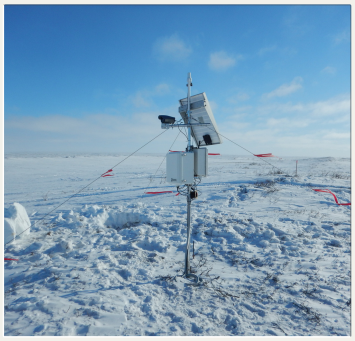

ConocoPhillips
Alaska

2017

Willow
Spring Breakup & Summer Monitoring & Hydrological Assessment

Prepared by:

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EXECUTIVE SUMMARY

This report presents the results from the 2017 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 provide data to support design and permitting.

Spring breakup typically occurs during a three-week period in May and June. The spring breakup event historically produces flooding, and rapid rise and fall of stage can occur as the result of ice jam formation and release. This year's spring breakup flood was characterized as a low magnitude, prolonged event, drawn out over three weeks.

Spring breakup and summer hydrological conditions were monitored at three creeks and 10 swales throughout the Willow project area. Spring breakup stage and discharge were measured at Judy Creek, Willow 2, Judy Creek Kayyaaq, Swale 1, Swale 5, Swale 8, Swale 10, and SN171 (Swale 7). Spring breakup stage was measured at Swale 4. Spring breakup peak discharge was calculated at Judy Creek. Summer stage was measured at Judy Creek and summer stage and discharge were measured at Willow 2 and Judy Creek Kayyaaq. Spring breakup and summer events were documented with visual observations and photography from a helicopter and from the ground. Peak spring breakup conditions occurred between May 30 and June 4 across the monitoring area. During peak conditions, floodwater was generally confined within channels and swales. Stage was receding at all gage stations by June 5. 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
BMP	best management practice
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
ft.	feet
GPS	global positioning system
HWM	high water mark
IAP	Integrated Activity Plan
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
UMIAQ	Umiaq, LLC (LCMF)
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

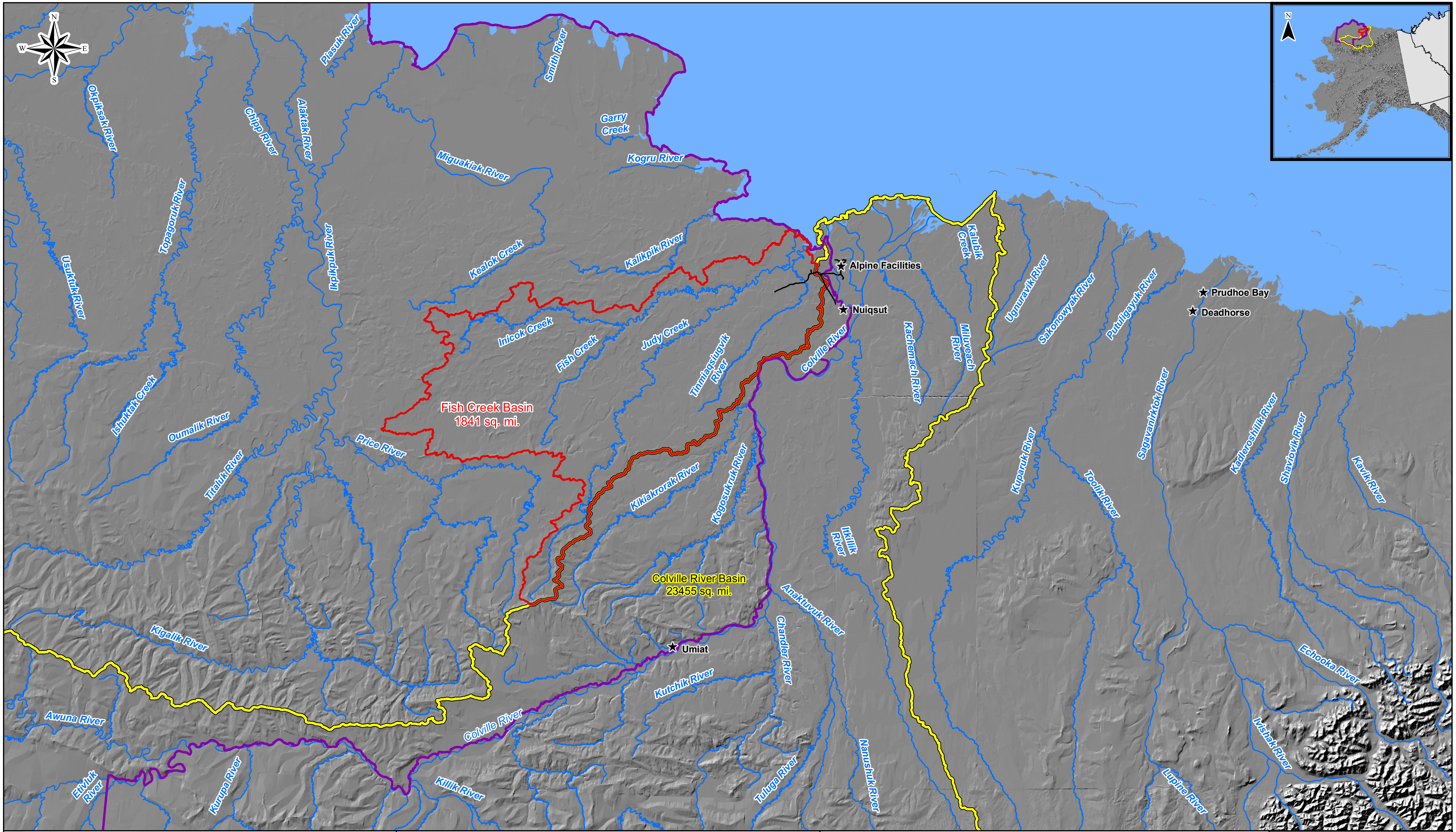
1. INTRODUCTION

The Willow Spring Breakup and Summer Monitoring and Hydrological Assessment supports ConocoPhillips Alaska, Inc. (CPAI) in meeting the National Petroleum Reserve–Alaska Integrated Activity Plan Record of Decision requirement E-14 which states that "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 and the Fish Creek Basin (FCB) (Figure 1.1), share similar hydrologic and hydraulic 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 2017 Willow spring breakup and summer monitoring and hydrological assessment program included monitoring 20 new gage stations and one existing gage station at river mile (RM) 13.8 of Judy Creek (gage station J 13.8). Hydrologic and hydraulic assessments at gage station J 13.8 were conducted by URS in 2001 and 2002 (URS 2001 and 2003). Spring breakup monitoring and hydrological assessments at gage station J 13.8 were conducted annually by Michael Baker International (Michael Baker) from 2003 to 2006 (Michael Baker 2003, 2005a, 2005b, 2007).

The 2017 field program took place from April 20 to September 11. Spring breakup setup began on April 20 and concluded on May 6. Spring breakup monitoring began on May 13 and concluded on June 8. Summer monitoring was broken up into two field programs; the first program began on June 27 and concluded on June 29 and the second program began on September 5 and concluded on September 11. Primary field tasks included measuring stage and discharge at select locations. Umiaq, LLC (UMIAQ), CPAI Alpine Field Environmental Coordinators, Alpine Helicopter Coordinators, and Soloy Helicopters, LLC provided support during the field programs and contributed to a safe and productive field season.



ConocoPhillips
Alaska

0 7.5 15 30 miles

Date: 11/28/2017
Project: 159730
Drawn: JEG
File: Figure 1.1
Checked: JMG
Scale: 1 in = 15 miles

★ Place Name
〰 Stream
— Road
Fish Creek Basin
Colville River Basin
National Petroleum Reserve Alaksa Boundary

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Fish Creek & Colville River

Drainage Basins

FIGURE: 1.1

(SHEET 1 of 1)

1.1 MONITORING OBJECTIVES

The primary objective of the Willow spring breakup and summer monitoring and hydrological assessment 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 and summer 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. 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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Date: 11/30/2017	Project: 159730
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0 0.5 1 2 Miles

((●)) RTFM

⊕ Gage Location

— Proposed Road

National Hydrography Dataset

〰 Stream/River

Waterbody

Imagery Source : GeoNorth SDMI SPOT 5 2.5-meter Statewide Ortho

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2017 Willow Gage Stations & Proposed Roads

FIGURE: 1

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

Monitoring Location	Gage Station	Gage Station Description	Observations	Spring Breakup PT	Summer PT	Spring Breakup Measured Discharge	Summer Measured Discharge	Spring Breakup Real-Time Monitoring	Summer Real-Time Monitoring
Judy Creek	J 13.8U	West bank, 13.8 river miles upstream of Fish Creek, downstream of Willow 2 tributary, upstream of Judy Creek Kayyaaq tributary	✓	✓	✓	✓	--	✓	✓
	J 13.8		✓	✓	✓				
	J 13.8D		✓	✓	✓				
	J 16.5	East bank, 16.5 river miles upstream of Fish Creek, upstream of Willow 2 tributary	✓	✓	✓	--	--	--	--
	J 21.4	West bank, 21.4 river miles upstream of Judy Creek	✓	✓	✓	--	--	--	--
Willow 2	UC1B	East bank, approximately 4.7 river miles upstream of Judy Creek	✓	✓	✓	--	--	--	--
	UC1C	East bank, approximately 3.0 river miles upstream of Judy Creek	✓	✓	✓	--	--	--	--
	UC1AU	East bank, approximately 1.4 river miles upstream of Judy Creek, upstream of J 13.8	✓	✓	✓	✓	✓	✓	✓
	UC1A		✓	✓	✓				
	UC1AD		✓	✓	✓				
Judy Creek Kayyaaq	UC2C	East bank, approximately 13.0 river miles upstream of Judy Creek	✓	✓	✓	--	--	--	--
	UC2B	East bank, approximately 10.2 river miles upstream of Judy Creek	✓	✓	✓	--	--	--	--
	UC2AU	West bank, approximately 8.4 river miles upstream of Judy Creek, downstream of J 13.8	✓	✓	✓	✓	✓	✓	✓
	UC2A		✓	✓	✓				
	UC2AD		✓	✓	✓				
Swales/Small Drainages	SW1	Shallow drainage with beads between two unnamed lakes upstream of SW8; conveys flow toward Judy Creek upstream of J 16.5	✓	✓	✓	✓	--	--	--
	SW2	Low-lying area with occasional beads	✓	--	--	--	--	--	--
	SW3	Low-lying area downstream of Lake M0017/R0054	✓	--	--	--	--	--	--
	SW4	Polygon trough paleochannel of Judy Creek	✓	✓	--	✓	--	--	--
	SW5	Shallow drainage with bead features in defined topographic depression conveying flow from lakes/low-lying areas into Judy Creek oxbow lake upstream of J 13.8	✓	✓	--	✓	--	--	--
	SW6	Low-lying area of polygon cracks upstream of Judy Creek Kayyaaq	✓	--	--	--	--	--	--
	SW7	Shallow drainage of polygon cracks between two unnamed lakes conveying flow into Judy Creek Kayyaaq upstream of UC2C. Drainage referenced as SN171.	✓	✓	--	✓	--	--	--
	SW8	Shallow drainage with beads downstream of an unnamed lake downstream of SW1; conveys flow toward Judy Creek upstream of J 16.5	✓	✓	--	✓	--	--	--
	SW9	Low-lying area of polygon cracks downstream of Lake M0016/R0065	✓	--	--	--	--	--	--
	SW10	Shallow drainage of polygon cracks between two unnamed lakes conveying flow into Judy Creek Kayyaaq upstream of UC2C	✓	✓	--	✓	--	--	--

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 (Photo 2.1). 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).

Photo 2.1: Field crew recording observations in field notebook at Swale 8; June 4, 2017

UMIAQ provided Hägglund track vehicle support to access gage stations during spring breakup setup before a helicopter was onsite for the summer season. Soloy Helicopters, LLC 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 pressure transducers (PTs) designed to measure stage. Detailed gage and PT methods and site-specific data are presented in Appendix A.

Spring breakup stage was measured at the following gage stations:

- Judy Creek at J 21.4, J 16.5, J 13.8U, J 13.8, and J 13.8D
- Willow 2 at UC1B, UC1C, and UC1AD
- Judy Creek Kayyaaq at UC2C, UC2B, UC2AU, UC2A, and UC2AD
- Swales 1, 4, 5, 7, 8 and 10

Summer stage was measured at the following gage stations:

- Judy Creek at J 21.4, J 16.5, J 13.8U, J 13.8, and J 13.8D
- Willow 2 at UC1B, UC1C, UC1AU, UC1A, and UC1AD
- Judy Creek Kayyaaq at UC2C, UC2B, UC2AU, UC2A, and UC2AD

HYDROLOGIC STAFF GAGES

Gage stations consist of one or more gage assemblies positioned perpendicular to the waterbody (Photo 2.2). The number of gage assemblies per gage station installed at Judy Creek, Willow 2, and Judy Creek Kayyaaq was dependent upon site specific conditions: primarily slope of the channel, bank, and overbank. In locations where terrain elevation varied by more than 3 feet (ft.), multiple gages were installed linearly from the edge of the channel up to the overbank. Individual gage assemblies were identified with alphabetical designations beginning with 'A' representing the location nearest to the channel. Gage stations were 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 10), 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.

Photo 2.2: Gage assembly J 13.8U-A, looking east; June 1, 2017

PRESSURE TRANSDUCERS

Primary PTs were installed at every gage station and supplemented by gage measurements to provide a continuous record of stage. Secondary PTs were installed to validate and backup the primary PT data at locations where discharge was measured. 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) attached to the telemetry system at Judy Creek. During data processing, the PT measurements were adjusted to stage recorded at the gages.

VERTICAL CONTROL

Two vertical control monuments were installed adjacent to all but three gage stations. Gage stations J 13.8U, J 13.8, and J 13.8D had one existing vertical control with a known benchmark elevation installed during a prior monitoring event; one new vertical control was installed adjacent to the existing vertical control. Each monument included an aluminum cap (Alcap) mounted on a piece of rebar driven into the ground. The top of the Alcap was stamped with an arbitrary naming convention. The location of each vertical control was recorded with a handheld GPS referenced to NAD83.

Gage and PT elevations were surveyed to their associated vertical control using standard differential leveling techniques relative to either a known benchmark elevation to determine a correction or arbitrary elevation where the project datum control was not available. A correction was applied to the J 13.8U, J 13.8, and J 13.8D gage readings, HWM measurements, and PT elevations to obtain elevations in ft. BPMSL. All other gage readings, HWM measurements, and PT elevations were assigned an elevation in ft of an arbitrary datum; elevation datum is local for each gage station and is not relative to other gage stations.

REAL-TIME FLOOD MONITORING NETWORK

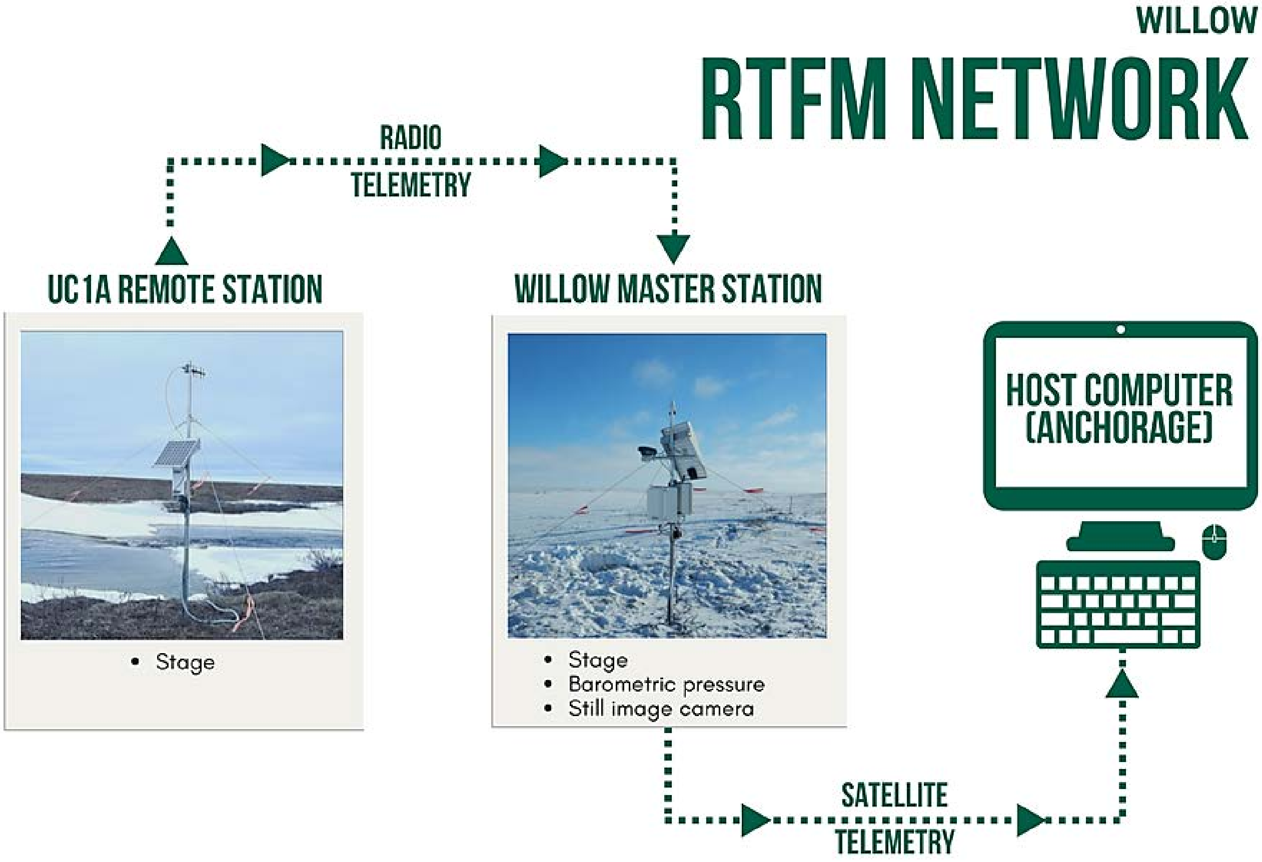
Table 2.1 presents the Real-Time Flood Monitoring (RTFM) Network locations and data collected at each location.

Table 2.1: Willow RTFM Network Stations

Monitoring Location (Gage Station)	Station	Real-Time Data
Judy Creek (J 13.8)	Master	• Stage • Barometric pressure • Conditions via remote camera images
Willow 2 (UC1AD)	Remote	• Stage
Judy Creek Kayyaaq (UC2A)	Remote	• 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. Real-time stage 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 Master Station consisted of a digital camera, barometric PT, 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 (Photo 2.3). 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 Willow 2 and Judy Creek Kayyaaq. 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 Willow 2 consisted of stage PTs, dataloggers, and a spread spectrum radio that transmitted data to the Willow Master station for satellite transmission to the host computer. A second remote station was established at Judy Creek Kayyaaq with the same configuration as the Willow 2 remote station. Unfortunately, a radio connection could not be established between the Judy Creek Kayyaaq remote station and the Willow Master station due to the distance and terrain features between stations and time limitations prevented the installation of a repeater.

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. Helicopter flight time to the Willow study area was approximately 35 minutes. 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.

Photo 2.3: Remote camera setup at J 13.8; April 25, 2017

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.2.

MEASURED DISCHARGE

Detailed spring breakup and summer measured discharge methods are presented in Appendix B.1.1. Spring breakup and summer locations of measured discharge are detailed in Appendix B.2.

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:

- Judy Creek at J 13.8
- Willow 2 downstream of UC1AD
- Judy Creek Kayyaaq at UC2A
- Swale 1 upstream of SW1
- Swale 5 downstream of SW5
- SN171 downstream of SW7
- Swale 8 upstream of SW8
- Swale 10 at SW10

Discharge was measured at J 13.8, UC1A, and UC2A using an Acoustic Doppler Current Profiler (ADCP) mounted in a tethered trimaran (Photo 2.4) 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 or small drainages using an electromagnetic velocity meter attached to a wading rod using the USGS midsection technique (USGS 1982). Discharge was calculated using measured velocities, flow depths, and station widths.

Photo 2.4. Measuring spring breakup discharge at J 13.8 with an ADCP in a trimaran, looking east; June 1, 2017

B. SUMMER

Summer discharge was measured at the following locations:

- Willow 2 at UC1A
- Judy Creek Kayyaaq at UC2A

Discharge was measured using an electromagnetic velocity meter attached to a wading rod using the USGS midsection technique (USGS 1982). Discharge was calculated using measured velocities, flow depths, and station widths.

CALCULATED DISCHARGE

A. SPRING BREAKUP

Spring breakup discharge was calculated indirectly at Judy Creek at J 13.8. 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.1.2.

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.

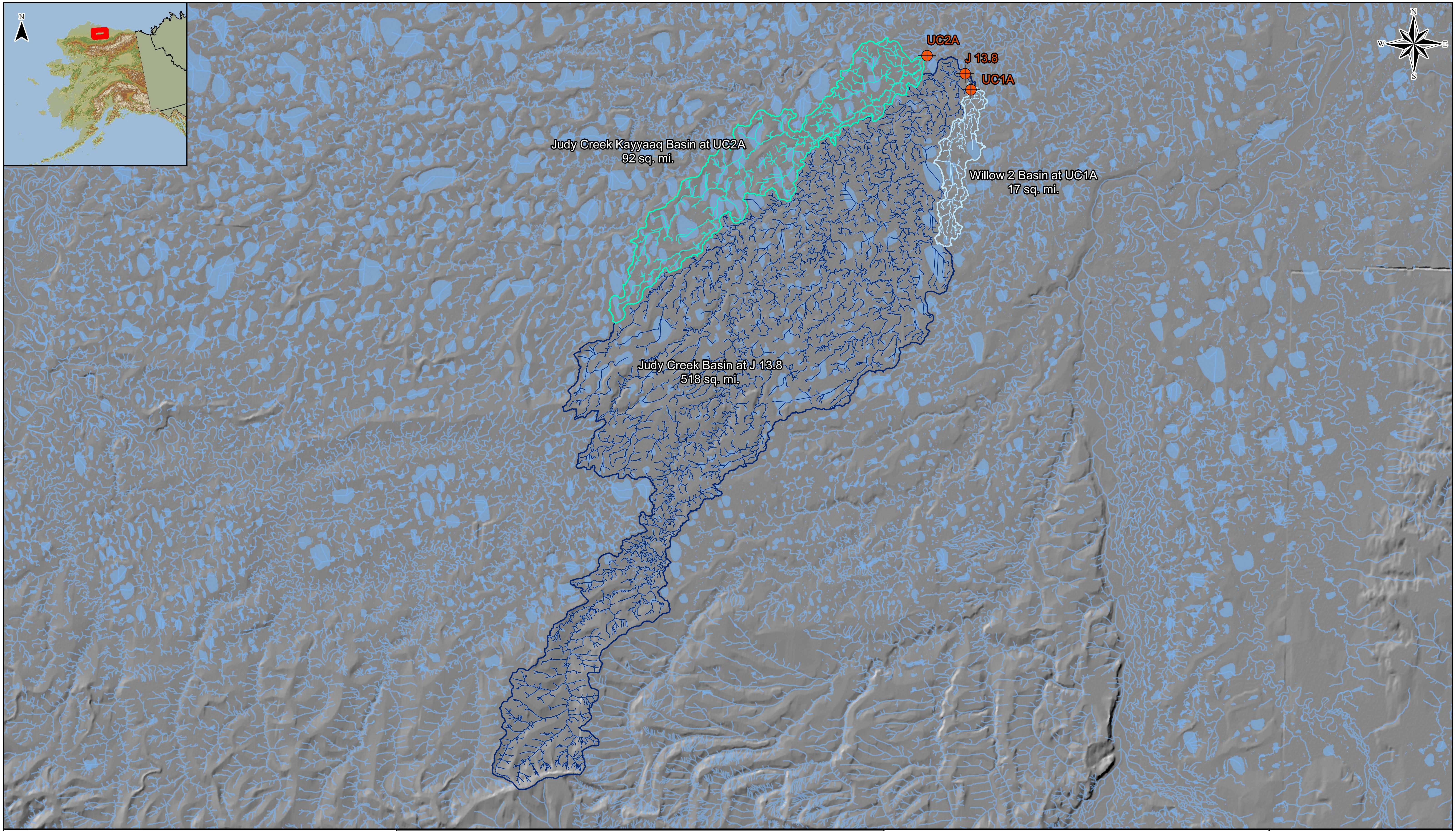
2.4 FLOOD FREQUENCY ANALYSIS

Estimates of the magnitude and frequency of peak discharge at Judy Creek at J 13.8, Willow 2 at UC1A, and Judy Creek Kayyaaq at UC2A were determined for the 2-, 10-, 25-, 50-, 100-, and 200-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 J 13.8 were determined for the 2-, 10-, 25-, 50-, 100-, and 200-year recurrence intervals using the 2002 URS peak discharge regional regression equations for Judy Creek, Fish Creek, and the Tinmiaqsiugvik River (URS 2003). 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 Judy Creek at J 13.8, Willow 2 at UC1A, and Judy Creek Kayyaaq at UC2A are presented in Table 2.3 and Figure 2.2.

Table 2.3: Judy Creek, Willow 2, & Judy Creek Kayyaaq Basin Areas

Monitoring Location (Gage Station)	Basin Area (square miles)
Judy Creek (@ J 13.8)	518
Willow 2 (@ UC1A)	17
Judy Creek Kayyaaq (@ UC2A)	92

Basin areas were delineated based on the USGS National Hydrography Dataset (USGS 2017) and available Digital Elevation Model (DEM) data and were manually adjusted to the respective gage station. DEM data was derived from Light Detection and Ranging (LiDAR) data collected in 2013 (Aero-Metric, Inc. 2013). The LiDAR resolution is 1 meter/0.25 meters and the accuracy is 15 centimeters. The Judy Creek at J 13.8 basin was previously delineated resulting in a basin area of 593 square miles, a difference of 75 square miles (URS 2001). Differences in the drainage basin area are attributed to improved accuracy of the 2017 USGS NHD.



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Alaska

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Date:	12/20/2017	Project:	159730
Drawn:	BTG	File:	Basin_11X17L.mxd
Checked:	JMG	Scale:	1 in = 6 miles

⊕ Gage Location
〰 Stream/River
● Waterbody
〰 J13.8 Stream
〰 Judy Creek Kayyaaq Stream
〰 Willow 2 Stream
▢ Judy Creek Basin
▢ Judy Creek Kayyaaq Basin
▢ Willow 2 Basin

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Willow 2
Judy Creek Kayyaaq & Judy Creek Basins

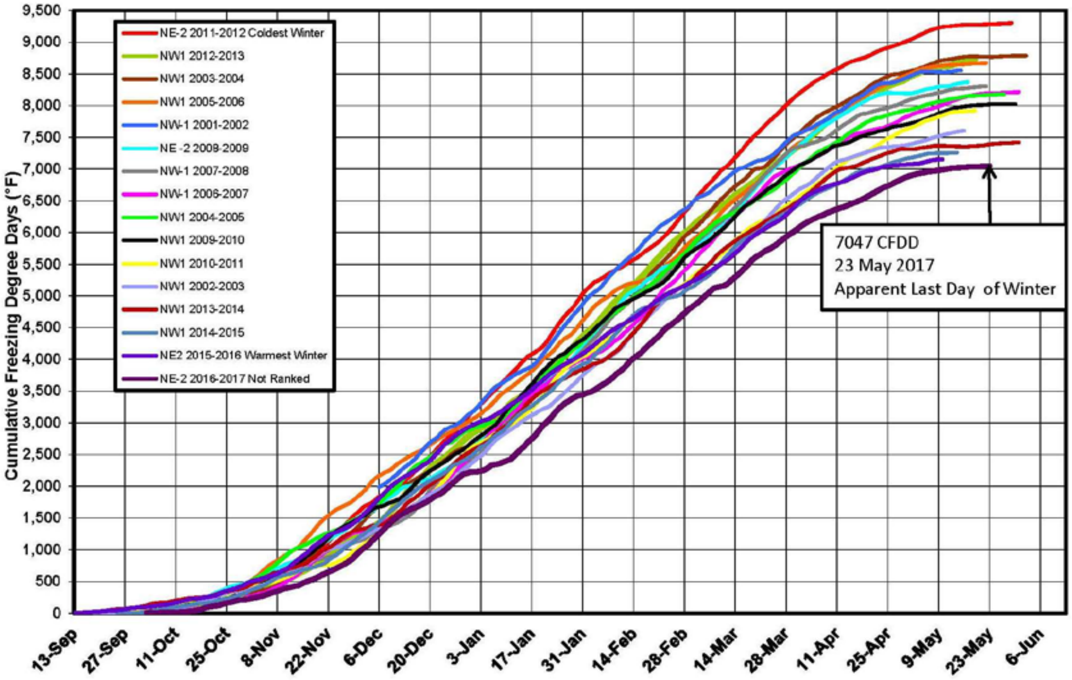
FIGURE: 2.2

(SHEET 1 of 1)

3. OBSERVATIONS

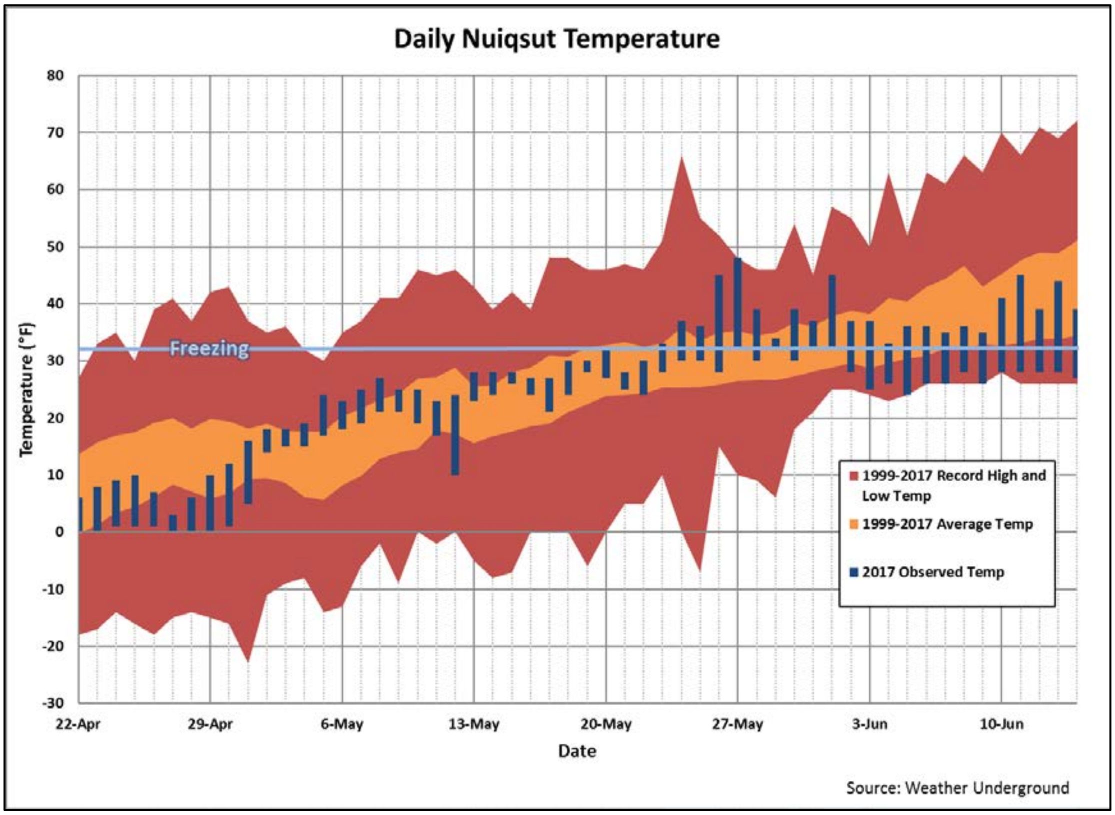
3.1 GENERAL CLIMATIC SUMMARY

According to cumulative freezing degree days (CFDD) measured at the NPR-A tundra monitoring station, the 2016-2017 (September – May) winter was the warmest on record for the past 16 years, as shown in Graph 3.1 (ICE 2017). In April and May 2017, all North Slope snowpack was reported as 90-109% of the 1981-2010 median (Natural Resources Conservation Service 2017).



Graph 3.1: NPRA N. Tundra Monitoring Station, CFDD, Winters 2002-2017 (ICE 2017)

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 at or below freezing throughout breakup which slowed local breakup processes. 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 2017).



Source: Weather Underground

Graph 3.2: Nuiqsut Daily High and Low Ambient Air Temperatures

3.2 GENERAL BREAKUP SUMMARY

Spring breakup was characterized as a low magnitude, prolonged event, drawn-out over three weeks due to extended cold weather in the arctic coastal plain.

Water was first observed flowing in Judy Creek on May 24 (Photo 3.1). Flow through drifted snow was observed through much of the Judy Creek drainage in the study area. Ice floes were present, but no ice jams were observed. Snow covered approximately 80% of the surrounding tundra and drifted snow remained in both Willow 2 and Judy Creek Kayyaaq (Photo 3.2 and Photo 3.3). Stage in Judy Creek increased for a day until cold weather resulted in reduced flows over the next three days (Photo 3.2).

Photo 3.1: Initial floodwater in Judy Creek downstream of J 16.5; looking northeast (downstream); May 24, 2017

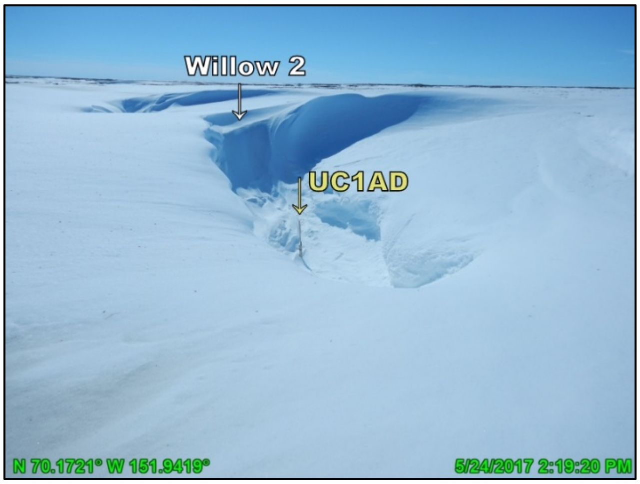


Photo 3.2: Drifted snow in Willow 2 at UC1AD, looking south (upstream); May 24, 2017

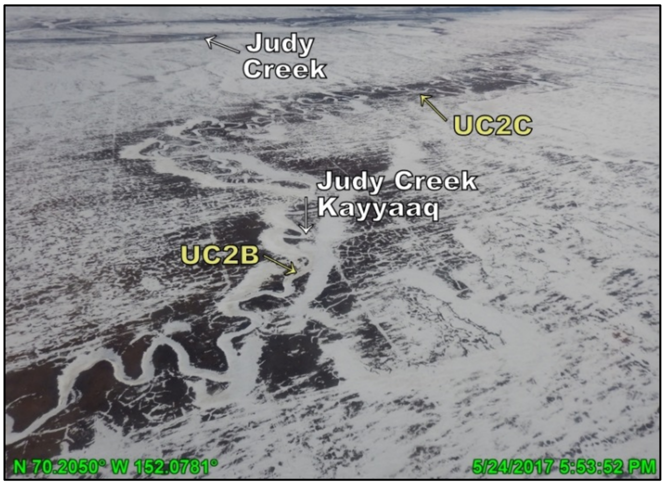


Photo 3.3: Drifted snow in Judy Creek Kayyaaq at UC2B, looking southwest (upstream); May 24, 2017

Photo 3.4: Remote monitoring of reduced flow in Judy Creek at J 13.8, looking northeast (downstream); May 26, 2017

On May 28, stage in Judy Creek began steadily increasing (Photo 3.5). The channel was mostly ice free and drifted snow remained along the cut banks. Tundra snow cover was approximately 40% and isolated pools of melt water were observed in both Willow 2 and Judy Creek Kayyaaq (Photo 3.6). Peak conditions in both Willow 2 and Judy Creek Kayyaaq occurred between May 30 and May 31. By May 31, very little snow remained on the surrounding tundra and meltwater was observed in polygon depressions, lake basins, and swales (Photo 3.7). Stage in Judy Creek continued to rise and the channel was mostly free of snow and ice. Stage in both Willow 2 and Judy Creek Kayyaaq was significantly elevated by the considerable amounts of drifted snow remaining in the channel and adjacent floodplain (Photo 3.8).

Photo 3.5: Increasing stage in Judy Creek at the confluence with Willow 2, looking north (downstream); May 28, 2017

Photo 3.6: Isolated pools forming in Judy Creek Kayyaaq upstream of UC2C, looking west (upstream); May 28, 2017

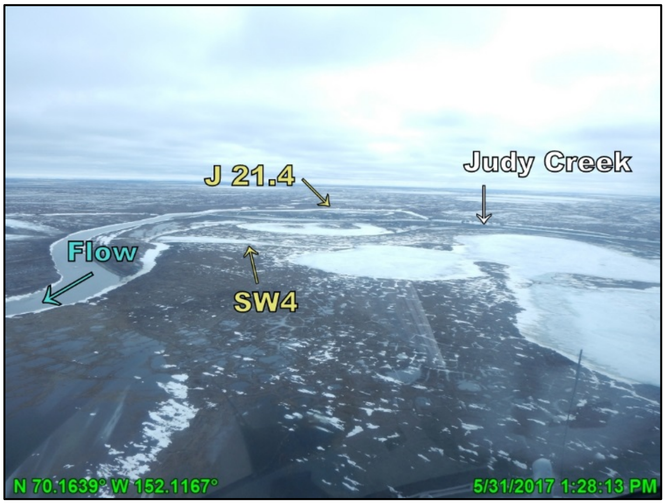


Photo 3.7: Meltwater in tundra depressions and rising stage in Judy Creek downstream of J 21.4, looking southeast; May 31, 2017

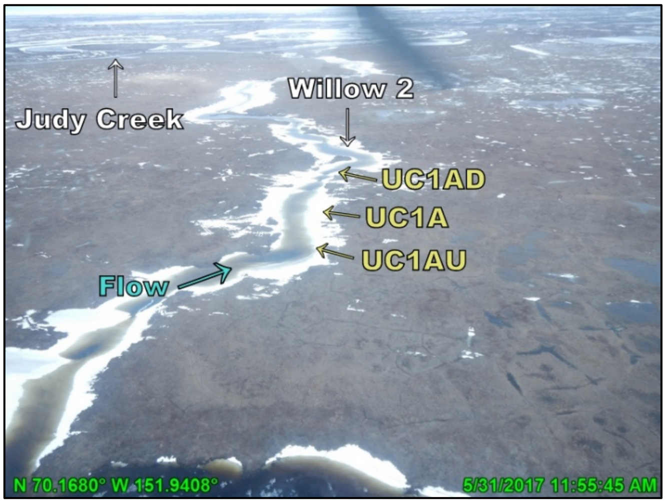


Photo 3.8: Integrated flow and elevated stage in Willow 2, looking north (downstream); May 31, 2017

Peak conditions in Judy Creek occurred between June 3 and 4. The channel was mostly free of snow and ice and floodwater was contained within the channel banks (Photo 3.9). Flow remained high in Willow 2 and Judy Creek Kayyaaq, but stage was receding as the moving water eroded the drifted snow pack. By June 6, water levels had receded in Judy Creek and in both Willow 2 and Judy Creek Kayyaaq (Photo 3.10) and all swales were hydraulically disconnected from adjacent waterbodies or along the swale. The tundra was snow free and minimal snow remained in the smaller drainages. Most swales continued conveying low flow.

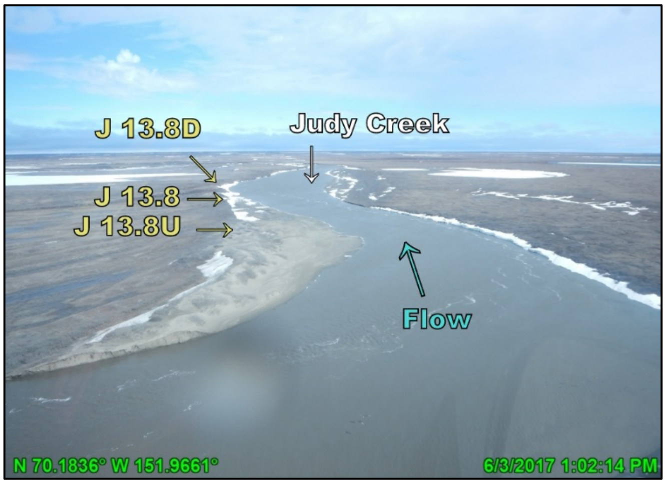
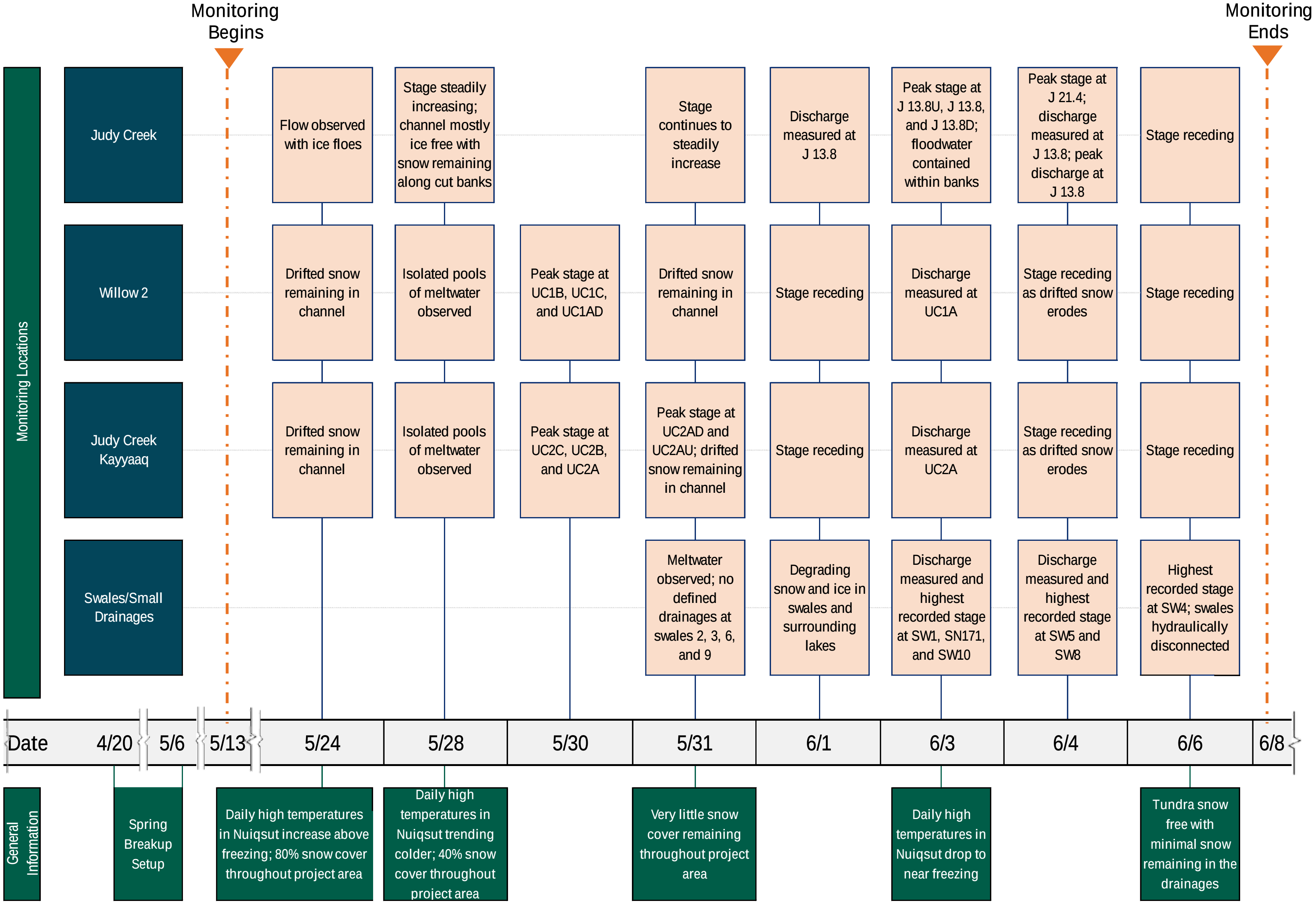


Photo 3.9: Open water in Judy Creek upstream of J 13.8, looking northeast (downstream); June 3, 2017

Photo 3.10: Decreasing stage in Willow 2 at UC1B, looking north (downstream); June 6, 2017

Figure 3.1 provides a visual timeline summarizing the major spring breakup events.

Figure 3.1: Spring Breakup Hydrologic Timeline



	Date	4/20	5/6	5/13	5/24	5/28	5/30	5/31	6/1	6/3	6/4	6/6	6/8
				Monitoring Begins									Monitoring Ends
Monitoring Locations	Judy Creek				Flow observed with ice floes	Stage steadily increasing; channel mostly ice free with snow remaining along cut banks		Stage continues to steadily increase	Discharge measured at J 13.8	Peak stage at J 13.8U, J 13.8, and J 13.8D; floodwater contained within banks	Peak stage at J 21.4; discharge measured at J 13.8; peak discharge at J 13.8	Stage receding	
	Willow 2				Drifted snow remaining in channel	Isolated pools of meltwater observed	Peak stage at UC1B, UC1C, and UC1AD	Drifted snow remaining in channel	Stage receding	Discharge measured at UC1A	Stage receding as drifted snow erodes	Stage receding	
	Judy Creek Kayyaaq				Drifted snow remaining in channel	Isolated pools of meltwater observed	Peak stage at UC2C, UC2B, and UC2A	Peak stage at UC2AD and UC2AU; drifted snow remaining in channel	Stage receding	Discharge measured at UC2A	Stage receding as drifted snow erodes	Stage receding	
	Swales/Small Drainages							Meltwater observed; no defined drainages at swales 2, 3, 6, and 9	Degrading snow and ice in swales and surrounding lakes	Discharge measured and highest recorded stage at SW1, SN171, and SW10	Discharge measured and highest recorded stage at SW5 and SW8	Highest recorded stage at SW4; swales hydraulically disconnected	
General Information		Spring Breakup Setup			Daily high temperatures in Nuiqsut increase above freezing; 80% snow cover throughout project area	Daily high temperatures in Nuiqsut trending colder; 40% snow cover throughout project area		Very little snow cover remaining throughout project area		Daily high temperatures in Nuiqsut drop to near freezing		Tundra snow free with minimal snow remaining in the drainages	

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 arbitrary	Date & Time	Discharge cfs	Stage ft arbitrary	Date & Time	Discharge cfs	Stage ft arbitrary	Date & Time
Judy Creek	J 21.4	90.15	6/4, 3:00 AM	--	--	--	--	--	--
	J 16.5	91.79 [1]	6/8, 1:45 PM	--	--	--	--	--	--
	J 13.8U [2]	34.80	6/3, 11:45 AM	3,500	34.52	6/4, 3:45 PM	3,900	34.79	6/3, 11:00 AM
	J 13.8 [2]	34.68 [3]	6/3, 1:30 PM		34.51			34.66 [3]	
	J 13.8D [2]	34.51	6/3, 3:15 PM		34.21			34.46	
Willow 2	UC1B	96.87	5/30, 11:30 AM	--	--	--	--	--	--
	UC1C	98.00	5/30, 6:15 PM	--	--	--	--	--	--
	UC1AU	81.62 [4]	6/8, 9:45 PM	125	-- [5]	6/3, 12:15 PM	not calculated [6]		
	UC1A	81.39 [4]	6/8, 5:15 PM		-- [5]				
	UC1AD	91.99	5/30, 10:00 PM		88.72				
Judy Creek Kayyaaq	UC2C	99.88	5/30, 5:45 PM	--	--	--	--	--	--
	UC2B	93.47	5/30, 3:00 AM	--	--	--	--	--	--
	UC2AU	91.34	5/31, 3:00 AM	190	87.90	6/3, 2:00 PM	not calculated [6]		
	UC2A	91.19	5/30, 6:30 AM		87.81				
	UC2AD	90.81	5/31, 12:00 PM		87.72				
Swales	SW1	95.61 [4]	6/3, 5:30 PM	6	95.61	6/3, 5:30 PM	--	--	--
	SW4	97.35 [4]	6/6, 1:30 PM	not measured [7]			--	--	--
	SW5	88.52 [4]	6/4, 4:30 PM	5	88.44	6/4, 3:45 PM	--	--	--
	SN171	91.04 [4]	6/3, 4:45 PM	2	91.04	6/3, 4:45 PM	--	--	--
	SW8	97.34 [4]	6/4, 4:30 PM	6	97.33	6/4, 2:15 PM	--	--	--
	SW10	97.39 [4]	6/3, 10:00 AM	3	97.33	6/3, 2:15 PM	--	--	--

Notes:

[1] PT could not be retrieved; value presented is the highest recorded gage reading

[2] Stage elevations at J 13.8U, J 13.8, and J 13.8D are ft BPMSL

[3] Peak stage interpolated between upstream and downstream gage stations

[4] Gage and PT were installed after peak, peak stage not recorded; value presented is the highest recorded stage

[5] Gage and PT were installed after discharge measurement, stage data not recorded

[6] Discharge was not calculated; dynamic changes in channel cross-section during spring breakup

[7] Discharge was not measured; not hydraulically connected to surrounding waterbodies

Table 4.2 presents a summary of summer peak stage, minimum stage, and measured discharge.

Table 4.2: Summer Stage & Discharge Summary

Monitoring Location	Gage Station	Summer Peak Stage		Summer Minimum Stage		Summer Measured Discharge		
		Stage ft arbitrary	Date & Time	Stage ft arbitrary	Date & Time	Discharge cfs	Stage ft arbitrary	Date & Time
Judy Creek	J 21.4	89.28	8/17, 7:30 PM	86.77	7/19, 8:30 PM	--	--	--
	J 16.5 [1]	--	--	--	--	--	--	--
	J 13.8U [2]	31.46	8/17, 8:00 PM	28.67	7/19, 8:00 AM	--	--	--
	J 13.8 [2]	31.54	8/17, 6:30 PM	28.65	7/19, 7:15 AM	--	--	--
	J 13.8D [2]	31.60	8/17, 6:45 PM	28.64	7/19, 9:00 AM	--	--	--
Willow 2	UC1B	88.12	9/8, 1:45 PM	85.48	7/19, 9:00 PM	--	--	--
	UC1C	84.63	9/8, 1:45 PM	83.01	7/19, 9:00 PM	--	--	--
	UC1AU	81.17	9/8, 2:15 PM	78.45	7/19, 8:30 PM	6	79.88	6/28, 4:30 PM
	UC1A	81.08	9/8, 2:15 PM	78.41	7/19, 7:15 PM		81.43	
	UC1AD	80.86	9/8, 2:15 PM	78.40	7/19, 9:00 PM		88.54	
Judy Creek Kayyaaq	UC2C	93.10	9/8, 1:45 PM	90.85	7/19, 8:30 PM	--	--	--
	UC2B	86.41	9/8, 1:45 PM	84.21	7/19, 6:15 PM	--	--	--
	UC2AU	84.30	9/8, 1:45 PM	82.11	8/1, 2:15 PM	70	82.93	6/28, 11:15 AM
	UC2A	84.18	9/8, 1:45 PM	81.99	7/19, 5:45 PM		82.90	
	UC2AD	84.25	9/8, 1:45 PM	82.15	8/1, 3:15 PM		82.84	

Notes:

[1] PT could not be retrieved, no stage data to report

[2] Stage elevations at J 13.8U, J 13.8, and J 13.8D are ft BPMSL

4.1 JUDY CREEK

The J 13.8D, J 13.8, J 13.8U, J 16.5, and J 21.4 gage stations are located in Judy Creek 13.8, 16.5, and 21.4 RMs upstream of the confluence with Fish Creek, respectively. The J 13.8 gage stations are downstream of the Willow 2 tributary and upstream of the Judy Creek Kayyaaq tributary. Judy Creek is a low gradient, highly sinuous channel flowing generally northeast into Fish Creek. This is the first year the J 13.8D, J 13.8U, J 16.5 and J 21.4 gage stations have been monitored. Hydrologic and hydraulic assessments of the J 13.8 gage station were completed by URS in 2001 and 2002 (URS 2001 and 2003). Spring breakup monitoring and hydrological assessments of J 13.8 were completed by Michael Baker annually from 2003 to 2006 (Michael Baker 2003, 2005a, 2005b, 2007). Historical peak stage at J 13.8 is presented in Table 4.3. This year's peak stage was the lowest on record by 0.88 ft.

Table 4.3: Judy Creek at J 13.8 Historical Peak Stage

Year	Peak Stage	
	Stage ft BPMSL	Date
2017	34.68 [2]	6/4
2006 [1]	35.56	5/30
2005 [1]	37.25	6/4
2004 [1]	NM [3]	--
2003 [1]	36.58	6/6
2002 [1]	35.86	5/25
2001 [1]	39.66	6/7

Notes:

[1] Michael Baker 2007

[2] Stage interpolated between upstream and downstream gage stations

[3] NM = not measured

SPRING BREAKUP

All Judy Creek locations experienced a highly mobile channel bed. The bed is comprised of fine sands and the mobile effects were most pronounced during the spring when seasonal flows were greatest. The dynamics of this channel bed have been historically documented. For example, bed elevation in the thalweg at Judy Creek RM 7 increased by over 5 ft. between June 9 and September 5, based on open water observations in 2001 (URS 2001).

The highly mobile channel bed caused some gages to list from an upright position, affecting the PT sensor elevation. When listing happened quickly, the effect was more pronounced, represented by a sharp increase in the stage hydrograph. In these cases, it was possible to identify the vertical shift, correct the PT data accordingly, and verify the adjustment with subsequent gage readings during the next site visit. However, if listing was gradual, data slowly drifted over time and definite corrections were not possible until the next site visit. This was the case during peak conditions at gage station J 13.8. PT data for this gage station, between June 1 and June 4, was interpolated from the slope between J 13.8U and J 13.8D gage stations. Aerial photos and RTFM camera images suggests that there were no ice jams in this reach during this time and bankfast ice and snow influences were minimal. The slope used for data interpolation was confirmed with the slope observed with gage readings during site visits.

The channel was mostly free of ice and snow during peak stage at J 13.8D, J 13.8, J 13.8U, and J 21.4 (Photo 4.3 and Photo 4.5). The staff gage and PT at J 16.5 were either buried or displaced because of the mobile channel bed conditions and were not recovered. As a result, stage data at J 16.5 is limited to gage readings at the time of site visits. It is assumed peak stage at J 16.5 occurred on the same day as peak stage at J 21.4 and reached an elevation no greater than 95.00 ft. This was determined by the lack of a HWM on gage J 16.5 indicating stage remained below the gage throughout spring breakup.

Discharge was measured twice at J 13.8, three days prior to and one day after peak stage. During both measurements, the reach was generally free of ice and snow during both measurements though some intermittent ice floes were observed during the first measurement and snow was present along the right bank (Photo 4.1, Photo 4.2, and Photo 4.4). Both measurements were influenced by moving channel bed conditions and corrections were applied. The quality of both measurements was classified as fair based on the highly mobile channel bed.

Peak discharge coincided with peak stage at J 13. 8. Peak discharge at J 13.8 was calculated using the cross-section from the direct measurement on June 4, the day following peak discharge. The estimated peak discharge was assigned a fair quality rating (Table 2.2) because of the dynamic channel geometry associated with the moving channel bed, the use of interpolated stage at J 13.8, and the quality of the direct discharge measurement. Indirect discharge calculated at the time of the direct measurements was 1.3% less than the discharge measured on June 4 and 8.9% greater than the discharge measured on June 1.

Judy Creek J 13.8 spring breakup stage and discharge data is provided in Graph 4.1; Judy Creek J 16.5 and J 21.4 stage data and top of ice elevations observed prior to spring breakup flooding are provided in Graph 4.2 and Graph 4.3, respectively. Detailed measured discharge data and plan and profile drawings are presented in Appendix B.2.1.

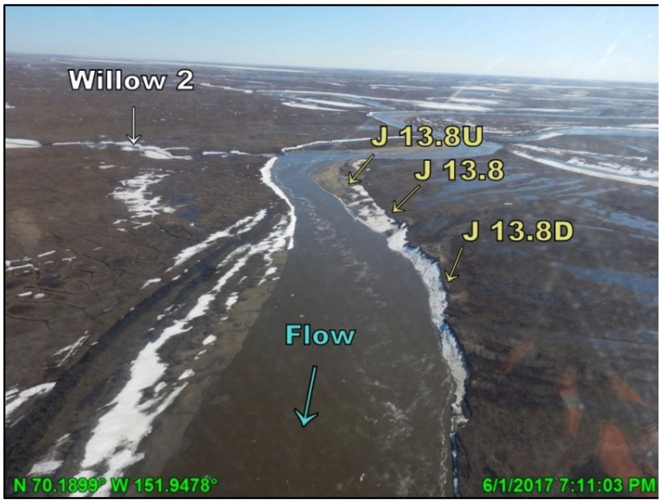


Photo 4.1: Conditions at J 13.8 the day of the first discharge measurement, looking southwest (upstream); June 1, 2017

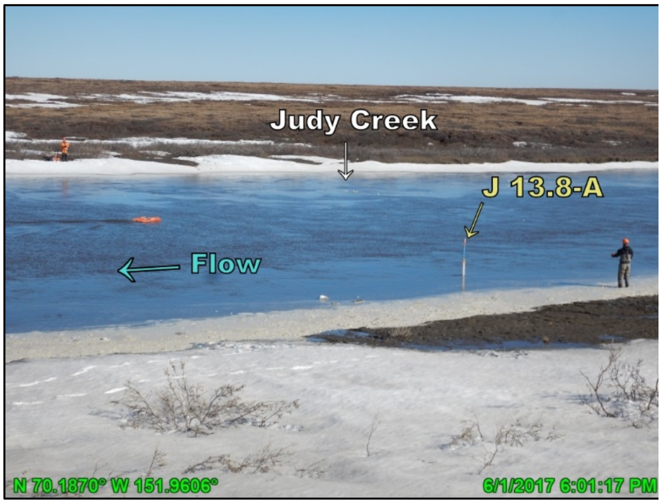
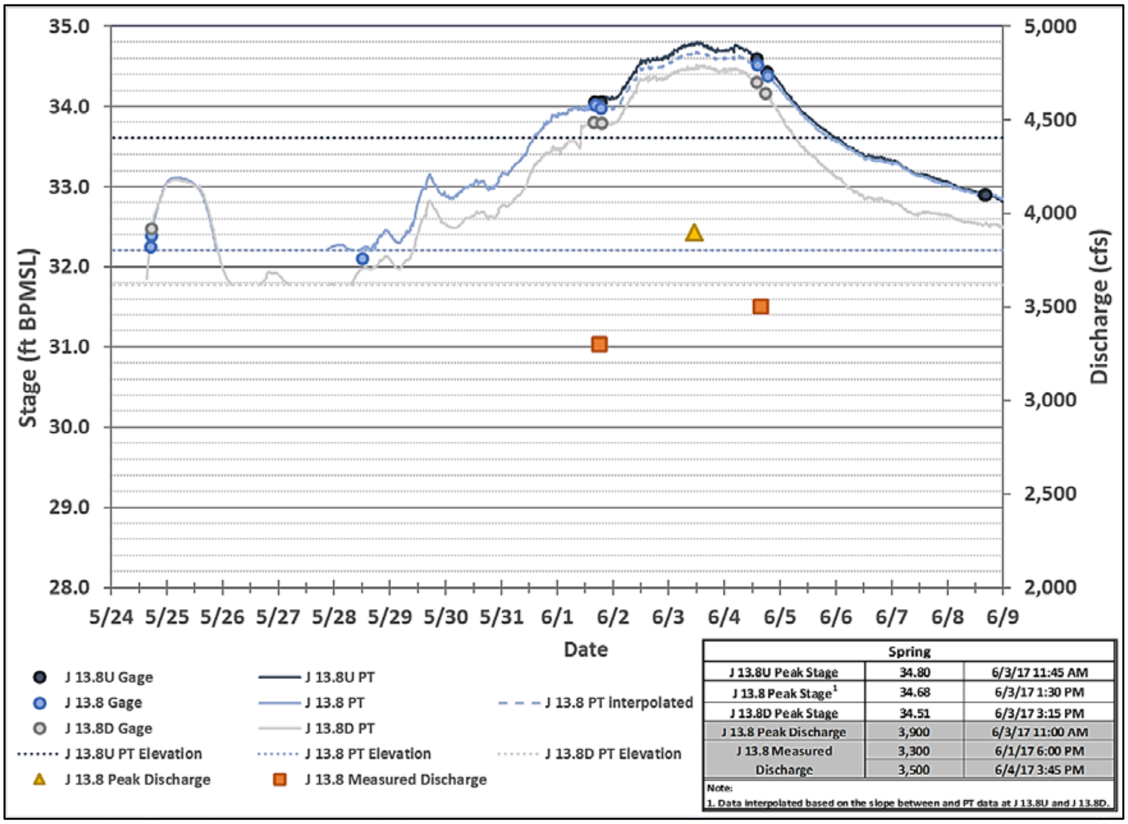


Photo 4.2: Conditions at J 13.8 the day of the first discharge measurement, looking southeast; June 1, 2017

Photo 4.3: Conditions at J 13.8 the day of peak stage, looking northeast (downstream); June 3, 2017

Photo 4.4: Conditions at J 13.8 the day of the second discharge measurement, looking southwest; June 4, 2017

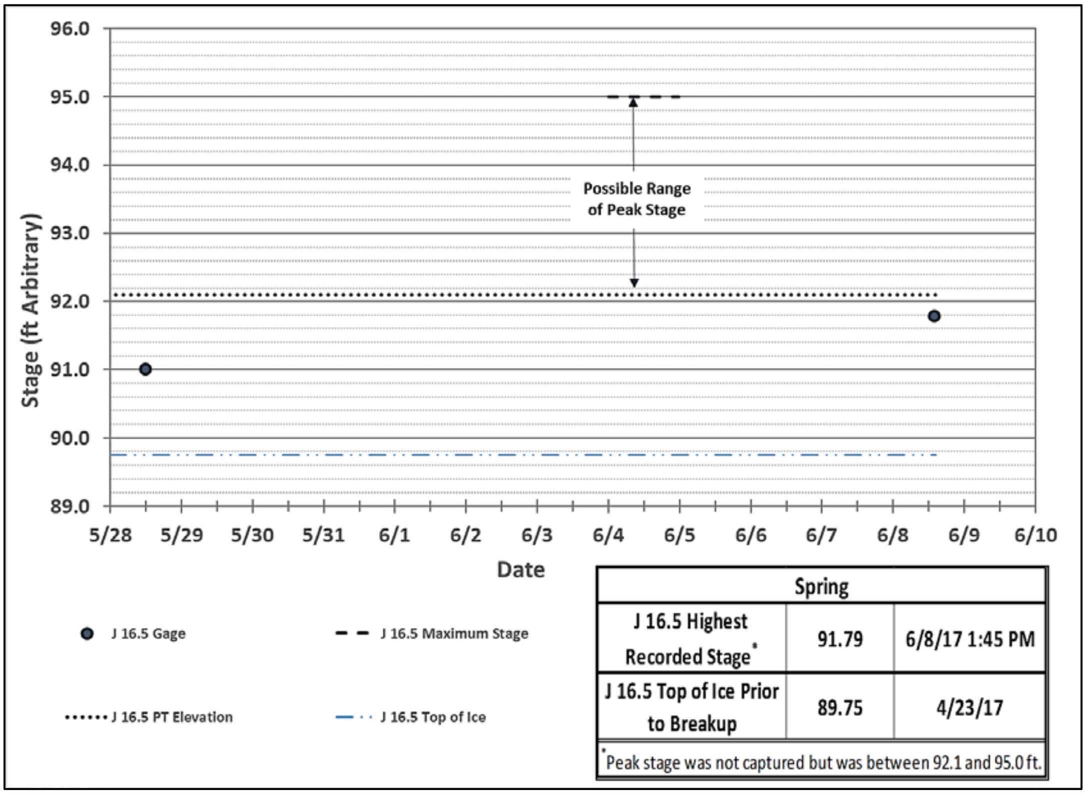
Photo 4.5: Conditions at J 21.4 the day of peak stage, looking southwest (upstream); June 4, 2017



Spring		
J 13.8U Peak Stage	34.80	6/3/17 11:45 AM
J 13.8 Peak Stage[1]	34.68	6/3/17 1:30 PM
J 13.8D Peak Stage	34.51	6/3/17 3:15 PM
J 13.8 Peak Discharge	3,900	6/3/17 11:00 AM
J 13.8 Measured Discharge	3,300	6/1/17 6:00 PM
	3,500	6/4/17 3:45 PM

Note:
1. Data interpolated based on the slope between and PT data at J 13.8U and J 13.8D.

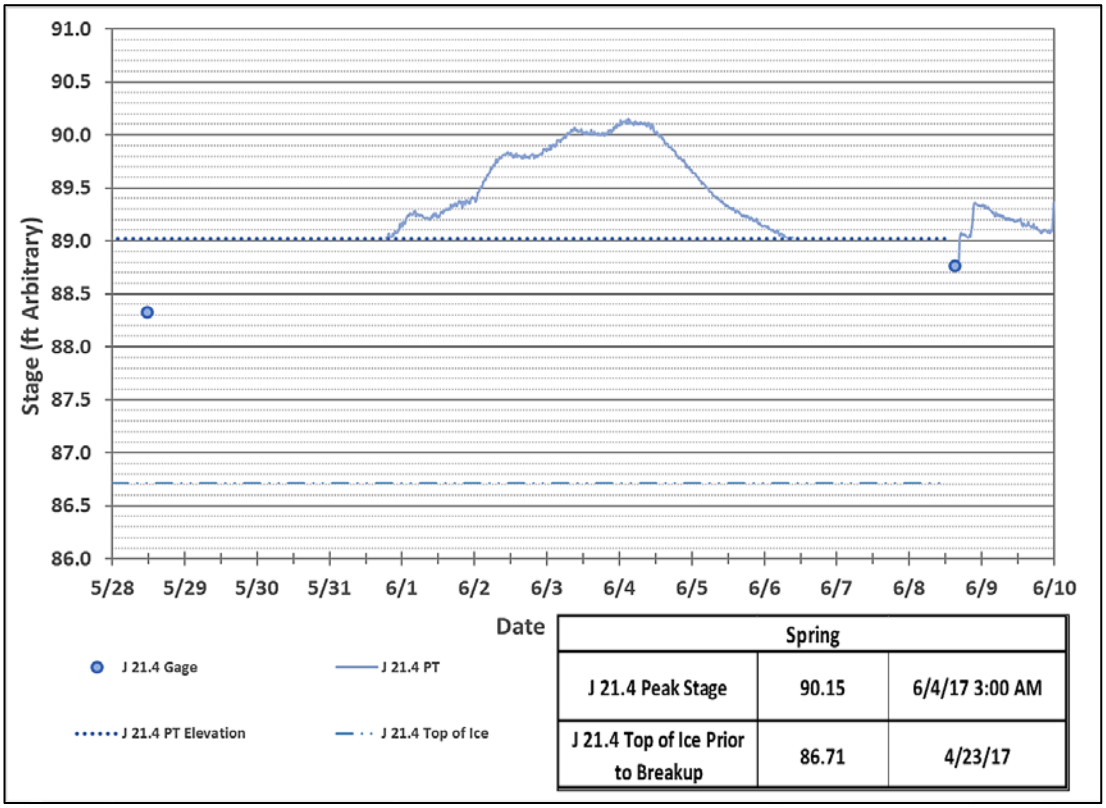
Graph 4.1: Judy Creek at J13.8U, J 13.8, & J 13.8D Spring Breakup Stage & Discharge



Spring		
J 16.5 Highest Recorded Stage[*]	91.79	6/8/17 1:45 PM
J 16.5 Top of Ice Prior to Breakup	89.75	4/23/17

[*] Peak stage was not captured but was between 92.1 and 95.0 ft.

Graph 4.2: Judy Creek at J 16.5 Spring Breakup Stage



Spring		
J 21.4 Peak Stage	90.15	6/4/17 3:00 AM
J 21.4 Top of Ice Prior to Breakup	86.71	4/23/17

Graph 4.3: Judy Creek at J 21.4 Spring Breakup Stage

SUMMER

Stage fluctuations associated with precipitation events were recorded throughout the summer, but water levels remained below peak stage measured during spring breakup (Photo 4.6 and Photo 4.7). The PT was buried and not recovered at J 16.5, and as a result, summer stage data is unavailable for this location. The top of ice elevation observed prior to spring breakup (Graph 4.2) provides a reasonable estimate of minimum stage at J 16.5.

Summer stage at Judy Creek J 13.8 and J 21.4 is presented in Graph 4.4 and Graph 4.5, respectively.

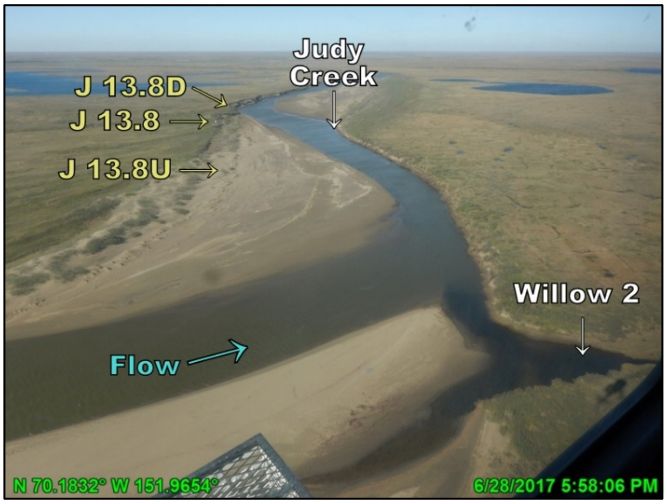
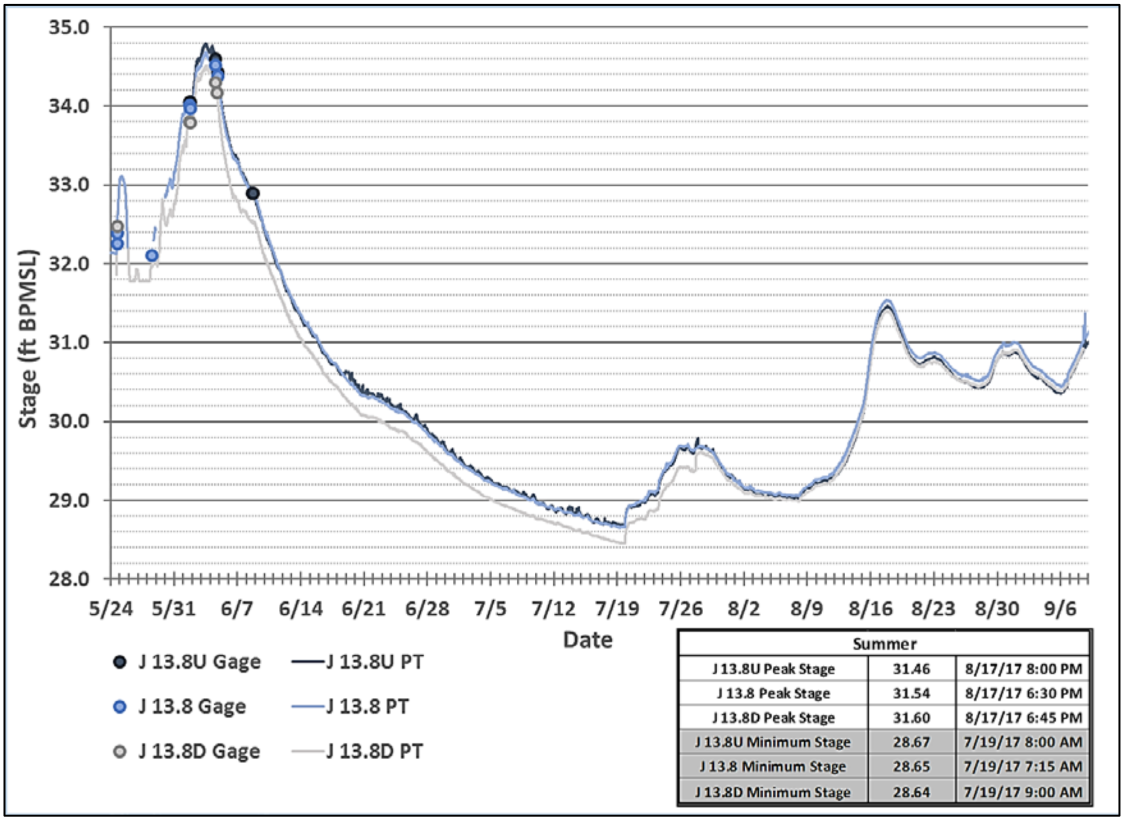


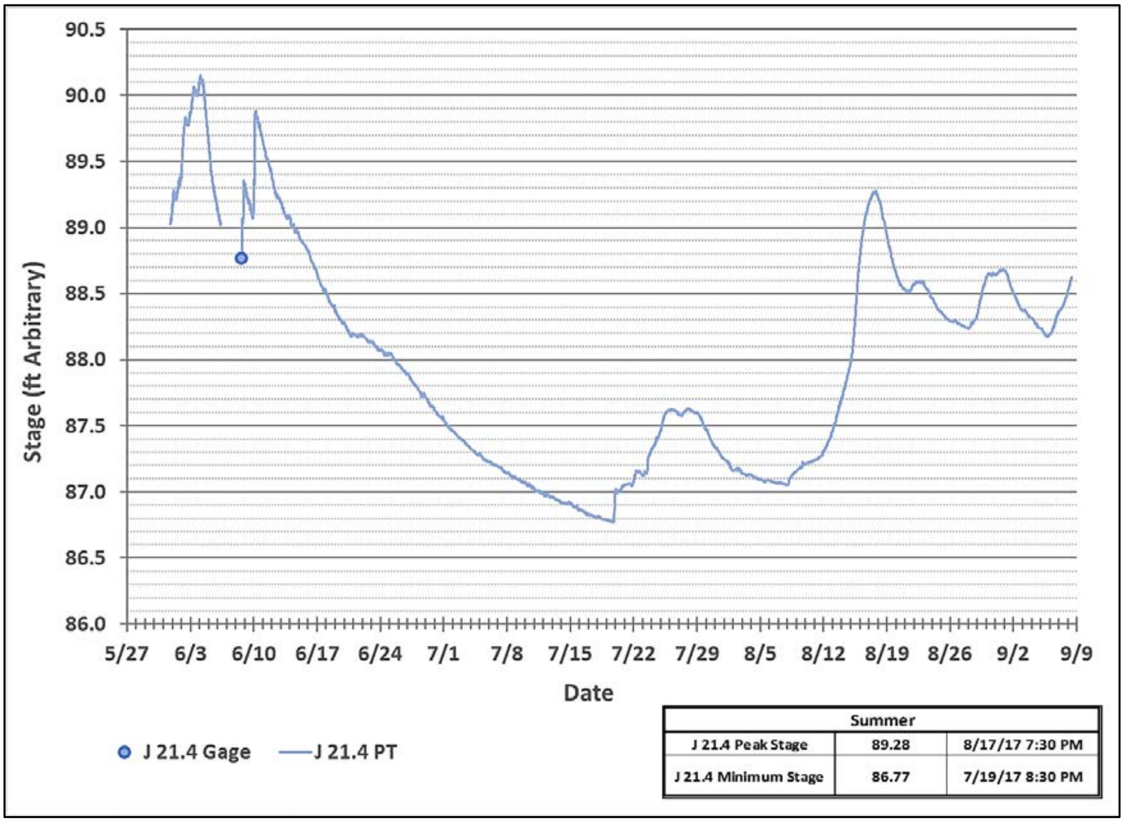
Photo 4.6: Summer conditions at J 13.8, looking northeast (downstream); June 28, 2017

Photo 4.7: Summer conditions at J 21.4, looking southwest (upstream; August 8, 2017



Summer		
J 13.8U Peak Stage	31.46	8/17/17 8:00 PM
J 13.8 Peak Stage	31.54	8/17/17 6:30 PM
J 13.8D Peak Stage	31.60	8/17/17 6:45 PM
J 13.8U Minimum Stage	28.67	7/19/17 8:00 AM
J 13.8 Minimum Stage	28.65	7/19/17 7:15 AM
J 13.8D Minimum Stage	28.64	7/19/17 9:00 AM

Graph 4.4: Judy Creek at J 13.8U, J 13.8, & J 13.8D Spring Breakup & Summer Stage



Summer		
J 21.4 Peak Stage	89.28	8/17/17 7:30 PM
J 21.4 Minimum Stage	86.77	7/19/17 8:30 PM

Graph 4.5: Judy Creek at J 21.4 Spring Breakup & Summer Stage

4.2 WILLOW 2

The UC1A, UC1C, and UC1B gage stations are located in Willow 2 approximately 1.4, 3.0, and 4.7 RMs upstream of the confluence with Judy Creek, respectively. Willow 2 is a highly sinuous, deep, and incised beaded channel (over 10 ft. from top of bank to creek bed) flowing generally north into Judy Creek upstream of the J 13.8 gage stations. This is the first year the Willow 2 gage stations have been monitored.

Spring and summer measured discharge data and plan and profile drawings are presented in Appendix B.2.2.

SPRING BREAKUP

Aside from some crevasse-like openings, Willow 2 was filled with wind-driven snow throughout the winter. The extent and depth of snow accumulation prior to spring breakup prevented field crews from finding the channel at UC1A and UC1AU (Photo 3.2). Gages at these locations were installed after breakup flows cleared some of the snow; available spring breakup data at these gages is limited to post-peak conditions. Single gages were installed in the low flow channel at UC1AD, UC1B, and UC1C. Large snow drifts at these gage stations made locating the channel banks challenging and additional gages were not installed linearly up to the bank until after breakup flows had melted the snow.

Breakup flows at all Willow 2 locations began on top of the drifted snow then progressively cut channels through the snow-filled drainage. Peak stage at all Willow 2 locations was elevated to bankfull conditions by snow and ice in the channel and likely did not coincide with peak discharge (Photo 4.8 through Photo 4.11). The spikes in the stage hydrograph are likely the result of dynamic changes to channel geometry from flow cutting through drifted snow throughout breakup.

Discharge during spring breakup was measured in a riffle approximately 100 ft. downstream of the UC1AD gage location. The UC1AD gage is located in a deep pool. Snow was present along the banks and in the bed of the discharge reach at the time of measurement. The average channel velocity was 2.2 fps. The quality of the measurement was classified as good based on conditions at the time of measurement (Photo 4.12 and Photo 4.13). Indirect calculations of peak discharge were heavily influenced by the continually changing channel geometry as flow cut through the drifted snow. As a result, reasonable peak discharge values were not obtained or reported. Based on observations, the measured discharge at UC1AD is believed to be representative of peak discharge.

Willow 2 UC1A spring breakup stage data is provided in Graph 4.6; Willow 2 UC1A, UC1B, and UC1C stage data is provided in Graph 4.7. Elevation datum is arbitrary and local for each location; elevations are not relative.

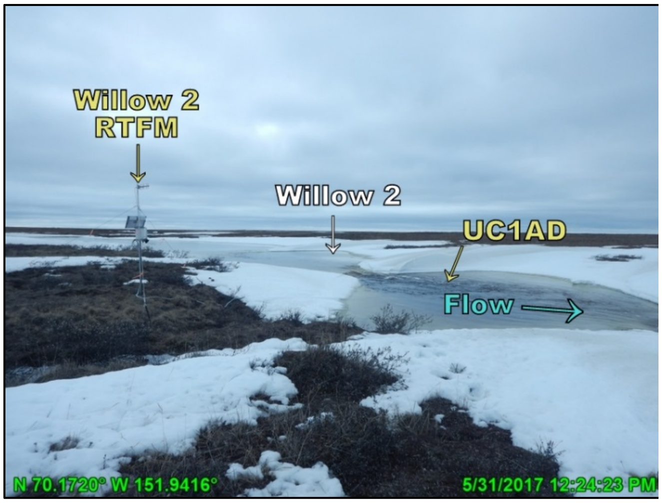


Photo 4.8: Conditions at UC1AD the day after peak stage, looking south (upstream); May 31, 2017

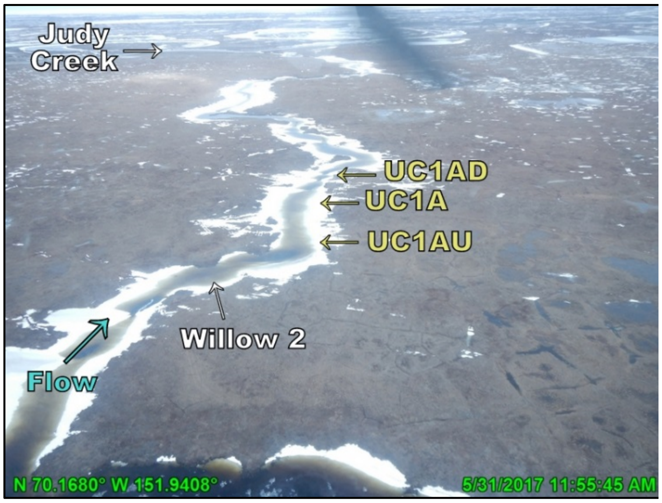


Photo 4.9: Conditions at UC1A the day after peak stage at UC1AD, looking north (downstream); May 31, 2017

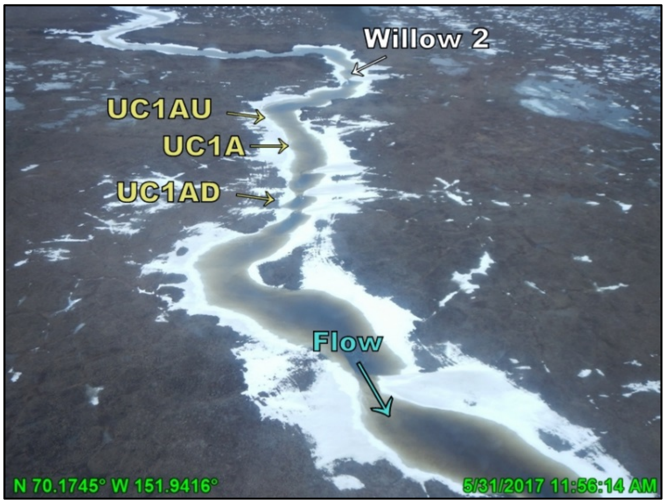


Photo 4.10: Conditions at UC1A the day after peak stage at UC1AD, looking north (downstream); May 31, 2017

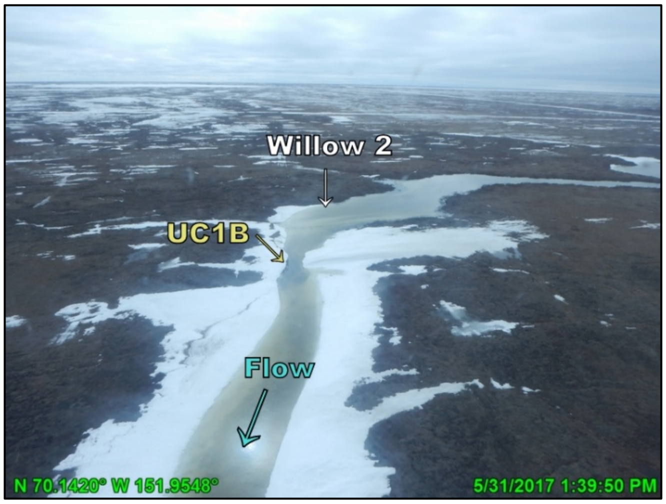


Photo 4.11: Conditions at UC1B the day after peak stage at UC1AD, looking southwest (upstream); May 31, 2017

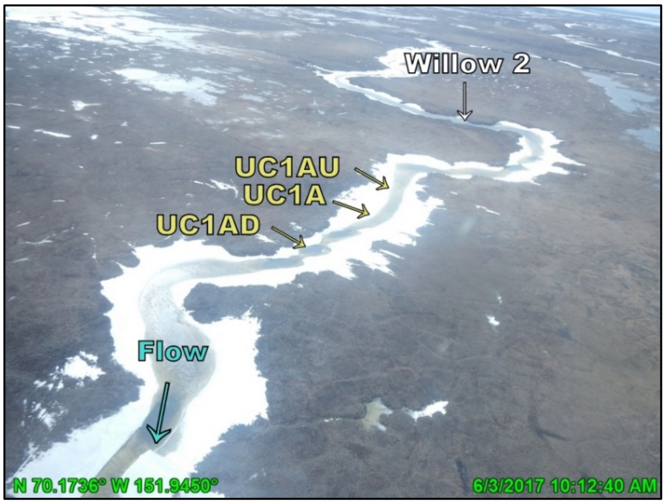
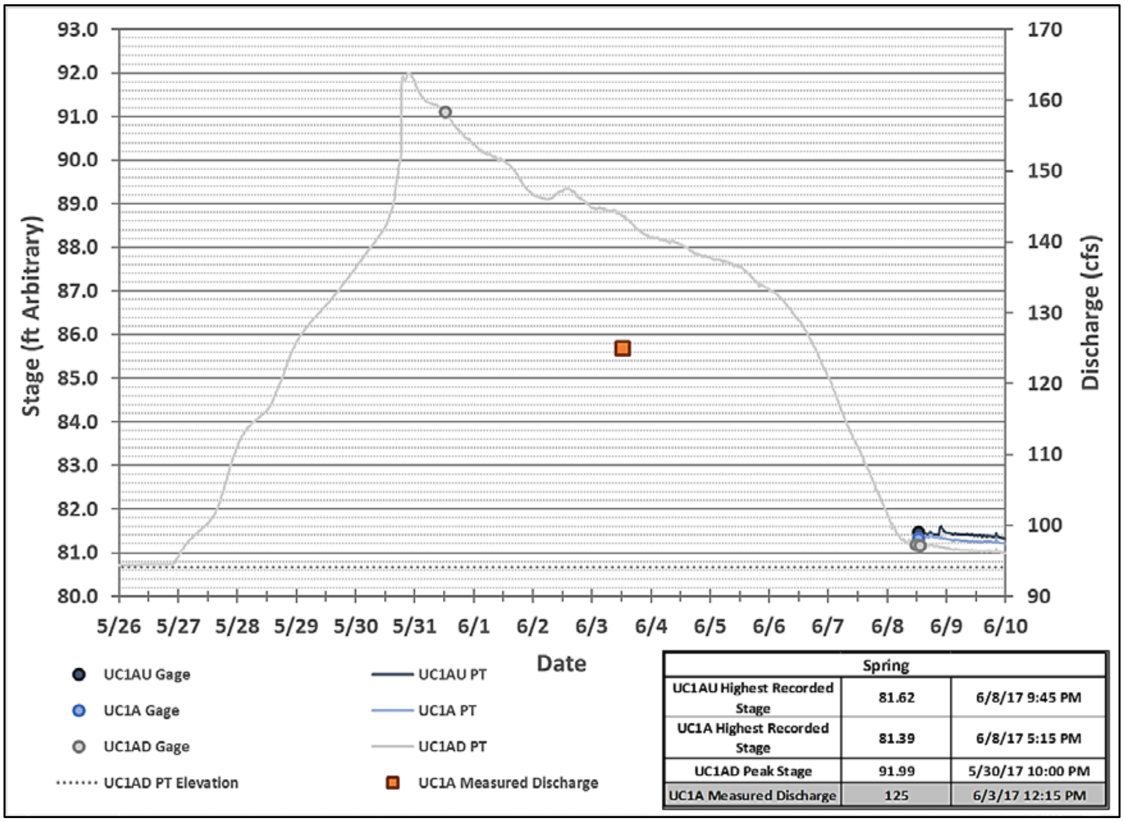


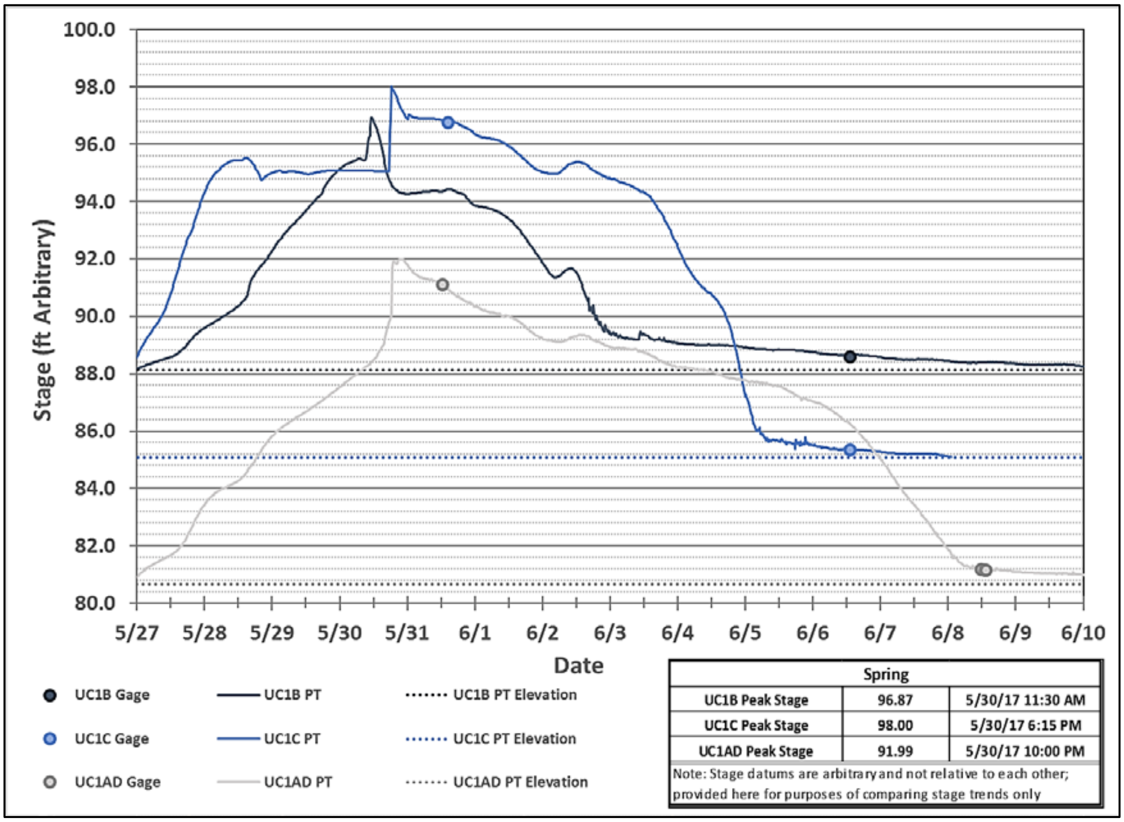
Photo 4.12: UC1A reach the day of discharge measurement, looking upstream (southeast); June 3, 2017

Photo 4.13: Discharge cross-section at UC1A, looking east; June 3, 2017



Spring		
UC1AU Highest Recorded Stage	81.62	6/8/17 9:45 PM
UC1A Highest Recorded Stage	81.39	6/8/17 5:15 PM
UC1AD Peak Stage	91.99	5/30/17 10:00 PM
UC1A Measured Discharge	125	6/3/17 12:15 PM

Graph 4.6: Willow 2 at UC1AU, UC1A, & UC1AD Spring Breakup Stage & Discharge



Spring		
UC1B Peak Stage	96.87	5/30/17 11:30 AM
UC1C Peak Stage	98.00	5/30/17 6:15 PM
UC1AD Peak Stage	91.99	5/30/17 10:00 PM
Note: Stage datums are arbitrary and not relative to each other; provided here for purposes of comparing stage trends only		

Graph 4.7: Willow 2 at UC1B, UC1C, & UC1AD Spring Breakup Stage

SUMMER

Summer stage in Willow 2 at UC1A and UC1AD, UC1B, and UC1C is presented in Graph 4.8 and Graph 4.9, respectively. Stage fluctuations associated with summer precipitation events were recorded in the data but water levels remained below spring breakup peak stage at all locations (Photo 4.14 through Photo 4.16). Discharge measured during the summer was considerably lower than spring breakup flows.

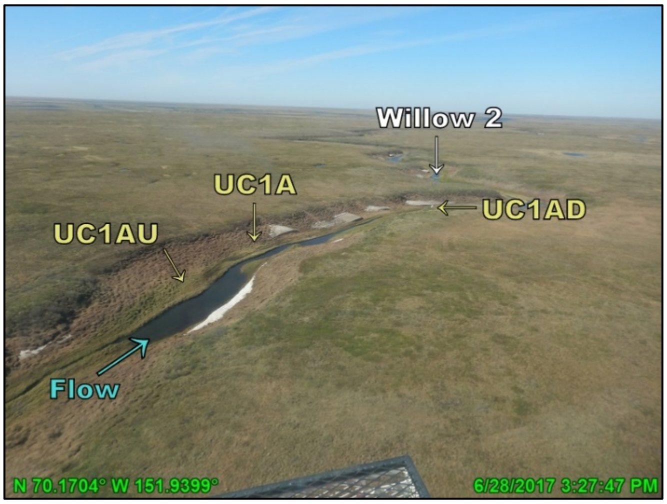


Photo 4.14: Summer conditions at UC1A, looking north (downstream); June 28, 2017

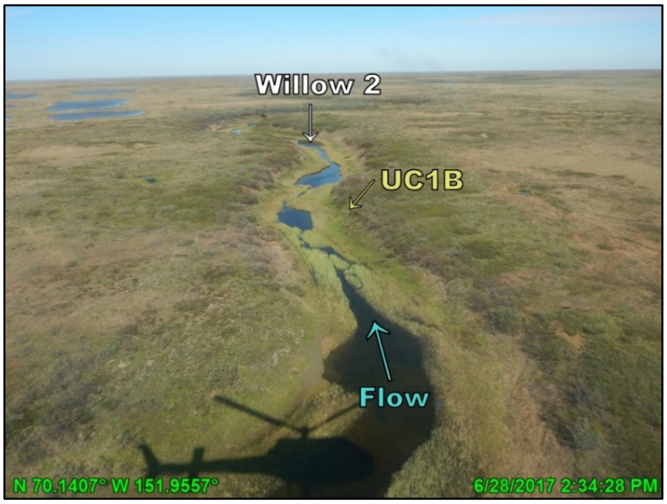


Photo 4.15: Summer conditions at UC1B, looking north (downstream); June 28, 2017

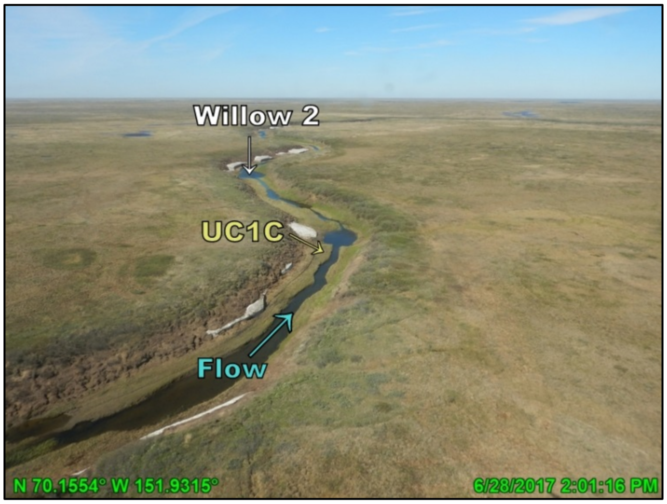
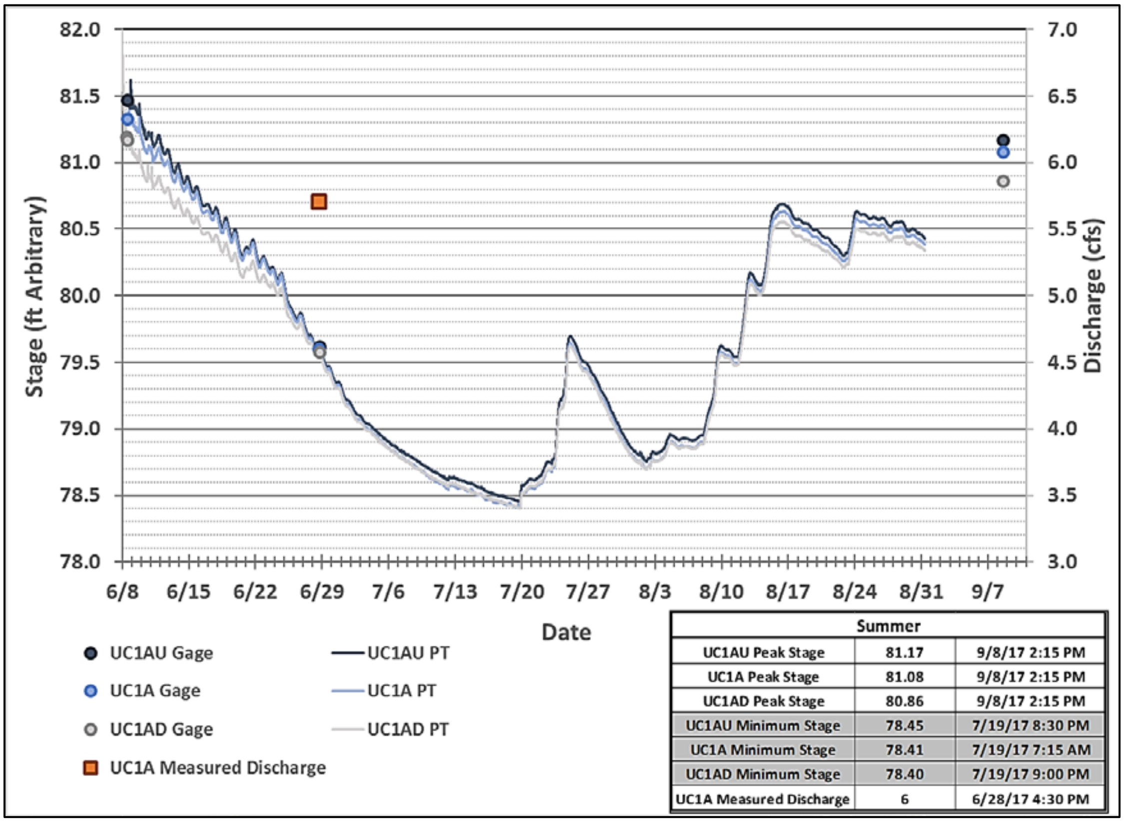
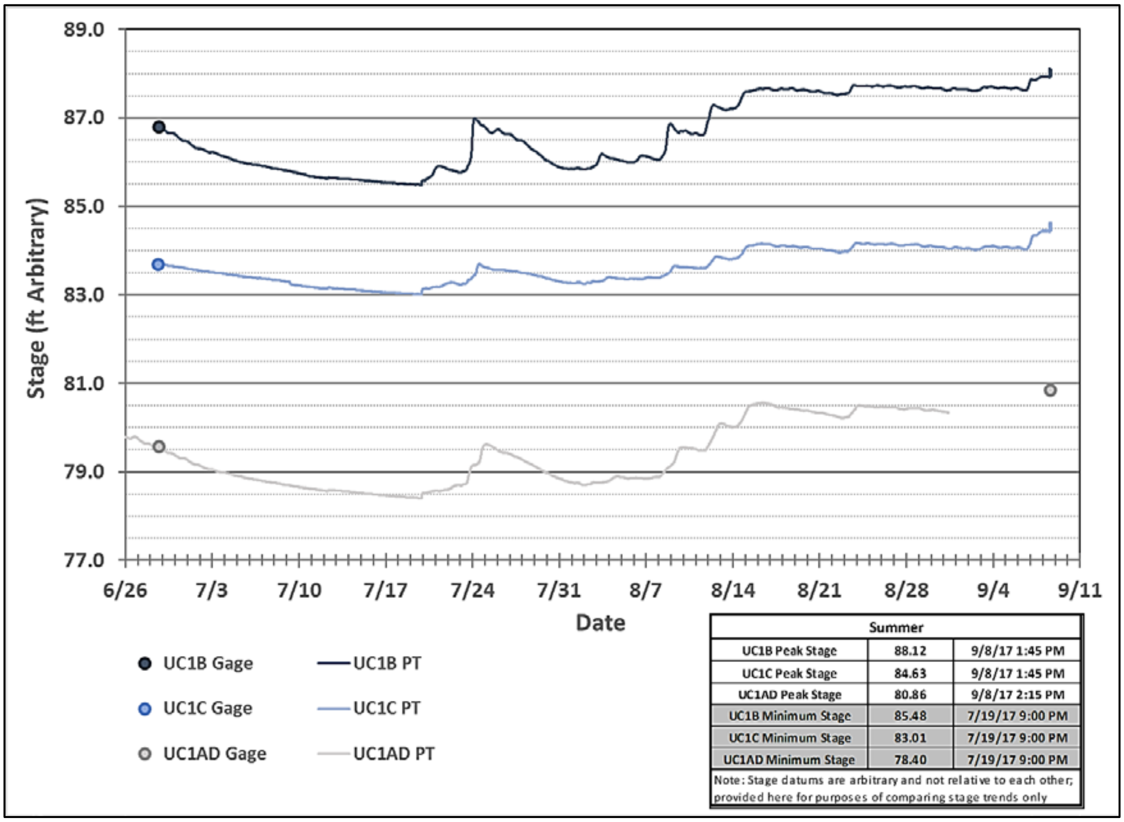


Photo 4.16: Summer conditions at UC1C, looking north (downstream); June 28, 2017



Summer		
UC1AU Peak Stage	81.17	9/8/17 2:15 PM
UC1A Peak Stage	81.08	9/8/17 2:15 PM
UC1AD Peak Stage	80.86	9/8/17 2:15 PM
UC1AU Minimum Stage	78.45	7/19/17 8:30 PM
UC1A Minimum Stage	78.41	7/19/17 7:15 AM
UC1AD Minimum Stage	78.40	7/19/17 9:00 PM
UC1A Measured Discharge	6	6/28/17 4:30 PM

Graph 4.8: Willow 2 at UC1AU, UC1A, & UC1AD Summer Stage & Discharge



Summer		
UC1B Peak Stage	88.12	9/8/17 1:45 PM
UC1C Peak Stage	84.63	9/8/17 1:45 PM
UC1AD Peak Stage	80.86	9/8/17 2:15 PM
UC1B Minimum Stage	85.48	7/19/17 9:00 PM
UC1C Minimum Stage	83.01	7/19/17 9:00 PM
UC1AD Minimum Stage	78.40	7/19/17 9:00 PM

Note: Stage datums are arbitrary and not relative to each other; provided here for purposes of comparing stage trends only

Graph 4.9: Willow 2 at UC1B, UC1C, & UC1AD Summer Stage

4.3 JUDY CREEK KAYYAAQ

The UC2A, UC2B, and UC2C gage stations are located in Judy Creek Kayyaaq approximately 8.4, 10.2, and 13 RMs upstream of the confluence with Judy Creek, respectively. Judy Creek Kayyaaq is a highly sinuous and incised channel (over 8 ft. from top of bank to creek bed) flowing generally northeast into Judy Creek downstream of the J 13.8 gage stations. This is the first year the Judy Creek Kayyaaq gage stations have been monitored.

Spring and summer measured discharge data and plan and profile drawings are presented in Appendix B.2.3.

SPRING BREAKUP

Judy Creek Kayyaaq was filled with wind-driven snow throughout the winter but it is less incised in the study locations than Willow 2. Breakup flows at all Judy Creek Kayyaaq locations began on top of the drifted snow then progressively cut a channel through the snow-filled creek. Peak stage at all Judy Creek Kayyaaq locations was elevated above bankfull conditions by the snow and ice in the channel and likely did not coincide with peak discharge (Photo 4.17 through Photo 4.20).

Discharge during spring breakup was measured at the UC2A centerline gage station. Snow and ice was present in the reach at the time of measurement. The average channel velocity was 2.1 fps. The quality of the measurement was classified as good based on conditions at the time of measurement (Photo 4.23 and Photo 4.24). Indirect calculations of peak discharge were heavily influenced by the continually changing channel geometry as flow cut through the drifted snow. As a result, reasonable peak discharge values were not obtained or reported. Based on flow observations, the measured discharge at UC2A is believed to be representative of peak discharge.

Judy Creek Kayyaaq UC2A spring breakup stage data is provided in Graph 4.10. Judy Creek Kayyaaq UC2A, UC2B, and UC2C stage data is provided in Graph 4.11. Elevation datum is arbitrary and local for each location; elevations are not relative.

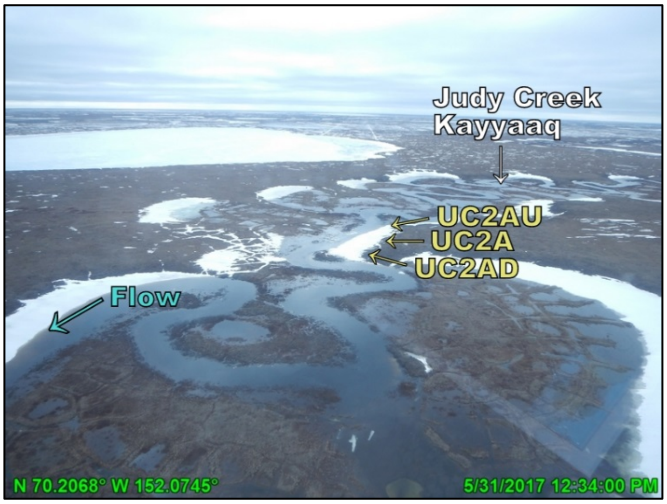


Photo 4.17: Conditions at UC2A the day after peak stage, looking southwest (upstream); May 31, 2017

Photo 4.18: Conditions at UC2A the day after peak stage, looking east; May 31, 2017

Photo 4.19: Conditions at UC2B the day after peak stage, looking northeast (downstream); May 31, 2017

Photo 4.20: Conditions at UC2C the day after peak stage, looking southwest; May 31, 2017

Photo 4.21: Conditions at UC2A during the discharge measurement, looking west; June 3, 2017

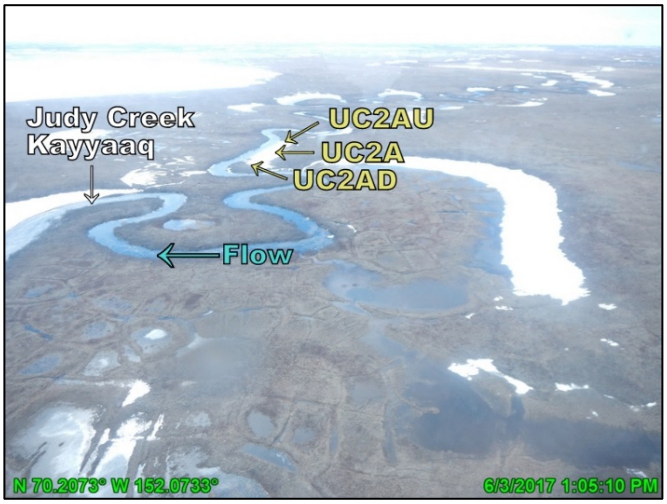
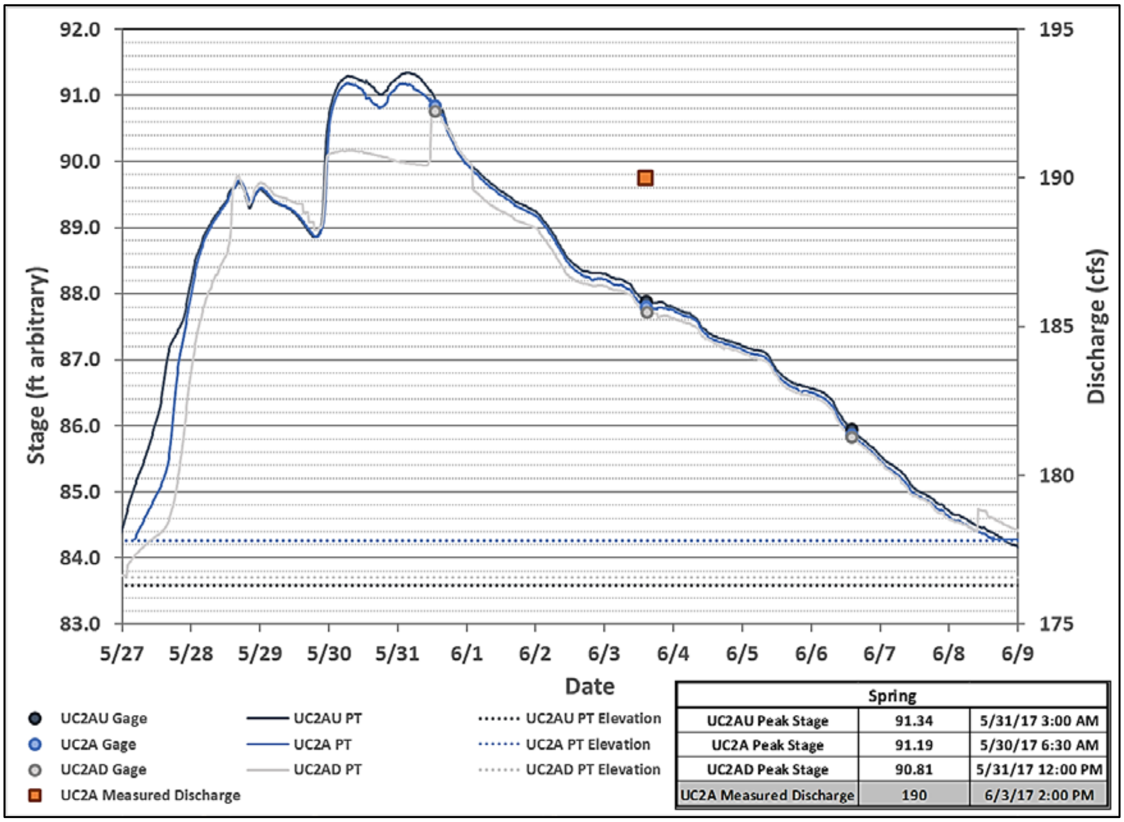
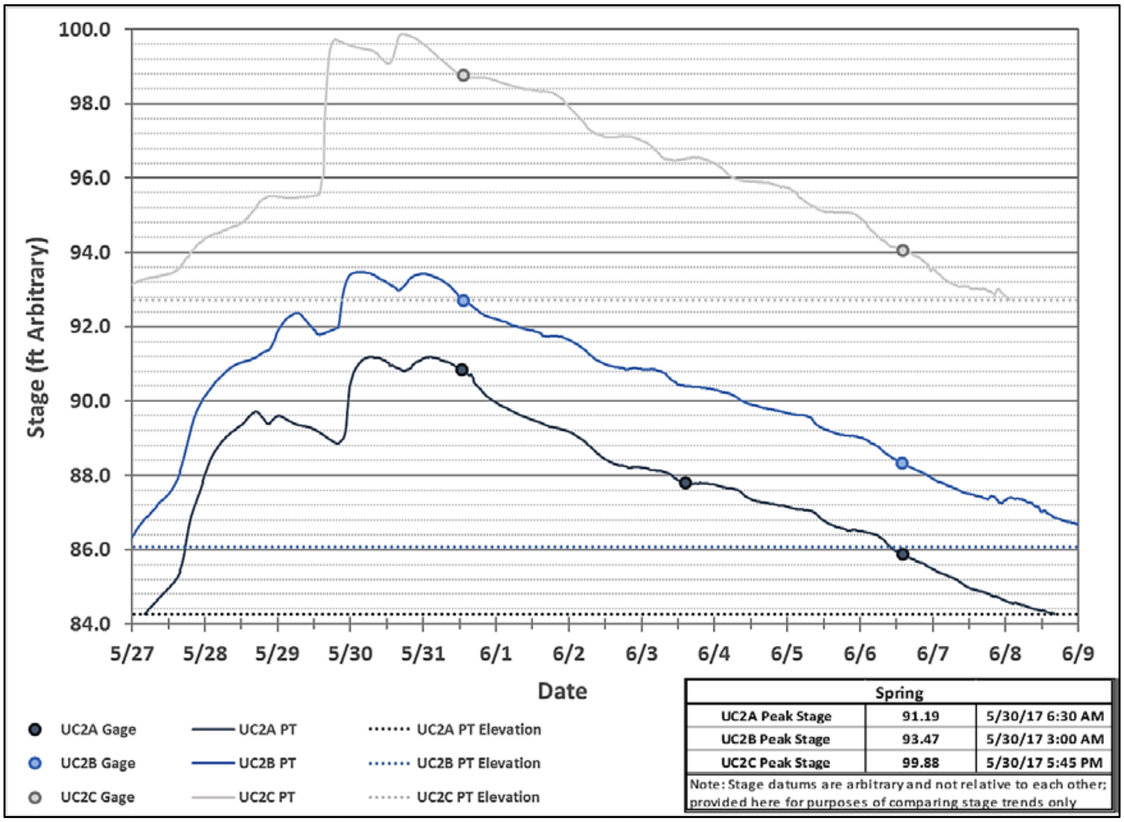


Photo 4.22: Conditions at UC2A during the discharge measurement, looking southwest (downstream); June 3, 2017



Spring		
UC2AU Peak Stage	91.34	5/31/17 3:00 AM
UC2A Peak Stage	91.19	5/30/17 6:30 AM
UC2AD Peak Stage	90.81	5/31/17 12:00 PM
UC2A Measured Discharge	190	6/3/17 2:00 PM

Graph 4.10: Judy Creek Kayyaaq at UC2AU, UC2A, & UC2AD Spring Breakup Stage & Discharge



Spring		
UC2A Peak Stage	91.19	5/30/17 6:30 AM
UC2B Peak Stage	93.47	5/30/17 3:00 AM
UC2C Peak Stage	99.88	5/30/17 5:45 PM

Note: Stage datums are arbitrary and not relative to each other; provided here for purposes of comparing stage trends only

Graph 4.11: Judy Creek Kayyaaq at UC2C, UC2B, & UC2A Spring Breakup Stage

SUMMER

Summer stage in Judy Creek Kayyaaq at UC2A and UC2AD, UC2B, and UC2C is presented in Graph 4.12 and Graph 4.13 respectively. Stage fluctuations associated with summer precipitation events were recorded in the data but water levels remained below spring breakup peak stage at all locations (Photo 4.23 and Photo 4.24).

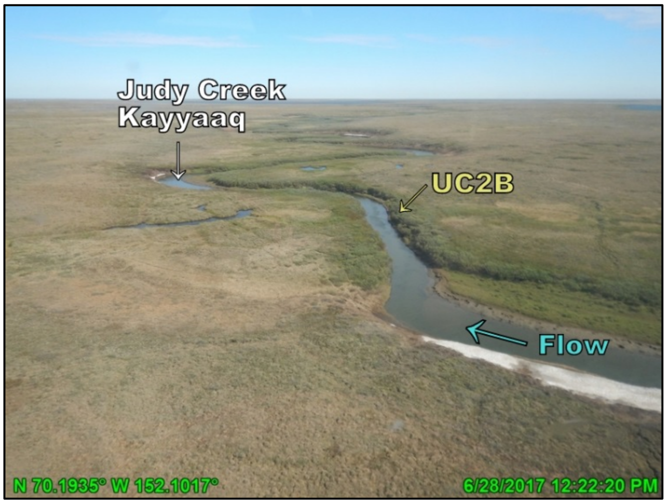


Photo 4.23: Summer conditions at UC2B, looking northeast (downstream); June 28, 2017

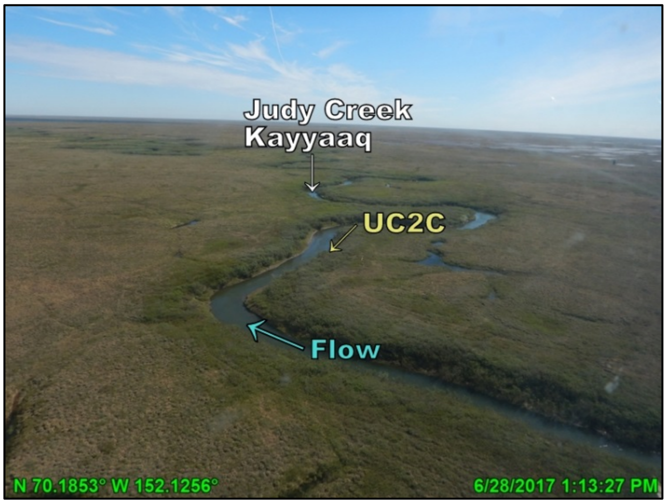
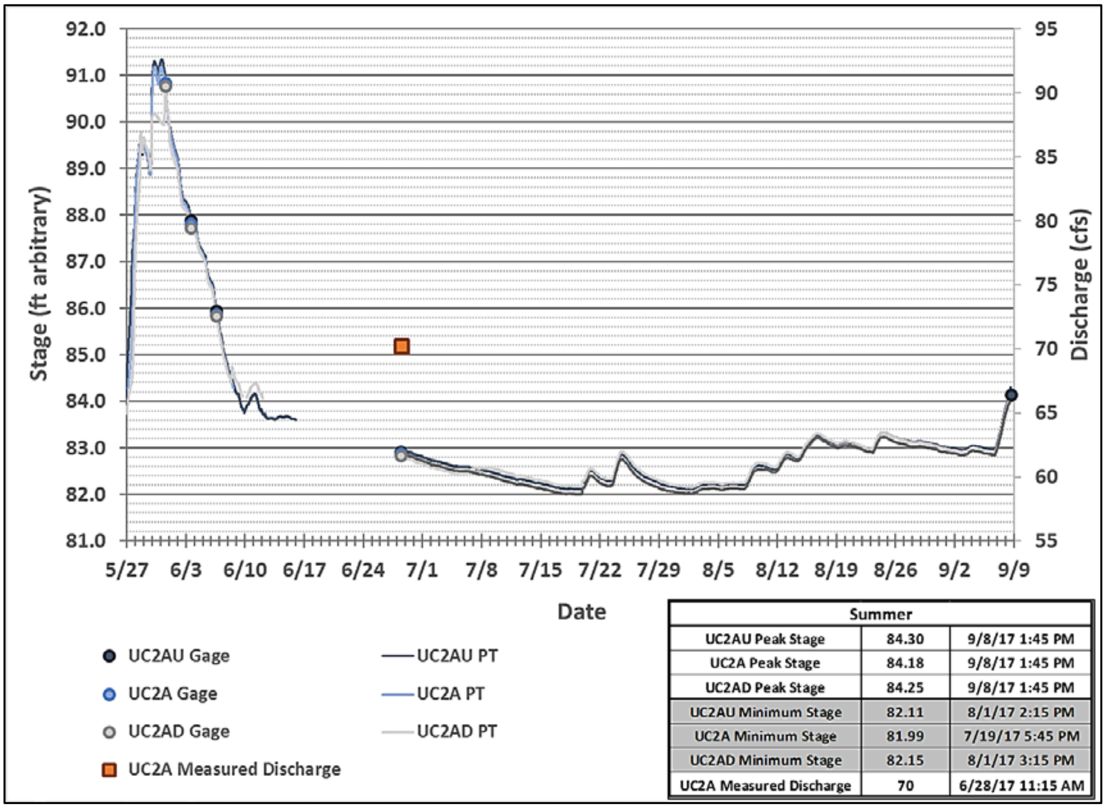
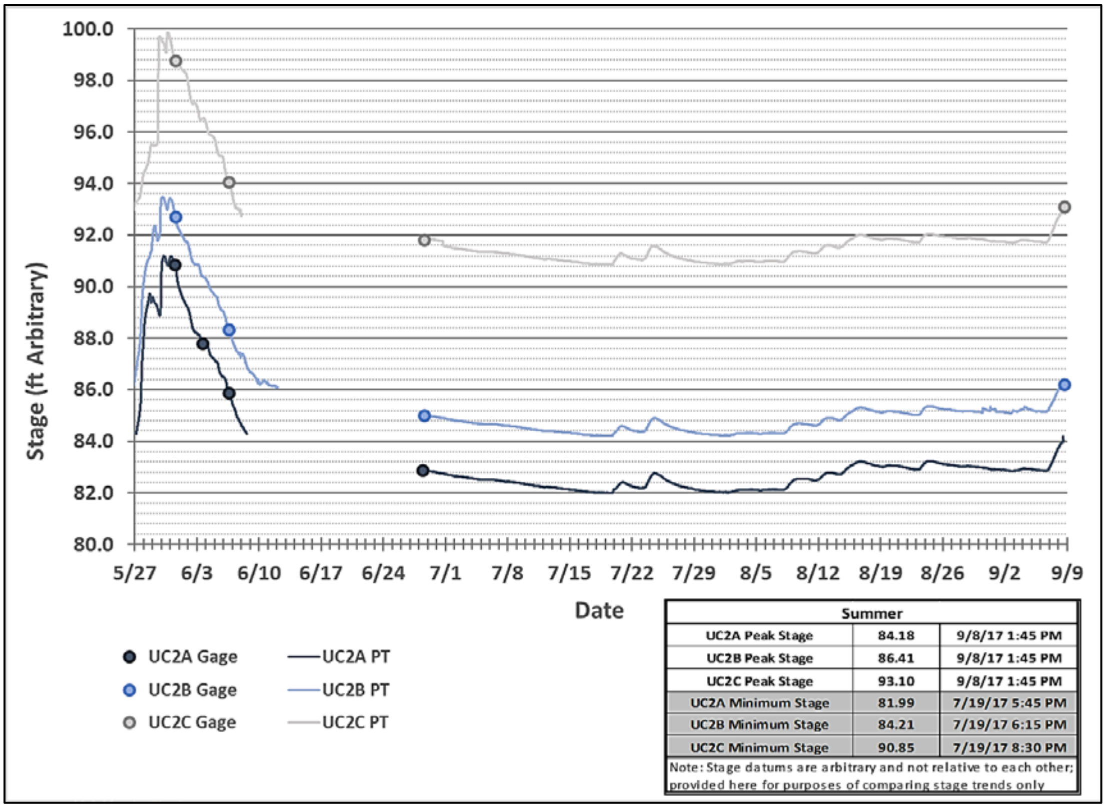


Photo 4.24: Summer conditions at UC2C, looking east (downstream); June 28, 2017



Summer		
UC2AU Peak Stage	84.30	9/8/17 1:45 PM
UC2A Peak Stage	84.18	9/8/17 1:45 PM
UC2AD Peak Stage	84.25	9/8/17 1:45 PM
UC2AU Minimum Stage	82.11	8/1/17 2:15 PM
UC2A Minimum Stage	81.99	7/19/17 5:45 PM
UC2AD Minimum Stage	82.15	8/1/17 3:15 PM
UC2A Measured Discharge	70	6/28/17 11:15 AM

Graph 4.12: Judy Creek Kayyaaq at UC2AU, UC2A, & UC2AD Spring Breakup & Summer Stage & Discharge



Summer		
UC2A Peak Stage	84.18	9/8/17 1:45 PM
UC2B Peak Stage	86.41	9/8/17 1:45 PM
UC2C Peak Stage	93.10	9/8/17 1:45 PM
UC2A Minimum Stage	81.99	7/19/17 5:45 PM
UC2B Minimum Stage	84.21	7/19/17 6:15 PM
UC2C Minimum Stage	90.85	7/19/17 8:30 PM
Note: Stage datums are arbitrary and not relative to each other; provided here for purposes of comparing stage trends only		

Graph 4.13: Judy Creek Kayyaaq at UC2C, UC2B, & UC2A Spring Breakup & Summer Stage

4.4 SWALES

This is the first year the swale gage stations have been monitored. Snow cover during spring breakup setup masked the subtle topographic features defining the swales and small drainages, preventing field crews from accurately determining the location of new gage station installations. As a result, gages were installed after the snow cover diminished enough to reveal the drainages. It is assumed peak stage occurred prior to the installation of the SW gages and PTs and therefore the highest recorded stage is reported rather than peak stage. Based on observations, measured discharge is believed to be representative of peak discharge.

SWALES 2, 3, 6, & 9

During spring breakup, field crews did not observe defined drainages at SW2, 3, 6, and 9. Aerial photographs were collected, but no gage stations were established (Photo 4.25, Photo 4.26, Photo 4.27, and Photo 4.28).

Photo 4.25: Swale 2, looking south; May 31, 2017

Photo 4.26: Swale 3, looking south; May 31, 2017

Photo 4.27: Swale 6, looking south; May 31, 2017

Photo 4.28: Swale 9, looking northwest; May 31, 2017

SWALE 1

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 J 16.5. Gage station SW1 is approximately 0.3 miles south (upstream) of gage station SW8, separated by an unnamed lake.

Ponded local melt was observed in Swale 1 at the end of May with ice remaining on the surrounding lakes (Photo 4.29). Swale 1 was flowing under generally open channel conditions by June 3, the day the gage and PT were installed and the highest stage was recorded (Photo 4.31). Flow was being conveyed from the ponded area to the south of SW1 into the lake to the north of SW1. Hydraulically connected meltwater was ponded in the low-lying adjacent areas to the east and west of SW1. The PT remained dry throughout spring breakup and therefore continuous stage data is not reported. Discharge was measured upstream of the SW1 gage where flow was confined to a single riffle (Photo 4.32). By the end of June, water was confined to beads within the drainage path, adjacent low-lying areas were dry, and no flow was present, based on aerial observations (Photo 4.32).

Swale 1 spring breakup stage and measured discharge data are presented in Graph 4.14. Measured discharge data and plan and profile figures are provided in Appendix B.2.4.

Photo 4.29: Ponded local melt at Swale 1, looking northeast (downstream); May 31, 2017

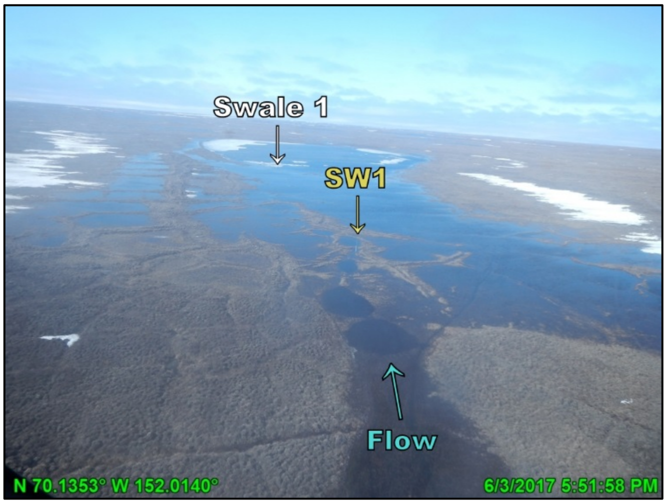
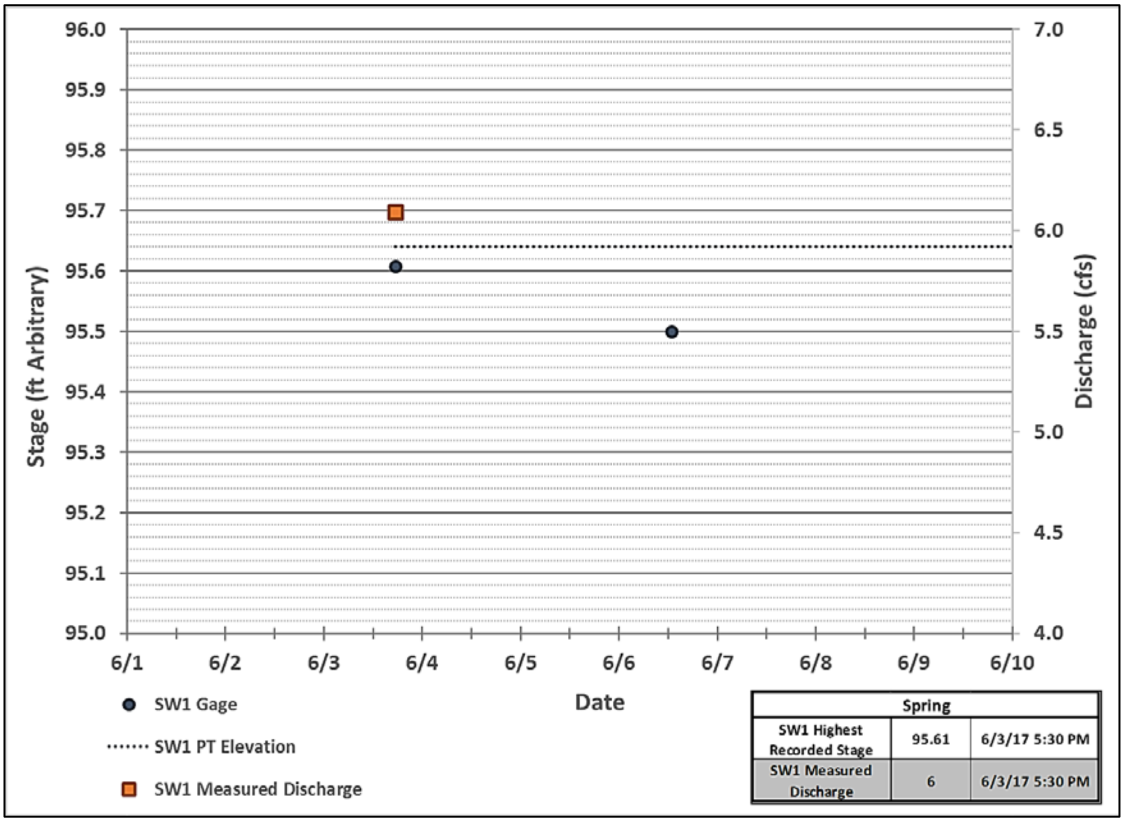


Photo 4.30: Conditions at Swale 1 the day of measured discharge and highest recorded stage, looking north (downstream); June 3, 2017

Photo 4.31: Conditions at Swale 1 the day of measured discharge and highest recorded stage, looking northeast; June 3, 2017

Photo 4.32: Summer conditions at Swale 1, looking north (downstream); June 28, 2017



	Spring	
SW1 Highest Recorded Stage	95.61	6/3/17 5:30 PM
SW1 Measured Discharge	6	6/3/17 5:30 PM

Graph 4.14: Swale 1 Spring Breakup Stage & Discharge

SWALE 4

Gage station SW4 is situated in a swale connecting Lakes M1523A, B, and C to Judy Creek downstream of gage station J 21.4. This swale, consisting of interconnected polygon troughs, is a paleochannel of Judy Creek.

Ponded local melt was observed in Swale 4 at the end of May with ice remaining on the upstream lakes and in the swale (Photo 4.33). On June 6, the day the SW4 gage and PT were installed, the upstream lakes and downstream portion of Swale 4 remained ice covered (Photo 4.35 and Photo 4.36). Hydraulically connected ponded water was observed in polygon cracks, low-lying areas, ponds, and lakes upstream, downstream, and adjacent to Swale 4. Flow was not present and therefore discharge was not measured. Ponded water remained throughout the area at the end of June, based on aerial observations (Photo 4.36). No flow was observed between hydraulically connected waterbodies.

Swale 4 spring breakup stage is presented in Graph 4.15.

Photo 4.33: Ponded local melt at Swale 4, looking southeast; May 31, 2017

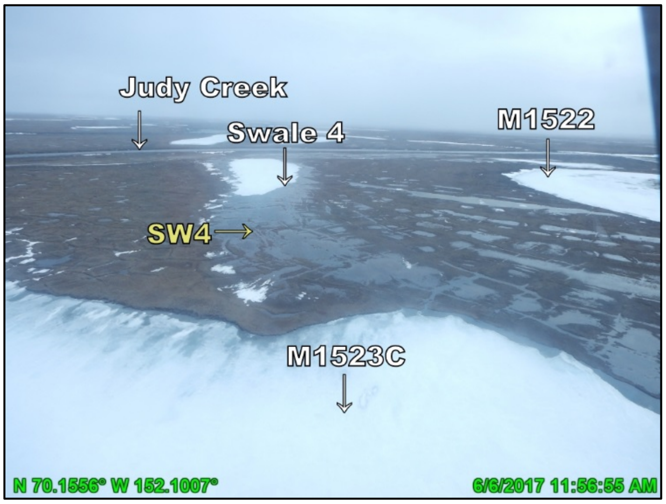


Photo 4.34: Conditions at Swale 4 the day of highest recorded stage, looking northeast; June 6, 2017

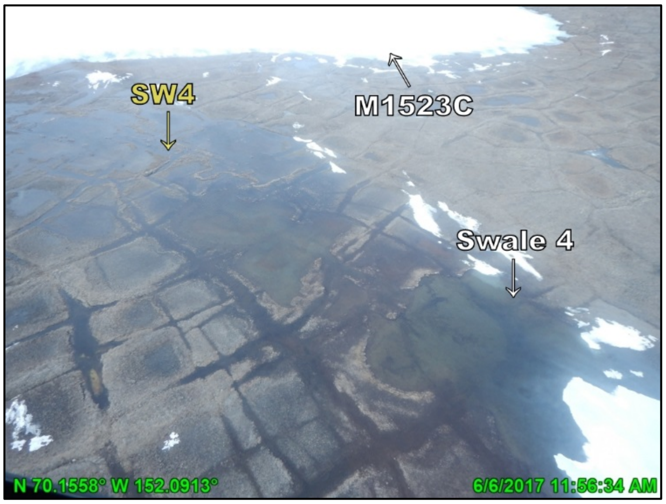


Photo 4.35: Conditions at Swale 4 the day of highest recorded stage, looking southwest; June 6, 2017

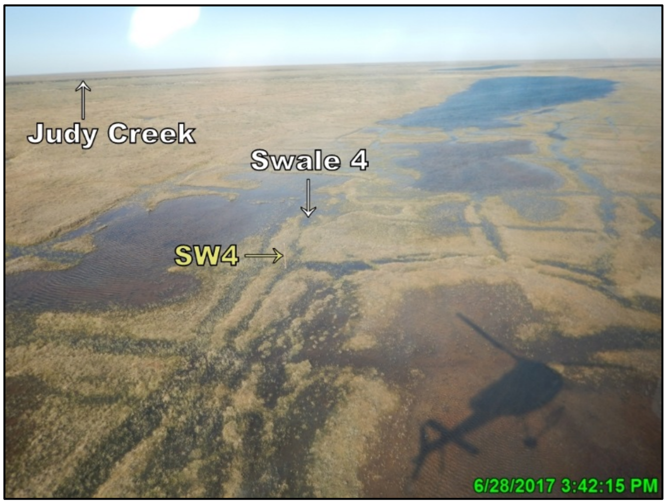
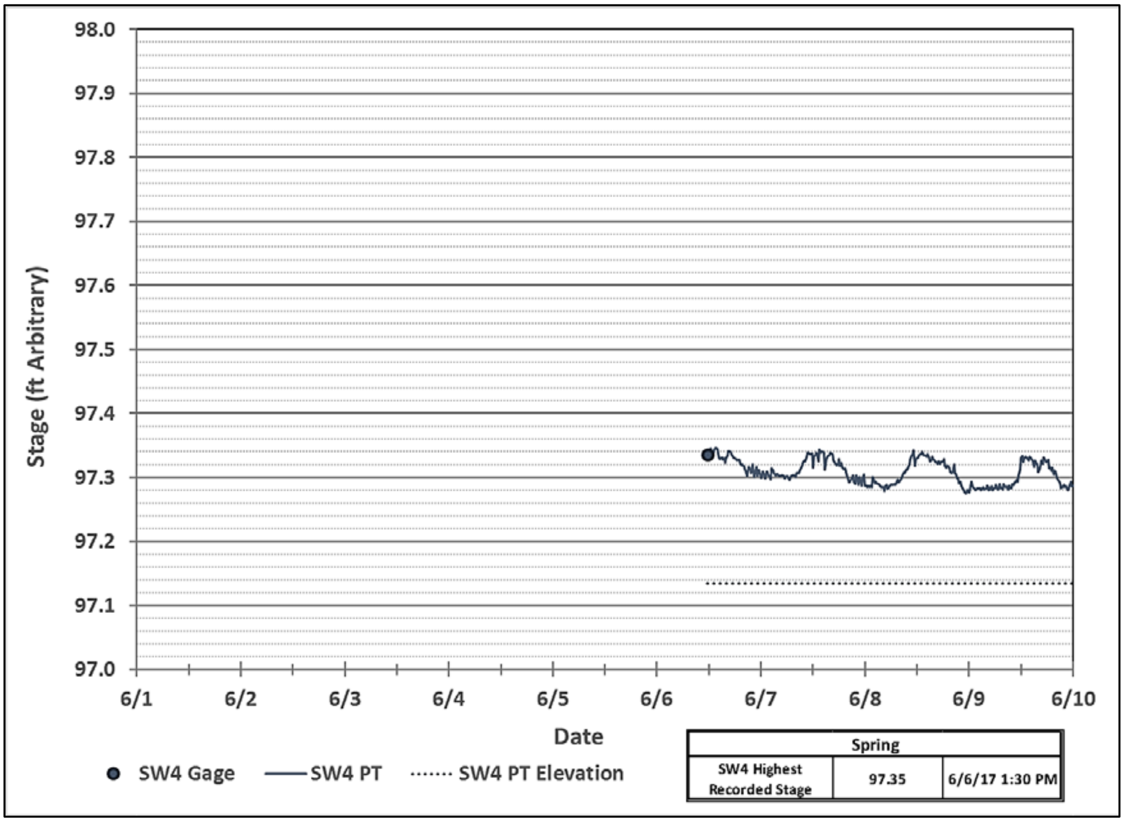


Photo 4.36: Summer conditions at Swale 4, looking northeast; June 28, 2017



Graph 4.15: Swale 4 Spring Breakup Stage

SWALE 5

Gage station SW5 is situated in a swale with bead-like features in a well-defined topographic depression draining upstream lakes/low-lying areas generally north into a paleochannel of Judy Creek upstream of gage station J 13.8.

Flow over snow was observed in Swale 5 at the end of May (Photo 4.37). Swale 5 was flowing under approximately 4 ft. of snowpack along the left and right banks by June 4; the day the gage and PT were installed, highest stage was recorded, and discharge was measured (Photo 4.39 and Photo 4.40). Meltwater was not observed in overbank areas. Discharge was measured approximately 10 ft. downstream of SW5 in a riffle. At the time of the discharge measurement, the swale had bottomfast ice and flow was uniform (Photo 4.41 and Photo 4.42). By the end of June, water was confined to beads within the drainage path and no flow was present, based on aerial observations (Photo 4.42).

Swale 5 stage and measured discharge data are presented in Graph 4.16. Measured discharge details and plan and profile figures are provided in Appendix B.2.5.

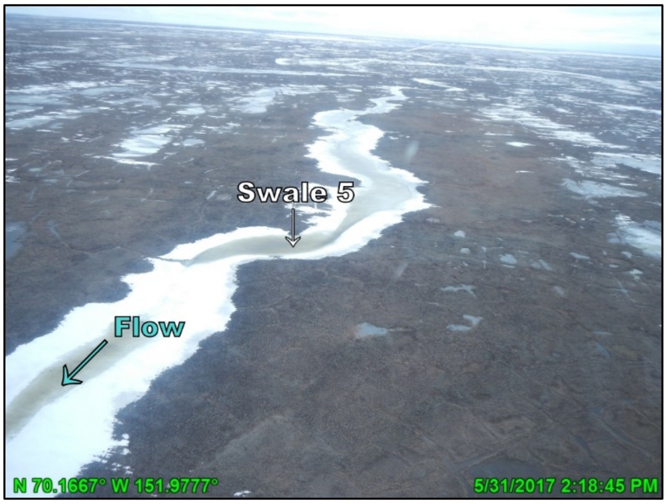


Photo 4.37: Flow over snow at Swale 5, looking south (upstream); May 31, 2017

Photo 4.38: Conditions at Swale 5 the day of measured discharge and highest recorded stage, looking north (downstream); June 4, 2017

Photo 4.39: Conditions at Swale 5 the day of measured discharge and highest recorded stage, looking south (upstream); June 4, 2017

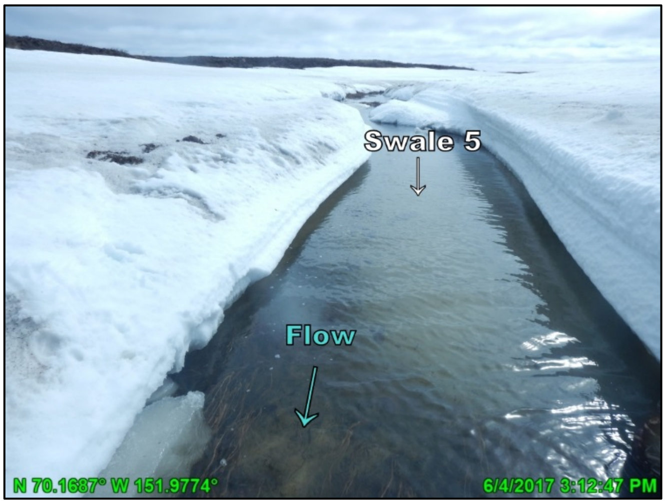


Photo 4.40: Conditions at Swale 5 the day of measured discharge and highest recorded stage, looking south (upstream); June 4, 2017

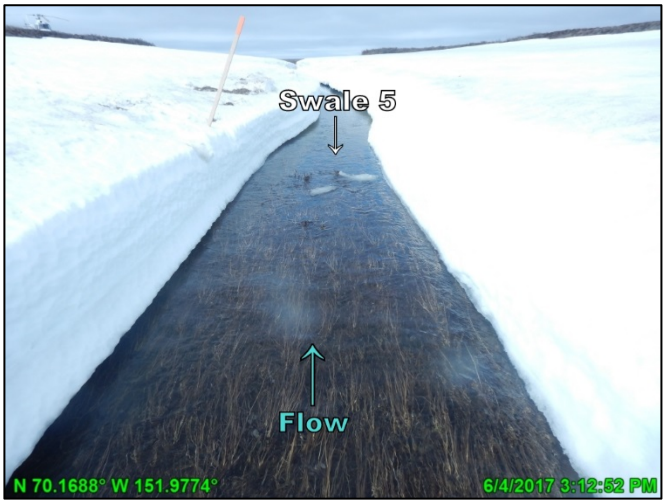


Photo 4.41: Conditions at Swale 5 the day of measured discharge and highest recorded stage, looking north (downstream); June 4, 2017

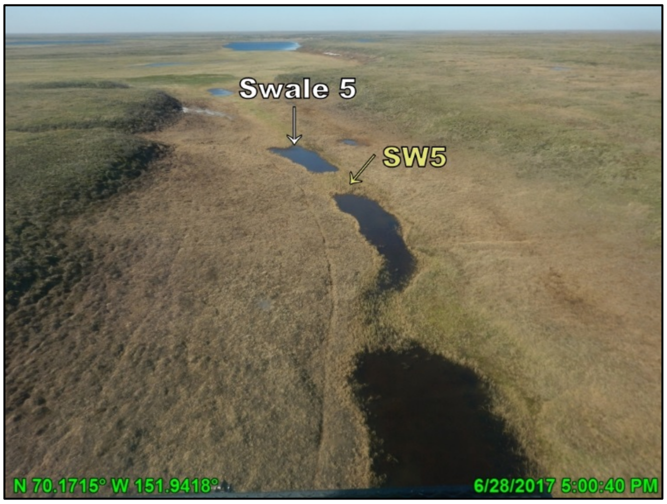
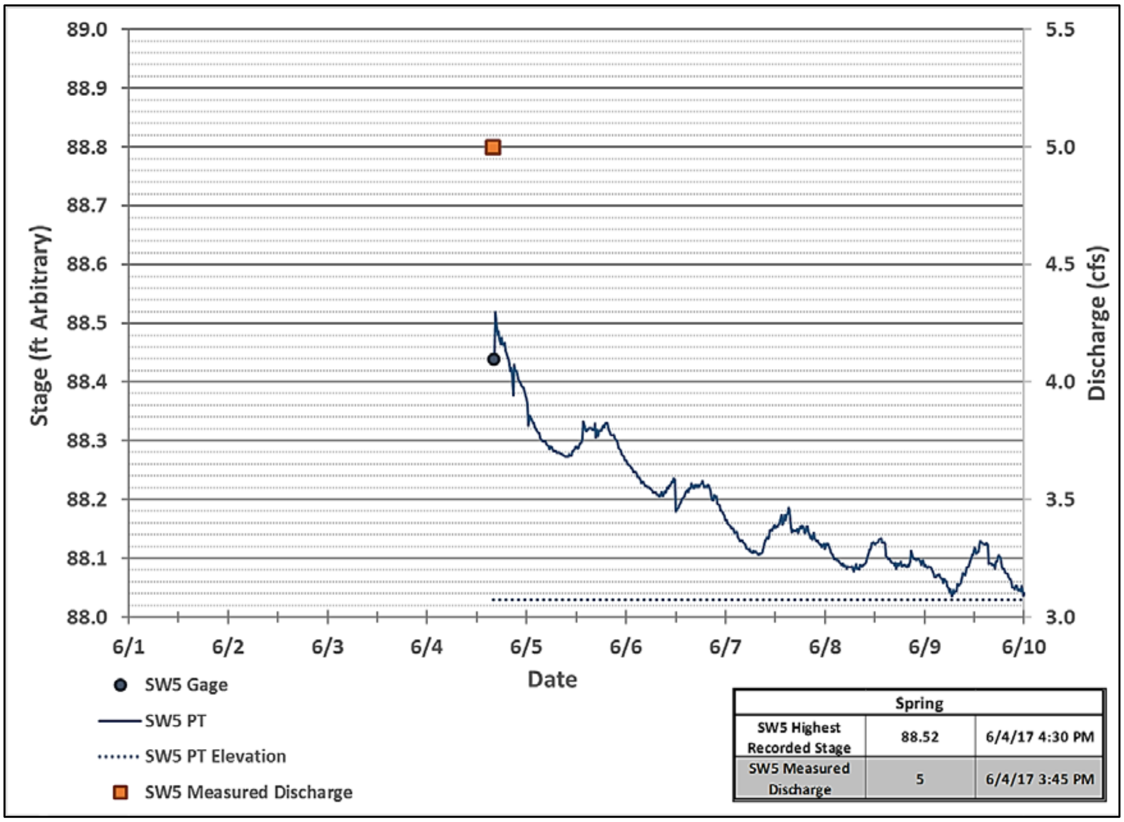


Photo 4.42: Summer conditions at Swale 5, looking north (downstream); June 28, 2017



Graph 4.16: Swale 5 Spring Breakup Stage & Discharge

SN171 (SWALE 7)

Gage station SW7 is situated in a low-lying area of polygon cracks, referenced as drainage SN171, between Lake N77099 and Lakes MM1708 and MM1709. The drainage flows into Judy Creek Kayyaaq upstream of gage station UC2C.

A narrow flow path through the snow in SN171 was observed at the end of May (Photo 4.44). SN171 was flowing under generally open channel conditions by June 3, the day the gage and PT were installed, the highest stage was recorded, and discharge was measured (Photo 4.45). Discharge was measured downstream of the SW7 gage in a riffle (Photo 4.46). By the end of June, water was confined to polygon cracks within the drainage path and no flow was present, based on aerial observations (Photo 4.46).

SW7 stage and measured discharge data are presented in Graph 4.17. Measured discharge data and plan and profile figures are provided in Appendix **Error! Reference source not found.**.

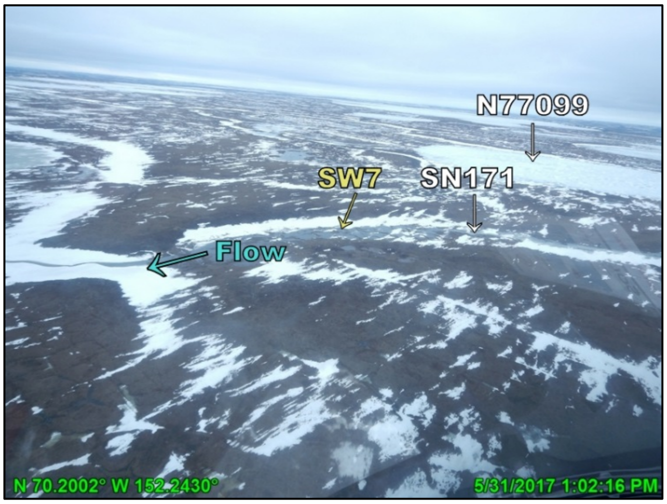


Photo 4.43: Flow through snow at SW7, looking west (upstream); May 31, 2017

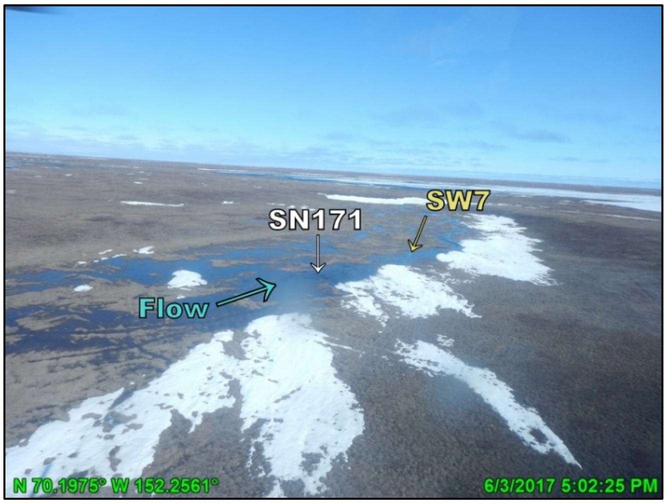


Photo 4.44: Conditions at SW7 the day of measured discharge and highest recorded stage, looking east (downstream); June 3, 2017

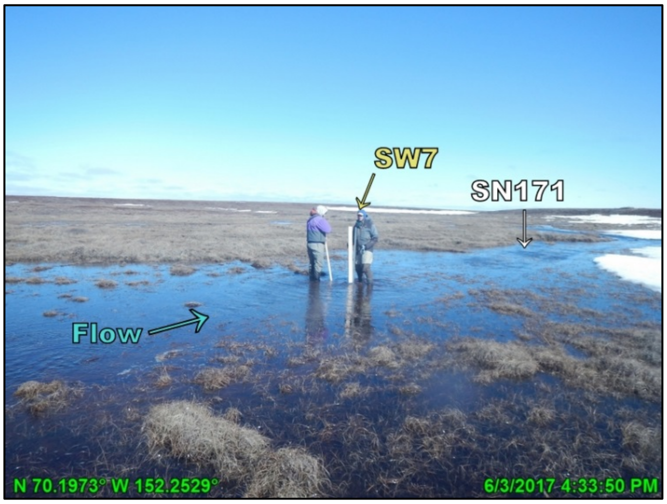
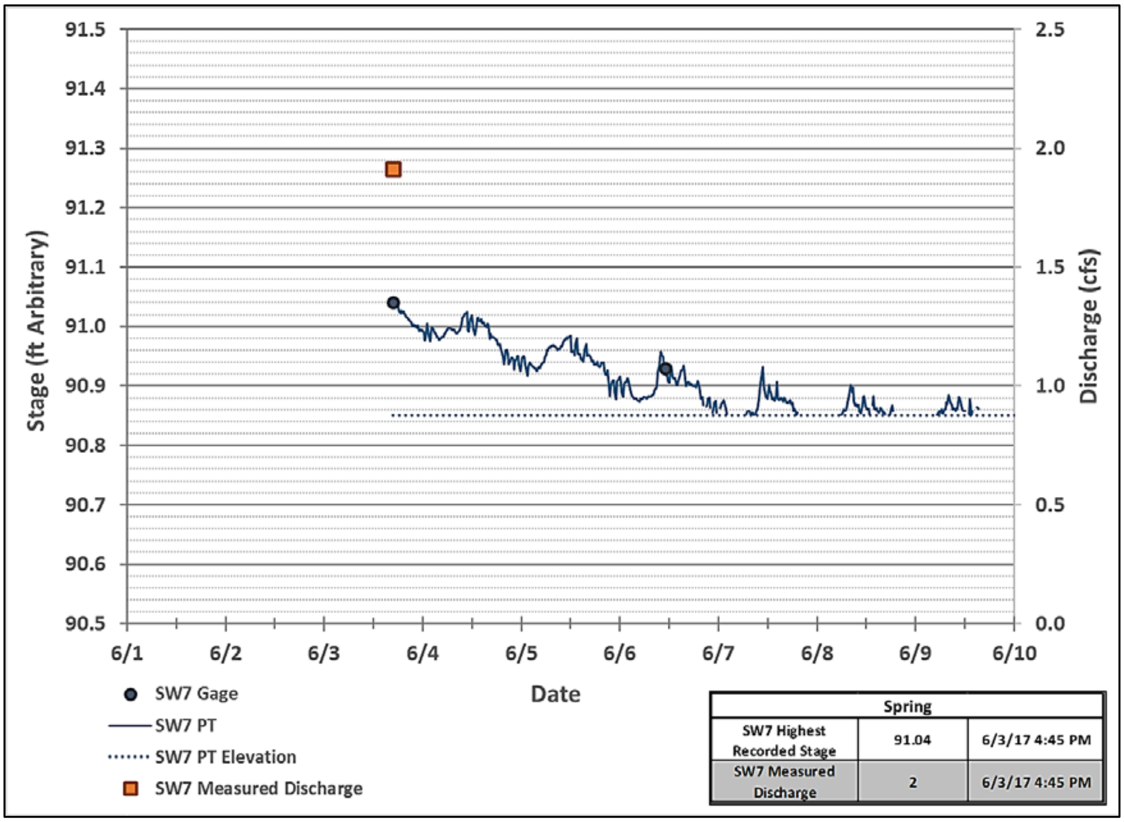


Photo 4.45: Conditions at SW7 the day of measured discharge and highest recorded stage, looking southeast (downstream); June 3, 2017

Photo 4.46: Summer conditions at SW7, looking north; June 28, 2017



	Spring	
SW7 Highest Recorded Stage	91.04	6/3/17 4:45 PM
SW7 Measured Discharge	2	6/3/17 4:45 PM

Graph 4.17: Swale 7 Spring Breakup Stage & Discharge

SWALE 8

Gage station SW8 is situated in a low-lying area of polygon cracks and beads downstream of an unnamed lake. Downstream of SW8, flow is conveyed into Judy Creek upstream of gage station J 16.5. Gage station SW8 is approximately 0.3 miles north (downstream) of gage station SW1, separated by an unnamed lake.

Ponded local melt was observed in Swale 8 at the end of May with ice remaining on the surrounding lakes (Photo 4.47). Swale 8 was flowing under open channel conditions by June 4, the day the gage and PT were installed, the highest stage was recorded, and discharge was measured (Photo 4.48 and Photo 4.49). Discharge was measured just upstream of the SW8 gage at the inlet of a bead (Photo 4.50). By the end of June, water was confined to beads within the drainage path and no flow was present, based on aerial observations (Photo 4.51).

Swale 8 stage and measured discharge data are presented in Graph 4.18. Measured discharge data and plan and profile figures are provided in Appendix B.2.7.

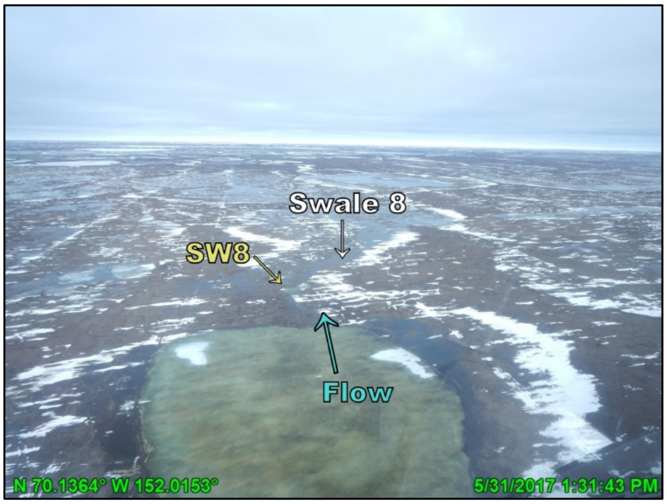


Photo 4.47: Ponded local melt at Swale 8, looking north; May 31, 2017

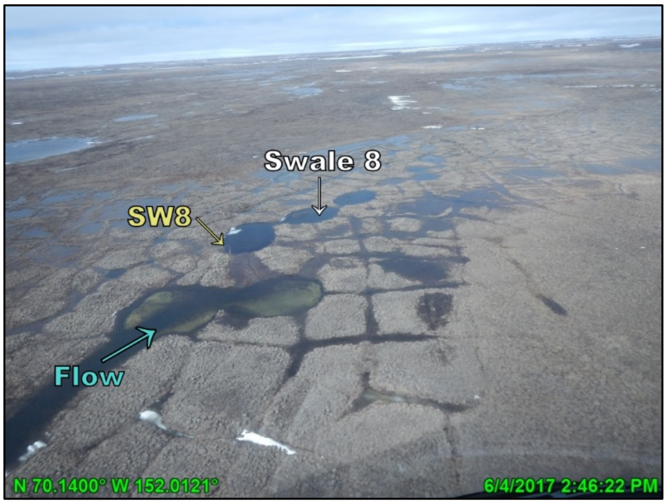


Photo 4.48: Conditions at Swale 8 the day of measured discharge and highest recorded stage, looking northwest (downstream); June 4, 2017

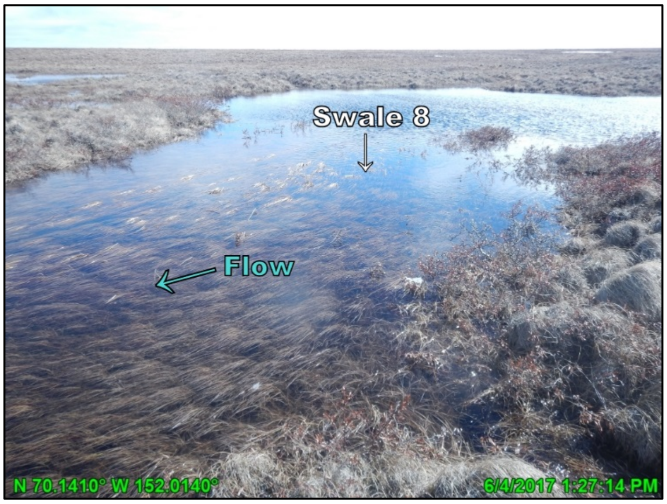
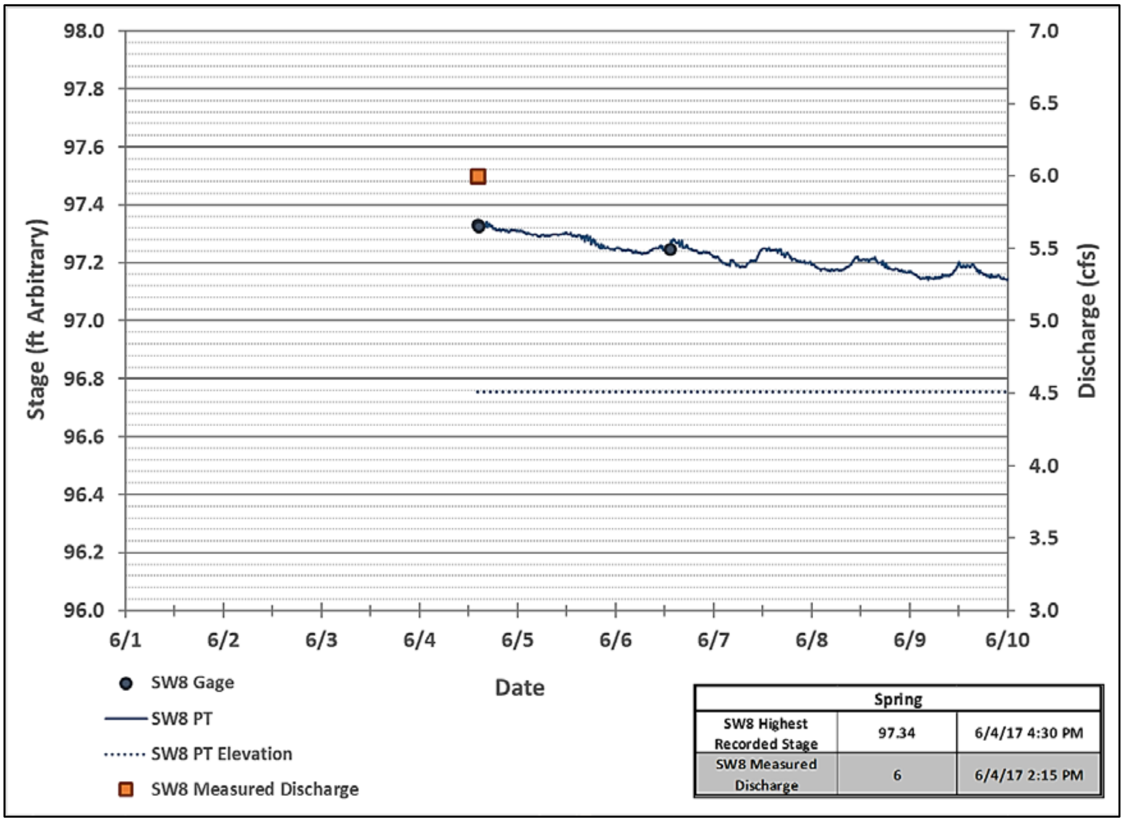


Photo 4.49: Conditions at Swale 8 the day of measured discharge and highest recorded stage, looking south (upstream); June 4, 2017

Photo 4.50: Conditions at Swale 8 the day of measured discharge and highest recorded stage, looking north (downstream); June 4, 2017

Photo 4.51: Summer conditions at Swale 8, looking north (downstream); June 28, 2017



	Spring	
SW8 Highest Recorded Stage	97.34	6/4/17 4:30 PM
SW8 Measured Discharge	6	6/4/17 2:15 PM

Graph 4.18: Swale 8 Spring Breakup Stage & Discharge

SWALE 10

Gage station SW10 is situated in a beaded swale conveying flow into Lakes MM1708 and MM1709 into Judy Creek Kayyaaq upstream of gage station UC2C.

Ponded local melt was observed in Swale 10 at the end of May with ice remaining on the surrounding lakes (Photo 4.52). Swale 10 was flowing under open channel conditions by June 3, the day the gage and PT were installed, the highest stage was recorded, and discharge was measured (Photo 4.53 and Photo 4.54). Discharge was measured adjacent to gage SW10 where flow was being conveyed through three small drainages. By the end of June, water was confined to polygon cracks within the drainage path and no flow was present, based on aerial observations (Photo 4.55).

Swale 8 stage and measured discharge data are presented in Graph 4.18. Measured discharge data and plan and profile figures are provided in Appendix B.2.7.

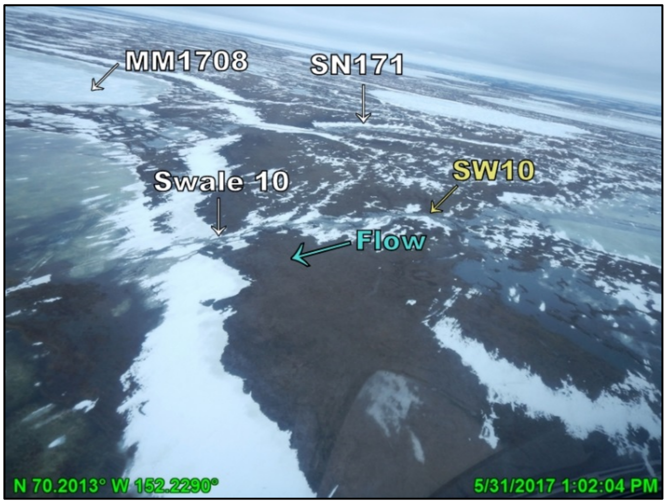


Photo 4.52: Ponded local melt at Swale 10, looking west; May 31, 2017

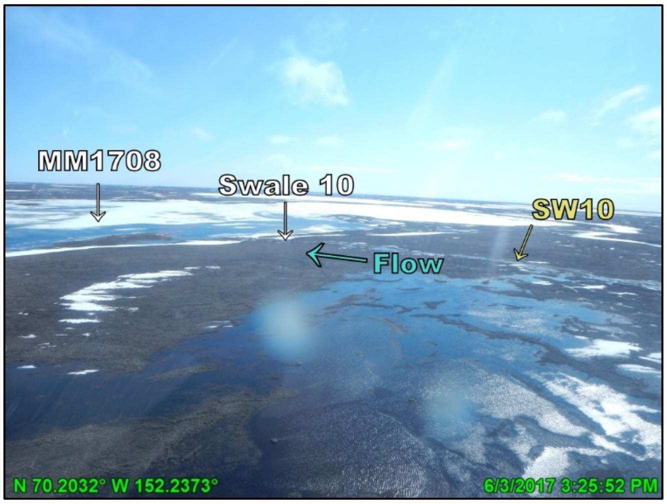


Photo 4.53: Conditions at Swale 10 the day of measured discharge and highest recorded stage, looking southwest (upstream); June 3, 2017

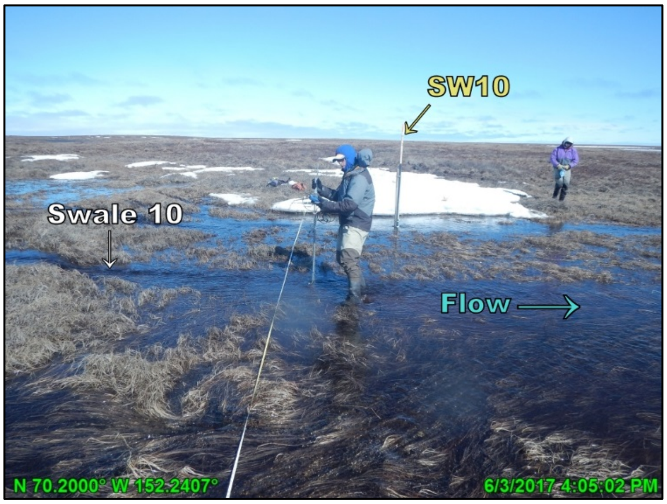
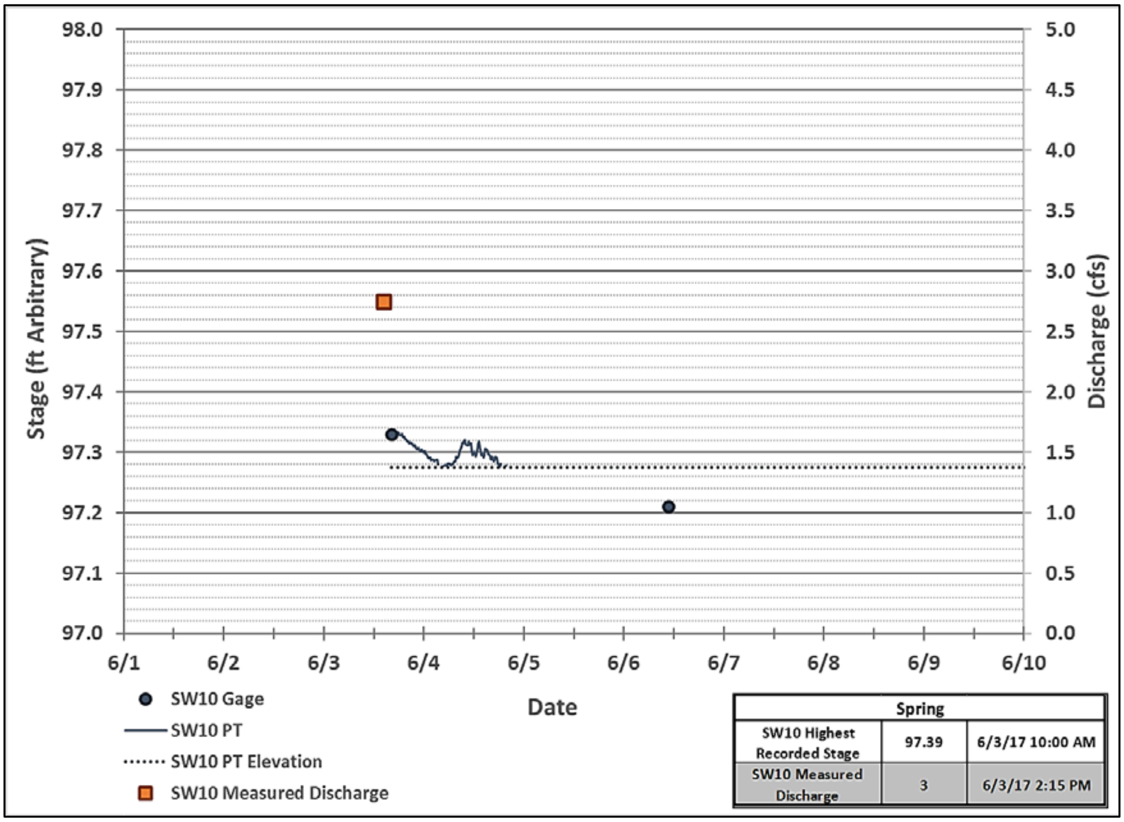


Photo 4.54: Conditions at Swale 10 the day of measured discharge and highest recorded stage, looking northeast; June 3, 2017

Photo 4.55: Summer conditions at Swale 10, looking northwest; June 28, 2017



	Spring	
SW10 Highest Recorded Stage	97.39	6/3/17 10:00 AM
SW10 Measured Discharge	3	6/3/17 2:15 PM

Graph 4.19: Swale 10 Spring Breakup Stage & Discharge

5. FLOOD FREQUENCY ANALYSIS

Table 5.1 presents the Judy Creek at J 13.8 flood frequency analysis results from the URS peak discharge regional regression analysis (URS 2003) and the USGS peak discharge regional regression analysis (USGS 2003). This year's J 13.8 peak discharge of 3,900 cfs has a recurrence interval of less than 2 years.

Table 5.1: J 13.8 Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	URS Peak Discharge[1]	USGS Peak Discharge
%	years	cfs	cfs
50	2	5,100	7,400
20	5	8,000	10,900
10	10	10,000	13,100
4	25	12,900	15,800
2	50	15,300	17,700
1	100	17,700	19,500
0.5	200	20,400	21,300

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

Table 5.2 presents the Willow 2 at UC1A and Judy Creek Kayyaaq at UC2A flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003). This year's Willow 2 measured discharge of 125 cfs and Judy Creek Kayyaaq measured discharge of 190 cfs have recurrence intervals of less than 2 years.

Table 5.2: UC1A and UC2A Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	Willow 2	Judy Creek Kayyaaq
		USGS Peak Discharge [1]	USGS Peak Discharge [1]
%	years	cfs	cfs
50	2	350	1,580
20	5	560	2,420
10	10	700	2,960
4	25	870	3,630
2	50	990	4,120
1	100	1,120	4,590
0.5	200	1,240	5,040

Notes:
[1] USGS 2003

The recurrence interval should be considered with respect to conditions at the time of peak discharge. Detailed USGS regression analysis results are provided in Appendix C.

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Appendix A STAGE METHODS & SITE-SPECIFIC DATA

A.1 STAGE METHODS

A.1.1 GAGE SETUP METHODS

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

A.1.2 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 Judy Creek at J 13.8.

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

Gage Station	Gage Assembly	Gage Assembly Location		Associated Vertical Control	Vertical Control Elevation (ft arbitrary)	Vertical Control Location	
		Latitude (NAD83)	Longitude (NAD83)			Latitude (NAD83)	Longitude (NAD83)
J 13.8U	J 13.8U-A	70.18519	-151.96097	Line 4BW GILLY	40.869[1] 45.217[1]	70.18664 70.18680	-151.96120 -151.96170
	J 13.8U-B	70.18549	-151.96287				
	J 13.8U-C	70.18554	-151.96309				
J 13.8	J 13.8-A	70.18688	-151.96046				
	J 13.8-B	70.18694	-151.96097				
	J 13.8-C	70.18697	-151.96139				
J 13.8D	J 13.8D-A	70.18917	-151.95723				
	J 13.8D-B	70.18920	-151.95731				
	J 13.8D-C	70.18923	-151.95742				
J 16.5	J 16.5-A	70.17731	-152.02776	RANCOR SARLACC	100.000 100.245	70.17628 70.17630	-152.02673 -152.02673
	J 16.5-B	70.17706	-152.02749				
	J 16.5-C	70.17661	-152.02700				
J 21.4	J 21.4-A	70.14623	-152.09056	OTIS LUCKY	100.000 100.176	70.14671 70.14672	-152.09075 -152.09079
	J 21.4-B	70.14658	-152.09087				
	J 21.4-C	70.14664	-152.09096				
UC1AD	UC1AD-A	70.17191	-151.94187	TAUNTAUN WAMPA	100.055 100.000	70.17142 70.17120	-151.94022 -151.94019
	UC1A-A	70.17134	-151.94194				
	UC1AU-A	70.17106	-151.94166				
UC1B	UC1B-A	70.14127	-151.95547	LUKE LEIA	100.003 99.203	70.14097 70.14126	-151.95461 -151.95486
UC1C	UC1C-A	70.15666	-151.93322	BANTHA EWOK	99.990 99.730	70.15665 70.15654	-151.93426 -151.93372
UC2AU	UC2AU-A	70.20307	-152.07433	C3PO R2D2	100.000 100.039	70.20359 70.20360	-152.07523 -152.07525
	UC2AU-B	70.20305	-152.07443				
UC2A	UC2A-A	70.20360	-152.07384				
	UC2A-B	70.20360	-152.07402				
UC2AD	UC2AD-A	70.20397	-152.07316				
	UC2AD-B	70.20398	-152.07321				
UC2B	UC2B-A	70.19477	-152.09782	CHEWIE HAN	100.005 100.790	70.19499 70.19482	-152.09589 -152.09590
	UC2B-B	70.19477	-152.09778				
	UC2B-C	70.19478	-152.09774				
UC2C	UC2C-A	70.18479	-152.12103	ANAKIN VADER	100.000 100.518	70.18473 70.18474	-152.12135 -152.12127
	UC2C-B	70.18479	-152.12105				
SW1	SW1-A	70.13612	-152.01333	GREEDO WINDU	100.000 99.598	70.20007 70.20006	-152.24010 -152.24008
SW4	SW4-A	70.15596	-152.09442	BOBA FETT	100.000 100.070	70.15620 70.15619	-152.09503 -152.09500
SW5	SW5-A	70.16865	-151.97731	MAUL TARKIN	100.000 99.830	70.16835 70.16835	-151.97800 -151.97794
SN171	SW7-A	70.19729	-152.25259	REY WEDGE	100.000 98.580	70.19664 70.19673	-152.25235 -152.25202
SW8	SW8-A	70.14075	-152.01401	MOE SUNNY	99.725 100.000	70.14080 70.14073	-152.01222 -152.01209
SW10	SW10-A	70.20003	-152.24048	OBIWAN KENOBI	100.000 99.940	70.13572 70.13573	-152.01192 -152.01191

Notes:
1. Line 4BW and GILLY elevations are ft BPMSL

Table A.2: Gage & Spring PT Elevations

Gage Station	Gage Assembly	Gage Elevation		Spring PT Elevation
		Minimum (ft arbitrary)	Maximum (ft arbitrary)	(ft arbitrary)
J 13.8U [1]	J 13.8U-A	33.56	44.68	33.61
	J 13.8U-B			
	J 13.8U-C			
J 13.8 [1]	J 13.8-A	32.15	41.13	32.20
	J 13.8-B			
	J 13.8-C			
J 13.8D [1]	J 13.8D-A	31.70	40.54	31.77
	J 13.8D-B			
	J 13.8D-C			
J 16.5	J 16.5-A	92.01	99.90	92.10
	J 16.5-B			
	J 16.5-C			
J 21.4	J 21.4-A	88.97	97.61	89.02
	J 21.4-B			
	J 21.4-C			
UC1AU	UC1AU-A	80.97	84.38	--
UC1A	UC1A-A	80.61	84.02	--
UC1AD	UC1AD-A	80.39	83.80	80.46
UC1B	UC1B-A	88.08	91.49	88.14
UC1C	UC1C-A	85.03	88.44	85.09
UC2AU	UC2AU-A	83.52	86.93	83.59
	UC2AU-B	85.83	89.24	--
UC2A	UC2A-A	84.16	87.57	84.27
	UC2A-B	86.96	90.37	--
UC2AD	UC2AD-A	83.63	87.04	83.70
	UC2AD-B	86.45	89.86	--
UC2B	UC2B-A	86.03	89.44	86.08
	UC2B-B	88.54	91.95	--
	UC2B-C	90.00	93.41	--
UC2C	UC2C-A	92.65	96.06	92.71
	UC2C-B	95.63	99.04	--
SW1	SW1-A	95.57	98.98	95.64
SW4	SW4-A	97.69	101.10	97.14
SW5	SW5-A	87.84	91.25	88.03
SN171	SW7-A	90.78	94.19	90.85
SW8	SW8-A	96.26	99.67	96.76
SW10	SW10-A	97.19	100.60	97.28

Notes:
1. J 13.8U, J 13.8, and J 13.8D elevations are ft BPMSL
2. A dash "--" indicates spring PT was not installed

Appendix B DISCHARGE METHODS, SITE SPECIFIC DATA, PLANS, & PROFILES

B.1 DISCHARGE METHODS

B.1.1 MEASURED DISCHARGE

1) 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.

2) 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).

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.

Pre-Deployment Testing

Prior to deployment of the ADCP unit, a full suite of diagnostic tests were run 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.

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, so the measured discharges varied by less than five percent of their 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.

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.1.2 CALCULATED DISCHARGE

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.

B.2 SITE SPECIFIC DATA, PLANS, & PROFILES

B.2.1 JUDY CREEK AT J 13.8

1) SPRING BREAKUP MEASURED DISCHARGE

Location: J 13.8

Date & Time: June 1, 6:00 PM

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

Final Discharge (cfs): 3,300

Average Velocity (fps): 3.5

Measurement Rating: Fair

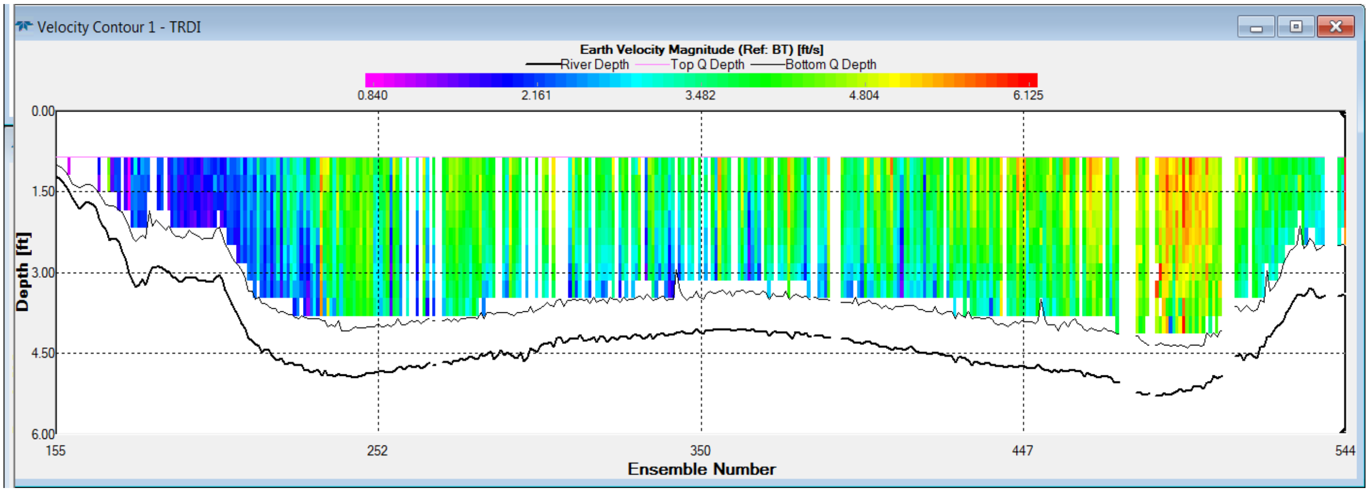
Measurement Notes: Moving bed conditions were identified; discharge was corrected for the moving bed using data acquired from a loop test performed before the three measured transects. The fourth measurement transect was extracted from the first stretch (right bank to left bank) of the loop test.

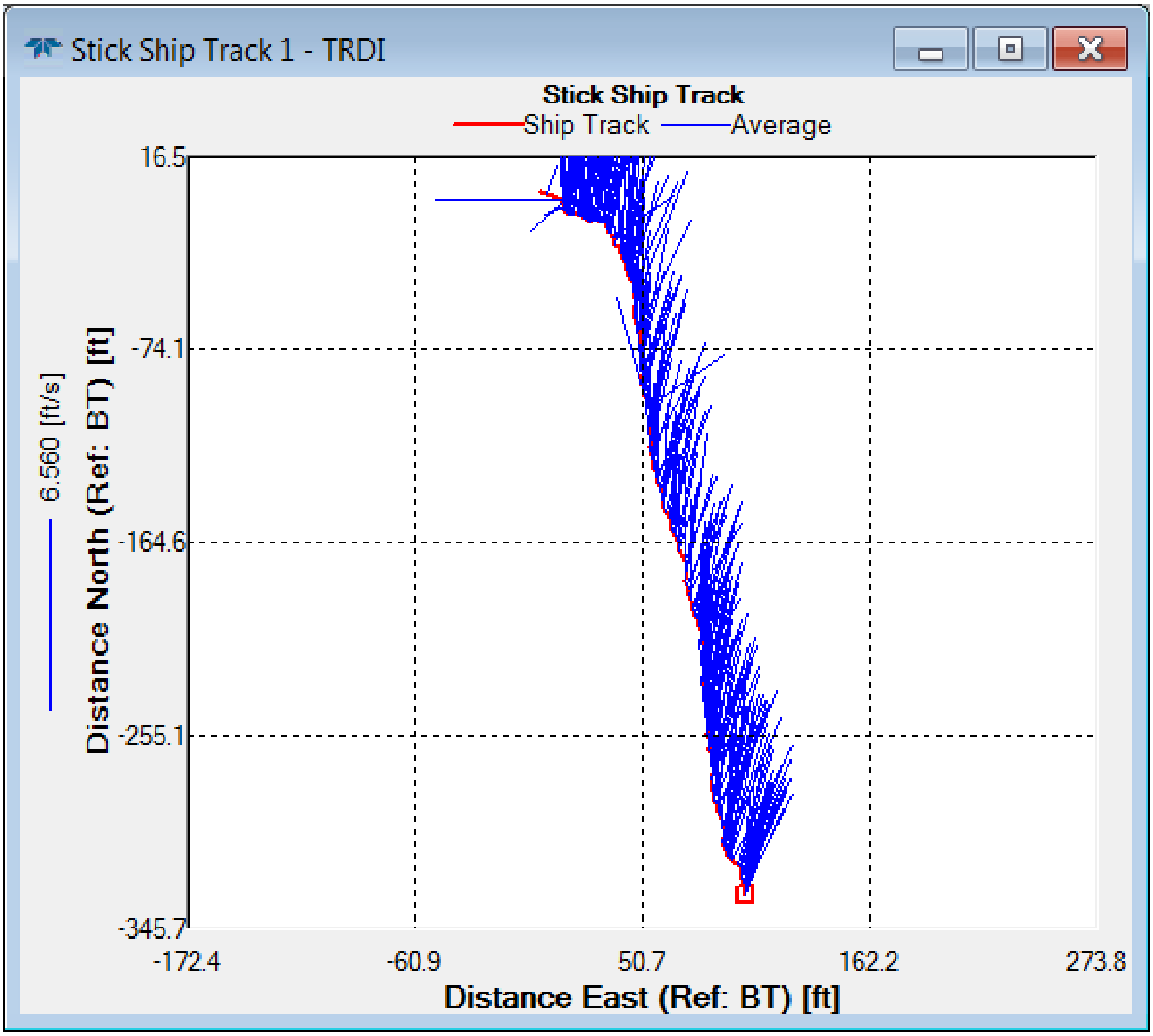
At the time of the measurement, the river was mostly clear of snow and ice with intermittent ice floes and some snow along the right bank. Prior to deployment, diagnostic tests were performed and the internal compass calibrated. The overall discharge measurement is considered fair based on the highly mobile bed detected at the time of measurements. Moving bed velocity estimated using the loop test was 1.2 fps. The percentage of bad bottom track values (10.5%) exceeded the recommended 5% and factored into the overall quality rating of the measurement.

Table B.1: J 13.8 June 1 Spring Breakup Measured Discharge Summary

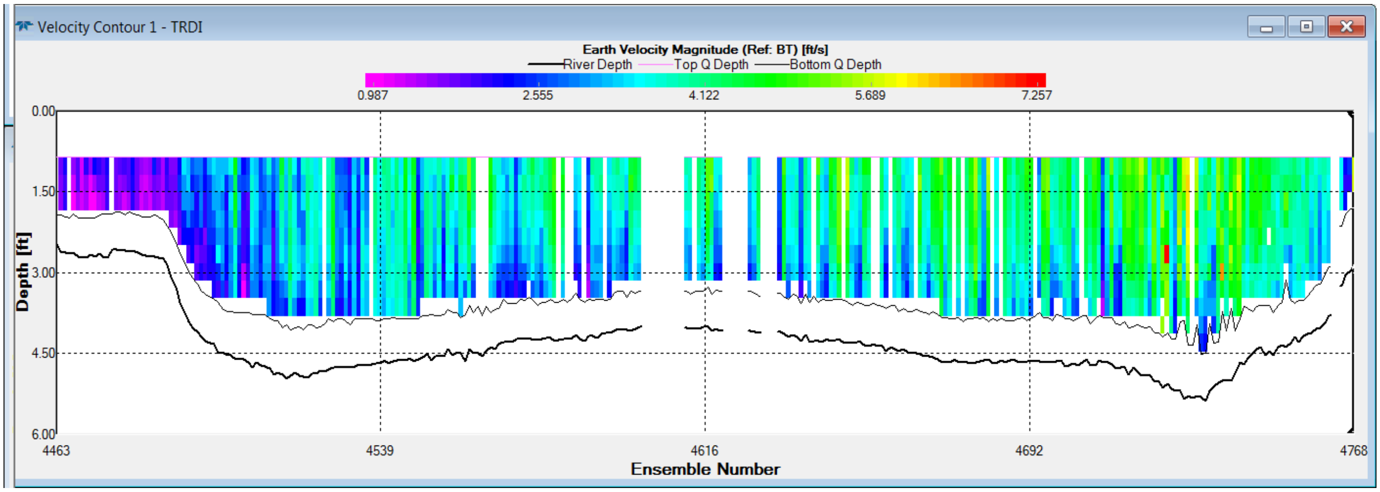
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
J138006	Left	3335	-0.05%	2033	1.20%	384	567	1,565	2.13	3.59
J138014	Left	3338	0.06%	2002	-0.34%	346	572	1,415	2.36	3.50
J138015	Right	3241	-2.86%	1931	-3.87%	300	565	1,206	2.69	3.42
J138016	Left	3431	2.84%	2069	3.01%	478	589	1,955	1.76	3.51
Average		**3,336**		**2,009**		**377**		**1,535**	**2.23**	**3.50**

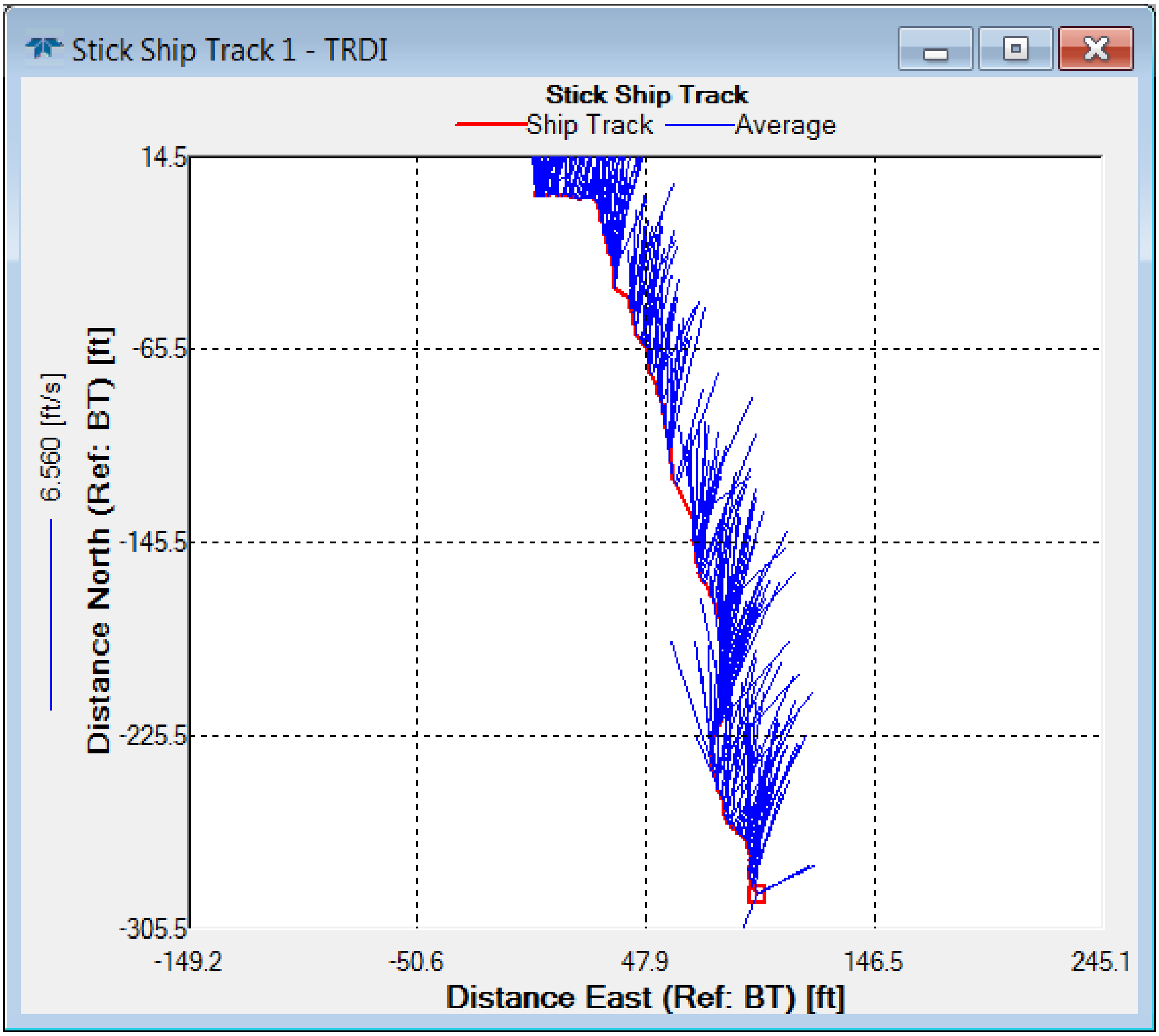
Transect J138006 Raw Data Output



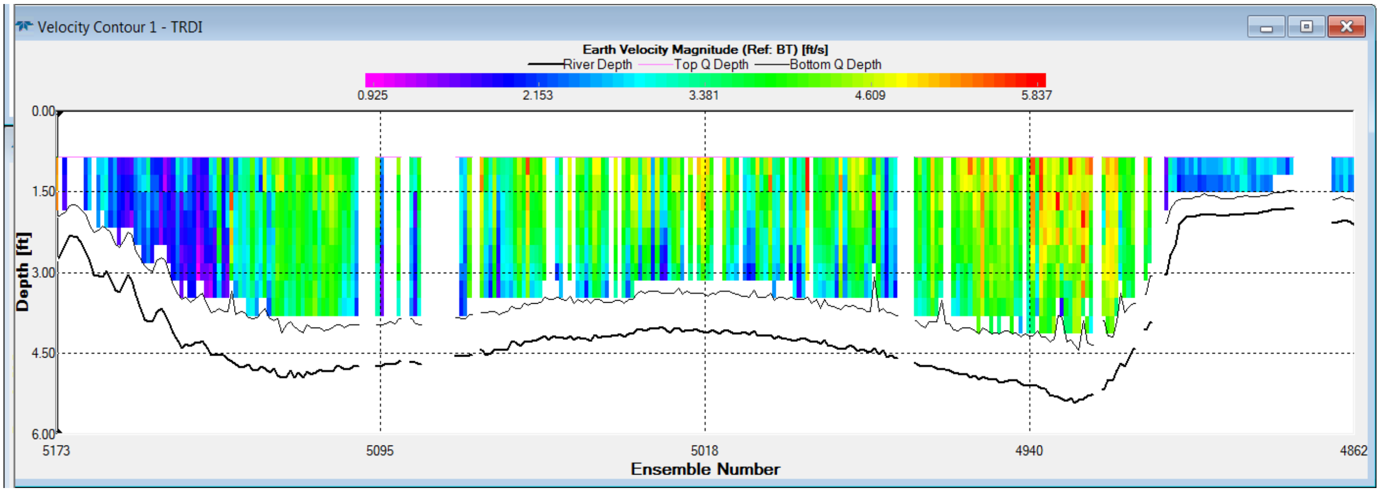


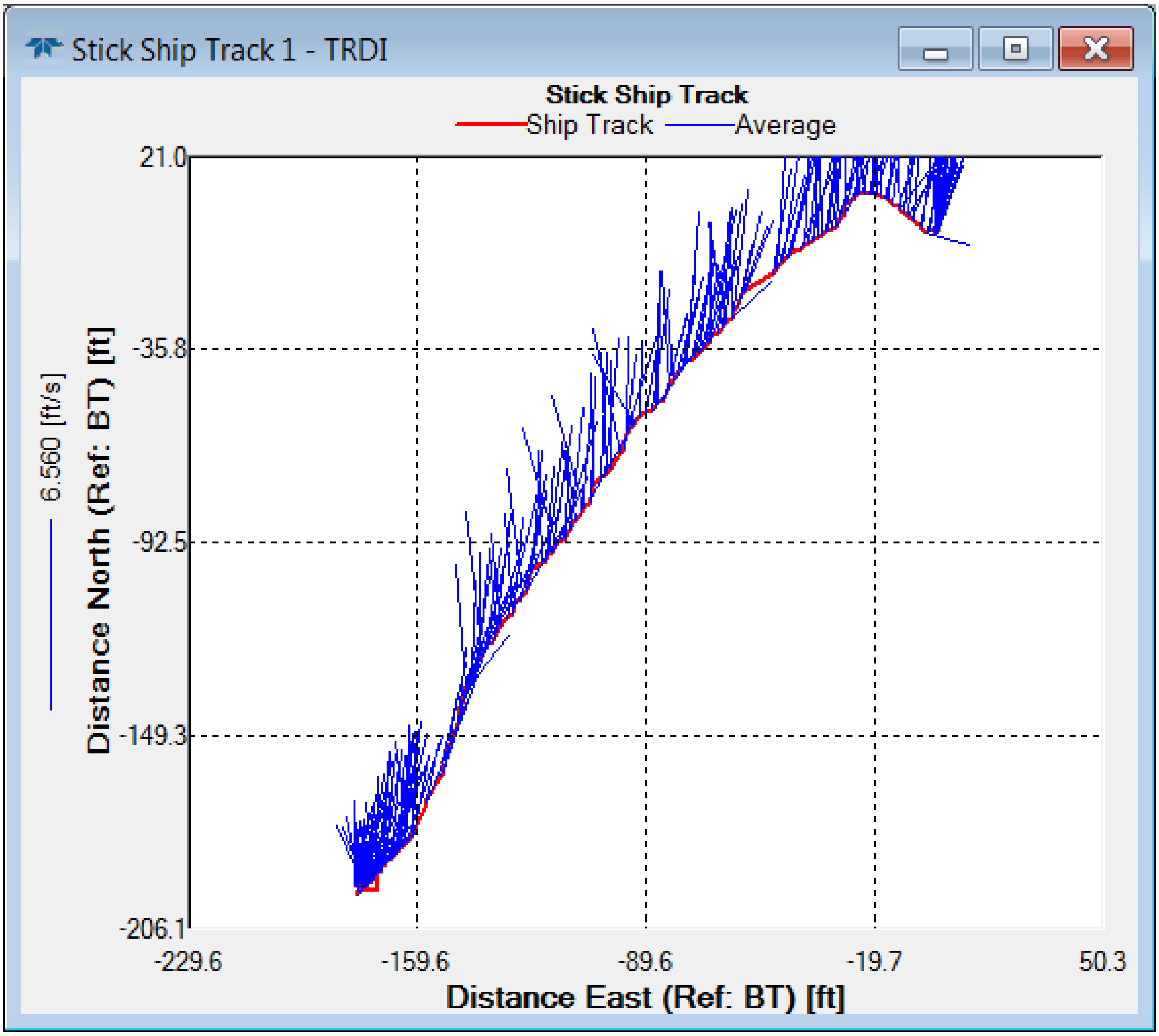
Transect J138014 Raw Data Output



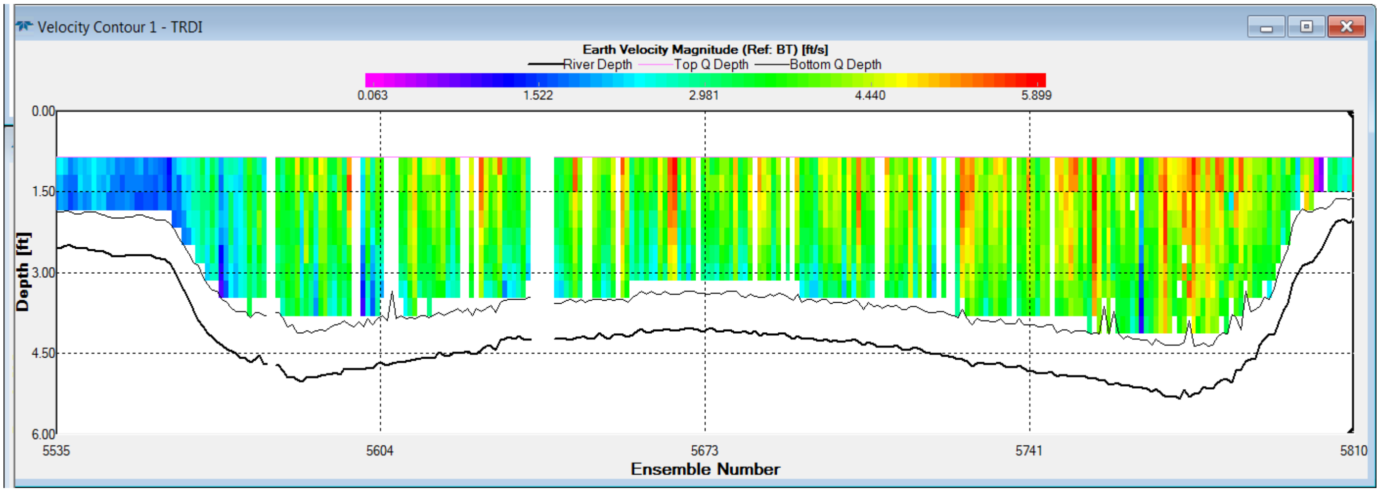


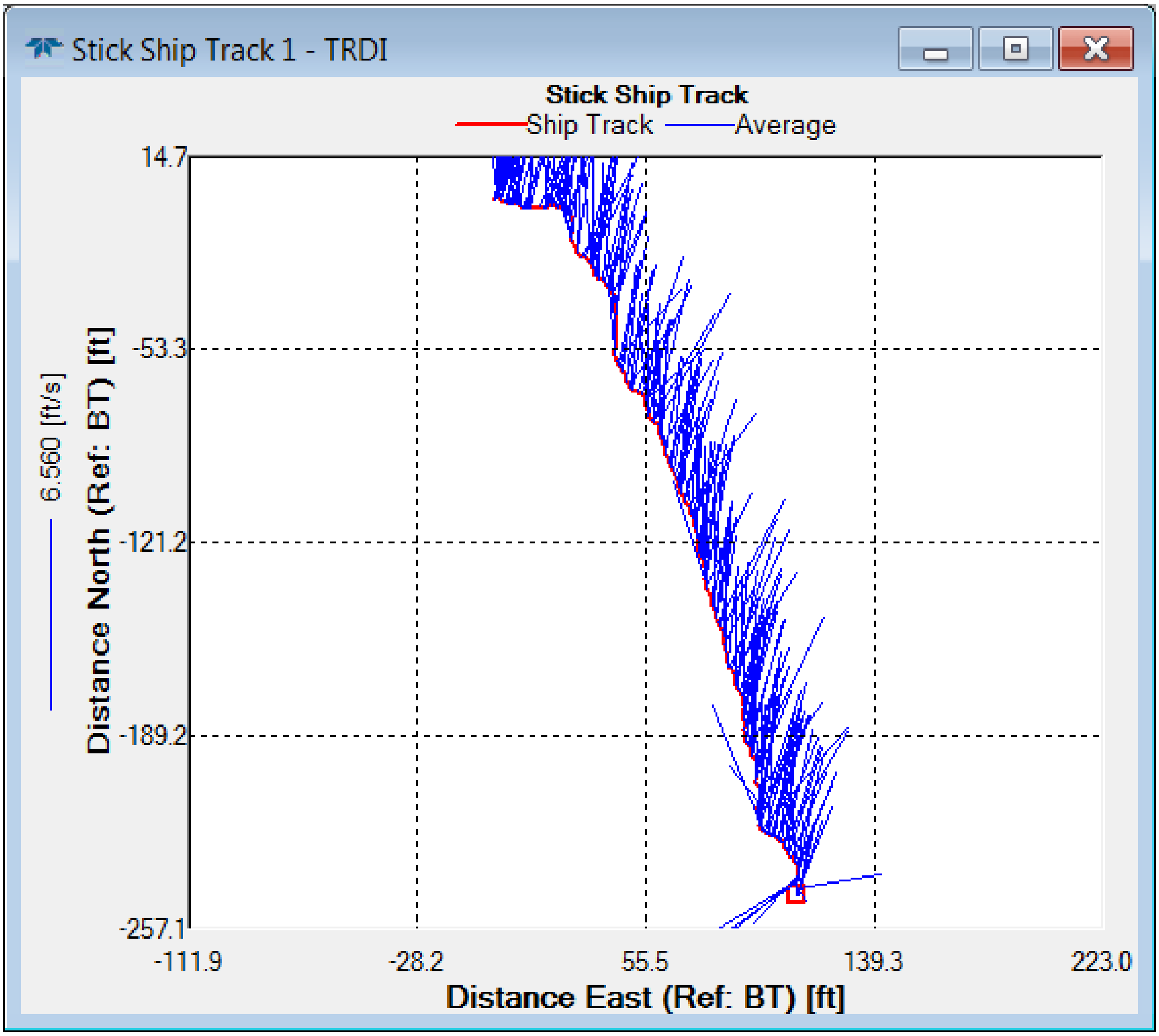
Transect J138015 Raw Data Output





Transect J138016 Raw Data Output





Location: J 13.8

Date & Time: June 4, 3:45 PM

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): 3.5

Measurement Rating: Fair

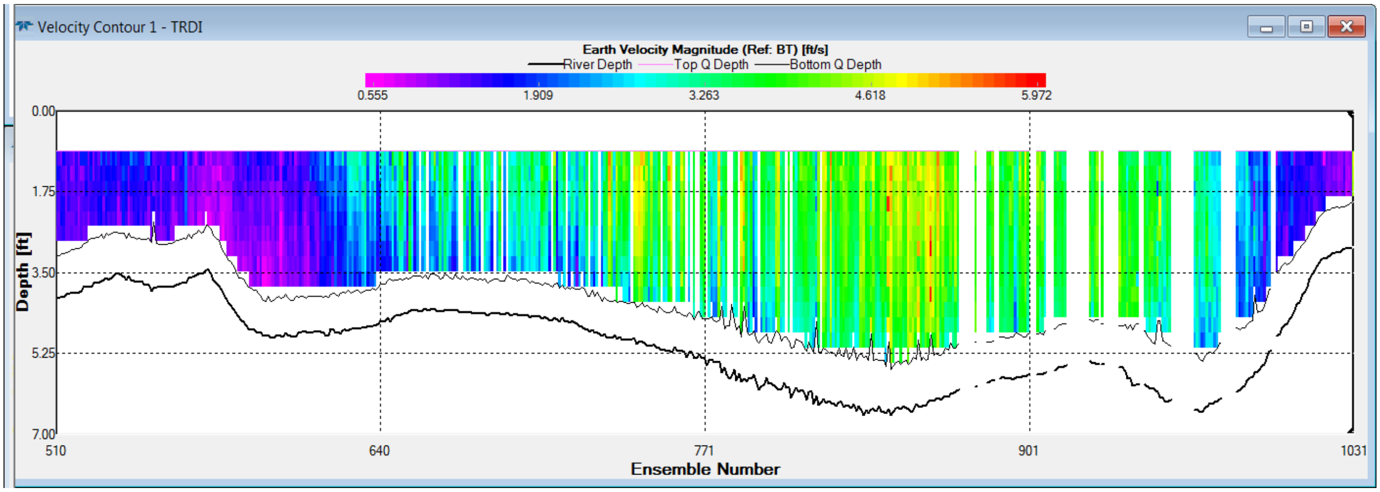
Measurement Notes: Moving bed conditions were identified and the discharge was corrected for moving bed using data acquired from two stationary moving bed tests performed before the four measured transects. A stationary moving bed test was selected because of bottom track errors experienced during the June 1 loop test.

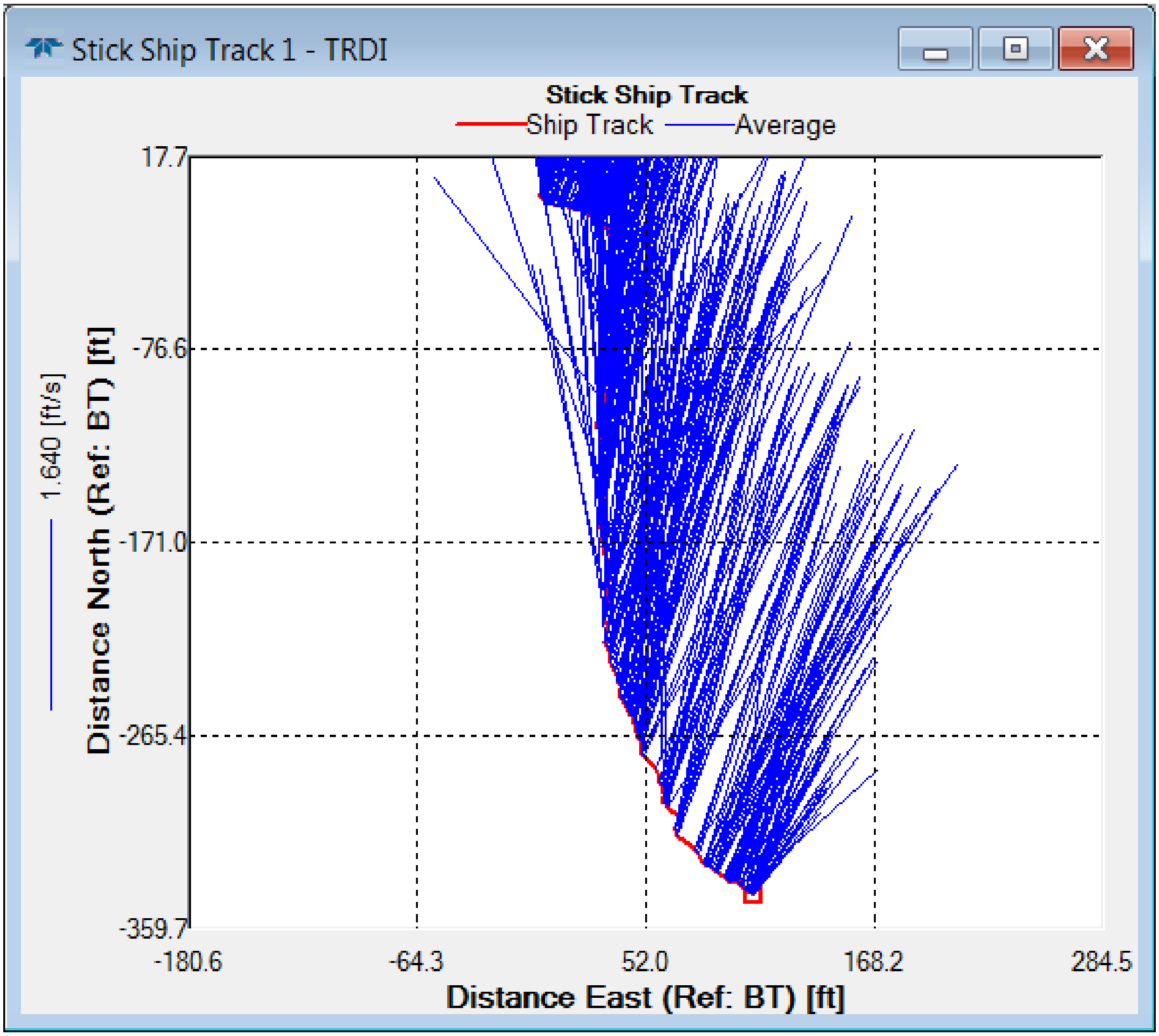
At the time of the measurement, the river was mostly clear of snow and ice. Some snow remained along the right bank but had little influence on discharge. Prior to deployment, diagnostic tests were performed and the internal compass calibrated. The overall discharge measurement is considered fair based on the highly mobile bed detected at the time of measurements. Moving bed velocity estimated using the stationary moving bed test was 0.7 fps.

Table B.2: J 13.8 June 4 Spring Breakup Measured Discharge Summary

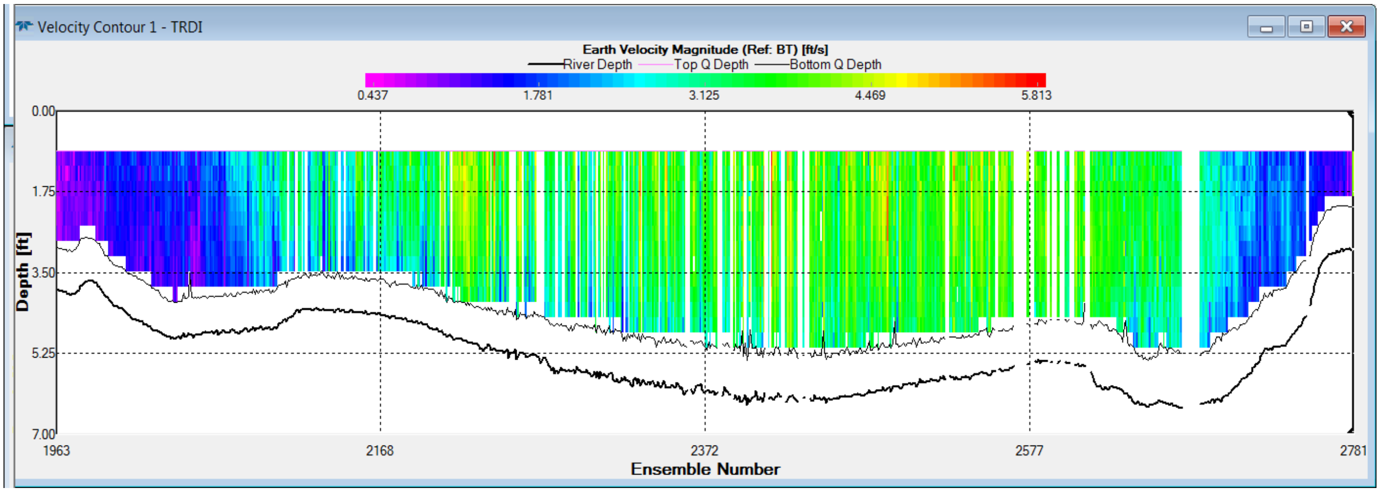
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
J138003	Left	3549	0.51%	2341	1.00%	397	653	1,984	1.79	3.59
J138005	Left	3390	-4.00%	2236	-3.54%	632	639	3,324	1.02	3.50
J138006	Right	3506	-0.70%	2292	-1.13%	554	670	2,802	1.25	3.42
J138015	Right	3679	4.19%	2403	3.67%	373	684	1,834	2.01	3.51
Average		**3,531**		**2,318**		**489**		**2,486**	**1.52**	**3.50**

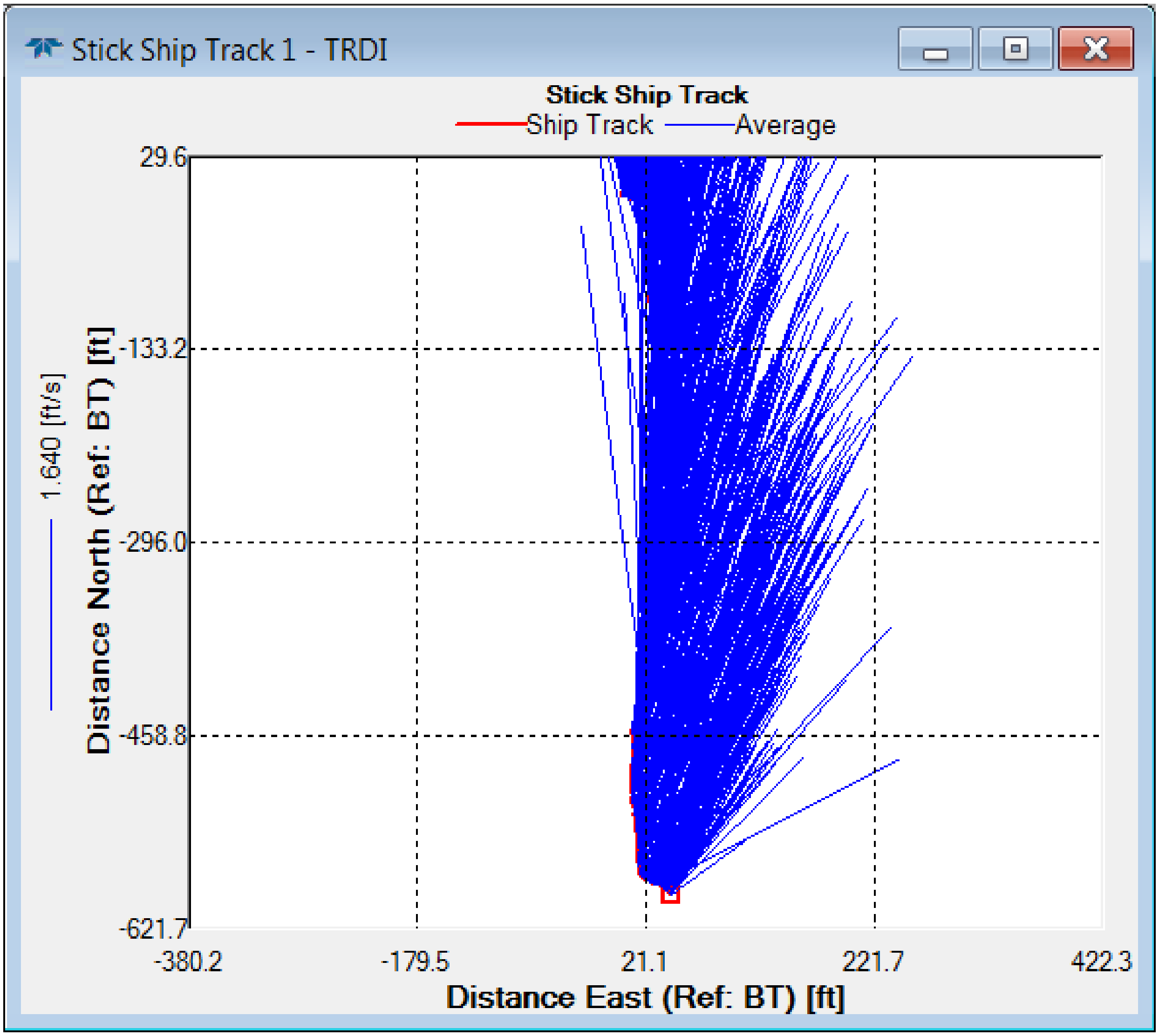
Transect J138003 Raw Data Output



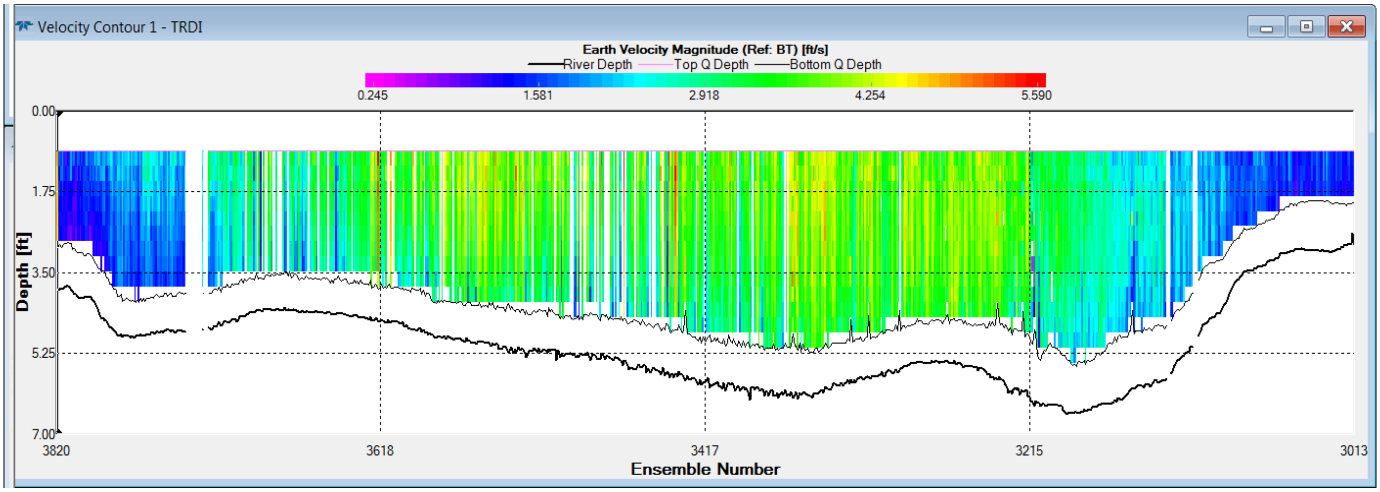


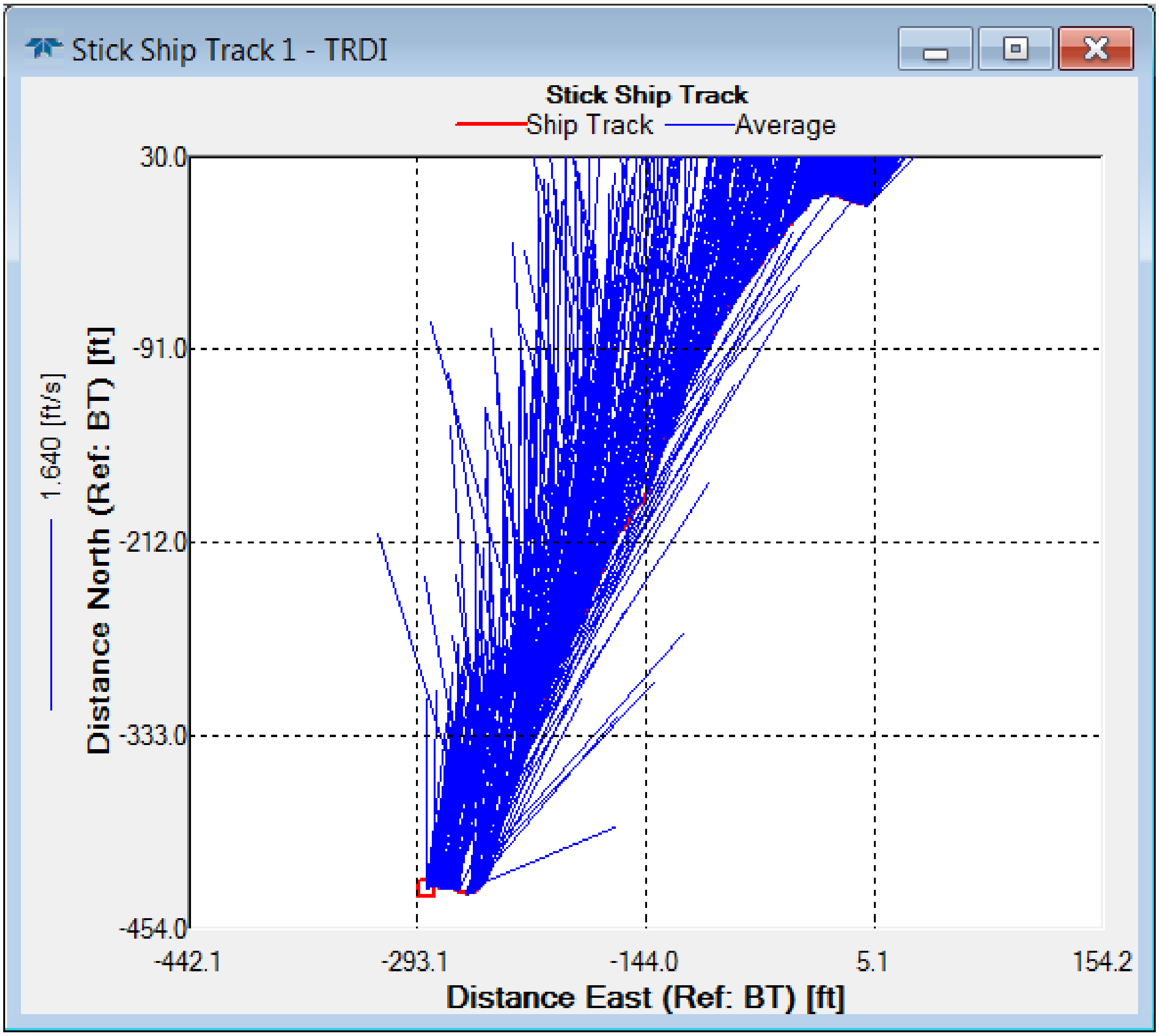
Transect J138005 Raw Data Output



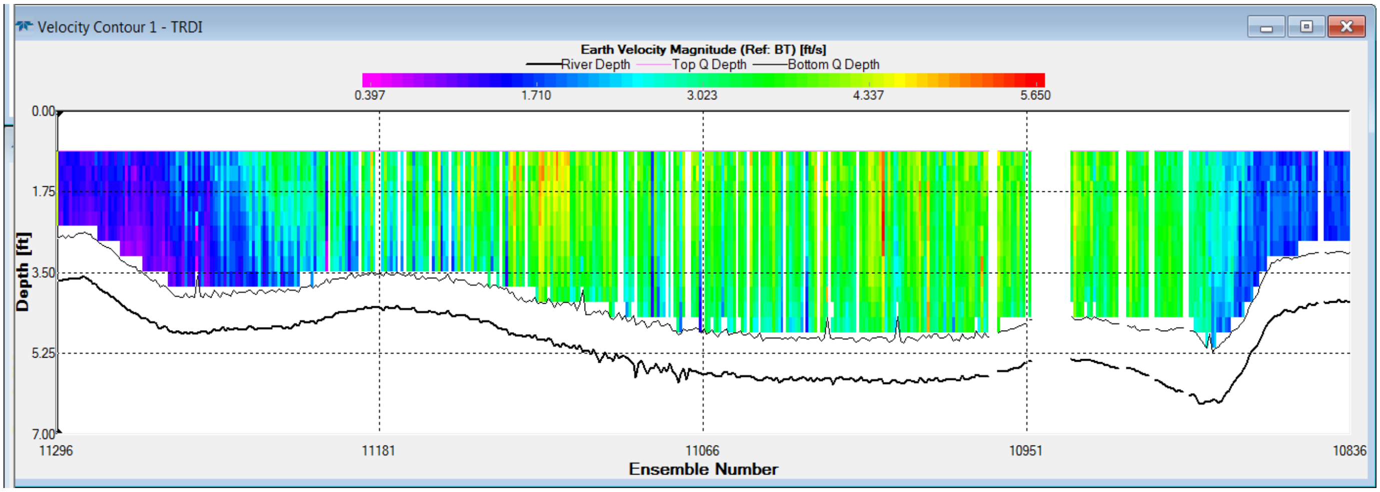


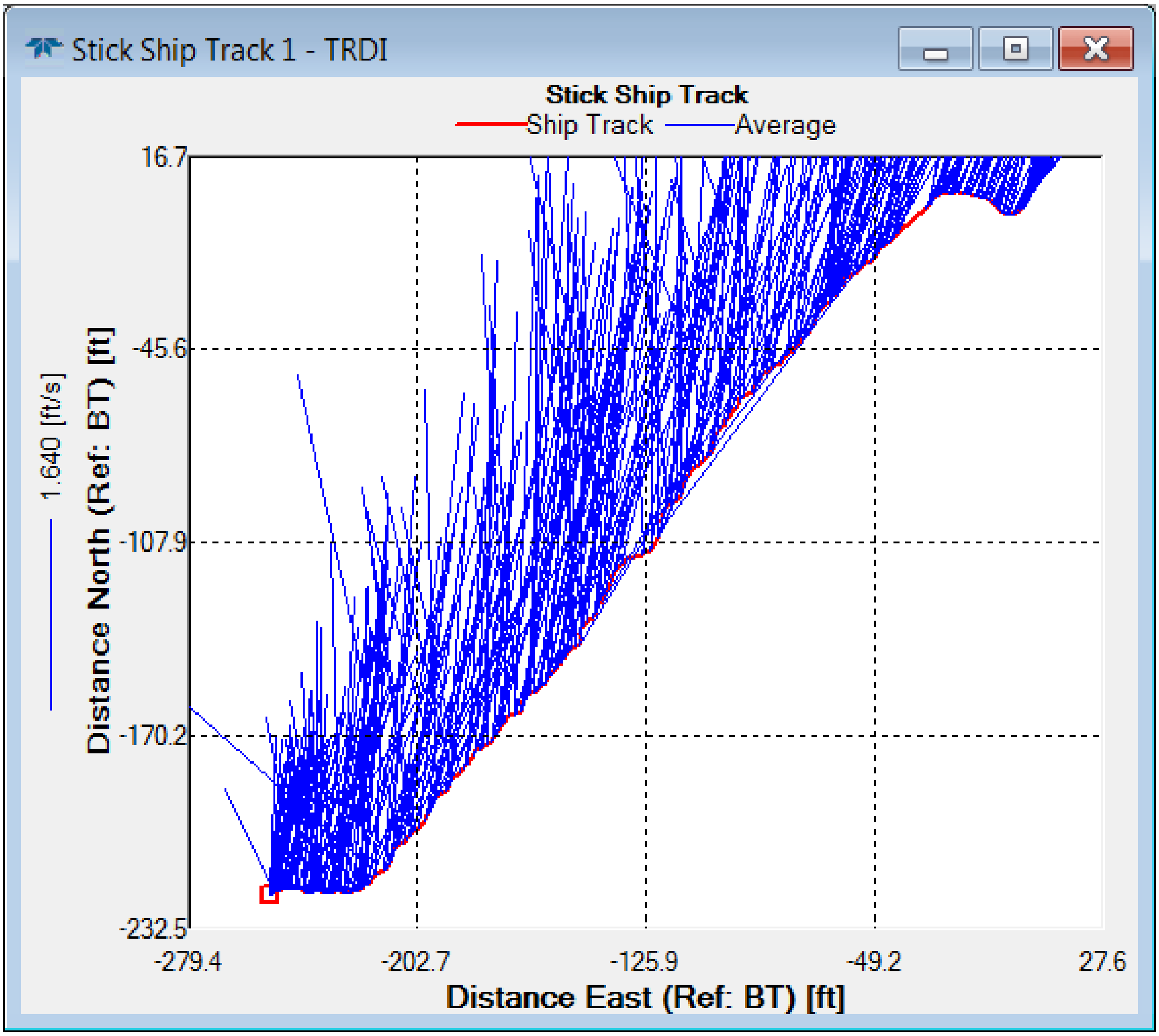
Transect J138006 Raw Data Output





Transect J138015 Raw Data Output





2) 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 J 13.8 June 4 ADCP direct discharge measurement. The energy grade line was approximated by the average water surface slope between J 13.8U and J 13.8D. Stage at J 13.8 was interpolated between J 13.8U and J 13.8D. Manning's n values were selected from reference documents (URS 2001) and calibrated to the measured discharge values. The calibrated Manning's n values used in the calculations were 0.035 for the left overbank, 0.018 for the main channel, and 0.035 for the right overbank.

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Feet
0 250 500

Date:	11/15/2017	Project:	159730
Drawn:	JEG	File:	PlanView_J13.8_C_8X11L.mxd
Checked:	JMG	Scale:	1 in = 250 feet

●	Gage Location
●	Stationing
—	Spring Cross Section

Imagery Source: Digital Globe, 2015

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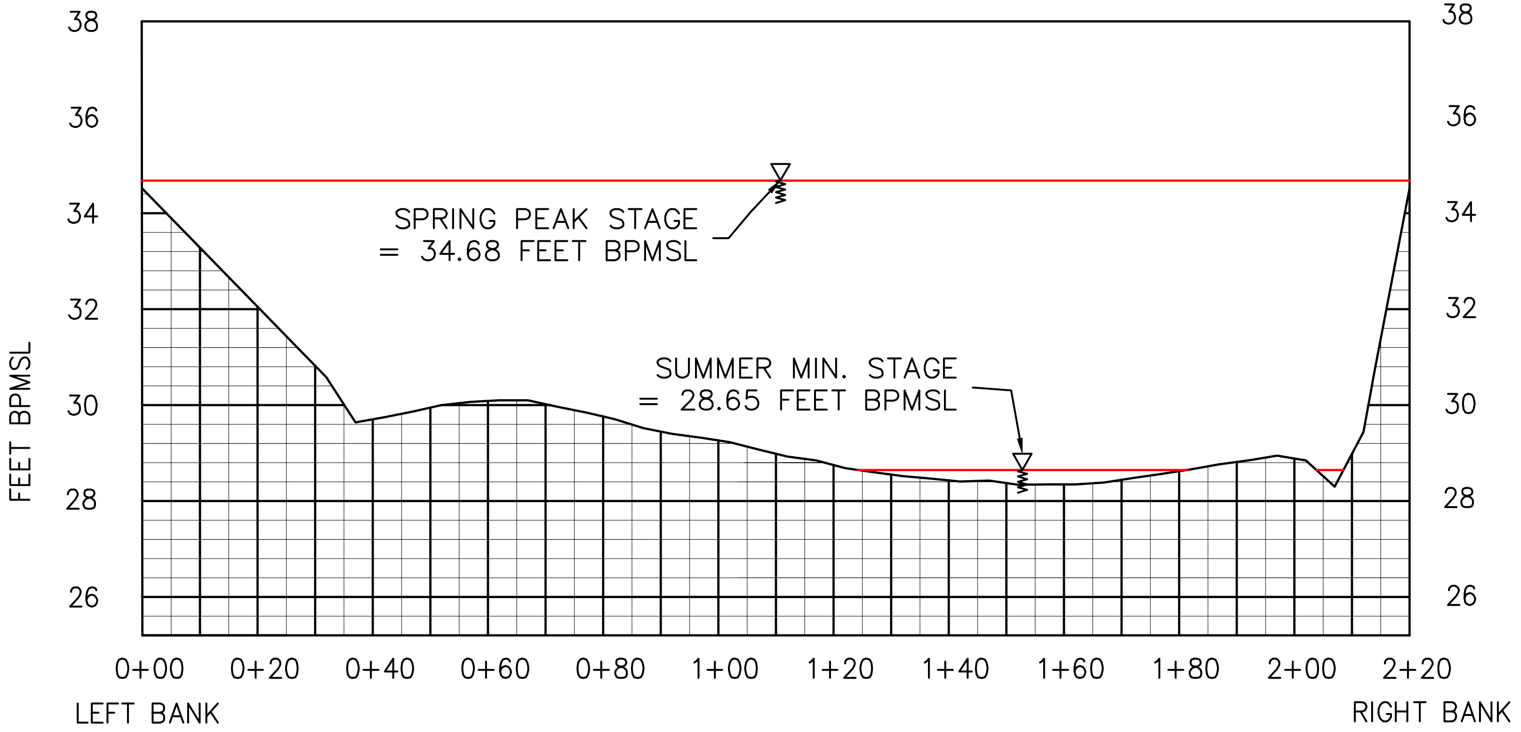
2017 Spring Breakup
Judy Creek at
J 13.8 Plan

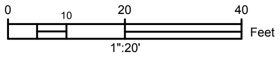
(SHEET 1 of 1)

NOTES

1. BASIS OF ELEVATION, LINE 4BW, LOUNSBURY 2001.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED JUNE 2017 BY MICHAEL BAKER INTL.



1 JUDY CREEK AT J 13.8 CENTERLINE CROSS-SECTION



ConocoPhillips
Alaska, Inc.

DATE: 11/13/2017
PROJECT: 159730
DRAWN: DTR
FILE: J13.8 X-SECTION.DWG
CHECKED: GCY
SCALE: AS SHOWN

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2017 SPRING BREAKUP
J 13.8 CENTERLINE
PROFILE

(SHEET 2 OF 2)

B.2.2 WILLOW 2 AT UC1A

1) SPRING BREAKUP MEASURED DISCHARGE

Location: 100 ft. downstream of UC1AD

Date & Time: June 3, 12:30 PM

Equipment: RiverRay ADCP mounted in a trimaran and pulled across the channel.

Final Discharge (cfs): 125

Average Velocity (fps): 2.2

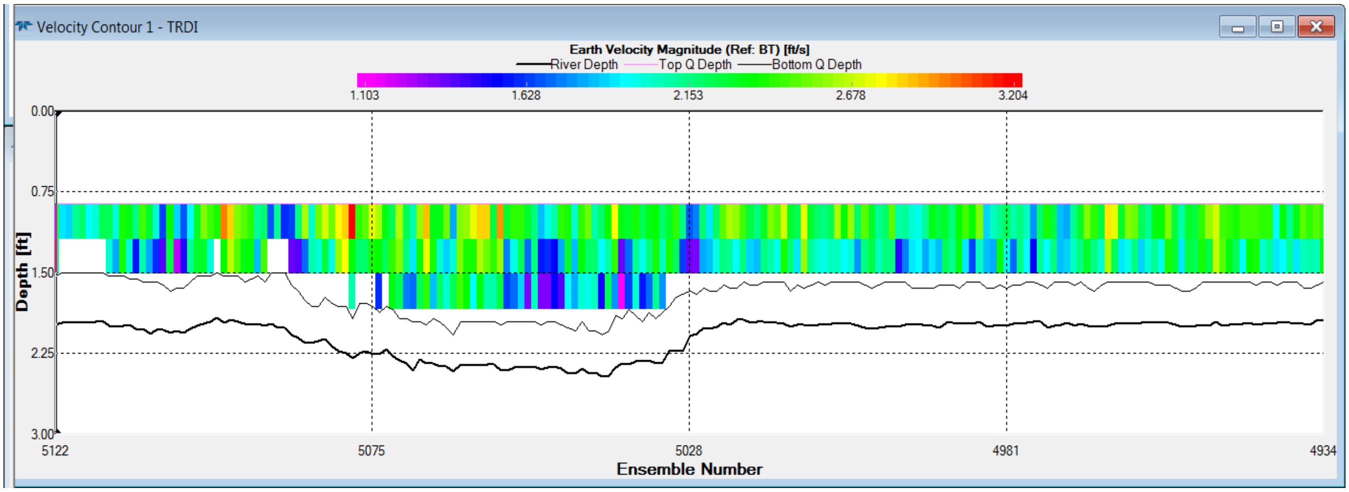
Measurement Rating: Fair

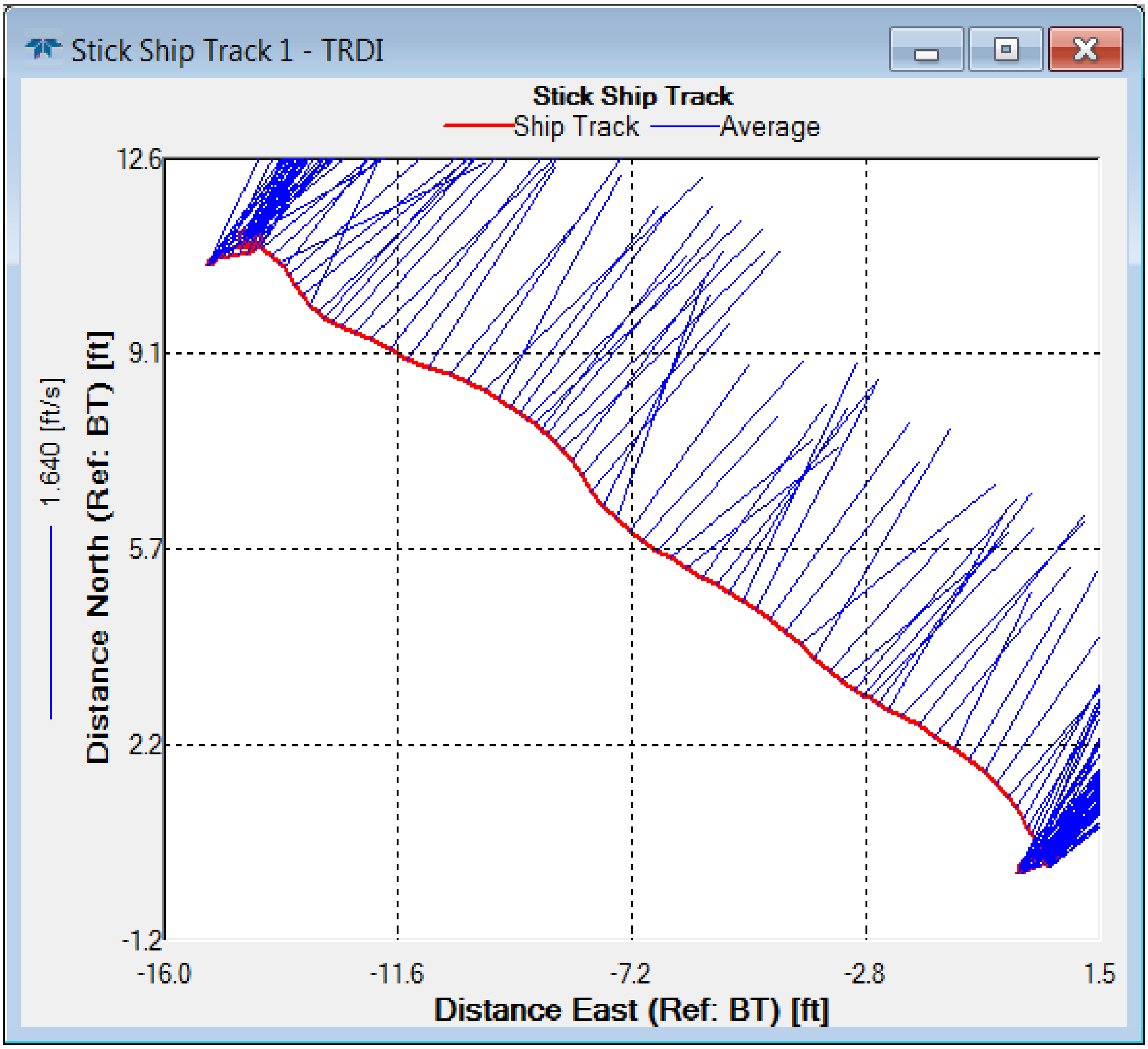
Measurement Notes: A stationary moving bed test was performed, but no moving bed was identified. The creek had snow and ice present and flow was on top of saturated snow. Prior to deployment, diagnostic tests were performed and the internal compass calibrated. The overall discharge measurement is considered fair, because of unaccounted flow through saturated snow.

Table B.3: UC1A Spring Breakup Measured Discharge Summary

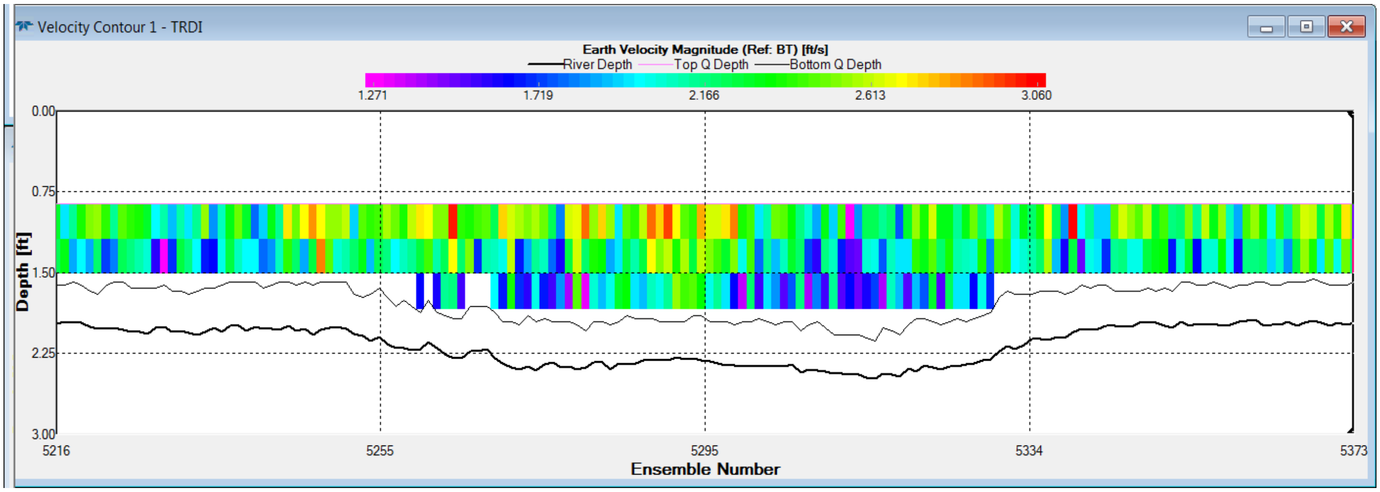
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
T001	Right	121	-2.88%	33.30	-5.14%	41.3	15.5	64.4	1.88	2.14
T002	Left	127	2.23%	35.21	0.30%	41.9	16.4	65.6	1.94	2.15
T003	Right	126	0.81%	35.63	1.50%	41.9	16.6	65.6	1.91	2.15
T004	Left	124	-0.16%	36.28	3.34%	41.6	16.7	65.3	1.90	2.17
Average		**125**		**35.10**		**41.7**		**65.2**	**1.91**	**2.15**

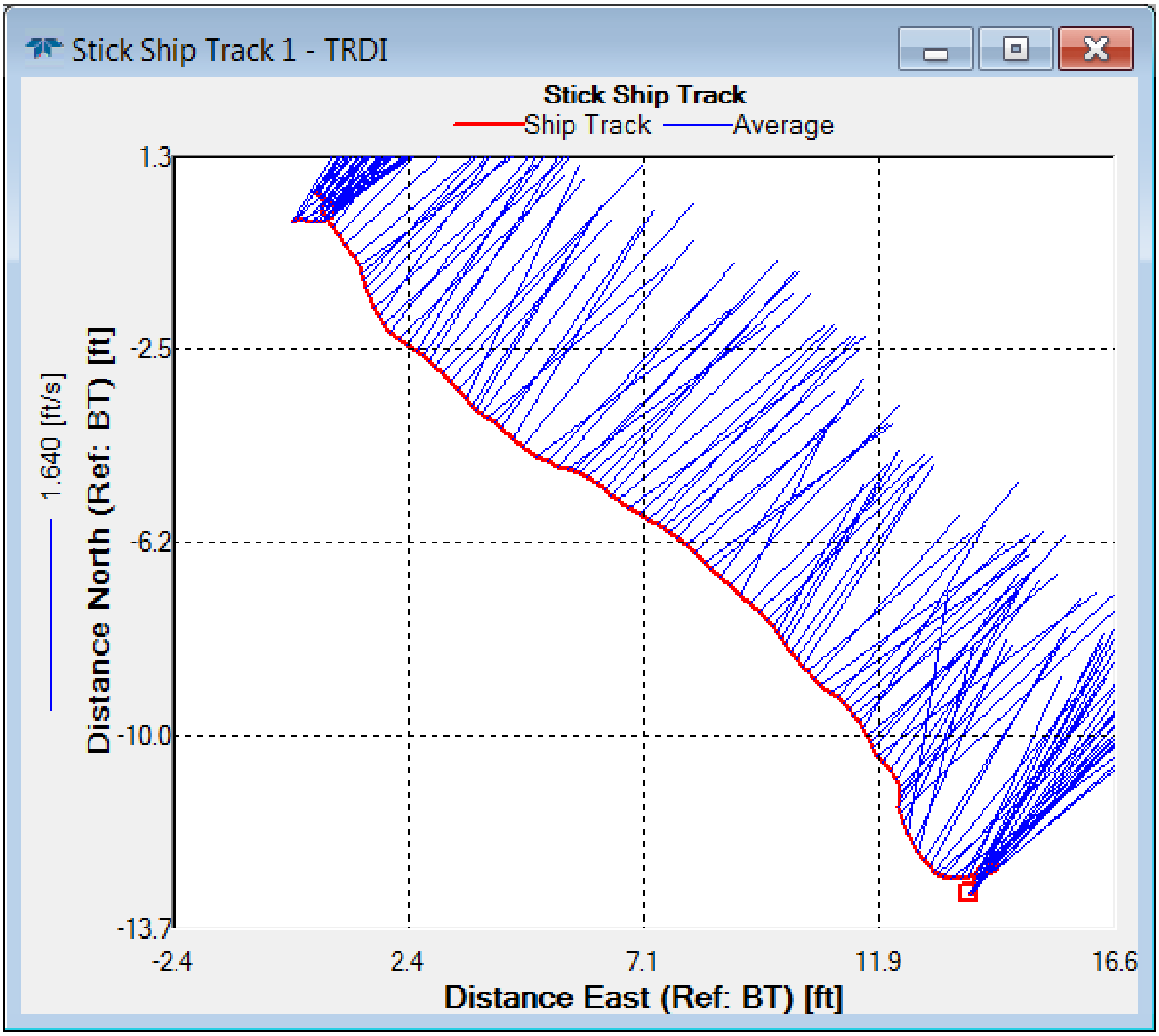
Transect T001 Raw Data Output



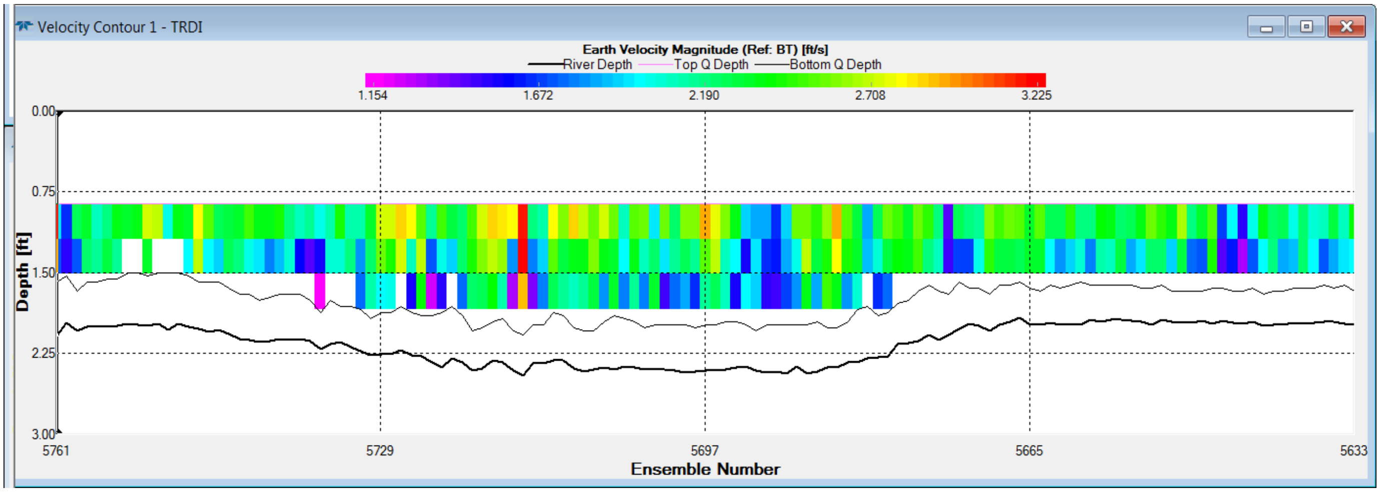


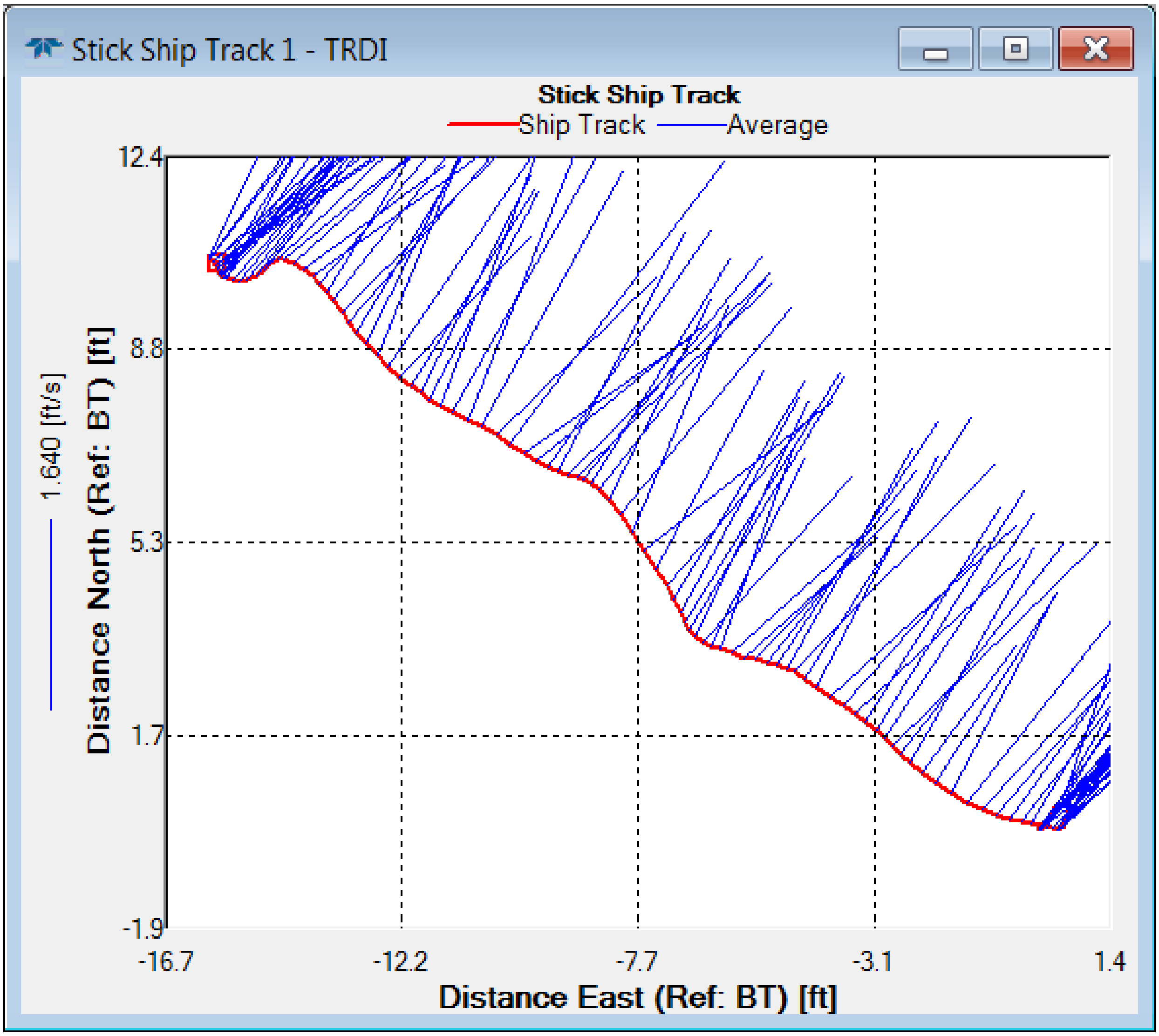
Transect T002 Raw Data Output



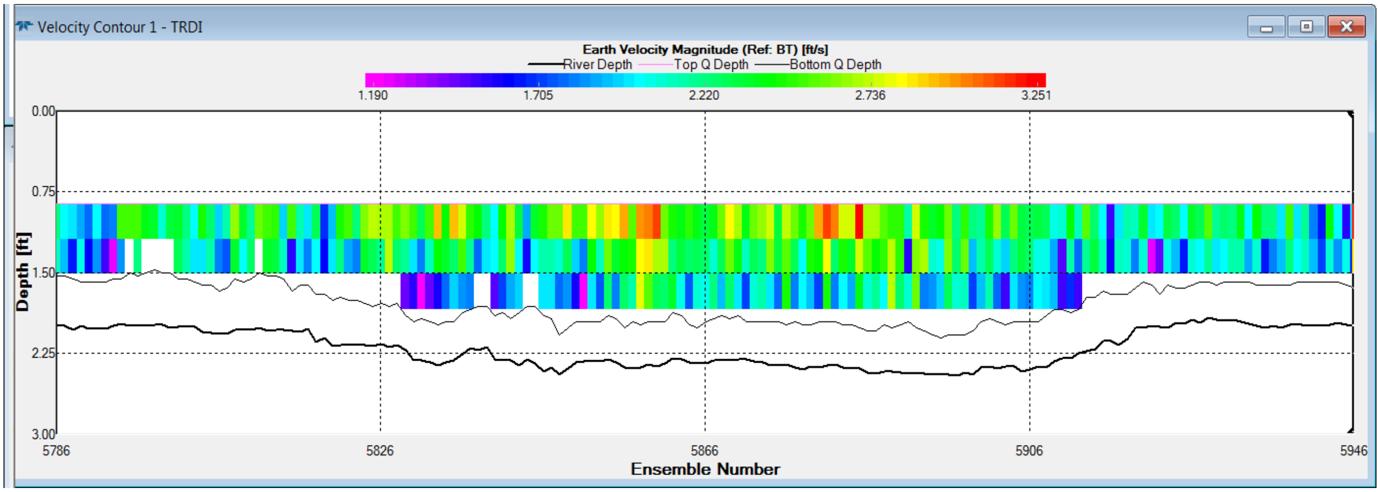


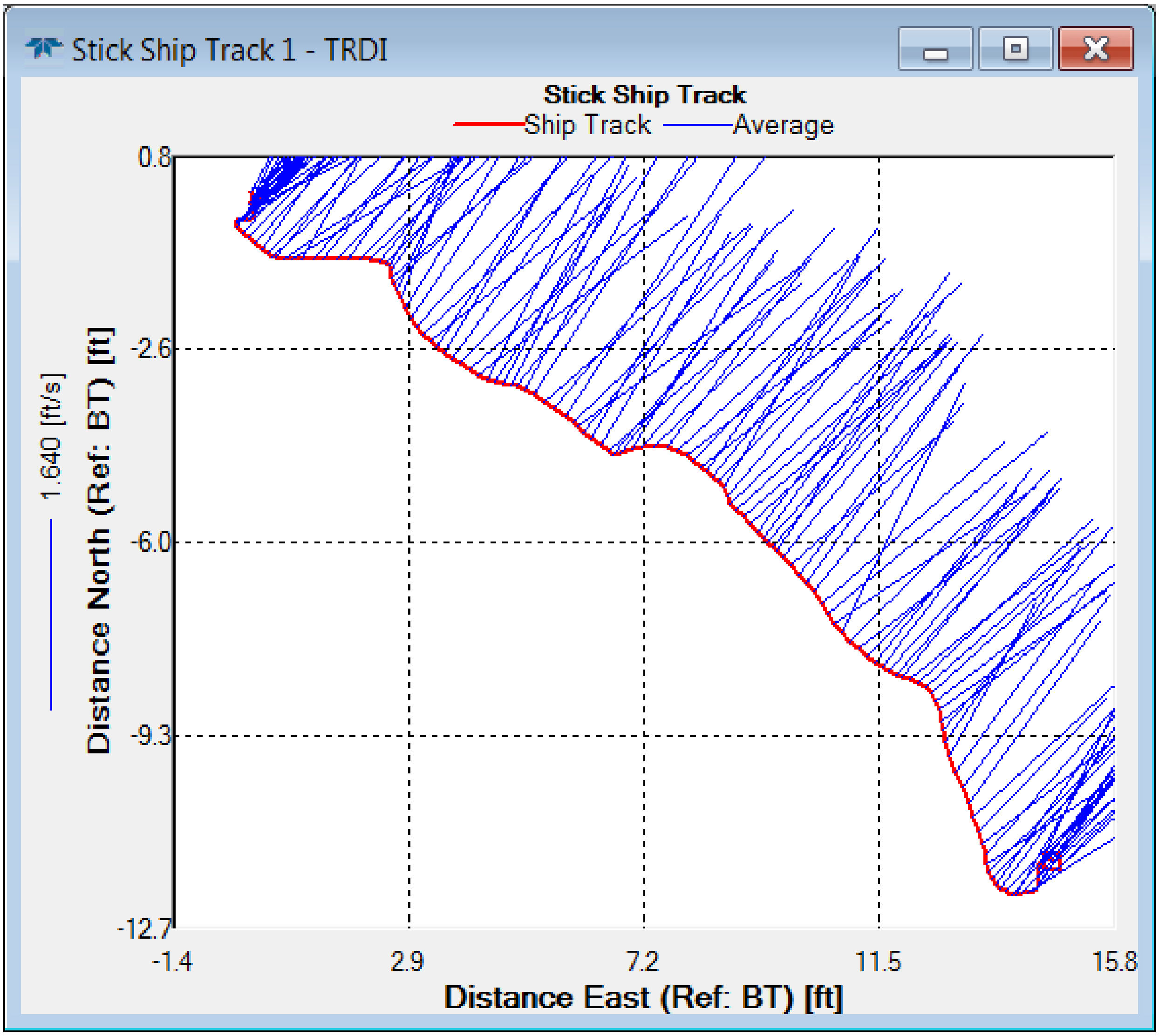
Transect T003 Raw Data Output





Transect T004 Raw Data Output





2) SUMMER MEASURED DISCHARGE

Table B.4: UC1A Summer Measured Discharge Summary

Date:	6/28/2017	**Time:**	4:23 PM	**Method:**	USGS Midsection
Location:	UC1A	**Crew:**	JMG & WAB	**Depth:**	0.6 of measured depth
Lat:	N 70.17134°	**Long:**	W 151.942°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+00.0	86.50		-	-	-	-	Left bank
0+05.0	85.35		-				Overbank; short veg, grassy
0+10.0	84.84		-				Overbank; short veg, grassy
0+15.0	83.39		-				Overbank; short veg, grassy
0+20.0	82.66		-				Overbank; short veg, grassy
0+25.0	81.32		-				Overbank; short veg, grassy
0+30.0	80.47		-				Overbank; short veg, grassy
0+35.0	80.10		-				Overbank; short veg, grassy
0+40.0	80.23		-				Overbank; short veg, grassy
0+41.0	79.61	-0.01	0.00				Top of channel bank; grassy lip
0+42.0	78.10	1.50	0.70	1.0	1.50	1.05	Channel;
0+43.0	77.30	2.30	0.62	1.5	3.45	2.14	Channel;
0+45.0	77.10	2.50	0.39	1.5	3.75	1.46	Channel;
0+46.0	77.30	2.30	0.18	1.5	3.45	0.62	Channel;
0+48.0	78.38	1.22	0.18	2.0	2.44	0.44	Channel;
0+50.0	79.60	0.00	0.00				Top of channel bank; short veg
0+51.0	80.41						Overbank; short veg, grassy
0+55.0	81.42						Overbank; short veg, grassy
0+60.0	82.25						Overbank; short veg, grassy
0+65.0	84.50						Overbank; short veg, grassy
0+70.0	85.87						Overbank; short veg, grassy
0+75.0	86.62						Overbank; short veg, grassy
0+80.0	87.00						Overbank; short veg, grassy
1+00.0	89.03						Right bank

Notes:

1. Measurement performed near UC1AD gage.

Total Width (ft)	Average Channel Elevation (ft)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)	
9.0	77.6	2.0	0.41	-	14.6	5.7	

ConocoPhillips
Alaska

0 100 200 Feet

Date:	12/202017	Project:	159730
Drawn:	JEG	File:	PlanView_UC1_8X11L.mxd
Checked:	GCY	Scale:	1 in = 100 feet

● Spring Stationing

● Summer Stationing

⊕ Gage Location

— Spring Cross Section

— Summer Cross Section

Imagery Source: Digital Globe, 2015

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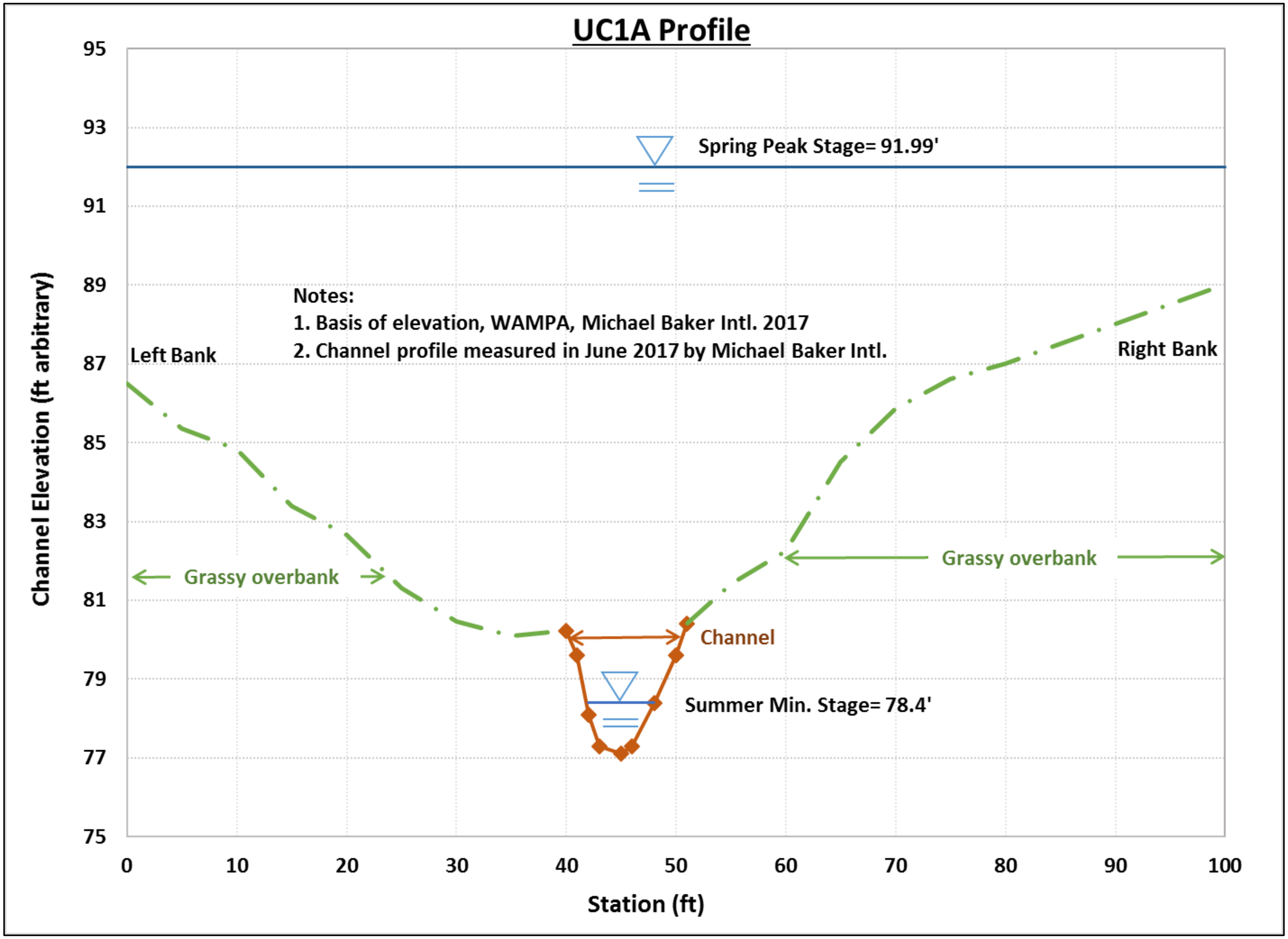
2017 Spring Breakup Willow 2 at UC1A Plan

(SHEET 1 of 1)

4) SUMMER CROSS-SECTION PROFILE



B.2.3 JUDY CREEK KAYYAAQ AT UC2A

1) SPRING BREAKUP MEASURED DISCHARGE

Location: UC2A

Date & Time: June 3, 2:00 PM

Equipment: RiverRay ADCP mounted in a trimaran and pulled across the channel.

Final Discharge (cfs): 200

Average Velocity (fps): 2.1

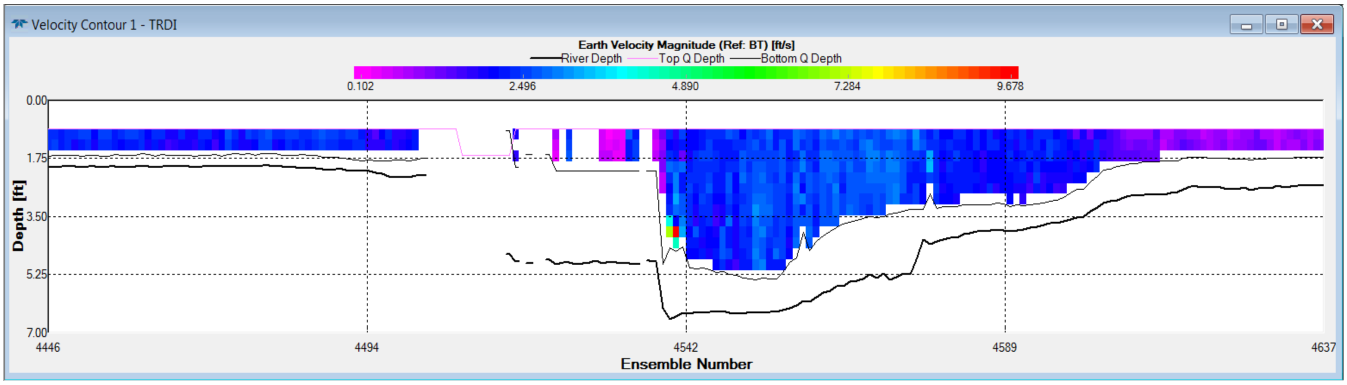
Measurement Rating: Fair

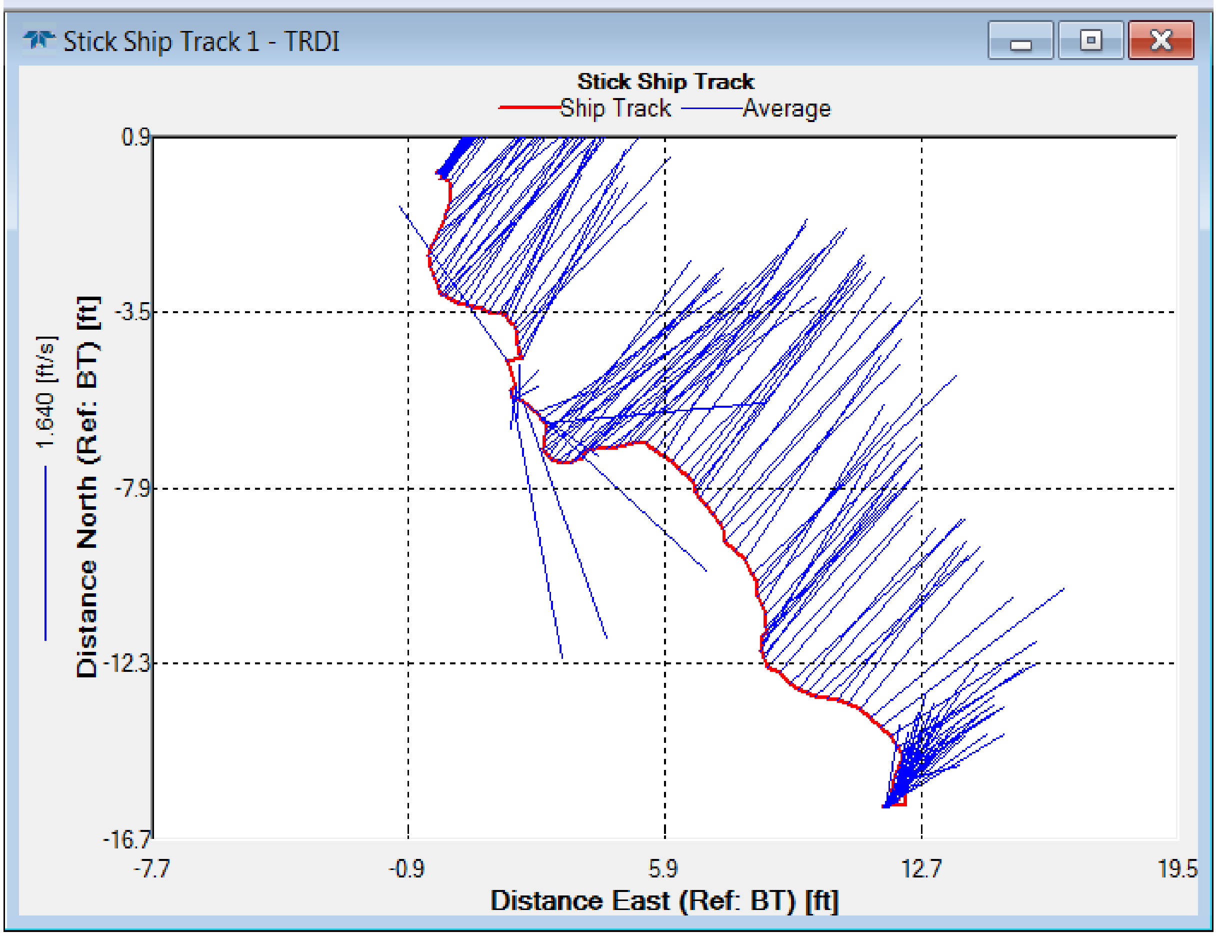
Measurement Notes: A moving bed test was performed, but no moving bed was identified. The creek had snow and ice present and flow was on top of saturated snow. Prior to deployment, diagnostic tests were performed and the internal compass calibrated. The overall discharge measurement is considered fair, because of unaccounted flow through saturated snow.

Table B.5: UC2A Spring Breakup Measured Discharge Summary

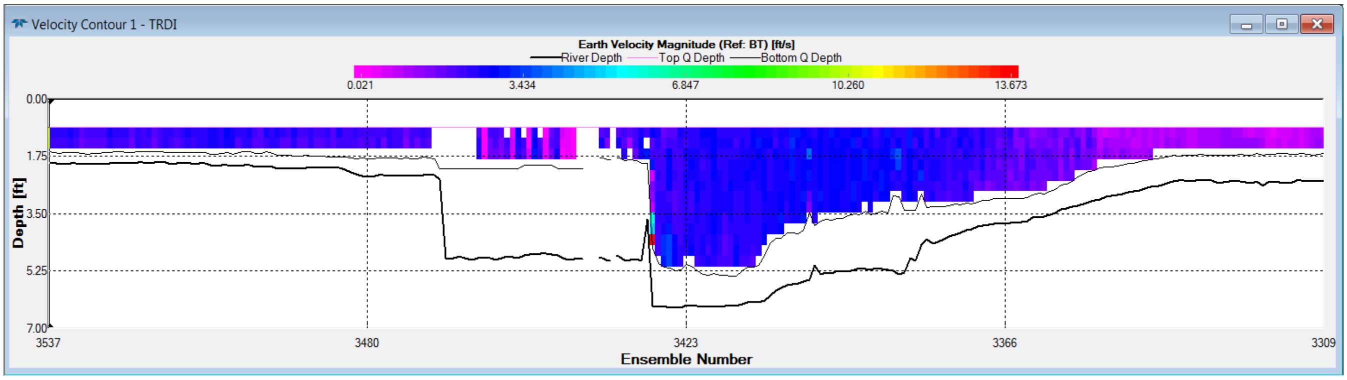
Transect #	Starting Bank	Total Q (cfs)	Delta Q (%)	Measured Q (cfs)	Delta Measured Q (%)	Measured Width (ft)	Measured Area (Q/V) (ft^2)	Total Area (ft^2)	Q/A (ft/s)	Flow Speed (ft/s)
T001	Right	189	-0.10%	83.799	2.43%	44.58	40.6	107.8	1.75	2.06
T003	Right	187	-1.25%	81.595	-0.27%	43.78	39.9	103.5	1.81	2.05
T004	Left	193	1.99%	82.472	0.80%	43.75	39.8	104.9	1.84	2.07
T006	Left	188	-0.64%	79.393	-2.96%	43.82	37.9	104.9	1.79	2.10
Average		**189**		**81.815**		**43.98**		**105.3**	**1.80**	**2.07**

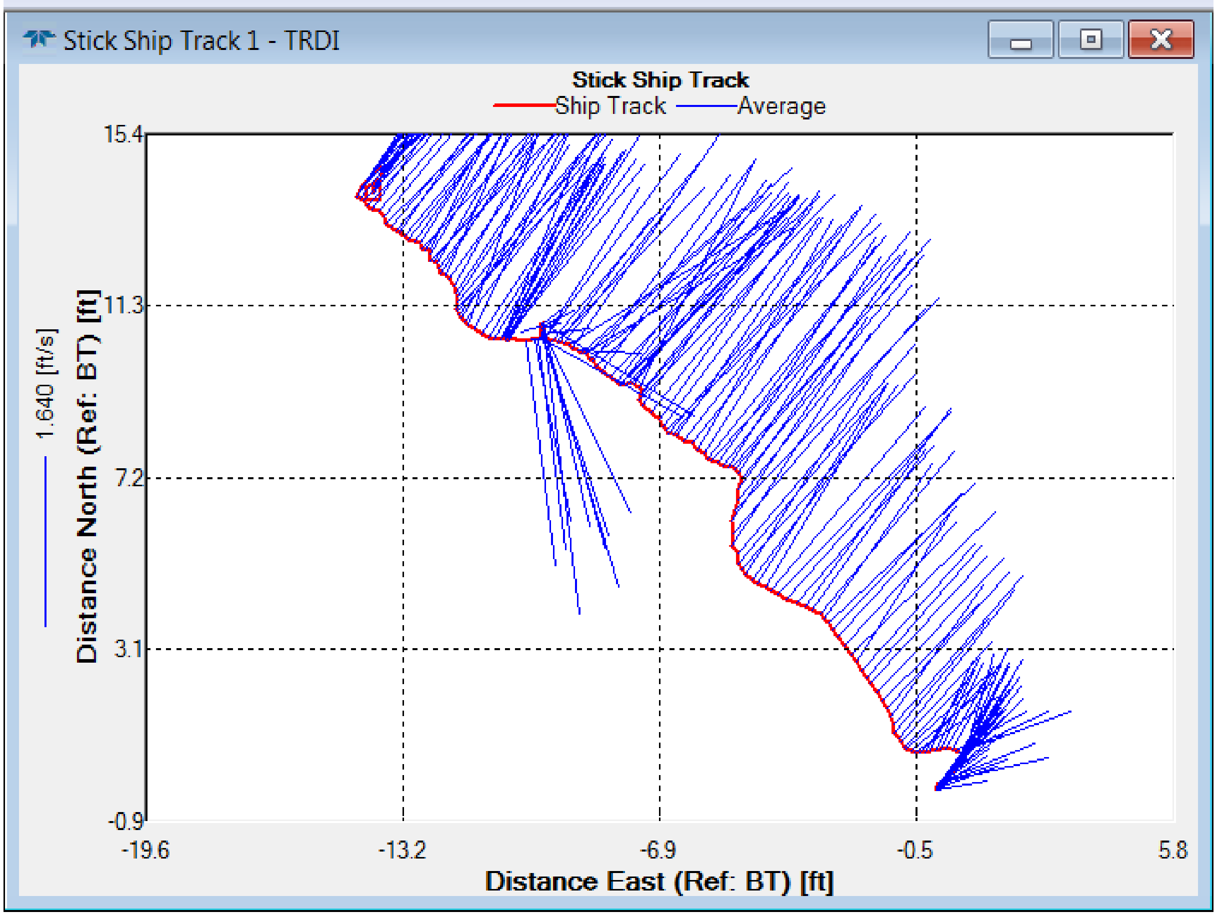
Transect T001 Raw Data Output



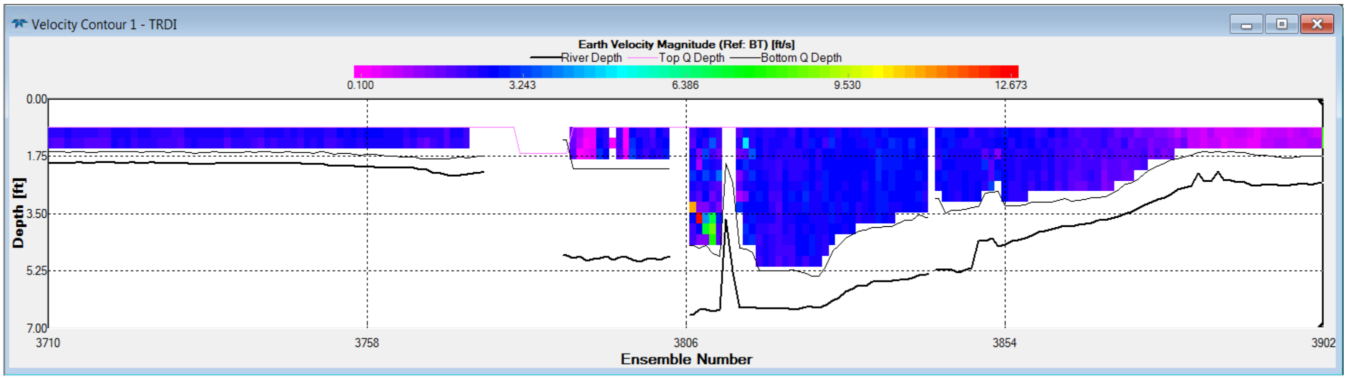


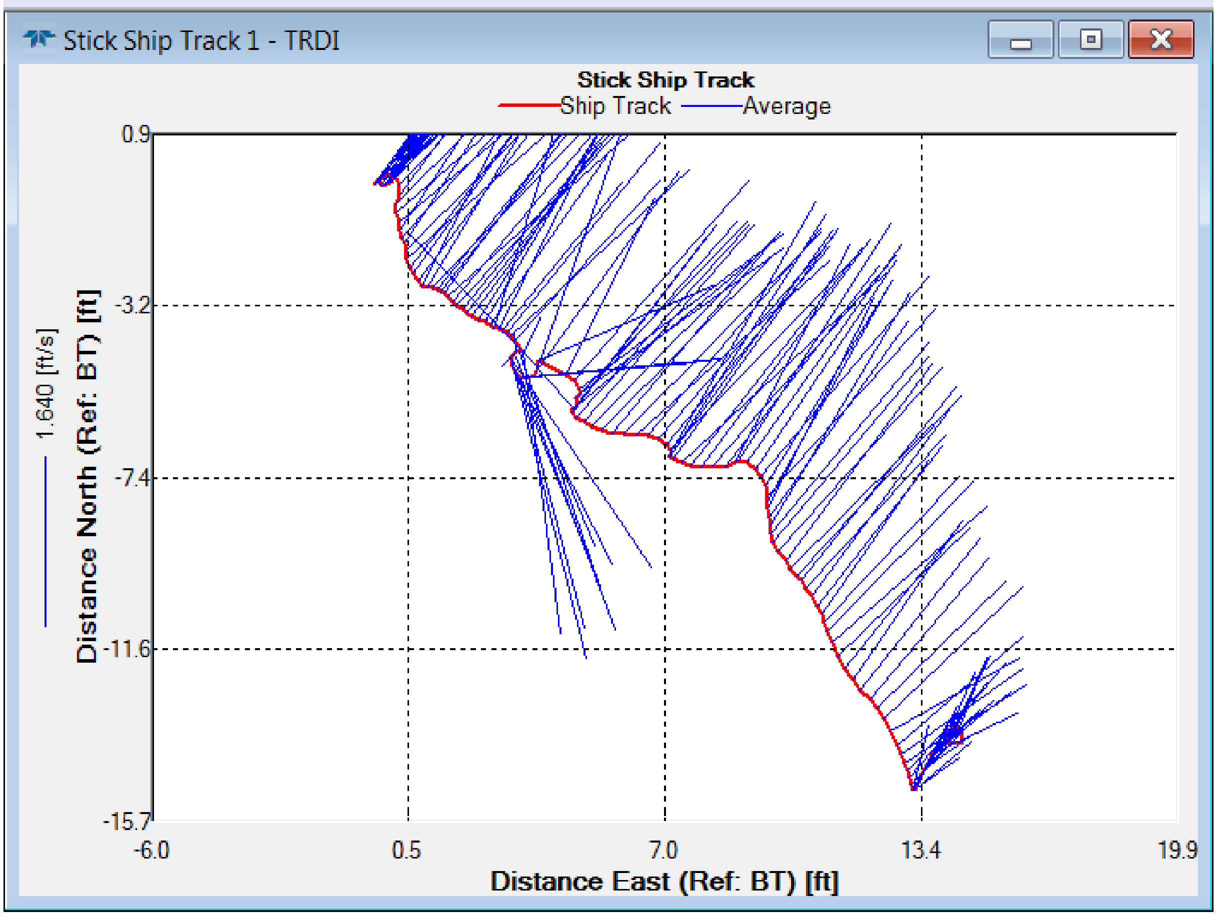
Transect T003 Raw Data Output



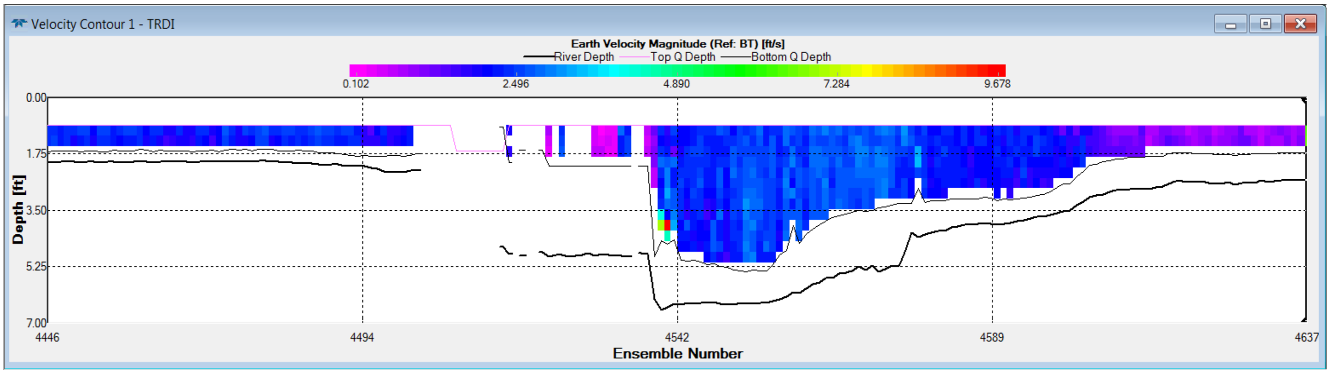


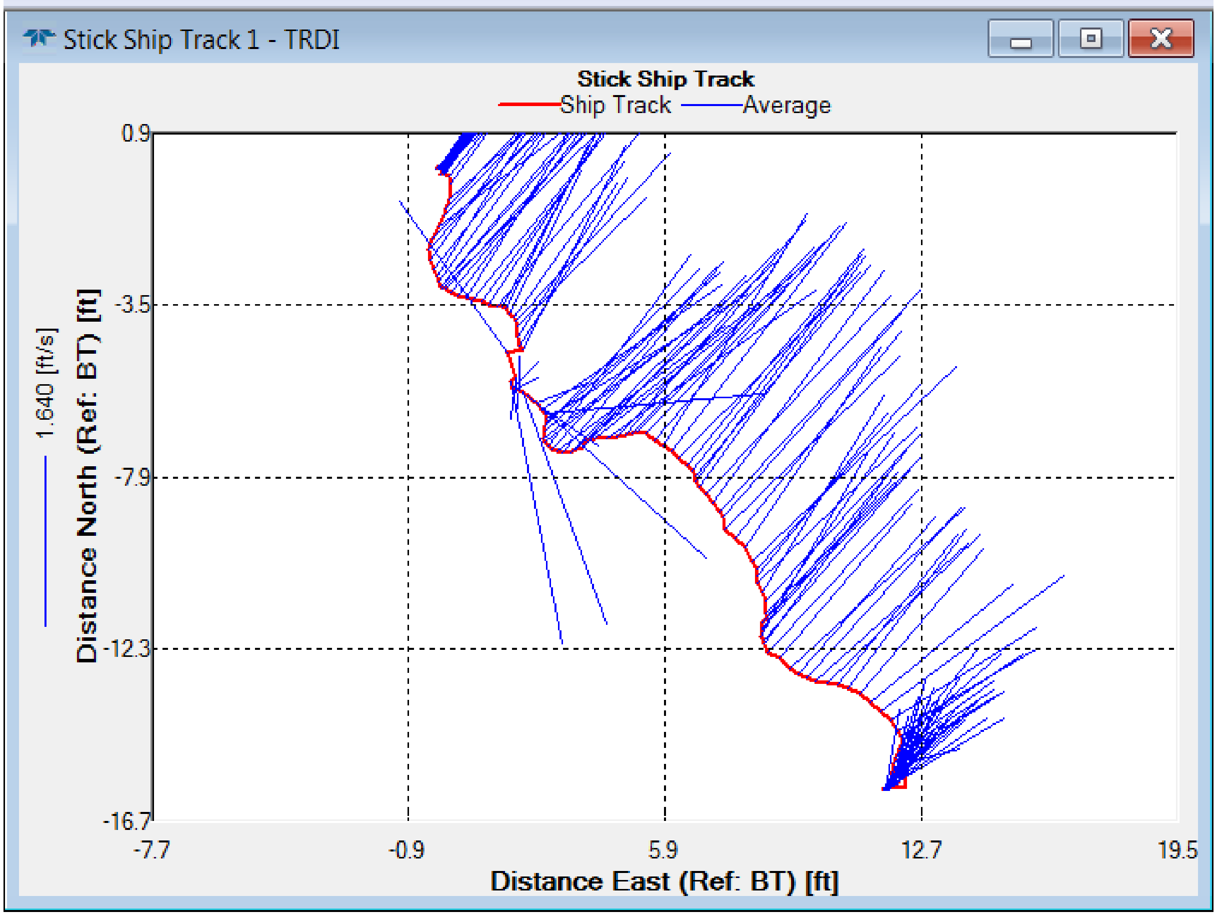
Transect T004 Raw Data Output





Transect T006 Raw Data Output





2) SUMMER MEASURED DISCHARGE

Table B.6: UC2A Summer Measured Discharge Summary

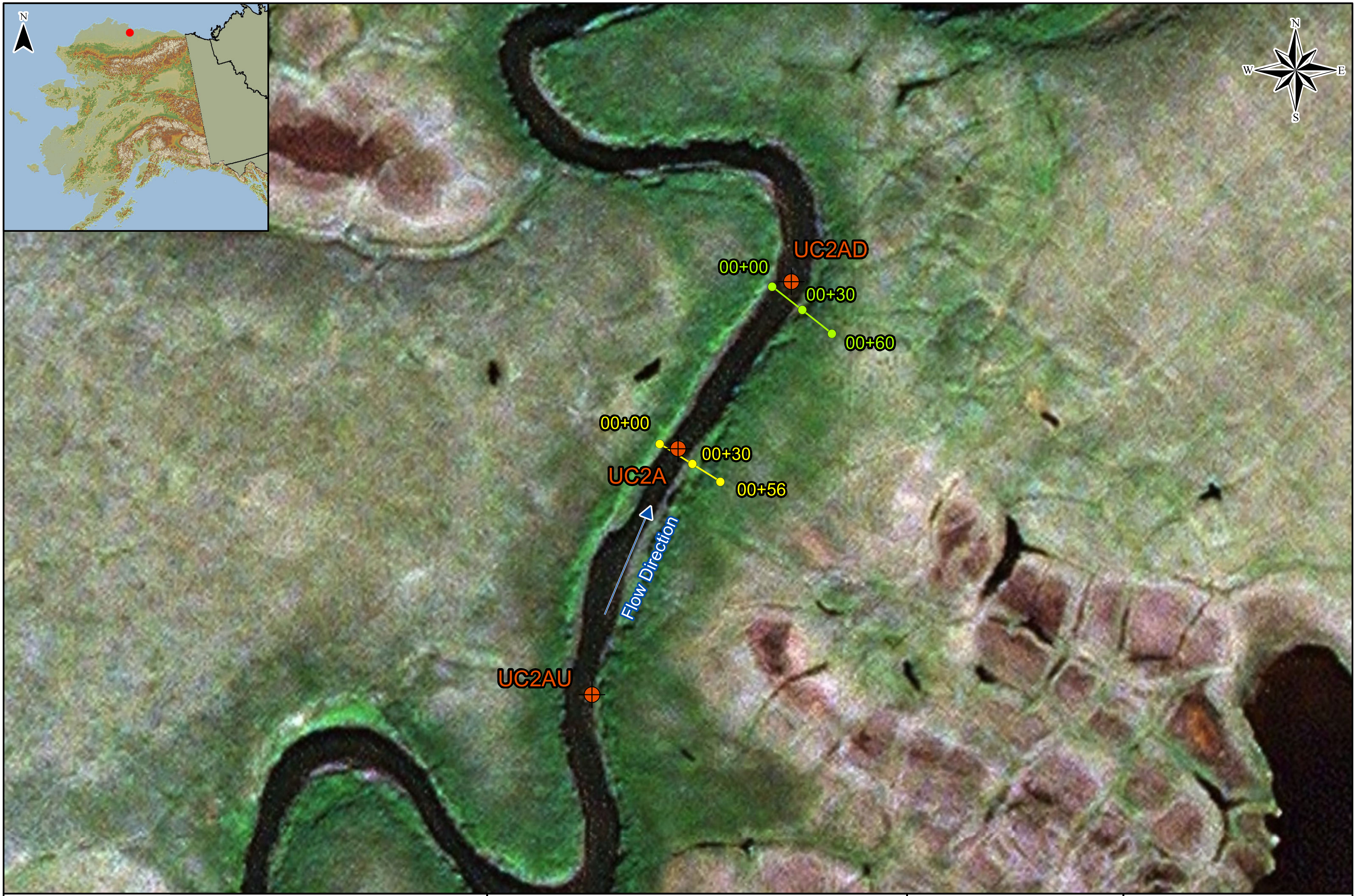
Date:	6/28/2017	**Time:**	11:21 AM	**Method:**	USGS Midsection
Location:	UC2A	**Crew:**	JMG & WAB	**Depth:**	0.6 of measured depth
Lat:	N 70.20396°	**Long:**	W 152.07328°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+00.0	89.97		-	-	-	-	Left bank
0+02.0	88.71		-				Overbank; willow
0+05.0	87.43		-				Overbank; willow
0+06.0	87.36		-				Overbank; willow
0+07.0	87.84		-				Overbank; willow
0+09.0	87.08		-				Overbank; willow ends at 0+10.5
0+12.0	84.96		-				Overbank; short veg
0+14.0	83.90		-				Overbank; short veg
0+18.0	84.40		-				Overbank; mudflat
0+20.0	82.77	0.00	-				Toe of bank; edge of water, silt, mud
0+22.0	80.27	2.50	0.90	2.00	0.0	0.00	Channel;
0+24.0	79.37	3.40	1.38	2.00	5.0	6.90	Channel;
0+26.0	79.37	3.40	1.66	2.00	6.8	11.29	Channel;
0+28.0	80.17	2.60	1.73	2.00	6.8	11.76	Channel;
0+30.0	79.37	3.40	1.63	2.00	5.2	8.48	Channel;
0+32.0	79.47	3.30	1.60	2.00	6.8	10.88	Channel;
0+34.0	79.47	3.30	1.43	2.00	6.6	9.44	Channel;
0+36.0	79.77	3.00	1.34	2.00	6.6	8.84	Channel;
0+38.0	80.77	2.00	0.59	1.50	4.5	2.66	Channel;
0+39.0	82.37	0.40	0.00	1.25	2.5	0.00	Channel;
0+40.5	82.70	0.07	-				Top of channel bank; short veg
0+42.0	83.98		-				Overbank; edge of veg, cut bank
0+43.0	84.08		-				Overbank; edge of willows
0+46.0	86.22		-				Overbank; willows
0+53.0	86.64		-				Overbank; willows
0+60.0	88.12		-				Right bank

Notes:

1. Measurement performed near UC2AD gage.

Total Width (ft)	Average Channel Elevation (ft)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
19.0	80.0	2.7	1.23	-	50.8	70.2



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Date:	12/20/2017	Project:	159730
Drawn:	JEG	File:	PlanView_UC2_8X11L.mxd
Checked:	GCY	Scale:	1 in = 100 feet

●	Spring Stationing	—	Spring Cross Section
●	Summer Stationing	—	Summer Cross Section
⊕	Gage Location		

Imagery Source: Digital Globe, 2015

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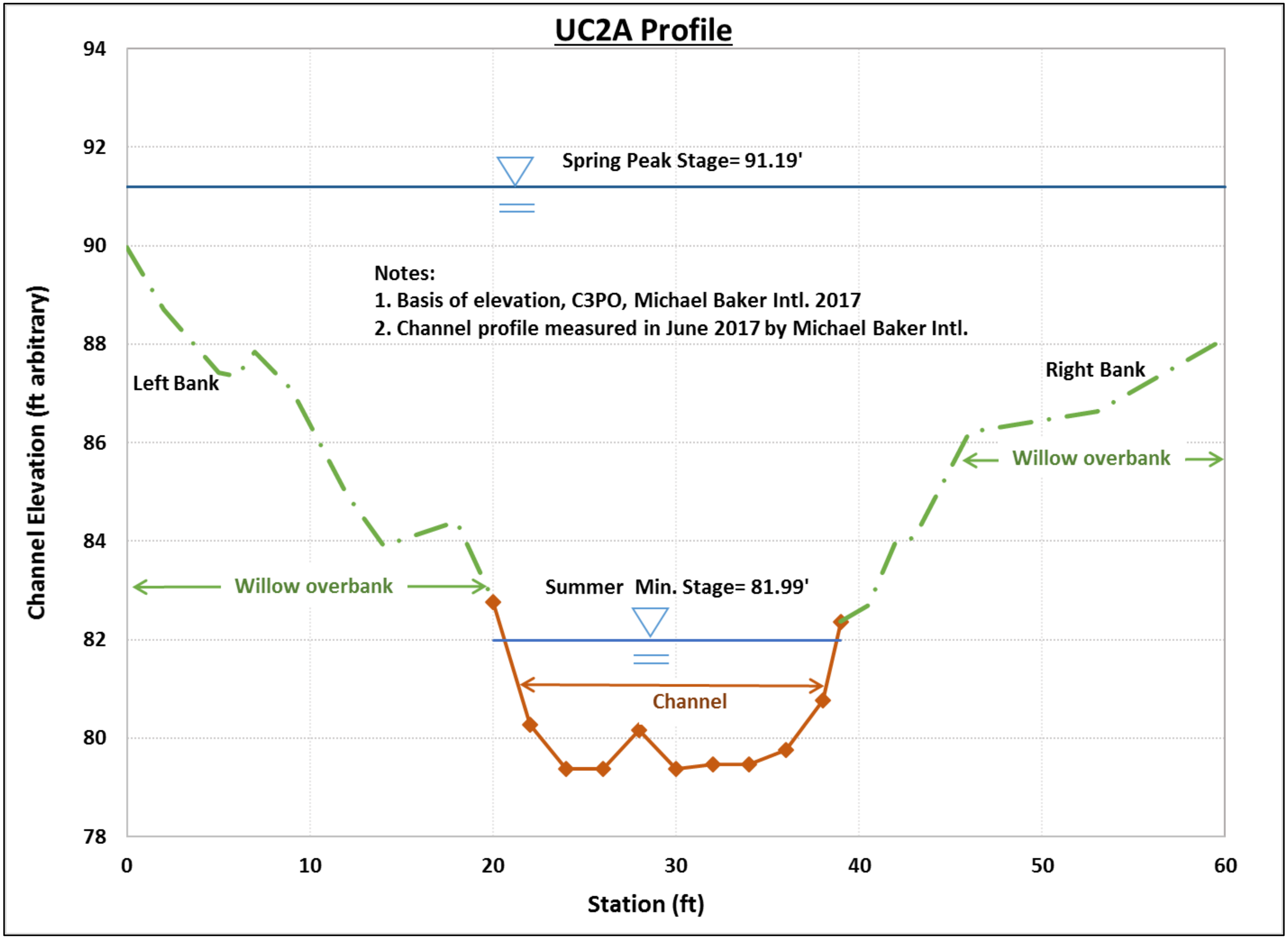
2017 Spring Breakup Judy Creek Kayyaaq at UC2A Plan

(SHEET 1 of 1)

4) SUMMER PROFILE CROSS-SECTION PROFILE



B.2.4 SWALE 1

1) SPRING BREAKUP MEASURED DISCHARGE

Table B.7: SW1 Spring Breakup Measured Discharge Summary

Date:	6/3/2017	**Time:**	5:23 PM	**Method:**	USGS Midsection
Location:	SW1	**Crew:**	DTR, WAB, & GCY	**Depth:**	Water Surface
Lat:	N 70.13549°	**Long:**	W 152.01343°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+00.0	95.608		-	-	-	-	Left edge of water, start of a beaded stream
0+01.0	95.11	0.50	0.32	1	0.50	0.16	Grassy
0+02.0	94.91	0.70	0.50	1	0.70	0.35	Grassy
0+03.0	94.81	0.80	1.57	1	0.80	1.26	Grassy
0+04.0	94.71	0.90	2.06	1	0.90	1.85	Start of beaded stream
0+05.0	94.86	0.75	1.54	1	0.75	1.16	Grassy
0+06.0	95.26	0.35	0.50	1	0.35	0.18	Grassy
0+07.0	95.26	0.35	0.86	1	0.35	0.30	Grassy
0+08.0	95.31	0.30	0.96	1	0.30	0.29	Grassy
0+09.0	95.41	0.20	0.65	1	0.20	0.13	Surface flow measured
0+10.0	95.46	0.15	0.70	1	0.15	0.11	Surface flow measured
0+11.0	95.46	0.15	1.10	1	0.15	0.17	Grassy
0+12.0	95.41	0.20	0.77	1	0.20	0.15	Grassy
0+13.0	95.61		-				Right edge of water

Notes:

1. Measurement performed upstream of SW1 gage.
2. Velocity measured at surface. Flow confined to single riffle.

Total Width (ft)	Average Channel Elevation (ft arbitrary)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
13.0	95.2	0.4	0.96	-	5.4	6.1

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Alaska

Date:	11/15/2017	Project:	159730
Drawn:	JEG	File:	PlanView_SW1_8X11L.mxd
Checked:	JMG	Scale:	1 in = 100 feet

● Spring Stationing

Spring Cross Section

Gage Location

Imagery Source: Digital Globe, 2015

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2017 Spring Breakup SW1 Plan

(SHEET 1 of 1)

3) SPRING BREAKUP CROSS-SECTION PROFILE

Notes:
1. Basis of elevation, OBIWAN, Michael Baker Intl. 2017
2. Channel profile measured in June 2017 by Michael Baker Intl. during discharge measurement.

B.2.5 SWALE 5

1) SPRING BREAKUP MEASURED DISCHARGE

Table B.8: SW5 Spring Breakup Measured Discharge Summary

Date:	6/4/2017	**Time:**	3:42 PM	**Method:**	USGS Midsection
Location:	SW5	**Crew:**	JMG & JPM	**Depth:**	0.6 of measured depth
Lat:	N 70.16869°	**Long:**	W 151.97728°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+00.0	88.44	-	-	-	-	-	
0+03.5	88.04	0.40	0.4	2.5	1.00	0.40	Left edge of water, snow pack edge
0+05.0	87.54	0.90	0.56	1.25	1.13	0.63	Grassy channel
0+06.0	87.44	1.00	0.55	1	1.00	0.55	Grassy channel
0+07.0	87.49	0.95	0.57	1	0.95	0.54	Grassy channel
0+08.0	87.44	1.00	0.76	1	1.00	0.76	Grassy channel
0+09.0	87.84	0.60	0.62	1	0.60	0.37	Grassy channel
0+10.0	87.39	1.05	0.71	1	1.05	0.75	Grassy channel
0+11.0	87.54	0.90	0.55	1	0.90	0.50	Grassy channel
0+12.0	87.64	0.80	0.25	1	0.80	0.20	Grassy channel
0+13.0	88.14	0.30	0	1	0.30	0.00	Right edge of water, snow pack edge
0+14.0	88.44						

Notes:

1. Measurement performed near SW5.

2. Right and left banks are flowing under snow pack. Snow about 4' deep on both sides. Streambed mostly solid bottom ice-uniform. Very little, if any, back water.

Total Width (ft)	Average Channel Elevation (ft arbitrary)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
9.5	87.7	0.8	0.50	-	8.7	4.7

ConocoPhillips
Alaska

Feet
0 100 200

Date:	11/15/2017	Project:	159730
Drawn:	JEG	File:	PlanView_SW5_8X11L.mxd
Checked:	JMG	Scale:	1 in = 100 feet

● Spring Stationing

— Spring Cross Section

⊕ Gage Location

Imagery Source: Digital Globe, 2015

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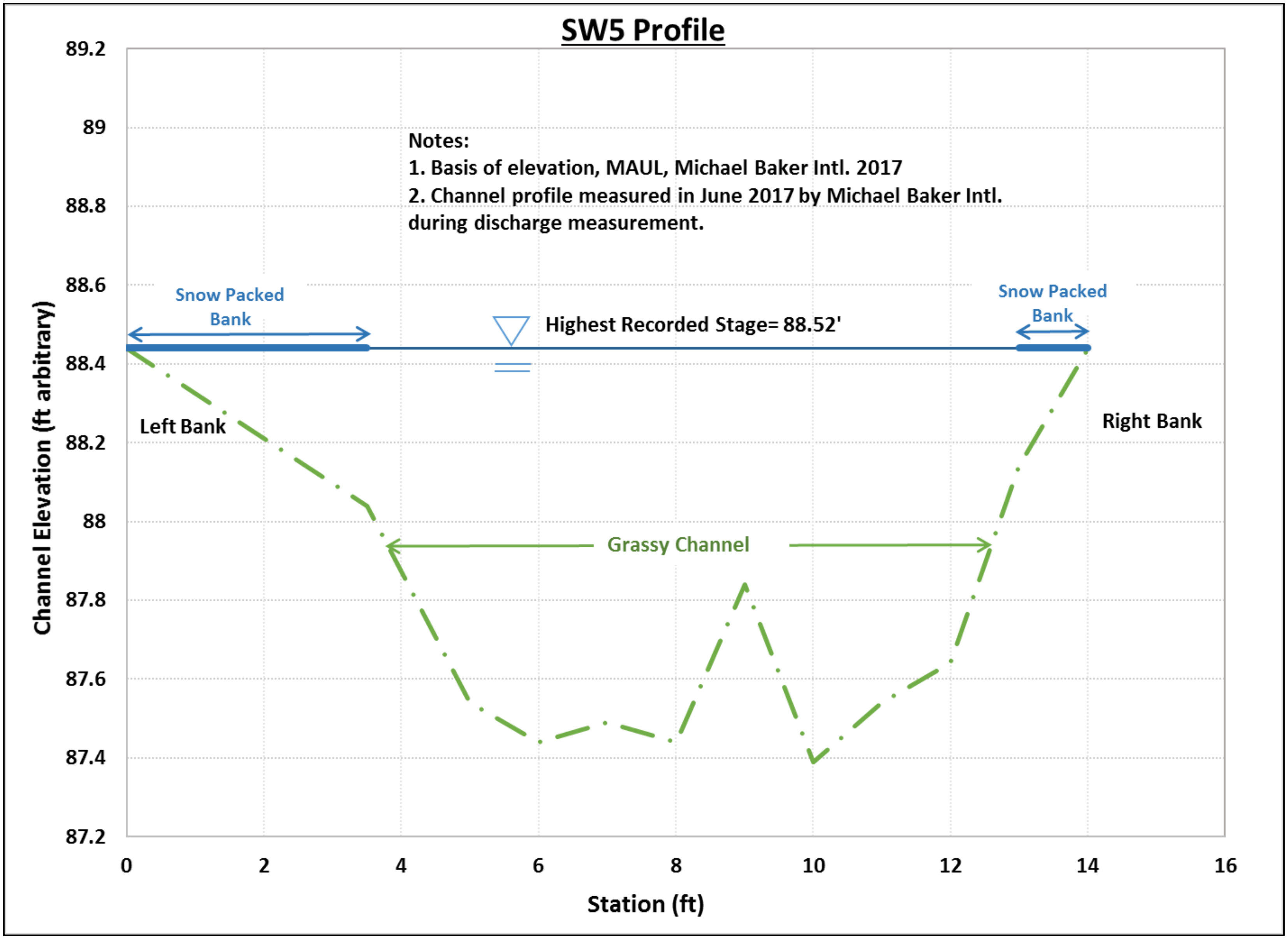
2017 Spring Breakup SW5 Plan

(SHEET 1 of 1)

3) SPRING BREAKUP CROSS-SECTION PROFILE



Notes:
1. Basis of elevation, MAUL, Michael Baker Intl. 2017
2. Channel profile measured in June 2017 by Michael Baker Intl. during discharge measurement.

B.2.6 SN171

1) SPRING BREAKUP MEASURED DISCHARGE

Table B.9: SN171 Spring Breakup Measured Discharge Summary

Date:	6/3/2017	**Time:**	4:42 PM	**Method:**	USGS Midsection
Location:	SN171	**Crew:**	DTR, WAB, & GCY	**Depth:**	Water Surface
Lat:	N 70.19724°	**Long:**	W 152.25263°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+00.0	91.04		-	-	-	-	
0+03.0	91.04	0.00	-	-	-	-	Left edge of water, start of a beaded stream
0+04.0	90.64	0.40	0.05	1	0.40	0.0	Grassy
0+05.0	90.44	0.60	0.21	0.75	0.45	0.1	Sensor ~0.2 ft below surface
0+05.5	90.24	0.80	1.21	0.5	0.40	0.5	Thalweg
0+06.0	90.44	0.60	2.36	0.75	0.45	1.1	Grassy
0+07.0	90.64	0.40	0.63	1	0.40	0.3	Grassy
0+08.0	90.74	0.30	0	1.5	0.45	0.0	Grassy
0+10.0	90.69	0.35	0	1.5	0.53	0.0	Grassy
0+11.0	90.69	0.35	0	1	0.35	0.0	Grassy
0+12.0	91.04	0.00	-				Right edge of water

Notes:

1. Measurement performed 30' upstream of SN171.
2. Velocity measured at surface. Flow confined to single riffle.

Total Width (ft)	Average Channel Elevation (ft arbitrary)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)	
12.0	90.7	0.4	0.56	-	3.4	1.9	

ConocoPhillips
Alaska

Date:	12/202017	Project:	159730
Drawn:	JEG	File:	PlanView_SW7_8X11L.mxd
Checked:	GCY	Scale:	1 in = 100 feet

● Spring Stationing

— Spring Cross Section

⊕ Gage Location

Imagery Source: Digital Globe, 2015

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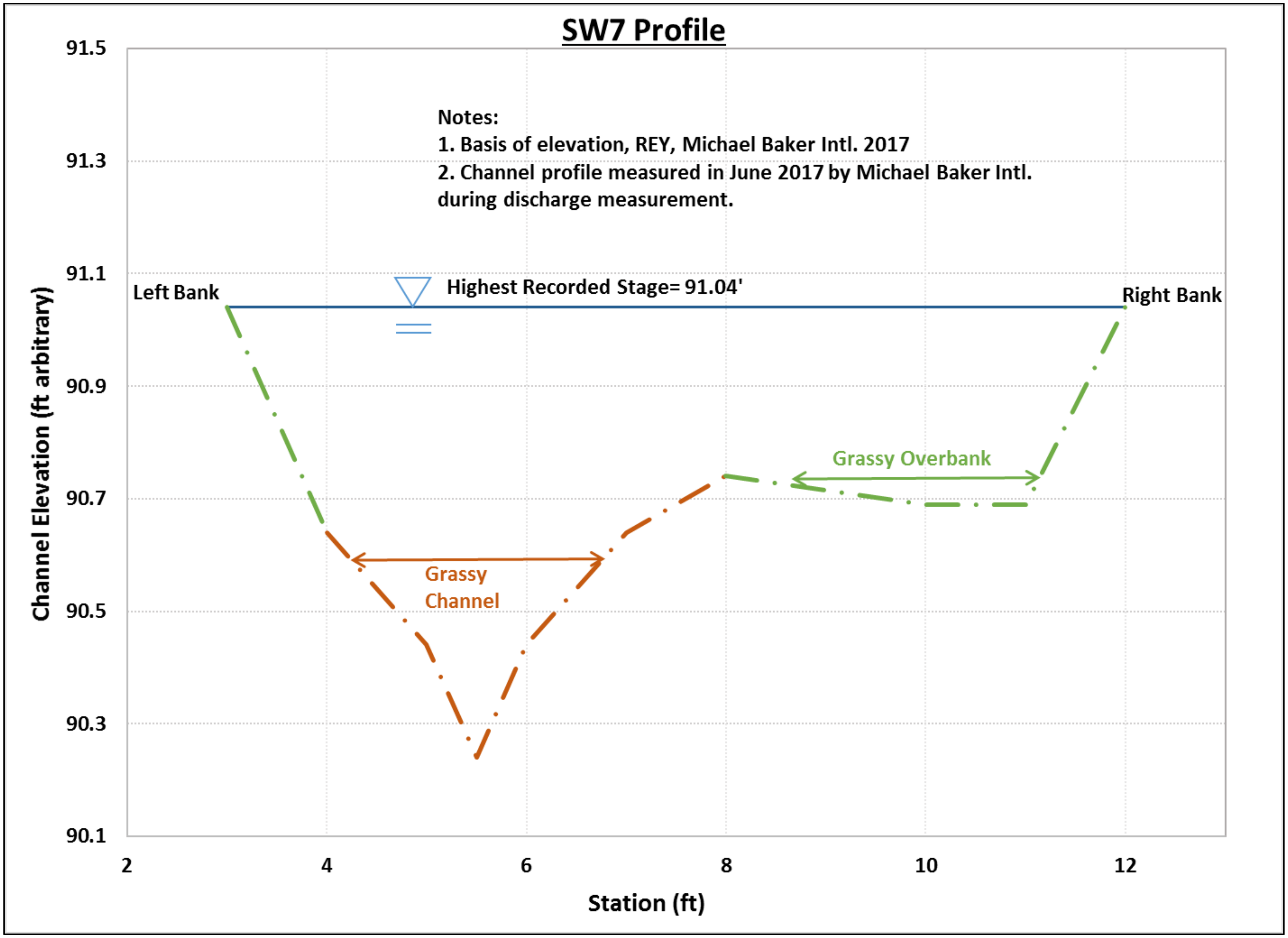
2017 Spring Breakup SN171 at SW7 Plan

(SHEET 1 of 1)

3) SPRING BREAKUP CROSS-SECTION PROFILE



B.2.7 SWALE 8

1) SPRING BREAKUP MEASURED DISCHARGE

Table B.10: SW8 Spring Breakup Measured Discharge Summary

Date:	6/4/2017	**Time:**	2:11 PM	**Method:**	USGS Midsection
Location:	SW8	**Crew:**	JPM & JMG	**Depth:**	Water Surface
Lat:	N 70.14075°	**Long:**	W 152.01401°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+00.0	97.333	-	-	-	-	-	Left edge of water
0+07.0	97.333	0.00	-	-	-	-	Grassy
0+09.0	96.933	0.40	0.31	2	0.8	0.2	Grassy
0+11.0	96.883	0.45	1.01	2	0.9	0.9	Grassy
0+13.0	96.783	0.55	1.29	2	1.1	1.4	Grassy
0+15.0	96.583	0.75	1.53	2	1.5	2.3	Grassy
0+17.0	96.633	0.70	0.82	2	1.4	1.1	Top, grassy
0+19.0	96.983	0.35	0.34	2	0.7	0.2	Toe, grassy
0+21.0	97.333	0.00	-				Grassy

Notes:

1. Measurement performed near SW8.

2. Velocity measured at surface. Streambed firm, long sedge growth, bent over, for entire section. Section uniform.

Total Width (ft)	Average Channel Elevation (ft arbitrary)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
21.0	96.80	0.5	0.9	-	6.4	6.3

ConocoPhillips
Alaska

0 100 200 Feet

Date:	11/15/2017	Project:	159730
Drawn:	JEG	File:	PlanView_SW8_8X11L.mxd
Checked:	JMG	Scale:	1 in = 100 feet

● Spring Stationing

▬ Spring Cross Section

⊕ Gage Location

Imagery Source: Digital Globe, 2015

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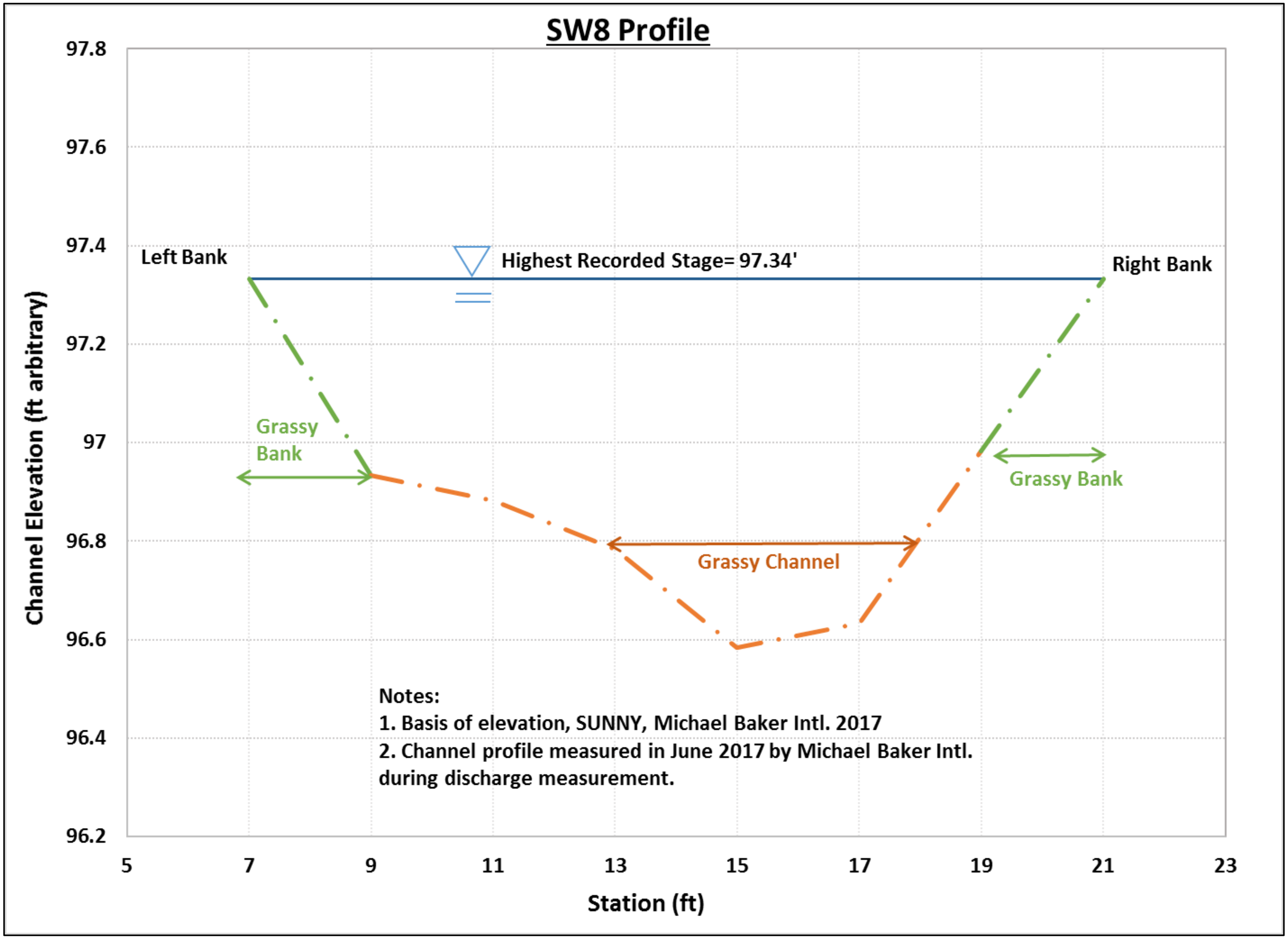
2017 Spring Breakup SW8 Plan

(SHEET 1 of 1)

3) SPRING BREAKUP CROSS-SECTION PROFILE



Notes:
1. Basis of elevation, SUNNY, Michael Baker Intl. 2017
2. Channel profile measured in June 2017 by Michael Baker Intl. during discharge measurement.

B.2.8 SWALE 10

1) SPRING BREAKUP MEASURED DISCHARGE

Table B.11: SW10 Spring Breakup Measured Discharge Summary

Date:	6/3/2017	**Time:**	2:11 PM	**Method:**	USGS Midsection
Location:	SW10	**Crew:**	DTR, WAB, & GCY	**Depth:**	Water Surface
Lat:	N 70.20007°	**Long:**	W 152.24010°	**Equipment:**	Hach Flow Meter

Station (ft)	Channel Elevation (ft arbitrary)	Measured Depth (ft)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+00.0	97.33	0	-	-	-	-	Left edge of water
0+02.5	97.18	0.15	0.29	2.25	0.3375	0.1	Grassy
0+04.5	96.83	0.50	0.31	1.25	0.625	0.2	Grassy
0+05.0	96.73	0.60	1	1.25	0.75	0.8	Grassy
0+07.0	96.83	0.50	0.04	3	1.5	0.1	Grassy
0+11.0	97.13	0.20	0.02	4.5	0.9	0.0	Grassy
0+16.0	97.18	0.15	0	3	0.45	0.0	Top, grassy
0+17.0	97.23	0.10	0.64	1	0.1	0.1	Toe, grassy
0+18.0	96.78	0.55	0.84	1	0.55	0.5	Grassy
0+19.0	96.88	0.45	0.3	1.5	0.675	0.2	Toe, grassy
0+21.0	97.23	0.10	0	3	0.3	0.0	Top, grassy
0+25.0	96.88	0.45	0.07	3	1.35	0.1	Top, grassy
0+27.0	96.93	0.40	0.41	1.5	0.6	0.2	Grassy
0+28.0	96.93	0.40	0.42	1	0.4	0.2	Grassy
0+29.0	96.93	0.40	0.76	1	0.4	0.3	Grassy
0+30.0	97.03	0.30	0.29	1	0.3	0.1	Grassy
0+31.0	97.33	0.00					Right edge of water

Notes:

1. Measurement performed near SW10.
2. Velocity measured at surface. 3 small drainages in grass.

Total Width (ft)	Average Channel Elevation (ft arbitrary)	Average Depth (ft)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
31.0	97.0	0.4	0.36	-	9.2	2.7

ConocoPhillips
Alaska

Feet
0 100 200

Date: 11/15/2017
Project: 159730
Drawn: JEG
File: PlanView_SW10_8X11L.mxd
Checked: JMG
Scale: 1 in = 100 feet

● Spring Stationing
— Spring Cross Section
⊕ Gage Location

Imagery Source: Digital Globe, 2015

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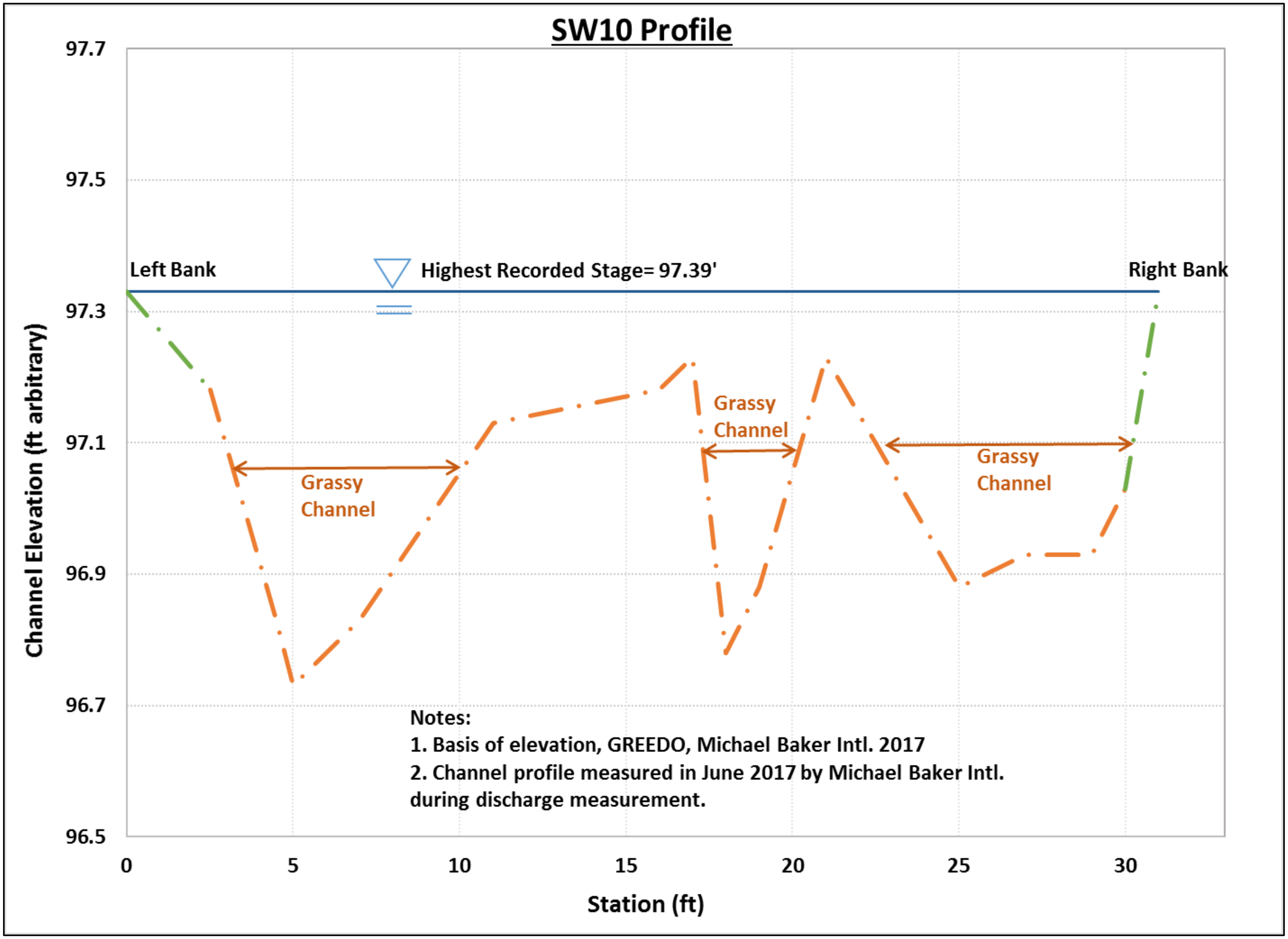
2017 Spring Breakup SW10 Plan

(SHEET 1 of 1)

3) SPRING BREAKUP CROSS-SECTION PROFILE



Notes:
1. Basis of elevation, GREEDO, Michael Baker Intl. 2017
2. Channel profile measured in June 2017 by Michael Baker Intl. during discharge measurement.

Appendix C FLOOD FREQUENCY ANALYSIS

The tables below 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 J 13.8, UC1A, and UC2A using the USGS computer program that automates site-specific estimates of accuracy (USGS 2003).

Table C.1: Judy Creek at J 13.8 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	7,380	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 C.2: Willow 2 at UC1A 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	351	61.7	-38.2	157	783	1.4
20	5	557	58.7	-37.0	258	1,210	1.6
10	10	695	58.4	-36.9	322	1,500	2.0
4	25	867	59.0	-37.1	400	1,880	2.6
2	50	993	60.0	-37.5	453	2,180	3.0
1	100	1,116	61.4	-38.1	502	2,480	3.3
0.5	200	1,237	63.1	-38.7	546	2,800	3.6

Table C.3: Judy Creek Kayyaaq at UC2A 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	1,582	61.3	-38.0	712	3,510	1.2
20	5	2,418	58.3	-36.8	1,120	5,210	1.3
10	10	2,964	57.9	-36.7	1,380	6,360	1.6
4	25	3,634	58.5	-36.9	1,680	7,840	2.1
2	50	4,118	59.5	-37.3	1,890	8,980	2.5
1	100	4,587	60.8	-37.8	2,080	10,100	2.8
0.5	200	5,045	62.5	-38.4	2,240	11,300	3.0

2017 Willow Spring Breakup & Summer Monitoring & Hydrological Assessment