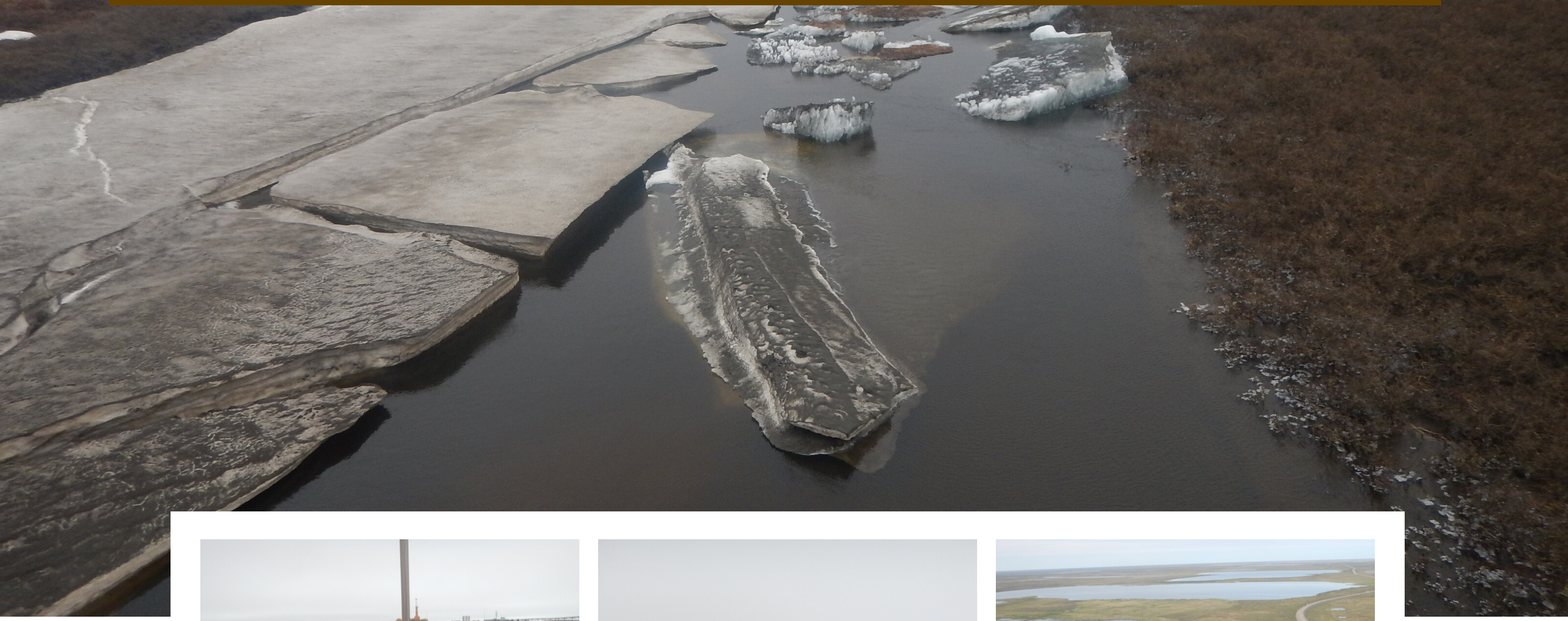
2019 GMT1 /MT6 Spring Breakup & Summer Monitoring & Hydrological Assessment



Michael Baker International
3900 C Street Suite 900
Anchorage, AK 99503

Prepared for:

ConocoPhillips
Alaska

MSA Contract No. 296937

EXECUTIVE SUMMARY

This report presents the results from the 2019 Greater Moose's Tooth 1/Moose's Tooth 6 (GMT1/MT6) Spring Breakup and Summer Monitoring and Hydrological Assessment conducted by Michael Baker International for ConocoPhillips Alaska. This monitoring is required per the U.S. Army Corps of Engineers (USACE) permit POA-2013-461, Special Condition 6.g. Previously, USACE received a culvert monitoring report, as required per the same permit, Special Condition 6.c. The culvert monitoring report was transmitted to USACE on July 29, 2019.

Spring breakup typically occurs during 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 in larger streams, and snow impedance in smaller drainages. 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/MT6 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, Tinmiaqsiugvik Bridge, and the Barely Creek culvert battery. 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/MT6 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 May 30. 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 late August.

Table of Contents

Figures

Tables

Graphs

Photos

Appendix D Tables

Appendix E Photos

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/MT6	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

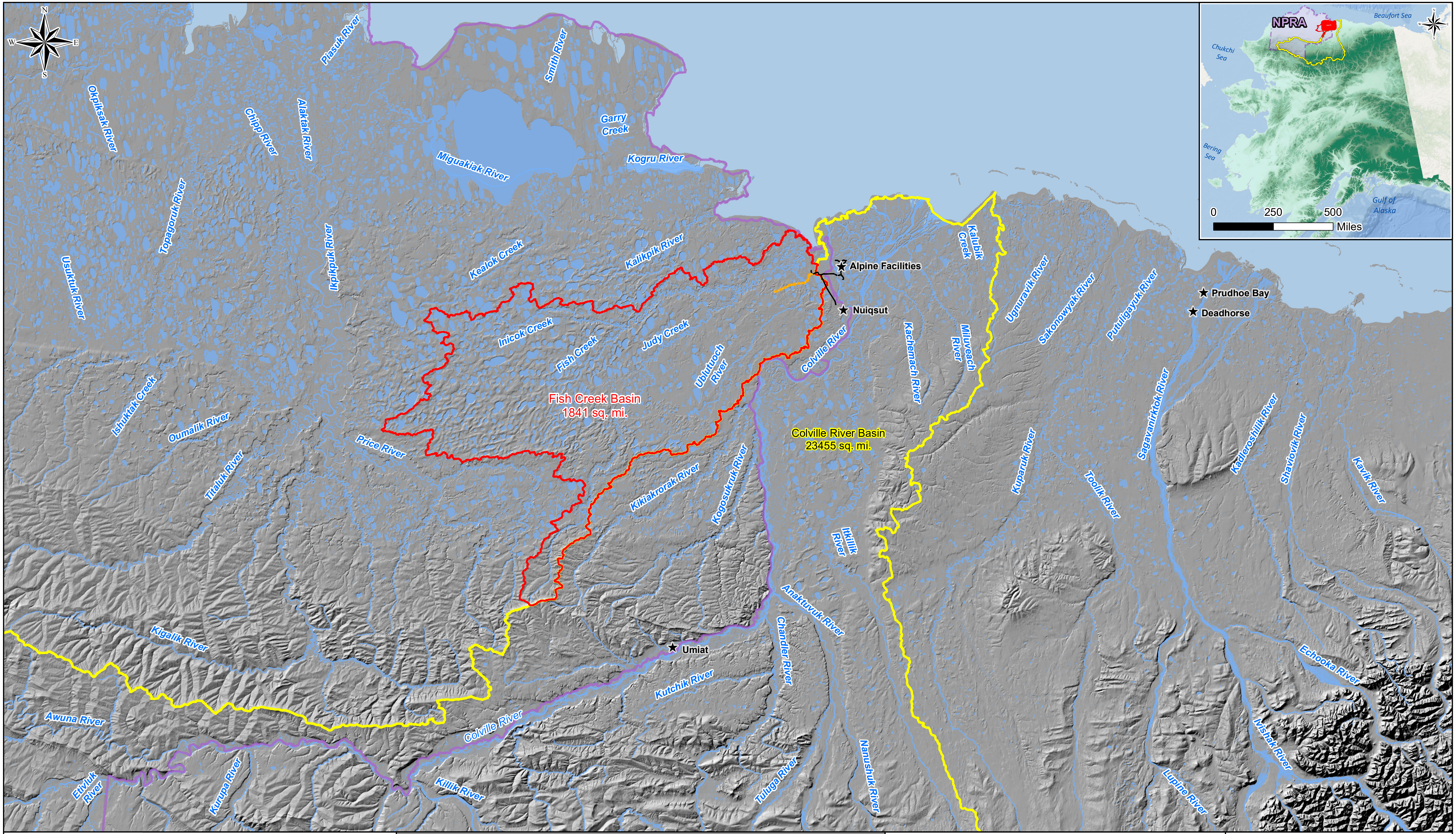
1. INTRODUCTION

The 2019 Greater Moose's Tooth 1/Moose's Tooth 6 (GMT1/MT6) 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/MT6 pads, access roads, and pipelines. The GMT1/MT6 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. 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 GMT1/MT6 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 third year of post-construction spring breakup and summer monitoring and hydrological assessment along the GMT1/MT6 access road and pad, constructed in 2017.

The 2019 field program took place from April 19 to September 10. Spring breakup setup began on April 19 and concluded on May 16 and monitoring began on May 17 and concluded on June 5. Summer monitoring was split into two field programs; the first program began on July 1 and concluded on July 3 and the second program began on September 7 and concluded on September 10. 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/MT6 access road and pad and at all drainage structures. The 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

Miles
0 5 10 20

Date:	10/25/2019	Scale:	1 Inch = 15 Miles
Drawn:	JEG	Project:	171384
Checked:	GCY	File:	FishCreekBasin_11x17L.mxd

★ Place Name
Road
GMT1/MT6 Access Road
River
National Petroleum Reserve Alaksa Boundary
Fish Creek Basin
Colville River Basin
Waterbody

Michael Baker INTERNATIONAL

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

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

2019 GMT1 / MT6

Fish Creek & Colville River Drainage Basins

FIGURE: 1.1

1.1 Monitoring Objectives

The primary objective of the GMT1/MT6 spring breakup and summer monitoring and hydrological assessment was to monitor and estimate the magnitude of breakup flooding in relation to GMT1/MT6 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 permit requirements.

Permit stipulations by USACE permit POA-2013-461, Special Condition 6.c requires monitoring all culverts for the three summer seasons following fill placement. A GMT1/MT6 Spring Breakup Culvert Monitoring Report was transmitted to USACE on July 29, 2019 which detailed spring breakup monitoring results at all GMT1/MT6 access road culverts (Michael Baker 2019). Those results are not included in this report.

Permit stipulations by USACE permit POA-2013-461, Special Condition 6.g requires monitoring the Tinmiaqsiugvik (formerly Ublutuoch) Bridge, Crea Bridge, and Barely Creek culvert battery for the first three thaw seasons following construction of the crossings. Monitoring shall include:

- spring breakup stage and discharge measurements
- continuous stage and discharge monitoring until seasonal flows cease or steady base flows are observed
- documenting highest and lowest stage, velocities, and discharge during seasonal flow
- photo documentation of all bridge abutments at the ground surface, creek culvert inlets and outlets, and channel and bank conditions on each side of the road
- demonstrating adequate conveyance of surface water flow and maintenance of natural drainage patterns

The GMT1/MT6 Spring Breakup Culvert Monitoring Report, transmitted to USACE on July 29, 2019, detailed spring breakup monitoring results at all GMT1/MT6 access road culverts (Michael Baker 2019). Those results are also included in this report. 2019 represent the third year of post-construction hydrology monitoring of the GMT1/MT6 access road.

1.2 Gage Stations

Figure 1.2 shows the GMT1/MT6 access road and pad gage stations. Table 1.1 details the gage stations and monitoring tasks per location.

ConocoPhillips Alaska	0 0.25 0.5 1 Miles	
Date: 10/25/2019	Scale: 1 Inch = 0.5 Miles	
Drawn: JEG	Project: 171384	
Checked: GCY	File: 2019_GMT1_GageStations.mxd	

Road Culvert
gage(s)+PT
Road
Pipeline
Ice Road
Ice Pad
Facility

Michael Baker INTERNATIONAL

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

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

2019 GMT1 / MT6
Gage Stations

FIGURE: 1.2

Table 1.1: GMT1/MT6 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 Stage</th><th>Summer Stage</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">X</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>--</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">X</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>--</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>--</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</td><td>X</td><td>X</td></tr>
<tr><td rowspan="8">Swales[1]</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">--</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">--</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/MT6 Pad</td><td>S8</td><td>West side of GMT1/MT6 pad, downstream of Lake M9925, upstream of Blackfish Creek</td><td>X</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td colspan="10">Notes:
1. Site specific spring breakup observations and stage records for swales and associated culverts are available in the 2019 GMT1/MT6 Spring Breakup Culvert Monitoring Report</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/MT6 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/MT6 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 0.01 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 S7-A with PT; May 27, 2019

Photo 2.2: Chalked gage S6-B with High Water Mark and PT; May 27, 2019

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. The 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.

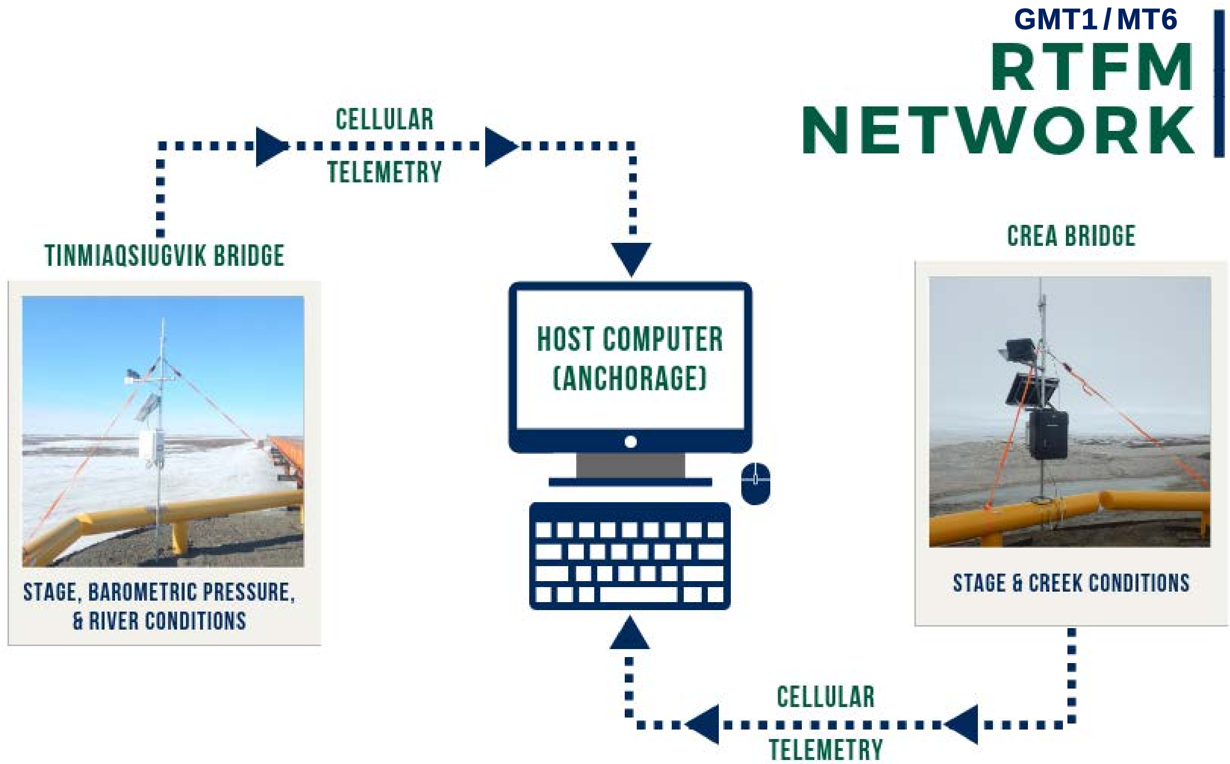
REAL-TIME FLOOD MONITORING NETWORK

The ability to remotely monitor stage and river conditions allows for round-the-clock monitoring of conditions, limiting unnecessary driving to the GMT1/MT6 crossings. In addition, a network of real-time monitoring stations helps hydrologists deploy resources during peak conditions when critical measurements are required. The remote monitoring capabilities installed for this effort reduced unnecessary site visits to assess conditions prior to spring flooding and during extended periods of unvarying conditions. Table 2.1 presents the Real-Time Flood Monitoring (RTFM) Network locations and data collected at each location. Figure 2.1 illustrates the components of the RTFM stations.

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 2019.

B. Sensors

The 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
- Tinmiaqsiugvik Bridge
- Barely Creek culvert battery

Tinmiaqsiuvik Bridge and Crea Bridge discharges were measured using the USGS midsection technique (USGS 1982). Discharge at the Barely Creek culverts was measured using the USGS velocity/area technique (USGS 1968). Flow depths and velocities at Tinmiaqsiuvik Bridge were measured using the Price AA current meter suspended by cable with a sounding weight. Flow depths and velocities at Crea Bridge and Barely Creek culverts were measured using a HACH FH950 electromagnetic velocity 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 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

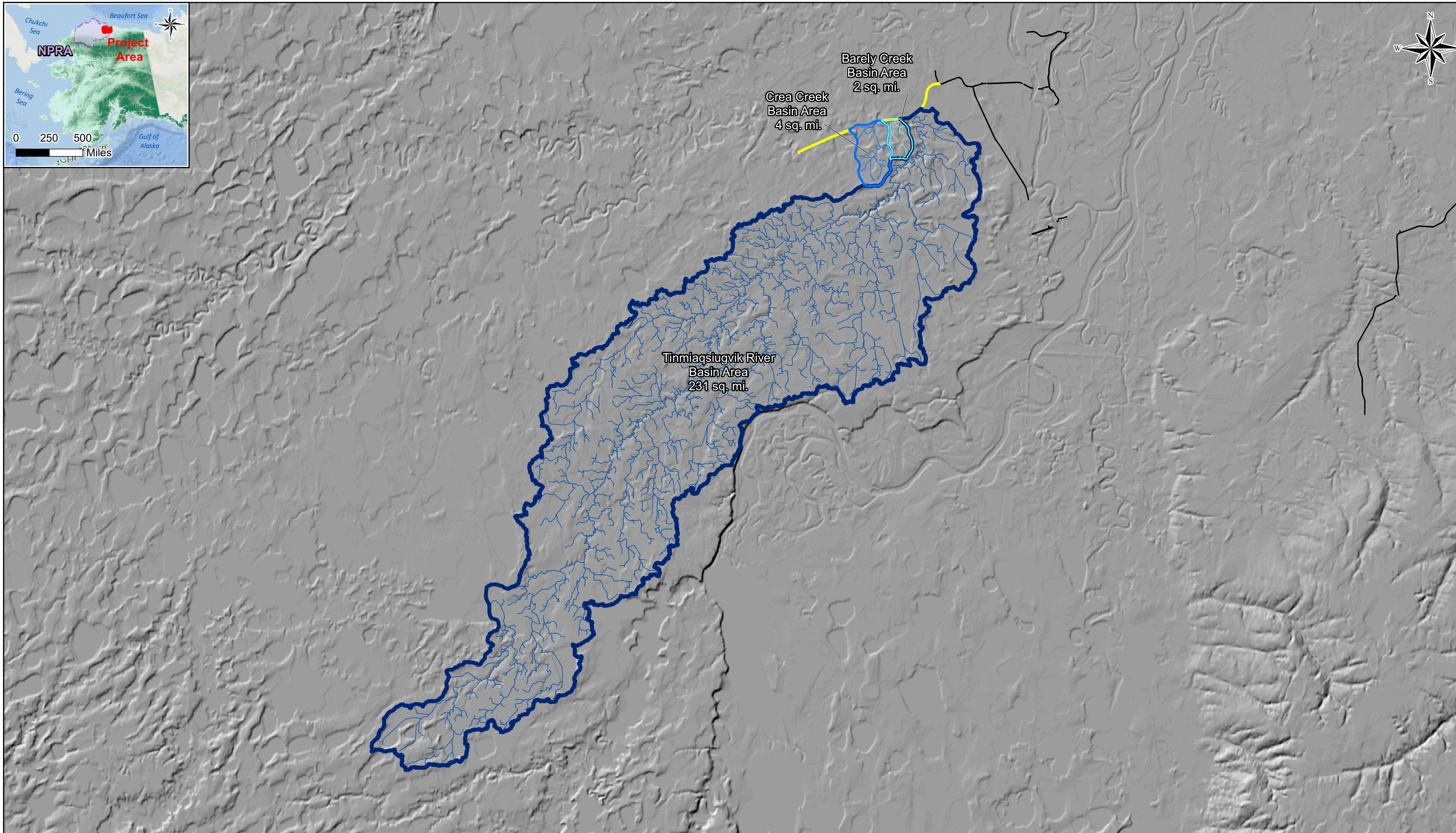
2.4 Flood Frequency Analysis

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)	2017 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/MT6 access road)	1.91	1.6



ConocoPhillips Alaska

0 2 4 8 Miles

Date:	10/25/2019	Scale:	1 Inch = 4 Miles
Drawn:	JEG	Project:	171384
Checked:	GCY	File:	2019_Barely_Crea_Tin_Basin.mxd

Road
GMT1/MT6 Access Road
Stream / River
Waterbody
Barely Creek Flowline
Crea Creek Flowline
Tinmiaqsiugvik River Flowline
Barely Creek Basin
Crea Creek Basin
Tinmiaqsiugvik River Basin

Michael Baker INTERNATIONAL

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

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

2019 GMT1/MT6

Tinmiaqsiugvik Bridge Crea Bridge & Barely Creek Culvert Battery Basins

FIGURE: 2.2

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/MT6 access road, and Barely Creek 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

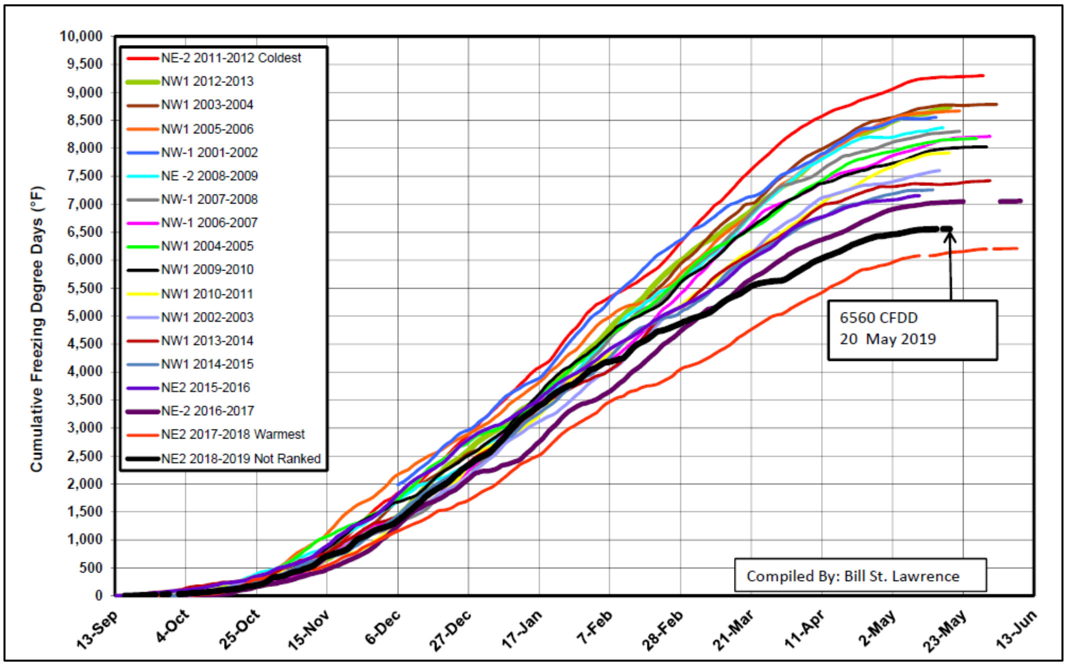
Aerial observations of the hydraulic effects of winter ice road crossings (Figure 1.2) before breakup, during breakup, and post-breakup included:

- Crea Creek, south side of Crea Bridge
- Tinmiaqsiugvik River, south side of Tinmiaqsiugvik Bridge

3. OBSERVATIONS

3.1 General Climatic Summary

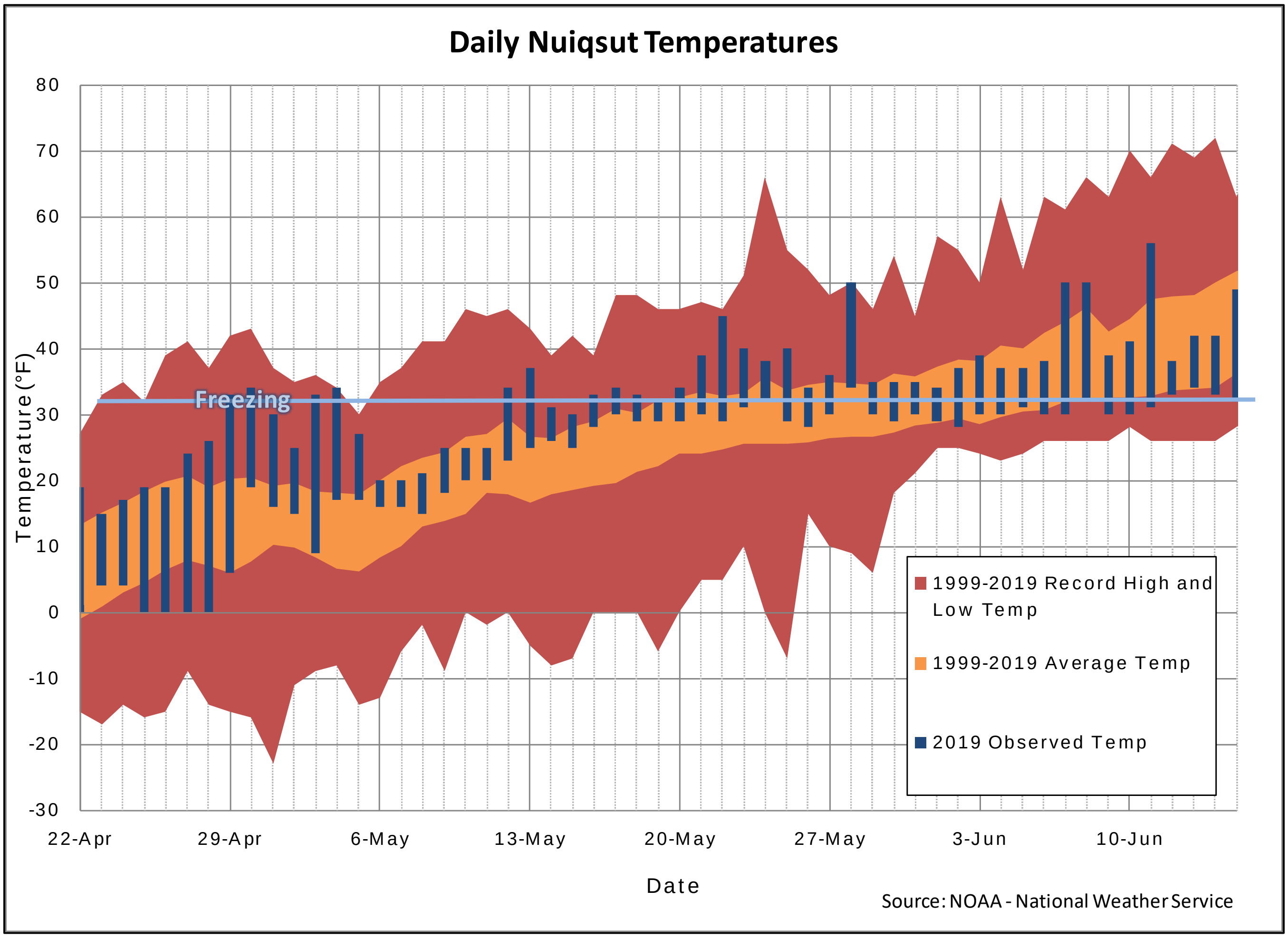
According to cumulative freezing degree-days (CFDD) measured at the National Petroleum Reserve Alaska (NPR-A) tundra monitoring station, the 2018-2019 (September – May) winter was the second warmest on record for the past 18 years, as shown in Graph 3.1 (ICE 2019).



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

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

A warming trend in the Upper Colville River watershed (the Brooks Range foothills, as recorded at Umiat) started April 23 (USGS 2019). Daily maximum temperatures began to exceed freezing on May 12 and daily minimum temperatures began to exceed freezing on May 21. In the CRD, daily maximum temperatures exceeded freezing from April 29 to May 4, followed by a cooler period with sub-freezing temperatures (Weather Underground 2019). Daily high temperatures consistently exceeded freezing on May 16 and continued through the breakup monitoring period. Daily minimum temperatures remained below freezing through the breakup monitoring period. Graph 3.2 illustrates daily high and low ambient air temperatures recorded in Nuiqsut superimposed on the average and record daily highs and lows during the breakup monitoring period (National Oceanic and Atmospheric Administration: National Weather Service 2019).



Graph 3.2: Nuiqsut Daily High and Low Ambient Air Temperatures

3.2 General Breakup Summary

The Tinmiaqsiugvik and Crea Bridge openings and Barely Creek culverts were cleared in April by mechanically removing snow, ice, and bladders from the inlets and outlets prior to spring breakup flooding. Visual inspections performed at the end of April confirmed that snow had been cleared from all culvert inlets and outlets.

On May 15, local melt was observed in isolated areas around the GMT1/MT6 access road (Photo 3.1). By May 22, increasing local meltwater was accumulating in and around natural drainage areas, including the Tinmiaqsiugvik and Crea Bridges (Photo 3.2). Meltwater was observed meeting the GMT1/MT6 road embankment at limited locations along the alignment, particularly around the drainage areas associated with the S2 and S6 monitoring stations. Snow cover on the surrounding tundra was approximately 70 percent. The historical average date of peak stage conditions in the GMT1/MT6 area is May 25.

On May 27, discharge measurements were performed at the Crea Bridge, Tinmiaqsiugvik Bridge and Barely Creek Culvert Battery. At the time of measurements, increased meltwater had elevated stage to near peak conditions throughout most of the GMT1/MT6 area (Photo 3.3). By May 29, aerial observations suggest meltwater was hydraulically connected through drainage structures at most GMT1/MT6 monitoring locations (Photo 3.4).

Aerial observations around the GMT1/MT6 sites was limited after May 30 due to local subsistence hunting activity. By May 30 stage had peaked and was receding at most monitoring locations in GMT1/MT6.

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

Photo 3.1: Local melt near S6, looking northeast; May 15, 2019

Photo 3.2: Tinmiaqsiugvik River, looking south (upstream); May 22, 2019

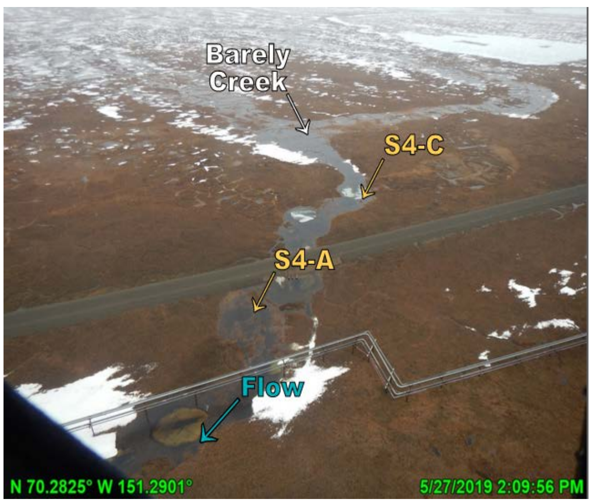
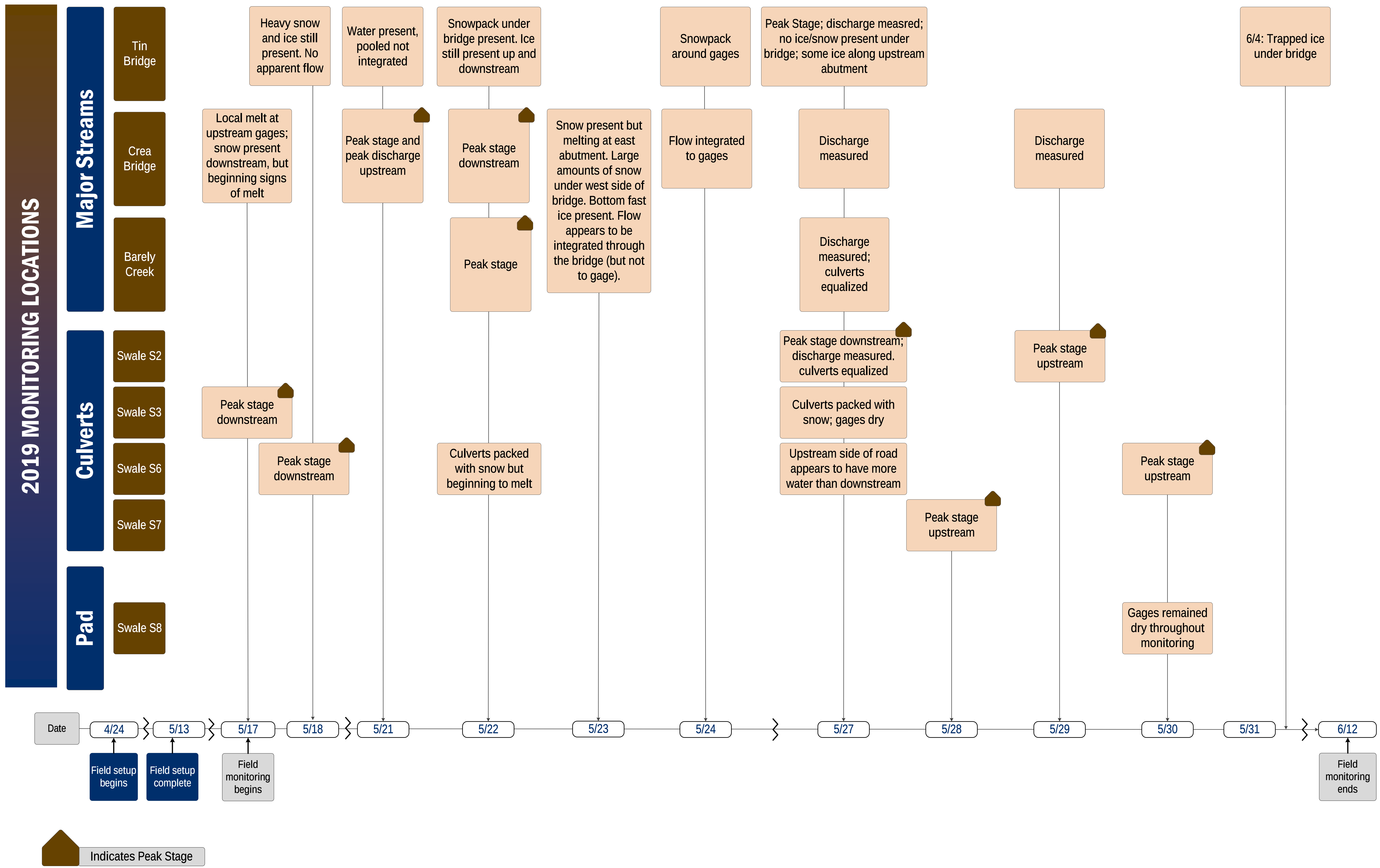


Photo 3.3: Minor overbank flooding at Barely Creek, looking south (upstream); May 27, 2019

Photo 3.4: Tinmiaqsiugvik River, looking northeast (downstream), May 29, 2019

Figure 3.1: GMT1/MT6 Spring Breakup Hydrologic Timeline



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	8.87	5/27 8:30 AM	1.1	1,400	8.78	5/27 3:30 PM	1.4	8.83	5/27 12:00 PM	1,475	8.83	5/27 12:30 PM
	UB6.7	8.43	5/27 12:45 PM			8.39			8.43			8.43	
Barely Creek Culvert Battery	S4-C	14.90	5/22 12:15 AM	0.7 [1]	13	14.33	5/27 5:30 PM	0.7 [1]	14.33	5/27 5:30 PM	50	14.77	5/27 7:30 AM
	S4-A	14.41	5/22 12:15 AM			14.28			14.28			14.34	
Crea Bridge	S5-C	18.59	5/21 8:00 PM	1.37	135	18.16	5/29 12:00 PM	2.4	18.22	5/29 4:45 AM	135	18.16	5/29 12:00 PM
	S5-A	17.55	5/22 1:15 AM			17.45			17.47			17.45	
GMT1/MT6 Pad	S8	Dry	--	--	--	--	--	--	--	--	--	--	--

Notes:
-- Indicates measurement not performed or calculated
[1.] Average through all associated culverts conveying flow

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	3.85	8/30 6:30 AM	1.57	3.85	8/30 6:30 AM	780	3.85	8/30 6:30 AM
	UB6.7[1]	--	--		--			--	
Barely Creek Culvert Battery	S4-C[1]	--	--	0.98	--	8/27 3:30 PM	23	--	8/27 3:30 PM
	S4-A	14.24	8/27 3:30 PM		14.24			14.24	
Crea Bridge	S5-C[1]	--	--	1.68	--	8/28 1:15AM	40	--	8/28 1:15AM
	S5-A	16.94	8/28 1:15 AM		16.94			16.94	

Notes:
[1] PT not deployed at UB6.7, S4-C, nor S5-C during summer monitoring period.

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	0.89	7/13 9:45 AM	1.08[2]	260[2]	0.89	7/13 9:45 AM
	UB6.7[1]	--	--			--	
Barely Creek Culvert Battery	S4-C[1]	--	--	0.29	0.1	--	7/15 3:45 AM
	S4-A	13.22	7/15 3:45 AM			13.22	
Crea Bridge	S5-C[1]	--	--	0.84	3	--	7/14 9:00 PM
	S5-A	15.26	7/14 9:00 PM			15.26	

Notes:
[1] PT not deployed at UB6.7, S4-C, nor S5-C during summer monitoring period
[2] Indirect discharge and velocity is calculated for flow through the entire channel

4.1 Tinmiaqsiugvik Bridge

The UB6.7 and UB6.9 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 approximately 231 square miles at the upstream side of the Tinmiaqsiugvik Bridge. The Tinmiaqsiugvik River 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.

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	
2019	8.64[1]	5/27	1,475	5/27	This Report
2018	12.31[2]	6/10	2,600[3]	6/11	Baker 2018
2017	7.81[1]	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 interpolated from stage between UB6.7 & UB6.9
[2]Value taken from PT installed at the bridge. Value is heavily influenced by the impact of drifted snow under the bridge
[3]Discharge quality rated as poor due to significant ice and snow influence

SPRING

On May 22 small quantities of local melt were initially observed around the bridge, with snow and ice still present under the bridge and around the gage stations (Photo 4.1). On May 26 a sharp increase in stage was recorded at both site PTs, and on May 27 peak stage occurred. Overbank flooding occurred on the south (upstream) side of the GMT1/MT6 road (Photo 4.2). On May 28, minimal snow was present both in the channel and along the banks (Photo 4.3). Stage remained elevated and began decreasing on June 1, lasting through the end of the monitoring period. Drifted snow was still present along the banks through the end of the spring monitoring period and flow was confined within the channel banks by June 2 (Photo 4.4).

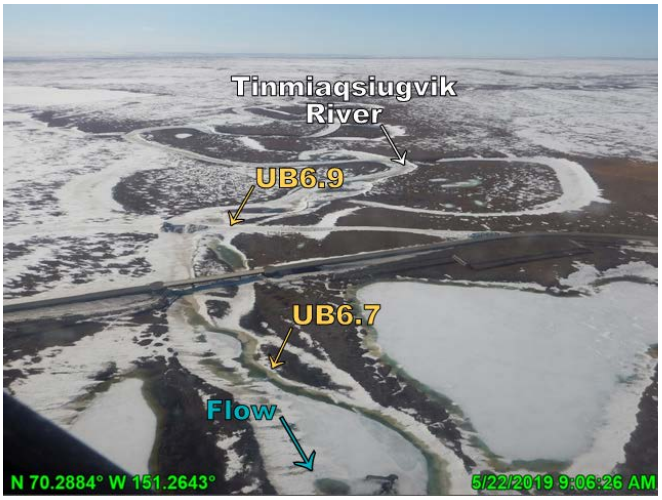


Photo 4.1: Tinmiaqsiugvik River, looking south (upstream); May 22, 2019

Photo 4.2: Backwater upstream of the Tinmiaqsiugvik Bridge, looking south; May 27, 2019

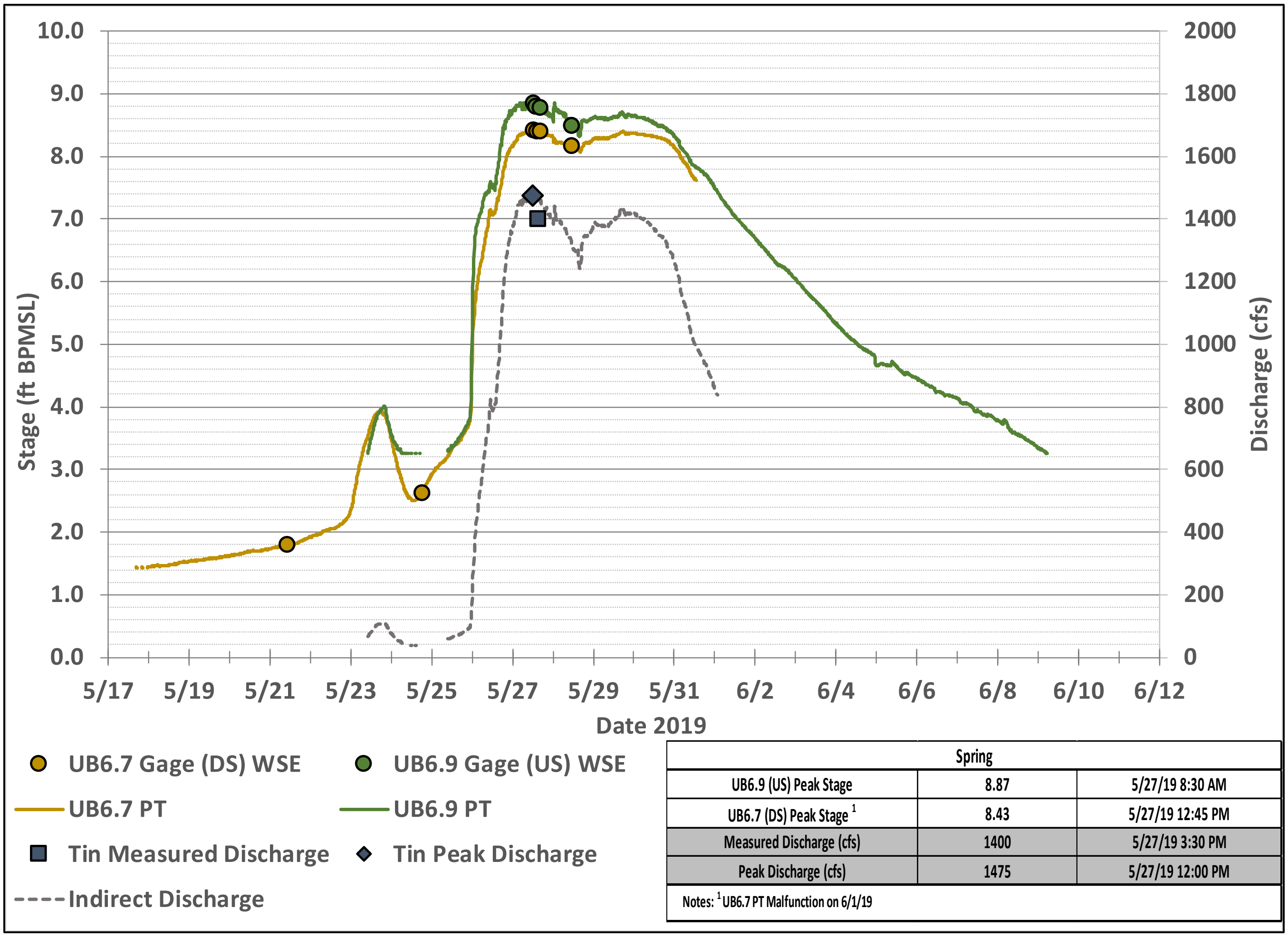
Photo 4.3: Tinmiaqsiugvik River, looking northeast (downstream); May 28, 2019

Photo 4.4: Tinmiaqsiugvik River, looking northeast; June 2, 2019

Continuous discharge and velocity were 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 impacts river hydraulics by elevating the riverbed and constricting the banks, affecting the size, shape, and roughness of the channel, and increasing stage above snow- and ice-free levels. As snow and ice melt, channel geometry, slope, and roughness continuously change until the channel is snow- and ice-free. Bottomfast ice can persist long into the breakup flood. These dynamic characteristics of the channel were documented in 2006 when Tinmiaqsiugvik River channel profiles were measured daily during breakup (Michael Baker 2007).

Discharge was measured at the upstream edge of the Tinmiaqsiugvik Bridge on May 27. At the time of the measurement, snow was present along the banks and stranded ice floes were observed in the channel. An ice floe located directly upstream of the discharge cross section likely impacted river hydraulics and negatively affected the quality of the measurement. The overall quality of the discharge measurement was classified as fair based on conditions at the time of the measurement. Continuous discharge was estimated using the differential slope from the PT data and the known channel geometry from the May 27 discharge measurement. The estimated peak discharge occurred three hours prior to the discharge measurement.

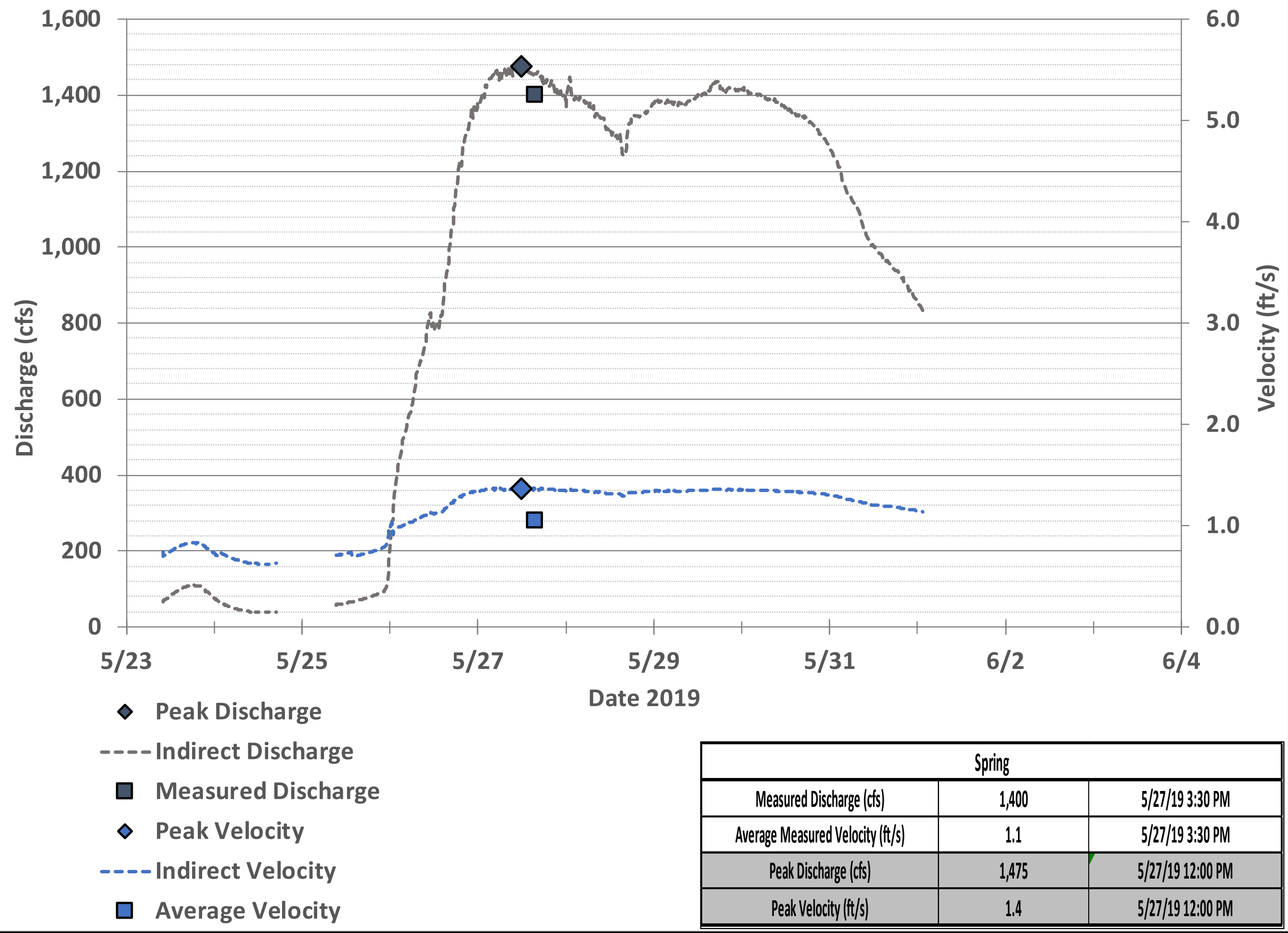
Tinmiaqsiugvik Bridge spring breakup stage and discharge data is provided in Graph 4.1; discharge and average velocity data is provided in Graph 4.2. Detailed information regarding discharge calculations is provided in Appendix C.



Spring		
UB6.9 (US) Peak Stage	8.87	5/27/19 8:30 AM
UB6.7 (DS) Peak Stage [1]	8.43	5/27/19 12:45 PM
Measured Discharge (cfs)	1400	5/27/19 3:30 PM
Peak Discharge (cfs)	1475	5/27/19 12:00 PM

Notes: [1] UB6.7 PT Malfunction on 6/1/19

Graph 4.1: Tinmiaqsiugvik Bridge Spring Breakup Stage & Discharge



Spring		
Measured Discharge (cfs)	1,400	5/27/19 3:30 PM
Average Measured Velocity (ft/s)	1.1	5/27/19 3:30 PM
Peak Discharge (cfs)	1,475	5/27/19 12:00 PM
Peak Velocity (ft/s)	1.4	5/27/19 12:00 PM

Graph 4.2: Tinmiaqsiugvik Bridge Spring Breakup Velocity & Discharge

SUMMER

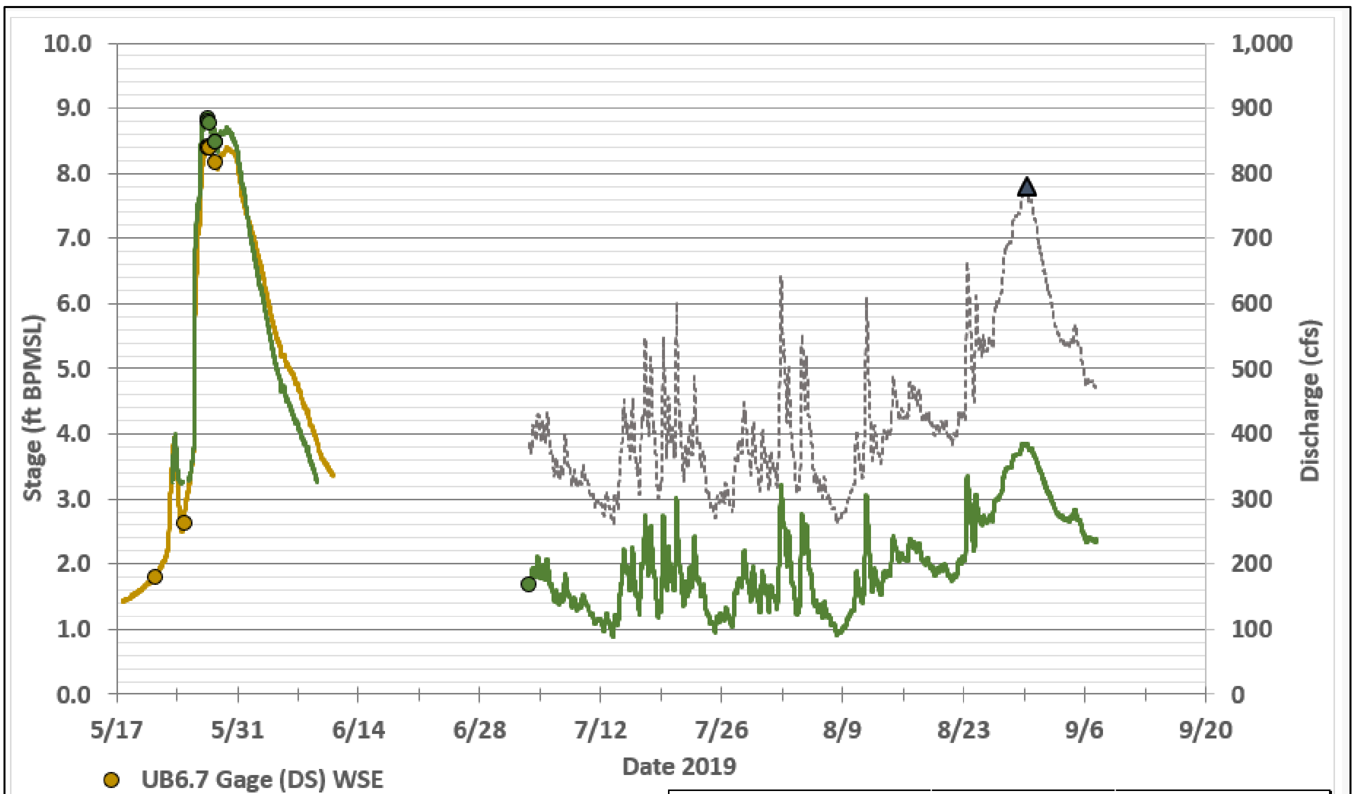
The Tinmiaqsiugvik River was ice and snow free and flow was confined within the main channel when field crews returned in early July. The PT installed at UB6.9 during spring monitoring was moved lower in the channel to capture low-flow summer conditions. Summer stage remained lower than stage measured during spring breakup. Peak summer stage occurred on August 30 during a notable precipitation event.

Continuous discharge and average 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 velocity and discharge were calculated using the average recorded slope between UB 6.7 and UB 6.9 during summer 2018.

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

Photo 4.5: Tinmiaqsiugvik River, looking southwest; July 3, 2019

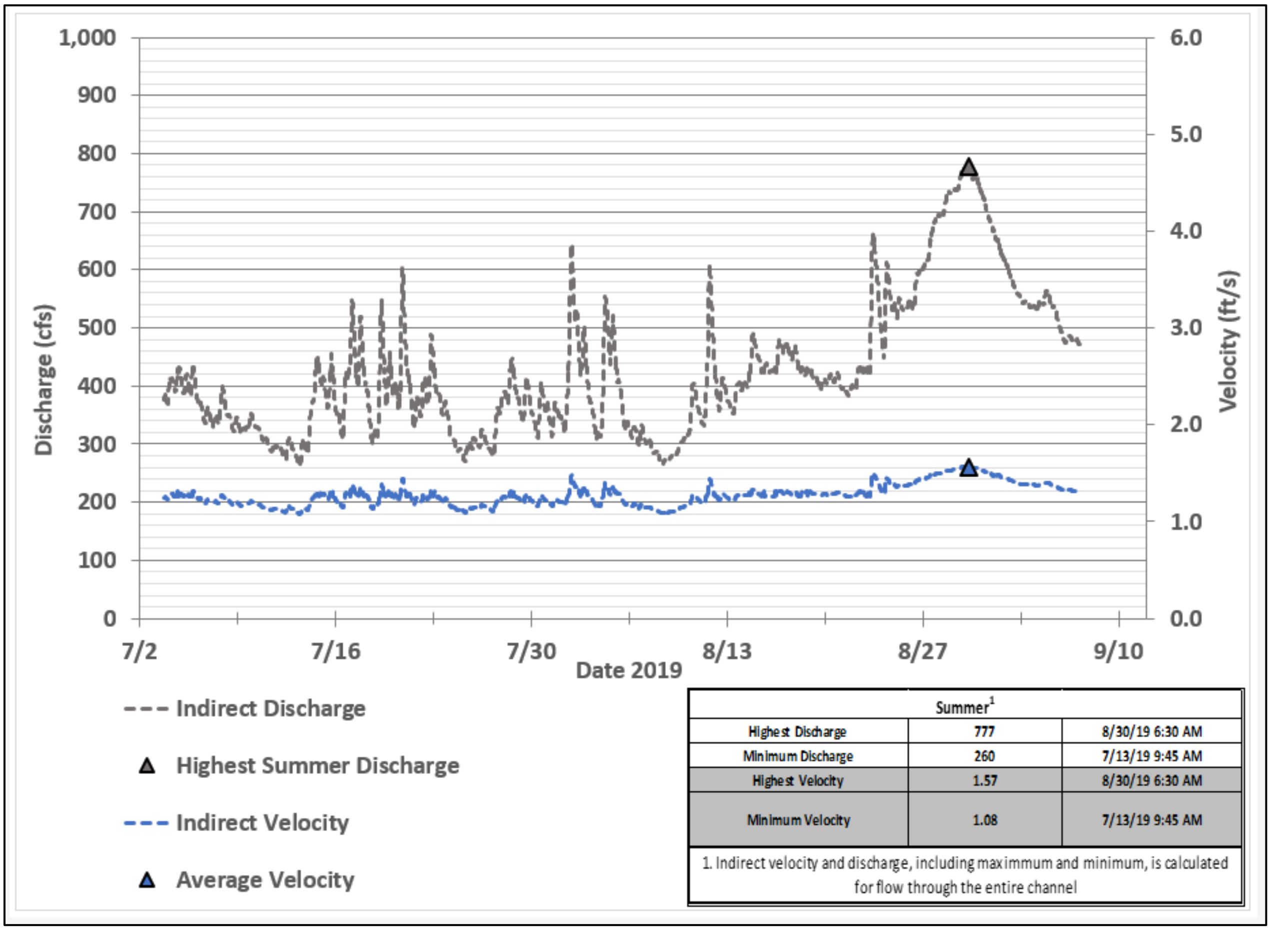
Photo 4.6: Tinmiaqsiugvik River, looking southwest (upstream); July 2, 2019



Summer		
UB6.9 (US) Highest Recorded Stage	3.85	8/30/19 6:30 AM
UB6.9 (US) Minimum Stage	0.89	7/13/19 9:45 AM
Highest Summer Discharge (cfs)	780	8/30/19 6:30 AM

*PT not deployed at UB6.7 during summer monitoring period. Calculation of indirect discharge utilized a constant slope of 0.00035, determined as the average slope between UB6.7 and UB6.9 during the summer of 2018.

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 Bridge. Historical peak stage and discharge data is presented in Table 4.5.

Table 4.5: Crea Bridge at S5 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)[1]	Date	
2019	18.59	5/21	This Report
2018	19.27	6/6	Baker 2018
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 (S5-C) gage station. Peak stage values at the centerline crossing location are generally slightly less than upstream stage values.

SPRING

Spring breakup peak stage and discharge at the Crea Bridge were influenced by ice and snow at the bridge. An initial stage increase was recorded on May 13. On May 15, disconnected meltwater was observed ponding near the bridge (Photo 4.7). Peak stage at S5-C occurred on May 21 and was the result of rapid snowmelt and backwater impounded behind the snow-filled bridge opening, based on RTFM images (Photo 4.8). Immediately following peak stage at S5-C, stage at S5-C dropped sharply and downstream stage at S5-A increased, indicating meltwater had established a flow path through the snow-filled bridge opening. On May 22, there was a rapid fall in stage both upstream and downstream of the bridge throughout the day, suggesting flow was becoming increasingly integrated downstream of the bridge. Observations on May 23 revealed a narrow flow path established under the bridge along the east abutment (Photo 4.9). Flow continued cutting through the snowpack, causing minor variability in stage until a second crest in stage was observed on May 28. Stage did not reach the same magnitude as peak during this crest and began to steadily decrease after May 28. This second crest represented peak flow conditions with fully integrated flow. Stage steadily decreased after cresting on May 28.

Photo 4.7: Initial meltwater at Crea Creek, looking north (downstream); May 15, 2019

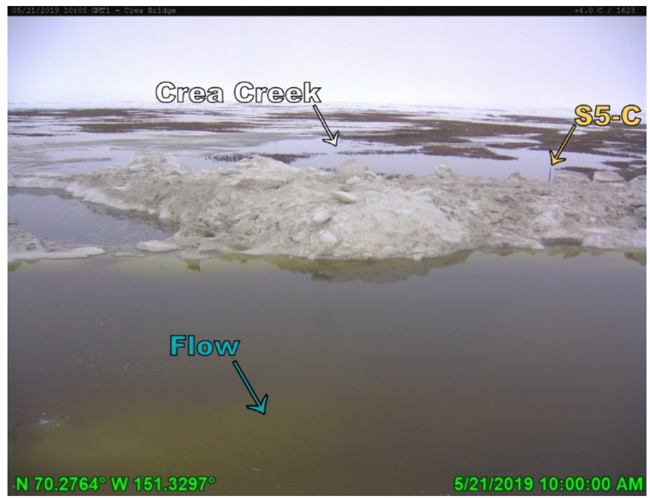


Photo 4.8: RTFM image at Crea Bridge on the day of peak stage at S5-C, looking south (upstream); May 21, 2019

Photo 4.9: Crea Creek after peak stage, looking west; May 23, 2019

Discharge was measured on May 27 and May 29 (Photo 4.10 and Photo 4.11) upstream of the bridge near the abutments. Large amounts of snow and bottomfast ice were still present around the bridge during the May 27 measurement. Most snow and ice at the bridge had cleared by the second measurement on May 29. The overall quality of both discharge measurements was classified as fair based on the conditions at the time of the measurements.

Peak discharge at the Crea Bridge occurred during the second crest in stage on May 28, when flow was fully integrated through the creek. Discharge was calculated using the differential slope from the PTs and channel cross-section measured during the discharge measurement on May 29. The estimated peak discharge value corresponds with the May 29 measured discharge value.

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 4.10: Crea Creek during the first discharge measurement, looking southeast (upstream); May 27, 2019

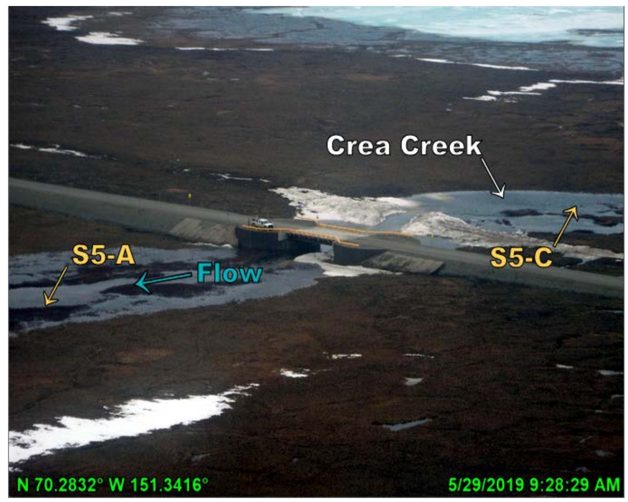
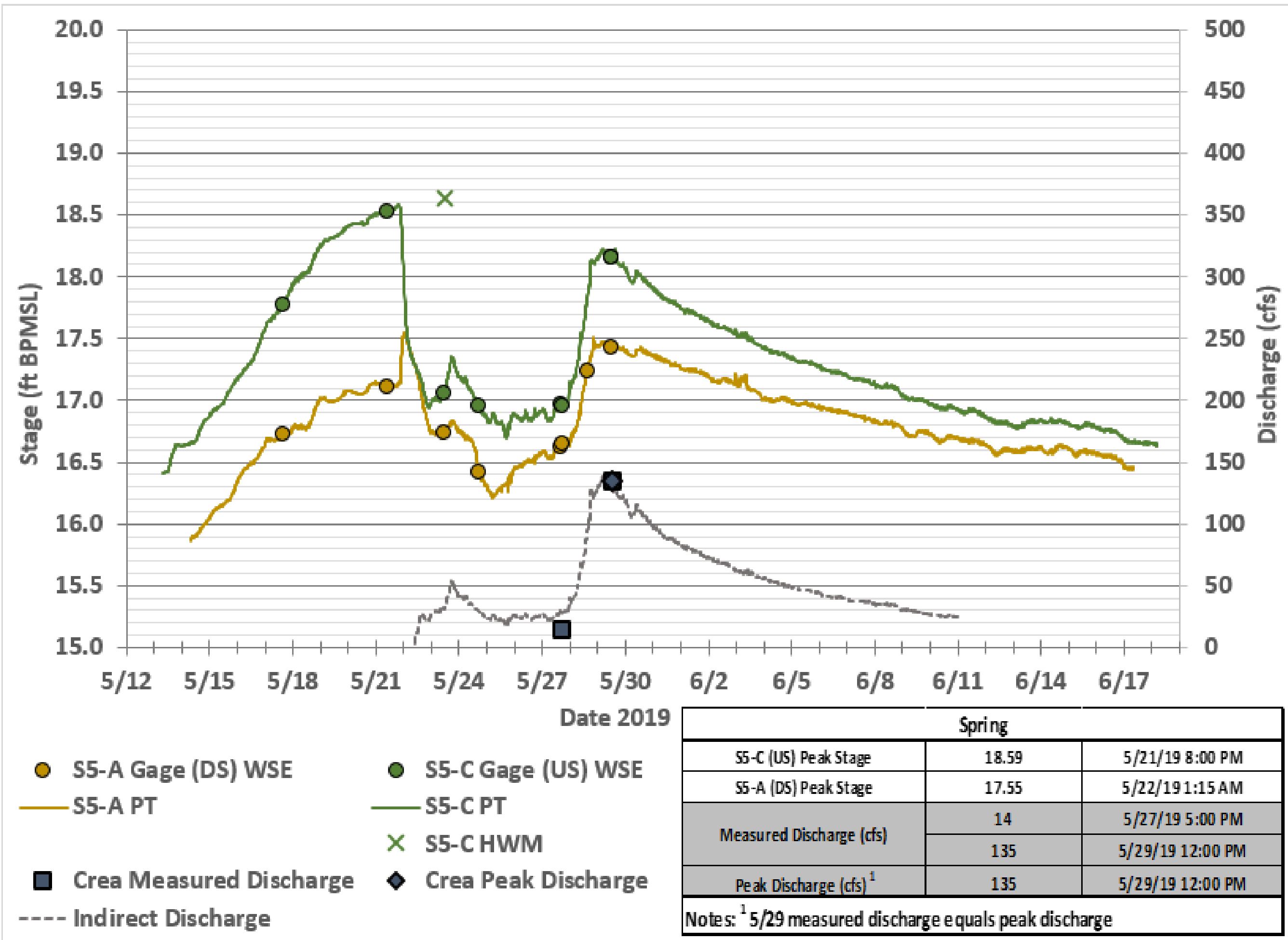


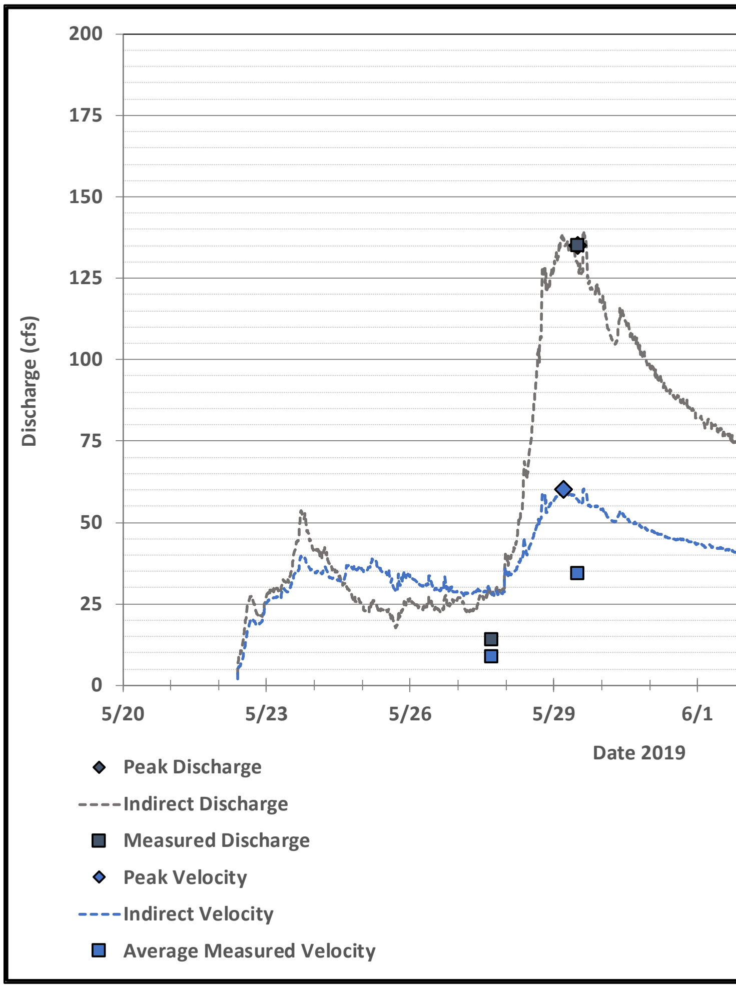
Photo 4.11: Crea Creek the day of second discharge measurement, looking southeast (downstream); May 29, 2019



Spring		
S5-C (US) Peak Stage	18.59	5/21/19 8:00 PM
S5-A (DS) Peak Stage	17.55	5/22/19 1:15 AM
Measured Discharge (cfs)	14	5/27/19 5:00 PM
	135	5/29/19 12:00 PM
Peak Discharge (cfs) [1]	135	5/29/19 12:00 PM

Notes: [1] 5/29 measured discharge equals peak discharge

Graph 4.5: Crea Bridge Spring Breakup Stage & Discharge



Spring		
Measured Discharge (cfs)	14	5/27/19 5:00 PM
	135	5/29/19 12:00 PM
Average Measured Velocity (ft/s)	0.35	5/27/19 5:00 PM
	1.37	5/29/19 12:00 PM
Peak Discharge (cfs)	135	5/29/19 12:00 PM
Peak Velocity (ft/s)	2.4	5/29/19 4:45 AM
Notes: [1] 5/29 measured discharge equals peak discharge		

Graph 4.6: Crea Bridge Spring Breakup Velocity & Discharge

SUMMER

Crea Creek was generally ice and snow free and flow was confined within the main channel when field crews returned in early July. Summer stage, discharge, and velocities at the Crea Bridge and S5 gages remained lower than during spring breakup (Photo 4.12 and Photo 4.13). Stage was only monitored at the downstream gage (S5-A) during summer monitoring. Peak summer stage occurred on August 28 during a notable precipitation event.

Continuous summer discharge and average velocity was calculated using the cross-section profile measured during the May 29 discharge measurement and using the average slope between S5-A and S5-C during summer of 2018.

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

Photo 4.12: Crea Creek, looking northeast (upstream); July 2, 2019

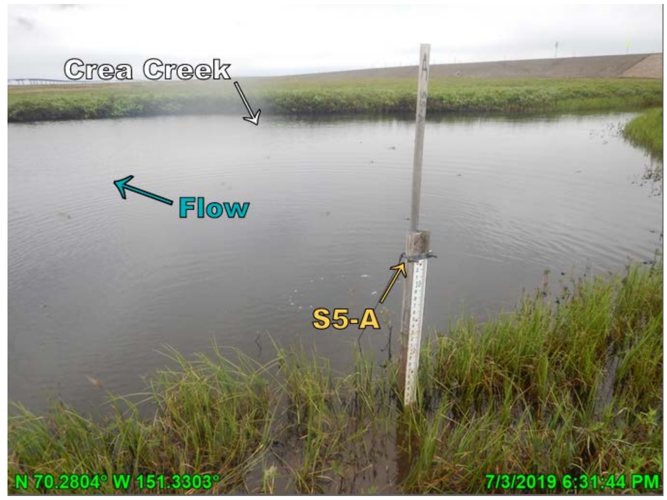
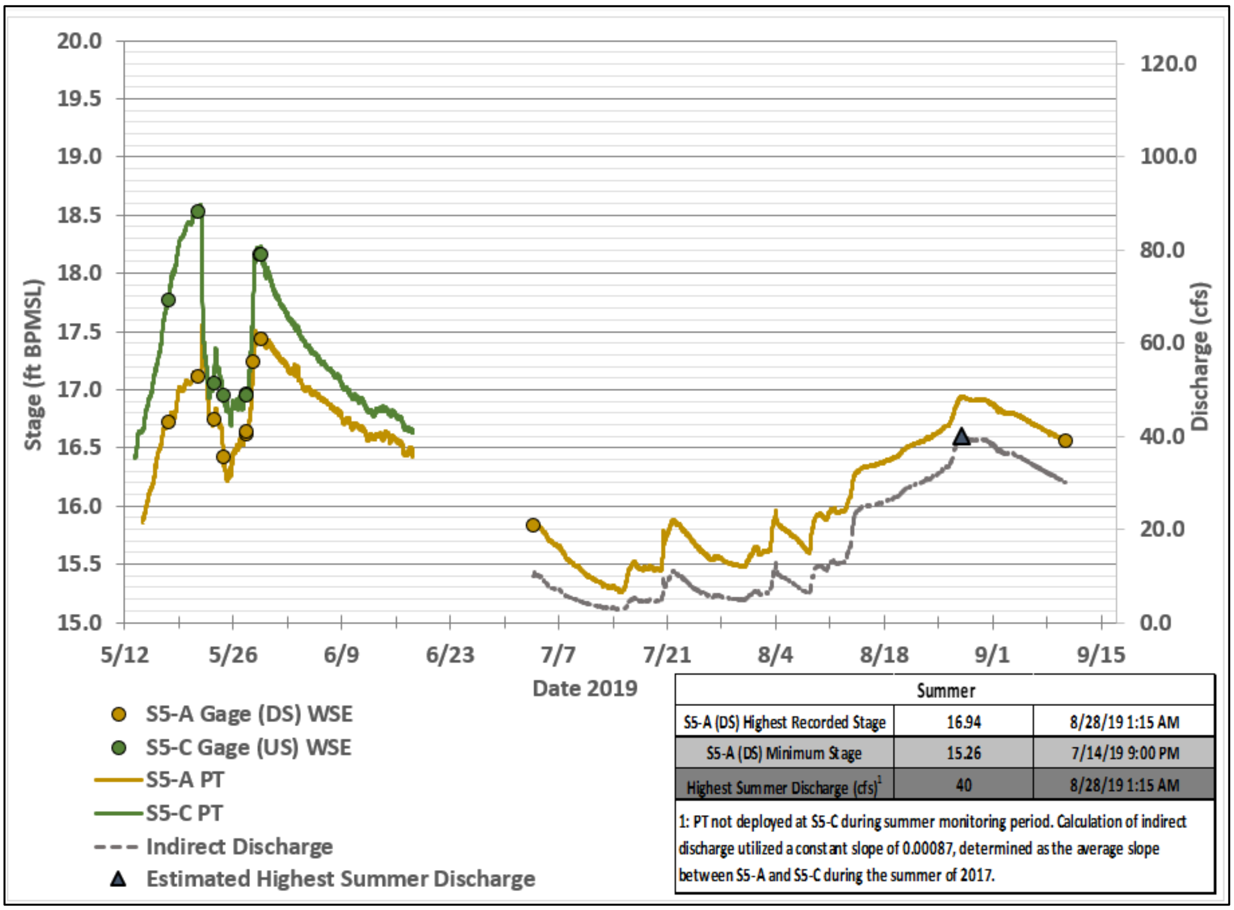


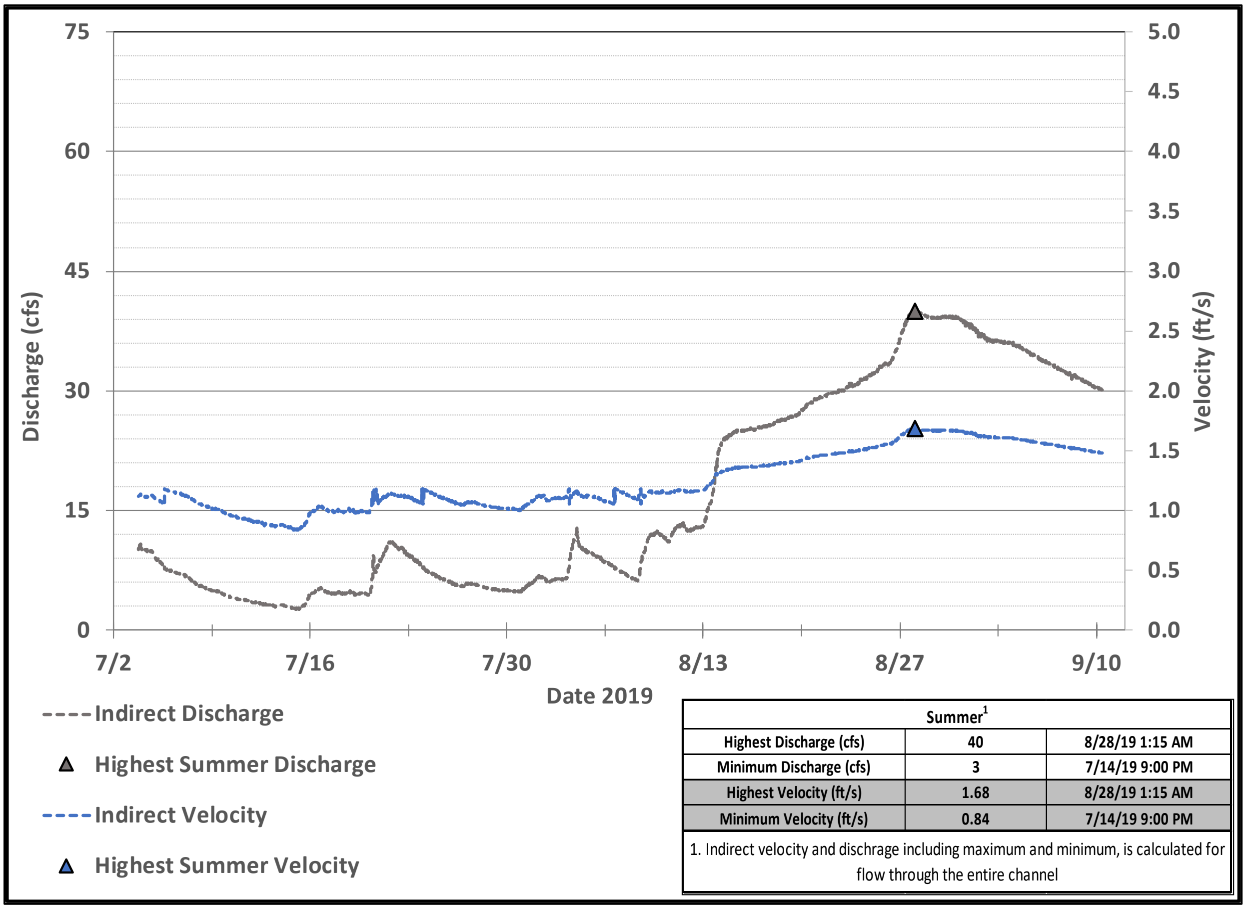
Photo 4.13: S5-A gage (downstream), looking east; July 3, 2019



Summer		
S5-A (DS) Highest Recorded Stage	16.94	8/28/19 1:15 AM
S5-A (DS) Minimum Stage	15.26	7/14/19 9:00 PM
Highest Summer Discharge (cfs)[1]	40	8/28/19 1:15 AM

1: PT not deployed at S5-C during summer monitoring period. Calculation of indirect discharge utilized a constant slope of 0.00087, determined as the average slope between S5-A and S5-C during the summer of 2017.

Graph 4.7: Crea Bridge Summer Stage & Discharge



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 approximately 1.6 square miles upstream of the GMT1/MT6 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. Historical peak stage data at Barely Creek is presented in 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 S4 Historical Peak Stage

Year	Stage		Reference
	Peak WSE (feet BPMSL)[1]	Date	
2019	14.90	5/22	This Report
2018	15.57	6/4	Baker 2018
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 19. Snow cover on the surrounding tundra was approximately 70 percent. Peak stage occurred on May 22. Aerial observations from May 22 show flow paths forming through the drifted snowpack in the drainage on both sides of the GMT1/MT6 road, suggesting hydraulic connection had been initiated (Photo 4.14). With the exception of temporary blockage from a bladder frozen in place, all culverts were observed to be functioning as designed and natural drainage patterns in the area were maintained.

On May 25 stage began to gradually increase until reaching a second crest on May 27. On May 27, flow was observed through all three culverts and minimal snow cover remained in the channel and along the downstream banks (Photo 4.15). Discharge through the culverts was measured and minor overbank flooding in the drainage was observed. On the south (upstream) side of the GMT1/MT6 road, meltwater from two flow paths was flowing unimpeded through the culverts. On May 28, snow was observed on the north (downstream) side of the GMT1/MT6 access road along the channel banks and meltwater was hydraulically connected to the Tinmiaqsiugvik River (Photo 4.16). Conditions remained consistent and stage remained elevated through May 29 (Photo 4.17) until gradually dropping on June 3.

Discharge was measured at the Barely Creek culverts on May 27. The total discharge reflects the sum of the discharge measurements through the individual culvert outlets. The quality of the May 27 measurement was classified as good based on the clear culvert conditions at the time of the measurements.

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 4.14: Barely Creek, looking southwest (upstream); May 22, 2019

Photo 4.15: Barely Creek on the day of the discharge measurement, looking south (upstream); May 27, 2019

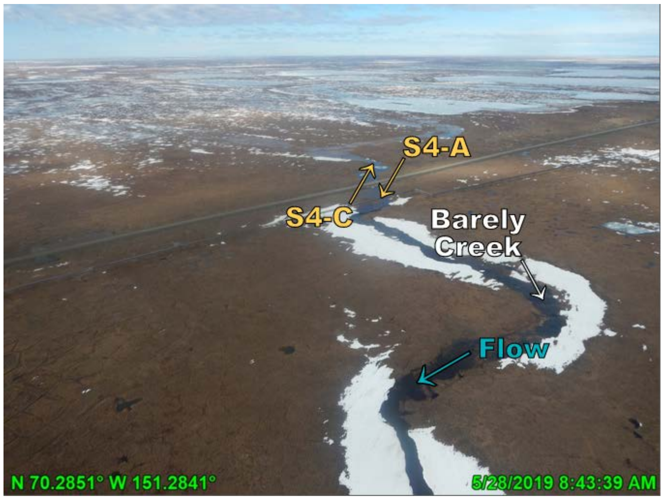
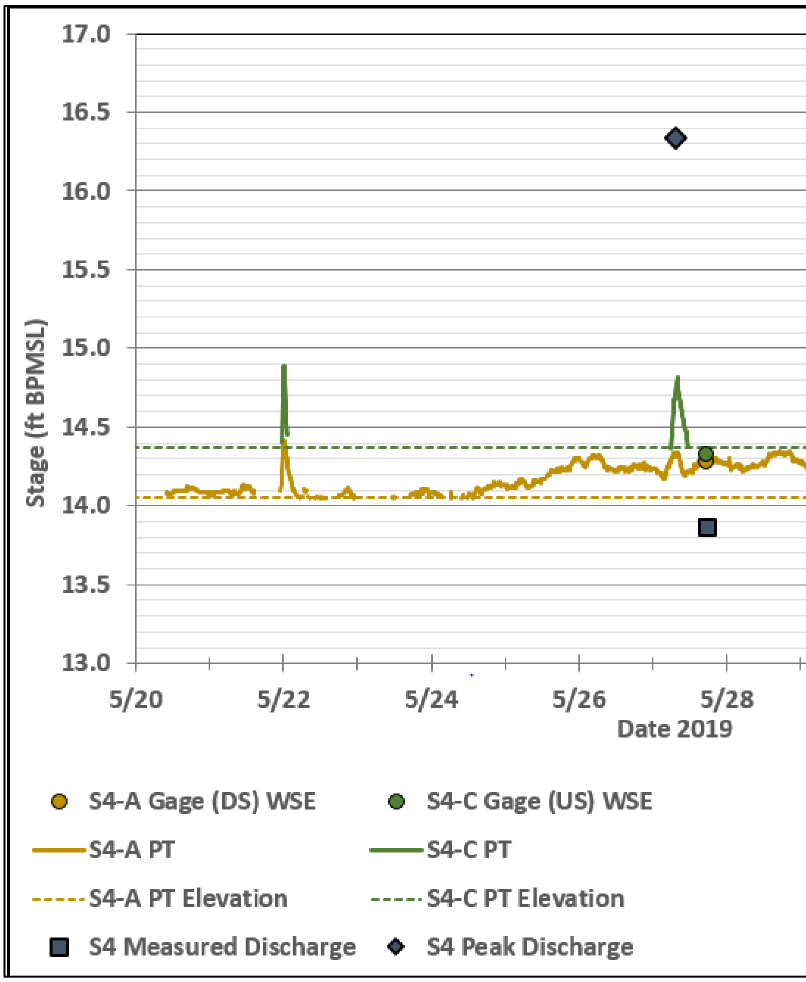


Photo 4.16: Barely Creek, looking southwest (upstream); May 28, 2019

Photo 4.17: Barely Creek, looking southwest (upstream); May 29, 2019



Spring		
S4-C (US)	14.90	5/22/19 12:15 AM
S4-A (DS)	14.41	5/22/19 12:15 AM
Measured Discharge (cfs)	13	5/27/19 5:30 PM
Peak Discharge (cfs)	50	5/27/19 7:30 AM
Measured Velocity (ft/s)[1]	0.7	5/27/19 5:30 PM

1. Taken as the average measured velocity through all three Barely Creek culverts conveying flow on 5/27/19

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

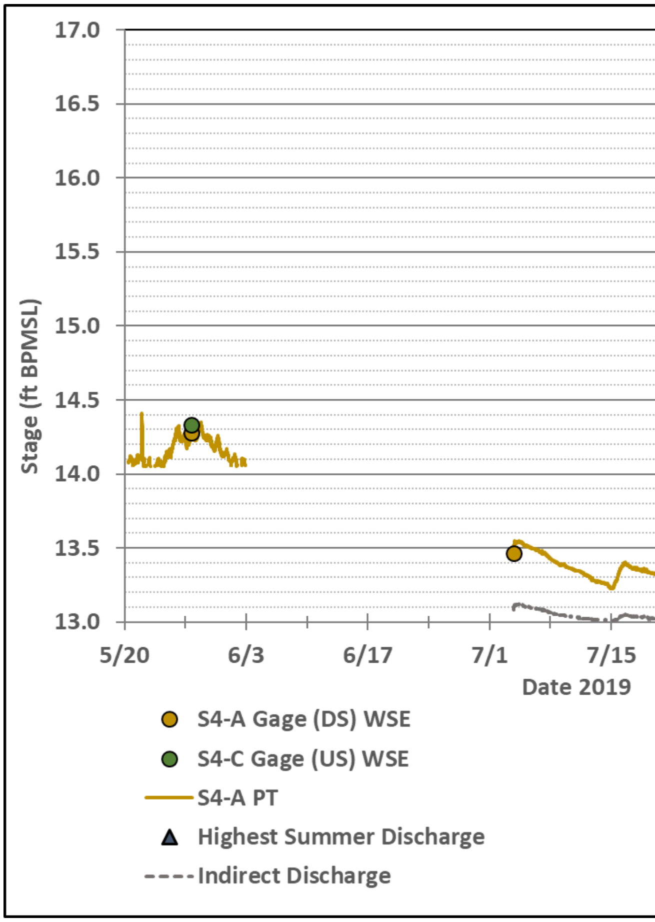
SUMMER

Summer stage, discharge, and velocity at the Barely Creek culvert battery remained lower than peak conditions during spring breakup. However, between August 25 and September 1, a notable precipitation event resulted in the highest summer stage that was within 0.2 feet of peak stage during breakup. Highest summer discharge and velocity coincided with the highest summer stage on August 27. No PT was deployed at the upstream gage during the summer monitoring period. Consequently, indirect discharge was calculated using the average slope between the upstream and downstream S4 gages during the summer of 2018.

Aerial observations from July 2 show hydraulic connection were maintained through the Barely Creek culverts. The upstream stage hydrograph and observations on July 3 indicate that water was present with minimal discernable flow in the early summer (Photo 4.18 and Photo 4.19). Barely Creek culvert battery summer stage and discharge data is provided in Graph 4.10.

Photo 4.18: Barely Creek, looking southwest (upstream); July 2, 2019

Photo 4.19: Barely Creek gage S4-A, looking east; July 3, 2019



Summer		
S4-A (DS) Highest Recorded Stage	14.24	8/27/19 3:30 PM
S4-A (DS) Minimum Recorded Stage	13.22	7/15/19 3:45 AM
Highest Summer Discharge (cfs)[1]	23	8/27/19 3:30 PM
Minimum Summer Discharge (cfs)[1]	0.1	7/15/19 3:45 AM
Highest Summer Velocity (ft/s)[1]	0.98	8/27/19 3:30 PM
Minimum Summer Velocity (ft/s)[1,2]	0.29	7/15/19 3:45 AM

1. Calculated as average discharge and velocity through all three culverts
2. PT not deployed at S4-C during summer monitoring period. Calculation of indirect discharge utilized a constant slope of 0.00352, determined as the average slope between S4-A and S4-C during summer of 2018.

Graph 4.10: Barely Creek Culvert Battery Summer Stage & Discharge

4.4 GMT1/MT6 Pad

The S8 gage station is located approximately 900 feet west of GMT1/MT6 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 4.20 and Photo 4.21).

Photo 4.20: S8 drainage area, looking northeast; May 29. 2019

Photo 4.21: S8 drainage area, looking north; June 3, 2019

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 1,475 cfs has a recurrence interval of less than 2 years based on both the USGS results and 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 180 cfs and Barely Creek culvert battery peak discharge of 50 cfs have recurrence intervals of 7.5 years and 2.6 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 PERFORMANCE EVALUATION

No performance issues were identified at the Tinmiaqsiugvik and Crea Bridges or the Barely Creek culvert battery. 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 bridges and culverts all performed as designed and natural drainage patterns were maintained.

7. POST-BREAKUP CONDITIONS ASSESSMENT

Post-breakup conditions were assessed to evaluate erosion and scour at the Tinmiaqsiugvik Bridge and Crea Bridge abutments, Barely Creek culvert inlets and outlets, and along the banks upstream and downstream of all GMT1/MT6 access road crossings. In addition, the access road and pad were inspected for erosion and any displaced gravel fill onto the tundra. At the Tinmiaqsiugvik Bridge, bank erosion was first observed at the east abutment and along the east bank immediately downstream of the bridge in 2018. During the 2018-19 winter, the two VSMs most threatened by the bank erosion were abandoned and replaced with a single VSM with a cantilevered horizontal support. The 2019 observations show continued erosion along the bank at the abandoned VSMs (Photo 7.1 and Photo 7.2). Similar to 2018, thermo-erosional niching and subsequent riverbank block failure continue to occur. 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. A gully, also downstream of the Tinmiaqsiugvik Bridge on the east bank, has deepened since 2018. The gully, that now encompasses both VSMs of the support downstream (pipeline flow direction) of the new VSM, appears to be a thermokarst feature with exposed ice wedges (Photo 7.3 and Photo 7.4). The gully is approximately 4 feet deep at the VSMs.

No displaced gravel fill attributed with spring breakup flooding was observed along the road embankment, around culvert inlets and outlets, or around bridge abutments (Photo 7.5 through Photo 7.19). 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 south (upstream); July 3, 2019

Photo 7.2: East bank downstream of Tinmiaqsiugvik Bridge, looking north (downstream); July 3, 2019

Photo 7.3: Thermokarst gully on east bank, downstream of the Tinmiaqsiugvik Bridge, looking north; September 10, 2019

Photo 7.4: Exposed ice wedge in thermokarst gully on east bank, downstream of the Tinmiaqsiugvik Bridge, looking north; September 10, 2019

Photo 7.5: Tinmiaqsiugvik River east abutment, upstream, looking east; May 27, 2019

Photo 7.6: Tinmiaqsiugvik River west abutment, upstream, looking west (upstream); August 1, 2019

Photo 7.7: Tinmiaqsiugvik River east abutment, downstream, looking east; September 10, 2019

Photo 7.8: Tinmiaqsiugvik River east bank downstream, looking east (downstream); September 10, 2019

Photo 7.9: Tinmiaqsiugvik River west bank downstream, looking southwest (upstream); July 2, 2019

Photo 7.10: Tinmiaqsiugvik River east bank upstream, looking northeast (downstream); July 3, 2019

Photo 7.11: Tinmiaqsiugvik River west bank upstream, looking west; August 1, 2019

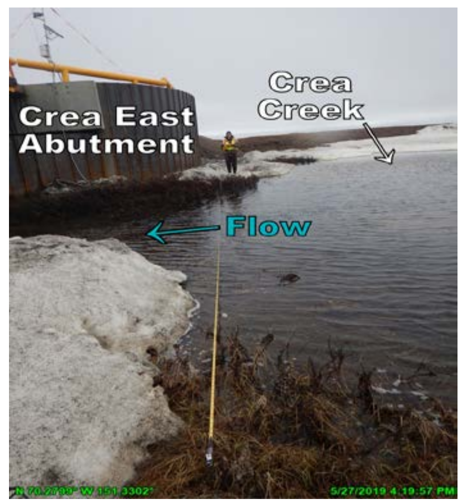


Photo 7.12: Crea Creek east abutment upstream, looking northeast (upstream); May 27, 2019

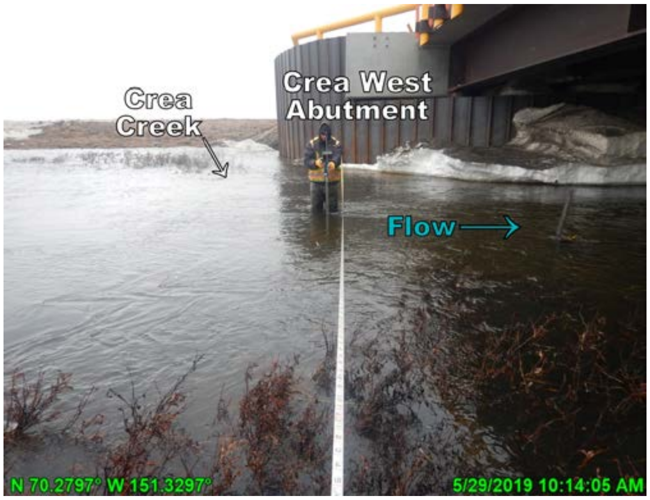


Photo 7.13: Crea Creek west abutment upstream, looking west (upstream); May 29, 2019

Photo 7.14: Crea Creek east abutment downstream, looking south (upstream); July 2, 2019

Photo 7.15: Crea Creek west abutment downstream, looking southwest (upstream); July 2, 2019

Photo 7.16: Crea Creek bank conditions, looking southwest (upstream); July 3, 2019

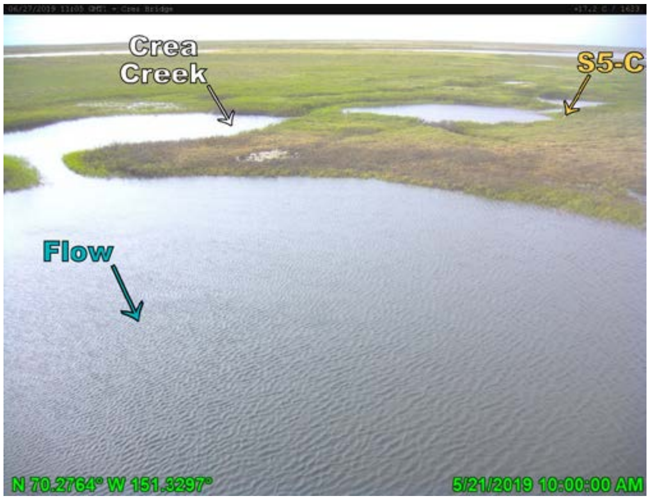


Photo 7.17: Crea Creek bank upstream, looking southwest (upstream); June 27, 2019

Photo 7.18: Barely Creek culverts outlets, looking south (upstream); May 27, 2019

Photo 7.19: Barely Creek culvers inlets, looking southeast (upstream); May 27, 2019

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 meltwater 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). 2019. NPR-A North Tundra Monitoring Station. Cumulative Freezing Degree Days. Winters 2002-2019 Coldest to Warmest Year. June 2019. 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 and Summer Monitoring and Hydrological Assessment. December 2018. Prepared for ConocoPhillips Alaska, Inc.

———2019. 2019 GMT1/MT6 Spring Breakup Culvert Monitoring Report. July 2019. 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: National Weather Service. Weather.gov. Retrieved from Nuiqsut weather observations: https://w1.weather.gov/data. Accessed September 2019.

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/.

Office of Surface Water (OSW). 1999a. Development of New Standard Rating Tables for the Price Type AA and Pygmy Current Meters. Technical Memorandum No. 99.05. Website access 2009. (http://water.usgs.gov/admin/memo/SW/sw99.05.html). U.S. Geological Survey (USGS).

———1999b. Care and Maintenance of Vertical-Axis Current Meters. Technical Memorandum No. 99.06. Website access 2009. (http://water.usgs.gov/admin/memo/SW/sw99.06.html). USGS.

Wunderground. 2019. Temperature data at Alpine Airstrip, AK, April 1 through June 25, 2019. Accessed online at https://www.wunderground.com on June 26, 2019.

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	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	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 at the Tinmiaqsiugvik Bridge were taken from the upstream side of the bridge deck using a sounding reel mounted on a USGS Type A crane with 4-wheel frame. A Price AA velocity meter was attached to the sounding reel and stabilized with a counter weight. A tag line was placed along the bridge rail to define the cross section and to delineate measurement subsections within the channel. The standard rating table No.2 for Price AA velocity meters, developed by the USGS Office of Surface Water (OSW) Hydraulic Laboratory as announced in the OSW Technical Memorandum No. 99.05 (OSW 1999a), was used to convert revolutions to stream velocity. The Price AA velocity meter was serviced prior to spring breakup monitoring in accordance with USGS precise standards. A spin test of the meter was completed prior to and after each measurement. Procedures outlined in OSW Technical Memorandum No. 99.06 (OSW 1999b) were followed to confirm accurate meter performance. Discharge was calculated based on velocity and flow depth.

Flow depth and velocity measurements at the Crea Bridge were taken using a HACH FH950 electromagnetic velocity meter attached to a wading rod. The accuracy of the meter is ± 2% of the reading, ± 0.05 ft/s between 0 ft/s and 10 ft/s, and ± 4% of the reading from between 10 ft/s and 16 ft/s. Discharge was calculated based on velocity, flow depth, and cross-section geometry.

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 Barely Creek culverts. Flow depth and velocity were measured on the downstream end using a HACH FH950 electromagnetic velocity meter attached to a wading rod. The accuracy of the meter is ± 2% of the reading, ± 0.05 ft/s between 0 ft/s and 10 ft/s, and ± 4% of the reading from between 10 ft/s and 16 ft/s. Discharge was calculated based on velocity, flow depth, and culvert geometry.

Indirect Velocity & Discharge

A. CULVERTS

Bentley CulvertMaster® software was used to calculate spring and summer velocity through the Barely Creek culvert battery. 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 assume 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 discharge events, and again during summer for the Tinmiaqsiugvik Bridge. 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 MEASURED DISCHARGE

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: May 27, 2019
Computed By: KDB
Checked By:

Location Name: Tin Bridge

Party: GCY, MDM, ACG Start: 5/27/2019 00:00 Finish:

Temp: 30 °F Weather: Freezing Rain, 20-30 MPH

Channel Characteristics:

Width: 297.5 ft Area: 1100 sq ft Velocity: 1.27 fps Discharge: 1401 cfs

Method: Mid-section technique Number of Sections: Count:

Spin Test: OK minutes after OK seconds Meter: Price AA

GAGE READINGS			
Gage	Start	Finish	Change
UB6.7	8.39	8.39	0.00
UB6.9	8.80	8.78	-0.02

Meter: 0.94 ft above bottom of weight

Weight: 30 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GPS Data:
Left Edge of Water:
Right Edge of Water:

LE Floodplain: ° ' . "
RE Floodplain: ° ' . "

Measurement Rated: Excellent Good **Fair** Poor based on "Descriptions"

Descriptions:

Cross Section:

Flow:

Remarks:

Tin Bridge
May 27, 2019

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
1	0	-	-	-	-	-					
1	20	22.5	1.8						0.00	40.5	0.00
1	25	12.5	2.0	1.2	50	47	2.36	2.36	2.36	25.0	59.08
1	45	19.0	3.1	1.9	40	41	2.17	2.17	2.17	58.9	127.74
1	63	20.0	3.4	2	30	52	1.29	1.29	1.29	68.0	87.71
0.99	85	21.0	2.6	1.6	7	54	0.30	0.30	0.30	54.6	16.41
1	105	20.0	2.2	1.3	20	56	0.81	0.81	0.81	44.0	35.43
1	125	21.0	2.3	1.4	30	51	1.31	1.31	1.31	48.3	63.50
0.98	147	20.0	3.1	1.9	20	59	0.77	0.77	0.75	62.0	46.49
0.98	165	19.0	2.9	1.7	5	49	0.24	0.24	0.24	55.1	13.11
0.98	185	20.0	3.4	2.0	10	42	0.54	0.54	0.53	68.0	36.17
0.98	205	12.5	5.8	3.5	5	52	0.23	0.23	0.23	72.5	16.33
0.98	210	5.0	6.8	5.4	5 10	46 54	0.26 0.43	0.34	0.33	34.0	11.39
0.99	215	7.0	6.8	5.4 1.4	15 40	47 48	0.72 1.86	1.29	1.28	47.6	60.71
0.99	224	7.5	7.1	5.6 1.4	30 50	40 44	1.67 2.52	2.10	2.08	53.3	110.57
1	230	5.5	7.5	6.0 1.5	60 70	42 44	3.17 3.53	3.35	3.35	41.3	138.04
1	235	5.0	7.7	6.2 1.5	80 90	44 42	4.03 4.74	4.38	4.38	38.5	168.80
1	240	5.0	7.6	6.1 1.5	60 100	43 49	3.09 4.52	3.81	3.81	38.0	144.62
1	245	5.0	6.9	5.5 1.4	40 70	48 46	1.86 3.37	2.61	2.61	34.5	90.18
1	250	7.5	6.4	5.1 1.3	10 40	49 51	0.47 1.75	1.11	1.11	48.0	53.16
0.98	260	12.5	5.2	4.2 1	15 10	63 42	0.54 0.54	0.54	0.53	65.0	34.57
0.98	275	17.5	3.8	2.3	20	45	1.00	1.00	0.98	66.5	65.02
0.98	295	12.5	2.9	1.7	15	54	0.63	0.63	0.62	36.3	22.39
1	300	-	-	-	-	-					

Total Discharge: 1401.43 cfs

B. SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Peak discharge was calculated using the normal depth method. The cross-section measurement taken during the May 27 discharge measurement was used for analysis of spring discharge. The cross-section measurement taken on September 9, 2017 was used for analysis of summer discharge as ice impacted the measurement taken in May. The energy gradient used for the spring calculation 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.

C. PLAN & CROSS SECTION PROFILE

ConocoPhillips Alaska

Feet
0 50 100 200 300

Date:	10/25/2019	Scale:	1 Inch = 250 Feet
Drawn:	JEG	Project:	171384
Checked:	GCY	File:	2019_GMT1_Tin.mxd

Gage Location
Ice Road
Facility
Station
Road
Ice Pad
Discharge Measurement Cross Section
Pipeline
Flow Direction

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

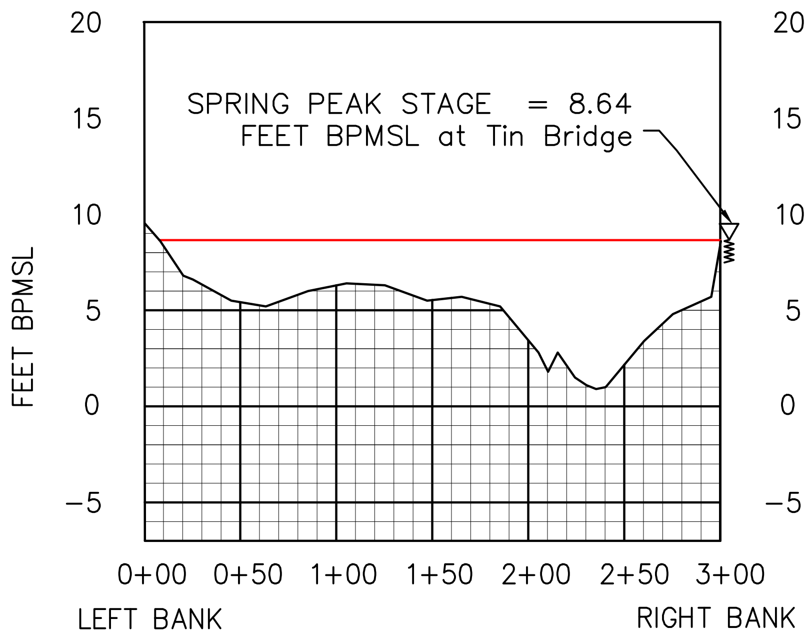
2019 Spring Breakup Tinmiaqsiuqvik River Plan

FIGURE C.1

Sheet 1 of 2

Imagery Source: Willow Aerial (COPA), 2018

NOTES
1. BASIS OF ELEVATION, PBM-35.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED MAY 27, 2019 BY MICHAEL BAKER INTL.
3. SUMMER LOWEST STAGE MEASURED DRY (0.89').



1 GMT1 CROSSING – TINMIAQSIUGVIK BRIDGE CROSS-SECTION

0 50 100 200 Feet
1":100'

ConocoPhillips Alaska, Inc.

DATE:	10/16/2019	PROJECT:	171384
DRAWN:	ACG	FILE:	TINMIAQSIUGVIK X-SECTION.DWG
CHECKED:	CSL	SCALE:	AS SHOWN

Michael Baker INTERNATIONAL

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

2019 SPRING BREAKUP
TINMIAQSIUGVIK RIVER
PROFILE

Crea Bridge

A. SPRING BREAKUP MEASURED VELOCITY & DISCHARGE

Date:	5/27/2019	**Time:**	4:20 PM	**Method:**	Mid Section Method	**Measurement Rating:**
Loc:	South side of Crea Bridge	**Crew:**	KDB, CMB	**Observed Depth:**	0.6 below water surface	Fair
Lat:	N 70.2797°	**Long:**	W 151.3295°	**Equip:**	HACH Meter	

Station (ft)	Measured Bottom Elevation (ft BPMSL)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+00.0	16.96	-	-	-	-	LEW
0+02.0	16.66	0.02	2	0.60	0.01	Grass
0+04.0	16.51	0.14	2	0.90	0.13	Grass
0+06.0	16.46	0.13	2	1.00	0.13	Grass
0+08.0	16.36	0.14	2	1.20	0.16	Grass
0+10.0	16.26	0.17	2	1.40	0.23	Grass
0+12.0	16.06	0.39	2	1.80	0.71	Grass
0+14.0	15.91	0.44	2	2.10	0.93	Grass
0+16.0	15.61	0.29	2	2.70	0.77	Grass
0+18.0	15.46	1.03	1.5	2.25	2.33	Grass
0+19.0	15.21	1.28	1	1.75	2.23	Grass
0+20.0	14.91	1.30	1	2.05	2.67	Thalweg
0+21.0	15.26	0.22	1	1.70	0.38	Grass - affected
0+22.0	15.46	0.47	1.5	2.25	1.07	Grass
0+24.0	15.66	0.38	2	2.60	0.99	Grass
0+26.0	15.86	0.15	2	2.20	0.34	Grass
0+28.0	15.96	0.38	2	2.00	0.75	Grass
0+30.0	16.26	0.12	2	1.40	0.17	Willows
0+32.0	16.55	0.12	2	0.80	0.10	Willows
0+34.0	16.65	0.06	2	0.60	0.03	Willows
0+36.0	16.65	0.13	2	0.60	0.08	Willows
0+38.0	16.65	0.05	2	0.60	0.03	Willows
0+40.0	16.95	-	-	-	-	REW

Notes:
1. *Measurement performed upstream of Crea Bridge.*
2. *Channel free of ice and snow during measurement.*

Total Width (ft)	Average Channel Bottom Elevation (ft BPMSL)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
40	16.06	0.35	-	32.5	14.2

Date:	5/29/2019	**Time:**	11:25 AM	**Method:**	Mid Section Method	**Measurement Rating:**
Loc:	South side of Crea Bridge	**Crew:**	JAB, MDM, GCY	**Observed Depth:**	0.6 below water surface	Fair
Lat:	N 70.2797°	**Long:**	W 151.3296°	**Equip:**	HACH Meter	

Station (ft)	Measured Bottom Elevation (ft BPMSL)	Velocity (ft/s)	Section Width (ft)	Area (ft^2)	Discharge (ft^3/s)	Note
0+00.0	18.16	-	-	-	-	LEW
0+01.0	16.46	0.85	2.5	4.25	3.60	Grass
0+05.0	17.06	1.39	4.5	4.95	6.89	Grass
0+10.0	17.06	0.41	4	4.40	1.79	Grass
0+13.0	16.46	1.07	3	5.10	5.48	Grass
0+16.0	16.86	1.45	3	3.90	5.64	Grass
0+19.0	16.56	1.87	2.5	4.00	7.47	Grass
0+21.0	16.36	2.12	2.5	4.50	9.56	Grass
0+24.0	15.86	2.24	3	6.90	15.48	Thalweg
0+27.0	14.96	2.35	3	9.60	22.61	Thalweg
0+30.0	15.76	2.23	3	7.20	16.05	Thalweg
0+33.0	16.36	0.75	5	9.00	6.77	Willows
0+40.0	16.76	0.80	6.5	9.10	7.28	Willows
0+46.0	16.36	0.46	4.5	8.10	3.71	Willows
0+49.0	15.26	0.88	2.5	7.25	6.35	Willows
0+51.0	15.36	1.12	2	5.60	6.25	Willows
0+53.0	14.86	1.94	1.5	4.95	9.61	Willows
0+54.0	18.16	-	-	-	-	REW

Notes:

1. *Measurement performed upstream of Crea Bridge.*
2. *Channel free of ice and snow during measurement.*

Total Width (ft)	Average Channel Bottom Elevation (ft BPMSL)	Average Velocity (ft/s)	-	Total Area (ft^2)	Total Discharge (ft^3/s)
54.0	16.37	1.37	-	98.8	134.5

B. SPRING BREAKUP & SUMMER CALCULATED DISCHARGE

Peak discharge was calculated using the normal depth method. The May 29 direct discharge measurement was performed when snow and ice impacts were minimized, so this second spring cross-section was used for spring and summer discharge calculations. The energy gradient used for the spring calculation 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, 0.025 for the main channel, and 0.080 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

Date:	10/25/2019
Drawn:	JEG
Checked:	GCY
Scale:	1 Inch = 100 Feet
Project:	171384
File:	2019_GMT1_CreaCreek.mxd

Gage Location
Station
Discharge Measurement Cross Section
Flow Direction
Ice Road
Road
Pipeline
Facility

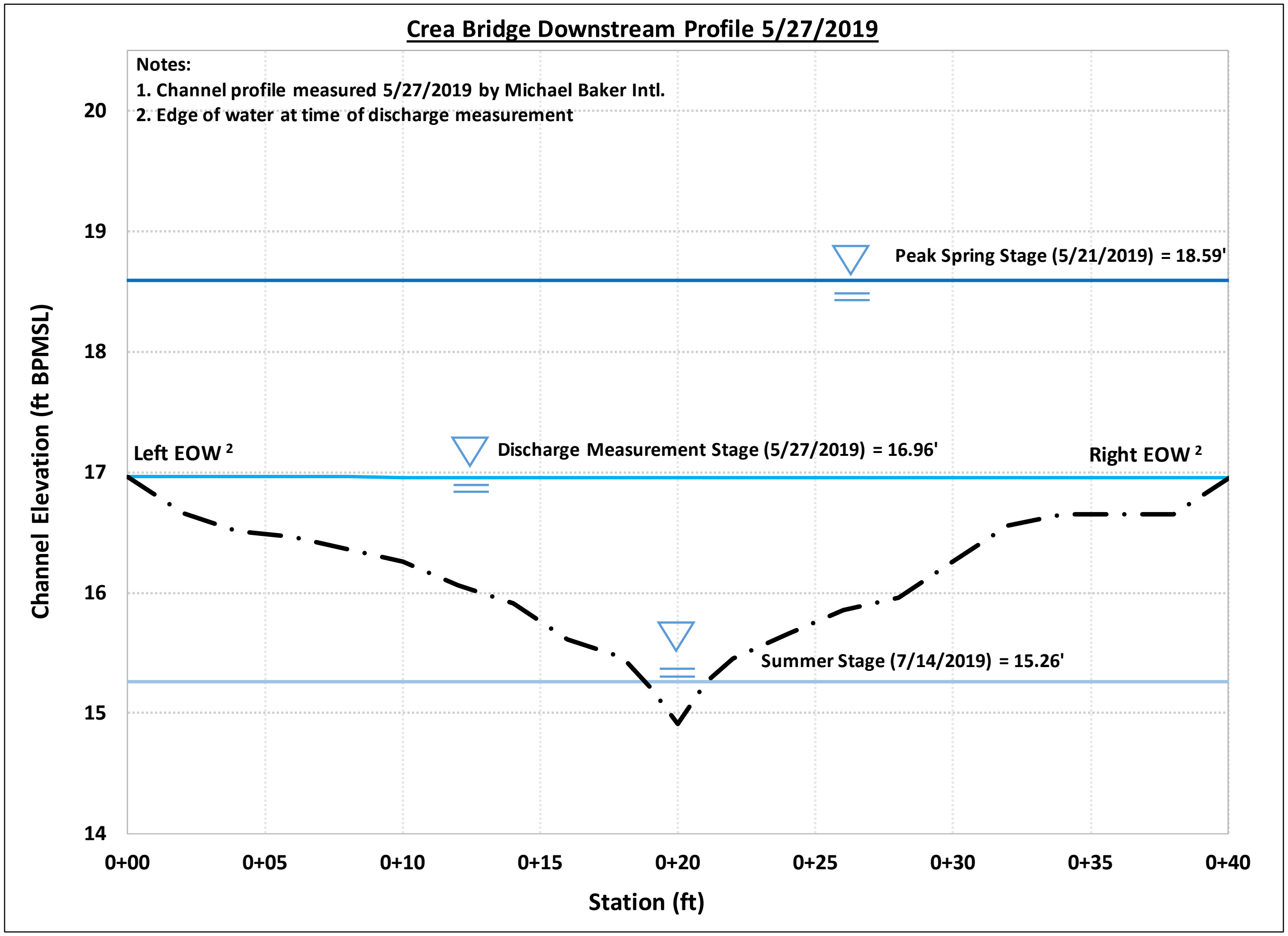
Michael Baker INTERNATIONAL
Michael Baker International, Inc.
3900 C. Street Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

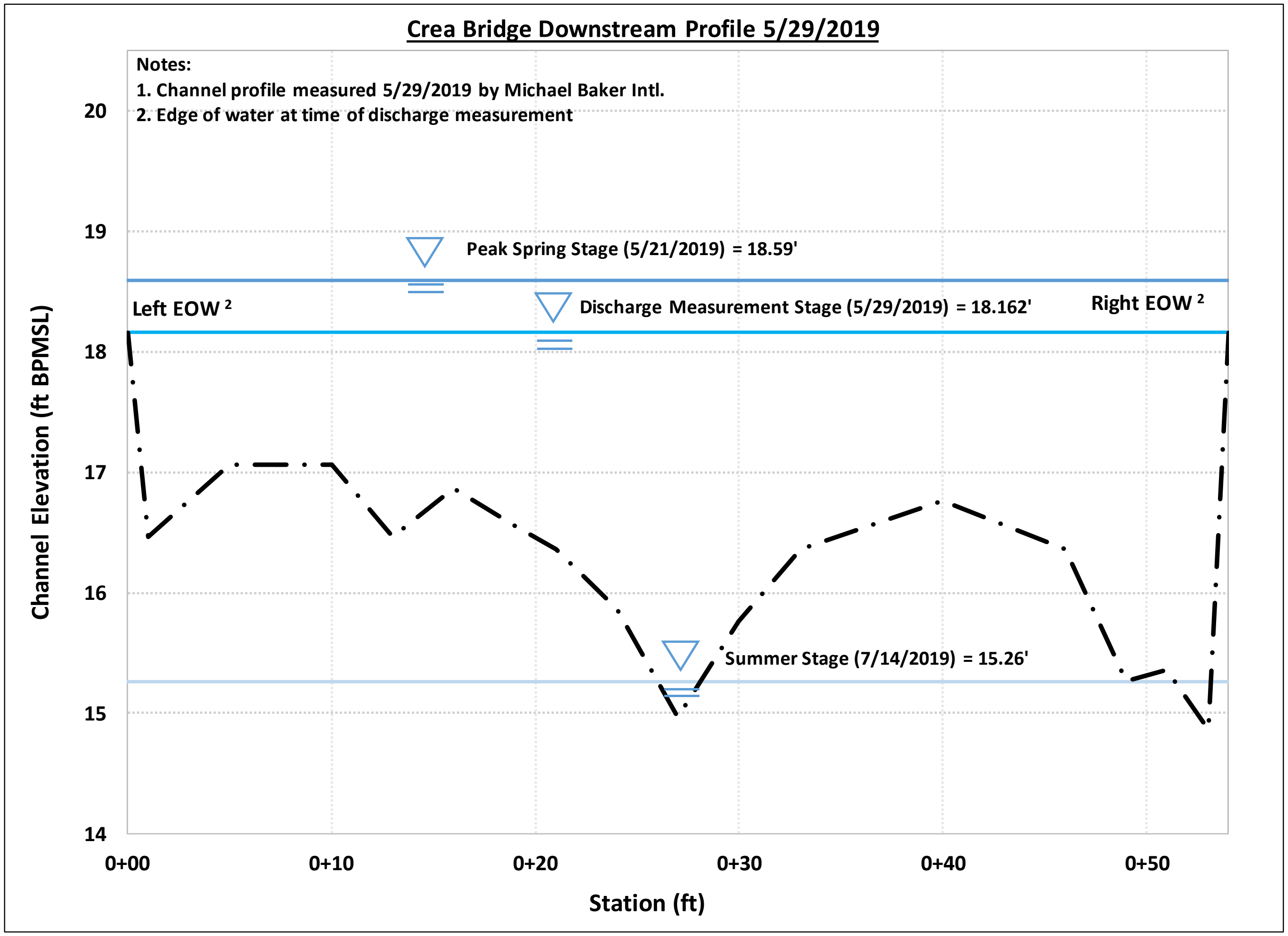
2019 Spring Breakup Crea Creek Plan

FIGURE C.2

Sheet 1 of 2

Imagery Source: Willow Aerial (COPA), 2018


Crea Bridge Downstream Profile 5/27/2019
Notes:
1. Channel profile measured 5/27/2019 by Michael Baker Intl.
2. Edge of water at time of discharge measurement
Peak Spring Stage (5/21/2019) = 18.59'
Left EOW 2
Discharge Measurement Stage (5/27/2019) = 16.96'
Right EOW 2
Summer Stage (7/14/2019) = 15.26'
Channel Elevation (ft BPMSL)
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
Station (ft)


Crea Bridge Downstream Profile 5/29/2019
Notes:
1. Channel profile measured 5/29/2019 by Michael Baker Intl.
2. Edge of water at time of discharge measurement
Peak Spring Stage (5/21/2019) = 18.59'
Left EOW [2]
Discharge Measurement Stage (5/29/2019) = 18.162'
Right EOW [2]
Summer Stage (7/14/2019) = 15.26'
Channel Elevation (ft BPMSL)
20
19
18
17
16
15
14
0+00
0+10
0+20
0+30
0+40
0+50
Station (ft)

Barely Creek Culvert Battery

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)
GMT1-42	5/27/2019 5:12pm	4.80	10.48	1.08	0.80	8.42
GMT1-43	5/27/2019 5:31pm	2.80	4.95	0.84	0.69	3.43
GMT1-44	5/27/2019 5:34pm	2.80	3.36	0.60	0.48	1.61

B. SUMMER CALCULATED DISCHARGE

Discharge was calculated using the Normal Depth method based on an open-channel cross-section surveyed in 2011. The energy gradient was taken as the average slope between S4-A and S4-C during the summer of 2108. The spring indirect calculations.

C. PLAN & CROSS SECTION PROFILES

ConocoPhillips Alaska

0 50 100 200 300 Feet

Date:	10/25/2019	Scale:	1 Inch = 250 Feet
Drawn:	JEG	Project:	171384
Checked:	GCY	File:	2019_GMT1_Barely.mxd

Gage Location
Station
Discharge Measurement Cross Section
Flow Direction
Road
Pipeline
Facility

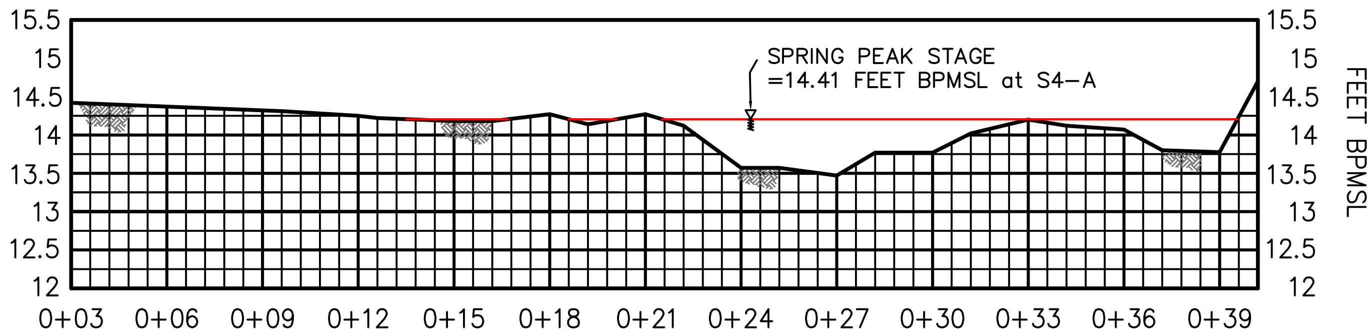
Michael Baker INTERNATIONAL
Michael Baker International, Inc.
3900 C. Street Suite 900
Anchorage, AK 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2019 Spring Breakup Barely Creek Plan

FIGURE C.3 | Sheet 1 of 2

Imagery Source: Willow Aerial (COPA), 2018

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 = 13.22 FEET BPMSL at S4-A



1 GMT1 CROSSING – BARELY CREEK CROSS-SECTION

0 9 18

HORIZONTAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/16/2019	PROJECT:	171384
DRAWN:	ACG	FILE:	BARELY X-SECTION.DWG
CHECKED:	CSL	SCALE:	AS SHOWN

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

2019 SPRING BREAKUP
BARELY CREEK
PROFILE

(SHEET 2 OF 2)

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 D. 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 D. 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 D. 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 E.1:Barely Creek culvert battery, looking southwest; July 2, 2019

Photo E.2: Barely Creek culvert battery inlet, looking northeast; July 3, 2019

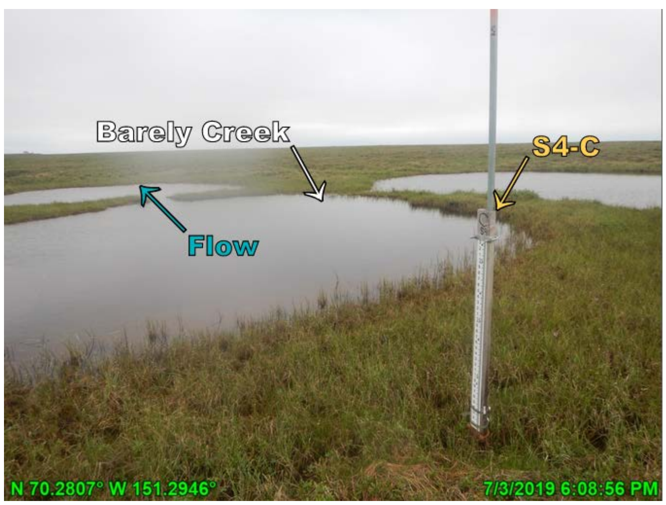


Photo E.3: Gage S4, looking south; July 3, 2019

B. CREA CREEK

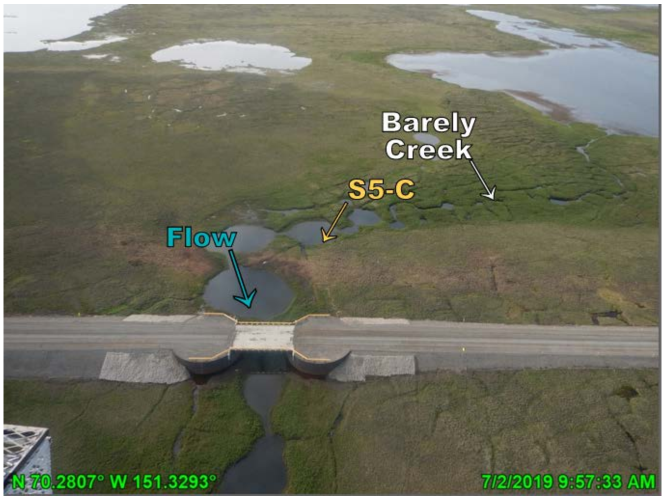


Photo E.4: Crea bridge, looking south (upstream); July 2, 2019

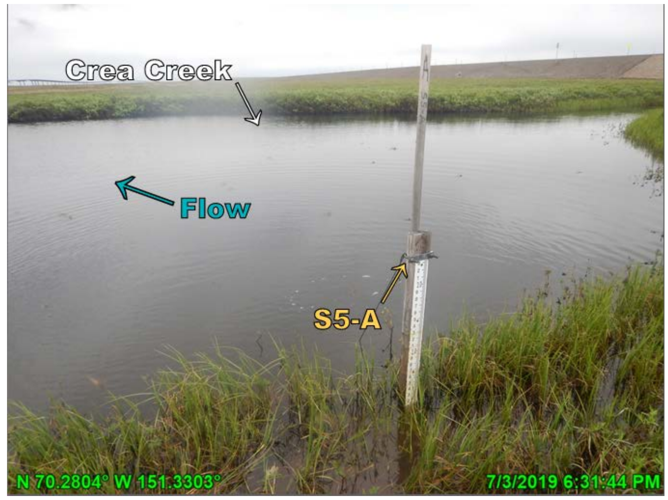


Photo E.5: Gage S5-A in Crea Creek, looking southeast; July 3, 2019

C. TINMIAQSIUGVIK RIVER

Photo E.6: Tinmiaqsiugvik Bridge, looking south (upstream); July 3, 2019

Photo E.7: Tinmiaqsiugvik River, looking northwest; July 3, 2019

Photo E.8: Tinmiaqsiugvik River at gage UB6.9-A; July 3, 2019

Photo E.9: Tinmiaqsiugvik Bridge, looking east; July 3, 2019

E.2 ICE ROAD CROSSINGS BREAKUP

D. CREA CREEK

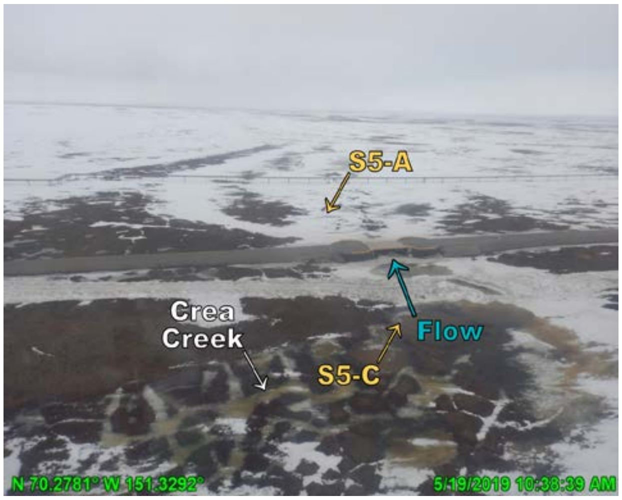


Photo E.10: Crea Creek with slotted ice road, looking north (downstream); May 19, 2019

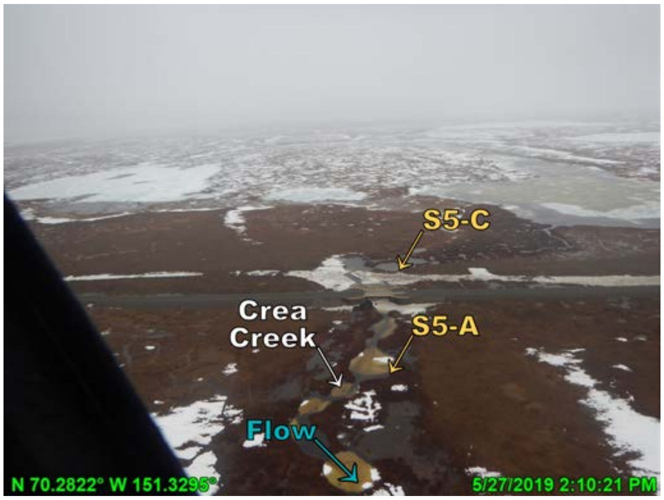


Photo E.11: Crea Creek during breakup, looking south; May 27, 2019

Photo E.12: Crea Creek during high flow conditions, looking south (upstream); May 29, 2019

E. TINMIAQSIUGVIK RIVER

Photo E.13: Tinmiaqsiugvik River with slotted ice road pre-breakup, looking east; May 29, 2019

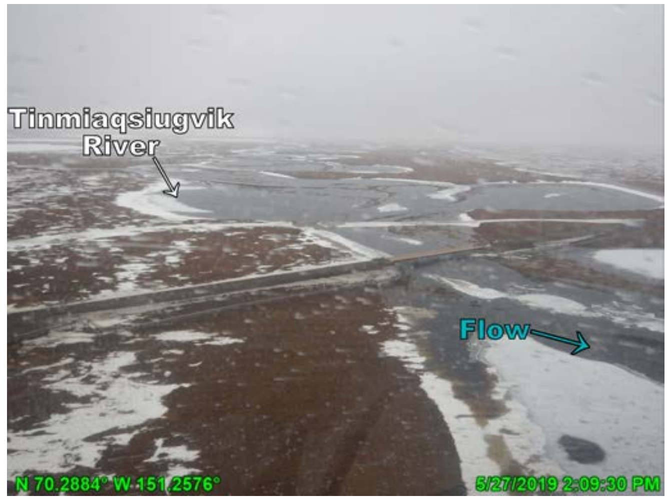


Photo E.14: Tinmiaqsiugvik River during breakup, looking north; May 27, 2019

Photo E.15: Tinmiaqsiugvik River post-breakup, looking southwest (upstream); June 2, 2019

2019 GMT1/MT6 Spring Breakup & Summer Monitoring & Hydrological Assessment