NOVEMBER 2018

2018

WILLOW SPRING BREAKUP & SUMMER MONITORING & HYDROLOGICAL ASSESSMENT

PREPARED BY:

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EXECUTIVE SUMMARY

This report presents the results from the 2018 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 2018 spring breakup flood event was characterized as a low magnitude, prolonged event, drawn out over three weeks. Spring breakup and summer hydrological conditions were monitored at various locations throughout the Willow project area. Spring breakup and summer events were documented with visual observations and aerial and ground photography. Peak spring breakup conditions occurred between June 3 and June 23 across the monitoring area. During peak conditions, floodwater was generally confined within channels and swales. Stage was receding at all gage stations by June 25. Stage and discharge generally declined over the summer months, with occasional increases resulting from rainfall events. Summer peak conditions occurred between mid-August through the end of summer monitoring in mid-September.

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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

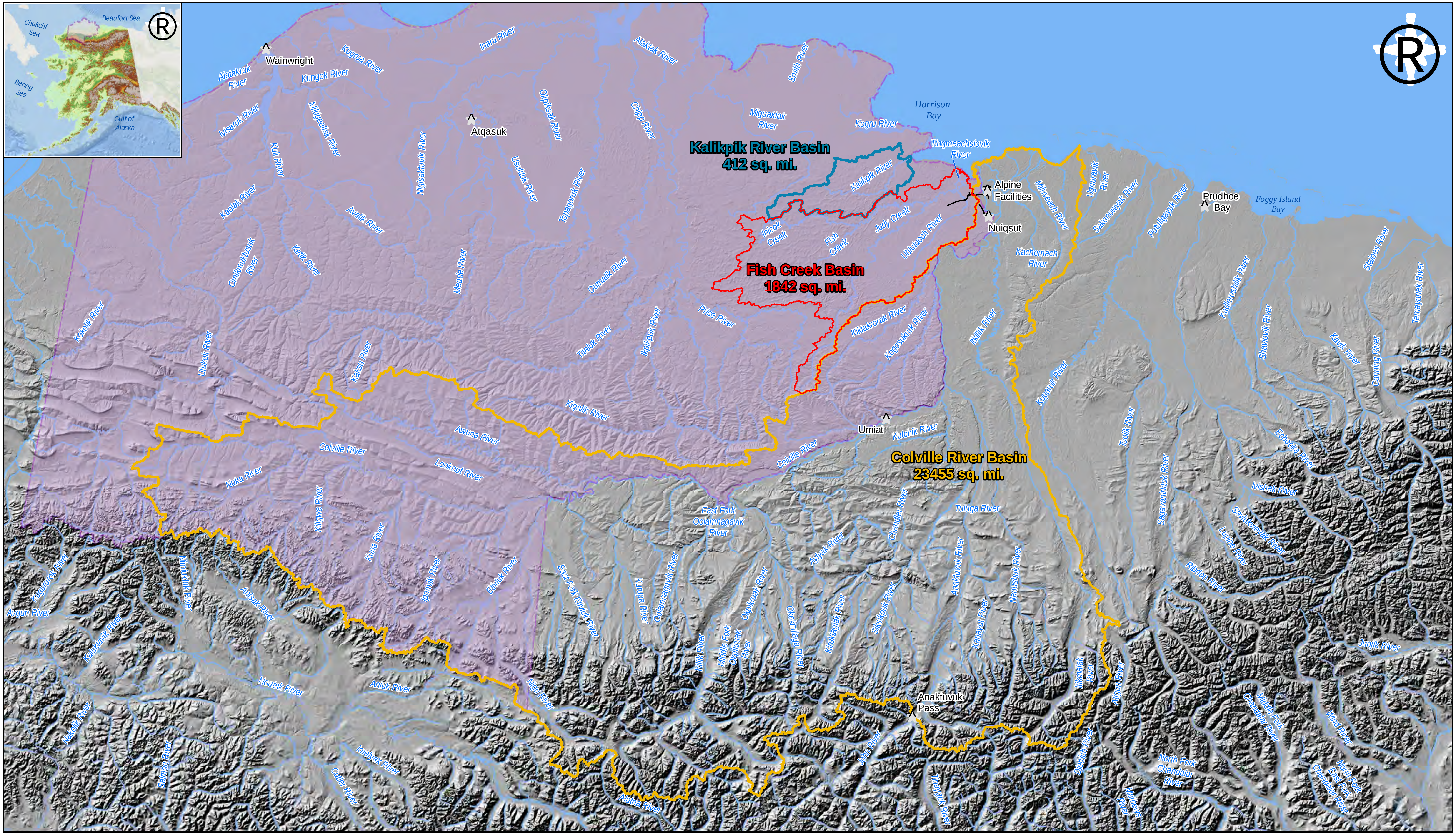
1 INTRODUCTION

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. 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" (BLM, 2013, 63).

Spring breakup is generally considered the largest annual flooding event in this region of 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 during 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 FCB 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 2018 Willow Spring Breakup and Summer Monitoring and Hydrological Assessment program included monitoring 23 new gage stations and eight existing gage stations including J13.8U, J13.8, J13.8D, J21.4, UC2C, UC1B, SW1, and SW4. H&H assessments at gage station J13.8 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 and 2018 (Michael Baker 2003, 2005a, 2005b, 2007, 2017, 2018).

The 2018 field program took place from April 24 to September 12. Spring breakup setup began on April 24 and concluded on May 13. Spring breakup monitoring began on May 16 and concluded on June 18. Summer monitoring was broken up into two field programs. During the first program, July 6-July 11, 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 7 – September 12, equipment was retrieved from the field and gages were rehabilitated and repositioned for monitoring the 2019 spring breakup. 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.



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

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Fish Creek, Kalikpik, & Colville River Drainage Basins

FIGURE: 1.1

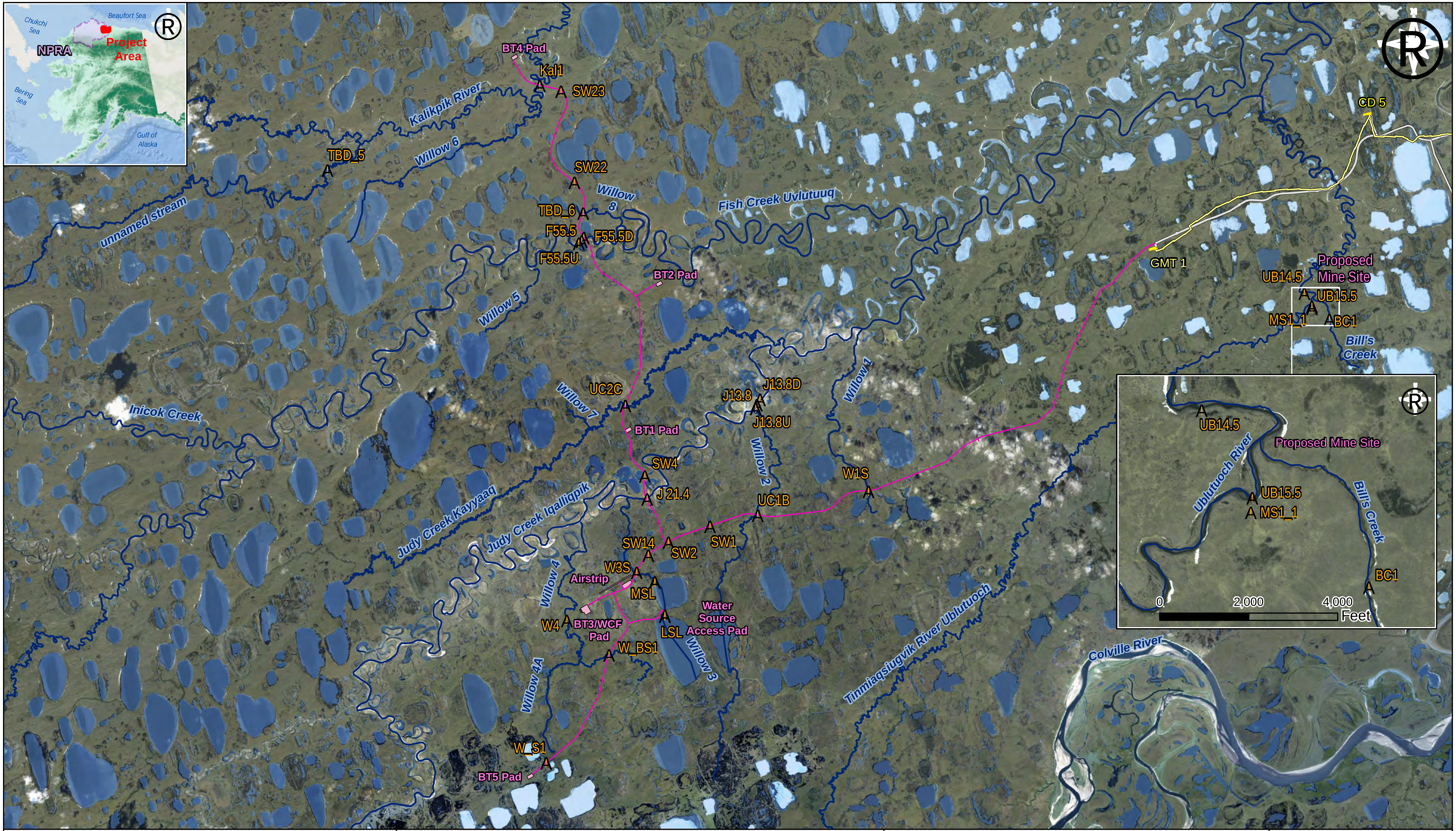
1.1 MONITORING OBJECTIVES

The primary objective of the 2018 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 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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Gage Location
Stream / River
Lake
Pipeline
Road
Facility

Alternative 1
Proposed Road
Proposed Facility

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2018 Willow Gage Stations

Proposed Roads & Facilities

FIGURE: 1.2

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Miles
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Date:	11/13/2018	Project:	166429
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Gage Location
Stream / River
Lake

Alternative 1
Proposed Road
Proposed Facility

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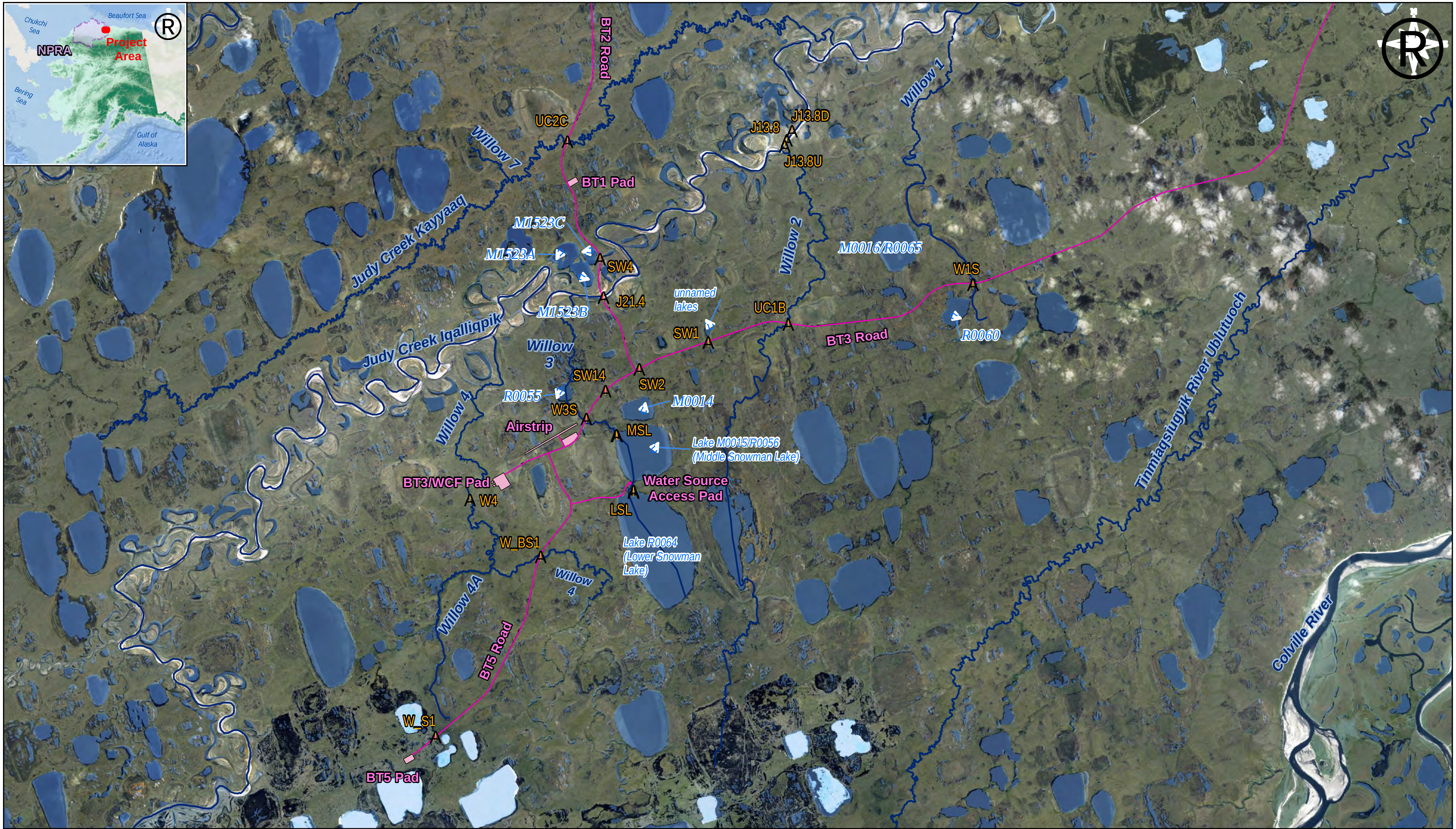
2018 Willow Gage Stations North Detail

Proposed Roads & Facilities

FIGURE: 1.3



ConocoPhillips Alaska

Miles
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Checked:	GCY	Scale:	1 Inch = 1.5 Miles

Gage Location
Stream / River
Lake

Alternative 1
Proposed Road
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2018 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	Summer Stage	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	1	✓	✓	✓	✓	✓
		F55.5		1	✓	✓			
		F55.5D		1	✓	✓			
	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	2	✓	--	✓	--	--
		J13.8		6	✓	--			
		J13.8D		2	✓	--			
		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	2	✓	✓	--	✓	--
	Kalikpik River	Kal1	Proposed Kalikpik River crossing, west bank	1	✓	✓	✓	✓	✓
Small Streams	Judy Creek Kayyaaq	UC2C	Proposed Judy Creek Kayyaaq crossing, east bank, approximately 13.0 RM upstream of Judy Creek	2	✓	✓	✓	--	✓
	Willow 1	W1S	Proposed Willow 1 crossing, in swale upstream of well-defined channel draining in to Judy Creek	1	--	✓	--	--	--
	Willow 2	UC1B	Proposed Willow 2 crossing, east bank, approximately 4.5 RM upstream of Judy Creek	2	✓	✓	✓	--	✓
	Willow 3	W3S	Proposed Willow 3 crossing, west of the middle and lower Snowman Lakes	1	✓	✓	--	--	--
	Willow 4	W4	On Willow 4 adjacent to proposed BT3/WCF pad, approximately 5.3 RM upstream of Judy Creek	1	✓	✓	✓	--	--
		W_BS1	Proposed Willow 4 crossing, approximately 9 RM upstream of Judy Creek	1	✓	✓	✓	--	✓
	Willow 4a	W_S1	Proposed Willow 4A crossing,	1	✓	✓	✓	--	--
	Willow 8	TBD_6	Proposed Willow 8 crossing, 1.7 RM upstream of Fish Creek, well defined channel	1	✓	✓	✓	--	--
		SW22	Proposed Willow 8 crossing, 3 RM upstream of Fish Creek, poorly defined channel	1	--	--	--	--	--
	TBD_5	TBD_5	Proposed crossing at TBD_5, a well-defined channel draining into the Kalikpik River	1	✓	✓	✓	--	--
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	2	--	--	✓	--	--
	Swale 2	SW2	Proposed crossing of Swale 2, a low-lying area with occasional beads between Lake M0014 and Judy Creek	1	--	--	✓	--	--
	Swale 4	SW4	Proposed crossing of Swale 4, a polygon trough paleochannel of Judy Creek	2	--	--	--	--	--
	Swale 14	SW14	Proposed crossing of Swale 14, a low-lying area between Lake M0014 and Judy Creek	1	--	--	✓	--	--
	Swale 23	SW23	Proposed crossing of Swale 23, a beaded swale flowing from unnamed lake to the Kalikpik River	1	--	--	✓	--	--
Minesite	Tinmiaqsiugvik River	UB14.5	On Tinmiaqsiugvik River at the proposed minesite	1	✓	--	--	--	--
	Tinmiaqsiugvik River	UB15.5	On Tinmiaqsiugvik River at the proposed minesite	1	✓	--	--	--	--
	Bills Creek	BC1	Beaded stream that boarders the proposed minesite to the east	1	✓	✓	--	--	--
	MS1_1	MS1_1	Swale through proposed minesite	1	✓	✓	--	--	--
Source Lakes	Lake M0015/R0056 aka Middle Snowman Lake	MSL	Northwest corner of middle Snowman Lake	1	✓	✓	--	--	--
	Willow 3/Lake M0015/R0056 (aka Middle Snowman Lake) outlet	MSL_OUT	Lake outlet, approximately 75 feet west of MSL	1	✓	✓	--	--	--
	Lake R0064 (aka Lower Snowman Lake)	LSL	Northwest corner of lower Snowman Lake	1	✓	✓	--	--	--
	Willow 3/Lake R0064 (aka Lower Snowman Lake) outlet	LSL_OUT	Lake outlet, approximately 135 feet northwest of LSL	1	✓	✓	--	--	--

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 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 every gage station and supplemented by gage measurement readings to provide a continuous record of stage. PTs are designed to collect and store pressure and temperature data at discrete pre-set intervals; 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, facing gages, were installed to photograph site conditions and record water levels at 15-minute intervals. Cameras were installed at 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 their associated vertical control using standard differential leveling techniques. Two vertical control monuments were installed at each new monitoring location. Monitoring locations installed in 2017 were referenced to the same control points established in 2017. 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. All monitoring locations were assigned an arbitrary elevation except for J13.8. 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 new vertical control was installed adjacent to the existing vertical control during the 2017 monitoring period and was also referenced to BPMSL. In July 2018, UMIAQ surveyors established elevations tied to the North American Vertical Datum of 1988 (NAVD88) at many of the control monuments using GPS. At other locations, where the control monuments were not directly surveyed, NAVD88 elevations were assigned to the control monuments using WSEs measured at the time of survey and concurrent PT data. Arbitrary elevations were retained at most of the swales, where survey data was not collected.

REAL-TIME FLOOD MONITORING NETWORK

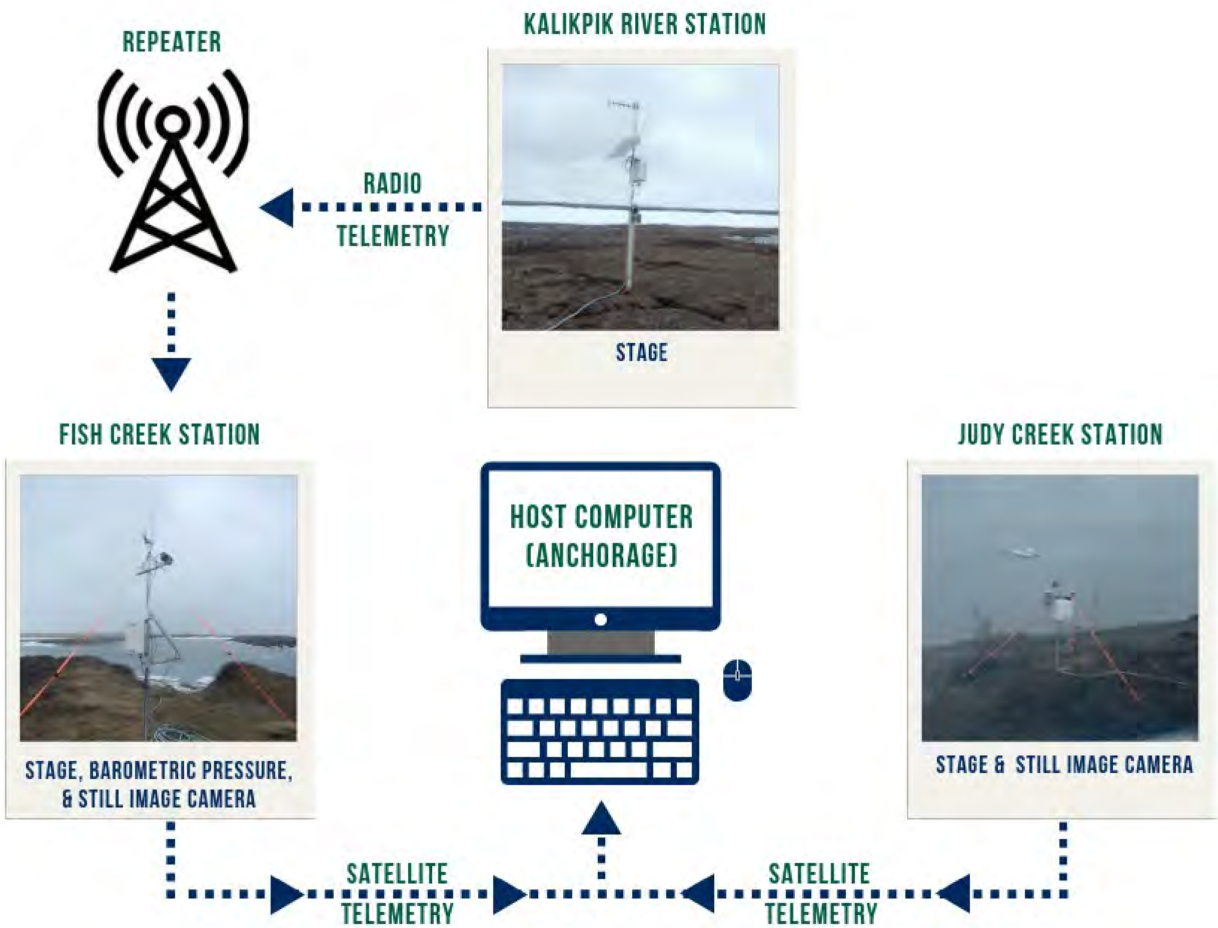
The ability to remotely monitor stage and river conditions helps reduce helicopter traffic, allows for round-the-clock monitoring of conditions, and allows for remote monitoring when helicopter travel is restricted due to weather or other circumstances. In addition, a network of real-time monitoring 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 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

Channel cross-section profiles were surveyed by Michael Baker during spring breakup or summer discharge measurements. Site specific spring breakup and summer channel cross-section geometry is detailed in Appendix B.

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
- Willow 4a at W_S1
- Willow 8 at TBD_6
- Kalikpik River at Kal1
- Small swales and drainages at SW1, SW2, SW14, TBD_5, and SW23

Discharge was measured at J13.8, UC1B, UC2C, F55.5, Kal1, TBD_5, TBD_6, W_BS1, and W4 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.

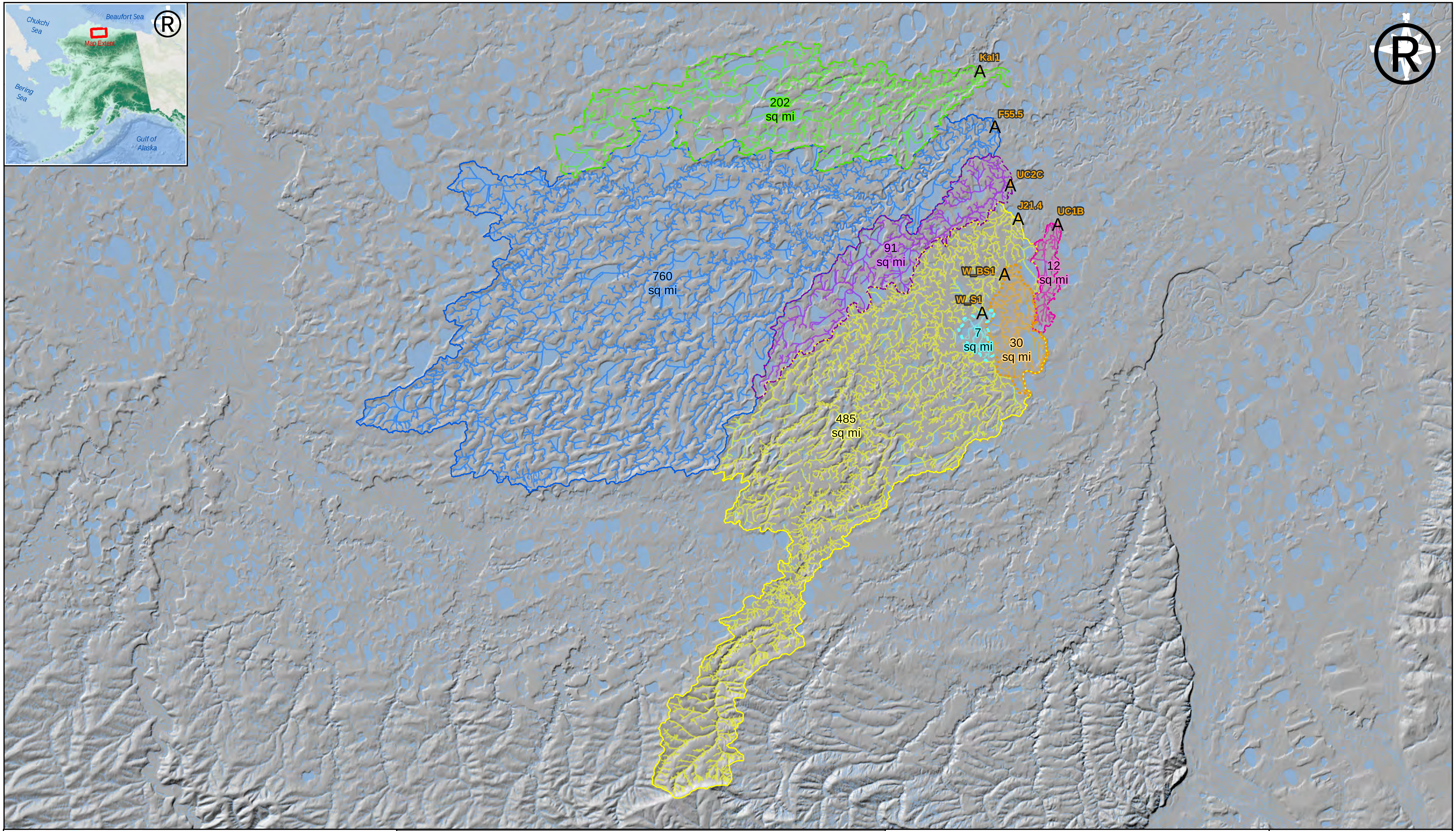
2.4 Flood Frequency Analysis

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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0 3.5 7 14 Miles

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	Gage_Station_Basins.mxd
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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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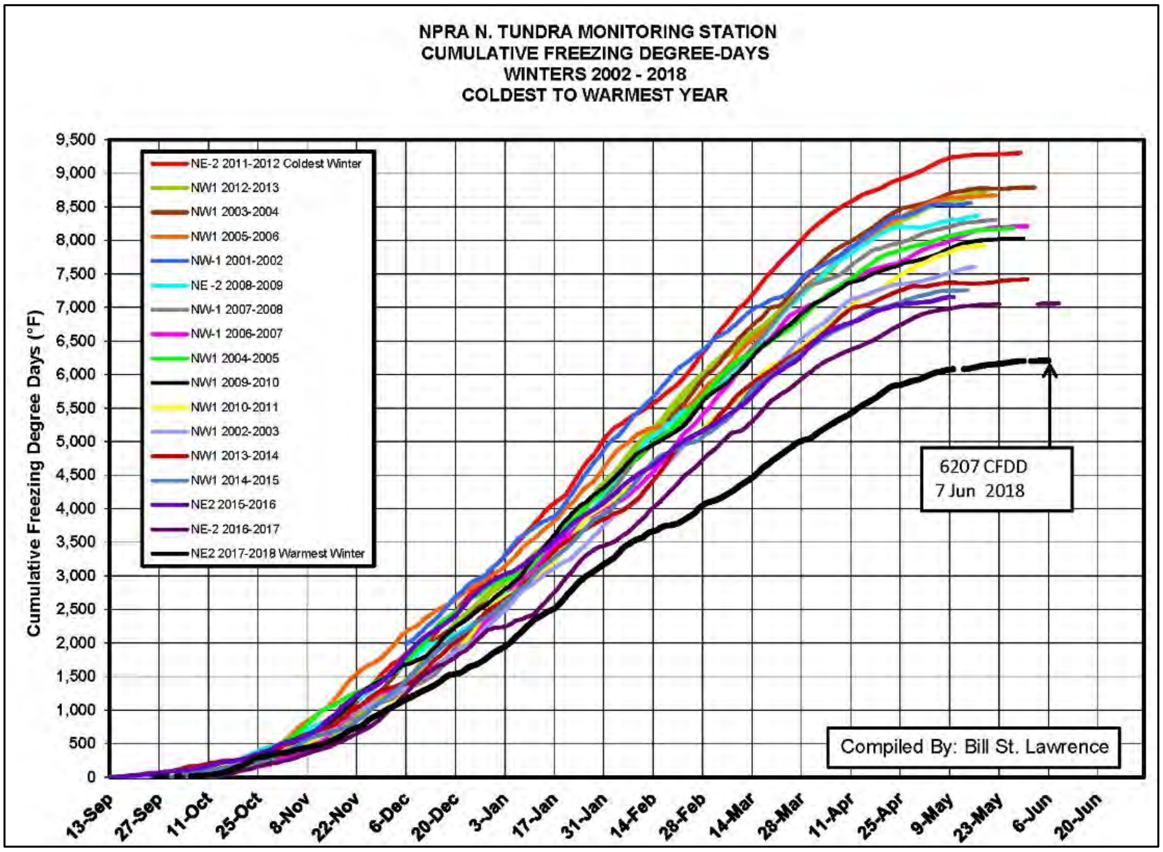
Willow Drainage Basins

FIGURE: 2.2

3 OBSERVATIONS

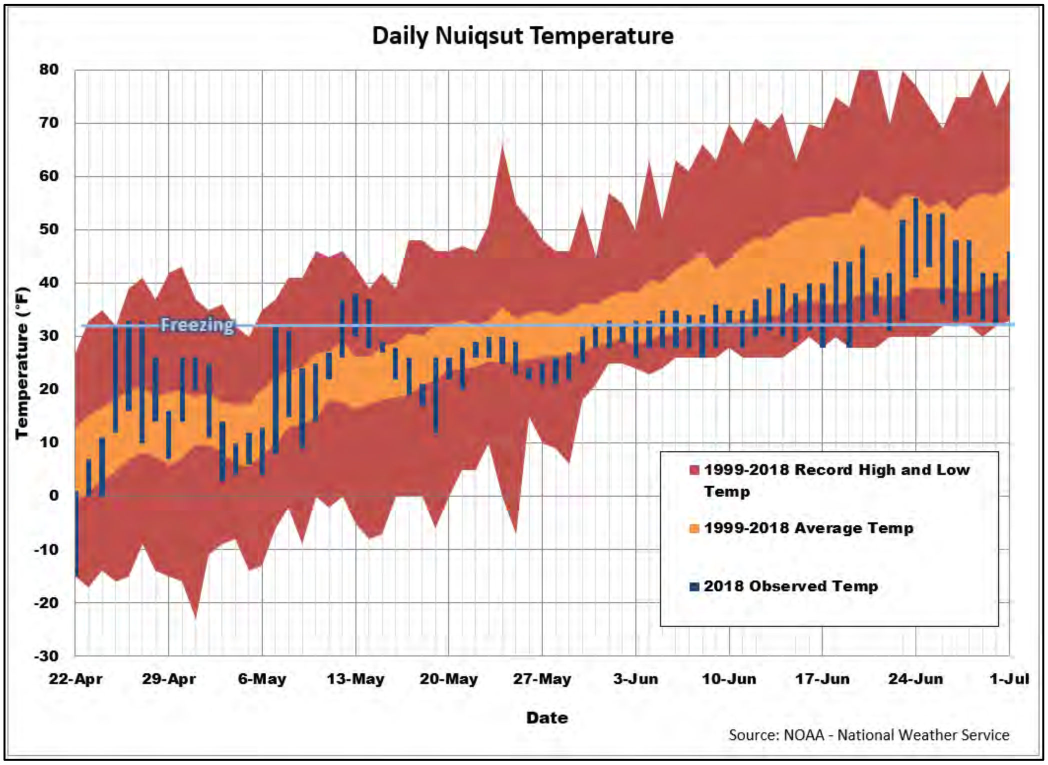
3.1 GENERAL CLIMATIC SUMMARY

The cumulative freezing degree days (CFDD) measured at the NPR-A tundra monitoring station indicate that the 2017-2018 (September – May) winter was the warmest on record for the past 17 years, as shown in Graph 3.1 (ICE 2018). As of April 30, 2018, snowpack in the Brooks Range south of the Colville river was reported as approximately 150% of the 1981-2010 median (NRCS 2018).



Graph 3.1: NPR-A N. Tundra Monitoring Station, CFDD, Winters 2002-2018 (ICE 2018)

Temperatures for the Alpine area are available from the Nuiqsut weather station, located approximately 23 air miles east of Judy Creek. Daily low ambient air temperatures remained below freezing and significant cloud cover persisted throughout the breakup monitoring period. As a result, breakup in the Willow area was characterized as a low magnitude, prolonged event, drawn out over three weeks due to extended cold weather and persistent cloud cover in the arctic coastal plain. 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 (Weather Underground 2018).



Graph 3.2: Nuiqsut Daily High and Low Ambient Air Temperatures

3.2 General Breakup Summary

Water was first observed in the Willow area on June 4 with initial flow observed in Judy Creek (Photo 3.1) and rising stage observed in many small streams and swales. Local melt was also observed on both Judy Creek Kayyaaq and Fish Creek (Photo 3.2 and Photo 3.3). By June 6, peak stage was observed on Judy Creek while stage continued to rise elsewhere in the Willow area. Judy Creek was free of ice by June 8 (Photo 3.4). Snow still covered approximately 60% of the surrounding tundra on June 9. Stage on the Kalikpik River peaked on June 11 and receded rapidly afterwards.

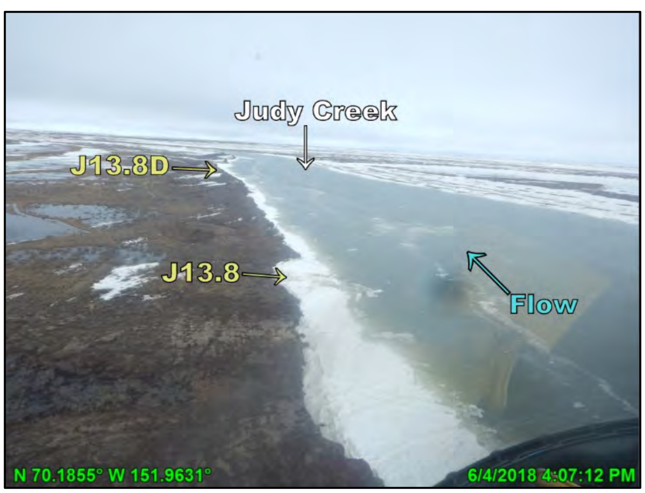


Photo 3.1: J13.8 looking north (downstream); June 4, 2018

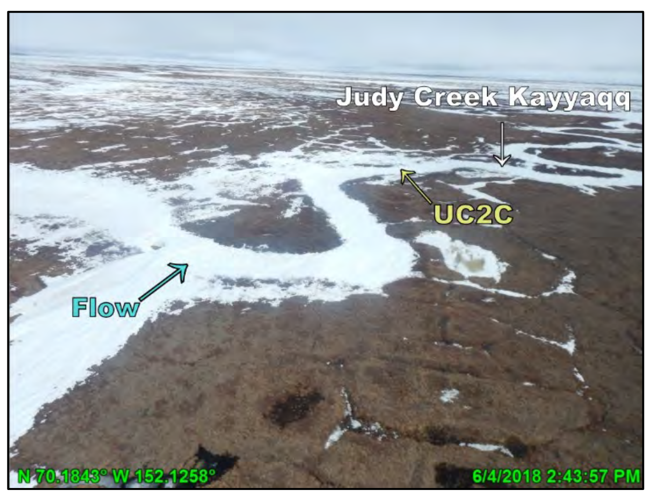


Photo 3.2: UC2C looking northeast (downstream); June 4, 2018

Photo 3.3: Fish Creek at F55.5 looking northeast (downstream); June 4, 2018

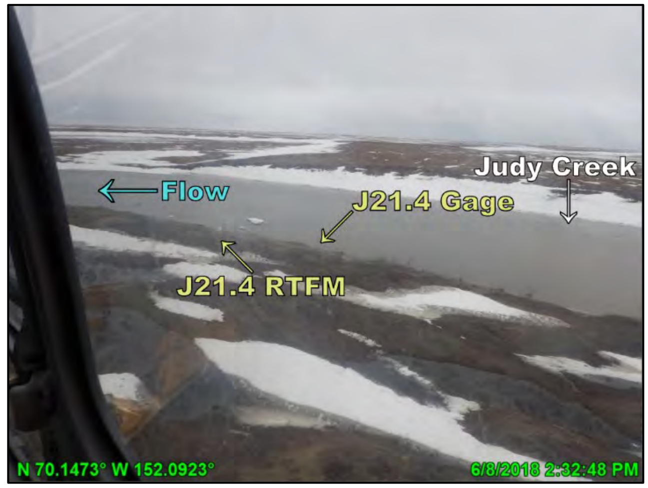


Photo 3.4: Judy Creek at J21.4 looking south; June 8, 2018

Peak stage was observed at small streams between June 3 and June 13 and was the result of elevated water levels associated with flow through snow packed channels. By June 13, stage was receding at most Willow monitoring locations except Fish Creek, where stage increased slowly after the first indication of flow on June 9. By June 16, very little snow was observed on the surrounding tundra, but was still present in channels and along river banks (Photo 3.5 and Photo 3.6). The swales peaked at different dates, ranging from June 7 to June 12, and most were hydraulically connected by June 17. Fish Creek did not reach peak stage until June 23, approximately two weeks after all other streams and swales in the Willow area had peaked.

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 a ½ inch of rain recorded at Nuiqsut between September 2 and September 7 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.

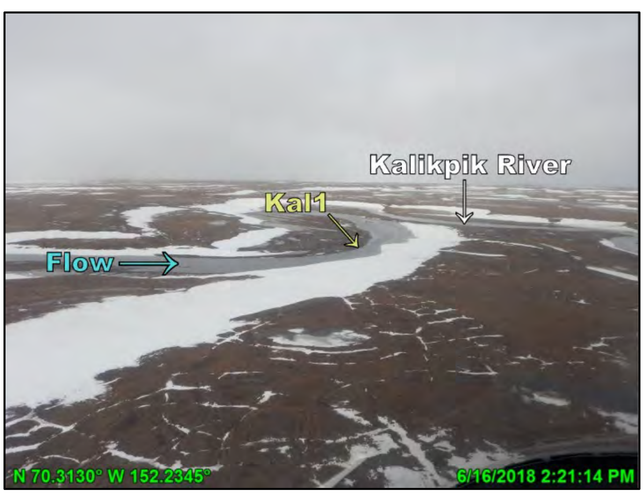


Photo 3.5: Kal1 looking north (downstream); June 16, 2018

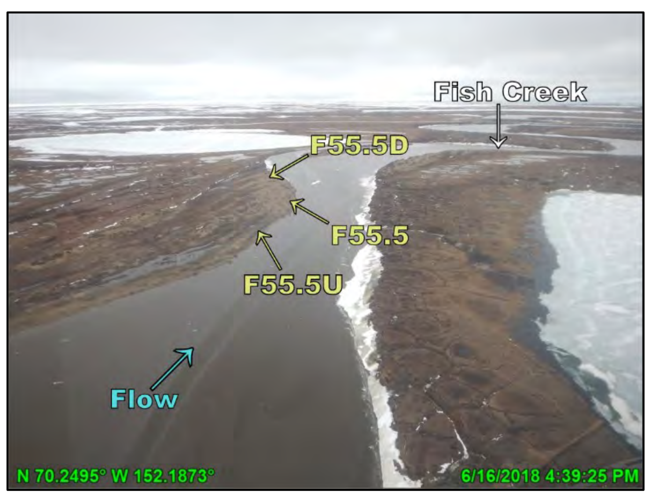


Photo 3.6: Fish Creek at F55.5 looking north (downstream); June 16, 2018


2018 MONITORING LOCATIONS
Major Streams
6/4 – Local melt apparent at Fish Creek & Judy Creek Kayyaaq; flow apparent & transporting floes at Judy Creek
6/6 – Peak stage at Judy Creek sites
6/7 – Discharge measured at J 13.8
6-9 – Flow at Fish Creek
6/10 – Local melting apparent at Kal1
6/11 – Peak Stage at Kal1; flow is transporting floes
6/15 – Small ice jam briefly forms at Fish Creek
6/16 – Discharge measured at Kal1
6/17 – Discharge measured at Fish Creek & Judy Creek
6/23 -Peak stage & peak discharge at Fish Creek
Small Streams
6/2 – Local melting apparent at W4, W_BS1, & W_S1
6/3 – Local melting apparent at W1S &W3S
6/4 – Peak stage at W3S due to local melt; local melting apparent at UC2C & UC1B
6/5 – Local melting apparent at TBD_5
6/6 – Peak stage at W1S due to local melt
6/7 – Flow apparent at W1S, W4, & W_BS1; Peak stage at W4 & W_BS1
6/8 – Flow apparent at UC2C & W_S1; Discharge measured at W_BS1; peak stage at W_S1
6/10 – Peak stage at W1S; local melting apparent at TBD_6
6/11 – Discharge measured at UC2C & W4; flow apparent & peak stage at TBD_5
6/12 – Flow apparent at W3S; peak stage at TBD_6
6/13 – Peak stage at UC2C; Discharge measured at UC1B & W_S1
6/15 – Local melting apparent at SW22
6/16 – Discharge measured at TBD_6
6/18 – Discharge measured at TBD_5
Swales
6/3 – Local melting apparent at SW4
6/5 – Flow apparent & peak stage at SW14
6/6 – Local melting apparent at SW2
6/7 – Peak stage due to local melt at SW2; Discharge measured at SW14, local melting apparent at SW1
6/10 – Peak stage & flow apparent at SW1; local melting apparent at SW23
6/12 – Peak stage & flow apparent at SW23
6/13 Discharge measured at SW1 & SW2; flow apparent at SW2
6/18 – Discharge measured at SW23
Minesite
6/3 – Flow apparent at UB14.5 & UB15.5
6/4 – Local melting apparent at MS1_1
6/5 – Peak stage at MS1_1
6/8 – Peak stage at UB 15.5
6/9 – Peak stage at UB 14.5; flow apparent at MS1_1 & BC1
6/11 – Peak stage at BC1
Source Lakes
6/1 – Local melting apparent at MSL & MSL_OUT
6/3 – Peak stage at MSL_OUT
6/4 – Peak stage at MSL
6/7 – Overbank flooding around Middle Snowman Lake (MSL & MSL_OUT)
6/11 – Flow apparent from MSL to MSL_OUT; flow apparent from LSL to LSL_OUT
6/15 – Peak stage at LSL_OUT
6/26 – Peak stage at LSL
Date
4/24
5/13
5/16
5/27
6/1
6/2
6/3
6/4
6/5
6/6
6/7
6/8
6/9
6/10
6/11
6/12
6/13
6/14
6/15
6/16
6/17
6/18
6/19
6/23
6/26
GENERAL INFORMATION
Hydrologic gage setup begins
Hydrologic gage setup complete
Breakup monitoring begins
Daily high temperatures at Umiat Increase above freezing
6/9 – Tundra approximately 60% snow covered
6/11 – Tundra approximately 50% snow covered
6/13 – Tundra approximately 30% snow covered
6/15 – Tundra approximately 10-20% snow covered
6/17 – Tundra approximately 5-10% snow covered
Field monitoring ends; remote monitoring continues
Remote monitoring ends

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 [1,8]	46.06	6/22 12:15 PM	2,700	44.36	6/17 3:00 PM	4,400	46.03	6/23 2:00 PM
	F55.5 [8]	46.25	6/23 2:30 AM						
	F55.5D [8]	46.23	6/23 2:15 AM						
Judy Creek	J21.4	51.24	6/6 7:45 AM	--	--	--	--	--	--
	J13.8U [2]	37.35	6/6 2:00 PM	3,700	36.35	6/7 2:30 PM	4,100	36.37	6/7 8:30 PM
	J13.8 [2]	37.09	6/6 2:30 PM						
	J13.8D [2]	37.04	6/6 1:45 PM	3,500	34.24	6/17 12:00 PM			
Kalikpik River	Kal1 [8]	50.30	6/11 7:45 AM	320	48.18	6/16 4:00 PM	--	--	--
Judy Creek Kayyaaq	UC2C [8]	54.78	6/13 8:00 AM	140	53.69	6/11 3:30 PM	--	--	--
Willow 1	W1S [3]	79.16	6/6 4:15 PM	--	--	--	--	--	--
Willow 2	UC1B	84.42	6/10 11:15 AM	120	81.17	6/13 5:00 PM	--	--	--
Willow 3	W3S [3]	84.13	6/4 11:00 AM	--	--	--	--	--	--
Willow 4	W4 [7]	96.38	6/7 10:45 PM	600	95.12	6/11 12:00 PM	--	--	--
	W_BS1	87.87	6/7 2:45 PM	240	87.18	6/8 1:00 PM	--	--	--
Willow 4a	W_S1	101.93	6/8 8:45 PM	40	99.77	6/13 1:00 PM	--	--	--
Willow 8	SW22	No Recorded Water		--	--	--	--	--	--
	TBD_6 [8]	52.71	6/13 12:45 PM	65	51.36	6/15 4:30 PM	--	--	--
TBD_5	TBD_5 [7]	98.42	6/11 4:00 PM	250	98.08	6/18 3:00 PM	--	--	--
Swales	SW1 [3,7]	96.47	6/10 6:15 PM	10	95.78	6/13 3:00 PM	--	--	--
	SW2 [3]	83.11	6/7 7:45 AM	2	81.30	6/13 2:00 PM	--	--	--
	SW4	No Recorded Water		--	--	--	--		
	SW14 [4]	78.30	6/5 11:30 PM	7	76.75	6/7 4:00 PM	--	--	--
	SW23 [5,7]	91.86	6/12 4:30 PM	4	90.14	6/18 4:00 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
Mine Site	UB14.5 [7]	98.97	6/9 4:30 AM	1200 [6]	94.20	6/10 10:00 AM	--	--	
	UB15.5 [7]	92.78	6/8 9:15 AM				--	--	--
	MS1_1 [7]	96.86	6/5 11:15 PM	--	--	--	--	--	--
	BC1 [7]	93.05	6/11 12:30 PM	--	--	--	--	--	--
Source Lakes	MSL [7]	97.24	6/4 12:15 PM	--	--	--	--	--	--
	MSL_OUT [7]	97.15	6/3 3:15 PM	--	--	--	--	--	--
	LSL [7]	98.26	6/26 9:15 PM	--	--	--	--	--	--
	LSL_OUT [7]	98.09	6/15 8:15 PM	--	--	--	--	--	--

Notes:

1. PT malfunction occurred before peak stage was achieved. Reported value is based on highest recorded reading before malfunction. Actual peak value is estimated to be between 81.70 and 81.80.
2. Stage elevations at J13.8U, J13.8, and J13.8D are feet BPMSL
3. Highest recorded stage and timing values are accurately reported based on game camera images. No PT installed at the site.
4. Highest recorded stage and timing are estimated based on game camera images. No PT installed at the site.
5. Highest recorded stage and timing based on gage readings from site visit. Game camera footage suggests peak stage occurred close to reported time. No PT installed at the site.
6. Discharge measured about 10 RM upstream of UB15.5 gage site.
7. Stage elevations are ft arbitrary.
8. Stage elevations were derived from concurrent WSE survey and pressure transducer reading.

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 [2]	43.24	7/8 12:45 AM	41.39	7/29 12:30 PM
	F55.5 [2]	43.17	7/9 12:45 AM	40.74	8/12 6:15 PM
	F55.5U [2]	43.18	7/9 12:00 AM	41.75	8/31 7:30 PM
Judy Creek	J21.4	47.49	9/4 10:00 PM	44.78	8/2 10:00 PM
Kalikpik River	KAL1 [2]	48.24	9/7 3:00 AM	46.83	8/31 4:15 PM
Judy Creek Kayyaaq	UC2C [2]	47.81	9/7 1:45 AM	46.45	8/31 11:45 AM
Willow 1	W1S	78.59	9/1 3:30 AM	78.39	7/26 8:00 PM
Willow 2	UC1B	74.43	9/6 9:30 AM	72.72	7/27 3:30 PM
Willow 3	W3S	83.40	7/12 4:00 PM	82.86	7/16 1:45 AM
Willow 4	W4 [1]	87.96	9/7 12:45 AM	85.11	8/4 4:00 AM
	W_BS1	83.79	9/6 7:00 PM	81.96	8/4 4:15 AM
Willow 4a	W_S1	98.67	9/8 6:00 AM	98.22	8/3 7:30 PM
Willow 8	TBD_6 [2]	50.18	9/6 6:30 PM	49.03	8/28 5:30 AM
TBD_5	TBD_5 [1]	94.75	7/9 12:45 AM	92.42	8/29 1:00 PM
Minesite	BC1 [1]	88.67	9/6 11:15 PM	87.01	8/15 11:30 PM
	MS1_1 [1]	95.40	9/2 7:30 PM	95.01	7/25 9:45 AM
Source Lakes	MSL [1]	96.78	9/6 6:30 PM	96.48	7/28 3:15 AM
	MSL_OUT [1]	96.54	7/19 11:30 AM	96.36	8/16 1:45 AM
	LSL [1]	98.29	7/11 9:45 AM	97.87	8/31 8:30 PM
	LSL_OUT [1]	97.95	7/14 7:30 AM	97.67	7/16 4:30 PM

Notes:
1. Stage elevations are ft arbitrary
2. Stage elevations were derived from concurrent WSE survey and pressure transducer reading

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 channel bed and banks consist of predominately silt and sand. 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. CPAI's 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-Fish confluences. This is the first year of monitoring Fish Creek at F55.5.

Historical data is available for Fish Creek at locations further downstream of F55.5. Records from 2005 and 2006 (Michael Baker 2005-2006) show monitoring locations at RM 0.7, 10.3, 25.1, and 32.4 along Fish Creek.

A. Spring Breakup

Meltwater was first observed at F55.5 on June 4 (Photo 4.1). Stage initially crested on the evening of June 11, elevated by snowpack in the channel. A second small crest was observed on June 14 (Photo 4.2). PT data suggests a small ice jam was situated in the F55.5 reach on June 15, resulting in rising stage at F55.5U and falling stage at F55.5 and F55.5D. On June 16, a general trend of increasing stage began, reaching peak stage on June 23. Aerial observations on June 18 indicate floodwater was confined within channel banks (Photo 4.3). RTFM camera observations confirmed that the channel was ice-free during peak stage (Photo 4.4). The 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. The highly mobile channel bed at Fish Creek produced conditions which compromised the lowest oriented upstream gage (F55.5U-A) on June 22.

Photo 4.1: F55.5 before peak stage, looking east (downstream); June 4, 2018

Photo 4.2: F55.5 before peak stage, looking southwest (upstream); June 14, 2018

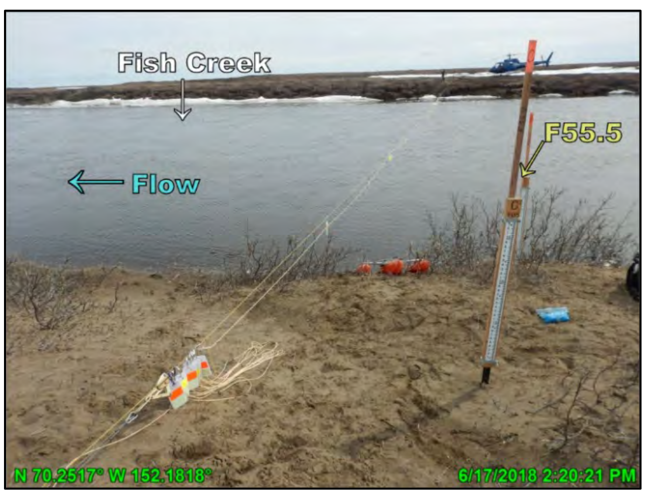
Discharge was measured using a tethered ADCP at F55.5 on June 17, approximately one week before peak stage conditions. At the time of the measurement, the channel was free of ice and minimal snow remained along the south bank (Photo 4.5). The measurement was influenced by a moving bed, which was analyzed and applied as a correction to the discharge data. The overall quality of the discharge measurement was classified as fair.

Photo 4.3: F55.5, 4 days before peak stage, looking east (downstream); June 18, 2018

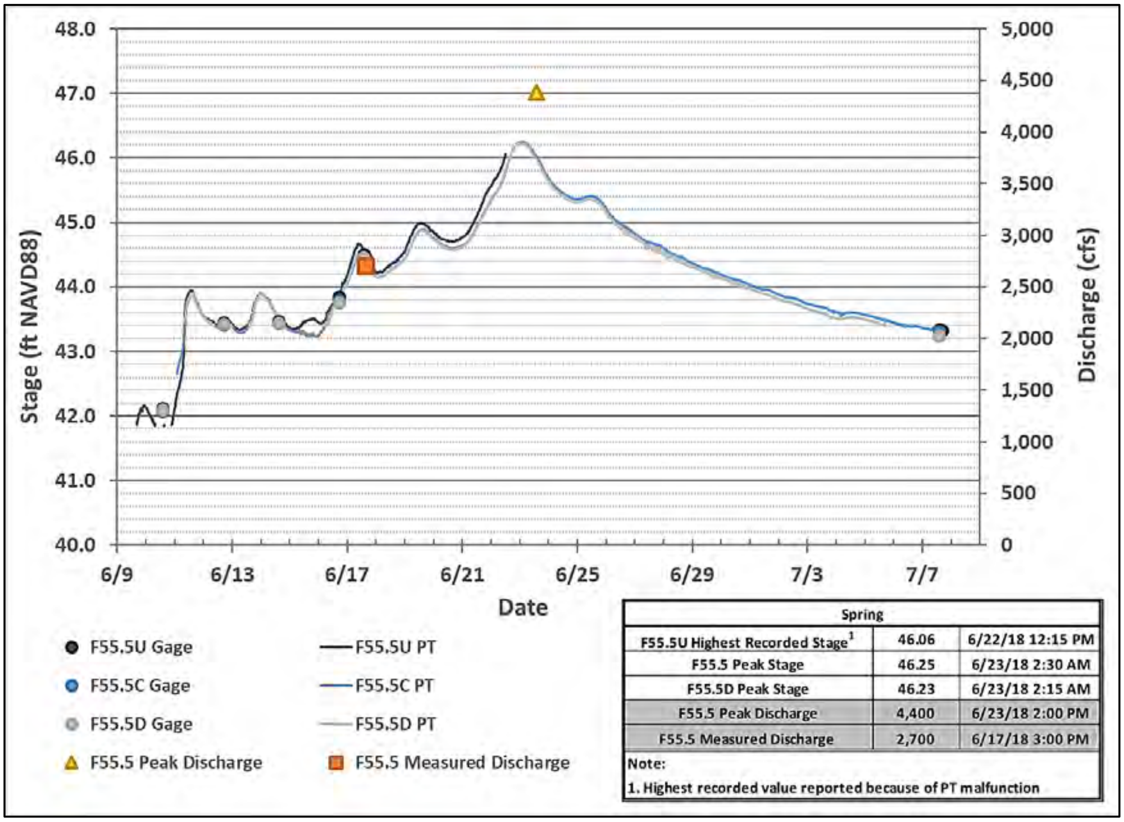
Photo 4.4: Peak Stage at F55.5D as seen from RTFM station, looking southeast (downstream); June 23, 2018

Peak discharge was calculated indirectly based on stage values and the differential stage levels between gage sites. The cross-section used to calculate peak discharge was determined from the direct discharge measurement on June 17. The estimated peak discharge calculation was assigned a fair quality rating based on the dynamic channel geometry associated with the moving bed, the compromised PT data from the upstream monitoring location, and the overall quality of the direct discharge measurement.

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, determined by concurrent WSE survey and PT data on August 8.



'hoto 4.5: F55.5 the day of the discharge measureme looking south; June 17, 2018



Spring		
F55.5U Highest Recorded Stage[1]	46.06	6/22/18 12:15 PM
F55.5 Peak Stage	46.25	6/23/18 2:30 AM
F55.5D Peak Stage	46.23	6/23/18 2:15 AM
F55.5 Peak Discharge	4,400	6/23/18 2:00 PM
F55.5 Measured Discharge	2,700	6/17/18 3:00 PM

Note:
1. Highest recorded value reported because of PT malfunction

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

B. SUMMER

Stage fluctuations associated with precipitation were recorded throughout the summer, but water levels remained below peak spring stage (Photo 4.6 and Photo 4.7). The stage increase at the end of the summer monitoring period is associated with a late summer precipitation event. Summer stage at Fish Creek F55.5 is presented in Graph 4.2.

Photo 4.6: Summer conditions at F55.5, looking west (upstream); July 7, 2018

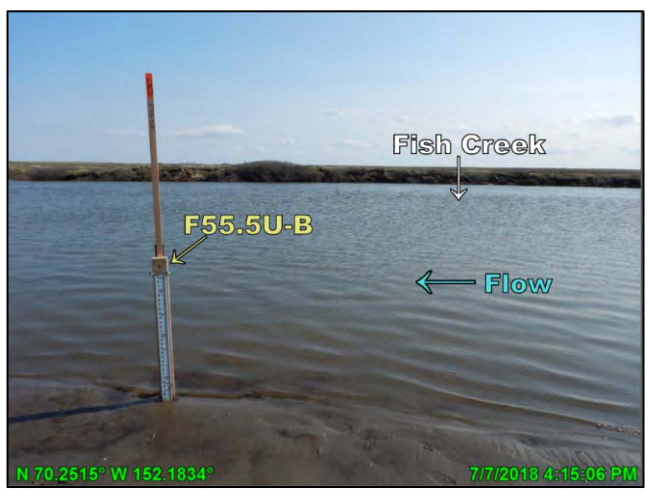
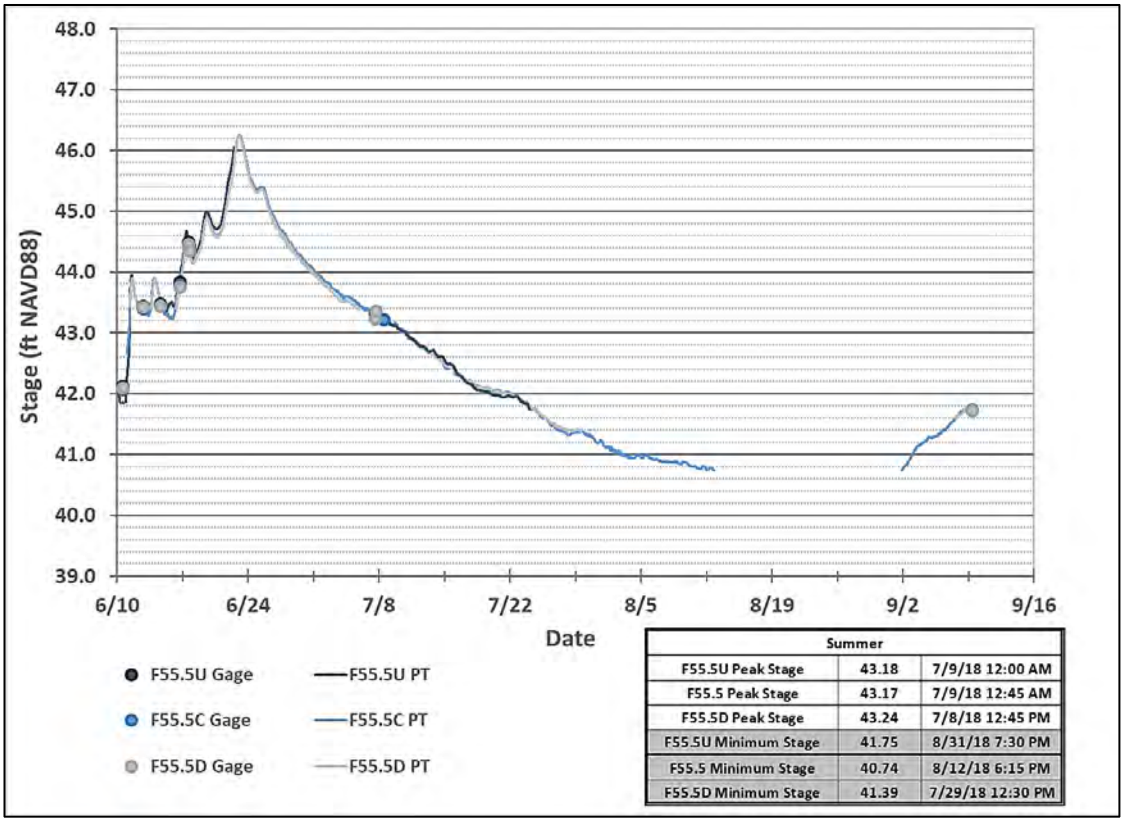


Photo 4.7: Summer conditions at F55.5, looking southeast; July 7, 2018



Graph 4.2: Fish Creek at F55.5 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 2018 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 518 square miles.

The J21.4 gage station is 21.4 RMs upstream of the influence 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. This year's monitoring period represents the second year of stage observations 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 is presented in Table 4.3. The J13.8 gage station was installed in 2001 and the J13.8D, J13.8U gage stations were installed in 2017.

Table 4.3: Judy Creek at J13.8 & J21.4 Historical Peak Stage

Year	J13.8		J21.4	
	Peak Stage (ft BPMSL)	Date	Peak Stage (ft NAVD88)	Date
2018	37.09	6/6	51.24	6/6
2017 [3]	34.68 [4]	6/4	48.56	6/4
2006 [2]	35.56	5/30	--	--
2005 [2]	37.25	6/4	--	--
2004 [2]	NM [5]	--	--	--
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. Stage interpolated between upstream and downstream gage stations
5. NM = not measured

A. Spring Breakup

Floodwater was first observed in Judy Creek on June 4. Quickly rising stage at J13.8, elevated by snowpack in the channel (Photo 4.8), initially crested on June 4. An initial crest in stage was also observed at J24.1 on June 4. Ice floes were present, but no ice jams were observed at either monitoring location. All Judy 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. The lowest orientated upstream gage (J13.8U-A), which housed the monitoring station PT, was knocked over by ice and/or instability from the moving bed sometime on June 6. The gage was manually straightened and resurveyed the following day.

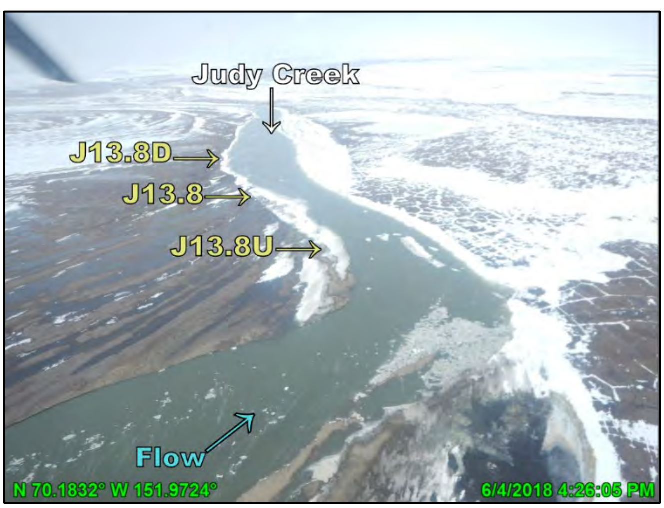


Photo 4.8: Initial floodwater at J13.8, two days before peak stage, looking north (downstream); June 4, 2018

Peak stage at J13.8 and J21.4 occurred on June 6. No intact channel ice was present, but ice floes were observed in the channel and snow remained along the channel banks (Photo 4.9 and Photo 4.10). Discharge was measured at J13.8, on June 7, one day after peak stage, and again on June 17. During the June 7 measurement, some intermittent ice floes were observed, and considerable snow was present along each bank (Photo 4.11). The June

17 measurement was free of ice floes while minimal snow remained on the banks (Photo 4.12). 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 0.7 foot per second (fps) was observed during the ADCP discharge measurements. The quality of each measurement was classified as fair due to the remaining snowpack along the banks and moving bed conditions.

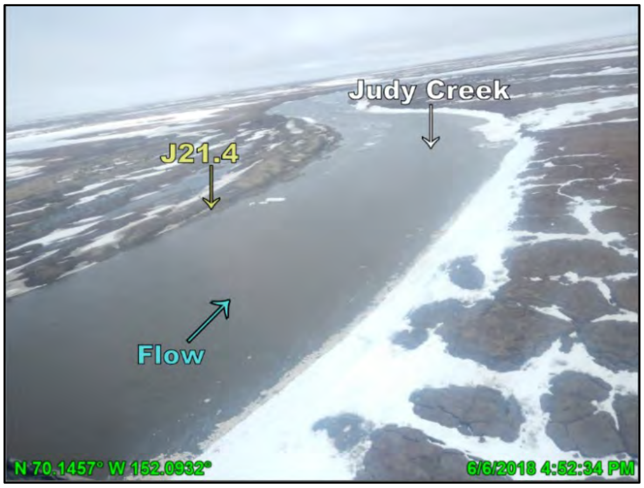


Photo 4.9: Peak stage at J21.4, looking northeast (downstream); June 6, 2018

Photo 4.10: Peak Stage at J13.8, looking west (upstream); June 6, 2018

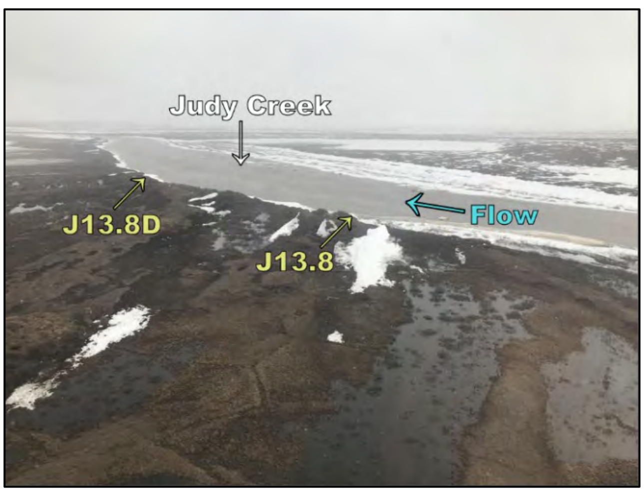


Photo 4.11: J13.8 during the first discharge measurement, looking southeast; June 7, 2018

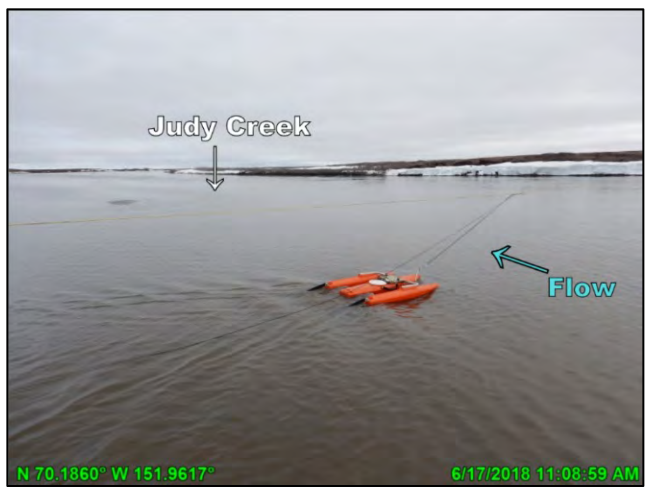
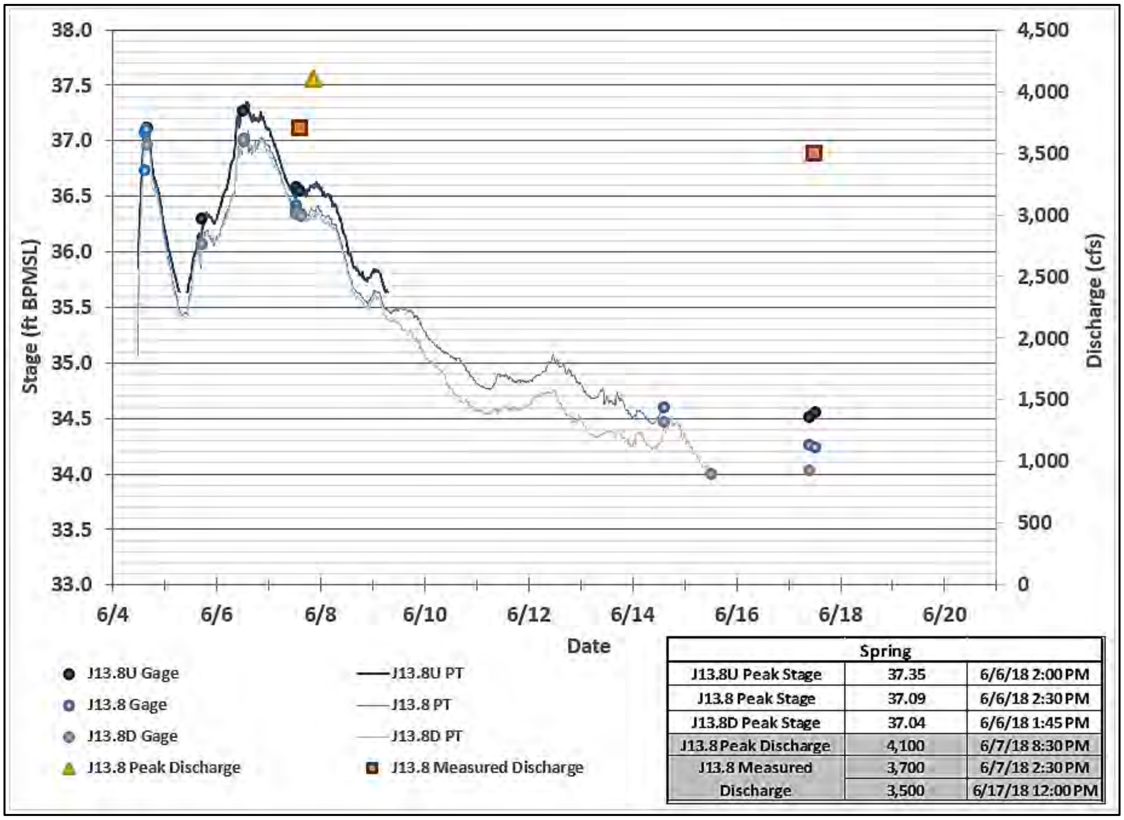


Photo 4.12: J13.8 during the second discharge measurement, looking north (downstream); June 17, 2018

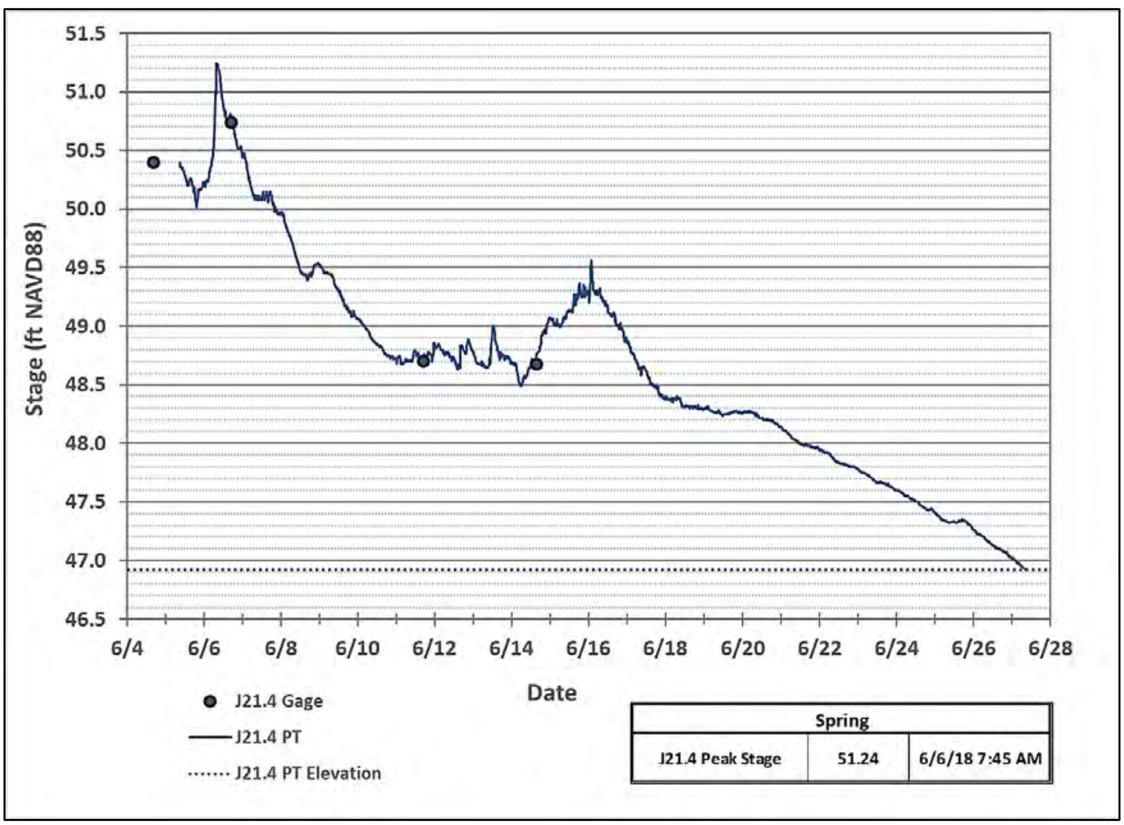
Peak discharge at J13.8 was calculated using the cross-section from the direct measurement on June 7. The estimated peak discharge was assigned a fair quality rating because of the dynamic channel geometry associated with the moving bed and the overall quality of the direct discharge measurement. Indirect discharge calculated at the time of the June 7 direct measurement was 2.5% more than that measured discharge.

Judy Creek J13.8 spring breakup stage and discharge data is provided in Graph 4.3. J21.4 stage data is provided in Graph 4.4. Detailed measured discharge data and plan and profile drawings are presented in Appendix C.



Spring		
J13.8U Peak Stage	37.35	6/6/18 2:00 PM
J13.8 Peak Stage	37.09	6/6/18 2:30 PM
J13.8D Peak Stage	37.04	6/6/18 1:45 PM
J13.8 Peak Discharge	4,100	6/7/18 8:30 PM
J13.8 Measured Discharge	3,700	6/7/18 2:30 PM
	3,500	6/17/18 12:00 PM

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



Spring		
J21.4 Peak Stage	51.24	6/6/18 7:45 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, but water levels remained below peak spring stage (Photo 4.13). The stage increase at the end of the summer monitoring period is due to the late summer precipitation event. Summer stage at Judy Creek J21.4 is presented in Graph 4.5.

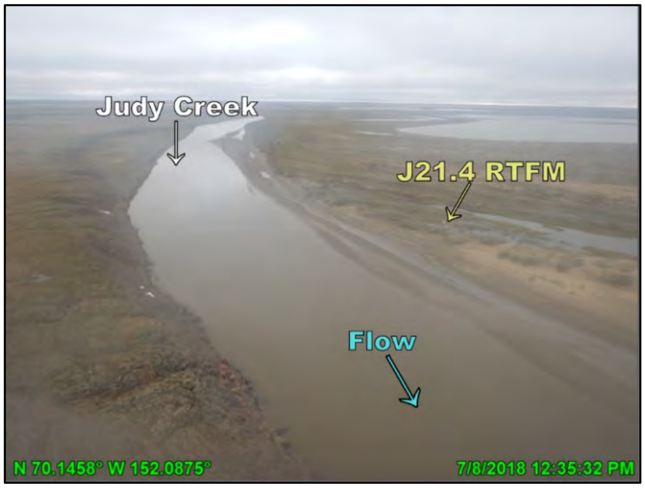
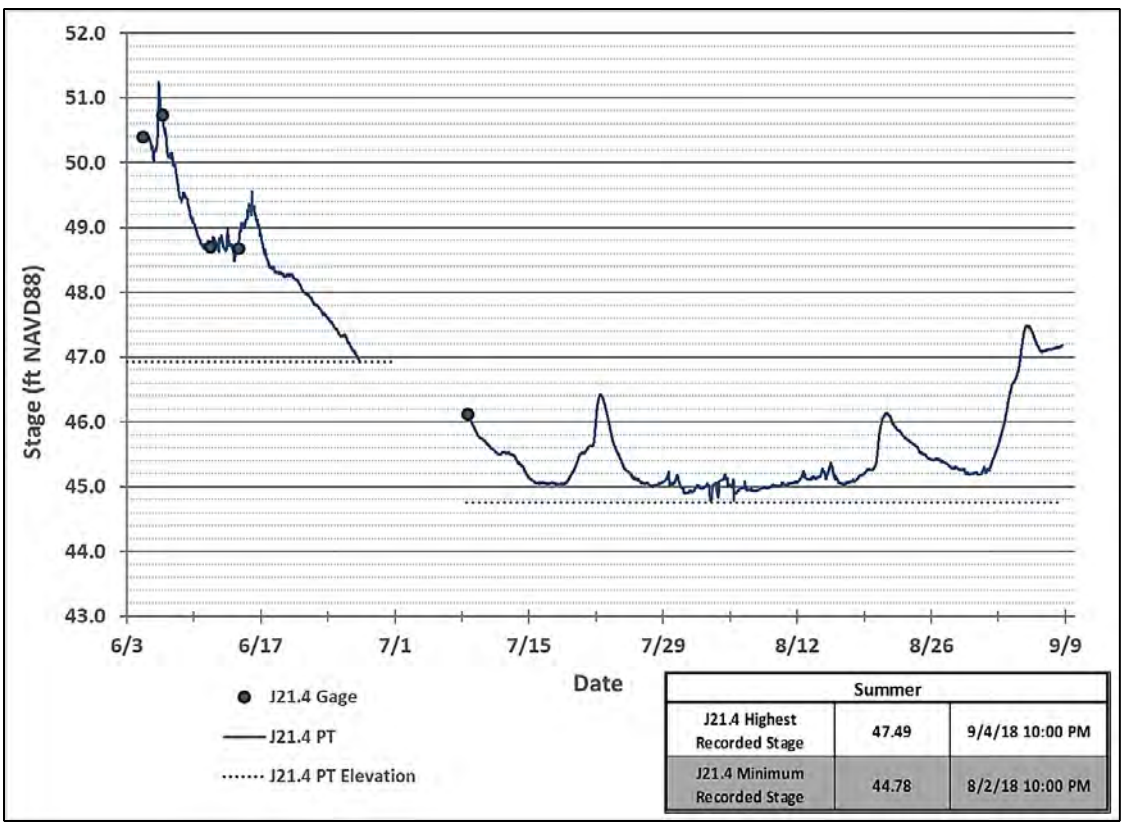


Photo 4.13: Summer conditions at J21.4, looking west (upstream); July 8, 2018



Graph 4.5: Judy Creek at J21.4 Summer Stage

KALIKPIK RIVER

The Kalikpik River is a separate drainage basin that borders the FCB to the north. The Kalikpik River is a relatively low gradient, highly sinuous channel flowing generally northeast until its outlet into Harrison Bay. Like Judy Creek and Fish Creek, the channel bed and banks consist of predominately silt and sand. The headwaters of the Kalikpik River originate in a complex lake network approximately 15 miles south of Teshsepuk Lake. The Kalikpik River drainage basin encompasses an area of approximately 200 square miles. CPAI's proposed alignment crosses the Kalikpik River at the Kal1 monitoring location. This is the first year of data collection and observations at the Kal1 monitoring location.

A. SPRING BREAKUP

The Kalikpik River 2018 spring breakup was classified as a prolonged, low magnitude event. During spring setup, accurately locating the river channel banks was challenging due to a large quantity of wind driven snow in the channel. Therefore, the gages were not ideally placed in the channel and PT data was captured only during a 24-hour window around peak stage conditions. Gage readings, aerial observations, HWM data, and game camera footage were used to verify and qualify peak stage conditions at Kal1. Saturated snow remained in the Kalikpik River at Kal1 into mid-June. On June 10, disconnected pockets of local melt were present over saturated snow, but no integrated flow was observed (Photo 4.14).

Photo 4.14: Kal1, the day prior to peak stage, looking south (upstream); June 10, 2018

Peak stage occurred at the Kal1 gage site on June 11. PT data recorded a sharp rise in stage during the morning of June 11, with a relatively quick drop in stage soon after. Game camera footage during peak stage and aerial observations the following day indicate peak stage was influenced by saturated snow, which elevated water levels. Snow remained along the banks and large ice floes were present in the channel for a couple days following peak stage (Photo 4.15). Stage decreased as snow and ice were removed from the channel, increasing channel conveyance. A second, smaller rise in stage was observed on June 16 and with the increased channel conveyance, was likely indicative of peak discharge conditions. Discharge was measured at Kal1 on June 16. During the measurement, stage was just below bankfull conditions. No ice or snow was observed in the channel, but saturated snow remained along the south bank (Photo 4.16). These factors resulted in a discharge measurement with a quality classification of fair.

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, determined by concurrent WSE survey and PT data on August 10.

Photo 4.15: Kal1, the day after peak stage, looking southeast (upstream); June 12, 2018

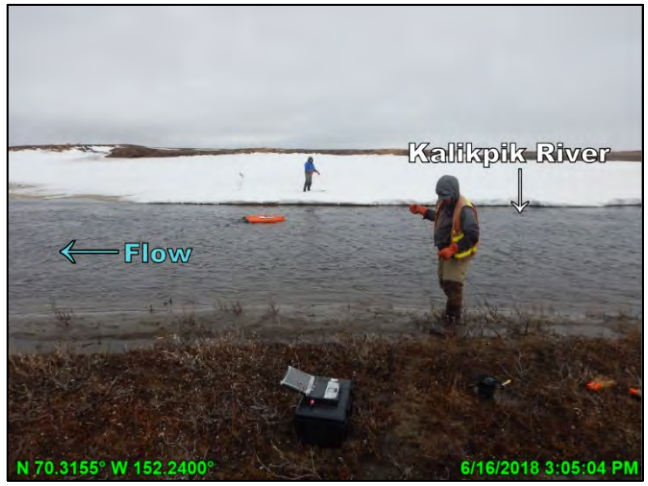
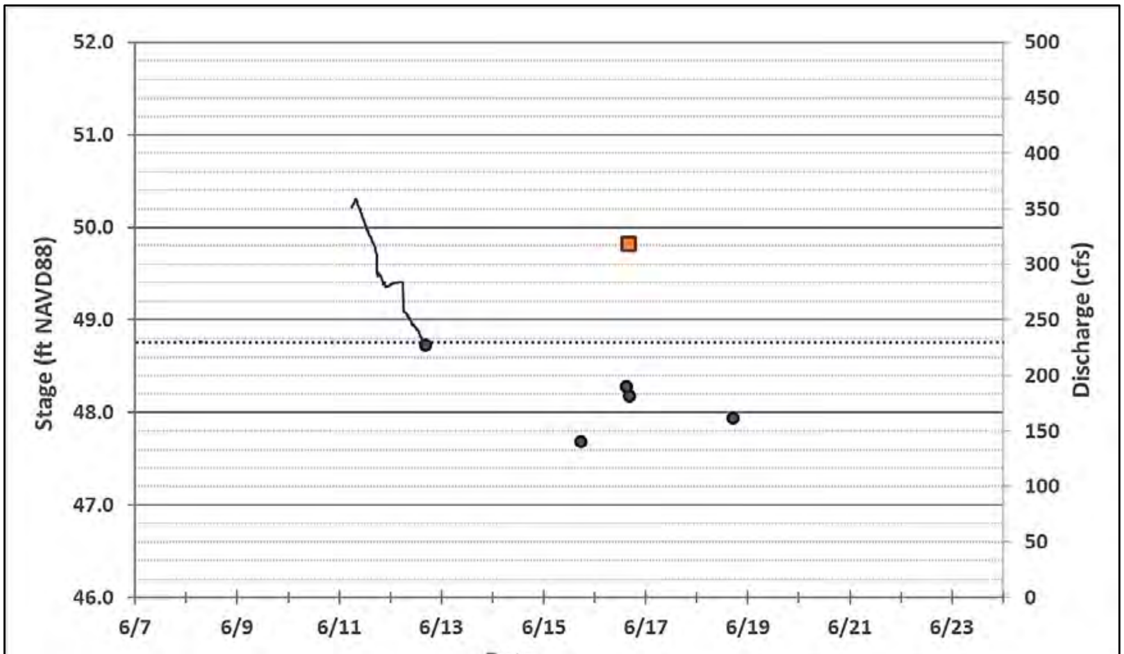


Photo 4.16: Kal1, the day of the discharge measurement, looking east; June 16, 2018



Spring		
Kal1 Peak Stage	50.30	6/11/18 7:45 AM
Kal1 Measured Discharge (cfs)	320	6/16/18 4:00 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, but water levels remained below spring breakup peak stage at all locations (Photo 4.17 and Photo 4.18). 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.

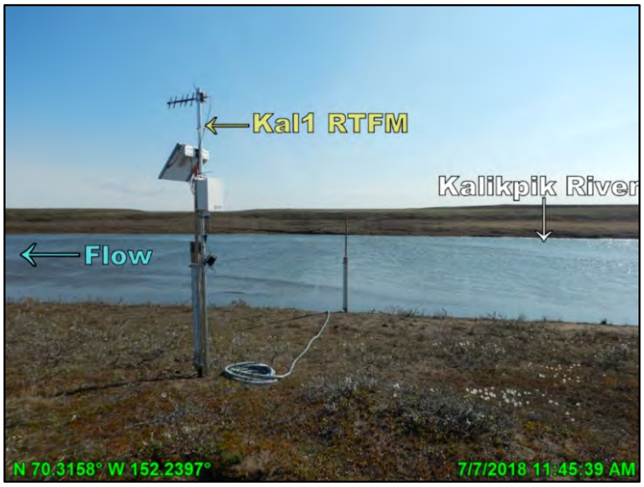
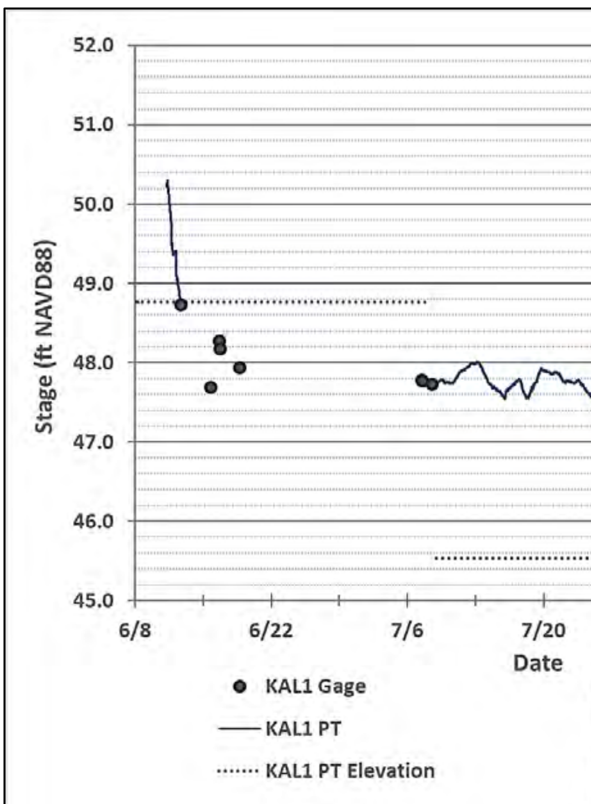


Photo 4.17: Summer conditions at Kal1, looking east; July 7, 2018

Photo 4.18: Summer conditions at Kal1, looking south (upstream); July 7, 2018



Summer		
Kal1 Highest Recorded Stage	48.24	9/7/18 3:00 AM
Kal1 Minimum Recorded Stage	46.83	8/31/18 4:15 PM

Graph 4.7: Kalikpik River at Kal1 Summer Stage

4.2 SMALL STREAMS

JUDY CREEK KAYYAAQ

Judy Creek Kayyaaq is a highly sinuous and 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. CPAI's 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 second year of data collection and observations at the UC2C monitoring location.

A. SPRING BREAKUP

Judy Creek Kayyaaq was observed to be filled with wind-driven snow during set up, most of which remained through the beginning of June. Ponded local melt was observed underneath the drifted snow and PT data recorded an increase in stage on June 4. Aerial observations from June 6 show large disconnected pools of meltwater accumulating on top of snow in the channel. On June 8, hydraulically connected flow was observed at UC2C, with water cutting channels underneath saturated snow in some isolated locations (Photo 4.19). Bankfull conditions with minimal overbank flooding in polygon troughs were observed. Stage continued to increase until cresting on June 10. Aerial observations from this day show widespread overbank flooding around the low-lying areas at UC2C (Photo 4.20) and minimal snow remaining in the channel and along the banks. Peak stage was recorded at UC2C on June 13.

Photo 4.19: UC2C, approximately 1 week before peak stage, looking north; June 8, 2018

Photo 4.20: UC2C, three days before peak stage, looking west (upstream); June 10, 2018

Conditions at peak stage were similar to those recorded on June 10; with overbank flooding and minimal impedance from snow. Aerial observations from June 18 showed bankfull conditions persisting at UC2C. Overbank flooding was still present in some low-lying areas and polygon troughs, but flow was mostly confined to the defined channel (Photo 4.21).

Discharge during spring breakup was measured at the UC2C gage station on June 11. No snow or ice was present in the reach at the time of measurement (Photo 4.22). Main channel discharge was measured with the ADCP while overbank contributions were measured using a wading rod and conventional mid-section technique. The overbank flooding and uncertainty in whether all flow was captured resulted in a downgraded discharge quality rating of fair. Peak stage two days later was approximately 1 foot higher than stage observed during the discharge measurement and likely coincided with peak discharge. The measured discharge on June 11 is believed to be lower than peak discharge.

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, determined by concurrent WSE survey and PT data on August 4.

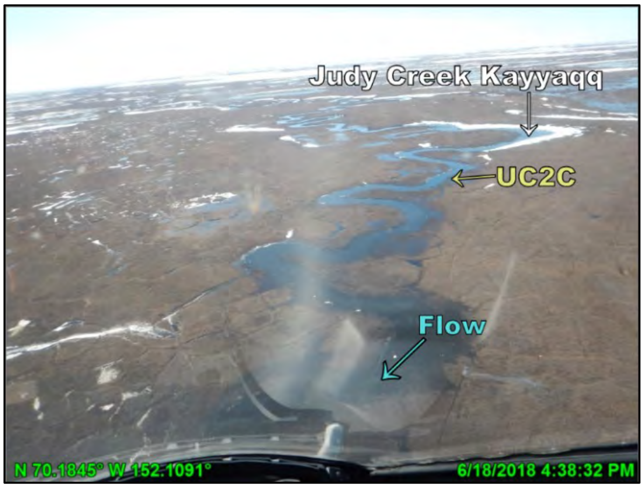


Photo 4.21: UC2C about a week after peak stage, looking west (upstream); June 18, 2018

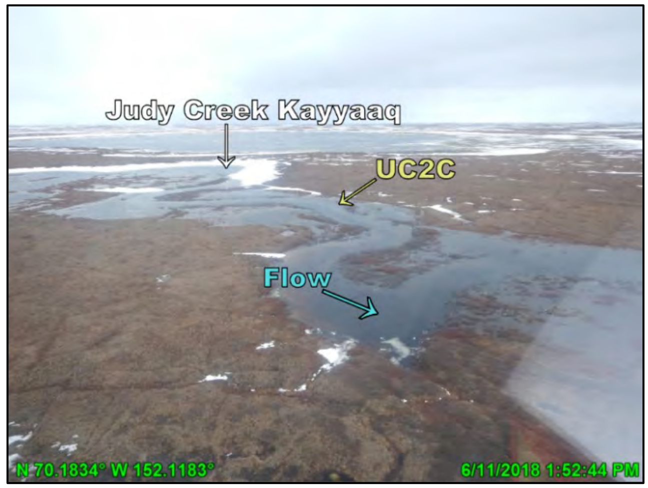
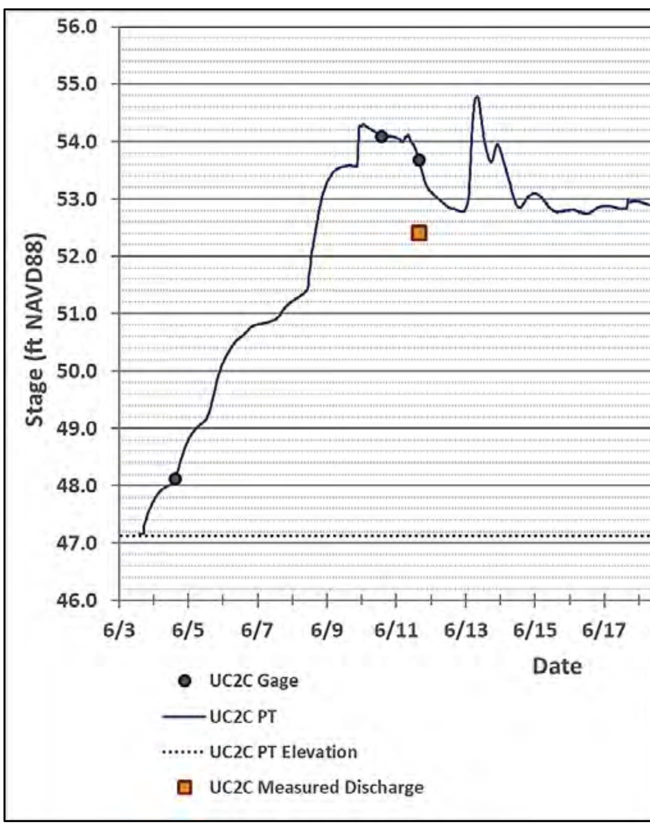


Photo 4.22: UC2C the day of the discharge measurement, two days before peak stage, looking northwest (upstream); June 11, 2018



Spring		
UC2C Peak Stage	54.78	6/13/18 8:00 AM
UC2C Measured Discharge (cfs)	140	6/11/18 3:30 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, but water levels remained below spring breakup peak stage (Photo 4.23 and Photo 4.24). 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.

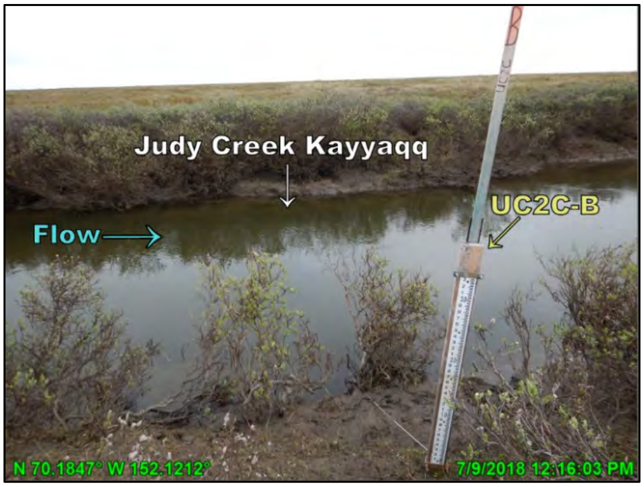


Photo 4.23: Summer conditions at UC2C, looking north; July 9, 2018

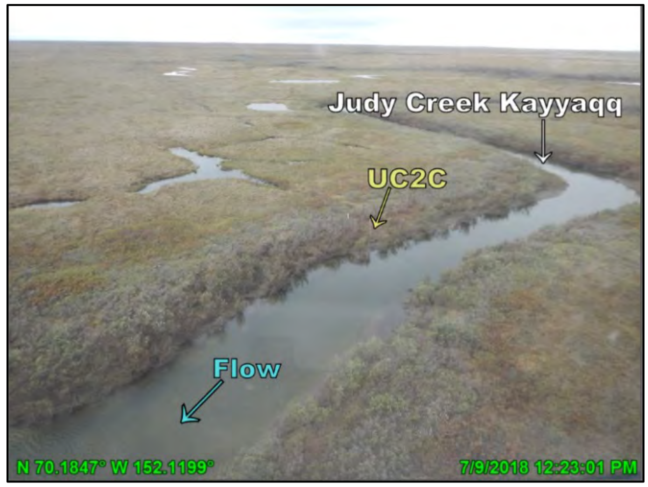
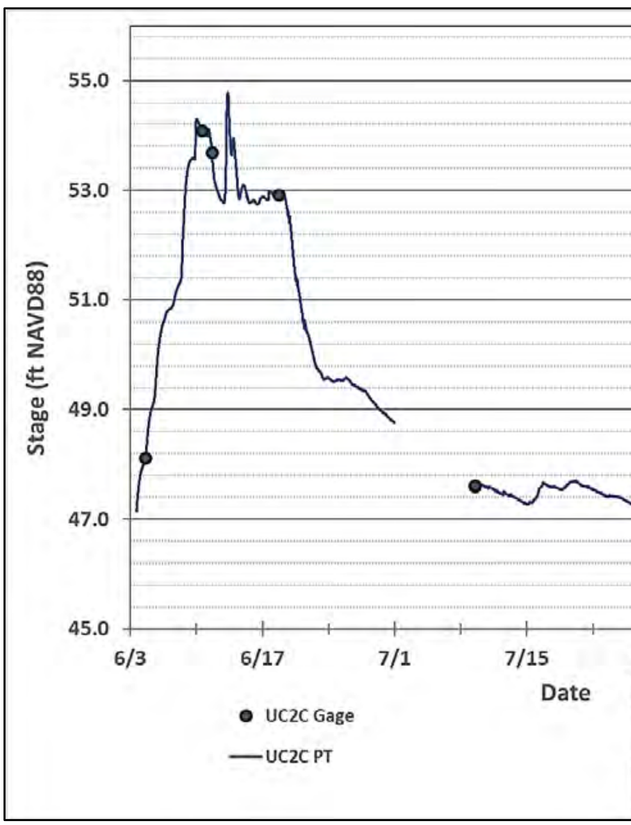


Photo 4.24: Summer conditions at UC2C, looking west (upstream); July 9, 2018



Summer		
UC2C Highest Recorded Stage	47.81	9/7/18 1:45 AM
UC2C Minimum Recorded Stage	46.45	8/31/18 11:45 AM

Graph 4.9: Judy Creek Kayyaaq at UC2C Summer Stage

WILLOW 1

W1S gage station on Willow 1 is situated in a poorly defined low-lying area between Lake R0060 and Lake M0016. CPAI's proposed Willow alignment crosses Willow 1 at the W1S monitoring location. The Willow 1 drainage is better defined further north before draining into Judy Creek. This is the first year the W1S gage station has been monitored. The reported peak stage and timing values are based on gage readings from game camera images.

A. SPRING BREAKUP

Ponded local melt was first observed through game camera footage at W1S on June 3. Aerial observations from June 6 showed the gage site covered with snow and ice with minimal open water (Photo 4.25). Game camera footage recorded peak stage conditions on June 6. The observed peak stage was likely the result of ponded local melt. On June 7, water was widely dispersed across the gage site, but no distinguishable channel or flow path was observed from the air. Snow was observed in isolated areas higher in elevation than the ponded water around the gage site. By June 9, minimal snow was present, and water was still widely dispersed across the low-lying area surrounding the gage site (Photo 4.26). No distinguishable channel or discernable flow was ever identified near W1S throughout the entire breakup monitoring period, therefore discharge was not measured.

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

Photo 4.25: Peak stage at W1S, looking north; June 6, 2018

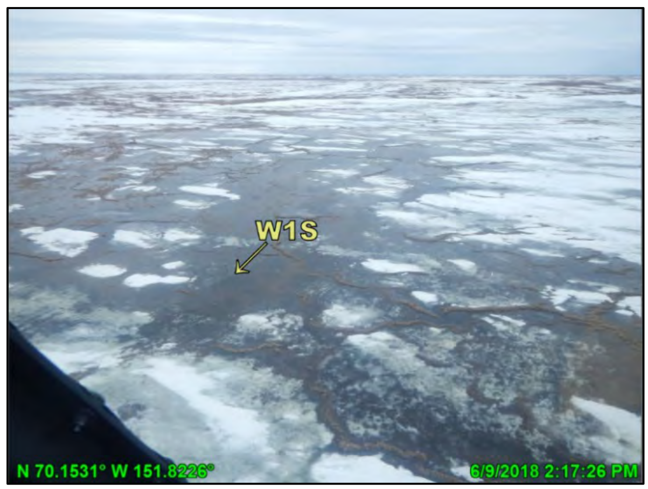
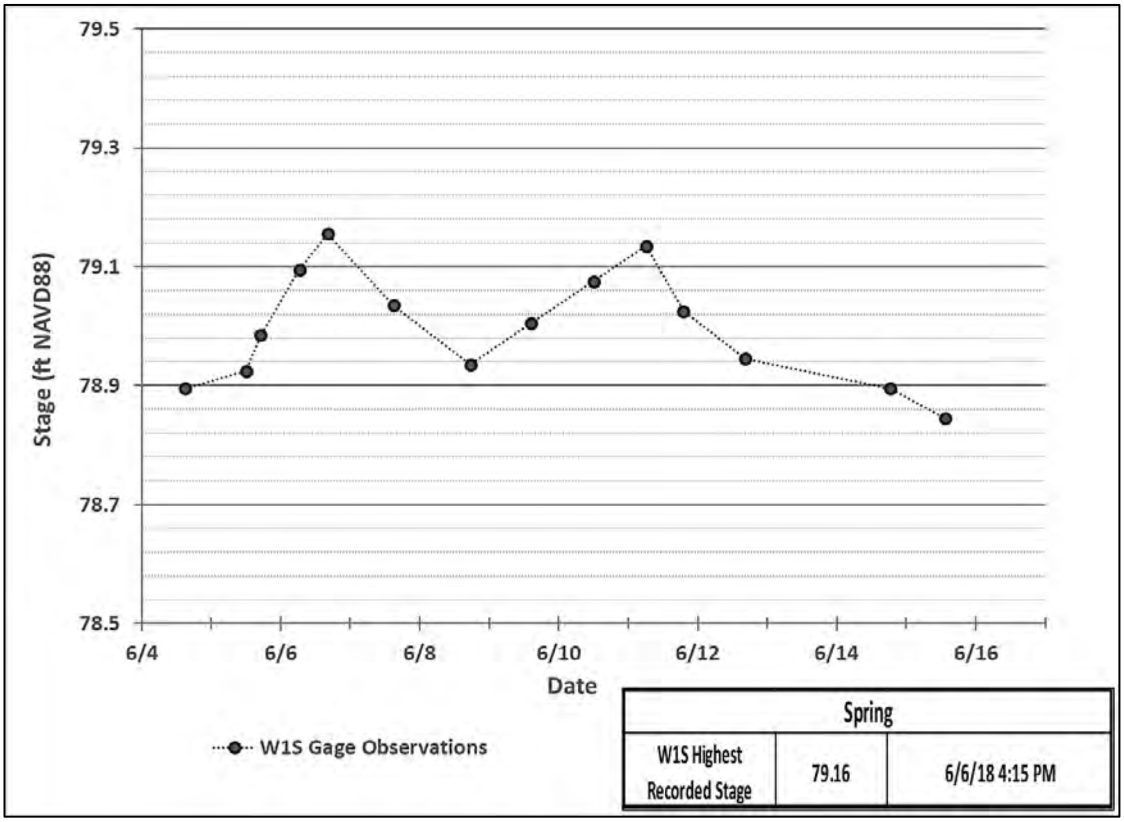


Photo 4.26: Conditions at W1S, looking south; June 9, 2018



Graph 4.10: Willow 1 at W1S Spring Breakup Stage

B. Summer

Small stage fluctuations associated with summer precipitation events were recorded in the PT data, but water levels remained below spring breakup peak spring stage (Photo 4.27). During the summer observations, no defined channel or flow was present. Only standing water was observed around the gage. Summer stage in Willow 1 at W1S is presented in Graph 4.11.

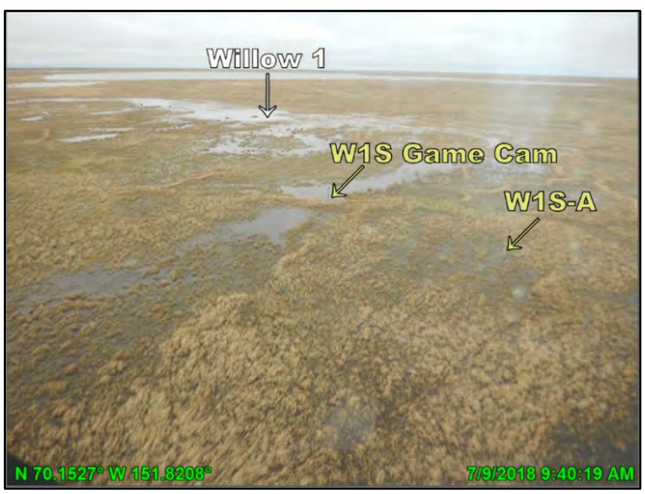


Photo 4.27: Summer conditions at W1S, looking west; July 9, 2018

Summer		
W1S Highest Recorded Stage	78.59	9/1/18 3:30 AM
W1S Minimum Recorded Stage	78.39	7/26/18 8:00 PM

Graph 4.11: Willow 1 at W1S Summer 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. CPAI's proposed Willow alignment crosses Willow 2 at the UC1B monitoring location. This is the second year the UC1B gage station has been monitored.

A. Spring Breakup

Willow 2 was filled with wind-driven snow at the onset of spring breakup. Isolated pockets of local melt were observed, and PT data recorded an increase of stage on June 4. Aerial observations from June 6 show isolated pockets of local melt and substantial amounts of wind-driven still snow present in the channel; little change from conditions on June 4. On June 7, the leading edge of water was observed in Willow 2 upstream of the UC1B gage site (Photo 4.28). The flow began on top of the drifted snow then progressively cut a channel through the snow-filled drainage. The presence of snow quickly elevated floodwaters to bankfull conditions. Peak stage was recorded on June 10. Considerable snow remained in the channel during peak stage, maintaining elevated water levels (Photo 4.29). Overbank flooding was observed in some areas. By June 11, stage had receded as flow cut through the snowpack (Photo 4.30). A second smaller crest in stage occurred on June 13. Aerial observations on the 13 showed a well-defined flow path through saturated snow along the banks. Snow was also observed in the channel underneath the flow. Game camera footage suggest the area was clear of snow by June 23. Peak stage at Willow 2 was influenced by the presence of snow and ice in the channel and did not coincide with peak discharge.

Discharge during spring breakup was measured about 100 feet downstream of the UC1B gage station on June 13. Saturated snow was present on the banks of the channel and snow was observed in the channel underneath the flow at the time of measurement (Photo 4.31). The quality of the measurement was classified as fair based on these conditions. Snow continued to cut through the snowpack following the discharge measurement, however, flow conditions observed on June 13 are believed to be representative of peak discharge.

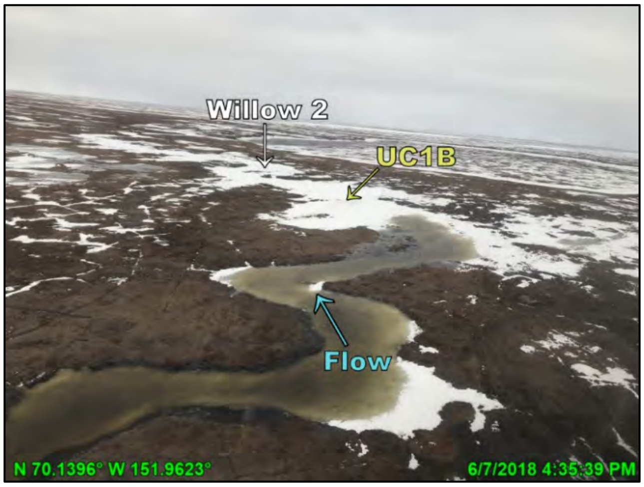


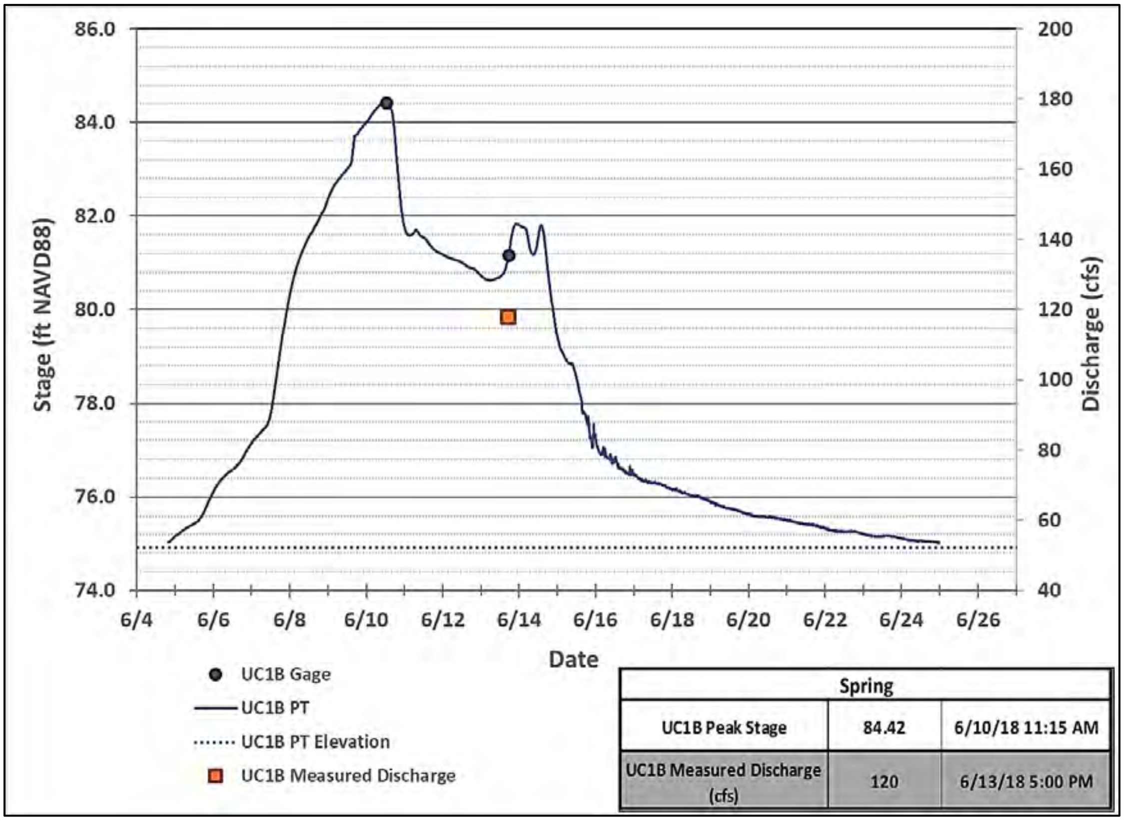
Photo 4.28: UC1B, three days before peak stage, looking north (downstream); June 7, 2018

Photo 4.29: Peak stage at UC1B, looking south (upstream); June 10, 2018

Photo 4.30: UC1B the day after peak stage, looking north; June 11, 2018.

Photo 4.31: UC1B the day of the discharge measurement, looking north (downstream); June 13, 201

Willow 2 at UC1B spring breakup stage data is provided in Graph 4.12. Detailed measured discharge data and plan and profile drawings are presented in Appendix C. Elevations are referenced to NAVD88.



Spring		
UC1B Peak Stage	84.42	6/10/18 11:15 AM
UC1B Measured Discharge (cfs)	120	6/13/18 5:00 PM

Graph 4.12: Willow 2 at UC1B Breakup Stage & Discharge

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the PT data, but water levels remained below spring breakup peak stage at all locations (Photo 4.32). Summer stage in Willow 2 at UC1B is presented in Graph 4.13.

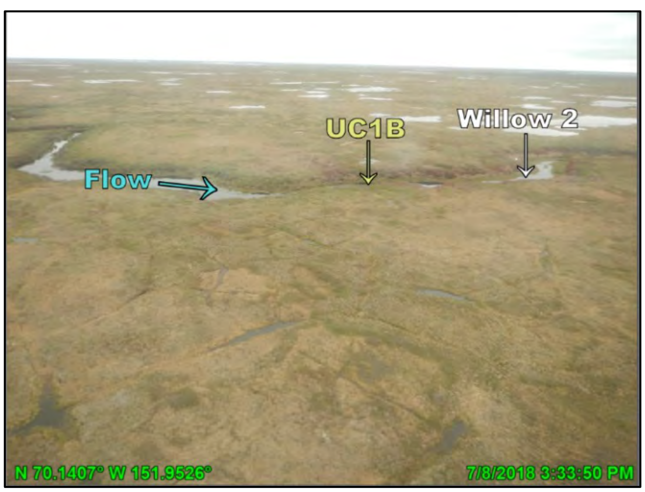
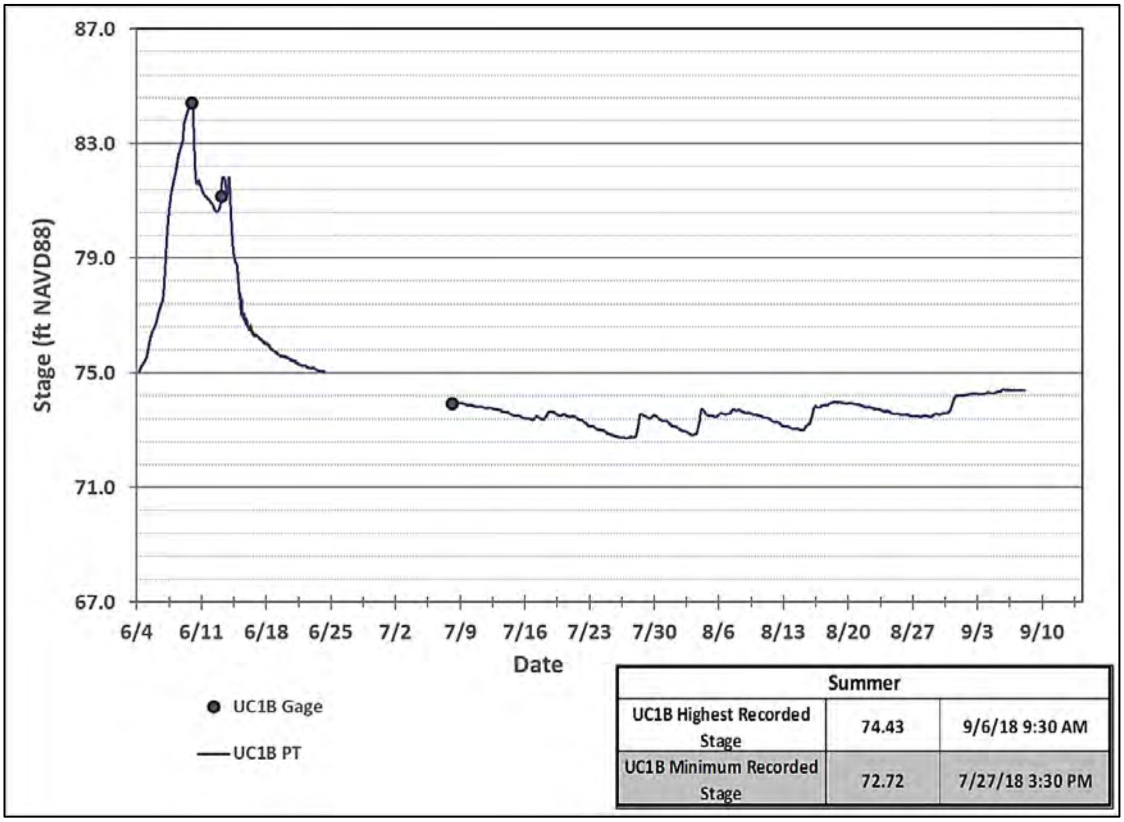


Photo 4.32: Summer conditions at UC1B, looking south (upstream); July 8, 2018



Graph 4.13: Willow 2 at UC1B 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. CPAI's proposed Willow alignment crosses Willow 3 at the W3S monitoring location. This is the first year of data collection and observations at the W3S monitoring location. The reported peak stage and timing values are based on gage readings from game camera images.

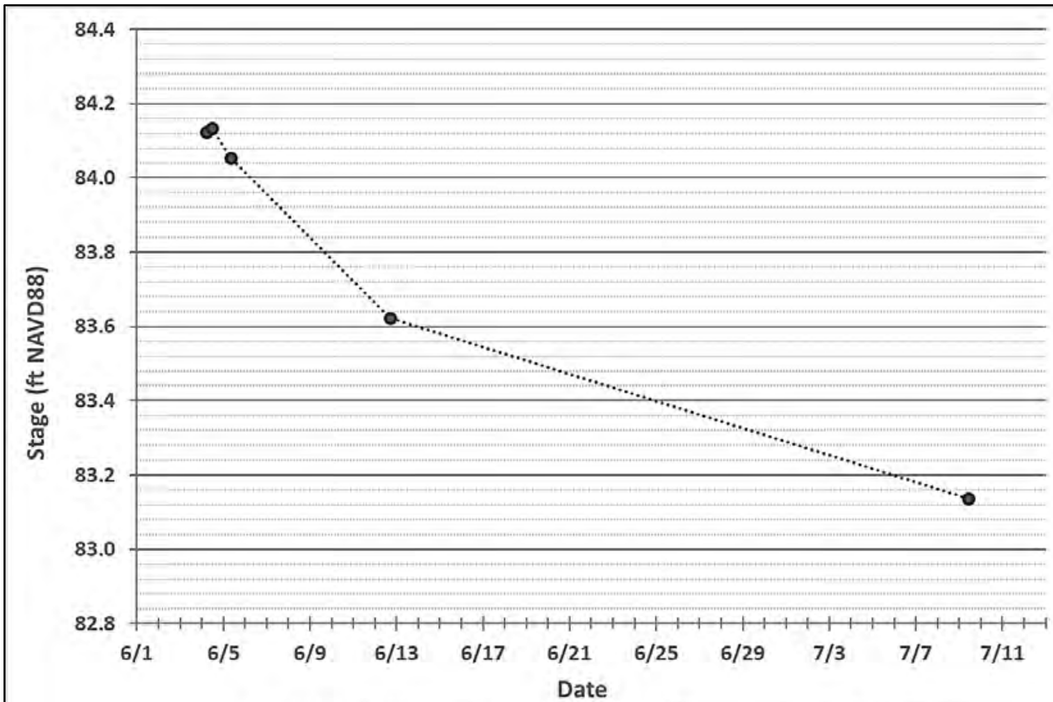
A. SPRING BREAKUP

Ponded local melt was observed through game camera footage at W3S on June 3. The surrounding area was still covered with snow and the channel was not distinguishable. On June 4, peak stage was recorded at W3S and game camera images indicate stage was elevated by saturated snow. No integrated flow was observed. Aerial observations from June 7 showed significant amounts of saturated snow around the gage site and small pockets of isolated melt through the drainage (Photo 4.33). On June 10, aerial observations revealed flooding in low-lying areas and polygon troughs. No distinguishable channel was seen from the air. Observations from June 12 documented low-velocity flow and saturated snow in isolated portions around the gage site. Widely distributed flooding was prevalent (Photo 4.34). Game camera footage suggests that the site was mostly free of snow and ice by June 19.

W3S stage data is presented in Graph 4.14. Elevations are referenced to NAVD88.

Photo 4.33: Conditions at W3S, looking south; June 7, 2018

Photo 4.34: Conditions at W3S, looking west; June 12, 2018



Spring		
W3S Highest Recorded Stage	84.13	6/4/18 11:00 AM

Graph 4.14: Willow 3 at W3S Spring Breakup Stage

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the PT data, but water levels remained below spring breakup peak stage at all locations. Low velocity flow through a poorly defined ephemeral channel was observed on July 9 (Photo 4.35). Summer stage at W3S gage site is presented in Graph 4.15.

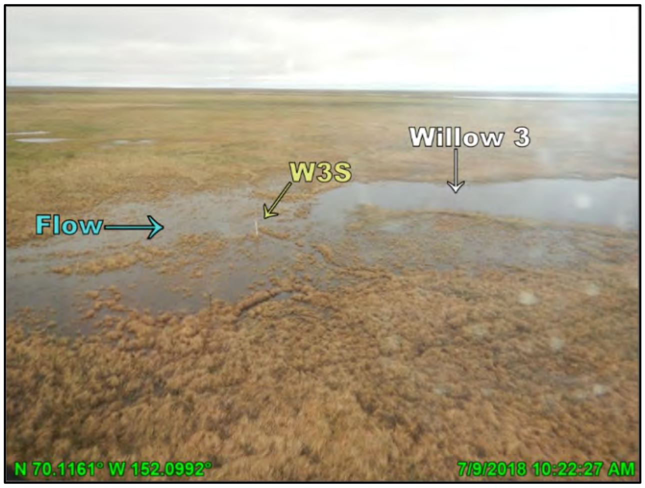
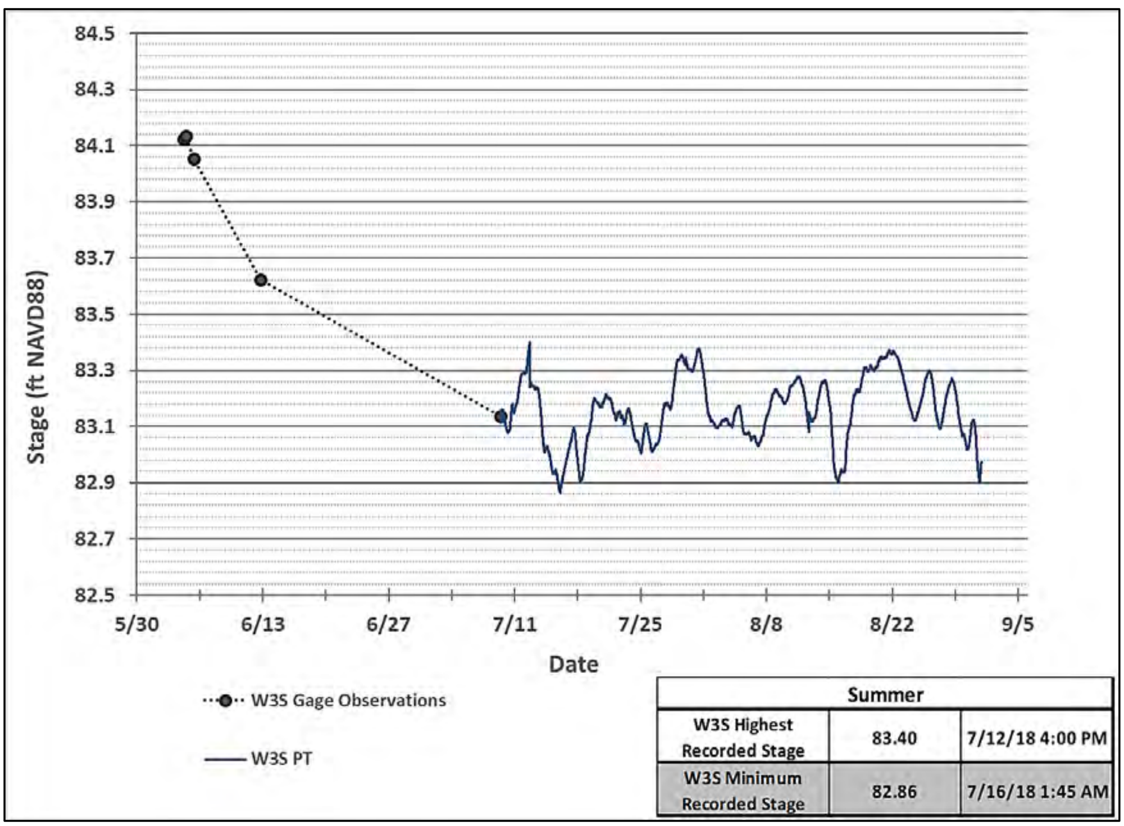


Photo 4.35: Summer conditions at W3S, looking northwest; July 9, 2018



Graph 4.15: Willow 3 At W3S 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. CPAI's 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. W4 and W_BS1 are situated approximately 5.2 and 9 RM upstream of the Judy Creek confluence, respectively. This is the first 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.

A. SPRING BREAKUP

Drifted snow remained in the Willow 4 drainage through early June. PT data showed a steady stage increase from June 2 to June 7 at both Willow 4 monitoring locations. On June 7, the W_BS1 monitoring location was observed to be near bankfull, with saturated snow present on the banks of the channel. On the afternoon of June 7, a sudden stage escalation of nearly 1.5 feet in two hours culminated in peak stage conditions at W_BS1 (Photo 4.36). At W4, aerial observations on the afternoon of June 7 show that the monitoring location had saturated snow in the channel with no integrated flow and the leading edge of water present just upstream of the monitoring location (Photo 4.37). Similar to W_BS1, W4 PT data shows a rapid stage increase of more than 2 feet in one hour around 9:00 PM on June 7, also culminating in peak stage at W4. The sudden rise in stage at each location was likely in response to the integration of flow through the Willow 4 reach.

Photo 4.36: Peak stage at W_BS1, looking north; June 7, 2018.

Photo 4.37: Conditions prior to peak stage at W4, looking north (downstream); June 7, 2018

On June 8, conditions at each gage site were similar to that on June 7, with integrated flow in the channels and saturated snow along the banks. No overbank flooding was observed at either gage location. Observations from June 11 show slightly less saturated snow along the banks of W_BS1, while W_4 conditions remained the same from that observed on June 8 (Photo 4.38). On June 18, stage conditions at each gage site had receded. Minimal saturated snow remained on the bank at W_BS1 (Photo 4.39) while significant saturated bank snow was present at W_4 (Photo 4.40).

Photo 4.38: W4 three days after peak stage, looking south (upstream); June 10, 2018

Photo 4.39: W_BS1 looking northeast (upstream); June 18, 2018

Photo 4.40: W4, looking southwest (upstream); June 18, 2018

Discharge was measured at the W_BS1 and W4 monitoring stations on June 8, and June 11, respectively. Both discharge measurements were performed while considerable amounts of saturated snow remined in the channel and along the banks (Photo 4.41 and Photo 4.42) and as a result, the quality of the discharge measurement at both sites was classified as fair. Minimal snow had been removed from the W_BS1 channel on June 8, and as a result the measured discharge likely underestimates peak discharge in this reach. Conversely, the measurement at W_4 was performed later (June 11), allowing more snow to be removed from the channel, and is likely a better representation of peak discharge. Discharge at W_BS1 will naturally be lower than W4 since it is upstream of the Willow 4A confluence.

W_BS1 and W4 stage and measured discharge data are presented in Graph 4.16 and Graph 4.17, respectively. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations at W_BS1 are referenced to NAVD88. Elevations at W4 are arbitrary.

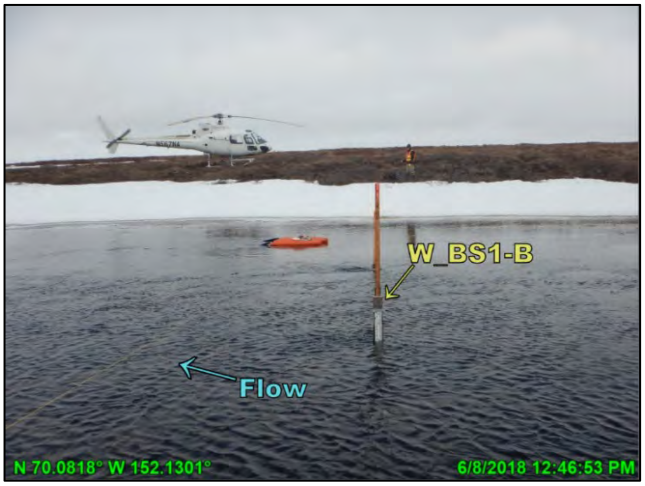
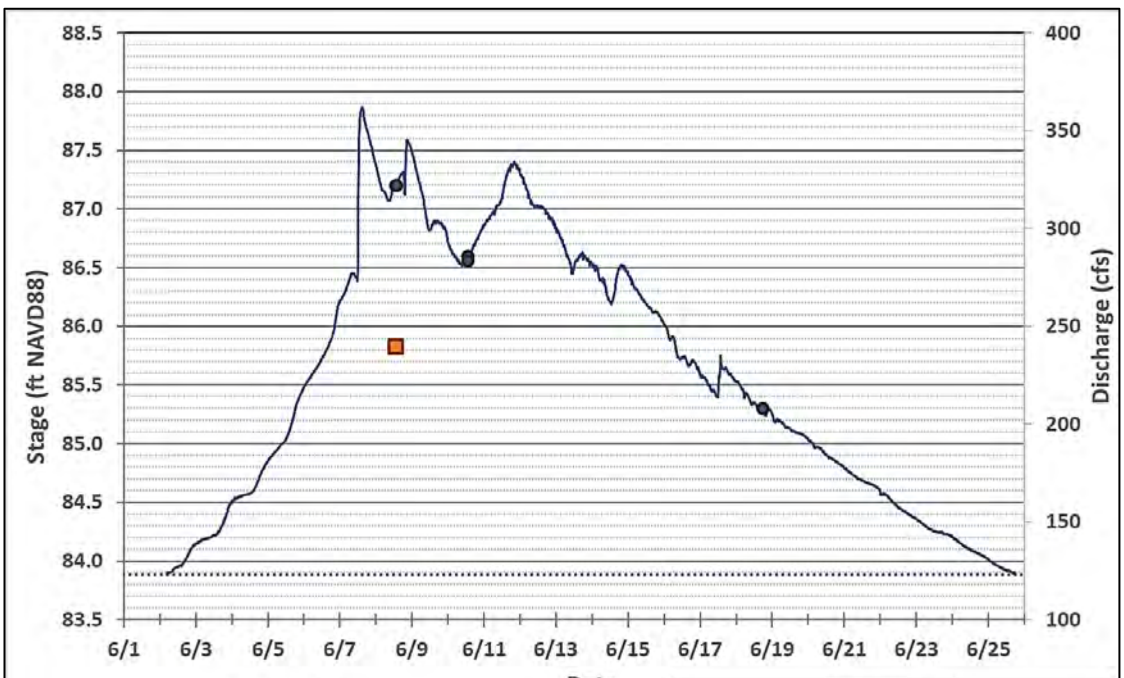


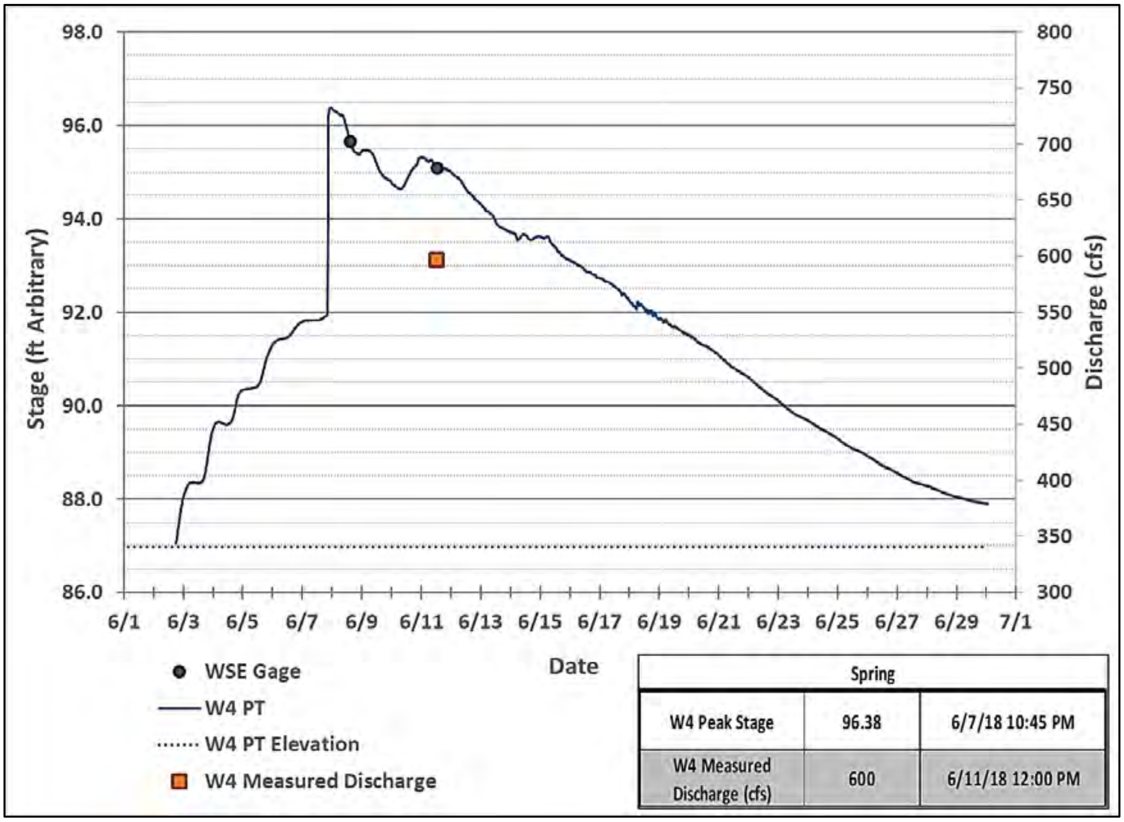
Photo 4.41: W_BS1 discharge measurement, looking north; June 8, 2018

Photo 4.42: W4 discharge measurement, looking northeast (downstream); June 11, 2018



Spring		
W_BS1 Peak Stage	87.87	6/7/18 2:45 PM
W_BS1 Measured Discharge (cfs)	240	6/8/18 1:00 PM

Graph 4.16: Willow 4 At W_BS1 Spring Breakup Stage & Discharge



Graph 4.17: Willow 4 At W4 Spring Breakup Stage & Discharge

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the data at each monitoring station, but water levels remained well below spring breakup peak stage (Photo 4.43 and Photo 4.44). The stage increase at the end of the summer monitoring period is associated with the late summer precipitation event. Summer stage at W_BS1 and W4 gage site is presented in Graph 4.18 and Graph 4.19, respectively.

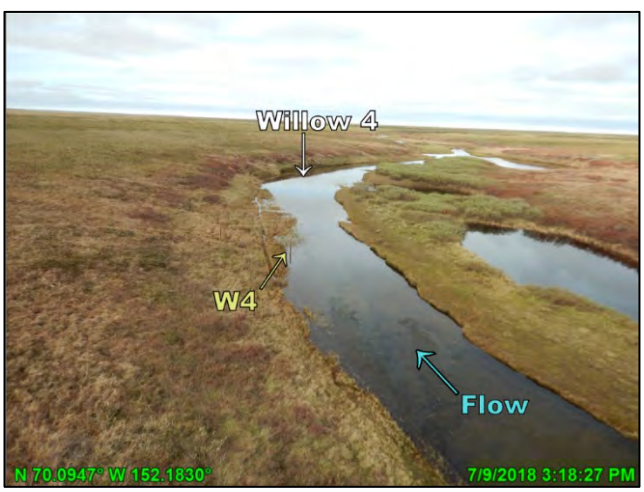
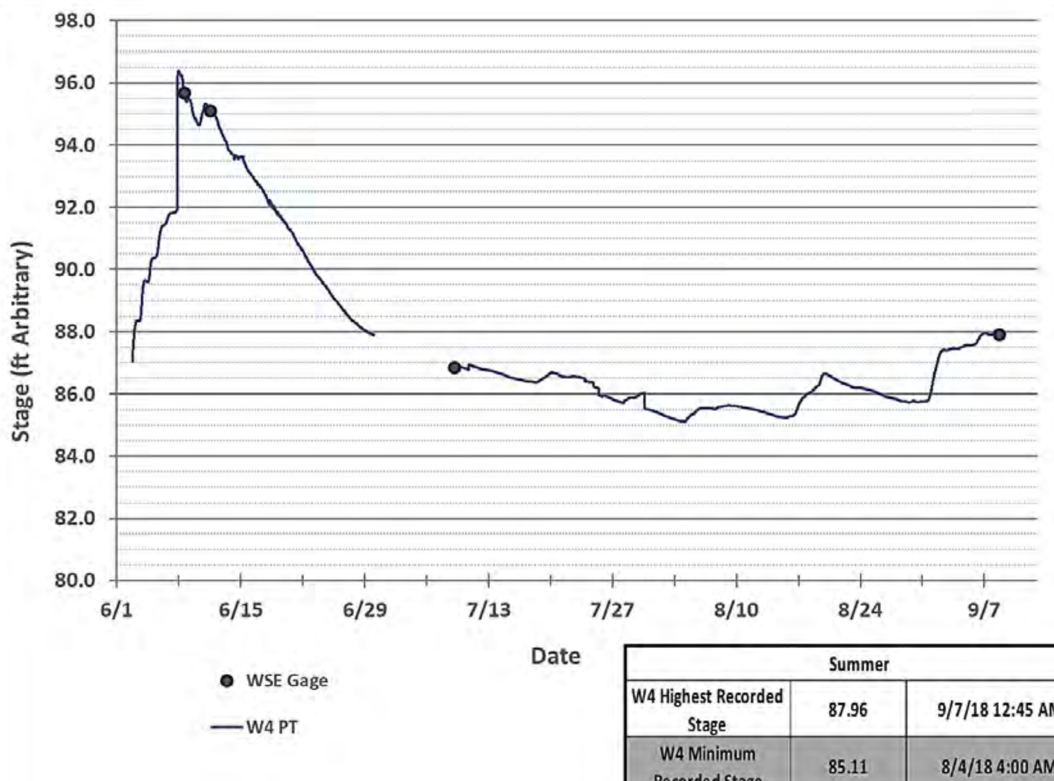


Photo 4.43: Summer conditions at W4, looking north (downstream); July 9, 2018

Photo 4.44: Summer conditions at W_BS1, looking west (downstream); July 12, 2018

Summer		
W_BS1 Highest Recorded Stage	83.79	9/6/18 7:00 PM
W_BS1 Minimum Recorded Stage	81.96	8/4/18 4:15 AM

Graph 4.18: Willow 4 At W_BS1 Summer Stage



Summer		
W4 Highest Recorded Stage	87.96	9/7/18 12:45 AM
W4 Minimum Recorded Stage	85.11	8/4/18 4:00 AM

Graph 4.19: Willow 4 At W4 Summer Stage

WILLOW 4A (W_S1)

Willow 4A is a tributary of Willow 4 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 first year of data collection and observations at the W_S1 monitoring location.

A. Spring Breakup

PT data indicated a rise in stage at W_S1 starting on June 2. Stage initially crested on June 5. On June 8, peak stage conditions were recorded as meltwater confined by saturated snow elevated stage 1.5 feet in nearly three hours. Observations before this rapid increase in stage showed saturated snow in the channel, with isolated pools of water present and the leading edge of water directly upstream of the gage site (Photo 4.45). Stage steadily decreased over the next three days. Bottomfast ice was observed through most of the channel on June 11, with minimal snow remaining along the banks.

Discharge was measured at W_S1 on June 13. Conditions at the time of measurement were similar to those observed on June 11, with bottomfast ice in the channel and minimal snow remaining along the banks (Photo 4.46). Flow was well-confined through a defined channel, with no overbank flooding observed. The overall quality of the discharge measurement was classified as fair due to bottomfast ice. Since stage at the time of the measurement was significantly lower that peak stage and very little snow remained around the drainage, discharge was likely higher in the channel on previous days. The measured discharge at W_S1 likely underrepresents peak discharge.

W_S1 stage and measured discharge data are presented in Graph 4.20. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.

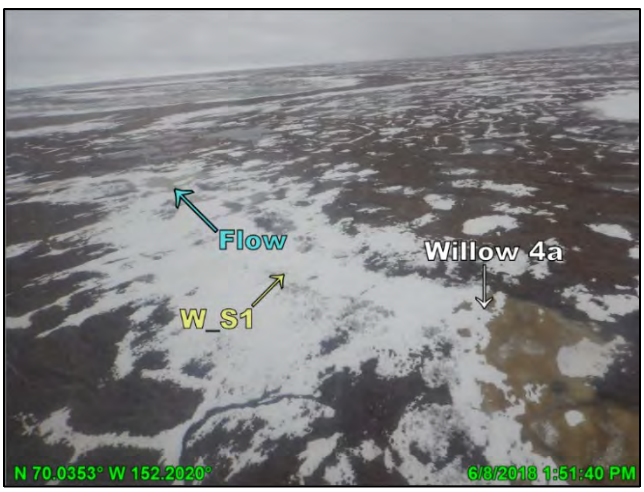
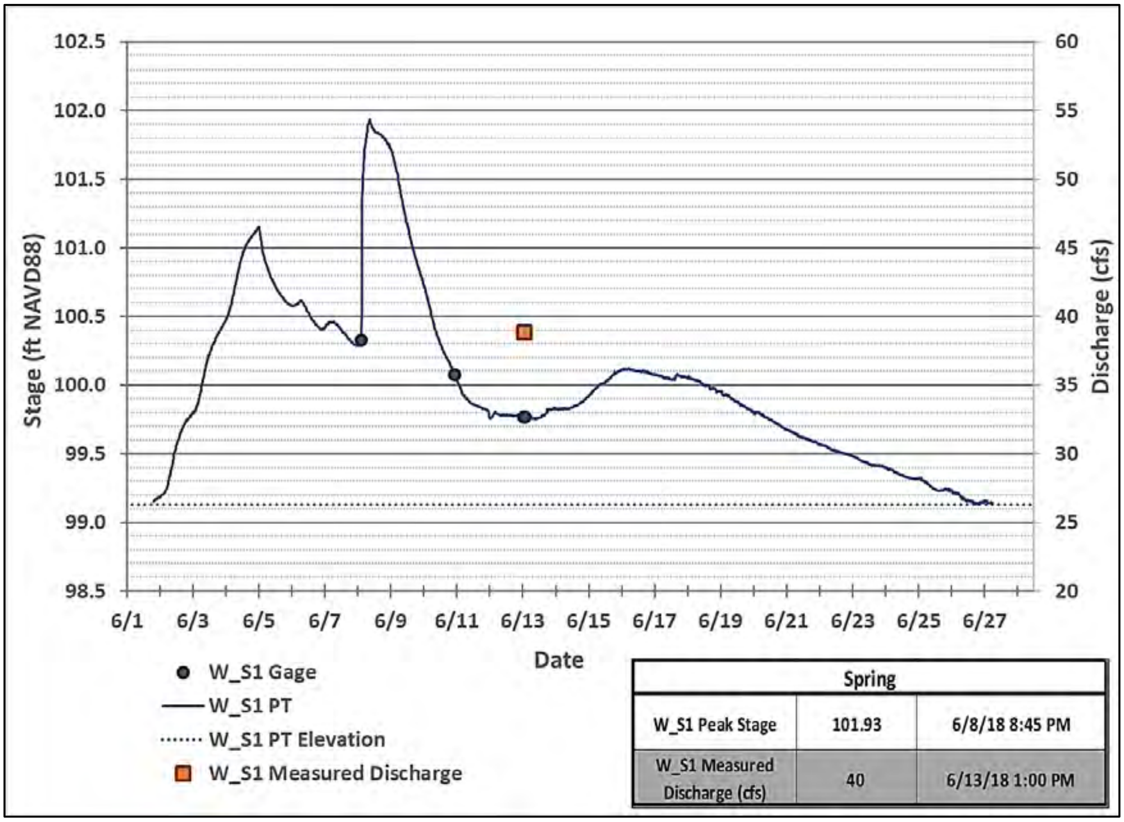


Photo 4.45: Peak stage at W_S1, looking north (downstream); June 8, 2018

Photo 4.46: W_S1, the day of the discharge measurement looking north (downstream); June 13, 2018



Spring		
W_S1 Peak Stage	101.93	6/8/18 8:45 PM
W_S1 Measured Discharge (cfs)	40	6/13/18 1:00 PM

Graph 4.20: Willow 4a Stream W_S1 Spring Breakup Stage & Discharge

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the data, but water levels remained well below spring breakup peak stage at all locations (Photo 4.47). The stage increase at the end of the summer monitoring period is associated with a significant precipitation event. Summer stage at W_S1 gage site is presented in Graph 4.21.

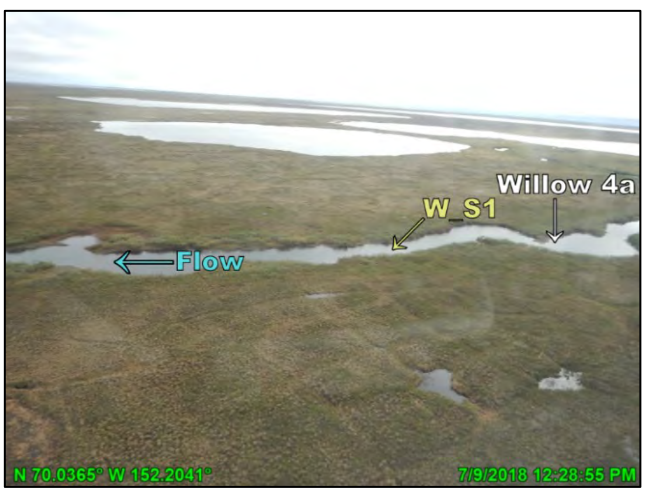
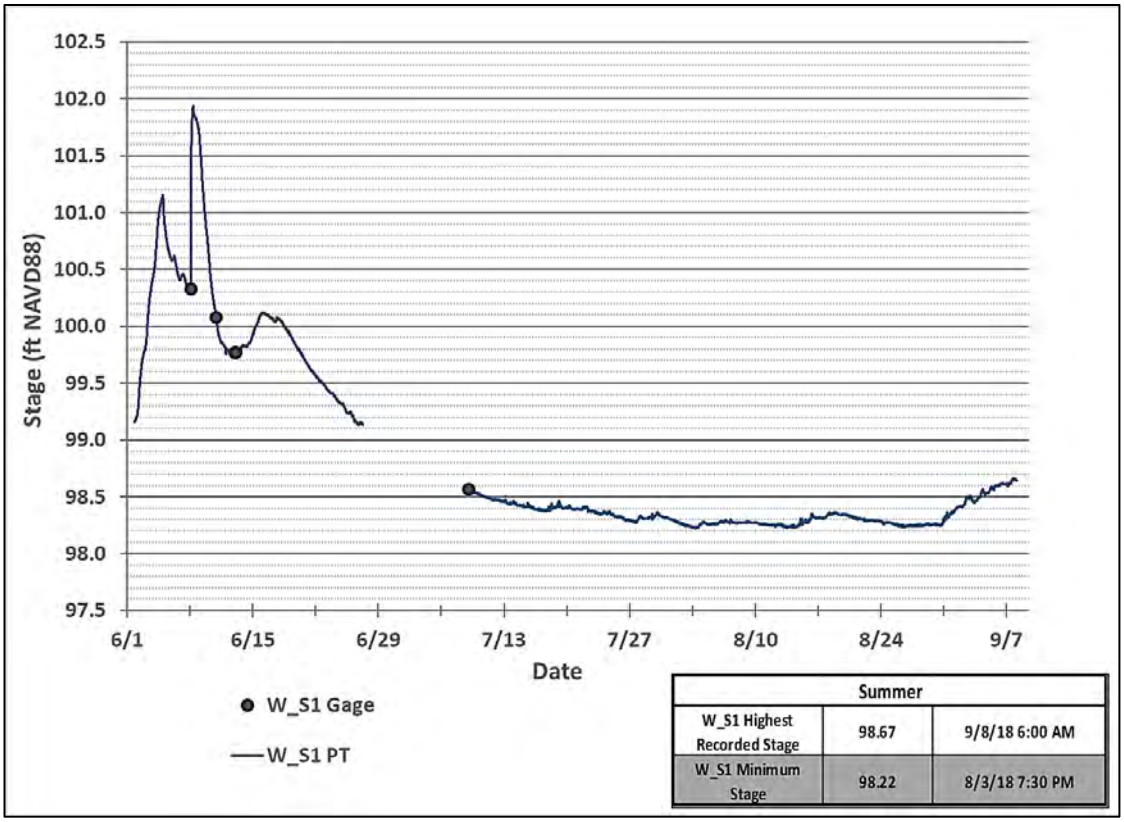


Photo 4.47: Summer conditions at W_S1, looking east; July 9, 2018



Graph 4.21: Willow 4a Stream W_S1 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 first year of data collection and observations at the TBD_6 and SW22 monitoring locations.

A. SPRING BREAKUP

The low relief and wide area of possible flow paths at the SW22 monitoring location made it difficult to place the gage and game camera in the actual drainage. As a result, the gage and game camera were isolated from the flow path that developed during spring breakup and only aerial and ground observations are available for SW22. On June 12, aerial observations showed a hydraulically connected pathway through an eroding ice road around the SW22 gage location. Snow was present around the channel and in low-lying areas and polygon cracks. Saturated snow was observed along the banks of the channel (Photo 4.48). On June 15, water was observed widely dispersed around the low-lying areas by the gage station. Flow was only discernable where saturated snow adhered to the banks, making the main channel easily visible from the air (Photo 4.49).

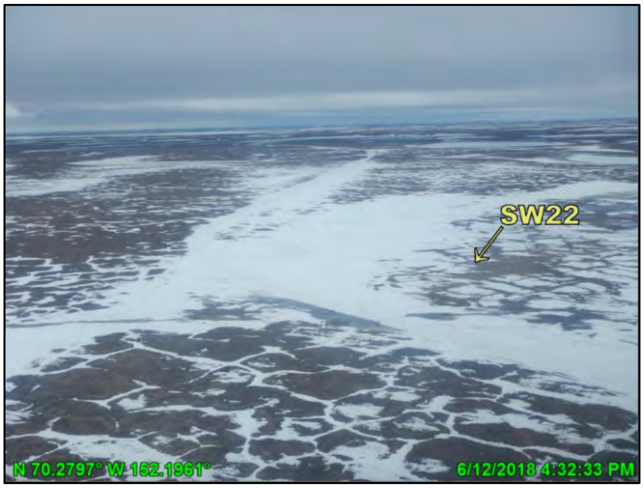


Photo 4.48: SW22 looking south; June 12, 2018

Photo 4.49: SW22 looking south; June 15, 2018

Drifted snow remained in Willow 8 at the TBD_6 crossing well into June. On June 10, long stretches of meltwater were accumulating at TBD_6 but no integrated flow was observed (Photo 4.50). Peak stage was recorded at TBD_6 on June 12, when overbank flooding and flow through saturated snow in the channel was observed (Photo 4.51). Peak stage at TBD_6 was elevated by snow and ice in the channel and likely occurred prior to peak discharge. By June 15, the channel was free of snow and ice and stage had receded to bankfull conditions (Photo 4.52).

Discharge was measured at TBD_6 on June 15. The quality of the measurement was classified as good based on snow- and ice-free conditions at the time of measurement (Photo 4.53). The channel was at bankfull conditions and flow was not impeded by snow in the channel, however, since stage later increased approximately 1.3 feet on June 21 the measured discharge at TBD_6 likely underrepresents peak discharge in Willow 8.

TBD_6 stage and measured discharge data are presented in Graph 4.22. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88, determined by concurrent WSE survey and PT data on August 6.

Photo 4.50: TBD_6, three days before peak stage, looking southwest (upstream); June 10, 2018

Photo 4.51: Conditions at TBD_6 the day before peak stage, looking west (upstream); June 12, 2018

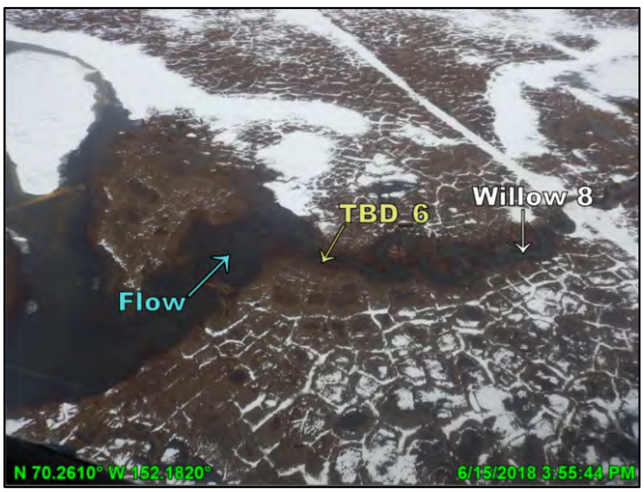
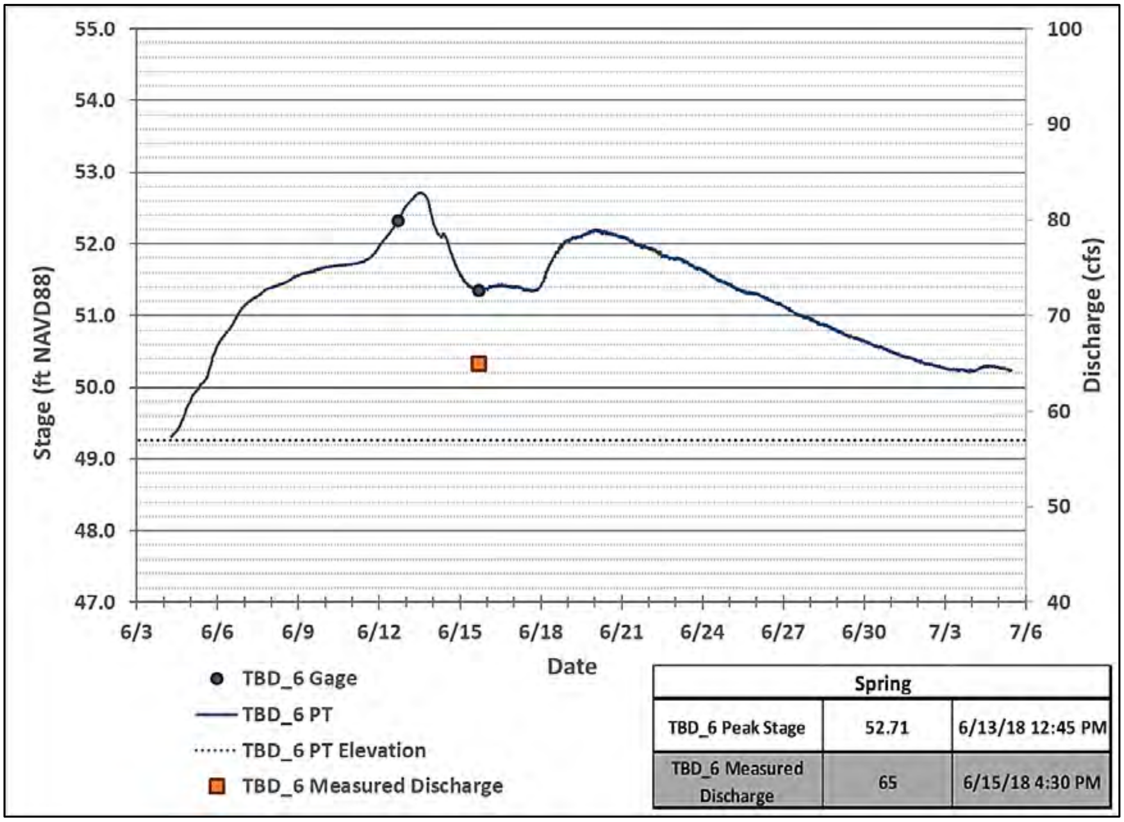


Photo 4.52: TBD_6 the day of the discharge measurement, June 15, 2018

Photo 4.53: TBD_6 the day of the discharge measurement, looking north; June 15, 2018



Graph 4.22: Willow 8 TBD_6 Spring Breakup Stage & Discharge

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the data, but water levels remained well below spring breakup peak stage at all locations (Photo 4.54 and Photo 4.55). The stage increase at the end of the summer monitoring period is associated with a significant precipitation event. Summer stage at TBD_6 gage site is presented in Graph 4.23.

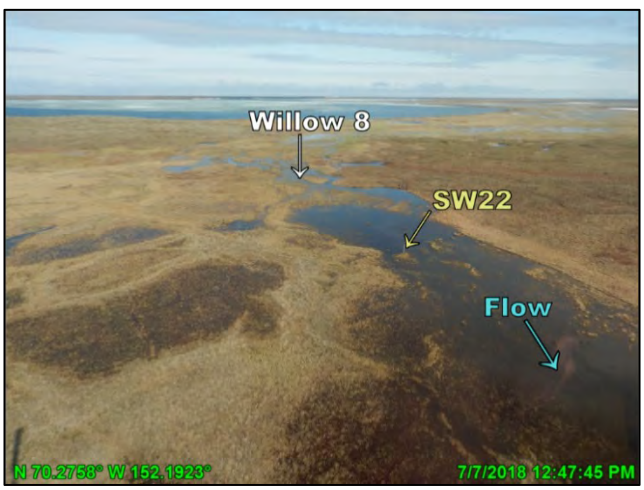


Photo 4.54: Summer conditions at SW22, looking north (upstream) July 7, 2018

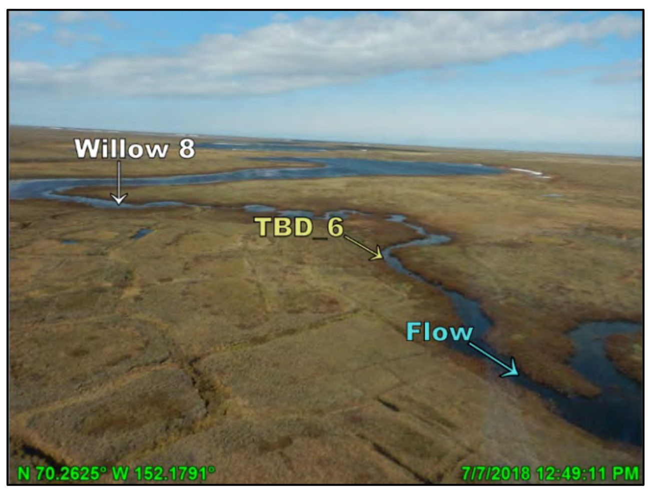
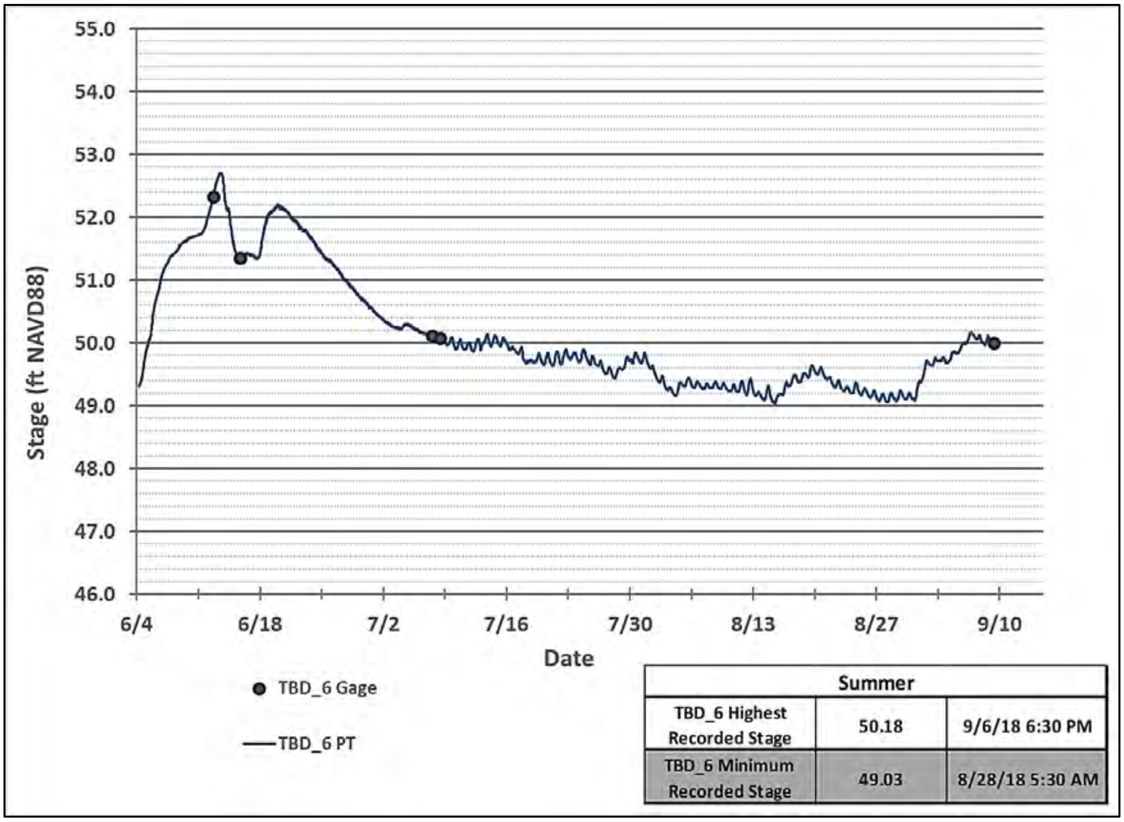


Photo 4.55: Summer Conditions at TBD_6, looking north (upstream); July 7, 2018



Graph 4.23: Willow 8 TBD_6 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 first year of data collection and observations at the TBD_5 monitoring location.

A. Spring Breakup

Ponded local melt was observed in disconnected low-lying areas around TBD_5 on June 6 (Photo 4.56). Aerial observations show the channel was still filled with drifted snow that was saturated based on increasing stage data. On June 10, conditions were similar with isolated pockets of local melt observed in the channel and increasing stage (Photo 4.57). A sharp increase in stage was recorded on June 11. Observations on game camera footage show the rapid arrival of hydraulically connected flow on top of saturated snow around 3 PM which led to peak stage shortly after. This observation was verified with PT data, which recorded a stage increase of nearly 2.5 feet in 1 hour at this time. Stage receded slightly over the next few days.

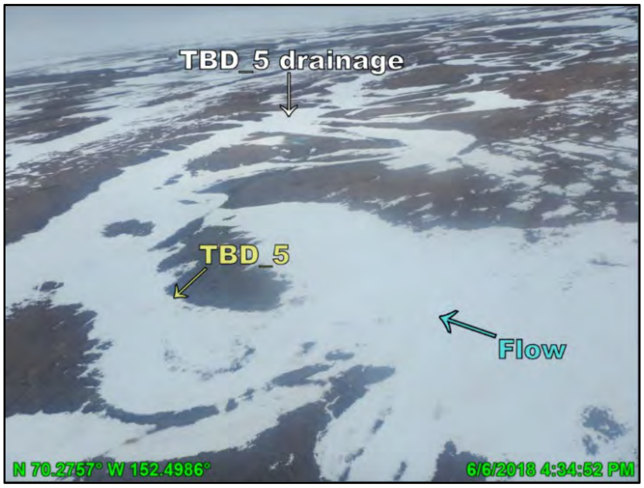


Photo 4.56: TBD_5 approximately a week before peak stage, looking northeast (downstream); June 6, 2018

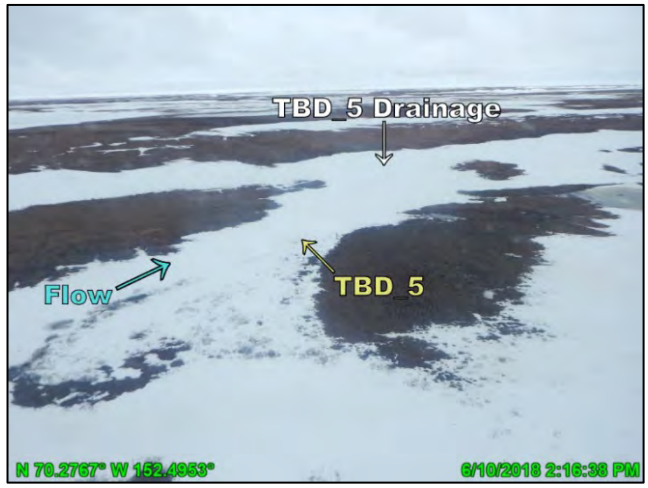


Photo 4.57: TBD_5 the day before peak stage, looking northeast (downstream); June 10, 2018

On June 14, overbank flooding was observed in the low-lying areas around TBD_5 (Photo 4.58). Snow was observed both in the channel and along the banks. Stage continued to recede until June 17, when increased stage led to a second crest on June 18. Stage from the June 18 crest was slightly lower than that observed during peak stage. Overbank flooding was observed on June 18, along with areas of saturated snow along the banks (Photo 4.59). A third crest was recorded at TBD_5 on June 23. Game camera images suggest overbank flooding conditions and minimal snow impedance during this final stage crest.

Discharge was measured at TBD_5 on June 18, corresponding with the seconded stage crest at TBD_5. Conditions at the time of measurement included overbank flooding and saturated snow along the banks. 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 good and the measured discharge is believed to be representative of peak discharge at TBD_5.

TBD_5 spring breakup stage and measured discharge data are presented in Graph 4.24. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are arbitrary.

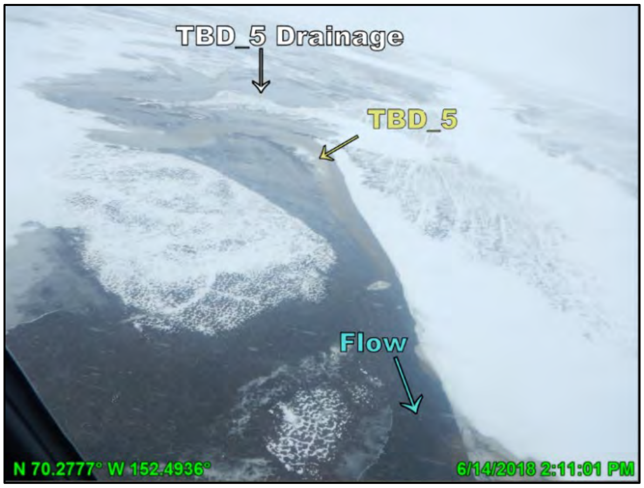
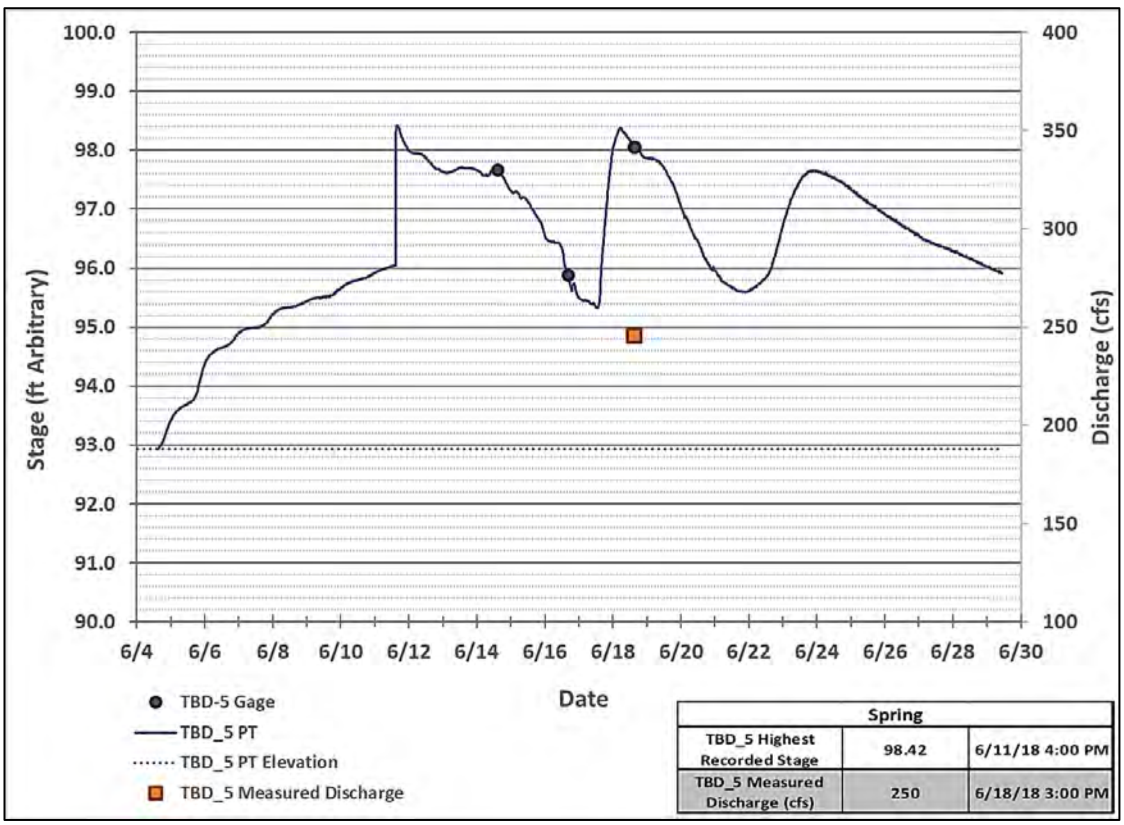


Photo 4.58: TBD_5 three days after peak stage, looking west (upstream) June 14, 2018

Photo 4.59: TBD_5 the day of the discharge measurement, looking west (upstream); June 18, 2018



Graph 4.24: TBD_5 Spring Breakup Stage & Discharge

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the data, but water levels remained well below spring breakup peak stage at all locations (Photo 4.60). The stage increase at the end of the summer monitoring period is associated with the late summer precipitation event. Summer stage at TBD_5 gage site is presented in Graph 4.25.

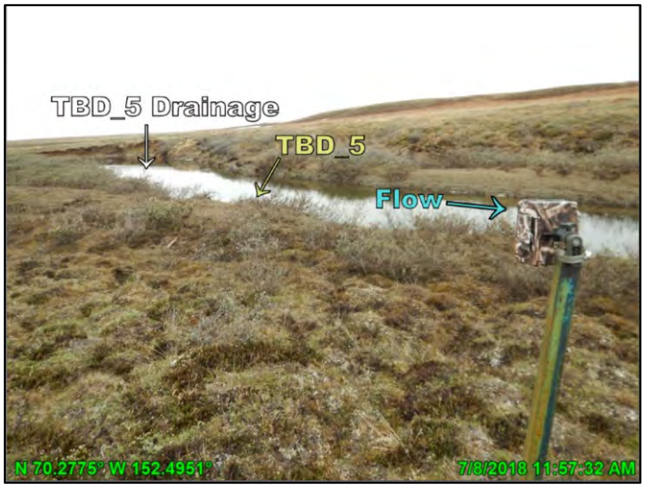
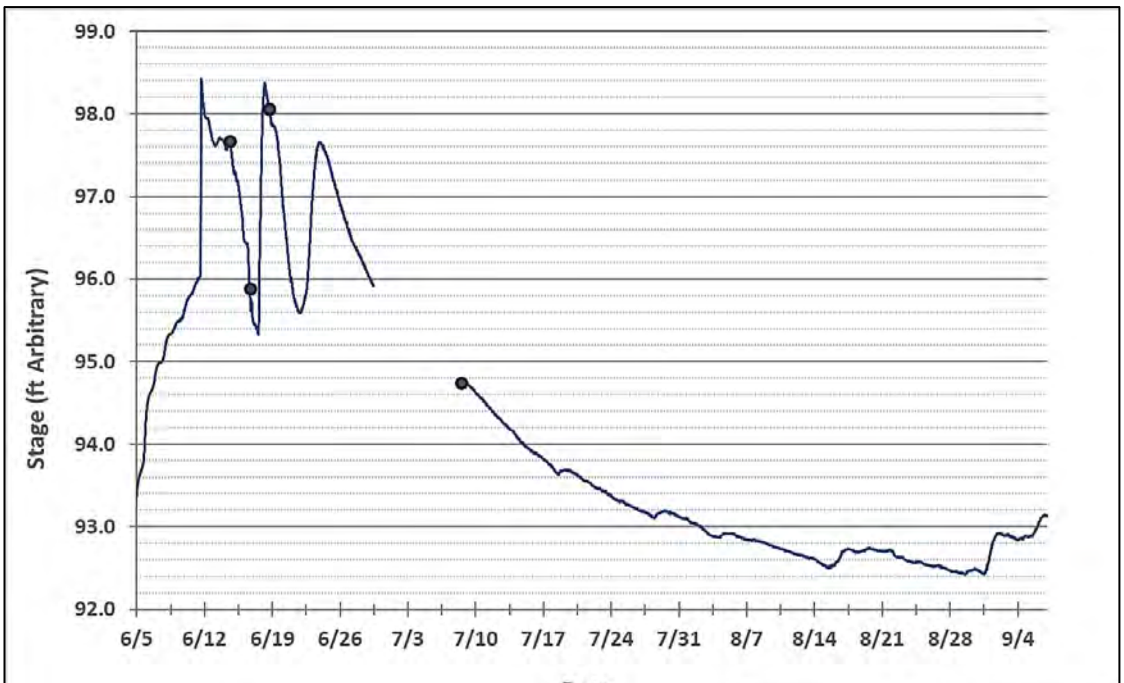


Photo 4.60: Summer conditions at TBD_5, looking west (upstream); July 8, 2018



	Summer	
TBD_5 Highest Recorded Stage	94.75	7/9/18 12:45 AM
TBD_5 Minimum Recorded Stage	92.42	8/29/18 1:00 PM

Graph 4.25: Willow 8 TBD_5 Spring Breakup Stage & Discharge

4.3 SWALES

Swales 1, 2, and 4 (SW1, SW2, and SW4) were established in 2017 and this represents the second year of data collection and observations. Swales 14 and 23 (SW14 and SW23) were established in 2018 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 low-lying area with occasional beads between two unnamed lakes. The drainage conveys flow north into Judy Creek upstream of gage station J13.8. The reported peak stage and timing values are based on gage readings from game camera images.

Ponded local melt was observed in SW1 on June 7, with ice remaining on the surrounding lakes. Swale 1 was flowing under generally open channel conditions by June 10. Flow was being conveyed from the ponded area, south of SW1, into the lake to the north of SW1 (Photo 4.61). Hydraulically connected meltwater was observed in the low-lying areas east and west of SW1. Peak stage conditions were observed on June 10. Discharge was measured on June 13 downstream of the SW1 gage where flow was well confined (Photo 4.62). By early July, water was confined to beads within the drainage path, adjacent low-lying areas were dry, and no flow was observed (Photo 4.63).

Swale 1 spring breakup stage and measured discharge data are presented in Graph 4.26. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are arbitrary.

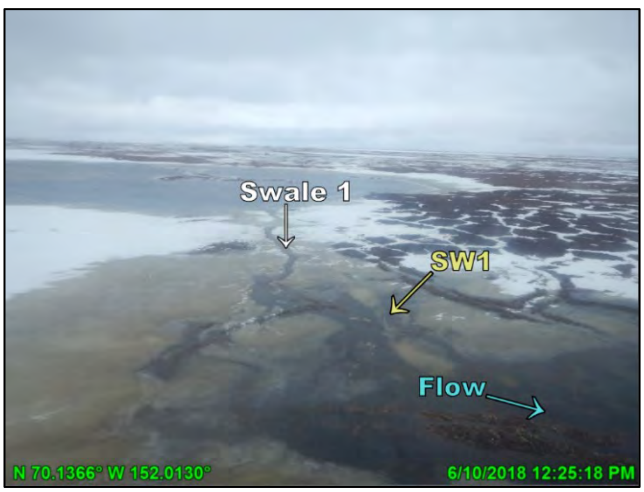


Photo 4.61: Peak stage at SW1, looking south (upstream) June 10, 2018

Photo 4.62: SW1, the day of the measured discharge, looking north (downstream); June 13, 2018

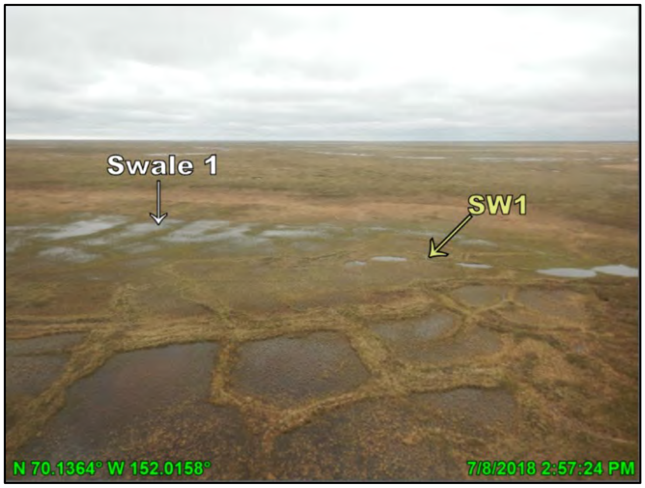
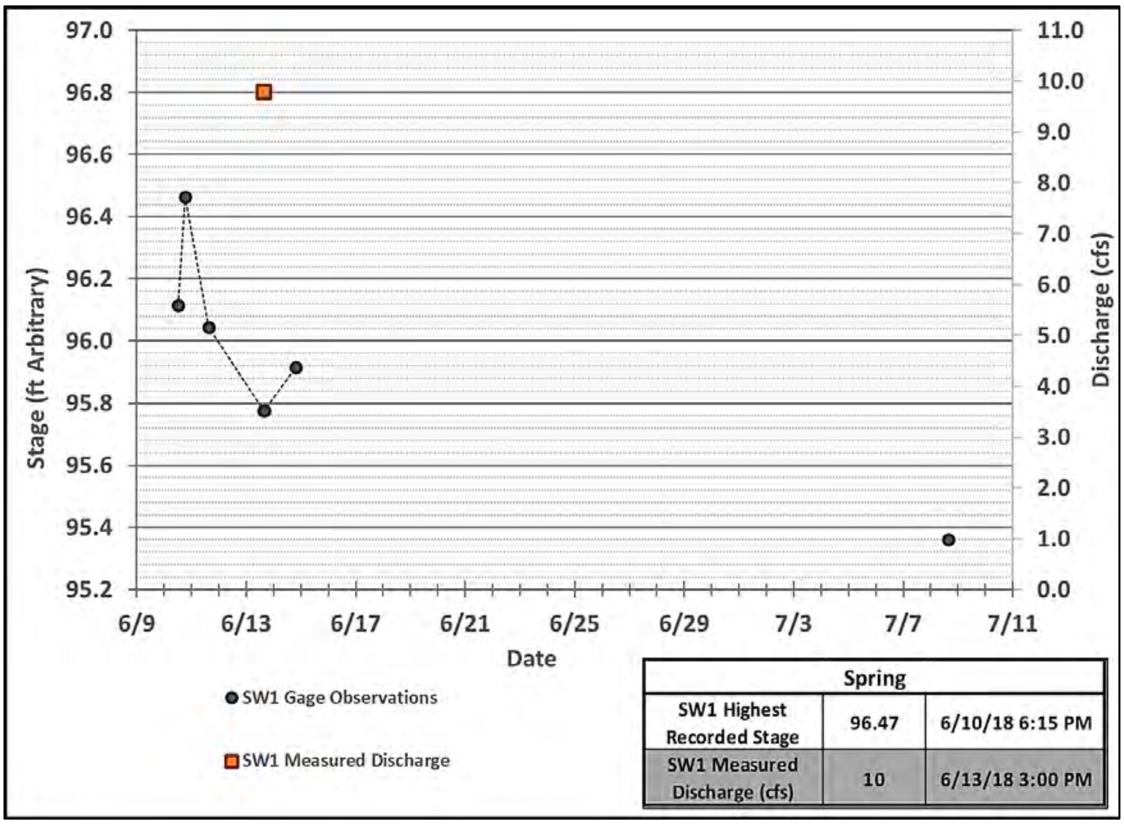


Photo 4.63: Summer conditions at SW1, looking east; July 8, 2018



	Spring	
SW1 Highest Recorded Stage	96.47	6/10/18 6:15 PM
SW1 Measured Discharge (cfs)	10	6/13/18 3:00 PM

Graph 4.26: 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, slightly downstream of J21.4 gage station. The reported peak stage and timing values are based on gage readings from game camera images.

Ponded local melt was observed at the SW2 gage on June 6. Analysis of game camera images showed that the SW2 gage recorded peak stage on June 7. Aerial observations from June 7 showed significant snow cover confining the swale and bottomfast ice along the length of the swale. Water was observed in the low-lying adjacent areas and polygon cracks on June 10 and no discernable flow was present (Photo 4.64). On June 13, discernable flow was observed, and a discharge measurement was performed. The discharge measurement was taken slightly downstream of the gage station with snow and ice remaining in the drainage (Photo 4.65). Once flow was observed and hydraulic connection established, water was generally well confined within the defined swale. By June 21, game camera footage showed minimal snow remaining in the drainage. Summer site observations on July 8 showed minimal flow and stage through a poorly defined grassy flow path near the SW2 gage site (Photo 4.66).

Swale 2 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.

Photo 4.64: SW2, looking southwest (upstream); June 10, 2018

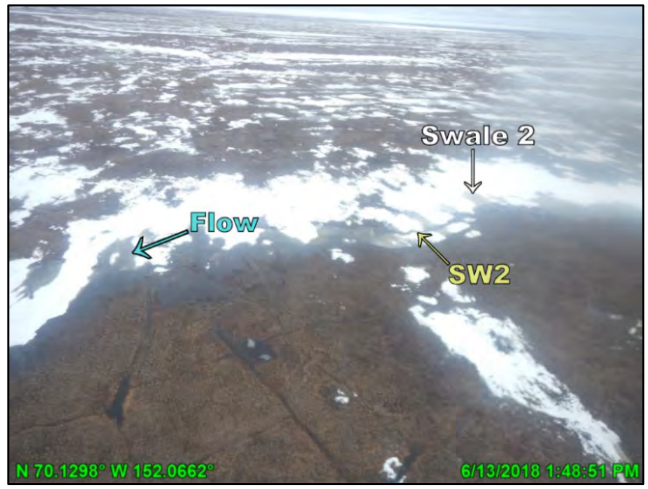
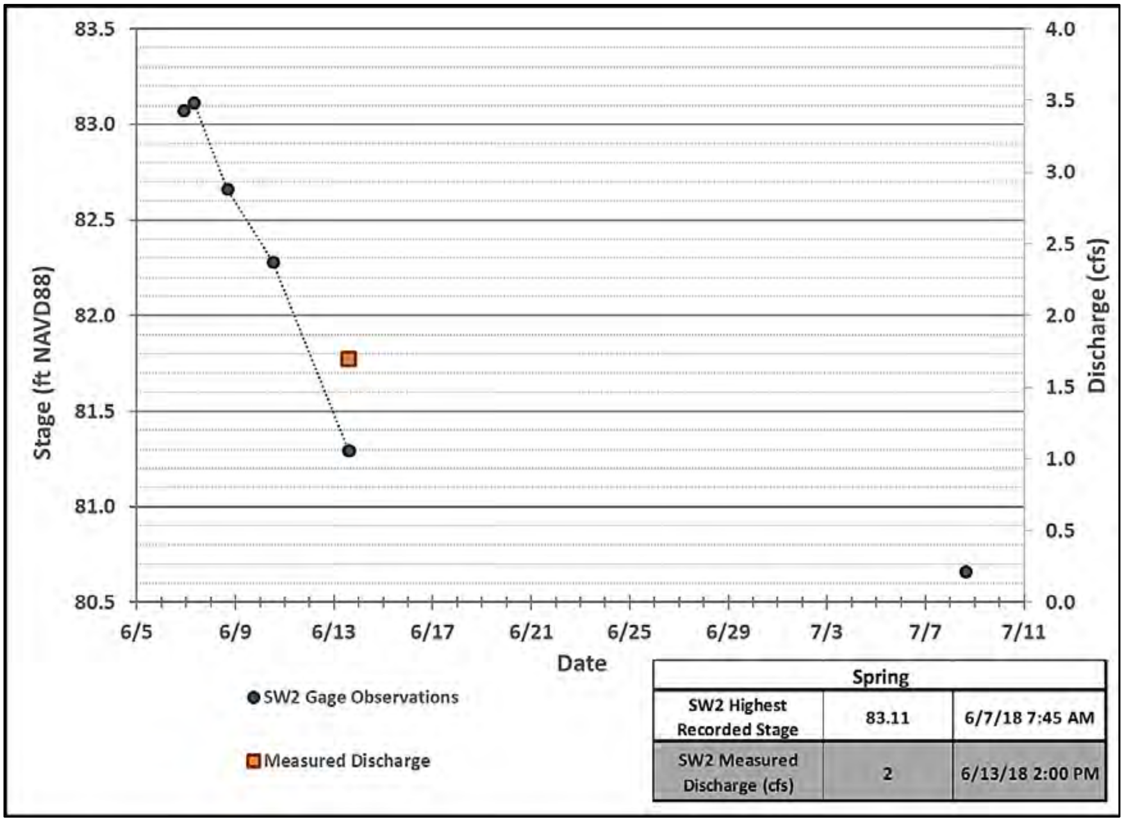


Photo 4.65: SW2 the day of the measured discharge, looking east; June 13, 2018

Photo 4.66: Summer conditions at SW2, looking north; July 8, 2018



Graph 4.27: Swale 2 Spring Breakup Stage & Discharge

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.

Ponded local melt was observed accumulating in Swale 4 around June 3. On June 6, game camera images show ponded water in polygon cracks in the immediate vicinity of the SW4 gage site. Aerial observations from this day show low-lying areas, ponds, and lakes upstream, downstream, and adjacent to Swale 4 still had considerable snow and minimal melt water. On June 10, the snow pack in the adjacent low-lying areas had declined, but only local melt was observed at SW4 (Photo 4.67). Observations on June 13 showed more local melt had accumulated at SW4 site (Photo 4.68). During breakup, minimal stage fluctuations were observed through game camera footage and only local melt was documented through aerial observations. Since hydraulic connections to surrounding waterbodies were never observed, stage and discharge were not measured at this location in 2018. Ponded water remained throughout the area into early July, based on aerial observations and game camera photos. Breakup conditions were similar to what was observed in 2017.

Photo 4.67: SW4 looking south; June 10, 2018

Photo 4.68: SW4 looking southwest; June 13, 2018

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. Since no PT was installed and the game camera had shifted such that the gage was not in view, the reported peak stage and timing values are estimated based on game camera images of the swale.

Flow over snow was first observed through game camera images during the morning of June 5. SW14 reached peak stage around noon of June 5 and rapidly receded by late that afternoon. Aerial observations from late afternoon on June 6 show the swale was hydraulically connected between Lake M0014 and Judy Creek with saturated snow remaining in the drainage. On June 7, flooding was observed in some low-lying areas around the swale, but most flow was confined to a well-defined swale cut through the snowpack (Photo 4.69). Discharge was measured on June 7. Based on conditions at the time of the measurement, the measured discharge was assigned a good quality rating and is believed to be representative of peak discharge on Swale 14. On June 18, little snow remained in the drainage and the swale was flowing freely through its defined channel (Photo 4.70). Flow was observed through a small defined grass-lined swale during summer observation on July 7 (Photo 4.71).

Swale 14 stage and measured discharge data are presented in Graph 4.28. Measured discharge details and plan and profile figures are provided in Appendix C. Elevations are referenced to NAVD88.

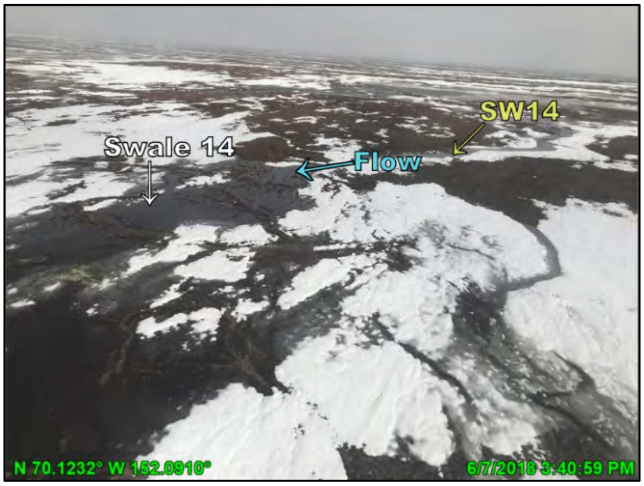


Photo 4.69: SW14, looking east (upstream); June 7, 2018

Photo 4.70: SW14, looking northeast; June 18, 2018

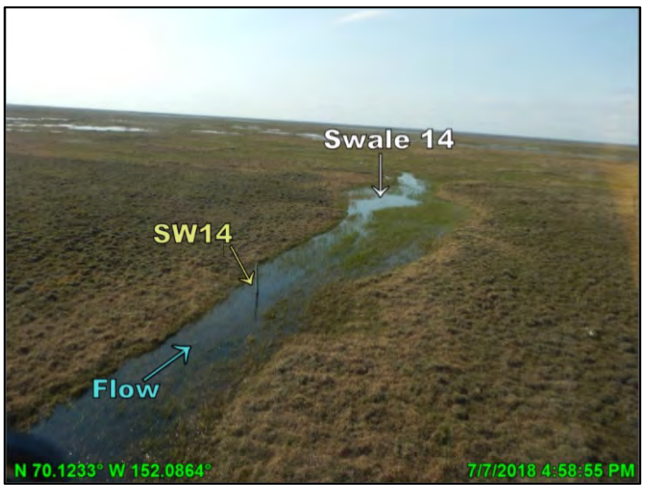
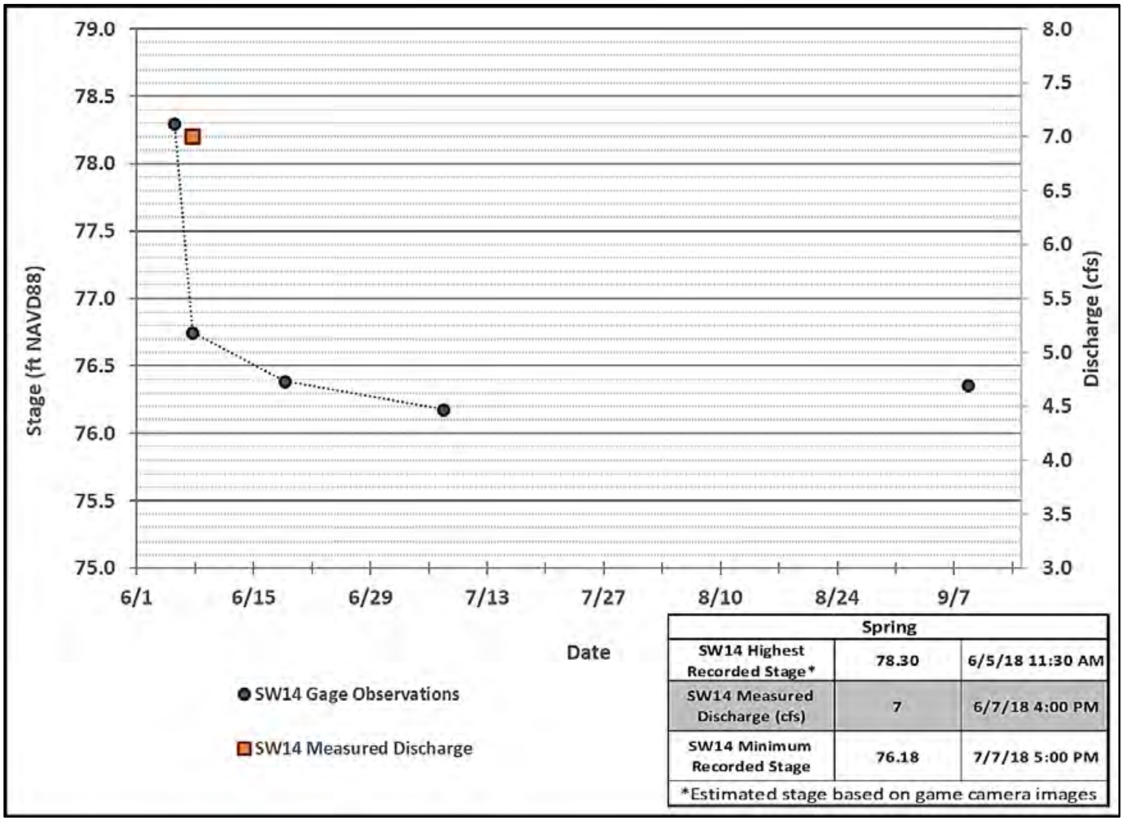


Photo 4.71: Summer conditions at SW14, looking east (downstream); July 7, 2018



Graph 4.28: Swale 14 Spring Breakup Stage & Discharge

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. Since no PT was installed and the game camera was positioned such that the gage was not in view, the reported peak stage and timing values are estimated based on site observations. However, enough data was captured on the game camera images to verify that the actual timing of peak stage was near to the reported timing.

Ponded local melt first appeared in Swale 23 on June 10, based on game camera footage. Aerial observations for this day show the channel still completely covered with saturated snow. On June 12, peak stage was recorded at the SW23 gage station and flow was observed in a channel cut through the snowpack. Aerial observations show hydraulic connectivity through the entire length of the swale (Photo 4.72). Water was well-confined to the swale cut through the snowpack and no overbank flooding was observed. By June 15, stage had receded, and saturated snow remained in the swale (Photo 4.73). Discharge was measured on June 18. The overall quality of the discharge measurement was classified as good. Since discharge was measured nearly a week after peak stage, the measured discharge is not believed to be representative of peak discharge in Swale 23. Summer observations showed no discernable flow and water was confined within the disconnected beaded pools of the swale (Photo 4.74).

Swale 23 stage and measured discharge data are presented in Graph 4.29. Measured discharge data and plan and profile figures are provided in Appendix C. Elevations are arbitrary.

Photo 4.72: SW23, looking northeast (upstream); June 12, 2018

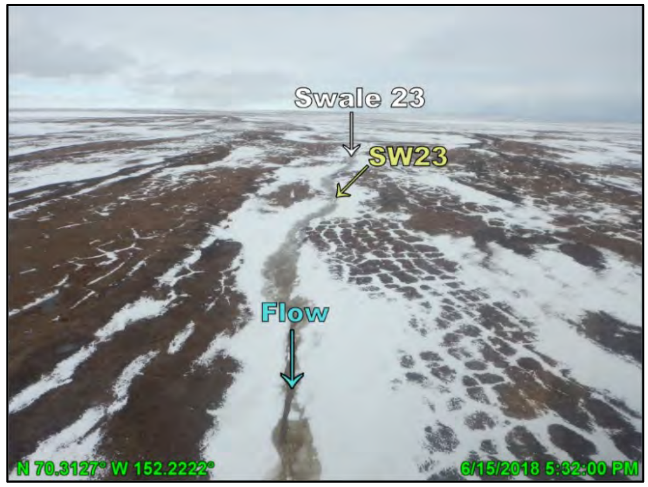
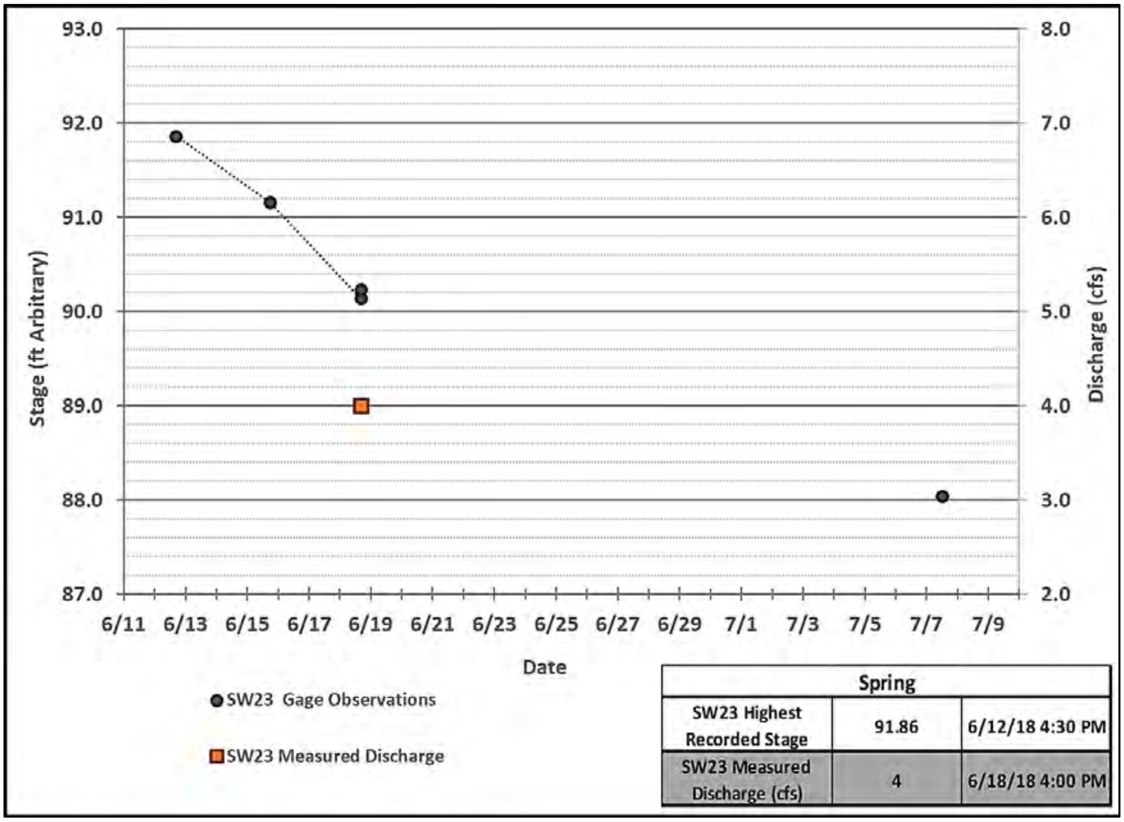


Photo 4.73: SW23, looking east (upstream); June 15, 2018

Photo 4.74: Summer conditions at SW23, looking west; July 7, 2018



Graph 4.29: Swale 23 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 road near the Tinmiaqsiugvik River. Gage stations UB14.5 and UB15.5 are on the Tinmiaqsiugvik River and situated at low points along the bank where backwater from the Tinmiaqsiugvik River would encroach into the proposed minesite. MS_1 is a small swale that flows through the proposed minesite into the Tinmiaqsiugvik River at UB15.5. 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 first year of data collection and monitoring at these sites. The Tinmiaqsiugvik River at this location is a sinuous, deeply incised channel flowing north. Since there are no proposed crossings at these locations, discharge was not measured at any of the sites.

UB14.5

Gage station UB14.5 is located downstream from UB15.5 on the Tinmiaqsiugvik River and downstream of the mouth of Bill's Creek where it enters the Tinmiaqsiugvik. The winter months fill the deep, incised channel with windblown snow.

Water reached the PT on June 3, with water surface elevations rising until peak stage was observed on June 9. Initial meltwater flooded over the snow packed channel and spread out across the drainage, before cutting a channel through the snowpack. Low-lying areas were inundated with water surrounding the gage location (Photo 4.75 and Photo 4.76). Snow remained along the banks through mid-June, contributing to the extended, drawn out breakup. Stage began dropping sharply on June 16. Mid-summer and end-of-summer conditions can be seen in Photo 4.77 and Photo 4.78.

UB14.5 stage data are presented in Graph 4.30. Elevations are arbitrary.

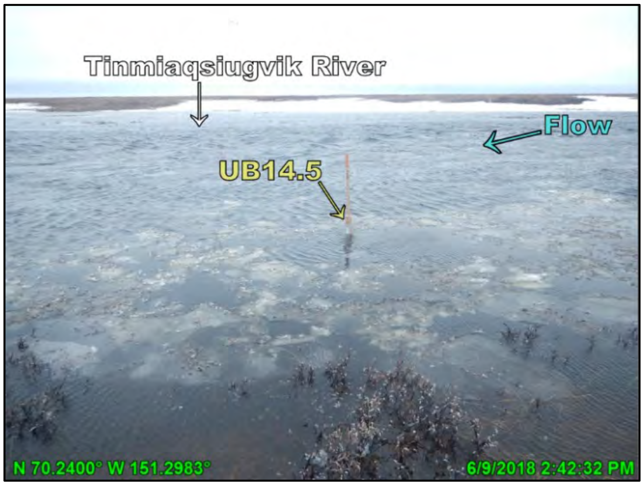


Photo 4.75: Peak stage at UB14.5, looking southeast (upstream); June 9, 2018

Photo 4.76: UB14.5, three days after peak stage, looking north (downstream); June 12, 2018

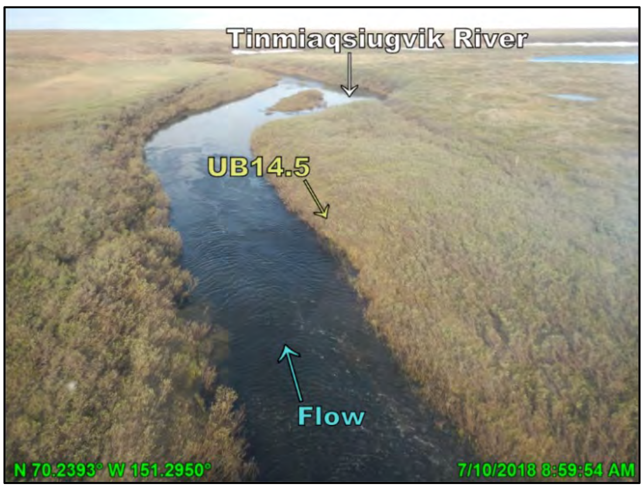


Photo 4.77: Summer conditions at UB14.5, looking east (downstream); September 8, 2018

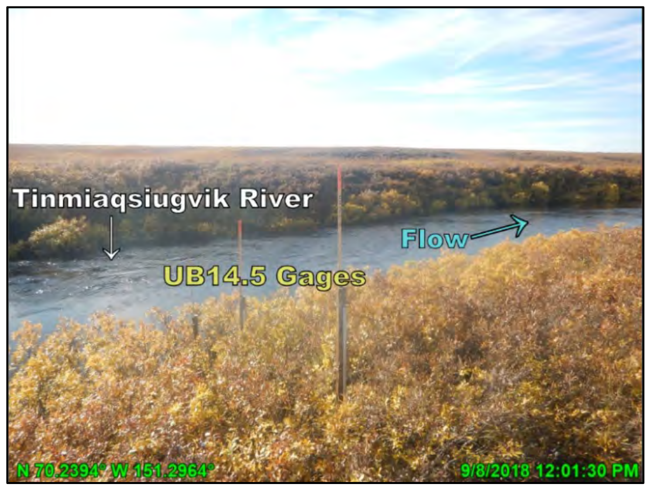
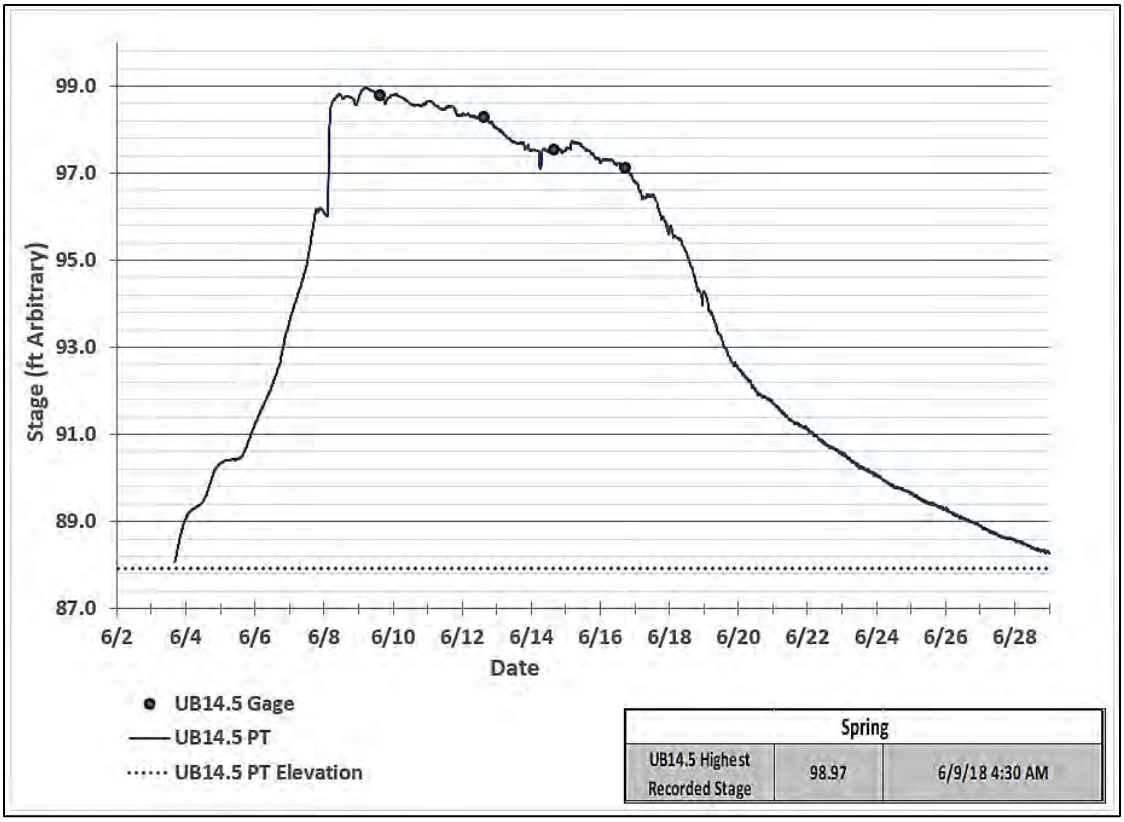


Photo 4.78: End of summer conditions at UB14.5, looking south (downriver); September 8, 2018



Graph 4.30: UB14.5 Spring Breakup Stage

UB15.5

Gage station UB15.5 is located upstream around a bend from UB14.5 on the Tinmiaqsiugvik River (Photo 4.79). The channel at this location passes by UB15.5 and flows around a corner to U14.5. Similar to UB14.5, the winter months filled the deep, incised channel with windblown snow and the slow onset of breakup led by meltwater that initially flowed over the snowpack.

Water reached the PT on June 3, with water surface elevations rising until peak stage was observed on June 9. Floodwater on June 9 overtopped all gages at UB15.5 and floodwater spread across a large area before a sharp downstream bend in the river. Snow and rafted ice was observed at UB15.5 on June 16 (Photo 4.80). Stage remained elevated until mid-June, until a steady decline in stage began.

UB15.5 stage data are presented in Graph 4.31. Elevations are arbitrary.

Photo 4.79: UB15.5, the day after peak stage, looking north (downstream); June 9, 2018

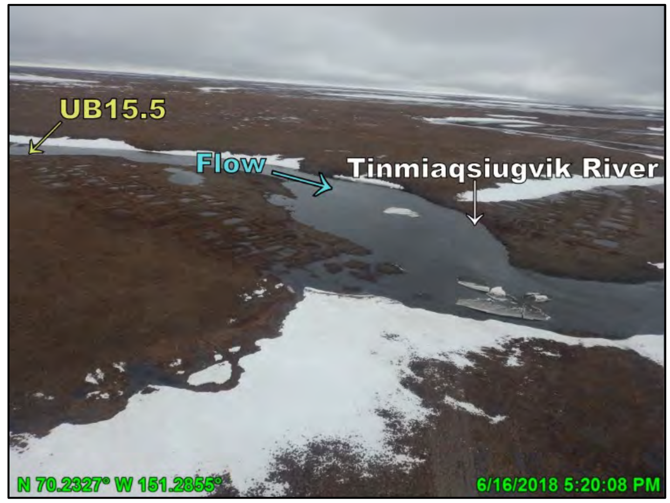
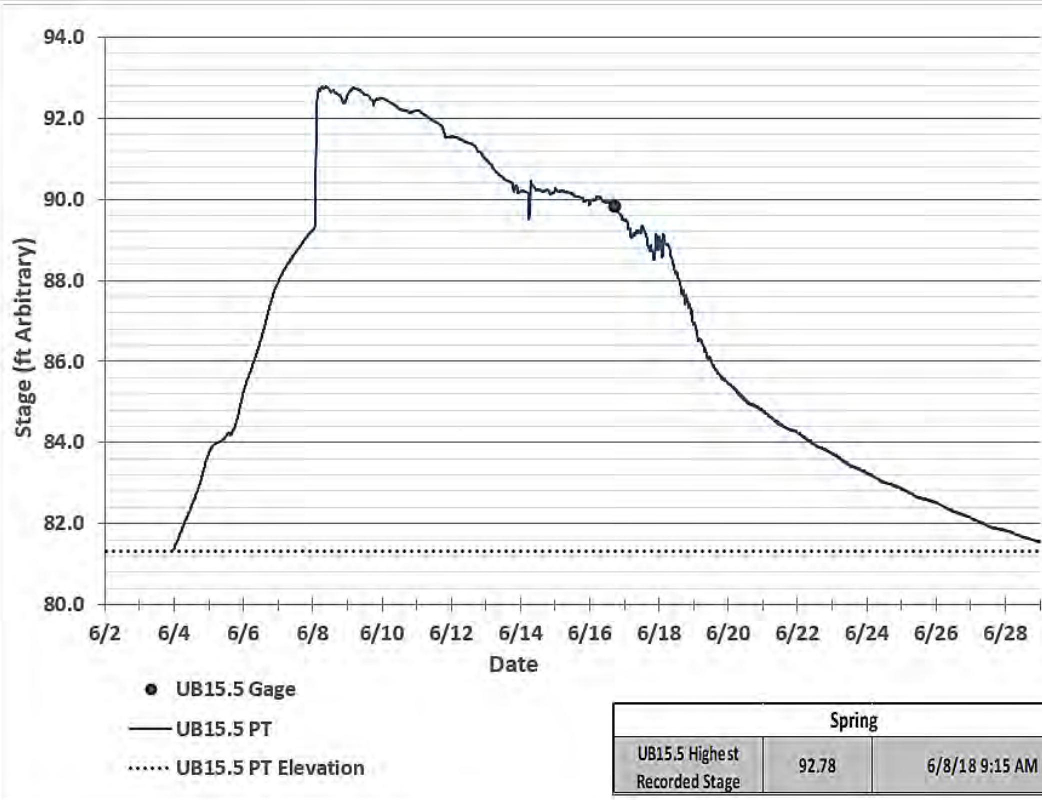


Photo 4.80: UB15.5, looking east; June 16, 2018



	Spring	
UB15.5 Highest Recorded Stage	92.78	6/8/18 9:15 AM

Graph 4.31: UB15.5 Spring Breakup Stage

MS1_1

Gage station MS1_1 is situated in a small beaded swale flowing north to the Tinmiaqsiugvik River adjacent to UB15.5. Installation of the MS1_1 during winter conditions made it difficult to locate the channel as it is a broad and shallow swale with a relatively steep gradient to the nearby Tinmiaqsiugvik River. It drains a low-lying area of polygonal ground with Bill's Creek (BC1) to the east and the Tinmiaqsiugvik River to the north.

A. SPRING BREAKUP

Water was first recorded on the PT at MS1_1 on June 4. Initial local melt around the gage location, continued ponding in place, producing peak stage on June 5. Once the meltwater began flowing, the steep gradient to the river contributed to stage dropping as flow meandered through the snowpack, as observed on June 9 (Photo 4.81). On June 14, snow had melted over a portion of the swale and flow was observed running over the tundra around the gage (Photo 4.82).

Note that the arbitrary control for UB15.5 and MS1_1 are the same. Peak stage at UB15.5 was 92.78 feet; PT elevation at MS1_1 was 95.71 feet; therefore, peak stage in the Tinmiaqsiugvik River for 2018 was approximately 3 feet below the gage at MS1_1 indicating Tinmiaqsiugvik River backwater did not reach the MS1_1 gage. For reference, the difference in PT elevations at the two gage locations is roughly 14.4 feet.

MS1_1 stage data are presented in Graph 4.32. Elevations are arbitrary.

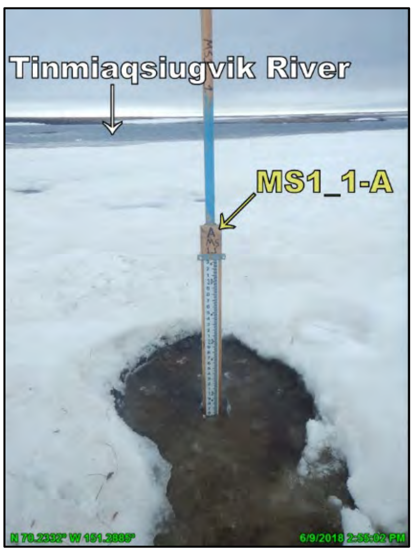


Photo 4.81: MS1_1, looking northwest; June 9, 2018

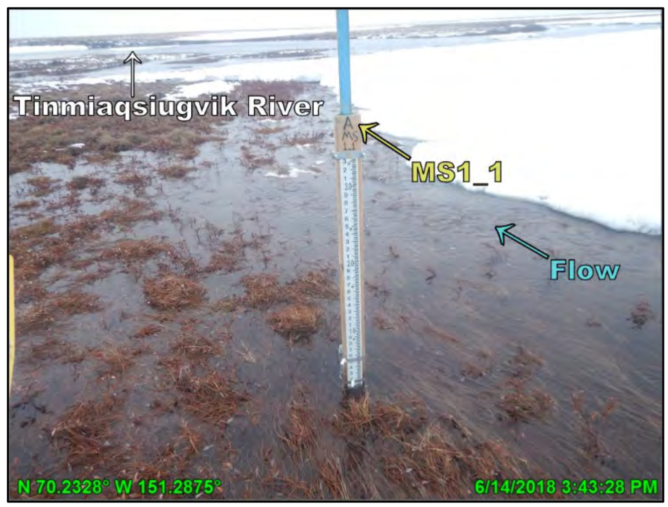
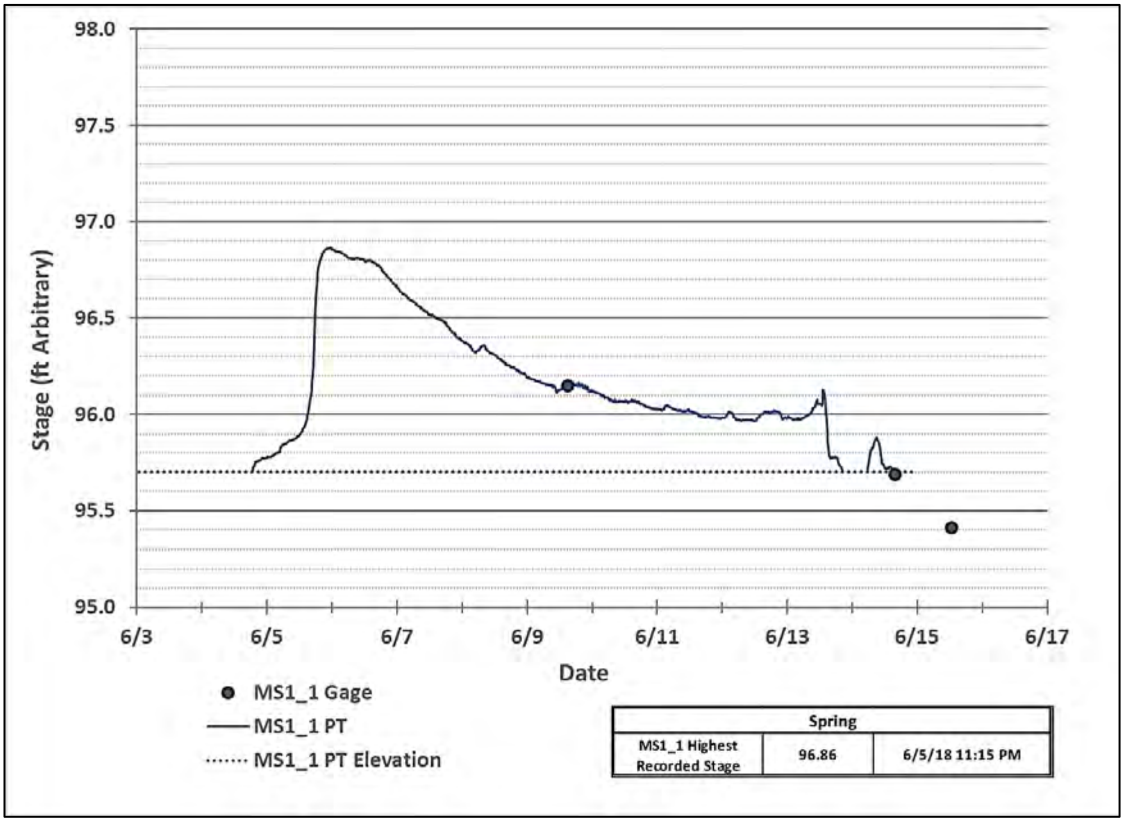


Photo 4.82: MS1_1, looking northwest; June 14, 2018



Graph 4.32: MS1_1 Spring Breakup Stage

B. Summer

Stage fluctuations associated with summer precipitation events were recorded in the data at each monitoring station, but water levels remained well below spring breakup peak stage. The stage increase at the end of the summer monitoring period is associated with a large precipitation event. Summer conditions are shown in (Photo 4.83) and summer stage data at MS1_1 is presented in Graph 4.33.

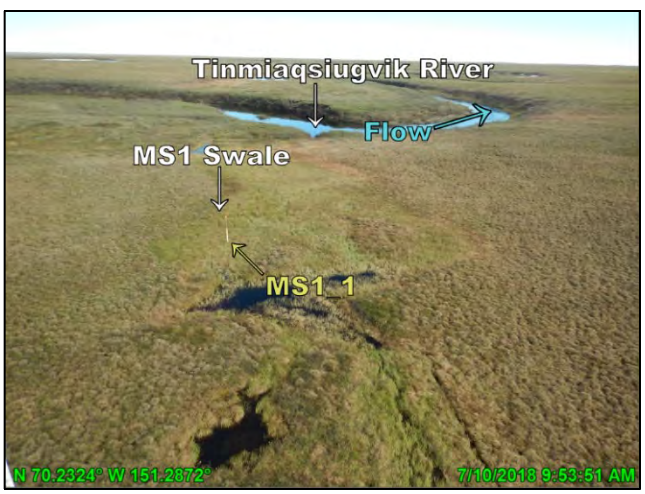
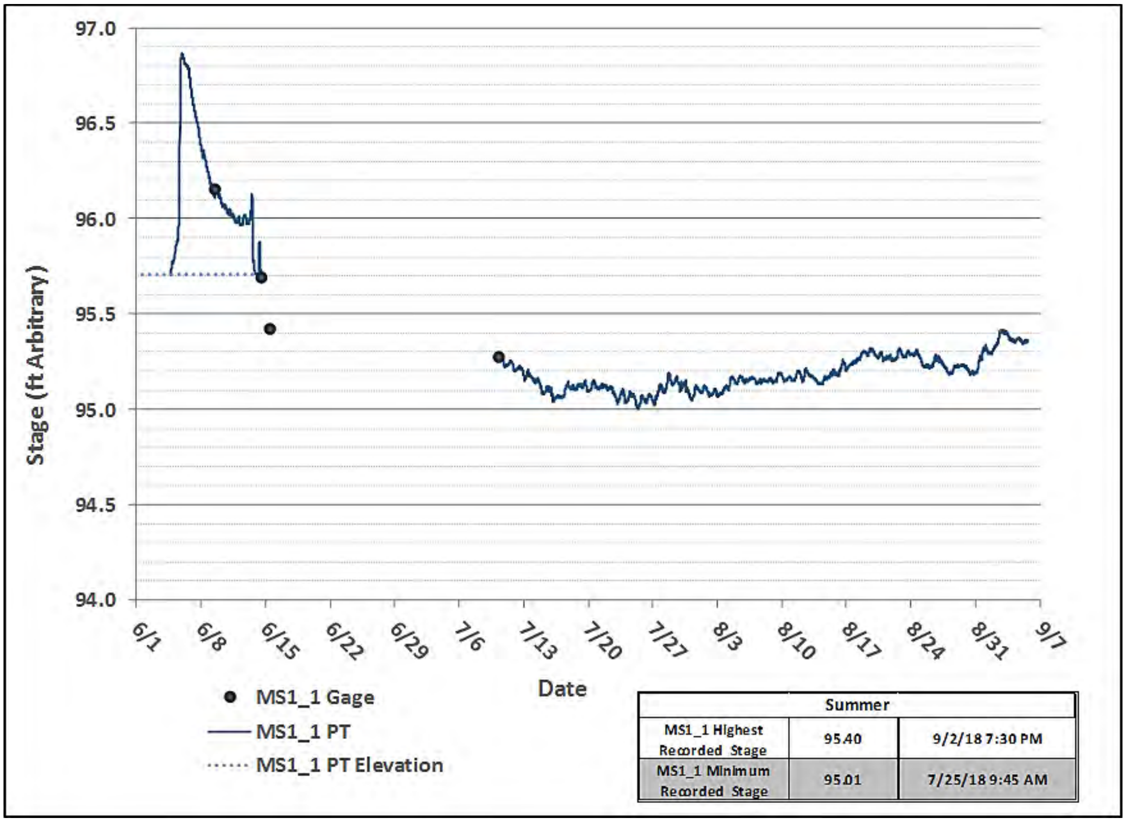


Photo 4.83: Summer conditions at MS1_1, looking north; July 10, 2018



Graph 4.33: MS1_1 Summer 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.

A. Spring Breakup

Initial floodwater was observed flowing at BC1 on June 9. Floodwaters cut a channel through the snow, filling the drainage and melting a channel in the snowpack. Flow was observed running over the saturated snowpack (Photo 4.84) on June 14. Observation of the channel on June 14 showed high velocity, turbulent flow. By June 16, floodwater had melted through the snowpack, with several feet of snow remaining along the banks of BC1 (Photo 4.85).

BC1 stage data are presented in Graph 4.34. Elevations are arbitrary.

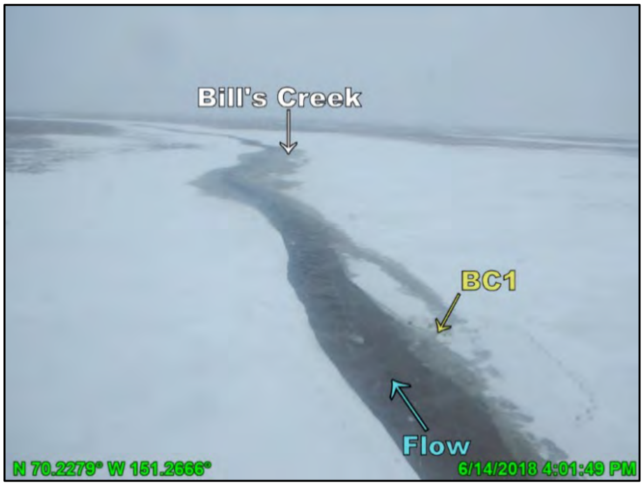


Photo 4.84: BC1, three days after peak stage, looking north (downstream); June 14, 2018

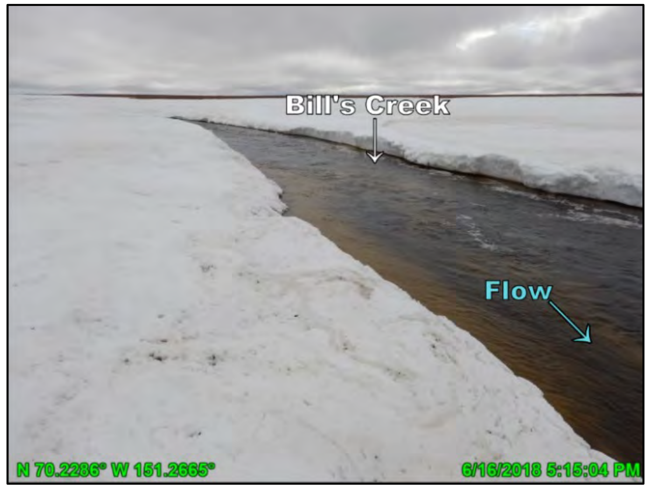
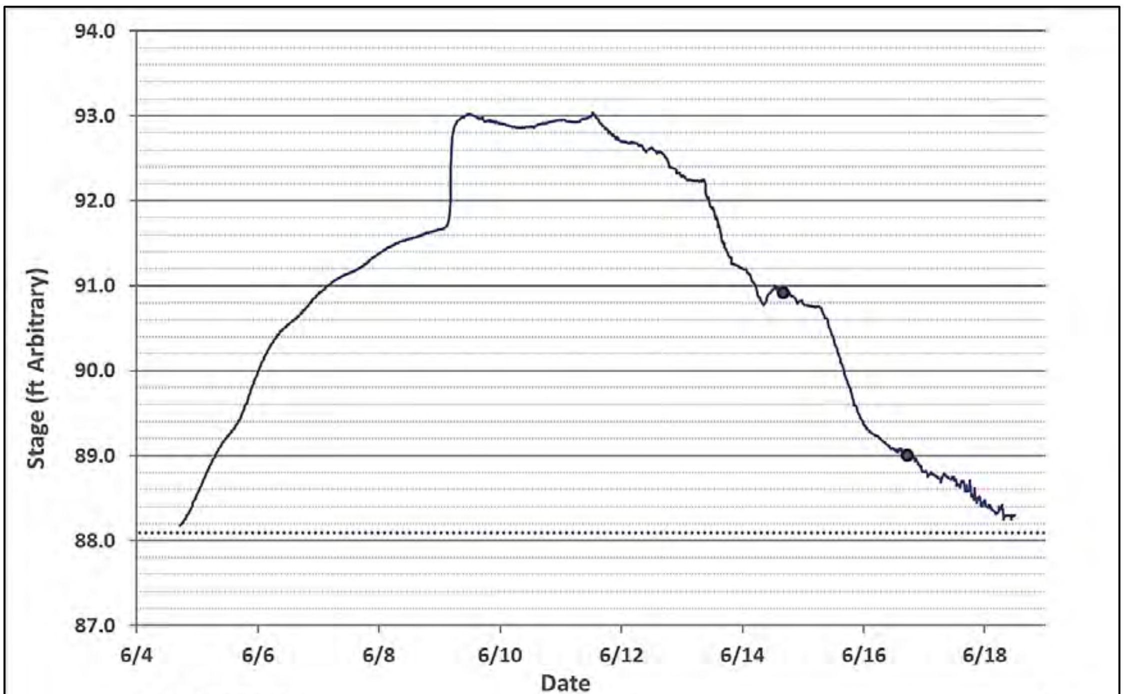


Photo 4.85: BC1, looking south; June 16, 2018



Spring		
BC1 Highest Recorded Stage	93.05	6/11/18 12:30 PM

Graph 4.34: BC1 Spring Breakup Stage

B. SUMMER

Stage fluctuations associated with summer precipitation events were recorded in the data at BC1, but water levels remained below spring breakup peak stage (Photo 4.86). The stage increase at the end of the summer monitoring period is associated with a significant precipitation event. Summer stage at BC1 is presented in Graph 4.35.

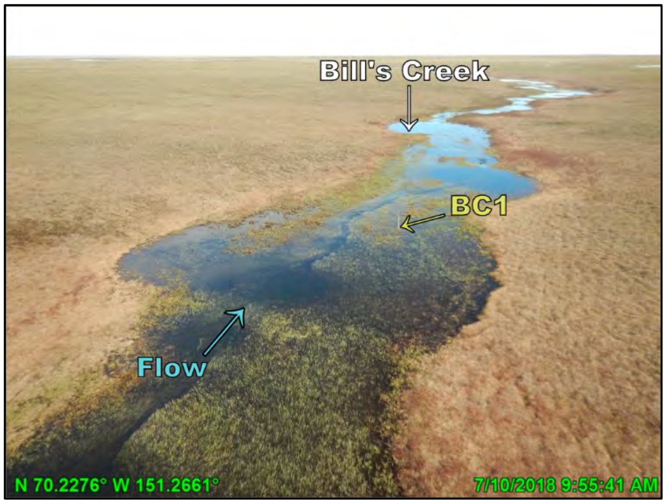
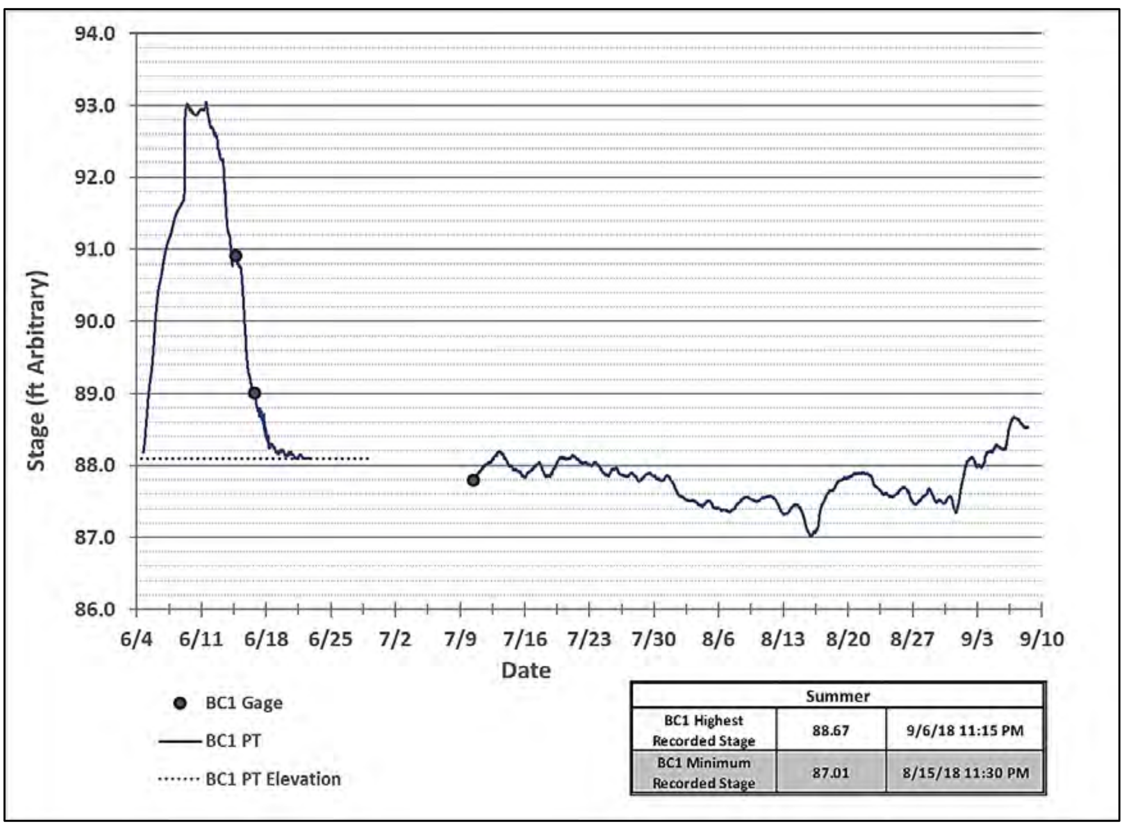


Photo 4.86: Summer conditions at BC1, looking north; July 10, 2018



Graph 4.35: BC1 Summer Stage

4.5 SOURCE LAKES

MIDDLE SNOWMAN LAKE (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 the lakes' outlet while MSL_OUT is placed in the swale draining M0015, about 100 feet from the lakes' outlet and gage station MSL. This is the first year that these gage stations have been monitored.

A. SPRING BREAKUP

PT data recorded an initial stage increase at both gage sites around June 1. Peak stage occurred at MSL_OUT on June 3 and at MSL on June 4. Site observations from June 7 show significant overbank flooding in the low-lying areas around the gage stations with saturated snow present (Photo 4.87). On June 11, aerial observations confirmed the presence of integrated flow at MSL_OUT (Photo 4.88). A well-defined, but very small (about 1 foot across) grass-lined channel was observed at MSL_OUT, with overbank flooding observed on each side of the channel. Aerial observations suggest the small channel at MSL_OUT is a bifurcation of the main channel, which is situated about 30 feet to the north (Photo 4.89). The fork converges with the main channel about 100 feet downstream of the MSL_OUT gage station. Minimal saturated snow was observed at the gage sites but was more prevalent in the channel further downstream. By June 18, no snow was present in the channel, but ice was still intact on the surface of the lake close to gage site MSL (Photo 4.90). Overbank flooding was still observed at the lake outlet.

MSL and MSL_OUT stage and is presented in Graph 4.36. Elevations are arbitrary.

Photo 4.87: MSL_OUT, looking east; June 7, 2018

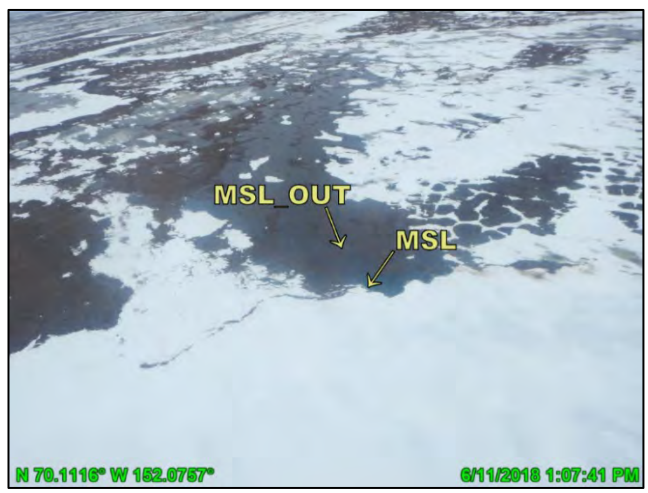


Photo 4.88: MSL & MSL_OUT, looking north; June 11, 2018

Photo 4.89: MSL & MSL_OUT, looking east; June 11, 2018

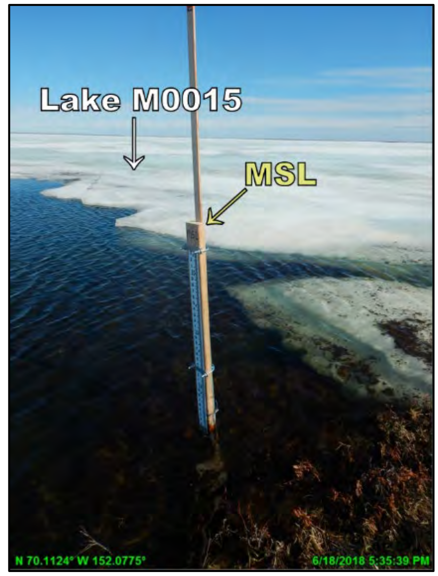
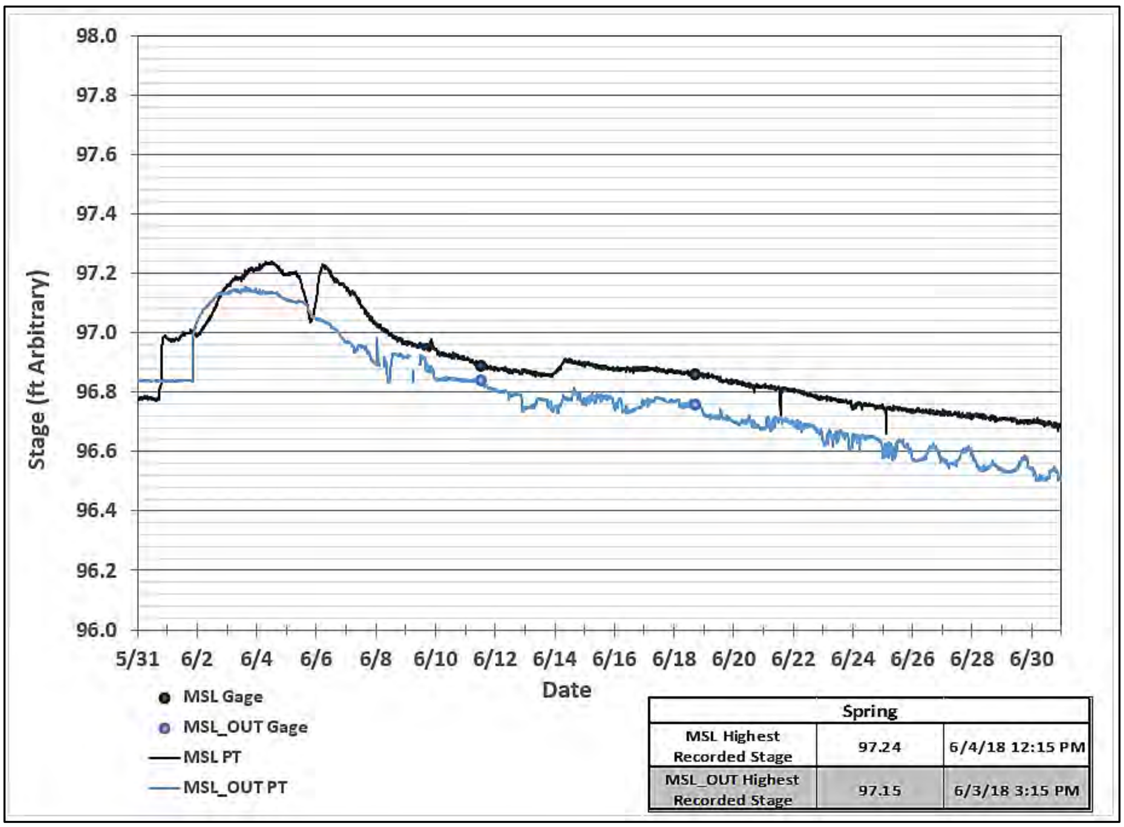


Photo 4.90: MSL, looking southeast; June 18, 2018



Graph 4.36: Middle Snowman Lake at MSL & MSL_OUT Spring Breakup Stage

B. SUMMER

Small stage fluctuations associated with summer precipitation events were recorded in the data, but water levels remained below spring breakup peak spring stage. During the summer observation period, no defined channel or flow was present, although standing water around the gage was observed (Photo 4.91). Summer stage at MSL and MSL_OUT is presented in Graph 4.37.

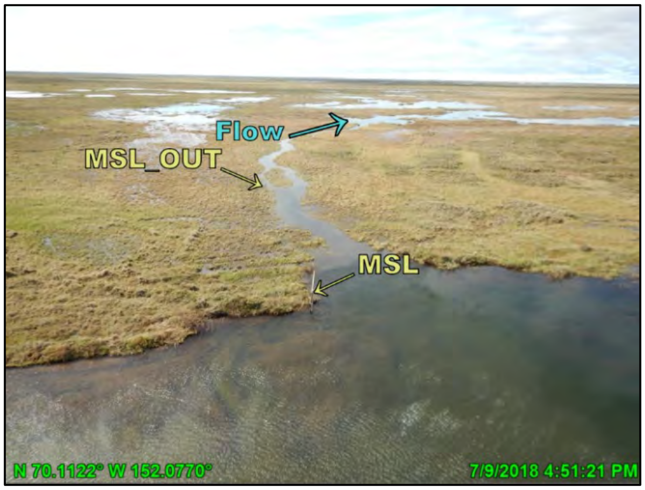
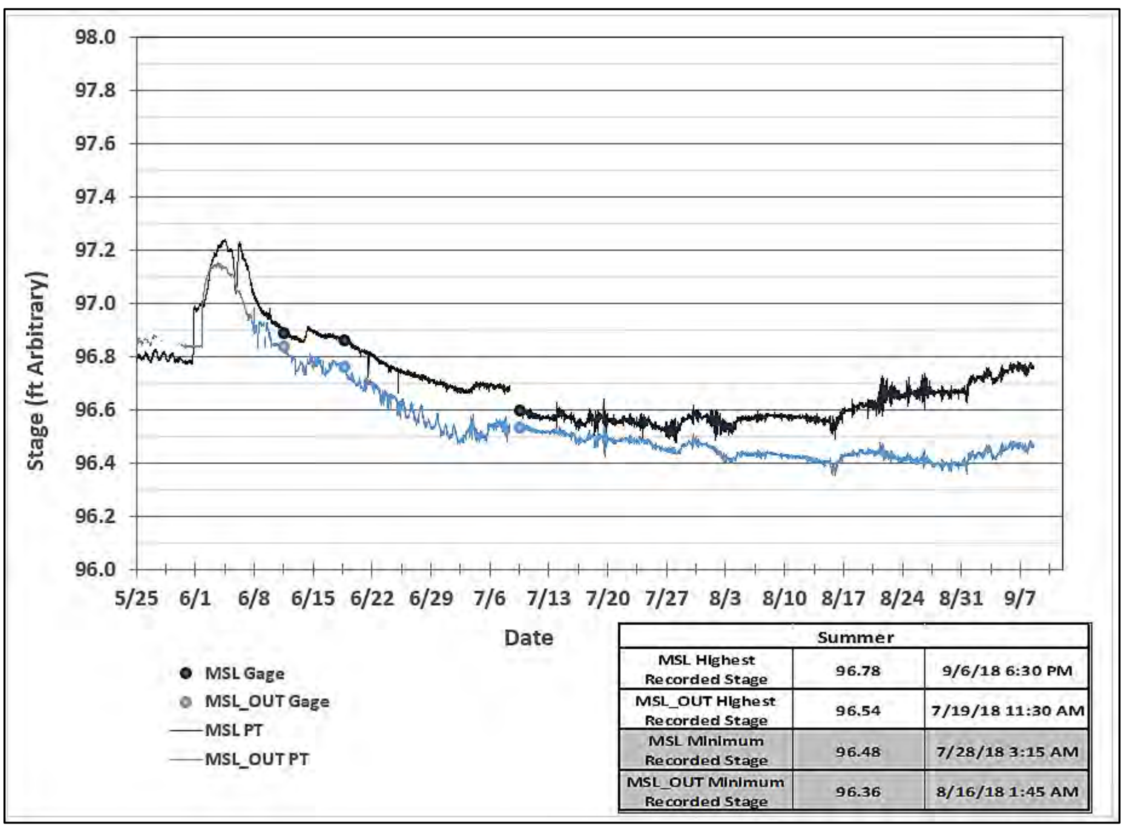


Photo 4.91: Summer conditions at MSL & MSL_OUT, looking east (downstream); July 9, 201



Summer		
MSL Highest Recorded Stage	96.78	9/6/18 6:30 PM
MSL_OUT Highest Recorded Stage	96.54	7/19/18 11:30 AM
MSL Minimum Recorded Stage	96.48	7/28/18 3:15 AM
MSL_OUT Minimum Recorded Stage	96.36	8/16/18 1:45 AM

Graph 4.37: Middle Snowman Lake at MSL & MSL_OUT Summer Stage

LOWER SNOWMAN LAKE (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 lakes' outlet while LSL_OUT is placed in the swale draining R0064, about 100 feet from the lakes' outlet and gage station MSL. This is the first year that these gage stations have been monitored.

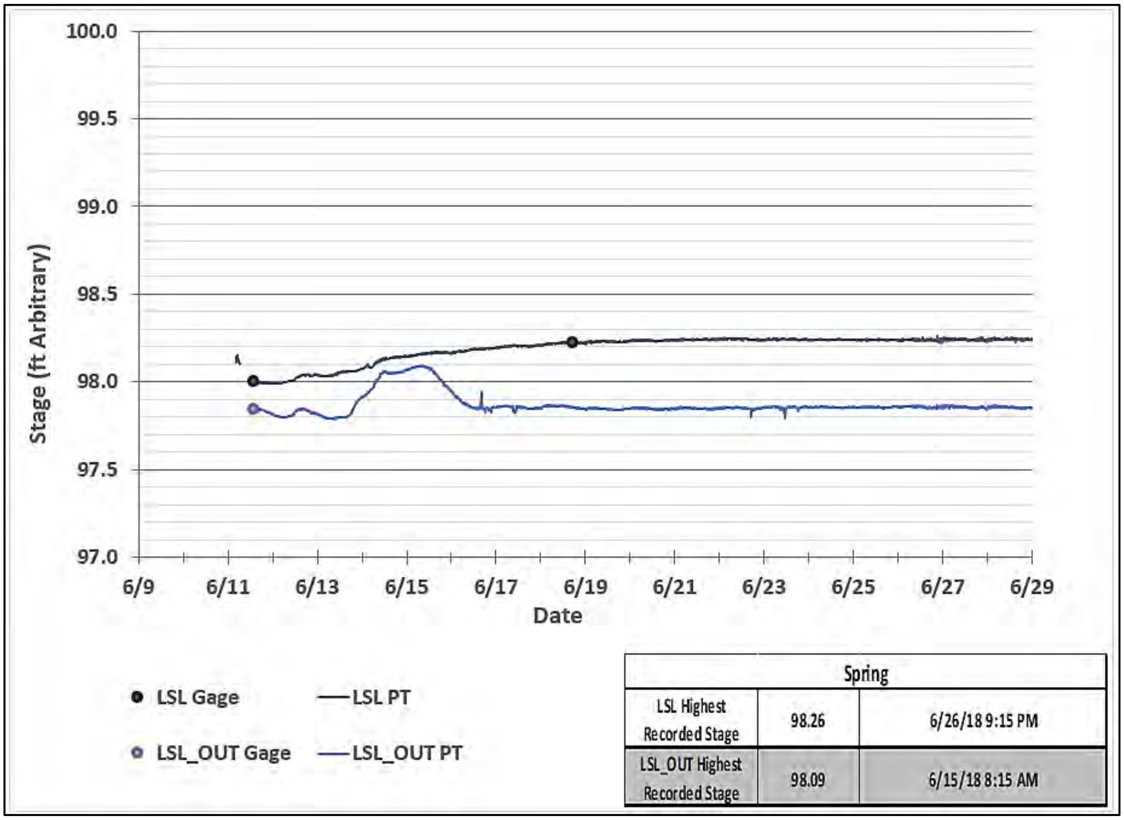
A. SPRING BREAKUP

Site observations at LSL and LSL_OUT from June 11 showed meltwater at each gage site with integrated flow forming a channel through snowpack near LSL_OUT. The snow confined the flow to the defined channels and minimal overbank flooding was observed (Photo 4.92). PTs recorded increasing stage from June 11 to around June 20. At LSL, saturated snow surrounded the gage, with standing water present underneath the snow. On June 18th, aerial observations showed a well-defined channel conveying flow from Lake R0064 past the gage stations, then across a poorly defined low-lying area, and eventually emptying into the south end of Middle Snowman Lake (Lake M0015) (Photo 4.93). Minimal snow remained in the area on this day. The flow-path observed upstream of the gage was well-defined, with various 90° turns present. A bifurcation was observed at gage station LSL_OUT, with the two distinct channels each conveying flow into low-lying areas about 200 feet downstream of the gage site. Overbank flooding was observed in the low-lying areas, but not in the well-defined channels around the gage sites, where bankfull conditions were observed. The lake, along with gage station LSL, was still covered with ice on the June 18. PT data recorded consistent stage at each gage site after the initial stage increase ceased around June 20.

LSL and LSL_OUT stage and is presented in Graph 4.38. Elevations are arbitrary.

Photo 4.92: LSL & LSL_OUT, looking northeast; June 11, 2018

Photo 4.93: LSL & LSL_OUT, looking northeast; June 18, 2018



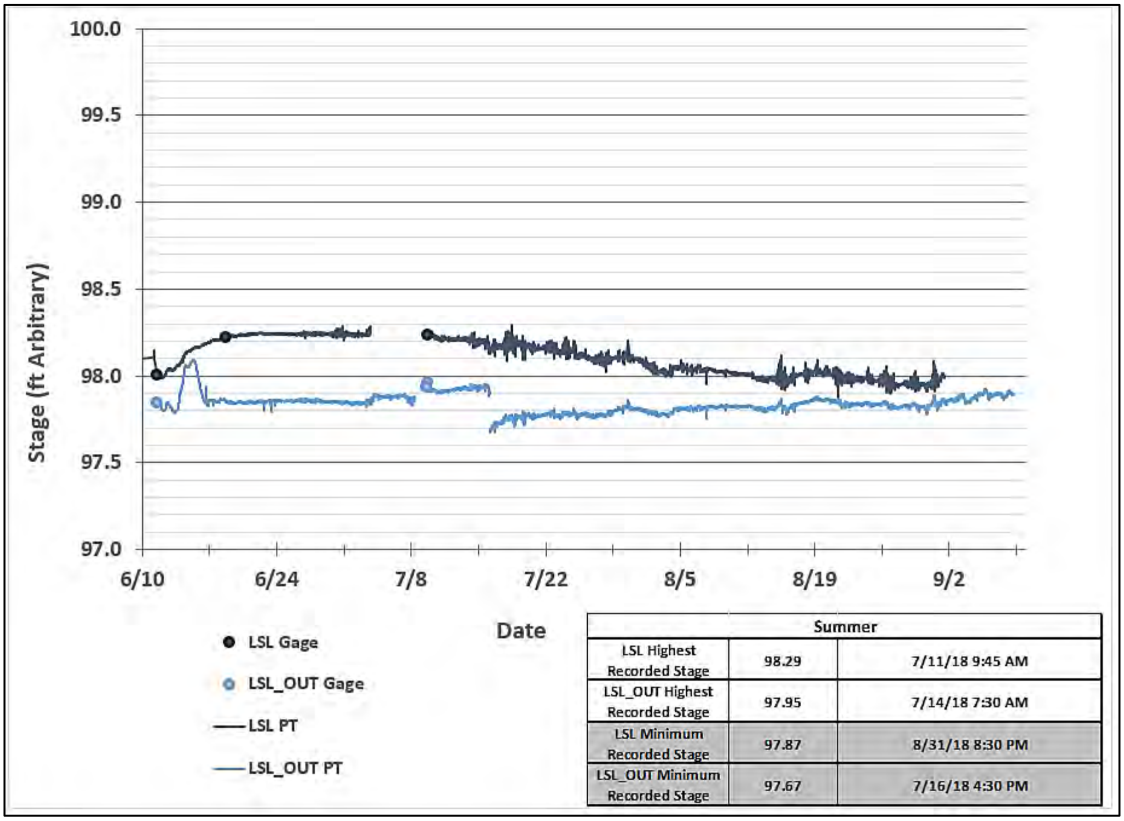
	Spring	
LSL Highest Recorded Stage	98.26	6/26/18 9:15 PM
LSL_OUT Highest Recorded Stage	98.09	6/15/18 8:15 AM

Graph 4.38: Lower Snowman Lake at LSL & LSL_OUT Spring Breakup Stage

B. Summer

Peak summer stage values were higher than peak spring stage recorded at gage LSL. This is not unusual given the fact that this was gage was situated in a lake, and lake stage exhibits different behavior, trends, and precipitation responses than swales or rivers (Photo 4.94). Summer stage at LSL and LSL_OUT is presented in Graph 4.39.

Photo 4.94: Summer conditions at LSL & LSL_OUT, looking east; July 9, 2018



Summer		
LSL Highest Recorded Stage	98.29	7/11/18 9:45 AM
LSL_OUT Highest Recorded Stage	97.95	7/14/18 7:30 AM
LSL Minimum Recorded Stage	97.87	8/31/18 8:30 PM
LSL_OUT Minimum Recorded Stage	97.67	7/16/18 4:30 PM

Graph 4.39: Lower Snowman at LSL & LSL_OUT Summer Stage

5 FLOOD FREQUENCY ANALYSIS

The flood frequency results and assigned recurrence intervals for 2018 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 4,100 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 4,400 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). This year's Kal1 peak discharge of 320 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). This year's UC1B peak discharge of 120 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). This year's UC2C peak discharge of 140 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). This year's W_BS1 peak discharge of 240 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). This year's W_S1 peak discharge of 40 cfs has a recurrence interval of less than 2 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

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Appendix A STAGE METHODS & SITE-SPECIFIC DATA

A.1 STAGE METHODS

Gage Setup Methods

Each gage assembly included a standard USGS metal faceplate mounted on a wooden two-by-four. The two-by-four was attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground. The faceplate is graduated and indicates water levels every 100th of a foot between 0.00 to 3.33 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	70.25118	-152.18469	3	BRECCIA SCORIA	70.25271 70.25272	-152.18027 -152.18033	64.520 [4] 64.530 [4]
		F55.5	70.25200	-152.18118	3				
		F55.5D	70.25348	-152.17888	4				
	Judy Creek[1]	J13.8U	70.18540	-151.96235	3	Line 4BW GILLY	70.18663 70.18680	-151.96200 -151.96170	40.880[2] 45.220[2]
		J13.8	70.18694	-151.96097	3				
		J13.8D	70.18920	-151.95731	3				
		J21.4	70.14645	-152.09077	3	OTIS LUCKY	70.14672 70.14672	-152.09075 -152.09080	58.390 58.625
	Kalikpik River	Kal1	70.31565	-152.23961	3	CHERT CHALK	70.31513 70.31510	-152.24211 -152.24196	62.800 [4] 62.360 [4]
Small Streams	Judy Creek Kayyaaq	UC2C	70.18479	-152.12103	2	ANAKIN VADER	70.18473 70.18475	-152.12135 -152.12127	53.966 [4] 54.461 [4]
	Willow 1	W1S	70.15256	-151.82179	1	ELORA DANAN	70.15323 70.15323	-151.82308 -151.82313	80.290 80.108
	Willow 2	UC1B	70.14127	-151.95547	1	LUKE LEIA	70.14097 70.14127	-151.95462 -151.95487	86.456 85.722
	Willow 3	W3S	70.11613	-152.10039	1	BLACK BLUE	70.11628 70.11648	-152.09948 -152.09965	85.366 85.717
	Willow 4	W4	70.09511	-152.18296	2	MAD MARTIGAN	70.09521 70.09523	-152.18439 -152.18440	100.000 [3] 100.165 [3]
		W_BS1	70.08163	-152.13015	2	SILVER COHO	70.08127 70.08130	-152.12978 -152.12970	94.590 94.285

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	-152.20167	1	DOLLY VARDEN	70.03610 70.03613	-152.20265 -152.20268	104.662 104.829
	Willow 8	TBD_6	70.26351	-152.18077	1	KING CHINOOK	70.26335 70.26333	-152.18123 -152.18113	53.897 [4] 54.097 [4]
		SW22	70.27622	-152.19284	1	TWOFISH ONEFISH	70.27628 70.27627	-152.19387 -152.19385	100.000 [3] 100.120 [3]
	TBD_5	TBD_5	70.27726	-152.49520	1	REDFISH BLUEFISH	70.27707 70.27707	-152.49460 -152.49450	100.000 [3] 99.915 [3]
Swales	SW1/SW8	SW1	70.13612	-152.01333	1	OBIWAN KENOBI	70.13573 70.13573	-152.01193 -152.01192	100.000 [3] 99.913 [3]
	SW2	SW2	70.12891	-152.06302	1	ARCTICA GLAUCA	70.12869 70.12870	-152.06447 -152.06435	84.065 84.053
	SW4	SW4	70.15596	-152.09442	1	BOBA FETT	70.15620 70.15620	-152.09503 -152.09500	100.000 [3] 100.088 [3]
	SW14	SW14	70.12328	-152.08699	1	GREENEGGS ANDHAM	70.12303 70.12312	-152.08725 -152.08725	79.448 78.835
	SW23	SW23	70.31352	-152.21316	1	POLARIS PULCHRA	70.31319 70.31328	-152.21268 -152.21272	100.000 [3] 99.040 [3]
Minesite	Tinmiaqsiugvik River	UB14.5	70.23904	-151.29692	5	PUMICE OBSIDIAN	70.23960 70.23962	-151.29662 -151.29649	100.592 [3] 100.000 [3]
		UB15.5	70.23373	-151.28742	3	LATITE ANDESITE	70.23325 70.23323	-151.28595 -151.28585	99.640 [3] 100.005 [3]
	MS1_1	MS1_1	70.23284	-151.28760	1				
	Bills Creek	BC1	70.22840	-151.26595	1	GNEISS SCHIST	70.22859 70.22860	-151.26833 -151.26842	99.685 [3] 100.000 [3]

Location Type	Stream Name	Site Name	Site Location Latitude (WGS84)	Site Location Longitude (WGS84)	Number of Gages	Associated Vertical Control	Vertical Control Location Latitude (WGS84)	Vertical Control Location Longitude (WGS84)	Vertical Control Elevation (ft NAVD88)
Source Lake	Lake M0015/R0056 aka Middle Snowman Lake	**MSL**	70.11227	-152.07749	1	PINK HUMPY	70.11280 70.11280	-152.07725 -152.07740	100.000 [3] 99.450 [3]
	Willow 3/Lake M0015/R0056 (aka Middle Snowman Lake) outlet	**MSL_Out**	70.11238	-152.07811	1				
	Lake R0064 (aka Lower Snowman Lake)	**LSL**	70.09833	-152.06414	1	RED SOCKEYE	70.09860 70.09860	-152.06425 -152.06423	100.000 [3] 100.450 [3]
	Willow 3/Lake R0064 (aka Lower Snowman Lake) outlet	**LSL_Out**	70.09872	-152.06417	1				

Notes:
1. The current proposed Judy Creek crossing is at J 21.4. the J 13.8 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)
		Minimum (ft NAVD88)	Maximum (ft NAVD88)	
F55.5U [4]	F55.5U-A F55.5U-B F55.5U-C	41.76	50.80	41.845
F55.5 [4]	F55.5-A F55.5-B F55.5-C	42.58	50.95	42.650
F55.5D [4]	F55.5D-A F55.5D-B F55.5-C	42.78	50.45	43.390
J13.8U [1]	J13.8U-A J13.8U-B J13.8U-C	35.59	45.15	35.628
J13.8 [1]	J13.8-A J13.8-B J13.8-C	34.12	41.69	34.190
J13.8D [1]	J13.8D-A J13.8D-B J13.8D-C	31.32	40.94	31.380
J21.4	J21.4-A J21.4-B J21.4-C	46.86	56.44	46.920
Kal1 [4]	KAL1-A KAL1-B KAL1-C	48.68	58.42	48.760
UC2C [4]	UC2C-A UC2C-B	46.59	53.68	47.126
W1S	W1S-A	78.84	83.03	--
UC1B	UC1B-A	74.82	78.83	74.916
W3S	W3S-A	83.54	87.24	--
W4 [3]	W4-A W4-B	86.91	92.34	86.980
W_BS1	W_BS1-A W_BS-B	83.81	88.80	83.880
W_S1	W_S1-A	99.06	102.83	99.127
TBD_6 [4]	TBD_6-A	49.20	53.10	49.267
TBD_5 [3]	TBD_5-A	92.91	94.83	92.925

Gage Station	Gage Assembly	Gage Elevation		Spring PT Elevation (ft NAVD88)
		Minimum (ft NAVD88)	Maximum (ft NAVD88)	
SW1 [3]	SW1-A	95.38	99.81	--
SW2	SW2-A	81.07	84.80	--
SW4 [3]	SW4-A	97.00	100.88	--
SW14	SW14-A	76.30	80.03	--
SW22 [3]	SW22-A	98.95	102.71	--
SW23 [3]	SW23-A	88.55	92.14	--
UB14.5 [3]	UB14.5-A	87.86	99.30	87.92
	UB14.5-B			
	UB14.5-C			
	UB14.5-D			
	UB14.5-E			
UB15.5 [3]	UB15.5-A	81.27	89.80	81.325
	UB15.5-B			
	UB15.5-C			
MS1_1 [3]	MS1_1-A	95.59	99.41	95.705
BC1 [3]	BC1-A	88.03	91.63	88.095
MSL [3]	MSL-A	96.70	100.17	97.093
MSL_OUT [3]	MSL_OUT-A	96.68	100.50	96.75
LSL [3]	LSL-A	97.74	101.34	98.073
LSL_OUT [3]	LSL_OUT-A	97.90	101.51	97.955

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 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: June 17, 3:00 PM

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

Final Discharge (cfs): 2,700

Average Velocity (fps): 2.7

Measurement Rating: Fair

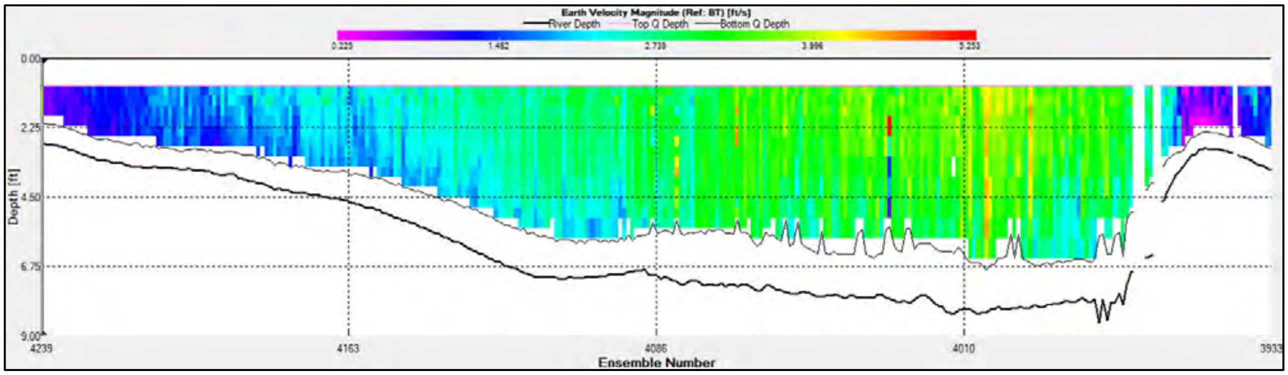
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from the loop test performed before measuring the five transects.

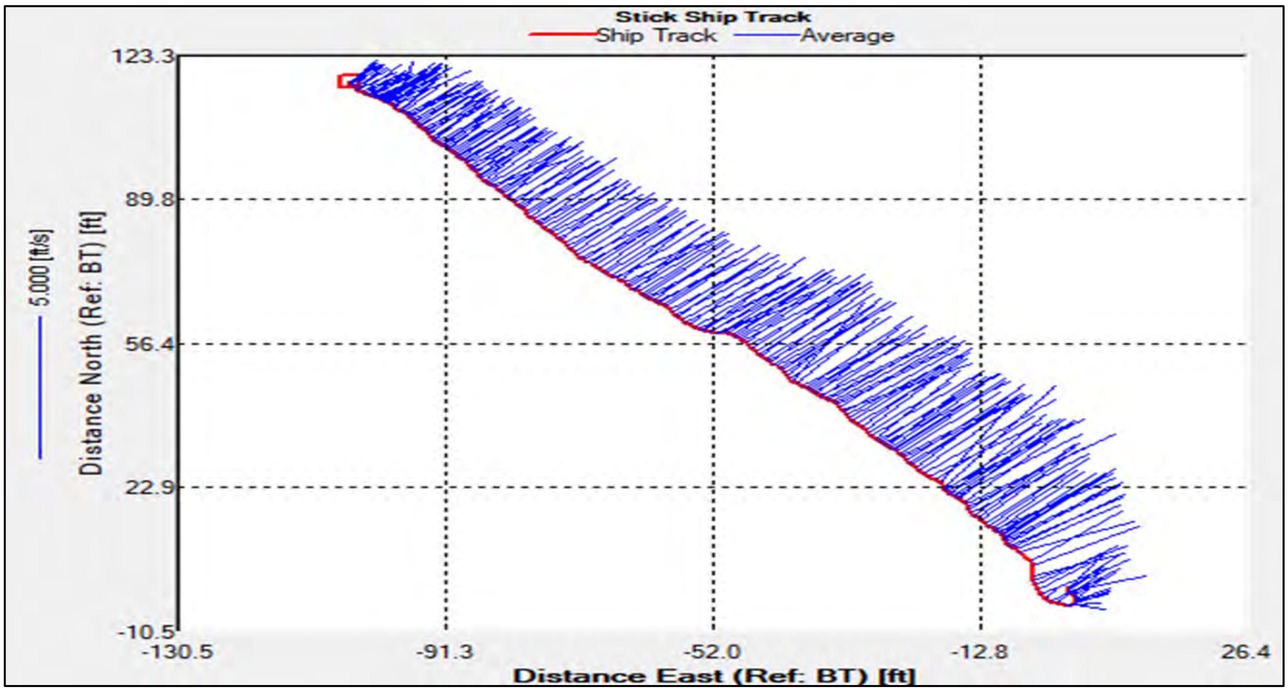
At the time of the measurement, open-channel conditions were present with small, intermittent ice floes and some snow along the right bank. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall quality of the discharge measurement is fair considered based on conditions at the time of the measurement. Moving bed velocity estimated using the loop test was 0.9 fps. The percentage of bad bottom track values (2.1%) was within the recommended maximum of 5% and factored into the overall quality rating of the measurement.

Table C.1: F55.5 June 17 Spring Breakup Measured Discharge Summary

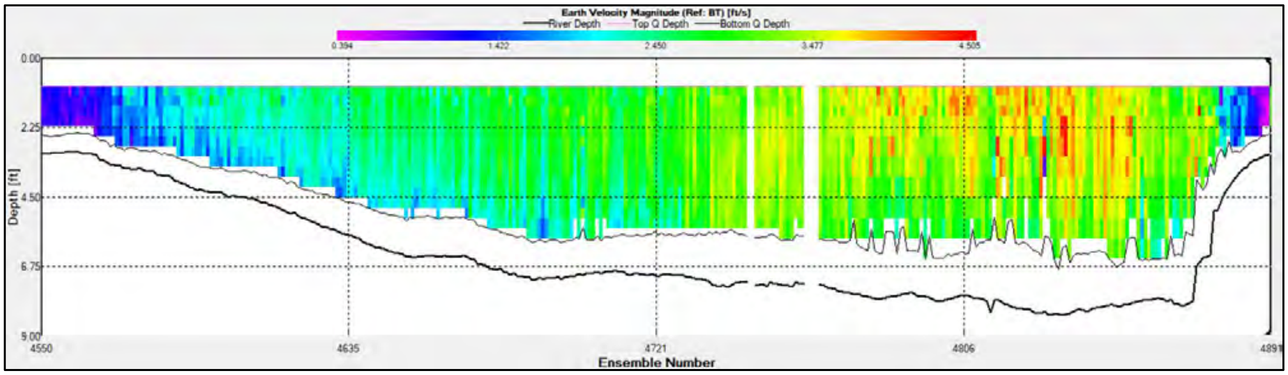
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
F55.5000	Right	2774	0.90%	1883	1.22%	175	1057	1,013	2.74	2.62
F55.5001	Left	2746	-0.11%	1855	-0.28%	179	1003	1,042	2.63	2.74
F55.5002	Right	2786	1.37%	1881	1.15%	179	1059	1,038	2.69	2.63
F55.5003	Left	2767	0.66%	1877	0.89%	182	1020	1,043	2.65	2.71
F55.5004	Right	2671	-2.82%	1805	-2.98%	172	1033	987	2.59	2.59
Average		**2749**		**1860**		**177**		**1,025**	**2.66**	**2.66**

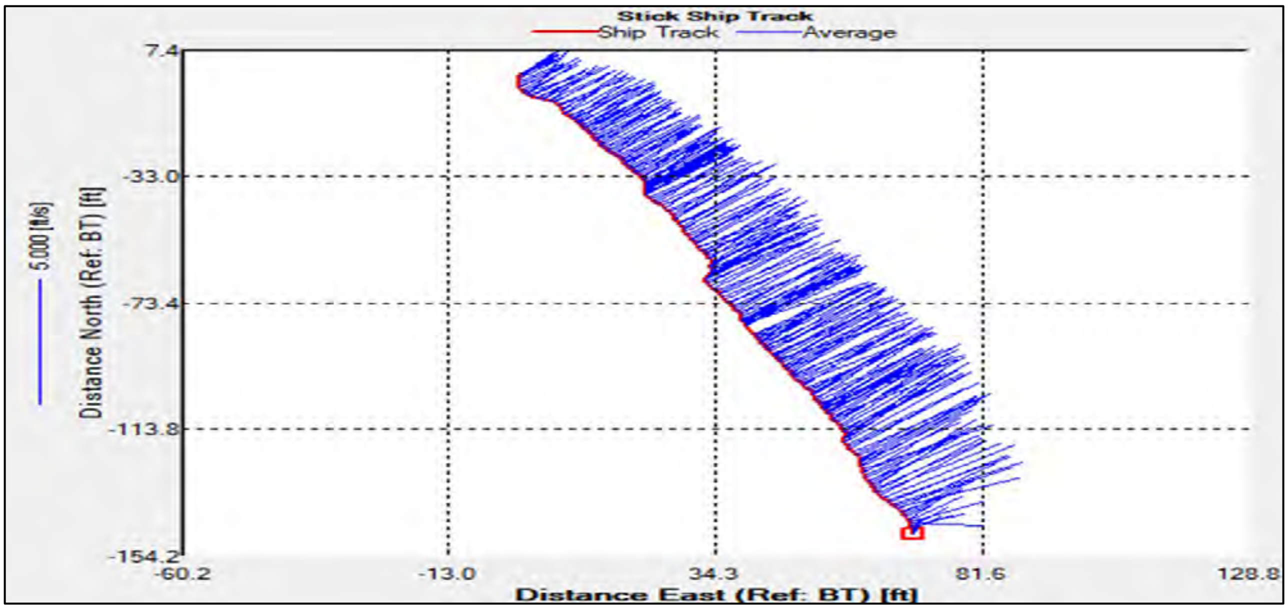
A. Transect F555000 Raw Data Output



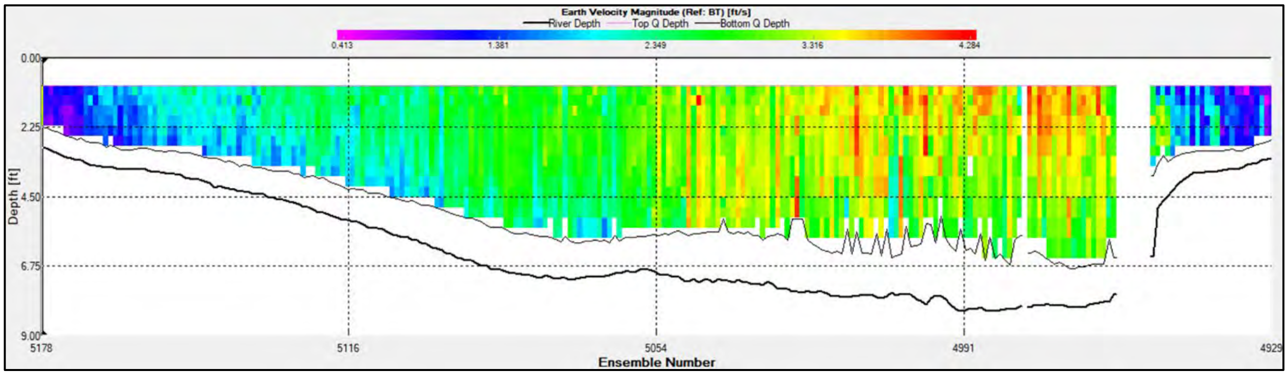


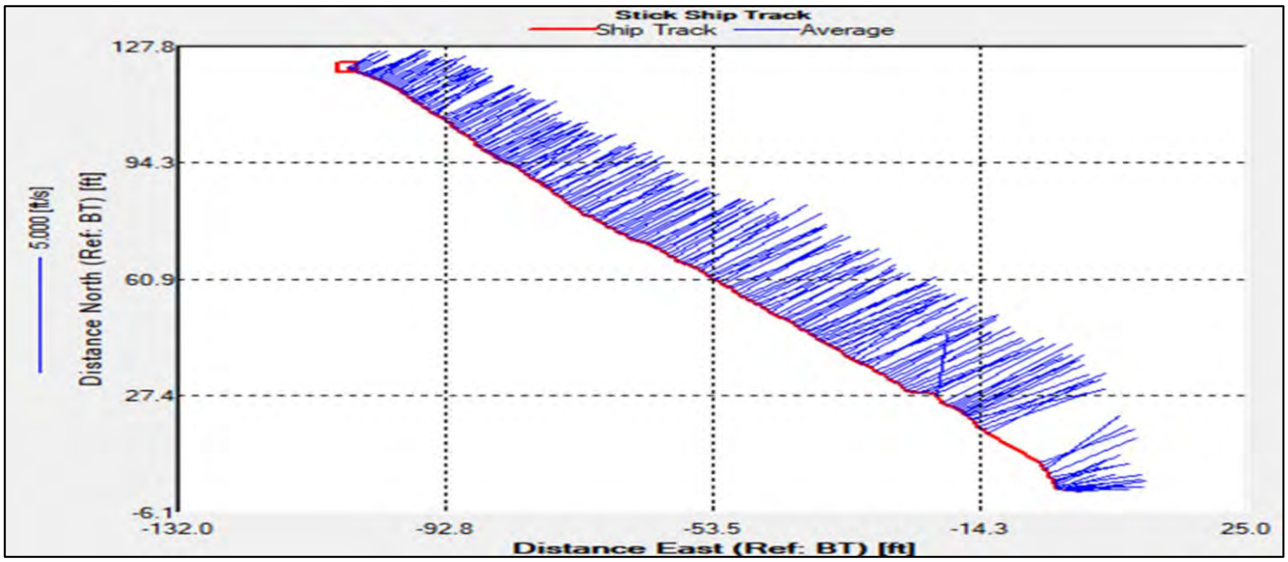
B. Transect F555001 Raw Data Output



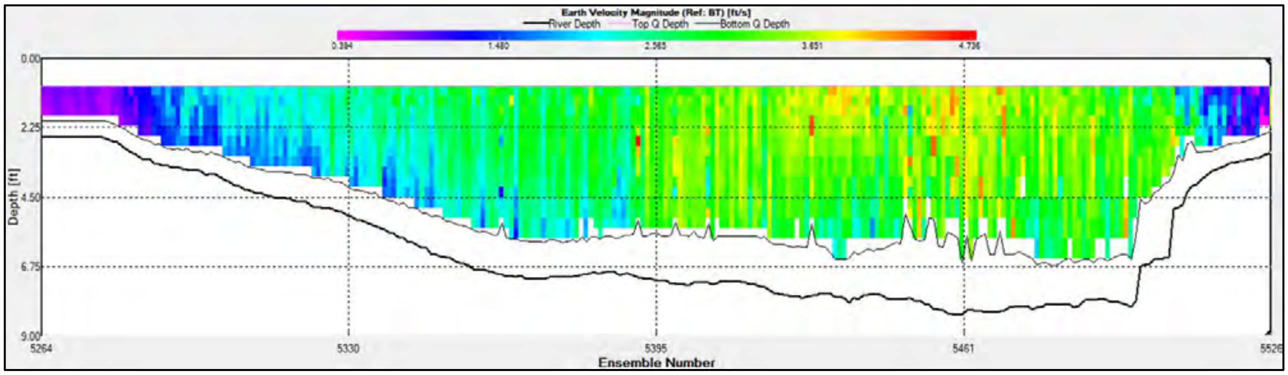


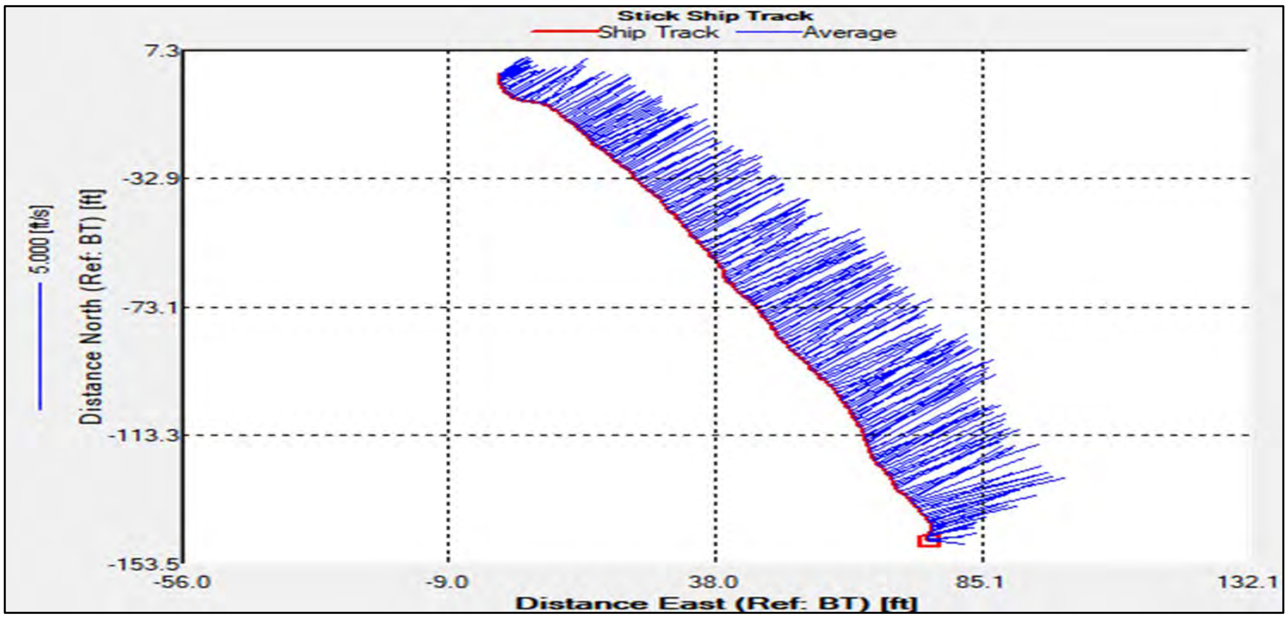
C. Transect F555002 Raw Data Output



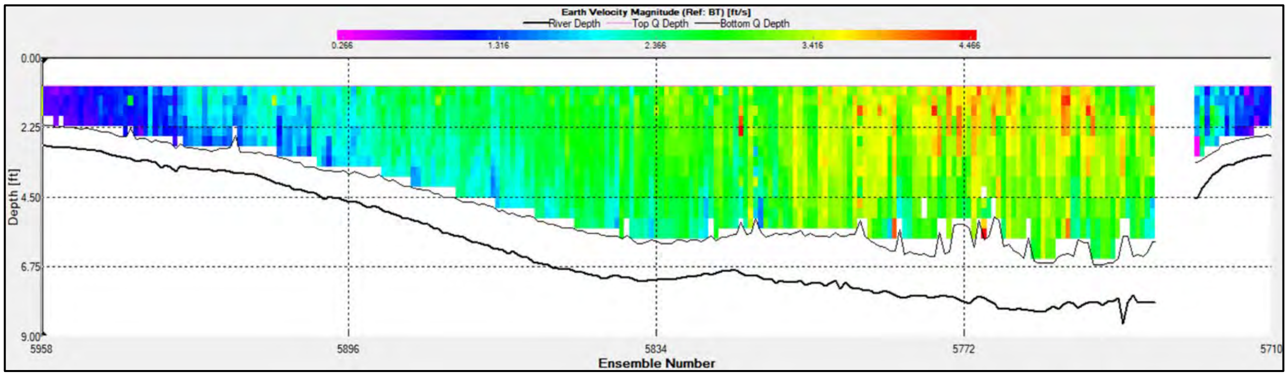


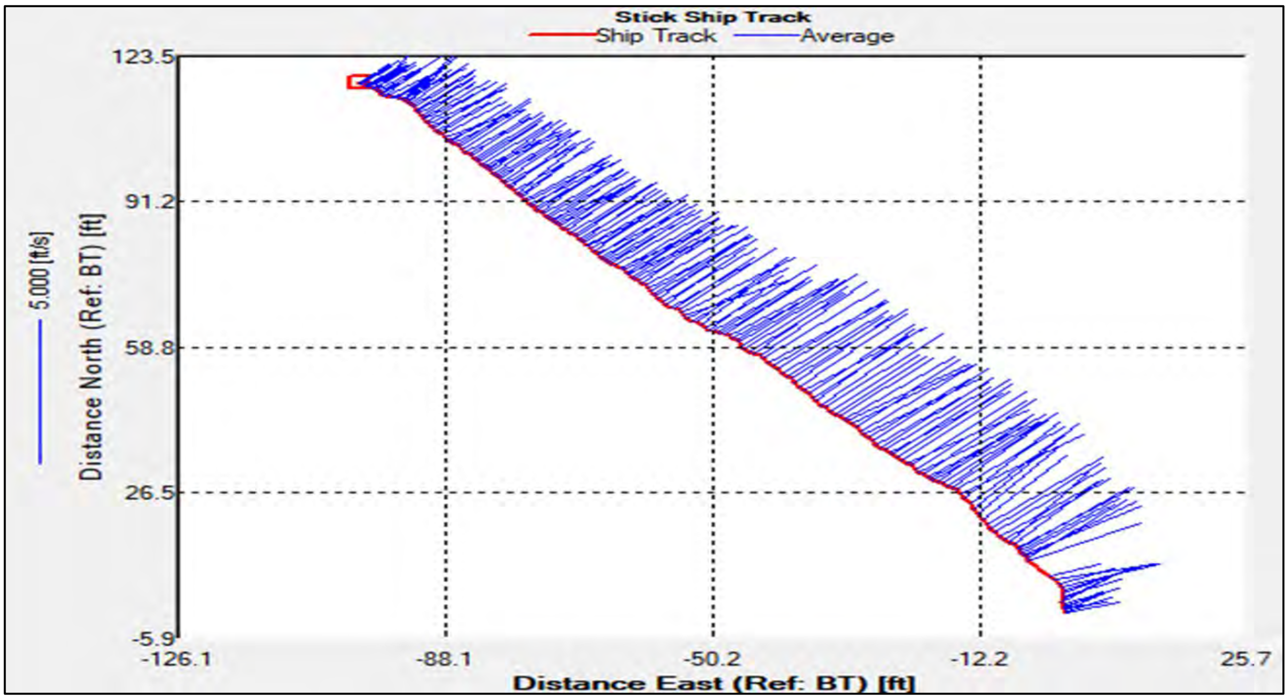
D. Transect F555003 Raw Data Output





E. Transect F555004 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 five cross-sections extracted from the F55.5 June 17, 2018 ADCP direct discharge measurement. The energy grade line was approximated by the average water surface slope between F55.5 and F55.5D. Manning's n values were selected from reference documents (URS 2001) and calibrated to the measured discharge values in 2017. The 2018 calculated discharge values were compared to the direct discharge for 2018 to verify Manning's n values from 2017 are still valid. The calibrated Manning's n values used in the calculations were 0.02 for the left overbank, 0.018 for the main channel, and 0.02 for the right overbank.

ConocoPhillips Alaska

Feet
0 600 1,200

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_F55.5.mxd
Checked:	GCY	Scale:	1 Inch = 600 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

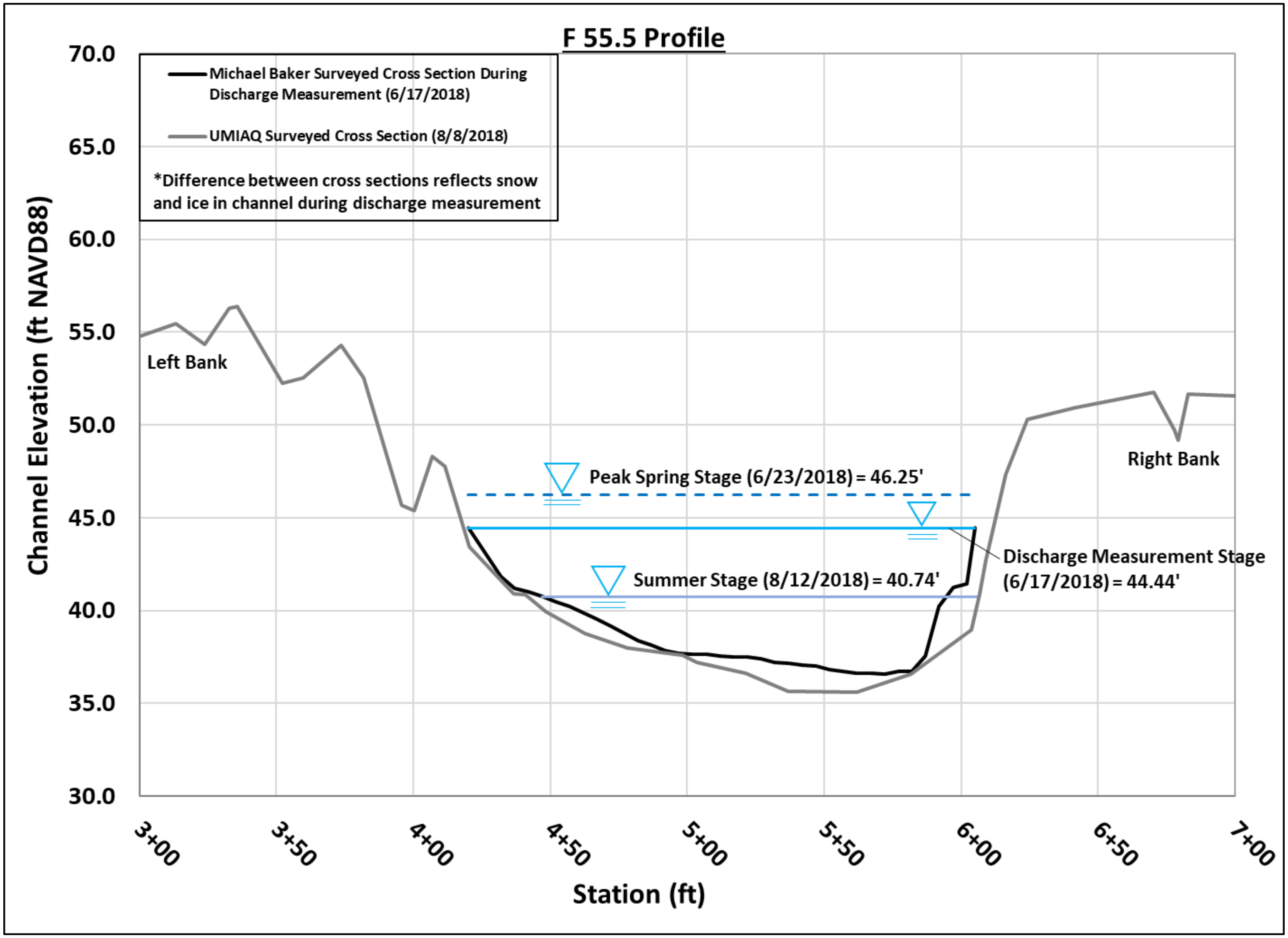
Imagery Source: Digital Globe, 2015

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

2018 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 – June 7, 2018

Location: J13.8

Date & Time: June 7, 2:00 PM

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

Final Discharge (cfs): 3,700

Average Velocity (fps): 4.2

Measurement Rating: Fair

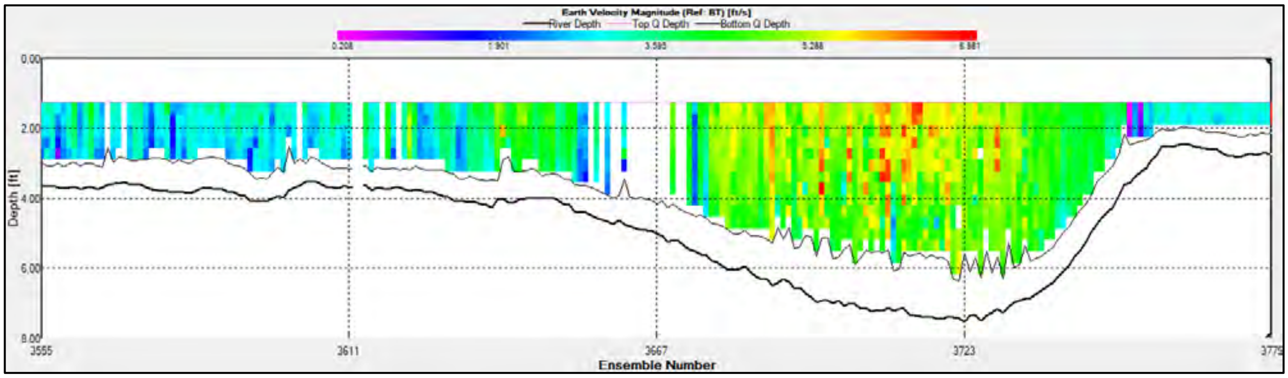
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from the loop test performed before measuring the four transects.

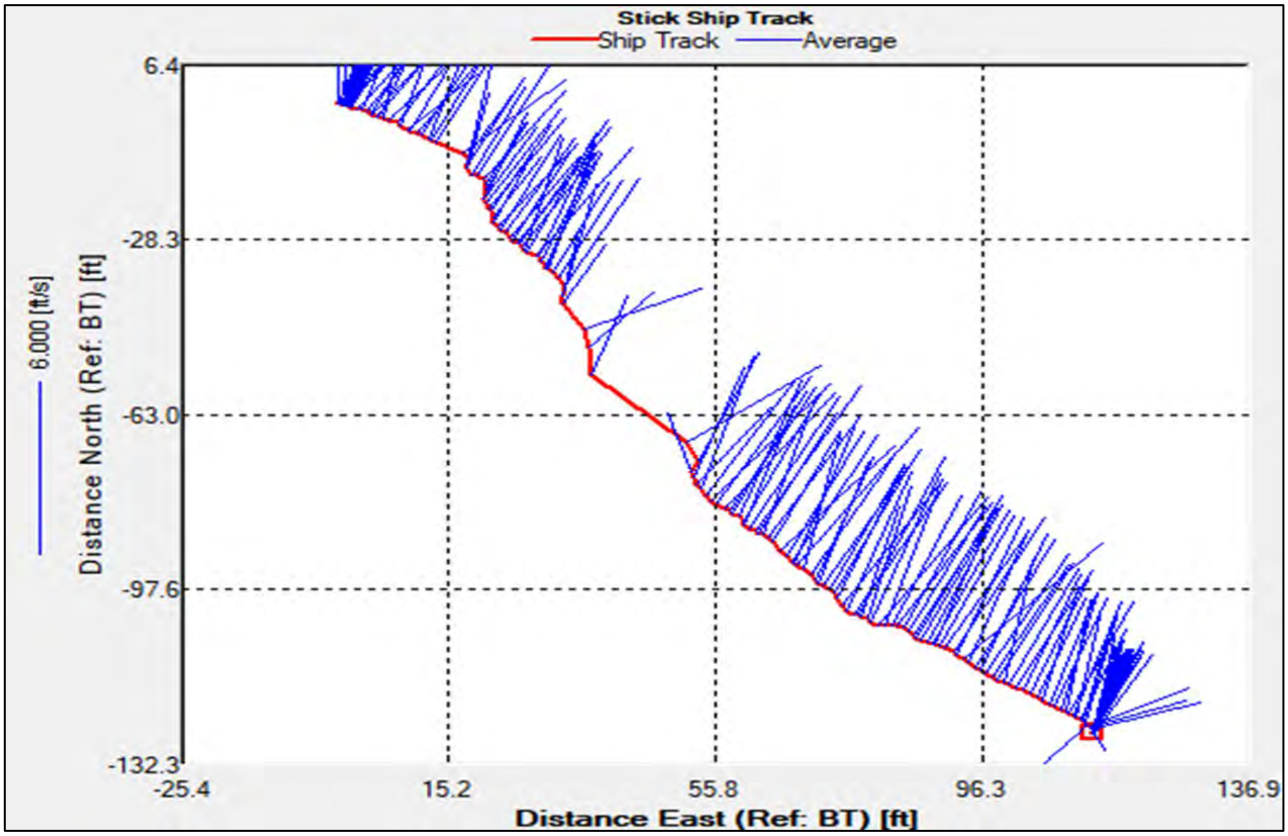
At the time of the measurement, the river was mostly clear of snow and ice with intermittent ice floes and snow along the left and right banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on the highly mobile bed detected at the time of measurements. Moving bed velocity estimated using the loop test was 0.55 fps. The percentage of bad bottom track values (9.8%) exceeded the recommended 5% and factored into the overall quality rating of the measurement.

Table C.2: J13.8 June 7 Spring Breakup Measured Discharge Summary

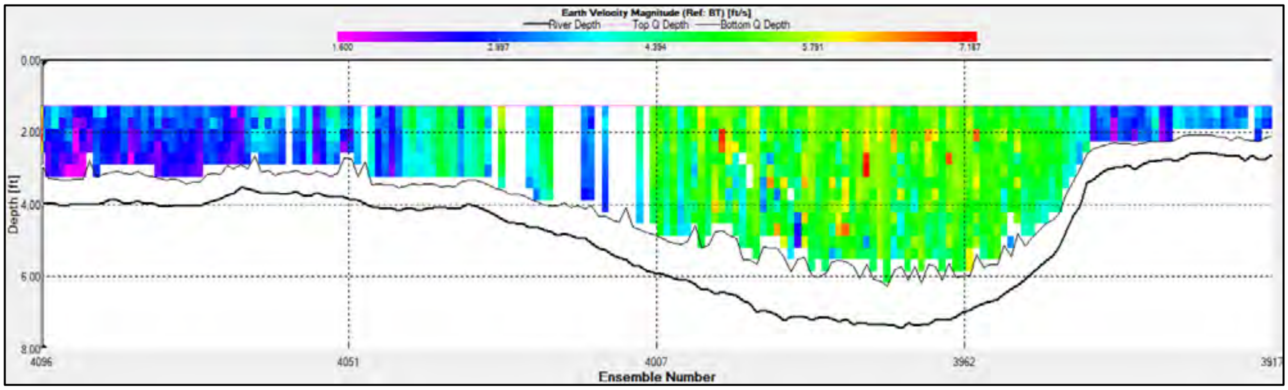
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
J13.8001	Left	3777	2.97%	2245	2.42%	259	929	941	4.01	4.06
J13.8002	Right	3734	1.79%	2257	3.00%	243	880	874	4.27	4.24
J13.8004	Right	3583	-2.31%	2132	-2.70%	238	854	850	4.24	4.20
J13.8008	Left	3578	-2.44%	2132	-2.73%	251	838	905	3.98	4.27
Average		**3668**		**2192**		**248**		**893**	**4.13**	**4.19**

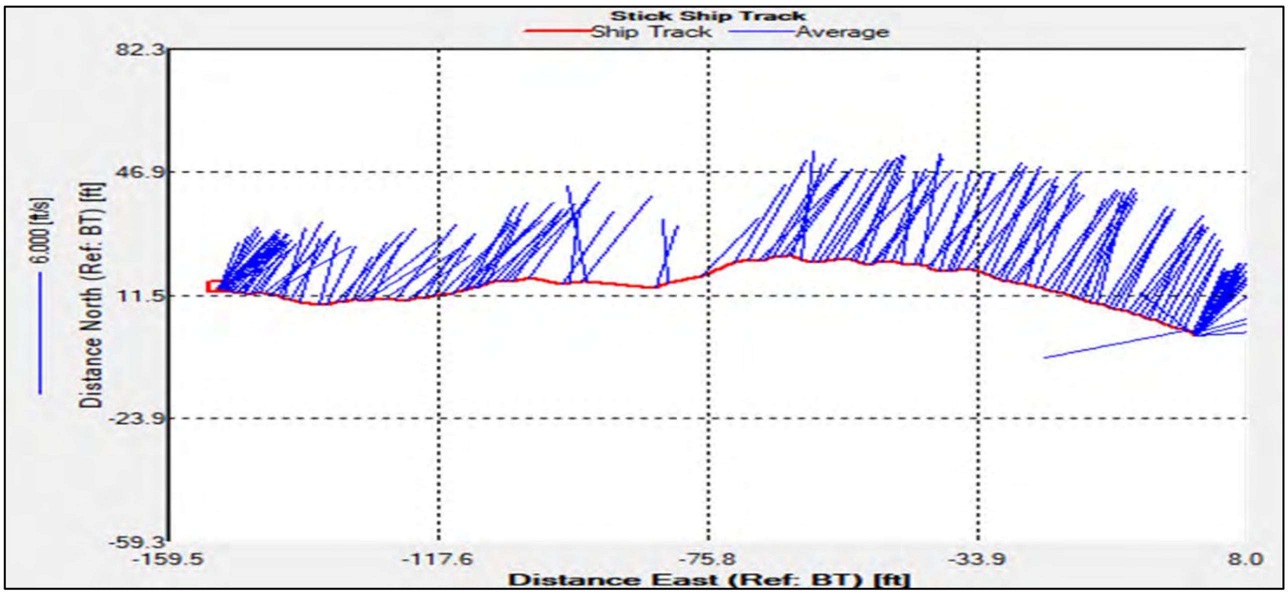
A. Transect J138001 Raw Data Output



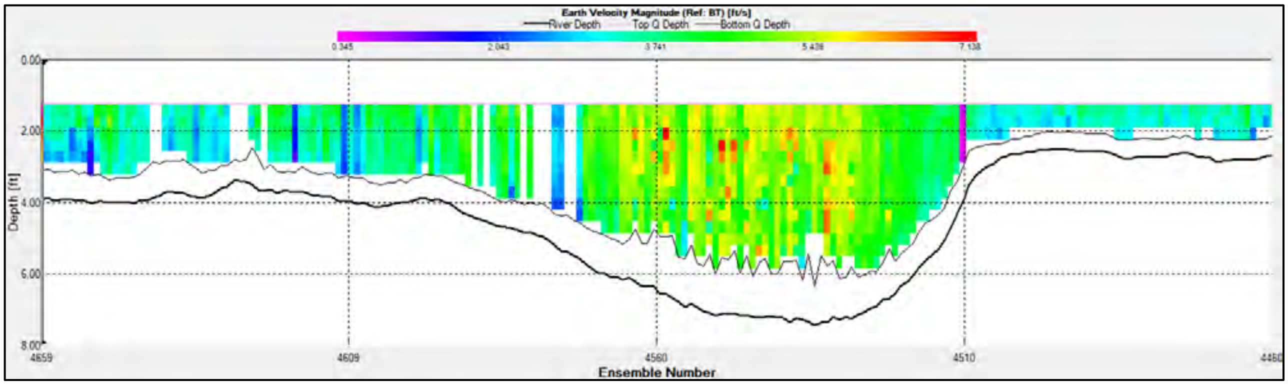


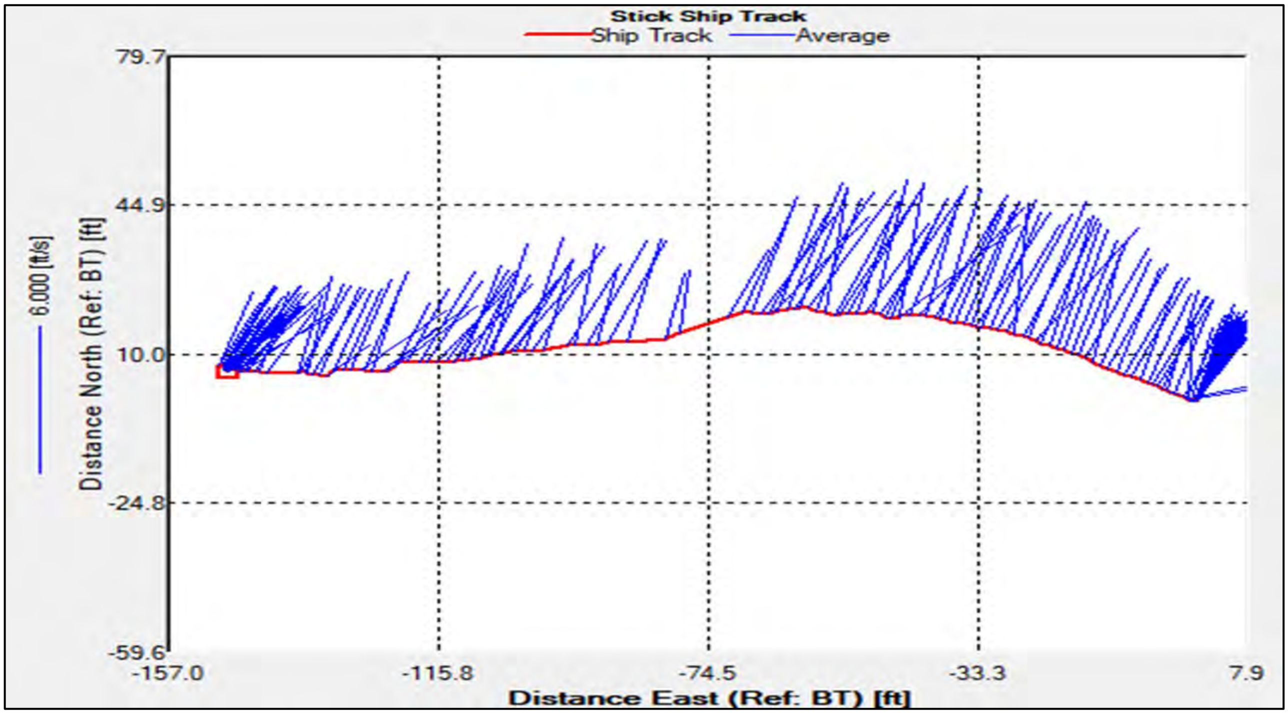
B. Transect J138002 Raw Data Output



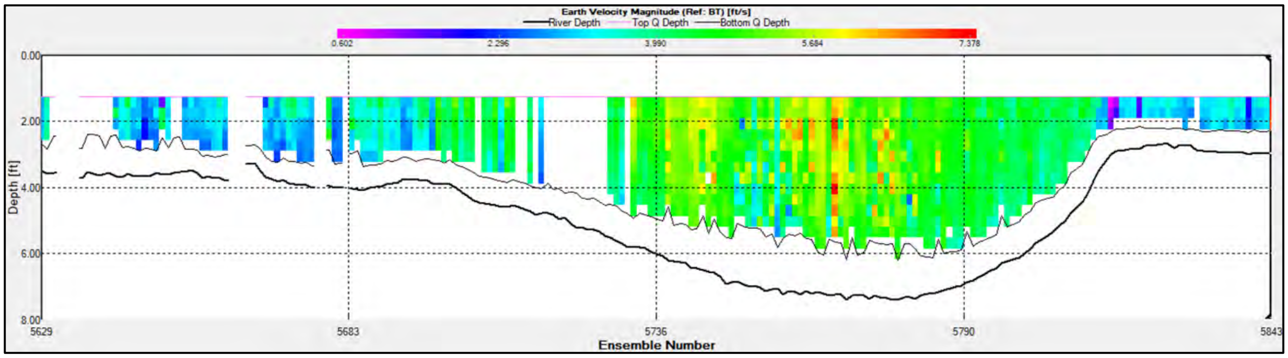


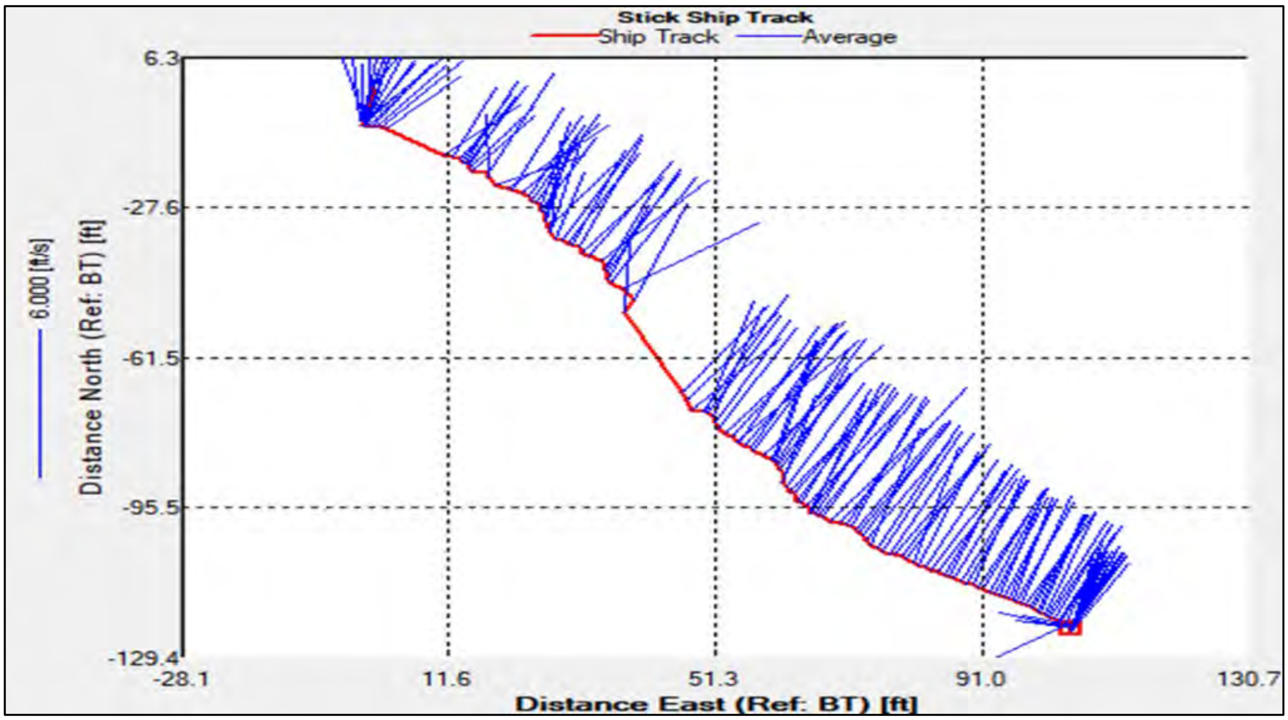
C. Transect J138004 Raw Data Output





D. Transect J138008 Raw Data Output





Spring Breakup Measured Discharge – June 17, 2018

Location: J13.8

Date & Time: June 17, 11:30 AM

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

Final Discharge (cfs): 3,500

Average Velocity (fps): 3.3

Measurement Rating: Fair

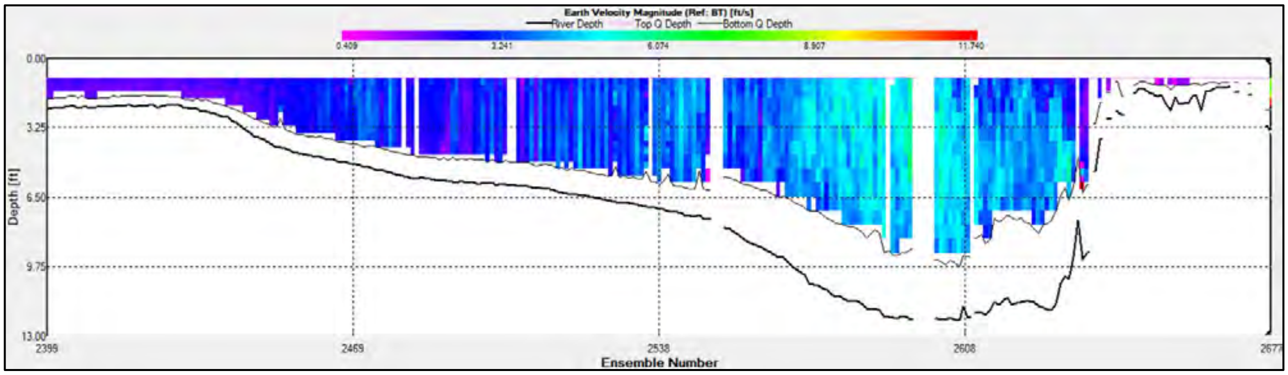
Measurement Notes: Moving bed conditions were identified and the discharge was corrected for moving bed using data acquired from the moving bed loop test performed before the four measured transects.

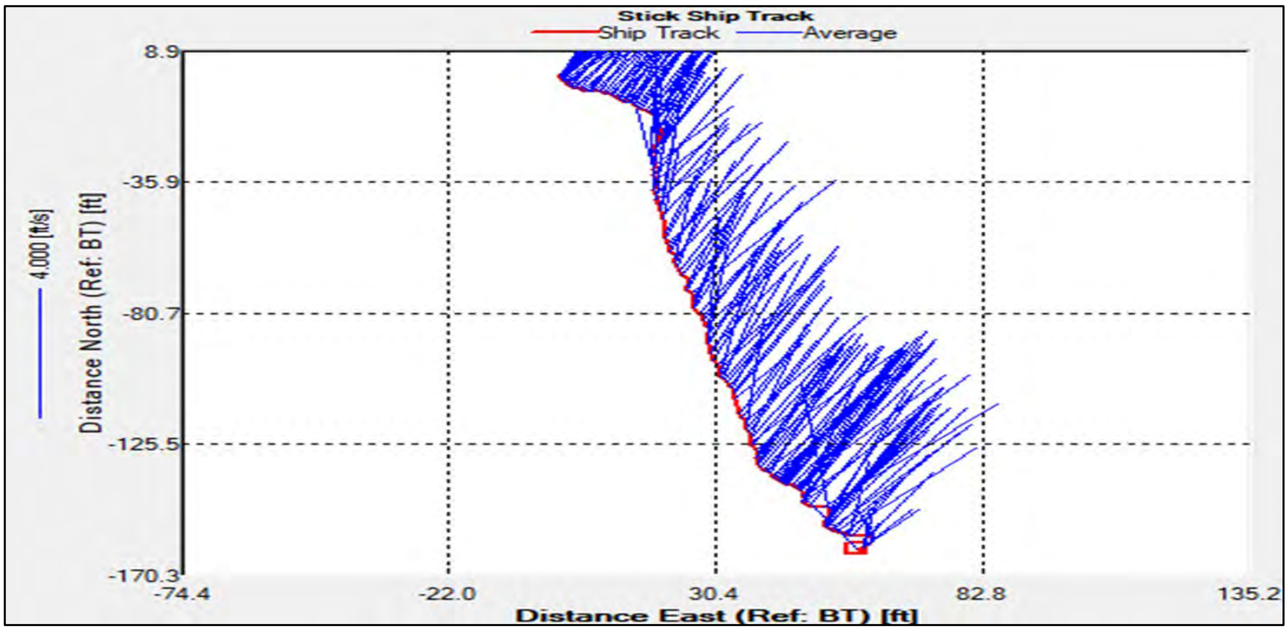
At the time of the measurement, the river was mostly clear of snow and ice. Some snow remained along the both banks but were outside the channel and did not affect flow in the channel. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on the highly mobile bed detected at the time of measurements. Moving bed velocity estimated using the stationary moving bed test was 0.85 fps.

Table C.3: June 17 Spring Breakup Measured Discharge Summary

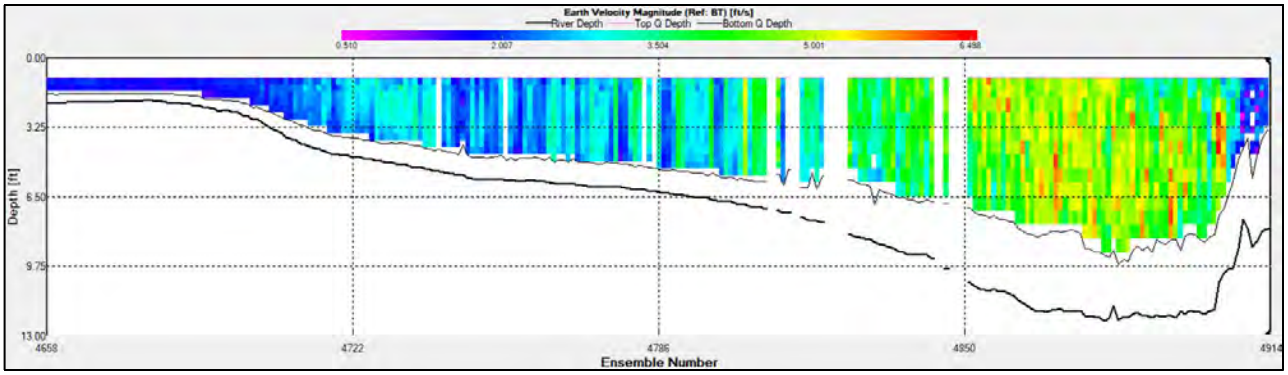
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
J13.8_6-18-18000	Left	3425	-3.37%	2166	-2.55%	252	1015	1,245	2.75	3.38
J13.8_6-18-18005	Left	3602	1.62%	2257	1.53%	270	1091	1,381	2.61	3.30
J13.8_6-18-18006	Right	3634	2.52%	2295	3.22%	220	1141	976	3.72	3.18
J13.8_6-18-18009	Right	3517	-0.77%	2174	-2.20%	214	1074	977	3.60	3.28
Average		**3545**		**2223**		**239**		**1,145**	**3.17**	**3.28**

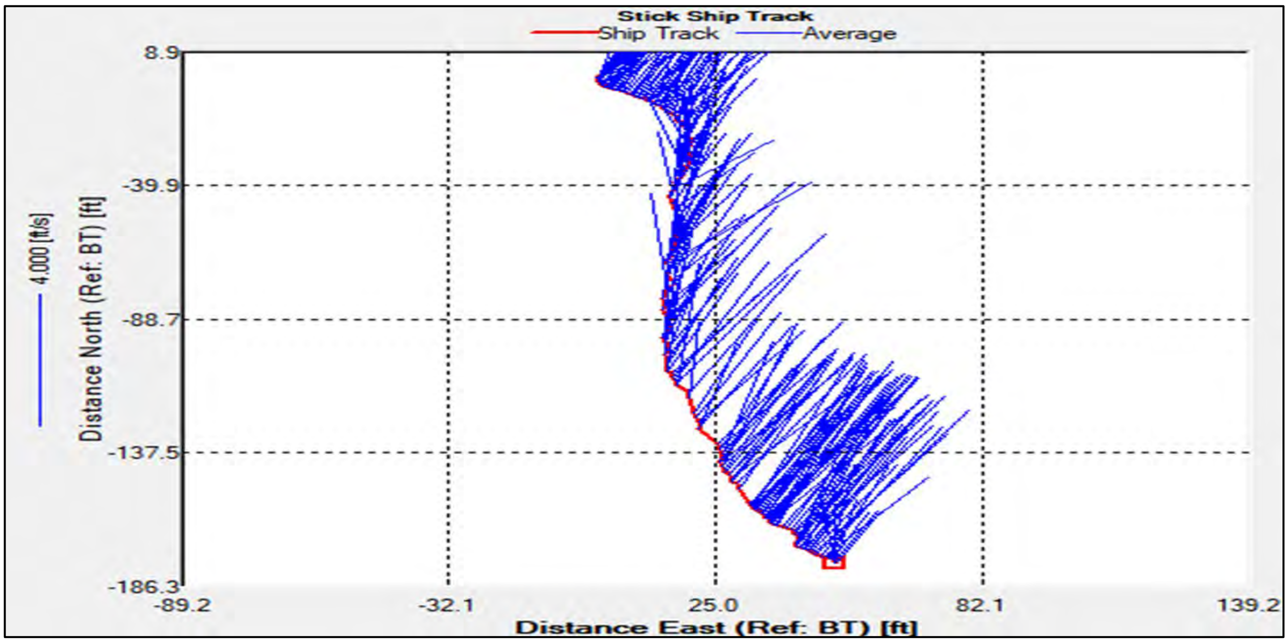
A. Transect J138000 Raw Data Output



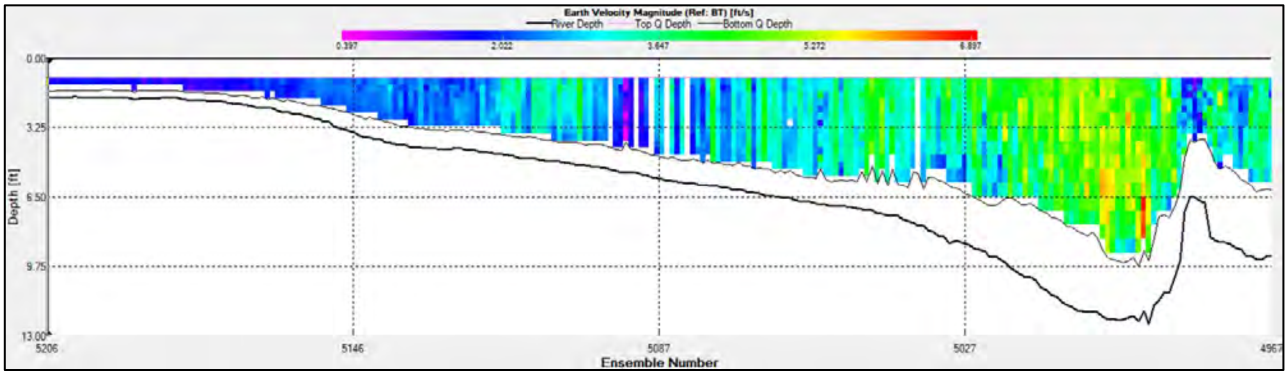


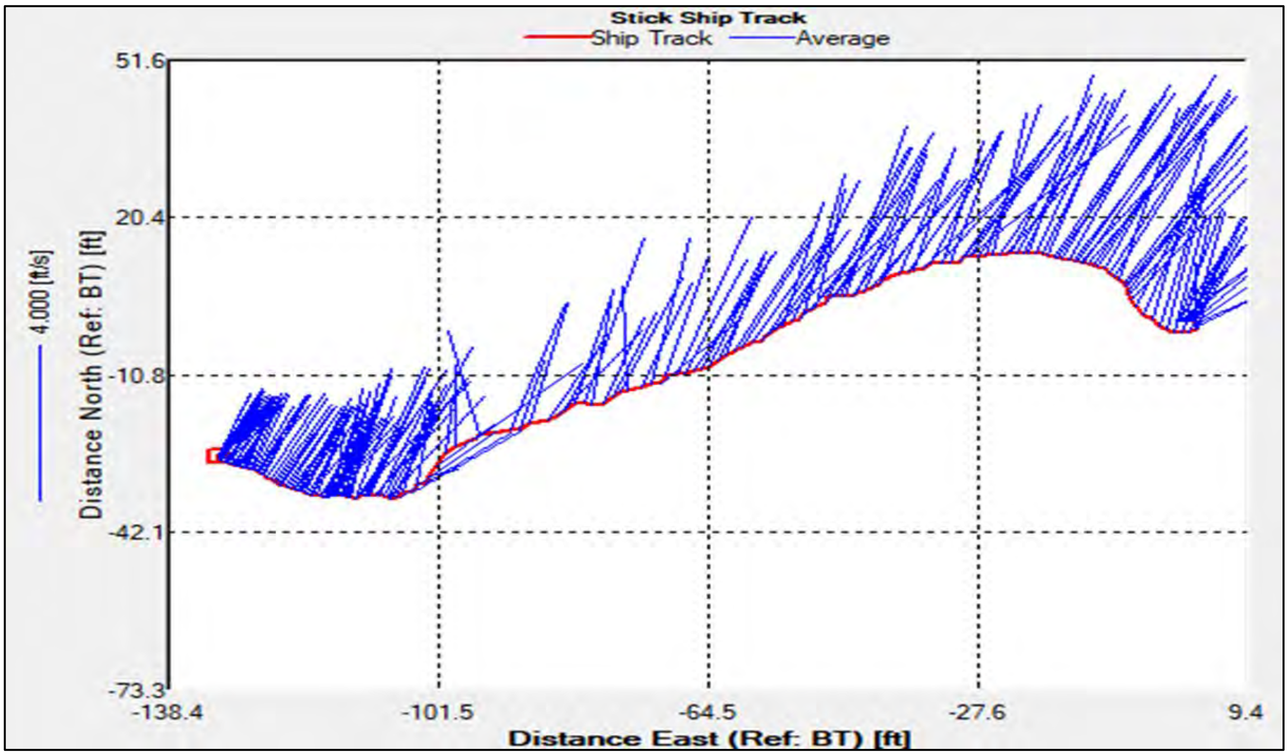
B. Transect J138005 Raw Data Output



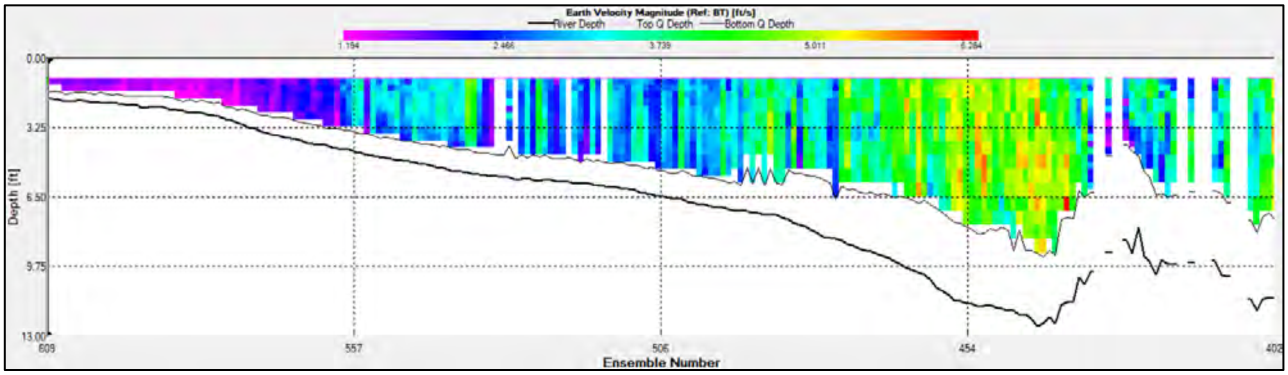


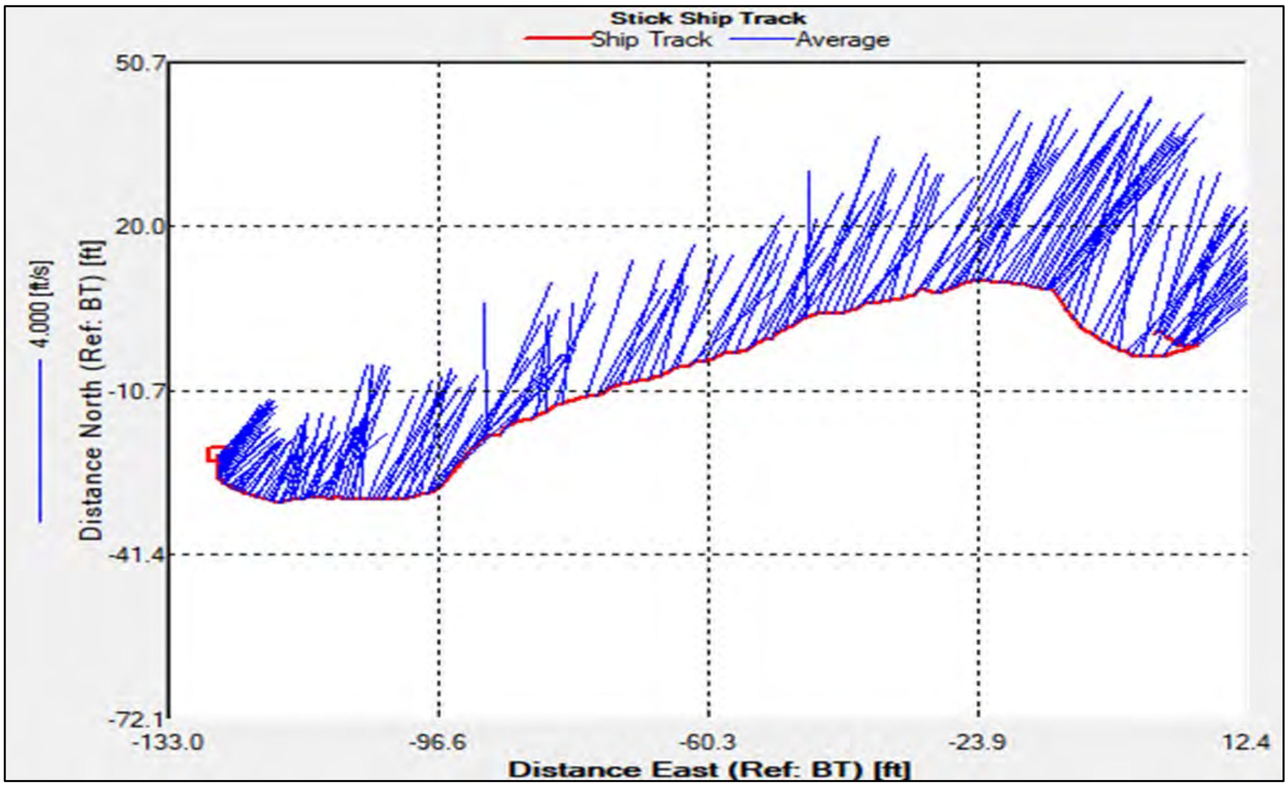
C. Transect J138006 Raw Data Output





D. Transect J138009 Raw Data Output





Spring Breakup Calculated Discharge

Discharge was calculated indirectly using the Normal Depth method. The cross-section was developed from the average of four cross-sections extracted from the J13.8 June 7, 2018 ADCP direct discharge measurement. The energy grade line was approximated by the average water surface slope between J13.8U and J13.8C. Stage at J13.8 was collected using PTs at the three gage locations (upstream, center, and down). The downstream PT data was not used for the calculation of the energy grade line due to gage locations flow characteristics. Manning's n values were selected from reference documents (URS 2001) and calibrated to the measured discharge values in 2017. The 2018 calculated discharge values were compared to the direct discharge for 2018 to verify Manning's n values from 2017 are still valid. The calibrated Manning's n values used in the calculations were 0.035 for the left overbank, 0.018 for the main channel, and 0.035 for the right overbank.

ConocoPhillips Alaska

Feet
0 600 1,200

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_J13.8.mxd
Checked:	GCY	Scale:	1 Inch = 600 Feet

Gage Location
Station
Discharge Measurement Cross Section
Flow Direction

Imagery Source: Digital Globe, 2015

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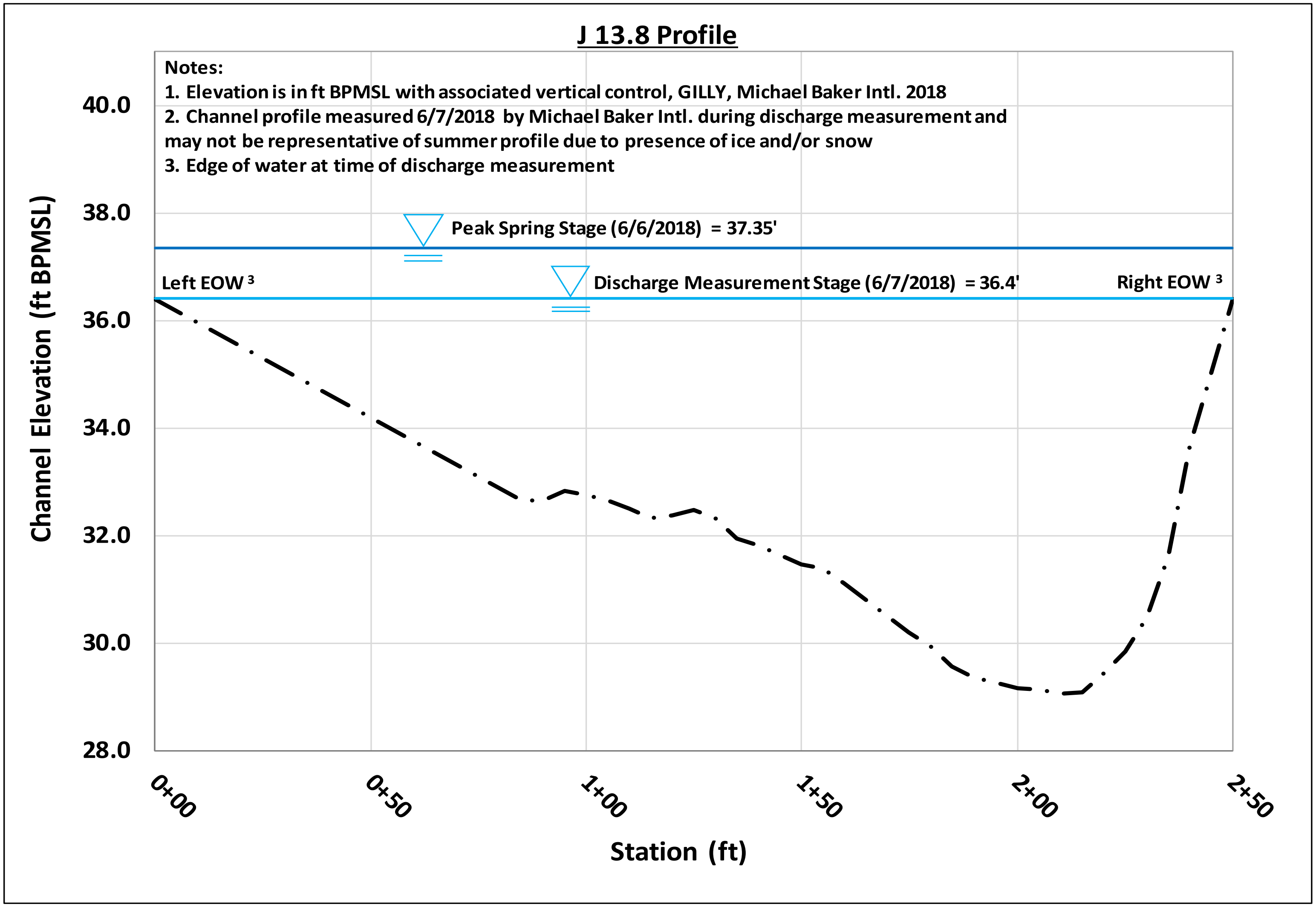
2018 Spring Breakup Judy Creek at J13.8 Plan

FIGURE C.2

Spring Breakup Cross-Section Profile



C.3 KALIKPIK RIVER AT KAL1

Spring Breakup Measured Discharge

Location: Kal1

Date & Time: June 16, 3:30 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): 2.8

Measurement Rating: Fair

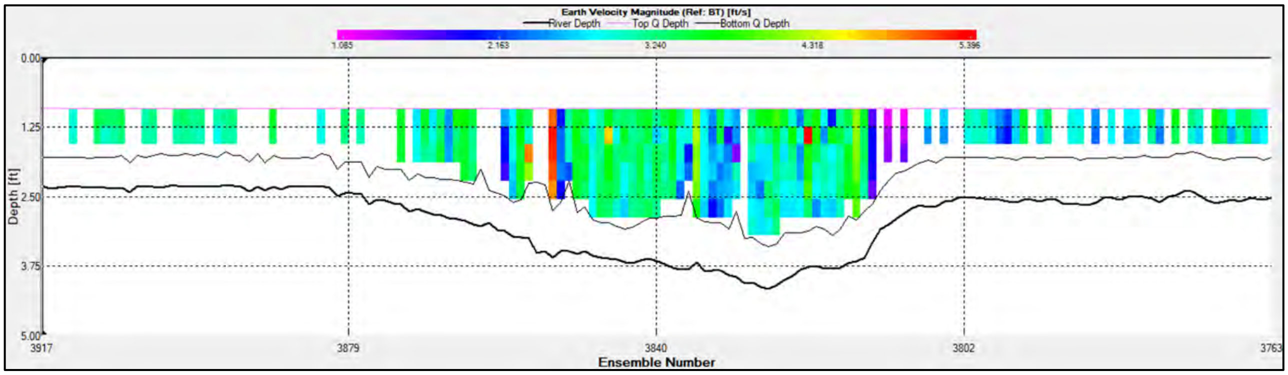
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from the loop test performed before measuring the four transects.

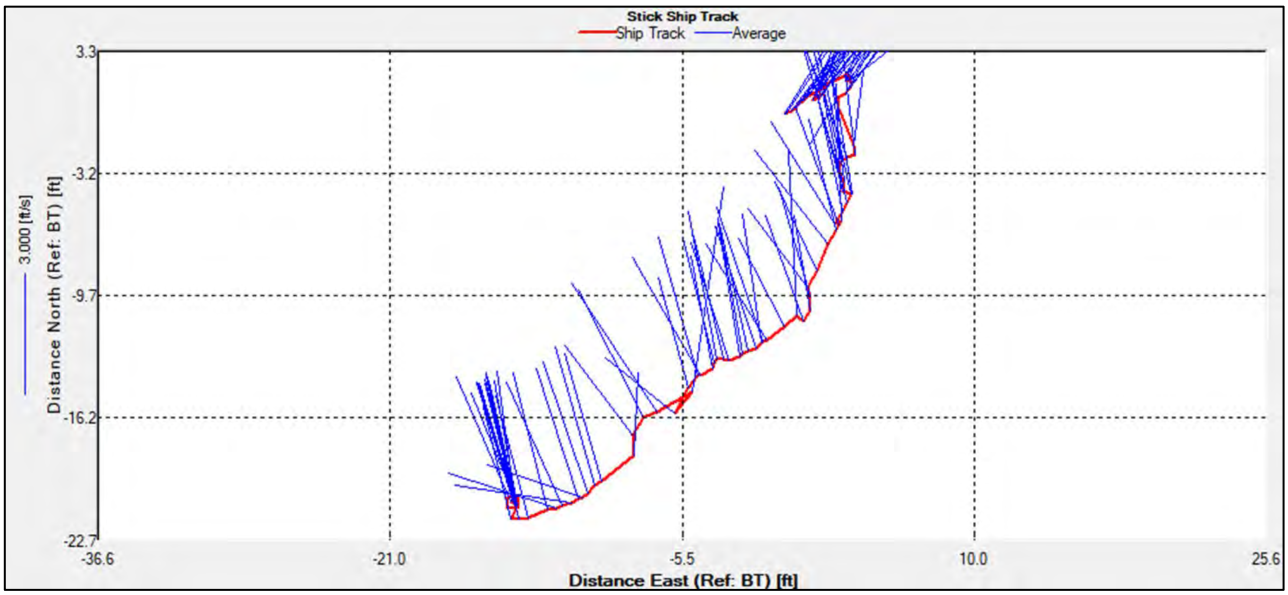
At the time of the measurement, the river was mostly clear of snow and ice along the left bank. Along the right bank, a large snowdrift remained in the channel. Intermittent ice floes and some snow were observed during the measurement. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on the channel conditions at the time of measurement. The moving bed velocity estimated using the loop test was 0.32 fps. The percentage of bad bottom track values (20.1%) exceeded the recommended 5% and was factored into the overall quality rating of the measurement.

Table C.4: Kal1 June 16 Spring Breakup Measured Discharge Summary

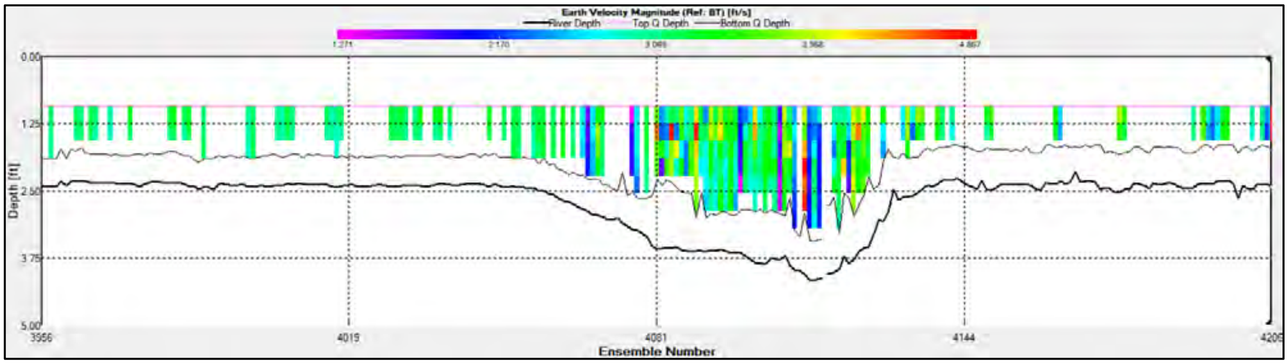
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
KAL001	Right	312	-2.40%	102	0.53%	48	111	117	2.35	2.81
KAL002	Left	333	4.39%	87	-14.67%	67	115	163	1.72	2.89
KAL010	Left	332	4.10%	113	10.58%	57	121	136	2.13	2.75
KAL011	Right	300	-6.10%	105	3.56%	51	102	102	2.22	2.93
Average		**319**		**102**		**56**		**130**	**2.11**	**2.84**

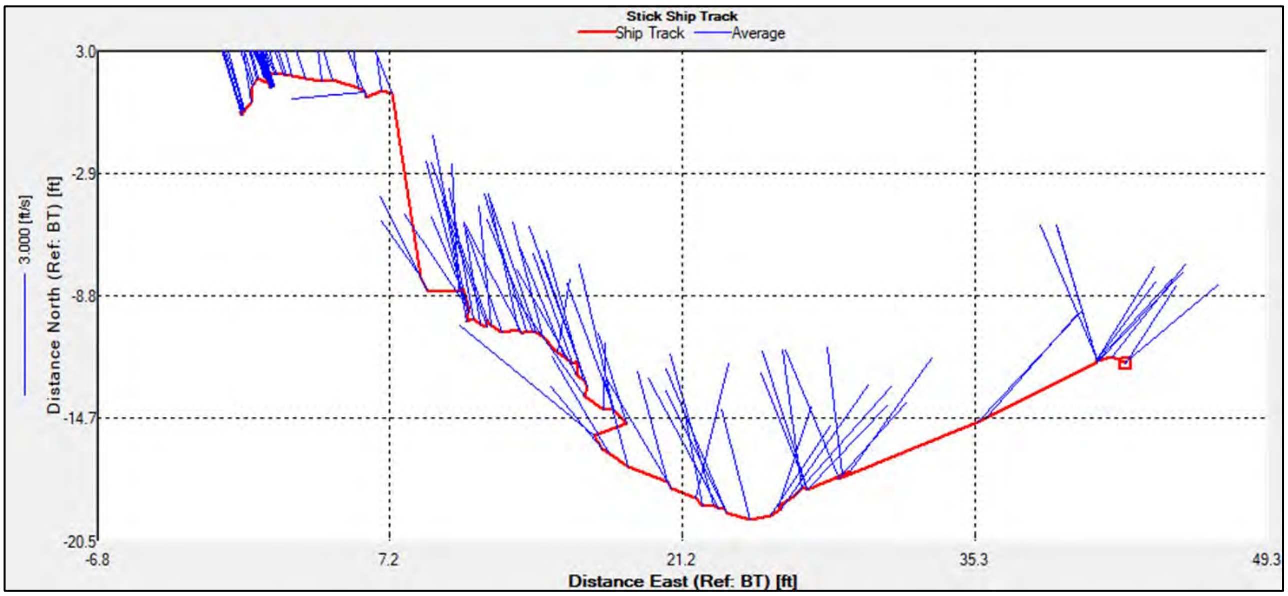
A. Transect KAL001 Raw Data Output



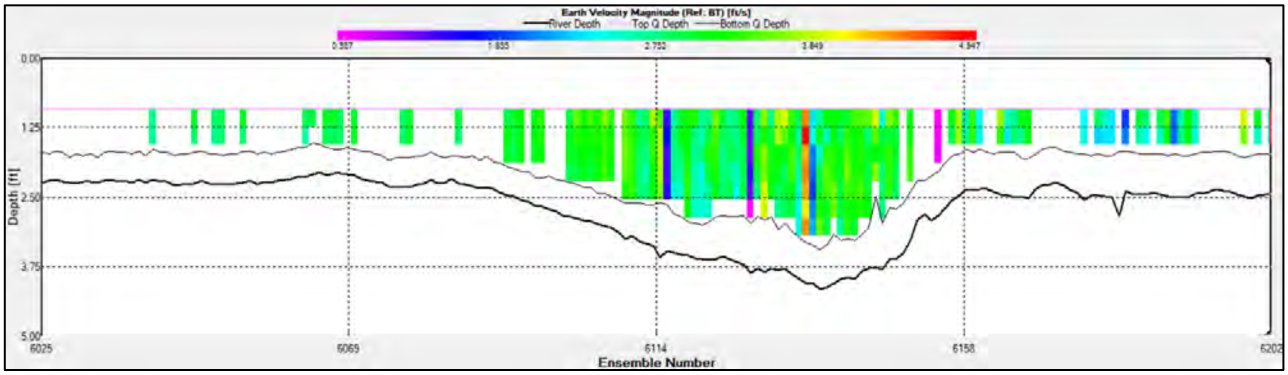


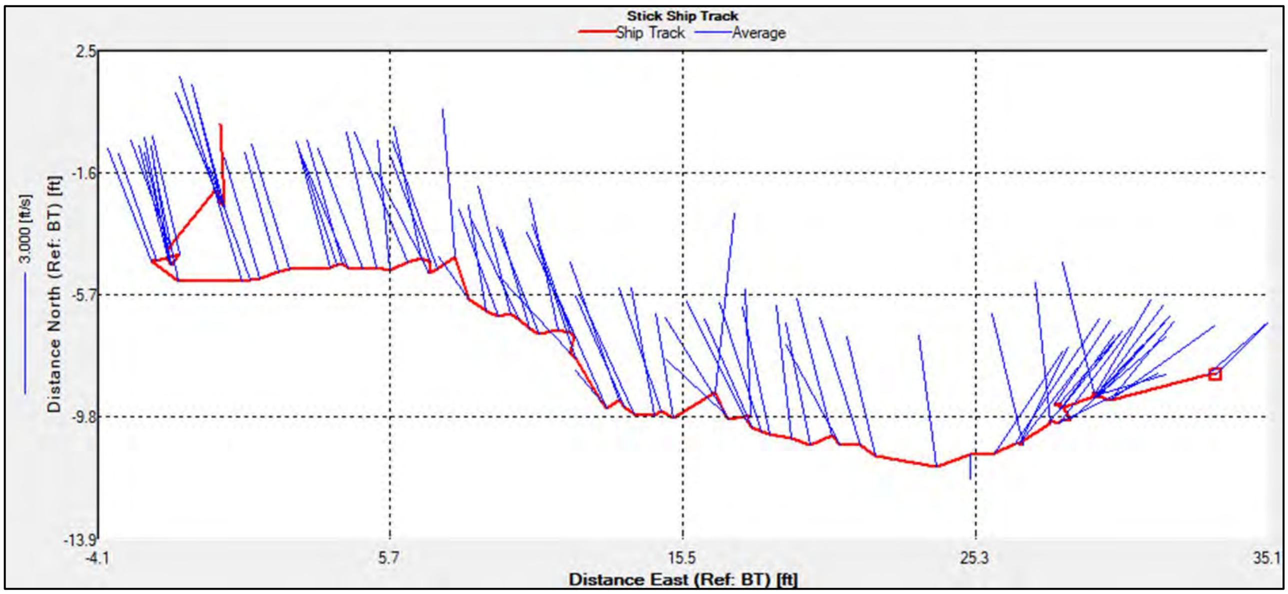
B. Transect KAL002 Raw Data Output



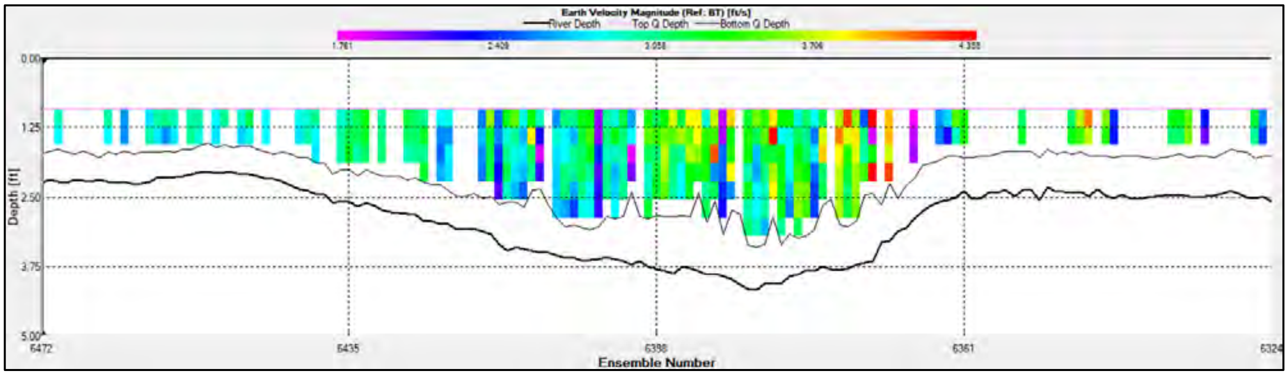


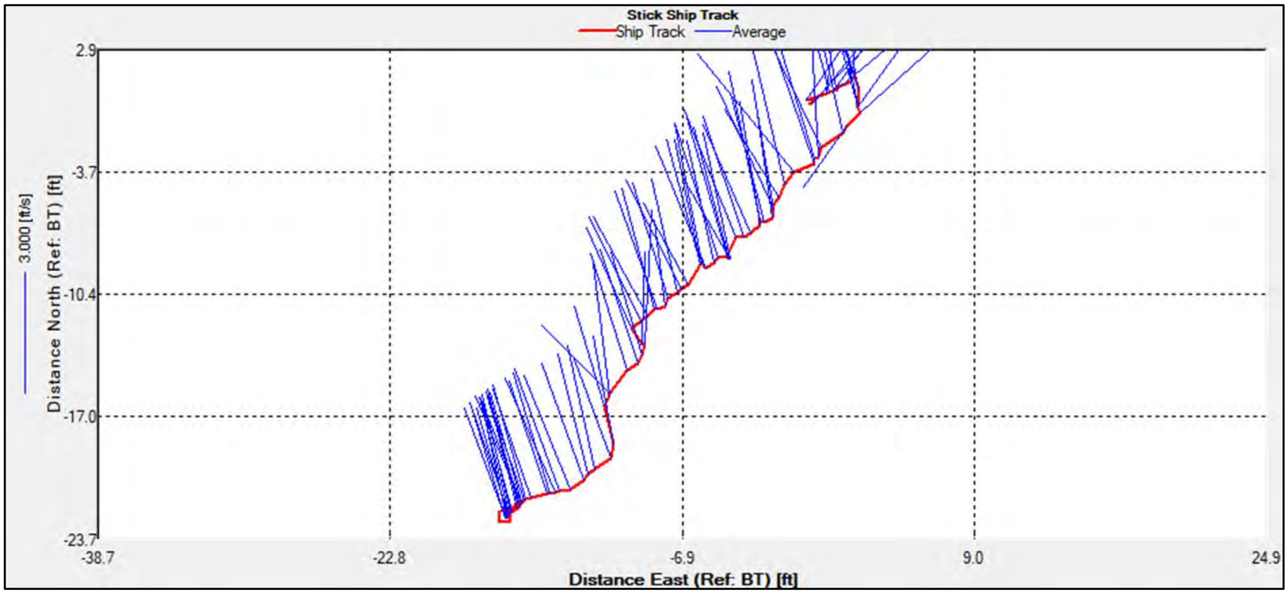
C. Transect KAL010 Raw Data Output





D. Transect KAL011 Raw Data Output





ConocoPhillips Alaska

Feet 0 200 400 600 800

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_Kal1.mxd
Checked:	GCY	Scale:	1 Inch = 400 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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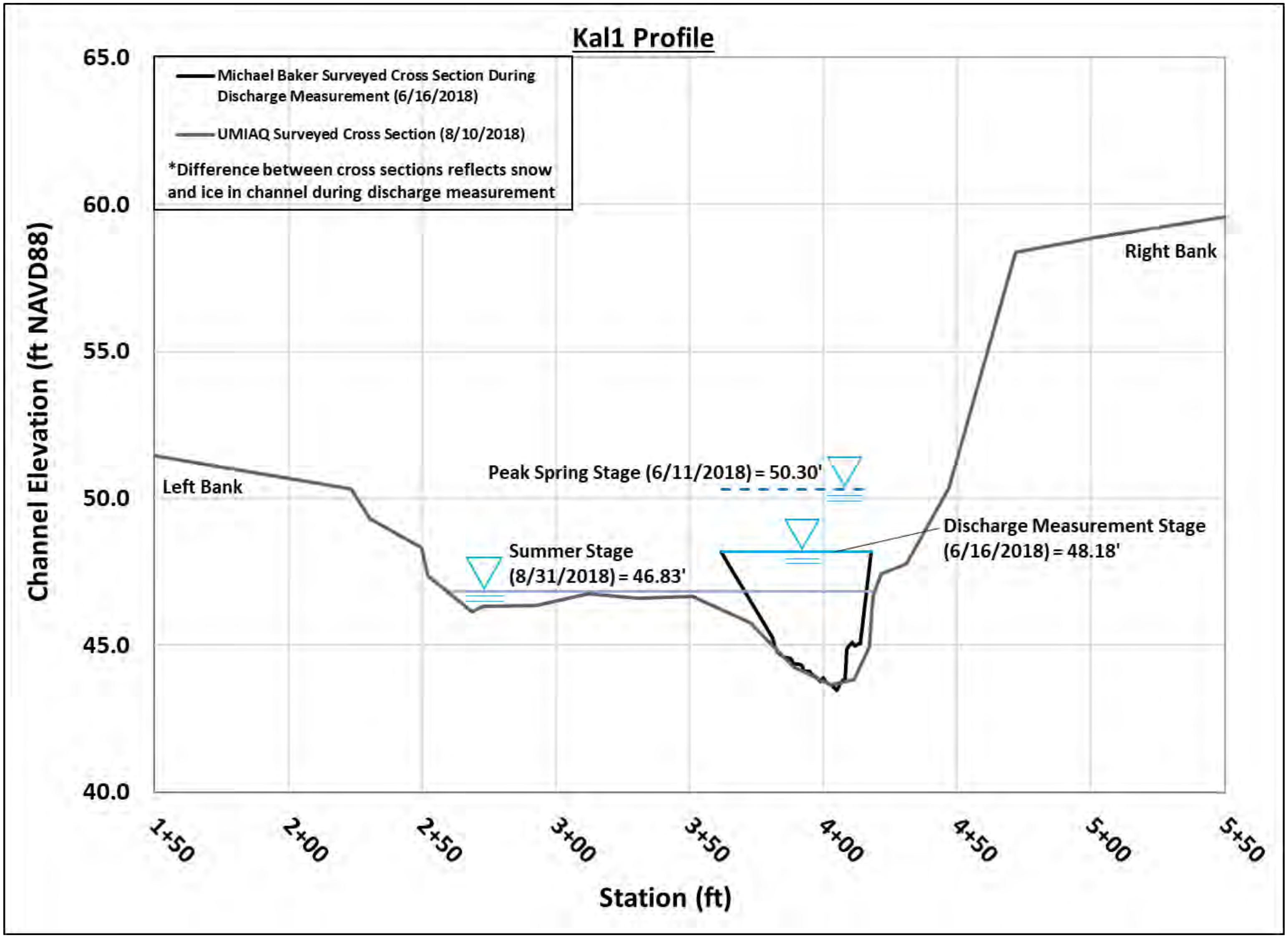
2018 Spring Breakup Kalikpik River at Kal1 Plan

FIGURE C.3

Spring Breakup Cross-Section Profile



C.4 TBD_5

Spring Breakup Measured Discharge

Location: TBD_5

Date & Time: June 18, 3:15 PM

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

Final Discharge (cfs): 250

Average Velocity (fps): 2.2

Measurement Rating: Good

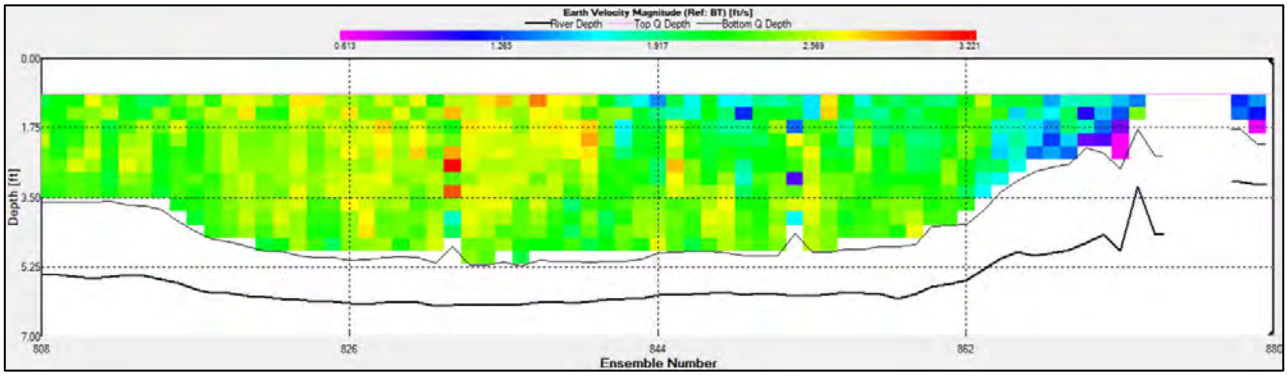
Measurement Notes: Moving bed conditions were identified as minimal and had no impact on the overall discharge measurement.

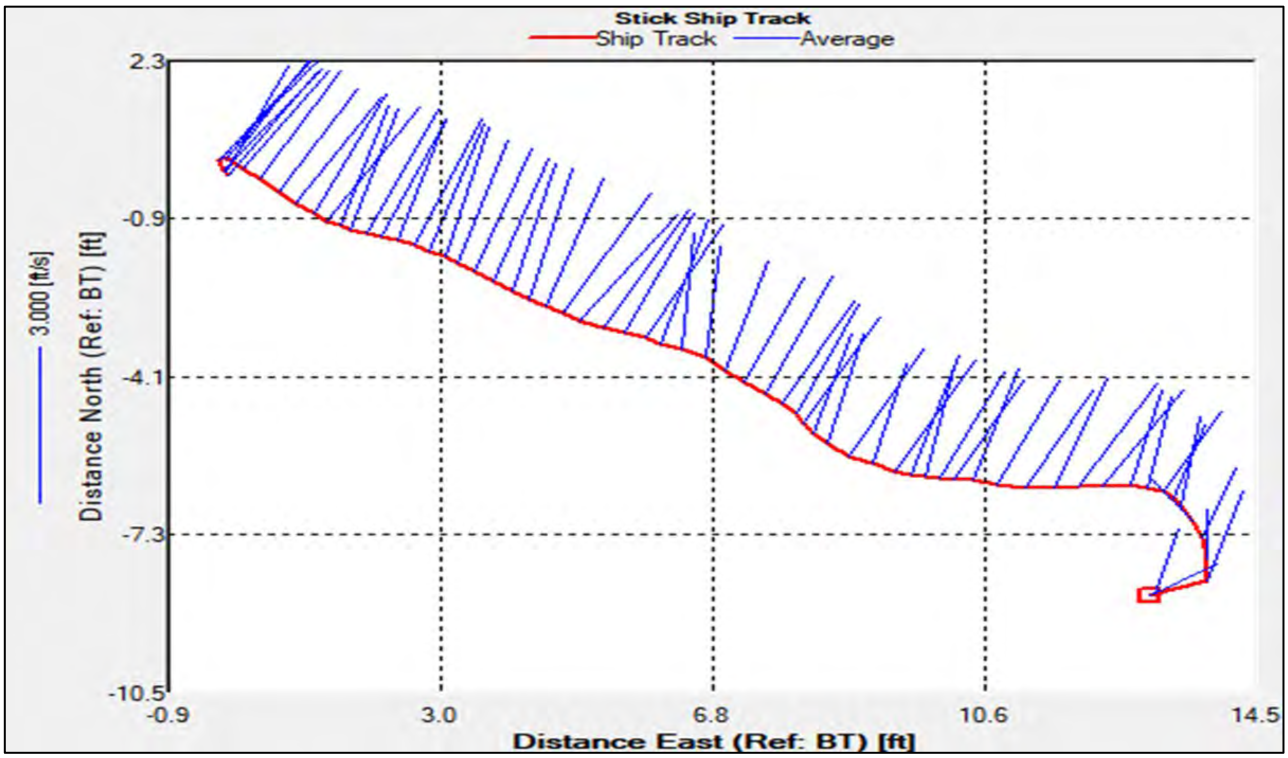
At the time of the measurement, the river was mostly clear of snow and ice, but snow remained along both banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered good based on the open channel conditions at the time of the measurement. The percentage of bad bottom track values (0.5%) was within the recommended 5% and factored into the overall quality rating of the measurement.

Table C.5: TBD_5 June 18 Spring Breakup Measured Discharge Summary

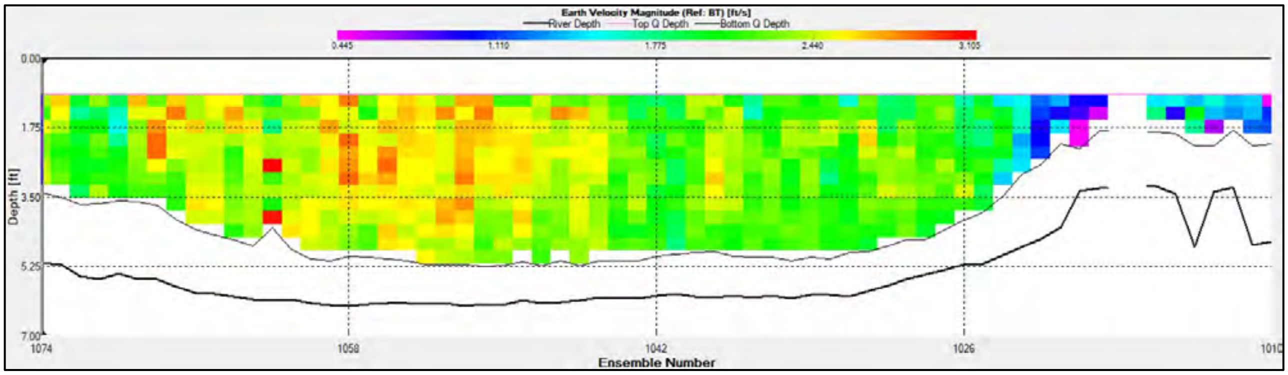
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
TBD_5001	Left	249	1.38%	123	-1.39%	42	110	148	1.68	2.26
TBD_5002	Right	239	-2.89%	126	1.05%	42	107	143	1.67	2.22
TBD_5003	Left	240	-2.38%	126	0.81%	42	107	145	1.66	2.25
TBD_5004	Right	256	3.89%	124	-0.46%	42	116	149	1.71	2.20
Average		**246**		**125**		**42**		**146**	**1.68**	**2.23**

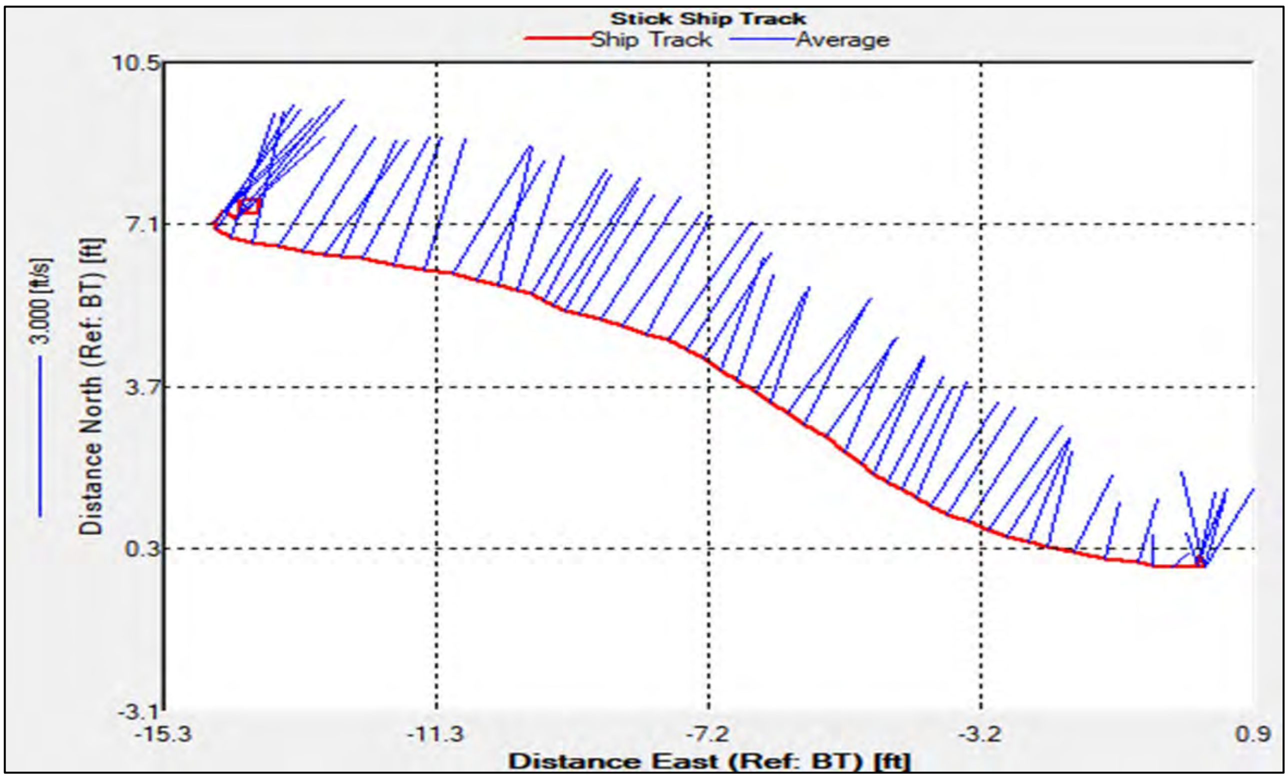
A. Transect TBD5001 Raw Data Output



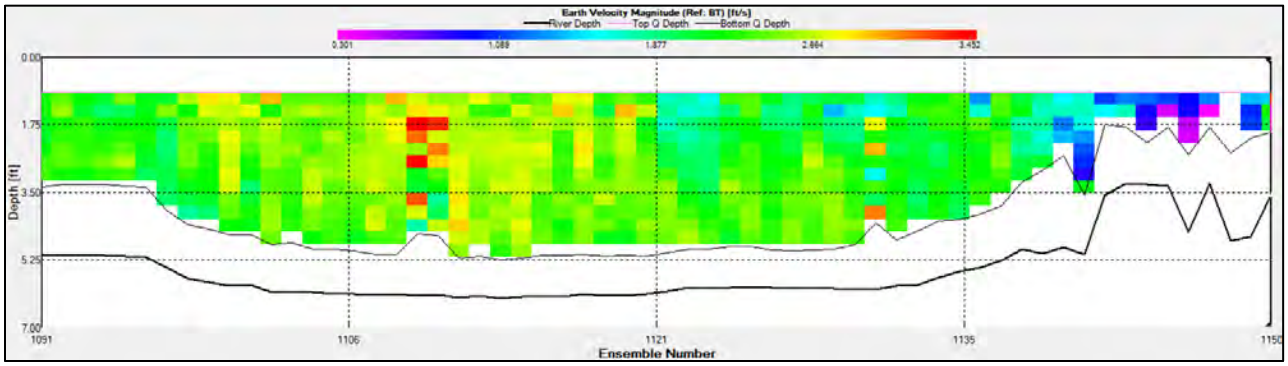


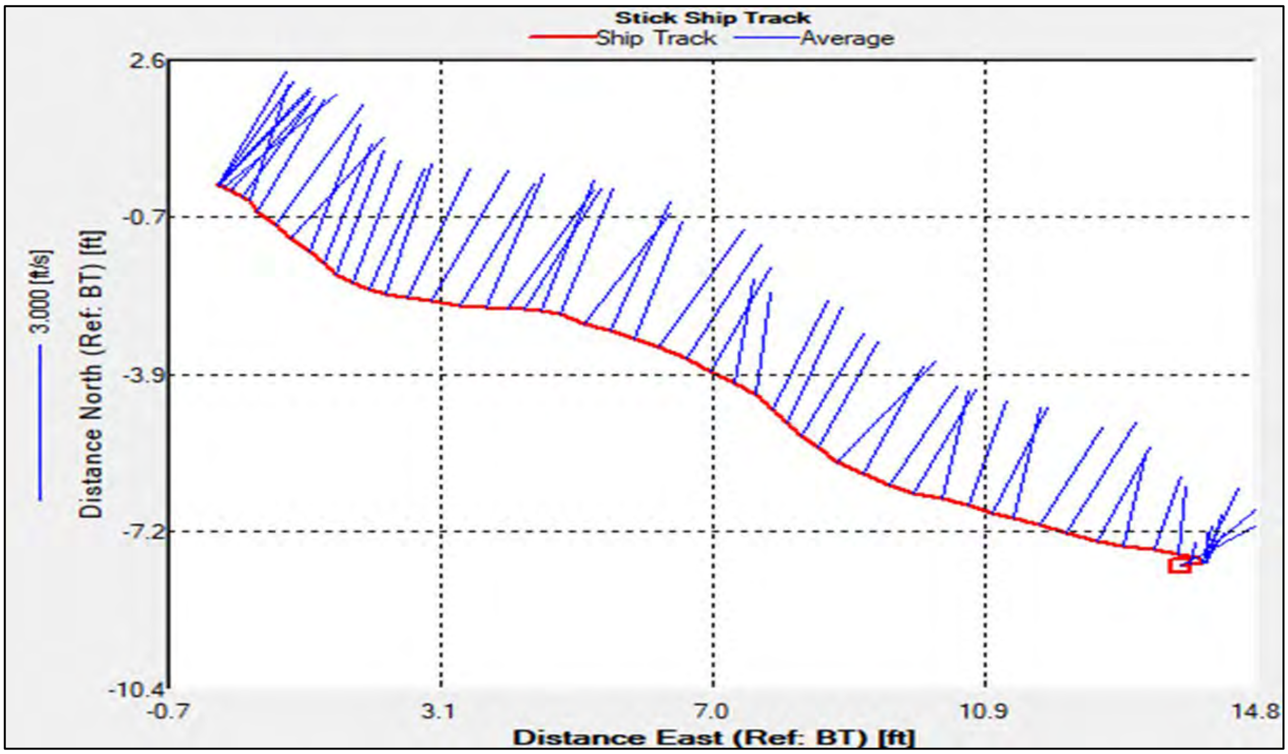
B. Transect TBD5002 Raw Data Output



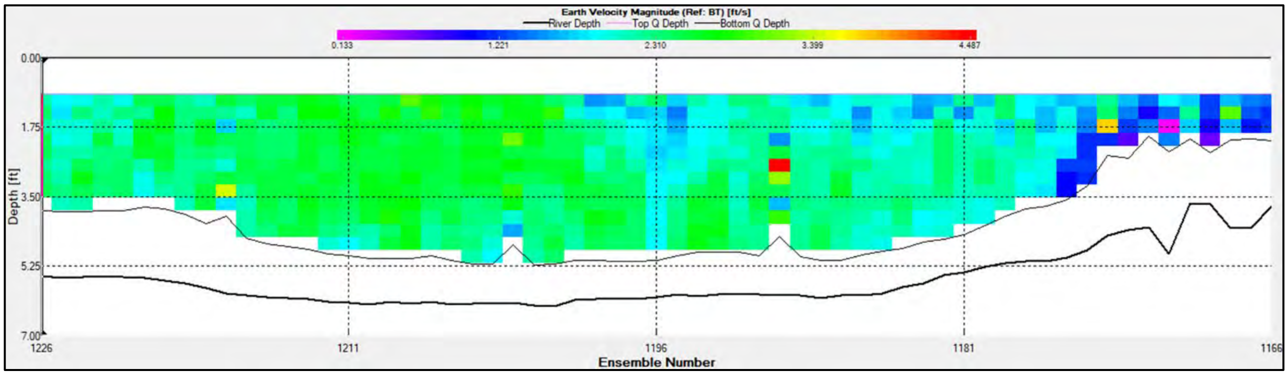


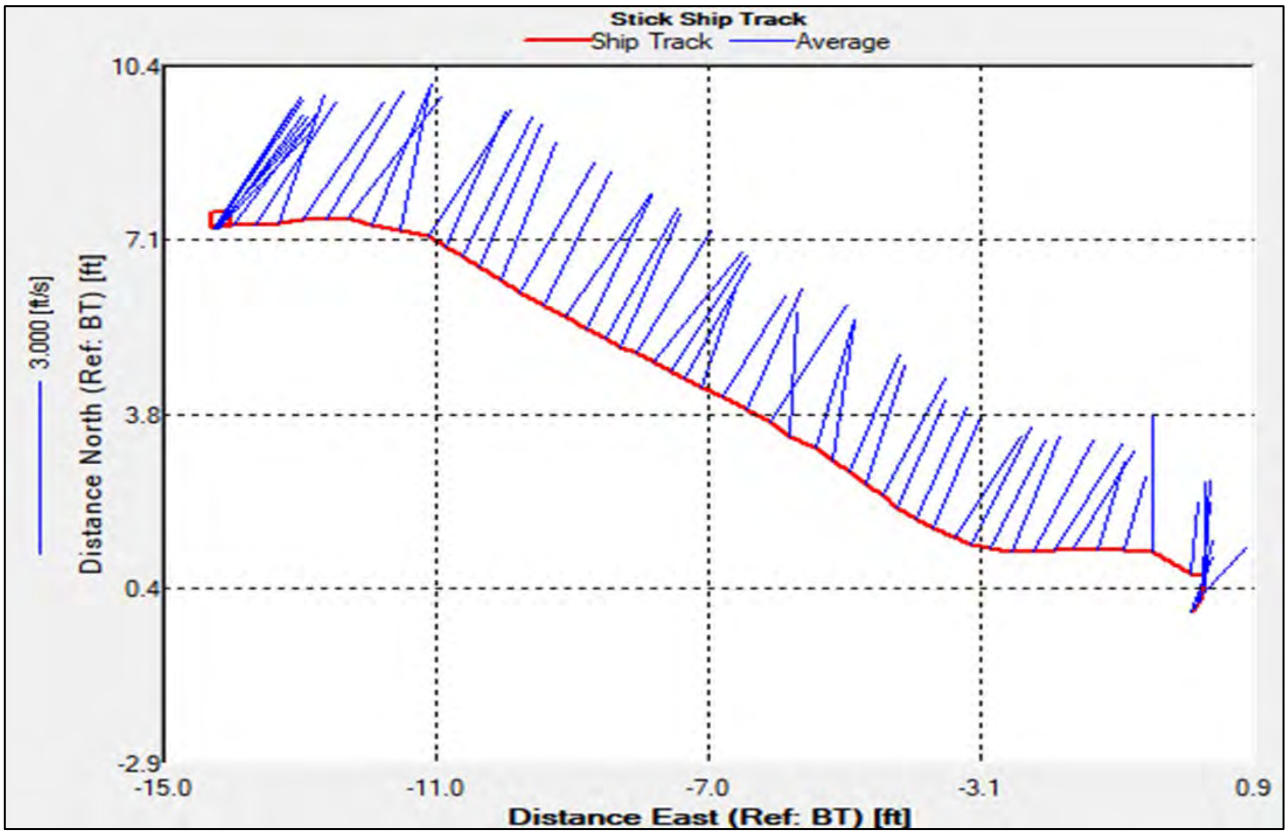
C. Transect TBD5003 Raw Data Output

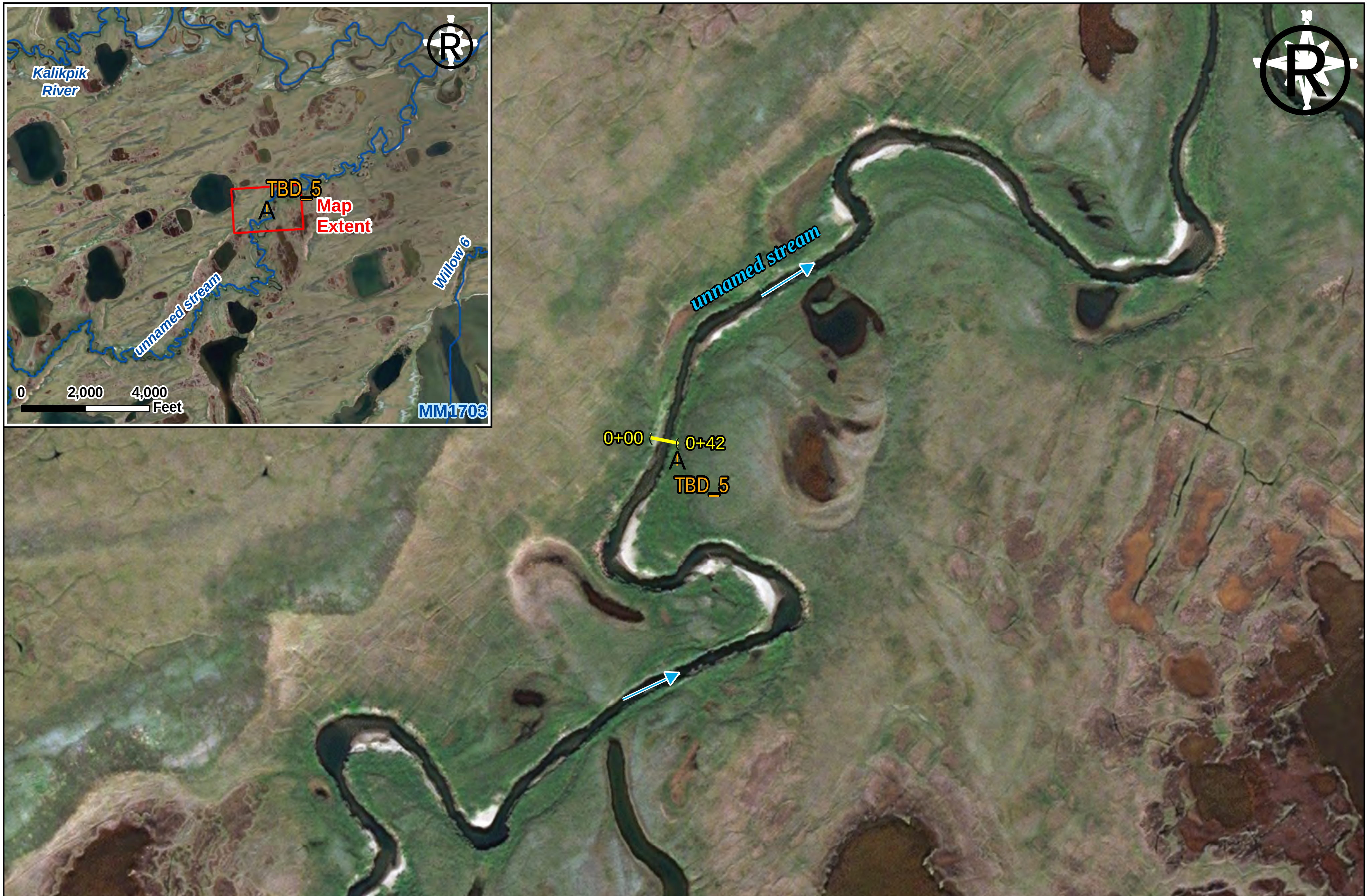




D. Transect TBD5004 Raw Data Output







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Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_TBD5.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

0 200 400 Feet

A Gage Location

Flow Direction

(Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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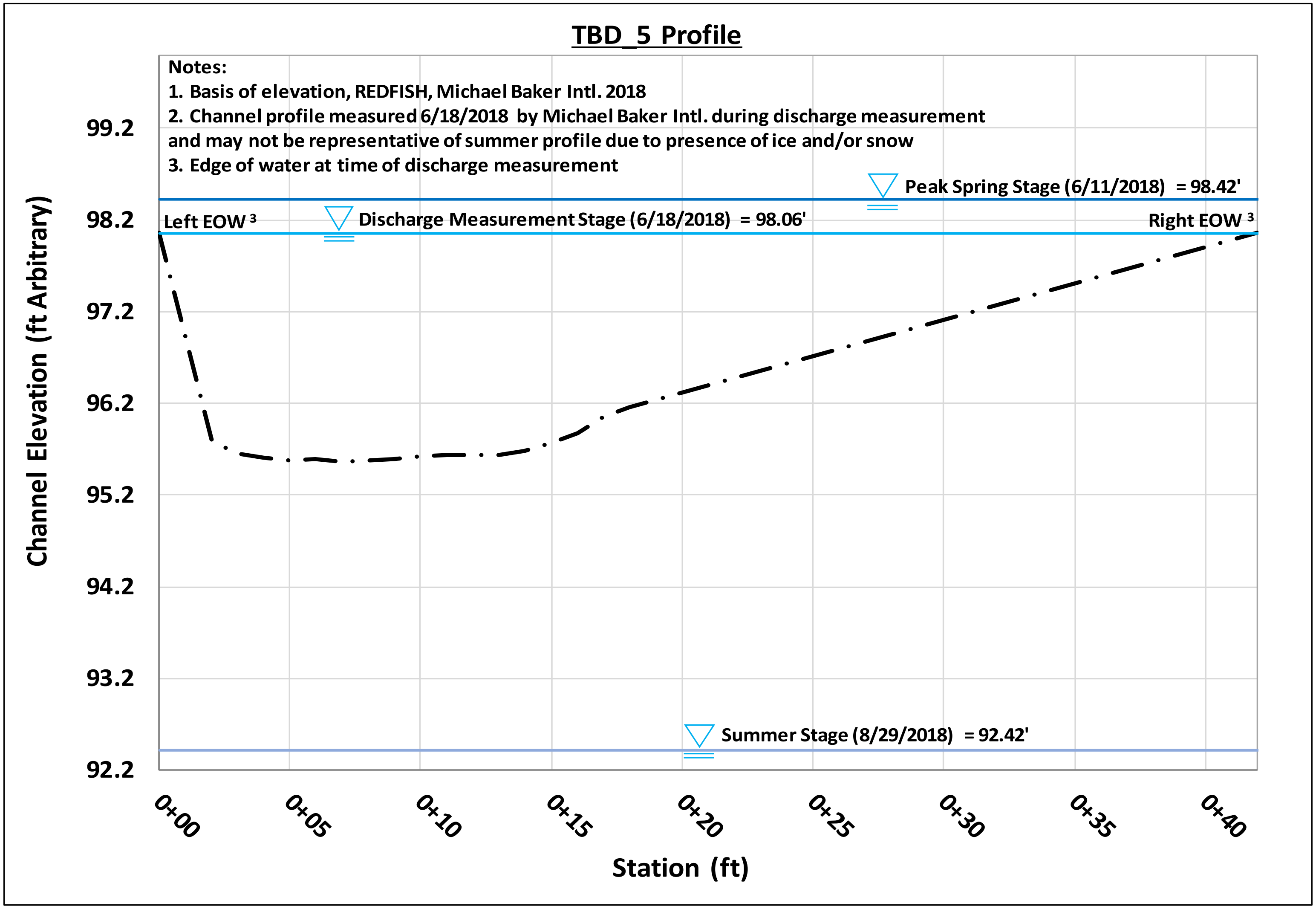
Fax: (907) 273-1699

2018 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: June 15, 4:30 PM

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

Final Discharge (cfs): 70

Average Velocity (fps): 2.0

Measurement Rating: Good

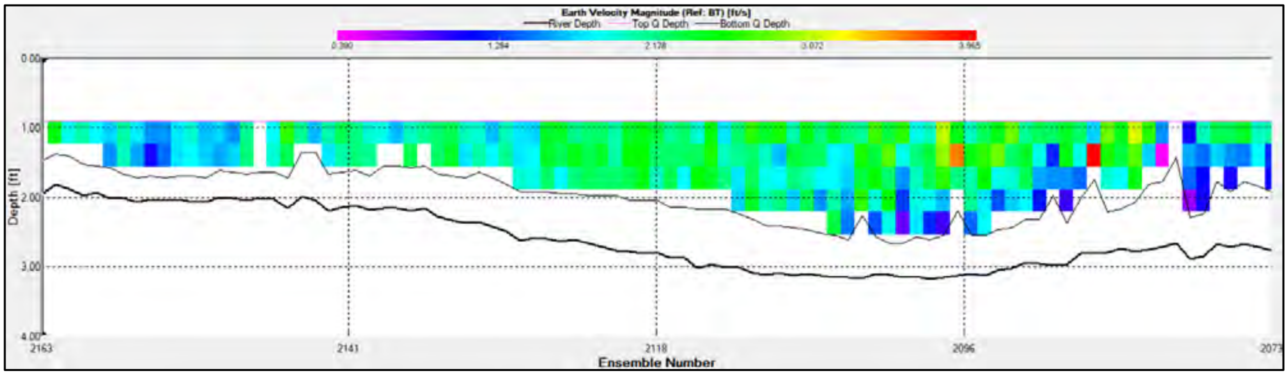
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from a stationary moving bed test performed before the four measured transects.

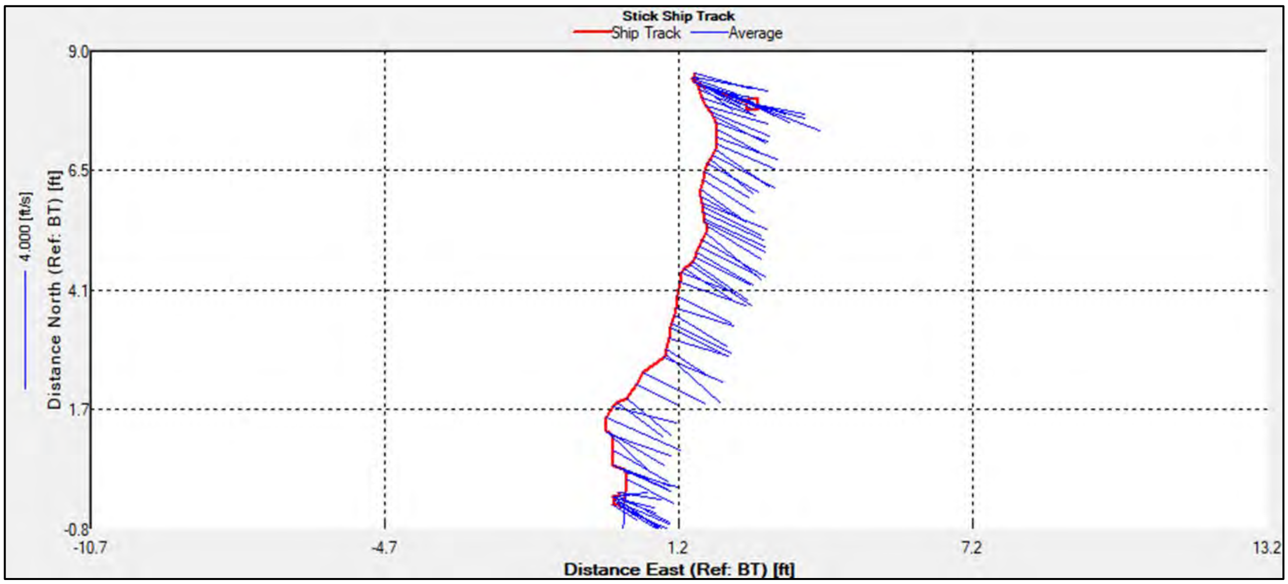
At the time of the measurement, the river was clear of snow and ice. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered good based on the open channel conditions and consistent results for each transect. The percentage of bad bottom track values (0%) was within the recommended 5% and factored into the overall quality rating of the measurement.

Table C.6: TBD_6 June 16 Spring Breakup Measured Discharge Summary

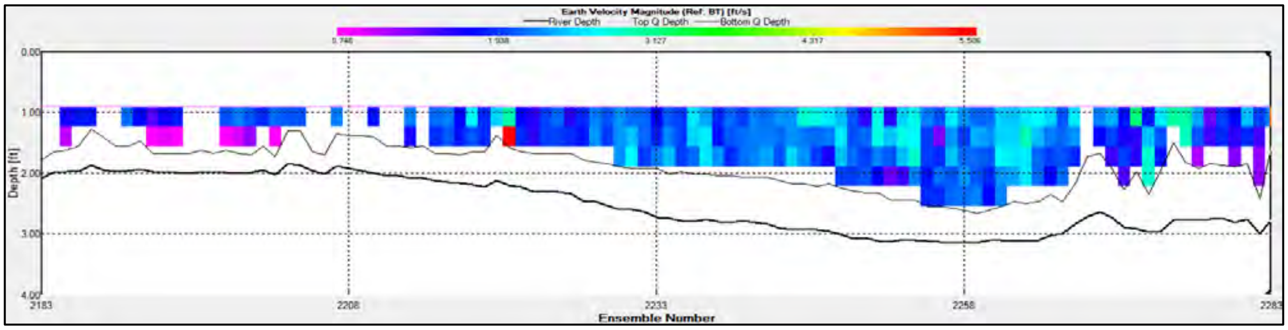
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
TBD6001	Right	65	-1.26%	19	3.92%	20	32	38	1.72	1.99
TBD6002	Left	64	-1.52%	18	-4.36%	20	33	37	1.74	1.93
TBD6003	Right	64	-1.58%	18	-4.84%	20	33	38	1.71	1.97
TBD6004	Left	68	4.37%	20	5.28%	21	34	39	1.74	2.01
Average		**65**		**19**		**20**		**38**	**1.73**	**1.98**

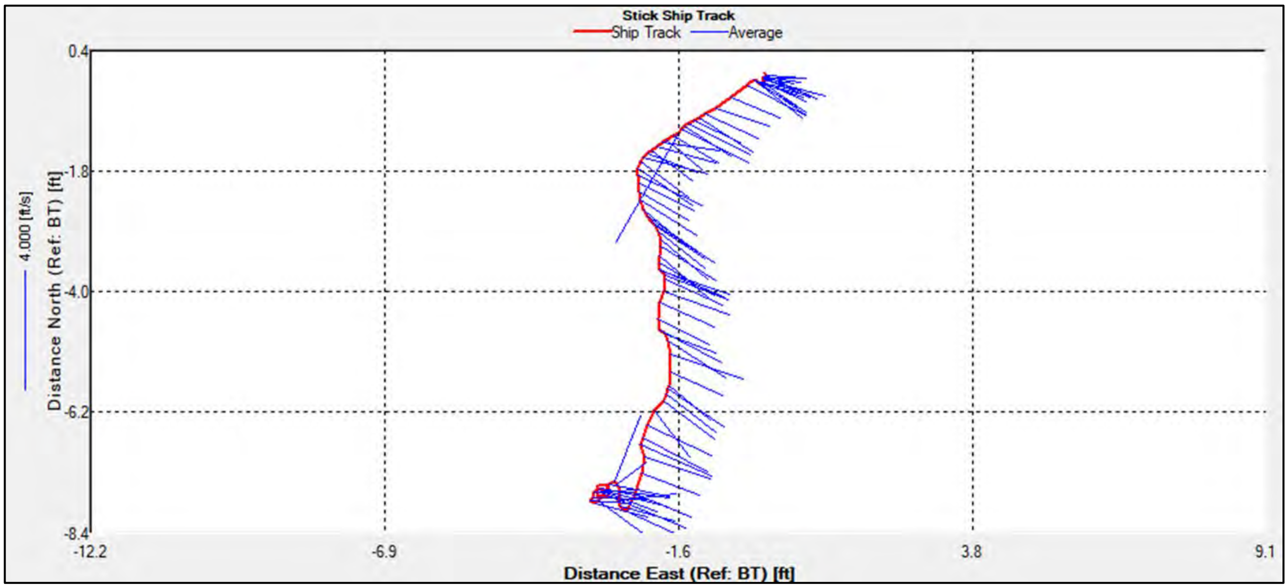
A. Transect TBD6001 Raw Data Output



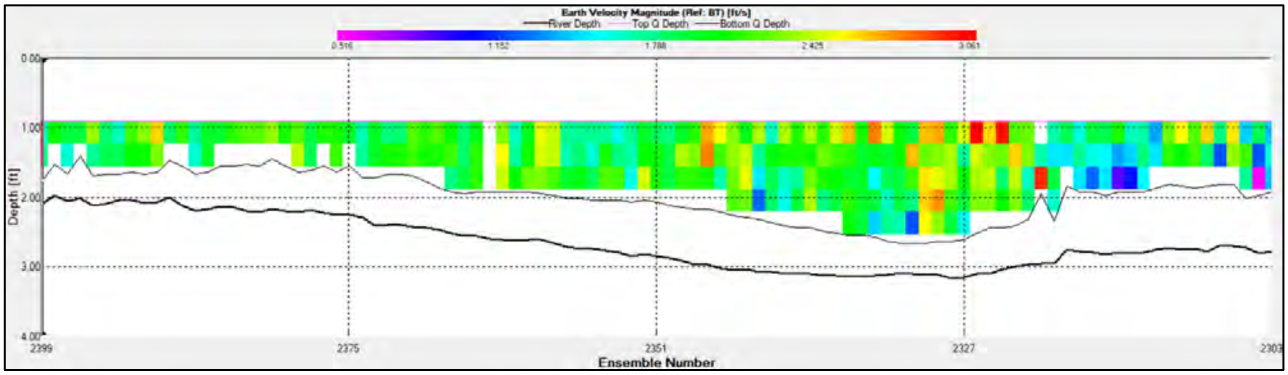


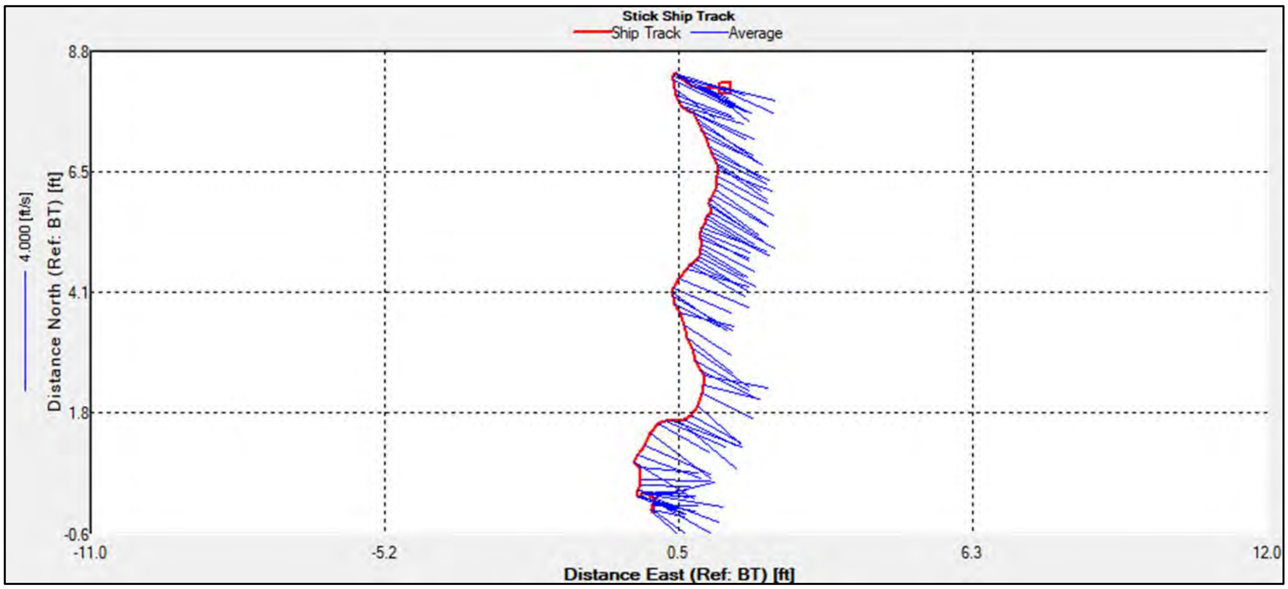
B. Transect TBD6002 Raw Data Output



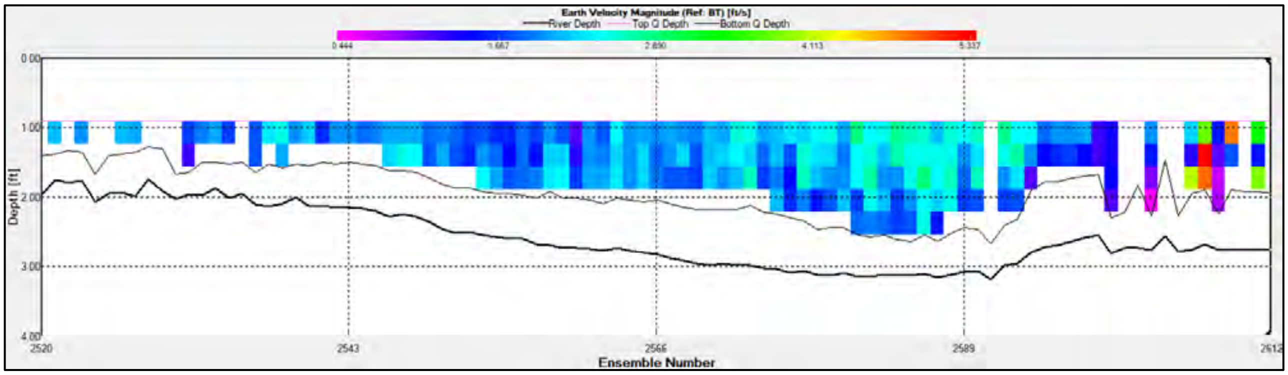


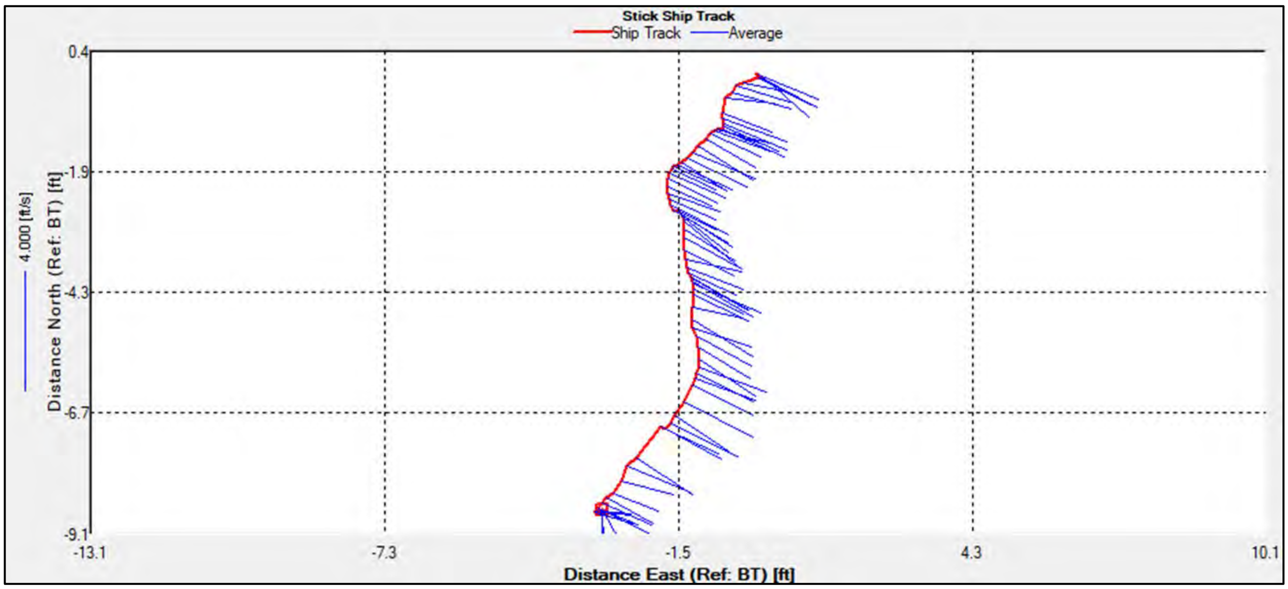
C. Transect TBD6003 Raw Data Output





D. Transect TBD6004 Raw Data Output





ConocoPhillips Alaska

Feet
0 200 400

Date: 11/13/2018		Project: 166429	
Drawn: JEG		File: PlanView_TBD6.mxd	
Checked: GCY		Scale: 1 Inch = 200 Feet	

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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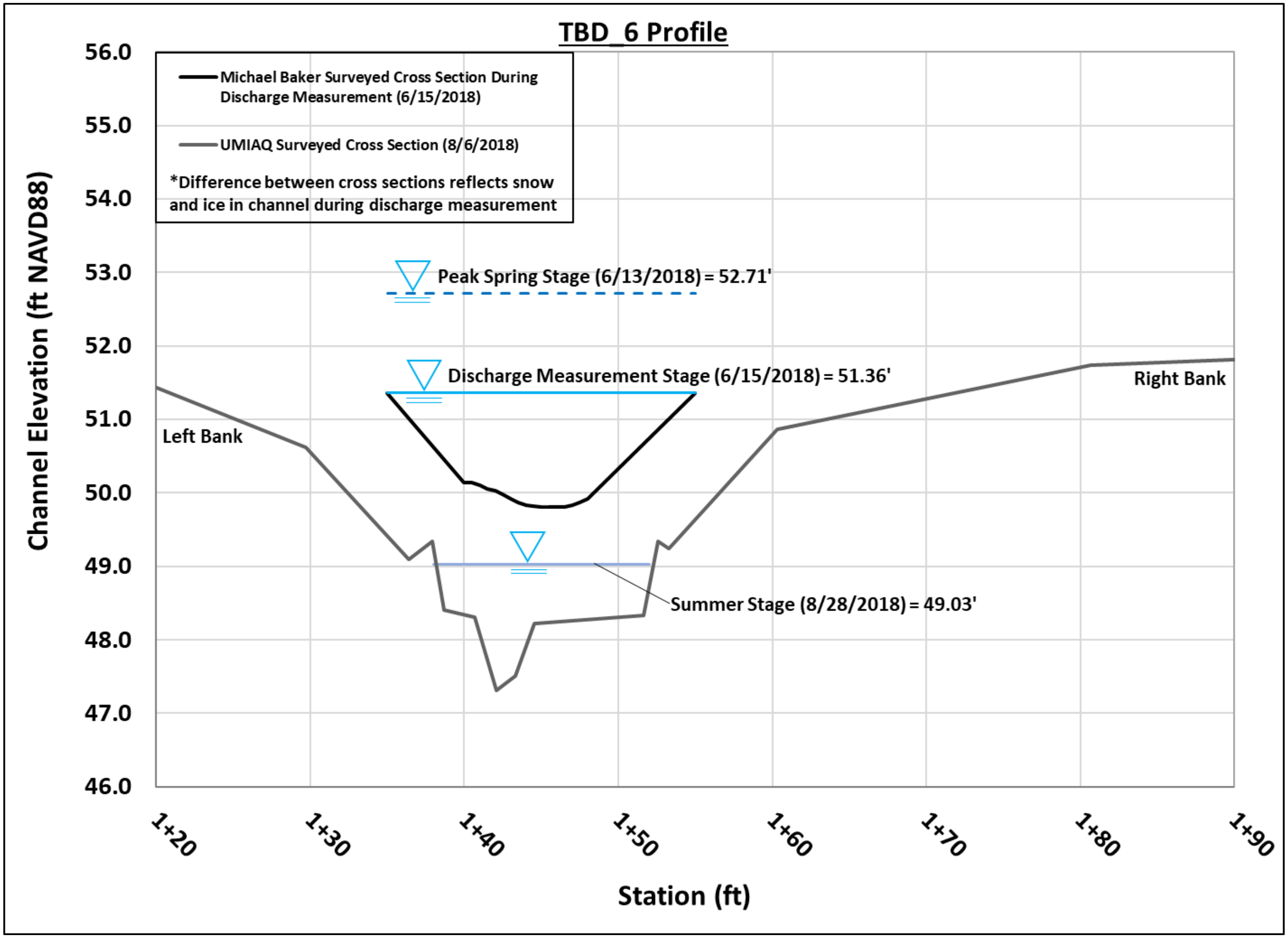
2018 Spring Breakup Willow 8 at TDB_6 Plan

FIGURE C.5

Spring Breakup Cross-Section Profile



C.6 WILLOW 2 AT UC1B

Spring Breakup Measured Discharge

Location: UC1B

Date & Time: June 13, 5:00 PM

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

Final Discharge (cfs): 120

Average Velocity (fps): 1.3

Measurement Rating: Fair

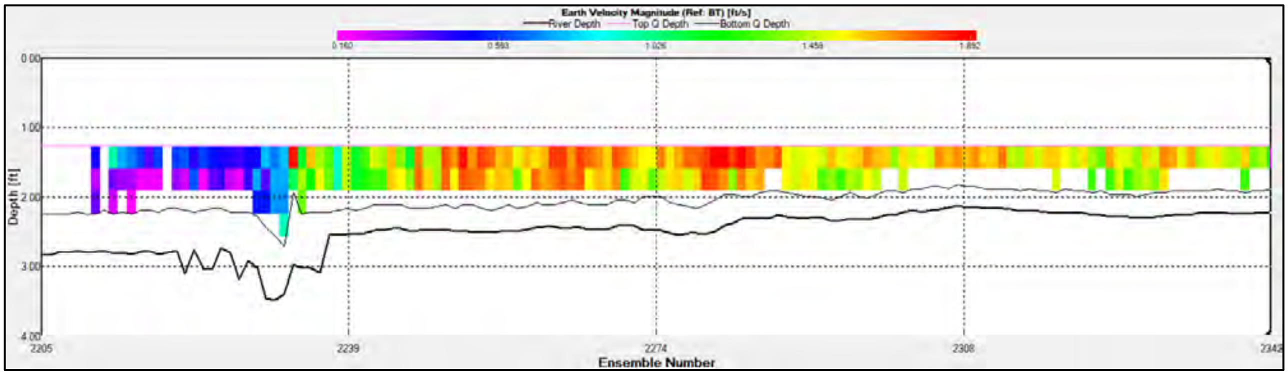
Measurement Notes: Moving bed conditions were identified as minimal and had no impact on the overall discharge measurement.

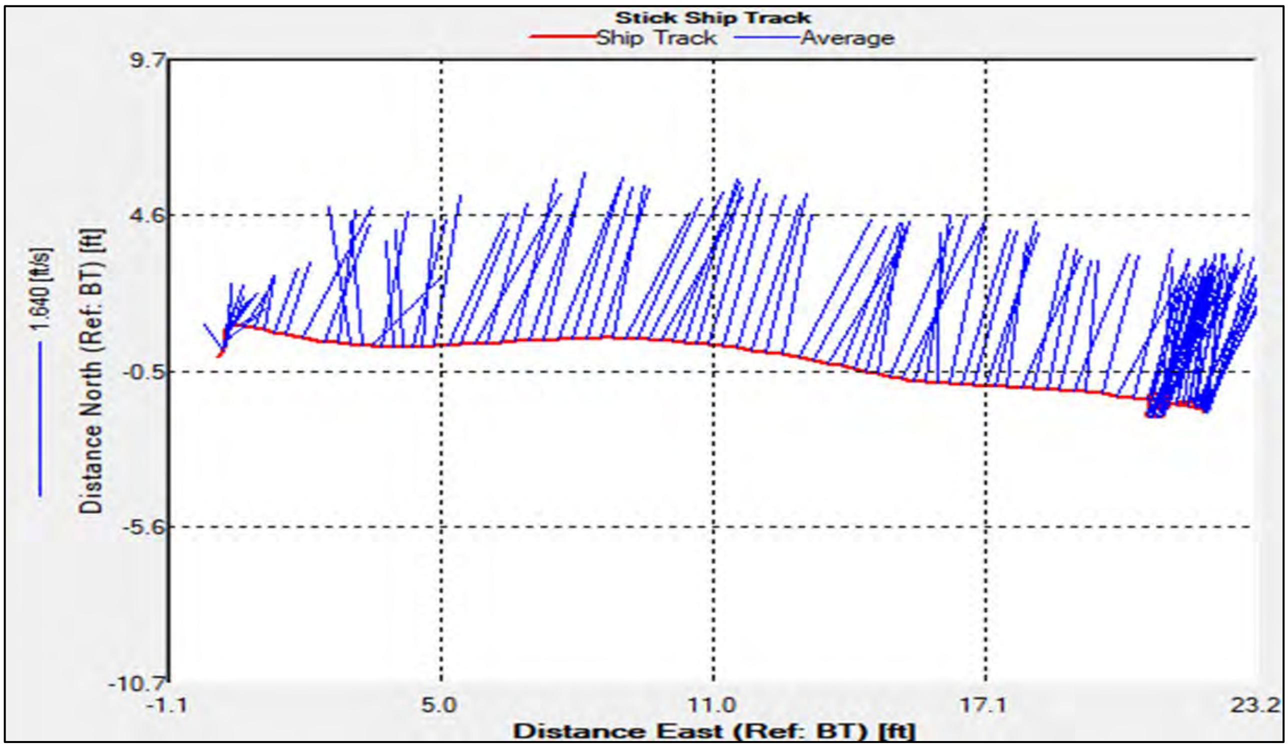
At the time of the discharge measurement, saturated snow remained in the bottom of the channel and along the banks. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on conditions at the time of measurement. The percentage of bad bottom track values (0%) were within the recommended 5% and factored into the overall quality rating of the measurement.

Table C.7: UC1B June 13 Spring Breakup Measured Discharge Summary

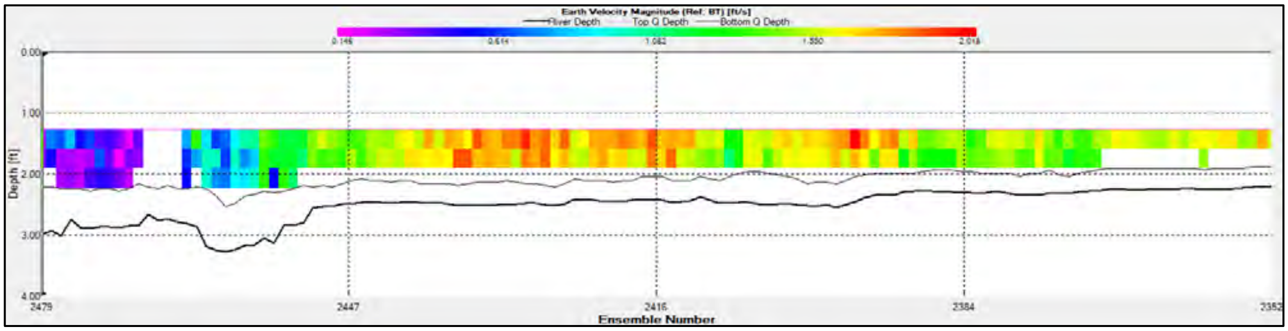
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
UC1B001	Left	115	-2.26%	21	-2.02%	66	88	109	1.05	1.31
UC1B002	Right	118	0.01%	21	0.73%	66	88	110	1.07	1.33
UC1B003	Left	119	1.22%	21	-1.98%	66	96	112	1.07	1.24
UC1B004	Left	119	1.03%	22	3.27%	66	88	109	1.09	1.36
Average		**118**		**21**		**66**		**110**	**1.07**	**1.31**

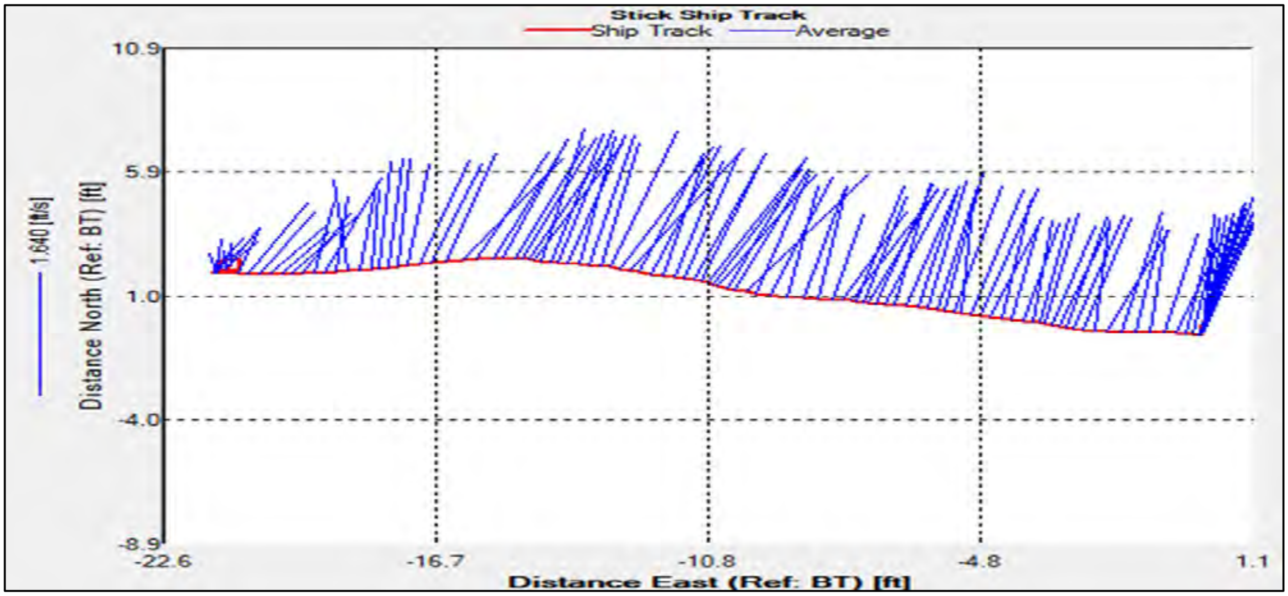
A. Transect UC1B001 Raw Data Output



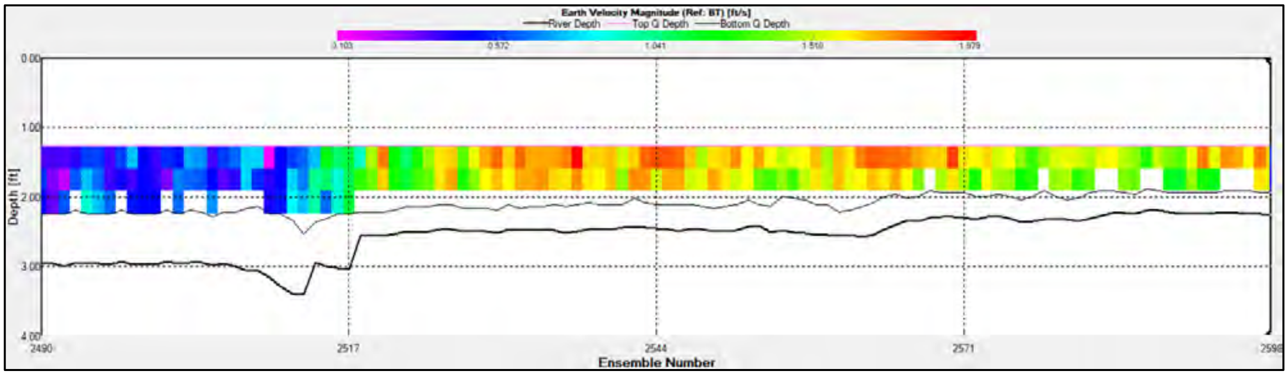


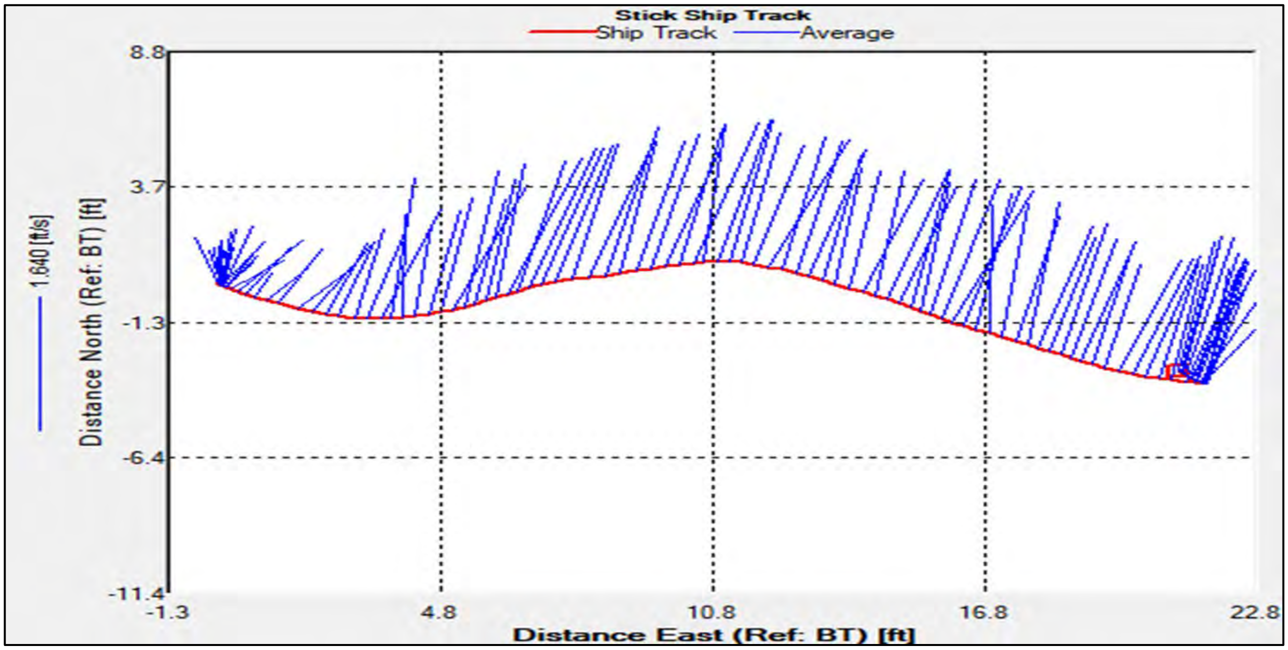
B. Transect UC1B002 Raw Data Output



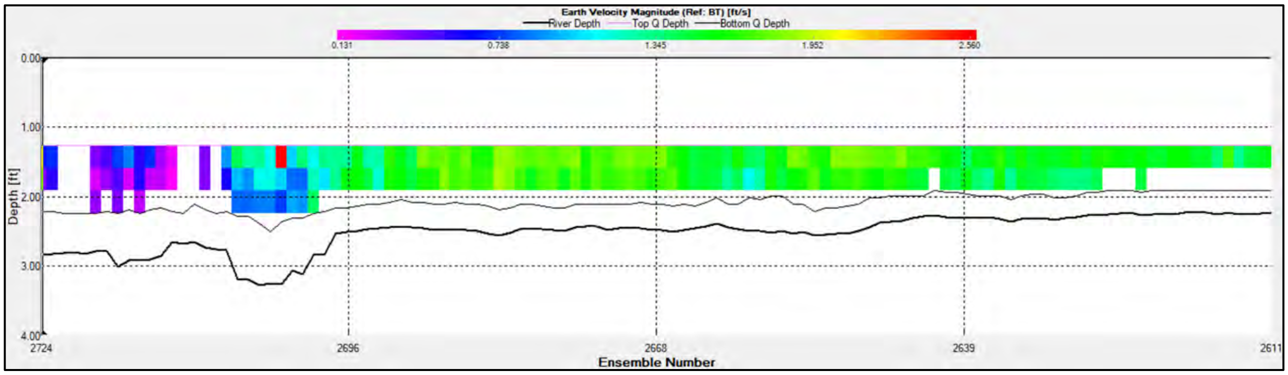


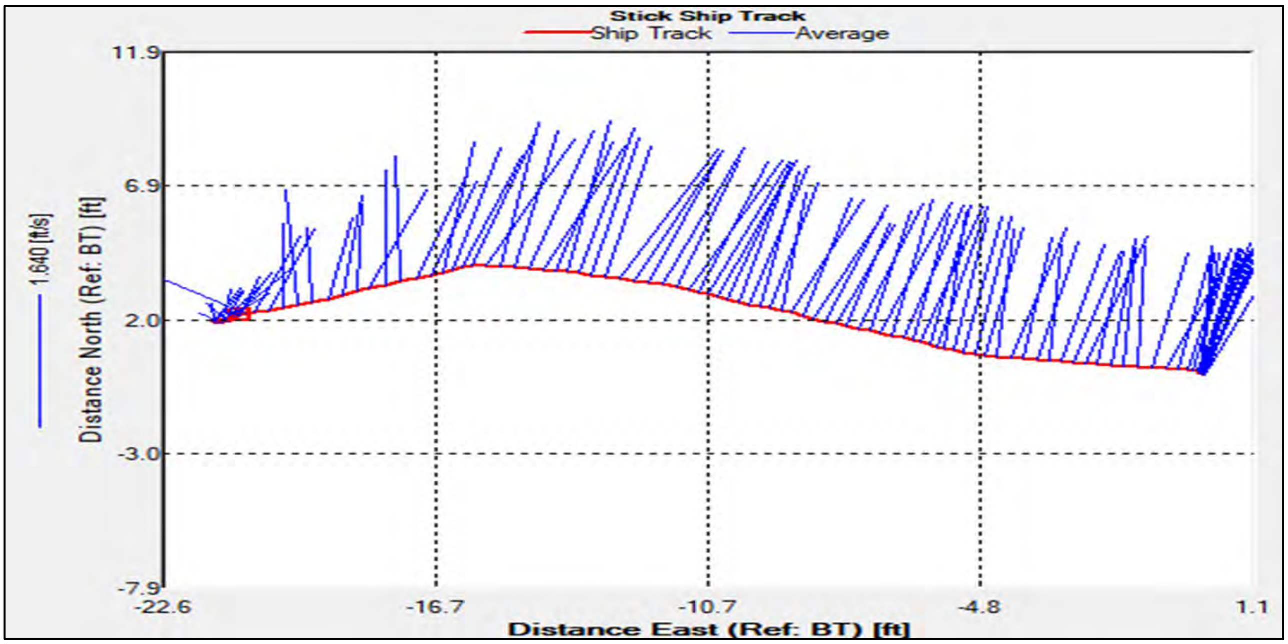
C. Transect UC1B003 Raw Data Output





D. Transect UC1B004 Raw Data Output





ConocoPhillips Alaska

0 200 400 Feet

Date: 11/13/2018	Project: 166429
Drawn: JEG	File: PlanView_UC1B.mxd
Checked: GCY	Scale: 1 Inch = 200 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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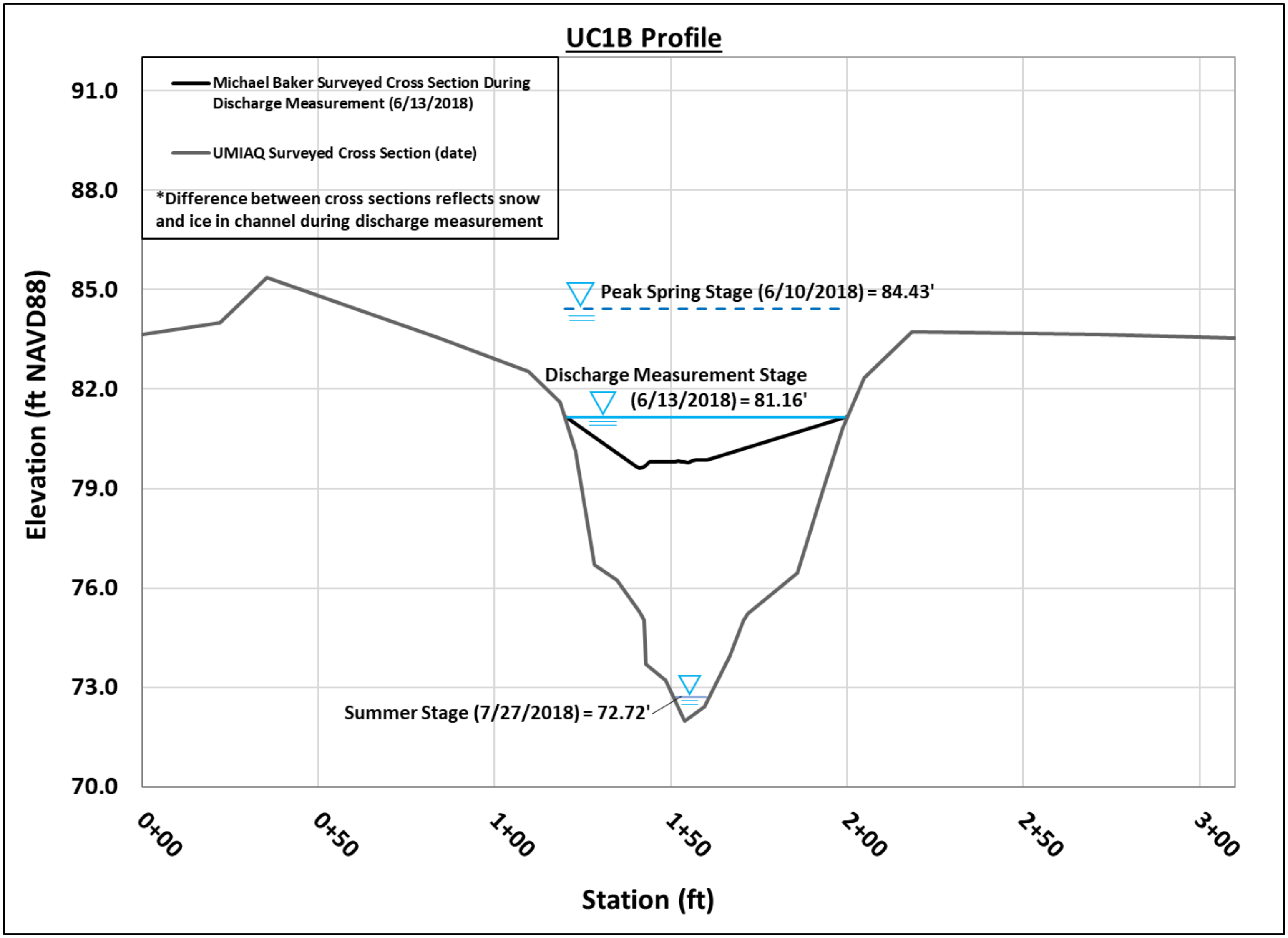
2018 Spring Breakup Willow 2 at UC1B Plan

FIGURE C.6

Spring Breakup Cross-Section Profile



C.7 JUDY CREEK KAYYAAQ AT UC2C

Spring Breakup Measured Discharge

Location: UC2C

Date & Time: June 11, 3:15 PM

Equipment: RiverRay ADCP mounted in a trimaran tethered to a tag line and pulled across the channel and HACH FH950 electromagnetic velocity meter attached to a wading rod.

Final Discharge (cfs): 140

Average Velocity (fps): 0.9

Measurement Rating: Fair

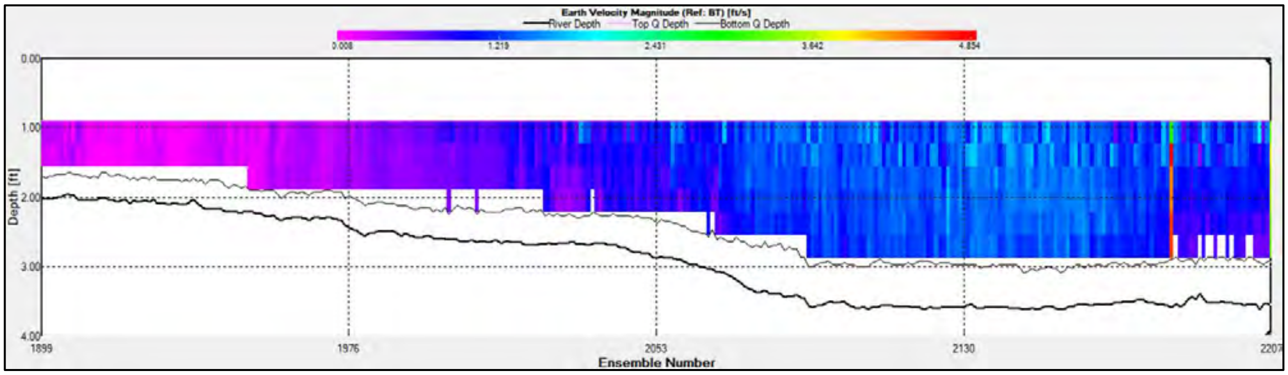
Measurement Notes: Moving bed conditions were identified as minimal and had no impact on the overall discharge measurement.

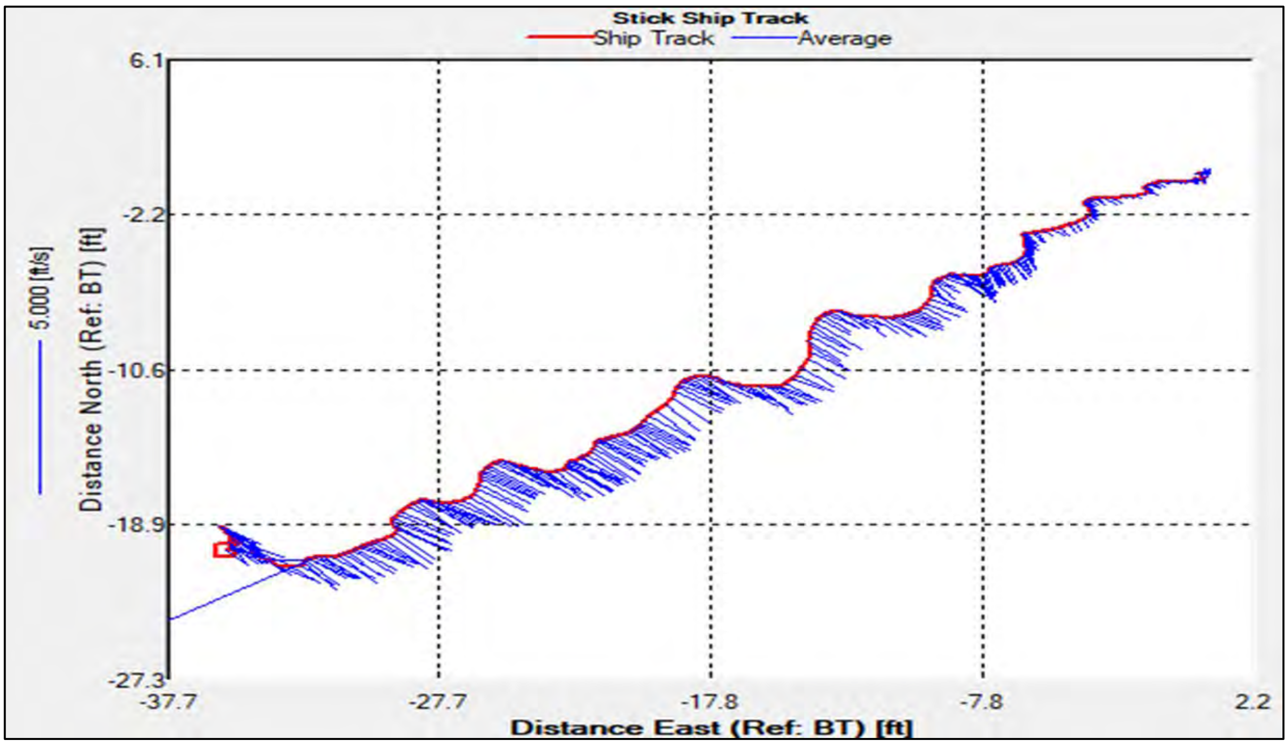
At the time of the measurement, the creek was mostly clear of snow and ice, with some submerged snow along the banks of the channel. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on the overbank flooding and width of the drainage. The percentage of bad bottom track values (0%) were within the recommended 5% and factored into the overall quality rating of the measurement. Observed overbank flow was measured using the HACH velocity meter and added to the ADCP measured discharge to get the reported discharge number. The supplemental overbank flow discharge is presented in Table C.9.

Table C.8: UC2C June 11 Spring Breakup Measured Discharge Summary

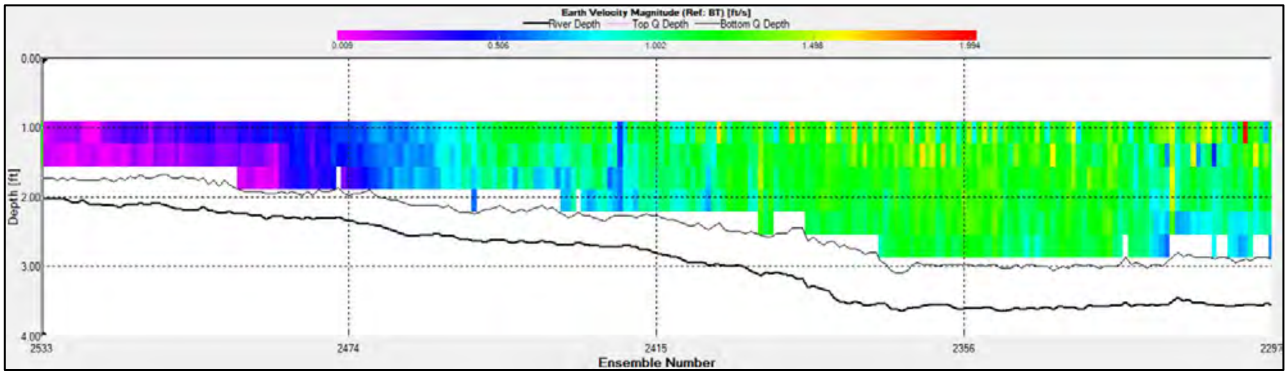
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
UC2C001	Left	133	-0.12%	60	0.18%	71	141	168	0.79	0.94
UC2C002	Right	132	-0.70%	58	-2.79%	70	143	166	0.80	0.93
UC2C003	Left	133	-0.21%	59	-0.12%	69	145	163	0.81	0.91
UC2C004	Right	134	1.03%	61	2.73%	69	152	160	0.84	0.89
Average		**133**		**59**		**70**		**164**	**0.81**	**0.92**

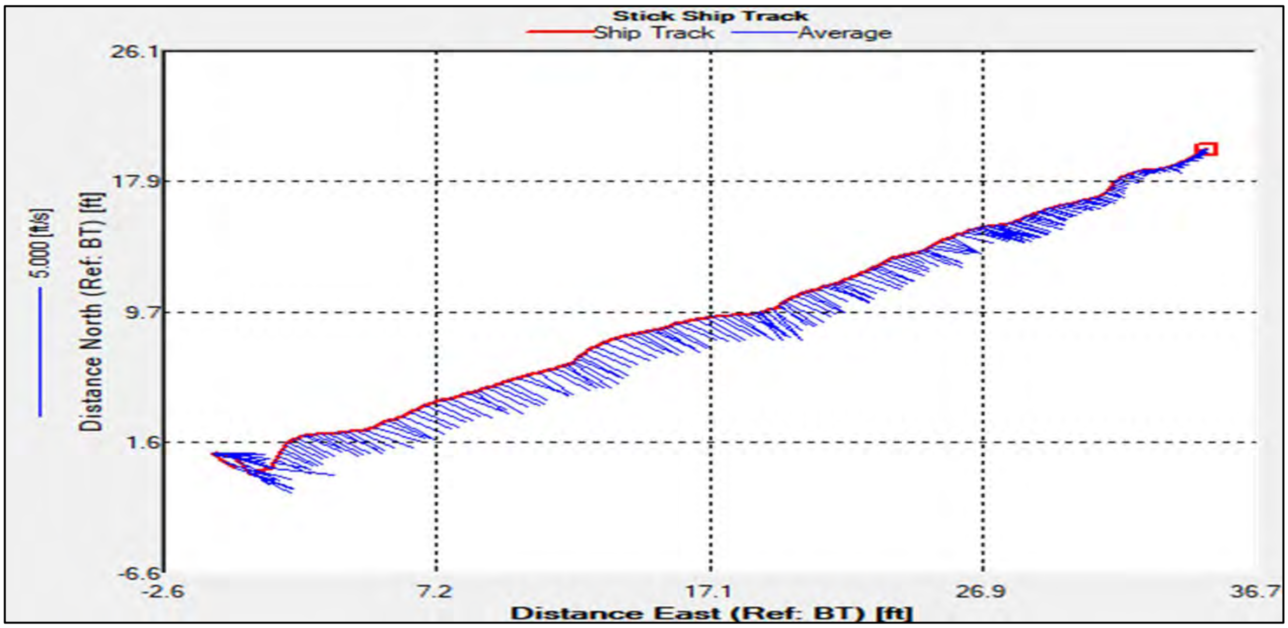
A. Transect UC2C001 Raw Data Output



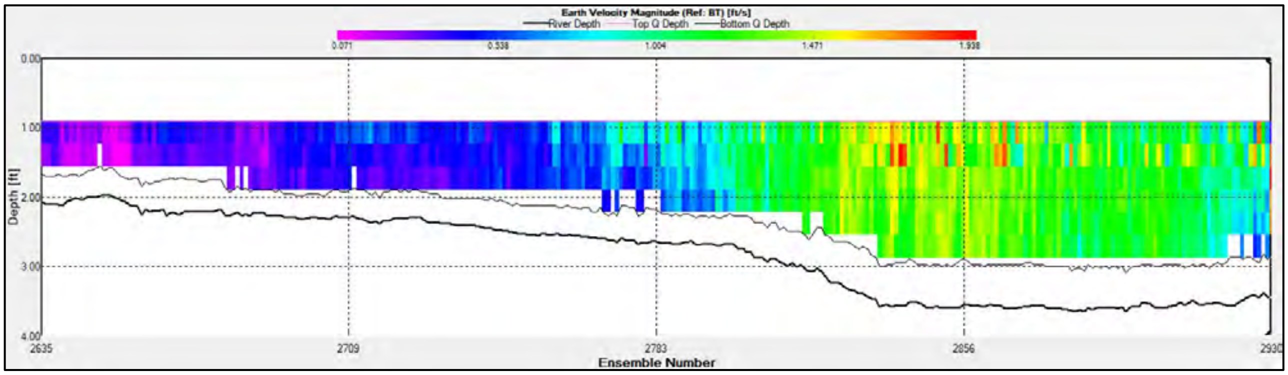


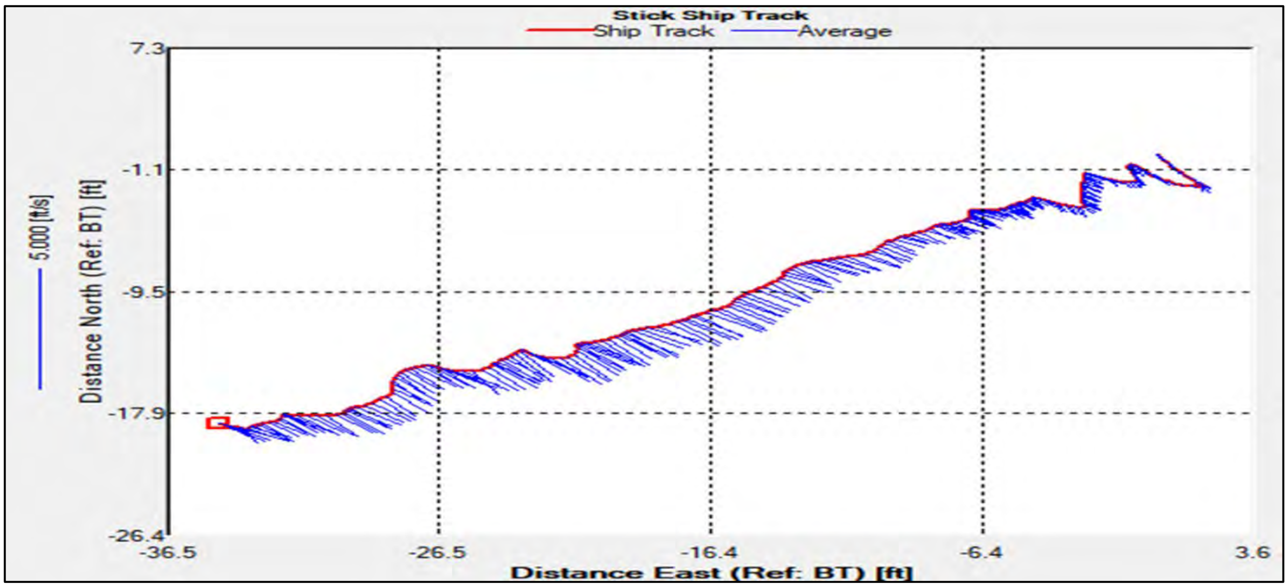
B. Transect UC2C002 Raw Data Output



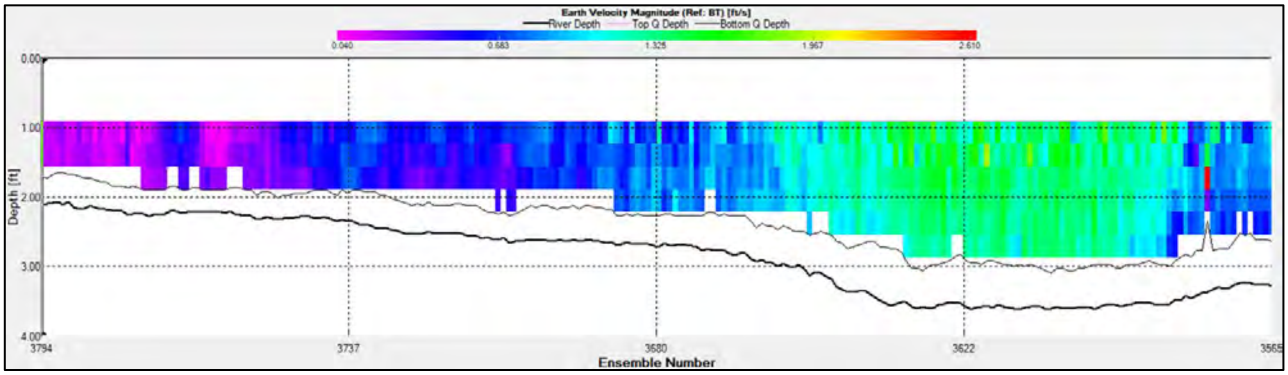


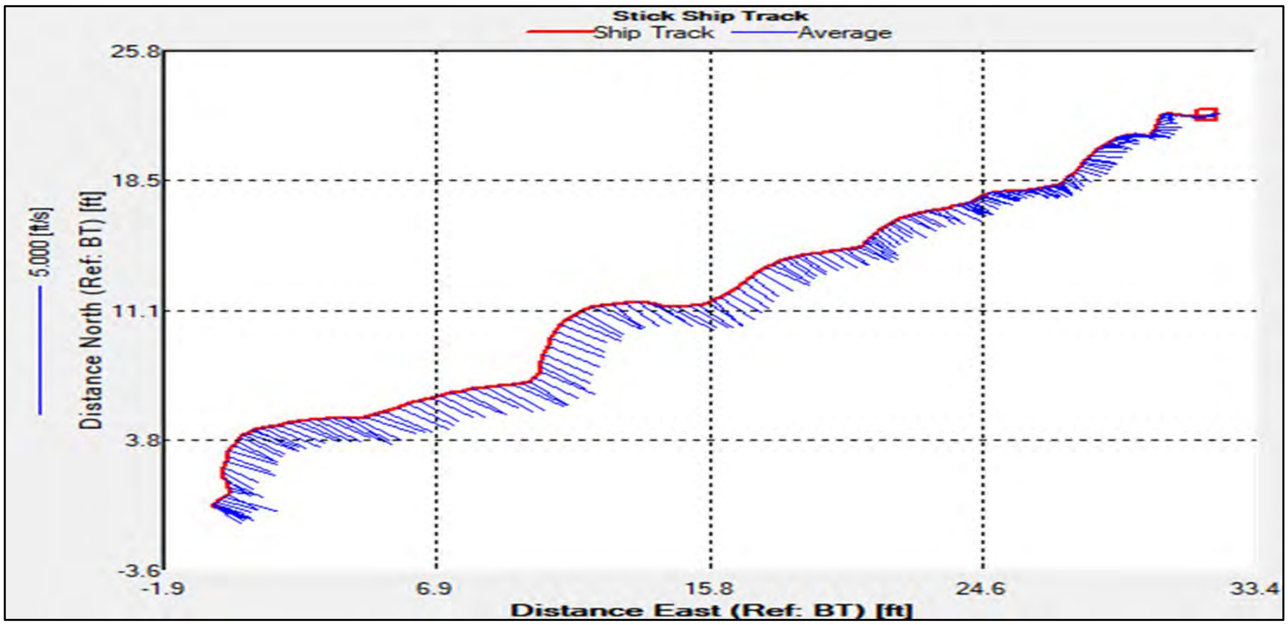
C. Transect UC2C003 Raw Data Output





D. Transect UC2C004 Raw Data Output





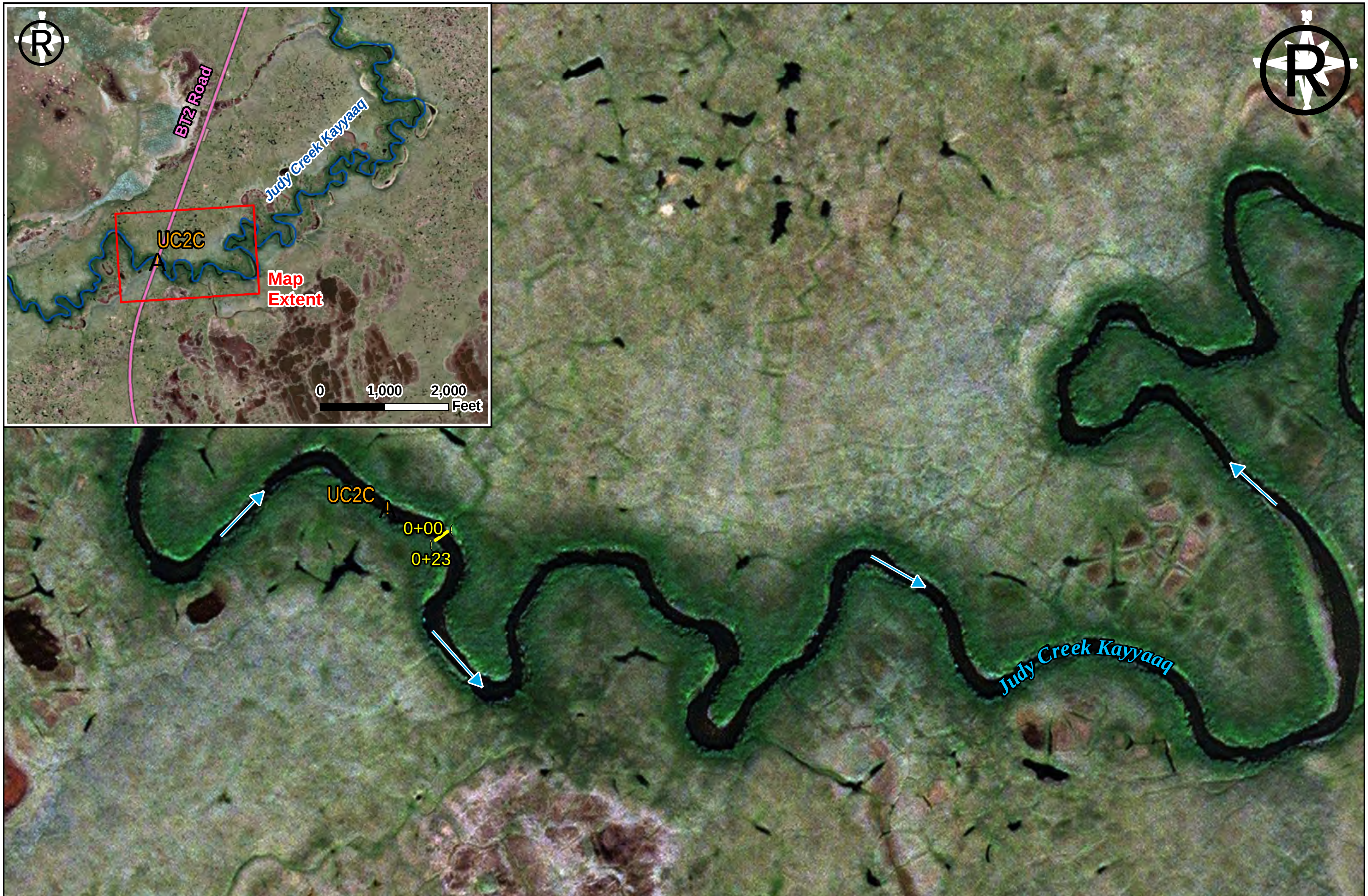
Supplemental Overbank Flow Discharge

Table C.9: UC2C Spring Breakup Measured Discharge Summary

Date:	6/11/2018	**Time:**	4:00 PM	**Method:**	USGS Midsection
Location:	UC2C	**Crew:**	KDB, GCY, SAO	**Depth:**	0.6 of measured depth
Lat:	N 70.1846°	**Long:**	W 152.119°	**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	53.69	-	-	-	-	-	LEFT BANK, lots of grass and willows
0+03.5	52.79	0.9	0.05	1	0.90	0.04	
0+05.0	52.69	1	0.11	1.75	1.75	0.19	
0+07.0	52.19	1.5	0.20	2	3.00	0.59	
0+09.0	51.59	2.1	0.15	1.5	3.15	0.48	
0+10.0	51.49	2.2	0.16	1	2.20	0.34	
0+11.0	51.49	2.2	0.18	1	2.20	0.39	
0+12.0	51.49	2.2	0.17	1	2.20	0.37	
0+13.0	51.59	2.1	0.11	1.5	3.15	0.36	
0+15.0	51.79	1.9	0.16	2	3.80	0.60	
0+17.0	52.29	1.4	0.15	2	2.80	0.42	
0+19.0	52.99	0.7	0.07	2	1.40	0.10	
0+21.0	52.79	0.9	0.02	2	1.80	0.04	
0+23.0	53.69	-	-	-	-	-	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)
20.0	52.09	1.6	0.13	-	28.4	3.9



ConocoPhillips Alaska

0 200 400 Feet

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_UC2C.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

A Gage Location

Flow Direction

(Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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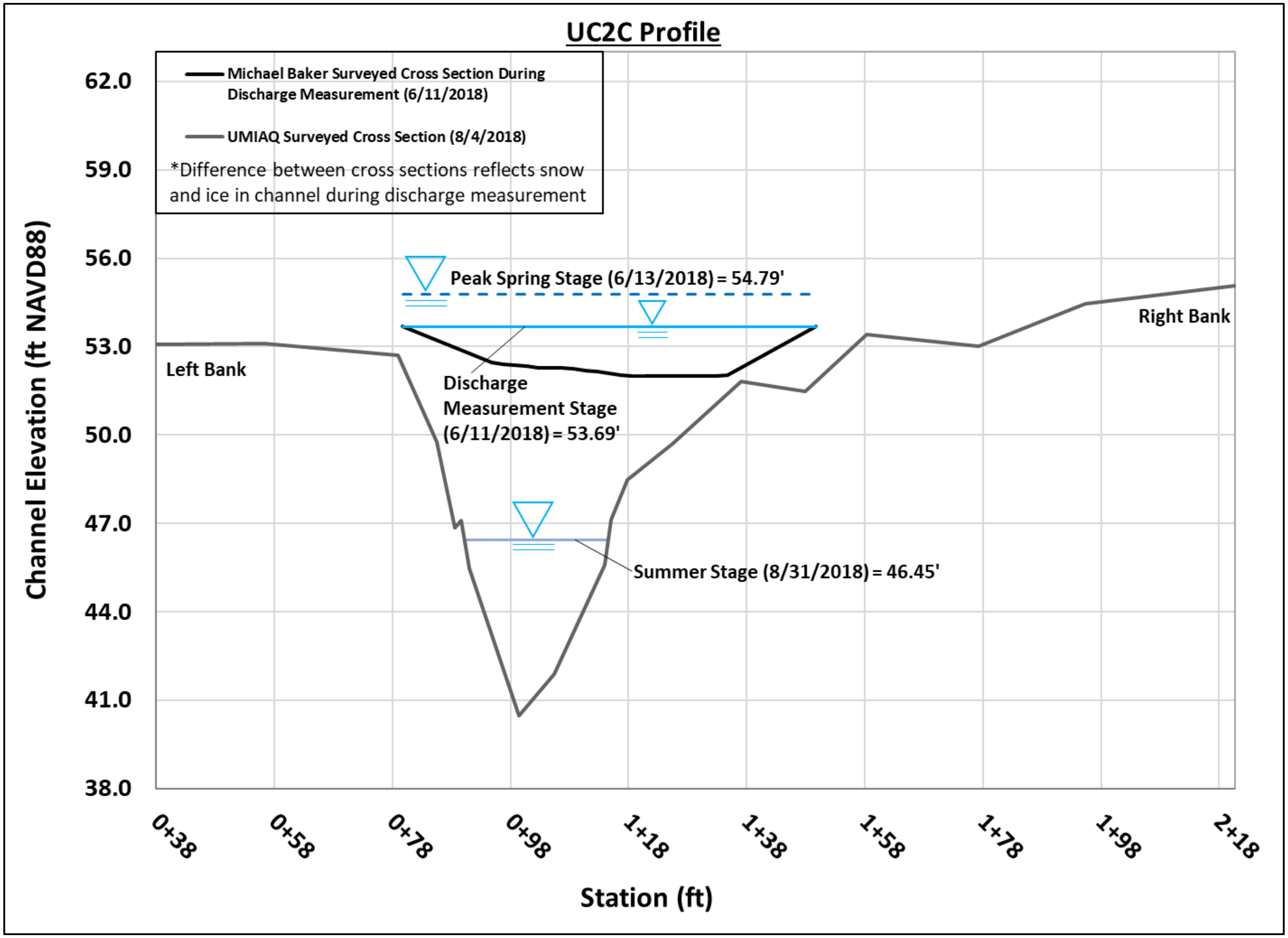
2018 Spring Breakup Judy Creek Kayyaaq at UC2C Plan

FIGURE C.7

Spring Breakup Cross-Section Profile



C.8 WILLOW 4 AT W_BS1

Spring Breakup Measured Discharge

Location: W_BS1

Date & Time: June 8, 1:00 PM

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

Final Discharge (cfs): 240

Average Velocity (fps): 1.7

Measurement Rating: Fair

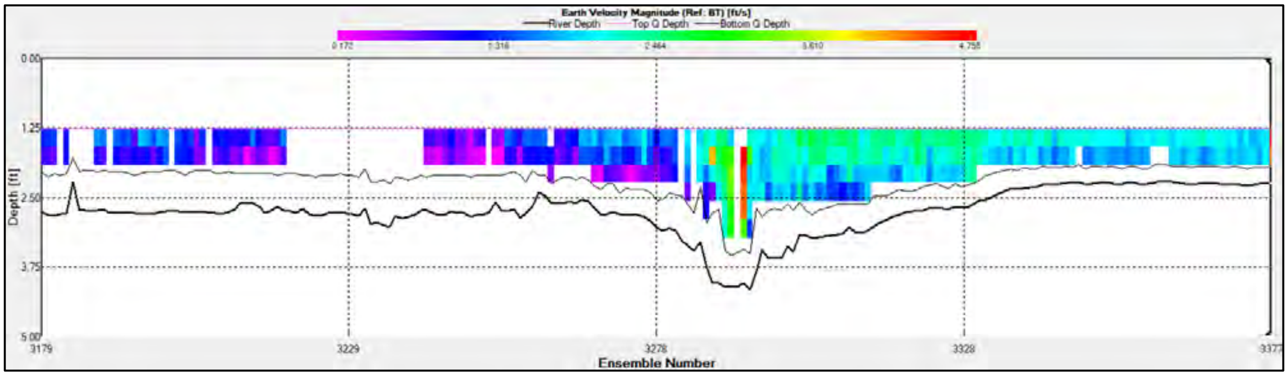
Measurement Notes: Moving bed conditions were identified as minimal and had no impact on the overall discharge measurement.

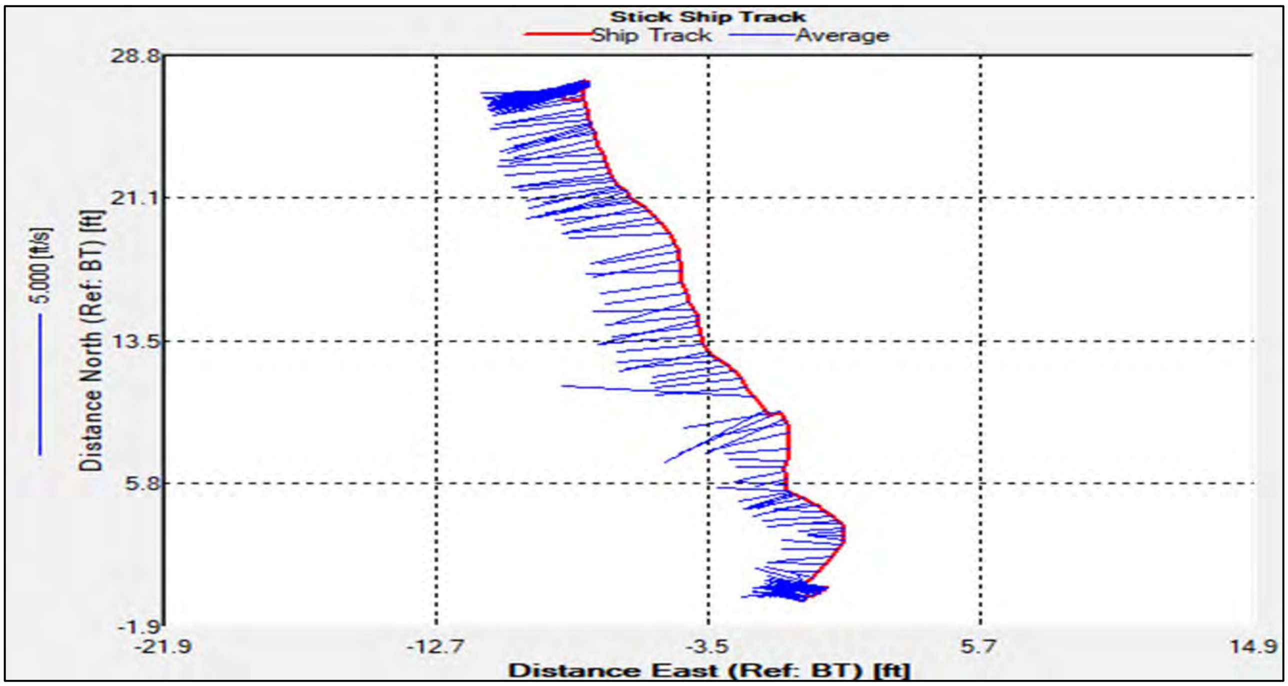
At the time of the measurement, the river was mostly clear of snow and ice with intermittent ice floes and some snow along the right bank. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on conditions at the time of the measurement. The percentage of bad bottom track values (3.7%) were within the recommended 5% and factored into the overall quality rating of the measurement.

Table C.10: W_BS1 June 8 Spring Breakup Measured Discharge Summary

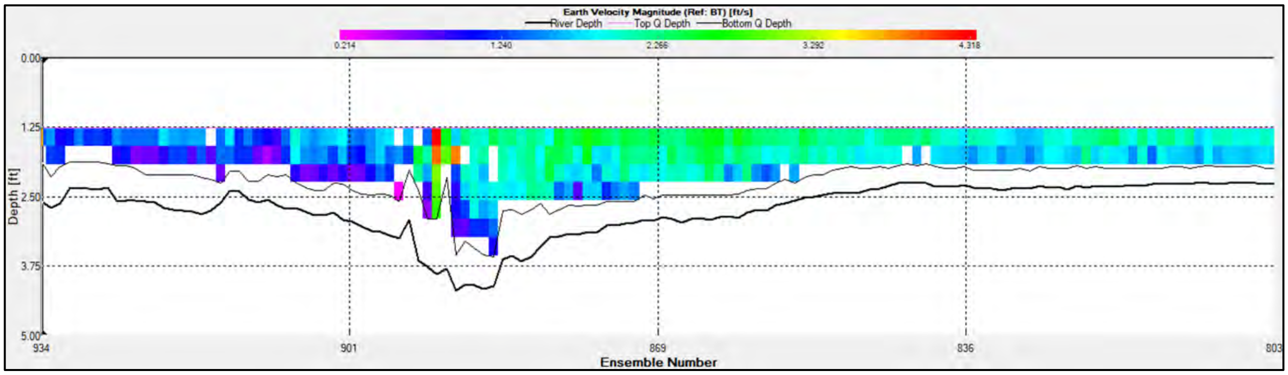
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
W_BS1000	Left	242	0.80%	58	4.18%	93	149	168	1.44	1.63
W_BS1005	Right	245	1.84%	58	4.97%	95	138	169	1.45	1.77
W_BS1006	Left	238	-0.74%	52	-6.35%	91	143	164	1.45	1.67
W_BS1007	Right	236	-1.89%	54	-2.80%	94	141	170	1.38	1.67
Average		**240**		**56**		**93**		**168**	**1.43**	**1.68**

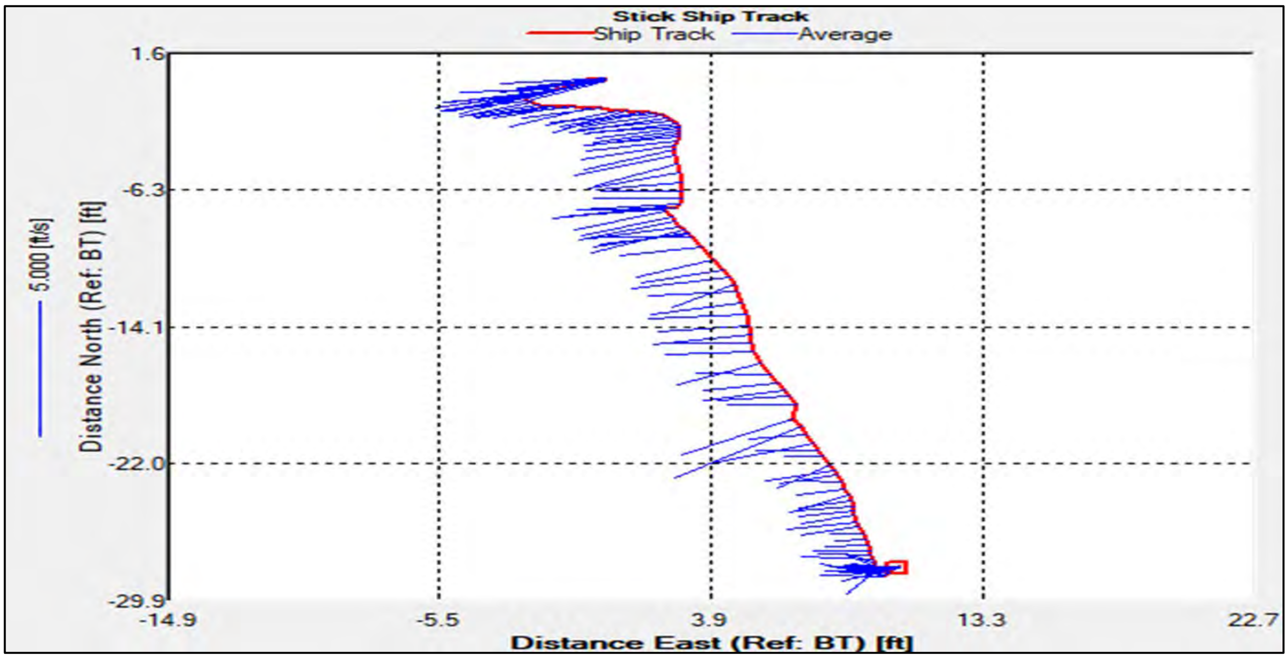
A. Transect WBS1000 Raw Data Output



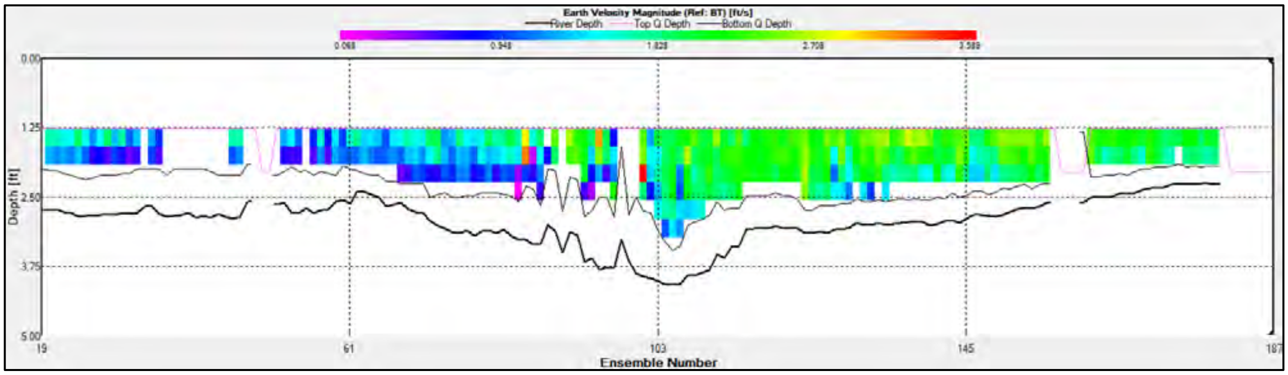


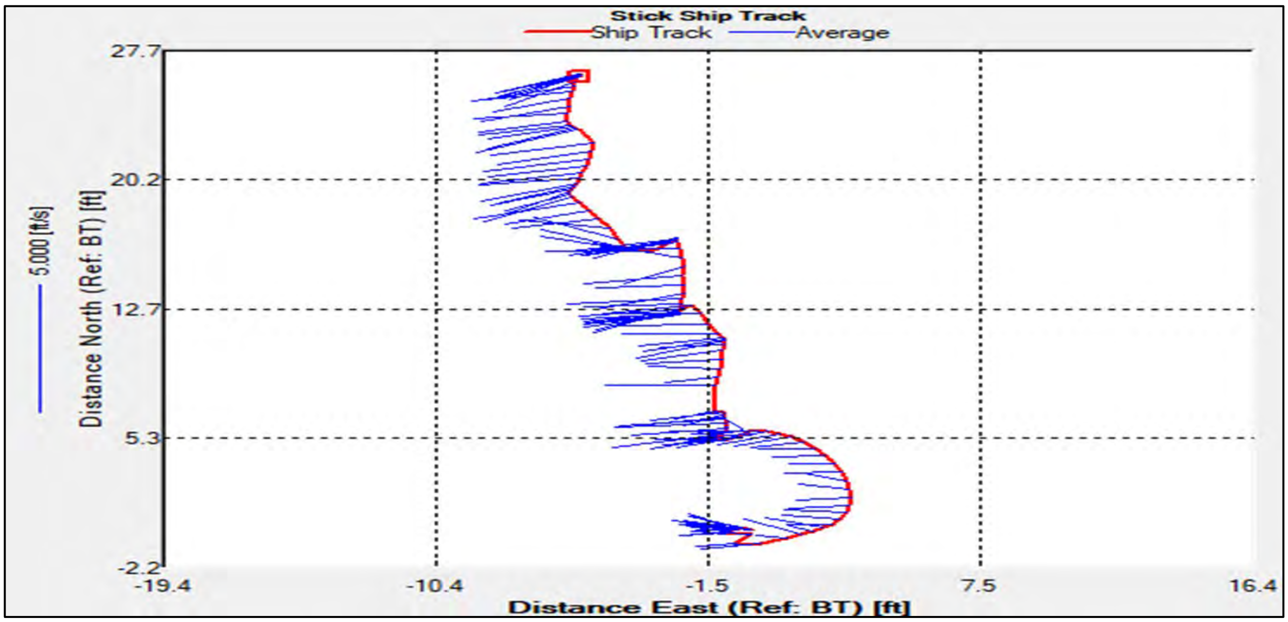
B. Transect WBS1005 Raw Data Output



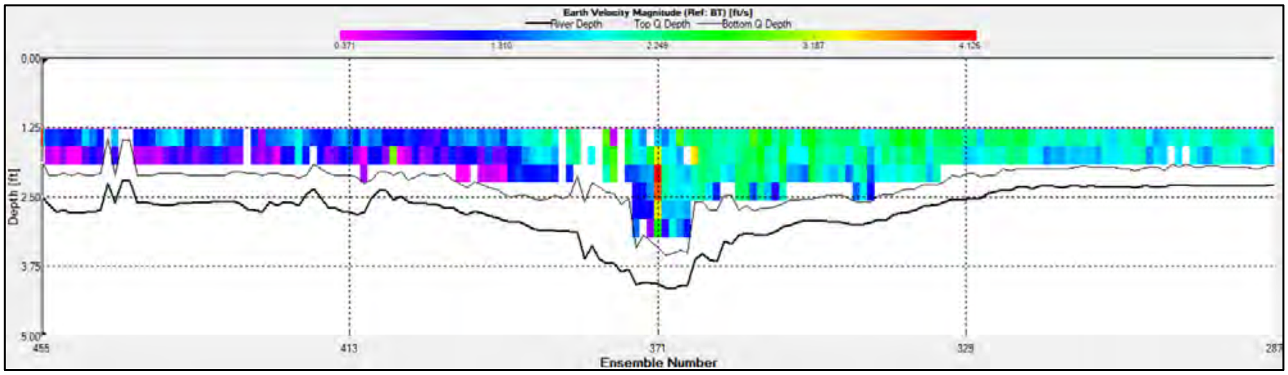


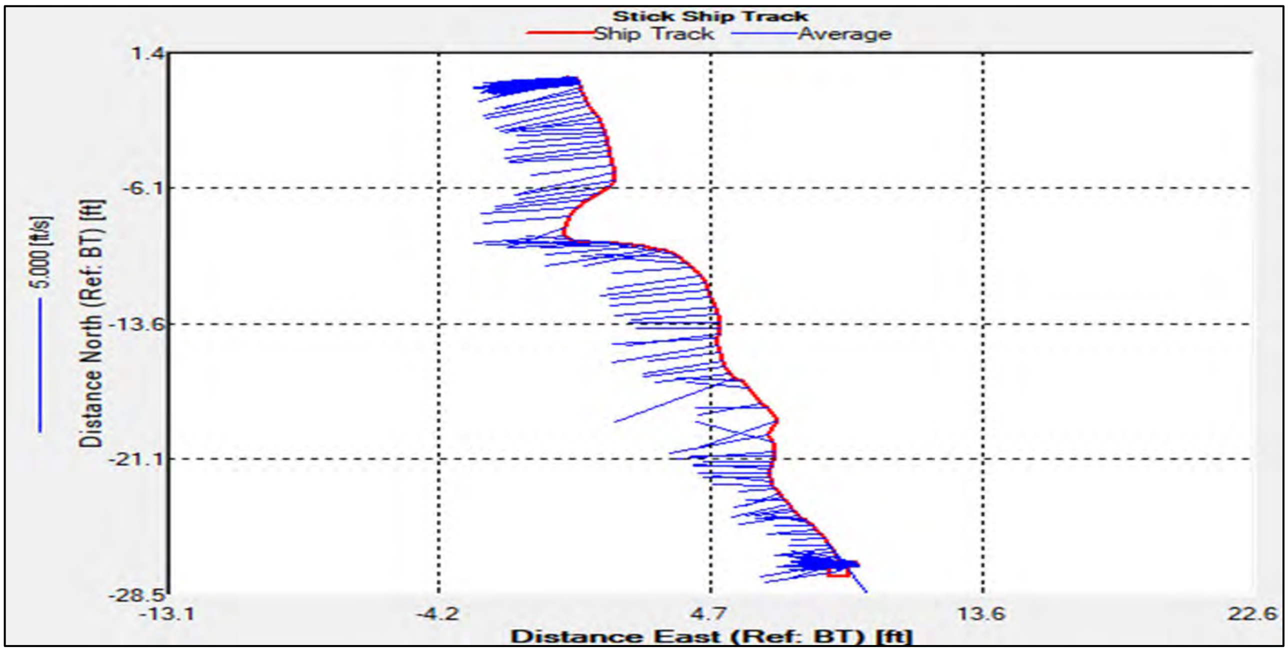
C. Transect WBS1006 Raw Data Output

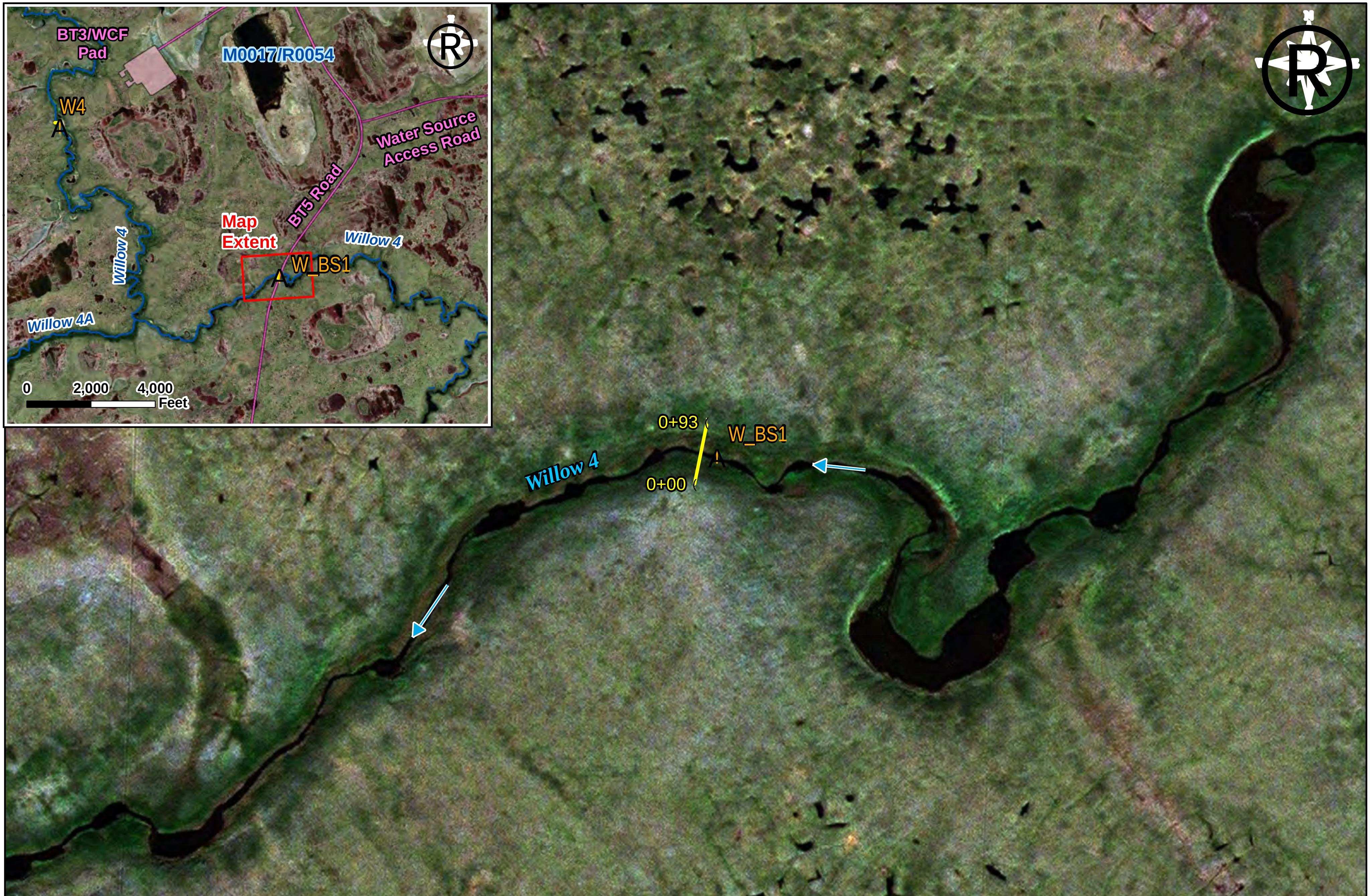




D. Transect WBS1007 Raw Data Output







ConocoPhillips Alaska

Feet
0 200 400

Date:	12/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_W_BS1.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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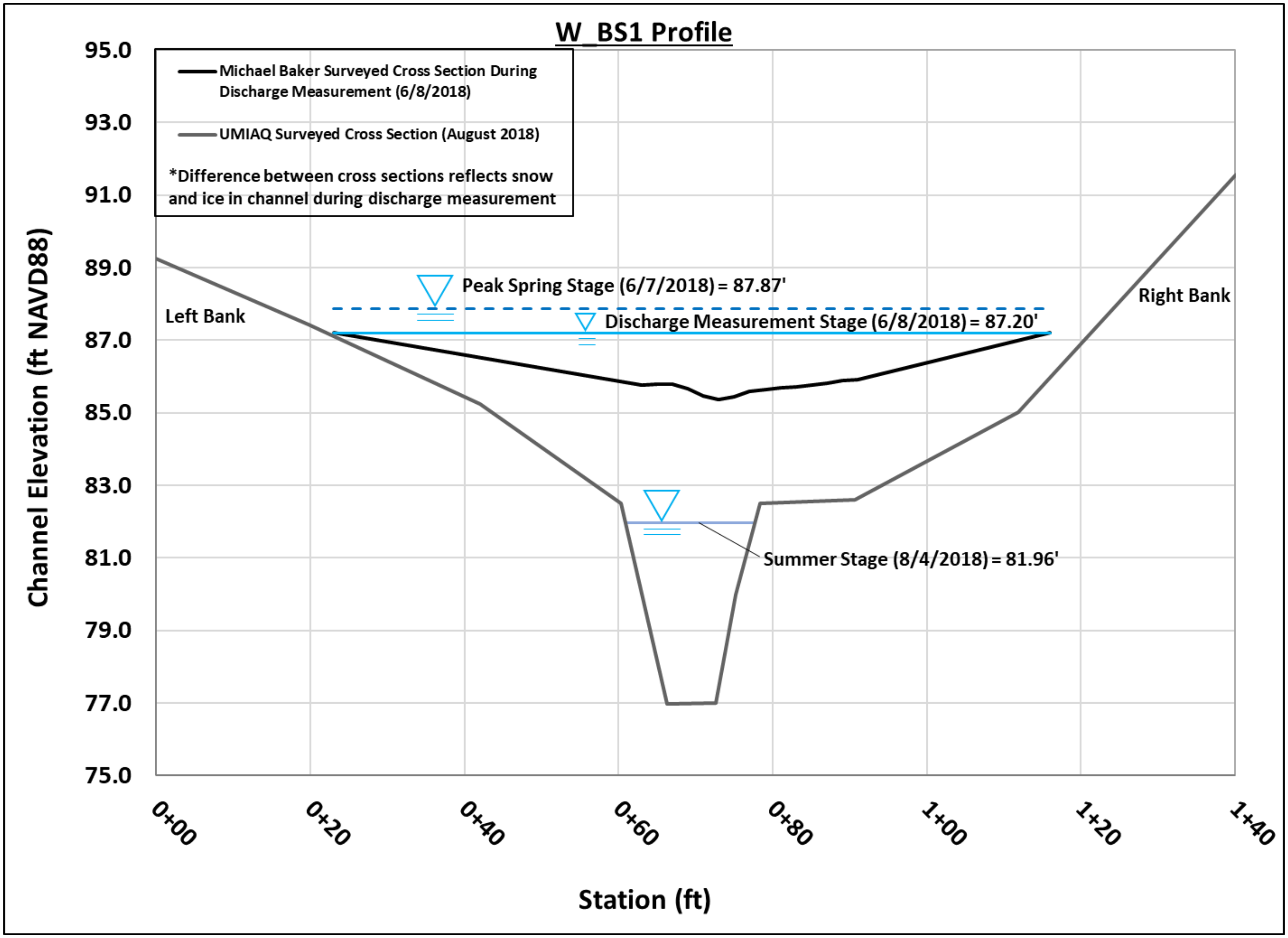
Phone: (907) 273-1600
Fax: (907) 273-1699

2018 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 11, 12:00 PM

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

Final Discharge (cfs): 600

Average Velocity (fps): 2.5

Measurement Rating: Fair

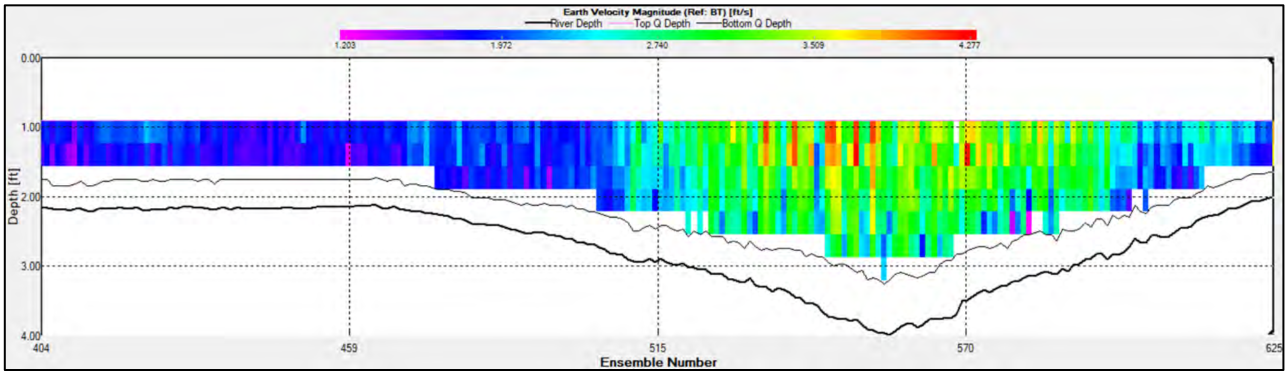
Measurement Notes: Moving bed conditions were identified as minimal and had no impact on the overall discharge measurement.

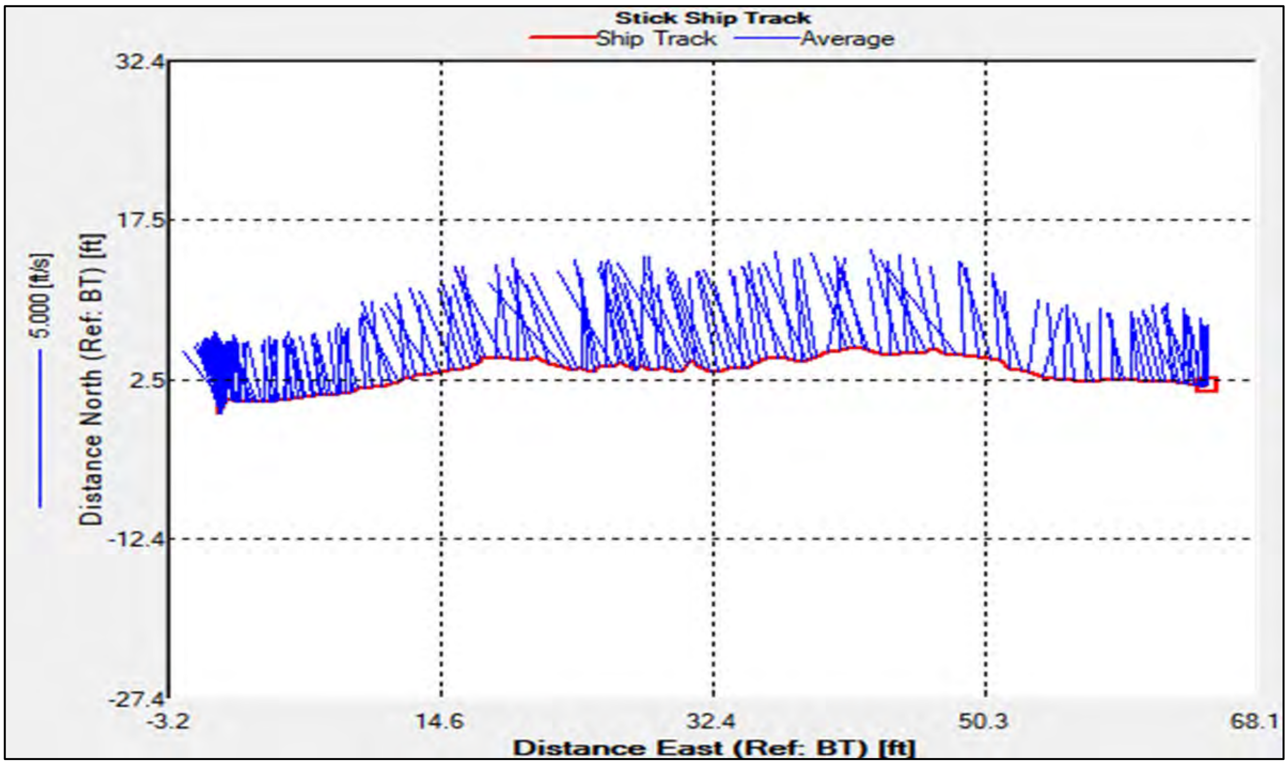
At the time of the measurement, the river banks were covered in snow and floodwater but was clear of ice floes. Prior to deployment, diagnostic tests were performed, and the internal compass calibrated. The overall discharge measurement is considered fair based on snow-influenced channel conditions. The percentage of bad bottom track values (2.4%) were within the recommended 5% and factored into the overall quality rating of the measurement.

Table C.11: W4 June 11 Spring Breakup Measured Discharge Summary

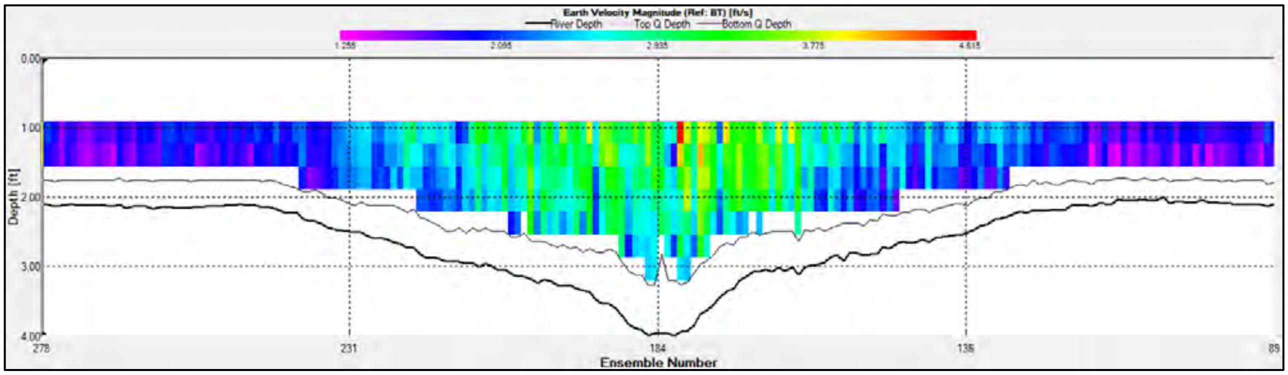
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
W4000	Left	605	1.32%	241	0.36%	133	243	269	2.25	2.49
W4001	Right	590	-1.24%	236	-1.64%	132	243	263	2.24	2.43
W4002	Left	599	0.31%	242	0.61%	133	238	270	2.22	2.52
W4003	Right	603	1.02%	238	-1.11%	132	235	266	2.27	2.57
W4004	Left	589	-1.41%	244	1.78%	133	239	270	2.18	2.47
Average		**597**		**240**		**133**		**268**	**2.23**	**2.49**

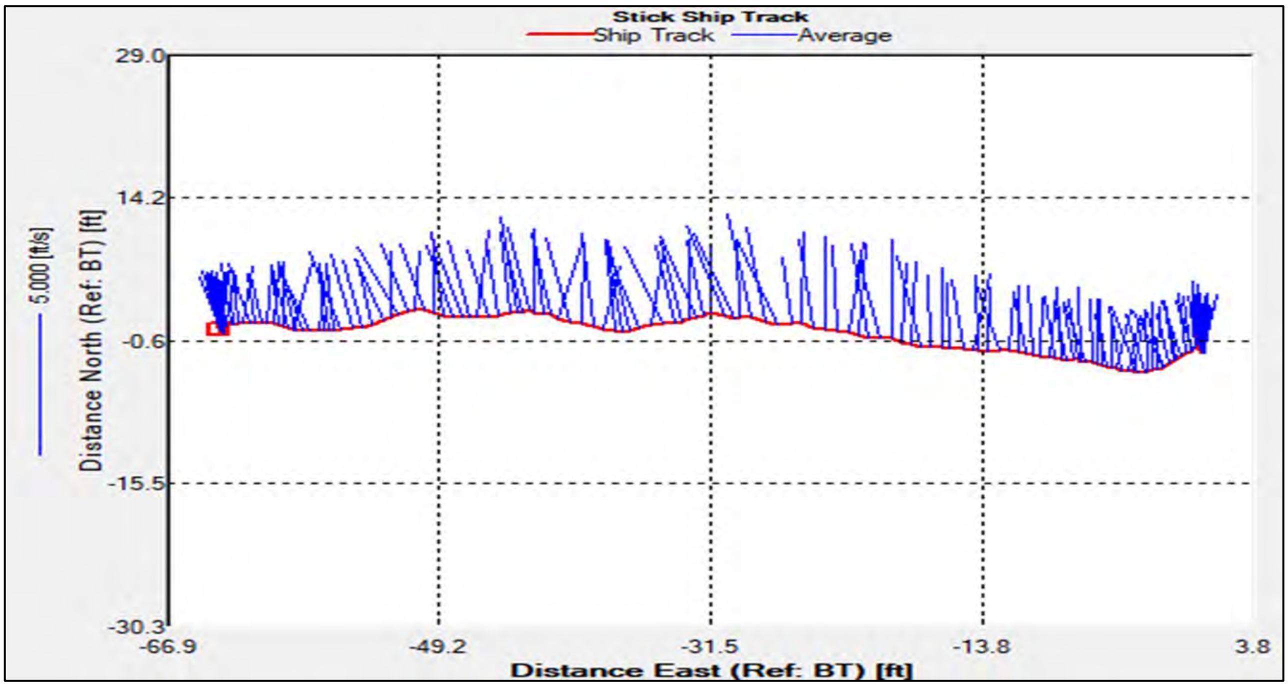
A. Transect W4000 Raw Data Output



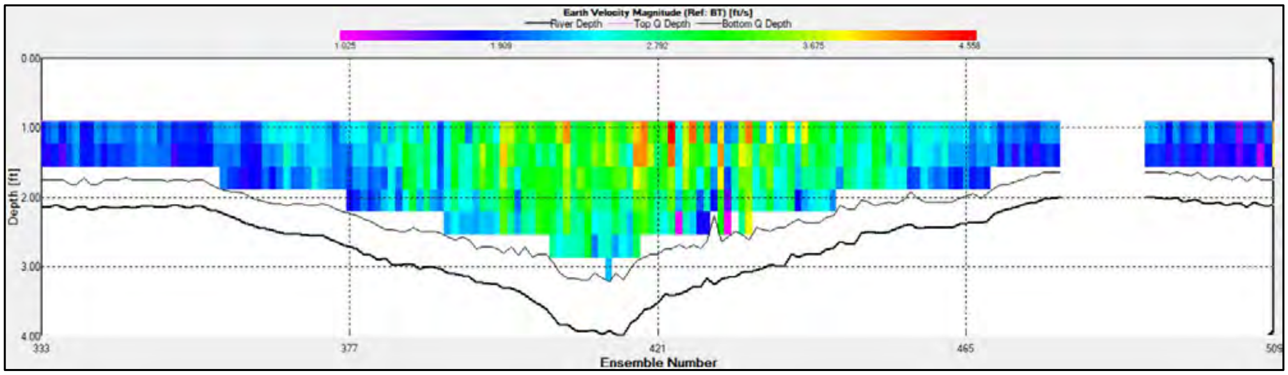


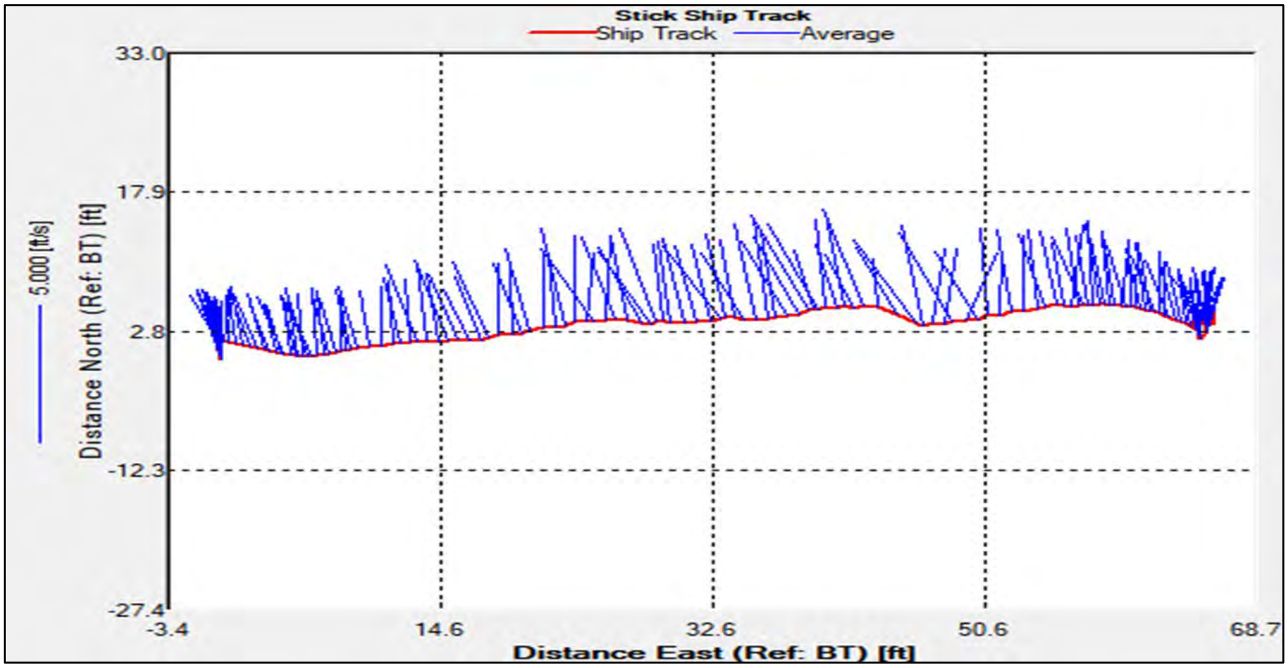
B. Transect W4001 Raw Data Output



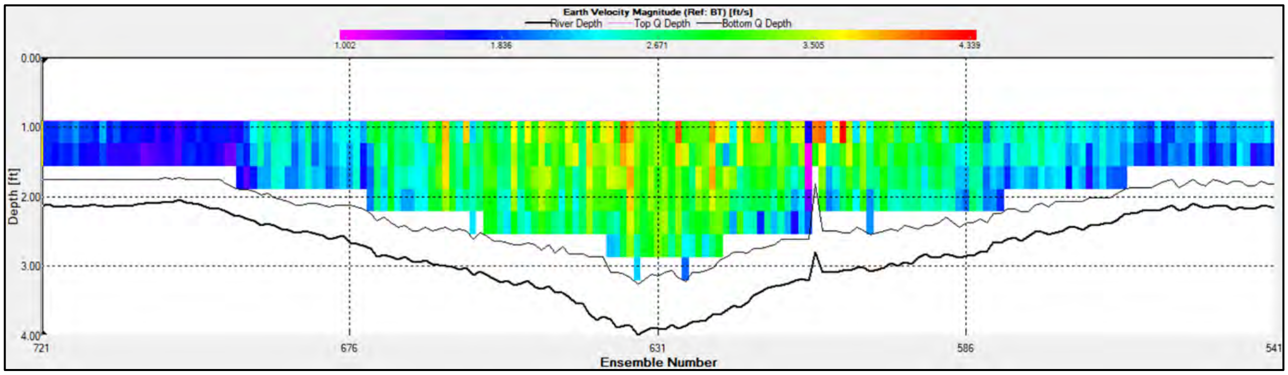


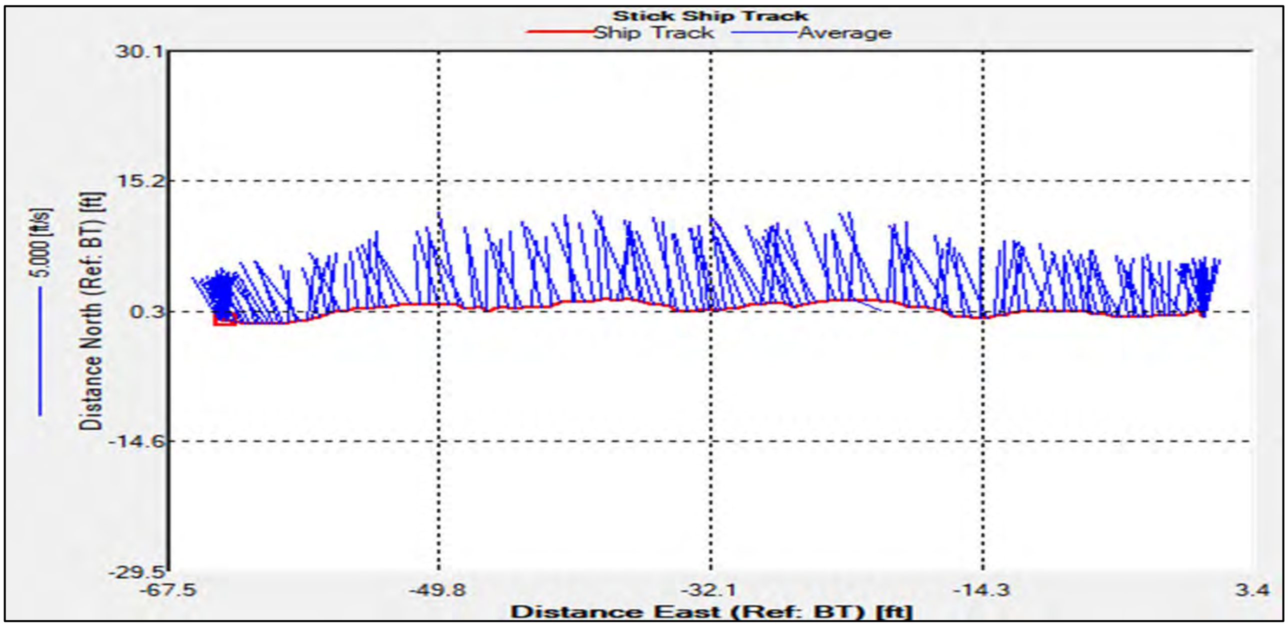
C. Transect W4002 Raw Data Output



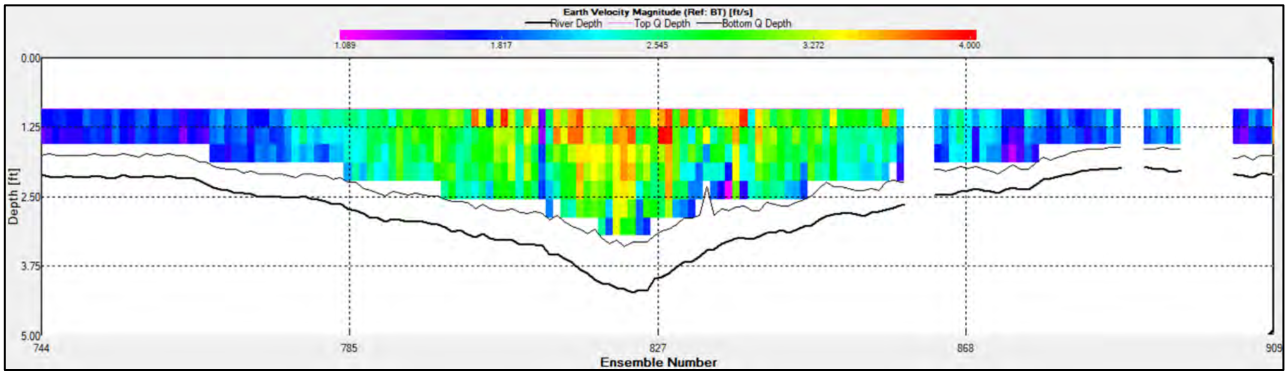


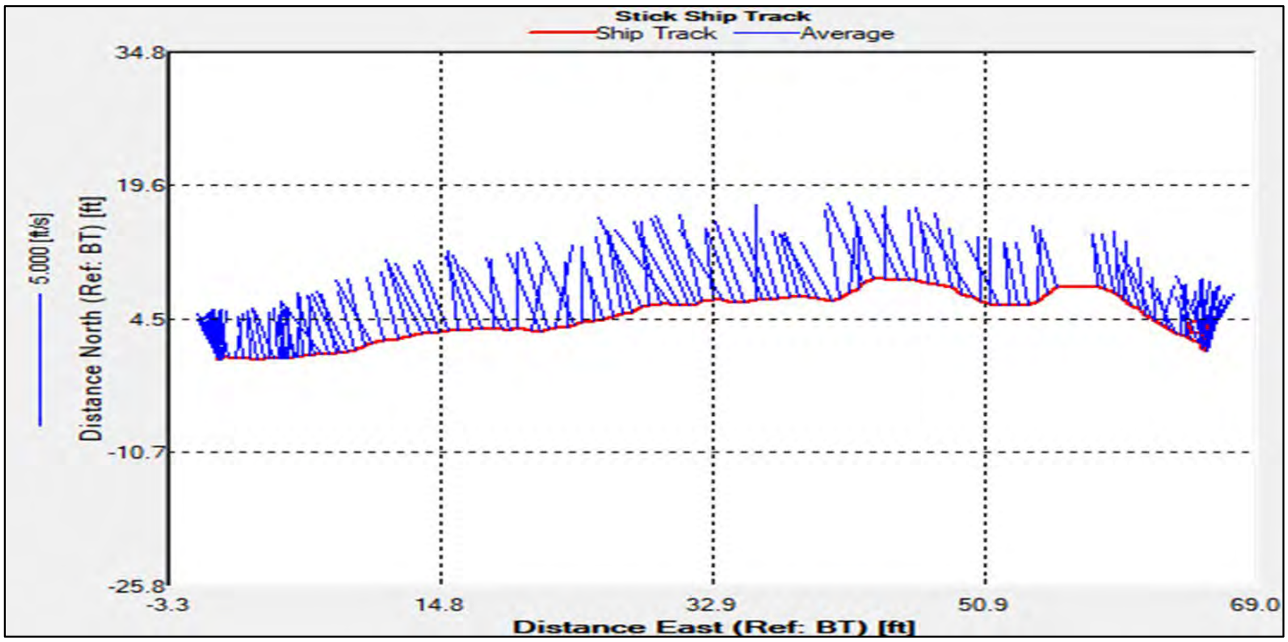
D. Transect W4003 Raw Data Output

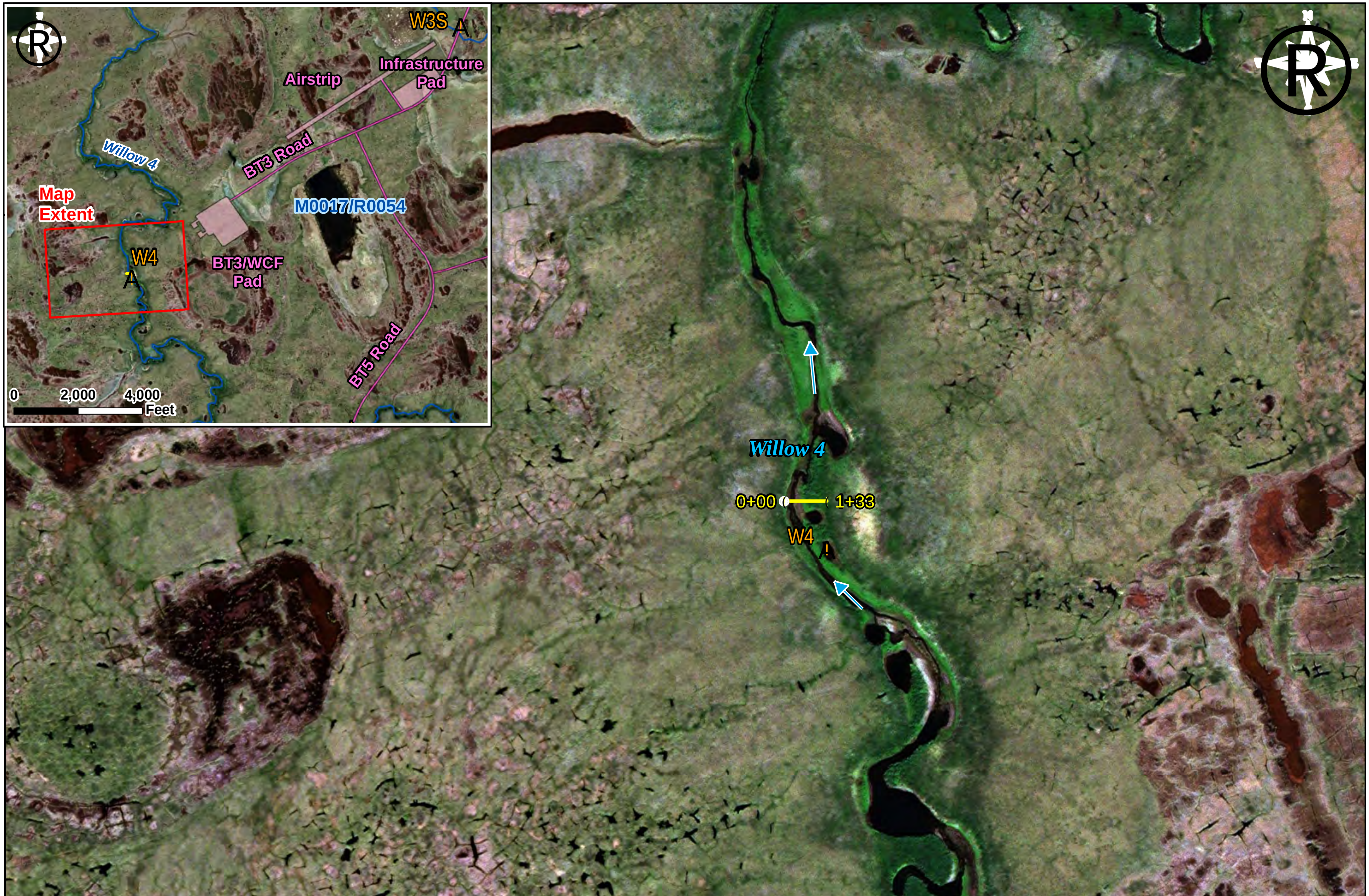




E. Transect W4004 Raw Data Output







ConocoPhillips Alaska

Feet
0 200 400 600

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_W4.mxd
Checked:	GCY	Scale:	1 Inch = 400 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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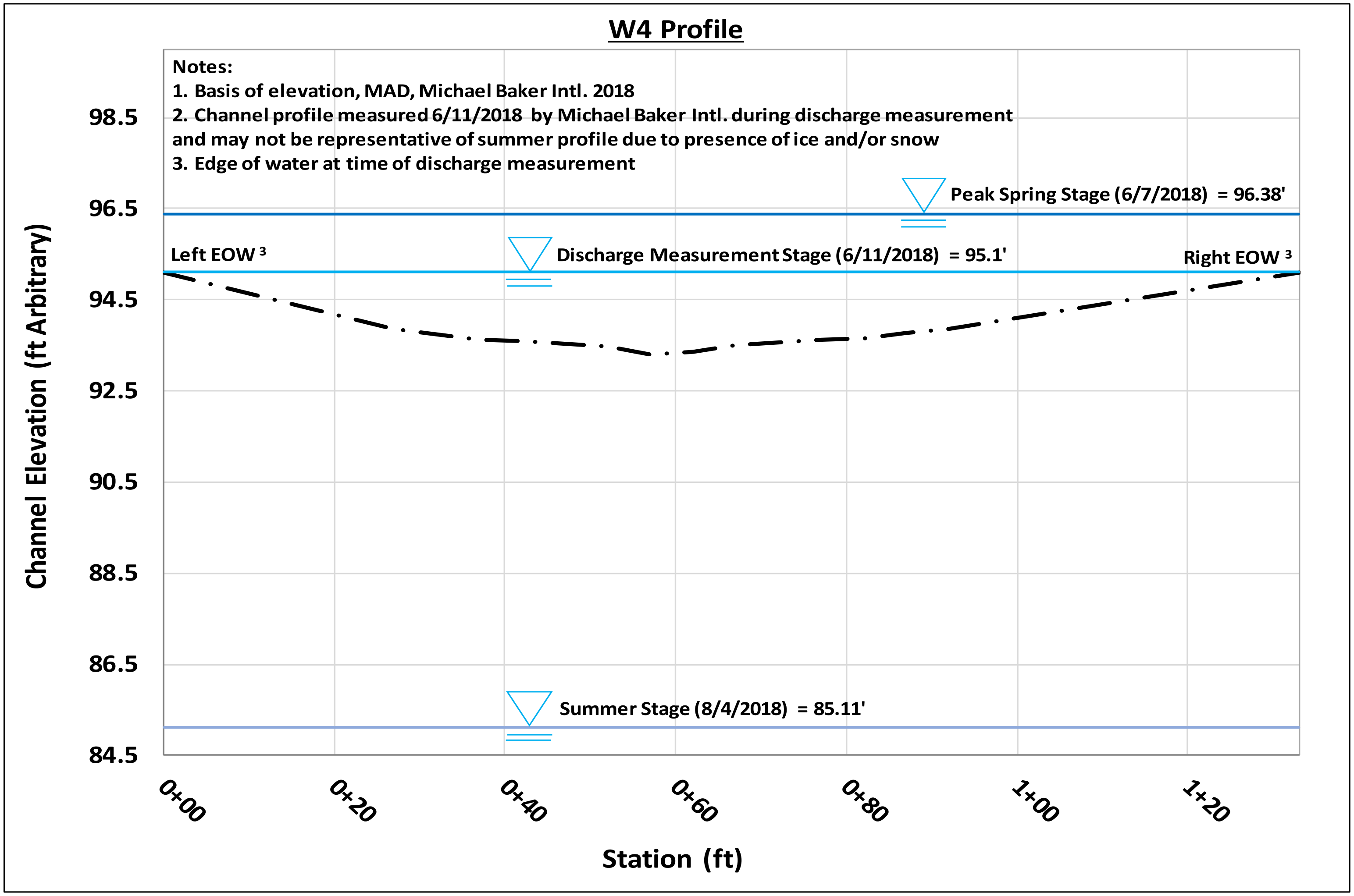
2018 Spring Breakup Willow 4 at W4 Plan

FIGURE C.9

Spring Breakup Cross-Section Profile



C.10 SWALE 1

Spring Breakup Measured Discharge

Table C.12: SW1 Spring Breakup Measured Discharge Summary

Date:	6/13/2018	Time:	3:00 PM	Method:	USGS Midsection
Location:	SW1	Crew:	SAO, SEM, DTR	Depth:	0.6 of measured depth
Lat:	N 70.1358°	Long:	W 152.0133°	Equipment:	SonTek Flow Tracker

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+05.0	95.78	-	-	-	-	-	LEFT BANK
0+08.0	95.28	0.5	0.03	2.5	1.25	0.03	
0+10.0	94.98	0.8	0.02	1.5	1.20	0.02	
0+11.0	94.88	0.9	0.05	1	0.90	0.05	
0+12.0	94.78	1	0.46	1	1.00	0.46	
0+13.0	94.78	1	0.68	1	1.00	0.68	
0+14.0	94.78	1	0.60	1	1.00	0.60	
0+15.0	94.78	1	0.53	1	1.00	0.53	
0+16.0	94.78	1	0.87	1	1.00	0.87	
0+17.0	94.78	1	1.36	1.25	1.25	1.70	
0+18.0	94.78	1	1.03	1.5	1.50	1.55	
0+18.5	94.68	1.1	0.86	2	2.20	1.90	
0+20.0	94.98	0.8	0.05	2.75	2.20	0.10	
0+22.0	94.98	0.8	0.06	3	2.40	0.15	
0+24.0	94.98	0.8	0.05	3	2.40	0.13	
0+26.0	94.98	0.8	0.03	3	2.40	0.06	
0+28.0	94.98	0.8	0.06	3	2.40	0.15	
0+30.0	94.98	0.8	0.30	2	1.60	0.48	
0+32.0	94.98	0.8	0.14	2	1.60	0.22	
0+34.0	95.18	0.6	0.08	2	1.20	0.09	
0+36.0	95.28	0.5	0.06	2.5	1.25	0.07	
0+39.0	95.78	-	-	-	-	-	RIGHT BANK

Total Width (ft)	Average Channel Elevation (ft arbitrary)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
34.0	94.9	0.9	0.37	-	30.8	9.8

ConocoPhillips Alaska

0 200 400 Feet

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_SW1.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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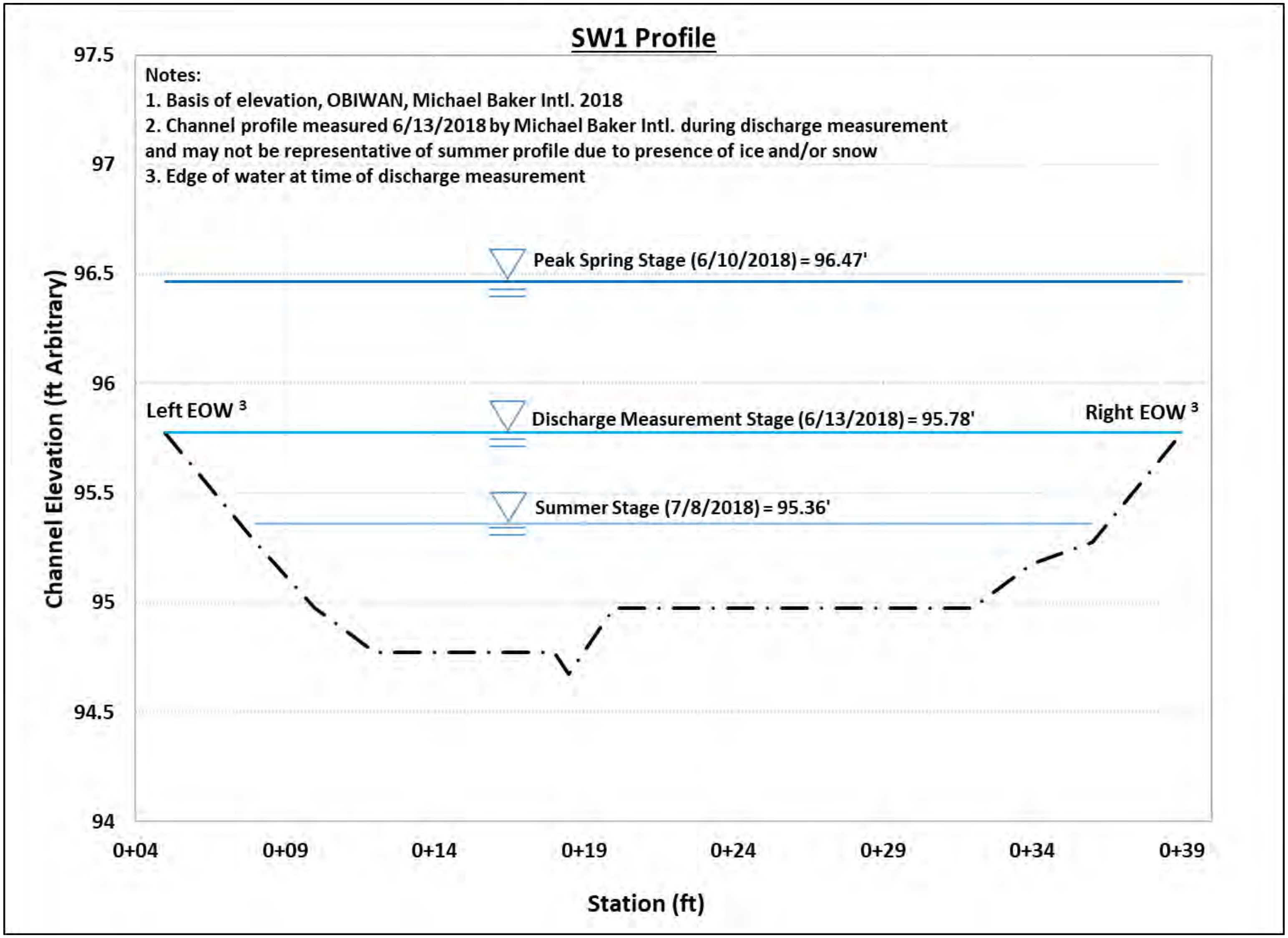
2018 Spring Breakup Swale 1 at SW1 Plan

FIGURE C.10

Spring Breakup Cross-Section Profile

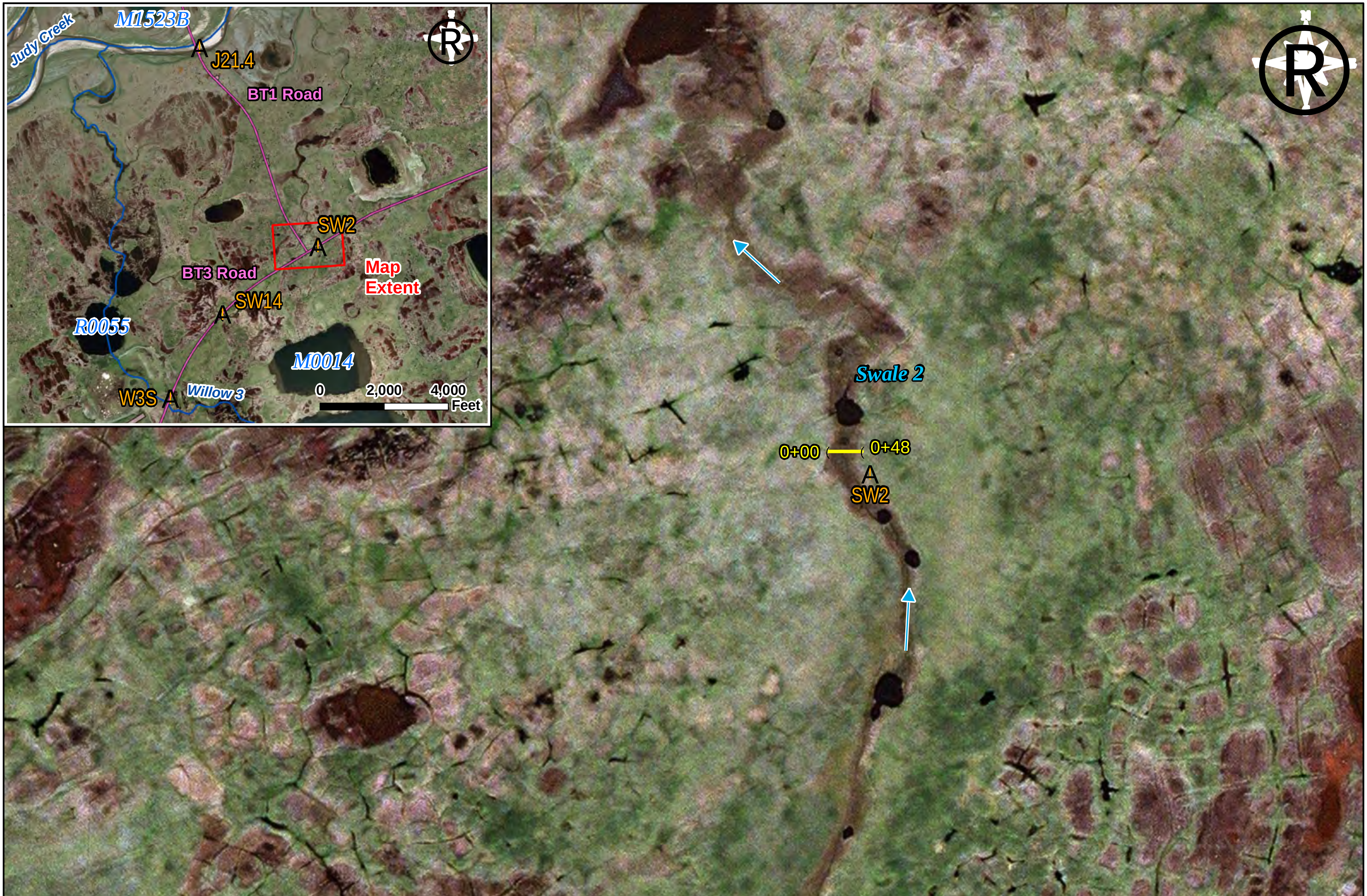


C.11 SWALE 2

Spring Breakup Measured Discharge

Table C.13: SW2 Spring Breakup Measured Discharge Summary

Date:	6/13/2018		**Time:**	2:00 PM	**Method:**	USGS Midsection	
Location:	SW2		**Crew:**	SAO, SEM, DTR	**Depth:**	0.6 of measured depth	
Lat:	N 70.129°		**Long:**	W 152.0632°	**Equipment:**	SonTek Flow Tracker	
Station (ft)	**Channel Elevation (ft NAVD88)**	**Measured Depth (ft)**	**Velocity (ft/s)**	**Section Width (ft)**	**Area (ft²)**	**Discharge (ft³/s)**	**Note**
0+06.0	81.29	-	-	-	-	-	LEFT BANK
0+09.0	80.69	0.6	0.01	2.25	1.35	0.01	Grassy/Ice
0+10.5	80.69	0.6	0.00	15.5	9.30	0.03	Grassy/Ice
0+40.0	80.79	0.5	-0.03	15.25	7.63	-0.25	Grassy/Ice
0+41.0	80.89	0.4	0.04	1	0.40	0.02	Grassy/Ice
0+42.0	80.89	0.4	0.60	1	0.40	0.24	Grassy/Ice
0+43.0	80.79	0.5	0.58	1	0.50	0.29	Grassy/Ice
0+44.0	80.79	0.5	0.49	1	0.50	0.25	Grassy/Ice
0+45.0	80.89	0.4	0.66	1	0.40	0.26	Grassy/Ice
0+46.0	80.69	0.6	0.27	1.5	0.90	0.24	Grassy/Ice
0+47.0	80.79	0.5	0.21	1.5	0.75	0.16	Grassy/Ice
0+48.0	80.69	0.6	0.12	1.5	0.90	0.11	Grassy/Ice
0+49.0	80.69	0.6	0.10	1.5	0.90	0.09	Grassy/Ice
0+50.0	80.89	0.4	0.05	1.5	0.60	0.03	Saturated Snow
0+51.0	80.79	0.5	0.09	2	1.00	0.09	Saturated Snow
0+52.0	80.79	0.5	0.19	1.5	0.75	0.14	Grassy/Ice
0+54.0	81.29	-	-	-	-	-	RIGHT BANK
Total Width (ft)	**Average Channel Elevation (ft NAVD88)**	**Average Depth (ft)**	**Average Velocity (ft/s)**	**-**	**Total Area (ft²)**	**Total Discharge (ft³/s)**	
48.0	80.79	0.5	0.22	-	26.3	1.7	



ConocoPhillips Alaska

Feet 0 200 400

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_SW2.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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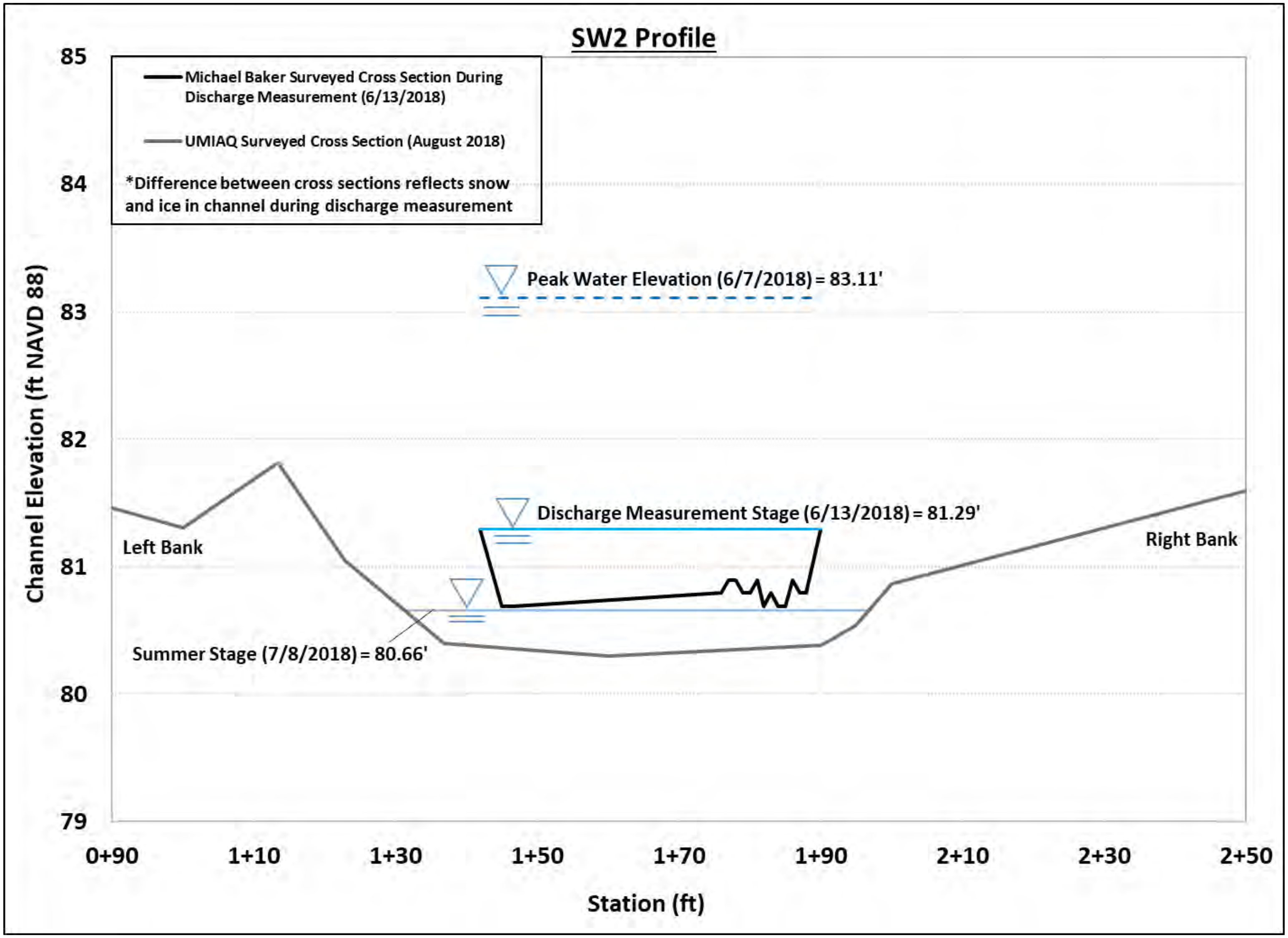
2018 Spring Breakup Swale 2 at SW2 Plan

FIGURE C.11

Spring Breakup Cross-Section Profile



C.12 SWALE 14

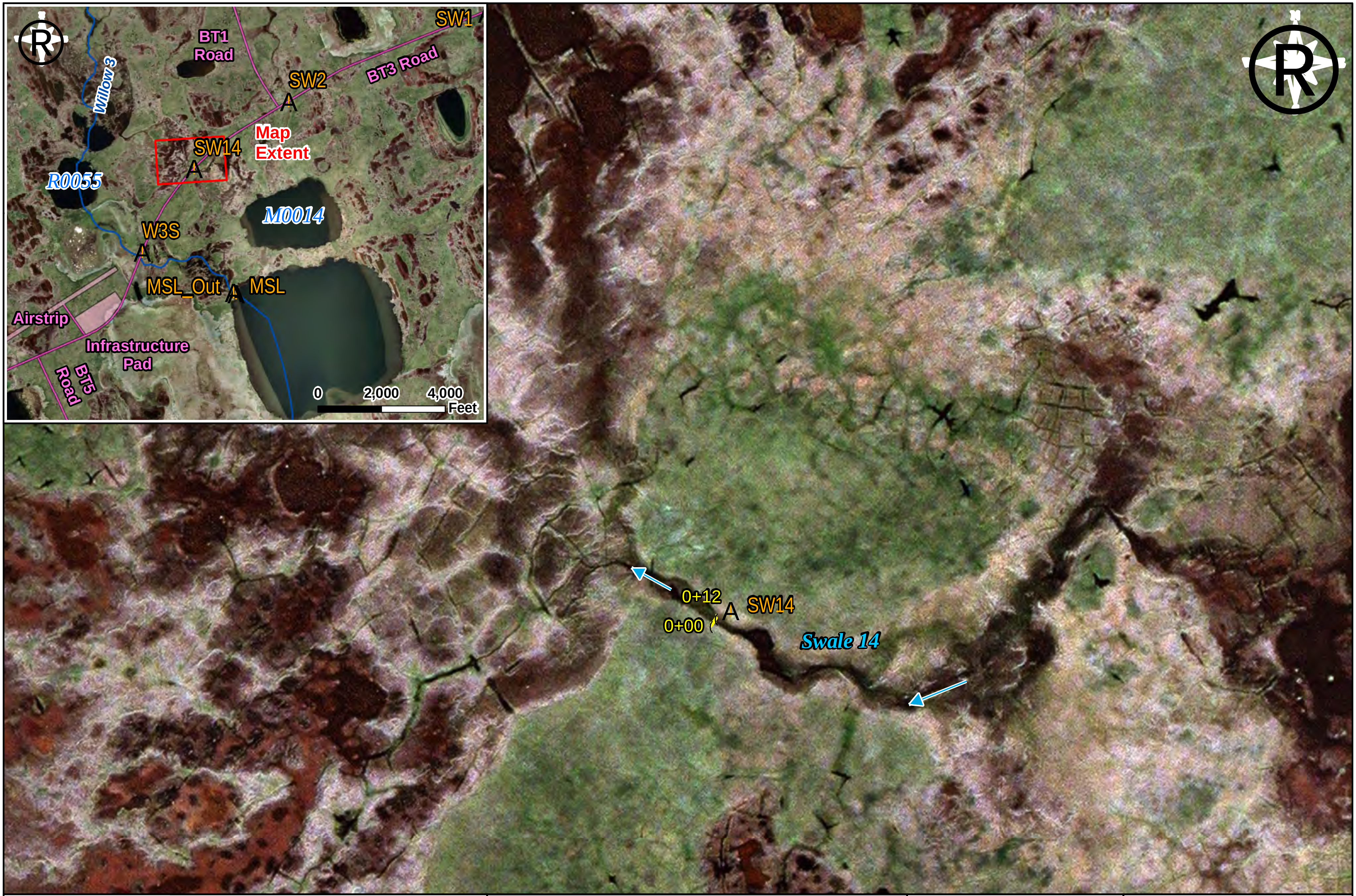
Spring Breakup Measured Discharge

Table C.14: SW14 Spring Breakup Measured Discharge Summary

Date:	6/7/2018	**Time:**	4:00 PM	**Method:**	USGS Midsection
Location:	SW14	**Crew:**	KDB, GCY, DTR	**Depth:**	0.6 of measured depth
Lat:	N 70.1232°	**Long:**	W 152.0870°	**Equipment:**	SonTek Flow Tracker

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	76.75	0	0.00	-	-	-	LEFT BANK/Edge of Water
0+05.0	76.25	0.5	0.29	1.5	0.75	0.22	
0+06.0	75.95	0.8	1.06	2	1.60	1.69	Minimal bottom fast ice
0+07.0	75.75	1	1.18	1	1.00	1.18	
0+08.0	75.75	1	1.04	1	1.00	1.04	
0+09.0	75.75	1	0.92	1	1.00	0.92	
0+10.0	75.75	1	0.67	1	1.00	0.67	
0+11.0	75.85	0.9	0.76	1	0.90	0.68	
0+12.0	76.05	0.7	0.17	1	0.70	0.12	
0+13.0	75.95	0.8	0.24	1	0.80	0.19	
0+14.0	76.15	0.6	0.41	1	0.60	0.25	
0+15.0	76.35	0.4	0.05	1	0.40	0.02	Marsh
0+16.0	76.75	0			0.00	0.00	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)
11.0	75.96	0.8	0.65	-	8.2	5.9



ConocoPhillips Alaska

Feet 0 200 400

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_SW14.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

Gage Location
Flow Direction
Station
Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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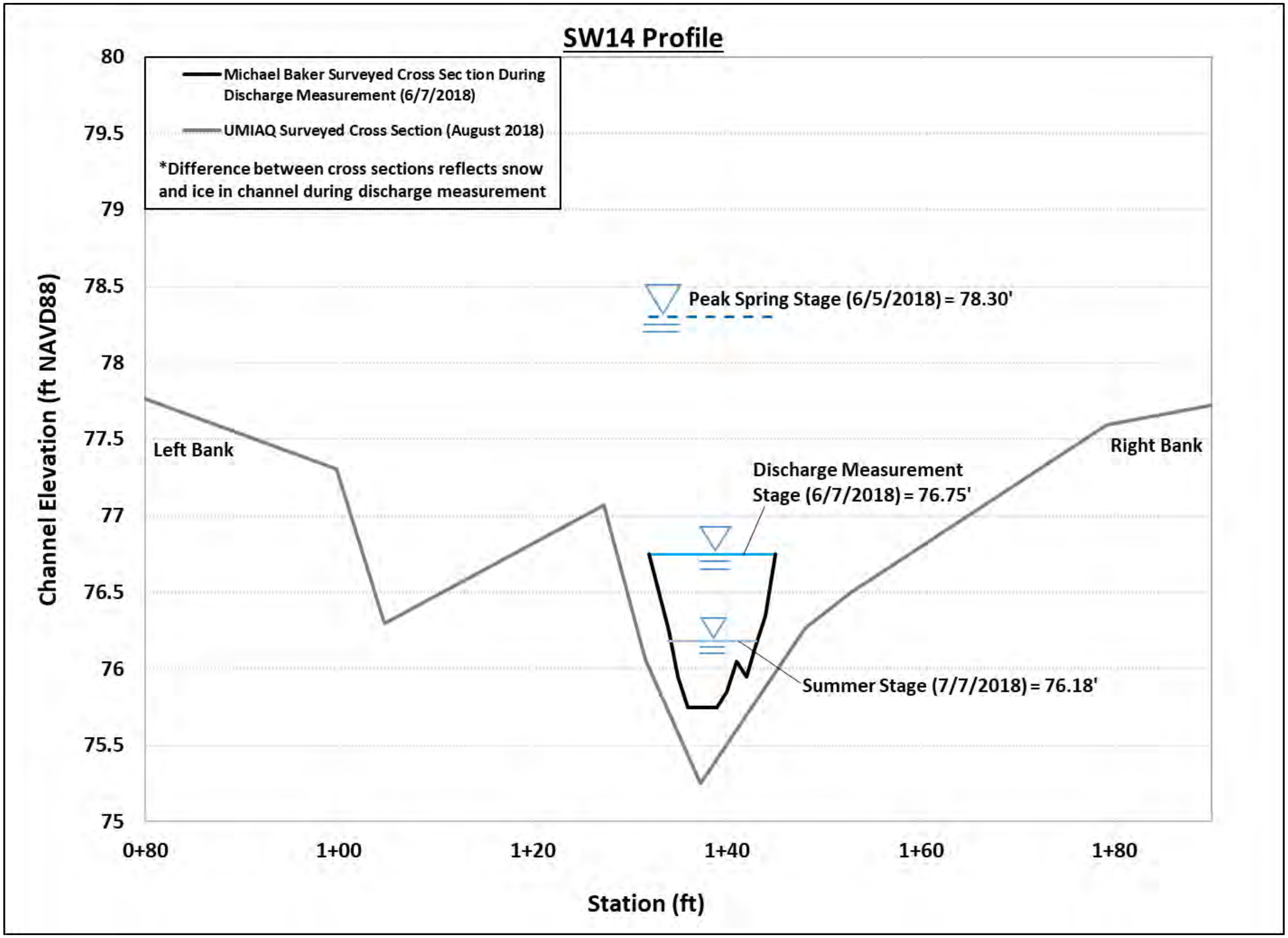
2018 Spring Breakup Swale 14 at SW14 Plan

FIGURE C.12

Spring Breakup Cross-Section Profile



C.13 SWALE 23

Spring Breakup Measured Discharge

Table C.15: SW23 Spring Breakup Measured Discharge Summary

Date:	6/18/2018		**Time:**	4:00 PM	**Method:**	USGS Midsection	
Location:	SW23		**Crew:**	GCY, SAO, WAB	**Depth:**	0.6 of measured depth	
Lat:	N 70.3136°		**Long:**	W 151.213°	**Equipment:**	SonTek Flow Tracker	
Station (ft)	**Channel Elevation (ft arbitrary)**	**Measured Depth (ft)**	**Velocity (ft/s)**	**Section Width (ft)**	**Area (ft²)**	**Discharge (ft³/s)**	**Note**
0+01.0	90.14	-	-	-	-	-	RIGHT BANK
0+02.0	89.55	0.6	0.03	1	0.60	0.02	
0+03.0	89.45	0.7	0.21	0.75	0.53	0.11	
0+03.5	89.46	0.7	0.25	0.9	0.63	0.16	
0+04.8	89.36	0.8	0.24	0.75	0.60	0.15	
0+05.0	89.42	0.75	0.34	0.6	0.45	0.15	
0+06.0	89.27	0.9	0.41	1	0.90	0.37	
0+07.0	89.08	1.1	0.41	1	1.10	0.45	
0+08.0	88.98	1.2	0.16	1	1.20	0.20	
0+09.0	88.39	1.8	0.20	0.75	1.35	0.27	
0+09.5	88.39	1.8	0.41	0.5	0.90	0.37	
0+10.0	88.40	1.8	0.63	0.5	0.90	0.56	
0+10.5	88.30	1.9	0.81	0.5	0.95	0.77	
0+11.0	88.31	1.9	0.12	0.75	1.43	0.18	
0+12.0	88.32	1.9	-0.01	1	1.90	-0.02	
0+13.0	90.23	-	-	-	-	-	LEFT BANK/Saturated Snow
Total Width (ft)	**Average Channel Elevation (ft arbitrary)**	**Average Depth (ft)**	**Average Velocity (ft/s)**	**-**	**Total Area (ft²)**	**Total Discharge (ft³/s)**	
12.0	88.9	1.3	0.3	-	13.4	3.7	

ConocoPhillips Alaska

0 200 400 Feet

Date:	11/13/2018	Project:	166429
Drawn:	JEG	File:	PlanView_SW23.mxd
Checked:	GCY	Scale:	1 Inch = 200 Feet

Gage Location

Flow Direction

Station

Discharge Measurement Cross Section

Imagery Source: Digital Globe, 2015

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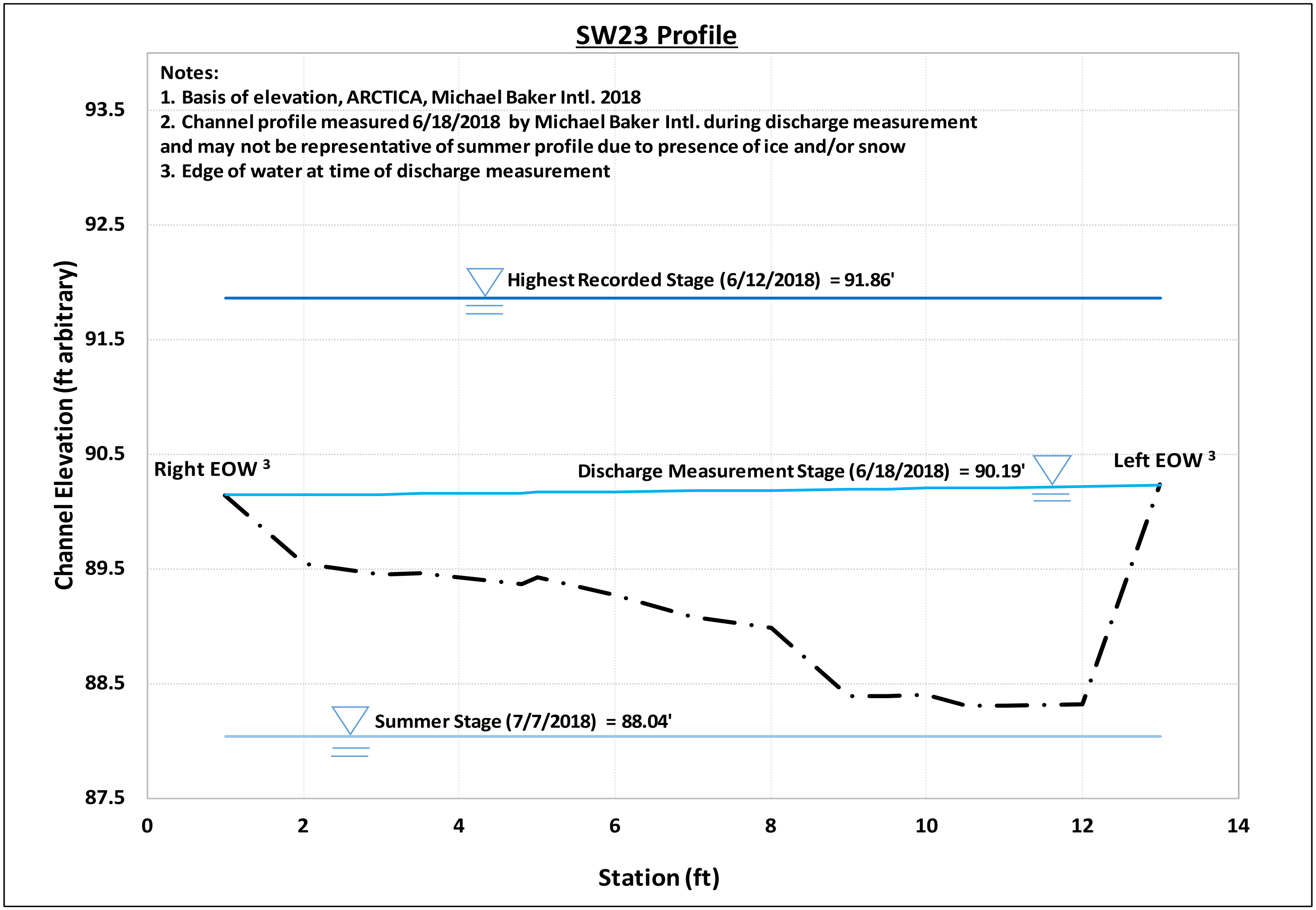
2018 Spring Breakup Swale 23 at SW23 Plan

FIGURE C.13

Spring Breakup Cross-Section Profile



C.14 W_S1

Spring Breakup Measured Discharge

Table C.16: W_S1 Spring Breakup Measured Discharge Summary

Date:	6/13/2018		Time:	1:00 PM	Method:	USGS Midsection	
Location:	W_S1		Crew:	SAO, SME, DTR	Depth:	0.6 of measured depth	
Lat:	N 70.0361°		Long:	W 152.2018°	Equipment:	Hach Flow Meter	
Station (ft)	Channel Elevation (ft NAVD88)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+05.0	99.77	-	-	-	-	-	LEFT BANK
0+12.0	99.17	0.6	0.05	4	2.40	0.12	Willows
0+13.0	98.37	1.4	0.39	1	1.40	0.55	Grassy
0+14.0	97.77	2	0.53	1	2.00	1.06	Channel Ice
0+15.0	97.67	2.1	0.51	1	2.10	1.07	Channel Ice
0+16.0	97.77	2	0.60	1	2.00	1.20	Channel Ice
0+17.0	97.77	2	0.57	1	2.00	1.15	Channel Ice
0+18.0	97.77	2	0.67	1	2.00	1.34	Channel Ice
0+19.0	97.67	2.1	0.68	1	2.10	1.42	Channel Ice
0+20.0	97.77	2	0.76	1.5	3.00	2.29	Channel Ice
0+21.0	97.57	2.2	0.77	1.5	3.30	2.54	Channel Ice
0+22.0	97.37	2.4	0.80	1.5	3.60	2.89	Channel Ice
0+23.0	97.37	2.4	0.75	1.5	3.60	2.69	Channel Ice
0+24.0	97.47	2.3	0.77	1.5	3.45	2.66	Channel Ice
0+25.0	97.47	2.3	0.76	1.5	3.45	2.61	Channel Ice
0+26.0	97.47	2.3	0.70	1.5	3.45	2.43	Channel Ice
0+27.0	97.37	2.4	0.69	1.5	3.60	2.47	Channel Ice
0+28.0	97.27	2.5	0.64	1	2.50	1.60	Channel Ice
0+29.0	97.27	2.5	0.70	1	2.50	1.76	Channel Ice
0+30.0	97.27	2.5	0.69	1	2.50	1.73	Channel Ice
0+31.0	97.37	2.4	0.68	1	2.40	1.64	Channel Ice
0+32.0	97.57	2.2	0.68	1	2.20	1.49	Channel Ice
0+33.0	97.57	2.2	0.57	1	2.20	1.26	Channel Ice
0+34.0	97.57	2.2	0.39	1	2.20	0.86	Channel Ice
0+35.0	98.87	0.9	0.14	1	0.90	0.12	Grassy
0+36.0	99.77	-	-	-	-	-	RIGHT BANK
Total Width (ft)	Average Channel Elevation (ft NAVD88)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)	
31.0	97.69	2.1	0.6	-	60.9	38.9	

ConocoPhillips Alaska

0 200 400 Feet

Date: 11/13/2018	Project: 166429
Drawn: JEG	File: PlanView_W_S1.mxd
Checked: GCY	Scale: 1 Inch = 200 Feet

Gage Location

Station

Discharge Measurement Cross Section

Flow Direction

Imagery Source: Digital Globe, 2015

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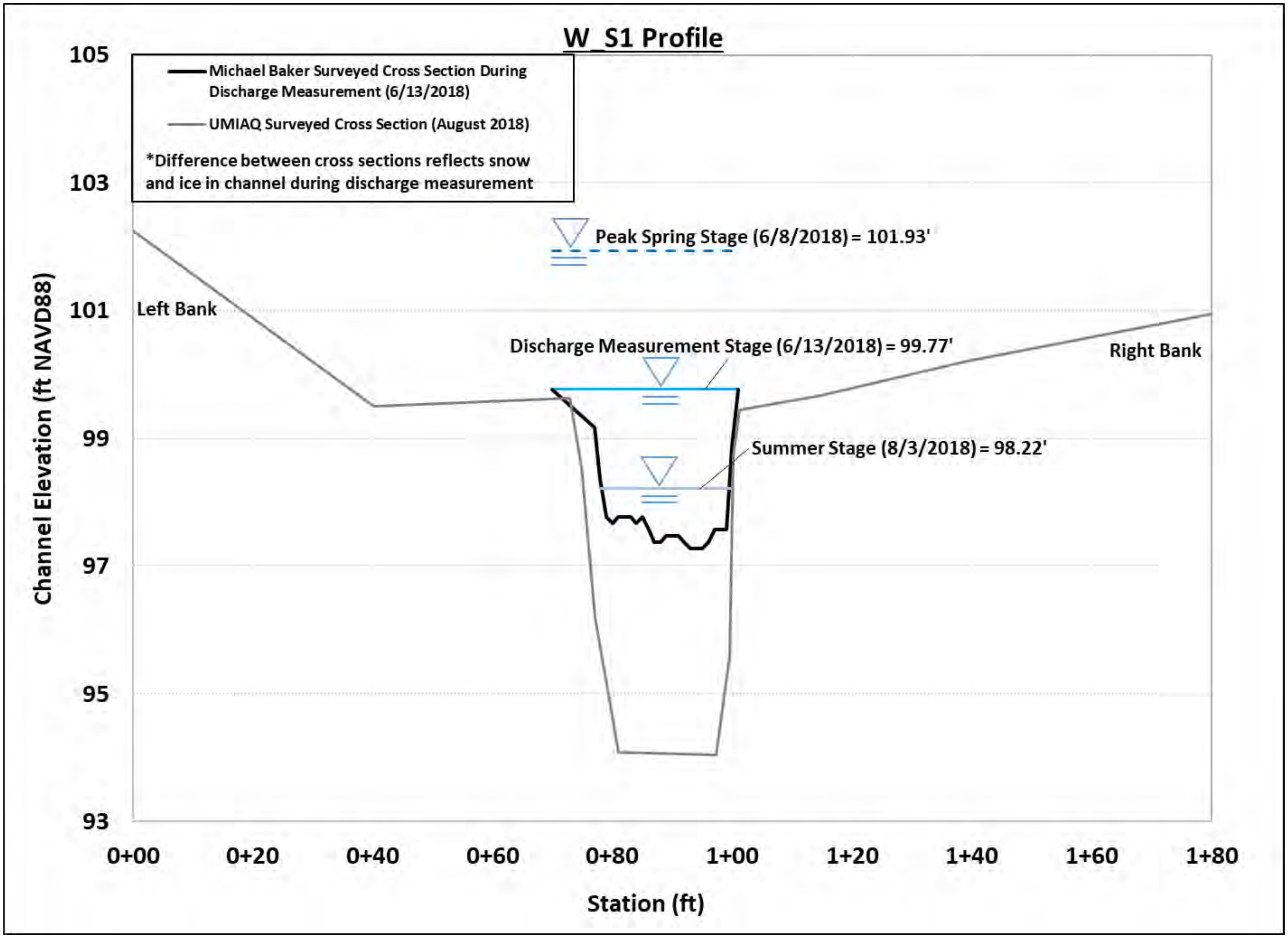
2018 Spring Breakup Willow 4a at W_S1 Plan

FIGURE C.14

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

2018 Willow Spring Breakup & Summer Monitoring & Hydrological Assessment