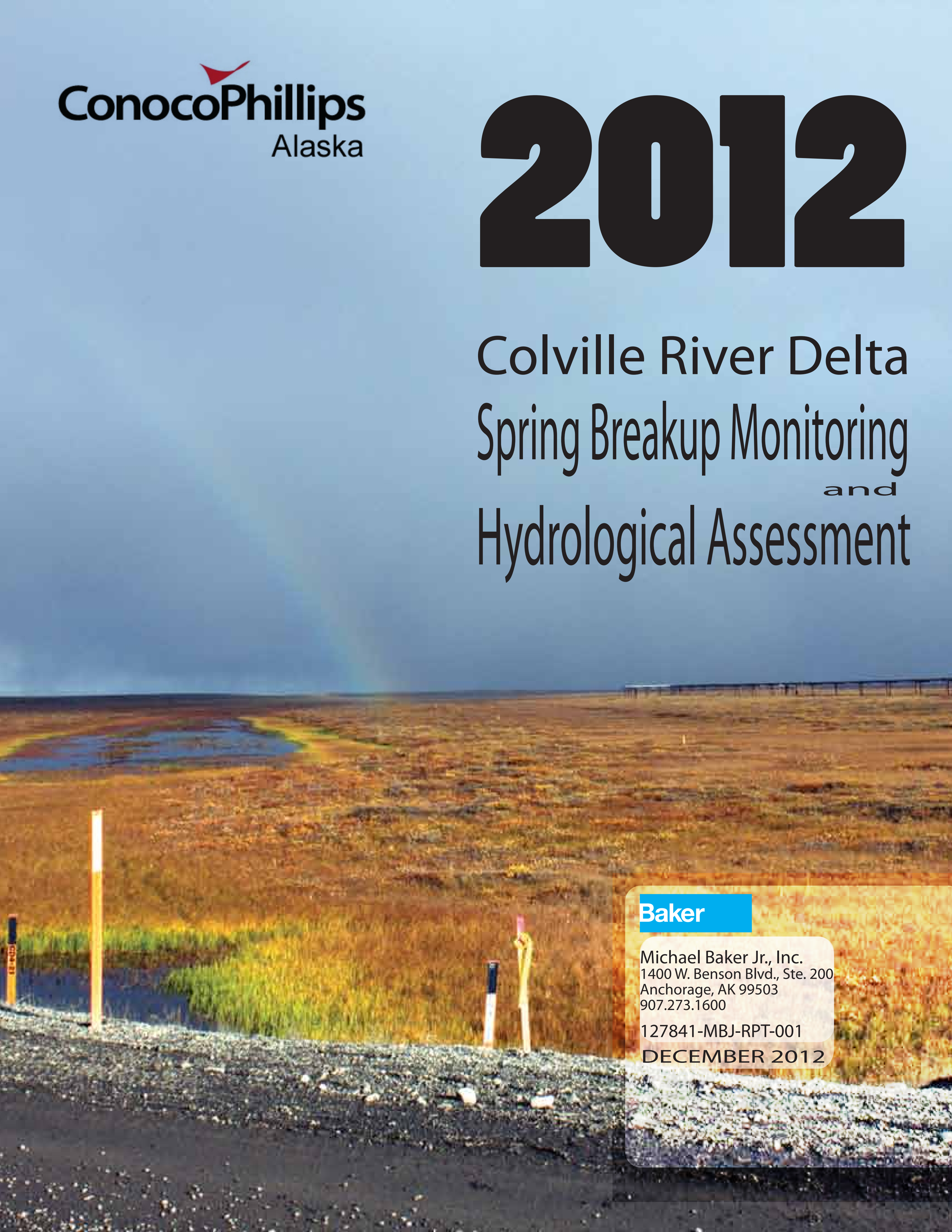
ConocoPhillips
Alaska

2012

Colville River Delta Spring Breakup Monitoring and Hydrological Assessment



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127841-MBJ-RPT-001
DECEMBER 2012

EXECUTIVE SUMMARY

This report presents the observations and findings of the 2012 Colville River Delta (CRD) Spring Breakup Hydrologic Assessment conducted by Michael Baker Jr., Inc. for ConocoPhillips Alaska (CPAI). The primary objective is to monitor and estimate the magnitude of breakup flooding within the CRD in relation to the CPAI Alpine facilities. General breakup observations were made at locations of interest across the CRD. Measurements and data were collected at predetermined monitoring locations adjacent to major hydrologic features and existing or proposed facilities, roads, and pipelines. Monitoring locations included:

- 11 sites along the Colville River, Colville River East Channel (East Channel), and Nigliq Channel
- 12 sites in the vicinity of Alpine facilities, roads, and drinking water lakes
- Drainage structures and road prisms along the CD2 and CD4 access roads
- 2 primary ice road crossings at the East Channel and the Kachemach River and 6 secondary ice road crossings
- 3 sites at the CD3 pipeline crossings
- 8 sites at proposed CD5 access road crossings

The 2012 spring breakup was characterized by an initial low stage flow peaking and receding with little progression of melt or ice movement as ice jams grounded out in place. Floodwaters then rose once again to a second, higher peak which resulted in the clearing of ice from all major channels. Flows receded for a final time as breakup events concluded. No significant effects to or from Alpine infrastructure was observed as a result of breakup flooding.

The peak stage at the head of the CRD (at Monument 1 [MON1]) was 14.18 feet above British Petroleum mean sea level (BPMSL) occurring on May 27. This is 5.67 feet lower than the historic maximum peak stage. The recurrence interval for the peak stage is less than two years based on the 2012 stage frequency analysis results and the CRD two-dimensional (2D) surface water model.

The peak discharge at MON1 was 366,000 cubic feet per second (cfs) occurring on June 1. Stage at the time of peak discharge was at 13.61 feet BPMSL. The peak discharge has a recurrence interval of 4.9 years based on the current (2002) CRD design magnitude flood frequency results.

Channel ice and ice jams annually affect spring breakup flood flow throughout the CRD. Ice floes accumulate at stream bends, constrictions, and shoals. Floes jam up on competent ribbon ice, eventually release, and then the ice travels downstream. By May 26, a significant ice jam had formed upstream of MON1. This jam released on the evening of June 1, jamming again near the Colville River horizontal directionally drilled (HDD) pipeline crossing before releasing to the coast. Ice floes from the June 1 release traveled into the Nigliq Channel where they jammed adjacent to Nuiqsut. This ice jam released later that day, jamming again near CD4 before releasing overnight between June 2 and 3. Floes also entered the Nigliagvik, Sakoonang, and Tamayayak channels, jamming and releasing as they moved downstream.

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
2D	Two-dimensional
ADCP	Acoustic Doppler Current Profiler
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADP	Alpine Development Plan
ASDP	Alpine Satellite Development Plan
ASP	Alpine sales pipeline
Baker	Michael Baker Jr., Inc.
BPMSL	British Petroleum mean sea level
CD	Colville Delta (facility names, CD1, CD2)
cfs	Cubic feet per second
CMP	Corrugated metal pipe
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DGPS	Differential global positioning system
D/S	Downstream
EOSDIS	Earth Observing System Data and Information System
fps	Feet per second
GPS	Global positioning system
HDD	Horizontal directional drilled
HWM	High water mark
LCMF	UMIAQ, LLC
MON	Monument
NASA	National Aeronautics and Space Administration
NPR-A	National Petroleum Reserve, Alaska
NUC	Non-uniform channel
OSW	Office of Surface Water
PT	Pressure transducer
RM	River mile
UC	Uniform channel
UMIAQ	UMIAQ, LLC; also known as LCMF
USACE	United States Army Corps of Engineers
U/S	Upstream
USGS	United States Geological Survey
WGS 84	World Geodetic System of 1984
WSE	Water surface elevation(s)

1.0 INTRODUCTION

This 2012 Colville River Delta Spring Breakup Hydrologic Assessment supports the ConocoPhillips Alaska, Inc. (CPAI) Alpine Development Project (ADP) and the Alpine Satellite Development Plan (ASDP). Michael Baker Jr., Inc. (Baker) conducted spring breakup monitoring to determine the extent and magnitude of this annual flooding event within the Colville River Delta (CRD). Primary tasks included documentation of the distribution of floodwater and the measurement of water levels and discharge quantities. Observations of lake recharge, ice jam activities, ice road crossing degradation, and post-breakup floodwater effects were collected. Measurements and observations were used to determine peak discharge and stage at key CRD locations, and are evaluated and compared to current flood and stage frequency values and the CRD two-dimensional (2D) surface water model results. Hydrologic observations were collected at the Colville East Channel, Nigliq Channel, Alpine facilities and roads, Colville Delta 3 (CD3) pipeline crossings, and the proposed CD5 road crossings. The results of the 2012 spring breakup monitoring activities are presented in this report.

Spring breakup on Alaska's North Slope typically occurs during a three-week period. The Colville River is the largest river on the North Slope. Its approximately 23,500 square mile drainage basin includes a significant portion of the western and central areas north of the Brooks Range. CRD breakup is generally considered to be the largest annual flooding event in the region. Figure 1.1 shows the CRD drainage basin delineation. Breakup monitoring is integral to understanding regional hydrology and ice effects, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and existing facilities during the flooding event.

In many areas of the North Slope, including the CRD, similar hydrologic and hydraulic characteristics are created in part by the arctic climate and presence of continuous regional permafrost. Groundwater is shallow and is generally restricted to isolated zones beneath deep lakes and river channels. Groundwater influx is largely nonexistent. After breakup, flow generally declines during the summer months with some temporary increases from rainfall events until winter freeze up begins. Surface water is frozen for much of the year. In deeper channels velocities tend to approach zero where water remains under the ice during winter months with no contributing flow. Nearer to the coast, under-ice flows are influenced by tidal flux and oceanic storm surges.

Operated by CPAI, the Alpine facilities are owned by CPAI and Anadarko Petroleum Company. Figure 1.2 shows the existing Alpine facilities, the proposed CD5 facilities, the Colville River and Nigliq Channel monitoring locations, and the locations of the ice road crossings. The existing Alpine facilities are the CD1 processing facility (Alpine), CD2, CD3, and CD4 drilling pads, access roads, and associated pipelines. Alpine facilities CD1 and CD2 were built for the ADP and CD3 and CD4 were built as part of the ASDP. Proposed CD5 facilities are also part of the ASDP.

Existing and proposed Alpine facilities and associated monitoring locations are shown in Figure 1.3. The proposed CD5 facilities presented in Figure 1.3 and Figure 5.4 to Figure 5.7 were provided by PND Engineers, Inc. and CPAI.

Spring breakup monitoring activities have been conducted in the CRD since 1992. Monitoring was expanded in 2004 to include ASDP facilities. The 2012 hydrologic field program is the 21st consecutive year of CRD spring breakup investigations.

This report is organized as outlined below.

Section 1 – Introduction: Discusses the objectives of the monitoring program and presents climatic and breakup timing information.

Section 2 – 2012 Monitoring Locations: Presents the 2012 monitoring sites.

Section 3 – Methods: Describes the methods of the fieldwork and the data analyses.

Section 4 –2012 Spring Breakup Hydrologic Observations and Water Surface Elevations: Presents the 2012 hydrologic observations and stage (or water surface elevation [WSE]) in the CRD. Additional breakup observations include drinking water lakes recharge, drainage structure assessment, pad and road erosion investigations, and ice bridge degradation.

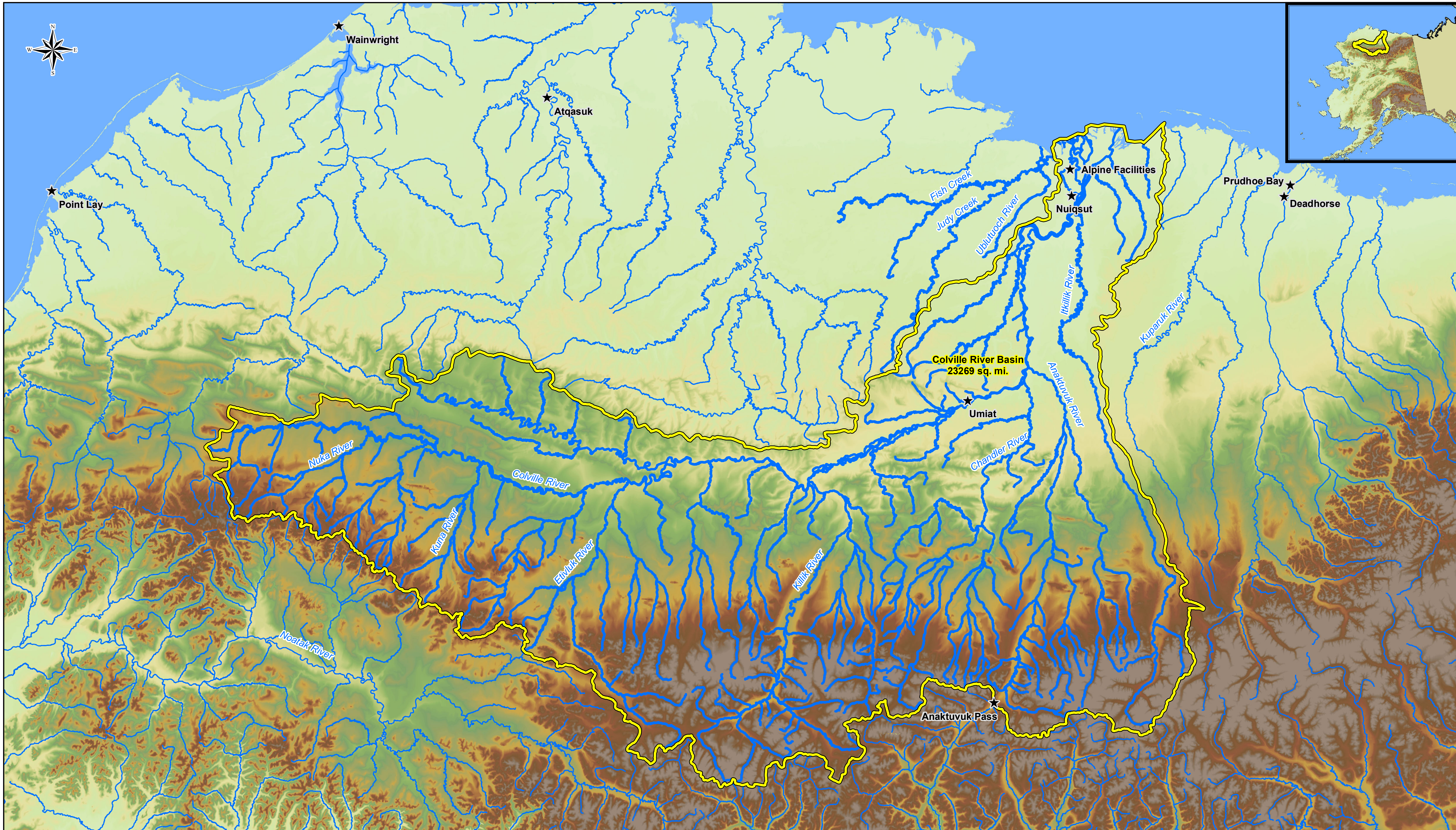
Section 5 – 2012 Discharge and Statistical Analysis: Presents the 2012 CRD direct (measured) and peak (calculated) discharge results. Results of the 2012 flood and stage frequency analyses compared to 2002 design values (flood recurrence) and the 2012 2D surface water model (stage recurrence) is also included.

Section 6 – References: Contains the references used in the development of this report.

Appendix A – 2012 Gage Locations and Vertical Control: Includes survey control for monitoring gages and the geographic locations for gages and control.

Appendix B – 2012 Alpine Bridge Direct Discharge Notes: Contains discharge notes for measurements performed at the Alpine swale bridges.

UMIAQ, LLC (LCMF), the Alpine environmental coordinators, Bristow Helicopters, and Fircroft provided support during the 2012 CRD breakup field work and contributed to a safe and productive monitoring season.



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Legend

★ Place Names

Streams

Colville River Basin

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2012 SPRING BREAKUP

COLVILLE RIVER DELTA

Drainage Basin

FIGURE: 1.1

(SHEET 1 of 1)

ConocoPhillips Alaska	Miles 0 1 2	Baker	2012 SPRING BREAKUP COLVILLE RIVER DELTA MONITORING LOCATIONS
Date: 10/01/2012	Project: 127841	Michael Baker Jr., Inc. 1400 West Benson Blvd., Suite 200 Anchorage, AK 99503 Phone: (907) 273-1600 Fax: (907) 273-1699	FIGURE: 1.2
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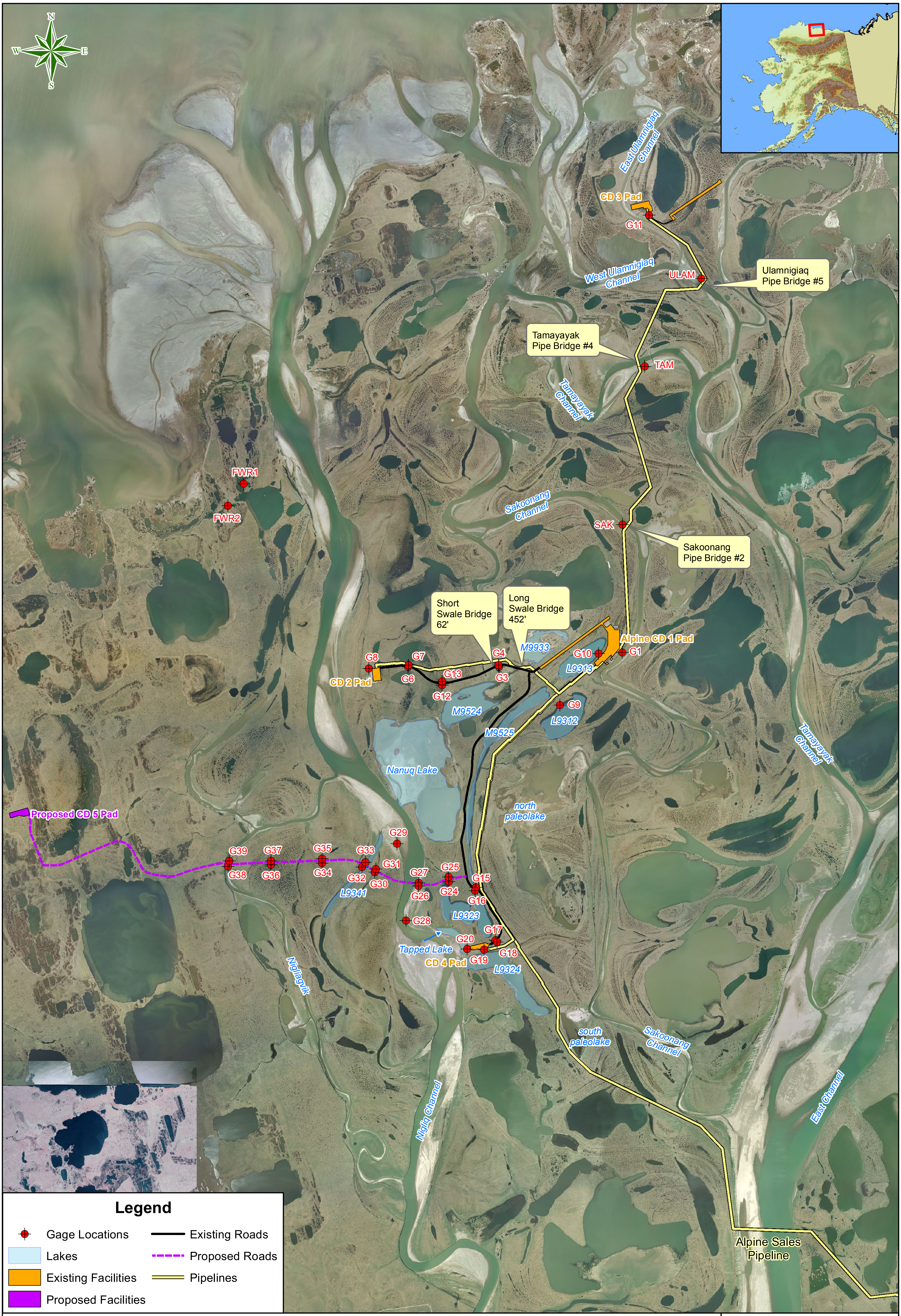

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2012 SPRING BREAKUP

ALPINE AREA FACILITIES

MONITORING LOCATIONS

FIGURE: 1.3

(SHEET 1 of 1)

1.1 Monitoring Objectives

The primary objective of the Colville River Delta Spring Breakup 2012 Hydrologic Assessment is to monitor and estimate the magnitude of breakup flooding within the CRD in relation to the CPAI Alpine facilities.

Annual monitoring provides a basis for the record used to evaluate the effect of breakup flooding events and associated ice activities on existing Alpine and ASDP roads, pads, and pipelines. Flood stage and discharge data and observations are also used for planning and design of proposed infrastructure, including the CD5 facilities. Flood data collection supports refinement of the CRD 2D surface water model.

The 2012 spring breakup program documented observations of effects to flow and channel morphology caused by the construction of winter ice bridges across the Colville River East Channel near the HDD crossing and the Kachemach River. Additional ice road crossing locations were observed during breakup for any significant impacts.

Permit stipulations identified in U.S. Army Corps of Engineers (USACE) Permit No. POA-2004-253 and the State of Alaska Department of Natural Resources (ADNR) Fish Habitat Permit FH04-III-0238 require monitoring of the Alpine facilities during spring breakup. Permit requirements include direct and indirect measurements of discharge through drainage structures and documentation of pad and access road erosion caused by spring breakup flooding.

Alaska Department of Fish and Game (ADF&G) permits FG99-III-0051-Amendment #7 and FG97-III-0190-Amendment #5 require monitoring of recharge to Lakes L9312 and L9313. The Alpine facilities rely on water withdrawal from these lakes for daily operations, the volume of which is dictated in part by annual spring recharge.

1.2 Climatic Review

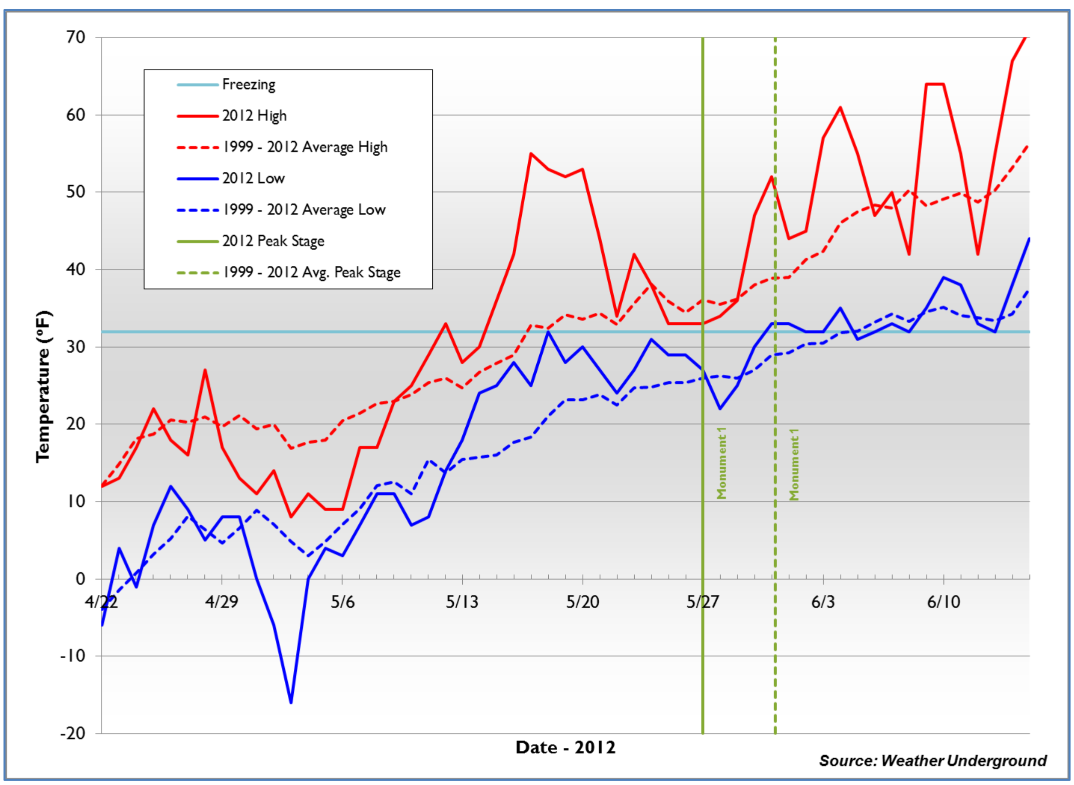
Breakup flooding dominates the Alaska North Slope landscape for approximately three weeks each spring. The open water season, a four-month period generally from June through September follows shortly after breakup. Factors contributing to the breakup cycle include snow pack, sustained cold or warm temperatures, ice thickness, wind speed and direction, precipitation, and solar radiation.

The Brooks Range stretches approximately 700 miles across northern Alaska and the Yukon Territory of Canada. The annual spring runoff in the Brooks Range contributes to rising stage in the Colville River and other regionally related streams. The Brooks Range is located approximately 150 air miles south of the head of the CRD. Monument 1 (MON1) (Figure 1.2), located at the head of the delta, is the site farthest downstream (north) on the Colville River where the majority of contributing flow is confined to a single channel before the channel bifurcates as it approaches the coast of the Beaufort Sea.

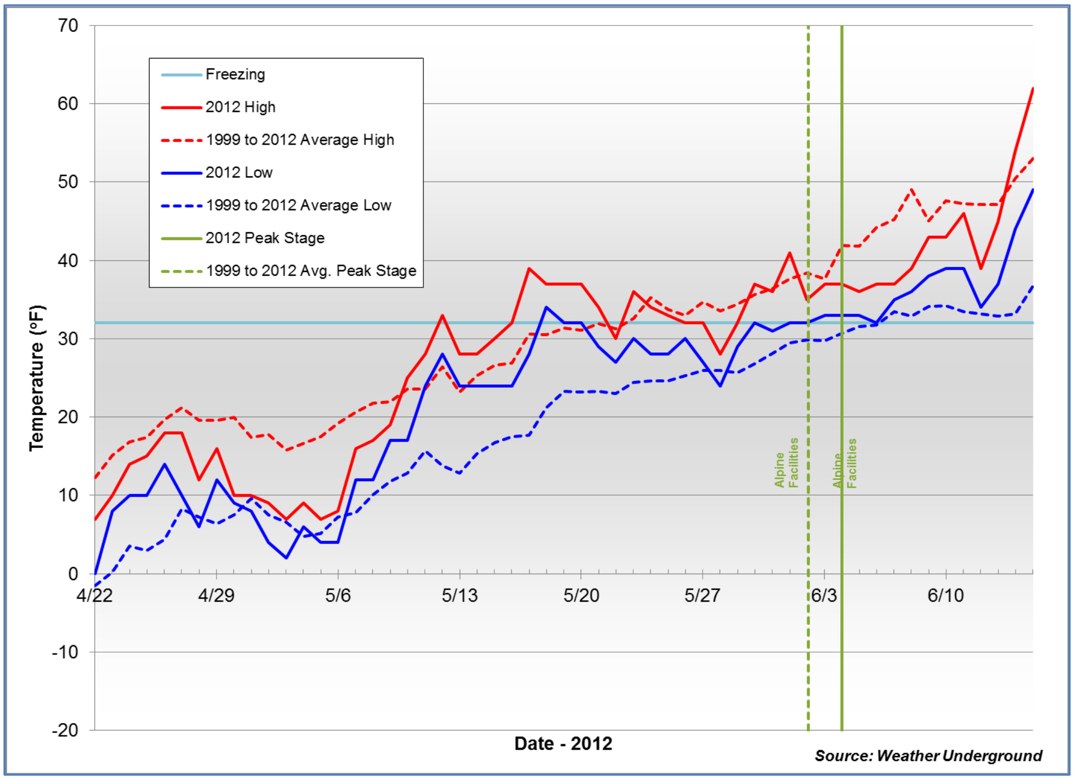
Increasing spring temperatures initiate breakup processes. Although not solely responsible, of particular importance is the rise of daily high ambient air temperatures in the Brooks Range, where the headwaters of the Colville River originate. As these daily highs begin to approach and exceed freezing, breakup processes accelerate, with subsequent snow melt progressing downstream towards the CRD. As such, daily high and low ambient air temperatures are used in the evaluation of breakup timing.

Climate data for this region of the Brooks Range foothills are available from the Umiat weather station. Umiat (shown in Figure 1.1) is located approximately 60 air miles south of MON1. The 2012 ambient air temperatures at Umiat were generally above historical averages, with the exception of late May through early June. Nighttime ambient air temperatures did not stay above freezing until early June. Graph 1.1 illustrates high and low ambient air temperatures recorded for Umiat from April 22 to June 15 during the breakup monitoring period. Average highs and lows for the same period for 1999 through 2012 are shown as dashed lines. Dates of 2012 peak stage and average peak stage from 1999 to 2012 from the centerline gage at MON1 (MON1C) are included for comparison.

Temperatures for the Alpine area were obtained from the Nuiqsut weather station. Nuiqsut is located on the west bank of the Nigliq Channel, approximately 3.5 air miles northwest of MON1, and approximately 9 air miles south of the Alpine facilities, as shown in Figure 1.2. Ambient air temperatures at Nuiqsut remained below freezing until around May 12. Local melting in the vicinity of the Alpine facilities occurred around May 25 and was accelerated once daily highs and lows in the area approached and exceeded freezing in late May and early June. Graph 1.2 provides high and low ambient air temperatures recorded for Nuiqsut during 2012 breakup monitoring. Dates of 2012 peak stage and average peak stage from 1999 to 2012 at Alpine facilities are included for comparison.



Graph 1.1: Daily High and Low Breakup Ambient Air Temperatures at Umiat and Peak Stage at MON1



Graph 1.2: Daily High and Low Breakup Ambient Air Temperatures at Nuiqsut and Peak Stage at Alpine Facilities

1.3 Breakup Timing

Since initial breakup studies began in 1962, Colville River breakup monitoring has been intermittently conducted at various locations in the delta. Monitoring of MON1 provides the most consistent historical record of annual peak stage and discharge observations available. MON1 is located at the head of the delta before the river bifurcates (see Figure 1.2).

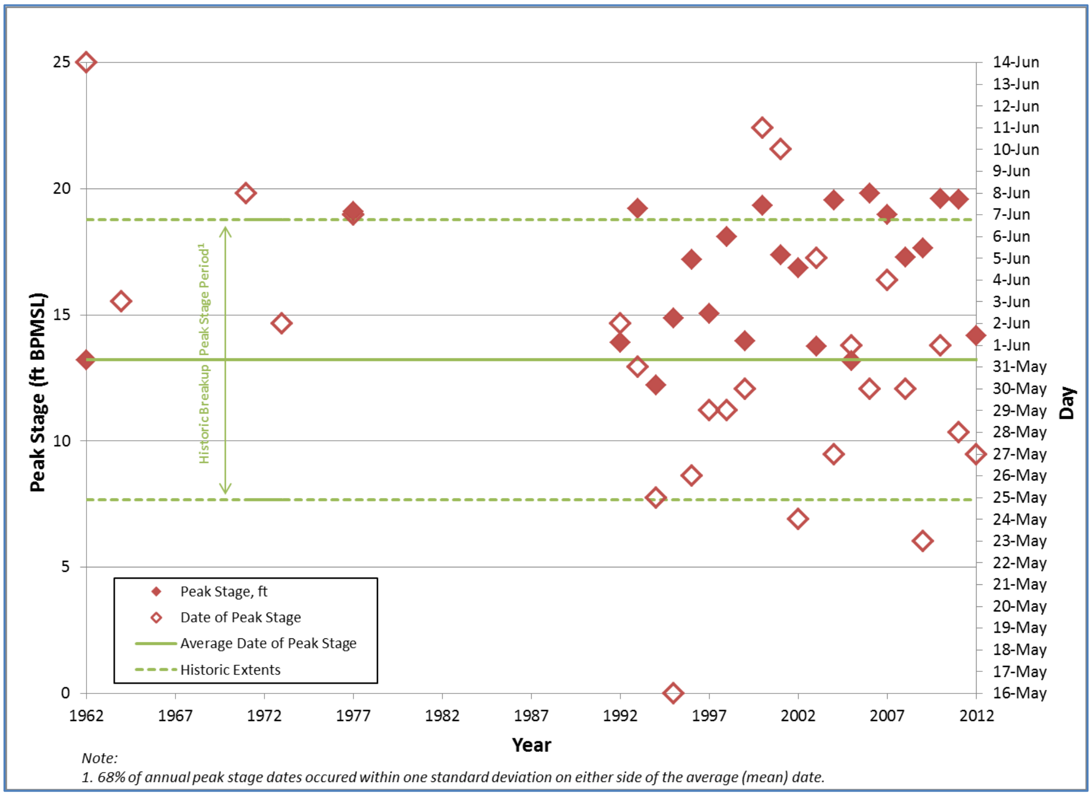
Table 1.1 shows the annual peak discharge and peak stage at gage MON1C. MON1C is the control for the three gage set. These data are considered to be typical for the direct discharge measurement.

Table 1.1: Colville Historical Peak Discharge, Stage & Date

Year	Discharge: Peak Discharge (cfs)	Discharge: Date	Stage (WSE): Peak Stage (ft BPMSL)	Stage (WSE): Date	Reference
2012	**366,000**	**1-Jun**	**14.18**	**27-May**	**This report**
2011	590,000	28-May	19.56	28-May	Baker 2012
2010	320,000	31-May	19.59	1-Jun	Baker 2010
2009	266,000	23-May	17.65	23-May	Baker 2009b
2008	221,000	28-May	17.29	30-May	Baker 2008
2007	270,000	3-Jun	18.97	4-Jun	Baker 2007b
2006	281,000	30-May	19.83	30-May	Baker 2007a
2005	195,000	9-Jun	13.18	1-Jun	Baker 2005b
2004	360,000	26-May	19.54	27-May	Baker 2005a
2003	232,000	11-Jun	13.76	5-Jun	Baker 2006a
2002	249,000	27-May	16.87	24-May	Baker 2006a
2001	255,000	11-Jun	17.37	10-Jun	Baker 2006a
2000	580,000	11-Jun	19.33	11-Jun	Baker 2000
1999	203,000	30-May	13.97	30-May	Baker 1999
1998	213,000	3-Jun	18.11	29-May	Baker 1998b
1997	177,000	-	15.05	29-May	Baker 2002b
1996	160,000	26-May	17.19	26-May	Shannon & Wilson 1996
1995	233,000	-	14.88	16-May	ABR 1996
1994	159,000	25-May	12.20	25-May	ABR 1996
1993	379,000	31-May	19.20	31-May	ABR 1996
1992	188,000	-	13.90	2-Jun	ABR 1996
1977	407,000	-	19.10	7-Jun	ABR 1996
1973	-	-	-	2-Jun	ABR 1996
1971	-	-	-	8-Jun	ABR 1996
1964	-	-	-	3-Jun	ABR 1996
1962	215,000	-	13.20	14-Jun	ABR 1996

The 2012 peak discharge value at MON1 was 366,000 cfs. The maximum historical peak discharge was 590,000 cfs in 2011 (Baker 2012) and the average historical peak is 283,000 cfs. Peak discharge occurred on June 1, 2012. The average date of peak discharge is May 31, based on 18 recorded peak discharge dates.

The 2012 peak stage value at MON1C was 14.18 feet British Petroleum mean sea level (BPMSL). The maximum historical peak stage was 19.83 feet BPMSL in 2006 (Baker 2007a) and the average historical peak is 16.69 feet BPMSL. In 2012, peak stage at MON1C occurred on May 27. The average date of peak stage is May 31 based on the 26 recorded peak stage dates. Graph 1.3 presents the date and WSE of peak stage at MON1 for years with available data.



Graph 1.3: MON1 Annual Peak Stage and Dates

In 2012, stage peaked twice at all monitoring locations in the CRD. At the three MON1 gage locations, the first peak occurred on May 27, as the result of initial flood melt while significant ribbon ice was present in the channel. The second peak occurred on June 2, as the result of increased flood melt after a period of inhibited melting combined with an upstream ice jam release. The higher stage at gages MON1U and MON1C occurred during the first peak. At each location, WSE was within 0.1 feet of the maximum recorded during the second peak. A higher stage at MON1D occurred during the second peak, and the WSE was within 0.2 feet of the maximum recorded during the first peak at this location.

Peak stage in the vicinity of the Alpine facilities typically occurs one or two days following peak at MON1. This pattern remained somewhat consistent in 2012. Alpine facilities also experienced two peaks, the first occurring at all locations between May 27 and May 29, and the second overnight between June 3 and June 4. Stage was higher during the second peak at all Alpine facilities gage locations.

Statistical analysis of the dates available for the 26-year historical peak stage record shows 68% of peak WSE for the CRD at MON1 have occurred during the 13-day period from May 24 to June 6. This represents one standard deviation of 6.4 days on either side of the average (mean) peak stage date of May 31 based on a normal distribution, as illustrated in Graph 1.3. The 2012 peak stage at MON1 on May 27 falls within this 13-day timeframe.

2.0 2012 MONITORING LOCATIONS

Observations of significant breakup flooding and ice effects near existing and proposed Alpine infrastructure were collected throughout the CRD. In 2012, key locations near the planned CD5 infrastructure were updated and new sites near the proposed CD5 pipeline/access road alignment were added. Other CRD 2012 monitoring locations were consistent with those studied in 2011 (Baker 2012). The 2012 gaging and monitoring sites are listed in Table 2.1 and Table 2.2. CRD gage locations, including monuments, are shown in Figure 1.2; Alpine area facilities gage locations are shown in Figure 1.3.

Stage monitoring is accomplished using a network of established hydrologic gages. The majority of monitoring locations are adjacent to major hydrologic features and are selected based on topography; proximity and hydraulic significance to existing or proposed facilities, temporary infrastructure, and relevant terrain features; and their importance to the historical record.

Gages are used to monitor WSE and flow at major hydrologic features adjacent to Alpine facility pads and roads. Observations are recorded for water source lake recharge, drainage structure performance, gravel road prism erosion, and breakup of ice bridges. Stage data and breakup observations are collected at pipeline channel crossings between CD3 and Alpine, and the Colville River HDD crossing. Gage sites in the vicinity of the proposed CD5 infrastructure were updated and expanded to include additional crossing locations and low overbank areas.

Geographic reference for all locations is provided in Appendix A.

In this report, locations are identified in river miles (RM) with RM 0 indicating the terminus of the river. The terminus is where smaller stream channels converge with larger channels and water bodies. The terminus of the East and Nigliq Channels of the Colville River is RM 0 at Harrison Bay. Measurement upstream is identified along the East Channel (E) and Nigliq Channel (N).The RM increases on the Colville River as distance from Harrison Bay increases upstream (south).

RM locations in this report are based on the following assumptions: Monument 35 (MON35) is located at RM E3.0 for East Channel locations; Monument 28 (MON28) is located at RM N0.8 for Nigliq Channel locations.

Table 2.1: Colville River Delta Primary Monitoring Locations

Monitoring Area	
Location	**Notes**
Monuments - Colville East Channel	
MON1 (MON1U, MON1C & MON1D)	Entire Colville flow confined to a single channel
MON9	HDD crossing
MON35	Helmericks Homestead
Monuments - Nigliq Channel	
MON20	S of CD4
MON22	S of CD2
MON23	N of CD2
MON28	At Harrison Bay
Alpine Facilities and Roads	
G1*	CD1 betweeen pad and Sakoonang Channel
G9*	Lake L9312
G10*	Lake L9313
G3*/G4*	CD2 access road, swale bridge vicinity
G12/G13	CD2 access road
G6*/G7*	CD2 access road
G8	CD2 between pad and Nigliq Channel
G11*	CD3 pad area
G15/G16	CD4 access road
G17/G18	CD4 access road
G19*	CD4 between SE corner of pad and Lake L9324
G20	CD4 between W end of pad and Nigliq Channel
CD3 Pipeline Stream Crossings	
SAK	Sakoonang (Pipe Bridge #2)
TAM	Tamayayak (Pipe Bridge #4)
ULAM	Ulamnigiaq (Pipe Bridge #5)
Proposed CD5 Crossings	
G24/G25	Lake L9323
G26/G27	E bank, Nigliq Channel adjacent to crossing - formerly known as G21 (2009-20
G28/G29	E bank/W bank, Nigliq Channel
G30/G31	Small drainage area
G32/G33	Lake L9341 - formerly known as G22 (2009-2011)
G34/G35	Small drainage area
G36/G37	Small drainage area
G38/G39	W bank, Nigliagvik - formerly known as G23 (2009-2011)

* Direct-read permanent staff gage

Paired gages are upstream/downstream of existing or proposed road crossings

Table 2.2: Colville River Delta Additional Monitoring Locations

Additional Monitoring Areas	
Location	Notes
Alpine Swale Bridges	
62-foot bridge	Along CD2 access road
452-foot bridge	Along CD2 access road
Alpine Culverts	Performance surveys
CD2 Road	26 culverts
CD4 Road	38 culverts
Alpine Roads	Post-breakup erosion visual surveys
CD2 Access Road	
CD4 Access Road	
Ice Road Stream Crossings	Area visual surveys
Colville East Channel	North of HDD
Kachemach River	South of pipeline crossing to 2L Pad - Kuparuk
Downstream Nigliq Channel	
FWR1	Small drainage in the western Nigliq overbank area
FWR2	Small drainage in the western Nigliq overbank area

2.1 Monuments

Satellite imagery[1] shown in Photo 2.1 provides an overview of the Colville River transporting breakup flow originating in the Brooks Range through the CRD and into Harrison Bay.

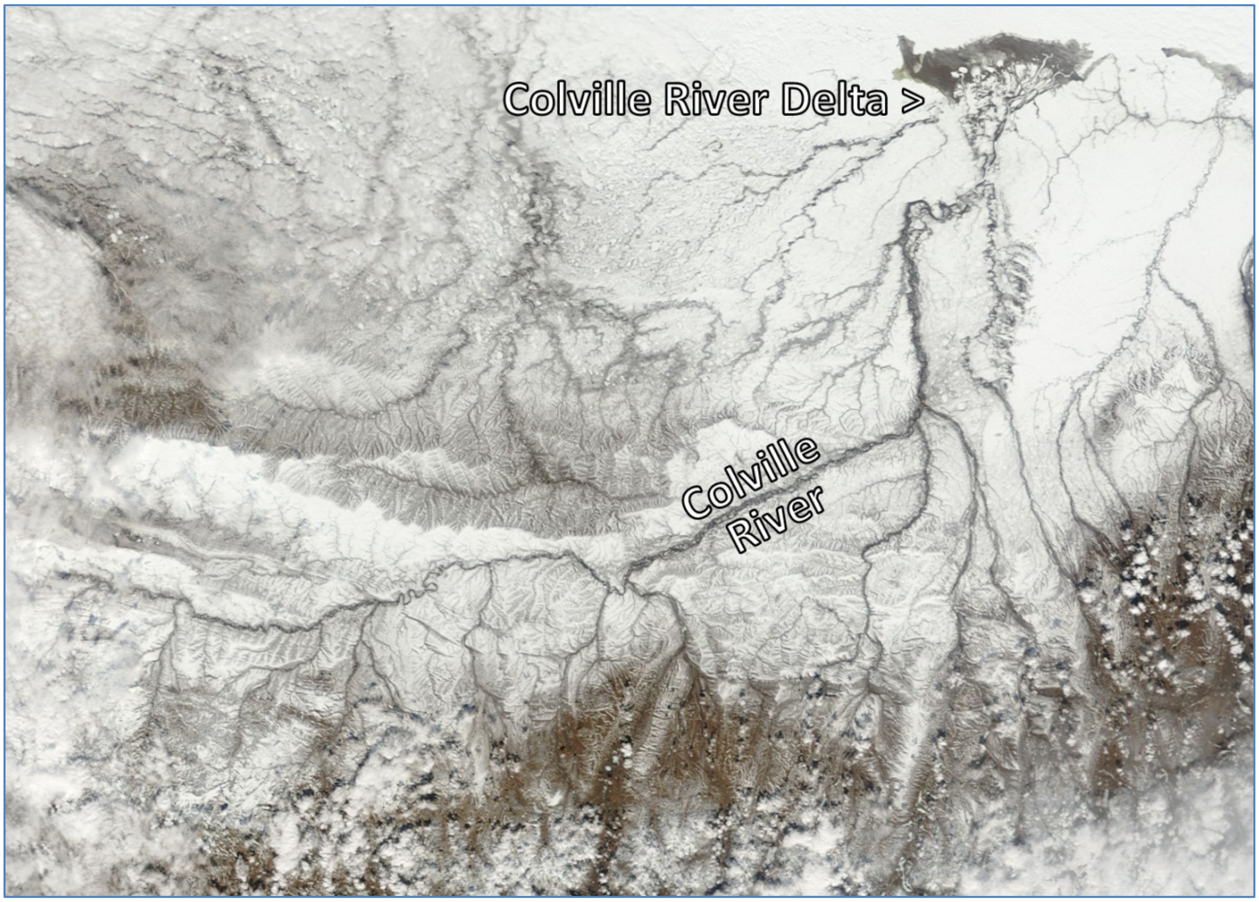


Photo 2.1: Satellite Imagery of the Colville River
Colville River transporting breakup meltwater from the origination in the Brooks Range through the CRD and out into Harrison Bay; May 30, 2012 (*reprinted with permission of NASA EOSDIS*)

Located at the head of the CRD, MON1 is the farthest downstream reach of the Colville River where all flow is confined to a single channel before it bifurcates. The Colville River divides into the Nigliq and East Channels approximately one mile downstream from MON1. The larger East Channel flows east of the Alpine facilities. The smaller Nigliq Channel flows past the village of Nuiqsut to the west of the Alpine facilities. The mouth of the delta lies downstream at the end of a series of dendritic channels and empties into Harrison Bay.

[1] Imagery is from the AERONET (Barrow, Terra) MODIS subset, courtesy of the National Aeronautics and Space Administration's (NASA) Earth Observing System Data and Information System (EOSDIS).

MON1 has been monitored annually since 1992 and periodically since 1962. Because of its location at the head of the delta and long historical record, MON1 is the primary spring breakup monitoring site. Three gaging stations are installed at MON1 along the west bank (Photo 2.2); one upstream (MON1U) at RM E23.5, one at the centerline (MON1C) at RM E22.9, and one downstream (MON1D) at RM E22.3. All Colville River, East Channel, and Nigliq Channel monument locations are shown in Figure 1.2.

Photo 2.2: MON1 reach and gage locations prior to breakup, looking downstream (north); May 23, 2012

2.1.1 East Channel

Monument 9 (MON9), located on the west bank at RM E16.8, is the first gaging station on the East Channel downstream of MON1. It is used to monitor the HDD crossing of the Alpine Sales Pipeline (ASP) and is in the downstream vicinity of the Colville River ice bridge crossing (Photo 2.3). It is downstream of the Putu Channel, connecting the Nigliq and East Channels, and upstream of the Sakoonang Channel distributary which flows past Alpine facilities. MON9 has been monitored annually since 2005.

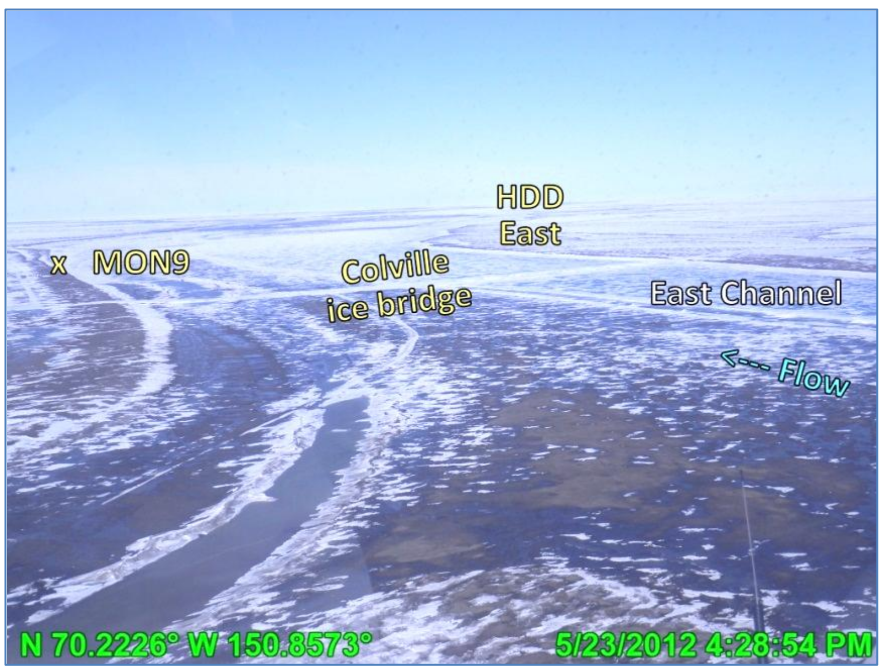


Photo 2.3: MON9 gage location with Colville ice bridge prior to breakup, looking downstream (north); May 23, 2012

Photo 2.4: MON35 gage location at Helmericks, looking downstream (north); June 3, 2012

Monument 35 (MON35) is located at the Helmericks Homestead (Colville Village) on Anachlik Island at RM E3.0 (Photo 2.4). Located on the west bank, it is the farthest downstream gage site on the East Channel and is the nearest to Harrison Bay. MON35 has been monitored intermittently since 1999. Stage data, observations, and photographs for this location are collected and provided by Jim Helmericks.

2.1.2 Nigliq Channel

Four monument monitoring locations are positioned along the Nigliq Channel: Monument 20 (MON20), Monument 22 (MON22), Monument 23 (MON23), and Monument 28 (MON28). Nigliq Channel gages have been monitored intermittently since 1998. MON28 has been intermittently monitored since 1999.

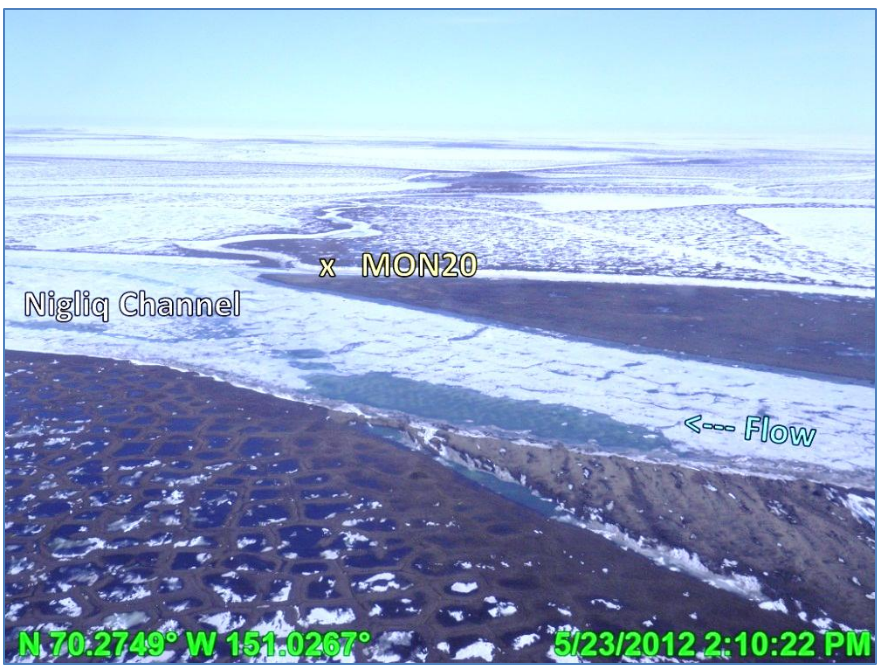


Photo 2.5: MON20 reach of the Nigliq Channel prior to breakup, looking east; May 23, 2012

MON20 is positioned on the Nigliq Channel east bank at RM N12.2. This is upstream (south) of all ADP and ASDP facilities and approximately 11 RM downstream from MON1C (Photo 2.5).

The next site downstream along the Nigliq Channel, MON22, is located on the west bank approximately midway between CD2 and CD4 at RM N8.8 (Photo 2.6).

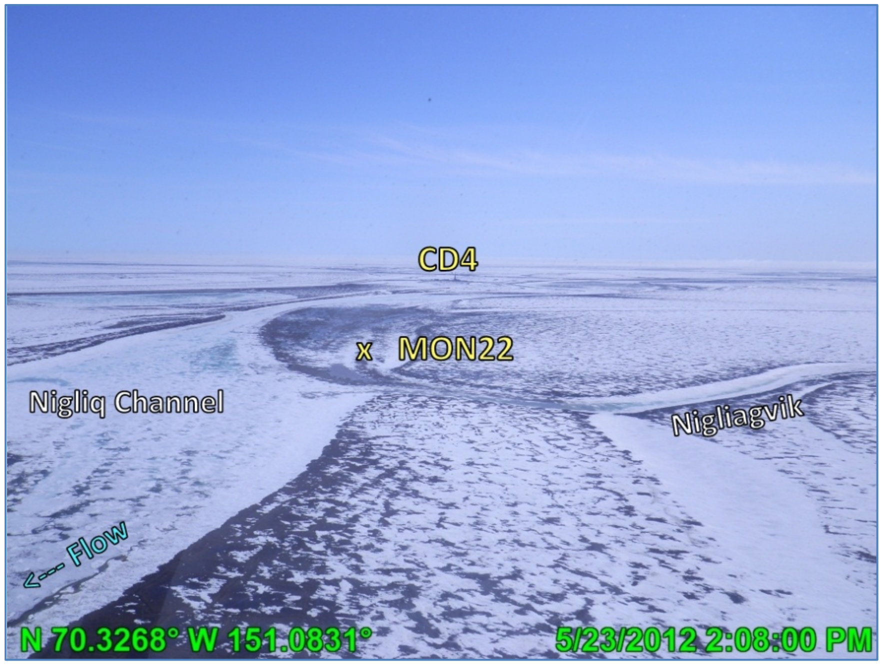


Photo 2.6: MON22 reach of the Nigliq Channel prior to breakup, looking upstream (south); May 23, 2012

MON23 gages are on the east bank of the Nigliq at RM N6.9, downstream of CD2 (Photo 2.7).

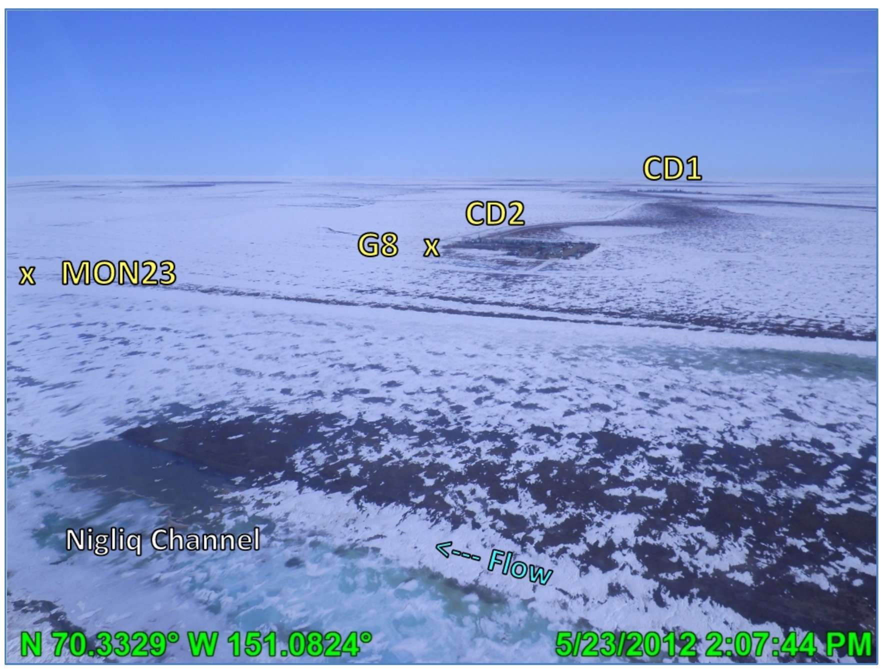


Photo 2.7: MON23 reach of the Nigliq Channel prior to breakup, looking east; May 23, 2012

MON28 is on the east bank at RM N0.8. Nearest to Harrison Bay (Photo 2.8), it is the northernmost gage location along the Nigliq Channel.

Two additional sites in the downstream vicinity of the west Nigliq Channel overbank area were monitored in 2012. These areas are identified as FWR1 and FWR2 and are located in the northwest section of the CRD.

Photo 2.8: MON28 gage location prior to breakup, looking west; May 23, 2012

2.2 Alpine Facilities and Roads

2.2.1 Gage Locations and Drainage Structures

Both direct-read permanent staff gages and indirect-read staff gages are used to monitor water levels at Alpine facilities and lakes. Gages have been established at all pads adjacent to major water feature to monitor the effects of breakup flood stage on facilities infrastructure. Photo 2.9 shows gage 1 (G1) in the Sakoonang Channel adjacent to CD1 (Alpine) pad and Photo 2.10 shows the location of gage G11 at CD3 adjacent to the West Ulamnigiaq Channel. Additional gages have been established along the CD2 and CD4 access roads adjacent to drainage structures that have historically experienced the passage of breakup flood flow. These gages are paired, one on the upstream and one on the downstream side of the drainage structure, to determine stage differential.

Photo 2.9: G1 in the Sakoonang Channel off CD1 (Alpine) pad prior to breakup, looking east; May 25, 2012

Photo 2.10: G11 at CD3 pad adjacent to the East Ulamnigiaq Channel prior to breakup, looking east; May 25, 2012

Drainage structures installed along the Alpine access roads are intended to allow for the natural flow of sediment-laden floodwaters, provide fish passage, and maintain the structure and function of habitats near the facilities. These drainage structures include a series of single culverts and multi-culvert batteries along both CD2 and CD4 access roads, two bridges along the CD2 access road, and the 62-foot (short) and the 452-foot (long) swale bridges.

To promote the passage of breakup flow, CPAI maintains the drainage structures to keep them free of ice and snow blockages that would otherwise accumulate during the winter months. Techniques include covering the culvert inlets and outlets and mechanically removing wind driven snow from the immediate upstream and downstream areas of all culverts (Photo 2.11) and bridges (Photo 2.12). Drainage structures are monitored for stage differential and functionality during spring breakup flooding. Spring breakup is typically the only event that produces sufficient quantities of water and increased stage which results in these structures passing flow.

Culvert inlets and outlets are surveyed annually by LCMF to compare structure elevations on either side of the road to satisfy ADF&G permit FH04-III-0328. Observations on functionality and flooding effects to the swale bridges are recorded to satisfy ADF&G permit FG97-III-0260.

Photo 2.11: Snow removed from vicinity of culvert inlets along the east side of the CD4 access road near G15 prior to breakup, looking south; May 25, 2012

Photo 2.12: View of south side of long swale bridge with snow mechanically removed prior to breakup and local melt in area, looking east; May 24, 2012

2.2.2 Alpine Drinking Water Lakes

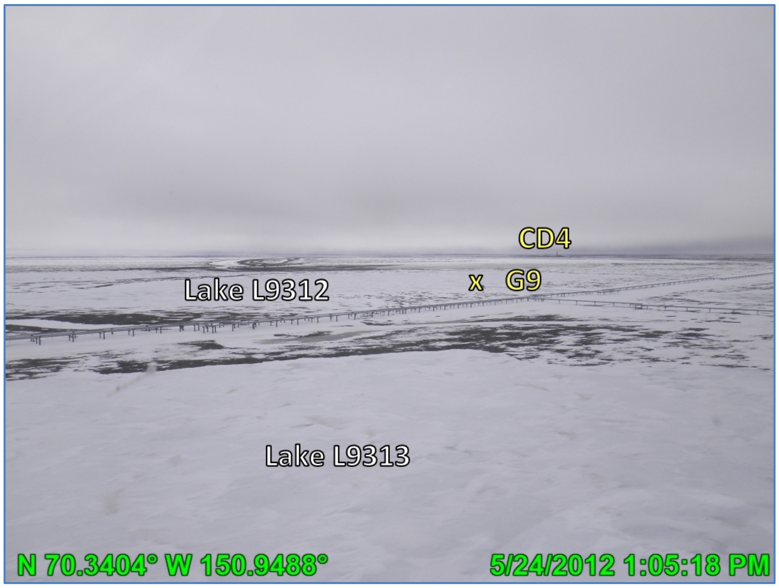


Photo 2.13: G9 location in Lake L9312 prior to breakup, looking southeast; May 24, 2012

Photo 2.14: G10 location in Lake L9313 prior to breakup, looking southeast; May 24, 2012

Lakes L9312 and L9313 are the primary water sources for Alpine facilities, annually supplying the necessary daily quantities for camp and industrial operations. Influent and effluent is processed by the onsite Alpine water and wastewater treatment plant, and documentation of recharge is required by State water use permits. Recharge of these lakes is monitored using direct-read gages: G9 at Lake L9312 (Photo 2.13) and G10 at Lake L9313 (Photo 2.14). Bankfull lake recharge is achieved when the stage hydrograph exhibits a rise and then fall indicating either overland flow or local melt from within the drainage basin increased the lake WSE above bankfull conditions.

2.2.3 Erosion

Following breakup, the Alpine access roads are evaluated for visual evidence of erosion caused by flooding. Observations were made along the length of both shoulders of the gravel roads and pads.

2.2.4 Ice Bridges

Ice roads are constructed annually to link the CD3 pad with the rest of Alpine facilities, and Alpine facilities and the village of Nuiqsut with the permanent gravel road system to the east. These temporary routes are used for supply delivery and transportation of drilling equipment to and from isolated areas. An ice road was constructed during the winter 2011-2012 between Alpine and 2L Pad, the nearest extent of the Kuparuk road system. This route crosses several drainages and channels. Slots are mechanically cut into the road prior to spring breakup to promote the passage of flood flows.

Ice road crossings were monitored at the Colville East Channel, less than one-half-mile upstream from the HDD crossing (Photo 2.15), and at the Kachemach River (Photo 2.16). Monitoring included visual observation of degradation and photo documentation of each crossing.

Photo 2.15: Colville River ice bridge crossing slotted to facilitate flood flow prior to breakup, looking downstream (northeast); May 23, 2012

Photo 2.16: Kachemach River ice bridge crossing slotted to facilitate flood flow prior to breakup, looking upstream (south); May 27, 2012

2.3 CD3 Pipeline River Crossings

Excerpt from Figure 1.2

The CD3 pipeline crosses three channels between CD1 and CD3; Crossing 2 at the Sakoonang, Crossing 4 at the Tamayayak, and Crossing 5 at the Ulamnigiaq. Sakoonang (SAK) gages are located on the southwest bank (Photo 2.17), Tamayayak (TAM) gages are on the south bank (Photo 2.18), and Ulamnigiaq (ULAM) gages are on the northeast bank (Photo 2.19). The gages are located downstream of the pipeline crossings. Observations of breakup processes, effects of flooding on infrastructure, and stage data has been collected at these locations intermittently since 2000.

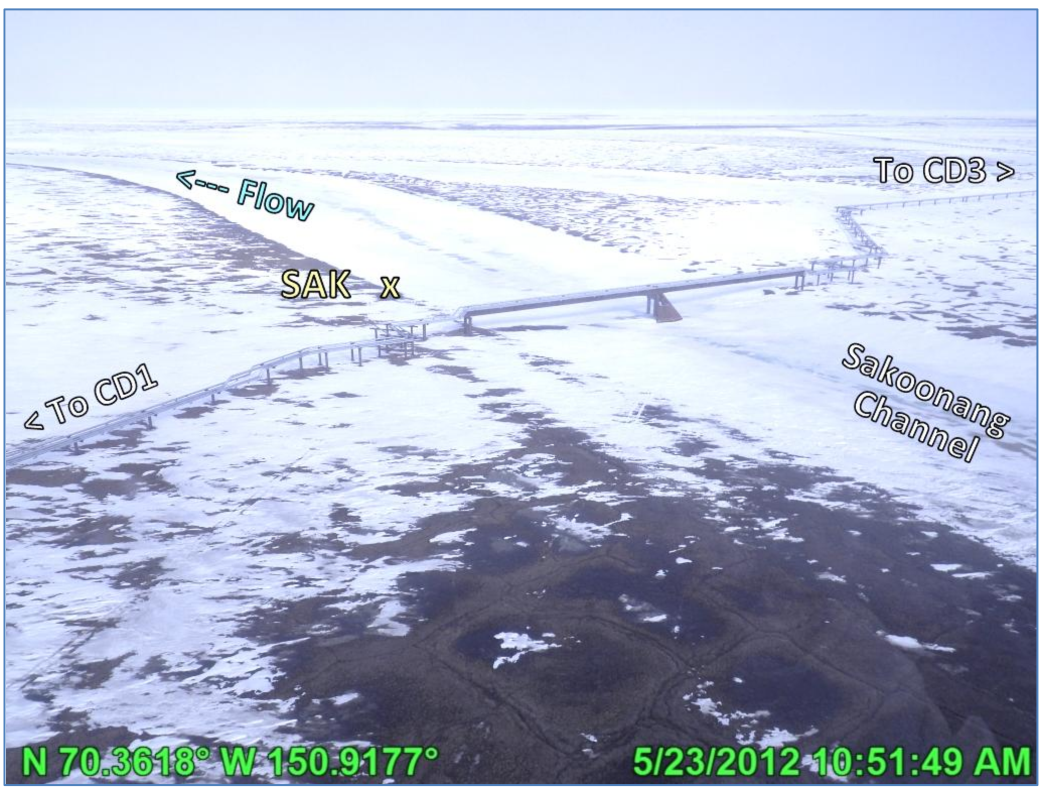


Photo 2.17: Sakoonang pipeline crossing (#2) prior to breakup, looking downstream (north); May 23, 2012

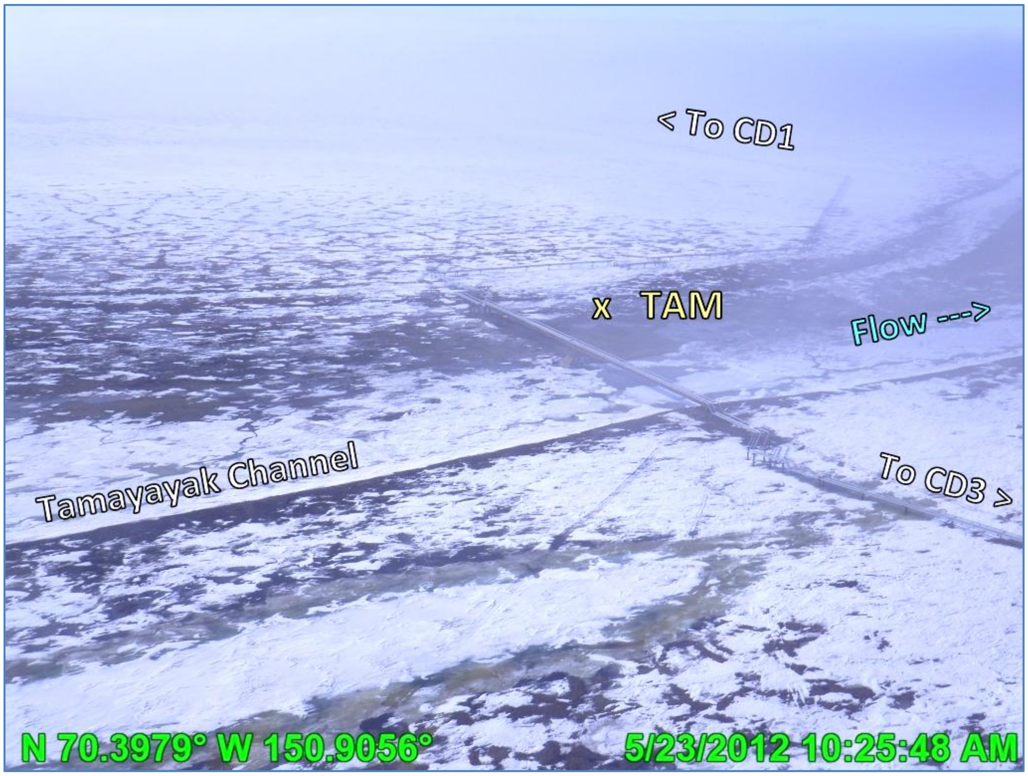


Photo 2.18: Tamayayak pipeline crossing (#4) prior to breakup, looking south; May 23, 2012

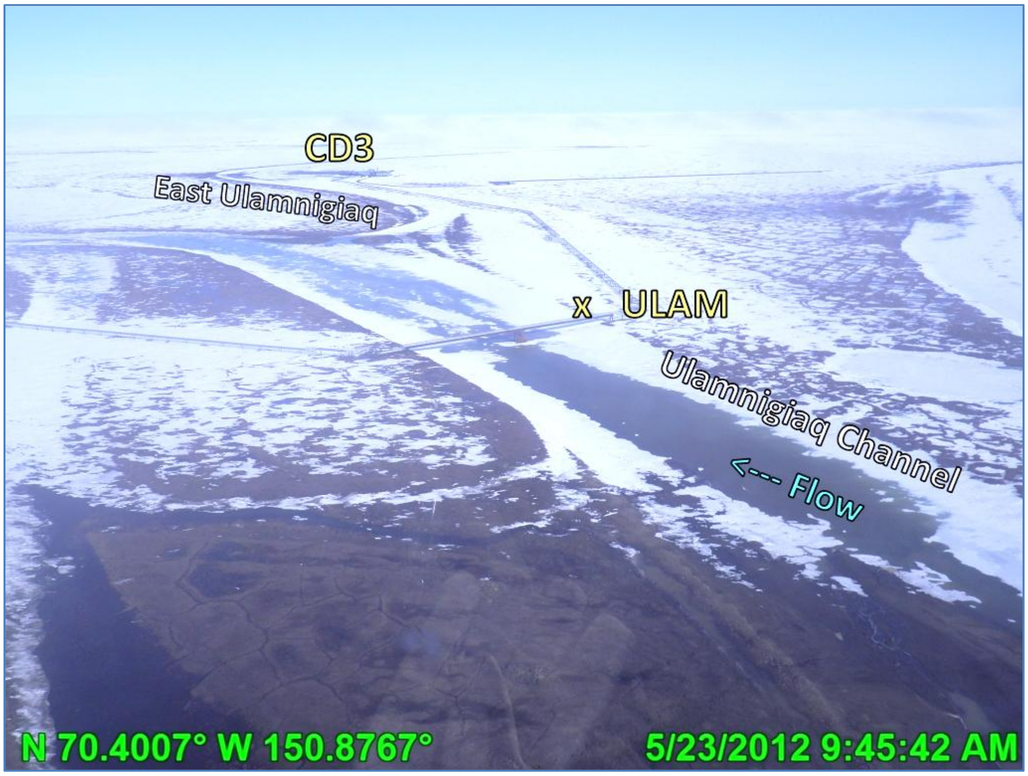
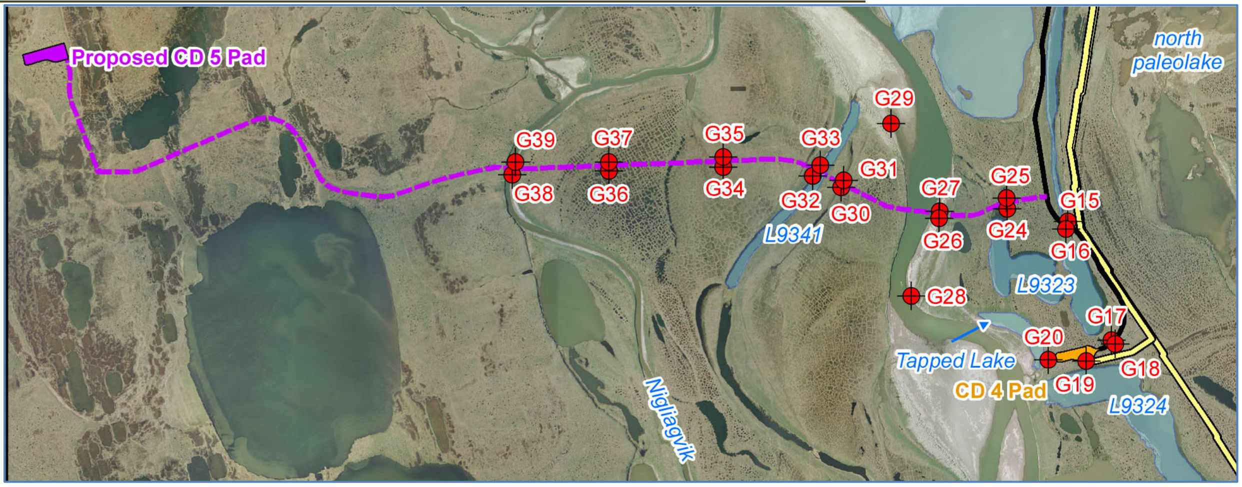


Photo 2.19: Ulamnigiaq pipeline crossing (#5) prior to breakup, looking downstream (north); May 23, 2012

2.4 Proposed CD5 Pipeline/Road Crossings



Excerpt from Figure 1.3

2.4.1 Proposed CD5 Pipeline/Road Crossings

In 2009, 2010, and 2011, three gage sites were used to monitor breakup conditions along the proposed CD5 pipeline/access road (CD5) route (G21 at the Nigliq Channel crossing, G22 at the Lake L9341 crossing, and G23). Changes were made in 2012 in support of continuing project design. Upstream and downstream gage sets were established to collect additional stage and discharge data for each crossing. Existing gages G21, G22, and G23 were upgraded to paired sets and given new identifiers: G26/G27 (Photo 2.21), G32/G33 (Photo 2.23), and G38/G39 (Photo 2.24), respectively. Five new locations were monitored. One pair of gages was installed at the Lake L9323 crossing (G24/G25 in Photo 2.20); one pair upstream and downstream of the Nigliq crossing (G28/G29 in Photo 2.21); and three pairs at shallow drainages along the route (G30/G31, G34/G35, and G36/G37 in Photo 2.22). Monitoring was confined to east of the National Petroleum Reserve – Alaska (NPR-A) boundary.

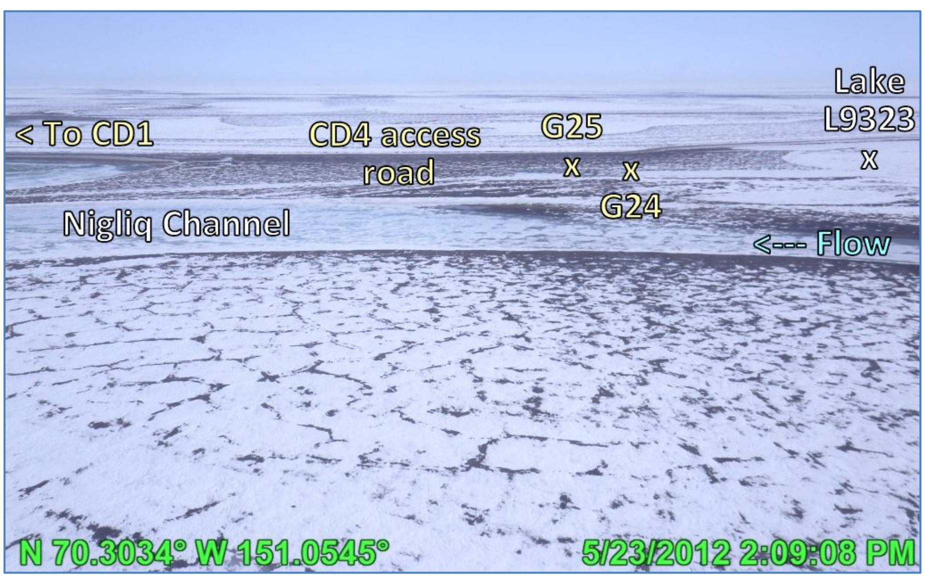


Photo 2.20: Vicinity of proposed CD5 crossing of Lake L9323; G24/G25, looking east; May 23, 2012

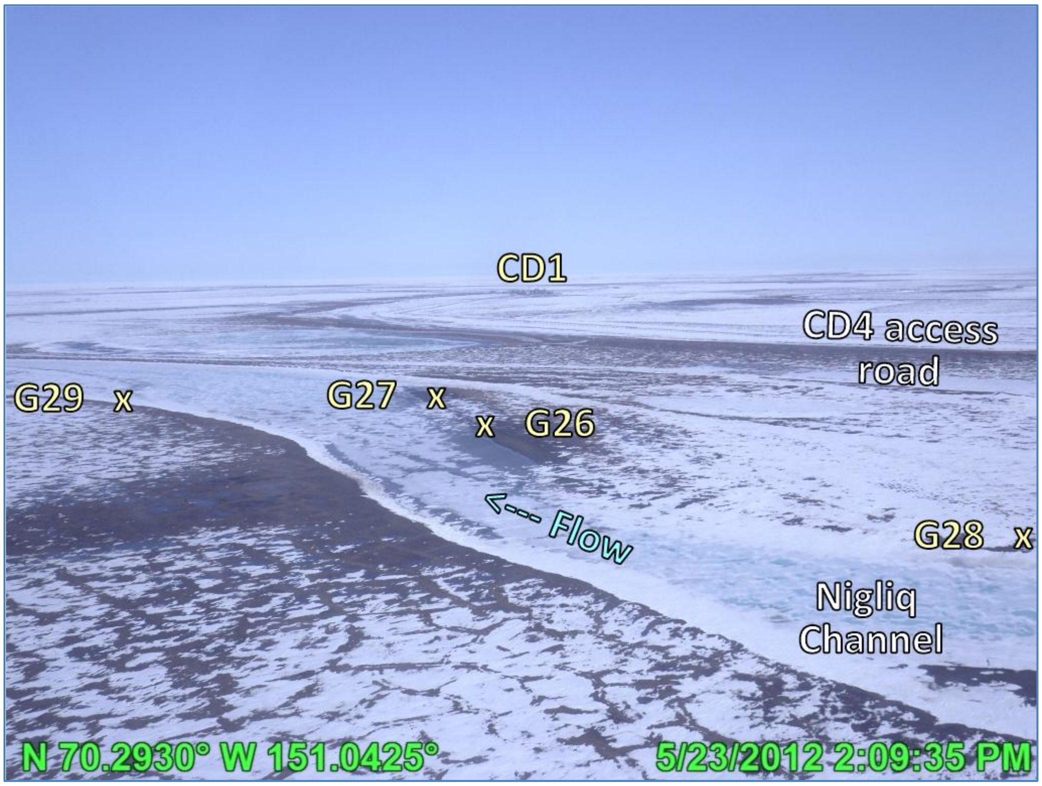


Photo 2.21: Vicinity of proposed CD5 crossing of the Nigliq Channel; G26/G27 and G28/G29, looking downstream (northeast); May 23, 2012

Photo 2.22: Example of small drainage area along proposed CD5 route prior to breakup; G36/G37, looking southeast; May 24, 2012

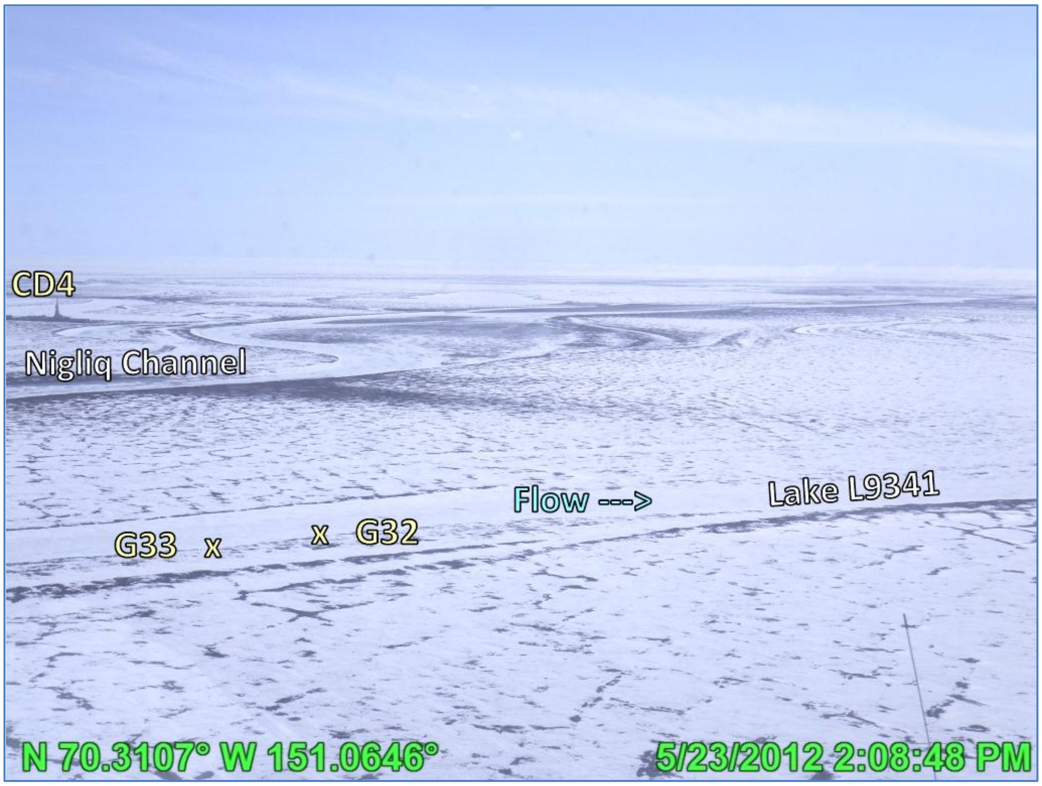


Photo 2.23: Vicinity of proposed CD5 crossing at Lake L9341; G32/G33, looking north; May 23, 2012

Photo 2.24**: Vicinity of proposed CD5 crossing at the Nigliagvik; G38/G39, looking downstream (south); May 24, 2012.**

3.0 METHODS

The field program consists of setup and monitoring activities. Prior to breakup, field crews rehabilitate existing gages, install new gages, and survey gages to tie into a control elevation. Setup was completed between May 2 and May 10, 2012. LCMF provided personnel and Hägglund BV206 tracked vehicles for overland transportation.

The 2012 spring breakup monitoring activities included documenting observations of floodwater flow, distribution, and ice conditions; recording stage at gaging locations; and measuring discharge at channels and drainage structures. Spring breakup monitoring was performed between May 23 and June 8. CPAI contracted Bristow to provide helicopter support to access remote sites (Photo 3.1), and a CPAI pickup truck was used to access local sites.

Field methodologies have been proven safe, efficient, and accurate for the conditions encountered on the North Slope of Alaska during spring breakup. Data collection is affected by safety, weather, and logistics.

Photo 3.1: Breakup monitoring at MON28 with Bristow helicopter support; June 5, 2012

3.1 Visual Observations

Field data collection and observations of breakup progression, channel morphology, ice events, lake recharge, and interactions between floodwaters and infrastructure were recorded in notebooks. Digital cameras with integrated global positioning systems (GPS) were used for photographic documentation of spring breakup prior to, during, and after peak conditions. The geographic position of the camera in latitude and longitude (lat-long), date, and time were automatically imprinted onto each photo. The photo datum was World Geodetic System of 1984 (WGS 84). At times when the camera had difficulty locking onto a geographic position, the locations were manually geographically referenced and then imprinted onto each photograph.

3.2 Stage (WSE) Monitoring

Photo 3.2: Reading water level off a staff gage at MON9; May 27, 2012

Stage or WSE monitoring of spring breakup flooding conditions is key to understanding CRD regional hydrology. Stage data was collected using hydrologic gages and pressure transducers (PTs). Daily site visits were performed as conditions allowed (Photo 3.2).

3.2.1 Hydrologic Staff Gages

Hydrologic staff gages were used to determine stage from observed water levels. Chalk was applied to the iron gage support during each site visit. Subsequent high water marks (HWM) were recorded when floodwaters removed the chalk; and peak WSE, often occurring between site visits, were captured. When water levels were not high enough to be recorded on the gage faceplates or when gages were impacted by ice, standard level-loop survey techniques were used to measure stage.

Each gage faceplate elevation was surveyed from a local benchmark tied to BPMSL using standard level-loop techniques. The most current elevation for vertical control was used for each survey. The horizontal position of each gage was recorded using a handheld Garmin® Rino® 520HCx in WGS 84. The basis of elevation for each gage and the horizontal positions of respective benchmarks and gages are included in Appendix A.

Both permanent and temporary staff gages are located throughout the CRD. Permanent, direct-read staff gages are located at CD1 and CD2. These consist of metal gage faceplates attached to drill stems driven into the ground or to pipeline supports and assembled so the gage faceplate corresponds directly to BPMSL elevation (Photo 3.3). The faceplates were surveyed prior to breakup in May 2012 by LCMF. The pre-breakup survey is used to determine if correction factors must be applied to adjust elevation during flooding conditions. Adjustments are made annually by LCMF during ice-free conditions to correct for jacking or settlement induced by the freeze-thaw cycle.

Photo 3.3: Permanent direct-read staff gage G3 near CD2 road swale bridges; June 6, 2012

Temporary, indirect-read gage sets (Photo 3.4) are designed to measure floodwater levels and consist of one to multiple staff gage assemblies. Each gage assembly includes a metal gage faceplate marked to indicate water levels between 0.00 to 3.33 feet mounted on a two-by-four timber. The timber is attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground.

Indirect-read staff gages are established with a faceplate that does not directly correspond to a BPMSL elevation. The gages are surveyed relative to a known benchmark elevation to determine a correction factor. The correction factor is then applied to the faceplate reading to obtain the elevation in feet BPMSL. For example, a HWM reading of 2.40 on G20-A is corrected by 5.92 feet, based on survey tie-in to local control. After the correction factor is applied, the HWM elevation is 8.32 feet BPMSL.

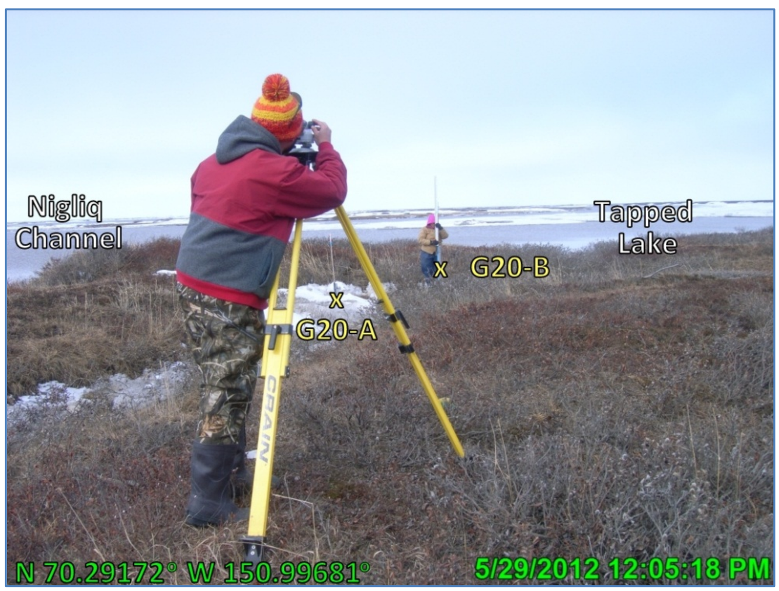


Photo 3.4: Surveying temporary indirect-read gages (G20) to BPMSL elevation; gage A is nearest to the channel centerline; May 29, 2012

Rehabilitation or installation and survey of the temporary staff gages were completed prior to the arrival of breakup floodwater.

Extreme stage, thaw, and ice effects during breakup can require re-installation, rehabilitation, and re-survey of affected gages and is performed as needed.

The quantity of gage assemblies per set depends on site specific conditions, primarily slope of the channel bank and overbank. In locations where terrain elevation varied by more than three feet or where the loss of gages due to ice impacts was considered to be likely, multiple gages were installed linearly from the edge of the low water channel up to the overbank so elevations overlapped by approximately one foot. Individual gage assemblies were identified with alphabetical designations beginning with “A” representing the location nearest to the stream centerline.

3.2.2 Pressure Transducers (PT)

Pressure transducers (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; this supplements gage measurements, which are used to validate and adjust PT data. Each PT consists of an unvented pressure sensor designed to collect and store pressure and temperature data at discrete pre-set intervals.

In-Situ® Level TROLL® 500 PTs were installed at MON28 and G38. Solinst® Levelogger® Model 3001 PTs were installed at thirteen locations: MON1U, MON1C, MON1D; G28 and G29; MON9 and MON9D; MON20, MON23; and at SAK, TAM, and ULAM.

The reported pressure datum 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® (primary) and Solinst Barologger® (secondary). A correction of barometric pressure was obtained from the BaroTROLL sensor installed at MON9 and the Barologger installed at G19. See Appendix A for PT and barometric pressure logger basis of elevation and horizontal positions.

Baker tested the PTs before mobilization to Alpine. The PTs were configured using Win-Situ® LT 5.6.21.0 (for the Level TROLL 500s) or Solinst Levelogger v4.0.3 (for the Solinst Leveloggers) prior to placement in the field. Absolute pressure was set to zero. Each PT was housed in a segment of perforated galvanized steel pipe and clamped to the angle iron or the base of the gage assembly nearest to the bed of the active channel. The PT sensor was surveyed during setup to establish a vertical datum using local control. For 2012, the PTs were programmed to collect gage pressure and water temperature at 15-minute intervals from May 24 to Aug 24, 2012.

PT-based stage values were determined by adding the calculated water depth and the surveyed sensor elevation. Gage WSE readings were used to validate and adjust the data collected by the PTs. PTs have the potential to drift and can be affected by ice floe impacts. A standard conversion using the density of water at 0°C was used to calculate all water depths from adjusted gage pressure. Fluctuations in water temperature during the sampling period did not affect WSE calculations because of the limited range in temperature and observed water depths.

3.3 Discharge Measurements

Discharge was measured directly as close to the observed peak stage and estimated peak discharge as possible. Discharge was calculated indirectly based on direct measurements and observed water surface elevations. Standard U. S. Geological Survey (USGS) techniques were used for direct measurements at Alpine drainage structures. An attempt to measure direct discharge at MON1 using an Acoustic Doppler Current Profiler (ADCP) was unsuccessful. Industry standard methods were used to indirectly calculate peak discharge. Indirect peak discharge was also calculated for MON9, MON23, and the proposed CD5 drainage structure locations that experienced flow in 2012: the Nigliq Channel, Lake L9341, and the Nigliagvik.

3.3.1 USGS Techniques

Standard USGS midsection techniques (USGS 1982) were used to directly measure velocities and determine discharge at the two CD2 road swale bridges.

Photo 3.5: Price AA velocity meter and 30-Pound Columbus-Type sounding weight (*Baker file photo*)

Swale bridge depth and velocity measurements were taken from the upstream side of each bridge deck using a sounding reel mounted on a wooden boom. A Price AA velocity meter was attached to the sounding reel and stabilized with a 30-pound Columbus-type lead sounding weight. Photo 3.5 shows the Price AA velocity meter assembly. A tag line was placed along the bridge rail to define the cross section and to delineate measurement subsections within the channel. The Price AA velocity meter was rated by the USGS Office of Surface Water (OSW) Hydraulic Laboratory in 2011. A spin test of the meter was successfully completed before and after the swale bridge measurements. To ensure accurate performance of meters, procedures outlined in OSW Technical Memorandum No. 99.06 (OSW 1999) were followed.

Velocity measurements at the outlets of those CD2 and CD4 road culverts experiencing flow were conducted using a wading rod and Marsh-McBirney Flo-Mate™ meter, as shown in Photo 3.6. Discharge was determined based on velocity and culvert geometry. Visual observations of culvert performance and overall condition were also recorded.

Photo 3.6: Measuring velocity at a culvert along CD2 access road; May 27, 2012

3.3.2 Acoustic Doppler Current Profiler (ADCP)

A direct discharge measurement of the Colville River during the breakup season presents unique challenges. Implementation of accurate USGS midsection techniques are challenging because of water depths, flow velocities, channel ice movement, and weather conditions. The ADCP is a good alternative for collecting repeatable and accurate direct river discharge measurements in challenging conditions. The ADCP discharge measurement system can be faster than traditional methods and provides equivalent levels of accuracy (USGS 2009).

The 2012 attempt to collect direct discharge was aborted because of weather-related logistics. Later attempts were not made because of continued poor weather conditions. Direct discharge measurements using an ADCP have been collected at MON1 each year since 2005, with the exception of 2012 and 2010 (weather limited helicopter transportation).

Direct discharge measurements are performed using ADCP techniques and procedures following the USGS *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (2005). The following sections outline the standard procedures for collecting direct discharge measurements at MON1. The 2012 measurements were aborted.

Hardware and Software

A Teledyne RD Instruments 600-kilohertz Workhorse Sentinel broadband ADCP is used. The unit has a phased array, Janus four-beam transducer with a 20-degree beam angle. The ADCP unit and supporting laptop (Panasonic Toughbook® CF-19) are self-powered via internal batteries.

BBTalk® v3.06, a DOS-based communication program, is used to perform pre-deployment tests. WinRiverII® v2.07 is used to configure, initiate, and communicate with the ADCP while on the river. WinRiverII® is also used to review and evaluate collected discharge data after returning from the field.

Pre-Deployment Testing

Prior to deployment of the ADCP unit, a full suite of tests are run in accordance with the manufacturer's instructions using BBTalk.® The tests confirm the signal path and all major signal processing subsystems are functioning properly. Tests also confirm accurate tilt and pitch readings. A beam continuity test is performed to verify the transducer beams are connected and operational. Additional diagnostic tests are performed using WinRiverII.® Pre-deployment tasks also include compass calibration and verification. Internal compass error must be within the specified two-degree limit. This was completed in 2012.

ADCP Deployment and Data Collection

The Workhorse Sentinel ADCP is mounted to an Achilles SGX-132 inflatable raft powered by a Tohatsu 9.8 horsepower outboard motor. A fabricated aluminum tube framework spanning the boat's gunwales provide a rigid and secure placement of the ADCP unit, and allows necessary navigation adjustments as river conditions require.

A cross section is identified at an established monitoring site (MON1). A minimum of four transects are typically completed to ensure the measured discharges vary by less than 5% of their mean. No transects were completed in 2012.

Cross section end points are dependent on a minimum water depth of about 8 feet to provide acceptable data. Cross section end points are marked with handheld GPS units having wide area augmentation system-enabled accuracy. High flow velocities and debris floe impacts negate the use of anchored buoys as viable cross section end point markers. The position of the boat is determined by tracking the bottom of the channel with the ADCP. Distances to the right and left edge of water from respective end points are estimated from GPS coordinates.

ADCP Background and Data Processing

An ADCP measures the velocity of particles in the water which, on average, move at the same horizontal velocity of the water relative to the ADCP unit. The velocity of flow is then calculated relative to the earth, based on the simultaneous velocity and position of the boat. The velocity and position of the boat are recorded by tracking the bottom of the channel with the ADCP unit.

Colville River channels are composed of fine-grained sediment, and water velocities are sufficient to entrain the materials resulting from a moving river bed. When using bottom tracking, a moving bed will tend to affect the accuracy of the results by biasing the velocity and discharge lower than actual values. This phenomenon can be eliminated with the use of either a differential global positioning system (DGPS) or the loop method (USGS 2006b). To account for the bias introduced by a moving bed, the loop method is employed.

The loop method is a technique to determine whether a moving bed is present and, if present, to provide an approximate correction to the final discharge. The USGS established guidance for the loop method by outlining procedures for mean correction and distributed correction (USGS 2006b). Both procedures yield results within 2% of the actual discharge, as measured using DGPS. The mean correction procedure is applied to the Colville River discharge calculations because of the simple geometry of the channel cross section. The results of a loop test performed immediately following completion of discharge measurements can be used to estimate the mean velocity of the moving bed. This mean velocity is multiplied by the cross sectional area perpendicular to the mean observed flow to yield a discharge correction. The resulting correction is applied to each transect, and the daily direct discharge measurement is determined by averaging the corrected discharge measurements.

3.3.3 Indirect Discharge Calculations

Indirect discharge for the CD2 and CD4 road culverts, Alpine swale bridges, the Colville River at MON1 and MON9, the Nigliq Channel at MON23, and proposed CD5 crossings at the Nigliq Channel, Lake L9341, and Nigliagvik were calculated using physical characteristics obtained during field observations. These physical characteristics, including measured stage and velocity data, culvert dimensions, and channel cross sections, are used as hydraulic equation input variables to calculate indirect discharge to determine peak discharge at each location.

Industry accepted engineering methods and Bentley CulvertMaster® software were used to estimate discharge through the CD2 and CD4 road culverts. Time and magnitude of peak discharge through the culverts was determined based on recorded WSE and peak stage observations on both sides of the road prism.

Average velocity and discharge through the culverts assumes ice-free open-water conditions and were estimated based on several variables, including:

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from LCMF as-built surveys (UMIAQ 2002); as-built information is not available for the slip-lined culverts – field measurements and approximations for slip-lined culverts were used
- Culvert upstream and downstream invert elevation (UMIAQ 2012)
- Culvert Manning's roughness coefficient (0.012 for smooth steel and 0.024 for corrugated metal pipe [CMP])

Results are evaluated in terms of culvert functionality based on visual inspection.

The calculation for peak discharge through the swale bridges was performed by correlating the hydraulic depths and velocities measured during the direct discharge measurements with peak stage using the velocity-area method.

The slope-area method (Benson and Dalrymple 1967) for a uniform channel (UC) and non-uniform channel (NUC) was used to develop the estimates of peak discharge. This method is based on channel cross section geometry and stage differential between gage sites as an estimate for hydraulic gradient. The UC and NUC methods differ by the number of cross sections used in the calculations. The NUC method uses all three cross sections at MON1 (cross section geometry current as of 2004, UMIAQ 2004) and the UC method uses a single cross section at MON1C. Accuracy of each method depends on conditions at the time of calculation, particularly the presence of ribbon and bottom fast ice, ice jam activity, and backwater effects. The NUC method was used at MON1.

Lacking additional cross sections, the UC method was used to estimate peak discharge at all other locations. Cross sectional geometry for MON9 is the result of data from the 2009 HDD survey by LCMF for the Alpine Pipelines Monitoring report (Baker 2009c). Cross sectional geometry at MON23 is current as of 2005 (UMIAQ 2005) and at the proposed CD5 crossing locations as of 2008 (UMIAQ 2008). Because of channel bed morphology, cross sectional geometry becomes less accurate with time, particularly for those channels of the CRD that are predominantly comprised of fine grained soils or have bottom-fast ice. Stage and hydraulic gradient data were obtained from observations made at nearby gages and PT results.

3.4 Flood and Stage Frequency Analysis

Flood and stage frequency statistical analyses are performed using historic annual peak discharge and stage data to determine recurrence in terms of years. Analyses assume open channel conditions. CRD breakup flood conditions are usually characterized by channel ice and ice jams. Even though these analyses are not representative of peak spring breakup flooding conditions, it provides the most accurate results possible. Frequency analyses are completed every three years, as a single year of data is unlikely to significantly affect previous findings. When frequency analyses are not performed, peak discharge and stage values are compared to the results of the most current analysis to determine respective returns.

The results of flood and stage frequency analyses are the discharge magnitudes and WSE used in facility design. The discharge basis for comparison is the 2002 design-magnitude flood frequency analysis for the Colville River and MON1 (Baker and Hydroconsult 2002). Stage frequency basis for comparison is the 2D surface water model developed during the original design of ADP. The model has been updated throughout the life of the Alpine facilities, most recently in 2012 (Baker 2012). The most recent flood and stage frequency analyses for the CRD were performed in 2009. Flood frequency findings supported maintaining existing design criteria based on the 2002 analysis; stage frequency findings supported maintaining existing design criteria based on the most current version of the CRD 2D surface water model. Flood and stage frequency analyses were completed in 2012.

3.4.1 Flood Frequency

Flood frequency was analyzed using methods outlined in the U.S. Water Resources Council *Guidelines for Determining Flood Flow Frequency*, otherwise known as "Bulletin 17B" (USWRC 1981). A Weibull distribution was applied to determine recurrences of data within the continuous record, and PeakFQ hydrologic frequency analysis software based on Bulletin 17B (USGS 2006a) was used to statistically fit and extrapolate discharge data for design-magnitude recurrence intervals.

Since 1992, annual peak discharges have been recorded at the head of the CRD (MON1) culminating in 21 years of continuous data. These peak discharge values are fitted to a Weibull distribution, which assigns recurrence intervals to each annual peak discharge. This method requires a continuous data record and is performed as an analysis of that record only; flood recurrences are not extrapolated beyond the continuous record. The Weibull distribution ranks the peak annual discharge values and assigns a return period to those observed discharges with a maximum return period equal to the number of years' continuous data available plus one.

To predict design-magnitude flood recurrence intervals, such as a 50-year or 200-year event, alternate analysis methods are used. Bulletin 17B (USWRC 1981) outlines the industry standard for flood frequency analysis using the Log-Pearson Type III station skew method. The Log-Pearson Type III method is a statistical technique using annual peak discharge data to determine the probability of various magnitude floods by allowing for extrapolation of design events with return periods beyond the continuous record.

In 2002, a design-magnitude flood frequency analysis was performed for the Colville River at MON1 (Baker and Hydroconsult 2002). There was limited data recorded for the Colville River at that time, so the 2002 analysis used extrapolated peak discharge data based on peak discharge records for the Kuparuk and Sagavanirktok Rivers. The 2002 analysis also used estimated historic peaks for the Colville River. The analysis was used to estimate peak discharge values for the Colville River. These estimated peaks for large flood events relied on local knowledge and surviving physical evidence. Based on this extrapolated and estimated data, a body of "continuous" data extending back to 1971 was developed and used to conduct the 2002 flood frequency analysis. Because of uncertainties in the developed data, the 2002 analysis was believed to be reasonably conservative.

The 2002 analysis was revisited in 2006 (Baker 2007a). The 2006 design-magnitude analysis was based entirely on reported annual peak discharge data from 1992 through 2006 at MON1 and did not include the estimated historic peaks. This 2006 analysis supported the accuracy of the 2002 flood frequency discharge estimates, which were on average 15% more conservative than the 2006 values. While the 2002 values are recognized to be somewhat conservative, the 2002 flood peak discharge design estimates have remained the accepted design criteria values.

In 2009, both continuous record and design-magnitude flood frequency analyses were performed. The annual peak discharge data from 1992 through 2009 and the extrapolated data extending back to 1971 were used. This is recommended for design-magnitude extrapolation with less than 50-years' worth of record. The 2009 data, similar to the 2006 and 2002 data, were ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for design-magnitude extrapolation. The 2009 design-magnitude results were compared to the results of the 2002 analysis. On average, the discharge estimates from the 2002 analysis were 3% more conservative than those derived from the 2009 analysis. Since the 2002 results fell within the 95% confidence interval of the 2009 analysis results, 2002 flood design criteria was maintained.

3.4.2 Stage Frequency

Stage frequency was analyzed using Federal Emergency Management Agency (FEMA 2003) and USACE (1991, 2002) guidelines. A Weibull distribution was applied to determine recurrences of data within the continuous record. A Log-Pearson III station skew distribution was used to statistically fit and extrapolate stage data for design-magnitude recurrence intervals.

Records of peak stage at most 2012 CRD monitoring locations begin in 1998. A continuous record does not exist at all locations since site monitoring varies annually based on each year's field program objectives. At MON1, the continuous record begins in 1992. Locations were selected for stage frequency analysis based on completeness of historic record and proximity to major existing or proposed facilities. Annual peak stages at locations throughout the CRD are estimated or extrapolated to 1992 based on MON1 data. The annual observed record of each location's peak WSE was compared to the annual observed record at MON1, and an independent best-fit line was developed for each set. The linear equations were used to calculate extrapolated peak stages. Values were linearly extrapolated for those years when peak stage was known, and the differences between the data were compared.

Peak stage data was statistically fit to a Weibull distribution for the purposes of ranking by recurrence interval relative to the continuous record. Stage data was extrapolated beyond the continuous record to design magnitudes. It is generally considered risky to extrapolate stage data for a river impacted by ice and ice jamming beyond the continuous record (USACE 2002; FEMA 2003). This is true because of the inherently unpredictable nature of ice jams and since the quantity of water in high magnitude flood events will be less affected by ice than smaller-magnitude floods. The 20-year continuous record for the

MON1 reach and stage has been impacted by upstream ice jam releases during each spring breakup event with peak stage often being temporarily inflated.

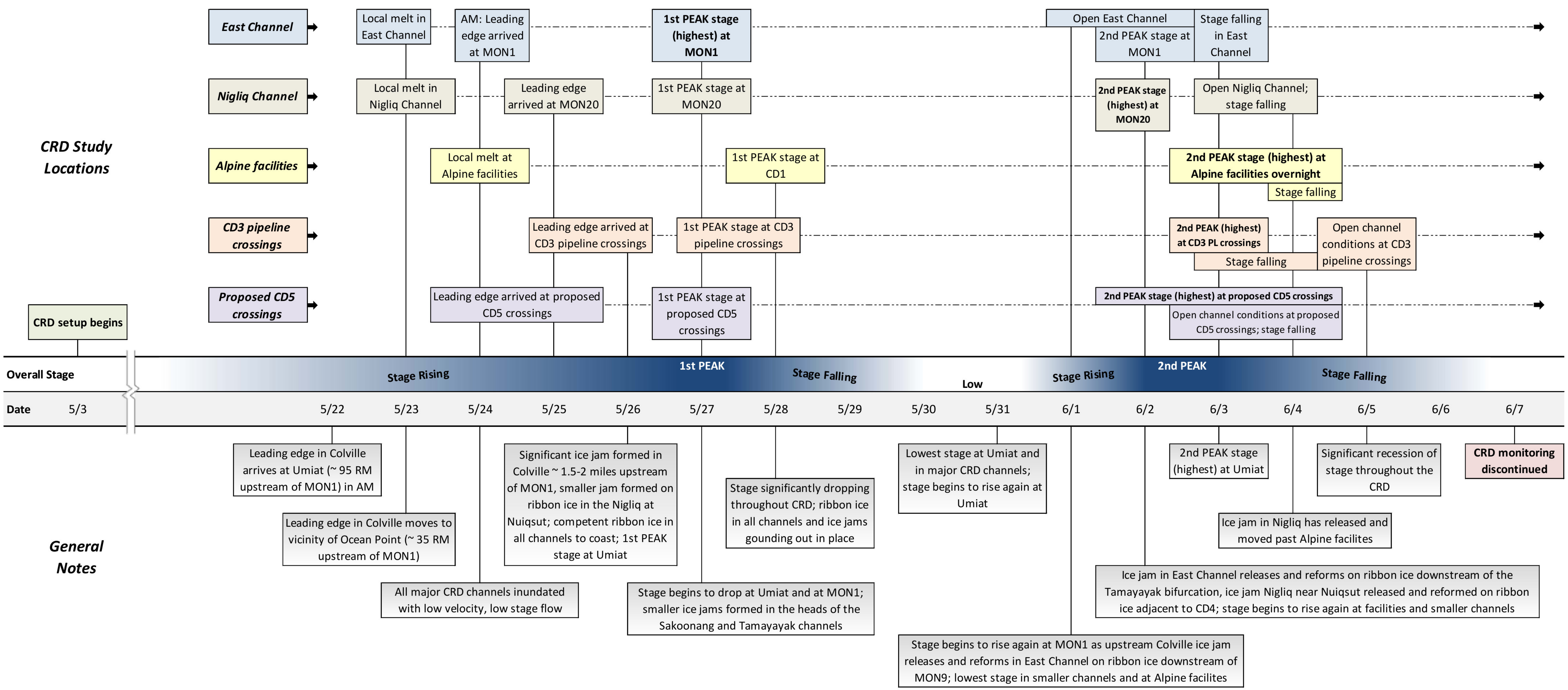
For the purpose of comparing observed stage between 1992 and 2012 with the 2D open water model predictions, extreme value statistical analysis was used to extend the record to 50 years, 2.5 times the record length. The objective of this analysis is not intended to redefine the Alpine design criteria based on the 2D model; but to supplement these criteria for low-magnitude, ice-impacted flood events similar to the events observed between 1992 and 2012.

A design-magnitude stage frequency analysis for the CRD was performed in 2012. The data were fitted to a Log-Pearson type III station skew distribution. The results were then compared to the stage frequency data generated by the current 2D model, the Weibull distribution of observed data, and the previous year's stage frequency analysis results.

4.0 2012 SPRING BREAKUP HYDROLOGIC OBSERVATIONS AND WATER SURFACE ELEVATIONS

The images, data, and observations of the 2012 field program are presented in this chapter. Setup was completed between May 2 and May 10, 2012. Data and observations described in the following sections were documented between May 23 and June 8, 2012. Limited observations were also made during setup and a return to the area June 26 and 27, 2012, to assess lake recharge for a separate project. Figure 4.1 provides a visual timeline summarizing the major 2012 CRD breakup events.

2012 Colville River Delta Spring Breakup Hydrologic Timeline



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2012 SPRING BREAKUP
COLVILLE RIVER DELTA
HYDROLOGIC TIMELINE
FIGURE: 4.1
(SHEET 1 of 1)

4.1 Colville River Delta

Breakup floodwaters entering the CRD originate upstream in the Brooks Range. This melt accumulates along the base of the mountains and flows into the Colville River via a network of smaller drainages before the Colville branches out into a delta terminating at Harrison Bay (Figure 1.1 through Figure 1.3). MON1, located at the head of the delta, is the farthest downstream reach and conveys approximately 22,500 square miles worth of runoff in a single channel. Breakup events are monitored upstream of this location as floodwaters progress downstream toward the CRD.

A USGS gaging station and live camera is located on the Colville River at Umiat approximately 93 RM upstream of MON1. The stage and discharge data from this station represents conditions upstream of the CRD and is used for forecasting peak conditions, having a typical flood routing time of 24 hours before reaching MON1. The Umiat station data are presented as preliminary and do not account for melt contribution from the Chandler or Anaktuvuk rivers. These are larger drainages that join the Colville River upstream of MON1 and downstream of Umiat. Figure 4.2 presents the stage data from the USGS gage at Umiat during the CRD breakup monitoring period.

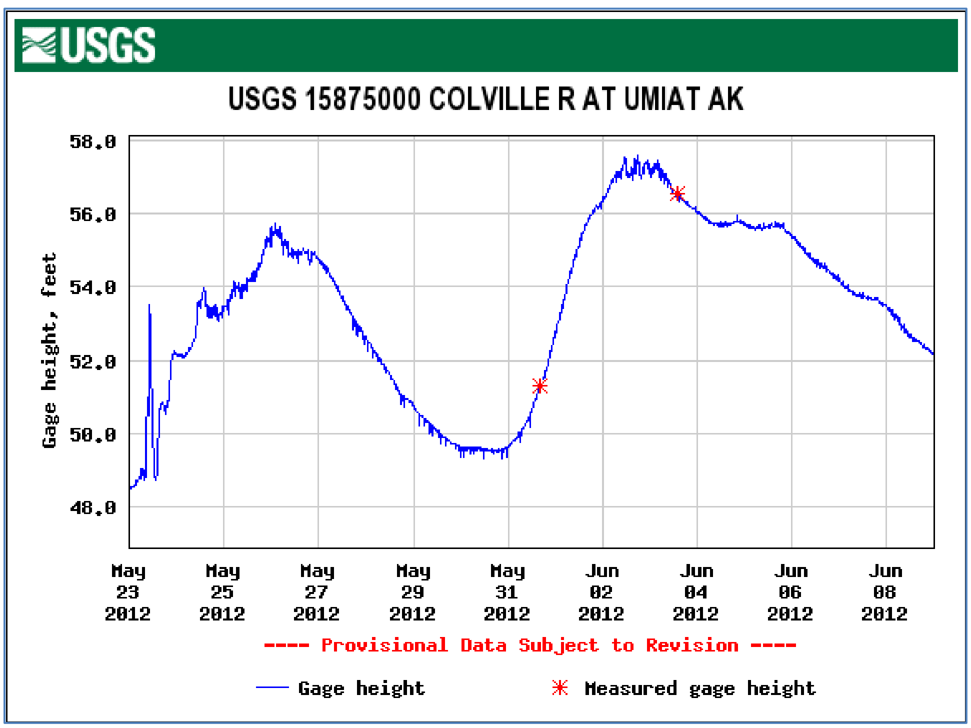


Figure 4.2: USGS Gage at Umiat Stage Data for the CRD Monitoring Period (USGS 2012a); May 23 through June 8, 2012

The live camera recorded a leading edge in the Colville River passing Umiat on May 22 at some time between 5:10 and 5:30 AM (Photo 4.1 and Photo 4.2).

On May 23 at 2:20 PM, the leading edge of breakup flow in the Colville River had progressed to approximately 4.5 RM past Ocean Point and was located approximately 30.5 RM upstream of MON1 (Photo 4.3). Ocean Point is 35 RM from MON1. Flow velocity was relatively low and carried few ice floes.

By the evening of May 24, the leading edge passed MON1 and was downstream of MON9 in the East Channel (Photo 4.4). The leading edge in the Nigliq Channel was approaching MON20 (Photo 4.5). Flow continued at low velocity, and WSE were not yet high enough to reach the gages. For approximately two weeks prior to May 24, day and night air temperatures in the upstream Colville region at Umiat (Graph 1.1) and locally at Nuiqsut (Graph 1.2) were higher than average. Nighttime air temperatures returned to average in both areas, and daytime temperatures were below average. Neither day nor night temperatures stayed consistently above freezing until after May 31.

All major channels in the CRD were inundated by May 25. The leading edge had passed MON28 in the Nigliq Channel (Photo 4.6) and MON35 in the East Channel and was approaching Alpine facilities which were experiencing local melt. Stage had increased at many gage locations though flow remained low velocity transporting only occasional floes.

Photo 4.1: Prior to leading edge arrival in Colville River at Umiat; May 22, 2012 at 5:10 AM *(USGS 2012b)*

Photo 4.2: Leading edge passing in Colville River at Umiat; May 22, 2012 at 5:30 AM *(USGS 2012b)*

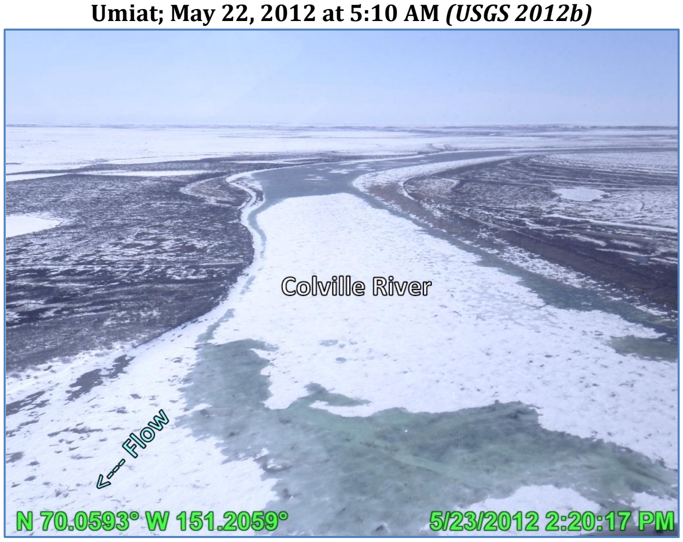


Photo 4.3: Low velocity leading edge approximately 30.5 RM upstream of MON1, looking upstream (south); May 23, 2012

Photo 4.4: Leading edge in the East Channel past MON9, looking downstream (north); May 24, 2012

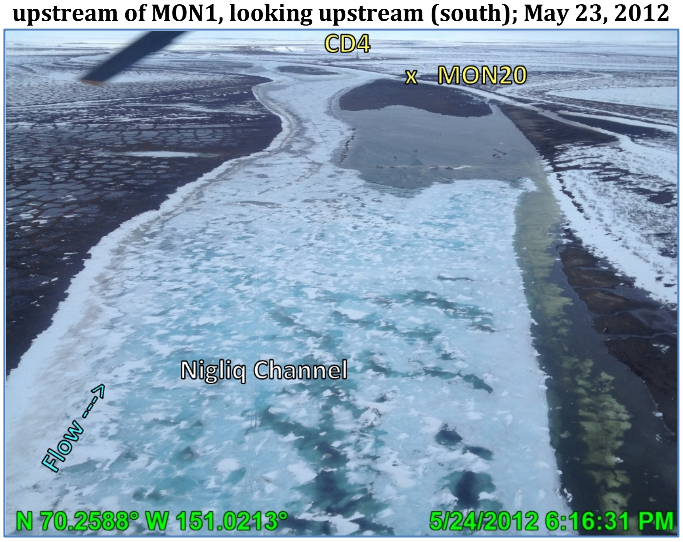


Photo 4.5: Leading edge in the Nigliq Channel approaching MON20, looking downstream (north); May 24, 2012

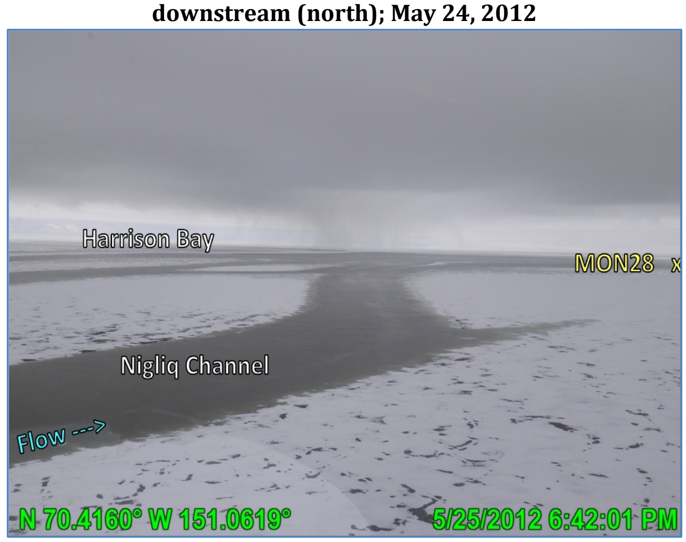


Photo 4.6: Leading edge in the Nigliq Channel past MON28 and into Harrison Bay, looking downstream (north); May 25, 2012

4.2 Monuments

4.2.1 Colville River East Channel

Daily monitoring of the East Channel gages began on May 24; stage was first measureable on East Channel gages MON9 and MON35 on May 25. Table 4.1 through Table 4.3 contains stage data for MON1 and the East Channel gages.

By May 26, the rate of stage increase slowed at all East Channel monitoring locations. An ice jam formed approximately 1.5 to 2 RM upstream of MON1 (Photo 4.7) and competent ribbon ice was present through the entire channel to the coast. Flow was confined to the active channel with no water in overbank areas. Very few ice floes were present, and no other ice jams were observed throughout the East Channel.

Stage peaked upstream at the Umiat gage on May 26, and the effects were seen downstream approximately 24 hours later. Stage peaked at MON1U and MON1C early on May 27, at 14.31 and 14.18 feet BPMSL, respectively. By evening, water levels began to fall. Photo 4.8 shows the MON1 reach just after peak stage at MON1U and MON1C. Ribbon ice was competent along the east bank and occasional ice floes were in the channel.

Stage fell consistently after May 27 until a low was reached on May 31 (June 1 at MON35) in the East Channel and upstream at Umiat. Conditions in the East Channel remained relatively consistent throughout this period.

The ice jam upstream of MON1 grew slightly (Photo 4.9 from May 30) then grounded out beginning with the downstream end. Flow was confined to the active channel as stage receded and backwater conditions resulting from the jam were relieved (Photo 4.10 from May 30).

Ribbon ice was competent throughout the channel downstream of the jam, and flow stayed within the active channel banks. The occasional floes began grounding out and no other ice jams formed. During this period, large quantities of snow remained throughout the Colville River drainage.

On June 1, stage once again rose rapidly in the Colville at Umiat and in the East Channel to MON9. An evening reconnaissance past Ocean Point revealed predominantly open channels with few floes and limited overbank inundation (Photo 4.11). The results of reconnaissance indicated additional flood storage capacity was available in the Colville upstream of MON1.

PT data at MON1 on June 1 suggests the upstream ice jam released about 5:00 PM. The release cleared ribbon ice as the flood wave moved through the channel. The ice jam was re-forming just downstream of MON9 by 8:00 PM (Photo 4.12). A portion of the floes diverted down the Nigliq Channel contributing to the ice jam that formed May 26 adjacent to Nuiqsut.

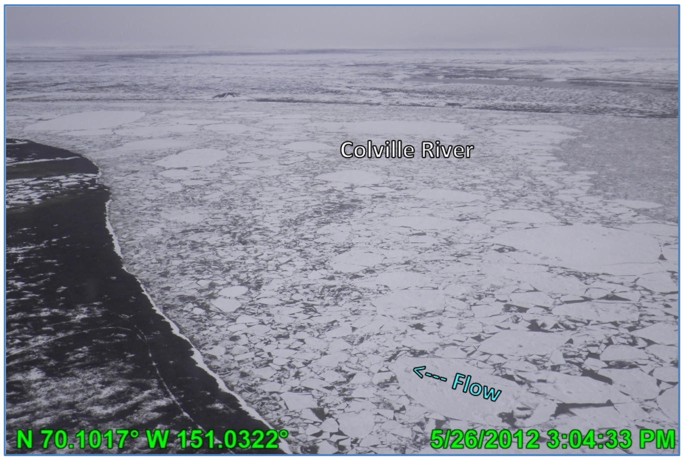


Photo 4.7: Ice jam in the Colville upstream of MON1, looking downstream (northeast); May 26, 2012

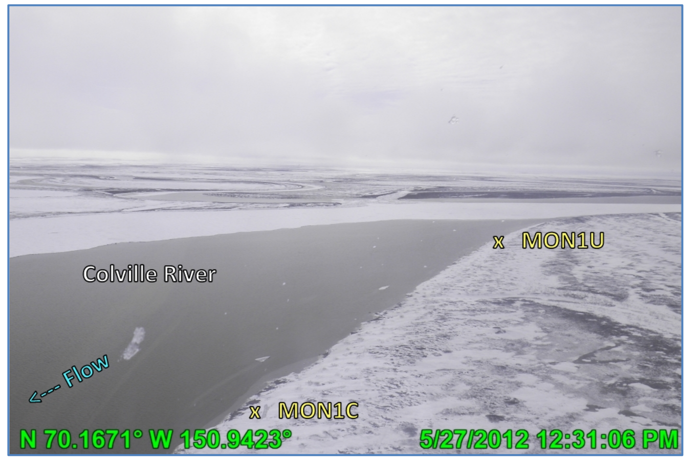


Photo 4.8: Just after peak stage at MON1U and MON1C, looking upstream (south); May 27, 2012

Photo 4.9: Ice jam upstream of MON1 grounding out with stage recession, downstream end looking downstream (south); May 30, 2012

Photo 4.10: Ice jam upstream of MON1 grounding out with stage recession with non-inundated upstream overbanks, upstream end looking upstream (south); May 30, 2012

Photo 4.11: Ice free flow in the Colville River upstream of the CRD fairly confined within the active channels, looking upstream (south); June 1, 2012

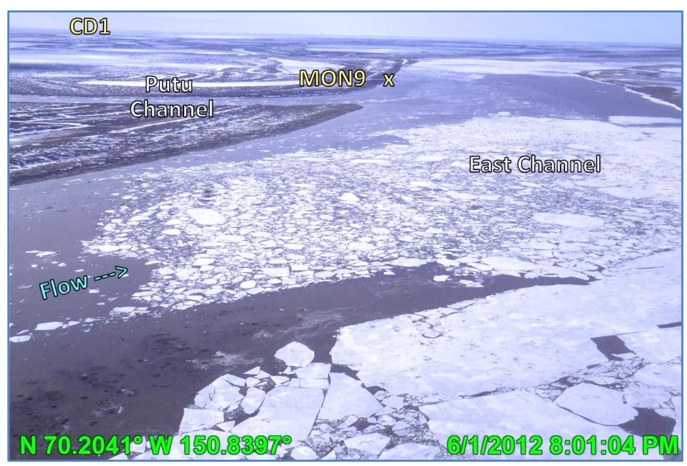


Photo 4.12: Floes from ice jam release upstream of MON1 moving downstream toward re-formation past MON9, looking downstream (north); June 1, 2012

Though the increase in stage was dramatic with respect to previous levels, it still remained relatively low. Flow continued to be confined within the active channel though some ice floes were pushed toward the west overbanks in the jam vicinity (Photo 4.13). Occasional floes grounded along the west bank through the MON1 reach and on the sandbar in the MON1D vicinity as the ice jam passed. Ribbon ice downstream of the jam to the coast began to melt.

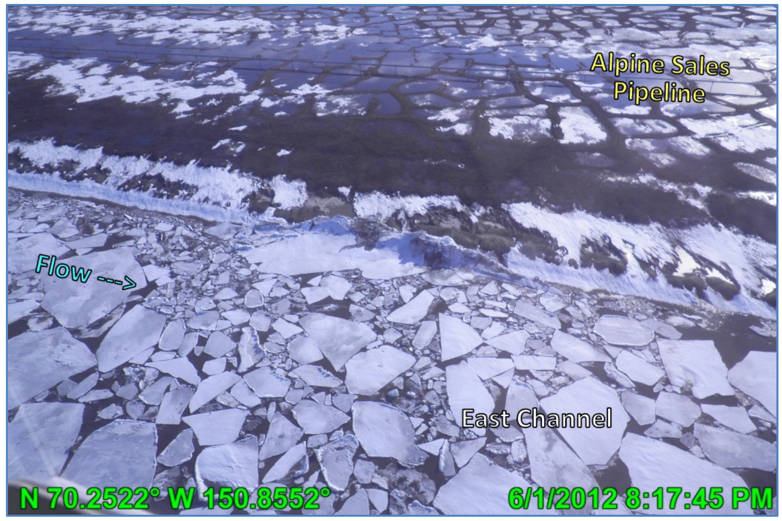


Photo 4.13: Ice jam formation downstream of MON9 pushing floes toward west overbanks, looking west; June 1, 2012

Increased stage was apparent at MON35 by June 2 as the Umiat gage WSE continued to rise. Peak stage occurred at MON1D on the afternoon of June 2 at 13.88 feet BPMSL (Photo 4.14).

This peak was likely the result of backwater from the ice jam downstream of MON9. The jam released about 1:00 PM based on PT data and re-formed again downstream of the Tamayayak bifurcation (Photo 4.15). Peak stage at MON9 occurred midday on June 2, at 12.49 feet BPMSL (Photo 4.16). The MON9 peak was also likely from backwater prior to the ice jam release.

The ice jam in the Nigliq Channel adjacent to Nuiqsut moved downstream and re-formed adjacent to CD4. The East Channel was open upstream of the jam near the Tamayayak, and some grounded floes were present in the vicinity of MON9. No grounded ice floes were on the overbanks near the HDD infrastructure. Ribbon ice remained downstream of the ice jam. The jam likely released on the evening of June 2.

WSE at the Umiat gage once again decreased on June 3. Stage was receding slowly at MON1 and more rapidly at MON9, and stage continued to rise at MON35. A discharge measurement with the ADCP was attempted at MON1, but fog delayed the helicopter departure from Alpine until midday. The measurement was initiated, but not completed because of the late start. Few floes were in the channel, and the ice jam was moving past MON35 by midday.

The East Channel was clear of ice to the coast on June 4. Peak stage of 4.39 feet BPMSL occurred overnight at MON35 (Photo 4.17). Foggy weather grounded the helicopter until the afternoon, and a discharge measurement at MON1 was not completed. The rate of stage decrease slowed both upstream at Umiat and at all East Channel monitoring locations with the exception of MON35.

Winds and waves were too high for crews to complete a discharge measurement at MON1 on June 5. Safety was a concern and choppy water results in poor ADCP accuracy. Umiat, MON1, and MON9 stage plateaued. Rate of recession beginning June 6 was observed to be consistent at all Colville and East Channel locations until monitoring was discontinued on June 8.

Photo 4.18 and Photo 4.19 show open channel conditions at MON1 and MON9, respectively, on June 7.

Photo 4.14: Just prior to peak stage at MON1D, looking upstream (south); June 2, 2012

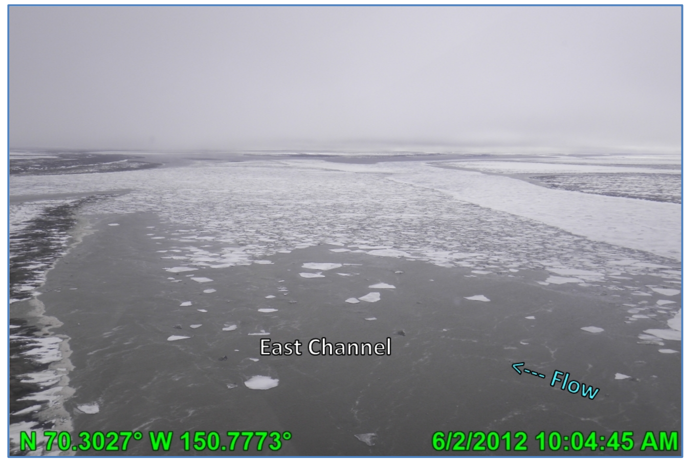


Photo 4.15: Ice jam in East Channel downstream of Tamayayak bifurcation, looking downstream (north); June 2, 2012

Photo 4.16: Just prior to peak stage at MON9, looking upstream (south); June 2, 2012

Photo 4.17: Just after peak stage at MON35 as ice moves through on the way to Harrison Bay, looking upstream (south) in a photo provided by Jim Helmericks; June 4, 2012

Photo 4.18: Open channel conditions through the MON1 reach, looking downstream (north); June 7, 2012

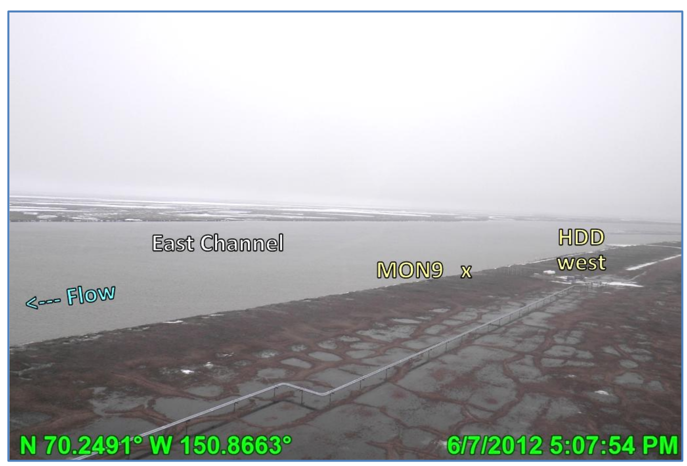


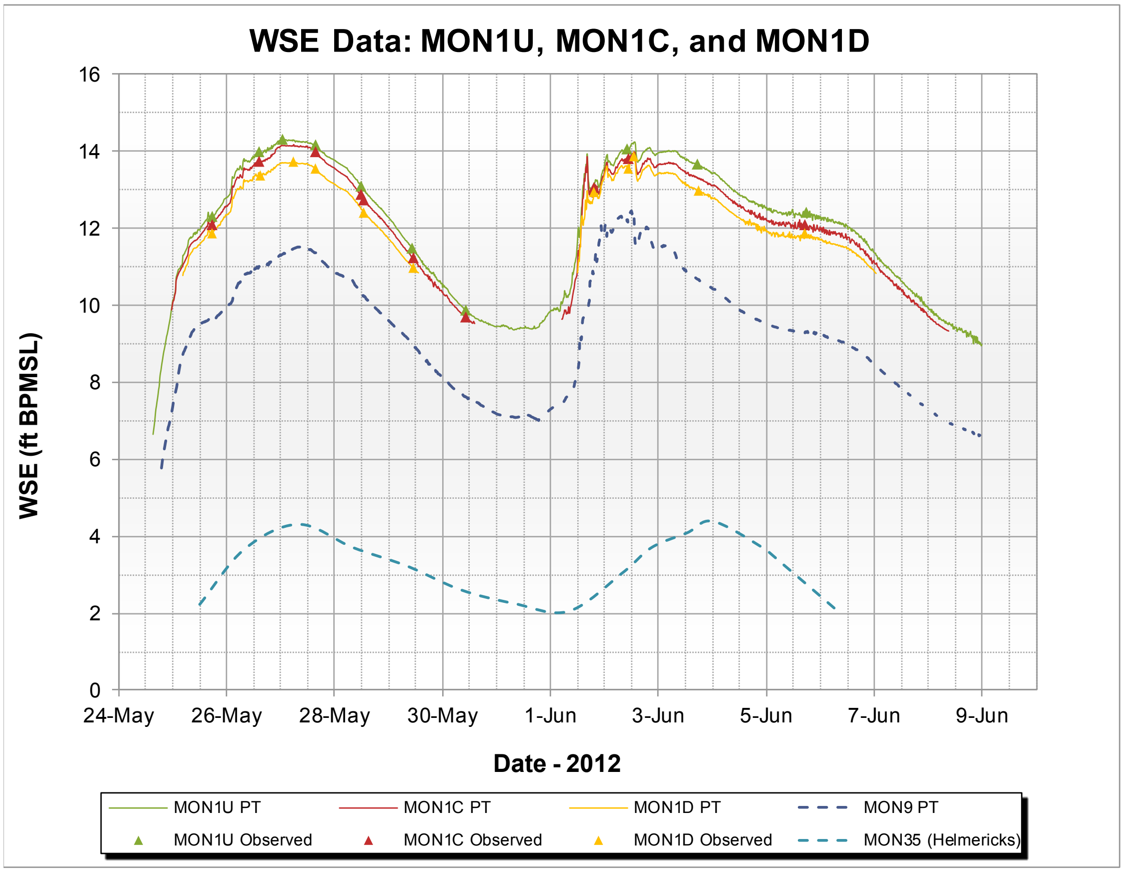
Photo 4.19: Open channel conditions at MON9, looking upstream (southeast); June 7, 2012

Table 4.1: 2012 Stage Data for MON1

Date and Time	WSE (feet BPMSL)			Observations
	MON1U	MON1C	MON1D	
5/24/12 6:00 PM	-	-	-	Leading edge past MON1; no water on gages
5/25/12 5:20 PM	12.28	12.09	11.87	
5/26/12 2:45 PM	13.96	13.71	13.38	Ice jam formed 1.5-2 river miles upstream of MON1
5/27/12 1:00 AM	**14.31**	-	-	**Peak Stage at MON1U**; based on PT and HWM
5/27/12 5:45 AM	-	**14.18**	13.73	**Peak Stage at MON1C**; based on PT
5/27/12 3:35 PM	14.14	13.96	13.53	
5/28/12 11:50 AM	13.08	12.73	12.41	
5/29/12 10:30 AM	11.47	11.21	10.97	Intact ribbon ice along E bank; occasional grounded ice floes along W bank, upstream ice jam grounded out due to low stage
5/30/12 10:10 AM	9.87	9.69	12.94	
6/1/12 7:30 PM	13.05	13.05	13.55	Channel clear of ribbon ice; upstream ice jam released and reformed downstream of MON9
6/2/12 1:00 PM	14.06	13.80	**13.88**	**Peak Stage at MON1D**; based on PT and HWM; ice jam downstream of MON9 releases and reforms downstream of the Tamayayak
6/3/12 5:45 PM	13.65	-	12.97	Open channel in reach; discharge measurement initiated, not completed
6/5/12 5:45 PM	12.41	12.08	11.85	Open East Channel

Notes:

1. Elevations are based on MONUMENT 1 at 27.93 feet BPMSL, surveyed by UMIAQ in 2006.
2. Weather and river conditions did not permit a direct discharge measurement at this location for 2012.
3. Gage readings were not taken on May 31 (helicopter mechanical issues) or June 4 (weather).



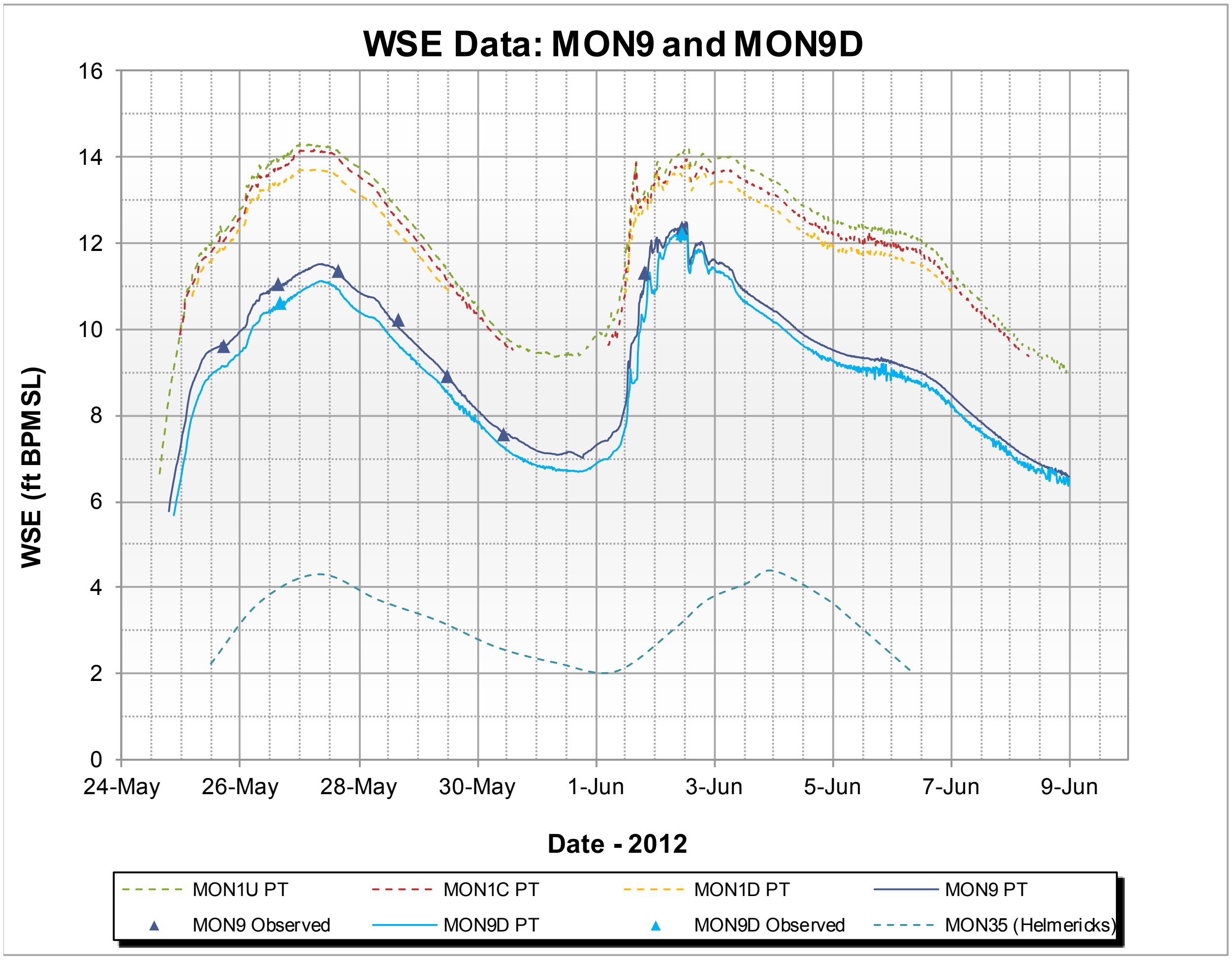
Graph 4.1: 2012 Stage Data for MON1 (including MON9 PT and MON35 Observed)

Table 4.2: 2012 Stage Data for MON9

Date and Time	WSE (feet BPMSL)		Observations
	MON9	MON9D	
5/24/12 5:45 PM	-	-	Leading edge past MON9; no water on gages
5/25/12 5:50 PM	9.62	-	Intact ribbon ice in channel
5/26/12 3:30 PM	11.03	10.61	
5/27/12 4:00 PM	11.34	-	
5/28/12 1:35 PM	10.22	-	Some grounded ice on banks
5/29/12 11:45 AM	8.90	-	
5/30/12 11:15 AM	7.57	-	Ribbon ice still intact; occasional grounded floes
6/1/12 8:00 PM	11.31	-	Ice jam released upstream of MON1 reforms just downstream of MON9
6/2/12 11:00 AM	12.37	12.24	Open channel conditions
6/2/12 12:30 PM	**12.49**	**12.34**	**Peak stage at MON9 and MON9D**; based on PT data, ice jam downstream of MON9 releases and reforms downstream of the

Notes:

1. Elevations are based on MONUMENT 9 at 25.06 feet BPMSL, surveyed by UMIAQ in 2008.



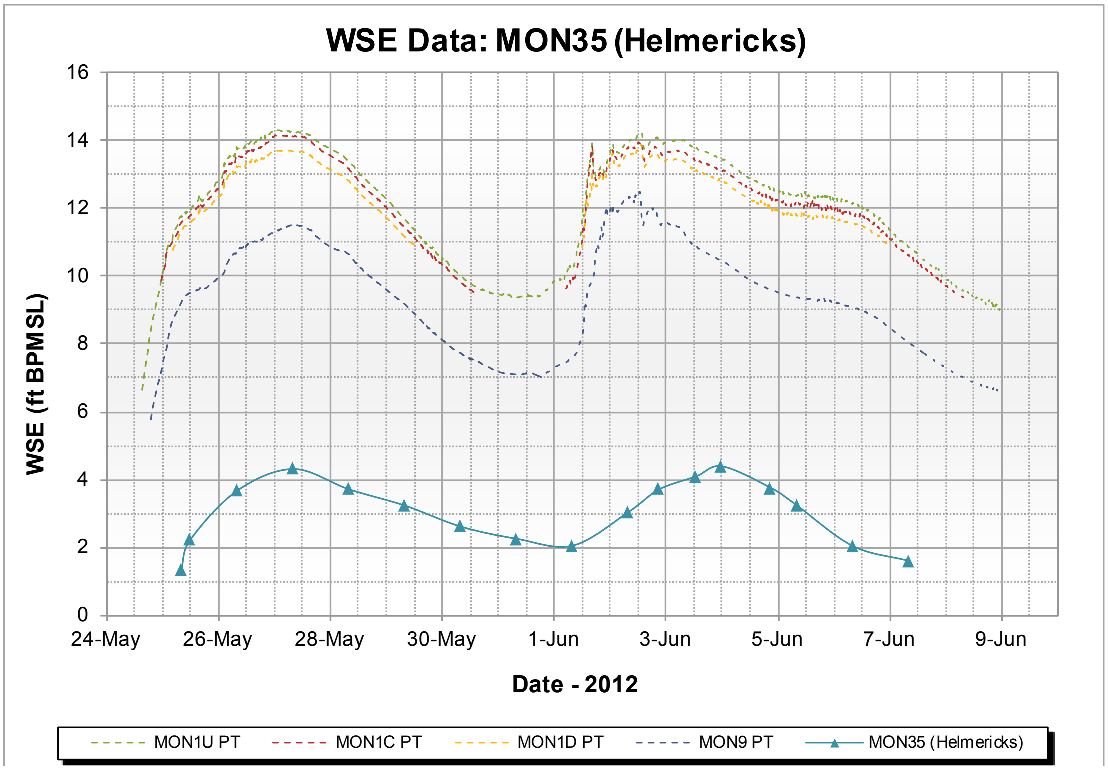
Graph 4.2: 2012 Stage Data for MON9 (including MON1 PT and MON35 Observed)

Table 4.3: 2012 Stage Data for MON35

Date and Time	WSE (feet BPMSL) MON35 (Helmericks)	Observations
5/25/12 8:00 AM	1.35	Leading edge arrives
5/25/12 12:00 PM	2.23	
5/26/12 8:00 AM	3.67	
5/27/12 8:00 AM	4.31	Initial Peak; Ribbon ice solid, some slush moving in shorelead
5/28/12 8:00 AM	3.71	Channel ribbon ice no movement, still lots of snow on the ice; shorelead skimmed over with light layer of tissue ice.
5/29/12 8:00 AM	3.23	No drifting ice in shoreleads, channel ice solid, still lots of snow on ice; island still >90% snow cover
5/30/12 8:00 AM	2.61	Only shoreleads, no ice movement
5/31/12 8:00 AM	2.25	Ribbon ice solid, shorelead no drifting ice, several feet of pancake ice along shoreline.
6/1/12 8:00 AM	2.05	Shorelead, no ice movement
6/2/12 8:00 AM	3.05	
6/2/12 9:00 PM	3.71	
6/3/12 12:45 PM	4.09	Ice moving past on west side of the island
6/4/12 12:00 AM	**4.39**	**Peak Stage at MON35 (Helmericks)**; secondary peak
6/4/12 9:00 PM	3.75	Channel clear of ice
6/5/12 8:00 AM	3.24	
6/6/12 8:00 AM	2.04	
6/7/12 8:00 AM	1.60	

Notes:

1. Elevations are based on MONUMENT 35 at 5.57 feet BPMSL, installed by Lounsbury 1996.
2. Shorelead refers to open w ater betw een pack ice and coastline.



Graph 4.3: 2012 Stage Data for MON35 (including MON1/MON9 PT)

4.2.2 Nigliq Channel

Daily monitoring began on May 24 for the Nigliq Channel gages: MON20, MON 22, MON23, and MON28. Stage was first measureable on the Nigliq gages by May 25, except at MON28 with measureable water on May 26. Stage data is shown in Table 4.4 through Table 4.7.

Similar to the East Channel gages, by the evening of May 26, the rate of stage increase slowed at all Nigliq Channel monitoring locations. An ice jam formed in the Colville upstream of MON1 (Photo 4.7) and in the Nigliq adjacent to Nuiqsut (Photo 4.20). Floes accumulated at the Nigliq-Putu Channel confluence; the Putu Channel was free of ice. Ribbon ice was competent through the entire channel to the coast downstream of the Nuiqsut jam, with the exception of some breaking and rafting in the upstream vicinity of the proposed CD5 Nigliq Bridge crossing. Flow was confined to the active channel, overbank areas were predominantly dry. Lake L9341 and Tapped Lake were hydraulically connected to the Nigliq Channel, as was Nanuq Lake with flow moving toward the CD2 access road. Water from the Sakoonang Channel entered the Nigliq Channel via Lake L9324.

On the afternoon of May 27, stage was peaking and by evening had begun to fall. Stage fell consistently after May 27 until a low was reached on May 31. Conditions in the Nigliq Channel remained relatively consistent throughout this period. Hydrologic connections remained between the Nigliq Channel and Nanuq, Tapped, L9341, and L9324 lakes, though flow was limited.

On June 1, stage rose at all Nigliq Channel gage locations, excluding MON28. Similar to the East Channel, the increase was rapid compared to previous conditions. However, stage remained low with respect to historical breakup flooding extents. Ribbon ice through the channel was beginning to melt. By evening, the competent ice between MON20 and CD4 degenerated into floes and accumulated upstream of the proposed Nigliq CD5 bridge location (Photo 4.21).

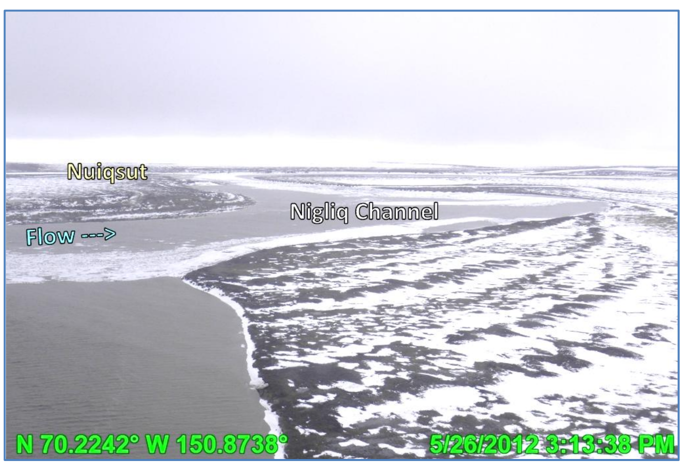


Photo 4.20: Ice jam in the Nigliq adjacent to Nuiqsut, looking downstream (northwest); May 26, 2012

Photo 4.21: Ribbon ice through MON20 reach disintegrating into floes which accumulated upstream of the proposed CD5 Nigliq Bridge location, looking downstream (north); June 1, 2012

The ice jam upstream of MON1 released in the evening. Some ice floes diverted down the Nigliq and contributed to the jam adjacent to Nuiqsut (Photo 4.22).

Increased stage was apparent at MON28 on June 2. By midday, the ice jam adjacent to Nuiqsut had released contributing to a peak stage at MON20 (Photo 4.23) of 10.43 feet BPMSL, and re-formed upstream of the proposed Nigliq CD5 bridge location. The ice jam released late in the evening according to PT data, and cleared the ribbon ice as it continued downstream.

Flow remained fairly confined within the Nigliq Channel banks during this peak period. However, there was some overbank inundation primarily on the east side of the channel around the upstream end of the ice jam adjacent to CD4 (Photo 4.24). Stage receded quickly at all Nigliq monitoring locations as the ice jam cleared the channel leaving occasional ice floes grounded within the active channel banks at all sites.

Peak stage at MON22 (8.17 feet BPMSL) occurred overnight between June 2 and June 3. Peak at MON23 (7.43 feet BPMSL) occurred early in the morning on June 3, and peak at MON28 (4.41 feet BPMSL) occurred later that evening.

Photo 4.25 shows MON22 after peak on June 4.

Photo 4.26 and Photo 4.27 show MON23 and MON28 prior to peak on June 2.

Photo 4.22: Floes from a jam release upstream of MON1 diverting into the Nigliq to contribute to the ice jam adjacent to Nuiqsut, looking west; June 1, 2012

Photo 4.23: Peak stage at MON20, looking downstream (north); June 2, 2012

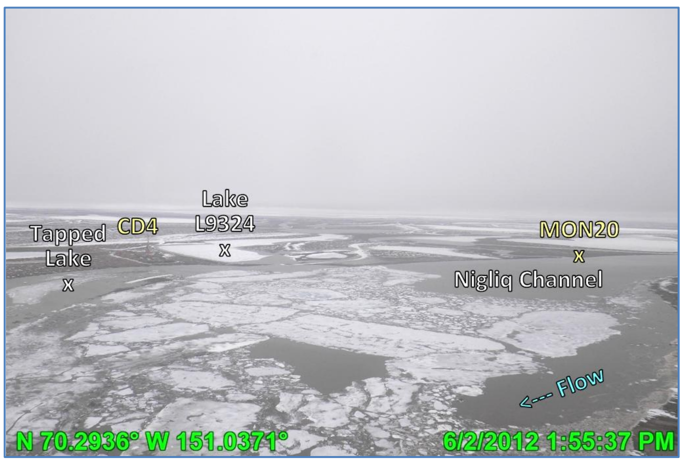


Photo 4.24: Upstream end of ice jam upstream of proposed Nigliq bridge location, looking southeast; June 2, 2012

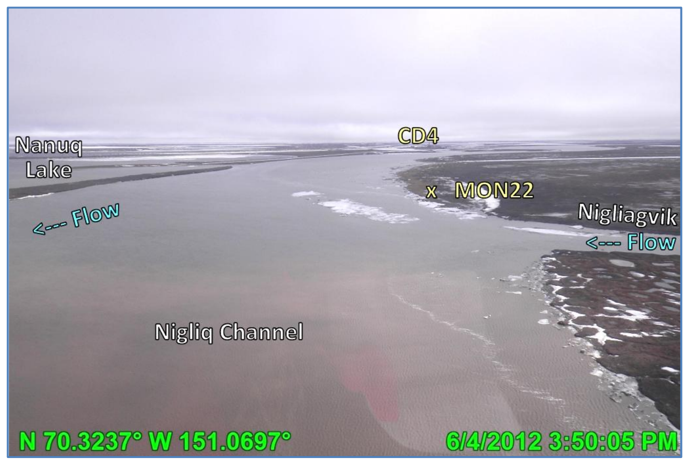


Photo 4.25: After peak stage at MON22, looking upstream (south); June 4, 2012

Photo 4.26: Prior to peak stage at MON23, looking downstream (northeast); June 2, 2012

Photo 4.27: Prior to peak stage at MON28, looking downstream (north); June 2, 2012

By June 4, ice had cleared out of the Nigliq Channel to the coast.

Photo 4.28, Photo 4.29, Photo 4.30, and Photo 4.31 show MON20, MON22, MON23, and MON28, respectively during open channel conditions as stage recedes on June 7.

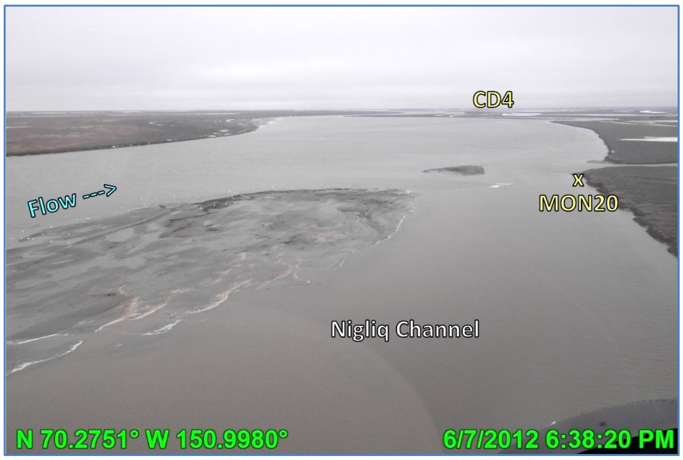


Photo 4.28: Open reach at MON20, looking downstream (north); June 7, 2012

Photo 4.29: Open reach at MON22, looking downstream (northwest); June 7, 2012

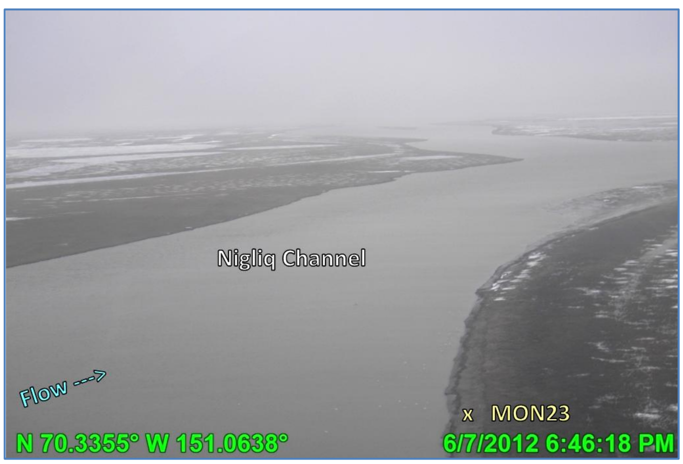


Photo 4.30: Open reach at MON23, looking downstream (northwest); June 7, 2012

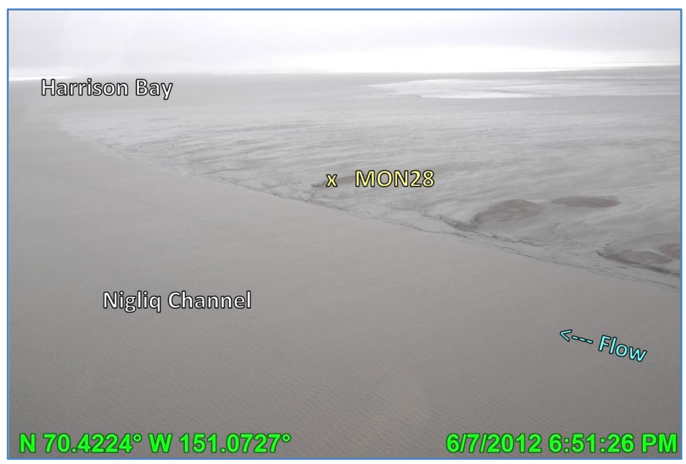


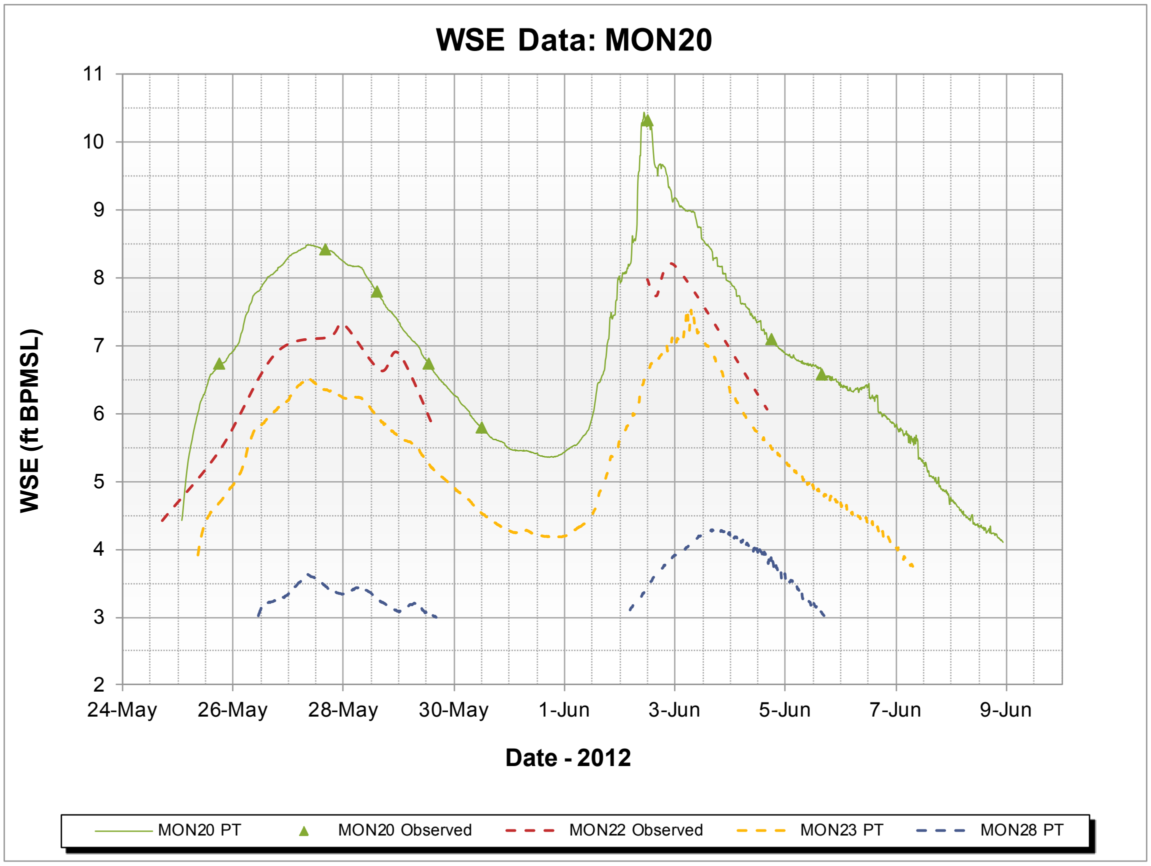
Photo 4.31: Open reach at MON28, looking downstream (northeast); June 7, 2012

Table 4.4: 2012 Stage Data for MON20

Date and Time	WSE (feet BPMSL)	Observations
	MON20	
5/24/12 6:00 PM	-	Low velocity leading edge approaching MON20
5/25/12 6:00 PM	6.73	
5/27/12 4:15 PM	8.41	Some floes caught on ribbon ice; ice jam upstream in Nigliq adjacent to Nuiqsut
5/28/12 2:15 PM	7.79	Stage receding
5/29/12 1:45 PM	6.74	Competent ribbon ice in channel
5/30/12 11:45 AM	5.79	Floes caught on cross-channel ice grounding out
6/2/12 10:30 AM	**10.43**	**Peak Stage at MON20**; based on PT data
6/2/12 12:15 PM	10.31	Ice jam adjacent to Nuiqsut released and reformed downstream adjacent to CD4; open upstream and channel ice downstream becoming less competent
6/4/12 5:45 PM	7.10	Channel ice cleared; grounded floes on banks
6/5/12 3:30 PM	6.58	Open channel and bankfull conditions

Notes:

1. Elevations are based on CP08-12-61 at 12.196 feet BPMSL, surveyed by Baker in 2011.
2. Gage readings were not taken on May 31-June 1 (helicopter mechanical issues) or June 3 (MON1 discharge).



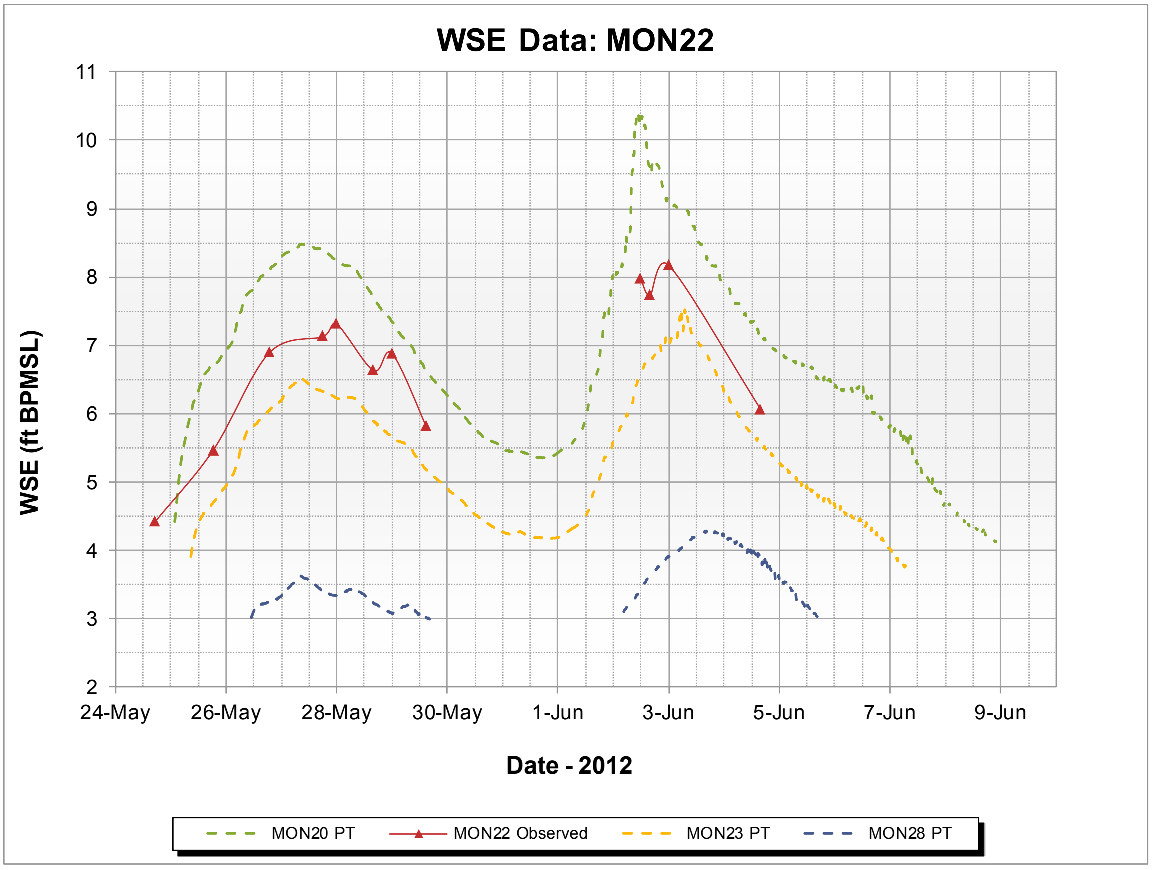
Graph 4.4: 2012 Stage Data for MON20 (including MON23/MON28 PT and MON22 Observed)

Table 4.5: 2012 Stage Data for MON22

Date and Time	WSE (feet BPMSL) MON22	Observations
5/24/12 5:15 PM	4.42	Local melt, leading edge upstream of MON20
5/25/12 6:30 PM	5.47	
5/26/12 6:45 PM	6.89	Competent ribbon ice through channel
5/27/12 6:15 PM	7.13	
5/28/12 12:00 AM	7.31	HWM - time estimated
5/28/12 4:00 PM	6.63	
5/29/12 12:00 AM	6.88	HWM - time estimated
5/29/12 2:45 PM	5.82	Competent ribbon ice in channel
6/2/12 12:00 PM	7.97	Small ice jam in mouth of Nigliagvik
6/2/12 4:00 PM	7.73	
6/3/12 12:00 AM	**8.17**	**Peak Stage at MON22**; based on HWM - time estimated
6/4/12 4:00 PM	6.06	Channel ice cleared, few grounded floes on W bank; stage decreasing

Notes:

1. Elevations are based on MONUMENT 22 at 10.030 feet BPMSL, surveyed by Baker in 2010.
2. Gage readings were not taken on May 30, May 31-June 1 (helicopter mechanical issues) or June 3 (MON1 discharge).



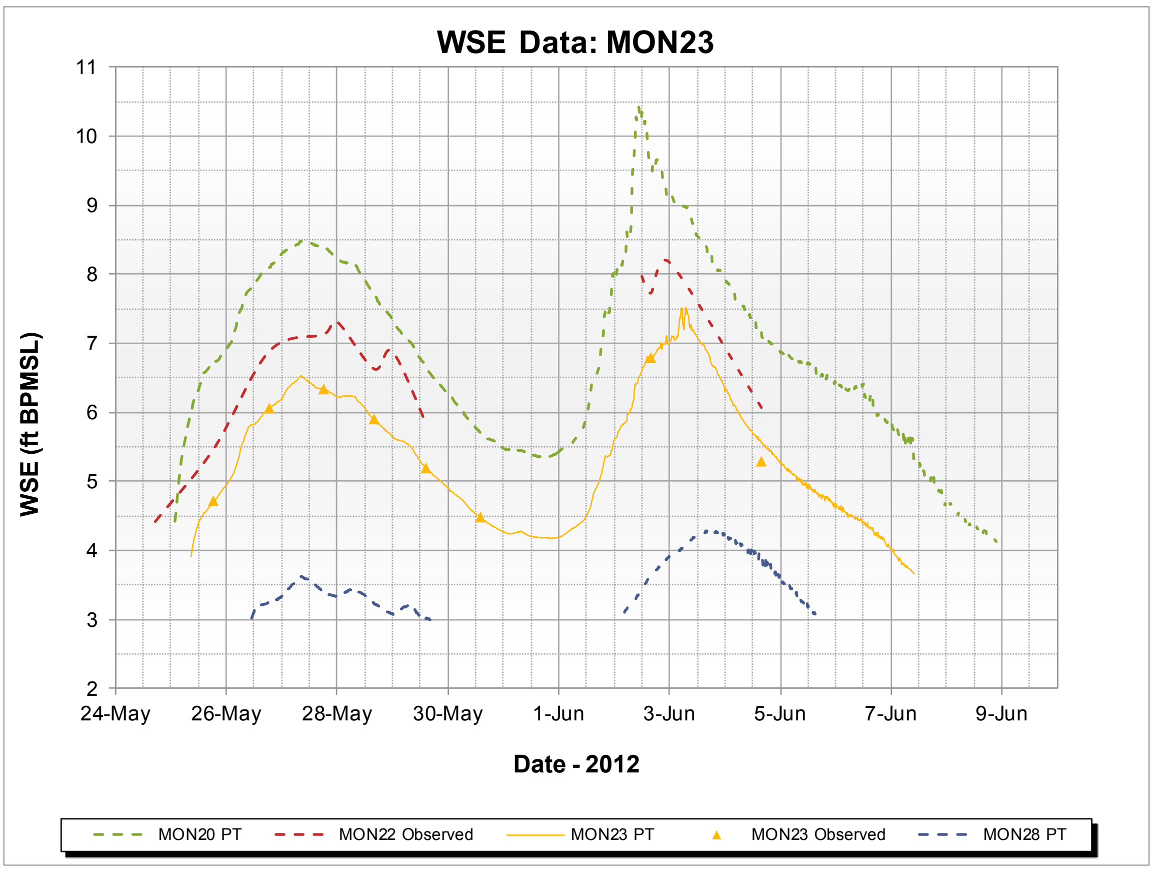
Graph 4.5: 2012 Stage Data for MON22 (including MON20/MON23/MON28 PT)

Table 4.6: 2012 Stage Data for MON23

Date and Time	WSE (feet BPMSL)	Observations
	MON23	
5/25/12 6:30 PM	4.70	
5/26/12 6:45 PM	6.05	Competent ribbon ice through channel
5/27/12 6:30 PM	6.33	
5/28/12 4:15 PM	5.89	Stage receeding
5/29/12 3:00 PM	5.19	Channel ice still competent
5/30/12 2:30 AM	4.47	HWM - time estimated
6/2/12 4:00 PM	6.78	
6/3/12 7:00 AM	**7.52**	**Peak Stage at MON23**; based on PT data
6/4/12 3:45 PM	5.28	Channel ice cleared, grounded floes; stage decreasing

Notes:

1. Elevations are based on MONUMENT 23 at 9.546 feet BPMSL, surveyed by Baker in 2009.
2. Gage readings were not taken on May 31-June 1 (helicopter mechanical issues) or June 3 (MON1 discharge).



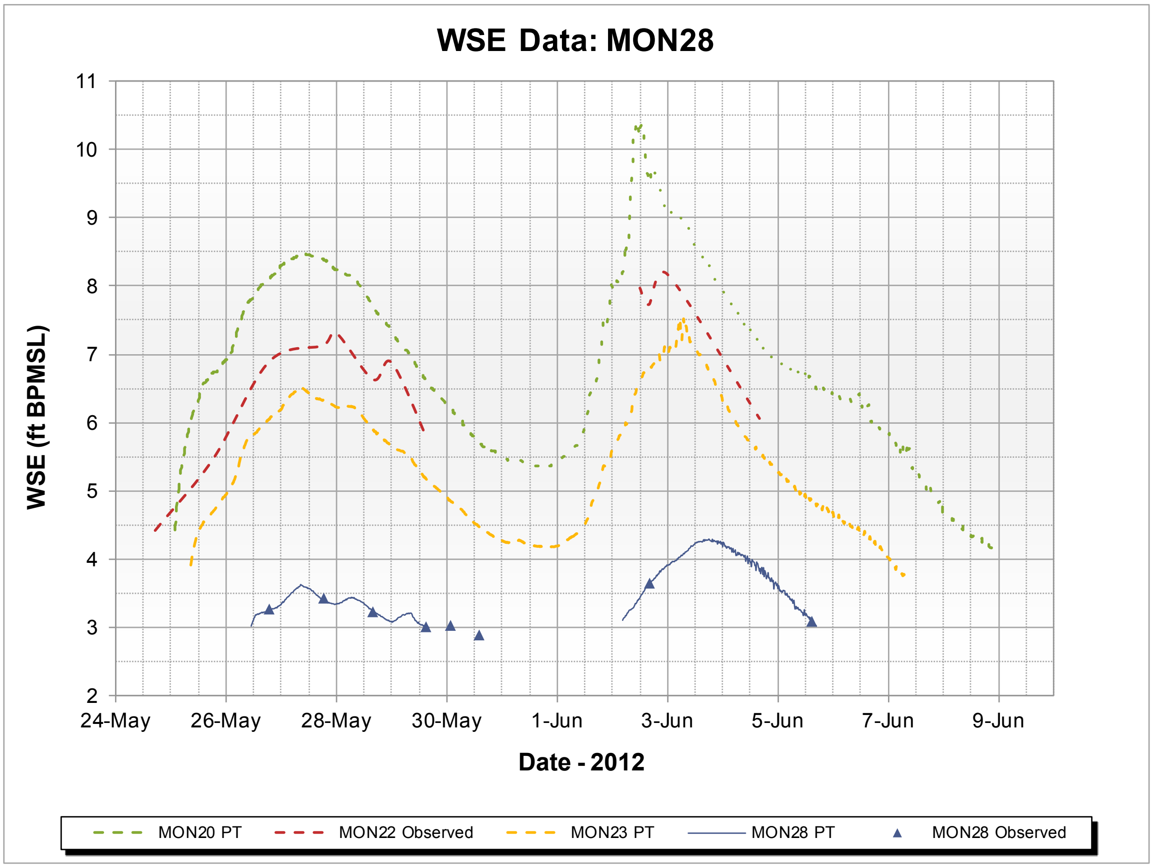
Graph 4.6: 2012 Stage Data for MON23 (including MON20/MON28 PT and MON22 Observed)

Table 4.7: 2012 Stage Data for MON28

Date and Time	WSE (feet BPMSL) MON28	Observations
5/25/12 6:45 PM	-	Low velocity leading edge past MON28, no H2O on gages
5/26/12 7:00 PM	3.26	Competent ribbon ice through channel
5/27/12 6:30 PM	3.41	
5/28/12 4:15 PM	3.23	Stage receding
5/29/12 3:15 PM	3.01	Channel ice still competent
5/30/12 1:45 AM	3.03	HWM - time estimated
6/2/12 4:15 PM	3.64	
6/3/12 6:00 PM	**4.29**	**Peak Stage at MON28**; based on PT
6/5/12 3:00 PM	3.08	Open channel and bankfull conditions

Notes:

1. Elevations are based on MONUMENT 28 at 3.65 feet BPMSL, updated by UMIAQ (GPS) in 2002.
2. Gage readings were not taken on May 31-June 1 (helicopter mechanical issues) or June 4 (weather).



Graph 4.7: 2012 Stage Data for MON28 (including MON20/MON23 PT and MON22 Observed)

4.2.3 Downstream of Nigliq Channel

Breakup progression at the FWR1 and FWR2 monitoring locations was typical of the NPR-A which lags behind breakup in the CRD. Daily monitoring of these locations began when melting was first recorded on June 2 (Photo 4.32 and Photo 4.33) and continued through the conclusion of CRD breakup monitoring on June 7. No well-defined drainages exist at either monitoring site, and WSE data collected was the result of local melt with potential contribution from overland sheet flow. Hydrographs for this data are not included in this report.

Breakup progression at both FWR1 and FWR2 was slow. By June 5 little additional melt had occurred by June 5. At this time, much of the area was still frozen with snow cover and ponded water on top of bottom-fast ice in polygons.

There was less snow and ice in the area at the conclusion of monitoring on June 7 (Photo 4.34). Ponded water remained, but no flowing drainages were observed in the vicinity of either gage location.

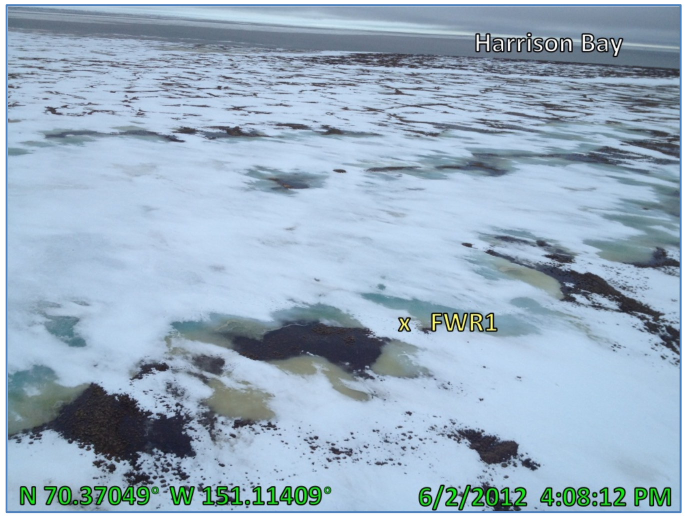


Photo 4.32: Local melt in the vicinity of FWR1, looking west; June 2, 2012

Photo 4.33: Local melt in the vicinity of FWR2, looking south; June 2, 2012

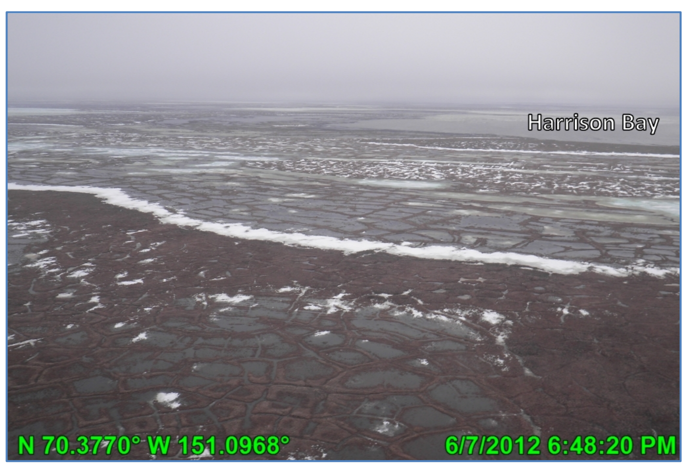


Photo 4.34: Breakup progression in the vicinity of FWR1 and FWR2 at the conclusion of monitoring, looking southwest; June 7, 2012

4.3 Alpine Facilities and Roads

Breakup progression at Alpine facilities is driven by conditions in the major streams to the east, the Colville East Channel, and the Nigliq Channel to the west. Sakoonang, Tamayayak, and Ulamnigiaq channels also convey flow in the vicinity of facilities. Floodwaters typically overtop the active channel banks of the Nigliq and Sakoonang and contribute to the annual recharge of many lakes and paleolake areas through overbank inundation or established drainages. The extent of flow depends on WSE and ice/snow presence, which has a greater impact during lower stage conditions. Breakup at Alpine facilities generally begins with local melt and floodwaters arrive one to two days after the leading edge reaches MON1.

4.3.1 Gages and Drainage Structures

Conditions at gage locations at CD1 (G1) and along the CD4 access road (G15/G16 and G17/G18) tend to be more influenced by events in the Sakoonang Channel. Conditions at gage locations at CD2 (G8), along the CD2 access road (G3/G4, G12/G13, and G6/G7), and at CD4 (G19 and G20) tend to be more influenced by events in the Nigliq Channel. Conditions at the CD3 gage location (G11) are influenced by events in the Tamayayak and Ulamnigiaq channels. Daily stage monitoring at Alpine facilities gages occurred between May 25 and June 5. Peak stage at most of these locations occurred overnight between June 3 and June 4. Breakup flow began approaching facilities gages from the Sakoonang Channel and the Nigliq Channel via Nanuq Lake on May 25. Driven by upstream conditions, breakup at facilities progressed slowly toward an initial low peak, then a recession followed by a secondary peak. The second peak was low, but of greater magnitude than the first. Overland flood flows did not reach some facility gage locations during the 2012 spring breakup, including the CD2 pad, CD3 pad, along the CD4 access road at G17/G18, and the CD4 pad at G19. Stage data are available for the Alpine facilities and road gages that experienced flood flow. WSE is shown in Table 4.8 through Table 4.13.

May 25 was the first day measureable water reached any Alpine facilities gage, G20. By May 26, the Sakoonang was conveying limited flow into Lake M9525 via the north paleolake (Photo 4.35) and past G1. Both Alpine swale bridges were hydraulically connected to the Nigliq Channel (Photo 4.35 and Photo 4.36) as low velocity floodwaters moved through Nanuq Lake into Lake M9524. Meltwater was not in the vicinity of any CD4 access road gages.

The channel adjacent to CD1 was fairly ice free by May 27. A small jam formed at the head, and water transporting floes was moving from the south paleolake under the Alpine Sales Pipeline toward Lake L9324. Flow had increased into the north paleolake and was moving under the pipeline into Lake M9525. Flow through the swale bridges remained low and inadequate to remove the snow underneath. Stage in the vicinity experienced a low peak overnight (G3/G4). A small overnight peak was recorded at the gage on the south side of the eastern end of the CD2 access road (G6). Low stage and blockages of drainage structures restricted the limited flow from reaching the north side (G7).

No floodwater was in the vicinity of G12/G13 drainage structures in the middle of the CD2 road. An equalized hydraulic connection between G15/G16 was established. Similar conditions at G6/G7 limited flow to Lake M9525 (G15) southwest across the road (G16). No floodwaters approached G16 from Lake L9323 which remained frozen and hydraulically isolated.

Floodwaters were not observed in the vicinity of G17/G18 drainage structures. G20 experienced an initial shallow peak on the afternoon of May 27.

Earlier recession of stage upstream in the CRD began to affect WSE at the Alpine facilities by May 28. Initial shallower peaks were experienced by G15 overnight and G1 later in the evening. WSE declined throughout the area reaching a low on June 1. G16 had the highest peak stage prior to the second peak at 8.54 feet BPMSL overnight between May 28 and May 29. WSE at this gage was heavily influenced by drainage structure performance in the vicinity, and the timing and magnitude of this peak was not necessarily representative of overall flooding conditions at Alpine facilities. As stage fell, flow reservoir in the G16 vicinity gradually drained back toward G15.

Nanuq Lake remained hydraulically connected to the Nigliq Channel. Lake M9525 was connected to the north paleolake, and the north and south paleolakes were connected to the Sakoonang. Channel ice in the Sakoonang continued to slowly break into floes accumulating in the bends as the ice jam at the head began to ground out. Flow through the small swale bridge stopped by May 30 though it remained hydraulically connected to M9524 until June 1. Flow decreased but continued through the long swale bridge throughout the recession period. Water was no longer in the area of G6/G7 and G12/G13 drainage structures through June 1.

By June 2, stage had once again begun to rise at Alpine facilities. Floodwater was present at all gages including G12/G13 which had measurable water for the first time. Any snow still remaining under either swale bridge was no longer present as flow increased through the long bridge and again began passing through the short bridge. Floes from ice jam releases in the East Channel on June 1 and 2 diverted into the Sakoonang, jamming and releasing with some overflowing into the north and south paleolakes as they progressed downstream in the channel past facilities. Photo 4.37 shows increased G20 just prior to peak stage. Flow extents did not approach G19 or G17/G18 as WSE rose again in the vicinity of CD4.

Photo 4.37 shows stage at G20 just prior to peak and flow extents not approaching G19 or G17/G18 as WSE rises again in the vicinity of CD4.

Stage peaked overnight between June 2 and June 3 at G3/G4 (7.60/7.19 feet BPMSL, post peak in Photo 4.38), G6/G7 (8.02/7.81 feet BPMSL, post peak in Photo 4.39 and /Photo 4.40), G12/G13 (7.88/7.78 feet BPMSL), and G20 (10.00 feet BPMSL, prior to peak in Photo 4.37). Similar to other CRD monitoring areas, peak stage at these locations were relatively low compared to the historical record.

During peak stage, some culverts were performing well passing sediment laden flow across access roads (Photo 4.41). Performance of many culverts was limited by natural blockages such as snow (Photo 4.42), or covers. Some fabric culvert covers were cut to allow flow and others were not completely removed (Photo 4.43). The covers allow the passage of water, but inhibit the transport of sediment.

Stage peaked overnight between June 3 and June 4 at G1 (7.97 feet BPMSL, post peak in Photo 4.44) and at G15 (8.28 feet BPMSL, post peak in Photo 4.45). Decreasing stage left ice floes grounded along the west bank at G1. G16 experienced a secondary peak overnight as the result of increased stage in M9525. Lake L9323 remained predominantly frozen (Photo 4.46).

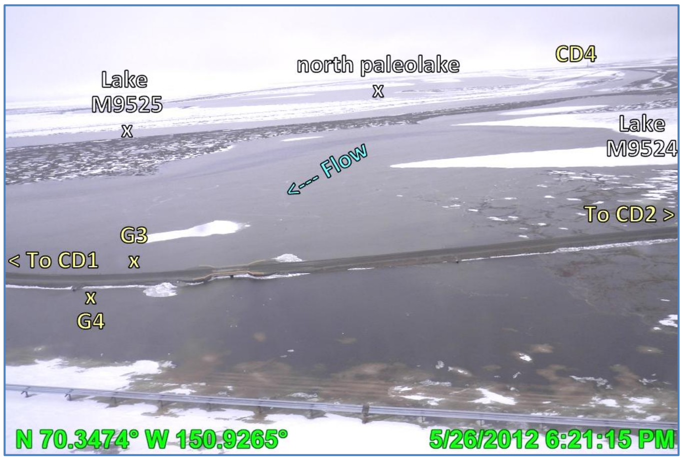


Photo 4.35: Flow into Lake M9525 from the Sakoonang via north paleolake and short swale bridge hydraulically connected to the Nigliq via Nanuq Lake, looking south; May 26, 2012

Photo 4.36: Initial flow through the long swale bridge, looking north; May 26, 2012

Photo 4.37: Flood extents remain away from G17/G18 and G19 as stage increases again at Alpine facilities, G20 prior to peak; June 2, 2012

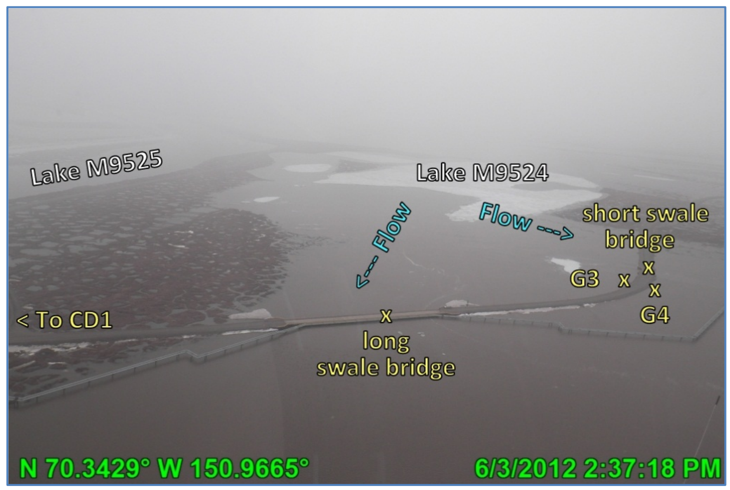


Photo 4.38: G3/G4 area following peak stage, looking south; June 3, 2012

Photo 4.39: G6 following peak stage, looking southeast; June 3, 2012

Photo 4.40: G7 following peak stage, looking northeast; June 3, 2012

Photo 4.41: Discharge measurement at CD2 road culvert CD2-22, performing as designed to pass sediment laden flow, downstream (north) side; June 3, 2012

Photo 4.42: Snow removed from outlet area of CD2 road culvert CD2-8 with significant quantities in surrounding vicinity, downstream (north) side; June 3, 2012

Photo 4.43: CD2 road culvert CD2-9 with fabric cover partially removed, downstream (north) side; June 3, 2012

Photo 4.44: Grounded floes at G1 following peak stage, looking east; June 4, 2012

Photo 4.45: G15 following peak stage, looking south; June 4, 2012

Photo 4.46: G16 following secondary peak, looking southwest; June 4, 2012

Floodwaters recession continued without additional increases following the second peak at Alpine facilities. Photo 4.47 through Photo 4.54 show facilities gage locations as stage recedes.

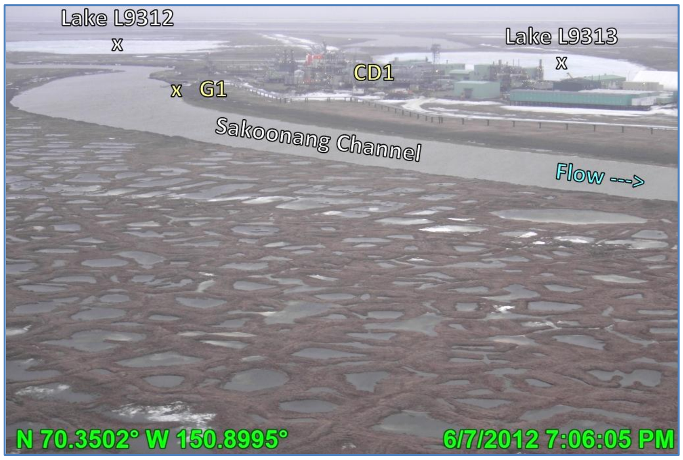


Photo 4.47: Open Sakoonang Channel as stage recedes at G1, looking west; June 7, 2012

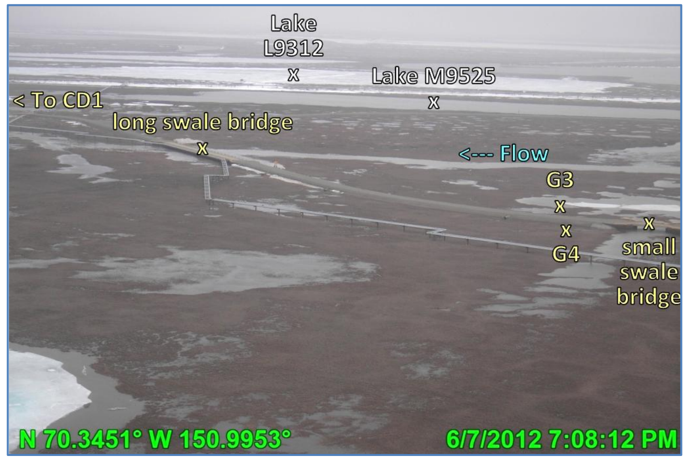


Photo 4.48: Limited flow through the long swale bridge and ponded water at the short swale bridge as stage recedes at G3/G4, looking south; June 7, 2012

Photo 4.49: Ponded water at G6/G7 as stage recedes, looking west; June 7, 2012

Photo 4.50: No floodwater in the vicinity of G8 as stage recedes, looking east; June 4, 2012

Photo 4.51: Local melt draining into West Ulamnigiaq Channel as stage recedes at G11, looking east; June 7, 2012

Photo 4.52: Stage recession at G15/G16, Lake L9232 predominantly frozen but draining limited melt toward G16, looking northwest; June 7, 2012

Photo 4.53: No floodwaters reached G17/G18 vicinity as stage recedes, looking northwest; June 7, 2012

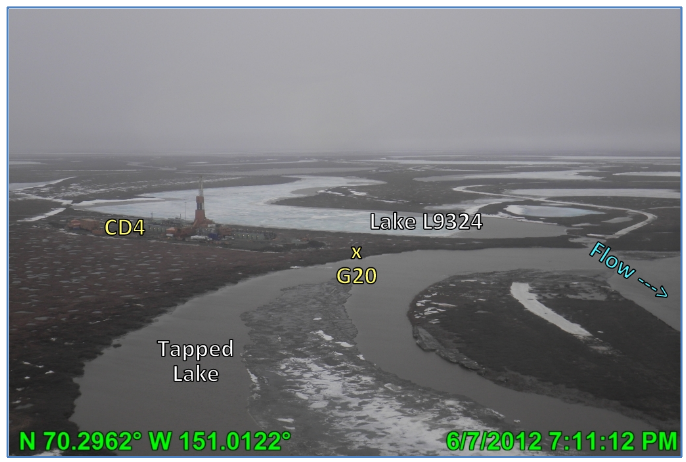


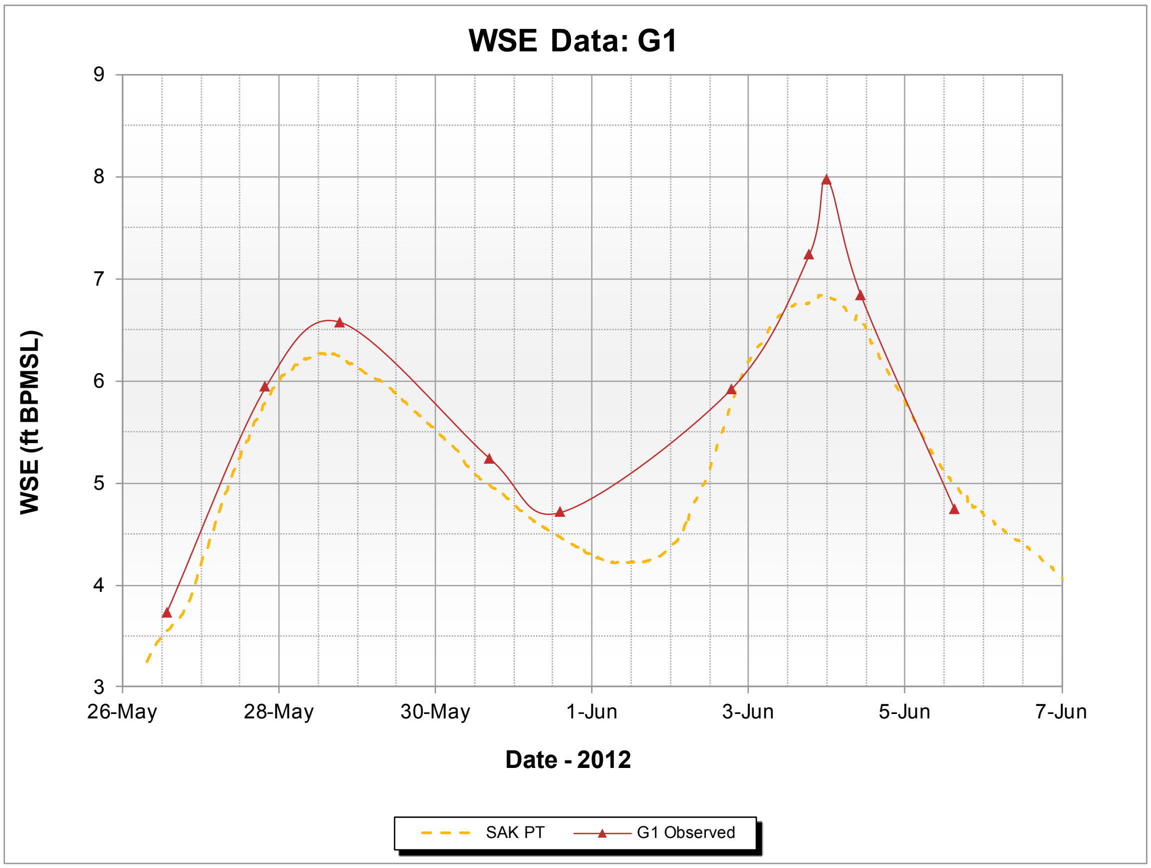
Photo 4.54: G20 as stage recedes, looking southeast; June 7, 2012

Table 4.8: 2012 Stage Data for G1

Date and Time	WSE (feet BPMSL) G1	Observations
5/25/12 10:50 AM	-	Leading edge enters Sakoonang, no H2O in G1 vicinity
5/26/12 1:35 PM	3.73	Some floes jammed in mouth of Sakoonang; flow into N paleolake
5/27/12 8:00 PM	5.94	Upstream Sakoonang - floes into S paleolake; channel open near G1
5/28/12 6:53 PM	6.57	Upstream Sakoonang - some grounded ice at head
5/30/12 4:30 PM	5.24	Stage dropping; occasional floes in vicinity
5/31/12 2:30 PM	4.71	
6/2/12 6:50 PM	5.92	Ice jam at Sakoonang first bend and upstream of North paleolake
6/3/12 6:35 PM	7.23	Floes jammed at bend just upstream of CD1
6/4/12 12:00 AM	**7.97**	**Peak Stage at G1**; based on HWM - time estimated
6/4/12 10:30 AM	6.83	Stage decreasing; stranded ice on bank
6/5/12 3:10 PM	4.74	Open channel

Notes:

1. Elevations are based on UMIAQ Monument 21 at 13.273 feet BPMSL, updated by UMIAQ in 2009.
2. Gage 1 is a permanent staff gage surveyed for elevation by UMIAQ in May 2012.



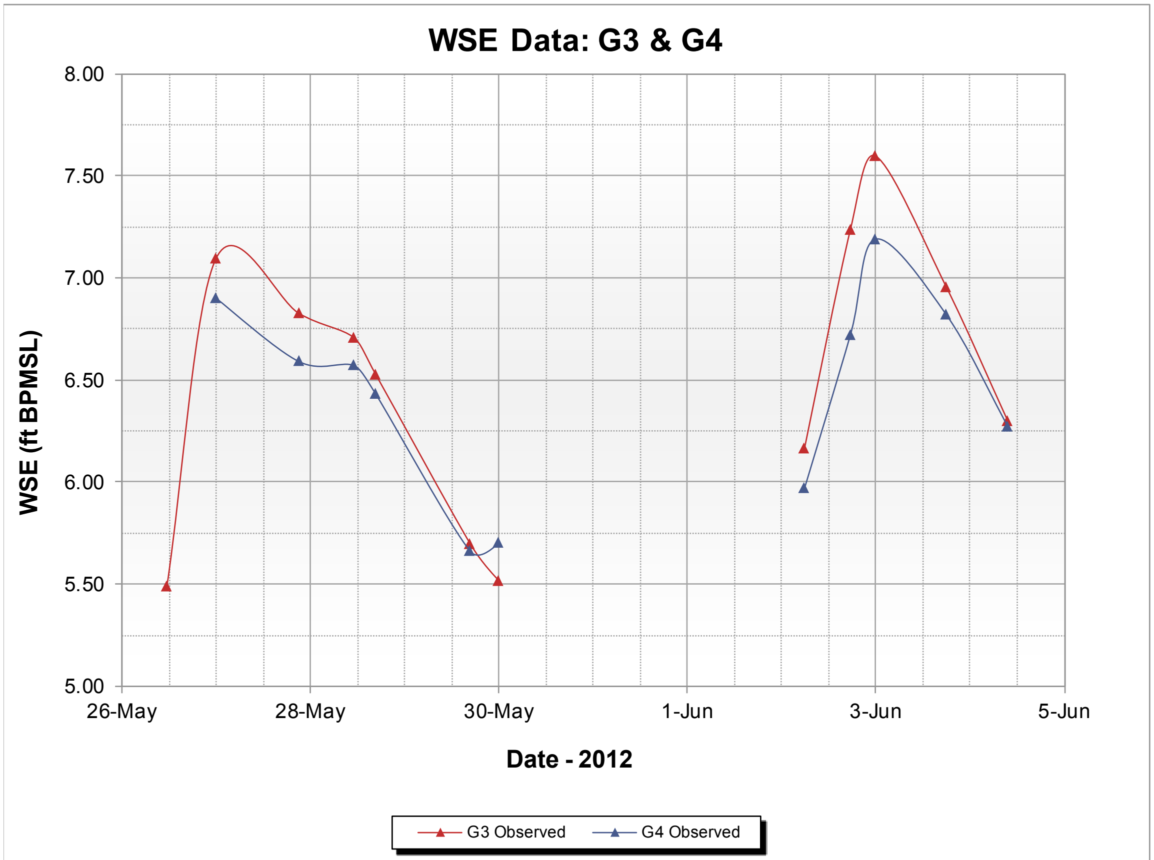
Graph 4.8: 2012 Stage Data for G1 (including SAK PT)

Table 4.9: 2012 Stage Data for G3/G4

Date and Time	WSE (feet BPMSL)		Observations
	G3	G4	
5/26/12 11:26 AM	5.49	-	Both swale bridges hydraulically connected to Nanuq Lake
5/27/12 12:00 AM	7.10	6.90	HWM - time estimated
5/27/12 9:05 PM	6.83	6.59	Flow through both swale bridges
5/28/12 11:10 AM	6.71	6.57	
5/28/12 4:40 PM	6.53	6.43	Discharge measurement at both bridges
5/29/12 4:45 PM	5.70	5.66	
5/30/12 12:00 AM	5.52	5.70	HWM - time estimated; stage decrease results in ponded H2O only at gages and no flow through short bridge, low flow through long bridge
6/2/12 5:50 AM	6.17	5.97	
6/2/12 5:30 PM	7.24	6.72	Stage increase results in flow through both swale bridges; occasional floes
6/3/12 12:00 AM	**7.60**	**7.19**	**Peak Stage at G3 & G4**; based on HWM - time estimated
6/3/12 5:55 PM	6.96	6.82	Discharge measurement at both bridges
6/4/12 9:40 AM	6.30	6.27	Stage decreasing

Notes:

1. Elevations are based on Monument 12 at 9.00 feet BPMSL, updated by UMIAQ in 2009.
2. Gages 3 and 4 are permanent staff gages surveyed for elevation by UMIAQ in May 2012.



Graph 4.9: 2012 Stage Data for G3/G4

Table 4.10: 2012 Stage Data for G12/G13

Date and Time	WSE (feet BPMSL)		Observations
	G12	G13	
6/2/12 5:30 PM	7.57	7.49	First flow in vicinity of gages
6/3/12 12:00 AM	**7.88**	**7.78**	**Peak Stage at G12 and G13**; based on HWM - time estimated
6/3/12 11:45 AM	7.49	7.60	Limited flow through culverts
6/4/12 12:00 AM	7.49	7.66	HWM - time estimated
6/4/12 9:45 AM	-	7.19	Stage decreasing

Notes:

1. Elevations for Gage 12 are based on CD2 access road culvert CD2-14 south top at 10.904 feet BPMSL, surveyed by UMIAQ in May 2012.
2. Elevations for Gage 13 are based on CD2 access road culvert CD2-14 north top at 10.903 feet BPMSL, surveyed by UMIAQ in May 2012.

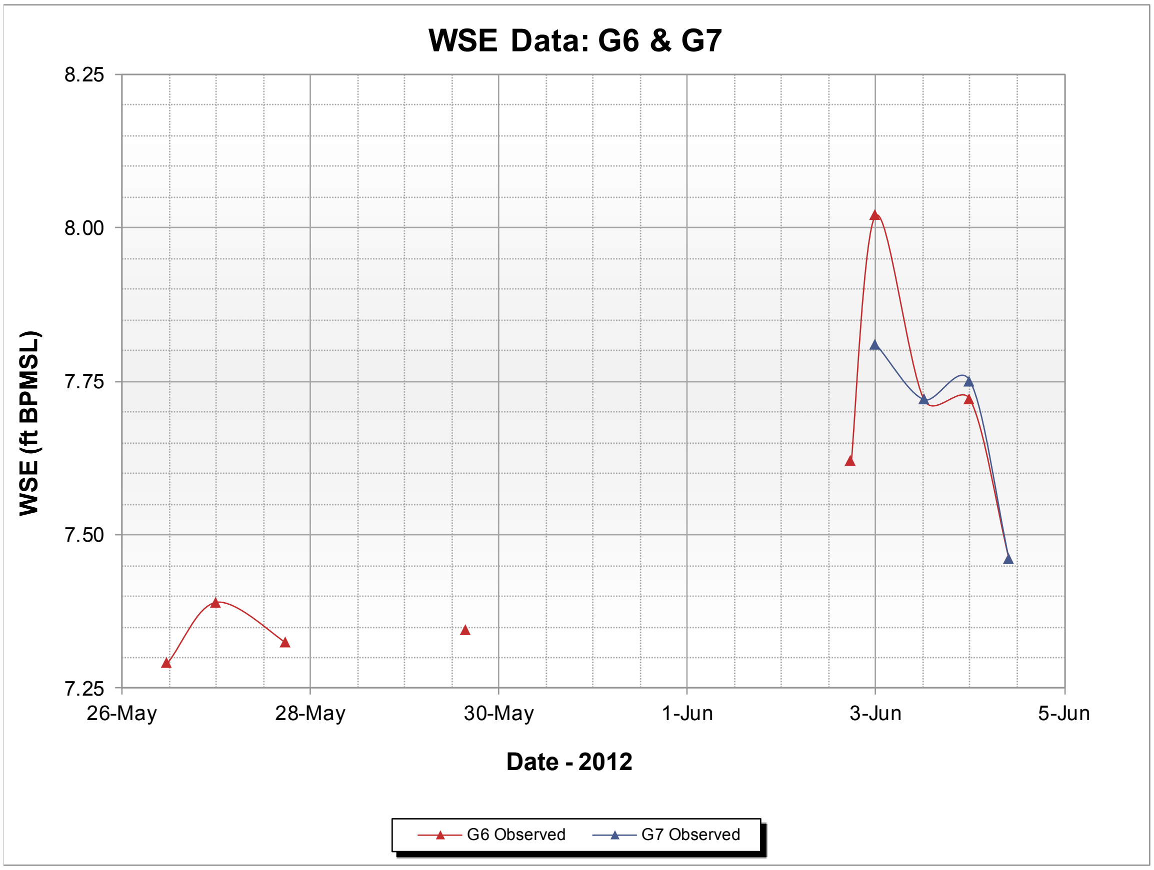
Graph 4.10: 2012 Stage Data for G12/G13

Table 4.11: 2012 Stage Data for G6/G7

Date and Time	WSE (feet BPMSL)		Observations
	G6	G7	
5/26/12 11:30 AM	7.29	-	G6 connected to L9321; local melt at G7
5/27/12 12:00 AM	7.39	-	HWM - time estimated
5/27/12 5:35 PM	7.33	-	
5/29/12 3:35 PM	7.35	-	Local melt
6/2/12 5:45 PM	7.62	-	
6/3/12 12:00 AM	**8.02**	**7.81**	**Peak Stage at G6 and G7**; based on HWM - time estimated
6/3/12 12:15 PM	7.72	7.72	Limited flow through culverts
6/4/12 12:00 AM	7.72	7.75	HWM - time estimated
6/4/12 9:55 AM	7.46	7.46	Stage decreasing

Notes:

1. Elevations are based on Monument 12 at 9.00 feet BPMSL, updated by UMIAQ in 2009.
2. Gages 6 and 7 are permanent staff gages surveyed and adjusted for elevation by UMIAQ in May 2012.



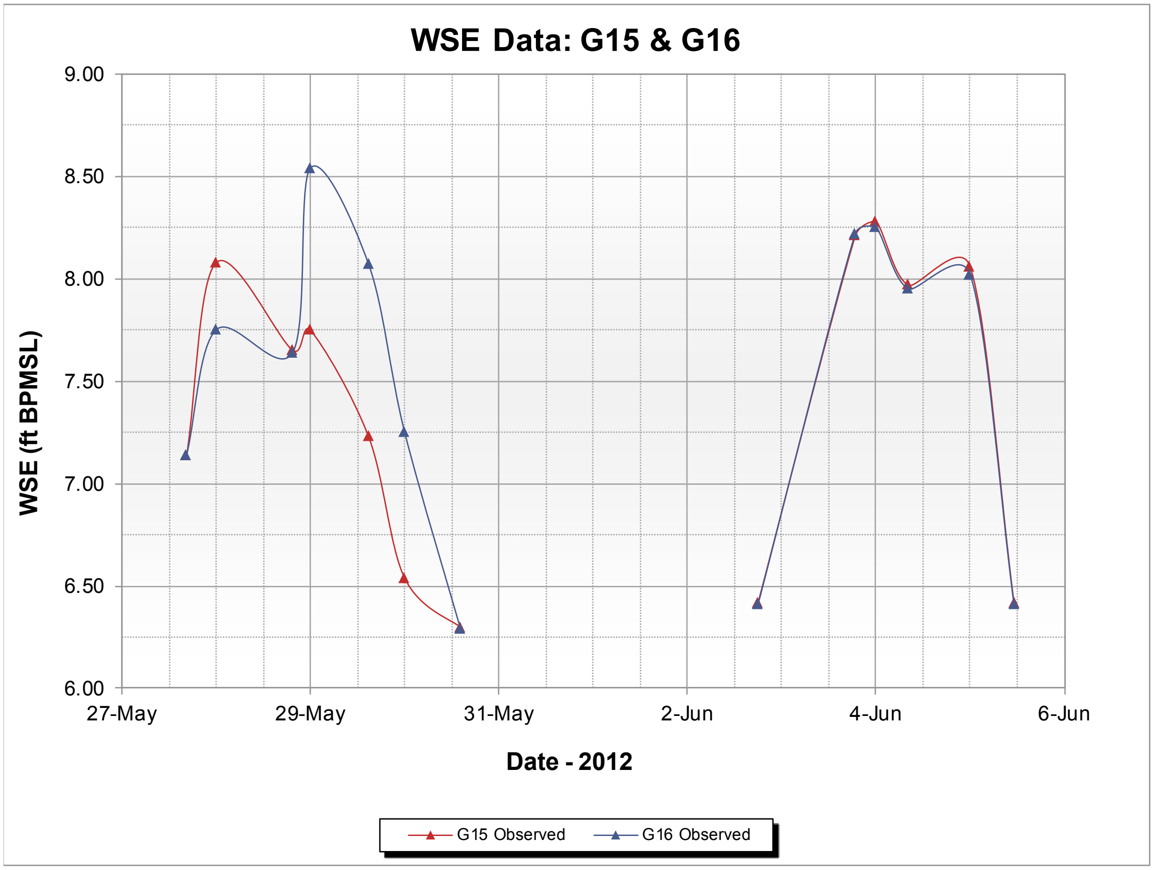
Graph 4.11: 2012 Stage Data for G6/G7

Table 4.12: 2012 Stage Data for G15/G16

Date and Time	WSE (feet BPMSL)		Observations
	G15	G16	
5/27/12 4:30 PM	7.14	7.14	Culverts mostly blocked, some connectivity of flow from M9525, none from L9323
5/28/12 12:00 AM	8.08	7.75	HWM - time estimated
5/28/12 7:30 PM	7.65	7.64	
5/29/12 12:00 AM	7.75	**8.54**	**Peak Stage at G16**; based on HWM - time estimated
5/29/12 2:50 PM	7.23	8.07	The only flow in vicinity of CD4 road; max differential through culverts
5/30/12 12:00 AM	6.54	7.25	HWM - time estimated
5/30/12 2:15 PM	6.30	6.29	No flow from L9323, WSE equalizing as stage receeds
6/2/12 6:00 PM	6.42	6.41	
6/3/12 6:45 PM	8.21	8.22	M9525 just connnected with L9323 via limited flow through culverts
6/4/12 12:00 AM	**8.28**	8.25	**Peak Stage at G15**; based on HWM - time estimated
6/4/12 8:20 AM	7.97	7.95	
6/5/12 12:00 AM	8.06	8.02	HWM - time estimated
6/5/12 11:10 AM	6.42	6.41	Some flow from L9323 local melt, equalized through partially blocked culverts

Notes:

1. Elevations are based on CD4 access road culvert CD4-20A west top at 7.099 feet BPMSL, surveyed by UMIAQ in May 2012.



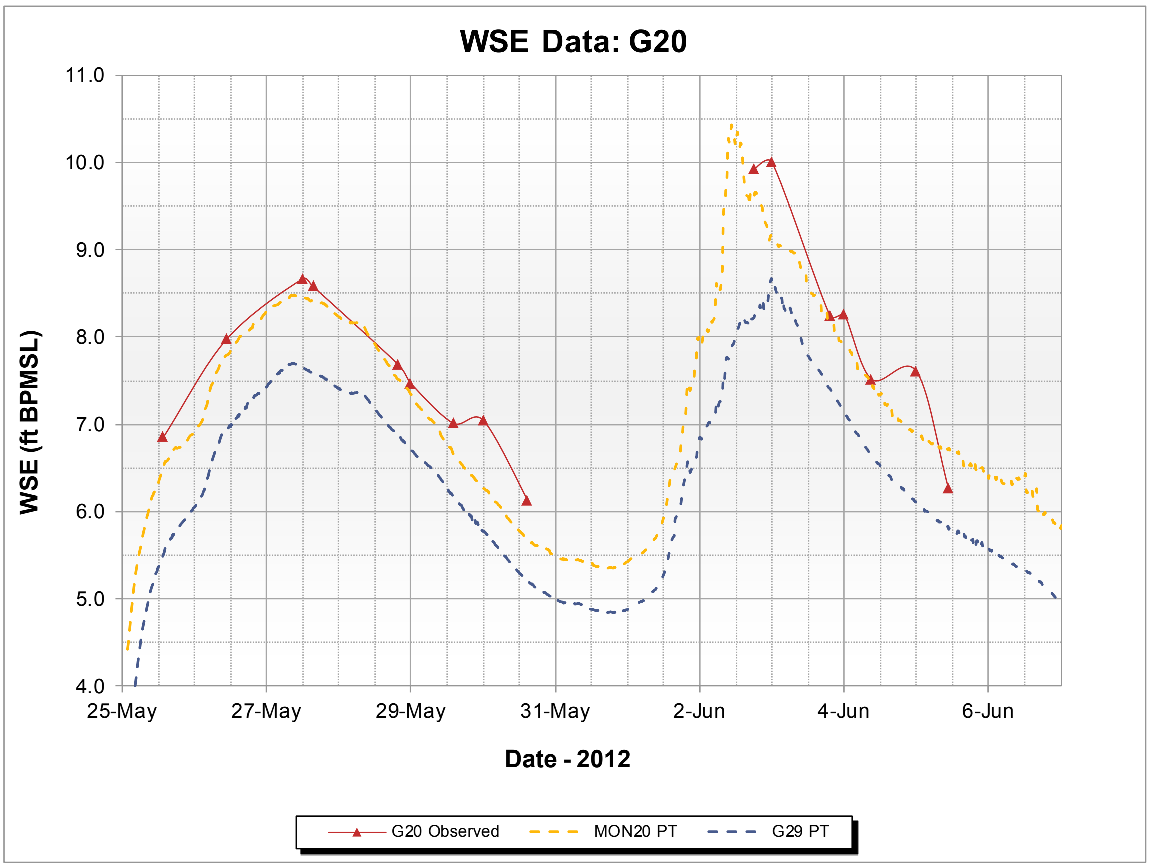
Graph 4.12: 2012 Stage Data for G15/G16

Table 4.13: 2012 Stage Data for G20

Date and Time	WSE (feet BPMSL)	Observations
	G20	
5/25/12 1:45 PM	6.86	Tapped Lake connected to Nigliq Channel
5/26/12 10:45 AM	7.98	Ice jam upstream in Nigliq Channel adjacent to Nuiqsut
5/27/12 12:00 PM	8.67	HWM - time estimated
5/27/12 3:30 PM	8.58	Sakoonang connected to Nigliq Channel via L9324
5/28/12 7:40 PM	7.69	
5/29/12 12:00 AM	7.47	HWM - time estimated
5/29/12 2:05 PM	7.01	
5/30/12 12:00 AM	7.05	HWM - time estimated
5/30/12 2:45 PM	6.13	Nigliq still connected to Tapped Lake and L9324
6/2/12 6:05 PM	9.92	Upstream Nigliq ice jam released and reforms in vicinity of gage
6/3/12 12:00 AM	**10.00**	**Peak Stage at G20**; based on HWM - time estimated
6/3/12 7:15 PM	8.25	Nigliq Channel free of ice in vicinity of gage
6/4/12 12:00 AM	8.26	HWM - time estimated
6/4/12 9:05 AM	7.52	
6/5/12 12:00 AM	7.61	HWM - time estimated
6/5/12 10:40 AM	6.27	Tapped Lake and L9324 still connected to Nigliq Channel

Notes:

1. Elevations are based on PBM-P at 20.969 feet BPMSL, surveyed by UMIAQ in May 2012.



Graph 4.13: 2012 Stage Data for G20 (including MON20/G29 PT)

4.3.2 Alpine Drinking Water Lakes

Documentation of recharge conditions of the Alpine drinking water lakes L9312 and L9313 was conducted in accordance with ADF&G permits FG99-III-0051, Amendment #7, and FG97-III-0190, Amendment #5. Lakes L9312 and L9313 were monitored before, during, and after breakup to assess recharge and to evaluate recharge mechanisms. Primary recharge mechanisms are overland flood flow and local melt. Evaluation of recharge was made using photographic documentation, WSE surveys, and analysis of hydrographs generated by stage monitoring at gages G9 (L9312) and G10 (L9313).

Table 4.14: Alpine Drinking Water Lakes Historical Summary of Recharge during Spring Breakup as a Result of Overland Flood Flow, 1998 to 2012

Year	Lake L9312	Lake L9313	Reference
2012	no	yes	This report
2011	yes	yes	Baker 2011
2010	no	yes	Baker 2011
2009	no	yes	Baker 2011
2008	no	yes	Baker 2011
2007	yes	yes	Baker 2011
2006	yes	yes	Baker 2011
2005	no	no	Baker 2011
2004	yes	yes	Baker 2005a
2003	no	yes	Baker 2003
2002	yes	yes	Baker 2002b
2001	no	yes	Baker 2001
2000	yes	yes	Baker 2000
1999	no	no	Baker 1999
1998	yes	yes	Baker 1998b

Note:
1. This data does not include recharge as a result of local melt

Local melt of snow and ice within the lake drainage basins annually contributes to recharge. Lake L9313 typically receives additional annual recharge during spring breakup from overland flood flow. Lake L9312 is surrounded by higher tundra than L9313 and receives overland flood flow less frequently. A historical summary of Alpine drinking water lakes recharge from overland breakup flooding is included in Table 4.14.

Lakes were determined to be fully recharged if bankfull conditions were met and either overland flood flow was observed overbanking into the lake drainage basin or there was evidence of a stage rise and fall on the hydrograph. Stage-hydrographs for G9 and G10 are provided in Table 4.15 and Table 4.16.

Lake L9312 and L9313 Recharge

Recharge monitoring of lakes L9312 and L9313 began on May 8 when WSE was surveyed prior to breakup as part of the Alpine Lakes Recharge Project. Daily observations were recorded during breakup monitoring between May 24 and June 7. Final data collection took place on June 26 and 27 for the recharge project.

On May 25, the leading edge of breakup melt from upstream was approaching Alpine facilities. By May 26, the Sakoonang was conveying flow into the north paleolake which recharges Lake M9525. Overflow from this lake is typically the primary source of recharge into Lake L9313. Photo 4.55 shows these two lakes as flood flow approaches Lake L9313.

The hydraulic connection between Lake M9525 and L9313 occurred on the evening of May 27. Measureable water was first at G10 overnight between May 27 and 28, and Alpine facilities experienced a first shallow peak. Overland floodwater did not reach Lake L9312, which remained frozen.

Stage decreased at Alpine facilities after May 28, and by June 1, Lake L9313 was no longer connected to Lake M9525. Stage was lowest at G10 on June 2, after which it increased once again. The hydraulic connection with Lake M9525 was re-established on June 3 (Photo 4.56), and peak stage of 8.20 feet BPMSL occurred overnight between June 3 and June 4. This peak was low compared to the historical record, and stage was not sufficient to reach Lake L9312. Lake L9312 was still predominantly frozen with significant quantities of snow remaining. By June, some limited local melting had occurred.

After June 5, stage receded at Lake L9313 which remained connected to Lake M9525 until the conclusion of daily monitoring on June 7. Based on recorded observations of overland flood flow entering the drainage and a rise and fall of the hydrograph, Lake L9313 recharged to bankfull conditions. Local melting at Lake L9312 had not progressed significantly by June 7, and no sources of overland flow were identified (Photo 4.57). Though ice remained, more water was seen in the lake on June 27 (Photo 4.58). A HWM was recorded at G9, and the rise and fall of the hydrograph indicates Lake L9312 recharged to bankfull conditions.

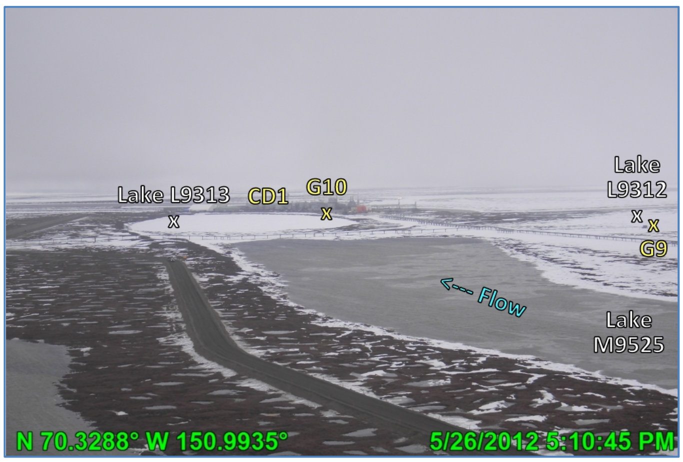


Photo 4.55: Initial recharge from the Sakoonang approaching Lake L9313 via Lake M9525, looking east; May 26, 2012

Photo 4.56: Lake L9313 receiving additional recharge from the Sakoonang prior to peak stage; no melt or overland flow into Lake L9312, looking east; June 3, 2012

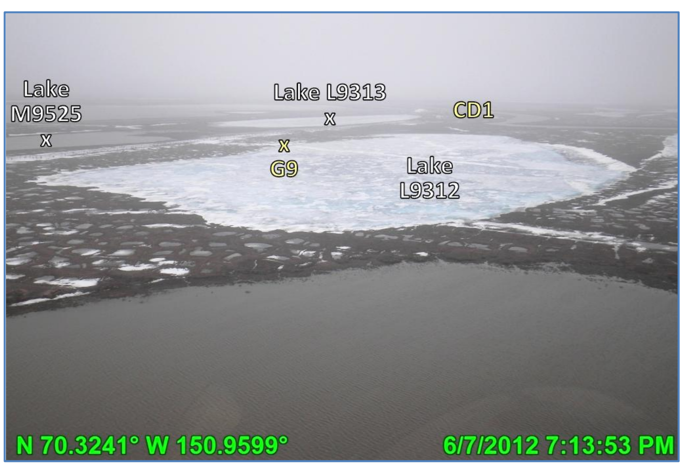


Photo 4.57: Lake L9312 still frozen and hydraulically isolated at the conclusion of daily monitoring, looking northeast; June 7, 2012

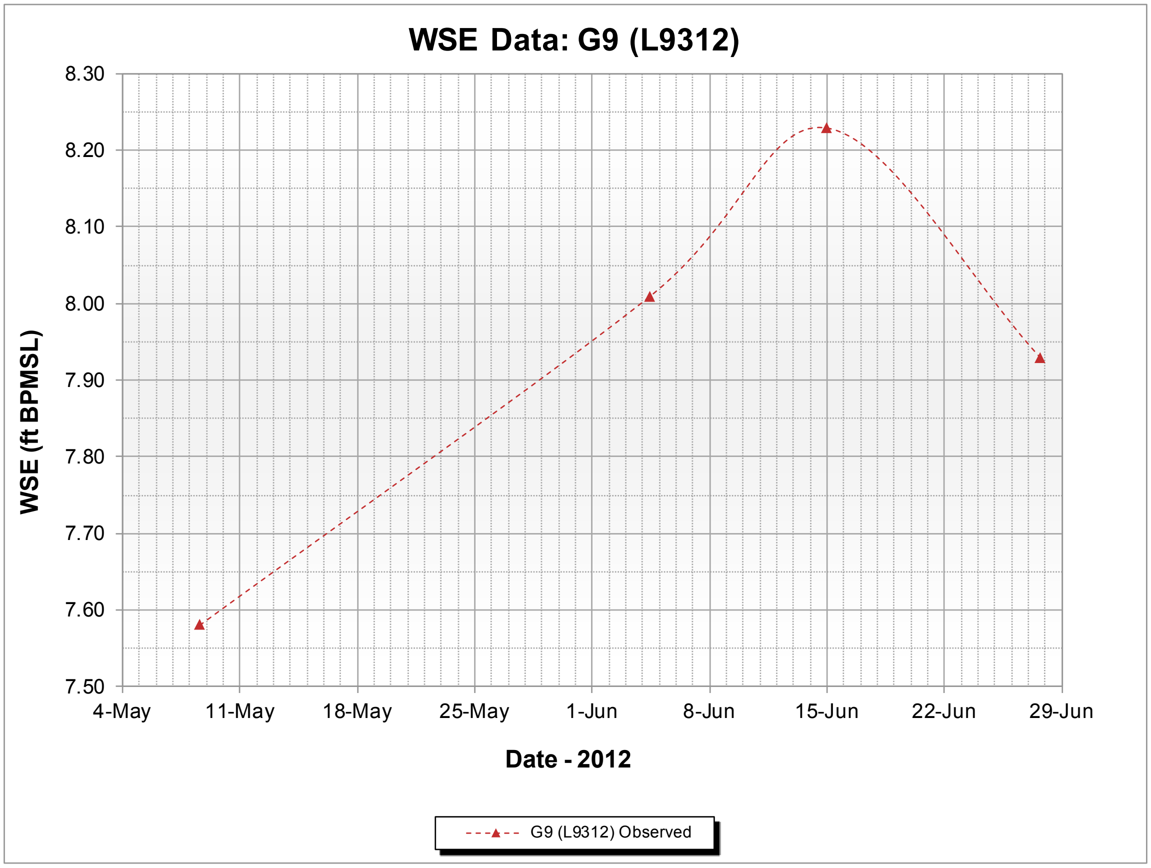
Photo 4.58: Lake L9312 recharged to bankfull conditions as the result of local melt though significant ice remains in lake, looking northeast; June 27, 2012

Table 4.15: Stage Data for G9 (Lake L9312)

Date and Time	WSE (feet BPMSL) G9 (L9312)	Observations
5/8/12 2:30 PM	7.58	Drill through lake ice and survey to WSE
5/25/12 12:00 AM	-	Lake still frozen
6/1/12 12:00 AM	-	Isolated; no flow in
6/4/12 10:20 AM	8.01	Limited local melt - significant snow
6/5/12 12:00 AM	-	No connectivity with other water bodies, lake still frozen with significant snow
6/15/12 12:00 AM	**8.23**	**Peak Stage at G9**; based on HWM - time estimated
6/27/12 5:46 PM	7.93	Recharge from lake catchment only, significant ice still present

Notes:

1. Elevations are based on TBM 02-01-39O of 11.517 feet BPMSL, updated by UMIAQ in 2012.
2. Gage 9 is a permanent staff gage surveyed for elevation by UMIAQ in May 2012.
3. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct.



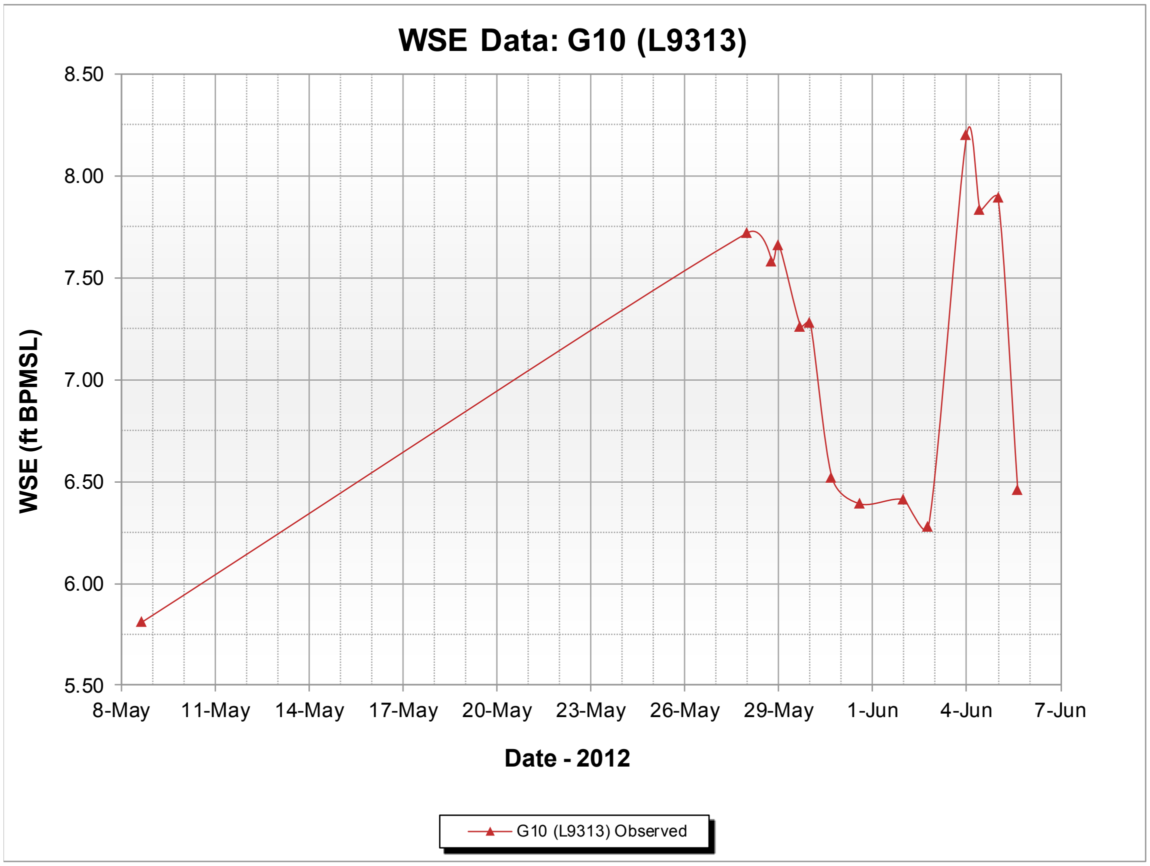
Graph 4.14: 2012 Stage Data for G9 (Lake L9312)

Table 4.16: Stage Data for G10 (Lake L9313)

Date and Time	WSE (feet BPMSL) G10 (L9313)	Observations
5/8/12 3:45 PM	5.81	Drill through lake ice and survey to WSE
5/27/12 12:00 AM	-	Local melt in the morning, flow in from M9525 in the evening; no H20 on gage
5/28/12 12:00 AM	7.72	HWM - time estimated
5/28/12 6:43 PM	7.58	
5/29/12 12:00 AM	7.66	HWM - time estimated
5/29/12 4:40 PM	7.26	
5/30/12 12:00 AM	7.28	HWM - time estimated
5/30/12 4:40 PM	6.52	
5/31/12 2:15 PM	6.39	
6/2/12 12:00 AM	6.41	HWM - time estimated
6/2/12 6:45 PM	6.28	No longer connected to M9525
6/4/12 12:00 AM	**8.20**	**Peak Stage at G10**; based on HWM - time estimated
6/4/12 10:20 AM	7.83	Again connected to M9525
6/5/12 12:00 AM	7.89	HWM - time estimated
6/5/12 3:05 PM	6.46	Stage decreasing, still connected to M9525; significant ice remains on lake

Notes:

1. Elevations are based on TBM L99-32-60 of 15.879 feet BPMSL, updated by UMIAQ in 2012.
2. Gage 10 is a permanent staff gage surveyed for elevation by UMIAQ in May 2012.



Graph 4.15: 2012 Stage Data for G10 (Lake L9313)

4.3.3 Erosion

The peak stage of floodwater passing by Alpine roads and facilities was relatively low in 2012 compared to historical records. No large ice floes were observed in the area. Breakup effect on gravel pads, roads, and drainage structures was negligible. Floodwater did not inundate any of the gravel embankments at the CD1, CD2, CD3, or CD4 pads.

The Alpine gravel pads and access roads were inspected for erosion before, during, and after breakup. Photographic documentation of the condition of the gravel facilities was first recorded on May 23, 2012.

On May 26, floodwater was observed around the CD2 road prism in the vicinity of the swale bridges (G3 and G4) and peaked on June 3. By June 3, floodwater had reached the remainder of the CD2 road prism (G6, G7, G12, and G13).

Following peak stage, visual inspections of the CD2 and CD4 gravel road prism were conducted. The HWM is indicated by erosion, debris stranded on the road prism side slopes, or where silts and fine-grained sands washed away. Photo 4.59 shows an example of fine-grained material washed away on the upstream side of the CD2 road near culvert CD2-23. Orange-topped lath were positioned into the road prism to better show the location and upper limit of erosion due to floodwater. The lath placed into the road prism was used to highlight erosion limits for photos and were removed after the photos were taken.

HWMs in the road prism were observed along the south side of the CD2 road as a result of floodwaters (Photo 4.60). Negligible erosion was observed along the CD2 road prism following peak stage of breakup floodwater (Photo 4.61 through Photo 4.63). Generally, erosion of the CD2 access road was limited to the upstream (south) side of the road prism in the vicinity of the swale bridges, and consisted of fine sediment removal. No floodwater damage to either swale bridge structure was observed.

Minimal floodwater reached the base of the CD4 gravel road prism in some areas and did not result in any noteworthy erosion. Photo 4.64 is a representative photo of the conditions observed along the CD4 gravel road prism post peak stage.

No indications of significant erosion due to breakup floodwater were observed on the Alpine gravel pads or facilities.

Photo 4.59: Minimal winnowing of fine-grained material on the south side of CD2 road; June 6, 2012

Photo 4.60: Lath defining the high water mark on the south side of CD2 road; June 6, 2012

Photo 4.61: Erosion survey of CD2 road prism post-breakup, looking east; June 6, 2012

Photo 4.62: Erosion survey CD2 road prism post-breakup, looking west; June 6, 2012

Photo 4.63: Erosion survey CD2 road post-breakup, between swale bridges, looking east; June 6, 2012

Photo 4.64: Erosion survey CD4 road prism post-breakup vicinity of CD4 pad, looking north; June 6, 2012

4.3.4 Ice Bridges

Ice road stream crossings are mechanically slotted by CPAI at the conclusion of the season to facilitate melt and the natural progression of breakup flooding. Ice bridge melt progressed smoothly throughout the breakup period at the East Channel and Kachemach River crossings; no significant erosion or scour was observed as a result of ice bridge interaction with breakup flooding.

The leading edge went by the Colville ice bridge on May 24. The majority of flow passed over the shallower west side; some water was present on the surface of the east side above the channel thalweg (Photo 4.65).

Melt had progressed little at the Colville ice bridge by May 27 when the first shallower peak stage occurred in the East Channel, and conditions were similar as stage subsequently decreased on May 30 prior to the lowest breakup stage.

On June 1, stage had once again risen in the East Channel and was sufficient to release the ice jam upstream of MON1. The Colville ice bridge broke up and moved downstream as floodwater and floes from the jam release passed leaving only the west and east ramps (Photo 4.66).

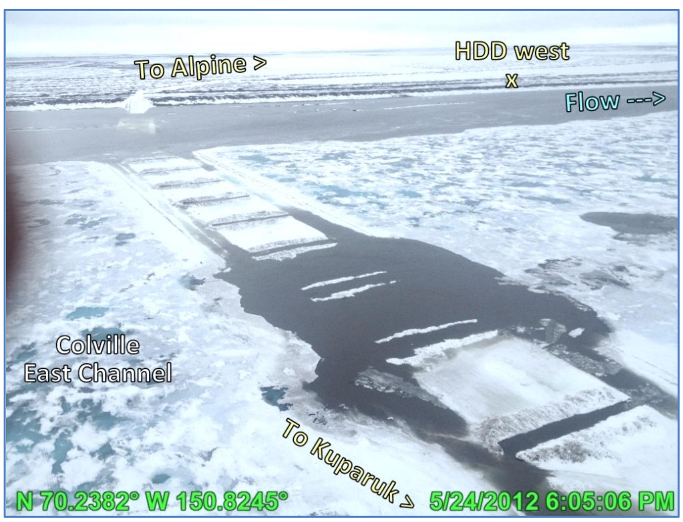


Photo 4.65: The leading edge in the East Channel passing the Colville ice bridge, looking west; May 24, 2012

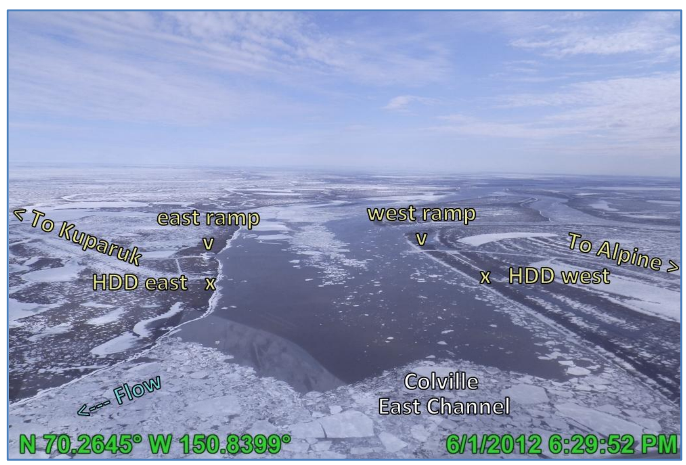


Photo 4.66: Colville ice bridge gone as jam release from upstream of MON1 passes through, looking upstream; June 1, 2012

Breakup progression at the Kachemach ice road crossing was slower than at the Colville. The leading edge in the Kachemach River passed by June 2 as low velocity flow moved downstream (Photo 4.67). A large amount of snow remained in the area.

Photo 4.68 and Photo 4.69 show the remains of the west and east ramps of the Colville ice bridge at the conclusion of breakup monitoring on June 7.

Breakup flooding and melt at all other ice road crossings in the CRD progressed unimpeded.

Photo 4.67: Low velocity flow passing Kachemach ice road crossing, looking downstream (north); June 2, 2012

Photo 4.68: Remains of Colville ice bridge – west ramp, looking upstream (southeast); June 7, 2012

Photo 4.69: Remains of Colville ice bridge – east ramp, looking downstream (northeast); June 7, 2012

4.4 CD3 Pipeline Crossings

Daily monitoring of the pipeline crossings began May 24. The leading edge entered all channels and was moving downstream past the gage locations by May 25. Flow quantities and velocities were low at each location (Photo 4.70, Photo 4.71, and Photo 4.72). Rafted ice floes suggest a more robust leading edge passed the TAM gages downstream of the pipe bridge (Photo 4.71). Measurable stage was not present at the TAM and ULAM gages until May 26 and at the SAK gages until May 27. Breakup flows at all CD3 pipeline crossing locations progressed without any effects to infrastructure. Stage data for all CD3 pipeline crossing gage locations is included in Table 4.17.

Stage at the CD3 pipeline crossing gages rose initially to a shallow peak, decreased, and rose again to a higher second peak before breakup recession. Ribbon ice remained in place along the north bank of all pipeline crossing locations during the first peak stage. The first peak stage occurred overnight between May 27 and 28 at TAM and ULAM, and on the morning of May 29 at SAK.

Stage decreased after the first peak at all locations and reached a spring breakup low on June 1 at TAM and ULAM, and on June 2 at SAK. Flow conditions at the pipeline crossings did not change significantly during low stage.

Peak stage at all three locations: 6.91 feet BPMSL at SAK, 7.26 feet BPMSL at TAM, and 6.01 feet BPMSL at ULAM, occurred on June 4. Ice remaining in the channel at the Sakoonang, Tamayayak, and Ulamnigiaq pipeline crossings cleared by June 5 following the higher second peak (Photo 4.73, Photo 4.74, and Photo 4.75).

Daily monitoring concluded at the CD3 pipeline crossing locations on June 7. Photo 4.76, Photo 4.77, and Photo 4.78 show the SAK, TAM, and ULAM sites as spring breakup stage recedes for the final time.

Photo 4.70: The leading edge in the Sakoonang moving downstream past the pipe bridge gages, looking downstream (northwest); May 25, 2012

Photo 4.71: Low velocity flow in the Tamayayak moving downstream past the pipe bridge gages, with rafted ice, looking upstream (east); May 25, 2012

Photo 4.72: Initial low velocity flow in the Ulamnigiaq moving downstream past the pipe bridge gages, looking upstream (southeast); May 25, 2012

Photo 4.73: After peak stage at SAK, looking upstream (east); June 5, 2012

Photo 4.74: After peak stage at TAM, looking north; June 5, 2012

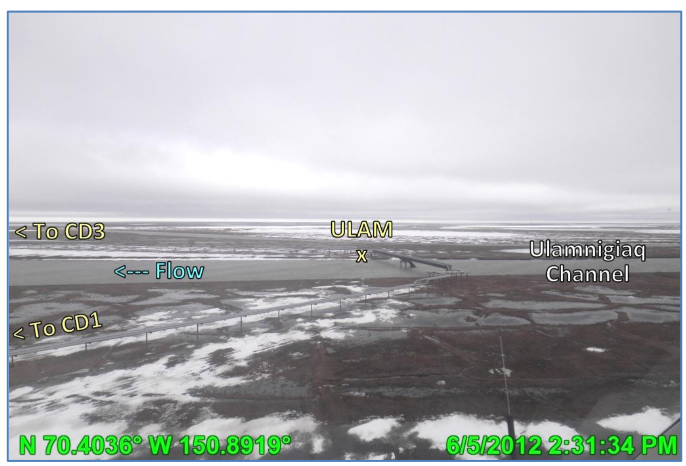


Photo 4.75: After peak stage at ULAM, looking north; June 5, 2012

Photo 4.76: Recession at SAK gages, looking northeast; June 7, 2012

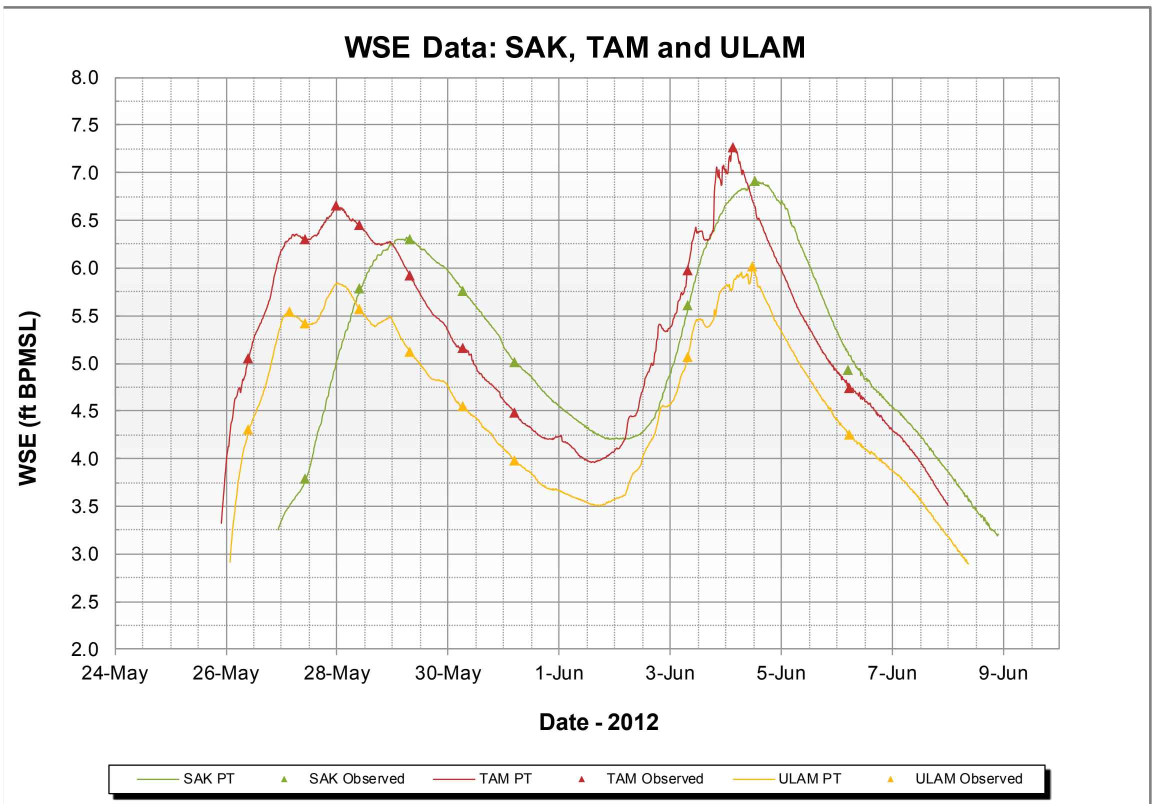
Photo 4.77: Recession at TAM gages, looking southeast; June 7, 2012

Photo 4.78: Recession at ULAM gages, looking northeast; June 7, 2012

Table 4.17: 2012 Stage Data for CD3 Pipeline Crossing Gages

Date and Time	WSE (feet BPMSL)			Observations
	SAK	TAM	ULAM	
5/26/12 10:00 AM	-	5.05	4.30	Leading edge at gages
5/27/12 3:45 AM	-	-	5.54	Time based on PT and HWM
5/27/12 10:15 AM	3.78	6.29	5.41	Ribbon ice in all channels; small ice jams at the mouths of both the Sakoonang and theTamayak channels
5/27/12 11:45 PM	-	6.65	-	Time based on PT and HWM
5/28/12 9:45 AM	5.78	6.44	5.57	
5/29/12 7:30 AM	6.30	5.92	5.12	
5/30/12 6:15 AM	5.76	5.15	4.54	
5/31/12 5:00 AM	5.01	4.48	3.97	
6/3/12 7:30 AM	5.60	5.97	5.06	Ribbon ice still in all channels; PT data suggests ice jams begin to release
6/4/12 3:00 AM	-	**7.26**	-	**Peak Stage at TAM**; based on PT and HWM
6/4/12 11:30 AM	-	-	**6.01**	**Peak Stage at ULAM**; based on PT and HWM
6/4/12 12:30 PM	**6.91**	-	-	**Peak Stage at SAK**; based on PT and HWM
6/6/12 5:30 PM	4.93	4.73	4.24	Open channels, no ice floes on banks

Notes:
1. SAK at Saknoonang (Pipe Bridge Crossing #2), TAM at Tamayayak (Pipe Bridge Crossing #4), ULAM at Ulamnigiak (Pipe Bridge Crossing #5)
2. Elevations for SAK are based on Pile 568 at 23.719 feet BPMSL, surveyed by UMIAQ in 2010; and CP08-11-12 at 7.365 surveyed by Baker in 2012.
3. Elevations for TAM are based on CP08-11-23 of 8.524 feet BPMSL, surveyed by UMIAQ in 2008.
4. Elevations for ULAM are based on CP08-11-35 of 9.146 feet BPMSL, surveyed by UMIAQ in 2008.



Graph 4.16: 2012 Stage Data for CD3 Pipeline Crossing Gages

4.5 Proposed CD5 Crossings

Daily stage monitoring at the proposed CD5 crossing locations began May 24 with the arrival of the leading edge in the Nigliq Channel and continued through June 7 with the final recession of breakup stage. The 2012 breakup process at locations along the proposed CD5 route was consistent with the other CRD monitoring locations. Breakup consisted of an initial low peak, recession, and a second peak of greater magnitude than the first. Overland flood flows did not reach CD5 gages installed in the floodplain between the Nigliq and the Nigliagvik: G30/G31, G34/G35, and G36/G37. Stage data tables are not included for these locations. Lake L9323 (G24/G25) experienced local melt and no overbank flow from the Nigliq. A drainage structure is proposed for this location. Table 4.18 contains WSE data for G24/G25 at Lake L9323. Stage data for G26/G27 and G28/G29 at the Nigliq, G32/G33 at Lake L9341, and G38/G39 at the Nigliagvik are presented in Table 4.19 through Table 4.21. These gages, located at the proposed CD5 crossings, experienced flood flow.

By May 25, water had passed and was measurable on all Nigliq gages (Photo 4.79). Initial flow was low, but ribbon ice upstream of the proposed bridge location (G28) at a sharp westward bend in the channel began to break up and raft (Photo 4.80). Flow entered the Nigliagvik at the upstream Nigliq bifurcation moving downstream and at the downstream confluence with the Nigliq moving upstream. No flow was in the vicinity of the gages.

Flow from the Nigliq entered Lake L9341 via the northeast paleochannel by May 26 (Photo 4.81). Water progressed further downstream and upstream (Photo 4.82) in the Nigliagvik and met at the gages where snow and ice remained.

By May 27, local melting had resulted in measureable water on Lake L9323 gages. All other CD5 crossing locations experienced an initial shallow peak on the morning of May 27, but the flow did not clear ice or snow. Flow was mostly confined in the active channel banks with the exception of the of the east overbank point bar between G28 and G26/G27 which was previously inundated. Rafted ice was present at G28. Stage differential between the Nigliagvik gages was shallow. Fluctuations in stage differential indicated no dominant upstream or downstream direction of flow.

Changes in ice and hydraulic connection conditions were minimal at all CD5 crossing locations as stage decreased after May 27. An overnight low occurred between May 31 and June 1.

As stage increased on June 1, a portion of the ribbon ice upstream of the Nigliq CD5 crossing broke up and jammed at the bend upstream of G28. A separate ice jam released at the head of the CRD and contributed ice floes to the jam in the Nigliq channel that had been in place since May 26. The ice jams and displacement of water by competent ribbon ice along the west bank resulted in east overbank flooding. The competent ribbon ice in the Nigliq channel extended downstream to the coast. Overbank flow from the Nigliq did not reach Lake L9323 (Photo 4.83).

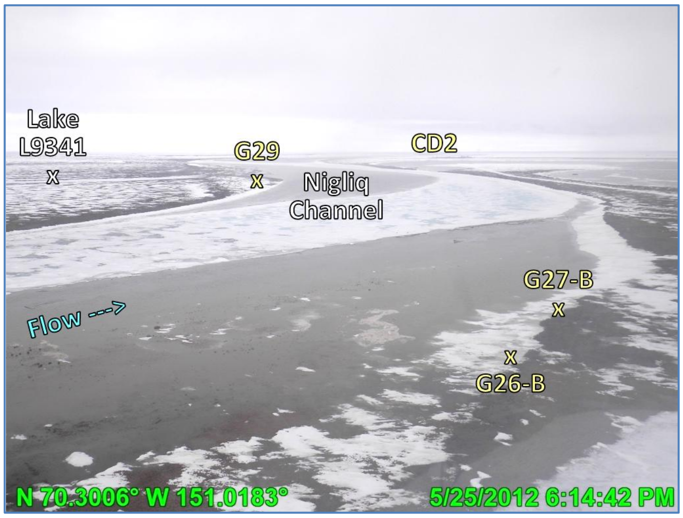


Photo 4.79: Initial flow passing the Nigliq bridge location, looking downstream (north); May 25, 2012

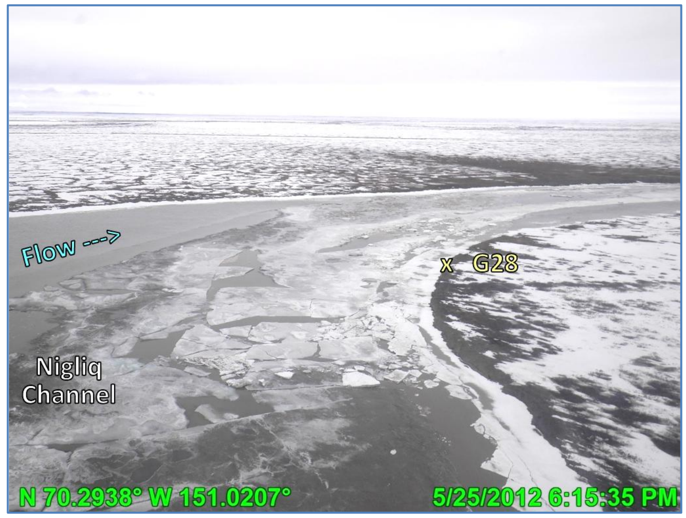


Photo 4.80: Rafted ice upstream of the Nigliq bridge location as initial flow moves through, looking west; May 25, 2012

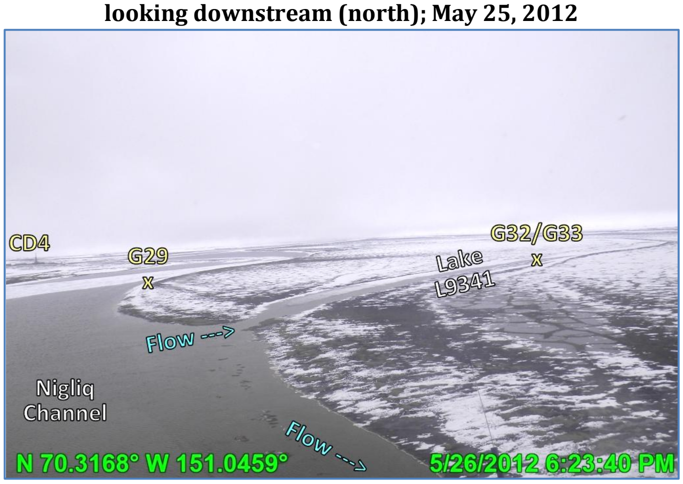


Photo 4.81: Initial flow into the northeast end of Lake L9341 from the Nigliq Channel, looking south; May 26, 2012

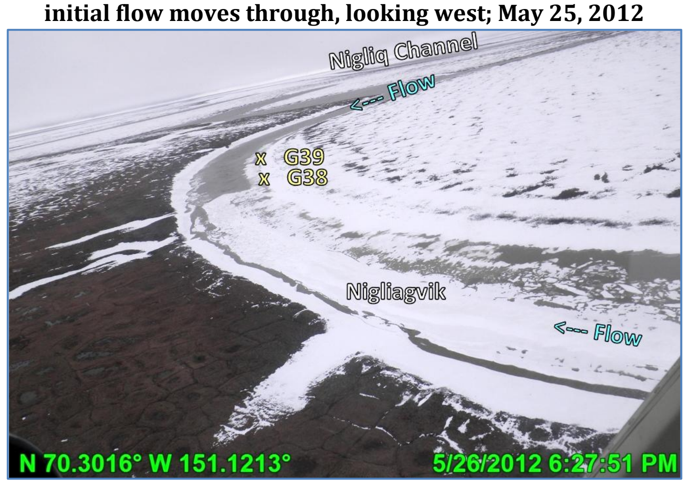


Photo 4.82: Initial flow approaching Nigliagvik crossing location from upstream, looking downstream (northeast); May 26, 2012

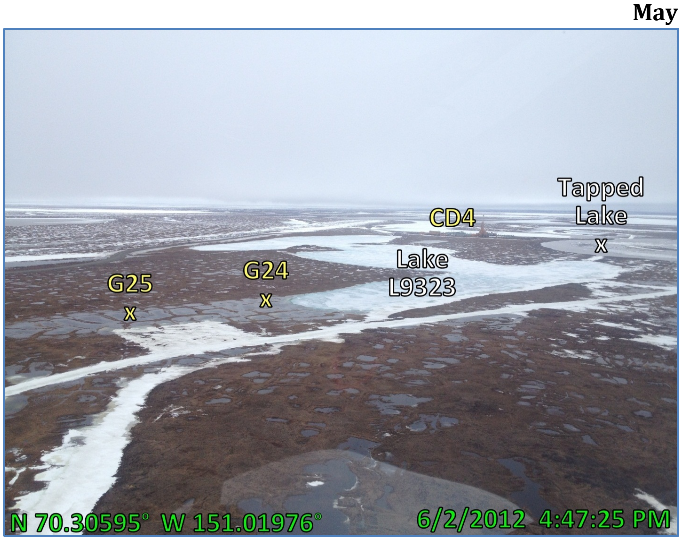


Photo 4.83: Stage was not high enough in the Nigliq during peak to overflow into Lake L9323 resulting in local melt only at crossing location, looking south; June 2, 2012

Stage peaked at the Nigliq bridge gages on the evening of June 2 (8.82 feet BPMSL at G26) coinciding with the estimated time of the upstream jam release. Photo 4.84, Photo 4.85, and Photo 4.86 show the upstream ice jam, bridge location reach, and ribbon ice downstream, respectively, in the Nigliq Channel on June 2 prior to peak. Primarily influenced by hydraulic connectivity with the Nigliq Channel at the northeast end, peak stage at Lake L9341 gages (8.92 feet BPMSL at G32) occurred late at night on June 2 (prior to peak in Photo 4.87).

Stage differential at the Nigliagvik gages prior to and during peak on the morning of June 3 (8.51 BPMSL at G38) indicated flow was somewhat dominant in the downstream direction. The differential was likely influenced by a backwater effect from the floes accumulated upstream of G38 (Photo 4.88). Ice from the June 1 Nigliq jam release was likely diverted down the Nigliagvik bifurcation creating the backwater effect.

Peak stage overnight between June 3 and June 4 at Lake L9323 gages (8.55 feet BPMSL at G24) was primarily the result of local melt. Ice still covered the majority of the lake.

Stage receded quickly after it peaked at all CD5 crossing locations. By June 4, the Nigliq Channel was clear of ribbon ice. Some floes were grounded along the banks. The overbanks were beginning to dry. The east point bank at G28 sheared because of flooding and ice conditions (Photo 4.89). Ice floes remained wedged fast against the bank (Photo 4.90).

Photo 4.84: Ice jamming upstream of the Nigliq bridge location, looking upstream (southeast); June 2, 2012

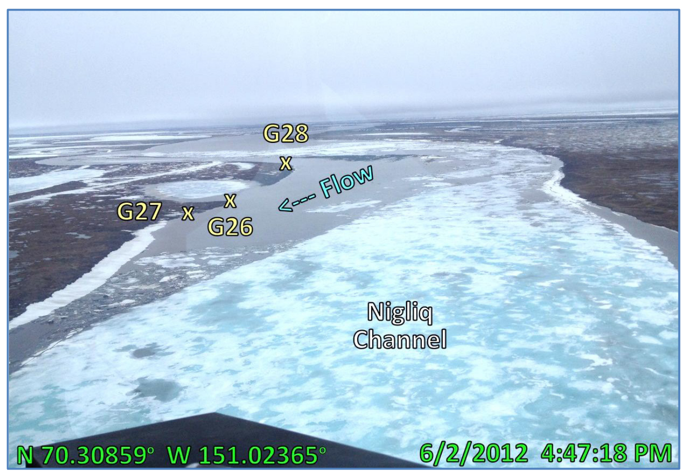


Photo 4.85: Nigliq bridge location just prior to peak, looking upstream (south); June 2, 2012

Photo 4.86: Channel ice rotting just prior to peak stage at the Nigliq bridge location, looking downstream (northeast); June 2, 2012

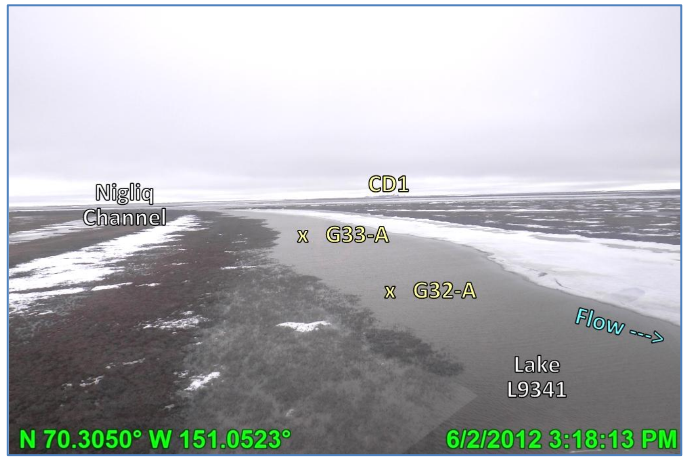


Photo 4.87: Lake L9341 crossing location prior to peak stage, looking east; June 2, 2012

Photo 4.88: Ice jamming in the Nigliagvik at the crossing location prior to peak stage, looking downstream; June 2, 2012

Photo 4.89: East bank of the Nigliq Channel upstream of the bridge location (G28) sheared off, looking upstream (south); June 4, 2012

Photo 4.90: Floes wedged against the east bank of the Nigliq Channel upstream of the bridge location (G28), looking downstream (northwest); June 4, 2012

Evidence of continued local melt was recorded in the west Nigliq floodplain gage locations (Photo 4.91 near G36/G37). Ice was no longer present in the channel at the Nigliagvik crossing location. Flow direction was still not dominant upstream or downstream and stage differential continued to be negligible.

Lake L9323 remained predominantly frozen by the conclusion of breakup monitoring on June 7. Limited melt water volume was draining from the east arm toward the CD4 access road. As stage continued to recede, the majority of flow was conveyed between the active channel banks through the proposed Nigliq bridge location reach (Photo 4.92).

Ice remained on the east bank of Lake L9341, and the hydraulic connection with the Nigliq Channel was maintained (Photo 4.93). Photo 4.94 shows the Nigliagvik crossing location on June 7 as stage continued to recede.

Photo 4.91: Local melt in the vicinity of G36/G37, looking northeast; June 4, 2012

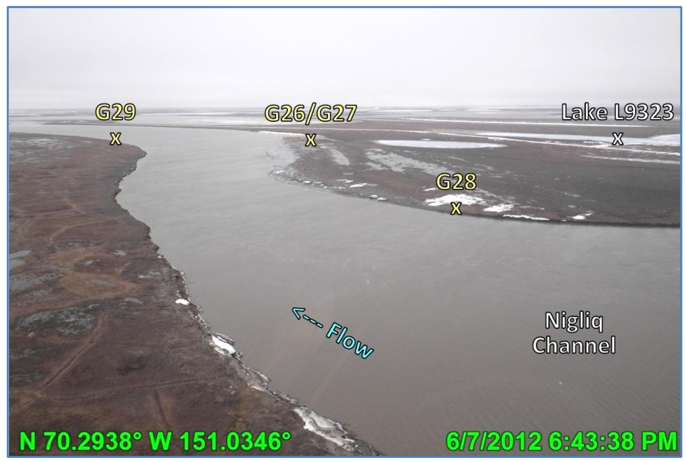


Photo 4.92: Stage receding at the Nigliq bridge location at the conclusion of breakup monitoring, looking downstream (northeast); June 7, 2012

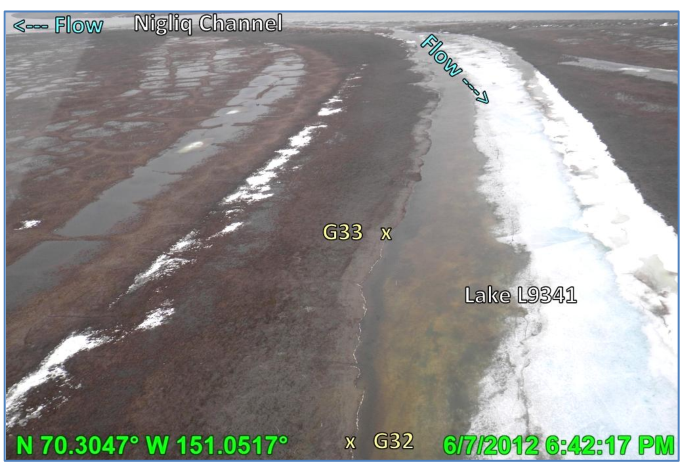


Photo 4.93: Stage receding at the Lake L9341 crossing location at the conclusion of breakup monitoring, looking northeast; June 7, 2012

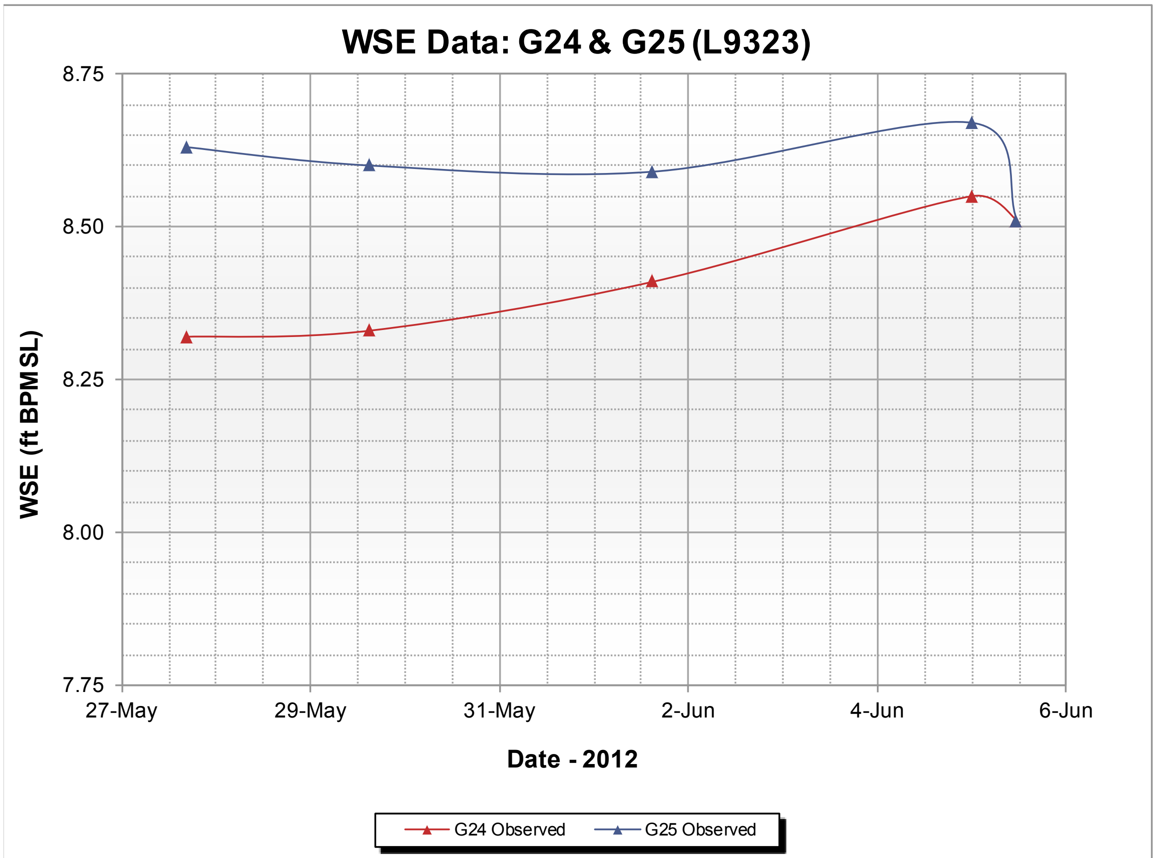
Photo 4.94: Stage receding at the Nigliagvik crossing location at the conclusion of breakup monitoring, looking downstream (northeast); June 7, 2012

Table 4.18: Stage Data for Proposed CD5 Crossing - Lake L9323 (G24/G25)

Date and Time	WSE (feet BPMSL) G24	WSE (feet BPMSL) G25	Observations
5/27/12 4:50 PM	8.32	8.63	Local melt only
5/29/12 3:10 PM	8.33	8.60	Local melt - lake frozen
6/1/12 3:00 PM	8.41	8.59	Local melt - lake still frozen, no flow in or out
6/3/12 7:30 PM	-	-	Limited flow into drainage from CD4 road culvert to SE, potential limited flow into drainage from M9525
6/5/12 12:00 AM	**8.55**	**8.67**	**Peak Stage at G24 and G25**; based on HWM - time estimated
6/5/12 11:30 AM	8.51	8.51	
6/6/12 11:05 AM	-	-	Limited drainage out of lake toward M9525, significant ice remains on lake

Notes:

1. Elevations are based on CP08-11-52A at 9.935 feet BPMSL, surveyed by UMIAQ in 2012.
2. Gage readings were not taken on May 30-31 (helicopter mechanical issues) or June 3 (MON1 discharge).



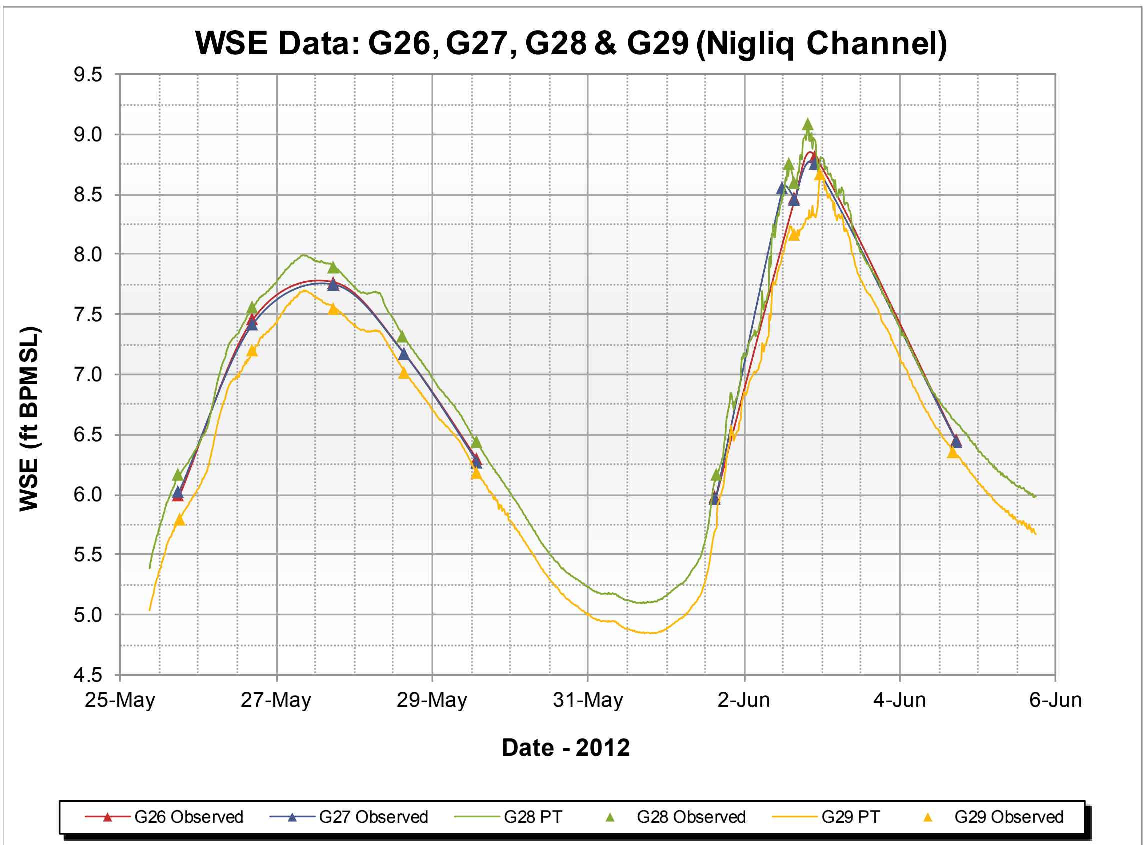
Graph 4.17: 2012 Stage Data for Proposed CD5 Crossing - Lake L9323 (G24/G25)

Table 4.19: Stage Data for Proposed CD5 Crossing – Nigliq Bridge (G26/G27 & G28/G29)

Date and Time	WSE (feet BPMSL)				Observations
	G26	G27	G28	G29	
5/24/12 1:40 PM	-	-	2.04	-	Leading edge arrives
5/25/12 6:15 PM	5.99	6.03	6.16	5.80	Flow inundates E overbank due to channel ice through thalweg along W ba
5/26/12 4:45 PM	7.46	7.42	7.56	7.20	Ice jam in upstream Nigliq Channel adjacent to Nuiqsut
5/27/12 5:45 PM	7.77	7.75	7.89	7.55	Competent ribbon ice through reach
5/28/12 3:30 PM	7.18	7.17	7.31	7.02	
5/29/12 2:00 PM	6.29	6.27	6.43	6.18	
6/1/12 3:15 PM	5.98	5.97	6.16	-	
6/2/12 12:00 PM	-	8.56	-	-	HWM - time estimated
6/2/12 2:00 PM	-	-	8.75	-	Upstream ice jam adjacent to Nuiqsut released and reformed upstream adjacent to CD4, significant E overbank flooding; channel ice through reach rafting
6/2/12 3:45 PM	8.47	8.46	8.59	8.17	
6/2/12 7:45 PM		-	**9.09**	-	**Peak Stage at G28**; based on G28PT and HWM
6/2/12 9:45 PM	**8.82**	**8.75**	-	-	**Peak Stage at G26 and G27**; based on G28/G29PT and HWM - time estima
6/2/12 11:45 PM	-	-	-	**8.67**	**Peak Stage at G29**; based on G29PT and HWM
6/4/12 5:00 PM	6.45	6.44	-	6.36	Reach clear of ice, E bank sheared with grounded floes

Notes:

1. Elevations at G26 and G27 are based on CP08-11-53A at 8.075 feet BPMSL, surveyed by UMIAQ in 2012.
2. Elevations at G28 are based on Baker TBM 2010 at 11.380 feet BPMSL, surveyed by Baker in 2011.
3. Elevations at G29 are based on CP08-11-60B at 9.859 feet BPMSL, surveyed by UMIAQ in 2012.
4. From the proposed Nigliq bridge centerline: G28 is farthest upstream, G26 is adjacent upstream, G27 is adjacent dow nstream, and G29 is farthest dow nstream.
5. Gage readings w ere not taken on May 30-31 (helicopter mechanical issues) or June 3 (MON1 discharge).

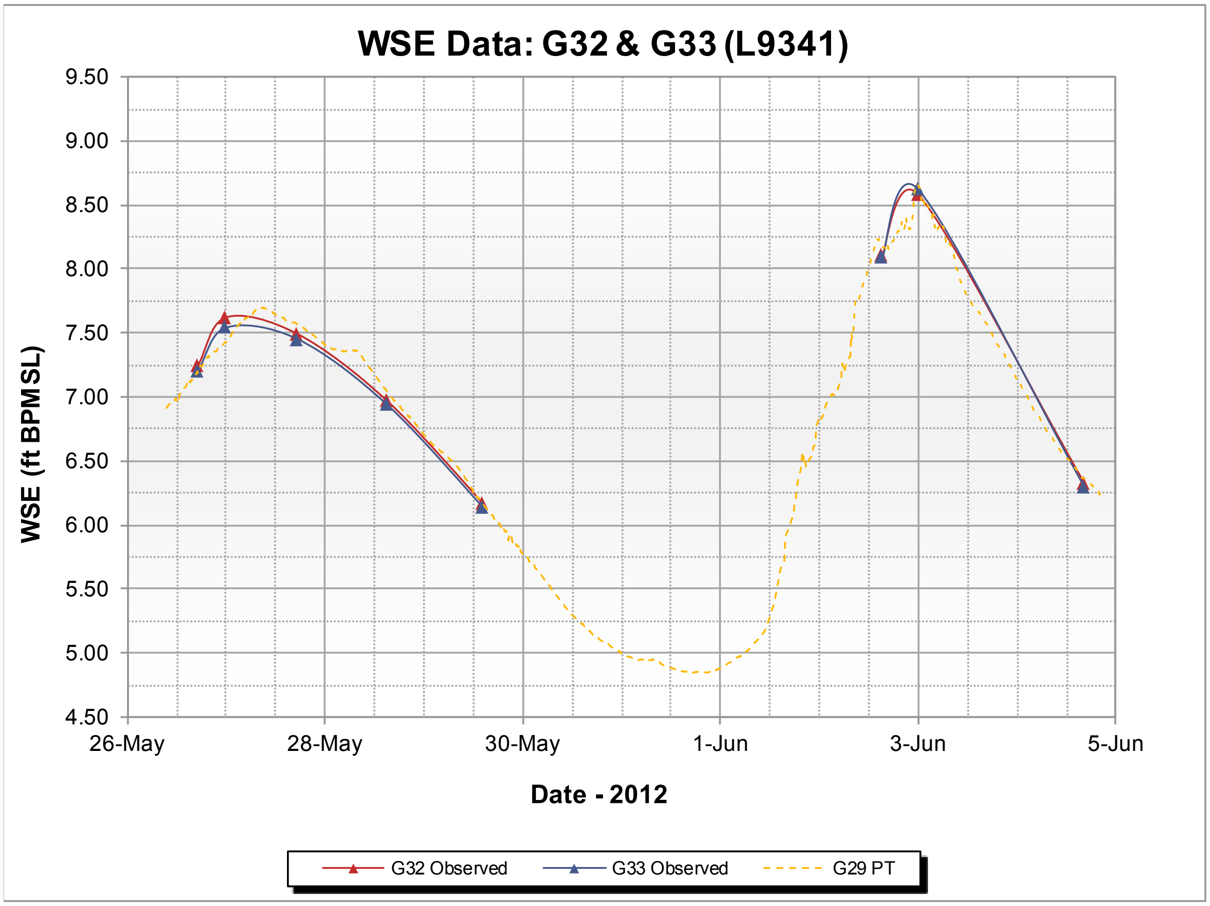


Graph 4.18: 2012 Stage Data for Proposed CD5 Crossing – Nigliq Bridge (G26/G27 & G28/G29)

Table 4.20: Stage Data for Proposed CD5 Crossing - Lake L9341 (G32/G33)

Date and Time	WSE (feet BPMSL)		Observations
	G32	G33	
5/26/12 5:05 PM	7.24	7.20	Flow entering NE end of lake only via Nigliq
5/27/12 12:00 AM	7.62	7.54	HWM - time estimated
5/27/12 5:20 PM	7.49	7.45	
5/28/12 3:00 PM	6.97	6.94	Still connected with Nigliq Channel NE end
5/29/12 2:15 PM	6.17	6.14	
6/2/12 3:20 PM	8.11	8.09	
6/3/12 12:00 AM	**8.58**	**8.62**	**Peak Stage at G32 and G33**; based on G29PT and HWM
6/4/12 4:15 PM	6.33	6.30	Still connected with Nigliq Channel NE end

Notes:
1. Elevations are based on CP08-11-60C at 10.541 feet BPMSL, surveyed by UMIAQ in 2012.
2. Gage readings were not taken on May 30, May 31-June 1 (helicopter mechanical issues) or June 3 (MON1 discharge).

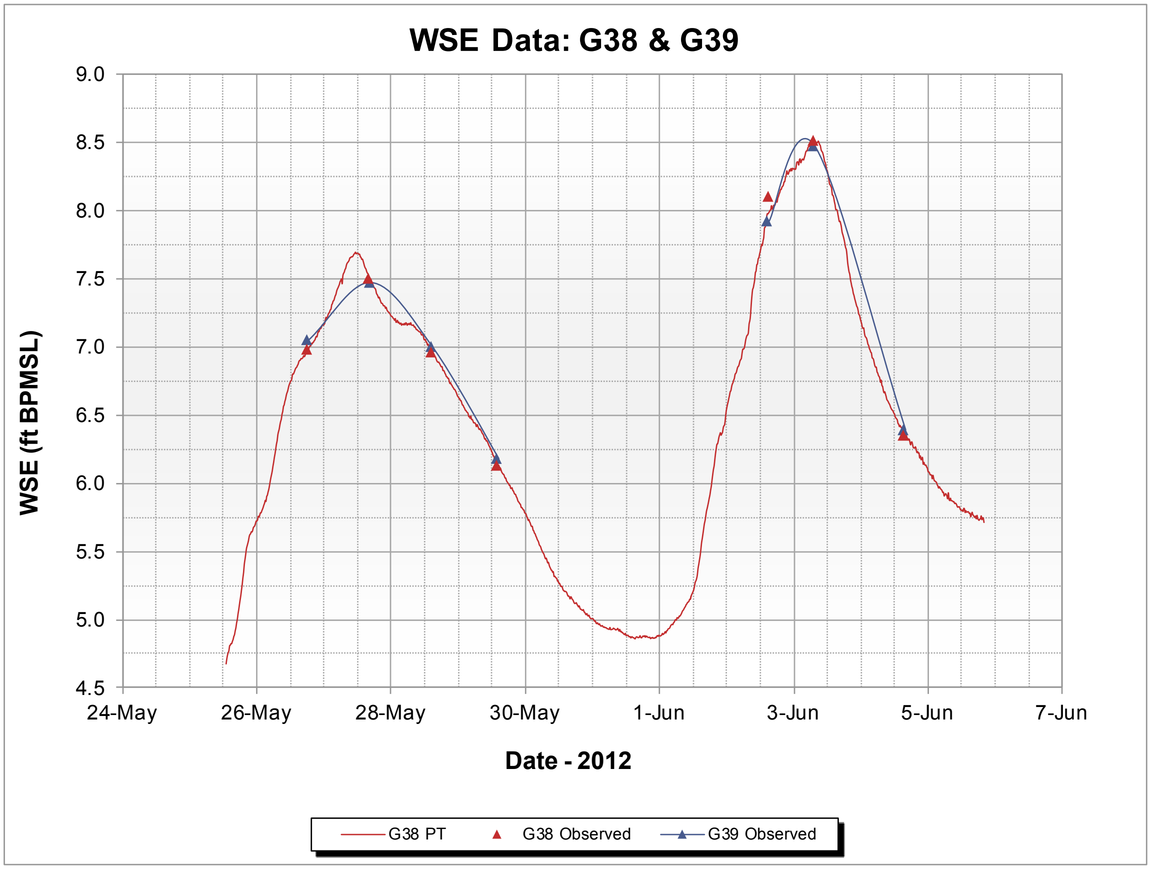


Graph 4.19: 2012 Stage Data for Proposed CD5 Crossing - Lake L9341 (G32/G33)

Table 4.21: Stage Data for Proposed CD5 Crossing - Nigliagvik (G38/G39)

Date and Time	WSE (feet BPMSL)		Observations
	G38	G39	
5/25/12 12:00 PM	-	-	Flow into channel from both N and S ends, not yet meeting at gages
5/26/12 6:30 PM	6.98	7.05	Low velocity flow from N and S just meeting at gages, significant ice/snow in channel in vicinity
5/27/12 4:25 PM	7.50	7.47	
5/28/12 2:45 PM	6.96	7.00	
5/29/12 2:25 PM	6.13	6.18	
6/2/12 3:10 PM	8.10	7.92	Small ice jam upstream of G38
6/3/12 7:30 AM	**8.51**	**8.47**	**Peak Stage at G38 and G39**; based on G38PT and HWM
6/4/12 4:00 PM	6.35	6.39	Open channel; stage decreasing significantly

Notes:
1. Elevations are based on CP08-11-66C at 10.674 feet BPMSL, surveyed by UMIAQ in 2012.
2. Gage readings were not taken on May 30, May 31-June 1 (helicopter mechanical issues) or June 3 (MON1 discharge).



Graph 4.20: Stage Data for Proposed CD5 Crossing - Nigliagvik (G38/G39)

5.0 2012 DISCHARGE AND STATISTICAL ANALYSIS

Direct discharge measurements were made at the long swale bridge, short swale bridge, and the CD2 and CD4 access road culverts. Indirect calculations were performed for the following locations:

- MON1
- MON9
- MON23
- Proposed CD5 crossing locations at the Nigliq Channel (G28/G29),Lake L9341, and the Nigliagvik (G38/G39)
- Short and long swale bridges
- CD2 road culverts near gages G3/G4, G12/G13, G6/G7
- CD4 road culverts near gage G15/G16 and G17/G18

In open channel conditions, peak discharge typically occurs at the same time as peak stage. This is not always the case in the arctic which experiences major annual flooding during spring breakup. Flow is affected by ice and snow conditions. Ice-affected channels often produce backwater effects and can temporarily inflate stage, or can reduce stage and velocity to quantities not representative of actual discharge.

5.1 MON1 Discharge

5.1.1 Direct Discharge

Photo 5.1: Crew preparing to perform a direct discharge measurement at MON1 with the ADCP; June 3, 2012

Direct discharge measurements were attempted on the Colville River at MON1 using an ADCP. Timing the direct discharge measurements with the peak stage provides valuable data that can be used for comparison with indirect calculations and historical measurements. A variety of factors impacted direct discharge attempts for 2012 and no direct discharge measurements were obtained. The June 3, 2012 direct discharge effort was initiated, but not completed due to available time and helicopter logistics. Once initiated, the ADCP direct discharge measurements must be completed within a short timeframe to be considered valid. Photo 5.1 shows the Baker field crew preparing to perform direct discharge. Inclement weather, including fog and high winds, prevented the field crew from attempting a second measurement the following day. Strong winds and waves raised safety concerns and would have had an adverse effect on the data. Weather was suitable only after flow had receded and peak stage was over.

5.1.1 Indirect Discharge

The slope-area method for a uniform channel (UC) and non-uniform channel (NUC) was used to calculate the indirect discharge at MON1. Indirect discharge is calculated using the following: 1) energy grade-line slope approximated using the water surface slope as measured by the gages and pressure transducers at MON1U, MON1C, and MON1D; 2) WSE at MON1C at the time of estimated peak discharge; and 3) 2004 topographic survey data provided by LCMF (Figure 5.1). Changes in the bedform geometry are likely to have occurred since 2004 cross sections were surveyed. This can introduce error and can skew indirect discharge calculations. The accuracy of future indirect discharge values would benefit from updated topographic surveys. The channel bed morphology and cross sections have likely changed in the 8 years since this data was last collected.

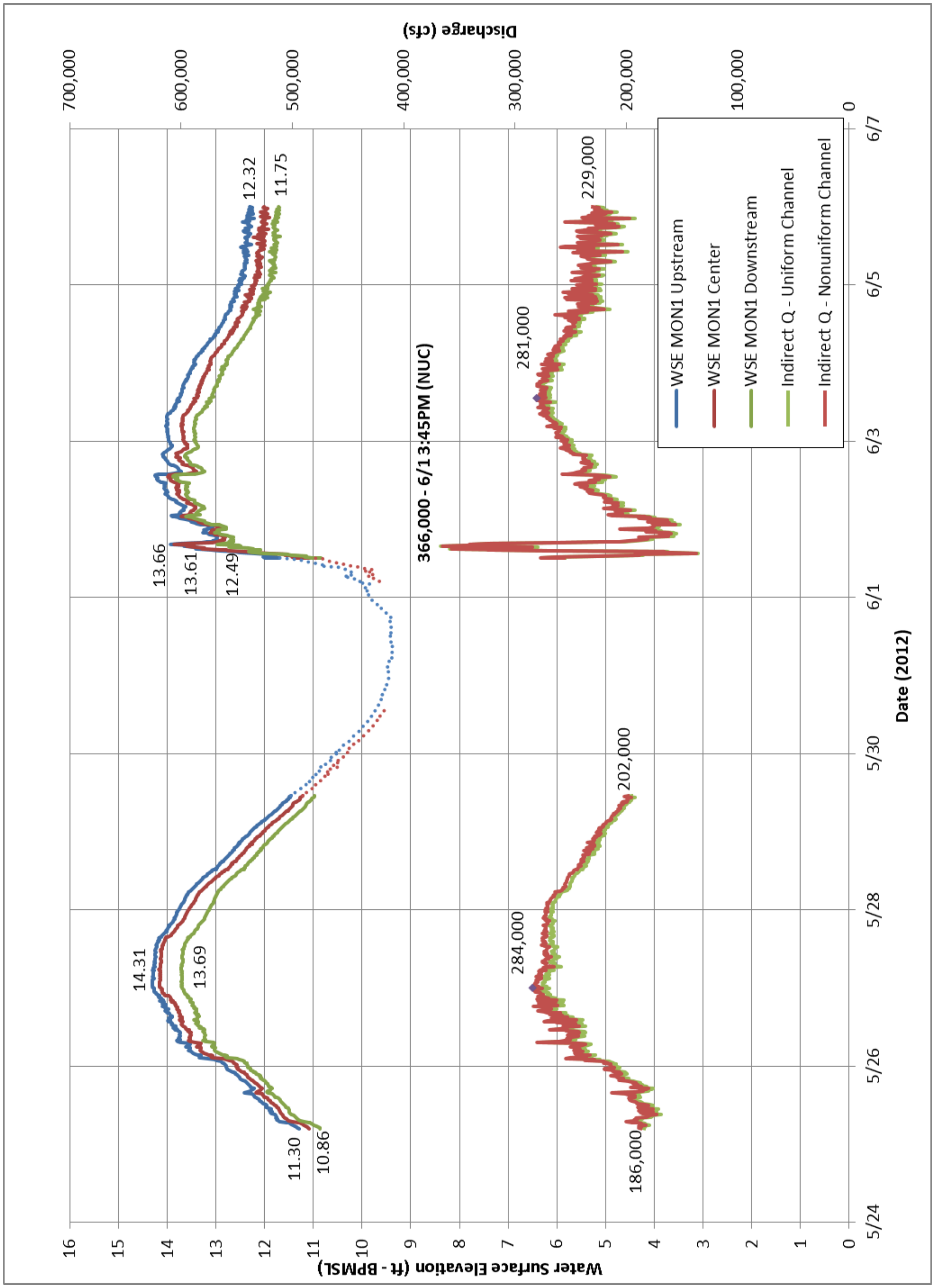
The most accurate peak indirect discharge values are calculated at or near peak stage with a relatively ice-free channel and current-year channel topographic cross sections. These reflect ideal open channel conditions. Discharge in the CRD during spring breakup is typically ice affected (Photo 5.2 and Photo 5.3), causing separation between peak stage and peak discharge. For 2012, the peak stage and the peak discharge were separated by 6 days. Peak stage occurred May 27 (14.18 feet BPMSL) and peak discharge occurred June 1 (366,000 cfs).

Photo 5.2: Ice jam upstream of MON1, looking upstream (south); May 30, 2012

Photo 5.3: Floes in the Colville River passing MON1 after an upstream ice jam release, looking upstream (south); June 1, 2012

Both UC and NUC methods were used to calculate discharge to determine an accurate value of the peak discharge surge that occurred as stage was rising again on June 1. Both methods are considered to yield conservative results and are performed assuming an ice-free channel. Graph 5.1 presents the UC and NUC method discharge results plotted versus time. The WSE recorded by the PTs at 15-minute intervals for the three MON1 locations are included as a reference. The gap in discharge values from May 29 to June 1 is because of stage dropping below the PTs at MON1C and MON1D.

The peak UC and NUC discharge occurred June 1 at approximately 3:45 PM, with a stage of 13.61 feet BPMSL at MON1C. The difference in the methods was less than 1%. Averaging the maximum values for both methods results in a peak discharge at MON1 of 366,000 cfs.



Graph 5.1: 2012 MON1 WSE and Indirect Discharge

ConocoPhillips Alaska

Miles
0 0.25 0.5

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.1
Checked:	HLR/SME	Scale:	1 in = .5 miles

Legend

- Gage Locations
- 2004 Cross Section Alignment

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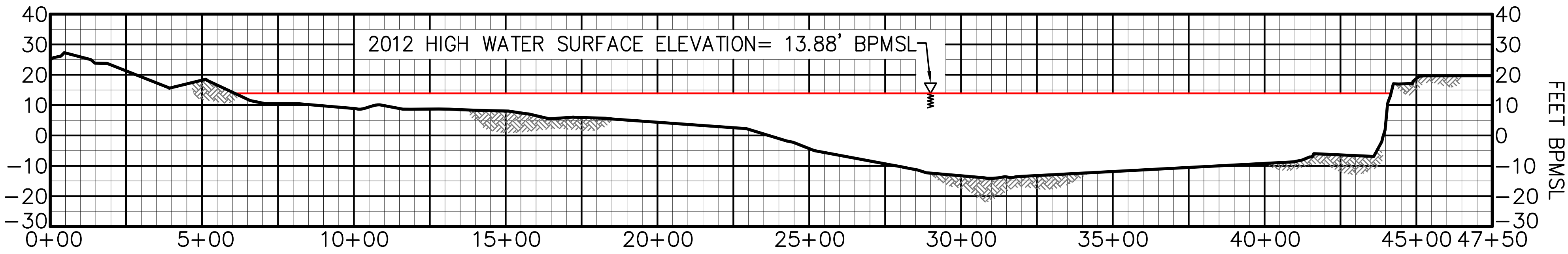
2012 SPRING BREAKUP
MONUMENT 1
PLAN

FIGURE: 5.1

(SHEET 1 of 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)



(1D) COLVILLE RIVER CROSS SECTION AT MONUMENT 1 DOWNSTREAM

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE: 10/1/12	PROJECT: 127841
DRAWN: KRH	FILE: FIGURE 5.1_2.DWG
CHECKED: HLR	SCALE: AS SHOWN

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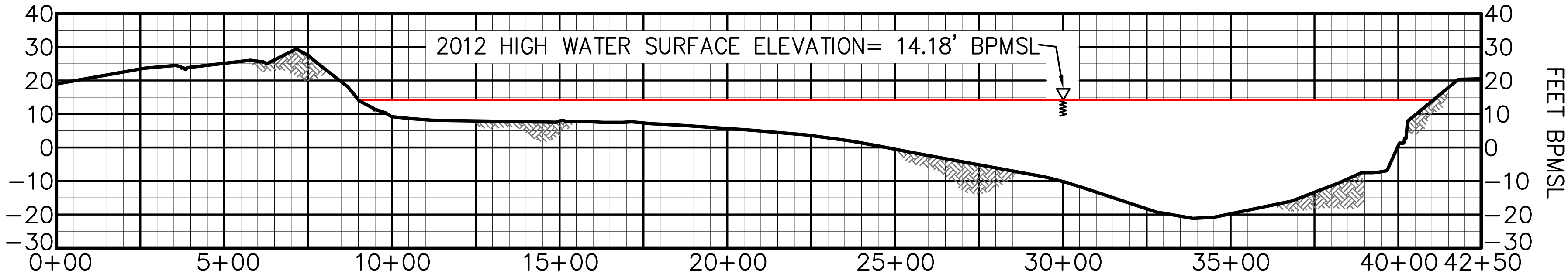
2012 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
DOWNSTREAM CROSS SECTION
FIGURE 5.1
(SHEET 2 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)



1C COLVILLE RIVER CROSS SECTION AT MONUMENT 1 CENTERLINE

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.1_3.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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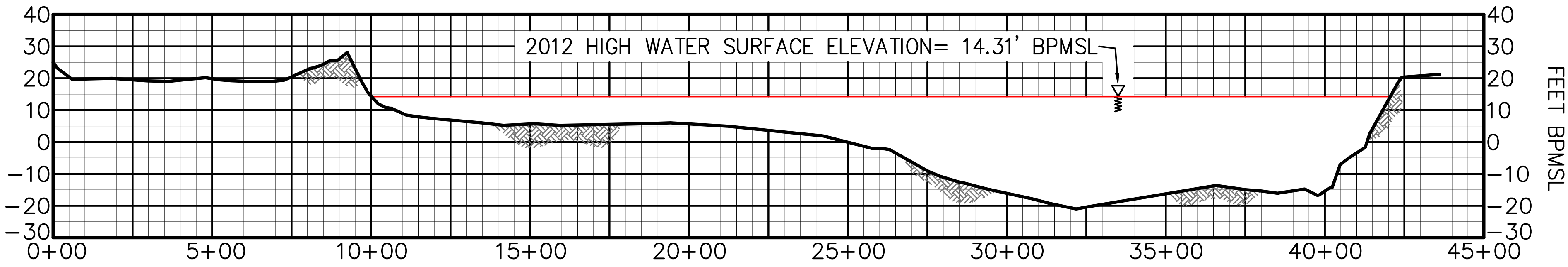
2012 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
CENTERLINE CROSS SECTION

FIGURE 5.1
(SHEET 3 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT 1.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY UMIAQ (KUUKPIK/LCMF INC.)



1U COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE: 10/1/12	PROJECT: 127841
DRAWN: KRH	FILE: FIGURE 5.1_4.DWG
CHECKED: HLR	SCALE: AS SHOWN

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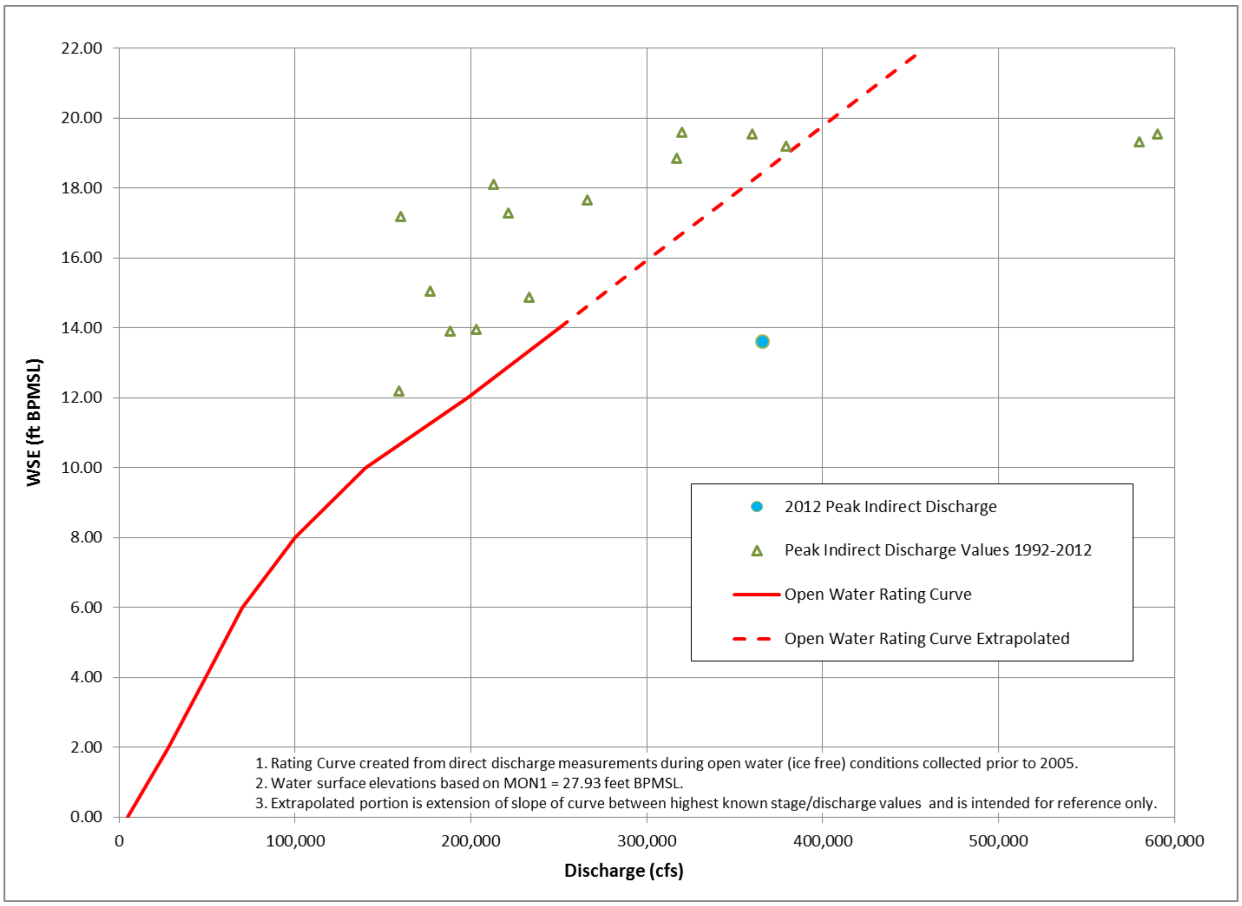
2012 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
UPSTREAM CROSS SECTION
FIGURE 5.1
(SHEET 4 OF 4)

The MON1 stage-discharge rating curve, provided in Graph 5.2, represents a comparison between known stage and peak indirect discharge measurements collected between 1992 and 2012. It was calculated using ice-free conditions. These values generally represent the relationship between stage and discharge at lower stage values when ice-free direct discharge measurements are possible. The stage-discharge rating curve may be used as a basis of comparison for accuracy of indirect discharge calculated values. The limitations of this curve are the ice effects on stage and discharge, common during peak-flow periods. Open-water conditions rarely occur at or near recorded historical peak stage levels during breakup. The 2012 peak discharge of 366,000 cfs at 13.61 feet BPMSL falls to the right of the rating curve which is typical of values that tend to result from an upstream ice jam release. Conversely, values that fall to the left of the rating curve tend to be the result of downstream ice jam backwater effects.



Graph 5.2: MON1 Stage-Discharge Rating Curve with 2012 and Historical Peak Discharge Values

To plot the 2012 stage-discharge values to the rating curve in Graph 5.2, the rating curve was extrapolated beyond known values for lower stage-discharge periods. For the purpose of extrapolation, the slope is based on the highest known values. This section of the curve is used for general reference.

5.2 MON9 Discharge

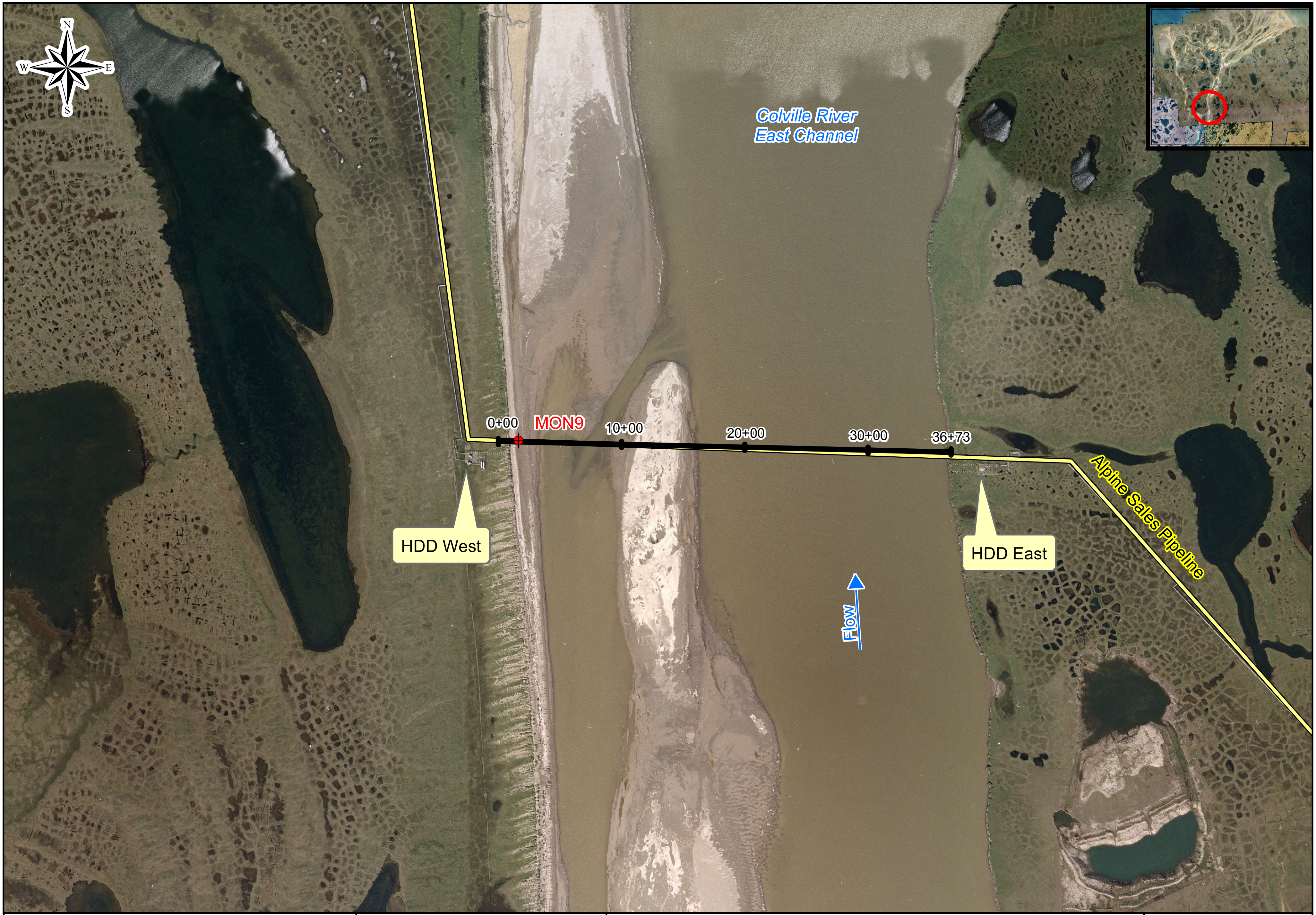
The slope-area method was used to calculate the indirect discharge at MON9. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from MON9 or MON9-PT to a pressure transducer MON9D-PT, WSE at MON9, and the 2009 LCMF topographic channel cross sectional survey.

The location and cross section of the area is presented in Figure 5.2. Indirect discharge calculations were performed assuming an ice-free channel. The discharge values are considered a conservative estimate, because of the likelihood of persistent bottom-fast ice remaining in-channel and changes to the channel bed from sediment transport.

The 2012 indirect results at MON9 are influenced by ice events in the East Channel. The events include the release of an ice jam upstream of MON1, its re-formation downstream of MON9 (Photo 5.4), and the subsequent release.

Peak discharge at MON9 did not occur simultaneously with peak stage because of ice effects. Peak discharge, calculated to be 346,000 cfs based on PT data, occurred around midnight on June 2 with a corresponding WSE of 12.24 feet BPMSL. This was approximately 12 hours prior to peak stage at this location.

Photo 5.4: Ice jam forming downstream of MON9 prior to peak, looking upstream (south); June 1, 2012



ConocoPhillips Alaska

Feet
0 500 1,000

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.2
Checked:	HLR/SME	Scale:	1 in = 1000 feet

Legend

Gage Location

2009 Cross Section Alignment

Pipeline

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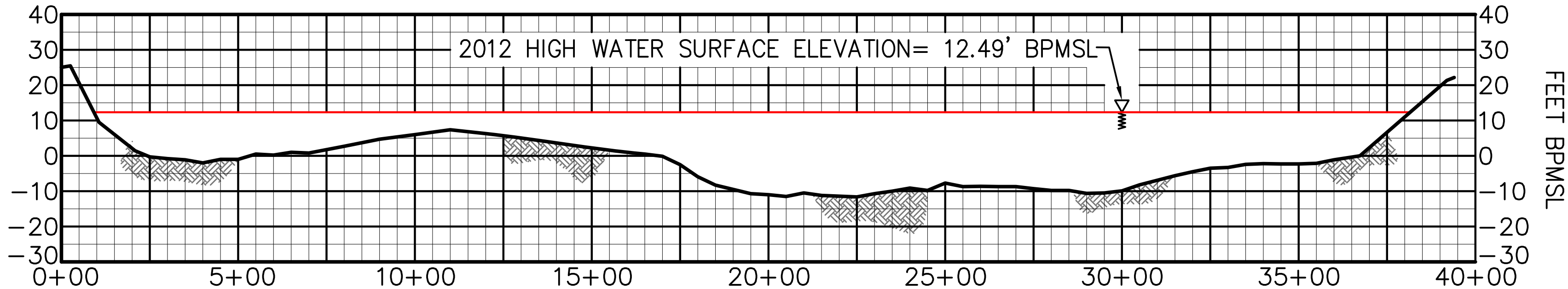
2012 SPRING BREAKUP
Monument 9/HDD
PLAN

FIGURE: 5.2

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, MONUMENT 9.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED NOVEMBER 2009 BY UMIAQ (KUUKPIK/LCMF INC.)



1 COLVILLE EAST CHANNEL CROSS SECTION AT MONUMENT 9

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.2_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2012 SPRING BREAKUP
COLVILLE EAST CHANNEL
MONUMENT 9 CROSS SECTION

FIGURE 5.2
(SHEET 2 OF 2)

5.3 MON23 Discharge

The slope-area method was used to calculate the indirect discharge at MON23. The discharge was calculated using the energy grade-line slope as approximated by the water surface slope from MON22 to MON23, the WSE at MON22, and the 2005 LCMF topographic channel cross sectional survey. The location and cross section of the area is presented in Figure 5.3. Based on the age of the channel survey and likelihood of changes to bedform geometry, the accuracy of indirect discharge calculations at MON23 would be benefit from an updated survey.

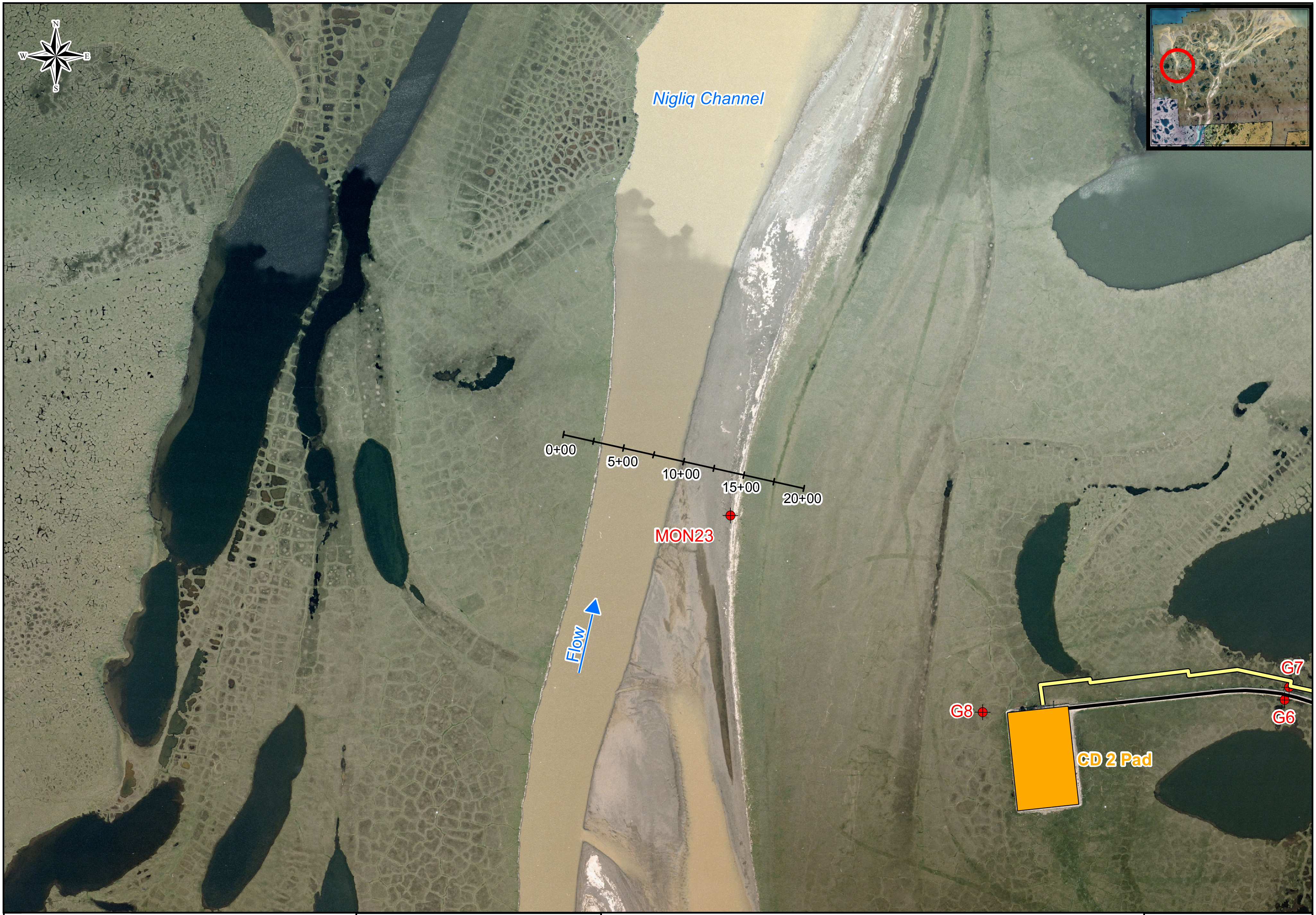
Indirect discharge calculations are performed assuming an ice-free channel and are considered a conservative estimate. Discharge calculations at MON23 in the Nigliq Channel during the 2012 breakup were influenced by ice, which is typical throughout the spring breakup flooding period. Channel ice in the Nigliq can be seen in Photo 4.26.

Peak stage occurred at MON23 on the morning of June 3 (7.52 feet BPMSL). Rising stage, along with significant ribbon ice observed in the channel from May 25 to June 2, contributed to ice jam and release events as ice moved downstream. Channel ice and ice jam activity will affect indirect discharge calculations. The Nigliq Channel became largely ice free around June 4.

Peak discharge occurred prior to peak stage. Peak discharge at MON23 was estimated to have occurred on the afternoon of June 2 with a magnitude of 58,000 cfs. The historical record of peak discharge at MON23 is presented in Table 5.1.

Table 5.1: Nigliq Channel Breakup Peak Annual Discharge and Stage (2005-2012)

Year	Monument 23 Peak Discharge (cfs)			Monument 23 Peak Water Surface Elevation (feet - BPMSL)	
	Discharge	Method	Reference	MON23	Reference
2012	58,000	Indirect Calculation	This Report	7.52	This Report
2011	65,000	Indirect Calculation	Baker 2011	8.15	Baker 2012
2010	65,000	Indirect Calculation	Baker 2010	7.77	Baker 2010
2009	59,000	Indirect Calculation	Baker 2009	7.09	Baker 2009b
2008	21,500	Indirect Calculation	Baker 2008	5.79	Baker 2008
2007	73,500	Indirect Calculation	Baker 2007b	7.63	Baker 2007b
2006	68,000	Indirect Calculation	Baker 2007a	8.99	Baker 2007a
2005	29,000	ADCP Measurement	Baker 2005b	5.95	Baker 2005b



ConocoPhillips Alaska

Feet
0 500 1,000

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.3
Checked:	HLR/SME	Scale:	1 in = 1000 feet

Legend
- Gage Locations
- 2005 Cross Section Alignment
- Pipelines
- Facilities

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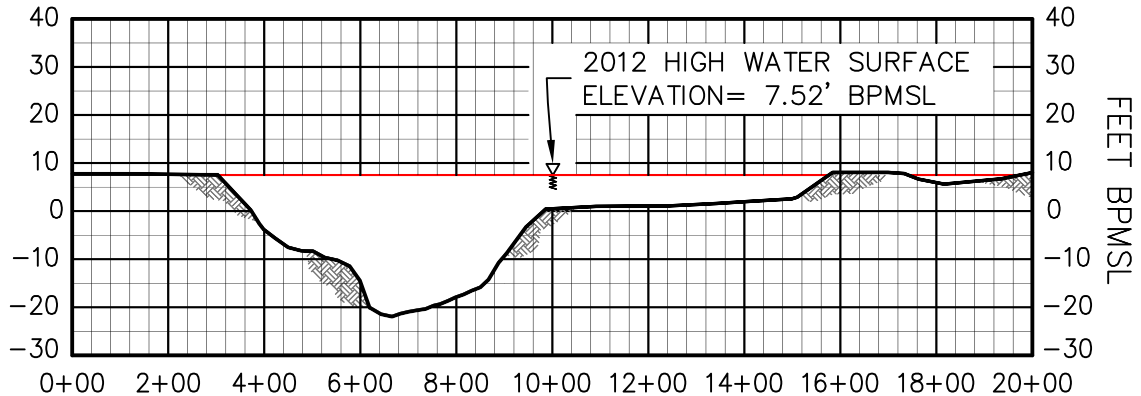
2012 SPRING BREAKUP
MONUMENT 23
PLAN

FIGURE: 5.3

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, MONUMENT 23.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2005 BY UMIAQ (KUUKPIK/LCMF INC.)



1 NIGLIQ CHANNEL CROSS SECTION AT MONUMENT 23

200 0 200 400
HORIZONTAL SCALE IN FEET

20 0 20 40
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.3_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2012 SPRING BREAKUP
NIGLIQ CHANNEL
MONUMENT 23 CROSS SECTION

FIGURE 5.3
(SHEET 2 OF 2)

5.4 Proposed CD5 Crossings Discharge

5.4.1 CD5 Nigliq Bridge Location Discharge

Indirect discharge was calculated using the slope-area method. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from G28 to G29, PTs at both locations, WSE from gage readings, and the 2008 LCMF topographic channel cross section survey. The location and cross section of the area is presented in Figure 5.4. Indirect discharge calculations were performed assuming an ice-free channel and are considered a conservative estimate.

As discussed in Section 5.3, flow in the Nigliq Channel was affected by ice during the 2012 breakup (Photo 5.5). The difference in the discharge at G28 and at MON23 can be contributed to the loss of channelized flow to overbank areas. For instance, Nanuq Lake recharges via the Nigliq Channel and is located between G29 and MON23.

Peak discharge at G28 was estimated to have occurred in the evening of June 2, coinciding with peak stage and influenced by ice jam activity. Peak discharge was 94,000 cfs with a corresponding WSE of 9.09 feet BPMSL.

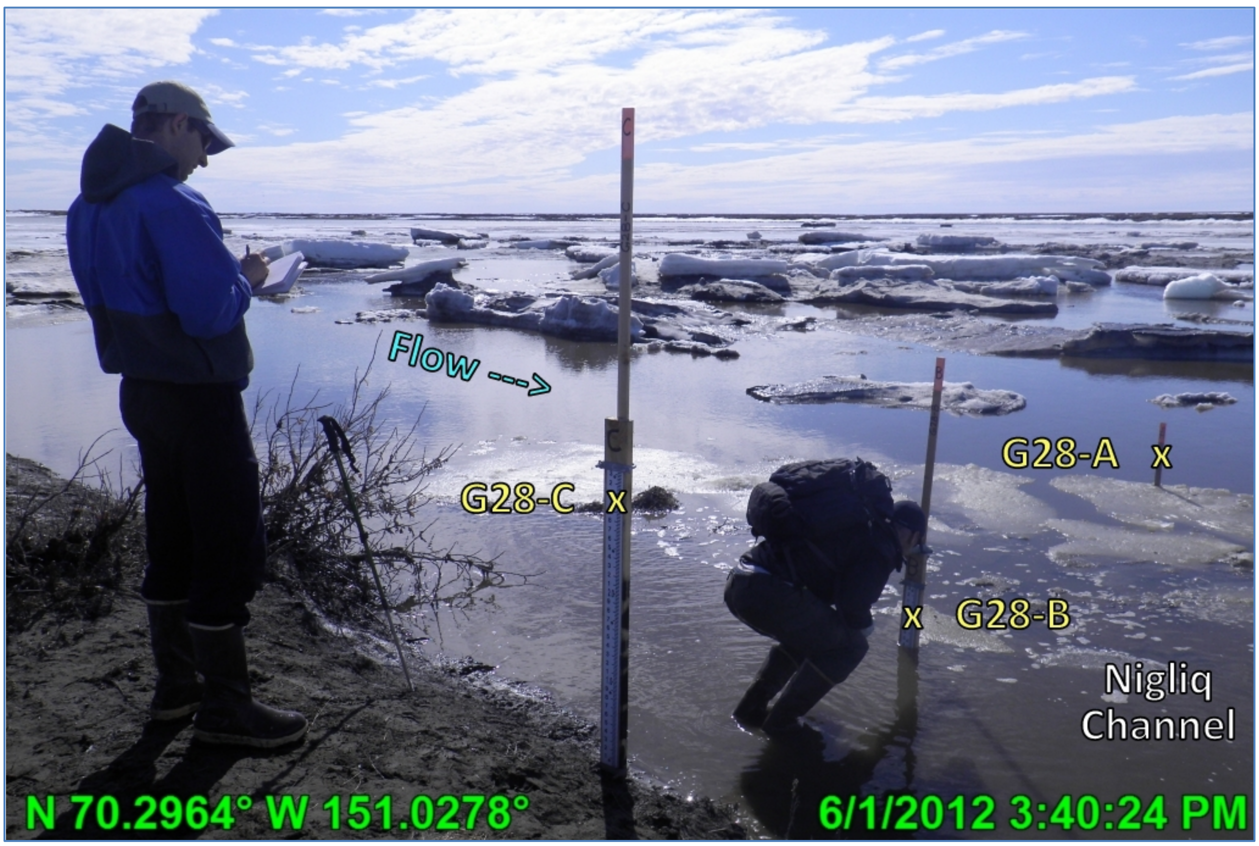
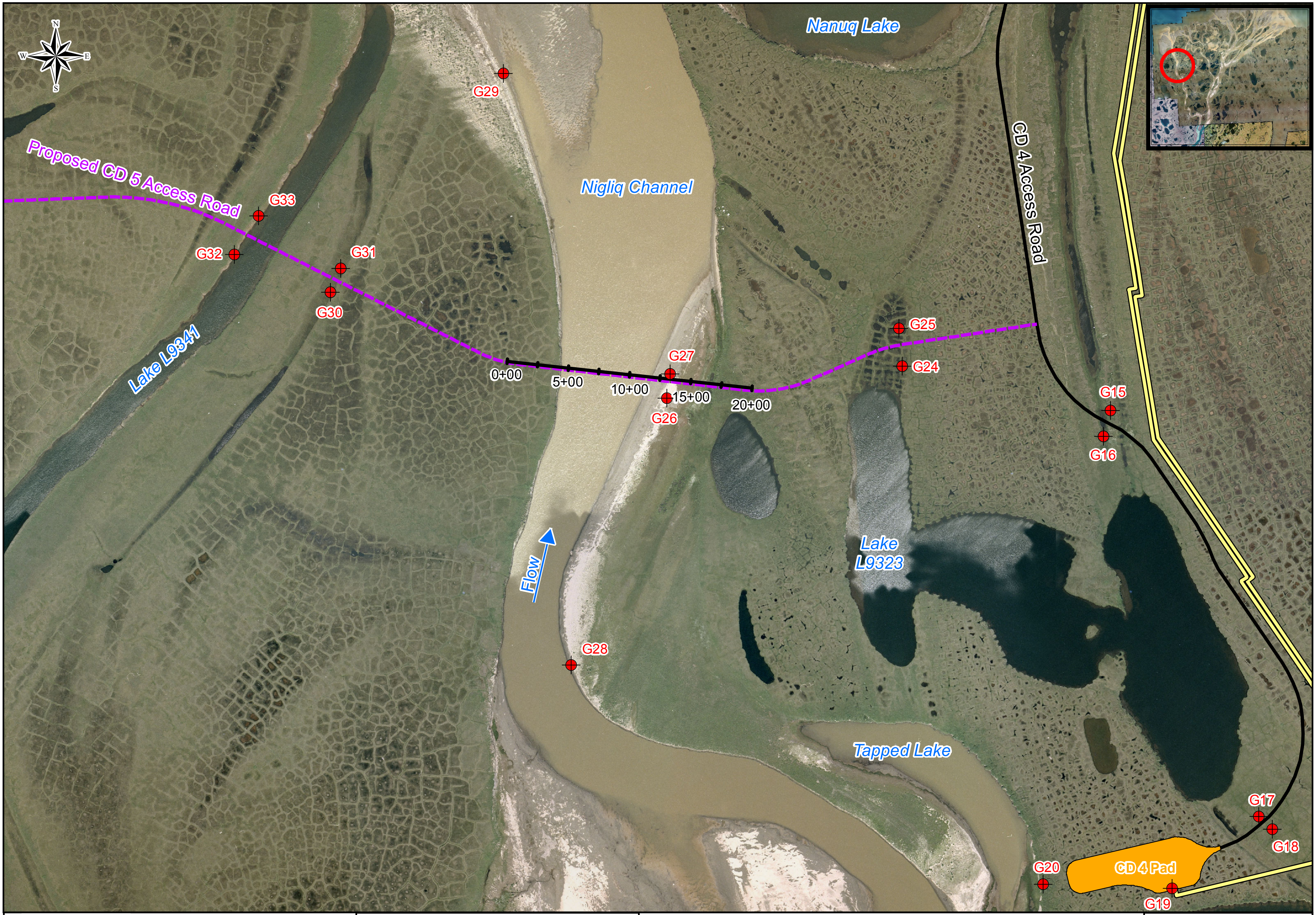


Photo 5.5: Gage reading at G28 with grounded ice in the background; June 1, 2012



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Feet
0 500 1,000

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.4
Checked:	HLR/SME	Scale:	1 in = 1000 feet

Legend

- Gage Locations
- 2005 Cross Section Alignment
- Pipelines
- Existing Roads
- Proposed Roads
- Facilities

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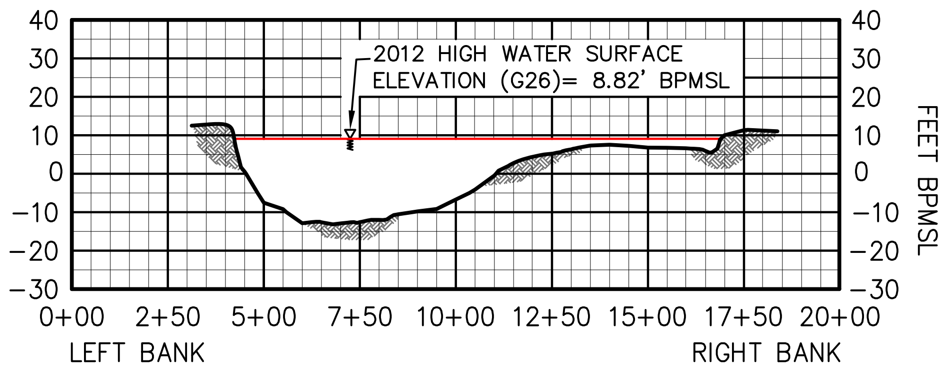
2012 SPRING BREAKUP
Gage 26
Nigliq Channel Plan

FIGURE: 5.4

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, BAKER TBM 2010.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2003 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – NIGLIQ CHANNEL CENTERLINE CROSS SECTION

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

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Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.4_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2012 SPRING BREAKUP
PROPOSED CD5 CROSSING
NIGLIQ CHANNEL CENTERLINE

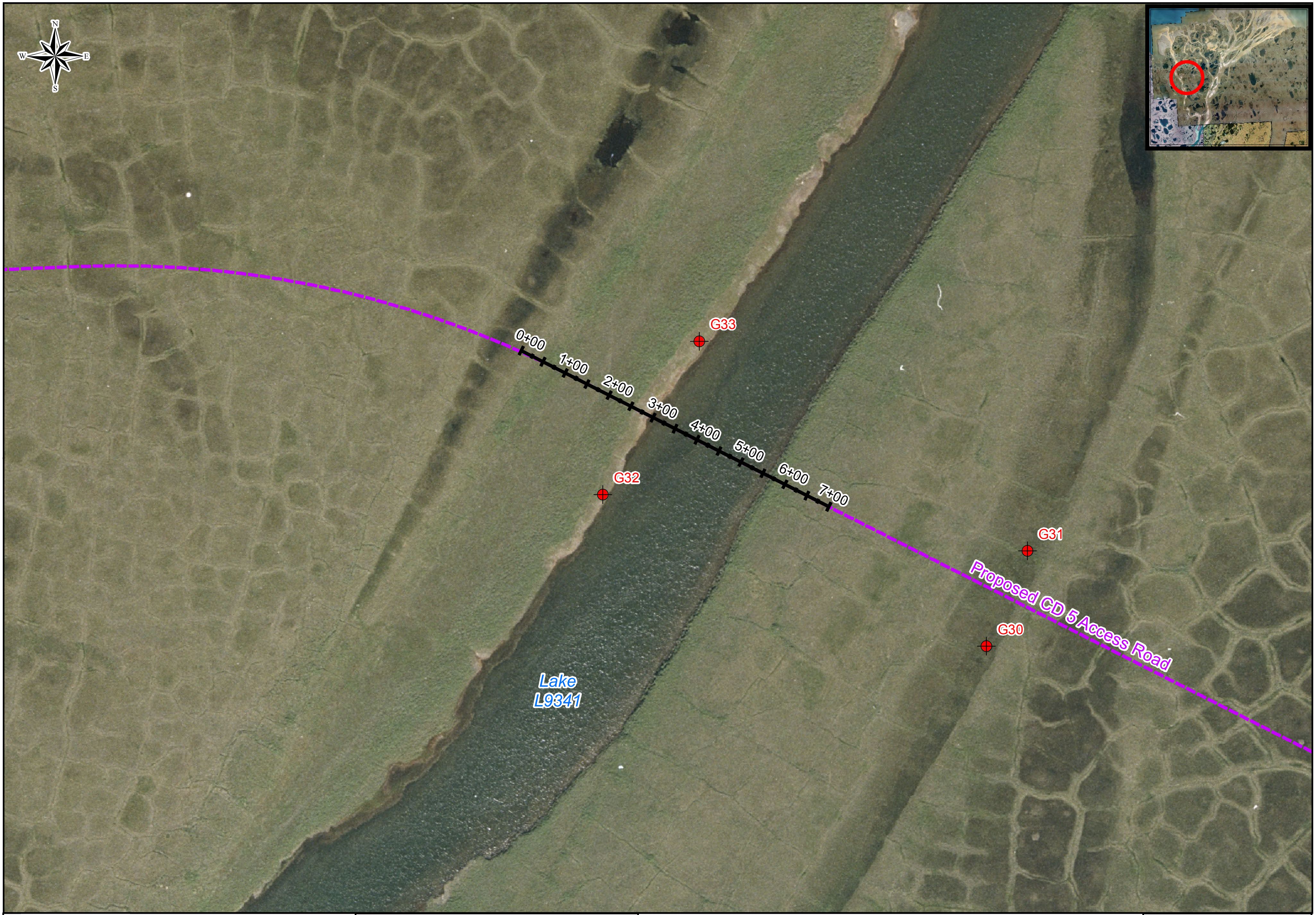
FIGURE 5.4
(SHEET 2 OF 2)

5.4.2 CD5 Lake L9341 Crossing Location Discharge

The slope-area method was used to calculate indirect discharge. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from G32 to G33, WSE at G32, and the 2008 cross section survey by LCMF. The location and cross section of the area is presented in Figure 5.5. Indirect discharge calculations were performed assuming an ice-free channel and are to be considered a conservative estimate.

Paleochannels connecting Lake L9341 to the Nigliq Channel inundate during spring breakup flooding, and can carry flow when stage rises sufficiently. Ice jams during 2012 were observed causing backwater to flow into Lake L9341 via the paleochannels. Significant snow and ice were present and can be seen in Photo 4.87.

Peak discharge at G32 was estimated to have occurred May 27 early in the morning. Peak discharge was 6,000 cfs with a corresponding WSE of 7.62 feet BPMSL. Peak stage was observed June 3 from a HWM with an elevation of 8.58 feet BPMSL.



ConocoPhillips Alaska

Feet
0 125 250

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.5
Checked:	HLR/SME	Scale:	1 in = 250 feet

Legend

- Gage Locations
- 2012 Cross Section Alignment
- Proposed Roads

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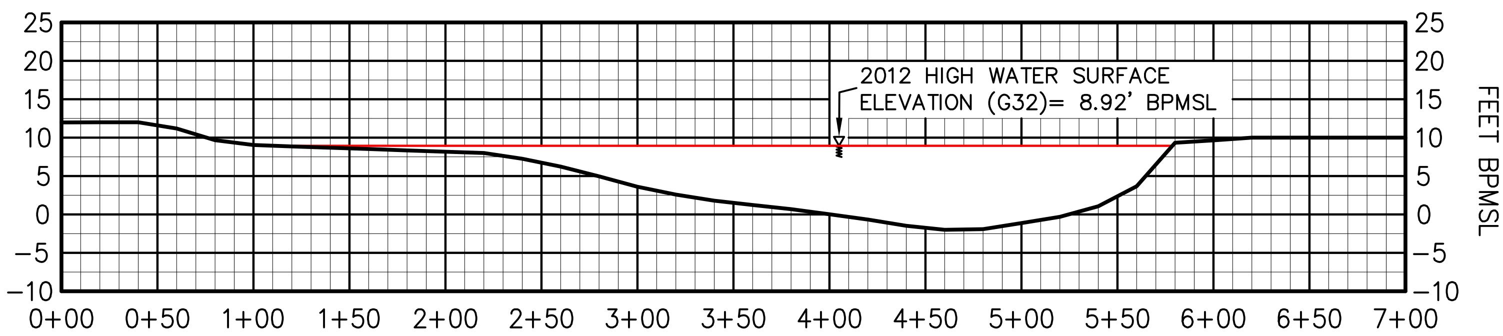
2012 SPRING BREAKUP
Gage 32
Lake L9341 Plan

FIGURE: 5.5

(SHEET 1 of 2)

NOTES

1. BASIS OF ELEVATION, CP08-11-60C.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2008 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – LAKE L9341 CENTERLINE CROSS SECTION

50 0 50 100
HORIZONTAL SCALE IN FEET

12.5 0 12.5 25
VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.5_2.DWG
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2012 SPRING BREAKUP
PROPOSED CD5 CROSSING
LAKE L9341 CENTERLINE
FIGURE 5.5
(SHEET 2 OF 2)

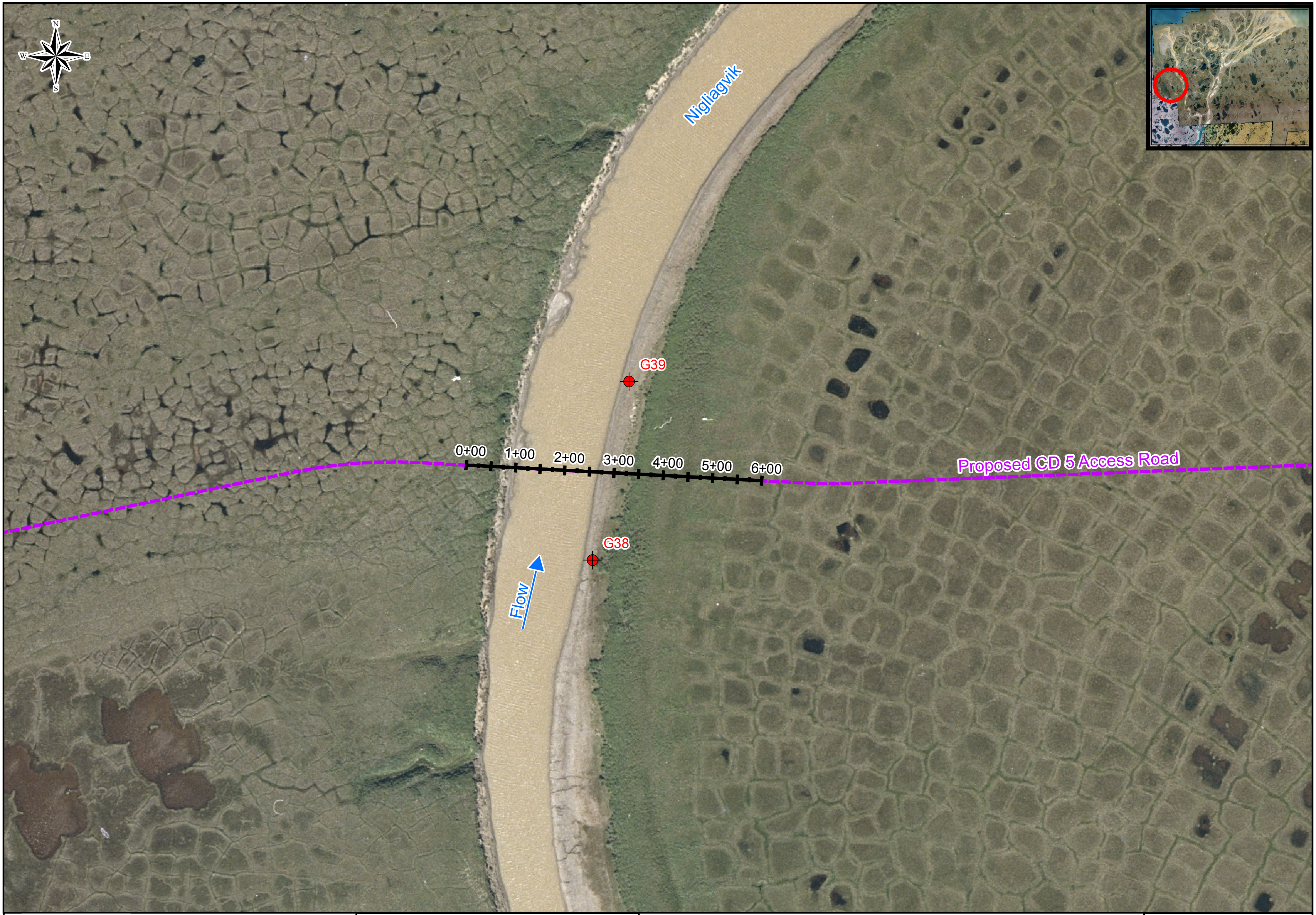
5.4.3 CD5 Nigliagvik Crossing Location Discharge

The slope-area method was used to calculate indirect discharge. Discharge was calculated using the energy grade-line slope as approximated by the water surface slope from G38 to G39, WSE at G38, and the 2008 cross section survey by LCMF. Location and cross section of the area is presented in Figure 5.6. Indirect discharge calculations were performed assuming an ice-free channel and are considered a conservative estimate.

Significant snow and ice were present in the Nigliagvik throughout monitoring, and affected the 2012 discharge calculations. Photo 4.88 shows an ice jam on the afternoon of June 2 at the proposed crossing site. The WSE differential between G38 (upstream gage) and G39 (downstream gage) fluctuated. At times, G39 was higher than G38 indicating changes in flow direction through the channel, which are dependent on events in the Nigliq Channel.

Peak discharge at G38 was estimated to have occurred the afternoon of June 2, coinciding with peak stage and influenced by ice jam activity. Peak discharge was approximately 11,000 cfs with a corresponding WSE of 8.10 feet BPMSL.

Photo 5.6: Ice jam in the Nigliagvik during peak discharge, looking downstream (north); June 2, 2012



ConocoPhillips Alaska

Feet
0 125 250

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.6
Checked:	HLR/SME	Scale:	1 in = 250 feet

Legend

- Gage Locations
- 2012 Cross Section Alignment
- Proposed Roads

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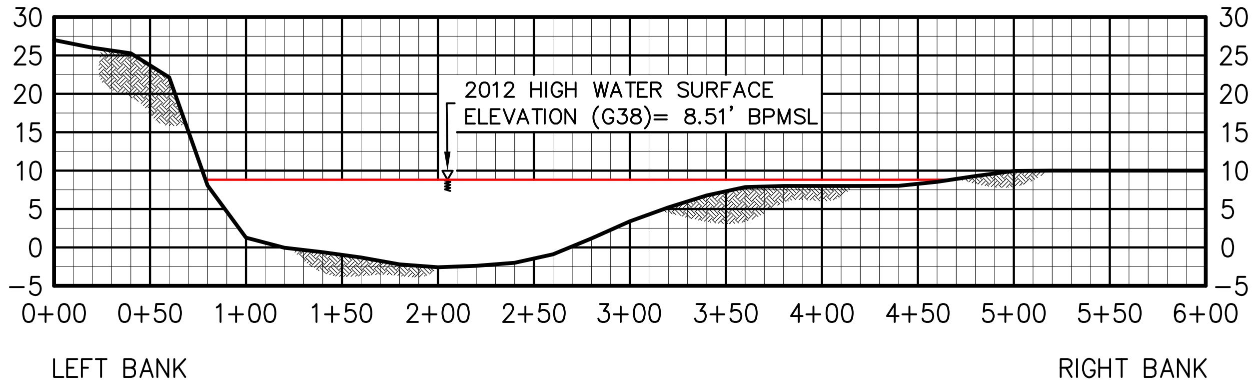
2012 SPRING BREAKUP
Gage 38
Nigliagvik Channel Plan

FIGURE: 5.6

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, CP08-11-66C.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2008 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – NIGLIAGVIK CENTERLINE CROSS SECTION

HORIZONTAL SCALE IN FEET: 50 0 50 100

VERTICAL SCALE IN FEET: 12.5 0 12.5 25

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DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.6_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2012 SPRING BREAKUP
PROPOSED CD5 CROSSING
NIGLIAGVIK CENTERLINE

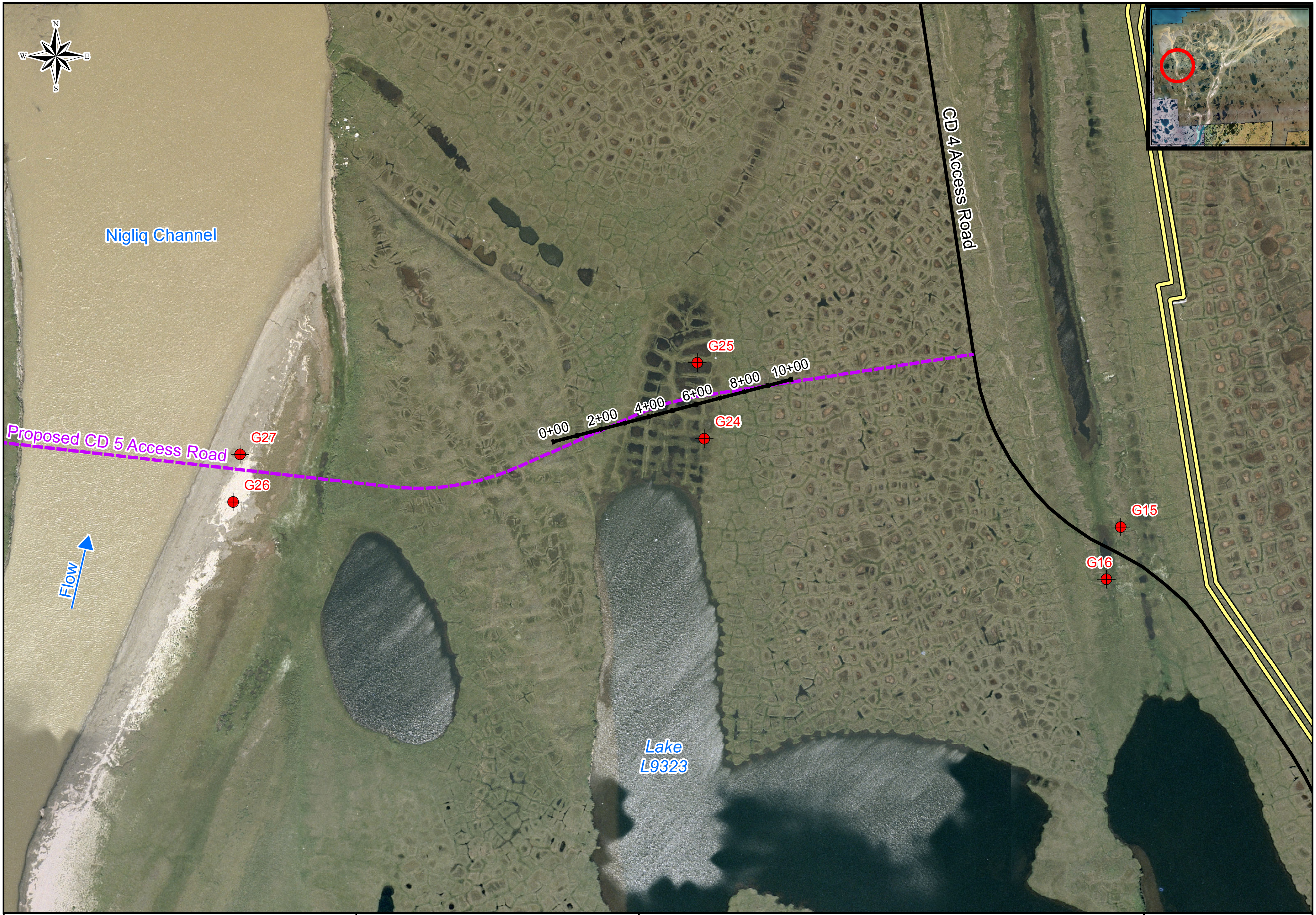
FIGURE 5.6
(SHEET 2 OF 2)

5.4.4 CD5 Lake L9323 Crossing Location Discharge

The proposed CD5 crossing of Lake L9323 was monitored during the 2012 breakup study. No indirect discharge was calculated for this area, as only local melt was observed in the low lying polygons. Cross sections gathered from a 2008 cross section survey by LCMF and a plan view of area are presented in Figure 5.7.

Overbank flow from the Nigliq Channel did not enter Lake L9323, which kept water surface levels in L9323 at or below bankfull. This was reflected at G24 and G25, where only local melt was observed in the low lying polygons of the area.

Peak stage was an estimated 8.55 feet BPMSL based on a HWM observed overnight between June 4 and June 5 at G24.



ConocoPhillips Alaska

Feet
0 250 500

Date:	10/01/2012	Project:	127841
Drawn:	BTG	File:	Figure 5.7
Checked:	HLR/SME	Scale:	1 in = 500 feet

Legend

- Gage Locations
- 2012 Cross Section Alignment
- Pipelines
- Existing Roads
- Proposed Roads

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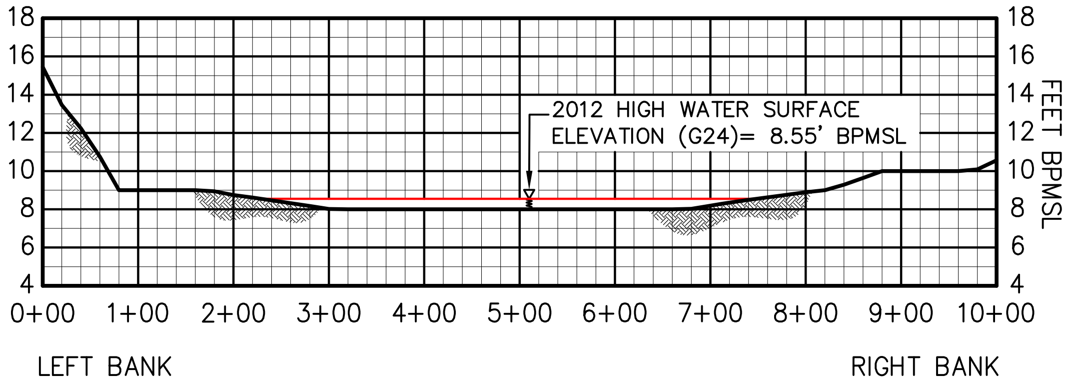
2012 SPRING BREAKUP
Gage 24
Lake L9323 Plan

FIGURE: 5.7

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, CP08-11-52A.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2008 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – LAKE L9323 CENTERLINE CROSS SECTION

100 0 100 200
HORIZONTAL SCALE IN FEET

5 0 5 10
VERTICAL SCALE IN FEET

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Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.7_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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2012 SPRING BREAKUP
PROPOSED CD5 CROSSING
LAKE L9323 CENTERLINE

FIGURE 5.7
(SHEET 2 OF 2)

5.5 Alpine Swale Bridges Discharge

5.5.1 Direct Discharge

Discharge measurements at the 452-foot (long) and the 62-foot (short) swale bridges were performed twice at each location because of the two peak events in 2012. The lower, first peak occurred overnight between May 27 and 28; the higher, second peak occurred overnight between June 3 and June 4. Discharge measurements at both bridges were performed on May 28 as stage was falling, and on June 3 as stage was rising. Stage data is based on WSE measurements at nearby gages G3/G4, see Table 4.9.

The resulting discharge and velocity values from the first measurement at the long swale bridge on May 28, was 1,315 cfs with an average velocity of 0.90 feet per second (fps). These values were lower than the second measurement taken on June 3. The resulting discharge value is 2,582 cfs with an average velocity of 1.53 fps. The May 28 measurement was rated “fair” based on restrictions to flow from snow pack presence beneath the bridge and snow banks immediately upstream of each abutment (Photo 5.7 and Photo 5.8). For the June 3 measurement, the bridge was mostly free of snow and ice and was rated “good.” Small snow piles east and west of the upstream abutments did not significantly affect flow (Photo 5.9 and Photo 5.10).

Photo 5.7: Discharge measurement at the long swale bridge, looking west; May 28, 2012

Photo 5.8: Conditions at the long swale bridge during the discharge measurement, looking northeast; May 28, 2012

Photo 5.9: Conditions upstream of the long swale bridge during the discharge measurement, looking east; June 3, 2012

Photo 5.10: Conditions downstream of the long swale bridge during the discharge measurement, looking east; June 3, 2012

The resulting discharge and velocity values from the first measurement at the short swale bridge on May 28 was 152 cfs with an average velocity 0.79 fps. These values were lower than the second measurement taken on June 3. The resulting discharge is 425 cfs with an average velocity 1.26 fps. The May 28 measurement was rated "good" regardless of snow blocking approximately 15% of the area at the downstream west abutment (Photo 5.11 shows upstream conditions). The bridge was approximately 90% clear of ice and snow on June 3; some snow remained at the west abutment downstream, but did not appreciably affect flow. Occasional ice floes passing through the area also did not affect the measurement, rated "fair," based on these conditions (Photo 5.12 and Photo 5.13).

A summary of the 2012 direct discharge measurements at both bridges is presented with historical data in Table 5.2 and complete notes for all direct discharge measurements at both swale bridges are included in Appendix B.

Photo 5.11: Conditions upstream of the short swale bridge while preparing for the discharge measurement, looking east; May 28, 2012

Photo 5.12: Conditions upstream of the short swale bridge while preparing for the discharge measurement, looking east; June 3, 2012

Photo 5.13: Conditions downstream of the short swale bridge while preparing for the discharge measurement, looking east; June 3, 2012

Table 5.2: Direct Discharge Historical Summary: Alpine Swale Bridges (2000 – 2012)

Site	Date	WSE[1] (ft)	Width (ft)	Area (ft^2)	Mean Velocity (ft/s)[2]	Discharge (cfs)	Measurement Rating[3]	Number of Sections	Measurement Type	Reference
62-foot Bridge	**06/03/12**	**7.04**	**52**	**306**	**1.26**	**386**	**F**	**19**	**Cable**	**This report**
	05/28/11	8.15	52	336	2.51	840	F	27	Cable	Baker 2012
	06/03/10	7.58	55	316	1.79	570	F	28	Cable	Baker 2010
	–[4]	–	–	–	–	–	–	–	–	Baker 2009b
	05/29/08	6.35	55	211	0.58	120	P	14	Cable	Baker 2008
	06/05/07	7.83	55	292	1.18	350	F	20	Cable	Baker 2007b
	05/31/06	8.49	55	615	1.59	980	F	20	Cable	Baker 2007a
	–[4]	–	–	–	–	–	–	–	–	Baker 2005b
	05/29/04	8.34	55	451	1.60	720	F	17	Cable	Baker 2005a
	–[4]	–	–	–	–	–	–	–	–	Baker 2003
	05/25/02	6.74	56.0	283	1.52	430	G	17	Cable	Baker 2002b
	06/11/01	7.64	56	336	1.79	600	G	15	Cable	Baker2001
	06/10/00	7.87	47	175	3.30	580	F	13	Cable	Baker2000
452-foot Bridge	**06/03/12**	**7.10**	**445**	**1686**	**1.53**	**2582**		**26**	**Cable**	**This report**
	05/29/11	8.16	447	2027	2.22	4500	F	26	Cable	Baker 2012
	06/01/10	7.97	441	1699	2.66	4500	G	25	Cable	Baker 2010
	05/26/09	5.89	445	1592	0.82	730	F	27	Wading	Baker 2009b
	05/29/08	6.35	445	949	2.03	1930	F	21	Wading	Baker 2008
	06/05/07	7.76	447	1670	0.74	1240	F	20	Cable	Baker 2007b
	05/31/06	8.42	409	1730	1.89	3260	F	29	Cable	Baker 2007a
	06/02/05	6.13	445	841	1.37	1100	G	20	Wading	Baker 2005b
	05/29/04	8.34	446	1700	1.40	2400	F	18	Cable	Baker 2005a
	06/08/03	5.48	444	478	0.88	420	G	16	Wading	Baker 2003
	05/25/02	6.74	445	930	3.47	3200	G	17	Cable	Baker 2002b
	06/11/01	7.64	460	1538	2.4	3700	G	16	Cable	Baker2001
	06/09/00	7.34	437	1220	3.27	4000	F	15	Cable	Baker2000

Notes:
1. Source of WSE is G3.
2. Mean velocities adjusted with angle of flow coefficient
3. Measurement Rating -
   - E - Excellent: Within 2% of true value
   - G - Good: Within 5% of true value
   - F - Fair: Within 7-10% of true value
   - P - Poor: Velocity < 0.70 ft/s; Shallow depth for measurement; less than 15% of true value
4. Bridge obstructed with snow or ice, no measurement made

5.5.2 Indirect Discharge

The 2012 peak discharge through the swale bridges is likely to have occurred around the same time as peak stage and the corresponding peak high-water surface differential, as determined by comparison of G3 (headwater) and G4 (tailwater) WSE readings. The peak stage at G3, 7.60 feet BPMSL, occurred overnight between June 3 and June 4 (see Table 4.9). The headwater-tailwater differential at that time was 0.41 feet, the second-highest G3/G4 differential calculated during monitoring.

Peak discharge through the swale bridges was calculated assuming the highest measured average adjusted velocity was representative of the average velocity at peak stage. The headwater-tailwater differential at the time of the highest measured velocity (June 3) was 0.17 feet. Comparing this to the differential calculated at peak stage indicates that both the velocity and discharge were likely to have been somewhat higher during peak stage, after the measurement.

The peak discharge estimate is 2,940 cfs through the long swale bridge and 425 cfs through the short swale bridge, coinciding with peak stage overnight between June 3 and June 4. Table 5.3 summarizes the calculated peak annual discharge data at the Alpine swale bridges between 2000 and 2012.

Table 5.3: Calculated Peak Discharge Historical Summary: Alpine Swale Bridges (2000 - 2012)

Date & Time[1]	Peak WSE (ft)[2]	452-Foot Bridge		62-Foot Bridge		References
		Discharge (cfs)[3]	Mean Vel (ft/s)	Discharge (cfs)[3]	Mean Vel (ft/s)	
6/3/12 12:00 AM	**7.6**	**2940**	**1.53**	**425**	**1.26**	**This report**
5/29/11 10:00 PM	8.89	5200	2.22	940	2.51	Baker 2012
6/2/10 8:15 AM	8.64	5300	2.66	670	1.79	Baker 2010
5/25/09 1:00 PM	7.63	1400	0.82	–[4]	–[4]	Baker 2009b
5/30/08 12:00 PM	6.49	2100	0.49	100	0.58	Baker 2008
6/5/07 4:00 AM	8.60	1500	1.35	400	1.18	Baker 2007b
5/31/06 3:00 AM	9.72	4400	1.77	1100	1.59	Baker 2007a
5/31/05 8:00 AM	6.48	1400	1.37	–[4]	–[4]	Baker 2005b
5/27/04 1:30 PM	9.97	3400	1.38	900	1.59	Baker 2005a
06/07/2003[5]	6.31	700	0.88	–[4]	–[4]	Baker 2003
05/26/2002[5]	7.59	4000	3.47	500	1.52	Baker 2002b
06/11/2001[5]	7.95	3900	2.40	600	1.79	Baker 2001
06/12/2000[5]	9.48	7100	3.60	1000	4.30	Baker 2000

Notes:
1. Based on HWM, time is estimated
2. Source of WSE is Gage 3
3. Estimated peak discharge
4. Bridge obstructed with snow or ice, no measurement made
5. Unknown time of peak stage

5.6 Alpine Culvert Discharge

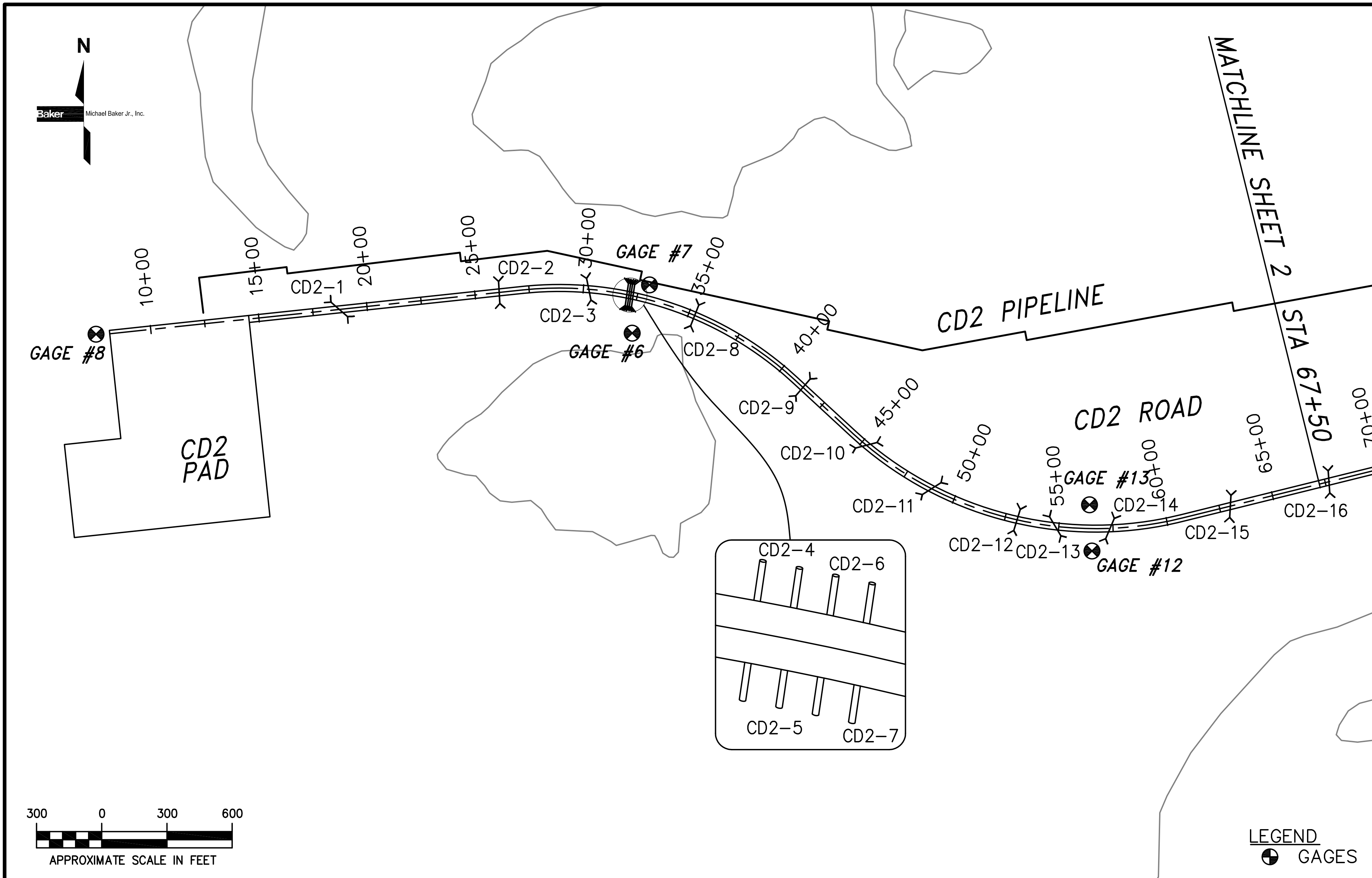
CD2 and CD4 access road culverts were monitored to assess flow conditions. Peak stage and head differential were measured and peak flow and velocities were calculated using indirect methods to determine the effectiveness of the drainage structures and to comply with monitoring requirements, as outlined in USACE Permit Number POA-2004-253 and the State of Alaska Fish Habitat Permit FH04-III-0238. Direct discharge during peak stage was also computed from velocity and depth measurements taken at accessible culverts.

Both observed WSE data and measured culvert dimensions are used to perform indirect culvert discharge calculations for a variety of conditions during the course of breakup. The CD2 and CD4 culvert invert elevations were surveyed by LCMF in May 2012. Culvert length and diameter were obtained using as-built surveys performed by LCMF in 2002 and 2005. Figure 5.8 illustrates the locations of the Alpine facilities drainage structures. WSE data for facilities gages are presented in Table 4.9 to Table 4.16.

In September 2008, changes were made to 6 of the corrugated metal pipe culverts (CMPs); CD2-9 through CD2-14. These culverts were deformed because of road prism loading. The CMPs were retrofitted by inserting circular smooth steel sleeves anchored at each end. 48-inch-diameter sleeves were installed in the five 60-inch diameter CMPs, and a 60-inch-diameter sleeve was inserted into the 72-inch diameter CMP. The sleeves reduce some friction losses in the culvert, but there is smaller diameter available for conveyance of flow. Also, the smooth sleeves are centered in the CMP and do not extend the full length.

Flow through the CD2 road culverts first occurred on May 27, 2012. Many culverts were blocked with snow, ice, and winter culvert covers. Flow was limited to unobstructed culverts, which included CD2-5, CD2-12 through CD2-14, and CD2-20 through CD2-24. Flow was not observed in the vicinity of CD2-15 through CD2-19, CD2-25, and CD2-26 during monitoring. Flow through the CD2 culverts was estimated to have stopped sometime between 6:00 PM on June 3, 2012 and 9:40 AM on June 4, 2012 when a differential in WSE was no longer observed, indicating stagnant or ponded water. Calculated peak discharge and velocity through the CD2 road culverts occurred sometime between June 2, 2012 and June 3, 2012.

Flow through the CD4 road culverts first occurred sometime between 4:30 PM on May 27, 2012 and 7:30 PM on May 28, 2012. Many culverts were blocked with snow, ice, and winter culvert covers. Flow was limited to unobstructed culverts, which included CD4-22 and CD4-24. Flow was not observed in the vicinity of CD4-18, CD4-19, and CD4-25 through CD4-33. Flow through the CD4 culverts was estimated to have stopped sometime after June 5, 2012 when only ponded water was observed in the area. Calculated peak discharge and velocity through the CD4 road culverts occurred sometime between May 28, 2012 and May 29, 2012.



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DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.9_1.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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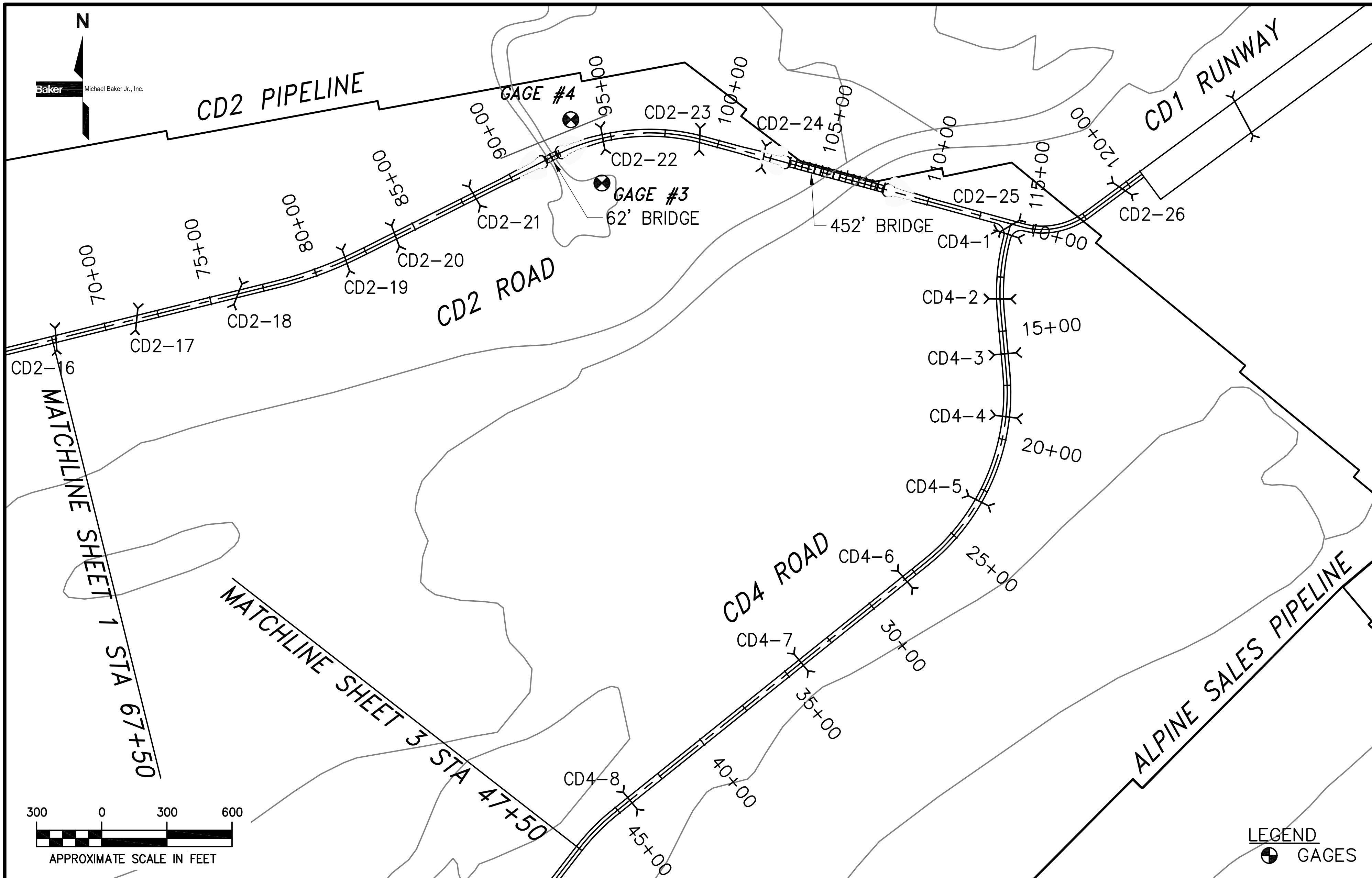
2012 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

FIGURE 5.8
(SHEET 1 OF 6)



ConocoPhillips Alaska, Inc.

DATE:	10/1/12	PROJECT:	127841
DRAWN:	KRH	FILE:	FIGURE 5.9_2.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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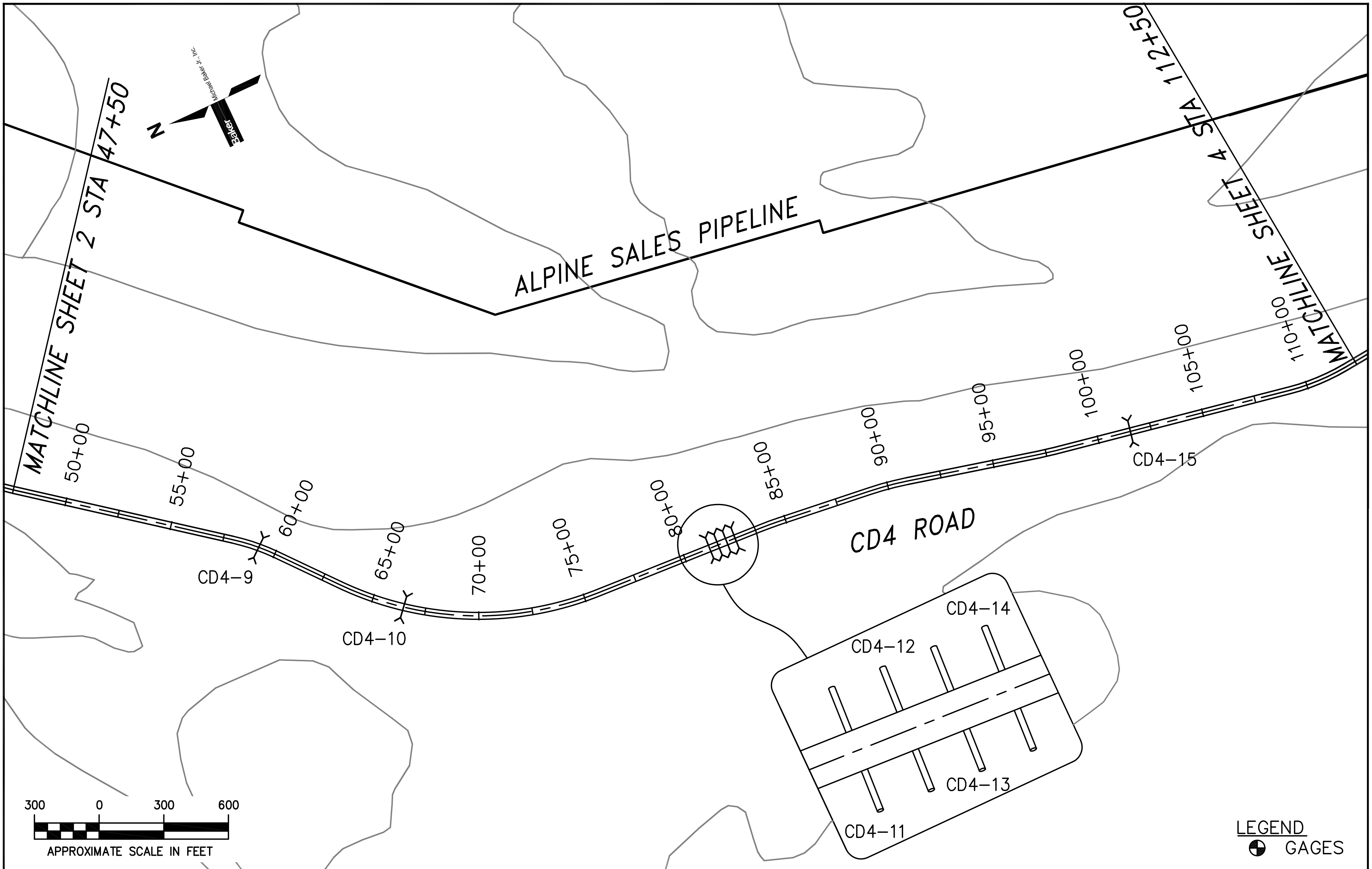
2012 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.8
(SHEET 2 OF 6)



ConocoPhillips
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DATE: 10/1/12		PROJECT: 127841	
DRAWN: KRH		FILE: FIGURE 5.9_3.DWG	
CHECKED: HLR		SCALE: AS SHOWN	

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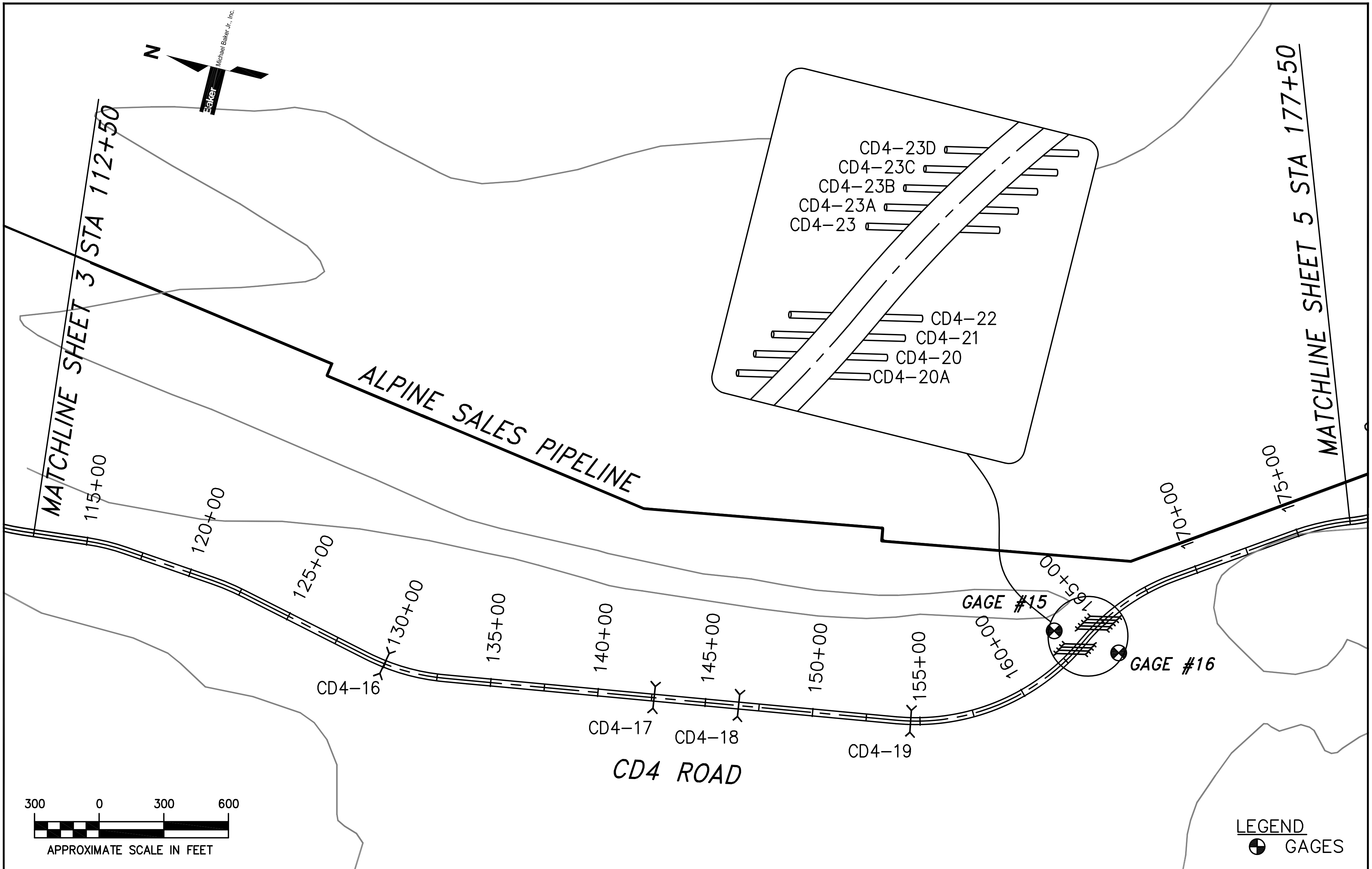
2012 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 5.8

(SHEET 3 OF 6)



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DRAWN:	KRH	FILE:	FIGURE 5.9_4.DWG
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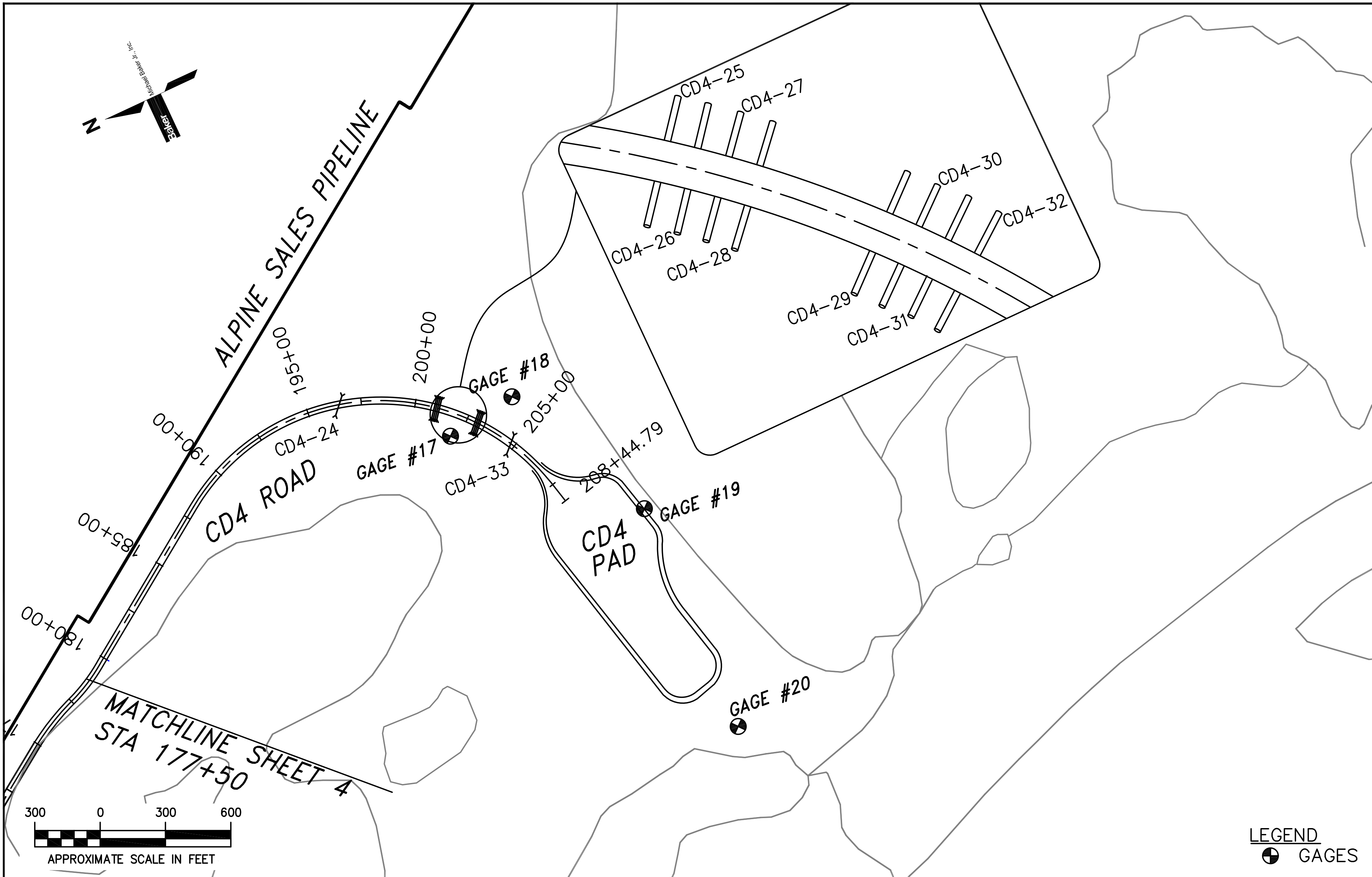
2012 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

FIGURE 5.8
(SHEET 4 OF 6)



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DRAWN:	KRH	FILE:	FIGURE 5.9_5.DWG
CHECKED:	HLR	SCALE:	AS SHOWN

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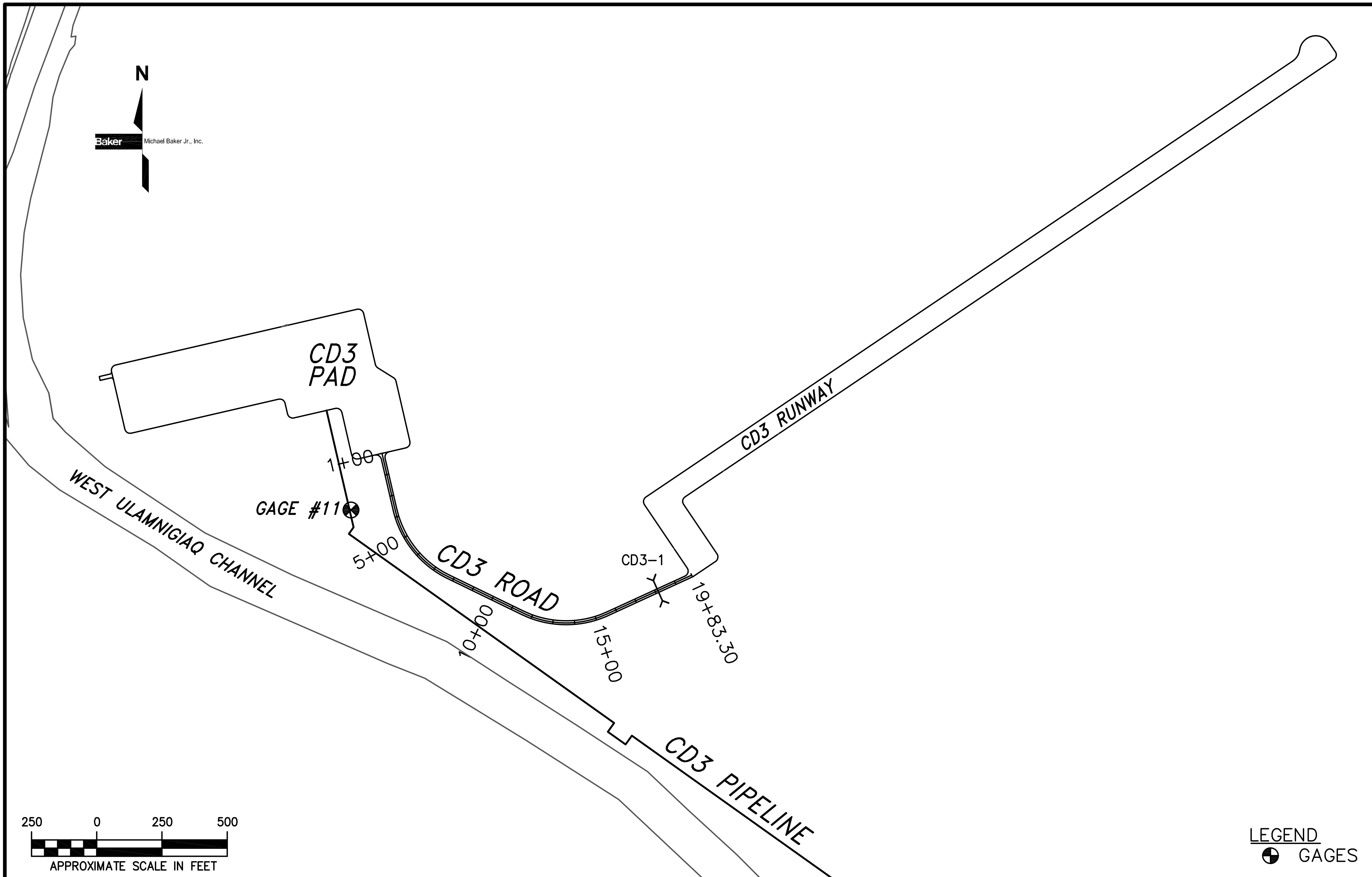
2012 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

FIGURE 5.8
(SHEET 5 OF 6)



ConocoPhillips
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DATE: 10/1/12	PROJECT: 127841
DRAWN: KRH	FILE: FIGURE 5.9_6.DWG
CHECKED: HLR	SCALE: AS SHOWN

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2012 SPRING BREAK-UP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.8
(SHEET 6 OF 6)

5.6.1 Direct Discharge and Velocity

On May 27 and June 3, 2012, water depth and velocity measurements were obtained at the CD2 road culverts passing flow to calibrate indirect culvert calculations. Velocity measurements were taken at the downstream side of the culvert. A Marsh-McBirney Flo-Mate™ and graduated USGS wading rod were used to measure a single point velocity, typically at six-tenths of the culvert's total water depth. This velocity was used as a representative average cross sectional velocity in the culvert.

The water depths and velocities measured on June 3, 2012 are provided in Table 5.4. The June 3 measurements represent conditions at culverts close to the time of peak stage as observed at the CD2 road gages (Photo 4.41). The measured velocities ranged from less than 0.1 fps to 3.0 fps. Negative velocities indicate the flow was moving from north to south. Based on direct depth and velocity measurements, the total discharge flowing through CD2 culverts was 54 cfs, ranging from 0.1 cfs to 24.1 cfs.

Table 5.4: CD2 Road Culvert Direct Velocity and Discharge, June 3, 2012

Culvert ID	Date Time	Depth (ft)	Area (ft^2)	Measured Velocity (ft/s)	Direct Discharge (cfs)
CD2-12	6/3/12 11:50 AM	2.64	10.52	-2.19	-23.03
CD2-13	6/3/12 11:45 AM	1.45	4.73	-0.03	-0.14
CD2-14	6/3/12 11:40 AM	1.73	6.03	-1.74	-10.49
CD2-20	6/3/12 11:35 AM	1.08	2.74	3.02	8.27
CD2-21	6/3/12 11:30 AM	1.82	5.56	2.73	15.19
CD2-22	6/3/12 11:25 AM	1.8	5.48	3	16.45
CD2-23	6/3/12 11:20 AM	2.5	8.26	2.92	24.13
CD2-24	6/3/12 11:15 AM	2.74	9.17	2.61	23.94
Average Measured Velocity (ft/s)				**1.29**	
Total Measured Discharge (cfs)				**54**	
Notes:	**1. Negative velocity indicates flow is moving from north to south through culvert 2. Culverts not listed were blocked with snow and ice, covered or had not observed flow**				

5.6.2 Indirect Discharge and Velocity

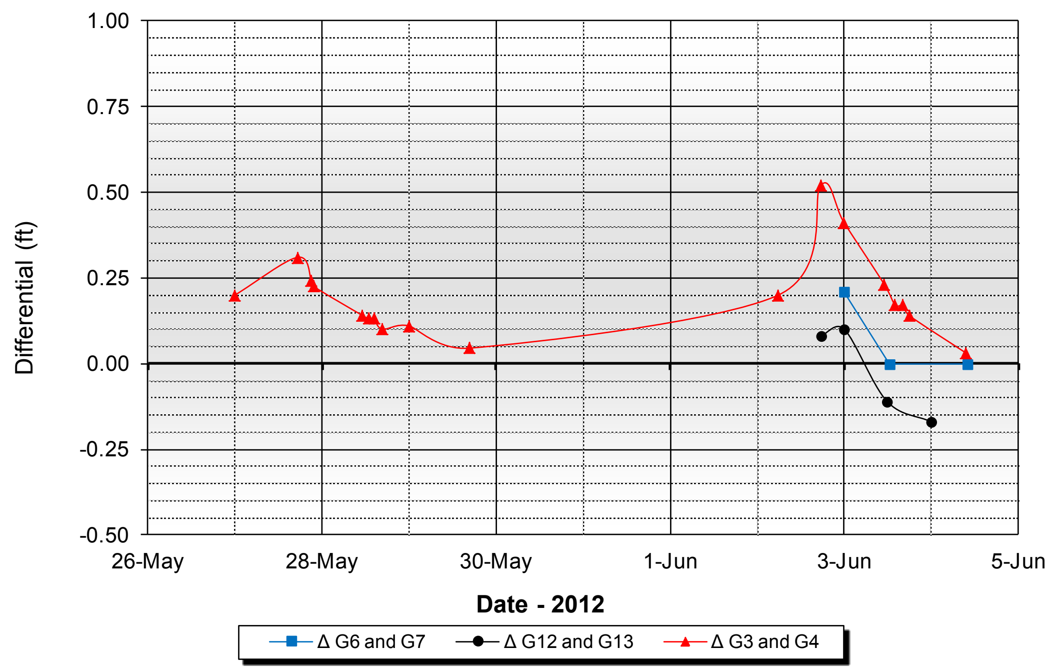
Indirect discharge and velocity values for culverts passing flow are calculated based on observed WSE. This data is collected from gaging stations located upstream and downstream of the culverts along the CD2 and CD4 roads that pass the most significant quantity of flow. Upstream and downstream WSE are used with culvert geometry, roughness, and invert elevations to model the indirect discharge and velocity through the culverts.

The measured (direct) discharge and calculated (indirect) discharge values can vary as a result of modeled conditions. Debris such as snow and ice in culvert inverts, culvert deformations, and dirt and vegetation at inlets and outlets, are factors that contribute to reductions in actual velocity and discharge values, as compared to indirect estimates. Peak indirect velocity and discharge values are adjusted to account for the discrepancy between calculated and measured values.

Alpine Culverts' Headwater and Tailwater Differential

The differential between headwater and tailwater elevations for the CD2 culverts passing flow was based on the observed WSE at the paired gages G6/G7 (near culverts CD2-1 through CD2-8), G12/G13 (near culverts CD2-9 through CD2-18), and G3/G4 (near culverts CD2-19 through CD2-26). The CD4 road culvert headwater and tailwater differential uses data collected at paired gages G15/G16 (near culverts CD4-18 through CD4-23D) and G17/G18 (near culverts CD4-24 through CD4-33). The WSE used in culvert indirect discharge calculations matches the WSE at the corresponding gages based on the proximity of the gage to the culverts.

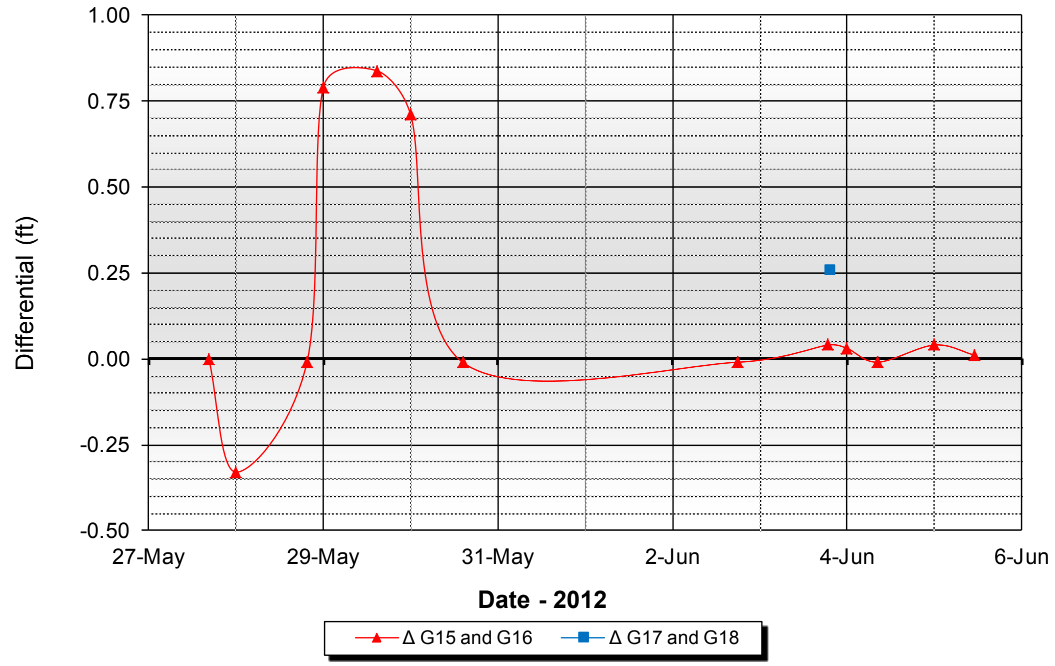
Along the CD2 road, a maximum differential of 0.21 feet between G6/G7 occurred early in the morning on June 3 coinciding with peak stage based on HWM. A maximum differential of -0.17 feet between G12/G13 occurred early in the morning on June 4. A maximum differential of 0.52 feet between G3/G4 occurred in the evening on June 2. The differential WSE throughout breakup at all paired gage locations along the CD2 road is presented in Graph 5.3.



Note: Negative values indicate WSE at gage G13 was greater than WSE at gage G12

Graph 5.3: CD2 Road Water Surface Elevation Differential

Along the CD4 road, a maximum differential of 0.84 feet between G15/G16 occurred early in the afternoon on May 29. A differential of 0.26 feet between G17/G18 occurred on the evening of June 3. The differential WSE throughout breakup at all gage locations along the CD4 road is presented in Graph 5.4.



Note: Negative values indicate WSE at gage G15 was greater than WSE at gage G16

Graph 5.4: CD4 Road Water Surface Elevation Differential

Alpine Culverts Indirect Velocity

The peak velocity for a single CD2 road culvert near G6/G7 was 2.60 fps through CD2-5. This velocity coincided with peak stage, estimated as 12:00 AM June 3. Average velocity for all culverts near G6/G7 during peak stage was 2.60 fps. The peak velocity for a singular CD2 road culvert near G12/G13 was -2.23 fps through CD2-12 on the early morning of June 4. A negative velocity indicates the flow through the culvert moved from G13 to G12. Average velocity for all culverts near G12/G13 during peak stage, estimated at 12:00 AM June 3, was 1.46 fps. The peak velocity for a single CD2 road culvert near G3/G4 was 4.24 fps through CD2-22 and CD2-23 on the evening of June 2. Average velocity for all culverts near G3/G4 during peak stage, estimated at 12:00 AM June 3, was 3.54 fps. Calculated indirect velocities for each culvert along the CD2 road that passed flood flow are presented in Table 5.5, Table 5.6, and Table 5.7.

Table 5.5: 2012 Indirect Velocity (fps) Summary, CD2 Road Culverts near G6/G7

Culvert	*Jun 03 12:00 AM*	Jun 03 12:15 PM	Jun 04 9:55 AM
CD2-1	-	-	-
CD2-2	-	-	-
CD2-3	-	-	-
CD2-4	-	-	-
CD2-5	2.60	0.00	0.00
CD2-6	-	-	-
CD2-7	-	-	-
CD2-8	-	-	-
Average Velocity	**2.60**	**0.00**	**0.00**

Table 5.6: 2012 Indirect Velocity (fps) Summary, CD2 Road Culverts near G12/G13

Culvert	Jun 02 5:30 PM	*Jun 03 12:00 AM*	Jun 03 11:45 AM	Jun 04 12:00 AM
CD2-9	-	-	-	-
CD2-10	-	-	-	-
CD2-11	-	-	-	-
CD2-12	1.49	1.69	-1.79	-2.23
CD2-13	1.06	1.27	-1.46	-1.85
CD2-14	1.23	1.43	-1.46	-1.84
CD2-15	-	-	-	-
CD2-16	-	-	-	-
CD2-17	-	-	-	-
CD2-18	-	-	-	-
Average Velocity	**1.26**	**1.46**	**-1.57**	**-1.97**

Note: Negative values indicate flow through culvert moving from gage G13 to gage G12

Table 5.7: 2012 Indirect Velocity (fps) Summary, CD2 Road Culverts near G3/G4

Culvert	May 27 12:00 AM	May 27 5:15 PM	May 27 9:05 PM	May 27 9:40 PM	May 28 11:10 AM	May 28 1:00 PM	May 28 2:20 PM	May 28 4:40 PM	May 29 12:00 AM
CD2-19	-	-	-	-	-	-	-	-	-
CD2-20	2.19	2.82	2.34	2.28	1.66	1.56	1.54	1.26	1.47
CD2-21	2.29	2.80	2.45	2.40	1.85	1.77	1.77	1.53	1.65
CD2-22	2.52	3.19	2.78	2.72	2.09	2.01	2.01	1.75	1.85
CD2-23	2.58	3.25	2.85	2.78	2.16	2.08	2.08	1.83	1.91
CD2-24	2.53	3.18	2.79	2.73	2.12	2.04	2.04	1.79	1.88
CD2-25	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-
Average Velocity	**2.42**	**3.05**	**2.64**	**2.58**	**1.98**	**1.89**	**1.89**	**1.63**	**1.75**

Culvert	May 29 4:45 PM	Jun 02 5:50 AM	Jun 02 5:30 PM	*Jun 03 12:00 AM*	Jun 03 11:05 AM	Jun 03 2:00 PM	Jun 03 4:10 PM	Jun 03 5:55 PM	Jun 04 9:40 AM
CD2-19	-	-	-	-	-	-	-	-	-
CD2-20	0.00	0.00	4.07	3.36	2.40	2.01	1.99	1.77	0.50
CD2-21	0.67	2.01	3.75	3.37	2.48	2.11	2.11	1.90	0.81
CD2-22	1.02	2.54	4.24	3.66	2.71	2.32	2.32	2.10	0.95
CD2-23	1.15	2.63	4.24	3.69	2.76	2.42	2.37	2.15	1.00
CD2-24	1.12	2.55	4.15	3.63	2.71	2.33	2.33	2.11	0.98
CD2-25	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-
Average Velocity	**0.79**	**1.95**	**4.09**	**3.54**	**2.61**	**2.24**	**2.22**	**2.01**	**0.85**

Based on the calculations, the peak velocity for a single CD4 road culvert near G15/G16 was 4.71 fps through CD4-22. This velocity was estimated to have occurred during peak stage around 12:00 AM May 29. Calculated average velocity for all culverts near G15/G16 during peak stage was also 4.71 fps since CD4-22 was the only culvert left unblocked or passed any flow during peak stage. The velocity for a singular CD4 road culvert near G17/G18 was 2.83 fps through CD4-24, the only culvert left unblocked or passing any flow. This velocity was estimated to have occurred at around 7:00 PM June 3.

Calculated velocities for each culvert along CD4 road that passed flood flow are presented in Table 5.8 and Table 5.9.

Table 5.8: 2012 Indirect Velocity (fps) Summary, CD4 Road Culverts Near G15/G16

Culvert	May 27 4:30 PM	May 28 12:00 AM	May 28 7:30 PM	*May 29 12:00 AM*	May 29 2:50 PM	May 30 12:00 AM	May 30 2:15 PM
CD4-18	-	-	-	-	-	-	-
CD4-19	-	-	-	-	-	-	-
CD4-20A	-	-	-	-	-	-	-
CD4-20	-	-	-	-	-	-	-
CD4-21	-	-	-	-	-	-	-
CD4-22	0.00	-3.19	-0.56	4.71	4.69	4.10	-0.60
CD4-23	-	-	-	-	-	-	-
CD4-23A	-	-	-	-	-	-	-
CD4-23B	-	-	-	-	-	-	-
CD4-23C	-	-	-	-	-	-	-
CD4-23D	-	-	-	-	-	-	-
Average Velocity	**0.00**	**-3.19**	**-0.56**	**4.71**	**4.69**	**4.10**	**-0.60**

Note: Negative values indicate flow through culvert moving from gage G15 to gage G16

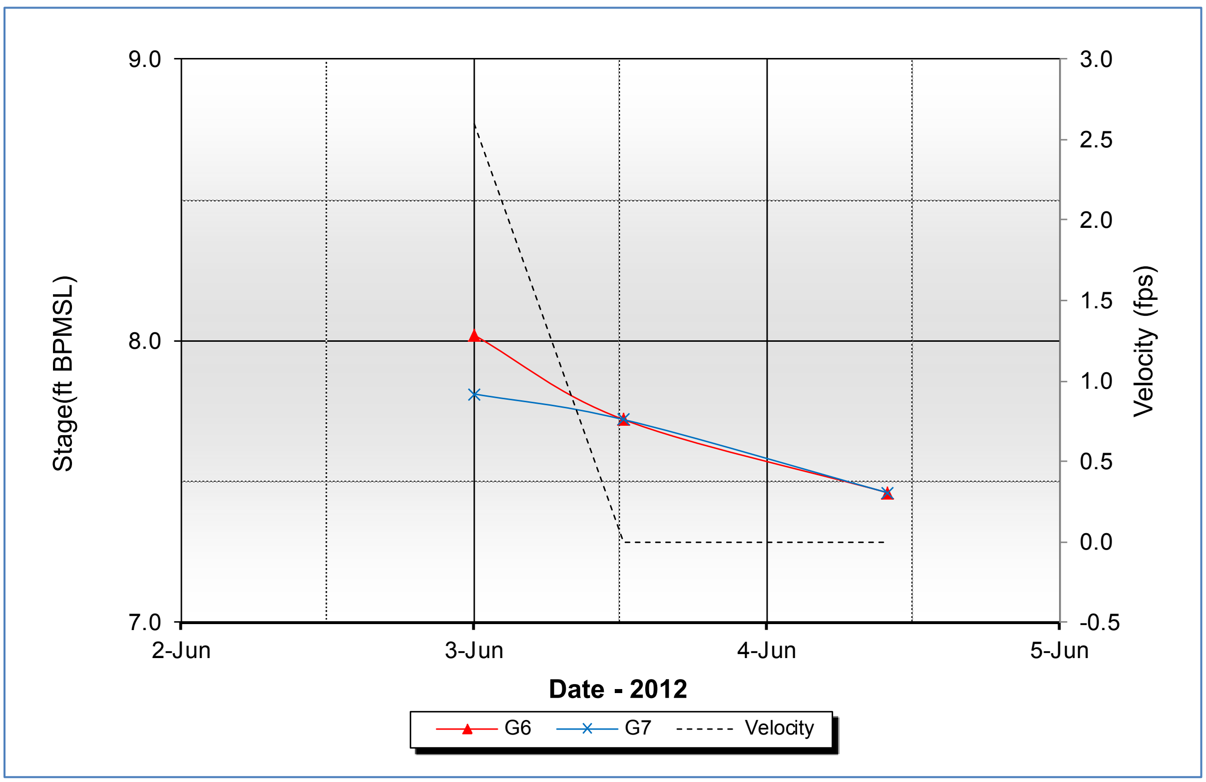
Culvert	Jun 02 6:00 PM	Jun 03 6:45 PM	Jun 04 12:00 AM	Jun 04 8:30 AM	Jun 05 12:00 AM	Jun 05 11:10 AM
CD4-18	-	-	-	-	-	-
CD4-19	-	-	-	-	-	-
CD4-20A	-	-	0.93	-0.54	1.07	0.56
CD4-20	-	-	0.93	-0.54	1.07	0.60
CD4-21	-	-	0.93	-0.54	1.07	0.59
CD4-22	-0.60	1.07	0.93	-0.54	1.07	0.49
CD4-23	-	-	-	-	-	-
CD4-23A	-	-	-	-	-	-
CD4-23B	-	-	-	-	-	-
CD4-23C	-	-	-	-	-	-
CD4-23D	-	-	-	-	-	-
Average Velocity	**-0.60**	**1.07**	**0.93**	**-0.54**	**1.07**	**0.56**

Note: Negative values indicate flow through culvert moving from gage G15 to gage G16

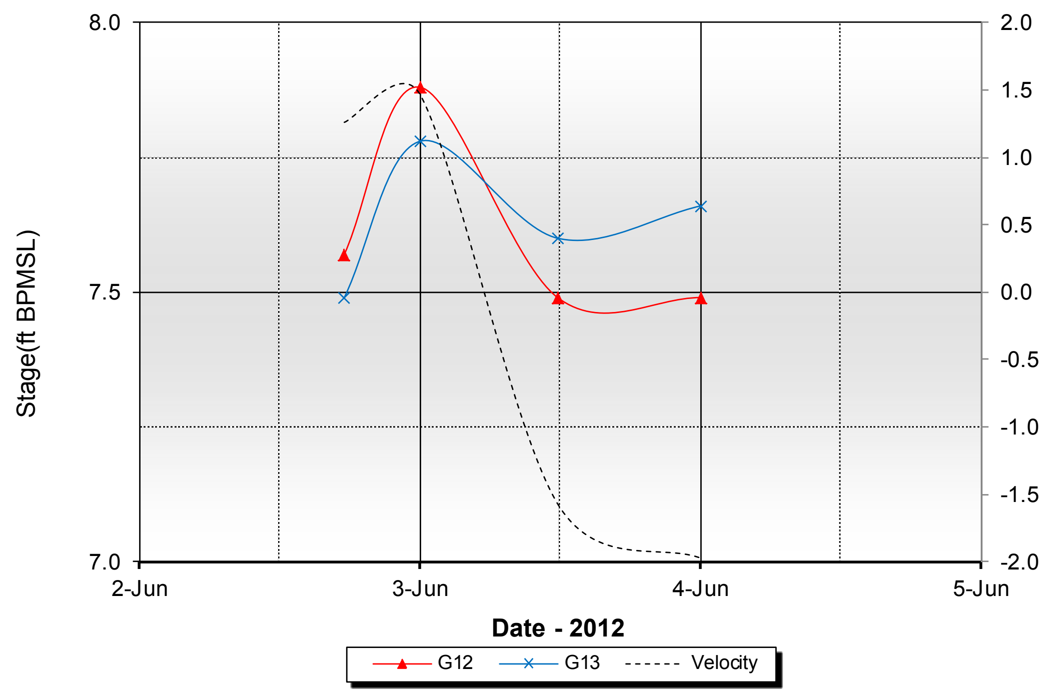
Table 5.9: 2012 Indirect Velocity (fps) Summary, CD4 Road Culverts near G17/G18

Culvert	Jun 03 7:00 PM
CD4-24	2.83
CD4-25	-
CD4-26	-
CD4-27	-
CD4-28	-
CD4-29	-
CD4-30	-
CD4-31	-
CD4-32	-
CD4-33	-
Average Velocity	**2.83**

Calculated velocity for all culverts is related to WSE differentials between the culvert headwater and tailwater. A comparison of observed stage and indirect velocity for the CD2 and CD4 road culverts is presented in Graph 5.5 through Graph 5.9.

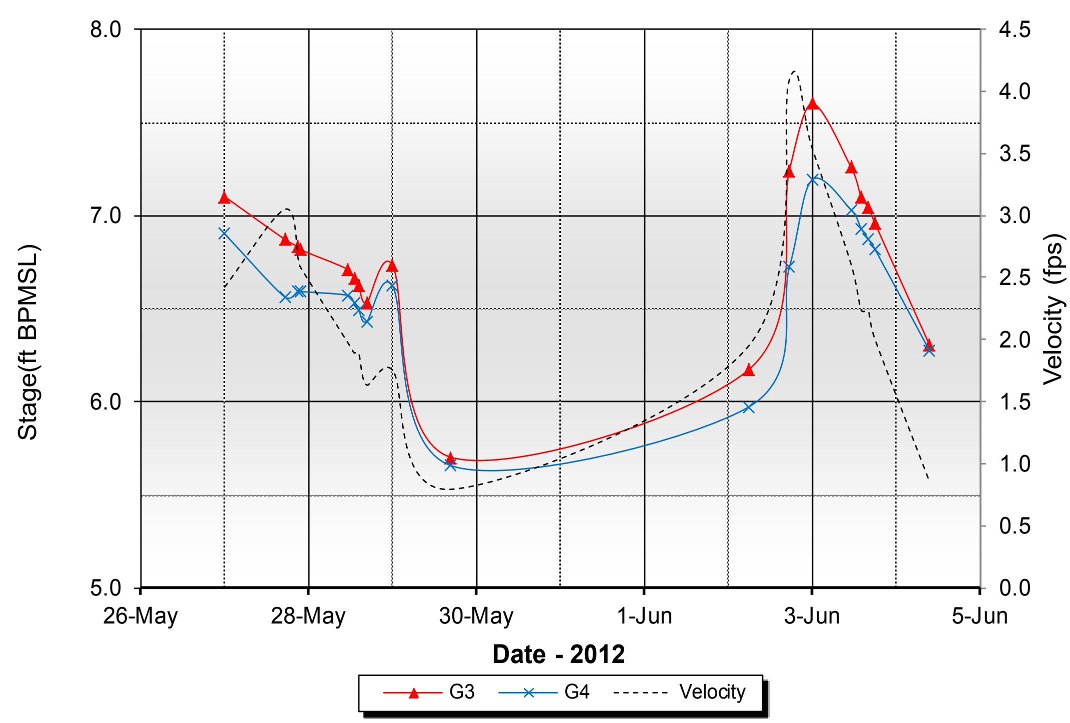


Graph 5.5: Indirect Velocity v. Observed Stage, CD2 Road Culverts near G6/G7

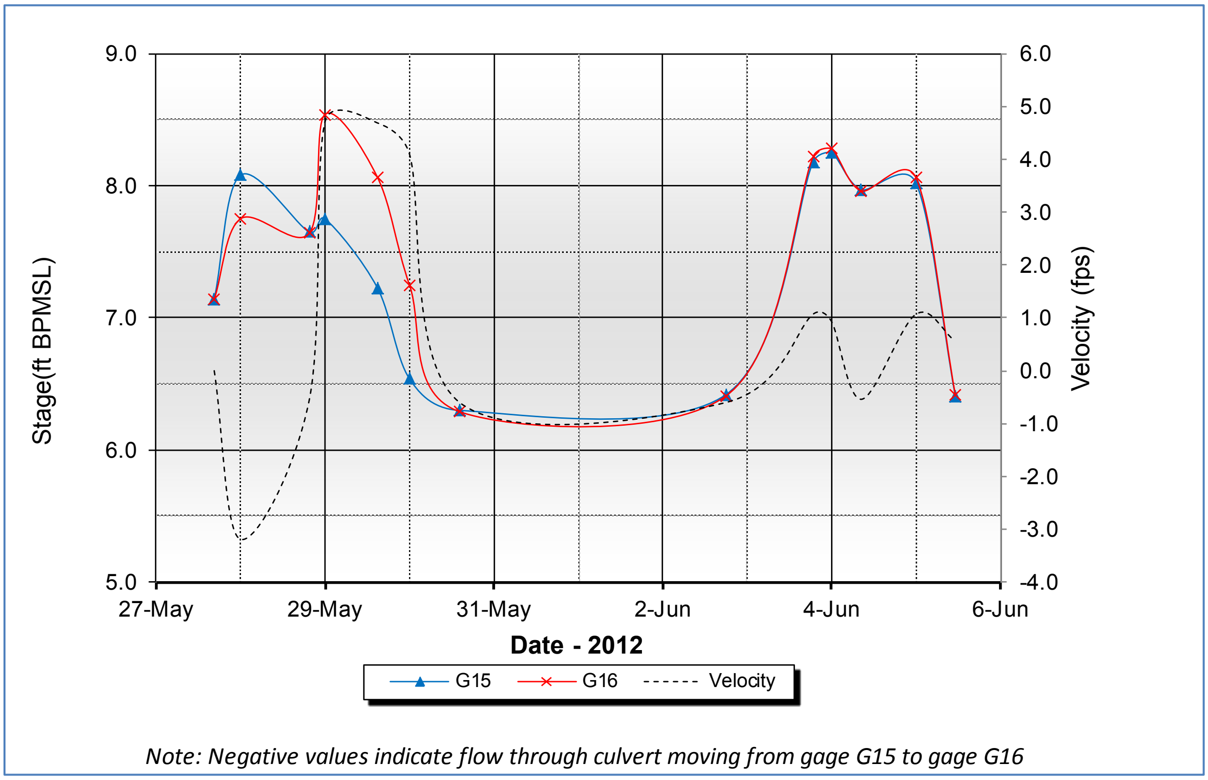


Note: Negative values indicate flow through culvert moving from gage G13 to gage G12

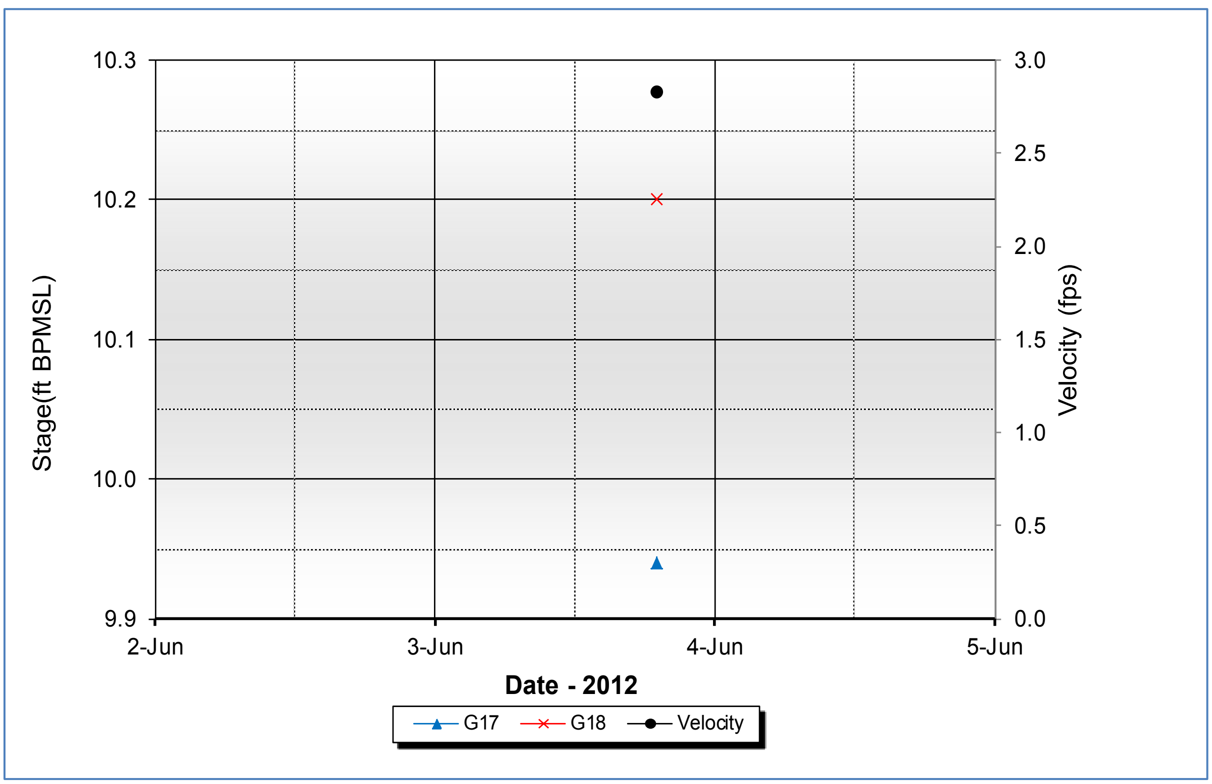
Graph 5.6: Indirect Velocity v. Observed Stage, CD2 Road Culverts near G12/G13



Graph 5.7: Indirect Velocity v. Observed Stage, CD2 Road Culverts near G3/G4



Graph 5.8: Indirect Velocity v. Observed Stage, CD4 Road Culverts near G15/G16



Graph 5.9: Indirect Velocity v. Observed Stage, CD4 Road Culverts near G17/G18

Alpine Culverts Indirect Discharge

The peak indirect discharge for a single CD2 road culvert near G6/G7 was 22.97 cfs through CD2-5. This discharge coincided with peak stage estimated around 12:00 AM on June 3. Since CD2-5 was the only culvert unblocked or passing any flow, total peak discharge for all eight culverts near G6/G7 was also 22.97 cfs. The peak discharge for a single CD2 road culvert near G12/G13 was calculated to have been -10.76 cfs through CD2-12. A negative discharge indicates the flow through the culvert moved from G13 to G12. This discharge was estimated at around 12:00 AM on June 4. Total peak discharge for all 10 culverts near G12/G13 occurred around 12:00 AM on June 4 and was calculated as -27.82 cfs. This negative value also indicates the flow through the culvert moved from G13 to G12. The peak discharge for a single CD2 road culvert near G3/G4 was 35.67 cfs through culvert CD2-24 during peak stage. Calculated total peak discharge for all six culverts near G3/G4 occurred during peak stage (June 3 at 12:00 AM) and was 123.27 cfs. The calculated peak total discharge through all CD2 road culverts at a single time was 173.95 cfs, which occurred during peak stage, estimated between late in the night of June 2 and early in the morning of June 3. The CD2 road culvert indirect discharge results are presented in Table 5.10, Table 5.11, and Table 5.12.

Table 5.10: 2012 Indirect Discharge (cfs) Summary, CD2 Road Culverts near G6/G7

Culvert	*Jun 03 12:00 AM*	Jun 03 12:15 PM	Jun 04 9:55 AM
CD2-1	-	-	-
CD2-2	-	-	-
CD2-3	-	-	-
CD2-4	-	-	-
CD2-5	22.97	0.00	0.00
CD2-6	-	-	-
CD2-7	-	-	-
CD2-8	-	-	-
Total Discharge	**22.97**	**0.00**	**0.00**

Table 5.11: 2012 Indirect Discharge (cfs) Summary, CD2 Road Culverts near G12/G13

Culvert	Jun 02 5:30 PM	*Jun 03 12:00 AM*	Jun 03 11:45 AM	Jun 04 12:00 AM
CD2-9	-	-	-	-
CD2-10	-	-	-	-
CD2-11	-	-	-	-
CD2-12	7.32	10.60	-8.60	-10.76
CD2-13	4.80	7.45	-5.67	-7.20
CD2-14	6.62	9.66	-7.82	-9.86
CD2-15	-	-	-	-
CD2-16	-	-	-	-
CD2-17	-	-	-	-
CD2-18	-	-	-	-
Total Discharge	**18.74**	**27.71**	**-22.09**	**-27.82**

Note: Negative values indicate flow through culvert moving from gage G13 to gage G12

Table 5.12: 2012 Indirect Discharge (cfs) Summary, CD2 Road Culverts near G3/G4

Culvert	May 27 12:00 AM	May 27 5:15 PM	May 27 9:05 PM	May 27 9:40 PM	May 28 11:10 AM	May 28 1:00 PM	May 28 2:20 PM	May 28 4:40 PM	May 29 12:00 AM
CD2-19	-	-	-	-	-	-	-	-	-
CD2-20	4.70	3.10	2.77	2.69	1.86	1.58	1.39	0.95	1.86
CD2-21	11.66	10.55	9.52	9.31	7.05	6.49	6.19	5.02	6.59
CD2-22	12.82	12.00	10.79	10.54	7.96	7.36	7.05	5.76	7.39
CD2-23	20.18	21.09	18.79	18.39	14.10	13.25	12.92	10.88	12.84
CD2-24	22.17	23.66	21.06	20.61	15.85	14.95	14.63	12.39	14.39
CD2-25	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-
Total Discharge	**71.53**	**70.40**	**62.93**	**61.54**	**46.82**	**43.63**	**42.18**	**35.00**	**43.07**

Culvert	May 29 4:45 PM	Jun 02 5:50 AM	Jun 02 5:30 PM	*Jun 03 12:00 AM*	Jun 03 11:05 AM	Jun 03 2:00 PM	Jun 03 4:10 PM	Jun 03 5:55 PM	Jun 04 9:40 AM
CD2-19	-	-	-	-	-	-	-	-	-
CD2-20	0.00	0.00	6.50	10.66	6.23	4.52	4.08	3.34	0.19
CD2-21	0.54	3.40	16.45	21.04	13.91	11.01	10.46	9.07	2.18
CD2-22	0.82	4.31	18.58	22.84	15.18	12.07	11.51	10.00	2.55
CD2-23	3.44	10.91	30.23	33.06	23.01	18.85	18.30	16.18	5.31
CD2-24	4.36	13.00	33.49	35.67	25.07	20.67	20.16	17.88	6.13
CD2-25	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-
Total Discharge	**9.16**	**31.62**	**105.25**	**123.27**	**83.40**	**67.12**	**64.51**	**56.47**	**16.36**

The peak discharge for a single CD4 road culvert near G15/G16 was 92.42 cfs through CD4-22. This discharge coincided with peak stage, estimated as 12:00 AM May 29. Total peak discharge for all 11 culverts near G15/G16 occurred during peak stage and is also calculated as 92.42 cfs, since CD4-22 was the only culvert unblocked or passing any flow during peak stage. The discharge for a single CD4 road culvert near G17/G18 was 6.94 cfs through CD4-24. This discharge was estimated as 7:00 PM June 3 and was the only measured discharge on G17/G18 gages.

The calculated peak total discharge through all CD4 road culverts was 92.42 which occurred on the afternoon of May 29. The CD4 road culvert indirect discharge results are presented in Table 5.13 and Table 5.14.

Table 5.13: 2012 Indirect Discharge (cfs) Summary, CD4 Road Culverts near G15/G16

Culvert	May 27 4:30 PM	May 28 12:00 AM	May 28 7:30 PM	*May 29 12:00 AM*	May 29 2:50 PM	May 30 12:00 AM	May 30 2:15 PM
CD4-18	-	-	-	-	-	-	-
CD4-19	-	-	-	-	-	-	-
CD4-20A	-	-	-	-	-	-	-
CD4-20	-	-	-	-	-	-	-
CD4-21	-	-	-	-	-	-	-
CD4-22	0.00	-59.30	-10.25	92.42	89.23	68.36	-7.47
CD4-23	-	-	-	-	-	-	-
CD4-23A	-	-	-	-	-	-	-
CD4-23B	-	-	-	-	-	-	-
CD4-23C	-	-	-	-	-	-	-
CD4-23D	-	-	-	-	-	-	-
Total Discharge	**0.00**	**-59.30**	**-10.25**	**92.42**	**89.23**	**68.36**	**-7.47**

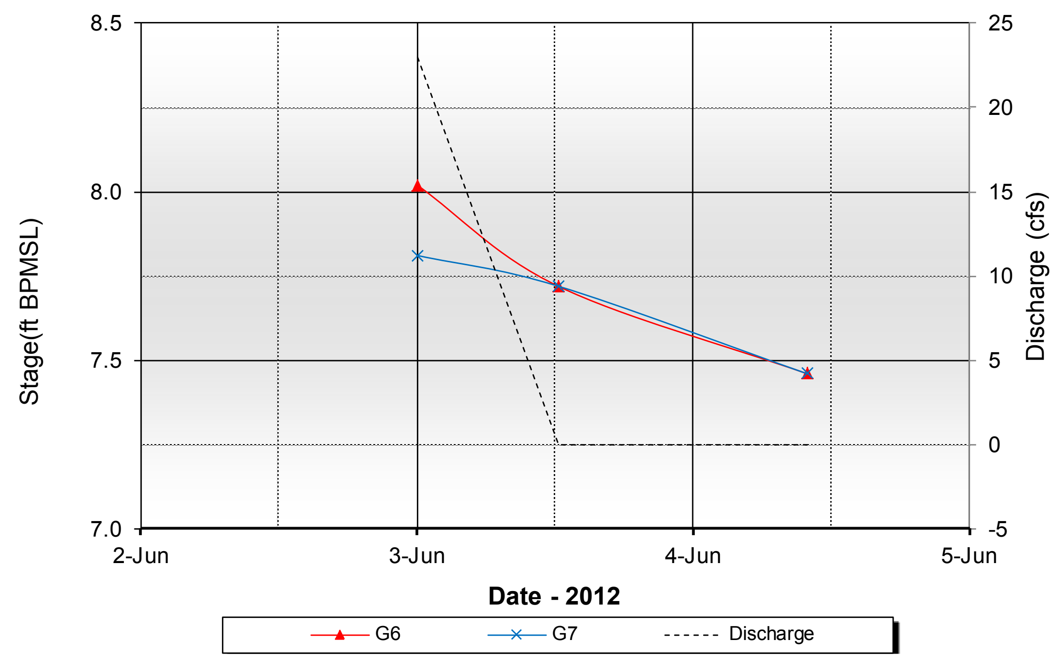
Culvert	Jun 02 6:00 PM	Jun 03 6:45 PM	Jun 04 12:00 AM	Jun 04 8:30 AM	Jun 05 12:00 AM	Jun 05 11:10 AM
CD4-18	-	-	-	-	-	-
CD4-19	-	-	-	-	-	-
CD4-20A	-	-	18.22	-10.52	21.04	9.25
CD4-20	-	-	18.22	-10.52	21.04	8.71
CD4-21	-	-	18.22	-10.52	21.04	8.51
CD4-22	-7.79	21.03	18.22	-10.44	20.95	7.85
CD4-23	-	-	-	-	-	-
CD4-23A	-	-	-	-	-	-
CD4-23B	-	-	-	-	-	-
CD4-23C	-	-	-	-	-	-
CD4-23D	-	-	-	-	-	-
Total Discharge	**-7.79**	**21.03**	**72.88**	**-42.00**	**84.07**	**34.32**

Note: Negative values indicate flow through culvert moving from gage G15 to gage G16

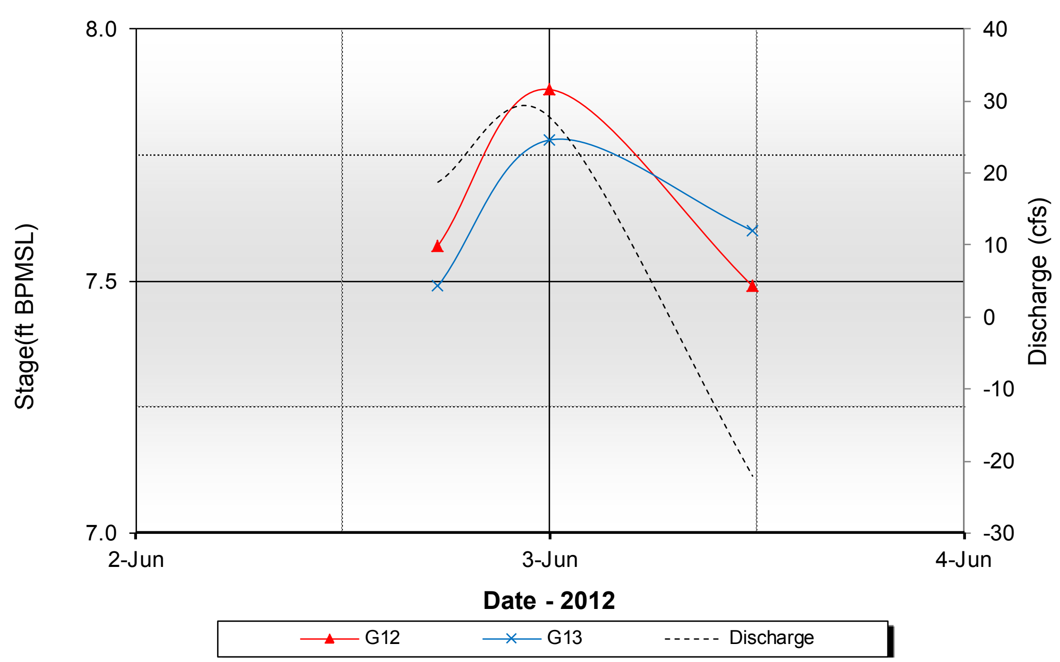
Table 5.14: 2012 Indirect Discharge (cfs) Summary, CD4 Road Culverts near G17/G18

Culvert	Jun 03 7:00 PM
CD4-24	6.94
CD4-25	-
CD4-26	-
CD4-27	-
CD4-28	-
CD4-29	-
CD4-30	-
CD4-31	-
CD4-32	-
CD4-33	-
Total Discharge	**6.94**

Calculated indirect discharge for all culverts is directly related to WSE. A comparison of observed stage and indirect discharge during spring breakup 2012 for CD2 and CD4 road culverts is presented in Graph 5.10 through Graph 5.14.

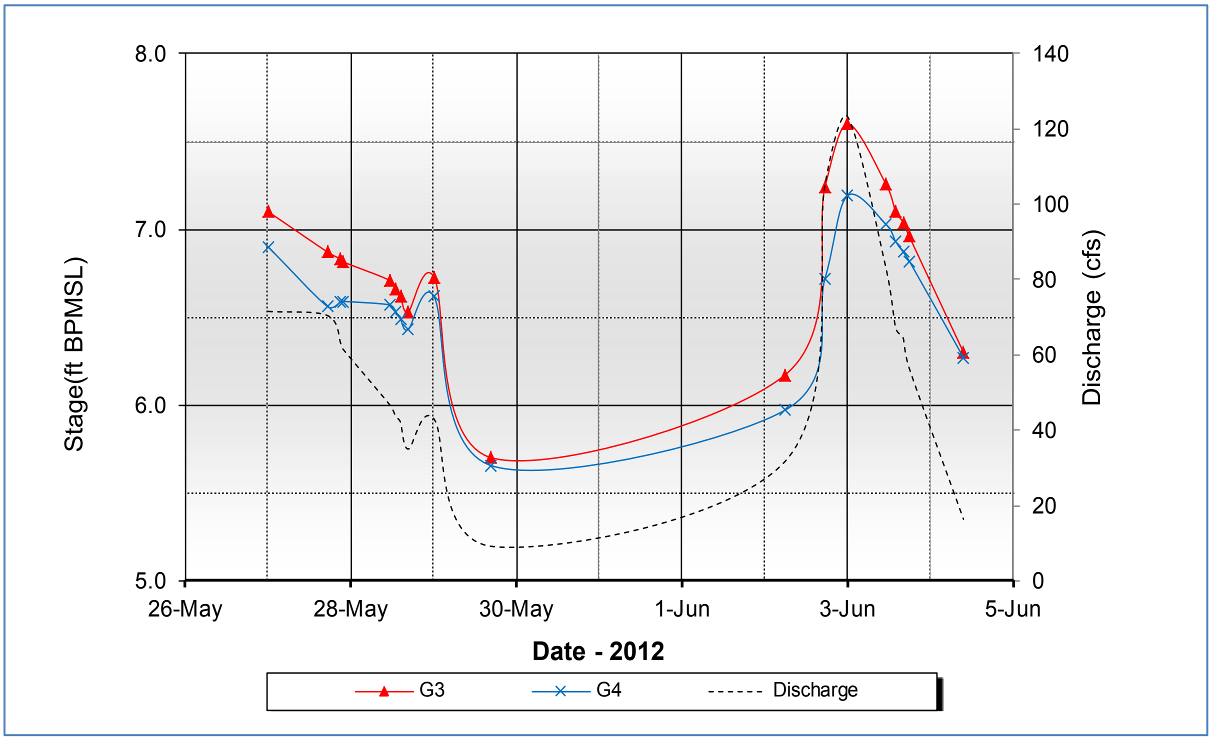


Graph 5.10: Indirect Discharge v. Observed Stage, CD2 Road Culverts near G6/G7

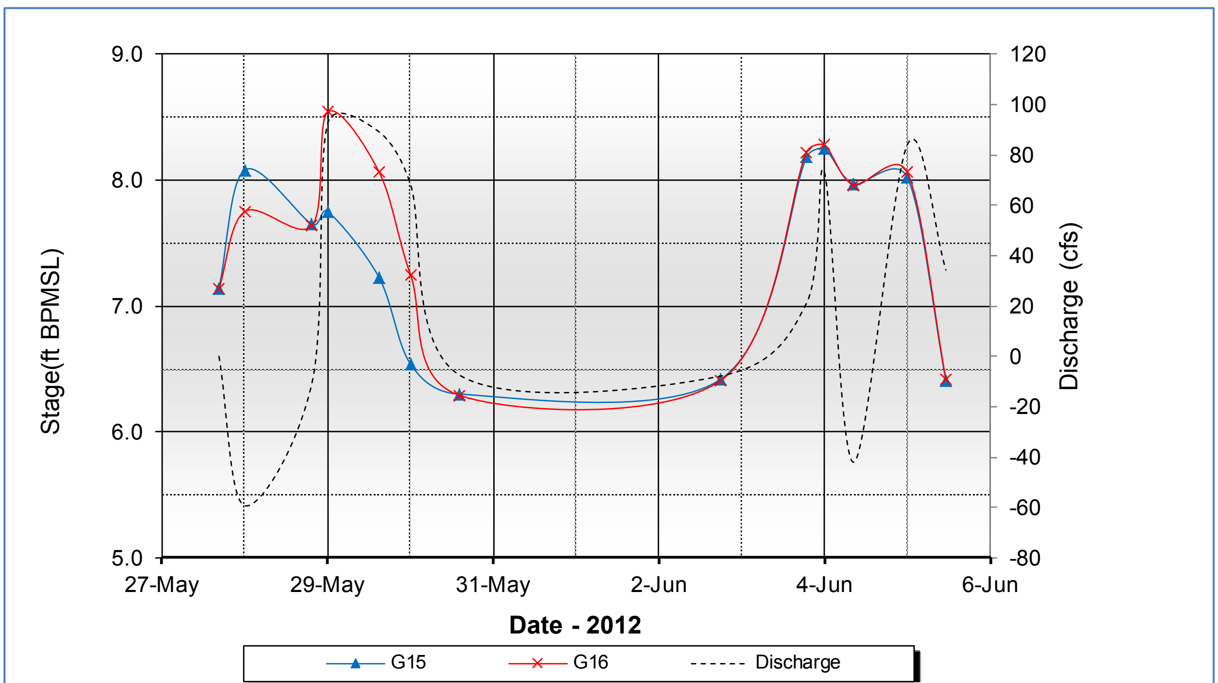


Note: Negative values indicate flow through culvert moving from gage G13 to gage G12

Graph 5.11: Indirect Discharge v. Observed Stage, CD2 Road Culverts near G12/G13

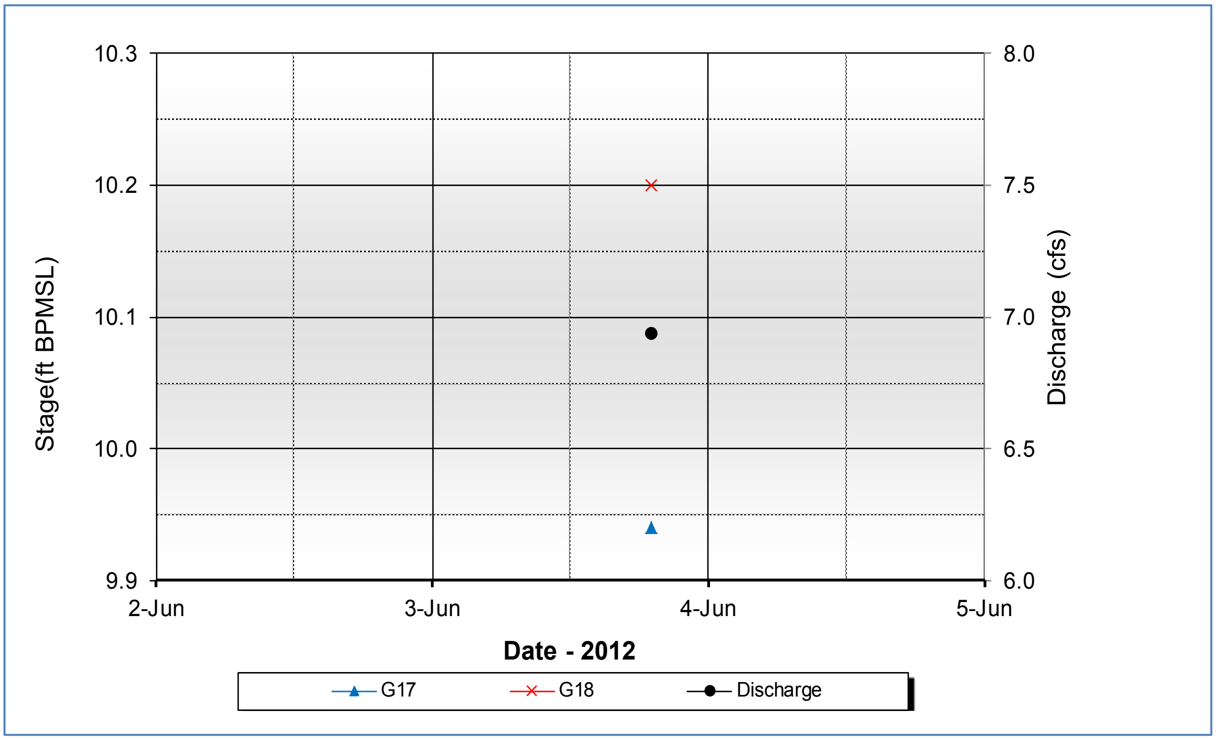


Graph 5.12: Indirect Discharge v. Observed Stage, CD2 Road Culverts near G3/G4



Note: Negative values indicate flow through culvert moving from gage G15 to gage G16

Graph 5.13: Indirect Discharge v. Observed Stage, CD4 Road Culverts near G15/G16



Graph 5.14: Indirect Discharge v. Observed Stage, CD4 Road Culverts near G17/G18

5.6.3 Alpine Culverts Indirect/Direct Discharge Estimates Comparison

Indirect calculations were used to estimate peak discharge values. The indirect estimates were compared with the respective direct velocity measurements and associated discharge quantities to determine the relative accuracy of the indirect calculations. Discrepancies in these values are a result of culvert performance. Field conditions at the time of measurement differed from conditions assumed for calculations. Many culverts were partially or entirely blocked during measurement. The indirect calculations assume unobstructed conditions. The largest discrepancy was at culvert CD2-13. It was largely blocked at the south end. Flow was moving upstream, from north to south. The percent difference between measured and calculated mean velocity and total discharge was -19% and 13% respectively. The comparison between the June 3, 2012 CD2 road culverts direct and indirect measurements are presented in Table 5.15.

Table 5.15: CD2 Road Culverts – Indirect/Direct Discharge Comparison

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement June 3	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 3	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD2-12	11:50 AM	-2.19	-23.03	11:45 AM	-1.79	-8.60	18%	63%
CD2-13	11:45 AM	-0.03	-0.14	11:45 AM	-1.46	-5.67	-4767%	-3899%
CD2-14	11:40 AM	-1.74	-10.49	11:45 AM	-1.46	-7.82	16%	25%
CD2-20	11:35 AM	3.02	8.27	11:05 AM	2.40	6.23	21%	25%
CD2-21	11:30 AM	2.73	15.19	11:05 AM	2.48	13.91	9%	8%
CD2-22	11:25 AM	3	16.45	11:05 AM	2.71	15.18	10%	8%
CD2-23	11:20 AM	2.92	24.13	11:05 AM	2.76	23.01	5%	5%
CD2-24	11:15 AM	2.61	23.94	11:05 AM	2.71	25.07	-4%	-5%
Average Measured Velocity (ft/s)			1.29	Average Calculated Velocity (ft/s)		1.04	Avg. V Difference	19%
Total Measured Discharge (cfs)			54.32	Total Calculated Discharge (cfs)		61.31	Tot. Q Difference	-13%

5.7 Colville River Delta Peak Discharge Flow Distribution

Approximately 82% of the flow in the CRD passed through the East Channel during the 2012 spring breakup peak discharge event. Peak discharge was estimated to have occurred at MON1 the afternoon of June 1, 2012. Approximately 16% of the flow passed down the Nigliq Channel at MON23/proposed CD5 bridge crossing. The remaining 2% of flow was calculated to have gone through the CD2 road culverts and the swale bridges. Figure 5.9 presents the 2012 estimated peak flow distribution within the CRD.

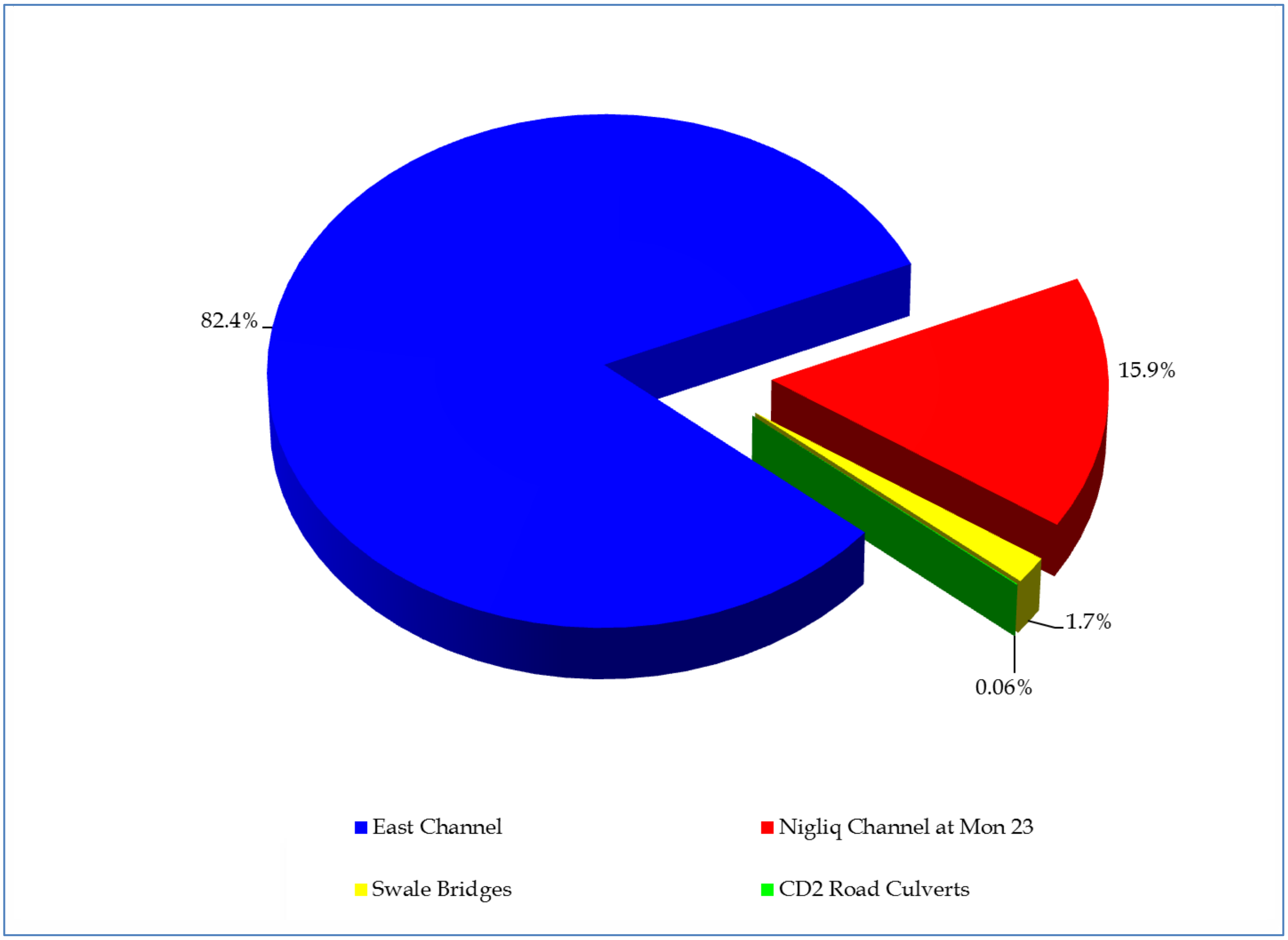


Figure 5.9: 2012 CRD Estimated Peak Flow Distribution Chart

5.8 Flood and Stage Frequency Analyses

5.8.1 Colville River Flood Frequency

Both continuous record and design-magnitude flood frequency analyses were performed for the Colville River at the head of the delta in 2012. These were based on reported annual peak discharge data from 1992 through 2012 and the extrapolated data extending back to 1971, which is recommended for design-magnitude extrapolation with less than 50 years of record. The 2012 data, similar to previous years, was ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for design-magnitude extrapolation. Results were compared between the 2012 Weibull and Log-Pearson Type III analyses for the period of continuous record; the 2002, 2009, and 2012 Log-Pearson Type III analyses for the period of continuous record; and the 2002, 2009, and 2012 Log-Pearson Type III analyses for design-magnitude returns. The 2002 results are the current design criteria.

Comparison of the 2012 Weibull and Log-Pearson Type III flood frequency analyses for the period of continuous record (1992 to 2012) are presented in Table 5.16, ranked in order (largest to smallest) of peak discharge. As noted, the Weibull analysis limits the return period to the number of record years plus one. As a result, the return period for each year is based solely on the ranked position within the continuous record with a maximum return period of 22 years assigned to the event with the largest peak discharge.

Table 5.16: Comparison of Colville River 2012 Weibull and Log-Pearson Type III Analysis Returns for the Period of Continuous Record (1992-2012)

Year	Discharge (cfs)	Weibull Return Period (years)	Log-Pearson Type III Return Period (years)	Difference
2011	590,000	22.00	22.58	2.6%
2000	580,000	11.00	21.47	95.2%
1993	379,000	7.33	5.00	-31.9%
2012	**366,000**	**5.50**	**4.67**	**-15.0%**
2004	360,000	4.40	4.52	2.8%
2010	320,000	3.67	3.53	-3.7%
2006	281,000	3.14	2.56	-18.6%
2007	270,000	2.75	2.30	-16.2%
2009	266,000	2.44	2.25	-8.1%
2001	255,000	2.20	2.09	-5.2%
2002	249,000	2.00	2.00	-0.1%
1995	233,000	1.83	1.83	-0.4%
2003	232,000	1.69	1.82	7.3%
2008	221,000	1.57	1.70	8.0%
1998	213,000	1.47	1.61	9.9%
1999	203,000	1.38	1.50	9.4%
2005	195,000	1.29	1.45	11.7%
1997	177,000	1.22	1.32	7.9%
1994	165,000	1.16	1.24	7.0%
1992	164,000	1.10	1.23	12.3%
1996	160,000	1.05	1.22	16.1%

Overall, the Weibull analysis tends to be more influenced by outliers while the Log-Pearson III analysis tends to over-predict returns for lower magnitude events. When comparing the 2012 results of the Weibull and Log-Pearson III analyses, the calculated return period for the discharge values are fairly close for small return periods. However, the limitations of the Weibull distribution are evident when looking at the recurrence interval for the larger return periods. The Weibull distribution assigns an 11-year return period to the 580,000 cfs in 2000, which is significantly less than the 21.5-year return period assigned by the 2012 flood frequency analysis. The large discrepancy can be attributed to the higher magnitude discharge events in 2000 and 2011. Therefore, even though the 2000 and 2011 have comparable discharges, the Weibull distribution assigns a shorter return period to the 2000 observation.

A comparison of the 2012 and 2009 Log-Pearson Type III flood frequency results for the period of continuous record (1992 to 2012) is presented in Table 5.17. The inclusion of the additional three years of observations (2010, 2011, and 2012) in the 2012 analysis resulted in a slight shift of the frequency distribution toward larger magnitude floods, which shortens the return periods for past observations.

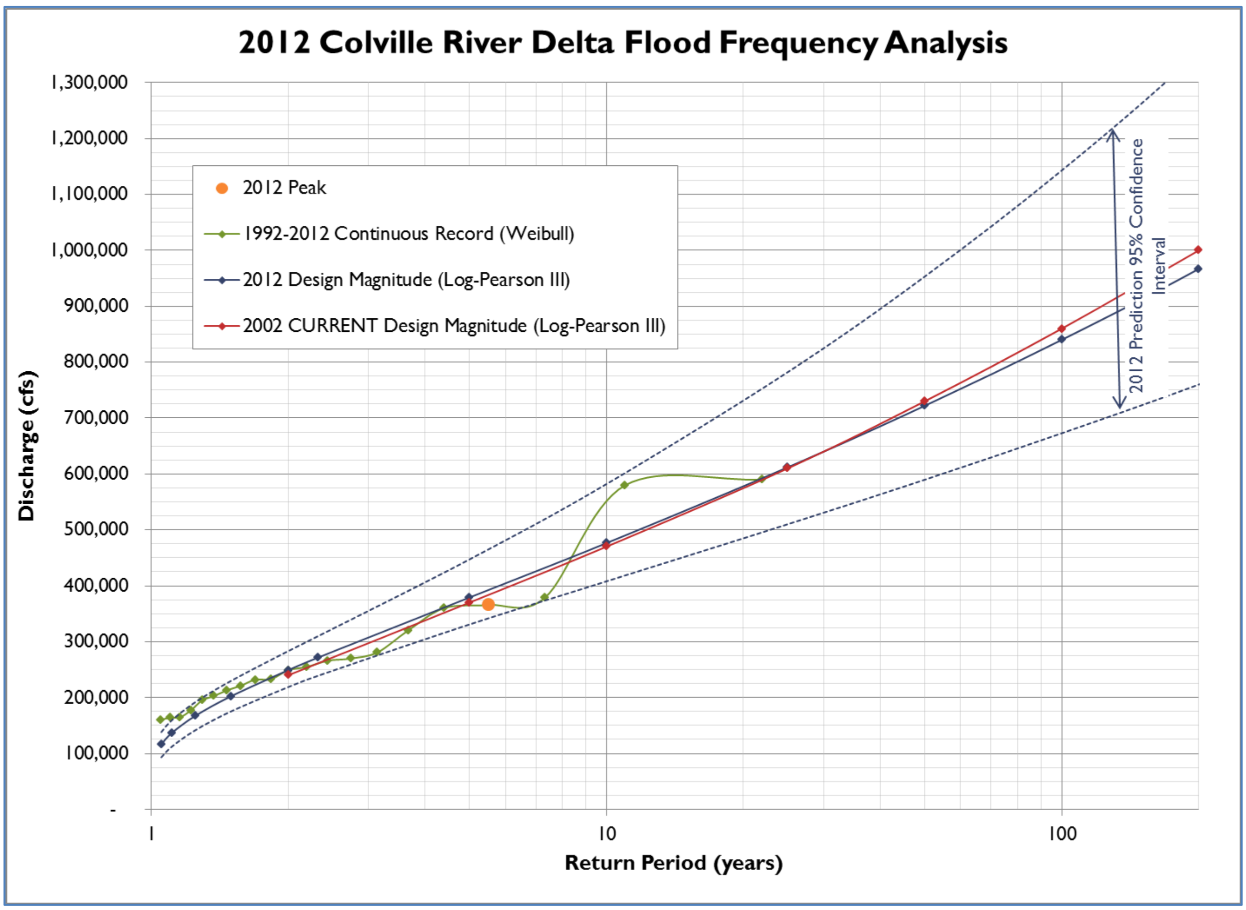
Table 5.17: Comparison of Colville River 2002, 2009 and 2012 Log-Pearson Type III Analysis Returns for the Period of Continuous Record (1992-2012)

Year	Discharge (cfs)	2002 Return Period-Basis for Current Design (years)	2009 Log-Pearson Type III Return Period (years)	2012 Log-Pearson Type III Return Period (years)
2011	590,000	22.9	24.9	22.6
2000	580,000	21.8	23.8	21.5
1993	379,000	5.5	5.9	5.0
2012	**366,000**	**4.9**	**5.3**	**4.7**
2004	360,000	4.8	5.0	4.5
2010	320,000	3.8	3.9	3.5
2006	281,000	2.9	2.9	2.6
2007	270,000	2.7	2.6	2.3
2009	266,000	2.6	2.5	2.2
2001	255,000	2.3	2.3	2.1
2002	249,000	2.2	2.2	2.0
1995	233,000	<2	2.0	1.8
2003	232,000	<2	1.9	1.8
2008	221,000	<2	1.8	1.7
1998	213,000	<2	1.7	1.6
1999	203,000	<2	1.6	1.5
2005	195,000	<2	1.5	1.4
1997	177,000	<2	1.4	1.3
1994	165,000	<2	1.3	1.2
1992	164,000	<2	1.3	1.2
1996	160,000	<2	1.2	1.2

A comparison of the 2002, 2009, and 2012 Log-Pearson Type III flood frequency analyses for design magnitudes is presented in Table 5.18. The return intervals from the 2002 analysis were within 4% of those derived from the 2012 analysis. Since the 2002 results fell within the 95% confidence interval of the 2012 analysis results (Graph 5.15), it is recommended that the results of the 2002 flood analysis be maintained as current design criteria. The 2012 peak discharge of 366,000 has a return interval of 4.9 years. Peak discharge was the result of an ice jam release that sent a surge of floes and backwater through the MON1 reach and was not a sustained event. The associated recurrence interval should be considered with respect to conditions at the time of peak discharge. Graph 5.15 provides a plotted comparison of the 2012 continuous record, 2012 design-magnitude, and 2002 design-magnitude flood frequency analysis results.

Table 5.18: Comparison of Colville River 2002, 2009 and 2012 Log-Pearson Type III Analysis Results for Design Magnitudes

Return Period	2002 Results (Basis for Current Design Criteria)	2009 Results	2012 Results
	Flood Peak Discharge (cfs)	Flood Peak Discharge (cfs)	Flood Peak Discharge (cfs)
2-year	240,000	240,000	249,000
5-year	370,000	360,000	379,000
10-year	470,000	460,000	476,000
25-year	610,000	590,000	612,000
50-year	730,000	700,000	722,000
100-year	860,000	830,000	840,000
200-year	1,000,000	960,000	967,000

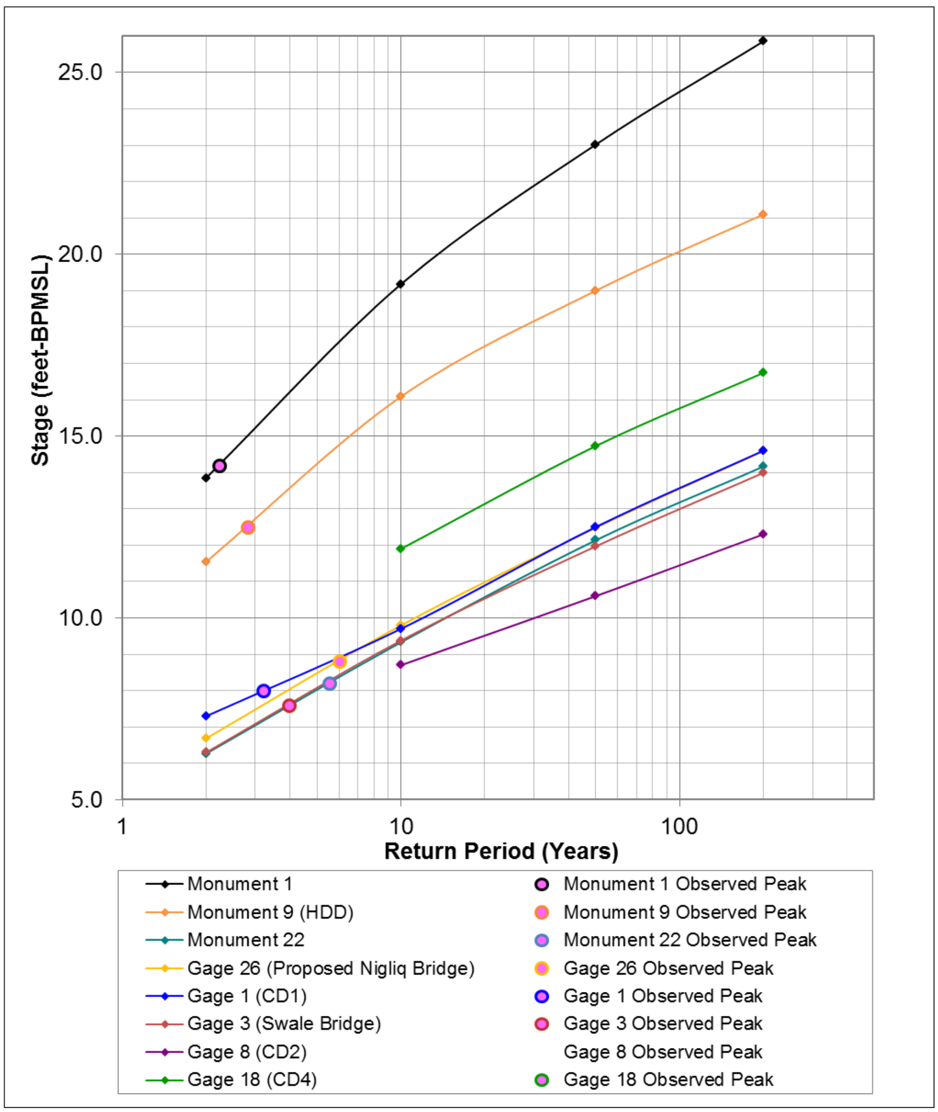


Graph 5.15: Colville River Delta Flood Frequency Analysis Distribution

5.8.2 CRD 2D Surface Water Model Predicted and Observed WSE

The Colville River 2D surface water model was first developed in 1997 to estimate WSE and velocities at the proposed ADP facilities locations (Baker 1998a). The model has undergone numerous revisions since 1997. Proposed CD3 and CD4 satellite developments were incorporated in 2002, including additional floodplain topographic survey data (Baker 2002a). In 2006, the model was modified to include as-built alignment conditions along the CD4 access road and pad and the 2004-2005 survey data of the Nigliq Channel near MON23 (Baker 2006b). The model was completely reconstructed in 2009 (Baker 2009a). In 2012, the model was revised to incorporate refined topography along the proposed CD5 road alignment and channel crossings.

Graphical representation of the 2012 observed peak stage and predicted WSE for 2-, 10-, 50-, and 100-year floods are shown in Graph 5.16. The current 2D surface water model predictions and the 2012 observations are presented in Table 5.19.



Graph 5.16: CRD 2D Model Predicted and 2012 Observed Peak WSE

Table 5.19: CRD 2D Model Predicted and 2012 Observed Peak WSE

Monitoring Sites	2D Model Predicted Water Surface Elevation [based on open water conditions] (feet BPMSL)				2012 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (years)
	2-year	10-year	50-year	200-year		
Monuments - Colville East Channel						
Monument 1 (Centerline)	13.9	19.2	23.0	25.9	14.2	2
Monument 9 (HDD)	11.5	16.1	19.0	21.1	12.5	3
Monument 35 (Helmericks)	4.3	5.4	6.1	6.5	4.4	2
Monuments - Nigliq Channel						
Monument 20	7.8	11.4	14.6	16.8	10.4	6
Monument 22	6.3	9.3	12.1	14.2	8.2	6
Monument 23	5.1	7.4	10.2	12.0	7.4	10
Monument 28	3.1	3.4	3.9	4.3	4.4	Influenced by Storm Surge
CD1 Pad						
Gage 1	7.3	9.7	12.5	14.6	7.8	3
Gage 9	8.3	10.8	13.4	15.7	8.2	<2
Gage 10	8.3	10.8	13.4	15.7	8.2	<2
CD2 Pad						
Gage 8	\	8.7	10.6	12.3	-	-
CD2 Road						
Gage 3	6.3	9.4	12.0	14.0	7.6	4
Gage 4	6.2	8.5	10.1	11.7	7.2	4
Gage 6	\	9.5	12.2	14.2	8.0	<10
Gage 7	\	8.4	10.0	11.6	7.8	<10
Gage 12	\	9.5	12.1	14.2	7.9	<10
Gage 13	\	8.4	10.0	11.6	7.8	<10
CD3 Pad						
Gage 11	5.2	6.4	6.9	8.0	-	-
CD4 Pad						
Gage 19	\	\	14.6	16.6	-	-
Gage 20	\	11.1	14.2	16.3	10.0	<10
CD4 Road						
Gage 15	8.4	10.8	13.5	15.8	8.3	<2
Gage 16	8.4	11.1	14.2	16.1	8.5	2
Gage 17	\	11.1	14.2	16.2	-	-
Gage 18	\	11.9	14.7	16.7	-	-
CD3 Pipeline Crossings						
Sakoonang (Crossing #2) Gage	6.4	8.9	11.2	12.9	6.9	3
Tamayagiaq (Crossing #4) Gage	6.7	8.5	9.0	9.8	7.3	3
Ulamnigiaq (Crossing #5) Gage	5.5	7.1	7.8	8.7	6.0	3
Proposed CD5 Road Crossings						
Gage 32 (L9323)	\	11.1	14.0	15.8	8.6	<10
Gage 26 (Nigliq Channel)	6.7	9.8	12.5	14.6	8.8	6
Gage 30	\	\	12.8	14.8	-	-
Gage 32 (L9341)	\	\	12.8	14.8	8.9	<50
Gage 34	\	\	12.7	14.8	-	<2
Gage 36	\	\	12.7	14.8	-	<2
Gage 38 (Nigliagvik)	6.9	9.9	12.7	14.9	8.5	5

Notes:
1. Sites having dry ground in 2D model are denoted with a backward slash "\"
2. Sites having no observed WSE in 2012 are denoted with a dash "-"

The 2D surface-water model was developed to predict open water conditions during low-frequency, high-magnitude flood events having 50- and 200-year recurrence intervals. To estimate the relationship between discharge and stage during lower-magnitude flood events, 2- and 10-year flood events have been modeled. The model assumes open water, steady-state conditions, and does not account for snow, channel ice, or ice jams.

In general, the 2D model under-predicts stage for lower-return periods of approximately 10 years and less, as can be seen in Table 5.20. This is to be expected as the 2D model does not account for ice- and snow-related events, which can have a large effect on lower-magnitude flood events and less of an effect on higher-magnitude flood events. With an extended period of record, a stage frequency analysis can be a better estimate of low flood stage within the delta affected by recurrent ice jamming.

Table 5.20: Average Differences Between 2D Model Predicted and 2012 Observed WSE

Range of Return Period (years)	MON1	MON22	Gage 1	Gage 3	Gage 18
	(feet)				
Greater than 10	0.23	-0.40	0.73	-0.02	-1.45
Between 2 and 10	-3.56	-2.06	-0.49	-1.47	-2.80
Less than 2	-1.08	-1.13	0.75	-0.60	-1.25
	Note: Negative sign "-" indicates a lower 2D model prediction				

5.8.3 Colville River Delta Stage Frequency

Observed, estimated, and extrapolated peak annual stage data from 1992 through 2012 for locations used in the stage frequency analysis are presented in Table 5.21. Table 5.22 presents the Log-Pearson Type III 2012-stage frequency analysis results at selected locations. Graph 5.17 through Graph 5.21 compare visually the stage frequency analysis and 2D model results to the observed record for each selected location.

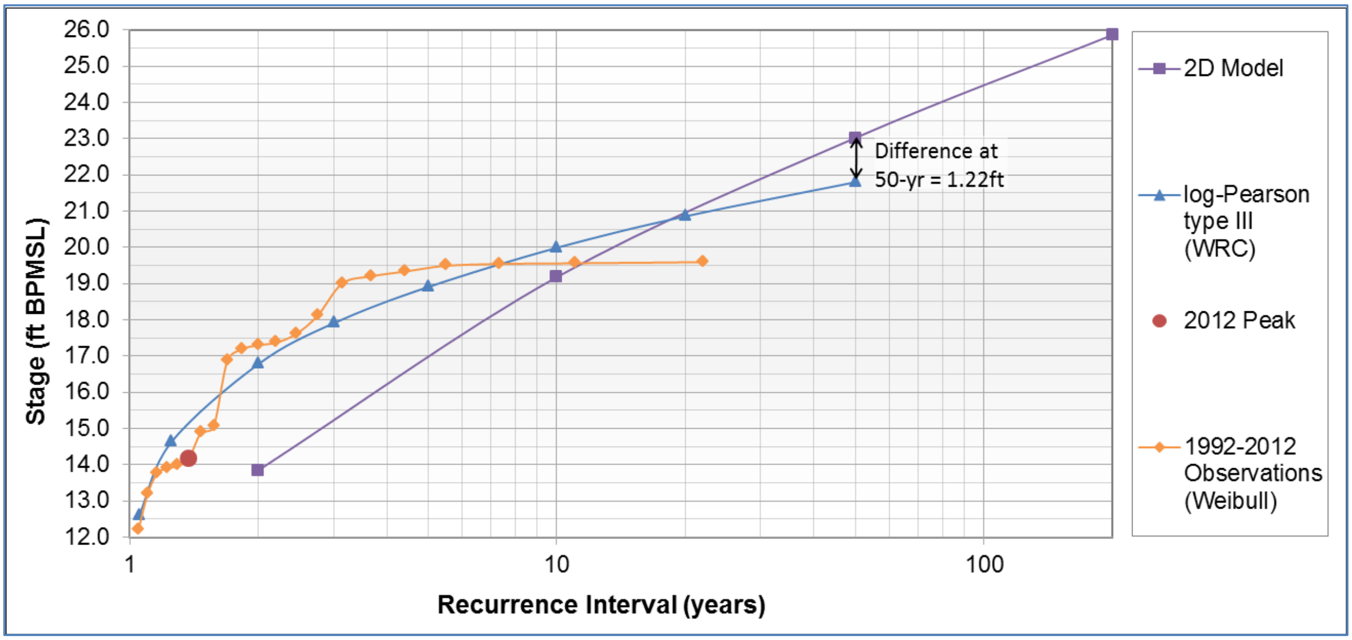
Table 5.21: CRD Peak Annual Stage for Selected Locations (1992-2012)

Year	Monument 1 (Head of Delta)	Monument 22 (Nigliq/CD2)	Gage 1 (CD1)	Gage 3 (Swale Bridge)	Gage 18 (CD4)
2012	14.18	8.17	7.97	7.60	-
2011	19.56	8.97	9.33	8.89	12.84
2010	19.59	8.69	7.15	8.64	11.72
2009	17.65	7.76	6.65	7.63	11.34
2008	17.30	6.78	5.61	8.60	8.60
2007	19.00	9.04	8.64	6.49	10.98
2006	19.49	9.95	9.29	9.72	14.67
2005	13.18	7.65	4.46	6.48	*8.17*
2004	19.54	10.17	8.88	9.97	*11.58*
2003	13.76	7.02	6.07	6.31	*8.03*
2002	16.87	7.94	7.68	7.59	*9.60*
2001	17.37	8.80	6.95	7.95	*10.16*
2000	19.33	9.58	*9.10*	*9.48*	*10.44*
1999	13.97	5.89	*4.64*	*5.79*	*7.10*
1998	18.11	10.20	**9.51**	**8.02**	**11.39**
1997	15.05	**7.56**	**6.27**	**7.02**	**8.64**
1996	17.19	**8.41**	**7.42**	**7.91**	**10.26**
1995	14.88	**7.49**	**6.18**	**6.94**	**8.52**
1994	12.20	**6.42**	**4.73**	**5.82**	**6.50**
1993	19.20	**9.22**	**8.51**	**8.76**	**11.77**
1992	13.90	**7.10**	**5.65**	**6.53**	**7.78**
Average:	16.73	8.23	7.18	7.72	10.00
Linear Equations:	-	y = 0.4x+1.5382	y = 0.5401x-1.8595	y = 0.4203x+0.6897	y = 0.7528x+2.6853

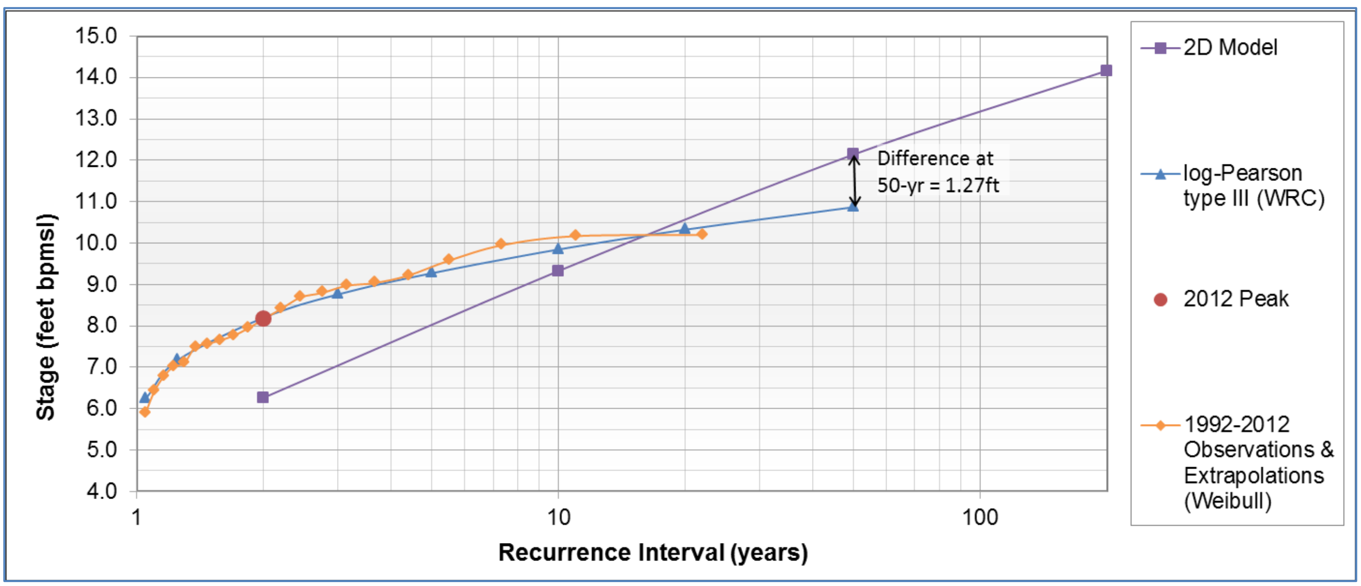
Notes:
1. Italicized values w ere estimated based on linear comparison to peak stage at proximal monitoring locations.
2.Bold values w ere linearly extrapolated based on peak stage at Monument 1.

Table 5.22: CRD 2012 Stage Frequency Analysis Results

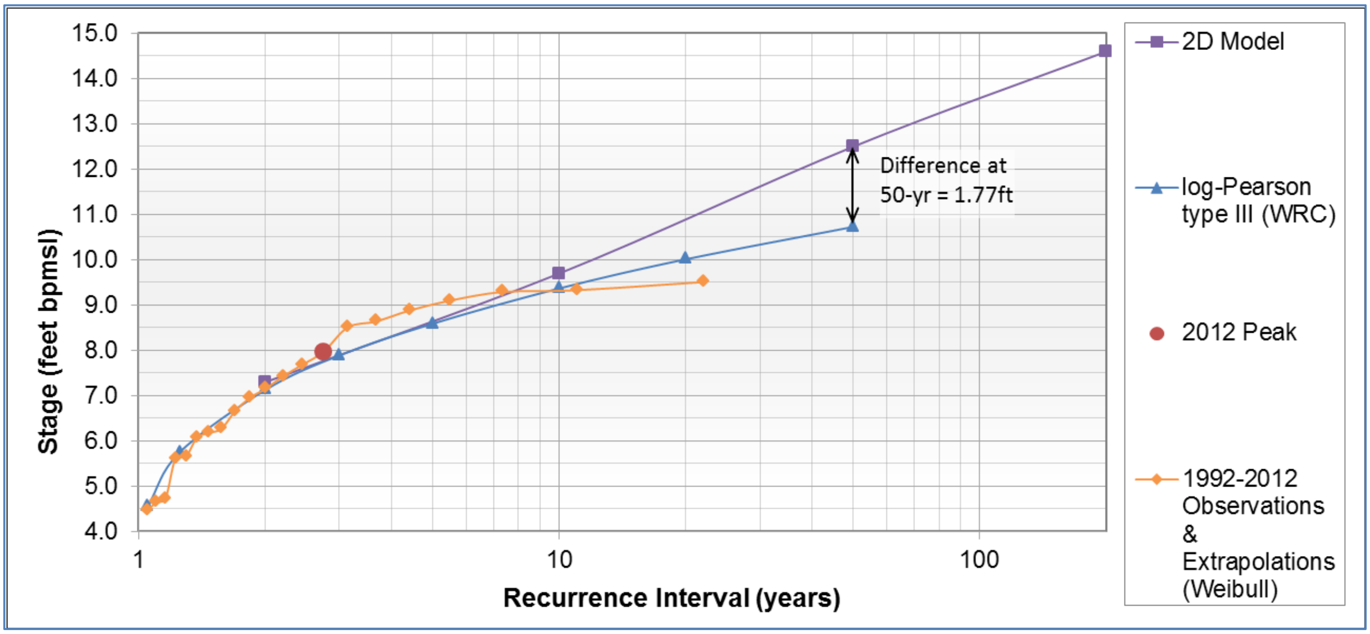
Monitoring Sites	Stage Frequency - Log-Pearson Type III (feet BPMSL)						2012 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of
	2-year	3-year	5-year	10-year	20-year	50-year		
Monument 1	16.8	17.9	18.9	20.0	20.9	21.8	14.2	<2
Monument 22	8.2	8.8	9.3	9.9	10.3	10.9	8.2	2
Gage 1	7.1	7.9	8.6	9.4	10.0	10.7	8.0	3
Gage 3	7.6	8.2	8.8	9.4	9.9	10.6	7.6	2
CD4 Pad (Gage 18)	9.9	10.8	11.7	12.8	13.7	14.8	-	-



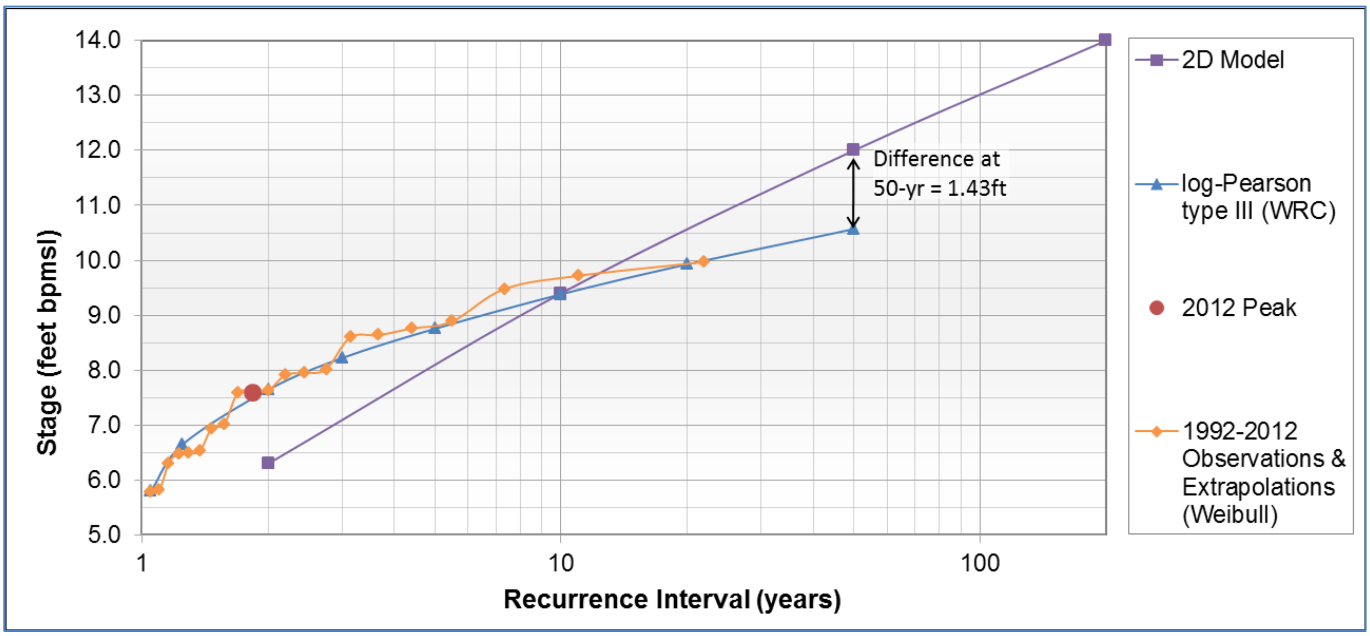
Graph 5.17: MON1 Stage Frequency Analysis, 2D Model Results, and 2012 Observed Data



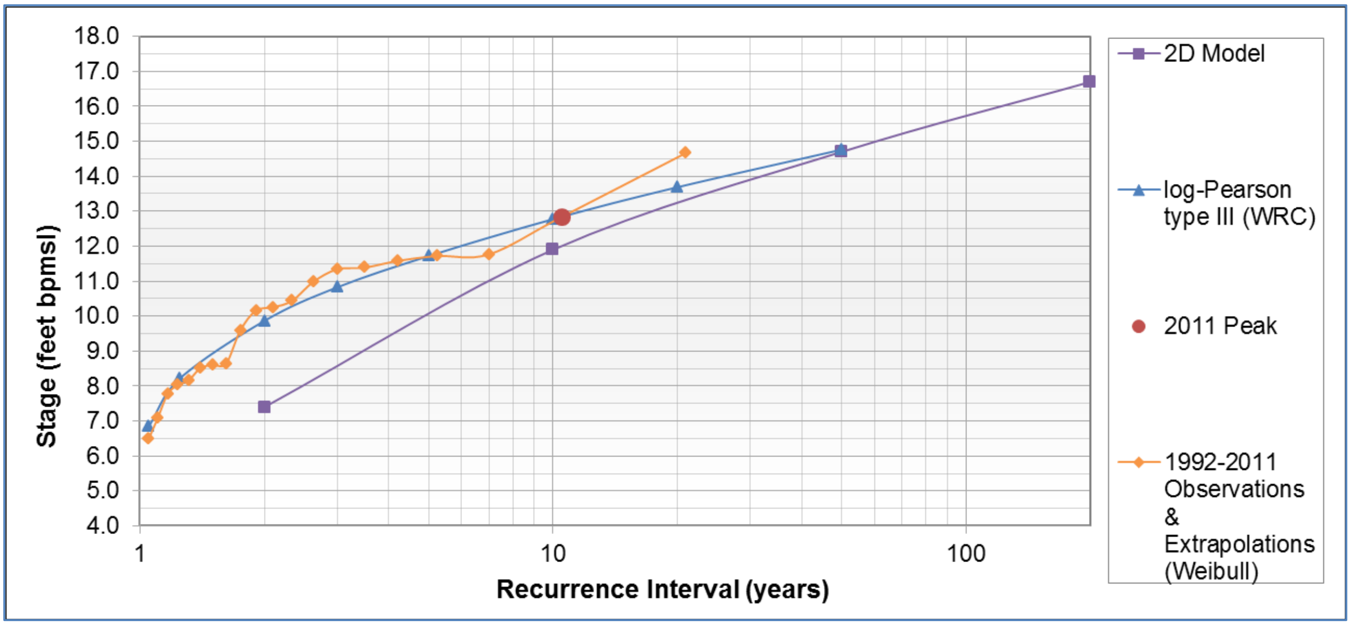
Graph 5.18: MON22 Stage Frequency Analysis, 2D Model Results, and 2012 Observed Data



Graph 5.19: G1 Stage Frequency Analysis, 2D Model Results, and 2012 Observed Data



Graph 5.20: G3 Stage Frequency Analysis, 2D Model Results, and 2012 Observed Data



Graph 5.21: G18 Stage Frequency Analysis, 2D Model Results, and 2012 Observed Data

The recurrence intervals for peak stage at all locations were comparatively lower for 2012; the maximum being 3 years at G1. The difference in the relationship between analysis methods that include ice events (Log-Pearson Type III) and those that do not (2D model) can be seen in the above graphs. In most cases, significant deviation between the 2D model and the Log-Pearson Type III in the high-magnitude flood region becomes apparent at return intervals greater than 10 years. Based on a comparison of these analyses, it is recommended that the Log-Pearson Type III fit be consulted for stage frequency for the lower return intervals (1 to 10 years, generally), and the 2D model be consulted for stage frequency for the higher return intervals (greater than 10 years, generally) as ice impacts are expected to decrease with larger return intervals. For those return intervals where a discrepancy occurs, the model analysis that produces the more conservative prediction is recommended.

5.8.4 2012 Discharge and Stage Summary

The 2012 peak discharge in the CRD is expected to be exceeded once every 4.9 years based on PeakFQ (Log-Pearson Type III) analysis results. The 2012 peak stage throughout the CRD is expected to be exceeded once every 2-3 years based on Log-Pearson Type III analysis results.

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Appendix A 2012 GAGE LOCATIONS AND VERTICAL CONTROL

2012 Gage Locations

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Colville East Channel				
Monument 1 Upstream	MON1U-A	N 70.15855°	W 150.94499°	MONUMENT 1
	MON1U-B	N 70.15853°	W 150.94562°	
	MON1U-C	N 70.15849°	W 150.94616°	
	MON1U-D	N 70.15846°	W 150.94637°	
	MON1U-E	N 70.15849°	W 150.94641°	
	MON1U-F	N 70.15849°	W 150.94653°	
	MON1U-PT[1]	N 70.15857°	W 150.94346°	
Monument 1 Centerline	MON1C-A	N 70.16575°	W 150.93838°	MONUMENT 1
	MON1C-B	N 70.16580°	W 150.93886°	
	MON1C-C	N 70.16582°	W 150.93923°	
	MON1C-D	N 70.16582°	W 150.93932°	
	MON1C-E	N 70.16583°	W 150.93946°	
	MON1C-F	N 70.16586°	W 150.93967°	
	MON1C-PT[1]	N 70.16569°	W 150.93778°	
Monument 1 Downstream	MON1D-A	N 70.17383°	W 150.93591°	MONUMENT 1
	MON1D-B	N 70.17378°	W 150.93656°	
	MON1D-C	N 70.17376°	W 150.93715°	
	MON1D-D	N 70.17375°	W 150.93737°	
	MON1D-PT[1]	N 70.17393°	W 150.93429°	
	MON1D-Z[2]	N 70.17371°	W 150.93758°	
Monument 9	MON9-A	N 70.24465°	W 150.85729°	MONUMENT 9
	MON9-B	N 70.24465°	W 150.85749°	
	MON9-C	N 70.24465°	W 150.85778°	
	MON9-D	N 70.24462°	W 150.85796°	
	MON9-E	N 70.24462°	W 150.85798°	
	MON9-F	N 70.24462°	W 150.85801°	
	MON9-G	N 70.24463°	W 150.85808°	
	MON9-BARO[3]	N 70.24424°	W 150.86045°	
	MON9-PT[1]	N 70.24465°	W 150.85732°	
	MON9D-PT[1]	N 70.25857°	W 150.85938°	
Monument 35 (Helmericks)	MON35-A	N 70.42603°	W 150.40575°	MONUMENT 35
	MON35-B	N 70.42604°	W 150.40575°	
	MON35-C	N 70.42606°	W 150.40581°	
	MON35-D	N 70.42607°	W 150.40578°	
	MON35-E	N 70.42608°	W 150.40581°	

[1] pressure transducer
[2] angle iron without gage
[3] BaroTROLL or Barologger barometer

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Nigliq Channel				
Monument 20	MON20-A	N 70.27857°	W 150.99862°	CP08-12-61
	MON20-B	N 70.27856°	W 150.99852°	
	MON20-C	N 70.27856°	W 150.99830°	
Monument 22	MON22-A	N 70.31862°	W 151.05456°	MONUMENT 22
	MON22-B	N 70.31850°	W 151.05487°	
	MON22-C	N 70.31846°	W 151.05504°	
	MON22-D	N 70.31830°	W 151.05548°	
Monument 23	MON23-A	N 70.34360°	W 151.06587°	MONUMENT 23
	MON23-B	N 70.34362°	W 151.06570°	
	MON23-C	N 70.34363°	W 151.06522°	
	MON23-D	N 70.34360°	W 151.06491°	
Monument 28	MON28-A	N 70.42580°	W 151.06970°	MONUMENT 28
	MON28-B	N 70.42573°	W 151.06923°	
	MON28-C	N 70.42556°	W 151.06716°	
Alpine Facilities and Roads				
CD 1	**G1**	N 70.34278°	W 150.92083°	*
Lake L9312	**G9**	N 70.33361°	W 150.95194°	*
Lake L9313	**G10**	N 70.34250°	W 150.93278°	*
CD 2	**G3**	N 70.34000°	W 150.98306°	*
	G4	N 70.34028°	W 150.98333°	*
	G6	N 70.33972°	W 151.02917°	*
	G7	N 70.34000°	W 151.02889°	*
	G8	N 70.33933°	W 151.04905°	PBM-F
	G12	N 70.33672°	W 151.01172°	CD2-14S
	G13	N 70.33732°	W 151.01184°	CD2-14N
CD3	**G11**	N 70.41750°	W 150.91053°	Pile 08 cap SW bolt
CD 4	G15-A	N 70.30225°	W 150.99289°	CD4-20AW
	G15-B	N 70.30244°	W 150.99389°	
	G16-A	N 70.30167°	W 150.99333°	
	G16-B	N 70.30175°	W 150.99431°	
	G17	N 70.29330°	W 150.98272°	CD4-32W
	G18-A	N 70.29302°	W 150.98182°	CD4-32E
	G18-B	N 70.29245°	W 150.98276°	
	G18-Z[1]	N 70.29253°	W 150.98373°	
	G19	N 70.29167°	W 150.98833°	PBM-P
	G20-A	N 70.29172°	W 150.99681°	PBM-Q
	G20-B	N 70.29171°	W 150.99681°	

GX - direct-read permanent staff gage

* this direct-read gage is surveyed and adjusted for elevation annually by LCMF

[1] angle iron without gage

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Pipeline River Crossings				
Sakoonang Pipe Bridge	SAK-A	N 70.36457°	W 150.92165°	Pile 568 cap SW bolt
	SAK-B	N 70.36450°	W 150.92195°	and
	SAK-C	N 70.36448°	W 150.92201°	CP08-11-12
Tamayagiaq Pipe Bridge	TAM-A	N 70.39166°	W 150.91149°	CP08-11-23
	TAM-B	N 70.39151°	W 150.91129°	
	TAM-C	N 70.39142°	W 150.91126°	
Ulamnigiaq Pipe Bridge	ULAM-A	N 70.40682°	W 150.88347°	CP08-11-35
	ULAM-B	N 70.40690°	W 150.88330°	
	ULAM-C	N 70.40701°	W 150.88308°	
Proposed CD5 Crossings				
Lake L9323	G24-A	N 70.30316°	W 151.00666°	CP08-11-52A
	G24-B	N 70.30337°	W 151.00407°	
	G25-A	N 70.30400°	W 151.00692°	
	G25-B	N 70.30421°	W 151.00442°	
Nigliq Channel	G26-A	N 70.30237°	W 151.02211°	CP08-11-53A
	G26-B	N 70.30222°	W 151.01918°	
	G26-C	N 70.30219°	W 151.01901°	
	G27-A	N 70.30290°	W 151.02190°	
	G27-B	N 70.30291°	W 151.02173°	
	G27-C	N 70.30287°	W 151.01977°	
	G27-D	N 70.30288°	W 151.01882°	
	G27-PT	N 70.30291°	W 151.02235°	
	G28-A	N 70.29641°	W 151.02809°	Baker TBM 2010
	G28-B	N 70.29641°	W 151.02798°	
	G28-C	N 70.29643°	W 151.02792°	
	G28-D	N 70.29646°	W 151.02755°	
	G28-PT[1]	N 70.29641°	W 151.02799°	
	G29-A[1]	N 70.30951°	W 151.03322°	CP08-11-60B
	G29-B	N 70.30948°	W 151.03344°	
	G29-C	N 70.30945°	W 151.03367°	
	G29-D	N 70.30937°	W 151.03433°	
	G29-E	N 70.30925°	W 151.03500°	
Lake L9341	G32-A	N 70.30539°	W 151.05069°	CP08-11-60C
	G32-B	N 70.30551°	W 151.05127°	
	G33-A	N 70.30625°	W 151.04914°	
	G33-B	N 70.30637°	W 151.04965°	

[1] pressure transducer
[2] angle iron without gage

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Proposed CD5 Crossings (cont)				
CD5 Small Drainages	G30	N 70.30459°	W 151.04434°	CP08-11-60B
	G31	N 70.30512°	W 151.04369°	
	G34	N 70.30597°	W 151.07097°	CP08-11-64C
	G35	N 70.30674°	W 151.07109°	
	G36	N 70.30552°	W 151.09677°	CP08-11-65C
	G37	N 70.30621°	W 151.09687°	
Nigliagvik	G38-A	N 70.30508°	W 151.11857°	CP08-11-66C
	G38-B	N 70.30507°	W 151.11847°	
	G38-C	N 70.30506°	W 151.11822°	
	G39-A	N 70.30608°	W 151.11802°	
	G39-B	N 70.30607°	W 151.11790°	
	G39-C	N 70.30606°	W 151.11765°	
Additional Monitoring Sites				
Downstream Nigliq Channel	FWR1-A	N 70.37049°	W 151.11409°	SHEWMAN
	FWR2-A	N 70.36666°	W 151.12189°	

[1] pressure transducer

[2] angle iron without gage

2012 Control

Control	Elevation (BPMSL - Feet)	Latitude (NAD 83)	Longitude (NAD83)	Control Type	Reference
Baker TBM 2010	11.380	N 70.29631°	W 151.02686°	Angle Iron	Baker 2011
CD2-14S	10.929	N 70.33691°	W 151.01119°	Culvert top	LCMF 2010
CD2-14N	11.010	N 70.33712°	W 151.01101°	Culvert top	LCMF 2010
CD4-20AW	7.350	N 70.30192°	W 150.99363°	Culvert top	LCMF 2010
CD4-32W	13.222	N 70.29301°	W 150.98321°	Alcap	LCMF 2010
CD4-32E	12.685	N 70.29286°	W 150.98284°	Alcap	LCMF 2010
CP08-11-12	7.365	N 70.36395°	W 150.92047°	Alcap	Baker 2012
CP08-11-23	8.524	N 70.39158°	W 150.90787°	Alcap	LCMF 2008
CP08-11-35	9.146	N 70.40661°	W 150.88220°	Alcap	LCMF 2008
CP08-11-52A	9.935	N 70.30339°	W 151.00572°	Alcap	LCMF 2012
CP08-11-53A	8.075	N 70.30222°	W 151.01896°	Alcap	LCMF 2012
CP08-11-60B	9.859	N 70.30459°	W 151.04531°	Alcap	LCMF 2012
CP08-11-60C	10.541	N 70.30504°	W 151.04836°	Alcap	LCMF 2012
CP08-11-64C	9.474	N 70.30594°	W 151.06811°	Alcap	LCMF 2012
CP08-11-65C	10.410	N 70.30525°	W 151.09266°	Alcap	LCMF 2012
CP08-11-66C	10.674	N 70.30505°	W 151.11638°	Alcap	LCMF 2012
CP08-12-61	12.196	N 70.27775°	W 150.99353°	Alcap	Baker 2011
CP08-23-34B	24.117	N 70.27117°	W 151.10236°	Alcap	LCMF 2008
MONUMENT 1	27.930	N 70.16588°	W 150.93995°	Alcap	LCMF 2006
MONUMENT 9	25.060	N 70.24458°	W 150.85831°	Alcap	LCMF 2008
MONUMENT 20	18.980	N 70.28000°	W 151.01158°	Alcap	Baker 2011
MONUMENT 22	10.030	N 70.31809°	W 151.05605°	Alcap	Baker 2010
MONUMENT 23	9.546	N 70.34445°	W 151.06131°	Alcap	Baker 2009
MONUMENT 28	3.650	N 70.42557°	W 151.06698°	Alcap	LCMF GPS 2002
MONUMENT 35	5.570	N 70.43250°	W 150.38344°	Alcap	Lounsbury 1996
PBM-F	18.045	N 70.33933°	W 151.04675°	PBM in Casing	LCMF 2010
PBM-P	21.009	N 70.29140°	W 150.98890°	PBM in Casing	LCMF 2010
PBM-Q	16.735	N 70.29175°	W 150.99511°	PBM in Casing	LCMF 2010
Pile 08	16.735	-	-	HSM - cap SW bolt	LCMF 2010
Pile 568	23.719	N 70.36387°	W 150.92060°	HSM - cap SW bolt	LCMF 2010
SHEWMAN	7.085	N 70.37228°	W 151.11483°	Alcap	BAKER 2009

Appendix B 2012 ALPINE BRIDGE DIRECT DISCHARGE NOTES

Baker

Discharge Measurement Notes

Date: May 28, 2012
Computed By: SMC
Checked By: HLR

Location Name: Long Swale Bridge

Party: MDM, GCY, KMB   Start: 14:50   Finish: 16:40

Temp: 21-28 °F   Weather: Overcast, slight wind (~10 MPH)

Channel Characteristics:

Width: 451 ft   Area: 1471 sq ft   Velocity: 0.89 fps   Discharge: 1315 cfs

Method: 0.6/Two-Point   Number of Sections: 24   Count: N/A

Spin Test: Yes revolutions after 120 seconds   Meter: Price AA s/n NY4743

GAGE READINGS			
Gage	Start	Finish	Change
3	6.62	6.53	-0.09
4	6.49	6.43	-0.06

Meter: 0.6 ft above bottom of weight

Weight: 30 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GPS Data: W Bridge Abutment

Left Edge of Water: N 70 ° 20 ' 23.8 " / W 150 ° 58 ' 32.7 "

Right Edge of Water: N 70 ° 20 ' 22.7 " / W 150 ° 58 ' 19.7 "

E Bridge Abutment

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

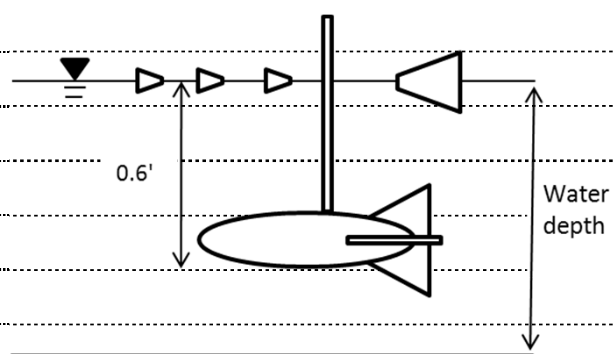
Measurement Rated: Excellent Good **Fair** Poor based on "Descriptions"

Descriptions:

Cross Section: Snow present beneath bridge, station 80-160, snow at right abutment, approx 7 feet.

Flow: Slow, some ice/debris (floating and grounded u/s and d/s), inhibited by snow beneath bridge.

Remarks: Snow banks extending upstream of each abutment, slow flows.



Long Swale Bridge
May 28, 2012

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (fraction)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ 14:50											
	0	0.5								0.0	0.00
0.92	1	10.5	2.9	0.6	5	55	0.220	0.220	0.203	30.5	6.17
1	20	19.5	2.5	0.6	20	42	1.076	1.076	1.076	48.8	52.47
0.96	40	20.0	2.9	0.6	30	49	1.379	1.379	1.324	58.0	76.77
0.98	60	20.0	3.1	0.6	25	48	1.176	1.176	1.152	62.0	71.43
0.99	80	20.0	2.6	0.6	20	42	1.076	1.076	1.066	52.0	55.41
1	100	20.0	2.9	0.6	20	56	0.812	0.812	0.812	58.0	47.09
1	120	20.0	3.3	0.6	15	62	0.556	0.556	0.556	66.0	36.68
0.98	140	20.0	3.0	0.6	15	50	0.685	0.685	0.671	60.0	40.27
0.98	160	20.0	2.9	0.6	15	45	0.759	0.759	0.744	58.0	43.14
0.99	180	20.0	3.2	0.6	20	55	0.826	0.826	0.818	64.0	52.35
0.99	200	20.0	2.9	0.6	20	47	0.964	0.964	0.954	58.0	55.34
0.99	220	20.0	3.2	0.6	20	57	0.798	0.798	0.790	64.0	50.55
0.99	240	20.0	4.4	0.2 0.8	10 25	51 51	0.454 1.108	0.781	0.773	88.0	68.01
1	260	20.0	4.1	0.2 0.8	20 30	53 52	0.857 1.300	1.078	1.078	82.0	88.44
1	280	20.0	3.9	0.2 0.8	20 30	42 50	1.076 1.352	1.214	1.214	78.0	94.69
1	300	20.0	4.0	0.2 0.8	20 25	55 45	0.826 1.253	1.040	1.040	80.0	83.16
0.99	320	20.0	3.2	0.6	15	43	0.793	0.793	0.785	64.0	50.27
0.98	340	20.0	3.4	0.6	25	45	1.253	1.253	1.228	68.0	83.48
1	360	20.0	3.6	0.6	25	53	1.066	1.066	1.066	72.0	76.78
0.99	380	20.0	3.4	0.6	20	55	0.826	0.826	0.818	68.0	55.62
0.99	400	20.0	3.8	0.6	15	49	0.698	0.698	0.691	76.0	52.55
1	420	20.0	3.1	0.6	15	58	0.593	0.593	0.593	62.0	36.76
0.99	440	15.0	2.7	0.6	15	45	0.759	0.759	0.751	40.5	30.43
0.99	450	5.5	2.4	0.6	15	63	0.547	0.547	0.542	13.2	7.15
	451	1.0									
REW 452' @ 16:40											

Total Discharge: 1315.01

Baker

Discharge Measurement Notes

Date: June 3, 2012
Computed By: SMC
Checked By: KRH

Location Name: Long Swale Bridge

Party: HLR, JPM   Start: 14:30   Finish: 15:54

Temp: 35 °F   Weather: Overcast, 5 MPH wind

Channel Characteristics:

Width: 445 ft   Area: 1686 sq ft   Velocity: 1.53 fps   Discharge: 2582 cfs

Method: Two-Point   Number of Sections: 26   Count: N/A

Spin Test: N/A revolutions after N/A seconds   Meter: Price AA s/n NY4743

Meter: 0.6 ft above bottom of weight

Weight: 30 lbs

Wading   Cable   Ice   Boat

Upstream   or   Downstream   side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	7.10	7.04	-0.06
4	6.93	6.87	-0.06

GPS Data: W Bridge Abutment

Left Edge of Water: N ° ' " W ° ' "   LE Floodplain: ° ' . "

Right Edge of Water: N ° ' " W ° ' "   RE Floodplain: ° ' . "

E Bridge Abutment

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

Descriptions:

Cross Section: No ice/snow under bridge, grassy bottom, some snow piles east and west of u/s abutments (no significant effect)

Flow: South to North

Remarks: Stage is falling

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)
LEW @ 14:30											
	0	1.0	2.5							2.5	0.00
0.95	2	11.0	3.4	0.2 0.8	30 40	41 45	1.64 1.99	1.82	1.73	37.4	64.63
0.92	20	19.0	3.1	0.2 0.8	40 50	44 40	2.04 2.80	2.42	2.22	58.9	130.99
0.95	40	20.0	3.5	0.2 0.8	40 50	53 42	1.70 2.66	2.18	2.07	70.0	144.94
0.92	60	20.0	3.7	0.2 0.8	25 40	44 40	1.28 2.24	1.76	1.62	74.0	119.87
0.94	80	20.0	3.0	0.2 0.8	25 40	42 44	1.34 2.04	1.69	1.59	60.0	95.30
0.95	100	20.0	3.3	0.2 0.8	25 40	44 50	1.28 1.80	1.54	1.46	66.0	96.46
0.95	120	20.0	3.7	0.2 0.8	15 30	43 41	0.79 1.64	1.22	1.16	74.0	85.68
0.96	140	20.0	3.3	0.2 0.8	20 30	41 40	1.10 1.68	1.39	1.34	66.0	88.30
0.98	160	20.0	3.3	0.2 0.8	20 30	42 40	1.08 1.68	1.38	1.35	66.0	89.30
0.98	180	20.0	3.7	0.2 0.8	15 30	41 41	0.83 1.64	1.24	1.21	74.0	89.76
0.97	200	20.0	3.5	0.2 0.8	20 40	44 51	1.03 1.76	1.39	1.35	70.0	94.70
0.94	220	20.0	3.7	0.2 0.8	20 40	44 48	1.03 1.87	1.45	1.36	74.0	100.81
0.95	240	20.0	5.0	0.2 0.8	20 40	52 48	0.87 1.87	1.37	1.30	100.0	130.29
0.96	260	20.0	4.6	0.2 0.8	25 40	41 43	1.37 2.09	1.73	1.66	92.0	152.73
0.98	280	20.0	4.3	0.2 0.8	40 50	51 48	1.76 2.33	2.05	2.01	86.0	172.53
0.95	300	20.0	4.6	0.2 0.8	30 50	42 47	1.61 2.38	1.99	1.89	92.0	174.27
0.94	320	20.0	3.7	0.2 0.8	40 50	46 46	1.95 2.43	2.19	2.06	74.0	152.49
0.90	340	20.0	3.9	0.2 0.8	30 40	42 43	1.61 2.09	1.85	1.66	78.0	129.55
0.96	360	20.0	4.2	0.2 0.8	25 40	42 46	1.34 1.95	1.65	1.58	84.0	132.72
0.95	380	20.0	3.8	0.2 0.8	20 30	40 45	1.13 1.50	1.31	1.25	76.0	94.91
0.98	400	20.0	4.3	0.2 0.8	20 30	42 46	1.08 1.47	1.27	1.25	86.0	107.20
0.97	420	20.0	3.8	0.2 0.8	15 25	50 41	0.68 1.37	1.03	1.00	76.0	75.86
0.99	440	11.0	3.5	0.2 0.8	25 30	47 46	1.20 1.47	1.33	1.32	38.5	50.84
0.99	442	2.0	3.9	0.2 0.8	15 30	47 47	0.73 1.44	1.08	1.07	7.8	8.36
	444	1.0	2.5							2.5	0.00
REW @ 15:54 AM											
										Total Discharge:	**2582.47**

Baker

Discharge Measurement Notes

Date: May 28, 2012
Computed By: SMC
Checked By: KRH

Location Name: Short Swale Bridge

Party: MDM, GCY, KMB   Start: 11:17   Finish: 12:50

Temp: 21-28 °F   Weather: Clear with patchy fog

Channel Characteristics:

Width: 55 ft   Area: 174 sq ft   Velocity: 0.79 fps   Discharge: 137 cfs

Method: Standard   Number of Sections: 19   Count: N/A

Spin Test: Yes revolutions after 120 seconds   Meter: Price AA s/n NY4743

Meter: 0.6 ft above bottom of weight

Weight: 30 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	6.71	6.66	-0.05
4	6.57	6.53	-0.04

GPS Data:

Left Edge of Water: N 70 ° 20 ' 23.8 " W 150 ° 59 ' 5.0 "

Right Edge of Water: N 70 ° 20 ' 24.2 " W 150 ° 59 ' 3.5 "

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

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

Descriptions:

Cross Section: Open, except left abutment which is blocking approx 15% of area at d/s end of opening

Flow: slow, no debris

Remarks: Relatively good measurement other than left abutment snow

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (fraction)	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)
LEW ~ 6' deep scar hole, eddy											
0.97	1	2.0	2.0	0.6	15.0	55.0	0.624	0.624	0.605	4.0	2.42
0.94	3	2.5	2.3	0.6	20.0	63.0	0.724	0.724	0.680	5.8	3.91
0.92	6	3.0	2.9	0.6	20.0	46.0	0.984	0.984	0.906	8.7	7.88
0.92	9	3.0	3.0	0.6	20.0	50.0	0.907	0.907	0.834	9.0	7.51
0.94	12	3.0	3.1	0.6	19.0	41.0	1.048	1.048	0.985	9.3	9.16
0.97	15	3.0	3.3	0.6	24.0	51.0	1.064	1.064	1.032	9.9	10.22
1.00	18	3.0	3.7	0.6	20.0	47.0	0.964	0.964	0.964	11.1	10.70
1.00	21	3.0	3.6	0.6	15.0	44.0	0.776	0.776	0.776	10.8	8.38
0.97	24	3.0	3.5	0.6	20.0	53.0	0.857	0.857	0.831	10.5	8.73
0.98	27	3.0	3.5	0.6	15.0	46.0	0.743	0.743	0.728	10.5	7.64
0.99	30	3.0	3.3	0.6	15.0	52.0	0.659	0.659	0.653	9.9	6.46
0.99	33	3.0	3.4	0.6	15.0	45.0	0.759	0.759	0.751	10.2	7.66
0.98	36	3.0	3.4	0.6	20.0	51.0	0.890	0.890	0.872	10.2	8.89
0.94	39	3.0	3.2	0.6	15.0	53.0	0.647	0.647	0.608	9.6	5.84
0.94	42	3.0	3.2	0.6	20.0	52.0	0.873	0.873	0.820	9.6	7.88
0.94	45	3.0	3.2	0.6	20.0	45.0	1.006	1.006	0.945	9.6	9.08
0.92	48	3.0	3.3	0.6	20.0	52.0	0.873	0.873	0.803	9.9	7.95
0.90	51	3.0	3.1	0.6	10.0	52.0	0.445	0.445	0.401	9.3	3.73
0.90	54	2.5	2.4	0.6	15.0	70.0	0.494	0.494	0.445	6.0	2.67
REW estimated 7.0 feet deep at wall											
										Total Discharge:	**136.70**

Baker

Discharge Measurement Notes

Date: June 3, 2012
Computed By: SMC
Checked By: KRH

Location Name: Short Swale Bridge

Party: HLR, JPM   Start: 16:34   Finish: 17:37

Temp: 21-28 °F   Weather: Overcast, 5 MPH wind

Channel Characteristics:

Width: 52 ft   Area: 306 sq ft   Velocity: 1.26 fps   Discharge: 386 cfs

Method: Two-Point   Number of Sections: 19   Count: N/A

Spin Test: revolutions after seconds   Meter: Price AA s/n NY4743

Meter: 0.6 ft above bottom of weight

Weight: 30 lbs

Wading **Cable** Ice Boat

Upstream or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
3	7.04	6.96	-0.08
4	6.87	6.82	-0.05

GPS Data:

Left Edge of Water: N 70 ° 20 ' 23.8 "; W 150 ° 59 ' 5.0 "

Right Edge of Water: N 70 ° 20 ' 24.2 "; W 150 ° 59 ' 3.5 "

LE Floodplain: ° ' . "

RE Floodplain: ° ' . "

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

Descriptions:

Cross Section: No Snow/ice under bridge, some snow on west abutment on d/s side, not significantly affecting flow

Flow:

Remarks: Stage is falling

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (fraction)	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)
LEW @ 16:34											
1.00	2	0.5	3.5				Est	0.270	0.270	1.8	0.47
1.00	3	2.0	4.4	0.2 0.8	15 20	48 50	0.713 0.907	0.810	0.810	8.8	7.13
0.97	6	3.0	4.3	0.2 0.8	20 15	47 48	0.964 0.713	0.838	0.813	12.9	10.49
0.98	9	3.0	4.5	0.2 0.8	25 10	48 44	1.176 0.523	0.849	0.832	13.5	11.24
0.94	12	3.0	5.0	0.2 0.8	20 30	43 46	1.052 1.467	1.260	1.184	15.0	17.76
0.96	15	3.0	5.4	0.2 0.8	25 30	52 43	1.087 1.569	1.328	1.274	16.2	20.65
0.99	18	3.0	5.4	0.2 0.8	40 35	50 45	1.796 1.747	1.771	1.754	16.2	28.41
1.00	21	3.0	5.2	0.2 0.8	30 40	42 49	1.606 1.832	1.719	1.719	15.6	26.82
1.00	24	3.0	5.8	0.2 0.8	30 40	49 53	1.379 1.695	1.537	1.537	17.4	26.74
1.00	27	3.0	5.9	0.2 0.8	30 30	40 43	1.685 1.569	1.627	1.627	17.7	28.79
1.00	30	3.0	6.6	0.2 0.8	25 30	43 42	1.310 1.606	1.458	1.458	19.8	28.87
1.00	33	3.0	6.5	0.2 0.8	25 30	46 45	1.226 1.500	1.363	1.363	19.5	26.57
0.98	36	3.0	7.5	0.2 0.8	40 30	49 44	1.832 1.533	1.683	1.649	22.5	37.11
0.96	39	3.0	7.6	0.2 0.8	40 25	50 45	1.796 1.253	1.524	1.463	22.8	33.37
0.94	42	3.0	6.9	0.2 0.8	40 25	42 45	2.135 1.253	1.694	1.592	20.7	32.96
0.92	45	3.0	6.9	0.2 0.8	30 25	43 48	1.569 1.176	1.372	1.262	20.7	26.13
0.80	48	3.0	6.2	0.2 0.8	20 30	50 44	0.907 1.533	1.220	0.976	18.6	18.16
0.20	51	3.0	6.1	0.2 0.8	25 25	46 42	1.226 1.341	1.283	0.257	18.3	4.70
	54	1.5	5.5				Est	0.000	0.000	8.3	0.00
REW @ 17:37											

Total Discharge: 386.35

Baker

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127841-MBJ-RPT-001

DECEMBER 2012