2008 Colville River Delta
Spring Breakup & Hydrologic Assessment

Prepared for

ConocoPhillips Alaska

Baker

Michael Baker Jr., Inc.
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Executive Summary

This report presents observations and findings of the 2008 Colville River Delta spring breakup and hydrologic assessment conducted by Michael Baker Jr., Inc. (Baker) at the request of ConocoPhillips Alaska (CPAI). The assessment was conducted in support of the Alpine Development Project and Alpine Satellite Development Plan, representing the seventeenth consecutive year of study.

Observations and measurements of water surface elevation were recorded at 9 locations throughout the Delta and 20 locations adjacent to Alpine facilities. The peak water surface elevation at the head of the Delta (Monument 1) occurred in the early evening of May 30. The peak water surface was measured at 17.29 feet (BPMSL) approximately 2.5 feet lower than the maximum peak water surface elevation observed over the historic record. The peak was a result of ice jamming immediately downstream at the Nigliq and East Channel bifurcation of the Colville River.

The 2008 peak discharge occurred on May 28 and was estimated to be 221,000 cfs. The water surface elevation at the time of the peak discharge was estimated to be approximately 12.7 feet, well below the measured peak water surface elevation. The peak discharge has a recurrence interval of 2 years based on the Colville River flood frequency analysis.

Ice jams occurred in both the East and Nigliq Channels. Ribbon ice remained intact in the Nigliq Channel until June 1. No impacts to the HDD Colville River crossing site or Alpine facilities were observed as a result of ice jams.

Alpine drinking water lake L9313 recharged to bankfull conditions from flooding out of the Sakoonang Channel. Lake L9312 did not receive floodwaters and did not recharge to bankfull, but did see a rise in water surface elevation from snowmelt runoff. Peak water surface elevations around Alpine facilities had a recurrence interval of less than 2 years based on the 2006 stage frequency analysis.

Conveyance of flow through Alpine drainage structures was only observed along the CD2 access road at the Alpine swale bridges and five neighboring culverts. No flow was observed in culverts of the CD4 road. Snow and ice had little impact on the hydraulic performance of facilities drainage structures. No significant erosion was observed on any of the gravel structures subjected to floodwater. All facilities withstood breakup floodwaters without erosion or damage.

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Table of Contents

List of Figures

List of Charts

List of Graphs

List of Tables

List of Photographs

Appendices

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1.0 Introduction

The Alpine facilities are owned by ConocoPhillips, Alaska (CPAI) in conjunction with Anadarko Petroleum Company, and are operated by CPAI. The facilities are located within the floodplain of the Colville River Delta (Delta or CRD) on the North Slope of Alaska. Alpine facilities refers to the CD1 processing facility (Alpine) and CD2, CD3, and CD4 drilling pads, access roads, and associated pipelines. Spring breakup flooding is the largest annual flooding event in the CRD and monitoring of this event is integral to understanding regional hydrology and maintaining the continued safety of the environment, oilfield personnel, and facilities during the annual flooding event. Spring breakup monitoring activities have been conducted specifically for the Alpine Development Project since 1992 and the 2008 hydrologic field program represents the 12th consecutive year of Michael Baker Jr. Inc. (Baker) investigations.

Observations and measurements in 2008 were recorded at 9 locations in the CRD and 20 locations adjacent to existing Alpine facilities, including the CD3 pipeline bridge crossings. In addition, observations were recorded for 67 drainage structures. Fieldwork began May 8 and was completed June 2, 2008. Figure 1-1 identifies the 2008 monitoring region.

This 2008 Spring Breakup and Hydrologic Assessment report presents results of the 2008 spring breakup monitoring program.

- Section 1.0, Introduction, discusses the objectives of the monitoring program and presents climatic and breakup timing information.
- Section 2.0, 2008 Monitoring Locations, outlines and discusses the 2008 monitoring sites.
- Section 3.0, Methods, describes the methods of both the fieldwork and the data analyses.
- Section 4.0, 2008 Spring Breakup, presents the observations, stage, and discharge results as well as a discussion of the Alpine pad and erosion survey, drinking water lakes recharge, and ice bridge monitoring.
- Section 5.0, Reference Material, contains the references used in the development of this report. A list of Acronyms (Section 5.2) and a Glossary (Section 5.3) are included to assist the reader.
- Appendices include survey control, gage locations, and direct discharge measurement reports.

We would like to thank Alaska Kuukpik/LCMF, Inc., and Maritime Helicopters for their continued assistance with the CRD water resources field work. Their support contributed to another safe and productive breakup monitoring season and is sincerely appreciated. We would especially like to thank CPAI for their continued trust in us to complete this work.

1.1 2008 Monitoring Objectives

The primary objective of the 2008 spring breakup monitoring program was to estimate the magnitude of breakup flooding by documenting the distribution of floodwater, measuring water levels throughout the CRD, and directly measuring discharge at Monument 1. Monument 1 is located approximately 3 miles southeast of Nuiqsut. All flows within the Colville River pass through this reach before entering the Delta. Figure 1-1 is an aerial of the program area showing the CRD monuments monitored in 2008.

Alpine facilities were monitored to satisfy permit stipulations identified in USACE Permit No. POA-2004-253 and State of Alaska Fish Habitat Permit FH04-III-0238. This included direct and indirect measurements of discharge through existing drainage structures, and documentation of pad and access road erosion. Figure 1-2 shows the Alpine facilities gages monitored in 2008.

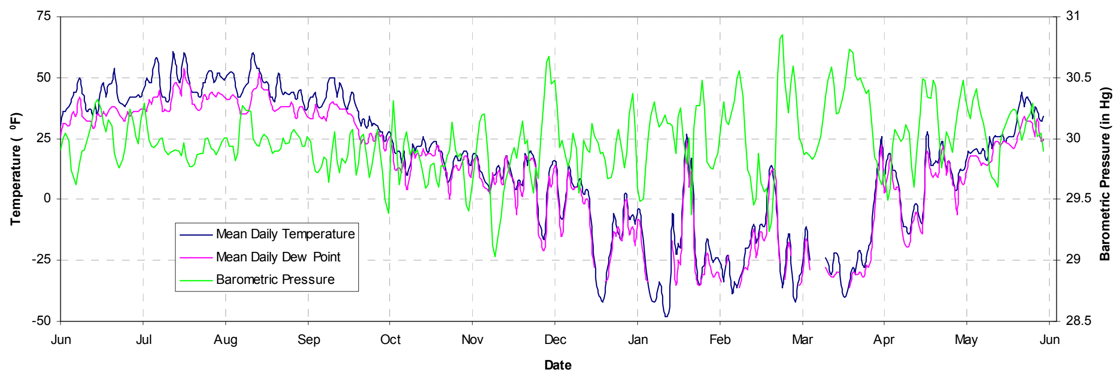
Monitoring of recharge to Lakes L9312 and L9313 was completed to comply with State of Alaska permits FG99-111-0051-Amendment #5 and FG97-111-0190-Amendment #5, respectively. The Alpine facilities rely on water withdrawal from these lakes for daily operations, the volume of which is dictated in part by annual spring recharge.

The 2008 spring breakup program also documented observations of impacts to flow and channel morphology due to the winter ice bridges across the Colville River at the HDD crossing and the Nigliq Channel.

1.2 Climatic Review

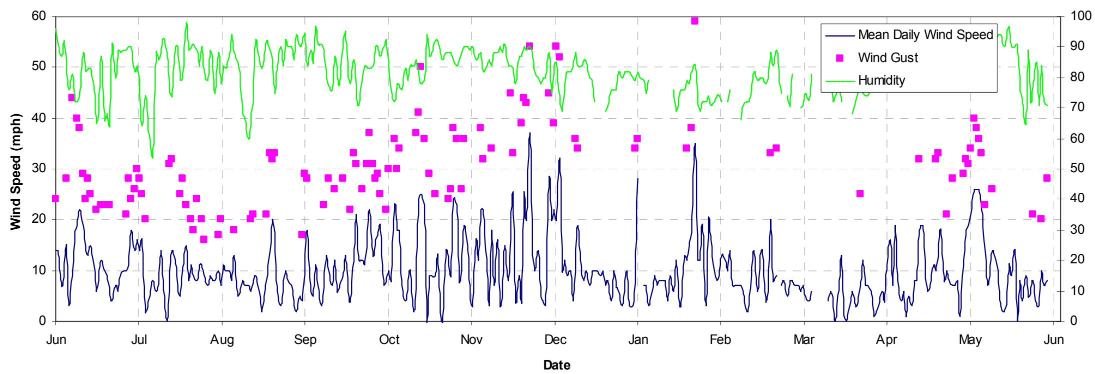
The open water season for the CRD is generally limited to a four month period (June – September). Spring is dominated by flooding, which can be divided into pre-breakup flooding, breakup flooding, and post-breakup flooding (Walker and Hudson 2003). Conditions such as snow pack, sustained cold or warm temperatures, ice thickness, wind speed and direction, and precipitation contribute to the breakup cycle.

Consistent historic climatic data, which can be used as a corollary to the magnitude and timing of breakup, is limited to daily temperatures and mean daily wind speeds. The CRD spring breakup has been monitored intermittently since 1962 and has generally occurred between May 11 and June 17. Historic daily mean air temperatures, from 1992 to 2006, were compiled from weather stations at Anaktuvuk Pass, Nuiqsut, Kuparuk, and Alpine. Historic record temperatures ranged from -8°F to 70°F during the May 11 to June 17 spring breakup period; in 2008, daily mean temperatures ranged from 14°F to 69°F. Mean daily temperatures, dew point and barometric pressure over the year, from June 1, 2007 to May 31, 2008, are presented in Graph 1-1. Mean daily wind speeds, maximum daily wind gusts, and humidity are presented for the year in Graph 1-2.



Graph 1-1 Mean Daily Temperature, Dew Point, and Barometric Pressure (June 2007 – May 2008)

Source: Weather Underground



Graph 1-2 Mean Daily Wind Speed and Maximum Daily Wind Gust (June 2007 – May 2008)

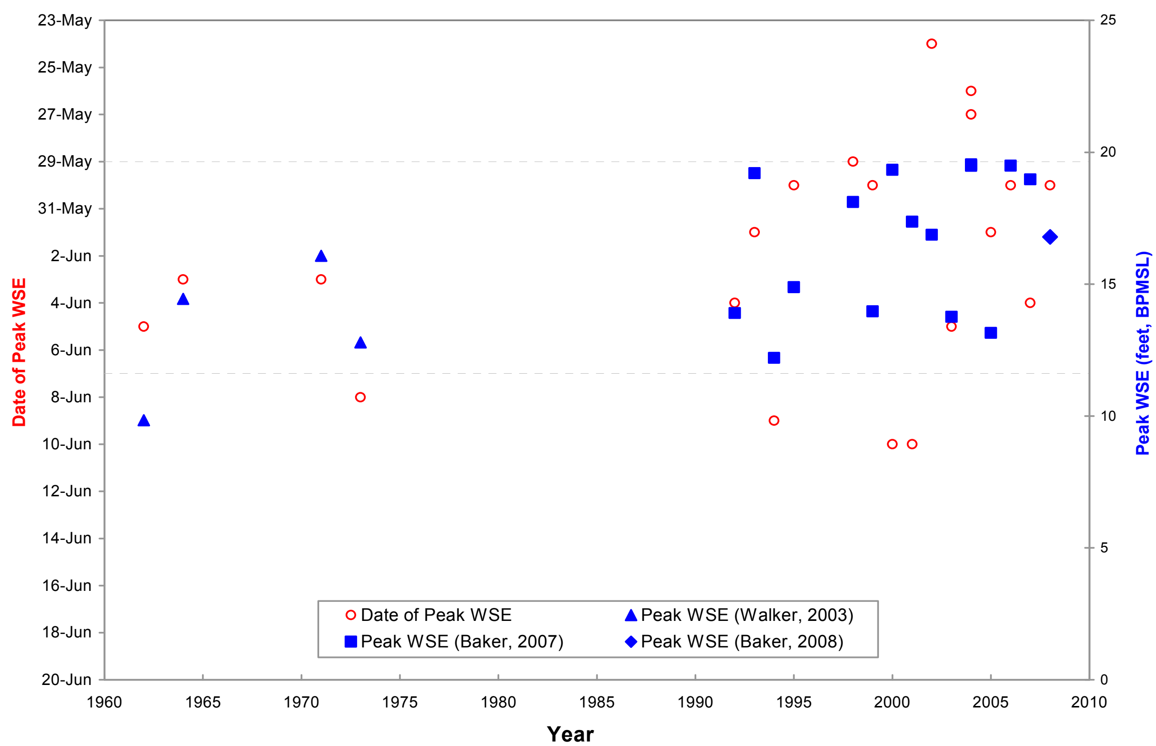
Source: Weather Underground

The quantity of pre-breakup snow pack and its associated snow water equivalence are largely impacted by wind and relative humidity. Snow density and depth, and ultimately snow water equivalence and snowmelt runoff, can increase as wind deposits snow across topographic irregularities and reduces particle size via ablation. Increased winds and reduced relative humidity accelerate sublimation (equivalent to evaporation), in effect reducing snow water equivalence and available snowmelt runoff.

1.3 2008 Breakup Timing and Water Surface Elevation

Graph 1-3 presents the date and stage of peak water surface elevations (WSE) near Monument 1 for those years where data is available. The elevations and dates of breakup at the head of the Delta for 1962, 1964, 1971, and 1973 were presented in Walker and Hudson (2003) and for 1992 through 2007 in Baker (2007b). Elevations presented by Walker and Hudson were in reference to meters above sea level (MASL) and were converted to feet BPMSL (British Petroleum mean sea level), assuming that zero MASL is equal to zero feet BPMSL, for this graphical presentation.

All elevations presented in this report are in feet and are based on the BPMSL datum.



Graph 1-3 Monument 1 Annual Peak Water Surface Elevations and Dates

Peak water surface elevations in the CRD have typically occurred within a 10-day period, from May 29 to June 7, as shown in Graph 1-3. The 2008 peak WSE occurred at Monument 1 on May 30, within the historic 10-day period for peak WSE. The peak WSE was measured at 17.29 feet (BPMSL). This value is lower than maximum peak water surface elevation of 19.83 observed over the historic record. The peak discharge was estimated to have occurred on May 28, prior to peak stage.

The timing and magnitude of peak WSE in the vicinity of the Alpine facilities is typically one or two days following the peak at Monument 1 and that pattern was consistent in 2008, with peak stage initially occurring near facilities on May 30. Section 4.1 discusses the timing of spring breakup events within the Delta.

Section 4.3.3 addresses historic annual peak water surface elevations across the CRD and presents a comparison with 2008 peak WSE.

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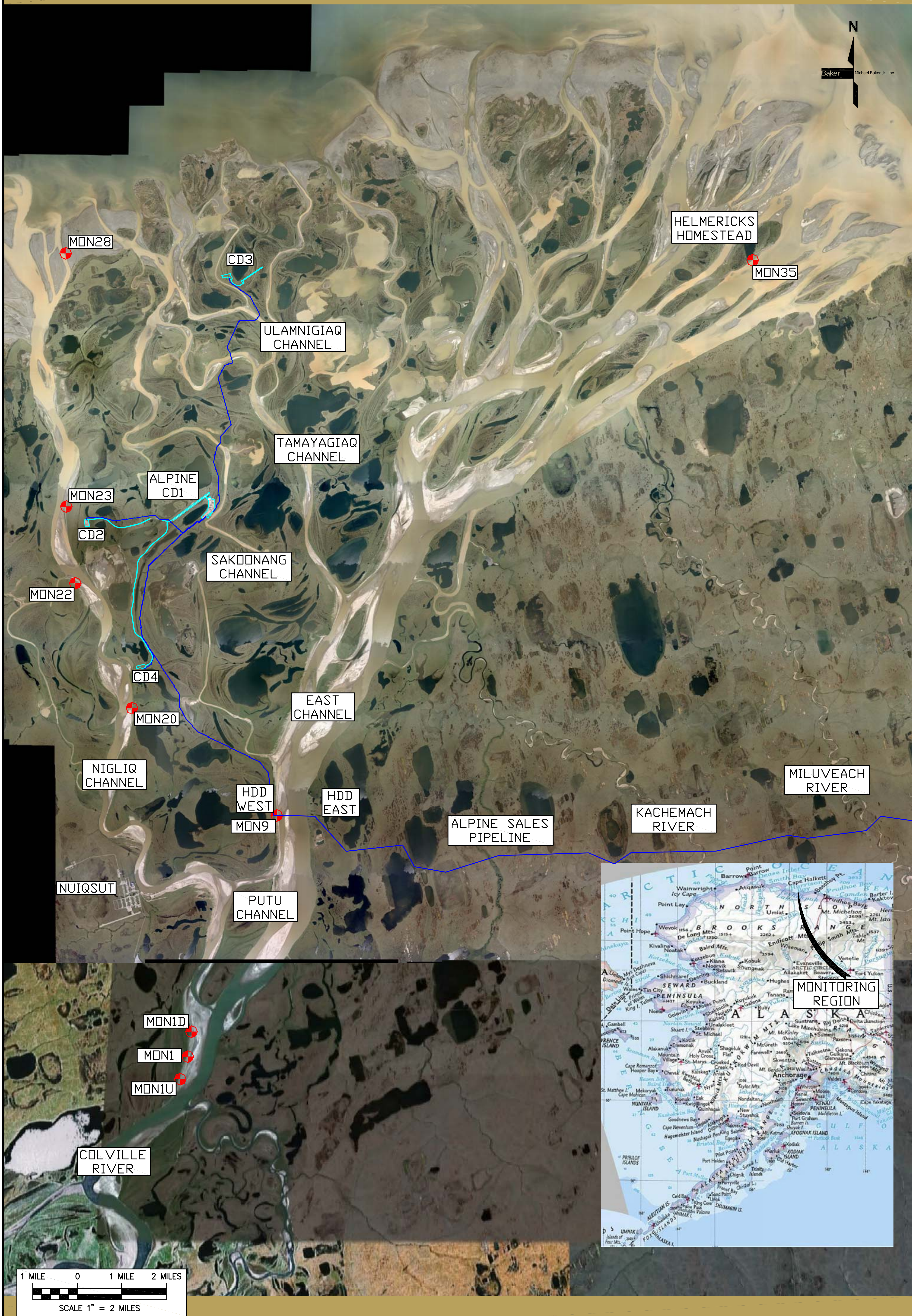

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2008 SPRING BREAKUP
COLVILLE RIVER DELTA
MONUMENTS

FIGURE 1-1
(SHEET 1 OF 1)

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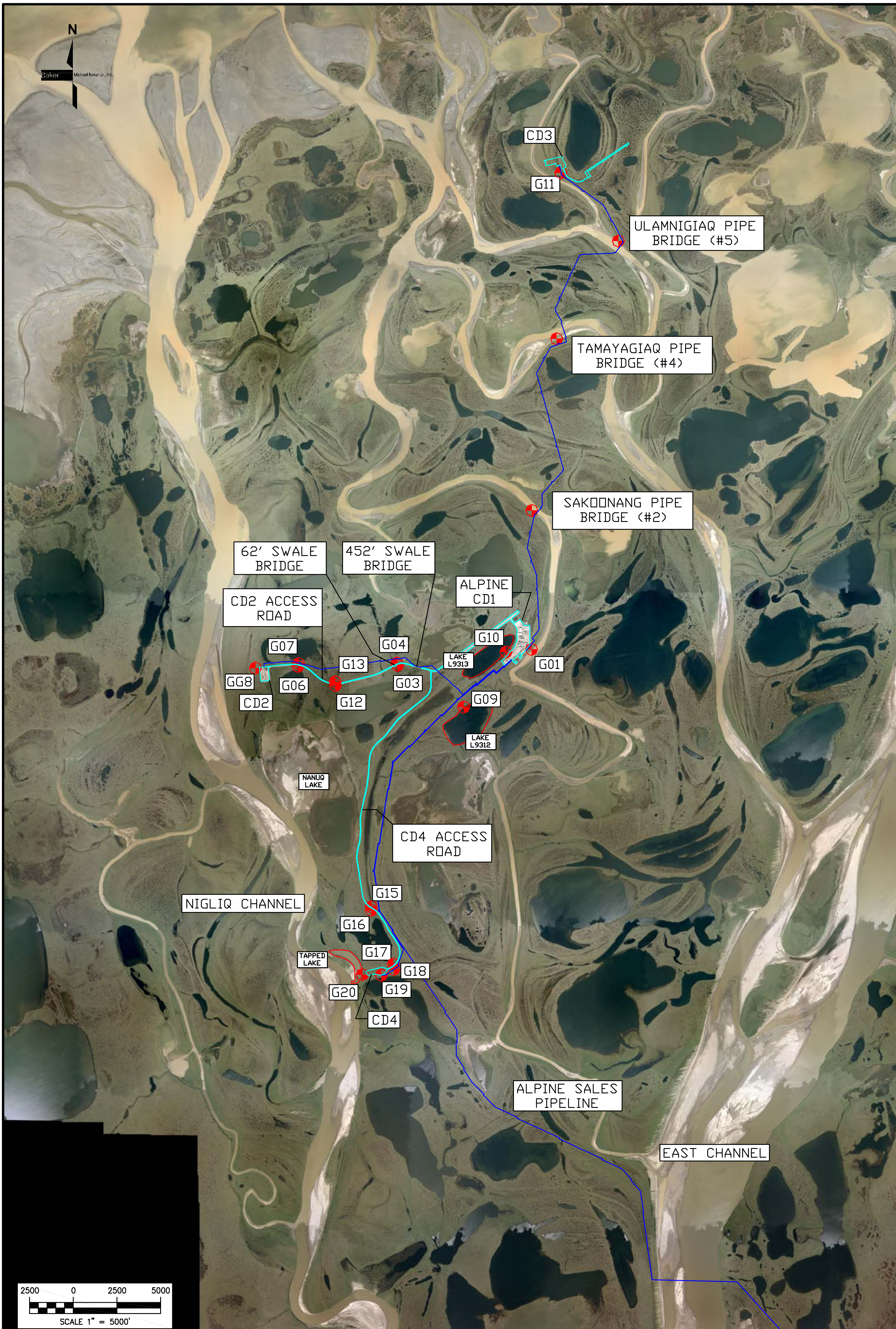

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2008 SPRING BREAKUP
ALPINE FACILITIES
GAGES

FIGURE 1-2
(SHEET 1 OF 1)

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2.0 2008 Monitoring Locations

The CRD 2008 monitoring locations were the same as those presented in the *2007 Colville River Delta Spring Breakup and Hydrologic Assessment* (Baker 2007b), except for the addition of Alpine Gages 8, 12, and 13. Gage 8 was added as a replacement gage for one that was removed during the CD2 Qannik pad expansion two winters ago. This gage provides WSE for overbank floodwater from the Nigliq Channel at the CD2 pad. Gages 12 and 13 were added to gain a better understanding of WSE along the CD2 road. Details of the 2008 monitoring program locations are outlined in Table 2-1, identified in Figure 1-1 and Figure 1-2, and tabulated in Appendix A.

Table 2-1 2008 Monitoring Program Locations

Colville River Delta (CRD)	17	Alpine Gage Locations (Gages)	Located at CD1, CD2, CD3, and CD4
	3	River Crossings	Study sites at each CD3 pipeline river crossing bridge
	9	Monument Gage Locations (Monuments)	Includes Monument 35 at Helmericks Homestead
Drainage Structures	2	Alpine Swale Bridges	62-foot and 452-foot bridges
	65	Alpine Culverts	CD2 (26), CD3 (1), CD4 (38)
Total	96		

2.1 Colville River Delta

2.1.1 Monuments

The 2008 CRD monitoring sites extended from the head of the CRD at Monument 1, river mile (RM) E27.1, to near the downstream boundaries of the Delta at Monument 28 (RM N1.7) and the Helmericks Homestead (Monument 35 at RM E3.0) (Figure 1-1). River miles start at the mouth of the Delta (Harrison Bay) and project upstream along the Nigliq (N) and East (E) Channels.

The Monument 1 reach includes gage sets at Monument 1 Downstream (RM E26.6), Monument 1 (RM E27.1), and Monument 1 Upstream (RM E27.6); each is installed on the west bank of the Colville River. Photo 2-1 shows the Monument 1 reach on May 24, 2008. This is the only portion of the Colville River where the flow from all primary contributors is confined in a single channel prior to the East Channel and Nigliq Channel bifurcation. Monument 1 has been monitored annually since 1992.

Monument 28 and the Helmericks Homestead (Monument 35) monitoring locations are within the braided floodplain of the Delta's downstream boundary at Harrison Bay. Monuments 28 and Helmericks Homestead have been monitored intermittently since 1999.

Monitoring of the East Channel included Monument 9 gages (RM E20.5), located on the west bank of the East Channel (Photo 2-2) at the horizontal directionally drilled (HDD) crossing of the Alpine Sales Pipeline. This location is downstream of the Putu Channel and upstream of the Sakoonang Channel distributary. Monument 9 was selected to represent the conditions in the Colville River East Channel at the HDD crossing site.

Monitoring locations along the Nigliq Channel included gages at Monument 20 (RM N13.1) near CD4 pad, Monument 22 (RM N9.7), and Monument 23 (RM N7.6) near CD2 pad. These locations were selected to represent conditions along the Nigliq Channel extending upstream and downstream of existing facilities. Monument 20 and Monument 23 are located on the east bank and Monument 22 is located on the west bank. These gages have been monitored intermittently since 1998.

Photo 2-1 Monument 1 Reach, May 24, 2008

Photo 2-2 Monument 9, May 24, 2008

2.1.2 Alpine Gages

Gages 1, 3, 4, 6, 7, 8, 9, 10, 12, and 13 are located adjacent to Alpine facilities at CD1 and CD2 (Figure 1-2) and represent conditions between the Sakoonang and Nigliq Channels. These gages were established to monitor conditions adjacent to existing facilities and have been monitored annually since 1998. Gage 11 (adjacent to the CD3 pad) and CD3 pipeline crossings at the Sakoonang (Crossing #2), Tamayagiaq (Crossing #4), and Ulamnigiaq (Crossing #5) Channels were established to monitor conditions at these facilities and have been monitored intermittently since 2000. Gages 15 through 20 are located adjacent to the CD4 road and pad to document water surface elevation and conveyance of flow near these facilities and have been monitored since 2005.

3.0 Methods

This section describes the methods used in 2008. Field methods are based on standard techniques proven to be safe, reliable, efficient, and accurate for the conditions found in the CRD during spring breakup.

3.1 Visual Observations

Visual observations were conducted from the ground via Hägglund tracked vehicles between May 10 and May 20, and from the air via helicopter between May 21 and June 2, 2008. Observations were recorded daily in field notebooks. Additionally, digital photographs were collected to document the extent of spring breakup prior to, during, and after peak breakup. With each photograph, the horizontal position of the camera, date, and time were electronically imprinted onto each electronic file.

Particular attention was paid to the Alpine facilities, including access roads and pipelines, and the ice bridge crossings of the East Channel and Nigliq Channel. Visual inspections were performed daily throughout breakup and after floodwaters receded to determine any significant erosion to the Alpine facilities' pads and roads. Observations were recorded with geo-referenced photographs.

3.2 Water Surface Elevation (Stage)

3.2.1 Staff Gages

Water surface elevation was monitored using graduated stream staff gages. Measurements were collected daily. The elevation of each gage was surveyed to a local benchmark using optical differential level loop surveys. The basis of elevation for each gage and the horizontal position of respective benchmarks and gages are presented in Appendix A. The most recent basis of elevation of vertical control, as of spring 2008, was used. Gages located on the Colville River, East Channel, and Nigliq Channel were given the name of their associated benchmark monument. Surveys were completed between May 8 and May 16, 2008, prior to breakup.

Permanent staff gages (PSG) located at CD1 (Gages 1, 9, and 10), CD2 (Gages 3, 4, 6, and 7), CD3 (Gage 11), and CD4 (Gages 18 and 19) consist of permanently-mounted metal gage faceplates attached to drill steel.

Temporary staff gages set at all other locations consisted of one to five gage assemblies. Each gage assembly consisted of a metal gage faceplate mounted on a two-by-four timber attached with U-bolts to 1.5-inch angle iron posts driven into the ground. The horizontal position of each gage was recorded using a handheld Garmin 60 GPS in North American Datum of 1983 (NAD 83).

3.2.2 Pressure Transducer

Five pressure transducers were installed to collect WSE data. Pressure transducers were set at Monument 1 Upstream, Monument 1, Monument 1 Downstream, Monument 9, and Monument 23. Pressure transducers measure the pressure imparted by water at the sensor, allowing the depth of water above the sensor to be calculated. The respective effects of variations in temperature and barometric pressure were taken into account. Resulting data yielded a near complete record of the fluctuations in WSE not captured by visual measurements.

In-Situ, Inc. Level TROLL® 500 sensors were used. The instrument is a non-vented pressure sensor that collects and stores pressure data points and temperature. The factory calibrated transducers collected absolute pressure and water temperature at 15-minute intervals. The measured pressure datum is the sum of the forces imparted by both the water column and atmospheric conditions. As a result, a correction of local barometric pressure was required and obtained from an In-Situ, Inc. BaroTROLL® sensor located at HDD West (Monument 9).

Prior to deployment of each pressure transducer, the transducers were configured using Win-Situ 5®. Absolute pressure was set to zero. Transducers were housed in a segment of perforated galvanized steel pipe and clamped to angle iron set in the active channel near ground surface. The sensor of each transducer was surveyed to establish a vertical datum using local control. An additional survey was conducted prior to removal to quantify potential disturbance during breakup. Water depth was determined based on the recorded absolute pressure and barometric pressure data.

Water surface elevations were then 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 pressures. Fluctuations in water temperature have historically varied little over the sampling period (Baker 2007a, 2007b). Due to the limited range in temperature and observed water depths, the impact of temperature on the calculation of water surface elevation is less than 0.01 feet.

3.3 Discharge Measurements

Discharge was both directly measured and indirectly estimated. The methods used to directly measure discharge were standard United States Geological Survey (USGS) midsection techniques and Acoustic Doppler Current Profiler (ADCP) measurements. Generally, velocity and discharge measurements were taken as close to the observed peak stage as possible. An indirect discharge estimate is based on calculations and not a physical measurement of discharge.

3.3.1 USGS Midsection Techniques

Standard USGS midsection techniques (USGS 1982) and a Price AA velocity meter were used to measure velocities and discharge at the Alpine swale bridges. A Pygmy velocity meter was used to measure point velocities and discharge in the CD2 and CD4 access road culverts. The Price AA and Pygmy velocity meters were calibrated by the USGS at the Office of Surface Water Hydraulic Laboratory in 2006. The discharge measurement at the 452-foot swale bridge was conducted in channel using a wading rod. Measurement at the 62-foot swale bridge was conducted from the bridge deck using a sounding reel mounted on a boat-type boom with a 30-pound Columbus-type lead sounding weight. In addition, a tag line was used to define the cross section and delineate measurement subsections within the channel. Velocity measurements in the Alpine culverts were conducted using a USGS wading rod.

3.3.2 Acoustic Doppler Current Profiler (ADCP)

A direct discharge measurement of the Colville River during the breakup season presents unique and extreme challenges. Given the location, depths and velocities of flow, the presence of passing channel ice, and weather conditions, implementation of accurate USGS midsection techniques can be very difficult. ADCP allows the direct measurement of repeatable and accurate river discharge in such difficult conditions. In many cases, the ADCP discharge measurement system is considerably faster than traditional methods and can provide equivalent levels of accuracy (USGS 2006).

Direct discharge measurements on the Colville River at Monument 1 were performed using ADCP techniques and procedures following the USGS *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (2005).

HARDWARE AND SOFTWARE

A Teledyne RD Instruments™ 600 kHz Workhorse Sentinel broadband ADCP was used. The unit has a four-beam transducer with 20-degree beam. Power was supplied to the unit and supporting laptop (Panasonic Toughbook® CF-19) via a deep-cycle marine battery and 400-watt power inverter.

BBTalk v3.06, a DOS-based communication program, was used to perform pre-deployment tests. WinRiverII v1.01 was used to configure, initiate, and communicate with the ADCP while on the river. WinRiverII was also used to review and evaluate collected discharge data after returning from the field.

PRE-DEPLOYMENT TESTING

Prior to deployment of the ADCP unit, a full suite of tests were run according to the manufacturer's instructions using BBTalk. The tests confirmed that the signal path and all major signal processing subsystems were functioning properly. Tests also confirmed accurate tilt and pitch readings. A beam continuity test was performed to verify that the transducer beams were connected and operational. Pre-deployment tasks also included compass calibration and verification. Internal compass error was within the specified 2-degree limit.

ADCP Deployment and Data Collection

The Sentinel ADCP was mounted to an Achilles SGX-132 inflatable raft powered by a 25 hp outboard motor using a fabricated aluminum tube framework spanning the boat's fore gunwales (Photo 3-1). The aluminum framework provided a rigid and secure placement of the ADCP unit while allowing necessary adjustments as river conditions required.

A sampling cross section was identified at an established monitoring site (Monument 1). A minimum of four transects were completed such that measured discharges varied by less than 5% of their mean. Cross section end points were dependent on a minimum water depth to provide acceptable data, which was approximately 8 feet.

Photo 3-1 ADCP Direct Discharge Measurement Boats at Monument 1, June 1, 2008

Cross section end points were marked with handheld GPS units having WAAS enabled accuracy. The position of the boat was determined by tracking the bottom of the channel with the ADCP. Distances to the right and left edge of water from respective end points were estimated from GPS identified coordinates.

ADCP Background and Data Processing

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

In channels like the Colville, where the bed material is composed of fine-grained material and water velocities are sufficient to entrain bed materials, a moving bed can result. When using bottom tracking, a moving bed will tend to impact the accuracy of the results by biasing the velocity and discharge lower than actual values. This phenomenon can be eliminated with the use of DGPS or the Loop Method (USGS 2006). To account for the bias introduced by a moving bed, the Loop Method was employed in the absence of DGPS.

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

3.3.3 Indirect Discharge Calculations

The indirect discharge calculations used physical characteristics, such as WSE and slope, as input variables of hydraulic equations to calculate discharge. Indirect discharge calculations were performed for the Alpine infield culverts and swale bridges, and the Colville River and Nigliq Channel.

The software CulvertMaster® v1.0 was used to estimate discharge through the in-field culverts. Recorded water surface elevations and times of peak stage observations were used to estimate the timing of peak discharge. The average velocity and discharge through the culverts were estimated based on the following variables:

- Headwater and tailwater elevations adjacent to each culvert;
- Culvert diameter and length (from Kuukpik/LCMF as-built surveys);
- 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 calculations of peak discharge through the swale bridges were performed by correlating hydraulic depths observed during direct discharge measurements and peak discharge conditions. This method assumes that the average measured velocity varies little between direct measurements and peak discharge. The assumption is valid if the observed increase in stage and upstream-downstream stage differential is relatively low. Direct discharge measurements are thus collected as near to peak discharge as possible.

Indirect estimates of peak discharge for the Colville River and Nigliq Channel were also calculated using the slope-area method for a uniform channel (Benson and Dalrymple 1967). Water surface elevation and slope data were obtained from observations made at gages. Cross-section geometry was based on cross sections surveyed by Kuukpik/LCMF in 2005 and 2004 on the Nigliq Channel and Colville River, respectively. Adjustments were made to the cross sectional flow area, wetted perimeter, and roughness coefficients to account for the presence and impact of ribbon ice in both channels at the time of peak discharge.

3.4 Flood and Stage Frequency Analysis

The flood recurrence interval was determined by comparing the estimated 2008 peak discharge to the flood frequency analysis results developed for the Colville River Delta (Baker and Hydroconsult 2002).

Observed 2008 peak water surface elevations were compared to those predicted by the 2-dimensional surface water model of the Colville River Delta to estimate the 2008 flood recurrence interval. The model was developed during the original design of Alpine and has been updated throughout the life of the Alpine facilities. Stage recurrence intervals were also estimated by comparing the 2008 observations to the historic stage frequency analysis results within the CRD (Baker 2007a).

4.0 2008 Spring Breakup

This chapter presents data, images, and analyses for the 2008 CPAI CRD spring breakup monitoring program. Section 4.1 summarizes the spring breakup observations and monitoring activities. Section 4.2 details discharge measurements and analyses for Monuments 1, the Alpine swale bridges, and the Alpine culverts. Section 4.3 addresses peak stage within the CRD relative to flood frequency and stage frequency analyses. The results of the Alpine pad and road erosion survey are addressed in Section 4.4. The Alpine lakes recharge assessment is presented in Section 4.5 and Section 4.6 discusses the Colville River and Nigliq Channel ice bridge monitoring. Figures are collected in Section 4.7. Tabulated stage, discharge measurements, and observation records are at the end of the chapter in Section 4.8.

4.1 Hydrologic Observations Summary (May 21 – June 2)

Hydrologic observations in the Colville River Delta and for the Alpine facilities were documented between May 21 and June 2, 2008; they are described in the following sections. Chart 4-1 is a timeline of the major 2008 breakup events.

4.1.1 Colville River Delta

Initial flow was observed on the morning of May 21 in the Chandler (Photo 4-1), Colville (Photo 4-2), and Anaktuvuk Rivers. The leading edge of flow in the Chandler River had reached the Colville River, while the leading edge of flow in the Colville River was about a half mile upstream of the Chandler-Colville confluence, approximately 77 river miles upstream from the head of the CRD (Monument 1). The leading edge of flow in the Anaktuvuk River was about 3.5 miles upstream of the Anaktuvuk-Colville confluence. Magnitude of flow in all three rivers on May 21 was relatively low and progressing at a slow rate.

On the following day, May 22, flow in the Colville and Chandler Rivers had converged and progressed downstream approximately 6 miles. Vigorous flow was observed in the Anaktuvuk River and Anaktuvuk floodwaters reached the Colville River that evening (Photo 4-3).

The leading edge of flow in the Colville River progressed at a rate of about 0.8 miles per hour and, on May 24, was approximately 20 river miles upstream of Monument 1 (about 10 river miles upstream of Ocean Point).

Early on May 26, the floodwaters reached Monument 1 (Photo 4-4). By midday on May 27, the leading edge had progressed through the west channel (Nigliq Channel) and reached Harrison Bay.

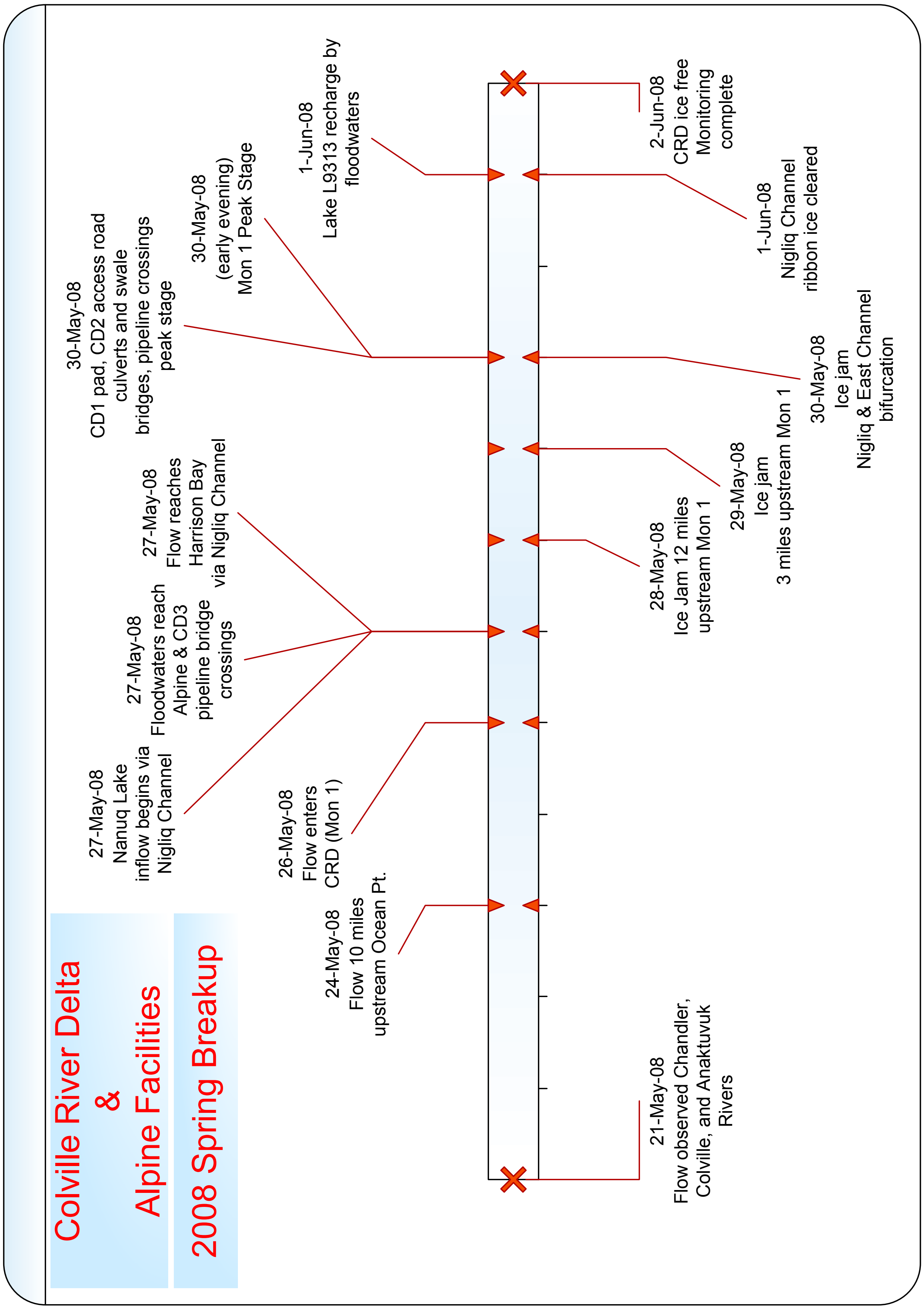


Chart 4-1 Timeline 2008 Spring Breakup

Photo 4-1 Leading Edge of Chandler River at Colville River Confluence, May 21, 2008

Photo 4-2 Leading Edge of Colville Floodwaters (77 Miles Upstream of Nuiqsut), May 21, 2008

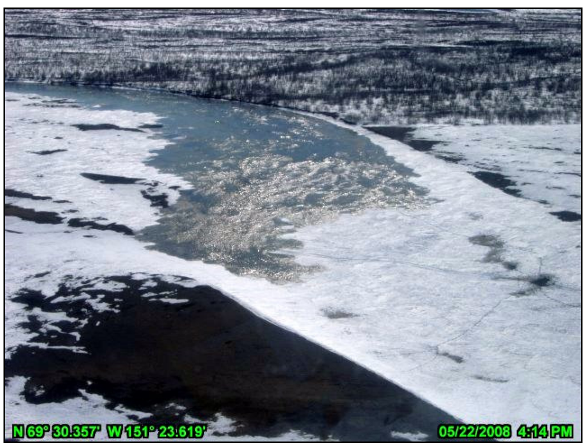


Photo 4-3 Leading Edge of Anaktuvuk River near Colville River Confluence, May 22, 2008

Photo 4-4 Floodwaters reach Monument 1 at Head of Colville River Delta, May 26, 2008

An ice jam was observed approximately 12 miles upstream of Monument 1 in the morning on May 28 (Photo 4-5). This ice jam likely slowed the steady rise in water surface elevation in the Delta. On May 29, the ice jam had released and another jam formed approximately 3 miles upstream of Monument 1; the reach at Monument 1 was clear of channel ice (Photo 4-6 and Photo 4-7). By midday on May 30 (Photo 4-8), the ice jam released and ice flowed through the reach at Monument 1. Ice jammed again near the Nigliq and East Channels bifurcation, causing significant backwater at Monument 1. The water surface elevation began rising at the rate of about 1.5 feet per hour. Peak stage at Monument 1 occurred in the early evening on May 30 at an elevation of 17.29 feet.

Photo 4-5 Ice Jam 12 Miles Upstream Monument 1, May 28, 2008

Photo 4-6 Ice Jam 3.5 Miles Upstream Monument 1, May 30, 2008

Photo 4-7 Monument 1 Ice Free Channel, May 30, 2008

Photo 4-8 Ice Jam at Monument 1, May 30, 2008

The ice had cleared from the reach at Monument 1 on May 31 allowing a discharge measurement to be collected (Photo 4-11). Water levels throughout the CRD started to recede on May 31, except at the Monument 28 and the Sakoonang Channel gages, which began to recede on June 1.

Over the next two days (May 31-June1), random ice jams were evident within the East Channel and Nigliq Channel. Ice in the Nigliq Channel caused easterly flow through the Putu Channel throughout the spring breakup observation period. Ribbon ice in the Nigliq Channel remained until late on June 1 (Photo 4-9 and Photo 4-10).

Floodwaters continued to recede throughout the CRD until June 2, when the 2008 field observations ceased (Photo 4-12).

Photo 4-9 Nigliq Channel Ribbon Ice, June 1, 2008

Photo 4-10 Nigliq Channel Post Breakup, June 3, 2008

Photo 4-11 Monument 1 Ice Free, May 31, 2008

Photo 4-12 Monument 1 Post Breakup, June 3, 2008

Stage and observation records for the Monuments in the East and Nigliq Channels are presented in Section 4.8 (Table 4-16 through Table 4-19).

4.1.2 Alpine Facilities

Water surface elevations were monitored at gages placed around CD1, CD2, CD3, and CD4 roads, pads, and pipelines (Alpine Gages). Figure 1-2 shows the locations of the gages and pipeline bridge crossing locations where measurements were recorded.

Breakup floodwaters first reached Alpine facilities on May 27 when flow began to enter Nanuq Lake from the Nigliq Channel (Photo 4-13) and also began to arrive at the CD3 pipeline bridge crossings (Photo 4-14).

Water surface elevations around Alpine facilities rose more than one foot on May 28 prior to the formation of the ice jam 12 miles upstream of Monument 1. The approximately one river mile long ice jam dramatically slowed the rate of rise in the Nigliq Channel.

As floodwaters reached the CD2 access road swale bridges on the morning of May 28, flow under the bridges was impeded by a significant amount of packed snow (Photo 4-15). This packed snow caused a damming effect on the south side of the bridges before releasing later in the afternoon on May 28 (Photo 4-16).

In the afternoon of May 29, water was freely flowing under the long (452-foot) swale bridge. Flow under the short (62-foot) swale bridge was significantly impeded by the presence of packed snow. Discharge measurements were made at both swale bridges on May 29. Only the first four culverts (CD2-21 through CD2-24) west of the 452-foot swale bridge were observed with flow.

Photo 4-13 Floodwaters enter Nanuq Lake from Nigliq Channel, May 27, 2008

Photo 4-14 Floodwaters reach Tamayagiaq Pipeline Crossing, May 27, 2008

Photo 4-15 Snow Packed 452-foot Swale Bridge (upstream/south), May 28, 2008

Photo 4-16 452-foot Swale Bridge (upstream/south), May 29, 2008

Baker

Gage 1, located to the east of CD1 pad on the Sakoonang Channel, was monitored from May 28 to June 2 and reached a peak WSE of 5.61 feet in the early afternoon of May 30. Gage 3 and Gage 4 are located on the south and north side of the CD2 access road, respectively, between the long and short swale bridges. Gage 3 and Gage 4 were monitored from May 28 to June 2. In the early morning on May 30, they reached their respective peak WSE of 6.49 feet and 6.23 feet.

Gage 9 at Lake L9312 and Gage 10 at Lake L9313 were monitored from May 27 to June 2. Gage 9 had an initial WSE of 7.42 feet at approximately 4:55 PM on May 27 and reached a peak WSE of 7.45 feet at approximately 4:05 PM on May 31. Lake 9312 did not receive overland recharge. Gage 10 had an initial WSE of 5.84 feet at approximately 9:55 AM on May 28 and reached a peak WSE of 6.95 feet at approximately 9:00 AM on June 1. Lake L9313 did receive overland floodwater recharge beginning at approximately 4:00 PM on May 30.

Gage 15 and Gage 16 are respectively located on the east and west side of the CD4 access road. Peak WSE for Gage 15 and Gage 16 were 6.91 feet and 6.90 feet, respectively, and their peaks occurred on the evening of May 31.

Gage 20 was monitored from May 27 to June 2. It is located on the western side of the CD4 pad. A peak WSE of 7.84 feet was estimated to have occurred on the morning of May 30.

Gages 6, 7, 8, 11, 12, 13, 17, 18, and 19 were monitored throughout the spring breakup event and no floodwater was observed reaching these gages. Gages 8, 12, 13 were newly installed for the 2008 spring breakup event.

The CD 3 pipeline crossings (from south to north) are the Sakoonang, Tamayagiaq, and the Ulamnigiaq Channels. The Sakoonang pipeline crossing first recorded flood water at approximately 10:30 AM on May 28 and reached a peak WSE of 5.39 feet on May 30. The Tamayagiaq pipeline crossing first recorded an initial WSE of 1.89 feet at approximately 3:20 PM on May 26 and a peak WSE of 6.07 feet on May 30. The Ulamnigiaq pipeline crossing recorded an initial WSE of 4.79 feet on approximately 9:30 AM on May 28 and a peak WSE of 5.52 feet on May 31.

Stage and observation records for the Alpine Gages are presented in Section 4.8 (Table 4-20 through Table 4-25).

4.2 2008 Discharge

Direct measurements were made at Monument 1, the two swale bridges, and all culverts conveying flow along the gravel access roads. Indirect calculations were performed for Monument 1, Monument 23, both swale bridges, and culverts conveying flow.

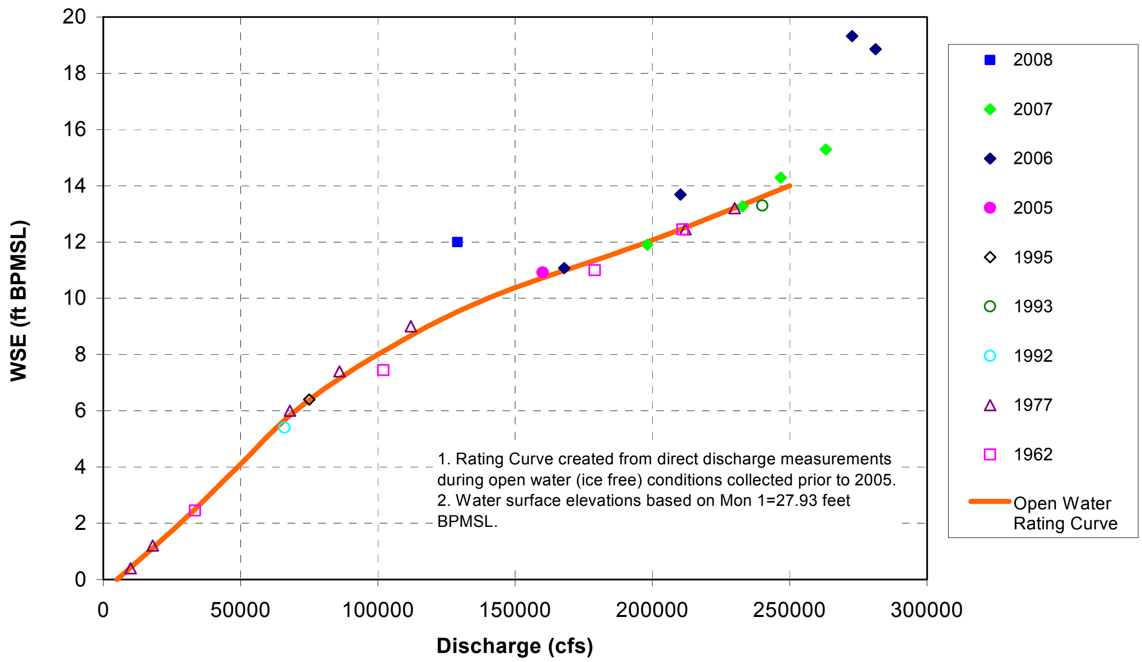
4.2.1 Monument 1 Discharge

DIRECT DISCHARGE

On May 31, a direct discharge measurement was completed on the Colville River at Monument 1 using standard ADCP techniques. Discharge was approximately 129,000 cubic feet per second (cfs) having an average velocity of 3.0 feet per second with a maximum measured velocity of 6.2 feet per second and an associated stage of 12.02 feet. A summary of direct discharge measurements and the WinRiver output windows for each transect are presented in Appendix B.

Four transects and one loop test were completed during the direct discharge measurement. Measurements could not be completed prior to May 31 due to the presence of ice along the eastern bank of the Colville River and/or the presence of large ice floes in the Monument 1 reach. After May 31, the Colville River stage was too low for a safe and accurate ADCP measurement.

The direct discharge is plotted against the Monument 1 stage-discharge rating curve in Graph 4-1. The direct discharge plots off of the rating curve. The shift is likely due to backwater from downstream ice jamming and/or sediment deposition in the channel resulting from low flow velocities. Backwater can raise water surface elevations without the normal associated increase in discharge while sediment deposition can change the bedform geometry, changing the relationship between stage and discharge. Figure 4-1 shows the location of the discharge measurement.



Graph 4-1 Monument 1 Stage-Discharge Rating Curve with Direct Discharge

Indirect Discharge

Indirect calculations used 2004 topographic survey data provided by LCMF and presented in Figure 4-1. Estimated discharge was calculated using the slope-area method and stage at Monuments 1 Upstream, Monument 1, and Monument 1 Downstream.

Indirect calculations at the time of peak stage (May 30) were largely skewed by ice jams at the Nigliq and East Channel bifurcation immediately downstream of Monument 1. Ice jamming of this magnitude and proximity causes significant backwater effects that are not accounted for when using indirect calculations. Resulting estimates cannot be presented with any level of confidence and are thus not presented here. Such impacts to indirect estimates can be seen when compared to direct measurements, as was done on the following day. By May 31, the ice jam remained in the Nigliq Channel, but had migrated several miles downstream in the East channel. Backwater was still present but not to the extent observed on May 30. Indirect calculations estimated a discharge of 161,000 cfs, whereas the corrected direct discharge measurement was 129,000 cfs.

Peak discharge at the head of the CRD was estimated to be 221,000 cfs on May 28 using indirect discharge methods at a stage of 12.68 feet. The energy grade-line slope, approximated by the water surface slope from Monument 1 Upstream to Monument 1 Downstream, and water surface elevation at

Monument 1 were used to calculate indirect discharge. The presence of ribbon ice was also taken into account by reducing cross sectional area by the displacement of the ribbon ice and increasing the wetted perimeter by the ice width. The peak indirect discharge estimate and direct discharge measurement are presented in Section 4.8 (Table 4-12 and Table 4-13).

Table 4-1 presents a historic tabulation of published peak annual discharge and peak stage between 1992 and 2008.

Table 4-1 Colville River Breakup Annual Discharge, 1992-2008

Year	Monument 1 Peak Discharge (cfs)			Monument 1 Peak Water Surface Elevation (feet-BPMSL)	
	Discharge	Method	Reference	Mon 1	Reference
2008	221,000	Estimated-Indirect Calculation	This report	17.29	This report
2007	270,000	ADCP Measurement	Baker 2007b	18.97	Baker 2007b
2006	281,000	ADCP Measurement	Baker 2007a	19.83	Baker 2007a
2005	195,000	Estimated-Mon 1 Rating Curve	Baker 2005b	13.18	Baker 2005b
2004	360,000	Estimated-Indirect Calculation	Baker 2005a	19.54	Baker 2005a
2003	232,000	Estimated-Mon 1 Rating Curve	Baker 2006a	13.76	Baker 2003
2002	249,000	Estimated-Mon 1 Rating Curve	Baker 2006a	16.87	Baker 2002a
2001	255,000	Estimated-Mon 1 Rating Curve	Baker 2006a	17.37	Baker 2001
2000	580,000	Estimated-Indirect Calculation	Baker 2000	19.33	Baker 2000
1999	203,000	Estimated-Indirect Calculation	Baker 1999	13.97	Baker 1999
1998	213,000	Estimated-Indirect Calculation	Baker 1998	18.11	Baker 1998
1997	177,000	Estimated-Indirect Calculation	Baker 2002b	15.05	Baker 1999
1996	160,000	Estimated-Indirect Calculation	Shannon & Wilson 1996	17.19	Shannon & Wilson 1996
1995	233,000	Estimated-Indirect Calculation	ABR 1996	14.88	Shannon & Wilson 1996
1994	165,000	Estimated-Indirect Calculation	ABR 1994b	12.20	ABR 1996
1993	379,000	Estimated-Indirect Calculation	ABR 1994a	19.20	ABR 1996
1992	164,000	Estimated-Indirect Calculation	ABR 1993	13.90	ABR1996

4.2.2 Monument 23 Discharge

Due to low stage and the presence of in-channel ice, a direct discharge measurement was not conducted at Monument 23. An indirect analysis was performed at Monument 23 to estimate peak discharge in the Nigliq Channel. Indirect calculations used 2005 topographic survey data provided by LCMF and presented in Figure 4-2. Estimated discharge was calculated using the slope-area method and stage at Monuments 22 and 23. Peak discharge was approximately 21,500 cfs and occurred on May 29. Ribbon ice within the channel extended from Nuiqsut into Harrison Bay crossing the channel at a number of locations. Ribbon ice geometry at Monument 23 was taken into account when calculating peak discharge.

4.2.3 Alpine Swale Bridge Discharge

DIRECT DISCHARGE

To comply with stipulated monitoring requirements outlined in USACE Permit Number POA-2004-253, direct discharge measurements at the swale bridges were conducted. On May 29, at approximately 5:00 PM, discharge at the 62-foot and 452-foot swale bridges was measured to be 123 cfs and 1,930 cfs, respectively. Table 4-2 presents a summary of the 2008 discharge measurement data at the Alpine swale bridges. The complete discharge notes are presented in Appendix C.

Table 4-2 Discharge Measurement Summary – Alpine Swale Bridges 2008

Site Name	Date Time	WSE (ft)	Made By	Width (ft)	Area (ft^2)	Mean Vel (ft/s)[1]	Discharge (cfs)	MMT Rating[2]	Number of Sections	MMT Type
62-foot Bridge	05/29/08 16:30	6.35	JPM, OOO, MDM	55	211	0.58	123	P	14	Cable
452-foot Bridge	05/29/07 15:10	6.35	JPM, OOO, MDM	445	949	2.03	1930	F	21	Wading

Notes:
1. Mean velocities adjusted with angle of flow coefficient
2. Measured 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

The mean adjusted velocity for the 62-foot swale bridge was 0.58 feet per second (fps) and the maximum adjusted velocity was 0.81 fps. The mean adjusted velocity for the 452-foot swale bridge was 2.03 fps and the maximum adjusted velocity was 2.68 fps. The maximum non-adjusted at-point velocity recorded was 0.87 fps at the 62-foot bridge and 2.79 fps at the 452-foot bridge.

The discharge and average adjusted velocity measured at the 62-foot swale bridge in 2008 were significantly less than historic averages; 80% to 68%, respectively. The average adjusted velocity at the 452-foot swale bridge was 5% greater in 2008 than the historic average while the discharge was approximately 20% less. The WSE at the time of the measurement at the 62-foot and the 452-foot swale bridge was 6.35 feet. This was lower than the historic averages of 7.82 feet and 7.23 feet, respectively. Table 4-3 summarizes the discharge measurement data at the Alpine swale bridges between 2000 and 2008.

Table 4-3 Historic Discharge Measurement Summary – Alpine Swale Bridges, 2000-2008

Site Name	Date	WSE (ft)	Made By	Width (ft)	Area (ft^2)	Mean Vel (ft/s)[1]	Discharge (cfs)	MMT Rating[2]	Number of Sections	MMT Type	Reference
62-foot Bridge	05/29/08	6.35	JPM, OOO, MDM	55	211	0.58	123	P	14	Cable	This report
	06/05/07	7.83	JPM, OOO, MDM	55	292	1.18	345	F	20	Cable	Baker 2007b
	05/31/06	8.49	JPM, SLB, EJK	55	615	1.59	980	F	20	Cable	Baker 2007a
	–[3]	–	–	–	–	–	–	–	–	–	Baker 2005b
	05/29/04	8.34	JWW, MTA	55	451	1.60	720	F	17	Cable	Baker 2005a
	–[3]	–	–	–	–	–	–	–	–	–	Baker 2003
	05/25/02	6.74	JWW, HA	56.0	283	1.52	430	G	17	Cable	Baker 2002a
	06/11/01	7.64	JWW, CD	56	336	1.79	600	G	15	Cable	Baker2001
	06/10/00	7.87	JA, JA, JC	47	175	3.30	580	F	13	Cable	Baker2000
452-foot Bridge	05/29/08	6.35	JPM, OOO, MDM	445	949	2.03	1930	F	21	Wading	This report
	06/05/07	7.76	JPM, OOO, MDM	447	1670	0.74	1240	F	20	Cable	Baker 2007b
	05/31/06	8.42	JPM, SLB, EJK	409	1730	1.89	3260	F	29	Cable	Baker 2007a
	06/02/05	6.13	JPM, MDC, EJK	445	841	1.37	1100	G	20	Wading	Baker 2005b
	05/29/04	8.34	JWW, MTA	446	1700	1.40	2400	F	18	Cable	Baker 2005a
	06/08/03	5.48	JWW, HA	444	478	0.88	420	G	16	Wading	Baker 2003
	05/25/02	6.74	JWW, HA	445	930	3.47	3200	G	17	Cable	Baker 2002a
	06/11/01	7.64	JWW, CD	460	1538	2.4	3700	G	16	Cable	Baker2001
	06/09/00	7.34	JA, JA	437	1220	3.27	4000	F	15	Cable	Baker2000

Notes:
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, no measurement made

INDIRECT DISCHARGE

The 2008 peak discharge through both the 62-foot and 452-foot swale bridges likely occurred at the time of peak stage and maximum water surface differential following discharge measurements. The peak stage occurred early morning on May 30 at an elevation of 6.49 feet (Gage 3). Maximum headwater-tailwater differential occurred simultaneously with peak stage. 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. It was also assumed that flow depth at peak discharge was 0.14 feet greater than during the discharge measurement at each swale bridge, given the observed difference in stage.

Peak discharge was estimated to have been 127 cfs through the 62-foot swale bridge and 2,053 cfs through the 452-foot swale bridge. Table 4-4 summarizes the estimated peak annual discharge data at the Alpine swale bridges between 2000 and 2008.

Table 4-4 Estimated Peak Discharge Summary – Alpine Swale Bridges, 2000-2008

Date & Time	Peak WSE (ft)[1]	452-Foot Bridge Discharge (cfs)[2]	452-Foot Bridge Mean Vel (ft/s)	62-Foot Bridge Discharge (cfs)[2]	62-Foot Bridge Mean Vel (ft/s)	References
05/30/08 12:00	6.49	2053	0.49	127	0.58	This report
06/05/07 04:00	8.60	1514	1.35	395	1.18	Baker 2007b
05/31/06 03:00	9.72	4400	1.77	1100	1.59	Baker 2007a
05/31/05 08:00	6.48	1400	1.37	–[3]	–	Baker 2005b
05/27/04 13:30	9.97	3400	1.38	860	1.59	Baker 2005a
06/07/2003[4]	6.31	730	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	620	1.79	Baker2001
06/12/2000[4]	9.48	7085	3.60	975	4.30	Baker2000

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

4.2.4 Alpine Culverts Discharge

Stage, velocity, and discharge were 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 4-3.

Water surface elevation data and culvert dimensions were used to perform indirect culvert discharge calculations for a variety of conditions. 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.

Floodwater was observed flowing through five CD2 road culverts (CD2-20 through CD2-24) and standing backwater was observed in four CD4 culverts (CD4-20A through CD4-22). This standing backwater resulted in no discernable flow through the CD4 culverts. Though snow and ice were present in the Alpine vicinity during breakup, its presence had limited impact on the hydraulic performance and discharge of the CD2 and CD4 culverts.

INDIRECT ESTIMATED DISCHARGE AND VELOCITY

Alpine Culverts Discharge

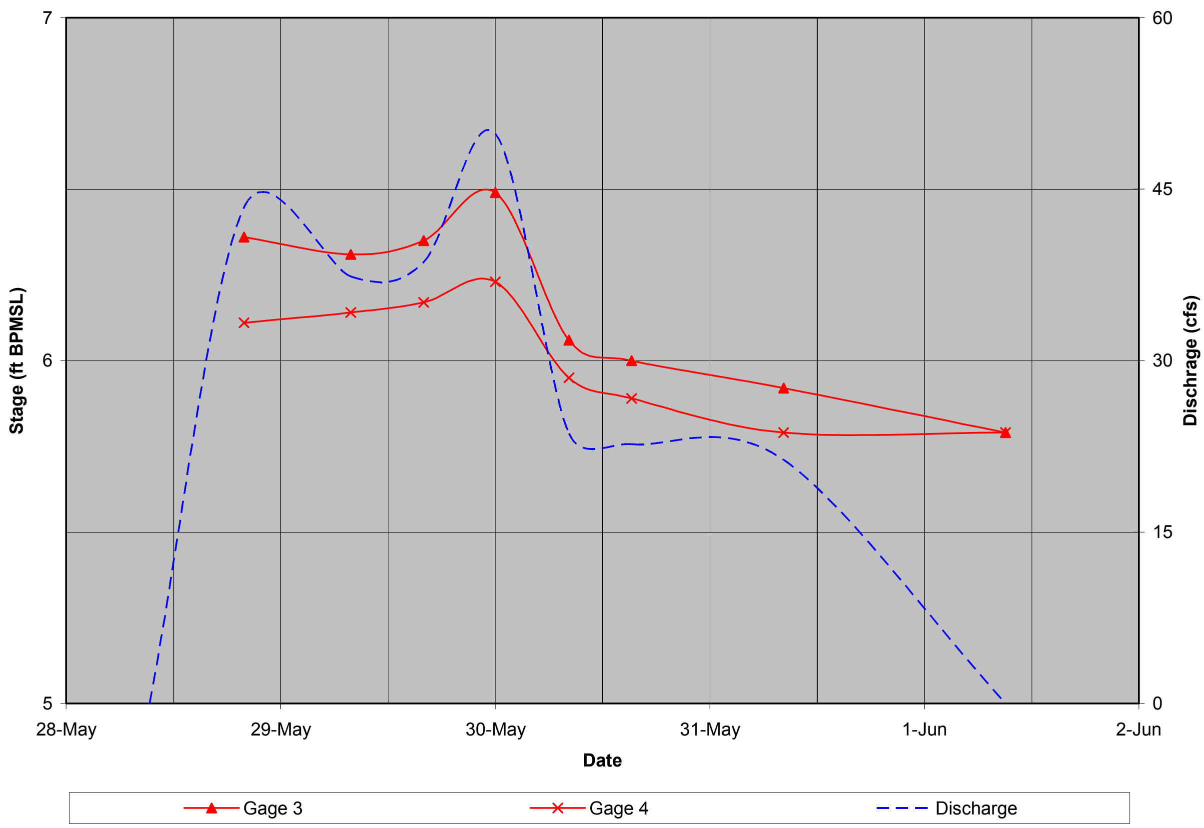
Flow through the CD2 access road culverts was estimated to have first occurred on May 28. The peak discharge through CD2 culverts coincided with peak stage and ranged from 1.0 cfs to 18.2 cfs. The sum total discharge through all CD2 culverts during peak stage was approximately 49.8 cfs. The estimated discharge passing through the CD2 culverts are presented in Table 4-5. In the tabulation of discharge, a zero discharge represents a culvert having water with zero velocity or a culvert void of water.

Table 4-5 CD2 Road Culverts Estimated Discharge Summary

Culvert	5/28/08 9:20 AM	5/28/08 7:54 PM	5/29/08 7:50 AM	5/29/08 4:00 PM	5/30/08 12:00 AM	5/30/08 8:15 AM	5/30/08 3:15 PM	5/31/08 8:15 AM	6/1/08 9:05 AM
CD2-20	0	0.5	0.3	0.5	1.0	0.0	0.0	0.0	0
CD2-21	0	5.5	5.7	5.0	6.7	2.6	2.3	1.9	0
CD2-22	0	6.8	5.7	6.1	8.1	3.3	3.0	2.6	0
CD2-23	0	14.2	11.9	12.5	15.9	8.1	7.7	7.6	0
CD2-24	0	16.5	13.8	14.5	18.2	9.6	9.8	9.2	0
Discharge	0	43.5	37.4	38.6	49.9	23.6	22.8	21.3	0

Alpine Culverts Headwater and Tailwater Differential

In 2008, the differential between headwater and tailwater elevations for the CD2 culverts that passed water is based on the water surface elevation observed at Gages 3 and 4, given their proximity to the culverts. The maximum differential between Gages 3 and 4 occurred during peak stage on May 30 with a differential of 0.26 feet. Flow through the CD2 culverts is estimated to have stopped on June 1 when headwater and tailwater elevations were observed to be near equal. A comparison of stage and discharge during breakup for CD2 culverts is presented in Graph 4-2.



Graph 4-2 CD2 Road Culverts Estimated Discharge vs. Stage

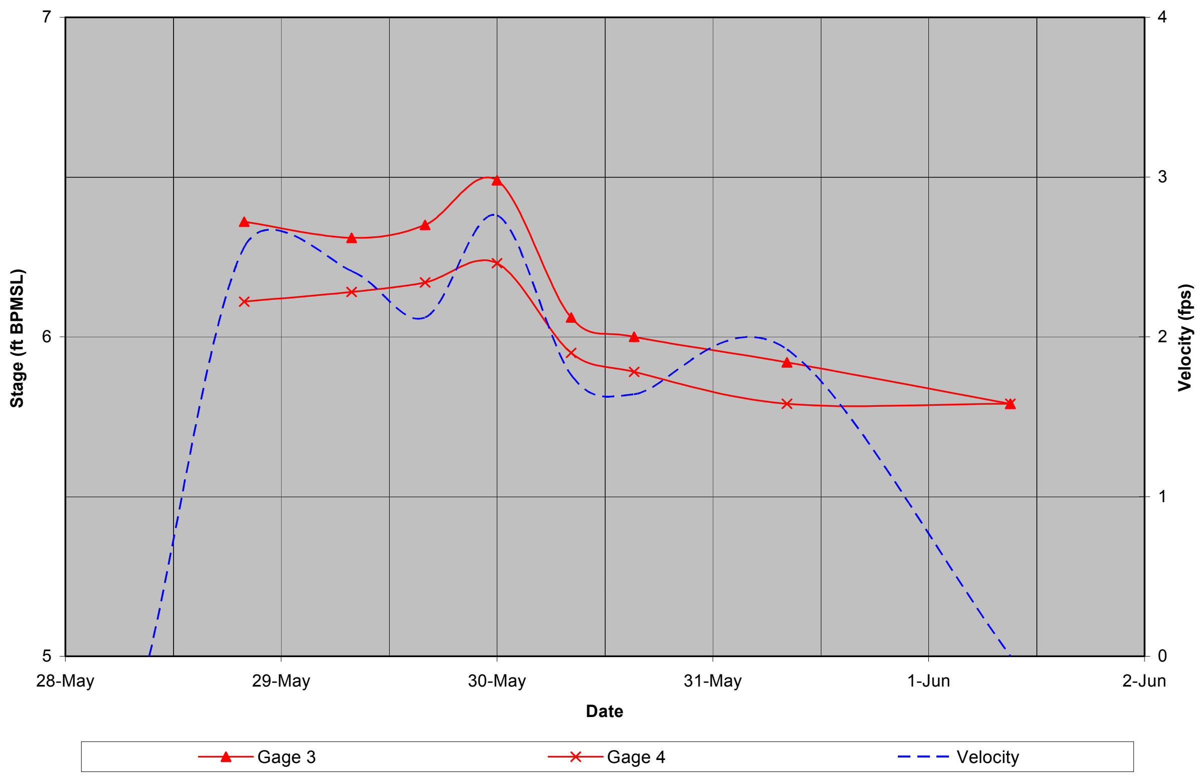
Alpine Culverts Velocity

Peak velocities for CD2 road culverts coincided with peak stage and discharge in the early morning of May 30. At peak discharge, average velocities through the culverts ranged from 2.5 fps to 3.0 fps. A summary of average velocities for each culvert is presented in Table 4-6. In the tabulation of velocities, a cell containing a dash represents a culvert having water with zero velocity or a culvert void of water.

Table 4-6 CD2 Road Culverts Estimated Velocity Summary

Culvert	5/28/08 9:20 AM	5/28/08 7:54 PM	5/29/08 7:50 AM	5/29/08 4:00 PM	5/30/08 12:00 AM	5/30/08 8:15 AM	5/30/08 3:15 PM	5/31/08 8:15 AM	6/1/08 9:05 AM
CD2-20	-	2.1	1.7	1.8	2.5	-	-	-	-
CD2-21	-	2.0	2.0	2.0	2.5	1.5	1.4	1.5	-
CD2-22	-	2.9	3.7	2.4	2.9	1.8	1.8	2.0	-
CD2-23	-	3.0	2.4	2.5	3.0	1.9	1.4	2.1	-
CD2-24	-	2.9	2.4	1.9	2.9	1.8	1.9	2.1	-
Average Velocity	**-**	2.6	2.4	2.1	2.8	1.8	1.6	1.9	**-**

The velocity estimates for the CD2 culverts is related to water surface differentials between the headwater and the tailwater elevations. The velocity for each culvert was greatest during the largest differential between headwater and tailwater. A comparison of stage and velocity for the CD2 culverts is presented in Graph 4-3.



Graph 4-3 CD2 Road Culverts Estimated Velocity vs. Stage

Direct Discharge and Velocity Measurements

Direct water depth and velocity measurements were conducted at the CD2 (CD2-21 through CD2-24) road culverts to validate indirect culvert calculations. Velocity measurements were taken at the outlet of the culvert. A calibrated Pygmy velocity meter and graduated USGS wading rod were used to measure a single at-point velocity at six-tenths of the culvert's total water depth. This velocity was used as a representative average cross-sectional velocity in the culvert.

On May 30 between 8:00 AM and 8:20 AM, water depth and velocities were measured at the CD2 road culverts (Table 4-7). These measurements represent conditions at culverts approximately 8 hours after peak stage occurred at Gages 3 and 4. The measured velocities ranged from 0.68 to 3.44 fps, averaging 2.28 fps. The total measured discharge flowing through CD2 culverts was 41.2 cfs, ranging from 1.2 cfs to 18.9 cfs in individual culverts. The timing of the data collection suggests that direct measurements are a fair representation of the near-peak flow conditions at the CD2 culverts.

Table 4-7 CD2 Road Culverts – May 30 Discharge Measurements

Culvert #	Date Time	Made By	Depth (ft)	Area (ft^2)	Mean Vel (ft/s)	Discharge (cfs)	Number of Sections	MMT Type
CD2-1	– (1)	–	–	–	–	–	–	–
through	– (1)	–	–	–	–	–	–	–
CD2-20	– (1)	–	–	–	–	–	–	–
CD2-21	5/30/08 8:20 AM	MDM, EJK	0.80	1.8	0.68	1.2	1	Wading
CD2-22	5/30/08 8:10 AM	MDM, EJK	0.80	1.8	2.06	3.7	1	Wading
CD2-23	5/30/08 8:05 AM	MDM, EJK	1.80	5.5	3.44	18.9	1	Wading
CD2-24	5/30/08 8:00 AM	MDM, EJK	1.90	5.9	2.96	17.4	1	Wading
CD2-25	– (1)	–	–	–	–	–	–	–
CD2-26	– (1)	–	–	–	–	–	–	–
Notes: 1. No water flowing through culvert, no measurement made							**Average Measured Velocity (ft/s)**	**2.28**
							Total Measured Discharge (cfs)	**41.2**

Alpine Culverts Indirect and Direct Discharge Estimates Comparison

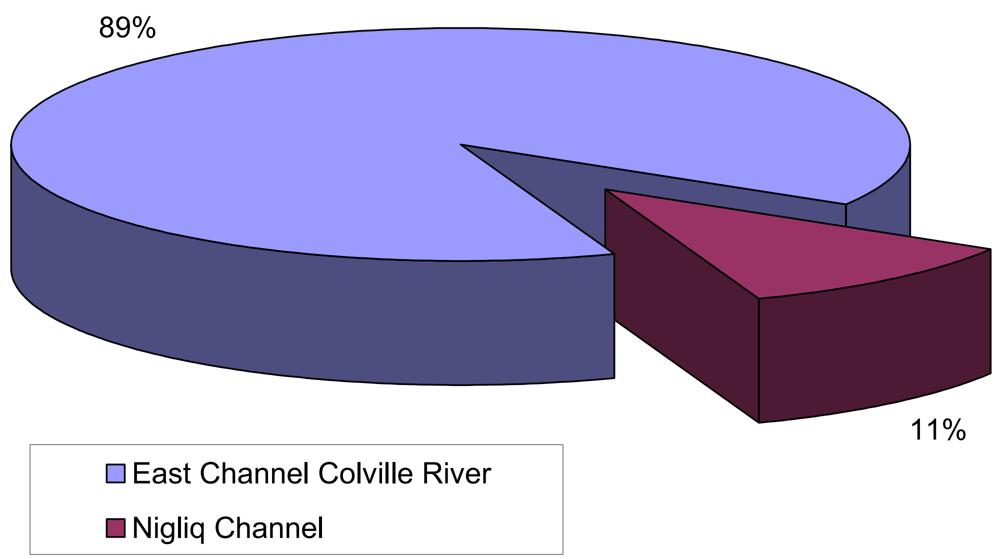
Indirect calculations were used to estimate peak discharge values. The indirect estimates were compared with the respective direct velocity measurements and associated discharge estimates to get a sense of relative accuracy of the indirect calculations. The comparison between the May 30 CD2 culverts direct and indirect measurements is presented in Table 4-8. The percent difference between measured and calculated mean velocity and total discharge was 22% and 43%, respectively.

Table 4-8 CD2 Road Culverts –Discharge Comparison

Culvert	Time of Direct Measurement	Mean Velocity (ft/s)	Direct Measured Discharge (cfs)	Time of Indirect Measurement	Indirect Calculated Velocity (ft/s)	Indirect Calculated Discharge (cfs)	Percent Difference [1]	
							Velocity	Discharge
CD2-21	5/30/08 8:20 AM	0.68	1.2	5/30/08 8:15 AM	1.5	2.6	-119%	-112%
CD2-22	5/30/08 8:10 AM	2.06	3.7	5/30/08 8:15 AM	1.8	3.3	12%	10%
CD2-23	5/30/08 8:05 AM	3.44	18.9	5/30/08 8:15 AM	1.9	8.1	44%	57%
CD2-24	5/30/08 8:00 AM	2.96	17.4	5/30/08 8:15 AM	1.9	9.6	36%	45%
Average Measured Velocity (ft/s)		**2.28**			**Average Calculated Velocity (ft/s)**	**1.8**	**V Difference**	**22%**
Total Measured Discharge (cfs)		**41.2**			**Total Calculated Discharge (cfs)**	**23.6**	**Q Difference**	**43%**
Notes:	1. Percent difference is computed using direct to indirect velocity and discharge values.							

4.2.5 Peak Discharge Flow Distribution

During the 2008 spring breakup peak discharge, approximately 89% of the flow in the CRD passed through the East Channel with the remaining 11% passing down the Nigliq Channel, including the Alpine facilities drainage structures. Graph 4-4 presents the 2008 estimated peak flow distribution in the CRD.



Graph 4-4 2008 CRD Estimated Peak Discharge Distribution

4.3 Flood and Stage Frequency

4.3.1 Colville River Flood Frequency

A flood frequency analysis was performed in 2002 to estimate recurrence interval and magnitude of peak flood discharge on the Colville River (Baker and Hydroconsult 2002) and was revisited in 2006 (Baker 2007a). The results of this analysis are presented in Table 4-9.

Table 4-9 Colville River Flood Frequency Analysis

Return Period	Flood Peak Discharge (cfs)
2-year	240,000
5-year	370,000
10-year	470,000
25-year	610,000
50-year	730,000
100-year	860,000
200-year	1,000,000

The 2008 peak discharge of 221,000 cfs has an estimated recurrence interval of less than 2 years, based on flood frequency analysis.

4.3.2 Colville River Delta 2-Dimensional Surface Water Model Predicted and Observed Water Surface Elevations

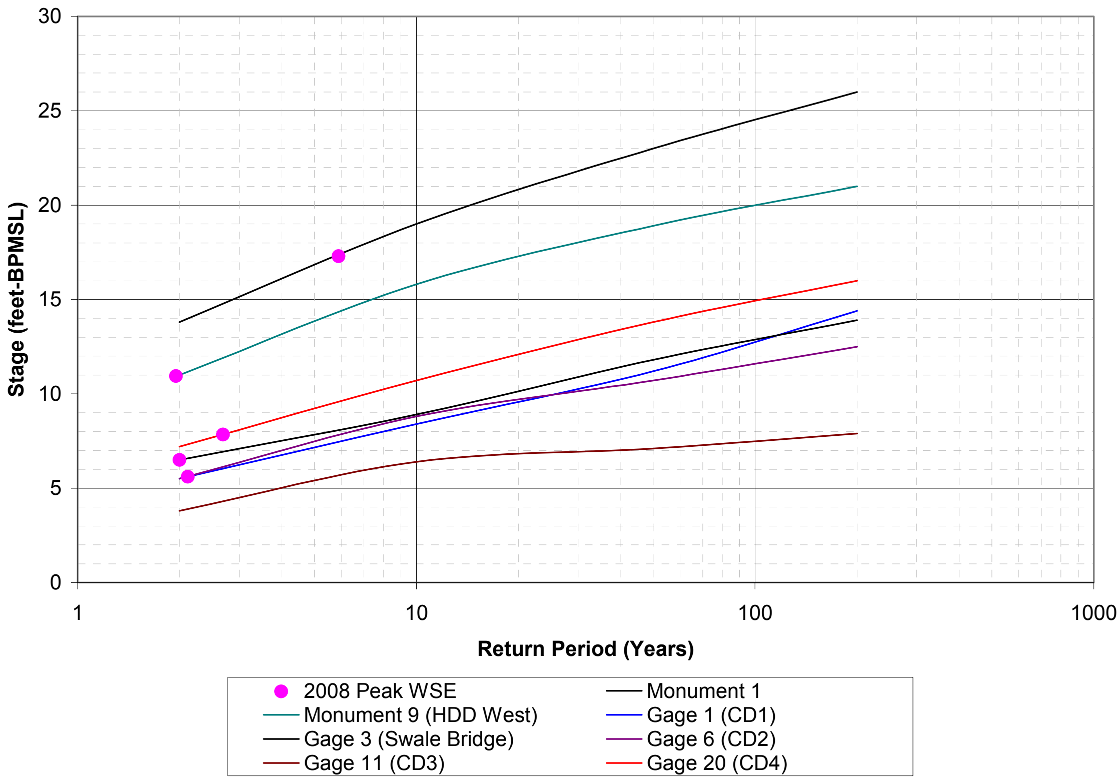
The Colville River 2-dimensional (2D) surface water model was first developed in 1997 to estimate water surface elevations and velocities at the proposed Alpine Development Project facilities locations. The model has undergone numerous revisions since the original 1997 version (Baker 1998b). Proposed CD3 and CD4 satellite developments were incorporated in 2002, including additional floodplain topographic survey data (Baker 2002b). In 2006, the model was once again modified to include as-built alignment conditions along the CD4 access road and pad and 2004/2005 survey data of the Nigliq Channel near Monument 23 (Baker 2006b). A supplemental analysis was performed in 2006 to incorporate the proposed Qannik extension of the existing CD2 pad (Baker 2006c). The current 2D surface water model predictions and the 2008 observations are presented in Table 4-10.

Table 4-10 Colville River 2D Model Predicted Water Surface Elevations and 2008 Observations

Monitoring Sites	2D Model Predicted Water Surface Elevation based on open water conditions (feet-BPMSL)				2008 Observed WSE (feet-BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (yrs)
	2-year	10-year	50-year	200-year		
Colville River - East Channel						
Monument 1	13.8	19.0	23.0	26.0	17.3	6
Monument 9 (HDD)	11.0	15.8	18.9	21.0	10.9	<2
Helmericks	3.8	5.3	5.9	6.3	0.0	-
Colville River - Nigliq Channel						
Monument 20	7.8	11.3	14.4	16.5	8.1	2
Monument 22	5.9	8.6	11.8	14.0	6.8	3
Monument 23	4.9	7.0	10.1	12.1	5.9	4
Monument 28	3.1	3.3	3.7	4.4	3.3	10
CD1 Pad						
Gage 1	5.5	8.4	11.2	14.4	5.6	2
Gage 9	6.7	9.7	11.1	15.3	0.0	-
Gage 10	6.7	9.7	12.8	15.3	0.0	-
CD2 Pad						
Gage 8	*5.5*	*8.8*	10.7	12.5	0.0	-
CD3 Pad						
Gage 11	*3.8*	6.4	7.1	7.9	0.0	-
CD4 Pad						
Gage 19	*7.2*	11.0	14.1	16.4	0.0	-
Gage 20	*7.2*	10.7	13.8	16.0	7.8	3
CD2 Road						
Gage 3	6.5	8.9	11.8	13.9	6.5	2
Gage 4	6.5	8.2	9.9	11.8	6.2	<2
Gage 6	*5.6*	9.2	11.9	14.1	0.0	-
Gage 7	*5.6*	8.3	9.8	11.8	0.0	-
Gage 12	*6.5*	9.1	12.0	14.1	0.0	-
Gage 13	*6.5*	8.3	9.9	11.7	0.0	-
CD3 Pipeline						
Crossing #2 (SAK) Gage	4.9	8.4	11.1	12.8	5.4	3
Crossing #4 (TAM) Gage	5.8	8.3	9.2	9.9	6.1	2
Crossing #5 (ULAM) Gage	4.4	7.1	7.9	8.7	5.5	4
CD4 Road						
Gage 15	*7.2*	9.9	12.9	15.4	7.3	2
Gage 16	*7.2*	10.1	13.7	15.8	7.3	2
Gage 17	*7.2*	10.4	13.7	15.8	0.0	-
Gage 18	*7.2*	11.0	14.3	16.6	0.0	-

Notes: Italicized water surface elevations are below ground elevation monitoring sites. Values represent nearest WSE.
Sites having no observed WSE in 2008 are denoted with a dash "-"

The 2D surface water model was developed to predict open water conditions during low frequency, high magnitude flood events having 50- and 200-year recurrence intervals. To estimate the relationship between discharge and stage during lower magnitude flood events, 2- and 10-year flood events have been modeled. The model assumes open water, steady-state conditions, and does not account for snow, channel ice, or ice jams. Graph 4-5 presents predicted water surface elevations at selected locations for 2-, 10-, 50-, and 200-year floods and the respective 2008 peak stage (big pink dots).



Graph 4-5 Colville River Delta 2D Model Predicted Water Surface Elevation & Return Interval

Typically, observed water surface elevations will be greater than those predicted by the 2D model during small magnitude flood events due to the presence of ice and snow in the channels. With an extended period of record, a stage frequency analysis can be performed to better estimate low flood stage within the delta impacted by recurrent ice jamming. This was done in 2006 and is described in the next section.

4.3.3 Colville River Delta Stage Frequency

A stage frequency analysis was performed for a limited group of sites in 2006 (Baker 2007a). The location and distribution of sites monitored since 1992 in support of Alpine development has varied based on the objectives of each year's field program. Monument 1, Monument 22, Gage 1, Gage 3, and Gage 18 (near CD4) were selected because each had a relatively long-term tabulation of data. The data reflected ice-impacted flooding conditions and so the stage analysis reflects these conditions. Resulting values from the analysis are presented in Table 4-11 and are compared to 2008 observed peak WSE.

Table 4-11 Colville River Delta Stage Frequency Analysis

Monitoring Sites	Stage Frequency (feet-BPMSL)						2008 Observed WSE (feet-BPMSL)	Approximate Recurrence Interval of Observed Peak WSE (yrs)
	2-year	3-year	5-year	10-year	20-year	50-year		
Monument 1	16.1	17.2	18.4	19.7	20.9	22.3	17.3	3
Monument 22	8.2	8.8	9.5	10.3	11	11.8	6.8	<2
Gage 1	6.7	7.6	8.6	9.8	10.8	12.2	5.6	<2
Gage 3	7.7	8.3	8.9	9.7	10.4	11.2	6.5	<2
CD4 Pad (Gage 18)	9.5	10.4	11.4	12.6	13.7	15.1	0.0	-

Stage frequency elevations are consistently greater than those estimated by the 2D model (Table 4-10) for the respective recurrence intervals. The presence of in-channel ice and snow during breakup stalls and displaces flow through the delta, which results in consistently higher water surface elevations during lower magnitude flood events.

4.4 Alpine Pad and Road Erosion Survey Results

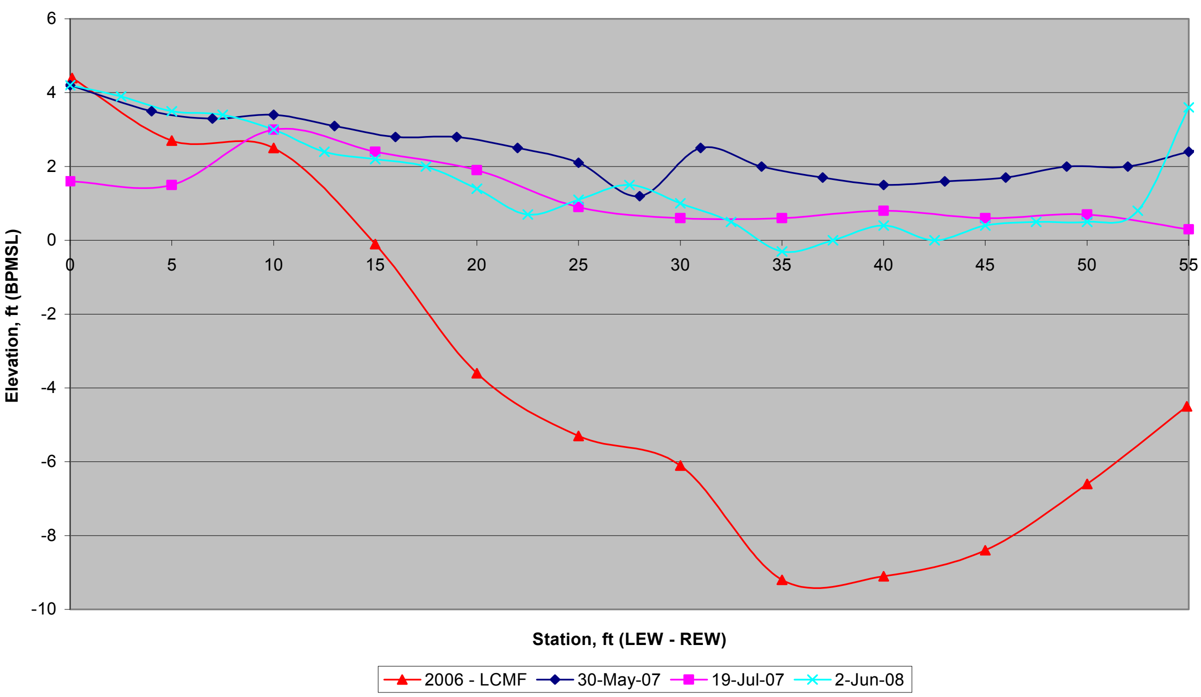
Alpine's gravel pads and access roads were inspected for erosion following spring breakup. Visual inspections were performed daily throughout breakup and after floodwaters receded to determine any significant erosion to the Alpine facilities' pads and roads. Observations were recorded with geo-referenced photographs.

Nowhere along the gravel structures was a significant amount of erosion observed. The edges of the Alpine facility pads (CD1, CD2, CD3, and CD4) were not inundated with, or structurally affected by, floodwater; however, the CD2 and CD4 gravel access roads were partially submerged near the swale bridges (CD2) and the north culvert battery (CD4). Flow through the 462-foot swale bridge was temporarily impeded by packed snow causing a damming effect on the south side of the CD2 road before releasing on May 29 (Photo 4-15 and Photo 4-16). No slumping or side slope deterioration was observed along the CD2 access road or any of the other Alpine gravel structures (Photo 4-17and Photo 4-18). All of the Alpine facilities erosion pictures were taken on June 2, 2008.

In April 2007, riprap was placed under the 62-foot swale bridge to prevent further thermoerosion and hydraulic-scour at the east sheet pile abutment. Annual survey profiles of the channel bed at the bridge crossing conducted by LCMF are presented in Baker 2007a. In 2007, the channel was surveyed by Baker pre- and post-breakup to identify potential settlement of the placed material. Survey data collected on the upstream (south) side of the swale bridge are presented in Graph 4-6. Survey profiles collected by Baker indicate that minor settlement of the riprap material occurred between May 30, 2007, July 19, 2007, and June 2, 2008.

Photo 4-17 CD2 Access Road near 62-foot Swale Bridge, June 2, 2008

Photo 4-18 CD4 Access Road Fine Grained Sediment Settlement from 2007 Breakup at North Culvert Battery, June 2, 2008



Graph 4-6 2008 62-foot Swale Bridge Channel Survey (Upstream/South)

4.5 Alpine Drinking Water Lakes Recharge

The Alpine drinking water lakes L9312 and L9313 were monitored before, during, and after breakup to assess recharge and to evaluate the mechanisms causing recharge. Water level surveys and water surface elevation records of Gages 9 (L9312) and 10 (L9313) were the primary references used in evaluating the water surface elevations. Lake L9312 did not receive overland recharge of floodwater. Lake L9313 did receive floodwater recharge from the Sakoonang Channel and reached a bankfull condition. Both Lake L9312 and Lake L9313 received recharge from snowmelt.

Recharge of Lakes L9312 and L9313 was determined by visual observations of floodwaters and by direct measurements of water surface elevations of the lakes. Observations during aerial surveys can generally document the presence of floodwater inflow and observations were recorded with geo-referenced photographs. Staff gages are located at each of the lakes and water surface elevations were visually recorded during breakup. Recharge conditions were documented in accordance with ADF&G permits FG99-111-0051-Amendment #5 and FG97-111-0190-Amendment #5.

4.5.1 Lake L9312 Recharge

Between May 27 and May 30, the WSE of Lake L9312 increased slightly from 7.42 feet to 7.45 feet. The increase in Lake L9312 WSE was due to local snowmelt in the lake's catchment basin since the lake did not receive overland floodwater recharge. Lake L9312 had a peak WSE of 7.45 feet that was recorded in the early evening on May 30. The final recorded WSE for Lake L9312 was documented on June 1 at 7.44 feet. Bankfull conditions were not achieved at Lake L9312. The water surface elevations observed during the monitoring period are presented in Table 4-21.

The lack of floodwater recharge to Lake L9312 provides an opportunity to compare the estimated snowmelt runoff recharge with the observed changes in water surface elevation. A water balance calculation was performed equating the observed change in storage, based on observed water surface elevations and ice thickness, to an estimated change in storage based on contributing snowmelt runoff, precipitation, pumping, and evaporation. The resulting analysis is presented in Appendix D. Additional sources were referenced to supplement necessary data and check assumptions. The inclusion/exclusion of precipitation and evaporation, estimates with potentially high error, resulted in estimated changes in storage having 6% to 9% error relative to the observed change in storage. The given errors are deemed acceptable given the accuracy of available data and assumptions.

The estimated total volume of snow water equivalence contributing to lake recharge was approximately 1.64 million cubic feet (12.3 million gallons). The observed rise in water surface elevation was equivalent to approximately 1.135 million cubic feet (8.5 million gallons).

4.5.2 Lake L9313 Recharge

Between May 28 and June 1, the WSE of Lake L9313 increased from 5.84 feet to 6.95 feet. The increase in WSE is attributed to overland floodwater from the Sakoonang Channel. In the afternoon of May 30, Lake L9313 began to receive overland floodwater from the Sakoonang Channel and exceeded bankfull conditions on May 31. Observed water surface elevations and notes are presented in Table 4-21.

Photo 4-19 and Photo 4-20 show Lake L9313 being recharged by floodwater near peak stage. In the background of Photo 4-19 Lake L9312 is isolated from floodwater.

Photo 4-19 Lake L9313 receiving overland floodwater and L9312 isolated from overland floodwater , May 30, 2008

Photo 4-20 Lake L9313 receiving overland floodwaters from the Sakoonang Channel, May 30, 2008

4.6 Ice Bridge Monitoring

No significant erosion or scour was observed during breakup at or near the Colville River East Channel or Nigliq Channel ice bridge crossings. Photo 4-21 and Photo 4-22 represent the conditions observed at the Colville River East Channel ice bridge crossing before and after breakup. Photo 4-23 and Photo 4-24 represent the conditions at the Nigliq Channel ice bridge during and after breakup.

Photo 4-21 Colville East Channel Ice Bridge prior to Breakup, May 22, 2008

Photo 4-22 Colville East Channel Ice Bridge Location after Breakup, June 2, 2008

Photo 4-23 Nigliq Channel Ice Bridge during Breakup, May 26, 2008

Photo 4-24 Nigliq Channel Ice Bridge Location after Breakup, August 27, 2008

4.7 Figures

Figures begin on the following page: Figure 4 1, Monument 1 Plan and Profile (4 Sheets); Figure 4 2, Monument 23 Plan and Profile (2 Sheets); and Figure 4 3, Alpine Facilities Drainage Structures Location (6 Sheets).

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Alaska, Inc.

DATE:	9/23/08	PROJECT:	114132
DRAWN:	MDM	FILE:	DISCHARGE.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

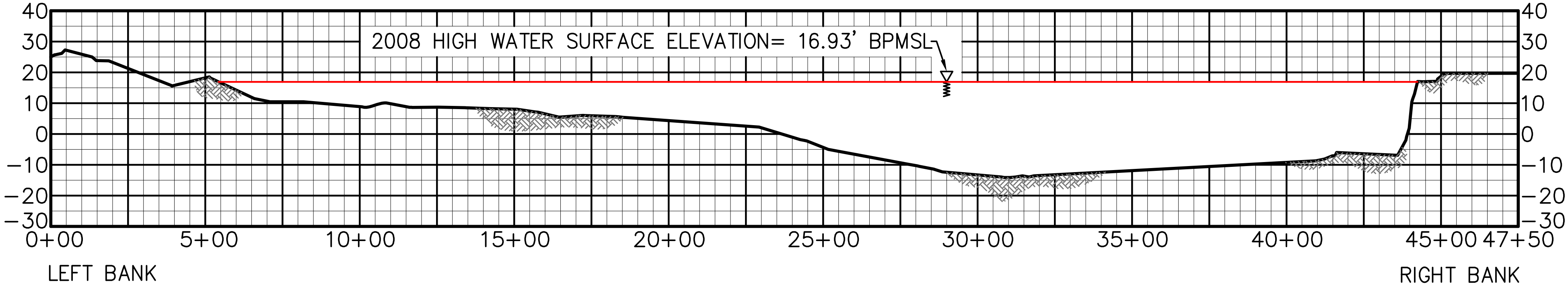
Baker

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

2008 SPRING BREAKUP
MONUMENT 1
PLAN

FIGURE 4-1
(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
SCALE: HORZ. 1"= 500' / VERT. 1" = 50'

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

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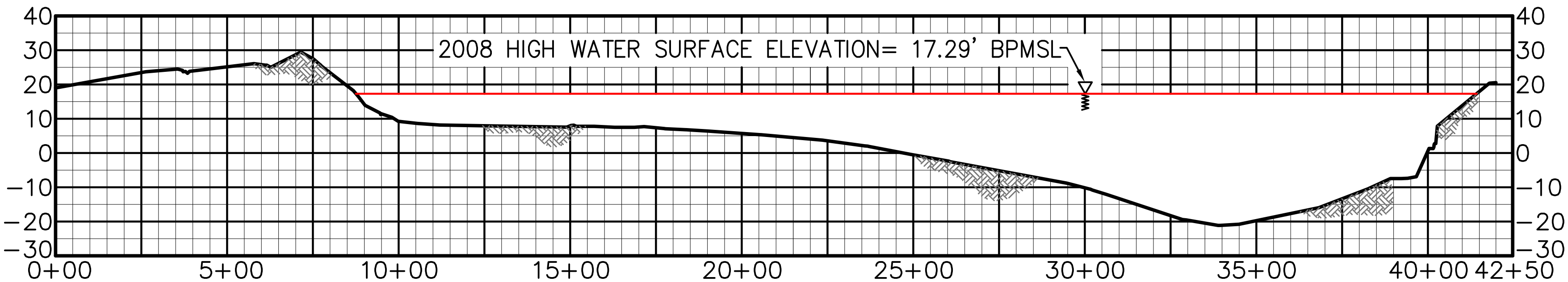
2008 SPRING BREAKUP
MONUMENT 01 DOWNSTREAM
2004 CROSS SECTION
FIGURE 4-1
(SHEET 2 OF 4)

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



1 COLVILLE RIVER CROSS SECTION AT MONUMENT 1
SCALE: HORZ. 1"= 500' / VERT. 1" = 50'

250 0 250 500
HORIZONTAL SCALE IN FEET

25 0 25 50
VERTICAL SCALE IN FEET

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DATE:	9/23/08	PROJECT:	114132
DRAWN:	MDM	FILE:	MON_1_PROFILES.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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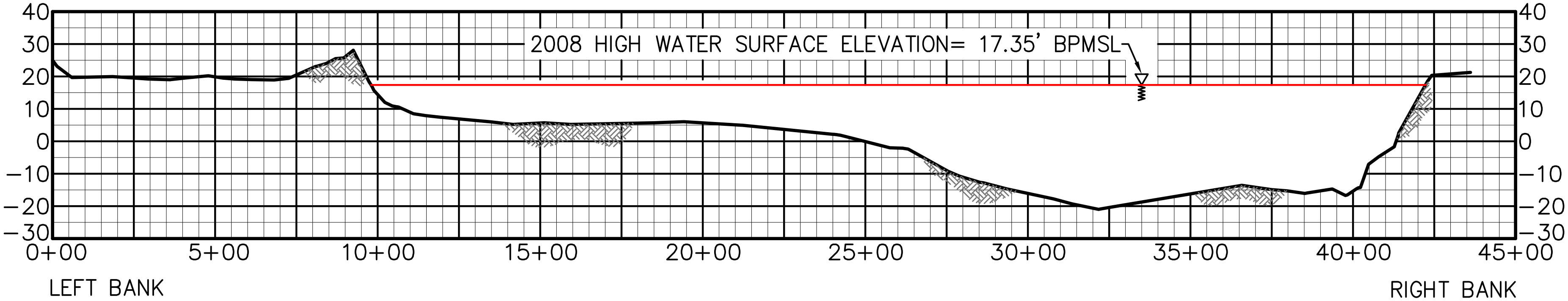
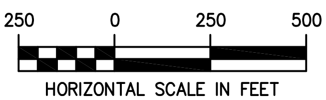
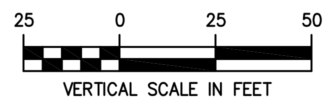
2008 SPRING BREAKUP
MONUMENT 01
2004 CROSS SECTION
FIGURE 4-1
(SHEET 3 OF 4)

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
SCALE: HORZ. 1"= 500' / VERT. 1" = 50'





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CHECKED:	OOO	SCALE:	AS SHOWN

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2008 SPRING BREAKUP
MONUMENT 01 UPSTREAM
2004 CROSS SECTION

FIGURE 4-1
(SHEET 4 OF 4)

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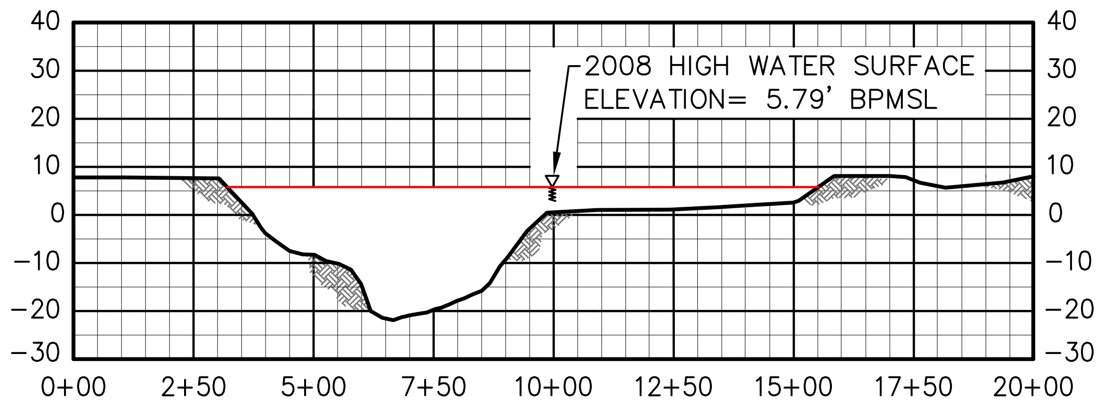
2008 SPRING BREAKUP
MONUMENT 23
PLAN

FIGURE 4-2
(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
SCALE: HORZ. 1"= 400' / VERT. 1" = 40'

200 0 200 400
HORIZONTAL SCALE IN FEET

20 0 20 40
VERTICAL SCALE IN FEET

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DRAWN:	MDM	FILE:	MON_23_PROFILE.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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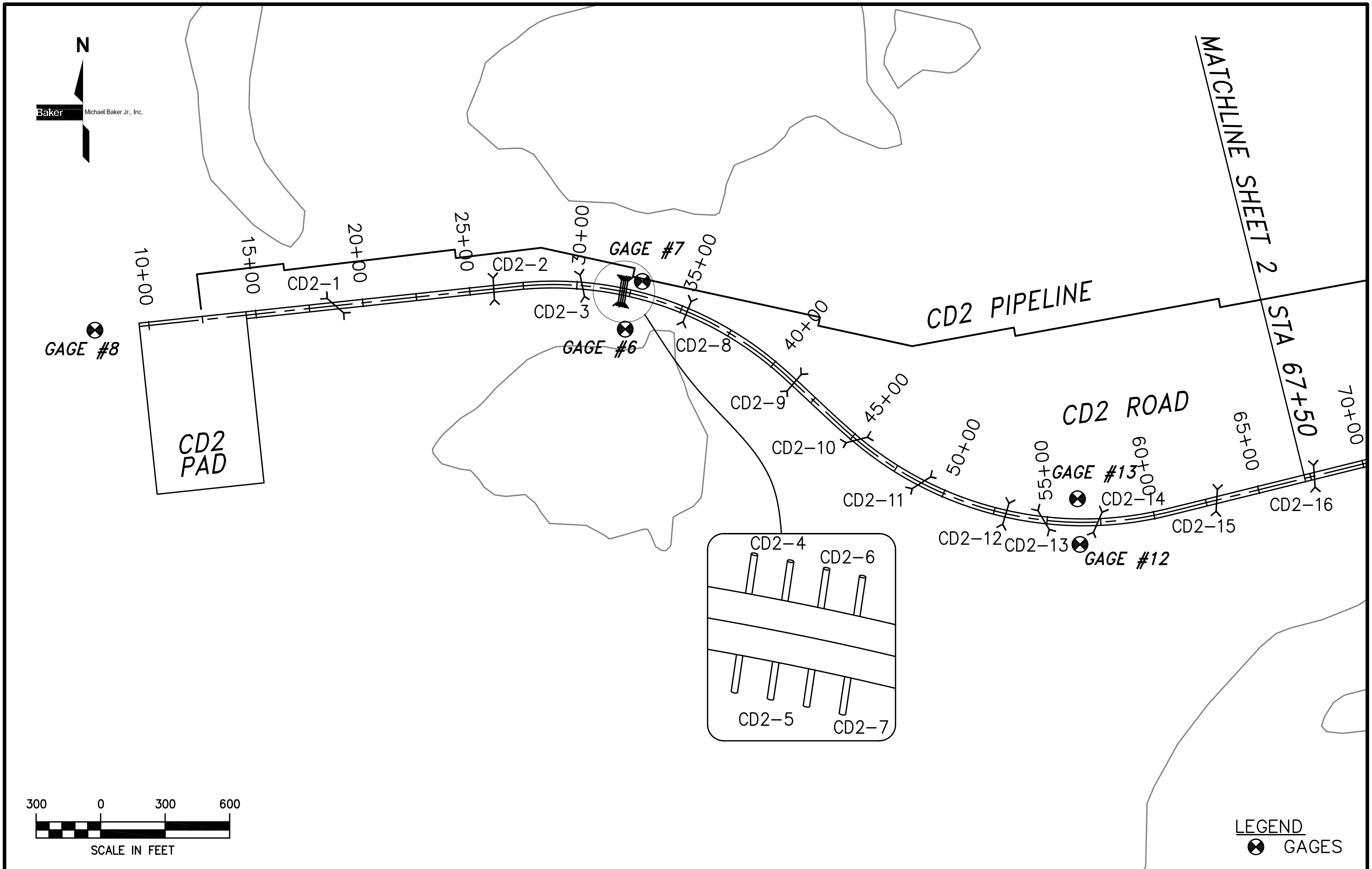
2008 SPRING BREAKUP
MONUMENT 23
2005 CROSS SECTION
FIGURE 4-2
(SHEET 2 OF 2)



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2008 SPRING BREAKUP

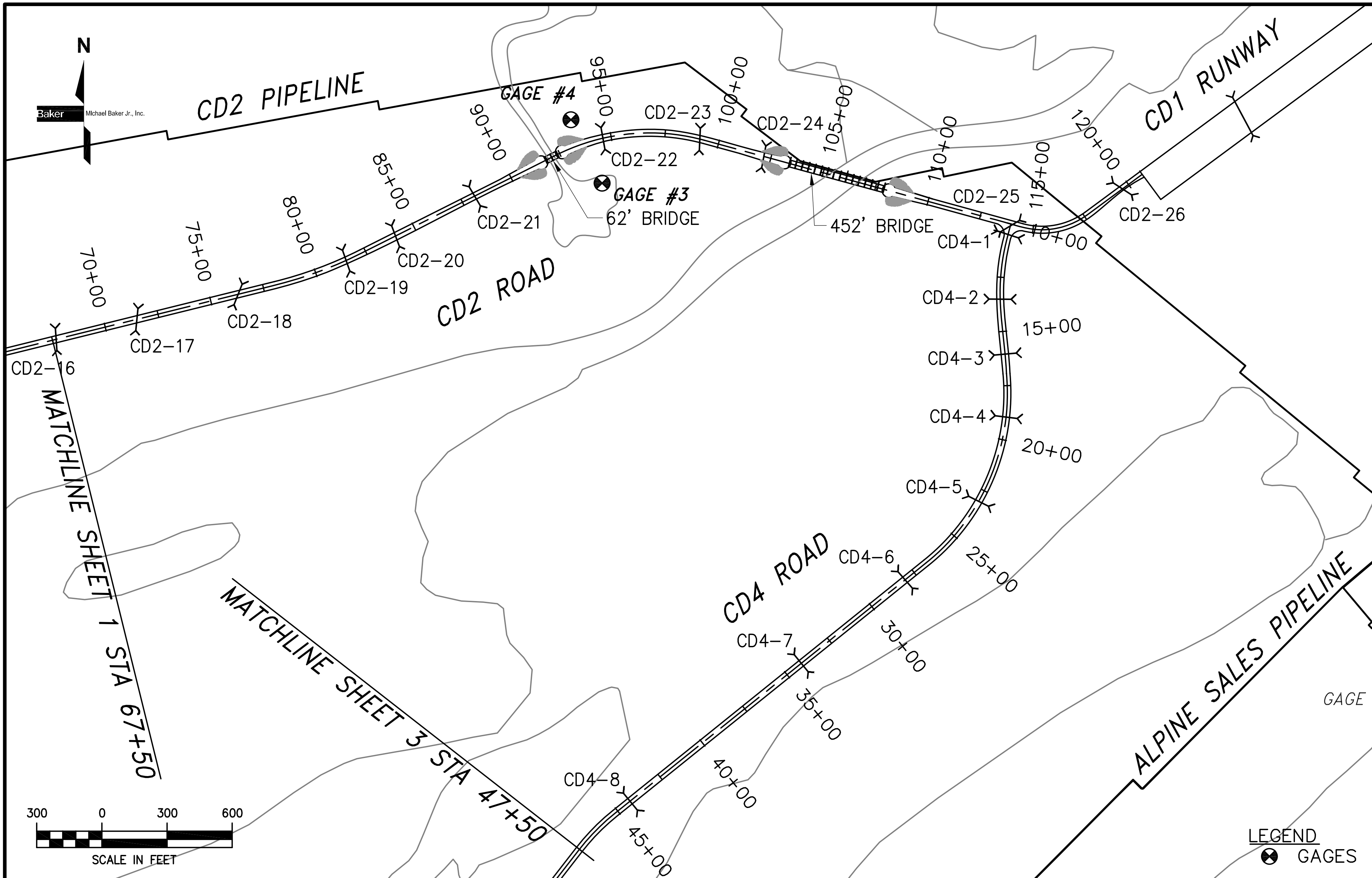
ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 4-3

(SHEET 1 OF 6)

DATE:	6/27/08	PROJECT:	114132
DRAWN:	MDM	FILE:	FIGURE_4_3
CHECKED:	OOO	SCALE:	1"= 600'



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DATE:	6/27/08	PROJECT:	114132
DRAWN:	MDM	FILE:	FIGURE_4_3
CHECKED:	OOO	SCALE:	1"= 600'

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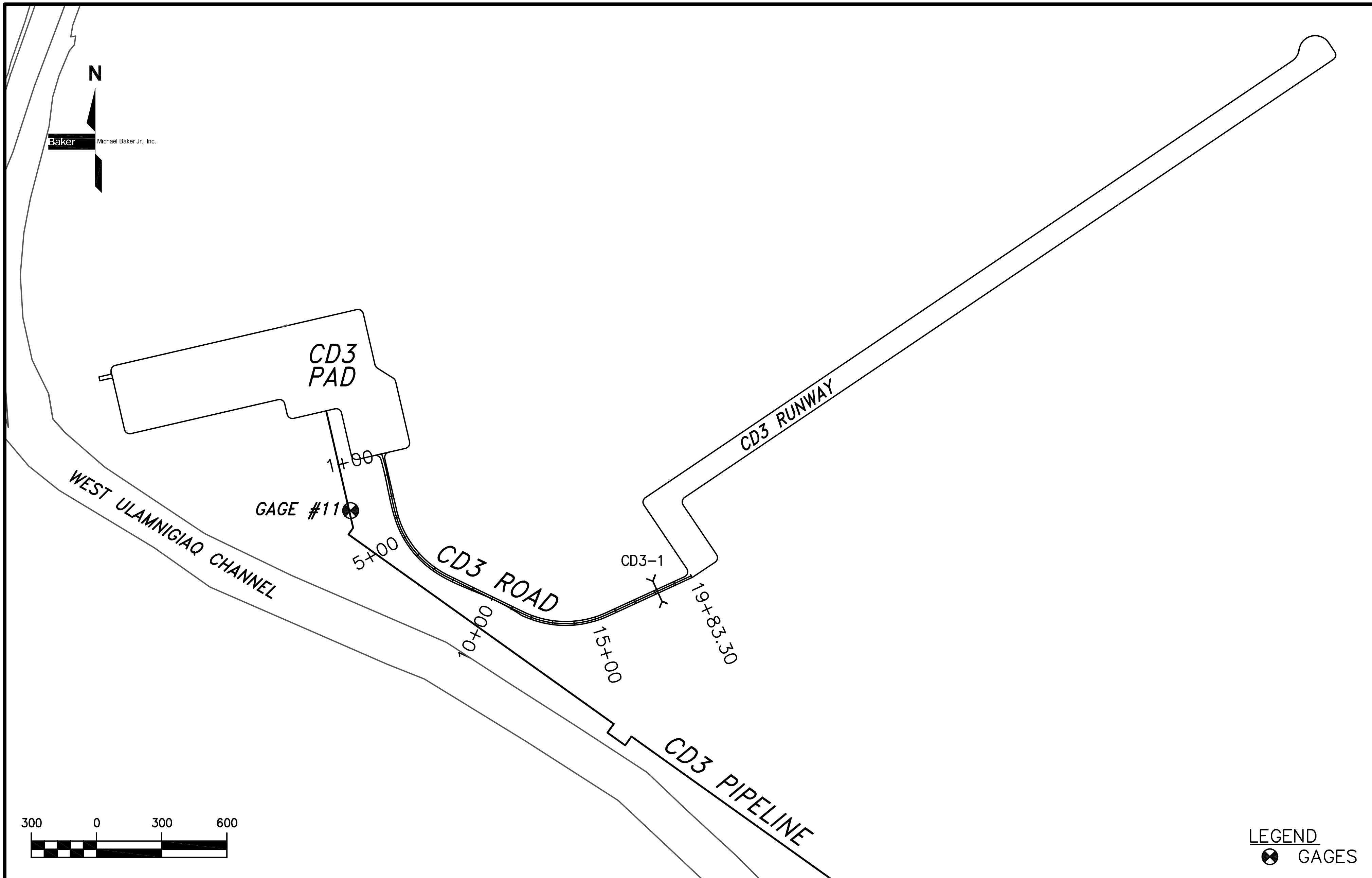
2008 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 4-3
(SHEET 2 OF 6)



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DATE:	6/27/08	PROJECT:	114132
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CHECKED:	OOO	SCALE:	1"= 600'

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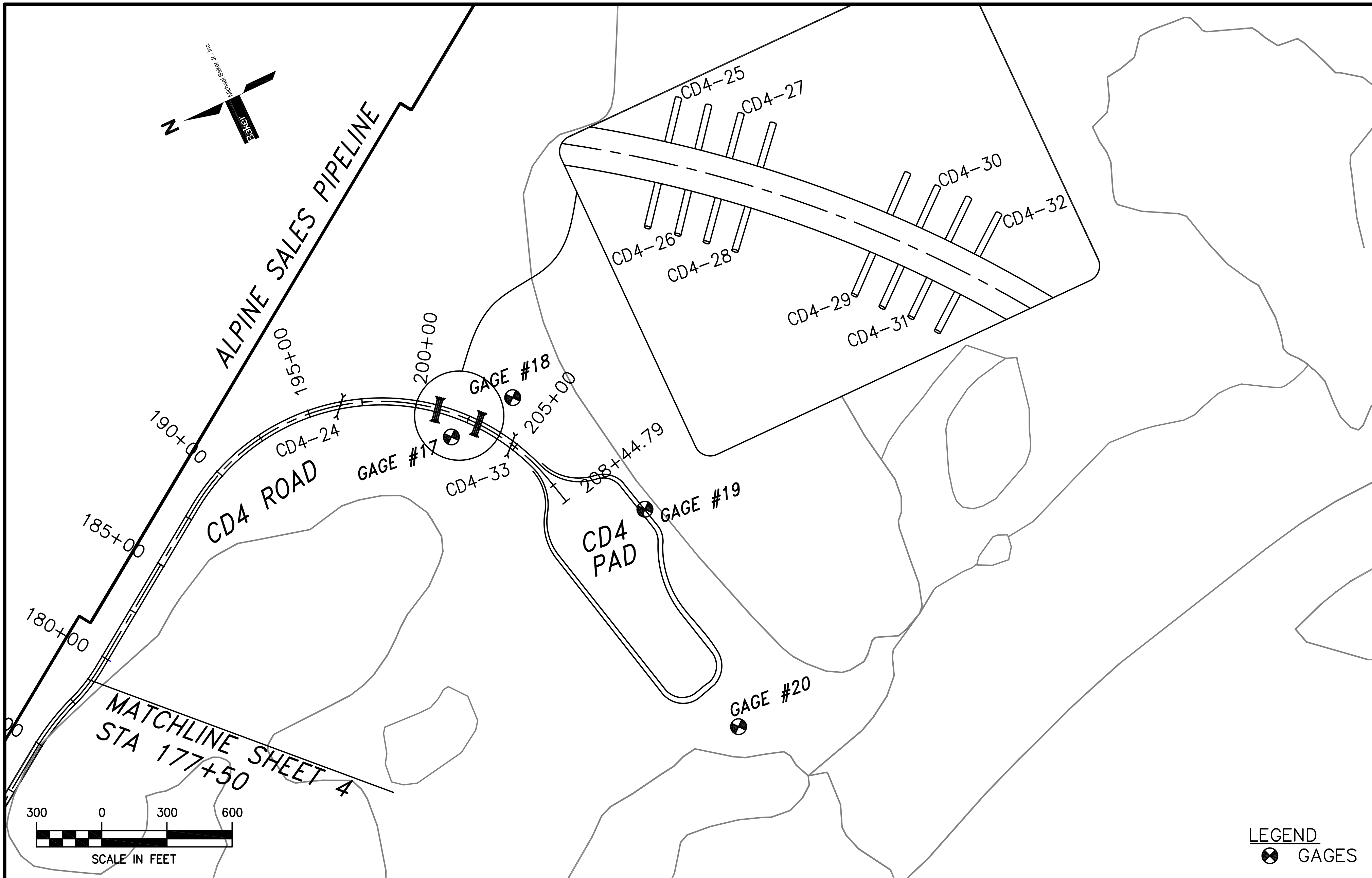
2008 SPRING BREAK-UP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 4-3
(SHEET 6 OF 6)



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DATE:	6/27/08	PROJECT:	114132
DRAWN:	MDM	FILE:	FIGURE_4_3
CHECKED:	OOO	SCALE:	1"= 600'

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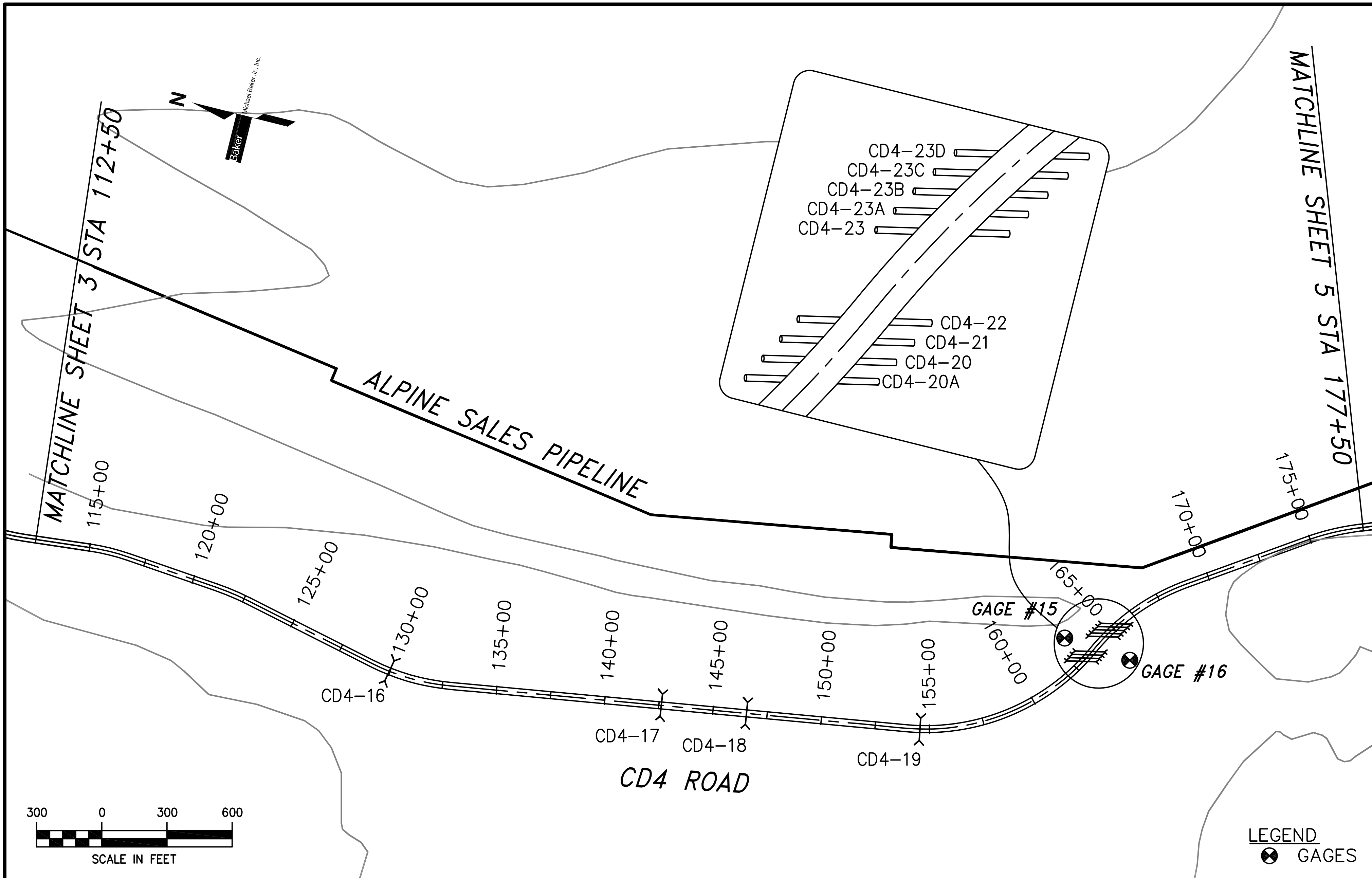
2008 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

FIGURE 4-3
(SHEET 5 OF 6)



ConocoPhillips Alaska, Inc.

DATE:	6/27/08	PROJECT:	114132
DRAWN:	MDM	FILE:	FIGURE_4_3
CHECKED:	OOO	SCALE:	1"= 600'

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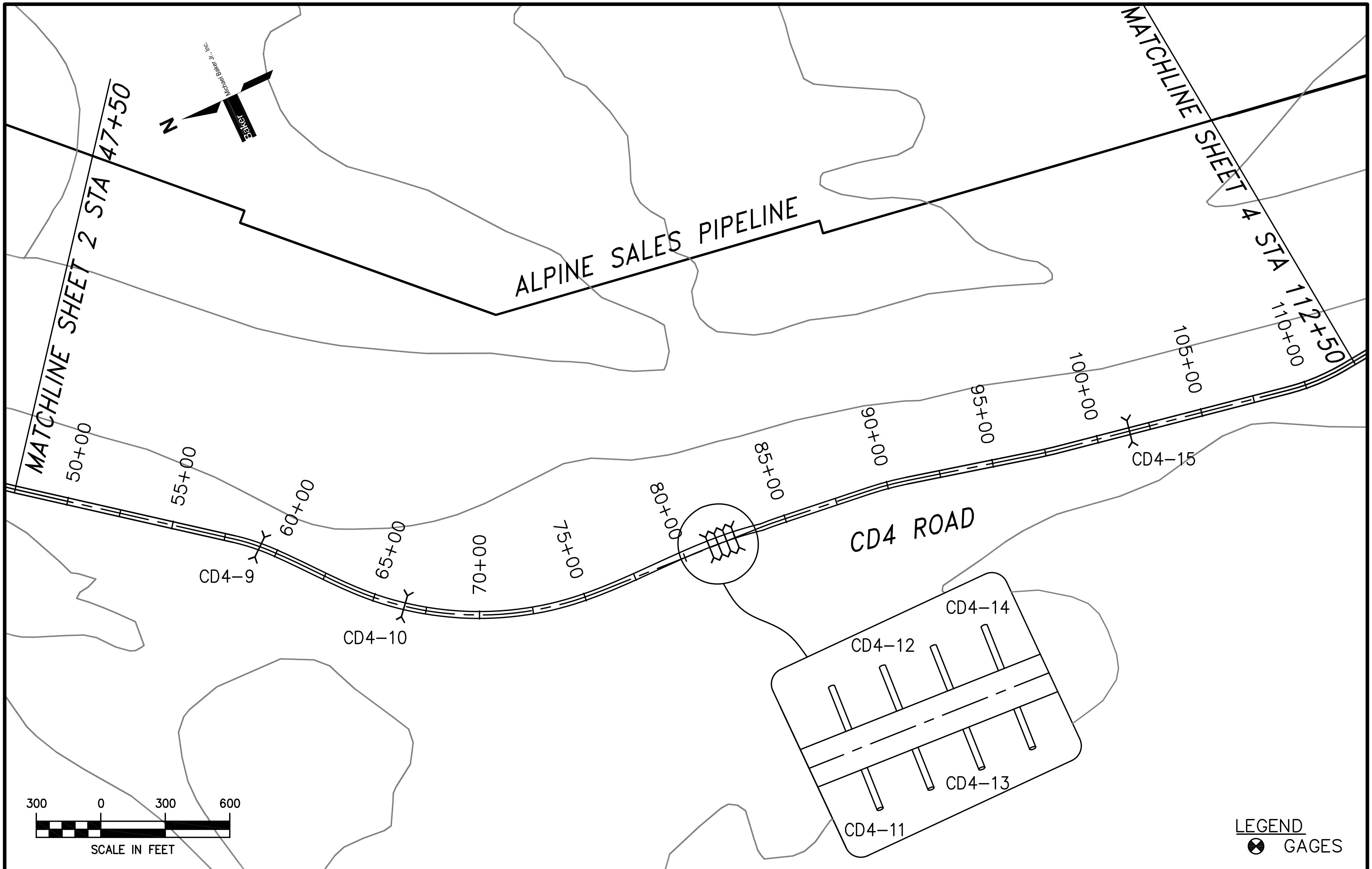
2008 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 4-3
(SHEET 4 OF 6)



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Alaska, Inc.

DATE:	6/27/08	PROJECT:	114132
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CHECKED:	OOO	SCALE:	1"= 600'

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2008 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION
FIGURE 4-3
(SHEET 3 OF 6)

4.8 Tables

Table 4-12 Monument 1

Date and Time	WSE (ft BPMSL) Mon 1	Discharge (cfs)	Observations
5/27/08 9:00 AM	11.08		
5/27/08 4:10 PM	11.71		
5/28/08 8:40 AM	12.68	335,000	Indirect Discharge. Significant ice jam upstream
5/29/08 8:03 AM	13.95	322,000	Indirect Discharge. Channel free of ice except ribbon along east bank
5/30/08 8:10 AM	13.29		Ice jam at East -Nigliq Channels bifurcation spanning both channels
HIGHWATER	17.29	293,000	Highwater mark on the evening of May 30. Indirect discharge
5/31/08 1:45 PM	12.16	129,000	Direct Discharge Measurment (161,000 cfs Indirect Discharge)
6/1/08 8:06 AM	10.26		

Notes:
1. Elevations are based on Monument 1 of 27.93 feet BPMSL, established by LCMF in 2006
2. WSE line for Mon9 and Helmericks included for reference
3. Pressure transducer (PT) data presented as solid line

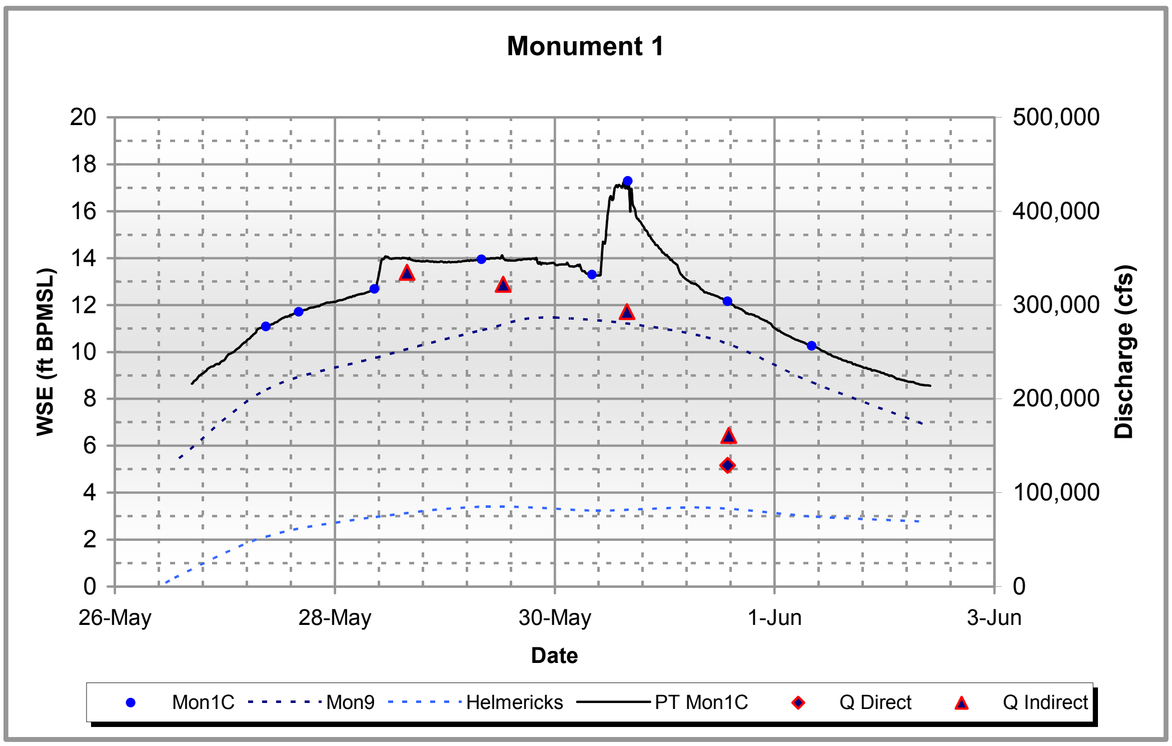


Table 4-13 Monument 1 Upstream and Monument 1 Downstream

Date and Time	WSE (ft BPMSL)		Discharge (cfs)	Observations
	Mon 1U	Mon 1D		
5/26/08 8:40 AM	7.31			
5/27/08 8:50 AM	11.36	10.75		
5/28/08 8:35 AM	13.07	12.28	335,000	Indirect Discharge.
5/29/08 3:25 PM	14.35	13.46	322,000	Indirect Discharge. Ribbon ice spanning channel at Putu Island
5/30/08 10:15 AM	14.49	14.05		Ice jam at East -Nigliq Channels bifurcation spanning both channels
HIGHWATER	17.35	16.93	293,000	Highwater mark on the evening of May 30, Indirect Discharge
5/31/08 2:05 PM	12.29	11.82	129,000	Direct Discharge Measurement (161,000 cfs Indirect Discharge)
6/1/08 8:00 AM	10.47	10.13		Stranded ice spanning Mon1 D
6/2/08 8:10 AM	8.75	8.45		

Notes:

1. Elevations are based on Monument 1 of 27.93 feet BPMSL, established by LCMF in 2006
2. Tabulated values and graph data points from gage readings at Mon 1U and Mon 1D
3. Pressure transducer (PT) data presented as solid line

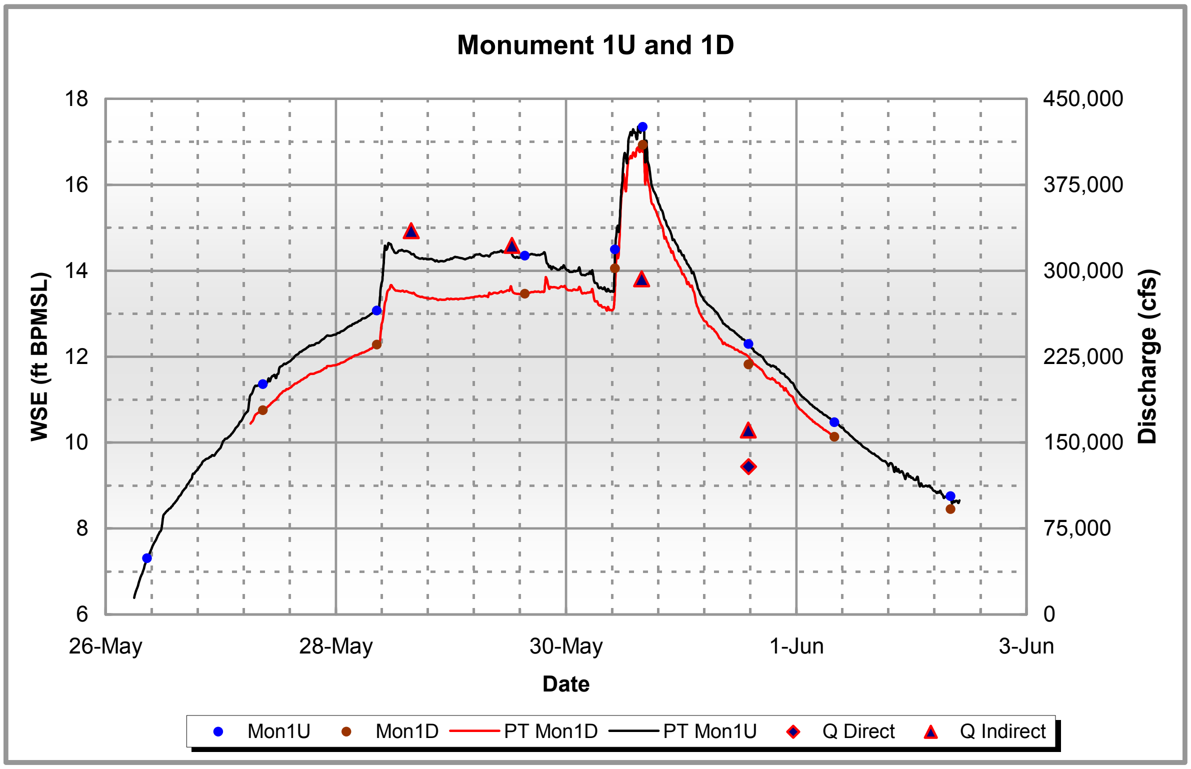


Table 4-14 Monument 9 (HDD East)

Date and Time	WSE (ft BPMSL) Mon 9	Observations
5/26/08 2:00 PM	5.46	
5/27/08 9:05 AM	8.39	Ribbon ice extending from east bank over half of channel. West ice bridge
5/28/08 9:00 AM	9.76	Ramp extending into channel
5/29/08 8:15 AM	10.93	Ribbon ice, east half of ice bridge, and west ramp remain
HIGHWATER	11.47	Highwater mark estimated around noon on May 30 (PT Mon9)
5/31/08 9:00 AM	10.63	Remaining ice bridge has broken up and moved downstream to HDD
6/1/08 8:06 AM	8.71	West ice bridge ramp remains. Channel and banks clear of most ice
6/2/08 9:10 AM	6.87	

Notes:

1. Elevations are based on Monument 9 of 25.06 feet BPMSL, established by LCMF in 2008
2. WSE lines for Mon1 and Helmericks are presented for reference
3. Pressure transducer (PT) data presented as solid line
4. No discharge measurements were collected for this site

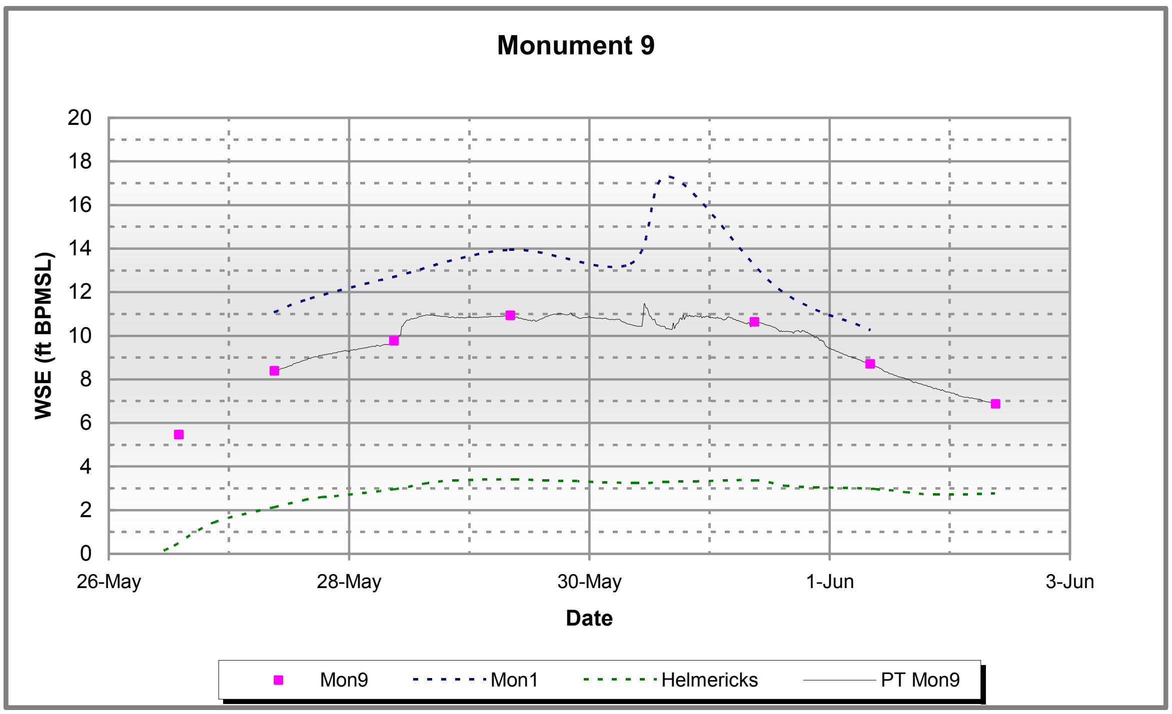


Table 4-15 Helmericks Homestead (Monument 35)

Date and Time	WSE (ft BPMSL) Helmericks	Observations
5/26/08 11:00 AM	0.15	Standing melt water
5/26/08 1:00 PM	0.36	Flooding reached the staff gages, still clear brackish water
5/27/08 9:00 AM	2.13	
5/28/08 9:00 AM	2.96	
HIGHWATER	3.42	Highwater mark estimated on the morning of May 29
5/30/08 9:00 AM	3.24	
5/31/08 9:00 AM	3.37	
6/1/08 9:00 AM	2.98	
6/2/08 9:00 AM	2.76	

Notes:

1. Elevations based on Monument 35 of 5.57 feet BPMSL, established by Lounsbury in 1996
2. Gages survey by Baker with observations conducted by James Helmericks
3. WSE lines for Mon1 and Mon9 are presented for reference
4. No discharge measurements were collected for this site

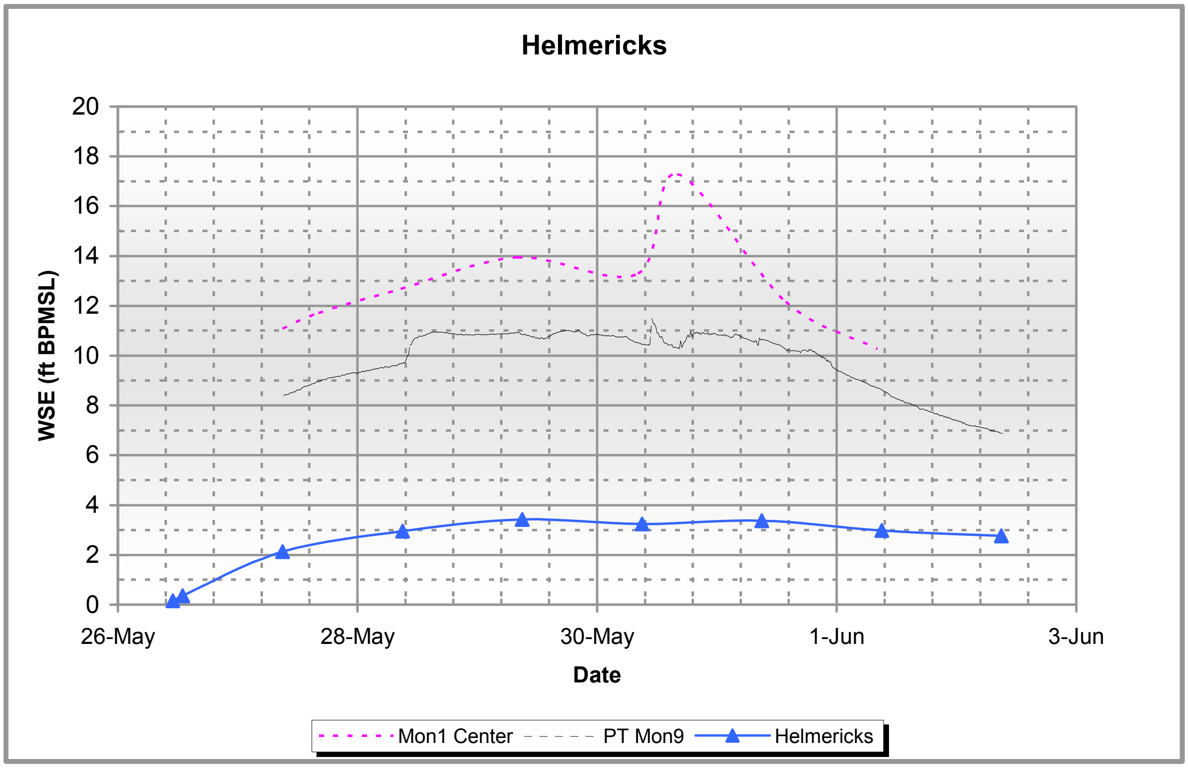


Table 4-16 Monument 20

Date and Time	WSE (ft BPMSL) Mon 20	Observations
5/26/08 8:40 AM	2.12	Riboon ice present spanning nearly entire channel down entire reach
5/27/08 9:25 AM	5.52	Broken ice building along bank
5/28/08 9:05 AM	7.04	Ribbon ice on west bank, stranded ice on east bank - narrow flow passage
5/29/08 8:40 AM	8.00	West bank open though channel choked with ice
HIGHWATER	8.07	Highwater mark estimated on the morning of May 30
5/30/08 4:10 PM	7.35	Ice jamming East-Nigliq Channels bifurcation
5/31/08 9:07 AM	7.35	West bank open though channel remains choked with ice
6/1/08 9:10 AM	7.22	Ribbon ice remains intact
6/2/08 12:40 PM	5.41	Ribbbon ice clearing

Notes:

1. Elevations are based on 05-20-01A of 25.73 BPMSL, established by LCMF in 2007
2. WSE lines for Mon22, Mon23 and Mon28 are presented for reference
3. No discharge measurements were collected at this site

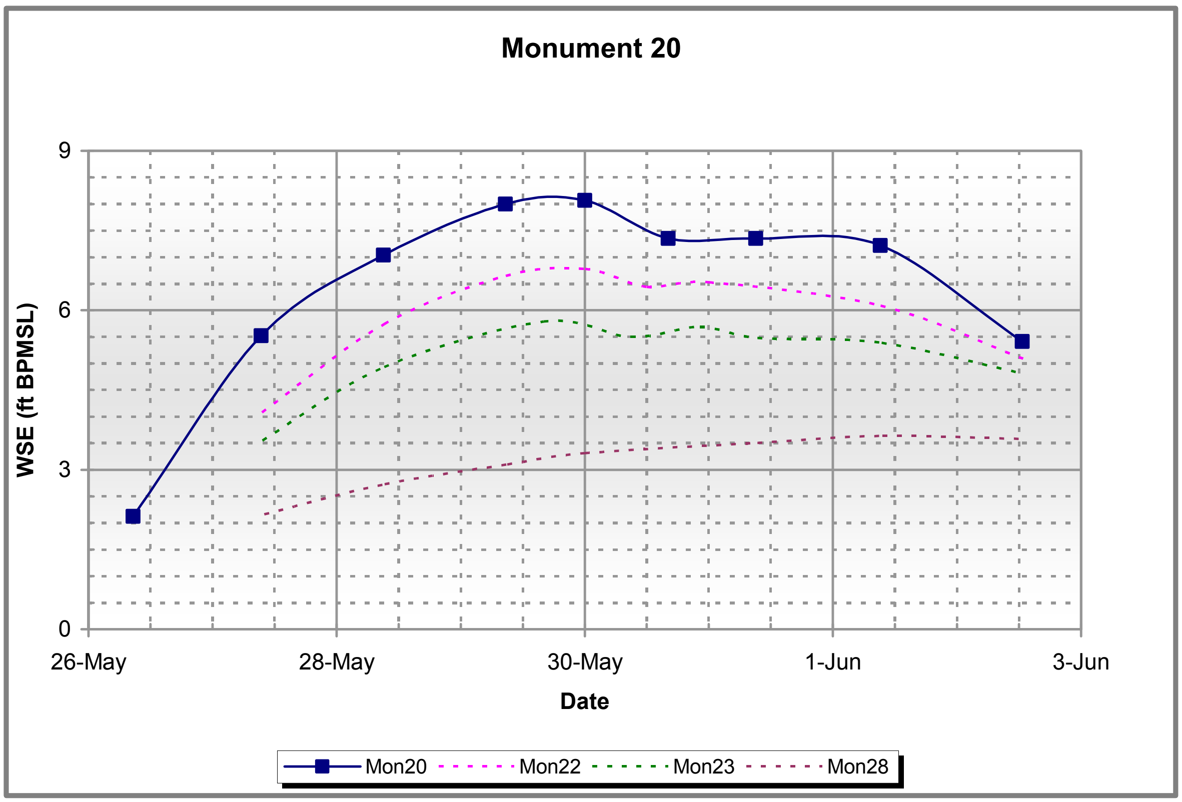


Table 4-17 Monument 22

Date and Time	WSE (ft BPMSL) Mon 22	Observations
5/27/08 9:35 AM	4.08	Riboon ice present spanning nearly entire channel down entire reach
5/28/08 9:10 AM	5.74	Ribbon ice spanning inlet to Nanuq Lake which is filling
5/29/08 8:45 AM	6.65	Nanuq continues to rise, Large & small bridges see flow
HIGHWATER	6.78	Highwater mark estimated on morning of May 30
5/30/08 12:00 PM	6.44	Ice jamming East-Nigliq Channels bifurcation
5/31/08 12:00 AM	6.53	Ribbon ice spanning entire channel downstream of Nanuq inlet
6/1/08 9:13 AM	6.09	Ribbon ice remains intact
6/2/08 12:45 PM	5.09	Ribbbon ice clearing

Notes:

1. Elevations are based on Monument 22 of 10.10 feet BPMSL, established by LCMF in 2003
2. WSE lines for Mon20, Mon23 and Mon28 are presented for reference
3. No discharge measurements were collected at this site

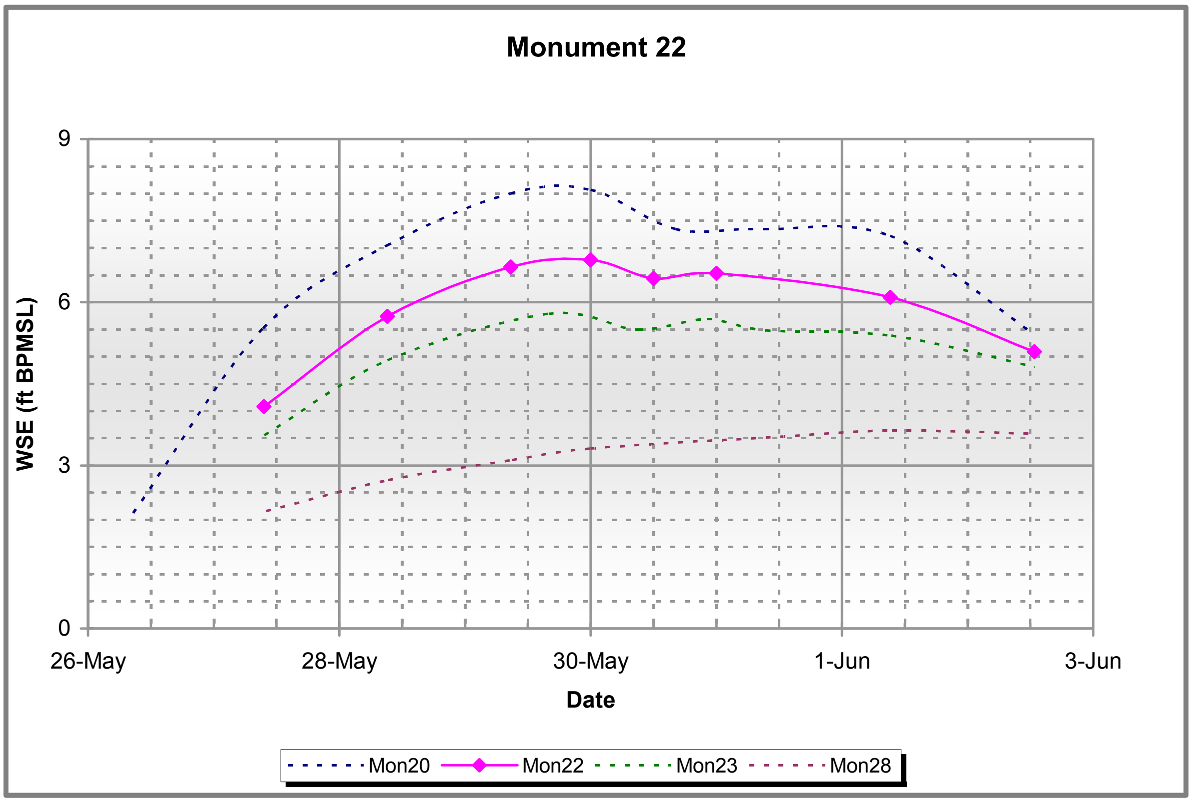


Table 4-18 Monument 23

Date and Time	WSE (ft BPMSL) Mon 23	Dischrage (cfs)	Observations
5/27/08 9:40 AM	3.55		Riboon ice present spanning nearly entire channel down entire reach
5/28/08 9:15 AM	4.93		
HIGHWATER	5.79	50,000	Highwater occurred in evening of May 29
5/30/08 8:55 AM	5.50		Ice jamming East-Nigliq Channels bifurcation
5/30/08 10:15 PM	5.69		Secondary peak. Minor ice jamming and ice floes in Nigliq
5/31/08 9:25 AM	5.48		Ribbon ice spanning channel (east to west) downstream of CD2
6/1/08 9:23 AM	5.39		Ribbon ice remains intact
6/2/08 12:50 PM	4.81		Ribbbon ice clearing

Notes:

1. Elevations are based on Monument 23 of 9.52 feet BPMSL, established by Baker in 2008
2. WSE lines for Mon20, Mon22 and Mon28 are presented for reference
3. Pressure transducer (PT) data presented as solid line

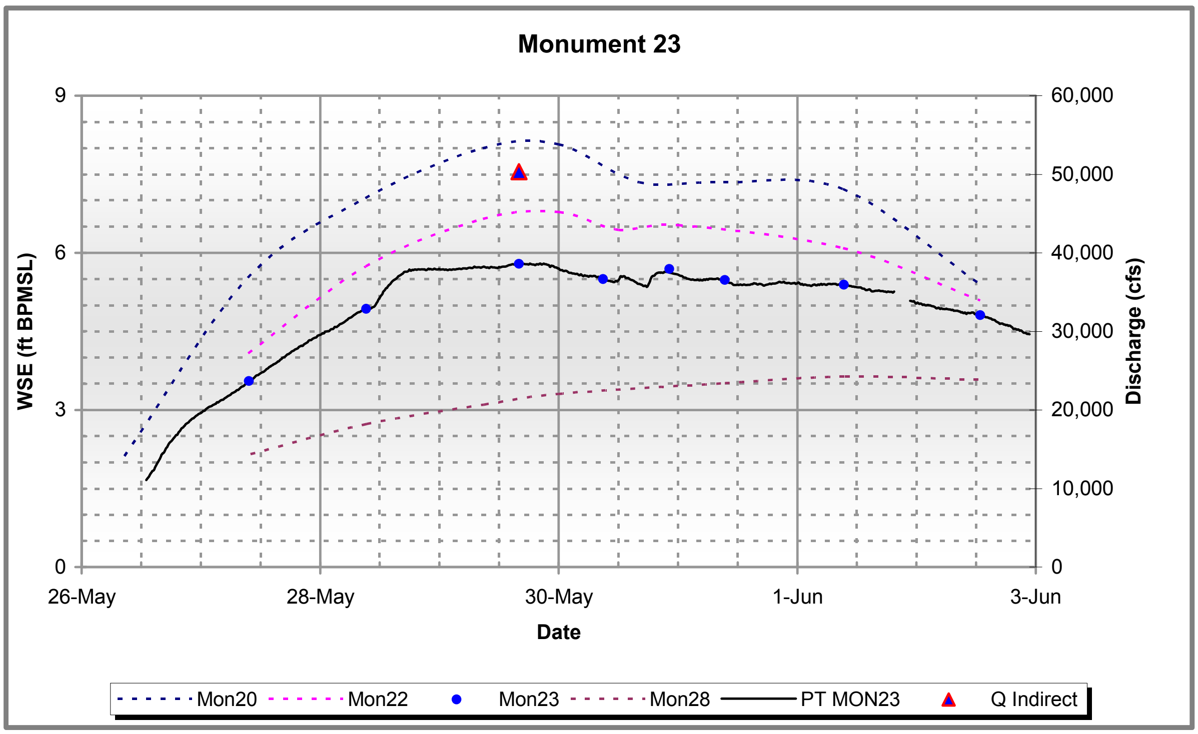


Table 4-19 Monument 28

Date and Time	WSE (ft BPMSL) Mon 28	Observations
5/27/08 10:00 AM	2.16	Sea ice still intact. Water flowing over ice
5/28/08 9:20 AM	2.73	
5/29/08 9:00 AM	3.10	
5/30/08 12:00 AM	3.31	Water continues to rise over sea ice
5/31/08 9:25 AM	3.51	
HIGHWATER	3.64	Highwater estimated on the morning of May 30
6/2/08 12:50 PM	3.58	

Notes:

1. Elevations are based on Monument 28 of 3.66 feet BPMSL, established by Lounsbury in 1996
2. WSE lines for Mon20, Mon22 and Mon23 are presented for reference
3. No discharge measurements were collected for this site

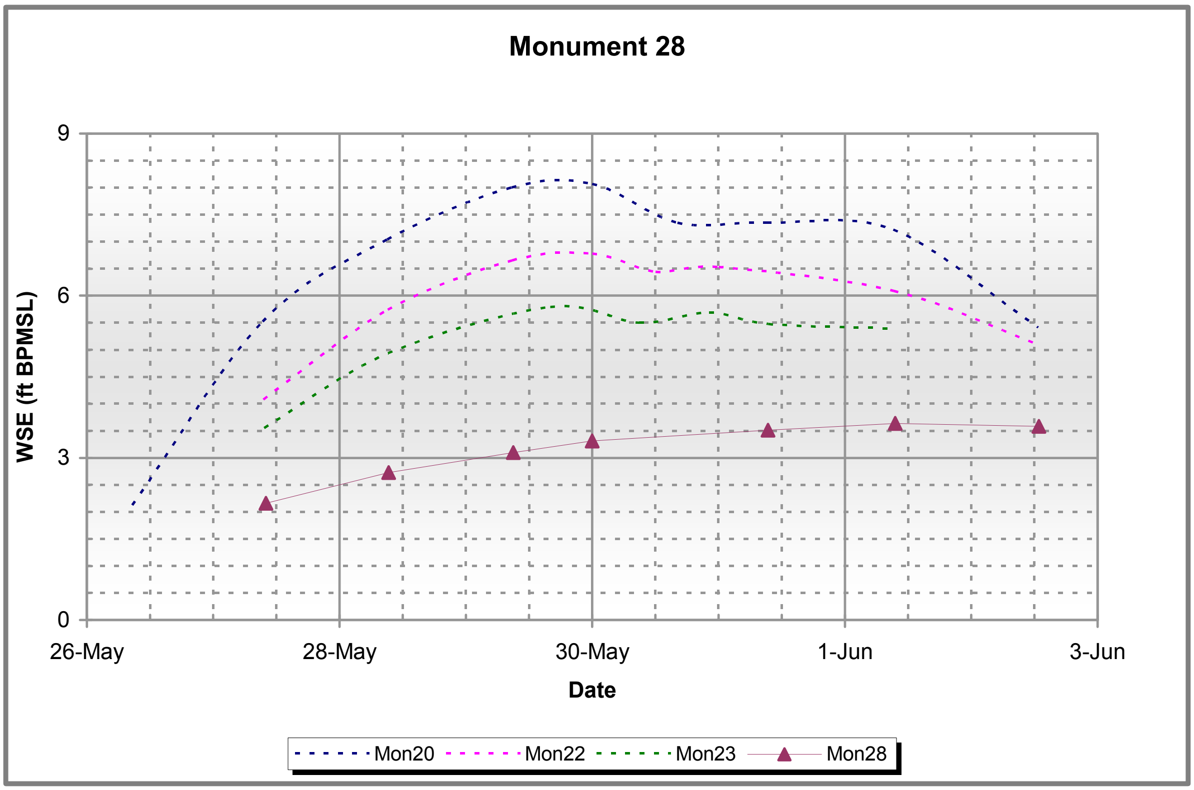


Table 4-20 Gage 1

Date and Time	WSE (ft BPMSL) Gage1	Observations
5/28/08 8:40 AM	3.12	
5/29/08 8:50 AM	4.77	Rapid rise as ice/snow flows through channel
HIGHWATER	5.61	Highwater mark estimated at noon on May 30
5/31/08 8:55 AM	5.42	Snow/ice still present upstream of gage in channel
6/1/08 9:05 AM	5.48	
6/2/08 9:45 AM	4.92	

Notes:

1. Elevation of Gage 1 based on Monument 21 of 13.27 feet BPMSL, established by LCMF in 2005
2. Gage surveyed and set by LCMF in 2007

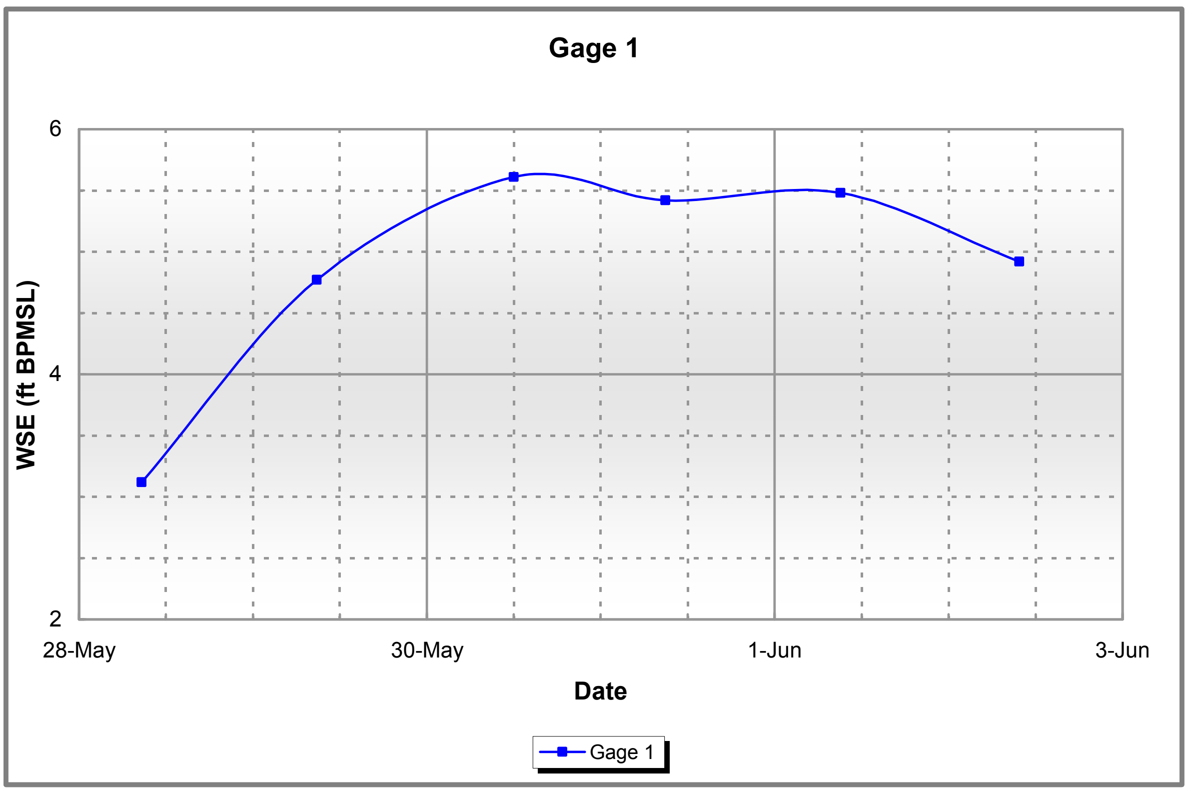


Table 4-21 Gage 9 and Gage 10

Date and Time	WSE (ft BPMSL)		Observations
	Gage 9	Gage 10	
5/27/08 4:55 PM	7.42		Snow melt significant around lakes
5/28/08 9:55 AM		5.84	Standing water evident at lakes' edge
5/29/08 8:45 AM	7.45	5.84	
5/30/08 4:00 PM	7.45	5.91	Floodwater hydraulically connected to L9313 (west shore)
5/31/08 8:45 AM		6.57	Flood water recharge of L9313 evident
HIGHWATER	7.44	6.95	Highwater mark estimated in morning of June 1.
6/2/08 9:35 AM		6.48	Ice remains competent with some standing water around periphery

Notes:

1. Gage 9 is located near Lake L9312 and Gage 10 is located near Lake L9313
2. Elevation for Gage 9 based on TBM 02-01-39-P of 11.46 feett BPMSL, established by LCMF in 2005
3. Elevation for Gage 10 based on Monument 22 of 11.27 ft BPMSL, established by LCMF in 2005

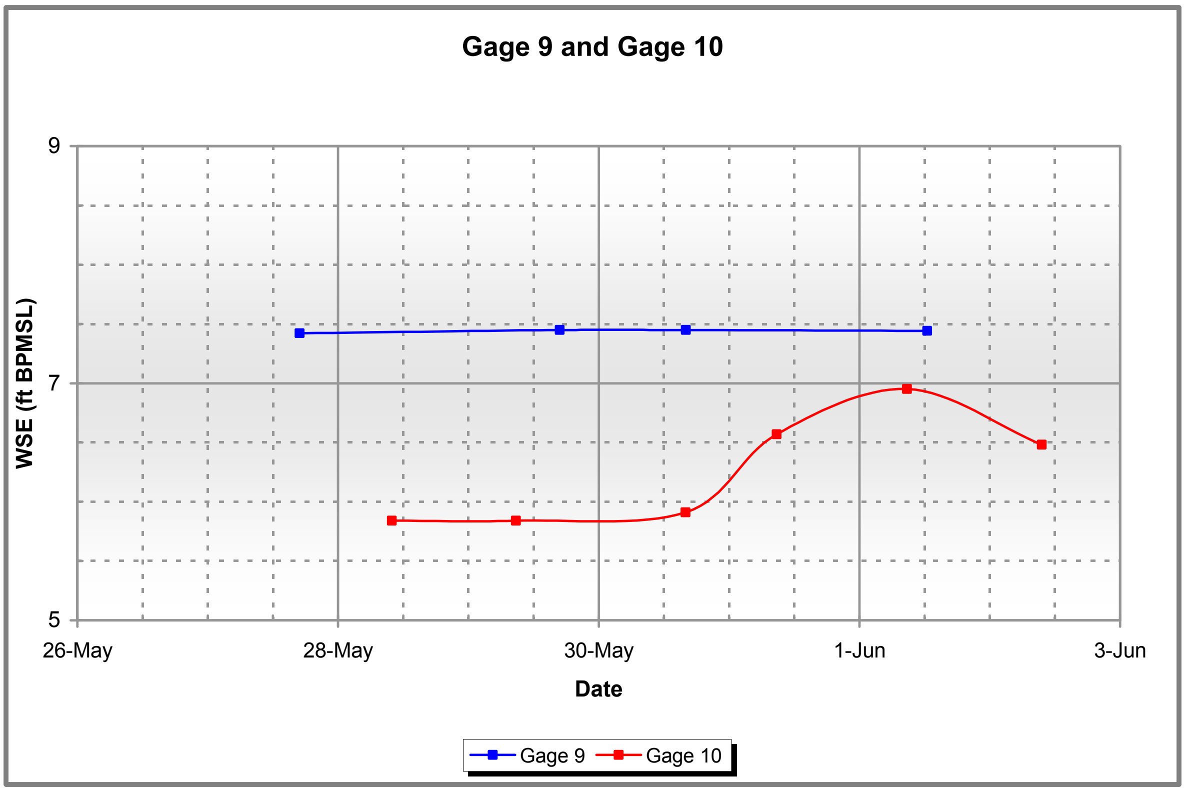


Table 4-22 Gage 3, Gage 4, Gage 6, and Gage 7

Date and Time	WSE (ft BPMSL)				Observations
	Gage 3	Gage 4	Gage 6	Gage 7	
5/28/08 7:54 PM	6.36	6.11			High differential the result of snow under long bridge - clearing
5/29/08 7:50 AM	6.31	6.14			Snow has cleared completely from under long bridge
HIGHWATER	6.49	6.23			Highwater mark estimated on the morning of May 30
5/30/08 3:15 PM	6.00	5.89			Some snow still present under short bridge
5/31/08 8:15 AM	5.92	5.79			
6/1/08 9:05 AM	5.79	5.79			Hydraulic connectivity from Nigliq Channel to Lake M9933
6/2/08 9:05 AM					

Notes:

1. Elevation for Gage 3, Gage 4, Gage 6 and Gage 7 based on Monument 12 of 9.00 feet BPMSL, established by LCMF in 2008
2. Gages surveyed and set by LCMF
3. Gage 6 and Gage 7 did not record any floodwater

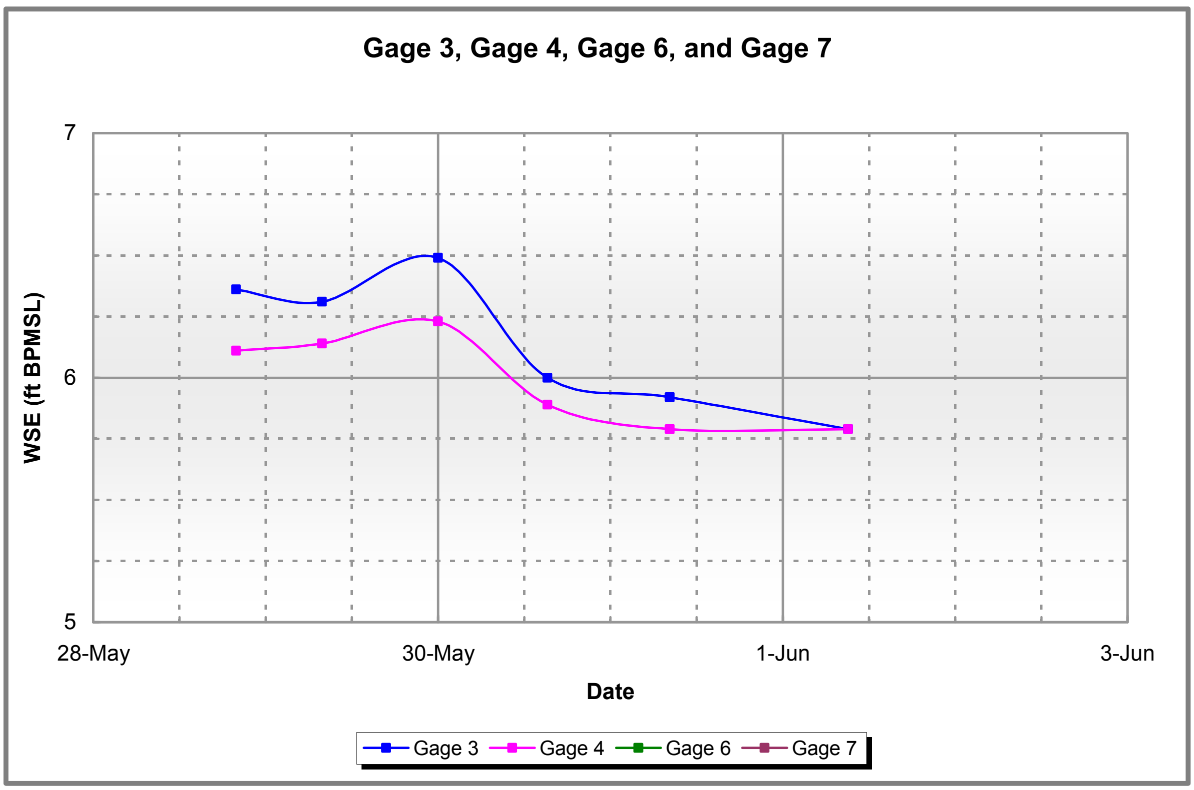


Table 4-23 Pipeline Crossings: SAK, TAM, and ULAM

Date and Time	WSE (ft BPMSL)			Observations
	SAK	TAM	ULAM	
5/26/08 3:20 PM		1.89		
5/27/08 10:00 AM		4.16		Flow evident in Tam only. Local melt in Sak and Ulam.
5/28/08 10:15 AM	3.12	5.09	4.79	Flow evident in all channels. Ice and snow still present.
5/29/08 9:15 AM	4.80	5.92	5.50	
HIGHWATER	5.39	6.07	5.13	Highwater mark estimated in the morning of May 30
HIGHWATER	5.23	5.50	5.52	Highwater mark estimated in the evening of May 30
5/31/08 9:50 AM	5.19	5.83	5.50	
6/1/08 9:50 AM	5.15	5.33	5.05	
6/2/08 1:20 PM	4.67	4.62	4.50	Ice floes still present though limited in density and size

Notes:

1. Basis of elevation for Crossing #2 (SAK) on Pile 568 of 23.73 feet BPMSL, established by LCMF 2008
2. Basis of elevation for Crossing #4 (TAM) on Pile 330 of 16.182 feet BPMSL, established by LCMF 2008
3. Basis of elevation for Crossing #5 (ULAM) on Pile 119 of 18.121 feet BPMSL, established by LCMF 2008

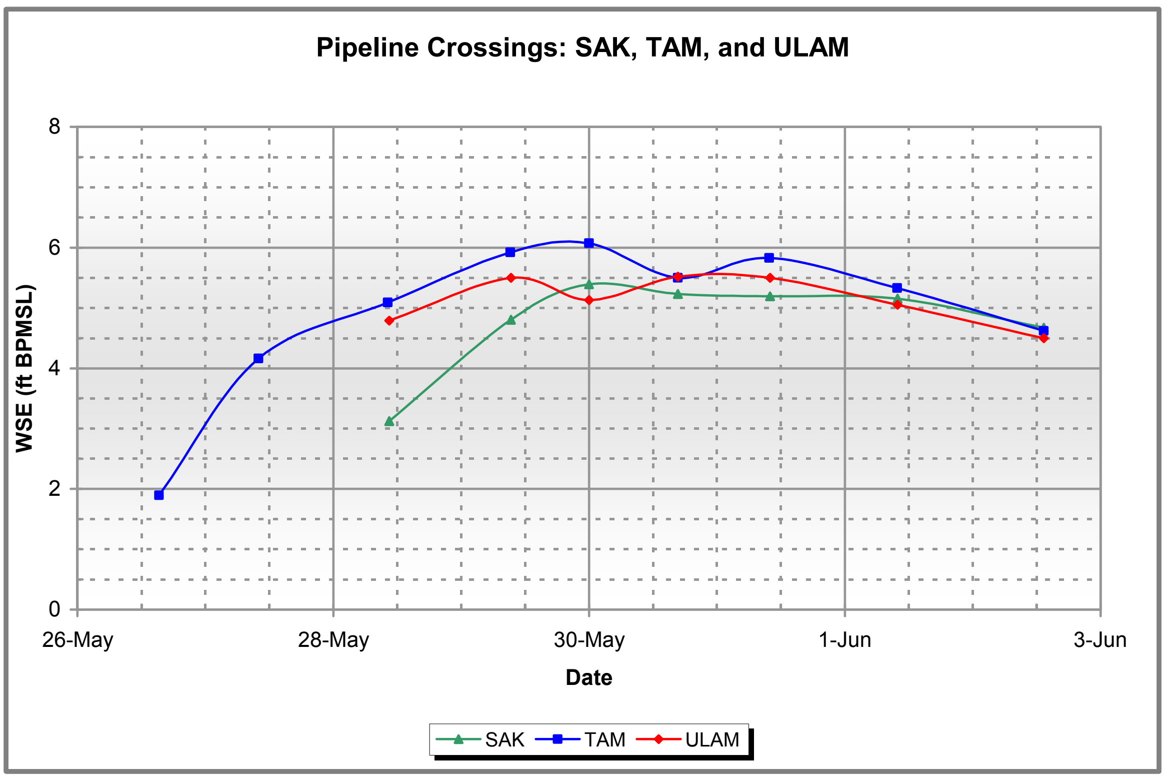
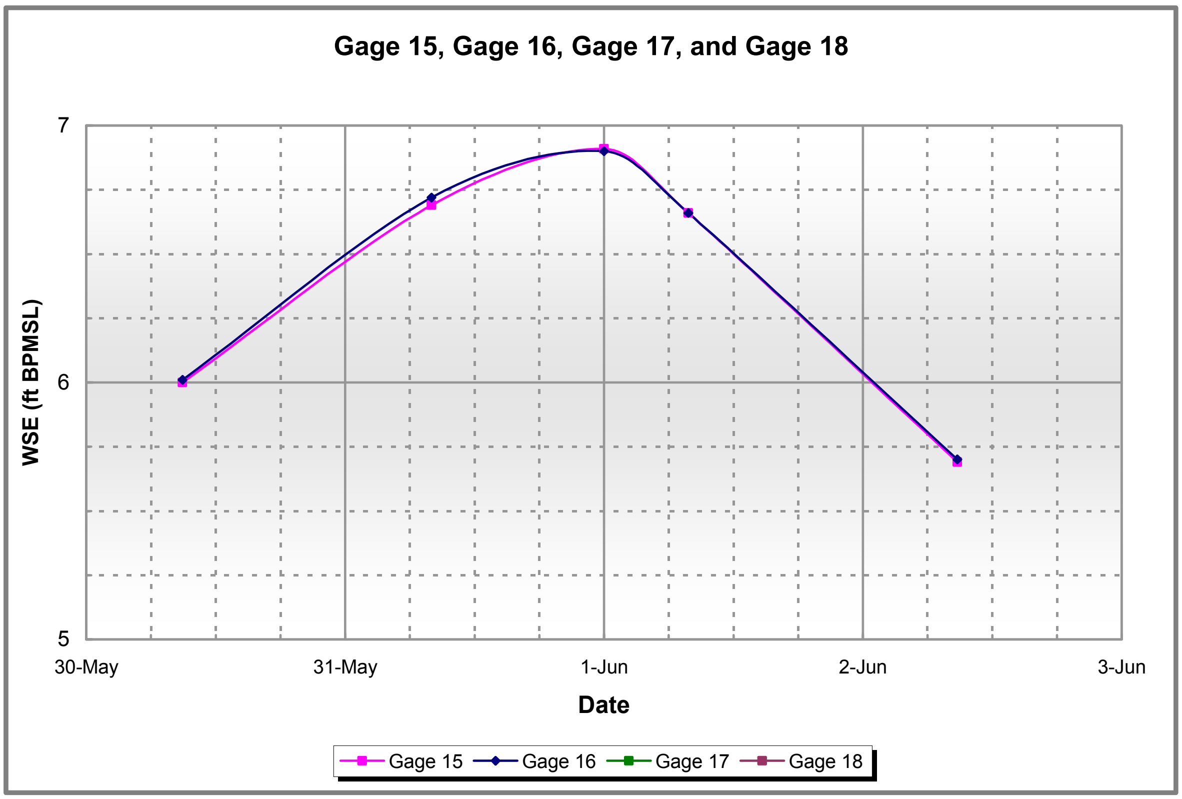


Table 4-24 Gage 15, Gage 16, Gage 17, and Gage 18

	WSE (ft BPMSL)				
Date and Time	Gage 15	Gage 16	Gage 17	Gage 18	Observations
5/30/08 8:55 AM	6.00	6.01			
5/31/08 8:00 AM	6.69	6.72			No discernable flow
HIGHWATER	6.91	6.90			Highwater mark estimated in late evening of May 31
6/1/08 7:50 AM	6.66	6.66			No hydraulic connectivity to L9323 from north culvert battery
6/2/08 8:45 AM	5.69	5.70			Standing water - no flow

Notes:

1. Elevation for Gages 15 and 16 based on NAN2 of 13.31 feett BPMSL, established by LCMF in 2005
2. Elevation for Gages 17 and 18 based on 05-20-01B of 25.73 feet BPMSL, established by LCMF in 2007
3. Gage 17 and Gage 18 did not record any floodwater



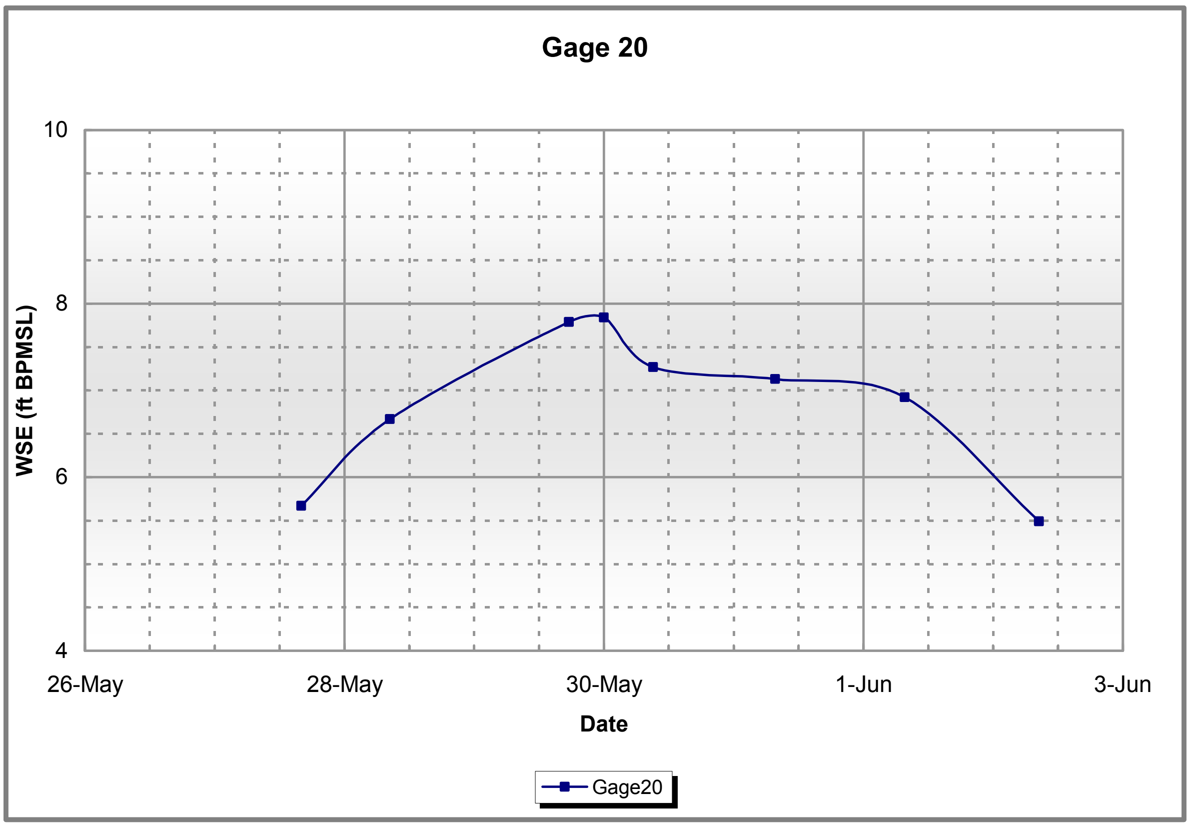
Baker

Table 4-25 Gage 20

Date and Time	WSE (ft BPMSL)) Gage 20	Observations
5/27/08 4:00 PM	5.67	Ribbon ice spanning lake inlet. See next line
5/28/08 8:25 AM	6.67	Lake hydraulically connecetd to L9324
5/29/08 5:32 PM	7.79	Water near bankfull. Ribbon ice remains
HIGHWATER	7.84	Highwater mark estimated morning of May 30.
5/30/08 9:07 AM	7.27	
5/31/08 7:40 AM	7.1	
6/1/08 7:40 AM	6.92	
6/2/08 8:30 AM	5.49	Lake remains hydraulically connecetd to L9324

Notes:

1. Elevations for Gage 20 based on 05-20-01A of 25.73 ft BPMSL, established by LCMF in 2007



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5.2 Acronyms

ADCP	Acoustic Doppler Current Profiler
ADF&G	Alaska Department of Fish and Game
BPMSL	British Petroleum Mean Sea Level
CMP	Corrugated Metal Pipe
CPAI	ConocoPhillips, Alaska, Inc.
CRD	Colville River Delta
DGPS	Differentially Corrected Global Positioning System
DNR	Alaska Department of Natural Resources
GPS	Global Positioning System
HDD	Horizontal Directionally Drilled
MASL	Meters Above Sea Level
MMT	Measurement
NAD83	North American Datum of 1983
PSG	Permanent Staff Gage
PT	Pressure Transducer
RM	River Mile
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
WSE	Water Surface Elevation

5.3 Glossary

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

Catchment Basin
See Drainage Basin

Conveyance
A measure of the carrying capacity of a river channel

Direct Discharge
A measurement of discharge based on observed flow velocities and the local cross sectional area of flow

Discharge
The volume of a fluid passing through a cross section of a stream per unit time

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

Flood Frequency Analysis
Procedure of interpreting a record of flood events in terms of future probabilities of flood magnitude (discharge) occurrence

Floodplain
Land area adjoining a water body that is not normally submerged but may be submerged during flood conditions

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

Headwater
The water surface elevation upstream of a structure such a culvert, bridge, or weir

Ice Bridge
A continuous ice cover of limited size extending from shore to shore; often man-made

Ice Floe
Free-floating piece of ice that is greater than about 1 meter (3 feet) in size

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

Ice Jamming
Process of ice accumulation to form an ice jam

Indirect Discharge
An estimate of discharge based on hydraulic equations relating the discharge to the water surface profile and the geometry of the channel. Measured water surface elevation and channel characteristics collected during field surveys are used in the discharge calculation.

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

Paleochannel
An ancient streambed or channel

Pressure Transducer
A type of measurement device that converts pressure-induced mechanical changes into an electrical signal

Reach
(1) The length of a channel uniform with respect to discharge, depth, area, and slope (e.g. "typical channel reach"), (2) the length of a stream between two specified gaging stations, control points, or computational points

Recurrence Interval
The average time interval between the actual occurrence of a hydrological event of a given or greater magnitude

Runoff
Flow that is discharged from an area by stream channels; sometimes subdivided into surface runoff, ground water runoff, and seepage

Scour
The enlargement of a channel cross section by the erosion of streambed or bank material due to flowing water; often considered as being localized

Sheet Ice
A smooth, continuous ice cover formed by the in situ freezing or by the arrest and juxtaposition of ice floes in a single layer

Snow Density
The mass volume unit of snow expressed in mass/volume. Most commonly, it is expressed as a percentage – for a unit area, the depth of the SWE divided by the depth of the snow.

Snow Survey
A general term for the manual sampling of snow

Sounding
Water depth measurement using a weighted line

Spring Breakup
See Breakup

Staff Gage
See Gage

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

Stage Frequency Analysis
Procedure of interpreting a stage record of events in terms of future probabilities of flood stage occurrence

Stranded Ice
Ice that has been floating and has been deposited on the shore by a lowering of the water level

Tailwater
The water surface elevation downstream of a structure such a culvert, bridge, or weir

Thalweg
Deepest portion of the river channel; the line of major flow

Thermoerosion (subaqueous)
The thermal and mechanical erosion of ice-bonded sediment caused by the energy of moving water

Transect
A sample area, cross section, or line chosen as the basis for sampling one or more characteristics of a particular assemblage

Velocity Measurement Depth
Depth down from water surface; commonly 60% total depth in water of 2.5 feet or less or 20% and 80% total depth in water greater than 2.5 feet in depth

Water Slope
Change in water surface elevation per unit distance

Water Surface Elevation (WSE)
See Stage

Appendix A Survey Control and Gage Summary

Table A-1 Summary of 2008 Vertical Control

Monument	Elevation (BPMSL - Feet)	Latitude (NAD83)	Longitude (NAD83)	Monument	Reference
Mon 01	27.93	N 70° 09' 57.2"	W 150° 56' 23.8"	Alcap	LCMF 2006
Mon 09	25.06	N 70° 14' 40.6"	W 150° 51' 29.6"	Alcap	LCMF 2008
Mon 22	10.10	N 70° 19' 05.2"	W 151° 03' 21.9"	Alcap	LCMF 2003
Mon 23	9.52	N 70° 20' 40.0"	W 151° 03' 40.7"	Alcap	Baker 2008
Mon 28	3.66	N 70° 25' 31.9"	W 151° 04' 01.2"	Alcap	Lounsbury 1996
Mon 35	5.57	N 70° 25' 57.0"	W 150° 23' 00.4"	Alcap	Lounsbury 1996
Mon 12	9.01	N 70° 20' 22.9"	W 151° 02' 34.2"	Drill Stem	LCMF 2007
Mon 21	13.27	N 70° 20' 32.7"	W 150° 55' 25.0"	Drill Stem	LCMF 2005
Mon 22	11.24	N 70° 20' 32.1"	W 150° 55' 55.6"	Drill Stem	LCMF 2007
02-01-39O	11.45	N 70° 20' 01.5"	W 150° 57' 07.2"	HSM	LCMF 2007
02-01-39P	11.71	N 70° 20' 01.5"	W 150° 57' 06.6"	HSM	LCMF 2007
05-20-01B	25.73	N 70° 17' 31.4"	W 150° 59' 19.9"	HSM	LCMF 2007
05-20-01A	25.73	N 70° 17' 30.3"	W 150° 59' 32.9"	HSM	LCMF 2007
Pile 568	23.73	N 70° 21' 50.0"	W 150° 55' 13.9"	VSM	LCMF 2008
Pile 330	16.18	N 70° 23' 25.0"	W 150° 54' 50.5"	VSM	LCMF 2008
Pile 119	18.12	N 70° 24' 25.9"	W 150° 52' 54.0"	VSM	LCMF 2008
NAN2	13.67	N 70° 18' 14.9"	W 150° 59' 50.6"	Alcap	LCMF 2008

Table A-2 Summary of 2008 Gage Locations

Gage Site	Gage	Latitude (NAD83)	Longitude (NAD83)	Basis of Elevation
CD 1	GG1	N 70° 20' 34.0"	W 150° 55' 15.0"	Mon 21
	GG9	N 70° 20' 1.0"	W 150° 57' 7.0"	TBM 02-01-39-O
	GG10	N 70° 20' 33.0"	W 150° 55' 58.0"	TBM L99-27-3
CD 2	GG3	N 70° 20' 24.0"	W 150° 58' 59.0"	CD2-14N
	GG4	N 70° 20' 25.0"	W 150° 59' 00.0"	CD2-14N
	GG6	N 70° 20' 23.0"	W 151° 01' 45"	CD2- 6S
	GG7	N 70° 20' 24.0"	W 151° 01' 44.0"	CD2-7N
	GG8	N 70° 20' 21.3"	W 151° 02' 56.5"	CD2-14N
	GG12	N 70° 20' 12.2"	W 151° 00' 42.2"	CD2-14N
	GG13	N 70° 20' 14.3"	W 151° 00' 42.6"	CD2-14N
SAK Pipe Bridge	TBM A	N 70° 21' 52.5"	W 150° 55' 18.2"	Pile 568
	TBM B	N 70° 21' 52.2"	W 150° 55' 19.2"	Pile 568
	TBM C	N 70° 21' 52.1"	W 150° 55' 19.2"	Pile 568
TAM Pipe Bridge	TBM A	N 70° 23' 30.5"	W 150° 54' 43.1"	Pile 330
	TBM B	N 70° 23' 29.4"	W 150° 54' 41.0"	Pile 330
	TBM C ANG	N 70° 23' 28.3"	W 150° 54' 39.1"	Pile 330
ULAM Pipe Bridge	TBM A	N 70° 24' 25.0"	W 150° 52' 59.8"	Pile 119
	TBM B ANG	N 70° 24' 25.3"	W 150° 52' 59.1"	Pile 119
CD 3	Gage 11	N 70° 25' 03.0"	W 150° 54' 37.9"	Pile 08
CD 4	GG15	N 70° 18' 07.9"	W 150° 59' 36.0"	NAN 2
	GG15 A	N 70° 18' 08.1"	W 150° 59' 34.4"	NAN 2
	GG15 B	N 70° 18' 08.8"	W 150° 59' 38.0"	NAN 2
	GG16	N 70° 18' 06.0"	W 150° 59' 36.0"	NAN 2
	GG16 A	N 70° 18' 06.2"	W 150° 59' 35.7"	NAN 2
	GG16 B	N 70° 18' 06.3"	W 150° 59' 39.5"	NAN 2
	GG17	N 70° 17' 36.0"	W 150° 58' 58.0"	05-20-01 B
	GG18	N 70° 17' 33.0"	W 150° 58' 57.0"	05-20-01 B
	GG19	N 70° 17' 30.0"	W 150° 59' 18.0"	05-20-01 B
	GG20	N 70° 17' 30.0"	W 150° 59' 50.0"	05-20-01 A
	GG20 A	N 70° 17' 30.2"	W 150° 59' 48.5"	05-20-01 A
	GG20 A-1	N 70° 17' 29.6"	W 150° 59' 49.3"	05-20-01 A
	GG20 B	N 70° 17' 30.1"	W 150° 59' 48.1"	05-20-01 A

Gage Site	Gage	Latitude (NAD83)	Longitude (NAD83)	Basis of Elevation
Mon 01U	TBM A-1	N 70° 09' 29.6"	W 150° 56' 32.6"	Mon 1
	TBM A	N 70° 09' 30.4"	W 150° 56' 43.0"	Mon 1
	TBM B	N 70° 09' 30.1"	W 150° 56' 44.6"	Mon 1
	TBM C	N 70° 09' 30.5"	W 150° 56' 45.7"	Mon 1
	TBM D	N 70° 09' 30.1"	W 150° 56' 46.4"	Mon 1
	TBM E	N 70° 09' 30.5"	W 150° 56' 46.8"	Mon 1
	TBM F	N 70° 09' 30.6"	W 150° 56' 47.3"	Mon 1
Mon 01 CL	TBM A-2	N 70° 09' 56.2"	W 150° 56' 09.7"	Mon 1
	TBM A-1	N 70° 09' 56.6"	W 150° 56' 17.9"	Mon 1
	TBM A	N 70° 09' 56.7"	W 150° 56' 18.7"	Mon 1
	TBM B	N 70° 09' 56.9"	W 150° 56' 20.4"	Mon 1
	TBM C	N 70° 09' 56.9"	W 150° 56' 21.4"	Mon 1
	TBM D	N 70° 09' 56.9"	W 150° 56' 21.7"	Mon 1
	TBM E	N 70° 09' 57.0"	W 150° 56' 21.9"	Mon 1
	TBM F	N 70° 09' 57.1"	W 150° 56' 22.6"	Mon 1
Mon 01D	TBM A-1	N 70° 10' 26.6"	W 150° 55' 57.5"	Mon 1
	TBM A	N 70° 10' 25.8"	W 150° 56' 09.4"	Mon 1
	TBM B	N 70° 10' 25.7"	W 150° 56' 11.2"	Mon 1
	TBM C	N 70° 10' 25.6"	W 150° 56' 13.7"	Mon 1
	TBM D	N 70° 10' 25.5"	W 150° 56' 14.5"	Mon 1
Mon 9	TBM A	N 70° 14' 40.0"	W 150° 51' 24.0"	Mon 09
	TBM B	N 70° 14' 40.0"	W 150° 51' 27.0"	Mon 09
	TBM C	N 70° 14' 40.0"	W 150° 51' 27.0"	Mon 09
	TBM D	N 70° 14' 40.0"	W 150° 51' 28.0"	Mon 09
	TBM E	N 70° 14' 40.0"	W 150° 51' 28.0"	Mon 09
Mon 20	TBM A	N 70° 16' 42.7"	W 150° 59' 55.8"	05-20-01 A
	TBM B	N 70° 16' 42.8"	W 150° 59' 55.2"	05-20-01 A
	TBM C	N 70° 16' 42.8"	W 150° 59' 55.0"	05-20-01 A
	TBM D	N 70° 16' 42.8"	W 150° 59' 54.5"	05-20-01 A
	TBM E	N 70° 16' 42.7"	W 150° 59' 53.9"	05-20-01 A
	REBAR	N 70° 16' 42.9"	W 150° 59' 50.0"	05-20-01 A
Mon 22	TBM A	N 70° 19' 07.0"	W 151° 03' 16.3"	Mon 22
	TBM B	N 70° 19' 06.6"	W 151° 03' 17.6"	Mon 22
	TBM C	N 70° 19' 06.5"	W 151° 03' 18.1"	Mon 22
	TBM D	N 70° 19' 05.8"	W 151° 03' 19.8"	Mon 22
Mon 23	TBM A	N 70° 20' 37.1"	W 151° 03' 58.9"	PBM F
	TBM B	N 70° 20' 37.0"	W 151° 03' 56.1"	PBM F
	TBM C	N 70° 20' 37.0"	W 151° 03' 55.0"	PBM F
	TBM D	N 70° 20' 37.0"	W 151° 03' 54.1"	PBM F
	PT	N 70° 20' 37.1"	W 151° 03' 59.7"	PBM F
Mon 28	TBM A	N 70° 25' 32".0	W 151° 04' 01.0"	Mon 28
	TBM B	N 70° 25' 33.0"	W 151° 04' 11.0"	Mon 28
Mon 35	TBM A	N 70° 25' 34.2"	W 150° 24' 17.5"	Mon 35

Appendix B ADCP Discharge Results

Monument 1 Colville River ADCP Direct Discharge, WinRiver II Summary Report
May 31, 2008

Station Number: Centerline — Meas. No: 1
Station Name: Colville River Monument 1 — Date: 05/31/2008

Party: MDM, OOO
Boat/Motor: Achilles, 25 HP
Gage Height: 0.00 ft

Width: 2,960 ft
Area: 41,700 ft²
G.H.Change: 0.00 ft

Processed by: MDM
Mean Velocity: 3.02 ft/s
Discharge: 126,000 ft³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: On Site (23.0°)
Depth Sounder: Not Used

ADCP Depth: 1.250 ft
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 ft/s — Rating No.: 1
Adj.Mean Vel: 0.00 ft/s — Qm Rating: U
Rated Area: 0.000 ft² — Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: NO
BT Error Vel.: 0.33 ft/s
WT Error Vel.: 3.50 ft/s
BT Up Vel.: 1.00 ft/s
WT Up Vel.: 10.00 ft/s
Use Weighted Mean Depth: YES

Max. Vel.: 6.10 ft/s
Max. Depth: 32.5 ft
Mean Depth: 14.1 ft
% Meas.: 69.25
Water Temp.: None
ADCP Temp.: 36.6 °F

ADCP:
Type/Freq.: Workhorse/600 kHz
Serial #: — Firmware: 16.30
Bin Size: 50 cm — Blank: 25 cm
BT Mode: 5 — BT Pings: 1
WT Mode: 1 — WT Pings: 1
WV : 254

Performed Diag. Test: NO
Performed Moving Bed Test: NO
Performed Compass Test: YES
Meas. Location:

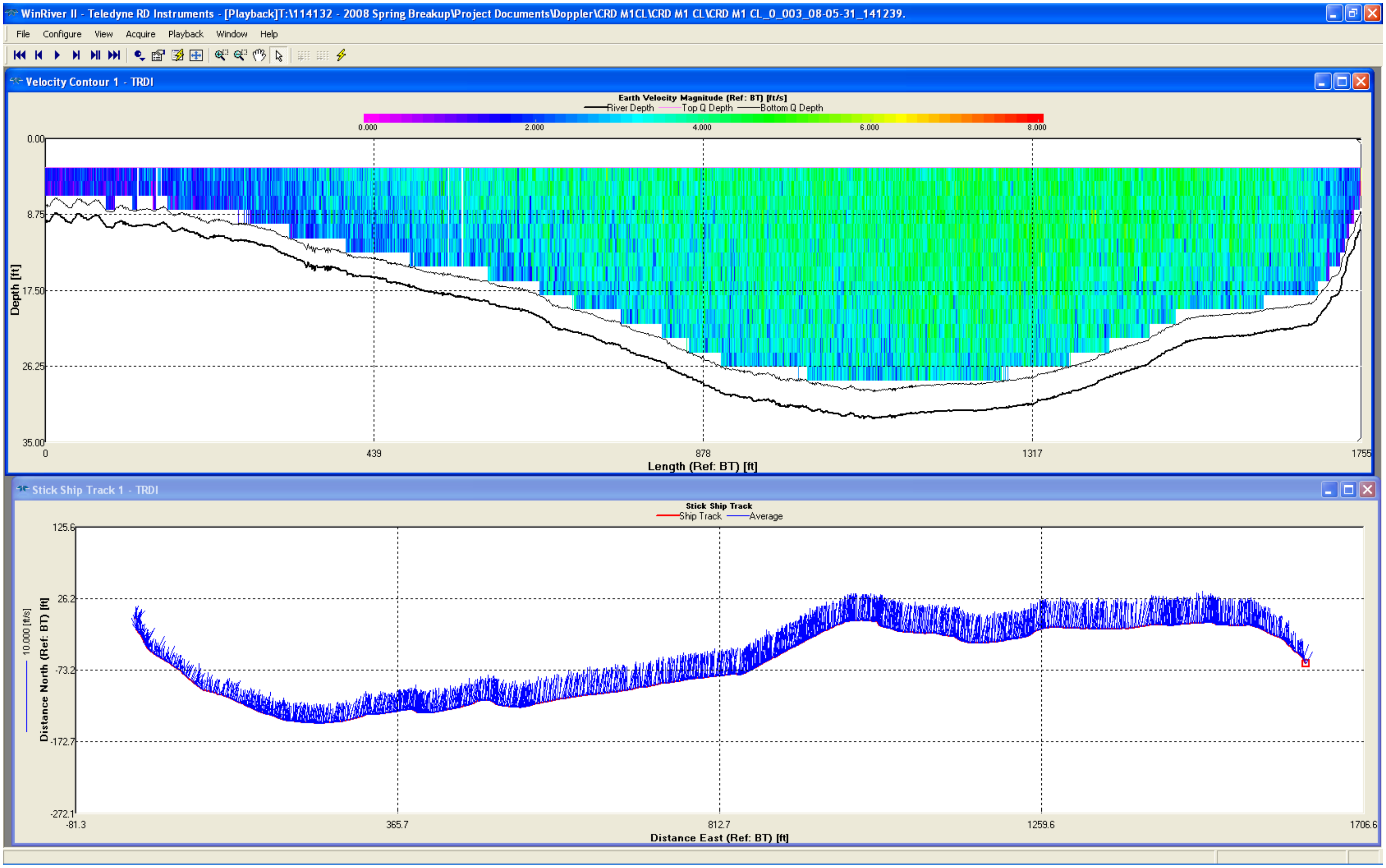
Project Name: CRD M1 CL.mmt
Software: 1.01

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
003	L	1320	8	1476	19078	86633	12520	6187	54.3	124472	2952	42300	14:13	14:31	1.65	2.94	0	0
004	R	1390	8	1157	19133	87283	12409	6586	47.0	125459	2969	40874	14:32	14:46	2.19	3.07	0	0
005	L	1320	8	1307	19260	86066	12515	6635	72.2	124548	2979	42004	14:47	15:03	2.24	2.97	1	0
006	R	1310	8	993	19701	88494	12739	7732	44.8	128710	2942	41438	15:04	15:16	2.38	3.11	1	0
Mean		1335	8	1233	19293	87119	12546	6785	54.6	125797	2961	41654	**Total**	01:03	2.11	3.02	1	0
SDev		11	0	206	8.00	29.5	3.92	18.8	0.352	56.4	5.08	58.62			0.10	0.02		
R/M%		6	0	39.2	3.2	2.8	2.6	22.8	50.2	3.4	1.3	3.4			34.64	5.43		

Remarks: SOME DEBRIS IN CHANNEL. MINOR DOWNSTREAM CONTROL (ICE JAMS)

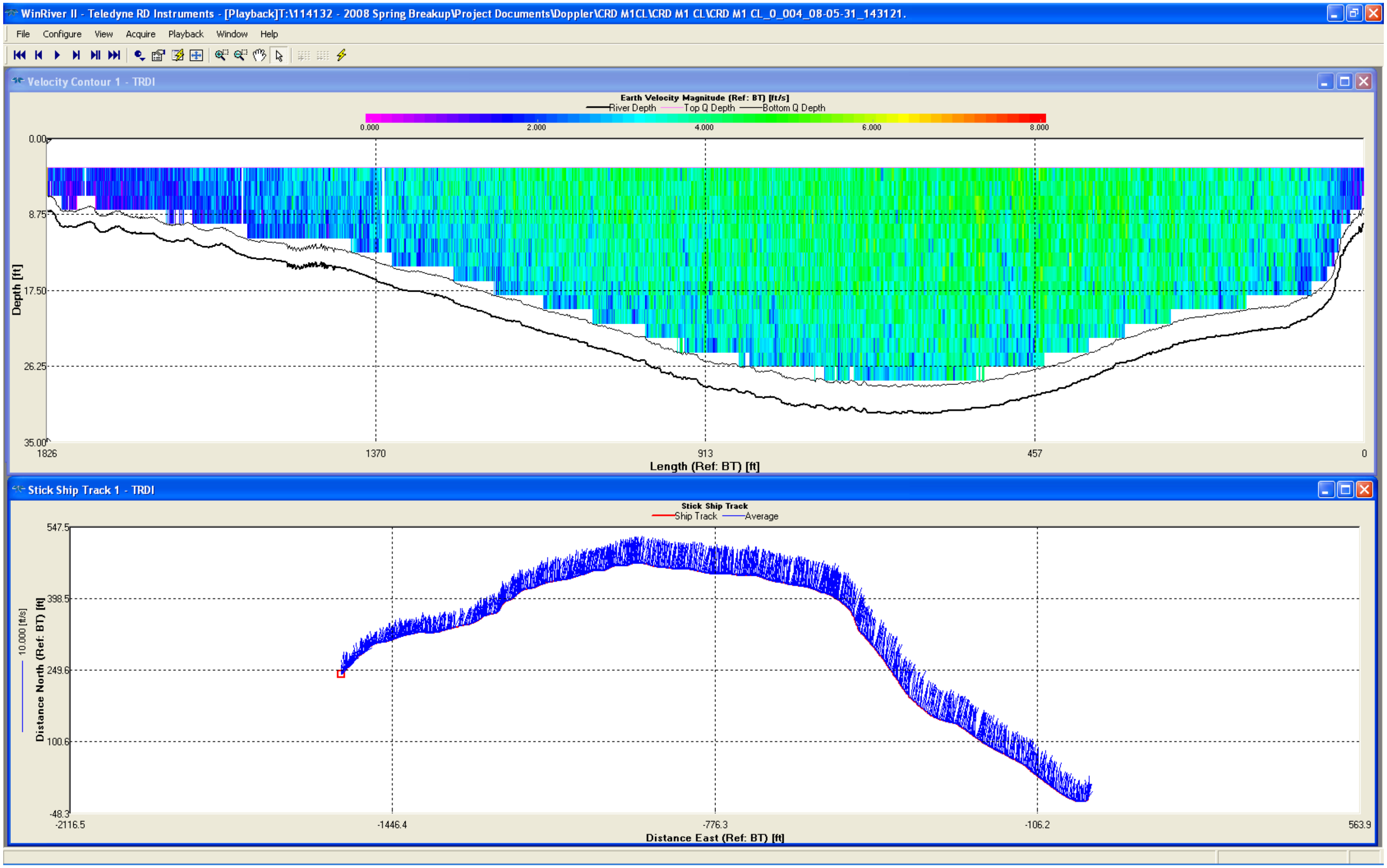
Monument 1 Colville River ADCP Direct Discharge Transect 1, WinRiver II Velocity and Ship Plots

May 31, 2008



Monument 1 Colville River ADCP Direct Discharge Transect 2, WinRiver II Velocity and Ship Plots

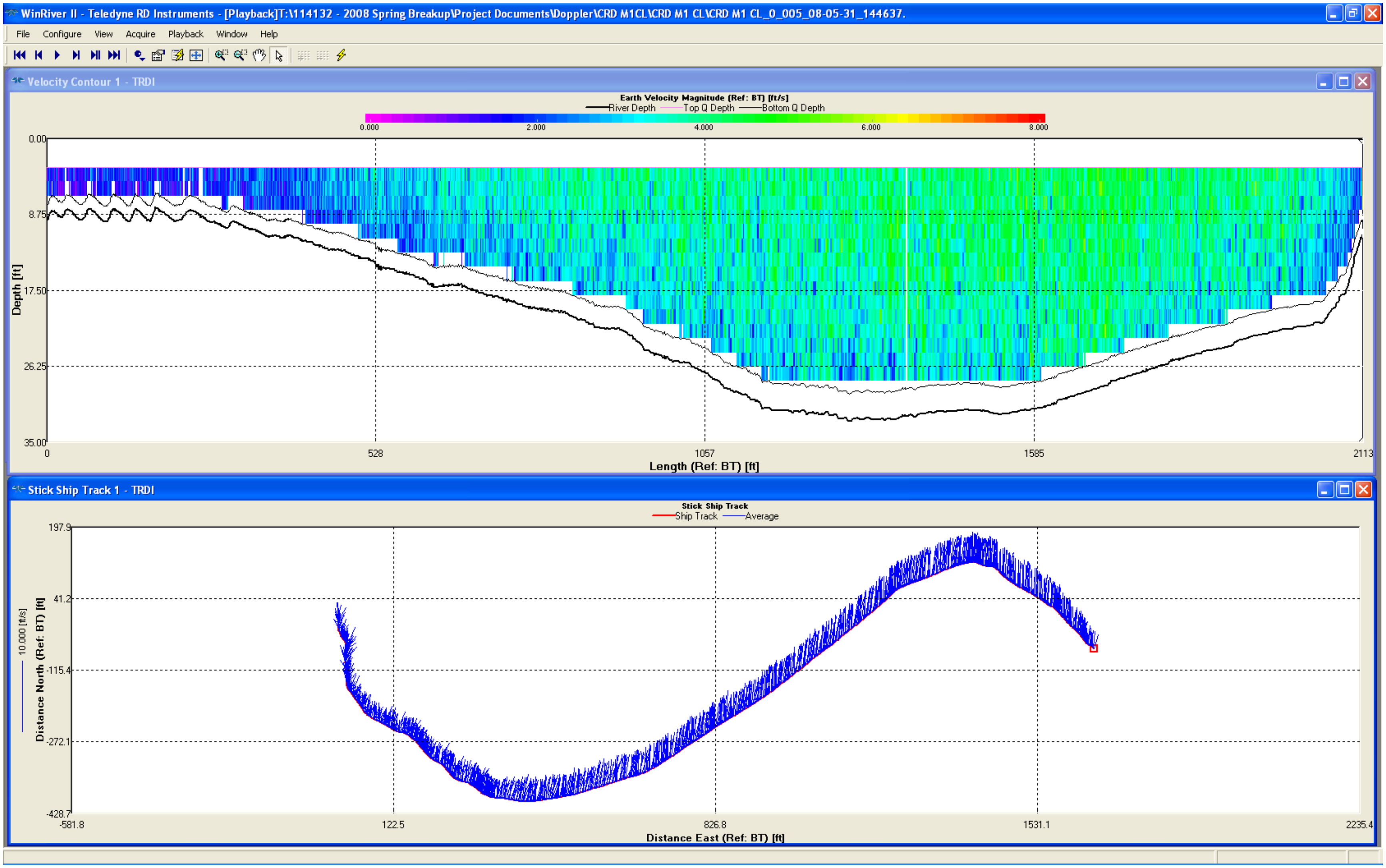
May 31, 2008



Baker

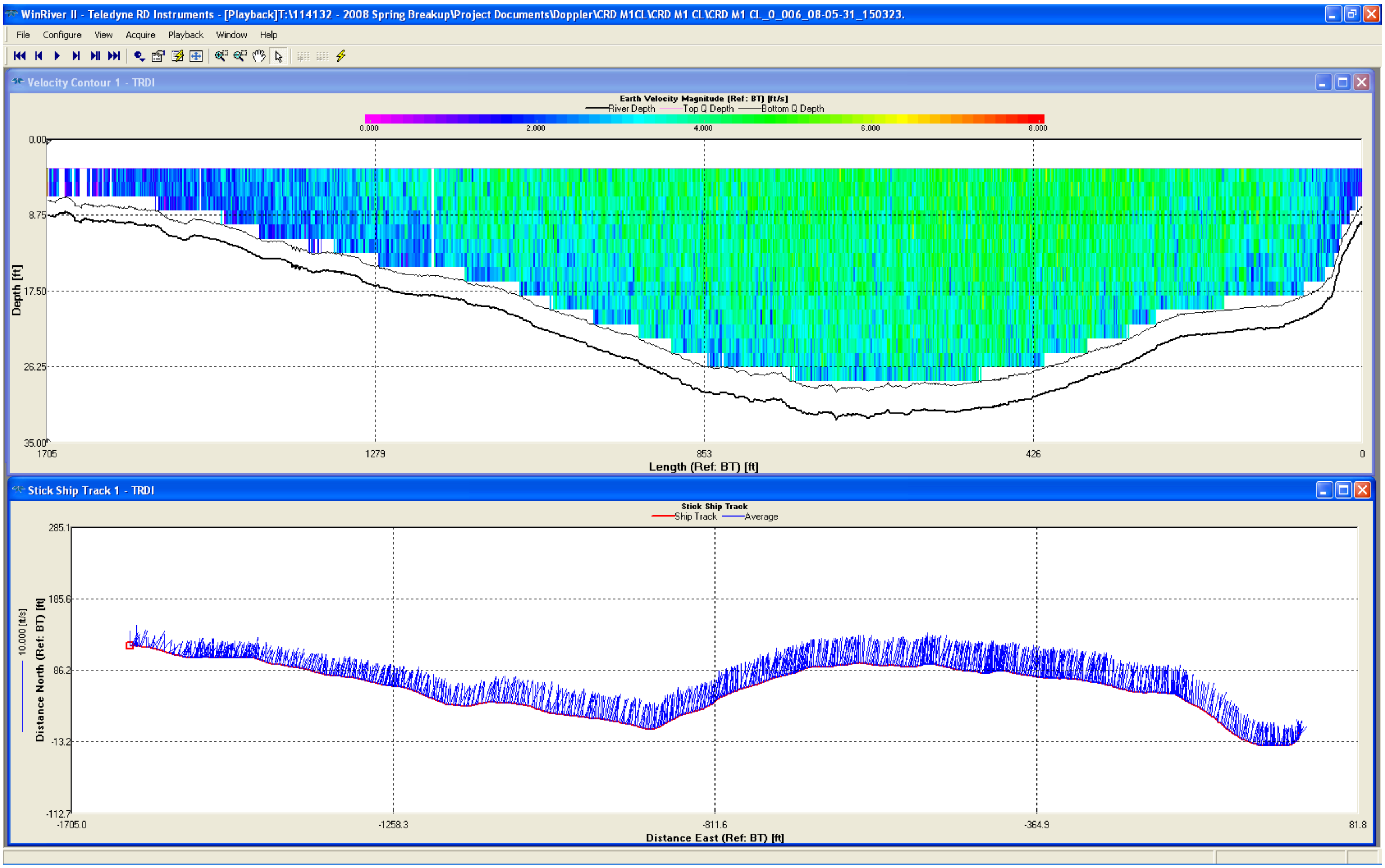
Monument 1 Colville River ADCP Direct Discharge Transect 3, WinRiver II Velocity and Ship Plots

May 31, 2008



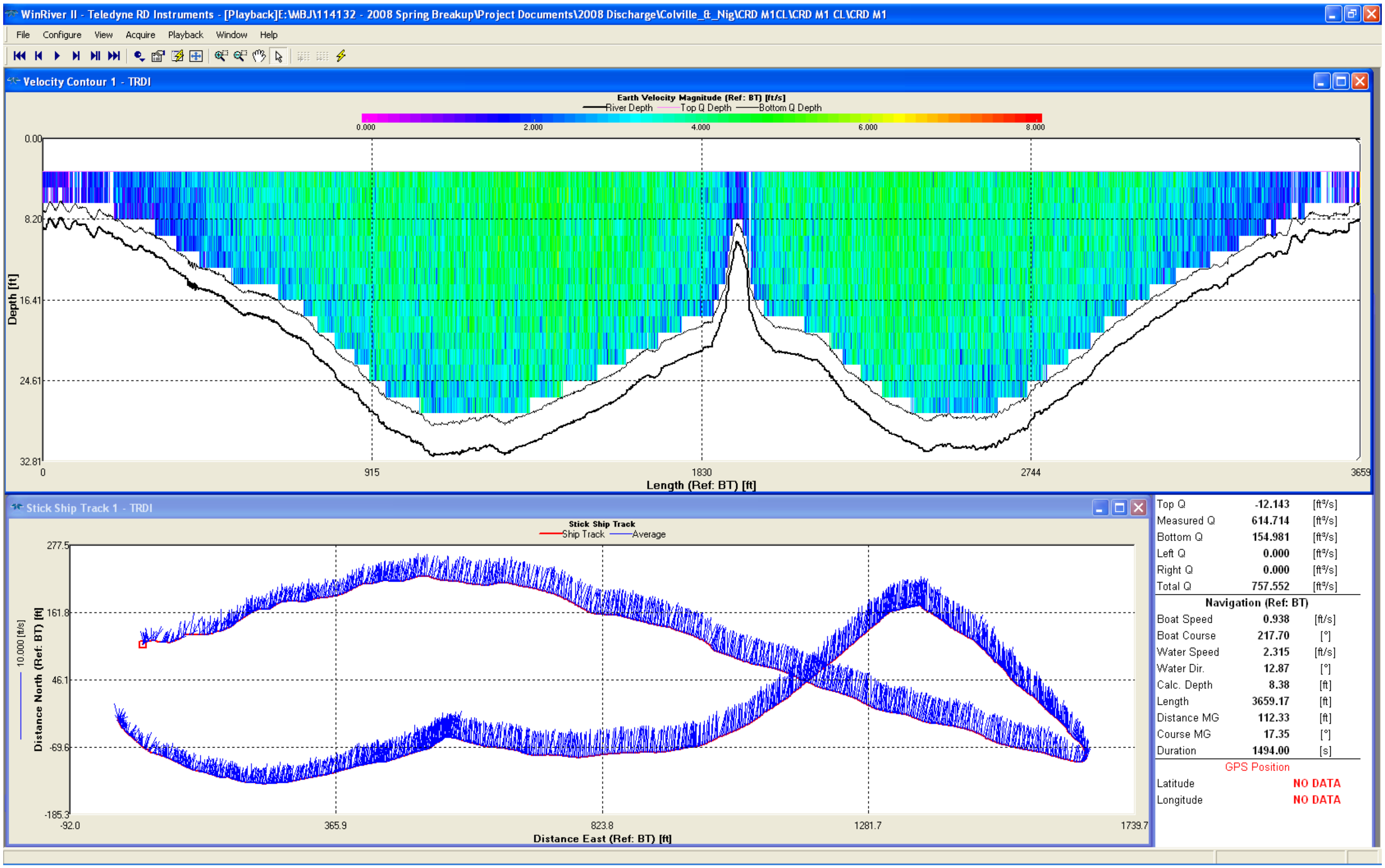
Monument 1 Colville River ADCP Direct Discharge Transect 4, WinRiver II Velocity and Ship Plots

May 31, 2008



Monument 1 Colville River ADCP Direct Discharge Loop Test, WinRiver II Velocity and Ship Plots

May 31, 2008



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Appendix C Direct Discharge Results

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Comp. By JPM
Check By OOO

Discharge Measurement Notes

Station No. Long Bridge Start: 1510 Finish: 1600

452-foot Bridge at Swale at Alpine, AK

Date 5/29/2008 Party OOO, MDM, JPM

Width 445 ft Area 949 sq ft Vel. 2.03 fps Disch. 1930 cfs

Method 0.6 No. Secs. 21 Count Variable

GAGE READINGS			
Gage	Start	Finish	Change
#3	6.35	6.35	0.00
#4	6.17	6.17	0.00

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter ft above bottom of weight

Weight lbs

Spin Test ok after ok Meter No. NY4743

Measurement Rated Excellent Good Fair Poor based on the following conditions

Cross Section: Uniform, firm short tundra - unaffected by ice/snow

Flow: Steady Weather: Overcast, Wind 10 mph

Other: Variable horizontal angles Temp: 36^{o}F

Gages: Staff gages #3 and #4

Remarks: Control by ponded water north of bridge - no backwater from ice or snow

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.75 0.80

Site/Date: 452-foot Bridge 5/29/2008

0.85

Angle Coeff.	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ 1510											
0.87	0	0.5	2.40	6/10			1.33		1.16	1.2	1.4
0.87	1	10.0	2.30	6/10	50	42	2.66		2.32	23.0	53.3
0.96	20	19.5	1.90	6/10	50	40	2.79		2.68	37.1	99.4
0.98	40	20.0	2.00	6/10	40	45	1.99		1.95	40.0	78.1
0.98	60	20.0	2.10	6/10	30	43	1.57		1.54	42.0	64.5
0.98	80	20.0	1.90	6/10	30	44	1.53		1.50	38.0	57.1
0.98	100	20.0	2.00	6/10	25	40	1.41		1.38	40.0	55.1
0.97	120	20.0	2.10	6/10	40	52	1.73		1.68	42.0	70.4
0.97	140	20.0	1.85	6/10	40	49	1.83		1.78	37.0	65.7
0.98	160	20.0	1.80	6/10	40	48	1.87		1.83	36.0	65.9
0.98	180	20.0	1.90	6/10	60	62	2.17		2.12	38.0	80.7
0.99	200	20.0	2.10	6/10	40	44	2.04		2.02	42.0	84.7
0.99	220	20.0	2.00	6/10	40	45	1.99		1.97	40.0	78.9
0.98	240	20.0	2.60	6/10	50	48	2.33		2.29	52.0	118.9
0.99	260	20.0	2.60	6/10	50	48	2.33		2.31	52.0	120.1
0.99	280	20.0	2.10	6/10	50	42	2.66		2.64	42.0	110.7
0.98	300	20.0	2.40	6/10	40	45	1.99		1.95	48.0	93.7
0.98	320	20.0	2.30	6/10	50	42	2.66		2.61	46.0	120.0
0.95	340	20.0	2.00	6/10	40	40	2.24		2.13	40.0	85.1
0.95	360	20.0	2.40	6/10	40	40	2.24		2.13	48.0	102.1
0.95	380	20.0	2.10	6/10	40	44	2.04		1.94	42.0	81.3
0.95	400	20.0	2.20	6/10	40	45	1.99		1.89	44.0	83.3
0.95	420	20.0	2.20	6/10	40	48	1.87		1.78	44.0	78.1
1.00	440	12.5	2.10	6/10	50	45	2.49		2.49	26.3	65.3
0.92	445	2.5	3.40	6/10	40	49	1.83		1.68	8.50	14.3
		445.0								**949.0**	**1928.3**
			Estimated values								
REW @ 1600											

0.90 0.92 0.94 0.96 0.97 0.98 0.99 1.00 0.99 0.98 0.97 0.96 0.94 0.92 0.90 0.85

Comp. By JPM
Check By OOO

Discharge Measurement Notes

Station No. Short Bridge Start: 1630 Finish: 1709

62-foot Bridge at Swale at Alpine, AK

Date 5/29/2008 Party OOO, MDM, JPM

Width 54.5 ft Area 211 sq ft Vel. 0.58 fps Disch. 123 cfs

Method 0.6 No. Secs. 14 Count variable

GAGE READINGS			
Gage	Start	Finish	Change
#3	6.35	6.35	0.00
#4	6.17	6.17	0.00

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter 0.6 ft above bottom of weight

Weight 30 lbs

Spin Test ok after ok Meter No. NY4743

Measurement Rated Excellent Good Fair Poor based on the following conditions

Cross Section: Non-uniform, bottom of riprap, small, variable horizontal angles

Flow: Steady Weather: Overcast, Wind 10 mph

Other: Snow under bridge Temp: 36^{o}F

Gages: Staff gages #3 & #4

Remarks: Flow distribution in measurement section affected by snow under bridge and affecting control conditions. Control is ponded water north of bridge

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.75 OOO

Site/Date: 62-foot Bridge 5/29/2008

Angle Coeff.	Distance from initial point (ft)	Section Width	Water Depth	Observed Depth	Revolution Count	Time Increment 16:30	VELOCITY At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)	Area 0.7	Discharge (cfs)
LEW @ 1630											
	0	1.0	2.00				0.09		0.07	2.00	0.14
0.85	2	2.5	1.60	S	3	42	0.18	0.16	0.14	4.00	0.54
0.85	5	4.0	1.60	6/10	7	40	0.41		0.34	6.40	2.21
0.90	10	5.0	2.80	6/10	7	40	0.41		0.37	14.00	5.11
0.90	15	5.0	3.00	6/10	10	46	0.50		0.45	15.00	6.74
0.92	20	5.0	4.20	6/10	15	45	0.76		0.70	21.00	14.65
0.93	25	5.0	4.80	6/10	20	52	0.87		0.81	24.00	19.47
0.96	30	5.0	5.10	6/10	15	44	0.78		0.74	25.50	18.98
1.00	35	5.0	6.00	6/10	10	40	0.57		0.57	30.00	17.12
0.98	40	5.0	5.60	6/10	15	46	0.74		0.73	28.00	20.38
0.85	45	5.0	5.30	6/10	15	52	0.66		0.56	26.50	14.85
0.97	50	4.0	2.30	S	7	54	0.31	0.28	0.27	9.20	2.45
0.97	53	2.25	1.90	6/10	0	0	0.00		0.00	4.28	0.00
	54.5	0.75	1.90	6/10	0	0	0.00		0.00	1.43	0.00
SUM		**54.5**					0.45			**211.31**	**122.64**
			Estimated values								
REW @ 1630											

0.90 0.92 0.94 0.96 0.97 0.98 0.99 1.00 0.99 0.98 0.97 0.96 0.94 0.92 0.90 0.85

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.75

Appendix D Lake L9312 Water Balance

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Project Number:	114132	**Date:**	9/23/2008
Subject:	Lake L9312 2008 Snow Melt Recharge and Water Balance		
Computed by:	MDM	**Checked by:**	OOO

Description:

This calculation sheet describes a water balance calculation for Lake L9312 during breakup 2008. The lake recharged solely from snow melt (not flood waters). The water balance is used to check the accuracy of calculating potential lake recharge from end of season terrain-specific snow water equivalence (SWE).

References - (Data):

(1) Baker, 2008. *2008 Colville River Delat Lakes Recharge Monitoring and Analysis* - (Lake & Tundra Areas, SWE)

(2) DNR Fish Habitat Permit FG99-III-0051 Amendment #5, February 14, 2003. - (Evaporation Rate)

(3) Holland, K., et al., June 2008. *Lake Chemsitry and Physical Data for Selected North Slope, Alaska, Lakes: May 2008*. - (Ice Thickness and WSE)

(4) Baker, 2002. *Alpine Water Supply Risk Assessment 2002 Update*. - (Lake L9312 Bathymetry and Evaporation Rate)

(5) *CPAI Second Quarter 2008 Water Use Report* - (Monthly Water Use Volumes)

(6) *Doc LCMF-137 Water Source Lake Elevation Monitoring Rev18.xls* - (WSE)

(7) Weather Undergorund. *PALP CustomHistory.xls* - (Preciptitation, Humidity, Temperature)

(8) *L9312_Available Under Ice Volume_6-08.xls* - (Lake water volume)

(9) WebWIMP (The Web-based, Water-Budget, Interactive, Modeling Program). http://gcmd.nasa.gov/records/WebWimp.html Accessed 9/18/08

Attachments:

Available Data:

L9312 Physical parameters

Area [1]

Lake	4,861,000	ft^2
Tundra	4,943,500	ft^2
BasinTotal	9,804,500	ft^2

5/16/2008 L9312 Basin Specific SWE [1]

Lake	1.87	in
Tundra	3.20	in
Basin Average	2.54	in

May 10, 2008 Ice Thickness [3]

Sample 1	5.15	ft
Sample 2	5.20	ft
Sample 3	5.10	ft
Average	5.15	ft

Water Surface Elevation (WSE) [3, 2008 Breakup, 6]

10-May	7.14	ft
19-May	7.12	ft
20-May	7.12	ft
24-May	7.20	ft
27-May	7.42	ft
30-May	7.45	ft

Percent Lake Area with Grounded Ice (Bathymetry - Ref. 4)

Top of Ice Elevation (May 19)	7.36	ft	Ref 3
Bottom of Ice Elevation	2.2	ft	
Grounded Ice Area	33	%	

Respective Areas: Not to Scale (Grounded Ice.dwg)

Entire Lake	1424.248
Floating Ice	951.053

Observations (2008 Breakup)

Evaporation Rate (2,4)

1.5	mm/day	Average over an entire open water season (2,4)
0.005	ft/day	Value supported by WebWIMP for month of June

*Evaporation has typically been considered in previous water balance calculations to occur July1 - September 15

Water Removal - Pumping (5)

May	1,274,671	gallons	
	5497	ft^3/dy	*Average over the entire month (31 days)
June	1,266,806	gallons	
	5645	ft^3/dy	*Average over the entire month (30 days)

Precipitation (7)

May	4	mm/month
	0.000423	ft/day
June	12	mm/month
	0.00127	ft/day

Precipitation is based on WebWIMP monthly output for Lat 70.3N, Long 151.0W
According to Weather Underground for the dates of interest (May 20 to May 30) precipitation was noted on 5 days.
However, no quantity of precipitation was measured.
Between May 30 and June 11 precipitation was noted on 5 days with no mearement of quantity

Calculations:

Rising Water Volume [8]

May 20 to May 24 (Tundra snow has begun to melt. No visible ponding of lake snowmelt)

WSE (ft)	7.12	7.20		
Under Ice Volume (MG)	138.06533	140.3865		
Under Ice Volume (ft^3)	18456656	18766952	ΔV	310,297 ft^3

May 24 to May 27 (Tundra snow melts to near 100%. Some visible ponding of lake snowmelt)

WSE (ft)	7.20	7.42		
Under Ice Volume (MG)	140.38651	146.7887		
Under Ice Volume (ft^3)	18766952	19622797	ΔV	855,844 ft^3

May 27 to May 30 (Tundra snow melt 100%. Visible ponding of lake snowmelt around periphery)

WSE (ft)	7.42	7.45		
Under Ice Volume (MG)	146.78866	147.6617		
Under Ice Volume (ft^3)	19622797	19739503	ΔV	116,706 ft^3

Pumping - Water Withdrawal

May 20 to May 24

	May
Days	4
Volume (ft^3)	21988 ft^3

May 24 to May 27

	May
Days	3
Volume (ft^3)	16491 ft^3

May 27 to May 30

	May
Days	3
Volume (ft^3)	16491 ft^3

SWE Runoff Contribution

$Tundra_{Total}$ 1,318,267 ft^3

% of Total tundra snowmelt contibuting to lake recharge 67 % [4]

$Tundra_{Contirb}$ 883,239 ft^3

$Lake_{Total}$ 757,506 ft^3

$Lake_{Contirb}$ 251675.3 ft^3 Grounded Ice Area Only - Not accounted for in initial WSE

Total snowmelt volume entering lake

$(Tundra_{Contrib} + Lake_{Total}) =$ 1,640,745 ft^3

Snowmelt volume contributing to observed rise in WSE

$(Tundra_{Contrib} + Lake_{Contrib}) =$ 1,134,914 ft^3

Evaporation Loss (Grounded Ice Area)

May 27 to May 30

Volume 23,844 ft^3

*Standing water around lake periphery was not observed until May 27
**Contribution to water balance during time period of interest is questionable. Possibly exclude

Precipitation (Entire Lake Area + 68% Tundra Area)

May 20 to May 30

Volume 20,578 ft^3

**Contribution to water balance during time period of interest is questionable. Possibly exclude

Water Balance: ∆Storage = Rising Water Volume = (SWE Runoff + Precipitation) - (Pumping + Evaporation)

May 20 to May 30

Observed Change in Storage

Volume 1,166,141 ft^3

Estimated Change in Storage (Including Precipitation and Evaporation)

Volume 1,076,678 ft^3

Error 8%

Estimated Change in Storage (Excluding Evaporation)

Volume 1,100,522 ft^3

Error 6%

Estimated Change in Storage (Excluding Precipitation)

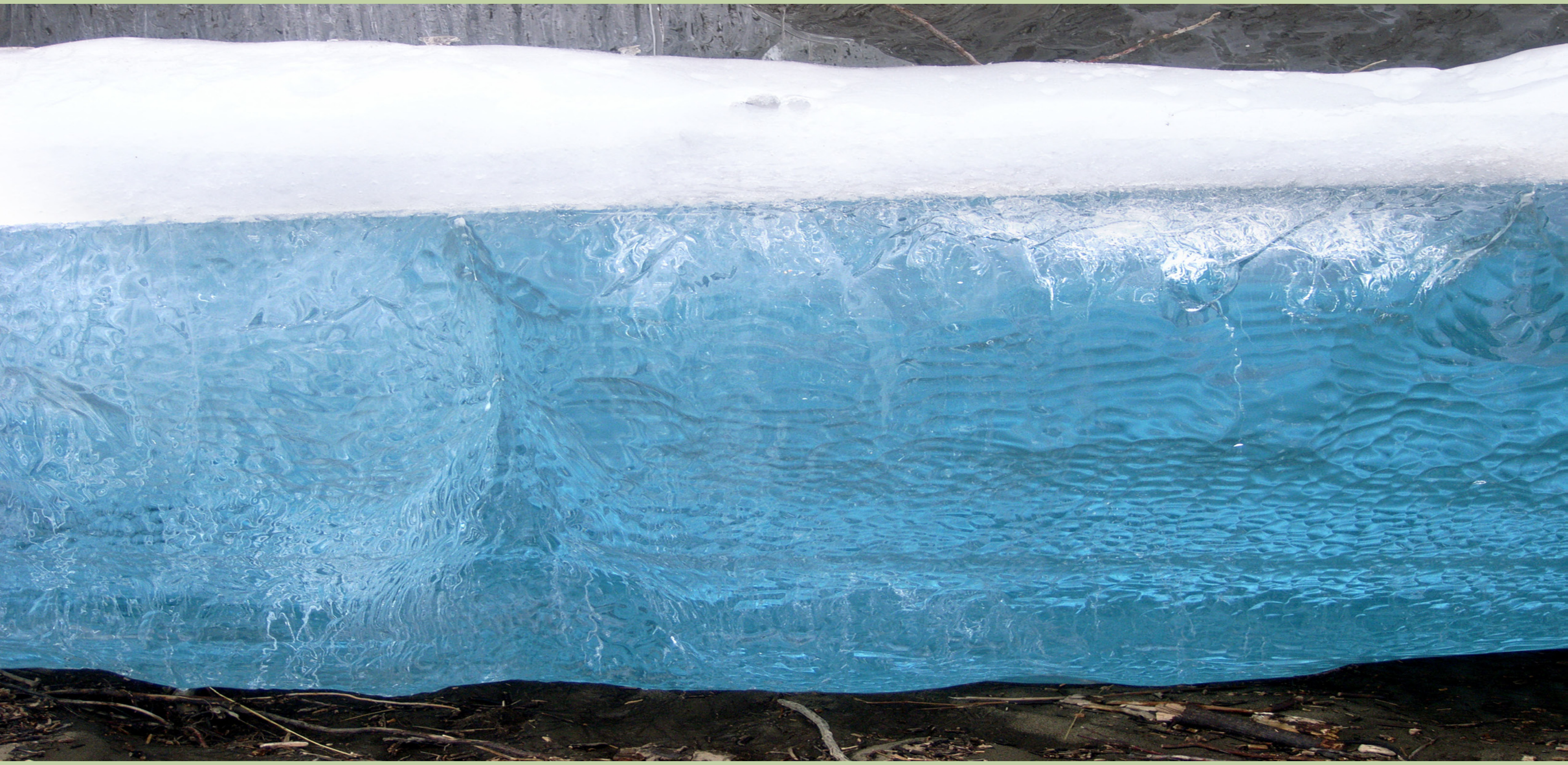
Volume 1,056,100 ft^3

Error 9%

Estimated Change in Storage (Excluding Evaporation and Precipitation)

Volume 1,079,944 ft^3

Error 7%



Michael Baker Jr., Inc.

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