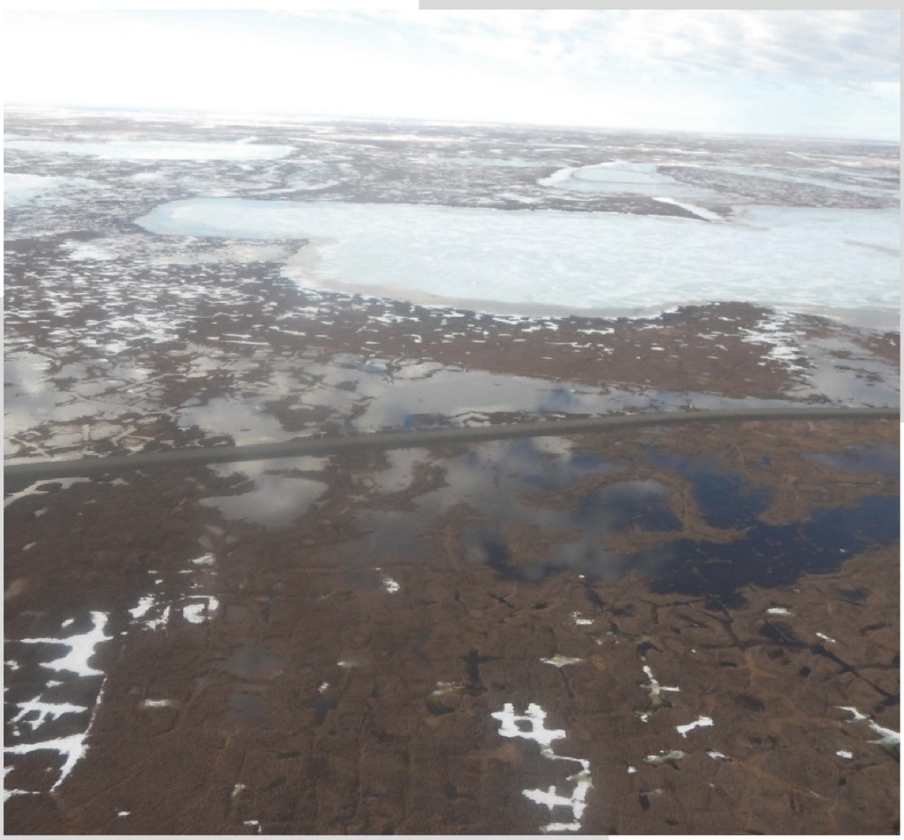
CULVERT MONITORING REPORT

2019 GREATER MOOSE'S TOOTH 1 (GMT1/MT6)

SPRING BREAKUP

ConocoPhillips
Alaska



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ACRONYMS & ABBREVIATIONS

Baro	Barometric
BPMSL	British Petroleum Mean Sea Level
CFDD	cumulative freezing degree days
cfs	cubic feet per second
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DS	Downstream
ft	Feet
fps	Feet per second
GMT1/MT6	Greater Moose's Tooth 1
GPS	Global positioning systems
HWM	High water mark(s)
Michael Baker	Michael Baker International
NAD83	North American Datum of 1983
NPR-A	National Petroleum Reserve Alaska
PT	Pressure transducer
UMIAQ	UMIAQ, LLC (formerly LCMF)
US	Upstream
USACE	U. S. Army Corps of Engineers
USGS	U.S. Geological Survey
WGS84	World Geodetic System of 1984
WSE	Water surface elevation(s)

1 INTRODUCTION

The ConocoPhillips Alaska Inc. (CPAI) Greater Moose's Tooth 1 (GMT1/MT6) facility is located within the Greater Moose's Tooth Unit and part of the Alpine Satellite Development program. GMT1/MT6 facilities include the GMT1/MT6 access road, pad, and pipelines. The GMT1/MT6 access road, pad, and a portion of the pipeline were constructed, and 71 culverts were installed during the winter of 2016-2017. One culvert labeled GMT1-39A was installed in September 2017.

The GMT1/MT6 access road spring breakup culvert monitoring field program took place during the 2019 GMT1/MT6 spring breakup monitoring and hydrologic assessment field program. This program began on April 19 and concluded on June 5. An additional site visit was performed on July 2 to retrieve field equipment and make summer observations. Figure 1 shows the GMT1/MT6 access road culvert monitoring locations. Culvert locations and properties are provided in Appendix A and indirect-read hydrologic staff gage (gage) and associated vertical control locations are provided in Appendix B.

UMIAQ, LLC (UMIAQ) and CPAI Alpine Field Environmental Coordinators provided support during the field program and contributed to a safe and productive monitoring season. 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.

1.1 Study Objective

This report addresses culvert performance and evaluation of areas where additional culverts or modifications to existing culverts are necessary to maintain natural drainage. This meets hydrology monitoring requirements set forth in the U.S. Army Corps of Engineers (USACE) permit POA-2013-461, Special Condition 6.c. This permit requires annual GMT1/MT6 access road culvert monitoring reports to be submitted for three years post-construction. This is the third and final year of required reporting.

The following tasks were performed to meet the permit requirements:

- Aerial and ground photo documentation of the GMT1/MT6 access road and pad to demonstrate hydraulic connections during spring breakup and post breakup (summer) conditions
- Identification of areas of ponding, drying, erosion, or stream channel changes adjacent to fill areas
- Demonstration of culvert conveyance of surface water flow based on the maintenance of natural drainage patterns and lack of evidence to the contrary (ponding, drying, erosion, stream channel changes)
- Evaluation of all areas where additional culverts are necessary to maintain natural drainage patterns
- Evaluation of all areas where culvert maintenance, repair, upgrade, setting adjustments, or replacement are necessary to maintain natural drainage patterns

Culvert locations and properties referenced in this report are from as-built surveys completed by UMIAQ in October 2017 and provided in Figure 1.

ConocoPhillips Alaska	0 0.25 0.5 1 miles
Date: 7/8/2019	Project: 171384
Drawn: JEG	File: Figure 1
Checked: GCY	Scale: 1 in = 0.5 miles

GMT1 Road Culvert — Ice Road — Road — Facility

gage(s)+PT — Ice Pad — Pipeline

Imagery Source : Conoco Phillips Alaska 2018 Aerial

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2019 GMT1 Gage Stations

FIGURE: 1

(SHEET 1 of 1)

1.2 FigData Collection

Data was collected at the following locations, as provided in Table 1.

Table 1: GMT1/MT6 Access Road Culvert Data Collection

Culverts	Associated Gages	Location Description
GMT1-01 through GMT1-20	Ungaged/Visual Observations	Cross drainage culverts located on high ground between GMT1/MT6 pad and Lake L9820
GMT1-21 through GMT1-29	S7-A/S7-B	Gages and culverts located in small swale north of Lake L9820
GMT1-30 through GMT1-37	S6-A/S6-B	Gages and culverts located in small swale north of Lake L9819
GMT1-38	Ungaged/Visual Observations	Cross drainage culvert located on high ground west of Crea Creek Bridge
GMT1-39	Ungaged/Visual Observations	Cross drainage culvert located on high ground east of Crea Creek Bridge
GMT1-40 through GMT1-44	S4-A/S4-C	Gages and culverts located at Barely Creek
GMT1-45 through GMT1-47	Ungaged/Visual Observations	Cross drainage culverts located on high ground west of the Tinmiaqsiugvik Bridge
GMT1-48 & GMT1-49	Ungaged/Visual Observations	Cross drainage culverts located on high ground east of the Tinmiaqsiugvik Bridge
GMT1-50 through GMT1-61	S3-A/S3-B	Gages and culverts located in small swale east of the Tinmiaqsiugvik Bridge
GMT1-62 through GMT1-71	S2-A/S2-B	Gages and culverts located in small swale near CD5 intersection

2 METHODS

2.1 Observations

Gage locations were selected based on topography and hydraulic significance. Field data collection and observations of interactions between floodwaters and infrastructure were recorded in field notebooks and on culvert monitoring field sheets. Photographic documentation of spring breakup conditions was collected using digital cameras with integrated global positioning systems (GPS). The latitude, longitude, data, and time are imprinted on each photo. The photo locations are referenced to the World Geodetic System of 1984 (WGS84) horizontal datum.

CPAI Alpine Field Environmental Coordinators provided a pickup truck for culvert access during spring breakup setup and monitoring. Soloy Helicopters provided helicopter support for performing overflights during spring breakup monitoring.

2.2 Water Surface Elevations

Water surface elevation (WSE) data was collected on both sides of the road prism to document WSE differential for assessing culvert performance. This was completed using a network of gages with pressure transducers (PTs) attached to each gage. For the purposes of this report, stage and WSE are used interchangeably.

2.2.1 Hydrologic Staff Gages

Gage assemblies (gage and PT) were installed or rehabilitated prior to breakup. Gage assemblies do not directly correspond to a British Petroleum Mean Sea Level (BPMSL) elevation. Elevations were surveyed relative to a known benchmark elevation using standard differential leveling techniques to determine a correction factor. The correction factor is applied to the gage and PT elevation to obtain the elevation in feet BPMSL (ft BPMSL).

Gage stations consist of one or more gage assemblies positioned on the upstream and downstream sides of the road prism. 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 gage support 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. Gage assemblies were identified with alphabetical designations, with the letter 'A' representing the gage assembly located on the north (downstream [DS]) side of the GMT1/MT6 access road and the letters 'B' and 'C' representing gage assemblies located on the south (upstream [US]) side of the GMT1/MT6 access road.

High water marks (HWMs) on the gages were recorded by applying chalk on the angle iron posts and measuring the wash line. HWMs were recorded to document peak stage.

2.2.2 Pressure Transducers

PTs were attached to all gages to supplement gage readings and provide a continuous record of WSE when the water column is above the PT sensor. PTs were programmed to collect data at 15-minute intervals from May 10th to August 31st. 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. Once collected from the field, the PT measurements will be adjusted to WSE readings at the gages. PT setup, testing, and processing methods are detailed in Appendix C.

2.3 Discharge Measurements

Site visits and direct measurements were performed as near to peak flow conditions as possible. Measurements were collected in all culverts observed conveying flow. Culvert velocity and flow depth were measured directly using a HACH FH950 electromagnetic velocity meter and a wading rod. Discharge was calculated using measured velocity, flow depth, and the inside culvert diameter. Inside culvert diameter was determined based on the outside culvert diameter and wall thickness data provided by UMIAQ (UMIAQ 2017). Discharge methods are detailed in Appendix D.

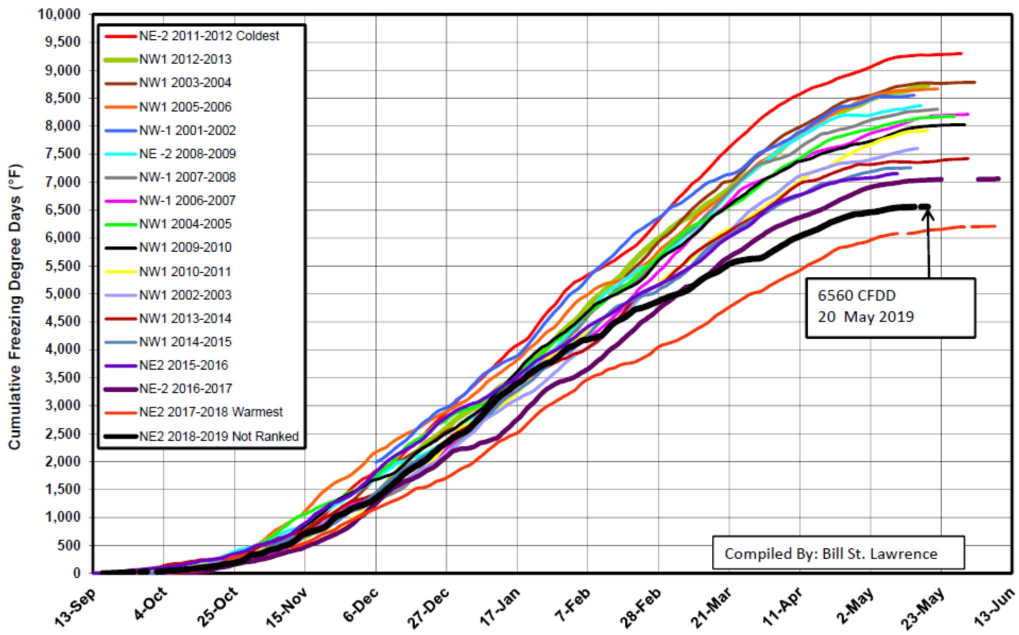
2.4 Culvert Performance Evaluation

Culvert performance was evaluated based on observations, WSE, and discharge measurements with a focus on maintenance, repair, upgrade, setting adjustments, and/or replacement. In addition, the condition of the road fill around the culverts was evaluated to identify areas of erosion.

3 Results

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 2nd warmest on record for the past 18 years (Graph 3.1).



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.

3.2 General Observations Summary

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 the end of April confirmed that snow had been cleared from all culvert inlets and outlets (Photo 3.1). Bladders had been removed from most culverts; however, many bladders remained frozen in place, temporarily blocking the culvert openings.

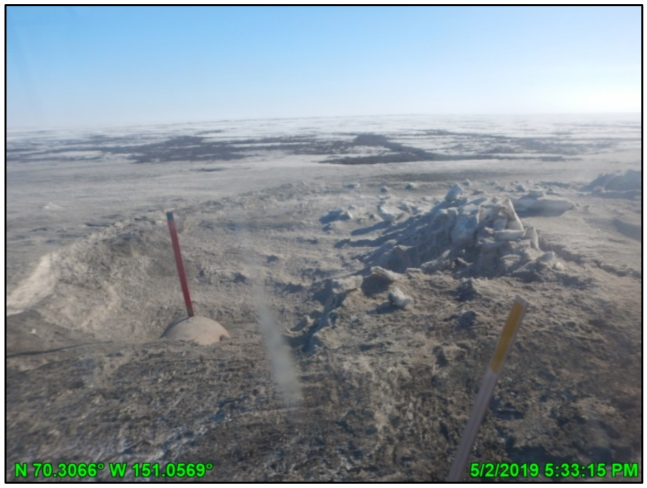


Photo 3.1: Excavated culvert along the GMT1/MT6 access road, looking north; May 2, 2019

On May 17, local melt was observed in isolated areas around the GMT1/MT6 access road. By May 22, increasing local meltwater was accumulating in and around natural drainage areas. 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%.

On May 27, discharge measurements were performed at all GMT1/MT6 culverts conveying flow. At the time of these measurements, increased meltwater had elevated stage to near peak conditions in the GMT1/MT6 monitoring area. By May 29, aerial observations suggest meltwater was hydraulically connected through drainage structures at most monitoring locations.

In general, all unblocked culverts in defined drainages along the alignment were observed to be conveying flow. Cross flow culverts, situated on higher ground outside of defined drainages, remained dry during spring breakup monitoring. The ability to visit GMT1/MT6 sites and perform flyovers for observation was limited after May 30 due to local subsistence hunting activity.

3.3 Site Specific Observations & Water Surface Elevations

Site specific observations are based on WSE and HWM gage readings, along with photographic documentation. Summarized observations of flow conditions are tabulated in Appendix E. Additional site-specific monitoring photos are provided in Appendix F.

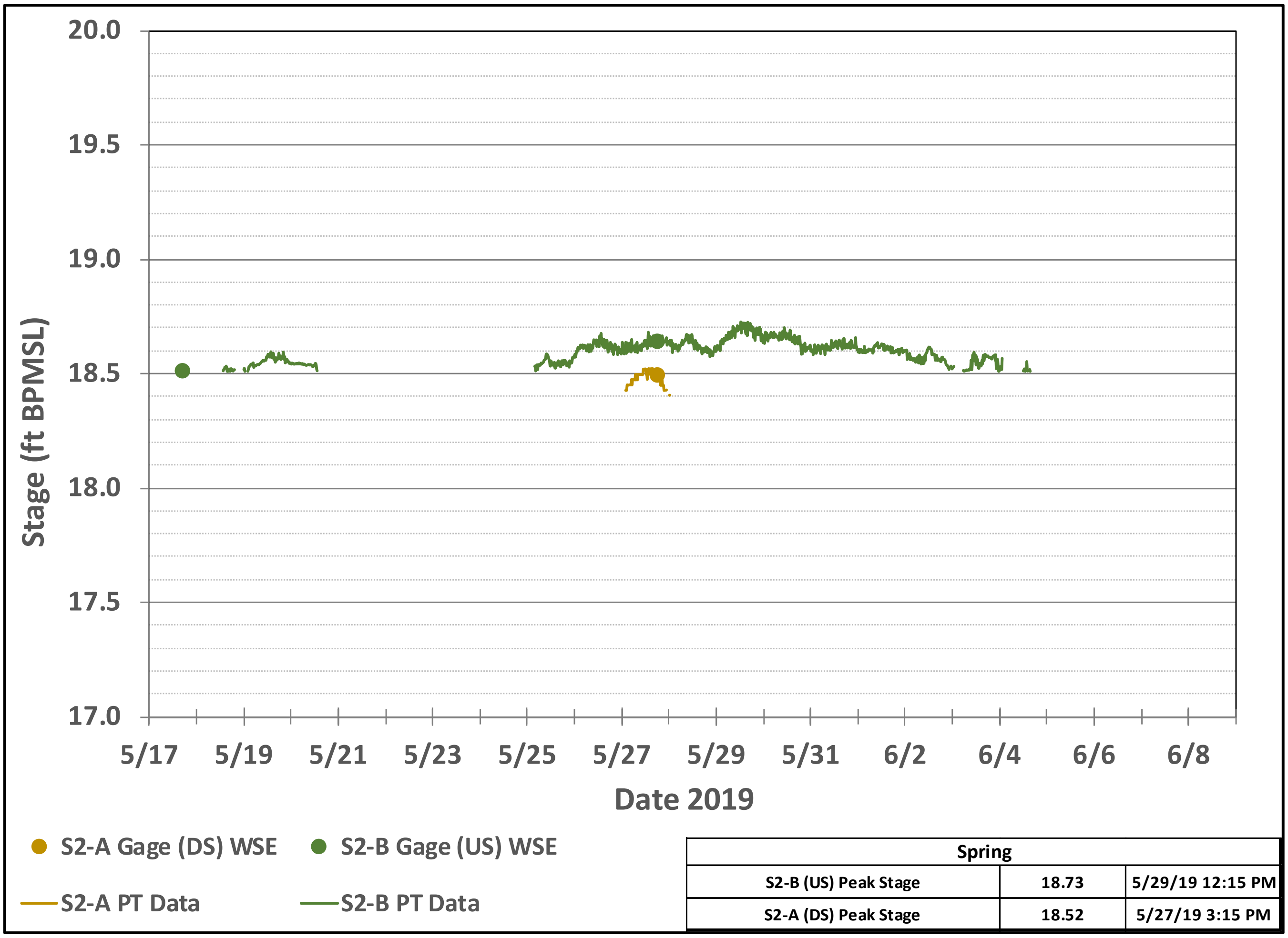
3.3.1 S2 Culverts (GMT1-60 through GMT1-71)

The S2 monitoring location is situated in a large natural depression which encompasses the CD5 road intersection and extends into the GMT1/MT6 access road. On the north side of the GMT1/MT6 access road, the drainage connects to a beaded stream which flows into the Tinmiaqsiugvik River, northwest of the S2 monitoring location. Culverts GMT1-60 through GMT1-71 equalize accumulating meltwater on the north and south side of the GMT1/MT6 access road.

Local melt was initially observed at gage station S2 on May 17. On May 22, widespread local meltwater was observed in low lying areas on each side of the GMT1/MT6 road and aerial observations suggest hydraulic connections were established through many of the culverts (Photo F.1). By May 27, meltwater was present on both sides of the GMT1/MT6 road and culverts GMT1-65 and GMT1-67 were conveying flow (Photo F.2). PT data indicated that meltwater stage remained elevated through June 5 at the S2-B (US) gage. Aerial observations from July 2 show equalized hydraulic conditions in the area (Photo F.3).

PT data indicates peak stage occurred at S2-A (DS) and S2-B (US) on May 27 and May 29, respectively. All culverts were observed to be functioning as designed and natural drainage patterns in the area were maintained.

S2 spring breakup stage data is provided in Graph 3.2. Measured discharge data is presented in section 3.4. Photos are provided in Appendix F.1.



Spring		
S2-B (US) Peak Stage	18.73	5/29/19 12:15 PM
S2-A (DS) Peak Stage	18.52	5/27/19 3:15 PM

Graph 3.2: S2 Water Surface Elevations

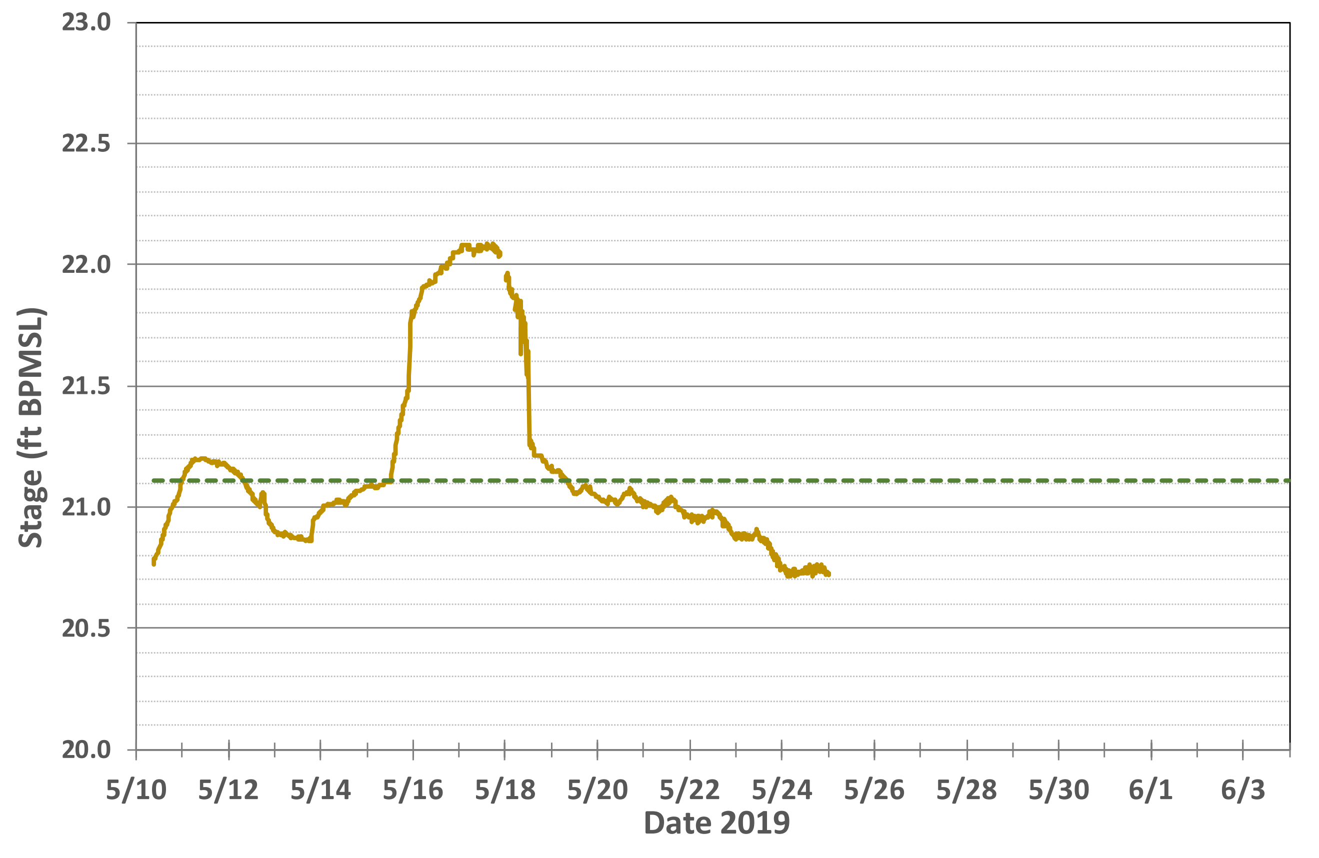
3.3.2 S3 Culverts (GMT1-50 through GMT1-59)

The S3 monitoring location is situated in a small, poorly defined network of high centered polygon troughs. The drainage connects the natural depression associated with S2 to the east to the Tinmiaqsiugvik River to the west. In the past, during periods of high flow, backwater from the Tinmiaqsiugvik River has been observed extending to this monitoring location. This was not the case in 2019 when spring breakup flows in the Tinmiaqsiugvik River remained low and confined within the channel banks. 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.

Local melt was first observed on the north (downstream) side of the GMT1/MT6 road near S3-A on May 22. On May 27, local melt was observed on both sides of the GMT1/MT6 road and GMT1-52 was conveying flow (Photo F.4). At this time, drifted snow accumulation was observed at some culvert inlets which temporarily inhibited drainage, leading to minor ponding on the south side of the road (Photo F.5). On May 29, snow cover on the surrounding tundra was minimal and local meltwater was still observed in the area (Photo F.6). Aerial observations from July 2 show equalized hydraulic conditions in the area (Photo F.7).

PT data indicates peak stage occurred at S3-A (DS) on May 17 and was likely the result of the temporary blockage from the drifted snow. Meltwater at the S2-B (US) gage did not reach the PT. With the exception of temporary blockage from drifted snow accumulation, all culverts were observed to be functioning as designed and natural drainage patterns in the area were maintained.

S3 spring breakup stage data is provided in Graph 3.3. Measured discharge data is presented in section 3.4. Photos are provided in Appendix F.2.



Spring		
S3-A (DS) Peak Stage	22.09	5/17/19 5:30 PM
*Meltwater at S3-B (US) did not reach the PT		

Graph 3.3: S3 Water Surface Elevations

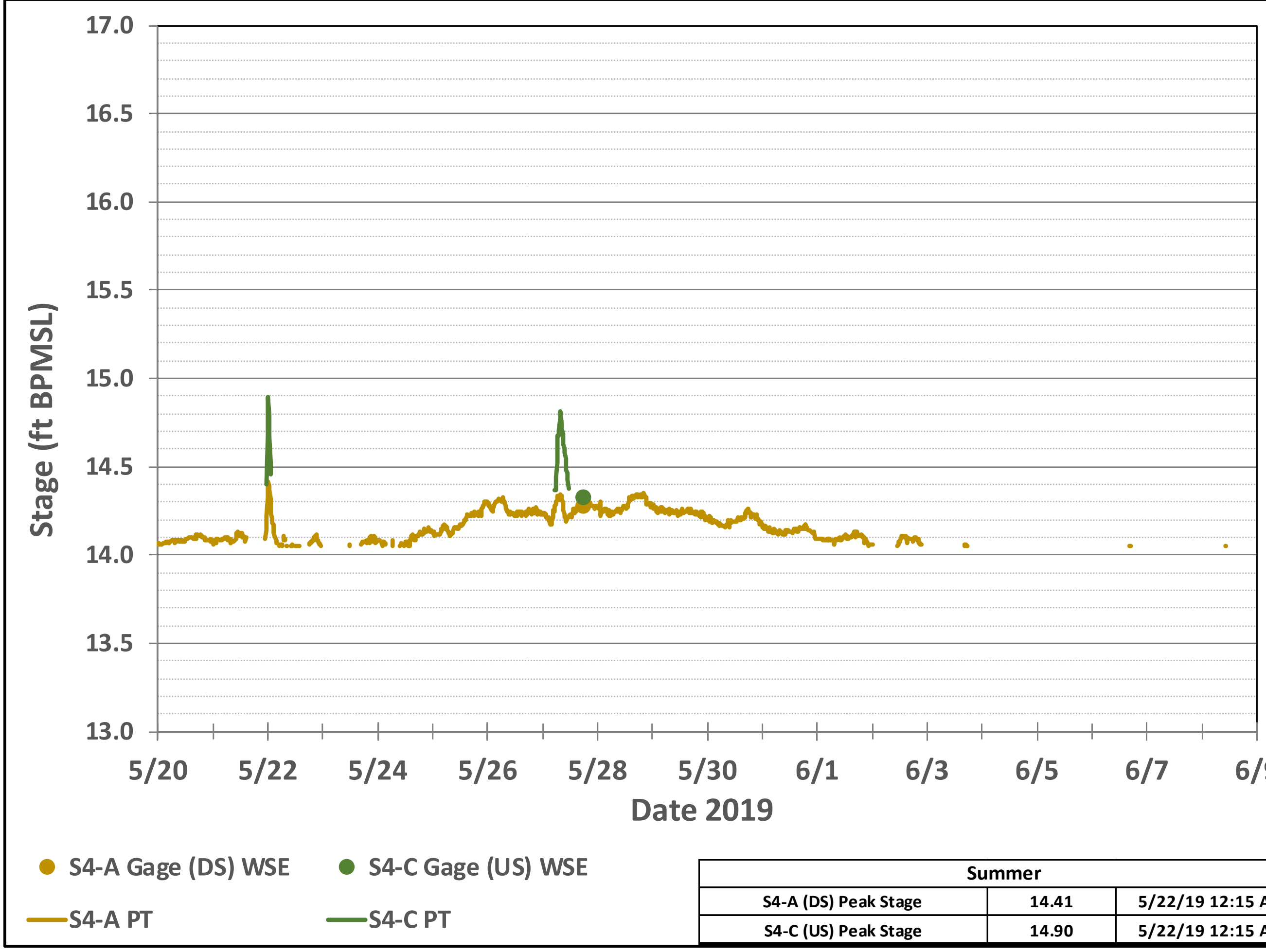
3.3.3 S4 (Barely Creek) Culverts (GMT1-40 through GMT1-44)

The S4 monitoring location is located on Barely Creek, a beaded stream that drains north across the GMT1/MT6 access road into the Tinmiaqsiugvik River. Culverts GMT1-42, 43, and 44 are located in Barely Creek.

On May 19th, ponded local melt was observed in the Barely Creek drainage (Photo F.8). Snow cover on the surrounding tundra was approximately 70%. Aerial observations from May 22 show flow paths forming through drifted snowpack in the drainage on both sides of the GMT1/MT6 road, suggesting hydraulic connection had been initiated (Photo F.9). On May 27, discharge through the culverts conveying flow was measured and minor overbank flooding in the drainage was observed. (Photo F.10). Stage remained elevated through May 29 (Photo F.11). Aerial observations from July 2 show a hydraulic connection maintained through the summer in Barely Creek (Photo F.12).

PT data indicates peak stage occurred at S4-A (DS) and S4-C (US) on May 22. 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.

S4 spring breakup stage data is provided in Graph 3.4. Measured discharge data is presented in section 3.4. Photos are provided in Appendix F.3.



Summer		
S4-A (DS) Peak Stage	14.41	5/22/19 12:15 AM
S4-C (US) Peak Stage	14.90	5/22/19 12:15 AM

Graph 3.4: S4 Water Surface Elevations

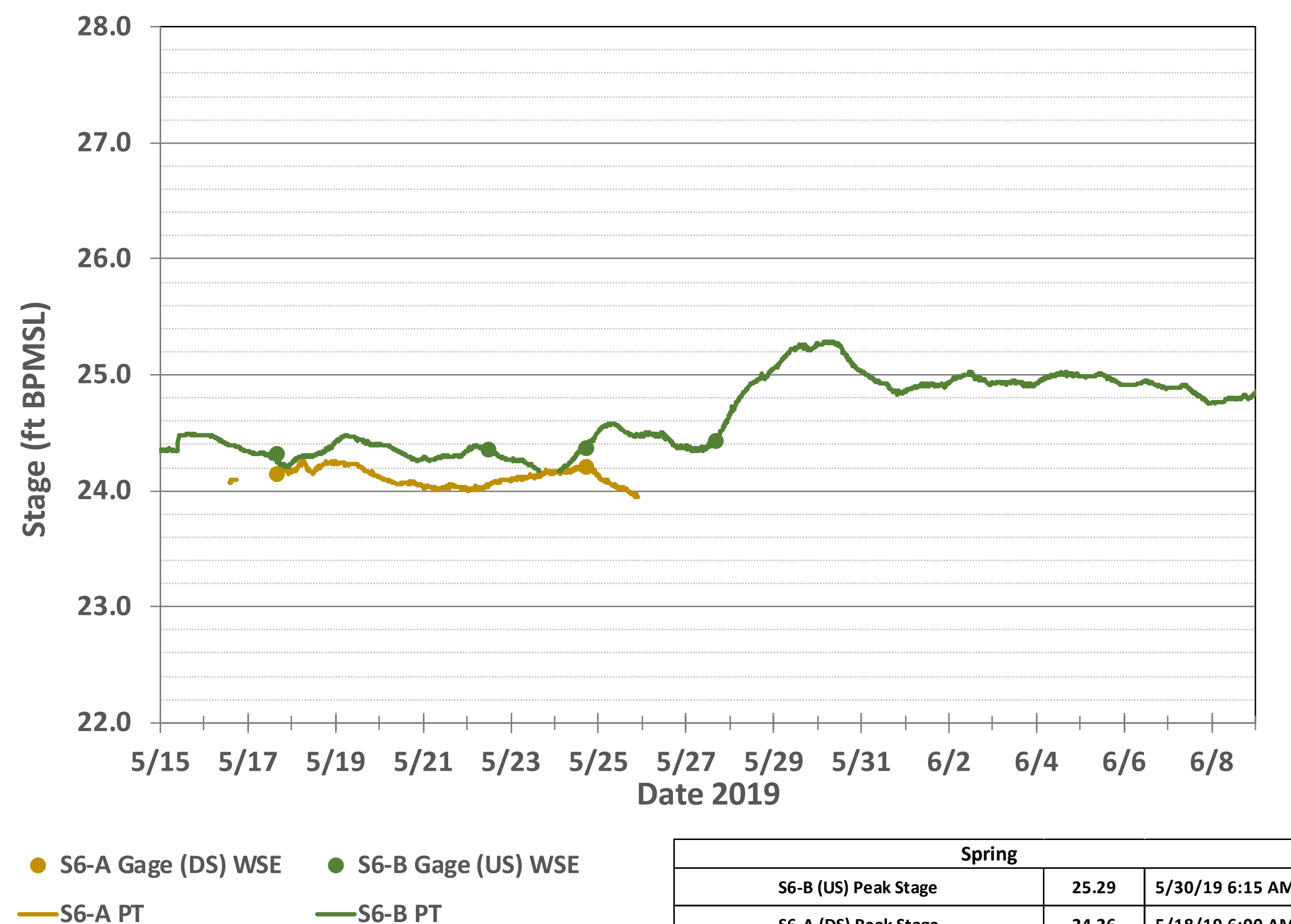
3.3.4 S6 Culverts (GMT1-30 through GMT1-37)

The S6 monitoring location is situated in a swale depression that drains Lake L9819 (south of the GMT1/MT6 access road) towards the north. Culverts GMT1-31 through GMT1-33 are located in the swale and culverts GMT1-30 and GMT1-34 through GMT1-37 are situated on higher ground outside of the defined drainage.

On May 19, local meltwater was accumulating near the S6 gage stations (Photo F.13). On May 22, ponded meltwater was observed on the south (upstream) side of the road and culverts situated in the drainage were blocked with snow and ice (Photo F.14). A small flow path through the snow was observed at culvert GMT1-31. On May 27, meltwater was present on both sides of the road, but continued ponding on the south (upstream) side near gage S6-B suggests partial blockage of the culverts (Photo F.15). On May 29, ponded water remained at S6-B (Photo F.16). Snow cover on the surrounding tundra was approximately 10%. PT data at S6-B (US) shows a steady drop in stage beginning on May 30, suggesting culvert blockage relief. Aerial observations from July 2 show equalized hydraulic conditions in the area (Photo F.17).

PT data indicates peak stage occurred at S6-A (DS) and S6-B (US) on May 18 and May 30, respectively. With the exception of temporary blockage from drifted snow accumulation, all culverts were observed to function as designed and natural drainage patterns in the area were maintained.

S6 spring breakup stage data is provided in Graph 3.5. Detailed measured discharge data is presented in section 3.4. Photos are provided in Appendix F.4.



Spring		
S6-B (US) Peak Stage	25.29	5/30/19 6:15 AM
S6-A (DS) Peak Stage	24.26	5/18/19 6:00 AM

Graph 3.5: S6 Water Surface Elevations

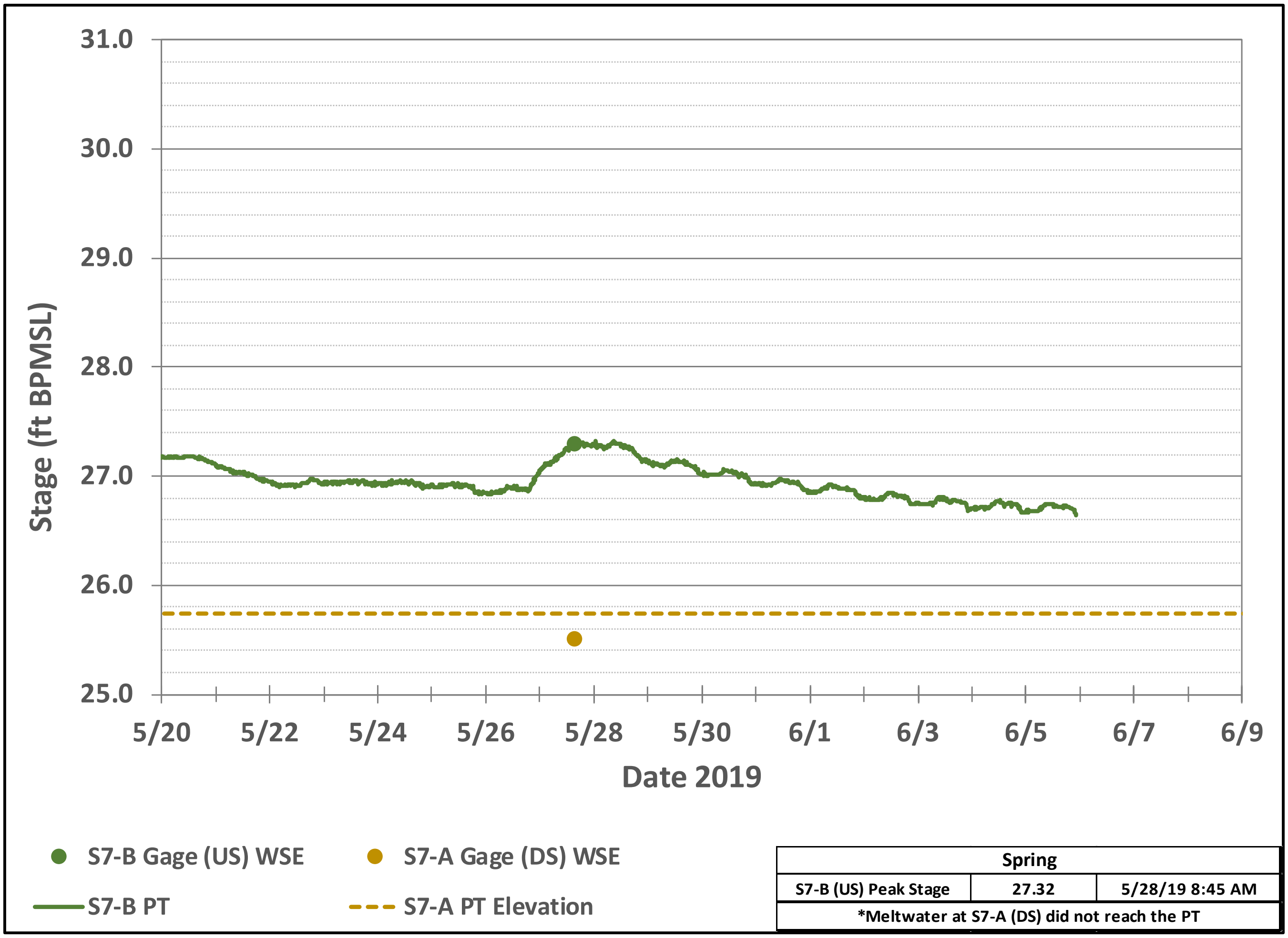
3.3.5 S7 Culverts (GMT1-21 through GMT1-29)

The S7 monitoring location is situated in a swale depression that drains Lake L9820 (south of the GMT1/MT6 access road) towards the north.

Local meltwater was first observed on May 19 (Photo F.18). On May 22, meltwater was observed on both sides of the GMT1/MT6 road near the S7 gage stations (Photo F.19). On May 27, flow was measured through culvert GMT1-27 (Photo F.20). Other culverts were partially blocked by snow and ice, leading to temporary ponding on the upstream side of the road (Photo F.21). Partially blocked culverts and accumulating ponded meltwater on the south side of the road near S7-B (upstream) forced flow through culverts situated further east. By May 29, aerial observations indicate meltwater equalization through the culverts. Snow cover on the surrounding tundra was approximately 10% (Photo F.22). Aerial observations from July 2 show equalized hydraulic conditions in the area (Photo F.23).

PT data indicates peak stage occurred at S7-B (US) on May 28. Meltwater at the S7-A (DS) gage did not reach the PT. With the exception of temporary blockage from drifted snow accumulation and a perched outlet at culvert GMT1-23, all culverts were observed to function as designed and natural drainage patterns in the area were maintained. Culvert GMT1-23 will be monitored over the coming year and plans to readjust or replace the culvert will be developed.

S7 spring breakup stage data is provided in Graph 3.6. Measured discharge data is presented in section 3.4. Photos are provided in Appendix F.5.



Graph 3.6: S7 Water Surface Elevations

3.4 Discharge Measurements

Discharge was measured on May 22 and May 27 at culverts observed conveying flow. A summary of the discharge measurements is presented in Table 2.

Table 2: GMT1/MT6 Access Road Culvert Discharge

Culvert	Measurement Date & Time	Culvert Inside Diameter (ft)	Flow Area (ft^2)	Measured Depth of Flow (ft)	Measured Velocity (fps)	Discharge (cfs)
GMT1-43	5/22/2019 11:38am	2.80	2.80	0.52	0.53	1.49
GMT1-07	5/27/2019 11:10am	1.91	1.14	0.32	0.15	0.17
GMT1-08	5/27/2019 11:15am	1.80	1.18	0.34	0.40	0.47
GMT1-10	5/27/2019 11:36am	1.91	0.77	0.24	1.53	1.18

Culvert	Measurement Date & Time	Culvert Inside Diameter (ft)	Flow Area (ft^2)	Measured Depth of Flow (ft)	Measured Velocity (fps)	Discharge (cfs)
GMT1-18	5/27/2019 12:05pm	1.91	1.23	0.34	0.15	0.18
GMT1-27	5/27/2019 1:28pm	1.80	0.74	0.24	0.29	0.22
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
GMT1-47	5/27/2019 5:49pm	3.80	3.07	0.48	0.26	0.79
GMT1-52	5/27/2019 5:58pm	1.80	1.27	0.36	0.37	0.47
GMT1-65	5/27/2019 6:19pm	2.80	3.36	0.60	1.87	6.29
GMT1-67	5/27/2019 6:27pm	2.80	3.91	0.68	1.03	4.03

3.5 Culvert Performance Evaluation

No performance issues were identified at any culverts along the GMT1/MT6 access road. Temporary ponded water was present at several locations along the access road but was attributed to snow or culvert bladders frozen in place, temporarily impeding flow, and not culvert placement (Photo 3.2 and 3.3).

Photo 3.2: Local ponding on south side of GMT1/MT6 access road at site S6, looking south; May 28, 2019

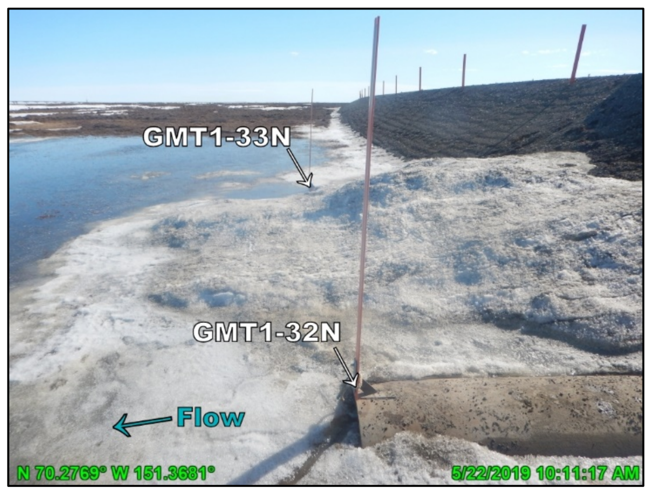


Photo 3.3: Culverts GMT1-32 and 33 impeded by ice and snow buildup, looking southwest; May 22, 2019

After snow was manually cleared in late April, drifted snow had accumulated at some of the culverts. Some culvert bladders remained frozen into the culverts and impeded flow (Photo 3.4). Several culverts contained ice and snow blockage which also impeded flow (Photo 3.5). Once conveyance paths were established through either removing culvert bladders or meltwater naturally cutting through snow and ice, the culverts all performed as designed and natural drainage patterns were maintained (Photo 3.6, 3.7, 3.8). Culvert GMT1-03 remains perched at the outlet, which may lead to the development of a scour hole (Photo 3.9). No displacement of uncompacted gravel fill attributed with spring breakup flooding was observed along the road embankment or around culvert inlets and outlets. No culvert maintenance, repair, upgrade, setting adjustments, and/or replacements are recommended at this time. Culvert GMT1-03 will be monitored over the coming year and plans to readjust or replace the culvert will be developed.

Photo 3.4: Culvert GMT1-17 with culvert bladder blockage, looking north; May 27, 2019

Photo 3.5: Culvert GMT1-21 with ice blockage, looking north; May 27, 2019

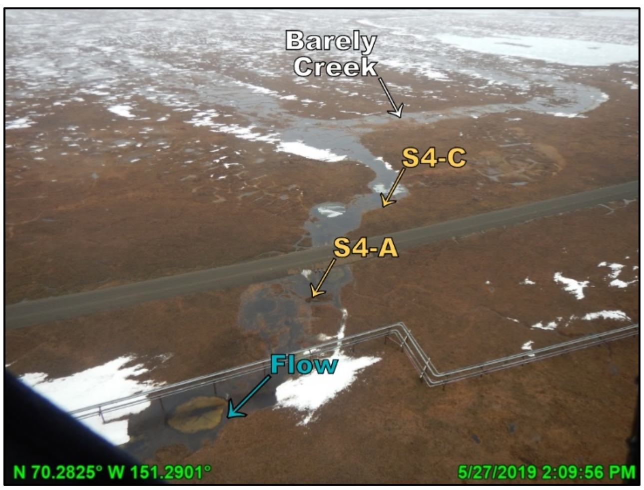


Photo 3.6: Barely Creek flowing north through GMT1/MT6 culverts, looking south; May 27, 2019

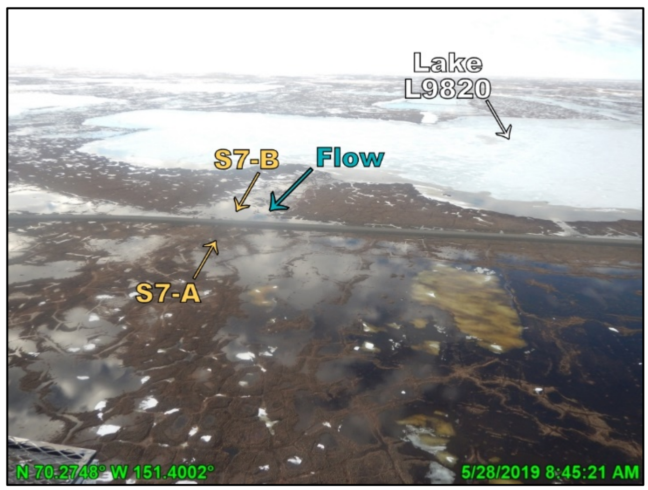


Photo 3.7: Hydraulic conditions at S7, looking south; May 28, 2019

Photo 3.8: Water flowing freely through culvert GMT1-07, looking north; May 27, 2019

Photo 3.9: Perched culvert GMT1-03 with minimal flow, looking north; May 27, 2019

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Appendix A Culvert Locations & Properties

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-01N	13+07	70.2577°	-151.4806°	24	2	0.045	1.910
GMT1-01S		70.2576°	-151.4800°				
GMT1-02N	16+87	70.2585°	-151.4788°	24	2	0.045	1.910
GMT1-02S		70.2583°	-151.4786°				
GMT1-03N	23+93	70.2593°	-151.4738°	24	2	0.085	1.830
GMT1-03S		70.2592°	-151.4733°				
GMT1-04N	31+15	70.2602°	-151.4684°	24	2	0.100	1.800
GMT1-04S		70.2600°	-151.4682°				
GMT1-05N	34+65	70.2606°	-151.4660°	24	2	0.045	1.910
GMT1-05S		70.2605°	-151.4655°				
GMT1-06N	41+61	70.2615°	-151.4608°	24	2	0.045	1.910
GMT1-06S		70.2613°	-151.4606°				
GMT1-07N	46+80	70.2621°	-151.4570°	24	2	0.045	1.910
GMT1-07S		70.2619°	-151.4568°				
GMT1-08N	52+33	70.2627°	-151.4531°	24	2	0.100	1.800
GMT1-08S		70.2626°	-151.4527°				
GMT1-09N	56+29	70.2632°	-151.4502°	24	2	0.100	1.800
GMT1-09S		70.2630°	-151.4498°				
GMT1-10N	57+91	70.2634°	-151.4491°	24	2	0.045	1.910
GMT1-10S		70.2633°	-151.4485°				
GMT1-11N	60+35	70.2637°	-151.4472°	24	2	0.045	1.910
GMT1-11S		70.2635°	-151.4469°				
GMT1-12N	63+36	70.2641°	-151.4450°	24	2	0.045	1.910
GMT1-12S		70.2639°	-151.4447°				
GMT1-13N	68+66	70.2647°	-151.4410°	24	2	0.085	1.830
GMT1-13S		70.2645°	-151.4410°				
GMT1-14N	71+55	70.2650°	-151.4390°	24	2	0.085	1.830
GMT1-14S		70.2648°	-151.4388°				
GMT1-15N	78+15	70.2658°	-151.4343°	24	2	0.085	1.830
GMT1-15S		70.2657°	-151.4339°				
GMT1-16N	82+36	70.2663°	-151.4311°	24	2	0.085	1.830
GMT1-16S		70.2661°	-151.4310°				
GMT1-17N	85+63	70.2667°	-151.4291°	36	3	0.045	2.910
GMT1-17S		70.2666°	-151.4282°				
GMT1-18N	89+03	70.2671°	-151.4264°	24	2	0.045	1.910
GMT1-18S		70.2669°	-151.4260°				
GMT1-19N	96+65	70.2680°	-151.4209°	24	2	0.045	1.910
GMT1-19S		70.2679°	-151.4204°				
GMT1-20N	99+27	70.2683°	-151.4189°	24	2	0.045	1.910
GMT1-20S		70.2682°	-151.4186°				
GMT1-21N	109+04	70.2693°	-151.4112°	24	2	0.045	1.910
GMT1-21S		70.2691°	-151.4115°				
GMT1-22N	117+10	70.2701°	-151.4054°	24	2	0.045	1.910
GMT1-22S		70.2699°	-151.4052°				
GMT1-23N	127+30	70.2712°	-151.3978°	24	2	0.045	1.910
GMT1-23S		70.2710°	-151.3976°				
GMT1-24N	130+95	70.2716°	-151.3952°	24	2	0.045	1.910
GMT1-24S		70.2714°	-151.3948°				
GMT1-25N	133+78	70.2719°	-151.3929°	24	2	0.045	1.910

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-25S		70.2717°	-151.3929°				
GMT1-26N	134+41	70.2720°	-151.3925°	24	2	0.045	1.910
GMT1-26S		70.2718°	-151.3924°				
GMT1-27N	138+78	70.2725°	-151.3895°	24	2	0.045	1.910
GMT1-27S		70.2724°	-151.3892°				
GMT1-28N	145+38	70.2735°	-151.3851°	24	2	0.100	1.800
GMT1-28S		70.2734°	-151.3846°				
GMT1-29N	149+20	70.2741°	-151.3823°	24	2	0.100	1.800
GMT1-29S		70.2739°	-151.3823°				
GMT1-30N	157+54	70.2754°	-151.3769°	24	2	0.100	1.800
GMT1-30S		70.2752°	-151.3766°				
GMT1-31N	168+63	70.2768°	-151.3689°	36	3	0.100	2.800
GMT1-31S		70.2766°	-151.3688°				
GMT1-32N	169+70	70.2769°	-151.3681°	24	2	0.100	1.800
GMT1-32S		70.2767°	-151.3679°				
GMT1-33N	169+92	70.2769°	-151.3679°	24	2	0.100	1.800
GMT1-33S		70.2767°	-151.3677°				
GMT1-34N	177+38	70.2771°	-151.3617°	24	2	0.100	1.800
GMT1-34S		70.2769°	-151.3619°				
GMT1-35N	182+16	70.2770°	-151.3582°	24	2	0.100	1.800
GMT1-35S		70.2768°	-151.3577°				
GMT1-36N	189+05	70.2770°	-151.3524°	24	2	0.100	1.800
GMT1-36S		70.2768°	-151.3523°				
GMT1-37N	192+11	70.2770°	-151.3499°	24	2	0.100	1.800
GMT1-37S		70.2768°	-151.3499°				
GMT1-38N	202+05	70.2779°	-151.3427°	24	2	0.100	1.800
GMT1-38S		70.2778°	-151.3423°				
GMT1-39N	225+46	70.2801°	-151.3250°	24	2	0.100	1.800
GMT1-39S		70.2799°	-151.3249°				
GMT1-39(A)N	229+82	70.2802°	-151.3224°	24	2	0.100	1.800
GMT1-39(A)S		70.2800°	-151.3220°				
GMT1-40N	237+46	70.2803°	-151.3154°	24	2	0.100	1.800
GMT1-40S		70.2801°	-151.3151°				
GMT1-41N	250+77	70.2807°	-151.3044°	24	2	0.100	1.800
GMT1-41S		70.2805°	-151.3047°				
GMT1-42N	264+24	70.2812°	-151.2936°	60	5	0.100	4.800
GMT1-42S		70.2809°	-151.2938°				
GMT1-43N	264+32	70.2812°	-151.2935°	36	3	0.100	2.800
GMT1-43S		70.2809°	-151.2937°				
GMT1-44N	264+39	70.2812°	-151.2935°	36	3	0.100	2.800
GMT1-44S		70.2809°	-151.2937°				
GMT1-45N	281+67	70.2817°	-151.2798°	24	2	0.100	1.800
GMT1-45S		70.2815°	-151.2796°				
GMT1-46N	294+82	70.2821°	-151.2693°	24	2	0.100	1.800
GMT1-46S		70.2819°	-151.2690°				
GMT1-47N	306+05	70.2838°	-151.2623°	48	4	0.100	3.800
GMT1-47S		70.2837°	-151.2612°				
GMT1-48N	321+48	70.2865°	-151.2521°	24	2	0.100	1.800
GMT1-48S		70.2863°	-151.2518°				
GMT1-49N	323+41	70.2868°	-151.2508°	24	2	0.100	1.800
GMT1-49S		70.2866°	-151.2507°				
GMT1-50N	331+97	70.2884°	-151.2460°	24	2	0.100	1.800

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-50S		70.2883°	-151.2456°				
GMT1-51N	334+13	70.2888°	-151.2450°	24	2	0.100	1.800
GMT1-51S		70.2888°	-151.2444°				
GMT1-52N	338+32	70.2898°	-151.2430°	24	2	0.100	1.800
GMT1-52S		70.2897°	-151.2425°				
GMT1-53N	342+15	70.2907°	-151.2414°	24	2	0.100	1.800
GMT1-53S		70.2906°	-151.2408°				
GMT1-54N	347+11	70.2919°	-151.2396°	24	2	0.100	1.800
GMT1-54S		70.2919°	-151.2390°				
GMT1-55N	354+46	70.2938°	-151.2376°	24	2	0.100	1.800
GMT1-55S		70.2937°	-151.2371°				
GMT1-56N	357+20	70.2945°	-151.2371°	24	2	0.100	1.800
GMT1-56S		70.2945°	-151.2366°				
GMT1-57N	362+05	70.2958°	-151.2366°	24	2	0.100	1.800
GMT1-57S		70.2958°	-151.2360°				
GMT1-58N	363+05	70.2961°	-151.2365°	36	3	0.100	2.800
GMT1-58S		70.2961°	-151.2359°				
GMT1-59N	363+57	70.2962°	-151.2364°	36	3	0.100	2.800
GMT1-59S		70.2962°	-151.2358°				
GMT1-60N	374+03	70.2991°	-151.2356°	24	2	0.100	1.800
GMT1-60S		70.2990°	-151.2351°				
GMT1-61N	378+19	70.3002°	-151.2347°	24	2	0.100	1.800
GMT1-61S		70.3001°	-151.2342°				
GMT1-62N	386+46	70.3022°	-151.2314°	24	2	0.100	1.800
GMT1-62S		70.3020°	-151.2310°				
GMT1-63N	389+34	70.3028°	-151.2298°	36	3	0.100	2.800
GMT1-63S		70.3026°	-151.2295°				
GMT1-64N	392+96	70.3034°	-151.2276°	36	3	0.100	2.800
GMT1-64S		70.3033°	-151.2273°				
GMT1-65N	397+59	70.3041°	-151.2243°	36	3	0.100	2.800
GMT1-65S		70.3039°	-151.2241°				
GMT1-66N	399+46	70.3043°	-151.2229°	36	3	0.100	2.800
GMT1-66S		70.3041°	-151.2227°				
GMT1-67N	403+48	70.3046°	-151.2197°	36	3	0.100	2.800
GMT1-67S		70.3044°	-151.2197°				
GMT1-68N	405+62	70.3047°	-151.2180°	36	3	0.100	2.800
GMT1-68S		70.3045°	-151.2180°				
GMT1-69N	407+08	70.3047°	-151.2168°	36	3	0.100	2.800
GMT1-69S		70.3045°	-151.2168°				
GMT1-70N	410+82	70.3048°	-151.2139°	36	3	0.100	2.800
GMT1-70S		70.3046°	-151.2137°				
GMT1-71N	410+58	70.3048°	-151.2138°	36	3	0.100	2.800
GMT1/-71S		70.3046°	-151.2137°				

Appendix B Gage & Associated Vertical Control Locations

Monitoring Location	Gage ID	Gage Position Relative to Road	Gage Location		Associated Vertical Control	Vertical Control Location	
			Latitude (NAD83)	Longitude (NAD83)		Latitude (NAD83)	Longitude (NAD83)
S2	S2-A	downstream	70.3048°	-151.2198°	MON-32	70.3022°	-151.2331°
	S2-B	upstream	70.3041°	-151.2199°			
S3	S3-A	downstream	70.2961°	-151.2368°			
	S3-B	upstream	70.2959°	-151.2350°			
S4	S4-A	downstream	70.2817°	-151.2922°	MON-37	70.2801°	-151.3018°
	S4-C	upstream	70.2804°	-151.2955°			
S6	S6-A	downstream	70.2772°	-151.3686°	MON-40	70.2764°	-151.3639°
	S6-B	upstream	70.2765°	-151.3677°			
S7	S7-A	downstream	70.2723°	-151.3929°	MON-41	70.2709°	-151.3948°
	S7-B	upstream	70.2711°	-151.3924°			

Appendix C PT Setup, Testing & Processing 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 water levels. The reported pressure is the sum of the forces imparted by the water column and atmospheric conditions. Variations in local barometric pressure are taken into account, using two independent barometric pressure loggers: In-Situ BaroTROLL® and Solinst Barologger®. A correction of barometric pressure was obtained from the Barologger installed at the Colville River East Channel horizontal directionally drilled pipeline crossing. The PT sensors were surveyed during spring breakup setup to establish a vertical datum using local control.

All PTs were tested before field mobilization and configured using Win-Situ® LT 5.6.21.0 (for the Level TROLL 500s) or Solinst Levelogger® v4.0.3 (for the Solinst Leveloggers) software prior to placement in the field. Absolute pressure was set to zero.

PT-based water level 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 D Discharge Methods

Standard USGS velocity/area techniques (Bodhaine 1968) were used to measure depth of flow and velocity to determine discharge at each culvert experiencing flow. Depth of flow and velocity were measured on the downstream end of the culvert using a HACH FH950 electromagnetic velocity meter attached to a wading rod. The accuracy of the HACH 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.

Appendix E GMT1/MT6 Road Culvert Visual Observation Summary

Observation Date	Time	Culvert ID	Flow Conditions	Flow Direction	Notes
5/22/2019	11:45	GMT1-43	Flowing	South to North	Center culvert flowing only
5/27/2019	10:45	GMT1-2	Dry	-	Minimal meltwater
5/27/2019	10:45	GMT1-3	Stagnant	-	Bladder present. Perched outlet. Trickle flow
5/27/2019	10:45	GMT1-4	Stagnant	-	Blocked with ice/snow
5/27/2019	11:00	GMT1-5	Stagnant	-	Blocked with ice/snow
5/27/2019	11:00	GMT1-6	Stagnant	-	Blocked with ice/snow
5/27/2019	11:15	GMT1-7	Flowing	South to North	-
5/27/2019	11:15	GMT1-8	Flowing	South to North	-
5/27/2019	11:15	GMT1-9	Stagnant	-	Blocked - Bladder present
5/27/2019	11:30	GMT1-10	Flowing	South to North	-
5/27/2019	11:45	GMT1-11	Stagnant	-	Blocked - Bladder present
5/27/2019	11:45	GMT1-12	Stagnant	-	Bladder removed, still blocked with ice/snow
5/27/2019	11:45	GMT1-13	Stagnant	-	Blocked with ice/snow
5/27/2019	12:00	GMT1-14	Stagnant	-	Blocked with ice/snow
5/27/2019	12:00	GMT1-15	Stagnant	-	Blocked with ice/snow
5/27/2019	12:00	GMT1-16	Stagnant	-	Blocked with ice/snow
5/27/2019	12:00	GMT1-17	Stagnant	-	Blocked - Bladder present
5/27/2019	12:00	GMT1-18	Flowing	South to North	Bladder removed
5/27/2019	12:15	GMT1-19	Stagnant	-	Blocked with ice/snow
5/27/2019	12:15	GMT1-20	Flowing	South to North	-
5/27/2019	15:00	GMT1-21	Stagnant	-	Blocked with ice/snow
5/27/2019	15:15	GMT1-22	Stagnant	-	Blocked with ice/snow
5/27/2019	15:15	GMT1-23	Stagnant	-	Blocked with ice/snow. Perched outlet.
5/27/2019	15:15	GMT1-24	Stagnant	-	Blocked with ice/snow
5/27/2019	15:15	GMT1-25	Stagnant	-	Blocked with ice/snow
5/27/2019	15:15	GMT1-26	Stagnant	-	Blocked with ice/snow
5/27/2019	15:30	GMT1-27	Flowing	South to North	Partial ice block
5/27/2019	15:30	GMT1-28	Stagnant	-	Blocked with ice/snow
5/27/2019	15:30	GMT1-29	Stagnant	-	Blocked with ice/snow
5/27/2019	15:30	GMT1-30	Stagnant	-	Equalized
5/27/2019	15:45	GMT1-31	Stagnant	-	Blocked with ice/snow
5/27/2019	15:45	GMT1-32	Stagnant	-	Blocked - Bladder present
5/27/2019	15:45	GMT1-33	Stagnant	-	Blocked with ice/snow
5/27/2019	16:00	GMT1-34	Stagnant	-	Blocked with ice/snow
5/27/2019	16:00	GMT1-35	Stagnant	-	Equalized
5/27/2019	16:00	GMT1-36	Stagnant	-	Blocked with ice/snow
5/27/2019	16:00	GMT1-37	Dry	-	-
5/27/2019	16:00	GMT1-38	Dry	-	-
5/27/2019	17:00	GMT1-39A	Stagnant	-	Equalized
5/27/2019	17:00	GMT1-40	Stagnant	-	Equalized
5/27/2019	17:00	GMT1-41	Stagnant	-	Blocked - Bladder present
5/27/2019	17:15	GMT1-42	Flowing	South to North	Partially blocked with ice/snow
5/27/2019	17:30	GMT1-43	Flowing	South to North	-
5/27/2019	17:30	GMT1-44	Flowing	South to North	Partially blocked with sediment
5/27/2019	17:45	GMT1-45	Stagnant	-	Equalized
5/27/2019	17:45	GMT1-46	Stagnant	-	Blocked with ice/snow
5/27/2019	17:45	GMT1-47	Flowing	South to North	Partial ice block
5/27/2019	17:45	GMT1-48	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-49	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-50	Stagnant	-	Blocked with ice/snow

Observation Date	Time	Culvert ID	Flow Conditions	Flow Direction	Notes
5/27/2019	18:00	GMT1-51	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-52	Flowing	South to North	-
5/27/2019	18:00	GMT1-53	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-54	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-55	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-56	Dry	-	Minimal meltwater
5/27/2019	18:00	GMT1-57	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-58	Stagnant	-	Blocked with ice/snow
5/27/2019	18:00	GMT1-59	Stagnant	-	Blocked with ice/snow
5/27/2019	18:15	GMT1-60	Stagnant	-	Blocked with ice/snow
5/27/2019	18:15	GMT1-62	Stagnant	-	Blocked with ice/snow
5/27/2019	18:15	GMT1-63	Stagnant	-	Blocked with ice/snow
5/27/2019	18:15	GMT1-61	Stagnant	-	Blocked with ice/snow
5/27/2019	18:15	GMT1-64	Stagnant	-	Blocked with ice/snow
5/27/2019	18:15	GMT1-65	Flowing	South to North	-
5/27/2019	18:30	GMT1-66	Stagnant	-	Equalized
5/27/2019	18:30	GMT1-67	Flowing	South to North	-
5/27/2019	18:30	GMT1-68	Stagnant	-	Equalized
5/27/2019	18:30	GMT1-69	Stagnant	-	Blocked with ice/snow
5/27/2019	18:30	GMT1-70	Stagnant	-	Equalized
5/27/2019	18:30	GMT1-71	Stagnant	-	Equalized

Appendix F Monitoring Location Photos

F.1 S2 Monitoring Location

Photo F.1: Local meltwater around S2, looking southwest; May 22, 2019

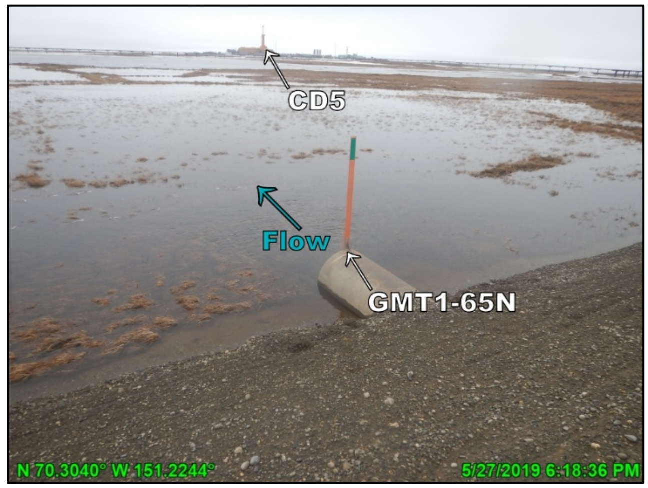

Photo F.2: Culvert GMT1-65 conveying flow, looking north; May 27, 2019

Photo F.3: Summer conditions at S2, looking west; July 2, 2019

F.2 S3 Monitoring Location

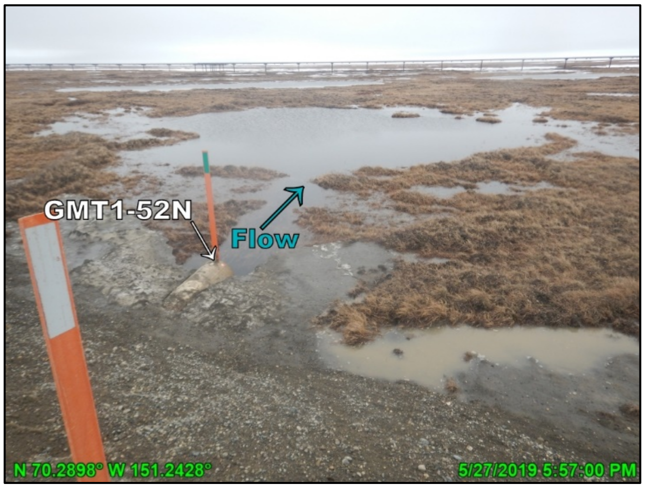

Photo F.4: Culvert GMT1-52, looking north; May 27, 2019

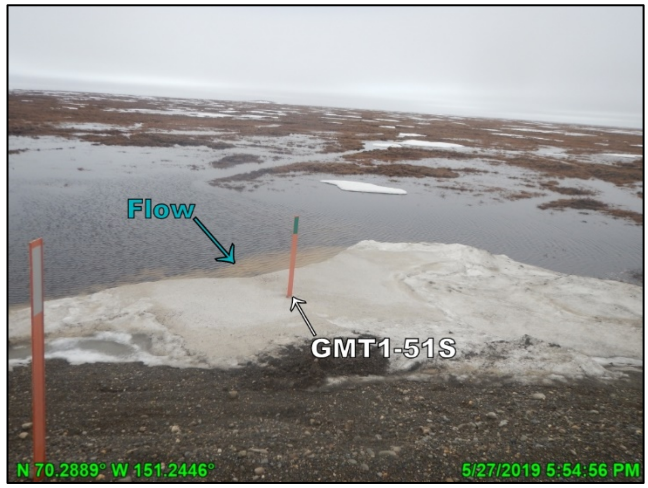

Photo F.5: Snow blockage at culvert GMT1-51, looking south; May 27, 2019

Photo F.6: S3 drainage area, looking south; May 29, 2019

Photo F.7: Summer conditions at S3, looking south; July 2, 2019

F.3 S4 Monitoring Location

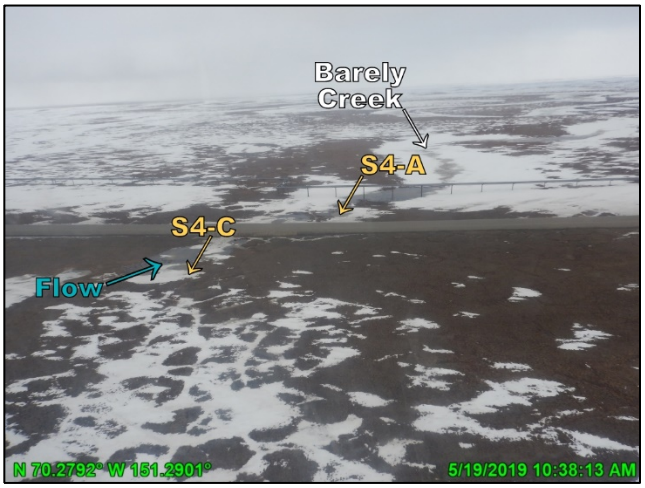

Photo F.8: S4 monitoring site and Barely Creek drainage area, looking north; May 19, 2019

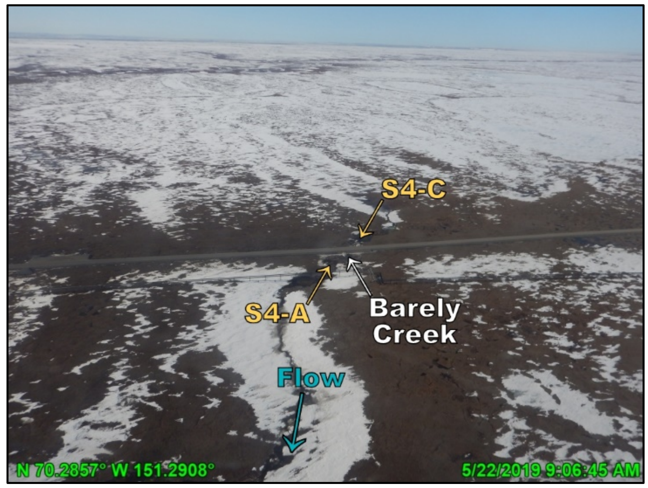

Photo F.9: Flow paths cut through the snow pack in Barely Creek, looking south; May 22, 2019

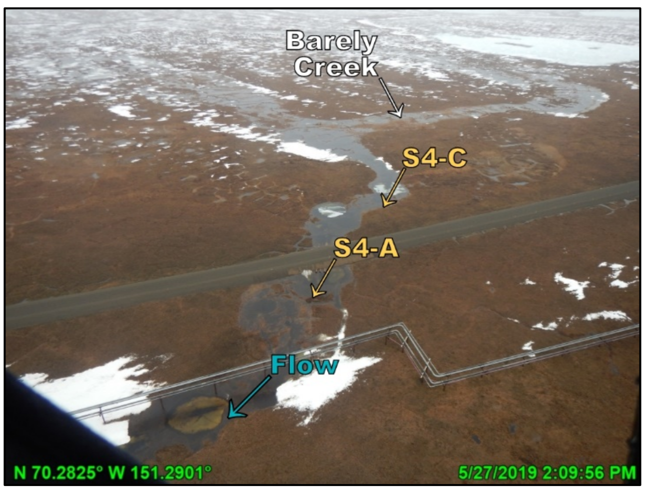

Photo F.10: Minor overbank flooding near S4; looking south; May 27, 2019

Photo F.11: Drainage conditions near S4, looking southwest; May 29, 2019

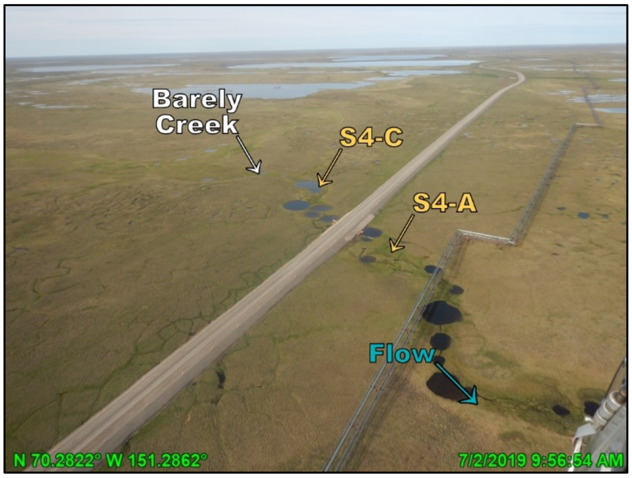

Photo F.12: Summer conditions at S4, looking southwest; July 2, 2019

F.4 S6 Monitoring Location

Photo F.13: Initial meltwater near S6 monitoring site, looking northeast; May 19, 2019

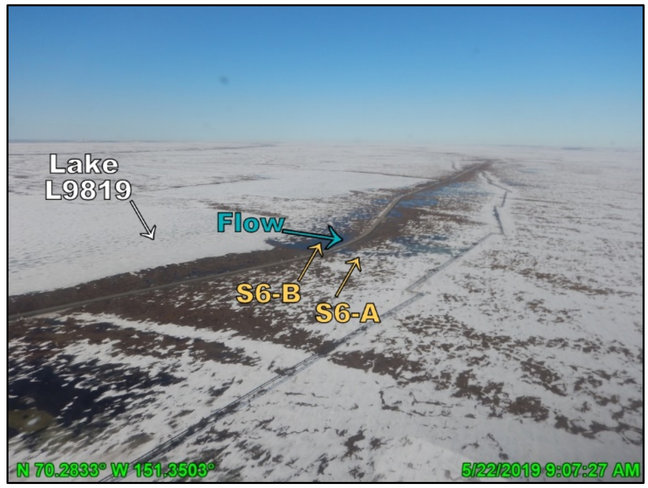

Photo F.14: S6 monitoring site and drainage area, looking southwest; May 22, 2019

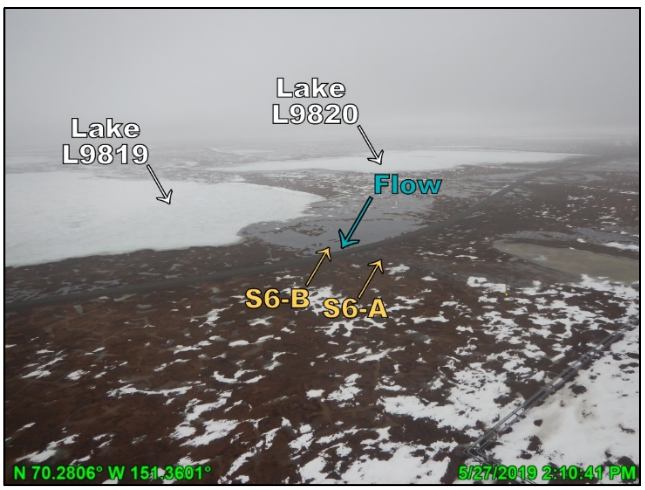

Photo F.15: Differential ponding near S6, looking southwest; May 27, 2019

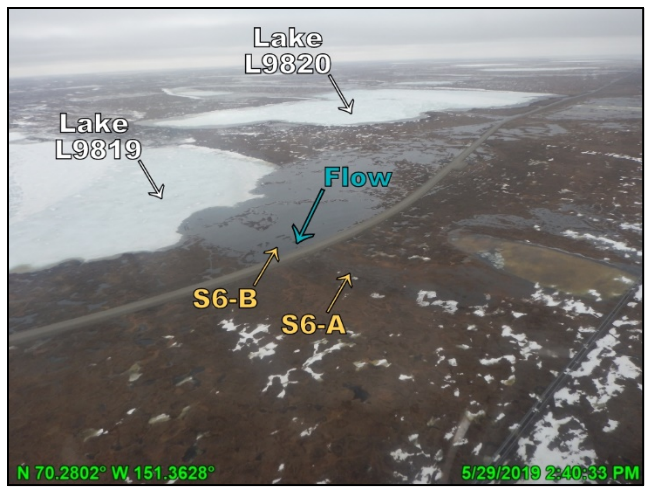

Photo F.16: Differential ponding near S6, looking southwest; May 29, 2019

Photo F.17: Summer conditions at S6, looking west; July 2, 2019

F.5 S7 Monitoring Location

Photo F.18: Initial meltwater near S7 monitoring site, looking east; May 19, 2019

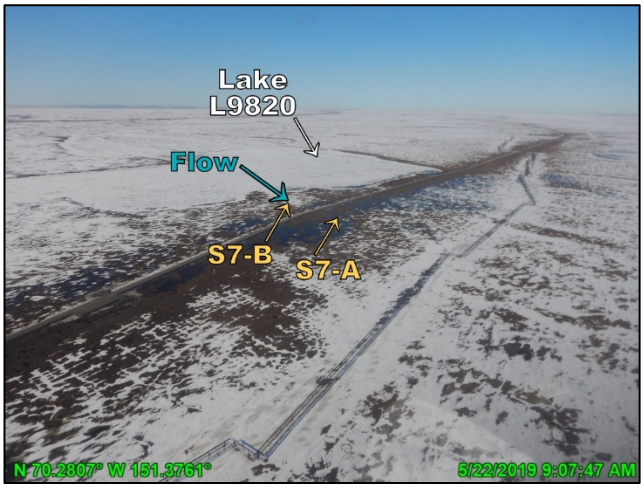

Photo F.19: Meltwater accumulation near S7, looking southwest; May 22, 2019

Photo F.20: Flow through GMT1-27N, looking north; May 27, 2019

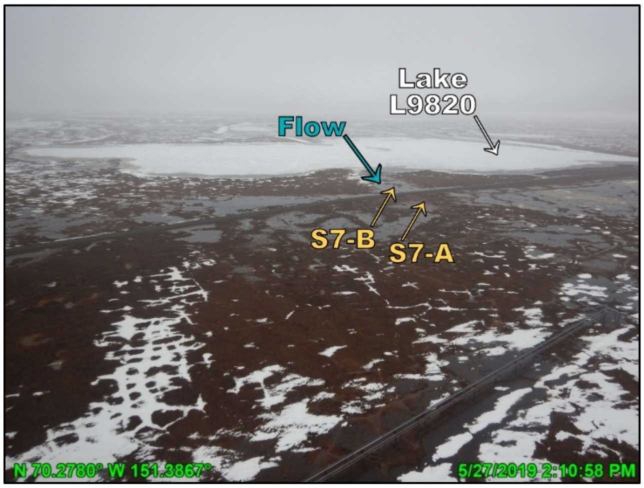

Photo F.21: S7 drainage area, looking south; May 27, 2019

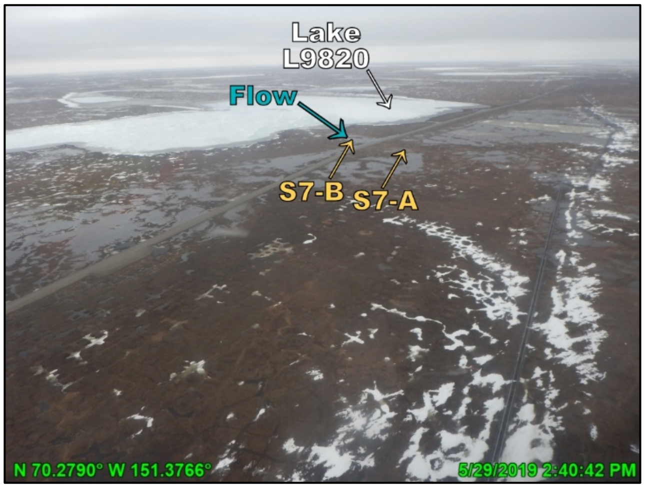

Photo F.22: S7 drainage area, looking southwest; May 29, 2019

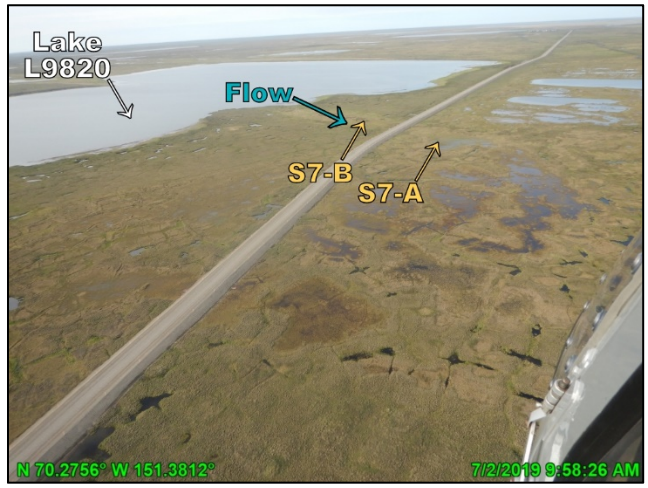

Photo F.23: Summer conditions at S7, looking southwest; July 2, 2019