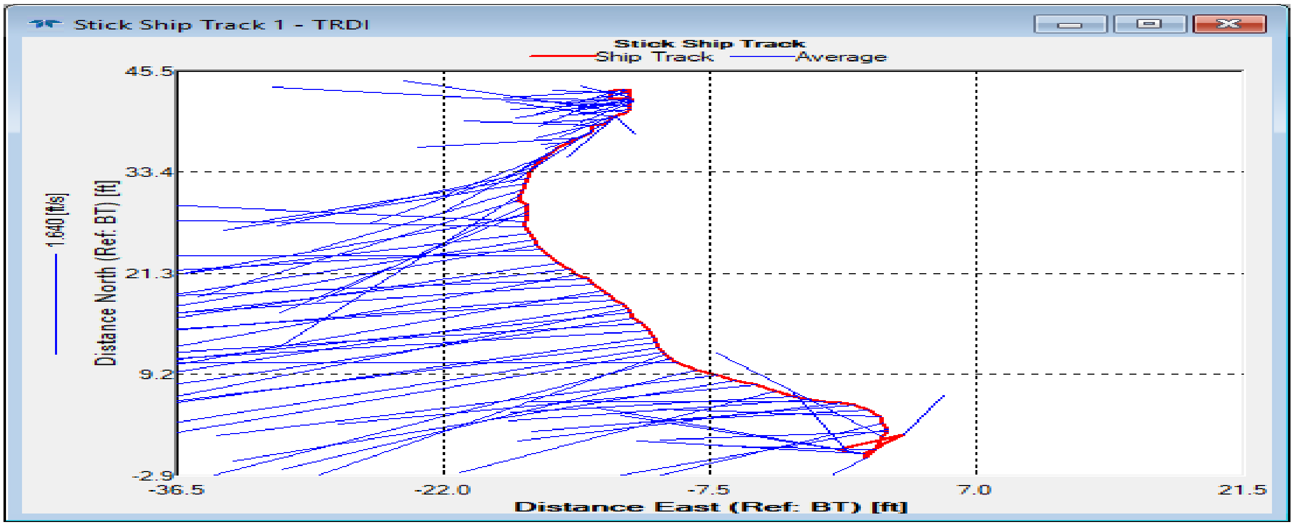


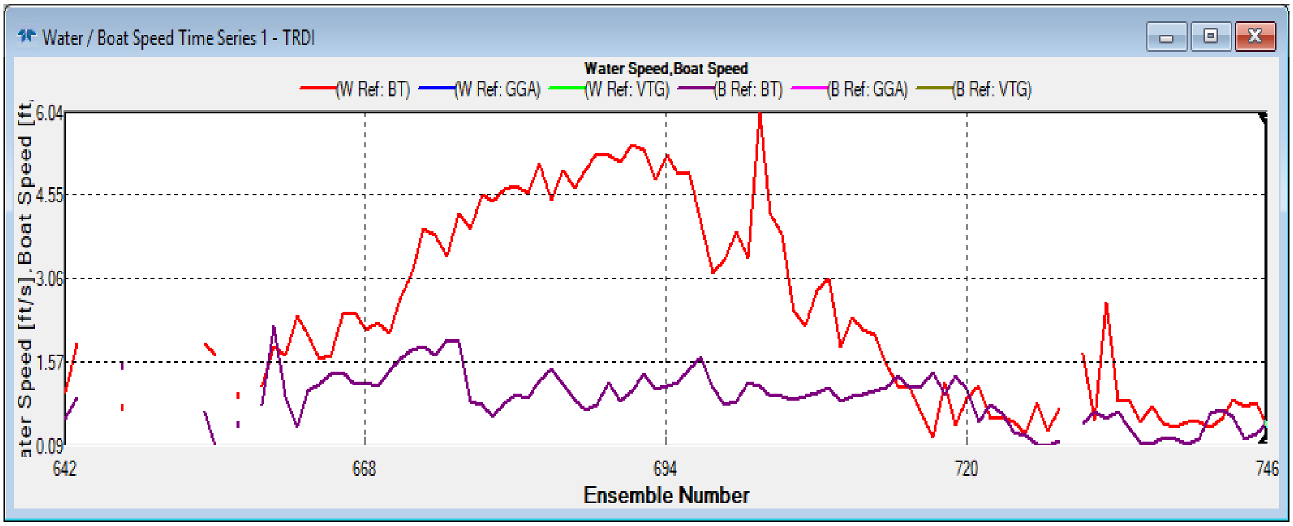




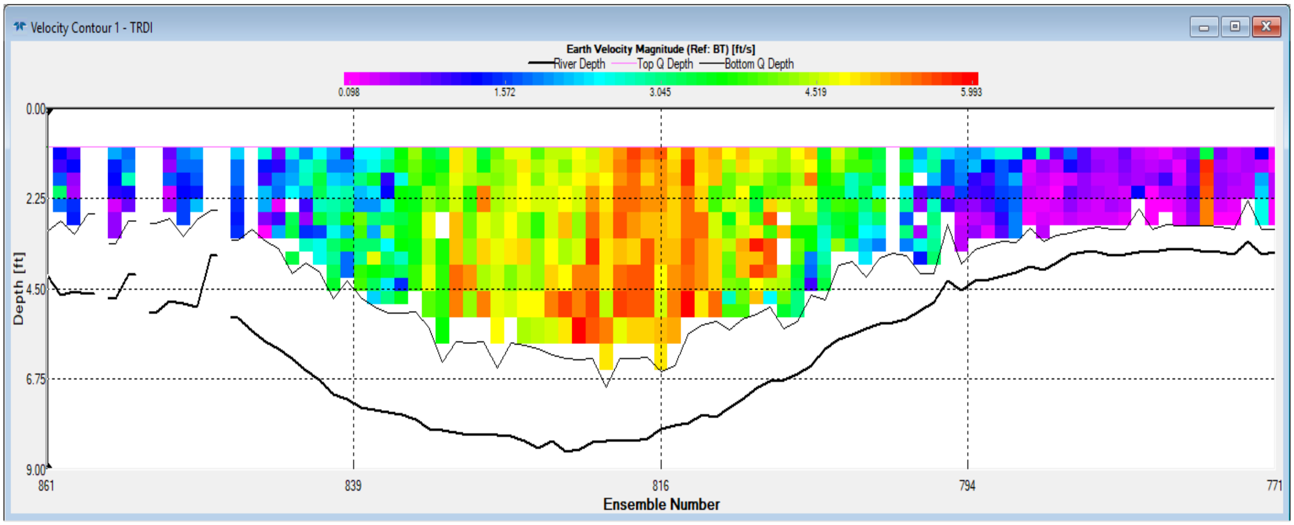
B. Transect UB14.5-002 Raw Data Output

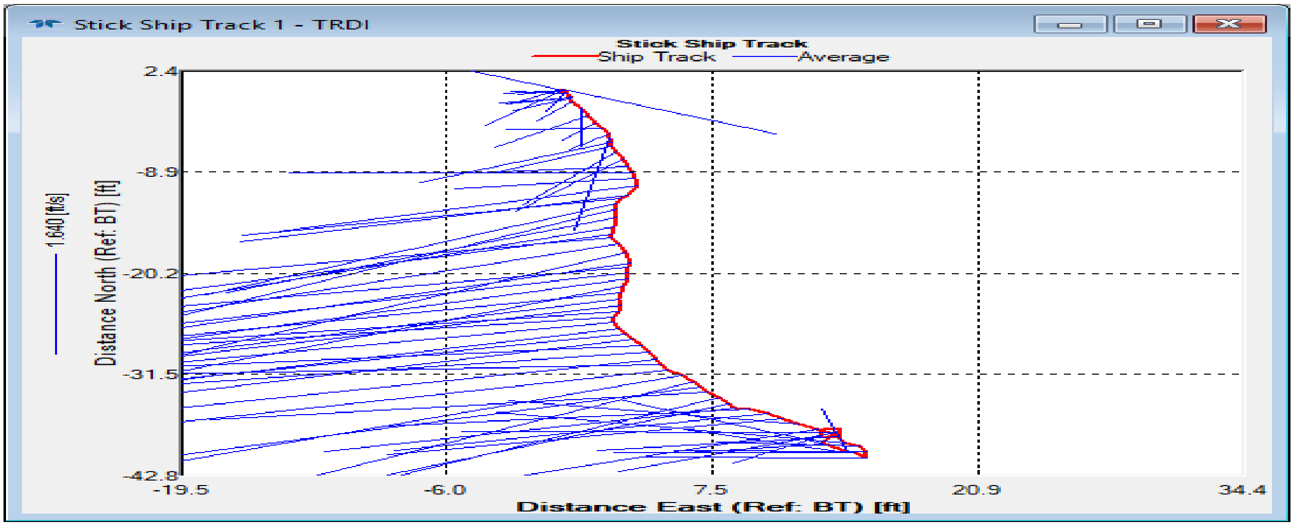


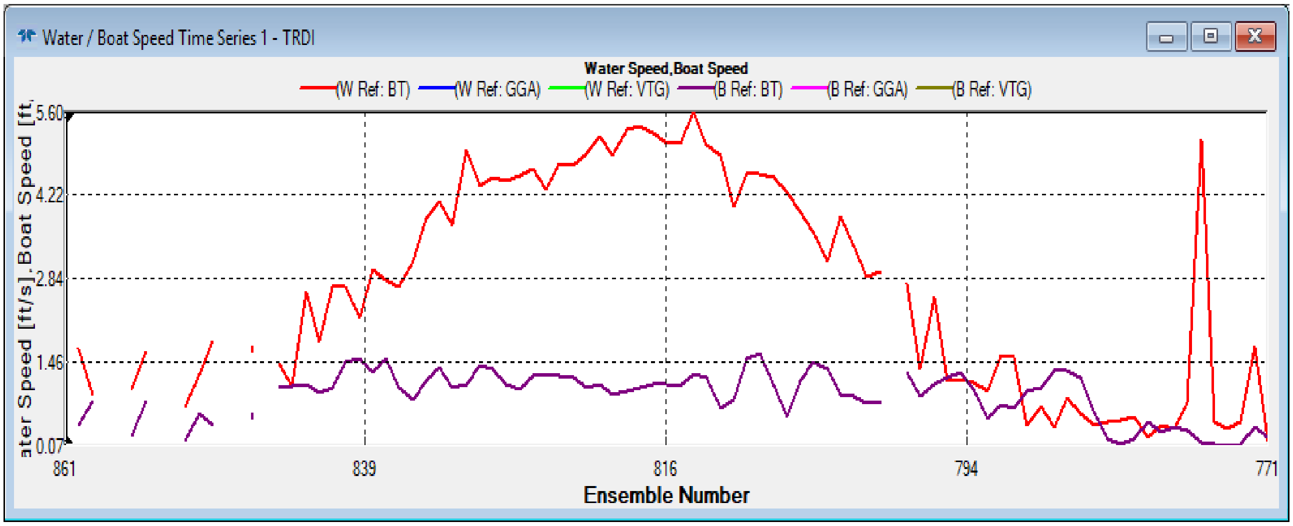




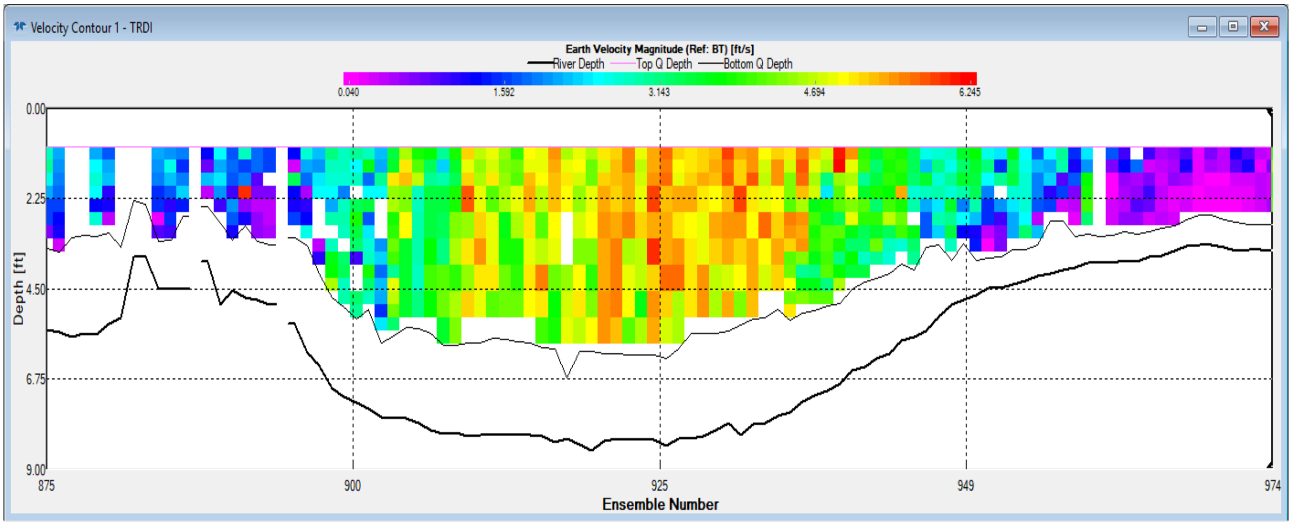
C. Transect UB14.5-003 Raw Data Output

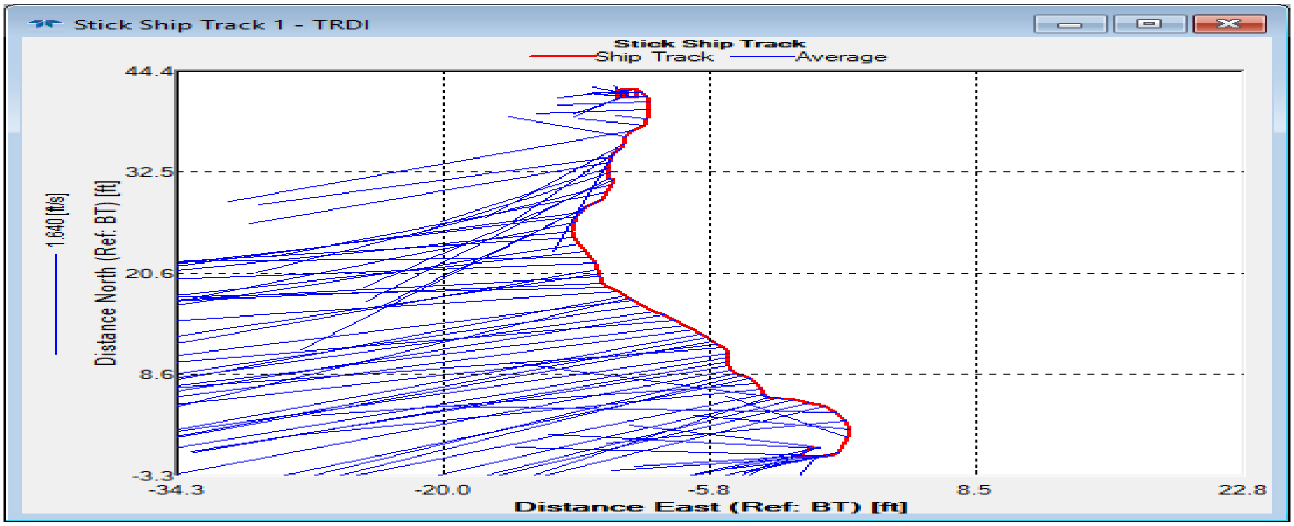


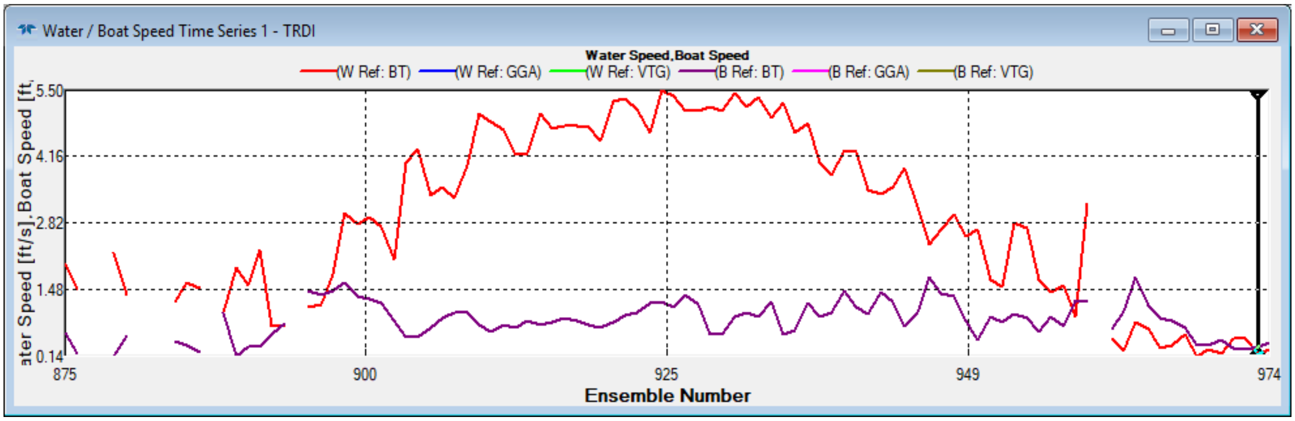




D. Transect UB14.5-004 Raw Data Output







ConocoPhillips Alaska

Feet
0 200 400

Date:	1/24/2020	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_UB14.5.mxd

⊕ Gage Location

● Station

— Discharge Measurement Cross Section

→ Flow Direction

Imagery Source: Willow Aerial (COPA), 2018

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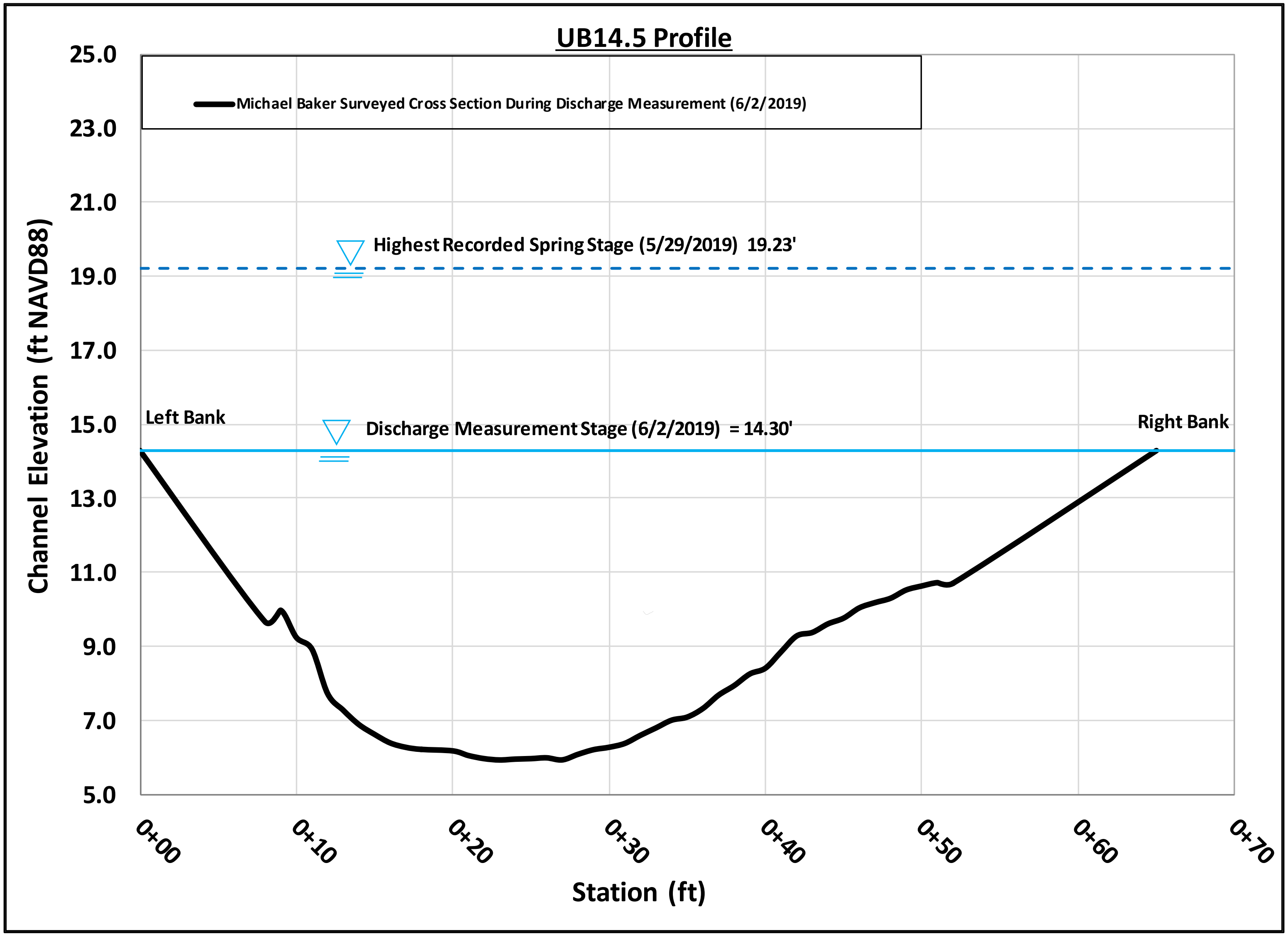
2019 Spring Breakup Tinmiaqsiugvik River UB14.5 Plan

FIGURE C.11

Spring Breakup Cross-Section Profile



C.12 SWALE 1

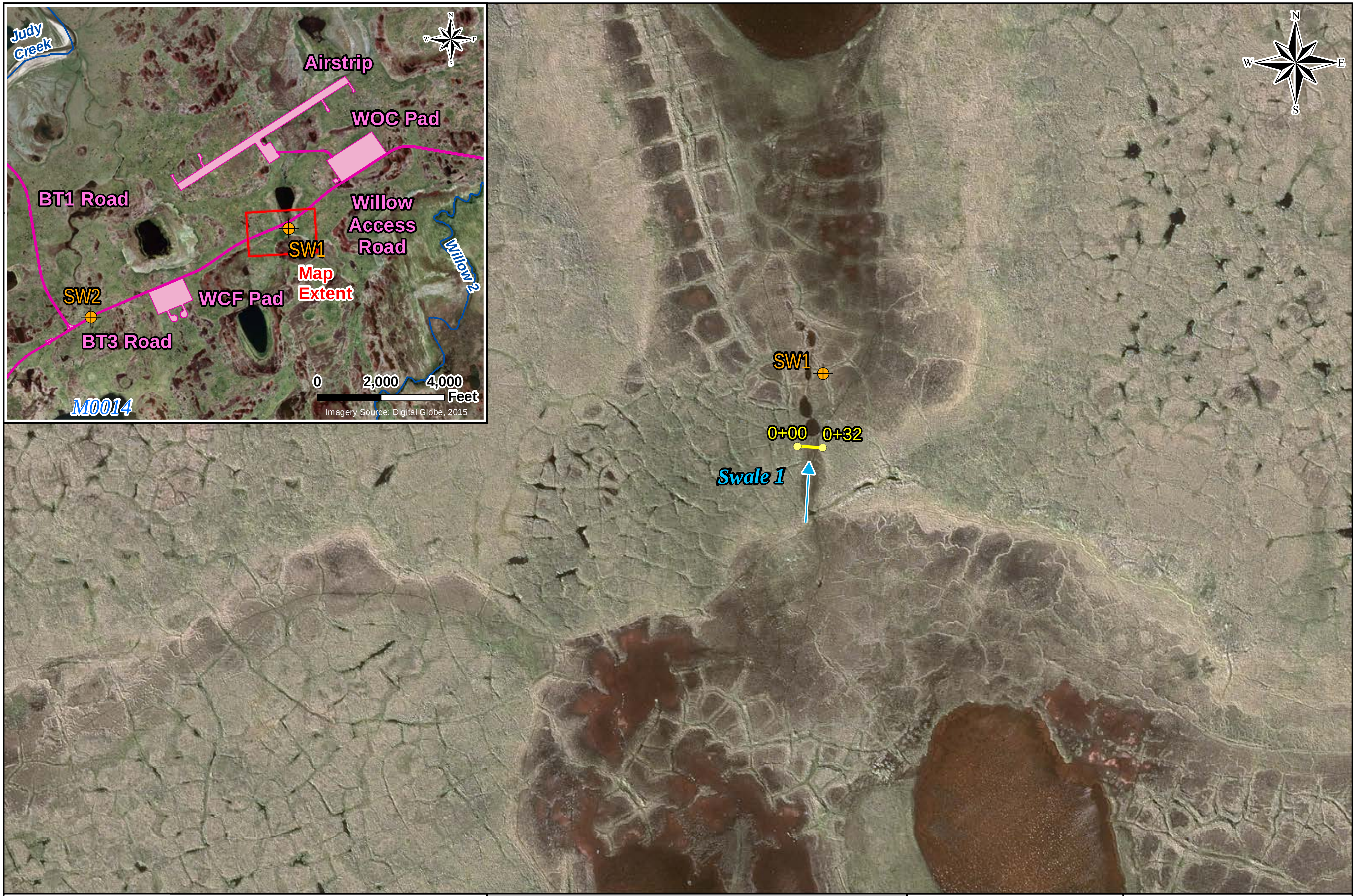
Spring Breakup Measured Discharge

Table C.13: SW1 Spring Breakup Measured Discharge Summary

Date:	5/29/2019	**Time:**	2:00 PM	**Method:**	USGS Mid-Section Technique
Location:	SW1	**Crew:**	KDB, DTR, CMB, ACG	**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 (ft^2)	Discharge (ft^3/s)	Note
0+00.0	79.96	0	-	-	-	-	LEFT BANK
0+02.0	79.46	0.50	0.06	2.0	1.00	0.06	Grass
0+04.0	79.26	0.70	0.43	2.0	1.40	0.61	Grass
0+06.0	79.21	0.75	0.43	2.0	1.50	0.64	Grass
0+08.0	79.11	0.85	0.26	2.0	1.70	0.44	Grass
0+10.0	79.11	0.85	0.57	2.0	1.70	0.97	Grass
0+12.0	79.06	0.90	0.60	1.5	1.35	0.81	Grass
0+13.0	78.96	1.00	0.37	1.0	1.00	0.37	Grass
0+14.0	78.86	1.10	0.61	1.0	1.10	0.67	Grass
0+15.0	78.96	1.00	0.68	1.0	1.00	0.68	Grass
0+16.0	79.06	0.90	0.31	1.0	0.90	0.28	Grass
0+17.0	79.11	0.85	1.01	1.5	1.28	1.28	Grass
0+19.0	79.06	0.90	1.40	1.5	1.35	1.89	Grass
0+20.0	78.96	1.00	0.53	1.0	1.00	0.53	Grass
0+21.0	78.96	1.00	0.48	1.0	1.00	0.48	Grass
0+22.0	79.01	0.95	1.11	1.0	0.95	1.05	Grass
0+23.0	78.96	1.00	1.11	1.0	1.00	1.11	Grass
0+24.0	78.96	1.00	0.83	1.5	1.50	1.25	Grass
0+26.0	79.16	0.80	0.08	2.0	1.60	0.12	Grass
0+28.0	79.46	0.50	0.13	2.0	1.00	0.13	Grass
0+30.0	79.36	0.60	0.05	2.0	1.20	0.06	Grass
0+32.0	79.96	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)
32.0	79.10	0.9	0.55		24.5	13.4



Imagery Source: Digital Globe, 2015

ConocoPhillips
Alaska

0 200 400 Feet

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW1.mxd

⊕ Gage Location

→ Flow Direction

● Station

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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INTERNATIONAL

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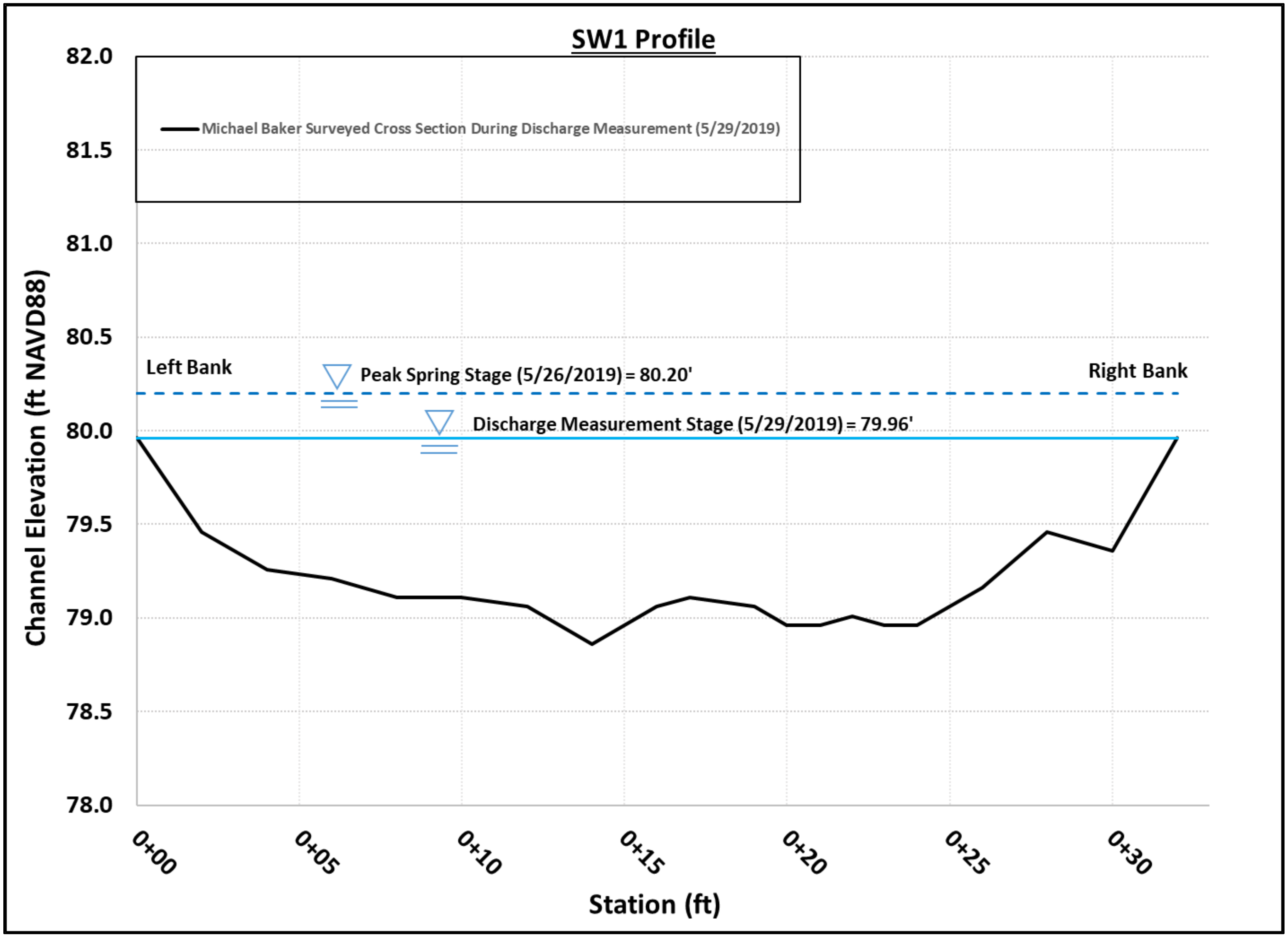
2019 Spring Breakup Swale 1 at SW1 Plan

FIGURE C.12

Spring Breakup Cross-Section Profile



C.13 SWALE 2

Spring Breakup Measured Discharge

Table C.14: SW2 Spring Breakup Measured Discharge Summary

Date:	5/29/2019	**Time:**	3:15 PM	**Method:**	USGS Mid-Section Technique		
Location:	SW2	**Crew:**	KDB, DTR, CMB, ACG	**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+00.5	81.17	0	-	-	-	-	RIGHT BANK
0+01.0	80.67	0.5	0.87	0.75	0.38	0.33	Grass
0+02.0	80.77	0.4	0.25	1.0	0.40	0.10	Grass
0+03.0	80.67	0.5	0.19	1.0	0.50	0.10	Grass
0+04.0	80.67	0.5	0.35	1.0	0.50	0.17	Grass
0+05.0	80.77	0.4	0.43	1.0	0.40	0.17	Grass
0+06.0	80.88	0.3	0.43	1.0	0.30	0.13	Grass
0+07.0	80.78	0.4	0.67	1.0	0.40	0.27	Grass
0+08.0	80.78	0.4	0.12	1.0	0.40	0.05	Grass
0+09.0	80.78	0.4	0.28	1.0	0.40	0.11	Grass
0+10.0	80.78	0.4	0.20	0.75	0.30	0.06	Grass
0+10.5	81.18	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)
10.0	80.80	0.4	0.38	-	4.0	1.5

ConocoPhillips Alaska

0 200 400 Feet

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW2.mxd

⌖ Gage Location

→ Flow Direction

● Station

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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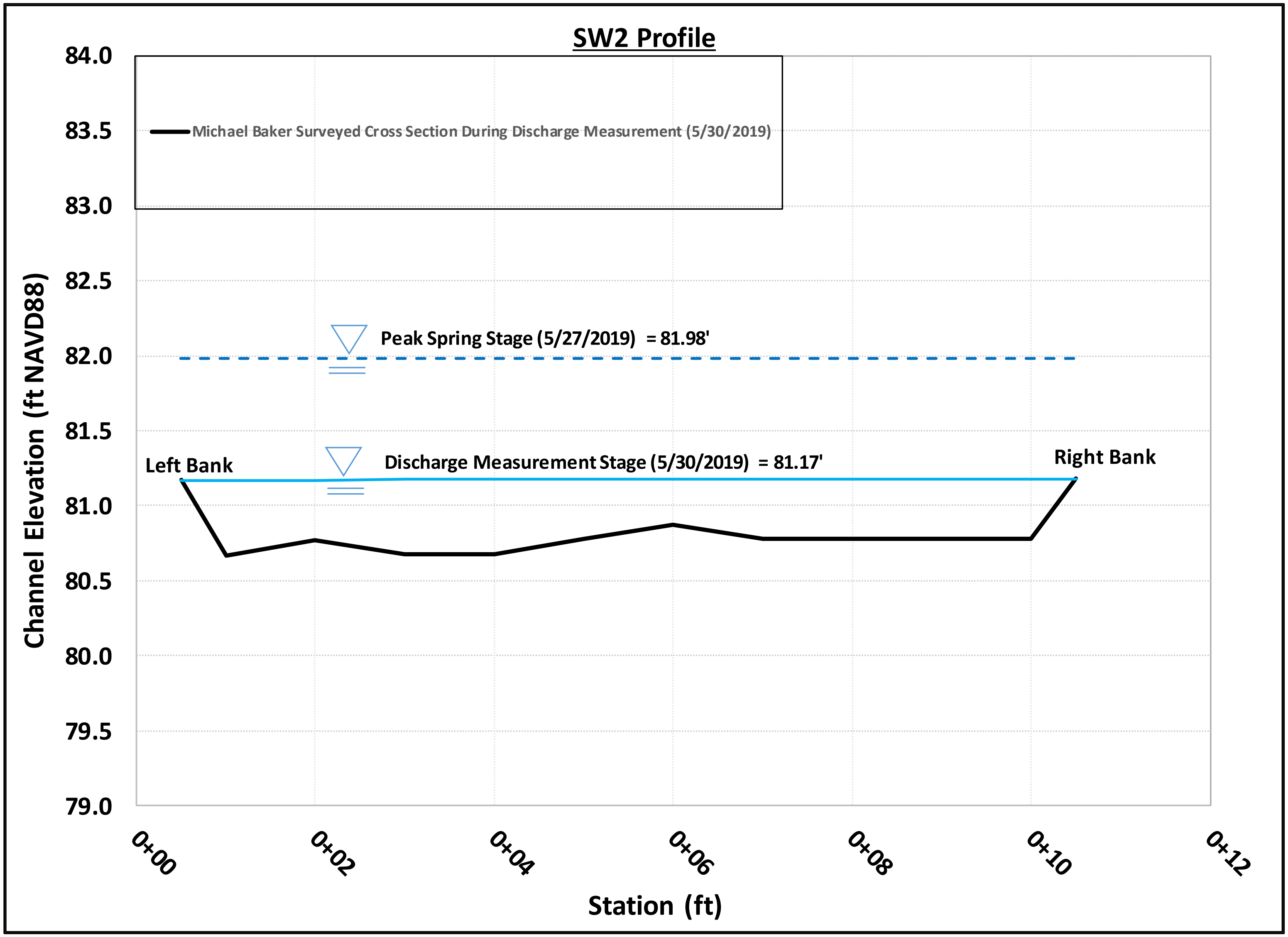
2019 Spring Breakup Swale 2 at SW2 Plan

FIGURE C.13

Spring Breakup Cross-Section Profile



C.14 SWALE 3

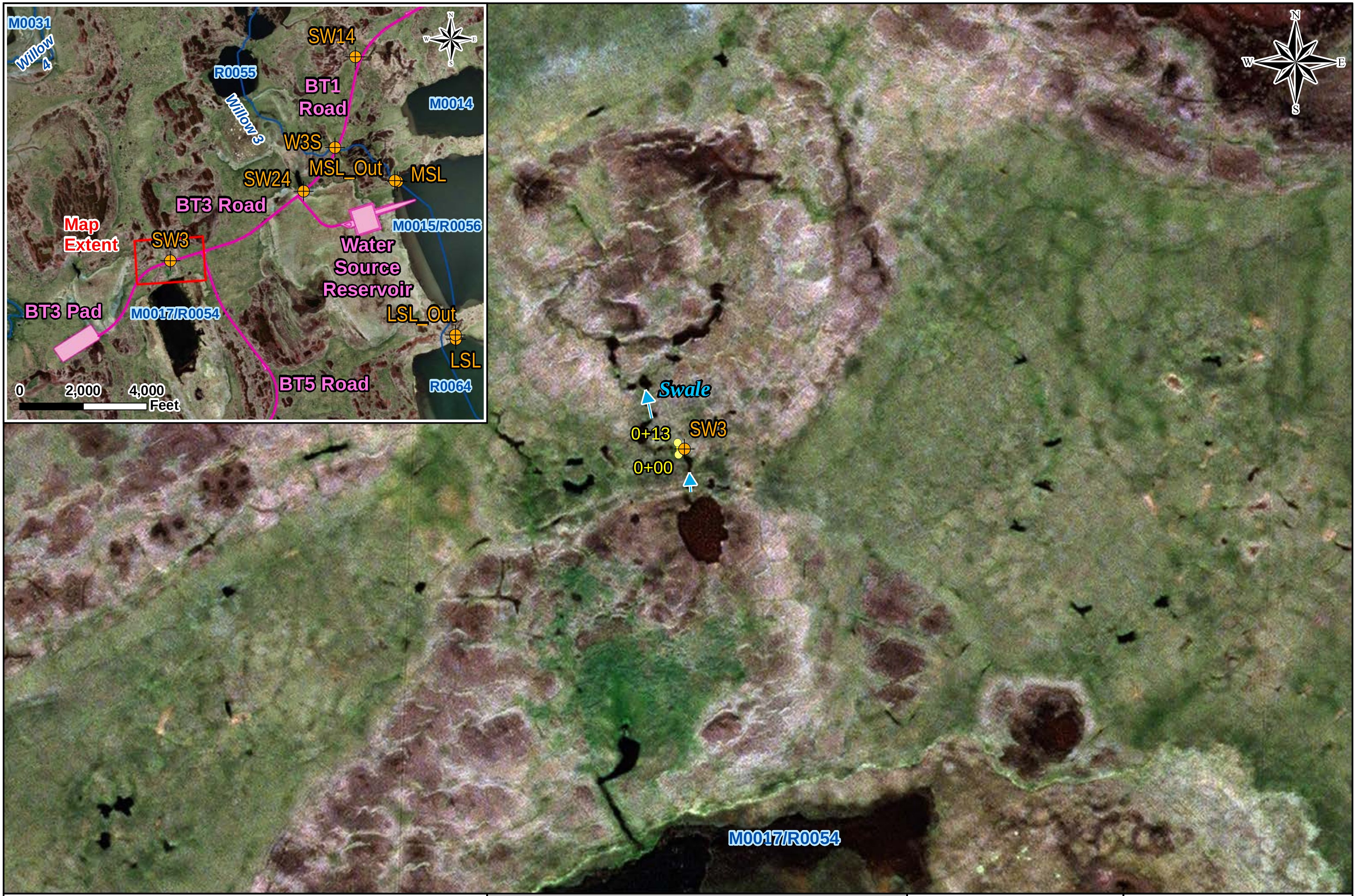
Spring Breakup Measured Discharge

Table C.15: SW3 Spring Breakup Measured Discharge Summary

Date:	6/2/2019	**Time:**	2:30 PM	**Method:**	USGS Mid-Section Technique
Location:	SW3	**Crew:**	CMB, MDM	**Depth:**	0.6 of measured depth
Lat:	N 70.1058°	**Long:**	W 152.1341°	**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+01.5	86.84	0	-	-	-	-	RIGHT BANK
0+04.6	86.84	0	0.00	1.75	0.00	0.00	Grass
0+05.0	86.84	0.8	0.39	0.70	0.56	0.22	Grass
0+06.0	86.04	0.9	0.68	1.0	0.90	0.62	Grass
0+07.0	85.94	1.0	0.60	1.0	1.00	0.60	Grass
0+08.0	85.84	1.15	0.54	1.0	1.15	0.62	
0+09.0	85.69	1.25	0.58	1.0	1.25	0.72	Grass
0+10.0	85.59	1.2	0.41	1.0	1.20	0.49	Grass
0+11.0	85.64	0.9	0.20	1.0	0.90	0.18	Grass
0+12.0	85.94	0.65	0.00	0.75	0.49	0.00	Grass
0+12.5	86.19	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)
11.0	86.10	0.8	0.38		7.4	3.4



ConocoPhillips Alaska

0 200 400 Feet

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW3.mxd

⊕ Gage Location

● Station

→ Flow Direction

— Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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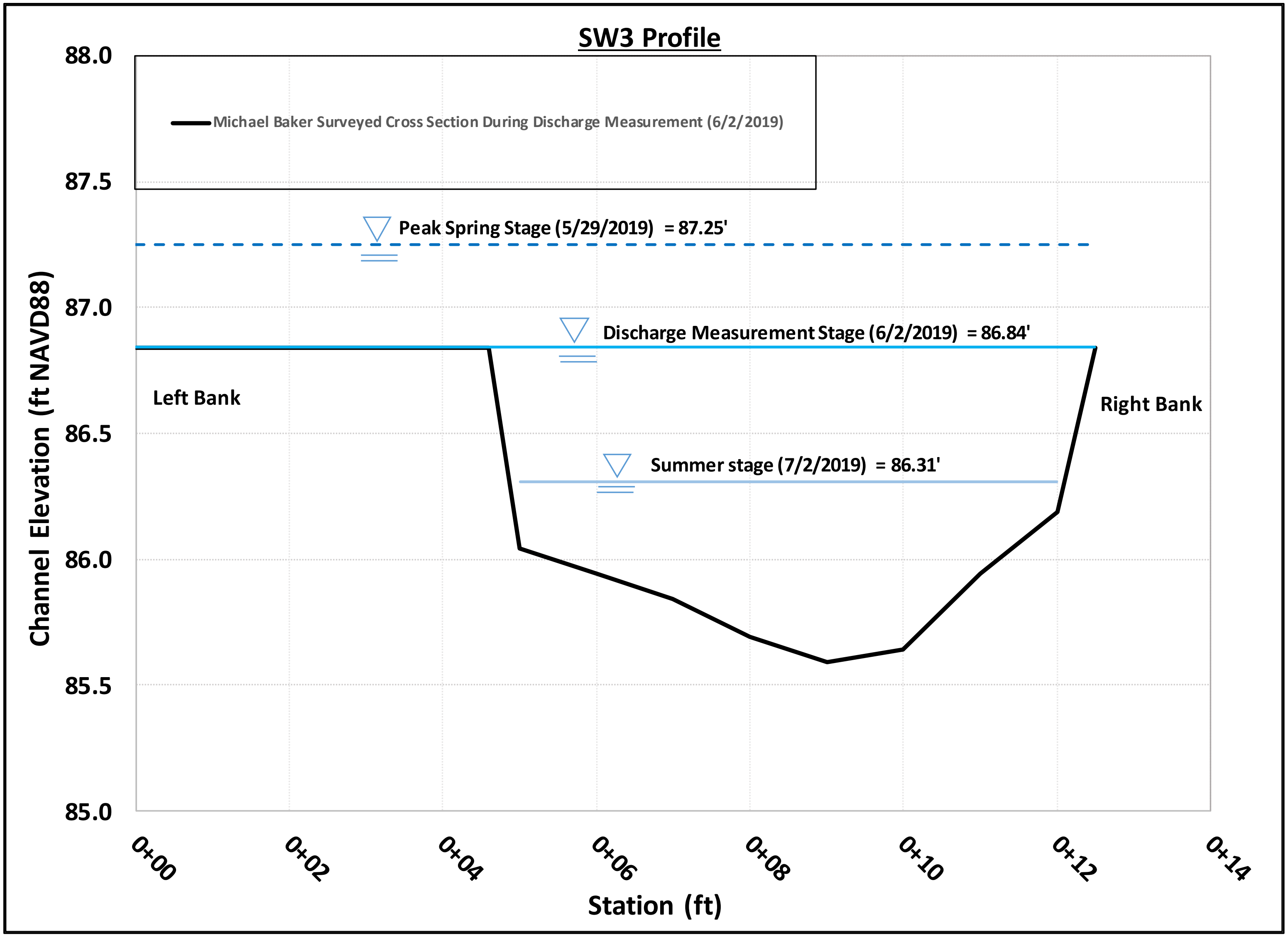
2019 Spring Breakup Unnamed Swale SW3 Plan

FIGURE C.14

Spring Breakup Cross-Section Profile



C.15 SWALE 4

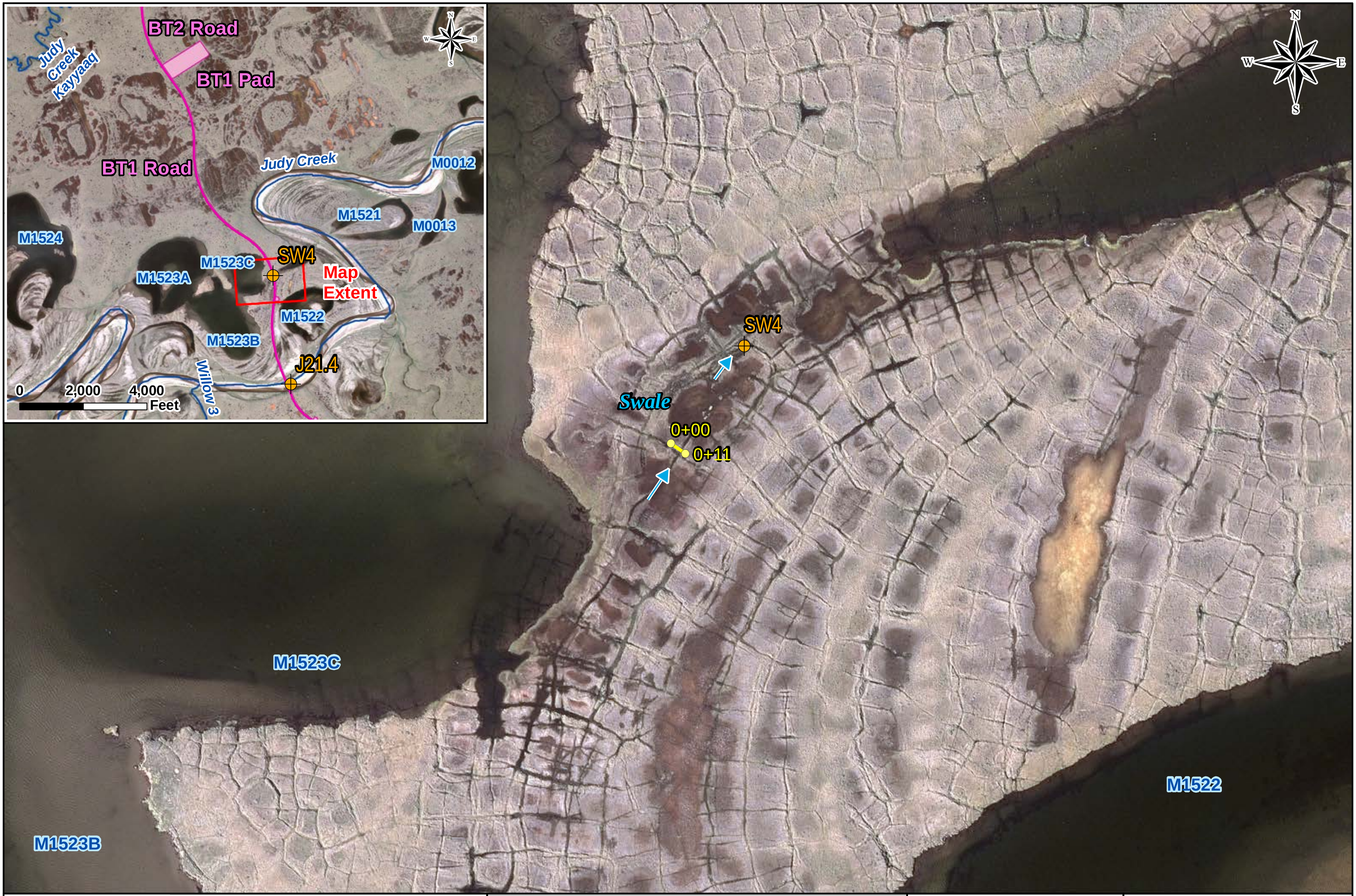
Spring Breakup Measured Discharge

Table C.16: SW4 Spring Breakup Measured Discharge Summary

Date:	6/1/2019	**Time:**	3:00 PM	**Method:**	USGS Mid-Section Technique
Location:	SW4	**Crew:**	CMB, MDM	**Depth:**	0.6 of measured depth
Lat:	N 70.1560°	**Long:**	W 152.0944°	**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+05.5	55.75	0	-	-	-	-	LEFT BANK
0+06.0	55.50	0.25	0.10	0.75	0.19	0.02	Grass
0+07.0	55.30	0.45	0.07	1.0	0.45	0.03	Grass
0+08.0	55.15	0.60	0.62	1.0	0.60	0.37	Grass
0+09.0	55.15	0.60	0.78	1.0	0.60	0.47	Grass
0+10.0	55.20	0.55	0.47	1.0	0.55	0.26	Grass
0+11.0	55.75	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)
5.5	55.30	0.4	0.41		2.4	1.1



ConocoPhillips
Alaska

0 200 400 Feet

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW4.mxd

⊕ Gage Location

● Station

Discharge Measurement Cross Section

→ Flow Direction

Imagery Source: Willow Aerial (COPA), 2018

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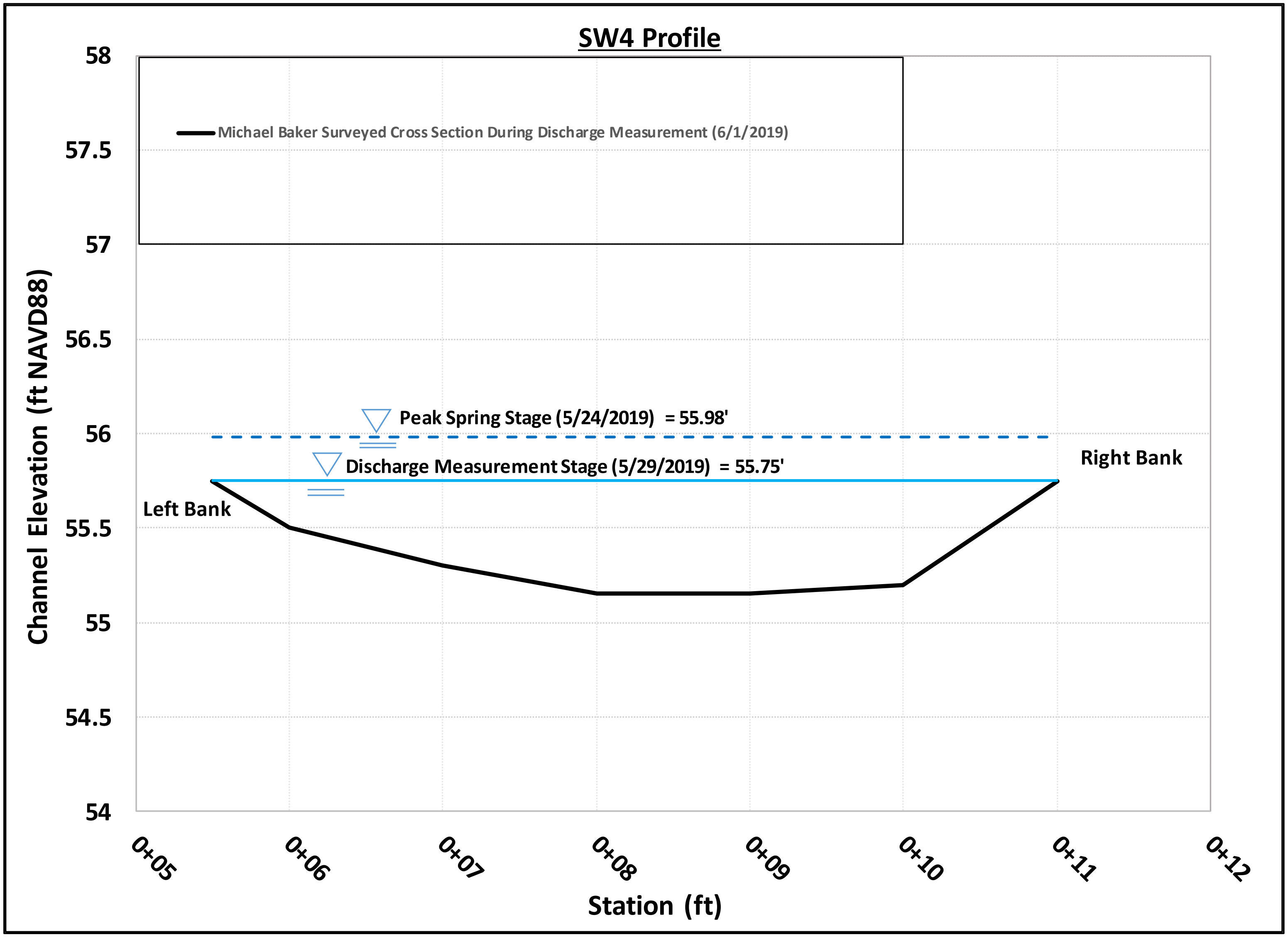
2019 Spring Breakup Unnamed Swale SW4 Plan

FIGURE C.15

Spring Breakup Cross-Section Profile



C.16 SWALE 14

Spring Breakup Measured Discharge

Table C.17: SW14 Spring Breakup Measured Discharge Summary

Date:	5/29/2019	**Time:**	1:00 PM	**Method:**	USGS Mid-Section Technique
Location:	SW14	**Crew:**	KDB, ACG, DTR, CMB	**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+00.0	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

0 200 400 Feet

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW14.mxd

⌖	Gage Location
●	Station
—	Discharge Measurement Cross Section
→	Flow Direction

Imagery Source: Digital Globe, 2015

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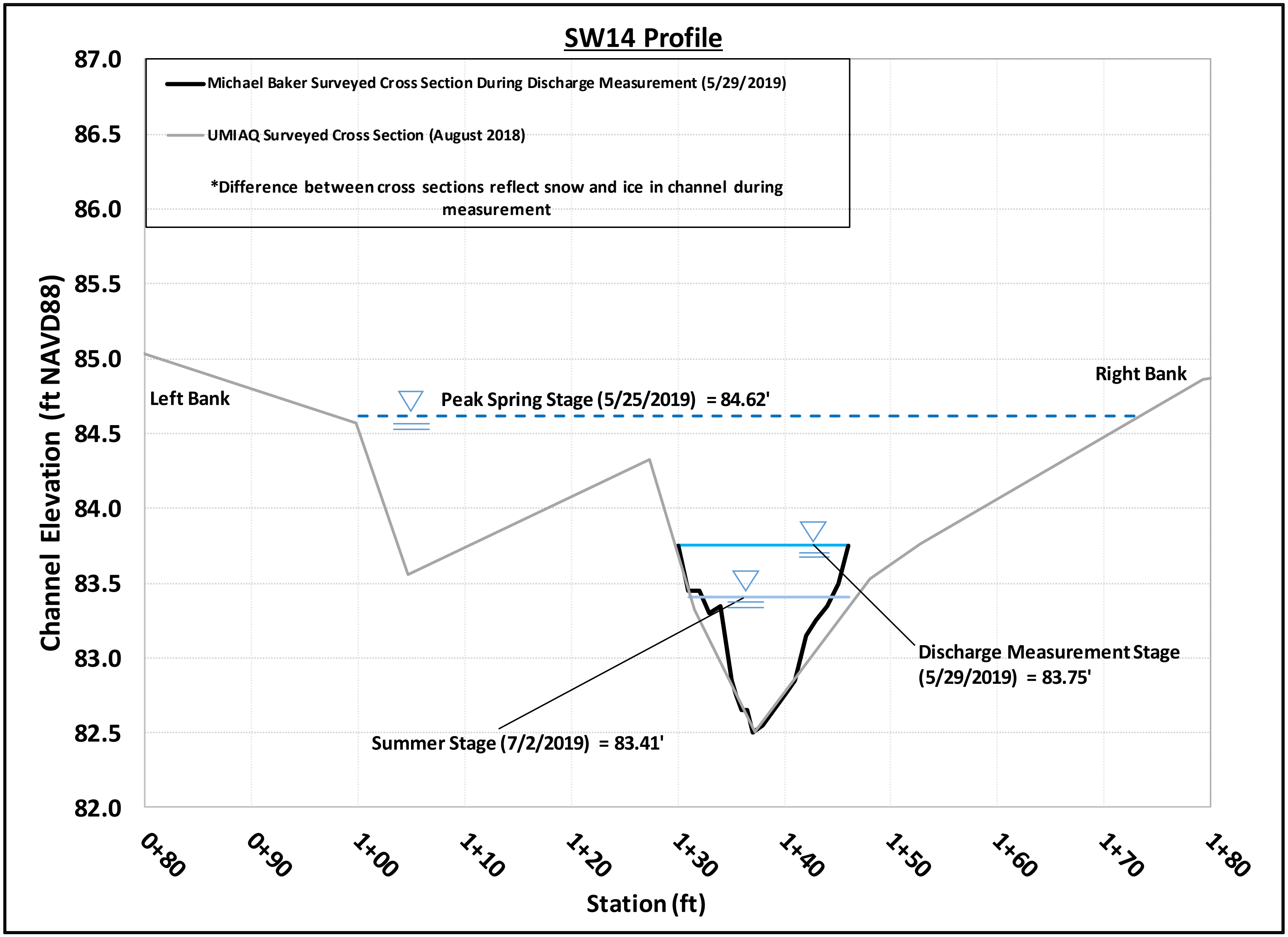
2019 Spring Breakup Swale 14 at SW14 Plan

FIGURE C.16

Spring Breakup Cross-Section Profile



C.17 SWALE 22

Spring Breakup Measured Discharge

Table C.18: SW22 Spring Breakup Measured Discharge Summary

Date:	6/1/2019	**Time:**	1:30 PM	**Method:**	USGS Mid-Section Technique
Location:	SW22	**Crew:**	CMB, MDM	**Depth:**	0.6 of Measured Depth
Lat:	N 70.2762°	**Long:**	W 152.1928°	**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+00.0	79.01	0	-	-	-	-	LEFT BANK
0+01.1	78.01	1.0	0.76	1.05	1.05	0.80	Ice
0+02.1	77.91	1.1	0.83	0.95	1.05	0.87	Grass/Ice
0+03.0	77.91	1.1	1.47	1.25	1.38	2.02	Grass/Ice
0+04.6	79.01	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)
4.6	78.20	0.8	1.02		3.5	3.7

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Feet
0 200 400

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW22.mxd

⊕ Gage Location

● Station

Discharge Measurement Cross Section

→ Flow Direction

Imagery Source: Willow Aerial (COPA), 2018

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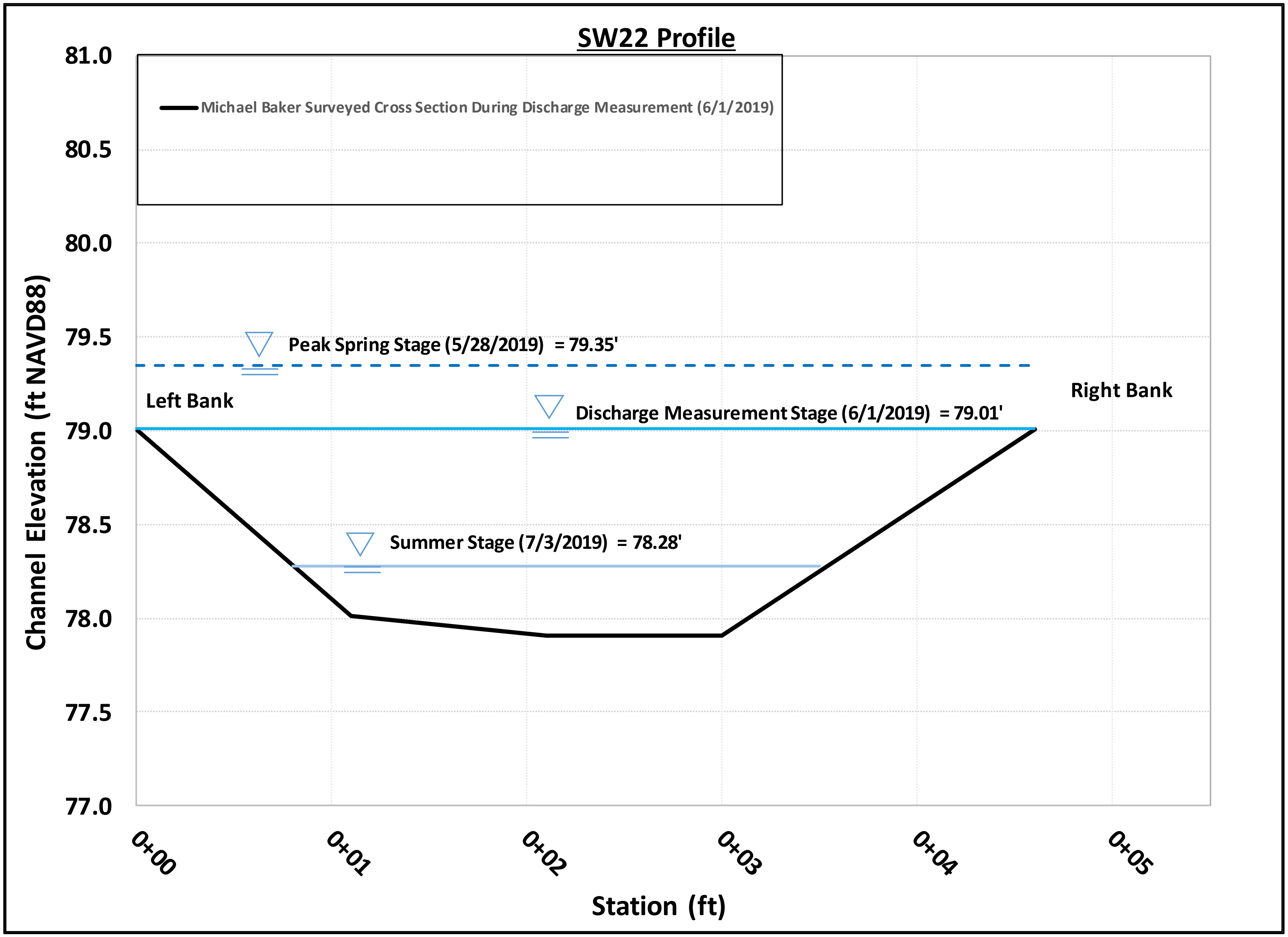
2019 Spring Breakup Unnamed Swale SW22 Plan

FIGURE C.17

Spring Breakup Cross-Section Profile



C.18 SWALE 23

Spring Breakup Measured Discharge

Table C.19: SW23 Spring Breakup Measured Discharge Summary

Date:	6/1/2019	**Time:**	12:30 PM	**Method:**	USGS Mid-Section Technique
Location:	SW23	**Crew:**	CMB, MDM	**Depth:**	0.6 of Measured Depth
Lat:	N 70.3150°	**Long:**	W 152.1990°	**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+00	79.27	0.1	-	-	-	-	RIGHT BANK
0+01	79.17	0.2	0.05	1.0	0.20	0.01	Grass
0+02	78.82	0.55	0.17	1.0	0.55	0.09	Grass
0+03	78.77	0.6	0.33	1.0	0.60	0.20	Grass
0+04	78.97	0.4	0.19	1.0	0.40	0.07	Grass
0+05	78.97	0.4	0.27	1.0	0.40	0.11	Grass
0+06	78.97	0.4	0.30	1.0	0.40	0.12	Grass
0+07	78.87	0.5	0.15	1.0	0.50	0.07	Grass
0+08	78.87	0.5	0.13	1.0	0.50	0.07	Grass
0+09	78.87	0.5	0.18	1.0	0.50	0.09	Grass
0+10	78.87	0.5	0.20	1.0	0.50	0.10	Grass
0+11	79.07	0.3	0.07	1.15	0.35	0.02	Grass
0+12.3	79.37	0	-	-	-	-	LEFT BAANK

Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
12.3	79.00	0.4	0.19		4.9	1.0

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0 200 400 Feet

Date: 10/18/2019
Scale: 1 Inch = 200 Feet
Drawn: JEG
Project: 172339
Checked: GCY
File: PlanView_SW23.mxd

⊕ Gage Location

→ Flow Direction

● Station

— Discharge Measurement Cross Section

Imagery Source: Willow Aerial (COPA), 2018

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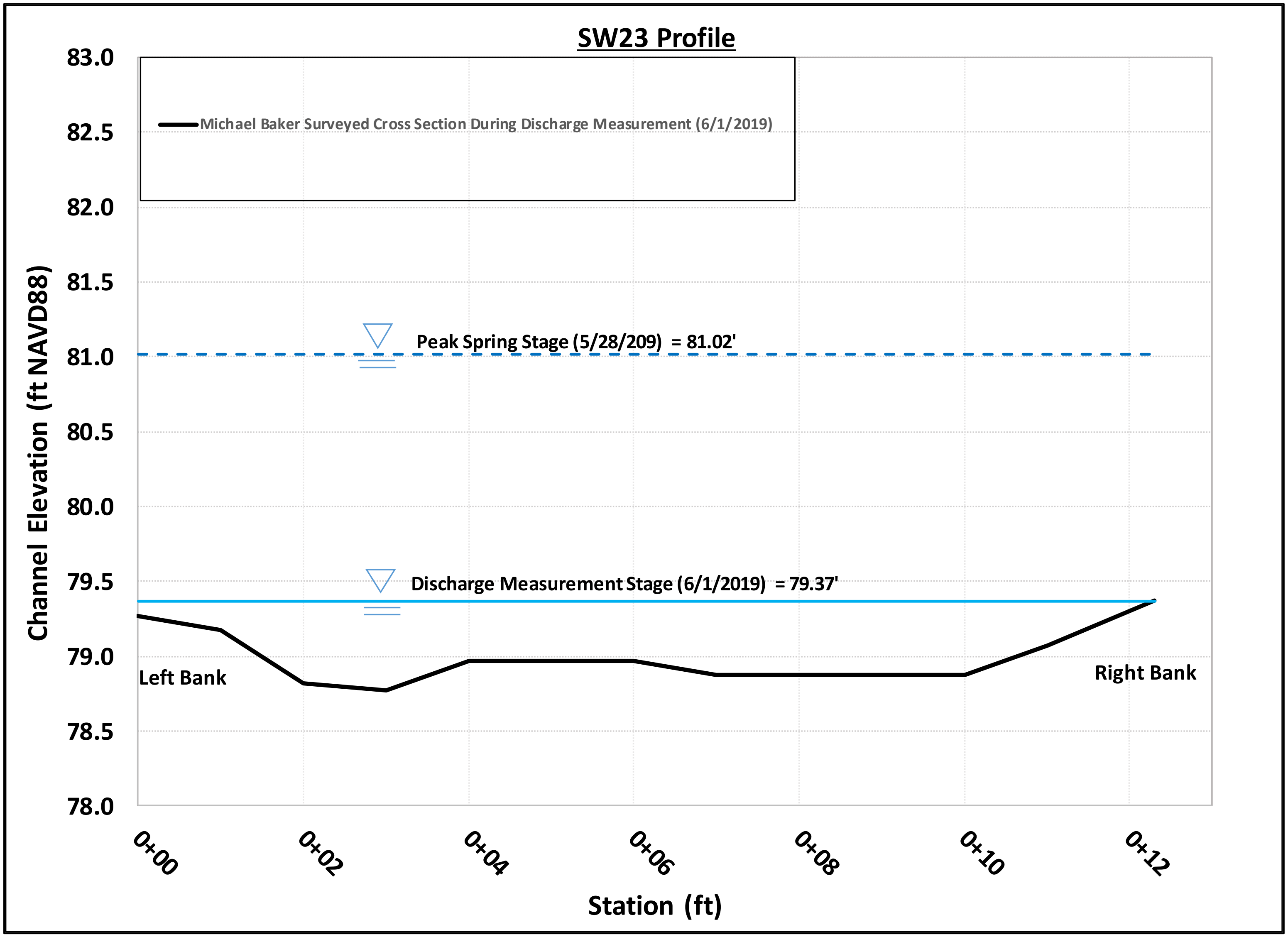
2019 Spring Breakup Swale 23 at SW23 Plan

FIGURE C.18

Spring Breakup Cross-Section Profile



C.19 SWALE 24

Spring Breakup Measured Discharge

Table C.20: SW24 Spring Breakup Measured Discharge Summary

Date:	5/29/2019	**Time:**	10:30 AM	**Method:**	USGS Mid-Section Technique
Location:	SW24	**Crew:**	KDB, DTR, CMB, ACG	**Depth:**	0.6 of Measured Depth
Lat:	N 70.1117°	**Long:**	W 152.1008°	**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+03.0	84.98	0	-	-	-	-	LEFT BANK
0+05.0	84.13	0.85	0.03	2.5	2.13	0.06	Grass
0+08.0	83.98	1.0	0.06	3.0	3.00	0.18	Grass
0+11.0	83.83	1.15	0.10	3.0	3.45	0.33	Grass
0+14.0	83.88	1.1	0.11	3.0	3.30	0.37	Grass
0+17.0	83.88	1.1	0.05	3.0	3.30	0.17	Grass
0+20.0	83.85	1.13	0.07	2.5	2.83	0.19	Grass
0+22.0	83.78	1.2	0.04	2.0	2.40	0.10	Grass
0+24.0	83.53	1.45	0.08	2.5	3.63	0.30	Grass
0+27.0	83.58	1.4	0.09	3.0	4.20	0.39	Grass
0+30.0	83.73	1.25	0.06	3.0	3.75	0.23	Grass
0+33.0	83.73	1.25	0.05	3.0	3.75	0.19	Grass
0+36.0	84.08	0.9	0.06	3.0	2.70	0.16	Grass
0+39.0	84.08	0.9	0.09	3.0	2.70	0.24	Grass
0+42.0	84.08	0.9	0.10	3.0	2.70	0.28	Grass
0+45.0	84.03	0.95	0.08	3.0	2.85	0.24	Grass
0+48.0	84.33	0.65	0.09	3.0	1.95	0.18	Grass
0+51.0	84.48	0.5	0.05	3.0	1.50	0.07	Grass
0+54.0	84.98	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)
51.0	83.94	1.0	0.07		50.1	3.7

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Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_SW24.mxd

⊕ Gage Location

● Station

— Discharge Measurement Cross Section

→ Flow Direction

Imagery Source: Willow Satellite (COPA), 2018

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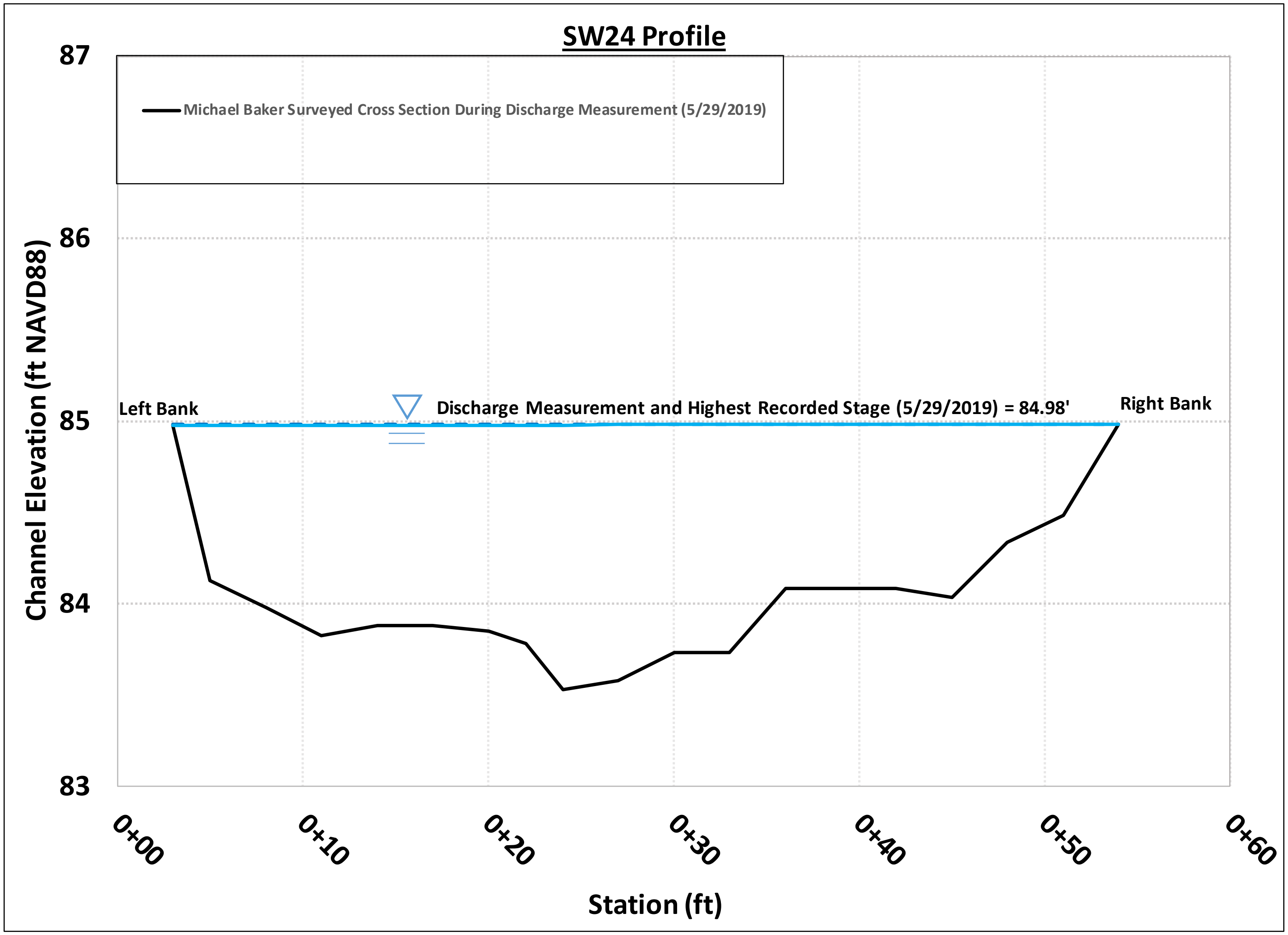
FIGURE C.19

Spring Breakup Cross-Section Profile



C.20 WILLOW 3 AT W3S

Spring Breakup Measured Discharge

Table C.21: W3S 5/30 Spring Breakup Measured Discharge Summary

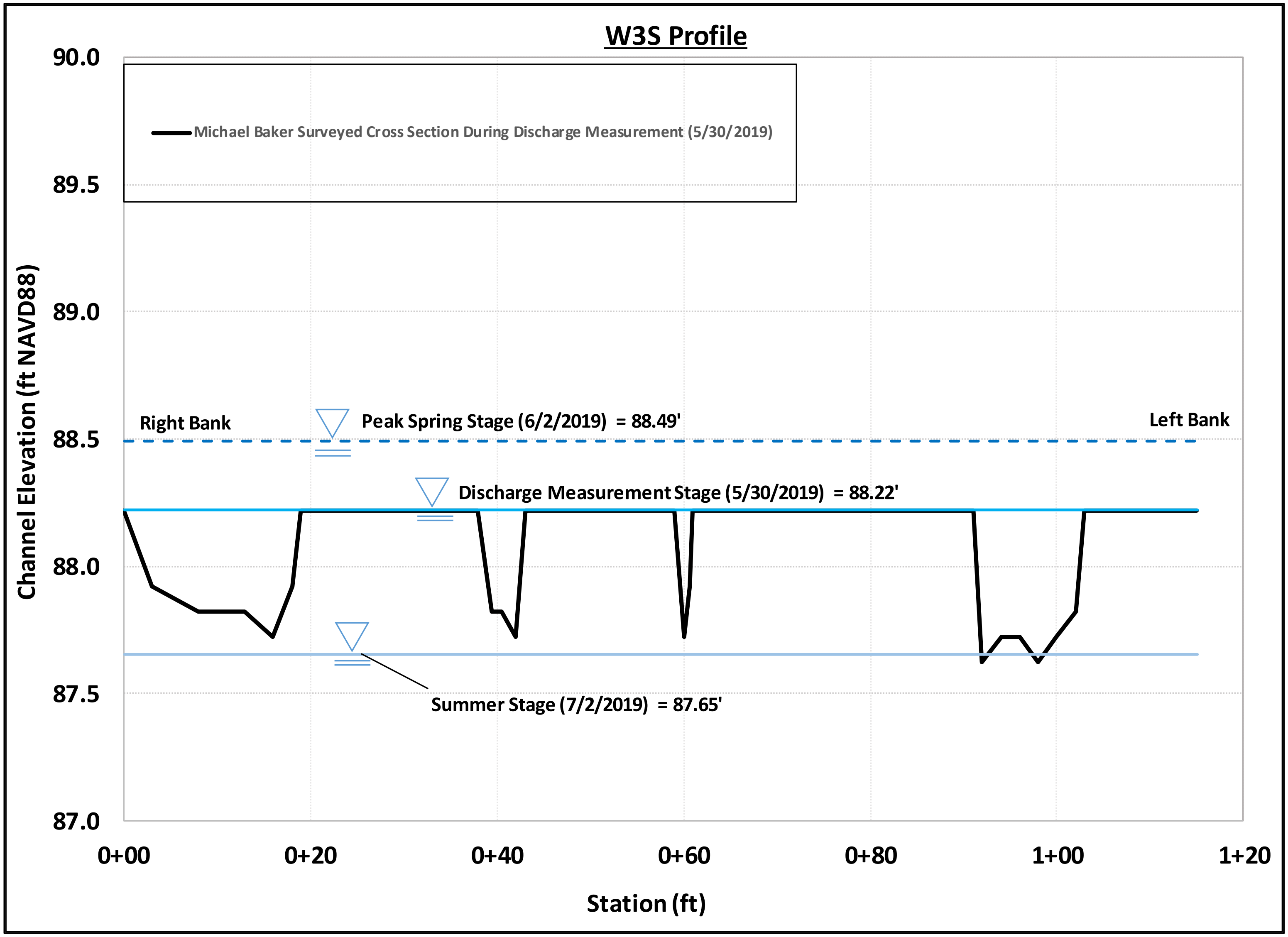
Date:	5/30/2019	**Time:**	1:00 PM
Location:	W3S	**Crew:**	ACG, DTR
Lat:	N 70.1155°	**Long:**	W 152.0924°

Method:	USGS Mid-Section Technique
Depth:	0.6 of Measured Depth
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+00.0	89.40	0	-	-	-	-	RIGHT BANK
0+03.0	89.10	0.3	0.00	4	1.20	0.00	Grass/Snow
0+08.0	89.00	0.4	0.08	5	2.00	0.15	Grass/Snow
0+13.0	89.00	0.4	0.17	4	1.60	0.27	Grass/Snow
0+16.0	88.90	0.5	0.09	2.5	1.25	0.12	Grass/Snow
0+18.0	89.10	0.3	0.64	1.5	0.45	0.29	Grass/Snow
0+19.0	89.40	0	0.00	10	0.00	0.00	Grass/Snow
0+38.0	89.40	0	0.00	10.25	0.00	0.00	Grass/Snow
0+39.5	89.00	0.4	0.05	1.25	0.50	0.02	Grass/Snow
0+40.5	89.00	0.4	1.33	1.25	0.50	0.67	Grass/Snow
0+42.0	88.90	0.5	0.13	1.25	0.63	0.08	Grass/Snow
0+43.0	89.40	0	0.00	8.5	0.00	0.00	Grass/Snow
0+59.0	89.40	0	0.00	8.5	0.00	0.00	Grass/Snow
0+60.0	88.90	0.5	1.28	0.85	0.43	0.55	Grass/Snow
0+60.7	89.10	0.3	1.32	0.5	0.15	0.20	Grass/Snow
0+61.0	89.40	0	0.00	15.15	0.00	0.00	Grass/Snow
0+91.0	89.40	0	0.00	15.5	0.00	0.00	Grass/Snow
0+92.0	88.80	0.6	1.20	1.5	0.90	1.08	Grass/Snow
0+94.0	88.90	0.5	0.20	2	1.00	0.20	Grass/Snow
0+96.0	88.90	0.5	0.38	2	1.00	0.38	Grass/Snow
0+98.0	88.80	0.6	0.29	2	1.20	0.35	Grass/Snow
1+00.0	88.90	0.5	0.39	2	1.00	0.39	Grass/Snow
1+02.0	89.00	0.4	0.60	1.5	0.60	0.36	Grass/Snow
1+03.0	89.40	0	0.00	6.5	0.00	0.00	Grass/Snow
1+15.0	89.40	0	0.00	-	-	-	LEFT BANK

Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
115	89.10	0.3	0.34		14.4	5.1

Spring Breakup Cross-Section Profile



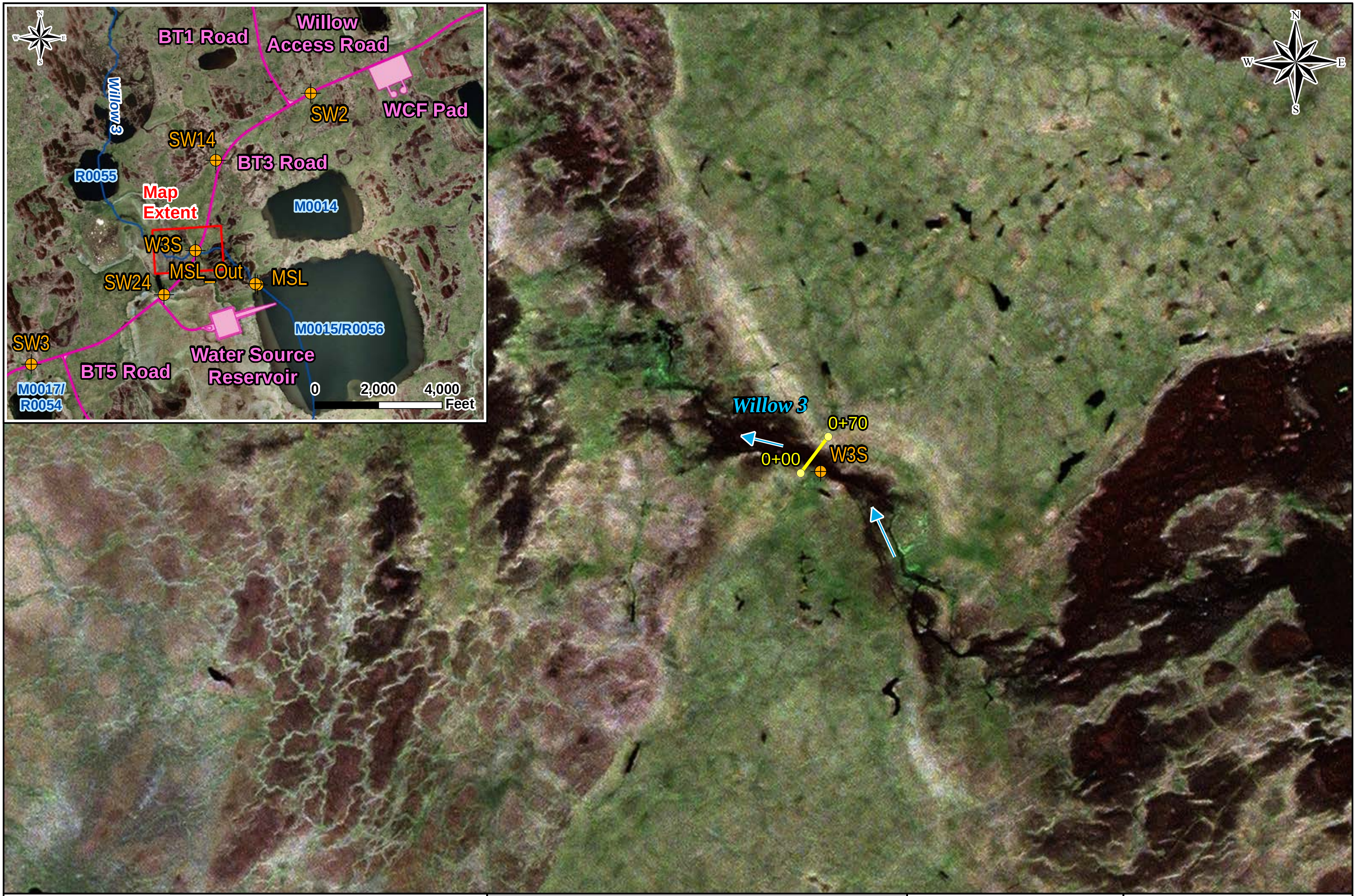
Spring Breakup Measured Discharge

Table C.22: W3S 6/2 Spring Breakup Measured Discharge Summary

Date:	6/2/2019	**Time:**	3:30 PM	**Method:**	USGS Mid-Section Technique
Location:	W3S	**Crew:**	CMB, MDM, CSL	**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 (ft²)	Discharge (ft³/s)	Note
0+00.0	88.20	0	-	-	-	-	LEFT BANK
0+01.0	87.90	0.3	0.50	1.0	0.30	0.15	Grass, ice
0+07.0	87.60	0.6	0.10	6.0	3.60	0.36	Grass, ice
0+12.0	87.70	0.5	0.20	5.0	2.50	0.50	Grass, ice
0+15.0	87.70	0.5	0.15	3.0	1.50	0.23	Grass, ice
0+18.0	87.80	0.4	0.20	3.0	1.20	0.24	Grass, ice
0+19.0	88.20	0	-	-	-	-	Snow pack – no flow
0+28.0	88.20	0	-	10.0	0.00	-	Snow pack – no flow
0+28.1	87.30	0.9	-	-	-	-	
0+41.0	87.30	0.9	0.90	13.0	11.70	10.53	Center channel
0+42.0	88.20	0	-	-	-	-	Snow pack – no flow
0+61.0	88.20	0	-	20.0	0.00	-	Left channel
0+61.1	87.45	0.75	-	-	-	-	
0+69.0	87.45	0.75	0.70	8.0	6.00	4.20	Grass
0+70.0	88.20	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)
70.0	87.80	0.4	0.31		26.8	16.2



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Alaska

0 200 400 Feet

Date:	10/18/2019	Scale:	1 Inch = 200 Feet
Drawn:	JEG	Project:	172339
Checked:	GCY	File:	PlanView_W3S.mxd

⊕ Gage Location

→ Flow Direction

● Station

— Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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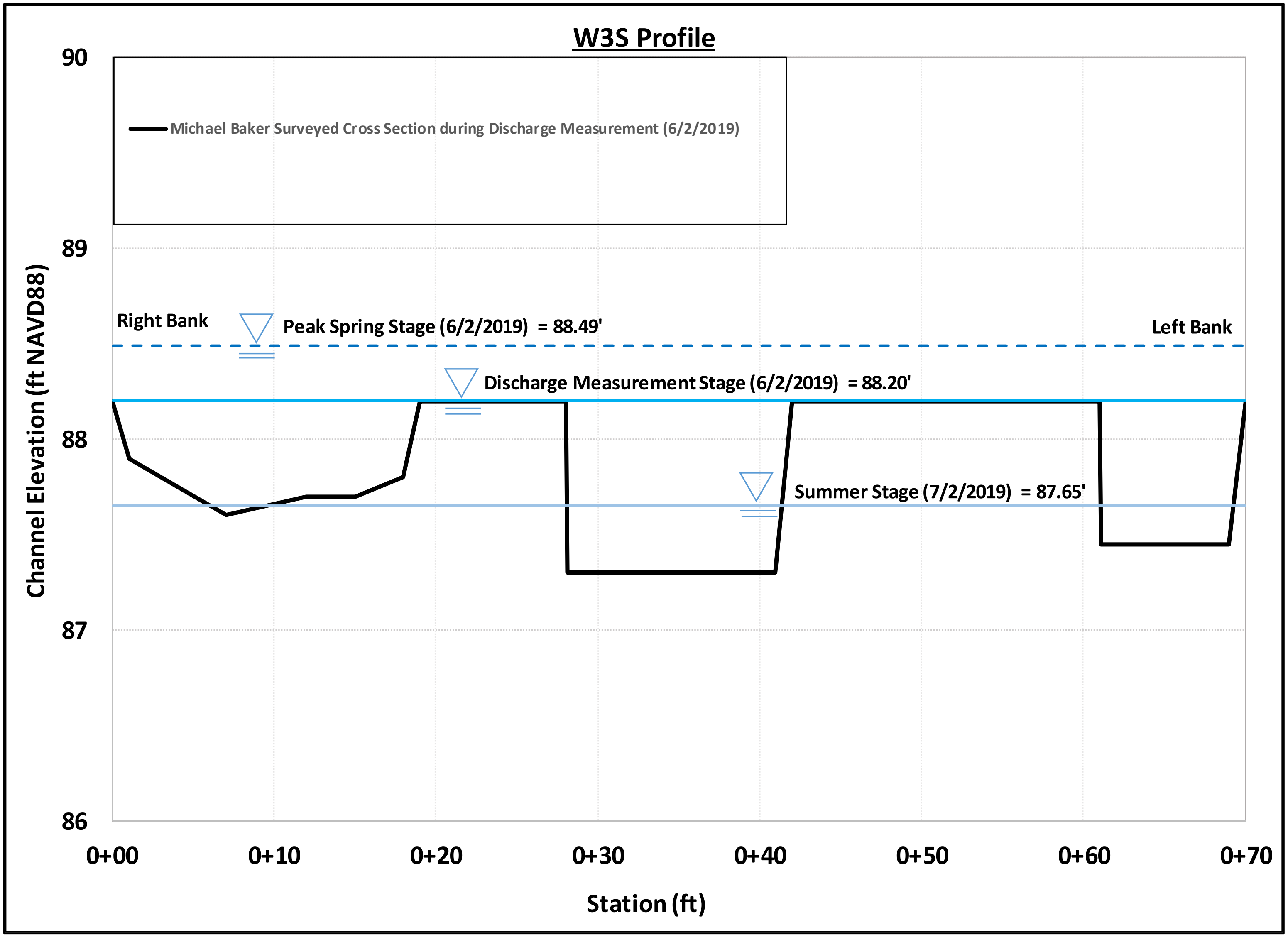
2019 Spring Breakup
Willow 3
W3S Plan

FIGURE C.20

Spring Breakup Cross-Section Profile



Appendix D Flood Frequency Analysis

Table D.1 through Table D.7 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, Kal1, UC1B, UC2C, W_BS1, and W_S1. 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 D.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 D.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 D.3: Kalikpik River at Kal1 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	3,200	61.4	-38.1	1,430	7,100	1.0
20	5	4,800	58.5	-36.9	2,220	10,300	1.2
10	10	5,800	58.1	-36.7	2,710	12,500	1.5
4	25	7,100	58.6	-37.0	3,280	15,300	1.9
2	50	8,000	59.6	-37.3	3,660	17,500	2.3
1	100	8,900	60.9	-37.9	4,000	19,600	2.5
0.5	200	9,700	62.6	-38.5	4,310	21,900	2.7

Table D.4: 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 D.5: 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 D.6: 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

Table D.7: Willow 4 at W_S1 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	200	62.4	-38.4	69	346	1.5
20	5	200	59.4	-37.3	115	544	1.7
10	10	300	59.1	-37.2	145	683	2.2
4	25	400	59.8	-37.4	181	866	2.8
2	50	500	60.9	-37.8	206	1,010	3.2
1	100	500	62.3	-38.4	229	1,160	3.6
0.5	200	600	64.1	-39.1	251	1,310	3.9

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