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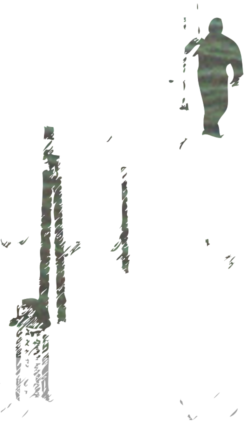

2010

COLVILLE RIVER DELTA SPRING BREAKUP

2010 HYDROLOGIC ASSESSMENT

Colville River Delta
Spring Breakup

2010 Hydrologic Assessment

Submitted to

ConocoPhillips
Alaska

Submitted by

Baker

Michael Baker Jr., Inc.
1400 W. Benson Blvd., Suite 200
Anchorage, Alaska 99503
907-273-1600

119863-MBJ-RPT-001
November 2010

EXECUTIVE SUMMARY

The 2010 Colville River Delta Spring Breakup Hydrologic Assessment was the nineteenth consecutive year of study in the region. Michael Baker Jr., Inc. (Baker) conducted the assessment at the request of ConocoPhillips Alaska (CPAI). This effort supports the Alpine Development Project (ADP) and Alpine Satellite Development Plan (ASDP). Highlights from the 2010 assessment are summarized below.

- ***Locations.*** Monitoring locations were consistent with the 2009 locations, including three sites at potential bridge crossings along the proposed CD5 pad access road. Two sites along the proposed Fiord West access road were included; they were monitored in 2009 as part of a separate project.
- ***Timing*** of the Colville River breakup was one day ahead of average peak discharge (historically June 1); and one day behind peak stage (historically May 31). Peak discharge occurred May 31, while peak stage at Monument 1 (MON1) occurred on June 1, 2010.
- ***Stage / Water surface elevation (WSE).*** The peak WSE at MON1 occurred on the evening of June 1. Peak WSE measured at 19.59 feet (BPMSL), approximately 0.24 feet lower than the maximum peak WSE observed over the historic record. Peak WSE around Alpine facilities had a recurrence interval of less than 6 years based on the stage frequency analysis.
- ***Peak discharge.*** The 2010 peak discharge of 320,000 cubic feet per second (cfs) was estimated to have occurred on May 31. The WSE at the time of peak discharge was estimated to be approximately 15.01 ft BPMSL. The peak discharge has a recurrence interval of 2-5 years based on the Colville River flood frequency analysis.
- ***Ice jamming.*** Ice jamming was observed on May 26, 18 miles upstream from MON1U. Ribbon ice and ice floes were observed May 31 through June 2 in the MON1 and Monument 9 (MON9) areas. Ice jamming in the Nigliq Channel occurred beginning June 2 upstream from Nuiqsut, moving down past MON20 by June 3, and past MON22 by June 5. Ice floes and stranded ice persisted in the Colville and East Channel through June 8. No adverse effect to the horizontal directional drilled (HDD) Colville River crossing site or Alpine facilities were observed as a result of ice jams.

- *Drinking water lakes recharge.* Floodwaters from the Nigliq Channel via Nanuq Lake and Lake M9524, in addition to waters from Sakoonang Channel, recharged drinking water Lake L9313 to bankfull condition. Lake L9312 did not receive floodwaters, and remained frozen for the majority of the monitoring period. Lake L9312 did not achieve bankfull recharge.
- *Drainage structures.* Conveyance through Alpine drainage structures was observed along the CD2 access road at the Alpine swale bridges and at 17 culverts. Backwater flow was observed in a single culvert along the CD4 road. Snow and ice had an effect on the hydraulic performance of the facilities drainage structures. No significant erosion was observed on any of the gravel structures subjected to floodwater.

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ACRONYMS AND ABBREVIATIONS

2D	Two-Dimensional
ADCP	Acoustic Doppler Current Profiler
ADF&G	Alaska Department of Fish and Game
ADP	Alpine Development Project
ASDP	Alpine Satellite Development Plan
ASP	Alpine Sales Pipeline
Baker	Michael Baker Jr. Inc.
BPMSL	British Petroleum Mean Sea Level
CD#	Colville Delta (facility number)
cfs	cubic feet per second
CMP	Corrugated Metal Pipe
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
DNR	Alaska Department of Natural Resources
fps	feet per second
FW	Fiord West
G	Gage
GPS	Global Positioning System
HDD	Horizontal Directional Drilled
HWM	High Water Mark
LCMF	Kuukpik/LCMF
MON	Monument
NAD83	North American Datum of 1983
OSW	Office of Surface Water
PT	Pressure Transducer
RM	River Mile
SAK	Sakoonang
SONAR	Sound navigation ranging
TAM	Tamayayak
ULAM	Ulamnigiaq
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USWRC	United States Water Resources Council
WGS 84	World Geodetic System of 1984
WSE	Water Surface Elevation

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1.0 INTRODUCTION

Alpine
CD1 pad

Alpine Facilities
CD1, CD2, CD3, and CD4 pads, including access roads and bridges

Breakup
Period of disintegration of ice cover in rivers and lakes

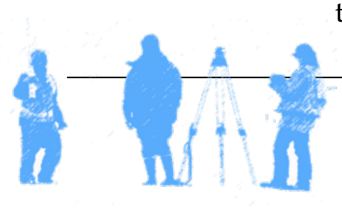
Drainage Basin
A region of land where surface water from precipitation drains downhill into a body of water (e.g. river or lake)

In many areas of the North Slope of Alaska, including the Colville River Delta (CRD), similar hydrologic and hydraulic characteristics are common due to the arctic climate and the continuous presence of regional permafrost. Groundwater is shallow and generally restricted to isolated zones beneath deep lakes and river channels. Groundwater influx is largely nonexistent. Surface water, including ponds, lakes, small streams and drainages, are frozen for much of the year.

Spring breakup on the North Slope occurs over a three-week period. Breakup flooding is the largest annual flooding event in the region. Monitoring is integral to understanding regional hydrology, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and facilities during the flooding event. After spring breakup, flow generally declines over the summer months, with some temporary flow increases from rainfall. Figure 1.1 shows the Colville River Delta drainage basin delineation.

Operated by ConocoPhillips Alaska Inc. (CPAI), the Alpine facilities are owned by CPAI and Anadarko Petroleum Company. Figure 1.2 shows the existing and proposed Alpine facilities within the extents of the monitoring region. "Alpine facilities" refers to the existing facilities including the CD1 processing facility (Alpine); CD2, CD3, and CD4 drilling pads; access roads; and associated pipelines. Since 1992, spring breakup monitoring activities have been conducted specifically for the Alpine Development Project (ADP). Monitoring was expanded in 2004 to include the Alpine Satellite Development Plan (ASDP) facilities, including CD3 and CD4. The 2010 hydrologic field program is the 19th consecutive year of CRD breakup investigations.

The results of the 2010 spring breakup monitoring activities conducted in the CRD by Michael Baker Jr., Inc. (Baker) are presented in this report. The existing Alpine facilities, roads, pipeline bridge crossings, the proposed CD5 road crossings, and the 2010 gage monitoring locations are shown in Figure 1.3. The Colville River and Nigliq Channel monument monitoring locations are illustrated in Figure 1.4. The proposed CD5 drilling pad and access road locations, as presented in Figure 1.3 and Figure 1.4, were provided by PND Engineers, Inc. and are current as of the time of this report. The specific monitoring locations at the proposed



CD5 crossings, designated Gage 21 (G21), G22, and G23, are shown in Figure 1.3.

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 - 2010 Monitoring Locations: Presents the 2010 monitoring sites.

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

Stage
The vertical distance from any selected and defined datum to the water surface

Water Surface Elevation (WSE)
Stage

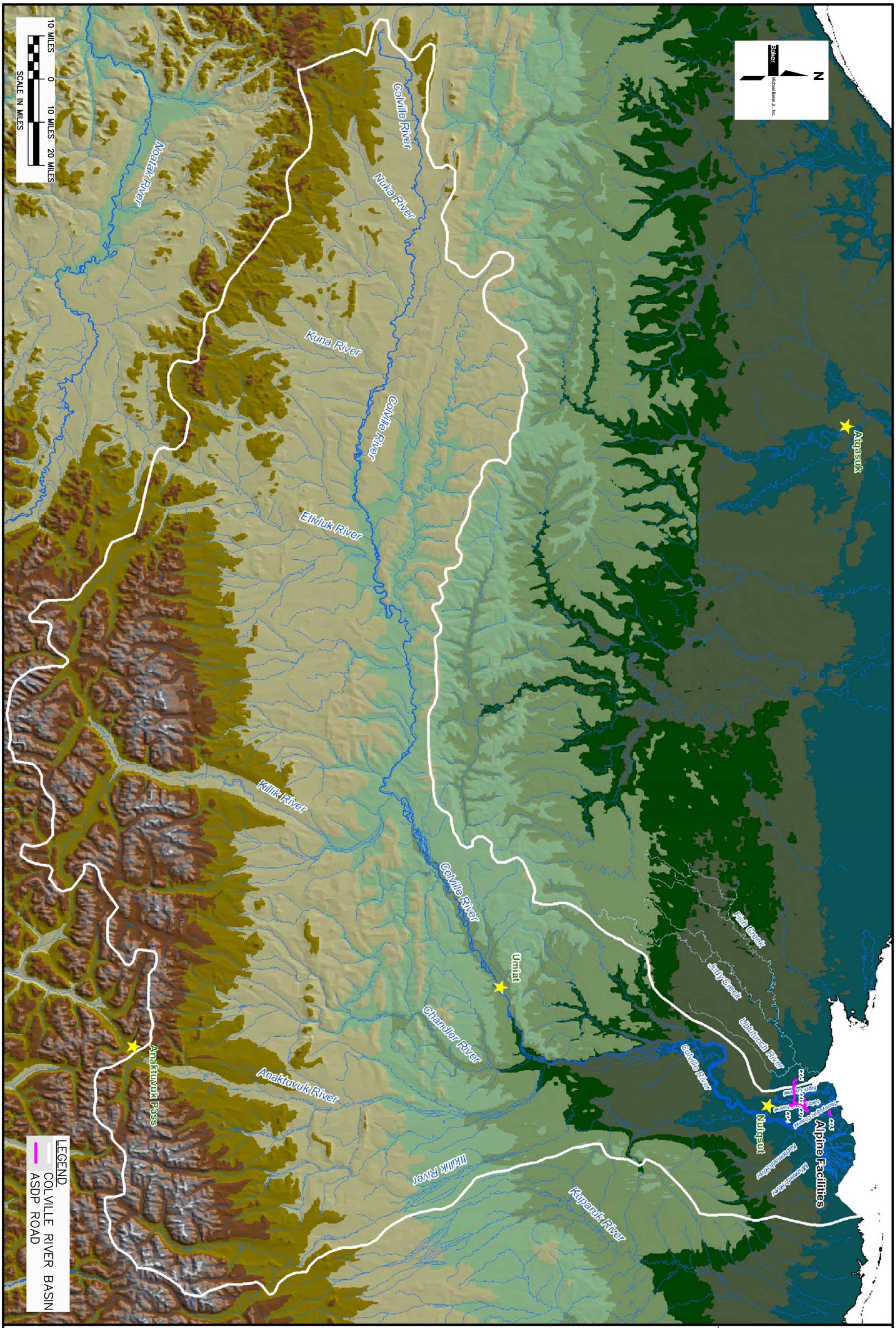
Section 4 - 2010 Spring Breakup – Hydrologic Observations: Presents the 2010 hydrologic observations in the CRD; Niqliq and East Channels; the Alpine facilities and roads including drinking water lakes, drainage structures, pads/roads erosion, and ice bridge breakups; CD3 pipeline crossings, the proposed CD5 road crossing; and proposed Fiord West access road monitoring.

Section 5 - 2010 Discharge: Presents the 2010 CRD stage and discharge results including a comparison of 2010 observed peak WSE and the 2009 two-dimensional (2D) hydrodynamic modeling analysis of the region. Also included in Section 5 is a discussion of the statistical analysis of the CRD stage/flood frequency recurrence.

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

Appendices: Appendix A includes survey control for monitoring gages as well as the geographic locations for gages and control. Swale bridge discharge notes are provided in Appendix B.

We would like to thank Alaska Kuukpik/LCMF, Inc., the Alpine Environmental Coordinators, and Bristow Helicopters for their assistance with the 2010 CRD breakup water resources field work. The support and diligence of these groups contributed to a safe and productive breakup monitoring season and is greatly appreciated. We would also like to express our gratitude to CPAI for their continued trust and confidence in Baker to perform this work.



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Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

COLVILLE RIVER DELTA
DRAINAGE BASIN
DELINEATION

FIGURE 1.1
(SHEET 1 OF 1)

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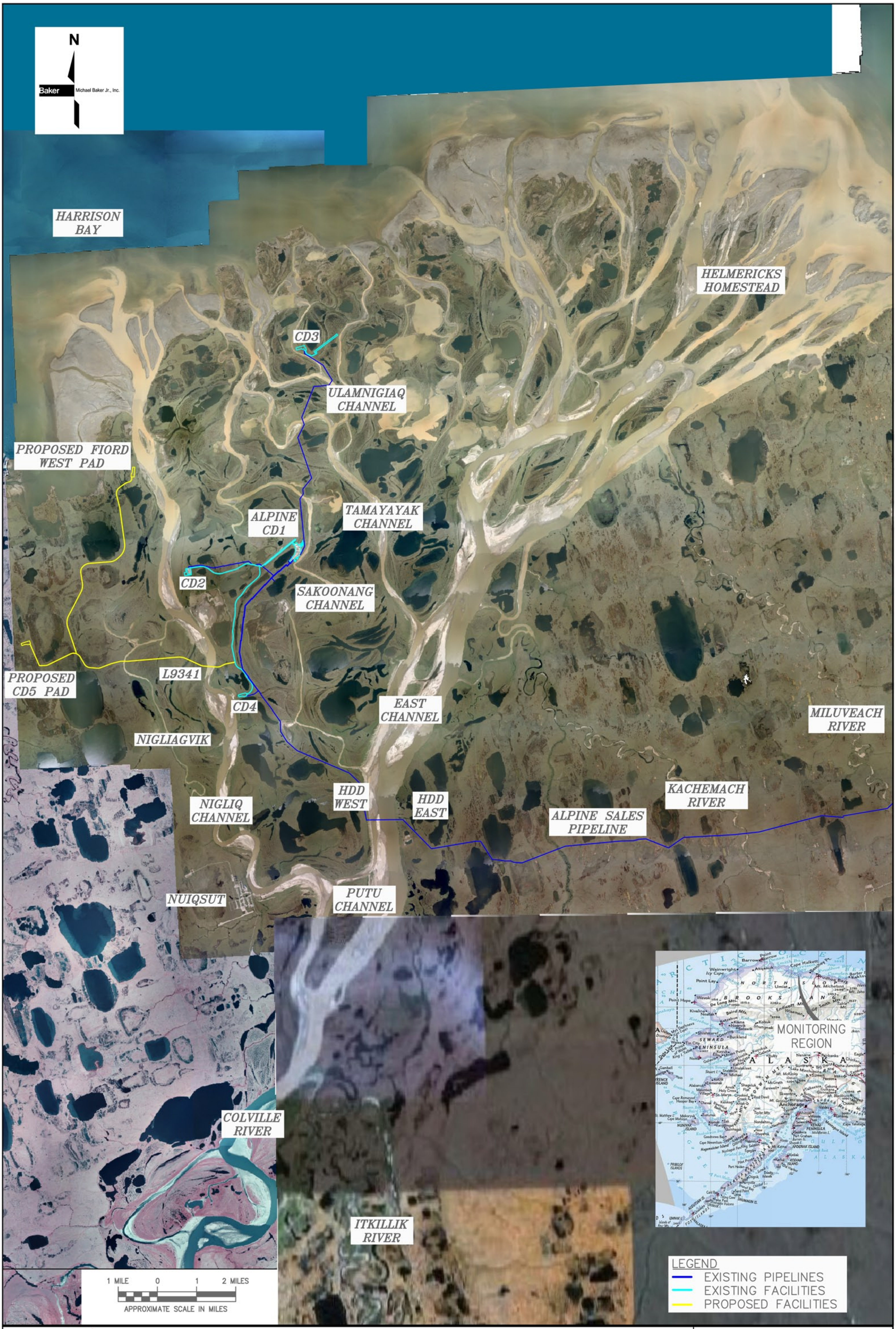

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Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
COLVILLE RIVER DELTA
EXISTING & PROPOSED FACILITIES
FIGURE 1.2
(SHEET 1 OF 1)

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Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
ALPINE AREA FACILITIES
GAGES

FIGURE 1.3
(SHEET 1 OF 1)

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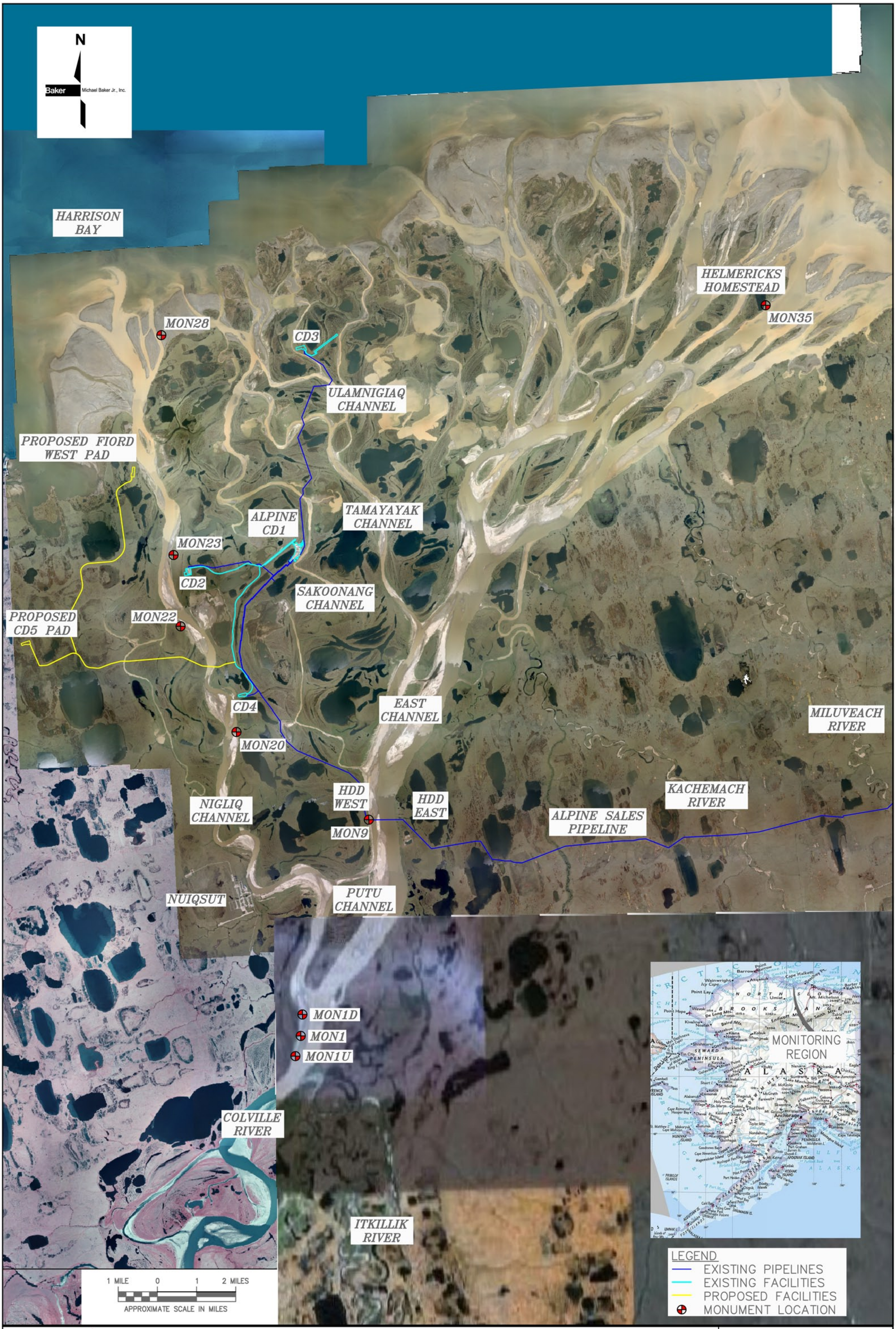

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Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
COLVILLE RIVER DELTA
MONUMENTS

FIGURE 1.4
(SHEET 1 OF 1)

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1.1 MONITORING OBJECTIVES

Annual monitoring provides a basis of record used to evaluate the effect of breakup flooding events on existing facilities and infrastructure. Data is also used for analysis and design of proposed infrastructure projects.

- Visual observation of breakup events
- Documentation of the distribution of floodwater
- Measurement of water levels throughout the project area
- Direct discharge measurement at selected locations
- Analysis of collected data

As during past spring breakup monitoring, the primary objective of the 2010 Colville River Delta Spring Breakup Hydrologic Assessment was to monitor and estimate the magnitude of breakup flooding within the Colville River Delta.

The 2010 spring breakup program also documented observations of any effects to flow and channel morphology caused by the construction of winter ice bridges across the East Channel of the Colville River at the horizontally directionally drilled (HDD) crossing and the Kachemach River.

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 (DNR) 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 existing drainage structures, and documentation of pad and access road erosion caused by spring breakup flooding.

State of 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

For approximately a three-week period, spring on the North Slope of Alaska is dominated by breakup flooding. Various factors, including snow pack, sustained cold or warm temperatures, ice thickness, wind speed and direction, precipitation, and solar radiation, contribute to the breakup cycle. The open water season for the CRD is generally limited to a four-month period from June through September.

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

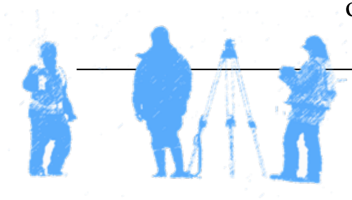
other regionally related streams. The Brooks Range is located approximately 150 air miles south of the head of the Colville River Delta. Monument 1 (MON1, Figure 1.4), located at the head of the delta, is the location farthest downstream (north) on the Colville River where the majority of contributing 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 nightly low ambient air temperatures in the Brooks Range where the headwaters of the Colville River originate. As these nightly lows begin to approach and exceed freezing, breakup processes accelerate, melting snow in the area of the Colville River headwaters. This melting process produces flow which progresses downstream towards the CRD.

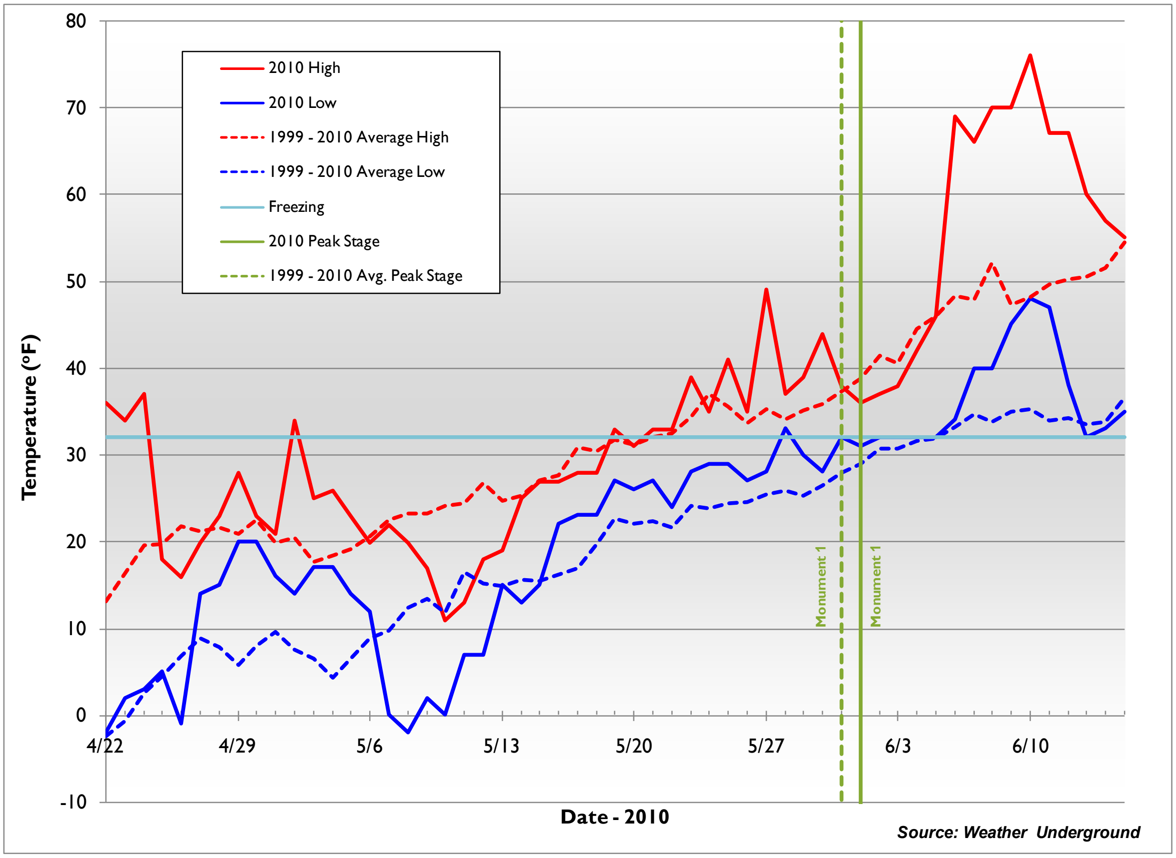
Climate data for this region of the Brooks Range foothills are available from the Umiat monitoring station. Umiat (shown in Figure 1.1) is located approximately 60 air miles south of MON1. Graph 1.1 illustrates high and low ambient air temperatures for Umiat as recorded from April 22 to June 15, during the 2010 breakup monitoring period. Average highs and lows for the same late-April to mid-June time period for 1999 through 2010 are shown as dashed lines. Dates of 2010 peak stage and average peak stage from 1999 to 2010 from the centerline gage at Monument 1 (MON1C) are included for comparison.

Review of daily high and low ambient air temperatures can be useful when evaluating breakup timing. Graph 1.1 illustrates the ambient air temperatures at Umiat during the day jumped above freezing for a few days in late April, and for a day in early May, but for the most part remained below freeing until about the third week in May. These ambient air temperatures trended very similar to the historical averages. Nighttime ambient air temperatures did not reach and stay above the freezing mark until after the first week of June.

Temperatures for the Alpine area are obtained from the Nuiqsut monitoring station. Graph 1.2 provides high and low ambient air temperatures for Nuiqsut as recorded during the same period. Nuiqsut is located on the west bank of the Nigliq channel approximately 3.5 air miles northwest of MON1, and approximately 9 air miles southwest of the Alpine facilities as shown in Figure 1.2. Local melting in the vicinity of the Alpine facilities was initiated as daily highs and lows in the area, as

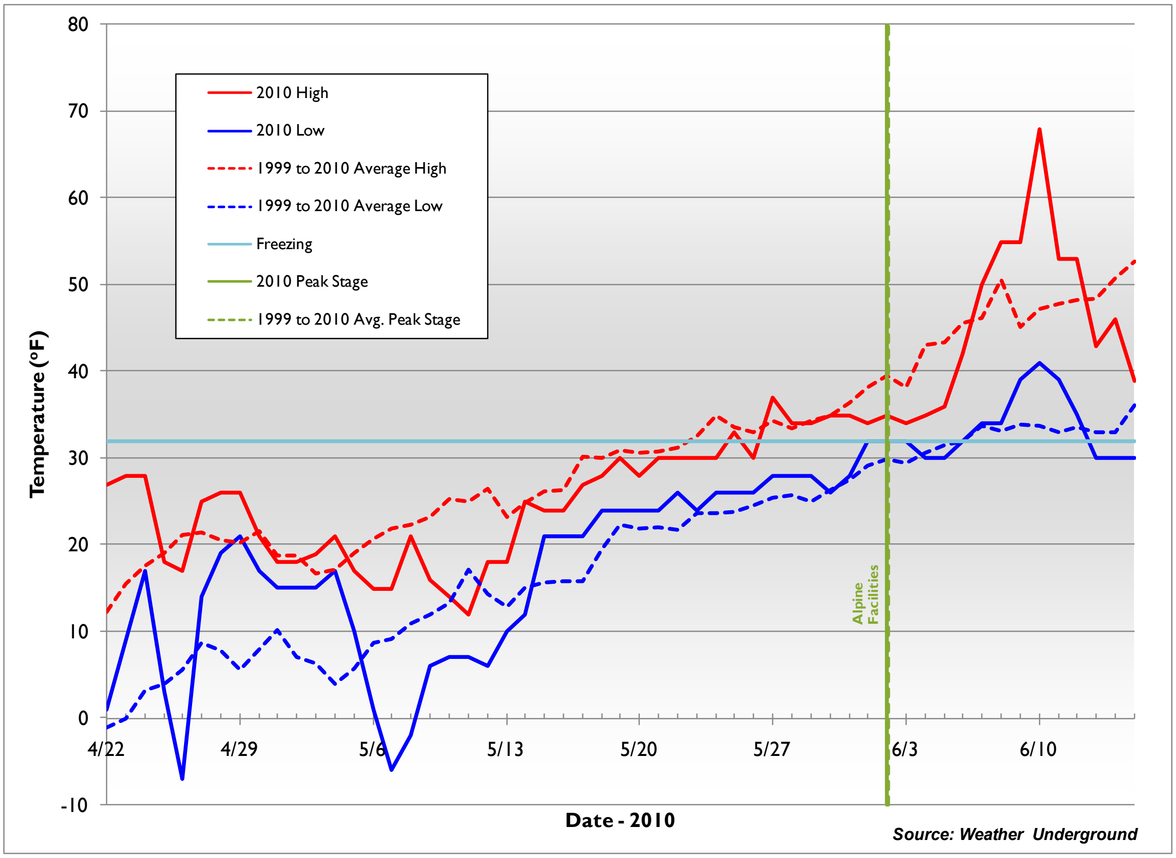


recorded in Nuiqsut, approached and exceeded freezing. Ambient air temperatures at Nuiqsut remained below freeing until late in May, reaching the freezing point during the day on May 25, approximately three days later than average. Nighttime ambient air temperatures did not reach the freezing mark until June 1, which coincided with peak stage at MON 1.



Source: Weather Underground

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



Source: Weather Underground

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 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 breakup peak stage and discharge observations available. Located at the head of the delta, it represents the furthest downstream reach on the Colville River where all flow is confined to a single channel before entering the delta (see Figure 1.4).

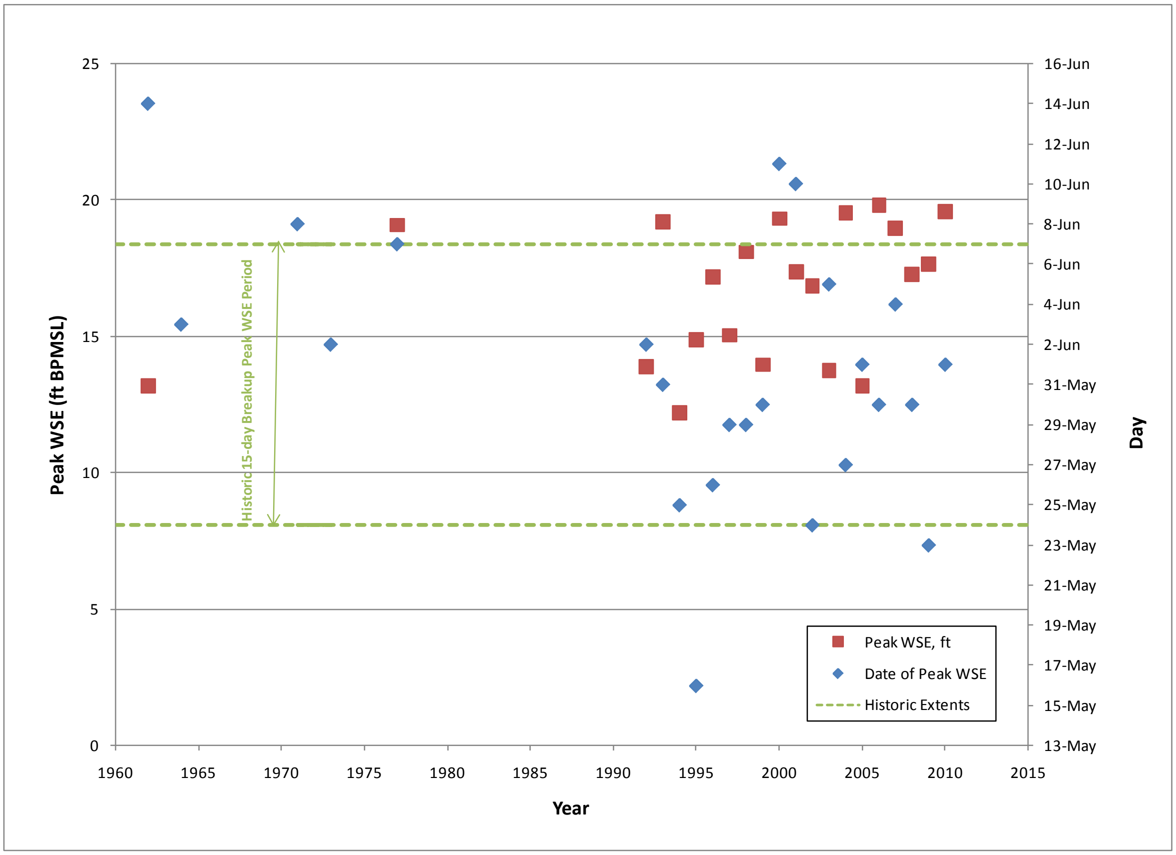
Table 1.1 shows the annual peak discharge, peak WSE, and the respective dates for those years' data available for MON1. For the purpose of this table, the 2010 peak WSE and peak discharge for MON1C are shown, since this location is most typical for the Acoustic Doppler Current Profiler (ADCP) measurement location and for the indirect discharge calculation. Note in subsequent discussions stage is synonymous with WSE.

Table 1.1: Colville Historical Peak Discharge, Stage & Date

Year	Discharge		Stage (WSE)		Reference
	Peak Discharge (cfs)	Date	Peak Stage (ft BPMSL)	Date	
2010	**320,000**	**31-May**	**19.59**	**1-Jun**	**This report**
2009	266,000	23-May	17.65	23-May	Baker 2009c
2008	221,000	28-May	17.29	30-May	Baker 2008b
2007	270,000	3-Jun	18.97	4-Jun	Baker 2007b
2006	281,000	30-May	19.83	30-May	Baker 2007a, 2007b
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 2006
2002	249,000	27-May	16.87	24-May	Baker 2006
2001	255,000	11-Jun	17.37	10-Jun	Baker 2006
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 1998a
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

Based on the 16 recorded peak discharge dates, the average date of peak discharge is June 1. The 2010 peak discharge was estimated to have occurred on May 31, one day earlier than the historical average. Based on the 24 recorded peak stage (peak water surface elevation or peak WSE) dates, the average date of peak stage is May 31. In 2010, peak stage occurred on June 1, one day later than the average.

Graph 1.3 presents the date and stage of peak WSE near MON1 for those years that data are available. All elevations presented in this report are in feet based on the BPMSL (British Petroleum Mean Sea Level) datum.



Graph 1.3: MON1 Annual Peak Water Surface Elevation and Dates

Based on the dates available for the 24-year historical peak WSE record, 75% of peak WSE for the CRD at MON1 have occurred during the 15-day period from May 24 to June 7, as illustrated on Graph 1.3. Eliminating the extreme peak WSE dates of May 16 and June 14, nearly 82% of the peak WSE dates, including the June 1, 2010 peak stage, falls within this 15-day window. The 2010 peak WSE at MON1 occurred on June 1, which falls within the more narrow May 24 to June 7 time frame.

The measured 2010 peak WSE value was 19.59 ft BPMSL. The maximum historical peak water surface elevation was in 2006 at 19.83 feet (Baker 2007b). The historical average peak WSE, based on the available 21 dates recorded is 16.68 feet. The timing and magnitude of peak WSE in the vicinity of the Alpine facilities is typically one or two days following the peak at MON1 and that pattern was consistent in 2010, with peak stage occurring around the facilities on or about June 2.

Section 4.0 further discusses the timing of spring breakup events within the CRD. Additional historic WSE information relating to flood and stage frequency is provided in Section 5.7.

2.0 2010 MONITORING LOCATIONS

The CRD 2010 monitoring locations were consistent with those presented in the *2009 Colville River Delta Spring Breakup and Hydrologic Assessment* (Baker 2009c). An overview of the 2010 proposed and existing Alpine facilities is shown in Figure 1.2.

Gage
Fixed vertical graduated scale for determining water surface elevation at a specific location

Monitoring is accomplished using a network of gages established in the CRD. The monument locations are along the Colville River, Nigliq Channel, and East Channel. Alpine facility gage locations are between the Sakoonang and Nigliq Channels. These facility gages allow monitoring WSE and flow at major hydrologic features adjacent to existing Alpine pads and roads. Selected locations are also monitored for lake recharge evaluation, road prism erosion assessment, and breakup of seasonal ice bridges.

Monument
Benchmark of known elevation and horizontal position relative to a defined datum, used for horizontal and vertical control in surveying

The 2010 gaging and monument monitoring sites are listed in Table 2.1, the facility gage locations are presented in Figure 1.3, and monument gage locations are shown in Figure 1.4. Additional monitoring sites are presented in Table 2.2. Referenced survey control for these locations is provided in Appendix A.

Selection of monitoring locations is based on topography, the proximity of existing and proposed facilities to relevant terrain features, hydraulically significant locations, as well as the historical hydrologic and hydraulic observation sites in the region. Repair and survey of all gages was completed during setup between May 5 and May 13, 2010.

As part of narrative descriptions, locations are often identified in river miles (RM). Measurement of river miles commences at RM 0 generally at the point of a stream or river terminus whether a smaller channel joins a larger channel, or a stream or river enters a large water body such as a lake or ocean. The measurement increases with increased distance upstream.

In the case of both the East Channel of the Colville River (East Channel) and the Nigliq Channel, RM 0 is located at the mouth of the delta at Harrison Bay. Therefore, measurement upstream is identified along the Nigliq (N) and East (E) channels of the Colville River. For example, RM N7.0 indicates a location 7.0 miles upstream from Harrison Bay on the Nigliq Channel. Note that RM locations were updated in this report based on the assumption Monument 35 (MON35) is located at RM E3.0

for East Channel locations, and Monument 28 (MON28) is located at RM N0.8 for Nigliq Channel locations.

Table 2.1: Colville River Delta Monitoring Program Locations

Gaging Stations	
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	South of CD4
MON22	South of CD2
MON23	North of CD2
MON28	At Harrison Bay
Alpine Facilities and Roads	
G1	CD1 betweeen Pad and Sakoonang Channel
G9	CD1 Pad area, Lake L9312
G10	CD1 Pad area, Lake L9313
G3	CD2 Access Road, S side, swale bridge vicinity
G4	CD2 Access Road, N side, swale bridge vicinity
G12	CD2 Access Road, S side of road
G13	CD2 Access Road, N side of road
G6	CD2 Access Road, S side of road
G7	CD2 Access Road, N side of road
G8	CD2 between Pad and Nigliq Channel
G15	CD4 Access Road, W side
G16	CD4 Access Road, E side
G17	CD4 Access Road, W side
G18	CD4 Access Road, E side
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	Tamayagiaq (Pipe Bridge #4)
ULAM	Ulamnigiaq (Pipe Bridge #5)
Proposed CD5 Crossings	
G21	East Bank, Nigliq Channel
G22	West Bank, Lake L9341
G23	West Bank, Nigliagvik
Fiord West	
FWR1	Proposed Fiord West Access Road
FWR2	Proposed Fiord West Access Road

Bold, larger font gage names indicate direct-read permanent staff gage

Table 2.2: Colville River Delta Additional Monitoring Sites

Additional Monitoring	
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
Nigliq Channel	Road along channel west of Colville bifurcation
Kachemach River	South of pipeline crossing to 2L Pad - Kuparuk
Additional Pipeline Crossings	Area visual surveys
Kachemach River	North of ice road crossing to 2L Pad - Kuparuk
Miluveach River	North of 2L Pad - Kuparuk

2.1 MONUMENTS

The Colville River Delta is bounded upstream by MON1 at the head of the delta. Photo 2.1 shows the Colville River reach at MON1, located at RM E27.1. 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 braided floodplain where the many channels empty into Harrison Bay.

Photo 2.1: Colville River at MON1, looking north (Nigliq Channel on the left and East Channel on the right); June 8, 2010.

2.1.1 EAST CHANNEL

All East Channel gages are located on the west bank of the East Channel of the Colville River.

Located farthest upstream, MON1 has been monitored annually since 1992, and sporadically since 1962. Three gaging stations are installed at MON1: one upstream (MON1U) at approximate RM E23.5, another at RM E22.9 designated MON1 centerline (MON1C), and one downstream (MON1D) at approximate RM E22.3. Locations are shown in Figure 1.4. Section 5.0 of this report includes a plan view and historical (2004) cross-sections at the MON1 gage locations.

Near Harrison Bay, the East Channel monitoring site is located at Helmericks Homestead in the vicinity of MON35 at RM E3.0. MON35 has been monitored intermittently since 1999.

Photo 2.2: MON35 surveying gages on Colville East Channel at Helmericks Homestead; May 6, 2010.

Between the MON1 and MON35 monitoring locations, a gaging station at Monument 9 (MON9 at RM E16.8) was selected to monitor the HDD crossing of the Alpine Sales Pipeline. This location is downstream of the Putu Channel and upstream of the Sakoonang Channel distributaries. MON9 has been monitored annually since 2005.

Photo 2.3: MON9, west bank of Colville River, looking east; May 7, 2010.

2.1.2 NIGLIQ CHANNEL

A total of four gage monuments are located along the Nigliq Channel. Approximately 11 miles downstream from MON1C, gages were established along the Nigliq Channel at MON20 (RM N12.2). Gages at this location were placed on the east bank, just south of the CD4 pad.

Monument 22 (MON22), the next site downstream (north) along the Nigliq Channel, is located approximately midway between CD2 and CD4 at RM N8.8. Gages are located on the west bank. Photo 2.4 shows the proximity of the MON22 gage location to the CD2 pad.

Monument 23 (MON23) gages are on the east bank at RM N6.9, north of CD2. A plan view and historical 2005 cross-section at the MON23 gage location is provided in Section 5.0.

MON28 at RM N0.8 at Harrison Bay represents the northernmost gage location along the Nigliq Channel.

All Nigliq Channel gages have been monitored intermittently since 1998, except MON28 where intermittent monitoring began in 1999.

Photo 2.4: MON22 gage reading, looking northeast (CD2 in background); May 31, 2010.

2.2 ALPINE AREA FACILITIES

Both direct-read permanent staff gages and indirect-read staff gages are utilized to monitor WSE at Alpine facilities and lakes. Section 3.2.1 further discusses gage assemblies.

2.2.1 LAKES

Recharge of Lakes L9312 and L9313 is monitored using direct-read gages G9 and G10, in accordance with lake-use permit requirements initially discussed in Section 1.1.

2.2.2 DRAINAGE STRUCTURES

Drainage structures installed along the Alpine pad access roads are intended to allow passage of sediment-laden flood waters to provide fish passage, and to maintain the structure and function of wetland habitats near the facilities. These drainage structures include a series of single culverts and multi-culvert batteries along both Alpine access roads (CD2 and CD4 roads) as well as two bridges along the CD2 access road, the 62-ft "short" and the 452-ft "long" swale bridges.

Photo 2.5: CD2 road, short swale bridge and culvert CD2-21 in foreground; June 1, 2010.

2.2.3 EROSION

Following breakup, the Alpine access roads were evaluated for visual evidence of erosion caused by flooding. Data were collected from observations along the length of both shoulders of each gravel road and pad within the Alpine system.

2.2.4 ICE BRIDGES

During the winter of 2009-2010, an ice road was constructed connecting the 2L Pad at Kuparuk and the Alpine facilities. The ice road crossed several drainages and channels, the most significant being the Kachemach River and the East Channel of the Colville River (less than ½ mile upstream from the HDD crossing). A spur road was constructed south from the west bank of the Colville River at the ice bridge crossing, extending along the Nigliq Channel to the village of Nuiqsut. The ice bridge crossings of the Kachemach and the Colville rivers were the primary monitoring focus before, during, and after breakup. Monitoring included visual observation and photography of each crossing area. Photo 2.6 shows the Colville River ice bridge near HDD during the early stages of breakup.

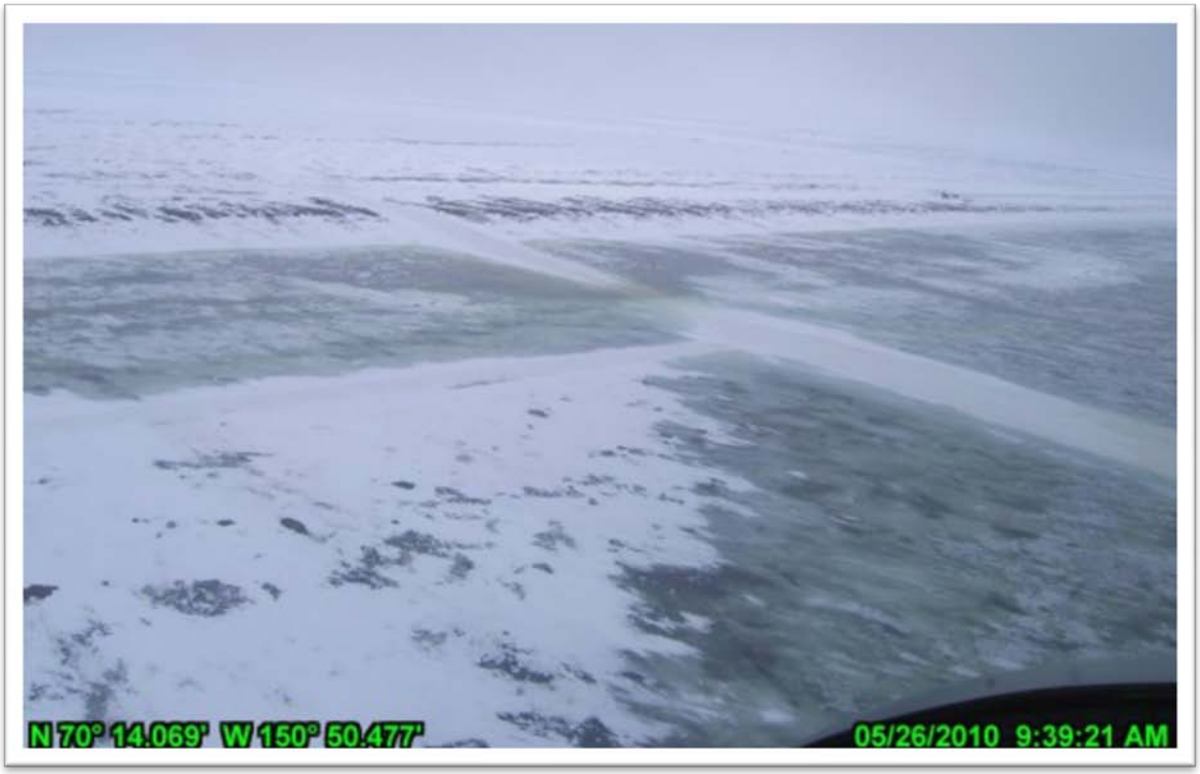


Photo 2.6: Colville River ice bridge prior to breakup; May 26, 2010.

2.3 CD3 PIPELINE RIVER CROSSINGS

The CD3 pipeline crosses three significant channels between CD1 and CD3. These locations include Crossing #2 on the southwest bank of the Sakoonang (SAK), Crossing #4 on the south bank of the Tamayayak (TAM), and Crossing #5 on the northeast bank of the Ulamnigiaq (ULAM). Gaging stations were installed at each of the three crossings to monitor breakup conditions at these locations, all of which have been monitored intermittently since 2000. Repair and survey of all CD3 pipeline crossing gages was completed on May 9.

Photo 2.7: Monitoring gages at Sakoonang Channel crossing looking east; May 31, 2010.

2.4 PROPOSED CD5 ROAD CROSSINGS

Three gage locations were installed to monitor flow at proposed CD5 road crossings. These locations include G21 on the east bank of the Nigliq Channel, G22 on the west bank of Lake L9341, and G23 on the east bank of the Nigliagvik (formerly referred to as Cody Creek).

2.5 PROPOSED FIORD WEST ACCESS ROAD CROSSINGS

In 2010, gages were installed along the proposed Fiord West (FW) road alignment at two locations. Data collected can be used to determine the potential for breakup flooding and the general nature of flow for the purposes of road design. Gage locations monitored during 2010 include FW Road 1 (FWR1) and FW Road 2 (FWR2), both located southwest of the proposed Fiord West pad location (Figure 1.3).

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3.0 METHODS

Visual observations of melt water flow and distribution of breakup flooding, documentation of WSE at the gaging locations throughout the delta, and measurement of discharge at various channels and structures are the primary methods utilized during the 2010 monitoring program. These field methods were based on standard techniques proven to be safe, reliable, efficient, and accurate for the conditions found on the North Slope of Alaska during spring break-up. Collection of the data was most affected by conditions related to safety, logistics, and weather.

3.1 VISUAL OBSERVATIONS

Pre-breakup setup and visual observations of breakup events in the project area were conducted from the ground via Hägglund BV206 tracked vehicles from May 5 to May 13, 2010. Observations were conducted by helicopter from May 23 to June 14, 2010.

Field observations were recorded daily in field notebooks by team members. Progression of spring breakup prior to, during, and after peak flooding events was documented using digital photographs. The geographic position of the camera in latitude and longitude (lat/long), date, and time were automatically imprinted onto each photo. As in past years, the photo datum was WGS 84. Additional photographs were taken and locations were manually geographically referenced, confirmed, and then imprinted onto each photograph to document the location of each image.

Photo 3.1: Reading gage B at the Ulamnigiaq Channel crossing; May 31, 2010.

3.2 WATER SURFACE ELEVATION (WSE)

3.2.1 STAFF GAGES

As indicated in Table 2.1 both permanent and temporary staff gages were installed throughout the delta. Permanent, direct-read staff gages are located at CD1 and CD2. These consist of a mounted metal gage faceplates attached to drill stem steel. The direct-read gages are permanently mounted staff gages surveyed and assembled such that the gage faceplate corresponds to actual BPMSL elevation. Therefore, a high water mark (HWM) reading of 8.64 on G3 along the CD2 road indicates a HWM elevation of 8.64 ft BPMSL.

Direct-read staff gages include G1, G3, G4, G6, G7, G9, G10, and G19. The faceplates are surveyed each breakup season to correct any error in elevation. In May 2010, LCMF surveyed and adjusted elevation on all direct-read permanent staff gages.

Photo 3.2: Direct-read gage G1 near CD1; June 3, 2010.

Temporary, indirect-read gage sets consist of between two and seven staff gage assemblies at any one location. Each gage assembly consists of a metal gage faceplate 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 not directly corresponding to actual elevation. Baker surveyed these gages relative to a known benchmark elevation to establish a correction factor. The correction factor is then applied to the faceplate reading to obtain the elevation in ft BPMSL. For example, a HWM reading of 2.87 on G20-B is corrected based on a Baker survey of local control. In this particular case, the gage correction is 7.86 feet. After adjustment is made, the indirect staff gage reading of 2.87 corresponds to a HWM elevation of 10.73 ft BPMSL. Installation of the temporary staff gages was completed prior to the arrival of breakup floodwater. The indirect-read gages were surveyed by Baker.

Water level is recorded based on the observed level on the gage plate during site visits. Chalk is applied to the angle iron during each site visit. Subsequent high water marks are recorded when floodwaters remove the chalk, as noted during field visits. When water levels were not sufficiently high to be recorded on the staff gage face plates, standard level loop survey techniques were used to measure WSE. The horizontal position of each gage was recorded using a handheld Garmin Rino 520HCx in North American Datum of 1983 (NAD83).

Each gage faceplate elevation was surveyed from a local benchmark tied to BPMSL using standard level loop techniques. The basis of elevation for each gage, as well as the horizontal position of respective benchmarks and gages, is presented in Appendix A. The most recent basis of elevation of vertical control was used for each survey.

Gages were identified based on the site location. In locations where terrain elevation varied by more than three feet, or where the loss of gages due to ice was considered likely, more than one gage was installed to effectively capture WSE data. These gages were further identified with alphabetical designations “A”, “B”, “C,” or “D”, with “A” typically being located nearest (lowest) to the water’s edge.

Photo 3.3: Surveying MON9 (HDD) gages; gage B in foreground, gages C, D, and E in background; May 7, 2010.

Photo 3.4: Reading gage D at MON9 (HDD) after ice and floodwater removed lower gages; June 2, 2010.

3.2.2 Pressure Transducers (PT)

Pressure Transducer (PT)
Measurement device converting pressure-induced mechanical changes to an electrical signal

Pressure transducers (PT) measure the absolute pressure imparted by the atmosphere and water at the sensor, allowing the depth of water above the sensor to be calculated. Resulting data yield a more complete record of the fluctuations in WSE than can be captured by visual measurements alone. Each PT consists of a non-vented pressure sensor designed to collect and store pressure and temperature data at discrete pre-set intervals.

In-Situ, Inc. Level TROLL® 500 pressure transducers (PT) were installed at six locations: MON1U, MON1C, and MON1D, and at MON9, G21, and G21U (approximately 0.5 miles upstream of G21, near the proposed CD5 road crossing of the Nigliq Channel).

The reported pressure datum is the sum of the forces imparted by both the water column and atmospheric conditions. Variations in barometric pressure are taken into account using an independent In-Situ, Inc. BaroTROLL® barometric pressure logger. A correction of local barometric pressure was obtained from BaroTROLL® sensors located at MON9 (primary) (Photo 3.5) and on the north side of the CD4 pad (backup). These BaroTROLL® locations are considered representative of the CRD. See Appendix A for PT and BaroTROLL® basis of elevation and horizontal positions.

Photo 3.5: BaroTroll® atmospheric pressure sensor installed at MON9; May 7, 2010.

The PT were configured using Win-Situ LT 5.1.1.0® prior to placement in the field. Absolute pressure was set to zero. Each PT was housed in a segment of perforated galvanized steel pipe, clamped to angle iron, and placed in the active channel as near to the channel bottom as possible. The PT sensor was surveyed during setup to establish a vertical datum using local control. For 2010, the PT were programmed to collect absolute pressure and water temperature at 15-minute intervals from May 10, 2010, to August 1, 2010.

PT-based WSE values were determined by summing the calculated water depth and the surveyed sensor elevation. 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 were not significant enough to affect WSE calculations due to the limited range in temperature and observed water depths.

3.3 DISCHARGE MEASUREMENTS

Discharge was measured directly and calculated indirectly based on field observations. Standard U. S. Geological Survey (USGS) midsection techniques were used to directly measure discharge. Velocity and discharge measurements were taken as close to the observed peak stage as possible to determine the peak direct discharge. Indirect discharge was calculated based on observed data.

3.3.1 USGS TECHNIQUES

Standard USGS midsection techniques (USGS 1982) and a Price AA velocity meter were used to directly measure velocities and discharge at the two CD2 road swale bridges. A Marsh McBirney Flo-mate™ meter was used to measure velocity at road culverts passing measureable flow.

Swale bridge depth and velocity measurements were taken from the upstream side of each bridge deck using a sounding reel mounted on a boom (Photo 3.6). The velocity meter was attached to the sounding reel and stabilized with a 30-pound Columbus-type lead sounding weight. A tag line was placed along the upstream bridge rail to define the cross-section and to delineate measurement subsections within the channel. The Price AA velocity meter was calibrated by the USGS at the Office of Surface Water (OSW) Hydraulic Laboratory in 2006. A spin test of the meter was successfully completed before and after the swale bridge measurements.

Velocity measurements at the Alpine culverts were conducted using a USGS wading rod and a Marsh-McBirney Flo-Mate™ meter. (Photo 3.7). Visual observations with regard to flow passage and overall condition at each culvert were recorded.

Photo 3.6: Direct discharge measurement on short swale bridge (CD1 in background), looking east; June 3, 2010.

Photo 3.7: Culvert velocity measurement using USGS wading rod on upstream side of culvert CD2-15, looking west; June 2, 2010.

3.3.2 Acoustic Doppler Current Profiler (ADCP)

Beginning in 2005, a direct discharge measurement has been taken at MON1 using an ADCP. The 2010 spring breakup was the first since 2005 when it was not possible to use the ADCP for a direct discharge at MON1. Motor testing, equipment coordination, and preparation of the sling loads were accomplished. However, fog and freezing rain limited helicopter travel in the delta during and immediately following peak stage, except for short periods. High winds prevented transport of the sling loads. As a result, it was not possible near peak stage to transport boats, equipment, or personnel to the site for an ADCP direct discharge measurement.

ADCP
Acoustic Doppler Current Profiler
An instrument that uses sonar to produce a record of water current velocities for a range of depths.

ADCP is used to measure how fast water is moving across a water column.

3.3.3 Indirect Discharge Calculations

Indirect discharge for the CD2 and CD4 road culverts, the swale bridges, the Colville River, and the Nigliq Channel are calculated using physical characteristics obtained during field observations. These physical characteristics, including WSE, culvert dimensions, and channel cross-sectional area are used as hydraulic equation input variables to calculate indirect discharge.

Industry accepted engineering methods and 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 water surface elevations and peak stage observations. Average velocity and discharge through the culverts assumes ice-free open water conditions, and were estimated based on several variables, including:

Tailwater
Water located immediately downstream from a hydraulic structure, such as a dam, bridge, or culvert

- Headwater and tailwater elevations at each culvert;
- Culvert diameter and length (from Kuukpik/LCMF as-built surveys, and field observations and measurements. As-built information is not available for the slip-lined culverts; we relied on field measurements and approximations for slip-lined culverts);
- Culvert upstream and downstream invert elevation (Kuukpik/LCMF surveys 2008); and
- Culvert Manning's roughness coefficient (0.012 for smooth steel and 0.024 for CMP).

Indirect calculation of peak discharge through the swale bridges was performed by correlating the hydraulic depths estimated during the direct discharge measurements with the observed peak discharge conditions.

The slope-area method for a uniform channel (Benson and Dalrymple 1967) was used to develop indirect estimates of peak discharge for the Colville River and the Nigliq Channel. Water surface elevation and slope data were obtained from observations made at nearby gages. Cross-sectional geometry was based on historic cross-sections surveyed by Kuukpik/LCMF in 2004 on the Colville River, 2005 near MON23, and 2008 near the proposed CD5 bridge crossing location on the Nigliq Channel.

3.4 FLOOD AND STAGE FREQUENCY ANALYSIS

Each year the estimate of observed peak discharge in the Colville River is analyzed in terms of flood frequency. Results of this analysis are the discharge magnitudes used in facilities design. The basis for comparison is the 2002 design-magnitude flood frequency analysis for the Colville River at MON1 (Baker and Hydroconsult 2002). The 2002 values continue to be the recommended design magnitudes. Section 5.7 discusses the flood frequency analysis in greater detail.

Observed peak WSE are analyzed each year in terms of stage frequency and compared to the predicted two-dimensional (2D) surface water model elevations at select locations in the CRD. The 2D model was developed during the original design of Alpine and has been updated throughout the life of the Alpine facilities, most recently in 2009 (Baker 2009a). The stage frequency analysis is used to validate the results of the 2D model and additionally provides returns for observed peak stage data.

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4.0 2010 SPRING BREAKUP – HYDROLOGIC OBSERVATIONS

The images, data, and observations of the 2010 field program are presented in this chapter. Field setup commenced on May 5, 2010. Data and observations described in the following sections were documented between May 23 and June 10, 2010. Limited observations were made during setup (May 8 to May 22) and cleanup (June 11 to June 15). Figure 4.1 provides a visual timeline summary addressing the major 2010 CRD breakup events.

4.1 COLVILLE RIVER DELTA

Breakup floodwaters into 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 at the Beaufort Sea as seen in Figure 1.1 though Figure 1.4 and discussed in Section 1.2. MON1 is considered to be the head of the CRD, and breakup events are monitored upstream of this location as floodwaters progress downstream toward the delta.

The confluence of the Anaktuvuk River into the Colville River lies approximately 65 river miles upstream of the head of the CRD (MON1). No signs of melt were observed during a reconnaissance flight on May 13, 2010, in either the Anaktuvuk River upstream from the confluence (Photo 4.1) or the Colville River downstream from the confluence (Photo 4.2).

Confluence
A flowing together of two or more streams

Photo 4.1: Anaktuvuk River, 9.5 miles upstream from the Colville River confluence; May 13, 2010.

Photo 4.2: Colville River, 4.8 miles downstream of Anaktuvuk River confluence; May 13, 2010.

Leading Edge
The initial flood flow as it moves downstream

On May 19, 2010, the Bristow helicopter pilot and NS Helicopter Coordinator reported some areas of open flow in the Colville River approximately 3 miles downstream from the Anaktuvuk confluence. This represented the initial observation of breakup events in 2010 and can be considered the leading edge. By May 23, 2010, the leading edge on the Colville River was approximately 2.7 miles upstream of Ocean Point, and approximately 22.4 miles upstream of MON1C. (Photo 4.3).

Photo 4.3: Leading edge in the Colville River upstream from Ocean Point; May 23, 2010.

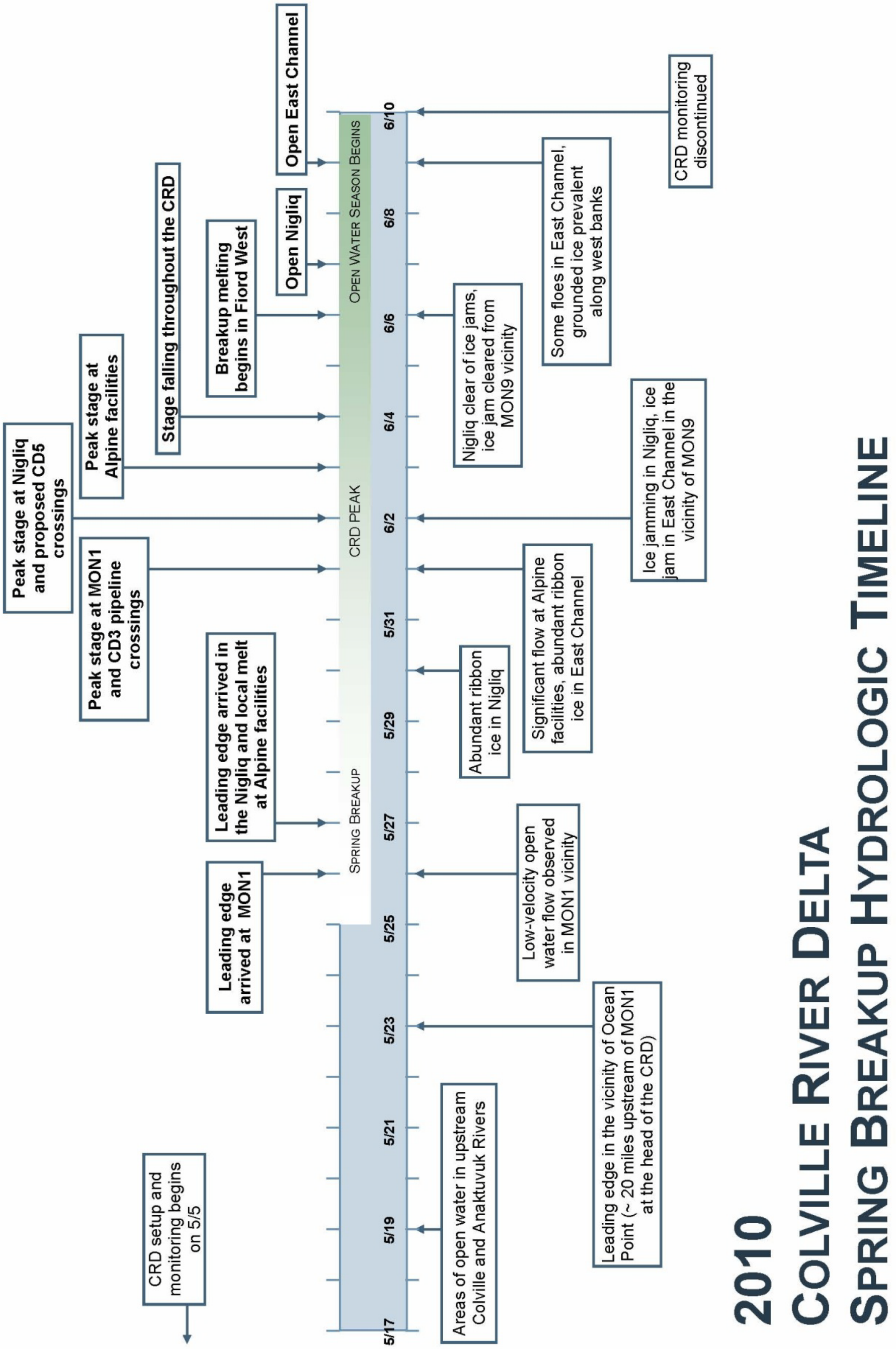


Figure 4.1: 2010 Spring Breakup Hydrologic Timeline

Over the next 18.5 hours, the leading edge on the Colville River had progressed 8.7 miles further downstream, at a rate of nearly 0.5 miles per hour. On the morning of May 24, 2010, the leading edge was approximately 13.6 miles upstream from MON1 (Photo 4.4).

Ice Jam
A stationary accumulation of fragmented ice or frazil, which restricts or blocks a stream channel

Photo 4.4: Leading edge in the Colville River 13.6 miles upstream from MON1; May 24, 2010.

During reconnaissance flights on May 25 and May 26, rafted ice observed from MON1 upstream towards the Anaktuvuk confluence indicate some ice jamming had been occurring in that area since early on May 24. Photo 4.5, taken on May 26, shows an ice jam located approximately 18 miles upstream from MON1U, and approximately 46 miles downstream of the Anaktuvuk confluence. Evidence suggests this small ice jam released during the morning of May 24, as low velocity flows and discontinuous areas of open water were observed at MON1 soon after on the morning of May 26.

Photo 4.5: Ice floes upstream from MON1; May 26, 2010.

Photo 4.6: Ice floes jamming 14.6 miles upstream from MON1; May 27, 2010.

Ice Floe
A floating piece of channel or sheet ice

4.2 MONUMENTS

The leading edge reached MON1 on the morning of May 26. From here, floodwaters continued downstream into either the Colville River East Channel (East Channel) or the Nigliq Channel.

4.2.1 COLVILLE RIVER EAST CHANNEL

Daily monitoring of the East Channel gages began on May 26. By May 27, the first measureable floodwater in the CRD was present on MON1U-A (Photo 4.7). The gages at MON1C and MON1D were still dry on the afternoon of May 28. Due to fog and freezing rain, it was not possible to collect gage WSE data in the East Channel on May 29. Measureable stage reached MON1C gages by May 30, and MON1D gages by May 31. The leading edge reached MON9 by the afternoon of May 26 and MON35 at Helmericks by the morning of May 27.

Photo 4.7: MON1U gages, Colville River; May 27, 2010.

Stage rose from 12.82 to 15.01 ft BPMSL at MON1C in the 27 hours between the initial gage reading on May 30 and the May 31 reading. By May 31, ribbon ice was abundant, but not moving in the vicinity of MON1. Significant ribbon ice and ice floes were observed in the channel until past June 2, as shown in Photo 4.8.

Beginning on May 31 and over the next 28 hours, water levels at MON1C rose an additional 4.6 feet, reaching a peak stage of 19.59 ft BPMSL on the evening of June 1 (Photo 4.9). On June 2 and 3, abundant stranded ice was observed at MON1, as shown in Photo 4.10 and Photo 4.11. By June 5, stage had dropped to 10.56 ft BPMSL at MON1C. On June 8, some in-channel ice floes persisted in the vicinity of MON1; the channel was largely open after June 8. WSE for MON1C is provided in Table 4.1. Table 4.2 shows WSE for MON1U and MON1D.

Channel Ice
Channel ice that is no longer attached to the stream banks due to melt, it may remain in place or move downstream with flood flow

Grounded Ice
Floating ice that is aground or in shallow water

Ribbon Ice
The layer of ice that forms at the air-water interface of a stream and is attached to the banks

Stranded Ice
Grounded ice

Photo 4.8: Ice floes in the vicinity of MON1D, near peak stage; June 1, 2010.

Photo 4.9: Reading gages at MON1U, near peak stage; June 1, 2010.

Photo 4.10: Stranded ice at MON1C; June 5, 2010.

Photo 4.11: Stranded ice at MON1D; June 5, 2010.

The leading edge arrived at MON9 on May 26 and brought measureable flood flow; earlier gage readings at this location represent standing water due to local melt only. Stage rose gradually from an initial May 26 gage reading of 5.42 ft BPMSL to 11.78 ft BPMSL on May 31. As shown in Photo 4.12, on May 28 channel ice was still substantial, covering approximately 50% of the channel. Ribbon ice was present in the MON9 vicinity on May 31 and evidence of an ice jam was seen on June 1, as shown in Photo 4.13, Photo 4.14, and Photo 4.15. Between May 31 and June 1, overnight water levels rose another 5.1 feet to reach a peak stage of 16.88 ft BPMSL on the evening of June 1. On June 2, another ice jam had formed approximately ¾ mile upstream from MON9. This jam moved downstream of MON9 by June 3. On June 8, grounded ice was abundant on the banks and some floes still remained in channel. The channel in this vicinity was open after June 9. WSE for MON9 is provided in Table 4.3.

Photo 4.12: Gage reading at MON9; May 28, 2010.

Photo 4.13: Water rising at MON9; May 31, 2010.

Photo 4.14: Aerial view of channel ice at MON9; June 1, 2010.

Photo 4.15: Channel ice as viewed from the west bank at MON9; June 1, 2010.

The leading edge is estimated to have arrived downstream at MON35 on May 27. After this initial gage reading of 2.56 ft BPMSL, water levels rose, and then dipped slightly to 2.50 ft BPMSL on May 29. Stage then rose steadily to reach a peak of 4.75 ft BPMSL on June 1. The channel in this vicinity was ice free by June 8. Table 4.4 provides WSE for MON35.

Data collected from pressure transducers installed at the East Channel gaging stations (MON1U, MON1C, MON1D) supported observed gage WSE measurements. The PT at MON9 failed to correctly record data.

Poor weather, low visibility, fog, and freezing rain in 2010 limited ability to make observations and collect measurements throughout the CRD, especially at locations farther from facilities requiring helicopter transportation to visit. Due to these conditions, Baker was not able to deploy equipment and personnel to perform an ADCP direct discharge measurement at MON1 or in the Nigliq Channel.

Table 4.1: WSE Data for MON1C

Date and Time	WSE (feet BPMSL)	Observations
	MON1C	
5/28/10 4:20 PM	-	Water had not reached the gages.
5/30/10 9:50 AM	12.82	
5/31/10 1:15 PM	15.01	Abundant ribbon ice in area.
6/1/10 6:00 PM	19.59	**Peak Stage;** channel ribbon ice and floating ice.
6/2/10 5:05 PM	17.75	Stranded ice present, strong winds.
6/5/10 3:15 PM	10.56	Survey to WSE.

Notes:

1. Elevations are based on Monument 01 at 27.93 feet BPMSL, surveyed by LCMF in 2006.
2. Weather and river conditions did not permit a direct discharge measurement at this location for 2010.
3. Weather conditons prohibited a gage run on May 29.

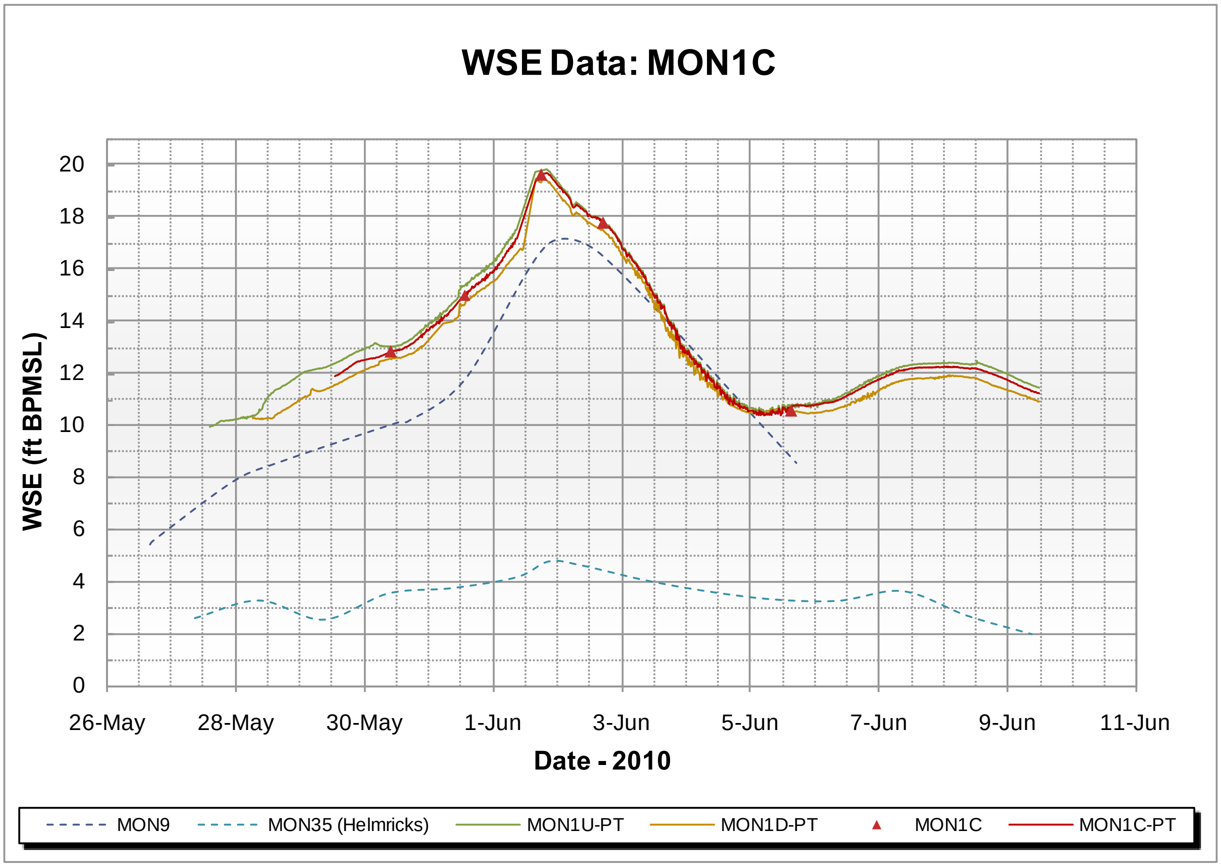


Table 4.2: WSE Data for MON1U and MON1D

Date and Time	WSE (feet BPMSL)		Observations
	MON1U	MON1D	
5/27/10 2:15 PM	9.92		1st water on MON1U gages; Water had not reached MON1D or MON1C.
5/28/10 4:15 PM	11.40		Water had not reached the Gages at MON1D.
5/30/10 9:52 AM	13.02		No HWM at MON1U; Water had not reached the Gages at MON1D.
5/31/10 1:23 PM	15.35	14.65	Abundant ribbon ice in area.
6/1/10 5:53 PM	19.73	19.48	**Peak Stage MON1D;** channel ribbon ice and floating ice.
6/1/10 8:00 PM	19.83		**Peak Stage MON1U;** based on HWM; estimated time.
6/2/10 5:13 PM	17.85	17.50	Stranded ice prevalent; channel clear of ribbon ice.
6/5/10 4:12 PM	10.77	10.53	Stranded ice, survey to WSE.
			Channel Ice Free by 6/8/10.

Notes:

1. Elevations are based on Monument 01 at 27.93 feet BPMSL, surveyed by LCMF in 2006.
2. Weather conditons prohibited a gage run on May 29.

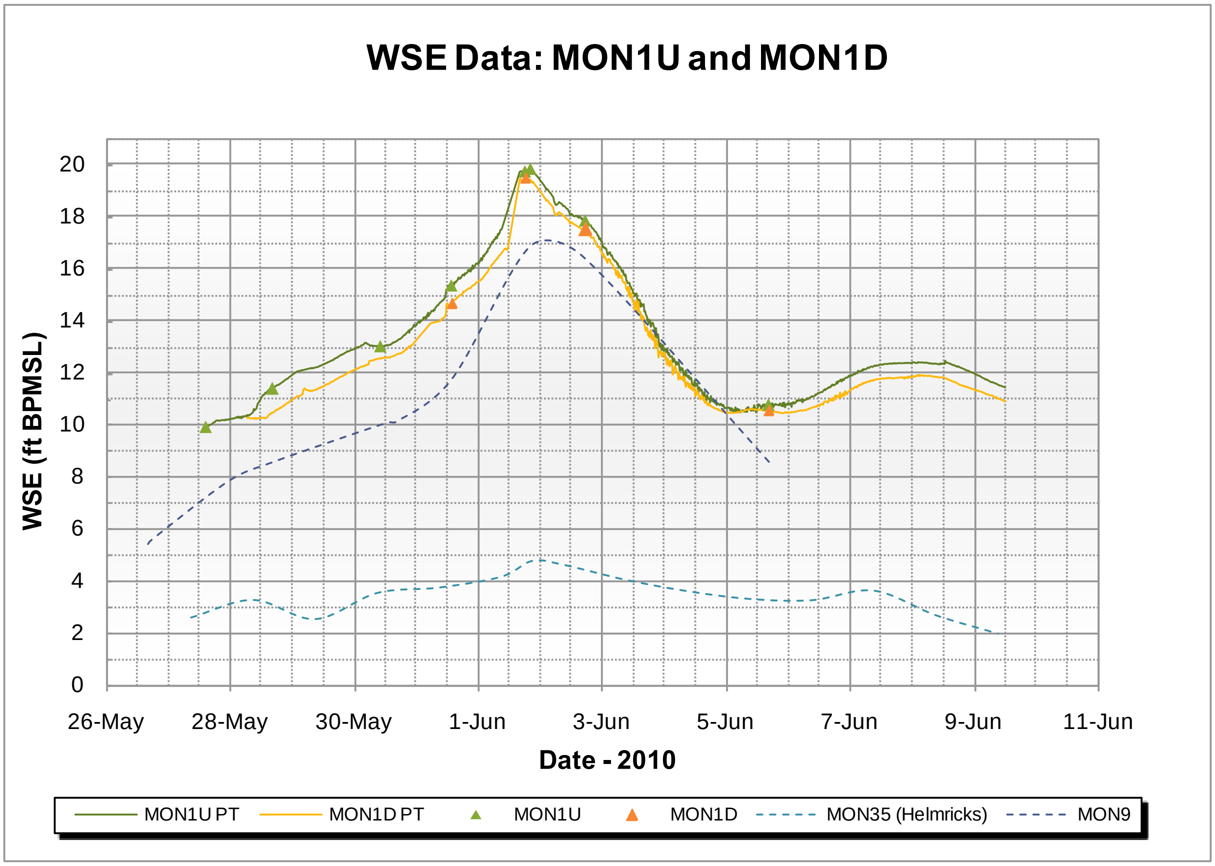

WSE Data: MON1U and MON1D

Table 4.3: WSE Data for MON9

Date and Time	WSE (feet BPMSL)	Observations
	MON9	
5/26/10 4:00 PM	5.42	Primarily local melt.
5/26/10 5:00 PM	5.55	
5/27/10 10:50 PM	7.82	
5/28/10 4:30 PM	8.58	50% open water; channel ice present.
5/30/10 12:30 PM	10.09	
5/30/10 4:00 PM	10.12	
5/31/10 1:45 PM	11.78	Ribbon ice in channel.
6/1/10 8:00 PM	16.88	**Peak Stage** based on HWM; abundant flooting ice, possible loosened ice jam.
6/2/10 4:25 PM	16.49	Ice jam 3/4 mile upstream.
6/5/10 4:55 PM	8.54	Ice jam downstream; only gages F&G remain.

Notes:

1. Elevations are based on Monument 09 at 25.06 feet BPMSL, surveyed by LCMF in 2008.
2. The Monument 9 Pressure Transducer failed to record data correctly.
3. Weather conditons prohibited a gage run on May 29.

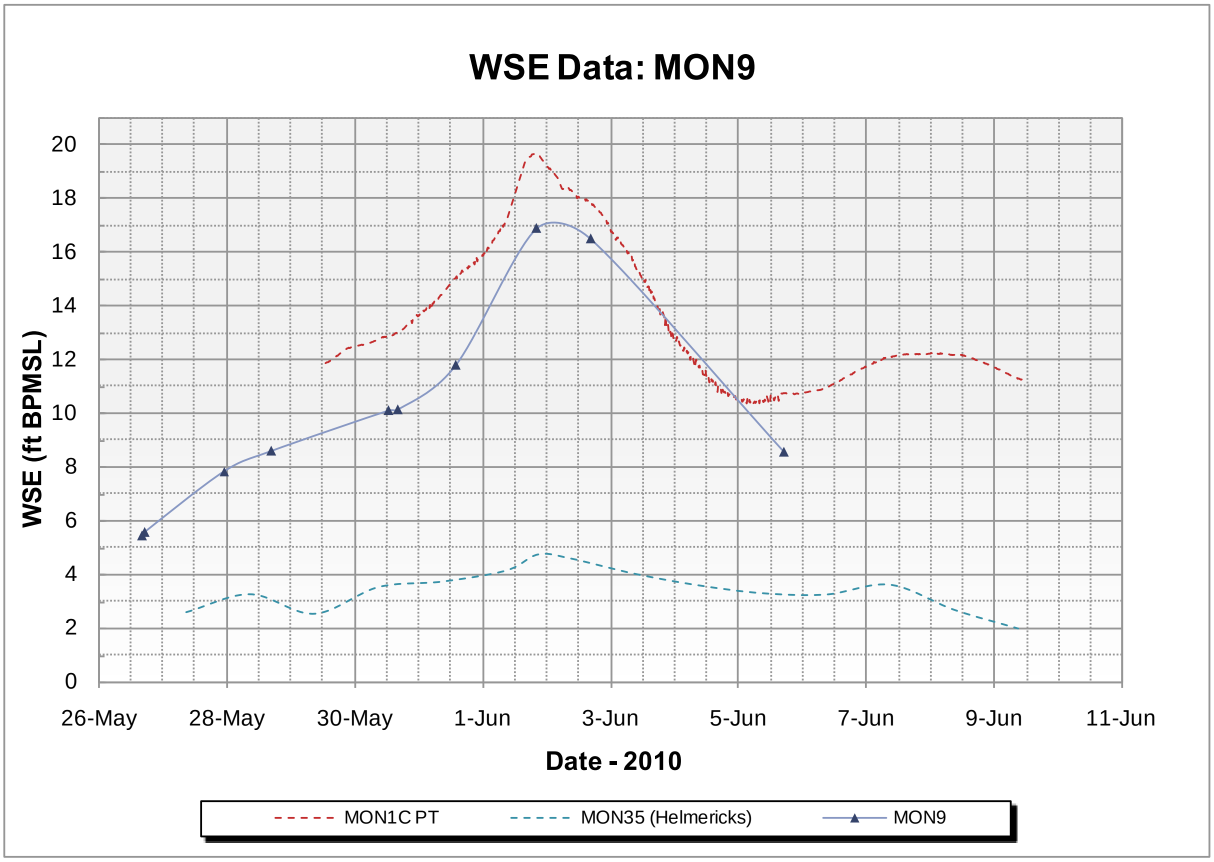
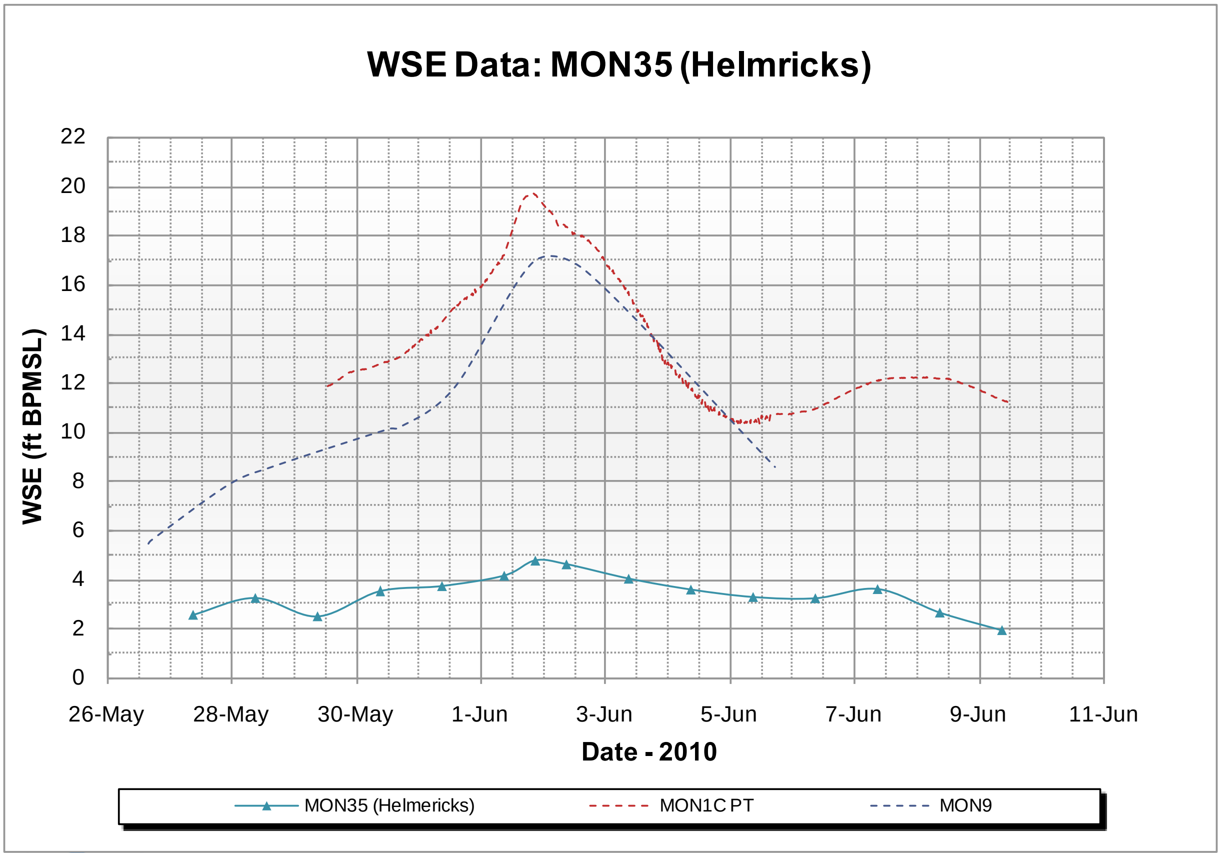


Table 4.4: WSE Data for MON35 (Helmericks Homestead)

Date and Time	WSE (feet BPMSL) MON35 (Helmricks)	Observations
5/26/10 9:00 AM		Breakup appears to be happening upstream of gages.
5/27/10 9:00 AM	2.56	Leading edge arrived.
5/28/10 9:00 AM	3.24	
5/29/10 9:00 AM	2.50	
5/30/10 9:00 AM	3.51	
5/31/10 9:00 AM	3.72	
6/1/10 9:00 AM	4.14	
6/1/10 9:00 PM	4.75	**Peak Stage.**
6/2/10 9:00 AM	4.60	
6/3/10 9:00 AM	4.02	River bottom ice moving in by shorelead.
6/4/10 9:00 AM	3.58	
6/5/10 9:00 AM	3.28	
6/6/10 9:00 AM	3.23	No drifting ice in shoreleads.
6/7/10 9:00 AM	3.60	
6/8/10 9:00 AM	2.65	River ice free.
6/9/10 9:00 AM	1.94	

Notes:

1. Elevations are based on Monument 35 at 5.57 feet BPMSL, surveyed by Lounsbury in 1996.
2. These data were collected from Helmricks property by Jim Helmricks.



4.2.2 NIGLIQ CHANNEL

Floodwaters entered the Nigliq Channel on May 26, but due to initial low velocities, did not reach Nuiqsut until May 27. Floodwaters began filling Tapped Lake and Nanuq Lake on May 27. Nigliq Channel gage readings began on May 28, when flood stage was first measureable. Due to fog and freezing rain, gage WSE data collection was not possible on May 29. During a 20-minute reconnaissance flight on May 29, it was noted floodwaters had overtopped the banks of the Nigliq Channel and were flowing across Nanuq Lake, as shown the following day in Photo 4.16.

Photo 4.16: Nigliq Channel floodwaters reach Nanuq Lake; CD1 shown in foreground; May 30, 2010.

Ice activity significantly affected the breakup processes in the Nigliq Channel in 2010. Abundant ribbon ice was observed throughout the channel May 30 through June 1. On June 1, an ice jam entered the Nigliq Channel. It was observed on June 2 in the vicinity of Nuiqsut (shown in Photo 4.17) when peak stage occurred at MON MON20, MON22, and MON23. The activity of this ice jam on June 2 is likely responsible in part for the quick water level rise on the Nigliq Channel that correlated with the more dramatic rise observed in the East Channel during the same period. This ice continued jamming and releasing as it progressed slowly downstream in the Nigliq Channel over the next six days until the channel was relatively open (with some grounded ice on banks and bars) on June 7.

Photo 4.17: Ice jam in the Nigliq Channel near Nuiqsut; June 2, 2010.

On May 30, abundant ribbon ice was present in the Nigliq in the vicinity of MON20, located just upstream of CD4. Stage rose quickly between May 30 and June 1 throughout the CRD, and by June 2, water levels in the vicinity of CD4 (MON20) had risen over 3 feet from 7.59 ft BPMSL on May 30 to a peak of 10.64 ft BPMSL. On June 3, the ice that had been gradually moving downstream from the Nuiqsut vicinity since June 1 was observed jammed just downstream of MON20. Ribbon ice in the area began breaking up on June 3 as well, which added to the jam. Flood flow began to recede after June 2 and the channel was open in the vicinity of MON20 after June 7. WSE data for MON20 is provided in Table 4.5.

Just upstream from CD2 at MON22, floodwater was measureable on the gages by May 30, with an initial reading of 5.83 ft BPMSL. Significant ribbon ice persisted in this vicinity from May 30 through June 1, as gage WSE levels quickly rose to 8.34 ft BPMSL on June 1 (see Photo 4.18), a change of 2.51 feet. The stage rise was less than at MON20 due to flood flow lost towards facilities, particularly via Nanuq Lake. Water levels at

MON22 peaked on June 2 at 8.69 ft BPMSL, after which stage receded. Remaining ribbon ice in the vicinity began to break up on June 3, and by June 5 the ice that had been in the MON20 vicinity on June 1 was observed jammed upstream of MON22. The channel was open by June 7, with grounded ice along the banks. WSE data for MON22 is provided in Table 4.6.

Photo 4.18: Floodwaters at MON22 one day prior to peak with CD2 in background; June 1, 2010.

Stage reached the MON23 gages just downstream from CD2 by May 28; the initial reading was 4.11 ft BPMSL. Water levels rose to 5.68 ft BPMSL on the morning of May 30, and then dropped slightly that afternoon, after which stage quickly rose 1.91 feet to 7.38 ft BPMSL on the evening of June 1. This rise was somewhat more moderate than at MON22 due again to flood flow lost towards facilities. There was abundant ribbon ice and ice floes throughout the channel in the MON23 vicinity on May 30, which remained through June 3 (see Photo 4.19), when the ribbon ice began to break up. MON23 stage peaked on June 2 at 7.77 ft BPMSL and then began to recede. The ice jamming observed at various locations upstream during breakup did not appear to jam in the MON23 vicinity, at least for any significant amount of time. By June 7, the channel was open, and some grounded ice remained along the banks. WSE data for MON23 is provided in Table 4.7.

Photo 4.19: Ribbon ice and floes in the Nigliq Channel 1.4 miles downstream from MON23; June 1, 2010.

Downstream at the coast, MON28 monitoring commenced on May 28, although measureable water was not yet present on the gages. Persistent poor weather hampered efforts to visit this gage site until June 1, as efforts were concentrated closer to facilities. On June 1, WSE was measured at 2.59 ft BPMSL. Stage peaked on June 3 at 3.02 ft BPMSL and then began to recede. Ice jamming was not observed in the area. WSE data for MON28 is provided in Table 4.8.

Table 4.5: WSE Data for MON20

Date and Time	WSE (feet BPMSL)	Observations
	MON20	
5/28/10 3:55 PM	6.19	Stranded ice in channel.
5/30/10 9:25 AM	7.66	No HWM; Gage A submerged.
5/30/10 12:00 PM	7.67	HWM, estimated time.
5/30/10 3:50 PM	7.61	Abundant ribbon ice throughout channel.
6/1/10 5:35 PM	10.18	No HWM.
6/2/10 7:00 AM	10.65	**Peak Stage based on HWM;** Estimated time.
6/2/10 4:15 PM	10.56	
6/3/10 5:25 PM	9.14	Ice jam downstream of MON20 between G20 and G21; riboon ice in channel.
6/7/10 12:00 PM		Grounded ice along banks.

Notes:

1. Elevations are based on CP-08-12-61 at 11.956 feet BPMSL, updated by LCMF in 2009.
2. Weather conditions prohibited a gage run on May 29.

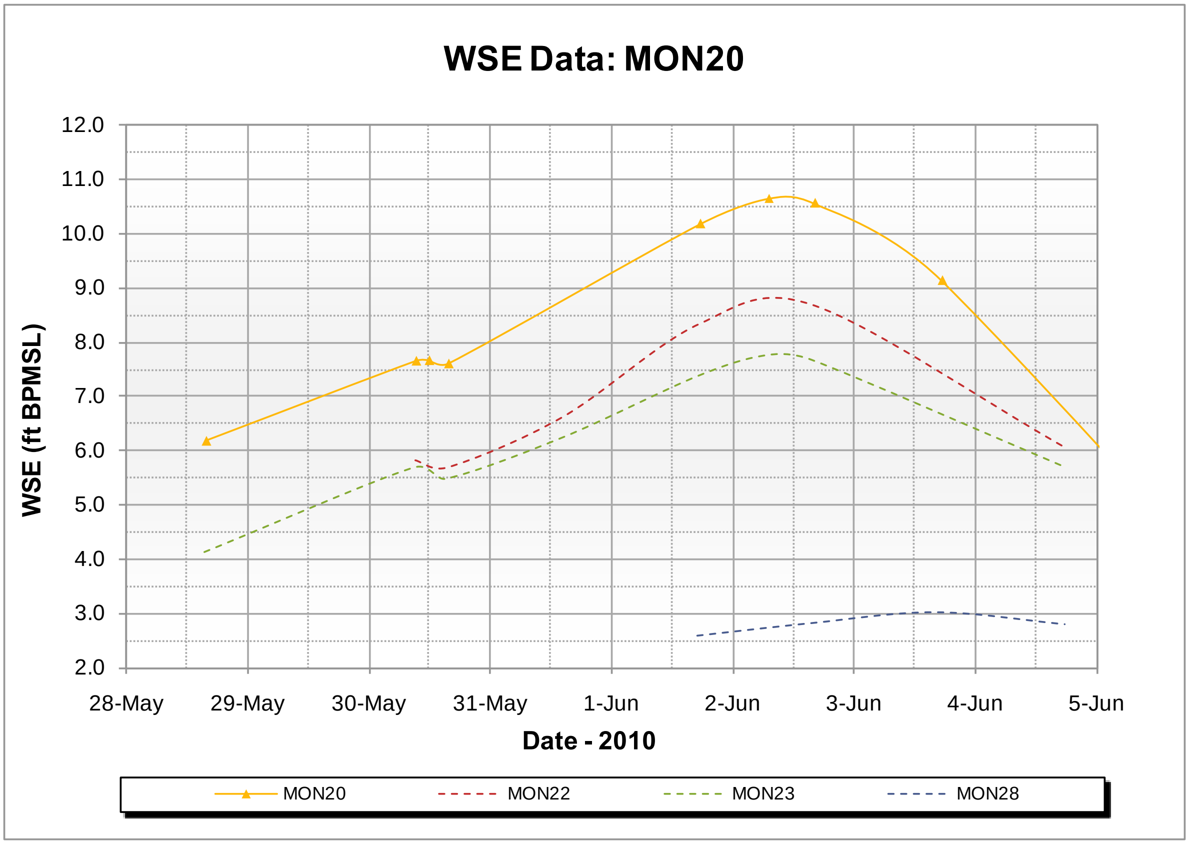


Table 4.6: WSE Data for MON22

Date and Time	WSE (feet BPMSL)	Observations
	MON22	
5/28/10 3:30 PM		No water on gages; channel ice present.
5/30/10 9:05 AM	5.83	
5/30/10 3:30 PM	5.70	Ribbon ice present.
5/31/10 2:20 PM	6.63	No HWM; ribbon ice.
6/1/10 5:20 PM	8.34	No HWM; ribbon ice.
6/2/10 3:50 PM	8.69	**Peak Stage based on HWM; time estimated.** Ice jam upstream from Nuiqsut.
6/3/10 12:00 PM		Ribbon ice in channel beginning to breakup.
6/4/10 5:45 PM	6.07	Read in very high wind, waves lapping against gage; no definite HWM.
6/5/10 12:00 PM		Ice jam noted upstream of MON22.
6/7/10 12:00 PM		Grounded ice along banks.

Notes:

1. Elevations are based on Monument 22 at 10.03 feet BPMSL, updated by Baker in 2010.
2. Weather conditions prohibited a gage run on May 29.

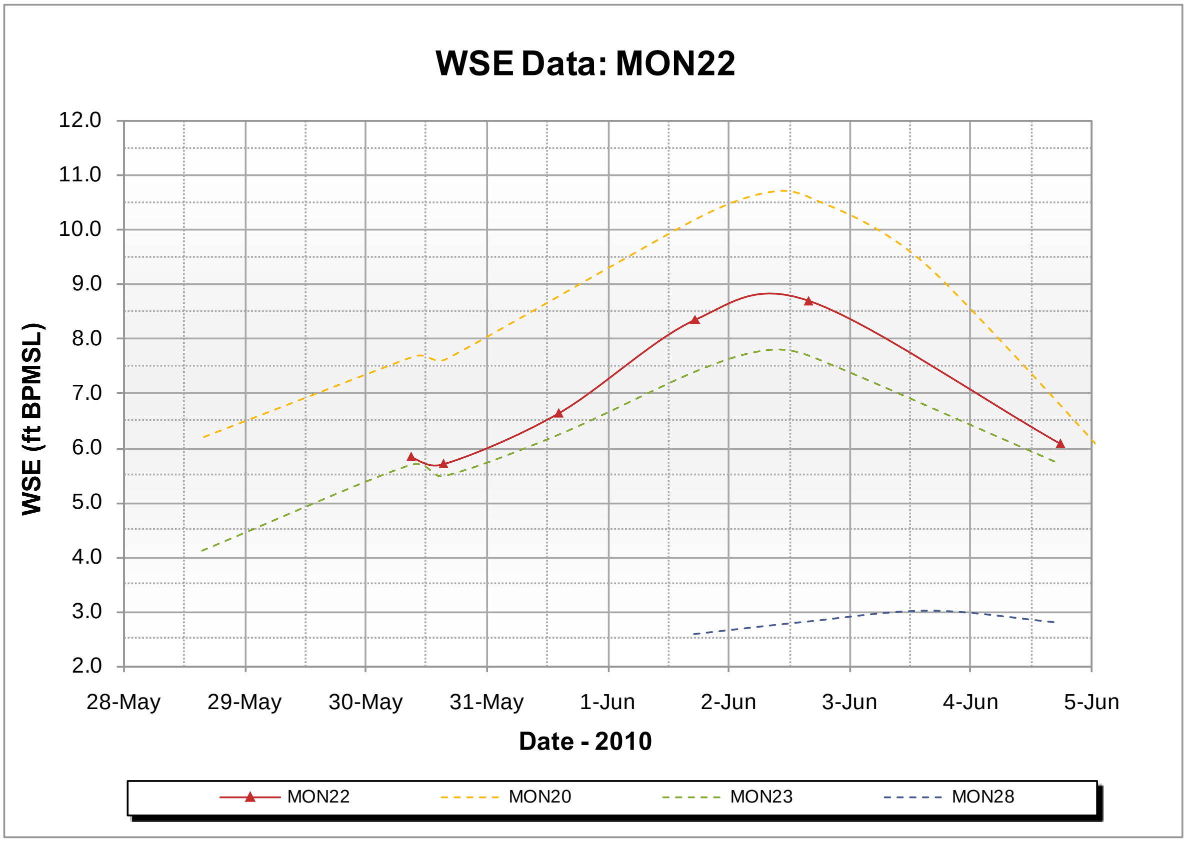


Table 4.7: WSE Data for MON23

Date and Time	WSE (feet BPMSL)	Observations
	MON23	
5/28/10 3:30 PM	4.11	
5/30/10 9:00 AM	5.68	No HWM; abundant ribbon ice throughout channel.
5/30/10 3:15 PM	5.47	Abundant ribbon ice throughout channel.
5/31/10 2:30 PM	6.24	No HWM; abundant ribbon ice throughout channel.
6/1/10 5:15 PM	7.38	No HWM; abundant ribbon ice throughout channel.
6/2/10 7:00 AM	7.77	**Peak Stage based on HWM**; time estimated; Ice jam near Nuiqsut.
6/2/10 3:45 PM	7.68	
6/3/10 12:00 PM		Ice jam downstream of MON20; ribbon ice breaking up.
6/4/10 5:50 PM	5.69	Channel ice present.
6/5/10 12:00 PM		Ice jam noted upstream of MON22.
6/7/10 12:00 PM		Grounded ice along banks.

Notes:

1. Elevations are based on Monument 23 at 9.546 feet BPMSL, updated by Baker in 2009.
2. The timing and elevation of the High Water Mark was adjusted to match PT data.
3. Weather conditions prohibited a gage run on May 29.

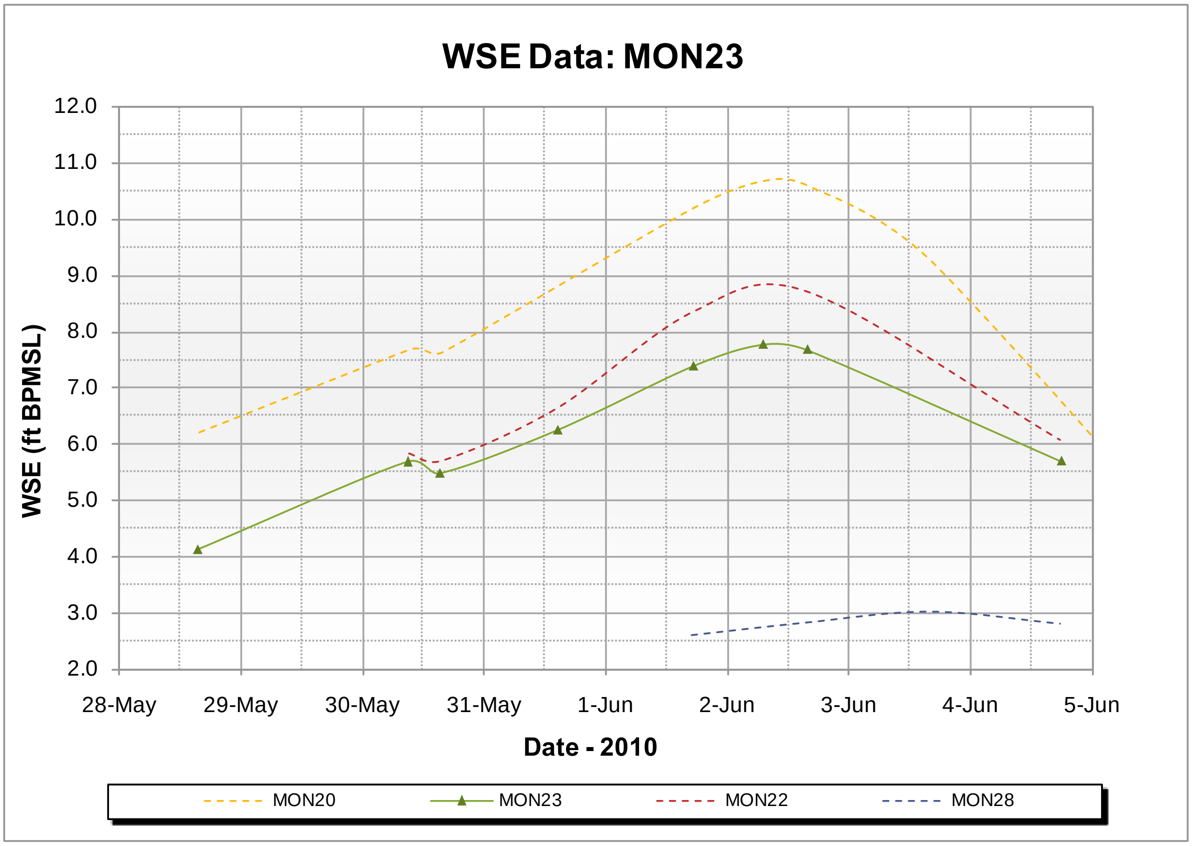
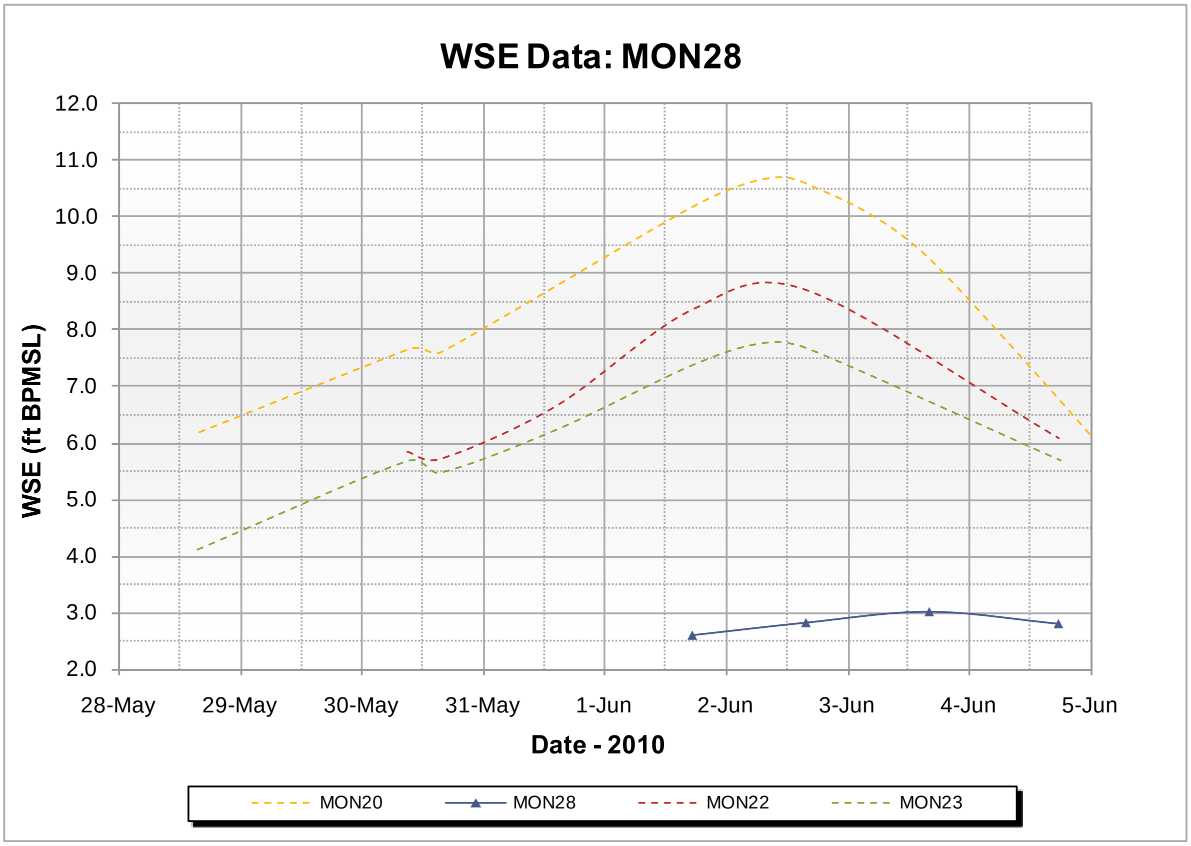


Table 4.8: WSE Data for MON28

Date and Time	WSE (feet BPMSL)	Observations
	MON28	
5/28/10 4:40 PM		No water on gages.
6/1/10 5:05 PM	2.59	Measure down from top of steel, no HWM.
6/2/10 3:35 PM	2.82	No HWM.
6/3/10 4:00 PM	3.02	**Peak Stage based on HWM;** *time estimated.*
6/4/10 5:35 PM	2.80	

Notes:

1. Elevations are based on Monument 28 at 3.65 feet BPMSL, updated by LCMF (GPS) in 2002.
2. Weather conditions prohibited a gage run on May 29.



4.3 ALPINE FACILITIES AND ROADS

Gage monitoring around Alpine facilities and roads began May 30 and ended on June 5. Facilities stage peaked first at all gages along the CD2 access road and at G18, the CD4 access road near the CD4 pad, on June 2. Peak at CD1, as measured by G1, occurred on June 3. Peak at CD4 road gages (G15 and G16) did not occur until June 4, and additional CD4 road G17 did not measure any flood flow in 2010. Flood waters did not reach CD2, CD4, or CD3 pads in 2010, as measured by G8, G19, and G11, respectively.

4.3.1 GAGES

Flood flow reached G1, on the east side of the CD1 pad in the Sakoonang Channel, on May 29 and was measureable on May 31. WSE climbed steadily at this location throughout breakup, reaching a peak of 7.15 ft BPMSL on June 3, after which it receded. Between these dates (May 29 to June 3), floodwaters in the Sakoonang Channel flowed north to south, backwards from the typical south to north flow that occurs during open channel conditions. This is likely the result of floodwaters diverting from the Tamayayak Channel downstream into the Sakoonang. Additionally, limited flow entered the mouth of the Sakoonang at the East Channel birfurcation, possibly due to insufficient pressures generated during breakup that would be required to clear the significant quantities of ice and snow that accumulate in the Sakoonang Channel.

During facility peak, significant flow passed under the CD2 access road in 2010. Initial facilities flood flow was observed passing through the 452-ft (large) swale bridge and some culverts along the CD2 road on May 29, although discharge was low with little floodwater in the area. Stage had reached measureable levels on G3 and G4 by May 30. Stage then rose steadily at G3, peaking at 8.64 ft BPMSL on the morning of June 2 and at G4 at 8.09 ft BPMSL later that afternoon.

Flow through drainage structures in the area of G3/G4 was affected by large quantities of ice and snow remaining throughout breakup. This is discussed in more detail in Section 4.3.3.

Both swale bridges, which pass the majority of the flow across the CD2 road, were clear of snow dams by June 1, prior to peak. Photo 4.20 shows floodwaters along the CD2 road on May 31. Photo 4.21 shows G4 near the swale bridges, one day prior to peak stage, on June 1. Floodwaters receded gradually after peak until June 4, then receded more quickly.

Flow was observed passing under the long swale bridge until observations were discontinued on June 9.

Photo 4.20: Floodwaters at CD2 road near swale bridges; May 31, 2010.

Photo 4.21: G4 along CD2 road one day prior to peak stage; June 1, 2010.

Floodwater reached measurable levels on G6, G7, G12, and G13 by June 1. Similar to G3/G4, these additional gages along the CD2 road showed a steady rise of flood water, each peaking on June 2, as shown in Photo 4.22 and Photo 4.23. Abundant snow quantities around these gages likely affected stage measurements during peak, and certainly affected flow though nearby drainage structures, as discussed in Section 4.3.3. WSE at these CD2 road locations receded steadily following peak until June 4, when measurements ceased.

Photo 4.22: Floodwaters along CD2 road near peak stage; June 2, 2010.

Photo 4.23: G6 near peak stage; June 2, 2010.

Floodwaters did not reach G8 on the north side of CD2 pad in 2010. Peak flood flow did pass on the east, west, and south sides of the pad via the Nigliq Channel, Nanuq Lake, and CD2 road drainage structures. Measured WSE at G8 was the result of local melt only.

Relatively little flood flow passed under the CD4 access road in 2010, due in part to topography and to the abundant quantities of snow that remained in place along the road throughout breakup. WSE rose quickly at G18 after initial measurements on June 1 to a peak of 11.72 ft BPMSL on June 2. This flow did not come from the Nigliq Channel, but was instead primarily backwater from the Sakoonang Channel filling the paleochannel adjacent to the CD4 road. Photo 4.24 shows water along the southwest side of the CD4 road east of G17/G18 on June 2. Flow did not pass under the road from G18 to G17 and G17 remained dry in 2010.

Photo 4.24: Water along CD4 road; June 2, 2010.

Rising water was recorded at G15 beginning June 2, but flow was limited in volume and velocity and unable to significantly penetrate the abundant quantities of snow in the area. Flow did not pass under the CD4 road between G15 and G16 in 2010 and WSE recorded on G16 was the result of local melt only.

G20 is located on the west side of the CD4 pad and the Nigliq Channel, adjacent to Tapped Lake. On the Nigliq Channel, it is located between MON20 (upstream) and G21 (downstream) and WSE at this gage is dependent on events occurring in the channel. For more discussion, see Section 4.2.2 and Section 4.5. Floodwaters rose quickly from May 30 to June 1, when they were first measured at G20. Stage peaked at G20 sometime during the night June 2 or early on June 3, at 10.73 ft BPMSL. Following peak, WSE receded quickly until June 4, when WSE levels

were no longer measureable. These data coincide with the formation and release processes of a major ice jam in the Nigliq Channel between June 1 and June 6. There was no grounded ice in the vicinity of G20 following breakup. The G20 area near peak stage is shown in Photo 4.25.

Photo 4.25: G20 near CD4 just prior to peak stage; June 2, 2010.

Floodwaters did not reach G19 on the south side of CD4 pad in 2010. Peak flood flow passed on the west and south sides of the pad via the Nigliq Channel, into Tapped Lake and towards the Sakoonang Channel, however, measured WSE was the result of local melt only.

Floodwaters did not reach G11 on the south side of CD3 pad and no WSE was measured.

Water surface elevations for the facility road and pad gages are provided in Table 4.9 through Table 4.14.

Table 4.9: WSE Data for G1

Date and Time	WSE (feet BPMSL) G1	Observations
5/31/10 11:30 AM	3.95	
5/31/10 4:35 PM	4.08	
6/1/10 7:04 PM	5.82	Back water through Sakoonang - Flowing North (N) to South (S)
6/2/10 10:10 AM	6.85	N to S flow
6/2/10 2:45 PM	7.02	High winds cause waves +/- 0.05 accuracy of reading; N to S flow
6/3/10 9:15 AM	7.15	**Peak Stage**; high winds cause waves +/- 0.02 accuracy of reading; N to S flow
6/4/10 9:40 AM	6.18	Read w/ binoculars and waves cause +/- 0.02 accuracy of reading; S to N flow

Notes:

1. Elevations are based on Monument 21 at 13.28 feet BPMSL, updated by LCMF in 2008.
2. Gage 1 is a permanent staff gage surveyed and adjusted for elevation by LCMF in May of 2010.

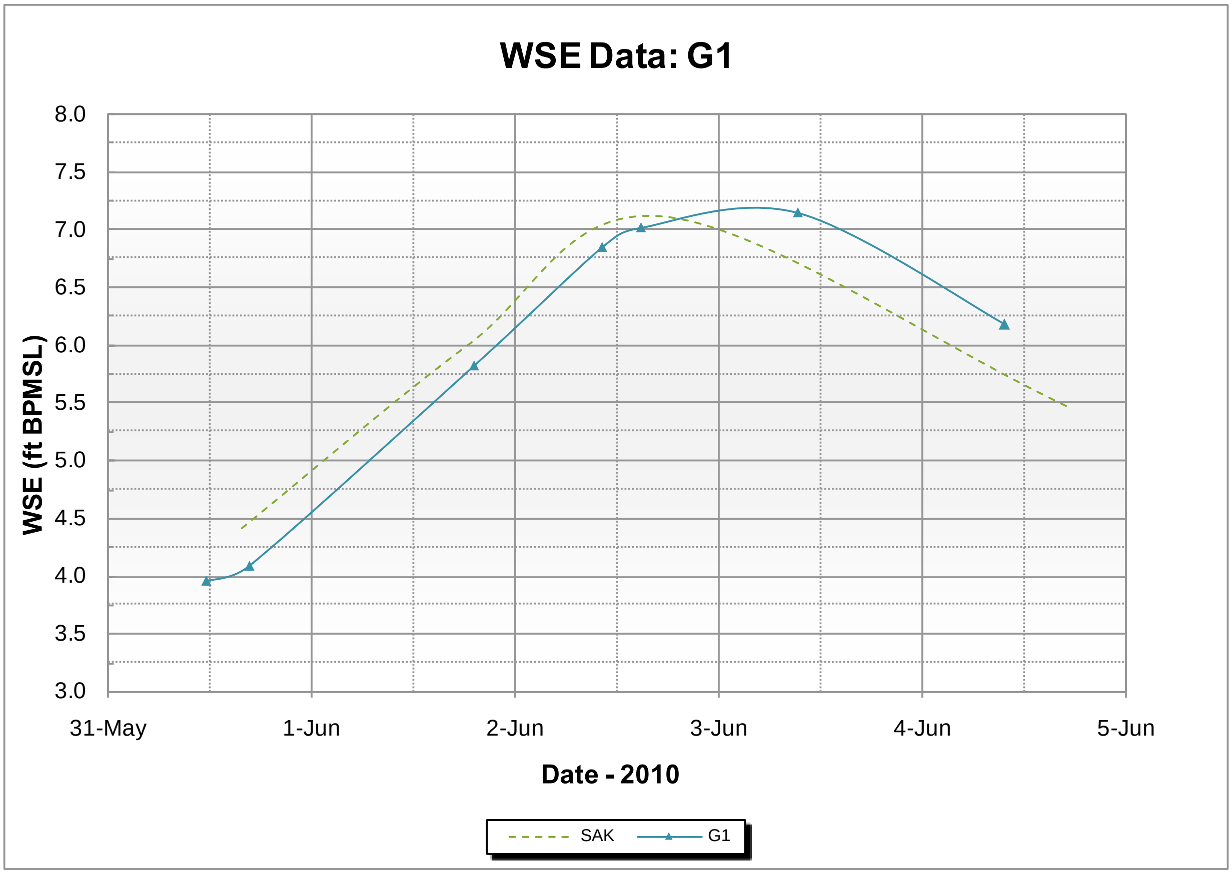
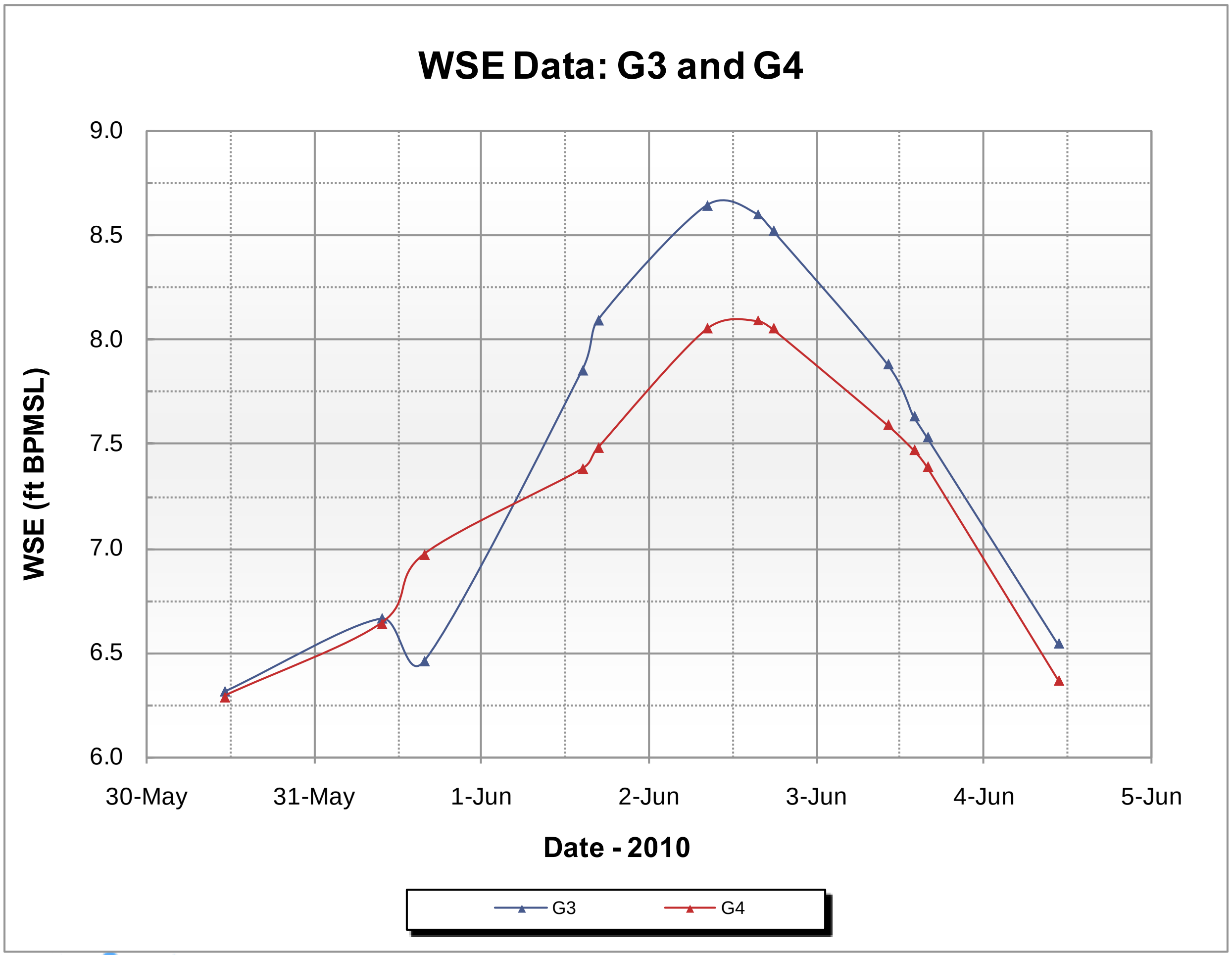


Table 4.10: WSE Data for G3 and G4

Date and Time	WSE (feet BPMSL)		Observations
	G3	G4	
5/30/10 11:10 AM	6.31	6.29	
5/31/10 9:40 AM	6.66	6.64	
5/31/10 3:45 PM	6.46	6.97	Small swale bridge blocked by snow and ice, estimate 95% blockage
6/1/10 2:25 PM	7.85	7.38	Ice dam at small swale bridge released
6/1/10 4:40 PM	8.09	7.48	
6/2/10 8:15 AM	8.64	8.05	**Peak Stage**; G4 - high winds cause waves +/- 0.02 accuracy of reading
6/2/10 3:30 PM	8.60	8.09	**Peak Stage**; G4 - high winds cause waves +/- 0.02 accuracy of reading
6/2/10 5:45 PM	8.52	8.05	Gage 4 - high winds cause waves +/- 0.04 accuracy of reading
6/3/10 10:10 AM	7.88	7.59	Gage 4 - high winds cause waves +/- 0.03 accuracy of reading
6/3/10 1:55 PM	7.63	7.47	
6/3/10 3:50 PM	7.53	7.39	
6/4/10 10:35 AM	6.54	6.37	

Notes:

1. Elevations are based on Monument 12 at 9.00 feet BPMSL, updated by LCMF in 2009.
2. Gages 3 and 4 are permanent staff gages surveyed and adjusted for elevation by LCMF in May of 2010.



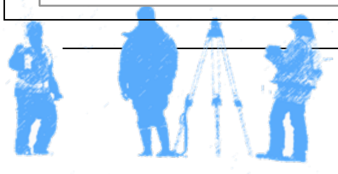


Table 4.11: WSE Data for G6 and G7

Date and Time	WSE (feet BPMSL)		Observations
	G6	G7	
5/31/10 10:10 AM	-	-	No water on Gages
6/1/10 5:37 PM	7.99	7.54	
6/2/10 8:40 AM	8.90	8.26	
6/2/10 12:00 PM	8.92	-	**Peak Stage**; Gage 6: high water mark - time estimated
6/2/10 4:55 PM	8.67	8.34	**Peak Stage**
6/3/10 10:20 AM	8.16	-	G6: high winds cause waves +/- 0.02 reading accuracy; G7: snow, innaccurate
6/4/10 10:45 AM	7.70	6.74	

Notes:

1. Elevations are based on Monument 12 at 9.00 feet BPMSL, updated by LCMF in 2009.
2. Gages 6 and 7 are permanent staff gages surveyed and adjusted for elevation by LCMF in May 2010.

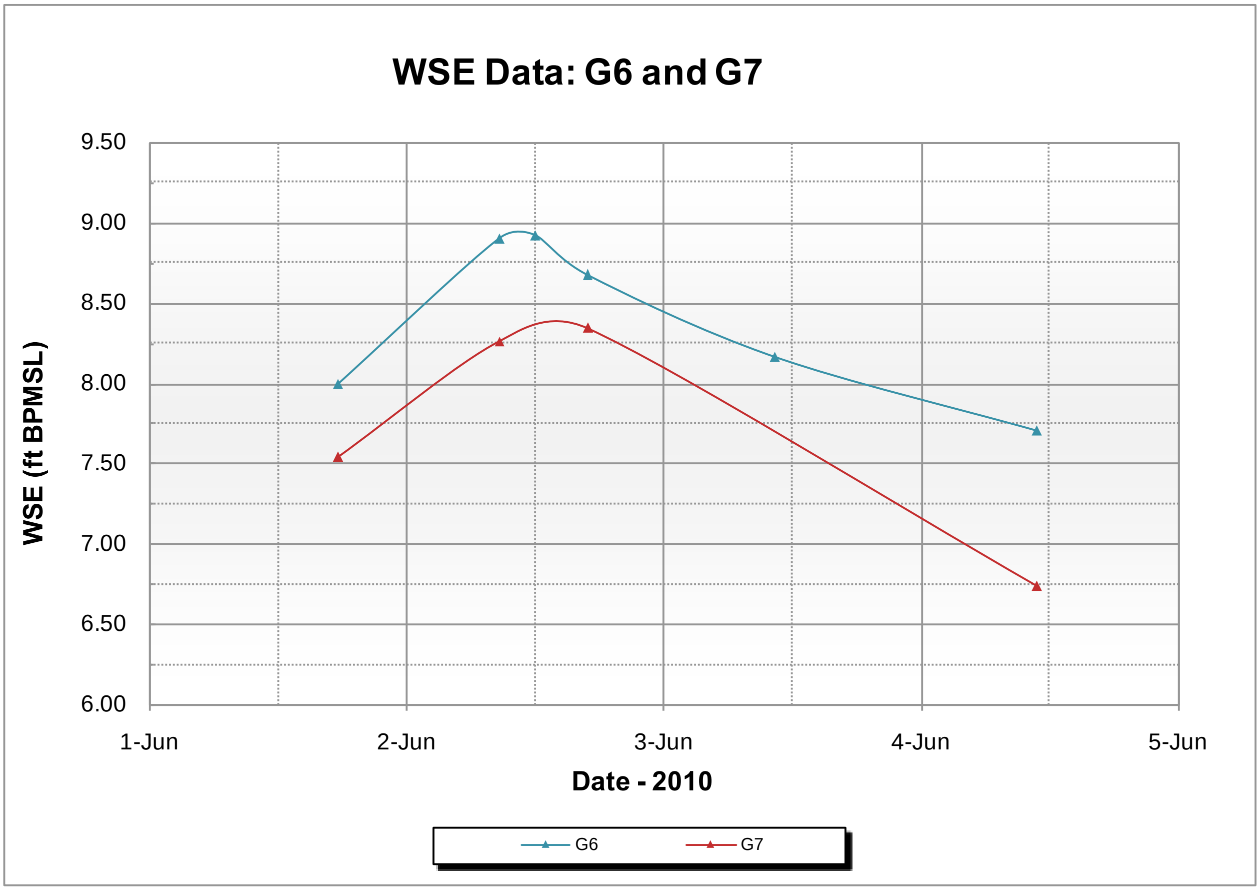


Table 4.12: WSE Data for G12 and G13

Date and Time	WSE (feet BPMSL) G12	G13	Observations
5/31/10 10:00 AM	-	-	No water on gages
6/1/10 5:25 PM	8.43	7.43	
6/2/10 8:30 AM	8.89	8.78	**Peak Stage**; Gage 12 and Gage 13 read by binoculars
6/2/10 5:35 PM	8.75	8.34	
6/3/10 10:15 AM	8.04	8.09	Gage 12 and Gage 13 - high winds cause waves +/- 0.03 accuracy of reading
6/4/10 10:40 AM	-	7.09	No water on Gage 12

Notes:

1. Elevations are based on CD2 access road culvert CD2-14 south invert at 10.929 feet BPMSL and north invert at 11.010 feet BPMSL updated by LCMF in 2010.

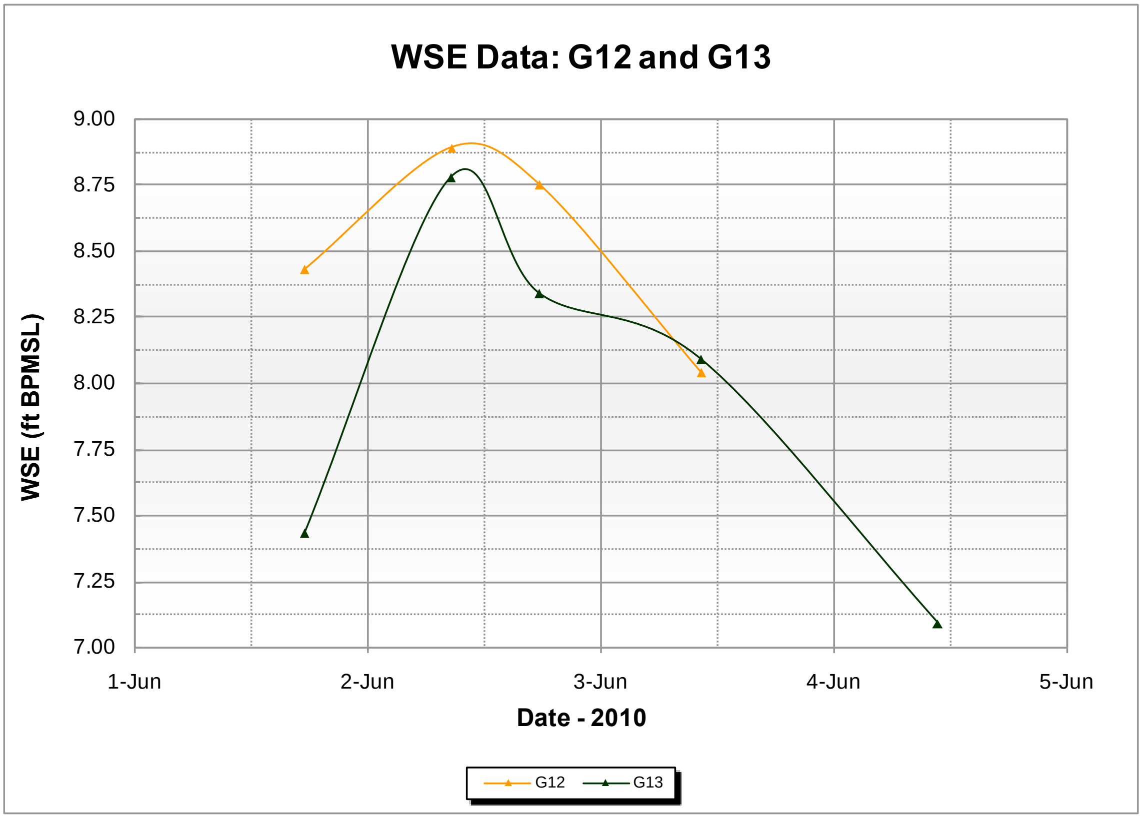


Table 4.13: WSE Data for G15/G16 and G17/G18

Date and Time	WSE (feet BPMSL)				Observations
	G15	G16	G17	G18	
5/31/10 10:40 AM	-	-	-	-	No water on gages
6/1/10 6:00 PM	-	-	-	10.55	No water on Gages 15 and 16
6/2/10 9:15 AM	6.54	-	-	11.72	**Peak Stage**; no water on Gage 16
6/2/10 5:55 PM	6.75	6.88	-	11.36	
6/3/10 9:35 AM	7.47	7.45	-	11.16	
6/4/10 10:00 AM	8.02	8.04	-	-	**Peak Stage**; no water on Gage 18
6/4/10 6:00 PM	7.68	7.43	-	-	Backwater through Gages 15 and 16
6/5/10 9:55 AM	6.97	6.69	-	-	Backwater through Gages 15 and 16

Notes:

1. Elevation for Gage 15 is based on culvert CD4-20A West at 7.350 feet BPMSL, updated by LCMF in 2010.
2. Elevation for Gage 16 is based on culvert CD4-20A West at 7.350 feet BPMSL, updated by LCMF in 2010.
3. Elevation for Gage 17 is based on culvert CD4-32W at 13.222 feet BPMSL, updated by LCMF in 2010.
4. Elevation for Gage 18 is based on culvert CD4-32E at 12.685 feet BPMSL, updated by LCMF in 2010.
5. Water did not reach Gage 17 in 2010.

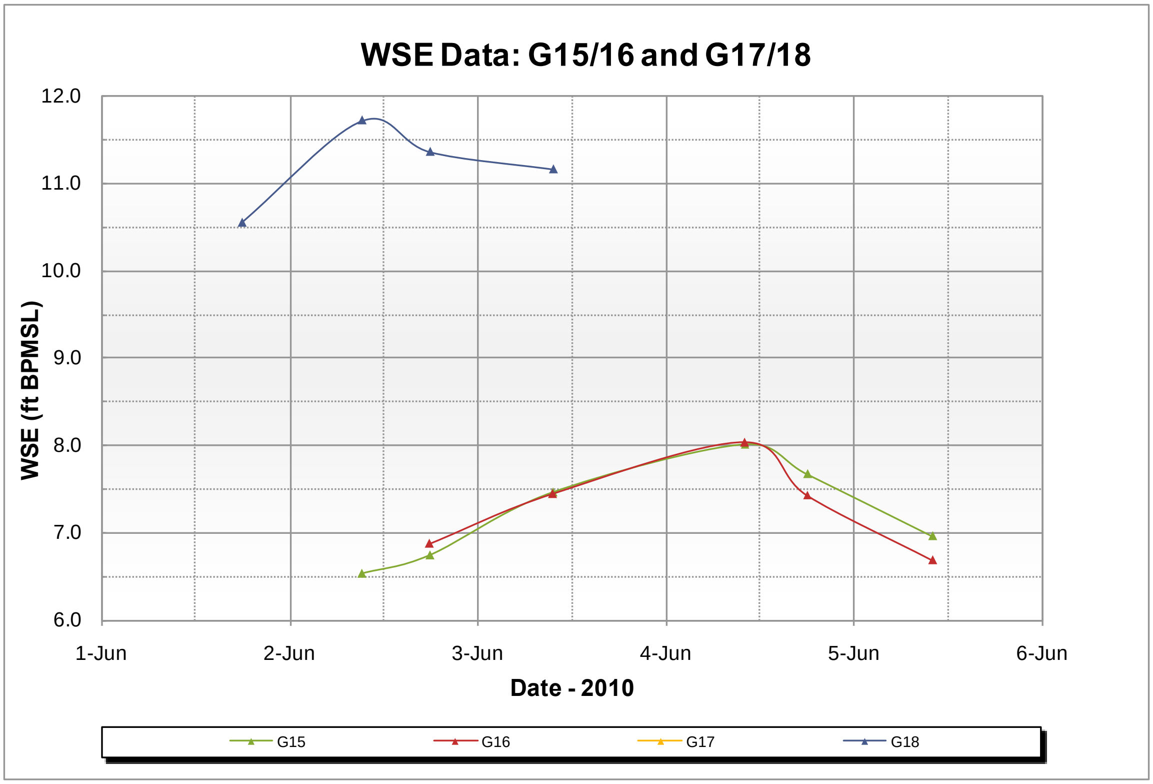
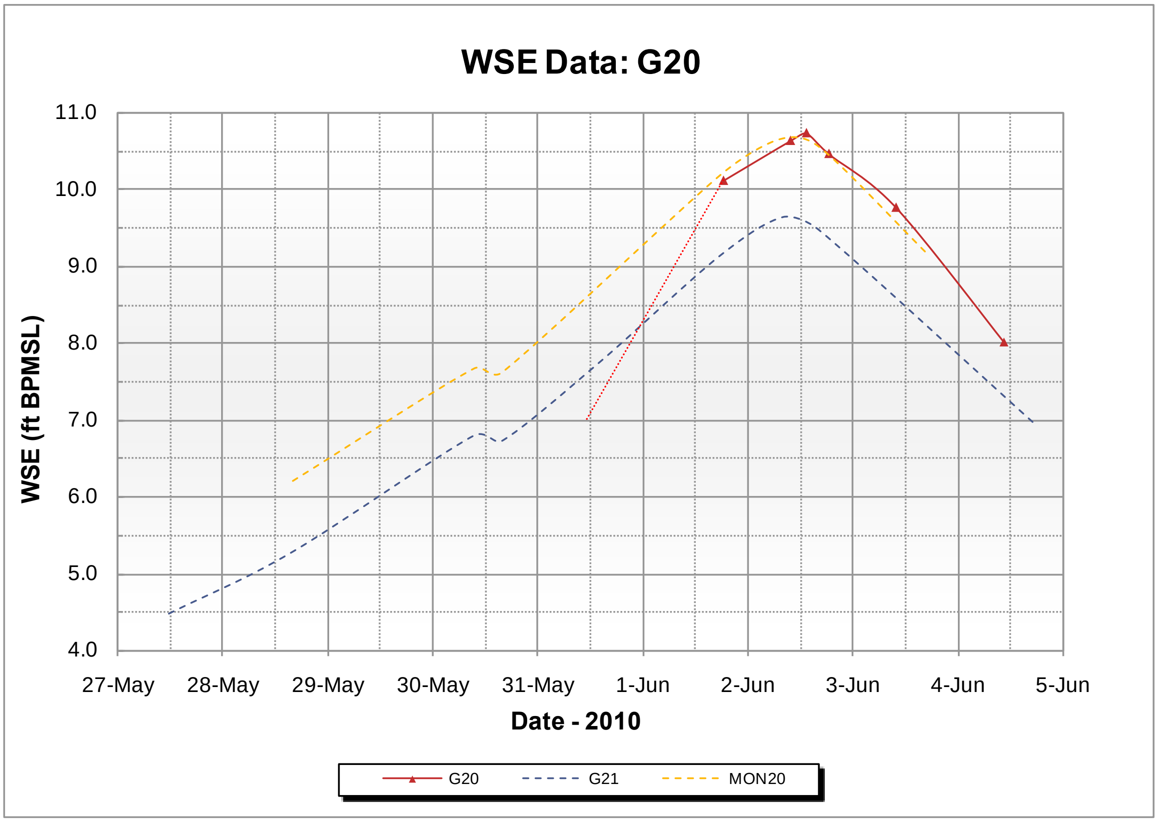


Table 4.14: WSE Data for G20

Date and Time	WSE (feet BPMSL) G20	Observations
5/31/10 10:55 AM	7.00	No water on Gages - *WSE Visually Estimated*
6/1/10 6:12 PM	10.11	
6/2/10 9:35 AM	10.63	
6/2/10 1:15 PM	10.73	**Peak Stage**; high water mark - time estimated
6/2/10 6:25 PM	10.46	High winds cause waves +/- 0.05 accuracy of reading
6/3/10 9:50 AM	9.76	
6/4/10 10:20 AM	8.02	

Notes:

1. Elevations are based on PBM-Q at 21.009 feet BPMSL, updated by LCMF in 2010.



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. L9312 and L9313 were monitored before, during, and after breakup to assess recharge and to evaluate recharge mechanisms.

Bankfull
Refers to a water body that has water at the top of its banks

Recharge of Lakes L9312 and L9313 was determined by visual observations of floodwaters as well as by direct observed measurements of water surface elevations at each lake during breakup. Water level surveys and water surface elevation observations of gages G9 (L9312) and G10 (L9313) were the primary references used to evaluate lake recharge.

Aerial observations generally document the presence of floodwater inflow. These observations were recorded with geo-referenced photographs. Lake L9313 received floodwater recharge from the Nigliq Channel via Nanuq Lake and Lake M9524 in addition to recharge from the Sakoonang Channel via the paleochannel along the CD4 road. Lake L9313 reached a bankfull condition. L9312 did not receive overland recharge of floodwater. Both L9312 and L9313 received recharge from snowmelt. At both lakes, stage dropped quickly after peak WSE was recorded.

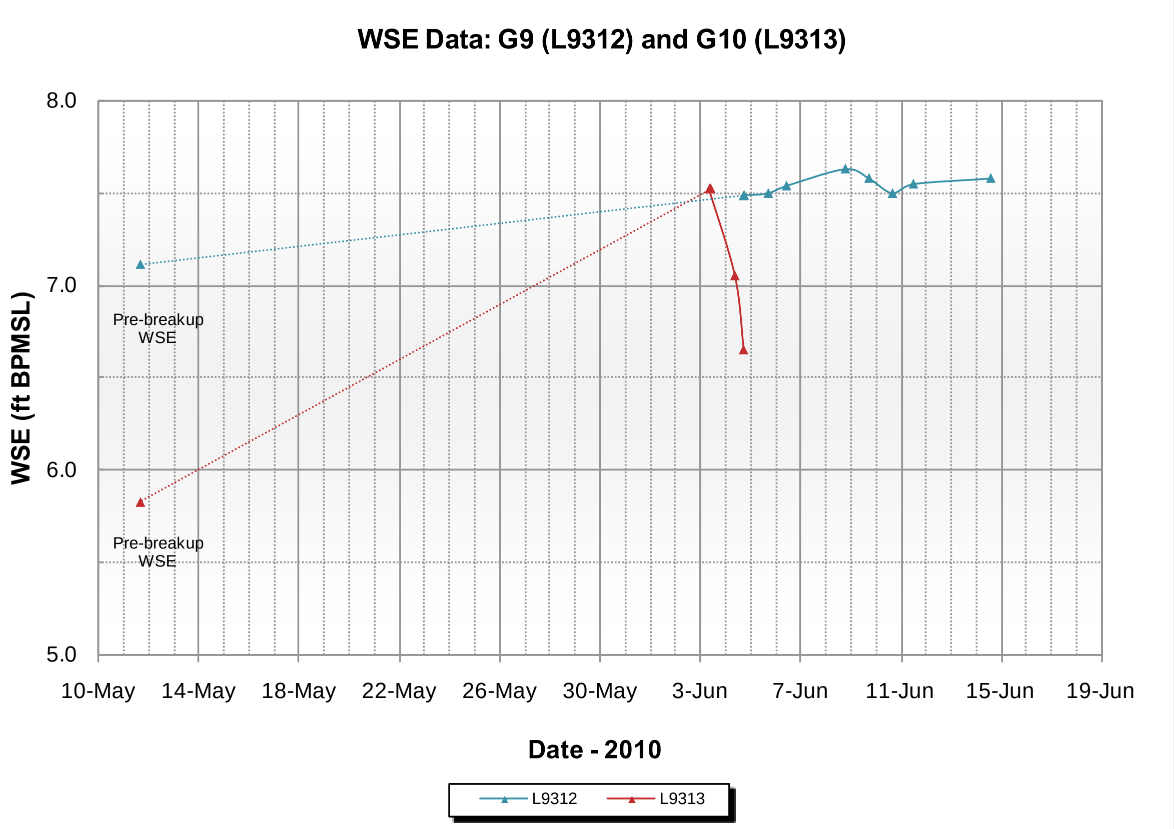
WSE data and observations for the Alpine Lakes are provided in Table 4.15.

Table 4.15: WSE Data for G9 (L9312) and G10 (L9313)

	WSE (feet BPMSL)		
	G9	G10	
Date and Time	L9312	L9313	Observations
5/11/10 5:15 PM	7.11	5.83	Pre-Breakup WSE
6/3/10 9:20 AM	-	7.52	Flood water recharge observed for Lake L9313 (G10) only
6/4/10 9:45 AM	-	7.05	Flood water recharge observed for Lake L9313 (G10) only
6/4/10 6:05 PM	7.49	6.65	High winds cause waves +/- 0.03 accuracy of reading for Gage 10
6/5/10 5:10 PM	7.50	-	
6/6/10 10:40 AM	7.54	-	Observed local melt recharge L9312 (G9) only
6/8/10 6:55 PM	7.63	-	Observed local melt recharge L9312 (G9) only
6/9/10 5:30 PM	7.58	-	Observed local melt recharge L9312 (G9) only
6/10/10 4:00 PM	7.50	-	
6/11/10 12:00 PM	7.55	-	
6/14/10 2:00 PM	7.58	-	

Notes:

1. Gage 9 is located on Lake L9312 and Gage 10 is located on Lake L9313.
2. Elevations for Gage 9 are based on TBM 02-01-39O of 11.45 feet BPMSL, established by LCMF in 2007.
3. Elevations for Gage 10 are based on TBM L99-32-60 of 15.90 feet BPMSL, established by LCMF in 2008.
4. Gages 9 and 10 are permanent staff gages surveyed and adjusted for elevation by LCMF in May of 2010.



4.3.2.1 LAKE L9312 RECHARGE

Lake L9312, located southwest of the CD1 pad, is surrounded by higher tundra than is Lake L9313. L9313 often receives floodwater recharge while L9312 does not, as shown in Photo 4.26 and Photo 4.27.

Photo 4.26: Lake L9312; June 5, 2010.

Photo 4.27: Local melt recharge, Lake L9312; June 8, 2010.

Water surface elevation was surveyed pre-breakup on May 11, 2010. At that time, the elevation of Lake L9312 was 7.11 ft BPMSL. Ice remained on the lake throughout the breakup season and into June as seen in Photo 4.28.

Photo 4.28: G9 and frozen Lake L9312; June 5, 2010.

Floodwater levels during the 2010 spring breakup did not reach L9312. Recharge was a result of local melt only. Bankfull conditions were not achieved at L9312. Based on the historical record, bankfull elevation is approximately 7.8 ft BPMSL (Baker 2005).

Peak WSE at L9312 (G9) was 7.63 ft BPMSL measured on June 8. WSE dropped off slightly following the peak elevation. Photo 4.29 shows G9 and L9312 one day after the peak WSE reading. Final WSE recorded for L9312 was 7.58 ft BPMSL on June 14. Water surface elevations for L9312 as measured at G9 are presented in Table 4.15.

Photo 4.29: Gage reading G9, one day after peak, Lake L9312; June 9, 2010.

4.3.2.2 LAKE L9313 RECHARGE

Lake L9313 is situated adjacent to the southwest side of the CD1 pad. Water surface elevation was surveyed pre-breakup on May 11, 2010. At that time, the elevation of L9313 was 5.83 ft BPMSL. Beginning on June 2, floodwaters reached L9313 from the Sakoonang-filled paleochannel along the east side of the CD4 road. L9313 also received floodwater recharge from the Nigliq Channel via Nanuq Lake and Lake M9524 (see Photo 4.30 and Photo 4.31).

Daily monitoring of G10 (Lake L9313) began on June 3 with a gage reading of 7.52 ft BPMSL, which was the peak WSE for L9313. This coincided with the time of peak stage around the CD1 facility. WSE on L9313 dropped off following June 3, and the last WSE reading of 6.65 ft BPMSL was taken on the evening of June 4 (see Photo 4.33).

WSE in Lake L9313 increased 1.69 feet between the pre-breakup and peak stage WSE readings. As indicated, floodwater recharged L9313 and bankfull conditions were reached. Based on the historical record, bankfull elevation is approximately 6.5 ft BPMSL (Baker 2006, 2007). Observed WSE and notes for G10 and L9313 are provided in Table 4.15.

Photo 4.30: Floodwater recharge Lake L9313; June 4, 2010.

Photo 4.31: Floodwater recharge Lake L9313; June 8, 2010.

Photo 4.32: Lake L9313 as floodwaters began to recharge; June 2, 2010.

Photo 4.33: G10, Lake L9313; June 4, 2010.

4.3.3 DRAINAGE STRUCTURES

By May 29, floodwaters began to reach the CD2 road area, and several culverts began to pass water from south to north. On May 30, the long swale bridge began to pass some discharge, though it was partly blocked with snow (see Photo 4.34). Also on May 30, the short swale bridge was completely blocked with ice and snow, preventing passage of flow, as shown in Photo 4.35. On May 30, gage readings began at G3 and G4, the easternmost gages along the CD2 road. By May 31, the short swale bridge remained 95% blocked by snow and ice. Ice rafts were noted on the upstream side of the CD2 road, but were not noticeably moving.

The snow and ice dam in the short swale bridge released early on June 1 as water levels continued to rise in the area. Flow in the vicinity of the 62-ft swale bridge is shown in Photo 4.36. By the afternoon of June 1, water levels were recorded on gages G6, G7, G12, and G13 along the CD2 road.

Photo 4.34: Snow blockage beneath 452-ft swale bridge; May 31, 2010.

Photo 4.35: 62-ft swale bridge blocked by snow; May 31, 2010.

Photo 4.36: Aerial view of 62-ft swale bridge; June 1, 2010.

Although both swale bridges were mostly clear and passing discharge by the afternoon of June 1, abundant snow blocked several of the CD2 and CD4 road culverts throughout the breakup period. In several locations, debris, including plywood, blocked the culverts.

Direct discharge measurements were taken on June 1 and June 3 at the long and short swale bridges, respectively. Photo 4.37 shows discharge beneath the 452-ft swale bridge at the time of the direct discharge measurement.

Photo 4.37: 452-ft swale bridge one day prior to peak stage; June 1, 2010.

Along the CD2 road, 17 of the 26 culverts passed measureable flow. Velocity measurements for direct discharge calculations for those culverts passing flow were taken on June 2. Peak WSE along the CD2 road occurred on June 2.

Along the CD4 road, water levels reached G18 by the afternoon of June 1. Water levels were recorded on G15 by the morning of June 2, and on G16 by the afternoon of June 2. Peak stage along the CD4 road was on June 2 at G18, near CD4. Peak stage occurred on June 4 farther north at G15 and G16, near the proposed CD5 road intersection. Culvert CD4-24 was the only CD4 road culvert to pass flow during the breakup period. The flow was a result of backwater from the Sakoonang Channel. Floodwater levels did not reach the other CD4 culvert inverts.

Discharge data for both the 452-ft swale bridge and the 62-foot swale bridge is provided in Appendix B. Calculated discharge for the culverts is provided in Table 5.5.

4.3.4 EROSION

The peak stage of flood water passing by Alpine roads and facilities was relatively moderate in 2010, based on comparison with the historical record. In addition, no significant ice floes were observed throughout the area. Breakup effect on gravel pads, roads, and drainage structures was negligible. Floodwater did not inundate any of the gravel pad 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 30.

On May 30, floodwater was first observed coming into contact with the CD2 road prism in the vicinity of the swale bridges (G3 and G4). On May 31, 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. High water marks due to erosion were identified by debris stranded on the road prism side slopes or where silts and fine-grained sands were washed away. Photo 4.38 is an example of fine-grained material washed away as a result of erosion on the upstream side of the CD2 gravel 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. All lath placed to identify erosion limits for photos was removed after photos were taken.

High water marks were observed along the CD2 road as a result of floodwater erosion. Photo 4.38, Photo 4.39, Photo 4.40, and Photo 4.41 are representative photos of the observed erosion along the CD2 gravel road prism following peak stage of breakup floodwater. Generally, the erosion of the CD2 access road was limited to the upstream (south) side of the road prism in the vicinity of the swale bridges.

Floodwater reached the base of the CD4 gravel road prism in some areas; however, the amount of floodwater was not significant enough to result in any noteworthy erosion. Photo 4.42, Photo 4.43, and Photo 4.44 are

representative photos of the conditions observed along the CD4 gravel road prism post peak stage of breakup floodwater.

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

Photo 4.38: Fine-grained sands washed away due to floodwater erosion, CD2 road near long swale bridge; June 12, 2010.

Photo 4.39: Orange lath used to indicate maximum elevation of erosion line along CD2 road; June 12, 2010.

Photo 4.40: Erosion of the north side of the CD2 road prism in the vicinity of culvert CD2-24; June 12, 2010.

Photo 4.41: High water mark (bottom of blue chalk line) on runway signal light CD2 road at base of road prism; June 12, 2010.

Photo 4.42: West side of CD4 road prism looking south, midway to CD4; June 7, 2010.

Photo 4.43: CD4 road prism looking east, vicinity of CD4; June 7, 2010.

Photo 4.44: Snow in place post breakup, vicinity of culverts CD4-25 through CD4-28, looking southeast; June 7, 2010.

4.3.5 ICE BRIDGES

Ice bridge melt progressed smoothly throughout the breakup period at both monitored crossing locations; no significant erosion or scour as a result of the ice bridges was observed.

The first visual evidence of melt at the East Channel ice bridge was recorded on May 25 when water was observed in the slots cut into the ice bridge (Photo 4.45). By May 27, floodwater was beginning to flow through the area and ice floes were observed (Photo 4.46). By June 5, the East Channel ice bridge was no longer visible and was not affecting flow, with the exception of the western ramp (Photo 4.47).

Photo 4.45: Water in slots of East Channel ice bridge, looking east; May 25, 2010.

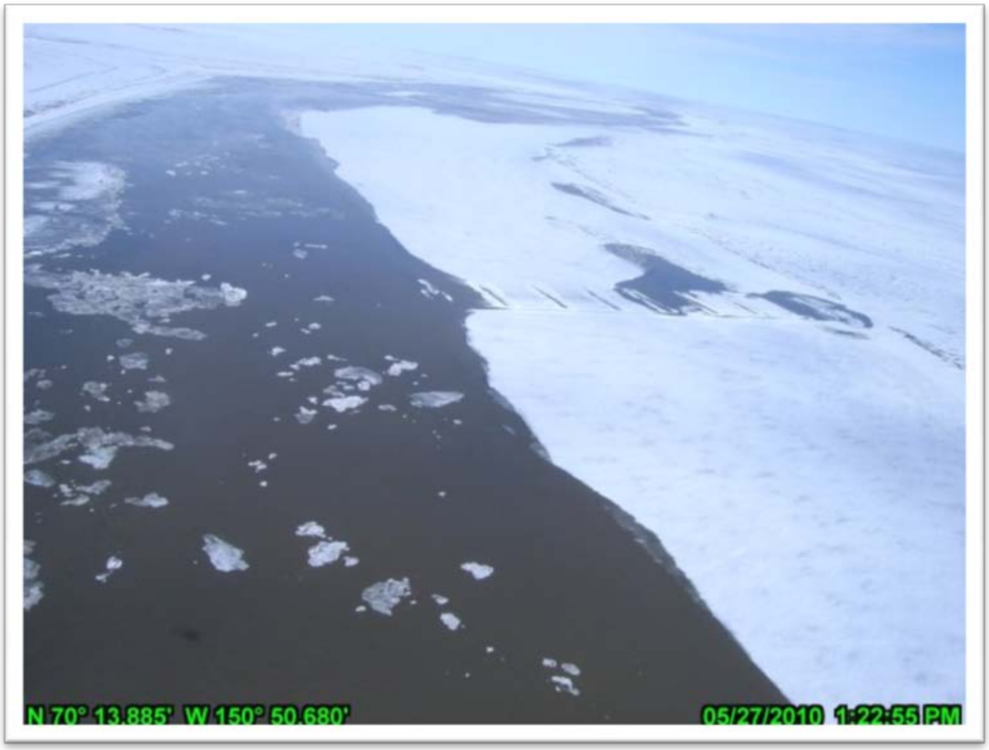


Photo 4.46: Flowing water and ice floes, looking north, East Channel Colville River; May 27, 2010.

Photo 4.47: Colville River East Channel ice bridge essentially melted with the exception of the western ramp, looking east; June 5, 2010.

Breakup of the Nigliq Channel ice road occurred without any notable event. No significant scour was observed along the Nigliq between the Putu Channel and village of Nuiqsut.

Initial aerial reconnaissance of the Kachemach River ice bridge crossing location was performed on May 13. The Kachemach River ice bridge was effectively wholly intact and no evidence of floodwater or local melt was observed. On June 5, the leading edge of floodwater had begun to overtop the Kachemach River ice bridge crossing location (Photo 4.48) and by June 8, floodwater had breached the ice bridge crossing and ice rafts were observed in the channel. An aerial reconnaissance made on June 10 revealed stranded ice on the banks of the channel indicating that peak stage had passed through the location. (Photo 4.50)

Photo 4.48: Floodwater starting to overtop Kachemach River ice bridge, looking north; June 5, 2010.

Photo 4.49: Kachemach River ice bridge breached and ice rafts observed in channel, looking east; June 8, 2010.

Photo 4.50: Stranded ice along the banks of the Kachemach River ice bridge location; June 10, 2010.

4.4 CD3 PIPELINE CROSSINGS

Data collection of the CD3 pipeline crossings at the Sakoonang (SAK), Tamayayak (TAM), and the Ulamnigiaq (ULAM) Channel gages began on May 9 with the installation of the gages (Photo 4.51). Daily monitoring of the pipeline crossings began on May 27. Recorded WSE rose and fell between May 28 and June 4. On May 28, water was observed in both the Tamayayak and Ulamnigiaq channels, and began backing up into the Sakoonang. By May 29, water from the Tamayayak backed up in the Sakoonang all the way to CD1, which was noted as an increased WSE on gages at CD1 by May 31. Initial observed rise of WSE at the SAK on May 31 was due to backwater from the Tamayayak (Photo 2.7) and the Ulamnigiaq, backing into the Sakoonang. Peak WSE for the TAM and ULAM crossings occurred on June 1; peak occurred on June 2 for the SAK crossing.

Table 4.16 presents the observations and WSE recorded for the SAK, TAM, and ULAM.

Elevated stage at all locations was most likely due to ice jamming within the local channels as well as effects due to ice jamming within the East Channel. Photo 4.52 shows the Sakoonang pipeline crossing post breakup. Photo 4.53 and Photo 4.54 show initial floodwater passing through the Tamayayak and Ulamnigiaq pipeline bridge crossings respectively.

Photo 4.51: Installation of gages pre-breakup, Sakoonang Channel pipeline crossing; May 9, 2010.

Photo 4.52: Sakoonang Channel pipeline crossing post breakup, looking south; June 12, 2010.

Photo 4.53: Initial floodwater passing under Tamayayak Channel pipeline bridge, looking northeast; May 27, 2010.

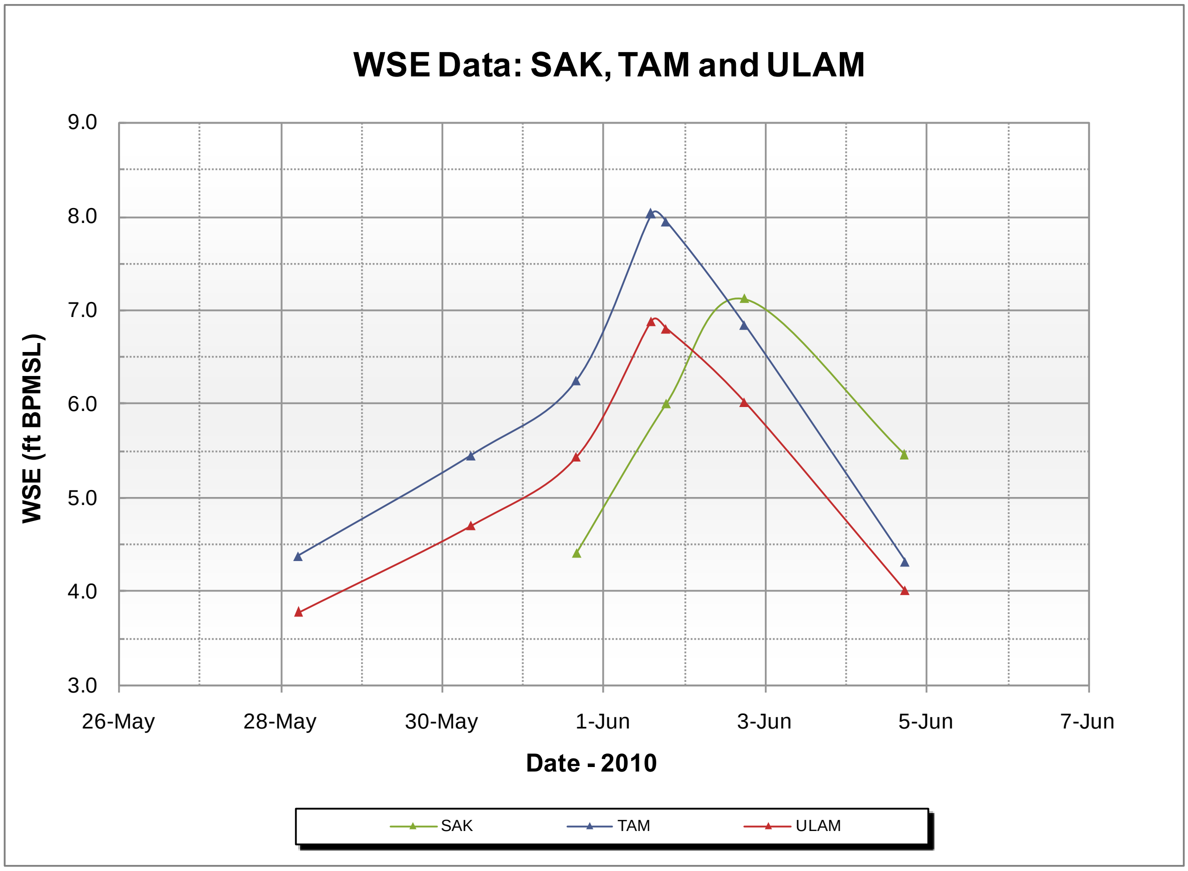
Photo 4.54: Initial floodwater passing under Ulamnigiaq Channel pipeline bridge crossing, looking northwest; May 27, 2010.

Table 4.16: WSE Data for SAK, TAM and ULAM (CD3 Pipeline Crossings)

Date and Time	WSE (feet BPMSL)			Observations
	SAK	TAM	ULAM	
5/28/10 5:20 AM	-	4.39	3.79	
5/30/10 8:35 AM	-	5.46	4.71	TAM Gage read with binoculars
5/31/10 3:45 PM	4.41	6.26	5.44	SAK flow is due to backwater from the TAM
6/1/10 2:00 PM	-	8.03	6.88	**Peak Stage**; high water mark on the TAM/ULAM - *time of occurrence estimated*
6/1/10 6:20 PM	6.00	7.95	6.80	
6/2/10 5:35 PM	7.12	6.85	6.02	**Peak Stage**
6/4/10 5:15 PM	5.46	4.33	4.02	

Notes:

1. Elevations for SAK are based on Pile 569 SW corner Bolt Pile Cap and SW corner HSM; basis of elevation = 23.719 and 24.068 feet BPMSL respectively, updated by LCMF in 2010.
2. Elevations for TAM are based on CP-08-11-23 of 8.524 feet BPMSL established by LCMF in 2008.
3. Elevations for ULAM are based on CP-08-11-35 of 9.146 feet BPMSL established by LCMF in 2008.



4.5 PROPOSED CD5 ROAD CROSSING

Monitoring of the three proposed CD5 road crossing locations were conducted at G21 (Nigliq), G22 (Lake L9341), and G23 (Nigliagvik). In addition to visual observation and documentation of gage readings, a pressure transducer was deployed at G21. Leading edge on the Nigliq Channel reached G21 on May 27, and reached G23 along the Nigliagvik on May 29 (as backup flow from the Nigliq Channel).

G21 is located between MON20 and MON22 on the Nigliq Channel, at the proposed CD5 crossing location. The G21 location experienced similar breakup events, including discharge, stage, and ice effects, as the other Nigliq Channel gages in the area. Photo 4.55 shows an ice jam near the CD5 road crossing on June 3.

Photo 4.55: Nigliq Channel ice jam near CD5 road crossing; June 3, 2010.

Daily gage readings commenced on May 27 at G21, with an initial reading of 4.48 ft BPMSL, and local melt only observed. Channel ice and abundant ribbon ice were present near the G21 location until ice began to breakup on June 3. Peak stage at the proposed Nigliq crossing occurred on June 2 with a WSE of 9.65 ft BPMSL. Photo 4.56 shows the Nigliq Channel just north of the proposed CD5 crossing near peak stage on June 2.

Photo 4.56: View north along Nigliq Channel from proposed CD5 road crossing at G21; June 2, 2010.

As water levels were dropping throughout the delta, daily monitoring ceased on June 4, at which time WSE was 6.93 ft BPMSL. WSE data and observations for Nigliq Channel G21 are provided in Table 4.17.

The proposed CD5 road crossing of Lake L9341 is monitored at G22. As of May 30, no water was identified on the G22 gage. Aerial observation on June 4 noted possible recharge of Lake L9341 from the southwest, with possible contribution from the Nigliagvik. As shown in Photo 4.57, by June 8, competent ice remained along the east bank. At the same time, L9341 was recharging through a small channel to the north of the lake. On June 8, WSE on the gage was 5.63 ft BPMSL. Stage rose 0.22 feet over the next two days to a WSE of 5.85 ft BPMSL recorded on June 10. By June 12, the WSE dropped to 5.34 ft BPMSL and monitoring was discontinued. WSE data and observations are provided in Table 4.18.

Photo 4.57: Lake L9341 at proposed CD5 road crossing (G22); June 8, 2010.

G23 along the Nigliagvik is utilized to monitor WSE at the proposed CD5 crossing. On May 30, local melt resulted in a WSE of 5.25 ft BPMSL. Flow from the Nigliq Channel was observed entering the Nigliagvik from both the upstream and downstream confluences, approaching the crossing location from both directions. Peak WSE occurred late on June 2 or early on June 3 at 8.69 ft BPMSL. By June 4, the flow direction was still not clear, and an abundant amount of snow remained in the channel. By June 8, the observed WSE was 4.85 ft BPMSL and monitoring was discontinued. Recorded WSE and observations for G23 are provided in Table 4.19.

Photo 4.58: Nigliagvik at proposed CD5 road crossing (G23); June 8, 2010.

Table 4.17: WSE Data for G21 (Nigliq)

Date and Time	WSE (feet BPMSL)	Observations
	G21	
5/27/10 11:35 AM	4.48	Local melt
5/28/10 3:40 PM	5.28	Wind affected measurement; channel ice
5/30/10 9:15 AM	6.80	Abundant ribbon ice
5/30/10 3:40 PM	6.73	
5/31/10 2:05 PM	7.76	
6/1/10 5:25 PM	9.14	
6/2/10 8:00 AM	9.65	**Peak Stage**; high water mark - time estimated
6/2/10 4:10 PM	9.48	
6/4/10 5:55 PM	6.93	Ribbon ice began to breakup on June 3
6/5/10 12:00 PM	-	Ice jam downstream on June 5 - time estimated

Notes:

1. Elevations are based on CP 08-11-53A at 7.787 feet BPMSL, updated by LCMF in 2008.

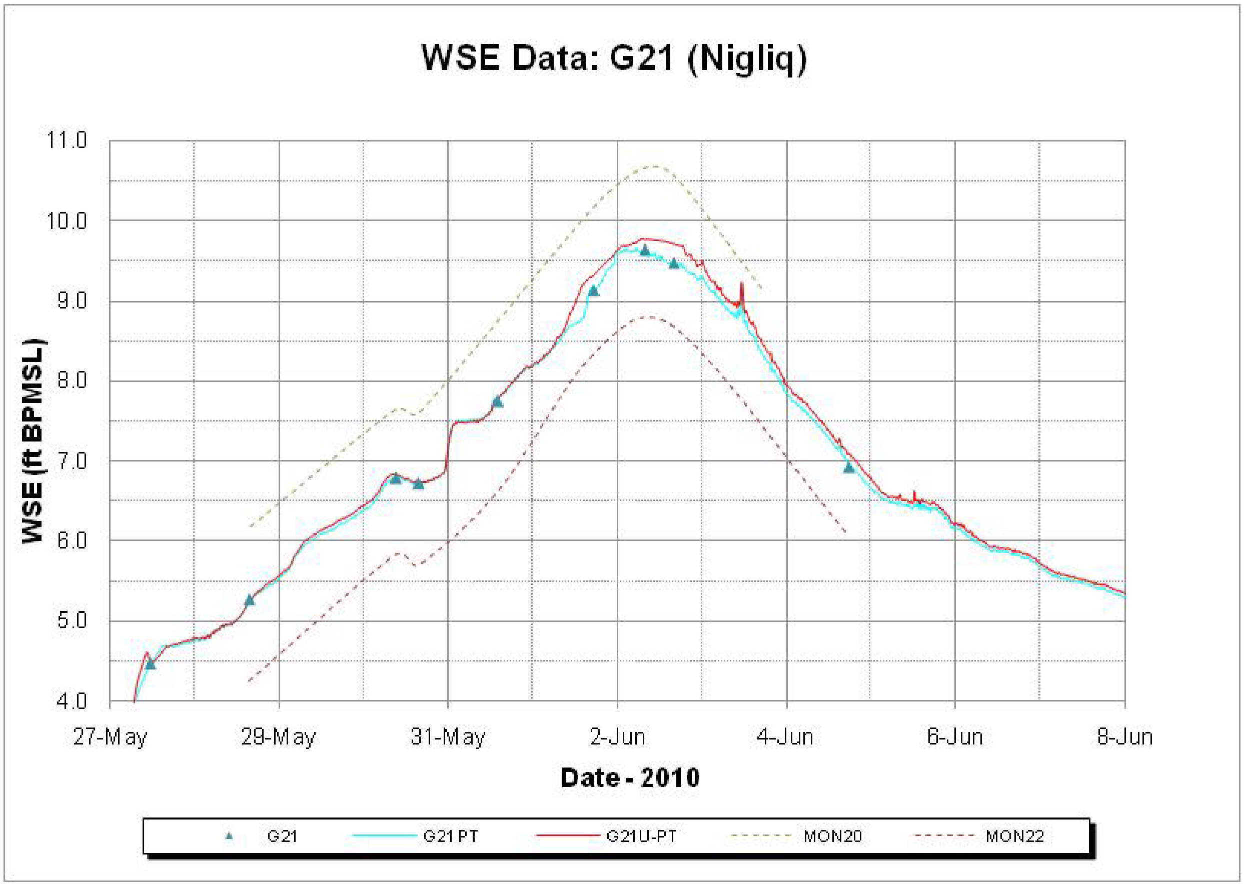


Table 4.18: WSE Data for G22 (L9341)

Date and Time	WSE (feet BPMSL)	Observations
	G22	
5/30/10 12:00 PM	-	No water on gages
6/4/10 12:00 AM	-	Possible recharge from southwest, Nigliagvik?
6/8/10 5:50 PM	5.63	Competent ice E bank, recharging via channel north of Lake L9341
6/10/10 3:50 PM	5.85	**Peak Stage**; local meltwater recharge only
6/12/10 10:15 AM	5.34	

Notes:

1. Elevations are based on CP 08-11-64A at 12.305 feet BPMSL, updated by LCMF in 2008.

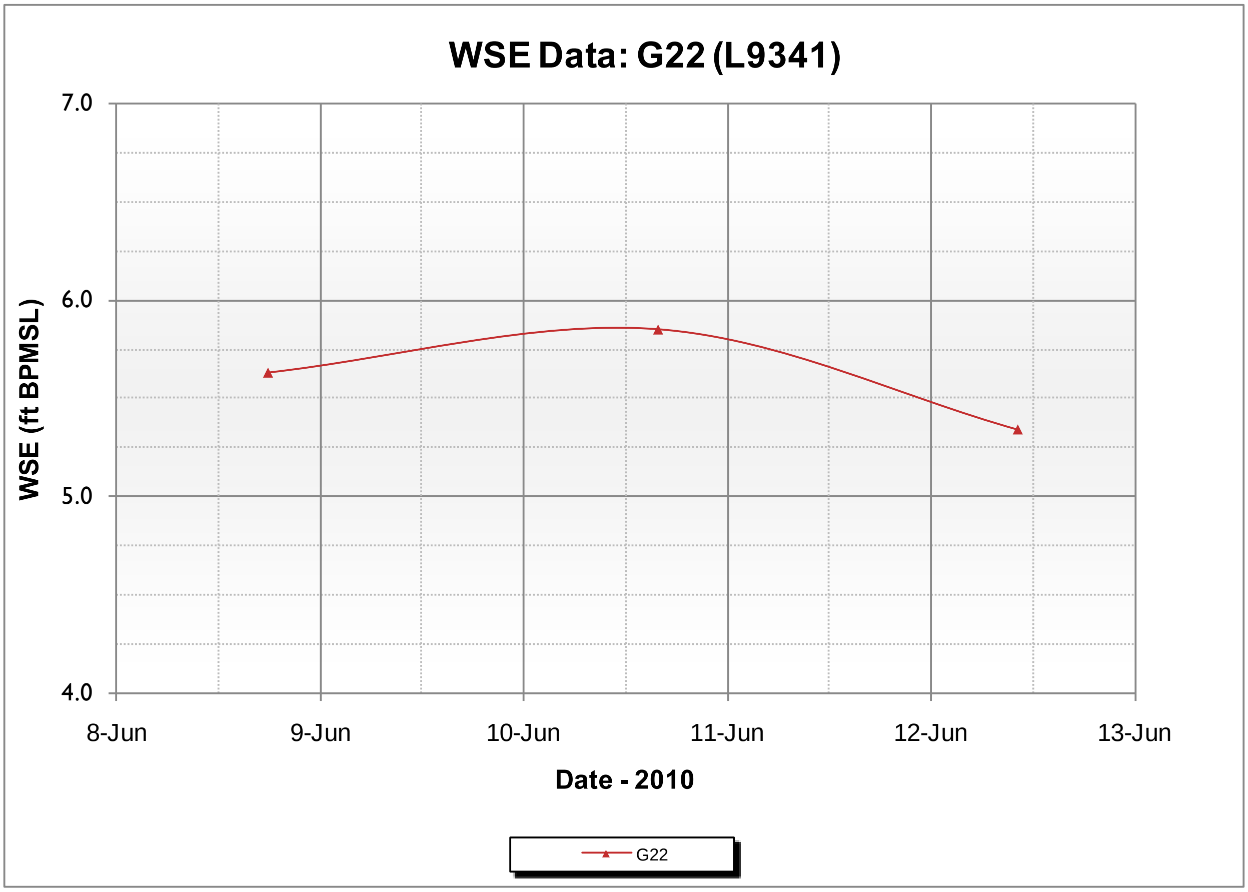
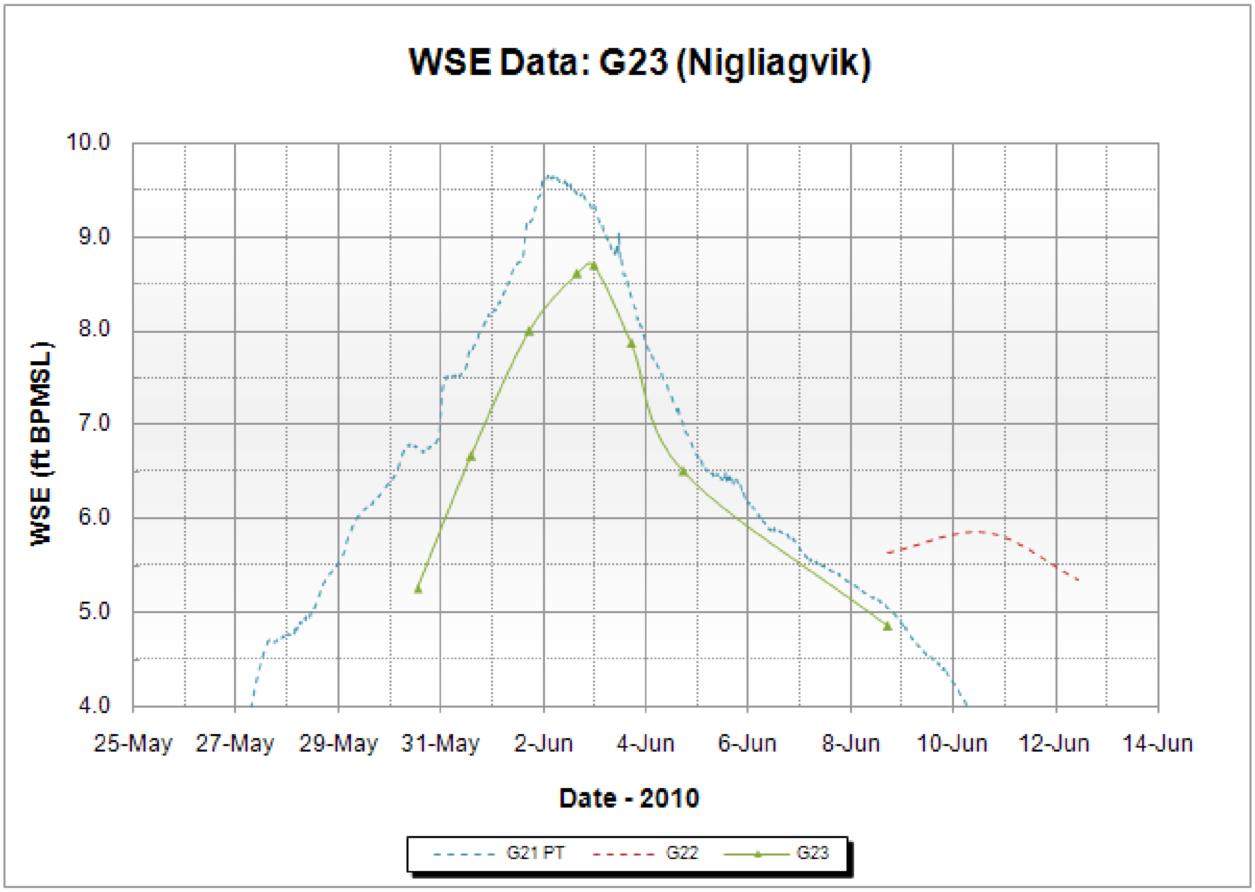


Table 4.19: WSE Data for G23 (Nigliagvik)

Date and Time	WSE (feet BPMSL) G23	Observations
5/30/10 1:15 PM	5.25	Local melt in vicinity of gage; Nigliq flow entering at up and downstream confl.
5/31/10 2:15 PM	6.66	
6/1/10 5:30 PM	7.99	
6/2/10 4:00 PM	8.60	
6/3/10 12:00 AM	8.69	**Peak Stage**; high water mark - time estimated
6/3/10 5:35 PM	7.86	
6/4/10 5:50 PM	6.50	Flow direction still not clear; abundant snow in channel
6/8/10 5:45 PM	4.85	

Notes:

1. Elevations are based on CP 08-11-66C at 10.418 feet BPMSL, updated by LCMF in 2008.



4.6 PROPOSED FIORD WEST ACCESS ROAD CROSSING

Observations at the proposed Fiord West access road crossings were recorded from setup on May 8 to June 14. Daily monitoring began on June 7. High water marks were documented at each of the proposed Fiord West road crossing locations. Monitoring of the Fiord West road crossing locations was discontinued on June 14.

The observation of a HWM on June 12 (Photo 4.59) indicated that the peak stage for FWR1 occurred sometime between the afternoon of June 10 and the morning of June 12. It was estimated that peak stage at FWR1 occurred midday on June 11 with an elevation of 5.40 ft BPMSL.

On June 7, the first hydrologic observation was made at FWR2, which turned out to be the peak stage with an elevation of 4.30 ft BPMSL. This peak stage observation was confirmed by the following day's observation (June 8) with an observed HWM of 4.30 ft BPMSL. Photo 4.60 is an aerial photo of the FWR2 gage site on the day of recorded peak stage.

Table 4.20 and Table 4.21 present the WSE observations for FWR1 and FWR2 respectively.

No significant flow was identified at FWR1 and FWR2 and observed WSE fluctuations are most likely due to the melting of snow and ice in the vicinity of the Fiord West access road gages.

Photo 4.59: FWR1 gage reading one day after peak (observation of HWM), looking north; June 12, 2010.

Photo 4.60: FWR2 Aerial photo peak stage (gage on left side of photo), looking southeast; June 7, 2010.

Table 4.20: WSE Data for FWR1

Date and Time	WSE (feet BPMSL)	Observations
	FWR1	
6/7/10 5:30 PM	4.96	No HWM, lcoal melt
6/8/10 5:30 PM	5.31	No HWM, lcoal melt
6/10/10 3:15 PM	5.31	No HWM, lcoal melt
6/11/10 6:00 PM	5.40	**Peak Stage;** high water mark - *time of occurrence estimated*
6/12/10 10:00 AM	5.27	local melt
6/14/10 1:30 PM	5.22	local melt

Notes:

1. Elevations are based on Monument SHEWMAN at 7.085 feet BPMSL, established by Baker in 2009.
2. Flow was not seen at this location in 2010, measurements taken were the result of local melt only.

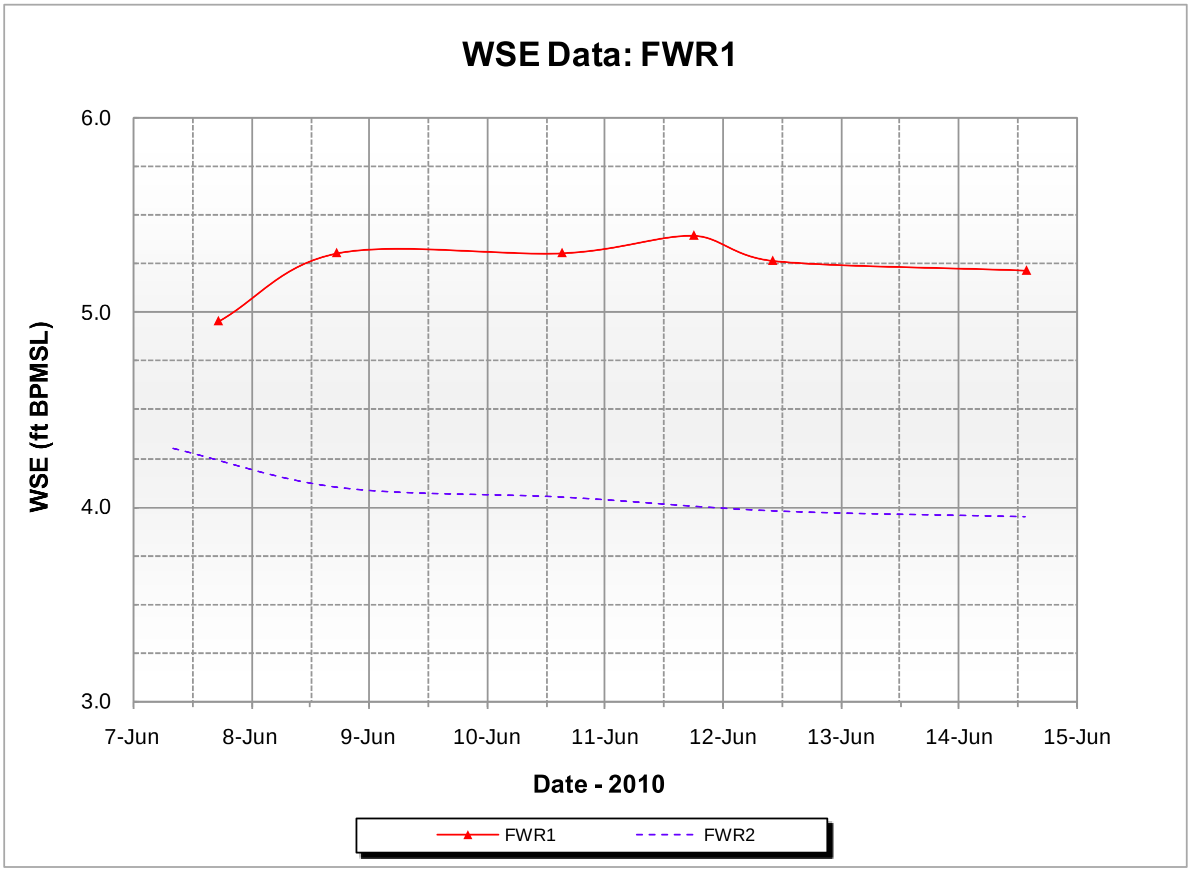
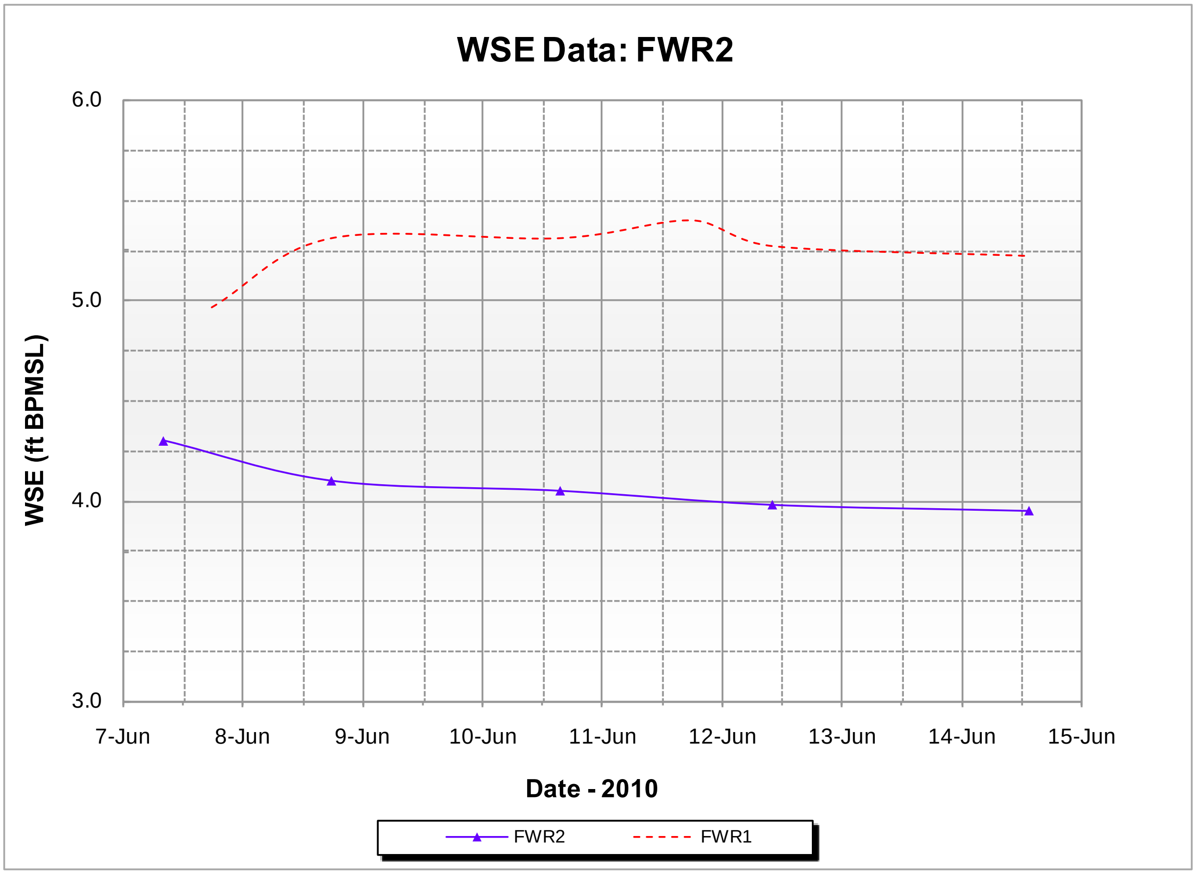


Table 4.21: WSE Data for FWR2

Date and Time	WSE (feet BPMSL)	Observations
	FWR2	
6/7/10 8:00 AM	4.30	**Peak Stage**
6/8/10 5:40 PM	4.10	No HWM
6/10/10 3:30 PM	4.05	No HWM
6/12/10 10:00 AM	3.98	No HWM
6/14/10 1:25 PM	3.95	No HWM

Notes:

1. Elevations are based on Monument SHEWMAN at 7.085 feet BPMSL, established by Baker in 2009.
2. Flow was not seen at this location in 2010, measurements taken were the result of local melt only.



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5.0 2010 DISCHARGE

Direct discharge measurements were made at the 452-ft swale bridge, the 62-ft swale bridge, and all culverts conveying flow along the CD2 and CD4 gravel access roads. Indirect calculations were performed for MON1, MON23, both swale bridges, all culverts conveying flow, and the Nigliq Channel proposed CD5 bridge crossing location, near G21.

5.1 MON1 DISCHARGE

5.1.1 DIRECT DISCHARGE

Direct discharge measurements utilizing the ADCP were not made in 2010 due to poor weather conditions, preventing access to the site near the time of peak discharge. Fog, freezing rain, and high winds made transport of personnel and equipment unsafe.

5.1.2 INDIRECT DISCHARGE

Indirect discharge methods provide an estimated discharge. Discharge at MON1 was calculated using the slope-area method. This method calculates indirect discharge based on the energy grade-line slope (approximated using the water surface slope as measured by the gages at MON1U and MON1D), the water surface elevation at MON1C at the time of estimated peak discharge, and the 2004 topographic survey data provided by LCMF (Figure 5.1). Changes in bedform geometry are likely to have occurred since the 2004 cross-sections were surveyed. This can introduce error and can skew indirect calculations. It would be helpful to update the topographic surveys for next year, as the channel bed moves and the cross-sections have likely changed over the past six years.

Bedform
Refers to a depositional feature on the bed of a river (fluvial processes) or other body of flowing water that is formed by the movement of the bed material due to the flow.

The most accurate indirect discharge values would be calculated at or near peak stage, at a time when the channel is relatively ice-free, and with current channel topographic cross-sections. Unfortunately, at the time of peak stage at MON1 (19.59 ft BPMSL at approximately 6:00 p.m. on June 1), discharge conditions were heavily influenced by ice jamming in two locations: in the Nigliq Channel near Nuiqsut (Photo 5.1) and downstream in the East Channel in the vicinity of MON9 (HDD) (Photo 5.2). Ice jamming of this magnitude and proximity can cause significant backwater effects, which are not accounted for when using indirect calculation methods.

Due to the ice-affected channel, the resulting peak discharge estimates at the time of peak stage could not be presented with any level of confidence

and are thus not considered as the peak annual discharge for 2010, and are not presented in this report.

Instead, peak discharge at the head of the CRD was estimated to be 320,000 cfs based on observed WSE values on May 31 and an observed WSE at MON1 of 15.01 ft BPMSL. This was approximately 29 hours before stage peaked June 1. On May 31, the channel was somewhat less ice-affected and thus provides better conditions for a more reasonable indirect discharge value.

Photo 5.1: Ice jam entering the Nigliq Channel; June 1, 2010.

Photo 5.2: Ice jam and channel ice in the vicinity of MON9 (HDD); June 1, 2010.

ConocoPhillips
Alaska, Inc.

DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.1-1.DWG
CHECKED:	JMS	SCALE:	AS SHOWN

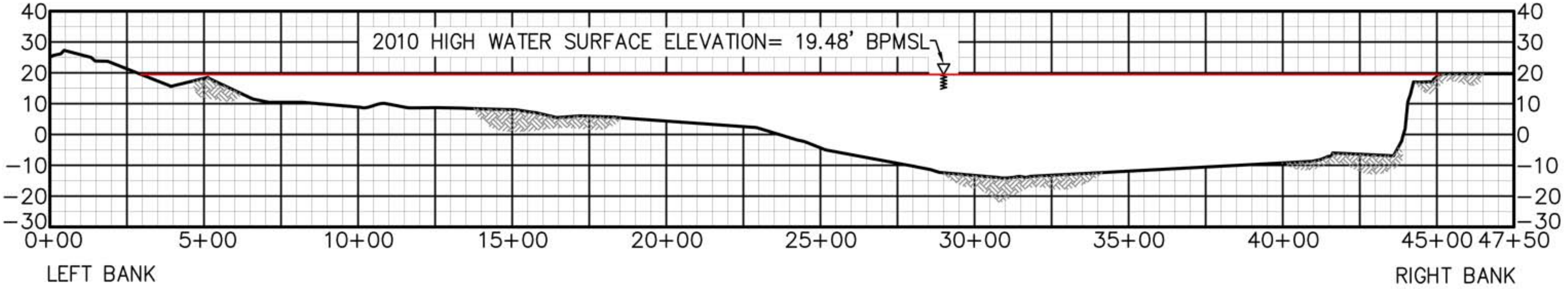
Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

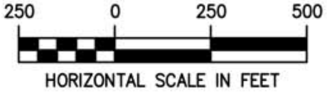
2010 SPRING BREAKUP
MONUMENT 1
PLAN

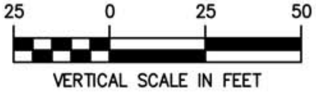
FIGURE 5.1
(SHEET 1 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT MON 01.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



1D COLVILLE RIVER CROSS SECTION AT MONUMENT 1 DOWNSTREAM





ConocoPhillips
Alaska, Inc.

DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	MON_1_PROFILES.DWG
CHECKED:	JMS	SCALE:	AS SHOWN

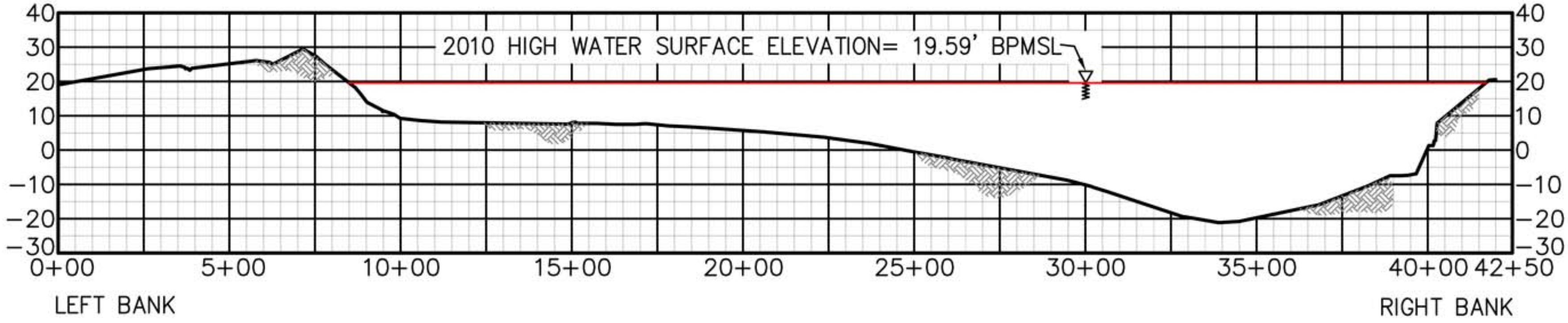
Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

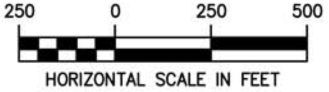
2010 SPRING BREAKUP
MONUMENT 01 DOWNSTREAM
2004 CROSS SECTION

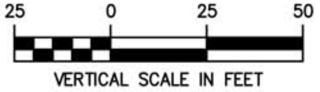
FIGURE 5.1
(SHEET 2 OF 4)

NOTES
1. BASIS OF ELEVATION, MONUMENT MON 01.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



(1C) COLVILLE RIVER CROSS SECTION AT MONUMENT 1





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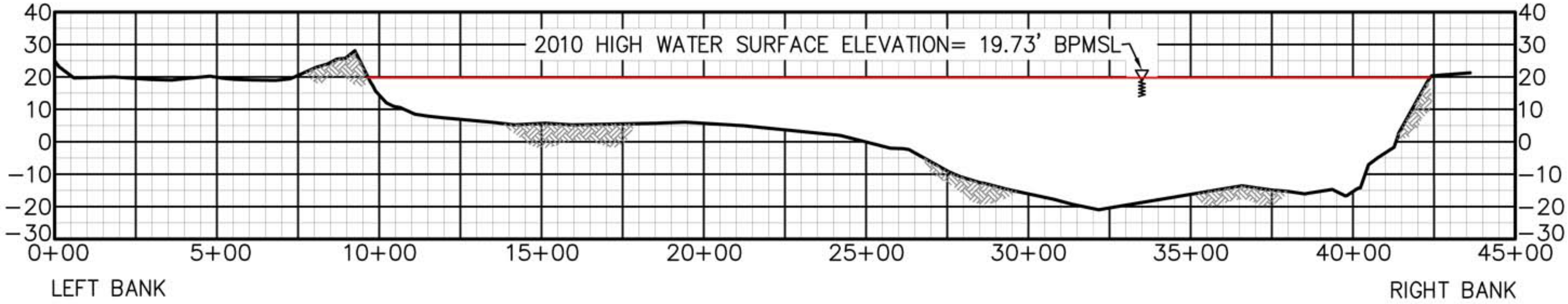
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

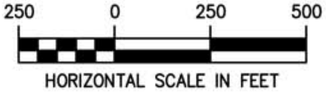
2010 SPRING BREAKUP
MONUMENT 01
2004 CROSS SECTION
FIGURE 5.1
(SHEET 3 OF 4)

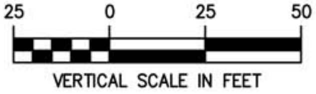
NOTES

1. BASIS OF ELEVATION, MONUMENT MON 01.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2004 BY KUUKPIK/LCMF INC.



(1U) COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM





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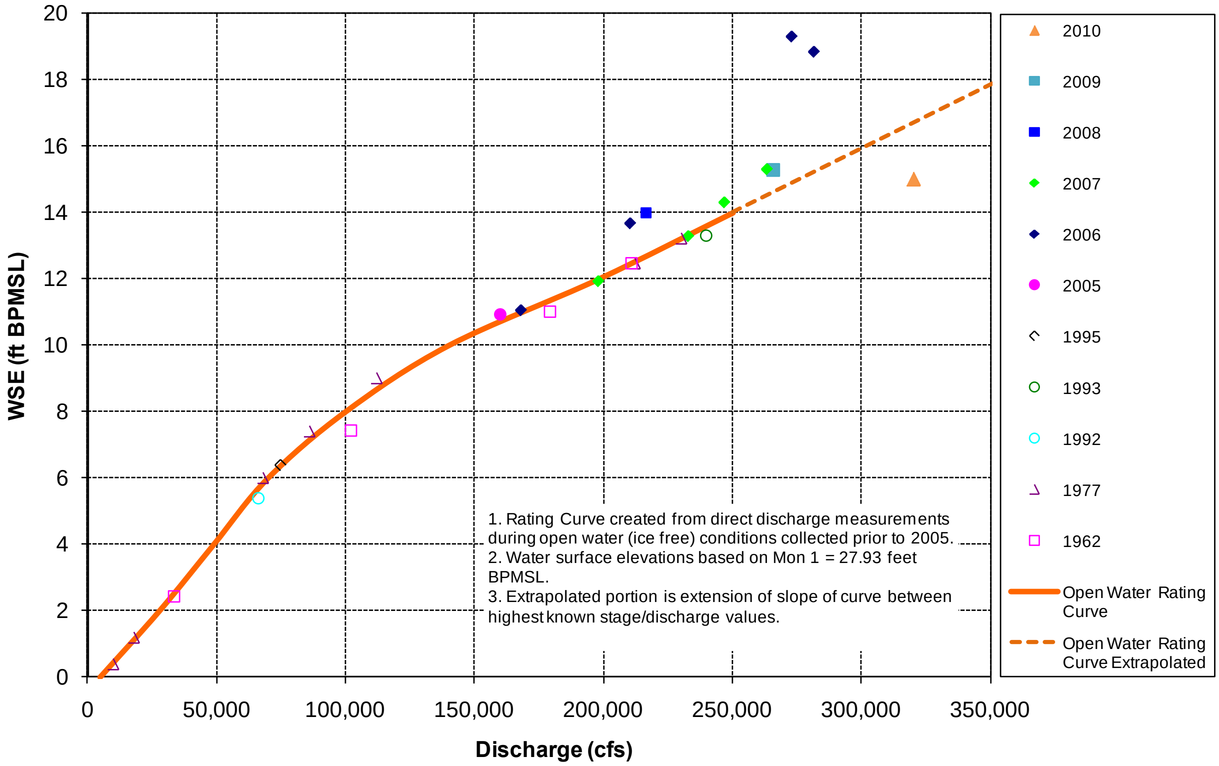
Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
MONUMENT 01 UPSTREAM
2004 CROSS SECTION

FIGURE 5.1
(SHEET 4 OF 4)

The MON1 stage-discharge rating curve, provided in Graph 5.1, represents a comparison between known stage and discharge measurements collected during open water (ice free) conditions. These values fairly accurately 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—as open water conditions rarely occur at or near recorded historical peak stage levels.



1. Rating Curve created from direct discharge measurements during open water (ice free) conditions collected prior to 2005.
2. Water surface elevations based on Mon 1 = 27.93 feet BPMSL.
3. Extrapolated portion is extension of slope of curve between highest known stage/discharge values.

Graph 5.1: MON1 Stage-Discharge Rating Curve with Indirect Discharge

To compare 2010 stage-discharge values to the rating curve, Graph 5.1 was extrapolated beyond known values (those values at 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 as a general reference only.

Table 5.1 presents a historic tabulation of published peak annual discharge and peak stage between 1992 and 2010.

Table 5.1: Colville River Breakup Peak Annual Discharge (1992-2010)

Year	Monument 1 Peak Discharge (cfs)			Monument 1 Peak Water Surface Elevation (feet-BPMSL)	
	Discharge	Method	Reference	Mon 1	Reference
2010	320,000	Indirect Calculation	This Report	19.59	This Report
2009	266,000	Indirect Calculation	Baker 2009	17.65	Baker 2009c
2008	221,000	Indirect Calculation	Baker 2008b	17.29	Baker 2008b
2007	270,000	ADCP Measurement	Baker 2007b	18.97	Baker 2007b
2006	281,000	ADCP Measurement	Baker 2007a	19.83	Baker 2007b
2005	195,000	Mon 1 Rating Curve	Baker 2005b	13.18	Baker 2005b
2004	360,000	Indirect Calculation	Baker 2005a	19.54	Baker 2005a
2003	232,000	Mon 1 Rating Curve	Baker 2006a	13.76	Baker 2003
2002	249,000	Mon 1 Rating Curve	Baker 2006a	16.87	Baker 2002a
2001	255,000	Mon 1 Rating Curve	Baker 2006a	17.37	Baker 2001
2000	580,000	Indirect Calculation	Baker 2000	19.33	Baker 2000
1999	203,000	Indirect Calculation	Baker 1999	13.97	Baker 1999
1998	213,000	Indirect Calculation	Baker 1998a	18.11	Baker 1998a
1997	177,000	Indirect Calculation	Baker 2002b	15.05	Baker 1999
1996	160,000	Indirect Calculation	Shannon & Wilson 1996	17.19	Shannon & Wilson 1996
1995	233,000	Indirect Calculation	ABR 1996	14.88	ABR 1996
1994	159,000	Indirect Calculation	ABR 1996	12.20	ABR 1996
1993	379,000	Indirect Calculation	ABR 1996	19.20	ABR 1996
1992	188,000	Indirect Calculation	ABR 1996	13.90	ABR1996

5.2 MON23 DISCHARGE

5.2.1 DIRECT DISCHARGE

A direct discharge measurement was not performed at MON23 due to difficult weather conditions as well as the presence of a large quantity of in-channel ice at the time of the estimated peak.

5.2.2 INDIRECT DISCHARGE

Indirect discharge was calculated using the slope-area method. Discharge is calculated using the energy grade-line slope (as approximated by the water surface slope from MON22 to MON23), the water surface elevation at MON23, and the 2005 LCMF topographic channel cross-sectional survey. Location and cross-section of the area is presented in Figure 5.2. It would be beneficial to update the surveys for future indirect calculations.

Indirect discharge calculations are performed assuming an ice-free channel and are considered to be a conservative estimate due to the likelihood of persistent bottom-fast ice remaining in-channel, changes to the channel bed due to sediment transport, and assumptions based on the presence and dimensions of in-channel ice if ice remains in the channel.

Bottom-Fast Ice
Ice that forms under water, attached to the channel bed (synonymous with "anchor ice")

Flow in the Nigliq Channel during 2010 breakup was influenced by ice, as shown in Photo 5.3.

Photo 5.3: Ribbon ice and ice jamming just downstream of MON22; June 1, 2010.

While peak stage at MON23 occurred on June 2, significant ribbon ice was observed in-channel from May 30 until June 3. A large ice jam entered the Nigliq Channel from the East Channel on June 1, eventually clearing past MON23 around June 6, resulting in a series of jam and release events as the obstruction moved downstream.

As stated, calculated indirect peak discharge at MON23 was based on observations made on the afternoon of June 2, at the same time as peak stage occurred at MON22, and approximately 9 hours after peak stage at MON23. Resulting peak discharge was calculated to be 65,000 cfs at MON23 with a corresponding WSE of 7.68 ft BPMSL. A historical record of peak discharge at MON23 is presented in Table 5.2.

Table 5.2: Nigliq Channel Breakup Peak Annual Discharge (2005 – 2010)

Year	Monument 23 Peak Discharge (cfs)			Monument 23 Peak Water Surface Elevation (feet-BPMSL)	
	Discharge	Method	Reference	Mon 23	Reference
2010	65,000	Indirect Calculation	This Report	7.77	This Report
2009	59,000	Indirect Calculation	Baker 2009	7.09	Baker 2009
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

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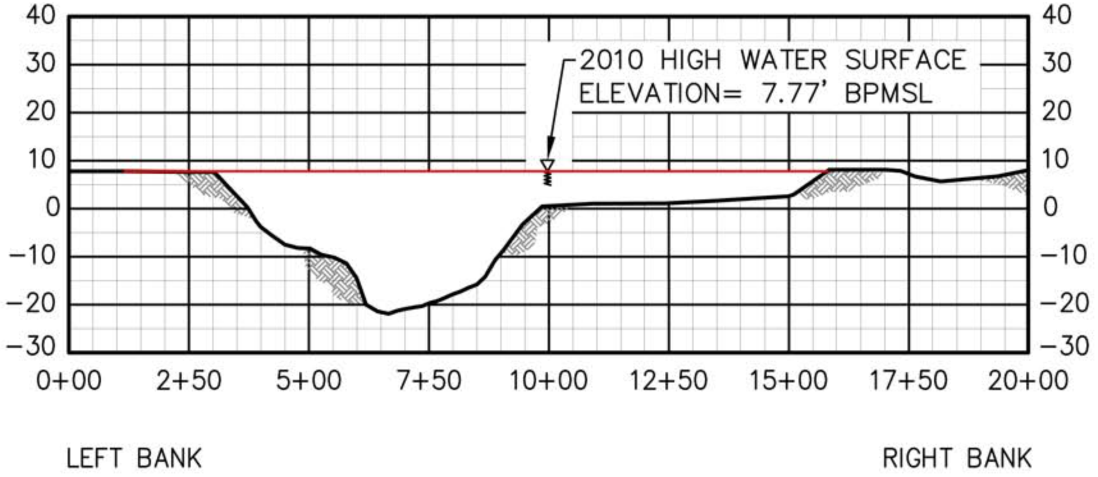
Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

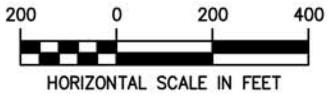
2010 SPRING BREAKUP
MONUMENT 23
PLAN

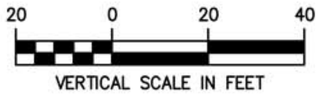
FIGURE 5.2
(SHEET 1 OF 2)

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



① MONUMENT 23 CROSS SECTION





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Fax: (907) 273–1699

2010 SPRING BREAKUP
MONUMENT 23
2005 CROSS SECTION
FIGURE 5.2
(SHEET 2 OF 2)

5.3 Proposed CD5 Nigliq Bridge Site Discharge

5.3.1 Direct Discharge

Similar to MON1 and MON23, a direct discharge measurement was not possible at the proposed Nigliq Channel CD5 bridge crossing location due to prohibitive weather conditions and the presence of in-channel ice.

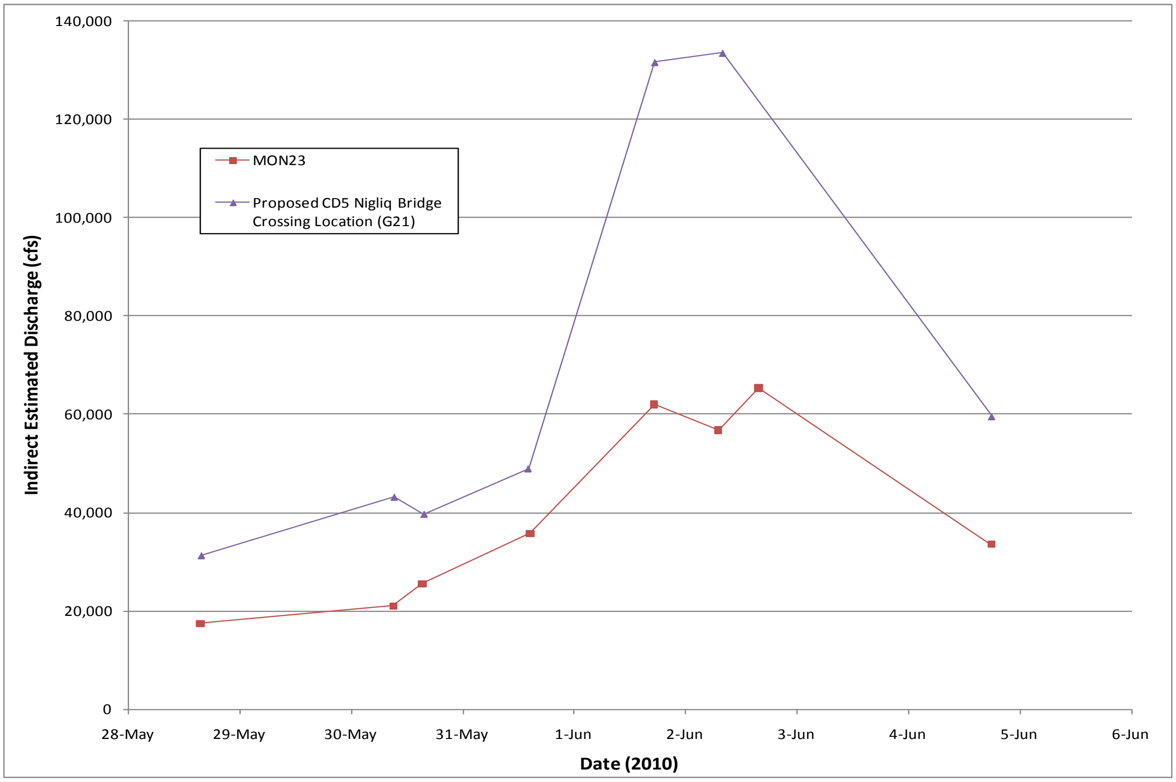
5.3.2 Indirect Discharge

Indirect discharge was calculated using the slope-area method, using the energy grade-line slope (as approximated by the water surface slope from G21 to a pressure transducer installed this year approximately 2400 feet upstream from G21, denoted G21U-PT), water surface elevation at G21, and the 2008 LCMF topographic channel cross-section survey. Location and cross-section of the area is presented in Figure 5.3.

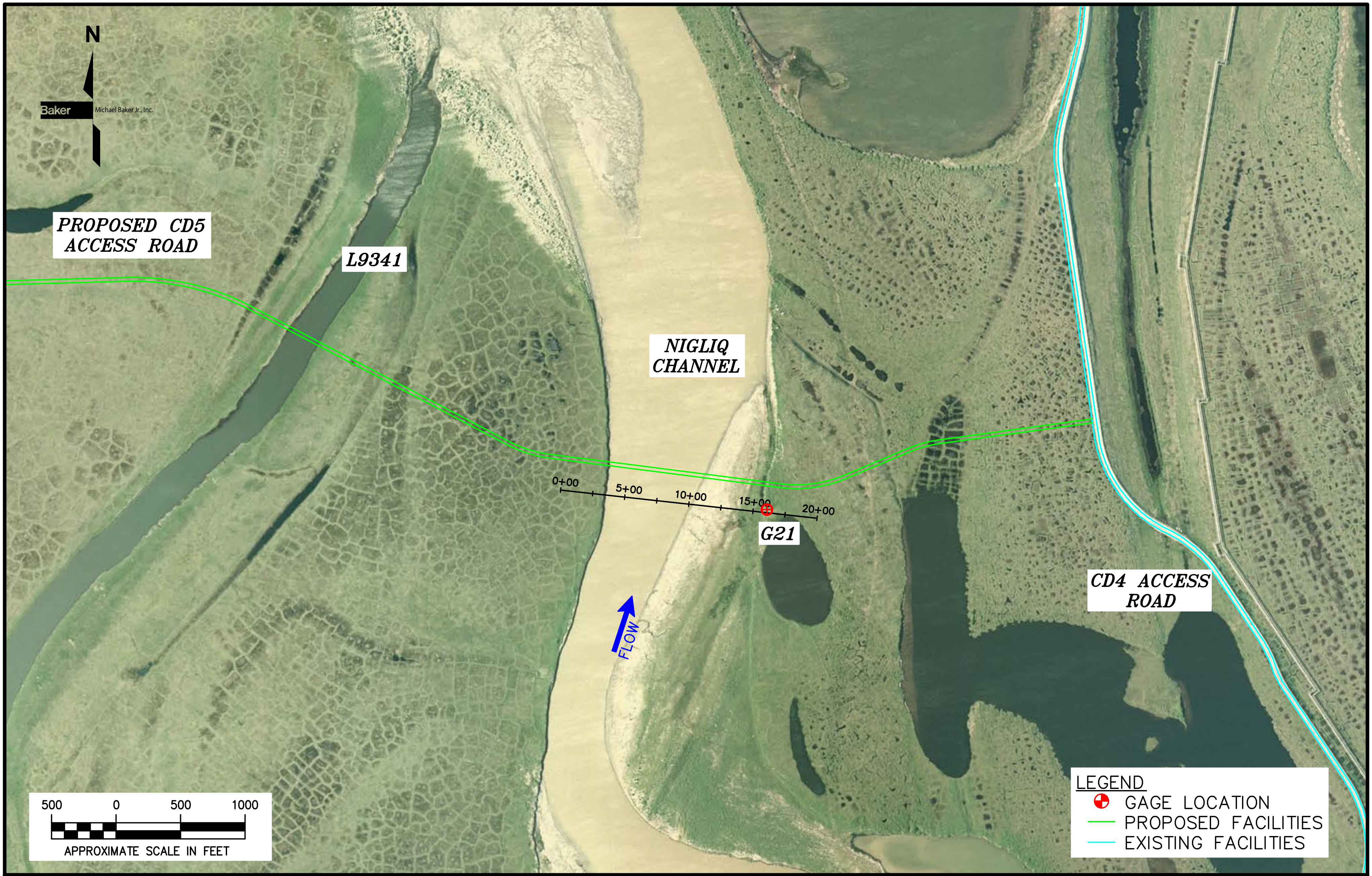
Indirect discharge calculations are performed assuming an ice-free channel and are to be considered a conservative estimate.

As discussed in Section 5.1, flow in the Nigliq Channel was affected by ice during 2010 breakup. A comparison of the estimated indirect discharge values over time at MON23 (3.4 river miles downstream of G21) show a reasonable correlation, as seen in Graph 5.2. This suggests that ice events were significant enough to affect both locations, although at different magnitudes due to ice jam proximity, loss of channel flow downstream of G21, and the location of the majority of ice jam events occurring upstream of the proposed bridge crossing location.

Peak discharge at G21 was estimated to have occurred on the morning of June 2, during peak stage at G21. Peak discharge was calculated to be 134,000 cfs at G21 with a WSE of 9.65 ft BPMSL.



Graph 5.2: Estimated Indirect Discharge Values over Time at MON23 and G21 in the Nigliq Channel



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Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP

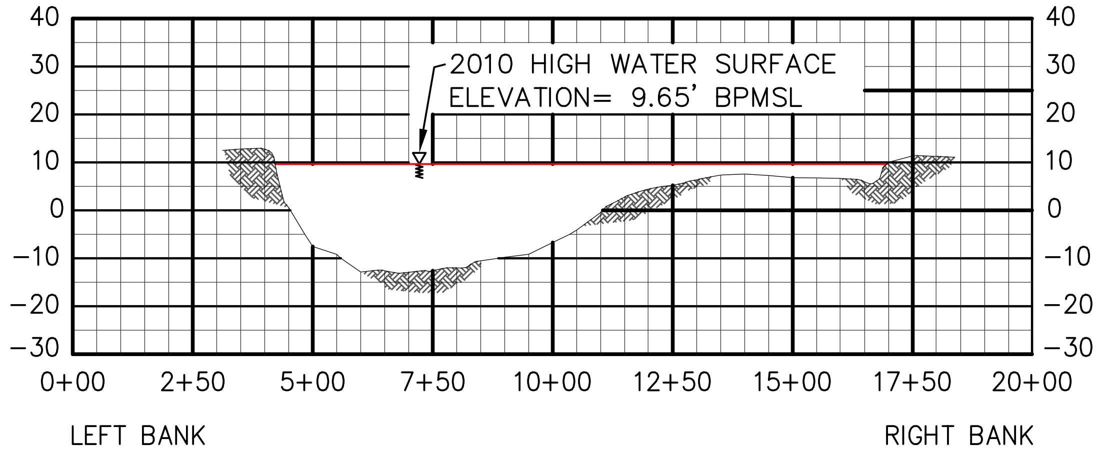
GAGE 21

NIGLIQ CHANNEL PLAN

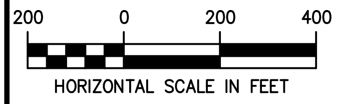
FIGURE 5.3

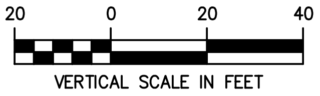
(SHEET 1 OF 2)

NOTES
1. BASIS OF ELEVATION, MONUMENT TBM CP–08–11–53A.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED OCTOBER 2003 BY KUUKPIK/LCMF INC.



① GAGE 21 CROSS SECTION





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Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273–1600
Fax: (907) 273–1699

2010 SPRING BREAKUP
GAGE 21
NIGLIQ CHANNEL PROFILE
FIGURE 5.3
(SHEET 2 OF 2)

5.4 ALPINE SWALE BRIDGES DISCHARGE

5.4.1 DIRECT DISCHARGE

A direct discharge measurement at the 452-ft swale bridge was conducted on June 1 beginning at 2:45 p.m., as close to peak flow as possible (17 hours before peak). At that time, discharge at the 452-ft bridge was measured to be 4500 cfs.

A direct discharge measurement at the 62-ft swale bridge was conducted on June 3 beginning at 2:10 p.m., approximately 30 hours after peak. Discharge at the 62-ft bridge was measured to be 574 cfs.

A summary of the 2010 direct discharge measurements at both bridges is presented in Table 5.3, which includes a summary of historical discharge measurements. Complete notes for the discharge measurement are in Appendix B.

Table 5.3: Direct Discharge Summary: Alpine Swale Bridges (2000 – 2010)

Site Name	Date	WSE (ft)	Width (ft)	Area (ft^2)	Mean Vel (ft/s)[1]	Discharge (cfs)	MMT Rating[2]	Number of Sections	MMT Type	Reference
62-foot Bridge	**06/03/10**	**7.58**	**55**	**316**	**1.79**	**574**	**F**	**28**	**Cable**	**This report**
	–[3]	–	–	–	–	–	–	–	–	Baker 2009
	05/29/08	6.35	55	211	0.58	123	P	14	Cable	Baker 2008b
	06/05/07	7.83	55	292	1.18	345	F	20	Cable	Baker 2007b
	05/31/06	8.49	55	615	1.59	980	F	20	Cable	Baker 2007a
	–[3]	–	–	–	–	–	–	–	–	Baker 2005b
	05/29/04	8.34	55	451	1.60	720	F	17	Cable	Baker 2005a
	–[3]	–	–	–	–	–	–	–	–	Baker 2003
	05/25/02	6.74	56.0	283	1.52	430	G	17	Cable	Baker 2002a
	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	**06/01/10**	**7.97**	**441**	**1699**	**2.66**	**4500**	**G**	**25**	**Cable**	**This report**
	05/26/09	5.89	445	1592	0.82	728	F	27	Wading	Baker 2009
	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 2002a
	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

1. Mean velocities adjusted with angle of flow coefficient
2. 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
3. Bridge obstructed with snow or ice, no measurement made

5.4.2 INDIRECT DISCHARGE

The 2010 peak discharge though the swale bridges likely occurred at the time of peak stage and high water surface differential, as determined by comparison of G3 (headwater) and G4 (tailwater) readings. The peak stage at G3, 8.64 ft BPMSL, occurred on the morning of June 2 (see Table 4.10). The headwater-tailwater differential at that time was 0.59 feet, the second highest G3-G4 differential calculated during the 2010 spring breakup flow period.

Headwater
The water level upstream of the point of interest

Peak discharge through the swale bridges was estimated based on the assumption that the measured average adjusted velocity was

representative of the average velocity at peak stage. This assumption is more accurate for the 452-ft bridge peak discharge estimate, considering the headwater-tailwater differential at the time of the velocity (discharge) measurement was similar at 0.61 feet. The headwater-tailwater differential for the 62-ft bridge at the time of the velocity measurement was 0.16 feet, which would indicate that both the velocity and discharge were likely somewhat higher at peak stage.

Peak discharge was estimated to have been 5,300 cfs through the 452-ft swale bridge and 670 cfs through the 62-ft bridge. Table 5.4 summarizes the estimated peak annual discharge data at the Alpine swale bridges between 2000 and 2010.

Table 5.4: Estimated Peak Discharge Summary: Alpine Swale Bridges (2000 - 2010)

Date & Time	Peak WSE (ft)[1]	452-Foot Bridge		62-Foot Bridge		References
		Discharge (cfs)[2]	Mean Vel (ft/s)	Discharge (cfs)[2]	Mean Vel (ft/s)	
6/2/10 8:15 AM	**8.64**	**5300**	**2.66**	**670**	**1.79**	**This report**
5/25/09 1:00 PM	7.63	1400	0.82	– [3]	-	Baker 2009
5/30/08 12:00 PM	6.49	2100	0.49	100	0.58	Baker 2008b
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	– [3]	–	Baker 2005b
5/27/04 1:30 PM	9.97	3400	1.38	900	1.59	Baker 2005a
06/07/2003[4]	6.31	700	0.88	– [3]	–	Baker 2003
05/26/2002[4]	7.59	4000	3.47	500	1.52	Baker 2002a
06/11/2001[4]	7.95	3900	2.40	600	1.79	Baker 2001
06/12/2000[4]	9.48	7100	3.60	1000	4.30	Baker 2000

Notes:
1. Gage 3 high water mark
2. Estimated peak discharge
3. Bridge obstructed with snow or ice, no measurement made
4. Unknown time of peak stage

5.5 ALPINE CULVERT DISCHARGE

During annual breakup monitoring, stage, velocity, and discharge are measured and estimated at the CD2 and CD4 culverts to monitor the performance of the drainage structures and to comply with stipulated monitoring requirements outlined in USACE Permit Number POA-2004-253 and the State of Alaska Fish Habitat Permit FH04-III-0238. The location and naming convention of the CD2 and CD4 culverts are presented in Figure 5.4. Both observed water surface elevation data and measured culvert dimensions are used to perform indirect culvert discharge calculations for a variety of conditions over the course of breakup. The CD2 and CD4 culvert invert elevations were surveyed by LCMF in May and June 2008, while culvert length and diameter was obtained using as-built surveys conducted by LCMF in 2002 and 2005, respectively.

In September of 2008, changes were made to six of the existing CMP culverts (CD2-9 through CD2-14). These culverts were experiencing deformation due to road prism loading. They were retrofitted by inserting a smooth circular sleeve, anchored at each end. Forty-eight inch diameter smooth sleeves were inserted into five existing 60-inch diameter CMPs; one 60-inch diameter smooth sleeve was inserted into the 72-inch diameter CMP. With regard to flow conveyance, the smooth sleeves reduce some friction losses in the culvert, but this is countered by smaller diameter available for flow compared to the larger original CMPs. Furthermore, the smooth sleeves do not extend the length of the CMP, but are centered in the CMP. Photo 5.4 shows the tie anchors for the smooth sleeves in culvert CD2-10.

Photo 5.4: Interior CD2 road culvert CD2-10 showing smooth sleeve tie anchors inside CMP culvert; June 2, 2010.

Floodwater was observed flowing through 17 CD2 road culverts (CD2-1, CD2-4 through CD2-7, CD2-10, CD2-13 through CD2-16, and CD2-18 through CD2-24) and backwater was observed in one CD4 culvert (CD4-24A). This backwater resulted in little flow through the CD4 culverts. Snow blockage and wood debris were present in the vicinity of several of the Alpine road culverts during breakup as shown in Photo 5.5 and Photo 5.6; this affected the hydraulic performance and discharge of the CD2 culverts in particular. Flow impediments, including snow and debris blockage, as well as the presence of damaged culvert inverts (Photo 5.7), were considered when comparing calculated discharge values with observed values.

Photo 5.5: Plywood blockage of culverts CD2-7 through CD2-7 upstream along CD2 road; June 1, 2010.

Photo 5.6: Snow blockage, downstream side CD2 road culverts CD2-4 through CD2-7; June 1, 2010.

Photo 5.7: Damaged culvert CD2-9; June 7, 2010.

5.5.1 DIRECT DISCHARGE AND VELOCITY

On June 2, water depth and velocity measurements were obtained at those 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.

June 2 water depths and velocities measured at the CD2 road culverts are provided in Table 5.5. This represents conditions at culverts close to the time of peak stage as observed at the CD2 road gages (Photo 5.8 and Photo 5.9). The measured velocities ranged from less than 0.1 feet per second (fps) to 4.5 fps. Based on direct depth and velocity measurements, the total discharge flowing through CD2 culverts was 319 cfs, ranging from 0.1 cfs to 49.2 cfs.

Photo 5.8: Near peak stage at culvert CD2-22; June 2, 2010.

Photo 5.9: Near peak stage at culvert CD2-24; June 2, 2010.

Table 5.5: CD2 Road Culvert Direct Velocity and Discharge. June 2, 2010

Culvert	Date Time	Depth (ft)	Area (ft^2)	Measured Vel (ft/s)	Direct Discharge (cfs)
CD2-1	6/2/10 4:25	1.3	3.54	0.55	1.95
CD2-2	-	-	-	-	-
CD2-3	-	-	-	-	-
CD2-4	6/2/10 4:45	1.0	2.46	0.70	1.72
CD2-5	6/2/10 4:50	1.7	5.09	1.62	8.24
CD2-6	6/2/10 4:55	1.5	4.30	1.84	7.92
CD2-7	6/2/10 5:00	0.7	1.48	1.24	1.83
CD2-8	-	-	-	-	-
CD2-9	-	-	-	-	-
CD2-10	6/2/10 5:15	1.9	6.85	0.05	0.34
CD2-11	-	-	-	-	-
CD2-12	-	-	-	-	-
CD2-13	6/2/10 5:35	2.2	8.32	3.23	26.88
CD2-14	6/2/10 5:40	2.6	10.32	3.76	38.79
CD2-15	6/2/10 4:10	1.8	5.48	2.99	16.40
CD2-16	6/2/10 4:00 PM	0.1	0.08	1.14	0.10
CD2-17	-	-	-	-	-
CD2-18	6/2/10 3:50	1.3	3.54	0.29	1.03
CD2-19	6/2/10 3:45	0.6	1.18	3.75	4.43
CD2-20	6/2/10 3:40	2.2	7.08	4.45	31.51
CD2-21	6/2/10 3:35	2.9	9.76	3.85	37.57
CD2-22	6/2/10 3:30	3.0	10.11	4.26	43.07
CD2-23	6/2/10 3:25	3.6	11.91	4.04	48.13
CD2-24	6/2/10 3:10	3.8	12.33	3.99	49.20
Average Measured Velocity (ft/s)				**2.46**	
Total Measured Discharge (cfs)				**319**	
Notes: 1. No water flowing through culvert, no measurement made					

5.5.2 Indirect Discharge and Velocity

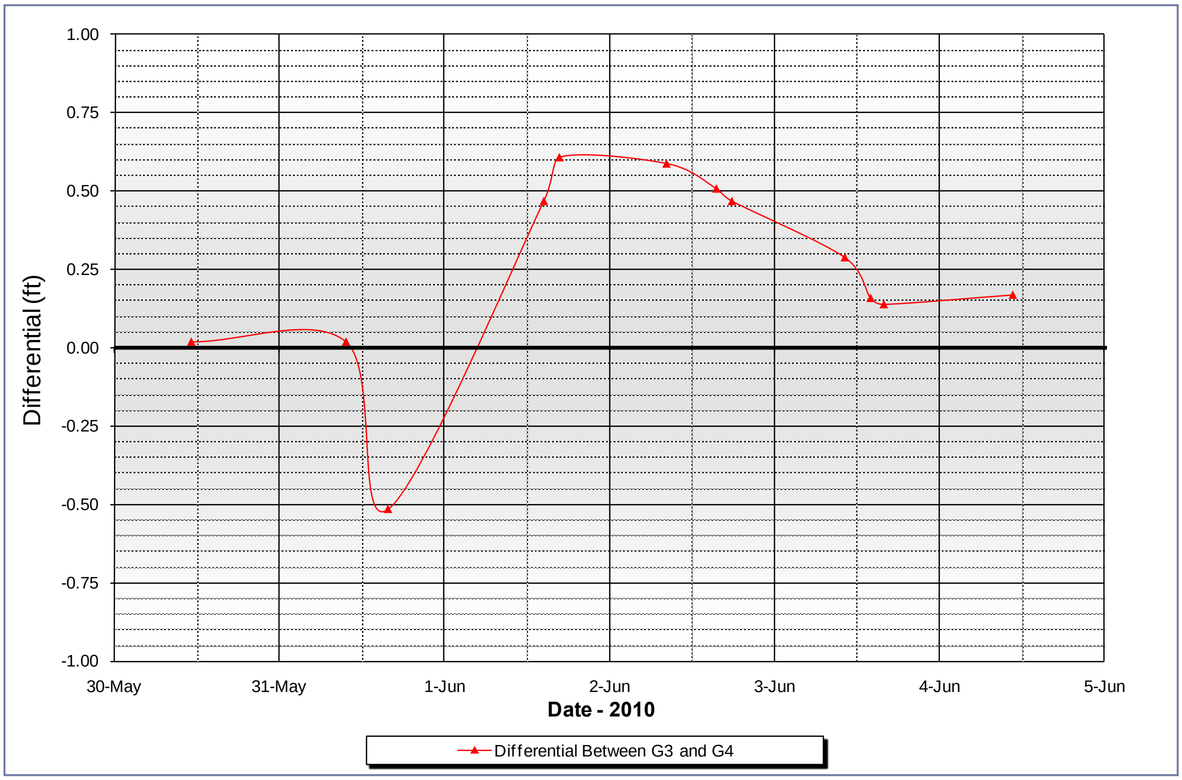
Flow through the CD2 access road culverts first occurred on May 30, 2010. The indirect peak discharge through CD2 culverts did not coincide with observed peak stage. Figure 5.4 illustrates the locations of the Alpine facilities drainage structures.

5.5.2.1 Alpine Culverts Headwater and Tailwater Differential

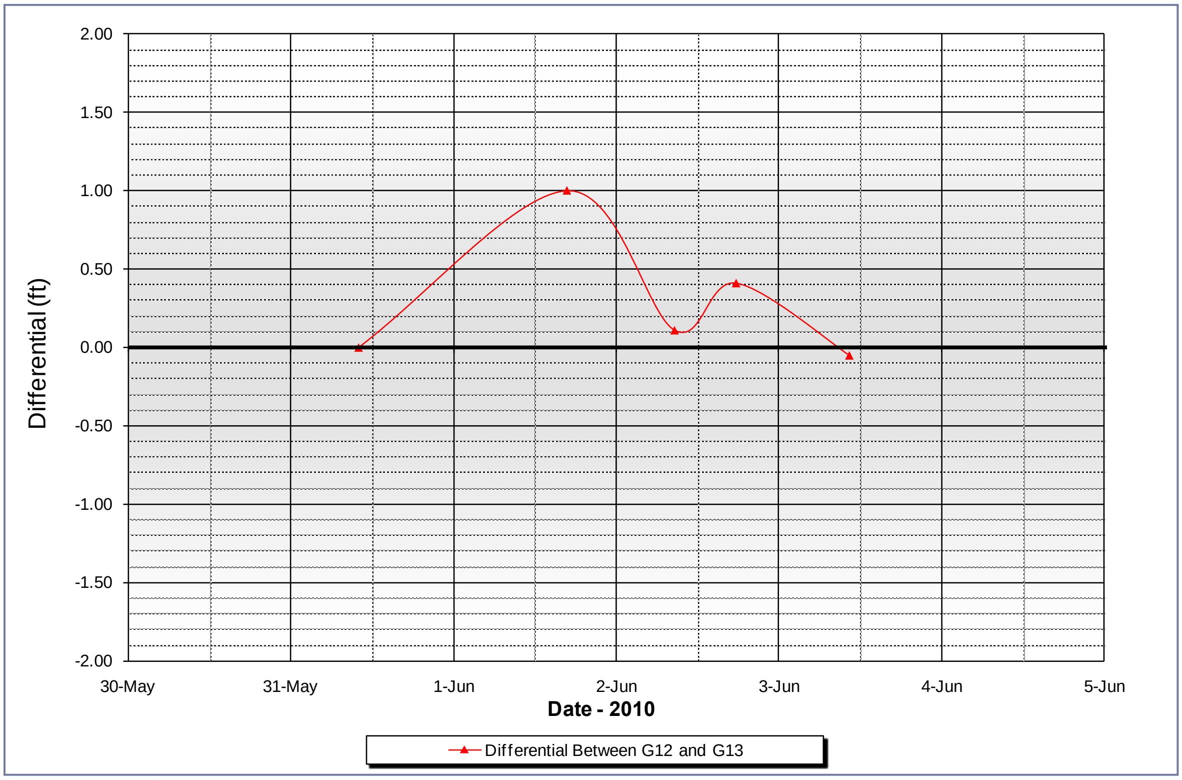
The differential between headwater and tailwater elevations for the CD2 culverts passing flow is based on the water surface elevation observed at the paired gages G3, G12, and G6 (upstream side of CD2 road) and G4, G13, and G7 (downstream side). Differential for use in culvert indirect discharge calculations matches the gage differential with the culverts based on the proximity of the gage set to the culverts.

A maximum slope differential between G3 and G4 of 0.61 feet occurred on June 1 as shown on Graph 5.3. For G12 and G13, a maximum slope differential of 0.41 feet occurred on June 2 (Graph 5.4). For G6 and G7, the maximum slope differential occurred on June 4, measuring 0.96 feet (Graph 5.5). Both G6 and G7 were heavily affected by snow and ice in the vicinity and it is not likely that this WSE differential is consistent with an open-water flow situation.

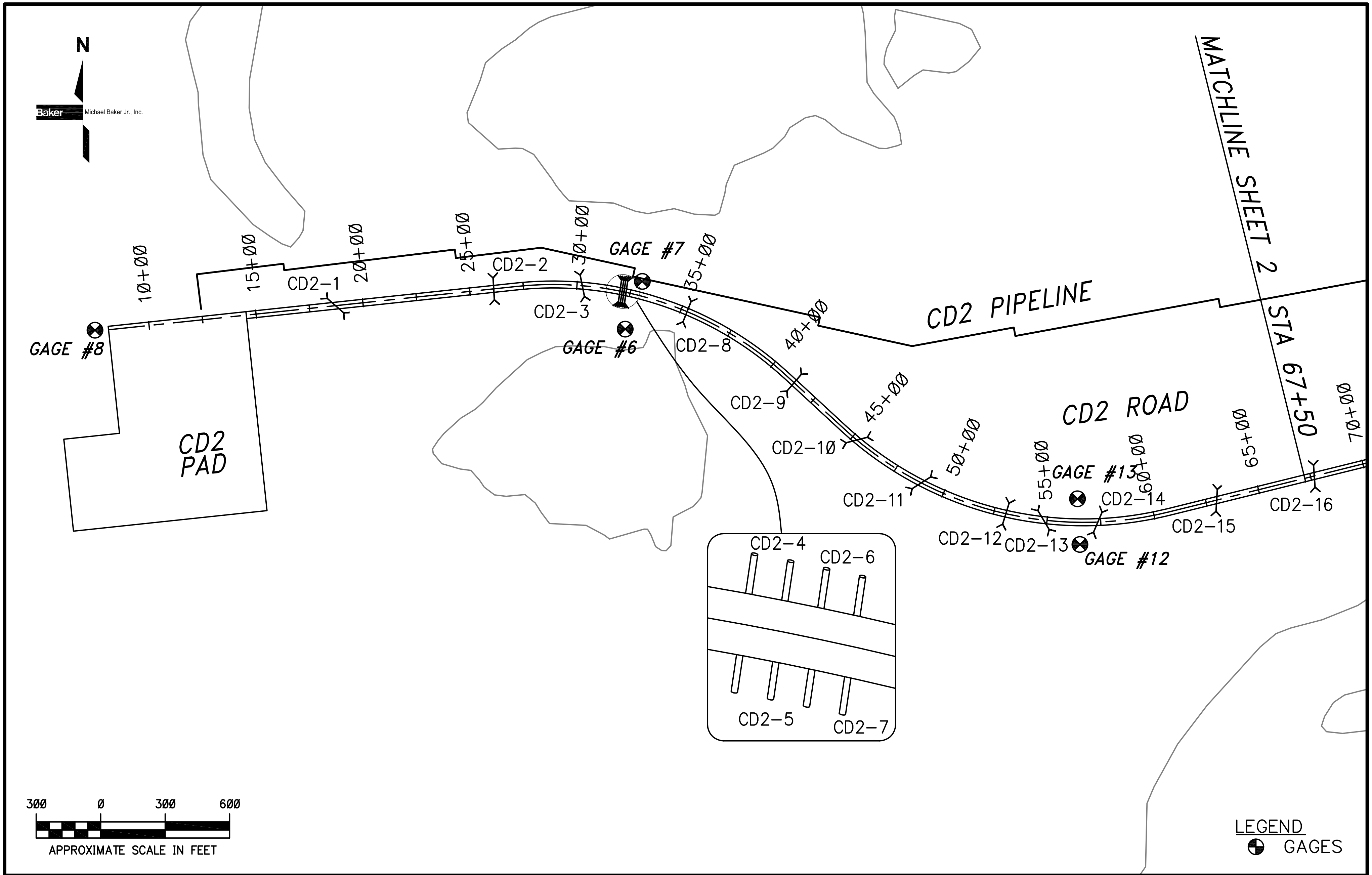
Flow through the CD2 culverts is estimated to have stopped late in the evening of June 4 or in the early morning of June 5 when water receded below culvert inverts.



Graph 5.3: G3 and G4 WSE Differential



Graph 5.4: G12 and G13 WSE Differential



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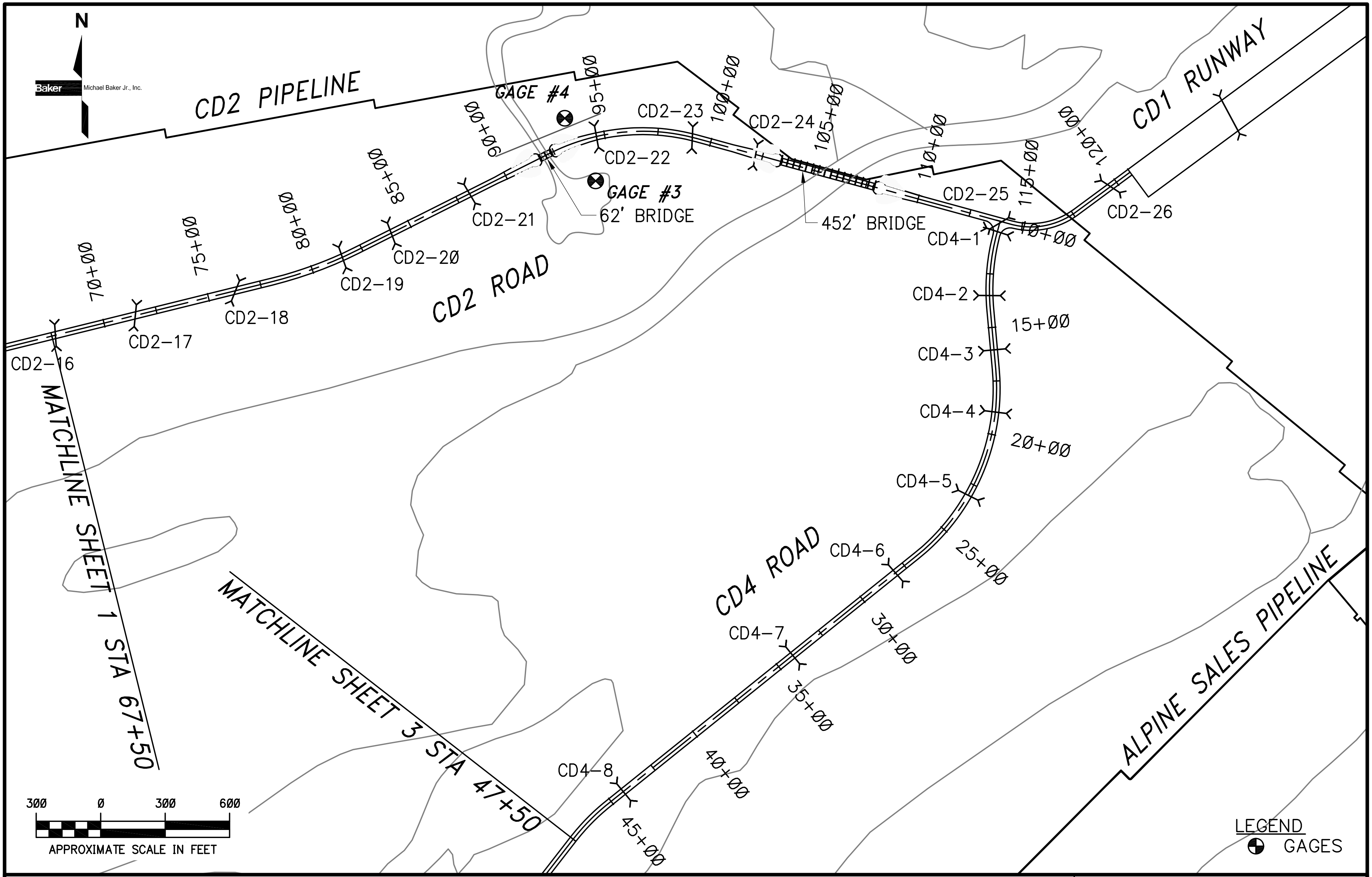
DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.4
CHECKED:	JMS	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 1 OF 6)



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DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.4
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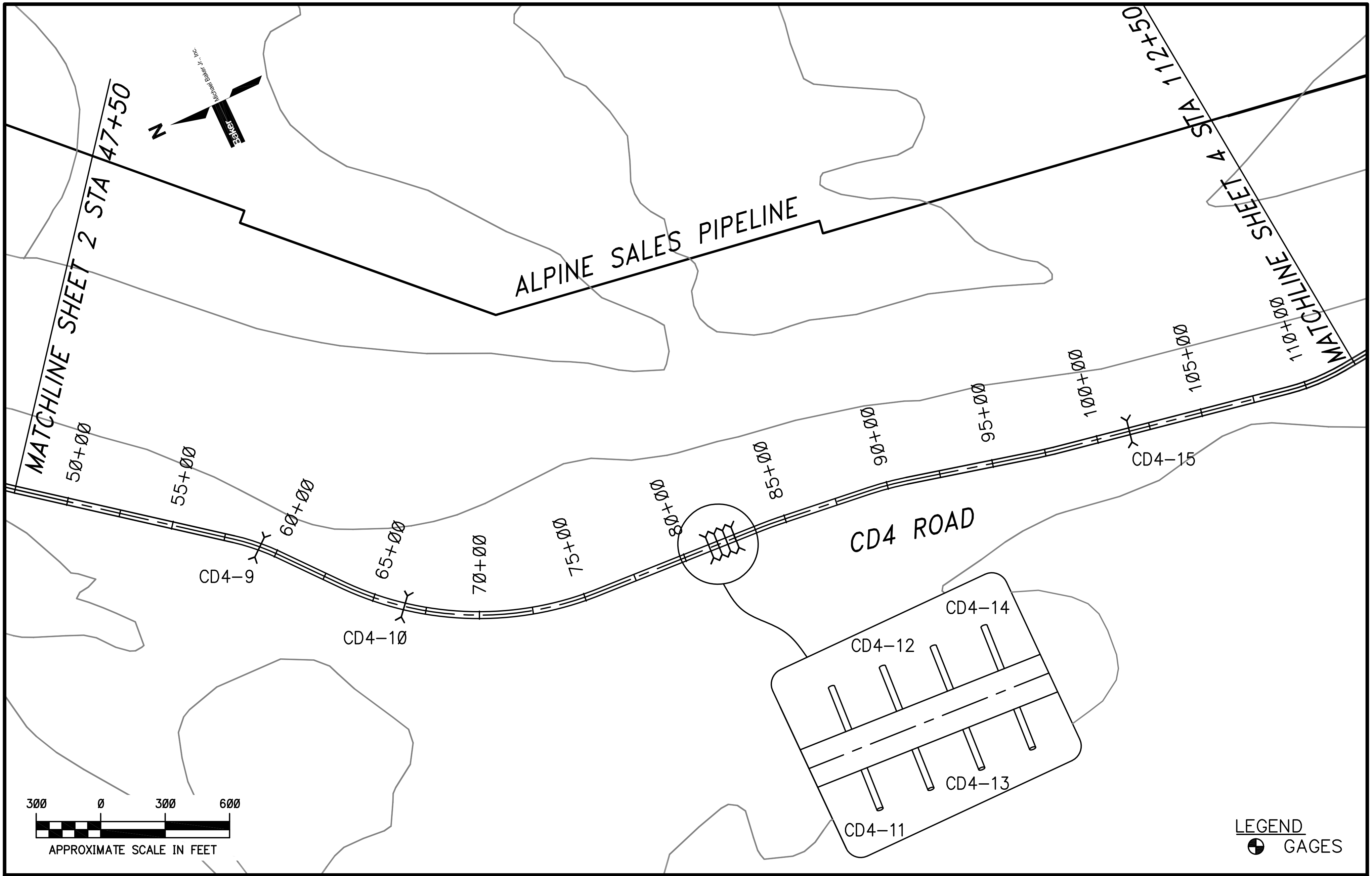
Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 2 OF 6)



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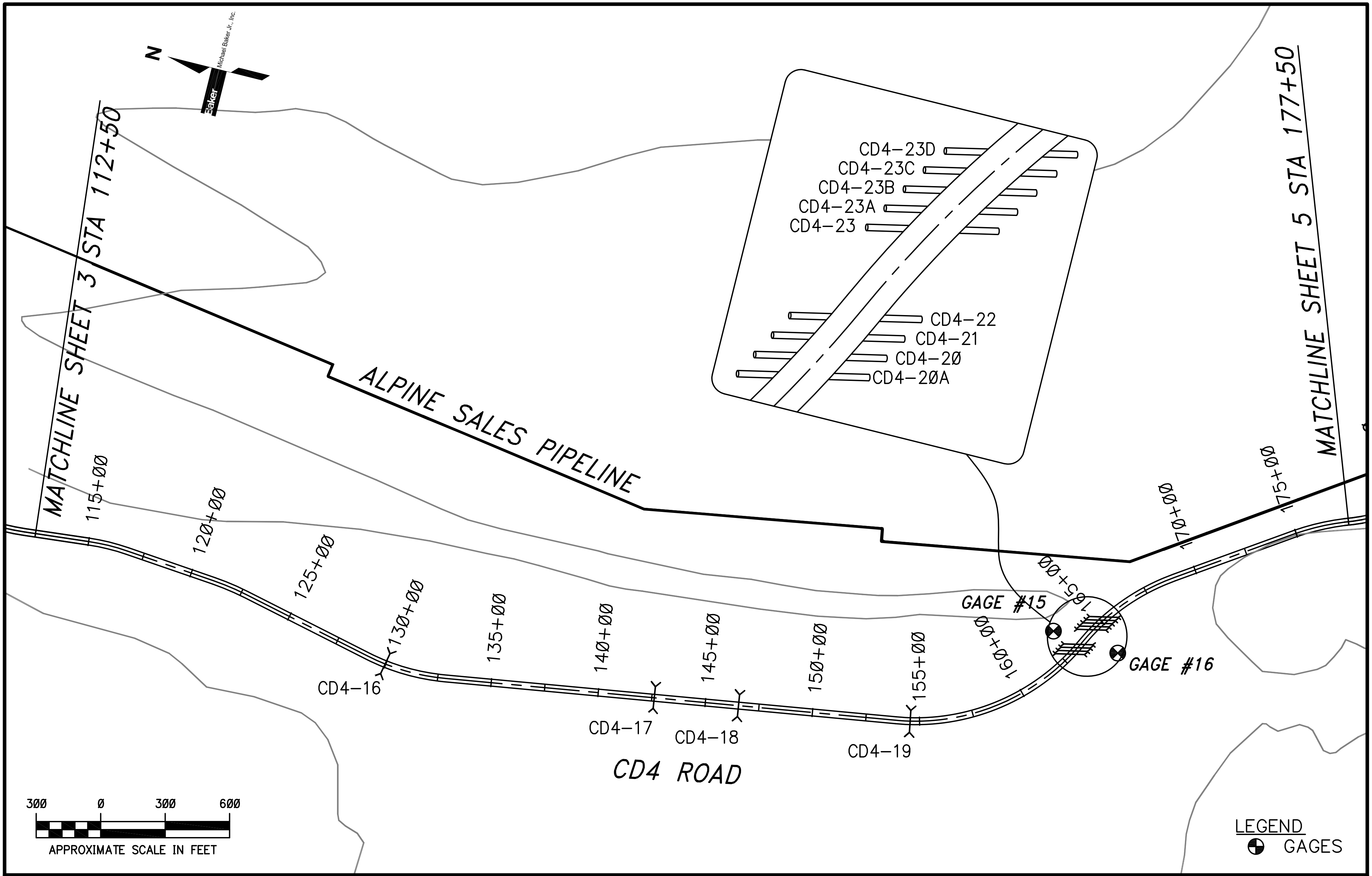
DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.4
CHECKED:	JMS	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 3 OF 6)



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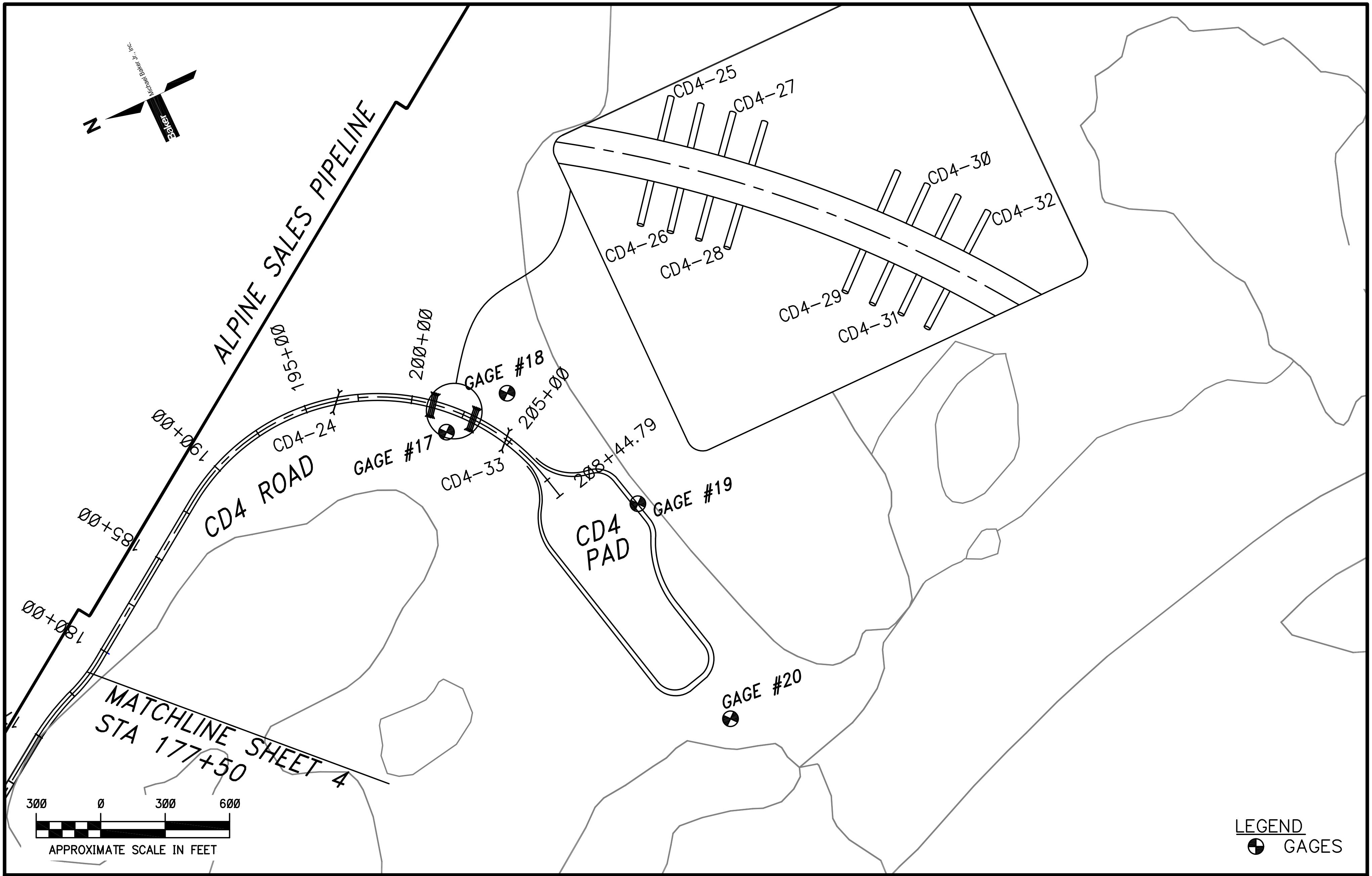
DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.4
CHECKED:	JMS	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 4 OF 6)



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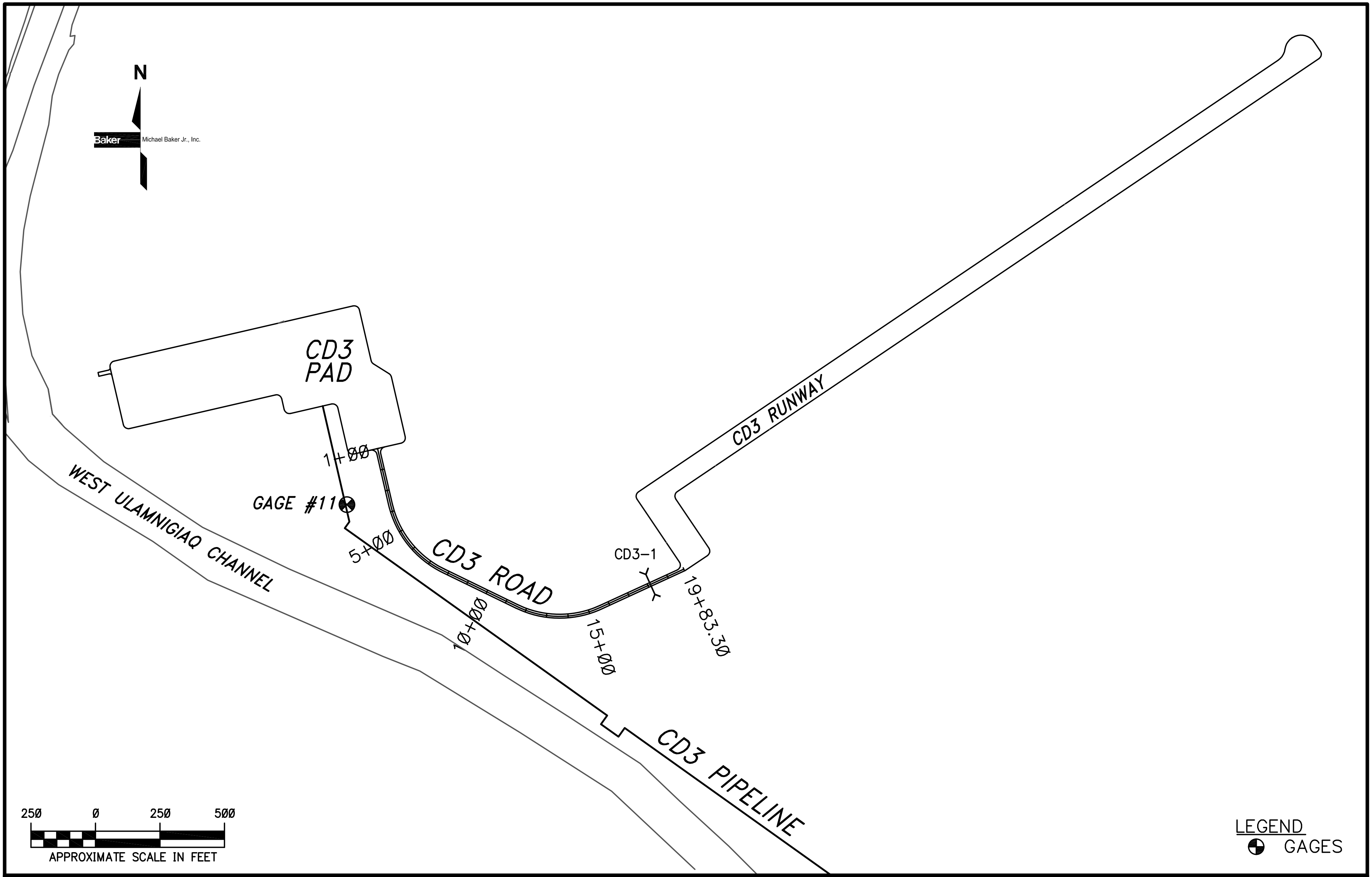
Alaska, Inc.

DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.4
CHECKED:	JMS	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 5 OF 6)



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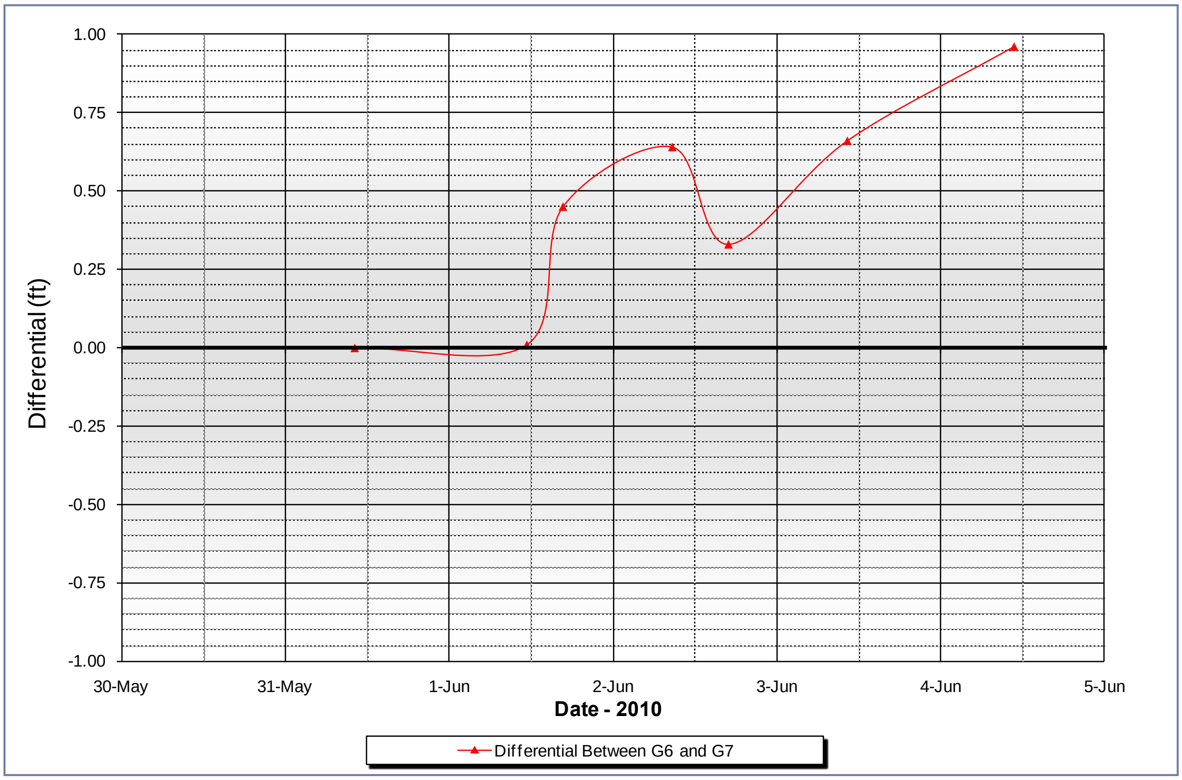
DATE:	8/10/10	PROJECT:	119863
DRAWN:	EJK	FILE:	FIGURE 5.4
CHECKED:	JMS	SCALE:	AS SHOWN

Baker

Michael Baker Jr., Inc.
A Unit of Michael Baker Corporation
1400 West Benson Blvd., Suite 200
Anchorage, Alaska 99503
Phone: (907) 273-1600
Fax: (907) 273-1699

2010 SPRING BREAK-UP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 5.4
(SHEET 6 OF 6)



Graph 5.5: G6 and G7 WSE Differential

5.5.2.2 ALPINE CULVERTS ADJUSTED INDIRECT VELOCITY

Indirect velocity calculations rely on the headwater/tailwater differential at nearby gages, as well as the physical characteristics of the culverts including length, diameter, invert elevation, and material. Indirect calculations assume an open water, "best-case" scenario with regard to hydraulic conditions. As a result, indirect calculations tend to overestimate both velocity and discharge compared to field-observed values.

Observed velocities (and associated headwater/tailwater differential when velocity measurements were taken) provide a basis of reference to calibrate the open-water indirect calculations. Adjustments are made to the model to correlate observed velocities with model output velocities, and subsequently model output discharge values. These adjusted values more closely account for field conditions at each culvert and provide a more reasonable assessment of adjusted indirect velocity and adjusted indirect discharge for various headwater/tailwater conditions observed over the course of the breakup.

Peak adjusted indirect velocities for the CD2 road culverts near G3 and G4 were estimated to have occurred on the evening of June 1, with a maximum adjusted velocity of 4.7 fps through CD2-22. Peak adjusted velocities for the culverts near G12 and G13 were estimated to have occurred in the evening of June 1, with a maximum adjusted velocity of 5.7 fps through CD2-14. CD2 culverts near G6 and G7 were estimated to have peak adjusted velocities the morning of June 4, with a maximum adjusted velocity of 3.5 fps through CD2-6. As stated, ice and snow in the vicinity of G6 and G7, and nearby culverts, persisted throughout breakup. Indirectly calculated values in this area are suspect due to a lack of observed hydraulic connectivity in the area.

A summary of average adjusted indirect velocities for each culvert is shown in Table 5.6, Table 5.7, and Table 5.8.

Table 5.6: Adjusted Indirect Velocity Summary (fps), CD2 Road Culverts, G3 and G4

Culvert	5/30/10 11:08 AM	5/31/10 9:40 AM	5/31/10 3:45 PM	6/1/10 2:20 PM	6/1/10 4:40 PM	6/2/10 8:14 AM	6/2/10 3:30 PM	6/2/10 5:45 PM	6/3/10 10:11 AM	6/3/10 1:55 PM	6/3/10 3:51 PM	6/4/10 10:35 AM
CD2-19	0.00	0.00	0.00	0.00	1.60	3.23	3.75	2.96	0.00	0.00	0.00	0.00
CD2-20	0.59	0.74	0.00	3.66	4.08	4.29	4.45	3.85	3.00	2.23	2.08	1.67
CD2-21	0.65	0.69	0.00	3.62	4.16	4.13	3.85	3.68	2.64	2.09	1.95	1.96
CD2-22	0.00	0.00	0.00	4.11	4.69	4.56	4.26	4.06	3.21	2.38	2.23	2.53
CD2-23	0.00	0.00	0.00	3.99	4.55	4.36	4.04	3.89	3.10	2.30	2.16	2.44
CD2-24	1.00	0.95	0.00	4.15	4.66	4.30	3.99	3.84	3.17	2.39	2.26	2.89
CD2-25	-	-	-	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-	-	-	-
Average Velocity	0.75	0.79	0.00	3.91	3.96	4.15	4.06	3.71	3.02	2.28	2.14	2.30

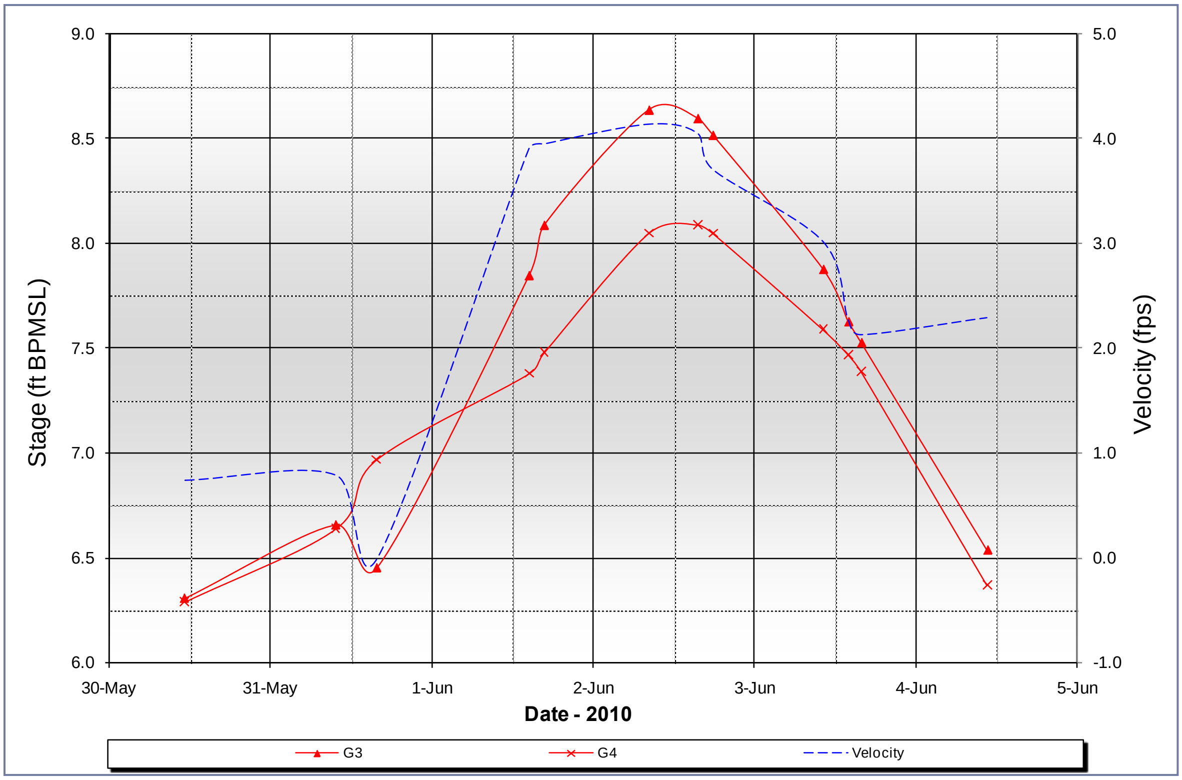
Table 5.7: Adjusted Indirect Velocity Summary (fps), CD2 Road Culverts, G12 and G13

Culvert	5/31/10 10:00 AM	6/1/10 4:40 PM	6/2/10 8:31 AM	6/2/10 5:35 PM	6/3/10 10:15 AM	6/4/10 10:40 AM
CD2-9	0.00	0.00	0.00	0.00	-	-
CD2-10	0.00	0.00	0.00	0.05	0.00	0.00
CD2-11	0.00	0.00	0.00	0.00	-	-
CD2-12	0.00	0.00	0.00	0.00	-	-
CD2-13	0.00	5.61	1.65	3.23	0.00	0.00
CD2-14	0.00	5.65	1.92	3.76	0.00	0.00
CD2-15	0.00	4.91	1.48	2.99	0.00	0.00
CD2-16	0.00	0.00	1.75	1.14	0.00	0.00
CD2-17	0.00	0.00	0.00	0.00	-	-
CD2-18	0.00	0.00	0.14	0.29	0.00	0.00
Average Velocity	0.00	5.39	1.39	1.91	0.00	0.00

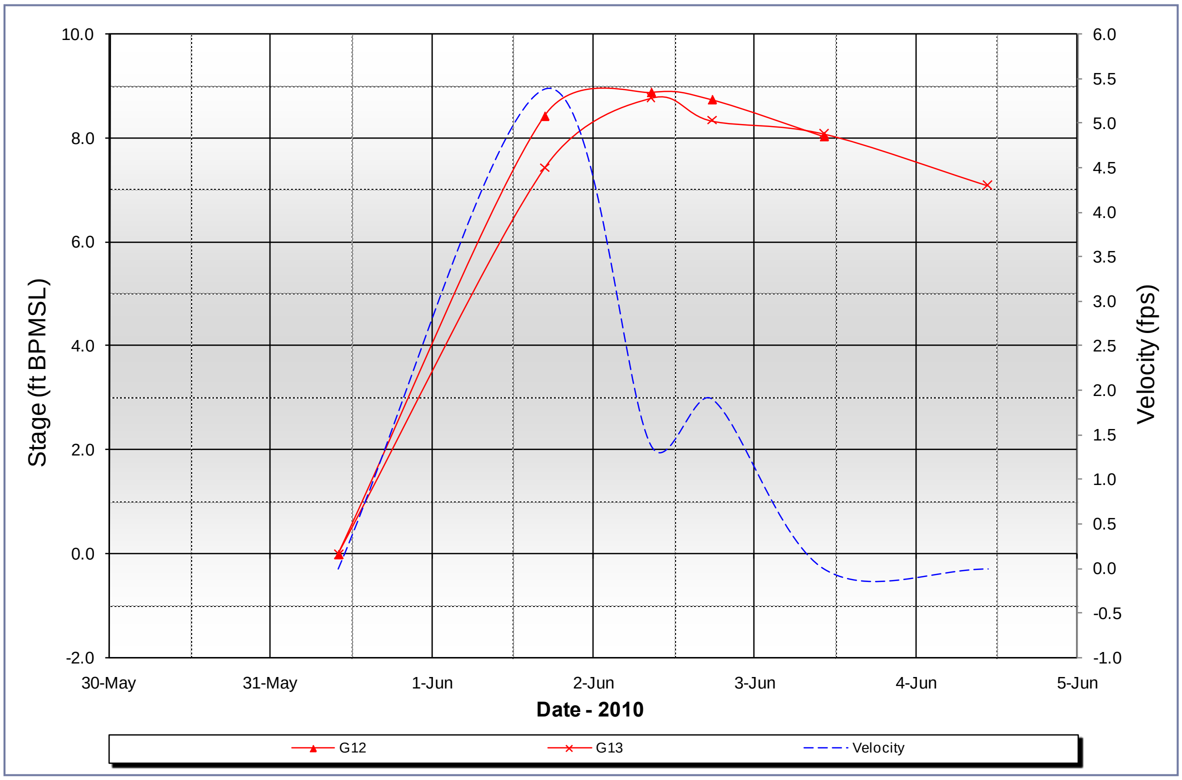
Table 5.8: Adjusted Indirect Velocity Summary (fps), CD2 Road Culverts, G6 and G7

Culvert	5/31/10 10:10 AM	6/1/10 11:23 AM	6/1/10 4:40 PM	6/2/10 8:41 AM	6/2/10 4:55 PM	6/3/10 10:20 AM	6/4/10 10:45 AM
CD2-1	0.00	0.00	0.00	0.00	0.55	0.87	1.61
CD2-2	0.00	0.00	0.00	0.00	0.00	-	-
CD2-3	0.00	0.00	0.00	0.00	0.00	-	-
CD2-4	0.00	0.00	0.86	1.00	0.70	1.09	1.45
CD2-5	0.00	0.00	1.93	2.32	1.62	2.43	3.22
CD2-6	0.00	0.00	2.18	2.63	1.84	2.73	3.53
CD2-7	0.00	0.00	1.49	1.77	1.24	1.88	2.45
CD2-8	0.00	0.00	0.00	0.00	0.00	-	-
Average Velocity	0.00	0.00	1.62	1.93	1.19	1.80	2.45

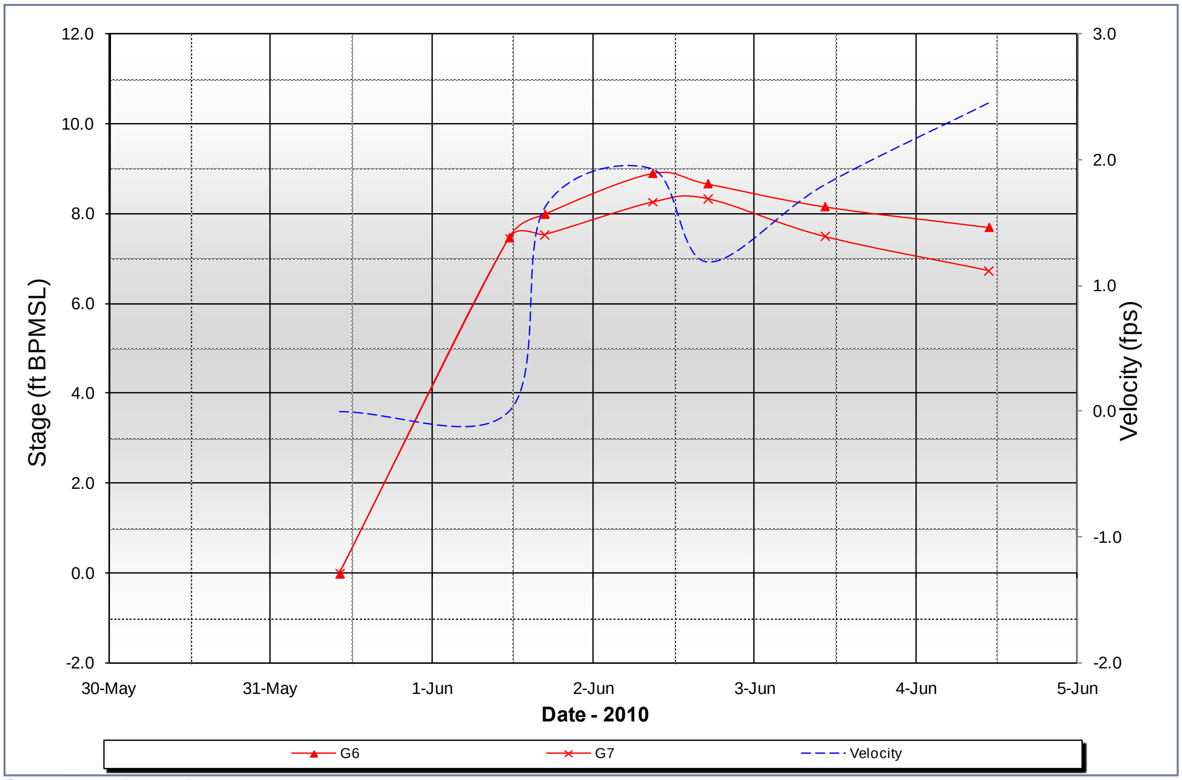
As indicated, the adjusted velocity estimates for the CD2 culverts are related to water surface differentials between the culvert headwater and the tailwater elevations. The adjusted velocity for each culvert was greatest on June 2, which had the largest differential between headwater and tailwater. A comparison of observed stage and adjusted velocity for the CD2 culverts is presented in Graph 5.6, Graph 5.7, and Graph 5.8.



Graph 5.6: Indirect Velocity v. Observed Stage, CD2 Road Culverts, G3 and G4



Graph 5.7: Indirect Velocity v. Observed Stage, CD2 Road Culverts, G12 and G13



Graph 5.8: Indirect Velocity v. Observed Stage, CD2 Road Culverts, G6 and G7

5.5.2.1 ALPINE CULVERTS INDIRECT DISCHARGE

Adjusted peak discharge for those culverts passing flow, as calculated using indirect methods and calibrated based on observed velocities on June 2, ranged from less than 0.1 cfs to 52.8 cfs. The indirectly calculated maximum total discharge through all CD2 culverts on the morning of June 2 was 355 cfs. The adjusted indirect discharge of the CD2 road culverts is presented in Table 5.9, Table 5.10, and Table 5.11.

Table 5.9: CD2 Road Culverts Adjusted Indirect Discharge Summary (cfs) G3 and G4

Culvert	5/30/10 11:08 AM	5/31/10 9:40 AM	5/31/10 3:45 PM	6/1/10 2:20 PM	6/1/10 4:40 PM	6/2/10 8:14 AM	6/2/10 3:30 PM	6/2/10 5:45 PM	6/3/10 10:11 AM	6/3/10 1:55 PM	6/3/10 3:51 PM	6/4/10 10:35 AM
CD2-19	0.0	0.0	0.0	0.0	0.2	2.7	2.4	1.9	0.0	0.0	0.0	0.0
CD2-20	0.2	1.0	0.0	14.0	17.1	27.7	26.5	24.9	13.9	9.3	8.0	1.0
CD2-21	1.7	2.8	0.0	25.0	30.4	39.2	37.0	34.9	20.8	15.2	13.5	5.8
CD2-22	0.0	0.0	0.0	28.9	34.7	43.7	41.2	39.0	25.2	17.6	15.7	7.8
CD2-23	0.0	0.0	0.0	38.0	45.0	50.9	47.6	45.4	31.8	22.7	20.6	13.6
CD2-24	6.3	7.3	0.0	43.2	50.1	52.8	49.2	47.1	35.1	25.6	23.6	19.1
CD2-25	-	-	-	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-	-	-	-
Discharge	8.3	11.0	0.0	149.0	177.5	217.0	204.0	193.2	126.8	90.4	81.6	47.3

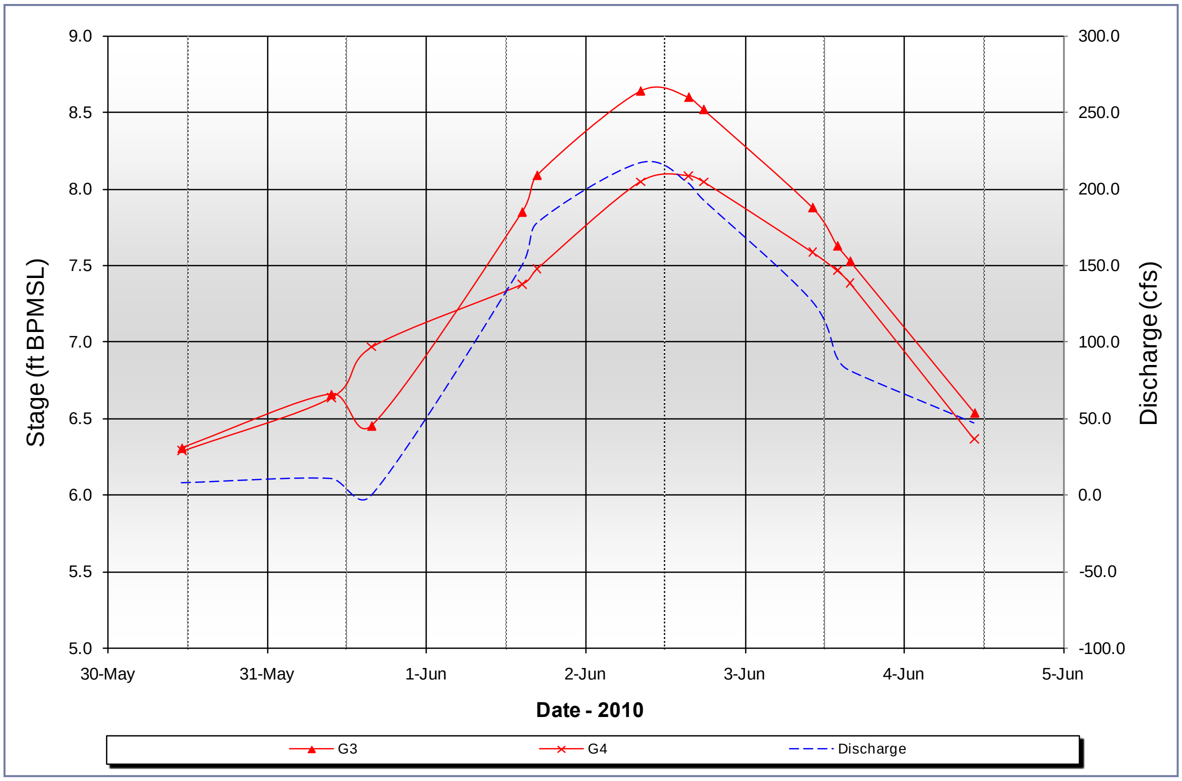
Table 5.10: CD2 Road Culverts Adjusted Indirect Discharge Summary (cfs) G12 and G13

Culvert	5/31/10 10:00 AM	6/1/10 10:55 AM	6/1/10 4:40 PM	6/2/10 8:31 AM	6/2/10 5:35 PM	6/3/10 10:15 AM	6/4/10 10:40 AM
CD2-9	0.0	0.0	0.0	0.0	0.0	-	-
CD2-10	0.0	0.0	0.0	0.0	0.3	-	-
CD2-11	0.0	0.0	0.0	0.0	0.0	-	-
CD2-12	0.0	0.0	0.0	0.0	0.0	-	-
CD2-13	0.0	0.0	30.4	19.9	31.8	0.0	0.0
CD2-14	0.0	0.0	31.5	23.5	37.3	0.0	0.0
CD2-15	0.0	0.0	13.0	10.7	16.2	0.0	0.0
CD2-16	0.0	0.0	0.0	0.8	0.1	0.0	0.0
CD2-17	0.0	0.0	0.0	0.0	0.0	-	-
CD2-18	0.0	0.0	0.0	0.6	0.7	0.0	0.0
Discharge	0.0	0.0	74.9	55.5	86.4	0.0	0.0

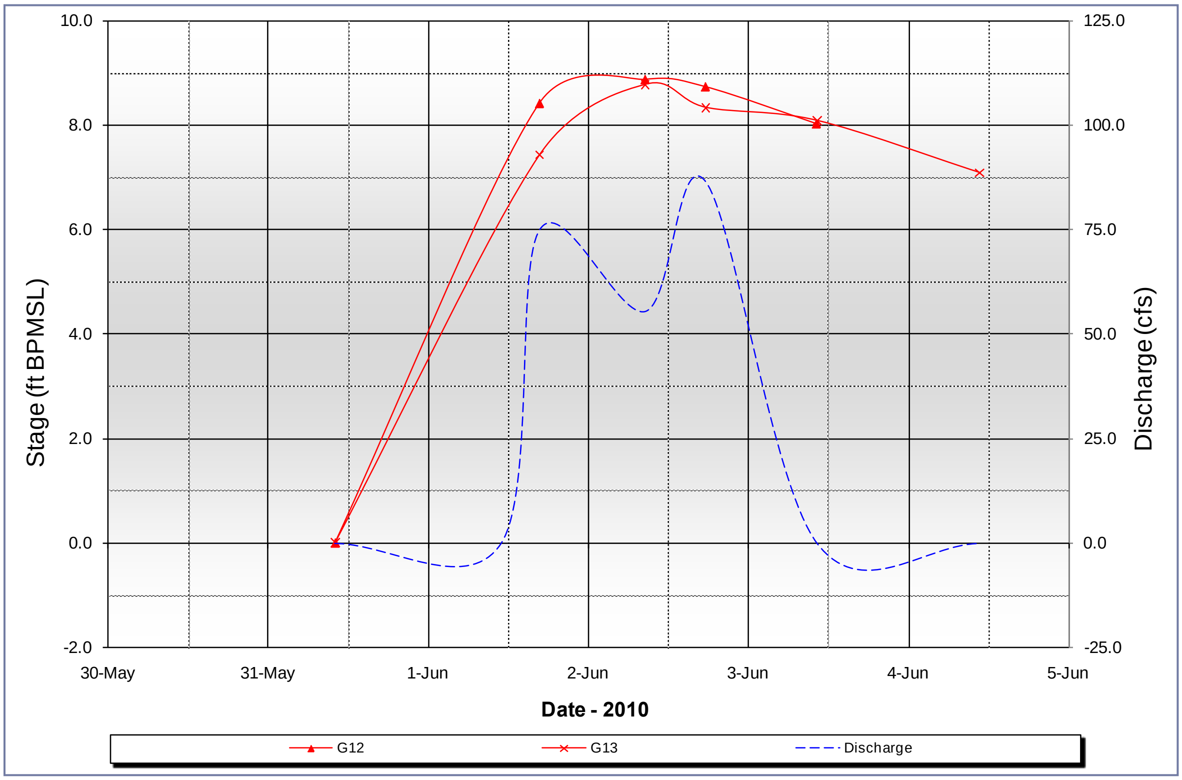
Table 5.11: CD2 Road Culverts Adjusted Indirect Discharge Summary (cfs) G6 and G7

Culvert	5/31/10 10:10 AM	6/1/10 11:23 AM	6/1/10 4:40 PM	6/2/10 8:41 AM	6/2/10 4:55 PM	6/3/10 10:20 AM	6/4/10 10:45 AM
CD2-1	0.0	0.0	0.0	0.0	3.6	2.9	1.4
CD2-2	0.0	0.0	0.0	0.0	0.0	-	-
CD2-3	0.0	0.0	0.0	0.0	0.0	-	-
CD2-4	0.0	0.0	7.0	10.8	7.7	8.8	7.3
CD2-5	0.0	0.0	14.7	23.9	17.1	18.2	14.3
CD2-6	0.0	0.0	18.4	28.9	20.6	22.6	18.5
CD2-7	0.0	0.0	12.7	19.5	14.0	15.7	13.1
CD2-8	0.0	0.0	0.0	0.0	-	-	-
Discharge	0.0	0.0	52.8	83.0	63.0	68.2	54.7

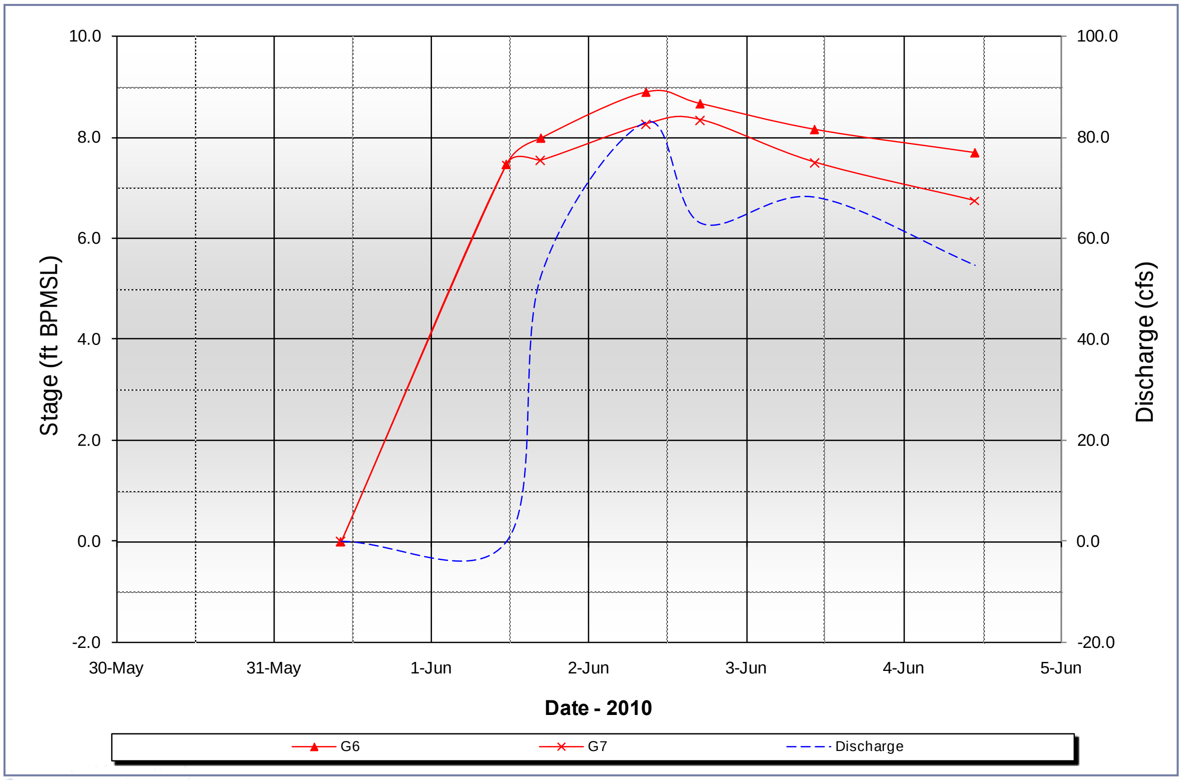
A comparison of stage and adjusted discharge during breakup for CD2 culverts is presented in Graph 5.9, Graph 5.10, and Graph 5.11.



Graph 5.9: Adjusted Indirect Discharge v. Stage, CD2 Road Culverts, G3 and G4.



Graph 5.10: Adjusted Indirect Discharge v. Stage, CD2 Road Culverts, G12 and G13.



Graph 5.11: Adjusted Indirect Discharge v. Stage, CD2 Road Culverts, G6 and G7

5.5.3 Alpine Culverts Unadjusted Indirect/Direct Discharge Comparison

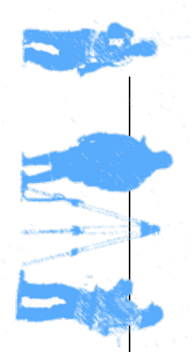
Adjusted indirect calculations were used to estimate peak discharge values. Both adjusted and unadjusted indirect estimates were compared with the respective direct velocity measurements and direct discharge estimates to get a sense of relative accuracy of the indirect calculations. The comparison between the June 2 CD2 road culverts direct and indirect measurements are presented in Table 5.12.

The percent difference between direct and unadjusted indirect mean velocity and total discharge was -37% and -50%, respectively. In other words, the unadjusted indirect velocity and discharge values overestimate the actual observed velocity and discharge.

Similarly, the percent difference between direct and adjusted indirect mean velocity and total discharge was -0% and -11%, respectively. The adjusted indirect velocity is equal to the observed velocity and used to calibrate the model. The adjusted indirect discharge slightly overestimates the discharge compared to observed discharge. As stated previously, the adjusted indirect velocity and discharge calculations are based on estimates for the physical conditions of the culverts. These adjusted calculations do not fully account for flow constrictions including snow and ice, plywood debris at the culvert invert and outlets, or the actual field conditions, which constitute the basis for hydraulic connectivity between measured WSE at gages and actual conditions at the culverts.

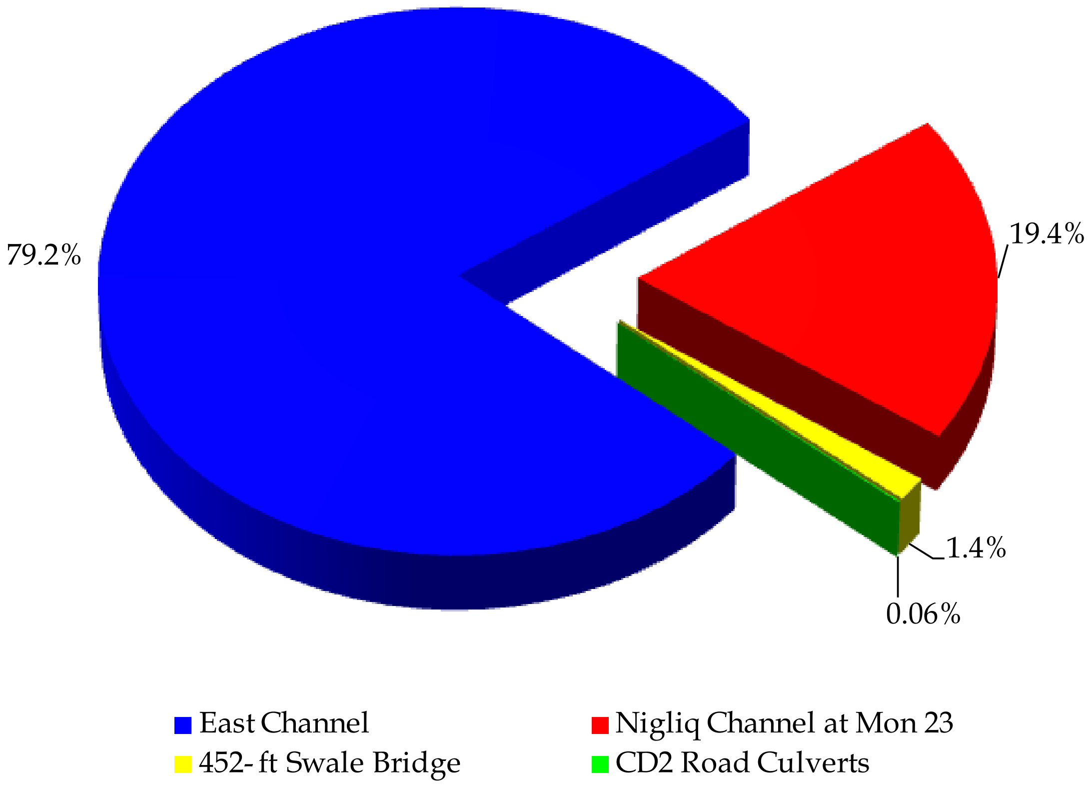
Table 5.12: CD2 Road Culverts - Velocity and Discharge Comparison

Culvert	Direct			Indirect					Percent Difference			
					Adjusted		Unadjusted		Direct v. Unadjusted		Direct v. Adjusted	
	Time of Measurement June 2	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation June 2	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD2-1	4:25 PM	0.55	1.95	4:55 PM	0.55	3.64	3.61	23.96	-556%	-1130%	0%	-87%
CD2-2	-	-	-	-	-	-	-	-	-	-	-	-
CD2-3	-	-	-	-	-	-	-	-	-	-	-	-
CD2-4	4:45 PM	0.70	1.72	4:55 PM	0.70	7.74	3.22	35.50	-360%	-1964%	0%	-350%
CD2-5	4:50 PM	1.62	8.24	4:55 PM	1.62	17.06	3.21	34.02	-98%	-313%	0%	-107%
CD2-6	4:55 PM	1.84	7.92	4:55 PM	1.84	20.63	3.10	34.71	-68%	-338%	0%	-160%
CD2-7	5:00 PM	1.24	1.83	4:55 PM	1.24	13.96	3.15	35.60	-154%	-1844%	0%	-662%
CD2-8	-	-	-	-	-	-	-	-	-	-	-	-
CD2-9	-	-	-	-	-	-	-	-	-	-	-	-
CD2-10	5:15 PM	0.05	0.34	5:35 PM	0.05	0.27	3.68	24.15	-7260%	-6955%	0%	21%
CD2-11	-	-	-	-	-	-	-	-	-	-	-	-
CD2-12	-	-	-	-	-	-	-	-	-	-	-	-
CD2-13	5:35 PM	3.23	26.88	5:35 PM	3.23	31.84	3.06	30.23	5%	-12%	0%	-18%
CD2-14	5:40 PM	3.76	38.79	5:35 PM	3.76	37.34	3.12	31.40	17%	19%	0%	4%
CD2-15	4:10 PM	2.99	16.40	5:35 PM	2.99	16.21	3.91	21.22	-31%	-29%	0%	1%
CD2-16	4:00 PM	1.14	0.10	5:35 PM	1.14	0.05	1.21	0.06	-6%	37%	0%	48%
CD2-17	-	-	-	-	-	-	-	-	-	-	-	-
CD2-18	3:50 PM	0.29	1.03	5:35 PM	0.29	0.71	3.35	8.13	-1055%	-692%	0%	31%
CD2-19	3:45 PM	3.75	4.43	3:30 PM	3.75	2.43	3.04	2.16	19%	51%	0%	45%
CD2-20	3:40 PM	4.45	31.51	3:30 PM	4.45	26.54	3.86	25.51	13%	19%	0%	16%
CD2-21	3:35 PM	3.85	37.57	3:30 PM	3.85	36.99	3.85	37.14	0%	1%	0%	2%
CD2-22	3:30 PM	4.26	43.07	3:30 PM	4.26	41.18	4.03	39.21	5%	9%	0%	4%
CD2-23	3:25 PM	4.04	48.13	3:30 PM	4.04	47.62	4.01	47.25	1%	2%	0%	1%
CD2-24	3:10 PM	3.99	49.20	3:30 PM	3.99	49.19	3.90	48.15	2%	2%	0%	0%
CD2-25	-	-	-	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-	-	-	-
Average Velocity (ft/s)		2.46			2.46		3.37					
Total Discharge (cfs)			319.10			353.40		478.40				
							Velocity Difference		-37%		0%	
							Discharge Difference			-50%		-11%



5.6 CRD PEAK DISCHARGE FLOW DISTRIBUTION

Approximately 79% of the flow in the CRD passed through the East Channel during the 2010 spring breakup peak discharge event. Peak discharge was estimated to have occurred at MON1 late in the evening of May 31, 2010. Nineteen percent of the flow passed down the Nigliq Channel at MON23. The remaining 1% of flow was calculated to have gone through the CD2 road culverts and the 452-ft swale bridge. The 62-ft swale bridge was obstructed with snow and ice during peak discharge and it is assumed that the structure saw little of the peak flow. Flood waters were not observed flowing through CD4 road culverts during peak flow. Graph 5.12 presents the 2010 estimated peak flow distribution within the CRD.



Graph 5.12: 2010 CRD Estimated Peak Flow Distribution

5.7 FLOOD AND STAGE FREQUENCY ANALYSIS

5.7.1 COLVILLE RIVER FLOOD FREQUENCY

A flood frequency analysis was performed in 2002 to estimate the recurrence interval and magnitude of peak flood discharge on the Colville River (Baker and Hydroconsult 2002). The analysis was revisited in 2006 (Baker 2007a) and again more recently in 2009 (Baker 2009). The results of the 2009 and 2002 analyses are presented in Table 5.13.

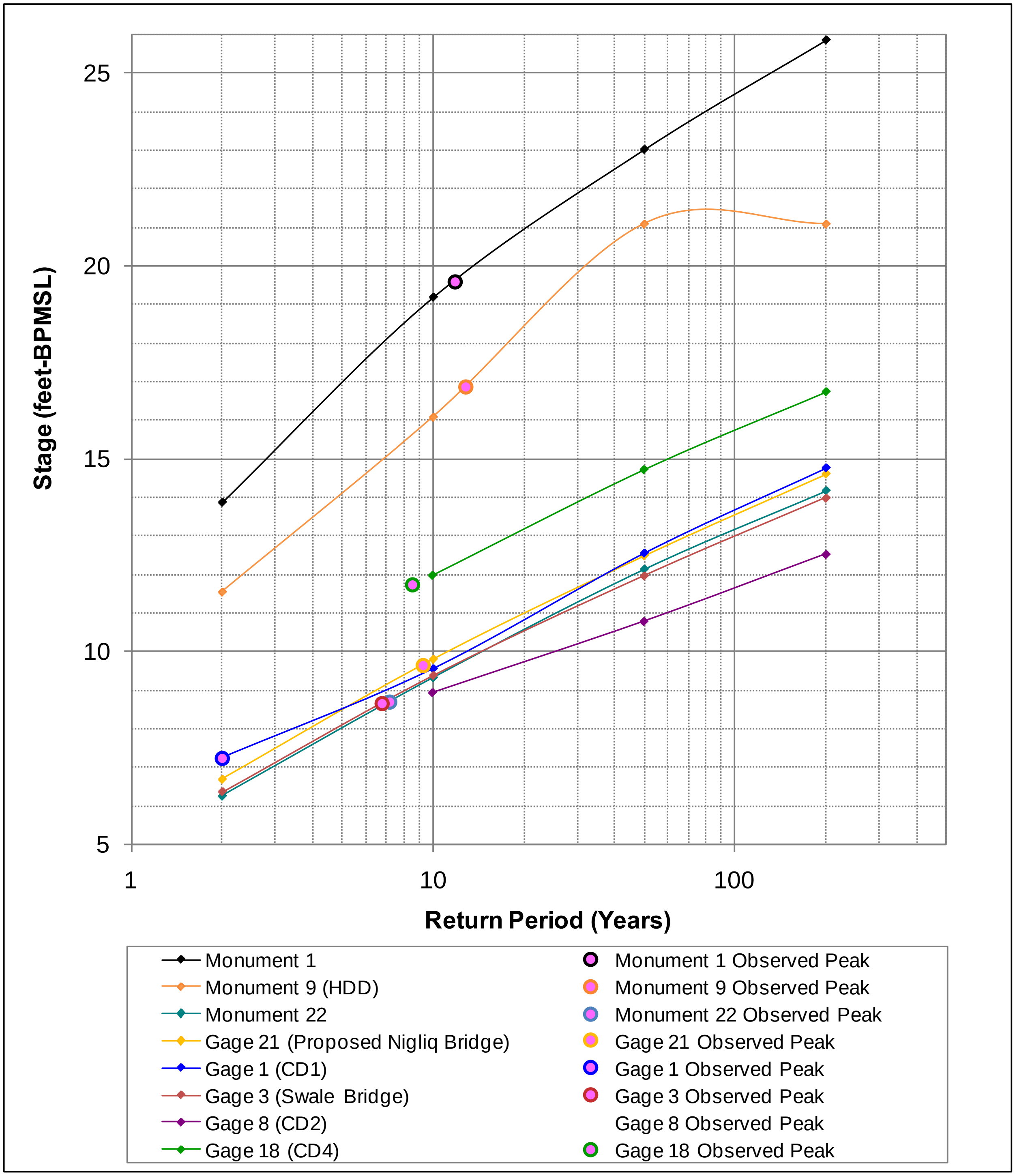
Table 5.13: Colville River Flood Frequency Analysis Results

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

The 2010 peak discharge of 320,000 cfs has an estimated recurrence interval of between 2 to 5 years, based on flood frequency analysis.

5.7.2 COLVILLE RIVER DELTA TWO-DIMENSIONAL SURFACE WATER MODEL PREDICTED AND OBSERVED WATER SURFACE ELEVATIONS

The Colville River 2D surface water model was first developed in 1997 to estimate WSE and velocities at the proposed ADP facilities locations (Baker 1998b). 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 2002b). In 2006, the model was modified to include as-built alignment conditions along the CD4 access road and pad and 2004/2005 survey data of the Nigliq Channel near MON23 (Baker 2006b). The model was completely reconstructed in 2009 (Baker 2009). Graphical representation of the 2010 observed peak stage and predicted WSE for 2-, 10-, 50-, and 200-year floods are shown in Graph 5.13. The current 2D surface water model predictions and the 2010 observations are presented in Table 5.14.



Graph 5.13: CRD 2009 2D Model Predicted and 2010 Observed Peak WSE

Table 5.14: CRD 2009 2D Model Predicted and 2010 Observed Peak WSE

Monitoring Sites	2D Model Predicted Water Surface Elevation [based on open water conditions] (feet BPMSL)				2010 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	13.9	19.2	23.0	25.9	19.6	12
Monument 9 (HDD)	11.5	16.1	21.1	21.1	16.9	13
Monument 35 (Helmericks)	4.3	5.4	6.1	6.5	4.8	4
Monuments - Nigliq Channel						
Monument 20	7.8	11.4	14.6	16.8	10.7	7
Monument 22	6.3	9.3	12.1	14.2	8.7	7
Monument 23	5.1	7.4	10.2	12.0	7.8	12
Monument 28	3.1	3.4	3.9	4.3	3.0	<2
CD1 Pad						
Gage 1	7.2	9.6	12.6	14.8	7.2	2
Gage 9	8.3	10.8	13.4	15.7	7.6	<2
Gage 10	\	10.9	13.4	15.8	7.5	<10
CD2 Pad						
Gage 8	\	8.9	10.8	12.5	-	-
CD2 Road						
Gage 3	6.4	9.4	12.0	14.0	8.6	7
Gage 4	6.2	8.5	10.1	11.7	8.1	8
Gage 6	\	9.6	12.2	14.2	8.9	<10
Gage 7	\	8.4	10.0	11.6	8.3	<10
Gage 12	\	9.5	12.1	14.1	8.9	<10
Gage 13	\	8.4	10.0	11.6	8.8	15
CD3 Pad						
Gage 11	3.8	6.4	7.1	7.9	-	-
CD4 Pad						
Gage 19	\	11.9	14.6	16.6	-	-
Gage 20	\	11.1	14.2	16.3	10.7	<10
CD4 Road						
Gage 15	\	10.9	13.5	15.9	8.0	<10
Gage 16	\	11.2	14.2	16.1	8.0	<10
Gage 17	\	11.2	14.2	16.2	-	-
Gage 18	\	12.0	14.7	16.7	11.7	<10
CD3 Pipeline Crossings						
Sakoonang (Crossing #2) Gage	6.4	8.9	11.1	12.8	7.1	3
Tamayagiaq (Crossing #4) Gage	6.7	8.6	9.1	9.9	8.0	6
Ulamnigiaq (Crossing #5) Gage	5.5	7.1	7.8	8.7	6.9	8
Proposed CD5 Road Crossings						
Gage 21 (Nigliq Channel)	6.7	9.8	12.5	14.6	9.7	9
Gage 22 (L9341)	\	\	12.8	14.9	5.9	<50
Gage 23 (Nigliagvik)	6.9	10.0	12.7	14.9	8.7	5

Notes:

1. Sites having dry ground in 2D model are denoted with a backward slash "\"
2. Sites having no observed WSE in 2010 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 the snow, channel ice, or ice jams present during the 2010 spring breakup.

In general, the 2D model under-predicts stage for lower return periods (approximately 10 years and less). This is to be expected as the 2D model does not account for ice- and snow-related events, which can have a large affect 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.

5.7.3 COLVILLE RIVER DELTA STAGE FREQUENCY

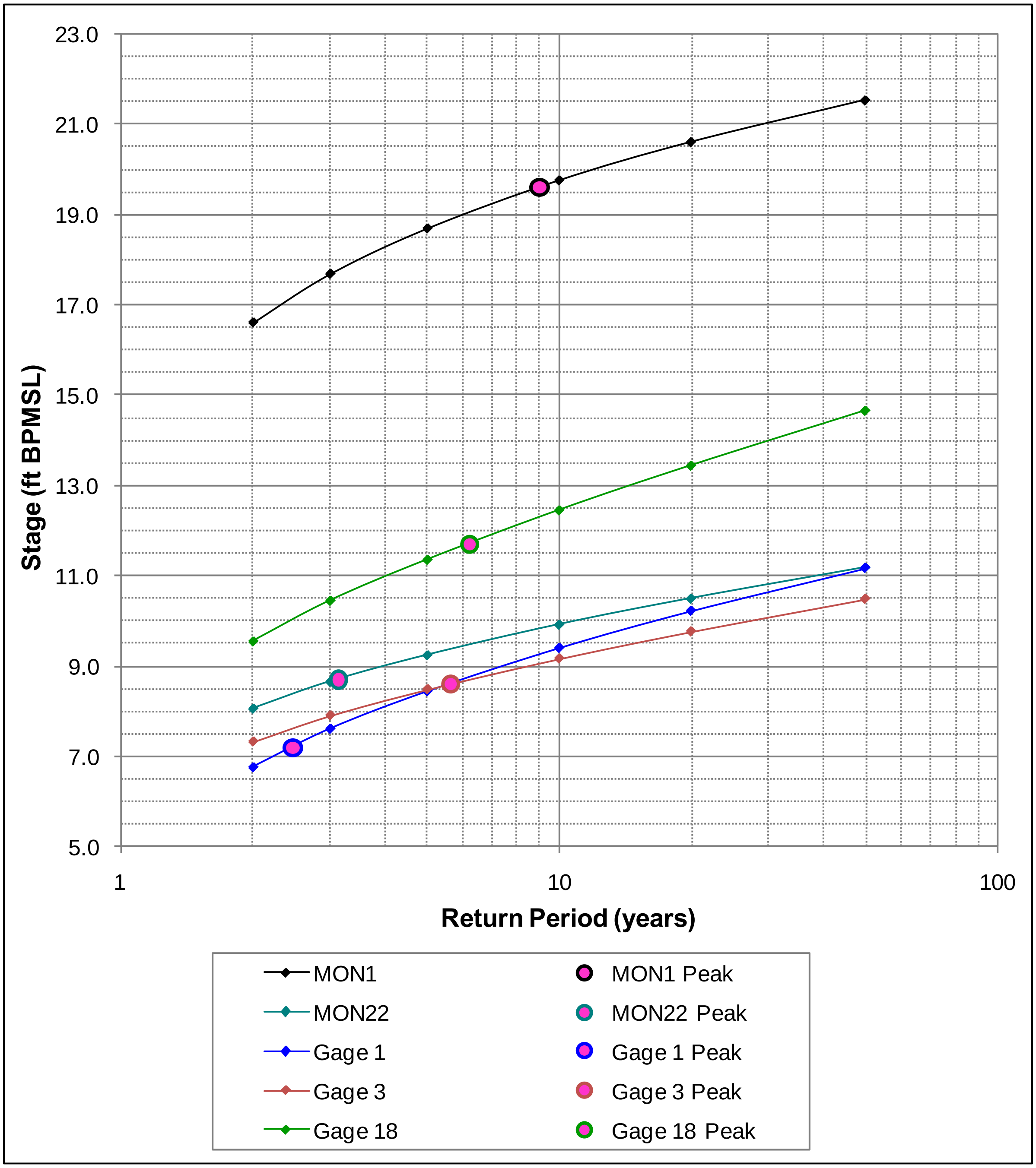
A stage frequency analysis was performed for a limited group of sites in 2006 (Baker 2007a) and again in 2009 (Baker 2009). The location and distribution of sites monitored since 1992 has varied based on the objectives of each year's field program. MON1, MON22, G1, G3, and G18 (near CD4) were selected because each had a relatively long-term tabulation of data. The data reflected ice-affected flooding conditions and thus the stage analysis reflects these conditions. Resulting values from the 2009 analysis are compared to 2010 observed peak WSE and presented in Table 5.15 and Graph 5.14.

Table 5.15: CRD 2009 Stage Frequency Analysis Results and 2010 Observed Peak WSE for Various Locations

Monitoring Sites	Stage Frequency - Log-Pearson Type III (feet BPMSL)						2010 Observed Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (years)
	2-year	3-year	5-year	10-year	20-year	50-year		
MON1	16.6	17.7	18.7	19.8	20.6	21.5	19.6	9
MON22	8.1	8.7	9.2	9.9	10.5	11.2	8.7	3
G1	6.8	7.6	8.4	9.4	10.2	11.2	7.2	2
G3	7.3	7.9	8.5	9.2	9.8	10.5	8.6	6
CD4 Pad (G18)	9.5	10.4	11.4	12.5	13.4	14.7	11.7	6

Stage frequency elevations are consistently higher than those estimated by the 2D model (as seen in Table 5.14) for the respective recurrence intervals. The presence of in-channel ice and snow during breakup acts to

stall and displace flow throughout the delta, which results in consistently higher water surface elevations during lower magnitude flood events.



Graph 5.14: CRD 2009 Stage Frequency Analysis Results and 2010 Observed Peak WSE for Selected Locations

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Appendix A 2010 GAGE LOCATIONS AND VERTICAL CONTROL

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Colville East Channel				
Monument 1 Upstream	MON1U-A	N 70° 09' 30.5"	W 150° 56' 42.5"	MONUMENT 1
	MON1U-B	N 70° 09' 30.7"	W 150° 56' 44.2"	
	MON1U-C	N 70° 09' 30.5"	W 150° 56' 46.2"	
	MON1U-D	N 70° 09' 30.5"	W 150° 56' 46.9"	
	MON1U-E	N 70° 09' 30.6"	W 150° 56' 47.1"	
	MON1U-F	N 70° 09' 30.6"	W 150° 56' 47.5"	
	MON1U-PT[1]	N 70° 09' 30.8"	W 150° 56' 36.5"	
Monument 1 Centerline	MON1C-A	N 70° 09' 56.8"	W 150° 56' 18.8"	MONUMENT 1
	MON1C-B	N 70° 09' 56.9"	W 150° 56' 19.9"	
	MON1C-C	N 70° 09' 56.9"	W 150° 56' 21.2"	
	MON1C-D	N 70° 09' 56.9"	W 150° 56' 21.5"	
	MON1C-E	N 70° 09' 57.0"	W 150° 56' 22.0"	
	MON1C-F	N 70° 09' 57.1"	W 150° 56' 22.8"	
	MON1-PT[1]	N 70° 09' 56.6"	W 150° 56' 15.8"	
Monument 1 Downstream	MON1D-A	N 70° 10' 25.7"	W 150° 56' 9.7"	MONUMENT 1
	MON1D-B	N 70° 10' 25.6"	W 150° 56' 11.6"	
	MON1D-C	N 70° 10' 25.5"	W 150° 56' 13.7"	
	MON1D-D	N 70° 10' 25.5"	W 150° 56' 14.5"	
	MON1D-PT[1]	N 70° 10' 26.2"	W 150° 56' 3.4"	
	MON1D-Z[2]	N 70° 10' 25.4"	W 150° 56' 15.3"	
Monument 9	MON9-A	N 70° 14' 40.7"	W 150° 51' 26"	MONUMENT 9
	MON9-B	N 70° 14' 40.6"	W 150° 51' 27.5"	
	MON9-C	N 70° 14' 40.7"	W 150° 51' 28.1"	
	MON9-D	N 70° 14' 40.6"	W 150° 51' 28.7"	
	MON9-E	N 70° 14' 40.6"	W 150° 51' 28.7"	
	MON9-F	N 70° 14' 40.6"	W 150° 51' 28.8"	
	MON9-G	N 70° 14' 40.7"	W 150° 51' 29.1"	
	MON9-PT[1]	N 70° 14' 40.8"	W 150° 51' 25.0"	
	MON9-BARO[3]	N 70° 14' 39.3"	W 150° 51' 37.6"	
Monument 35 (Helmricks)	MON35-A	N 70° 25' 33.7"	W 150° 24' 20.7"	MONUMENT 35
	MON35-B	N 70° 25' 33.8"	W 150° 24' 20.7"	
	MON35-C	N 70° 25' 33.8"	W 150° 24' 20.9"	
	MON35-D	N 70° 25' 33.8"	W 150° 24' 20.8"	
	MON35-E	N 70° 25' 33.9"	W 150° 24' 20.9"	

[1] pressure transducer

[2] angle iron without gage

[3] BaroTROLL barometer

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Monuments - Nigliq Channel				
Monument 20	MON20-A	N 70° 16' 42.8"	W 150° 59' 55.2"	CP08-12-61
	MON20-B	N 70° 16' 42.8"	W 150° 59' 54.7"	
	MON20-C	N 70° 16' 42.8"	W 150° 59' 53.9"	
Monument 22	MON22-A	N 70° 19' 7.0"	W 151° 03' 16.3"	MONUMENT 22
	MON22-B	N 70° 19' 6.6"	W 151° 03' 17.5"	
	MON22-C	N 70° 19' 6.5"	W 151° 03' 18.1"	
	MON22-D	N 70° 19' 5.9"	W 151° 03' 19.7"	
Monument 23	MON23-A	N 70° 20' 37.0"	W 151° 03' 57.1"	MONUMENT 23
	MON23-B	N 70° 20' 37.0"	W 151° 03' 56.5"	
	MON23-C	N 70° 20' 37.1"	W 151° 03' 54.8"	
	MON23-D	N 70° 20' 37.0"	W 151° 03' 53.7"	
Monument 28	MON28-A	N 70° 25' 32.9"	W 151° 04' 10.9"	MONUMENT 28
	MON28-B	N 70° 25' 32.1"	W 151° 04' 01.1"	
Alpine Facilities and Roads				
CD 1	**G1**	N 70° 20' 34.0"	W 150° 55' 15.0"	*
	G9	N 70° 20' 01.0"	W 150° 57' 07.0"	*
	G10	N 70° 20' 33.0"	W 150° 55' 58.0"	*
CD 2	**G3**	N 70° 20' 24.0"	W 150° 58' 59.0"	*
	G4	N 70° 20' 25.0"	W 150° 59' 00.0"	*
	G6	N 70° 20' 23.0"	W 151° 01' 45.0"	*
	G7	N 70° 20' 24.0"	W 151° 01' 44.0"	*
	G8	N 70° 20' 21.2"	W 151° 02' 56.5"	*
	G12	N 70° 20' 12.2"	W 151° 00' 42.2"	CD2-14S
	G13	N 70° 20' 14.3"	W 151° 00' 42.6"	CD2-14N
CD3	**G11**	N 70° 25' 03.0"	W 150° 54' 37.9"	Pile 08
CD 4	G15-A	N 70° 18' 08.1"	W 150° 59' 34.4"	CD4-20AW
	G15-B	N 70° 18' 08.8"	W 150° 59' 38.0"	
	G16-A	N 70° 18' 06.0"	W 150° 59' 36.0"	
	G16-B	N 70° 18' 06.3"	W 150° 59' 39.5"	
	G17	N 70° 17' 35.9"	W 150° 58' 57.8"	CD4-32W
	G18-A	N 70° 17' 34.9"	W 150° 58' 54.6"	CD4-32E
	G18-B	N 70° 17' 32.8"	W 150° 58' 58.0"	*
	G18-Z	N 70° 17' 33.1"	W 150° 59' 01.4"	CD4-32E
	G19	N 70° 17' 30.0"	W 150° 59' 18.0"	PBM-P
	G20-A	N 70° 17' 30.2"	W 150° 59' 48.5"	PBM-Q
	G20-B	N 70° 17' 30.2"	W 150° 59' 48.5"	

GX - direct-read permanent staff gage

* direct-read gages are surveyed and adjusted for elevation by LCMF

Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Pipeline River Crossings				
Sakoonang Pipe Bridge	SAK-A	N 70° 21' 52.4"	W 150° 55.0' 18.1"	Pile 568 cap SW bolt
	SAK-B	N 70° 21' 52.2"	W 150° 55.0' 19.0"	
	SAK-C	N 70° 21' 52.1"	W 150° 55.0' 19.3"	
Tamayagiaq Pipe Bridge	TAM-A	N 70° 23' 29.9"	W 150° 54' 41.3"	CP08-11-23
	TAM-B	N 70° 23' 29.5"	W 150° 54' 40.6"	
	TAM-C	N 70° 23' 29.1"	W 150° 54' 40.6"	
	TAM-Z[2]	N 70° 23' 28.3"	W 150° 54' 39.1"	
Ulamnigiaq Pipe Bridge	ULAM-A	N 70° 24' 24.5"	W 150° 53' 0.5"	CP08-11-35
	ULAM-B	N 70° 24' 24.8"	W 150° 52' 59.9"	
	ULAM-Z[2]	N 70° 24' 25.3"	W 150° 52' 59.1"	
Proposed CD5 Crossings				
Nigliq Channel	G21-A	N 70° 18' 10.5"	W 151° 01' 18.8"	CP08-11-53A
	G21-B	N 70° 18' 10.4"	W 151° 01' 18.2"	
	G21-C	N 70° 18' 10.3"	W 151° 01' 11.2"	
	G21-D	N 70° 18' 10.4"	W 151° 01' 07.7"	
	G21-PT[1]	N 70° 18' 10.4"	W 151° 01' 19.7"	
	G21U-PT[1]	N 70° 17' 47.1"	W 151° 01' 40.7"	
Lake L9341	G22-A	N 70° 18.0' 21.5"	W 151° 02' 59.6"	CP08-11-64A
	G22-B	N 70° 18.0' 22.0"	W 151° 03' 02.7"	
Nigliagvik	G23-A	N 70° 18.0' 19.9"	W 151° 07' 07.3"	CP08-11-66C
	G23-B	N 70° 18.0' 19.9"	W 151° 07' 05.5"	
Proposed Fiord West Crossings				
Fiord West Road	FWR1-A	N 70° 22' 13.7"	W 151° 06' 50.7"	SHEWMAN
	FWR2-A	N 70° 22' 00.0"	W 151° 07' 18.8"	

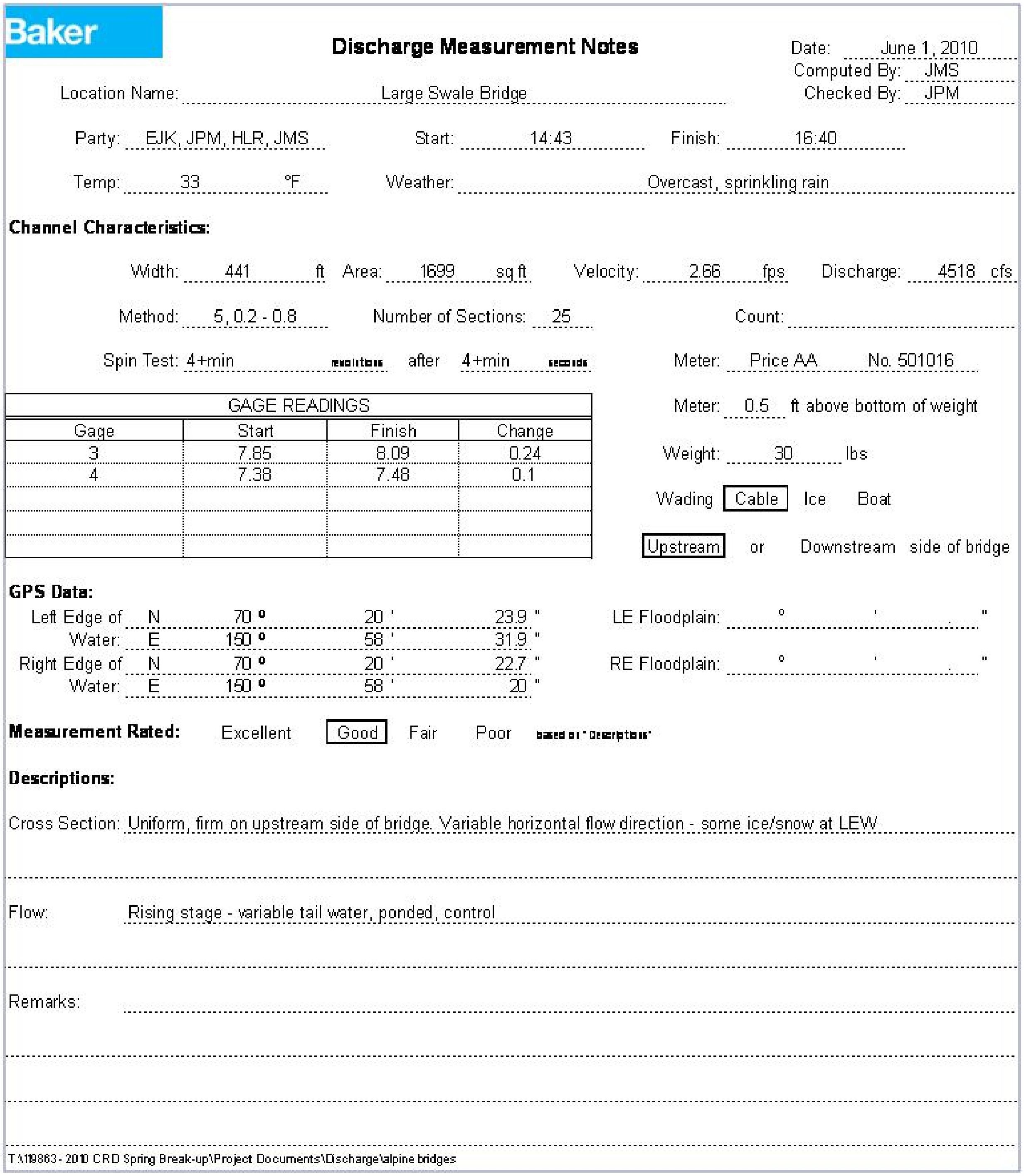
[1] pressure transducer

[2] angle iron without gage

Control	Elevation (BPMSL - Feet)	Latitude (NAD 83)	Longitude (NAD83)	Control Type	Reference
CD2-14N	11.010	N 70º 20' 13.6"	W 151º 00' 39.7"	Culvert	LCMF 2010
CD2-14S	10.929	N 70º 20' 12.9"	W 151º 00' 40.3"	Culvert	LCMF 2010
CD4-20AW	7.350	N 70º 18' 06.9"	W 150º 59' 37.1"	Culvert	LCMF 2010
CD4-32E	12.685	N 70º 17' 34.3"	W 150º 58' 58.2"	Culvert	LCMF 2010
CD4-32W	13.222	N 70º 17' 34.9"	W 150º 58' 59.6"	Culvert	LCMF 2010
CP08-11-23	8.524	N 70° 23' 29.7"	W 150° 54' 28.3"	Alcap	LCMF 2008
CP08-11-35	9.146	N 70° 24' 23.8"	W 150° 52' 55.9"	Alcap	LCMF 2008
CP08-11-53A	7.787	N 70° 18' 08.0"	W 151° 01' 07.9"	Alcap	LCMF 2008
CP08-11-64A	12.305	N 70° 18' 20.9"	W 151° 03' 08.3"	Alcap	LCMF 2008
CP08-11-66C	10.418	N 70° 18' 18.2"	W 151° 06' 59.0"	Alcap	LCMF 2008
CP08-12-61	11.956	N 70° 16' 39.9"	W 150° 59' 36.5"	Alcap	LCMF 2009
MONUMENT 1	27.930	N 70° 09' 57.2"	W 150° 56' 23.8"	Alcap	LCMF 2006
MONUMENT 22	10.030	N 70° 19' 05.2"	W 151° 03' 21.9"	Alcap	BAKER 2010
MONUMENT 23	9.546	N 70° 20' 40.0"	W 151° 03' 40.7"	Alcap	BAKER 2009
MONUMENT 28	3.650	N 70° 25' 31.9"	W 151° 04' 01.2"	Alcap	LCMF GPS 2002
MONUMENT 35	5.570	N 70° 25' 57.0"	W 150° 23' 00.4"	Alcap	Lounsbury 1996
MONUMENT 9	25.060	N 70° 14' 40.6"	W 150° 51' 29.6"	Alcap	LCMF 2008
PBM-P	21.406	N 70º 17' 29.0"	W 150º 59' 20.0"	PBM in Casing	LCMF 2010
PBM-Q	21.009	N 70º 17' 30.3"	W 150º 59' 42.4"	PBM in Casing	LCMF 2010
Pile 08	16.662	-	-	HSM - cap SW bolt	LCMF 2010
Pile 568	23.719	-	-	HSM - cap SW bolt	LCMF 2010
SHEWMAN	7.085	N 70º 22' 20.2"	W 151º 06' 53.4"	Alcap	BAKER 2009

Appendix B BRIDGE DISCHARGE NOTES

452-ft Swale Bridge



Baker

Discharge Measurement Notes

Date: June 1, 2010
Computed By: JMS
Checked By: JPM

Location Name: Large Swale Bridge

Party: EJK, JPM, HLR, JMS
Start: 14:43
Finish: 16:40

Temp: 33 °F
Weather: Overcast, sprinkling rain

Channel Characteristics:

Width: 441 ft
Area: 1699 sq ft
Velocity: 2.66 fps
Discharge: 4518 cfs

Method: 5, 0.2 - 0.8
Number of Sections: 25
Count:

Spin Test: 4+min revolutions after 4+min seconds
Meter: Price AA No. 501016

GAGE READINGS			
Gage	Start	Finish	Change
3	7.85	8.09	0.24
4	7.38	7.48	0.1

Meter: 0.5 ft above bottom of weight

Weight: 30 lbs

Wading [✓ Cable] Ice Boat

[✓ Upstream] or Downstream side of bridge

GPS Data:

Left Edge of	N	70 °	20 '	23.9 "
Water:	E	150 °	58 '	31.9 "
Right Edge of	N	70 °	20 '	22.7 "
Water:	E	150 °	58 '	20 "

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

Measurement Rated: Excellent [✓ Good] Fair Poor based on "Descriptions"

Descriptions:

Cross Section: Uniform, firm on upstream side of bridge. Variable horizontal flow direction - some ice/snow at LEW

Flow: Rising stage - variable tail water, ponded, control

Remarks:

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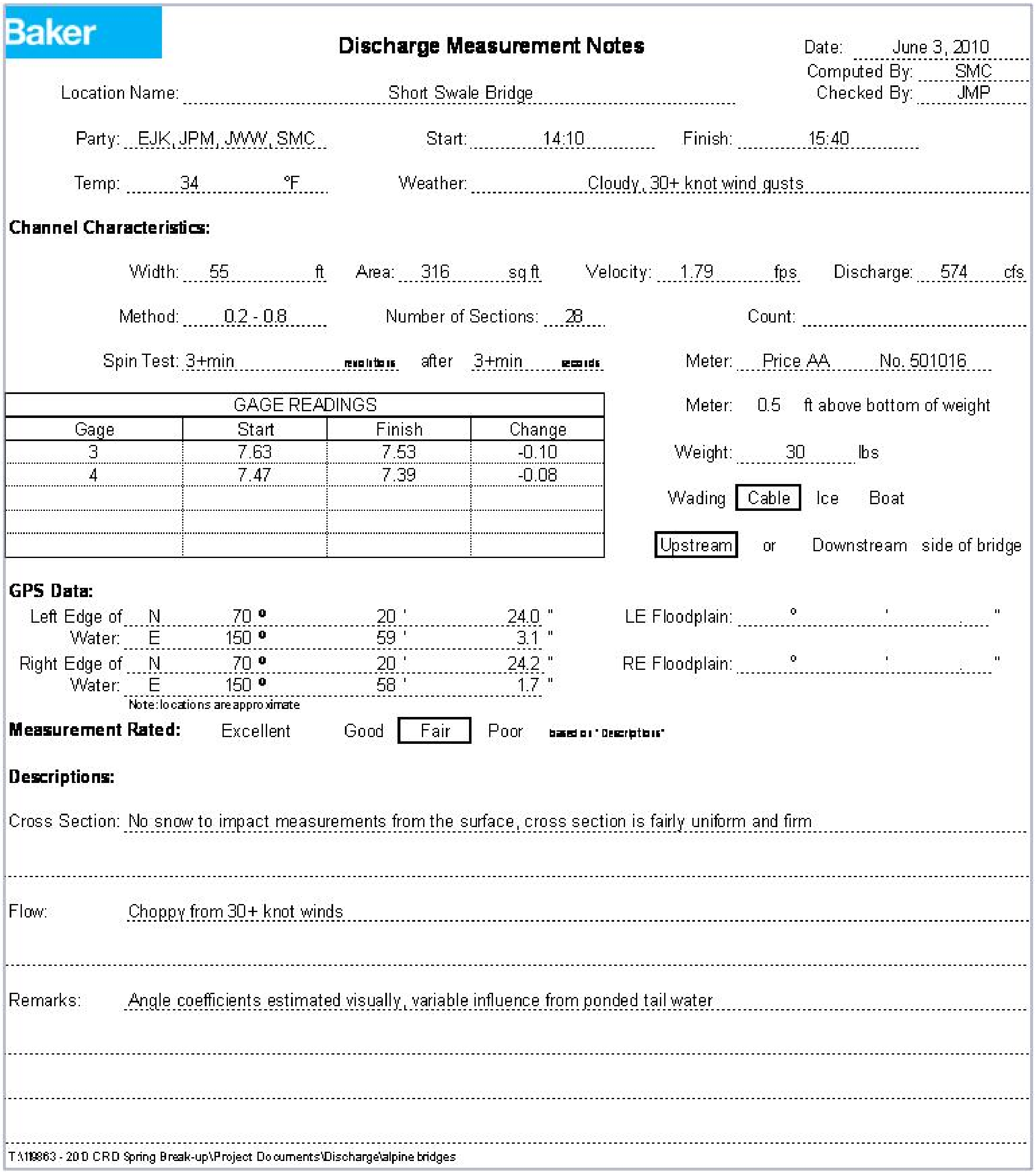
Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
	5	0.5	1.0							0.5	0
	6	2.5	3.2							8.0	0
-0.65	10	9.5	3.1		10	47	0.49	0.44	-0.28	29.5	-8.4
0.92	25	15.0	3.5	2.8 0.7	5 5	75 55	0.16 0.22	0.19	0.18	52.5	9.3
1	40	22.5	3.3	2.6 0.7	25 25	40 48	1.40 1.17	1.28	1.28	74.3	95.1
1	70	27.5	3.3	2.6 0.7	70 50	43 41	3.61 2.71	3.16	3.16	90.8	286.5
1	95	25.0	3.4	2.7 0.7	70 50	42 40	3.69 2.77	3.23	3.23	85.0	274.8
0.98	120	25.0	3.8	3.0 0.8	60 50	40 48	3.33 2.31	2.82	2.76	95.0	262.5
0.99	145	25.0	3.9	3.1 0.8	60 50	42 47	3.17 2.36	2.77	2.74	97.5	266.9
0.99	170	22.5	3.6	2.9 0.7	70 50	46 48	3.37 2.31	2.84	2.82	81.0	228.0
0.99	190	20.0	3.5	2.8 0.7	80 50	52 46	3.41 2.41	2.91	2.88	70.0	201.8
0.99	210	20.0	4.1	3.3 0.8	80 50	52 46	3.41 2.41	2.91	2.88	82.0	236.4
0.99	230	20.0	4.1	3.3 0.8	80 50	48 43	3.69 2.58	3.14	3.11	82.0	254.7
0.98	250	20.0	4.3	3.4 0.9	80 50	44 42	4.03 2.64	3.33	3.27	86.0	281.0
0.97	270	20.0	5.0	4.0 1.0	80 60	46 50	3.85 2.66	3.26	3.16	100.0	316.0
0.98	290	20.0	4.0	3.2 0.8	80 60	41 43	4.32 3.09	3.71	3.63	80.0	290.6
0.98	310	20.0	3.8	3.0 0.8	80 60	46 41	3.85 3.24	3.55	3.48	76.0	264.3
0.97	330	20.0	4.1	3.3 0.8	80 50	52 46	3.41 2.41	2.91	2.82	82.0	231.6
0.95	350	20.0	3.8	3.0 0.8	60 40	45 48	2.96 1.86	2.41	2.29	76.0	173.7
0.94	370	22.5	4.2	3.4 0.8	60 50	46 45	2.89 2.47	2.68	2.52	94.5	238.1
0.94	395	25.0	4.4	3.5 0.9	60 40	45 40	2.96 2.22	2.59	2.43	110.0	267.8
0.97	420	22.5	4.1	3.3 0.8	50 40	41 45	2.71 1.98	2.34	2.27	92.3	209.6
0.99	440	12.5	3.8	3.0 0.8	60 40	51 40	2.61 2.22	2.42	2.39	47.5	113.7
0.98	445	3.0	4.5	3.6 0.9	40 30	44 41	2.02 1.63	1.83	1.79	13.5	24.2
	446	0.5	4.0					0.9		2.0	0.0

Total Discharge: 4518.3

62-ft Swale Bridge



Baker

Discharge Measurement Notes

Date: June 3, 2010
Computed By: SMC
Checked By: JMP

Location Name: Short Swale Bridge

Party: EJK, JPM, JWW, SMC
Start: 14:10
Finish: 15:40

Temp: 34 °F
Weather: Cloudy, 30+ knot wind gusts

Channel Characteristics:

Width: 55 ft
Area: 316 sq ft
Velocity: 1.79 fps
Discharge: 574 cfs

Method: 0.2 - 0.8
Number of Sections: 28
Count:

Spin Test: 3+min revolutions after 3+min seconds

Meter: Price AA No. 501016

Meter: 0.5 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	7.63	7.53	-0.10
4	7.47	7.39	-0.08

GPS Data:

Left Edge of	N	70 °	20 '	24.0 "
Water:	E	150 °	59 '	3.1 "
Right Edge of	N	70 °	20 '	24.2 "
Water:	E	150 °	58 '	1.7 "

Note: locations are approximate

LE Floodplain: ° ' "

RE Floodplain: ° ' "

Measurement Rated: Excellent Good [✓ Fair] Poor based on "Descriptions"

Descriptions:

Cross Section: No snow to impact measurements from the surface, cross section is fairly uniform and firm

Flow: Choppy from 30+ knot winds

Remarks: Angle coefficients estimated visually, variable influence from ponded tail water

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Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY			Area (s.f.)	Discharge (cfs)
							At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)		
0.8	3	0.5	3.0					0.52	0.42	1.5	0.6
0.86	4	1.5	4.0	3.2	30	51	1.31	1.04	0.90	6.0	5.4
				0.8	15	44	0.77				
0.9	6	2.0	4.5	3.6	20	41	1.09	0.99	0.89	9.0	8.0
				0.9	20	51	0.88				
0.96	8	2.0	4.3	3.4	20	50	0.90	1.18	1.13	8.6	9.7
				0.9	30	46	1.46				
0.96	10	2.0	4.8	3.8	40	47	1.89	1.89	1.82	9.6	17.5
				1.0	40	47	1.89				
0.96	12	2.0	4.5	3.6	40	49	1.82	1.94	1.87	9.0	16.8
				0.9	41	44	2.07				
0.97	14	2.0	5.1	4.1	40	47	1.89	1.98	1.92	10.2	19.6
				1.0	40	43	2.07				
0.99	16	2.0	5.2	4.2	30	41	1.63	2.02	2.00	10.4	20.8
				1.0	50	46	2.41				
1	18	2.0	5.5	4.4	30	42	1.59	1.93	1.93	11.0	21.2
				1.1	50	49	2.27				
1	20	2.0	5.9	4.7	30	43	1.56	1.94	1.94	11.8	22.8
				1.2	50	48	2.31				
1	22	2.0	5.4	4.3	40	50	1.78	2.00	2.00	10.8	21.6
				1.1	50	50	2.22				
1	24	2.0	5.5	4.4	40	52	1.71	1.94	1.94	11.0	21.4
				1.1	40	41	2.17				
1	26	2.0	6.6	5.3	30	52	1.29	1.66	1.66	13.2	21.9
				1.3	40	44	2.02				
1	28	2.0	6.0	4.8	40	54	1.65	1.81	1.81	12.0	21.8
				1.2	40	45	1.98				
1	30	2.0	6.2	5.0	40	52	1.71	1.82	1.82	12.4	22.6
				1.2	40	46	1.94				
1	32	2.0	7.0	5.6	30	41	1.63	1.74	1.74	14.0	24.4
				1.4	40	48	1.86				
1	34	2.0	6.5	5.2	40	47	1.89	1.94	1.94	13.0	25.2
				1.3	40	45	1.98				
1	36	2.0	6.8	5.4	40	45	1.98	2.07	2.07	13.6	28.2
				1.4	40	41	2.17				
1	38	2.0	7.2	5.8	40	45	1.98	2.12	2.12	14.4	30.6
				1.4	50	49	2.27				
1	40	2.0	8.0	6.4	30	40	1.67	2.02	2.02	16.0	32.3
				1.6	50	47	2.36				
0.99	42	2.0	7.6	6.1	30	41	1.63	2.00	1.98	15.2	30.1
				1.5	50	47	2.36				
0.98	44	2.0	7.4	5.9	25	41	1.36	1.97	1.93	14.8	28.6
				1.5	50	43	2.58				
0.96	46	2.0	7.4	5.9	30	41	1.63	2.08	1.99	14.8	29.5
				1.5	50	44	2.52				
0.94	48	2.0	7.2	5.8	20	43	1.04	1.78	1.68	14.4	24.1
				1.4	50	44	2.52				
0.92	50	3.0	6.8	5.4	20	45	1.00	1.76	1.62	20.4	33.0
				1.4	50	44	2.52				
0.92	54	3.5	3.3	2.6	40	40	2.22	2.56	2.35	11.55	27.2
				0.7	60	46	2.89				
0.9	57	2.0	3.0	2.4	40	43	2.07	1.66	1.49	6.0	8.9
				0.6	25	45	1.24				
0.85	58	0.5	2.0	1.6				0.83	0.70	1.0	0.7

Total Discharge: 574.5

Michael Baker Jr., Inc.
1400 W. Benson Blvd., Suite 200
Anchorage, Alaska 99503
907-273-1600

Colville River Delta Spring Breakup
2010 Hydrologic Assessment

119863-MBJ-RPT-001
November 2010