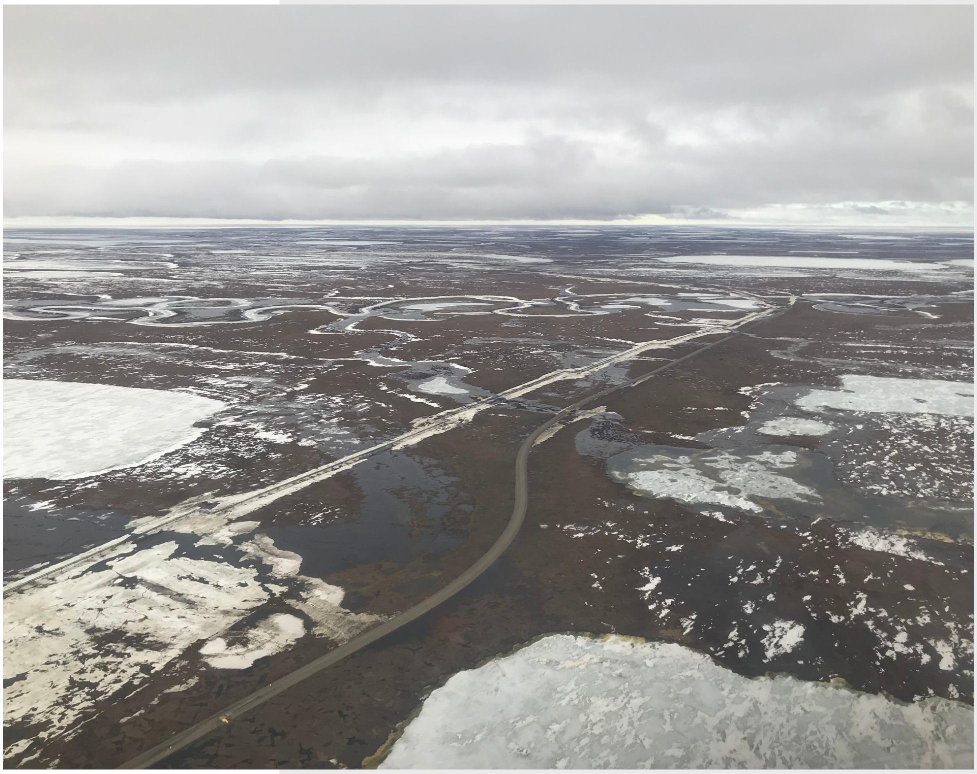
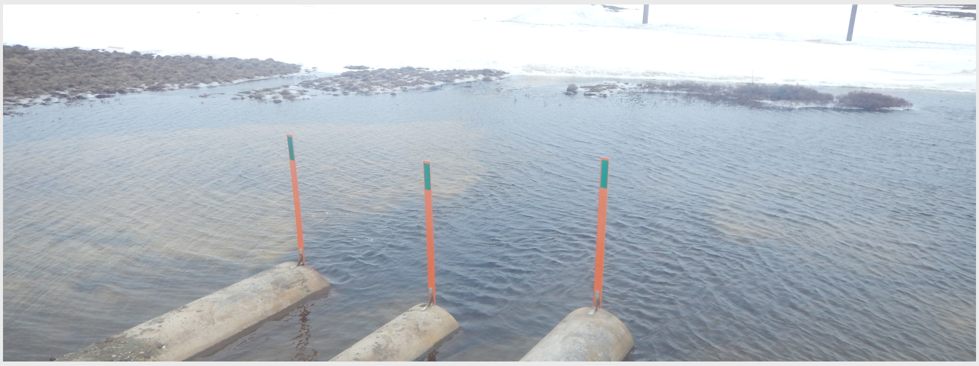
JULY 2018

2018 GREATER MOOSE'S TOOTH 1 (GMT1) SPRING BREAKUP CULVERT MONITORING REPORT





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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	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

Greater Moose's Tooth 1 (GMT1) Spring Breakup Culvert Monitoring supports the ConocoPhillips Alaska, Inc. (CPAI) Environmental group in meeting State of Alaska, federal, and local permit stipulations. GMT1 facilities include the GMT1 access road, pad, and pipelines. The GMT1 access road, pad, and a portion of the pipeline were constructed and 71 culverts were installed during the winter of 2016-2017. One new culvert labled GMT1-39A was installed in September 2017.

The GMT1 access road spring breakup culvert monitoring field program took place during the 2018 GMT1 spring breakup monitoring and hydrologic assessment field program. This program began on April 20th and concluded on June 20th. Figure 1 shows the GMT1 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. This permit requires annual GMT1 access road culvert monitoring reports to be submitted for three years post-construction. This is the second year of reporting.

The following tasks were performed to meet the permit requirements:

- Aerial and ground photo documentation of the GMT1 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.

ConocoPhillips Alaska		miles 0 0.25 0.5 1
Date: 7/2/2018	Project: 166427	
Drawn: JEG	File: GMT1_11X17L.mxd	
Checked: GCY	Scale: 1 in = 0.5 miles	

Culvert
Gage Location
Existing Facility
Existing Road
Pipeline

Imagery Source : Conoco Phillips Alaska 2015

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2018 GMT1 Gage Stations

FIGURE: 1

(SHEET 1 of 1)

1.2 Data Collection

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

Table 1: GMT1 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 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		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		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 were 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 access road and the letters 'B' and 'C' representing gage assemblies located on the south (upstream [US]) side of the GMT1 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. During data processing, the PT measurements were 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 either a HACH FH950 electromagnetic velocity meter, or a Sontek FlowTracker acoustic doppler 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.

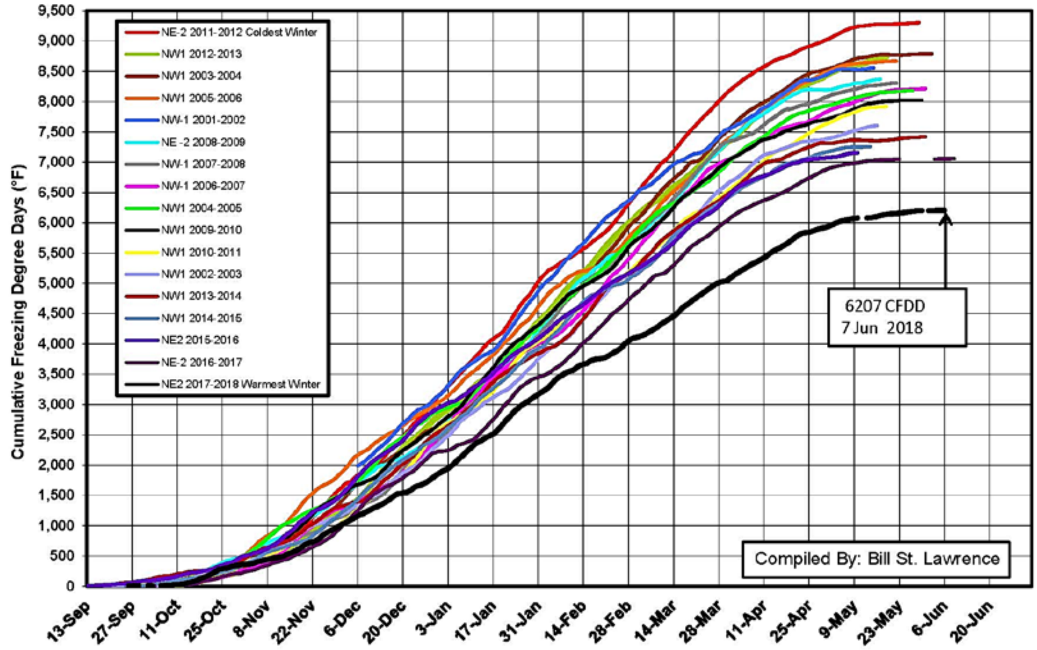
2.4 Culvert Performance Evaluation

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 2017-2018 (September – May) winter was the warmest on record for the past 17 years (Graph 3.1, ICE 2018).



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

As of April 30th, snowpack in the Brooks Range south of the Colville River basin was reported as approximately 150% of the 1981-2010 median (National Resource Conservation Service [NRCS] 2018). There is no NRCS North Slope snowpack data available for the North Slope for 2018, though general observations indicate snowpack was at or above normal levels.

Despite the relatively warm winter and early short term warm periods in late April and early May, spring in the GMT1 area was characterized as a delayed and gradual warming trend beginning in late May. This was accompanied by a consistent cloud cover in the Arctic Coastal Plain. A warming period with daily high temperatures above freezing in the Brooks Range foothills, as recorded at Umiat, occurred April 25th through April 30th (USGS 2018). Temperatures then cooled to below freezing until May 7th. Daily high temperatures at Umiat began consistently recording above freezing on May 27th. Daily low temperatures at Umiat began consistently recording above freezing on June 17th. Aside from periods in late April and mid-May, daily high air temperatures, recorded at Alpine, did not record above freezing until June 1st, after which they were consistently above freezing (Wunderground 2018). Daily low temperatures at Alpine did not began consistently recording above freezing until June 26th.

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 from April 27th through May 1st confirmed that snow, ice, and bladders had been cleared at most culvert inlets and outlets. Additional snow accumulation at culvert inlets and outlets was observed following snowfall events in early May.

On May 14th, local melt was observed in isolated areas around GMT1 access road. Cooler temperatures followed, re-freezing the local melt in the drainages. On May 26th, local melt was again ponding in isolated areas. Snow cover on surrounding tundra was still appoximetely 90%.

On June 2nd, local melt was observed accumulating at most monitoring stations and large areas of melt were becoming hydraulically connected. By June 4th, flow was observed in some GMT1 access road culverts, while local pooling was present in most others. By June 6, meltwater was hydraulically connected through drainage strucutres upstream and downstream of the road at most monitoring locations.

On June 11th, only 10-20% snow cover remained on the tundra along the GMT1 access road. Conveyance channels had cut through much of the remaining ice roads and drifted snow. All culverts in defined drainages along the road were observed conveying flow. Cross flow culverts, situated on higher ground outside of the defined drainages, remained dry during spring breakup monitoring.

3.3 Site Specific Observations & Water Surface Elevations

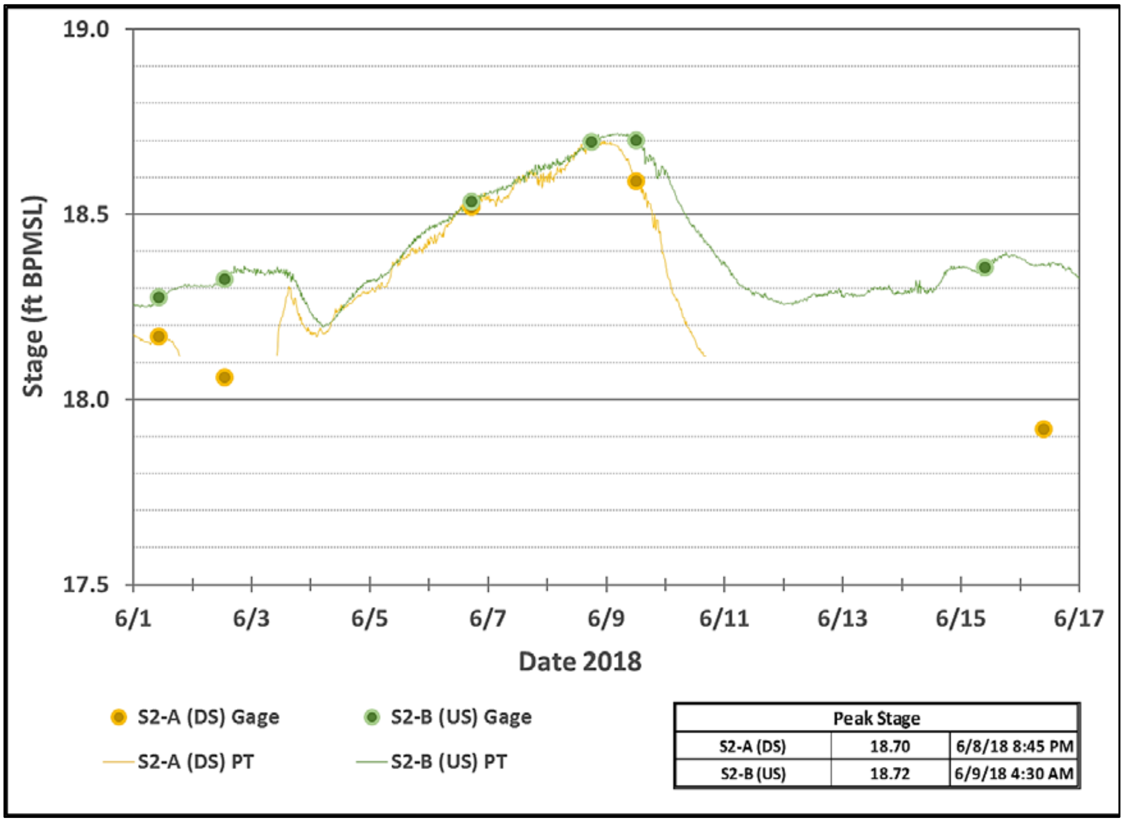
Summarized observations of flow conditions are tabulated in Appendix E. Additional site specific monitoring photos are provided in Appendix F.

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 access road. On the north side of the GMT1 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 access road.

On June 1st, initial local melt was recorded at the S2 monitoring stations and by June 4th, stage was steadly increasing upstream and downstream of the GMT1 road. On June 4th, the ice road located north of the GMT1 access road was still intact and meltwater was accumulating between the ice road, the CD5 road, and the GMT1 road.

In general, the upstream stage rose and fell consistently with the downstream stage, suggesting the S2 culverts were freely conveying flow through the GMT1 access road.

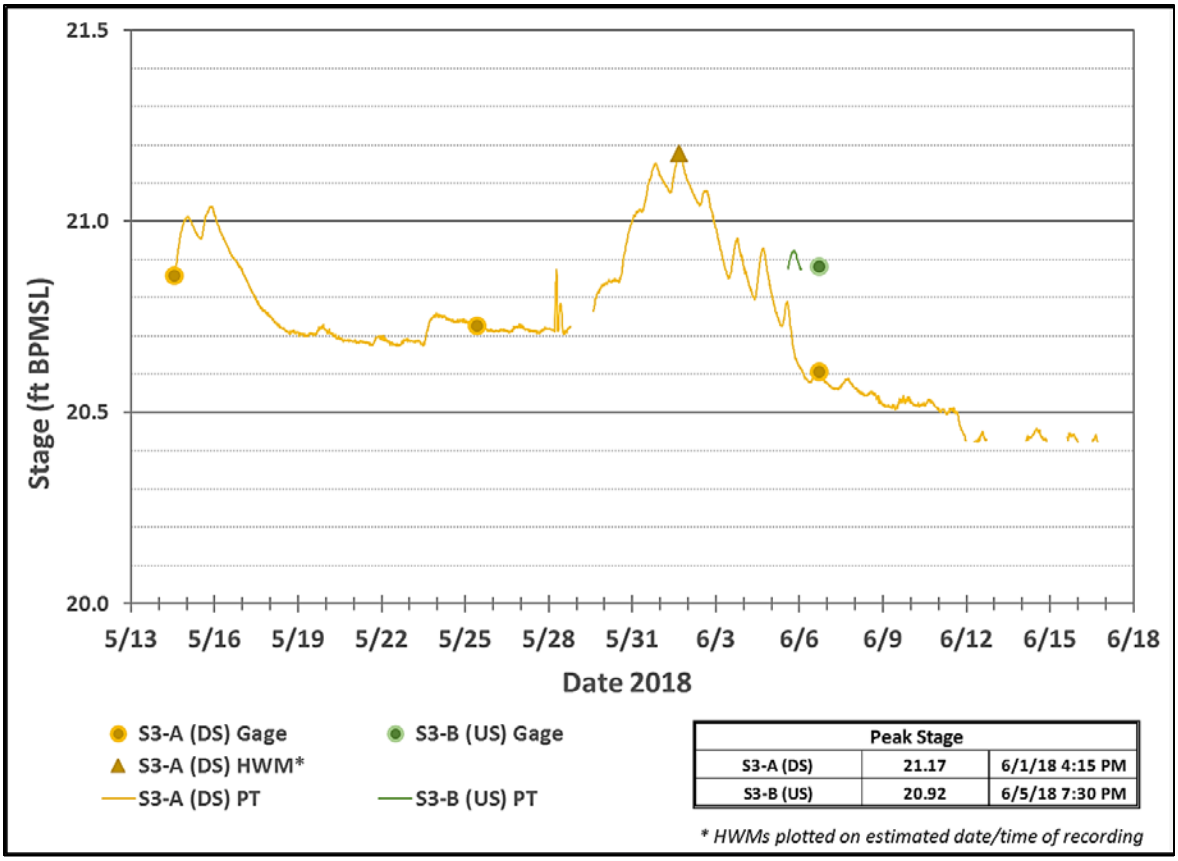


Graph 3.2: S2 Water Surface Elevations

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 in the east to the Tinmiaqsiugvik River in 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 2018 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.

The S3 monitoring station did not see appreciable flow during the 2018 monitoring period. Initial local melt was observed on the downstream (S3-A) gage on May 14th, and the upstream gage recorded a small amount of local melt on June 6th but was dry again two days later. With the exception of a small amount of flow observed in culvert GMT1-52 on June 8th, no hydraulic connections were established through the culverts associated with S3 during the breakup monitoring period because of the limited quantity of meltwater in the area.

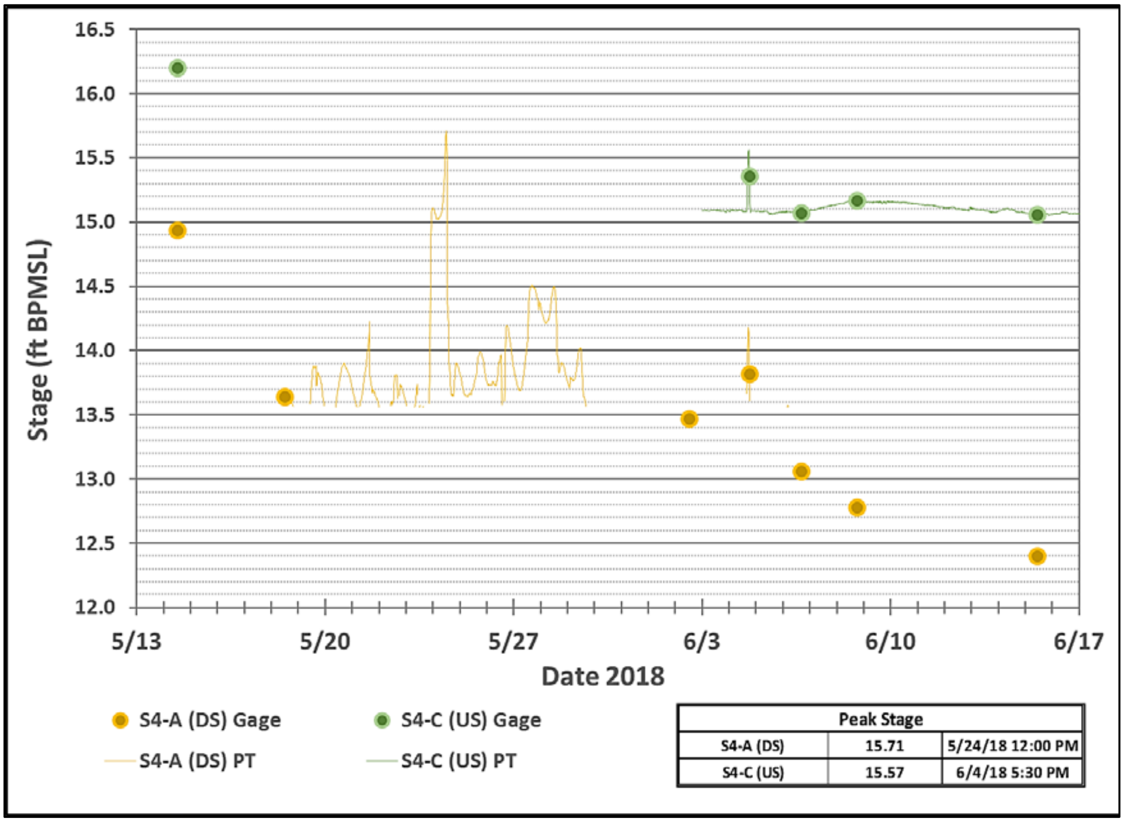


Graph 3.3: S3 Water Surface Elevations

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 access road into the Tinmiaqsiugvik River. Culverts GMT1-42, 43, and 44 are located in Barely Creek.

Stage data recorded at S4 gages throughout May were the result of local melt ponding. A hydraulic connection was established through the culverts in early June. Afterwards, stage remained relatively static in the pond at the upstream gage while stage decreased in the channelized reach at the downstream gage. Flow continued through the Barely Creek culverts throughout the spring breakup monitoring period.

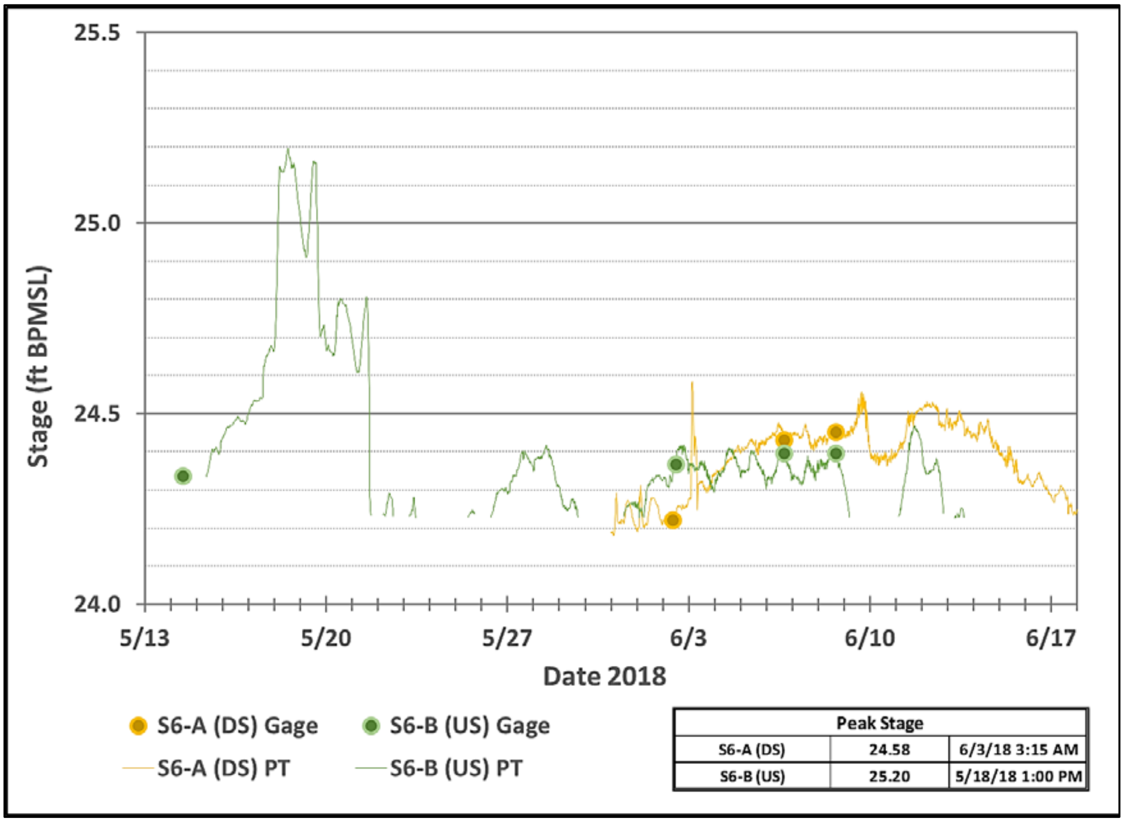


Graph 3.4: S4 Water Surface Elevations

3.3.4 S6 Culverts (GMT1-31 through GMT1-33)

The S6 monitoring location is situated in a swale depression that drains Lake L9819 (south of the GMT1 access road) towards the north. Culverts GMT1-31 through GMT1-33 are located in the swale.

Local meltwater was accumulating at the upstream gage (S6-B) by early May. Culverts melted out sufficiently to allow for a hydraulic connection across the road by June 5th, based on PT data. Meltwater was observed freely equalizing through culverts by June 6th.

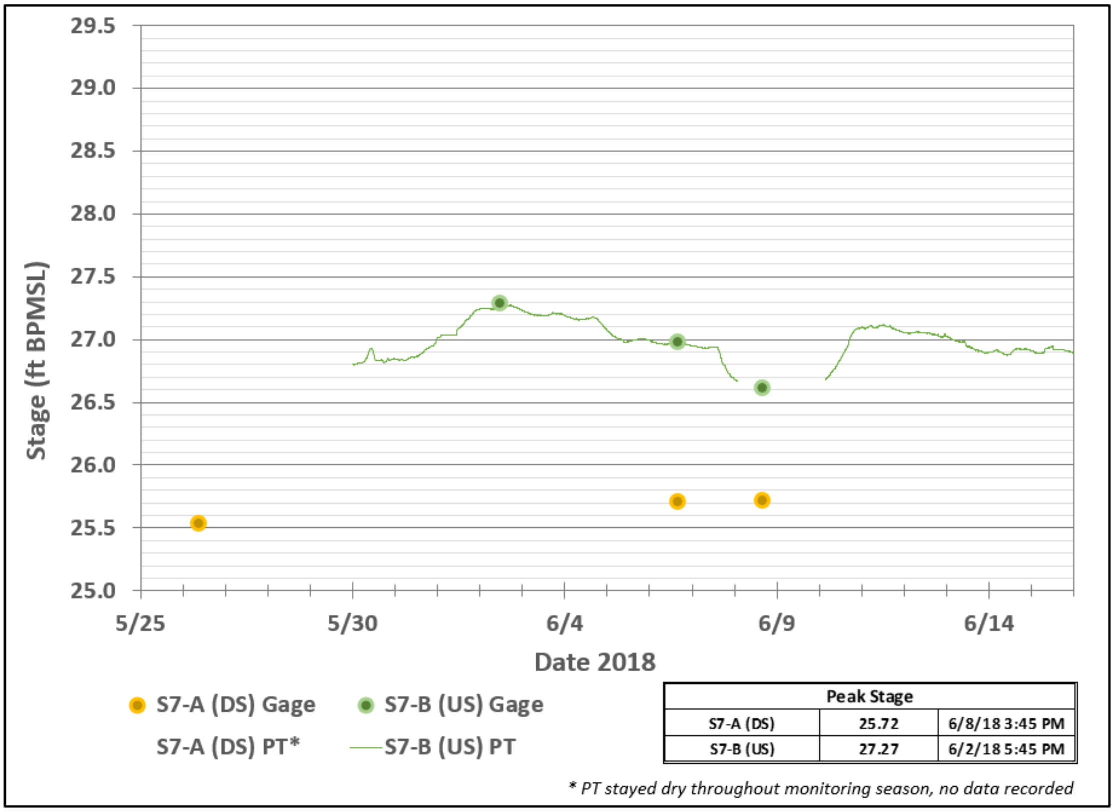


Graph 3.5: S6 Water Surface Elevations

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 access road) towards the north.

On May 26th, local melt was observed on the downstream gage (S7-A) along with saturated snow between the gage and the road. Snow and frozen bladders initially blocked flow from freely equalizing through the S7 drainage structures, but hydraulic connections were established once impediments were absent.



Graph 3.6: S7 Water Surface Elevations

3.4 Discharge Measurements

Discharge was measured on June 4th, June 8th, June 9th, and June 16th at culverts observed conveying flow. A summary of the discharge measurements is presented in Table 2.

Table 2: GMT1 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)
GMT1-07	6/4/2018 5:35pm	1.91	1.52	1.00	2.33	3.54
GMT1-08	6/4/2018 5:31pm	1.80	1.27	0.90	0.17	0.22
GMT1-09	6/4/2018 5:29pm	1.80	0.92	0.70	0.05	0.04
GMT1-19	6/4/2018 6:29pm	1.91	0.44	0.40	3.85	1.68
GMT1-42	6/4/2018 6:11pm	4.80	4.83	1.50	0.57	2.77
GMT1-43	6/4/2018 6:08pm	2.80	4.95	2.10	1.94	9.61
GMT1-44	6/4/2018 6:05pm	2.80	2.38	1.15	1.97	4.69
GMT1-02	6/8/2018 5:01pm	1.91	1.14	0.8	1.71	1.95
GMT1-03	6/8/2018 4:44pm	1.83		Perched		1.22
GMT1-07	6/8/2018 4:26pm	1.91	0.77	0.60	0.56	0.43
GMT1-08	6/8/2018 4:21pm	1.80	0.74	0.60	0.58	0.43
GMT1-09	6/8/2018 4:16pm	1.80	0.42	0.40	0.83	0.35
GMT1-18	6/8/2018 4:02pm	1.91	0.95	0.70	1.30	1.24
GMT1-42	6/8/2018 11:00am	4.80	7.61	2.10	0.61	4.64
GMT1-43	6/8/2018 11:00am	2.80	5.19	2.20	0.57	2.96

Culvert	Measurement Date & Time	Culvert Inside Diameter (ft)	Flow Area (ft^2)	Measured Depth of Flow (ft)	Measured Velocity (fps)	Discharge (cfs)
GMT1-44	6/8/2018 11:00am	2.80	3.91	1.70	0.63	2.45
GMT1-52	6/8/2018 10:23am	1.80	0.42	0.40	1.92	0.81
GMT1-52	6/9/2018 11:20am	1.80	1.09	0.80	0.63	0.69
GMT1-64	6/9/2018 11:20am	2.80	2.25	1.10	1.38	3.09
GMT1-65	6/9/2018 11:39am	2.80	3.08	1.40	1.41	4.35
GMT1-66	6/9/2018 11:40am	2.80	2.80	1.30	0.88	2.45
GMT1-67	6/9/2018 11:53am	2.80	4.18	1.80	1.52	6.37
GMT1-42	6/16/2018 10:31am	4.80	14.56	3.60	0.62	8.98
GMT1-43	6/16/2018 10:28am	2.80	4.18	1.80	0.62	2.58
GMT1-44	6/16/2018 10:26am	2.80	2.80	1.30	0.63	1.76
GMT1-64	6/16/2018 9:47am	2.80	1.97	1.00	1.29	2.55
GMT1-65	6/16/2018 11:39am	2.80	2.52	1.20	2.88	7.26
GMT1-66	6/16/2018 9:38am	2.80	2.52	1.20	0.66	1.66
GMT1-67	6/16/2018 9:30am	2.80	3.08	1.40	2.07	6.38

3.5 Culvert Performance Evaluation

No performance issues were identified at any culverts conveying flow along the GMT1 access road. Temporary ponded water was present in drainages at several locations along the access road but was attributed to snow or culvert bladders frozen inplace impeding flow and not culvert placement (Photo 1 and Photo 2).

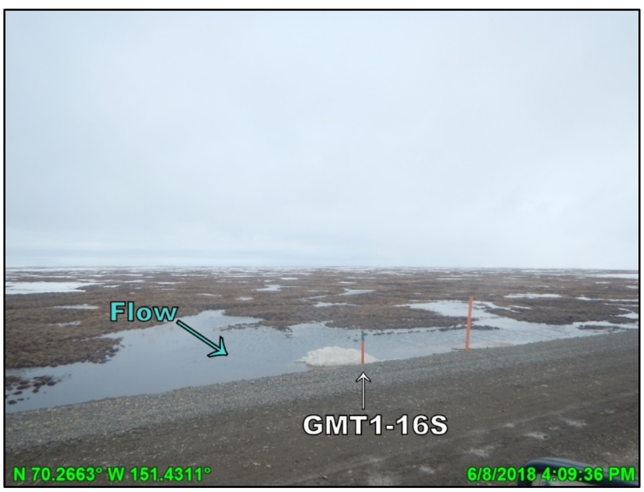


Photo 1: Local ponding at culvert GMT1-16 on south side of GMT1 access road, looking south; June 8, 2018

Photo 2: Culvert GMT1-16 on north side of GMT1 access road dry because a culvert bladder blocked flow, looking north; June 8, 2018

After snow was manually cleared in late April, drifting snow was observed burying the culverts. In addition, late spring snowfall events also contributed to blocked culverts. Some culvert bladders, in place to block snow from entering culverts during the winter, froze into the culverts during a freeze thaw cycle in mid May and impeded water flow (Photo 3 through Photo 5). Once conveyance paths were established through either removing culvert bladders or meltwater naturally cutting through snow/ice, the culverts all performed as designed and natural drainage patterns were maintained (Photo 6 and Photo 7). No displacement of uncompacted gravel fill attributed with spring breakup flooding was observed along the road embankment or around culvert inlets and outlets. There were no signs of sloughing or undermining at drainage structures and no stream channel changes were observed at access road crossings. With the exception of a culvert, GMT1-06, (Photo 8) perched on the north (DS) side of the road that may lead to the development of a scour hole at the outlet, no discernable culvert maintenance, repair, upgrade, setting adjustments, and/or replacements are recommended at this time.

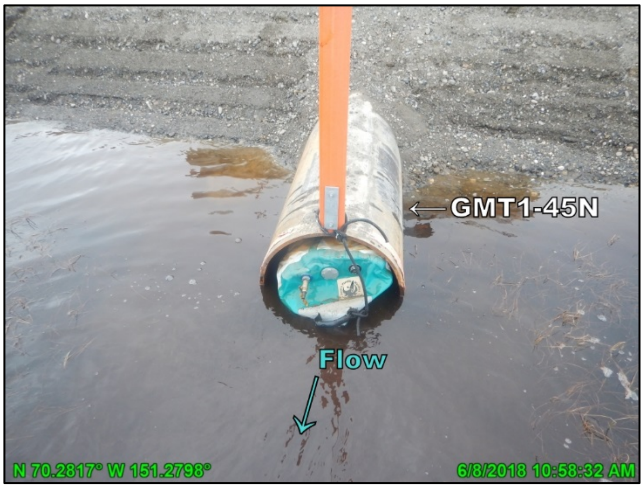


Photo 3: Culvert GMT1-45 on north side of GMT1 access road with culvert bladder blockage, looking south; June 8, 2018

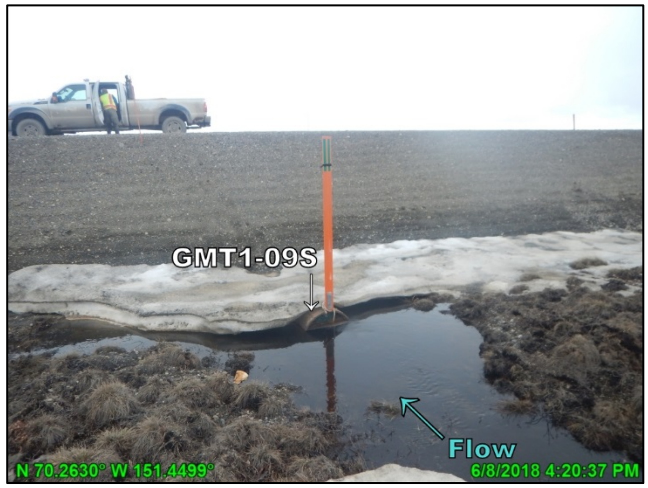


Photo 4: Culvert GMT1-09 on south side of GMT1 access road with culvert bladder blockage, looking north; June 8, 2018

Photo 5: Ponded water on upstream side of GMT1 access road, looking west; June 11, 2018

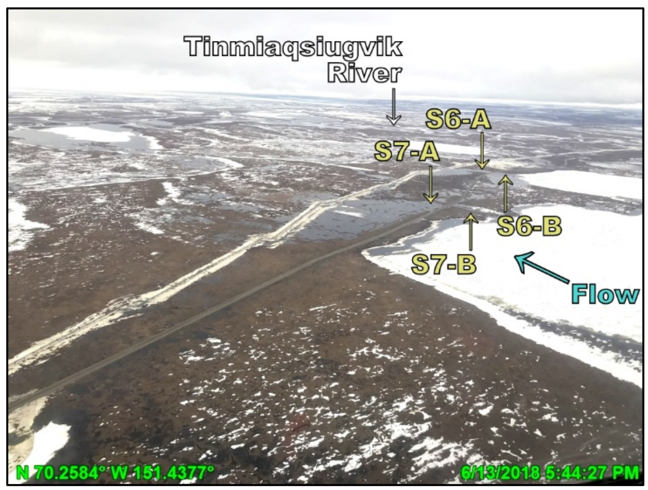


Photo 6: Water equalizing across the GMT1 access road, looking northeast; June 13, 2018

Photo 7: Water equalizing across the GMT1 access road, looking southwest; June 16, 2018

Photo 8: Culvert GMT1-06 perched on the north (DS) side of the GMT1 access road; June 8, 2018

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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+14	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
GMT1-25S		70.2717	-151.3929				

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
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				
GMT1-39A(N)		70.2802	-151.3224	24	2	0.100	1.800
GMT1-39A(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
GMT1-50S		70.2883	-151.2456				
GMT1-51N	334+13	70.2888	-151.2450	24	2	0.100	1.800

Culvert	Station	Latitude (NAD83)	Longitude (NAD83)	Outside Diameter (in)	Outside Diameter (ft)	Wall Thickness (ft)	Inside Diameter (ft)
GMT1-51S		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 Road Culvert Visual Observation Summary, June 4,8, 9, 16, 2018

Observation Date	Time	Culvert ID	Flow Conditions	Flow Direction	Notes
6/4/2018	18:30	GMT1-19	Flowing	South to North	
6/4/2018	18:15	GMT1-42	Flowing	South to North	
6/4/2018	18:00	GMT1-43	Flowing	South to North	
6/4/2018	18:00	GMT1-44	Flowing	South to North	
6/4/2018	17:45	GMT1-67	Stagnant	-	
6/8/2018	17:00	GMT1-01	Dry	-	-
6/8/2018	17:00	GMT1-02	Flowing	South to North	Field crew removed bladder
6/8/2018	17:00	GMT1-03	Perched	-	-
6/8/2018	16:45	GMT1-04	Stagnant	-	-
6/8/2018	16:45	GMT1-05	Stagnant	-	-
6/8/2018	16:45	GMT1-06	Stagnant	-	-
6/8/2018	16:30	GMT1-07	Flowing	South to North	Field crew removed bladder
6/8/2018	16:15	GMT1-08	Flowing	South to North	Field crew removed bladder
6/8/2018	16:15	GMT1-09	Flowing	South to North	Field crew removed bladder
6/8/2018	16:15	GMT1-10	Blocked	-	Bladder present
6/8/2018	16:15	GMT1-11	Blocked	-	Bladder present
6/8/2018	16:15	GMT1-12	Stagnant	-	-
6/8/2018	16:15	GMT1-13	Stagnant	-	-
6/8/2018	16:15	GMT1-14	Stagnant	-	-
6/8/2018	16:15	GMT1-15	Stagnant	-	-
6/8/2018	16:15	GMT1-16	Blocked	-	Bladder present
6/8/2018	16:00	GMT1-17	Stagnant	-	-
6/8/2018	16:00	GMT1-18	Flowing	-	Field crew removed bladder
6/8/2018	16:00	GMT1-19	Dry	-	-
6/8/2018	16:00	GMT1-20	Dry	-	-
6/8/2018	16:00	GMT1-21	Dry	-	-
6/8/2018	16:00	GMT1-22	Dry	-	-
6/8/2018	16:00	GMT1-23	Dry	-	-
6/8/2018	16:00	GMT1-24	Dry	-	-
6/8/2018	15:45	GMT1-25	Stagnant	-	-
6/8/2018	15:45	GMT1-26	Stagnant	-	Bladder present
6/8/2018	15:45	GMT1-27	Blocked	-	Snow blocking upstream flow
6/8/2018	15:45	GMT1-28	Stagnant	-	Bladder present
6/8/2018	15:45	GMT1-29	Stagnant	-	Bladder present
6/8/2018	15:30	GMT1-30	Stagnant	-	-
6/8/2018	15:30	GMT1-31	Stagnant	-	-
6/8/2018	15:30	GMT1-32	Stagnant	-	-
6/8/2018	15:30	GMT1-33	Stagnant	-	-
6/8/2018	15:30	GMT1-34	Stagnant	-	-
6/8/2018	15:30	GMT1-35	Dry	-	-
6/8/2018	15:30	GMT1-36	Blocked	-	Bladder present
6/8/2018	15:30	GMT1-37	Blocked	-	Bladder present
6/8/2018	15:30	GMT1-38	Dry	-	-
6/8/2018	15:00	GMT1-39	Dry	-	-
6/8/2018	11:11	GMT1-39A	Blocked	-	Bladder present. Culvert installed September 2017
6/8/2018	11:00	GMT1-40	Dry	-	-
6/8/2018	11:00	GMT1-41	Dry	-	-
6/8/2018	11:00	GMT1-42	Stagnant	-	-
6/8/2018	11:00	GMT1-43	Stagnant	-	-

Observation Date	Time	Culvert ID	Flow Conditions	Flow Direction	Notes
6/8/2018	11:00	GMT1-44	Stagnant	-	-
6/8/2018	11:00	GMT1-45	Stagnant	-	-
6/8/2018	11:00	GMT1-46	Blocked	-	-
6/8/2018	11:00	GMT1-47	Blocked	-	-
6/8/2018	10:30	GMT1-48	Dry	-	-
6/8/2018	10:30	GMT1-49	Dry	-	-
6/8/2018	10:30	GMT1-50	Dry	-	-
6/8/2018	10:30	GMT1-51	Dry	-	-
6/8/2018	10:30	GMT1-52	Flowing	South to North	Culvert paritally blocked by snow
6/8/2018	10:30	GMT1-53	Blocked	-	-
6/8/2018	10:30	GMT1-54	Blocked	-	-
6/8/2018	10:15	GMT1-55	Dry	-	-
6/8/2018	10:15	GMT1-56	Dry	-	-
6/8/2018	10:15	GMT1-57	Dry	-	-
6/8/2018	10:15	GMT1-58	Dry	-	-
6/8/2018	10:15	GMT1-59	Dry	-	-
6/8/2018	10:15	GMT1-60	Blocked	-	-
6/9/2018	11:30	GMT1-61	Dry	-	-
6/9/2018	11:30	GMT1-62	Dry	-	-
6/9/2018	11:30	GMT1-63	Dry	-	-
6/9/2018	11:30	GMT1-64	Flowing	South to North	-
6/9/2018	11:30	GMT1-65	Flowing	South to North	-
6/9/2018	11:45	GMT1-66	Flowing	South to North	-
6/9/2018	11:45	GMT1-67	Flowing	South to North	-
6/9/2018	12:00	GMT1-68	Buried	-	-
6/9/2018	12:00	GMT1-69	Buried	-	-
6/9/2018	12:00	GMT1-70	Stagnant	-	-
6/9/2018	12:00	GMT1-71	Stagnant	-	-
6/16/2018	10:30	GMT1-42	Flowing	-	-
6/16/2018	10:30	GMT1-43	Flowing	-	-
6/16/2018	10:30	GMT1-44	Flowing	-	-
6/16/2018	9:45	GMT1-64	Flowing	-	-
6/16/2018	9:45	GMT1-65	Flowing	-	-
6/16/2018	9:45	GMT1-66	Flowing	-	-
6/16/2018	9:30	GMT1-67	Flowing	-	-

Appendix F Monitoring Location Photos

F.1 S2 Monitoring Location

Photo F.1: Culvert GMT1-67 on north side of GMT1 access road, looking east; June 8, 2018

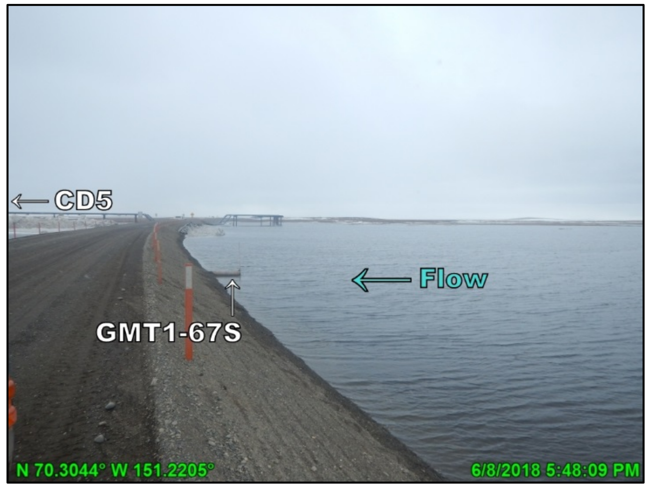

Photo F.2: Culvert GMT1-67 on south side of GMT1 access road, looking east; June 8, 2018

Photo F.3: GMT1 access road at CD5 intersection, looking southwest; June 9, 2018

F.2 S3 Monitoring Location

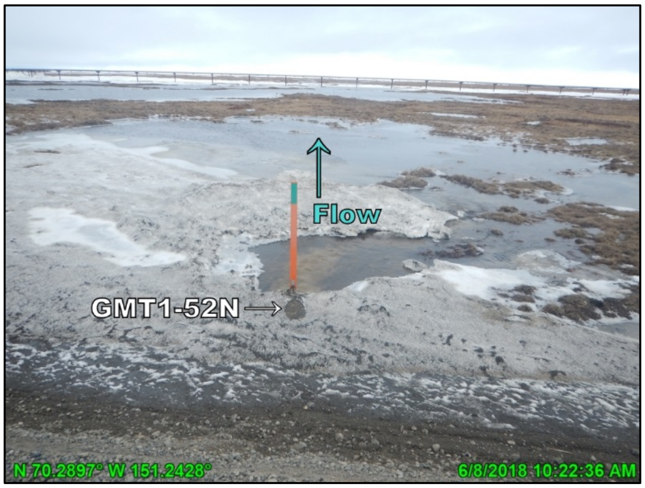

Photo F.4: Culvert GMT1-52 on north side of GMT1 access road, looking west; June 8, 2018

Photo F.5: Culvert GMT1-52 on south side of GMT1 access road, looking west; June 8, 2018

Photo F.6: Limited melt near S3 monitoring location, looking northeast; June 8, 2018

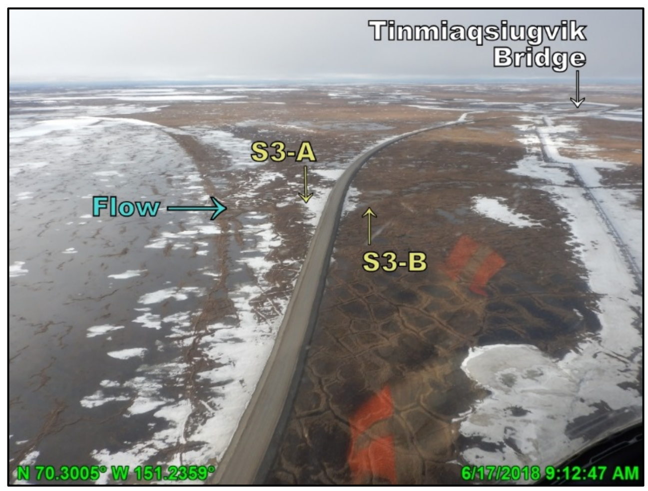

Photo F.7: Limited melt near S3 monitoring location, looking southwest; June 17, 2018

F.3 S4 Monitoring Location

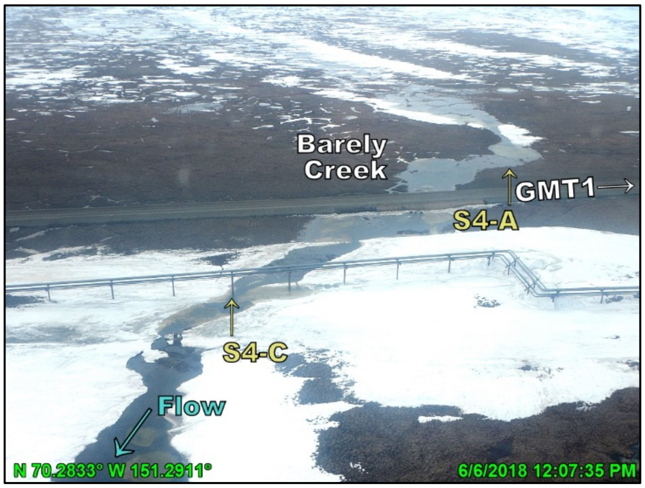

Photo F.8: Drainage at the S4 monitoring location (Barely Creek), looking southwest; June 6, 2018

Photo F.9: Culvert GMT1-39A on north side of GMT1 access road with culvert bladder still inside, looking south; June 8, 2018

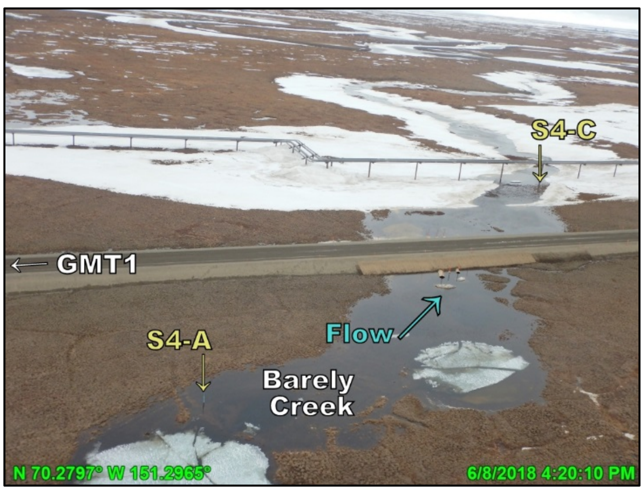

Photo F.10: Drainage at the S4 monitoring location (Barely Creek), looking northeast; June 8, 2018

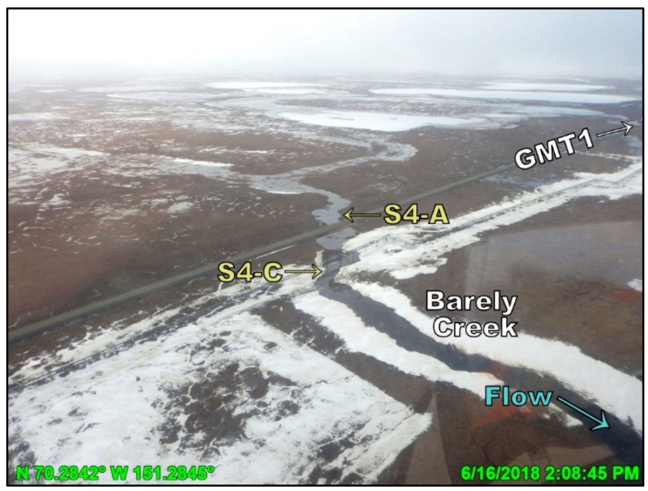

Photo F.11: Drainage at the S4 monitoring location (Barely Creek), looking southwest; June 16, 2018

F.4 S6 Monitoring Location

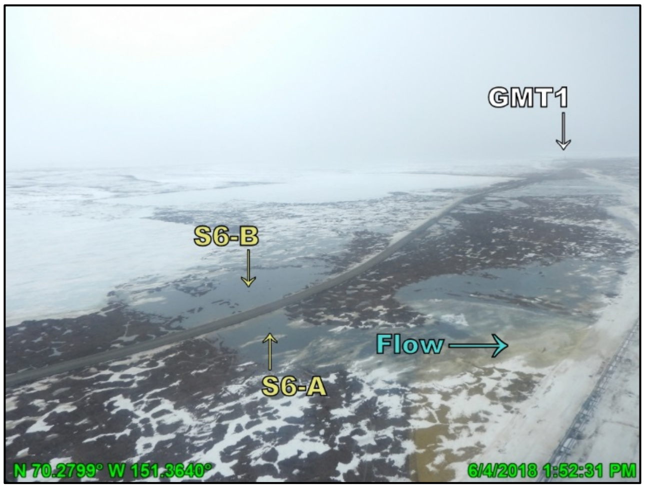

Photo F.12: Drainage equalized on both sides of the GMT1 access road near S6 monitoring location, looking southwest; June 4, 2018

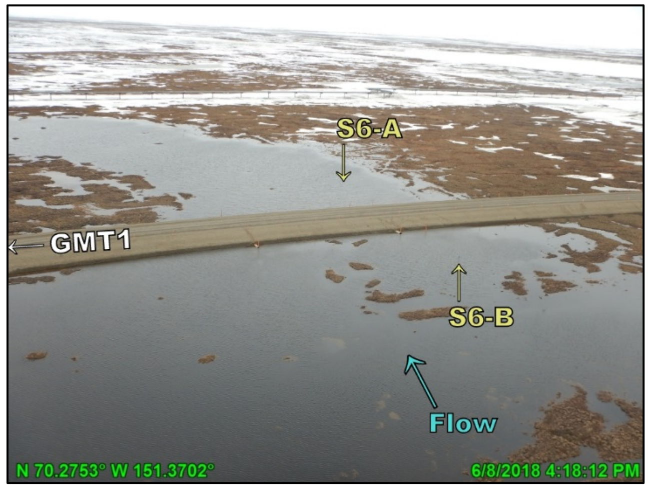

Photo F.13: Culverts GMT1-32 and GMT1-33, looking north; June 8, 2018

F.5 S7 Monitoring Location

Photo F.14: Culvert GMT1-25 on north side of GMT1 access road blocked, looking south; June 8, 2018

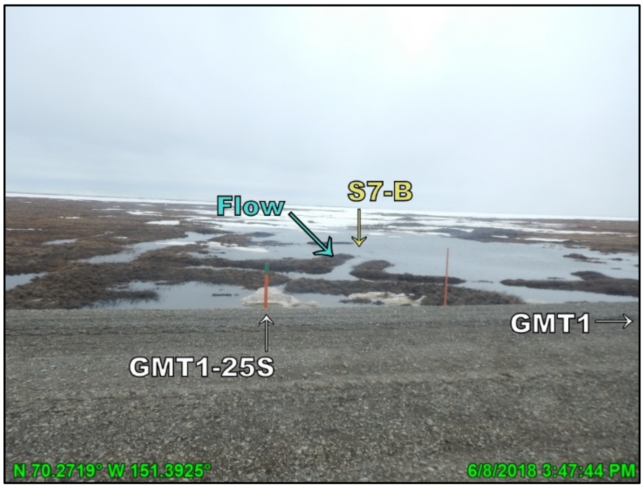

Photo F.15: Culvert GMT1-25 on south side of GMT1 access road with ponded water, looking south; June 8, 2018

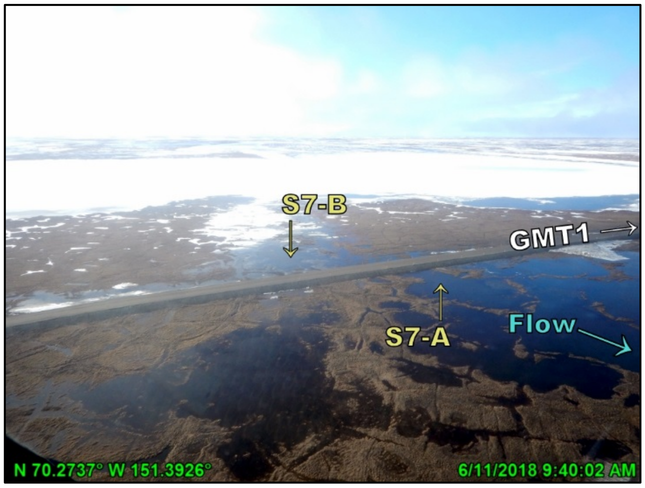

Photo F.16: Drainage equalized on both sides of the GMT1 access road near S7 monitoring location, looking southwest; June 11, 2018