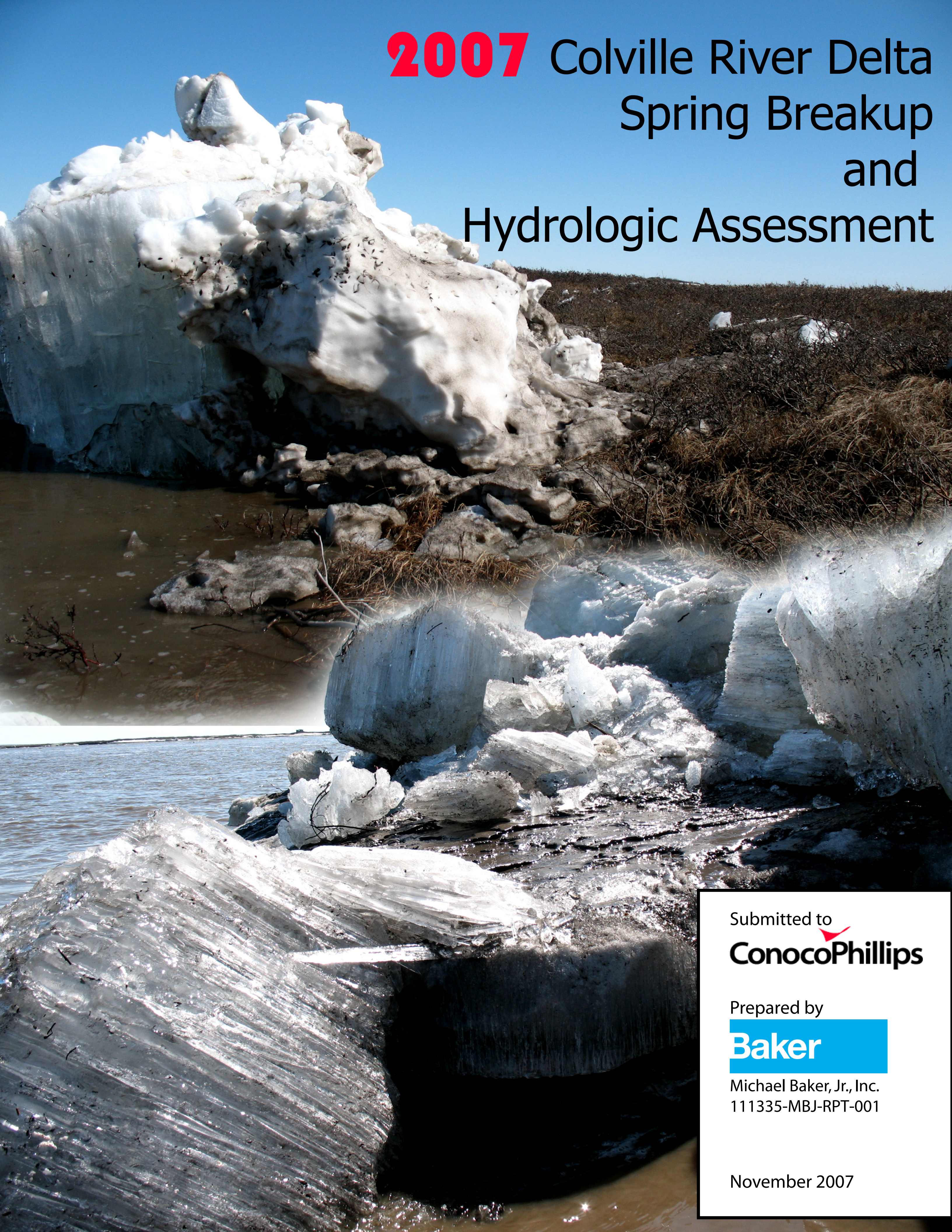
2007 Colville River Delta Spring Breakup and Hydrologic Assessment



Submitted to

ConocoPhillips

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Revision History

November 2007	Initial Issue
December 2007	Chapter 4 re-issued in its entirety; Contents and Revision History updated accordingly.

Executive Summary

This report presents observations and findings of the 2007 Colville River Delta spring breakup and hydrologic assessment. The assessment was conducted in support of the Alpine Development Project and Alpine Satellite Development Plan, representing the sixteenth consecutive season of study.

Observations and measurements of water surface elevations were recorded at 9 locations throughout the Delta and 17 locations adjacent to the Alpine facilities. The 2007 peak water surface elevation at Monument 1 occurred early on June 4, within the historic 10-day period for peak water surface elevations. The peak water surface elevation was measured at 18.97 feet (BPMSL), slightly lower than maximum peak water surface elevations observed over the historic record. The relatively high water surface elevation, occurring after the release of an upstream ice jam, was a result of backwater caused by intact channel ice. Water surface elevations around the Alpine facilities peaked late on June 4 and early on June 5.

The 2007 peak discharge was estimated to be 270,000 cfs with a recurrence interval of 3 years based on the Colville River flood frequency analysis. The highest measured discharge was 263,000 cfs and was measured on June 4, approximately 10 hours after the peak water surface elevation.

Ice jams occurred in both the East and Nigliq Channels. No impacts to the HDD crossing site were observed and no significant impacts from the ice jams occurred to any facilities.

The Alpine drinking water lakes recharged to bankfull conditions. Recharge resulted from flooding out of the Sakoonang Channel as floodwaters peaked around Alpine facilities.

No significant erosion was observed on any of the gravel structures inundated by floodwater. Facilities drainage structures passed approximately 1% of the Delta's peak discharge. All facilities withstood breakup floodwater without erosion or damage.

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1.0 Introduction

The Alpine facilities are owned by ConocoPhillips, Alaska, Inc. (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 2007 hydrologic field program represents the sixteenth year of investigations. Observations and measurements in 2007 were recorded at 9 locations in the CRD and 17 locations adjacent to existing Alpine facilities, including the CD3 pipeline bridge crossings. Fieldwork began May 9 and was completed June 16 of 2007. Figure 1-1 identifies the 2007 CRD monitoring region.

This 2007 Spring Breakup and Hydrologic Assessment report presents results of the 2007 spring breakup monitoring.

- **Section 1.0 Introduction,** discusses the objectives of the monitoring program and presents climatic and breakup timing information.
- **Section 2.0 2007 Monitoring Locations,** outlines and discusses the 2007 monitoring sites.
- **Section 3.0 Methods,** describes the methods of both the fieldwork and the data analyses.
- **Section 4.0 2007 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 Materials,** 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 and gage locations, direct discharge measurement reports, and snow survey notes.

We would like to thank Alaska Clean Seas (ACS), Kuukpik/LCMF, Inc., and Maritime Helicopter for their continued assistance with the CRD water resources 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 for them.

1.1 2007 Breakup Monitoring Objectives

The objective of the 2007 spring breakup program was to estimate the magnitude of breakup flooding by documenting the distribution of floodwater, measuring water levels throughout the Delta, 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 a map of the program area showing the CRD Monuments that were monitored in 2007.

Alpine facilities were monitored to satisfy permit stipulations identified in USACE Permit No. POA-2004-253 and State of Alaska Department of Natural Resources (DNR) Fish Habitat Permit FH04-III-0238. This included direct and indirect measurement of discharge through existing drainage structures, and documentation of pads and access roads erosion. Figure 1-2 shows the Alpine facilities Gages monitored in 2007.

Monitoring of recharge to Lakes L9312 and L9313 was completed to comply with State of Alaska Department of Fish and Game (ADF&G) 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. To help establish whether sufficient water is available for future withdrawal, it is important to determine if the lakes recharged during spring breakup.

Investigations of the 2007 spring breakup program also included documentation of the effects to flow and channel morphology caused by the ice bridge installed across the East Channel of the Colville River.

1.2 Climatic Review

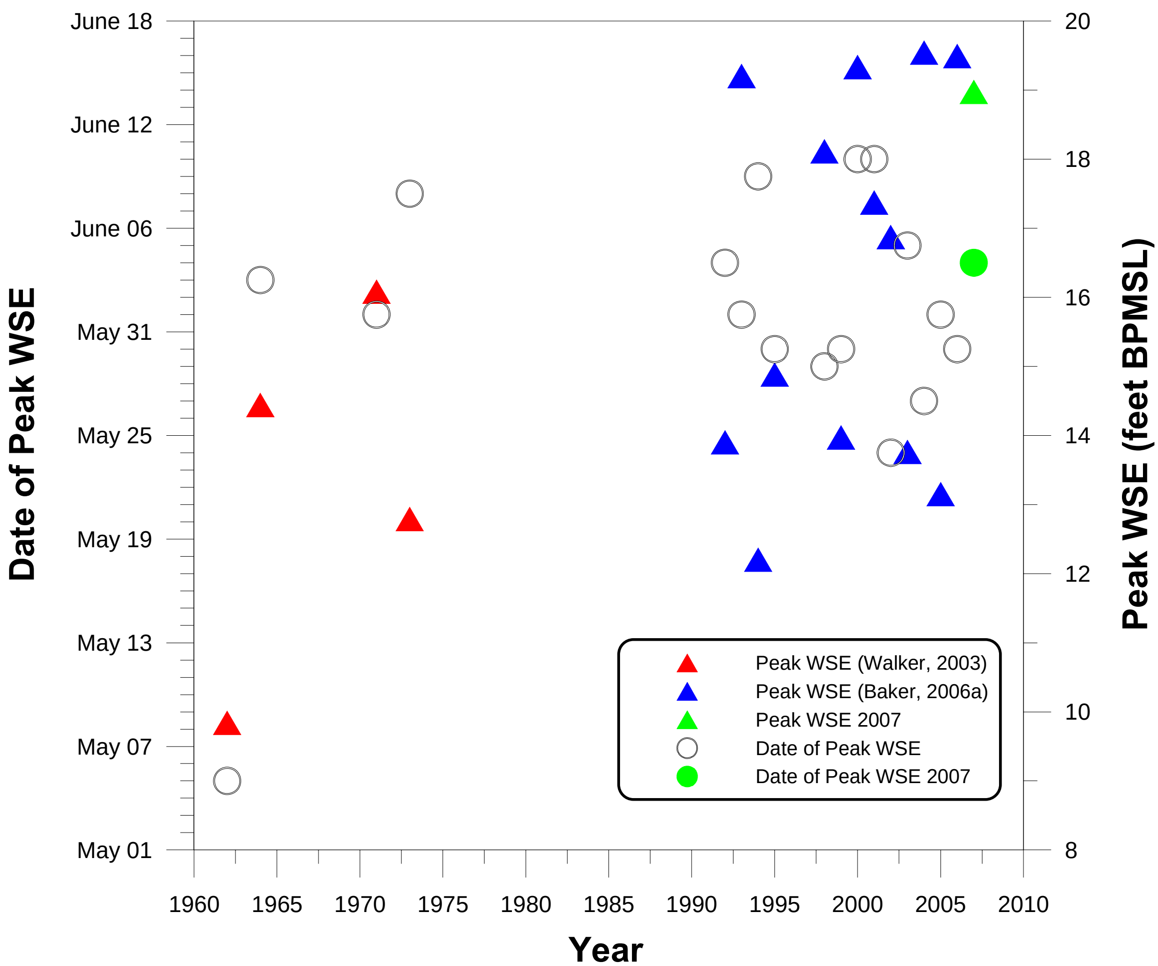
The open water season for the CRD is generally limited to a short four month period (June – September). Spring is dominated by flooding, which may be divided into pre-breakup flooding, breakup flooding, and post-breakup flooding (Walker and Hudson 2003). Conditions such as snow pack, sustained cold or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

The Colville River Delta 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 mean daily temperatures ranged from 3°F to 68°F during the May 11 to June 17 spring breakup period. In 2007, daily mean temperatures ranged from 6°F to 50°F.

1.3 2007 Breakup Timing and Water Surface Elevation

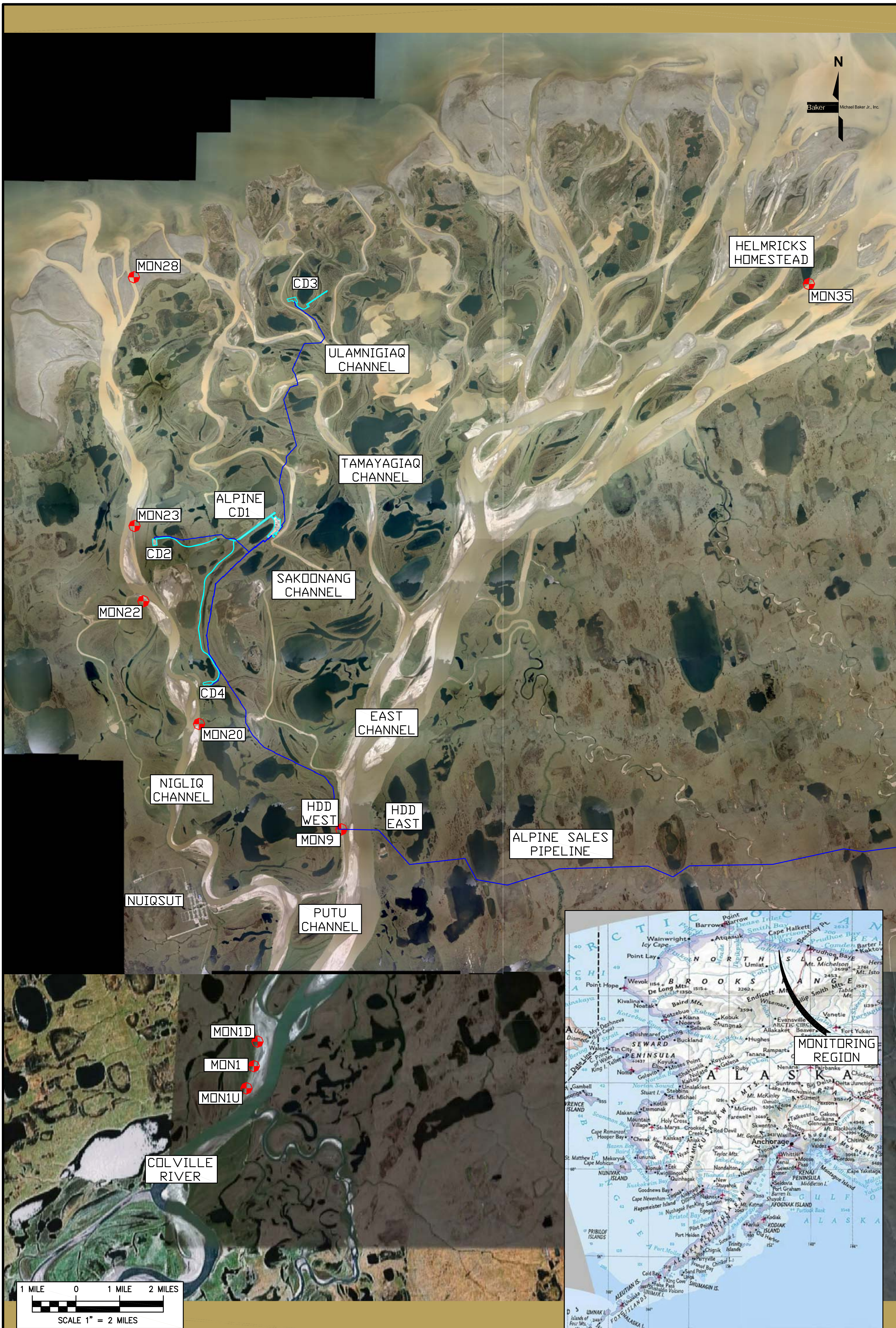
Graph 1-1 presents the date and elevation of peak water surface elevations (WSE) near Monument 1 for those years where data is available. The elevations and dates of breakup at the head of the Delta for 1962, 1964, 1971, and 1973 were presented in Walker and Hudson (2003) and for 1992 through 2006 in Baker (2006a). 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 1-1 Monument 1 Annual Peak Water Surface Elevations and Dates

Peak annual water surface elevations in the CRD have typically occurred within a 10-day period, from May 29 to June 7, as shown in Graph 1-1. The 2007 peak water surface elevation occurred at Monument 1 on June 4, within the historic 10-day period for peak water surface elevations. The peak water surface elevation was measured at 18.97 feet (BPMSL). This value is slightly lower than maximum peak water surface elevations observed over the historic record. The peak discharge was estimated to have occurred on June 4 sometime after the peak water surface elevation occurred. The timing and magnitude of peak water surface elevations in the vicinity of Alpine facilities is typically one or two days following the peak at Monument 1 and that pattern was consistent in 2007. Section 4.3 (Flood and Stage Frequency) addresses historic annual peak water surface elevations across the CRD and a comparison with 2007 peak water surface elevations.



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2007 SPRING BREAKUP
COLVILLE RIVER DELTA
MONUMENTS
FIGURE 1-1
(SHEET 1 OF 1)

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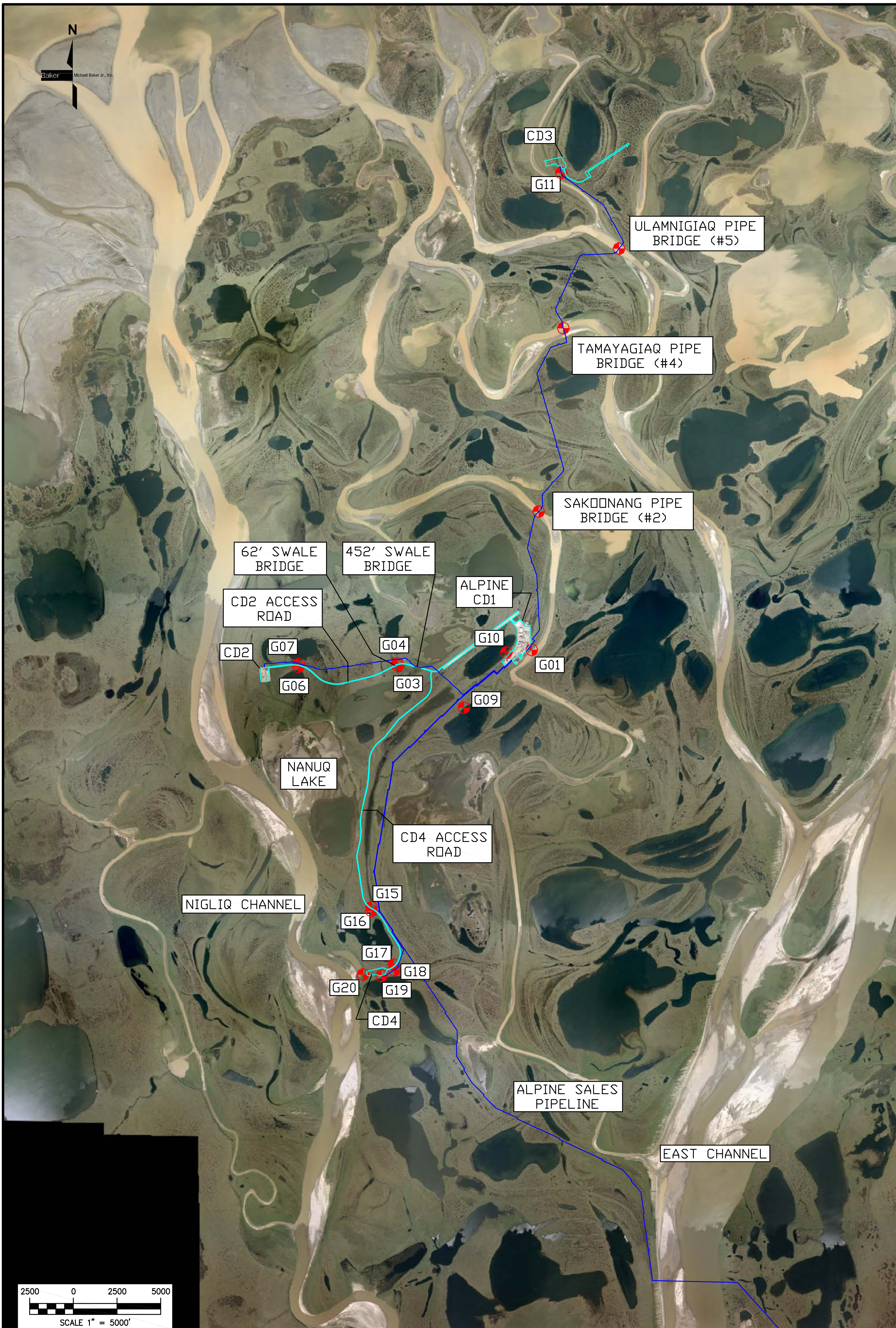

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2007 SPRING BREAKUP

ALPINE FACILITIES

GAGES

FIGURE 1-2

(SHEET 1 OF 1)

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2.0 2007 Monitoring Locations

The CRD 2007 monitoring locations were similar to those presented in the *2006 Colville River Delta and Fish Creek Basin Spring Breakup and Hydrological Assessment* (Baker 2007a). The primary differences in the CRD 2007 monitoring locations compared to 2006 was the replacement of temporary Gages 11, 18, and 19 with direct-read gages attached to nearby VSM. Permanent staff Gage 8 was discontinued as a result of the CD2 pad expansion; it was not replaced because Gages 3 and 4 and Monument 23 provide sufficient data for monitoring water surface elevations around the CD2 pad. Gage 12 was abandoned as it was unnecessary due to the new location of Gage 11. Details of the 2007 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 2007 Monitoring Program

Colville River Delta (CRD)	**14**	**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 Helmricks Homestead**
Drainage Structures	**2**	**Alpine swale bridges**	**62-foot and 452-foot bridges**
	65	**Alpine culverts**	**CD2 (26), CD3 (1), CD4 (38)**
Total	**93**		

2.1 Colville River Delta

2.1.1 Monuments

The 2007 CRD monitoring sites extended from the head of the Delta at Monument 1, river mile (RM) E27.1, to near the downstream boundaries of the Delta at Monument 28 (RM N1.7) and the Helmricks 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, and Monument 1 Upstream (RM E27.6); each installed on the west bank of the Colville River. Photo 2-1 shows the Monument 1 reach on May 31, 2007. 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 28 and the Helmricks Homestead monitoring locations are within the braided floodplain of the Delta's downstream boundary of Harrison Bay. Monument 1 has been monitored annually since 1992, while Monuments 28 and Helmricks 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) and Monument 22 (RM N9.7) near CD4 pad, 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 28, 2007

Photo 2-2 Monument 9, May 29, 2007

2.1.2 Alpine Gages

Gages 1, 3, 4, 6, 7, 9, and 10 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), Tamayayak (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.

3.0 Methods

The primary methods used during the 2007 spring breakup monitoring program included visual observations of flow distribution, measurements of water surface elevation (WSE), and measurements of discharge. The field methods were based on standard techniques proven to be safe, reliable, efficient, and accurate for the conditions found in the CRD during spring breakup. Also described are snow survey and flood frequency analysis methods.

3.1 Visual Observations

Visual observations were conducted from the ground via Hagglund tracked vehicles between May 9 and May 17, and from the air via helicopter between May 18 and June 16, 2007. Husky air boats operated by ACS were also employed to access Monument 1 on June 2 and June 3. Observations were recorded daily in field notebooks. Digital photographs were collected daily to document the extent of breakup. With each photograph, the horizontal position of the camera, date, and time were electronically imprinted onto each electronic file. Due to complications with the Global Positioning System (GPS) signal, not all photos are georeferenced. Particular attention was paid to the Alpine facilities, including access roads and pipelines, and the 2006/2007 ice bridge crossing at the East Channel.

3.2 Water Surface Elevation (Stage)

3.2.1 Staff Gages

Water surface elevation (stage) was monitored at the study locations using graduated stream staff gages. Water surface elevations were measured daily according to their hydrologic and hydraulic significance. 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 2007, was used. Gages located on the Colville River, East Channel, and Nigliq Channel were given the name of their associated benchmark monument. The surveys were completed in May 2007 just prior to breakup.

Permanent staff gages 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. Adhesive gages were attached to central, in-channel support members of CD3 pipeline bridge crossings.

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. Installation of each staff gage was completed prior to the arrival of breakup floodwater. 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

Four pressure transducers were installed to collect water surface elevation data. Pressure transducers were set at Monument 1 Upstream, Monument 1 Downstream, Monument 9, and Monument 23. The pressure transducers measured 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 water surface elevation not captured by visual measurements.

For the measurement of absolute water pressure, an In-Situ, Inc. Level TROLL® 500 sensor was 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. This data was 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 LT®, a Microsoft® Windows® based operating program. Absolute pressure was set to zero. Transducers were housed in a segment of perforated galvanized steel pipe and clamped to angle iron, which was 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 at 0°C was used to calculate all water depths from adjusted gage pressures. Fluctuations in water temperature varied from 0° to 11.3°C over the sampling period. Due to the limited range in temperature and observed water depths, the impact of temperature on the calculation of water surface elevation was less than 0.01 feet.

3.3 Discharge Measurements

Discharge was both directly measured and indirectly computed. Direct methods included single point velocity measurements, 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.

3.3.1 USGS Midsection Techniques

Standard USGS midsection techniques (USGS 1982) and a Price AA velocity meter were used to measure discharge at the Alpine swale bridges and velocity in the CD2 and CD4 access road culverts. The Price AA velocity meter was calibrated by the USGS at the Office of Surface Water Hydraulic Laboratory in 2006. The discharge measurements at the Alpine swale bridges were conducted from the bridge decks 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 woody debris, and weather conditions, implementation of accurate USGS midsection techniques can be very difficult, risky, and time intensive. The advent of the ADCP has allowed 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 and the Nigliq Channel at Monument 23 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 via a deep-cycle marine battery and 400-watt power inverter.

BBTalk, a DOS-based communication program, was used to perform pre-deployment tests. WinRiver, a Microsoft Windows based data acquisition and playback software, was used to configure, initiate, and communicate with the ADCP while on the river. WinRiver, in conjunction with WinADCP, 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 was 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 verification. Internal compass error was within the specified 2-degree limit.

ADCP Deployment and Data Collection

The Sentinel ADCP was mounted to a 13-foot 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.

Cross sections were identified at established monitoring sites and 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 one of the following two factors:

- The minimum water depth to provide acceptable data, which was approximately 10 feet; or
- Limited access to the east bank due to moving channel ice.

Photo 3-1 ADCP Direct Discharge Measurement on the Colville River, June 6, 2007

End points were marked with buoys and handheld GPS units. 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 were estimated from GPS coordinates and a Nikon laser rangefinder.

ADCP Background and Data Processing

Discharge measurements on June 4 and 7 were conducted near the Monument 1 Upstream gage due to the presence of stranded ice along the west bank of the Colville River near Monument 1. Discharge measurements on the Nigliq Channel were collected near Monument 23 on June 7 at the proposed CD5 bridge crossing location.

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. This is commonly obtained in one of two ways:

- Tracking the bottom of the channel with the ADCP; or
- Using an external, differentially corrected GPS (DGPS).

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. Due to a lack of the necessary GPS components, this technology was not used. To account for the bias introduced by a moving bed, the Loop Method was employed.

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 (USGS 2006) which include mean correction and distributed correction. Both procedures yield results within 2% of the actual discharge (USGS 2006). The mean correction procedure was applied to discharge calculations on the Colville River because of channel geometry characteristics. The results of daily loop tests 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 direction 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

An indirect discharge estimate is based on calculations and not a physical measurement of discharge. Other physical characteristics, such as water surface elevation and slope, are used as input variables of hydraulic equations to calculate discharge. Indirect discharge calculations were performed for the Alpine infield culverts and the Colville River and Nigliq Channel.

The software Haestad Methods Culvert Master version 1.0 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; and
- Culvert Manning’s roughness coefficient (0.012 for smooth steel and 0.024 for CMP).

Indirect calculations were also conducted to estimate discharge for the Colville River and Nigliq Channel 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 during direct discharge measurements. Cross-section geometry was based on cross sections surveyed by Kuukpik/LCMF in 2005 and 2004 on the Nigliq Channel and Colville River, respectively.

3.4 Flood and Stage Frequency Analysis

The flood recurrence interval was determined by comparing the estimated 2007 peak discharge to the Flood Frequency analysis results developed for the Colville River Delta (Baker and Hydroconsult 2002).

Observed 2007 peak water surface elevations were compared to water surface elevations predicted from the 2-dimensional surface water model of the Colville River Delta to estimate their respective recurrence interval. This model was developed during the original design of Alpine and has been updated during design of the Alpine Satellite Facilities. Alternatively, recurrence intervals were estimated for peak water surface elevations by comparing them to historic stage frequency analysis results within the CRD (Baker 2006a).

3.5 Erosion Survey

Visual erosion inspections were performed daily throughout breakup and after floodwaters receded to determine any significant erosion to the Alpine facilities' pads and roads.

3.6 Snow Water Equivalent (SWE) Surveys

Snow water equivalent (SWE) surveys were conducted for Alpine drinking water Lakes L9312 and L9313 catchment basins on May 10, 2007, prior to spring breakup. In addition, control Lake L9310 was also sampled. Presented in this report are methods and results of sampling on Lakes L9312, L9313, and L9310 only. Additional data and a more comprehensive SWE analysis of the CRD is described in the report *2007 Colville River Delta Lakes Recharge Monitoring and Analysis* (Baker 2007b).

In the arctic, where vegetation is not a major factor affecting snow distribution, terrain has a major effect. Thus, terrain-based snow surveys allow the determination of mean catchment snow values and produce sufficient spatial snow information for most hydrologic studies (Woo 1997).

3.6.1 Sampling Transects and Points

Each lake's water perimeter and its associated catchment basin were delineated using aerial imagery, topographic contours, and spot elevations provided by CPAI. Data specific to each terrain type was then identified, including respective area, shape, relief, and potential locations for drift formation. Most lake catchment basins in the CRD have a boundary ridge encircling the lake body, thus transects were positioned perpendicular to local relief radiating from a central location on the lake. Additional transects were positioned to cover irregularities of a typical "bowl" shape, such as drainage gullys, pingos and mounds, or basin arms.

Sampling points along each transect were identified. Initial point locations were selected independent of local topography and terrain type to maintain random sampling along transects. In the case of adjoining transects, like those radiating from a single location, a point was positioned at their intersection, with successive points positioned a fixed distance from the initial point. Uniform spacing of points was necessary to provide systematic sampling. The number of depth measurements was dependent on transect length and the variability of snow within the terrain unit. The number of depth measurements included those taken to determine snow density, of which there was no less than two points per transect (Woo 1997).

3.6.2 Double Sampling Method

At each of the three study lakes, a double sampling method snow survey was conducted to measure snow pack in two separate ways: (1) by measuring snow depth and mass at a smaller number of points, and (2) by measuring only snow depth at a large number of points. Each terrain type covered by a single transect contained at least one snow mass sampling point.

The double sampling method was selected based on the limited depth of snow cover characteristic of the arctic. Goodison, Ferguson, and McKay (1981) suggest that in shallow snowpacks (less than 1 meter) depth and density have been found to be essentially independent and density typically has less temporal and spatial variability than depth. Additionally, Rovansek, Kane, and Hinzman (1993) found that snow water equivalent estimates resulting from double sampling methods have less variance than estimates from measuring snow mass and depth at every location. The double sampling method can also accelerate the speed at which a sampling program is executed, with depth measurements taking a fraction of the time required for measuring both depth and sample weight.

3.6.3 Sampling

Density measurements were conducted according to procedures outlined in *NRCS Snow Survey Sampling Guide* (NRCS 2006) and *British Columbia Snow Survey Manual* (BC Ministry of Environment 1981), using a $1^{5}/_{8}$-inch ID Model 3600 Mt. Rose (Standard Federal) snow sampling tube and scale. This particular sampler was chosen based on its common acceptance and use by the Natural Resources Conservation Service (NRCS).

Snow depth alone was sampled using a graduated snow pole. In addition, if shallow snow was encountered having a SWE of less than 2 inches, a bulk sampling was conducted (NRCS 2006). A bulk sampling is a grouping of multiple samples collected in the immediate area of the sample point, recording sample depth of each sample and weighing the combined core samples.

3.6.4 Snow Water Equivalent (SWE) Computations

Methods used in computing snow density and the snow water equivalent are described in *2007 Colville River Delta Lakes Recharge Monitoring and Analysis* (Baker 2007b). Calculations were based on those presented by Woo (1997) with consideration of those presented by Rovansek, Kane, and Hinzman (1993). For each terrain type, an average snow depth, snow density, and snow water equivalent was calculated at each lake. An area weighted SWE was also calculated for each lake's associated catchment basin.

3.7 Drinking Water Lakes Recharge

Recharge of Lakes L9312 and L9313 was determined by visual observations of floodwaters and by 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 photographs. Staff gages are located at each of the lakes and water surface elevations were visually recorded during breakup.

4.0 2007 Spring Breakup

This chapter presents the images, data, and analyses for the 2007 spring breakup monitoring program in the Colville River Delta. Section 4.1 summarizes the spring breakup observations and water surface elevation (stage) monitoring activities. Section 4.2 contains discharge measurement descriptions and analyses for Monuments 1 and 23, the Alpine swale bridges, and the Alpine culverts. Section 4.3 addresses flood frequency and stage frequency of peak discharge and peak stage within the Delta. The results of the Alpine pad and road erosion survey are discussed in Section 4.4. The Alpine lakes recharge assessment is presented in Section 4.5, and Section 4.6 discusses the Colville River ice bridge monitoring. Figures are collected in Section 4.7 and tabulated stage, discharge measurements, and observation records are at the end of the chapter in Section 4.8.

4.1 Hydrologic Observations Summary (May 24 – June 7)

4.1.1 Colville River Delta

Initial flow was observed in the lower reaches of the Anaktuvuk and Chandler Rivers on May 24. At that time, the leading edge of flow in the Colville River was located about seven miles upstream from the confluence of the Anaktuvuk and Colville Rivers (Photo 4-1). The leading edge continued to advance and on May 25, snowmelt flow from the Anaktuvuk and Chandler Rivers converged with the Colville River (Photo 4-2). The leading edge of flow reached Ocean Point, about 25 river miles upstream from Nuiqsut, on May 26 and on May 27, flow reached the CRD. Water levels continued to increase in the Delta and the channel ice had lifted but remained in place (Photo 4-3). On May 28, Nanuq Lake, upstream of the Alpine facilities, began receiving flow from the Nigliq Channel. On May 29, flow was observed reaching Harrison Bay in both the East and Nigliq Channels.

An ice jam about four miles in length was observed approximately one mile downstream from Ocean Point on May 31 (Photo 4-4). This ice jam likely affected the amount of discharge entering the Delta from May 30 to June 2. The release of the ice jam on the afternoon of June 3 caused an increase in stage at the Monument 1 gages of approximately 4.5 feet in 7 hours.

Photo 4-1 Leading Edge of Colville Floodwaters (82 Miles Upstream of Nuiqsut), May 24, 2007

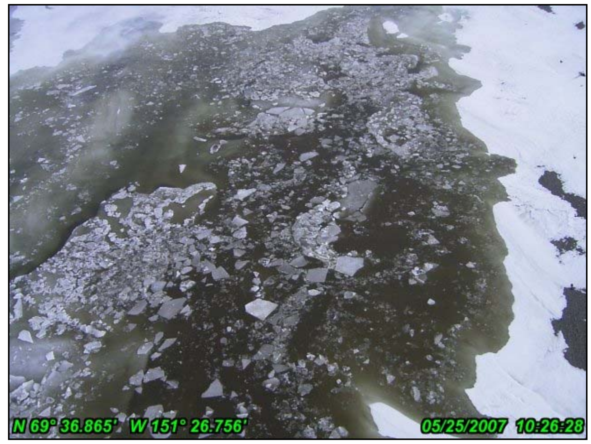


Photo 4-2 Leading Edge of Colville Floodwaters (65 Mile Upstream of Nuiqsut), May 25, 2007

Photo 4-3 Floating Channel Ice in Colville East Channel, May 29, 2007

Photo 4-4 Ice Jam One Mile Downstream of Ocean Point, May 31, 2007

The rapid increase in water surface elevations caused the breakup and downstream movement of the intact channel ice on the afternoon of June 3 (Photo 4-5). Ice floes from the ice jam release and the movement of the local channel ice created an ice jam in the East Channel immediately upstream from the HDD crossing and in the Nigliq Channel just upstream of Nuiqsut (Photo 4-6). The ice jam near Nuiqsut (Photo 4-7 and Photo 4-8) caused a minor decrease in the rate of rise at Monument 20 and 22 on June 3. Flow in the Putu Channel at that time was moving from the Nigliq Channel into the East Channel.

Photo 4-5 Moving Channel Ice at Monument 1, June, 3, 2007

Photo 4-6 Ice Jam in the East and Nigliq Channels, June 3, 2007

Photo 4-7 Nigliq Ice Jam Prior to Release, June 4, 2007

Photo 4-8 Nigliq Ice Jam Prior to Release, June 4, 2007

The peak water surface elevation at Monument 1 occurred in the early morning on June 4. Peak stage at Monuments 1 and 9 was 18.97 feet and 14.27 feet, respectively (noted as highwater marks). By mid-morning on June 4, ice jams in the Nigliq (Photo 4-9) and East Channels had released and stage at Monuments 1 and 9 was decreasing. As stage decreased, the Nigliq Channel ice jam reformed downstream near CD4, while the East Channel ice jam reformed downstream of the Tamayagiaq distributary. The reach at Monument 1 began to clear of ice on the afternoon of June 4 (Photo 4-10).

Helmricks reported a peak stage of 5.06 feet which occurred in the early morning of June 5. On the same day, peak stage at Monuments 20, 22, 23, and 28 occurred; following the release of the ice jam near the CD4 pad. Stage continued to decrease at Monument 1 as the ice jam in the East Channel weakened and the ice jam in the Nigliq Channel cleared out. By June 6, nearly all channels throughout the Delta were free of ice and stage continued to fall. Stage continued to decrease throughout the Delta until final gage readings were recorded on June 7.

Photo 4-9 Ice Jam at Nuiqsut, June 4, 2007

Photo 4-10 Monument 1 Nearly Clear of Ice, June 4, 2007

Stage and observation records for the Monuments in the East Channel are presented in Table 4-21 through Table 4-24 (beginning on page 4-53); Photo 4-11 through Photo 4-14 show breakup conditions in the East Channel at Monument 1. Stage and observation records for monuments in the Nigliq Channel are presented in Table 4-25, Table 4-26, Table 4-27, and Table 4-28. Chart 4-1 (page 4-9) is a timeline of the major 2007 breakup events in the Delta.

Photo 4-11 Colville East Channel at Monument 1, May, 28, 2007

Photo 4-12 Colville East Channel as Ice Flow Began, June 3, 2007

Photo 4-13 Colville East Channel Ice Jam, June 3, 2007

Photo 4-14 Colville East Channel Post Breakup, June 5, 2007

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 location of gages and pipeline bridge crossing locations where measurements were recorded.

Gage 1, located to the east of CD1 pad on the Sakoonang Channel, was monitored from May 30 to June 7. Gage 9 at Lake L9312 and Gage 10 at Lake L9313 were monitored from May 30 to June 10 and June 11, respectively. The first stage measurements at Gages 3 through 7 along the CD2 access road were recorded on June 3. The pipeline bridge crossings of the Sakoonang, Tamayagiaq, and Ulamnigiaq Channels near CD3 were observed from May 30 through June 6. Along the CD4 access road and pad, Gages 15, 16, and 20 were monitored from May 29 through June 7. Gages 17 and 18 were monitored over the two days they saw water; June 4 and 5. At Gages 15, 16, and 20 the stage increased approximately three feet between May 29 and June 4. Floodwater did not reach Gage 11 or Gage 19 during the breakup season.

Breakup floodwaters first reached the Alpine facilities on May 29 when flow began to enter Nanuq Lake from the Nigliq Channel (Photo 4-15). At this time, floodwaters also began to arrive at the CD3 pipeline bridge crossings. The leading edge first reached the Ulamnigiaq crossing on May 29 (Photo 4-16) followed by the Sakoonang and Tamayagiaq crossings on May 30. However, it was not until June 3, when the initial ice jams in the Nigliq and East Channels began to clear, that floodwater inundated the area around the Alpine facilities. The ice jam in the Nigliq Channel released on June 4 and reformed near the CD4 pad. As a result, peak stage at the CD4 south culvert battery occurred that evening with peak elevations at Gage 17 of 10.23 feet and at Gage 18 of 10.62 feet.

Photo 4-15 Early Floodwaters Entering Nanuq Lake from the Nigliq Channel, May 29, 2007

Photo 4-16 Early Floodwaters Reaching the Ulamnigiaq Pipeline Bridge Crossing, May 29, 2007

In the early morning of June 5, following the release and downstream reformation of ice jams in the Nigliq and East Channels on June 4, peak stage occurred at the CD1 gages (Gage 1, 9, and 10) and CD2 road gages (Gages 3 through 7). Peak stage at Gage 1, located to the east of CD1 pad on the Sakoonang Channel, Gage 10 at Lake L9313, and Gage 9 at Lake L9312 was recorded at 8.64 feet, 9.35 feet, and 9.47 feet, respectively. Drinking water lakes recharged via Sakoonang floodwaters routed through neighboring lakes and perennial channels (Figure 4-4 and Section 4.5). Gages 3 through 7 reached a peak stage of 9.60 feet at Gage 3, 8.17 feet at Gage 4, 8.80 feet at Gage 6, and 8.64 feet at Gage 7.

Peak stage at the pipeline bridge crossings of the Sakoonang (Photo 4-17), Tamayagiaq (Photo 4-18), and Ulamnigiaq (Photo 4-19) also occurred in the early morning on June 5. The Sakoonang, Ulamnigiaq, and Tamayagiaq Channel crossings reached elevations of 6.25 feet, 7.05 feet, and 7.75 feet, respectively. The Sakoonang crossing experienced the greatest differential between peak stage and initial gage reading (5.25 feet), while the Ulamnigiaq and Tamayagiaq crossings increased 3.53 feet and 2.95 feet, respectively.

Photo 4-17 Sakoonang Pipeline Crossing After Peak Stage, June 6, 2007

Around noon on June 5, peak stage at Gages 15, 16, and 20 was recorded at 9.67 feet, 9.76 feet, and 10.08 feet, respectively.

Photo 4-18 Tamayagiaq Pipeline Crossing After Peak Stage, June 6 2007

Photo 4-19 Ulamnigiaq Pipeline Crossing After Peak Stage, June 6 2007

Stage began dropping at Alpine facilities as floodwaters receded and ice jams released in the East and Nigliq Channels. By June 6, ice jams in the Nigliq and East Channels had cleared.

Table 4-29 and Table 4-30 present the stage and observation records for Gages 1, 9, and 10 near CD1. (Tables for the Alpine Gages begin on page 4-62.) Photo 4-20 illustrates the conditions around CD 1 gages following peak floodwaters on July 9. Table 4-31 presents the stage and observation records for Gages 3 through 7, near CD2. CD2 post breakup is shown in Photo 4-21. Photo 4-22 and Photo 4-23 show the receding floodwaters at the CD2 access road 62-foot and 452-foot swale bridges, respectively.

Photo 4-20 CD1 Gages Post Breakup, June 9, 2007

Photo 4-21 CD2 Post Breakup, June 7, 2007

Photo 4-22 62-foot Swale Bridge, June, 6, 2007

Photo 4-23 452-foot Swale Bridge, June, 6, 2007

Table 4-32 presents the stage and observation records for CD3 pipeline bridge crossings. Stage and observation records for the gages near CD4 are presented in Table 4-33. Photo 4-24 presents conditions at the CD4 north culvert battery during peak water and Photo 4-25 presents conditions of the CD4 pad following peak stage. Chart 4-2 is a timeline of the 2007 breakup events influencing the Alpine facilities.

Photo 4-24 Peak Headwater at CD4 North Culvert Battery, June 4, 2007

Photo 4-25 CD4 Following Peak Stage, June 4, 2007

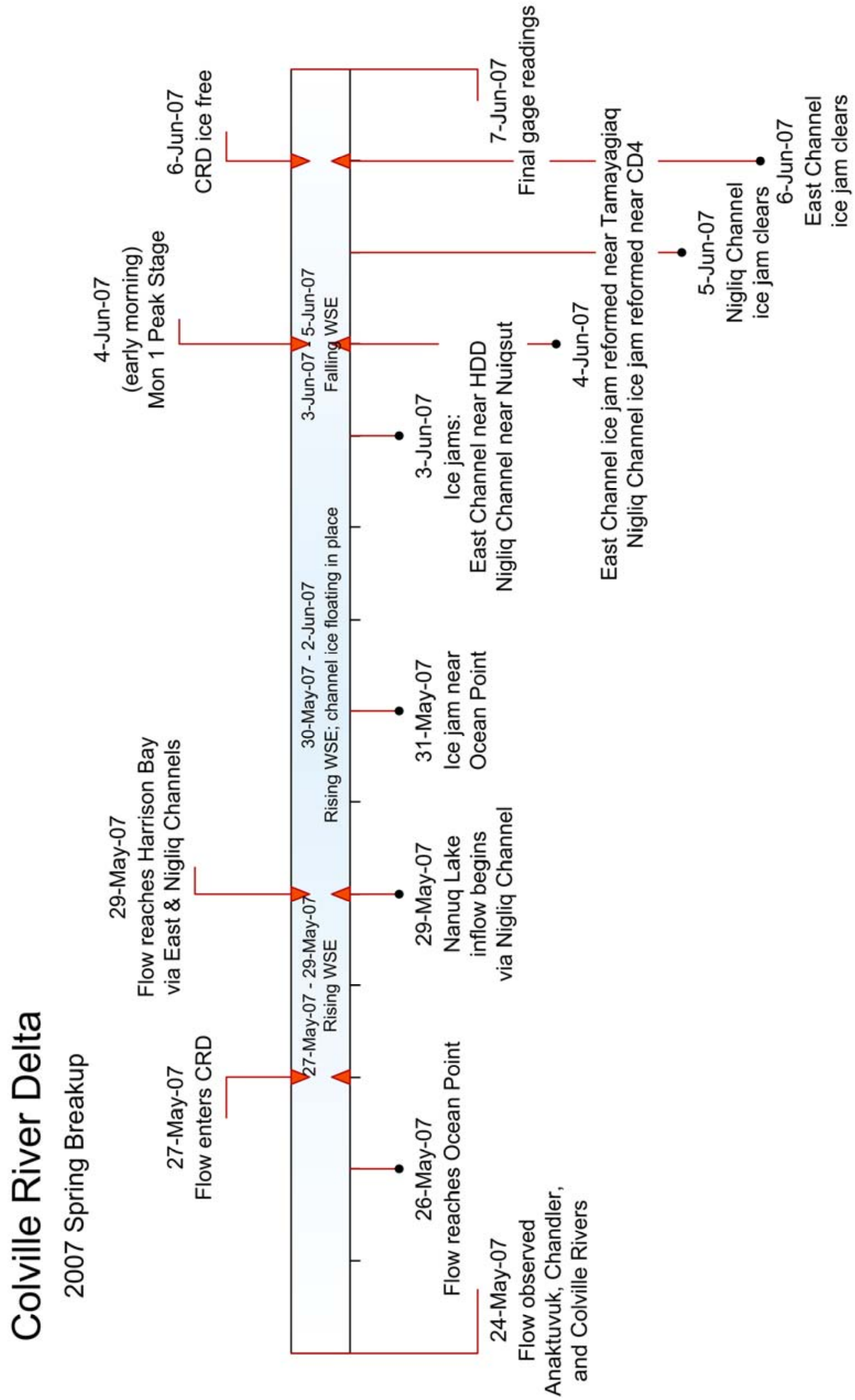


Chart 4-1 Colville River Delta 2007 Spring Breakup Timeline

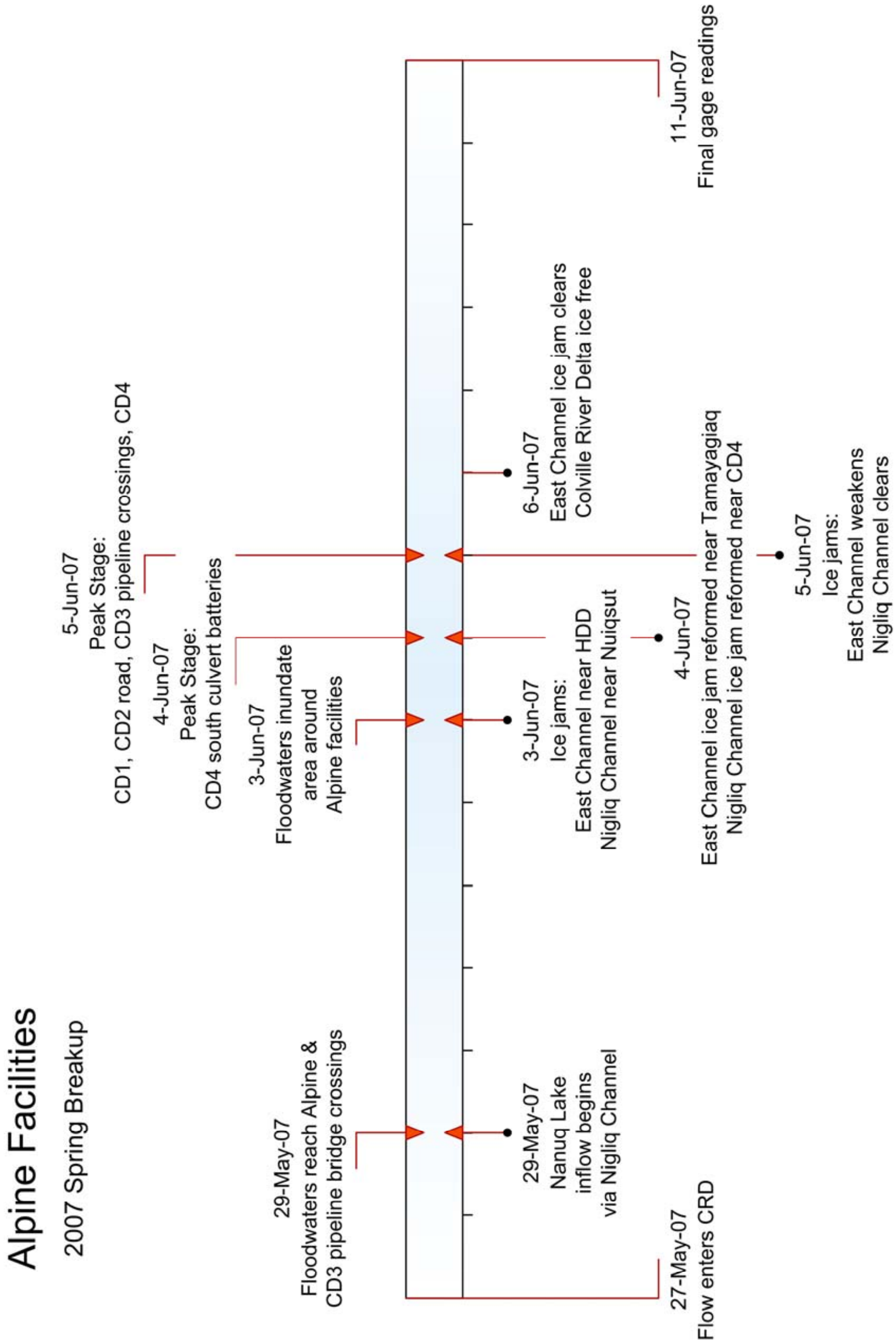


Chart 4-2 Alpine Facilities 2007 Spring Breakup Timeline

4.2 2007 Discharge

Over the span of four days between June 4 and June 7, direct and indirect discharge measurements were completed at specific locations in the CRD and Alpine facilities. Direct discharge measurements were obtained at Monument 1, Monument 23, and both swale bridges on the CD2 access road. Indirect measurements were completed at Monument 1, Monument 23, and the drainage structures of the Alpine facilities with the exception of the swale bridges.

4.2.1 Monument 1 Discharge

Between June 4 and June 7, four direct discharge measurements were completed on the Colville River at Monument 1 Upstream (1U) using ADCP techniques (Photo 4-26 and Photo 4-27). Processed discharge data is presented in Appendix B. A minimum of four transects and one loop test were completed on each of the four days. Standard deviation of measured discharges ranged from 0 to 4% of the mean total discharge. Loop tests were completed on all four sampling days and provided adjustment values for measured discharge.

Discharge measurements could not be obtained prior to June 4 due to shore fast ice and the amount of ice moving through the channel. A direct measurement could not be safely performed until after the amount ice floes subsided, which occurred on June 4.

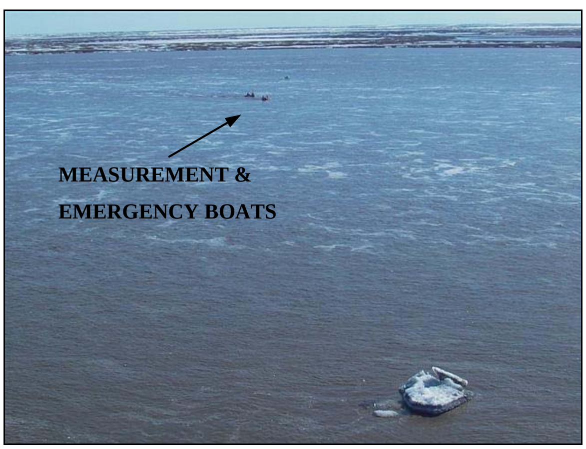


Photo 4-26 ADCP Discharge Measurement at Monument 1U, June 4, 2007

Photo 4-27 ADCP Discharge Measurement at Monument 1U, June 6, 2007

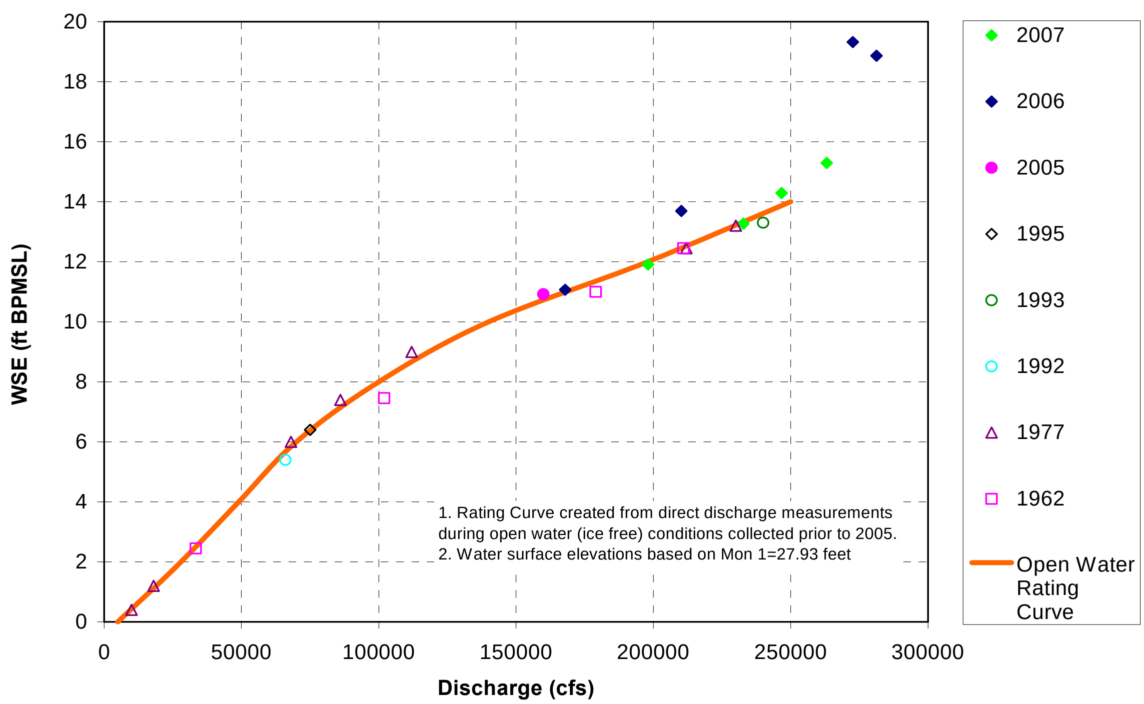
Measured discharge ranged from 198,000 to 263,000 cfs over the four day period. Mean discharge velocities ranged from 4.0 to 4.6 fps. The maximum mean velocity was measured on June 6 corresponding with the maximum observed water surface slope. Table 4-1 summarizes the 2007 discharge measurement data on the Colville River at Monument 1U and Figure 4-1 Sheet 1 presents the location of discharge measurements at Monument 1U.

Table 4-1 Measured Daily Discharge Summary – Monument 1

Site	Date & Time	WSE[1] (ft)	Made By	Mean Width (ft)	Mean Area (ft²)	Mean Velocity (ft/s)	Mean Discharge (cfs)[2]	Average Moving Bed Velocity[3] (ft/s)	Corrected Discharge[4] (cfs)	% Error[5]	MMT Rating[6]	MMT Method
Mon 1U	6/4/2007 15:00	15.29	MDM, OOO	2,870	53,500	4.20	225,000	0.72	**263,000**	-7.2%	F	ADCP
Mon 1U	6/5/2007 10:00	14.29	MDM, OOO	2,810	49,900	4.49	224,000	0.46	**247,000**	-4.2%	G	ADCP
Mon 1U	6/6/2007 16:00	13.27	MDM, OOO	2,860	49,600	4.55	225,000	0.15	**233,000**	0.8%	E	ADCP
Mon 1U	6/7/2007 10:00	11.91	MDM, OOO	2,800	45,000	4.04	182,000	0.35	**198,000**	1.2%	E	ADCP

Notes:
1. Water surface elevation (WSE) is reported for Monument 1 and referenced to BPMSL
2. Mean discharge based on four transects having measured discharge within 5% of mean.
3. Value obtained from loop test
4. Corrected discharge calculated using mean correction loop method (USGS 2006)
5. % Error is relative to rating curve discharge at reported WSE
6. Measurement rating is based on % error relative to rating curve discharge (true value)
   - E - Excellent: within 2% of true value
   - G - Good: within 5% of true value
   - F - Fair: within 7-10% of true value
   - P - Poor: within 15% of true value

Measurement ratings are based on the relationship of corrected mean discharge with the stage-discharge rating curve, expressed as a percent error. Channel ice and flowing debris caused a backwater effect and measured discharge values were slightly above the rating curve (Graph 4-1) on June 4 and 5 resulting in a fair and good rating, respectively. The June 6 and 7 measurements are considered excellent, based on the presence of open water conditions, calm water, and relationship to the stage-discharge rating curve (Graph 4-1).



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

The highest measured discharge of 263,000 cfs occurred on June 4, approximately 10 hours after peak stage occurred. Stage at the time of the measurement was approximately 3.6 feet lower than the peak stage. The rapid decrease in stage was the result of channel ice, both within and downstream of the Monument 1 reach, having cleared. The rapid decrease in stage does not represent a rapid decrease in discharge; our opinion is that the peak discharge occurred relatively close to the peak stage and that the discharge between peak stage and the time of the highest measurement varied little. Therefore, the highest measured discharge is considered to provide a reasonable representation of the peak discharge.

The peak discharge at the head of the Delta was estimated to be 270,000 cfs and to have occurred sometime late June 3 or early June 4 in concurrence with the rapid rise in stage. The timing was based on observed water surface elevations, measured discharges, and comparisons with indirect discharge calculations. It is estimated that this discharge would be equaled or exceeded, on average, approximately once every 3 years.

Due to the ice affected cross section, the discharge at the time of the peak stage plots well above the stage-discharge rating curve developed for open water conditions. Using the stage-discharge curve, Graph 4-1, to estimate discharge during ice affected conditions would over estimate discharge.

The June 6 and June 7 direct discharge measurements were collected during open water conditions with corrected discharges plotting within 1% of the stage-discharge rating curve. This suggests that the rating curve and channel at Monument 1 have not shifted significantly over time. The 2007 measurement is considered a verification of the rating curve, given that the June 6 and June 7 discharge measurements plot within 5% of the rating curve (USGS 1982, Vol. 2 pg 346).

Table 4-2 presents a historic tabulation of published peak annual discharge between 1992 and 2007 compared with historic peak water surface elevations.

Table 4-2 Colville River Breakup Peak Annual Discharge, 1992-2007

Year	Monument 1 Peak Discharge (cfs)			Monument 1 Peak Water Surface Elevation (feet-BPMSL)	
	Discharge	Method	Reference	Mon 1	Reference
2007	270,000	ADCP Measurement	This report	18.97	This report
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

ADCP techniques were used to measure discharge of the Nigliq Channel at Monument 23 on June 7, approximately four hours after completing direct discharge measurements at Monument 1. Processed discharge data is presented in Appendix B. High cross channel winds limited measurements to an east-west line. Failure to collect data in a west-east line reduced confidence in ADCP measurements and prohibited an accurate loop test. A moving bed was observed using a standard moving bed test. A total of four transects were completed falling within 3% of their mean. Table 4-3 summarizes discharge measurement data on the Nigliq Channel at Monument 23 and Figure 4-2 Sheet 1 presents the location of the discharge measurement at Monument 23.

A corrected mean discharge could not be estimated due to the presence of a moving bed and lack of a loop method correction for the Monument 23 mean measured discharge. For this reason, the ADCP direct measurement was rated as poor.

Table 4-3 Measured Discharge Summary – Monument 23

Site	Date & Time	WSE (ft)	Made By	Mean Width (ft)	Mean Area (ft²)	Mean Velocity (ft/s)	Mean Discharge (cfs)[1]	Average Moving Bed Velocity[2] (ft/s)	MMT Rating[3]	MMT Method
Mon 23	6/7/2007 14:00	4.32	MDM, OOO	1,079	12,885	2.78	35,800	NA	P	ADCP

Notes:
1. Mean discharge based on four transects having measured discharge within 5% of mean
2. Windy conditions did not allow for loop test
3. Measurement rating of poor based on presence of moving bed and no loop method correction

An indirect discharge analysis was conducted to estimate the 2007 peak discharge (June 6) and June 7 discharge of the Nigliq Channel. The indirect calculations used the most current topography surveyed by Kuukpik/LCMF in 2005, presented in Figure 4-2 Sheet 2. Estimated discharge using the slope-area method and stage measurements at Monuments 22 and 23 were approximately 73,500 and 42,700 cfs on June 6 and 7, respectively. The channel was free of ice during this time period. The reported 2007 annual peak discharge of the Nigliq Channel (Monument 23) is based on the maximum indirect discharge result.

4.2.3 Alpine Swale Bridge Discharge

To monitor the performance of drainage structures and to comply with stipulated monitoring requirements outlined in USACE Permit No. POA-2004-253, direct discharge measurements at the swale bridges were conducted. Peak stage discharge was also estimated. On June 5, discharges at the 62-foot (Photo 4-28) and 452-foot (Photo 4-27) swale bridges were measured at 345 and 1,240 cfs, respectively. Table 4-4 presents a summary of the 2007 discharge measurement data at the Alpine swale bridges. The complete discharge notes are presented in Appendix C.

Photo 4-28 Discharge Measurement at 62-foot Swale Bridge, June, 5, 2007

Photo 4-29 Discharge Measurement at 452-foot Swale Bridge, June, 5, 2007

Table 4-4 Discharge Measurement Summary – Alpine Swale Bridges 2007

Site Name	Date Time	WSE (ft)	Made By	Width (ft)	Area (ft²)	Mean Vel (ft/s)[1]	Discharge (cfs)	MMT Rating[2]	Number of Sections	MMT Type
62-foot Bridge	6/5/07 16:30	7.83	JPM, OOO, MDM	55	292	1.18	345	F	20	Cable
452-foot Bridge	6/5/07 17:40	7.76	JPM, OOO, MDM	447	1670	0.74	1240	F	20	Cable

Notes: 1. Mean velocities adjusted with angle of flow coefficient
2. Measured Rating -
E - Excellent: Point plots nearly on the rating curve; 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 of the 62-foot bridge was 1.18 fps and the maximum adjusted velocity was 1.96 fps. The mean adjusted velocity of the 452-foot bridge was 0.74 fps and the maximum adjusted velocity was 1.23 fps. The maximum non-adjusted at-point velocity recorded was 2.04 fps at the 62-foot bridge and 1.50 fps at the 452-foot bridge.

The discharge and average adjusted velocity measured at the swale bridges in 2007 was less than the 2000 to 2006 historic average at each site respectively. The stage at the time of the measurement at the 62-foot swale bridge was lower than the historic average, while the stage at the 452-foot swale bridge was greater than the historic average at the time of the measurements. Table 4-5 summarizes discharge measurement data at the Alpine swale bridges between 2000 and 2007.

Table 4-5 Historic Discharge Measurement Summary – Alpine Swale Bridges, 2000-2007

Site Name	Date	WSE (ft)	Made By	Width (ft)	Area (ft²)	Mean Vel (ft/s)[1]	Discharge (cfs)	MMT Rating[2]	Number of Sections	MMT Type	Reference
62-foot Bridge	06/05/07	7.83	JPM, OOO, MDM	55	292	1.18	345	F	20	Cable	This report
	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	06/05/07	7.76	JPM, OOO, MDM	447	1670	0.74	1240	F	20	Cable	This report
	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: Point plots nearly on the rating curve; 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

The 2007 peak discharge through the 62-foot and 452-foot swale bridges likely occurred at the time of peak stage and maximum water surface differential prior to discharge measurements. The peak stage occurred on June 5 at an elevation of 8.60 feet (Gage 3). Maximum headwater-tailwater differential occurred simultaneously with peak stage. Peak discharge through the 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 the average total depth at peak discharge was 0.77 and 0.84 feet greater than during the discharge measurement for the 62-foot and 452-foot swale bridges respectively. This assumption was based on the difference in stage between peak and observed stage at the time of the discharge measurement. The peak discharge through the 62-foot bridge is estimated to have been 395 cfs and 1,514 cfs through the 452-foot bridge. Table 4-6 summarizes estimated peak annual discharge data at the Alpine swale bridges between 2000 and 2007.

Between 2000 and 2002, the estimated peak discharge through the 452-foot bridge represented approximately 87% of the total estimated peak discharge through both swale bridges. The ratio changed in 2004, with the estimated peak discharge through the 452-foot bridge representing approximately 80% of the total estimated peak discharge through both swale bridges for 2004, 2006, and 2007; no measurements were taken in 2003 or 2005 at the 62-foot bridge due to snow and ice obstructing the bridge.

Table 4-6 Estimated Peak Discharge Summary – Alpine Swale Bridges, 2000-2007

Date & Time	Peak WSE (ft)[1]	452-Foot Bridge		62-Foot Bridge		References
		Discharge (cfs)[2]	Mean Vel (ft/s)	Discharge (cfs)[2]	Mean Vel (ft/s)	
06/05/07 04:00	8.60	1514	1.35	395	1.18	This report
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 No. POA-2004-253 and State of Alaska DNR 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 throughout breakup. CD2 and CD4 road culvert dimensions were determined using as-built surveys conducted by LCMF in 2002 and 2005, respectively. During the 2007 breakup, water was observed to have passed through all of the CD2 road culverts and each of the CD4 road culverts located in the paleochannel region north of the CD4 pad (CD4-20A through CD4-33). While 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 road culverts.

ALPINE CULVERTS INDIRECT ESTIMATED DISCHARGE AND VELOCITY

Alpine Culverts Discharge

Flow through the CD2 road culverts is estimated to have first occurred on June 4. The peak discharge through the CD2 culverts coincided with peak stage on June 5 at approximately 4:00 AM and ranged from 0.0 cfs to 44.4 cfs. The total discharge through all CD2 culverts during peak stage was approximately 527 cfs. The estimated discharges passing through the CD2 culverts are presented in Table 4-7. In the tabulation of discharge, a zero discharge represents a culvert having water and zero velocity or no water.

Flow through the CD4 south and north culvert batteries is estimated to have first occurred on June 5 and June 4, respectively. Peak discharge through the south culvert battery coincided with peak stage on June 4 at approximately 5:00 PM and ranged from 3.71 cfs to 7.89 cfs. The total discharge through the south culvert battery (CD4-24 – CD4-33) during peak stage was approximately 58.5 cfs. The peak discharge through the north culvert battery coincided with peak stage on June 5 at approximately 12:00 PM and ranged from 19.5 cfs to 31.6 cfs. Total discharge through the north culvert battery (CD4-20A – CD4-23D) during peak stage was approximately 241 cfs. Estimated discharges through the CD4 culverts are presented in Table 4-8 and Table 4-9. In the tabulation of discharge, a zero discharge represents a culvert having water and zero velocity or no water.

Table 4-7 CD2 Road Culverts Estimated Discharge Summary

Culvert	6/3/07 8:10 PM	6/4/07 8:15PM	6/5/07 4:00 AM	6/5/07 8:10 AM	6/5/07 5:40 PM	6/5/07 6:50 PM	6/6/07 9:05 AM	6/6/07 5:00 PM	6/7/07 11:00 AM
CD2-1	0	6.28	19.2	20.1	4.94	***5.82***	2.68	2.52	0
CD2-2	0	6.09	18.7	19.4	4.77	***5.57***	2.58	2.43	0
CD2-3	0	10.0	23.3	26.0	6.62	***7.82***	3.91	3.75	0
CD2-4	0	12.8	26.0	30.1	7.83	***9.30***	4.82	4.76	0
CD2-5	0	12.3	25.6	29.4	7.60	***9.05***	4.64	4.54	0
CD2-6	0	12.7	25.9	30.0	7.80	***9.25***	4.75	4.65	0
CD2-7	0	12.8	26.0	30.2	7.82	***9.30***	4.83	4.68	0
CD2-8	0	8.13	21.2	22.9	5.75	***6.74***	3.28	3.12	0
CD2-9	0	2.56	14.7	12.6	2.72	***2.50***	1.02	0	0
CD2-10	0	4.02	17.3	15.2	3.38	***3.14***	***1.34***	***1.43***	0
CD2-11	0	4.45	18.0	15.5	3.39	***3.22***	***1.23***	***1.23***	0
CD2-12	0	10.9	29.3	27.3	6.07	***4.11***	2.59	0	0
CD2-13	0	6.17	20.8	17.9	4.67	0	1.88	0	0
CD2-14	0	10.4	27.0	24.0	7.41	3.54	3.65	1.50	0
CD2-15	0	4.79	19.0	15.4	4.46	2.96	1.48	0.41	0
CD2-16	0	0	0	0	0	0	0	0	0
CD2-17	0	0	0.61	0	0	0	0	0	0
CD2-18	0	0	6.99	3.74	0.69	0.45	0	0	0
CD2-19	0	0	2.67	0.94	0	0	0	0	0
CD2-20	0	7.85	24.2	19.2	6.50	6.55	1.84	0.06	0
CD2-21	0	17.8	34.9	29.8	11.3	11.6	6.05	2.35	0
CD2-22	0	20.3	37.0	32.0	12.2	12.6	7.19	3.27	0
CD2-23	0	31.10	44.0	40.5	16.2	16.9	12.8	8.38	0
CD2-24	0	33.4	44.4	41.8	16.8	17.7	14.1	9.67	0
CD2-25	0	0	0	0	0	0	0	0	0
CD2-26	0	0	0	0	0	0	0	0	0
Northern Flow	0	235	527	504	149	72.3	51.5	25.6	0
Southern Flow	0	0	0	0	0	***75.8***	***2.57***	***2.66***	0
Notes:	Bolded italic text indicates discharge flowing in southern direction.								

Table 4-8 CD4 Road – South Culvert Battery Estimated Discharge Summary

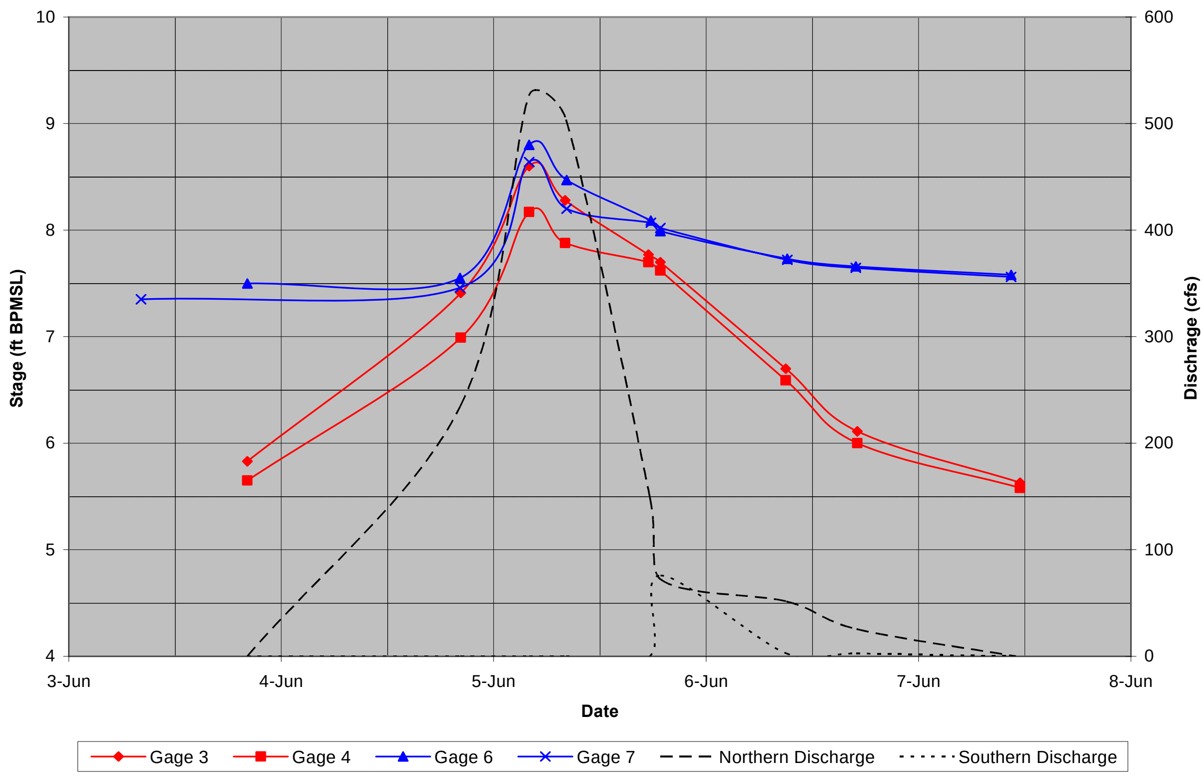
Culvert	6/4/07 8:29 PM	6/5/07 9:35 AM	6/5/07 12:00 PM	6/5/07 4:57 PM	6/6/07 8:40 AM	6/6/07 4:40 PM
CD4-20A	0	14.9	31.6	18.2	16.6	0
CD4-20	0	14.9	31.6	18.2	17.8	0
CD4-21	0	14.9	31.6	18.2	17.4	0
CD4-22	0	14.9	31.6	18.0	15.3	0
CD4-23	0	9.61	22.7	10.4	5.35	0
CD4-23A	0	10.1	23.8	11.0	5.99	0
CD4-23B	0	12.6	28.5	14.2	9.27	0
CD4-23C	0	8.77	19.5	9.96	6.28	0
CD4-23D	0	9.05	19.8	10.4	6.83	0
Total Discharge	0	110	241	129	101	0

Table 4-9 CD4 Road – North Culvert Battery Estimated Discharge Summary

Culvert	6/3/07 5:00 PM	6/4/07 5:00 PM	6/4/07 8:38 PM	6/5/07 9:45 AM	6/5/07 4:30 PM
CD4-24	0	5.31	2.26	0.65	0
CD4-25	0	3.71	1.31	0.15	0
CD4-26	0	5.17	2.00	0.37	0
CD4-27	0	5.15	1.99	0.36	0
CD4-28	0	4.83	1.94	0.46	0
CD4-29	0	7.59	3.75	1.52	0
CD4-30	0	7.89	3.90	1.66	0
CD4-31	0	6.66	3.06	0.98	0
CD4-32	0	5.19	1.91	0.47	0
CD4-33	0	7.04	3.79	1.68	0
Total Discharge	0	58.5	25.9	8.3	0

Alpine Culverts Headwater and Tailwater Differential

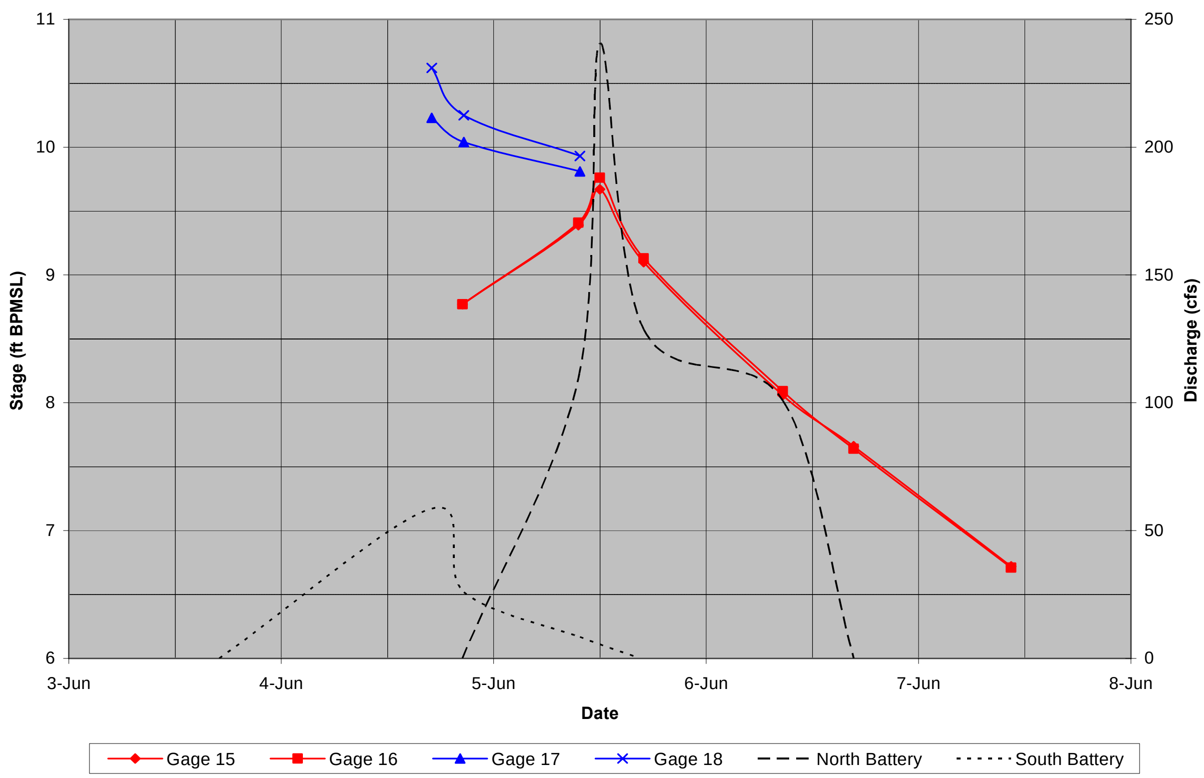
The differential between headwater and tailwater elevations for the CD2 culverts is based on the water surface elevation differential between Gages 3 and 4 and between Gages 6 and 7. At the CD2 culverts, the maximum WSE differential between the Gages 3 and 4 occurred during peak stage, while maximum WSE differential between Gages 6 and 7 occurred within approximately four hours of the peak on the falling limb. The maximum recorded WSE differential between Gages 3 and 4 was recorded on June 5 at approximately 4:00 AM with a differential of 0.43 feet. The maximum recorded WSE differential between Gages 6 and 7 was recorded on June 5 at 8:15 AM with a differential of 0.27 feet. Flow through the CD2 culverts is estimated to have stopped on June 7. 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

The normal direction of flow for the CD2 culverts is south to north. Flow in 12 of the CD2 culverts began flowing north to south (southern discharge) (see Table 4-7) around 6:50 PM on June 5. This reversal in flow direction was the result of higher water surface elevations at Gages 4 and 7 (downstream) than at Gages 3 and 6 (upstream). The cause is attributed to the release of the Nigliq Channel ice jam and subsequent backwater in the Nigliq Channel northwest of the CD2 pad. When the Nigliq Channel ice cleared, the CD2 culvert discharge began flowing south into the Nigliq Channel through Nanuq Lake.

The differential between headwater and tailwater elevations for the CD4 culverts is represented by the water surface elevation differential at the south culvert battery between Gages 17 and 18 and at the north culvert battery between Gages 15 and 16. The maximum differential between WSE at the south culvert battery occurred during peak stage on June 4 at approximately 5:00 PM with a differential of 0.39 feet. The maximum differential between recorded WSE at the north culvert battery occurred during peak stage on June 5 at approximately 12:00 PM with a differential of 0.09 feet. Flow is estimated to have stopped at the south and north CD4 culvert batteries on June 5 and June 6, respectively. A comparison of stage and discharge during breakup for the CD4 culverts is presented in Graph 4-3.



Graph 4-3 CD4 Road Culverts Estimated Discharge vs. Stage

The typical flow direction for the south culvert battery is from Gage 18 to Gage 17 (southeast to northwest). The flow pattern is the result of overbank flooding of the Nigliq Channel into Lake L9324 south of CD4 pad. As stage increases, floodwater passes through the south culvert battery into Lake L9323. Flow direction in 2007 was typical. The ice jam that formed near the CD4 pad on June 4 caused backwater to flow overbank. The floodwaters peaked that evening prior to release of the Nigliq Channel ice jam.

Alpine Culverts Velocity

The peak average velocity for the CD2 road culverts on June 5 at 8:10 AM, approximately four hours after peak stage. At the time of peak discharge in the early morning of June 5, the average velocity through the CD2 road culverts ranged from 2.41 fps to 3.58 fps. A summary of average velocity values for each CD2 culvert is presented in Table 4-10. In the tabulation of velocities, a cell containing a dash represents a culvert having water and zero velocity or no water.

A summary of average velocity values for the CD4 south and north culvert batteries is presented in Table 4-11 and, Table 4-12 respectively. For the southern culverts, the peak average velocity of 3.37 fps is estimated to have occurred on June 4 at 5:00 PM. At the time of peak discharge through the southern culverts, the average velocity of each culvert ranged from 1.57 fps to 3.93 fps. For the north CD4 culverts, the peak average velocity of 1.63 fps is estimated to have occurred at peak stage on June 5 at 12:00 PM. At the time of peak discharge through the northern culverts, the average velocity of each culvert ranged from 1.57 fps to 1.71 fps.

The average velocity estimated for the CD2 and CD4 culverts is related to the water surface differential between the headwater and the tailwater elevations. The average velocity for each culvert was found to be greatest during the largest differential between headwater and tailwater. A comparison of stage and average velocity for the CD2 and CD4 culverts is presented in Graph 4-4 and Graph 4-5 respectively.

Table 4-10 CD2 Road Culverts Estimated Average Velocity Summary

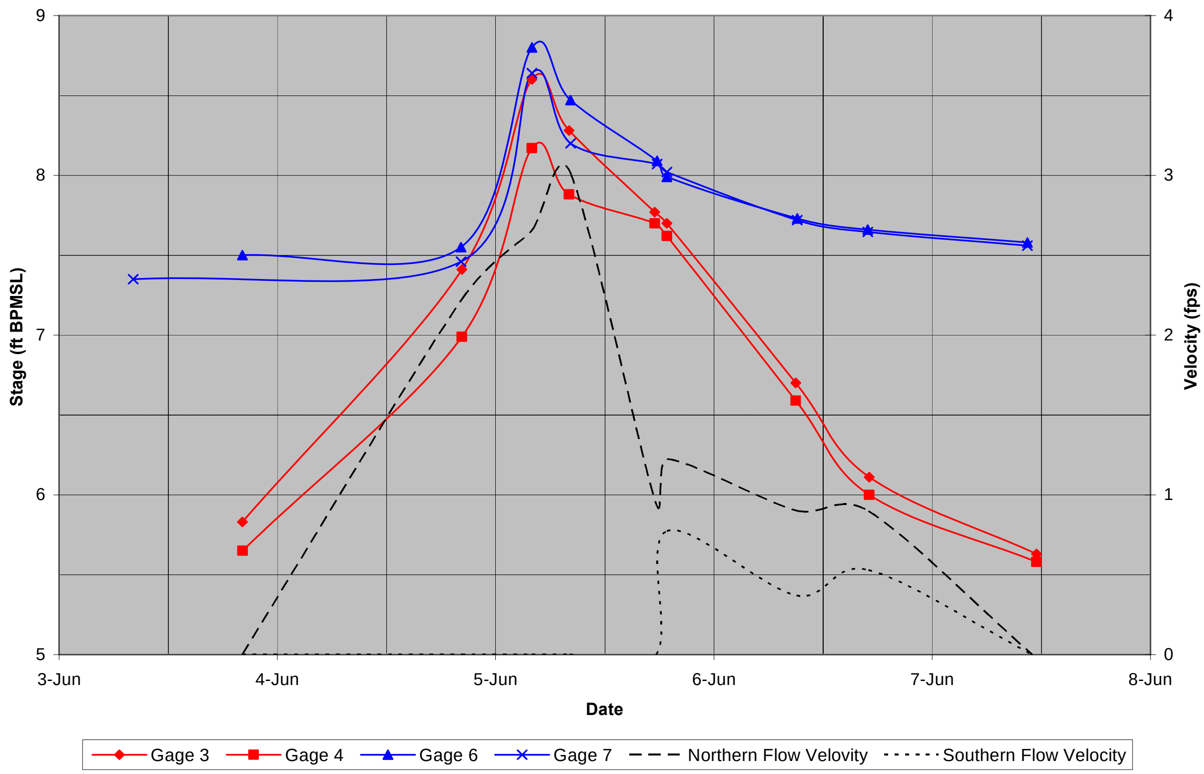
Culvert	6/3/07 8:10 PM	6/4/07 8:15PM	6/5/07 4:00 AM	6/5/07 8:10 AM	6/5/07 5:40 PM	6/5/07 6:50 PM	6/6/07 9:05 AM	6/6/07 5:00 PM	6/7/07 11:00 AM
CD2-1	-	1.89	2.42	3.24	0.87	***0.73***	0.62	0.62	-
CD2-2	-	1.78	2.32	3.07	0.82	***0.85***	0.58	0.58	-
CD2-3	-	1.65	2.21	2.89	0.78	***0.93***	0.55	0.55	-
CD2-4	-	1.59	2.17	2.81	0.76	***0.97***	0.53	0.53	-
CD2-5	-	1.62	2.19	2.85	0.77	***0.95***	0.54	0.55	-
CD2-6	-	1.55	2.15	2.77	0.75	***0.98***	0.52	0.52	-
CD2-7	-	1.63	2.19	2.86	0.77	***0.95***	0.55	0.55	-
CD2-8	-	1.65	2.22	2.90	0.78	***0.92***	0.55	0.55	-
CD2-9	-	1.47	2.15	2.58	0.64	***0.55***	0.42	-	-
CD2-10	-	1.67	2.08	2.65	0.66	***0.52***	***0.32***	***0.61***	-
CD2-11	-	1.43	2.09	3.33	0.57	***0.45***	***0.42***	***0.45***	-
CD2-12	-	1.84	2.32	2.66	0.64	***0.48***	0.42	-	-
CD2-13	-	1.64	2.22	2.41	0.70	-	0.48	-	-
CD2-14	-	2.09	2.52	2.72	0.92	0.45	0.74	0.40	-
CD2-15	-	3.31	3.30	3.55	1.20	0.84	1.20	1.05	-
CD2-16	-	-	-	-	-	-	-	-	-
CD2-17	-	-	2.20	-	-	-	-	-	-
CD2-18	-	-	3.30	3.41	1.06	0.91	-	-	-
CD2-19	-	-	3.22	2.46	-	-	-	-	-
CD2-20	-	3.07	3.39	3.26	1.25	1.34	1.30	0.52	-
CD2-21	-	3.36	3.53	3.38	1.40	1.49	1.62	1.44	-
CD2-22	-	3.67	3.67	3.55	1.47	1.57	1.82	1.76	-
CD2-23	-	3.78	3.65	3.58	1.50	1.61	1.92	1.95	-
CD2-24	-	3.70	3.56	3.52	1.47	1.58	1.88	1.89	-
CD2-25	-	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-	-
Northern Flow	**-**	2.22	2.66	3.02	0.94	1.22	0.90	0.90	**-**
Southern Flow	**-**	**-**	**-**	**-**	**-**	***0.77***	***0.37***	***0.53***	**-**
Notes:	Bolded text indicates discharge flowing in southern direction.								

Table 4-11 CD4 Road – South Culvert Battery Estimated Average Velocity Summary

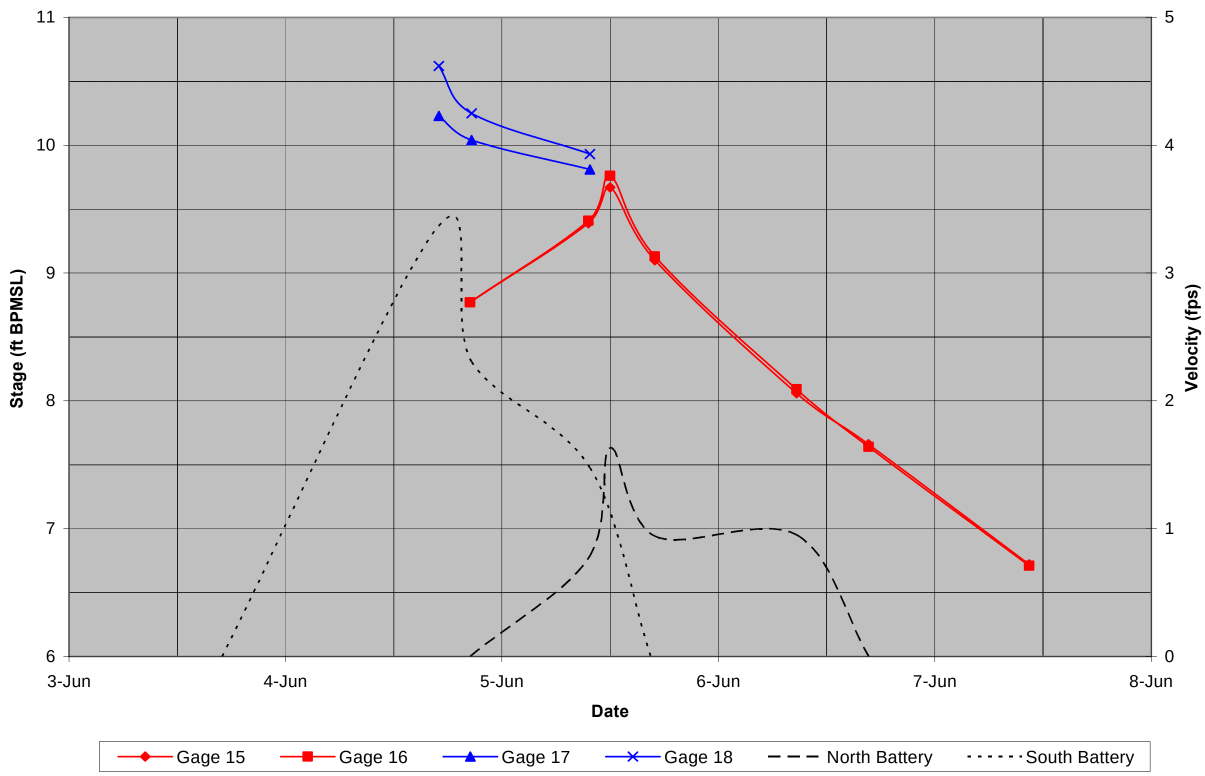
Culvert	6/3/07 5:00 PM	6/4/07 5:00 PM	6/4/07 8:38 PM	6/5/07 9:45 AM	6/5/07 4:30 PM
CD4-24	-	2.81	1.74	0.95	-
CD4-25	-	3.51	2.55	1.54	-
CD4-26	-	3.83	2.75	1.57	-
CD4-27	-	3.82	2.73	1.55	-
CD4-28	-	3.56	2.34	1.50	-
CD4-29	-	3.27	2.22	1.50	-
CD4-30	-	3.56	2.44	1.78	-
CD4-31	-	3.93	2.67	1.82	-
CD4-32	-	3.83	2.63	1.99	-
CD4-33	-	1.57	0.99	0.56	-
Southern Total	-	3.37	2.31	1.48	-

Table 4-12 CD4 Road – North Culvert Battery Estimated Average Velocity Summary

Culvert	6/4/07 8:29 PM	6/5/07 9:35 AM	6/5/07 12:00 PM	6/5/07 4:57 PM	6/6/07 8:40 AM	6/6/07 4:40 PM
CD4-20A	-	0.76	1.61	0.93	0.96	-
CD4-20	-	0.76	1.61	0.93	1.02	-
CD4-21	-	0.76	1.61	0.93	0.99	-
CD4-22	-	0.76	1.61	0.92	0.88	-
CD4-23	-	0.80	1.71	0.99	0.99	-
CD4-23A	-	0.80	1.69	0.97	0.97	-
CD4-23B	-	0.80	1.70	0.99	1.01	-
CD4-23C	-	0.73	1.57	0.89	0.85	-
CD4-23D	-	0.74	1.58	0.91	0.88	-
Northern Total	-	0.77	1.63	0.94	0.95	-



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



Graph 4-5 CD4 Road Culverts Estimated Average Velocity vs. Stage

ALPINE CULVERTS DISCHARGE AND VELOCITY DIRECT MEASUREMENTS

Direct water depth and velocity measurements were conducted at the CD2 and CD4 road culverts to validate the indirect culvert calculations. Velocity measurements were taken at the outlet of the culvert. A calibrated Price AA 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 June 5 between 5:31 PM and 6:55 PM, water depth and velocity were measured at the CD2 road culverts; Table 4-13 presents the field data. These measurements represent conditions at CD2 culverts approximately 14 hours after peak stage occurred at the CD2 road gages (Gages 3, 4, 6, and 7). Discharge through the culverts was observed flowing both north and south. The average velocity of CD2 culverts that were flowing north was 0.73 fps and ranged from 1.85 fps to 0.08 fps. The average velocity of CD2 culverts that were flowing south was 1.16 fps and ranged from 1.81 fps to 0.55 fps. The total measured discharge flowing north was 74.6 cfs and ranged from 15.8 cfs to 0.41 cfs. The total measured discharge flowing south was 44.9 cfs and ranged from 12.9 cfs to 2.30 cfs. The timing of the data collection was greater than 12 hours after peak stage, making this data set a poor representation of peak flow conditions at the CD2 culverts.

Table 4-13 CD2 Road Culverts – June 5 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	6/5/07 5:31 PM	MTA, EJK	1.75	5.29	0.08	0.41	1	Wading
CD2-2	6/5/07 5:31 PM	MTA, EJK	1.70	5.09	0.38	1.94	1	Wading
CD2-3	6/5/07 5:31 PM	MTA, EJK	1.40	3.92	0.39	1.53	1	Wading
CD2-4	6/5/07 5:31 PM	MTA, EJK	2.90	9.76	0.14	1.34	1	Wading
CD2-5	6/5/07 5:31 PM	MTA, EJK	2.75	9.21	0.18	1.68	1	Wading
CD2-6	6/5/07 5:31 PM	MTA, EJK	2.90	9.76	0.12	1.19	1	Wading
CD2-7	6/5/07 5:31 PM	MTA, EJK	2.90	9.76	0.14	1.41	1	Wading
CD2-8	6/5/07 6:06 PM	MTA, EJK	2.10	6.68	0.10	0.65	1	Wading
CD2-9	6/5/07 6:18 PM	MTA, EJK	1.20	3.62	***0.64***	***2.30***	1	Wading
CD2-10	6/5/07 6:19 PM	MTA, EJK	1.60	5.42	***0.87***	***4.73***	1	Wading
CD2-11	6/5/07 6:23 PM	MTA, EJK	1.40	4.5	***1.24***	***5.56***	1	Wading
CD2-12	6/5/07 6:26 PM	MTA, EJK	1.80	7.13	***1.81***	***12.9***	1	Wading
CD2-13	6/5/07 6:30 PM	MTA, EJK	1.45	4.73	***1.66***	***7.86***	1	Wading
CD2-14	6/5/07 6:33 PM	MTA, EJK	1.85	6.6	***1.39***	***9.16***	1	Wading
CD2-15	6/5/07 6:35 PM	MTA, EJK	1.50	4.3	***0.55***	***2.36***	1	Wading
CD2-16	– (1)	–	–	–	–	–	–	–
CD2-17	– (1)	–	–	–	–	–	–	–
CD2-18	– (1)	–	–	–	–	–	–	–
CD2-19	– (1)	–	–	–	–	–	–	–
CD2-20	6/5/07 6:39 PM	MTA, EJK	1.60	4.69	1.67	7.85		Wading
CD2-21	6/5/07 6:42 PM	MTA, EJK	2.40	7.87	1.85	14.5	1	Wading
CD2-22	6/5/07 6:48 PM	MTA, EJK	2.35	7.68	1.70	13.1	1	Wading
CD2-23	6/5/07 6:52 PM	MTA, EJK	3.10	10.45	1.51	15.8	1	Wading
CD2-24	6/5/07 6:55 PM	MTA, EJK	3.25	10.94	1.21	13.2	1	Wading
CD2-25	– (1)	–	–	–	–	–	–	–
CD2-26	– (1)	–	–	–	–	–	–	–
						Average Measured Velocity Flowing North (ft/s)		**0.73**
						Average Measured Velocity Flowing South (ft/s)		***1.16***
						Total Measured Discharge Flowing North (cfs)		**74.6**
						Total Measured Discharge Flowing South (cfs)		***44.9***

Notes: 1. No water flowing through culvert, no measurement made.
2. Bolded italic text indicate southern flowing water

On June 5 between 4:34 PM and 4:51 PM, the water depth and velocity were measured at the CD4 road culverts; Table 4-14 presents the field data. These measurements represent conditions at CD4 culverts approximately 5 hours after peak stage occurred at the CD4 road Gages 15 and 16. No measurable flow was observed in the south culvert battery or western half of the north culvert battery. Velocities were measured at culverts CD4-23 through CD4-23D of the north culvert battery. The average velocity of the measured north battery culverts was 0.48 fps and ranged from 0.56 fps to 0.58 fps. CD4-24, located east of the south battery, had a measured velocity of 0.40 fps. The total discharge of the measured CD4 culverts was 32.3 cfs and ranged from 9.25 cfs to 0.85 cfs. Considering the timing of the data collection, this data set is likely representative of flow conditions through the measured culverts during peak discharge along the CD4 access road.

Table 4-14 CD4 Road Culverts – June 5 Discharge Measurements

Culvert #	Date Time	Made By	Depth (ft)	Area (ft²)	Mean Vel (ft/s)	Discharge (cfs)	Number of Sections	MMT Type
CD4-1	– (1)	–	–	–	–	–	–	–
through	– (1)	–	–	–	–	–	–	–
CD4-19	– (1)	–	–	–	–	–	–	–
through	– (2)	–	–	–	–	–	–	–
CD4-22	– (2)	–	–	–	–	–	–	–
CD4-23	6/5/07 4:51 PM	MTA, EJK	2.75	11.1	0.38	4.22	1	Wading
CD4-23A	6/5/07 4:47 PM	MTA, EJK	3.00	12.3	0.53	6.46	1	Wading
CD4-23B	6/5/07 4:44 PM	MTA, EJK	3.90	16.4	0.56	9.25	1	Wading
CD4-23C	6/5/07 4:41 PM	MTA, EJK	3.90	12.5	0.47	5.90	1	Wading
CD4-23D	6/5/07 4:38 PM	MTA, EJK	3.80	12.3	0.53	6.47	1	Wading
CD4-24	6/5/07 4:34 PM	MTA, EJK	0.90	2.1	0.40	0.85	1	Wading
CD4-25	– (1)	–	–	–	–	–	–	–
through	– (1)	–	–	–	–	–	–	–
CD4-33	– (1)	–	–	–	–	–	–	–
Notes: 1. No water flowing through culvert, no measurement made; 2. Culverts with water though no measurable flow					**Average Measured Velocity (ft/s)**			**0.48**
					Total Measured Discharge (cfs)			**32.3**

ALPINE CULVERTS INDIRECT AND DIRECT DISCHARGE ESTIMATES COMPARISON

Collection of direct measurement data at peak breakup is difficult considering the timing and predictability of such an event. The number of culverts, change in local topography, and limited number of staff gages make estimating culvert-specific peak water surface elevations and peak velocity measurements difficult. This necessitates use of indirect calculations to estimate peak values. The indirect estimates were compared with respective direct velocity measurements and associated discharge estimates to get a sense of relative accuracy of the indirect calculations. The comparison between the June 5 CD2 culverts direct and indirect measurements is presented in Table 4-15; Table 4-16 presents the CD4 culverts comparison and summary. In almost all cases, the indirect calculations were higher than the direct measured values.

The indirect estimates will generally be greater than direct estimates based on the comparison. This would be particularly true during lower water conditions. At higher water surface elevations, velocities become less dependent on culvert slope while headwater and tailwater elevations are more consistent between staff gages. However, interpolation of water surface elevations between staff gages can impart error in headwater and tailwater elevations. Since indirect estimates are generally higher than direct measurements they are considered conservative and are acceptable for use in estimating peak velocities and discharges.

Table 4-15 CD2 Road Culverts – June 5 Discharge Measurement Comparison

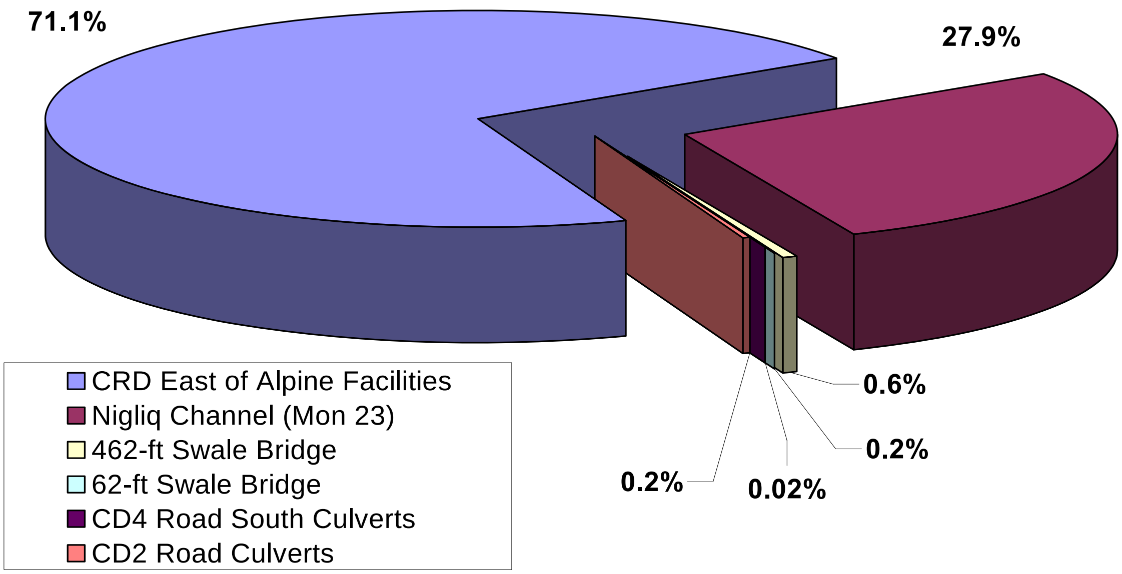
Culvert	Time of Direct Measurement	Mean Measured Velocity (ft/s)	Direct Measured Discharge (cfs)	Time of Indirect Measurement	Indirect Calculated Velocity (ft/s)	Indirect Calculated Discharge (cfs)	Percent Difference (1)	
							Velocity	Discharge
CD2-1	6/5/07 5:31 PM	0.08	0.41	6/5/07 5:45 PM	0.87	4.94	-1023%	-1105%
CD2-2	6/5/07 5:31 PM	0.38	1.94	6/5/07 5:45 PM	0.82	4.77	-115%	-146%
CD2-3	6/5/07 5:31 PM	0.39	1.53	6/5/07 5:45 PM	0.78	6.62	-100%	-332%
CD2-4	6/5/07 5:31 PM	0.14	1.34	6/5/07 5:45 PM	0.76	7.83	-453%	-484%
CD2-5	6/5/07 5:31 PM	0.18	1.68	6/5/07 5:45 PM	0.77	7.60	-323%	-354%
CD2-6	6/5/07 5:31 PM	0.12	1.19	6/5/07 5:45 PM	0.75	7.80	-513%	-553%
CD2-7	6/5/07 5:31 PM	0.14	1.41	6/5/07 5:45 PM	0.77	7.82	-434%	-455%
CD2-8	6/5/07 6:06 PM	0.10	0.65	6/5/07 5:45 PM	0.78	5.75	-701%	-784%
CD2-9	6/5/07 6:18 PM	***0.64***	***2.30***	6/5/07 6:50 PM	***0.55***	***2.5***	13%	-9%
CD2-10	6/5/07 6:19 PM	***0.87***	***4.73***	6/5/07 6:50 PM	***0.52***	***3.14***	40%	34%
CD2-11	6/5/07 6:23 PM	***1.24***	***5.56***	6/5/07 6:50 PM	***0.45***	***2.22***	64%	60%
CD2-12	6/5/07 6:26 PM	***1.81***	***12.9***	6/5/07 6:50 PM	***0.48***	***4.11***	73%	68%
CD2-13	6/5/07 6:30 PM	***1.66***	***7.86***	6/5/07 6:50 PM	0.00	0.00	-	-
CD2-14	6/5/07 6:33 PM	***1.39***	***9.16***	6/5/07 6:50 PM	0.45	3.54	68%	61%
CD2-15	6/5/07 6:35 PM	***0.55***	***2.36***	6/5/07 6:50 PM	0.84	2.96	-53%	-25%
CD2-16	-	-	-	-	-	-	-	-
CD2-17	-	-	-	-	-	-	-	-
CD2-18	-	-	-	6/5/07 6:50 PM	0.91	0.45	-	-
CD2-19	-	-	-	-	-	-	-	-
CD2-20	6/5/07 6:39 PM	1.67	7.85	6/5/07 6:50 PM	1.34	6.55	20%	17%
CD2-21	6/5/07 6:42 PM	1.85	14.5	6/5/07 6:50 PM	1.49	11.6	19%	20%
CD2-22	6/5/07 6:48 PM	1.70	13.1	6/5/07 6:50 PM	1.57	12.6	8%	4%
CD2-23	6/5/07 6:52 PM	1.51	15.8	6/5/07 6:50 PM	1.61	16.9	-6%	-7%
CD2-24	6/5/07 6:55 PM	1.21	13.2	6/5/07 6:50 PM	1.58	17.7	-31%	-34%
CD2-25	-	-	-	-	-	-	-	-
CD2-26	-	-	-	-	-	-	-	-
Notes:	1. Percent difference is computed using direct to indirect velocity and discharge values. 2. Bolded italic text indicate southern flowing water.							

Table 4-16 CD4 Road Culverts – June 5 Discharge Measurement Comparison with Summary

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
CD4-20A	-	-	-	6/5/07 4:37 PM	0.93	18.19	-	-
CD4-20	-	-	-	6/5/07 4:37 PM	0.93	18.22	-	-
CD4-21	-	-	-	6/5/07 4:37 PM	0.93	18.22	-	-
CD4-22	-	-	-	6/5/07 4:37 PM	0.92	18.04	-	-
CD4-23	6/5/07 4:51 PM	0.38	4.22	6/5/07 4:37 PM	0.99	10.37	-159%	-145%
CD4-23A	6/5/07 4:47 PM	0.53	6.46	6/5/07 4:37 PM	0.97	11.03	-85%	-71%
CD4-23B	6/5/07 4:44 PM	0.56	9.25	6/5/07 4:37 PM	0.99	14.18	-76%	-53%
CD4-23C	6/5/07 4:41 PM	0.47	5.90	6/5/07 4:37 PM	0.89	9.96	-88%	-69%
CD4-23D	6/5/07 4:38 PM	0.53	6.47	6/5/07 4:37 PM	0.91	10.39	-73%	-60%
CD4-24	6/5/07 4:34 PM	0.40	0.85	6/5/07 4:37 PM	-	-	-	-
Average Measured Velocity (ft/s)		**0.48**	**Average Calculated Velocity (ft/s)**			**0.94**	**V Difference**	**-97%**
Total Measured Discharge (cfs)		**33**	**Total Calculated Discharge (cfs)**			**129**	**Q Difference**	**-288%**
Notes:	1. Percent difference is computed using direct to indirect velocity and discharge values.							

4.2.5 Peak Discharge Flow Distribution

At the 2007 peak discharge, approximately 71% of flow in the Delta passed to the east of Alpine facilities in the East Channel. Only 1% of the peak discharge passed through the Alpine facilities culverts and swale bridges. Remaining floodwaters passed down the Nigliq Channel, constituting approximately 28% of peak discharge. Graph 4-6 presents the 2007 estimated flow distribution at the time of peak discharge.



Graph 4-6 2007 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). The results of this analysis are presented in Table 4-17.

Table 4-17 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

In 2006, a limited flood frequency analysis was performed to evaluate the 2002 estimates. The analysis was limited to 15 years of continuous data collected between 1992 and 2006. The 2006 analysis resulted in consistently lower discharge magnitudes than the 2002 analysis. However, because the 2006 analysis included only continuous data while the 2002 analysis incorporated all available data, including data collected by Walker and Hudson between 1962 and 1973 (Graph 1-1), no changes to the recommended flood frequency analysis were recommended.

The 2007 peak direct discharge of 270,000 cfs has an estimated recurrence interval of 3 years based on both the 2002 and 2006 flood frequency analyses.

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

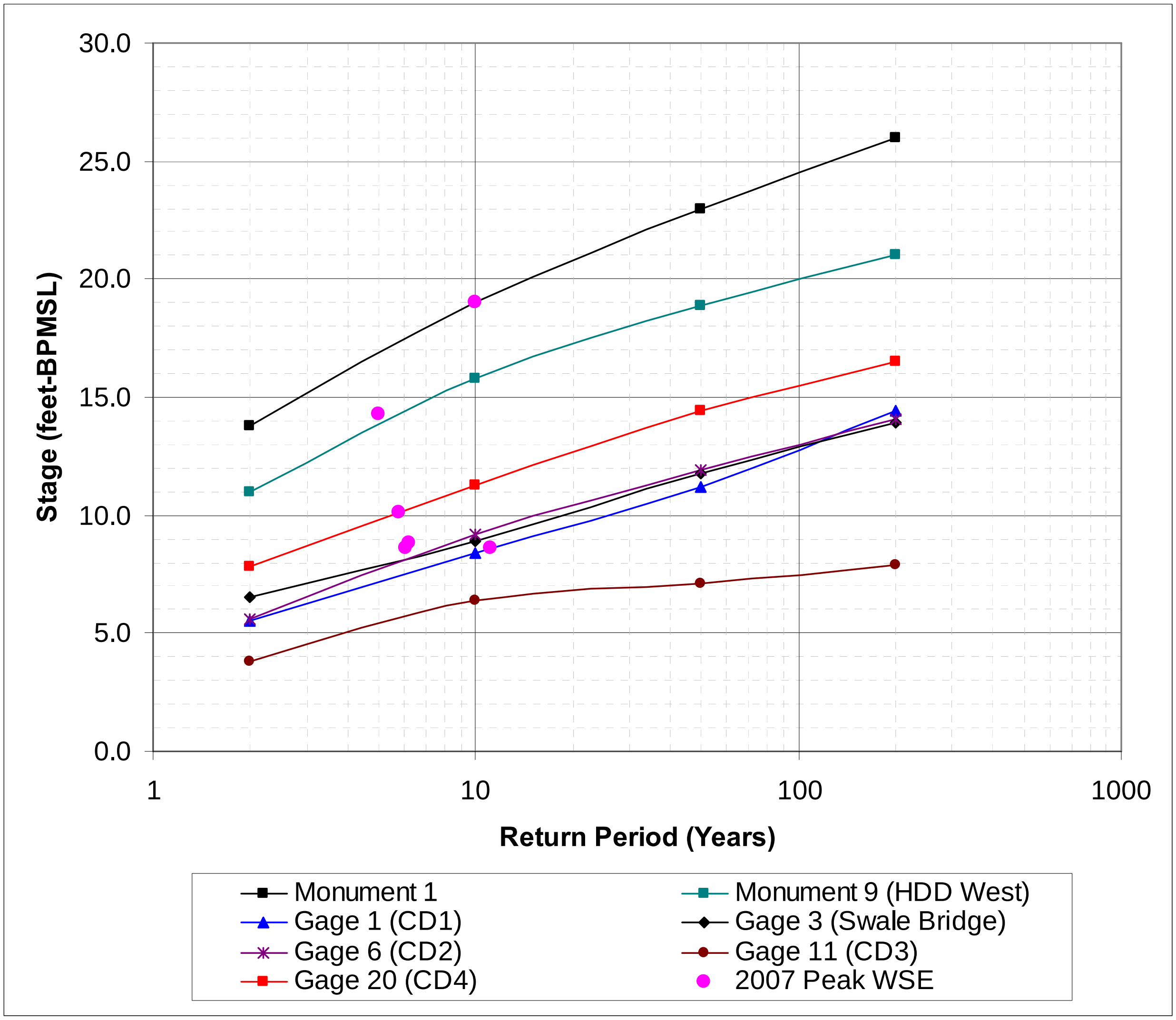
The Colville River 2-dimensional (2D) surface water model was first developed in 1997 to estimate water surface elevations and velocities at the proposed Alpine Development Project Facilities locations. The 2D Finite Element Surface Water Modeling System (FESWMS) was chosen as the modeling software. 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 2007 observations are presented in Table 4-18.

Table 4-18 Colville River 2D Model Predicted Water Surface Elevations and 2007 Observations

Monitoring Sites	2D Model Predicted Water Surface Elevation based on open water conditions (feet-BPMSL)				2007 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	19.0	10
Monument 9 (HDD)	11.0	15.8	18.9	21.0	14.3	5
Helmricks	3.8	5.3	5.9	6.3	5.1	6
Colville River - Nigliq Channel						
Monument 20	7.8	11.3	14.4	16.5	11.9	11
Monument 22	5.9	8.6	11.8	14.0	9.0	11
Monument 23	4.9	7.0	10.1	12.1	7.6	11
Monument 28	3.1	3.3	3.7	4.4	4.7	>200
CD1 Pad						
Gage 1	5.5	8.4	11.2	14.4	8.6	11
Gage 9	6.7	9.7	11.1	15.3	9.4	6
Gage 10	6.7	9.7	12.8	15.3	9.5	6
CD2 Pad						
Monument 23	4.9	7.0	10.1	12.1	7.6	11
Gage 6	*5.6*	9.2	11.9	14.1	8.8	6
CD3 Pad						
Gage 11	*3.8*	6.4	7.1	7.9	-	-
CD4 Pad						
Gage 19	*7.2*	11.0	14.1	16.4	-	-
Gage 20	*7.2*	10.7	13.8	16.0	10.1	6
CD2 Road						
Gage 3	6.5	8.9	11.8	13.9	8.6	6
Gage 4	6.5	8.2	9.9	11.8	8.2	10
Gage 6	*5.6*	9.2	11.9	14.1	8.8	6
Gage 7	*5.6*	8.3	9.8	11.8	8.6	11
CD3 Pipeline						
Crossing #2 (SAK) Gage	4.9	8.4	11.1	12.8	6.3	4
Crossing #4 (TAM) Gage	5.8	8.3	9.2	9.9	7.8	6
Crossing #5 (ULAM) Gage	4.4	7.1	7.9	8.7	7.1	10
CD4 Road						
Gage 15	*7.2*	9.9	12.9	15.4	9.7	6
Gage 16	*7.2*	10.1	13.7	15.8	9.8	6
Gage 17	*7.2*	10.4	13.7	15.8	10.2	7
Gage 18	*7.2*	11.0	14.3	16.6	10.6	6

Notes: Italicized water surface elevations are below ground elevation monitoring sites. Values represent nearest WSE.
Sites having no observed WSE in 2007 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-, 100-, 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 4-7 presents predicted water surface elevations at selected locations for 2-, 10-, 50-, and 200-year floods and their respective 2007 peak stage.



Graph 4-7 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. This was the case in 2007 (Table 4-18), with the measured peak discharge having a recurrence interval of approximately 3 years and observed water surface elevations generally having a recurrence interval of approximately 10 years based on 2D model predictions. Monument 28 had a peak stage with a recurrence interval of more than 200 years. Monument 28 is near the downstream boundary condition of the model and a very small variation in stage can cause a significant change in the local recurrence interval.

4.3.3 Colville River Delta Stage Frequency

A stage frequency analysis was performed for a limited group of sites in 2006 (Baker 2006a). 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 4-19 and are compared to 2007 observed peak water surface elevations.

Table 4-19 Colville River Delta Stage Frequency Analysis

Monitoring Sites	Stage Frequency (feet-BPMSL)						2007 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	19	6
Monument 22	8.2	8.8	9.5	10.3	11	11.8	9	4
Gage 1	6.7	7.6	8.6	9.8	10.8	12.2	8.6	5
Gage 3	7.7	8.3	8.9	9.7	10.4	11.2	8.6	4
CD4 Pad (Gage 18)	9.5	10.4	11.4	12.6	13.7	15.1	10.6	4

Stage frequency elevations are consistently greater than those estimated by the 2D model (Table 4-18) for the respective recurrence intervals. As was noted in Section 4.3.2, the presence of in-channel ice and snow during breakup 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. At no location 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 gravel bases along CD2 and CD4 were partially submerged (Photo 4-24).

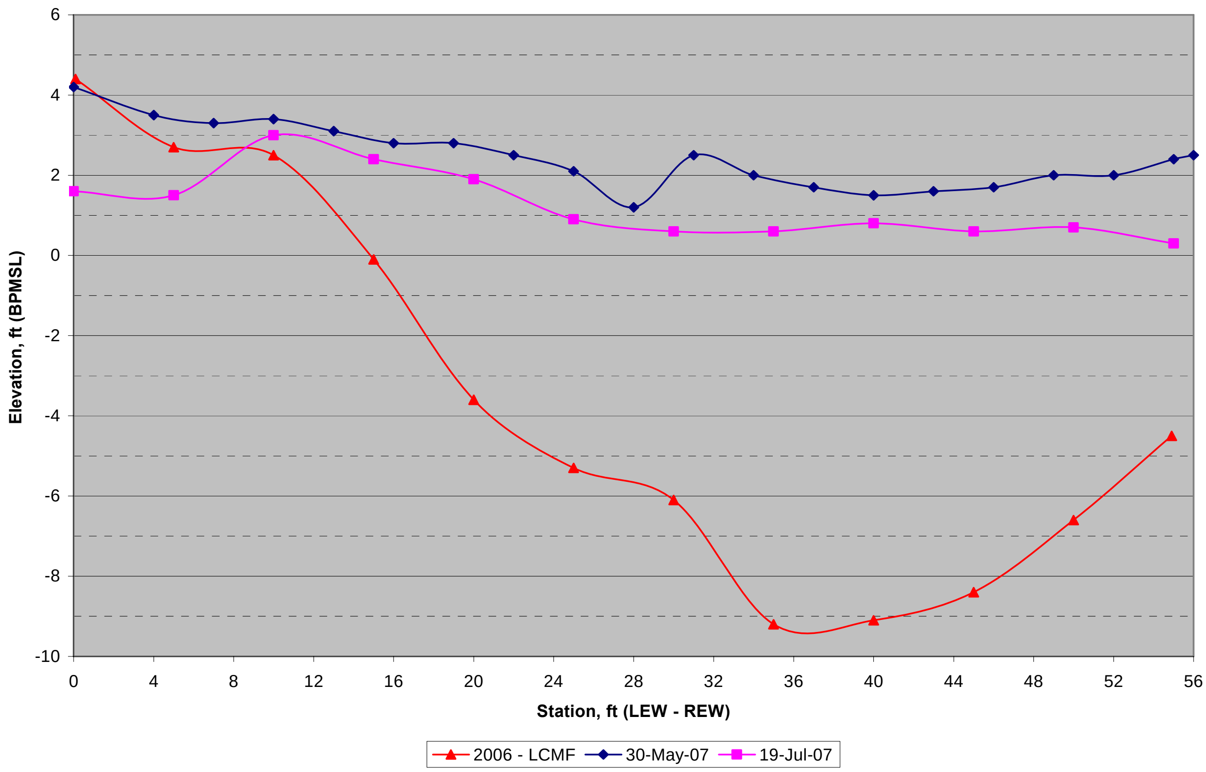
Photo 4-30 Fine Grained Sediment Settlement on Eastern Side of CD4 Road at STA 160+00 Looking South, August 28, 2007

A relatively small volume of fine-grained sediment was washed from the CD4 eastern road embankments near the northern culvert battery due to the inundation. No slumping or side slope deterioration was observed. Photo 4-30 and Photo 4-31 present the erosion observed on the east side of the CD4 road in the region of the north culvert battery which represents the only location along the CD2 and CD4 roads where erosion was observed. Photo 4-32 represents the condition of the majority of Alpine facility pads and roads after breakup. Pictures of the CD4 road were taken August 28, 2007.

Photo 4-31 Fine Grained Sediment Settlement on Eastern Side of CD4 Road at STA 160+00 Looking North, August 28, 2007

Photo 4-32 Western Side of CD4 Access Road after Breakup at STA 160+00 Looking South, August 28, 2007

In April 2007, riprap was placed at the 62-foot swale bridge, along the CD2 access road, to prevent further thermoerosion and scour at the east sheet pile abutment. Annual survey profiles of the channel bed at the bridge 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 erosion protection material. Survey data collected on the upstream (south) side of the swale bridge are presented in Graph 4-8. Survey profiles indicate that minor settlement of the riprap occurred between May 30, 2007, and July 19, 2007.



Graph 4-8 2007 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. Snow surveys were conducted within each lake's catchment basin to determine the volume of lake recharge due to snow melt for comparison with the observed increase in water surface elevation. Water level surveys and water surface elevation records of Gages 9 and 10 were the primary references used in evaluating the water surface elevations at Lakes L9312 and L9313, respectively. During the 2007 breakup, both lakes were recharged by snowmelt and the Colville River to above bankfull water surface levels. This condition was 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 10 and May 30, the water surface elevation in Lake L9312 decreased from 7.51 feet to 7.47 feet. The 0.04-foot fall in water surface elevation is attributed to water withdrawal from the lake to support Alpine operations. A peak water surface elevation of 9.35 feet was estimated to have occurred on the morning of June 5 and was the result of overland flow from the Sakoonang Cannel. As the discharge of the Colville River decreased and the ice jams in the East, Sakoonang, and Nigliq Channels released, the water surface elevation at Lake L9312 decreased to 8.60 feet on June 6. The water surface elevation of Lake L9312 continued to recede and on June 10, the stage was measured to be 8.13 feet. The water surface elevations for Lake L9312 (Gage 9) are presented in Table 4-30.

4.5.2 Lake L9313 Recharge

Between May 10 and May 30, the water surface elevation in Lake L9313 decreased from 5.85 feet to 5.83 feet. On the evening of June 4, the water surface elevation had risen to 8.78 feet due to flooding from the Sakoonang Channel. The water surface elevation at Lake L9313 continued to rise to a peak stage of 9.47 feet on June 5 at approximately 8:00 AM. The water surface elevation of L9313 decreased to 7.67 feet on June 6 and finally to 6.31 feet on June 11. The water surface elevations for Lake L9313 (Gage 10) are presented in Table 4-30.

Photo 4-33 and Photo 4-34 show the lakes fully recharged shortly after peak stage. Figure 4-4 illustrates the routes of floodwater recharge to the Alpine drinking water lakes.

Photo 4-33 Alpine Drinking Water Lakes Recharged, June 6, 2007

Photo 4-34 Alpine Drinking Water Lakes Recharged, June 6, 2007

4.5.3 Snow Survey

Snow surveys were conducted prior to breakup (May 9) at the Alpine drinking water Lakes L9312, L9313, and control Lake L9310. Figure 4-5 and Figure 4-6 present the sample locations and the catchment basin boundaries for each lake. The snow survey field data is presented in Appendix D.

Terrain specific snow depth, snow density, snow water equivalent, and area weighted snow water equivalent were computed based on methods described in the *2007 Colville River Delta Lakes Recharge Monitoring and Analysis* (Baker 2007b). These results are presented in Table 4-20. Snow survey results were used to estimate the amount of snowmelt water potentially available for lake recharge. Associated volumes are also presented in Table 4-20. The potential recharge volume estimates assume the presence of permafrost which inhibits notable loss of water to infiltration. The potential recharge volume for each lake was computed using the lake's corresponding area weighted snow water equivalent and is independent of the other sample lakes.

Table 4-20 Alpine Lakes Snow Survey Results – May 9, 2007

Lake Name	Drainage Area (ft^2)		Snow Density (lb/in^3)		Snow Depth (in)		Snow Water Equivalent (in)			Estimated Recharge Volume (million gallons)
	Lake	Tundra	Lake	Tundra	Lake	Tundra	Lake	Tundra	Area Weighted	
L9310	2,874,000	2,517,000	0.004	0.006	5.59	13.46	0.69	2.38	1.48	4.96
L9312	4,861,000	4,944,000	0.007	0.007	5.3	12.3	1.05	2.22	1.64	10.03
L9313	3,382,000	3,131,000	0.007	0.006	6.1	13.8	1.23	2.18	1.69	6.86

4.6 Ice Bridge Monitoring

No significant erosion or scour was observed during breakup at or near the Colville River East Channel ice bridge crossing. Photo 4-35 through Photo 4-38 represent conditions at the ice bridge crossing during and after breakup.

Photo 4-35 Colville East Channel Ice Bridge during Breakup (looking east), May 29, 2007

Photo 4-36 Colville East Channel Ice Bridge (east bank) after Breakup, June 9, 2007

Photo 4-37 Colville East Channel Ice Bridge during Breakup (west ramp), May 28, 2007

Photo 4-38 Colville East Channel Ice Bridge (west bank) after Breakup, June 6, 2007

4.7 Figures

ConocoPhillips Alaska, Inc.

DATE:	10/26/07	PROJECT:	111335
DRAWN:	MDM	FILE:	MON1.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

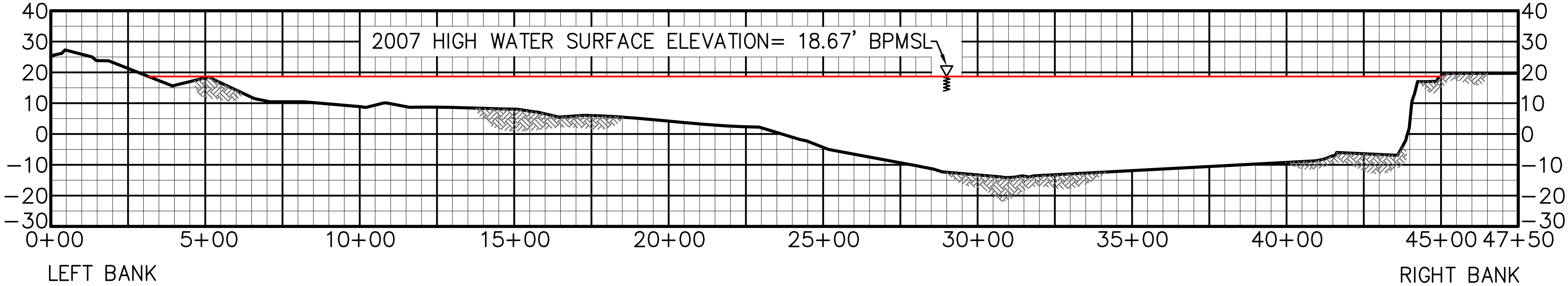
Baker

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

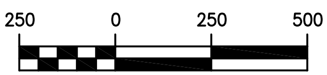
2007 SPRING BREAKUP
MONUMENT 1
PLAN

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'



HORIZONTAL SCALE IN FEET

VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE: 10/28/07		PROJECT: 111335	
DRAWN: MDM		FILE: MON_1_PROFILES.DWG	
CHECKED: OOO		SCALE: AS SHOWN	

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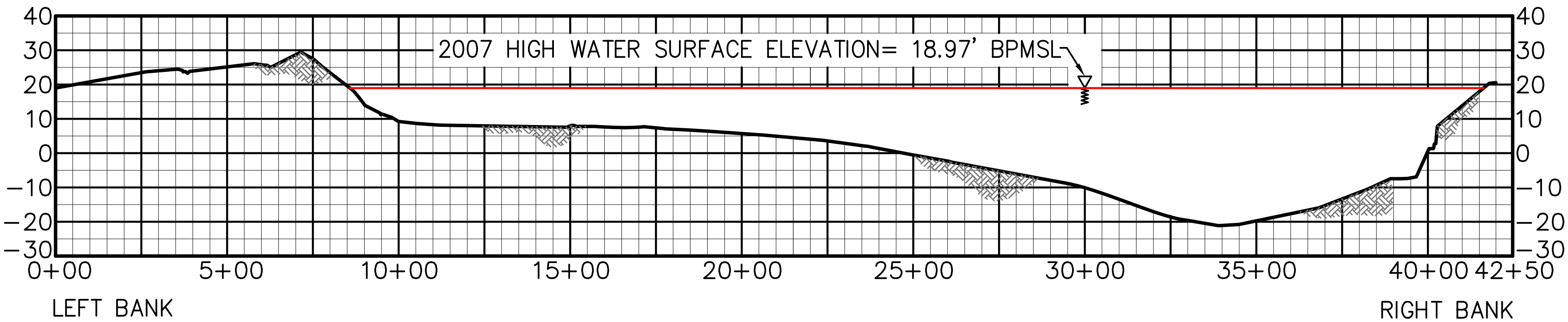
2007 SPRING BREAKUP
MONUMENT 01 DOWNSTREAM
2004 CROSS SECTION

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

ConocoPhillips Alaska, Inc.

DATE:	10/28/07	PROJECT:	111335
DRAWN:	MDM	FILE:	MON_1_PROFILES.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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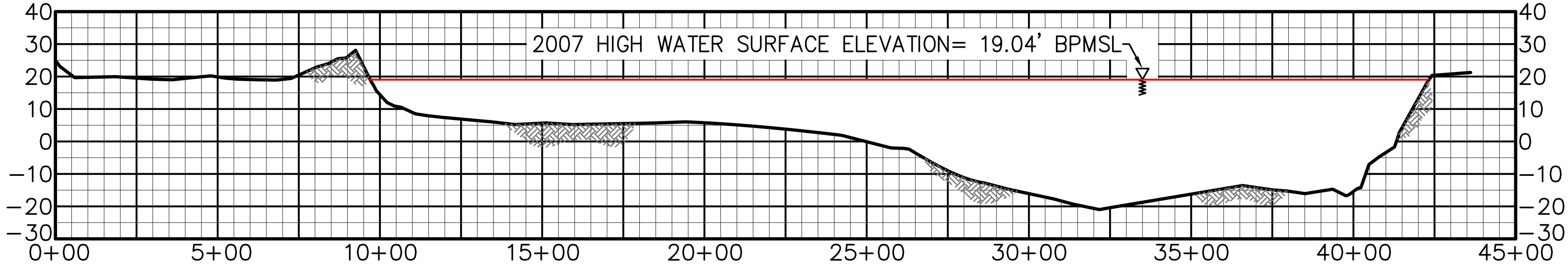
2007 SPRING BREAKUP
MONUMENT 01
2004 CROSS SECTION
FIGURE 4-1
(SHEET 3 OF 4)

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



LEFT BANK

RIGHT BANK

1U COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM

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

HORIZONTAL SCALE IN FEET

VERTICAL SCALE IN FEET

ConocoPhillips Alaska, Inc.

DATE:	10/28/07	PROJECT:	111335
DRAWN:	MDM	FILE:	MON_1_PROFILES.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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2007 SPRING BREAKUP
MONUMENT 01 UPSTREAM
2004 CROSS SECTION

FIGURE 4-1
(SHEET 4 OF 4)

ConocoPhillips
Alaska, Inc.

DATE:	10/26/07	PROJECT:	111335
DRAWN:	MDM	FILE:	DISCHARGE.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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

2007 SPRING BREAKUP

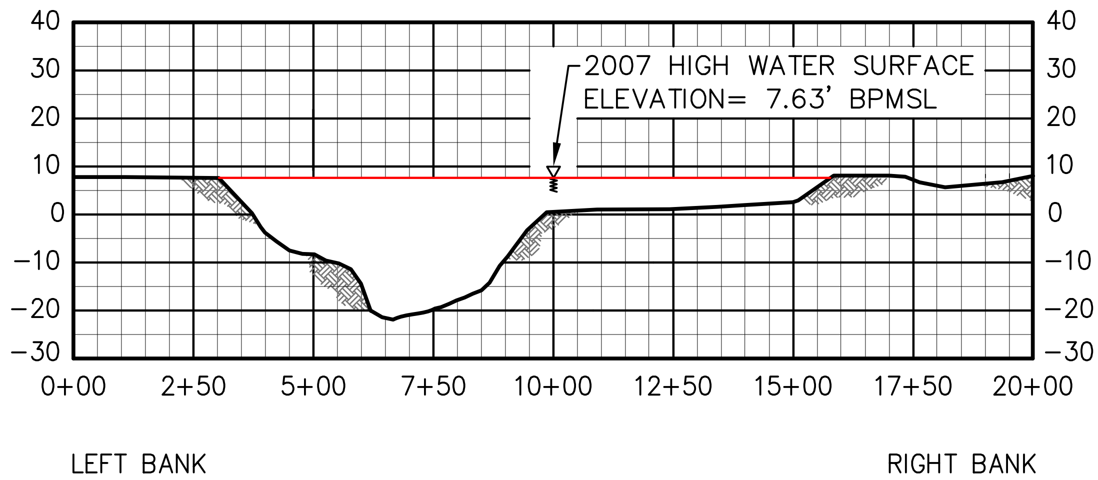
MONUMENT 23

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

ConocoPhillips Alaska, Inc.

DATE:	10/30/07	PROJECT:	111335
DRAWN:	MDM	FILE:	MON_23_PROFILE.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
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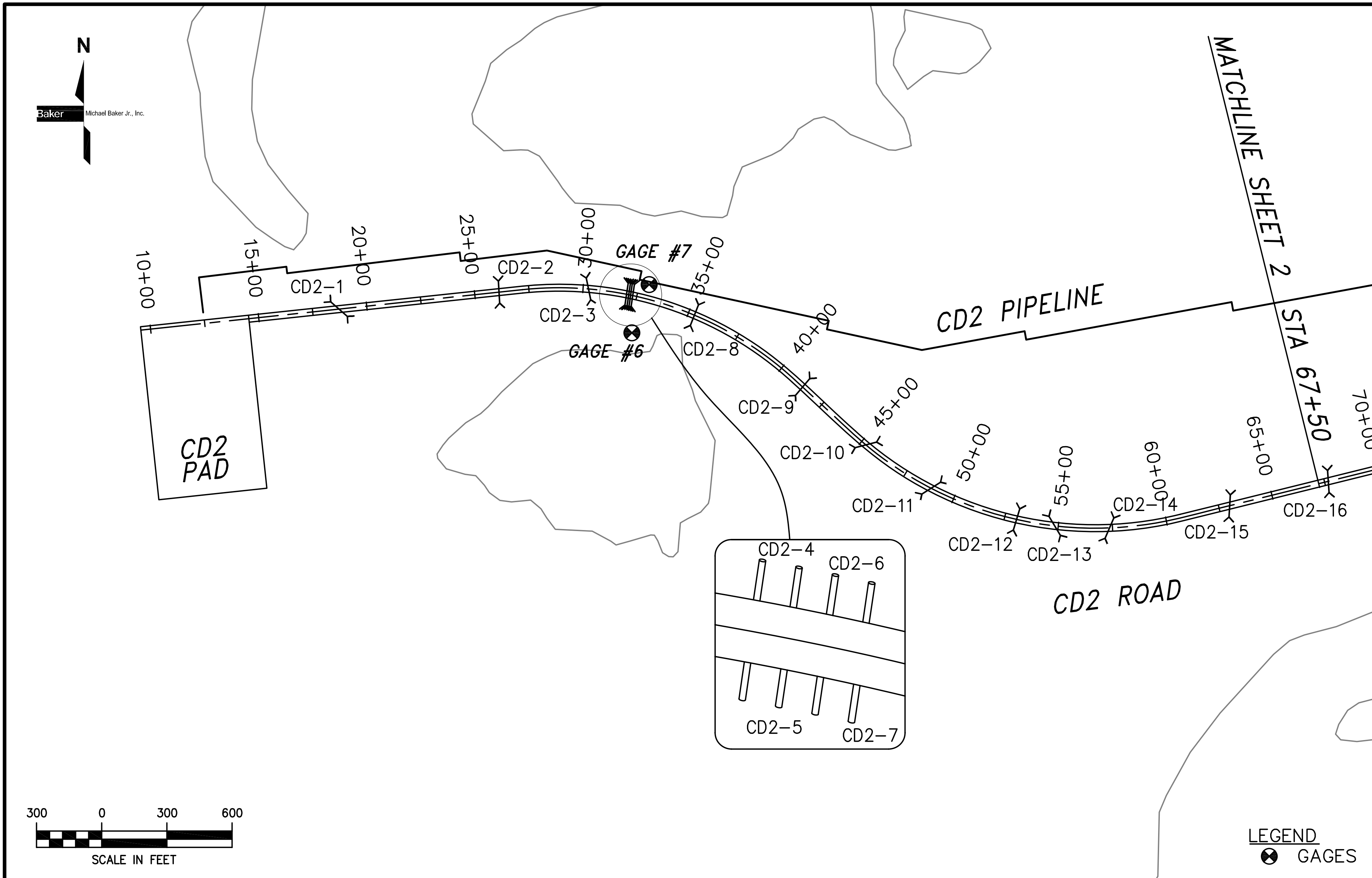
2007 SPRING BREAKUP
MONUMENT 23
2005 CROSS SECTION
FIGURE 4-2
(SHEET 2 OF 2)



ConocoPhillips Alaska, Inc.

DATE:	10/24/07	PROJECT:	111335
DRAWN:	OOO	FILE:	FIGURE_4_3
CHECKED:	MDM	SCALE:	1"= 600'

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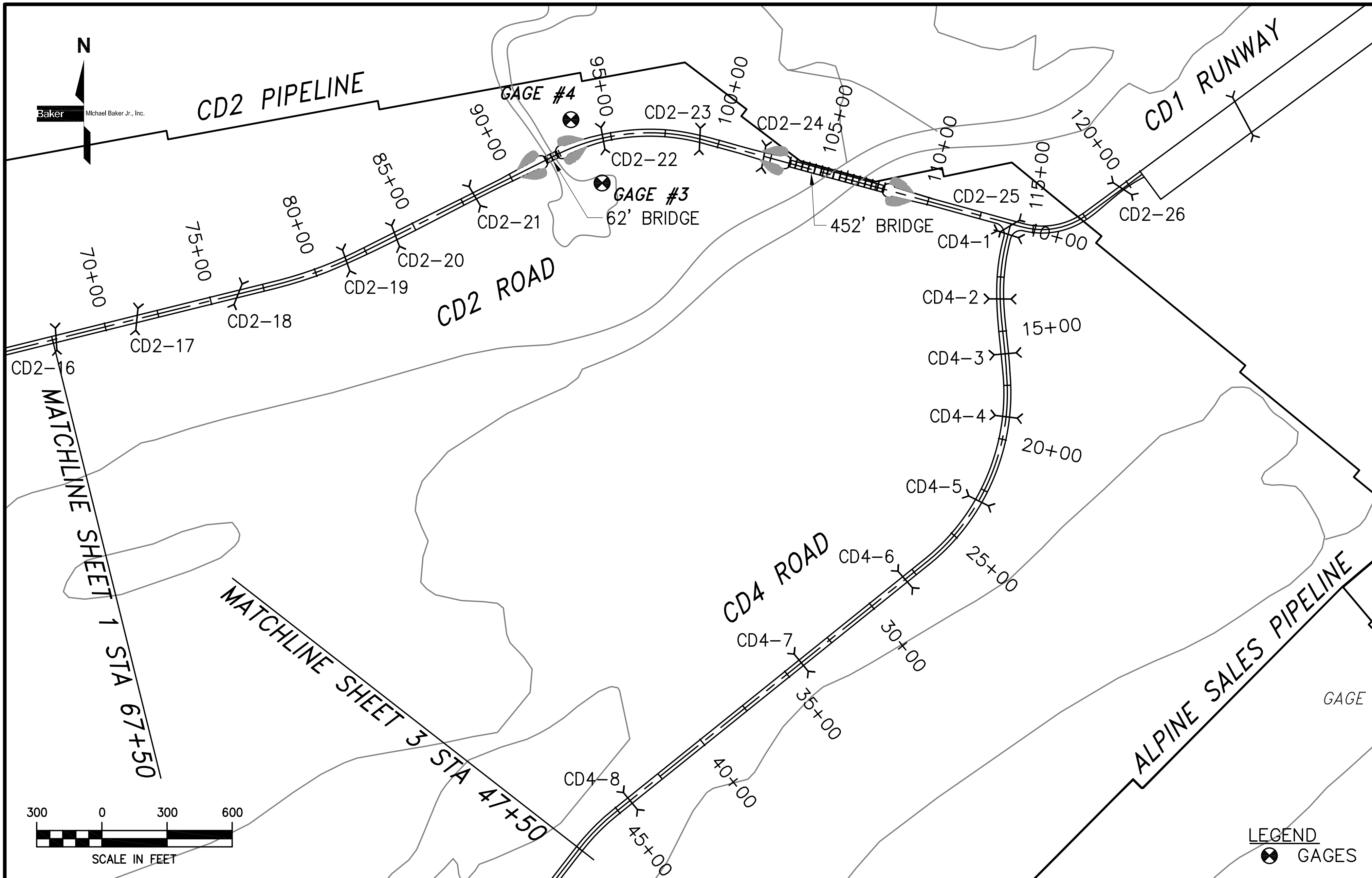
2007 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 4-3

(SHEET 1 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	10/24/07	PROJECT:	111335
DRAWN:	OOO	FILE:	FIGURE_4_3
CHECKED:	MDM	SCALE:	1"= 600'

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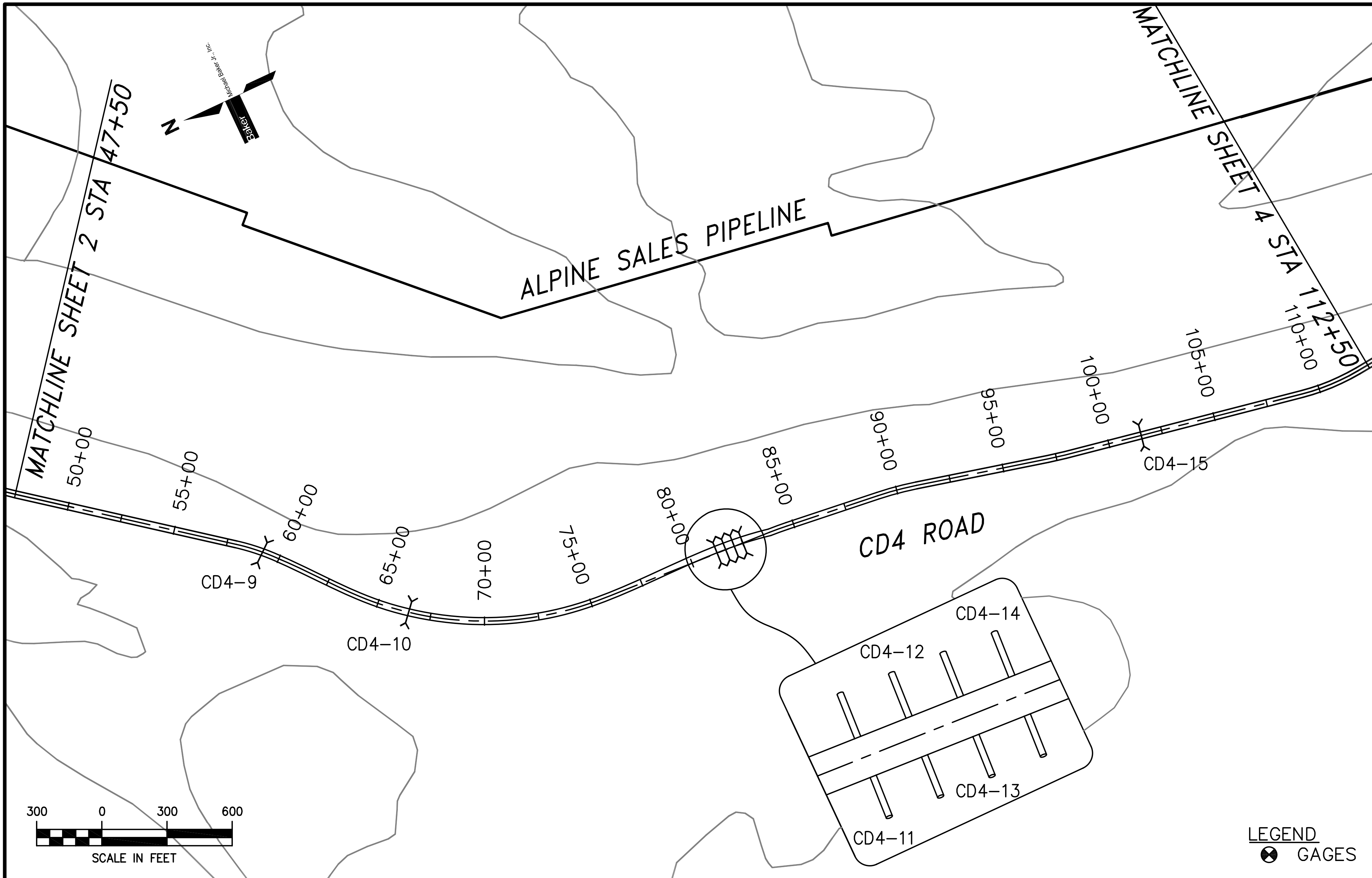
2007 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 4-3

(SHEET 2 OF 6)



ConocoPhillips
Alaska, Inc.

DATE: 10/24/07	PROJECT: 111335
DRAWN: OOO	FILE: FIGURE_4_3
CHECKED: MDM	SCALE: 1"= 600'

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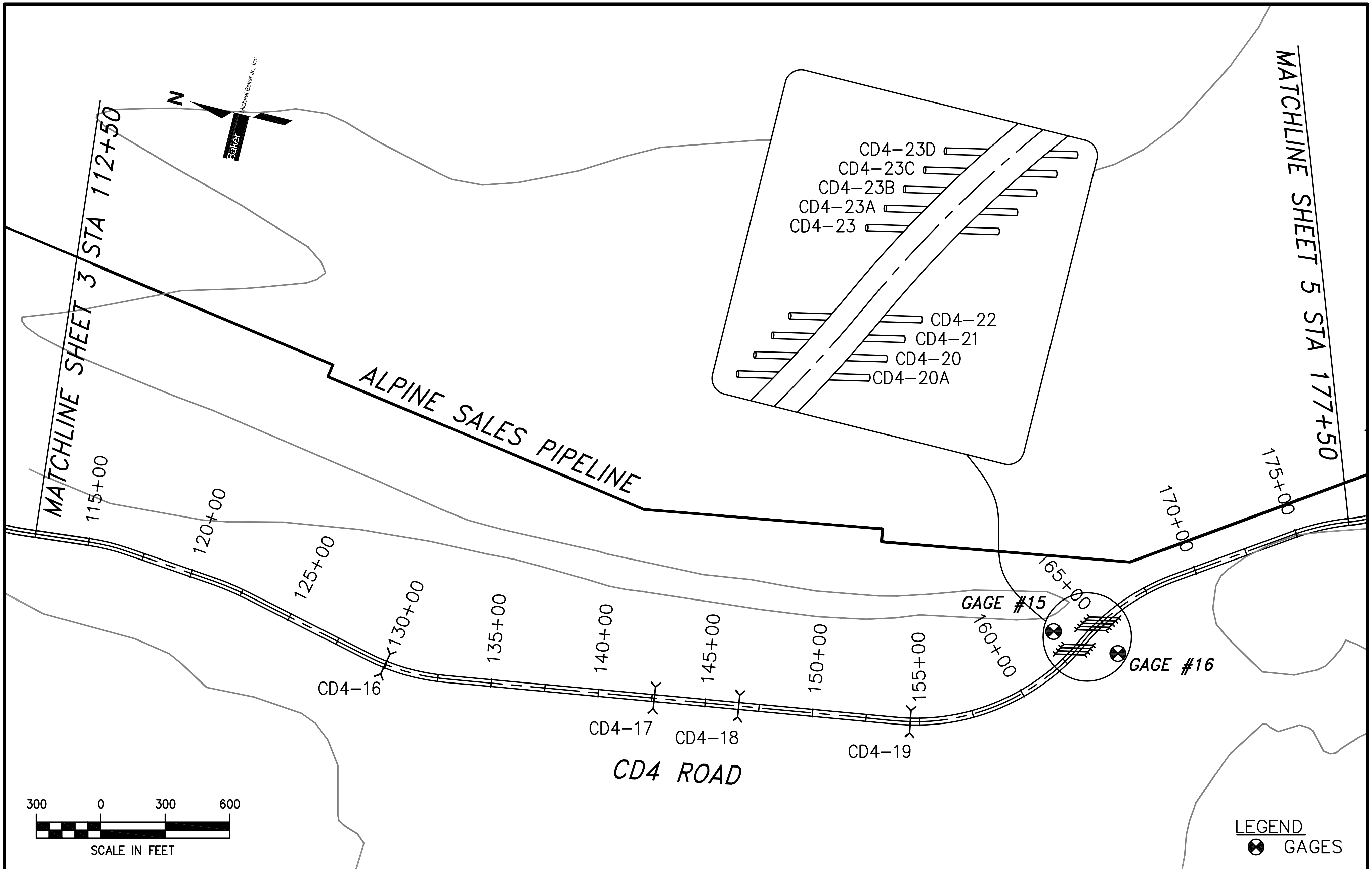
2007 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

FIGURE 4-3
(SHEET 3 OF 6)



ConocoPhillips Alaska, Inc.

DATE:	10/24/07	PROJECT:	111335
DRAWN:	OOO	FILE:	FIGURE_4_3
CHECKED:	MDM	SCALE:	1"= 600'

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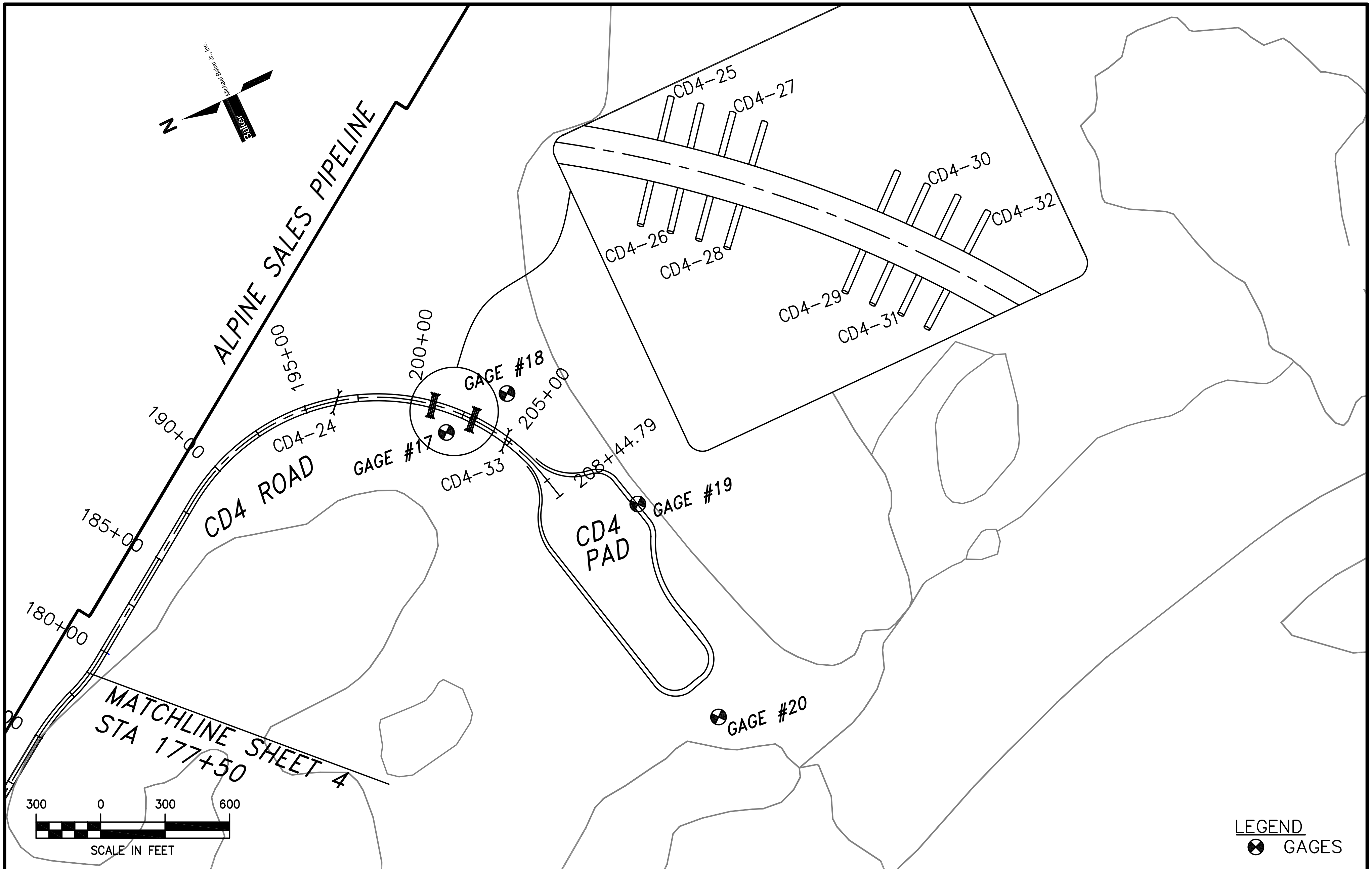
2007 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 4-3

(SHEET 4 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	10/24/07	PROJECT:	111335
DRAWN:	OOO	FILE:	FIGURE_4_3
CHECKED:	MDM	SCALE:	1"= 600'

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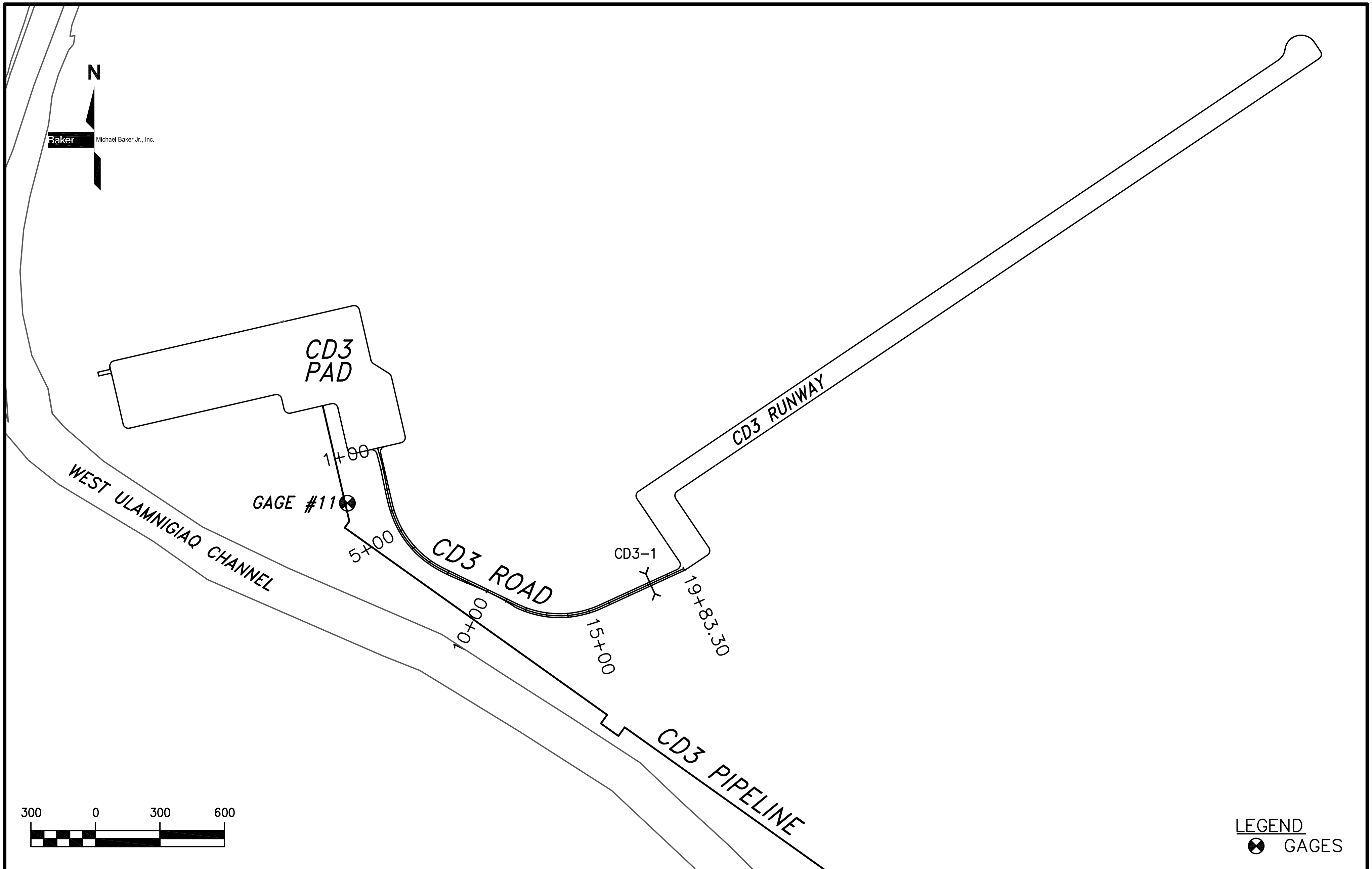
2007 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 4-3

(SHEET 5 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	10/24/07	PROJECT:	111335
DRAWN:	OOO	FILE:	FIGURE_4_3
CHECKED:	MDM	SCALE:	1"= 600'

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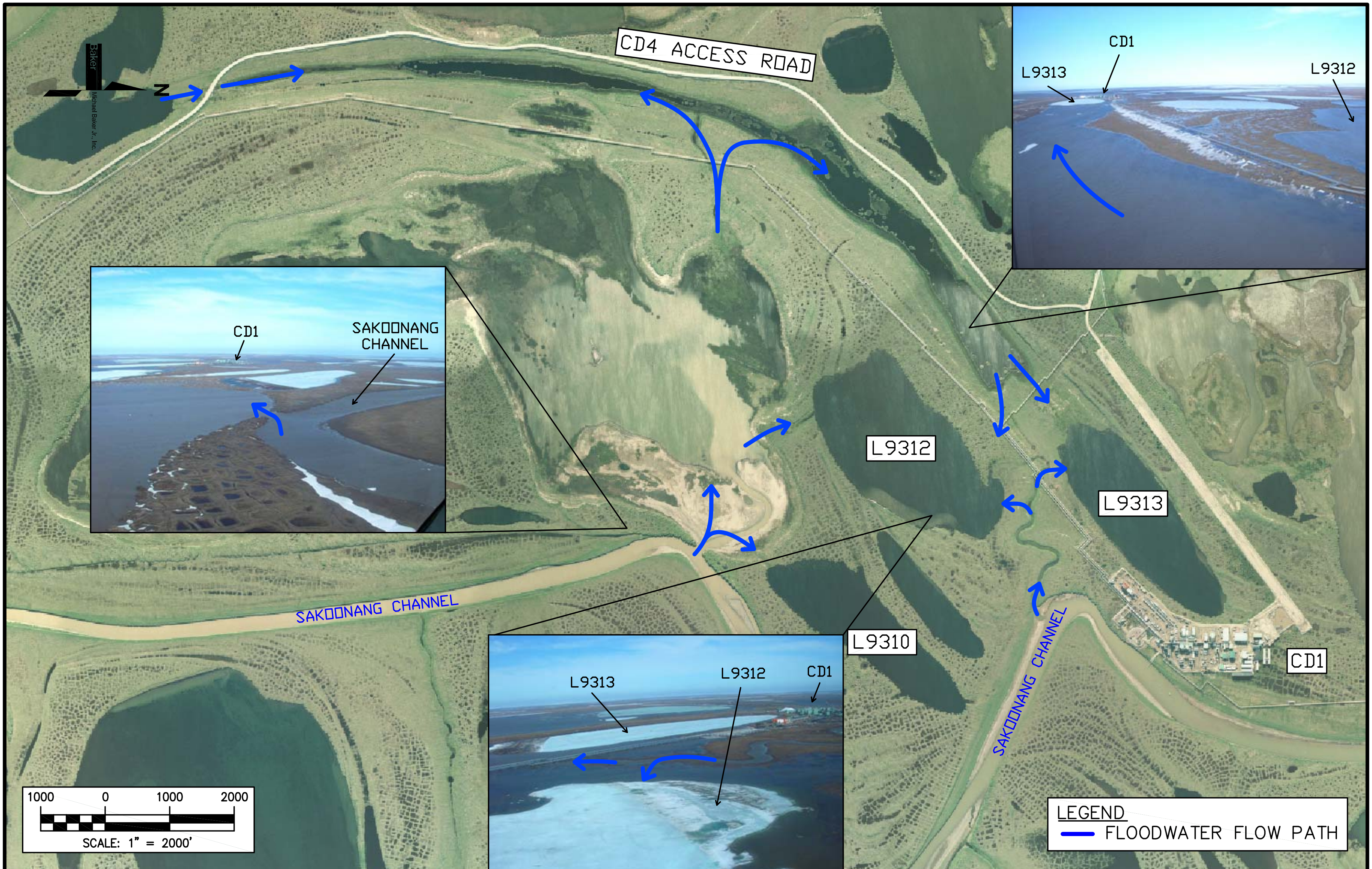
2007 SPRING BREAK-UP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

FIGURE 4-3

(SHEET 6 OF 6)



ConocoPhillips
Alaska, Inc.

DATE:	10/31/2007	PROJECT:	111335
DRAWN:	MDM	FILE:	DRINKING_WATER_LAKES.DWG
CHECKED:	OOO	SCALE:	AS SHOWN

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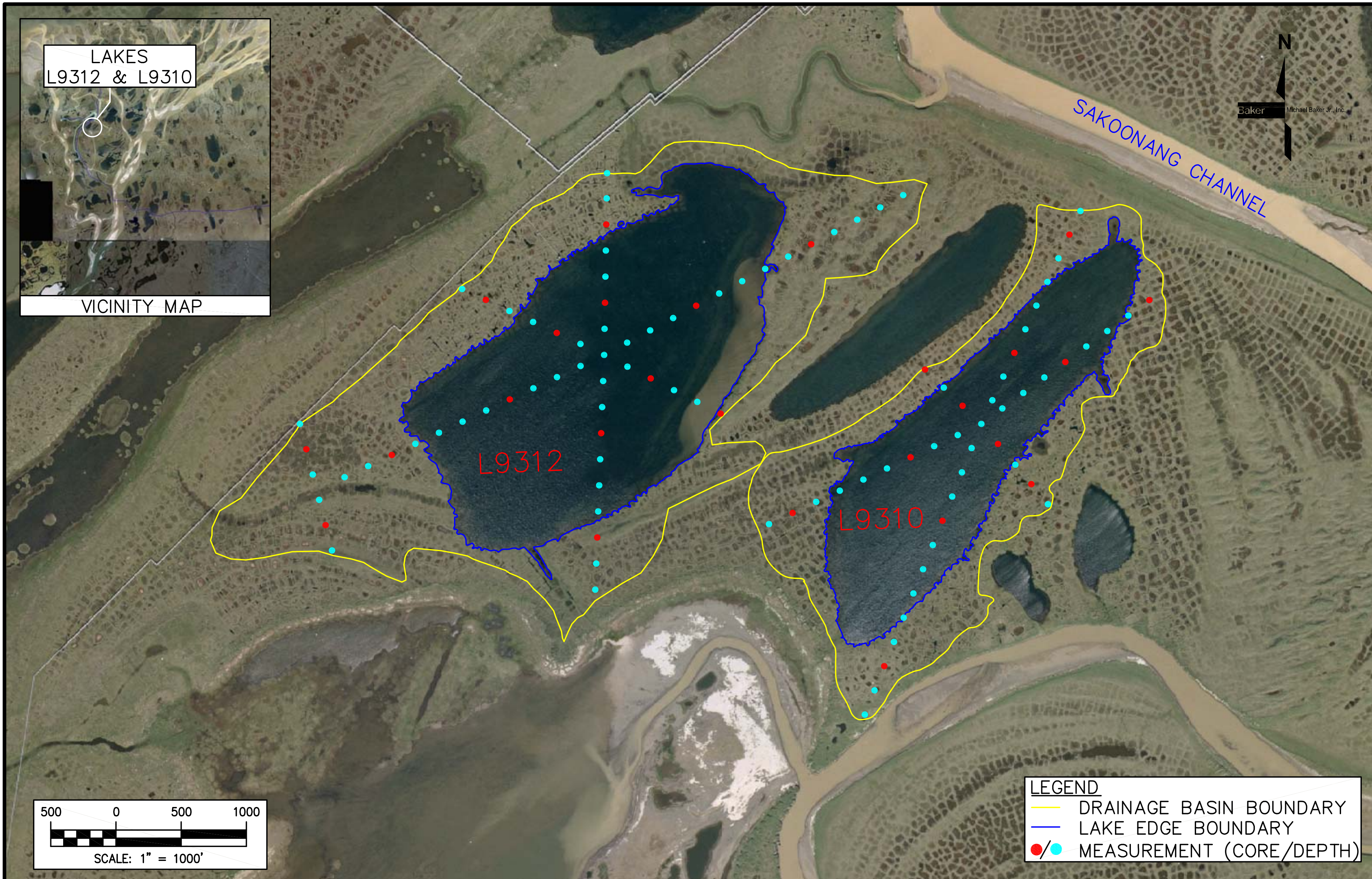
2007 SPRING BREAKUP
DRINKING WATER LAKES
RECHARGE

FIGURE 4-4
(SHEET 1 OF 1)



ConocoPhillips
Alaska, Inc.

DATE: 10/22/2007	PROJECT: 111335
DRAWN: OOO	FILE: SSL9313_L9312_L9310.DWG
CHECKED: MDM	SCALE: AS SHOWN

Baker
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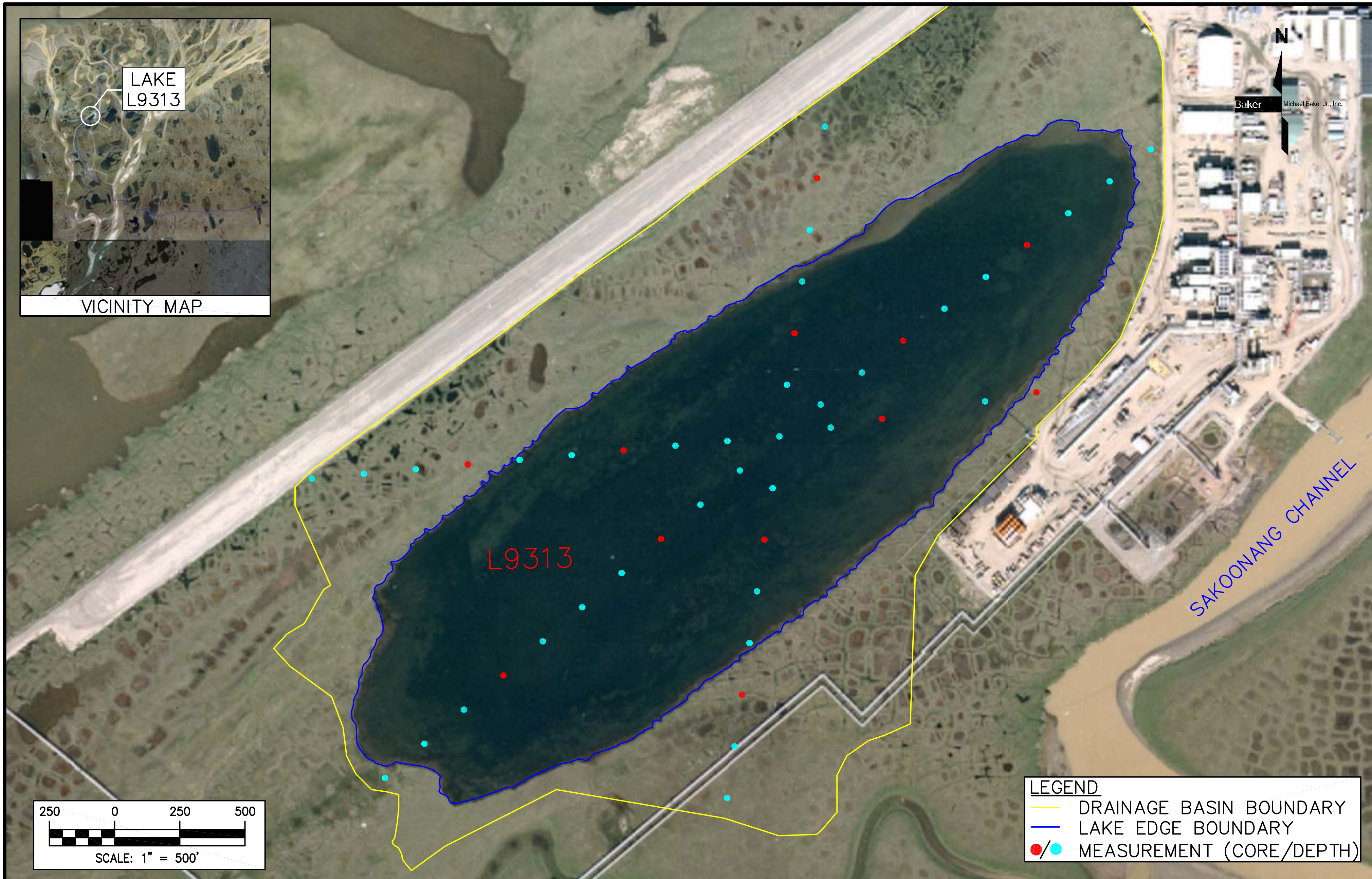
2007 SPRING BREAKUP
L9312 AND L9310
SNOW SURVEY POINTS

FIGURE 4-5
(SHEET 1 OF 1)



ConocoPhillips
Alaska, Inc.

DATE:	10/22/2007	PROJECT:	111335
DRAWN:	OOO	FILE:	SSL9313_L9312_L9310.DWG
CHECKED:	MDM	SCALE:	AS SHOWN

Baker

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2007 SPRING BREAKUP

L9313

SNOW SURVEY POINTS

FIGURE 4-6

(SHEET 1 OF 1)

4.8 Tables

Table 4-21 Monument 1

Date and Time	WSE (ft BPMSL) Mon 1	Discharge (cfs)	Observations
5/30/07 4:24 PM	9.69		Channel ice floating along east bank of East Channel
5/31/07 8:37 AM	9.89		Increasing stage
5/31/07 5:35 PM	10.06		Ice jam at Ocean Point forms
6/1/07 9:41 AM	10.42		Increasing stage
6/2/07 1:40 PM	10.96		Channel ice floating along east bank of East Channel
6/3/07 10:38 AM	11.58		Channel ice begins to flow.
6/3/07 5:23 PM	16.16		Ice jam forms in East Channel upstream of HDD and Nigliq Channel upstream of Nuiqsut
HIGHWATER	18.97		Highwater mark estimated on the morning of June 4
6/4/07 11:00 AM	15.62		Ice jams begin to clear from East and Nigliq Cahnnels
6/4/07 5:30 PM	15.30	263,000	Q measurement @ 5:30 PM, decreasing stage
6/5/07 9:45 AM	14.29	247,000	Q measurement @ 9:45 AM, ice jam in Nigliq Channel cleared
6/6/07 12:50 PM	13.27	233,000	Q measurement @ 12:50 PM, ice jam in East Channel cleared
6/6/07 4:25 PM	13.04		
6/7/07 10:00 AM	11.90	198,000	Q measurement @ 10:00 AM, delta channels free of ice

Notes:

1. Elevations are based on Monument 1 of 27.93 feet BPMSL, established by LCMF in 2006
2. WSE line for Mon9 and Helmricks included for reference

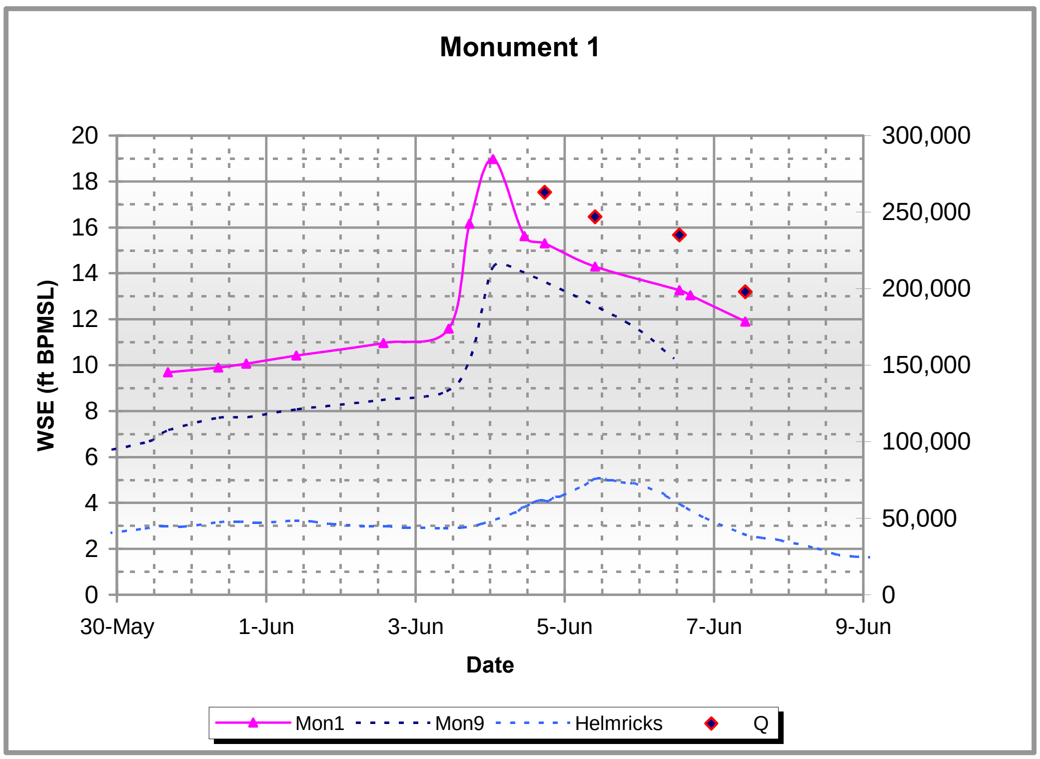


Table 4-22 Monument 1 Upstream and 1 Downstream

Date and Time	WSE (ft BPMSL)		Discharge (cfs)	Observations
	Mon 1U	Mon 1D		
5/30/07 4:15 PM	9.83	-		Channel ice floating along east bank
5/31/07 8:29 AM	10.07	-		Increasing stage
5/31/07 5:41 PM	10.34	9.95		Ice jam at Ocean Point forms
6/1/07 9:34 AM	10.67	10.28		Increasing stage
6/2/07 1:48 PM	11.26	10.75		Channel ice floating along east bank
6/3/07 10:43 AM	11.92	11.26		Channel ice begins to flow.
6/3/07 5:11 PM	16.35	15.00		Ice jam forms in East Channel and Nigliq Channel
HIGHWATER	19.04	18.67		Highwater mark timing obtained from pressure transducer
6/4/07 10:52 AM	15.97	15.54		Ice jams begin to move downstream of HDD and Nuiqsut
6/4/07 5:15 PM	15.61	14.97	263,000	Q measurement @ 5:30 PM, decreasing stage
6/5/07 12:41 PM	14.46	13.79	247,000	Q measurement @ 9:45 AM, ice jam in Nigliq Channel cleared
6/6/07 4:25 PM	13.48	12.76	233,000	Q measurement @ 12:50 PM, ice jam in East Channel cleared
6/7/2007 9:15AM	12.23	11.66	198,000	Q measurement @ 10:00 AM, delta channels free of ice

Notes:

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

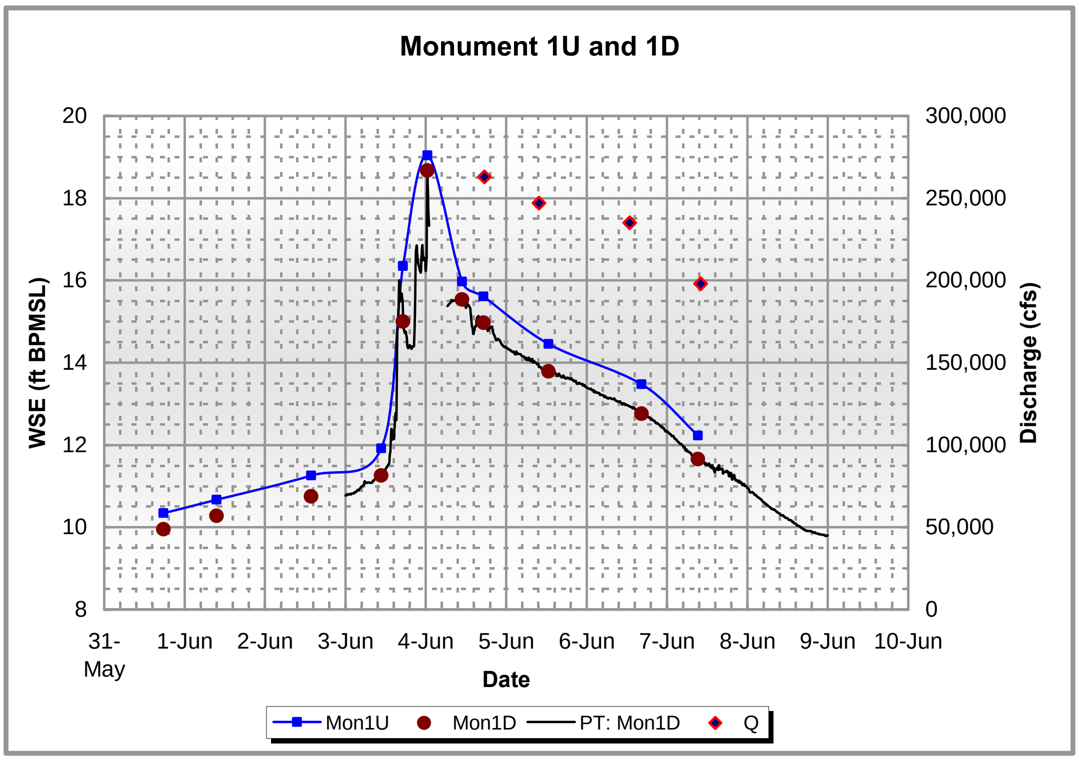


Table 4-23 Monument 9 (HDD East)

Date and Time	WSE (ft BPMSL) Mon 9	Discharge (cfs)	Observations
5/28/07 4:20 PM	4.68		Leading edge of floodwaters reach HDD, flow observed
5/29/07 8:48 AM	5.82		Channel ice floating along east bank of East Channel
5/29/07 5:42 PM	6.18		Increasing Stage
5/30/07 10:19 AM	6.69		West side of ice bridge submerged
5/30/07 4:35 PM	7.17		
5/31/07 8:49 AM	7.71		Increasing stage
5/31/07 6:10 PM	7.74		Ice jam at Ocean Point forms
6/1/07 9:55 AM	8.08		
6/2/07 12:56 PM	8.48		
6/3/07 10:00 AM	8.85		Channel ice begins to flow. Ice jam forms upstream of HDD
6/3/07 5:51 PM	10.39		Ice jam in East Channel released and reformed downstream of HDD
HIGHWATER	14.27		Highwater mark estimated on the morning of June 4
6/4/07 9:28 AM	14.11		
6/5/07 7:45 PM	11.87		Ice jam in Nigliq Channel cleared
6/6/07 11:10 AM	10.29		Ice jam in East Channel cleared

Notes:

1. Elevations are based on Monument 9 of 25.03 feet BPMSL, established by Lounsbury in 1996
2. WSE lines for Mon1 and Helmricks are presented for reference
3. No discharge measurements were collected for this site

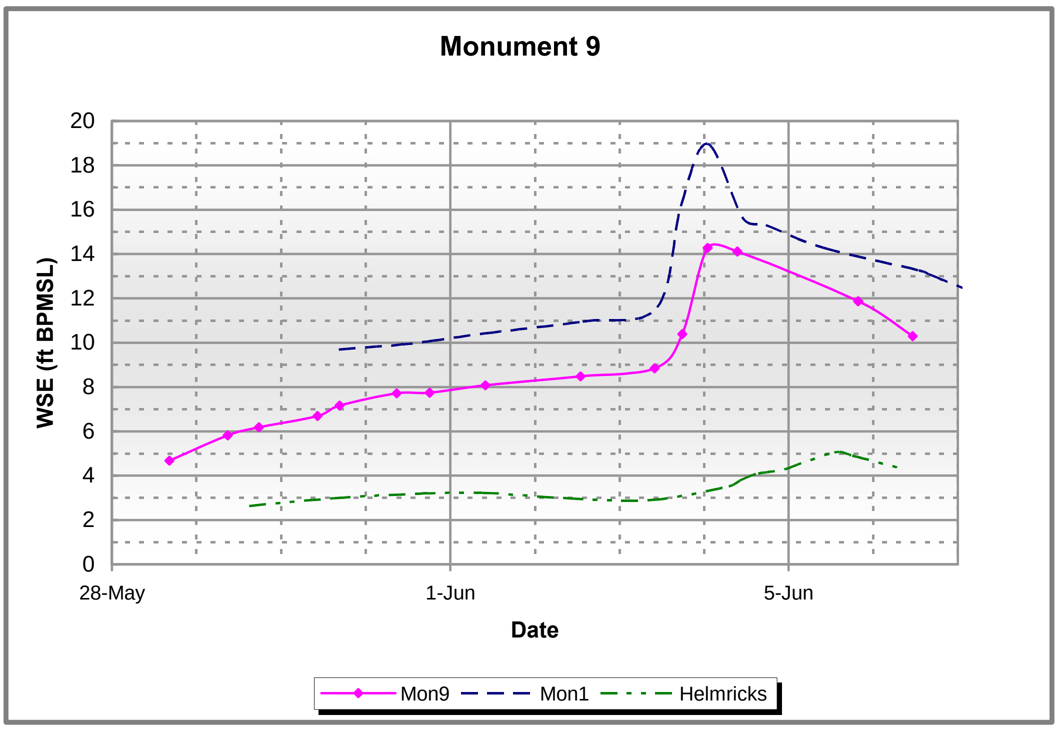


Table 4-24 Helmricks

Date and Time	WSE (ft BPMSL) Helmricks	Discharge (cfs)	Observations
5/29/07 3:00 PM	2.64		
5/30/07 3:00 PM	2.99		
5/31/07 3:00 PM	3.18		
6/1/07 9:00 AM	3.23		
6/2/07 9:00 AM	2.98		
6/3/07 9:00 AM	2.90		
6/4/07 7:00 AM	3.52		
6/4/07 10:10 AM	3.78		Ice jam starting up river by Dune Island
6/4/07 3:20 PM	4.10		Increasing stage.
6/4/07 11:00 PM	4.30		
HIGHWATER	5.06		Highwater mark estimated on the morning of June 5
6/5/07 6:00 PM	4.90		Decreasing stage
6/6/07 8:30 AM	4.30		

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 Helmricks
3. WSE lines for Mon1 and Mon9 are presented for reference
4. No discharge measurements were collected for this site

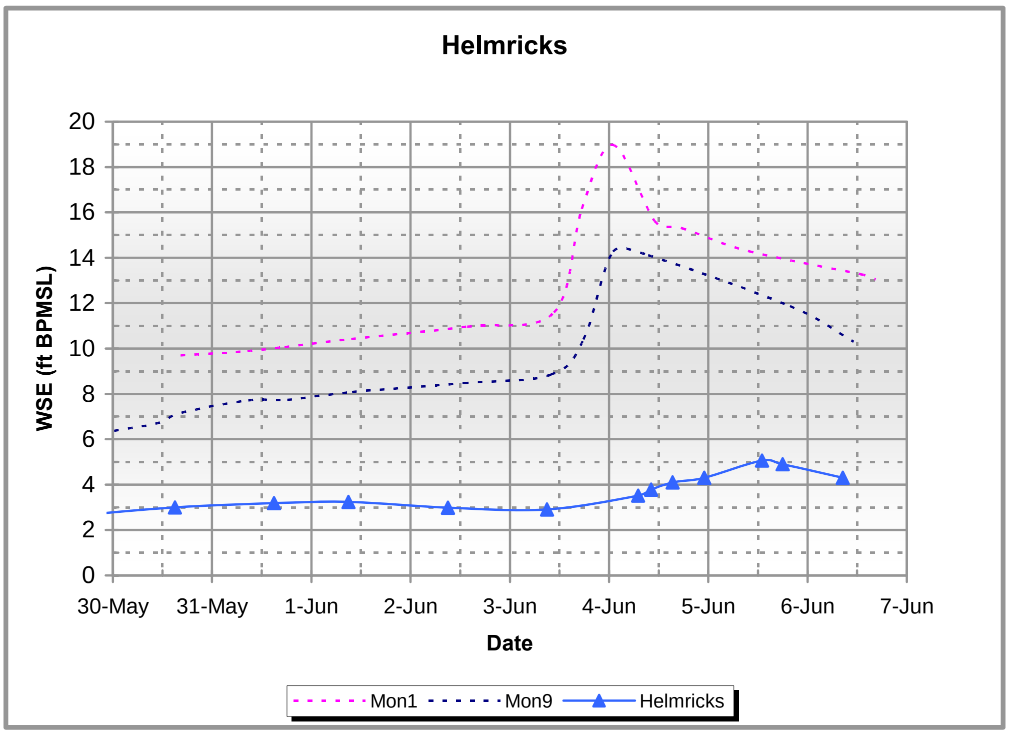


Table 4-25 Monument 20

Date and Time	WSE (ft BPMSL) Mon 20	Dischrage (cfs)	Observations
5/29/07 8:56 AM	3.87		Leading edge of floodwater reaches Nigliq Channel
5/29/07 5:54 PM	4.62		Increasing stage
5/30/07 10:27 AM	5.08		
5/30/07 4:45 PM	5.19		
5/31/07 9:00 AM	5.79		Increasing stage
5/31/07 6:20 PM	5.90		Ice jam at Ocean Point forms
6/1/07 10:03 AM	6.20		
6/3/07 5:58 PM	7.96		Ice jam forms in East Channel upstream of HDD and Nigliq Channel upstream of Nuiqsut
6/4/07 11:40 AM	8.44		
HIGHWATER	11.91		Highwater mark estimated on the morning of June 5, ice jam in Nigliq cleared out
6/6/07 8:28 AM	7.85		Decreasing stage
6/7/07 12:05	6.39		

Notes:

1. Elevations are based on Monument 20 of 19.17 feet BPMSL, established by Lounsbury in 1996
2. WSE lines for Mon 22, Mon 23 and Mon 28 are presented for reference
3. No discharge measurements were collected at this site

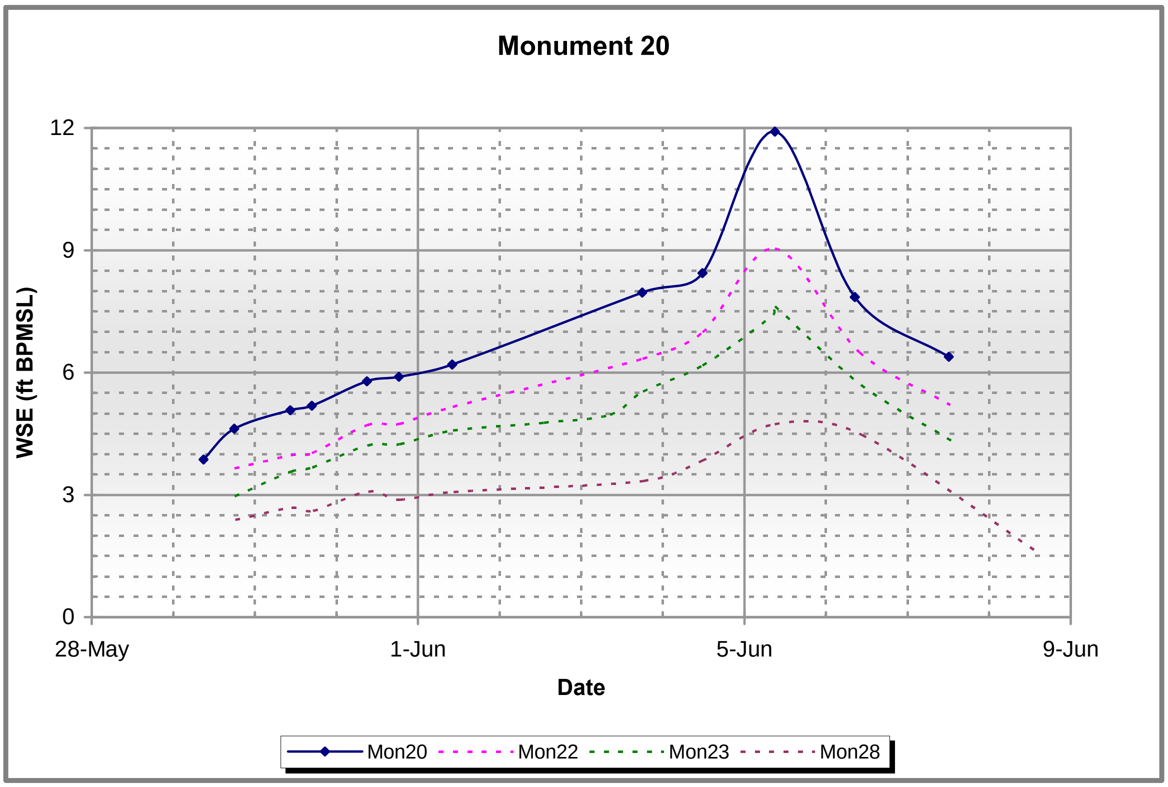


Table 4-26 Monument 22

Date and Time	WSE (ft BPMSL) Mon 22	Dischrage (cfs)	Observations
5/29/07 6:01 PM	3.65		Leading edge of floodwater reches Nigliq
5/30/07 10:34 AM	3.97		Increasing stage
5/30/07 4:50 PM	4.02		
5/31/07 9:07 AM	4.71		Increasing stage
5/31/07 6:27 PM	4.74		Ice jam at Ocean Point forms
6/1/07 10:13 AM	5.16		
6/3/07 6:04 PM	6.34		Ice jam forms in East Channel upstream of HDD and Nigliq Channel upstream of Nuiqsut
6/4/07 11:43 AM	6.99		Ice jam at Nuiqsut releases and reforms downstream at CD4
HIGHWATER	9.04		Highwater mark estimated on the morning of June 5, ice jam in Nigliq cleared out
6/6/07 9:50	6.50		Decreasing stage
6/7/07 12:34	5.20		

Notes:

1. Elevations are based on Monument 22 of 10.13 feet BPMSL, established by Lounsbury in 1996
2. WSE lines for Mon 20, Mon 23 and Mon 28 are presented for reference
3. No discharge measurements were collected at this site

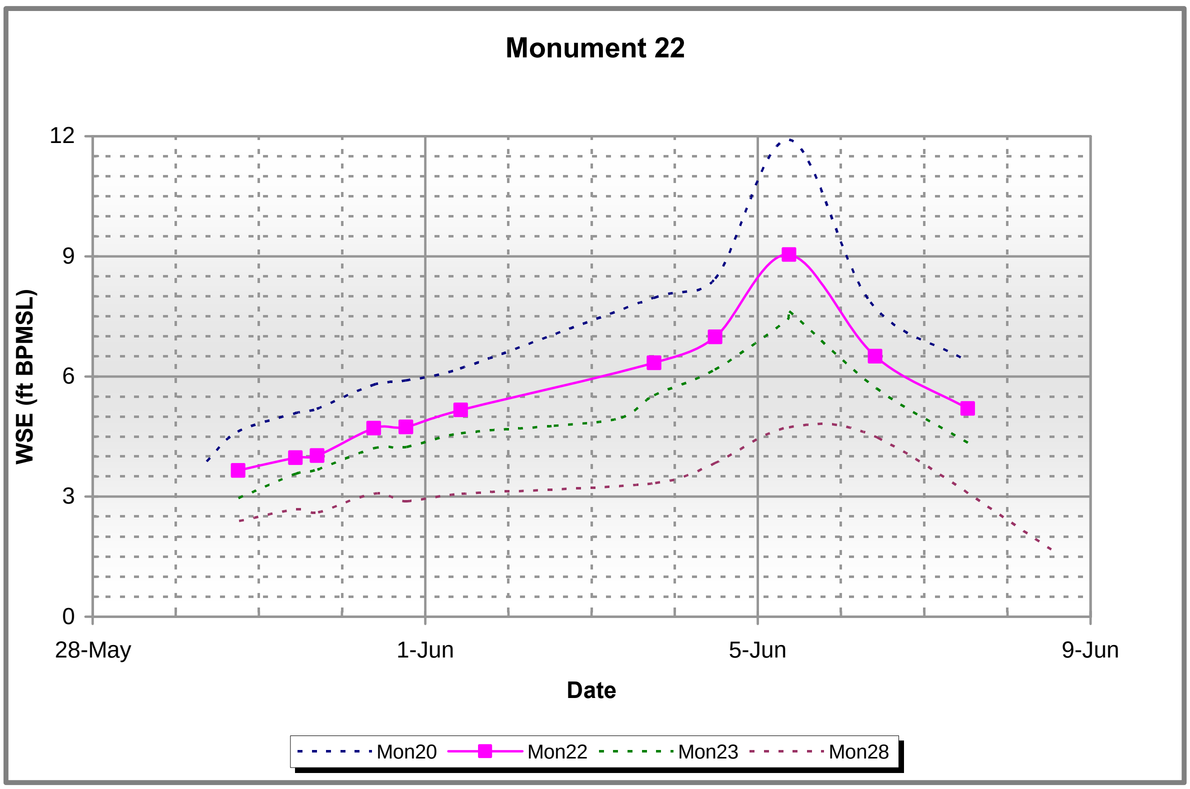


Table 4-27 Monument 23

Date and Time	WSE (ft BPMSL) Mon 23	Dischrage (cfs)	Observations
5/29/07 6:08 PM	2.96		Leading edge of floodwater reaches Nigliq Channel
5/30/07 10:40 AM	3.57		Increasing stage
5/30/07 4:56 PM	3.67		
5/31/07 9:14 AM	4.21		Increasing stage
5/31/07 6:35 PM	4.24		Ice jam at Ocean Point forms
6/1/07 10:20 AM	4.58		
6/2/07 1:04 PM	4.77		
6/3/07 8:30 AM	4.97		
6/3/07 6:10 PM	5.53		
6/4/07 11:37 AM	6.17		Ice jam at Nuiqsut releases and reforms downstream at CD4
6/5/07 8:37 AM	7.42		
HIGHWATER	7.63		Highwater mark estimated on the morning of June 5, ice jam in Nigliq Channel cleared
6/6/07 10:12 AM	5.70	73,500	Decreasing stage. Peak indirect discharge
6/7/07 13:00	4.32	35,800	Direct discharge (poor rating)

Notes:

1. Elevations are based on Monument 23 of 9.53 feet BPMSL, established by Lounsbury in 1996
2. WSE lines for Mon 20, Mon 22 and Mon 28 are presented for reference
3. Pressure transducer data collected from Mon 23

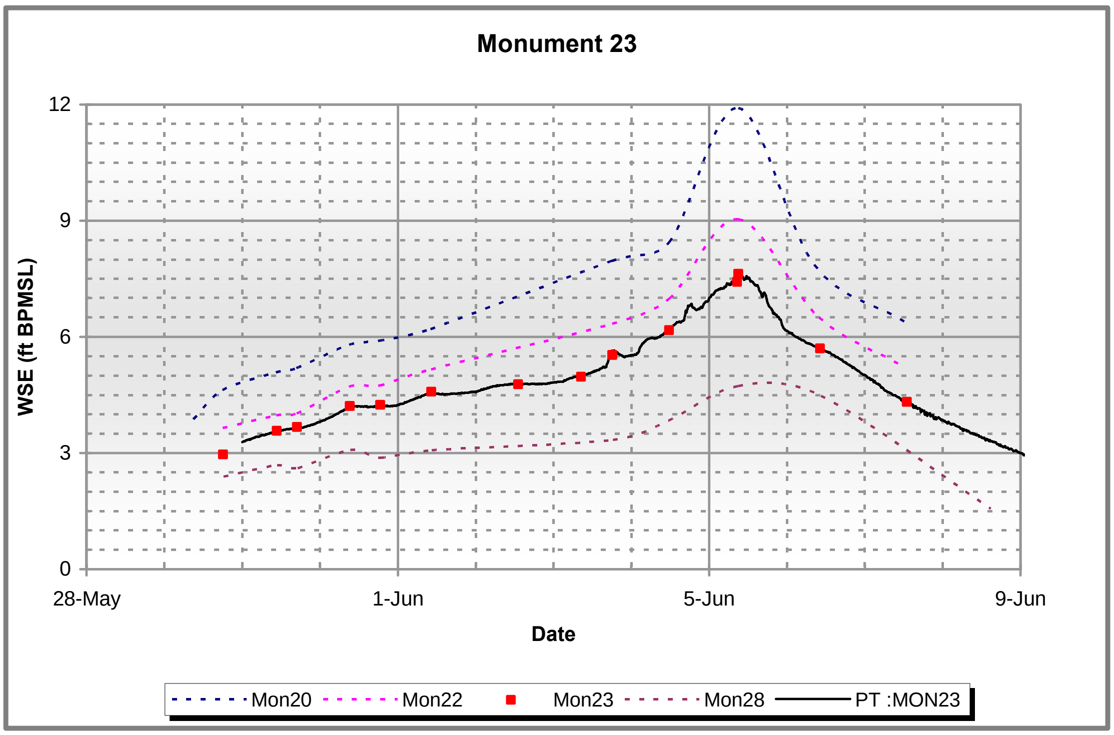


Table 4-28 Monument 28

Date and Time	WSE (ft BPMSL) Mon 28	Dischrage (cfs)	Observations
5/29/07 6:19 PM	2.39		Leading edge of floodwater reches Nigliq
5/30/07 10:49 AM	2.68		Increasing stage
5/30/07 5:06 PM	2.61		
5/31/07 9:25 AM	3.08		Increasing stage
5/31/07 6:43 PM	2.88		Ice jam at Ocean Point forms
6/1/07 10:29 AM	3.07		
6/3/07 6:22 PM	3.34		Ice jams form in East Channel and Nigliq Channel
6/4/07 11:29 AM	3.83		Ice jam at Nuiqsut releases and reforms downstream at CD4
HIGHWATER	4.73		Highwater mark estimated on the morning of June 5. Ice jam in Nigliq cleared out
6/6/07 10:30 AM	4.47		Decreasing stage
6/8/07 2:46 PM	1.56		

Notes:

1. Elevations are based on Monument 28 of 3.66 feet BPMSL, established by Lounsbury in 1996
2. WSE lines for Mon 20, Mon 22 and Mon 23 are presented for reference
3. No discharge measurements were collected for this site

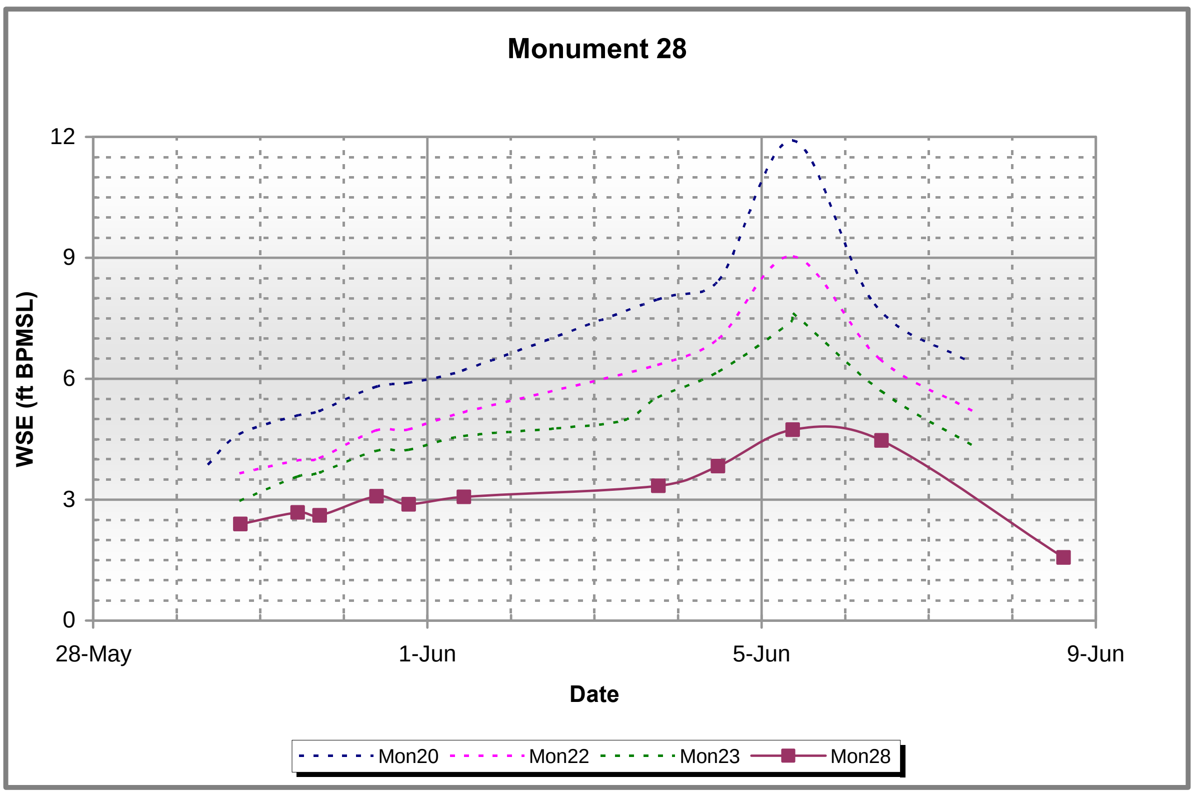


Table 4-29   Gage 1 (CD1)

Date and Time	WSE (ft BPMSL) Gage1	Observations
5/30/07 2:47 PM	2.74	
5/31/07 9:07 AM	2.57	
6/1/07 9:21 AM	3.59	
6/2/07 8:45 AM	4.50	
6/3/07 9:25 AM	5.14	Ice flow begins in Colville River and Sakoonang Channel
6/3/07 8:25 PM	5.43	Ice jam forms upstream of gage in Sakoonang Channel
6/4/07 6:27 AM	5.74	
6/4/07 9:20 PM	7.21	Ice jam released, ice begins to clear out of channel
HIGHWATER	8.64	Highwater mark estimated on the morning of June 5
6/5/07 2:15 PM	8.38	Ice jams in Nigliq Channel cleared and East Channel weakened
6/6/07 9:40 AM	6.92	
6/6/07 5:20 PM	6.35	Delta channels free of ice
6/7/07 11:28 AM	5.15	

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

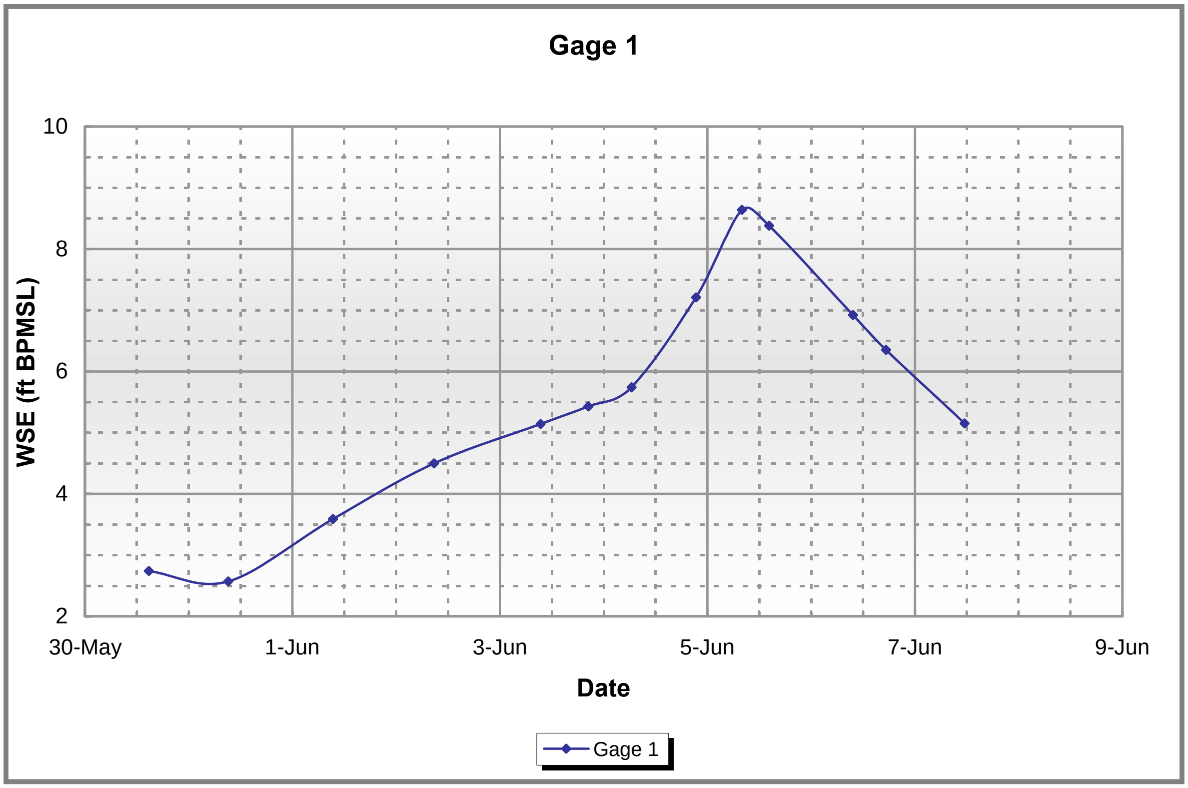


Table 4-30 Gages 9 (L9312) and 10 (L9313)

Date and Time	WSE (ft BPMSL)		Observations
	Gage 9	Gage 10	
5/30/07 2:14 PM	7.47	5.83	
6/4/07 9:15 PM		8.78	Sakoonang ice jam released, ice begins to clear out of channel
HIGHWATER	9.35	9.47	Highwater mark estimated on the morning of June 5
6/5/07 2:25 PM	8.60	9.20	Ice jams in Nigliq Channel cleared and East Channel weakened
6/6/07 9:30 AM	8.13	8.06	
6/6/07 5:15 PM		7.67	Delta channels free of ice
6/7/07 11:21 AM		6.88	
6/11/07 2:50 PM		6.31	

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 11.72 ft BPMSL, established by LCMF in 2005
3. Elevation for Gage 10 based on Monument 22 of 11.27 ft BPMSL, established by LCMF in 1997

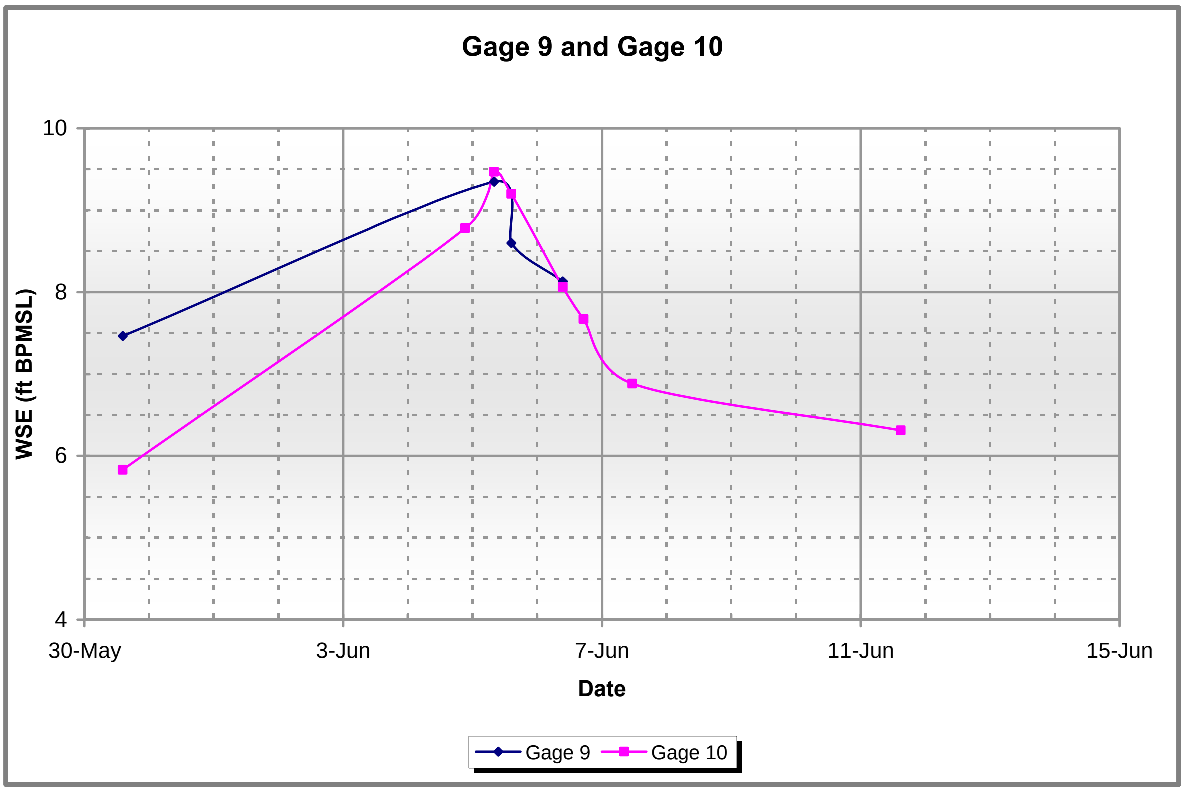


Table 4-31 Gages 3, 4, 6, and 7 (CD2 Access Road)

Date and Time	WSE (ft BPMSL)				Observations
	Gage 3	Gage 4	Gage 6	Gage 7	
6/4/07 6:15 AM	6.39	6.14			
6/4/07 8:17 PM	7.41	6.99	7.55	7.46	Ice jam in East Channel and Nigliq Channel.
HIGHWATER	8.60	8.17	8.80	8.64	Highwater mark estimated on the morning of June 5
6/5/07 8:05 AM	8.28	7.88	8.47	8.20	Peak discharge through facilities drainage structures
6/5/07 4:30 PM	7.89	7.80			Ice jams in Nigliq cleared and East Channel weakened
6/5/07 5:30 PM	7.77	7.70	8.09	8.07	Velocity measurements collected at access road culverts
6/5/07 6:42 PM	7.68	7.60			Direct discharge collected at swale bridges
6/5/07 6:50 PM	7.70	7.62	7.99	8.02	
6/6/07 9:00 AM	6.70	6.59	7.73	7.72	
6/6/07 5:05 PM	6.11	6.00	7.66	7.65	Delta channels free of ice
6/7/07 11:28 AM	5.63	5.58	7.58	7.56	

Notes:

1. Elevation for Gage 3, Gage 4, Gage 6 and Gage 7 based on Monument 12 of 9.01 feet BPMSL, established by LCMF in 1997
1. Gages surveyed and set by LCMF

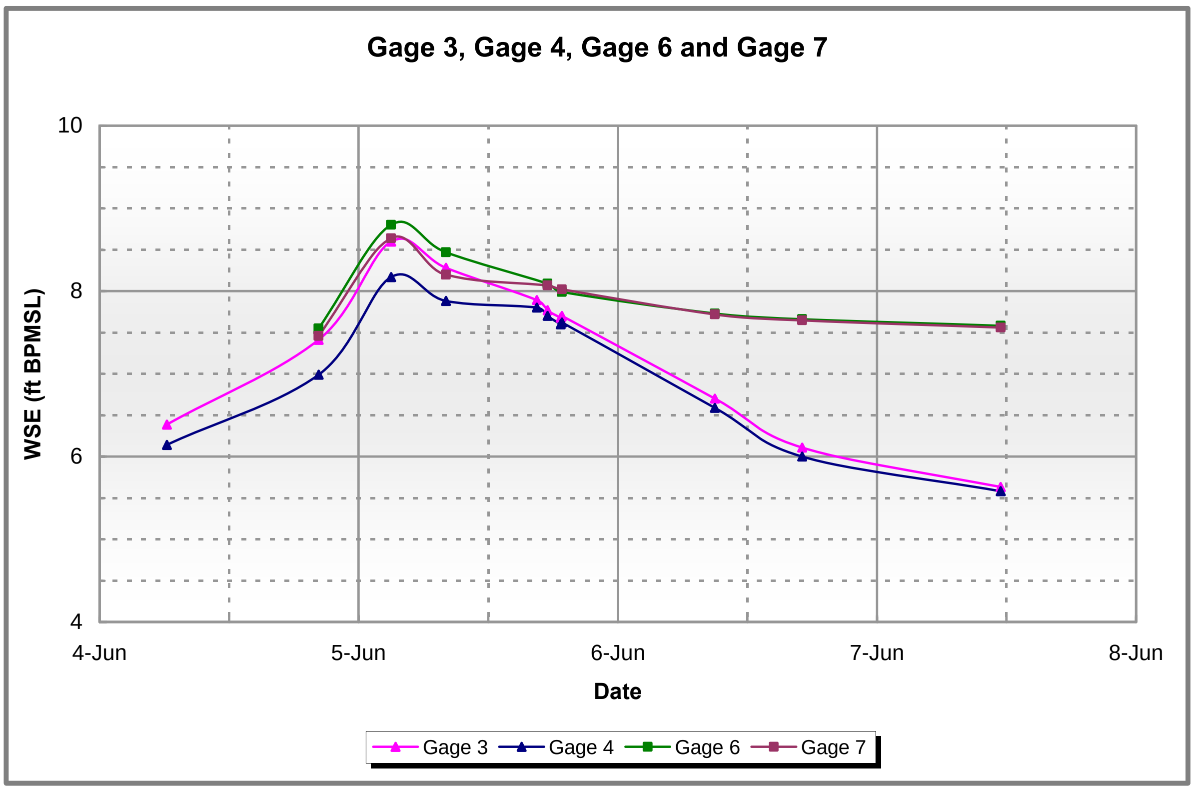


Table 4-32 Pipeline Crossings: Sakoonang, Tamayagiaq, and Ulamnigiaq Channels

Date and Time	WSE (ft BPMSL)			Observations
	SAK	TAM	ULAM	
5/30/07 10:58 AM			3.52	
5/31/07 9:37 AM	1.00	4.80	4.35	
6/1/07 10:48 AM	1.70	5.10	4.50	
6/3/07 6:38 PM	3.35	5.60	5.05	Ice jam forms upstream of gage in Sakoonang Channel
6/4/07				Ice jam released, ice begins to clear out of channel
HIGHWATER	6.25	7.75	7.05	Highwater mark estimated around noon on June 5.
6/6/07 10:49 AM	4.70	6.14	5.65	Delta channels free of ice.

Notes:

1. Basis of elevation for Crossing #2 (SAK) on SAK-LT of 10.17 feet BPMSL, established by LCMF 2004
2. Basis of elevation for Crossing #4 (TAM) on STM-RT of 10.07 feet BPMSL, established by LCMF 2004
3. Basis of elevation for Crossing #5 (ULAM) on monument FIORD1 of 9.30 feet BPMSL, established by LCMF 2004

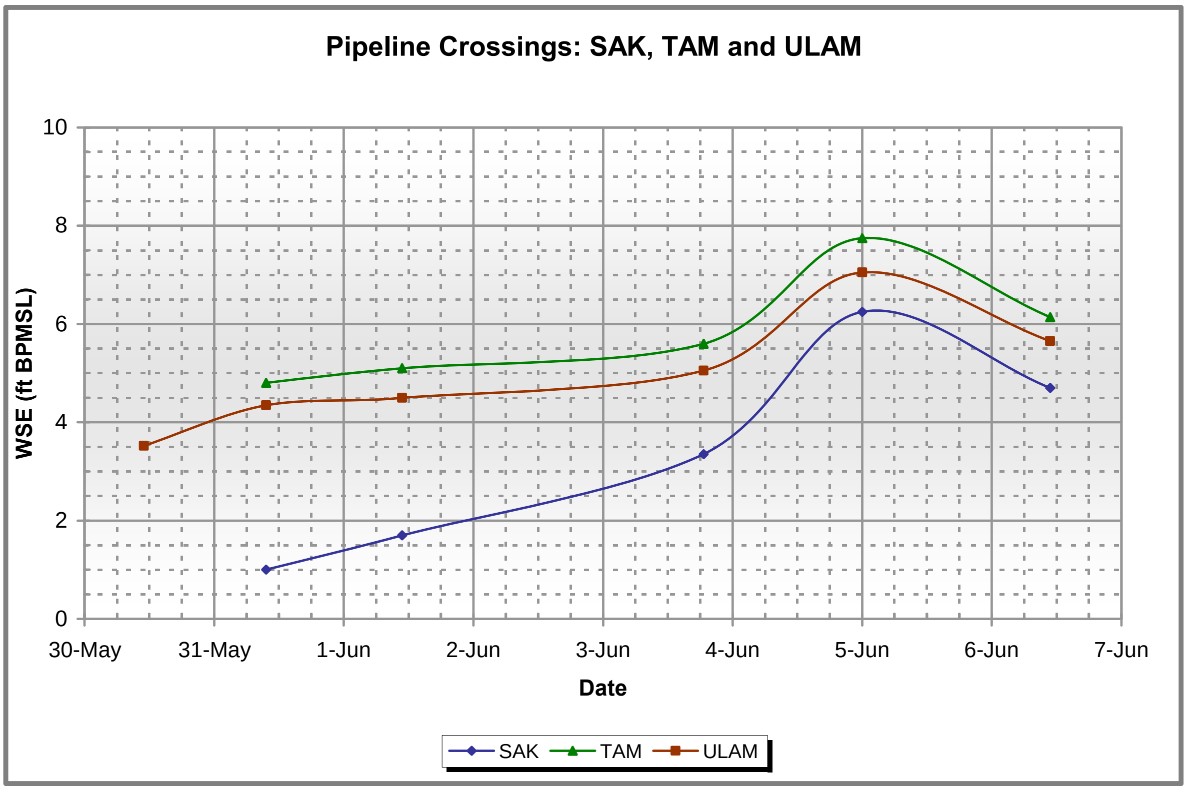


Table 4-33 Gages 15, 16, 17, and 18 (CD4 Access Road)

Date and Time	WSE (ft BPMSL) Gage 15	Gage 16	Gage 17	Gage 18	Observations
5/29/07 8:40 AM	5.94	5.61			
HIGHWATER			10.23	10.62	Highwater mark estimated on evening of June 4.
6/4/07 8:29 PM	8.78	8.77	10.04		Ice jam at Nuiqsut releases and reforms downstream at CD4
6/5/07 9:35 AM	9.39	9.41	9.81	9.93	
HIGHWATER	9.67	9.76			Highwater mark estimated at noon on June 5. Peak Discharge
6/5/07 4:57 PM	9.10	9.13			Ice jam clears. Velocity measurements at culverts
6/6/07 8:45 AM	8.07	8.09			
6/6/07 4:40 PM	7.66	7.64			Delta channels free of ice
6/7/07 10:28 AM	6.72	6.71			

Notes:

1. Elevation for Gages 15, 16, 17, and 18 based on 05-20-01B of 25.68 ft BPMSL, established by LCMF in 2005

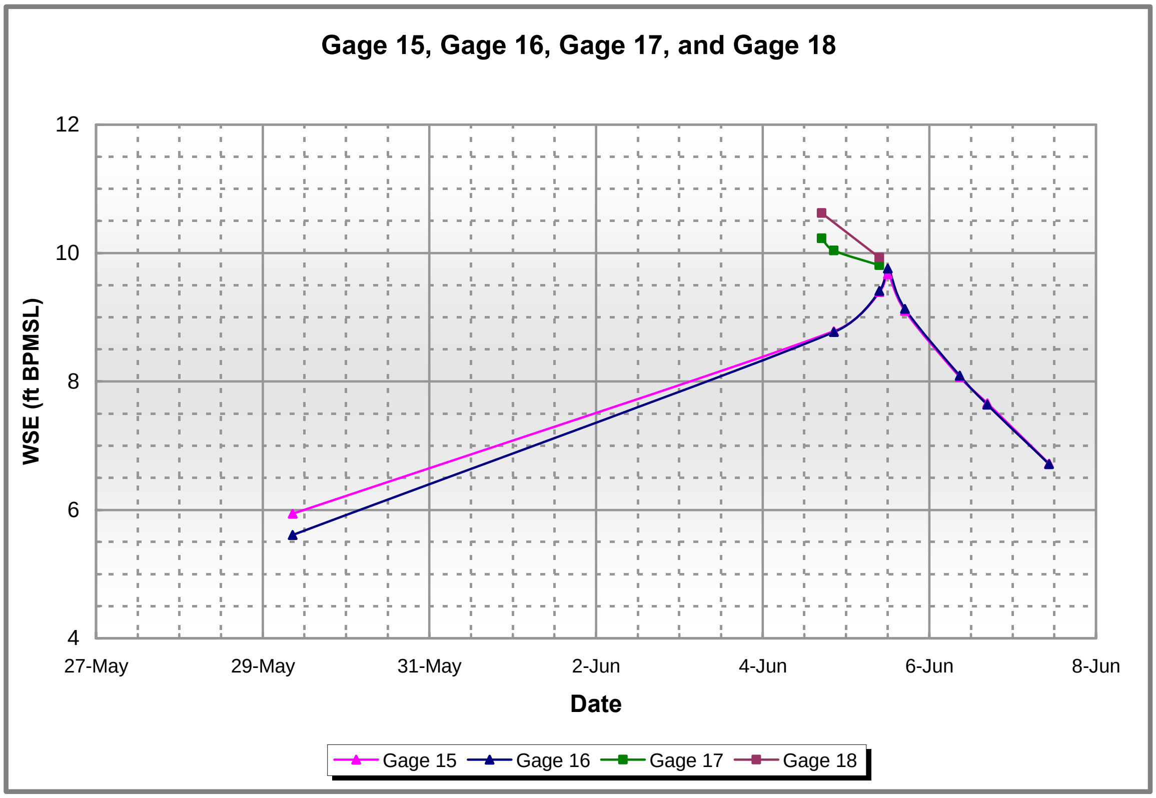
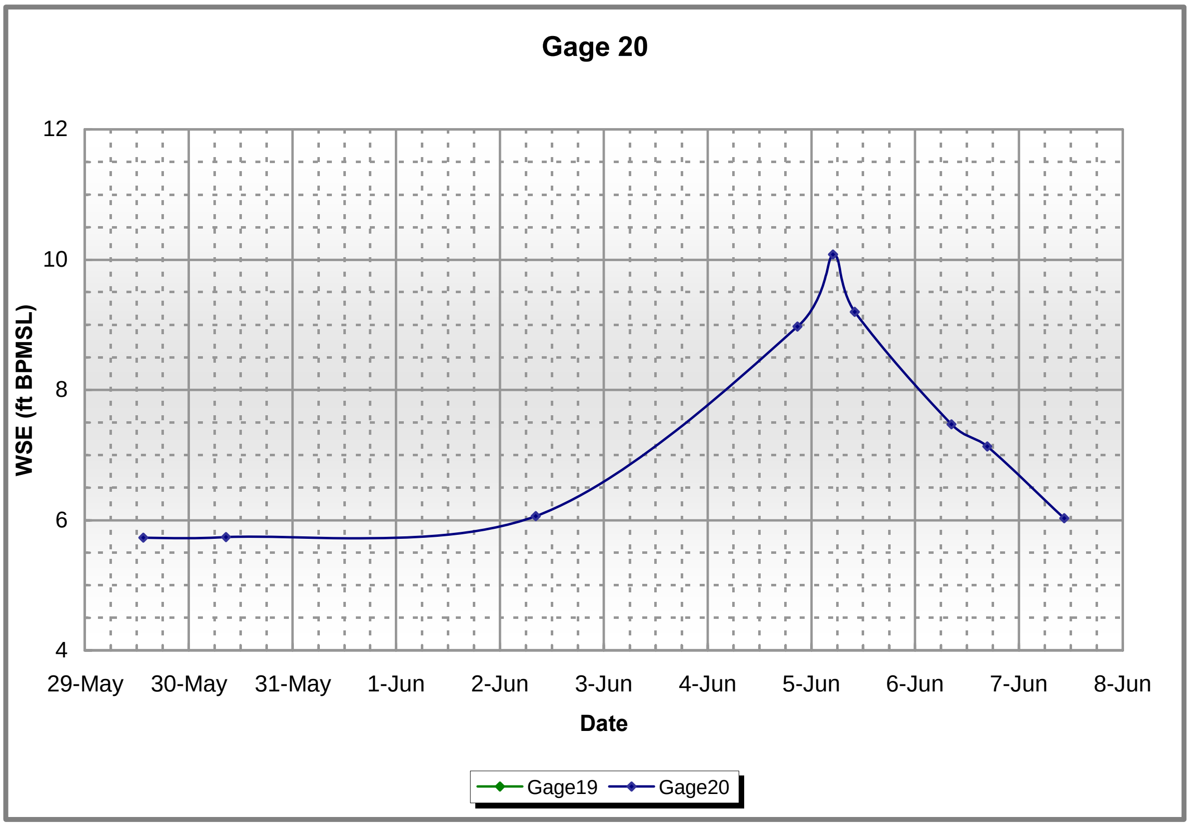


Table 4-34 Gage 20 (CD4)

Date and Time	WSE (ft BPMSL)) Gage 20	Observations
5/29/07 1:30 PM	5.73	
5/30/07 8:37 AM	5.74	
6/2/07 8:15 AM	6.06	
6/3/07		Ice jam forms in East Channel upstream of HDD and Nigliq Channel upstream of Nuiqsut.
6/4/07 8:48 PM	8.98	Ice jam at Nuiqsut releases and reforms downstream at CD4
HIGHWATER	10.1	Highwater mark estimated morning of June 5.
6/5/07 10:00 AM	9.20	Ice jams in Nigliq Channel cleared and East Channel weakened.
6/6/07 8:25 AM	7.47	
6/6/07 4:40 PM	7.13	Delta channels free of ice
6/7/07 10:28 AM	6.03	

Notes:

1. Elevations for Gage 20 based on 05-20-01A of 25.70 ft BPMSL, established by LCMF in 2005



5.0 Reference Materials

5.1 Reference List

Alaska Biological Research (ABR) and Arctic Hydrologic Consultants. 1993. Geomorphology and Hydrology of the Colville River Delta, Alaska, 1992. Prepared for ARCO Alaska, Inc.

Alaska Biological Research (ABR) and Shannon & Wilson. 1994a. Geomorphology and Hydrology of the Colville River Delta, Alaska, 1993. Prepared for ARCO Alaska, Inc.

—— 1994b. Geomorphology and Hydrology of the Colville River Delta, Alaska, 1994. Prepared for ARCO Alaska, Inc.

—— 1996. Geomorphology and Hydrology of the Colville River Delta, Alaska, 1995. Prepared for ARCO Alaska, Inc.

BC Ministry of Environment. 1981. British Columbia Snow Survey Manual.

Benson, M. A. and Tate Dalrymple. 1967. General Field and Office Procedures for Indirect Discharge Measurements. In *Techniques of Water-Resources Investigations of the United States Geological Survey*. Book 3, Chapter A1. United States Government Printing Office, Washington, DC. USGS. 1967.

Goodison, B.E., H.L. Ferguson, and G.A. McKay. 1981. Measurement and Data Analysis. Chapter 6 in Handbook of Snow. Gray, D.M. and Male, D.H. (Eds.), Pergamon Press Canada Ltd., pp. 191-274.

Kuukpik/LCMF, Inc. 2004. Cross-Section Survey, Colville River at Monument 01. Prepared for Michael Baker Jr.

Michael Baker Jr., Inc. (Baker). 1998a. 1998 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. Prepared for ARCO Alaska, Inc.

—— 1998b. Colville River Delta Two-Dimensional Surface Water Model Project Update. Prepared for ARCO Alaska, Inc. September 1998.

—— 1999. 1999 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. Prepared for ARCO Alaska, Inc.

—— 2000. Alpine Facilities Spring 2000 Breakup Monitoring and Hydrologic Assessment. Prepared for Phillips Alaska, Inc.

—— 2001. Alpine Facilities Spring 2001 Spring Breakup and Hydrologic Assessment. Prepared for Phillips Alaska, Inc.

—— 2002a. Alpine Facilities Spring 2002 Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2002b. Colville River Delta Two-Dimensional Surface Water Model, CD-Satellite Project Update. May 2002. Prepared for Phillips Alaska, Inc.

—— 2003. Alpine Facilities Spring 2003 Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2005a. Alpine Facilities 2004 Spring Breakup and Hydrologic Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2005b. Colville River Delta and Fish Creek Basin 2005 Spring Breakup and Hydrological Assessment. Prepared for ConocoPhillips Alaska, Inc.

—— 2006a. Annual Peak Discharge Colville River Monument 1 Estimate, Calculation, and Method Review, 1992 – 2005. Prepared for ConocoPhillips Alaska, Inc.

—— 2006b. Colville River Delta Two-Dimensional Surface Water Model, CD5 Update. February 2006. Prepared for ConocoPhillips Alaska, Inc.

—— 2006c. Project Note: Qannik Extension. CD2 Well Pad Extension Revised Hydrology. July 2006. Prepared for ConocoPhillips Alaska, Inc.

—— 2007a. 2006 Colville River Delta and Fish Creek Basin Spring Breakup and Hydrological Assessment. January 2007. Prepared for ConocoPhillips Alaska, Inc.

—— 2007b. Colville River Delta Lakes Recharge Monitoring and Analysis. Prepared for ConocoPhillips Alaska, Inc.

Michael Baker, Jr., Inc. (Baker) and Hydroconsult EN3 Services, Ltd. 2002. Colville River Flood Frequency Analysis, Update. September 2002. Prepared for ConocoPhillips Alaska, Inc.

Natural Resources Conservation Service (NRCS). 2006. United States Department of Agriculture. Snow Survey Sampling Guide. Web site accessed in spring 2006. (http://www.wcc.nrcs.usda.gov/factpub/ah169/ah169.htm)

Rovansek, R.J., D.L. Kane, and L.D. Hinzman. 1993. Improving Estimates of Snowpack Water Equivalent Using Double Sampling, Proceedings of the Eastern and Western Snow Conference, Quebec City.

Shannon & Wilson, Inc. 1996. 1996 Spring Breakup and Hydrologic Assessment, Colville River Delta, North Slope, Alaska. Prepared for Michael Baker Jr., Inc.

United States Geological Survey (USGS). 1982. Measurement and Computation of Streamflow, Vols. 1 and 2. S.E. Rantz and others. Water Supply Paper 2175.

—— 2005. Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers. Scientific Investigations Report 2005-5183.

—— 2006. Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport. Scientific Investigations Report 2006-5079.

Walker H.J. and P.F. Hudson. 2003. Hydrologic and Geomorphic Processes in the Colville River Delta, Alaska. Geomorphology, 56, 291-303.

Woo, Ming-ko. 1997. Arctic Snow Cover Information for Hydrological Investigations as Various Scales, Proceedings of the Northern Res. Basin Symposium/Workshop. Nordic Hydrology, 29 (4/5), 245–266.

5.2 Acronyms

ADCP	Acoustic Doppler Current Profiler
ADF&G	Alaska Department of Fish and Game
ADP	Alpine Development Project
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
PT	Pressure Transducer
RM	River Mile
SWE	Snow Water Equivalent
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

Snow Water Equivalent (SWE)
The liquid-water equivalent of the snowpack, expressed in terms of depth

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 2007 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	25.03	N 70° 14' 40.6"	W 150° 51' 29.6"	Alcap	Lounsbury 1996
Mon 20	19.17	N 70° 16' 48.0"	W 151° 00' 41.7"	Alcap	Lounsbury 1996
Mon 22	10.13	N 70° 19' 05.2"	W 151° 03' 21.9"	Alcap	Lounsbury 1996
Mon 23	9.53	N 70° 20' 40.0"	W 151° 03' 40.7"	Alcap	Lounsbury 1996 (9.523 LCMF 6-26-2005)
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
SAK-LT	10.17	N 70° 21' 49.5"	W 150° 55' 34.0"	Alcap	LCMF, 12-2004
STM RT	10.07	N 70° 23' 37.7"	W 150° 54' 54.4"	Alcap	LCMF, 11-2004
FIORD 01	9.30	N 70° 24' 27.7"	W 150° 52' 40.2"	Alcap	LCMF, 11-2004
WUL-LT	8.91	N 70° 24' 53.9"	W 150° 54' 28.8"	Alcap	LCMF 2005
Mon 12	9.01	N 70° 20' 22.9"	W 151° 02' 34.2"	Drill Stem	LCMF 1997
Mon 21	13.27	N 70° 20' 32.7"	W 150° 55' 25.0"	Drill Stem	LCMF 2005
Mon 22	11.27	N 70° 20' 32.1"	W 150° 55' 55.6"	Drill Stem	LCMF 1997
02-01-39O	11.46	N 70° 20' 01.5"	W 150° 57' 07.2"	HSM	LCMF 2002
02-01-39P	11.72	N 70° 20' 01.5"	W 150° 57' 06.6"	HSM	LCMF 2002
05-20-01B	25.68	N 70° 17' 31.4"	W 150° 59' 19.9"	HSM	LCMF 2005
05-20-01A	25.70	N 70° 17' 30.3"	W 150° 59' 32.9"	HSM	LCMF 2005

Table A-2 Summary of 2007 Gage Locations

Gage Site	Gage	Latitude (NAD83)	Longitude (NAD83)	Basis of Elevation
CD 1	PG1	N 70° 20' 34.3"	W 150° 55' 15.3"	Mon 21
	PG9	N 70° 20' 01.2"	W 150° 57' 07.2"	02-01-39O
	PG10	N 70° 20' 32.6"	W 150° 55' 57.8"	Mon 22 (LCMF)
CD 2	PG3	N 70° 20' 24.1"	W 150° 58' 58.7"	Mon 12
	PG4	N 70° 20' 25.5"	W 150° 59' 00.0"	
	PG6	N 70° 20' 22.7"	W 151° 01' 45.3"	
	PG7	N 70° 20' 24.2"	W 151° 01' 44.4"	
SAK Pipe Bridge	TBM A	N 70° 21' 52.2"	W 150° 55' 07.3"	SAK-LT
TAM Pipe Bridge	TBM A	N 70° 23' 35.6"	W 150° 54' 30.5"	STM-RT
ULAM Pipe Bridge	TBM A	N 70° 24' 20.9"	W 150° 52' 59.1"	FIORD 01
CD 3	Gage 11	N 70° 02' 53.0"	W 150° 54' 37.9"	WUL-LT
CD 4	Gage 15	N 70° 18' 08.0"	W 150° 59' 36.1"	05-20-01B
	Gage 16	N 70° 18' 06.1"	W 150° 59' 35.8"	
	Gage 17	N 70° 17' 35.9"	W 150° 58' 57.9"	
	Gage 18	N 70° 17' 34.8"	W 150° 58' 54.4"	
	Gage 19	N 70° 17' 29.5"	W 150° 59' 17.6"	
	Gage 20	N 70° 17' 30.1"	W 150° 59' 48.4"	05-20-01A
Mon 01U	TBM A - 1	N 70° 09' 30.0"	N 150° 56' 33.0"	Mon 01
	TBM A	N 70° 09' 30.4"	W 150° 56' 43.3"	
	TBM B	N 70° 09' 30.5"	W 150° 56' 44.6"	
	TBM C	N 70° 09' 30.6"	W 150° 56' 45.7"	
	TBM D	N 70° 09' 30.6"	W 150° 56' 46.2"	
	TBM E	N 70° 09' 30.6"	W 150° 56' 46.6"	
	TBM F	N 70° 09' 30.6"	W 150° 56' 47.2"	
	TBM G	N 70° 09' 30.6"	W 150° 56' 47.5"	
Mon 01	TBM A	N 70° 09' 56.7"	W 150° 56' 17.7"	Mon 01
	TBM B-1	N 70° 09' 56.7"	W 150° 56' 18.6"	
	TBM B	N 70° 09' 56.9"	W 150° 56' 20.5"	
	TBM C	N 70° 09' 57.0"	W 150° 56' 21.3"	
	TBM D	N 70° 09' 57.0"	W 150° 56' 21.7"	
	TBM E	N 70° 09' 57.0"	W 150° 56' 22.1"	
	TBM F	N 70° 09' 57.1"	W 150° 56' 22.9"	

Table A-2 Summary of 2007 Gage Locations (continued)

Gage Site	Gage	Latitude (NAD83)	Longitude (NAD83)	Basis of Elevation
Mon 01D	TBM A - 1	N 70° 10' 25.4"	W 150° 56' 14.5"	Mon 01
	TBM A	N 70° 10' 25.5"	W 150° 56' 13.8"	
	TBM B	N 70° 10' 25.6"	W 150° 56' 11.5"	
	TBM C	N 70° 10' 25.7"	W 150° 56' 10.1"	
	TBM D	N 70° 10' 26.4"	W 150° 55' 58.3"	
Mon 9	TBM A	N 70° 14' 40.2"	W 150° 51' 24.1"	Mon 09
	TBM B	N 70° 14' 40.1"	W 150° 51' 26.7"	
	TBM C	N 70° 14' 39.9"	W 150° 51' 27.5"	
	TBM D	N 70° 14' 39.9"	W 150° 51' 28.2"	
	TBM E	N 70° 14' 40.1"	W 150° 51' 28.5"	
Mon 20	TBM A	N 70° 16' 42.8"	W 150° 59' 55.4"	Mon 20
	TBM B	N 70° 16' 42.8"	W 150° 59' 54.9"	
	TBM C	N 70° 16' 42.8"	W 150° 59' 54.6"	
	TBM D	N 70° 16' 42.8"	W 150° 59' 54.3"	
Mon 22	TBM A	N 70° 19' 06.1"	W 151° 03' 19.9"	Mon 22 (Lounsbury)
	TBM B	N 70° 19' 06.6"	W 151° 03' 18.3"	
	TBM C	N 70° 19' 06.8"	W 151° 03' 17.9"	
	TBM D	N 70° 19' 07.6"	W 151° 03' 17.9"	
Mon 23	TBM A	N 70° 20' 37.0"	W 151° 03' 59.1"	Mon 23
	TBM B	N 70° 20' 37.0"	W 151° 03' 56.0"	
	TBM C	N 70° 20' 37.0"	W 151° 03' 54.9"	
	TBM D	N 70° 20' 36.9"	W 151° 03' 53.5"	
Mon 28	TBM A	N 70° 25' 32.0"	W 151° 04' 01.2"	Mon 28
	TBM B	N 70° 25' 32.5"	W 151° 04' 11.3"	
Mon 35	TBM A	N 70° 25' 34.2"	W 150° 24' 17.5"	Mon 35

Appendix B ADCP Discharge Results

Colville River

Monument 1
Upstream

Station No.: Mon 1U — Meas. No: 1

Station Name: Monument 1 Upstream — Date: 06/04/2007

Party:	MDM & OOO	Width:	2,870 ft	Processed by:	MDM
Boat/Motor:	Achilles/25hp	Area:	53,500 ft²	Mean Velocity:	4.20 ft/s
Gage Height:	0.00 ft	G.H.Change:	0.00	Discharge:	225,000 ft³/s

Area Method:	Mean Flow	ADCP Depth:	2.80 ft	Index Vel.:	0.00 ft/s	Rating No.:	1
Nav. Method:	Bottom Track	Shore Ens.:	*21	Adj.Mean Vel:	0.00 ft/s	Qm Rating:	U
MagVar Method:	Model (22.9°)	Top Est:	Power (0.1667)	Rated Area:	0.000 ft²	% Diff:	0.0%
Depth Sounder:	Not Used	Bottom Est:	Power (0.1667)	Control:	Unspecified		

Screening Thresholds:				ADCP:			
BT 3-Beam Solution:	ON	Max. Vel.:	8.70 ft/s	Type/Freq.:	Workhorse / 600 kHz		
WT 3-Beam Solution:	OFF	Max. Depth:	40.7 ft	Serial #:	6882	Firmware:	16.28
BT Error Vel.:	0.33 ft/s	Mean Depth:	18.7 ft	Bin Size:	50 cm	Blank:	50 cm
WT Error Vel.:	4.92 ft/s	% Meas.:	60.69%	BT Mode:	5	BT Pings:	1
BT Up Vel.:	32.81 ft/s	Water Temp.:	None	WT Mode:	1	WT Pings:	1
WT Up Vel.:	32.81 ft/s	ADCP Temp.:	39.4 °F	WV:	170		

Diag. Test:

Moving Bed Test:

Compass Test:

Meas. Location: Colville River

Filename Prefix: Colville_2007_Monument1U

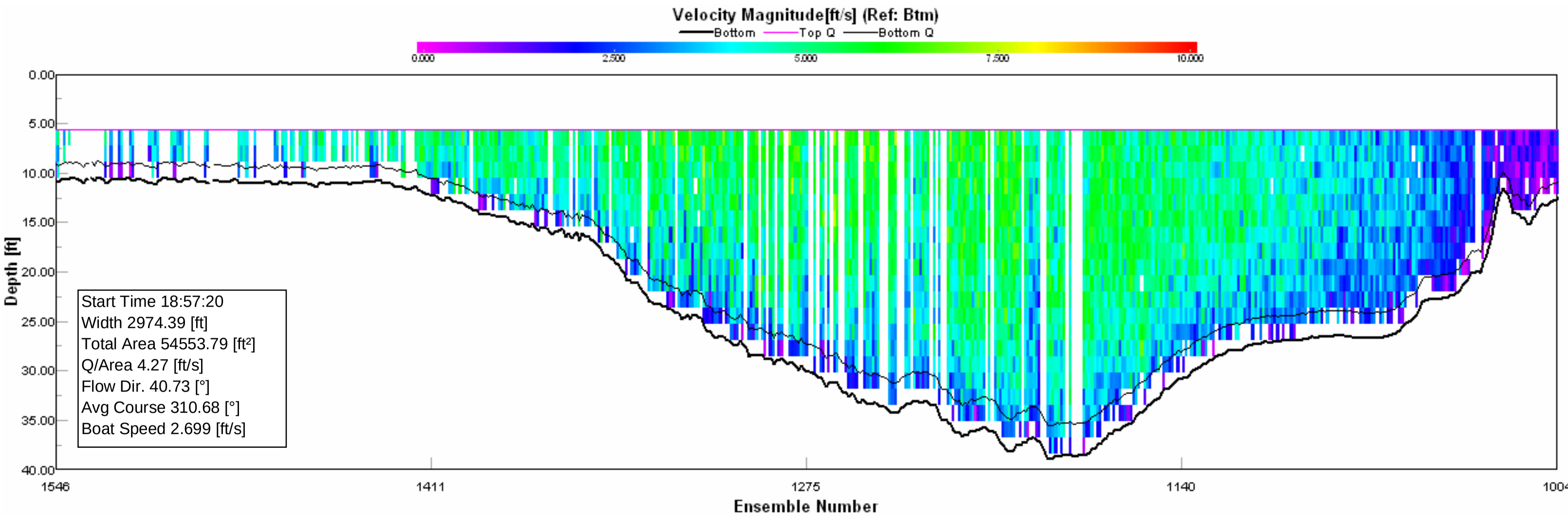
Software: 1.06.00

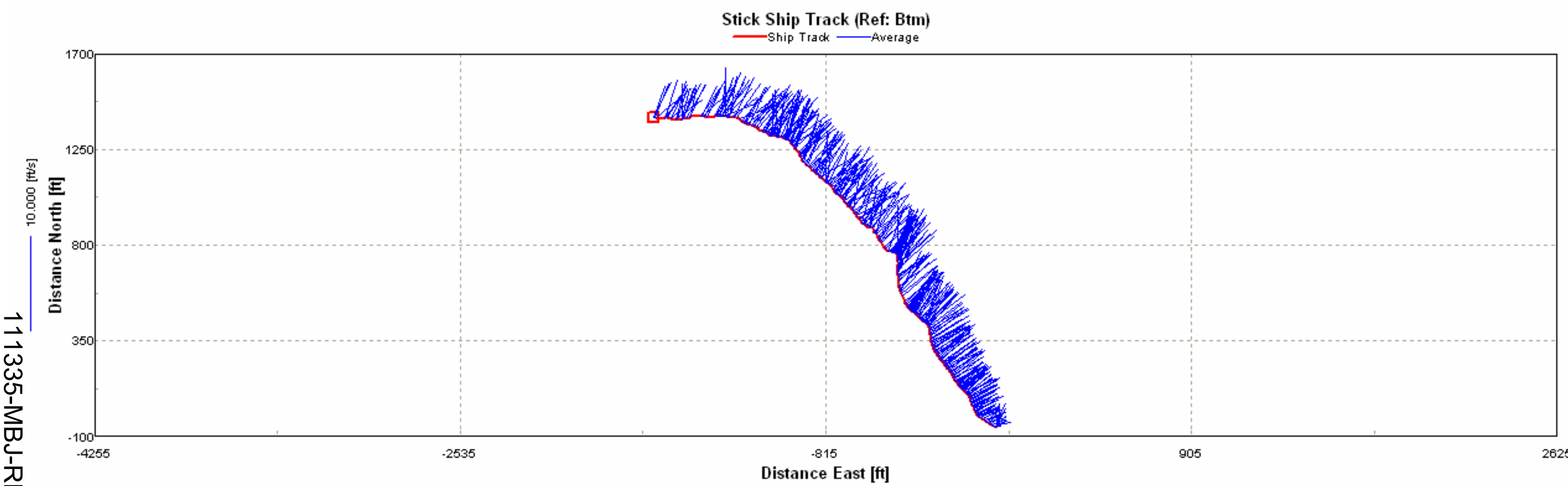
Tr.#		Edge D.		#Ens	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
001	R	765	60	543	60159	141070	21252	10355	254	233090	2974	54554	18:57	19:12	2.70	4.27	22	0
001	L	765	60	366	56438	138909	20103	12025	809	228284	2870	54151	19:27	19:37	3.67	4.22	12	0
001	R	935	60	607	52935	135590	19386	15282	224	223417	2712	51138	19:39	19:57	2.70	4.37	15	0
001	L	935	65	423	49739	130411	18483	15261	877	214772	2909	54334	20:06	20:18	2.86	3.95	8	0
Mean		850	61	485	54818	136495	19806	13231	541	224891	2866	53544	**Total**	01:21	2.98	4.20	14	0
SDev		98	3	110	4490	4640	1170	2453	350	7817	111	1613			0.47	0.18		
R/M%		20	8	49.7	19.0	7.8	14.0	37.2	120.6	8.1	9.1	6.4			32.70	9.90		

Remarks:

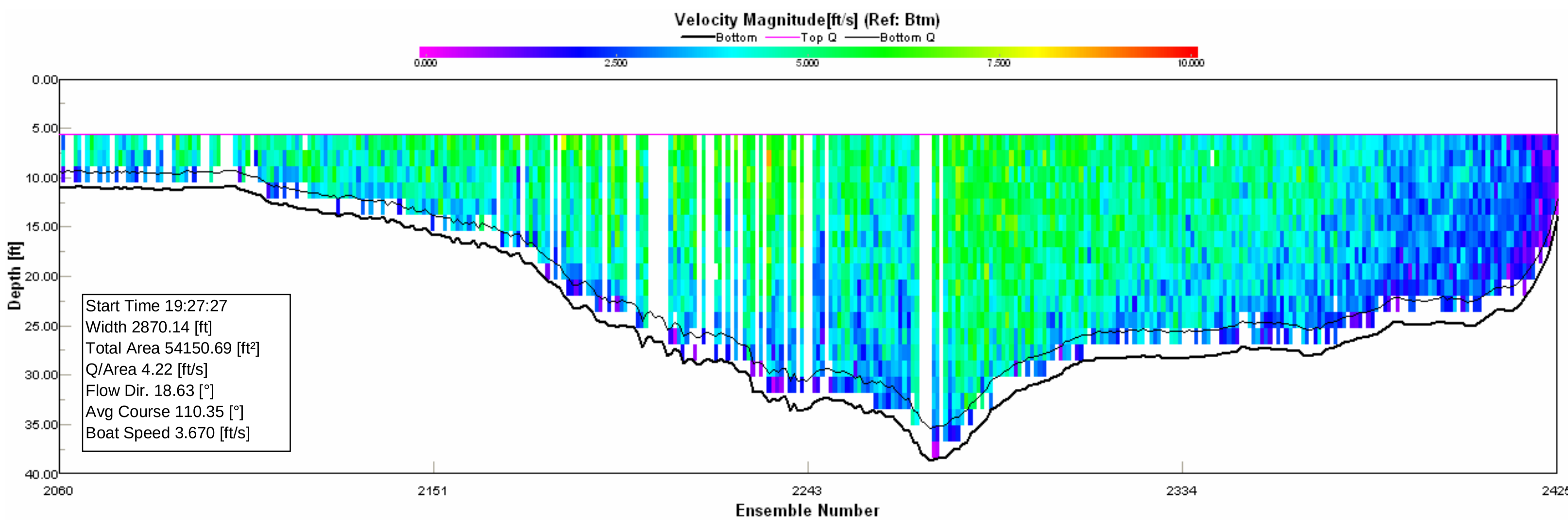
* - value not consistent for all transects

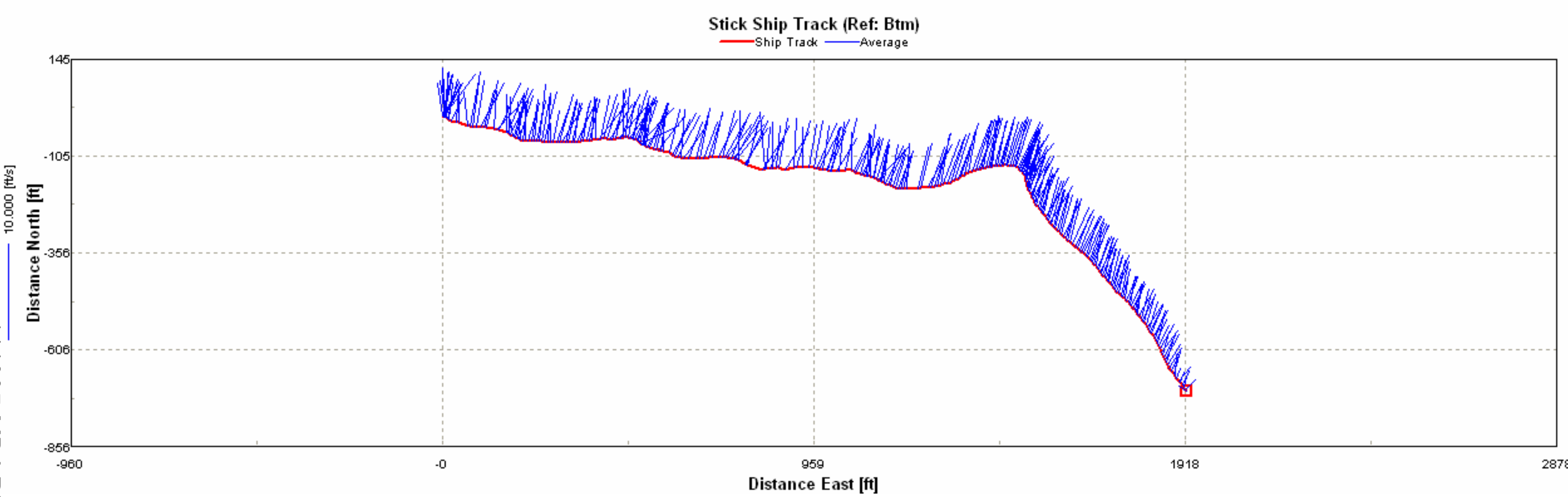
Monument 1 Upstream Colville River Discharge Transect 1, WinRiver Velocity and Ship Track Plots
June 4, 2007



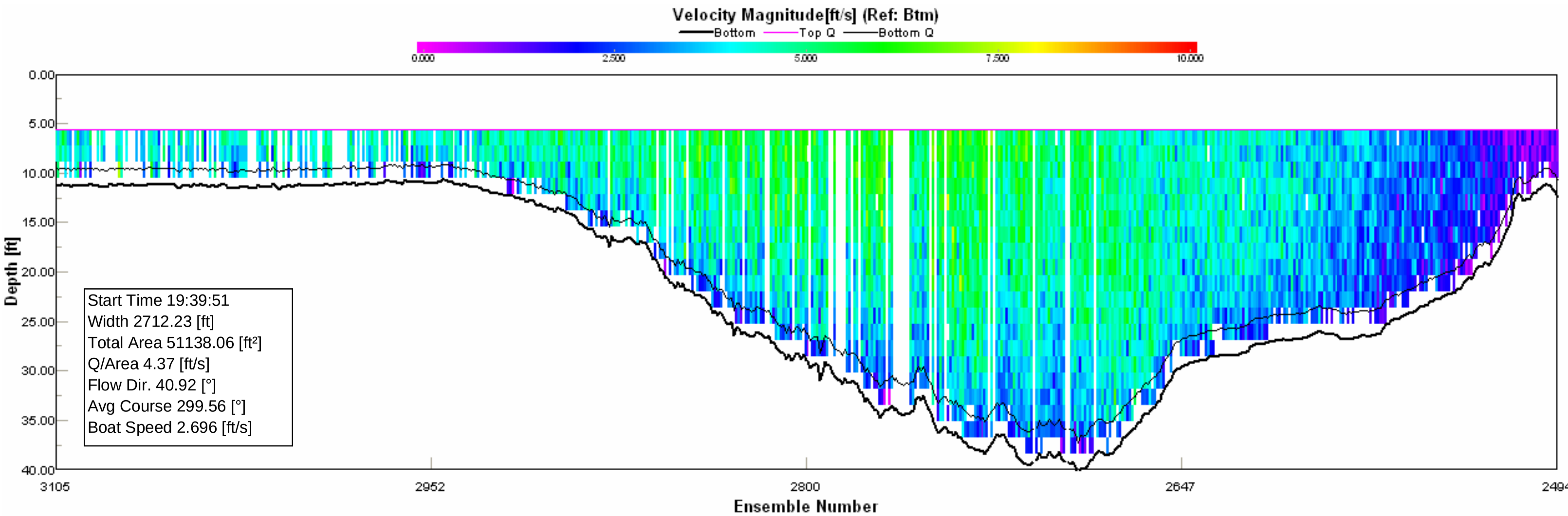


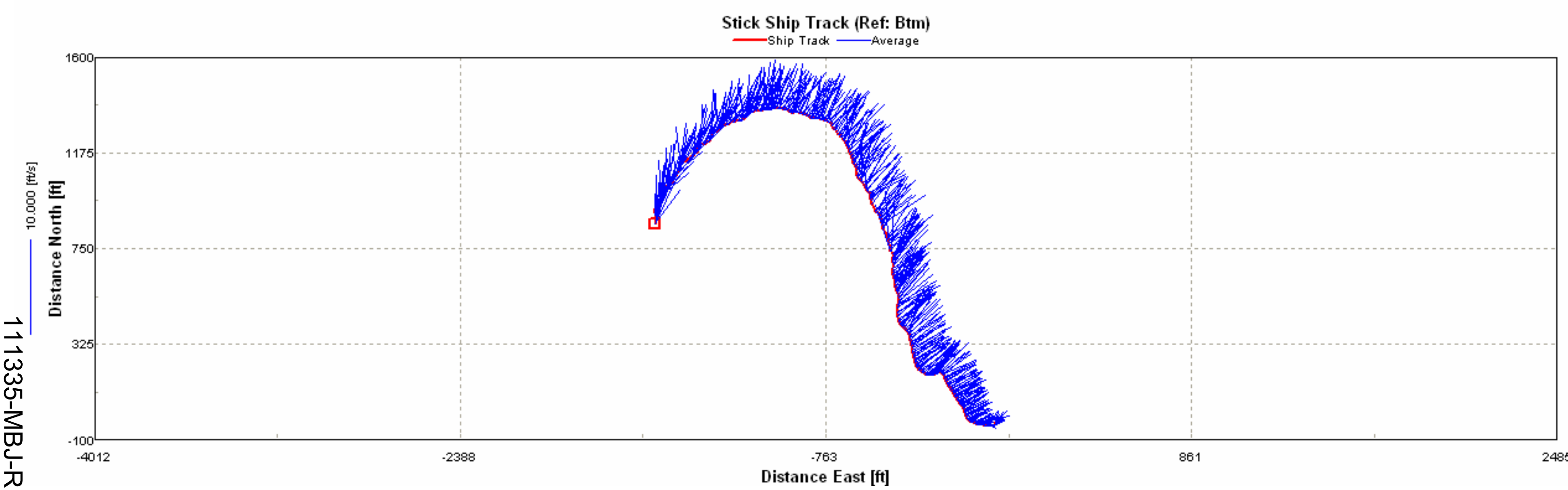
Monument 1 Upstream Colville River Discharge Transect 2, WinRiver Velocity and Ship Track Plots
June 4, 2007



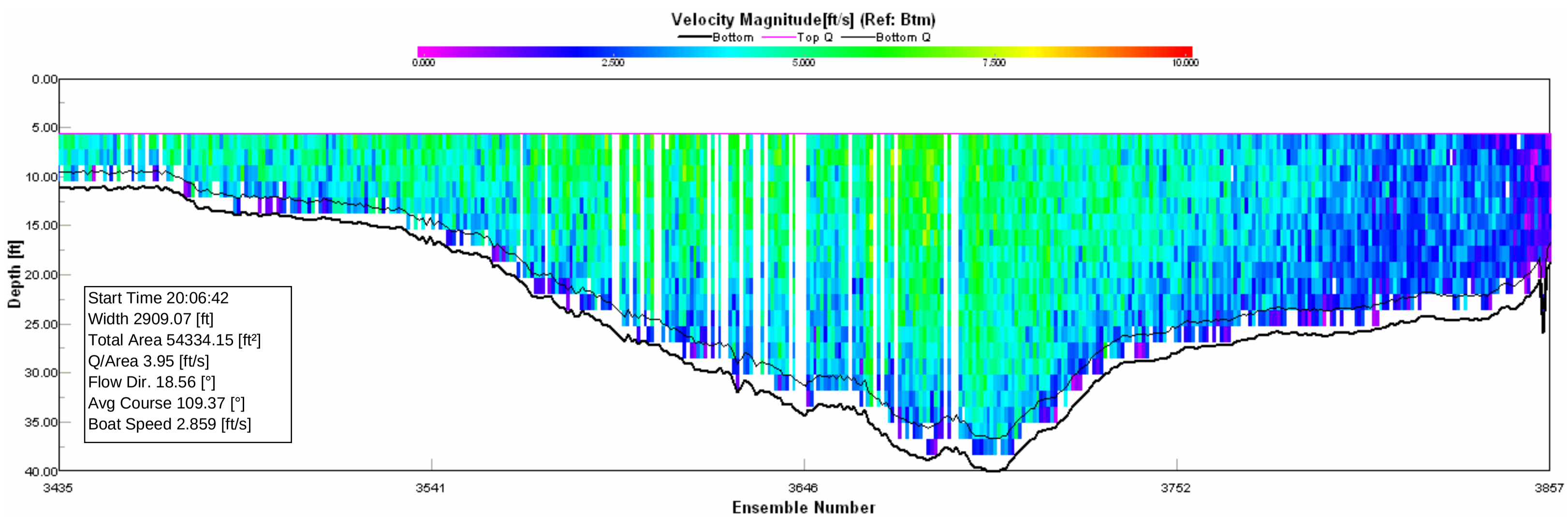


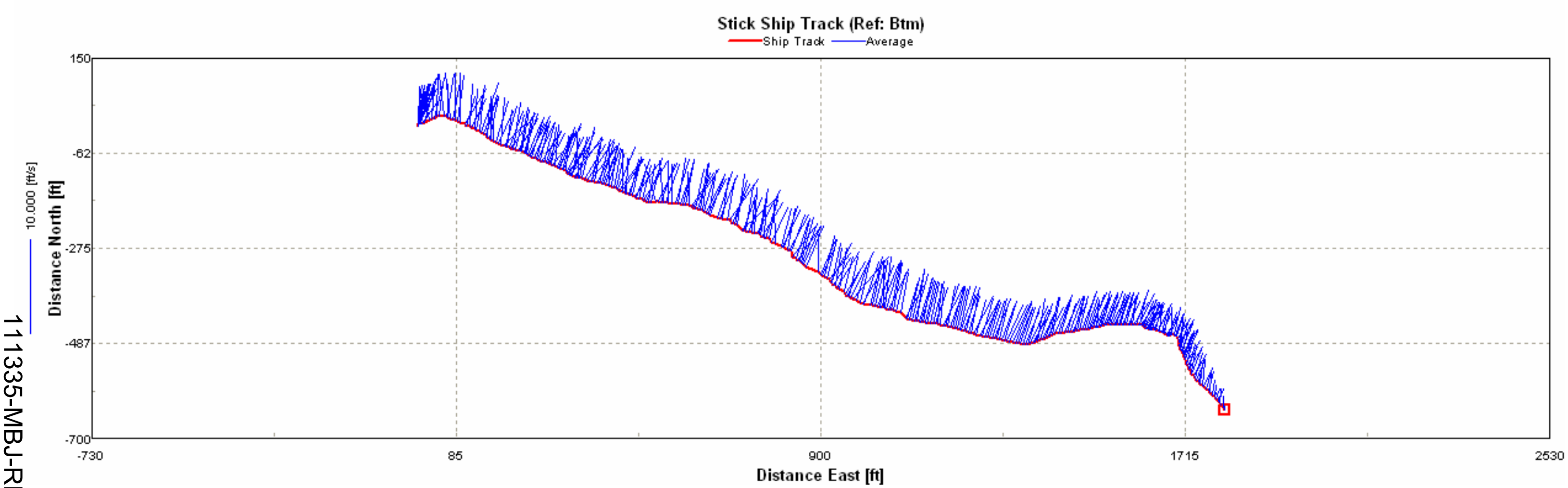
Monument 1 Upstream Colville River Discharge Transect 3, WinRiver Velocity and Ship Track Plots
June 4, 2007



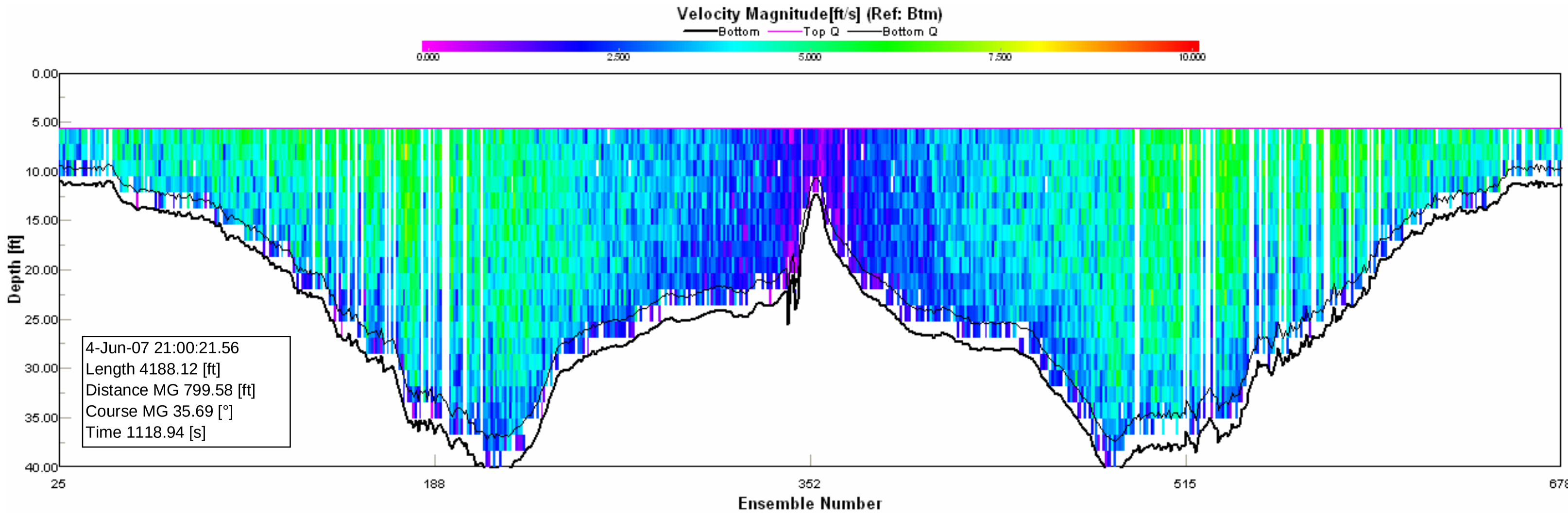


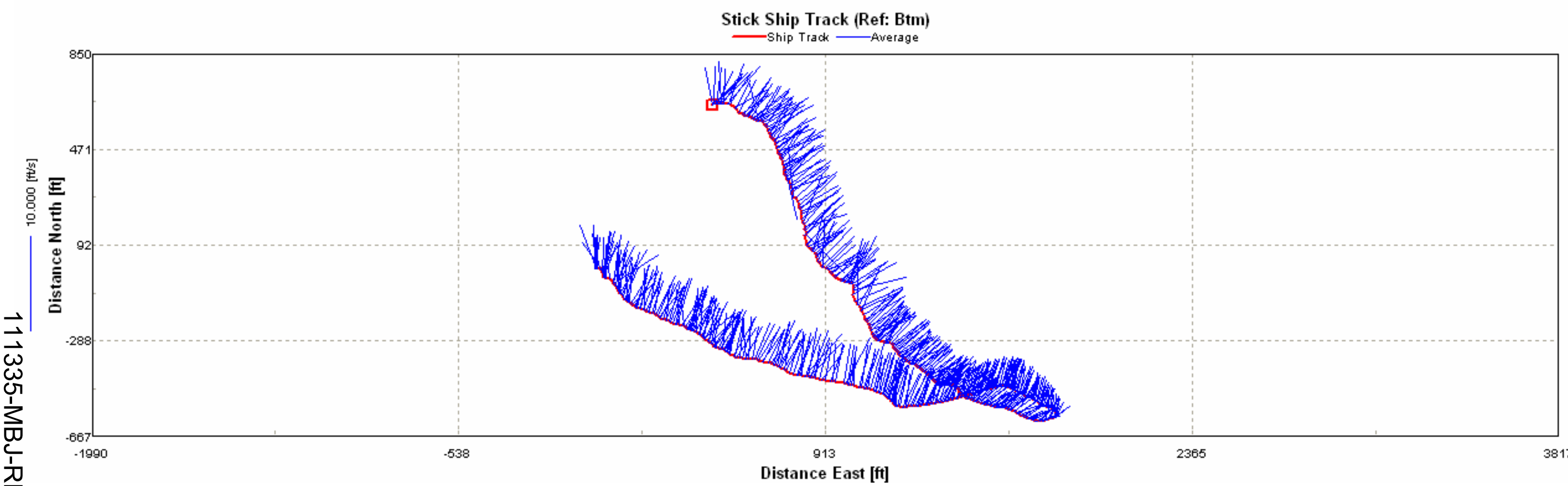
Monument 1 Upstream Colville River Discharge Transect 4, WinRiver Velocity and Ship Track Plots
June 4, 2007





Monument 1 Upstream Colville River Discharge Loop Test, WinRiver Velocity and Ship Track Plots
June 4, 2007





Station No.: Mon 1U	Meas. No: 2
Station Name: Monument 1 Upstream	Date: 06/05/2007

Party: MDM & OOO	Width: 2,810 ft	Processed by: MDM
Boat/Motor: Achilles/25hp	Area: 49,900 ft²	Mean Velocity: 4.49 ft/s
Gage Height: 0.00 ft	G.H.Change: 0.00	Discharge: 224,000 ft³/s

Area Method: Mean Flow	ADCP Depth: 2.75 ft	Index Vel.: 0.00 ft/s Rating No.:1
Nav. Method: Bottom Track	Shore Ens.: *13	Adj.Mean Vel: 0.00 ft/s Qm Rating:U
MagVar Method: Model (22.9°)	Top Est: Power (0.1667)	Rated Area: 0.000 ft² % Diff: 0.0%
Depth Sounder: Not Used	Bottom Est: Power (0.1667)	Control: Unspecified

Screening Thresholds:		ADCP:
BT 3-Beam Solution: ON	Max. Vel.: 10.7 ft/s	Type/Freq.: Workhorse / 600 kHz
WT 3-Beam Solution: OFF	Max. Depth: 39.5 ft	Serial #: 6882 Firmware: 16.28
BT Error Vel.: 0.33 ft/s	Mean Depth: 17.8 ft	Bin Size: 50 cm Blank: 50 cm
WT Error Vel.: 4.92 ft/s	% Meas.: 60.10%	BT Mode: 5 BT Pings: 1
BT Up Vel.: 32.81 ft/s	Water Temp.: None	WT Mode: 1 WT Pings: 1
WT Up Vel.: 32.81 ft/s	ADCP Temp.: 40.2 °F	WV:170

Diag. Test:
Moving Bed Test:
Compass Test:
Meas. Location: Colville River

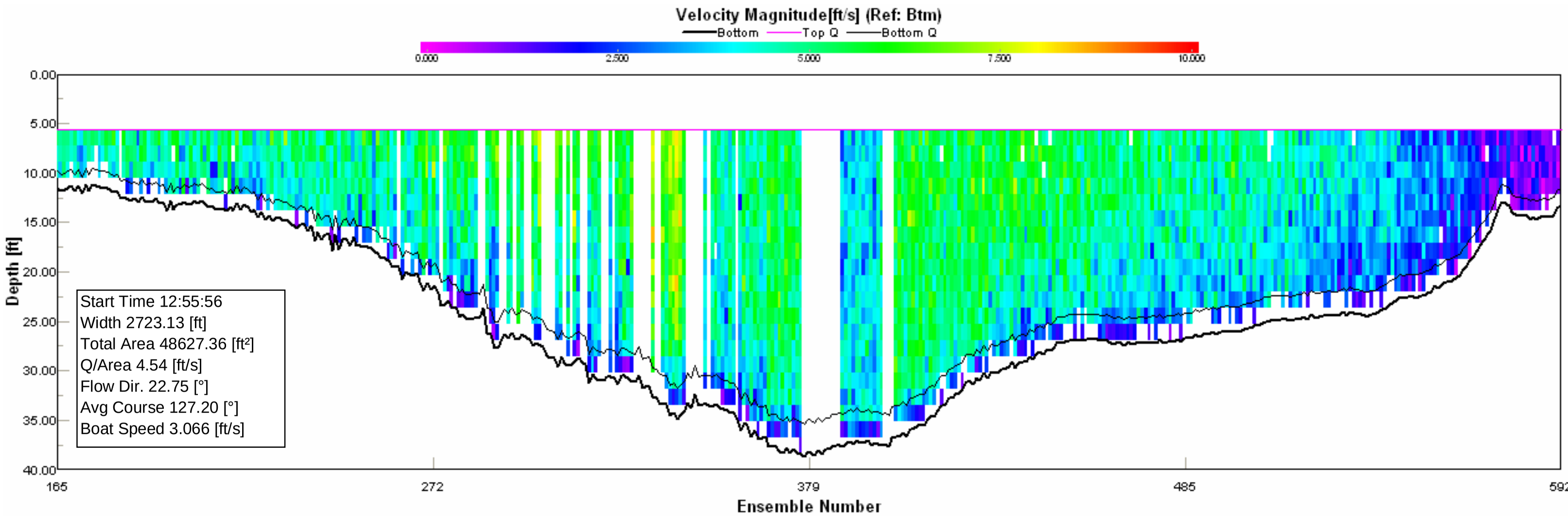
Filename Prefix: Colville_2007_Monument1U
Software: 1.06.00

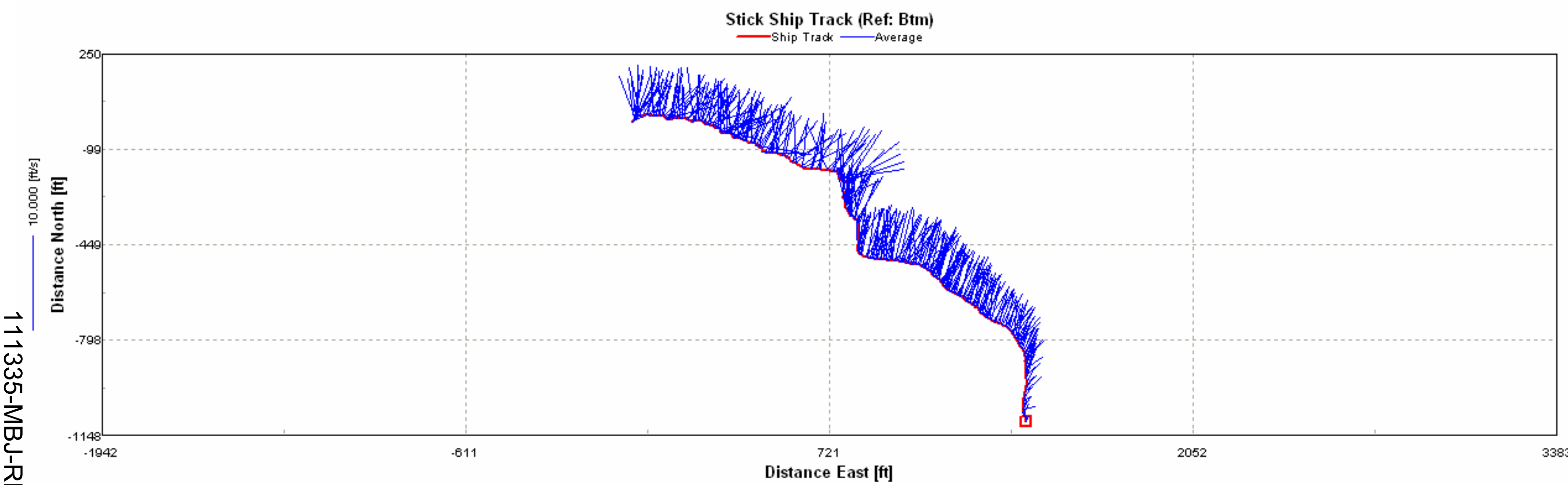
Tr.#		Edge D.		#Ens	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
001	L	955	19	428	52242	132580	19671	16038	199	220730	2723	48627	12:55	13:08	3.07	4.54	12	1
001	R	955	32	374	53142	135838	19574	14921	118	223593	2862	51784	13:09	13:20	3.33	4.32	10	0
001	L	955	31	371	54297	137796	20239	17922	247	230501	2815	49925	13:22	13:33	3.37	4.62	14	0
001	R	987	36	439	53833	132173	19780	15028	165	220979	2820	49208	13:50	14:03	2.97	4.49	15	0
Mean		963	29	403	53378	134597	19816	15977	182	223950	2805	49886	**Total**	01:07	3.19	4.49	12	0
SDev		16	7	36	894	2691	294	1391	54.3	4555	58	1372			0.20	0.13		
R/M%		3	58	16.9	3.9	4.2	3.4	18.8	70.4	4.4	4.9	6.3			12.61	6.66		

Remarks:

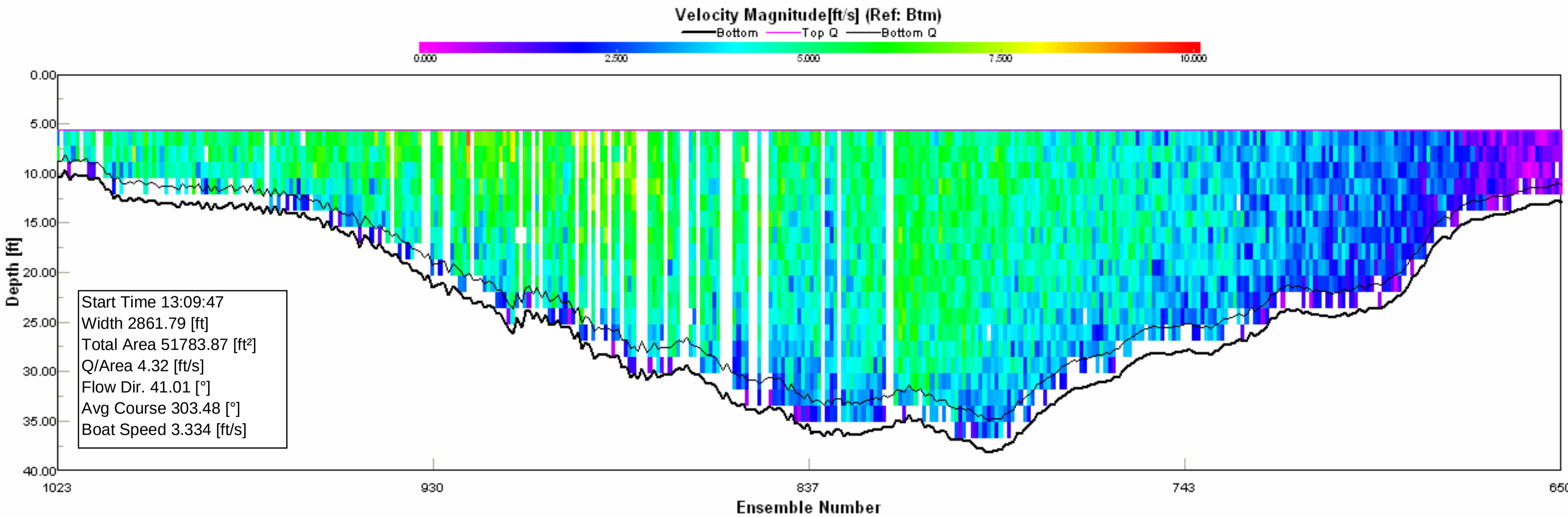
* - value not consistent for all transects

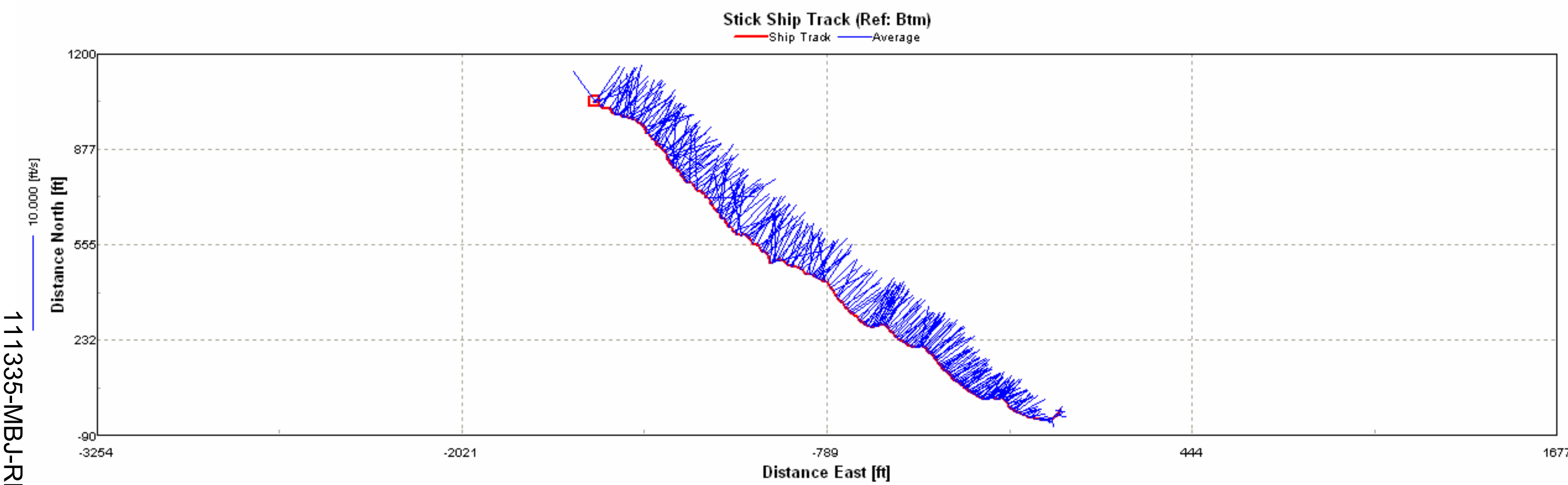
Monument 1 Upstream Colville River Discharge Transect 1, WinRiver Velocity and Ship Track Plots
June 5, 2007



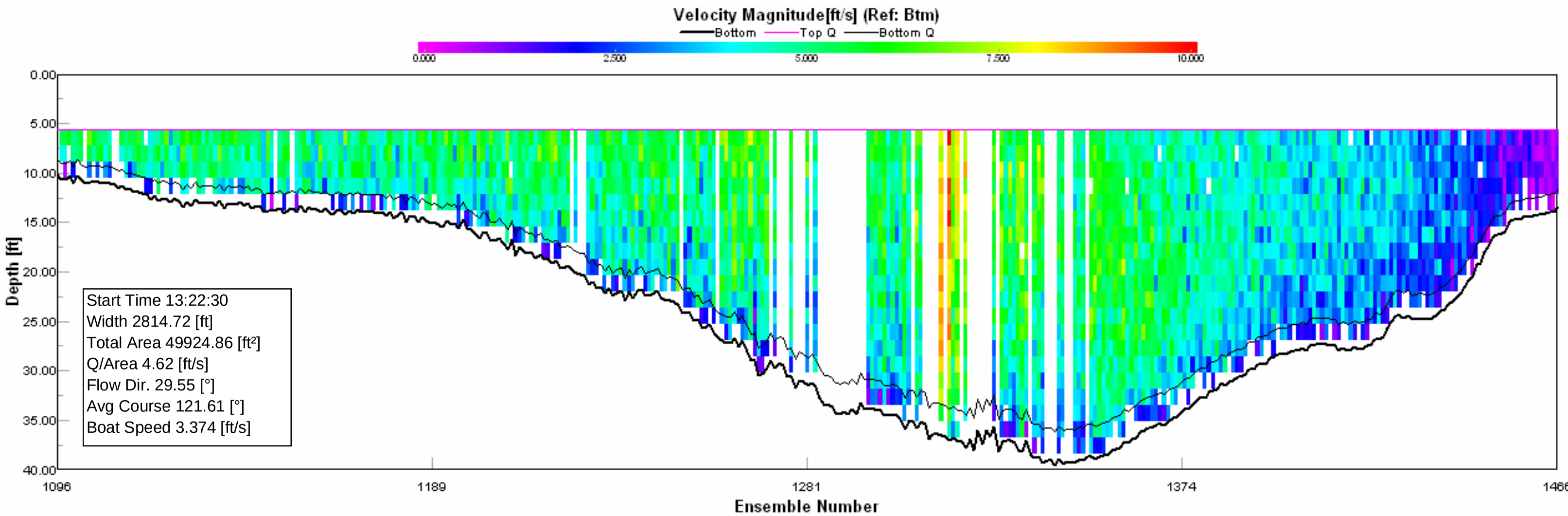


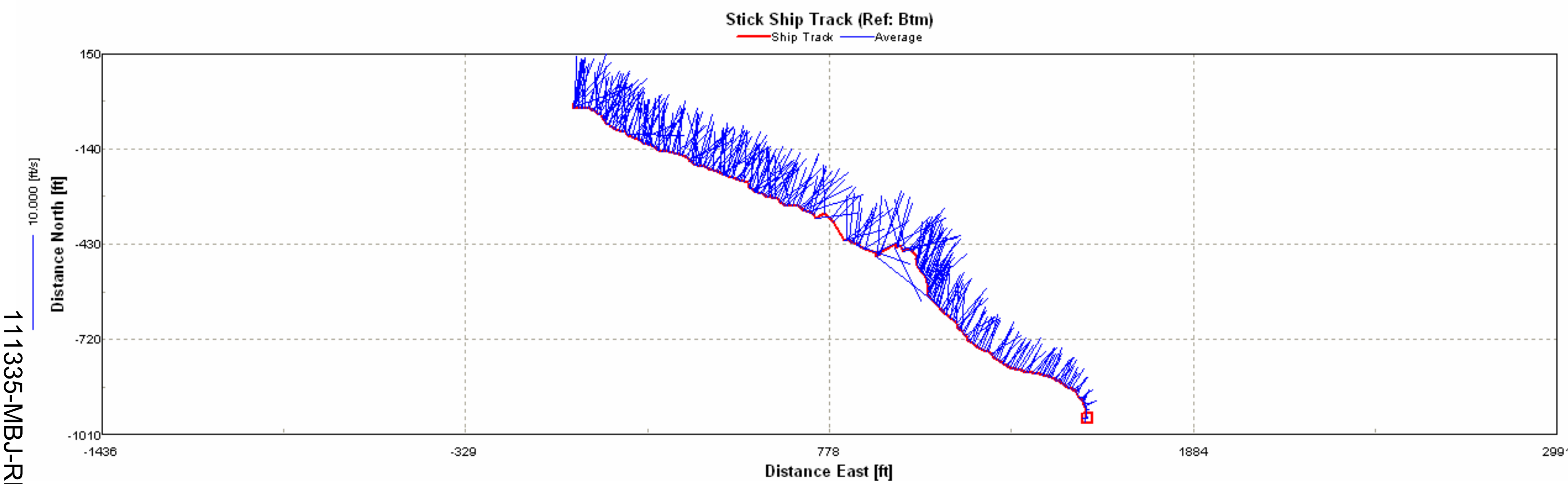
Monument 1 Upstream Colville River Discharge Transect 2, WinRiver Velocity and Ship Track Plots
June 5, 2007



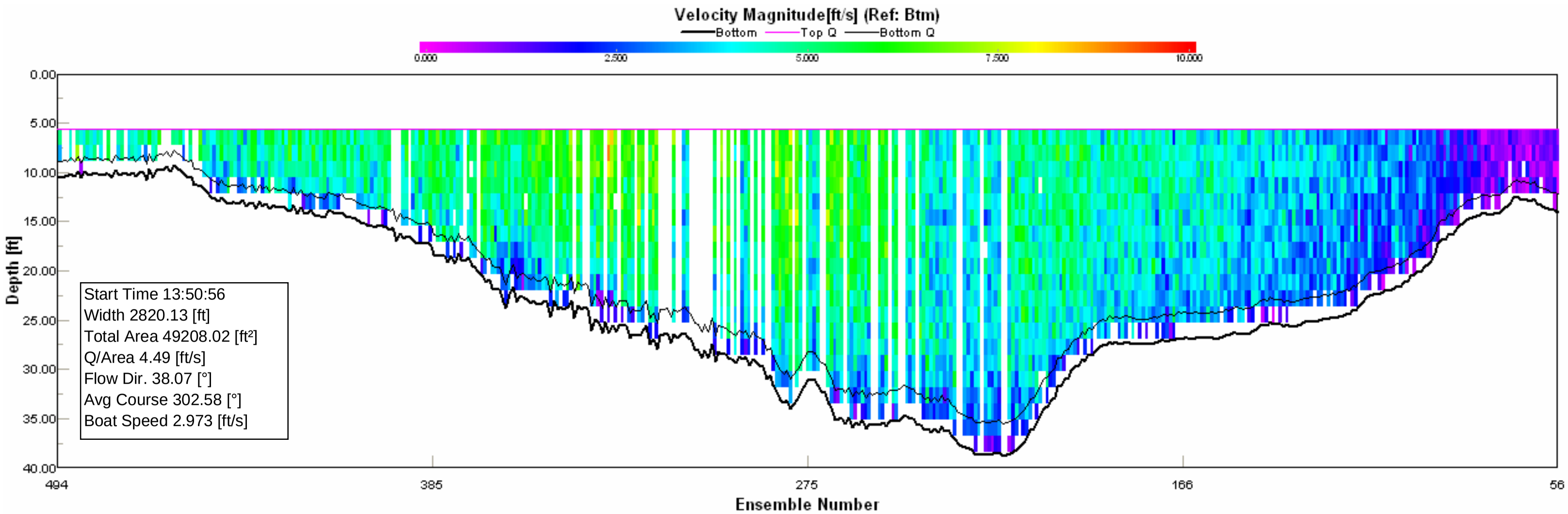


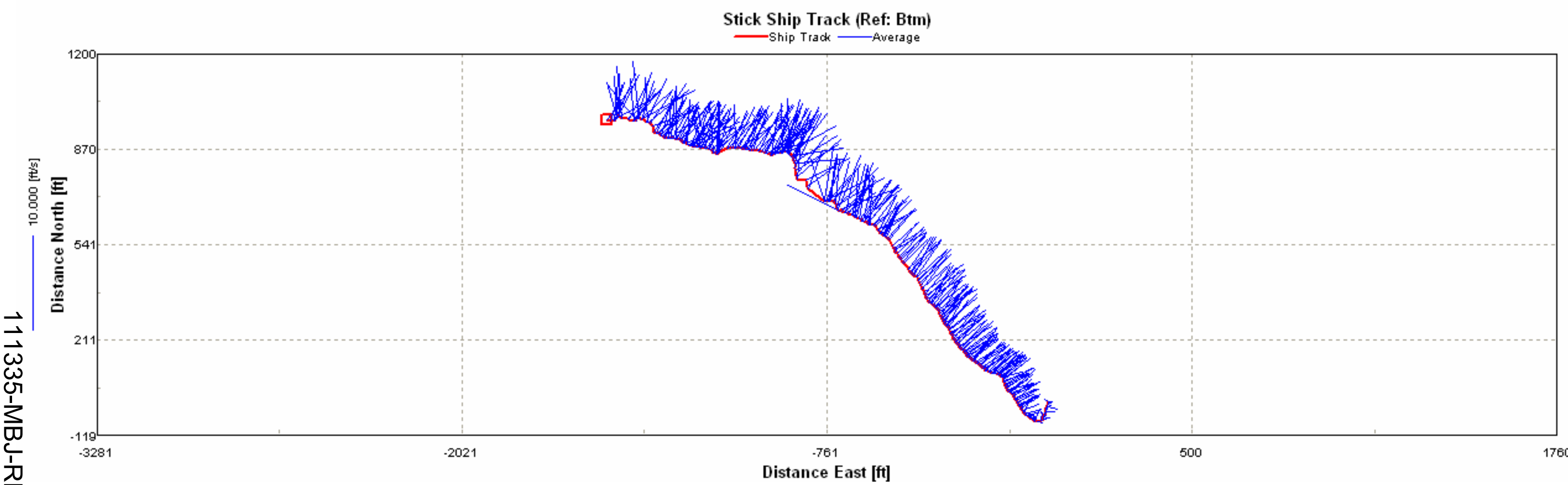
Monument 1 Upstream Colville River Discharge Transect 3, WinRiver Velocity and Ship Track Plots
June 5, 2007



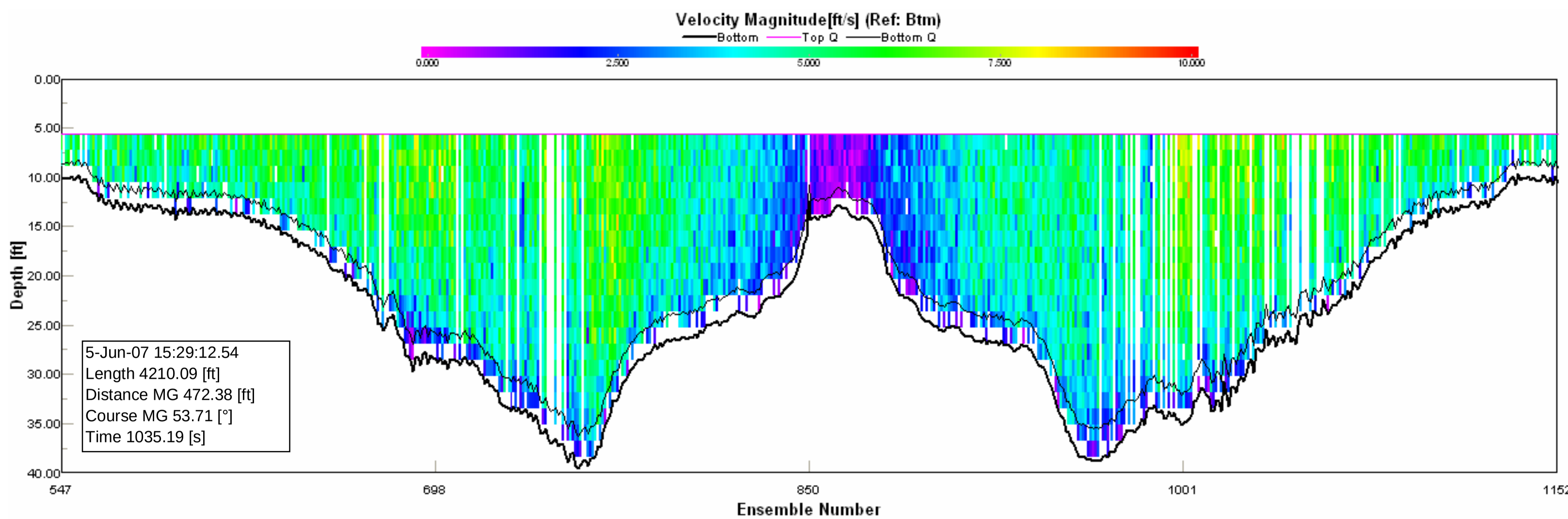


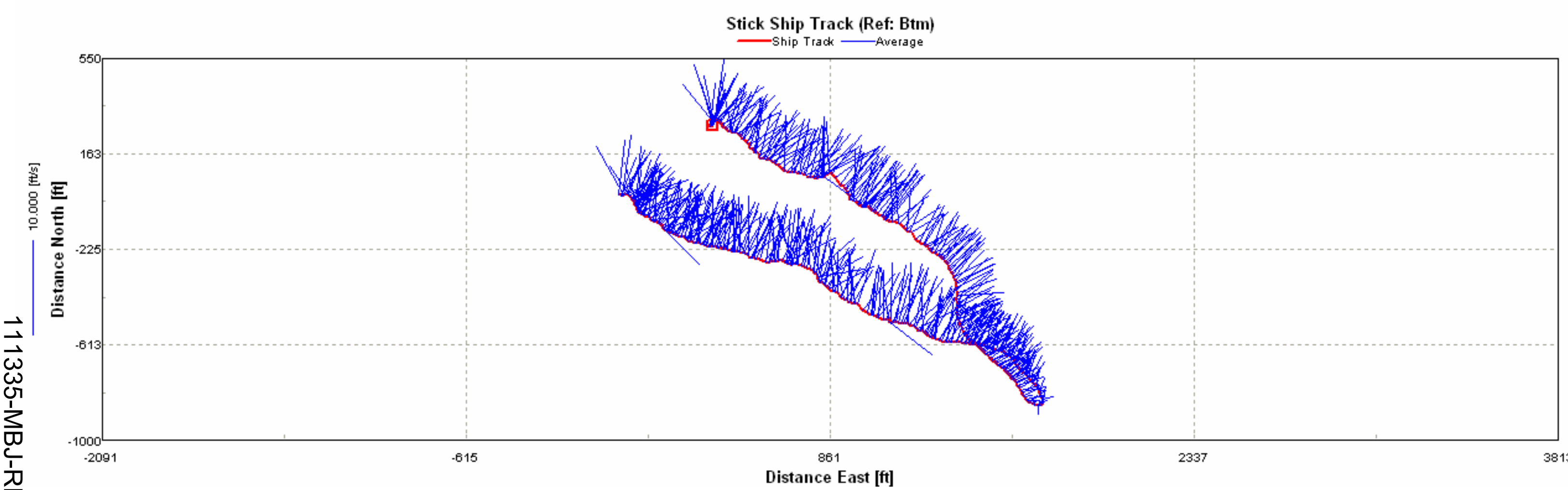
Monument 1 Upstream Colville River Discharge Transect 4, WinRiver Velocity and Ship Track Plots
June 5, 2007





**Monument 1 Upstream Colville River Discharge Loop Test, WinRiver Velocity and Ship Track Plots
June 5, 2007**





Station No.: Mon 1U — Meas. No: 3

Station Name: Monument 1 Upstream — Date: 06/06/2007

Party:	MDM & OOO	Width:	2,970 ft	Processed by:	MDM
Boat/Motor:	Achilles/25hp	Area:	50,100 ft²	Mean Velocity:	4.53 ft/s
Gage Height:	0.00 ft	G.H.Change:	0.00	Discharge:	227,000 ft³/s

Area Method:	Mean Flow	ADCP Depth:	2.75 ft	Index Vel.:	0.00 ft/s	Rating No.:	1
Nav. Method:	Bottom Track	Shore Ens.:	*7	Adj.Mean Vel:	0.00 ft/s	Qm Rating:	U
MagVar Method:	Model (22.9°)	Top Est:	Power (0.1667)	Rated Area:	0.000 ft²	% Diff:	0.0%
Depth Sounder:	Not Used	Bottom Est:	Power (0.1667)	Control:	Unspecified		

Screening Thresholds:				ADCP:			
BT 3-Beam Solution:	ON	Max. Vel.:	8.75 ft/s	Type/Freq.:	Workhorse / 600 kHz		
WT 3-Beam Solution:	OFF	Max. Depth:	37.7 ft	Serial #:	6882	Firmware:	16.28
BT Error Vel.:	0.33 ft/s	Mean Depth:	16.9 ft	Bin Size:	50 cm	Blank:	50 cm
WT Error Vel.:	4.92 ft/s	% Meas.:	58.90%	BT Mode:	5	BT Pings:	1
BT Up Vel.:	32.81 ft/s	Water Temp.:	None	WT Mode:	1	WT Pings:	1
WT Up Vel.:	32.81 ft/s	ADCP Temp.:	43.8 °F	WV:	170		

Diag. Test:

Moving Bed Test:

Compass Test:

Meas. Location: Colville River

Filename Prefix: Colville_Mon1U200706061

Software: 1.06.00

Tr.#		Edge D. L	Edge D. R	#Ens	Discharge Top	Middle	Bottom	Left	Right	Total	Width	Area	Time Start	End	Mean Vel. Boat	Water	% Bad Ens.	Bins	
001	L	1156	25	370	51750	130388	18468	23344	140	224090	2988	50384	19:20	19:30	3.01	4.45	12	0	
001	R	1156	25	495	51721	136770	19695	24787	126	233101	2866	49203	19:34	19:48	2.34	4.74	9	0	
001	L	1156	20	323	50691	133642	18463	21482	86.5	224365	2978	51112	19:55	20:05	3.43	4.39	9	0	
001	L	1119	22	296	56059	134202	20339	16051	116	226767	3043	49751	20:29	20:37	3.86	4.56	9	0	U#
Mean		1147	23	371	52555	133751	19241	21416	117	227081	2969	50112	**Total**	01:17	3.16	4.53	9	0	
SDev		19	2	88	2387	2623	933	3824	22.6	4190	74	823			0.65	0.15			
R/M%		3	22	53.6	10.2	4.8	9.7	40.8	45.4	4.0	6.0	3.8			48.13	7.67			

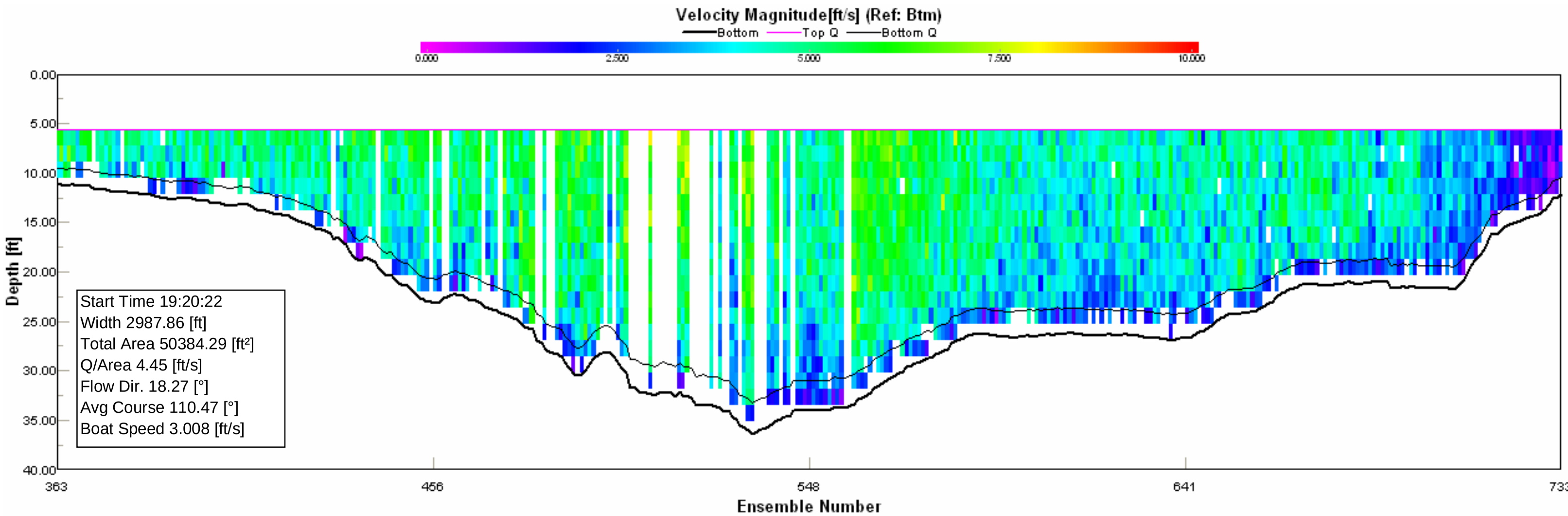
Remarks:

- transect has been subsectioned

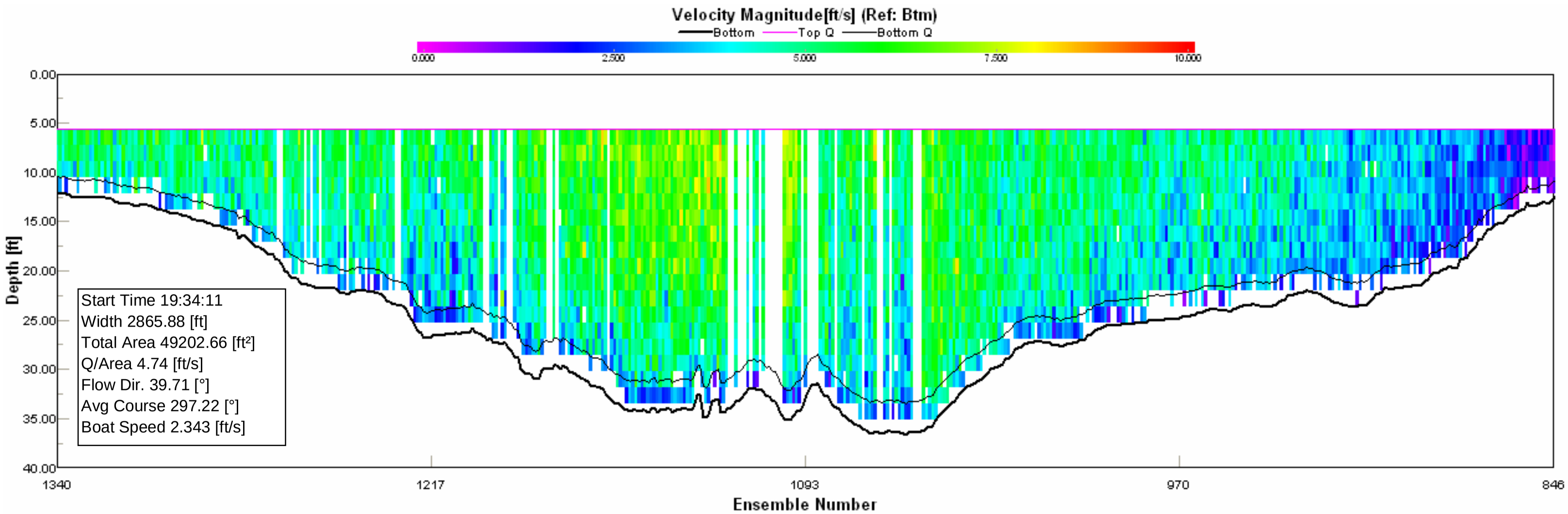
* - value not consistent for all transects

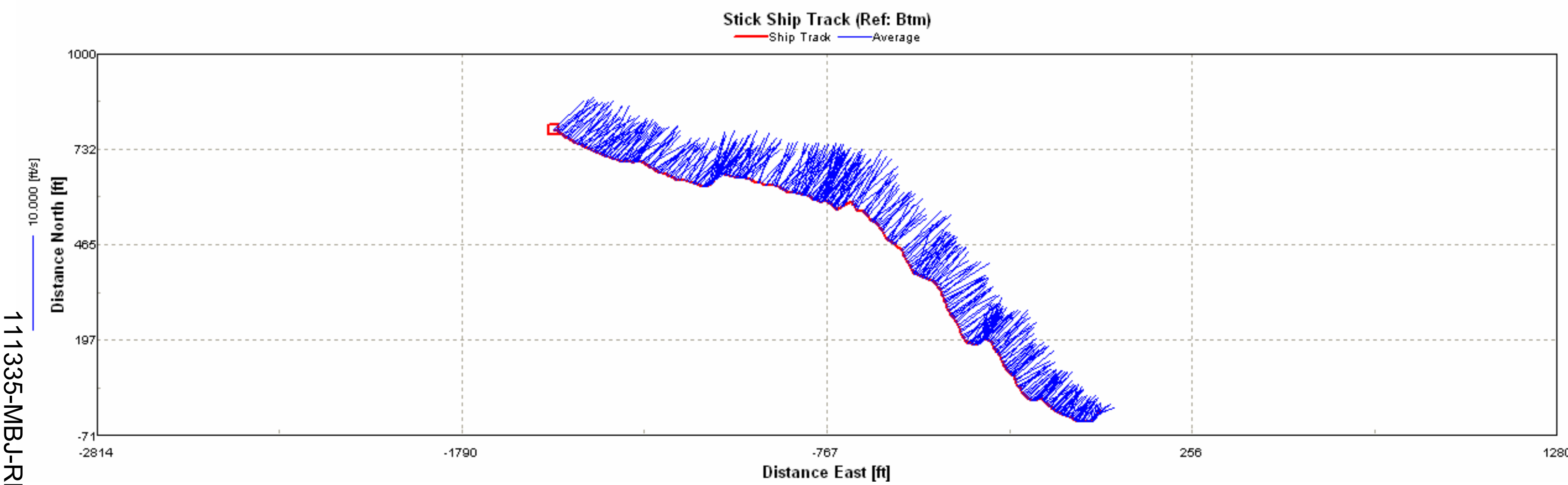
U - transect is unlocked

Monument 1 Upstream Colville River Discharge Transect 1, WinRiver Velocity and Ship Track Plots
June 6, 2007

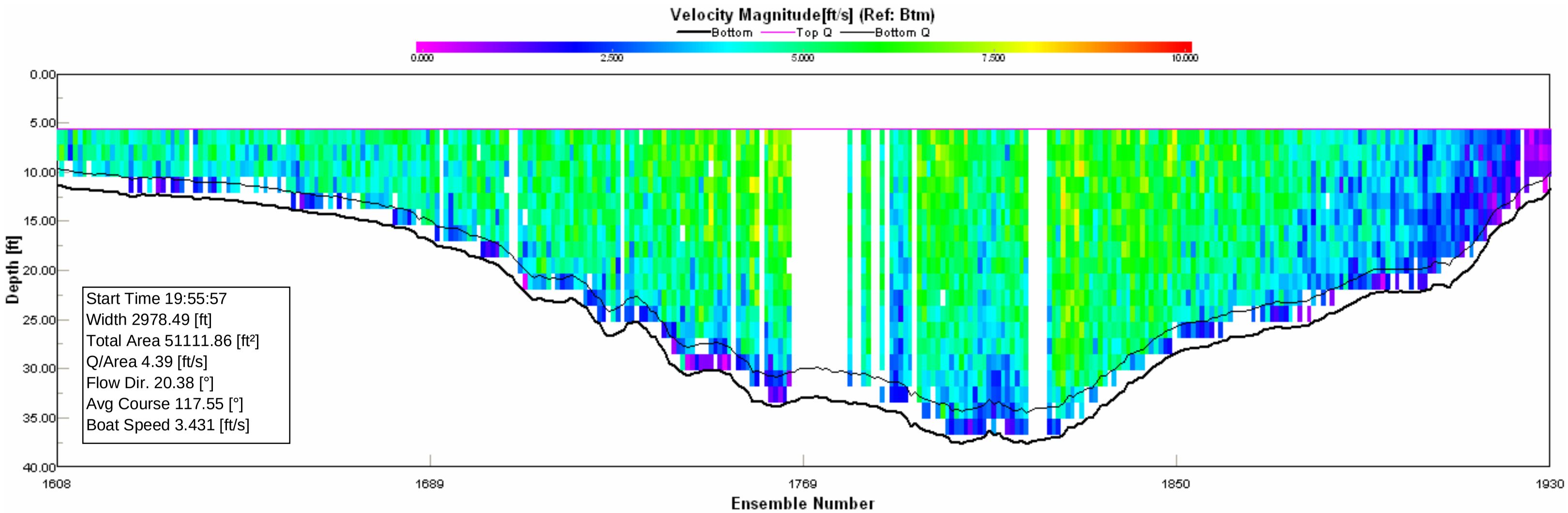


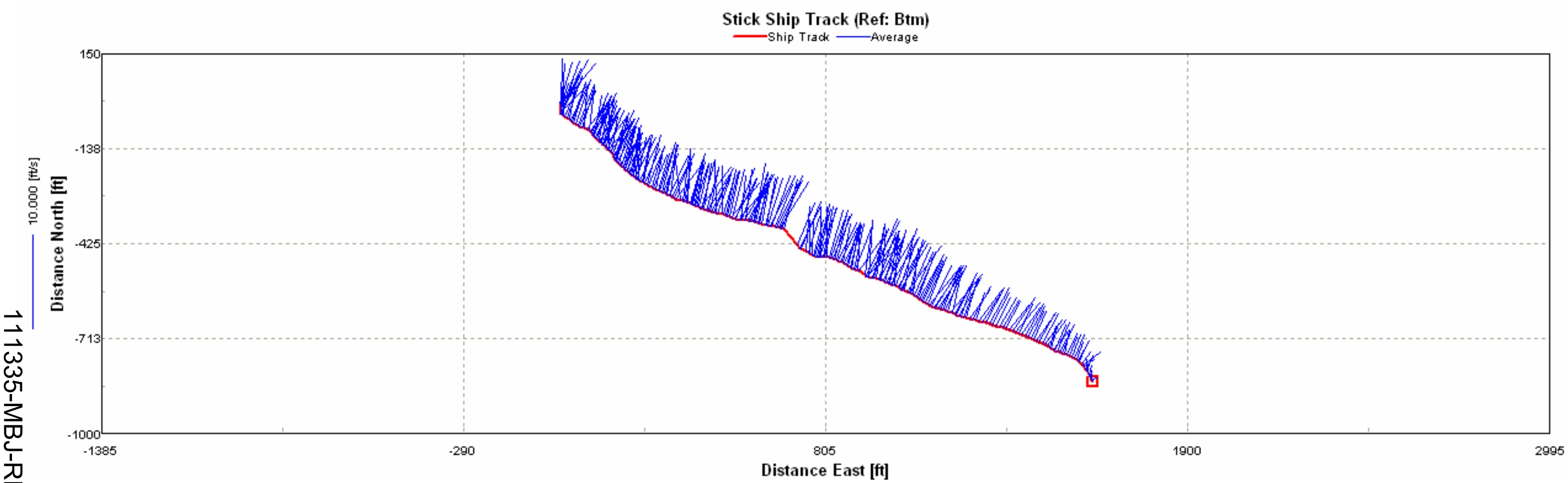
Monument 1 Upstream Colville River Discharge Transect 2, WinRiver Velocity and Ship Track Plots
June 6, 2007



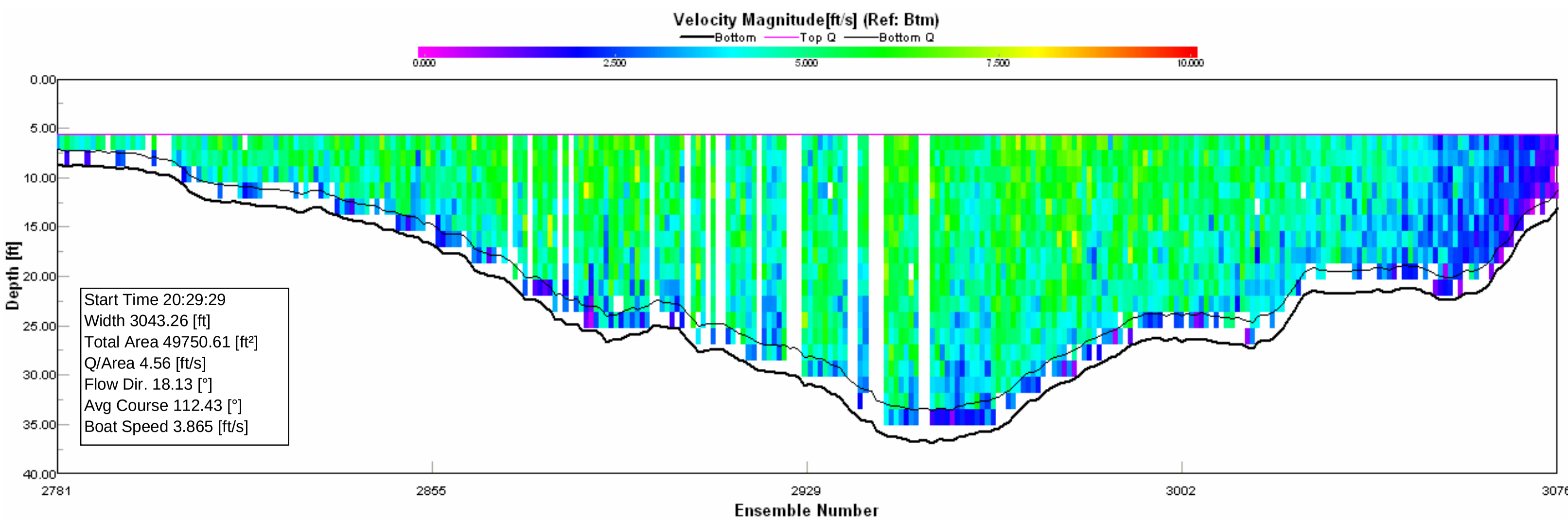


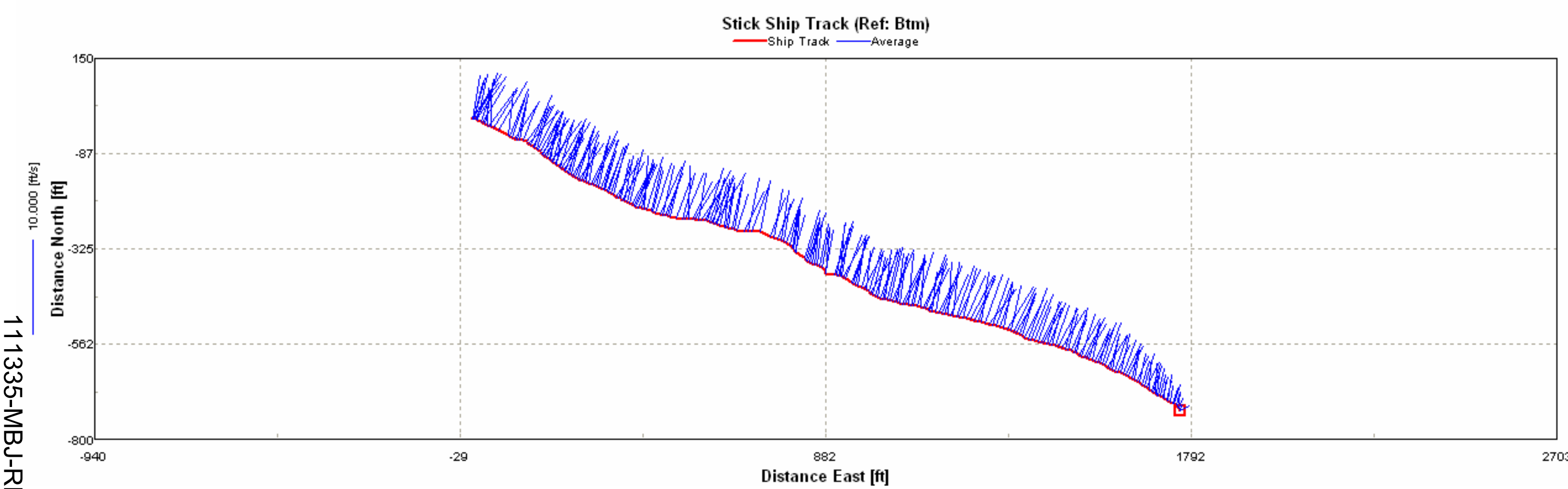
Monument 1 Upstream Colville River Discharge Transect 3, WinRiver Velocity and Ship Track Plots
June 6, 2007



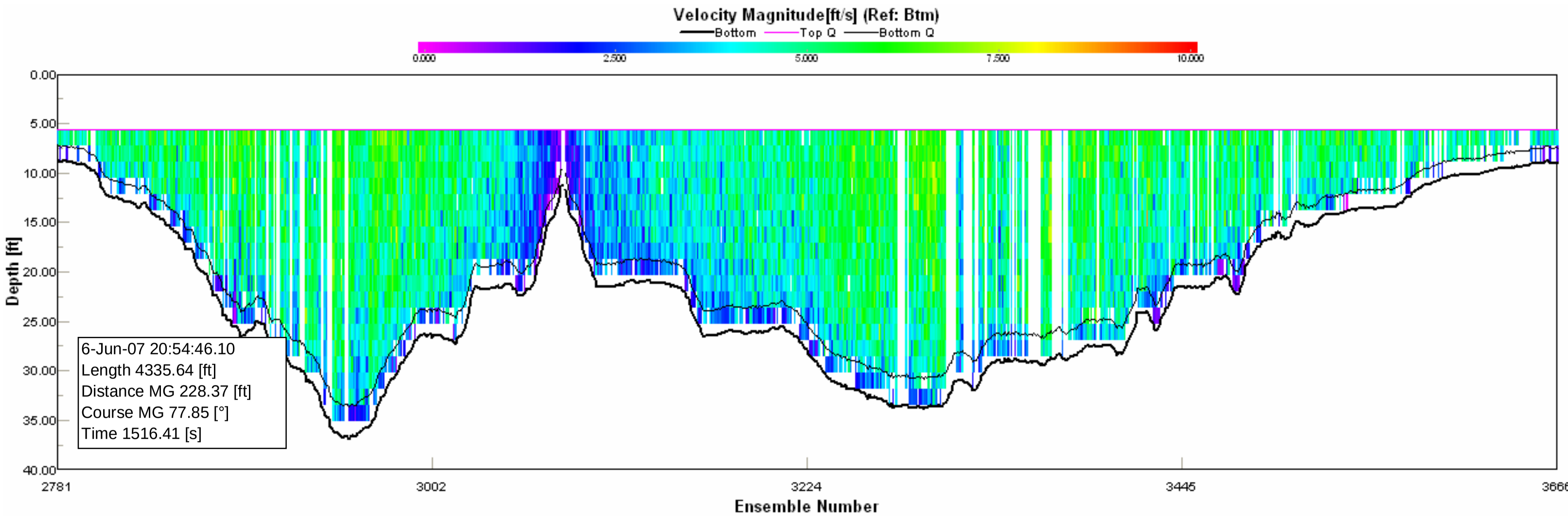


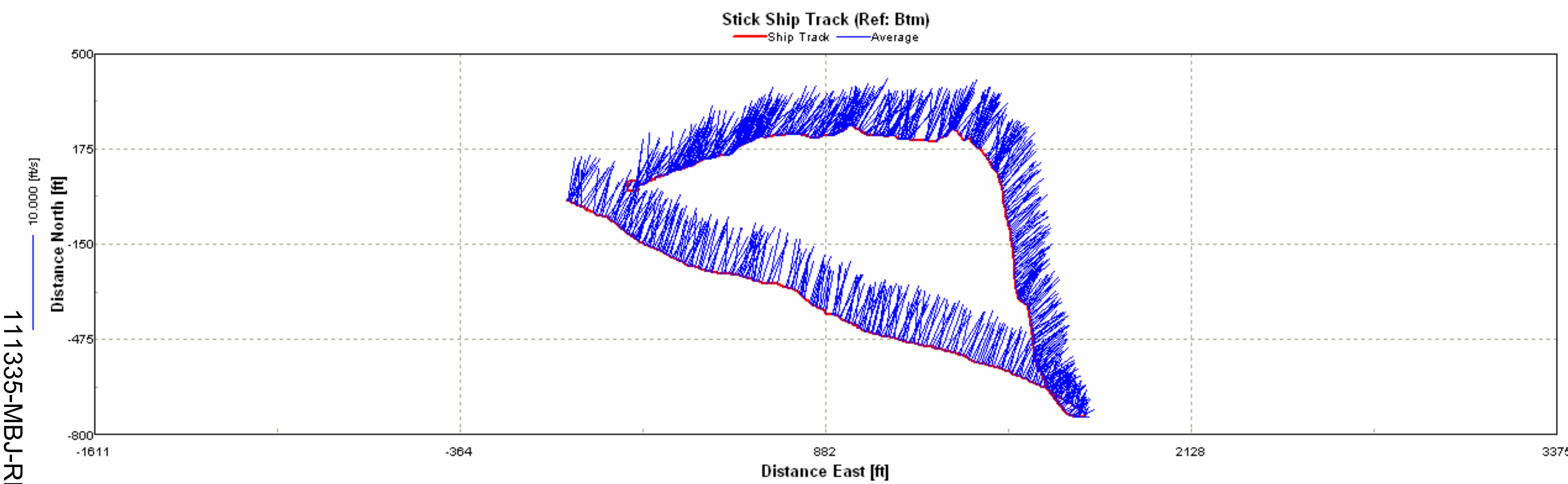
Monument 1 Upstream Colville River Discharge Transect 4, WinRiver Velocity and Ship Track Plots
June 6, 2007





Monument 1 Upstream Colville River Discharge Loop Test, WinRiver Velocity and Ship Track Plots
June 6, 2007





Station No.: Mon 1U | Meas. No: 4
Station Name: Monument 1 Upstream | Date: 06/07/2007

Party:	MDM & OOO	Width:	2,800 ft	Processed by:	MDM
Boat/Motor:	Achilles/25hp	Area:	45,000 ft²	Mean Velocity:	4.04 ft/s
Gage Height:	0.00 ft	G.H.Change:	0.00	Discharge:	182,000 ft³/s

Area Method:	Mean Flow	ADCP Depth:	1.75 ft	Index Vel.:	0.00 ft/s	Rating No.:	1
Nav. Method:	Bottom Track	Shore Ens.:	*1	Adj.Mean Vel:	0.00 ft/s	Qm Rating:	U
MagVar Method:	Model (22.9°)	Top Est:	Power (0.1667)	Rated Area:	0.000 ft²	% Diff:	0.0%
Depth Sounder:	Not Used	Bottom Est:	Power (0.1667)	Control:	Unspecified		

Screening Thresholds:				ADCP:			
BT 3-Beam Solution:	ON	Max. Vel.:	7.73 ft/s	Type/Freq.:	Workhorse / 600 kHz		
WT 3-Beam Solution:	OFF	Max. Depth:	41.9 ft	Serial #:	6882	Firmware:	16.28
BT Error Vel.:	0.33 ft/s	Mean Depth:	16.1 ft	Bin Size:	50 cm	Blank:	50 cm
WT Error Vel.:	4.92 ft/s	% Meas.:	62.68%	BT Mode:	5	BT Pings:	1
BT Up Vel.:	32.81 ft/s	Water Temp.:	None	WT Mode:	1	WT Pings:	1
WT Up Vel.:	32.81 ft/s	ADCP Temp.:	45.2 °F	WV:	170		

Diag. Test:
Moving Bed Test:
Compass Test:
Meas. Location: Colville River

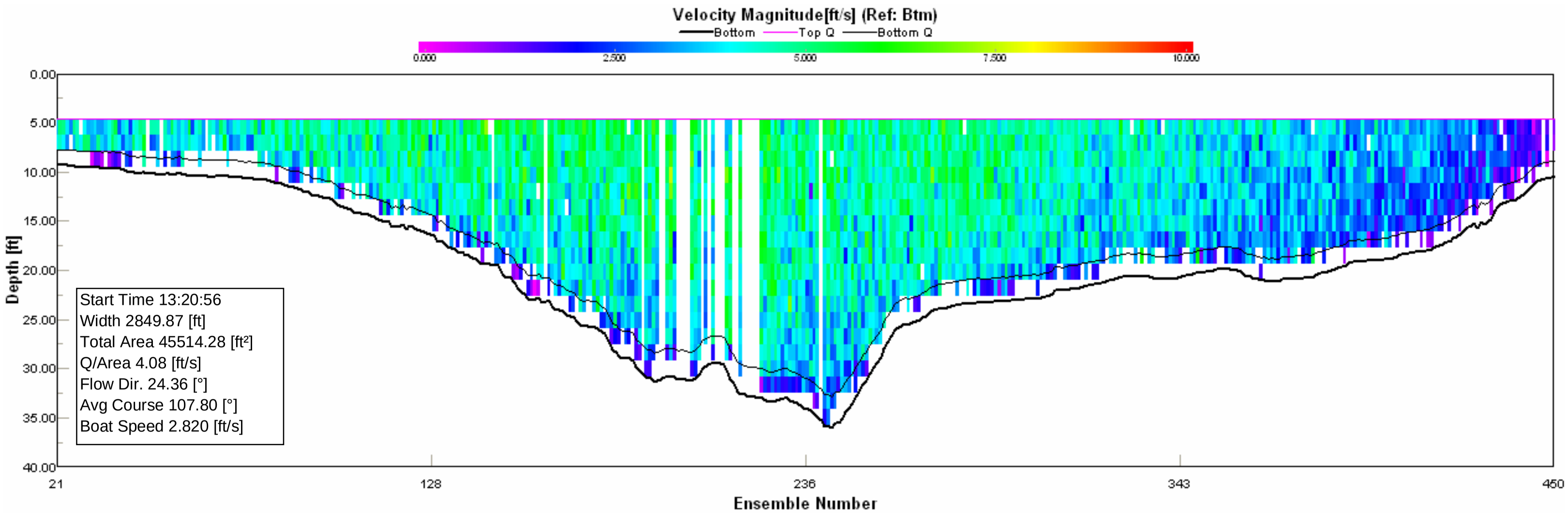
Filename Prefix: Colville_Monument1U2007(
Software: 1.06.00

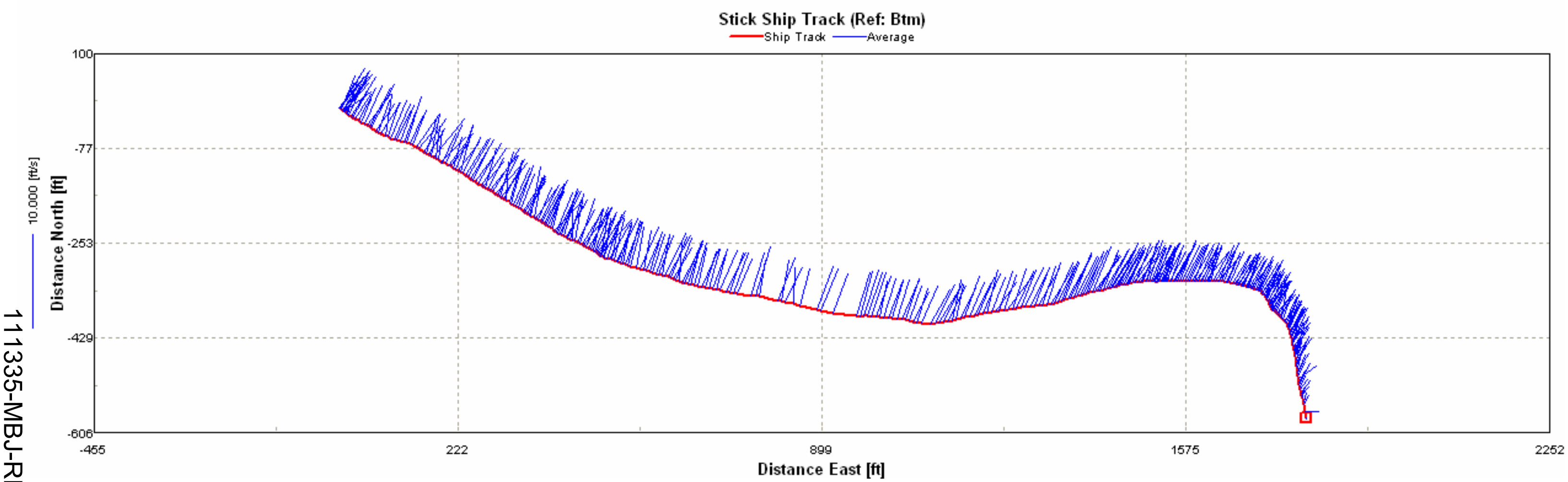
Tr.#		Edge D.		#Ens	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	949	25	430	40787	115824	18199	10771	-18.6	185562	2850	45514	13:20	13:33	2.82	4.08	7	1
000	R	944	46	577	37289	112668	16968	11997	155	179075	2732	44192	13:33	13:50	2.36	4.05	7	1
000	L	1018	59	340	37635	115792	16866	14748	189	185230	2792	45075	13:51	14:01	3.14	4.11	6	1
000	R	1035	51	421	36379	112264	16171	13526	140	178480	2824	45405	14:01	14:13	2.66	3.93	4	0
Mean		987	45	442	38022	114137	17051	12760	116	182087	2800	45047	**Total**	00:52	2.75	4.04	5	1
SDev		47	15	99	1918	1937	843	1740	92.2	3831	51	600			0.33	0.08		
R/M%		9	75	53.6	11.6	3.1	11.9	31.2	178.4	3.9	4.2	2.9			28.48	4.42		

Remarks:

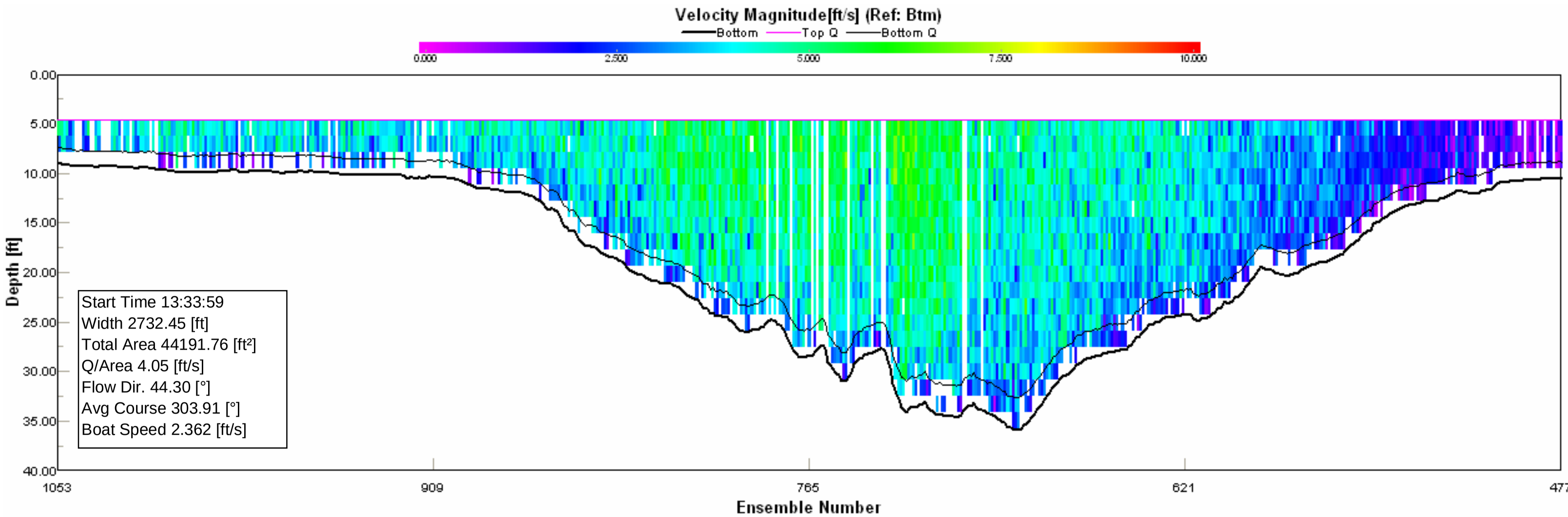
* - value not consistent for all transects

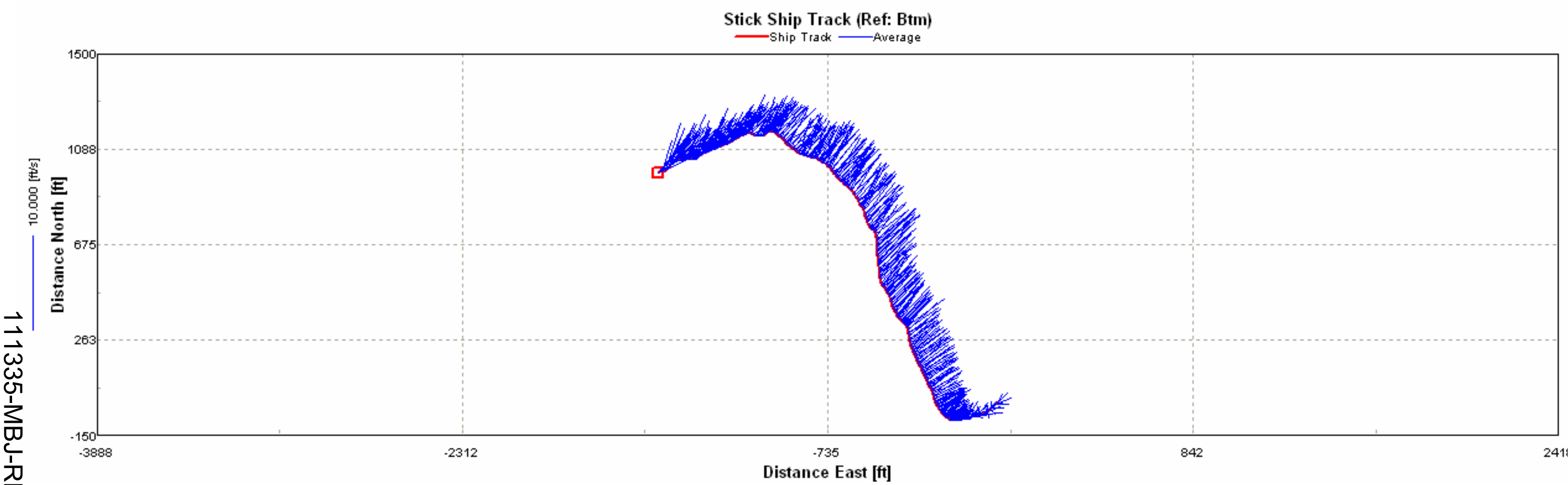
Monument 1 Upstream Colville River Discharge Transect 1, WinRiver Velocity and Ship Track Plots
June 7, 2007



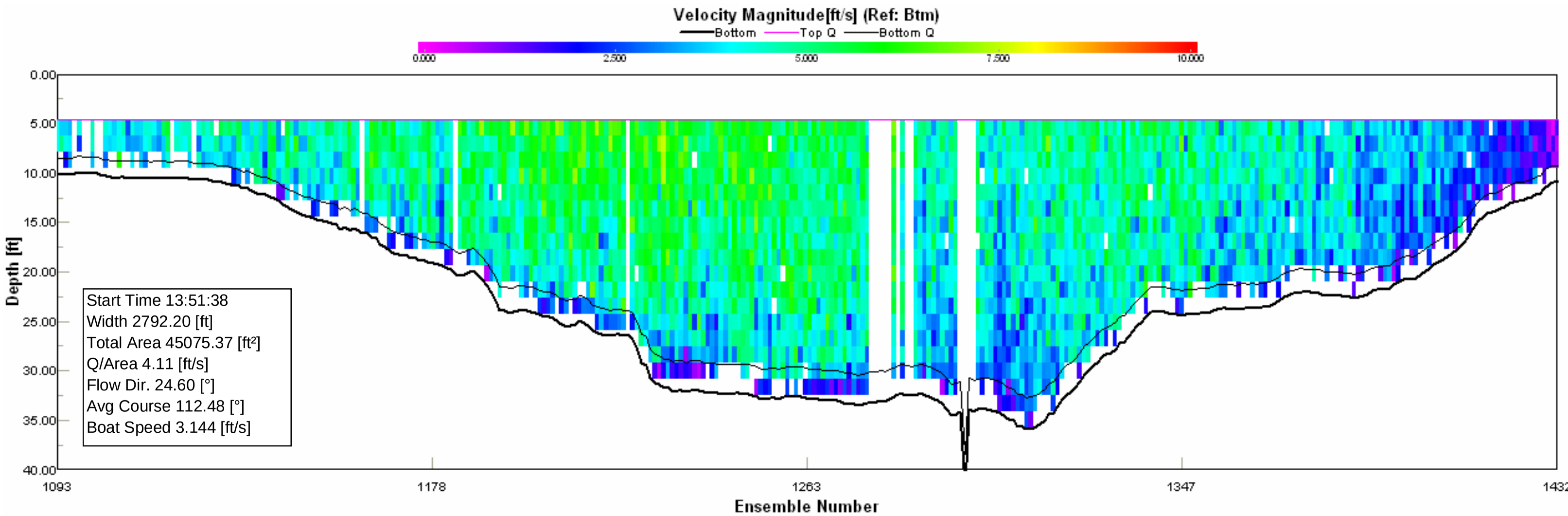


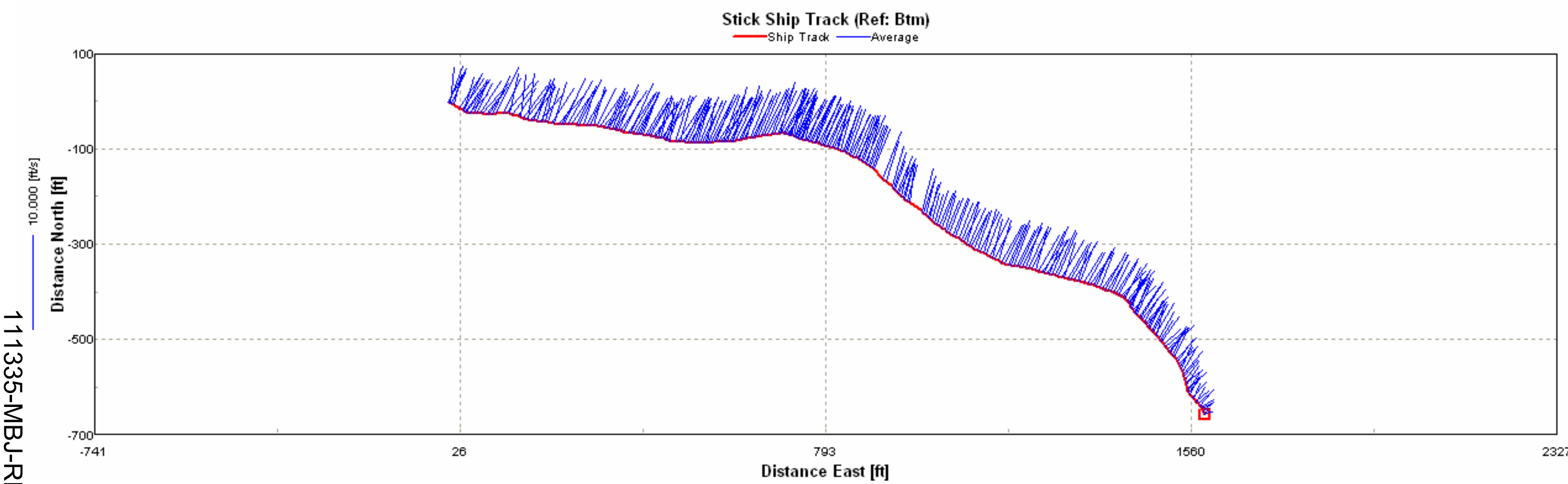
Monument 1 Upstream Colville River Discharge Transect 2, WinRiver Velocity and Ship Track Plots
June 7, 2007



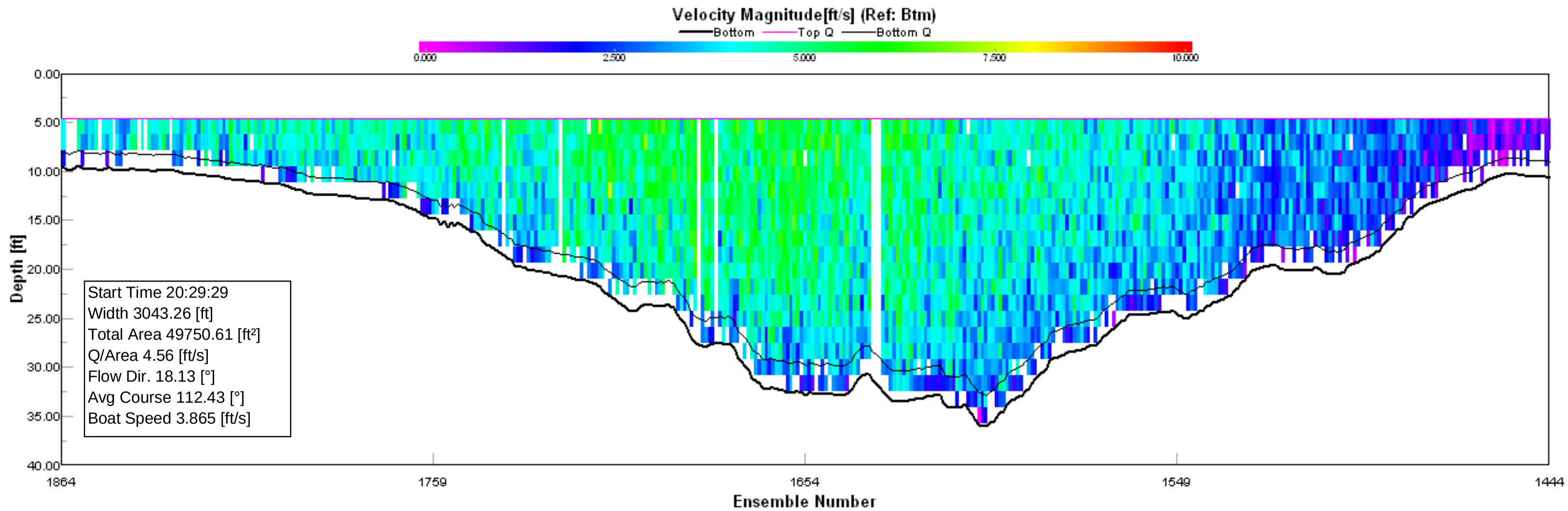


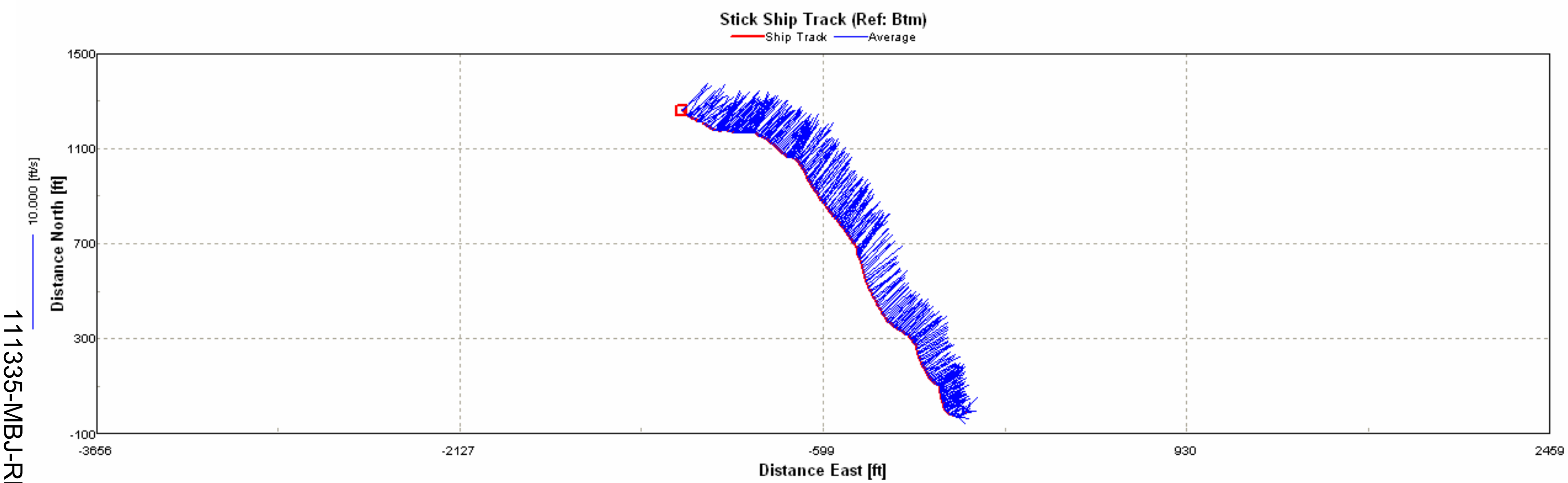
Monument 1 Upstream Colville River Discharge Transect 3, WinRiver Velocity and Ship Track Plots
June 7, 2007



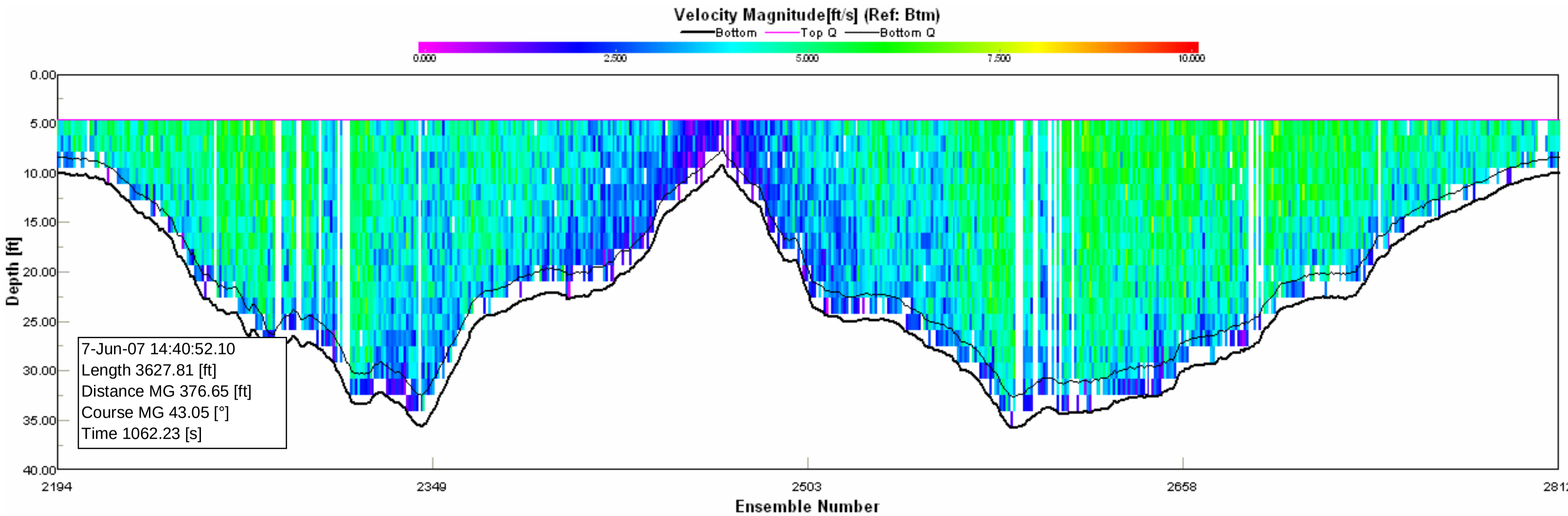


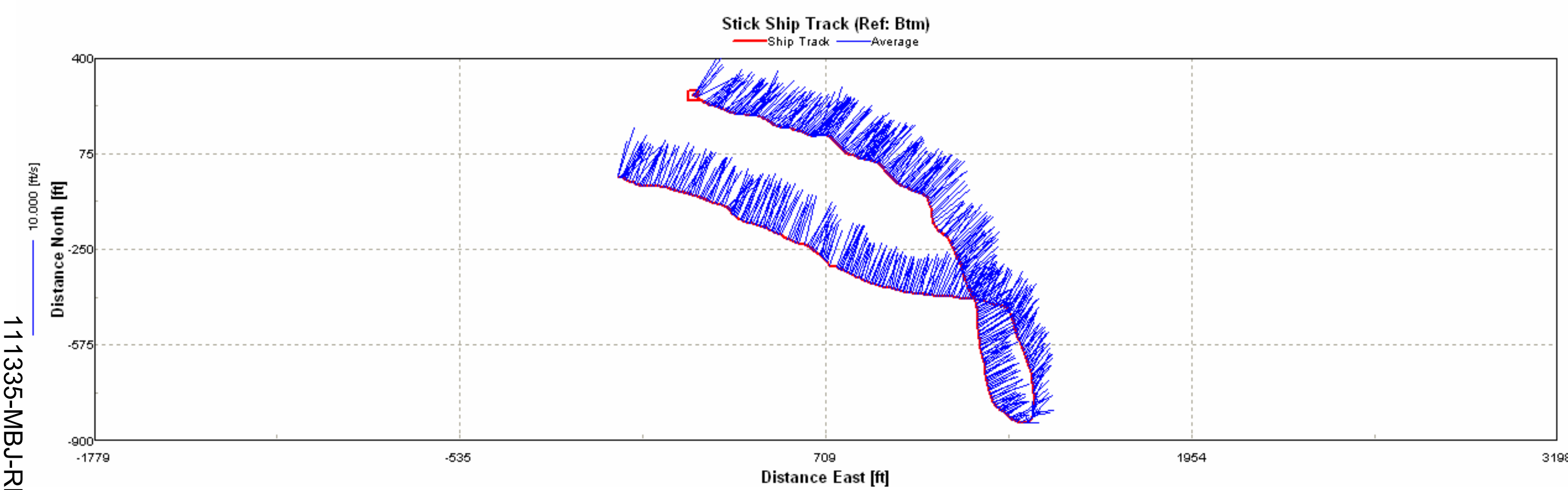
Monument 1 Upstream Colville River Discharge Transect 4, WinRiver Velocity and Ship Track Plots
June 7, 2007





Monument 1 Upstream Colville River Discharge Loop Test, WinRiver Velocity and Ship Track Plots
June 7, 2007





Nigliq Channel

Monument 23

Station No.: Mon 23 — Meas. No: 1

Station Name: Monument 23 — Date: 06/07/2007

Party:	MDM & OOO	Width:	1,080 ft	Processed by:	MDM
Boat/Motor:	Achilles/25hp	Area:	12,900 ft²	Mean Velocity:	2.78 ft/s
Gage Height:	0.00 ft	G.H.Change:	0.00	Discharge:	35,800 ft³/s

Area Method:	Mean Flow	ADCP Depth:	1.75 ft	Index Vel.:	0.00 ft/s	Rating No.:	1
Nav. Method:	Bottom Track	Shore Ens.:	*1	Adj.Mean Vel:	0.00 ft/s	Qm Rating:	U
MagVar Method:	Model (22.9°)	Top Est:	Power (0.1667)	Rated Area:	0.000 ft²	% Diff:	0.0%
Depth Sounder:	Not Used	Bottom Est:	Power (0.1667)	Control:	Unspecified		

Screening Thresholds:				ADCP:			
BT 3-Beam Solution:	ON	Max. Vel.:	7.13 ft/s	Type/Freq.:	Workhorse / 600 kHz		
WT 3-Beam Solution:	OFF	Max. Depth:	28.7 ft	Serial #:	6882	Firmware:	16.28
BT Error Vel.:	0.33 ft/s	Mean Depth:	11.9 ft	Bin Size:	50 cm	Blank:	25 cm
WT Error Vel.:	3.50 ft/s	% Meas.:	63.22%	BT Mode:	5	BT Pings:	1
BT Up Vel.:	1.00 ft/s	Water Temp.:	None	WT Mode:	1	WT Pings:	1
WT Up Vel.:	10.00 ft/s	ADCP Temp.:	45.7 °F	WV:	250		

Diag. Test:
Moving Bed Test:
Compass Test:
Meas. Location: Nigliq Channel

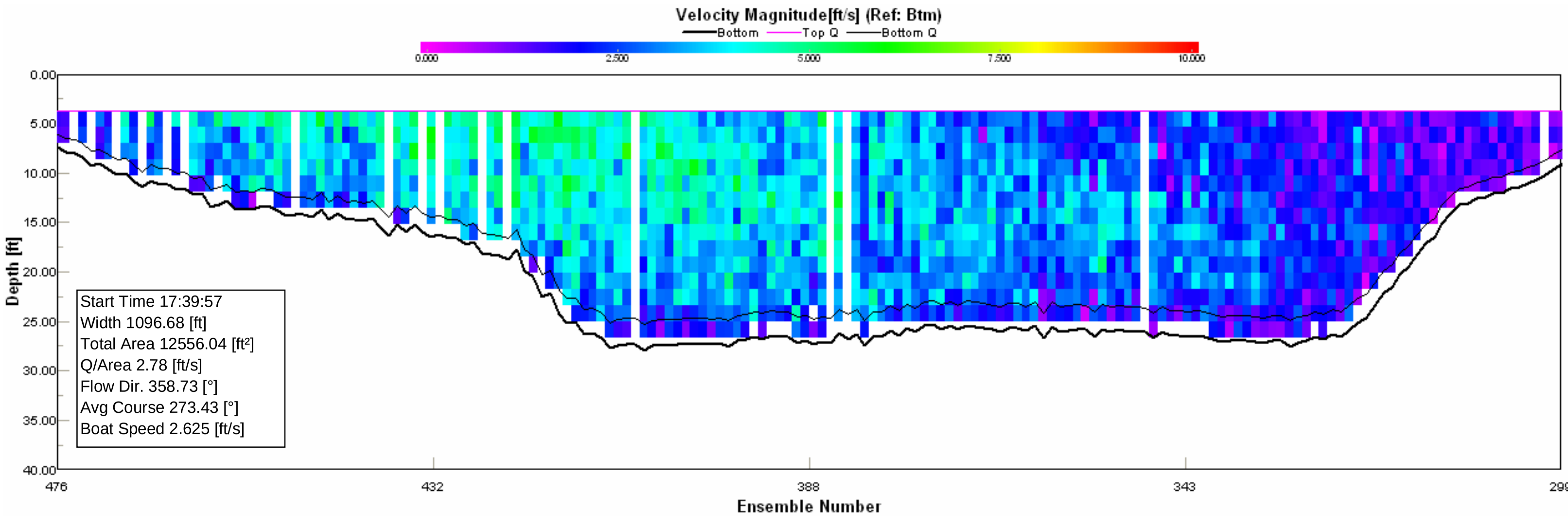
Filename Prefix: Nigliq_Monument23_20070
Software: 1.06.00

Tr.#		Edge D.		#Ens	Discharge						Width	Area	Time		Mean Vel.		% Bad		
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins	
000	R	29	586	178	6707	22466	3639	120	2032	34962	1097	12556	17:39	17:43	2.63	2.78	10	0	
000	L	63	520	225	6546	22217	3359	611	3780	36513	1050	13378	17:52	17:57	2.72	2.73	25	0	#
000	R	46	602	124	6670	22783	3524	520	1378	34875	1093	13053	18:07	18:09	3.58	2.67	10	0	
000	R	54	596	145	6743	23112	3577	514	2987	36932	1076	12555	18:16	18:19	3.17	2.94	6	0	
Mean		48	576	168	6666	22644	3525	441	2544	35821	1079	12885	**Total**	00:39	3.03	2.78	12	0	
SDev		14	38	44	85.6	388	120	219	1056	1056	21	403			0.44	0.12			
R/M%		71	14	60.1	3.0	4.0	7.9	111.5	94.4	5.7	4.3	6.4			31.61	9.70			

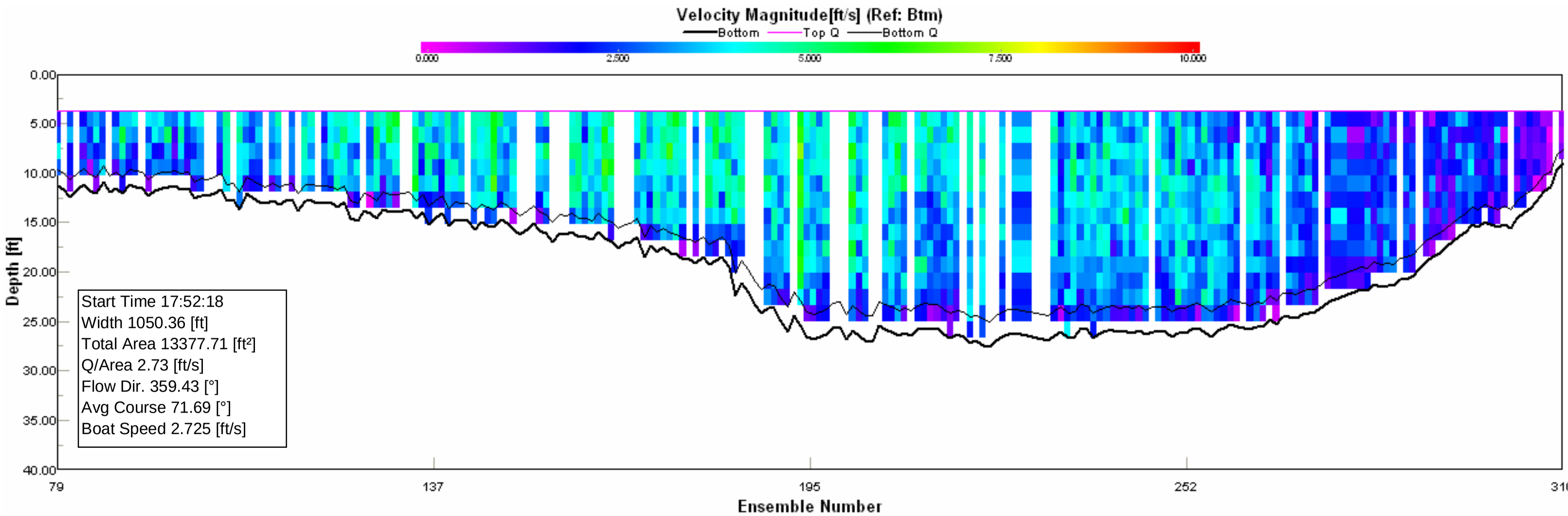
Remarks:

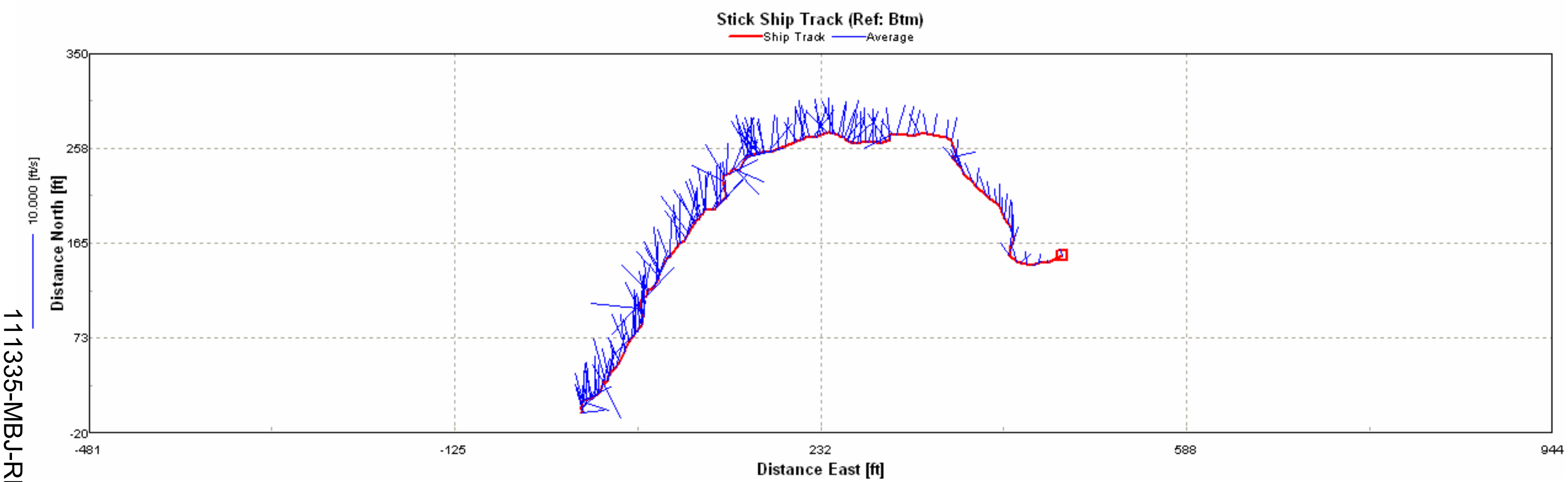
- transect has been subsectioned
* - value not consistent for all transects

Monument 23 Nigliq Channel Discharge Transect 1, WinRiver Velocity and Ship Track Plots
June 7, 2007

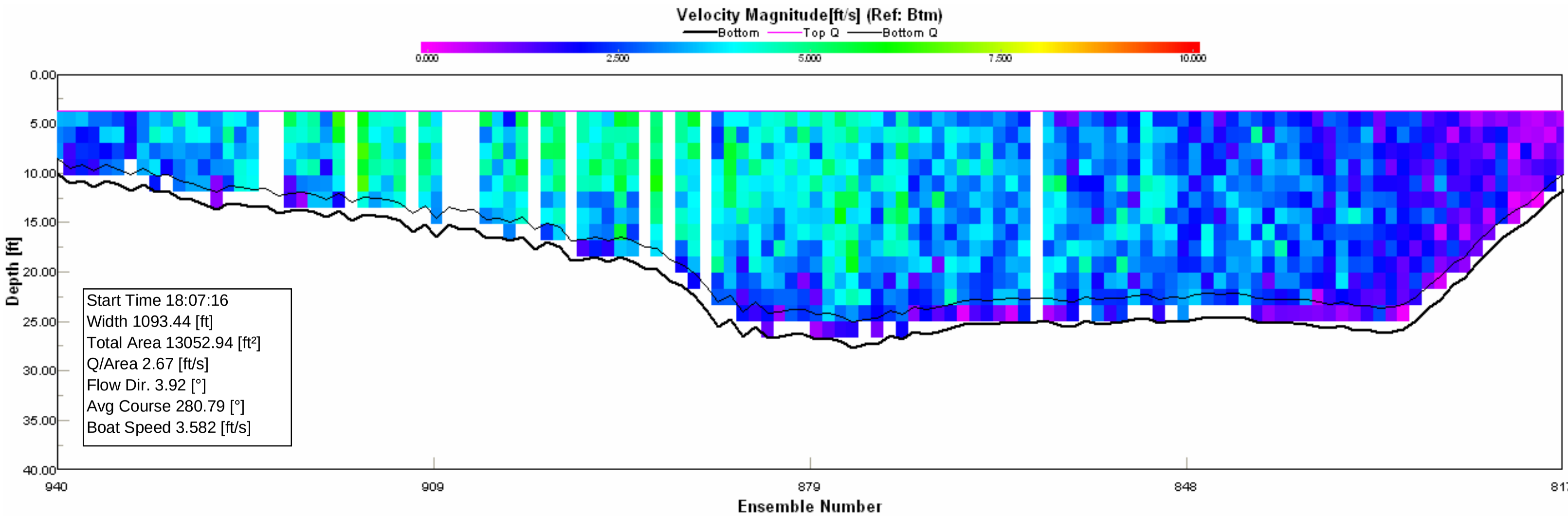


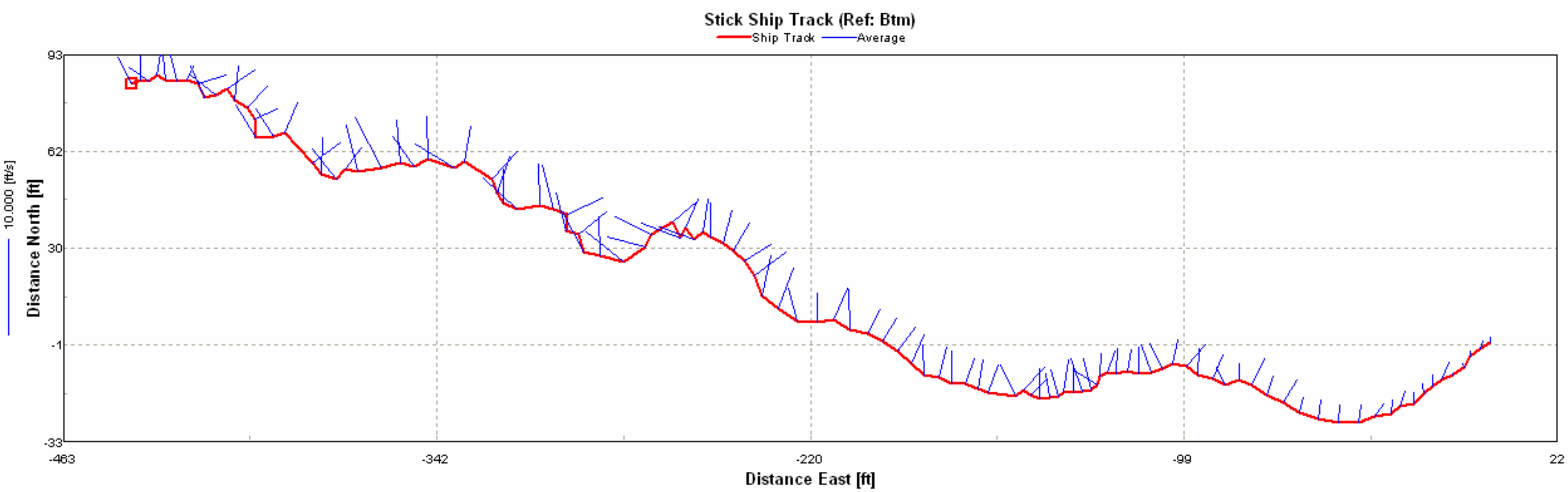
Monument 23 Nigliq Channel Discharge Transect 2, WinRiver Velocity and Ship Track Plots
June 7, 2007



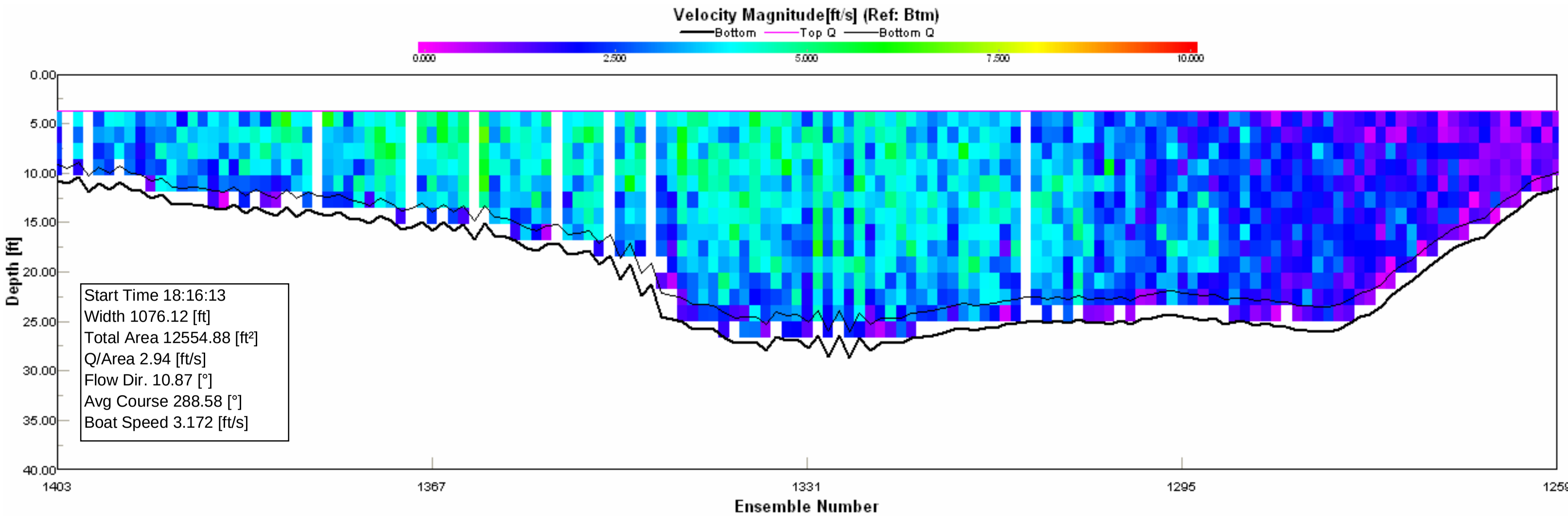


Monument 23 Nigliq Channel Discharge Transect 3, WinRiver Velocity and Ship Track Plots
June 7, 2007





Monument 23 Nigliq Channel Discharge Transect 4, WinRiver Velocity and Ship Track Plots
June 7, 2007



Appendix C Direct Discharge Results

Comp. By JPM
Check By OOO

Discharge Measurement Notes

Station No. ______ Start: 17:40 Finish: 18:32

452-foot Bridge at Swale at Alpine, AK

Date 6/5/2007 Party OOO, MDM, JPM

Width 447 ft Area 1670 sq ft Vel. 0.74 fps Disch. 1240 cfs

Method 0.6 No. Secs. 21 Count Variable

GAGE READINGS			
Gage	Start	Finish	Change
#3	7.80	7.71	-0.09
#4	7.72	7.68	-0.04

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter 1 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: Fairly uniform, firm, grass on bottom

Flow: Fairly steady Weather: Clear, Winds 15 - 25 mph

Other: Temp: 34°F

Gages: Staff gages #3 and #4

Remarks: channel clear of ice-snow. Control is large ponds downstream - section and tail water control.

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 5/31/2006

0.85

							VELOCITY				
Angle Coeff.	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	At Point (fps)	Mean in Vertical (fps)	Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW	0	1.0	3.00						0.60	3.00	1.80
0.80	2	12.5	4.00	6/10	25	41	1.37	1.37	1.10	50.00	54.91
0.82	25	24.0	4.00	6/10	30	45	1.50	1.50	1.23	96.00	118.01
0.82	50	25.0	3.30	6/10	25	48	1.18	1.18	0.96	82.50	79.49
0.80	75	25.0	3.50	6/10	20	46	0.98	0.98	0.79	87.50	68.88
0.82	100	25.0	3.60	6/10	20	51	0.89	0.89	0.73	90.00	65.63
0.84	125	25.0	3.60	6/10	15	40	0.85	0.85	0.71	90.00	64.34
0.84	150	25.0	3.80	6/10	15	40	0.85	0.85	0.71	95.00	67.92
0.86	175	25.0	3.70	6/10	15	40	0.85	0.85	0.73	92.50	67.70
0.90	200	25.0	3.60	6/10	20	53	0.86	0.86	0.77	90.00	69.38
0.90	225	25.0	3.60	6/10	15	46	0.74	0.74	0.67	90.00	60.15
0.92	250	25.0	4.10	6/10	15	50	0.68	0.68	0.63	102.50	64.54
0.92	275	25.0	4.20	6/10	10	45	0.51	0.51	0.47	105.00	49.21
0.87	300	25.0	3.90	6/10	15	44	0.78	0.78	0.67	97.50	65.77
0.88	325	25.0	3.80	6/10	10	41	0.56	0.56	0.49	95.00	46.59
0.92	350	25.0	3.60	2/10	15	49	0.70	0.70	0.64	90.00	57.81
0.96	375	25.0	3.70	8/10	15	44	0.78	0.78	0.74	92.50	68.86
0.99	400	25.0	3.80	6/10	15	45	0.76	0.76	0.75	95.00	71.34
0.98	425	22.5	3.70	6/10	15	40	0.85	0.85	0.83	83.25	69.44
0.75	445	11.0	4.00	6/10	20	52	0.87	0.87	0.65	44.00	28.79
REW	447	1.0	3.00						0.32	3.00	0.96
SUM		**447.0**								**1674.3**	**1241.5**
			Estimated values								

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. Start: 16:30 Finish: 17:23

62-foot Bridge at Swale at Alpine, AK

Date 6/5/2007 Party OOO, MDM, JPM

Width 55 ft Area 292 sq ft Vel. 1.18 fps Disch. 345 cfs

Method 0.6 No. Secs. 20 Count variable

GAGE READINGS			
Gage	Start	Finish	Change
#3	7.89	7.77	-0.12
#4	7.80	7.71	-0.09

Wading, cable, ice, boat

Upstrm or Dwnstrm side of bridge

Meter 1 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: Firm, fairly uniform

Flow: Falling stage, fairly steady

Weather: Clear, Winds 15 - 25 mph

Other: Variable horizontal angles

Temp: 40°F

Gages: Staff gages #3 & #4

Remarks: Channel clear of ice-snow. Control is large ponds downstream - section and tail water control.

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.75 OOO

Site/Date: 62-foot Bridge 6/5/2007

Angle Coeff.	Distance from initial point (ft)	Section Width	Water Depth	Observed Depth	Revolution Count	Time Increment 16:30	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area 0.7	Discharge (cfs)
LEW	8	1.5	3.00						0.84	4.50	3.78
0.80	11	3.0	4.00	6/10	30	40	1.68	1.68	1.35	12.00	16.17
0.95	14	3.0	4.00	6/10	15	41	0.83	0.83	0.79	12.00	9.47
0.96	17	3.0	4.20	6/10	20	42	1.08	1.08	1.03	12.60	13.01
0.96	20	3.0	4.70	6/10	40	44	2.04	2.04	1.96	14.10	27.58
0.96	23	3.0	4.70	6/10	30	43	1.57	1.57	1.51	14.10	21.22
0.97	26	3.0	5.20	6/10	30	40	1.68	1.68	1.63	15.60	25.49
0.98	29	3.0	5.90	6/10	30	48	1.41	1.41	1.38	17.70	24.40
0.99	32	3.0	5.80	6/10	20	49	0.92	0.92	0.92	17.40	15.93
1.00	35	3.0	5.30	6/10	30	53	1.28	1.28	1.28	15.90	20.28
1.00	38	3.0	5.50	6/10	30	50	1.35	1.35	1.35	16.50	22.29
1.00	41	3.0	5.60	6/10	25	43	1.31	1.31	1.31	16.80	22.00
1.00	44	3.0	6.30	6/10	30	47	1.44	1.44	1.44	18.90	27.14
0.99	47	3.0	6.40	6/10	25	49	1.15	1.15	1.14	19.20	21.89
0.96	50	3.0	5.50	6/10	20	48	0.94	0.94	0.91	16.50	14.95
0.85	53	3.0	6.10	6/10	25	42	1.34	1.34	1.14	18.30	20.85
0.85	56	3.0	5.50	6/10	25	40	1.41	1.41	1.20	16.50	19.73
0.82	59	3.0	5.80	6/10	25	42	1.34	1.34	1.10	17.40	19.12
0.20	62	2.0	6.40	6/10	0	40	0.00			12.80	0.00
REW	63	0.5	6.00		0	40	0.00			3.00	0.00
SUM		**55.0**								**291.80**	**345.30**
			Estimated values								

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 Snow Survey Field Sheets

Snow Survey Data Sheet

Date:	5/10/2007	Start Time:	8:13	End Time:	11:15	Observers:	MDM, OOO
Catchement Basin:	L9310	Driving Wrench Used:	Yes			Tube Section Used:	1

Snow Sample No.	Sample Type	Terrain Type	Snow Depth (in)		Core Length (in)	Tube & Core Weight (lb)	Empty Tube Weight (lb)	Water Equivalent (in)	Density (lb/in^3)
			w/ Dirt Plug	w/o Dirt Plug					
SS1*	Core	Lake	—	5.2	—	2.18	1.96	0.59	0.004
SS2*	Core	Tundra	—	9.4	—	2.28	1.96	1.07	0.004
SS3*	Core	Lake	—	5.0	—	2.24	1.98	0.69	0.005
SS4	Core	Tundra	18.5	17.3	—	2.28	1.98	4.01	0.008
SS5*	Core	Lake	—	4.3	—	2.22	1.98	0.64	0.005
SS6	Core	Tundra	20.5	18.0	—	3.08	2.74	4.54	0.009
SS7*	Core	Lake	—	5.0	—	2.20	2.00	0.53	0.004
SS8*	Core	Tundra	—	10.2	—	2.30	1.94	1.20	0.004
SS9*	Core	Lake	—	4.5	—	2.14	1.98	0.43	0.003
SS10*	Core	Tundra	—	16.2	—	2.58	1.98	2.00	0.004
SS11*	Core	Lake	—	5.0	—	2.16	1.96	0.67	0.005
SS12*	Core	Tundra	—	10.8	—	2.56	1.84	2.40	0.008
SS13	Depth	Lake	—	6.0					
SS14	Depth	Lake	—	7.1					
SS15	Depth	Lake	—	4.8					
SS16	Depth	Lake	—	5.0					
SS17	Depth	Tundra	—	10.8					
SS18	Depth	Lake	—	6.2					
SS19	Depth	Tundra	—	14.8					
SS20	Depth	Lake	—	5.5					
SS21	Depth	Lake	—	7.8					
SS22	Depth	Lake	—	7.2					
SS23	Depth	Lake	—	5.8					
SS24	Depth	Tundra	—	7.2					
SS25	Depth	Tundra	—	12.0					
SS26	Depth	Tundra	—	16.3					
SS27	Depth	Tundra	—	7.8					
SS28	Depth	Tundra	—	15.8					
SS29	Depth	Lake	—	4.2					
SS30	Depth	Lake	—	5.8					
SS31	Depth	Lake	—	4.8					
SS32	Depth	Lake	—	5.4					
SS33	Depth	Lake	—	4.2					
SS34	Depth	Lake	—	7.2					
SS35	Depth	Tundra	—	12.0					
SS36	Depth	Tundra	—	11.4					
SS37	Depth	Tundra	—	19.4					
SS38	Depth	Tundra	—	21.6					
SS39	Depth	Lake	—	4.2					
SS40	Depth	Lake	—	5.5					
SS41	Depth	Lake	—	4.8					
SS42	Depth	Lake	—	8.4					
SS43	Depth	Lake	—	4.8					
SS44	Depth	Tundra	—	10.8					
SS45	Depth	Tundra	—	13.8					
SS46	Depth	Lake	—	7.2					

Snow Survey Calculations

Average Area:	Tundra =	2516717	ft^2
	Lake =	2874091	ft^2
Average SWE:	Tundra =	2.38	in
	Lake =	0.69	in
Average Snow Depth:	Tundra =	13.46	in
	Lake =	5.59	in
Average Density:	Tundra =	0.006	lb/in^3
	Lake =	0.004	lb/in^3
Catchement Basin Weighted SWE =		1.48	in

NOTES:

* Pooled sample measurement conducted, snow depth without dirt plug, SWE, and density represents the average of pooled samples.

Pooled Snow Survey Data Sheet									
Date: 5/10/2007			**Start Time:** 8:13		**End Time:** 11:15		**Observers:** MDM, OOO		
Catchement Basin: L9310			**Driving Wrench Used:** Yes				**Tube Section Used:** 1		
Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Core Length (in)**	**Bucket & Core Weight (lb)**	**Empty Bucket Weight (lb)**	**Water Equivalent (in)**	**Density (lb/in^3)**
			w/ Dirt Plug	**w/o Dirt Plug**					
SS1	1	Tundra	—	5.0	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.5	—	—	—	—	—
	4	Lake	—	5.5	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**26.0**		2.18	**0.22**	—	—
			Average =	**5.2**			**0.04**	0.59	0.004
SS2	1	Tundra	11.0	9.0	—	—	1.96	—	—
	2	Tundra	12.0	10.5	—	—	—	—	—
	3	Tundra	11.0	9.5	—	—	—	—	—
	4	Tundra	11.0	8.5	—	—	—	—	—
			Sum =	**37.5**		2.28	**0.32**	—	—
			Average =	**9.4**			**0.08**	1.07	0.004
SS3	1	Lake	—	5.0	—	—	1.98	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**25.0**		2.24	**0.26**	0.69	0.005
			Average =	**5.0**			**0.05**		
SS5	1	Lake	—	4.0	—	—	1.98	—	—
	2	Lake	—	4.0	—	—	—	—	—
	3	Lake	—	4.4	—	—	—	—	—
	4	Lake	—	4.4	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**21.3**		2.22	**0.24**	—	—
			Average =	**4.3**			**0.05**	0.64	0.005
SS7	1	Lake	—	5.2	—	—	2.00	—	—
	2	Lake	—	4.8	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	4.9	—	—	—	—	—
	5	Lake	—	4.9	—	—	—	—	—
			Sum =	**24.8**		2.20	**0.20**	—	—
			Average =	**5.0**			**0.04**	0.53	0.004
SS8	1	Tundra	12.0	11.1	—	—	1.94	—	—
	2	Tundra	12.5	7.0	—	—	—	—	—
	3	Tundra	12.5	10.5	—	—	—	—	—
	4	Tundra	12.5	12.0	—	—	—	—	—
			Sum =	**40.6**		2.30	**0.36**	—	—
			Average =	**10.2**			**0.09**	1.20	0.004
SS9	1	Lake	—	4.5	—	—	1.98	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	4.5	—	—	—	—	—
	4	Lake	—	4.5	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**22.5**		2.14	**0.16**	—	—
			Average =	**4.5**			**0.03**	0.43	0.003
SS10	1	Tundra	17.0	15.8	—	—	1.98	—	—
	2	Tundra	17.0	16.5	—	—	—	—	—
	3	Tundra	18.0	16.5	—	—	—	—	—
	4	Tundra	17.5	16.0	—	—	—	—	—
			Sum =	**64.8**		2.58	**0.60**	—	—
			Average =	**16.2**			**0.15**	2.00	0.004
SS11	1	Lake	—	5.0	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
			Sum =	**20.0**		2.16	**0.20**	—	—
			Average =	**5.0**			**0.05**	0.67	0.005
SS12	1	Tundra	—	9.8	—	—	1.84	—	—
	2	Tundra	—	9.9	—	—	—	—	—
	3	Tundra	12.0	10.0	—	—	—	—	—
	4	Tundra	15.0	13.5	—	—	—	—	—
			Sum =	**43.2**		2.56	**0.72**	—	—
			Average =	**10.8**			**0.18**	2.40	0.008

Snow Sample #	Catchement Basin	Sample Type	Lat. (NAD 83)	Long. (NAD 83)
SS1	L9310	Core	N 70° 19' 48.16"	W 150° 55' 29.17"
SS2	L9310	Core	N 70° 19' 45.20"	W 150° 55' 21.51"
SS3	L9310	Core	N 70° 19' 54.42"	W 150° 55' 14.34"
SS4	L9310	Core	N 70° 19' 59.21"	W 150° 54' 55.73"
SS5	L9310	Core	N 70° 19' 55.07"	W 150° 55' 25.78"
SS6	L9310	Core	N 70° 20' 04.04"	W 150° 55' 13.85"
SS7	L9310	Core	N 70° 19' 51.0"	W 150° 55' 37.22"
SS8	L9310	Core	N 70° 19' 53.71"	W 150° 55' 45.77"
SS9	L9310	Core	N 70° 19' 42.33"	W 150° 55' 41.26"
SS10	L9310	Core	N 70° 19' 31.30"	W 150° 55' 53.88"
SS11	L9310	Core	N 70° 19' 47.06"	W 150° 55' 48.65"
SS12	L9310	Core	N 70° 19' 42.74"	W 150° 56' 14.87"
SS13	L9310	Depth	N 70° 19' 49.66"	W 150° 55' 32.95"
SS14	L9310	Depth	N 70° 19' 50.87"	W 150° 55' 28.32"
SS15	L9310	Depth	N 70° 19' 52.04"	W 150° 55' 23.60"
SS16	L9310	Depth	N 70° 19' 53.24"	W 150° 55' 18.97"
SS17	L9310	Depth	N 70° 19' 55.63"	W 150° 55' 09.71"
SS18	L9310	Depth	N 70° 19' 56.83"	W 150° 55' 05.08"
SS19	L9310	Depth	N 70° 19' 58.0"	W 150° 55' 00.36"
SS20	L9310	Depth	N 70° 19' 51.47"	W 150° 55' 30.56"
SS21	L9310	Depth	N 70° 19' 53.25"	W 150° 55' 28.17"
SS22	L9310	Depth	N 70° 19' 56.85"	W 150° 55' 23.40"
SS23	L9310	Depth	N 70° 19' 58.66"	W 150° 55' 21.01"
SS24	L9310	Depth	N 70° 20' 00.44"	W 150° 55' 18.62"
SS25	L9310	Depth	N 70° 20' 02.26"	W 150° 55' 16.23"
SS26	L9310	Depth	N 70° 20' 05.82"	W 150° 55' 11.46"
SS27	L9310	Depth	N 70° 19' 46.63"	W 150° 55' 25.20"
SS28	L9310	Depth	N 70° 19' 43.70"	W 150° 55' 17.73"
SS29	L9310	Depth	N 70° 19' 47.84"	W 150° 55' 35.05"
SS30	L9310	Depth	N 70° 19' 45.99"	W 150° 55' 37.15"
SS31	L9310	Depth	N 70° 19' 44.18"	W 150° 55' 39.16"
SS32	L9310	Depth	N 70° 19' 40.48"	W 150° 55' 43.37"
SS33	L9310	Depth	N 70° 19' 38.66"	W 150° 55' 45.47"
SS34	L9310	Depth	N 70° 19' 36.81"	W 150° 55' 47.57"
SS35	L9310	Depth	N 70° 19' 34.96"	W 150° 55' 49.68"
SS36	L9310	Depth	N 70° 19' 33.15"	W 150° 55' 51.78"
SS37	L9310	Depth	N 70° 19' 29.48"	W 150° 55' 55.89"
SS38	L9310	Depth	N 70° 19' 27.63"	W 150° 55' 57.99"
SS39	L9310	Depth	N 70° 19' 48.82"	W 150° 55' 38.21"
SS40	L9310	Depth	N 70° 19' 47.94"	W 150° 55' 43.38"
SS41	L9310	Depth	N 70° 19' 46.22"	W 150° 55' 53.91"
SS42	L9310	Depth	N 70° 19' 45.34"	W 150° 55' 59.17"
SS43	L9310	Depth	N 70° 19' 44.46"	W 150° 56' 04.44"
SS44	L9310	Depth	N 70° 19' 43.62"	W 150° 56' 09.61"
SS45	L9310	Depth	N 70° 19' 41.87"	W 150° 56' 20.14"
SS46	L9310	Depth	N 70° 19' 52.37"	W 150° 55' 41.49"

Snow Survey Data Sheet

Date: 5/10/2007 | **Start Time:** 13:00 | **End Time:** 15:30 | **Observers:** MDM, OOO

Catchement Basin: L9312 | **Driving Wrench Used:** Yes | **Tube Section Used:** 1

Snow Sample No.	Sample Type	Terrain Type	Snow Depth (in)		Core Length (in)	Tube & Core Weight (lb)	Empty Tube Weight (lb)	Water Equivalent (in)	Density (lb/in^3)
			w/ Dirt Plug	w/o Dirt Plug					
SS47*	Core	Tundra	—	12.5	—	2.9	1.98	3.07	0.009
SS48*	Core	Lake	—	5.0	—	2.24	1.98	0.69	0.005
SS49*	Core	Tundra	—	11.1	—	2.24	1.96	0.93	0.003
SS50*	Core	Lake	—	4.7	—	2.26	1.96	0.80	0.006
SS51*	Core	Lake	—	8.0	—	2.68	1.96	1.92	0.009
SS52	Core	Tundra	15.5	13.5	—	2.12	1.96	2.14	0.006
SS53	Core	Tundra	17.2	14.2	—	2.22	1.98	3.20	0.008
SS54*	Core	Lake	—	7.2	—	2.74	1.96	2.08	0.010
SS55*	Core	Lake	—	4.0	—	2.14	1.96	0.48	0.004
SS56*	Core	Lake	—	4.1	—	2.3	1.96	0.91	0.008
SS57	Core	Tundra	17.2	16.7	—	2.3	1.98	4.27	0.009
SS58*	Core	Tundra	—	8.9	—	2.26	1.98	0.93	0.004
SS59	Core	Tundra	16.0	15.0	—	2.22	1.98	3.20	0.008
SS60*	Core	Tundra	—	12.4	—	2.56	1.98	1.94	0.006
SS61	Depth	Lake	—	8.4					
SS62	Depth	Lake	—	5.4					
SS63	Depth	Tundra	—	15.0					
SS64	Depth	Tundra	—	10.8					
SS65	Depth	Lake	—	9.6					
SS66	Depth	Lake	—	4.8					
SS67	Depth	Lake	—	3.8					
SS68	Depth	Lake	—	5.8					
SS69	Depth	Lake	—	4.8					
SS70	Depth	Lake	—	4.8					
SS71	Depth	Lake	—	5.0					
SS72	Depth	Lake	—	5.3					
SS73	Depth	Lake	—	7.0					
SS74	Depth	Lake	—	4.0					
SS75	Depth	Lake	—	4.8					
SS76	Depth	Lake	—	3.6					
SS77	Depth	Tundra	—	11.0					
SS78	Depth	Tundra	—	19.0					
SS79	Depth	Tundra	—	8.6					
SS80	Depth	Tundra	—	15.6					
SS81	Depth	Tundra	—	19.0					
SS82	Depth	Tundra	—	26.4					
SS83	Depth	Lake	—	4.6					
SS84	Depth	Lake	—	3.6					
SS85	Depth	Lake	—	4.8					
SS86	Depth	Tundra	—	7.4					
SS87	Depth	Tundra	—	4.8					
SS88	Depth	Lake	—	6.0					
SS89	Depth	Lake	—	4.1					
SS90	Depth	Tundra	—	6.0					
SS91	Depth	Tundra	—	9.6					
SS92	Depth	Lake	—	4.1					
SS93	Depth	Lake	—	3.8					
SS94	Depth	Lake	—	3.6					
SS95	Depth	Lake	—	5.4					
SS96	Depth	Lake	—	7.4					
SS97	Depth	Lake	—	8.3					
SS98	Depth	Tundra	—	13.2					
SS99	Depth	Tundra	—	13.2					
SS100	Depth	Tundra	—	10.8					
SS101	Depth	Tundra	—	9.6					
SS102	Depth	Tundra	—	8.4					
SS103	Depth	Tundra	—	13.6					
SS104	Depth	Tundra	—	5.4					

Snow Survey Calculations

Average Area: Tundra = 4943536 ft^2; Lake = 4860982 ft^2

Average SWE: Tundra = 2.22 in; Lake = 1.05 in

Average Snow Depth: Tundra = 12.3 in; Lake = 5.3 in

Average Density: Tundra = 0.007 lb/in^3; Lake = 0.007 lb/in^3

Catchement Basin Weighted SWE = 1.64 in

NOTES:

* Pooled sample measurement conducted, snow depth without dirt plug, SWE, and density represents the average of pooled samples.

Pooled Snow Survey Data Sheet									
Date:	5/10/2007		**Start Time:**	13:00	**End Time:**	15:30	**Observers:**	MDM, OOO	
Catchement Basin:		L9312	**Driving Wrench Used:**		Yes		**Tube Section Used:**		1
Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Core Length (in)**	**Bucket & Core Weight (lb)**	**Empty Bucket Weight (lb)**	**Water Equivalent (in)**	**Density (lb/in^3)**
			w/ Dirt Plug	**w/o Dirt Plug**					
SS47	1	Tundra	14	12.5	—	—	1.98	—	—
	2	Tundra	14	13.0	—	—	—	—	—
	3	Tundra	13.5	13.5	—	—	—	—	—
	4	Tundra	13	11.0	—	—	—	—	—
			Sum =	**50.0**		2.9	**0.92**	—	—
			Average =	**12.5**			**0.23**	3.07	0.009
SS48	1	Lake	—	4.8	—	—	1.98	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**24.8**		2.24	**0.26**	—	—
			Average =	**5.0**			**0.05**	0.69	0.005
SS49	1	Tundra	14	11.7	—	—	1.96	—	—
	2	Tundra	13.5	11.0	—	—	—	—	—
	3	Tundra	13	10.5	—	—	—	—	—
	4	Tundra	13	11.0	—	—	—	—	—
			Sum =	**44.2**		2.24	**0.28**	—	—
			Average =	**11.1**			**0.07**	0.93	0.003
SS50	1	Lake	—	4.8	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	4.6	—	—	—	—	—
	4	Lake	—	4.6	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**23.5**		2.26	**0.3**	—	—
			Average =	**4.7**			**0.06**	0.80	0.006
SS51	1	Lake	—	8.0	—	—	1.96	—	—
	2	Lake	—	8.0	—	—	—	—	—
	3	Lake	—	8.0	—	—	—	—	—
	4	Lake	—	8.0	—	—	—	—	—
	5	Lake	—	8.0	—	—	—	—	—
			Sum =	**40.0**		2.68	**0.72**	—	—
			Average =	**8.0**			**0.14**	1.92	0.009
SS54	1	Lake	—	7.0	—	—	1.96	—	—
	2	Lake	—	7.5	—	—	—	—	—
	3	Lake	—	7.5	—	—	—	—	—
	4	Lake	—	7.0	—	—	—	—	—
	5	Lake	—	7.0	—	—	—	—	—
			Sum =	**36.0**		2.74	**0.78**	—	—
			Average =	**7.2**			**0.16**	2.08	0.010
SS55	1	Lake	—	4.0	—	—	1.96	—	—
	2	Lake	—	4.0	—	—	—	—	—
	3	Lake	—	4.0	—	—	—	—	—
	4	Lake	—	4.0	—	—	—	—	—
	5	Lake	—	4.0	—	—	—	—	—
			Sum =	**20.0**		2.14	**0.18**	—	—
			Average =	**4.0**			**0.04**	0.48	0.004
SS56	1	Lake	—	4.0	—	—	1.96	—	—
	2	Lake	—	4.0	—	—	—	—	—
	3	Lake	—	4.2	—	—	—	—	—
	4	Lake	—	4.2	—	—	—	—	—
	5	Lake	—	4.2	—	—	—	—	—
			Sum =	**20.6**		2.3	**0.34**	—	—
			Average =	**4.1**			**0.07**	0.91	0.008
SS58	1	Tundra	11.5	9.0	—	—	1.98	—	—
	2	Tundra	11	9.0	—	—	—	—	—
	3	Tundra	11	9.0	—	—	—	—	—
	4	Tundra	11	8.5	—	—	—	—	—
			Sum =	**35.5**		2.26	**0.28**	—	—
			Average =	**8.9**			**0.07**	0.93	0.004
SS60	1	Tundra	12	11.0	—	—	1.98	—	—
	2	Tundra	13.5	13.0	—	—	—	—	—
	3	Tundra	13.5	12.5	—	—	—	—	—
	4	Tundra	13.6	13.0	—	—	—	—	—
			Sum =	**49.5**		2.56	**0.58**	—	—
			Average =	**12.4**			**0.15**	1.94	0.006

Snow Sample #	Catchement Basin	Sample Type	Lat. (NAD 83)	Long. (NAD 83)
SS47	L9312	Core	N 70° 20' 03.02"	W 150° 56' 11.68"
SS48	L9312	Core	N 70° 19' 58.24"	W 150° 56' 37.19"
SS49	L9312	Core	N 70° 19' 50.13"	W 150° 56' 31.39"
SS50	L9312	Core	N 70° 19' 52.70"	W 150° 56' 47.14"
SS51	L9312	Core	N 70° 19' 58.38"	W 150° 56' 57.60"
SS52	L9312	Core	N 70° 20' 04.26"	W 150° 56' 57.58"
SS53	L9312	Core	N 70° 19' 40.66"	W 150° 56' 58.51"
SS54	L9312	Core	N 70° 19' 48.53"	W 150° 56' 58.01"
SS55	L9312	Core	N 70° 19' 56.04"	W 150° 57' 08.28"
SS56	L9312	Core	N 70° 19' 50.96"	W 150° 57' 18.57"
SS57	L9312	Core	N 70° 19' 46.64"	W 150° 57' 44.79"
SS58	L9312	Core	N 70° 19' 58.45"	W 150° 57' 24.34"
SS59	L9312	Core	N 70° 19' 41.28"	W 150° 57' 59.42"
SS60	L9312	Core	N 70° 19' 46.98"	W 150° 58' 03.93"
SS61	L9312	Depth	N 70° 19' 51.0"	W 150° 56' 36.57"
SS62	L9312	Depth	N 70° 19' 51.87"	W 150° 56' 41.85"
SS63	L9312	Depth	N 70° 19' 36.72"	W 150° 56' 58.81"
SS64	L9312	Depth	N 70° 19' 38.69"	W 150° 56' 58.71"
SS65	L9312	Depth	N 70° 19' 42.63"	W 150° 56' 58.41"
SS66	L9312	Depth	N 70° 19' 44.59"	W 150° 56' 58.31"
SS67	L9312	Depth	N 70° 19' 46.56"	W 150° 56' 58.11"
SS68	L9312	Depth	N 70° 19' 50.50"	W 150° 56' 57.91"
SS69	L9312	Depth	N 70° 19' 52.47"	W 150° 56' 57.71"
SS70	L9312	Depth	N 70° 19' 54.44"	W 150° 56' 57.61"
SS71	L9312	Depth	N 70° 19' 53.57"	W 150° 56' 52.33"
SS72	L9312	Depth	N 70° 19' 55.38"	W 150° 56' 52.53"
SS73	L9312	Depth	N 70° 19' 56.32"	W 150° 56' 47.45"
SS74	L9312	Depth	N 70° 19' 57.30"	W 150° 56' 42.27"
SS75	L9312	Depth	N 70° 19' 59.19"	W 150° 56' 32.11"
SS76	L9312	Depth	N 70° 20' 00.16"	W 150° 56' 26.93"
SS77	L9312	Depth	N 70° 20' 01.10"	W 150° 56' 21.84"
SS78	L9312	Depth	N 70° 20' 02.05"	W 150° 56' 16.76"
SS79	L9312	Depth	N 70° 20' 03.96"	W 150° 56' 06.50"
SS80	L9312	Depth	N 70° 20' 04.91"	W 150° 56' 01.42"
SS81	L9312	Depth	N 70° 20' 05.88"	W 150° 55' 56.33"
SS82	L9312	Depth	N 70° 20' 06.82"	W 150° 55' 51.25"
SS83	L9312	Depth	N 70° 19' 56.41"	W 150° 56' 57.60"
SS84	L9312	Depth	N 70° 20' 00.35"	W 150° 56' 57.59"
SS85	L9312	Depth	N 70° 20' 02.29"	W 150° 56' 57.59"
SS86	L9312	Depth	N 70° 20' 06.23"	W 150° 56' 57.58"
SS87	L9312	Depth	N 70° 20' 08.13"	W 150° 56' 57.58"
SS88	L9312	Depth	N 70° 19' 55.24"	W 150° 57' 02.99"
SS89	L9312	Depth	N 70° 19' 56.85"	W 150° 57' 13.67"
SS90	L9312	Depth	N 70° 19' 57.62"	W 150° 57' 18.96"
SS91	L9312	Depth	N 70° 19' 59.22"	W 150° 57' 29.64"
SS92	L9312	Depth	N 70° 19' 53.56"	W 150° 57' 02.87"
SS93	L9312	Depth	N 70° 19' 52.72"	W 150° 57' 08.14"
SS94	L9312	Depth	N 70° 19' 51.84"	W 150° 57' 13.31"
SS95	L9312	Depth	N 70° 19' 50.12"	W 150° 57' 23.83"
SS96	L9312	Depth	N 70° 19' 49.24"	W 150° 57' 29.10"
SS97	L9312	Depth	N 70° 19' 48.36"	W 150° 57' 34.36"
SS98	L9312	Depth	N 70° 19' 47.52"	W 150° 57' 39.53"
SS99	L9312	Depth	N 70° 19' 45.76"	W 150° 57' 50.06"
SS100	L9312	Depth	N 70° 19' 44.92"	W 150° 57' 55.32"
SS101	L9312	Depth	N 70° 19' 43.17"	W 150° 58' 00.86"
SS102	L9312	Depth	N 70° 19' 39.36"	W 150° 57' 57.88"
SS103	L9312	Depth	N 70° 19' 45.06"	W 150° 58' 02.40"
SS104	L9312	Depth	N 70° 19' 48.87"	W 150° 58' 05.47"

Snow Survey Data Sheet

Date:	5/10/2007	**Start Time:**	16:00	**End Time:**	18:00	**Observers:**	MDM, OOO
Catchement Basin:	L9313	**Driving Wrench Used:**	Yes			**Tube Section Used:**	1

Snow Sample No.	Sample Type	Terrain Type	Snow Depth (in)		Core Length (in)	Tube & Core Weight (lb)	Empty Tube Weight (lb)	Water Equivalent (in)	Density (lb/in^3)
			w/ Dirt Plug	w/o Dirt Plug					
SS105*	Core	Lake	—	3.5	—	2.28	1.98	0.80	0.008
SS106	Core	Tundra	17.0	16.0	—	2.2	1.98	2.94	0.007
SS107*	Core	Lake	—	5.0	—	2.24	1.96	0.75	0.005
SS108*	Core	Tundra	—	6.9	—	2.16	2.02	0.47	0.002
SS109*	Core	Lake	—	7.2	—	2.4	1.96	1.17	0.006
SS110*	Core	Lake	—	8.5	—	2.98	2.12	2.30	0.010
SS111*	Core	Lake	—	5.1	—	2.34	1.98	0.96	0.007
SS112*	Core	Tundra	—	9.4	—	2.5	1.96	1.80	0.007
SS113*	Core	Lake	—	4.5	—	2.32	1.96	0.96	0.008
SS114*	Core	Lake	—	4.4	—	2.28	1.96	0.85	0.007
SS115*	Core	Lake	—	5.0	—	2.34	1.96	1.01	0.007
SS116*	Core	Tundra	—	10.0	—	2.54	1.98	1.87	0.007
SS117	Depth	Lake	—	6.4					
SS118	Depth	Lake	—	8.4					
SS119	Depth	Lake	—	10.2					
SS120	Depth	Lake	—	7.8					
SS121	Depth	Lake	—	6.6					
SS122	Depth	Lake	—	7.3					
SS123	Depth	Lake	—	7.3					
SS124	Depth	Lake	—	8.4					
SS125	Depth	Lake	—	14.6					
SS126	Depth	Tundra	—	9.8					
SS127	Depth	Lake	—	6.6					
SS128	Depth	Lake	—	4.2					
SS129	Depth	Tundra	—	12.6					
SS130	Depth	Tundra	—	12.6					
SS131	Depth	Lake	—	4.2					
SS132	Depth	Lake	—	3.6					
SS133	Depth	Lake	—	4.2					
SS134	Depth	Tundra	—	12.0					
SS135	Depth	Tundra	—	14.2					
SS136	Depth	Lake	—	4.8					
SS137	Depth	Lake	—	7.8					
SS138	Depth	Lake	—	6.0					
SS139	Depth	Lake	—	4.8					
SS140	Depth	Lake	—	4.2					
SS141	Depth	Lake	—	5.4					
SS142	Depth	Lake	—	4.8					
SS143	Depth	Tundra	—	20.6					
SS144	Depth	Lake	—	4.2					
SS145	Depth	Lake	—	3.6					
SS146	Depth	Lake	—	7.2					
SS147	Depth	Tundra	—	14.6					
SS148	Depth	Tundra	—	18.6					
SS149	Depth	Tundra	—	19.8					
SS150	Depth	Tundra	—	16.6					
SS151	Depth	Lake	—	6.2					

Snow Survey Calculations

Average Area:	Tundra =	3131338 ft^2
	Lake =	3382142 ft^2
Average SWE:	Tundra =	2.18 in
	Lake =	1.23 in
Average Snow Depth:	Tundra =	13.8 in
	Lake =	6.1 in
Average Density:	Tundra =	0.006 lb/in^3
	Lake =	0.007 lb/in^3
Catchement Basin Weighted SWE =		1.69 in

NOTES:

* Pooled sample measurement conducted, snow depth without dirt plug, SWE, and density represents the average of pooled samples.

Pooled Snow Survey Data Sheet									
Date: 5/10/2007			**Start Time:** 16:00		**End Time:** 18:00		**Observers:** MDM, OOO		
Catchement Basin: L9313			**Driving Wrench Used:** Yes				**Tube Section Used:** 1		
Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Core Length (in)**	**Bucket & Core Weight (lb)**	**Empty Bucket Weight (lb)**	**Water Equivalent (in)**	**Density (lb/in^3)**
			w/ Dirt Plug	**w/o Dirt Plug**					
SS105	1	Lake	—	3.5	—	—	1.98	—	—
	2	Lake	—	3.5	—	—	—	—	—
	3	Lake	—	3.5	—	—	—	—	—
	4	Lake	—	3.5	—	—	—	—	—
	5	Lake	—	3.5	—	—	—	—	—
			Sum =	**17.5**		2.28	**0.3**	—	—
			Average =	**3.5**			**0.06**	0.80	0.008
SS107	1	Lake	—	4.5	—	—	1.96	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	5.5	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.5	—	—	—	—	—
			Sum =	**25.0**		2.24	**0.28**	—	—
			Average =	**5.0**			**0.06**	0.75	0.005
SS108	1	Tundra	9	8.5	—	—	2.02	—	—
	2	Tundra	8.5	8.0	—	—	—	—	—
	3	Tundra	8.5	5.5	—	—	—	—	—
	4	Tundra	8.5	5.5	—	—	—	—	—
			Sum =	**27.5**		2.16	**0.14**	—	—
			Average =	**6.9**			**0.04**	0.47	0.002
SS109	1	Lake	—	7.5	—	—	1.96	—	—
	2	Lake	—	7.0	—	—	—	—	—
	3	Lake	—	7.0	—	—	—	—	—
	4	Lake	—	7.5	—	—	—	—	—
	5	Lake	—	7.0	—	—	—	—	—
			Sum =	**36.0**		2.4	**0.44**	—	—
			Average =	**7.2**			**0.09**	1.17	0.006
SS110	1	Lake	—	8.5	—	—	2.12	—	—
	2	Lake	—	8.5	—	—	—	—	—
	3	Lake	—	8.5	—	—	—	—	—
	4	Lake	—	8.5	—	—	—	—	—
	5	Lake	—	8.5	—	—	—	—	—
			Sum =	**42.5**		2.98	**0.86**	—	—
			Average =	**8.5**			**0.17**	2.30	0.010
SS111	1	Lake	—	5.0	—	—	1.98	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.5	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**25.5**		2.34	**0.36**	—	—
			Average =	**5.1**			**0.07**	0.96	0.007
SS112	1	Tundra	12.5	10.5	—	—	1.96	—	—
	2	Tundra	11.5	9.5	—	—	—	—	—
	3	Tundra	11	9.5	—	—	—	—	—
	4	Tundra	11	8.0	—	—	—	—	—
			Sum =	**37.5**		2.5	**0.54**	—	—
			Average =	**9.4**			**0.14**	1.80	0.007
SS113	1	Lake	—	4.5	—	—	1.96	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	4.5	—	—	—	—	—
	4	Lake	—	4.5	—	—	—	—	—
	5	Lake	—	4.5	—	—	—	—	—
			Sum =	**22.5**		2.32	**0.36**	—	—
			Average =	**4.5**			**0.07**	0.96	0.008
SS114	1	Lake	—	4.5	—	—	1.96	—	—
	2	Lake	—	4.5	—	—	—	—	—
	3	Lake	—	4.5	—	—	—	—	—
	4	Lake	—	4.5	—	—	—	—	—
	5	Lake	—	4.0	—	—	—	—	—
			Sum =	**22.0**		2.28	**0.32**	—	—
			Average =	**4.4**			**0.06**	0.85	0.007
SS115	1	Lake	—	5.0	—	—	1.96	—	—
	2	Lake	—	5.0	—	—	—	—	—
	3	Lake	—	5.0	—	—	—	—	—
	4	Lake	—	5.0	—	—	—	—	—
	5	Lake	—	5.0	—	—	—	—	—
			Sum =	**25.0**		2.34	**0.38**	—	—
			Average =	**5.0**			**0.08**	1.01	0.007
SS116	1	Tundra	14	13.0	—	—	1.98	—	—
	2	Tundra	10	9.0	—	—	—	—	—
	3	Tundra	10	8.0	—	—	—	—	—
	4	Tundra	12	10.0	—	—	—	—	—
			Sum =	**40.0**		2.54	**0.56**	—	—
			Average =	**10.0**			**0.14**	1.87	0.007

Snow Sample #	Catchement Basin	Sample Type	Lat. (NAD 83)	Long. (NAD 83)
SS105	L9313	Core	N 70° 20' 30.42"	W 150° 56' 40.96"
SS106	L9313	Core	N 70° 20' 29.81"	W 150° 56' 58.38"
SS107	L9313	Core	N 70° 20' 34.95"	W 150° 56' 21.99"
SS108	L9313	Core	N 70° 20' 40.80"	W 150° 56' 19.77"
SS109	L9313	Core	N 70° 20' 34.72"	W 150° 56' 09.83"
SS110	L9313	Core	N 70° 20' 38.40"	W 150° 55' 56.12"
SS111	L9313	Core	N 70° 20' 31.77"	W 150° 56' 12.04"
SS112	L9313	Core	N 70° 20' 32.86"	W 150° 55' 54.76"
SS113	L9313	Core	N 70° 20' 27.11"	W 150° 56' 36.59"
SS114	L9313	Core	N 70° 20' 21.88"	W 150° 56' 54.0"
SS115	L9313	Core	N 70° 20' 27.14"	W 150° 56' 24.98"
SS116	L9313	Core	N 70° 20' 21.29"	W 150° 56' 27.30"
SS117	L9313	Depth	N 70° 20' 31.42"	W 150° 56' 17.74"
SS118	L9313	Depth	N 70° 20' 32.12"	W 150° 56' 06.25"
SS119	L9313	Depth	N 70° 20' 32.48"	W 150° 56' 00.56"
SS120	L9313	Depth	N 70° 20' 32.27"	W 150° 56' 18.90"
SS121	L9313	Depth	N 70° 20' 33.51"	W 150° 56' 14.36"
SS122	L9313	Depth	N 70° 20' 35.95"	W 150° 56' 05.19"
SS123	L9313	Depth	N 70° 20' 37.16"	W 150° 56' 00.66"
SS124	L9313	Depth	N 70° 20' 39.64"	W 150° 55' 51.48"
SS125	L9313	Depth	N 70° 20' 40.85"	W 150° 55' 46.95"
SS126	L9313	Depth	N 70° 20' 42.09"	W 150° 55' 42.41"
SS127	L9313	Depth	N 70° 20' 32.99"	W 150° 56' 22.76"
SS128	L9313	Depth	N 70° 20' 36.91"	W 150° 56' 21.21"
SS129	L9313	Depth	N 70° 20' 38.84"	W 150° 56' 20.44"
SS130	L9313	Depth	N 70° 20' 42.77"	W 150° 56' 18.99"
SS131	L9313	Depth	N 70° 20' 29.10"	W 150° 56' 24.21"
SS132	L9313	Depth	N 70° 20' 25.21"	W 150° 56' 25.75"
SS133	L9313	Depth	N 70° 20' 23.25"	W 150° 56' 26.52"
SS134	L9313	Depth	N 70° 20' 19.36"	W 150° 56' 27.97"
SS135	L9313	Depth	N 70° 20' 17.39"	W 150° 56' 28.74"
SS136	L9313	Depth	N 70° 20' 29.72"	W 150° 56' 27.89"
SS137	L9313	Depth	N 70° 20' 28.42"	W 150° 56' 32.24"
SS138	L9313	Depth	N 70° 20' 25.80"	W 150° 56' 40.94"
SS139	L9313	Depth	N 70° 20' 24.49"	W 150° 56' 45.29"
SS140	L9313	Depth	N 70° 20' 23.19"	W 150° 56' 49.65"
SS141	L9313	Depth	N 70° 20' 20.57"	W 150° 56' 58.35"
SS142	L9313	Depth	N 70° 20' 19.27"	W 150° 57' 02.70"
SS143	L9313	Depth	N 70° 20' 17.93"	W 150° 57' 07.05"
SS144	L9313	Depth	N 70° 20' 30.84"	W 150° 56' 29.31"
SS145	L9313	Depth	N 70° 20' 30.65"	W 150° 56' 35.18"
SS146	L9313	Depth	N 70° 20' 30.23"	W 150° 56' 46.73"
SS147	L9313	Depth	N 70° 20' 30.0"	W 150° 56' 52.61"
SS148	L9313	Depth	N 70° 20' 29.59"	W 150° 57' 04.16"
SS149	L9313	Depth	N 70° 20' 29.39"	W 150° 57' 10.03"
SS150	L9313	Depth	N 70° 20' 29.17"	W 150° 57' 15.81"
SS151	L9313	Depth	N 70° 20' 31.06"	W 150° 56' 23.53"

2007 Colville River Delta Spring Breakup and Hydrologic Assessment

111335-MBJ-RPT-001

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