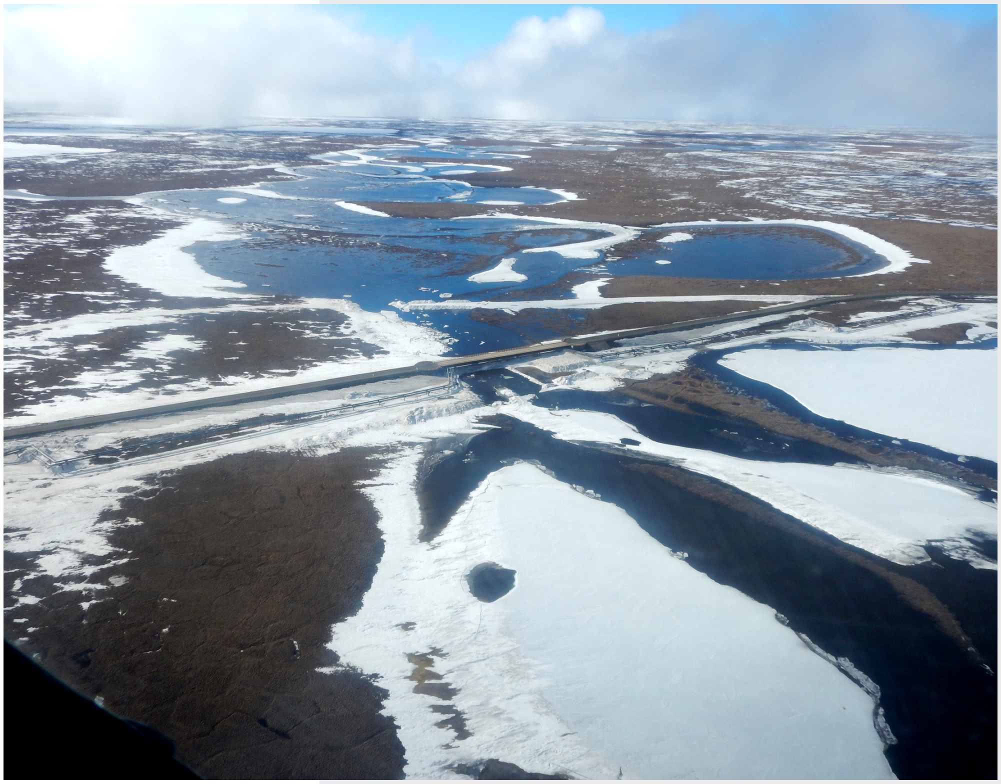
NOVEMBER 2018

2018

GMT1 SPRING BREAKUP & SUMMER MONITORING & HYDROLOGICAL ASSESSMENT



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EXECUTIVE SUMMARY

This report presents the results from the 2018 Greater Moose's Tooth 1 (GMT1) Spring Breakup and Summer Monitoring and Hydrological Assessment conducted by Michael Baker International for ConocoPhillips Alaska, Inc. This monitoring and report is required per the U.S. Army Corps of Engineers (USACE) permit POA-2013-461, stipulation #6.g. Previously, USACE received a culvert monitoring report, as required per the same permit, stipulation #6.c. That report was transmitted to USACE on July 27, 2018. Those results are also included in this report.

Spring breakup typically occurs within a three-week period in May and June. The spring breakup event historically produces flooding, and a 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.

Spring breakup and summer conditions were documented on both sides of the GMT1 access road and pad with visual observations and photography from a helicopter and from the roadway. Spring breakup stage, velocity, and discharge were measured, and peak velocity and discharge were calculated at Crea Bridge, Barely Creek culvert battery, and culverts where flow was present. Drifted snow in the Tinmiaqsiugvik Bridge opening persisted through spring breakup and prevented discharge measurements and the calculation of peak discharge. Continuous summer stage was measured and continuous velocity and discharge were calculated at the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery. Peak spring breakup conditions along the GMT1 access road and pad occurred between May 18 and June 14. During peak conditions, floodwater was generally confined within channels and swales. Stage was receding at all gage stations by June 15. Post-breakup visual inspections showed adequate conveyance of surface water flow and maintenance of natural drainage patterns. Stage and discharge generally declined over the summer months, with occasional increases resulting from precipitation events. Summer peak and minimum conditions at the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery occurred between mid-July through the end of summer monitoring in mid-September.

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ACRONYMS & ABBREVIATIONS

baro	barometric
BPMSL	British Petroleum Mean Sea Level
CD	Colville Delta
CFDD	Cumulative Freezing Degree Days
cfs	cubic feet per second
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
FCB	Fish Creek Basin
fps	feet per second
ft	feet
GMT1	Greater Moose's Tooth 1
GPS	global positioning system
HWM	High water mark
Michael Baker	Michael Baker International
NAD83	North American Datum of 1983
NPR-A	National Petroleum Reserve-Alaska
PT	pressure transducer
RM	river mile
RTFM	Real-Time Flood Monitoring
UMIAQ	UMIAQ, LLC
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VSM	Vertical support member
WSE	Water surface elevation

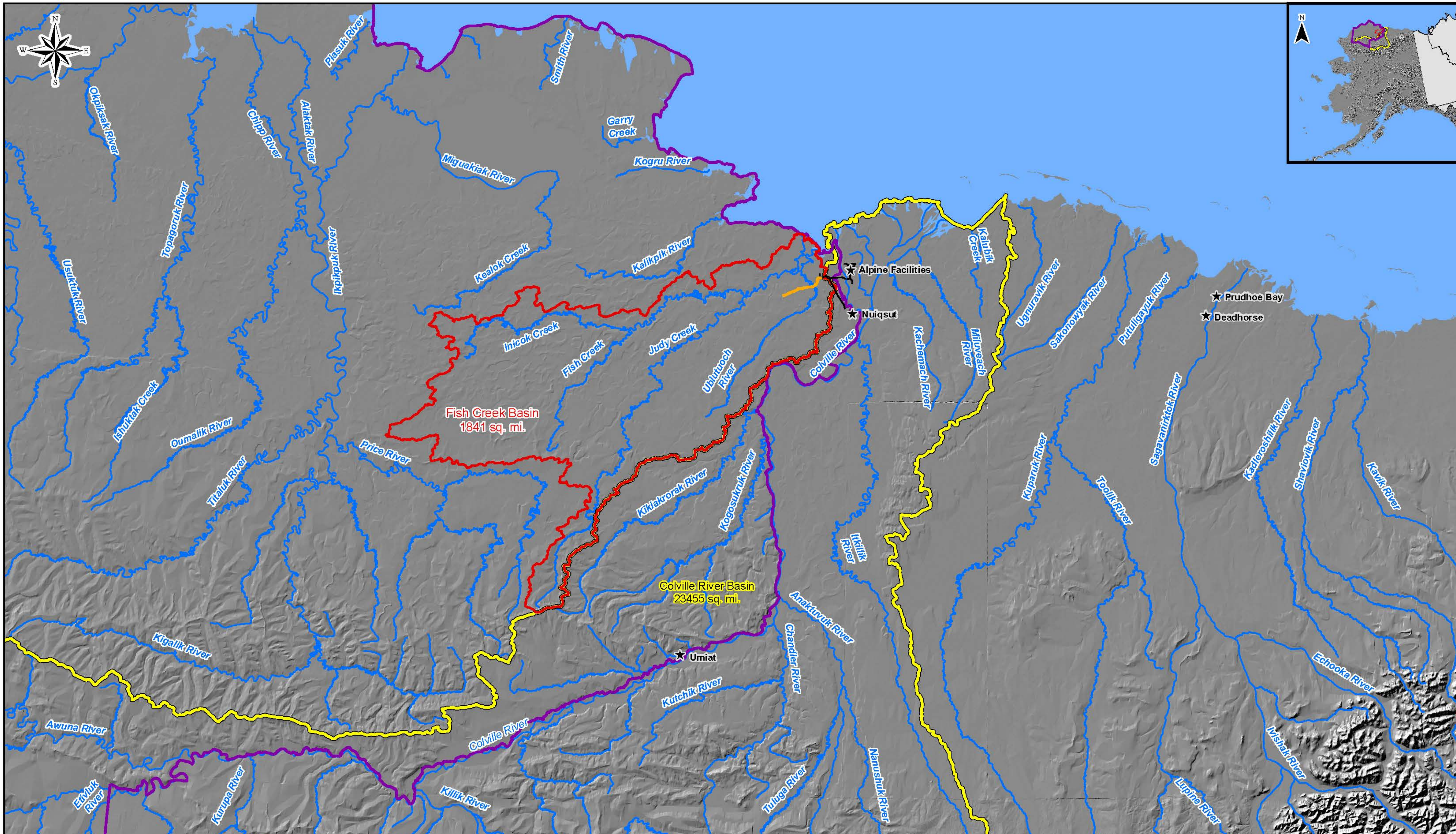
1 INTRODUCTION

The 2018 Greater Moose's Tooth 1 (GMT1) Spring Breakup and Summer Monitoring and Hydrological Assessment supports the ConocoPhillips Alaska, Inc. (CPAI) Alpine Satellite Development Plan. Alpine facilities are owned and operated by CPAI and include the Colville Delta (CD) 1 processing facility (Alpine) and the CD2, CD3, CD4, CD5, and GMT1 pads, access roads, and pipelines. The GMT1 pad, access road, and a portion of the pipeline were constructed during the 2016/2017 winter season.

Spring breakup is generally considered the largest annual flooding event in this region of the North Slope. Spring breakup 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 within a three-week period in May and June. Many areas on the North Slope of Alaska, including the Colville River Delta (CRD) 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, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and existing facilities. Discharge generally declines over the summer months, with occasional increases resulting from precipitation events. Discharge is typically present year-round in the major streams in the FCB. For much of the year, little to no flow is present in many small streams and tributaries in the FCB, and most freeze to the bottom in winter.

Preliminary hydrologic and hydraulic assessments of the Tinmiaqsiugvik (formerly the Ublutuoch) River were completed by URS in 2001 and 2002 (URS 2001, 2002, and 2003). Spring breakup monitoring and hydrologic assessments throughout the proposed GMT1 project area were completed by Michael Baker International (Michael Baker) annually from 2003 to 2006 and from 2009 to 2014, with the exception of 2012 (Michael Baker 2003, 2005, 2007, 2009, 2010, 2011, 2013, 2014). This marks the second year of post-construction spring breakup and summer monitoring and hydrological assessment along the GMT1 access road and pad, constructed in 2017.

The 2018 field program took place from April 26 to September 12. Spring breakup setup began on April 26 and concluded on May 14 and monitoring began on May 15 and concluded on June 19. Summer monitoring was split into two field programs; the first program began on July 7 and concluded on July 10 and the second program began on September 7 and concluded on September 12. Primary field tasks included measuring stage and discharge at select locations. Observations of ice jams, ice road crossings degradation, drainage structure performance, and post-breakup floodwater effects on infrastructure were also recorded. Hydrologic observations were documented on both sides of the GMT1 access road and pad and at all drainage structures. 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

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0 7.5 15 30 miles

★ Place Name
Road
GMT1 Access Road
Stream
National Petroleum Reserve Alaksa Boundary
Fish Creek Basin
Colville River Basin

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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 GMT1 spring breakup and summer monitoring and hydrological assessment was to monitor and estimate the magnitude of breakup flooding in relation to GMT1 drainage structures. Stage or water surface elevations ([WSE] used interchangeably in this report), velocity, discharge, and observations were used to validate design parameters of existing infrastructure and to satisfy the following permit requirements.

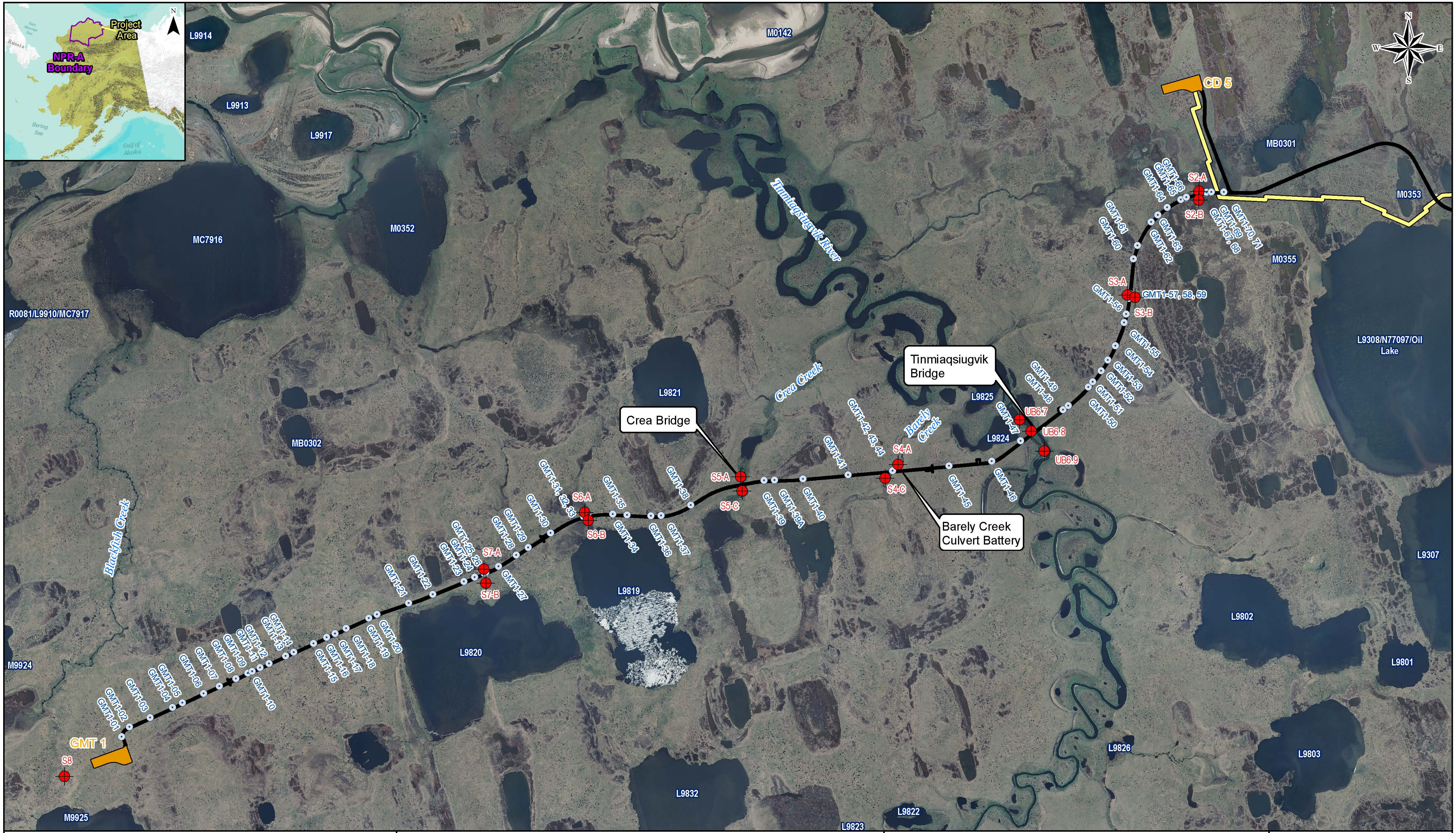
Permit stipulations by USACE permit POA-2013-461, stipulation #6.c states "*The permittee shall prepare and submit a culvert monitoring report to the USAGE, for the 3 summer seasons following fill placement authorized in this DA permit. The reports shall be submitted prior to July 30 of each year. The report shall include photographs of all road and pad areas to demonstrate the hydrologic conditions at spring break-up time and post break-up (summer conditions). The report shall include an evaluation of all areas where additional culverts are necessary to retain existing drainage patterns and where culvert maintenance, repair, upgrade, setting adjustments, or replacement are necessary. The culvert/drainage corrective work shall be completed by freeze-up within the same summer season the drainage problems are identified. Evidence of ponding, drying, erosion, or stream channel changes adjacent to authorized fill areas are indicators of necessary corrective action. Culverts shall be marked to facilitate snow removal operations to prevent excessive deposition of snow into creeks and drainage areas. Culverts shall be maintained to adequately convey surface waters throughout the life of the project (access road use).*"

Permit stipulations by USACE permit POA-2013-461, stipulation #6.g states "*Flow discharge measurements shall be collected throughout the first 3 thaw seasons following construction of the access road at the crossings of the Ublutuoch River, Barely Creek, and Crea Creek. Continuous stage and discharge monitoring shall be collected until seasonal flows cease. Flow discharge measurements shall be collected using the US Geological Survey methods appropriate for use on the North Slope. A report shall be provided to the USAGE and BLM by December 1 of the year following completion of the access road showing the highest and lowest data for water flows, stages, and velocities. Photographs showing all bridge abutments at the ground surface, creek culvert inlets and outlets, and channel and bank conditions for each crossing on each side of the access road shall be included.*"

A GMT1 Spring Breakup Culvert Monitoring Report was transmitted to USACE on July 27, 2018 which detailed spring breakup monitoring results at all GMT1 access road culverts (Michael Baker 2018). Those results are also included in this report.

1.2 GAGE STATIONS

Figure 1.2 shows the GMT1 access road and pad gage stations. Table 1.1 details the gage stations and monitoring tasks per location.



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Culvert
Gage Location
Existing
Road Pipeline
Existing Facility

Imagery Source : Conoco Phillips Alaska 2015

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2018 GMT1 Gage Stations

FIGURE: 1.2

(SHEET 1 of 1)

Table 1.1: GMT1 Access Road & Pad Gage Stations and Monitoring Tasks

<table>
<tr><th rowspan="2">Monitoring Location Description</th><th rowspan="2">Gage Station</th><th rowspan="2">Gage Station Description</th><th colspan="7">Monitoring Tasks Per Location</th></tr>
<tr><th>Observations</th><th>Spring Breakup PT</th><th>Summer PT</th><th>Spring Breakup Measured Discharge</th><th>Summer Measured Discharge</th><th>Spring Breakup Real-Time Monitoring</th><th>Summer Real-Time Monitoring</th></tr>
<tr><td rowspan="2">Tinmiaqsiugvik Bridge</td><td>UB6.9</td><td>West side of Tinmiaqsiugvik River at river mile(RM) 6.9, 650 feet south (upstream) of bridge centerline</td><td rowspan="2">X</td><td>X</td><td>X</td><td rowspan="2">--[1]</td><td rowspan="2">--</td><td rowspan="2">X</td><td rowspan="2">X</td></tr>
<tr><td>UB6.7</td><td>West side of Tinmiaqsiugvik River at RM 6.7, 600 feet north (downstream) of bridge centerline</td><td>X</td><td>X</td></tr>
<tr><td rowspan="2">Crea Bridge</td><td>S5-A</td><td>West side of Crea Creek, 260 feet north (downstream) of bridge centerline</td><td rowspan="2">X</td><td>X</td><td>X</td><td rowspan="2">X</td><td rowspan="2">--</td><td rowspan="2">X</td><td rowspan="2">--</td></tr>
<tr><td>S5-C</td><td>West side of Crea Creek, 300 feet south (upstream) of bridge centerline</td><td>X</td><td>X</td></tr>
<tr><td rowspan="2">Barely Creek Culvert Battery</td><td>S4-C</td><td>West side of Barely Creek, north (upstream) side of road and culvert battery</td><td rowspan="2">X</td><td>X</td><td>X</td><td rowspan="2">X</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td></tr>
<tr><td>S4-A</td><td>West side of Barely Creek, south (downstream) side of road and culvert battery, on vertical support member (VSM) 626</td><td>X</td><td>X</td></tr>
<tr><td rowspan="8">Culverts</td><td>S2-A</td><td>North (downstream) side of road, in small swale</td><td rowspan="2">X</td><td>X</td><td>--</td><td rowspan="2">X</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td></tr>
<tr><td>S2-B</td><td>South (upstream) side of road, in small swale</td><td>X</td><td>--</td></tr>
<tr><td>S3-A</td><td>West (downstream) side of road, in small swale</td><td rowspan="2">X</td><td>X</td><td>--</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td></tr>
<tr><td>S3-B</td><td>East (upstream) side of road, in small swale</td><td>X</td><td>--</td></tr>
<tr><td>S6-A</td><td>North (downstream) side of road, between Lake L9819 and Lake L9821</td><td rowspan="2">X</td><td>X</td><td>--</td><td rowspan="2">X</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td></tr>
<tr><td>S6-B</td><td>South (upstream) side of road, between Lake L9819 and Lake L9821</td><td>X</td><td>--</td></tr>
<tr><td>S7-A</td><td>North (downstream) side of road, downstream of Lake L9820</td><td rowspan="2">X</td><td>X</td><td>--</td><td rowspan="2">X</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td></tr>
<tr><td>S7-B</td><td>South (upstream) side of road, downstream of Lake L9820</td><td>X</td><td>--</td></tr>
<tr><td>GMT1 Pad</td><td>S8</td><td>West side of GMT1 pad, downstream of Lake M9925, upstream of Blackfish Creek</td><td>X</td><td>X</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td colspan="10">**Notes:**
1. No discharge measured because the majority of flow was under drifted snow in the channel prohibiting direct measurements and indirect calculations.</td></tr>
</table>

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 during spring breakup 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, interactions between floodwaters and infrastructure, and summer conditions were recorded in field notebooks. Photographic documentation of spring breakup and summer conditions was collected using digital cameras with integrated global positioning systems (GPS). Each photo was geotagged with the latitude and longitude, date, and time. The photo location is referenced to the North American Datum of 1983 horizontal datum (NAD83).

Soloy Helicopters, LLC and Alpine Environmental Coordinators provided helicopter support and a pickup truck, respectively, 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 water levels.

HYDROLOGIC STAFF GAGES

Gage stations were established at the GMT1 pad and along the access road adjacent to infrastructure and consist of one or more gage assemblies positioned perpendicular to the waterbody or road. The number of gage assemblies per gage station installed at the Tinmiaqsiugvik Bridge and Crea Bridge was dependent upon site specific conditions: primarily slope of the channel, bank, and overbank. In locations where terrain elevation varied by more than three feet, multiple gages were installed linearly from the edge of the channel up to the overbank. Individual gage assemblies were identified with alphabetical designations beginning with 'A' representing the location nearest to the stream. 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. Paired gages installed at locations along the access road captured water levels on the upstream and downstream side of drainage structures to determine stage differential and were identified with alphabetical designations with 'A' representing the location on the north side of the GMT1 access road. The location of each gage assembly was recorded with a handheld GPS referenced NAD83.

Each gage assembly includes a standard U.S. Geological Survey (USGS) metal faceplate mounted on a wooden two-by-four. The two-by-four is attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground. The faceplate is graduated and indicates water levels every 100th of a foot between 0.00 to 3.33 feet (Photo 2.1). High water marks (HWMs) were measured by applying chalk on the angle iron gage supports or VSMs and measuring the wash line (Photo 2.2).

Gage assemblies were surveyed to their associated vertical control using standard differential leveling techniques relative to a known benchmark elevation to determine a correction in feet (ft) British Petroleum Mean Sea Level (BPMSL). Gage locations and associated vertical control are detailed in Appendix A.

Photo 2.1: Gage S5-C; July 11, 2018

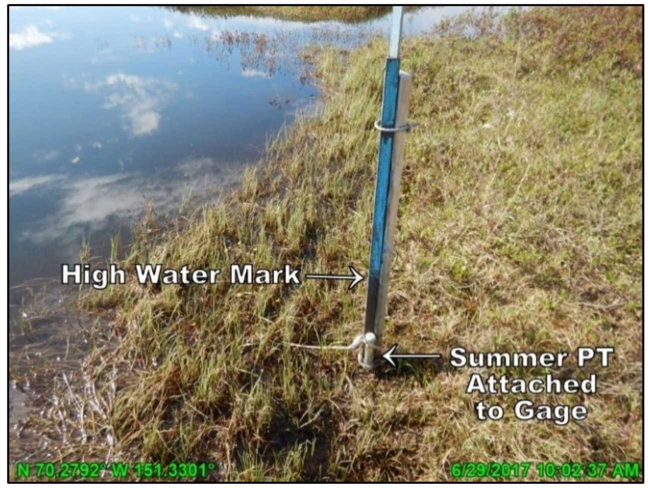


Photo 2.2: Chalked gage S5-C with HWM and PT; June 29, 2017

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 and calculated. 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 the Tinmiaqsiugvik Bridge. During data processing, the PT measurements were adjusted to WSEs recorded at the gages. PT setup and testing methods are detailed in Appendix B.

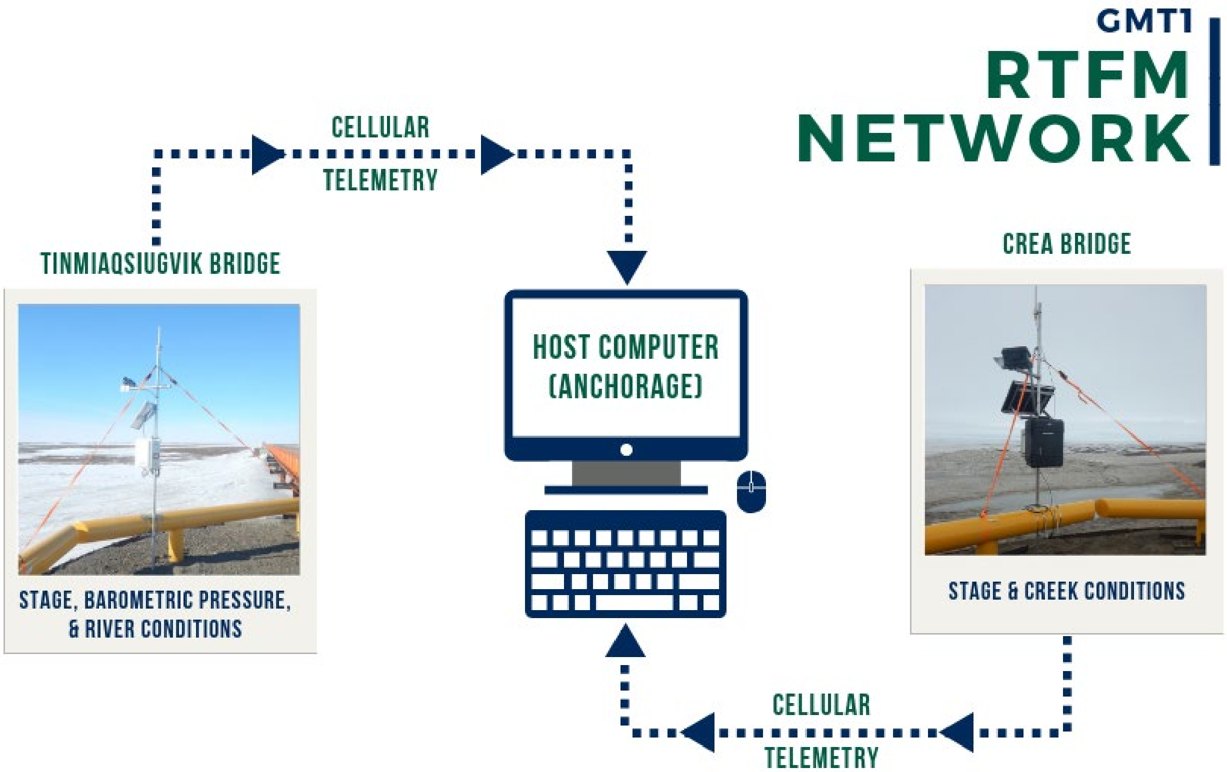
REAL-TIME FLOOD MONITORING NETWORK

Table 2.1 presents the Real-Time Flood Monitoring (RTFM) Network locations. The RTFM Network has the following components: remote cameras to monitor stage and river conditions, sensors 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). The ability to remotely monitor stage 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 mechanical conditions. In addition, a network of RTFM stations helps hydrologists deploy resources during peak conditions when critical measurements are required.

Table 2.1: RTFM Network Stations

Monitoring Location Description	Real-Time Data
Tinmiaqsiugvik Bridge	• Stage • Barometric pressure • River conditions via remote camera images
Crea Bridge	• Stage • Creek conditions via remote camera images

Figure 2.1: RTFM Network Schematic



A. Remote Cameras

High resolution digital cameras were programmed to take pictures at 15-minute intervals. Cameras collected photographs to document conditions and to help hydrologists determine when site visits were necessary. Cameras were installed at the Crea Bridge and the Tinmiaqsiugvik Bridge in 2018.

B. Sensors

PTs were programmed to read and record water levels and barometric pressure at 15-minute intervals. Data cables linking the PTs and dataloggers were housed in metal conduit.

C. Dataloggers & Telemetry

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. Data was transmitted using an onsite cellular modem and TCP/IP communication where each cellular modem has a unique static IP address. To conserve power, cellular modems were programmed to power-on every 60 minutes for data transmission. Systems were powered with 12v DC batteries and charged with onsite solar panels.

D. Host Computer & Data Access

A host computer monitored the internet for the cellular modem IP addresses and communicated with the dataloggers once the connection was established. The host computer received the data as an ASCII file and Campbell Scientific Loggernet software was used for data processing. 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.

2.3 VELOCITY & DISCHARGE

MEASURED VELOCITY & DISCHARGE

Discharge (in cubic feet per second [cfs]) was measured as close to observed spring breakup peak stage as possible at the following drainage structures:

- Crea Bridge
- Barely Creek culvert battery
- Culverts observed conveying flow

Crea Bridge discharge was measured using the USGS midsection technique (USGS 1982). Discharge at the Barely Creek culverts and other culverts observed conveying flow were measured using the USGS velocity/area technique (USGS 1968). Discharge was not measured at the Tinmiaqsiugvik Bridge in 2018 due to the influence of abundant ice and snow that remained at the site throughout breakup. Discharge was measured in the Tinmiaqsiugvik 18.2 RMs upstream of the bridge crossing (see Section 4.1 for more information). Flow depths and velocities at Crea Bridge and culverts were measured using a flow meter attached to a wading rod. Discharge was calculated based on velocity, flow depth, and channel cross-section geometry or culvert geometry. Measured velocity and discharge methods are further detailed in Appendix C.

CALCULATED VELOCITY & DISCHARGE

Velocity and discharge were calculated indirectly and, when possible, calibrated with the respective direct measurement and observed WSEs. Under open channel conditions, peak velocity and discharge typically occur at the same time as peak stage; however, peak velocity and 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.

Culvert peak velocity and discharge were calculated using the WSE differential between the headwater and tailwater elevation, approximated by WSEs at corresponding gages, and survey data provided by UMIAQ (UMIAQ 2017a).

Continuous velocity and discharge were calculated at the following locations:

- Tinmiaqsiugvik Bridge
- Crea Bridge
- Barely Creek culvert battery

Velocity and discharge results are estimates based on conditions at the time of data collection. In the spring, these conditions often include ice and snow effects, 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 velocity and discharge indirectly. In consideration of these conditions, calculations of peak velocity and discharge are presented with quality ratings, as described in Table 2.2. Detailed calculated velocity and discharge methods are presented in Appendix C.

Table 2.2: Peak Velocity and 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
Fair	Some ice floes and/or snow in the channel/drainage structure, some backwater effects, fairly uniform conditions through reach
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

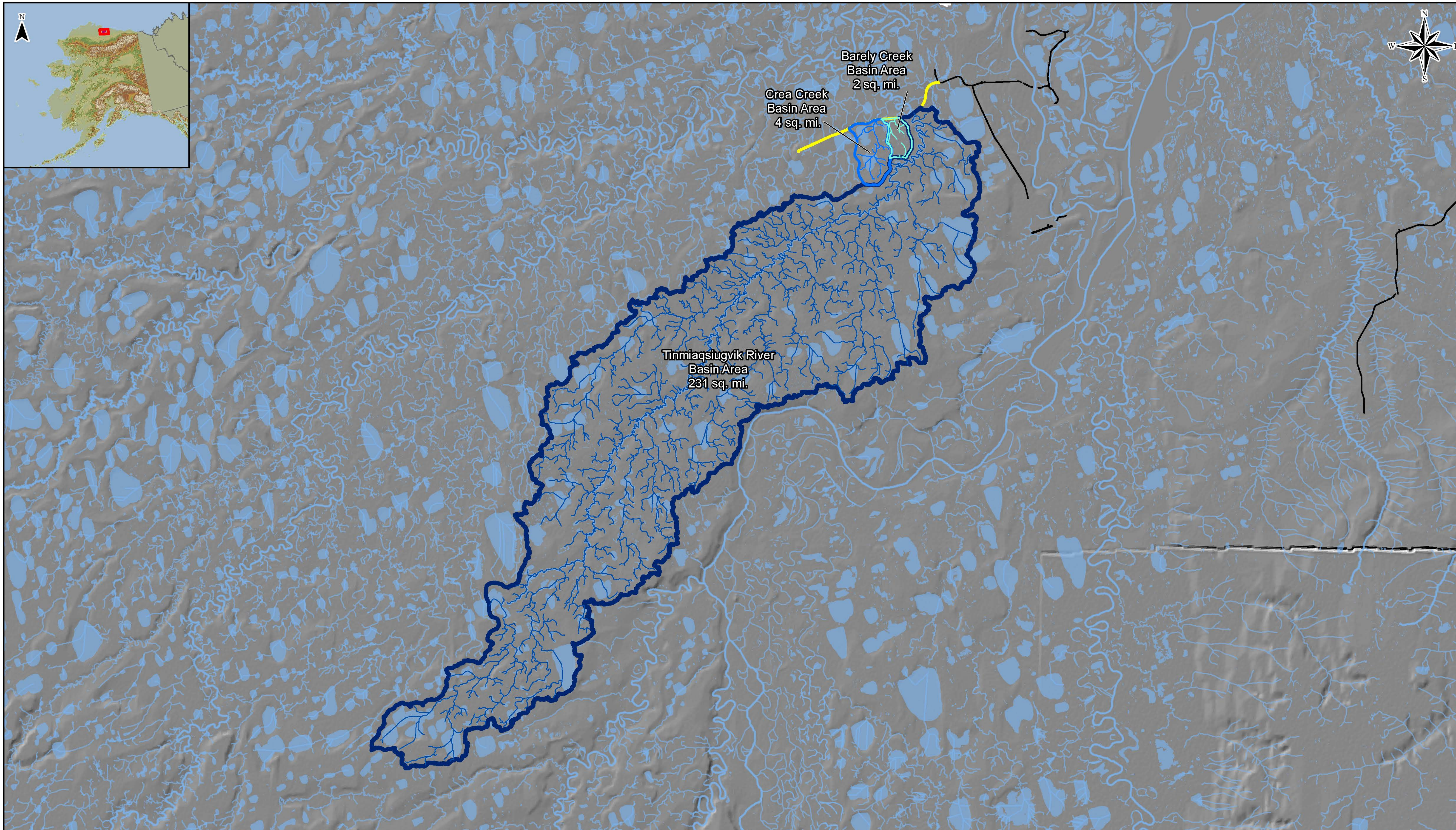
2.4 FLOOD FREQUENCY ANALYSIS

Estimates of the magnitude and frequency of peak discharge at the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery 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 Tinmiaqsiugvik Bridge were determined for the 2-, 10-, 25-, 50-, 100-, and 200-year recurrence intervals using the regional regression equations developed and revised by URS in 2002 (URS 2003). A recurrence interval was assigned to the peak discharge value at each location based on the results of the regression analysis. Region 7 USGS regression results tend to over-predict recurrence intervals, particularly for the lower recurrence intervals when ice and snow have more effect on stage and discharge.

Basins areas for each of the three sites were previously delineated (Michael Baker 2014) and were updated in 2017 to reflect the most current USGS National Hydrography Dataset and available Digital Elevation Model data. The basin areas for Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery are presented in Table 2.3 and Figure 2.2.

Table 2.3: Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek Culvert Battery Basin Areas

Basin	Original Basin Area (square miles)	Basin Area (square miles)
Tinmiaqsiugvik Bridge (upstream side of bridge)	228.3	231
Crea Bridge (upstream side of bridge)	4.16	4.0
Barely Creek (upstream side of GMT1 access road)	1.91	1.6



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0 2 4 8 miles

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Road
GMT1 Access Road
Stream / River
Waterbody
Barely Creek Flowline
Crea Creek Flowline
Tinmiaqsiugvik River Flowline
Barely Creek Basin
Crea Creek Basin
Tinmiaqsiugvik River Basin

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Tinmiaqsiugvik Bridge
Crea Bridge & Barely Creek Culvert
Battery Basins

Coordinate System: NAD 1983 Alaska State Pane Zone 4, US Foot

FIGURE: 2.2 | (SHEET 1 of 1)

2.5 DRAINAGE STRUCTURE PERFORMANCE EVALUATION

Culvert performance was evaluated based on observations, stage, and discharge measurements with a focus on maintenance, repair, upgrade, adjustments, or replacement. Bridge performance was evaluated based on observations, stage, and discharge measurements with a focus on maintenance of natural drainage patterns.

2.6 POST-BREAKUP CONDITIONS ASSESSMENT

Post-breakup conditions assessment included visual observations and photo documentation of Tinmiaqsiugvik Bridge and Crea Bridge abutments and bank conditions on each side of the GMT1 access road, and culvert inlets and outlets. In addition, the condition of the gravel fill around the bridges and culverts were evaluated to identify areas of erosion.

2.7 ICE ROAD CROSSINGS BREAKUP

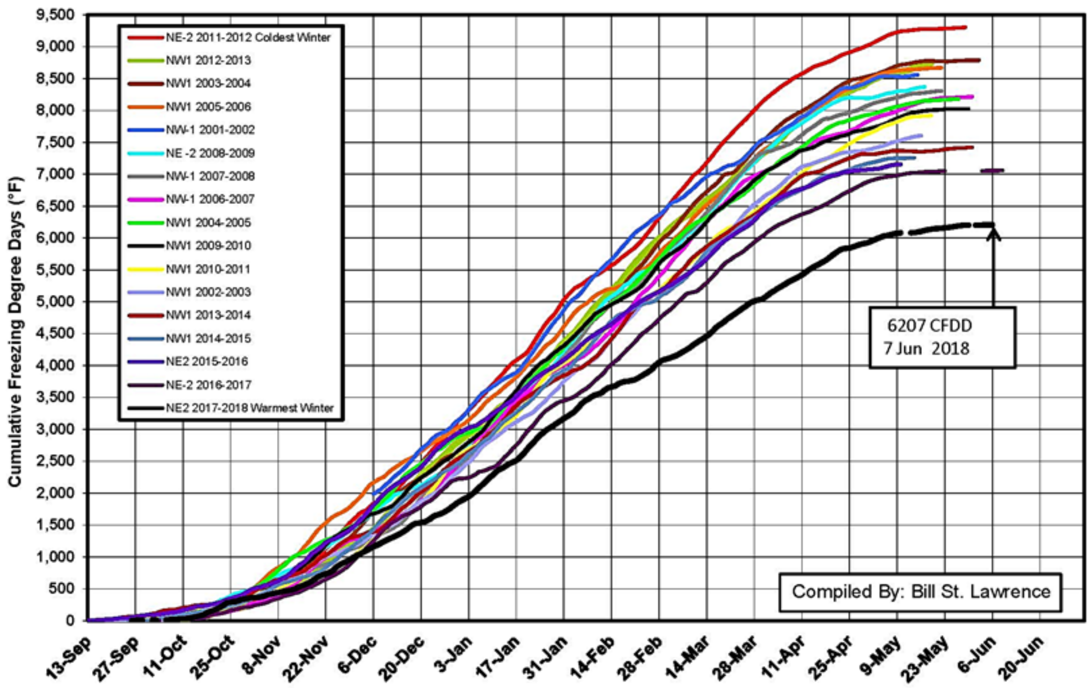
Aerial observations of the hydraulic effects of winter ice road crossings (Figure 1.2) before breakup, during breakup, and post-breakup included:

- Crea Creek, south side of Crea Bridge
- Tinmiaqsiugvik River, north and south side of Tinmiaqsiugvik Bridge
- Tinmiaqsiugvik River B70
- Tinmiaqsiugvik River Tributary

3 OBSERVATIONS

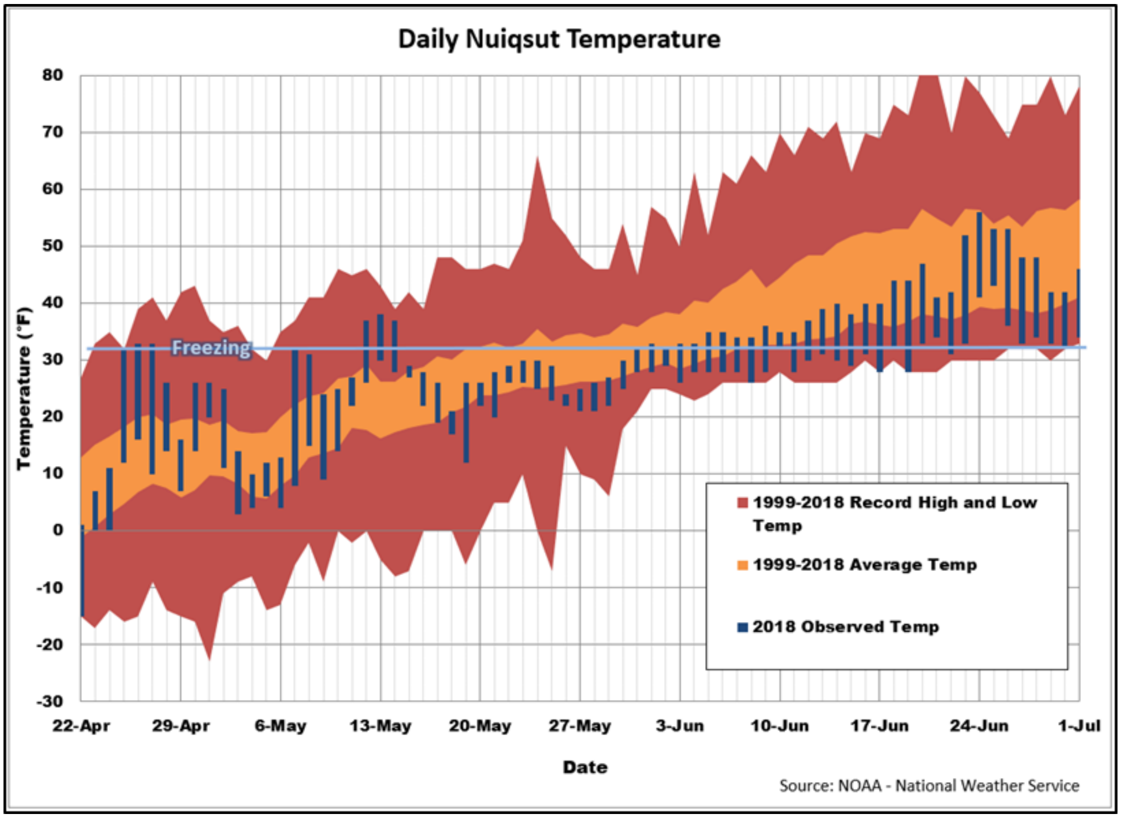
3.1 GENERAL CLIMATIC SUMMARY

According to cumulative freezing degree days (CFDD) measured at the National Petroleum Reserve–Alaska (NPR-A) tundra monitoring station, the 2017-2018 (September – May) winter was the warmest on record for the past 17 years, as shown in Graph 3.1 (ICE 2018). As of April 30, 2018, snowpack east of the Colville River was reported as 150% of the 1981-2010 median (National Resource Conservation Service [NRCS] 2018). There is no NRCS North Slope snowpack data available for 2018, though general observations indicate snowpack was at or above normal levels.



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

Temperatures for the Alpine area are available from the Nuiqsut weather station, located approximately 8 air miles southeast of the GMT1 access road. Daily low ambient air temperatures remained at or below freezing for much of 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 (National Oceanic and Atmospheric Administration [NOAA] 2018). Daily high temperatures were consistently above freezing after May 31.



Graph 3.2: Nuiqsut Daily High and Low Ambient Air Temperatures

3.2 GENERAL BREAKUP SUMMARY

Visual inspections from April 27 through May 1 confirmed that snow had been cleared at most culvert inlets and outlets, and ice roads were slotted at stream crossings. Some additional snowfall in May accumulated along the road embankment prior to spring breakup. Considerable drifted snow remained under the Tinmiaqsiugvik and Crea bridges during breakup.

When field monitoring began on May 14, local meltwater was starting to accumulate at some gage sites along the GMT1 access road but remined disconnected at most sites until early June. On June 4, minimal local melt was observed on top of channel ice in the Tinmiaqsiugvik River near the GMT1 access road, although no flow was observed in the drainage (Photo 3.1). Meltwater was accumulating in all other GMT1 drainages by this time and some drainages were hydraulically connected through drainage structures including the Crea Bridge and the Barely Creek culvert battery. Snow cover along the GMT1 access road was approximately 80%. On June 6, ponded, local melt was accumulating in the slotted sections of the construction ice roads and ice pads upstream and downstream of the Tinmiaqsiugvik Bridge, but no flow was observed (Photo 3.2).

On June 8, flow had developed at the Tinmiaqsiugvik Bridge following a sharp rise in stage. The surrounding tundra was about 60% snow covered. Drifted snow still remained along the banks and in the channels of all drainages.

By June 9, hydraulic connections had been established through all culverts in defined drainages, equalizing water levels across the road (Photo 3.3). Stage had peaked and was receding at most GMT1 monitoring locations by June 15. Remaining snow cover along the GMT1 access road was approximately 10-20% (Photo 3.4). On June 19, when field monitoring ended, minimal snow remained across the surrounding tundra, but snow was still present along the banks in some drainages.

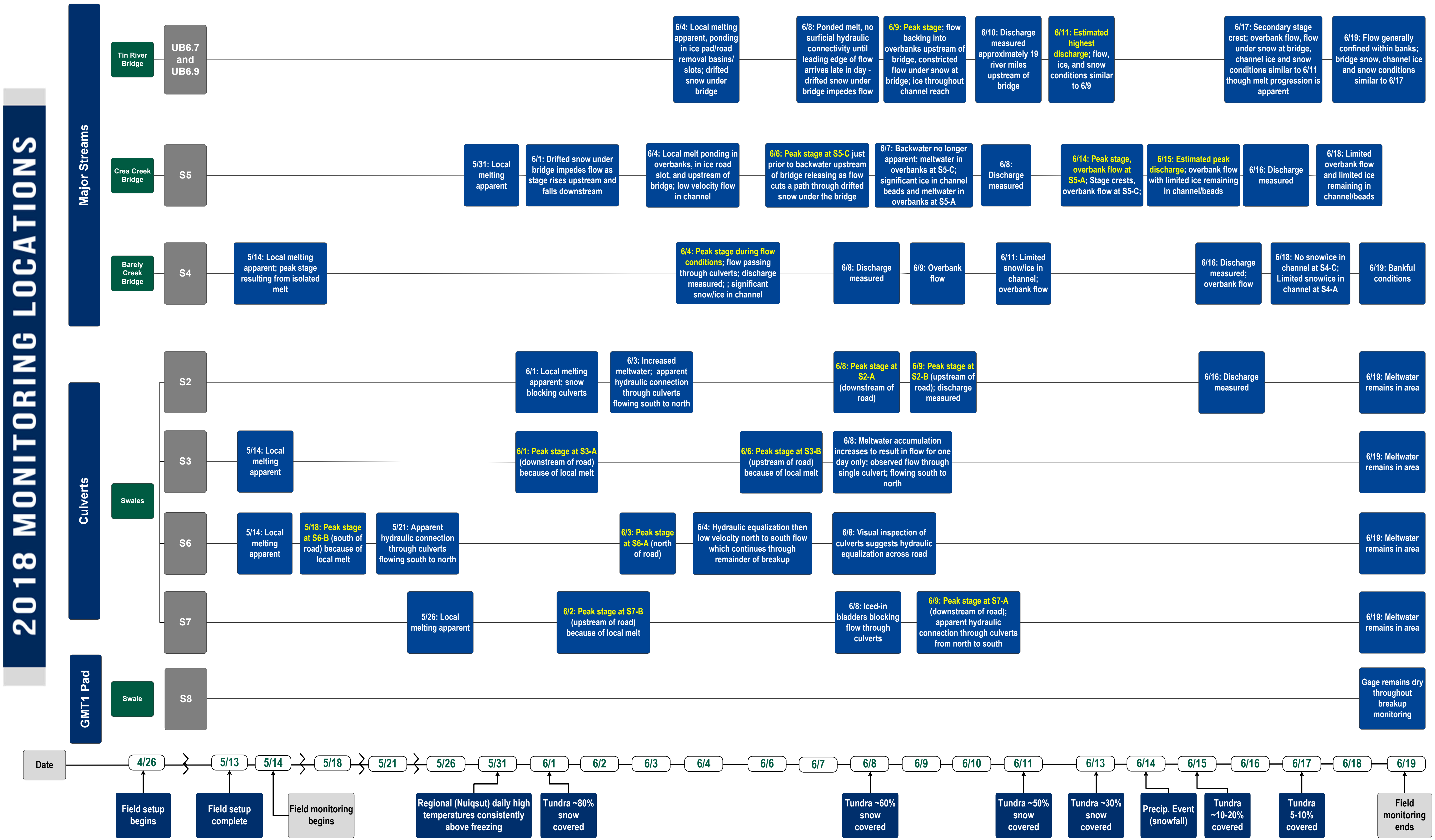
Figure 3.1: provides a visual timeline summarizing the major breakup events.

Photo 3.1: Tinmiaqsiugvik Bridge, looking north (downstream) June 4, 2018

Photo 3.2: Tinmiaqsiugvik Bridge, looking south (upstream); June 6, 2018.

Photo 3.3: Meltwater at S2, looking west; June 9, 2018

Photo 3.4: S6, looking west; June 15, 2018


2018 MONITORING LOCATIONS
Major Streams
Tin River Bridge
UB6.7 and UB6.9
6/4: Local melting apparent, ponding in ice pad/road removal basins/ slots; drifted snow under bridge
6/8: Ponded melt, no surficial hydraulic connectivity until leading edge of flow arrives late in day - drifted snow under bridge impedes flow
6/9: Peak stage; flow backing into overbanks upstream of bridge, constricted flow under snow at bridge; ice throughout channel reach
6/10: Discharge measured approximately 19 river miles upstream of bridge
6/11: Estimated highest discharge; flow, ice, and snow conditions similar to 6/9
6/17: Secondary stage crest; overbank flow, flow under snow at bridge, channel ice and snow conditions similar to 6/11 though melt progression is apparent
6/19: Flow generally confined within banks; bridge snow, channel ice and snow conditions similar to 6/17
Crea Creek Bridge
S5
5/31: Local melting apparent
6/1: Drifted snow under bridge impedes flow as stage rises upstream and falls downstream
6/4: Local melt ponding in overbanks, in ice road slot, and upstream of bridge; low velocity flow in channel
6/6: Peak stage at S5-C just prior to backwater upstream of bridge releasing as flow cuts a path through drifted snow under the bridge
6/7: Backwater no longer apparent; meltwater in overbanks at S5-C; significant ice in channel beads and meltwater in overbanks at S5-A
6/8: Discharge measured
6/14: Peak stage, overbank flow at S5-A; Stage crests, overbank flow at S5-C;
6/15: Estimated peak discharge; overbank flow with limited ice remaining in channel/beads
6/16: Discharge measured
6/18: Limited overbank flow and limited ice remaining in channel/beads
Barely Creek Bridge
S4
5/14: Local melting apparent; peak stage resulting from isolated melt
6/4: Peak stage during flow conditions; flow passing through culverts; discharge measured; ; significant snow/ice in channel
6/8: Discharge measured
6/9: Overbank flow
6/11: Limited snow/ice in channel; overbank flow
6/16: Discharge measured; overbank flow
6/18: No snow/ice in channel at S4-C; Limited snow/ice in channel at S4-A
6/19: Bankful conditions
Culverts
Swales
S2
6/1: Local melting apparent; snow blocking culverts
6/3: Increased meltwater; apparent hydraulic connection through culverts flowing south to north
6/8: Peak stage at S2-A (downstream of road)
6/9: Peak stage at S2-B (upstream of road); discharge measured
6/16: Discharge measured
6/19: Meltwater remains in area
S3
5/14: Local melting apparent
6/1: Peak stage at S3-A (downstream of road) because of local melt
6/6: Peak stage at S3-B (upstream of road) because of local melt
6/8: Meltwater accumulation increases to result in flow for one day only; observed flow through single culvert; flowing south to north
6/19: Meltwater remains in area
S6
5/14: Local melting apparent
5/18: Peak stage at S6-B (south of road) because of local melt
5/21: Apparent hydraulic connection through culverts flowing south to north
6/3: Peak stage at S6-A (north of road)
6/4: Hydraulic equalization then low velocity north to south flow which continues through remainder of breakup
6/8: Visual inspection of culverts suggests hydraulic equalization across road
6/19: Meltwater remains in area
S7
5/26: Local melting apparent
6/2: Peak stage at S7-B (upstream of road) because of local melt
6/8: Iced-in bladders blocking flow through culverts
6/9: Peak stage at S7-A (downstream of road); apparent hydraulic connection through culverts from north to south
6/19: Meltwater remains in area
GMT1 Pad
Swale
S8
Gage remains dry throughout breakup monitoring
Date
4/26
5/13
5/14
5/18
5/21
5/26
5/31
6/1
6/2
6/3
6/4
6/6
6/7
6/8
6/9
6/10
6/11
6/13
6/14
6/15
6/16
6/17
6/18
6/19
Field setup begins
Field setup complete
Field monitoring begins
Regional (Nuiqsut) daily high temperatures consistently above freezing
Tundra ~80% snow covered
Tundra ~60% snow covered
Tundra ~50% snow covered
Tundra ~30% snow covered
Precip. Event (snowfall)
Tundra ~10-20% covered
Tundra 5-10% covered
Field monitoring ends

4 STAGE, VELOCITY, & DISCHARGE

Table 4.1 presents a summary of spring breakup stage, velocity, and discharge.

Table 4.1: Spring Breakup Stage, Velocity, and Discharge Summary

Monitoring Location Description	Gage Station	Spring Peak Stage		Spring Measured Velocity & Discharge				Spring Peak Velocity			Spring Peak Discharge		
		Stage ft BPMSL	Date & Time	Average Velocity fps	Discharge cfs	Stage ft BPMSL	Date & Time	Average Velocity fps	Stage ft BPMSL	Date & Time	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	UB6.9	9.18[5]	6/9 5:30 AM	--[1]	--	--	--	2.6	8.70	6/11 7:00 PM	2,600	8.70	6/11 7:00 PM
	UB6.7	8.32	6/9 5:00 AM			--			7.46			7.46	
Barely Creek Culvert Battery	S4-C	15.57	6/4 5:30 PM	1.5[3]	17	15.46	6/4 6:00 PM	1.5[3]	15.46	6/4 6:00 PM	17	15.46	6/4 6:00 PM
	S4-A	14.18	6/4 5:15 PM			13.93			13.93			13.93	
Crea Bridge	S5-C	19.27	6/6 6:45 PM	0.8	85	18.04	6/16 12:00 PM	1.52	18.09	6/7 6:30 PM	100	18.32	6/15 6:00 PM
	S5-A	17.57	6/14 6:45 AM			17.44			17.00			17.44	
Culverts	S2-B	18.72	6/9 4:30 AM	1.3[3]	16[3]	18.70	6/9 12:00 PM	2.8[3]	18.58	6/10 2:00 AM	28[3]	18.58	6/10 2:00 AM
	S2-A	18.70	6/8 8:45 PM			18.59			18.31			18.31	
	S3-B	20.92	6/5 7:30 PM	Dry	Dry	--	--	Dry	--	--	Dry	--	--
	S3-A	21.17	6/1 4:15 PM			--			--			--	
	S6-B	25.20	5/18 1:00 PM	--[4]	--[4]	--	--	--[4]	--	--	--[4]	--	--
	S6-A	24.58	6/3 3:15 AM			--			--			--	
	S7-B	27.27	6/2 5:45 PM	--[4]	--[4]	--	--	--[4]	--	--	--[4]	--	--
	S7-A	25.83	6/9 9:15 PM			--			--			--	
GMT1 Pad	S8	Dry	--	--	--	--	--	--	--	--	--	--	--

Notes:
1. – Indicates measurement not performed or calculated
2. Stage not recorded due to PT malfunction
3. Average through all associated culverts conveying flow
4. Hydraulically equalized conditions occurred by the time field crews measured discharge on GMT1 road. No flow was observed on 6/8/18
5. UB6.9 PT malfunction. Peak stage is based on HWM observed on 6/9/18. Time of peak stage is an estimate.

Table 4.2 and Table 4.3 present summaries of summer stage, velocity, and discharge.

Table 4.2: Summer Maximum Stage, Velocity, & Discharge Summary

Monitoring Location Description	Gage Station	Summer Maximum Stage		Summer Maximum Velocity			Summer Maximum Discharge		
		Stage ft BPMSL	Date & Time	Average Velocity fps	Stage ft BPMSL	Date & Time	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	UB6.9	2.98	8/31 11:30 PM	0.53[1]	2.98	8/31 11:30 PM	220[1]	2.98	8/31 11:30 PM
	UB6.7	2.59	8/31 11:00 PM		2.59			2.59	
Barely Creek Culvert Battery	S4-C	14.75	9/6 6:15 PM	3.60	14.74	9/6 11:45 AM	5	14.74	9/6 11:45 AM
	S4-A	12.68	9/7 1:50 AM		12.67			12.67	
Crea Bridge	S5-C	16.72	9/6 1:00 AM	1.14	16.51	9/1 12:15 AM	15	16.62	9/1 9:30 AM
	S5-A	16.27	9/10 8:00 AM		15.76			16.02	

Notes:
1. Indirect discharge and velocity is calculated for flow through the entire channel

Table 4.3: Summer Minimum Stage, Velocity, & Discharge Summary

Monitoring Location Description	Gage Station	Summer Minimum Stage		Summer Minimum Velocity & Discharge			
		Stage ft BPMSL	Date & Time	Average Velocity fps	Discharge cfs	Stage ft BPMSL	Date & Time
Tinmiaqsiugvik Bridge	UB6.9	0.55	8/15 4:30 PM	0.37[1]	100[1]	.55	8/15 4:30 PM
	UB6.7	0.08	8/15 4:30 PM			.08	
Barely Creek Culvert Battery	S4-C	13.98	7/18 8:30 AM	0[2]	0[2]	--	Frequent
	S4-A	11.85	7/27 2:30 AM			--	
Crea Bridge	S5-C	15.33	8/14 11:30 PM	0[2]	0[2]	--	Frequent
	S5-A	15.52	8/3 7:15 PM			--	

Notes:
1. Indirect discharge and velocity is calculated for flow through the entire channel
2. Drainage frequently stagnant

4.1 TINMIAQSIUGVIK BRIDGE

The UB gage stations are located in the Tinmiaqsiugvik River at RM 6.7 (downstream of the Tinmiaqsiugvik Bridge) and at RM 6.9 (upstream of the Tinmiaqsiugvik Bridge), measured upstream from the confluence with Fish Creek. The drainage basin area is 231 square miles at the upstream side of the Tinmiaqsiugvik Bridge and drains northwest into Fish Creek downstream of the bridge. The UB gage stations have been monitored intermittently since 2003. Historical peak stage and discharge data is presented in Table 4.4.

Spring and summer measured and calculated velocity and discharge data and plan and profile drawings are provided in Appendix C.

Table 4.4: Tinmiaqsiugvik River at UB6.8 Historical Peak Stage & Discharge

Year	Stage		Discharge		Reference
	Peak WSE (feet BPMSL)	Date	Peak Discharge (cfs)	Date	
2018	12.31[1]	6/9	2,600[2]	6/11	This Report
2017	7.81[3]	5/31	2,800	5/31	Baker 2017
2014	8.34	5/19	1,600	5/20	Baker 2014
2013	9.83	6/5	2,110	6/5	Baker 2013
2011	9.39	6/2	2,350	6/2	Baker 2011
2010	10.38	6/8	5,360	6/8	Baker 2010
2009	8.45	5/29	1,990	5/30	Baker 2009
2006	6.19	6/7	1,290	6/6	Baker 2007
2005	10.01	6/7	1,680	6/9	Baker 2005b
2004	10.50	6/6	2,800	6/5	Baker 2005a
2003	10.14	6/6	1,300	6/9	Baker 2003

Notes:
1. Value taken from PT installed at the bridge. Value is heavily influenced by drifted snow under the bridge
2. Discharge quality rated as poor due to significant ice and snow influence
3. Value interpolated from stage between UB6.7 & UB6.9

SPRING

Prior to the onset of the 2018 spring breakup flooding, drifted snow was observed obstructing the Tinmiaqsiugvik Bridge opening. On the downstream side of the bridge, the construction ice pads had been excavated, leaving two large rectangular shaped basins. On June 4, local melt initially drained into and filled the excavated basins prior to the arrival of upstream floodwater. When the leading edge of floodwater reached the bridge on June 8, the drifted snow under the bridge impeded flow through the bridge opening (Photo 4.1). On June 9 peak stage was recorded. Flow was observed tunneling under the snow drift and plunging into the basin left by ice removal, evident by surface boils just downstream of the bridge. Significant backwater and overbank flooding was observed on the south (upstream) side of the GMT1 road. Snow was present both in the channel and along the banks (Photo 4.2). Aerial observations from June 11 and 14 show similar conditions to those observed on June 9, with drifted snow stretching along the length of the bridge and floodwater tunneling underneath the snowpack (Photo 4.3). On June 17, a lower stage crest was measured and flow conditions remained unchanged, though melt progression of the snow drift was apparent. By June 19, drifted snow was still present under the length of the bridge, albeit minimal, and flow was generally well-confined within the channel (Photo 4.4).

Photo 4.1: Tinmiaqsiugvik Bridge, looking west June 8, 2018

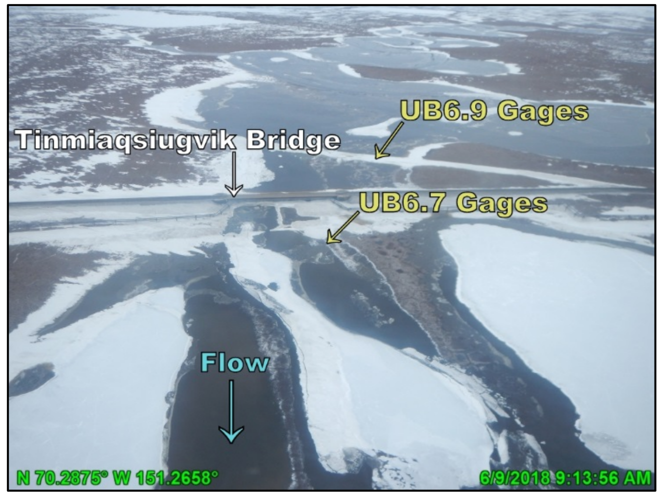


Photo 4.2: Backwater upstream of the Tinmiaqsiugvik Bridge, looking south; June 9, 2018

Photo 4.3: Tinmiaqsiugvik Bridge, looking southwest; June 14, 2018

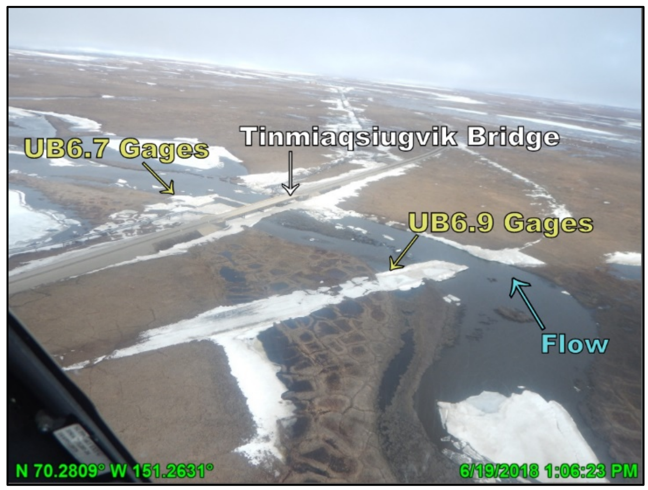
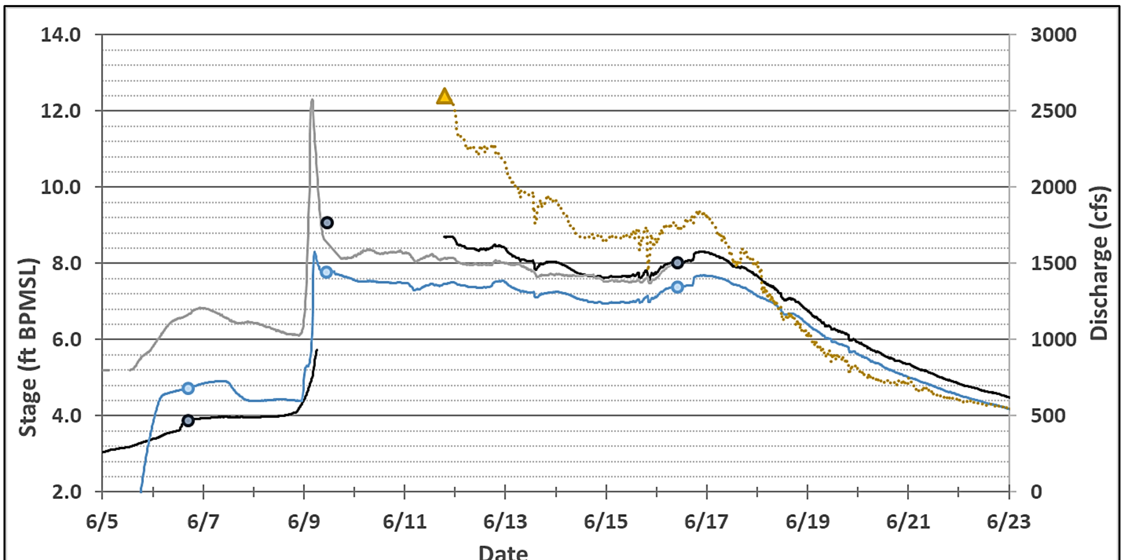


Photo 4.4: Tinmiaqsiugvik Bridge, looking northeast; June 19, 2018

Continuous discharge and velocity was calculated during spring breakup. The accuracy of these indirect calculations is dependent on conditions at the time of calculation, particularly the presence of snow, bottomfast ice, and ice jam backwater effects. The presence of snow and bottomfast ice in the channel impact river hydraulics by elevating the riverbed and constricting the banks, which raises stage above snow- and ice-free channel levels. The snow and ice also affect the size, shape, and roughness of the channel. Bottomfast ice can persist long into the breakup flood. Because the ice and snow are melting during breakup, factors such as channel geometry, slope, and roughness continuously change until the channel is snow- and ice-free. These dynamic characteristics of the channel were documented in 2006 when channel profiles were measured daily during breakup (Michael Baker 2007). This year, in addition to the ablation of naturally occurring snow and ice, channel conditions at the Tinmiaqsiugvik Bridge were influenced by the presence of constructed ice pads and roads as well as the drifted snow underneath the bridge. The accuracy of the indirect calculations, including the estimated peak discharge, were negatively impacted by the aforementioned factors and assigned a poor-quality rating.

Discharge was not measured at the Tinmiaqsiugvik Bridge due to the drifted snow in the bridge opening and large quantity of ice in the channel throughout the monitoring period. Any measurement would have been heavily influenced by the snow and ice and would have failed to yield reportable results. Discharge was measured approximately 18.2 RM upstream of the Tinmiaqsiugvik Bridge at gage site UB26.0 on June 10 as part of a separate CPAI program. The measured discharge at UB26.0 was 1,150 cfs. This measurement is an underestimate of discharge at the Tinmiaqsiugvik Bridge due to the meltwater contribution in the drainage between the two sites but is included in this section to supplement the data.

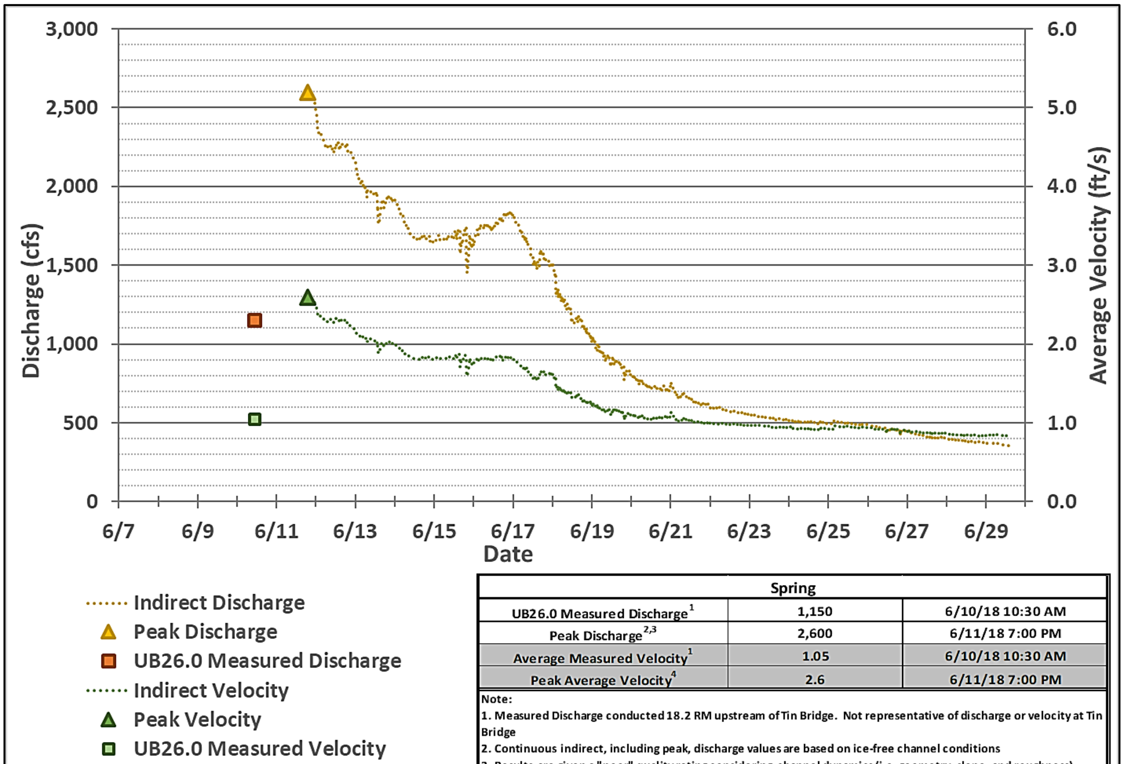
Tinmiaqsiugvik Bridge spring breakup stage and discharge data is provided in Graph 4.1,. and estimated discharge and velocity data for the Tinmiaqsiugvik Bridge is provided in Graph 4.2. Detailed information regarding discharge calculations is provided in Appendix C.



Spring		
UB6.9 (US) Peak Stage[1]	9.18	6/9/18 5:30 AM
UB6.7 (DS) Peak Stage	8.32	6/9/18 5:00 AM
Tin Bridge Peak Stage[2]	12.31	6/9/18 4:15 AM
Peak Discharge[3]	2600	6/11/18 7:00 PM

Notes:
1. UB6.9 PT malfunction. Peak stage is based on HWM observed on 6/9/18. Time of peak stage is an estimate.
2. RTFM PT located at bridge opening. High stage associated with snow drift under bridge. Stage value compared with aerial observations of flood extent and available topography data.
3. Continuous indirect, including peak, discharge values based on ice free conditions. Results are given a "poor" quality rating considering channel dynamics (i.e. geometry, slope, and roughness) during breakup.

Graph 4.1: Tinmiaqsiugvik Bridge Spring Breakup Stage & Discharge



Spring		
UB26.0 Measured Discharge[1]	1,150	6/10/18 10:30 AM
Peak Discharge[2,3]	2,600	6/11/18 7:00 PM
Average Measured Velocity[1]	1.05	6/10/18 10:30 AM
Peak Average Velocity[4]	2.6	6/11/18 7:00 PM

Note:
1. Measured Discharge conducted 18.2 RM upstream of Tin Bridge. Not representative of discharge or velocity at Tin Bridge
2. Continuous indirect, including peak, discharge values are based on ice-free channel conditions
3. Results are given a "poor" quality rating considering channel dynamics (i.e. geometry, slope, and roughness) during breakup.
4. Indirect velocity, including peak, is calculated for flow through the main channel only.

Graph 4.2: Tinmiaqsiugvik Bridge Spring Breakup Velocity & Discharge

SUMMER

The Tinmiaqsiugvik River was ice and snow free and flow was within the main channel when field crews returned in early July. The spring PTs were moved lower in the channel to capture low-flow summer conditions. Summer stage, velocity, and discharge were significantly lower than during spring breakup.

Continuous discharge and velocity was calculated based on ice- and snow-free conditions during the summer and remained well below peak discharge and peak velocity calculated during spring breakup (Photo 4.5 and Photo 4.6). Indirect summer calculations, including the estimated highest summer discharge and velocity, were assigned a good quality rating based on open-channel conditions.

Tinmiaqsiugvik Bridge summer stage and discharge data is provided in Graph 4.3; discharge and velocity data is provided in Graph 4.4.

Photo 4.5: Tinmiaqsiugvik Bridge, looking southeast; August 28, 2018

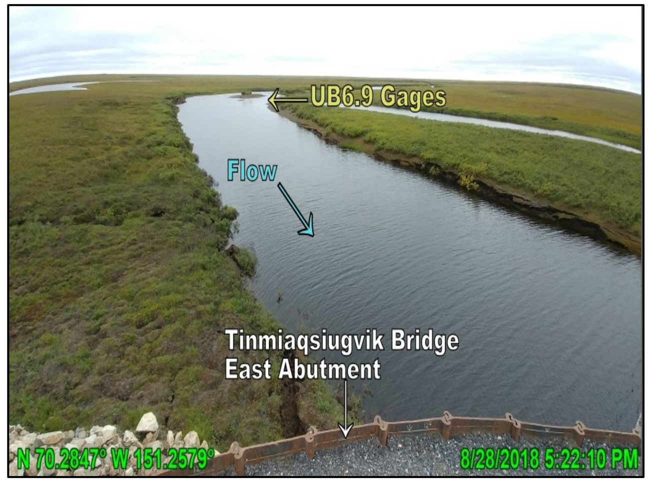
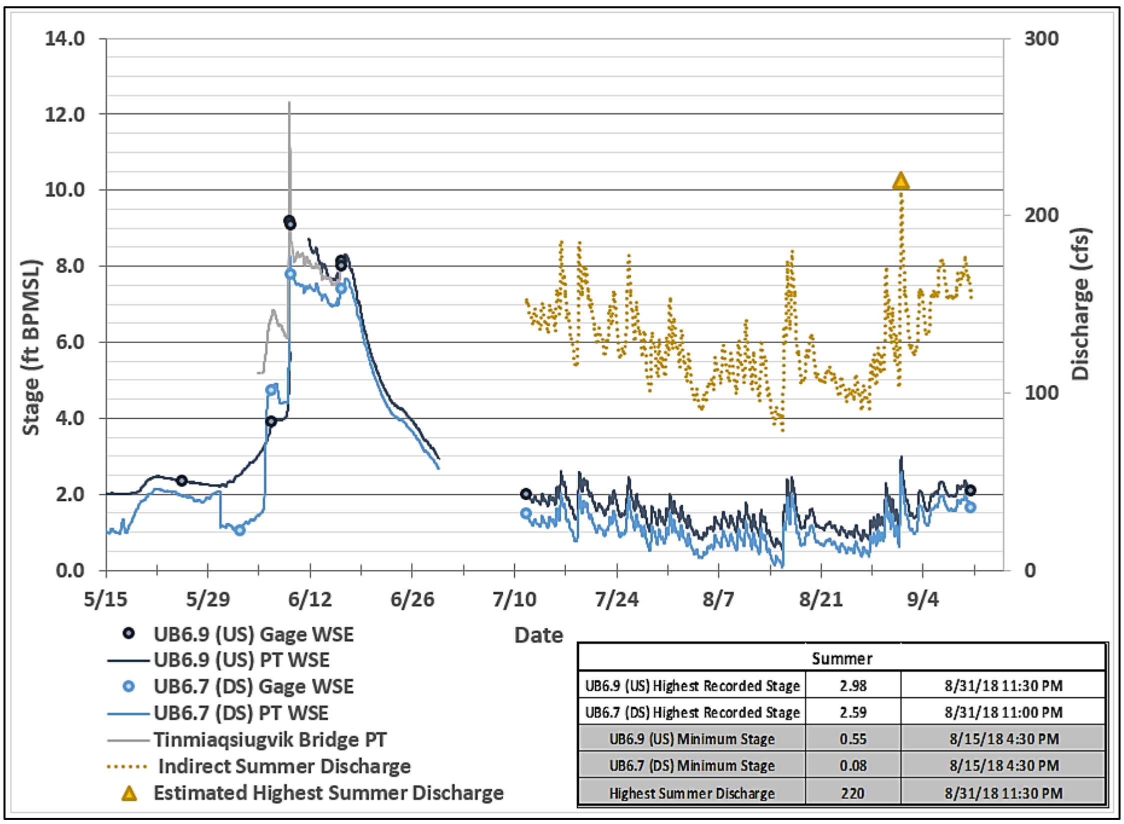
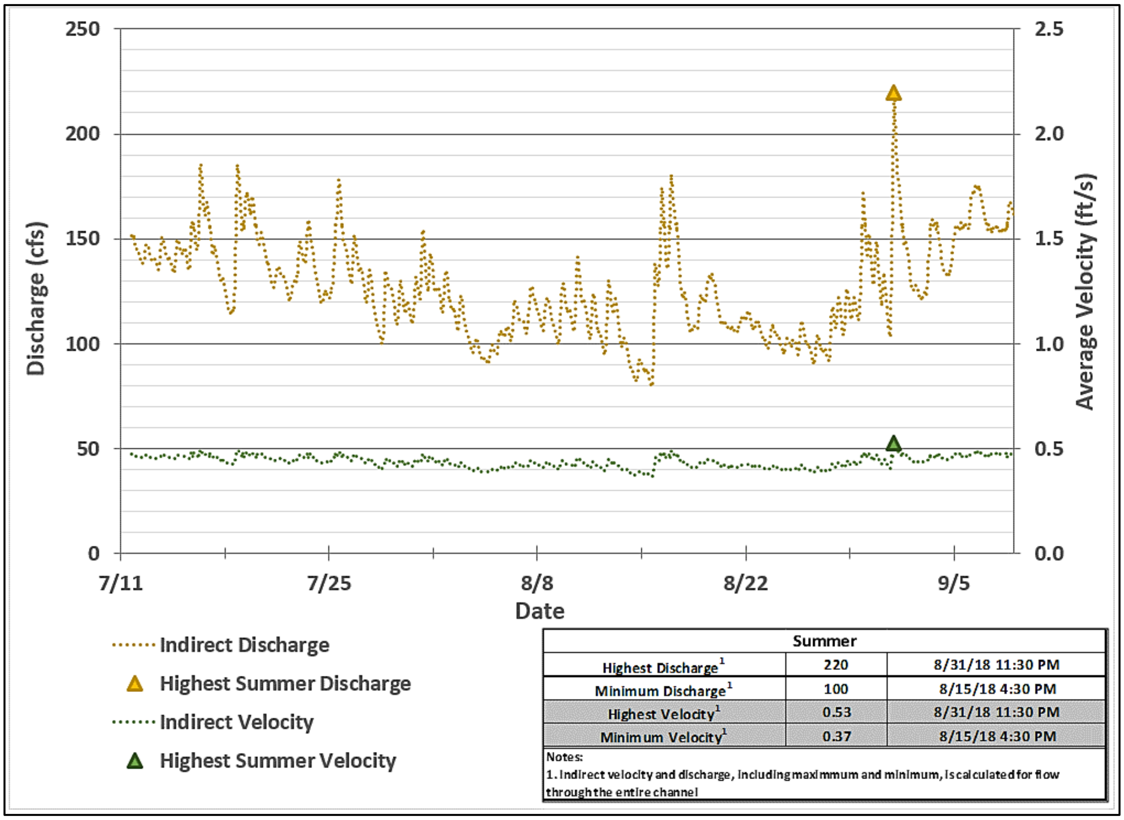


Photo 4.6: Tinmiaqsiugvik Bridge, looking south; August 28, 2018



Summer		
UB6.9 (US) Highest Recorded Stage	2.98	8/31/18 11:30 PM
UB6.7 (DS) Highest Recorded Stage	2.59	8/31/18 11:00 PM
UB6.9 (US) Minimum Stage	0.55	8/15/18 4:30 PM
UB6.7 (DS) Minimum Stage	0.08	8/15/18 4:30 PM
Highest Summer Discharge	220	8/31/18 11:30 PM

Graph 4.3: Tinmiaqsiugvik Bridge Summer Stage & Discharge



Graph 4.4: Tinmiaqsiugvik Bridge Summer Velocity & Discharge

4.2 CREA BRIDGE

The S5 gage stations are located in Crea Creek upstream (S5-C) and downstream (S5-A) of the Crea Bridge. Crea Creek is a beaded stream that drains an area of approximately 4 square miles at the upstream side of the Crea Bridge and flows northeast into the Tinmiaqsiugvik River downstream of the Crea Bridge and Tinmiaqsiugvik Bridges. The S5 gage stations have been monitored intermittently since 2005 (Table 4.5).

Table 4.5: Crea Bridge at S5 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)[1]	Date	
2018	19.27	6/6	This Report
2017	18.67	5/27	Baker 2017
2014	18.86	5/21	Baker 2011
2013	20.26	6/6	Baker 2013
2011	19.79	6/1	Baker 2011
2010	19.63	6/8	Baker 2010
2009	18.55	6/1	Baker 2009
2006	18.89	6/9	Baker 2006
2005	19.68	6/6	Baker 2005b

Notes:
1. Peak stage reported at the upstream gage station. Peak stage values at the centerline crossing location are generally slightly less than upstream stage values.

Spring and summer measured and calculated velocity and discharge data and plan and profile drawings are provided in Appendix C.

SPRING

Spring breakup peak stage and discharge at the Crea Bridge were influenced by ice and snow at the bridge opening. Drifted snow accumulated under the bridge during winter, nearly reaching the height of the bridge deck by spring. An initial increase in stage was recorded on May 31 with disconnected meltwater ponding upstream and downstream of the bridge. On June 1, stage was rising upstream of the bridge and receding downstream of the bridge, indicating the drifted snow beneath the bridge was impeding flow. Local melting continued and on June 4, low velocity flow was observed, suggesting seeping flow through the snow filled bridge opening. Peak stage at S5-C occurred on June 6 and was the result of floodwater backing up behind the bridge opening until a flow path was carved through the snow around the sheet pile abutment under the bridge (Photo 4.7). This caused a rapid fall in upstream stage at S5-C and a rapid rise and fall in downstream stage at S5-A. By June 7, the backwater behind the bridge was no longer apparent, but overbank flooding was observed upstream and downstream of the bridge. On June 9 overbank flooding was still observed downstream of the bridge (Photo 4.8). A second crest in stage was observed on June 14 that resulted in peak stage at S5-A. Stage steadily decreased through the remainder of spring breakup monitoring. By June 18, minimal snow remained in the surrounding area and some overbank flooding was observed (Photo 4.9).

Discharge was measured approximately 75 feet downstream of the Crea Bridge on June 8. Snow was present in the channel cross-section during the first discharge measurement. Discharge was measured a second time, approximately 10 feet upstream of the bridge, between the bridge abutments, on June 16 (Photo 4.10). The channel cross-section was ice- and snow-free during the second measurement. The average velocity for the June 8 and June 16 measurements was 0.96 feet per second (fps) and 0.80 fps, respectively, and the highest depth-averaged velocity within a particular section was 1.90 fps and 1.85, respectively. The quality of the measurements were classified as fair based on conditions at the time of measurements.

Peak discharge is estimated to have occurred as stage crested on the downstream gage on June 15 and was calculated using the open channel cross-section measured during the direct discharge measurement on June 16. The estimated peak discharge was assigned a fair to poor quality rating due to the influence of snow and ice observed during peak conditions and the direct measurement against which indirect calculations were calibrated. Indirect discharge calculated at the time of direct measurement was 4.3% less than the measured discharge.

Crea Bridge stage and discharge data is provided in Graph 4.5; discharge and velocity data is provided in Graph 4.6. Detailed information regarding discharge measurements and calculations is provided in Appendix C.

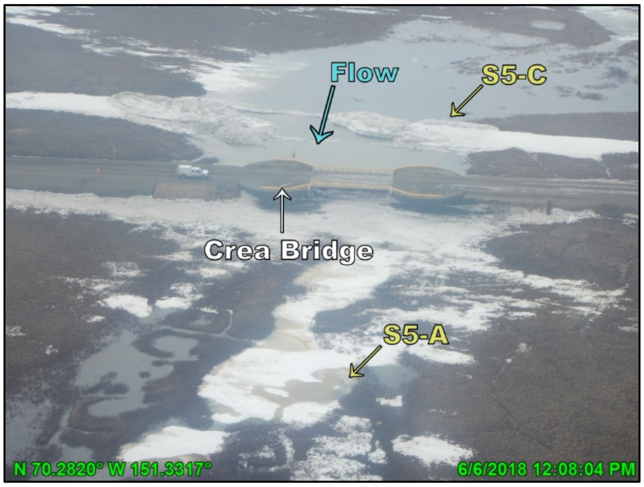


Photo 4.7: Backwater upstream of Crea Bridge, looking south; June 6, 2018

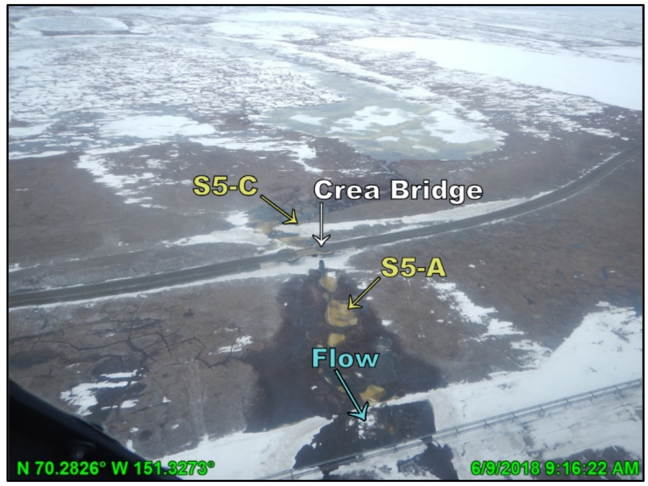


Photo 4.8: Crea Bridge, looking south; June 9, 2018

Photo 4.9: Crea Bridge, looking south; June 18, 2018

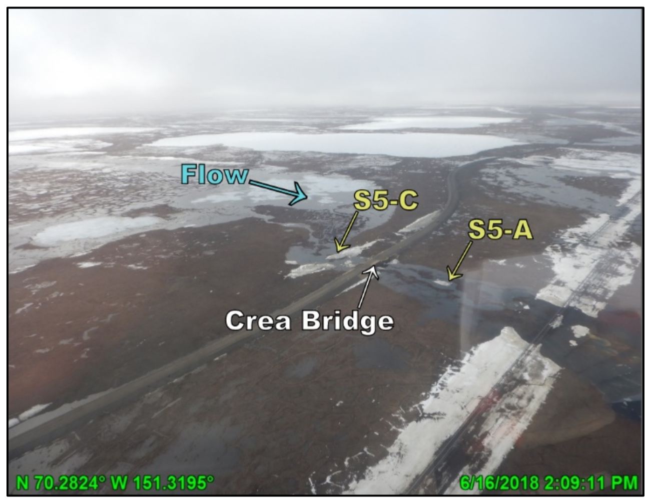
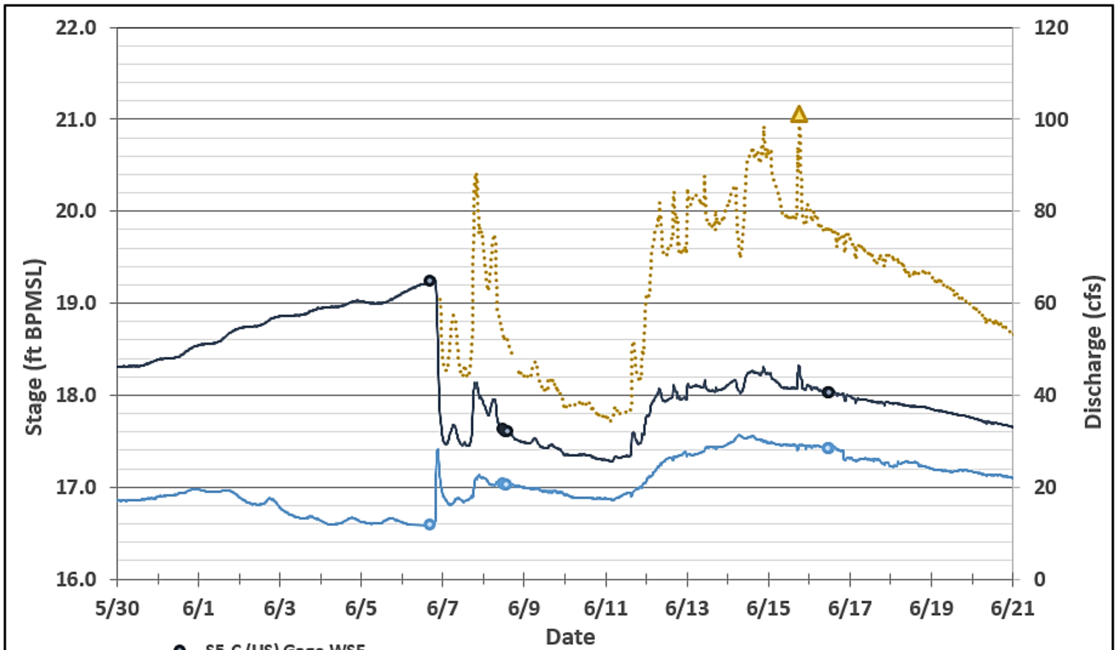
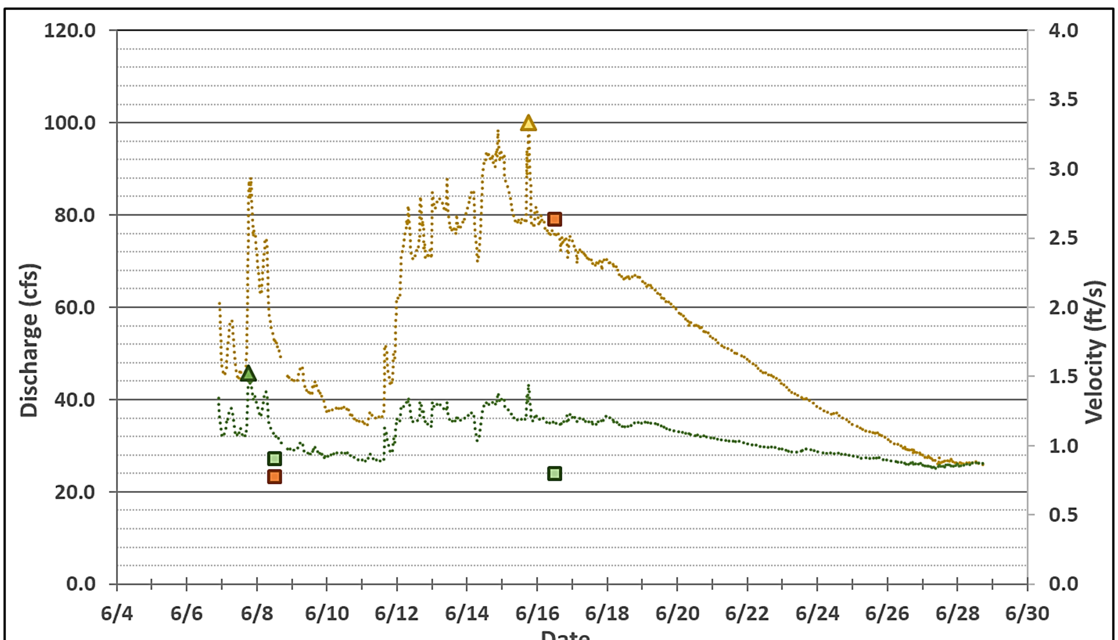


Photo 4.10: Crea Bridge the day of the discharge measurement, looking southwest; June 16, 2018



Spring		
S5-C (US) Peak Stage	19.27	6/6/18 6:45 PM
S5-A (DS) Peak Stage	17.57	6/14/18 6:45 AM
Peak Discharge	100	6/15/18 6:00 PM

Graph 4.5: Crea Bridge Spring Breakup Stage & Discharge



Spring		
Measured Discharge	23	6/8/18 12:00 PM
	85	6/16/18 12:00 PM
Peak Discharge	100	6/15/18 6:00 PM
Average Measured Velocity	0.91	6/8/18 12:00 PM
	0.80	6/16/18 12:00 PM
Peak Average Velocity	1.52	6/7/18 6:30 PM

Graph 4.6: Crea Bridge Spring Breakup Velocity & Discharge

SUMMER

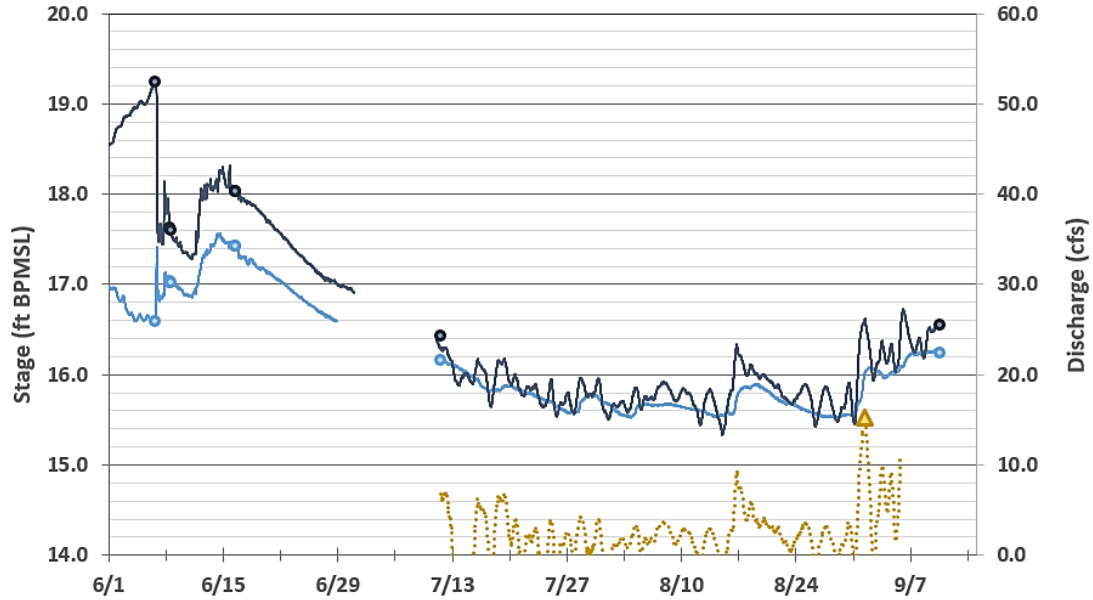
Crea Creek was ice and snow free and flow was conveyed within main channel banks when field crews returned to the site in early July. Summer stage, discharge, and velocities at the Crea Bridge were significantly lower than during spring breakup (Photo 4.11 and Photo 4.12).

Summer discharge was calculated using the cross-section profile measured during the June 16 direct discharge measurement when conditions were ice and snow free. The estimated highest summer discharge was assigned a good quality rating based on open channel conditions.

Crea Bridge stage and discharge data is provided in Graph 4.7; discharge and velocity data is provided in Graph 4.8.

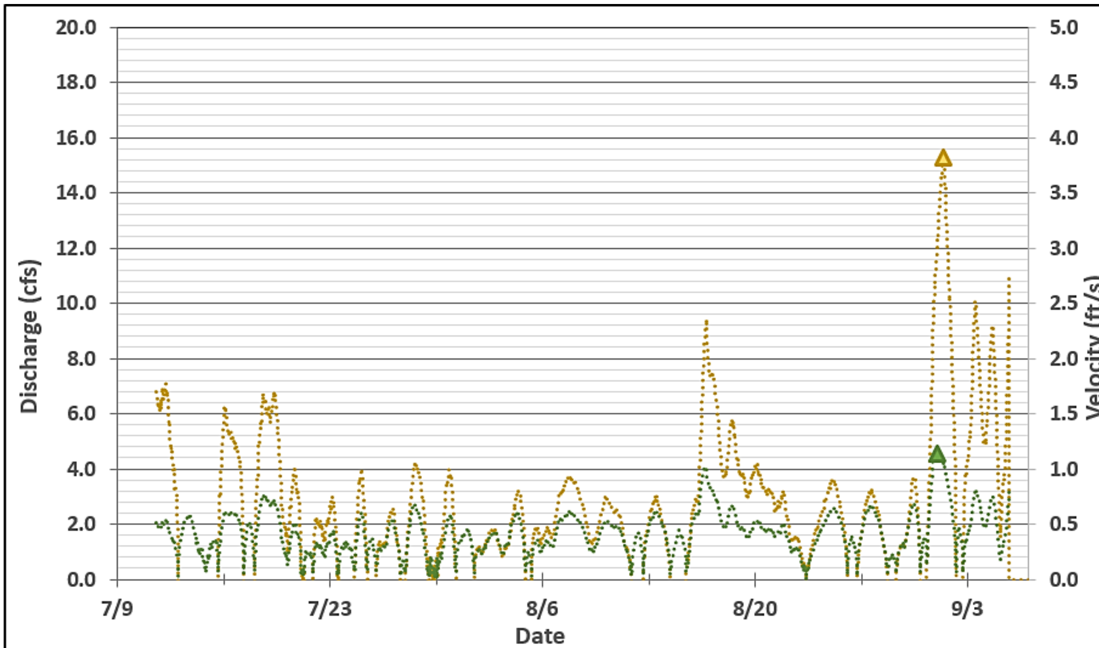
Photo 4.11: Crea Bridge, looking west; July 11, 2018

Photo 4.12: Crea Bridge, looking north (downstream); August 28, 2018



Summer		
S5-C (US) Highest Recorded Stage	16.72	9/6/18 1:00 AM
S5-A (DS) Highest Recorded Stage	16.27	9/10/18 8:00 AM
S5-C (US) Minimum Stage	15.33	8/14/18 11:30 PM
S5-A (DS) Minimum Stage	15.52	8/3/18 7:15 PM
Highest Summer Discharge	15	9/1/18 9:30 AM

Graph 4.7: Crea Bridge Summer Stage & Discharge



Summer		
Highest Discharge	15	9/1/18 9:30 AM
Minimum Discharge	0	Frequent
Highest Velocity	1.14	9/1/18 12:15 AM
Minimum Velocity	0	Frequent

Graph 4.8: Crea Bridge Summer Velocity & Discharge

4.3 BARELY CREEK CULVERT BATTERY

The S4 gage stations and culverts GMT1-42, GMT1-43, and GMT1-44 are located in Barely Creek, a beaded stream that drains an area of 1.6 square miles upstream of the GMT1 access road. Barely Creek flows northeast into lake L9824, then into the Tinmiaqsiugvik River downstream of the Tinmiaqsiugvik Bridge. Barely Creek has been monitored intermittently since 2005 (Table 4.6). Culvert GMT1-42 is 60 inches in diameter and culverts GMT1-43 and GMT1-44 are 36 inches in diameter.

Table 4.6: Barely Creek at S4Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)[1]	Date	
2018	15.57	6/4	This Report
2017	16.24	5/26	Baker 2017
2014	15.19	5/20	Baker 2011
2013	14.93	6/8	Baker 2013
2011	15.54	6/2	Baker 2011
2009	14.87	5/29	Baker 2009
2006	14.87	6/2	Baker 2006
2005	15.20	6/4	Baker 2005b

Notes:
1. Peak stage reported at the upstream gage station. Peak stage values at the centerline crossing location are generally slightly less than upstream stage values.

Plan and profile drawings and spring and summer measured and calculated velocity and discharge data is provided in Appendix C.

SPRING

Isolated meltwater was initially observed at the S4 gages on May 14 and was the highest observed stage. Although stage on this day was the highest reported (peak), no hydraulic connection was observed through the culverts at this time. Stage generally receded until a stage spike was recorded at both gage sites on June 4, which represents the highest measured stage while flow was established through the culverts. On this day, flow was observed through all three culverts and significant snow cover remained in the channel and along the banks. On the north (downstream) side of the GMT1 access road, meltwater had cut a narrow flow path overtop of the snow-filled channel and was hydraulically connected to the Tinmiaqsiugvik River. Less snow was observed on the south (upstream) side of the GMT1 road and water was accumulating in the deep beaded pools along the channel. Conditions remained consistent through the next week, with a slow decline in stage. On June 11, snow cover on the surrounding tundra had decreased, but significant snow cover was still observed along the banks on the north side of the road. Meltwater had filled the Lake 9824 basin by this day. On June 18, some snow remained along the banks on the north side of the road, but the total snow cover in the drainage area was less than 10%.

Conditions remained consistent through the next week, with a slow decline in stage observed. On June 11, snow on the surrounding tundra had decreased, but significant snow cover was still observed along the banks on the north side of the road (Photo 4.13). Meltwater had filled the Lake 9824 basin by this day. On June 18, some snow remained along the banks on the north side of the road, but the total snow cover in the drainage area was less than 10% (Photo 4.14). Bankfull conditions persisted through the end of monitoring on June 19.

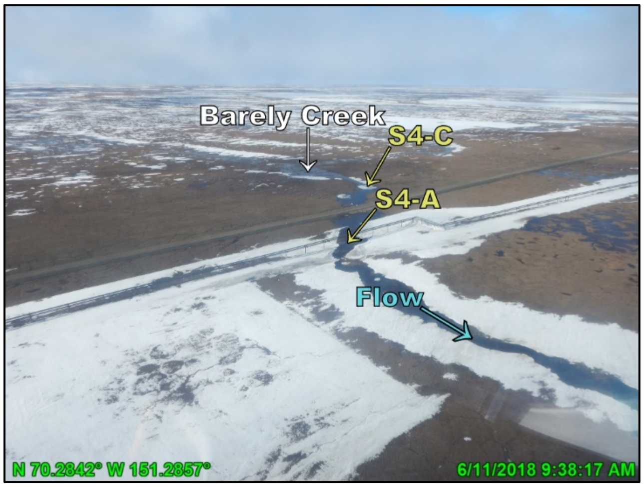


Photo 4.13: Barely Creek, looking southwest (upstream); June 11, 2018

Photo 4.14: Barely Creek, looking south (upstream); June 18, 2018

Discharge was measured at the culverts three separate times during the monitoring period; on June 4, June 8, and June 16 (Photo 4.15 and Photo 4.16). The total discharge for each measurement was the sum of the discharge measurements at the individual culvert outlets. The quality of the June 4 measurement was classified as fair since ice was observed at the culvert outlets. The other measurements were classified as good based on open channel conditions at the time of the measurements. Since the June 4 measurement coincided with the highest measured stage when flow was observed through the culverts, this measurement is believed to be representative of peak discharge through the Barely Creek culvert battery.

Barely Creek culvert battery spring breakup stage, velocity, and discharge data is provided in Graph 4.9. Detailed information regarding discharge measurements and calculations is provided in Appendix C.

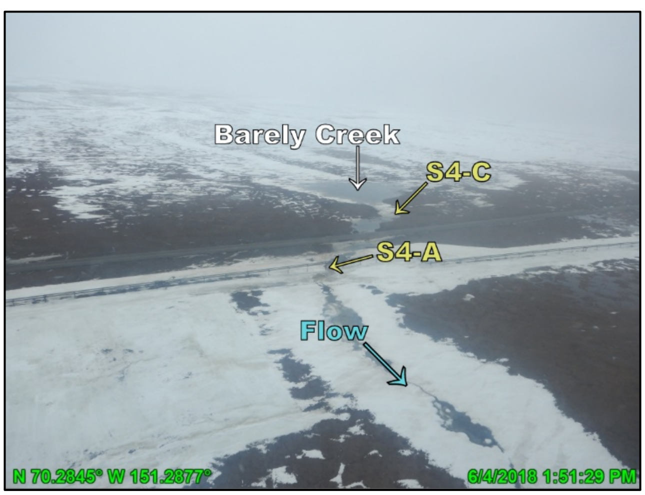


Photo 4.15: Barely Creek on day of a discharge measurement, looking south; June 4, 2018

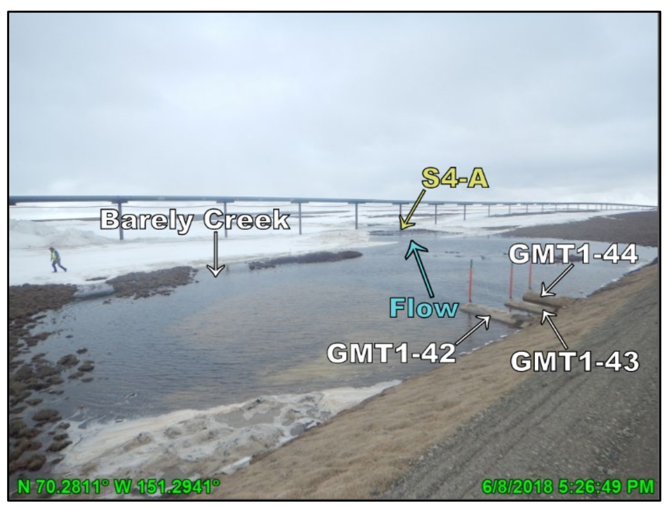
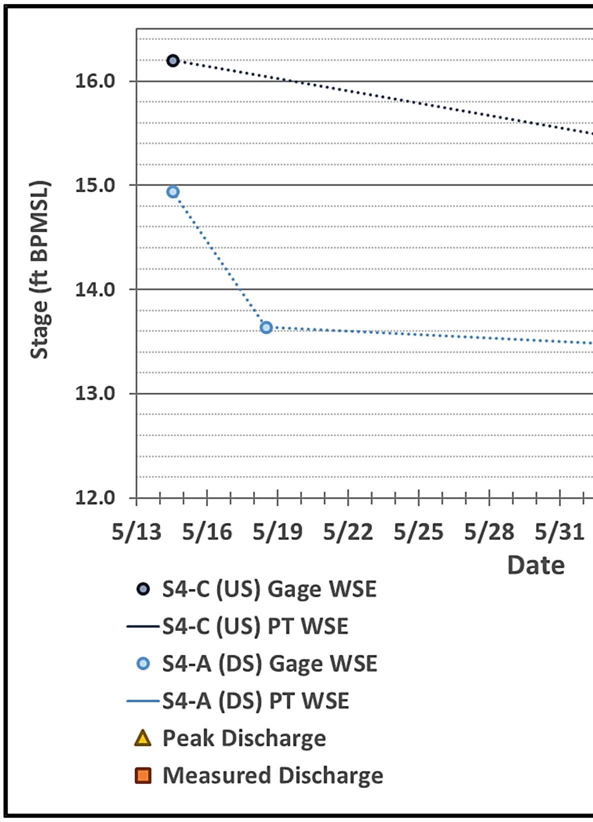


Photo 4.16: Barely Creek, looking north; June 8, 2018



Spring		
S4-C (US)	15.57	6/4/18 5:30 PM
S4-A (DS)	14.18	6/4/18 5:15 PM
Measured Discharge	17	6/4/18 6:00 PM
	10	6/8/18 11:00 AM
	13	6/16/18 10:30 AM
Peak Discharge	17	6/4/18 6:00 PM
Peak Average Velocity[1]	1.5	6/4/18 6:00 PM
Note: 1. Average velocity through all three culverts measured during direct discharge measurement		

Graph 4.9: Barely Creek Culvert Battery Spring Breakup Stage, Velocity, & Discharge

SUMMER

Summer stage, discharge, and velocity at the Barely Creek culvert battery were lower than during spring breakup. The upstream and downstream stage hydrographs and observations during the July 11 site visit indicate water was present with little to no discernable flow in the early summer (Photo 4.17 and Photo 4.18).

Highest summer discharge and velocity coincided with the highest summer stage. The calculation of highest summer discharge was assigned a good quality rating based on open channel conditions.

Barely Creek culvert battery summer stage and discharge data is provided in Graph 4.10.

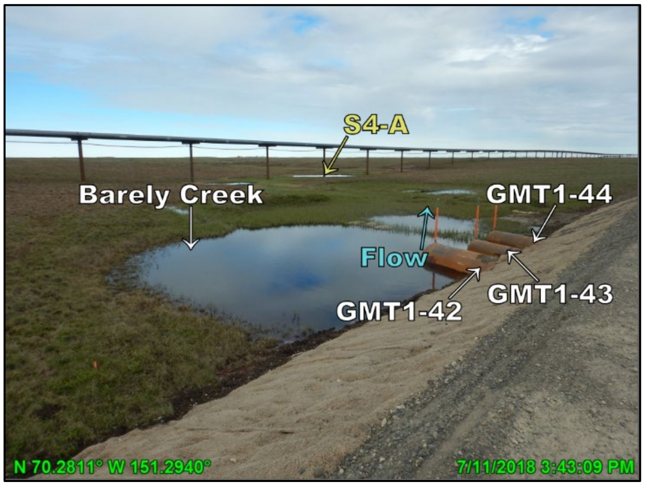
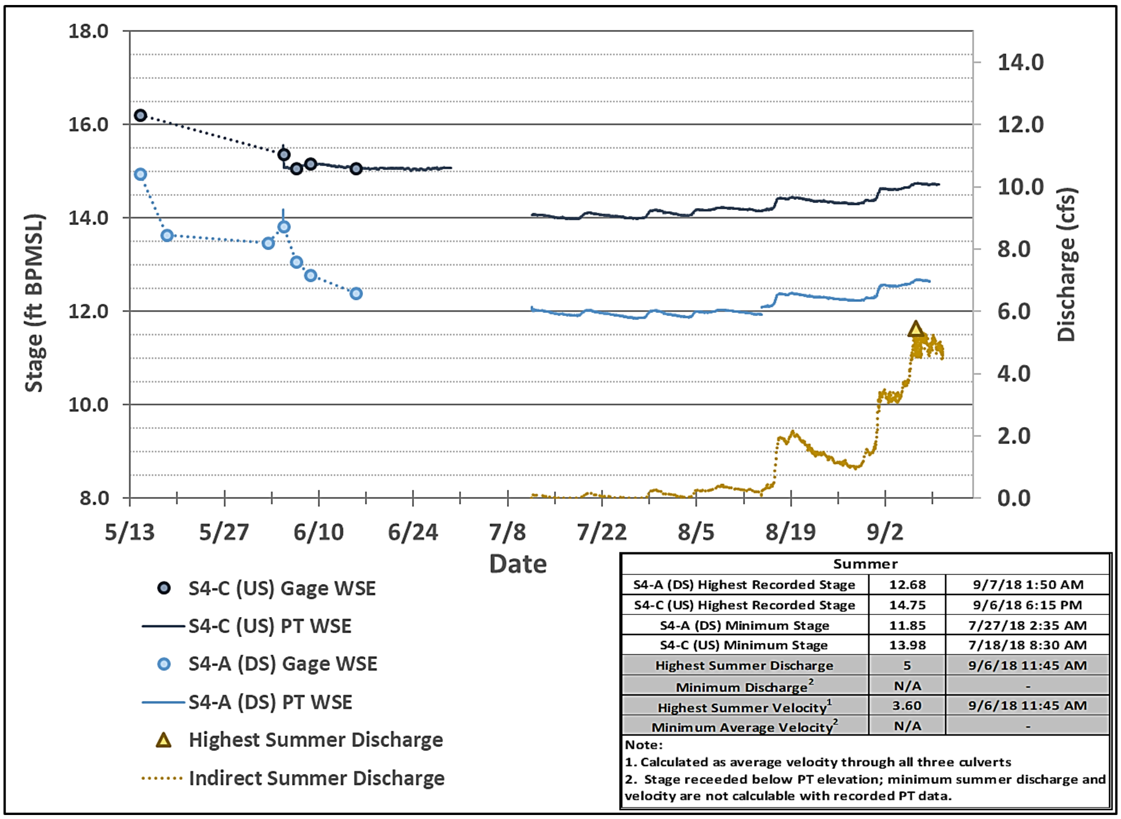


Photo 4.17: Barely Creak, looking northeast; July 11, 2018

Photo 4.18: Barely Creek, looking southwest; July 11, 2018



Summer		
S4-A (DS) Highest Recorded Stage	12.68	9/7/18 1:50 AM
S4-C (US) Highest Recorded Stage	14.75	9/6/18 6:15 PM
S4-A (DS) Minimum Stage	11.85	7/27/18 2:35 AM
S4-C (US) Minimum Stage	13.98	7/18/18 8:30 AM
Highest Summer Discharge	5	9/6/18 11:45 AM
Minimum Discharge[2]	N/A	-
Highest Summer Velocity[1]	3.60	9/6/18 11:45 AM
Minimum Average Velocity[2]	N/A	-

Note:
1. Calculated as average velocity through all three culverts
2. Stage receeded below PT elevation; minimum summer discharge and velocity are not calculable with recorded PT data.

Graph 4.10: Barely Creek Culvert Battery Summer Stage & Discharge

4.4 CULVERTS

The S2, S3, and S7 gage stations have been monitored intermittently since 2009. The S6 gage station has been monitored intermittently since 2005. Historical stage data is presented graphically in each section.

Spring measured and calculated velocity and discharge data is provided in Appendix C. Summer stage, velocity, and discharge were not measured or calculated at any of these locations.

S2 CULVERTS (GMT1-60 THROUGH GMT1-71)

The S2 gage stations are situated in a natural depression from a drained thermokarst lake basin which encompasses the CD5 road intersection. The drainage area at the upstream side of the culverts is approximately 0.01 square miles. On the downstream side of the GMT1 access road, the drainage connects to Lake MB0301 to the northeast and a beaded stream to the northwest which flows into the Tinmiaqsiugvik River downstream of the Tinmiaqsiugvik Bridge. Culverts GMT1-60 through GMT1-71 equalize accumulating meltwater on the north and south side of the GMT1 access road. Historical stage data for S2 is presented in Table 4.7.

Table 4.7: S2 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)	Date	
2018	18.72	6/9	This Report
2017	18.47	5/27	Baker 2017
2009	18.20	6/1	Baker 2009

On June 1, ponded meltwater was observed at the upstream (S2-B) gage on the south side of the GMT1 access road (Photo 4.19). Snow initially blocked the culverts from conveying flow and minimal local melt was observed at the downstream (S2-A) gage on the north side of the road (Photo 4.20). Observations from the evening of June 3 show significant meltwater at both S2 gages. PT data suggests that the culvert impediment was cleared early on June 3, as similar and concurrent stage trends between gage sites indicate a hydraulic connection was established through the culverts.

Photo 4.19: S2, looking south (upstream) June 1, 2018

Photo 4.20: S2-A, looking north; June 1, 2018

Stage increased consistently from June 4 till late June 8 and early June 9, when peak stage was recorded at the upstream and downstream gages, respectively. Observations from June 9 show hydraulically equalized conditions on each side of the road with culverts conveying flow from south to north (Photo 4.21). As upstream and downstream stage decreased after June 9, a hydraulic gradient developed and flow through the culverts increased. Meltwater was still observed at the gage sites on June 17 and minimal snow remained in the surrounding area (Photo 4.22).

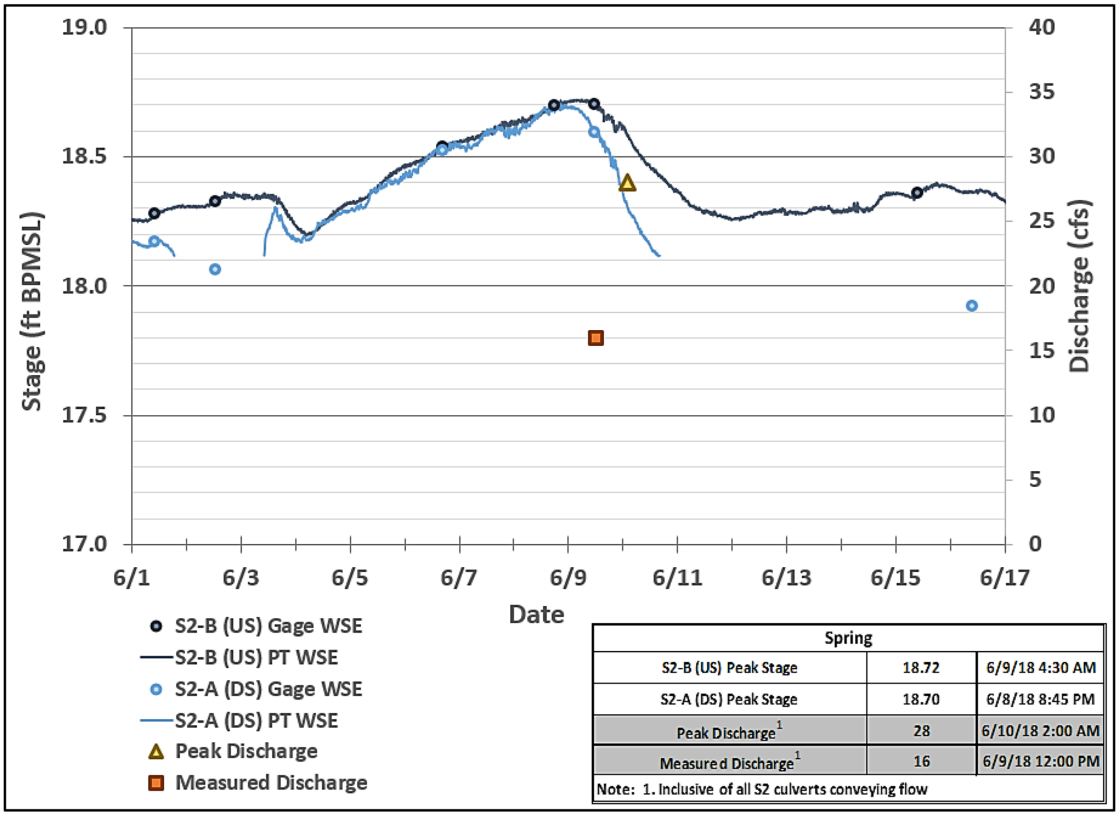
An ice road constructed on the north side of the GMT1 access road and running parallel to the CD5 road did not impede flow during the monitoring period and had mostly melted by June 19.

Spring velocity and discharge were measured at the outlets of culverts GMT1-64 through GMT1-67 on June 9 and June 16. The average velocity through these culverts was 1.3 fps on June 9 and 1.7 fps on June 16. The quality of the measurements was classified as good based on open channel conditions at the time of measurement.

S2 spring breakup stage and discharge data are provided in Graph 4.11.

Photo 4.21: Peak stage conditions at S2, looking west; June 9, 2018

Photo 4.22: S2, looking west; June 17, 2018



Graph 4.11: S2 Spring Breakup Stage & Discharge

S3 CULVERTS (GMT1-50 THROUGH GMT1-59)

The S3 gage stations are situated in a small, poorly defined network of high centered polygon troughs. The S3 drainage is approximately 0.9 square miles upstream of the culverts. The S2 drainage is downstream to the east and the Tinmiaqsiugvik River is downstream to the west. In the past, during periods of high flow, backwater from the Tinmiaqsiugvik River has been observed extending to this area. This was not the case in 2018 when spring breakup flows in the Tinmiaqsiugvik River remained low and confined within the channel banks downstream of the GMT1 access road. Culverts GMT1-57 through GMT1-59 are situated in the drainage depression while culverts GMT1-50 through GMT1-56 are situated on higher ground to the west. Historical Stage data for S3 is presented in Table 4.8.

Table 4.8: S3 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)	Date	
2018	20.92	6/5	This Report
2017	20.79	6/1	Baker 2017
2014	20.46	6/5	Baker 2011
2009	20.87	6/3	Baker 2009

The S3 monitoring station did not see appreciable water during the 2018 monitoring period (Photo 4.23 and Photo 4.24). Initial local melt was observed on the downstream (S3-A) gage on May 14, and the upstream gage recorded a small amount of local melt on June 6 but was dry again two days later. Peak stage was recorded at the downstream gage on June 1 and was the result of local melt around the gage site.

Except for a small amount of flow observed through culvert GMT1-52 on June 8, meltwater accumulation was not high enough to establish hydraulic connection through the culverts.

S3 spring breakup stage data is provided in Graph 4.12.

Photo 4.23: S3, looking south; June 4, 2018

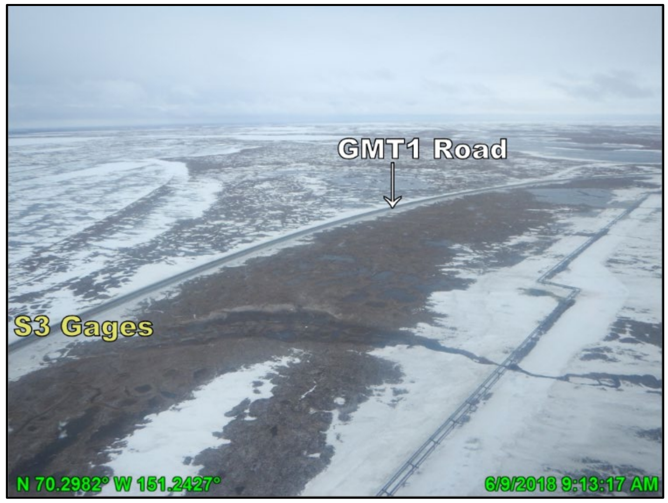
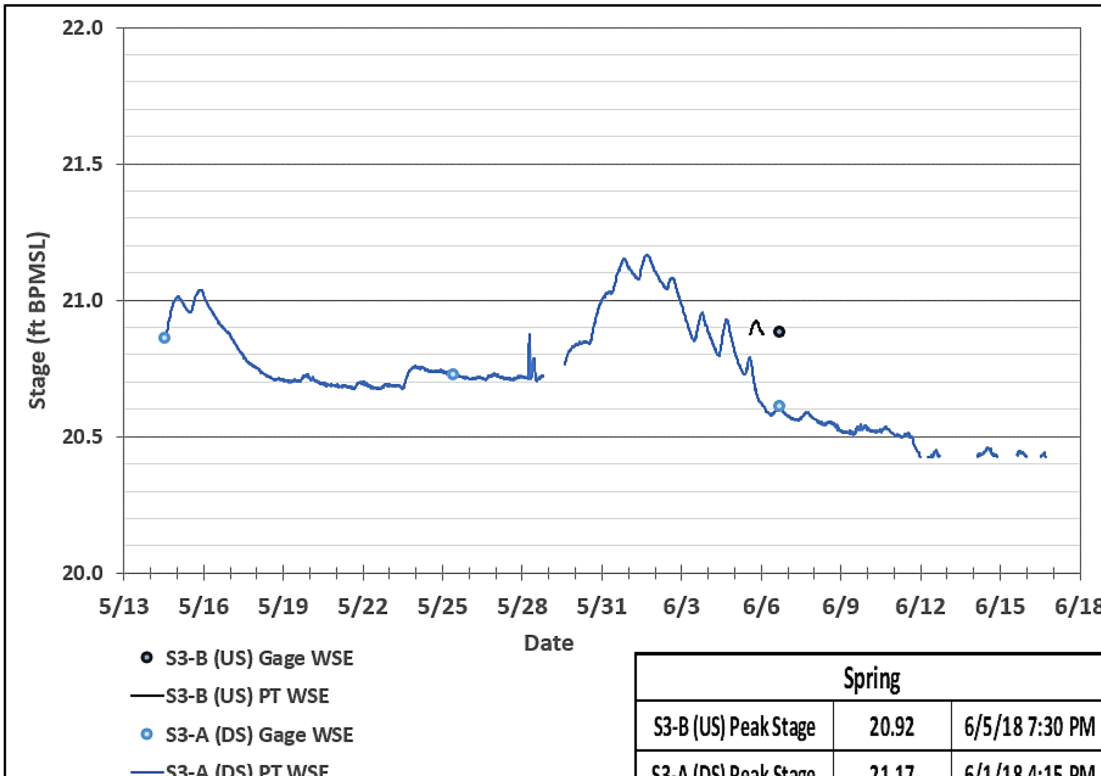


Photo 4.24: S3, looking south; June 9, 2018



Spring		
S3-B (US) Peak Stage	20.92	6/5/18 7:30 PM
S3-A (DS) Peak Stage	21.17	6/1/18 4:15 PM

Graph 4.12: S3 Spring Breakup Stage

S6 CULVERTS (GMT1-31 THROUGH GMT1-33)

The S6 gage stations and culverts GMT1-31 through GMT1-33 are situated in a swale that connects Lake L9819 (south of the GMT1 access road) to a smaller lake downstream to the north; Fish Creek is further downstream. The S6 drainage is approximately 0.7 square miles upstream of the culverts, 0.4 square miles of which is the Lake L9819 basin. Historical data for S6 is presented in Table 4.9.

Table 4.9: S6 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)	Date	
2018	25.20	5/18	This Report
2017	24.47	5/31	Baker 2017
2014	24.17	5/21	Baker 2011
2013	23.98	6/8	Baker 2013
2009	24.09	6/1	Baker 2009
2006	23.33	6/4	Baker 2006
2005	24.34	6/5	Baker 2005b

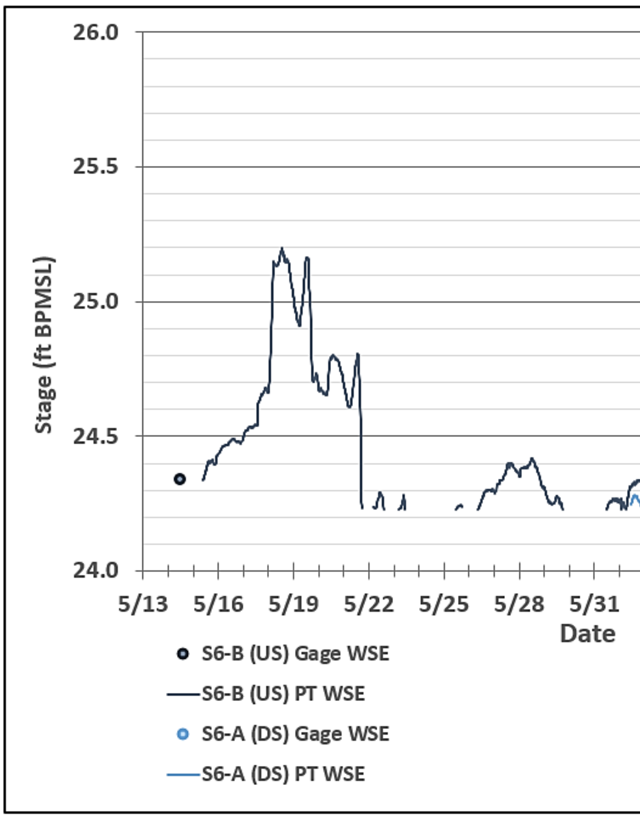
On May 14, local meltwater was accumulating on the upstream gage (S6-B). PT data shows an increase of stage at the upstream gage site around May 16. Peak stage was initially reported as June 8 in the GMT1 2018 Culvert Monitoring Report (Michael Baker 2018), however, after retrieving and analyzing PT data, peak stage occurred at the upstream gage on May 18 and was the result of isolated local melt. A hydraulic connection through the culverts was likely established around May 21, when the upstream stage data rapidly receded. Stage remained low until the start of June. Peak stage was recorded at S6-A on June 3. Aerial observations from June 4 show flooding over low-lying areas and equalized hydraulic conditions upstream and downstream of the road, suggesting the culverts were conveying low velocity flow (Photo 4.25). By June 18, minimal snow remained along the banks of the drainage and flow was generally well-confined to the defined channel (Photo 4.26).

While the gradient along the GMT1 road alignment generally conveys flow south to north (upstream to downstream), the stage hydrographs at S6 suggests equalization from north to south. On June 8, no discernable flow was observed through the culverts on June 8, and discharge was not measured.

S6 spring breakup stage and discharge is provided in Graph 4.13.

Photo 4.25: S6, looking south; June 4, 2018

Photo 4.26: S6, looking south; June 18, 2018



Spring		
S6-B (US) Peak Stage	25.20	5/18/18 1:00 PM
S6-A (DS) Peak Stage	24.58	6/3/18 3:15 AM

Graph 4.13: S6 Spring Breakup Stage

S7 CULVERTS (GMT1-21 THROUGH GMT1-29)

The S7 gage stations and culverts are situated in a swale that drains approximately 0.9 square miles upstream of the culverts, including Lake L9820. Flow direction is north toward Fish Creek. Historical data for S7 is presented in Table 4.10.

Table 4.10: S3 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)	Date	
2018	27.27	6/2	This Report
2017	27.28	5/26	Baker 2017
2014	25.64	5/24	Baker 2011
2009	25.67	6/3	Baker 2009

On May 26, local melt was observed at the downstream gage (S7-A) along with saturated snow between the gage and the road. Peak stage was recorded at the upstream gage (S7-B) on June 2 and was the result of local, disconnected meltwater (Photo 4.27). S7-B stage began steadily receding after June 2. Observations on June 8 show culverts GMT1-21 through GMT1-24 dry while culverts GMT1-25 through GMT1-29 had pooled, stagnant water on each side (Photo 4.28). The stagnant water was likely caused by iced-in culvert bladders. Hydraulic connection was likely established through culverts GMT1-25 and GMT1-26 around June 9, corresponding with a decrease in stage at the upstream gage and a rise in stage at the downstream gage. Peak stage at S7-A occurred on June 9 and was attributed to the hydraulic connection established through the GMT1-25 and GMT1-26 culverts (Photo 4.29). Discharge was not measured at any of the culverts related to the S7 drainage since no discernable flow was observed on June 8, the day culvert discharge measurements were taken. By June 17, minimal snow remained in the S7 drainage area. (Photo 4.30).

S7 spring breakup stage and discharge is provided in Graph 4.14.

Photo 4.27: S7-B, looking south June 2, 2018

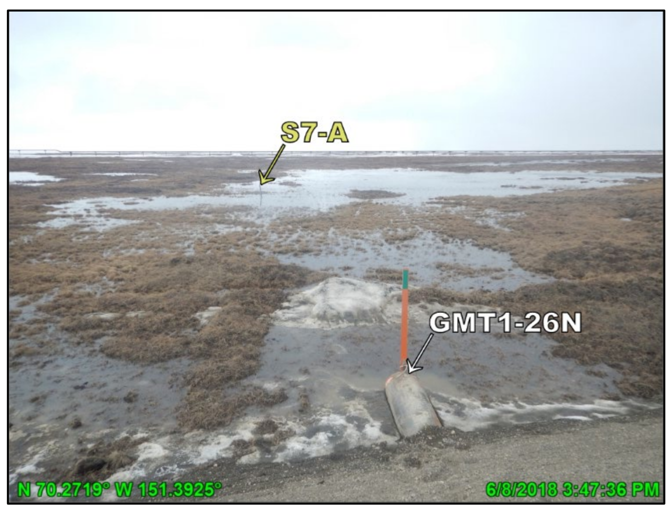


Photo 4.28: S7-A, looking north; June 8, 2018

Photo 4.29: Peak stage conditions at S7, looking south; June 9, 2018

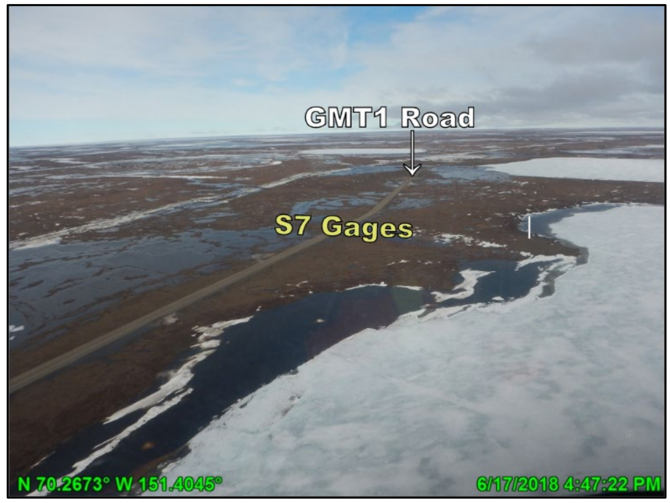
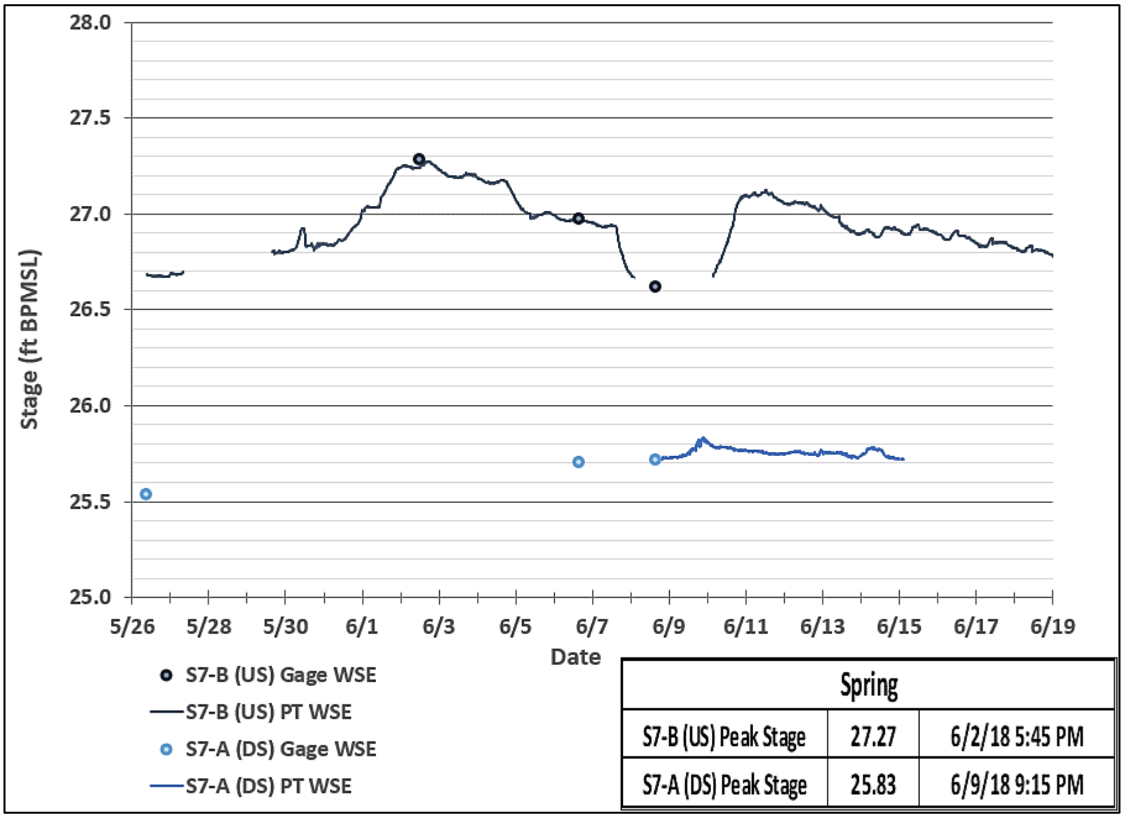


Photo 4.30: S7, looking northeast; June 17, 2018



Spring		
S7-B (US) Peak Stage	27.27	6/2/18 5:45 PM
S7-A (DS) Peak Stage	25.83	6/9/18 9:15 PM

Graph 4.14: S7 Spring Breakup Stage

4.5 GMT1 PAD

The S8 gage station is located approximately 900 feet west of GMT1 pad. The gage is located in a swale downstream of Lake M9925 that drains north into Blackfish Creek, a beaded stream that drains generally northeast into Lake MC7916 and into Fish Creek.

No rise in stage was observed at the G8 gage station. Surrounding meltwater was present but the gage and PT remained dry (Photo 4.31 and Photo 4.32).

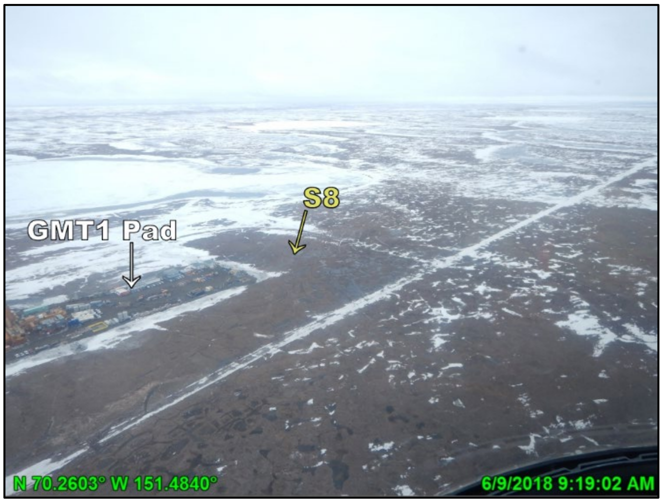


Photo 4.31: S8, looking southwest; June 9, 2018

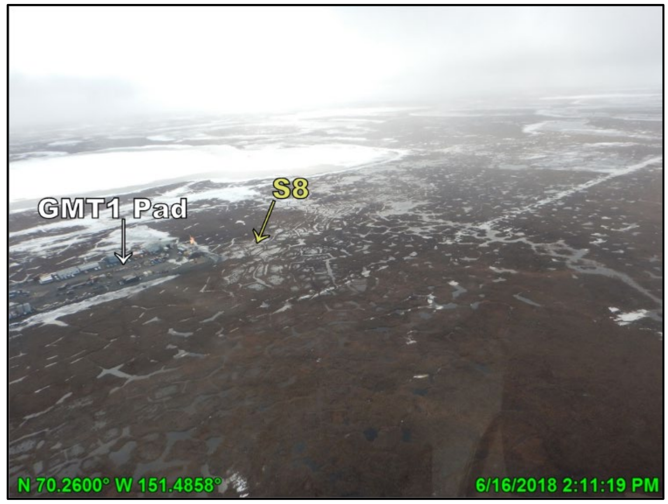


Photo 4.32: S8, looking southwest; June 16, 2018

5 FLOOD FREQUENCY ANALYSIS

Table 5.1 presents the Tinmiaqsiugvik Bridge 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 Tinmiaqsiugvik Bridge peak discharge of 2,600 cfs has a recurrence interval of less than 2 years based on the USGS results and around 2-years based on the URS results.

Table 5.1: Tinmiaqsiugvik Bridge Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	URS Peak Discharge [1]	USGS Peak Discharge [2]
%	years	cfs	cfs
50	2	2,330	3,600
20	5	3,700	5,400
10	10	4,800	6,500
4	25	6,200	7,900
2	50	7,500	8,900
1	100	8,800	9,900
0.5	200	10,300	10,900

Notes:
1. URS 2003
2. USGS 2003

Table 5.2 presents the Crea Bridge and Barely Creek culvert battery flood frequency analysis results from the USGS peak discharge regional regression analysis (USGS 2003). This year's Crea Bridge peak discharge of 100 cfs and Barely Creek culvert battery peak discharge of 17 cfs have recurrence intervals of 2.2 years and less than 2 years, respectively.

Table 5.2: Crea Bridge and Barely Creek Culvert Battery Flood Frequency Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge [1]	
		Crea Bridge	Barely Creek Culvert Battery
%	years	cfs	cfs
50	2	100	40
20	5	160	70
10	10	200	90
4	25	260	120
2	50	290	140
1	100	330	160
0.5	200	370	180

Notes:
1. USGS 2003

The recurrence intervals should be considered with respect to conditions at the time of peak discharge and associated quality rating of the reported discharge. Detailed USGS regression analysis results are provided in Appendix D.

6 DRAINAGE STRUCTURE PERFOMANCE EVALUATION

No performance issues were identified at any culverts conveying flow along the GMT1 access road. Temporary ponded water was present in drainages at several locations along the access road but was attributed to ice roads and snow along the road embankment. Once conveyance paths were established through the ice roads and drifted snow, the culverts all performed as designed and natural drainage patterns were maintained.

Culvert bladders were observed to be frozen and impeding flow in some culverts along the GMT1 access road. Once bladders were either removed or had melted loose, the culverts performed as designed. Otherwise, no culvert maintenance, repair, upgrade, setting adjustments, and/or replacements are recommended based on ground assessments and aerial observations.

The drifted snow observed beneath the Tinmiaqsiugvik Bridge had a notable impact to water levels during spring breakup. As described in section 4.1, aerial observations suggest floodwater was backed up behind the bridge before tunneling through the drifted snow. Backwater receded once drainage through the bridge opening was established, however, the drifted snow beneath the bridge remained intact throughout breakup, concentrating flow along the east abutment (Photo 6.1 and Photo 6.2).

Photo 6.1: Drifted snow remaining intact and flow concentrated along the east abutment at the Tinmiaqsiugvik Bridge, looking west; June 14, 2018

Photo 6.2: Drifted snow remaining under the Tinmiaqsiugvik Bridge, looking west; June 2, 2018

7 POST-BREAKUP CONDITIONS ASSESSMENT

Post-breakup conditions assessment of Tinmiaqsiugvik Bridge and Crea Bridge abutments and bank conditions on each side of the GMT1 access road, Barely Creek culvert battery inlets and outlets, GMT1 access road culverts, and the GMT1 pad was conducted during the summer. At the Tinmiaqsiugvik Bridge, notable bank erosion was observed at the east abutment and along the east bank immediately downstream of the bridge. Summer pictures indicate thermo-erosional niching and subsequent river bank block failure have occurred. This is caused when moving water undercuts an ice-rich bank through thermal and mechanical processes forming a "niche". At a point the niche is deep enough that the overhanging block collapses and further erodes at the toe of the bank. Downstream of the bridge abutment, the bank has migrated to the pipeline VSM which is now situated in the channel (Photo 7.1 and Photo 7.2). CPAI has spoken with the USACE in early November 2018 regarding the east bank on the Tinmiaqsiugvik Bridge and will be submitting permit applications for civil work which will address erosion by adding an additional VSM for pipeline support. This work is planned to be completed in the winter of 2019 and the area will continue to be monitored during the breakup event in the spring of 2019.

No displaced gravel fill attributed with spring breakup flooding was observed along the road embankment, around culvert inlets and outlets, or around bridge abutments. Other than at the Tinmiaqsiugvik Bridge, there were no signs of sloughing or undermining at drainage structures and no channel changes were observed at the crossings. Additional photo documentation of post-breakup conditions is provided in Appendix E.

Photo 7.1: Erosion along east bank of Tinmiaqsiugvik River, looking northeast; July 2018

Photo 7.2: Pipeline VSM in channel, east bank Tinmiaqsiugvik Bridge, looking north (downstream); July 2018

8 ICE ROAD CROSSINGS BREAKUP

Ice roads are constructed annually for ground transportation of supplies and equipment to Alpine facilities. Aerial surveys were conducted during spring breakup to observe and document the progression of melting and degradation of the ice road crossings. To facilitate melt and the progression of breakup flooding, ice road crossings are mechanically slotted at the conclusion of the winter season.

In general, ice road crossings melted at a similar rate as channel ice. Aerial surveys showed that slotting was completed and initial floodwaters in main channels were passing freely through the ice road crossings. The majority of the crossings were submerged during the peak of flooding. When flooding receded, the ice road crossings and channel ice had cleared at most locations. Photos of all monitored ice road crossings are presented in Appendix E.

9 REFERENCES

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

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

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

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

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

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

-------- 2009. Greater Moose's Tooth 1 (GMT1) Alpine Satellite Project 2009 Spring Breakup Hydrologic Assessment. December 2009. Prepared for ConocoPhillips Alaska, Inc.

-------- 2010. Fish Creek Basin Alpine Satellite Project 2010 Spring Breakup Hydrologic Assessment. December 2010. Prepared for ConocoPhillips Alaska, Inc.

-------- 2011. Fish Creek Basin Spring Breakup 2011 Hydrologic Assessment. November 2011. Prepared for ConocoPhillips Alaska, Inc.

-------- 2013. 2013 Fish Creek Basin Spring Breakup Monitoring and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

-------- 2014. 2014 Fish Creek Basin Spring Breakup Monitoring and Hydrological Assessment. December 2014. Prepared for ConocoPhillips Alaska, Inc.

-------- 2017. 2017 GMT1 Spring Breakup and Summer Monitoring and Hydrological Assessment. December 2017. Prepared for ConocoPhillips Alaska, Inc.

-------- 2018. 2018 GMT1 Spring Breakup Culvert Monitoring Report. July 2018. Prepared for ConocoPhillips Alaska, Inc.

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

National Oceanic and Atmospheric Administration (NOAA). Website access August 2018. (https://www.noaa.gov/weather).

UMIAQ LLC, Inc. 2017. As-built survey. GMT1 culverts. October 2017. Prepared for ConocoPhillips Alaska, Inc.

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

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

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

U.S. Geological Survey (USGS). Bodhaine G. L. 1968. Measurement of Peak Discharge at Culverts by Indirect Methods. Techniques of Water Resources Investigation of the United States Geological Survey, U.S. Geological Survey, Washington.

-------- 1982. Measurement and Computation of Streamflow, Vols. 1 and 2. S.E. Rantz and others. Water Supply Paper 2175.

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

APPENDIX A GAGE LOCATIONS & VERTICAL CONTROL

Gage Assembly	Gage Assembly Location		Associated Vertical Control	Vertical Control Elevation (ft BPMSL)	Vertical Control Location	
	Latitude (NAD83)	Longitude (NAD83)			Latitude (NAD83)	Longitude (NAD83)
S2-A[1]	70.3048	-151.2198	MON-32	27.546	70.3022	-151.2331
S2-B[1]	70.3041	-151.2199				
S3-A[1]	70.2961	-151.2368				
S3-B[1]	70.2959	-151.2350				
S4-A[1]	70.2817	-151.2922	MON-37	25.395	70.2801	-151.3018
S4-C[1]	70.2804	-151.2955				
S5-A[1]	70.2804	-151.3306	PBM-39	25.247	70.2792	-151.3325
S5-C[1]	70.2792	-151.3302				
S6-A[1]	70.2772	-151.3686	MON-40	28.267	70.2764	-151.3639
S6-B[1]	70.2765	-151.3677				
S7-A[1]	70.2723	-151.3929	MON-41	29.870	70.2709	-151.3948
S7-B[1]	70.2711	-151.3924				
S8-A[1]	70.2543	-151.4943	PBM-11	42.481	70.2559	-151.4896
UB6.7-A[1]	70.2856	-151.2626	PBM-35	15.957	70.2832	-151.2620
UB6.7-B[1]	70.2855	-151.2627				
UB6.7-C	70.2852	-151.2632				
UB6.7-D*	70.2852	-151.2633				
UB6.9-A[1]	70.2834	-151.2578				
UB6.9-B[1]	70.2830	-151.2571				

Notes:
*Historical location
[1]. Pressure transducer

APPENDIX B 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 a Solinst Barologger® barometric pressure logger. A correction of barometric pressure was obtained from the Solinst Levelogger installed at the Tinmiaqsiugvik Bridge.

The PTs were tested before field mobilization. The PTs were configured using Solinst Levelogger® v4.0.3 (for both the Solinst Leveloggers and Barologgers) software prior to placement in the field. Absolute pressure was set to zero. The PT sensor was surveyed during setup to establish a vertical datum using local control.

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 WSE 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 WSE calculations because of the limited range in temperature and observed water depths.

APPENDIX C VELOCITY & DISCHARGE METHODS, SITE SPECIFIC DATA, PLANS, & PROFILES

C.1 METHODS

Measured Velocity & Discharge

A. STANDARD USGS MIDSECTION TECHNIQUES

Flow depth and velocity measurements were taken at the Crea Bridge using an 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.

B. USGS VELOCITY/AREA TECHNIQUE

Standard USGS velocity/area techniques (USGS 1968) were used to measure flow depth and velocity to determine discharge at the culvert outlets. Flow depth and velocity were measured using an 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 culvert geometry.

Indirect Velocity & Discharge

A. CULVERTS

Bentley CulvertMaster® software was used to calculate spring and summer velocity through the Barely Creek culvert battery and spring velocity and discharge through the additional GMT1 road culverts. Barely Creek spring and summer discharge was calculated using the normal depth method and a cross-section profiled during a 2011 direct discharge measurement performed downstream of the road. Velocities through each Barely Creek culvert were calculated using distributed flow based on the flow distribution at the time of direct measurement. Timing and magnitude of velocity and discharge through the culverts were determined based on recorded stage on both sides of the road prism. Peak velocity and discharge results were evaluated against visual assessment of performance, when available. Velocity and discharge through the culverts assumes ice-free open-water conditions and were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from UMIAQ as-built surveys (UMIAQ 2017)
- Culvert Manning's roughness coefficients (0.013 for smooth steel)
- Culvert invert elevations (surveyed by UMIAQ summer 2017)
- For Barely Creek, spring and summer culvert upstream and downstream invert elevations (surveyed by Michael Baker spring 2017 and UMIAQ summer 2017)

B. NORMAL DEPTH

The Normal Depth method (Chow 1959) was used to calculate peak velocity and discharge at the Tinmiaqsiugvik Bridge and Crea Bridge using channel cross-section geometry and stage differential between gage sites as an estimate for the energy gradient. Velocity was calculated as a function of discharge and cross-sectional flow area and represents an average for the cross-section.

Cross-sectional geometry for the Tinmiaqsiugvik Bridge and Crea Bridge was surveyed by Michael Baker during spring breakup and summer 2017. Stage and energy gradient data were obtained from observations, gage data, and PT data.

C.2 SITE SPECIFIC DATA, PLANS, & PROFILES

Tinmiaqsiugvik Bridge

A. SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Discharge was calculated using the Normal Depth method. The June 3, 2017 cross-section measurement was used for analysis. During spring breakup, flow was impeded by drifted snow under the bridge. Meltwater eventually tunneled a path underneath the drifted snow. The energy gradient used for both seasons was estimated from WSEs at the UB6.7 and UB6.9 gage stations. The spring indirect calculations Manning's n values used for indirect calculations were 0.024 for the left overbank related to the presence of bedfast ice, 0.038 for the main channel, and 0.073 for the right overbank related to heavy brush. The summer indirect discharge Manning's n values were 0.035 for the right and left portions of the main channel, and 0.03 for the thalweg.

B. PLAN & CROSS-SECTION PROFILE

ConocoPhillips Alaska

Feet
0 125 250

Date:	11/20/2018	Project:	158968
Drawn:	BTG	File:	2017_GMT1_8x11L_TINMIAQSIUGVIK.mxd
Checked:	GCY	Scale:	1 in = 250 feet

Legend

Gage Location

Road

2017 Cross Section Alignment

Imagery Source: ConocoPhillips Alaska, 2015

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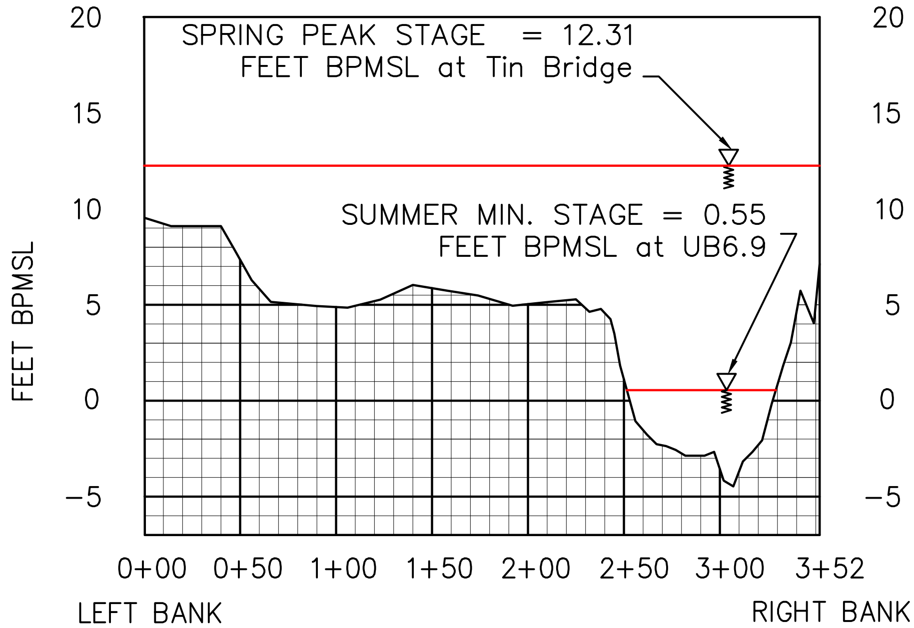
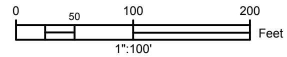
2018 SPRING BREAKUP
TINMIAQSIUGVIK RIVER
PLAN

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, PBM-35.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2017 BY MICHAEL BAKER INTL.



1 GMT1 CROSSING – TINMIAQSIUGVIK BRIDGE CROSS-SECTION



ConocoPhillips Alaska, Inc.

DATE:	11/20/2018	PROJECT:	158968
DRAWN:	GCY	FILE:	TINMIAQSIUGVIK X-SECTION.DWG
CHECKED:	CSL	SCALE:	AS SHOWN

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2018 SPRING BREAKUP
TINMIAQSIUGVIK RIVER
PROFILE

(SHEET 2 OF 2)

Crea Bridge

A. SPRING BREAKUP MEASURED VELOCITY & DISCHARGE

Date:	6/8/2018	**Time:**	12:00 PM	**Method:**	USGS cross-section	**Measurement Rating:**
Loc:	North side of Crea Bridge	**Crew:**	GCY, SAO	**Observed Depth:**	Water Surface	Fair
Lat:	N 70.2800°	**Long:**	W 151.3300°	**Equip:**	Sontek Flow Tracker	

Station (ft)	Measured Bottom Elevation (ft BPMSL)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+02.0	17.02	-	-	-	-	Right edge of water
0+04.0	16.72	0.00	2	0.60	0.00	
0+06.0	16.52	0.01	2	1.00	0.01	Willow and grass influenced
0+08.0	16.42	0.06	2	1.20	0.08	Willow and grass influenced
0+10.0	16.12	0.00	1.5	1.35	0.00	Willow and grass influenced
0+11.0	15.92	1.00	1	1.10	1.10	Willow and grass influenced
0+12.0	15.62	1.87	1	1.40	2.61	
0+13.0	15.42	2.01	1	1.60	3.21	
0+14.0	15.12	1.91	1	1.90	3.63	
0+15.0	14.82	1.74	0.75	1.65	2.87	
0+15.5	14.42	1.71	0.5	1.30	2.22	Thalweg
0+16.0	14.42	1.54	0.5	1.30	2.00	Thalweg
0+16.5	14.82	1.39	0.5	1.10	1.53	
0+17.0	15.02	1.26	0.75	1.50	1.89	
0+18.0	15.62	1.09	1	1.40	1.53	
0+19.0	16.02	0.46	1	1.00	0.46	
0+20.0	16.52	0.20	1	0.50	0.10	
0+21.0	16.42	0.01	1.5	0.90	0.01	Willows
0+23.0	16.82	0.15	4	0.80	0.12	Willows
0+29.0	17.02	-	-	-	-	Left edge of water/Willows

Notes:
1. Measurement performed downstream of Crea Bridge.

Total Width (ft)	Average Channel Bottom Elevation (ft BPMSL)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
27	15.71	0.91	-	21.6	23.4

Date:	6/16/2018	**Time:**	11:30 AM	**Method:**	USGS cross-section	**Measurement Rating:**
Loc:	South side of Crea Bridge	**Crew:**	SAO, WAB, & GCY	**Observed Depth:**	Water Surface	Fair
Lat:	N 70.2797°	**Long:**	W 151.3298°	**Equip:**	Wading Rod, Hach Meter	

Station (ft)	Measured Bottom Elevation (ft BPMSL)	Velocity (ft/s)	Section Width (ft)	Area (ft²)	Discharge (ft³/s)	Note
0+00.0	14.53	0.43	1.25	4.38	1.90	Left edge of water/W. Abutment
0+02.5	15.83	1.01	2.5	5.50	5.56	
0+05.0	16.23	0.45	2.5	4.50	2.04	Willows
0+07.5	16.33	0.22	2.5	4.25	0.92	Eddy
0+10.0	16.23	0.30	2.5	4.50	1.37	Grasses
0+12.5	15.93	0.42	2.5	5.25	2.21	Grasses
0+15.0	15.73	0.23	2.5	5.75	1.30	Grasses
0+17.5	15.63	1.53	2.5	6.00	9.18	
0+20.0	15.43	1.85	2.5	6.50	12.05	
0+22.5	15.23	1.80	2	5.60	10.08	
0+24.0	14.73	1.69	1.25	4.13	6.99	Thalweg
0+25.0	15.43	1.82	1.75	4.55	8.30	
0+27.5	15.63	1.09	2.5	6.00	6.56	
0+30.0	16.13	0.28	2.5	4.75	1.35	Eddy
0+32.5	16.43	0.22	2.5	4.00	0.88	
0+35.0	16.33	0.15	2.5	4.25	0.64	Willows
0+37.5	16.43	0.10	2.5	4.00	0.41	
0+40.0	15.83	0.09	2.5	5.50	0.50	
0+42.5	15.13	1.23	2.5	7.25	8.92	Scour hole right abutment
0+45.0	15.33	1.03	1.25	3.38	3.48	Right edge of water

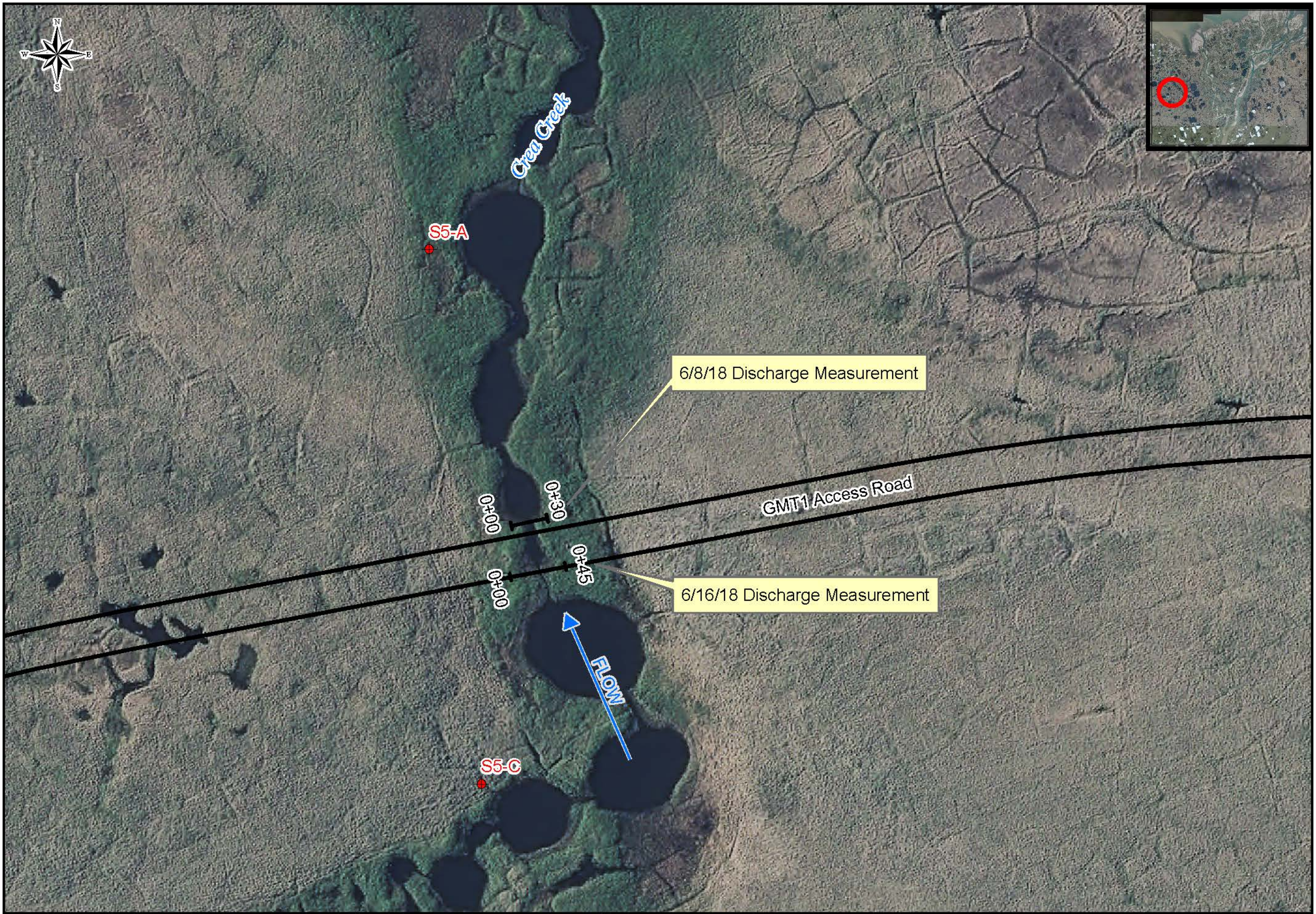
Notes:
1. Measurement performed upstream of Crea Bridge.

Total Width (ft)	Average Channel Bottom Elevation (ft BPMSL)	Average Velocity (ft/s)	-	Total Area (ft²)	Total Discharge (ft³/s)
45.0	15.73	0.80	-	100.0	84.6

B. SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Discharge was calculated using the Normal Depth method. The June 16 direct discharge measurement was performed during open channel conditions, so the spring cross-section was used for spring and summer calculations. The energy gradient used for both seasons was estimated from WSEs at the S5-C and S5-A gage stations. The spring indirect calculations Manning's n values were 0.150 for the left overbank, 0.035 for the main channel, and 0.100 for the right overbank. Overbank values are high because of heavy willows and brush. Roughness values were calibrated based on the spring direct measurement.

C. PLAN & CROSS-SECTION PROFILE



ConocoPhillips Alaska	Feet 0 50 100		
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Checked: CSL	Scale: 1 in = 125 feet		

Legend

- Gage Location
- Road
- 2017 Cross Section Alignment

Imagery Source: ConocoPhillips Alaska, 2015

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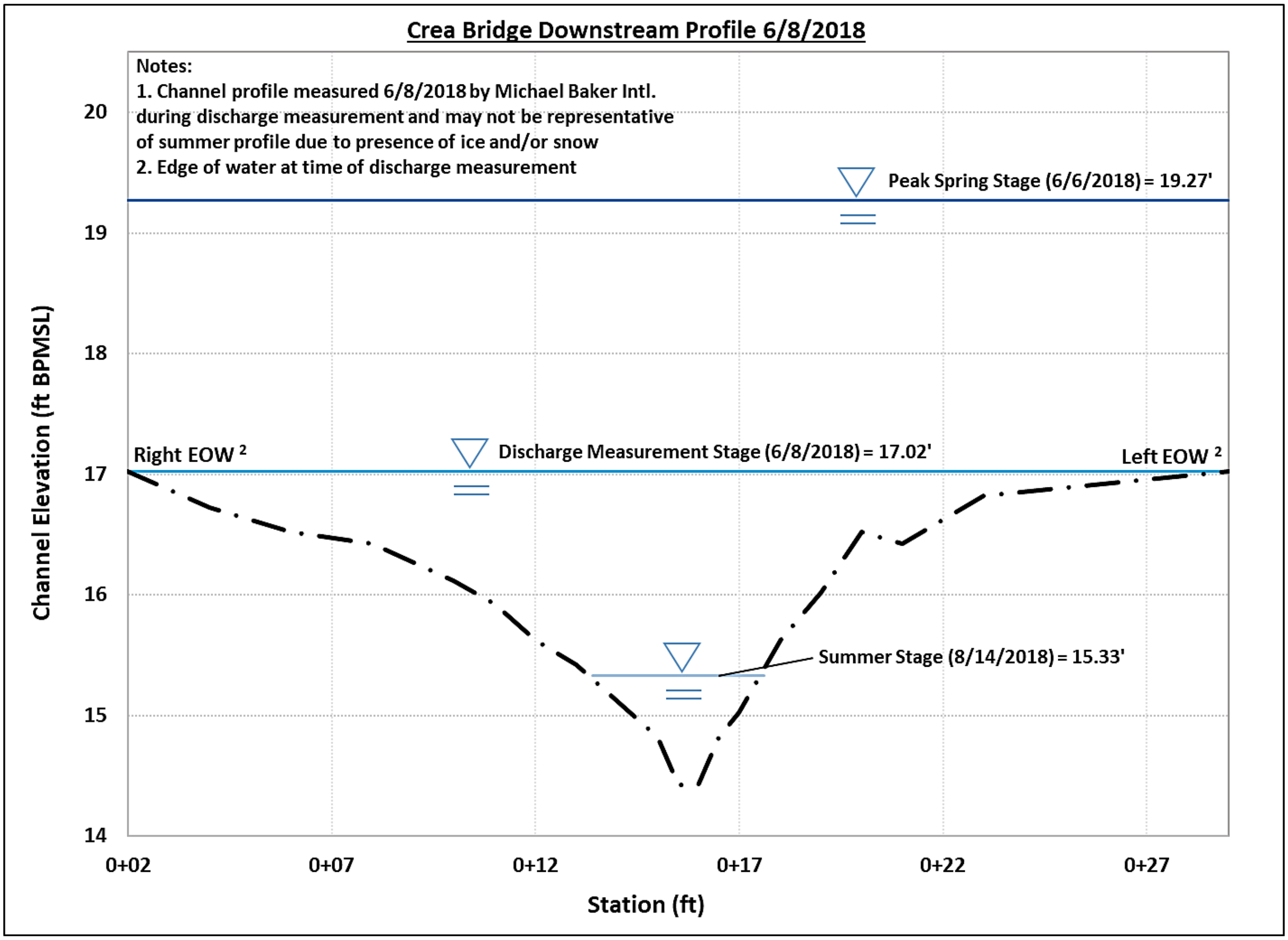
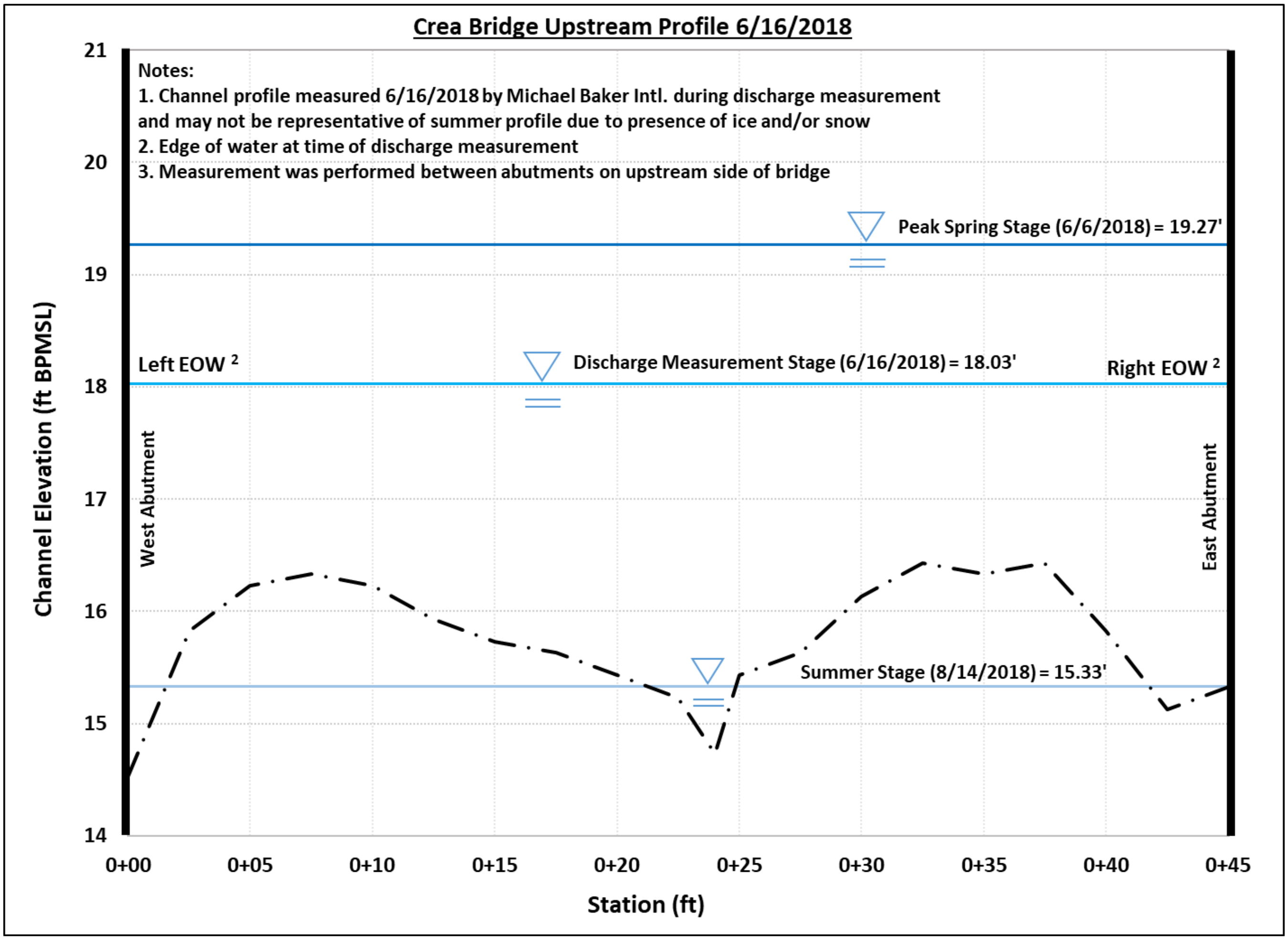
2018 SPRING BREAKUP
CREA CREEK
PLAN

(SHEET 1)


Crea Bridge Downstream Profile 6/8/2018
Notes:
1. Channel profile measured 6/8/2018 by Michael Baker Intl. during discharge measurement and may not be representative of summer profile due to presence of ice and/or snow
2. Edge of water at time of discharge measurement
Peak Spring Stage (6/6/2018) = 19.27'
Right EOW 2
Discharge Measurement Stage (6/8/2018) = 17.02'
Left EOW 2
Summer Stage (8/14/2018) = 15.33'
Channel Elevation (ft BPMSL)
20
19
18
17
16
15
14
0+02
0+07
0+12
0+17
0+22
0+27
Station (ft)


Crea Bridge Upstream Profile 6/16/2018
Notes:
1. Channel profile measured 6/16/2018 by Michael Baker Intl. during discharge measurement and may not be representative of summer profile due to presence of ice and/or snow
2. Edge of water at time of discharge measurement
3. Measurement was performed between abutments on upstream side of bridge
Peak Spring Stage (6/6/2018) = 19.27'
Left EOW 2
Discharge Measurement Stage (6/16/2018) = 18.03'
Right EOW 2
West Abutment
East Abutment
Summer Stage (8/14/2018) = 15.33'
Channel Elevation (ft BPMSL)
21
20
19
18
17
16
15
14
0+00
0+05
0+10
0+15
0+20
0+25
0+30
0+35
0+40
0+45
Station (ft)

Barely Creek Culvert Battery

A. SPRING BREAKUP MEASURED VELOCITY

Culvert	Measurement Date & Time	Culvert Inside Diameter (ft)	Flow Area (ft^2)	Measured Depth of Flow (ft)	Measured Velocity (fps)	Discharge (cfs)	Total Discharge (cfs)
GMT1-42	6/4/2018 6:1pm	4.80	4.83	1.50	0.57	2.77	17.0
GMT1-43	6/4/2018 6:08pm	2.80	4.95	2.10	1.94	9.61	
GMT1-44	6/4/2018 6:05pm	2.80	2.38	1.15	1.97	4.69	
GMT1-42	6/8/2018 11:00am	4.80	7.61	2.10	0.61	4.64	10.1
GMT1-43	6/8/2018 11:00am	2.80	5.19	2.20	0.57	2.96	
GMT1-44	6/8/2018 11:00am	2.80	3.91	1.70	0.63	2.45	
GMT1-42	6/16/2018 10:31am	4.80	14.56	3.60	0.62	8.98	13.3
GMT1-43	6/16/2018 10:28am	2.80	4.18	1.80	0.62	2.58	
GMT1-44	6/16/2018 10:26am	2.80	2.80	1.30	0.63	1.76	

B. SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Discharge was calculated using the Normal Depth method based on an open-channel cross-section surveyed in 2011. The energy gradient used for both seasons was estimated from WSEs at the S4-C and S4-A gage stations. The spring indirect calculations Manning's n values were 0.06 for the left overbank and 0.08 for the right overbank. Overbank values are high because of heavy willows and brush.

C. PLAN & CROSS-SECTION PROFILE

ConocoPhillips
Alaska

Feet
0 62.5 125

Date:	11/20/2018	Project:	158968
Drawn:	BTG	File:	2017_GMT1_8x11L_BARELY_CREEK.mxd
Checked:	GCY	Scale:	1 in = 125 feet

Legend

Gage Location
Road
2011 Cross Section Alignment

Imagery Source: ConocoPhillips Alaska, 2015

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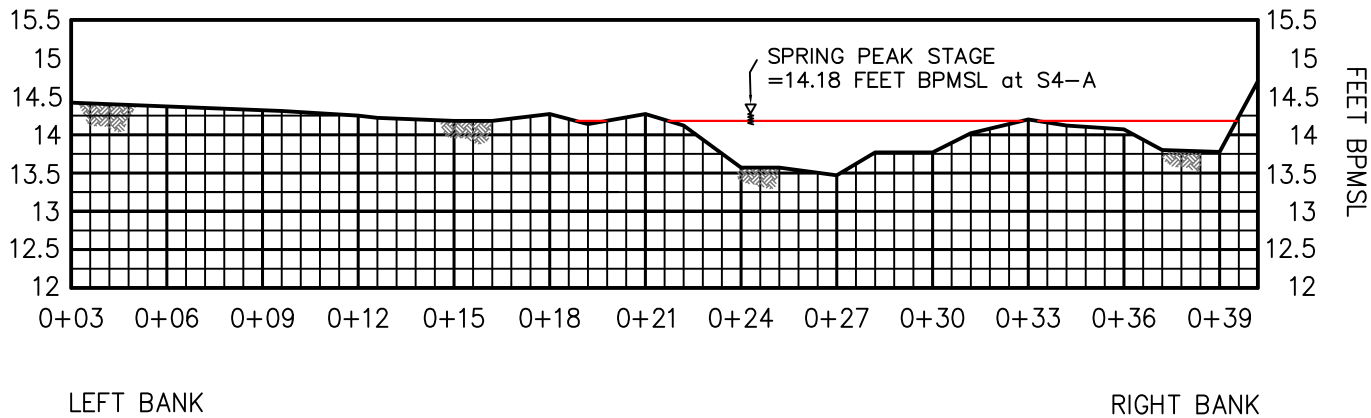
2018 SPRING BREAKUP
BARELY CREEK
PLAN

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, MON-37.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED JUNE 2011 BY MICHAEL BAKER INTL.
3. PROFILE IS APPROXIMATELY 175 FEET DOWNSTREAM OF CULVERT BATTERY
4. MINIMUM SUMMER STAGE = 11.85 FEET BPMSL at S4-A



1 GMT1 CROSSING – BARELY CREEK CROSS-SECTION

0 9 18
HORIZONTAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	11/20/18	PROJECT:	158968
DRAWN:	GCY	FILE:	BARELY X-SECTION.DWG
CHECKED:	CSL	SCALE:	AS SHOWN

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2018 SPRING BREAKUP
BARELY CREEK
PROFILE

(SHEET 2 OF 2)

Culverts

A. SPRING BREAKUP MEASURED VELOCITY & DISCHARGE

Culvert	Measurement Date & Time	Culvert Inside Diameter (ft)	Flow Area (ft^2)	Measured Depth of Flow (ft)	Measured Velocity (fps)	Discharge (cfs)
GMT1-07	6/4/2018 5:35pm	1.91	1.52	1.00	2.33	3.54
GMT1-08	6/4/2018 5:31pm	1.80	1.27	0.90	0.17	0.22
GMT1-09	6/4/2018 5:29pm	1.80	0.92	0.70	0.05	0.04
GMT1-19	6/4/2018 6:29pm	1.91	0.44	0.40	3.85	1.68
GMT1-42	6/4/2018 6:11pm	4.80	4.83	1.50	0.57	2.77
GMT1-43	6/4/2018 6:08pm	2.80	4.95	2.10	1.94	9.61
GMT1-44	6/4/2018 6:05pm	2.80	2.38	1.15	1.97	4.69
GMT1-02	6/8/2018 5:01pm	1.91	1.14	0.8	1.71	1.95
GMT1-03	6/8/2018 4:44pm	1.83		Perched		1.22
GMT1-07	6/8/2018 4:26pm	1.91	0.77	0.60	0.56	0.43
GMT1-08	6/8/2018 4:21pm	1.80	0.74	0.60	0.58	0.43
GMT1-09	6/8/2018 4:16pm	1.80	0.42	0.40	0.83	0.35
GMT1-18	6/8/2018 4:02pm	1.91	0.95	0.70	1.30	1.24
GMT1-42	6/8/2018 11:00am	4.80	7.61	2.10	0.61	4.64
GMT1-43	6/8/2018 11:00am	2.80	5.19	2.20	0.57	2.96
GMT1-44	6/8/2018 11:00am	2.80	3.91	1.70	0.63	2.45
GMT1-52	6/8/2018 10:23am	1.80	0.42	0.40	1.92	0.81
GMT1-52	6/9/2018 11:20am	1.80	1.09	0.80	0.63	0.69
GMT1-64	6/9/2018 11:20am	2.80	2.25	1.10	1.38	3.09
GMT1-65	6/9/2018 11:39am	2.80	3.08	1.40	1.41	4.35
GMT1-66	6/9/2018 11:40am	2.80	2.80	1.30	0.88	2.45
GMT1-67	6/9/2018 11:53am	2.80	4.18	1.80	1.52	6.37
GMT1-42	6/16/2018 10:31am	4.80	14.56	3.60	0.62	8.98
GMT1-43	6/16/2018 10:28am	2.80	4.18	1.80	0.62	2.58
GMT1-44	6/16/2018 10:26am	2.80	2.80	1.30	0.63	1.76
GMT1-64	6/16/2018 9:47am	2.80	1.97	1.00	1.29	2.55
GMT1-65	6/16/2018 11:39am	2.80	2.52	1.20	2.88	7.26
GMT1-66	6/16/2018 9:38am	2.80	2.52	1.20	0.66	1.66
GMT1-67	6/16/2018 9:30am	2.80	3.08	1.40	2.07	6.38

APPENDIX D 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 the Tinmiaqsiugvik Bridge, Crea Bridge, and Barely Creek culvert battery using the USGS computer program that automates site-specific estimates of accuracy (USGS 2003).

Table E.1: Tinmiaqsiugvik Bridge Peak Discharge Regression Analysis Results

Percent Chance Exceedance	Recurrence Interval	USGS Peak Discharge	Standard Error of Prediction		Confidence Limits		Equivalent Years of Record (EYR)
%	years	cfs	+%	-%	5%	95%	
50	2	3,600	61.5	-38.1	1,610	8,000	1.0
20	5	5,400	58.5	-36.9	2,490	11,600	1.2
10	10	6,500	58.1	-36.8	3,040	14,100	1.5
4	25	7,900	58.7	-37.0	3,670	17,200	1.9
2	50	8,900	59.7	-37.4	4,090	19,500	2.2
1	100	9,900	61.0	-37.9	4,480	22,000	2.5
0.5	200	10,900	62.7	-38.5	4,820	24,500	2.7

Table E.2: Crea Bridge 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	100	63.0	-38.6	43	219	1.6
20	5	160	59.9	-37.5	73	349	1.8
10	10	200	59.7	-37.4	92	440	2.3
4	25	260	60.4	-37.7	116	561	2.9
2	50	290	61.5	-38.1	132	656	3.4
1	100	330	63.0	-38.6	148	755	3.7
0.5	200	370	64.8	-39.3	162	858	4.0

Table E.3: Barely Creek Culvert Battery 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	40	64.1	-39.1	19	100	1.7
20	5	70	61.1	-37.9	33	162	1.9
10	10	90	60.9	-37.8	42	206	2.4
4	25	120	61.7	-38.1	53	266	3.1
2	50	140	62.8	-38.6	61	313	3.6
1	100	160	64.4	-39.2	69	362	4.0
0.5	200	180	66.3	-39.9	76	413	4.3

APPENDIX E ADDITIONAL PHOTOGRAPHS

E.1 POST-BREAKUP CONDITIONS ASSESSMENT

A. BARELY CREEK

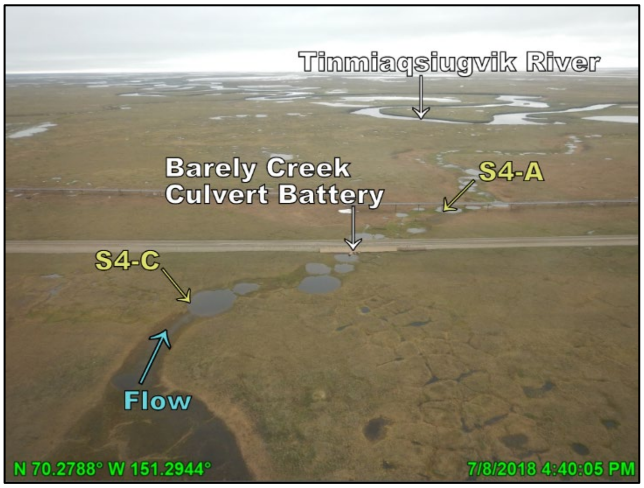

Photo D.1: Barely Creek culvert battery, looking north (downstream); July 8, 2018

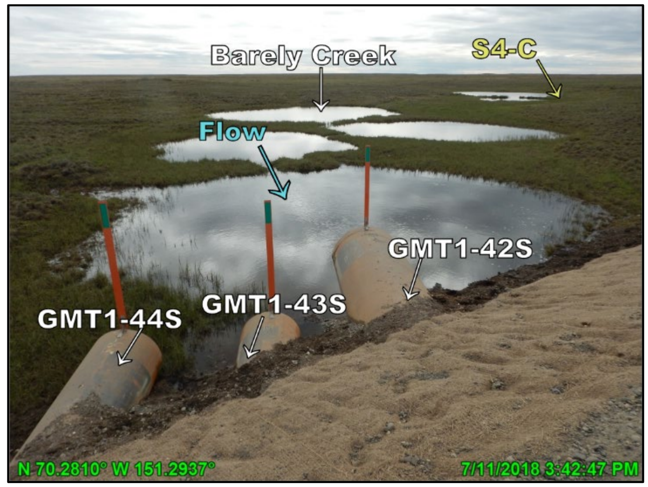

Photo D.2: Barely Creek culvert battery inlet, looking southwest (upstream); July 11, 2018

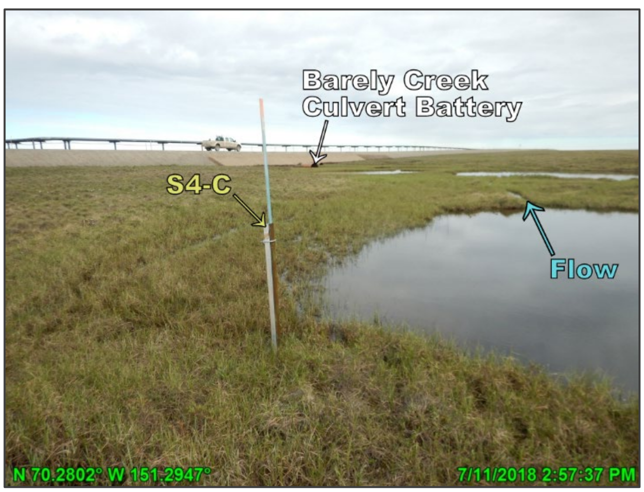

Photo D.3: Gage S4-C, looking northeast; July 11, 2018

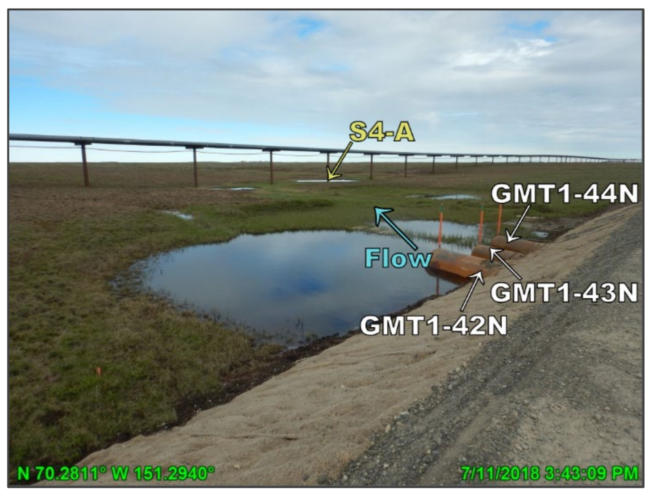

Photo D.4: Barely Creek culvert battery outlet, looking northeast (downstream); July 11, 2018

B. CREA CREEK

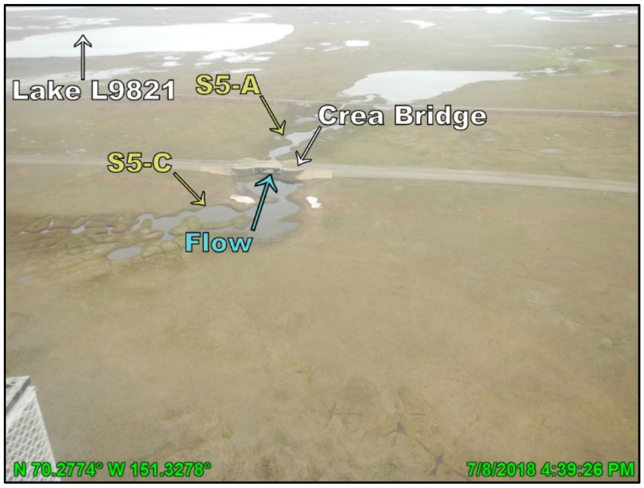

Photo D.5: Crea Creek, looking north (downstream); July 8, 2018

Photo D.6: Crea Creek, looking west; July 11, 2018

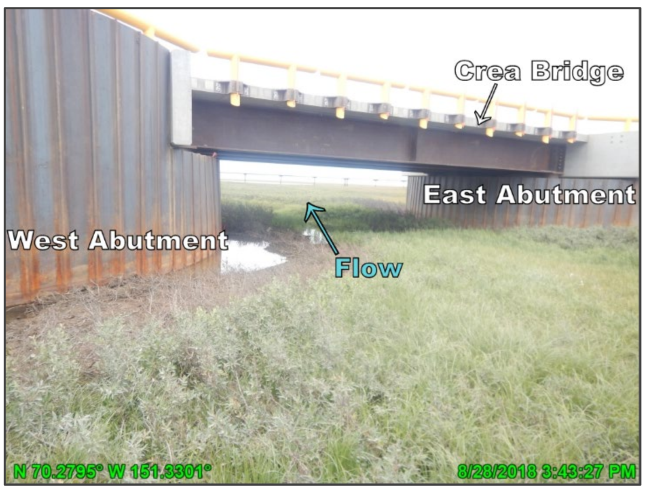

Photo D.7: Crea Bridge, looking northeast (downstream); August 28, 2018

Photo D.8: Flow under Crea Bridge, looking south (upstream); August 28, 2018

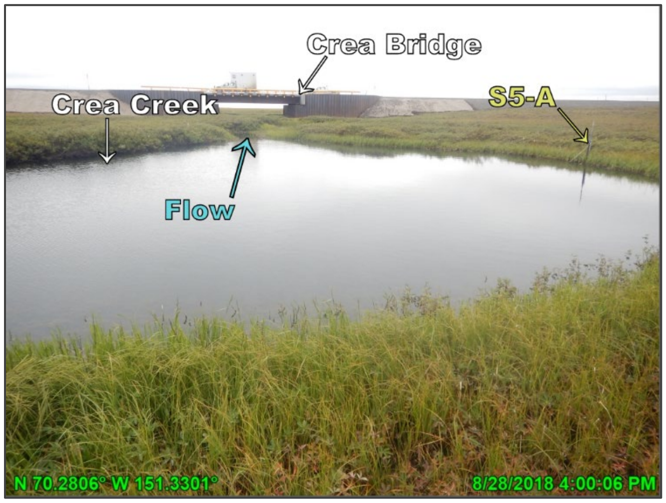

Photo D.9: Crea Bridge, looking south (upstream); August 28, 2018

C. TINMIAQSIUGVIK RIVER

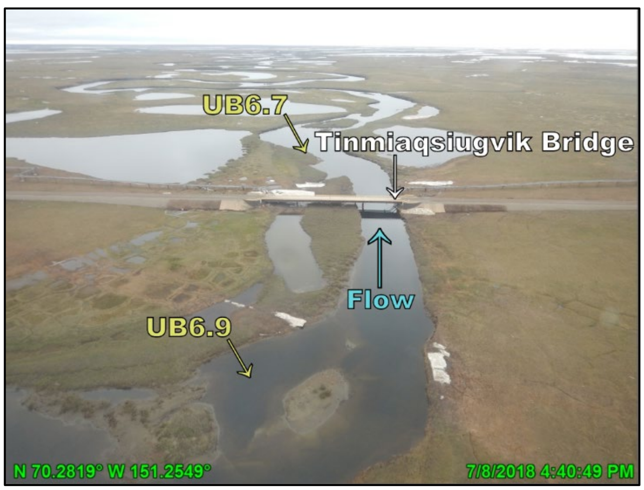

Photo D.10: Tinmiaqsiugvik River, looking north (downstream); July 8, 2018

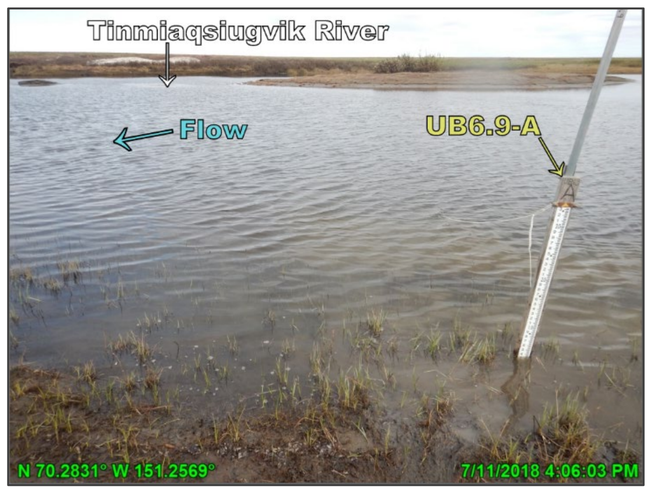

Photo D.11: Tinmiaqsiugvik River at gage station 6.9-A, looking east; July 11, 2018

Photo D.12: Tinmiaqsiugvik Bridge, looking southeast (upstream); August 28, 2018

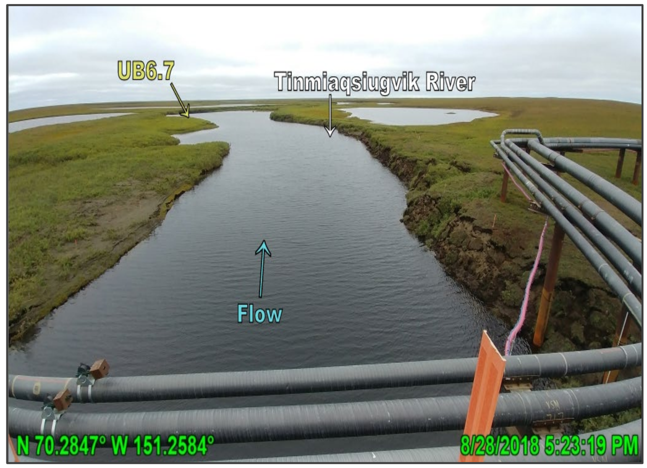

Photo D.13: Tinmiaqsiugvik River, looking north; August 28, 2018

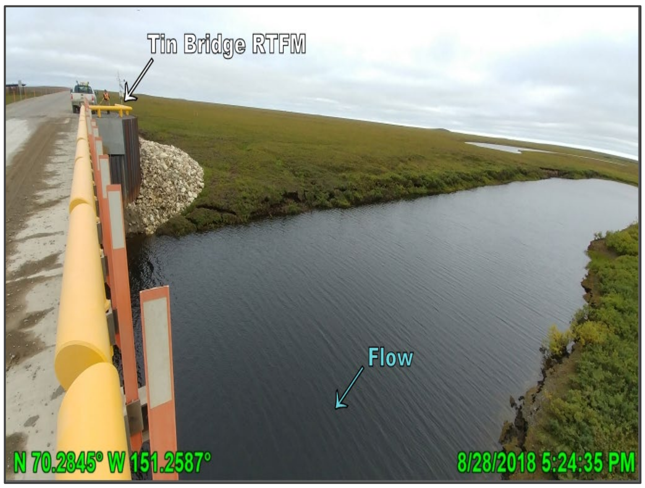

Photo D.14: Tinmiaqsiugvik River, looking southeast (upstream); August 28, 2018

Photo D.15: Tinmiaqsiugvik River, looking west; August 31, 2018

Photo D.16: Tinmiaqsiugvik River from Tinmiaqsiugvik Bridge, looking southwest; August 31, 2018

D. S2 & S3 CULVERTS

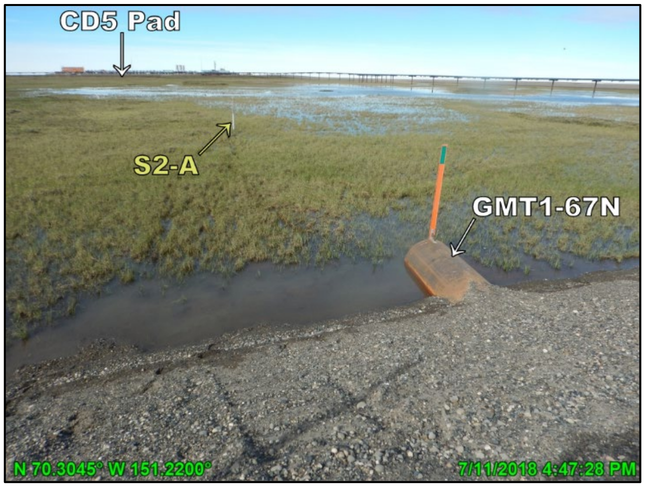

Photo D.17: S2 gages and culverts, looking north; July 11, 2018

Photo D.18: S2 gages and culverts, looking east; July 11, 2018

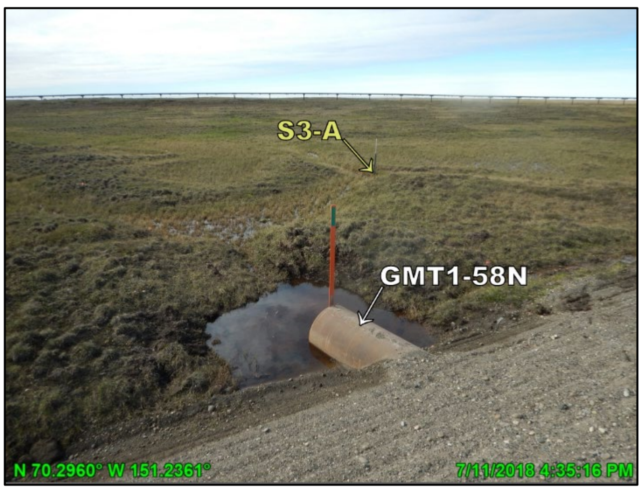

Photo D.19: S3 gages and culverts, looking north; July 11, 2018

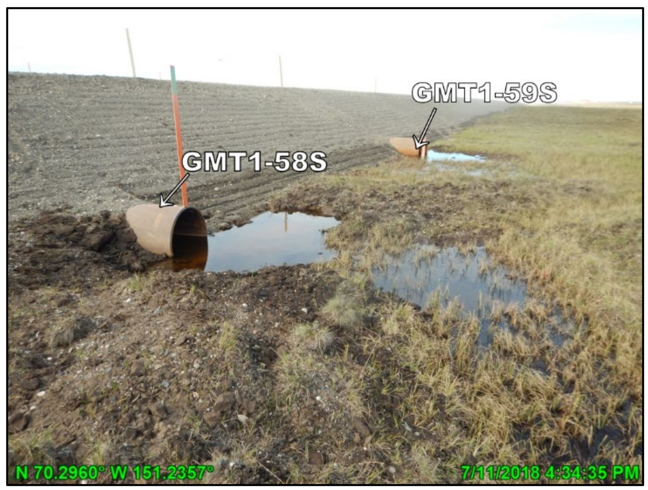

Photo D.20: S3 culverts GMT1-58 through 59, looking north; July 11, 2018

E. S6 CULVERTS

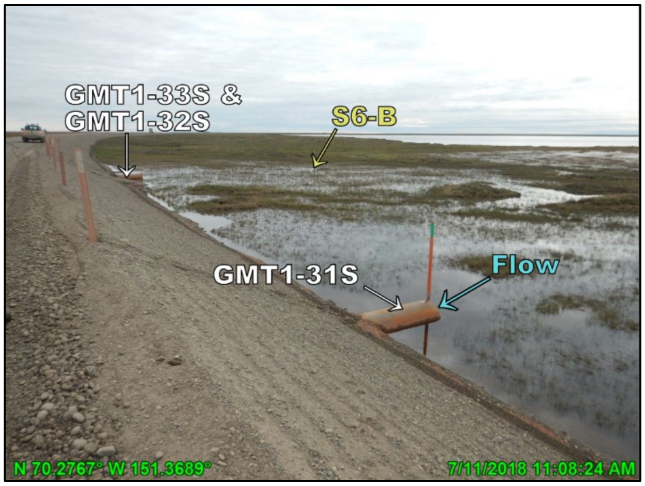

Photo D.21: S6 gages and culverts, looking southeast; July 11, 2018

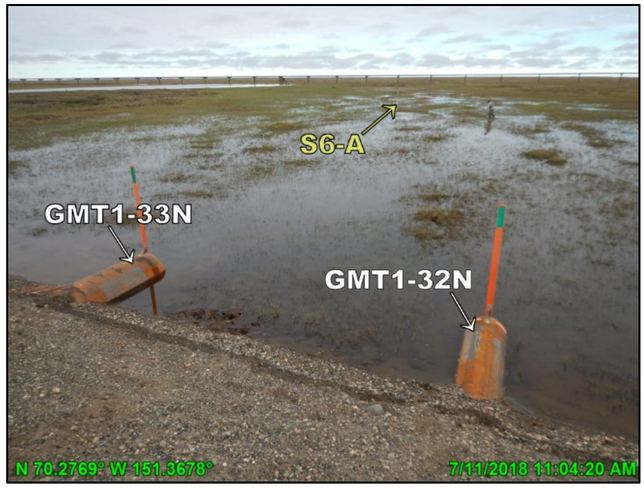

Photo D.22: S6 gages and culverts, looking north; July 11, 2018

E.2 ICE ROAD CROSSINGS BREAKUP

A. CREA CREEK

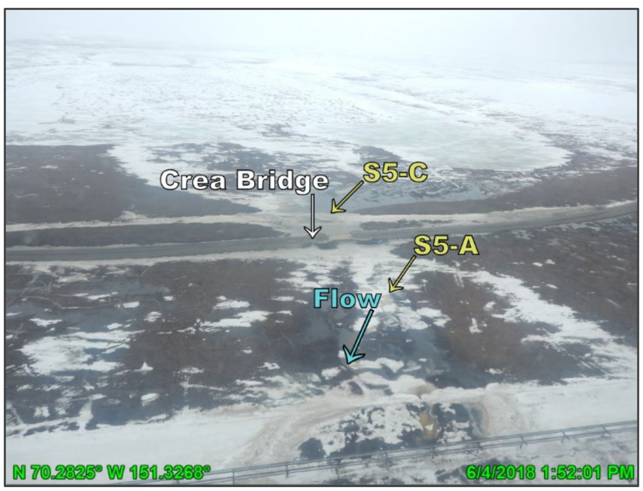

Photo D.23: Crea Creek, looking south; June 4, 2018

Photo D.24: Crea Creek during breakup, looking southwest; June 9, 2018

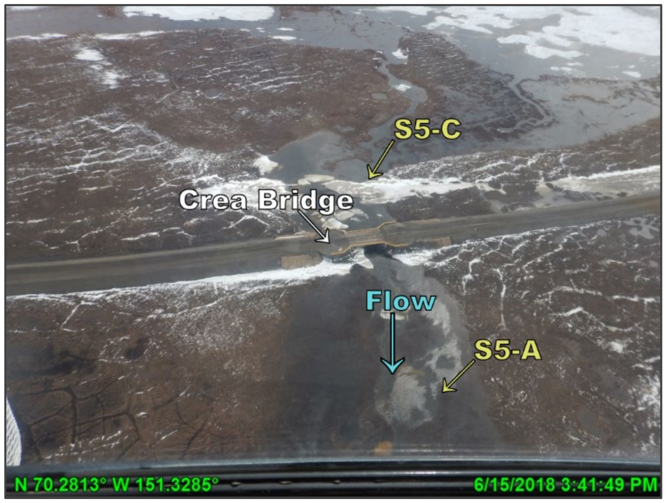

Photo D.25: Crea Creek post-breakup, looking south (upstream); June 15, 2018

B. TINMIAQSIUGVIK RIVER

Photo D.26: Tinmiaqsiugvik River pre-breakup, looking north (downstream); June 14, 2018

Photo D.27: Tinmiaqsiugvik River during breakup, looking northeast; June 9, 2018

Photo D.28: Tinmiaqsiugvik River, looking southwest (upstream); June 17, 2018

2018 GMT1 Spring Breakup & Summer Monitoring & Hydrological Assessment