2015 Colville River Delta Spring Breakup Monitoring and Hydrological Assessment

ConocoPhillips Alaska

Submitted by:

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EXECUTIVE SUMMARY

This report presents the observations and results from the 2015 Colville River Delta Spring Breakup Monitoring and Hydrological Assessment conducted by Michael Baker International for ConocoPhillips Alaska. In the Colville River, the breakup and downstream movement of river ice typically occurs during a three-week period in May and June. This spring breakup event historically produces flooding, and rapid rise and fall of stage can occur locally as the result of ice jam formation and release. Annual study and reporting of spring breakup supports the Alpine Development Project and the Alpine Satellite Development Plan by assessing the relative magnitude of flooding in the delta and documenting the interaction between floodwater and infrastructure. The analyses provides data to support design, permitting, and operation of oilfield development and satisfies permit requirements that include evaluating the effectiveness of road cross-drainage structures during flood events.

The 2015 hydrologic study is the 24th consecutive year of spring breakup investigations. Water surface elevations were monitored throughout the delta at locations of hydrologic interest and near infrastructure. Discharge was measured at key locations and peak discharge was indirectly computed. The entire breakup event was documented with observations and photography from helicopter and from roadways. Following breakup, roads, pads, and drainage structures were assessed for erosion damage.

The 2015 breakup was a high magnitude, short duration event, concentrated in an eight day period with peak conditions in the Alpine area occurring from May 21 to May 23. Peak stage at the head of the delta was 23.47 feet British Petroleum Mean Sea Level on May 21 and was the result of backwater behind a large ice jam that formed downstream in the East Channel at the Tamayayak bifurcation. Peak stage was estimated to have a 50-year recurrence interval and is the highest on record, exceeding the previous maximum by 2.78 feet. Peak discharge at the head of the delta was 469,000 cubic feet per second on May 22 as was the result of the release of the downstream ice jam. Peak discharge was estimated to have a 10.0-year recurrence interval and is the fourth highest on record.

During peak conditions, backwater behind the ice jam in the East Channel was diverted into the Nigliq and Sakoonang channels. A concurrent ice jam in the Nigliq Channel near the village of Nuiqsut caused extensive overland flooding east of the Nigliq Channel around Alpine facilities, where, in general, water surface elevations were the highest on record. Visual inspections of flowing culverts during peak conditions confirmed all culverts were conveying unobstructed flow. Overbank flooding south of the CD5 road inundated the surrounding floodplain, concentrating flow through the CD5 bridge openings. All bridges adequately conveyed the flow with no visible obstructions to ice breakup or movement. Observed channel scour and pier scour depths were minimal and did not exceed established bridge design criteria at any of the bridges.

On May 21, floodwater overtopped and breached the CD4 road between the CD4 pad and the CD5 road intersection. No other roads or pads were overtopped or breached. The horizontal directional drilled Colville River crossing site and other pipeline crossing were not adversely affected.

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ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
2D	Two-dimensional
ADF&G	Alaska Department of Fish and Game
ADCP	Acoustic Doppler Current Profiler
ADP	Alpine Development Project
ABR	Alaska Biological Research
Michael Baker	Michael Baker International
BPMSL	British Petroleum Mean Sea Level
CPAI	ConocoPhillips Alaska, Inc.
CD	Colville Delta
cfs	cubic feet per second
CRD	Colville River Delta
fps	feet per second
DGPS	Differential global positioning system
GPS	Global positioning system
HDD	Horizontal directional drill
HWM	High water mark
LCMF	UMIAQ LLC (LCMF)
MON	Monument
NWS	National Weather Service
OSW	USGS Office of Surface Water
PT	pressure transducer
RM	river mile
SAK	Sakoonang
TAM	Tamayayak
ULAM	Ulamnigiaq
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSE	Water surface elevation

1.0 INTRODUCTION

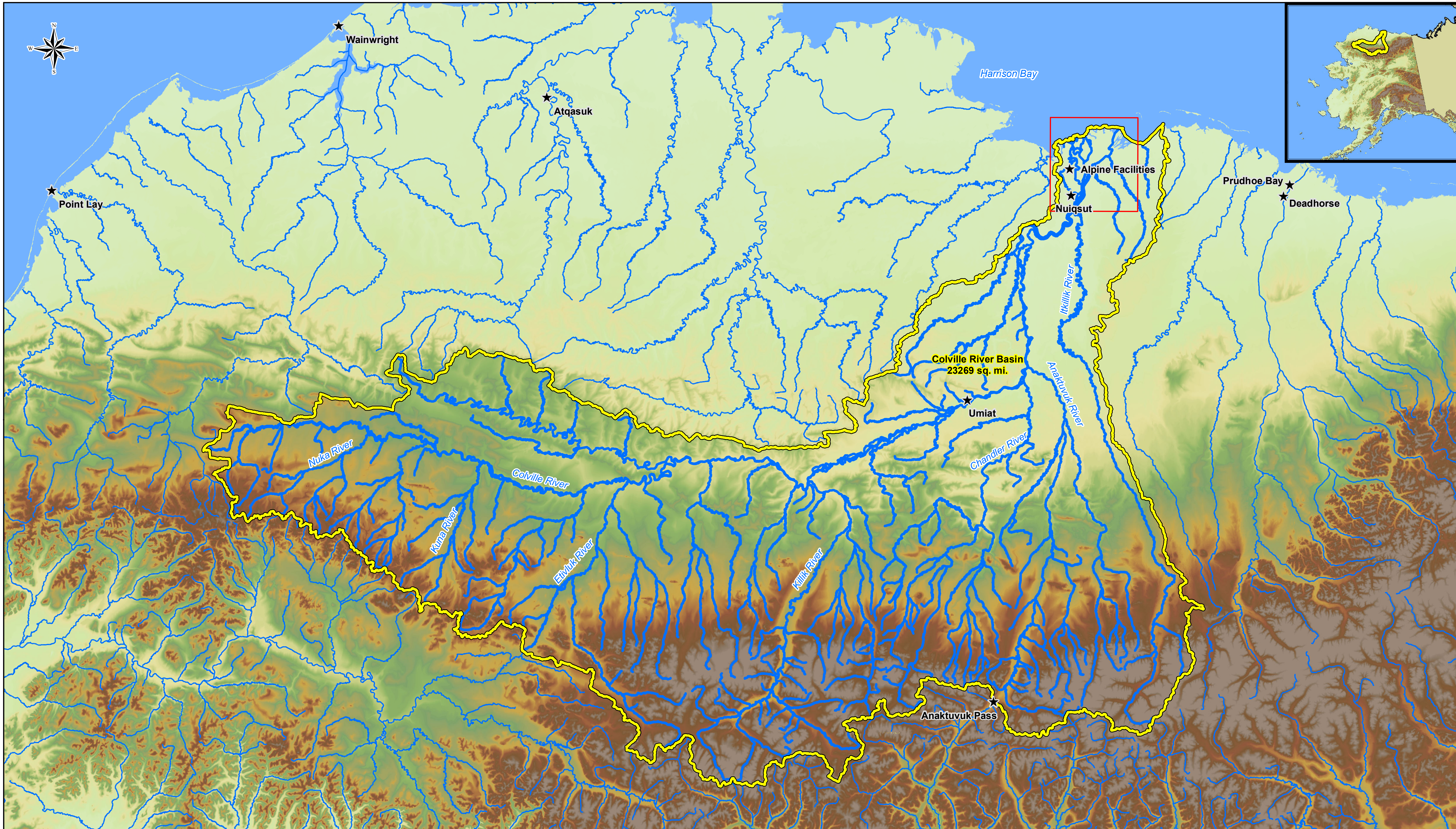
The Colville River is the largest river on the North Slope, initiating in the DeLong Mountains on the northern side of the Brooks Range, running north and east through the Arctic Coastal Plain, forming the Colville River Delta (CRD) where the river empties into the Beaufort Sea. The Colville River drainage basin is approximately 23,269 square miles and includes a significant portion of the western and central areas north of the Brooks Range (Figure 1.1). Spring breakup flooding commences with the appearance of meltwater in the delta and progresses with a rapid rise in stage which facilitates the breakup and downstream movement of river ice. CRD spring breakup is generally considered to be the largest annual flooding event in the region and typically occurs during a three-week period in May and June. Spring breakup monitoring is integral to understanding regional hydrology and ice effects, establishing appropriate design criteria for proposed facilities, and maintaining the continued safety of the environment, oilfield personnel, and existing facilities during the flooding event.

The CRD Spring Breakup Hydrologic Assessment supports the ConocoPhillips Alaska, Inc. (CPAI) Alpine Development Project (ADP) and the Alpine Satellite Development Plan. The Alpine facilities are operated by CPAI and owned by CPAI and Anadarko Petroleum Company. Alpine facilities include the Colville Delta (CD) 1 processing facility (Alpine) and the CD2, CD3, CD4, and CD5 pads, access roads, and pipelines.

Spring breakup monitoring activities have been conducted in the CRD since 1992. The program was expanded to include additional Alpine facilities in 2004 and the CD5 development area in 2009. The 2015 hydrologic field program is the 24th consecutive year of CRD spring breakup investigations.

The 2015 field program took place from April 24 to May 29. Field personnel set up and rehabilitated the monitoring gages between April 25 and May 16. Monitoring began on May 16 and concluded on May 29, 2015. Primary field tasks included documenting the distribution of floodwater and measuring water levels and discharge at select locations. Observations of lake recharge, ice jams, ice road crossing degradation, and post-breakup floodwater effects on infrastructure were also collected. Hydrologic observations were documented at the Colville East Channel, Nigliq Channel, Alpine facilities and roads, CD3 pipeline crossings, and the CD2 and CD5 bridges.

UMIAQ, LLC (LCMF), CPAI Alpine Field Environmental Coordinators, North Slope Environmental Field Studies Coordinators, Alpine Helicopter Coordinators, and Pathfinder Aviation provided support during the 2015 CRD spring breakup field work and contributed to a safe and productive monitoring season.



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- ★ Place Name
- Stream
- Study Area
- Colville River Basin

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2015 SPRING BREAKUP
COLVILLE RIVER DELTA

Drainage Basin

FIGURE: 1.1

(SHEET 1 of 1)

1.1 Monitoring Objectives

The primary objective of the CRD spring breakup monitoring and hydrologic assessment is to monitor and estimate the magnitude of breakup flooding within the CRD in relation to the Alpine facilities. Flood stage, discharge data, and observations are used to validate design parameters of existing infrastructure and for planning and design of proposed infrastructure. Flood data collection supports refinement of the CRD flood frequency analysis, two-dimensional (2D) surface water model, and stage frequency analyses.

CRD spring breakup monitoring is also conducted to satisfy permit requirements. Permit stipulations of the U.S. Army Corps of Engineers (USACE) Permit No. POA-2004-253-2 and the State of Alaska, Department of Natural Resources, Office of Habitat Management and Permitting, Fish Habitat Permit FH04-III-0238 require monitoring the Alpine facilities during spring breakup. Permit requirements include direct measurements and indirect calculations of discharge through drainage structures and documentation of pad and access road erosion caused by spring breakup flooding. USACE Permit No. POA-2005-1576 has similar requirements for breakup monitoring along the CD5 road and bridges. It also required submittal of a *Monitoring Plan with an Adaptive Management Strategy* (Michael Baker and Alaska Biological Research [ABR] 2013), which includes documenting annual hydrologic conditions, monitoring channel sedimentation and erosion, and assessing the performance of culverts and bridges for the CD5 development.

Culvert inlets and outlets are surveyed annually by LCMF to compare structure elevations on either side of the road to satisfy Alaska Department of Fish and Game (ADF&G) permit FH04-III-0238. Observations on functionality and flooding effects to the swale bridges are recorded to satisfy ADF&G permit FG97-III-0260.

Observations of the hydraulic effects of winter ice roads across the Colville East Channel near the Alpine horizontal directionally drilled (HDD) buried pipeline crossing, Nigliq Channel, Nigliagvik Channel, and the Kachemach River were documented. Additional ice road crossings also observed during breakup included:

- No Name Creek
- Pineapple Gulch
- Silas Slough
- Slemp Slough
- Tamayayak Channel
- Toolbox Creek

Observations were also documented at the construction ice pads for the CD5 crossings at the Nigliq Channel, Nigliagvik Channel, and lakes L9323 and L9341.

ADF&G permits FG99-III-0051-Amendment #8 and FG97-III-0190-Amendment #5 require monitoring of recharge to lakes L9312 and L9313, respectively. The Alpine facilities rely on water withdrawal from these lakes for daily operations; the volume of which is dictated in part by annual spring recharge.

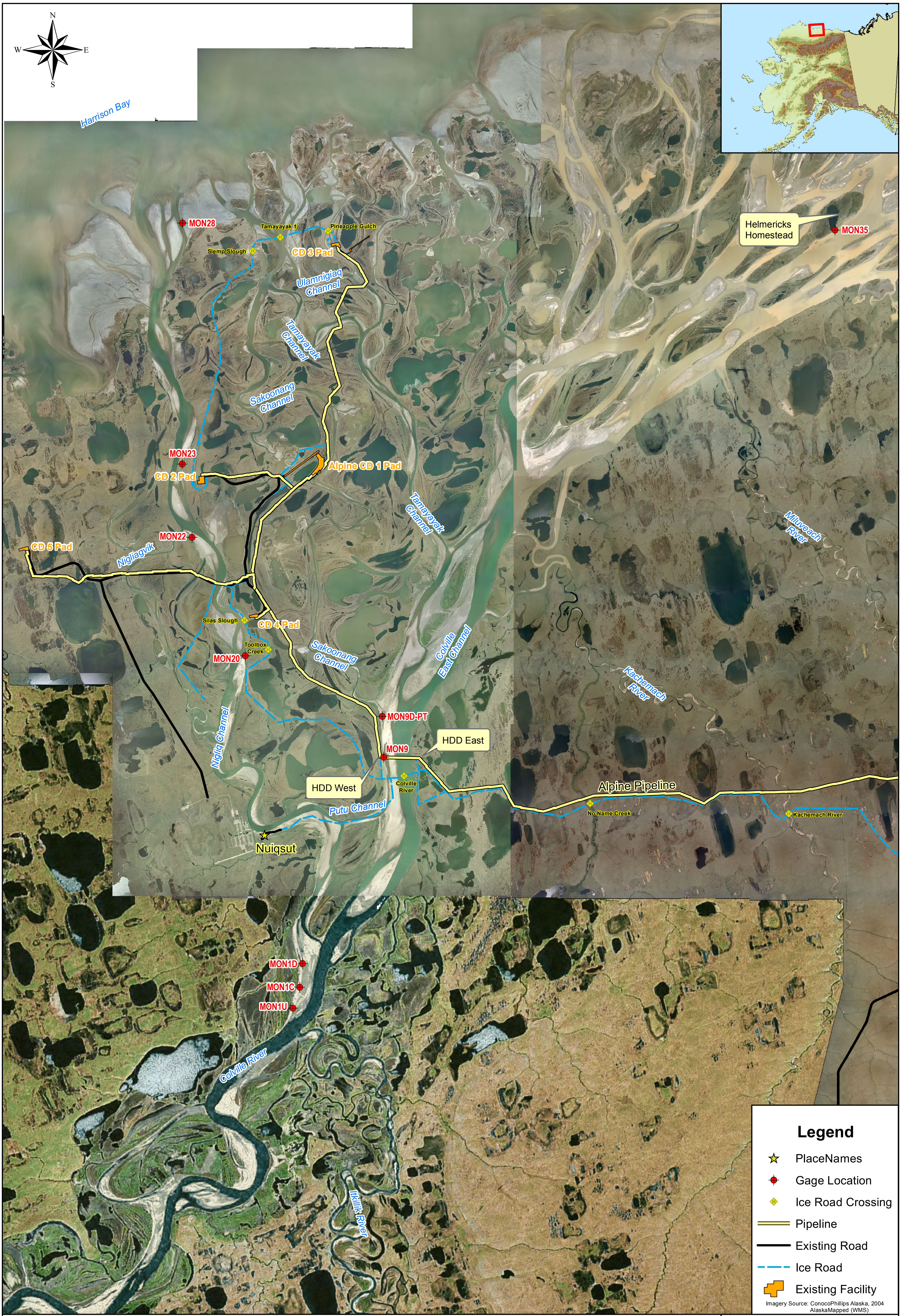
1.2 2015 Monitoring Locations

A network of hydrologic staff gages are used to monitor flood stage (Photo 1.1 and Photo 1.2). Most monitoring locations are adjacent to major hydrologic features. A location is selected based on topography, importance to the historical record, and its proximity and hydraulic significance to existing or proposed facilities or temporary infrastructure.

Photo 1.1: Staff gage at MON1C; April 28, 2015

Photo 1.2: Staff gages at MON9D, looking southwest; May 18, 2015

The 2015 monitoring locations are similar to those studied in 2014 (Michael Baker 2014). Figure 1.2 shows the historical CRD monitoring locations denoted with a MON prefex. Gage sites specific to the Alpine facilities are shown in Figure 1.3. The specific type of data collected and location descriptions for each gage site are listed in Table 1.1. Gage geographic coordinates and vertical control names are provided in Appendix A: A.1, 2015 Gage Locations and A.2, 2015 Vertical Control, respectively.



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2015 SPRING BREAKUP
COLVILLE RIVER DELTA

Monitoring Locations

FIGURE: 1.2

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2015 SPRING BREAKUP
ALPINE AREA FACILITIES

Monitoring Locations

FIGURE: 1.3

(SHEET 1 of 1)

Table 1.1: 2015 Monitoring Locations

Monitoring Locations		
Gage Name	**Data Collected**	**Location**
Colville River Upstream of Bifurcation		
MON1U	Staff Gage/PT	Colville River flow confined to a single channel
MON1C	Staff Gage/PT Direct Discharge	Colville River flow confined to a single channel
MON1D	Staff Gage/PT	Colville River flow confined to a single channel
Colville River East Channel		
MON9	Staff Gage/PT Baro PT	HDD crossing
MON9D	Staff Gage/PT	Downstream of the HDD crossing
MON35	Staff Gage	Helmericks Homestead
Nigliq Channel		
MON20	Staff Gage/PT	South of CD4
G28/G29	Staff Gage/PT	East bank south of crossing /west bank north of crossing, Nigliq Channel
G26/G27	Staff Gage/PT	East bank, Nigliq Channel adjacent to crossing - formerly known as G21 (2009-2011)
MON22	Staff Gage/PT	South of CD2
MON23	Staff Gage/PT	North of CD2
MON28	Staff Gage/PT	At Harrison Bay
Alpine Facilities and Roads		
CD1 Pad		
G1	Staff Gage/PT	CD1 betweeen pad and Sakoonang Channel
G9	Staff Gage/PT	Lake L9312 northwest side
G10	Staff Gage/PT	Lake L9313
CD2 Road and Pad		
G3/G4	Staff Gage/PT	CD2 access road, swale bridge vicinity
G12/G13	Staff Gage	CD2 access road
G6/G7	Staff Gage	CD2 access road
G8	Staff Gage	CD2 between pad and Nigliq Channel
CD3 Pad		
G11	Staff Gage	CD3 pad area
CD4 Road and Pad		
M9525	Staff Gage	CD4 access road
G42/G43	Staff Gage	CD4 access road
G40/G41	Staff Gage	CD4 access road
G15/G16	Staff Gage	CD4 access road
G17/G18	Staff Gage	CD4 access road
G19	Staff Gage Baro PT	CD4 between southeast corner of pad and Lake L9324
G20	Staff Gage	CD4 between west end of pad and Nigliq Channel
CD5 Road		
G24/G25	Staff Gage/PT	Lake L9323
G30/G31	Staff Gage	CD5 access road
G32/G33	Staff Gage/PT	Lake L9341 - formerly known as G22 (2009-2011)
G34/G35	Staff Gage	CD5 access road
G36/G37	Staff Gage	CD5 access road
G38/G39	Staff Gage/PT	West bank, Nigliagvik - formerly known as G23 (2009-2011)
S1/S1D	Staff Gage	South of Lake MB0301 and CD5 Road
CD3 Pipeline Stream Crossings		
SAK	Staff Gage/PT	Sakoonang (Pipe Bridge #2)
TAM	Staff Gage/PT	Tamayayak (Pipe Bridge #4)
ULAM	Staff Gage/PT	Ulamnigiaq (Pipe Bridge #5)
CD2 Road Bridges		
62-foot bridge	Direct Discharge	Along CD2 access road
452-foot bridge	Direct Discharge	Along CD2 access road
CD5 Road Bridges		
L9323 Bridge	Visual Survey	Along CD5 access road
Nigliq Bridge	Direct Discharge	Along CD5 access road
L9341 Bridge	Visual Survey	Along CD5 access road
Nigliagvik Bridge	Direct Discharge	Along CD5 access road
Road Culverts		
CD2 Road	Direct Discharge/ Visual Survey	26 culverts
CD4 Road	Direct Discharge/ Visual Survey	38 culverts
CD5 Road	Direct Discharge/ Visual Survey	43 culverts
Alpine Roads Erosion Survey		
CD2 Access Road	Visual Survey	Access road from CD1 to CD2
CD4 Access Road		Access road from CD1 to CD4
CD5 Access Road		Access road from CD4 road to CD5
Ice Road Crossings		
Colville East Channel	Visual Survey	North of HDD
Kachemach River		South of pipeline crossing to 2L Pad - Kuparuk
Nigliagvik Channel		West of Nigliq Exploration Crossing
Nigliq Channel		West of B8531/L9326
No Name Creek		East of HDD between lakes M9602 and M9605
Pineapple Gulch		North of CD3 along bifurcation of Ulamnigiaq Channel
Silas Slough		West of CD4 on south end of Tapped Lake
Slemp Slough		West of CD3 and Tamayayak Bridge
Tamayayak		West of CD3 and Tamayayak Bridge
Toolbox Creek		Swale connecting Nigliq Channel and M9934, south of CD4
Note: PT - Pressure Transducer Baro PT - Barometric Pressure Transducer		

2.0 METHODS

The CRD Spring Breakup Hydrologic Assessment field effort occurred from April 28 to May 29, 2015. Field personnel setup and rehabilitated the monitoring gages between April 28 and May 8. Spring breakup monitoring began on May 10 and concluded on May 29.

The 2015 spring breakup monitoring activities included documenting observations of floodwater flow, distribution, and ice conditions; recording stage at monitoring locations; and measuring discharge on river channels and at drainage structures. Pathfinder Aviation provided helicopter support to access remote sites. LCMF provided Hägglund track vehicle support to access gage locations during setup.

The field methodologies used to collect hydrologic data on the North Slope of Alaska during spring breakup are proven safe, efficient, and accurate for the conditions encountered.

2.1 VISUAL OBSERVATIONS

The U.S. Geological Survey (USGS) operates a hydrologic gaging station on the Colville River at Umiat, approximately 90 river miles (RM) upstream of the CRD. Real-time stage data and webcam photos from this site are used during the breakup study to help forecast the initial arrival of meltwater and timing of peak conditions in the CRD study area. Helicopter overflights were also conducted upstream of MON1 to Ocean Point and the Anaktuvuk River to track the progression of the floodwaters.

Field data collection and observations of breakup progression, flow distribution, bank erosion, ice events, scour, lake recharge, and interactions between floodwaters and infrastructure were recorded in field notebooks (Photo 2.1 and Photo 2.2). Photographic documentation of breakup conditions was collected using digital cameras with integrated global positioning systems (GPS). The latitude and longitude, date, and time are imprinted onto each photo. The photo location is based on the World Geodetic System of 1984 datum.

Photo 2.1: Field crew recording observations at G8; May 18, 2015

Photo 2.2: Field crew recording observations at G29; May 23, 2015

2.2 Water Surface Elevation

2.2.1 Staff Gages

For the purposes of this report, stage and water surface elevation (WSE) are used interchangeably. Stage or WSE data was collected using staff gages (designed to measure floodwater levels) and pressure transducers (PT). Site visits were performed daily as conditions allowed.

Gages were re-installed or rehabilitated as needed in the fall and re-surveyed in the early spring before breakup using standard differential leveling techniques.

Two types of gages were used:

1) Direct-read gages correlate to British Petroleum Mean Sea Level (BPMSL) elevation and were surveyed prior to breakup in May 2015 by LCMF. The pre-breakup survey is used to determine if correction factors must be applied to adjust elevation during flooding conditions. Adjustments are made annually by LCMF during ice-free conditions to correct for jacking or settlement induced by the freeze-thaw cycle.

   The gages consist of metal gage faceplates attached to drill stems permanently driven into the ground or attached to pipeline vertical support members (Photo 2.3).

Photo 2.3: Direct-read staff gage at G19; May 4, 2015

2) Indirect-read gages do not directly correspond to a BPMSL elevation. The gage elevations were surveyed relative to a known benchmark elevation to determine a correction factor. The correction factor is applied to the gage reading to obtain the elevation in feet BPMSL.

Gage sets consist of one or more gage assemblies positioned perpendicular to stream channels and lakes at monitoring locations throughout the CRD. Each gage assembly in a set includes a standard USGS metal faceplate mounted on a wooden two-by-four. The two-by-four is attached with U-bolts to a 1.5-inch-wide angle iron post driven into the ground. The faceplate is graduated and indicates water levels every 100th of a foot between 0.00 to 3.33 feet (Photo 2.4).

The number of gage assemblies per set depends on site specific conditions: primarily slope of the channel, bank, and overbank. In locations where terrain elevation varied by more than three feet, multiple gages were installed linearly from the edge of the low water channel up to the overbank (Photo 2.5). The gages are installed at elevations overlapping by approximately one foot. Individual gage assemblies were identified with alphabetical designations beginning with A representing the location nearest to the stream centerline. Chalk was applied to the angle iron gage supports. Subsequent high water marks (HWMs) were recorded when floodwaters removed the chalk.

Photo 2.4: Temporary staff gage at Lake M9602; April 29, 2015

Photo 2.5: Gage set at MON9D; April 29, 2015

2.2.2 PRESSURE TRANSDUCERS

PTs are used at monitoring locations to supplement gage measurements and provide a continuous record of WSEs. PTs are designed to collect and store pressure and temperature data at discrete pre-set intervals. PTs were programmed to collect data at 15-minute intervals from May 10 to August 30, 2015. Each PT was housed in a small perforated galvanized steel pipe and clamped to the angle iron or the base of the gage assembly nearest to the bed of the active channel (Photo 2.6). By sensing the absolute pressure of the atmosphere and water column above the PT, the depth of water above the sensor is calculated. Absolute pressure is accounted for using barometric pressure sensors (Baro PT) at two locations in the CRD. During data processing, the PT measurements are adjusted to WSEs recorded at the staff gages.

Photo 2.6: PT setup at G29-A; April 27, 2015

Secondary PTs were installed at some monitoring locations to validate and backup the primary PT data. During data processing, the secondary PT data was used for QA/QC of the primary PT data. The redundancy ensures data is available for sites where discharge measurements are calculated. Appendix A contains details regarding PT setup and testing (A.3). Table 1.1 indicates monitoring locations with PT installations.

2.3 DISCHARGE

2.3.1 DIRECT DISCHARGE

Discharge was measured as close to the observed peak stage as possible at the following locations:

- Colville River MON1
- Culverts along the CD2, CD4, and CD5 roads
- Long and Short Swale Bridges along the CD2 Road
- Nigliq Bridge (Photo 2.7 and Photo 2.8)
- Nigliagvik Bridge

Direct discharge at MON1 on the Colville River and downstream of the Nigliq Bridge was measured using an Acoustic Doppler Current Profiler (ADCP). Direct discharge measurements have been collected at MON1 on the Colville River using an ADCP each year since 2005, with the exception of 2010 and 2012. Measurements were conducted as outlined in the USGS *Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers* (USGS 2005). Discharge was measured at the Long and Short Swale Bridges, the Nigliagvik Bridge, and again at the Nigliq Bridge using conventional current meters and the USGS midsection technique. Culvert discharge was calculated using measured velocity, flow depth, and culvert geometry.

Photo 2.7: Discharge Measurements downstream of the Nigliq Bridge; May 22, 2015

Photo 2.8: Discharge Measurements at the Nigliagvik Bridge; May 23, 2015

2.3.2 PEAK DISCHARGE CALCULATION

Peak discharge was calculated indirectly and calibrated with the direct discharge measurements and observed WSEs. Under open channel conditions, peak discharge typically occurs at the same time as peak stage. However, this is not always the case in the arctic where peak discharge is typically affected by ice and snow. Ice-affected channels often produce backwater effects and can temporarily increase stage and reduce velocity yielding a lower discharge than an equivalent stage under open water conditions.

Peak discharge was indirectly calculated at the following locations:

- Colville River (MON1)
- Colville East Channel (MON9)
- Nigliq Bridge
- Nigliagvik Bridge
- Lake L9341 Bridge
- Lake L9323 Bridge
- CD2, CD4, and CD5 Road Culverts
- Long and Short Swale Bridges

Peak discharge at MON1 and MON9 was calculated indirectly based on the assumption of normal depth for a reach of uniform open channel flow. Peak discharge at MON1 was computed using both the Normal Depth equation and the Slope-Area method. Peak discharge at MON9 was determined using the Normal Depth equation.

Overbank flooding along the CD5 road was contained between the CD4 road to the east and the west bank of the Nigliagvik Channel to the west and resulted in contracted flow at the bridge openings. Flow contractions at bridges result in energy losses not accounted for in the Normal Depth or Slope-Area methods. The USGS width contraction method (USGS 1976) was used to estimate peak discharge through the Nigliq, Nigliagvik, Lake L9323, and Lake L9341 bridges.

At the Nigliq Bridge, the WSE results of the width contraction method were checked against results from a one-dimensional steady hydraulics model.

Bentley CulvertMaster® software was used to calculate discharge through the CD2, CD4, and CD5 road culverts. Timing and magnitude of peak discharge through the culverts was determined based on recorded WSEs at staff gages on both sides of the road prism.

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

- Headwater and tailwater elevations at each culvert (hydraulic gradient)
- Culvert diameter and length from LCMF as-built surveys (LCMF 2002, 2015)
- Culvert upstream and downstream invert elevation (LCMF 2015)
- Culvert Manning's roughness coefficients (0.012 for smooth steel and 0.024 for corrugated metal pipe)

Results were evaluated in terms of culvert functionality based on visual inspection. The peak discharge estimates for the Long and Short swale bridges were calculated by using the velocities measured during the discharge measurements and adjusting the hydraulic depth for peak conditions. Direct measurement techniques and peak discharge calculation methods are detailed in Appendix B.1.

2.4 Flood and Stage Frequency Analysis

Flood and stage frequency statistical analyses were performed using historic annual peak discharge and stage data to estimate the recurrence interval. The presence of channel ice and ice jams are common during spring breakup flooding, and the influence of the ice on peak stage and discharge ranges from little or no impacts to having major effects. Both ice affected and non-ice affected peak stage and discharge are grouped in the analyses to provide results representative of the ranging conditions.

Frequency analyses are completed every three years, as a single year of data is unlikely to significantly affect previous findings. When frequency analyses are not performed, peak discharge and stage values are compared to the results of the most current analysis to determine respective returns.

The results of flood and stage frequency analyses provide the discharge magnitudes and WSEs in support of facility design and operations. The discharge basis for comparison is the 2002 design-magnitude flood frequency analysis for the Colville River at MON1 (Michael Baker and Hydroconsult 2002). Stage frequency basis for comparison is the 2D surface water model developed during the original design of ADP. The model has been updated throughout the life of the Alpine facilities, most recently in 2012 (Michael Baker 2012b). The most recent flood and stage frequency analyses for the CRD were performed in 2012. Flood frequency findings supported maintaining existing design criteria based on the 2002 analysis; stage frequency findings supported maintaining existing design criteria based on the most current version of the CRD 2D surface water model. Flood and stage frequency analyses were completed in 2015.

2.4.1 Flood Frequency

Flood frequency was analyzed using methods outlined in the U.S. Water Resources Council *Guidelines for Determining Flood Flow Frequency*, otherwise known as "Bulletin 17B" (USWRC 1981). A Weibull distribution was applied to determine recurrences of data within the continuous record, and the Hydrologic Engineering Center Statistical Software Package, based on Bulletin 17B, was used to statistically fit and extrapolate discharge data for design-magnitude recurrence intervals (USACE 2010).

Since 1992, annual peak discharges have been recorded at the head of the CRD (MON1) culminating in 24 years of continuous data. These peak discharge values are fitted to a Weibull distribution requires a continuous data record and is performed as an analysis of that record only; flood recurrences are not extrapolated beyond the continuous record. The Weibull distribution ranks the peak annual discharge values and assigns a return period to those observed discharges with a maximum return period equal to the number of years' continuous data available plus one.

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

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

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

In 2009 and 2012, both continuous record and design-magnitude flood frequency analyses were performed. The annual peak discharge data from 1992 through 2009 and 1992 through 2012, respectively, and the extrapolated data extending back to 1971 were used. This is recommended for design-magnitude extrapolation with less than 50-years' worth of record. The 2009 and 2012 data, similar to the 2006 and 2002 data, were ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for design-magnitude extrapolation. The 2009 and 2012 design-magnitude results were compared to the results of the 2002 analysis. On average, the discharge estimates from the 2002 analysis were 3 percent and 2 percent less conservative than those derived from the 2009 and 2012 analyses respectively. Since the 2002 results fell within the 95% confidence interval of the 2009 and 2012 analyses results, 2002 flood design criteria was maintained.

Both continuous record and design-magnitude flood frequency analyses were performed for the Colville River at MON1 in 2015. The 2015 analysis includes the additional three years of observations (2013, 2014, and 2015). The annual peak discharge data from 1992 through 2015 and the extrapolated data extending back to 1971 were used. The 2015 data was ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for design-magnitude extrapolation. The 2015 results were compared to the results of the 2002 analysis. The results of the flood frequency analysis are discussed in Section 9.1.

2.4.2 Stage Frequency

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

Stage frequency analysis was performed at MON1, MON22, and gages G1, G3, and G18. A continuous record does not exist at all locations since site monitoring varies annually based on each year's field program objectives. At MON1, the continuous record begins in 1992. Locations were selected for stage frequency analysis based on completeness of historic record and proximity to major existing or proposed facilities. Annual peak stages at locations throughout the CRD are estimated or extrapolated to 1992 based on MON1 data. The annual observed record of each location's peak WSE was compared to the annual observed record at MON1, and an independent best-fit line was developed for each set. The linear equations were used to calculate extrapolated peak stages. Values were linearly extrapolated for those years when peak stage was known, and the differences between the data were compared.

Peak stage data was statistically fit to a Weibull distribution for the purposes of ranking by recurrence interval relative to the continuous record. Stage data was extrapolated beyond the continuous record to design magnitudes. It is generally considered risky to extrapolate stage data for a river impacted by ice and ice jamming beyond the continuous record (USACE 2002; FEMA 2003). This is true because of the inherently unpredictable nature of ice jams and since the quantity of water in high magnitude flood events will be less affected by ice than smaller-magnitude floods. The 24-year continuous record for stage at the MON1 reach has been impacted by upstream ice jam releases or backwater from downstream ice jams during the spring breakup event, inflating peak stage beyond what would be observed during open water conditions. The expansive floodplain of the CRD will also restrict peak stage to a reasonable upper limit, which can be grossly overestimated with the extrapolation of stage data.

For the purpose of comparing observed stage between 1992 and 2015 with the 2D open water model predictions, extreme value statistical analysis was used to extend the record to 50 years, 2.1 times the record length. The objective of this analysis is not intended to redefine the Alpine design criteria based on the 2D model but to supplement these criteria for low-magnitude, ice-impacted flood events.

A design-magnitude stage frequency analysis for the CRD was performed in 2006 (Michael Baker 2007a), 2009 (Michael Baker 2009a), 2012 (Michael Baker 2012b), and again in 2015. The data were fitted to a Log-Pearson Type III station skew distribution. The results were then compared to the stage frequency data generated by the current 2D model and the Weibull distribution of observed data. The results of the stage frequency analysis are discussed in Sections 9.2 and 9.3.

2.5 CD5 Real-Time Scour Monitoring and Channel Bathymetry

2.5.1 Pier Scour

The objective of the pier scour measurements is to yield maximum pier scour depths during flood conditions at bridge piers most susceptible to scour. This work supports the CD5 Monitoring Plan with Adaptive Management Strategy requirement for annual real-time pier scour measurements during spring breakup and other large flood events at the Nigliq and Nigliagvik channel bridges. Maximum scour occurring under the influence of peak velocities is often greater than the final scour measured after flood recession due to sediment deposition associated with lower flow velocities. For this reason it is imperative that real-time soundings are collected during peak flood conditions. A real-time pier scour monitoring system was installed on pier 3 of the Nigliagvik Bridge in the spring of 2015. Scour depths were measured using a sonar mounted on the bridge piers most susceptible to scour. The sonar was installed inside a steel pipe casing, welded to the downstream side of the bridge pier (Photo 2.9). Sonar measurements were recorded with an on-site datalogger (Photo 2.10). The sonar system was programmed to measure depths and record data at 30 minute intervals. A telemetry system, using cellular communication, provided remote access to the sonar measurements. Additional details of the real-time pier scour monitoring system are available in the system testing status report in Appendix G.3.1. A similar system will be installed on piers 2-5 on the Nigliq Bridge during the winter of 2015-2016. In the absence of a real-time pier monitoring system at the Nigliq Bridge, elevations at the base of the piers were collected during direct discharge measurements to assess pier scour as close to peak conditions as possible.

Photo 2.9: Steel pipe casing on Nigliagvik Bridge containing sonar for real-time scour monitoring; May 6, 2015

Photo 2.10: On-site data logger for Nigliagvik Bridge real-time scour sonar; May 6, 2015

2.5.2 Channel Bathymetry

Prior to construction of the bridges, topographic and bathymetric baseline surveys were performed by LCMF in August 2013 at the Nigliq Channel, Lake L9341, and Nigliagvik Bridge locations. Transect layouts and bathymetric cross sections are provided in Appendix G. Four transects at each bridge location were re-surveyed in August 2014 and again in August 2015 (Table 2.1). The 2015 survey data was compared to the 2014 and 2013 survey data. The maximum incremental change between 2014 and 2015 and the maximum cumulative change since 2013 were documented at each bridge. In addition, a post-breakup survey of the scour holes at the base of individual piers at the Nigliq and Nigliagvik bridges was completed to ensure maximum scour depth has been documented.

Table 2.1: 2014 and 2015 Channel Bathymetry Transects (Appendix G)

Bridge Crossing	Transect No.
Nigliq Channel	7-10
Lake L9341	36-39
Nigliagvik Channel	24-27

2.6 Post-Breakup Conditions Assessment

The Alpine facilities roads, pads, and drainage structures were assessed immediately following the breakup flood. A systematic inventory was completed to document the effects of flooding on the infrastructure with a focus on erosion. Both sides of the roads were photographed from the ground and the condition of the fill material was described.

The most common descriptors included:

1) No evidence of erosion;
2) HWM consisting of removal of fine sediments and/or deposition of small debris on the road embankment;
3) Wash line from water action on the road embankment creating a distinct eroded scarp, and;
4) Scour and deposition, further described by proximity to a drainage structure where higher velocities occurred, the material origin, and where material was transported to.

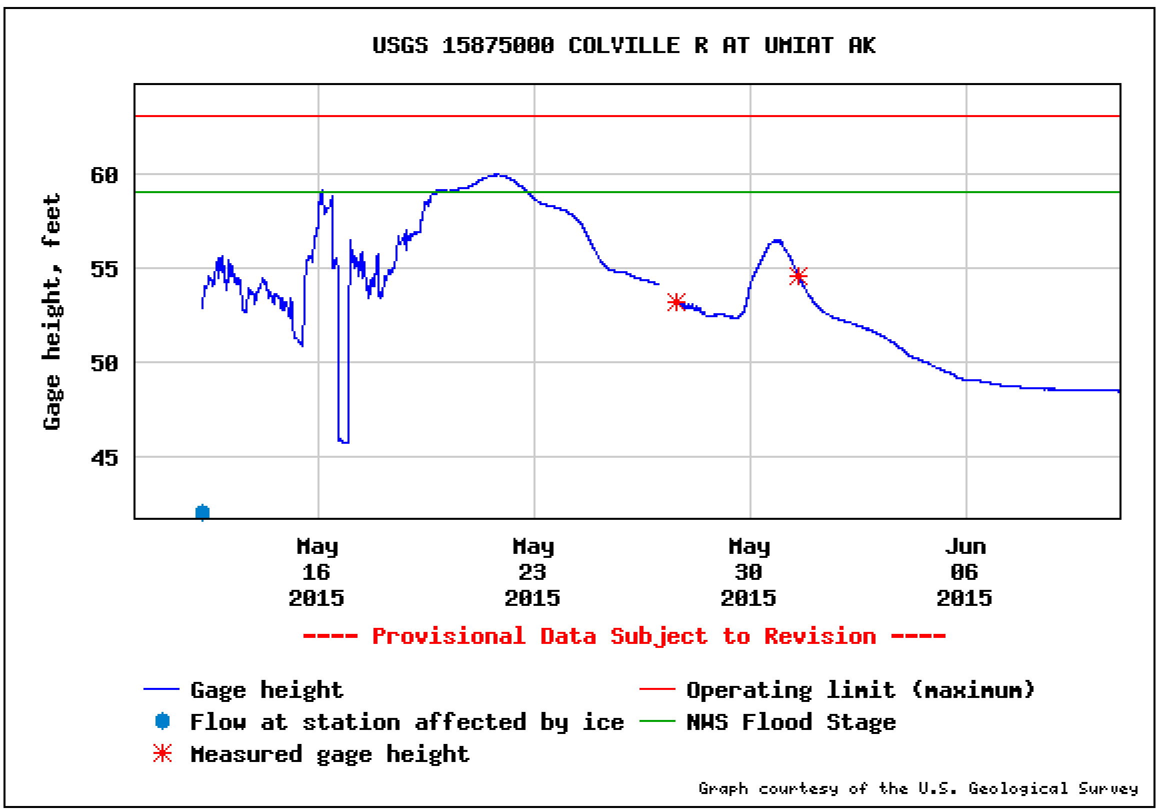
The information collected is intended to document conditions and was not used to quantify the volume of material that was eroded.

3.0 BREAKUP OBSERVATIONS

3.1 2015 SPRING BREAKUP CONDITIONS SUMMARY

Breakup in the CRD typically begins when daily low air temperatures consistently exceed freezing. In 2015, daily low air temperatures in the delta rose above freezing on May 17 and remained above freezing for the next ten days. This, combined with several days of maximum temperature in excess of 50 degrees Fahrenheit (°F) and direct solar radiation in the upper watershed, contributed to a high magnitude, short duration flood event.

There is typically a 24-hour lag time between flood crests at the Umiat gage and the CRD. The Umiat station is upstream of the Chandler and Anaktuvuk River confluences and the gage data does not account for the contribution from the two major tributaries. At Umiat, peak stage occurred on May 21, about one foot above the National Weather Service (NWS) flood stage for the site (Graph 3.1). The NWS established flood stage at Umiat indicates the magnitude of flooding upstream of the CRD, however, because of local ice effects, it does not always correlate with the magnitude of flooding in the CRD.



Graph 3.1: Colville River Stage Data at Umiat; May 1 to June 10, 2015 (USGS 2015)

On May 11, the webcam at Umiat showed accumulating local melt in the channel with no observable flow. On May 12, daily low temperatures at Anaktuvuk Pass in Colville River headwaters had remained above freezing for three of the previous four days with daily highs of 46°F and 48°F. An aerial reconnaissance flight was conducted on May 12 and the leading edge of flood water in the Anaktuvuk River was observed approximately

35 RM upstream from the Colville River confluence and 100 RM upstream from the MON1 gages. No flowing water was observed in the Chandler River.

On May 15, the leading edge of floodwater was observed in the Colville River on the Umiat webcam. The snow around the Alpine facilities was getting wetter and thinner each day and local meltwater was beginning to pond in low lying areas and tundra polygons. On May 17, meltwater was flowing from the Itkillik River onto the Colville River channel ice just upstream of MON1 (Photo 3.1).

The leading edge of floodwater slowly moved through the Nigliq Channel and East Channel on May 18 (Photo 3.2). On May 19, as water levels continued to rise, a large ice jam formed in the Colville River between Ocean Point and the Itkillik River confluence (approximately 5 RM upstream from MON1) and a smaller ice jam formed in the Nigliq Channel near Nuiqsut. Channel ice was still intact in the Nigliq Channel and in the Colville River at MON1. Flow was observed in the Sakoonang Channel near CD1 and flow from the Nigliq Channel entered Nanuq Lake and moved toward the Long Swale Bridge on the CD2 road via Lake M9524.

Photo 3.1: Leading edge of breakup floodwater from the Itkillik River at the Colville River confluence, looking west; May 17, 2015

Photo 3.2: Initial floodwater in the East Channel at HDD, looking southeast at the ice bridge crossing; May 18, 2015

The ice jam upstream of MON1 was still in place on May 20, resulting in widespread inundation of low lying areas. Minimal ice floes were observed upstream of the jam and the channel was mostly free of intact channel ice. The ice jam in the Nigliq Channel near Nuiqsut also remained in place. The ice jam was diverting flow outside the main channel near Nuiqsut (Photo 3.3). WSEs continued to rise throughout the delta and flow was observed at both swale bridges along the CD2 road.

Late on May 20, the ice jam upstream of MON1 released and reformed in the East Channel at the Tamayayak Channel bifurcation (Photo 3.4). Backwater from the East Channel ice jam inundated low lying areas and was diverted into the Nigliq Channel via the Putu Channel and at the Nigliq Channel bifurcation. Nigliq Channel ice remained intact, holding the ice jam near Nuiqsut in place. As a result, floodwater was diverted overland through the lake basins between the Nigliq and Sakoonang channels increasing water levels near Alpine facilities. On the evening of May 21, extensive overbank flooding occurred around the CD2 and CD4 roads and pads (Photo 3.5). At 7:00 PM, a HWM was observed at MON1, indicating water levels had crested at the head of the delta.

In the morning on May 22, the East Channel ice jam at the Tamayayak Channel bifurcation released resulting in a sudden drop in stage at upstream gage locations. Water levels around Alpine facilities peaked and quickly receded with the sudden backwater relief. In the lower delta, Helmerick's Island was mostly inundated (Photo 3.6).

Photo 3.3: Ice jam in the Nigliq Channel near the village of Nuiqsut, looking west; May 20, 2015

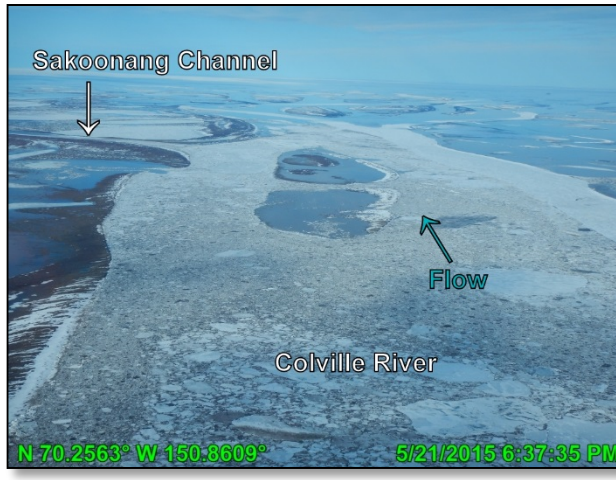


Photo 3.4: Ice jam in the East Channel extending from the Tamayayak bifurcation upstream to HDD, looking north; May 21, 2015

Photo 3.5: Extent of inundation near peak flooding around the CD2 road and pad, looking northwest; May 21, 2015

Photo 3.6: Lower delta showing Helmerick's Island mostly submerged, looking north; May 22, 2015

On May 23, most of the Alpine road drainage structures were still conveying relatively high flow. The majority of floating ice had cleared, reducing jam potential at drainage structures. Stranded ice was observed on the overbanks throughout the delta indicating water levels continued to recede. By the afternoon, water levels began to equalize along the CD4 and CD2 roads. Floodwater had not subsided enough to be contained within the channels and lakes along the CD5 road east of the Nigliagvik Channel.

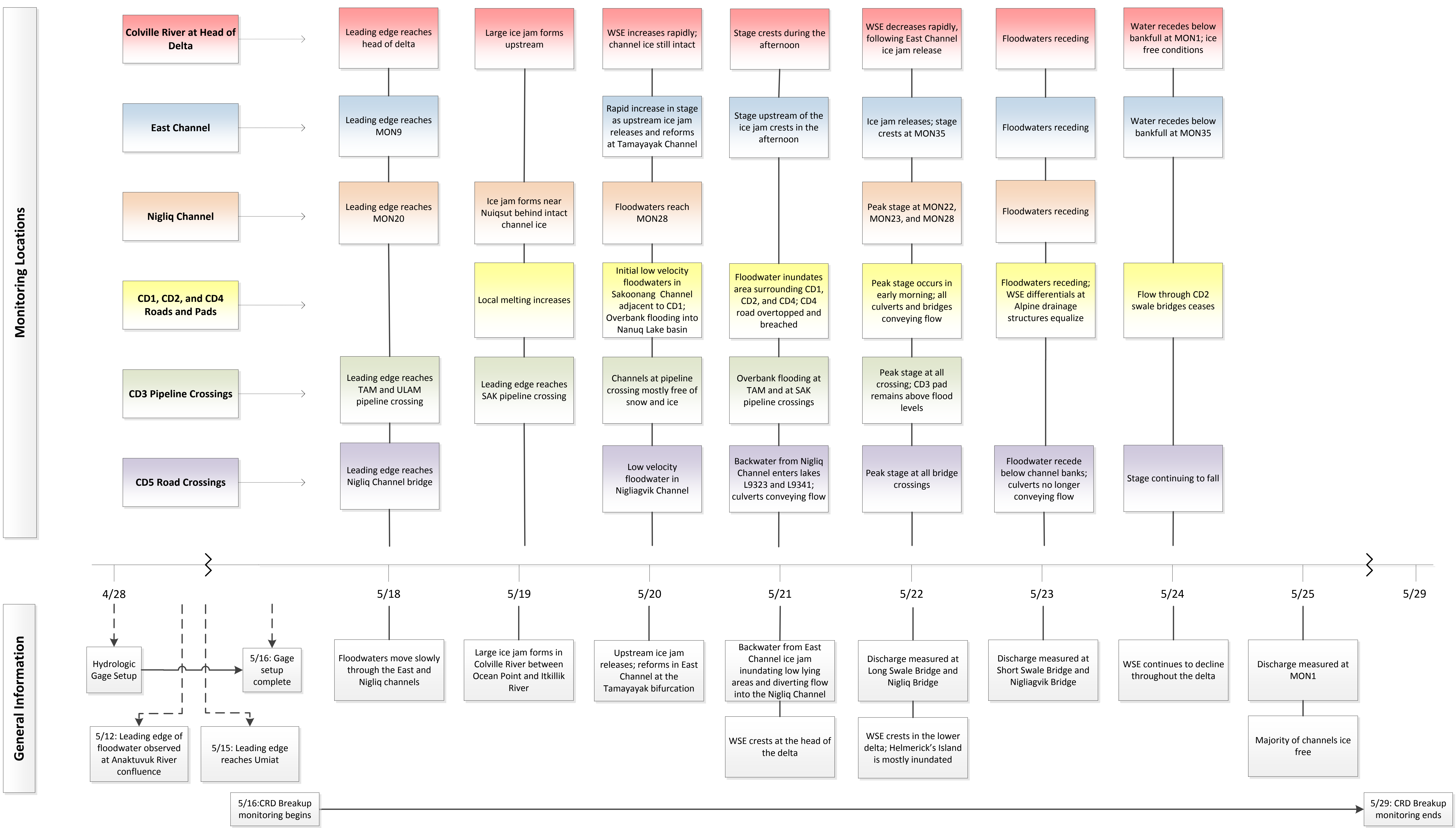
Discharge measurements were performed at the CD2 road Long Swale Bridge on May 22 and at the Nigliagvik Bridge and the CD2 road Short Swale Bridge on May 23. Water levels continued to drop around facilities and throughout the delta. On May 24, the Short Swale Bridge and most culverts were no longer conveying flow. On May 25, discharge was measured in the Colville River at MON1 and at the Nigliq Bridge. WSE continued to decrease throughout the delta.

During the peak flood conditions, at some monitoring locations, all hydrologic gages were submerged and staff gage readings were not possible. At these locations, HWMs were surveyed from a known elevation when floodwaters receded. HWM indicators included chalk lines on gage assemblies and nearby vertical support members, mud lines on bridge abutments and pipeline vertical supports, lath driven into the ground at water's edge, and wash lines in road embankments. Professional judgement was used to describe confidence in HWMs that were used to validate peak WSE in the PT data record and supplement staff gage readings where PT data was not available.

A second, smaller crest in water levels occurred at Umiat in early June, and was likely the result of rapid snow melt in the upper watershed during a period of above average temperatures. The channels in the CRD were ice free at this time, and as a result, the increase in stage at MON1 was insignificant compared with peak conditions and was further attenuated in the delta distributaries.

Figure 3.1 provides a visual timeline summarizing the major 2015 CRD breakup events. Detailed WSE and observations at specific monitoring locations are presented in the following subsections.

Figure 3.1: 2015 Colville River Delta Spring Breakup Hydrologic Timeline



3.2 Colville River – MON1

Located at the head of the delta, MON1 is on the farthest downstream confined reach of the Colville River, conveying approximately 22,500 square miles of runoff in a single channel. MON1 is the only monitoring site upstream of the Nigliq Channel bifurcation. Stage and discharge have been monitored at MON1 annually since 1992 and periodically since 1962. It is considered the primary spring breakup monitoring site because of its location at the head of the delta and long historical record.

Three gaging stations are installed along the west bank. MON1U is located farthest upstream, about 1.8 miles from the Nigliq Channel bifurcation. MON1C and MON1D are located approximately 0.5 mile and 1 mile downstream of MON1U, respectively. The WSEs at MON1U, MON1C, and MON1D are used to approximate the energy grade line for indirectly computing peak discharge at MON1.

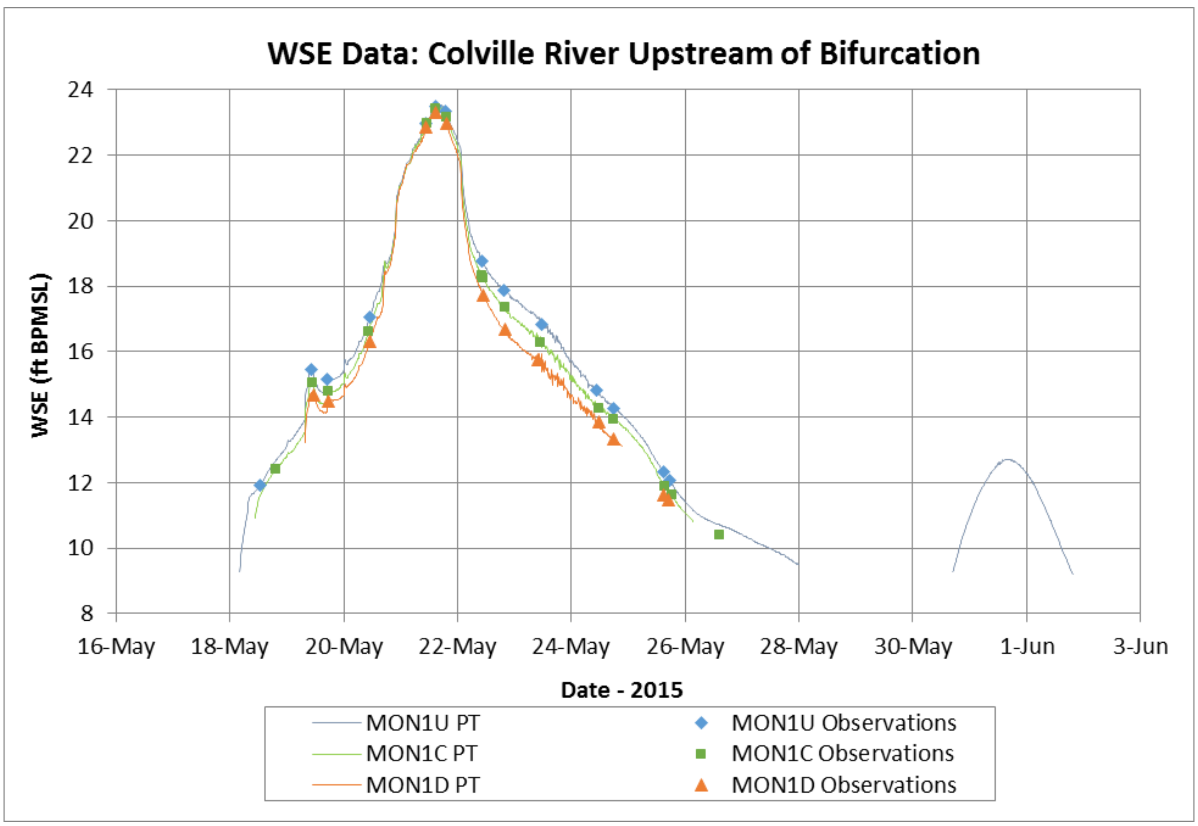
The leading edge of breakup floodwater reached MON1 on May 18. On May 19 a large ice jam was located upstream of the Itkillik River confluence. Stage at MON1 continued to rise throughout the day on May 20, increasing approximately six feet in 24 hours and channel ice was still intact. By the morning of May 21, the upstream jam had released and a large ice jam reformed downstream in the East Channel at the Tamayayak bifurcation. Backwater from the downstream ice jam resulted in overbank flooding at MON1 (Photo 3.7). Peak stage at the MON1 gages occurred in the afternoon on May 21, cresting at 23.47 feet BPMSL at MON1C (Table 3.1). Stage remained high until the morning of May 22 when the East Channel ice jam released, and stage rapidly declined, dropping six feet in 24 hours (Graph 3.2).

Photo 3.7: Overbank flooding in the Colville River at MON1 near the time of peak stage, looking southeast; May 21, 2015

Table 3.1: MON1 2015 Stage Data and Observations

Date	WSE (feet BPMSL)			Observations
	MON1U	MON1C	MON1D	
18-May	11.93	12.39	-	Initial low velocity flow
19-May	15.46	15.05	14.68	Large ice jam forms approximately 5 RM upstream between Ocean Point and Itkilik River
20-May	17.07	16.62	16.33	Upstream ice jam remains in place
21-May	*23.55*	*23.47*	*23.35*	Upstream ice jam releases and reforms downstream in the East Channel; Peak stage occurs around 5:00 PM
22-May	18.78	18.31	17.75	Floodwater recedes 6 feet in 24 hours
23-May	16.85	16.29	15.75	Floodwater recedes 1.5 feet in 24 hours
24-May	14.84	14.27	13.85	Floodwater recedes 2.5 feet in 24 hours
25-May	12.34	11.89	11.62	Ice free conditions, discharge measured at MON1C
26-May	-	10.38	-	Gages dry, mud flats on west bank at MON1C exposed

Note:
1. *Italicized* values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected



Graph 3.2: MON1 2015 Stage Data

3.3 COLVILLE RIVER EAST CHANNEL – MON9, MON9D, AND MON35

The East Channel is monitored at three gaging stations, MON9, MON9D, and MON35. The most upstream is MON9 on the west bank downstream of the resupply ice road and the Alpine Pipeline HDD crossing. This site has been monitored annually since 2005 and the data contributes to estimating the distribution of flow between the East Channel and Nigliq Channel.

MON9D is located about one mile downstream of MON9, also on the west bank, immediately upstream of the Sakoonang Channel bifurcation. The WSEs at MON9 and MON9D are used as the energy grade line for indirectly computing peak discharge at MON9. MON35 is located at the Helmericks Homestead and is the farthest downstream gage site on the East Channel. MON35 has been monitored since 1999 and provides WSE at the outer extents of the delta.

Stage trends at MON9 were very similar to MON1. The leading edge of floodwater reached MON9 during the morning on May 18 and stage gradually increased through May 19. Stage increased rapidly on the afternoon of May 20 when the ice jam upstream of the Itkillik River confluence released and reformed downstream at the Tamayayak Channel. On May 21 large ice floes were backing up at MON9 and WSE increased 8.7 feet in the 24 hours prior to peak stage. Extensive flooding occurred in the east overbank (Photo 3.8) and floodwater and ice floes were near the top of the west bank (Photo 3.9). Peak stage at the gage sites occurred in the afternoon on May 21 cresting at 22.57 feet BPMSL at MON9 (Table 3.2). Stage remained high until the morning of May 22 when the downstream ice jam released and stage rapidly declined, dropping 7.60 feet in 24 hours (Graph 3.3).

In the lower delta, overflow on the seasonal sea ice was observed on May 18 and floodwaters reached the MON35 gages on May 20. On the evening of May 22, ice was pushed over the bank, destroying the gages. The highest recorded WSE at MON35 on May 22, before the gages were destroyed, was 6.97 feet BPMSL. On May 24, water receded below bankfull conditions.

Photo 3.8: Ice floes and overbank flooding at MON9, looking east at Alpine Pipeline HDD east; May 21, 2015

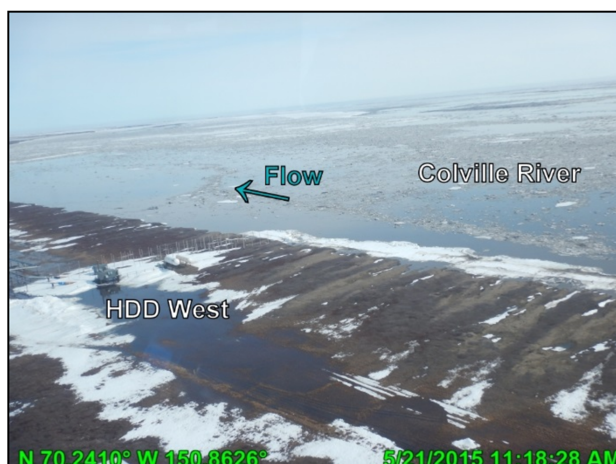


Photo 3.9: East Channel ice floes moving past MON9, looking northeast at Alpine Pipeline HDD West; May 21, 2015

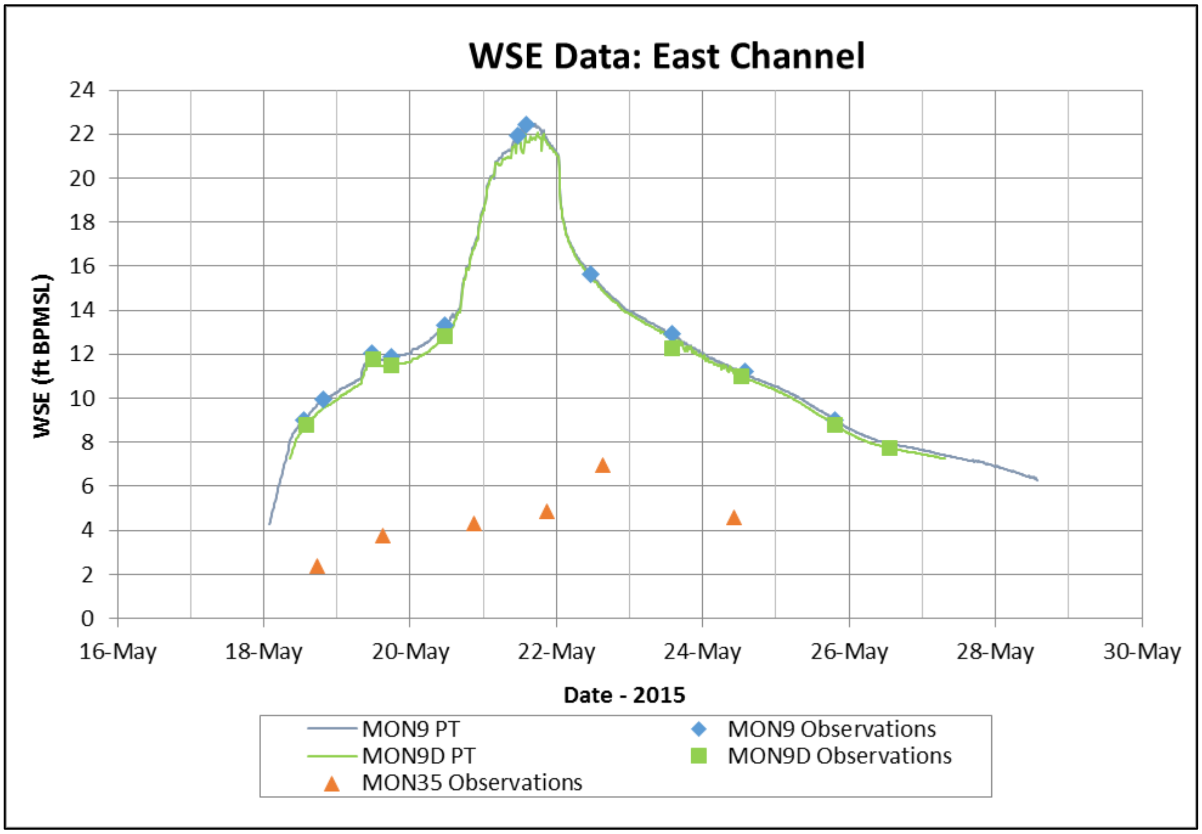
Table 3.2: Colville River East Channel Gages 2015 Stage Data and Observations

Date	WSE (feet BPMSL)			Observations
	MON9	MON9D	MON35	
18-May	9.95	8.77	2.37	Leading edge at MON9; shore lead opens at MON35
19-May	12.06	11.79	3.75	Stage increasing at MON9; no ice movement at MON35, water remains clear in the lower delta
20-May	13.31	12.82	4.30	Large ice jam forms downstream of MON9; muddy water reaches MON35
21-May	*22.57*	*22.08*	4.86	Peak stage at MON9 and MON9D, overbank flooding occurs on east bank
22-May	15.64	-	6.97	Peak stage at MON35, overbank ice destroys gages; stage receding at MON9
23-May	12.91	12.26	-	Floodwaters receding
24-May	11.19	11.03	4.60	Water recedes below bank at MON35
25-May	9.02	8.78	-	Floodwaters receding

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE

2. Dash (-) indicates no gage reading collected



Graph 3.3: East Channel Gages 2015 Stage Data

3.4 NIGLIQ CHANNEL

The Nigliq Channel has historically been monitored at four gaging stations, MON20, MON22, MON23, and MON28. Four additional gage locations provide site specific data upstream and downstream of the CD5 road crossing and are discussed in a separate section. MON20 is the most upstream gage in the Nigliq Channel, MON22 is located about one mile downstream of the Nigliq Bridge, MON23 is near the CD2 pad and downstream of the Nigliagvik Channel confluence, and MON28 is the northern most gage at the outer extents of the delta near Harrison Bay. Gages at MON20, MON22, and MON23 have been monitored intermittently since 1998 and at MON28 since 1999.

The leading edge of breakup floodwater reached MON20 on May 18. On May 19, an ice jam formed behind intact channel ice in the Nigliq Channel near Nuiqsut. Downstream of the CD5 road, low velocity floodwaters from the Nigliq Channel entered the Nanuq Lake basin and moved toward the Long Swale Bridge on the CD2 road via Lake M9524. Initial floodwater was observed at MON23 on May 19 and reached MON28 on May 20. On May 20, the ice jam in the Nigliq Channel near Nuiqsut remained in place and was diverting flow outside the main channel.

On May 21, water levels steadily increased as backwater in the East Channel was diverted into the Nigliq Channel (Photo 3.10 and Photo 3.11). PT data from MON20 shows that stage increased 7.13 feet in 24 hours reaching a peak WSE of 17.58 feet BPMSL (Table 3.3). The peak stage at MON20 was pronounced and WSE declined at nearly the same rate it had risen, dropping 6.38 feet in 24 hours (Graph 3.4). The peak WSEs at the downstream monuments occurred on May 22 and were less pronounced as floodwater spread through the lower delta.

Photo 3.10: Overbank flooding in the Nigliq Channel prior to peak stage, looking northwest at the ice road to Nuiqsut; May 21, 2015

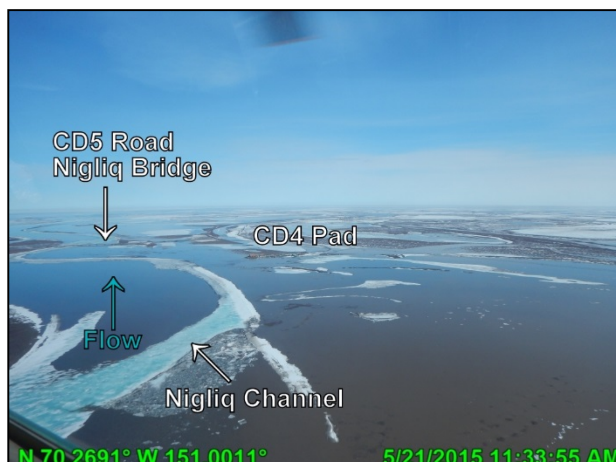


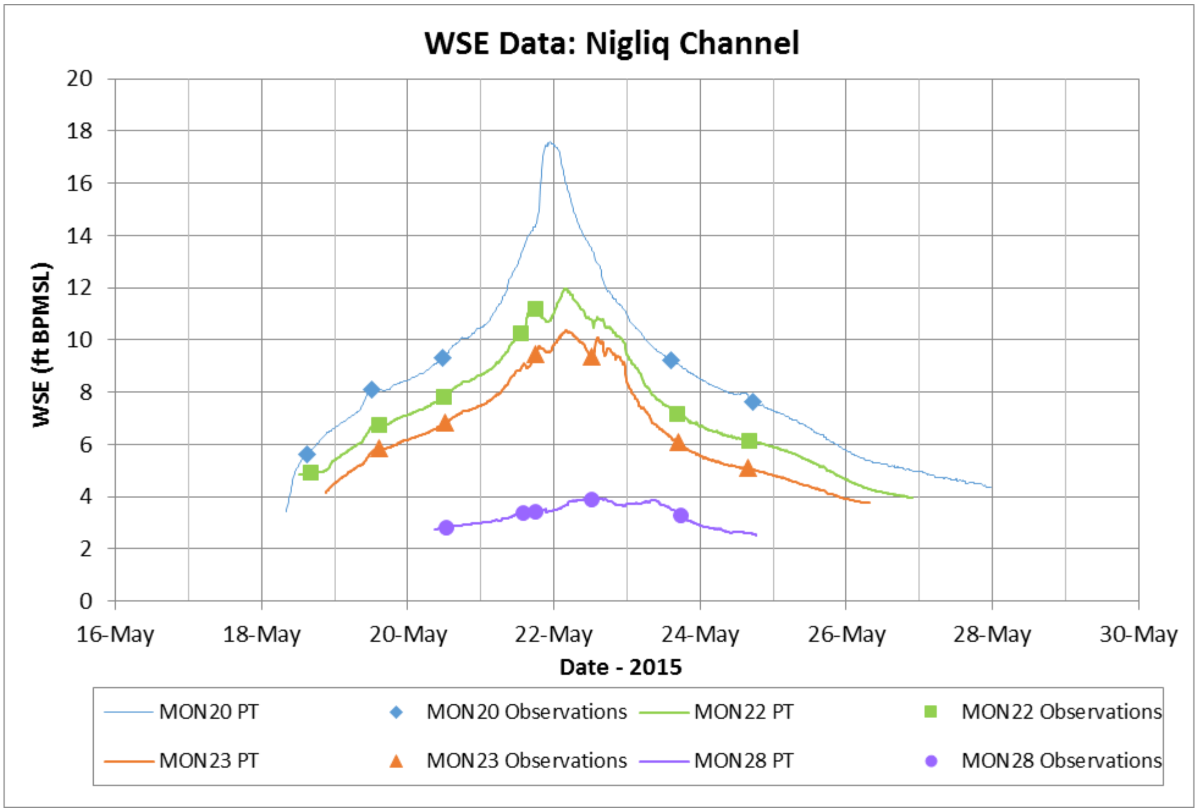
Photo 3.11: Overbank flooding in the Nigliq Channel prior to peak stage, looking north from the vicinity of MON20 toward CD4 pad; May 21, 2015

Table 3.3: Nigliq Channel Monuments 2015 Stage Data and Observations

Date	WSE (feet BPMSL)				Observations
	MON20	MON22	MON23	MON28	
18-May	5.62	4.93	-	-	Leading edge of floodwater arrives at MON20 and MON 22
19-May	8.12	6.76	5.84	-	Water observed at MON23; stage increasing at MON20 and MON22
20-May	9.31	7.84	6.82	2.84	Stage contuing to rise at all monuments
21-May	*17.58*	11.19	9.47	3.42	Peak stage at MON20
22-May	-	*11.98*	*10.37*	*3.94*	Peak stage at MON22, MON23, and MON28; Peak satge at MON22 and MON23 verified with HWMs surveyed following flooding
23-May	9.24	7.19	6.07	3.27	Floodwater receding at all monuments, flooding mostly contained within the channel
24-May	7.62	6.17	5.10	-	Stage continues to fall, MON28 dry

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected



Graph 3.4: Nigliq Channel Monuments 2015 Stage Data

3.5 Alpine Facilities and Roads

Monitoring stations are established at pads and roads adjacent to major water features and at drinking source lakes L9313 and L9312. Paired gages along the access roads capture water levels on the upstream and downstream side of drainage structures to determine stage differential.

CPAI maintains the drainage structures to keep them free of ice and snow accumulation and blockages during the winter months. Techniques include covering the culvert inlets and outlets during the winter and mechanically removing snow from the immediate upstream and downstream areas of all culverts and swale bridges in the spring prior to breakup flooding. Before the 2015 spring breakup, culvert covers were removed and snow was cleared from the culverts and swale bridges.

The progression of flooding around Alpine facilities is driven by conditions in the surrounding channels. Floodwaters typically overtop the active channel banks and spread overland through relic channels, swales, and lake basins. Stage and overbank flood extents around Alpine facilities are largely dependent on WSEs in the major distributaries, typically a function of the timing and location of ice jams.

Drainage structures were monitored for stage differential and functionality during flooding. 2015 spring breakup flooding produced extensive overland flooding resulting in most of the drainage structures conveying flow. Many culverts were completely submerged at their inlets and outlets during peak flood conditions which lasted around 24 hours before water levels rapidly receded. The CD2 road swale bridges conveyed flow near maximum capacity.

3.5.1 CD1 and Lakes L9312 and L9313

Gage G1 is located on the Sakoonang Channel adjacent to the CD1 pad. Gages G9 and G10 are on lakes L9312 and L9313, respectively. Recharge at Lakes L9312 and L9313 has been monitored annually since 1998. Historical observations indicate the Sakoonang Channel floodwater is the primary recharge mechanism for both lakes (Michael Baker 2013a).

Photo 3.12: Inundation around CD1 showing hydraulic connection between the Sakoonang Channel and the drinking water source lakes, looking northeast following peak stage; May 22, 2015

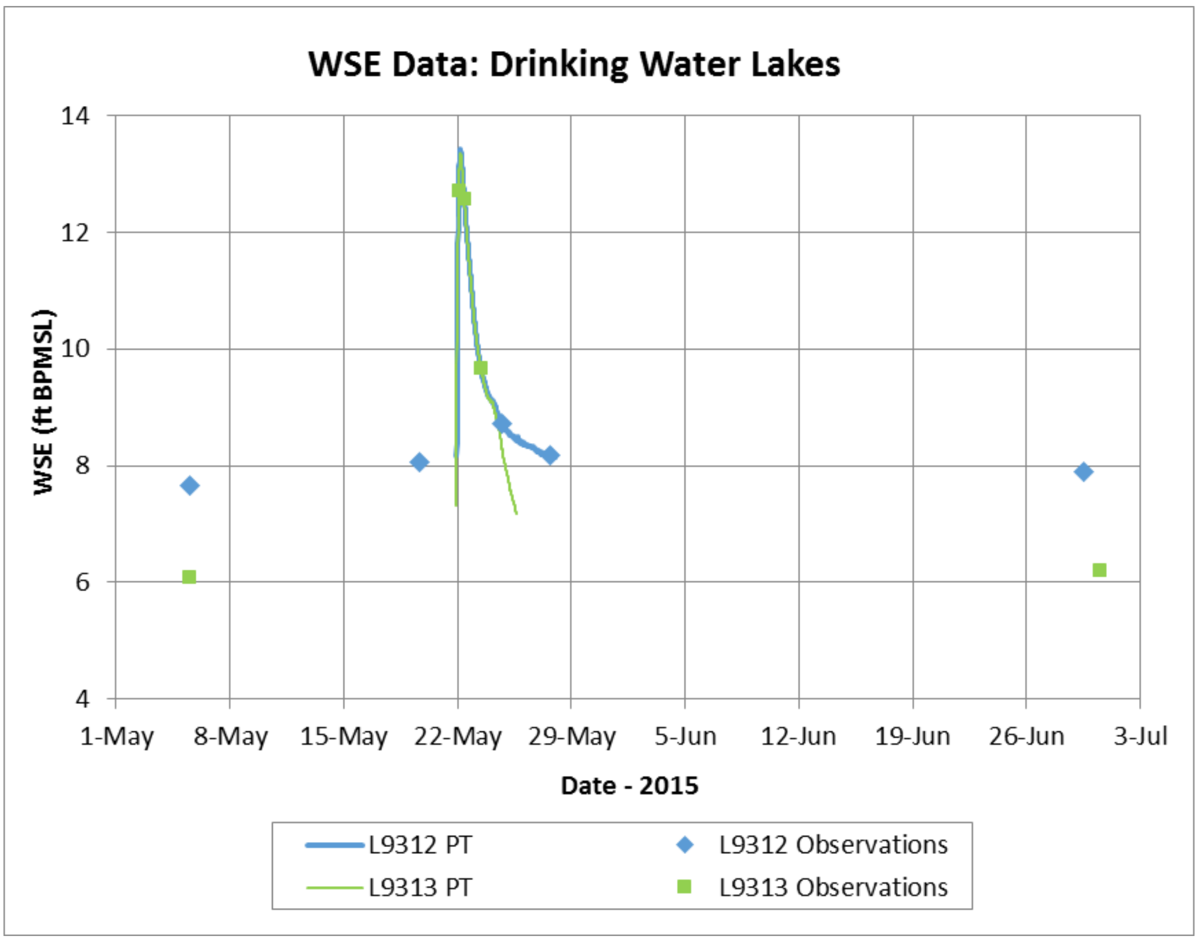
Floodwater stage increased throughout the day on May 21 and crested at all three gages on the morning of May 22 (Graph 3.5 and Graph 3.6). The entire area was inundated by overland flow from the Nigliq and Sakoonang channels (Photo 3.12). Peak stage at the drinking water source lakes was 13.41 and 13.36 feet BPMSL at lakes L9312 and L9313, respectively, well above bankfull (Table 3.4). In the Sakoonang Channel, adjacent to the CD1 pad at gage G1, stage was 11.22 feet BPMSL (Table 3.5).

Table 3.4: Alpine Drinking Water Source Lakes (Lakes L9312 and L9313) 2015 Stage Data and Observations

Date	WSE (feet BPMSL)		Observations
	L9312	L9313	
5-May	7.67	6.09	Frozen, ice approximately 6 ft thick, water quality data collected
19-May	8.07	-	Local melting, ponded water on top of ice
22-May	*13.41*	*13.36*	Peak stage, lakes inundated
23-May	-	9.67	Floodwaters receding
24-May	8.71	-	Lakes remain connected to Sakoonang Channel
27-May	8.17	-	Lakes mostly ice covered
29-Jun	7.91	-	Lakes ice free
30-Jun	-	6.20	

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected



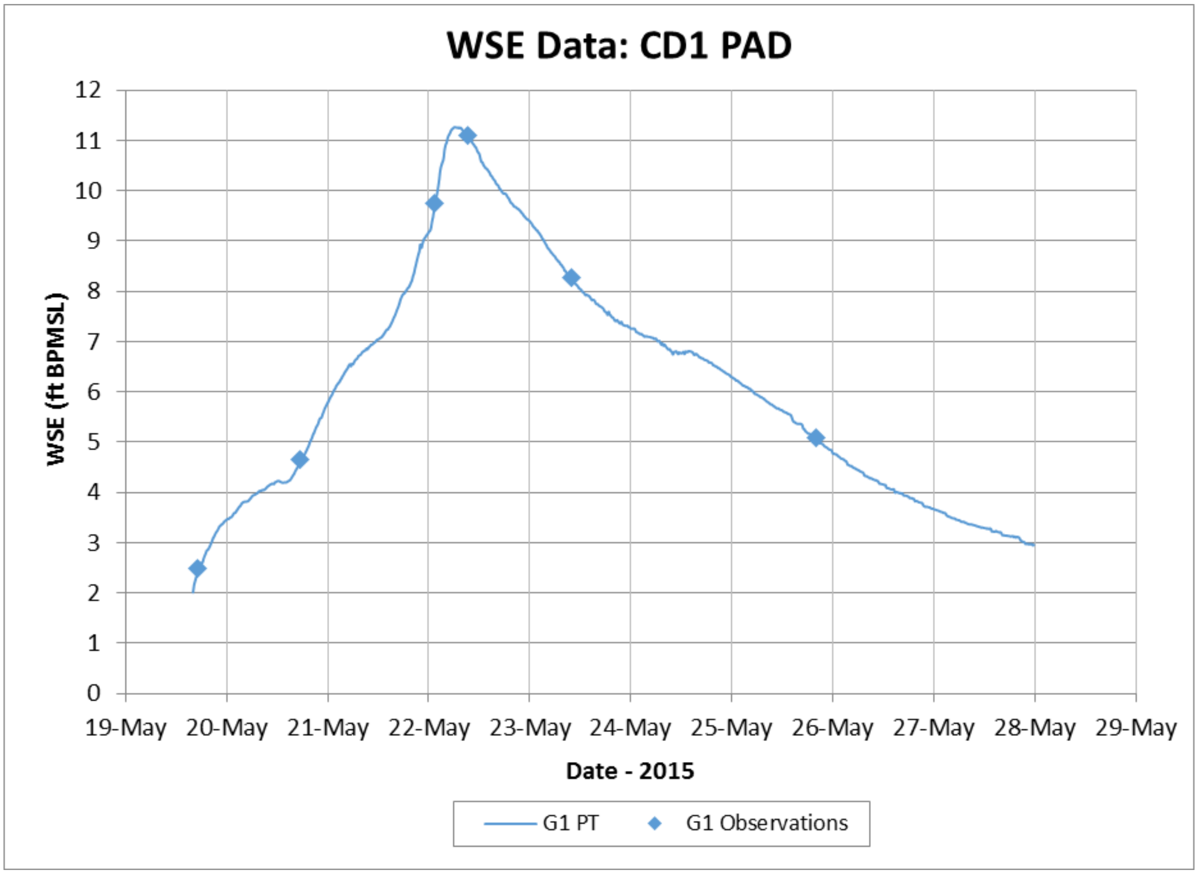
Graph 3.5: Alpine Drinking Water Source Lakes (Lakes L9312 and L9313) 2015 Stage Data

Table 3.5: CD1 Pad (Gage G1) 2015 Stage Data and Observations

Date	WSE (feet BPMSL)	Observations
	G1	
19-May	2.49	Local melting, ponded water
20-May	4.65	Initial low velocity floodwaters
22-May	*11.26*	Peak stage; widespread inundation around pad
23-May	8.28	Floodwaters receding
25-May	5.08	Flow contained within Sakoonang Channel

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE



Graph 3.6: CD1 Pad (Gage G1) 2015 Stage Data

3.5.2 CD2 Road and Pad

Three sets of paired gages are located near drainage structures along the CD2 road. Gages G3 and G4 monitor stage near the Long and Short swale bridges, G6 and G7 are located adjacent to the culvert battery near the west end of the road connecting lakes L9321 and L9322, and gages G12 and G13 are in the vicinity of several individual culverts west of the Short Swale Bridge. Stage at the northwest corner of the CD2 pad is monitored by gage G8.

All three paired gages along the CD2 road followed a similar trend, rising and falling rapidly over a 48 hour period. The first hydrologic connection of floodwaters between upstream and downstream was observed on May 20. On May 21, backwater behind the ice jam in the East Channel was being diverted into the Nigliq Channel and stage continued to increase throughout the day around the CD2 road and pad, submerging culvert inlets and increasing flow through the swale bridges (Photo 3.14). Peak WSE occurred in the early morning on May 22 and water levels reached the bottom chord of the swale bridges (Photo 3.14 and Photo 3.15).

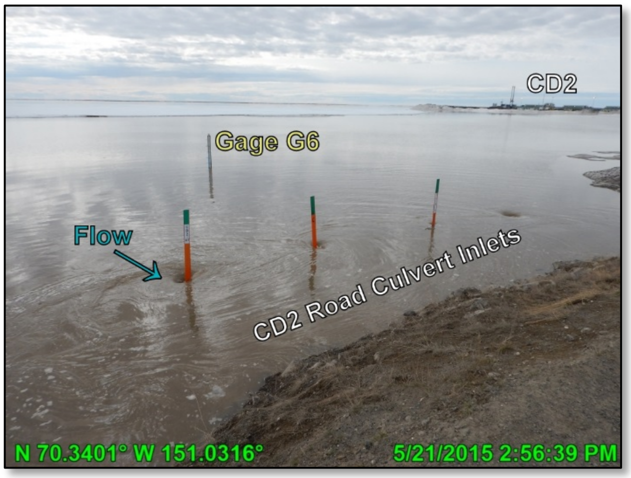


Photo 3.13: CD2 road culvert battery inlets inundated prior to peak WSE, looking west; May 21, 2015

Photo 3.14: Flow through the CD2 road Short Swale Bridge following peak WSE, looking west, May 22, 2015

At the the swale bridges, PT data shows the maximum WSE differential between upstream gage G3 and downstream gage G4 was 1.73 feet, one hour before the time of peak WSE upstream (Table 3.6). Peak WSE on the downstream side occurred two hours later and the differential equalized within about 24 hours (Graph 3.5). By May 24, flow through the swale bridges had ceased.

Gage readings and HWMs observed along the western portion of CD2 Road at gages G12 and G13 documented peak stage and maximum upstream gage G12 and downstream gage G13 differential slightly higher than at the swale bridges (Table 3.7). The timing of peak WSE and differential equalization was similar to the swale bridges (Graph 3.8).

Photo 3.15: CD2 road swale bridges near the time of peak WSE, looking northwest; May 21, 2015

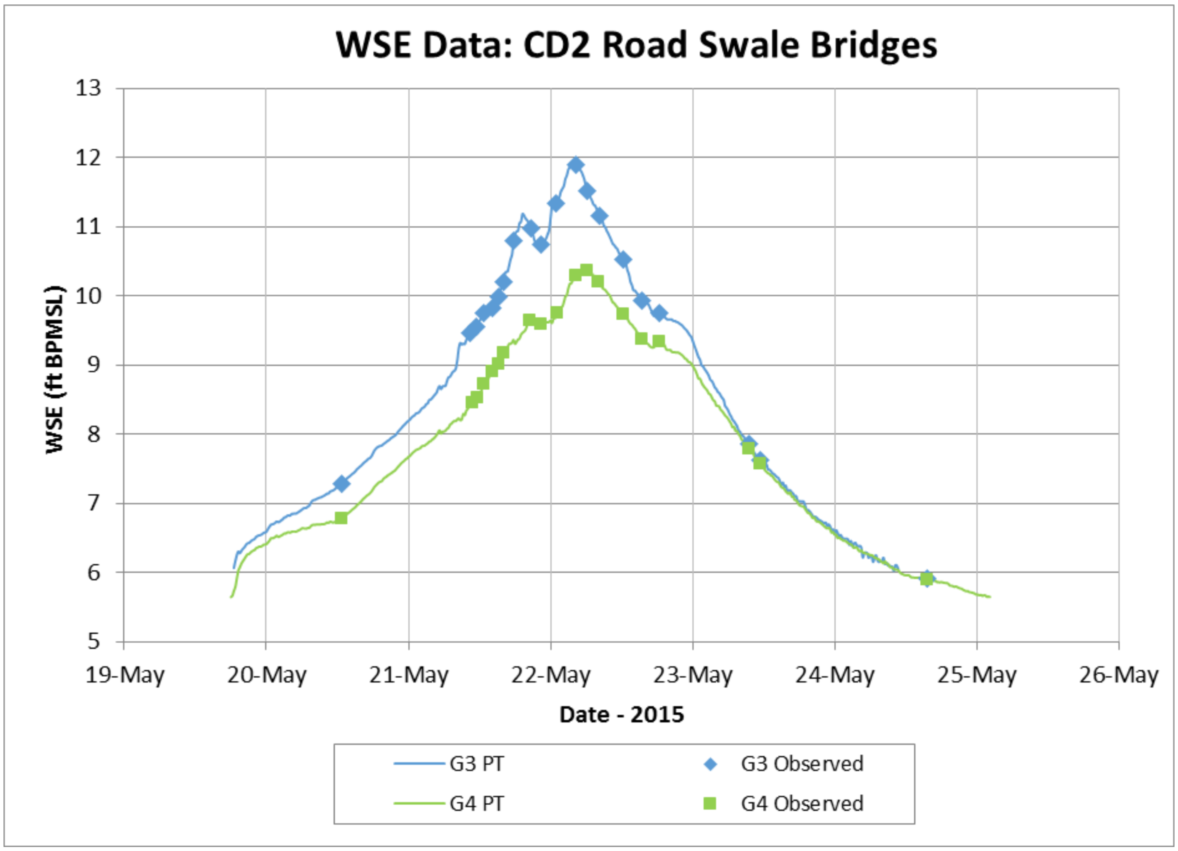
The highest peak WSE observed on the CD2 Road was near the west end at gage G6, but the maximum upstream and downstream differential between gages G6 and G7 was slightly lower than the other paired gages along the CD2 road (Table 3.8). Stage around the CD2 Pad (gage G8) reached a similar elevation as the downstream side of the CD2 Road (Graph 3.9).

Table 3.6: CD2 Road Swale Bridges (Gages G3 and G4) 2015 Stage Data and Observations

Date	WSE (feet BPMSL)		Observations
	G3	G4	
20-May	7.28	6.78	Hydraulic connection upstream and downstream of road
21-May	10.98	9.64	Stage rising, extensive flooding
22-May	*11.93*	*10.39*	Peak stage; maximum head differential of 1.73 feet
23-May	7.85	7.79	Floodwaters receding; discharge measurement completed
24-May	5.91	5.89	Stage falling
26-May	-	-	No flow, ponded water

Note:

1. Italicized values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected



Graph 3.7: CD2 Road Swale Bridges (Gages G3 and G4) 2015 Stage Data

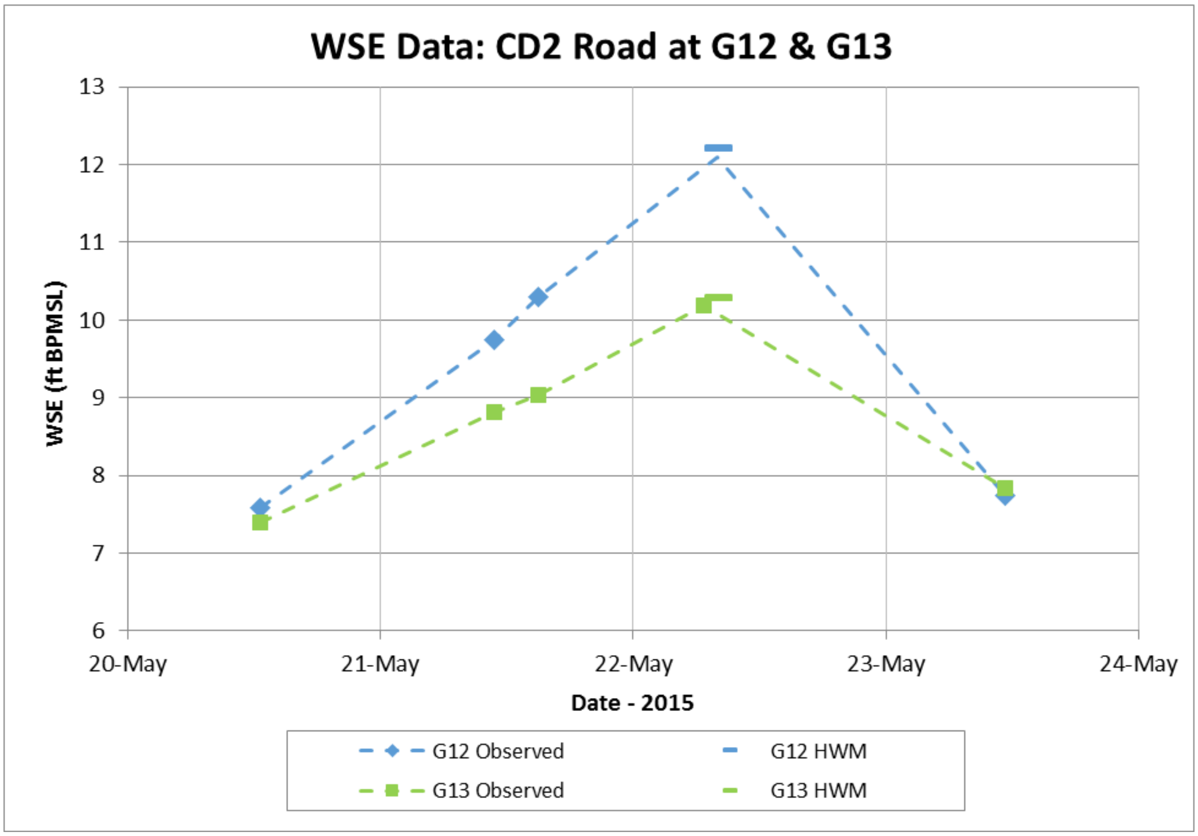
Table 3.7: CD2 Road Culverts (Gages G12 and G13) 2015 Stage Data and Observations

Date	WSE (feet BPMSL)		Observations
	G12	G13	
20-May	7.58	7.40	Stage rising
21-May	10.29	9.04	Stage rising, extensive flooding
22-May	12.21*	10.29*	Peak stage; maximum head differential of 1.92 feet based on high water marks
23-May	7.74	7.83	Floodwaters receding

Note:

1. Dash (-) indicates no gage reading collected

2. * Value from high water mark observed when flooding receded



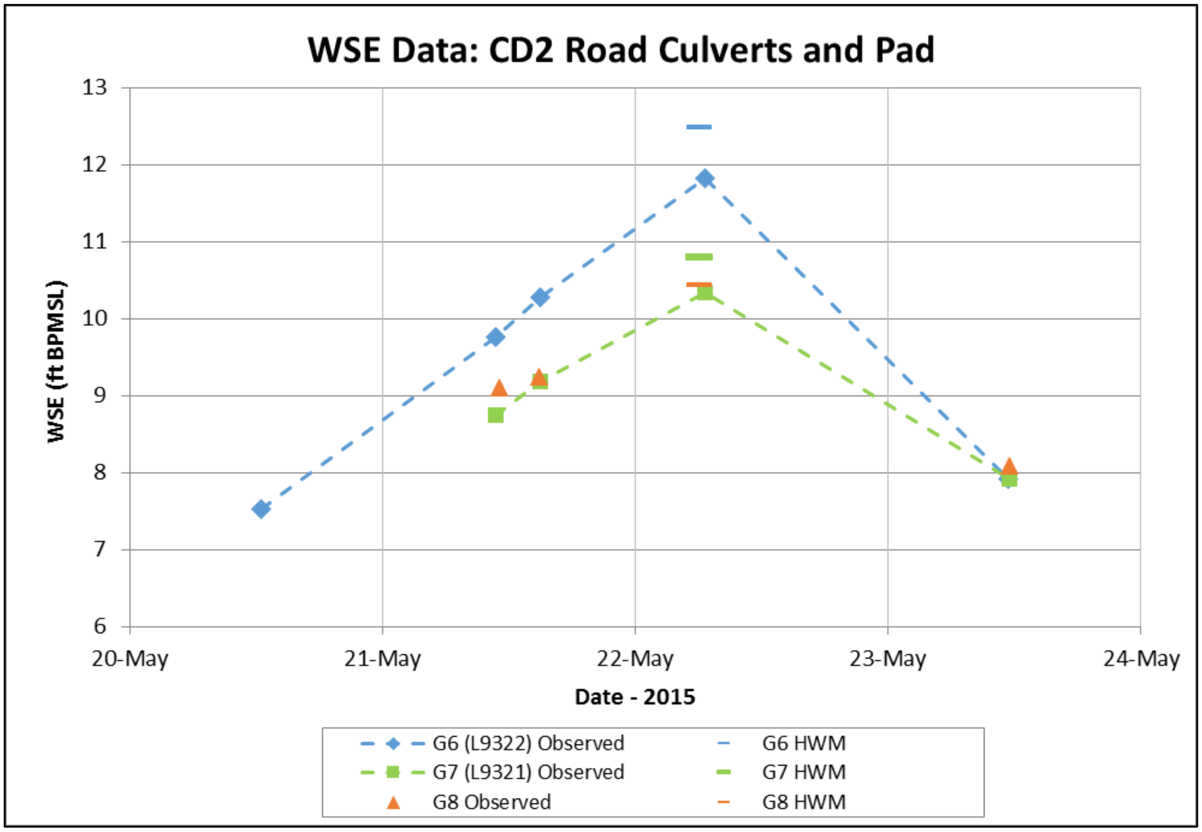
Graph 3.8: CD2 Road Culverts (Gages G12 and G13) 2015 Stage Data

Table 3.8: CD2 Road Culverts (Gages G6, G7, and G8) 2015 Stage Data and Observations

Date	WSE (feet BPMSL)			Observations
	G6 (L9322)	G7 (L9321)	G8 (CD2 Pad)	
18-May	Dry	Dry	-	Ponded local meltwater
20-May	7.53	Dry	-	Local meltwater rising at G6, G7 still snow covered
21-May	10.28	9.19	9.24	Stage rising, extensive flooding
22-May	12.48*	10.80*	10.43*	Peak stage; maximum head differential of 1.68 feet based on high water marks
23-May	7.92	7.91	8.09	Stage falling, no flow through culverts

Note:

1. Dash (-) indicates no gage reading collected
2. * Value from high water mark observed when flooding receded



Graph 3.9: CD2 Road Culverts (Gages G6, G7, and G8) 2015 Stage Data

3.5.3 CD3 PAD

The CD3 Pad and airstrip remained above flood level for the duration of the 2015 breakup flood event. No floodwater or ponded local melt was observed at gage G11 and the PT remained dry.

The CD3 pipeline crosses three major distributary channels between CD1 and CD3. WSE is monitored downstream of the pipeline crossings at the Sakoonang (SAK), Tamayayak (TAM), and Ulamnigiaq (ULAM) channels. Stage data and observations of breakup processes have been collected at these locations intermittently since 2000.

The leading edge of floodwater reached the TAM and ULAM pipeline crossing on May 18 and the SAK pipeline crossing on May 19. The channels at the pipeline crossings were mostly clear of snow and ice on May 20 and stage continued to rise. PT data shows the WSE trends at the TAM and ULAM gages were nearly identical (Graph 3.10). A large ice jam in the East Channel upstream of the Tamayayak Channel held back water on May 20 and 21. Stage peaked at the TAM and ULAM gages during the afternoon on May 22 (Table 3.9). At the time of peak stage there was minimal overbank flooding in the vicinity of the ULAM gage and moderate overbank flooding at the TAM gage (Photo 3.16 and Photo 3.17).

Photo 3.16: Ulamnigiaq Channel at the CD3 pipeline crossing near the time of peak flooding, looking southeast; May 22, 2015

Photo 3.17: Tamayayak Channel at the CD3 pipeline crossing near the time of peak flooding, looking southeast; May 22, 2015

Flooding was more pronounced in the Sakoonang Channel. Stage at the SAK gage began rising rapidly on May 20 and increased 6.20 feet over the next 48 hours as the East Channel ice jam diverted flow into the Sakoonang Channel (Graph 3.10). The peak WSE at SAK was 10.43 feet BPMSL during the morning of May 22. Many lakes and paleo lakes were hydraulically connected to the Sakoonang Channel during flood conditions (Photo 3.18).

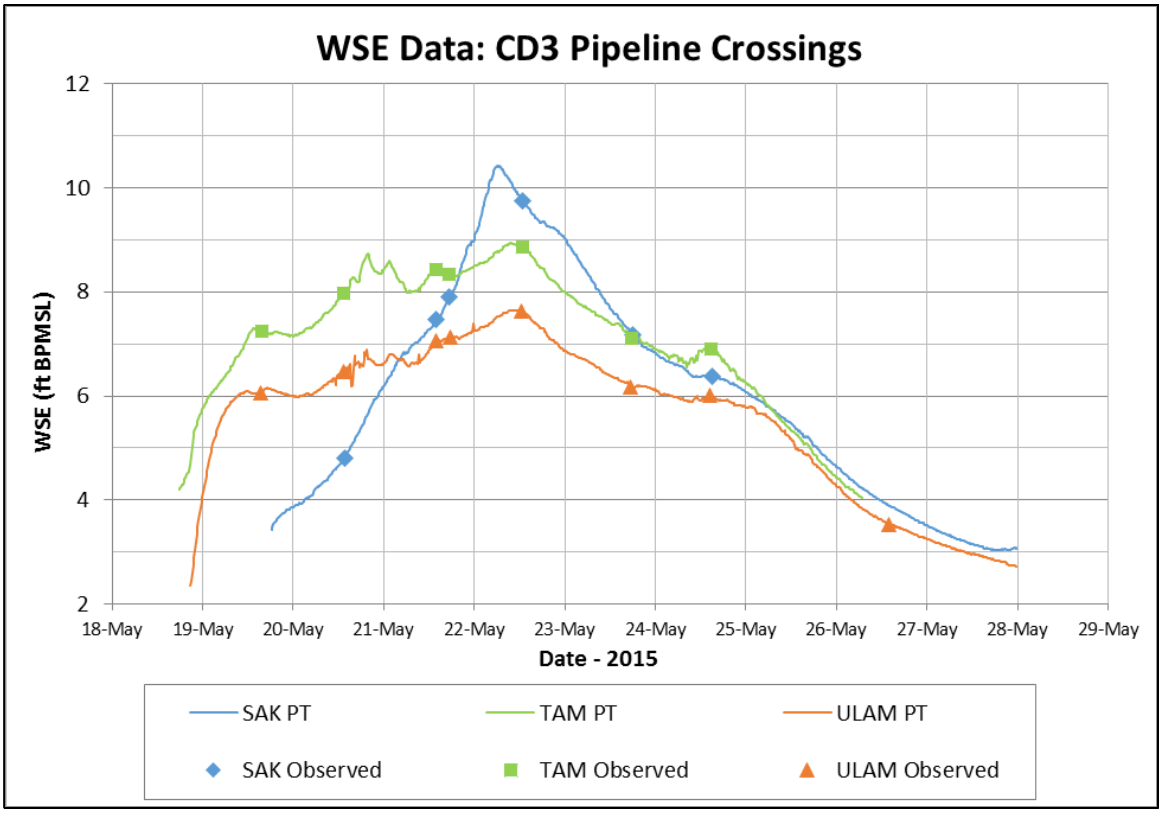
Photo 3.18: Sakoonang Channel at the CD3 pipeline crossing near the time of peak flooding, looking northwest; May 22, 2015

Table 3.9: CD3 Pipeline Crossings 2015 Stage Data and Observations

Date	WSE (feet BPMSL)			Observations
	SAK	TAM	ULAM	
19-May	-	7.24	6.07	Leading edge of floodwaters reaches gages, low velocity flow on top of snow and ice in channel
20-May	4.81	7.96	6.47	Channels mostly clear of snow and ice
21-May	7.91	8.42	7.13	Stage rising, overbank flooding at SAK and TAM
22-May	*10.43*	*8.94*	*7.65*	Peak stage
23-May	7.17	7.11	6.18	Stage falling, flow contained within channel banks
24-May	6.38	6.91	6.01	Ice floes observed at SAK and TAM; snow and ice remain in channel at ULM
26-May	-	-	3.52	Flooding receded, SAK and TAM gages dry, ponded water at ULAM

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected



Graph 3.10: CD3 Pipeline Crossings 2015 Stage Data

3.5.4 CD4 Road and Pad

The CD4 road does not cross active distributary channels; however, it is subject to flooding from overland flow through the surrounding lake basins. Four sets of paired gages are located near drainage structures along the CD4 road. Gages G40/G41 and G42/G43 monitor WSE north of the CD5 road junction. Gages G15/G16 are just south of the CD5 road junction at the north culvert battery and gages G17/G18 are at the south culvert battery. Additionally, gage M9525 measures WSE at Lake M9525 near the CD2 road junction and gages G19 and G20 are near the CD4 pad and at Tapped Lake, respectively.

Local melt was accumulating in polygon depressions and low lying areas around the CD4 road and pad on May 19 and May 20. On May 21, floodwater began to inundate the surrounding area (Photo 3.19). Stage increased rapidly during the day as backwater water behind the East Channel and the Nigliq Channel ice jams was diverted through the lake basins between the Sakoonang and Nigliq Channels.

The hydrograph at gages G15 and G16 was similar to that of the East Channel at MON9 and the Nigliq Channel at MON20 with stage rising over 10 feet in 24 hours and then receding at a similar rate. Peak stage observed at G16 was 15.43 feet BPMSL during the early morning on May 22, 10 hours after the peak WSE recorded in the East Channel at MON9 and three hours after the peak in the Nigliq Channel at MON20.

The culvert inlets and outlets at the south battery were submerged by water moving west overland from the Sakoonang Channel through the South Paleo Lake and eastward overbank flow from the Nigliq Channel (Photo 3.20). As the water flowed north around the CD4 pad, large head differentials formed at the north culvert battery. At 8:00 PM on May 21, WSEs at the north culvert battery were 15.17 feet BPMSL at gage G16 on the south side of the road and 9.43 feet BPMSL at gage G15 on the north side of the road. This equated to the maximum observed differential of 5.74 feet between gages G16 and G15 (Photo 3.21). The WSE south of the south culvert battery (gage G18), was 15.85 feet BPMSL. At this time, the CD4 road, northeast of gage G18, was overtopped and eventually breached. Three hours later the differential between gages G16 and G15 had dropped to 1.6 feet as stage increased in the low-lying area east of the road. At 8:00 AM on May 22, most of the culvert inlets were no longer submerged and the differential was 0.44 feet. Floodwater was still flowing through the breach in the road on the morning of May 22 (Photo 3.22). On May 23, floodwaters had receded from the area and flow through the culverts ceased. The peak WSE at gage G18, surveyed from a HWM, was 16.58 feet BPMSL occurring sometime on the morning or May 22. A HWM of 17.33 feet BPMSL was recorded at gage G19 on the south side of CD4 Pad.

Table 3.10 and Table 3.11 summarizes stage and ice observations during breakup. Graph 3.11 and Graph 3.12 show the stage data collected at the CD4 road culverts near gages G15 and G16 and the CD4 pad and road culverts near gages G17, G18, G19, and G20, respectively.

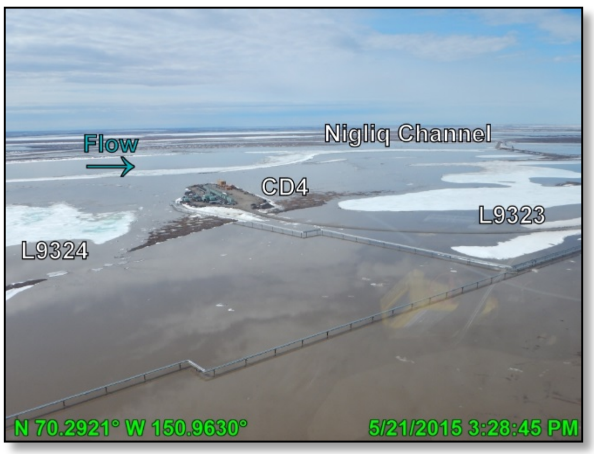


Photo 3.19: Flooding around the CD4 pad, looking northwest prior to peak WSE in the area; May 21, 2015

Photo 3.20: Floodwater overtopping the road near gage G18 prior to peak stage, looking south; May 21, 2015

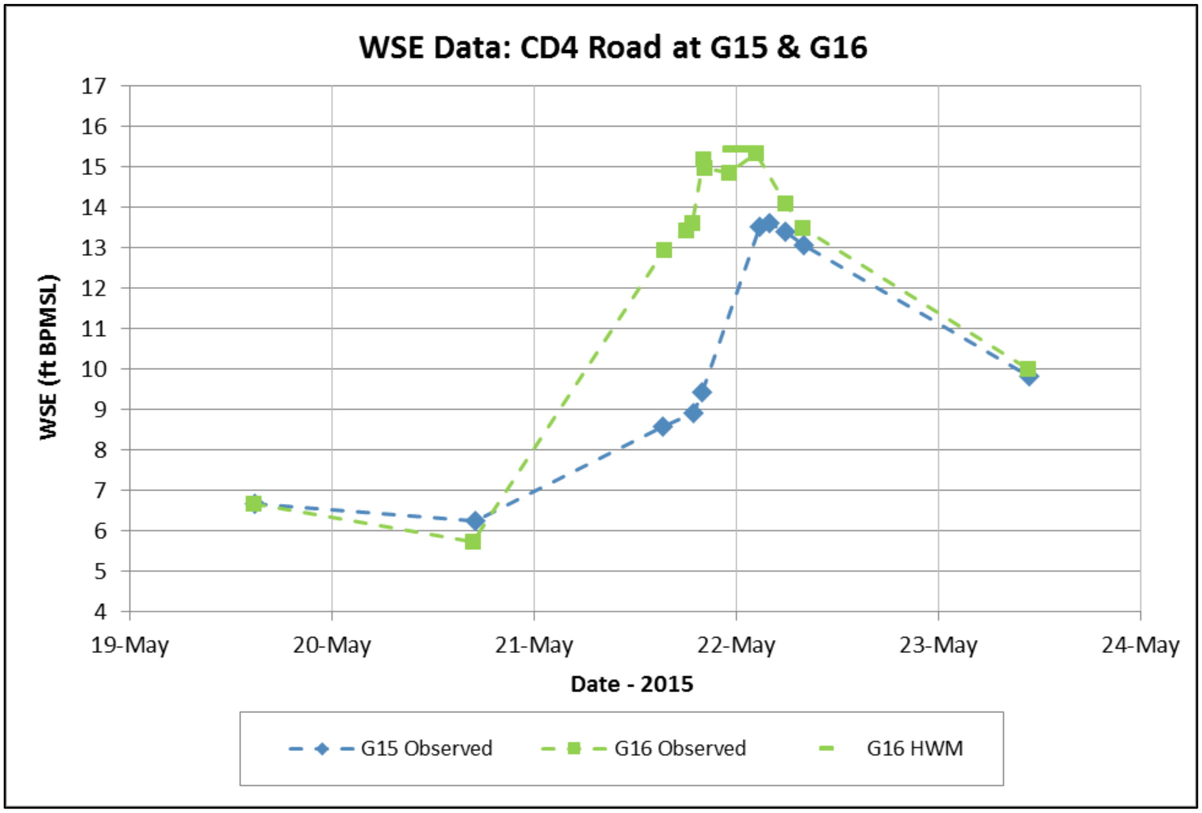
Photo 3.21: CD4 road looking southeast at north culvert battery at the time of the 5.74 foot WSE differential; May 21, 2015

Photo 3.22: CD4 road and pad following peak stage, looking west; May 22, 2015

Table 3.10: CD4 Road Culverts 2015 Stage Data and Observations

Date	WSE (feet BPMSL)		Observations
	G15	G16	
19-May	6.68	6.67	Local melting, ponded water
20-May	6.26	5.73	Local melting, ponded water
21-May	9.43	15.17	Flooding from overland flow; gages submerged, surveyed to waters edge
22-May	13.60	15.43*	Peak stage, gages submerged, surveyed to waters edge
23-May	9.83	10.00	Floodwaters receding

Note:
1. * Value from high water mark observed when flooding receded

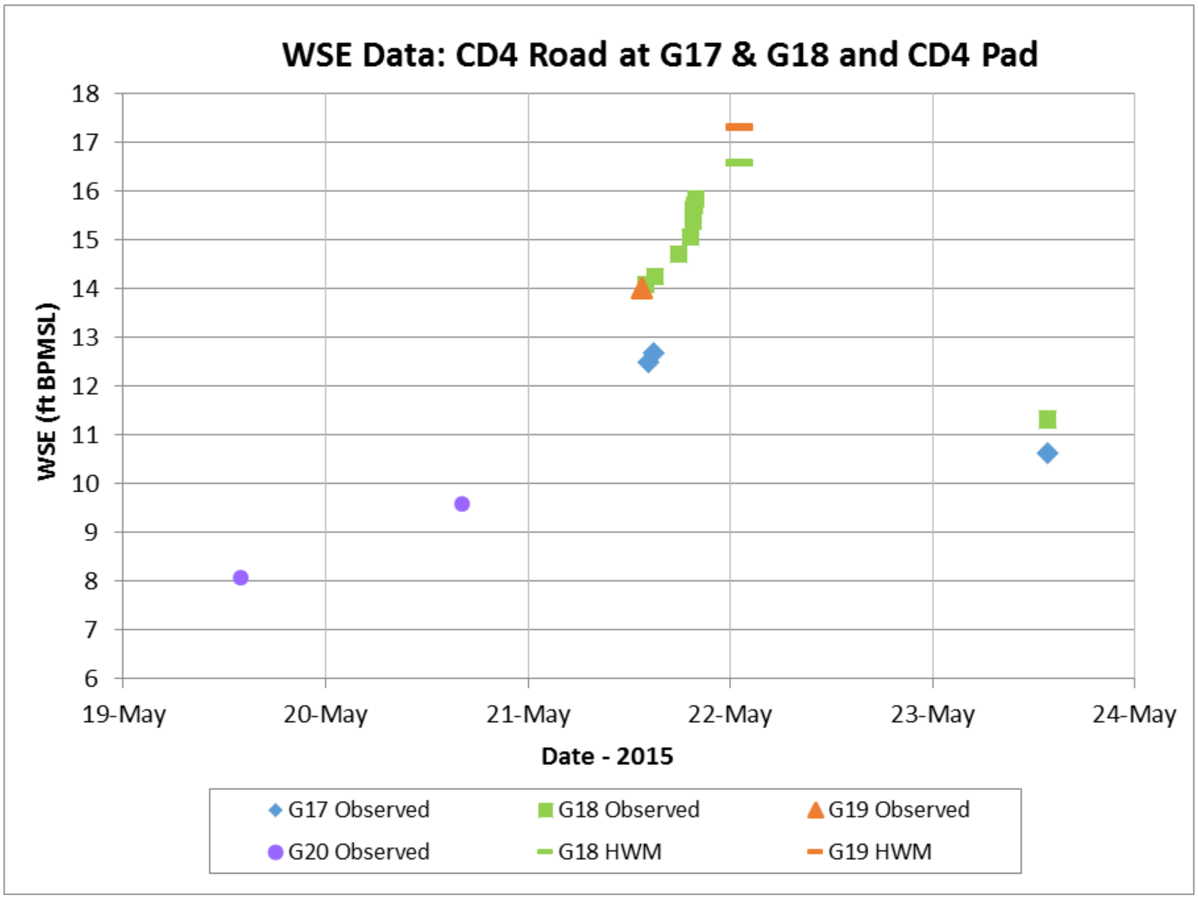


Graph 3.11: CD4 Road Culverts 2015 Stage Data

Table 3.11: CD4 Pad and Road at G17 and G18 2015 Stage Data and Observations

Date					Observations
	G17	G18	G19	G20	
19-May	Dry	Dry	8.06	Dry	Local melting, ponded water
20-May	Dry	Dry	9.58	Dry	Local melting, ponded water
21-May	12.68	15.85	-	14.02	Gages submerged, surveyed to waters edge
22-May	-	16.58*	17.33*	-	Peak stage, gages submerged, surveyed to waters edge
23-May	10.63	11.34	Dry	Dry	Floodwaters recede

Note:
1. Dash (-) indicates no gage reading collected
2. * Value from high water mark observed when flooding receded



Graph 3.12: CD4 Pad and Road at G17 and G18 2015 Stage Data

Flooding on the northern portion of the CD4 road was more moderate and the culverts did not experience large head differentials as water was conveyed north through the Sakoonang and Nigliq channels. The lake basins to the east and west were inundated and hydraulically connected (Photo 3.23). The peak WSE recorded in the area was a HWM of 12.32 feet BPMSL at gage G40 just north of Nanuq Lake (Table 3.12 and Graph 3.13). On May 23, floodwaters had receded.

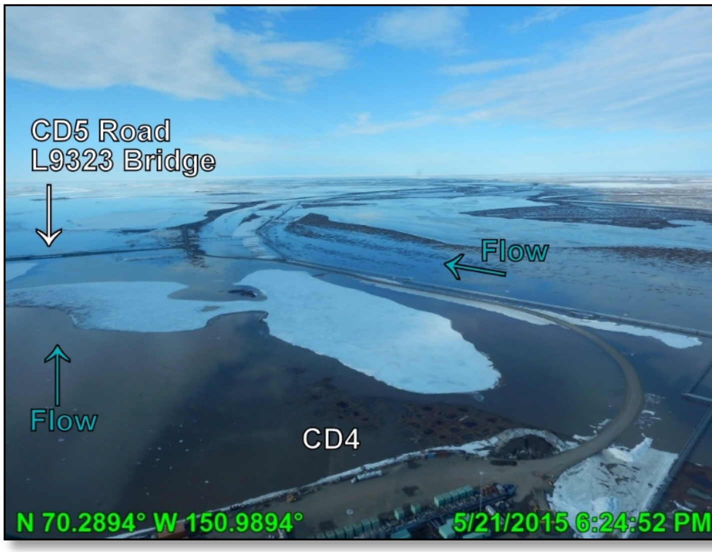
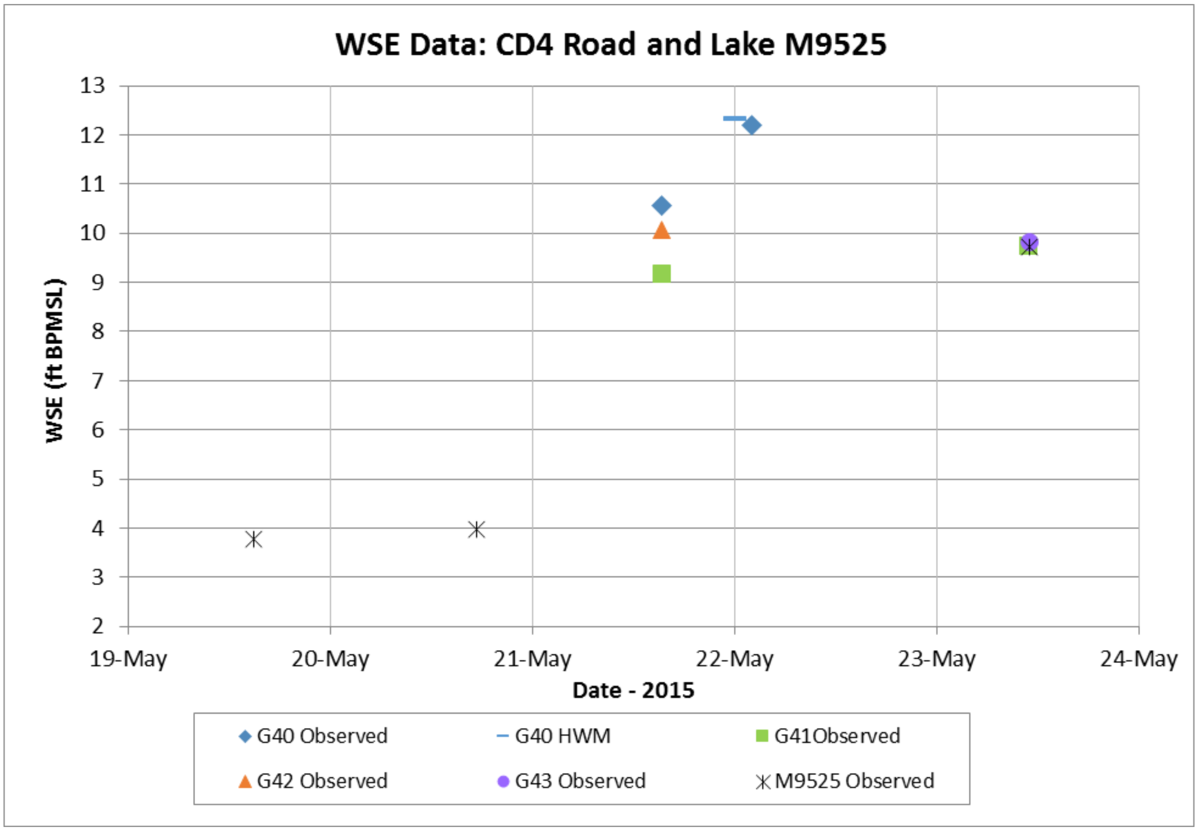


Photo 3.23: Inundation around CD4 Road prior to peak stage, looking north; May 21, 2015

Table 3.12: CD4 Road Culverts and Lake M9525 2015 Stage Data and Observations

Date	WSE (feet BPMSL)					Observations
	G40	G41	G42	G43	M9525	
19-May	-	-	-	-	3.77	Local melting, ponded water
20-May	-	-	-	-	3.97	Local melting, ponded water
21-May	10.57	9.17	10.06	-	-	Initial foodwaters; flow through culverts, lake M9525 connected to drinking water lake L9313
22-May	12.32*	-	-	-	-	Peak stage, gages submerged, widespread inundation
23-May	Dry	9.74	Dry	9.81	9.71	Floodwaters recede

Note:
1. Dash (-) indicates no gage reading
2. * Value from high water mark observed when flooding receded



Graph 3.13: CD4 Road Culverts and Lake M9525 2015 Stage Data and Observations

3.5.5 CD5 Road and Pad

Nine sets of paired gages are located along the CD5 road to monitor WSEs at drainage structures. From east to west the gages are G24/G25 located at Lake L9323 Bridge, G26/G27 and G28/G29 at the Nigliq Bridge, G30/G31 at culverts just west of the Nigliq Channel, G32/G33 at Lake L9341 Bridge, G34/G35 and G36/G37 at culverts east of the Nigliagvik Channel, G38/G39 at the Nigliagvik Bridge, and S1/S1D at a small stream near the CD5 pad.

A. Nigliq Bridge

Gage G26 is located immediately upstream of the Nigliq Bridge and gage G27 is immediately downstream. This gage set provides WSE differential at the bridge. Gages G28 and G29 are located about 0.5 miles upstream and downstream of the bridge, respectively. WSEs at these gages provide the energy grade line used to estimate peak discharge at the bridge and distribution of flow in the Nigliq Channel. These four gages have been monitored annually since 2013.

The leading edge of breakup flooding reached the Nigliq Bridge on May 18 and stage continued to gradually rise until the afternoon on May 21 when backwater behind the ice jam in the East Channel was diverted into the Nigliq Channel and stage rapidly increased. Stage at gage G28 increased 4.95 feet in 24 hours and overbank flooding began to inundate the surrounding floodplain (Photo 3.24). The hydrograph at both gage sets bracketing the bridge was very similar. Peak stage occurred at around 2:00 AM on May 22 and WSE decreased at the same rate, falling 4.55 feet on May 22 at gage G29.

Gage G27 was destroyed by an ice floe and the PT was lost limiting the WSE differential data at the Nigliq Bridge to gages G28 (upstream) and G29 (downstream); these gages are about one mile apart. The peak WSE differential was 1.18 feet 12 hours prior to peak stage. The differential declined to 0.52 feet in three hours and at the time of peak stage was 0.45 feet. The differential was constant over the next 12 hours before continuing to decline.

Table 3.13 summarizes stage and ice observations during breakup and Graph 3.14 shows the stage data collected at the CD5 road crossings near the Nigliq Channel.

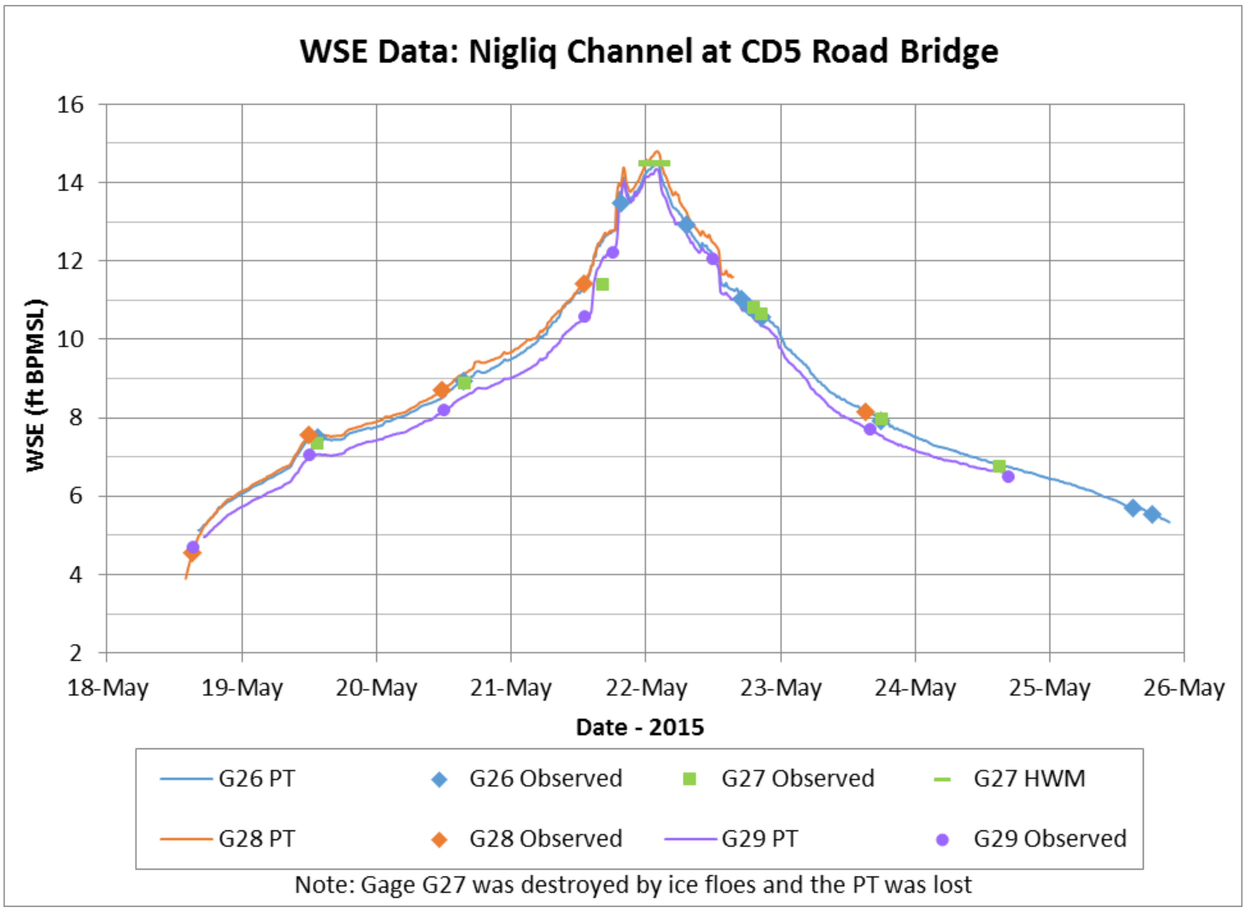
Photo 3.24: Inundation around the Nigliq Bridge 10 hours after peak stage, looking northeast; May 22, 2015

Table 3.13: Nigliq Channel at CD5 Road Bridge 2015 Stage Data and Observations

Date	WSE (feet BPMSL)				Observations
	G26	G27	G28	G29	
18-May	-	-	4.57	4.70	Leading edge of low velocity floodwaters
19-May	7.49	7.32	7.55	7.04	Ice jam forms upstream near Nuiqsut
20-May	8.93	8.87	8.71	8.18	Stage increasing, channel ice remains intact
21-May	13.48	11.38	11.43	12.21	Water diverted from the East Channel into Nigliq Channel; stage increasing rapidly
22-May	*14.50*	14.45*	*14.80*	*14.35*	Peak stage; extensive overbank flooding upstream and downstream of Nigliq Bridge
23-May	7.93	7.95	8.14	7.68	Floodwaters recede, flow nearly contained within the channel
24-May	-	6.73	-	6.49	Minimal overbank flooding
25-May	5.69	-	-	-	Stage continues to decline

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected
3. Value from a high water mark surveyed after flooding receded



Graph 3.14: Nigliq Channel at CD5 Road Bridge 2015 Stage Data

B. Lake L9323 and Lake L9341 Bridges

Lakes L9323 and L9341, located east and west of the Nigliq Channel, are spanned by bridges. Local meltwater was observed accumulating on the surrounding polygon depressions and on lake ice on May 19 and May 20. On May 21, overland flow from the Nigliq Channel began to inundate the area. Lake L9323 hydraulically connected with the Nigliq Channel via Tapped Lake. The hydrograph trend at both bridges was similar with stage rising about six feet in 20 hours and peak WSE occurring early on the morning of May 22, the same time as peak WSE at the Nigliq Bridge. Maximum WSE differential at Lake L9323 WSE occurred two hours prior to peak stage; WSE on the south side of the bridge (gage G24) was 1.00 feet higher than the north (gage G23) indicating water was flowing south to north. The maximum upstream (gage G32) and downstream (gage G33) differential at the L9341 Bridge was 0.28 feet at the time of peak stage. The differential had equalized by the afternoon on May 22 as floodwaters receded (Photo 3.25 and Photo 3.26). On May 23, there was no observable flow through the bridges. Stage continued to decrease and the gages were dry on May 25.

Table 3.14 summarizes stage and ice observations during breakup and Graph 3.15 shows the stage data collected at the CD5 road lakes L9323 and L9324 bridges.

Photo 3.25: Lake L9323 Bridge following peak flooding, looking north toward connection with Nanuq Lake; May 23, 2015

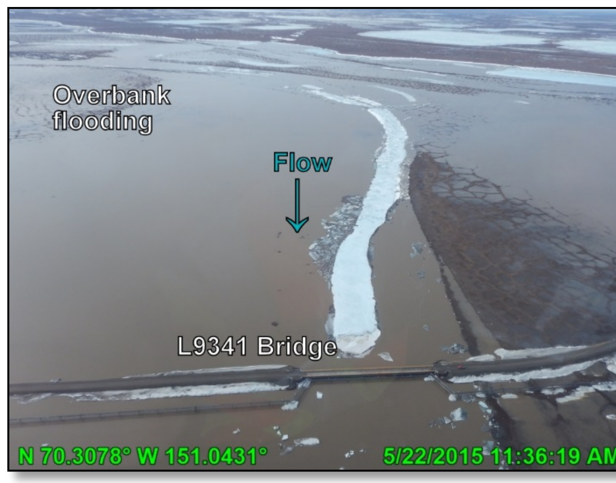


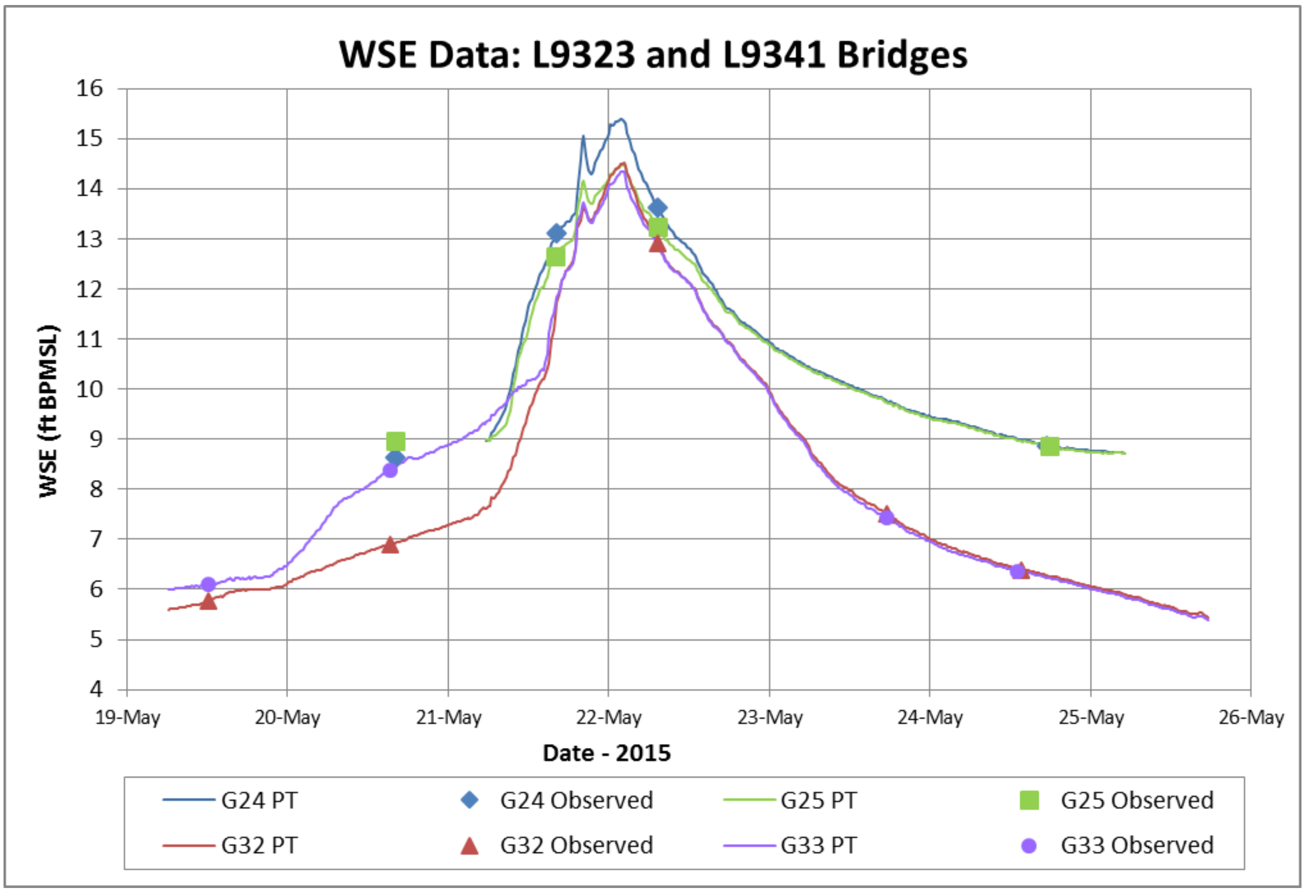
Photo 3.26: Lake L9341 Bridge following peak flooding, looking south toward the connection with Nigliq Channel; May 22, 2015

Table 3.14: CD5 Road Lake L9323 and Lake L9324 Bridges 2015 Stage Data and Observations

Date	WSE (feet BPMSL)				Observations
	G24	G25	G32	G33	
19-May	-	-	5.78	6.09	Local melt, ponded water at L9341 gages
20-May	8.63	8.97	6.90	8.39	Local melt, ponded water at gages
21-May	13.10	12.65	-	-	Initial floodwaters, L9323 connected to Nigliq Channel
22-May	*15.39*	*14.48*	*14.51*	*14.34*	Peak stage, low velocity flow; max differential at L9323 was 1.0 feet just prior to peak stage, differential at L9341 was 0.28 feet
23-May	-	-	7.50	7.42	Floodwaters recede, low velocity flow confined in channel
24-May	8.87	8.86	6.39	6.36	Stage continues to decrease

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE
2. Dash (-) indicates no gage reading collected



Graph 3.15: CD5 Road Lake L9323 and Lake L9324 Bridges 2015 Stage Data

C. Nigliagvik Bridge

Photo 3.27 Nigliagvik Bridge following peak stage, looking north east; May 22, 2015

At the Nigliagvik Bridge, local meltwater was accumulating in the channel on May 19 and initial low velocity floodwater began filling the channel on May 20. Stage increased at the bridge throughout the day on May 21, as water levels increased in the Nigliq Channel. The rate of rising stage at the Nigliagvik Bridge on May 21 was the same as at the Nigliq Bridge, increasing 5.07 feet in the 24 hours prior to peak. Overbank flooding was observed along the east bank on the evening of May 21, inundating the adjacent floodplain. A peak stage of 13.58 feet BPMSL at gage G38 occurred early in the morning on May 22. The maximum WSE differential between gages G38 and G39 was 2.36 feet a few hours prior to the time of peak stage. The large upstream and downstream differential was likely the result of a local ice jam at the bridge opening. The differential was short-lived and equalized quickly following peak stage. On the morning of May 22, ice was still present between the west-most bridge pier and the west bank and snow drifts remained along the west bank (Photo 3.27). Stage continued to decrease on May 22 and by May 23, floodwater was contained within the channel banks.

Aerial observation and HWMs along the CD5 road between the Nigliq and Nigliagvik channels show the culverts were inundated to the same elevation as the bridge locations. The entire area was flooded during the evening on May 21 through May 22 (Photo 3.28 and Photo 3.29). The maximum upstream and downstream differential was similar at all the culverts, less than 1.5 feet.

Photo 3.28: Inundation around the eastern half of the CD5 road, looking west after peak stage; May 22, 2015

Photo 3.29: CD5 road looking east, flooding is contained by the Nigliagvik Channel and Lake M0356; May 22, 2015

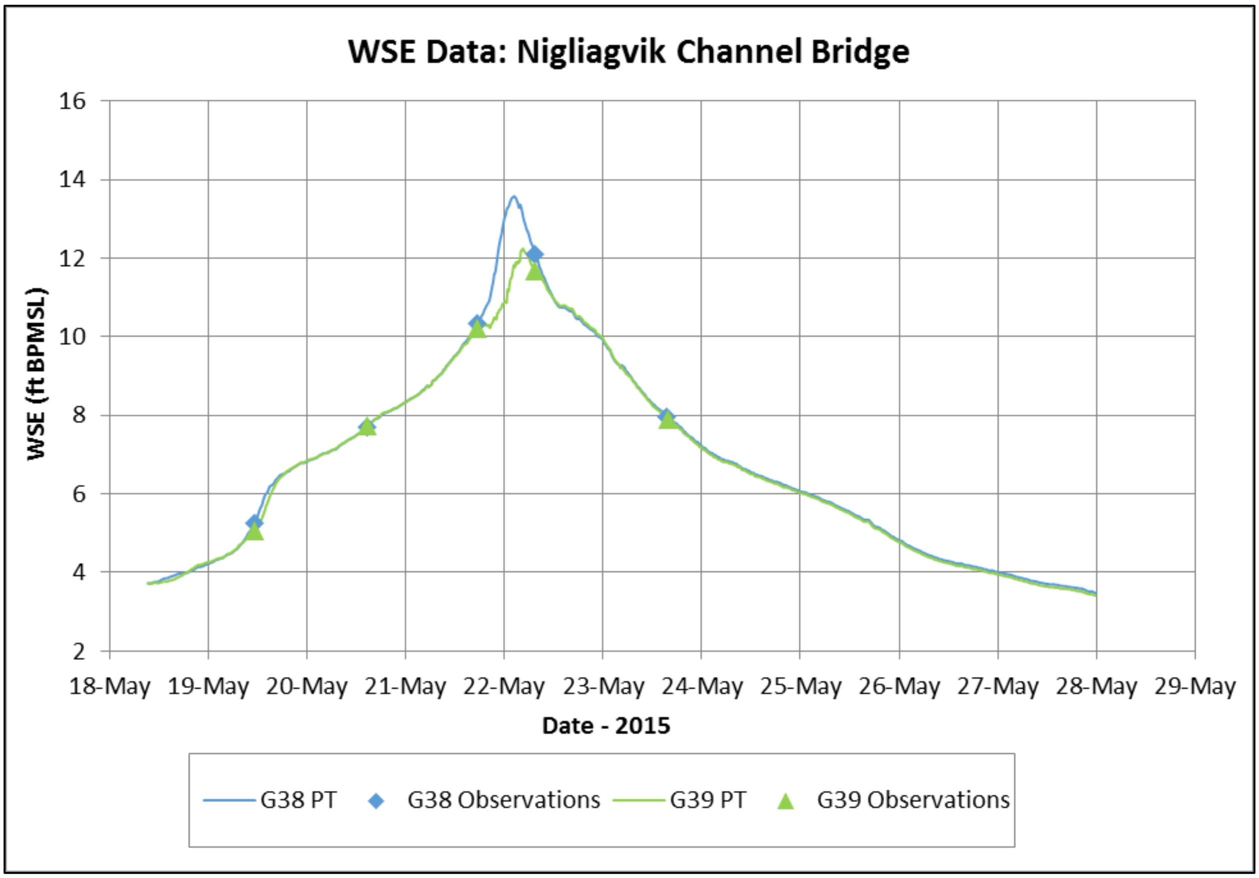
Table 3.15 and Table 3.16 summarize stage and ice observations during breakup and Graph 3.16 and Graph 3.17 show the stage data collected at the Nigliagvik Bridge and CD5 culverts, respectively.

Table 3.15: Nigliagvik Channel Bridges 2015 Stage Data and Observations

Date	WSE (feet BPMSL)		Observations
	G38	G39	
19-May	5.29	5.06	Local melt, ponded water
20-May	7.73	7.73	Initial low velocity floodwaters fill channel
21-May	10.33	10.21	Stage rising, overbank flooding on east bank
22-May	*13.58*	*12.24*	Peak stage, extensive overbank flooding; maximum WSE differential of 2.36 feet about 2 hours prior to peak stage
23-May	7.98	7.89	Floodwaters recede, flow mostly contained within banks, some snow and ice remain in channel

Note:

1. *Italicized* values are pressure transducer data indicating peak WSE



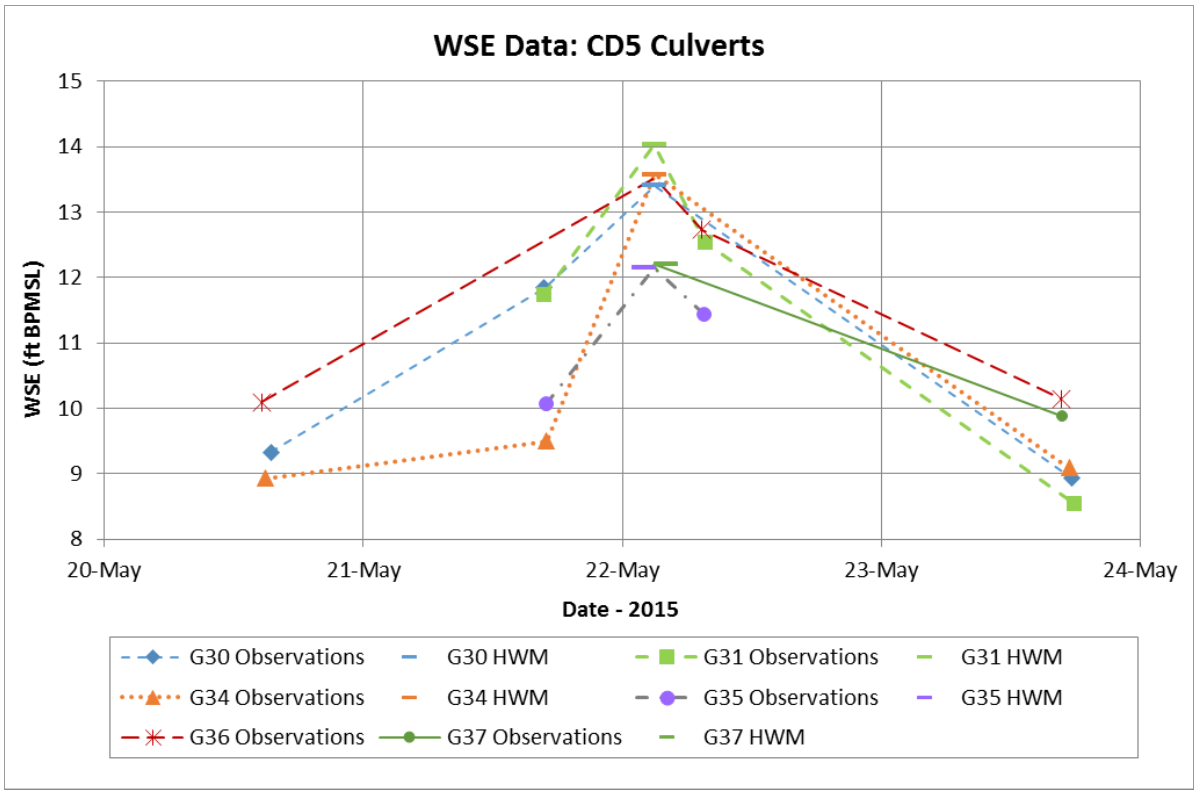
Graph 3.16: Nigliagvik Bridge 2015 Stage Data

Table 3.16: CD5 Culverts 2015 Stage Data and Observations

Date	WSE (feet BPMSL)						Observations
	G30	G31	G34	G35	G36	G37	
20-May	9.33	-	8.93	10.07	10.09	-	Local melting, ponded water
21-May	11.84	11.74	9.50	11.44	-	-	Initial flooding
22-May	13.40*	14.03*	13.57*	12.15*	13.52*	12.20*	Peak stage
23-May	8.93	8.55	9.09	-	10.15	9.88	Flooding recedes

Note:

1. Dash (-) indicates no gage reading collected
2. * Data from a high water mark surveyed after flooding receded



Graph 3.17: CD5 Culverts 2015 Stage Data

D. West of the Nigliagvik Channel

Flooding to the west of the Nigliagvik Channel was limited to the accumulation of local melt in surrounding lake basins and flow in small channels and swales forming hydraulic connections between lake basins. There was some flow through the culverts but the inlets were not submerged. There was no flooding observed around the CD5 pad, and local meltwater was contained within Lake MB0301 on the east side of the pad (Photo 3.30).

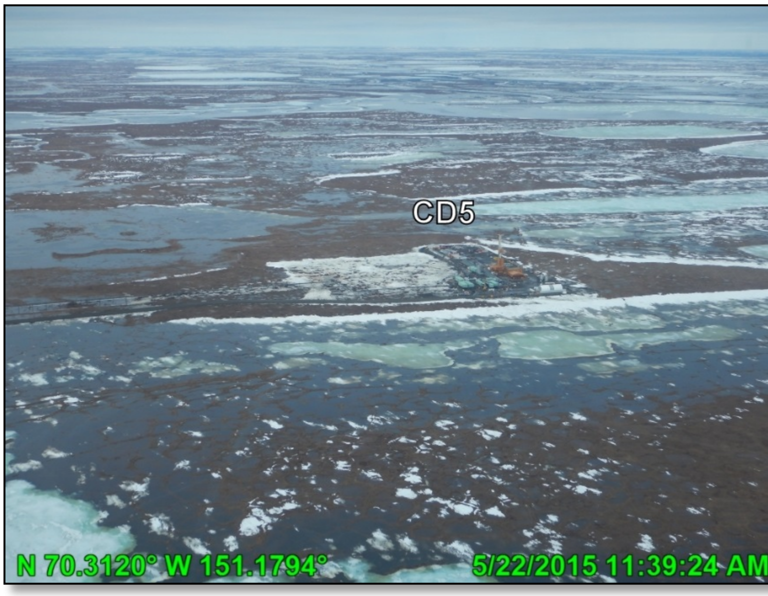


Photo 3.30: CD5 pad looking west after peak flooding; May 22, 2015

4.0 DISCHARGE

4.1 COLVILLE RIVER

4.1.1 MON1C

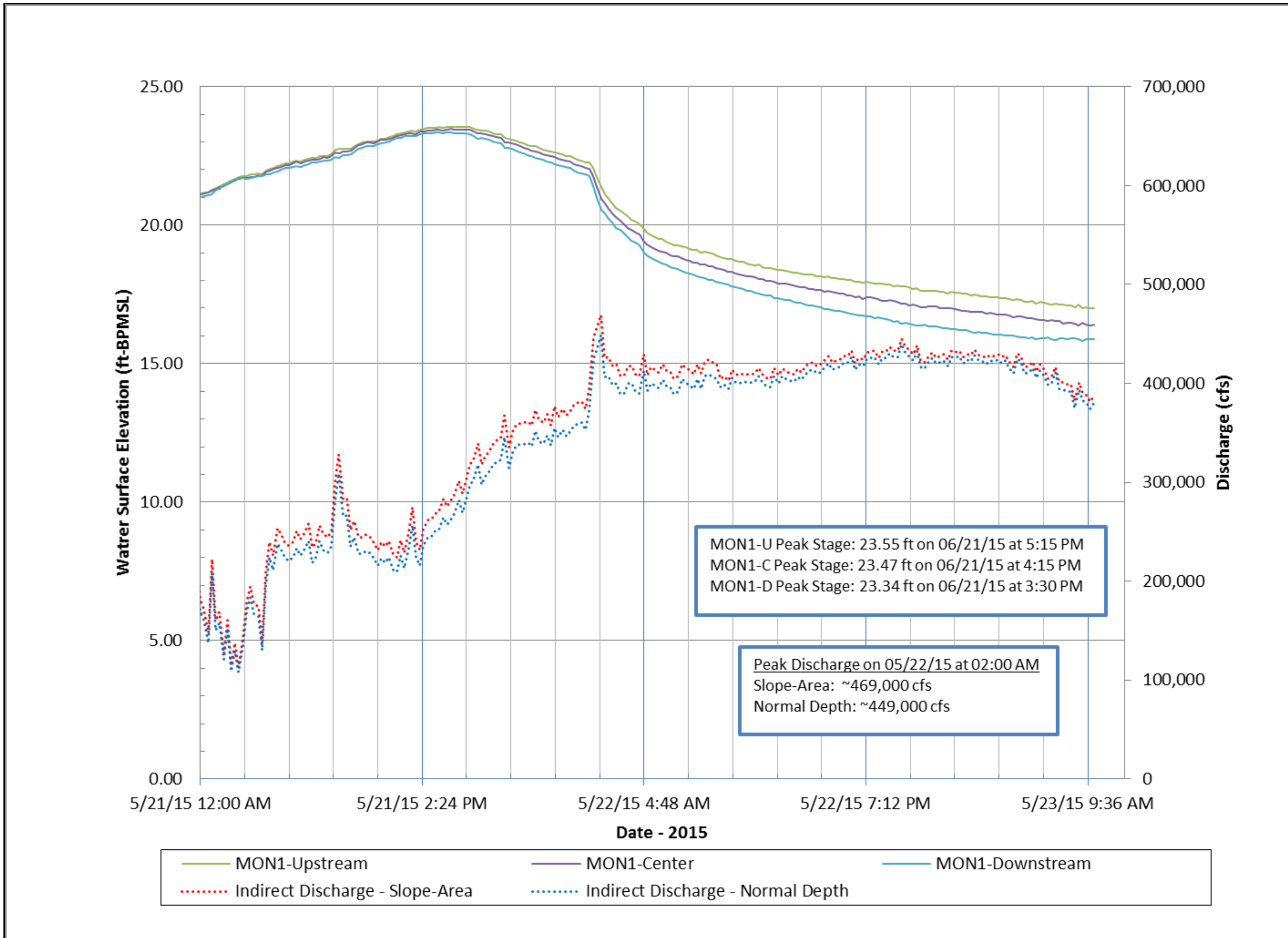
A. MEASURED DISCHARGE

On May 25, discharge was measured on the Colville River adjacent to MON1C using an ADCP (Appendix D.1). At the time of the measurement, the channel was mostly clear of snow and ice. Four transects and one loop test were completed during the discharge measurement. The loop test revealed a moving bed. Measured discharge, accounting for moving bed conditions, was approximately 177,600 cubic feet per second (cfs) with a corresponding stage of 11.84 feet BPMSL at MON1C. The average velocity was 4.7 feet per second (fps) and the maximum measured velocity was 9.0 fps. The measurement quality was rated good. The location of the discharge measurement and the cross section profile at MON1 are presented in Appendix B.2.1.1. A summary of the discharge measurement and the WinRiver II output for each transect are presented in Appendix D.1.

B. PEAK DISCHARGE

Peak discharge was calculated indirectly using the Normal Depth and Slope-Area methods (Appendix B.1.2.1). The Normal Depth calculation was based on a topographic survey of the channel geometry at MON1C (LCMF 2004). The Slope-Area method used the cross section data at MON1U, MON1C, and MON1D. The MON1 cross-section profiles are located in Appendix B.2.1.1. The energy grade-line was approximated by the average water surface slope between MON1U, MON1C, and MON1D. The channel roughness was calibrated from the measured discharge and corresponding WSEs.

Peak stage occurred approximately 10 hours prior to peak discharge. Peak stage at MON1 was the result of elevated stage from backwater behind downstream ice jams in the East Channel at the Tamayayak Channel bifurcation and in the Nigliq Channel. Peak discharge occurred with the release of the East Channel ice jam early in the morning of May 22. Peak discharge was estimated to be 449,000 cfs and 469,000 cfs for the Normal Depth and Slope-Area methods, respectively. The difference for these two methods is less than 5 percent. Based on the calculated peak discharge in the East and Nigliq Channels and the historical distribution of flow, the results from the Slope-Area method were considered a better estimate, resulting in a final peak discharge at MON1C of 469,000 cfs with a corresponding WSE of 20.94 feet BPMSL. The channel was free of snow and channel ice at the time of peak discharge. Graph 4.1 shows the discharge calculations and the WSEs versus time.



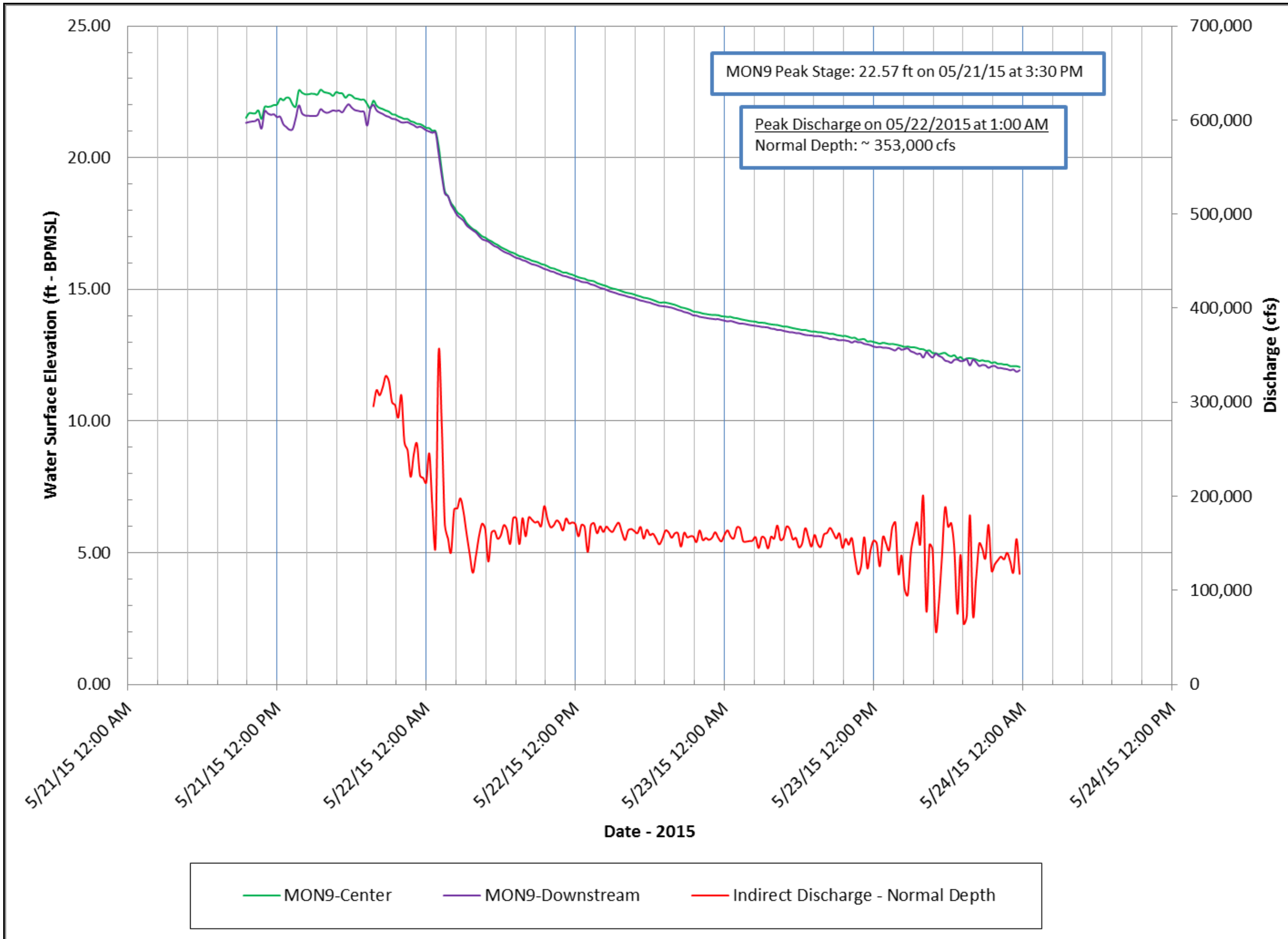
Graph 4.1: MON1 2015 WSE and Calculated Discharge versus Time

4.1.2 East Channel - MON9

A. Peak Discharge

Peak discharge in the East Channel at MON9 was calculated indirectly using the Normal Depth method. The Normal Depth calculation was based on a topographic survey of the channel geometry at MON9 (LCMF 2009). The energy grade-line was approximated by the average water surface slope between MON9 and MON9D. The cross-section profile for MON9 is located in Appendix B.2.1.2.

Similar to MON1, peak stage at MON9 occurred approximately 10 hours prior to peak discharge. Peak stage at MON9 was a result of elevated stage from backwater behind the downstream ice jam in the East Channel at the Tamayayak Channel bifurcation. Peak discharge occurred with the release of the East Channel ice jam during the early morning hours of May 22. Peak discharge, calculated indirectly, at MON9 is approximately 353,000 cfs with a corresponding WSE of 20.43 feet BPMSL. Ice floes associated with the ice jam were likely present at the time of peak discharge. Graph 4.2 shows the discharge calculations and the WSEs versus time.



Graph 4.2: MON9 2015 WSE and Calculated Discharge versus Time

4.2 CD5 Road Bridges

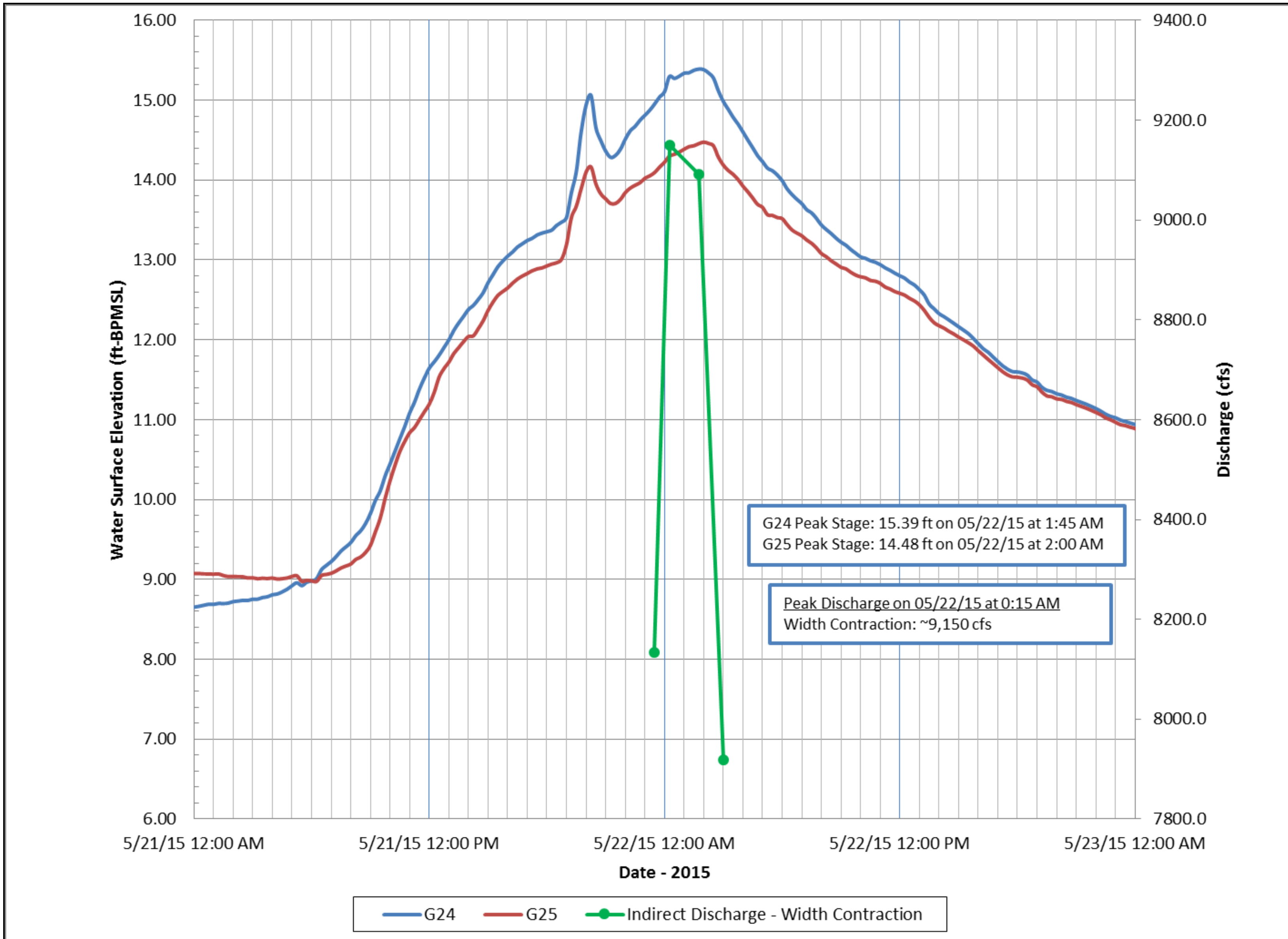
4.2.1 Lake L9323 Bridge

A. Peak Discharge

Discharge was not measured at Lake L9323 in 2015. On May 23, when discharge crews were on scene, Lake L9323 was no longer hydraulically connected at the downstream end.

Peak discharge at the Lake L9323 Bridge was estimated using the USGS width contraction method. Ground profile measurements collected by LCMF in 2012 were used for the cross section geometry (LCMF 2012). Upstream and downstream WSEs were based on measurements from gages G24 and G25, respectively. Manning's roughness coefficients were extracted from the 2D surface water model.

Lake L9323 received overland flow through the surrounding lake basins which was diverted from the East Channel by the ice jam at the Tamayayak Channel bifurcation. At the time of peak discharge, lake ice remained intact in Lake L9323, however, the crossing was mostly ice free. The calculated peak discharge was 9,150 cfs, with a corresponding WSE of 15.30 feet BPMSL at gage G24 and occurred early in the morning on May 22. The timing of peak discharge coincided with peak stage. Graph 4.3 shows the discharge calculations and the WSEs versus time. The cross-section profile for Lake L9323 is located in Appendix B.2.2.1.



Graph 4.3: Lake L9323 Bridge 2015 WSE and Calculated Discharge versus Time

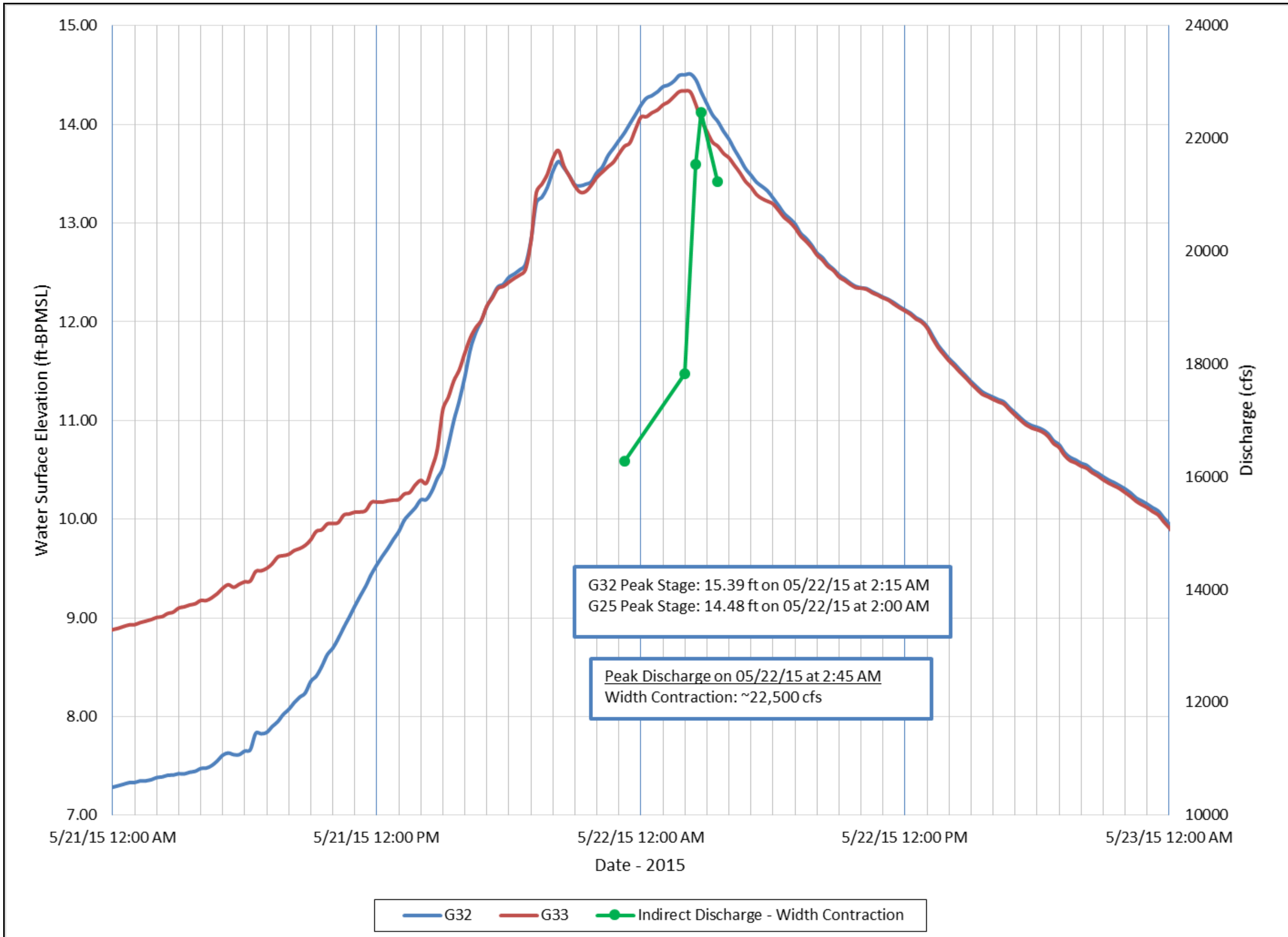
4.2.2 LAKE L9341 BRIDGE

A. PEAK DISCHARGE

Discharge was not measured at the Lake L9341 Bridge in 2015. On May 23, when discharge crews were on scene, a substantial amount of lake ice was still present upstream of the bridge.

Peak discharge at the Lake L9341 Bridge was estimated using the USGS width contraction method. Transect 39, upstream of bridge, and transect 38, downstream of the bridge, surveyed by LCMF in 2015, were used for the channel geometry (LCMF 2015). Upstream and downstream WSEs were based on measurements from gages G32 and G33, respectively. Manning's roughness coefficients were extracted from the 2D surface water model.

During peak flood conditions, Lake L9341 was hydraulically connected to the Nigliq Channel. Snow and lake ice remained upstream of the bridge crossing. The calculated peak discharge was 22,500 cfs, with a corresponding WSE of 14.32 feet BPMSL at gage G32 and occurred early in the morning on May 22. The timing of peak discharge coincided with peak stage. Graph 4.4 shows the discharge calculations and the WSEs versus time. The cross-section profile for Lake L9341 is located in Appendix B.2.2.2.



Graph 4.4: Lake L9341 Bridge 2015 WSE and Calculated Discharge versus Time

4.2.3 NIGLIQ BRIDGE

A. MEASURED DISCHARGE

On May 22, discharge was measured on the Nigliq Channel downstream of the Nigliq Bridge using an ADCP. At the time of measurement, the channel was mostly clear of snow and ice. Four transects and one loop test were completed during the discharge measurement. The loop test revealed considerable bedload transport. Measured discharge, accounting for moving bed conditions, was approximately 74,400 cfs with a corresponding stage of 10.66 feet BPMSL at gage G27. The average velocity was 4.1 fps and the maximum measured velocity was 8.6 fps. The swift moving bed resulted in intermittent data gaps, therefore the measurement quality was rated fair. The location of the discharge measurement and cross section profile at gage G27 is presented in Appendix B.2.2.3. A summary of the discharge measurements and the WinRiver II output for each transect are presented in Appendix D.2.

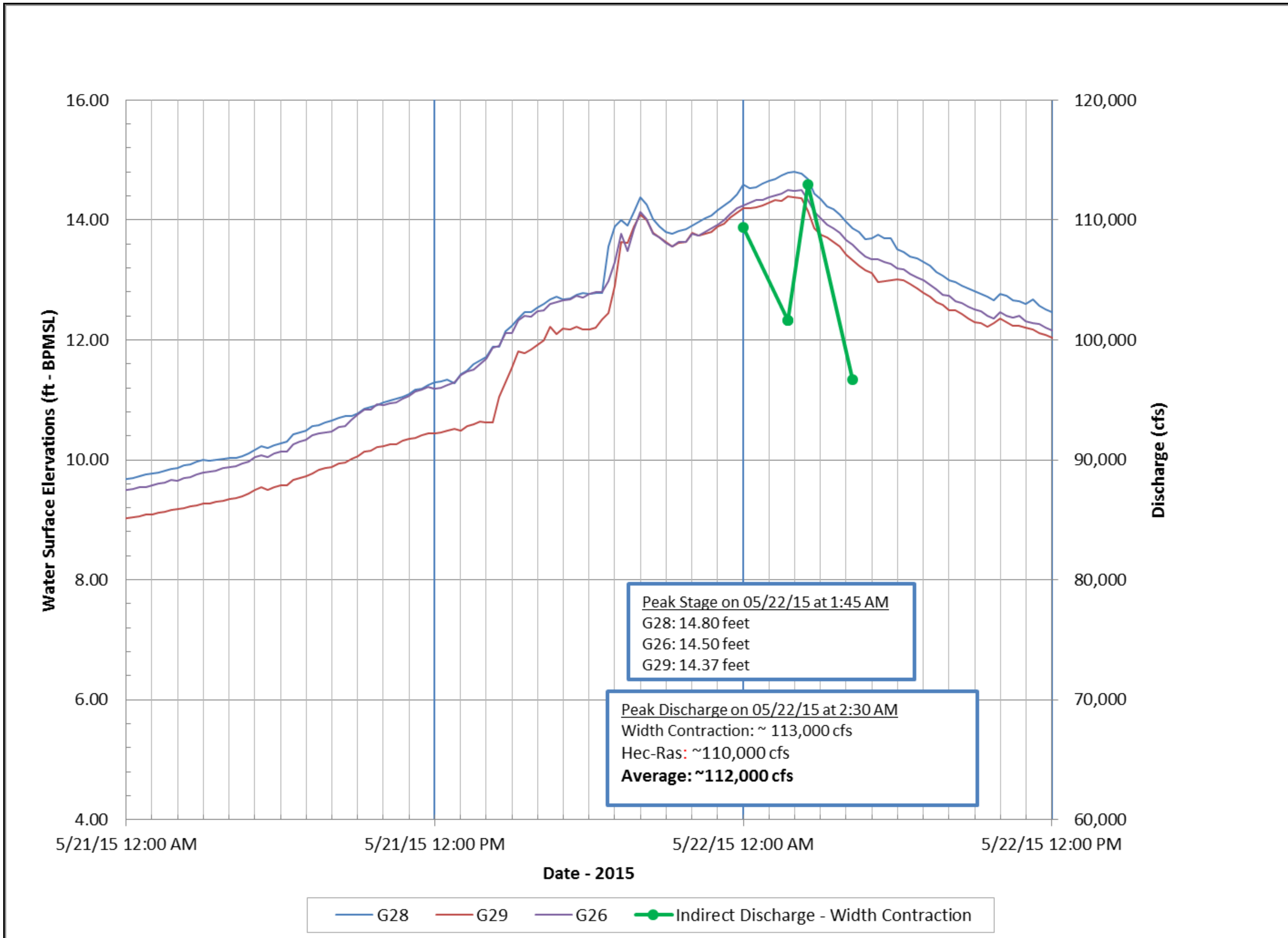
Discharge on the Nigliq Channel was measured a second time on May 25 from the upstream side of the Nigliq Bridge using the USGS midsection technique (Appendix B.1.1). At the time of the measurement the channel was free of snow and ice. Measured discharge was 33,700 cfs with a corresponding stage of 5.69 feet BPMSL at gage G26. The measurement was rated fair. Flow conditions were considered steady and uniform. The discharge measurement data is located in Appendix E.1.

B. PEAK DISCHARGE

Peak discharge was estimated using the width contraction method and checked with a HEC-RAS model. The channel geometry applied in the width contraction calculations were the upstream transect 12, surveyed in 2013 (LCMF 2013), and the downstream transect 9, surveyed in 2015 (LCMF 2015) and are shown in Appendix G.1 The drop in WSE at peak between the upstream section and the contraction section were measured between gages G28 and G27. The channel roughness was calibrated from the measured discharge and corresponding WSEs.

The channel geometry applied in the HEC-RAS model were transects 6, 11 and 12, surveyed in 2013 (LCMF 2013), and transects 7 through 10, surveyed in 2015 (LCMF 2015). Transects 12 and 6 are located in close proximity to gages G28 and G29, respectively. The known WSE at gage G29 at peak was used as the downstream boundary condition. Peak discharge was determined by trial and error, identifying the discharge that achieved the most reasonable agreement between calculated WSEs with measured WSEs at gages G26 and G28.

Peak discharge was 113,000 cfs using the width contraction method and 110,000 cfs from the HEC-RAS model, a difference of approximately 2 percent. Final peak discharge is estimated to be 112,000 cfs with a corresponding WSE of 14.33 feet at gage G26 and occurred early in the morning on May 22. The timing of peak discharge coincided with peak stage. Graph 4.5 presents the discharge calculations and the WSEs versus time.



Graph 4.5: Nigliq Bridge 2015 WSE and Calculated Discharge versus Time

4.2.4 Nigliagvik Bridge

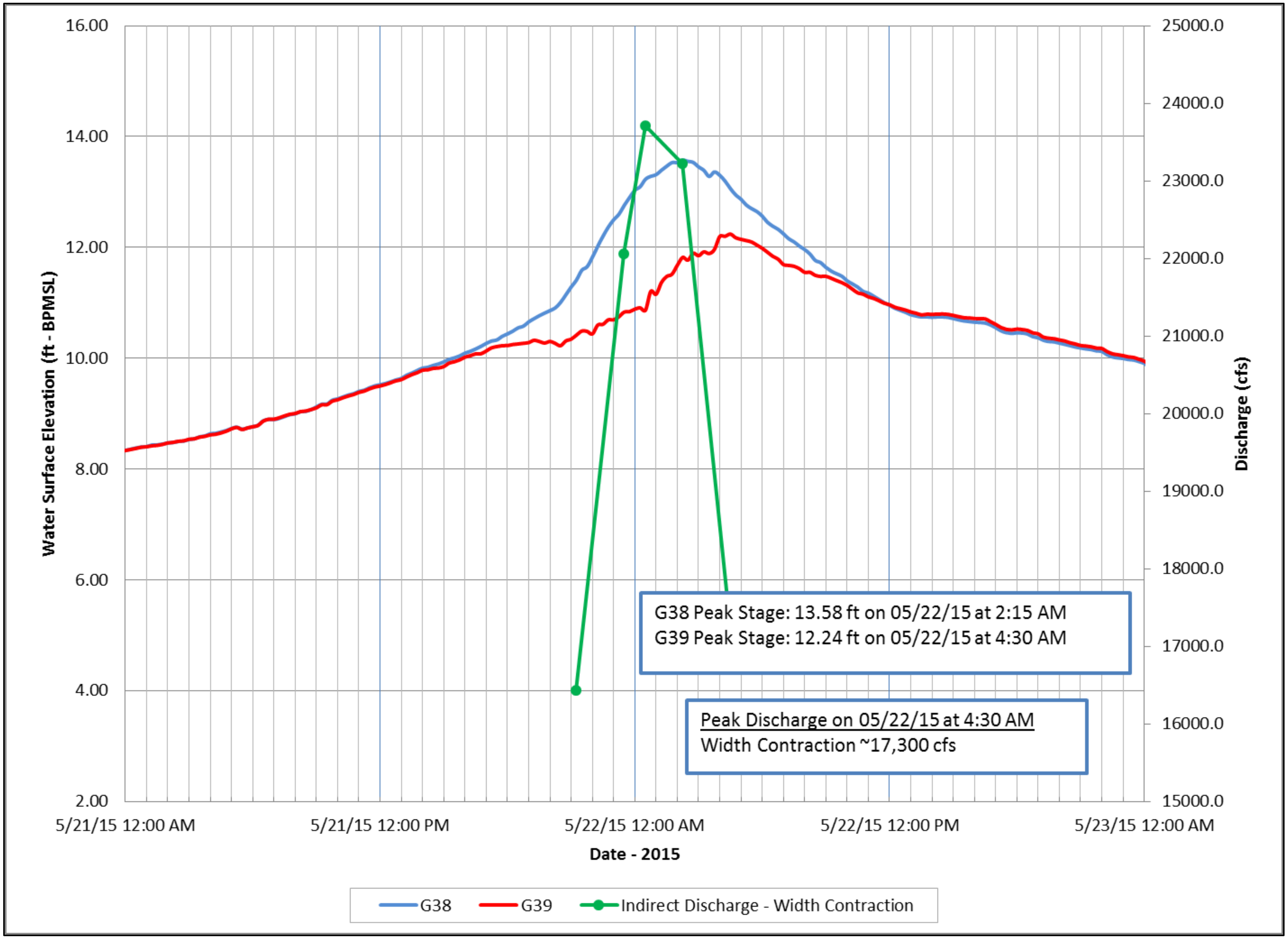
A. Measured Discharge

On May 23, discharge was measured on the Nigliagvik Channel from the upstream side of the Nigliagvik Bridge using the USGS midsection technique (Appendix B.1.1). At the time of the measurement, the channel had frequent ice floes. Measured discharge was 2,680 cfs with a corresponding stage of 7.95 feet BPMSL at gage G39. The measurement was rated fair. Flow conditions were considered steady and uniform. A small sheet of stranded ice was present at the bridge preventing some measurements in the shallow portion of the cross section. The discharge measurement data is located in Appendix E.1.

B. Peak Discharge

Peak discharge, was estimated using the USGS width contraction method. The channel geometry applied to the width contraction calculation were the upstream transect 28 and downstream transect 26, both surveyed in 2013 (LCMF 2013). WSEs for transect 28 and bridge transect 26 were based on measurements from gages G38 and G39, respectively. The channel roughness was calibrated from the measured discharge and corresponding WSEs.

The large upstream and downstream differential at 2:15 AM on May 22 was likely the result of a local ice jam at the bridge opening, and is believed to be an overestimate of peak discharge. A discharge of 17,300 cfs, with a corresponding WSE of 13.23 feet BPMSL at G38, was computed at 4:30 AM on May 22, and considered a more reasonable estimate of peak discharge because the high upstream and downstream differential had subsided and visual observations indicated the bridge opening was free of ice. Graph 4.6 presents the discharge calculations and the WSEs versus time.



Graph 4.6: Nigliagvik Bridge 2015 WSE and Calculated Discharge versus Time

4.3 CD2 Road Swale Bridges

A. Measured Discharge

Discharge was measured at the CD2 road swale bridges using the USGS midsection technique. On the afternoon of May 22, measured discharge at the Long Swale Bridge was 9,440 cfs with a corresponding stage of 9.93 feet BPMSL at G3 and average velocity of 2.8 fps. The measurement was rated good. The bridge was free of snow and ice at the time of measurement. On the morning of May 23, measured discharge at the Short Swale Bridge was 300 cfs with a corresponding stage of 7.85 feet BPMSL at G3 and an average velocity of 0.9 fps. The measurement was rated fair. The bridge was free of snow and ice at the time of measurement. The data collection forms for the discharge measurements are located in Appendix E.2.

B. Peak Discharge

Peak discharge, was estimated using the measured velocity and adjusting the hydraulic depth for peak conditions. Peak discharge was estimated to have occurred during peak stage which coincided with the greatest WSE differential between gages G3 (upstream) and G4 (downstream). At 3:45 AM on May 22, the peak observed stage was 11.93 feet BPMSL at gage G3, and the corresponding peak discharge was calculated to be 12,350 cfs for the Long Swale Bridge and 484 cfs for the Short Swale Bridge. The peak discharge estimate for the Long Swale Bridge is approximately 31% greater than the discharge measured in the late afternoon of May 22. The peak discharge estimate for the Small Swale Bridge is approximately 60% greater than the discharge measured in the morning of May 23. WSE differential upstream and downstream of the CD2 road equalized quickly, and as a result the measured discharge at the Short Swale Bridge is considerably low for the corresponding WSE.

4.4 Road Culverts

CD2, CD4, and CD5 road culverts were monitored to assess flow conditions before, during, and after peak conditions. Peak discharge calculations are dependent on the WSE differential between the headwater and tailwater elevation at the culvert. During peak stage, WSEs exceeded the top of many culverts and gages around facilities. As a result, culvert outlets were inaccessible during peak conditions. Furthermore, upstream and downstream differentials equalized quickly and stage rapidly declined after peak, limiting post-peak WSEs and direct measurements. In lieu of direct measurements during peak conditions, culvert performance at many culverts was assessed by documenting visual observations of culverts conveying flow. Drainage structure locations and proximity to gages are shown in Appendix F.1. Appendix F.2 contains road culvert discharge data including discharge calculated indirectly, corresponding average velocity, and the total discharge for all culverts.

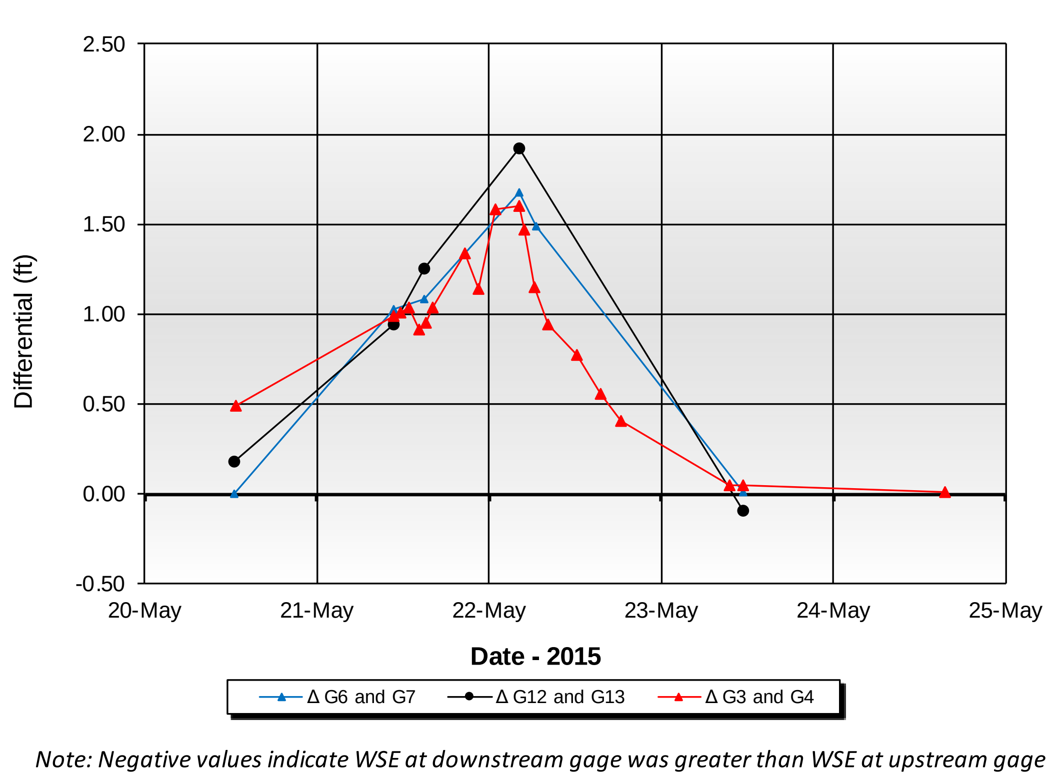
4.4.1 CD2 Road Culverts

Visual observations of flow conditions at each CD2 road culvert are summarized in Table 4.1 below. Photo 4.1 shows culverts along the CD2 road conveying flow at peak conditions. CD2 road culvert peak discharge was calculated using WSE data from the gages located in the vicinity of the culverts. The WSE differential for the CD2 road gages is presented in Graph 4.7.

Table 4.1: CD2 Road Culvert Visual Observation Summary

Culvert	Associated Gages	Observed Flow	Date & Time
CD2-1	G6/G7	Y	5/21/15 10:50
CD2-2		Y	5/21/15 10:50
CD2-3		Y	5/21/15 10:50
CD2-4		Y	5/21/15 10:46
CD2-5		Y	5/21/15 10:46
CD2-6		Y	5/21/15 10:46
CD2-7		Y	5/21/15 10:46
CD2-8		Y	5/21/15 10:40
CD2-9	G12/G13	Y	5/21/15 10:40
CD2-10		Y	5/21/15 10:40
CD2-11		Y	5/21/15 10:40
CD2-12		Y	5/21/15 10:40
CD2-13		Y	5/21/15 10:40
CD2-14		Y	5/21/15 10:40
CD2-15		Y	5/21/15 10:40
CD2-16		Y	5/21/15 10:40
CD2-17		Y	5/21/15 10:40
CD2-18		Y	5/21/15 10:40
CD2-19	G3/G4	Y	5/21/15 10:40
CD2-20		Y	5/21/15 10:40
CD2-21		Y	5/21/15 10:40
CD2-22		Y	5/24/15 15:57
CD2-23		Y	5/24/15 15:42
CD2-24		Y	5/24/15 15:49
CD2-25		Y	5/21/15 15:30
CD2-25		Y	5/21/15 15:30
CD2-26		Y	5/21/15 15:30

Photo 4.1: CD2 road culverts during peak conditions, looking northeast; May 22, 2015



Graph 4.7: CD2 Road WSE Differential

Total peak discharge of the CD2 road culverts was approximately 2,300 cfs at 4:15 AM on May 22. At the time of peak discharge, culverts CD2-1 through CD2-8, CD2-9 through CD2-18 and CD2-19 through CD2-26 were conveying 30%, 45%, and 25%, respectively, of the total discharge. Culverts CD2-9 through CD2-18 had the highest average velocity of 7.5 fps.

Discharge measurements were collected at three representative culverts along the CD2 road on the afternoon of May 24. The average discharge through the three culverts was 3 cfs and the average measured velocity was approximately 0.9 fps. Table 4.2 compares the measured velocity and discharge to the calculated velocity and discharge at the time of measurement.

Table 4.2: CD2 Road Culverts near G3/G4, Direct Measurement/Calculated Discharge Comparison

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement May 24	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation May 24	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD2-22	3:57 PM	0.7	1	3:40 PM	0.7	1	1%	9%
CD2-23	3:42 PM	1.0	4	3:40 PM	0.8	3	-18%	-16%
CD2-24	3:49 PM	1.0	5	3:40 PM	0.8	4	-19%	-24%
Average Measured Velocity (ft/s)			**0.9**	**Avg. Calculated Velocity (ft/s)**		**0.8**	**Avg. V Diff.**	**-13%**
Average Measured Discharge (cfs)			**3**	**Avg. Calculated Discharge (cfs)**		**3**	**Avg. Q Diff.**	**-17%**

4.4.2 CD4 Road Culverts

Visual observations of flow conditions at each CD4 road culvert are summarized in Table 4.3 below. Photo 4.2 and Photo 4.3 shows the CD4 north culvert battery and south culvert battery respectively conveying flow during peak conditions. CD4 culvert peak discharge was computed using WSE data from the gages located in the vicinity of the culverts. The WSE differential for the CD4 road gages is presented in Graph 4.8.

Table 4.3: CD4 Road Culvert Visual Observation Summary

Culvert	Associated Gages	Observed Flow	Date & Time
CD4-1	G3/M9525	Y	5/21/15 12:50
CD4-2		Y	5/21/15 23:30
CD4-3		Y	5/21/15 23:30
CD4-4		Y	5/21/15 23:30
CD4-5		Y	5/21/15 23:30
CD4-6		Y	5/21/15 23:30
CD4-7		Y	5/21/15 23:30
CD4-8	G42/G43	Y	5/21/15 23:30
CD4-9		Y	5/21/15 23:30
CD4-10		Y	5/21/15 23:30
CD4-11	G40/G41	Y	5/21/15 23:30
CD4-12		Y	5/21/15 23:30
CD4-13		Y	5/21/15 23:30
CD4-14		Y	5/21/15 23:30
CD4-15		Y	5/21/15 23:30
CD4-16		Y	5/21/15 23:30
CD4-17		Y	5/21/15 23:30
CD4-18		Y	5/21/15 23:30
CD4-19	G15/G16	Y	5/21/15 23:30
CD4-20		Y	5/21/15 23:30
CD4-20A		Y	5/21/15 23:30
CD4-20B		Y	5/21/15 23:30
CD4-20C		Y	5/21/15 23:30
CD4-23		Y	5/21/15 15:15
CD4-23A		Y	5/21/15 15:15
CD4-23B		Y	5/21/15 15:15
CD4-23C		Y	5/21/15 15:15
CD4-23D		Y	5/21/15 15:15
CD4-24	G17/G18	Y	5/21/15 15:00
CD4-25		Y	5/21/15 14:45
CD4-26		Y	5/21/15 14:45
CD4-27		Y	5/21/15 14:45
CD4-28		Y	5/21/15 14:45
CD4-29		Y	5/21/15 14:35
CD4-30		Y	5/21/15 14:35
CD4-31		Y	5/21/15 14:35
CD4-32		Y	5/21/15 14:35
CD4-33		Y	5/21/15 14:15

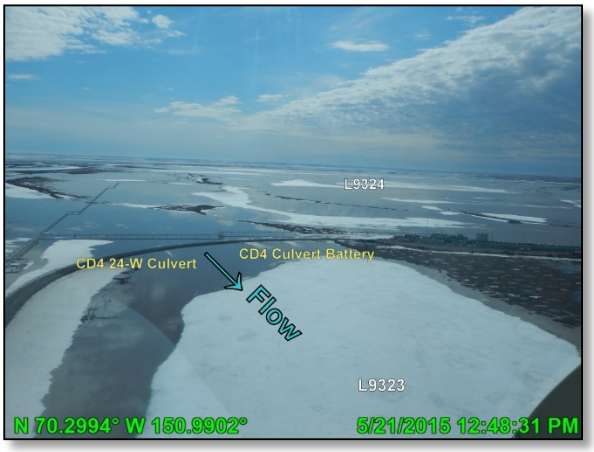
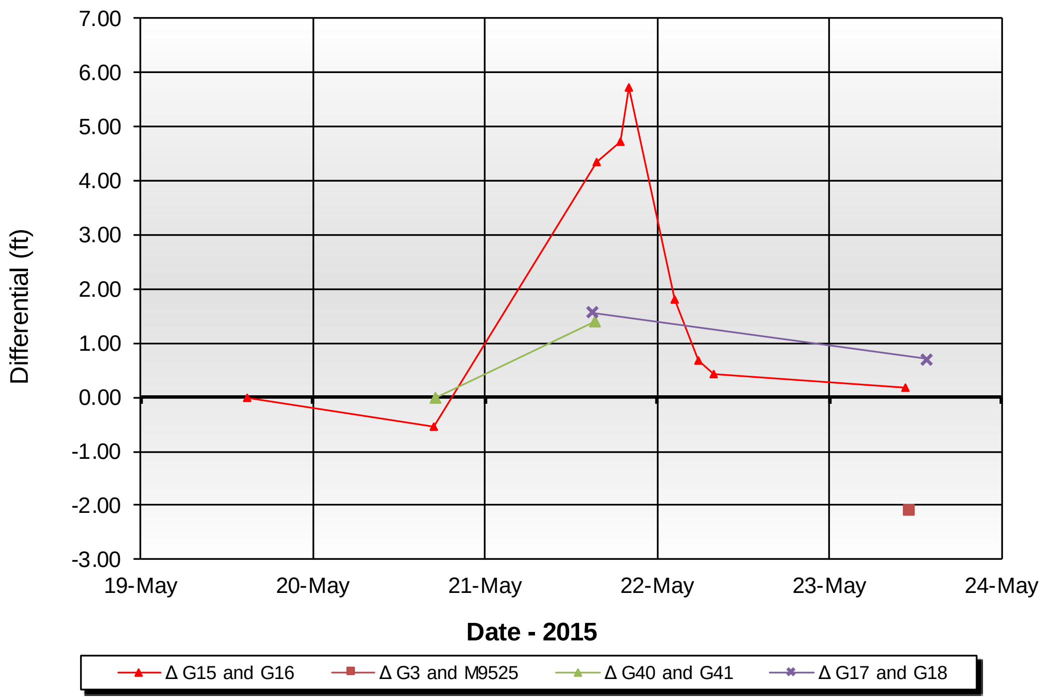


Photo 4.2: CD4 road south battery conveying flowing during peak conditions, looking southeast; May 21, 2015

Photo 4.3: CD4 road north battery conveying flowing during peak conditions, looking north; May 22, 2015



Note: Negative values indicate WSE at downstream gage was greater than WSE at upstream gage

Graph 4.8: CD4 Road WSE Differential

CD4 road culvert peak discharge for culvert CD4-1 through CD4-7 was approximately 20 cfs, CD4-8 through CD4-18 and CD4-24 through CD4-33 was approximately 884 cfs, and CD4-19 through CD4-23D was approximately 2,030 cfs. Culverts CD4-19 through CD4-23D had the highest average velocity of approximately 12.5 fps.

Discharge measurements were collected at the CD4 road culverts on the afternoon of May 21. The average discharge through the eight culverts was 243 cfs and the average measured velocity was approximately 6.6 fps.

Table 4.4 compares the measured velocity and discharge to the calculated velocity and discharge at the time of measurement for the representative culverts along the CD4 road.

Table 4.4: CD4 Road Culverts near G17/G18, Direct Measurement/Calculated Discharge Comparison

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement May 21	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation May 21	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD4-25	2:45 PM	6.8	86	3:00 PM	6.6	83	-3%	-3%
CD4-26	2:45 PM	6.8	86	3:00 PM	6.9	82	1%	-5%
CD4-27	2:45 PM	6.8	86	3:00 PM	7.0	83	2%	-3%
CD4-28	2:45 PM	6.8	86	3:00 PM	6.9	84	1%	-2%
CD4-29	2:35 PM	6.4	81	3:00 PM	6.9	84	7%	3%
CD4-30	2:35 PM	6.4	81	3:00 PM	6.7	85	5%	5%
CD4-31	2:35 PM	6.4	81	3:00 PM	6.7	85	5%	5%
CD4-32	2:35 PM	6.4	81	3:00 PM	6.7	85	5%	4%
Average Measured Velocity (ft/s)			**6.6**	**Avg. Calculated Velocity (ft/s)**		**6.8**	**Avg. V Diff.**	**3%**
Average Measured Discharge (cfs)			**83**	**Avg. Calculated Discharge (cfs)**		**84**	**Avg. Q Diff.**	**0%**

Notes:
1. Conditions near peak were not safe to perform a discharge measurement.

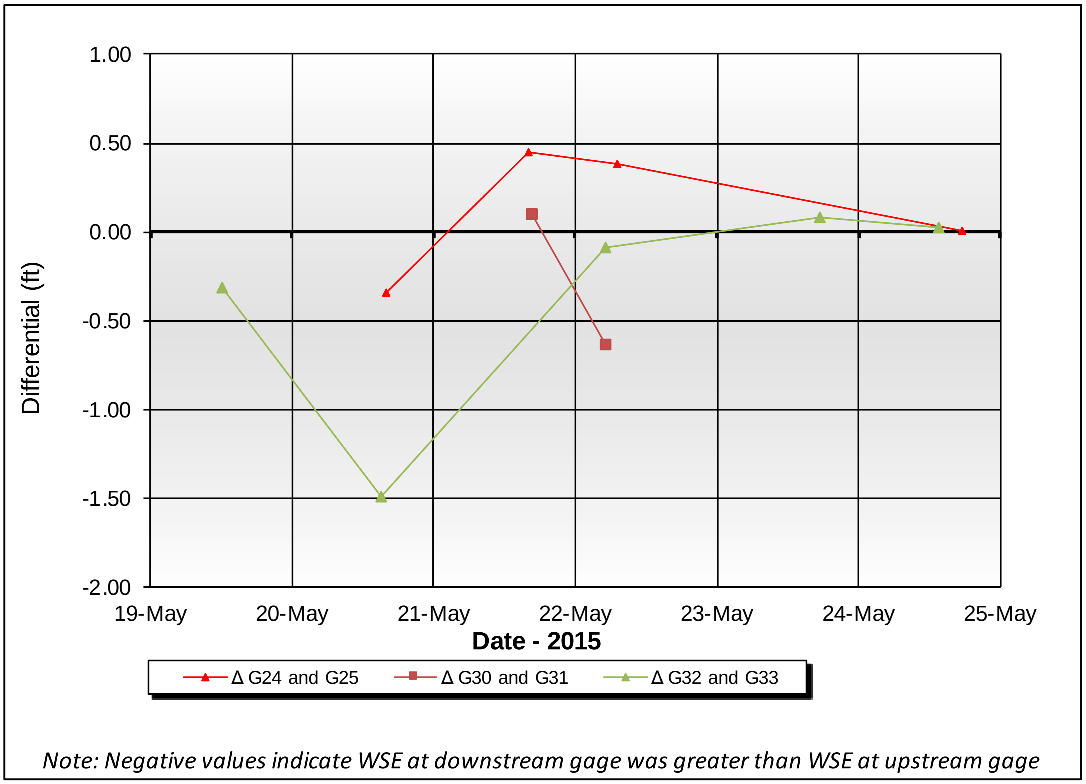
4.4.3 CD5 Road Culverts

Visual observations of flow conditions at each CD5 road culvert are summarized in Table 4.5 below. Photo 4.4 shows a culvert along the CD5 road conveying flow prior to peak stage. CD5 road culvert peak discharge was calculated using WSE data from the gages located in the vicinity of the culverts. The WSE differential for the CD5 road gages is presented in Graph 4.9 and Graph 4.10.

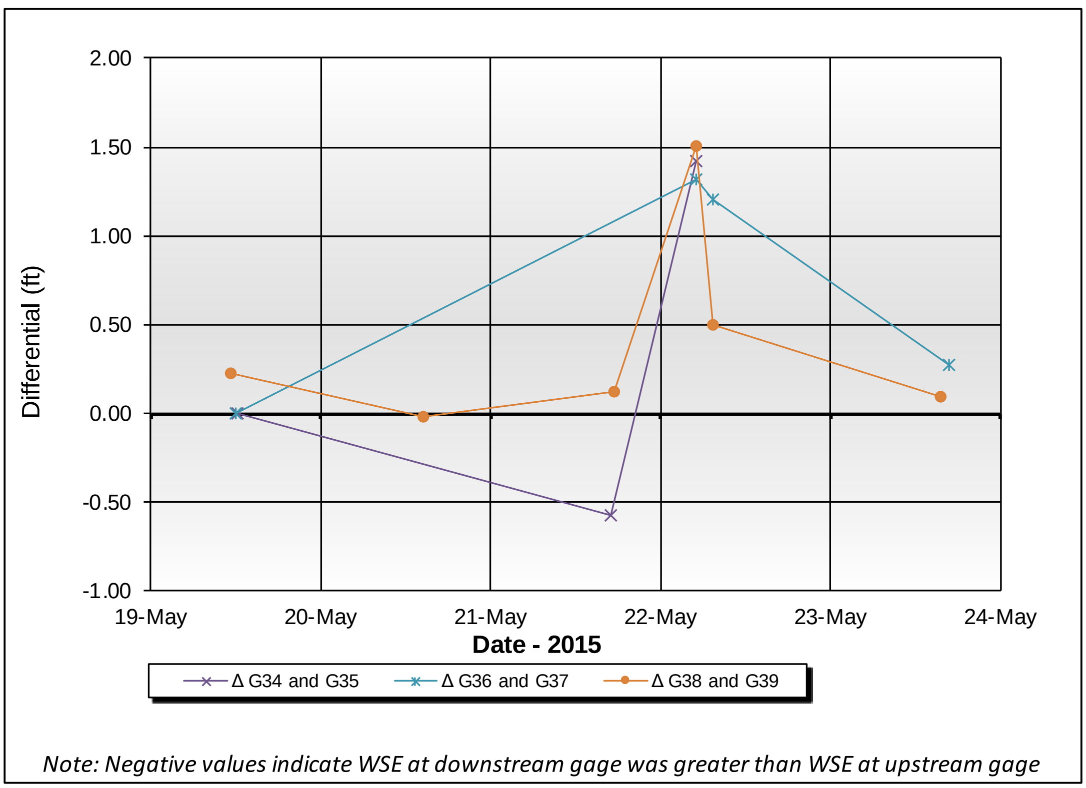
Photo 4.4: CD5 road culvert conveying flow during peak conditions; May 21, 2015

Table 4.5: CD5 Road Culvert Visual Observation Summary

Culvert	Associated Gages	Observed Flow	Date & Time
CD5-01	S2	Y	5/23/15 16:00
CD5-02		Y	5/23/15 16:00
CD5-03		Y	5/20/15 13:30
CD5-04		Y	5/20/15 13:45
CD5-05		Y	5/20/15 13:50
CD5-06	S1/S1D	Y	5/20/15 13:45
CD5-07		Y	5/20/15 13:45
CD5-08		Y	5/20/15 14:05
CD5-09		Y	5/20/15 14:05
CD5-10		Y	5/20/15 13:45
CD5-11		Y	5/20/15 13:45
CD5-12		Y	5/20/15 13:45
CD5-13		Y	5/20/15 13:45
CD5-14		Y	5/20/15 13:45
CD5-15		Y	5/20/15 13:45
CD5-16		Y	5/20/15 13:45
CD5-17		Y	5/20/15 13:45
CD5-18		Y	5/20/15 13:45
CD5-19		Y	5/20/15 13:45
CD5-20	G38/G39	Y	5/20/15 13:45
CD5-21		Y	5/20/15 13:45
CD5-22		Y	5/20/15 13:45
CD5-23		Y	5/20/15 13:45
CD5-24		Y	5/20/15 13:45
CD5-25		Y	5/20/15 13:45
CD5-26		Y	5/21/15 3:43
CD5-27	G36/G37	Y	5/21/15 3:42
CD5-28		Y	5/21/15 3:41
CD5-29		Y	5/21/15 3:36
CD5-30		Y	5/21/15 3:36
CD5-31		Y	5/21/15 3:35
CD5-32	G34/G35	Y	5/23/15 17:00
CD5-33		Y	5/21/15 3:34
CD5-34		Y	5/23/15 17:08
CD5-35		Y	5/21/15 17:00
CD5-36		Y	5/21/15 3:25
CD5-37	G32/G33	Y	5/21/15 3:24
CD5-38		Y	5/21/15 3:23
CD5-39		Y	5/21/15 3:21
CD5-40	G30/G31	Y	5/23/15 17:46
CD5-41		Y	5/21/15 3:12
CD5-42		Y	5/21/15 3:10
CD5-43	G24/G25	Y	5/21/15 2:55



Graph 4.9: CD5 Road WSE Differential – Gages G24/G25, G30/G31, and G32/G33



Graph 4.10: CD5 Road WSE Differential – Gages G34/G35, G36/G37, and G38/G39

Total peak discharge through the CD5 road culverts was estimate at 890 cfs at approximately 5:00 AM on May 22. At the time of peak discharge, culvert CD5-26 was conveying 7 percent of the flow, culverts CD5-27 through CD5-31 were conveying 43% of the flow, culverts CD5-32 through CD5-36 were conveying 22% of the flow, culverts CD5-37 through CD5-39 were conveying 7 percent of the flow, culverts CD5-40 through CD5-42 were conveying 18% of the flow, and culvert CD5-43 was conveying 3 percent of the flow. Culvert CD5-26 had the highest average velocity of 7.2 fps.

Discharge measurements were collected at the CD5 road culverts at between May 21 and May 23. With the exception of culvert CD5-40 on May 23, water levels were below the gages at the time of the survey and discharge was not computed for comparison. Table 4.6 compares the measured velocity and discharge and the calculated velocity and discharge at the time of measurement for culverts measured along the CD5 road.

Table 4.6: CD5-40 Road Culverts, Direct Measurement/Calculated Discharge Comparison

Culvert	Direct			Indirect			Percent Difference	
	Time of Measurement	Measured Velocity (ft/s)	Direct Discharge (cfs)	Time of Indirect Calculation	Velocity (ft/s)	Discharge (cfs)	Velocity (ft/s)	Discharge (cfs)
CD5-32	5/23/15 5:00 PM	1.9	21	5/23/15 4:42 PM	2.7	34	44%	64%
CD5-34	5/21/15 3:32 PM	1.8	11	5/21/15 5:00 PM	4.0	35	122%	226%
CD5-40	5/23/15 5:46 PM	2.2	12	5/23/15 5:43 PM	2.6	13	19%	9%
Average Measured Velocity (ft/s)			**2.0**	**Avg. Calculated Velocity (ft/s)**		**3.1**	**Avg. V Diff.**	**59%**
Average Measured Discharge (cfs)			**15**	**Avg. Calculated Discharge (cfs)**		**27**	**Avg. Q Diff.**	**88%**

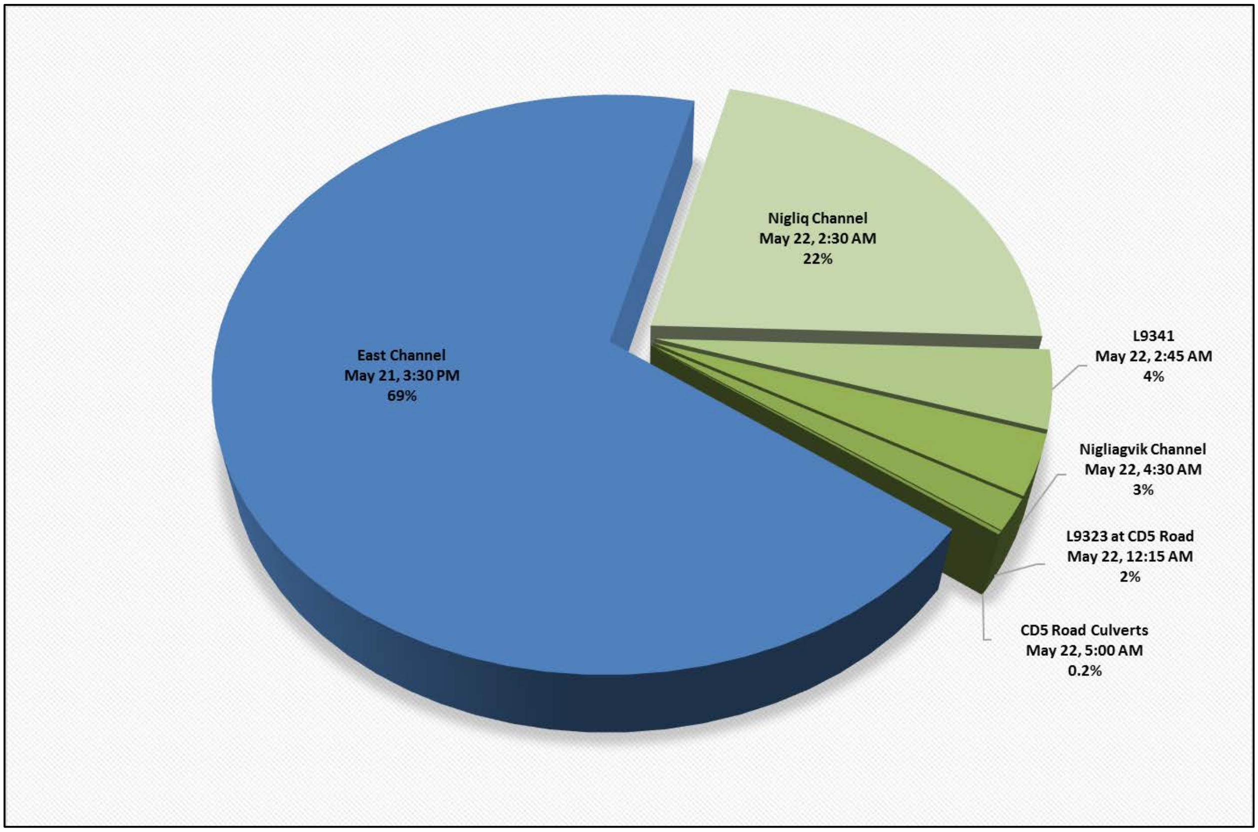
Note:
1. Conditions near peak were not safe to perform a discharge measurement.
2. CD5-32 indirect discharge was calculated using G36/G37 gage data on 5/23/2015 at 4:42pm.

4.5 Flow Distribution

During the 2015 period of peak discharge, the Colville East Channel accounted for 69% of the total discharge to the delta. The remaining flow passed through the CD5 road drainage structures; the Nigliq Channel Bridge is estimated to have conveyed 22% of the total discharge through the delta.

Figure 4.1 represents the distribution of discharge through the CRD. This figure compares peak discharge at MON1 with the peak discharges through MON9 in the Colville East Channel and all CD5 road drainage structures. Each section of the pie graph is represented by the location's peak discharge; however, peak discharge did not occur at the same time and date for each location. Total peak discharge in the delta was over estimated by 10% when compared to the peak discharge calculated for the Colville River at MON1.

Figure 4.1: 2015 Peak Flow Distribution



5.0 POST BREAKUP CONDITIONS ASSESSMENT

The extent of flooding and the depth and velocity of water around facilities was variable. High WSEs occurred around the CD2 and CD4 facilities as a result of ice jams in the East Channel and the Nigliq Channel diverting water overland through the lake basins south of CD4. The CD5 road bridges and culverts conveyed a large volume of flow mostly through the Nigliq Bridge. The effects of flooding in these areas occurred mostly as lateral wash lines formed by water action on road embankments and scour in areas where flow accelerated as water moved through drainage structures. The overtopping and breaching of CD4 Road was the most significant observed erosion. Lesser scour and deposition of road fill material was observed at CD2 and CD5 bridge abutments. Flooding was not as extensive around CD1 Pad and airstrip and was minimal around the CD3 Pad; no erosion was observed at CD1 or CD3. The specific conditions observed along each section of road and around the pads are described below and additional representative photographs are located in Appendix C.1.

5.1 CD2 ROAD AND PAD

Snow remained around much of the CD2 pad following flooding. No indication of erosion was observed at the pad or along the north side of the road nearest to the pad. HWMs and minor wash lines were visible on the south side of the road near the pad. Wash lines became more pronounced to the east and vegetation was scoured off the road embankment adjacent to some culverts. Ice floes impacted the road embankment in several locations on the south side of the road. All culverts appeared to be in good condition with no observed undercutting of the road embankment at the culverts. No long-term pooling of floodwater was observed on the upstream side of the road.

At the Short Swale Bridge a wash line was observed on both sides of the road and at the corners of the sheet pile abutments. At the Long Swale Bridge, fill was scoured from the south side of the road west of the bridge; gravel was deposited at the toe of the slope and outwash transported under the bridge and deposited in a line to the north. On the north side of the road, east of the bridge, a back eddy scoured the road embankment and material was redistributed along the toe of the embankment. Tension cracks and small cavities were observed in the Long Swale Bridge sheet pile backfill and along the cable tied concrete block mattress. The flooding did not compromise the structural integrity of the CD2 road and bridges.

5.2 CD4 ROAD AND PAD

Floodwater stage increased rapidly south of the CD5 road intersection during the evening on May 21. The culverts in this area were initially submerged on the west side as stage in the Nigliq Channel increased south of the CD5 road. At 8:00 PM, several hours prior to peak stage near the CD4 pad, water began overtopping the road. Later that evening a section of road located southeast of Lake L9323 was breached and the road material was deposited immediately to the northwest. The culverts in this area are armored with riprap and were not damaged. All other culverts along the CD4 road appeared to be in good condition with no observed undercutting of the road embankment at the culverts. No long-term pooling of floodwater was observed on the upstream side of the road.

During peak flooding ice from Lake L9324 lifted and moved northwest, coming in contact with pad embankment on the southwest corner of the CD4 pad. The ice remained in place when breakup monitoring ended on May 28.

Flooding occurred in the lake basins along the northern section of road from CD1 pad to the CD5 road intersection however; the flood stage and velocities were lower than what was observed on the south end of the road near the CD4 pad. The road embankment in this area is relatively vegetated and no wash lines formed during 2015.

5.3 CD5 Road and Pad

Flooding along the CD5 road west of the Nigliagvik Channel was minimal. Floodwater did not inundate the area around the CD5 pad. Along the section of road west of gage S1 much of the lower half of the embankment on the south and west side of the road remained saturated several days after water receded; the material was soft with some cracks and sloughing. There was a wash line on the lower portion of the north and east side. The embankment was generally not as saturated between gage S1 and the Nuiqsut Road intersection.

The floodplain along the CD5 Road east of the Nigliagvik Channel was flooded extensively for about 48 hours beginning on May 21. At the Nigliagvik Bridge, the west abutment on the high bank was unaffected. At the east abutment, fill at the toe of the road embankment was scoured from the south side and deposited at the base of the sheetpile under the bridge. Between the Nigliagvik and Lake L9341 bridges a wash line formed about half way up the road embankment on the south side and about a third of the way up the embankment on the north side. At the Lake L9341 Bridge there was some erosion and local deposition of fill around the east abutment. From the Nigliq Bridge east to the CD4 road intersection there were wash lines in the embankment. There was no visible scour or deposition at the Nigliq and Lake L9323 bridge abutments. The flooding did not compromise the structural integrity of the CD5 road and bridges. All culverts along the CD5 road appeared to be in good condition with no observed undercutting of the road embankment at the culverts. No long-term pooling of floodwater was observed on the upstream side of the road.

6.0 CD5 Bathymetry and Scour Monitoring

6.1 Channel Bathymetry

The 2015 survey results at each CD5 bridge location were compared with the 2014 and 2013 survey results to obtain maximum incremental scour and deposition between 2015 and 2014, and maximum cumulative scour and deposition between 2015 and 2013 and are presented in Table 6.1.

Table 6.1: 2015 Channel Bathymetry Transects

	Nigliq Channel Bridge			Lake L9341 Bridge			Nigliagvik Channel Bridge		
	Depth (ft)	Station (STA)	Transect	Depth (ft)	Station (STA)	Transect	Depth (ft)	Station (STA)	Transect
Maximum Incremental Scour (2014-2015)	6.1	2+67	10	1.9	3+55	39	2.3	2+32	26
Maximum Cumulative Scour (2013-2015)	12.6	2+67	10	0.5	2+01	37	1.3	2+48	25
Maximum Incremental Deposition (2014-2015)	11.4	7+70	10	2.4	1+52	36	1.6	3+90	36
Maximum Cumulative Deposition (2013-2015)	3.9	8+79	8	1.6	3+90	36	1.2	2+41	27

6.2 CD5 Pier Scour Elevations

Pier scour elevations were collected during the spring breakup flood event at piers most susceptible to scour at the Nigliq and Nigliagvik channel bridges. Post-breakup surveys of the scour holes at the base of individual piers were completed in August 2015 (LCMF 2015 b,c). Scour holes were surveyed around the perimeter of each pier to define the depth and general shape of the depression.

6.2.1 Nigliq Bridge

The minimum pier scour elevation, recorded by the ADCP during spring breakup, was -28.9 feet BPMSL at pier 4. The minimum pier scour elevation, surveyed by LCMF post-breakup, was -27.5 feet BMPSL at pier 4. The post-breakup scour elevation is 1.4 feet above the 50-year design scour elevation and 5.5 feet above the 200-year design scour elevation. Visual observations of piers 6, 7, and 8 after the breakup floodwaters receded showed no signs of excessive scour (Photo 6.1). A comparison of design and observed scour depths and elevations are presented in Table 6.2. Post-breakup contour plots around the piers are available in Appendix G.1.

Photo 6.1: Nigliq Bridge Piers Post-Breakup; May 27, 2015

Table 6.2: Nigliq Bridge Comparison of Design and Observed Scour Depths and Elevations

Niglig Channel Bridge Pier Scour		
During Breakup 2015		**Elevation (ft-BPMSL)[1]**
Pier 2		-21.1
Pier 3		-23.1
Pier 4		-28.9
Pier 5		-27.0
Post Breakup 2015		**Elevation (ft-BPMSL)[2]**
Pier 2		-19.0
Pier 3		-23.5
Pier 4		-27.5
Pier 5		-25.0
Design 2013		**Elevation (ft-BPMSL)[3,4]**
50-year	**Pier 2-6**	-28.9
	Pier 7-8	-7.1
200-year	**Pier 2-6**	-33.0
	Pier 7-8	-16.4

Notes:

1. Minimum channel bed elevations recorded by Michael Baker in May 2015 using an ADCP

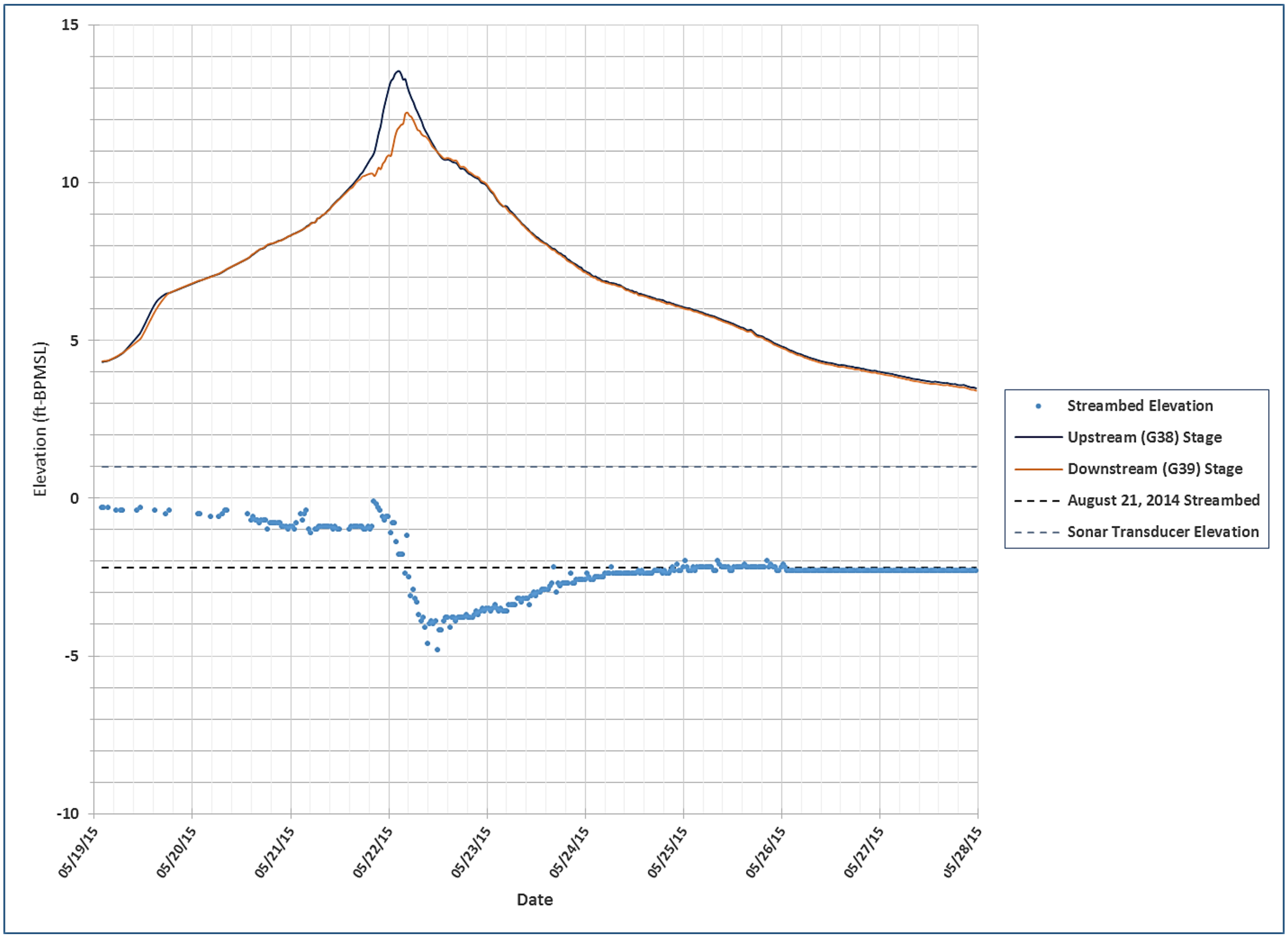
2. Minimum channel bed elevations recorded by LCMF in August 2015

3. Design values presented in PND 2013

4. Elevations based on LCMF 2008 survey

6.2.2 Nigliagvik Bridge

The minimum pier scour elevation, recorded by the real-time scour monitoring system during spring breakup, was -4.8 feet BPMSL at pier 3. The pier scour and corresponding WSEs as a function of time for pier 3 are presented in Graph 6.1. The maximum scour elevation was recorded just after peak stage. After peak conditions, the reduction in velocity resulted in infilling of the scour hole to an elevation comparable to post-breakup elevations measured in August 2014. Pier 4 does not have a real-time scour monitoring system attached to it, and scour elevations were not be obtained during breakup.



Graph 6.1: 2015 Spring Breakup Nigliagvik Bridge Pier 3 Scour

The minimum pier scour elevation of -6.0 feet BPMSL was observed at Pier 4 during the post-breakup survey. The post-breakup scour elevation is 8.2 feet above the 50-year design scour elevation and 15.8 feet above the 200-year design scour elevation. A comparison of design and observed scour depths and elevations are presented in Table 6.3. Post-breakup contour plots around the piers are available in Appendix G.3. The 2015 CD5 Bridge Real-Time Pier Scour Monitoring System Implementation System Testing and Nigliagvik Bridge Installation Status Report is included in Appendix G.3.1.

Table 6.3: Nigliagvik Bridge Comparison of Design and Observed Scour Depths and Elevations

Nigliagvik Channel Bridge Pier Scour	
During Breakup 2015	**Elevation (ft-BPMSL)[1]**
Pier 3	-4.8
Pier 4	-
Post Breakup 2015	**Elevation (ft-BPMSL)[2]**
Pier 3	-4.0
Pier 4	-6.0
Design 2013	**Elevation (ft-BPMSL)[3,4]**
50-year	-14.2
200-year	-21.8

Notes:

1. Minimum channel bed elevations recorded by Michael Baker in May 2015 using a Real-Time Pier Scour Monitoring System at Pier 3

2. Minimum channel bed elevations recorded by LCMF in August 2015

3. Design values presented in PND 2013

4. Elevations based on LCMF 2008 survey

7.0 ICE ROAD CROSSINGS DEGRADATION

Ice roads are constructed annually for ground transportation of supplies and equipment to the Alpine facilities. Ice pads are also used to support construction and exploration activities. During the spring of 2015, major ice road waterway crossings in the Alpine area were observed to document the degradation process.

Aerial surveys were conducted to observe and photo-document the progression of melting and degradation of the ice road crossings and construction ice pads. Observations were conducted at the following ice road crossings and ice pads (Figure 1.2):

- Colville River
- Kachemach River
- L9323 Pad
- L9341 Pad
- Lake L9341 Swale at CD5 Road
- Nigliagvik Channel at CD5 Road
- Nigliagvik Channel south of CD5 Road
- Nigliagvik Pad
- Nigliq Channel at CD5 Road
- Nigliq Pad
- Nigliq Channel south of CD5 Road
- No Name Creek
- Pineapple Gulch
- Silas Slough
- Slemp Slough
- Tamayayak Channel 1
- Toolbox Creek

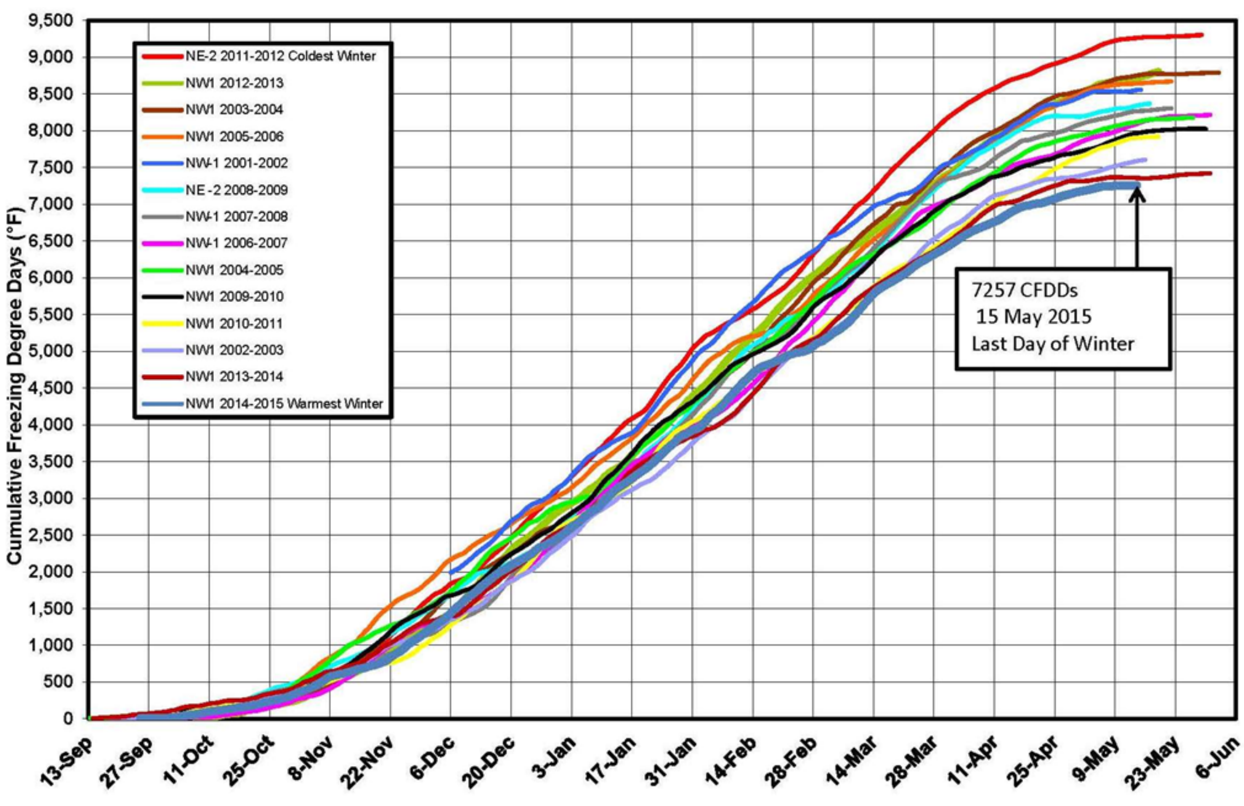
To facilitate melt and the progression of breakup flooding, ice road crossings and ice pads are mechanically slotted at the conclusion of the winter season. In general, ice road crossings melted at a similar rate as channel ice. Aerial surveys showed that slotting was completed and the initial floodwaters were minimally constricted and passing freely over intact channel ice prior to peak stage. The majority of the crossings were submerged during the peak of flooding. When flooding receded, the ice road crossings and channel ice, had cleared at most locations. Photos of all monitored crossings are shown in Appendix C.2

8.0 BREAKUP TIMING AND MAGNITUDE

Colville River breakup monitoring has been ongoing since 1962. The timing and magnitude of breakup flooding has been determined consistently since 1992 by measuring WSEs and discharge at established locations throughout the delta.

The daily high and low ambient air temperatures are used in the evaluation of breakup timing. The winter of 2014-2015 was the warmest on record for the past 14 years; the coldest was 2011-2012, as shown in Figure 8.1 (ICE 2015). Cumulative freezing degree days are a measurement in degrees of the daily mean air temperature below freezing accumulated over the total number of days the temperature remained below freezing. Snowpack north of the Brooks Range was average, and south of the Brooks Range was below average. Spring temperatures in 2015 were above average, and a warming trend started the second week of May.

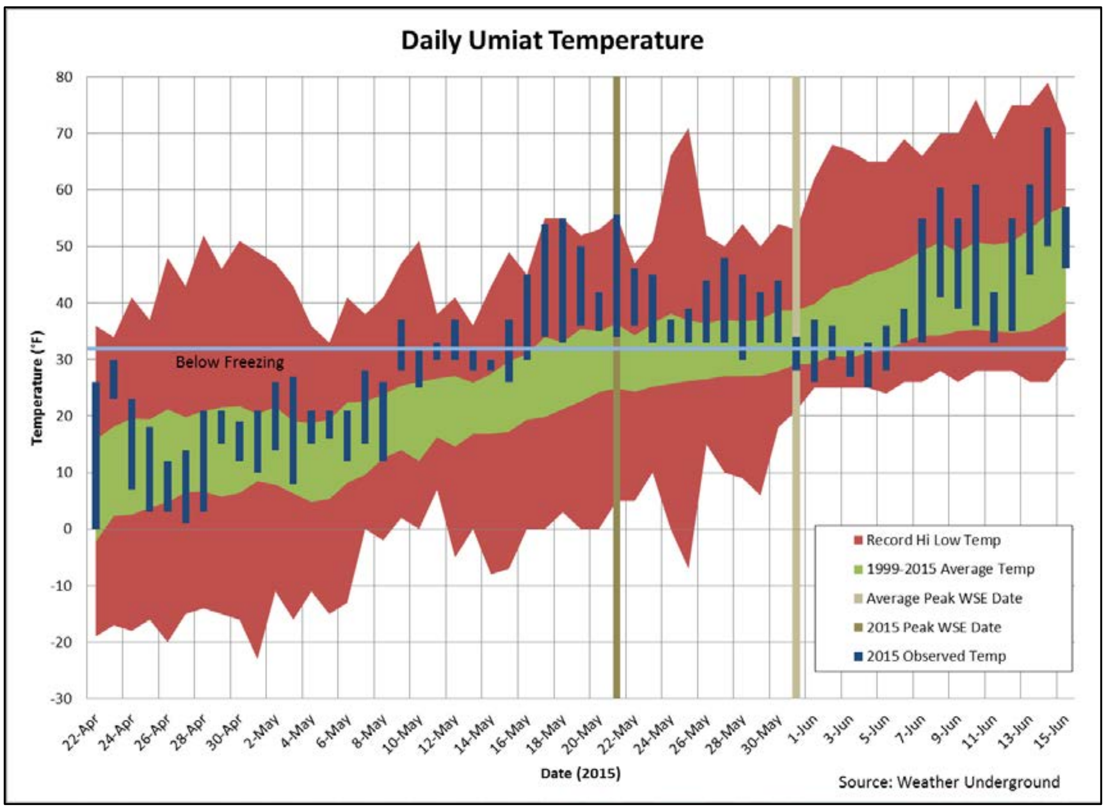
Figure 8.1: NPRA N. Tundra Monitoring Station, Cumulative Freezing Degree Days, Winters 2002-2015 (ICE 2015)



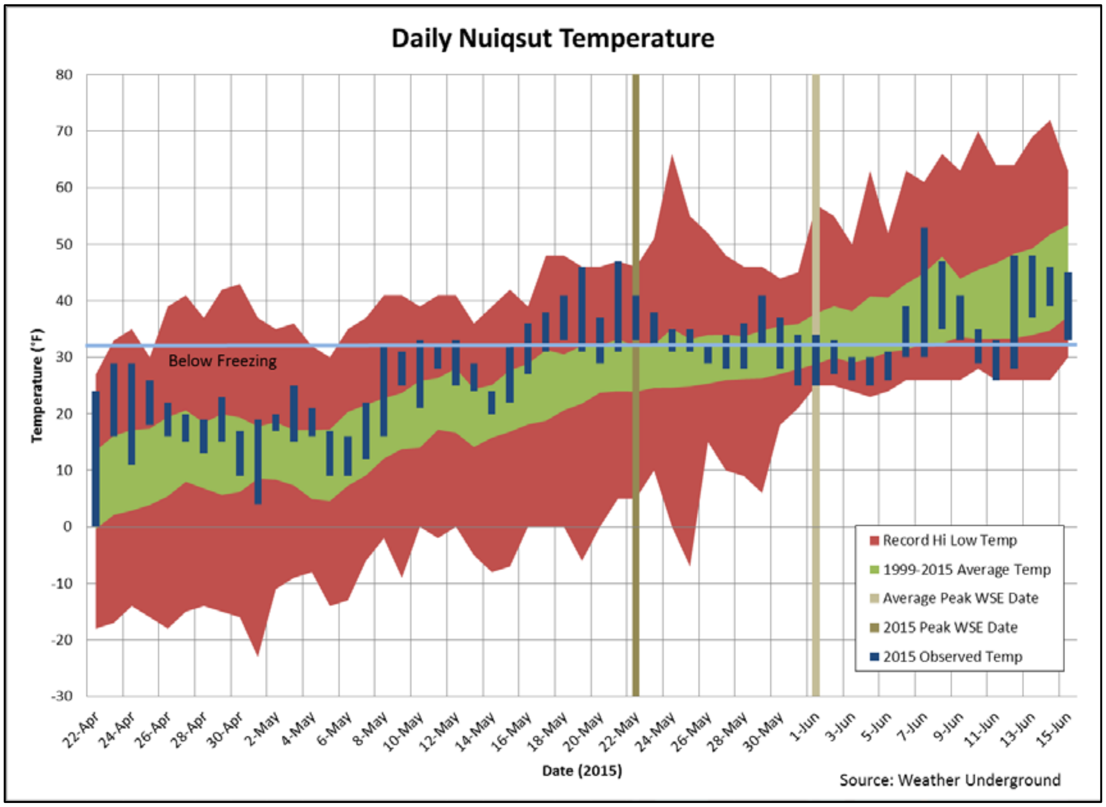
8.1 TEMPERATURES

Climate data upstream of the CRD is available from the Umiat weather station, located approximately 60 air miles south of MON1 at the northern extent of the Brooks Range foothills. The 2015 ambient air temperatures in Umiat were generally above historical averages. Nighttime ambient air temperatures in Umiat did not stay above freezing until mid-May. Near record temperature days from May 16 through May 22 accelerated melting of the snowpack. Graph 8.1: illustrates high and low ambient air temperatures recorded at Umiat from April 22 to June 15 during the breakup monitoring period (Weather Underground 2015). Average highs and lows for the same period for 1999 through 2015 are shown shaded in green. Dates of 2015 peak stage and average peak stage from 1999 to 2015 from the centerline gage at MON1 (MON1C) are included for comparison.

Temperatures for the Alpine area were obtained from the Nuiqsut weather station. Nuiqsut is located on the west bank of the Nigliq Channel, approximately 3.5 air miles northwest of MON1, and approximately 9 air miles south of the Alpine facilities, as shown in Figure 1.2. Nighttime ambient air temperatures in the CRD remained near or below freezing until the second week of June. Graph 8.2 provides high and low ambient air temperatures recorded for Nuiqsut from April 22 to June 15 (Weather Underground 2015). Dates of the 2015 peak stage and average peak stage from 1999 to 2015 at Alpine facilities are included for comparison.



Graph 8.1: Umiat Daily High and Low Breakup Ambient Air Temperatures and MON1 Peak Stage



Graph 8.2: Nuiqsut Daily High and Low Breakup Ambient Air Temperatures and Alpine Facilities Peak Stage

8.2 Colville River – MON1

MON1, at the head of the delta, provides the most consistent historical record of peak stage and discharge for the Colville River. Table 8.1 shows the annual peak stage and peak discharge at gage MON1C from 1962 to 2015.

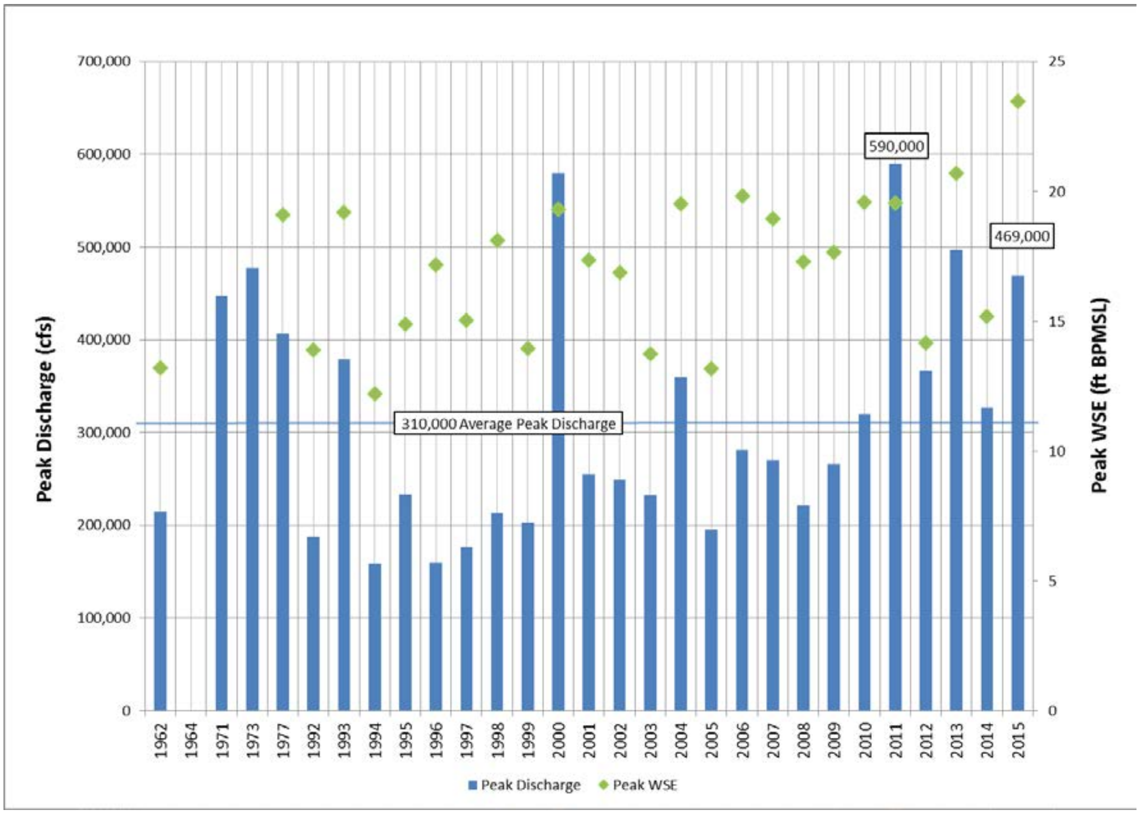
The 2015 peak WSE at MON1 was 23.47 feet BPMSL on May 21; 2.78 feet above the previous maximum historical peak stage of 20.69 feet BPMSL in 2013 (Michael Baker 2013a). The 2015 peak WSE was a result of backwater flooding behind concurrent ice jams in the East Channel and Nigliq Channel. The average historical peak is 17.05 feet BPMSL.

In 2015, peak discharge at MON1 occurred on May 22. Graph 8.3 shows the range of peak discharge and peak stage at MON1. The 2015 peak discharge at MON1C was 469,000 cfs, the maximum historical peak discharge was 590,000 cfs in 2011 (Michael Baker 2012a), and the average historical peak discharge is 312,000 cfs. The 2015 peak discharge resulted from the sudden backwater relief associated with the release of a downstream ice jam in the East Channel.

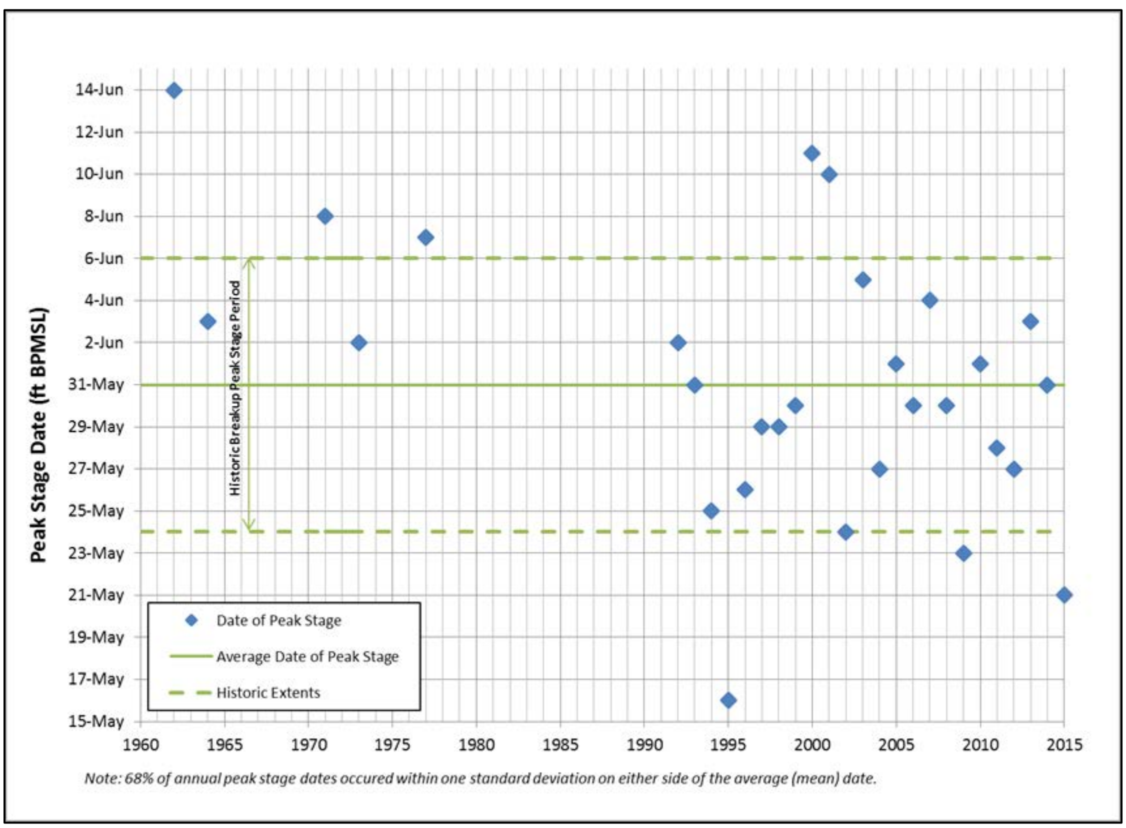
Statistical analysis of historical peak stage dates show 68% of the peaks at MON1 occur during the 13-day period from May 24 to June 6. This represents one standard deviation of 6.4 days on either side of the average (mean) peak stage date of May 31, based on a normal distribution, as illustrated in Graph 8.4. The 2015 peak stage at MON1 on May 21 was 10 days prior to the historical average.

Table 8.1: MON1C Colville River Historical Peak Discharge and Stage

Year	Discharge		Stage (WSE)		Reference
	Peak Discharge (cfs)	Date	Peak Stage (ft BPMSL)	Date	
2015	469,000	22-May	23.47	21-May	This Report
2014	327,000	1-Jun	15.18	31-May	Michael Baker 2014
2013	497,000	3-Jun	20.69	3-Jun	Michael Baker 2013
2012	366,000	1-Jun	14.18	27-May	Michael Baker 2012b
2011	590,000	28-May	19.56	28-May	Michael Baker 2012a
2010	320,000	31-May	19.59	1-Jun	Michael Baker 2010
2009	266,000	23-May	17.65	23-May	Michael Baker 2009b
2008	221,000	28-May	17.29	30-May	Michael Baker 2008
2007	270,000	3-Jun	18.97	4-Jun	Michael Baker 2007b
2006	281,000	30-May	19.83	30-May	Michael Baker 2007a
2005	195,000	9-Jun	13.18	1-Jun	Michael Baker 2005b
2004	360,000	26-May	19.54	27-May	Michael Baker 2005a
2003	232,000	11-Jun	13.76	5-Jun	Michael Baker 2006a
2002	249,000	27-May	16.87	24-May	Michael Baker 2006a
2001	255,000	11-Jun	17.37	10-Jun	Michael Baker 2006a
2000	580,000	11-Jun	19.33	11-Jun	Michael Baker 2000
1999	203,000	30-May	13.97	30-May	Michael Baker 1999
1998	213,000	3-Jun	18.11	29-May	Michael Baker 1998b
1997	177,000	-	15.05	29-May	Michael Baker 2002b
1996	160,000	26-May	17.19	26-May	Shannon & Wilson 1996
1995	233,000	-	14.88	16-May	ABR 1996
1994	159,000	25-May	12.20	25-May	ABR 1996
1993	379,000	31-May	19.20	31-May	ABR 1996
1992	188,000	-	13.90	2-Jun	ABR 1996
1977	407,000	-	19.10	7-Jun	ABR 1996
1973	478,000	-	-	2-Jun	ABR 1996
1971	447,000	8-Jun	-	8-Jun	ABR 1996
1964	-	-	-	3-Jun	ABR 1996
1962	215,000	-	13.20	14-Jun	ABR 1996

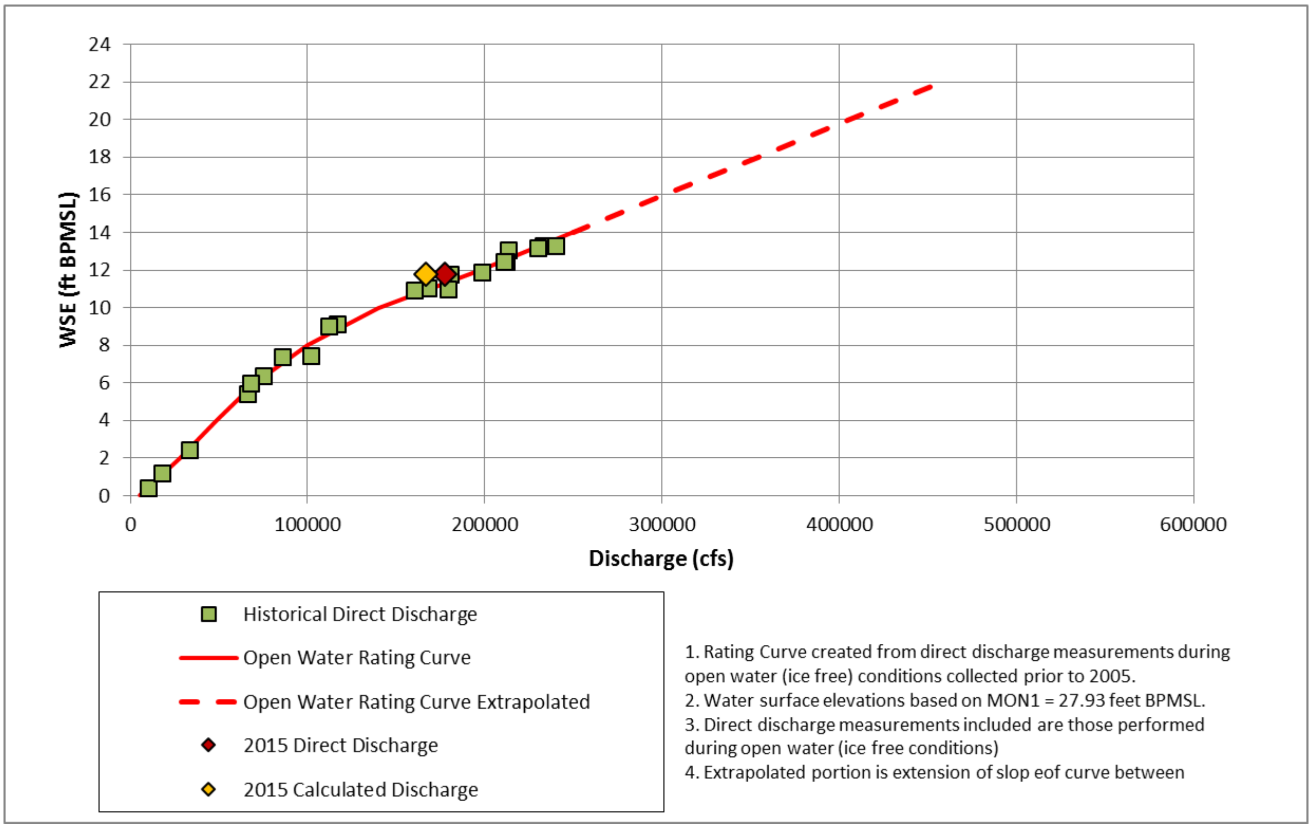


Graph 8.3: MON1 Annual Peak Discharge



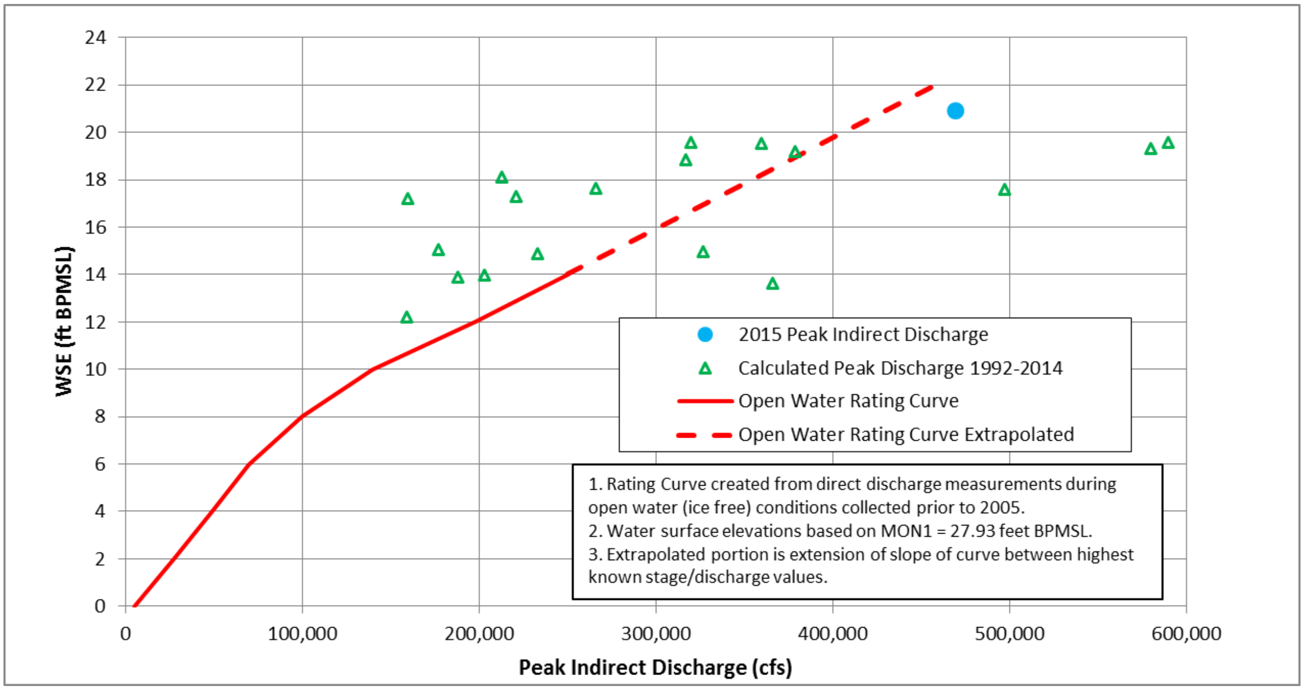
Graph 8.4: MON1 Annual Peak Stage and Dates

The MON1 stage-discharge rating curve, shown in Graph 8.5 represents a relationship between known stage and corresponding discharge measurements collected between 1992 and 2015. The rating curve was calculated from direct discharge measurements during ice-free conditions. The rating curve more accurately represents the relationship between stage and discharge at lower stage values when ice-free discharge measurements are possible. The 2015 direct discharge measurement of 177,600 cfs and the calculated discharge at the time of measurement of 166,900 cfs are plotted for comparison. The 2015 direct discharge measurement and the calculated discharge plot off the rateing curve by -7% and -13% of the rating discharge, respectively. The shift is likely due to changes in channel geometry, affecting the calculated discharge and changing the relationship between stage and discharge of the rating curve.



Graph 8.5: MON1 Stage-Discharge Rating Curve with Direct Discharge

Calculated (indirect) peak discharge between 1992 and 2014 are plotted against the open water rating curve in Graph 8.6. The limitations of the open water rating curve for predicting the stage-discharge relationship of large magnitude flood events is apparent. Differences between the indirect discharge and the open water rating curve are attributed to ice effects on stage and discharge, common during peak-flow periods. Open water conditions rarely occur at or near recorded historical peak stage levels during breakup. Values that fall to the right of the rating curve tend to be the result of an ice jam release. Conversely, values that fall to the left of the rating curve tend to be the result of downstream ice jam backwater effects. The 2015 calculated peak discharge of 469,000 cfs plots off the rateing curve by +9% of the rating discharge.



Graph 8.6: MON1 Stage-Discharge Rating Curve with Peak Discharge Values

8.3 CD2 Road and Pad – Swale Bridges

Discharge has been measured at the CD2 road swale bridges since 2000, and overall the measurements are estimated to be within 5-10% of the true discharge value based on the quality rating assigned to measurements. A summary of the 2015 discharge measurements at the Alpine swale bridges is presented with historical data in Table 8.2. In 2015, WSE differential upstream and downstream of the CD2 road equalized quickly, and as a result the measured discharge at the Short Swale Bridge is considerably low for the corresponding WSE.

Table 8.2: Alpine CD2 Road Swale Bridges (2000-2015) Direct Discharge Historical Summary

Site	Date	WSE[1] (ft)	WSE Differential[2] (ft)	Width (ft)	Area (ft^2)	Mean Velocity[3] (ft/s)	Discharge (cfs)	Measurement Rating[4]	Number of Sections	Measurement Type	Reference
Short Swale Bridge (62 ft)	05/23/15	7.85	0.05	54	373	0.81	302	F	19	Cable	This Report
	06/02/14	7.90	0.12	54	365	1.31	479	F	28	Cable	Michael Baker 2014
	06/05/13	9.75	0.46	54	446	3.60	1,608	G	36	Cable	Michael Baker 2013
	06/03/12	7.04	0.17	52	306	1.26	386	F	19	Cable	Michael Baker 2012b
	05/28/11	8.15	0.43	52	336	2.51	840	F	27	Cable	Michael Baker 2012a
	06/03/10	7.58	0.16	55	316	1.79	570	F	28	Cable	Michael Baker 2010
	–[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2009b
	05/29/08	6.35	0.18	55	211	0.58	120	P	14	Cable	Michael Baker 2008
	06/05/07	7.83	0.09	55	292	1.18	350	F	20	Cable	Michael Baker 2007b
	05/31/06	8.49	0.26	55	615	1.59	980	F	20	Cable	Michael Baker 2007a
	–[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2005b
	05/29/04	8.34	0.14	55	451	1.60	720	F	17	Cable	Michael Baker 2005a
	–[5]	–	–	–	–	–	–	–	–	–	Michael Baker 2003
	05/25/02	6.74	0.22	56	283	1.52	430	G	17	Cable	Michael Baker 2002b
	06/11/01	7.64	0.56	56	336	1.79	600	G	15	Cable	Michael Baker 2001
	06/10/00	7.87	0.61	47	175	3.30	580	F	13	Cable	Michael Baker 2000
Long Swale Bridge (452 ft)	05/22/15	9.93	0.55	447	3,024	3.12	9,440	G	24	Cable	This Report
	06/02/14	8.00	0.13	445	2,183	1.30	2,842	G	38	Cable	Michael Baker 2014
	06/05/13	9.87	0.42	448	2,947	2.47	7,286	G	36	Cable	Michael Baker 2013
	06/03/12	7.10	0.17	445	1,686	1.53	2,582	-	26	Cable	Michael Baker 2012b
	05/29/11	8.16	0.38	447	2,027	2.22	4,500	F	26	Cable	Michael Baker 2012a
	06/01/10	7.97	0.47	441	1,699	2.66	4,500	G	25	Cable	Michael Baker 2010
	05/26/09	5.89	0.09	445	1,592	0.82	730	F	27	Wading	Michael Baker 2009b
	05/29/08	6.35	0.18	445	949	2.03	1,930	F	21	Wading	Michael Baker 2008
	06/05/07	7.76	0.08	447	1,670	0.74	1,240	F	20	Cable	Michael Baker 2007b
	05/31/06	8.42	0.18	409	1,730	1.89	3,260	F	29	Cable	Michael Baker 2007a
	06/02/05	6.13	0.08	445	841	1.37	1,100	G	20	Wading	Michael Baker 2005b
	05/29/04	8.34	0.14	446	1,700	1.40	2,400	F	18	Cable	Michael Baker 2005a
	06/08/03	5.48	-0.05	444	478	0.88	420	G	16	Wading	Michael Baker 2003
	05/25/02	6.74	0.22	445	930	3.47	3,200	G	17	Cable	Michael Baker 2002b
	06/11/01	7.64	0.56	460	1,538	2.40	3,700	G	16	Cable	Michael Baker 2001
	06/09/00	7.34	0.78	437	1,220	3.27	4,000	F	15	Cable	Michael Baker 2000

Notes:
1. Source of WSE is G3
2. WSE differential between G3/G4 at time of peak discharge
3. Mean velocities adjusted with angle of flow coefficient
4. Measurement Rating -
   - E - Excellent: Within 2% of true value
   - G - Good: Within 5% of true value
   - F - Fair: Within 7-10% of true value
   - P - Poor: Velocity < 0.70 ft/s; Shallow depth for measurement; less than 15% of true value
5. Bridge obstructed with snow or ice, no measurement made

The 2015 calculated peak discharge of 12,834 cfs through both bridges combined is greater than the average peak historical discharge of 5,555 cfs. Velocities measured at the Short Swale Bridge were considerably lower than what would have been observed during peak conditions, and as a result, the 2015 calculated peak discharge at the Short Swale Bridge is underestimated. Table 8.3 summarizes the calculated peak annual discharge data at the Alpine swale bridges between 2000 and 2015.

Table 8.3: Alpine Swale Bridges Calculated Peak Discharge Historical Summary (2000-2015)

Date [1]	Peak WSE[2] (ft)	WSE Differential[3] (ft)	Long Swale Bridge (452 ft)		Short Swale Bridge (62 ft)		References
			Discharge[4] (cfs)	Mean Velocity (ft/s)	Discharge[4] (cfs)	Mean Velocity (ft/s)	
05/22/15	11.93	1.54	12,350	3.12	484	0.81	This Report
06/02/14	8.18	0.19	2,971	1.30	501	1.31	Michael Baker 2014
06/04/13	10.27	1.17	7,723	2.47	1,706	3.60	Michael Baker 2013
06/03/12	7.60	0.41	2,940	1.53	425	1.26	Michael Baker 2012b
05/29/11	8.89	0.30	5,200	2.22	940	2.51	Michael Baker 2012a
06/02/10	8.64	0.59	5,300	2.66	670	1.79	Michael Baker 2010
05/25/09	7.63	0.45	1,400	0.82	–[5]	–[5]	Michael Baker 2009b
05/30/08	6.49	0.26	2,100	0.49	100	0.58	Michael Baker 2008
06/05/07	8.60	0.43	1,500	1.35	400	1.18	Michael Baker 2007b
05/31/06	9.72	0.87	4,400	1.77	1,100	1.59	Michael Baker 2007a
05/31/05	6.48	0.20	1,400	1.37	–[5]	–[5]	Michael Baker 2005b
05/27/04	9.97	0.50	3,400	1.38	900	1.59	Michael Baker 2005a
06/07/03	6.31	0.12	700	0.88	–[5]	–[5]	Michael Baker 2003
05/26/02	7.59	0.69	4,000	3.47	500	1.52	Michael Baker 2002b
06/11/01	7.95	0.73	3,900	2.40	600	1.79	Michael Baker 2001
06/12/00	9.48	0.73	7,100	3.60	1,000	4.30	Michael Baker 2000

Notes:
1. Based on gage HWM readings
2. Source of WSE is Gage 3
3. WSE differential between G3/G4 at time of peak discharge
4. Estimated peak discharge
5. Bridge obstructed with snow or ice, no velocity measurements

8.4 CD5 Road Crossings

Peak annual discharge has been calculated at the Nigliq Channel CD5 road crossing since 2009 and at the Nigliagvik Channel and the Lake L9341 CD5 road crossings since 2012. The road and bridge abutments were in place starting in 2014. In 2014, floodwater did not reach the bridge abutments and therefore was not constricted by the bridge openings. In 2015, extensive overbank flooding along the CD5 road resulted in constricted flow between the bridge openings. A summary of the peak WSE and peak discharge during breakup flood events for the CD5 bridge crossing is shown in Table 8.4.

Table 8.4: CD5 Road Crossings Historical Summary of Peak WSE and Discharge

Year	Nigliq Channel Bridge		Lake L9341 Bridge		Nigliagvik Channel Bridge	
	Peak Indirect Discharge (cfs)	Peak WSE (ft-BPMSL)	Peak Indirect Discharge (cfs)	Peak WSE (ft-BPMSL)	Peak Indirect Discharge (cfs)	Peak WSE (ft-BPMSL)
2015 [5]	112,000	14.50	22,500	14.51	17,300	13.57
2014	66,000	9.38	– [1]	8.83	7,800	8.64
2013	110,000 [4]	12.42 [2]	5,000 [4]	11.07	7,800 [4]	11.41
2012	94,000 [3]	8.82	6,000 [3]	8.58	11,000 [3]	8.51
2011	141,000 [3]	9.89	- [1]	9.50	- [1]	8.78
2010	134,000 [3]	9.65	- [1]	5.85	- [1]	8.69
2009	57,000 [3]	7.91	- [1]	7.98	- [1]	7.71

Notes:
1. Data not available
2. Inferred from G25 at Lake L9323 Crossing
3. Indirect discharge computed as open water conditions, even though channel ice was present at time of peak discharge
4. Indirect discharge computed with consideration of intact channel ice present at time of peak discharge
5. Discharge influenced by flow contraction through bridges

8.5 Alpine Drinking Water Lakes Recharge – Lakes L9312, L9313

Recharge of lakes L9312 and L9313 has been documented annually since 1998. Primary recharge mechanisms for these lakes are overland flood flow and local melt. Local melt contributions come from snow and ice within the lake drainage basins. Lakes are determined to be fully recharged if bankfull conditions are met; either overland floodwater was observed flowing into the lake, or there was evidence of a stage rise and fall on the breakup hydrograph.

In most years, Lake L9313 is recharged by overland flow from the Sakoonang Channel near CD1 and through Lake M9525. Historical records indicate Lake L9313 bankfull elevation is approximately 6.5 feet BPMSL (Michael Baker 2006a, 2007b) at gage G10.

Lake L9312 is surrounded by higher tundra than Lake L9313 and is less frequently recharged by floodwater from the Sakoonang Channel relying more on local melt of snow and ice and precipitation. Bankfull elevation of Lake L9312 is 7.8 feet BPMSL per the Fish Habitat Permit FG99-III-0051-Amendment #8.

Table 8.5 provides a historical summary of Alpine drinking water lakes WSE and magnitude of recharge from overland breakup flooding. Lake L9313 has recharged to bankfull 16 of the last 18 years, and Lake L9312 has recharged to bankfull 14 of the last 18 years. In some years when overland flow did not inundate L9312, such as 2001 and 2010, local melt did fully recharge the lake to bankfull.

Table 8.5: Alpine Drinking Water Lakes Historical Summary of Recharge

Year	Lake L9312		Lake L9313	
	Peak WSE (observed)	Bankfull Recharge (7.8 ft BPMSL)[2]	Peak WSE (observed)	Bankfull Recharge (6.5 ft BPMSL)[3]
2015	13.32	Yes	12.71	Yes
2014	7.94	Yes	8.59	Yes
2013	8.79	Yes	10.44	Yes
2012	8.23	Yes	8.20	Yes
2011	10.72	Yes	10.67	Yes
2010	7.63	No	7.52	Yes
2009	7.65	No	7.12	Yes
2008	7.45	No	6.95	Yes
2007	9.35	Yes	9.47	Yes
2006	9.55	Yes	9.95	Yes
2005	8.00	Yes	6.12	No
2004	8.37	Yes	9.40	Yes
2003	8.01	Yes	7.12	Yes
2002	8.05	Yes	7.98	Yes
2001	7.55	No	8.31	Yes
2000	-	Yes	-	Yes
1999	7.93	Yes	6.14	No
1998	8.35	Yes	7.35	Yes

Notes:
1. This data does not include recharge as a result of local melt.
2. Bankfull recharge is based on peak WSE exceeding 7.8 ft BPMSL per Fish Habitat Permit FG99-III-0051, Amendment #8.
3. Bankfull recharge is based on visual observations of hydraulic connectivity of lake to breakup floodwater.

9.0 FLOOD FREQUENCY ANALYSIS

9.1 FLOOD FREQUENCY ANALYSIS RESULTS

Both continuous record and design-magnitude flood frequency analyses were performed for the Colville River at the head of the delta in 2015. These were based on reported annual peak discharge data from 1992 through 2015 and the extrapolated data extending back to 1971, which is recommended for design-magnitude extrapolation with less than 50 years of record. The 2015 data, similar to previous years, was ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for design-magnitude extrapolation. Results were compared between the 2015 Weibull and Log-Pearson Type III analyses for the period of continuous record; the 2002, 2012, and 2015 Log-Pearson Type III analyses for the period of continuous record; and the 2002, 2012, and 2015 Log-Pearson Type III analyses for design-magnitude returns. The 2002 results are the basis of current design criteria.

Comparison of the 2015 Weibull and Log-Pearson Type III flood frequency analyses for the period of continuous record (1992 to 2015) are presented in Table 9.1, ranked in order (largest to smallest) of peak discharge. As noted, the Weibull analysis limits the return period (also known as recurrence interval) to the number of record years plus one. As a result, the return period for each year is based solely on the ranked position within the continuous record with a maximum return period of 25 years assigned to the event with the largest peak discharge.

Table 9.1: Colville River Flood Frequency Analysis Results

Year	Discharge (cfs)	Weibull Return Period (years)	Log-Pearson Type III Return Period (years)	Difference
2011	590,000	25.0	21.3	-14.8%
2000	580,000	12.5	20.2	61.2%
2013	497,000	8.3	10.7	28.3%
2015	**469,000**	**6.3**	**8.9**	**41.9%**
1993	379,000	5.0	4.6	-7.4%
2012	366,000	4.2	4.3	3.5%
2004	360,000	3.6	4.2	16.7%
2014	327,000	3.1	3.4	7.6%
2010	320,000	2.8	3.2	14.9%
2006	281,000	2.5	2.3	-8.9%
2007	270,000	2.3	2.1	-6.6%
2009	266,000	2.1	2.1	-0.8%
2001	255,000	1.9	1.9	0.7%
2002	249,000	1.8	1.9	5.0%
1995	233,000	1.7	1.7	2.6%
2003	232,000	1.6	1.7	8.8%
2008	221,000	1.5	1.6	7.9%
1998	213,000	1.4	1.5	8.4%
1999	203,000	1.3	1.4	9.2%
2005	195,000	1.3	1.4	10.7%
1997	177,000	1.2	1.3	6.1%
1994	165,000	1.1	1.2	6.2%
1992	164,000	1.1	1.2	10.7%
1996	160,000	1.0	1.2	13.8%

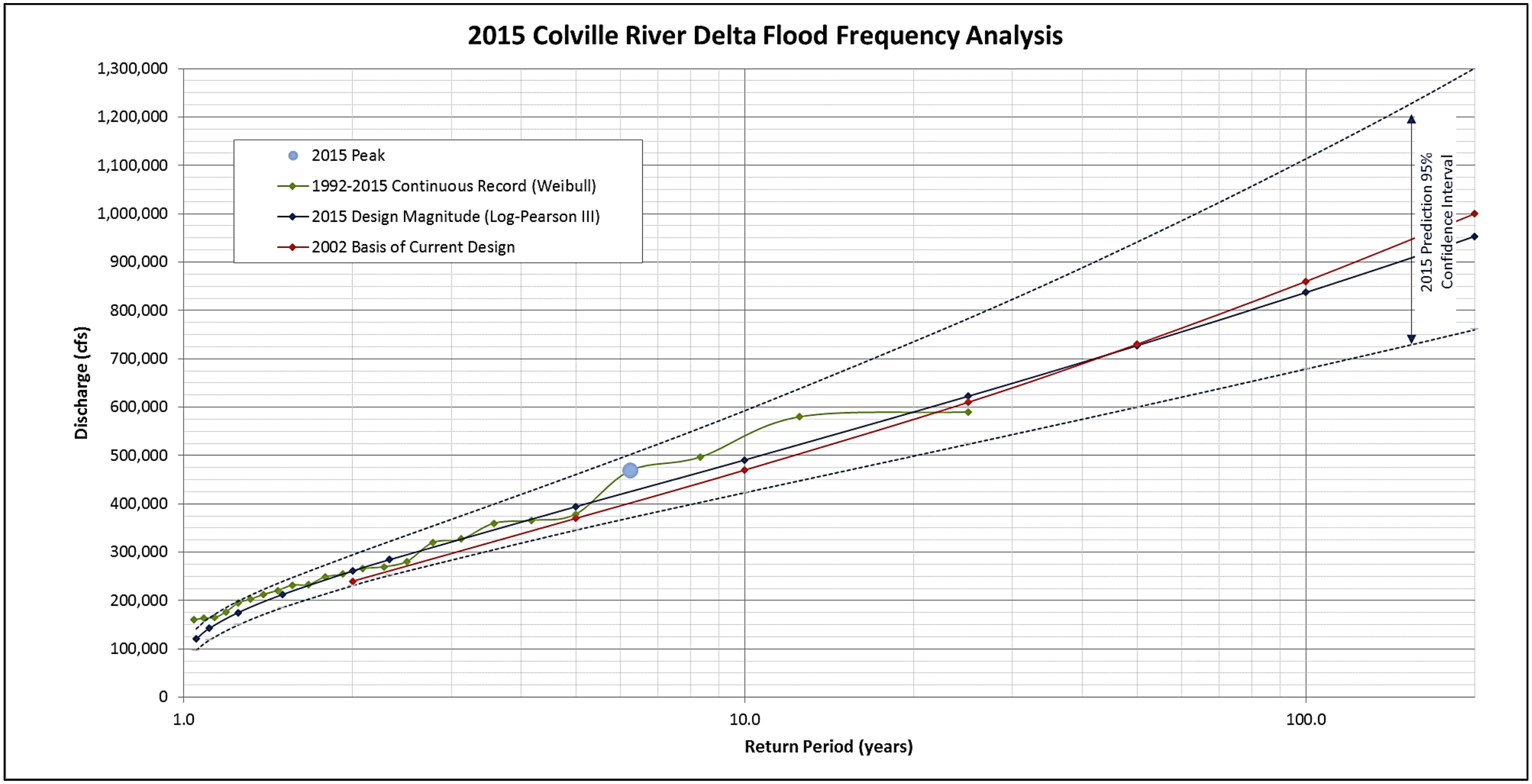
When comparing the 2015 results of the Weibull and Log-Pearson III analyses, the calculated return period for the discharge values are fairly close for small return periods; however, the limitations of the Weibull distribution are evident when looking at the recurrence interval for the larger return periods. The Weibull distribution assigns a 12.5-year return period to the 580,000 cfs in 2000, which is significantly less than the 20.2-year return period assigned by the Log-Pearson Type III analysis. The large discrepancy can be attributed to the higher magnitude discharge events in 2000 and 2011. Therefore, even though the 2000 and 2011 have comparable discharges, the Weibull distribution assigns a shorter return period to the 2000 observation.

A comparison of the 2002, 2012, and 2015 Log-Pearson Type III flood frequency analyses for design magnitudes is presented in Table 9.2. The return intervals from the 2002 analysis were within nine percent of those derived from the 2015 analysis. Since the 2002 results fell within the 95% confidence interval of the 2015 analysis results, it is recommended that the results of the 2002 flood analysis be maintained as current design criteria. Based on the 2002 analysis, the 2015 peak discharge of 469,000 has a return interval of 6.9 years. Peak discharge was the result of sudden backwater relief accompanying a downstream ice jam release. Although the ice jam release was not a sustained event, discharge remained high with comparable magnitude following the ice jam release. The associated recurrence interval should be considered with respect to conditions at the time of peak discharge. Graph 9.1 provides a plotted comparison of the 2015 continuous record, 2015 design-magnitude, and 2002 design-magnitude flood frequency analysis results.

A comparison of the 2002, 2012, and 2015 Log-Pearson Type III flood frequency results for the period of continuous record (1992 to 2015) is presented in Table 9.3. The inclusion of the additional three years of observations (2013, 2014, and 2015) in the 2015 analysis resulted in a slight shift of the frequency distribution toward larger magnitude floods, which shortens the return periods for past observations.

Table 9.2: Comparison of Colville River 2002, 2012, and 2015 Log-Pearson Type III Analysis Results for Design Magnitudes

Return Period	2002 Results (Basis of Current Design Criteria)	2012 Results	2015 Results
	Flood Peak Discharge (cfs)	Flood Peak Discharge (cfs)	Flood Peak Discharge (cfs)
2	240,000	249,000	261,000
5	370,000	379,000	394,000
10	470,000	476,000	491,000
25	610,000	612,000	623,000
50	730,000	722,000	727,000
100	860,000	840,000	837,000
200	1,000,000	967,000	953,000



Graph 9.1: CRD Flood Frequency Analysis Distribution

Table 9.3: Comparison of Colville River 2002, 2012, and 2015 Log-Pearson Type III Analysis Results for the Period of Continuous Record (1992-2015)

Year	Discharge (cfs)	2002 Return Period (Basis of Current Design Criteria) (years)	2012 Log-Pearson Type III Return Period (years)	2015 Log-Pearson Type III Return Period (years)
2011	590,000	22.9	22.6	21.3
2000	580,000	21.8	21.5	20.2
2013	497,000	12.9	12.3	10.7
2015	**469,000**	**10.0**	**9.6**	**8.9**
1993	379,000	5.5	5.0	4.6
2012	366,000	4.9	4.7	4.3
2004	360,000	4.8	4.5	4.2
2014	327,000	4.0	3.7	3.4
2010	320,000	3.8	3.5	3.2
2006	281,000	2.9	2.6	2.3
2007	270,000	2.7	2.3	2.1
2009	266,000	2.6	2.2	2.1
2001	255,000	2.3	2.1	1.9
2002	249,000	2.2	2.0	1.9
1995	233,000	<2	1.8	1.7
2003	232,000	<2	1.8	1.7
2008	221,000	<2	1.7	1.6
1998	213,000	<2	1.6	1.5
1999	203,000	<2	1.5	1.4
2005	195,000	<2	1.4	1.4
1997	177,000	<2	1.3	1.3
1994	165,000	<2	1.2	1.2
1992	164,000	<2	1.2	1.2
1996	160,000	<2	1.2	1.2

9.2 Two-Dimensional Surface Water Model

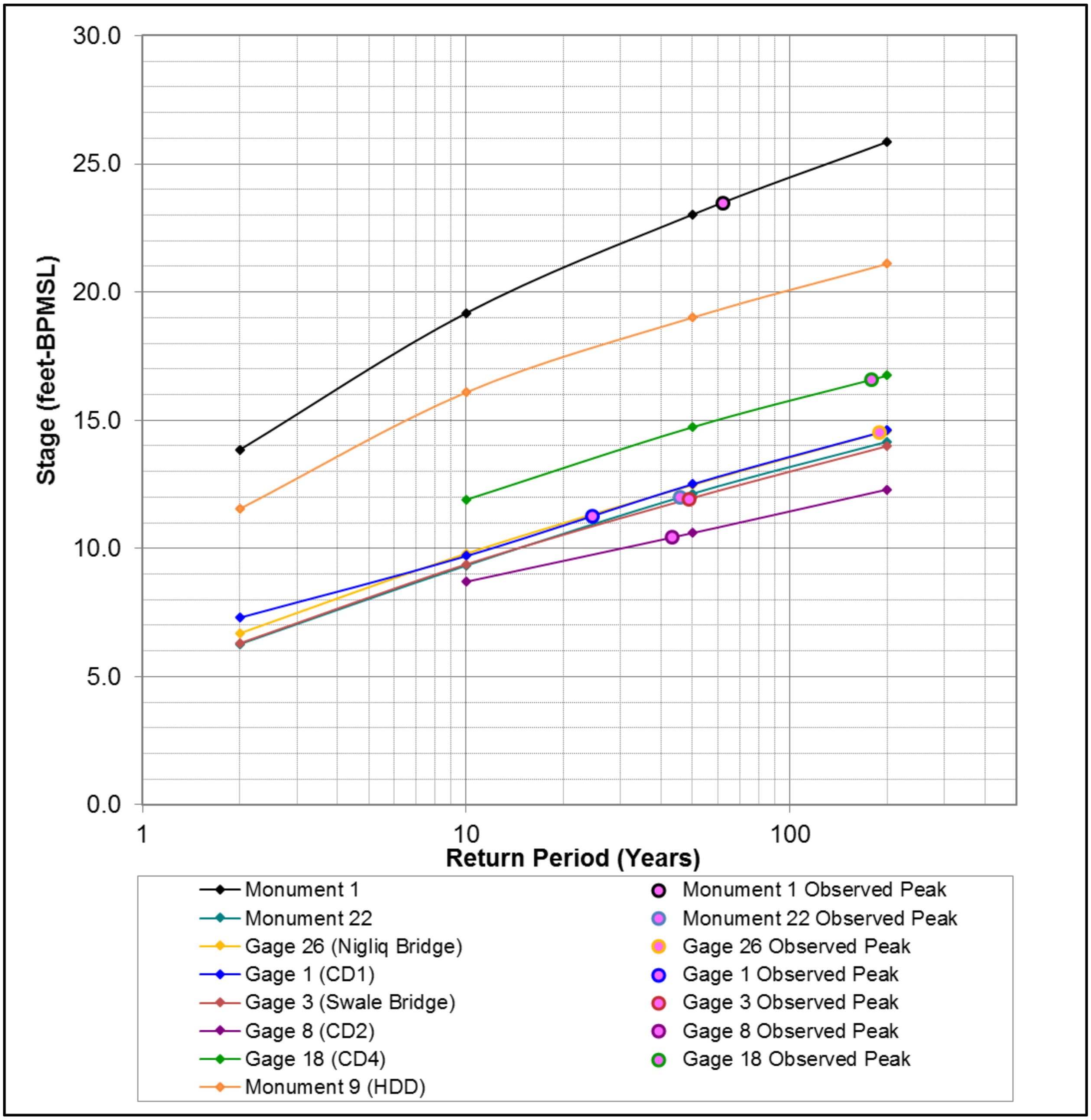
The CRD 2D surface water model was first developed in 1997 to estimate WSEs and velocities at the proposed Alpine facility locations (Michael Baker 1998a). The model has undergone numerous revisions since 1997. The proposed CD3 and CD4 developments were incorporated in 2002, including additional floodplain topographic survey data (Michael Baker 2002a). In 2006, the model was modified to include as-built alignment conditions along the CD4 access road and pad and the 2004-2005 survey data of the Nigliq Channel near MON23 (Michael Baker 2006b). The model was completely reconstructed in 2009 (Michael Baker 2009a). In 2012, additional topographic survey data at the proposed CD5 crossings were incorporated into the model (Michael Baker 2012b).

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

Graphical representations of the 2015 measured peak stage and predicted WSEs for the 2-, 10-, 50-, and 100-year recurrence intervals are shown in Graph 9.2. The 2012 2D surface water model predictions and the 2015 measurements are presented in Table 9.4.

Variance in recurrence intervals is the result of timing and locations of ice jam formation and release; it is not considered to be representative of actual volumes and related stage of breakup flow. Stage and discharge resulting from ice jam formation and release are not typically sustained, as they would otherwise be if sufficient breakup melt was present to induce lower-frequency flood recurrence intervals. 2015 flood stage recurrence throughout the CRD ranged from 25 years to greater than 200 years, based on the 2D model results. Outlying results are generally attributable to effects related to localized ice jam events as discussed below.

The formation of a major ice jam upstream of MON1, as occurred during the 2015 breakup season, is typical. When it released, it re-formed in the Nigliq and Colville East channels and sporadically advanced out of the CRD as lingering, intact channel ice obstructed ice floes. A substantial amount of backwater developed behind the ice jams, resulting in inflated stage at many monitoring locations throughout the CRD. MON35 and MON28 are near the coast where stage is influenced by intact coastal ice and to a certain extent tidal and wind events. Additionally, MON28 and MON35 are near the downstream boundary of the 2D model and are more susceptible to variance from modeled predictions.



Graph 9.2: CRD 2D Model Predicted and 2015 Measured Peak WSE

Table 9.4: 2012 2D Model Predicted and 2015 Measured Peak WSE

Monitoring Sites	2D Model Predicted Water Surface Elevations [based on open water conditions] (feet BPMSL)				2015 Peak WSE (feet BPMSL)	Approximate Recurrence Interval of 2015 Peak WSE (years)
	2-year	10-year	50-year	200-year		
Colville East Channel						
Monument 1 (Centerline)	13.9	19.2	23.0	25.9	23.5	62
Monument 9 (HDD)	11.5	16.1	19.0	21.1	22.6	>200
Monument 35 (Helmericks)	4.3	5.4	6.1	6.5	7.0	>200
Nigliq Channel						
Monument 20	7.8	11.4	14.6	16.8	17.6	>200
Monument 22	6.3	9.3	12.1	14.2	12.0	46
Monument 23	5.1	7.4	10.2	12.0	10.4	58
Monument 28	3.1	3.4	3.9	4.3	3.9	62
CD1 Pad						
Gage 1	7.3	9.7	12.5	14.6	11.3	25
Gage 9	8.3	10.8	13.4	15.7	13.4	50
Gage 10	8.3	10.8	13.4	15.7	13.4	48
CD2 Pad						
Gage 8	\	8.7	10.6	12.3	10.4	43
CD2 Road						
Gage 3	6.3	9.4	12.0	14.0	11.9	49
Gage 4	6.2	8.5	10.1	11.6	10.4	66
Gage 6	\	9.5	12.2	14.2	12.5	62
Gage 7	\	8.4	10.0	11.6	10.8	100
Gage 12	\	9.5	12.1	14.1	12.2	53
Gage 13	\	8.4	10.0	11.6	10.3	65
CD3 Pad						
Gage 11	5.2	6.4	6.9	8.0	Dry	-
CD4 Pad						
Gage 19	\	\	14.7	16.8	17.3	>200
Gage 20	\	11.1	14.3	16.4	10.7	9
CD4 Road						
Gage 15	8.4	10.8	13.5	15.9	13.6	54
Gage 16	8.4	11.1	14.2	16.3	15.4	114
Gage 17	\	11.1	14.2	16.3	13.3	31
Gage 18	\	11.9	14.8	16.8	16.6	172
CD3 Pipeline Crossings						
Sakoonang (Crossing #2) Gage	6.4	8.9	11.2	12.9	10.4	29
Tamayagiaq (Crossing #4) Gage	6.7	8.5	9.0	9.8	8.9	41
Ulamnigiaq (Crossing #5) Gage	5.5	7.1	7.8	8.7	7.7	36
CD5 Road						
Gage 24 (Lake L9323)	\	11.1	14.1	16.0	15.4	128
Gage 25 (Lake L9323)	\	\	13.9	15.4	14.5	85
Gage 26 (Nigliq Channel)	6.7	9.8	12.5	14.6	14.5	189
Gage 27 (Nigliq Channel)	6.7	9.8	12.5	14.5	14.5	193
Gage 30	\	\	13.3	15.5	13.4	53
Gage 31	\	\	13.2	14.7	14.0	108
Gage 32 (Lake L9341)	\	\	13.3	15.1	14.5	127
Gage 33 (Lake L9341)	\	\	13.2	14.8	14.3	134
Gage 34	\	\	13.3	15.7	13.6	58
Gage 35	\	\	12.4	14.3	12.2	48
Gage 36	\	\	13.3	15.7	13.5	57
Gage 37	\	\	12.3	14.3	12.2	49
Gage 38 (Nigliagvik Channel)	6.9	10.0	12.8	14.9	13.6	83
Gage 39 (Nigliagvik Channel)	6.9	9.9	12.5	14.3	12.2	43

Notes:
1. Sites having dry ground in 2D model are denoted with a backward slash "\"
2. Submerged gages during peak stage were assigned the top of gage elevation however, stage was higher.
3. 2D water surface elevations based on post-CD5 model results

9.3 Stage Frequency

Stage frequency was performed at MON1, MON22, and gages G1, G3, and G18. Similar to the flood frequency analysis, stage at the select locations was ranked by Weibull distribution for the continuous record and fitted to a Log-Pearson Type III distribution for design-magnitude extrapolation. Measured, estimated, and extrapolated peak annual stage data from 1992 through 2015 for locations used in the stage frequency analysis are presented in Table 9.5. Table 9.6 presents the Log-Pearson Type III 2015 stage frequency analysis results. Graph 9.3 through Graph 9.7 visually compare the stage frequency analysis and 2D model results to the measured or extrapolated peak annual stage for each selected location.

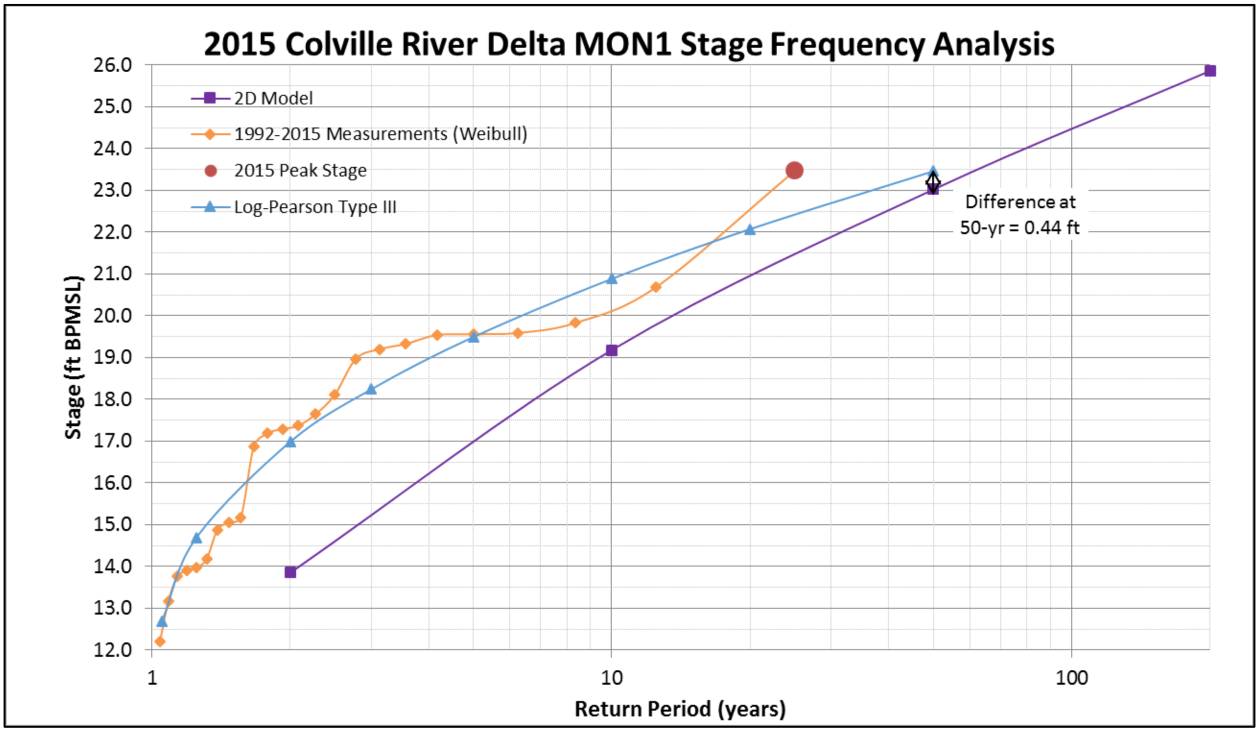
Table 9.5: CRD Peak Annual Stage for Selected Locations (1992-2015)

Year	Monument 1 (Head of Delta)	Monument 22 (Nigliq/CD2)	Gage 1 (CD1)	Gage 3 (Swale Bridge)	Gage 18 (CD4)
2015	23.47	11.98	11.26	11.93	16.58
2014	15.18	8.67	8.29	8.18	-
2013	20.69	10.56	9.90	10.27	14.20
2012	14.18	8.17	7.97	7.60	-
2011	19.56	8.97	9.33	8.89	12.84
2010	19.59	8.69	7.15	8.64	11.72
2009	17.65	7.76	6.65	7.63	11.34
2008	17.29	6.78	5.61	8.60	8.60
2007	18.97	9.04	8.64	6.49	10.98
2006	19.83	9.95	9.29	9.72	14.67
2005	13.18	7.65	4.46	6.48	*8.17*
2004	19.54	10.17	8.88	9.97	*11.58*
2003	13.76	7.02	6.07	6.31	*8.03*
2002	16.87	7.94	7.68	7.59	*9.60*
2001	17.37	8.80	6.95	7.95	*10.16*
2000	19.33	9.58	9.10	*9.48*	*10.44*
1999	13.97	5.89	*4.64*	*5.79*	*7.10*
1998	18.11	10.20	*9.51*	*8.02*	*11.39*
1997	15.05	**7.56**	**6.27**	**7.02**	**8.64**
1996	17.19	**8.41**	**7.42**	**7.91**	**10.26**
1995	14.88	**7.49**	**6.18**	**6.94**	**8.52**
1994	12.20	**6.42**	**4.73**	**5.82**	**6.50**
1993	19.20	**9.22**	**8.51**	**8.76**	**11.77**
1992	13.90	**7.10**	**5.65**	**6.53**	**7.78**
Average:	17.12	8.50	7.51	8.02	10.49
Linear Equations:	N/A	y=0.4x+1.5382	y=0.5401x-1.8595	y=0.4203x+0.6897	y=0.7528x-2.6853

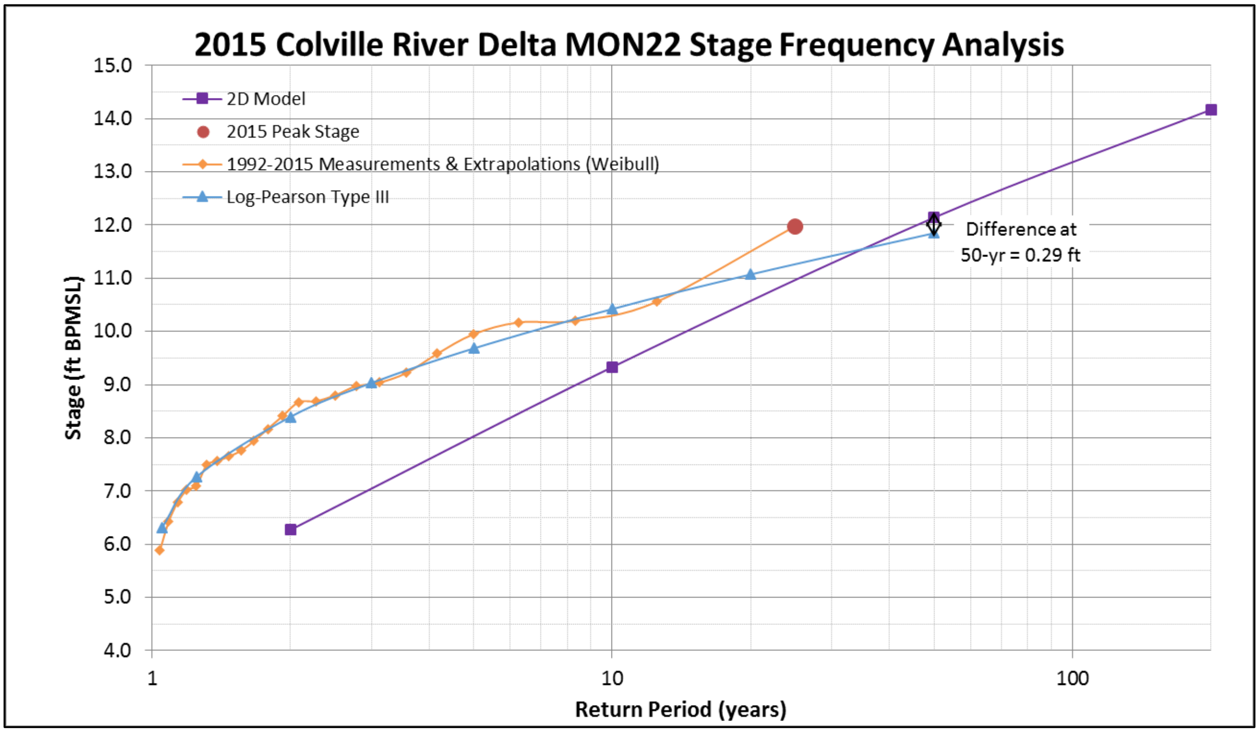
Notes:
1. Italicized values were estimated based on linear comparison to peak stage at proximal monitoring locations.
2. Bold values were linearly extrapolated based on peak stage at Monument 1.
3. Dash "-" indicates no observed WSE.

Table 9.6: CRD 2015 Stage Frequency Analysis Results

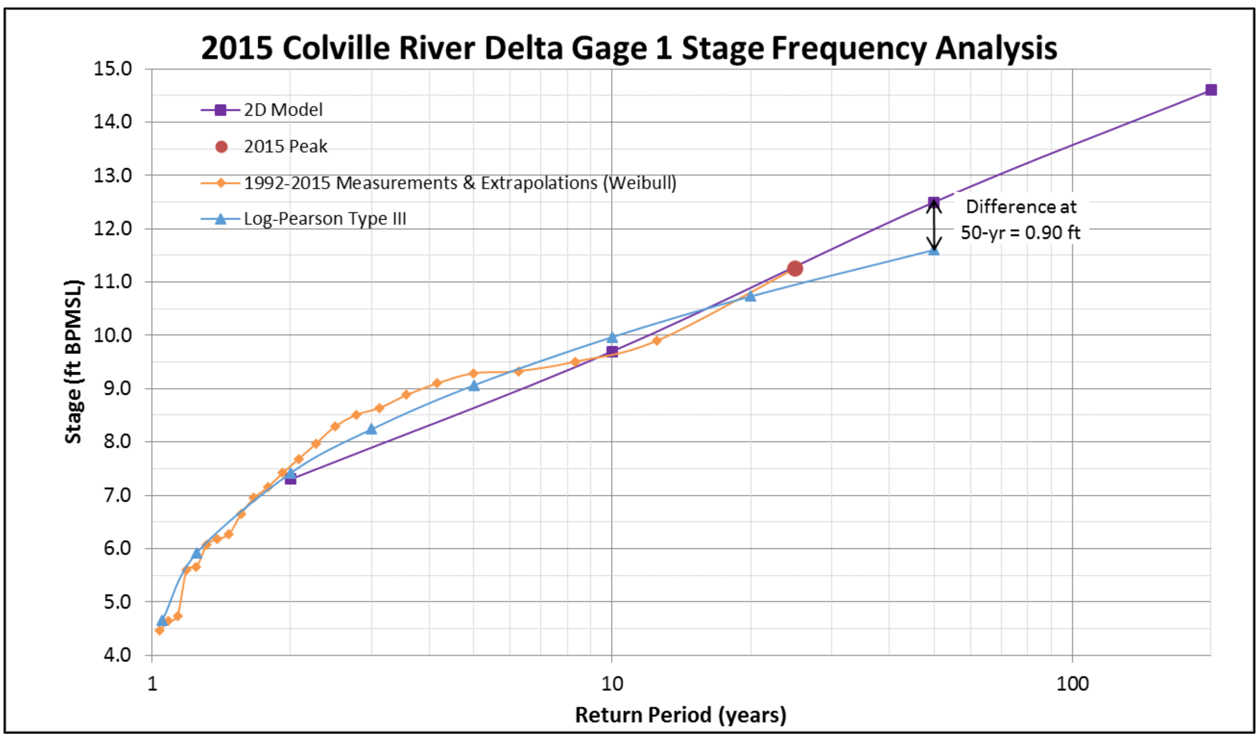
Monitoring Sites	Stage Frequency - Log-Pearson Type III (feet BPMSL)						2015 Peak WSE (feet BPMSL)	Approximate Recurrence Interval of Peak WSE (years)
	2-year	3-year	5-year	10-year	20-year	50-year		
Monument 1	17.0	18.2	19.5	20.9	22.1	23.5	23.5	>50
Monument 22	8.4	9.0	9.7	10.4	11.1	11.8	12.0	>50
Gage 1	7.4	8.2	9.1	10.0	10.7	11.6	11.3	35
Gage 3	7.8	8.5	9.2	10.1	10.8	11.8	11.9	>50
Gage 18 (CD4 Pad)	10.2	11.3	12.5	13.9	15.3	16.9	16.6	42



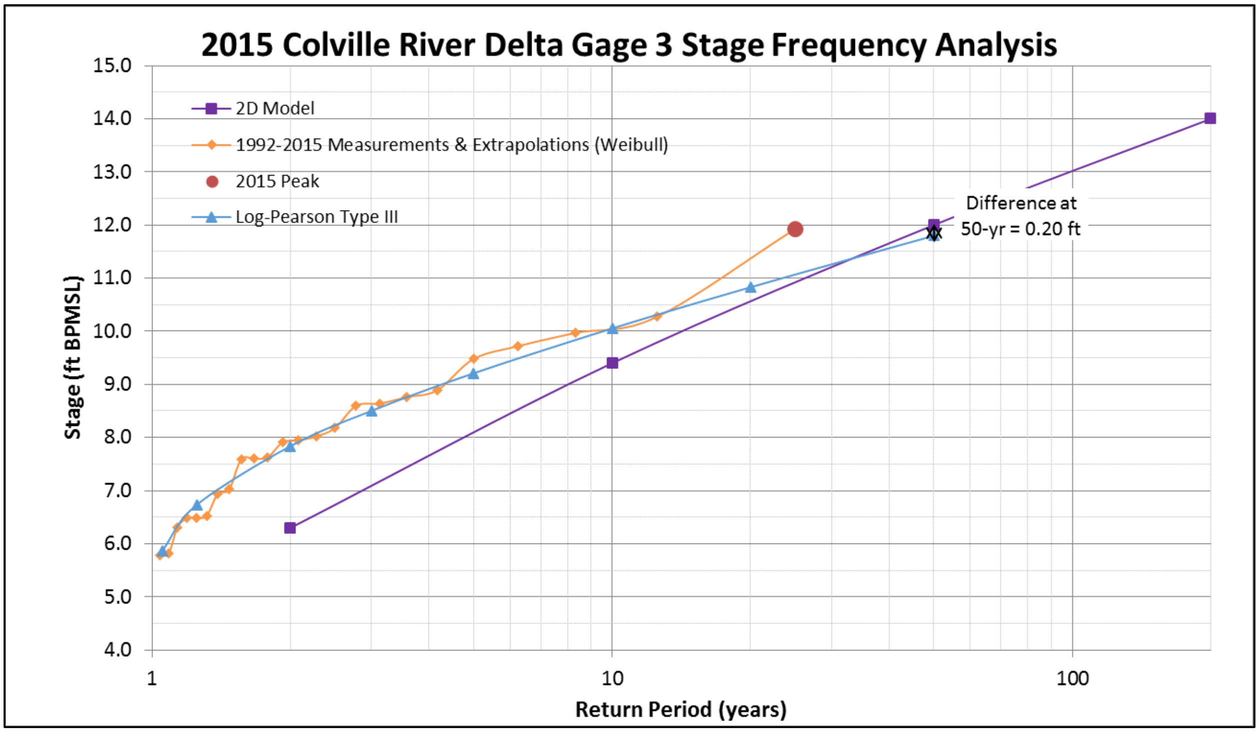
Graph 9.3: MON1 Stage Frequency Analysis, 2D Model Results, and Peak Annual Stage Data



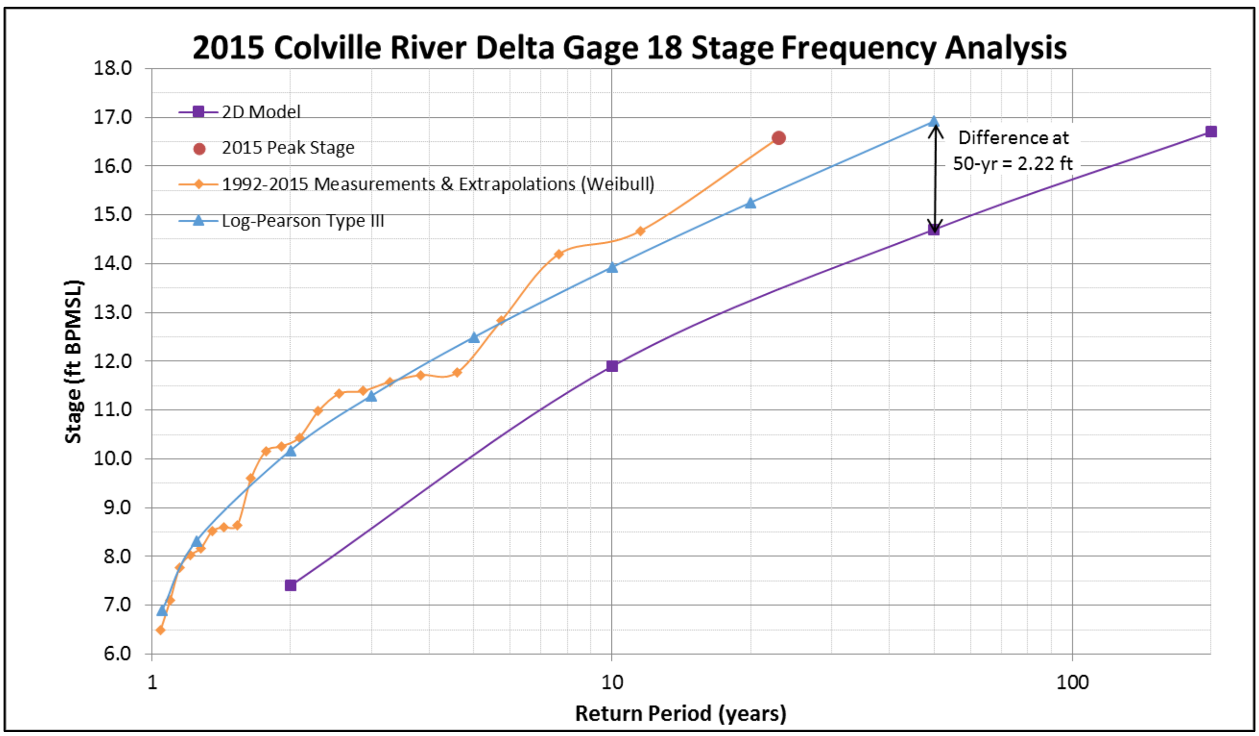
Graph 9.4: MON22 Stage Frequency Analysis, 2D Model Results, and Peak Annual Stage Data



Graph 9.5: G1 Stage Frequency Analysis, 2D Model Results, and Peak Annual Stage Data



Graph 9.6: G3 Stage Frequency Analysis, 2D Model Results, and Peak Annual Stage Data



Graph 9.7: G18 Stage Frequency Analysis, 2D Model Results, and Peak Annual Stage Data

The recurrence intervals for peak annual stage at all locations were comparatively higher for 2015; the maximum being greater than 50 years at MON1, MON22, and G3. The difference in the relationship between analysis methods that include ice events (Log-Pearson Type III) and those that do not (2D model) can be seen in the above graphs. In most cases, deviation between the 2D model and the Log-Pearson Type III in the high-magnitude flood region becomes apparent at return periods between 10 and 50 years. In general, the 2D model under-predicts stage for lower-return periods. This is to be expected, as the model does not account for ice and snow related events having a large effect on lower-magnitude floods and less of an effect on higher-magnitude floods. With an extended period of record, a stage frequency analysis can be a better estimate of low flood stage within the delta which is affected by recurrent ice jamming.

Based on a comparison of these analyses, it is recommended that the Log-Pearson Type III fit be consulted for stage frequency for the lower return periods (1 to 10 years, generally), and the 2D model be consulted for stage frequency for the higher return periods (greater than 10 years, generally) as ice impacts are expected to decrease with larger return periods. For those return intervals where a discrepancy occurs, the model analysis that produces the more conservative prediction is recommended.

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Appendix A 2015 Gage Locations, 2015 Vertical Control, and PT Methods

A.1 2015 Gage Locations

2015 Gage Locations				
Gage Site	Gage	Latitude (NAD 83)	Longitude (NAD83)	Basis of Elevation
Colville River Upstream of Bifurcation				
Monument 1 U	MON1U-A[1]	N 70.1585°	W 150.9453°	MONUMENT 1
	MON1U-B[1]	N 70.1585°	W 150.9455°	
	MON1U-C	N 70.1585°	W 150.9461°	
	MON1U-D	N 70.1585°	W 150.9462°	
	MON1U-E	N 70.1585°	W 150.9464°	
	MON1U-F	N 70.1585°	W 150.9465°	
Monument 1 C	MON1C-A[1]	N 70.1657°	W 150.9383°	MONUMENT 1
	MON1C-B[1]	N 70.1658°	W 150.9386°	
	MON1C-C	N 70.1658°	W 150.9392°	
	MON1C-D	N 70.1658°	W 150.9393°	
	MON1C-E	N 70.1658°	W 150.9395°	
	MON1C-F	N 70.1659°	W 150.9397°	
Monument 1 D	MON1D-A[1]	N 70.1738°	W 150.9359°	MONUMENT 1
	MON1D-B[1]	N 70.1738°	W 150.9371°	
	MON1D-C	N 70.1738°	W 150.9372°	
	MON1D-D	N 70.1738°	W 150.9373°	
	MON1D-Z	N 70.1737°	W150.9376°	
Colville River East Channel				
Monument 9	MON9-A[1]	N 70.2447°	W 150.8573°	MONUMENT 9
	MON9-B[1]	N 70.2447°	W 150.8575°	
	MON9-C[1]	N 70.2447°	W 150.8578°	
	MON9-D	N 70.2446°	W 150.8580°	
	MON9-E	N 70.2446°	W 150.8580°	
	MON9-F	N 70.2446°	W 150.8580°	
	MON9-G	N 70.2446°	W 150.8581°	
	MON9-BARO[2]	N 70.2442°	W 150.8605°	
Monument 9D	MON9D-A[1]	N 70.2586°	W 150.8593°	MONUMENT 9
	MON9D-B[1]	N 70.2586°	W 150.8597°	
	MON9D-C	N 70.2586°	W 150.8598°	
	MON9D-D	N 70.2586°	W 150.8600°	
	MON9D-E	N 70.2586°	W 150.8600°	

Notes:
1. Pressure Transducer
2. BaroTROLL or Barologger barometer
3. Staff gage surveyed and adjusted for elevation annually by LCMF

2015 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD83)**	**Basis of Elevation**
Colville River East Channel				
Monument 35 (Helmericks)	MON35-A	N 70.4260°	W 150.4058°	MONUMENT 35
	MON35-B	N 70.4260°	W 150.4058°	
	MON35-C	N 70.4261°	W 150.4058°	
	MON35-D	N 70.4261°	W 150.4058°	
	MON35-E	N 70.4261°	W 150.4058°	
	MON35-F	N 70.4261°	W 150.4058°	
	MON35-X	N 70.4261°	W 150.4058°	
	MON35-Z	N 70.4260°	W 150.4068°	
Nigliq Channel				
Monument 20	MON20-A[1]	N 70.2786°	W 150.9986°	PBM-P
	MON20-B	N 70.2786°	W 150.9985°	
	MON20-C	N 70.2786°	W 150.9983°	
Nigliq Channel Gages	G26-A[1]	N 70.3024°	W 151.0227°	MONUMENT 26
	G26-B	N 70.3022°	W 151.0206°	
	G26-C	N 70.3022°	W 151.0190°	
	G26-D	N 70.3022°	W 151.0190°	
	G27-A[1]	N 70.3033°	W 151.0224°	
	G27-B	N 70.3033°	W 151.0207°	
	G27-C	N 70.3033°	W 151.0194°	
	G27-D	N 70.3032°	W 151.0185°	
	G28-A[1]	N 70.2964°	W 151.0281°	
	G28-B	N 70.2964°	W 151.0280°	
	G28-C	N 70.2964°	W 151.0279°	
	G28-D	N 70.2965°	W 151.0276°	
	G29-A[1]	N 70.3095°	W 151.0332°	
	G29-B	N 70.3095°	W 151.0334°	
	G29-C	N 70.3095°	W 151.0337°	
	G29-D	N 70.3094°	W 151.0343°	
	G29-E	N 70.3093°	W 151.0350°	
Monument 22	MON22-A[1]	N 70.3186°	W 151.0546°	MONUMENT 22
	MON22-B	N 70.3185°	W 151.0549°	
	MON22-C	N 70.3185°	W 151.0550°	
	MON22-D	N 70.3183°	W 151.0555°	

Notes:
1. Pressure Transducer
2. BaroTROLL or Barologger barometer
3. Staff gage surveyed and adjusted for elevation annually by LCMF

2015 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD83)**	**Basis of Elevation**
Nigliq Channel				
Monument 23	MON23-A[1]	N 70.3436°	W 151.0659°	MONUMENT 23
	MON23-B	N 70.3436°	W 151.0657°	
	MON23-C	N 70.3436°	W 151.0652°	
	MON23-D	N 70.3436°	W 151.0649°	
	MON23-E	N 70.3436°	W 151.0648°	
Monument 28	MON28-A[1]	N 70.4258°	W 151.0697°	MONUMENT 28
	MON28-B	N 70.4257°	W 151.0692°	
	MON28-C	N 70.4256°	W 151.0672°	
Alpine Facilities and Roads				
CD1 Gages	G1[1]	N 70.3428°	W 150.9208°	[3]
Lake L9312	G9[1]	N 70.3336°	W 150.9519°	TBM 99-37-52-"A"
Lake L9313	G10[1]	N 70.3425°	W 150.9328°	[3]
CD2 Gages	G3[1]	N 70.3400°	W 150.9831°	[3]
	G4[1]	N 70.3403°	W 150.9833°	[3]
	G6	N 70.3397°	W 151.0292°	[3]
	G7	N 70.3400°	W 151.0289°	[3]
	G8	N 70.3393°	W 151.0491°	PBM-F
	G12	N 70.3367°	W 151.0117°	CD2-14S
	G13	N 70.3373°	W 151.0118°	CD2-14N
CD3 Gage	G11	N 70.4175°	W 150.9105°	Pile 08 Cap SW Bolt
CD4 Gages	G15-A	N 70.3023°	W 150.9929°	CD4-22W
	G15-B	N 70.3024°	W 150.9939°	
	G16-A	N 70.3017°	W 150.9933°	
	G16-B	N 70.3018°	W 150.9943°	
	G17-A	N 70.2933°	W 150.9827°	CD4-29E
	G18-A	N 70.2930°	W 150.9818°	
	G18-B	N 70.2925°	W 150.9828°	
	G19-A	N 70.2915°	W 150.9883°	PBM-P
	G19-Baro[2]	N 70.2915°	W 150.9883°	
	G20-A	N 70.2917°	W 150.9968°	PBM-P
	G20-B	N 70.2917°	W 150.9968°	
	G40-A	N 70.3234°	W 150.9968°	CD4-12W
	G41-A	N 70.3235°	W 150.9949°	
	G42-A	N 70.3276°	W 150.9939°	
	G43-A	N 70.3274°	W 150.9924°	
	M9525-A	N 70.3344°	W 150.9699°	CD4-6E
	M9525-B1	N 70.3344°	W 150.9703°	
	M9525-B	N 70.3345°	W 150.9706°	

Notes:
1. Pressure Transducer
2. BaroTROLL or Barologger barometer
3. Staff gage surveyed and adjusted for elevation annually by LCMF

2015 Gage Locations				
Gage Site	**Gage**	**Latitude (NAD 83)**	**Longitude (NAD83)**	**Basis of Elevation**
CD5 Gages				
Lake L9323	G24-A[1]	N 70.3030°	W 151.0066°	MONUMENT 25
	G24-B	N 70.3034°	W 151.0041°	
	G25-A[1]	N 70.3044°	W 151.0066°	
	G25-B	N 70.3046°	W 151.0049°	
Lake L9341	G32-A[1]	N 70.3054°	W 151.0507°	MONUMENT 27
	G32-B	N 70.3055°	W 151.0513°	
	G33-A[1]	N 70.3065°	W 151.0484°	
	G33-B	N 70.3065°	W 151.0487°	
Small Drainages	G30	N 70.3046°	W 151.0443°	CD5-40 (C141S)
	G31	N 70.3051°	W 151.0437°	CD5-40 (C141S)
	G34	N 70.3060°	W 151.0710°	CD5-35 (C136S)
	G35	N 70.3067°	W 151.0711°	CD5-35 (C136N)
	G36	N 70.3055°	W 151.0968°	MONUMENT 28
	G37	N 70.3063°	W 151.0971°	MONUMENT 28
	S1-A	N 70.3058°	W 151.1944°	MONUMENT 31
	S1-D	N 70.3066°	W 151.1957°	MONUMENT 31
Nigliagvik Channel Gages	G38-A[1]	N 70.3046°	W 151.1187°	MONUMENT 29
	G38-B	N 70.3046°	W 151.1185°	TBM 15-12-52
	G38-C	N 70.3046°	W 151.1183°	
	G38-D	N 70.3047°	W 151.1172°	
	G39-A[1]	N 70.3064°	W 151.1177°	
	G39-B	N 70.3063°	W 151.1175°	
	G39-C	N 70.3063°	W 151.1172°	
Pipeline River Crossings				
Sakoonang Pipe Bridge	SAK-A[1]	N 70.3646°	W 150.9217°	Pile 568 cap SW bolt
	SAK-B	N 70.3645°	W 150.9220°	CP-08-11-12
	SAK-C	N 70.3645°	W 150.9220°	
Tamayayak Pipe Bridge	TAM-A[1]	N 70.3917°	W 150.9115°	CP08-11-23
	TAM-B	N 70.3915°	W 150.9113°	
	TAM-C	N 70.3914°	W 150.9113°	
	TAM-Z	N 70.3912°	W 150.9109°	
Ulamnigiaq Pipe Bridge	ULAM-A[1]	N 70.4068°	W 150.8835°	CP08-11-35
	ULAM-B	N 70.4069°	W 150.8833°	
	ULAM-C	N 70.4070°	W 150.8831°	
	ULAM-Z	N 70.4070°	W 150.8831°	

Notes:
1. Pressure Transducer
2. BaroTROLL or Barologger barometer
3. Staff gage surveyed and adjusted for elevation annually by LCMF

A.2 2015 Vertical Control

2015 Vertical Control					
Control	**Elevation (feet BPMSL)**	**Latitude (NAD 83)[1]**	**Longitude (NAD83)**	**Control Type**	**Reference**
CD2-14S	10.888	N 70.3369°	W 151.0112°	Culvert top	LCMF 2015
CD2-14N	10.862	N 70.3371°	W 151.0110°	Culvert top	LCMF 2015
CD4-6E	14.446	N 70.3348°	W 150.9708°	Culvert top	LCMF 2015
CD4-10E	11.809	N 70.3274°	W 150.9930°	Culvert top	LCMF 2015
CD4-12W	12.517	N 70.3401°	W 150.9962°	Culvert top	LCMF 2015
CD4-22W	7.777	N 70.3018°	W 150.9931°	Culvert top	LCMF 2015
CD4-29E	12.378	N 70.2930°	W 150.9826°	Culvert top	LCMF 2015
CD5-35N (C136N)	13.167	N 70.3063°	W 151.0522°	Culvert top	LCMF 2015
CD5-35S (C136S)	13.366	N 70.3061°	W 151.0526°	Culvert top	LCMF 2015
CD5-40S (C141S)	11.130	N 70.3048°	W 151.0443°	Culvert top	LCMF 2015
CP08-11-12	7.365	N 70.3640°	W 150.9205°	Alcap	BAKER 2012
CP08-11-23	8.524	N 70.3916°	W 150.9079°	Alcap	LCMF 2008
CP08-11-35	8.880	N 70.4066°	W 150.8822°	Alcap	BAKER 2015 (LCMF 11)
MONUMENT 1	27.930	N 70.1659°	W 150.9400°	Alcap	LCMF 2006
MONUMENT 9	25.060	N 70.2446°	W 150.8583°	Alcap	LCMF 2008
MONUMENT 22	10.030	N 70.3181°	W 151.0560°	Alcap	Baker 2010
MONUMENT 23	9.546	N 70.3444°	W 151.0613°	Alcap	Baker 2009c
MONUMENT 25	17.952	N 70.3024°	W 151.0130°	Capped drill stem	LCMF 2014
MONUMENT 26	11.543	N 70.3025°	W 151.0322°	Capped drill stem	LCMF 2014
MONUMENT 27	13.906	N 70.3060°	W 151.0533°	Capped drill stem	LCMF 2014
MONUMENT 28 (CD5)	11.415	N 70.4256°	W 151.0670°	Capped drill stem	LCMF 2014
MONUMENT 28 (Colville @ Coast)	3.650	N 70.4256°	W 151.0670°	Alcap	LCMF GPS 2002
MOUNMENT 29	28.655	N 70.3052°	W 151.1229°	Capped drill stem	LCMF 2014
MONUMENT 31	26.891	N 70.3051°	W 151.1992°	Capped drill stem	LCMF 2013
MONUMENT 35	5.570	N 70.4325°	W 150.3834°	Alcap	Lounsbury 1996
PBM-F	17.841	N 70.3393°	W 151.0468°	PBM in Casing	LCMF 2014
PBM-P	20.920	N 70.2914°	W 150.9889°	PBM in Casing	LCMF 2014
Pile 08	16.740	-	-	SW Bolt	LCMF 2010
Pile 568	23.719	N 70.3639°	W 150.9206°	HSM cap SW bolt	LCMF 2010
TBM 15-12-52	18.023	N 70.3055°	W 151.1174°	Sheet Pile SE Abut.	LCMF 2015
TBM 99-32-59-A	14.613	N 70.3338°	W 150.9522°	-	-
1. North American Datum of 1989 (NAD83)					

A.3 PT Setup and Testing and Processing Methods

PTs measure the absolute pressure of the atmosphere and water, allowing the depth of water above the sensor to be calculated. Resulting data yield a comprehensive record of the fluctuations in stage. The reported pressure is the sum of the forces imparted by the water column and atmospheric conditions. Variations in local barometric pressure are taken into account, using two independent barometric pressure loggers: In-Situ BaroTROLL® and Solinst Barologger®. A correction of barometric pressure was obtained from the BaroTROLL sensor installed at CD4 and the Barologger installed at MON9.

The PTs were tested before field mobilization. The PTs were configured using Win-Situ® LT 5.6.21.0 (for the Level TROLL 500s) or Solinst Levelogger® v4.0.3 (for the Solinst Leveloggers) software prior to placement in the field. Absolute pressure was set to zero. The PT sensor was surveyed during setup to establish a vertical datum using local control.

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

Appendix B Discharge Methods, Discharge Locations, and Cross-Sections

B.1 Discharge Methods

B.1.1 Direct Measurement Methods

B.1.1.1 Standard USGS Midsection Techniques

Standard USGS midsection techniques (USGS 1982) were used to measure velocities and determine discharge at the Long and Short Swale Bridges on the CD2 road and at the Nigliq and Nigliagvik Channel Bridge on the CD5 road.

Bridge depth and velocity measurements were taken from the upstream side of each bridge deck using a sounding reel mounted on a wooden boom. A Price AA velocity meter was attached to the sounding reel and stabilized with a 30-pound Columbus-type lead sounding weight. A tag line was placed along the bridge rail to define the cross section and to delineate measurement subsections within the channel. The standard rating table No.2 for Price AA velocity meters, developed by the USGS Office of Surface Water (OSW) Hydraulic Laboratory as announced in the OSW Technical Memorandum No. 99.05 (OSW 1999a) was used to convert revolutions to stream velocity. The Price AA velocity meter was serviced in March 2014 in accordance to USGS precise standards. A spin test of the meter was successfully completed before and after the measurements. Procedures outlined in OSW Technical Memorandum No. 99.06 (OSW 1999b) were followed to confirm accurate meter performance.

Velocity measurements at the outlets of the CD2, CD4, and CD5 road culverts experiencing flow were conducted using a USGS wading rod and flow meter at the downstream side of the culvert. Discharge was determined based on velocity, flow depth, and culvert geometry.

B.1.1.2 ADCP Methods

Hardware and Software

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

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

Pre-Deployment Testing

Prior to deployment of the ADCP unit, a full suite of tests were run in accordance with the manufacturer's instructions using BBTalk.® The tests confirmed 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 the transducer beams were connected and operational. Additional diagnostic tests were performed using WinRiverII.® Pre-deployment tasks also included compass calibration and verification. Internal compass error was within the specified 5-degree limit.

ADCP Deployment and Data Collection

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

Cross sections were identified at established monitoring sites MON1C and downstream of gage G27. A minimum of four transects were completed, so the measured discharges varied by less than five percent of their mean. Cross section end points were dependent on a minimum water depth of approximately eight feet to provide acceptable data.

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

ADCP Background and Data Processing

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

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

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

B.1.2 Indirect Calculation Methods

B.1.2.1 Normal Depth and Slope-Area

The Normal Depth method (Chow 1959) and Slope-Area method (Benson and Dalrymple 1967) were used to develop the estimates of peak discharge at MON1. Both methods use channel cross section geometry and stage differential between gage sites as an estimate for energy gradient. The methods differ by the number of cross sections used in the calculations. At MON1, the Normal Depth method uses the cross section at MON1C where the Slope-Area Method uses the cross sections from MON1U, MON1C, and MON1D. Accuracy of each method depends on conditions at the time of calculation, particularly the presence of ribbon and bottom fast ice, ice jam activity, and backwater effects. The average of the Normal Depth and Slope-Area results were used to compute the peak indirect discharge at MON1.

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

B.1.2.2 USGS Width Contraction

The USGS Width Contraction method was used to indirectly calculate peak discharge through the CD5 bridges. The constriction formed by the bridge can be used to estimate flow by measuring the drop in water-surface elevation (WSE) between the upstream (approach) and contraction section at the bridge which are related to the corresponding change in velocity. The width contraction method assumes unobstructed open-channel flow.

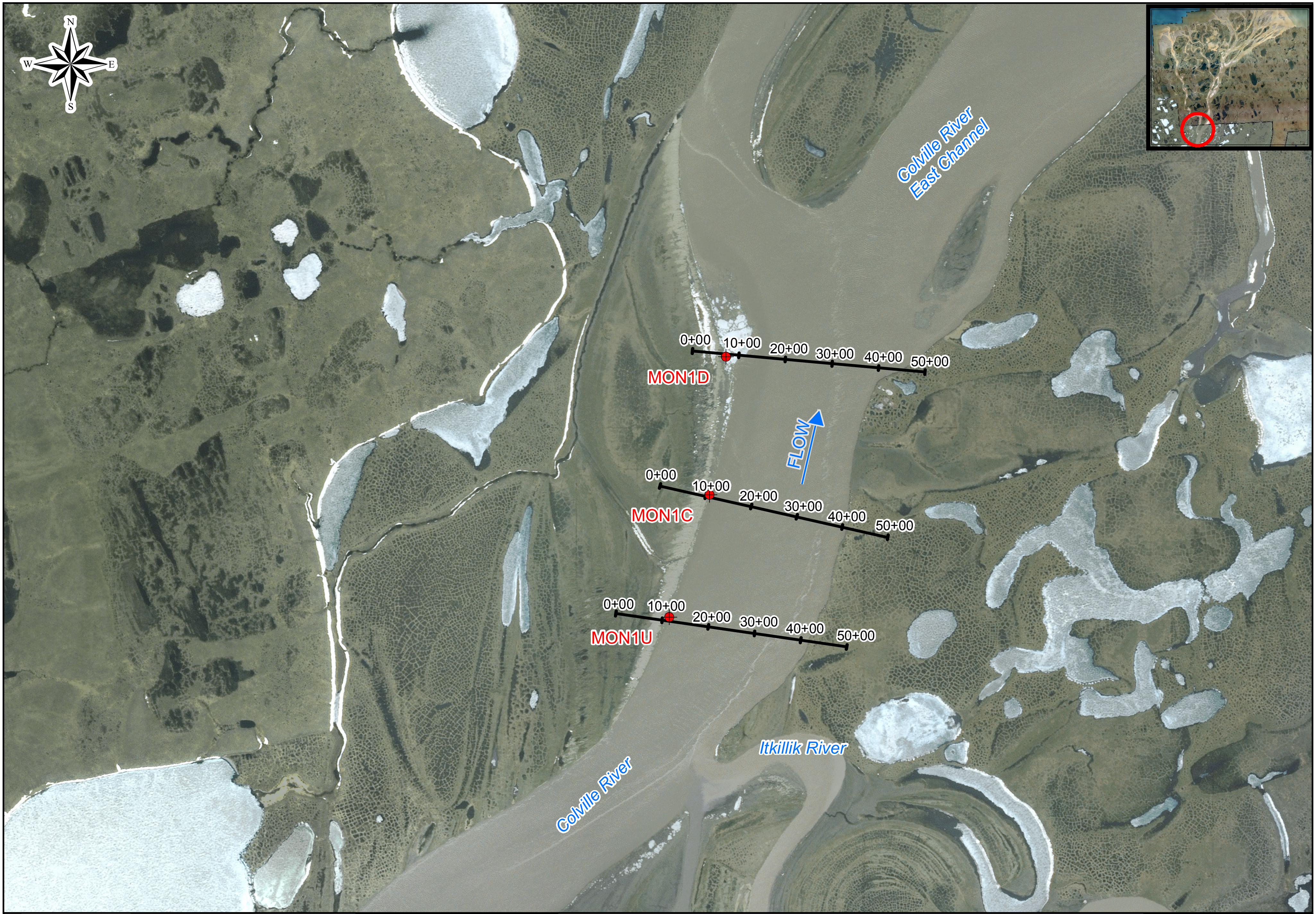
B.1.2.3 HEC-RAS Model

The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) was used to verify peak discharge measurements at the Nigliq Bridge. The model is capable of calculating water surface profiles for steady gradually varied flow and it was assumed steady flow conditions were applicable to the Nigliq Channel at peak. The computational procedure is based on the solution of the one-dimensional energy equation in a natural or constructed channel. Water surface profiles are computed from one cross-section to the next by solving the energy equation with an iterative procedure referred to as the standard step method. HEC-RAS is capable of predicting the energy losses in a contracting reach upstream and expanding reach downstream of a bridge.

B.2 Discharge Locations and Cross-Sections

B.2.1 Colville River Plan View and Cross-Sections

B.2.1.1 MON1



ConocoPhillips Alaska

Miles
0 0.25 0.5

Date:	10/01/2015	Project:	148414
Drawn:	BTG	File:	2015_CRD_8x11L_Mon1.mxd
Checked:	GCY	Scale:	1 in = .5 miles

Legend

Gage Location

2004 Cross Section Alignment

Imagery Source: AlaskaMapped (WMS)

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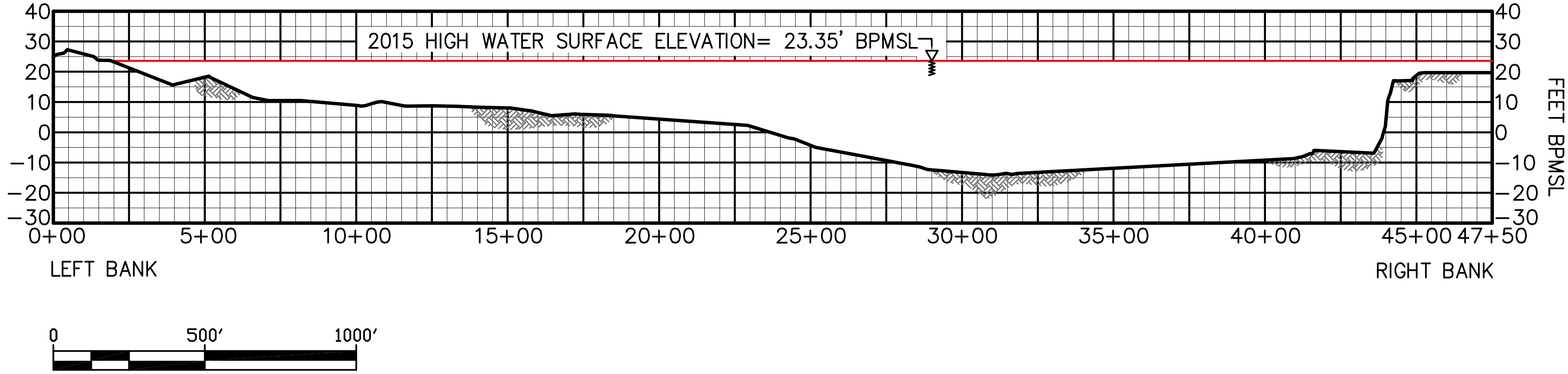
2015 SPRING BREAKUP
MONUMENT 1
PLAN

(SHEET 1 of 4)

NOTES

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



1D COLVILLE RIVER CROSS SECTION AT MONUMENT 1 DOWNSTREAM

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	MON1 X-SECTIONS.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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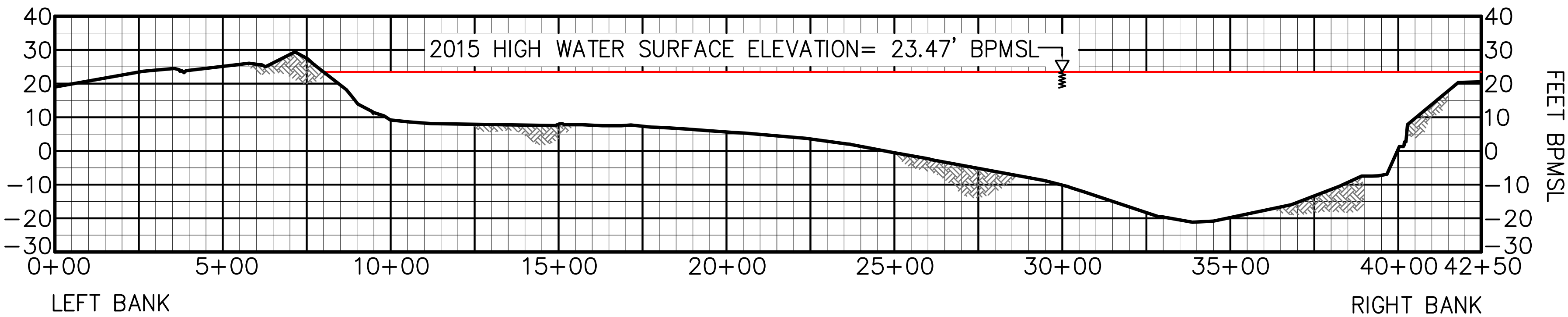
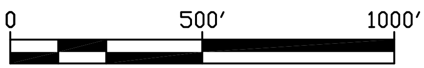
2015 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
DOWNSTREAM CROSS SECTION

(SHEET 2 OF 4)

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





1C COLVILLE RIVER CROSS SECTION AT MONUMENT 1 CENTERLINE

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	MON1 X-SECTIONS.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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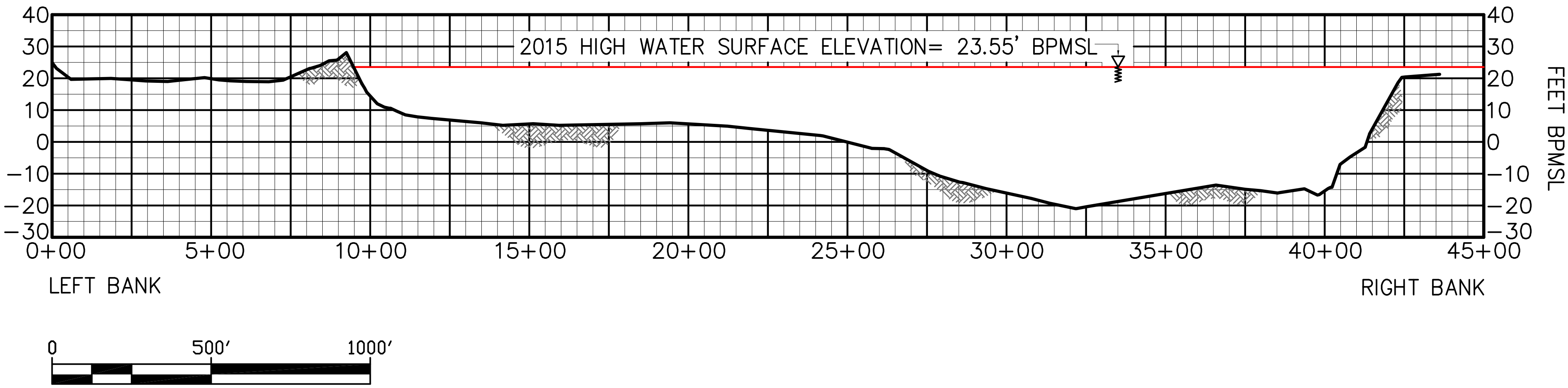
2015 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
CENTERLINE CROSS SECTION

(SHEET 3 OF 4)

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



1U COLVILLE RIVER CROSS SECTION AT MONUMENT 1 UPSTREAM

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	MON1 X-SECTIONS.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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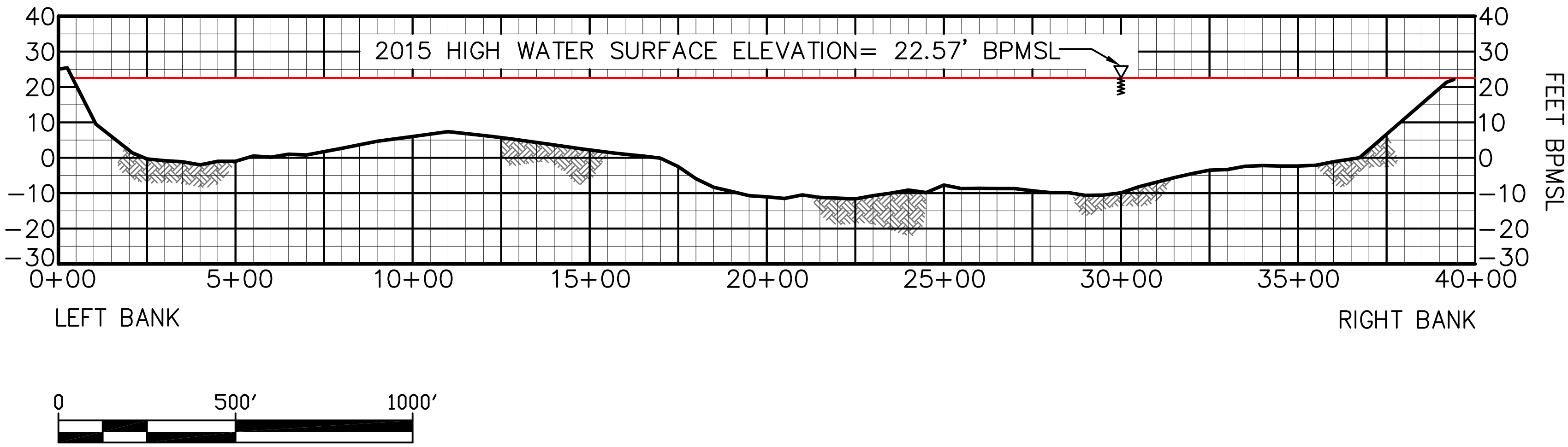
2015 SPRING BREAKUP
COLVILLE RIVER MONUMENT 1
UPSTREAM CROSS SECTION

NUMBER
(SHEET 4 OF 4)

B.2.1.2 MON9

ConocoPhillips Alaska	Feet 0 500 1,000	Legend	Michael Baker INTERNATIONAL	Michael Baker International 3900 C Street, Suite 900 Anchorage, AK 99503 Phone: (907) 273-1600 Fax: (907) 273-1699	2015 SPRING BREAKUP Monument 9 / HDD PLAN
Date: 10/01/2015	Project: 148414	Gage Location			
Drawn: BTG	File: 2015_CRD_8x11L_Mon9.mxd	2009 Cross Section Alignment			
Checked: GCY	Scale: 1 in = 1000 feet	Pipeline Imagery Source: ConocoPhillips Alaska, 2004			(SHEET 1 of 2)

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



1 COLVILLE EAST CHANNEL CROSS SECTION AT MONUMENT 9

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	MON9 X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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2015 SPRING BREAKUP
COLVILLE EAST CHANNEL
MONUMENT 9 CROSS SECTION

(SHEET 2 OF 2)

B.2.2 CD5 Road Crossings Plan View and Cross-Sections

B.2.2.1 Lake L9323 Bridge

ConocoPhillips Alaska

Feet
0 250 500

Date:	10/01/2015	Project:	148414
Drawn:	BTG	File:	2015_CRD_8x11L_L9323.mxd
Checked:	GCY	Scale:	1 in = 500 feet

Legend
- Gage Location
- 2012 Cross Section Alignment
- Pipeline
- Road

Imagery Source: ConocoPhillips Alaska, 2004

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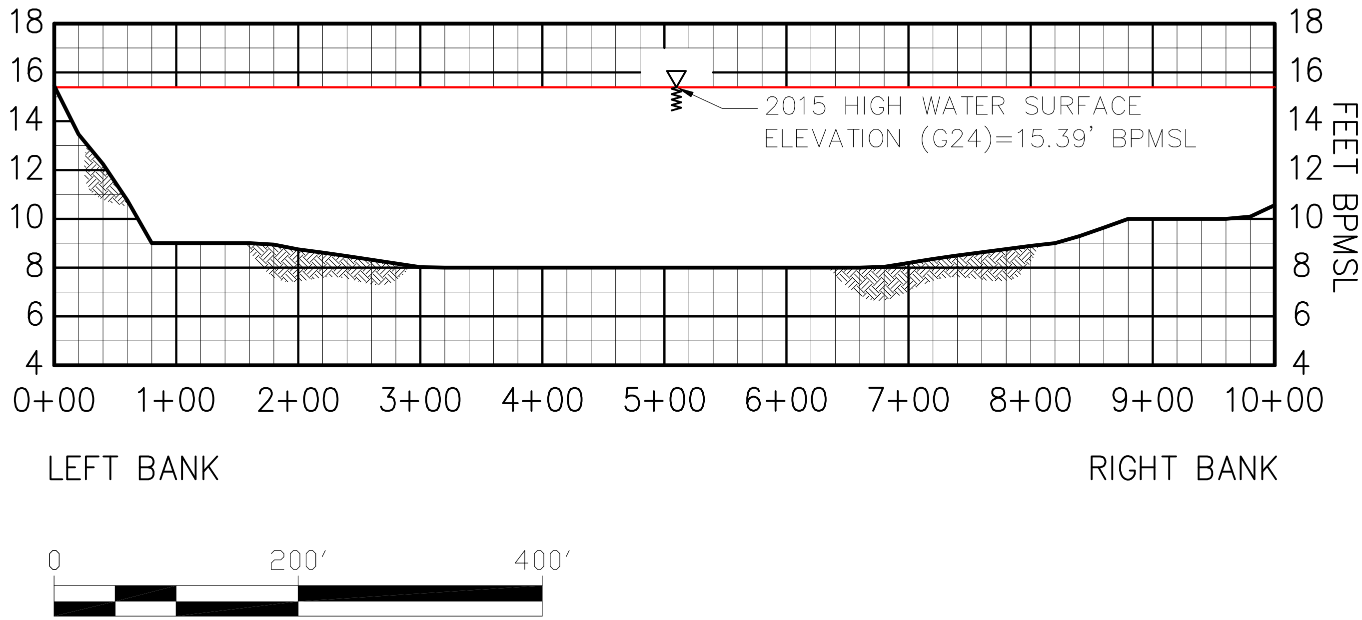
2015 SPRING BREAKUP
LAKE L9323
PLAN

(SHEET 1 of 2)

NOTES
1. BASIS OF ELEVATION, MON. 25.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED SEPTEMBER 2012 BY UMIAQ (KUUKPIK/LCMF INC.)



1 CONSTRUCTED CD5 CROSSING – LAKE L9323 CENTERLINE CROSS SECTION

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	L9323 X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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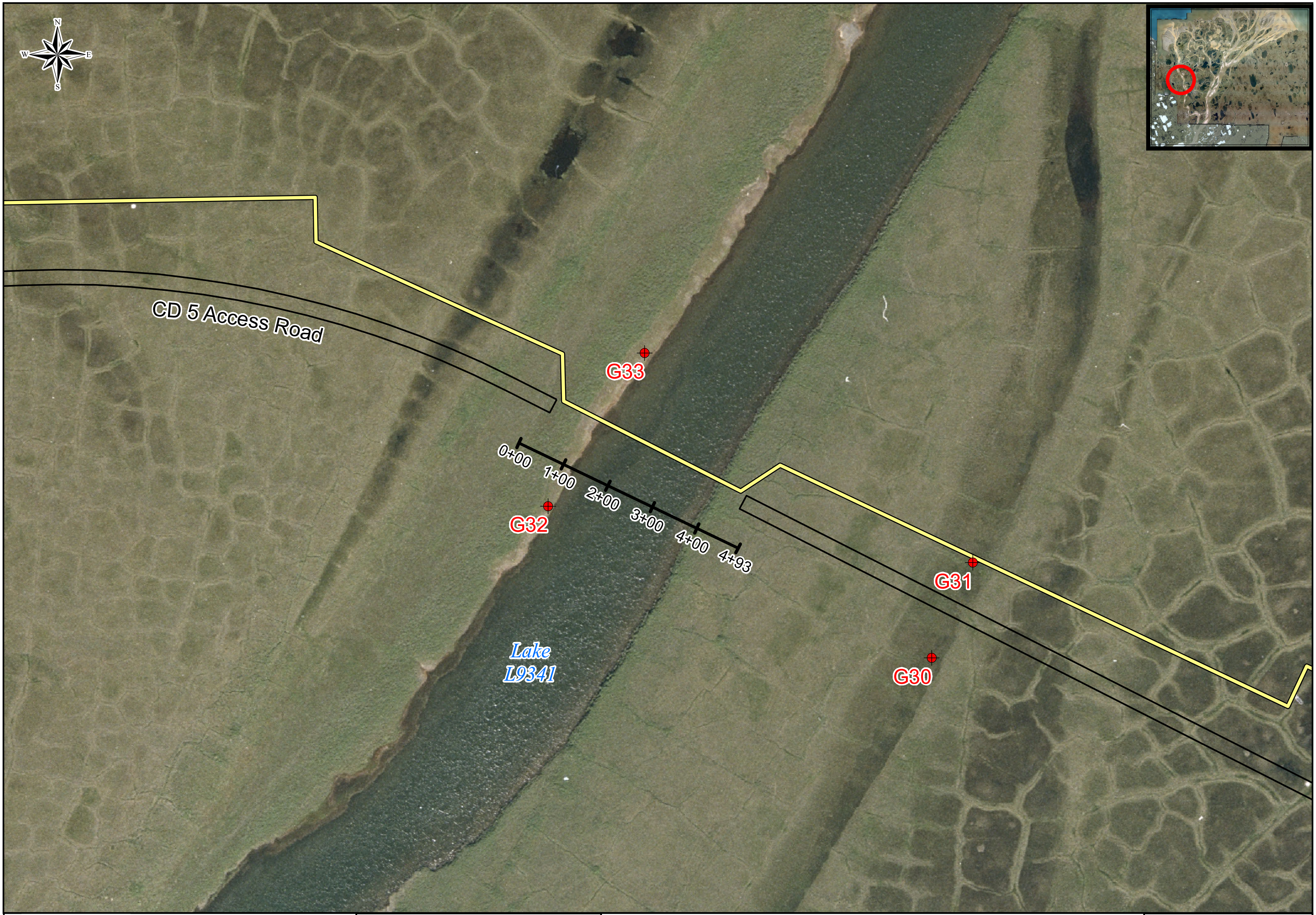
2015 SPRING BREAKUP
CONSTRUCTED CD5 CROSSING
LAKE L9323 CENTERLINE

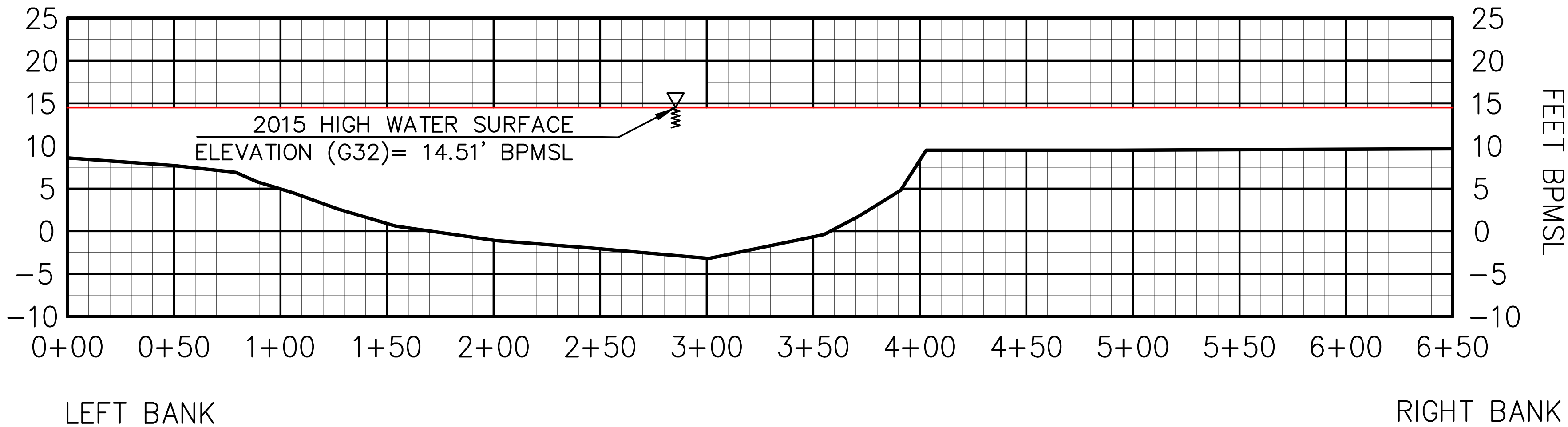
B.2.2.2 LAKE L9341 BRIDGE



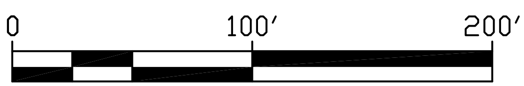
ConocoPhillips Alaska	Feet 0 125 250	Legend	Michael Baker International	2015 SPRING BREAKUP LAKE L9341 TRANSECT 39 PLAN
Date: 10/01/2015	Project: 148414	Gage Location	3900 C Street, Suite 900	DOC LCMF-156 REV3
Drawn: BTG	File: 2015_CRD_8x11L_L9341.mxd	2015 Cross Section Alignment	Anchorage, AK 99503	(SHEET 1 of 2)
Checked: GCY	Scale: 1 in = 250 feet	Pipeline	Phone: (907) 273-1600	
		Road	Fax: (907) 273-1699	
		Imagery Source: ConocoPhillips Alaska, 2004		

NOTES

1. BASIS OF ELEVATION, MON. 25.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2015 BY UMIAQ (KUUKPIK/LCMF INC.)



1 PROPOSED CD5 CROSSING – LAKE L9341 CENTERLINE CROSS SECTION
TRANSECT 39 (DOC LCMF–156 REV3)



ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	L9341 X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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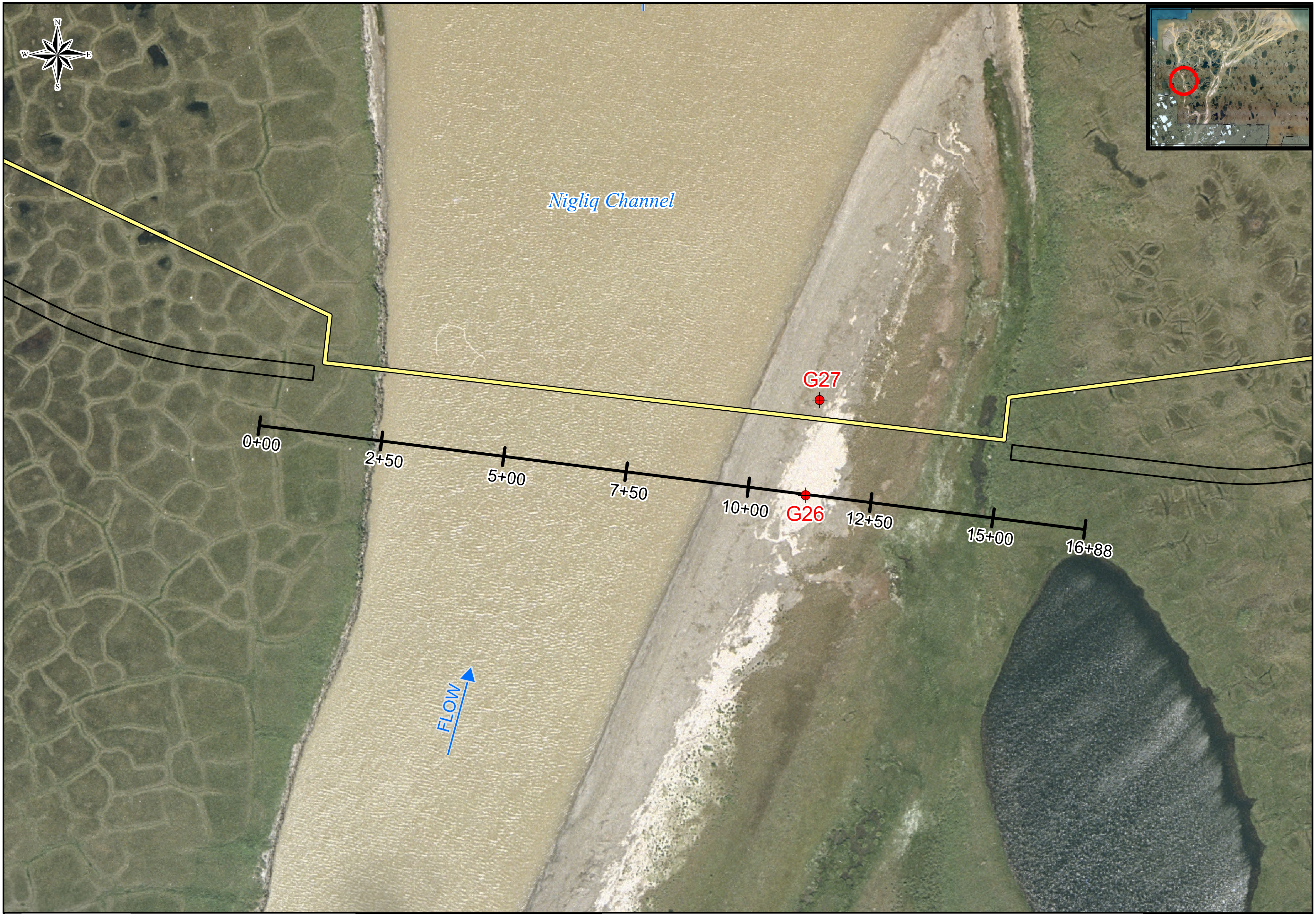
2015 SPRING BREAKUP
CD5 CROSSING
LAKE L9341 CENTERLINE

(SHEET 2 OF 2)

B.2.2.3 NIGLIQ BRIDGE



ConocoPhillips Alaska	Feet 0 125 250		
Date: 10/01/2015	Project: 148414		
Drawn: BTG	File: 2015_CRD_8x11L_Nigliq.mxd		
Checked: GCY	Scale: 1 in = 250 feet		

Legend

- Gage Location
- 2015 Cross Section Alignment
- Pipeline
- Road

Imagery Source: ConocoPhillips Alaska, 2004

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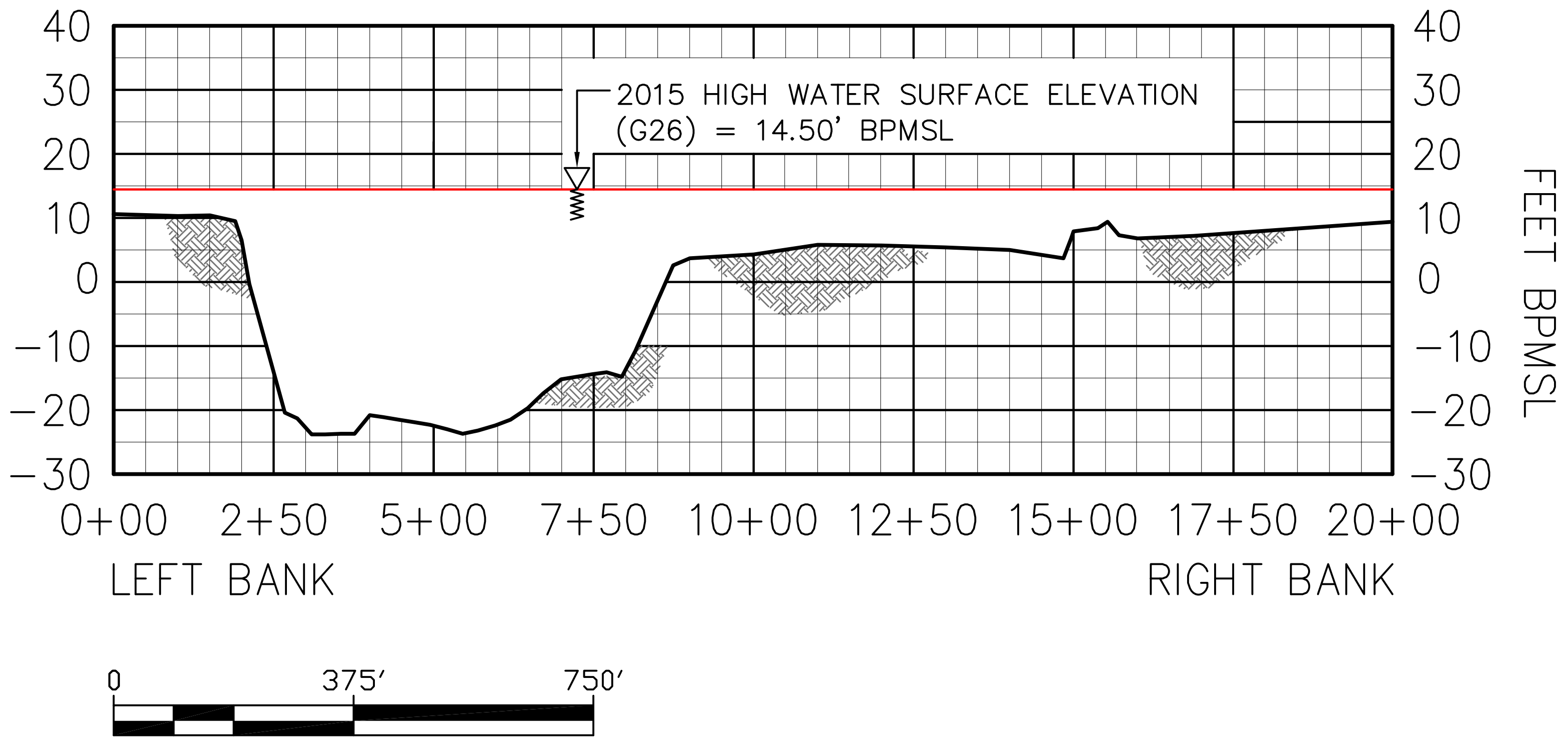
2015 SPRING BREAKUP
NIGLIQ CHANNEL
TRANSECT 10 PLAN

DOC LCMF-156 REV3

(SHEET 1 of 2)

NOTES

1. BASIS OF ELEVATION, MON. 26.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2015 BY UMIAQ (KUUKPIK/LCMF INC.)



1 CONSTRUCTED CD5 CROSSING – NIGLIQ CHANNEL CENTERLINE CROSS SECTION

TRANSECT 10 (DOC LCMF-156 REV3)

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	NIGLIQ X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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2015 SPRING BREAKUP

CD5 CROSSING

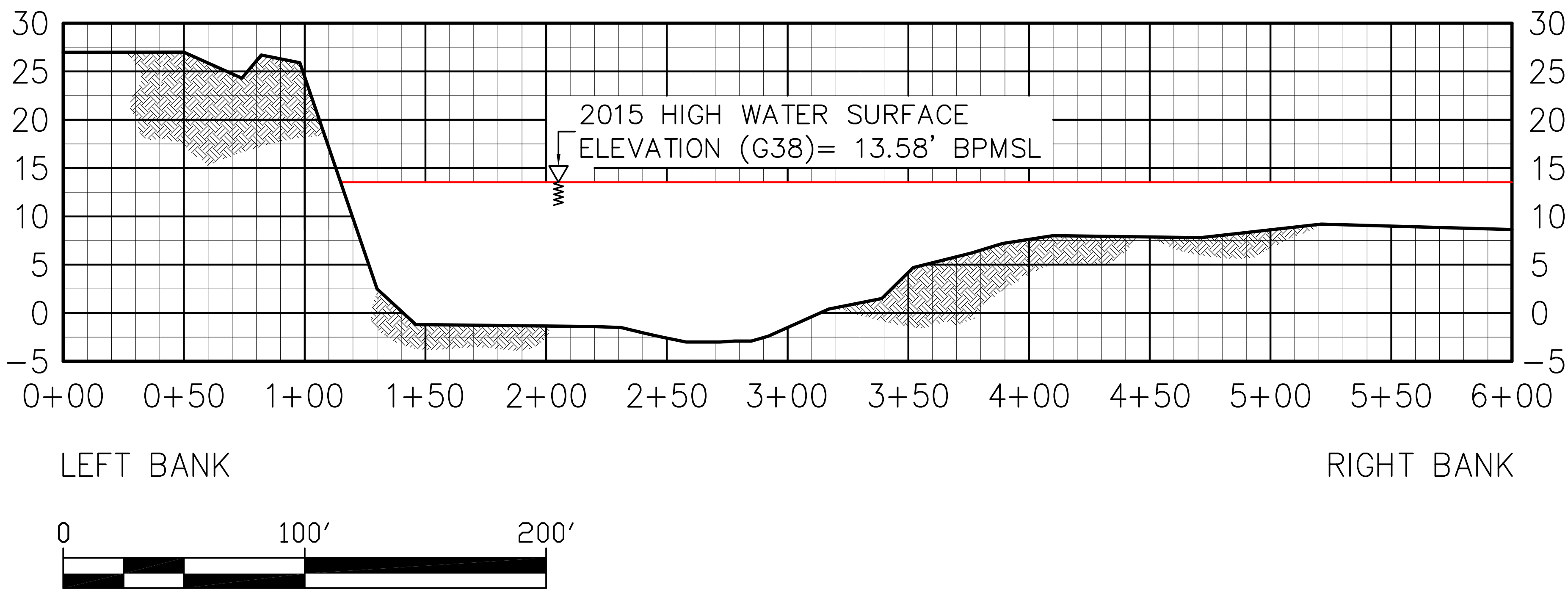
NIGLIQ CHANNEL CENTERLINE

(SHEET 2 OF 2)

B.2.2.4 NIGLIAGVIK BRIDGE

ConocoPhillips Alaska	Feet 0 125 250	Legend	Michael Baker INTERNATIONAL	Michael Baker International 3900 C Street, Suite 900 Anchorage, AK 99503 Phone: (907) 273-1600 Fax: (907) 273-1699	2015 SPRING BREAKUP NIGLIAGVIK CHANNEL TRANSECT 27 PLAN
Date: 10/01/2015	Project: 148414	Gage Location			DOC LCMF-156 REV3
Drawn: BTG	File: 2015_CRD_8x11L_Nigliagvik.mxd	2015 Cross Section Alignment Pipeline Road			(SHEET 1 of 2)
Checked: GCY	Scale: 1 in = 250 feet	Imagery Source: ConocoPhillips Alaska, 2004			

NOTES
1. BASIS OF ELEVATION, MON. 29.
2. CHANNEL PROFILE MEASUREMENTS COMPLETED AUGUST 2015 BY UMIAQ (KUUKPIK/LCMF INC.)



1 CONSTRUCTED CD5 CROSSING – NIGLIAGVIK CENTERLINE CROSS SECTION
TRANSECT 27 (DOC LCMF–156 REV3)

ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	NIGLIAGVIK X-SECTION.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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2015 SPRING BREAKUP
CD5 CROSSING
NIGLIAGVIK CENTERLINE

(SHEET 2 OF 2)

Appendix C Additional Photographs

C.1 Erosion Survey

C.1.1 CD2 Road and Pad

Photo C.1: CD2 pad showing snow coverage and ice road approach ramp remaining following flooding, looking west toward Nigliq Channel; May 28, 2015

Photo C.2: Section of CD2 road near CD2 pad showing vegetation cover where no erosion occurred, looking east at the north side of the road; May 26, 2015

Photo C.3: Wash line on the south side of the western section of CD2 road, looking west between gages G6 and G12; May 26, 2015

Photo C.4: HWMs along the south side of CD2 road near CD2 pad, looking west; May 26, 2015

Photo C.5: Wash lines and vegetation scour around culvert CD2-4 on the western section of CD2 road, looking west at the south side of the road toward culvert CD2-3; May 26, 2015

Photo C.6: Scarp from ice on the south side of CD2 road at gage G6, looking east; May 26, 2015

Photo C.7: Wash line at the Short Swale Bridge on the north side of the road, looking east; May 26, 2015

Photo C.8: Wash line at the Short Swale Bridge on the south side of the road showing scour at the sheet pile abutment, looking east; May 26, 2015

Photo C.9: Scour and deposition at the Long Swale Bridge west abutment, looking northeast; May 26, 2015

Photo C.10: Gravel outwash deposited on the north side of the Long Swale Bridge, looking north; May 26, 2015

Photo C.11: Scour and deposition along the north side road embankment east of the Long Swale Bridge, looking south east; May 26, 2015

Photo C.12: Cracks in the Long Swale Bridge abutment fill, southeast abutment; May 26, 2015

C.1.2 CD4 ROAD AND PAD

Photo C.13: Aerial view of the CD4 road washout showing the material deposit following initial clean up and road repair, looking southeast; May 26, 2015

Photo C.14: Ground view of the CD4 road breach outwash following initial clean up and road repair, looking northwest; May 26, 2015

Photo C.15: Ice floe grounded on the CD4 pad, looking north; May 23, 2015

Photo C.16: Section of the CD4 road north of the CD5 road intersection unaffected by flooding, looking south; May 28, 2015

Photo C.17: Section of the CD4 road north of the CD5 road intersection unaffected by flooding, looking north; May 28, 2015

C.1.3 CD5 ROAD AND PAD

Photo C.18: CD5 road near the CD5 pad showing water saturated embankment on the west side of the road, looking north toward CD5 pad; May 28, 2015

Photo C.19: CD5 road showing water saturated embankment and cracking, looking south on the west side of the road at culvert CD5-02; May 28, 2015

Photo C.20: CD5 road near the CD5 pad showing wash line on the east side of the road, looking north at Lake MB0301 toward CD5 pad; May 28, 2015

Photo C.21: CD5 road between gage S1 and the Nuiqsut Road intersection, looking west at culvert CD5-13; May 28, 2015

Photo C.22: Nigliagvik Bridge east abutment showing scour line and damaged erosion control material, looking west; May 28, 2015

Photo C.23: Deposition of fill material at the Nigliagvik Bridge east abutment, looking west; May 28, 2015

Photo C.24: Wash line on the south side of the CD5 road between the Nigliagvik and L9341 bridges, looking east at culvert CD5-35; May 28, 2015

Photo C.25: Wash lines on the south side of the CD5 road between the Nigliagvik and L9341 bridges, looking west; May 24, 2015

Photo C.26: Wash line and deposition at the north side of the L9341 Bridge east abutment, looking west; May 28, 2015

Photo C.27: Nigliq Bridge west abutment wash line and erosion control material, looking north east; May 25, 2015

Photo C.28: Wash lines east of the Nigliq Bridge, looking west at south side of road; May 24, 2015

Photo C.29: Wash lines along the CD5 road east of the L9323 Bridge, looking west at south side of the road; May 24, 2015

Photo C.30: Wash lines along the CD5 road east of the L9323 Bridge, looking west at north side of road; May 24, 2015

C.2 Ice Roads

Photo C.31: Colville River ice road crossing prior to breakup, looking west; May 17, 2015

Photo C.32: Colville River ice road crossing during breakup, looking south; May 18, 2015

Photo C.33: Colville River ice road crossing following breakup, looking south; May 23, 2015

Photo C.34: Kachemach River ice road crossing prior to breakup, looking south: May 18, 2015

Photo C.35: Kachemach River ice road crossing during breakup, looking north; May 22, 2015

Photo C.36: Lake L9341 ice road crossing at CD5 road prior to breakup, looking south; May 18, 2015

Photo C.37: Lake L9341 ice road crossing at CD5 road during breakup, looking south; May 23, 2015

Photo C.38: Lake L9341 ice road crossing at CD5 road following breakup, looking south; May 27, 2015

Photo C.39: Nigliagvik Channel ice road crossing south of CD5 road during breakup, looking west; May 20, 2015

Photo C.40: Nigliagvik ice road crossing at CD5 road prior to breakup, looking south; May 17, 2015

Photo C.41: Nigliagvik ice road crossing at CD5 road during breakup, looking south; May 20, 2015

Photo C.42: Nigliagvik ice road crossing at CD5 road following breakup, looking south; May23, 2015

Photo C.43: Nigliq Channel ice road crossing south of CD5 road prior to breakup, looking west; May 18, 2015

Photo C.44: Nigliq Channel ice road crossing south of CD5 road during breakup, looking south; May 20, 2015

Photo C.45: Nigliq Channel ice road crossing at CD5 road during initial breakup, looking south; May 18, 2015

Photo C.46: Nigliq Channel ice road crossing at CD5 road during breakup, looking north; May 20, 2015

Photo C.47: Nigliq Channel ice road crossing at CD5 road following breakup, looking west; May 27, 2015

Photo C.48: No Name Creek ice road crossing, prior to breakup, looking west; May 18, 2015

Photo C.49: No Name Creek ice road crossing, during breakup, looking north; May 22, 2015

Photo C.50: No Name Creek ice road crossing, following breakup, looking south; May 27, 2015

Photo C.51: Pineapple Gulch ice road crossing prior to breakup, looking south; May 20, 2015

Photo C.52: Pineapple Gulch ice road crossing during breakup, looking north; May 23, 2015

Photo C.53: Pineapple Gulch ice road crossing following breakup, looking north; May 26, 2015

Photo C.54: Silas Slough ice road crossing during breakup, looking northwest; May 18, 2015

Photo C.55: Silas Slough ice road crossing during breakup, looking east; May 20, 2015

Photo C.56: Silas Slough ice road crossing following breakup, looking north; May 27, 2015

Photo C.57: Slemp Slough ice road crossing prior to breakup, looking north; May 19, 2015

Photo C.58: Slemp Slough ice road crossing during breakup, looking north; May 20, 2015

Photo C.59: Tamayayak ice road crossing prior to breakup, looking north; May 18, 2015

Photo C.60: Tamayayak ice road crossing during breakup, looking north; May 20, 2015

Photo C.61: Tamayayak ice road crossing following breakup, looking south; May 26, 2015

Photo C.62: Toolbox Creek ice road crossing prior to breakup, looking west; May 18, 2015

Photo C.63: Toolbox Creek ice road crossing during breakup, looking northwest; May 20, 2015

Appendix D 2015 ADCP Direct Discharge Data

D.1 Colville River at MON1C

D.1.1 Measurement Summary

Station Number: Meas. No:
Station Name: Date: 05/25/2015

Party:	Width: 2,950 ft	Processed by:
Boat/Motor:	Area: 38,500 ft²	Mean Velocity: 4.62 ft/s
Gage Height: 0.00 ft	G.H.Change: 0.000 ft	Discharge: 178,000 ft³/s

Area Method: Mean Flow	ADCP Depth: 1.300 ft	Index Vel.: 0.00 ft/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj.Mean Vel: 0.00 ft/s	Qm Rating: U
MagVar Method: None (18.4°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 ft²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: Distributed		Control2: Unspecified	
% Correction: 8.78		Control3: Unspecified	

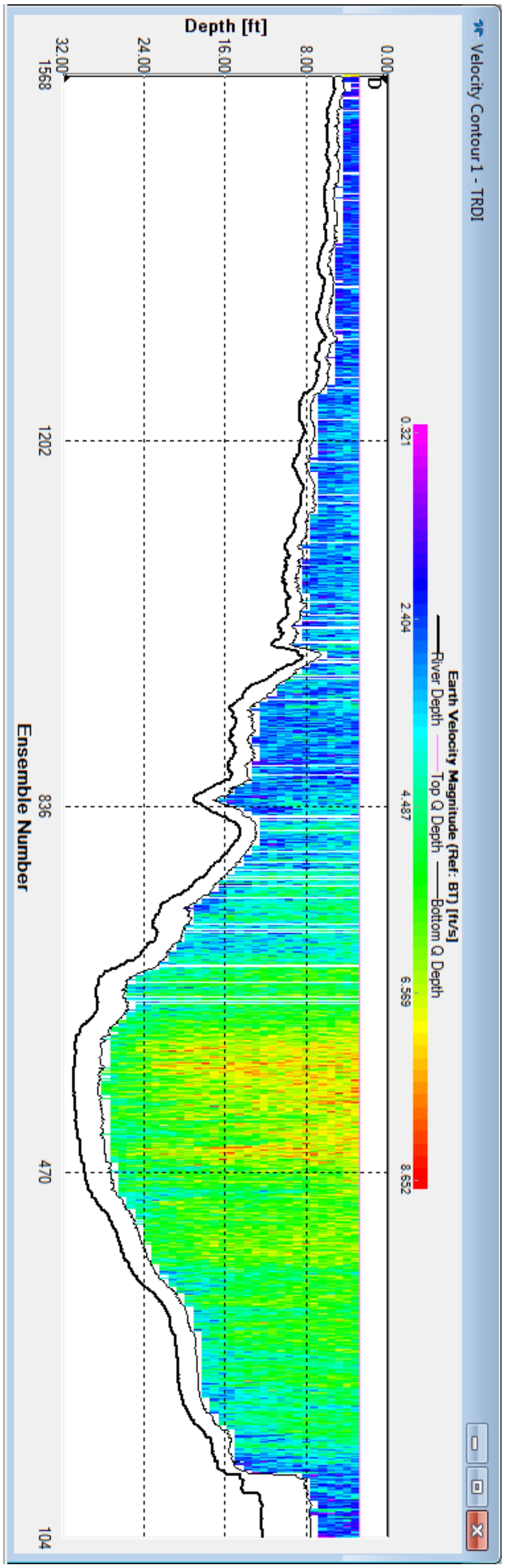
Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 9.07 ft/s	Type/Freq.: Workhorse / 1200 kHz	
WT 3-Beam Solution: NO	Max. Depth: 32.2 ft	Serial #: 5283	Firmware: 51.40
BT Error Vel.: 0.33 ft/s	Mean Depth: 13.1 ft	Bin Size: 25 cm	Blank: 25 cm
WT Error Vel.: 3.50 ft/s	% Meas.: 74.85	BT Mode: 5	BT Pings: 1
BT Up Vel.: 1.00 ft/s	Water Temp.: None	WT Mode: 1	WT Pings: 1
WT Up Vel.: 12.00 ft/s	ADCP Temp.: 36.9 °F	WV: 254	
Use Weighted Mean Depth: YES			

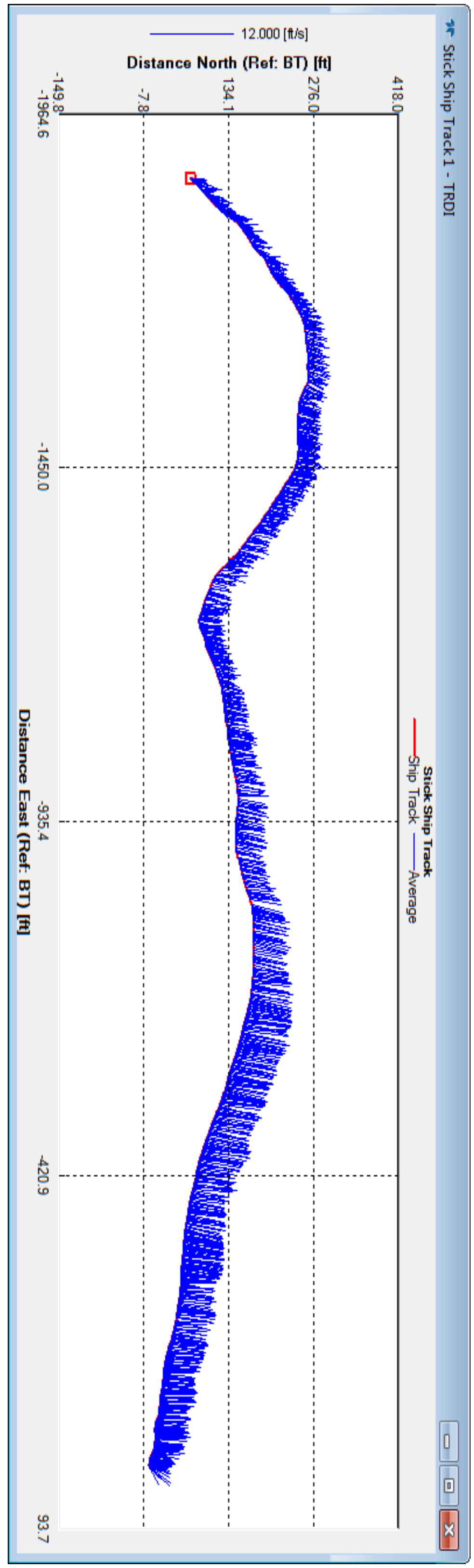
Performed Diag. Test: NO
Performed Moving Bed Test: YES
Performed Compass Calibration: NO Evaluation: NO
Meas. Location:

Project Name: mon1_discharge_2015_
Software: 2.13

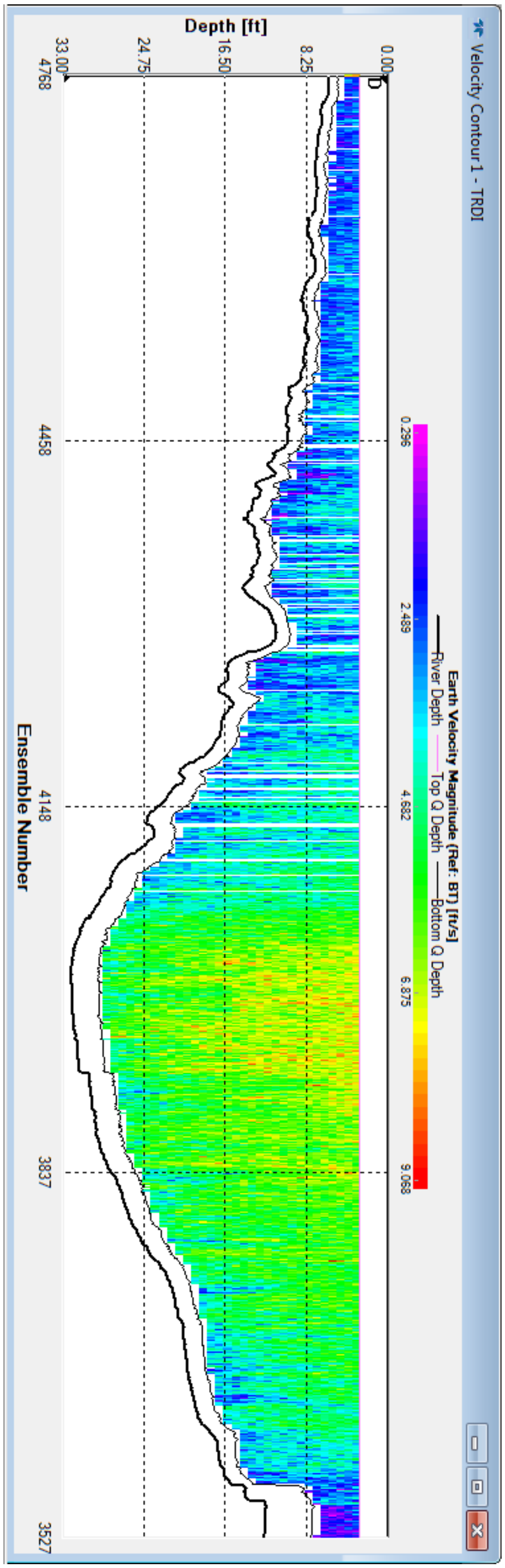
Tr.#		Edge Distance		#Ens.	MBT Corrected Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1100	0	1466	25164	130163	14787	4380	0.000	174494	2960	37857	16:26	16:37	2.87	4.63	5	0
002	R	1100	0	1240	25205	133714	14564	5865	0.000	179348	2914	38307	16:52	17:02	3.29	4.68	5	0
003	L	1100	0	1236	25320	133091	14505	4723	0.000	177639	2985	39244	17:13	17:22	3.43	4.53	7	0
004	R	1100	0	1254	25120	134759	14532	4465	0.000	178876	2929	38818	17:23	17:33	3.22	4.63	4	0
Mean		1100	0	1299	25200	132932	14599	4858	0.000	177589	2947	38558	Total	01:07	3.20	4.62	5	0
SDev		0	0	111	87.8	1970	134	687	0.000	2186	31.9	559.3			0.19	0.06		
SD/M		0.00	0.00	0.09	0.00	0.01	0.01	0.14	0.00	0.01	0.01	0.02			0.06	0.01		

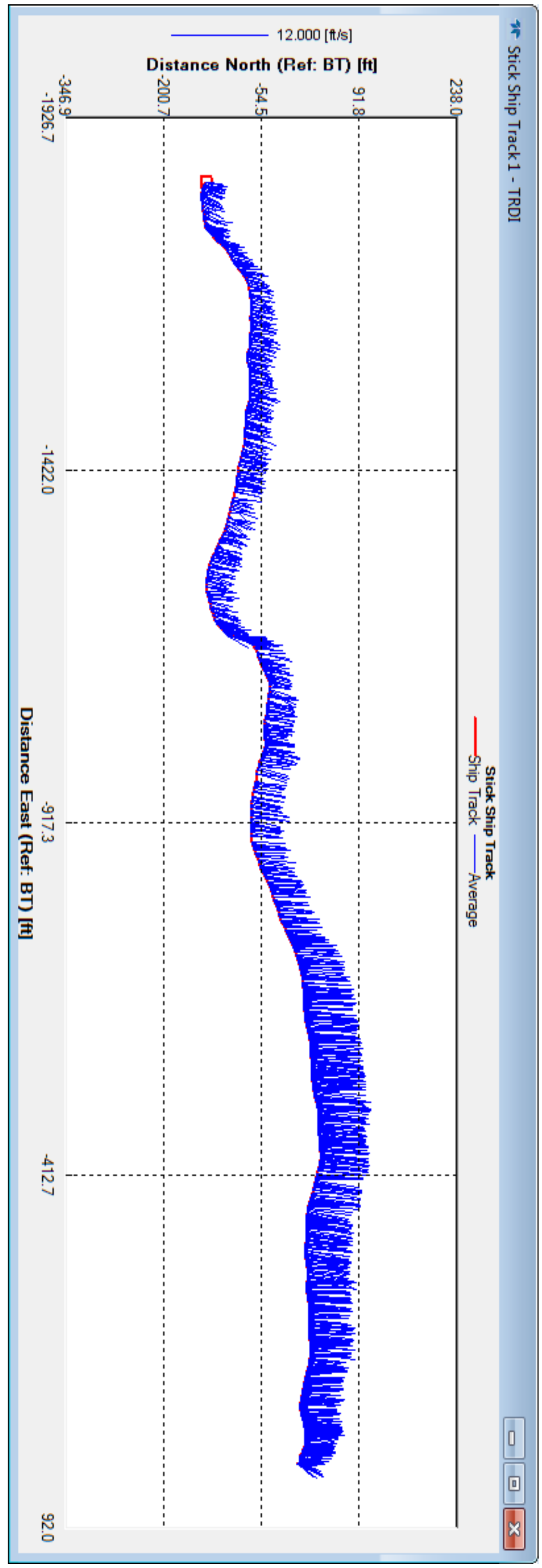
D.1.2 Transect 1 Velocity Profile and Track



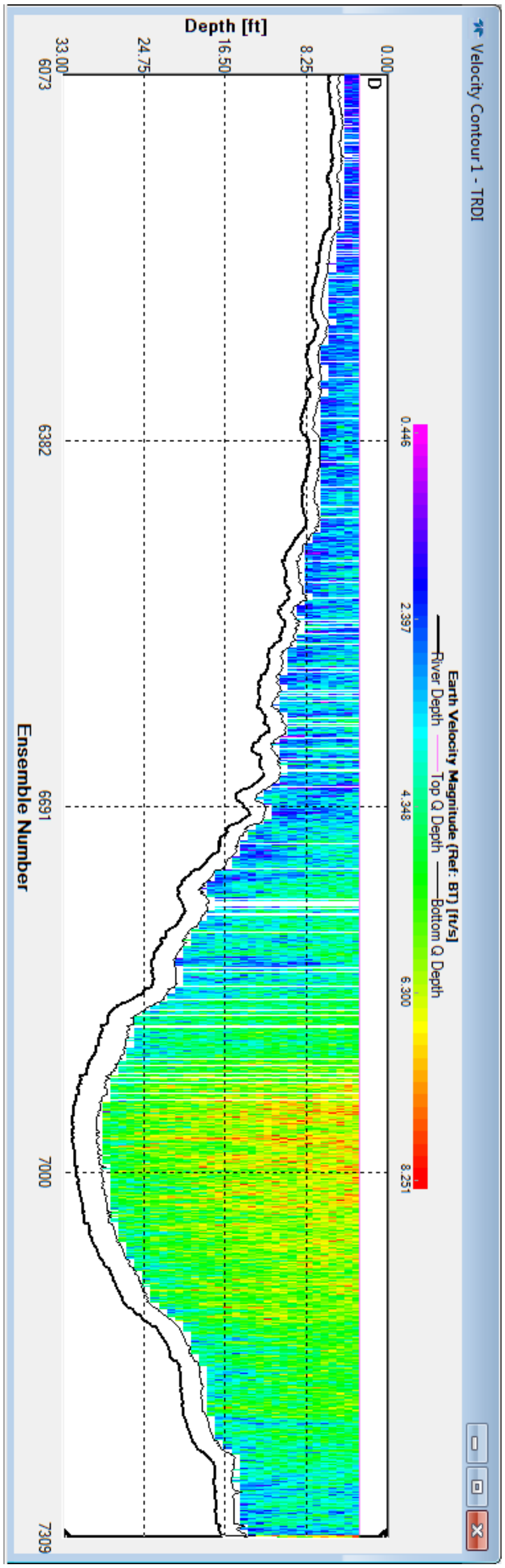


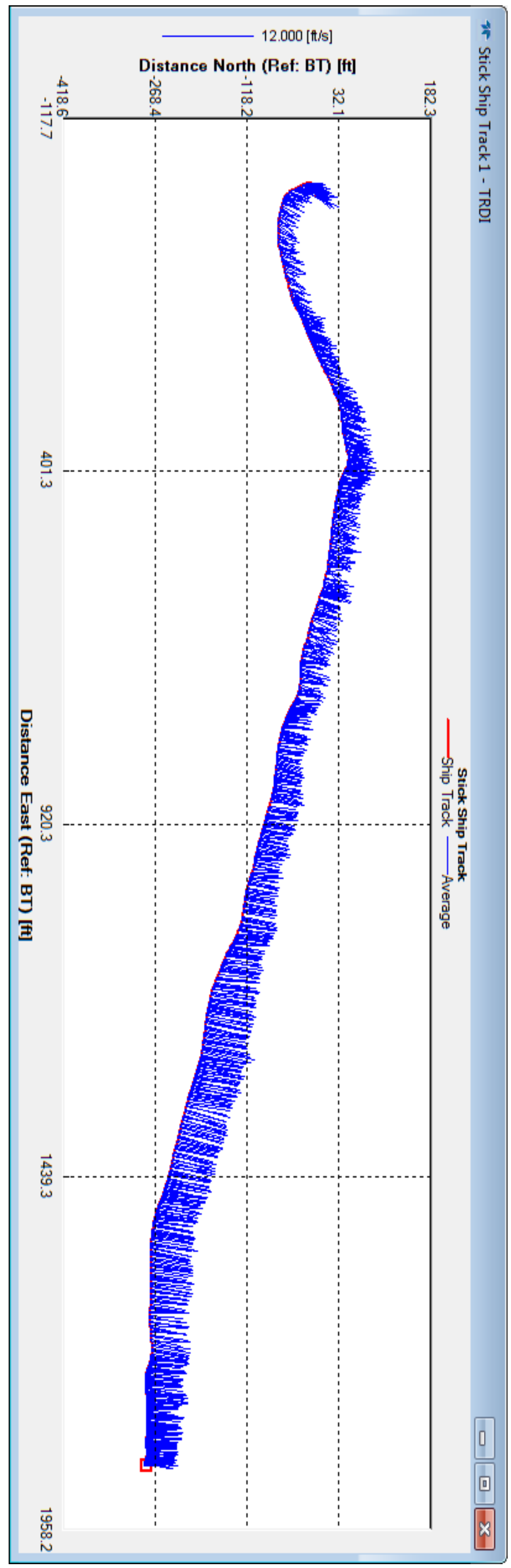
D.1.3 *TRANSECT 2 VELOCITY PROFILE AND TRACK*



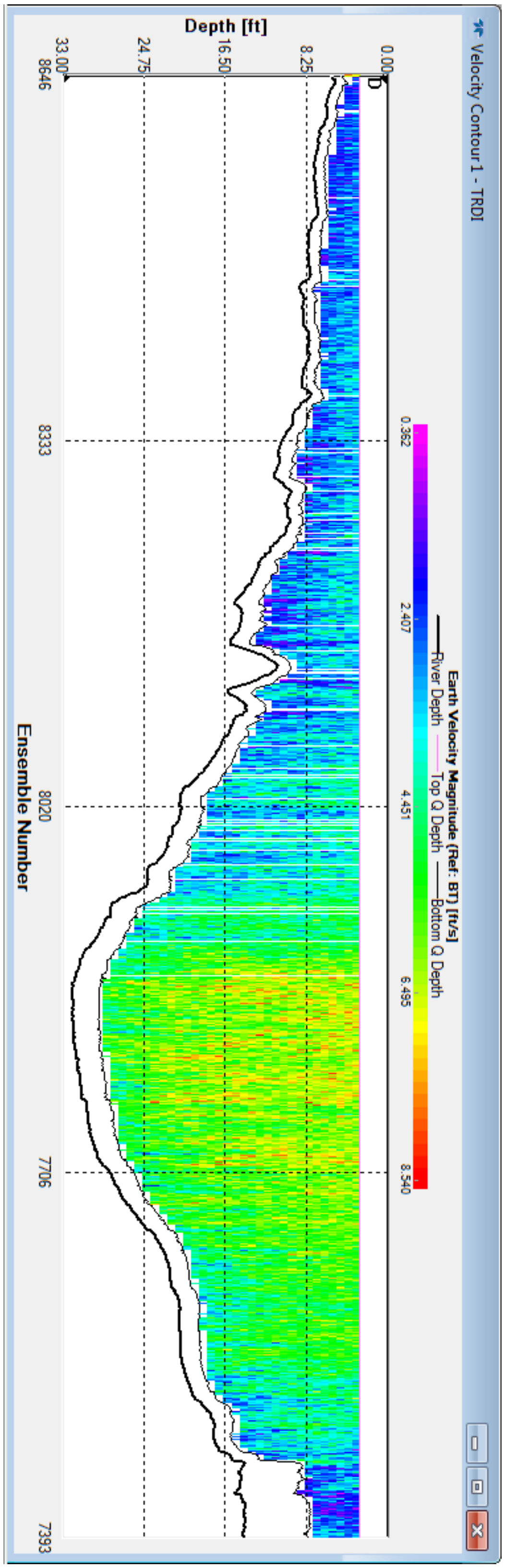


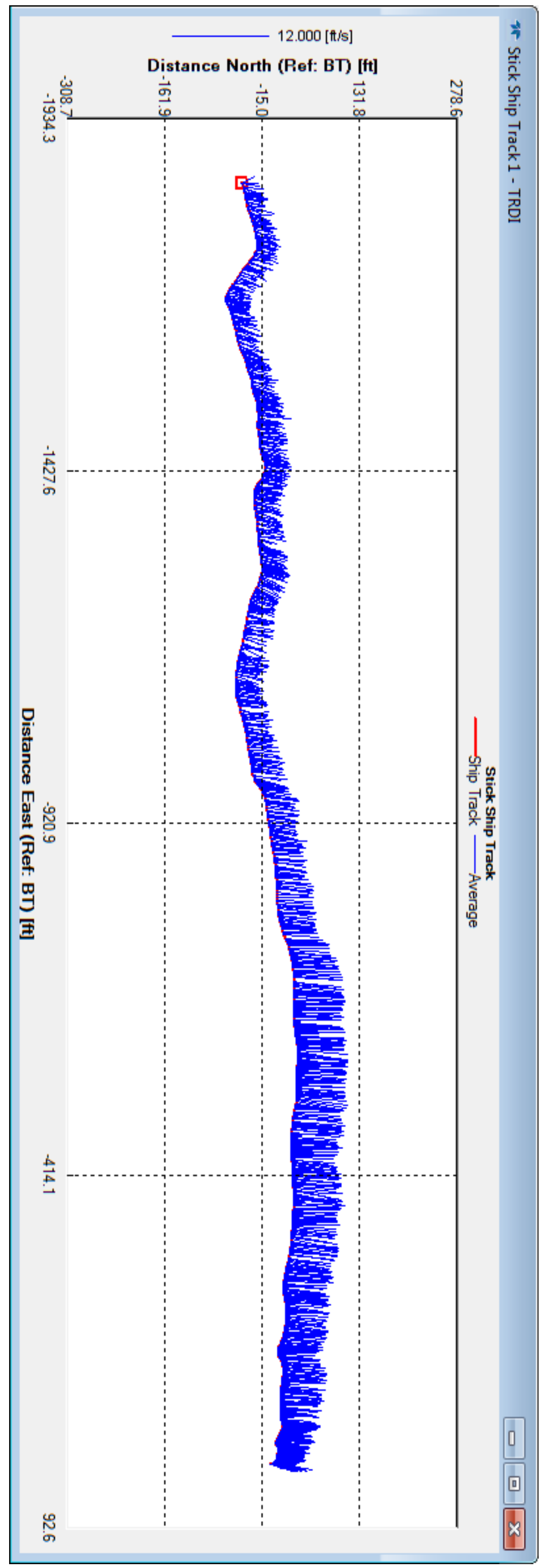
D.1.4 TRANSECT 3 VELOCITY PROFILE AND TRACK





D.1.5 Transect 4 Velocity Profile and Track





D.2 Nigliq Channel

D.2.1 MEASUREMENT SUMMARY

Station Number: Meas. No:
Station Name: Date: 05/22/2015

Party:	Width: 1,290 ft	Processed by:
Boat/Motor:	Area: 18,300 ft²	Mean Velocity: 4.06 ft/s
Gage Height: 0.00 ft	G.H.Change: 0.000 ft	Discharge: 74,400 ft³/s

Area Method: Mean Flow	ADCP Depth: 1.300 ft	Index Vel.: 0.00 ft/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj.Mean Vel: 0.00 ft/s	Qm Rating: U
MagVar Method: None (18.4°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 ft²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: Distributed		Control2: Unspecified	
% Correction: 17.68		Control3: Unspecified	

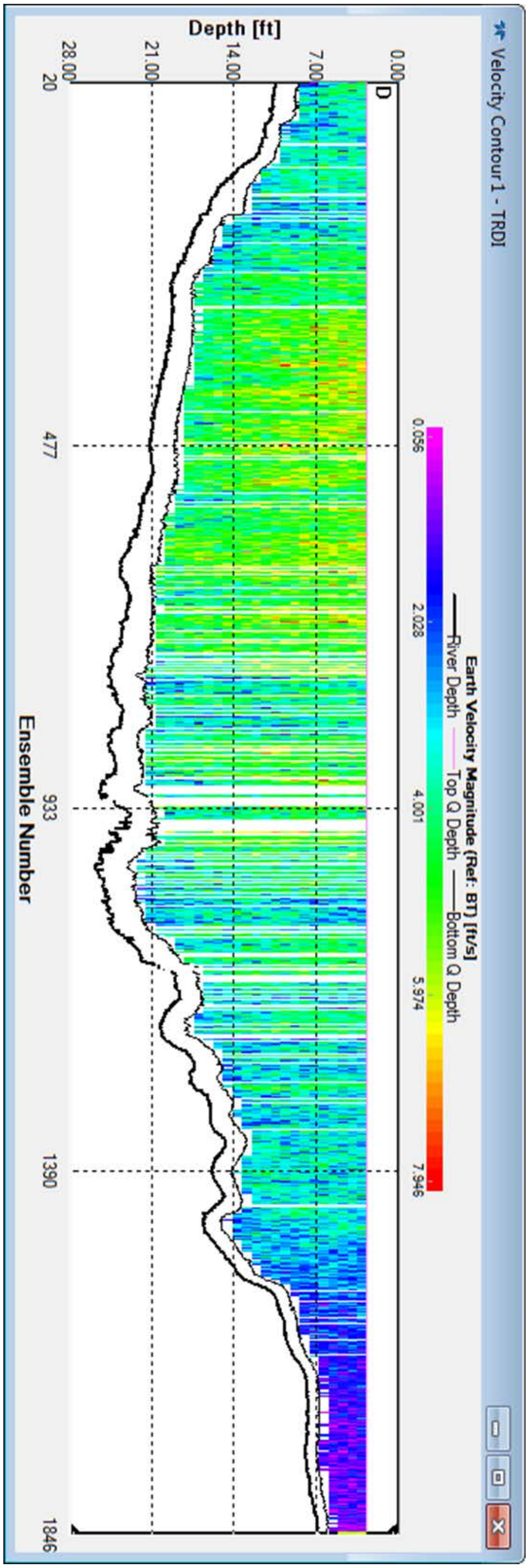
Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 8.55 ft/s	Type/Freq.: Workhorse / 1200 kHz	
WT 3-Beam Solution: NO	Max. Depth: 26.5 ft	Serial #: 5283	Firmware: 51.40
BT Error Vel.: 0.33 ft/s	Mean Depth: 14.2 ft	Bin Size: 25 cm	Blank: 25 cm
WT Error Vel.: 3.50 ft/s	% Meas.: 73.51	BT Mode: 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.: 34.6 °F	WV : 335	
Use Weighted Mean Depth: YES			

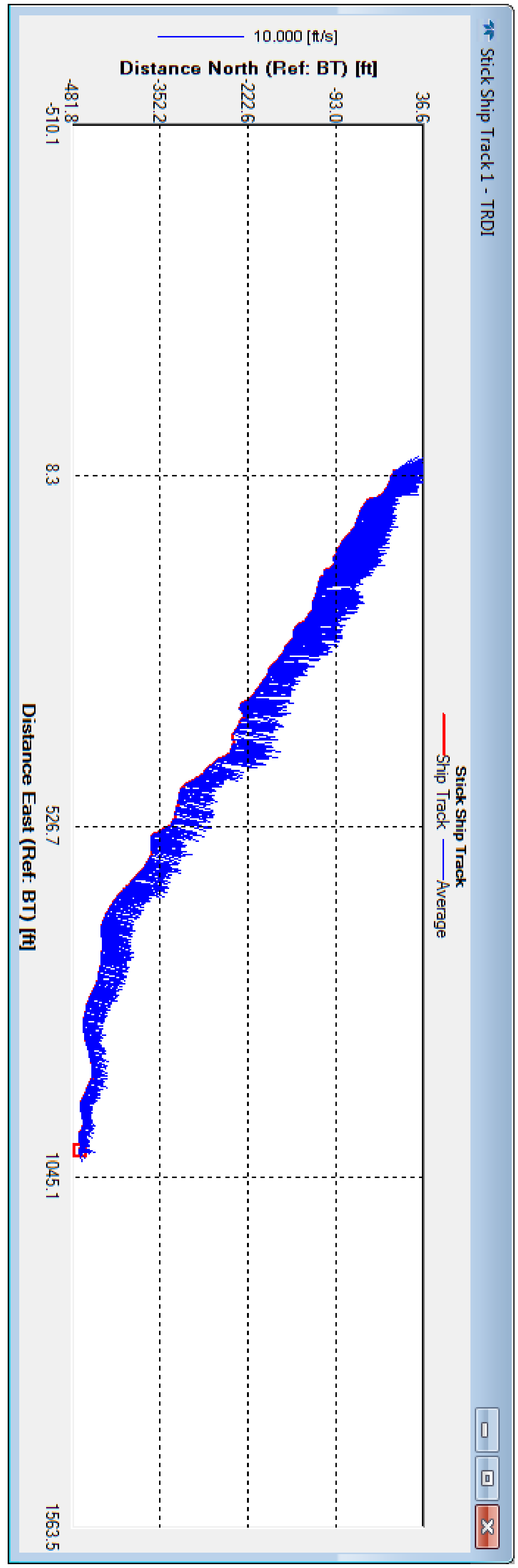
Performed Diag. Test: NO
Performed Moving Bed Test: YES
Performed Compass Calibration: NO Evaluation: NO
Meas. Location:

Project Name: nigliq_discharge_0_upda
Software: 2.13

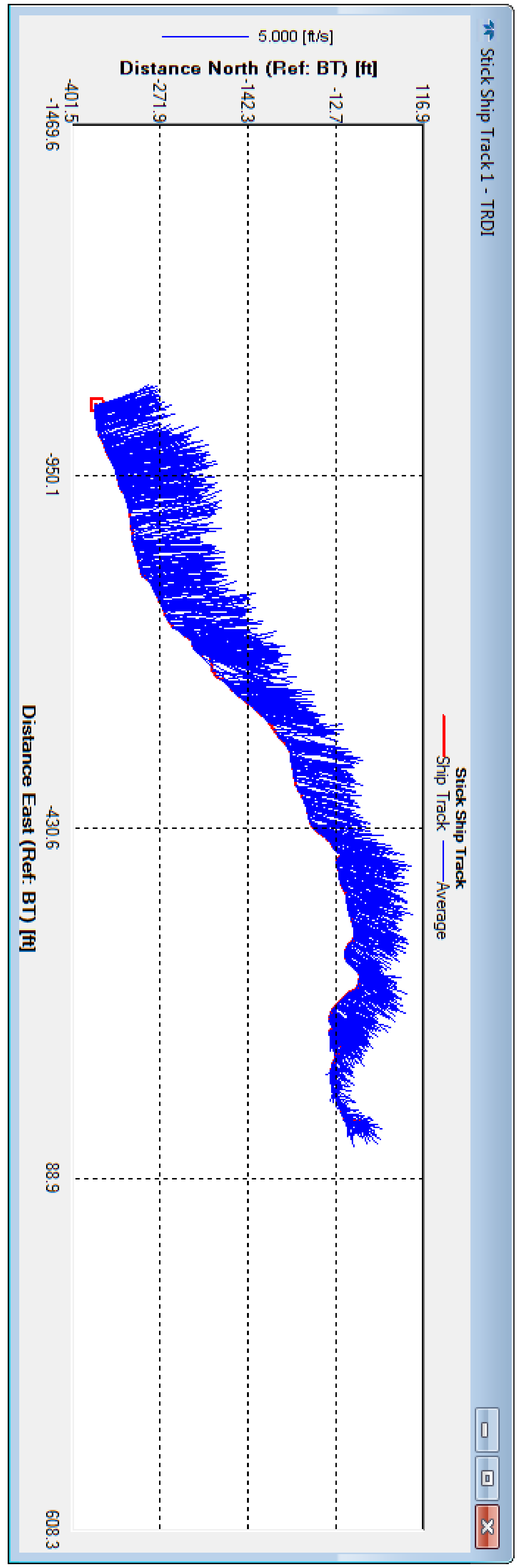
Tr.#		Edge Distance		#Ens.	MBT Corrected Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	20	260	1827	11943	55520	7270	232	449	75415	1289	18655	19:28	19:39	1.79	4.04	15	0
001	R	20	260	1735	11824	54281	7060	278	539	73982	1308	18416	19:39	19:50	2.13	4.02	14	0
002	L	20	260	1514	11758	54857	6943	278	436	74272	1262	18097	19:58	20:07	2.08	4.10	18	0
003	L	20	260	1358	11990	54130	7207	281	357	73965	1304	18160	20:14	20:22	2.35	4.07	16	0
Mean		20	260	1608	11878	54697	7120	267	446	74409	1291	18332	Total	00:54	2.09	4.06	16	0
SDev		0	0	212	107	632	147	23.3	74.5	686	20.9	255.5			0.23	0.04		
SD/M		0.00	0.00	0.13	0.01	0.01	0.02	0.09	0.17	0.01	0.02	0.01			0.11	0.01		

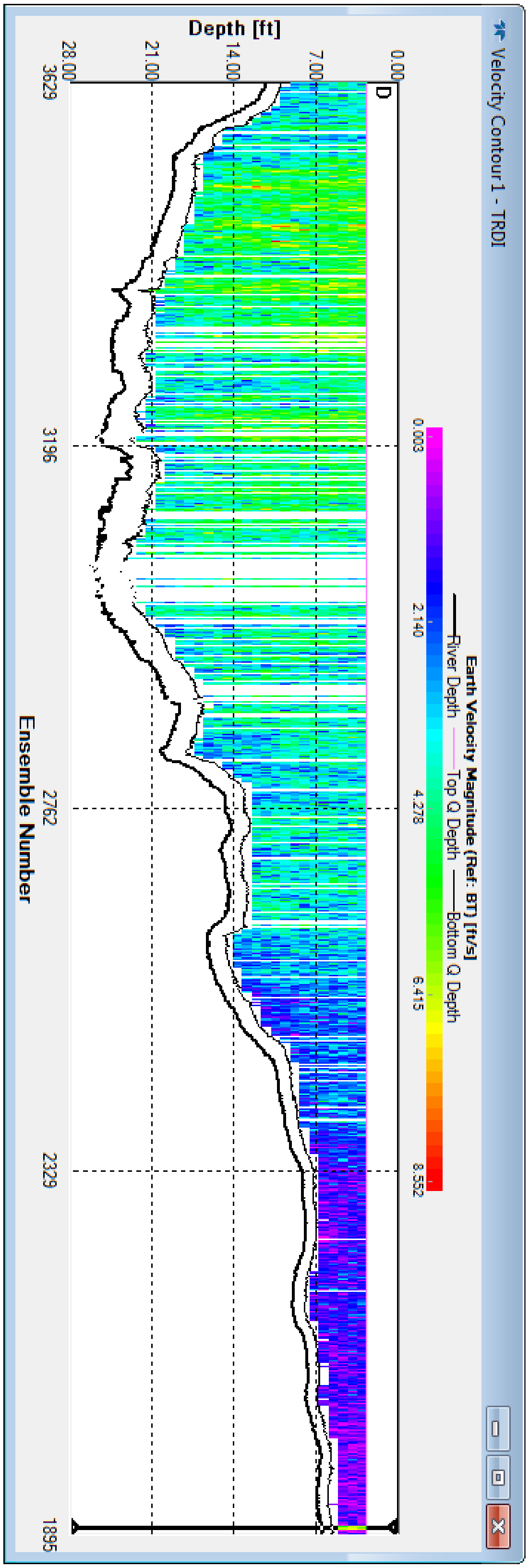
D.2.2 TRANSECT 1 VELOCITY PROFILE AND TRACK



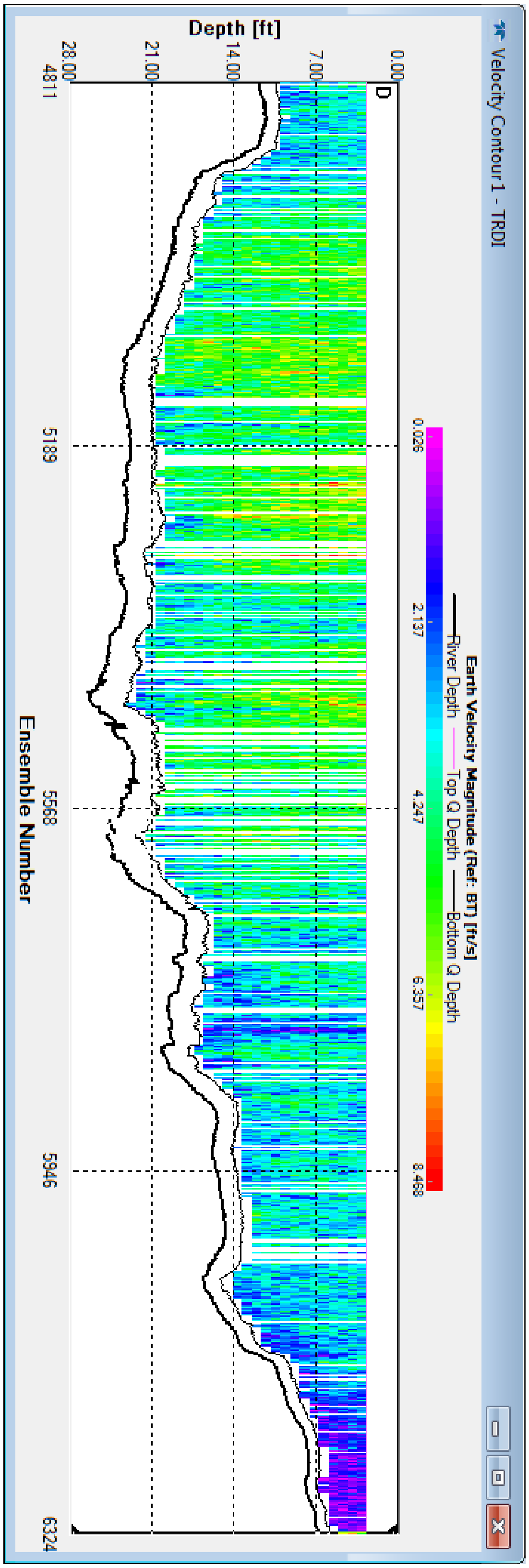


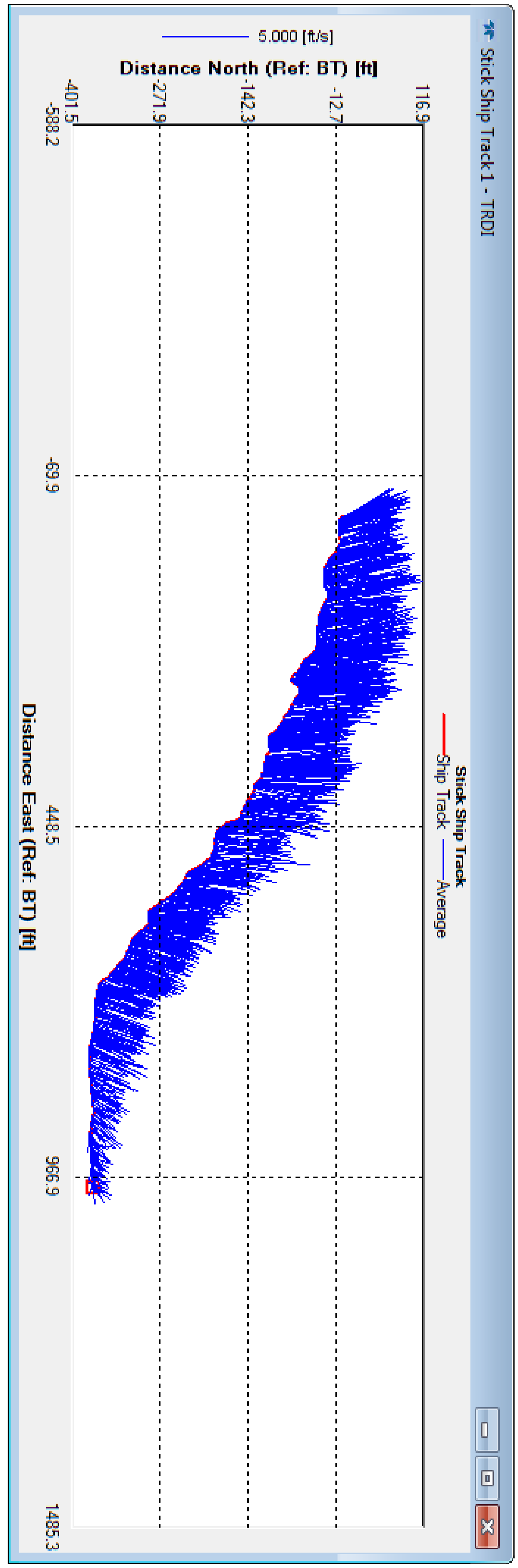
D.2.3 TRANSECT 2 VELOCITY PROFILE AND TRACK



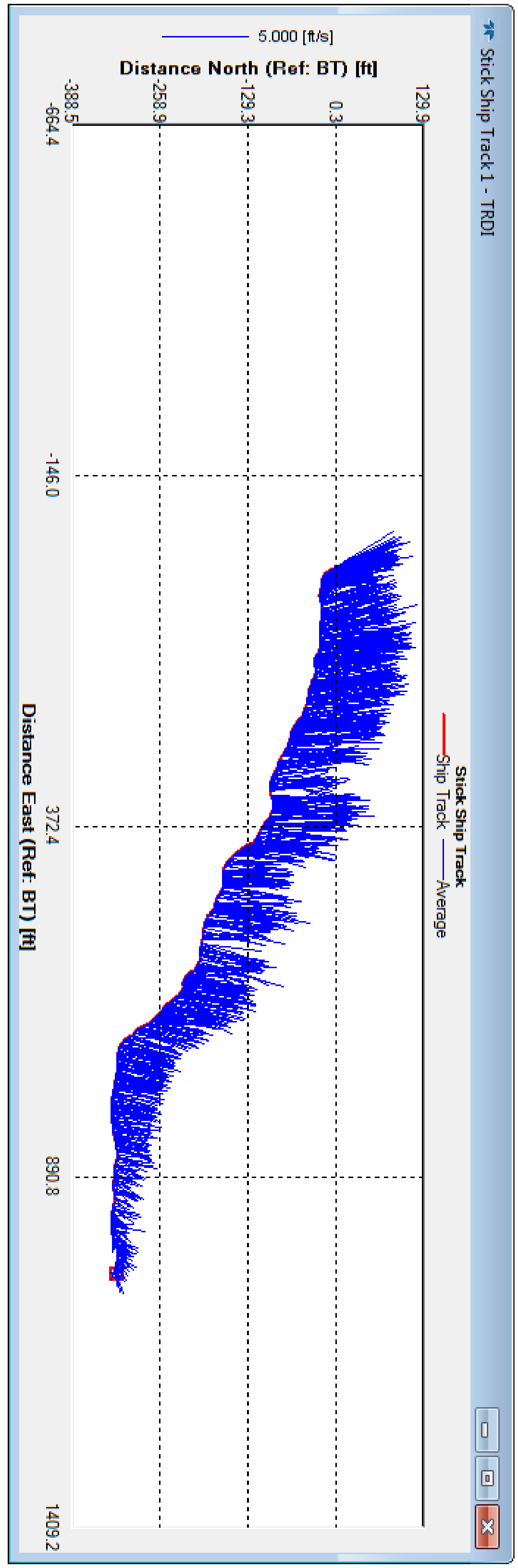


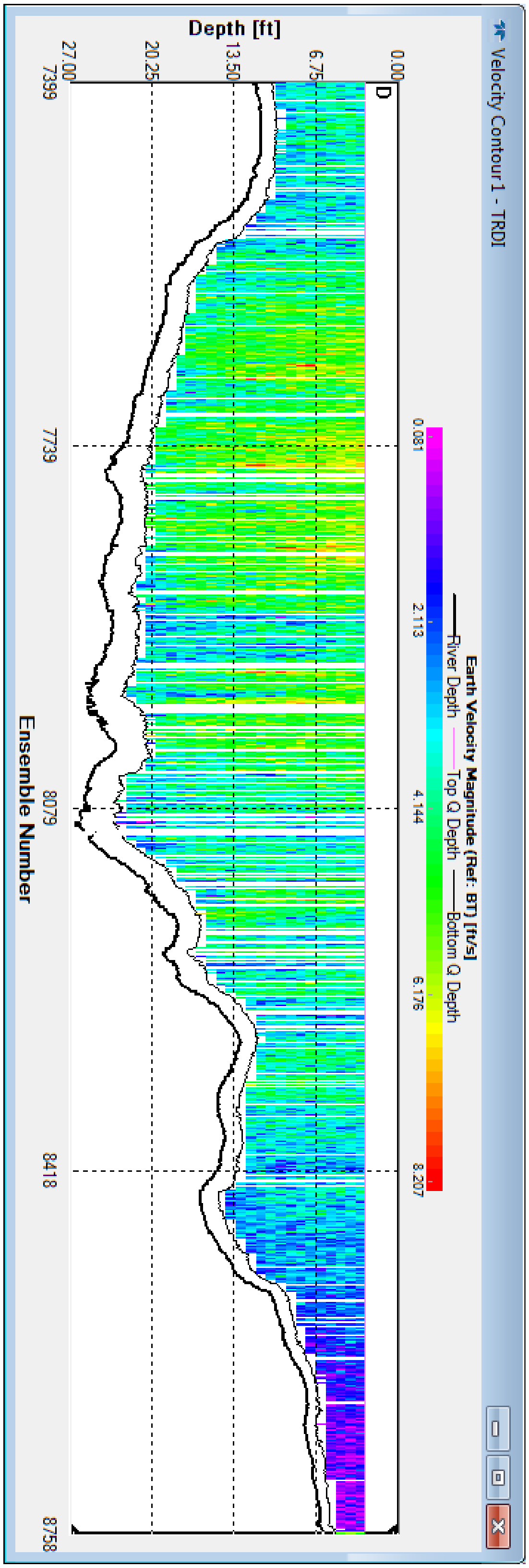
D.2.4 TRANSECT 3 VELOCITY PROFILE AND TRACK





D.2.5 TRANSECT 4 VELOCITY PROFILE AND TRACK





Appendix E Conventional Discharge Measurement Data

E.1 CD5 Road Bridges

E.1.1 Nigliq Bridge

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: May 25, 2015
Computed By: J. Mekel 5/29/15
Checked By: S. Prevatte 8/04/15

Location Name: Nigliq Channel Bridge

Party: J. Meckel, S. Prevatte   Start: 15:33   Finish: 17:45

Temp: 35 °F   Weather: Overcast, fog

Channel Characteristics:

Width: 896 ft   Area: 16709 sq ft   Velocity: 2.01 fps   Discharge: 33651 cfs

Method: .2 - .8   Number of Sections: 17   Count: N/A

Spin Test: 3.5 Minutes after 3.5 Minutes   Meter: Price AA NY4743

GAGE READINGS			
Gage	Start	Finish	Change
G26	5.69	5.53	0.16
G29	5.49	5.27	0.22

Meter: 1 ft above bottom of weight

Weight: 50 lbs

Wading **[Cable]** Ice Boat

[Upstream] or Downstream side of bridge

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

Descriptions:

Cross Section: Fairly uniform cross section
Sediment soft; soundings + or - 0.1 ft

Flow: Flow steady
Stage falling

Remarks: Downstream control is bed and banks mostly clear of snow and ice
Variable horizontal angles

Nigliq Channel Bridge
May 25, 2015

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ 15:33											
	0	10.0	0.0	0.0				0.00		0.0	0.0
0.78	20	30.0	6.8	0.2 0.8	10 10	49 41	0.47 0.56	0.51	0.40	204.0	81.4
1	60	40.0	26.7	0.2 0.8	40 30	43 45	2.07 1.49	1.78	1.78	1068.0	1899.1
1	100	45.0	29.1	0.2 0.8	60 50	46 49	2.89 2.27	2.58	2.58	1309.5	3379.3
1	150	50.0	29.6	0.2 0.8	60 35	47 43	2.83 1.81	2.32	2.32	1480.0	3437.2
1	200	50.0	26.5	0.2 0.8	60 50	43 48	3.09 2.31	2.70	2.70	1325.0	3583.3
1	250	50.0	26.6	0.2 0.8	60 50	47 44	2.83 2.52	2.68	2.68	1330.0	3561.5
1	300	50.0	26.6	0.2 0.8	60 40	47 40	2.83 2.22	2.53	2.53	1330.0	3361.6
1	350	50.0	26.6	0.2 0.8	60 50	46 47	2.89 2.36	2.63	2.63	1330.0	3495.9
1	400	50.0	27.0	0.2 0.8	50 50	43 48	2.58 2.31	2.45	2.45	1350.0	3304.8
1	450	50.0	26.9	0.2 0.8	50 40	48 48	2.31 1.86	2.08	2.08	1345.0	2804.1
1	500	50.0	21.1	0.2 0.8	40 30	53 41	1.68 1.63	1.66	1.66	1055.0	1747.5
1	550	50.0	23.4	0.2 0.8	30 30	47 48	1.43 1.40	1.41	1.41	1170.0	1650.2
0.98	600	50.0	32.1	0.2 0.8	15 15	45 42	0.75 0.81	0.78	0.76	1605.0	1225.3
0.75	650	60.0	11.2	0.2 0.8	1 10	49 65	0.06 0.36	0.21	0.16	672.0	105.8
0.55	720	123.0	1.1	0.6	4	50	0.19	0.19	0.11	135.3	14.5
	896	88.0	0.0							0.0	0.0
REW @ 17:45											

Total Discharge: **33651.5 cfs**

E.1.2 NIGLIAGVIK BRIDGE

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: May 23, 2015
Computed By: J. Meckel 5/29/15
Checked By: S. Prevatte 8/04/15

Location Name: Nigliagvik Bridge

Party: J. Meckel, S. Prevatte   Start: 14:10   Finish: 15:45

Temp: 45 °F   Weather: Clear, windy

Channel Characteristics:

Width: 192 ft   Area: 1419 sq ft   Velocity: 1.89 fps   Discharge: 2679 cfs

Method: 0.6, 0.2 - 0.8   Number of Sections: 22   Count: N/A

Spin Test: Pass   Meter: Price AA NY4743

Meter: 1 ft above bottom of weight

Weight: 30 lbs

Wading [Cable] Ice Boat

[Upstream] or Downstream side of bridge

GAGE READINGS			
Gage	Start	Finish	Change
G38	8.11	7.95	0.16
G39	8.06	7.89	0.17

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

Descriptions:

Cross Section: Stranded ice lodged into west upstream side of bridge reduced cross section length
Section uniform and firm

Flow: Steady waves
Frequent ice flows

Remarks: No ice jam downstream
Ice on banks
Downstream control clear
Stranded ice upstream of bridge released and flowed downstream just prior to completing the measurement

Nigliagvik Bridge
May 23, 2015

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
			LEW @ 14:10								
	2.0	2.5	0.0				0.00	0.00		0.0	0.0
1.00	7.0	7.0	2.5	0.6	10	41	0.56	0.56	0.56	17.5	9.7
0.80	16.0	6.0	5.6	0.2 0.8	40 40	45 43	1.98 2.07	2.02	1.62	33.6	54.4
1.00*	19.0	1.5*	5.0*	Left edge of ice				1.0*	1.0*	7.5	7.5
1.00*	87.0	1.5*	9.0*	Right edge of ice				2.0*	2.0*	13.5	27.0
1.00	90.0	6.5	9.8	0.2 0.8	55 50	43 49	2.84 2.27	2.55	2.55	63.7	162.6
1.00	100.0	10.0	7.5	0.2 0.8	50 50	40 45	2.77 2.47	2.62	2.62	75.0	196.6
1.00	110.0	10.0	8.1	0.2 0.8	60 50	48 46	2.77 2.41	2.59	2.59	81.0	210.1
1.00	120.0	10.0	9.1	0.2 0.8	50 40	43 40	2.58 2.22	2.40	2.40	91.0	218.6
1.00	130.0	10.0	9.5	0.2 0.8	50 50	44 52	2.52 2.14	2.33	2.33	95.0	221.4
1.00	140.0	10.0	9.5	0.2 0.8	50 40	54 41	2.06 2.17	2.11	2.11	95.0	200.8
1.00	150.0	10.0	10.1	0.2 0.8	50 40	46 41	2.41 2.17	2.29	2.29	101.0	231.4
1.00	160.0	10.0	10.5	0.2 0.8	50 50	50 53	2.22 2.10	2.16	2.16	105.0	226.8
1.00	170.0	10.0	9.9	0.2 0.8	40 40	41 49	2.17 1.82	1.99	1.99	99.0	197.3
1.00	180.0	10.0	9.4	0.2 0.8	40 40	43 44	2.07 2.02	2.05	2.05	94.0	192.3
1.00	190.0	10.0	12.6	0.2 0.8	40 20	50 59	1.78 0.77	1.27	1.27	126.0	160.5
1.00	200.0	10.0	9.0	0.2 0.8	40 30	53 40	1.68 1.67	1.68	1.68	90.0	150.9
1.00	210.0	10.0	7.9	0.2 0.8	30 20	49 43	1.37 1.04	1.21	1.21	79.0	95.2
1.00	220.0	10.0	6.4	0.2 0.8	20 20	45 46	1.00 0.98	0.99	0.99	64.0	63.2
1.00	230.0	10.0	3.7	0.6	20	64	0.71	0.71	0.71	37.0	26.2
1.00	240.0	17.5	2.9	0.6	10	43	0.53	0.53	0.53	50.8	26.9
	265.0	12.5	0.0							0.0	0.0
			REW @ 15:45								

* Estimated values

Total Discharge: 2679.4

E.2 CD2 Road Swale Bridges

E.2.1 Long Swale Bridge

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: May 22, 2015
Computed By: J. Mekel 5/29/15
Checked By: S. Prevatte 8/04/15

Location Name: Long Swale Bridge

Party: J. Meckel, S. Prevatte   Start: 16:15   Finish: 18:15

Temp: 45 °F   Weather: Mostly sunny, wind 5mph increasing to 15mph

Channel Characteristics:

Width: 447 ft   Area: 3024 sq ft   Velocity: 3.12 fps   Discharge: 9440 cfs

Method: .2 - .8   Number of Sections: 24   Count: N/A

Spin Test: 3.5 Minutes after 3.5 Minutes   Meter: Price AA NY4743

GAGE READINGS			
Gage	Start	Finish	Change
G3	9.93	9.75	-0.18 ft
G4	9.38	9.35	-0.03 ft

Meter: 1 ft above bottom of weight

Weight: 50 lbs

Wading **[Cable]** Ice Boat

[Upstream] or Downstream side of bridge

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

Descriptions:

Cross Section: Open channel with some floating ice
Section uniform and firm

Flow: High stage
Consistant angle from left to right

Remarks: Left edge water at abutment
Right edge water at abutment
Downstream control is ponded water clear of ice

Long Swale Bridge
May 22, 2015

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
LEW @ 16:15											
0.8	0	1.0	6.0*				1.00*	1.00	0.80	6.0	4.8
0.8	2	2.0	6.0*				1.00*	1.50	1.20	12.0	14.4
0.8	4	9.0	6.1	0.2 0.8	40 80	43 40	2.07 4.43	3.25	2.60	54.9	142.7
0.96	20	18.0	6.0	0.2 0.8	100 100	42 45	5.27 4.92	5.09	4.89	108.0	528.0
0.96	40	25.0	6.2	0.2 0.8	100 80	43 45	5.15 3.94	4.54	4.36	155.0	675.8
0.96	70	30.0	6.2	0.2 0.8	100 80	46 47	4.81 3.77	4.29	4.12	186.0	766.2
0.96	100	30.0	6.1	0.2 0.8	80 80	41 52	4.32 3.41	3.86	3.71	183.0	679.0
0.96	130	30.0	6.2	0.2 0.8	80 60	44 43	4.03 3.09	3.56	3.42	186.0	635.7
0.96	160	30.0	6.1	0.2 0.8	80 60	44 42	4.03 3.17	3.60	3.45	183.0	631.9
0.96	190	25.0	6.4	0.2 0.8	80 60	45 42	3.94 3.17	3.55	3.41	160.0	545.7
0.96	210	20.0	6.9	0.2 0.8	80 60	47 47	3.77 2.83	3.30	3.17	138.0	437.4
0.96	230	20.0	7.1	0.2 0.8	80 50	49 44	3.62 2.52	3.07	2.95	142.0	418.6
0.96	250	20.0	8.6	0.2 0.8	80 50	42 45	4.22 2.47	3.34	3.21	172.0	551.9
0.96	270	20.0	9.2	0.2 0.8	80 40	51 48	3.48 1.86	2.67	2.56	184.0	470.9
0.96	290	20.0	7.5	0.2 0.8	80 50	51 42	3.48 2.64	3.06	2.94	150.0	440.6
0.96	310	20.0	7.0	0.2 0.8	80 50	50 41	3.55 2.71	3.13	3.00	140.0	420.1
0.96	330	20.0	7.1	0.2 0.8	60 40	43 41	3.09 2.17	2.63	2.53	142.0	358.7
0.96	350	20.0	6.5	0.2 0.8	60 50	44 50	3.02 2.22	2.62	2.52	130.0	327.4
0.98	370	20.0	7.3	0.2 0.8	50 50	40 47	2.77 2.36	2.57	2.52	146.0	367.5
0.98	390	20.0	7.2	0.2 0.8	50 40	44 45	2.52 1.98	2.25	2.21	144.0	317.6
0.98	410	20.0	6.6	0.2 0.8	50 40	41 42	2.71 2.12	2.41	2.36	132.0	312.0
0.98	430	16.5	6.2	0.2 0.8	50 50	41 45	2.71 2.47	2.59	2.54	102.3	259.4
0.9	443	8.5	6.5	0.2 0.8	50 40	41 40	2.71 2.22	2.46	2.22	55.3	122.6
0.9	447	2.0	6.5*				1.00*	1.00*	0.90	13.0	11.7
REW @ 18:15											

*Estimated value

Total Discharge: **9440.3 cfs**

E.2.2 SHORT SWALE BRIDGE

Michael Baker INTERNATIONAL

Discharge Measurement Notes

Date: May 23, 2015
Computed By: J. Mekel 5/29/15
Checked By: S. Prevatte 8/04/15

Location Name: Short Swale Bridge

Party: J. Meckel, S. Prevatte   Start: 10:00   Finish: 11:08

Temp: 48 °F   Weather: Mostly sunny, windy

Channel Characteristics:

Width: 53.5 ft   Area: 373 sq ft   Velocity: 0.81 fps   Discharge: 302 cfs

Method: .2 - .8   Number of Sections: 19   Count: N/A

Spin Test: 3.5 Minutes after 3.5 Minutes   Meter: Price AA NY4743

GAGE READINGS			
Gage	Start	Finish	Change
G3	7.85	7.63	-0.22 ft
G4	7.80	7.58	-0.22 ft

Meter: 1 ft above bottom of weight

Weight: 50 lbs

Wading $\boxed{\text{Cable}}$ Ice Boat

$\boxed{\text{Upstream}}$ or Downstream side of bridge

Measurement Rated: Excellent Good $\boxed{\text{Fair}}$ Poor based on "Descriptions"

Descriptions:

Cross Section: Open channel no floating ice
Section uniform and firm

Flow: Falling stage
Steady flow

Remarks: Left edge water at abutment
Right edge water at abutment
Downstream control is ponded water clear of ice

Short Swale Bridge
May 23, 2015

Angle Coeff	Distance from initial point (ft)	Section Width (ft)	Water Depth (ft)	Observed Depth (ft)	Revolution Count	Time Increment (sec)	VELOCITY At Point (fps)	VELOCITY Mean in Vertical (fps)	VELOCITY Adjusted for Angle Coeff (fps)	Area (s.f.)	Discharge (cfs)
			LEW @ 10:00								
	3	1.5	5.0*					0.30*		7.5	2.3
0.85	6	3.0	5.5	0.2 0.8	12 10	46 48	0.59 0.48	0.54	0.45	16.5	7.5
0.85	9	3.0	5.6	0.2 0.8	14 20	44 46	0.72 0.98	0.85	0.72	16.8	12.1
0.97	12	3.0	5.4	0.2 0.8	18 20	48 44	0.84 1.02	0.93	0.90	16.2	14.7
0.99	15	3.0	5.8	0.2 0.8	25 24	46 44	1.22 1.22	1.22	1.21	17.4	21.0
0.99	18	3.0	6.4	0.2 0.8	25 20	47 49	1.19 0.92	1.05	1.04	19.2	20.0
1.00	21	3.0	6.2	0.2 0.8	20 20	42 44	1.07 1.02	1.04	1.04	18.6	19.4
1.00	24	3.0	6.4	0.2 0.8	20 20	41 43	1.09 1.04	1.07	1.07	19.2	20.5
1.00	27	3.0	7.0	0.2 0.8	25 20	52 41	1.08 1.09	1.09	1.09	21.0	22.8
0.99	30	3.0	6.9	0.2 0.8	20 20	42 48	1.07 0.94	1.00	0.99	20.7	20.5
1.00	33	3.0	7.4	0.2 0.8	20 20	45 44	1.00 1.02	1.01	1.01	22.2	22.4
0.98	36	3.0	8.0	0.2 0.8	27 20	52 42	1.16 1.07	1.12	1.09	24.0	26.2
0.90	39	3.0	8.4	0.2 0.8	25 20	47 45	1.19 1.00	1.09	0.98	25.2	24.8
0.85	42	3.0	8.5	0.2 0.8	25 20	43 46	1.30 0.98	1.14	0.97	25.5	24.7
0.70	45	3.0	7.5	0.2 0.8	25 20	41 53	1.36 0.85	1.11	0.77	22.5	17.4
0.60	48	3.5	7.5	0.2 0.8	20 20	50 58	0.90 0.78	0.84	0.50	26.3	13.2
0.40	52	3.5	6.9	0.2 0.8	20 25	49 46	0.92 1.22	1.07	0.43	24.2	10.3
0.20	55	3.0	7.0	0.2 0.8	15 15	43 42	0.79 0.81	0.80	0.16	21.0	3.3
	58	1.5	6.0*						0.10*	9.0	0.9

cfs

E.3 CD2, CD4, and CD5 Road Culverts

Culvert	Observed Flow	Date & Time	Depth (ft)	Area (ft^2)	Measured Velocity (ft/s)	Direct Discharge (cfs)
CD2-22	Y	5/24/15 15:57	0.65	1.33	0.72	0.96
CD2-23	Y	5/24/15 15:42	1.35	3.73	0.99	3.69
CD2-24	Y	5/24/15 15:49	1.70	5.09	0.97	4.94
				Average Measured Velocity	0.89	
				Average Measured Discharge	3.19	

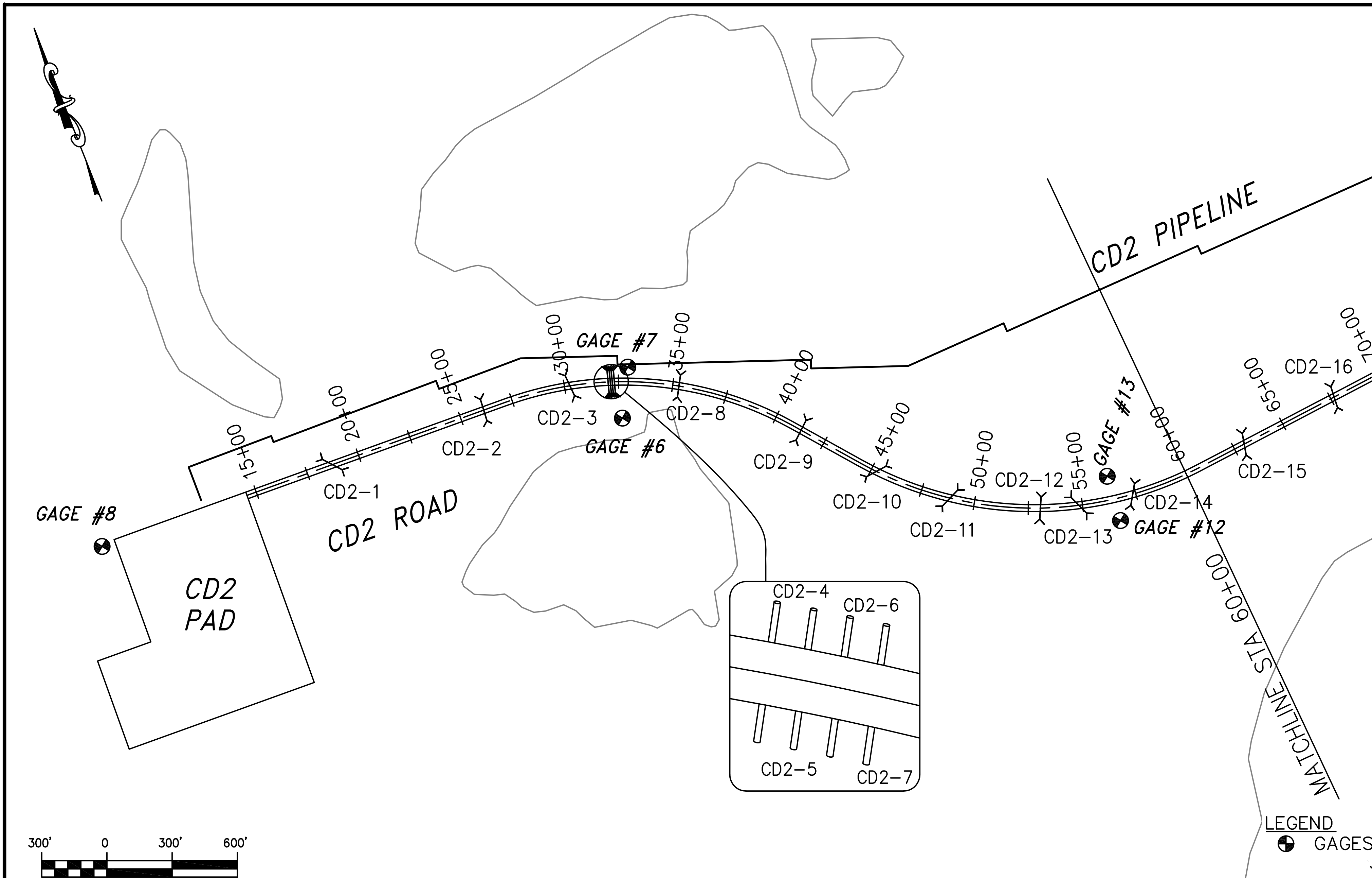
Culvert	Observed Flow	Date & Time	Depth (ft)	Area (ft^2)	Measured Velocity (ft/s)	Direct Discharge (cfs)
CD4-25	Y	5/21/15 14:45	4.00	12.57	6.82	85.64
CD4-26	Y	5/21/15 14:45	4.00	12.57	6.82	85.64
CD4-27	Y	5/21/15 14:45	4.00	12.57	6.82	85.64
CD4-28	Y	5/21/15 14:45	4.00	12.57	6.82	85.64
CD4-29	Y	5/21/15 14:35	4.00	12.57	6.44	80.93
CD4-30	Y	5/21/15 14:35	4.00	12.57	6.44	80.93
CD4-31	Y	5/21/15 14:35	4.00	12.57	6.44	80.93
CD4-32	Y	5/21/15 14:35	4.00	12.57	6.44	80.93
				Average Measured Velocity	6.63	
				Average Measured Discharge	83.28	

Culvert	Observed Flow	Date & Time	Depth (ft)	Area (ft^2)	Measured Velocity (ft/s)	Direct Discharge (cfs)
CD5-03	Y	5/20/15 13:30	2.00	5.01	2.97	14.87
CD5-05	Y	5/20/15 13:50	1.10	1.77	4.35	7.70
CD5-09	Y	5/20/15 14:05	1.55	4.50	1.16	5.22
CD5-32	Y	5/23/15 17:00	3.30	11.09	1.90	21.07
CD5-34	Y	5/23/15 17:08	1.90	5.88	1.81	10.65
CD5-40	Y	5/23/15 17:46	1.80	5.48	2.18	11.96
				Average Measured Velocity	2.40	
				Average Measured Discharge	11.91	

Appendix F 2015 Culvert Locations and Peak Discharge

F.1 Culvert Locations

F.1.1 CD2 Road



ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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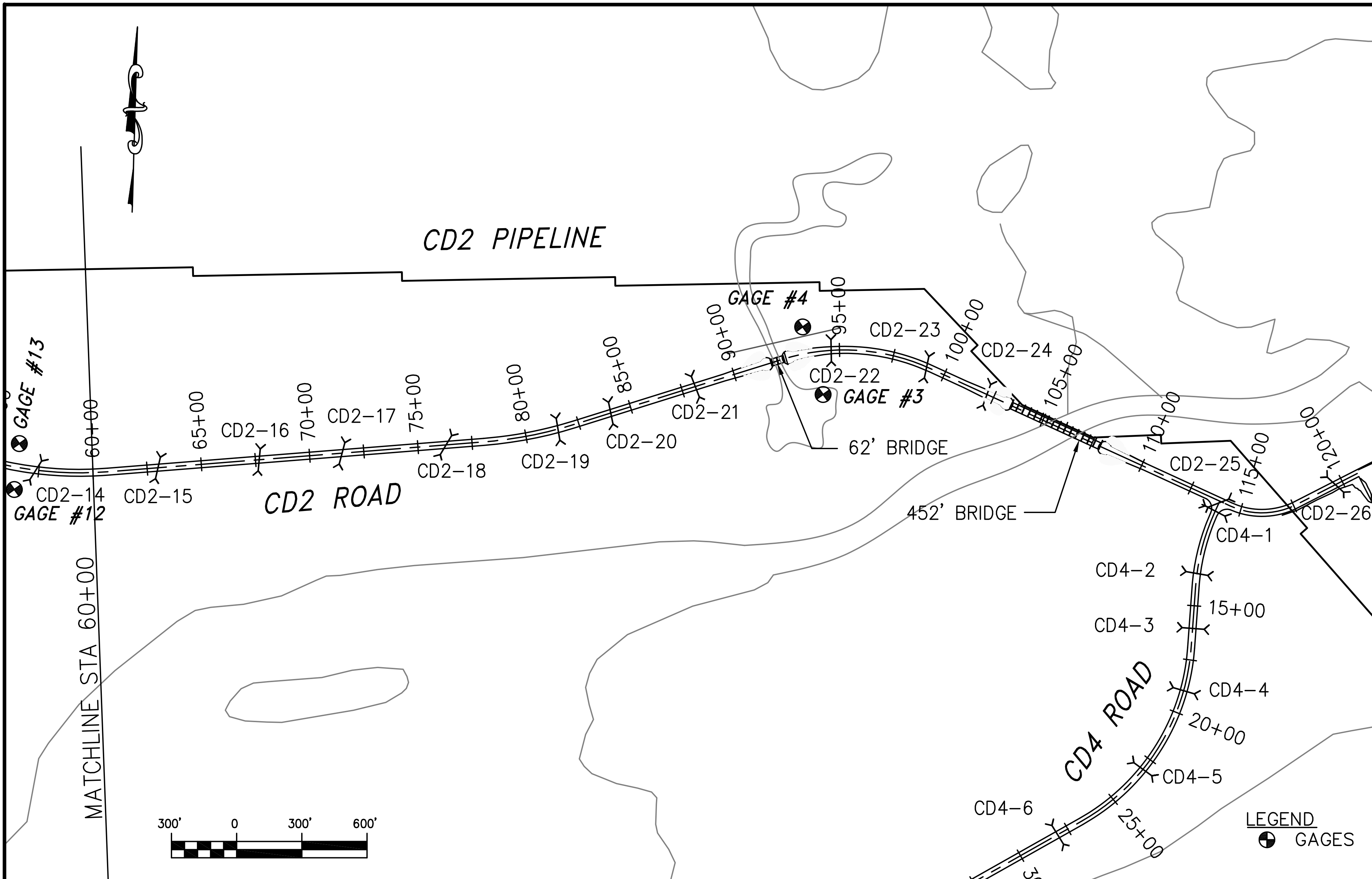
2015 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

(SHEET 1 OF 13)



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Alaska, Inc.

DATE: 10/01/2015	PROJECT: 148414
DRAWN: DTR	FILE: ALPINE_FACILITES.DWG
CHECKED: GCY	SCALE: AS SHOWN

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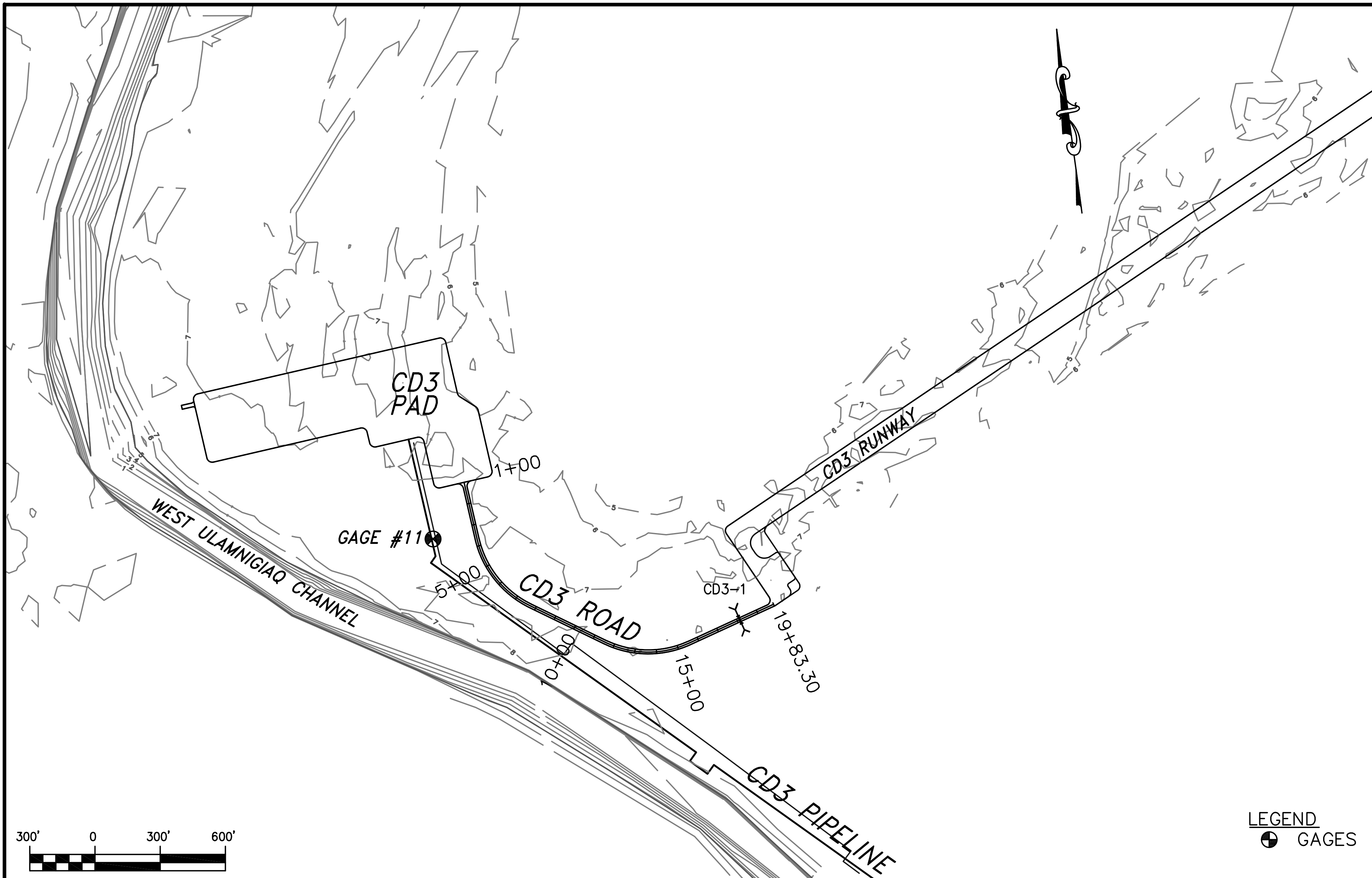
2015 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 2 OF 13)

F.1.2 CD3 PAD



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Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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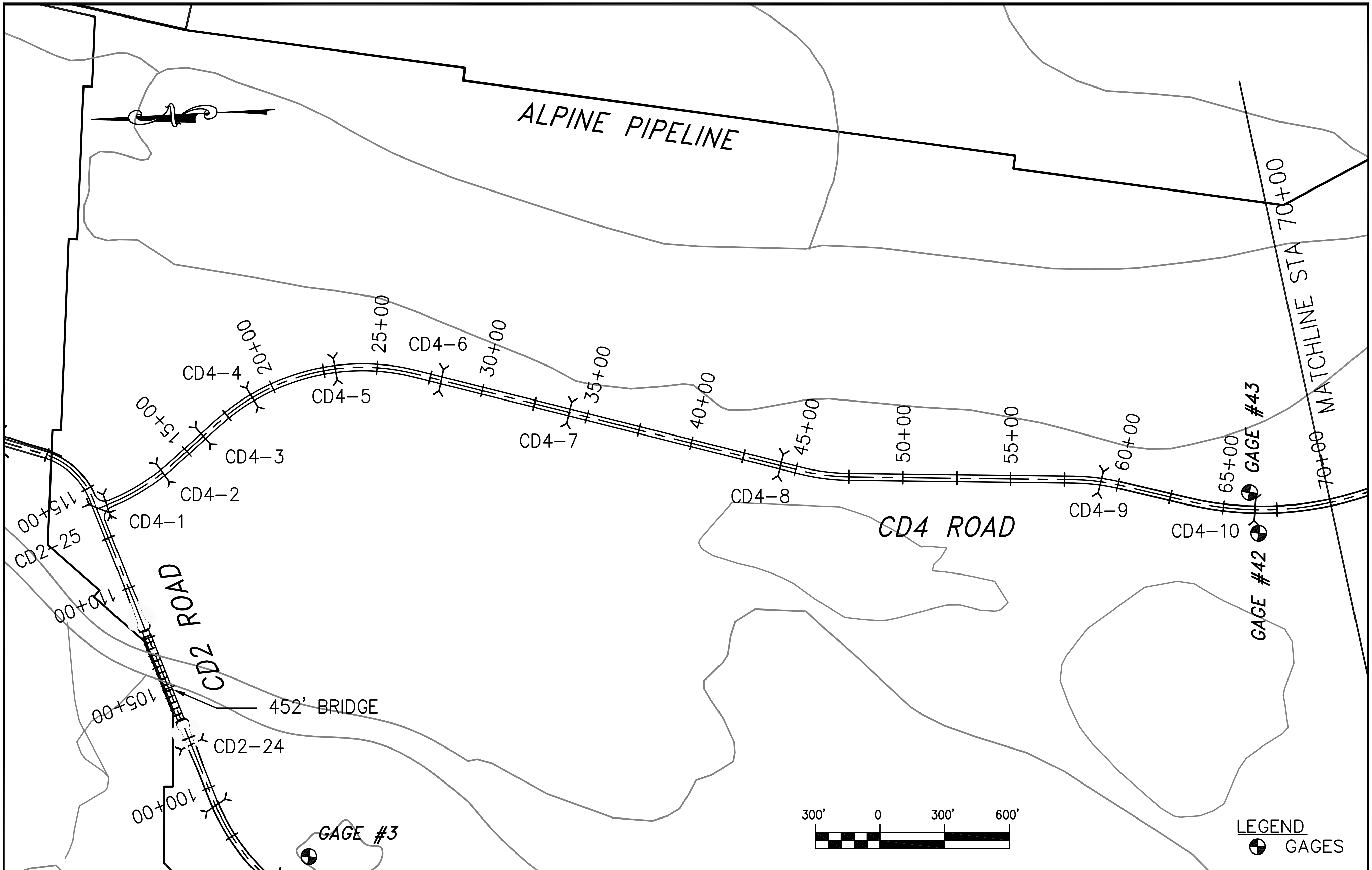
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET13 OF 13)

F.1.3 CD4 ROAD



ConocoPhillips Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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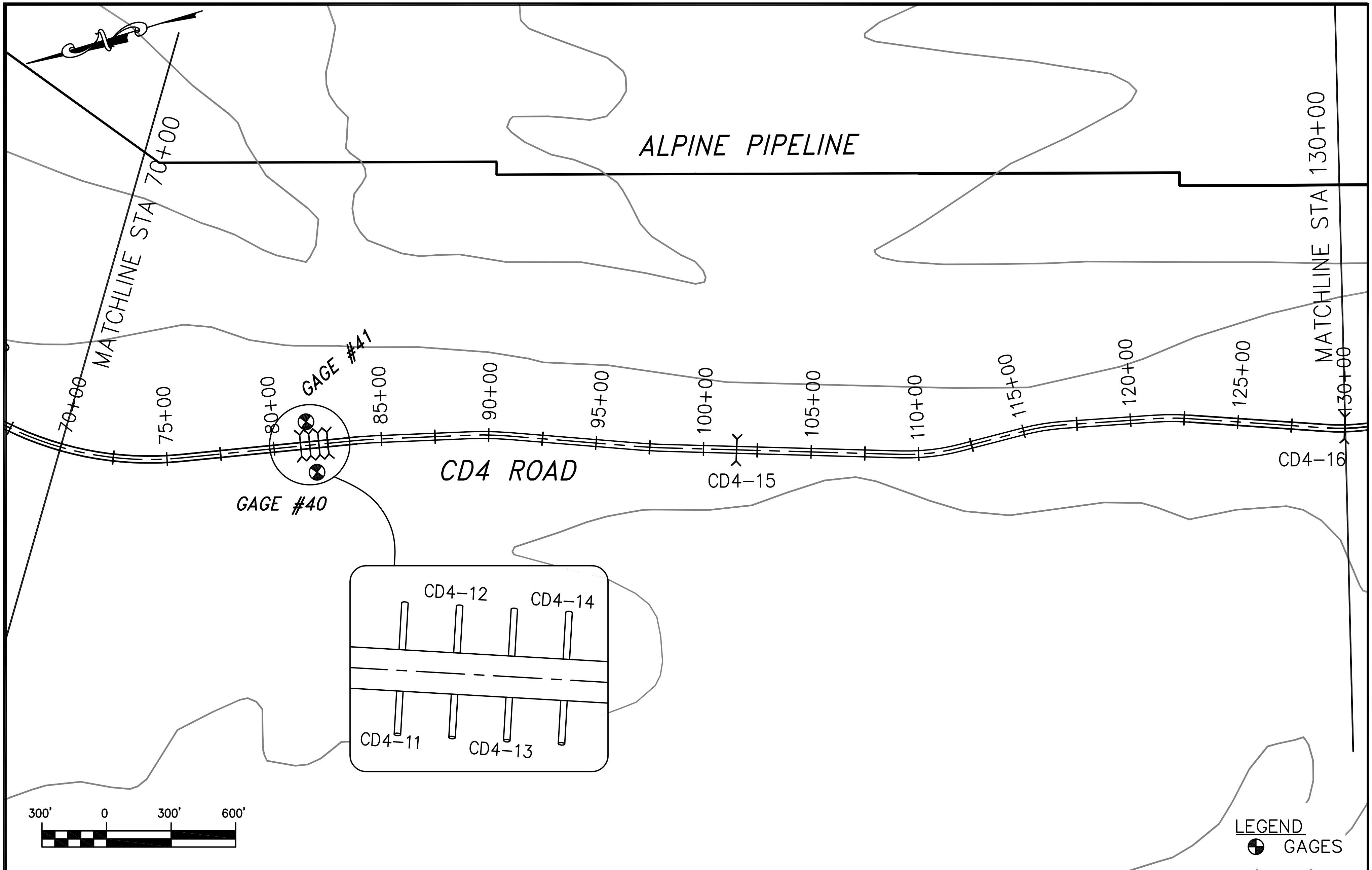
2015 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION



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Alaska, Inc.

DATE:	10/01/2015	PROJECT:	148414
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CHECKED:	GCY	SCALE:	AS SHOWN

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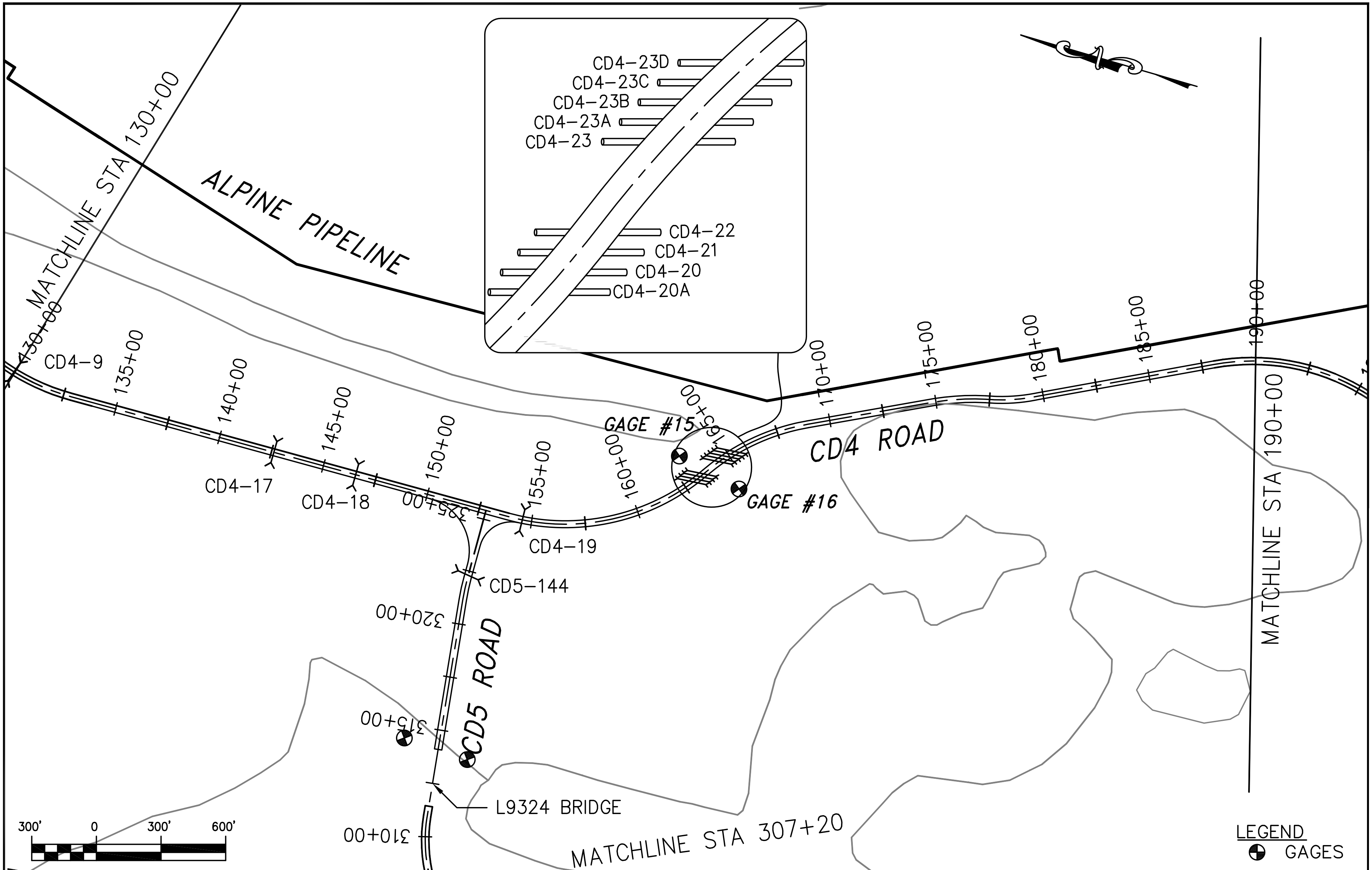
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 4 OF 13)



ConocoPhillips
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DATE: 10/01/2015	PROJECT: 148414
DRAWN: DTR	FILE: ALPINE_FACILITES.DWG
CHECKED: GCY	SCALE: AS SHOWN

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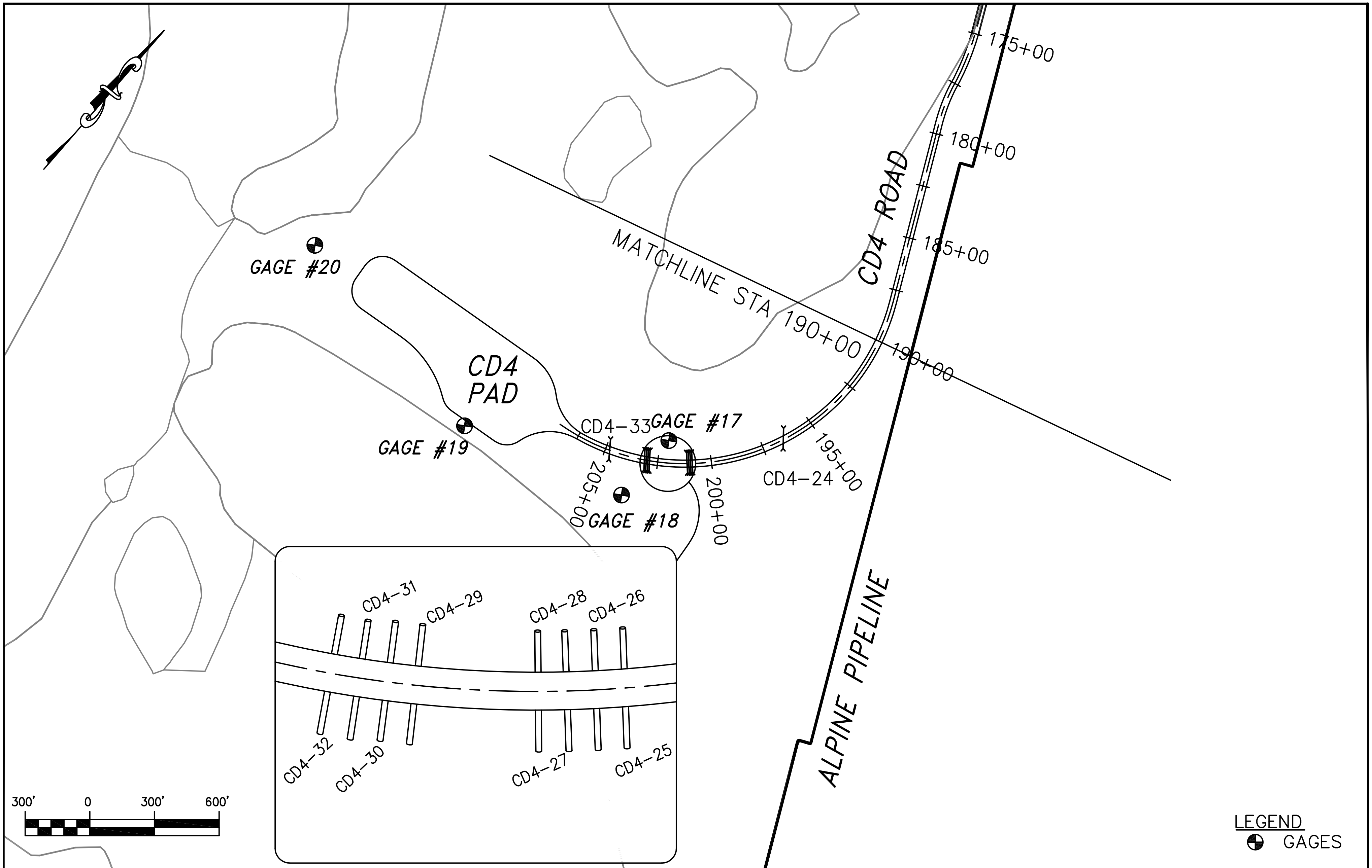
2015 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 5 OF 13)



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DATE: 10/01/2015	PROJECT: 148414
DRAWN: DTR	FILE: ALPINE_FACILITES.DWG
CHECKED: GCY	SCALE: AS SHOWN

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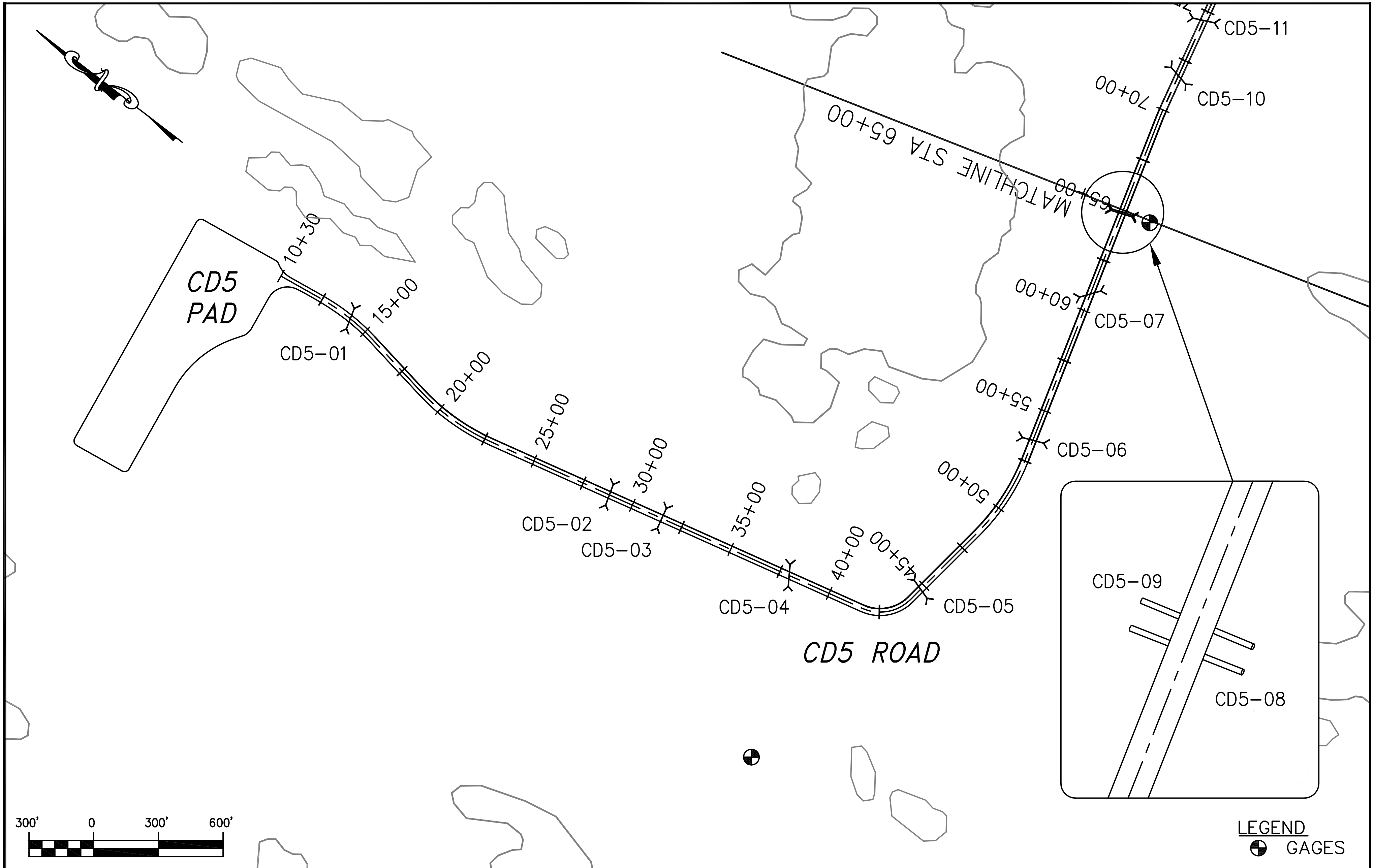
2015 SPRING BREAKUP

ALPINE FACILITIES

DRAINAGE STRUCTURE LOCATION

(SHEET 6 OF 13)

F.1.4 CD5 ROAD



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DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
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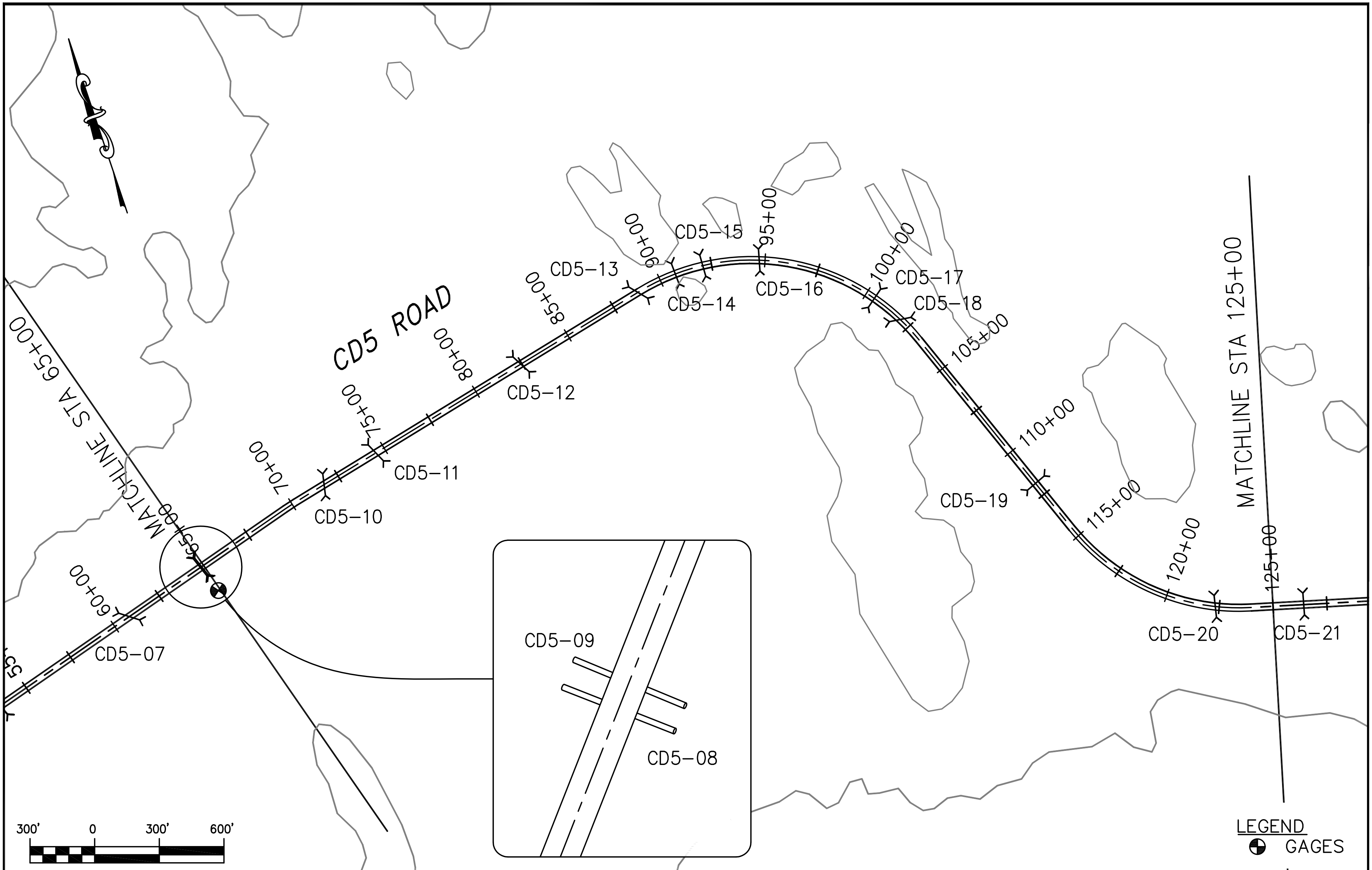
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 7 OF 13)



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DATE: 10/01/2015	PROJECT: 148414
DRAWN: DTR	FILE: ALPINE_FACILITES.DWG
CHECKED: GCY	SCALE: AS SHOWN

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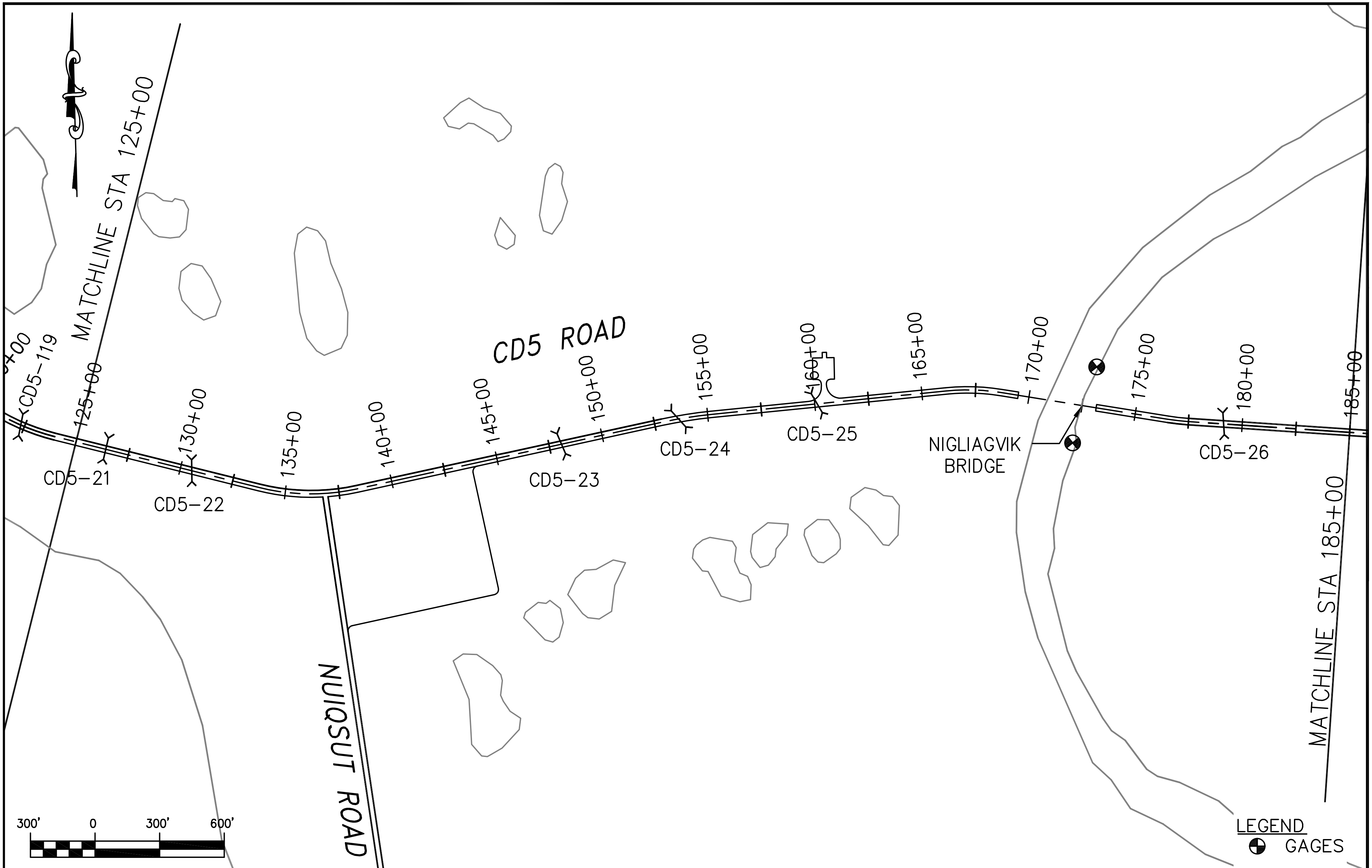
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET 8 OF 13)



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DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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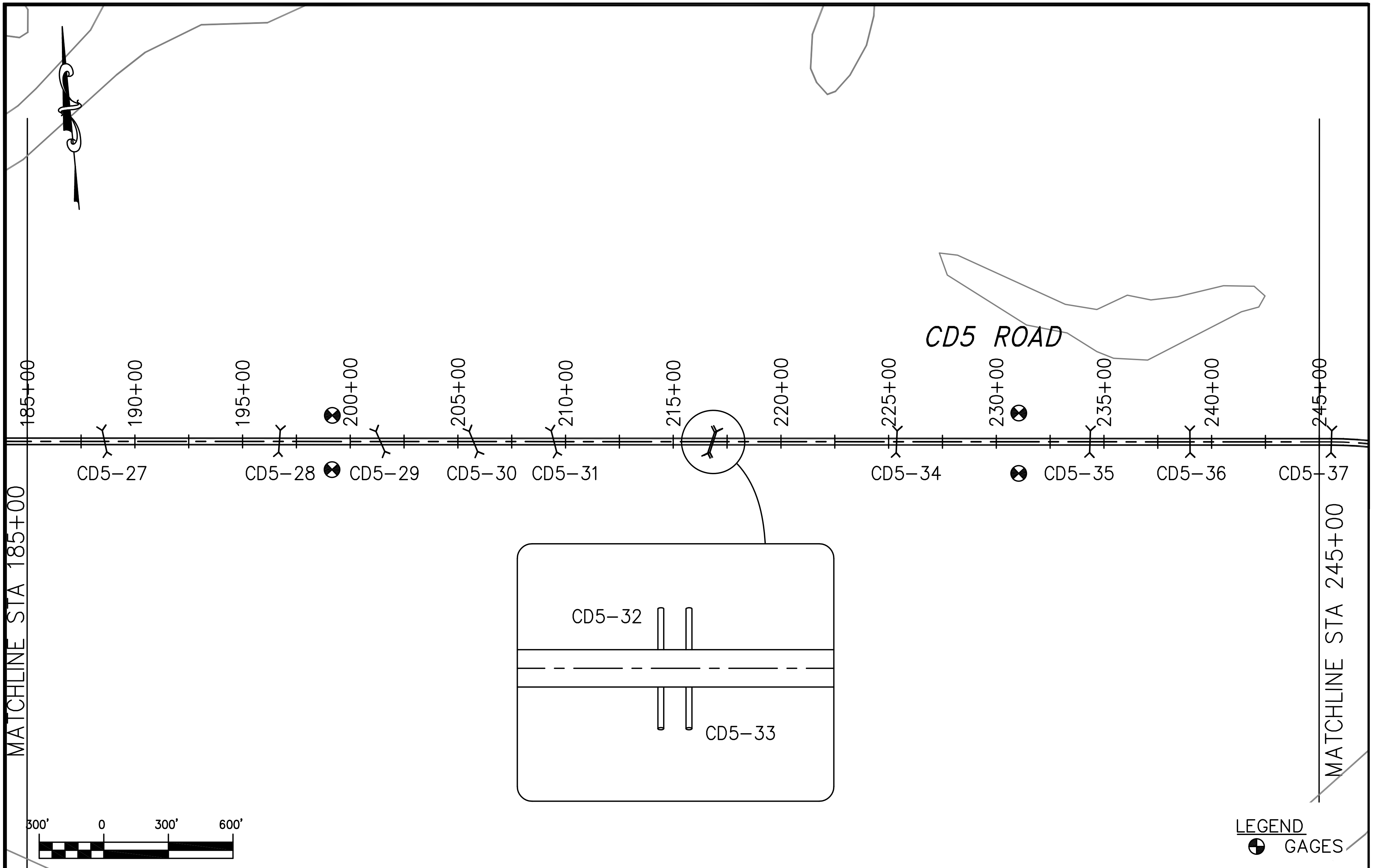
2015 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION



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DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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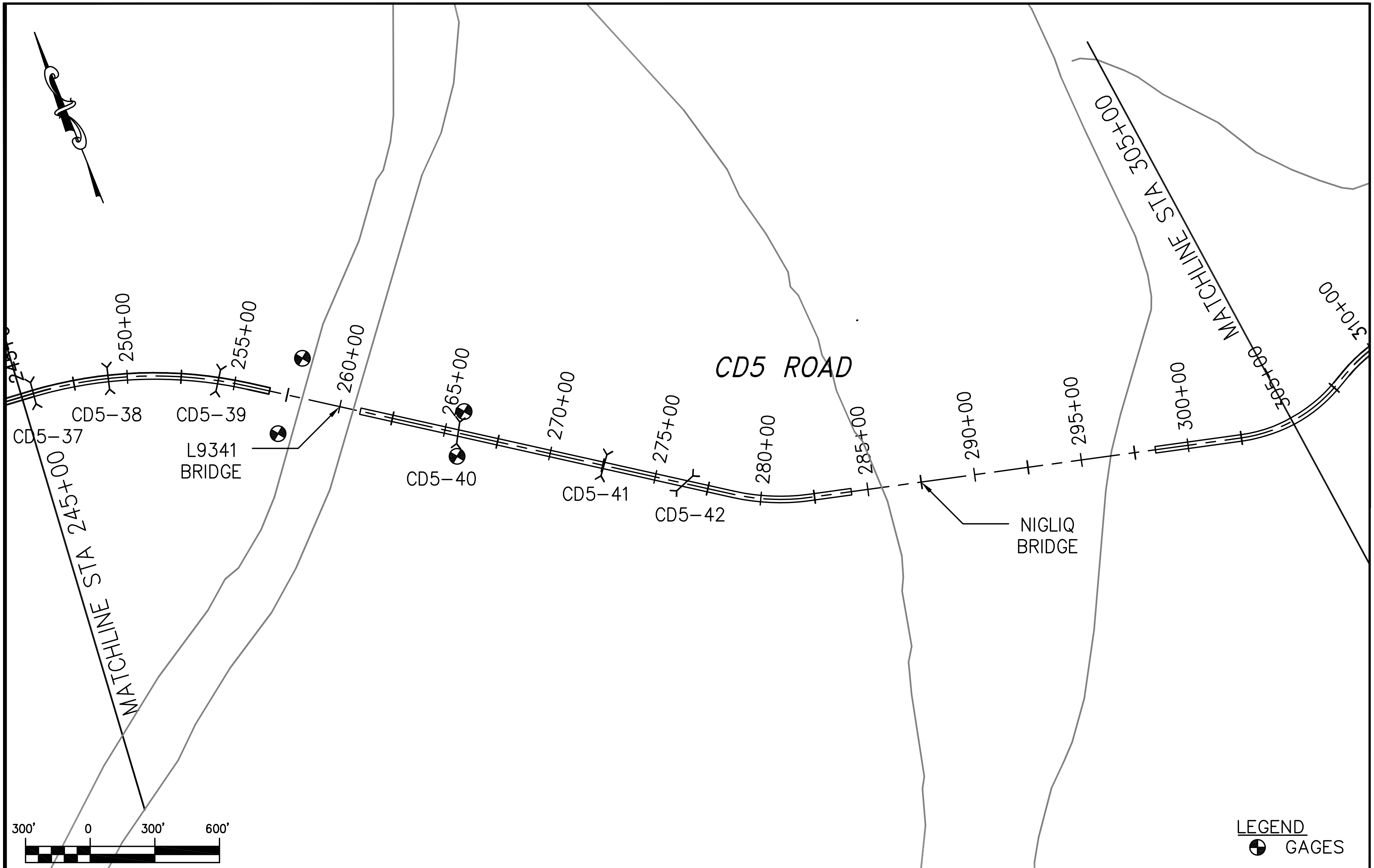
2015 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET10 OF 13)



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DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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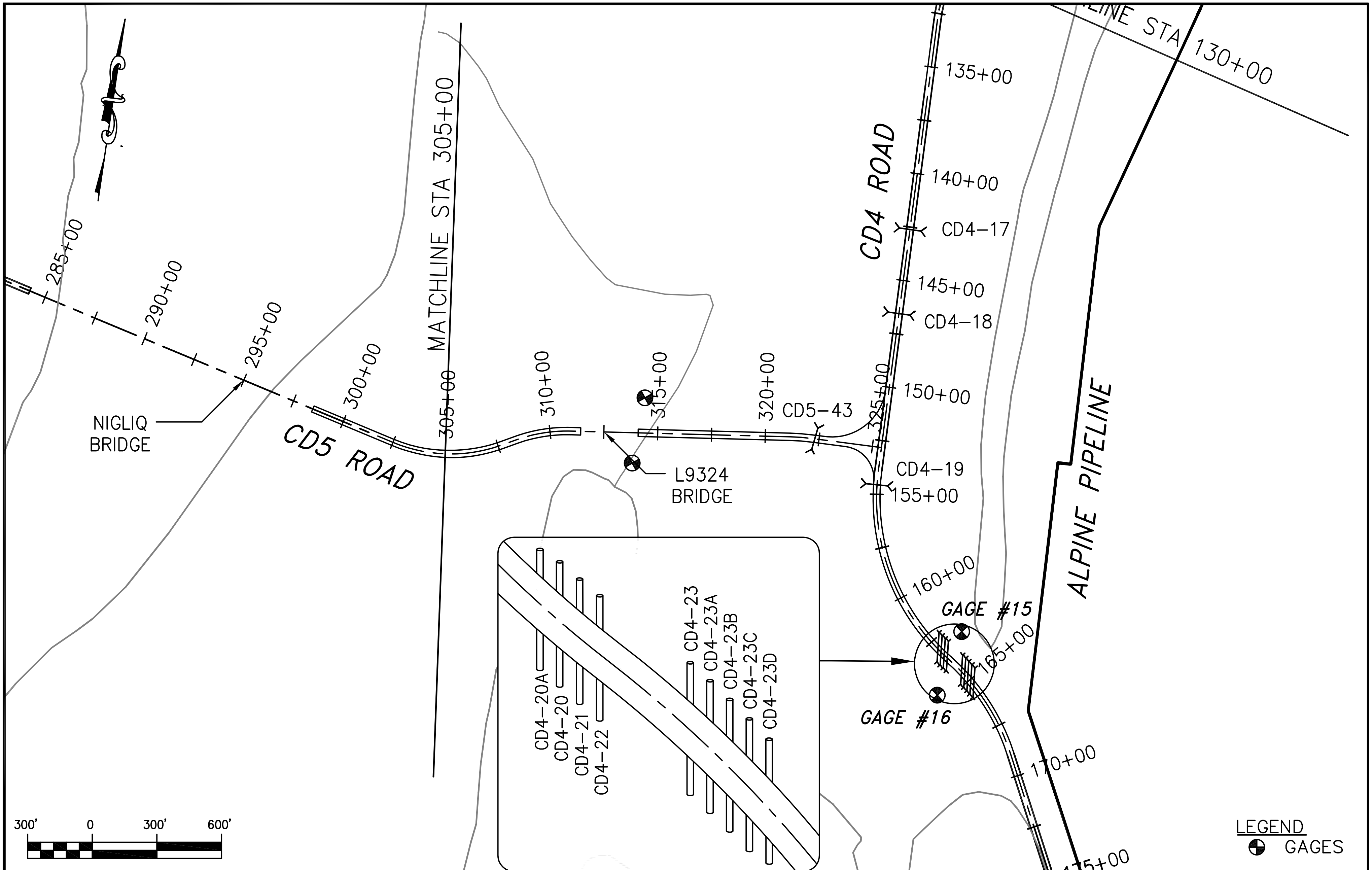
2015 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET11 OF 13)



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DATE:	10/01/2015	PROJECT:	148414
DRAWN:	DTR	FILE:	ALPINE_FACILITES.DWG
CHECKED:	GCY	SCALE:	AS SHOWN

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2015 SPRING BREAKUP
ALPINE FACILITIES
DRAINAGE STRUCTURE LOCATION

(SHEET12 OF 13)

F.2 Peak Velocity and Discharge

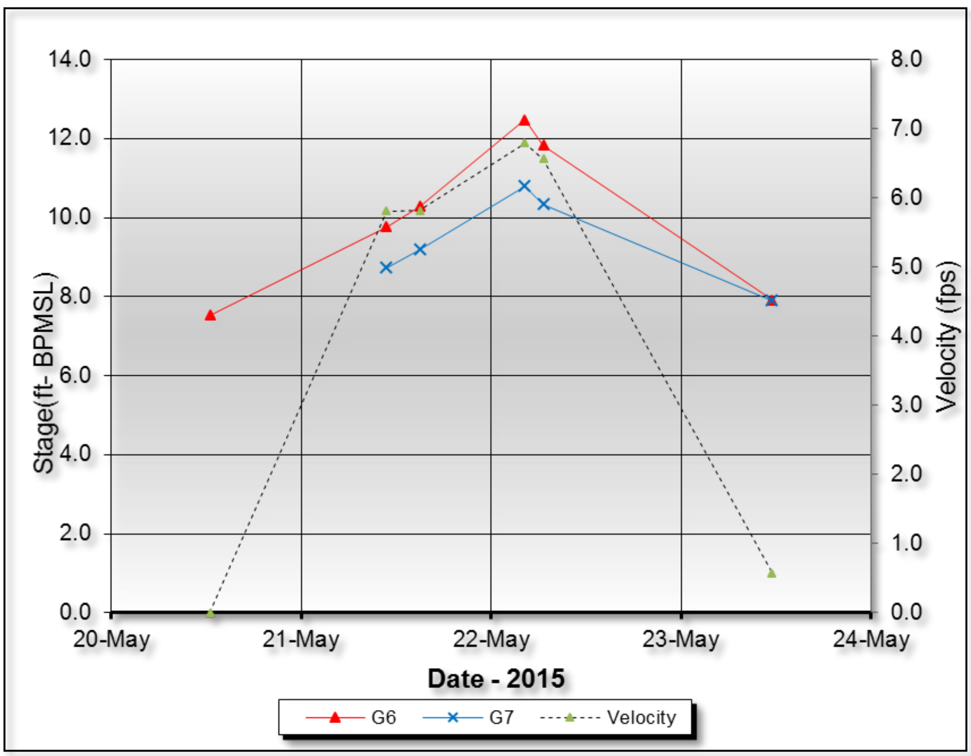
F.2.1 CD2 Road

F.2.1.1 Indirect Velocity

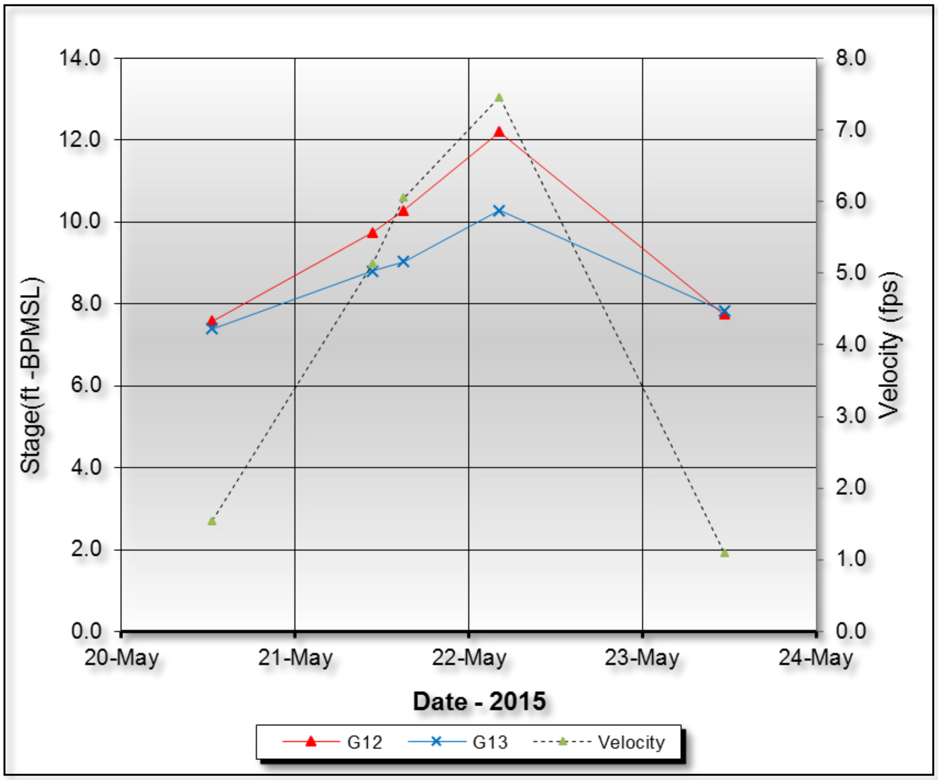
Table F.1: 2015 CD2 Road Culvert Indirect Velocity Summary

CD2 Culverts near G6/G7		CD2 Culverts near G12/G13		CD2 Culverts near G3/G4	
Culvert	May 22 4:15 AM	Culvert	May 22 4:15 AM	Culvert	May 22 4:15 AM
CD2-1	6.8	CD2-9	7.7	CD2-19	7.7
CD2-2	7.0	CD2-10	7.4	CD2-20	6.9
CD2-3	7.0	CD2-11	7.2	CD2-21	6.8
CD2-4	7.0	CD2-12	7.6	CD2-22	6.9
CD2-5	7.0	CD2-13	6.9	CD2-23	6.9
CD2-6	5.6	CD2-14	6.9	CD2-24	6.8
CD2-7	7.0	CD2-15	7.6	CD2-25	6.7
CD2-8	7.0	CD2-16	7.7	CD2-26	6.7
		CD2-17	7.9		
		CD2-18	8.0		
Average Velocity (ft/s)	6.8		7.5		6.9

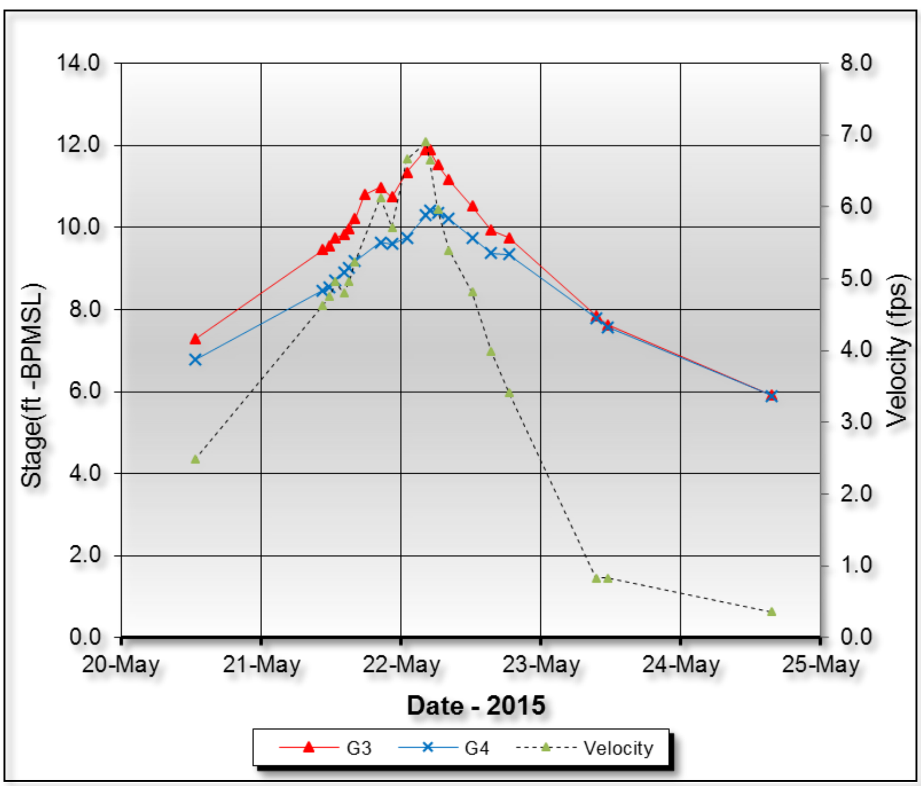
Notes:
1. The time of peak velocity at gages G6/G7 and G12/G13 is an estimate based on observations



Graph F.1: Indirect Velocity vs. Observed Stage, CD2 Road Culverts CD2-1 through CD2-8 near G6/G7



Graph F.2: Indirect Velocity vs. Observed Stage, CD2 Road Culverts CD2-9 through CD2-18 near G12/G13



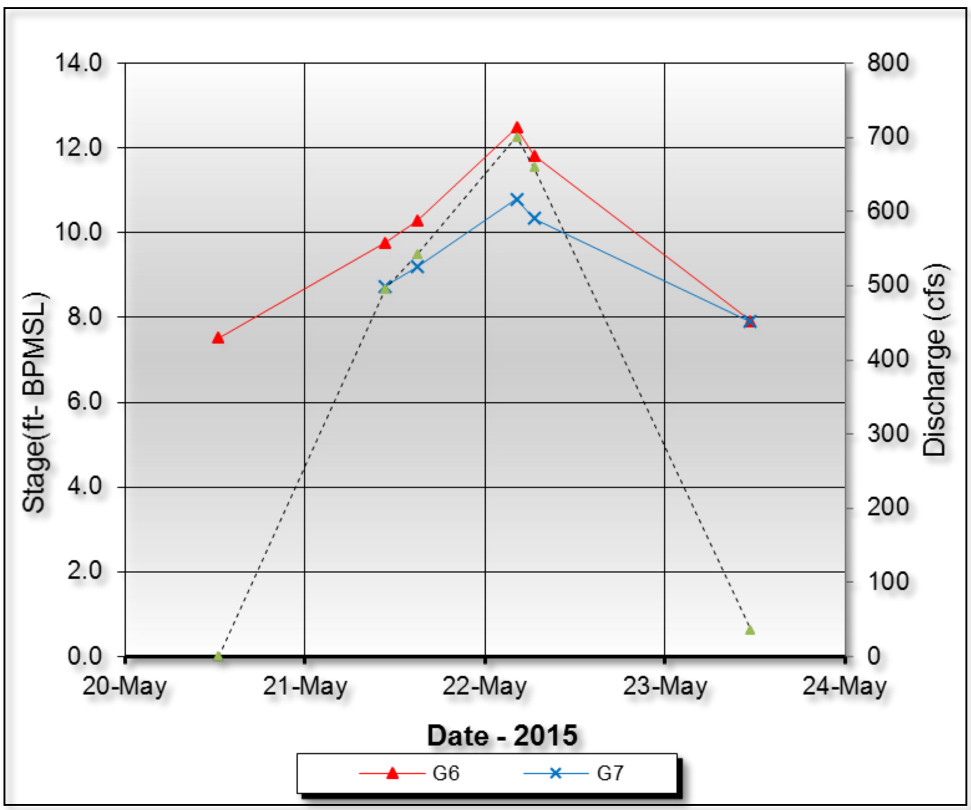
Graph F.3: Indirect Velocity vs. Observed Stage, CD2 Road Culverts CD2-19 through CD2-26 near G3/G4

F.2.1.2 Indirect Discharge

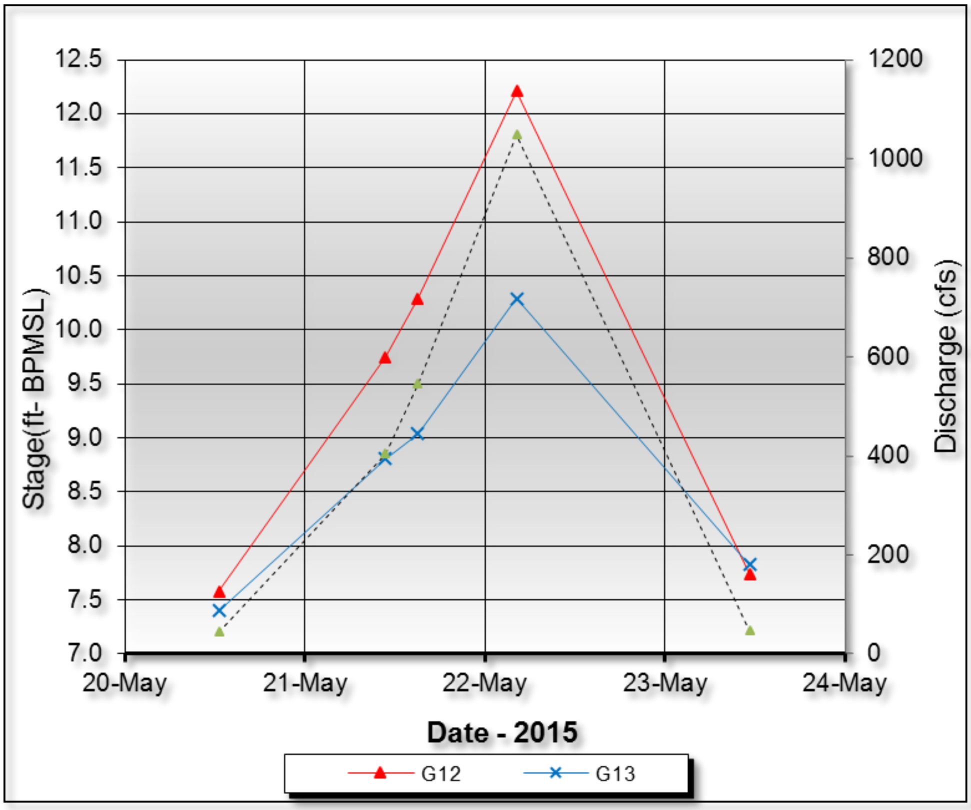
Table F.2: 2015 CD2 Road Culvert Indirect Discharge Summary

CD2 Culverts near G6/G7		CD2 Culverts near G12/G13		CD2 Culverts near G3/G4	
Culvert	May 22 4:15 AM	Culvert	May 22 4:15 AM	Culvert	May 22 4:15 AM
CD2-1	86	CD2-9	112	CD2-19	59
CD2-2	88	CD2-10	116	CD2-20	86
CD2-3	87	CD2-11	121	CD2-21	86
CD2-4	88	CD2-12	162	CD2-22	86
CD2-5	88	CD2-13	123	CD2-23	86
CD2-6	88	CD2-14	126	CD2-24	86
CD2-7	88	CD2-15	93	CD2-25	37
CD2-8	88	CD2-16	56	CD2-26	37
		CD2-17	60		
		CD2-18	79		
Total Discharge (cfs)	700		1,049		563

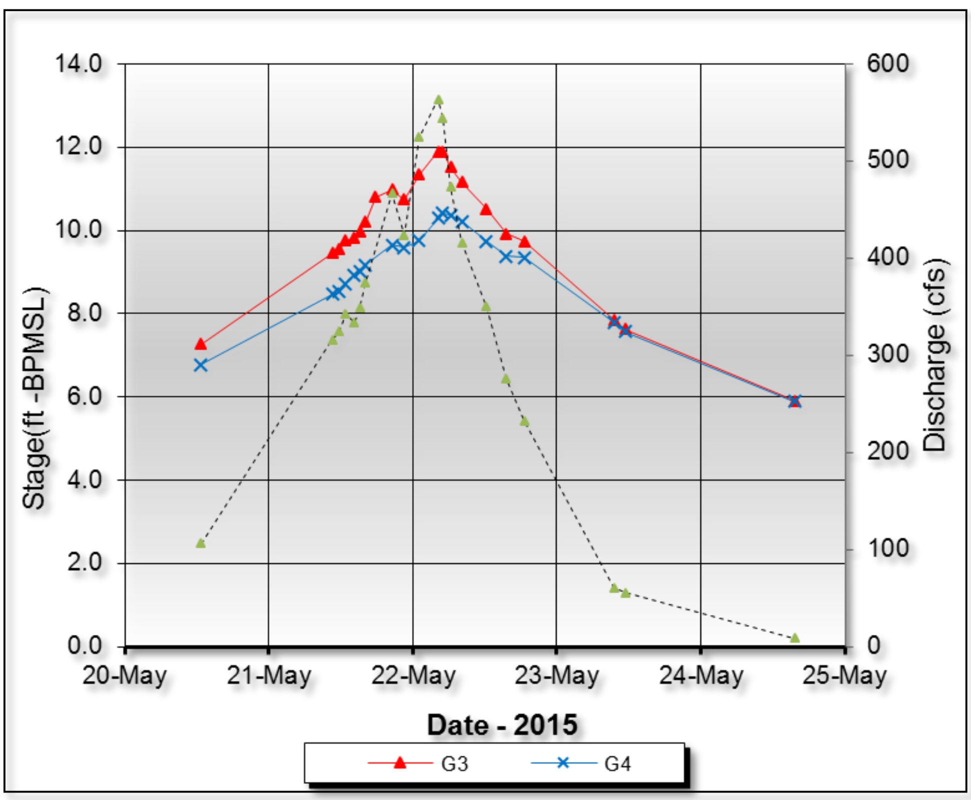
Notes:
1. The time of peak velocity at gages G6/G7 and G12/G13 is an estimate based on observations near gages G3/G4



Graph F.4: Indirect Discharge vs. Observed Stage, CD2 Road Culverts CD2-1 through CD2-8 near G6/G7



Graph F.5: Indirect Discharge vs. Observed Stage, CD2 Road Culverts CD2-9 through CD2-18 near G12/G13



Graph F.6: Indirect Discharge vs. Observed Stage, CD2 Road Culverts CD2-19 through CD2-26 near G3/G4

F.2.2 CD4 Road Culverts

F.2.2.1 Indirect Velocity

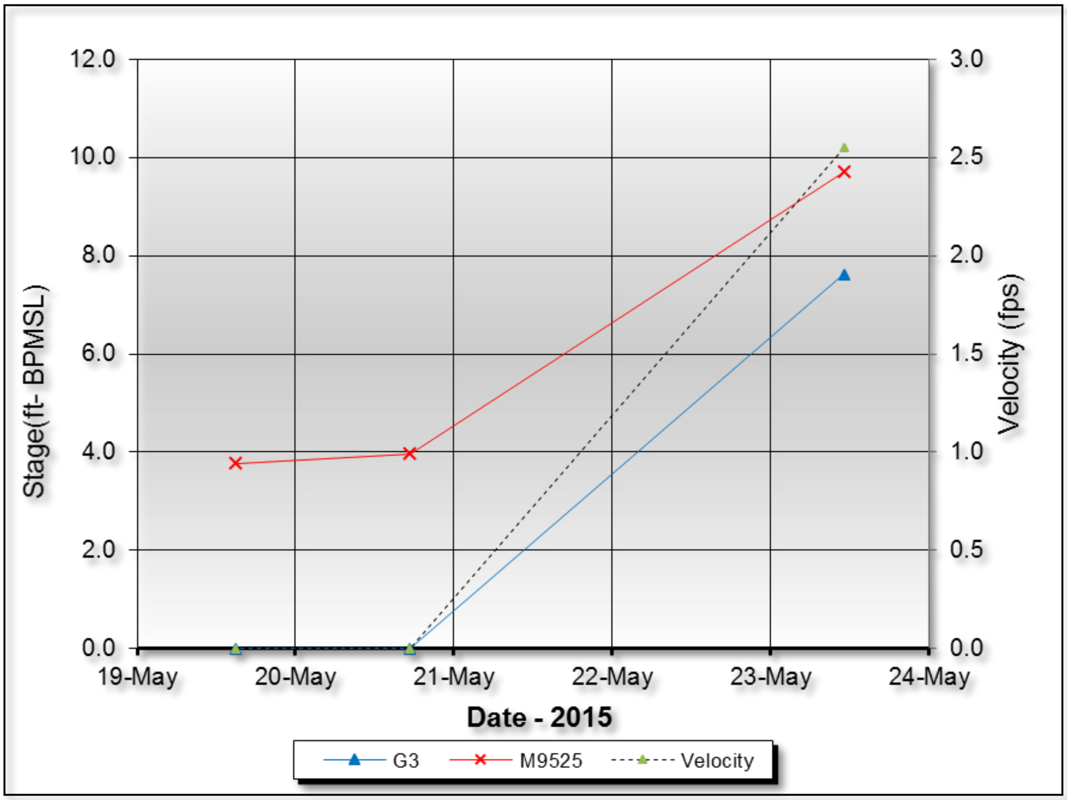
Table F.3: 2015 CD4 Road Culvert Indirect Velocity Summary

CD4 Culverts near G3/M9525		CD4 Culverts near G42/G43 [1]		CD4 Culverts near G40/G41	
Culvert	May 23 11:06 AM	Culvert	May 21 3:25 PM	Culvert	May 21 3:25 PM
CD4-1	4.3	CD4-8	5.3	CD4-11	0.0
CD4-2	0.0	CD4-9	4.3	CD4-12	3.3
CD4-3	4.6	CD4-10	7.3	CD4-13	5.1
CD4-4	5.0			CD4-14	0.0
CD4-5	0.0			CD4-15	0.0
CD4-6	0.0			CD4-16	0.0
CD4-7	4.0			CD4-17	0.0
				CD4-18	0.0
Average Velocity (ft/s)	**2.6**		**5.7**		**1.0**

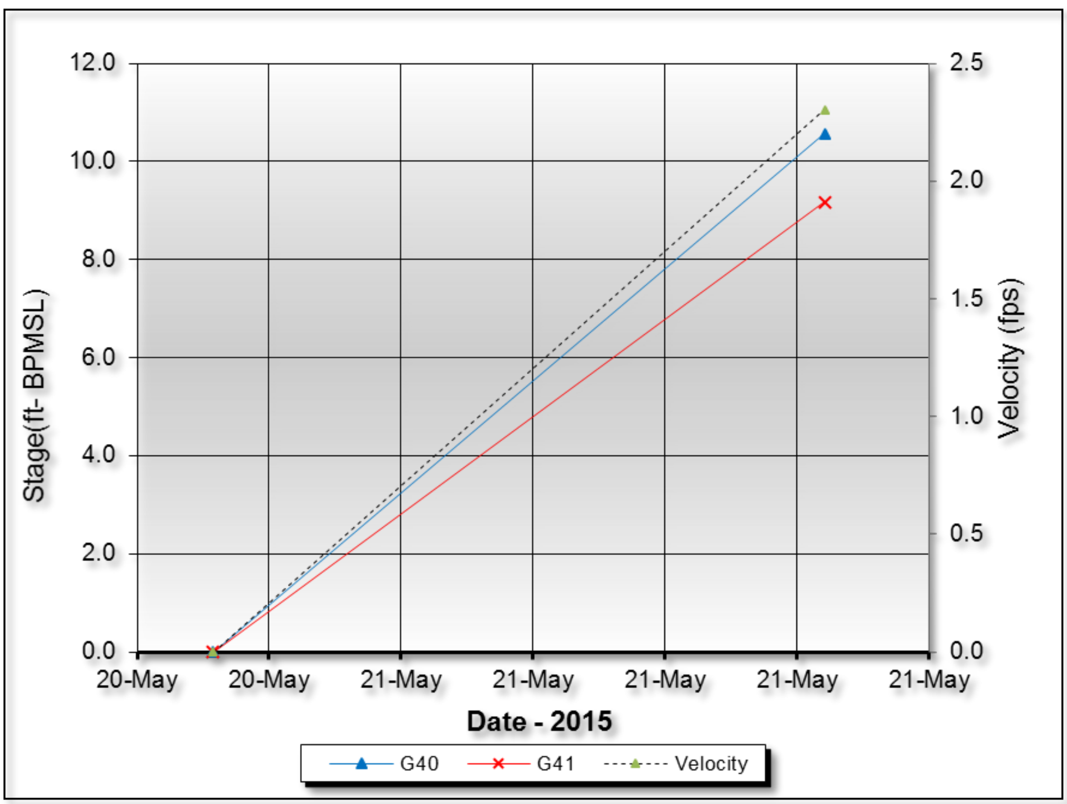
Notes:
1. Gages G42/G43 were submerged during peak stage; culverts CD4-8 through CD4-10 used gage G40/G41 WSEs to obtain velocity measurements.

Table F.4: 2015 CD4 Road Culvert Indirect Velocity Summary - Continued

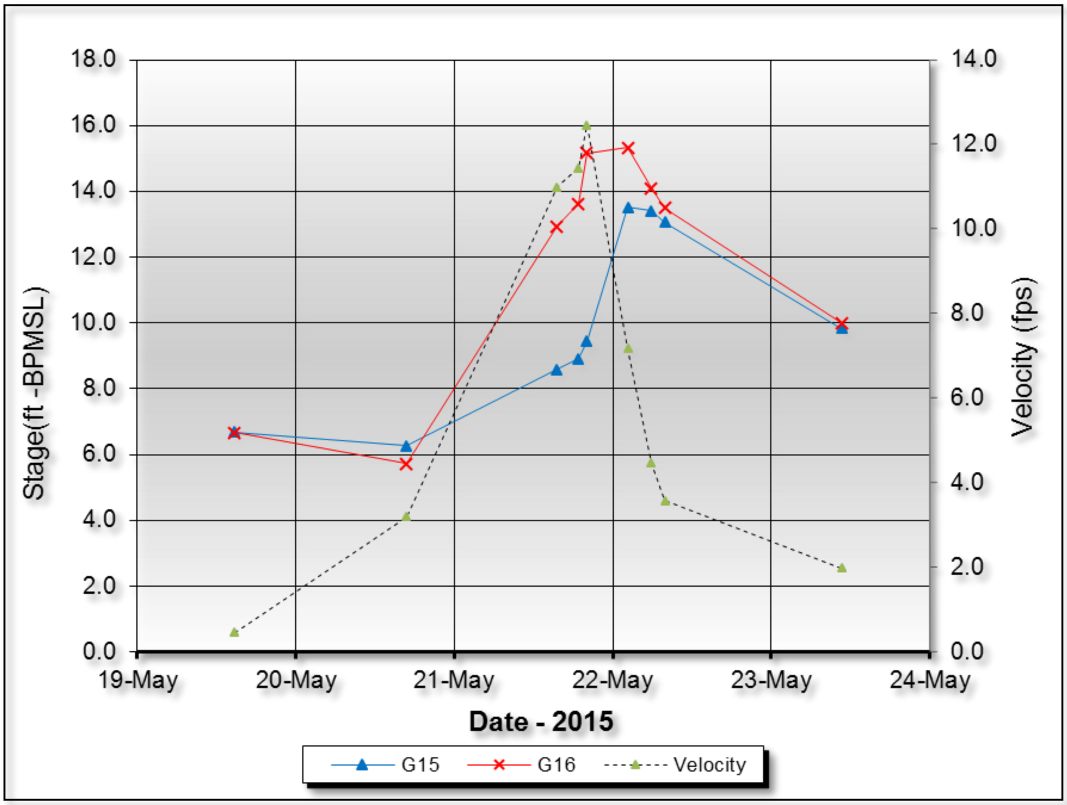
CD4 Culverts near G16/G15		CD4 Culverts near G18/G17	
Culvert	May 21 8:03 PM	Culvert	May 21 3:00 PM
CD4-19	7.1	CD4-24	6.6
CD4-20A	12.8	CD4-25	6.9
CD4-20	12.8	CD4-26	7.0
CD4-21	12.8	CD4-27	6.9
CD4-22	12.8	CD4-28	6.9
CD4-23	12.6	CD4-29	6.7
CD4-23A	12.1	CD4-30	6.7
CD4-23B	13.8	CD4-31	6.7
CD4-23C	15.2	CD4-32	6.9
CD4-23D	12.5	CD4-33	6.7
Average Velocity (ft/s)	**12.5**		**6.8**



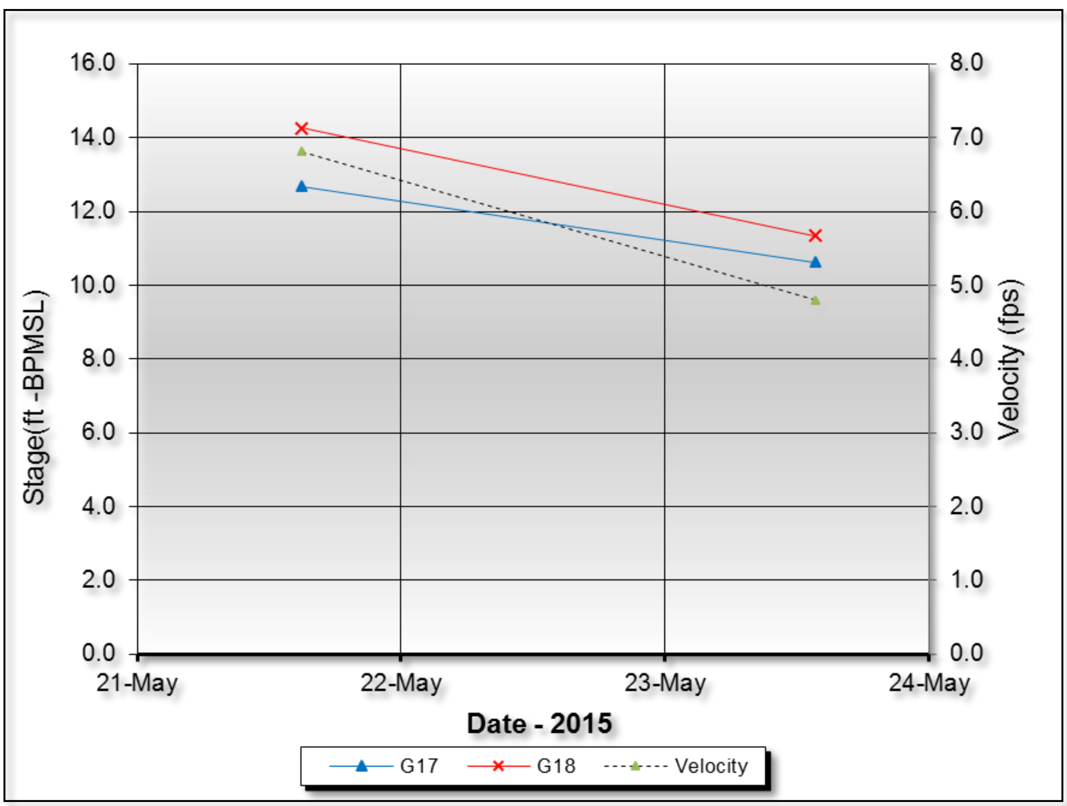
Graph F.7: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-1 through CD4-7 near G3/M9525



Graph F.8: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-8 through CD4-18 near G40/G41



Graph F.9: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-19 through CD4-23D near G16/G15



Graph F.10: Indirect Velocity vs. Observed Stage, CD4 Road Culverts CD4-24 through CD4-33 near G18/G17

F.2.2.2 Indirect Discharge

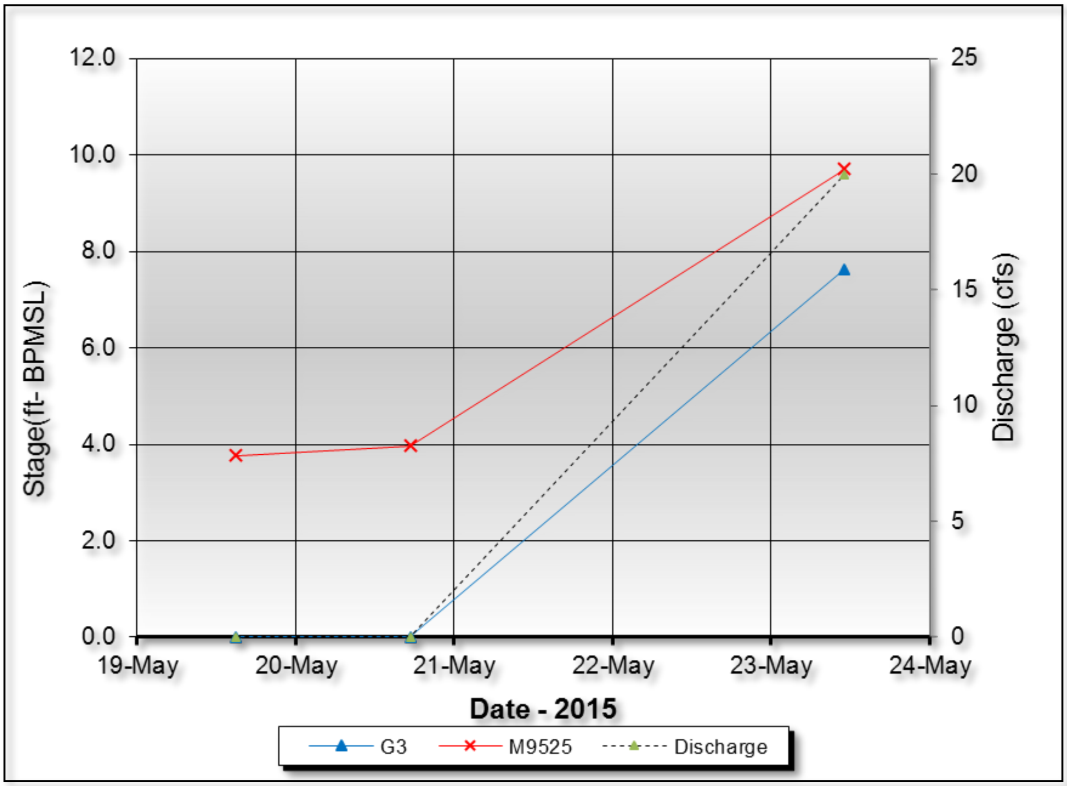
Table F.5: 2015 CD4 Road Culvert Indirect Discharge Summary

CD4 Culverts near G3/M9525		CD4 Culverts near G42/G43 [1]		CD4 Culverts near G40/G41	
Culvert	May 23 11:06 AM	Culvert	May 21 3:25 PM	Culvert	May 21 3:25 PM
CD4-1	-7	CD4-8	14	CD4-11	0
CD4-2	0	CD4-9	7	CD4-12	4
CD4-3	-5	CD4-10	19	CD4-13	5
CD4-4	-3			CD4-14	0
CD4-5	0			CD4-15	0
CD4-6	0			CD4-16	0
CD4-7	-5			CD4-17	0
				CD4-18	0
Total Discharge (cfs)	20		39		9

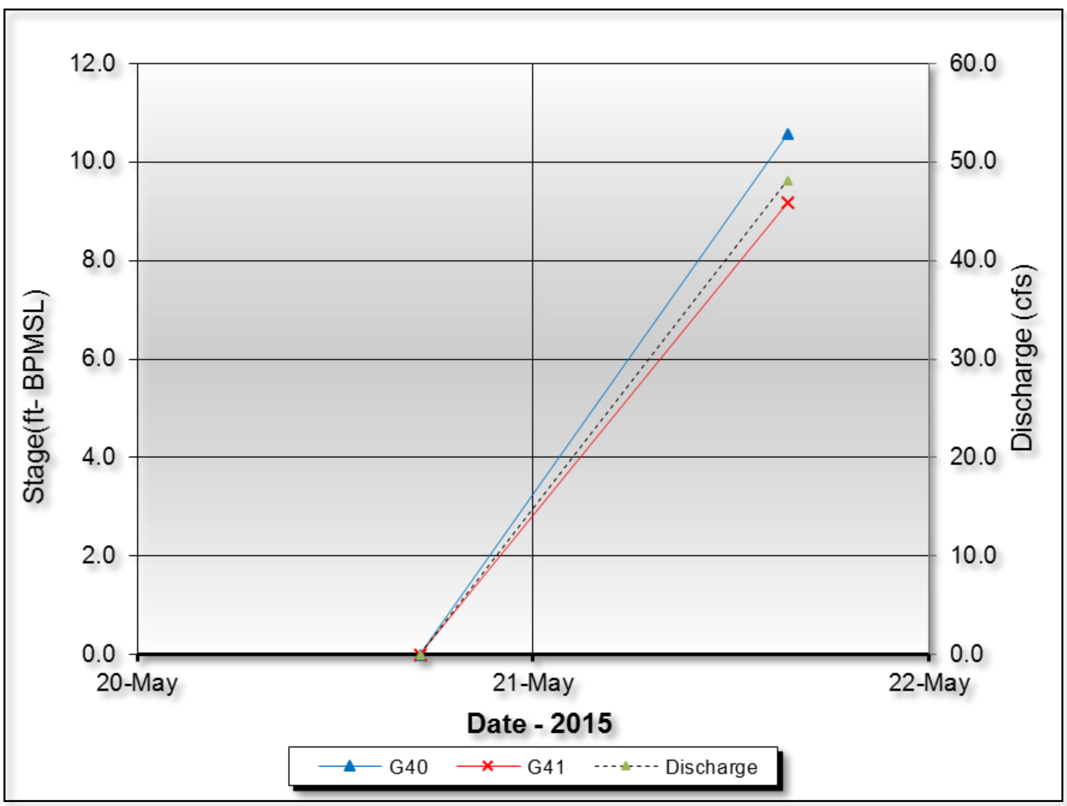
Notes:
1. Gages G42/G43 were submerged during peak stage; culverts CD4-8 through CD4-10 used gage G40/G41 WSEs to obtain discharge measurements.
2. Negative values indicate culvert is flowing west to east

Table F.6: 2015 CD4 Road Culvert Indirect Discharge Summary - Continued

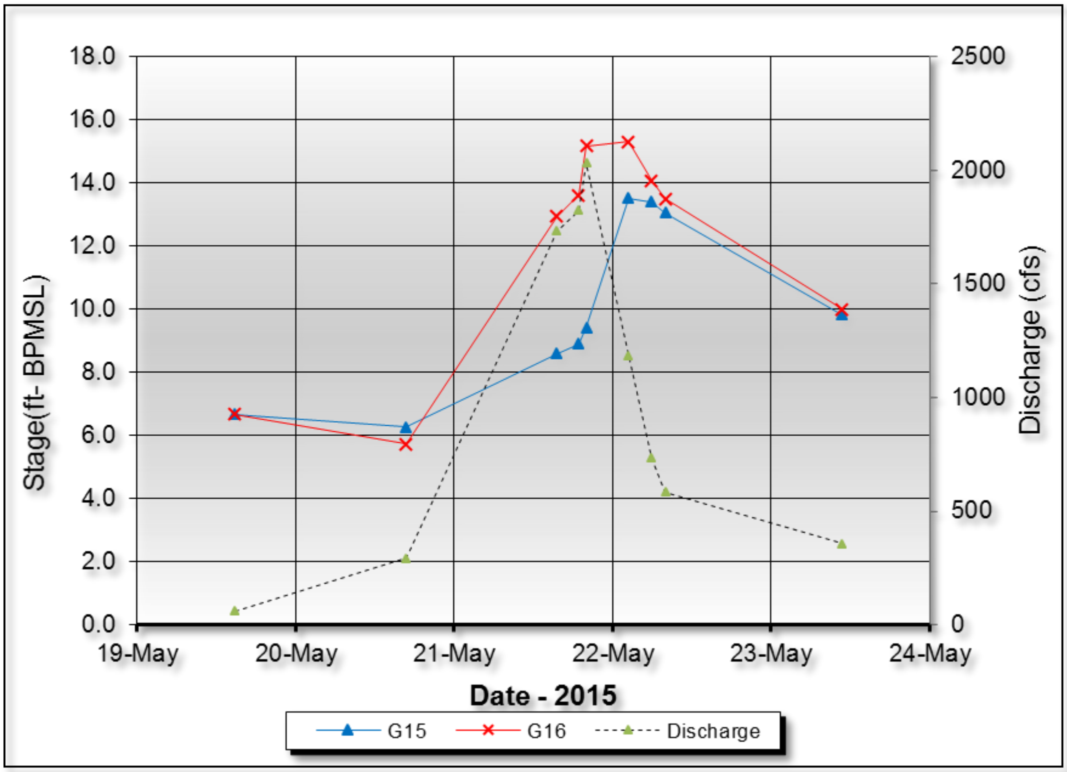
CD4 Culverts near G16/G15		CD4 Culverts near G18/G17	
Culvert	May 21 8:03 PM	Culvert	May 21 3:00 PM
CD4-19	19	CD4-24	83
CD4-20A	252	CD4-25	82
CD4-20	252	CD4-26	83
CD4-21	252	CD4-27	84
CD4-22	252	CD4-28	84
CD4-23	223	CD4-29	85
CD4-23A	234	CD4-30	85
CD4-23B	241	CD4-31	85
CD4-23C	152	CD4-32	83
CD4-23D	156	CD4-33	85
Total Discharge (cfs)	2,034		836



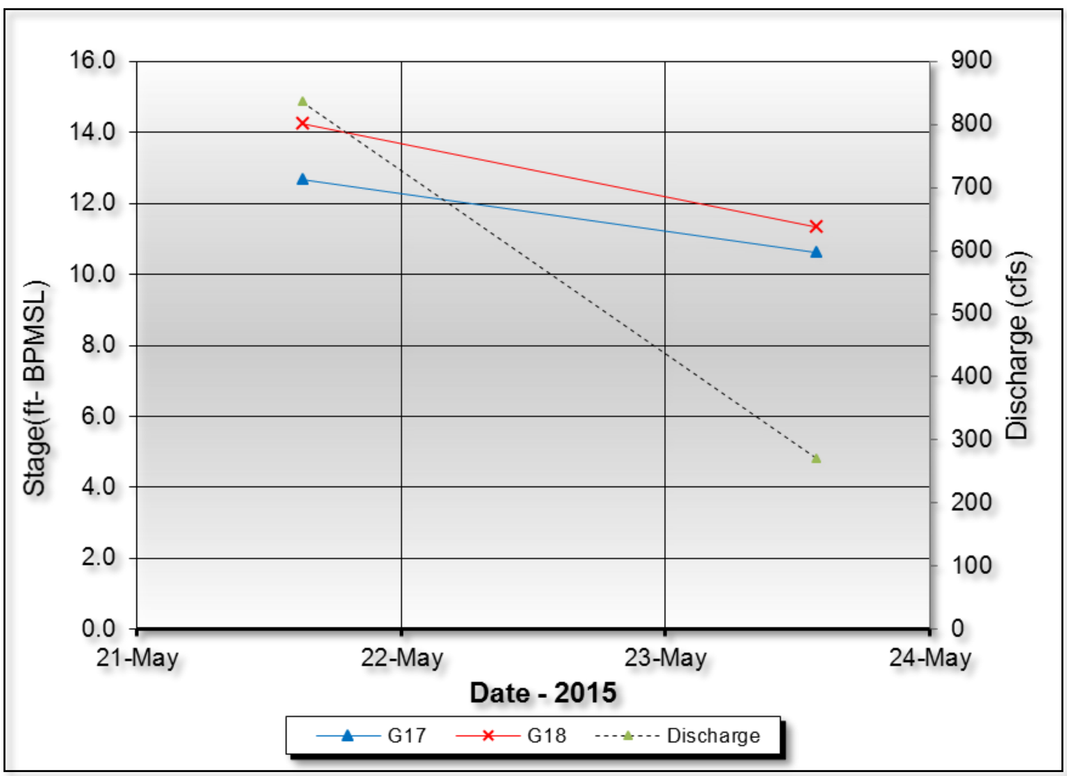
Graph F.11: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-1 through CD4-7 near G3/M9525



Graph F.12: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-8 through CD4-18 near G40/G41



Graph F.13: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-19 through CD4-23D near G16/G15



Graph F.14: Indirect Discharge vs. Observed Stage, CD4 Road Culverts CD4-24 through CD4-33 near G18/G17

F.2.3 CD5 Road Culverts

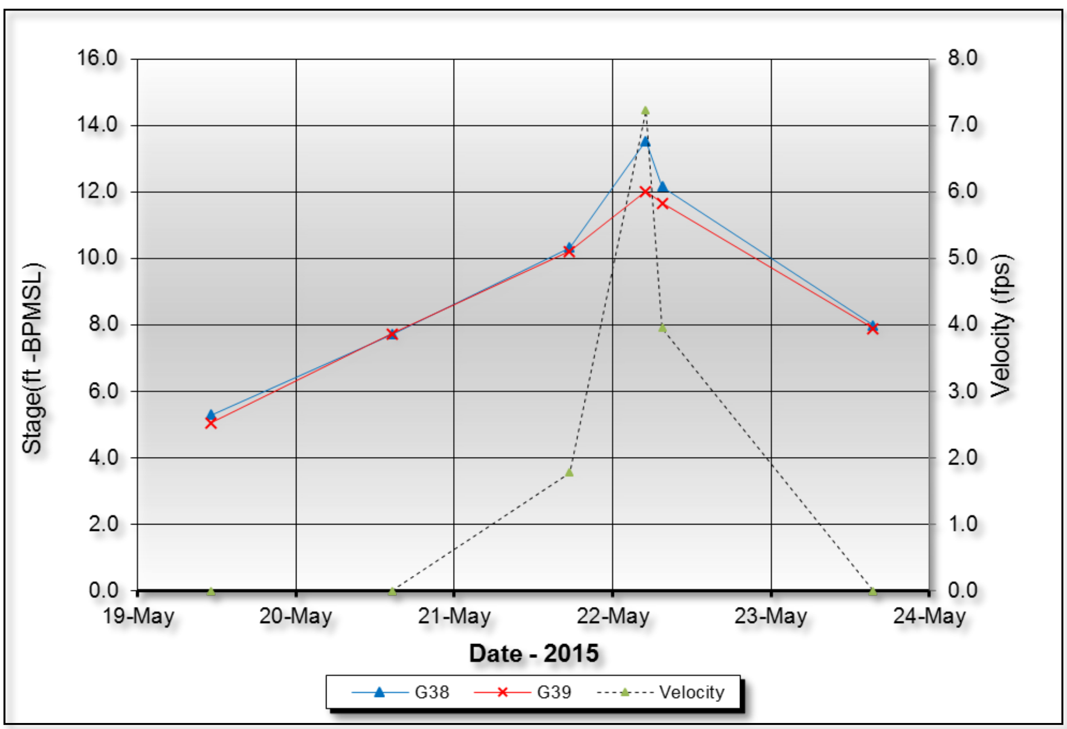
F.2.3.1 Indirect Velocity

Table F.7: 2015 CD5 Road Culvert Indirect Velocity Summary

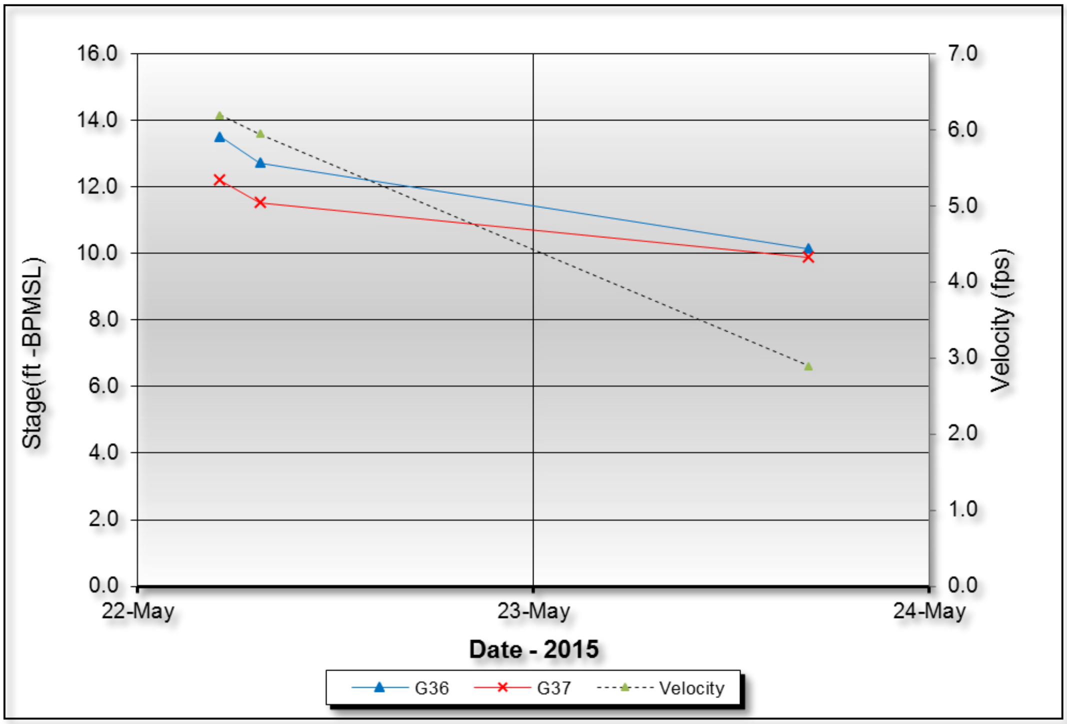
CD5 Culverts near G38/G39		CD5 Culverts near G36/G37		CD5 Culverts near G34/G35	
Culvert	May 22 5:00 AM	Culvert	May 22 5:00 AM	Culvert	May 22 5:00 AM
CD5-26	7.2	CD5-27	6.2	CD5-32	6.3
		CD5-28	6.2	CD5-33	6.3
		CD5-29	6.3	CD5-34	6.4
		CD5-30	6.2	CD5-35	6.4
		CD5-31	6.2	CD5-36	6.7
Average Velocity (ft/s)	**7.2**		**6.2**		**6.5**
Notes: 1. Gages without peak data are denoted with a dash "-"					

Table F.8: 2015 CD5 Road Culvert Indirect Velocity Summary - Continued

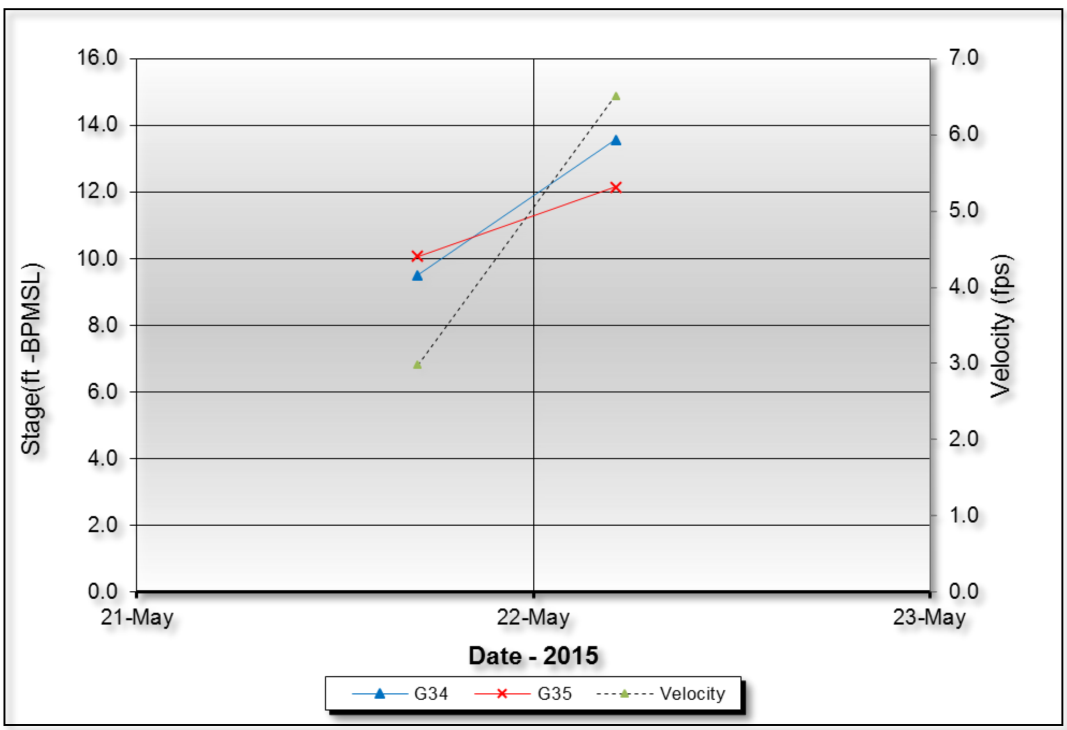
CD5 Culverts near G32/G33		CD5 Culverts near G30/G31		CD5 Culverts near G24/G25	
Culvert	May 22 5:00 AM	Culvert	May 22 5:00 AM	Culvert	May 22 7:10 AM
CD5-37	1.6	CD5-40	4.2	CD5-43	3.5
CD5-38	1.6	CD5-41	4.3		
CD5-39	1.6	CD5-42	4.2		
Average Velocity (ft/s)	**1.6**		**4.3**		**3.5**



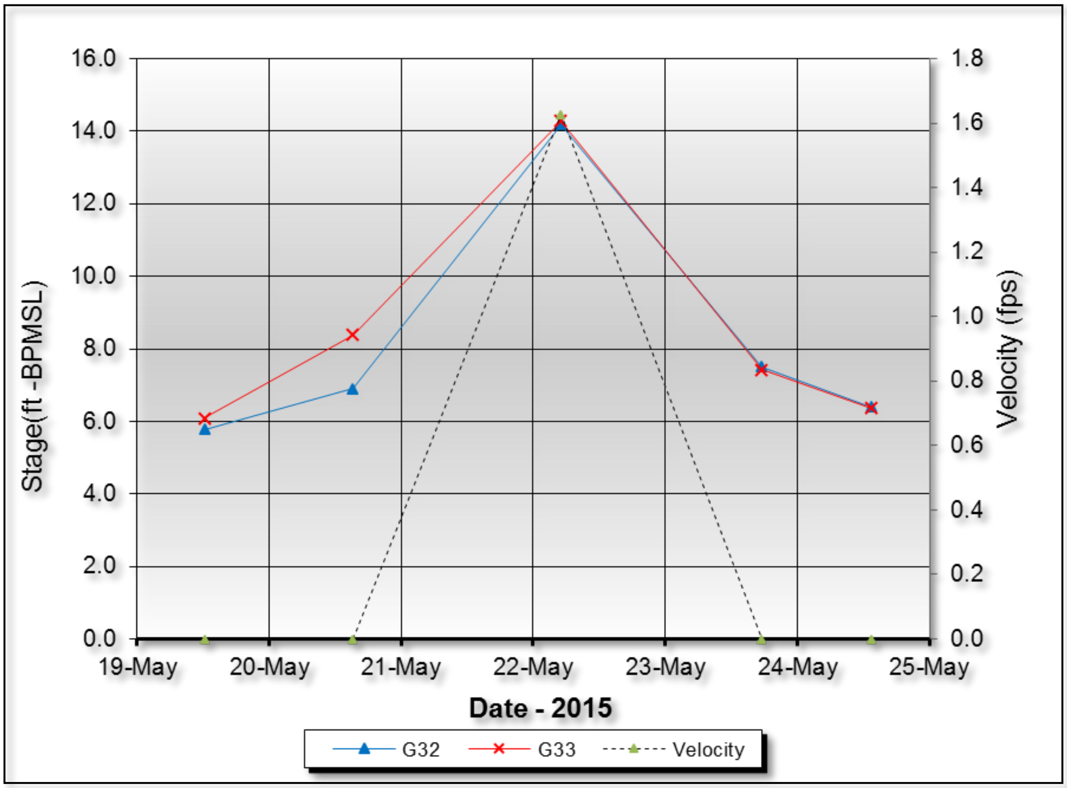
Graph F.15: Indirect Velocity vs. Observed Stage, CD5 Road Culvert CD5-26 near G38/G39



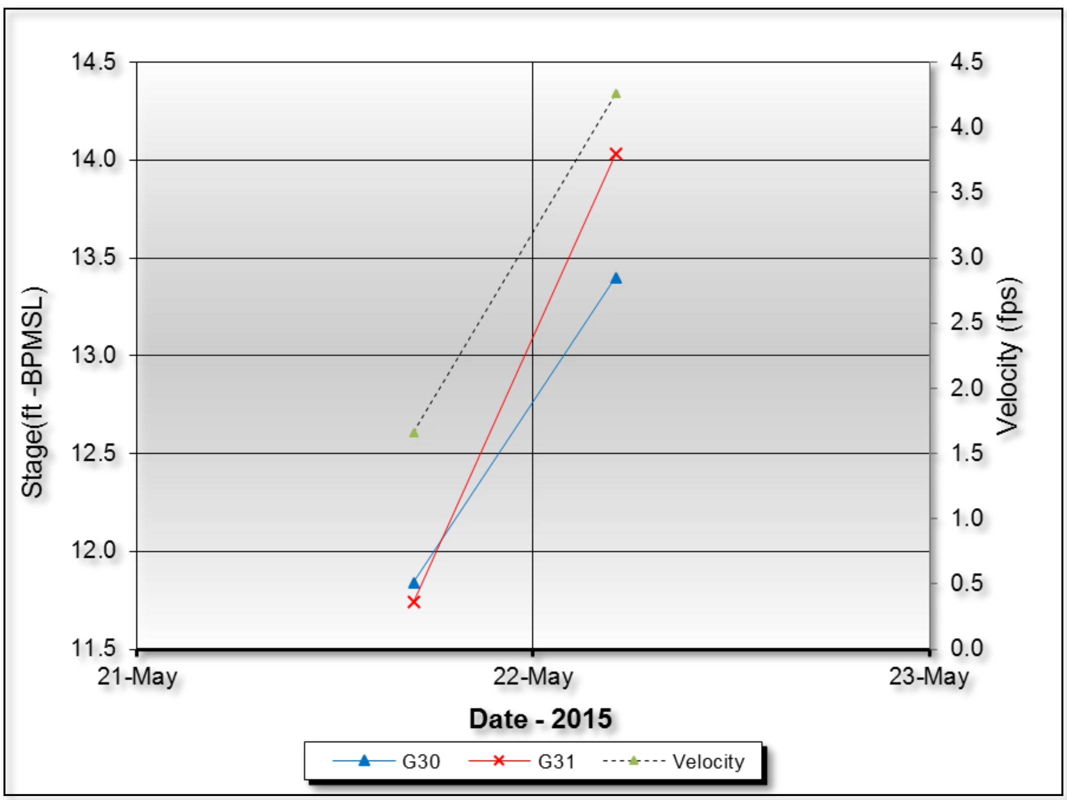
Graph F.16: Indirect Velocity vs. Observed Stage, CD5 Road Culvert CD5-28 and CD5-29 near G36/G37



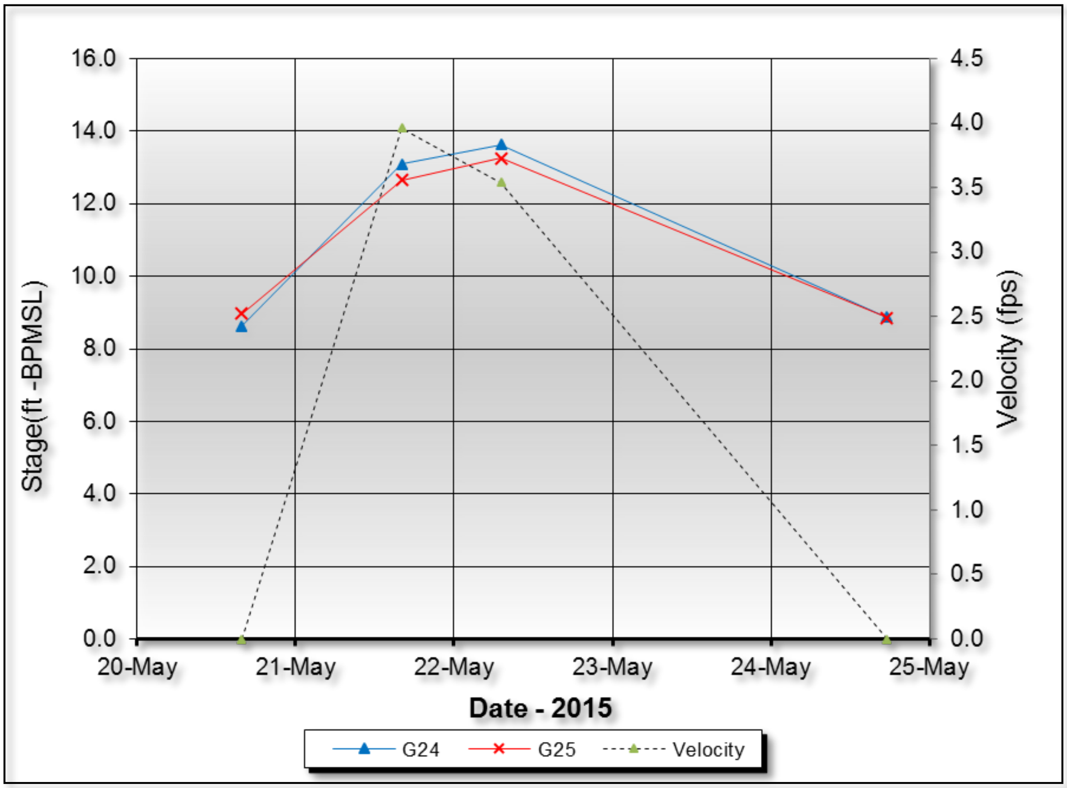
Graph F.17: Indirect Velocity vs. Observed Stage, CD5 Road Culvert CD5-34 and CD5-35 near G34/G35



Graph F.18: Indirect Velocity vs. Observed Stage, CD5 Road Culvert CD5-39 near G32/G33



Graph F.19: Indirect Velocity vs. Observed Stage, CD5 Road Culvert CD5-40 near G30/G31



Graph F.20: Indirect Velocity vs. Observed Stage, CD5 Road Culvert CD5-43 near G24/G25

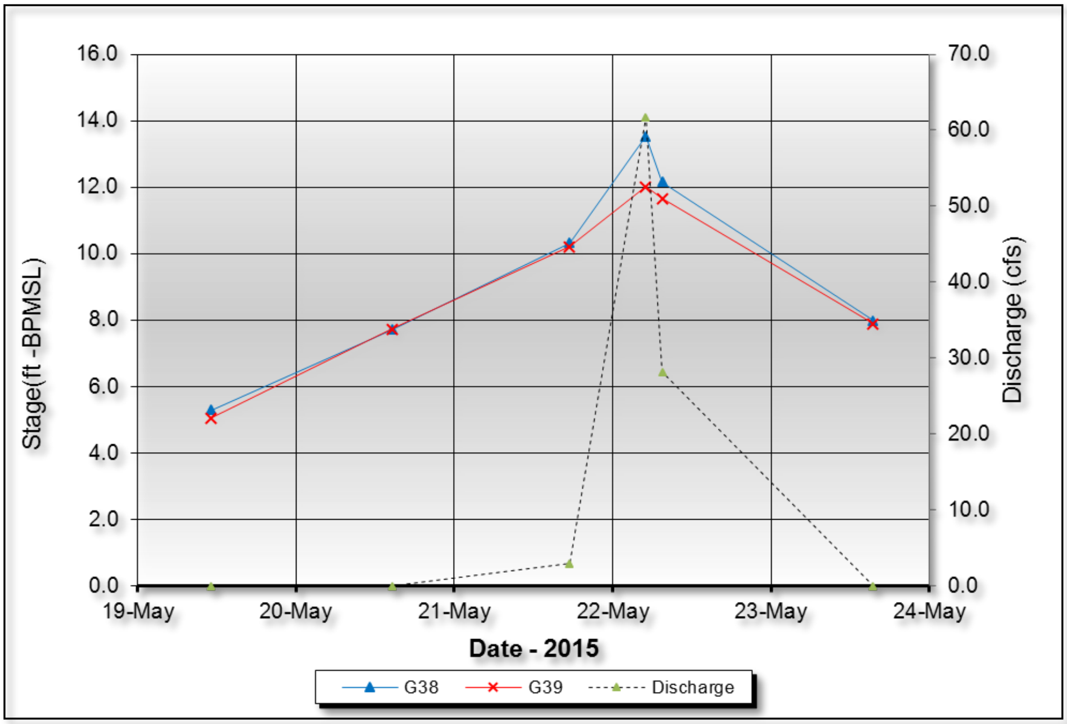
F.2.3.2 INDIRECT DISCHARGE

Table F.9: 2015 CD5 Road Culvert Indirect Discharge Summary

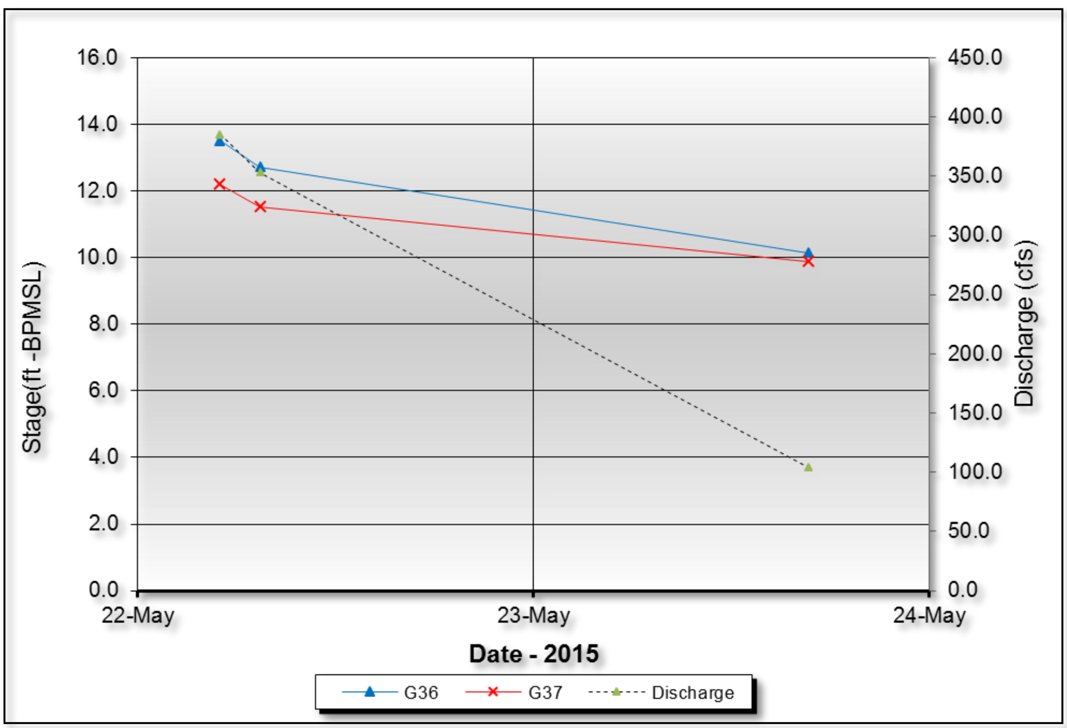
CD5 Culverts near G38/G39		CD5 Culverts near G36/G37		CD5 Culverts near G34/G35	
Culvert	May 22 5:00 AM	Culvert	May 22 5:00 AM	Culvert	May 22 5:00 AM
CD5-26	62	CD5-27	78	CD5-32	79
		CD5-28	78	CD5-33	80
		CD5-29	75	CD5-34	81
		CD5-30	77	CD5-35	62
		CD5-31	77	CD5-36	55
Total Discharge (cfs)	**62**		**385**		**198**
Notes: 1. Gages without peak data are denoted with a dash "-"					

Table F.10: 2015 CD5 Road Culvert Indirect Discharge Summary - Continued

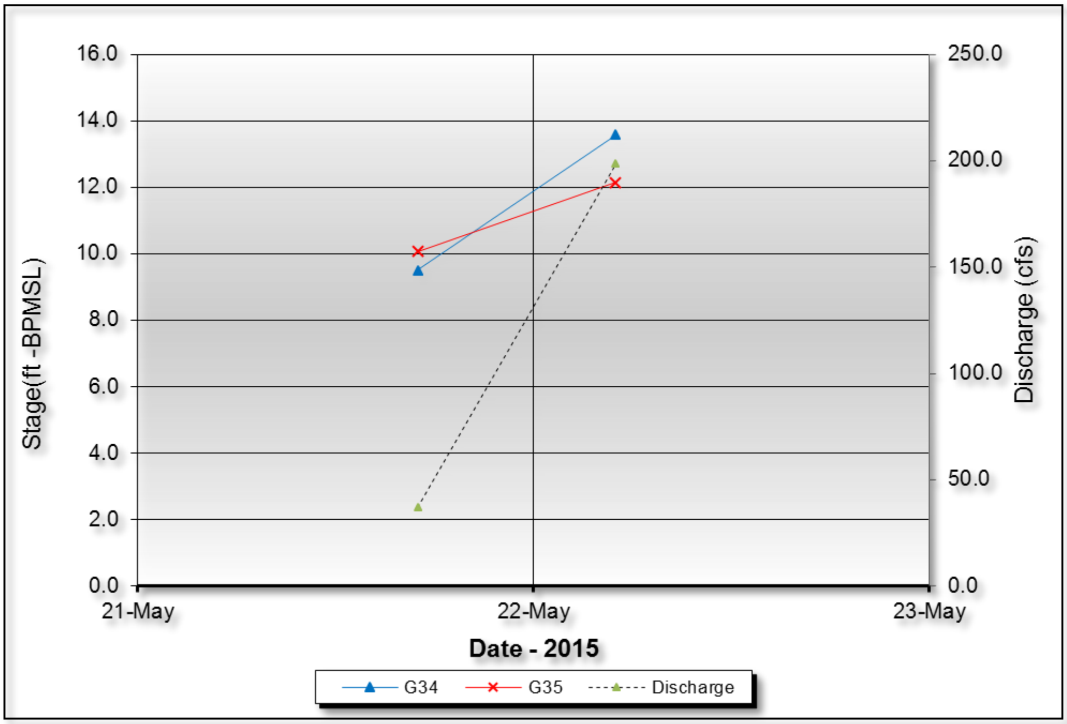
CD5 Culverts near G32/G33		CD5 Culverts near G30/G31		CD5 Culverts near G24/G25	
Culvert	May 22 5:00 AM	Culvert	May 22 5:00 AM	Culvert	May 22 7:10 AM
CD5-37	-20.5	CD5-40	-53.0	CD5-43	22.6
CD5-38	-20.6	CD5-41	-54.3		
CD5-39	-20.1	CD5-42	-53.3		
Total Discharge (cfs)	**61**		**161**		**23**
Notes: 1. Negative values indicate culvert is flowing north to south					



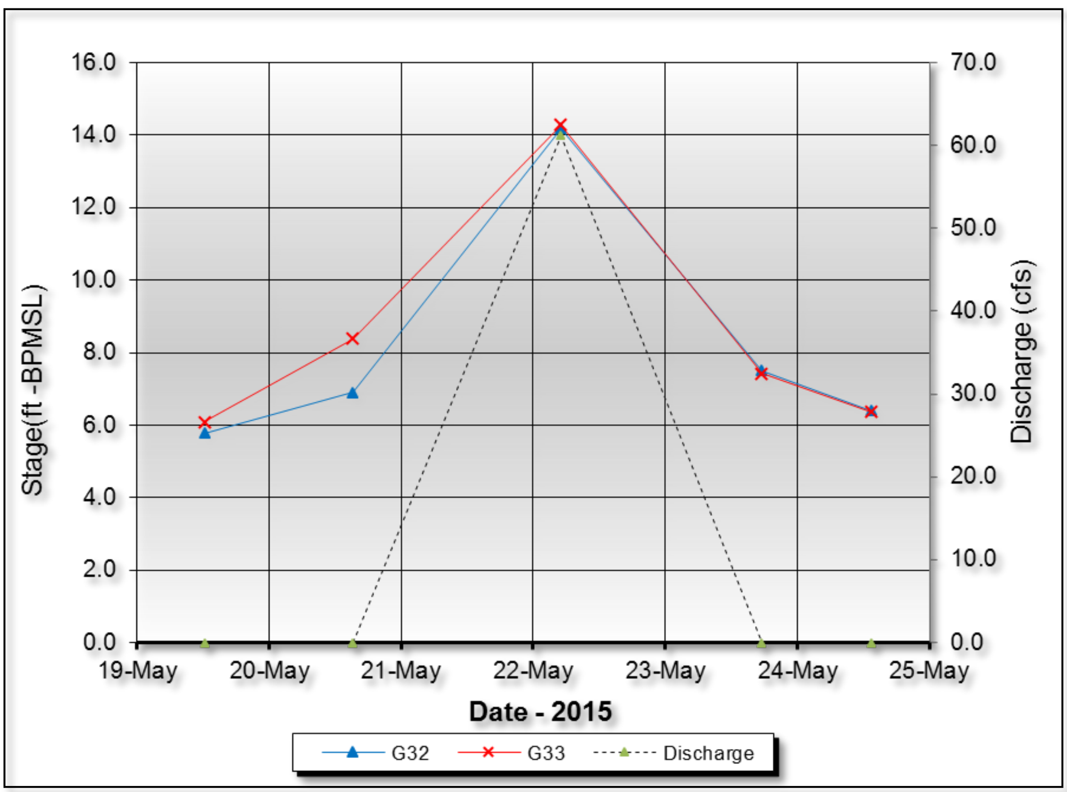
Graph F.21: Indirect Discharge vs. Observed Stage, CD5 Road Culvert CD5-26 near G38/G39



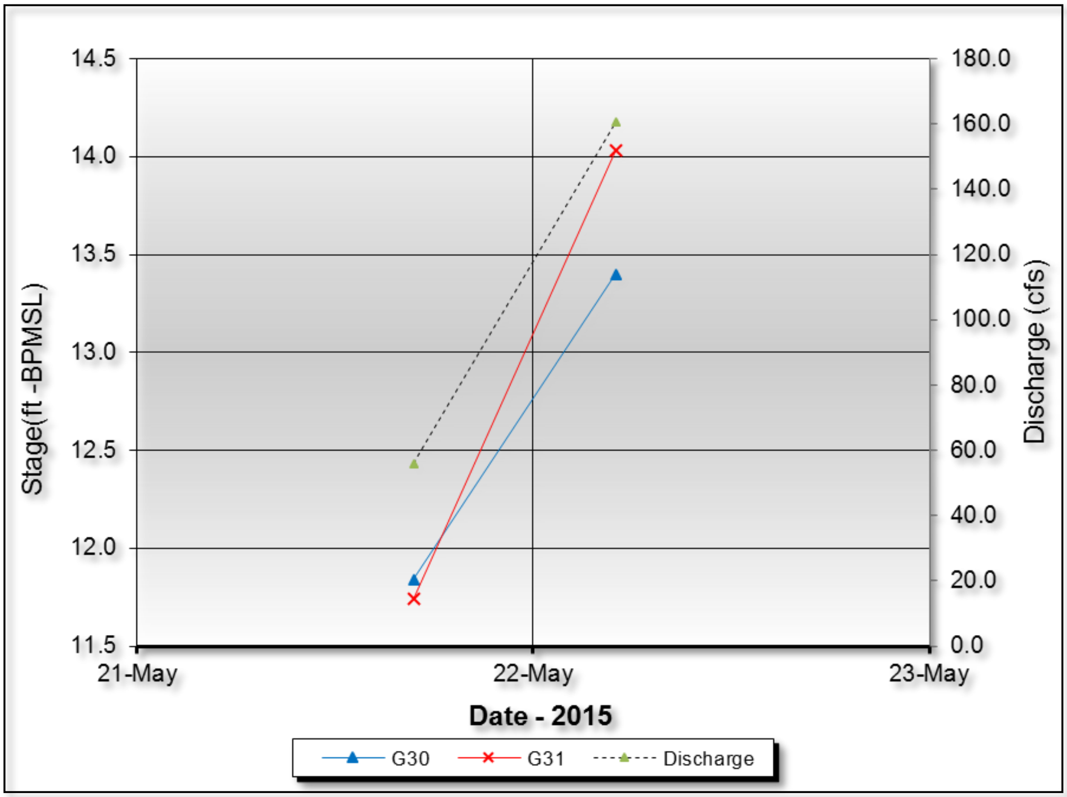
Graph F.22: Indirect Discharge vs. Observed Stage, CD5 Road Culvert CD5-28 and CD5-29 near G36/G37



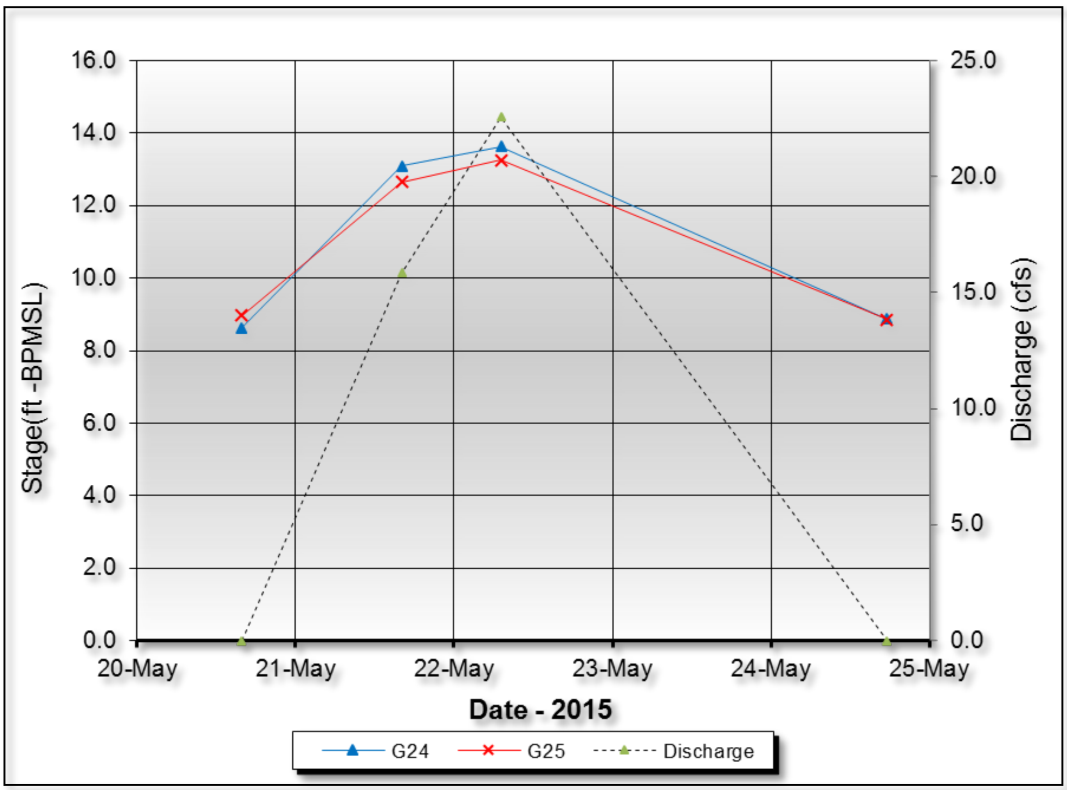
Graph F.23: Indirect Discharge vs. Observed Stage, CD5 Road Culvert CD5-34 and CD5-35 near G34/G35



Graph F.24: Indirect Discharge vs. Observed Stage, CD5 Road Culvert CD5-39 near G32/G33



Graph F.25: Indirect Discharge vs. Observed Stage, CD5 Road Culvert CD5-40 near G30/G31



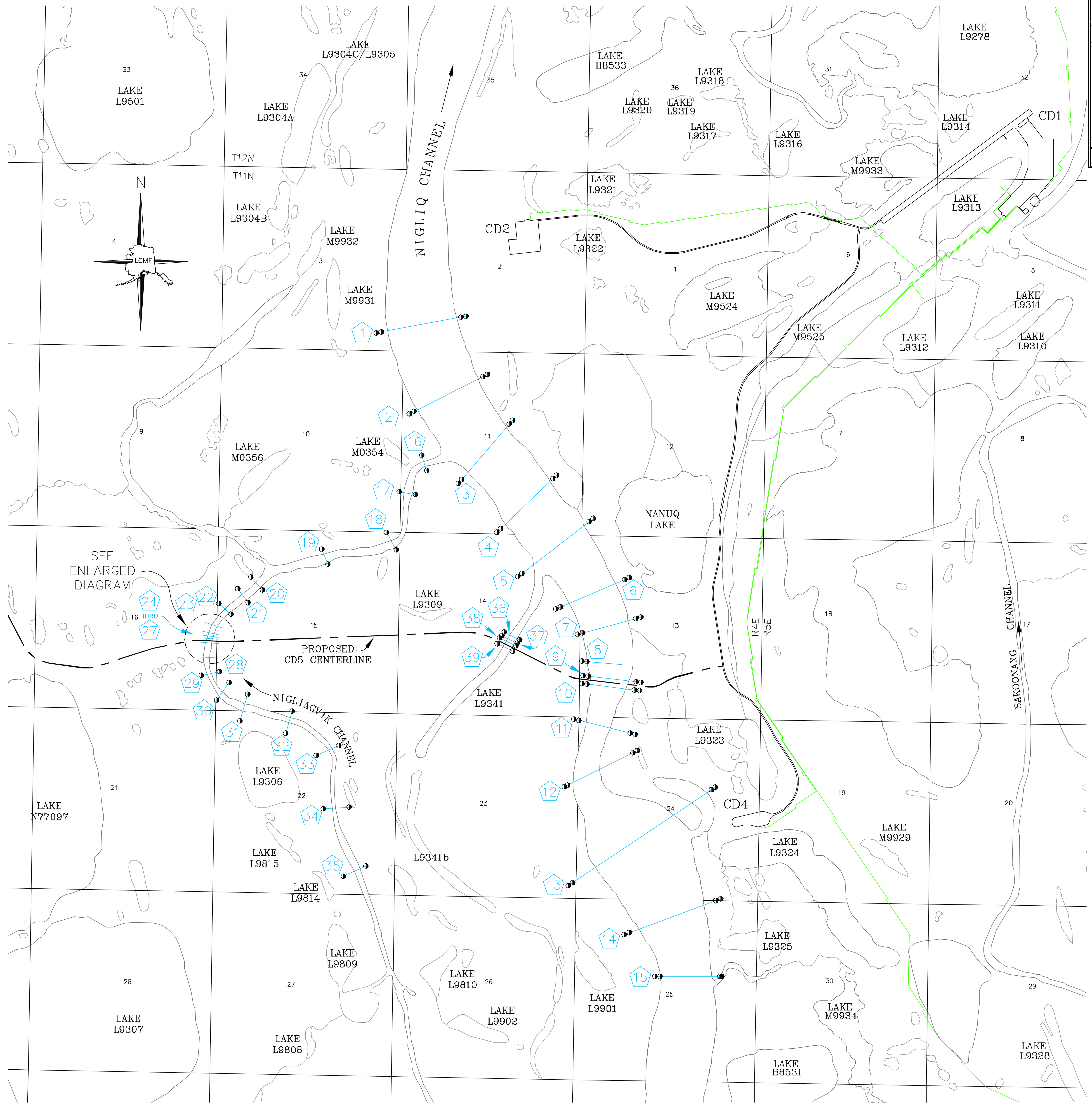
Graph F.26: Indirect Discharge vs. Observed Stage, CD5 Road Culvert CD5-43 near G24/G25

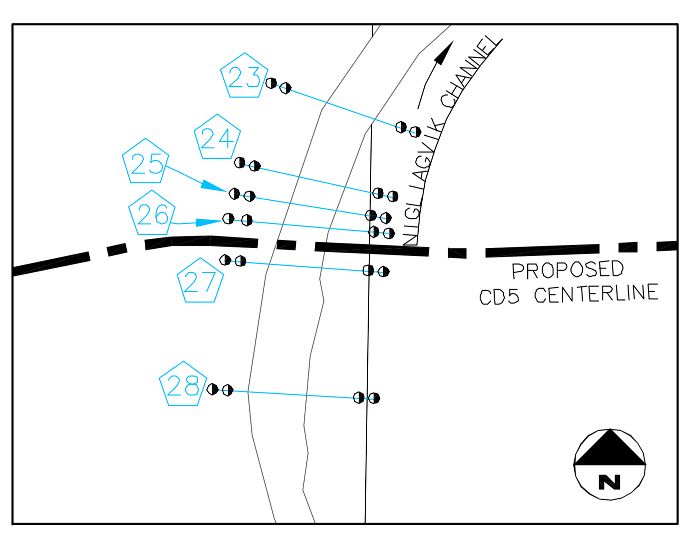
Appendix G CD5 Bathymetry and Scour

JOB NO: 02-204	SUB JOB NO: –	DRAWING NO: CE-CD50-1004	

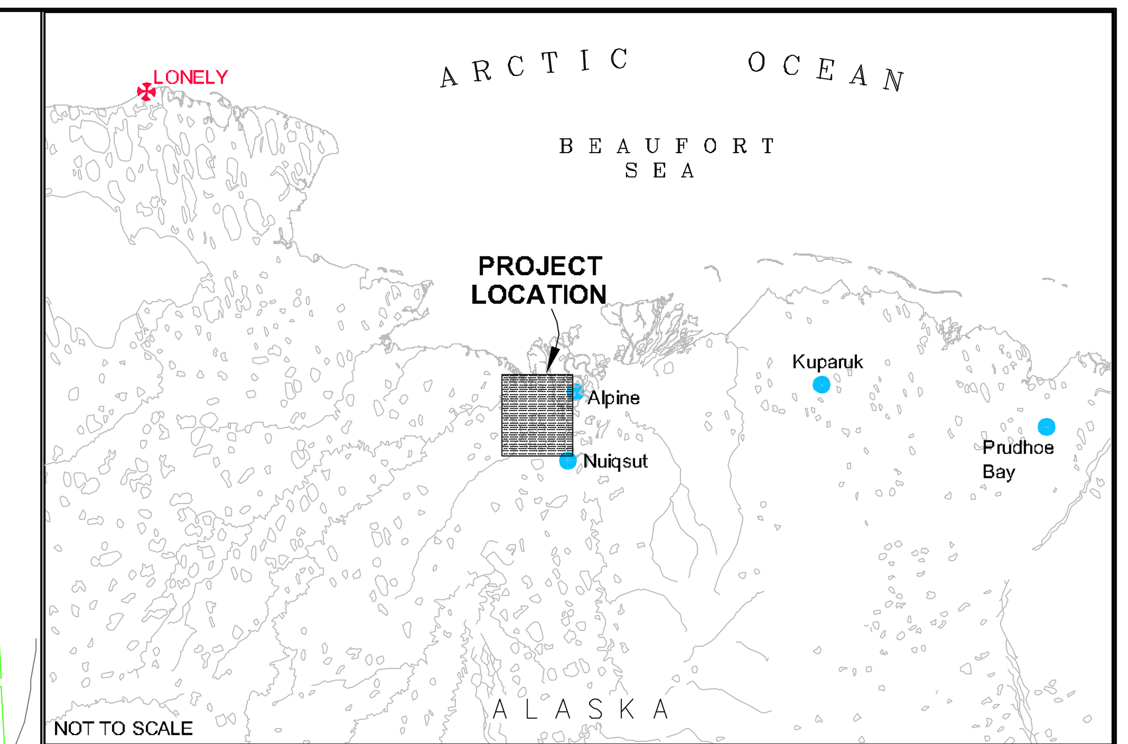
CD5 TRANSECT CONTROL

NORTHING	EASTING	ELEV	DESCRIPTION	NORTHING	EASTING	ELEV	DESCRIPTION
5,971,410.172	1,507,156.498	8.419	01-LB200 Al Cap Flush	5,963,935.690	1,503,847.826	7.458	20-RB100 Al Cap Flush
5,971,437.585	1,507,303.986	8.293	01-LB50 Al Cap Flush	5,963,972.576	1,503,814.200	7.417	20-RB50 Al Cap Flush
5,971,895.681	1,509,763.370	9.145	01-RB200 Al Cap Flush	5,963,970.128	1,503,127.995	24.412	21-LB100 Al Cap Flush
5,971,868.462	1,509,615.861	9.243	01-RB50 Al Cap Flush	5,963,930.056	1,503,157.752	20.803	21-LB50 Al Cap Flush
5,969,060.230	1,508,119.673	8.815	02-LB200 Al Cap Flush	5,963,562.391	1,503,430.566	8.697	21-RB100 Al Cap Flush
5,969,127.888	1,508,253.550	7.602	02-LB50 Al Cap Flush	5,963,602.565	1,503,400.675	9.087	21-RB50 Al Cap Flush
5,970,206.027	1,510,386.345	9.199	02-RB200 Al Cap Flush	5,963,540.647	1,502,578.266	26.015	22-LB110 Al Cap Flush
5,970,138.191	1,510,252.530	9.100	02-RB50 Al Cap Flush	5,963,500.955	1,502,623.070	23.980	22-LB50 Al Cap Flush
5,967,032.208	1,509,538.684	9.609	03-LB200 Al Cap Flush	5,963,224.555	1,502,936.088	8.555	22-RB100 Al Cap Flush
5,967,145.951	1,509,636.505	10.073	03-LB50 Al Cap Flush	5,963,257.687	1,502,898.557	9.083	22-RB50 Al Cap Flush
5,968,868.861	1,511,117.903	9.529	03-RB200 Al Cap Flush	5,962,989.577	1,502,198.675	25.176	23-LB100 Al Cap Flush
5,968,755.208	1,511,019.945	9.427	03-RB50 Al Cap Flush	5,962,973.595	1,502,246.059	25.141	23-LB50 Al Cap Flush
5,965,610.334	1,510,661.026	12.474	04-LB200 Al Cap Flush	5,962,828.922	1,502,671.946	10.028	23-RB100 Al Cap Flush
5,965,716.671	1,510,772.049	13.769	04-LB50 Al Cap 0.1' BGL	5,962,845.024	1,502,624.671	8.043	23-RB50 Al Cap Flush
5,967,272.757	1,512,396.890	10.300	04-RB200 Al Cap 0.2' BGL	5,962,728.638	1,502,095.588	26.467	24-LB100 Al Cap Flush
5,967,169.027	1,512,288.545	10.193	04-RB50 Al Cap Flush	5,962,717.892	1,502,144.420	27.045	24-LB50 Al Cap Flush
5,964,321.916	1,511,269.778	12.004	05-LB200 Al Cap Flush	5,962,617.894	1,502,598.227	9.107	24-RB100 Al Cap Flush
5,964,413.659	1,511,388.489	13.294	05-LB50 Al Cap Flush	5,962,628.649	1,502,549.420	8.314	24-RB50 Al Cap Flush
5,966,013.949	1,513,463.365	8.712	05-RB200 Al Cap Flush	5,962,627.162	1,502,078.344	27.446	25-LB100 Al Cap Flush
5,965,922.270	1,513,344.600	8.575	05-RB50 Al Cap Flush	5,962,619.301	1,502,127.772	26.188	25-LB50 Al Cap Flush
5,963,381.275	1,512,373.997	11.414	06-LB200 Al Cap Flush	5,962,547.931	1,502,575.394	8.171	25-RB100 Al Cap Flush
5,963,440.005	1,512,512.008	12.990	06-LB50 Al Cap Flush	5,962,555.825	1,502,525.976	8.195	25-RB50 Al Cap Flush
5,964,292.039	1,514,511.947	9.753	06-RB250 Al Cap Flush	5,962,545.484	1,502,058.928	27.484	26-LB110 Al Cap Flush
5,964,233.713	1,514,375.434	10.230	06-RB50 Al Cap Flush	5,962,539.978	1,502,118.584	27.711	26-LB50 Al Cap Flush
5,962,644.637	1,513,005.297	10.674	07-LB200 Al Cap Flush	5,962,497.866	1,502,585.674	9.555	26-RB100 Al Cap Flush
5,962,683.874	1,513,149.989	12.280	07-LB50 Al Cap Flush	5,962,502.417	1,502,535.991	8.293	26-RB50 Al Cap Flush
5,963,144.212	1,514,845.101	10.802	07-RB200 Al Cap Flush	5,962,410.033	1,502,047.844	26.997	27-LB100 Al Cap Flush
5,963,105.000	1,514,700.456	10.095	07-RB50 Al Cap Flush	5,962,406.342	1,502,097.705	27.070	27-LB50 Al Cap Flush
5,961,864.570	1,513,132.749	10.466	08-LB200 Al Cap Flush	5,962,371.997	1,502,567.626	9.566	27-RB100 Al Cap Flush
5,961,851.285	1,513,282.064	10.443	08-LB50 Al Cap Flush	5,962,375.740	1,502,517.809	8.014	27-RB50 Al Cap Flush
5,961,442.215	1,513,168.246	10.517	09-LB200 Al Cap Flush	5,961,986.435	1,502,006.076	21.011	28-LB100 Al Cap Flush
5,961,424.681	1,513,317.350	10.394	09-LB50 Al Cap Flush	5,961,983.639	1,502,055.975	21.172	28-LB50 Al Cap Flush
5,961,244.616	1,514,849.163	9.279	09-RB200 Al Cap Flush	5,961,959.919	1,502,486.658	8.400	28-RB50 Al Cap Flush
5,961,260.915	1,514,710.040	7.967	09-RB60 Al Cap Flush	5,961,957.165	1,502,536.545	9.177	28-RB100 Al Cap Flush
5,961,214.588	1,513,133.884	10.300	10-LB200 Al Cap Flush	5,961,446.941	1,502,073.292	24.206	29-LB100 Al Cap Flush
5,961,195.969	1,513,282.680	10.544	10-LB50 Al Cap Flush	5,961,457.435	1,502,122.177	23.598	29-LB50 Al Cap Flush
5,961,004.246	1,514,808.609	7.234	10-RB200 Al Cap Flush	5,961,559.109	1,502,597.016	9.800	29-RB100 Al Cap Flush
5,961,023.039	1,514,659.848	8.404	10-RB50 Al Cap Flush	5,961,548.659	1,502,548.070	8.629	29-RB50 Al Cap Flush
5,960,173.818	1,512,898.221	10.959	11-LB200 Al Cap Flush	5,960,727.368	1,502,515.791	23.658	30-LB100 Al Cap Flush
5,960,137.662	1,513,043.747	8.787	11-LB50 Al Cap Flush	5,960,768.276	1,502,544.696	23.216	30-LB50 Al Cap Flush
5,959,767.171	1,514,537.179	9.008	11-RB50 Al Cap 0.2' BGL	5,961,239.597	1,502,877.114	10.073	30-RB100 Al Cap Flush
5,958,209.502	1,512,625.605	11.011	12-LB200 Al Cap Flush	5,961,198.806	1,502,848.280	9.549	30-RB50 Al Cap Flush
5,958,253.951	1,512,715.217	11.300	12-LB100 Al Cap Flush	5,960,124.465	1,503,193.305	8.556	31-LB100 Al Cap Flush
5,959,260.248	1,514,746.096	10.244	12-RB200 Al Cap Flush	5,960,172.316	1,503,207.309	9.605	31-LB50 Al Cap Flush
5,959,193.539	1,514,611.534	8.799	12-RB50 Al Cap 0.3' BGL	5,960,896.154	1,503,418.934	10.757	31-RB100 Al Cap Flush
5,955,329.192	1,512,738.181	11.567	13-LB200 Al Cap Flush	5,960,848.113	1,503,404.835	11.123	31-RB50 Al Cap Flush
5,955,412.726	1,512,862.669	12.000	13-LB50 Al Cap Flush	5,959,762.590	1,504,523.209	8.369	32-LB100 Al Cap Flush
5,958,195.954	1,517,009.849	10.156	13-RB200 Al Cap Flush	5,959,810.483	1,504,537.155	7.694	32-LB50 Al Cap Flush
5,958,123.512	1,516,901.775	11.679	13-RB70 Al Cap Flush	5,960,406.262	1,504,711.395	10.790	32-RB100 Al Cap Flush
5,953,908.304	1,514,359.064	13.118	14-LB215 Al Cap Flush	5,960,358.154	1,504,697.383	11.437	32-RB50 Al Cap Flush
5,953,965.615	1,514,513.824	15.550	14-LB50 Al Cap 0.1' BGL	5,959,118.980	1,505,412.935	9.835	33-LB100 Al Cap Flush
5,954,950.395	1,517,166.201	9.597	14-RB200 Al Cap Flush	5,959,138.925	1,505,458.824	8.589	33-LB50 Al Cap Flush
5,954,898.238	1,517,025.621	9.608	14-RB50 Al Cap Flush	5,959,403.881	1,506,064.870	10.643	33-RB120 Al Cap Flush
5,952,688.522	1,515,254.050	13.908	15-LB200 Al Cap Flush	5,959,375.875	1,506,000.696	10.409	33-RB50 Al Cap Flush
5,952,688.752	1,515,404.121	16.582	15-LB50 Al Cap Flush	5,957,567.988	1,505,617.483	12.554	34-LB100 Al Cap Flush
5,952,691.471	1,517,145.169	12.616	15-RB50 Al Cap Flush	5,957,571.230	1,505,667.205	12.478	34-LB50 Al Cap Flush
5,952,691.489	1,517,195.117	12.432	15-RB100 Al Cap Flush	5,957,615.382	1,506,366.118	10.126	34-RB100 Al Cap Flush
5,967,852.367	1,508,476.551	10.009	16-LB100 Al Cap Flush	5,957,612.244	1,506,316.188	10.539	34-RB50 Al Cap Flush
5,967,804.938	1,508,492.145	9.412	16-LB50 Al Cap Flush	5,955,603.397	1,506,200.608	12.562	35-LB100 Al Cap Flush
5,967,407.545	1,508,622.063	9.108	16-RB100 Al Cap Flush	5,955,624.246	1,506,246.168	13.026	35-LB50 Al Cap Flush
5,967,455.122	1,508,606.515	8.774	16-RB50 Al Cap Flush	5,955,901.737	1,506,854.796	10.213	35-RB100 Al Cap Flush
5,966,795.100	1,507,822.749	8.513	17-LB100 Al Cap Flush	5,955,880.894	1,506,809.410	9.424	35-RB50 Al Cap Flush
5,966,786.380	1,507,871.976	8.246	17-LB50 Al Cap Flush	5,962,713.529	1,510,877.308	8.344	36-LB100 Al Cap Flush
5,966,712.363	1,508,294.902	8.485	17-RB100 Al Cap Flush	5,962,690.391	1,510,921.654	8.055	36-LB50 Al Cap Flush
5,966,720.830	1,508,245.661	8.457	17-RB50 Al Cap Flush	5,962,479.459	1,511,322.840	9.457	36-RB100 Al Cap Flush
5,965,609.725	1,507,451.169	8.512	18-LB100 Al Cap Flush	5,962,502.704	1,511,278.621	8.645	36-RB50 Al Cap Flush
5,965,566.257	1,507,475.942	8.621	18-LB50 Al Cap Flush	5,962,603.099	1,510,806.869	8.204	37-LB100 Al Cap Flush
5,965,103.267	1,507,739.379	7.676	18-RB100 Al Cap Flush	5,962,581.024	1,510,851.779	8.345	37-LB50 Al Cap Flush
5,965,146.802	1,507,714.587	7.539	18-RB50 Al Cap Flush	5,962,382.943	1,511,254.349	9.472	37-RB100 Al Cap Flush
5,965,119.470	1,505,573.359	8.506	19-LB100 Al Cap Flush	5,962,405.053	1,511,209.407	8.823	37-RB50 Al Cap Flush
5,965,073.111	1,505,592.239	8.506	19-LB50 Al Cap Flush	5,962,540.234	1,510,738.125	8.327	38-LB100 Al Cap Flush
5,964,684.565	1,505,750.603	8.083	19-RB100 Al Cap Flush	5,962,518.597	1,510,783.313	8.173	38-LB50 Al Cap Flush
5,964,730.797	1,505,731.738	8.636	19-RB50 Al Cap Flush	5,962,311.212	1,511,215.115	9.224	38-RB100 Al Cap Flush
5,964,307.477	1,503,508.726	13.755	20-LB100 Al Cap Flush	5,962,332.715	1,511,169.978	9.063	38-RB50 Al Cap Flush
5,964,270.626	1,503,542.452	15.545	20-LB50 Al Cap Flush	5,962,367.978	1,510,674.819	8.779	39-LB100 Al Cap Flush
				5,962,346.171	1,510,719.677	7.761	39-LB50 Al Cap Flush
				5,962,154.417	1,511,119.161	9.651	39-RB100 Al Cap Flush
				5,962,176.142	1,511,074.113	9.465	39-RB50 Al Cap Flush





ENLARGED DIAGRAM



VICINITY MAP

LEGEND:

◑ 2" ALUMINUM CAP ON 5/8" x 30" REBAR (TYPICAL 4 REBAR ON EACH TRANSECT)

NOTES:

1. DATE OF SURVEY: AUGUST 29 TO SEPTEMBER 18, 2013; OCTOBER 21, 2013.
2. COORDINATES SHOWN ARE ALASKA STATE PLANE, ZONE 4 N.A.D. 83, IN FEET. BASED ON THE 2013 CD-5 CONTROL SURVEY
3. ELEVATIONS SHOWN ARE BRITISH PETROLEUM MEAN SEA LEVEL (B.P.M.S.L.) DATUM.
4. SEE DOCUMENT RPT-CE-CD-113 FOR TRANSECT BASELINE SURVEY DATA.
5. REFERENCE FIELD BOOK LCMF 2013-18, PGS. 57-59. 67, 70-72. LCMF 2013-20 PGS. 4-14; LCMF 2013-21, PG. 29.
6. PROPOSED GRAVEL ROAD ALIGNMENT, AS SHOWN, BASED ON INFORMATION PROVIDED BY PND ENGINEERING, RECEIVED 9/25/2013.

KUUKPIK LCMF LLC
Alpine Survey Office

ConocoPhillips Alaska, Inc.

ALPINE | MODULE: CD50 | UNIT: CD

CD-5 ROAD MONITORING PLAN BASELINES ALPINE, ALASKA

REDRAWN FROM:

CONSTRUCTION SHEET OF

DO NOT SCALE — ABOVE SCALE FOR REFERENCE ONLY

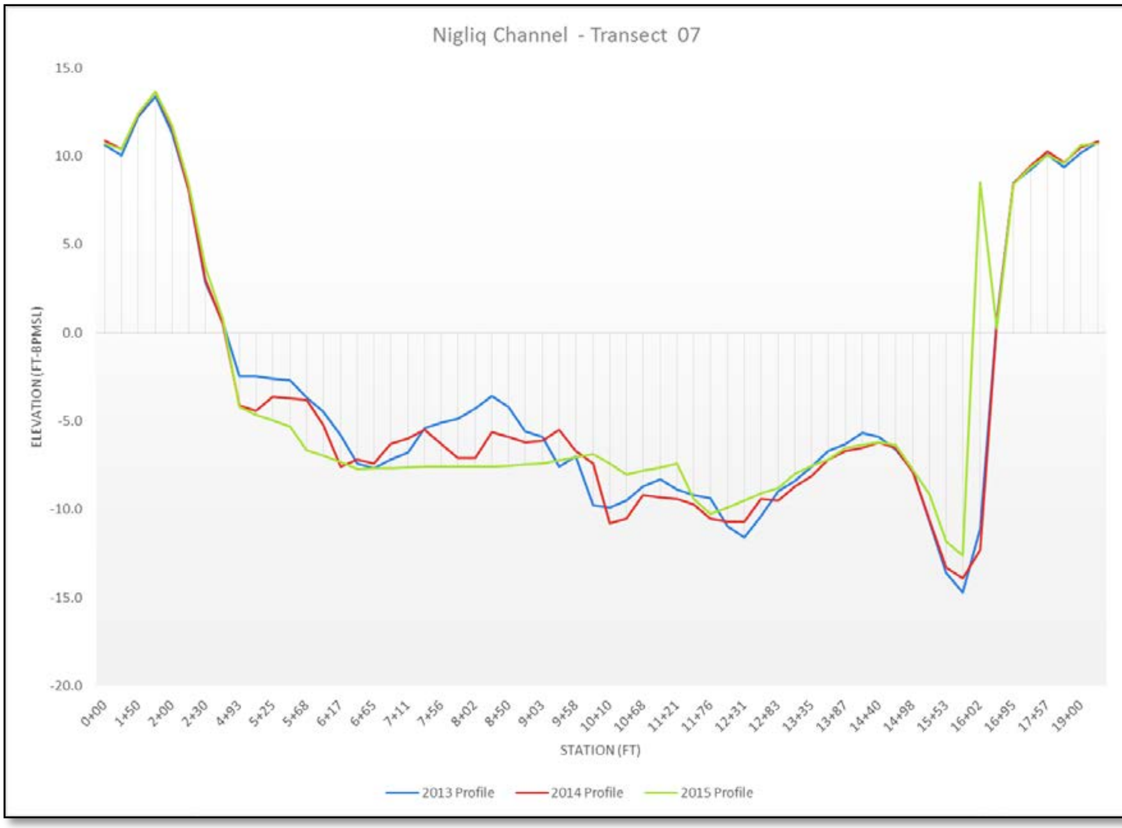
FORM: DSIZE

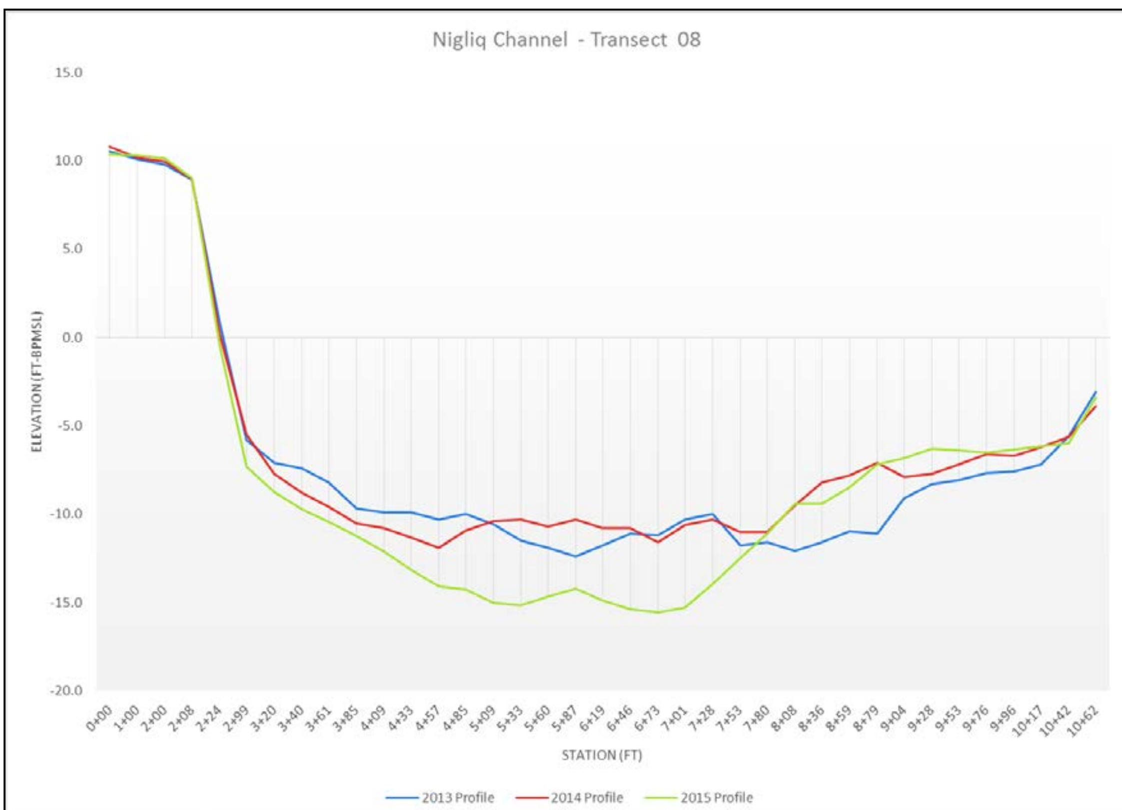
DATE: 8/26/13	DRAWN: CZ	DESIGN: –	ECM NO: –
SCALE: 1" = 2000'	CHECKED: DB		CC NO: –
	APPROVAL: –		CADD FILE NO. 13-08-07-1 –
JOB NO: 02-204	SUB JOB NO: –	DRAWING NO: CE-CD50-1004	PART: 1 OF – REV: 1

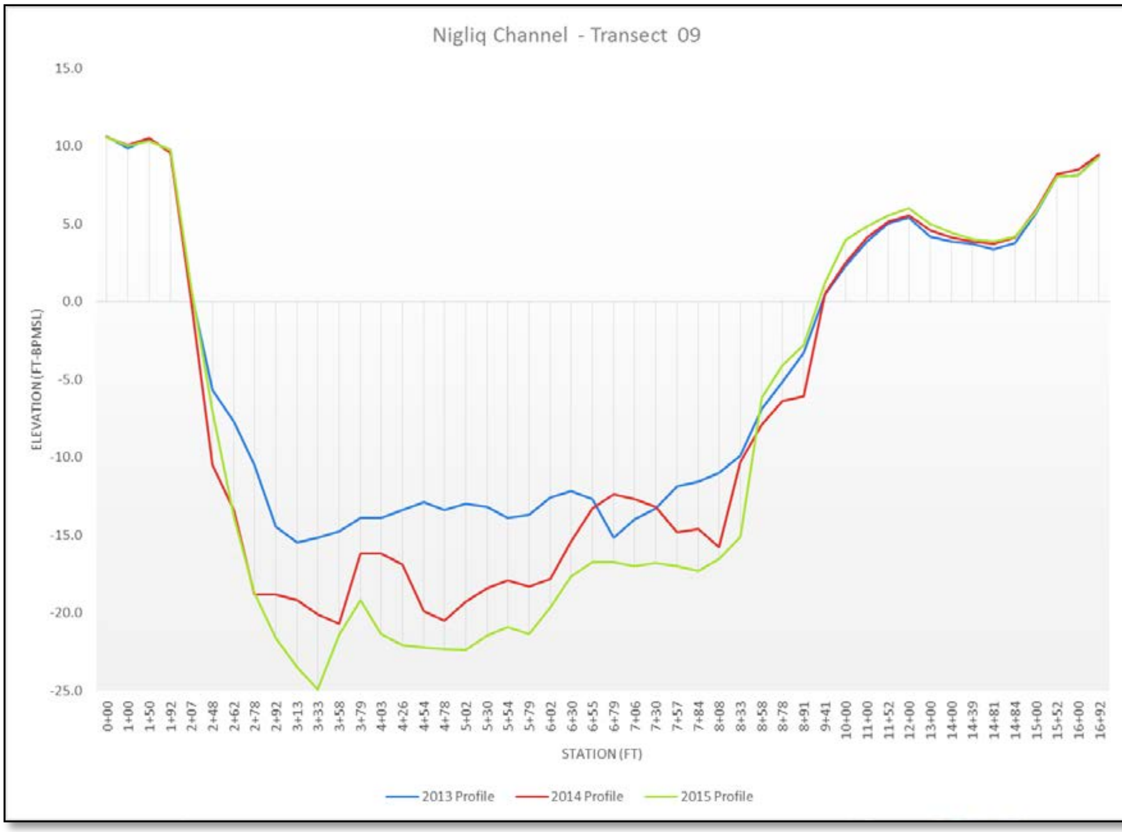
REFERENCE DWG NO/SHT NO:

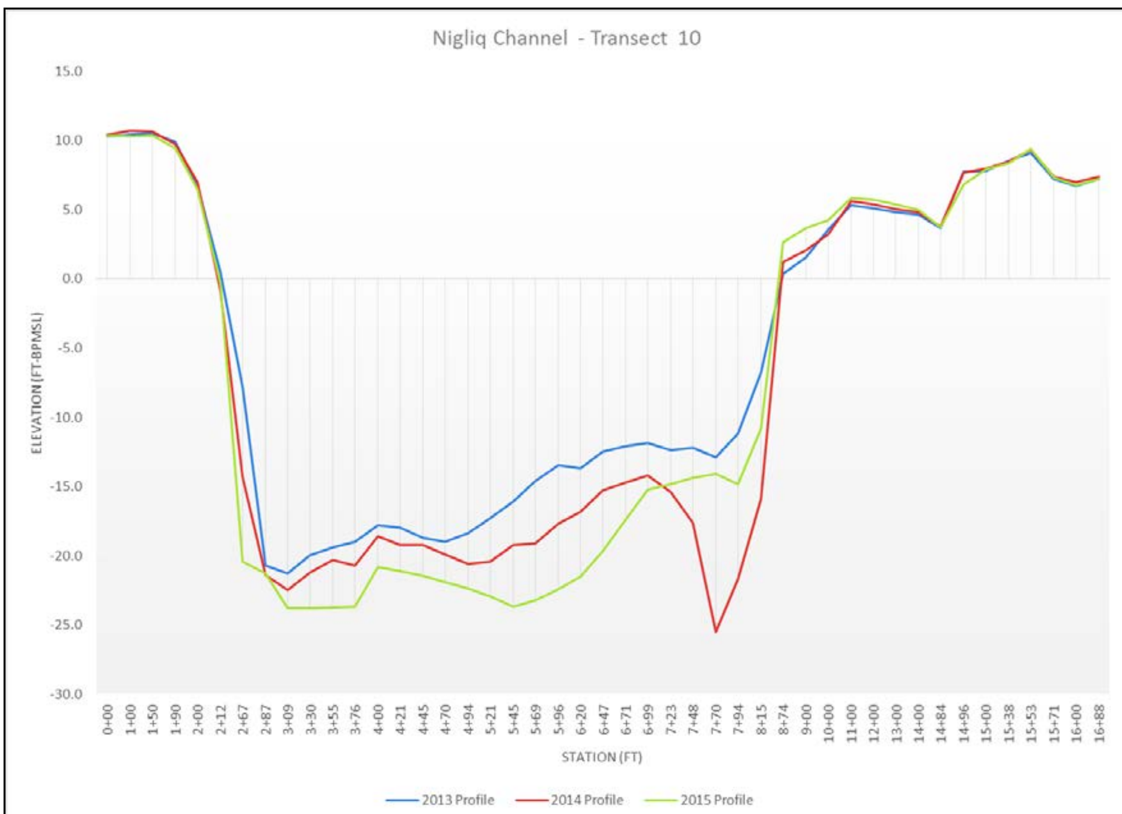
REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
1	10/22/13	ISSUED PER K130003ACS	AG	DB			

G.1 Nigliq Bridge






Nigliq Channel - Transect 09
ELEVATION (FT-BPMSL)
STATION (FT)
2013 Profile
2014 Profile
2015 Profile


Nigliq Channel - Transect 10
ELEVATION (FT-BPMSL)
STATION (FT)
2013 Profile
2014 Profile
2015 Profile

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	10.6	10.9	10.7	Ground Shot
1+00	10.1	10.4	10.4	Ground Shot
1+50	12.2	12.4	12.4	Ground Shot
1+77	13.4	13.7	13.7	Grade Break
2+00	11.3	11.6	11.7	Ground Shot
2+23	8.1	8.1	8.4	Top of Bank
2+30	2.8	3.0	3.7	Toe of Bank
2+47	0.6	0.5	0.8	Edge of Water
4+93	-2.5	-4.1	-4.2	River Bottom
5+06	-2.5	-4.4	-4.6	River Bottom
5+25	-2.6	-3.6	-5.0	River Bottom
5+45	-2.7	-3.7	-5.3	River Bottom
5+68	-3.7	-3.8	-6.6	River Bottom
5+91	-4.5	-5.2	-7.0	River Bottom
6+17	-5.8	-7.6	-7.3	River Bottom
6+42	-7.4	-7.2	-7.7	River Bottom
6+65	-7.7	-7.4	-7.7	River Bottom
6+88	-7.2	-6.3	-7.7	River Bottom
7+11	-6.8	-6.0	-7.6	River Bottom
7+37	-5.4	-5.5	-7.6	River Bottom
7+56	-5.1	-6.3	-7.6	River Bottom
7+82	-4.9	-7.1	-7.6	River Bottom
8+02	-4.3	-7.1	-7.6	River Bottom
8+25	-3.6	-5.6	-7.6	River Bottom
8+50	-4.2	-5.9	-7.5	River Bottom
8+74	-5.6	-6.2	-7.5	River Bottom
9+03	-5.9	-6.1	-7.4	River Bottom
9+32	-7.6	-5.5	-7.2	River Bottom
9+58	-7.0	-6.7	-7.0	River Bottom
9+84	-9.8	-7.4	-6.9	River Bottom
10+10	-9.9	-10.8	-7.4	River Bottom
10+39	-9.5	-10.5	-8.0	River Bottom
10+68	-8.7	-9.2	-7.8	River Bottom
10+91	-8.3	-9.3	-7.6	River Bottom
11+21	-8.9	-9.4	-7.4	River Bottom
11+50	-9.2	-9.7	-9.4	River Bottom
11+76	-9.4	-10.5	-10.3	River Bottom
12+02	-11.0	-10.7	-9.9	River Bottom
12+31	-11.6	-10.7	-9.5	River Bottom
12+57	-10.4	-9.4	-9.1	River Bottom
12+83	-9.0	-9.5	-8.8	River Bottom
13+09	-8.4	-8.7	-8.0	River Bottom
13+35	-7.6	-8.1	-7.6	River Bottom
13+64	-6.7	-7.2	-7.2	River Bottom
13+87	-6.3	-6.7	-6.5	River Bottom
14+17	-5.7	-6.5	-6.3	River Bottom
14+40	-5.9	-6.2	-6.2	River Bottom
14+69	-6.6	-6.5	-6.3	River Bottom
14+98	-7.8	-7.9	-7.8	River Bottom
15+24	-10.7	-10.6	-9.2	River Bottom
15+53	-13.6	-13.3	-11.8	River Bottom
15+79	-14.7	-13.9	-12.6	River Bottom
16+02	-11.1	-12.3	8.5	River Bottom

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 2 Transect_07

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
16+84	0.7	0.5	0.2	Edge of Water
16+95	8.5	8.4	8.4	Top of Bank
17+00	9.2	9.5	9.4	Ground Shot
17+57	10.1	10.3	10.0	Ground Shot
18+00	9.4	9.6	9.6	Ground Shot
19+00	10.2	10.5	10.6	Ground Shot
19+07	10.8	10.9	10.7	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 2 of 2 Transect_07

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	10.6	10.8	10.3	Ground Shot
1+00	10.1	10.2	10.3	Ground Shot
2+00	9.8	10.0	10.1	Ground Shot
2+08	8.9	9.0	9.0	Top of Bank
2+24	0.9	0.2	-0.4	Edge of Water
2+99	-5.8	-5.5	-7.3	River Bottom
3+20	-7.1	-7.7	-8.7	River Bottom
3+40	-7.4	-8.8	-9.7	River Bottom
3+61	-8.2	-9.6	-10.4	River Bottom
3+85	-9.7	-10.5	-11.2	River Bottom
4+09	-9.9	-10.8	-12.1	River Bottom
4+33	-9.9	-11.3	-13.1	River Bottom
4+57	-10.3	-11.9	-14.1	River Bottom
4+85	-10.0	-10.9	-14.3	River Bottom
5+09	-10.6	-10.4	-15.0	River Bottom
5+33	-11.5	-10.3	-15.2	River Bottom
5+60	-11.9	-10.7	-14.7	River Bottom
5+87	-12.4	-10.3	-14.2	River Bottom
6+19	-11.8	-10.8	-14.9	River Bottom
6+46	-11.1	-10.8	-15.4	River Bottom
6+73	-11.2	-11.6	-15.6	River Bottom
7+01	-10.3	-10.6	-15.3	River Bottom
7+28	-10.0	-10.3	-13.9	River Bottom
7+53	-11.8	-11.0	-12.5	River Bottom
7+80	-11.6	-11.0	-11.1	River Bottom
8+08	-12.1	-9.5	-9.4	River Bottom
8+36	-11.6	-8.2	-9.4	River Bottom
8+59	-11.0	-7.8	-8.5	River Bottom
8+79	-11.1	-7.1	-7.2	River Bottom
9+04	-9.1	-7.9	-6.8	River Bottom
9+28	-8.3	-7.7	-6.3	River Bottom
9+53	-8.1	-7.2	-6.4	River Bottom
9+76	-7.7	-6.6	-6.5	River Bottom
9+96	-7.6	-6.7	-6.4	River Bottom
10+17	-7.2	-6.2	-6.2	River Bottom
10+42	-5.6	-5.6	-6.0	River Bottom
10+62	-3.1	-3.9	-3.4	River Bottom

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_08

Calc'd By: TB
Date: 8/30/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	10.6	10.6	10.6	Ground Shot
1+00	9.9	10.0	10.0	Ground Shot
1+50	10.5	10.5	10.3	Ground Shot
1+92	9.6	9.6	9.7	Top of Bank
2+07	0.6	0.0	0.9	Edge of Water
2+48	-5.7	-10.5	-7.1	River Bottom
2+62	-7.7	-13.4	-13.8	River Bottom
2+78	-10.5	-18.8	-18.7	River Bottom
2+92	-14.5	-18.8	-21.6	River Bottom
3+13	-15.5	-19.2	-23.5	River Bottom
3+33	-15.2	-20.1	-24.9	River Bottom
3+58	-14.8	-20.7	-21.4	River Bottom
3+79	-13.9	-16.2	-19.2	River Bottom
4+03	-13.9	-16.2	-21.4	River Bottom
4+26	-13.4	-16.9	-22.1	River Bottom
4+54	-12.9	-19.9	-22.2	River Bottom
4+78	-13.4	-20.5	-22.3	River Bottom
5+02	-13.0	-19.3	-22.4	River Bottom
5+30	-13.2	-18.4	-21.5	River Bottom
5+54	-13.9	-17.9	-20.9	River Bottom
5+79	-13.7	-18.3	-21.3	River Bottom
6+02	-12.6	-17.8	-19.7	River Bottom
6+30	-12.2	-15.4	-17.7	River Bottom
6+55	-12.7	-13.3	-16.7	River Bottom
6+79	-15.2	-12.4	-16.8	River Bottom
7+06	-14.0	-12.7	-17.0	River Bottom
7+30	-13.3	-13.2	-16.8	River Bottom
7+57	-11.9	-14.8	-17.0	River Bottom
7+84	-11.6	-14.6	-17.3	River Bottom
8+08	-11.0	-15.8	-16.6	River Bottom
8+33	-9.9	-10.3	-15.1	River Bottom
8+58	-6.9	-7.9	-6.2	River Bottom
8+78	-5.2	-6.4	-4.1	River Bottom
8+91	-3.3	-6.1	-2.8	River Bottom
9+41	0.5	0.5	1.2	Edge of Water
10+00	2.3	2.5	4.0	Sand Bar
11+00	3.9	4.1	4.9	Sand Bar
11+52	5.0	5.2	5.5	Edge of Vegetation
12+00	5.4	5.5	6.0	Ground Shot
13+00	4.2	4.6	5.0	Ground Shot
14+00	3.9	4.1	4.5	Ground Shot
14+39	3.7	3.9	4.0	Edge of Water
14+81	3.4	3.7	3.9	Edge of Water
14+84	3.8	4.1	4.2	Toe of Bank
15+00	5.7	5.9	5.7	Top of Bank
15+52	8.0	8.2	8.0	Ground Shot
16+00	8.2	8.5	8.1	Ground Shot
16+92	9.4	9.4	9.3	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_09

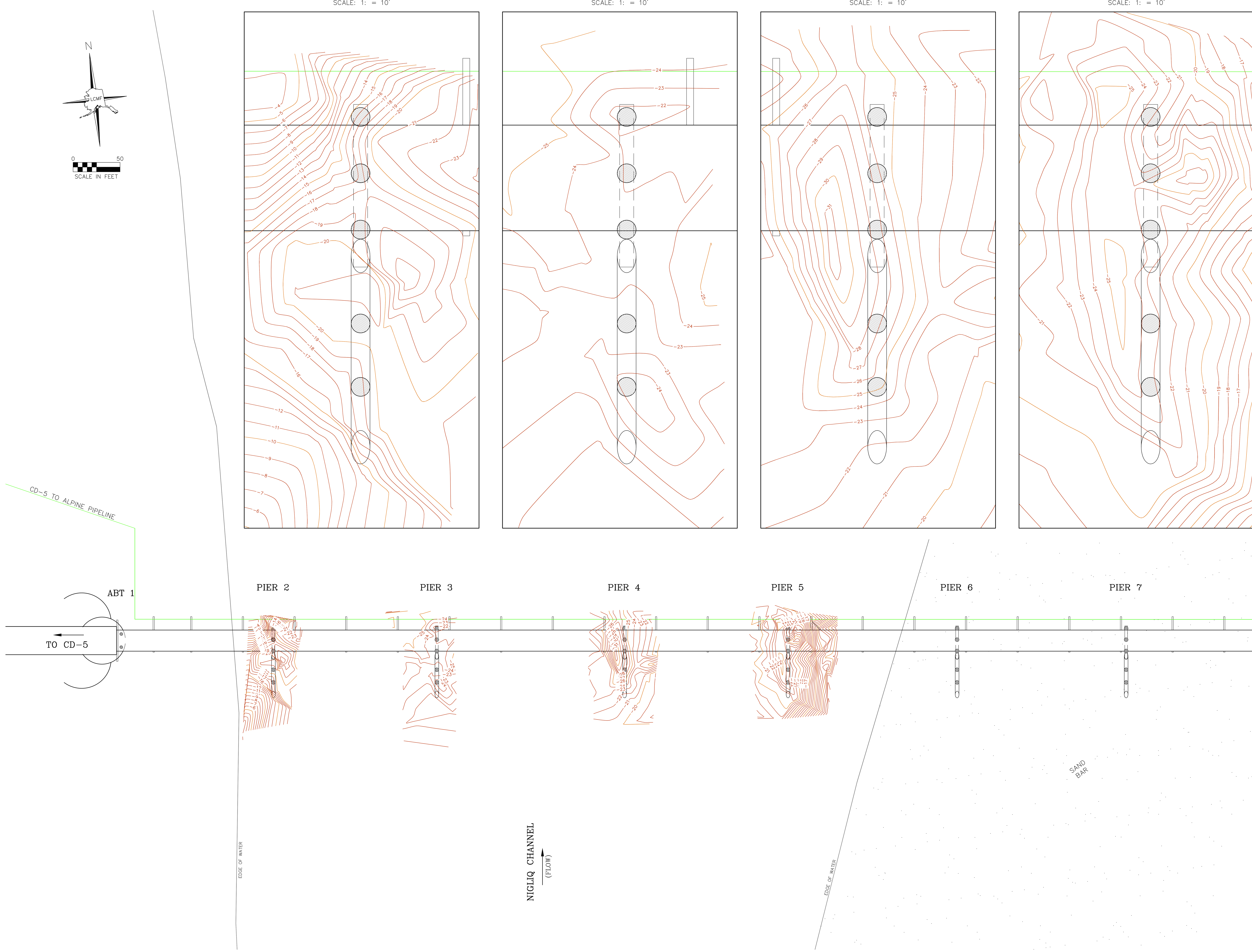
Calc'd By: TB
Date: 8/30/2015
RPT-CE-CD-114 REV3

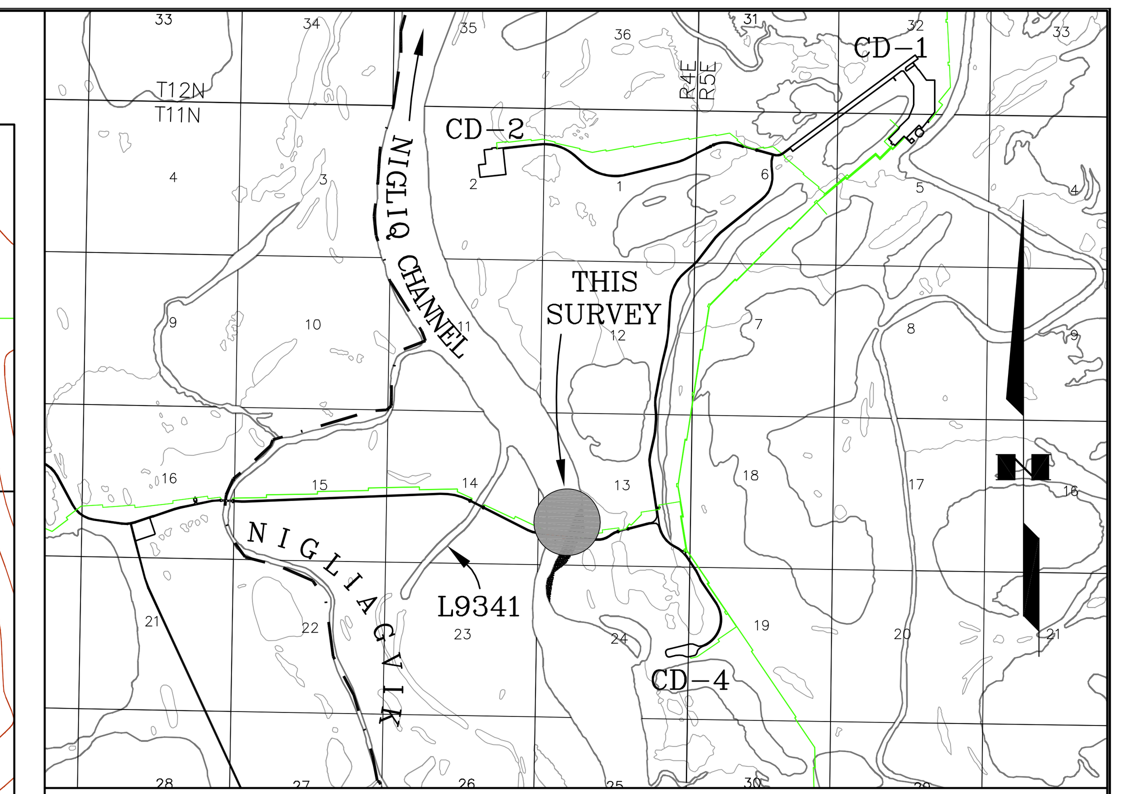
CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	10.3	10.4	10.3	Ground Shot
1+00	10.4	10.7	10.3	Ground Shot
1+50	10.5	10.6	10.4	Ground Shot
1+90	9.9	9.7	9.5	Top of Bank
2+00	6.7	7.0	6.5	Ground Shot
2+12	0.5	-0.8	-0.3	Edge of Water
2+67	-7.8	-14.3	-20.4	River Bottom
2+87	-20.7	-21.4	-21.3	River Bottom
3+09	-21.3	-22.5	-23.8	River Bottom
3+30	-20.0	-21.2	-23.8	River Bottom
3+55	-19.4	-20.3	-23.7	River Bottom
3+76	-19.0	-20.7	-23.7	River Bottom
4+00	-17.8	-18.6	-20.8	River Bottom
4+21	-18.0	-19.2	-21.1	River Bottom
4+45	-18.7	-19.2	-21.5	River Bottom
4+70	-19.0	-19.9	-21.9	River Bottom
4+94	-18.4	-20.6	-22.3	River Bottom
5+21	-17.3	-20.4	-23.0	River Bottom
5+45	-16.1	-19.2	-23.7	River Bottom
5+69	-14.6	-19.1	-23.2	River Bottom
5+96	-13.5	-17.7	-22.4	River Bottom
6+20	-13.7	-16.8	-21.5	River Bottom
6+47	-12.5	-15.3	-19.7	River Bottom
6+71	-12.1	-14.7	-17.4	River Bottom
6+99	-11.9	-14.2	-15.2	River Bottom
7+23	-12.4	-15.4	-14.8	River Bottom
7+48	-12.2	-17.6	-14.4	River Bottom
7+70	-12.9	-25.5	-14.1	River Bottom
7+94	-11.2	-21.7	-14.8	River Bottom
8+15	-6.8	-15.9	-10.8	River Bottom
8+74	0.4	1.2	2.6	Edge of Water
9+00	1.6	2.1	3.7	Sand Bar
10+00	3.6	3.2	4.3	Sand Bar
11+00	5.4	5.6	5.8	Edge of Vegetation
12+00	5.1	5.4	5.7	Ground Shot
13+00	4.8	5.0	5.4	Ground Shot
14+00	4.6	4.8	5.0	Ground Shot
14+84	3.7	3.8	3.7	Toe of Bank
14+96	7.7	7.7	6.8	Top of Bank
15+00	7.8	8.0	7.9	Ground Shot
15+38	8.6	8.5	8.4	Ground Shot
15+53	9.1	9.4	9.4	Grade Break
15+71	7.2	7.4	7.3	Grade Break
16+00	6.7	7.0	6.8	Ground Shot
16+88	7.2	7.4	7.2	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_10





VICINITY MAP

NOTES

1. DATE OF SURVEY: AUGUST 28, 2015.
2. REFERENCE FIELD BOOKS: LCMF2015-19, PG. 4.
3. ELEVATIONS ARE BRITISH PETROLEUM MEAN SEAL LEVLE (B.P.M.S.L.)
4. HORIZONTAL DATUM IS NAD 83 ALASKA STATE PLANE ZONE 4,.

KUUKPIK LCMF LLC
Alpine Survey Office

ConocoPhillips Alaska, Inc.

ALPINE | MODULE: CD50 | UNIT: CD

CD-5 ACCESS ROAD
NIGLIQ BRIDGE
SCOUR MONITORING

REDRAWN FROM: | CONSTRUCTION SHEET OF

DO NOT SCALE — ABOVE SCALE FOR REFERENCE ONLY

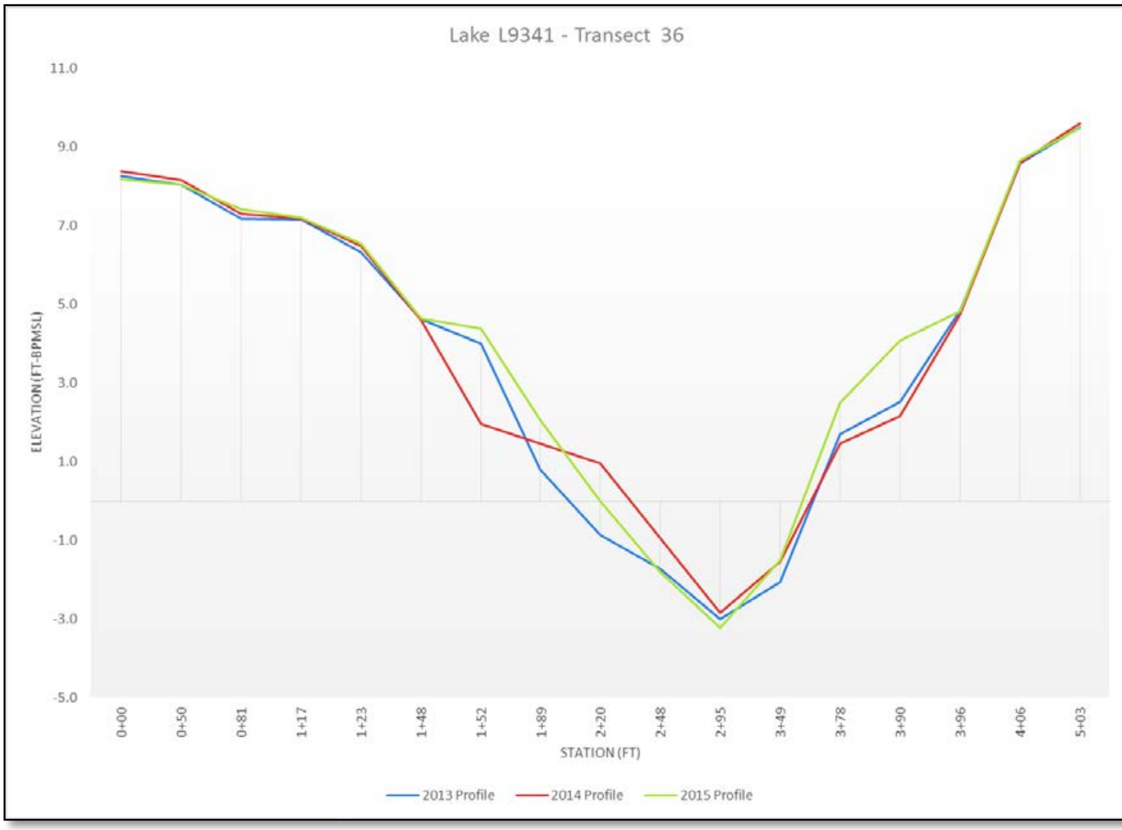
DATE: 08/23/14	DRAWN: CZ	DESIGN: GD	ECM NO: K140003ACS		
	CHECKED: —		CC NO: —		
SCALE: 1" = 50'	APPROVAL: —		CADD FILE NO. 14-08-12-1AW		
JOB NO: —	SUB JOB NO: —	DRAWING NO: CE-CD50-1022		PART: 1 OF 1	REV: 2

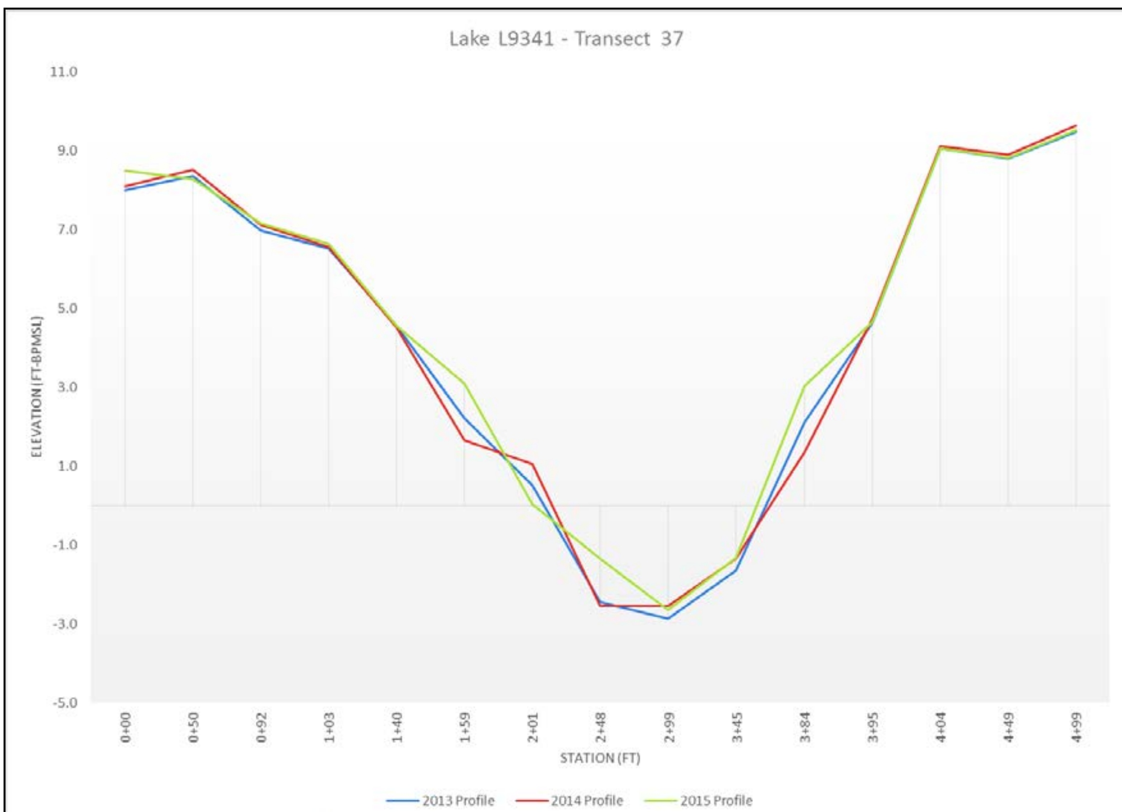
REFERENCE DWG NO/SHT NO:

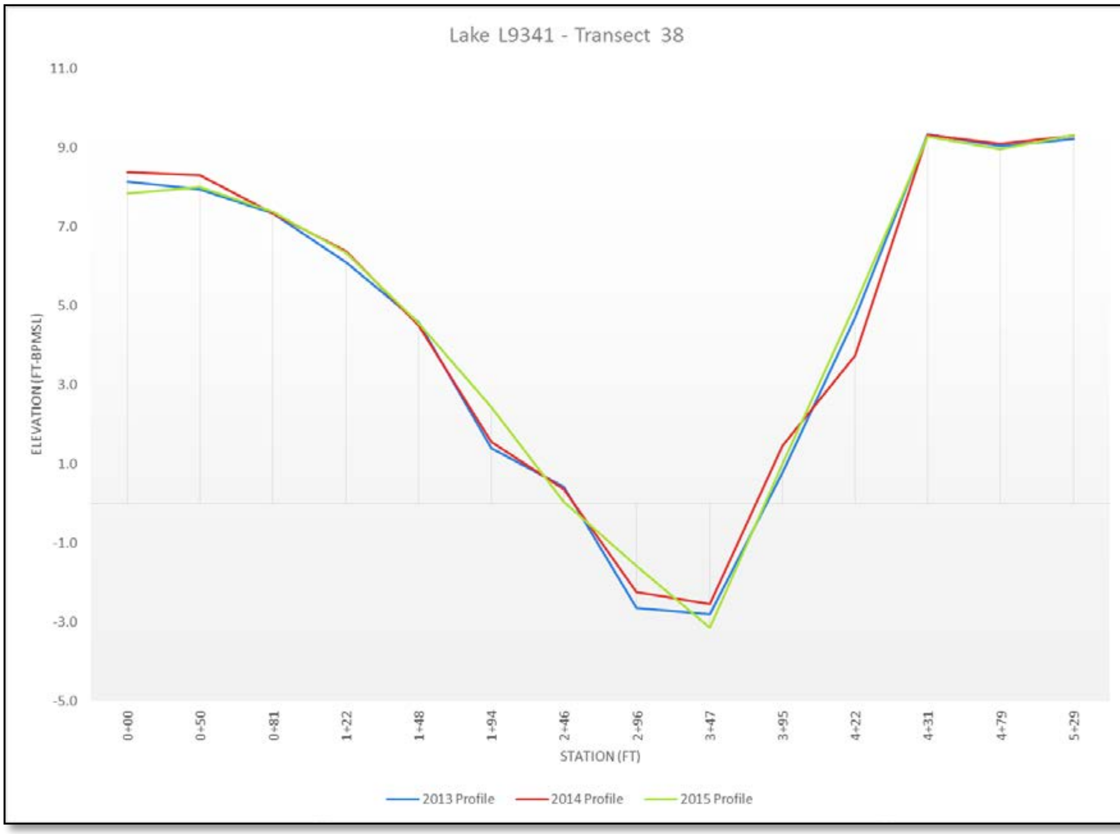
REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
2	8/30/15	UPDATED PER 20968257ACS	TB	DB			
1	08/25/14	ISSUED PER K140003ACS	CZ	GD			

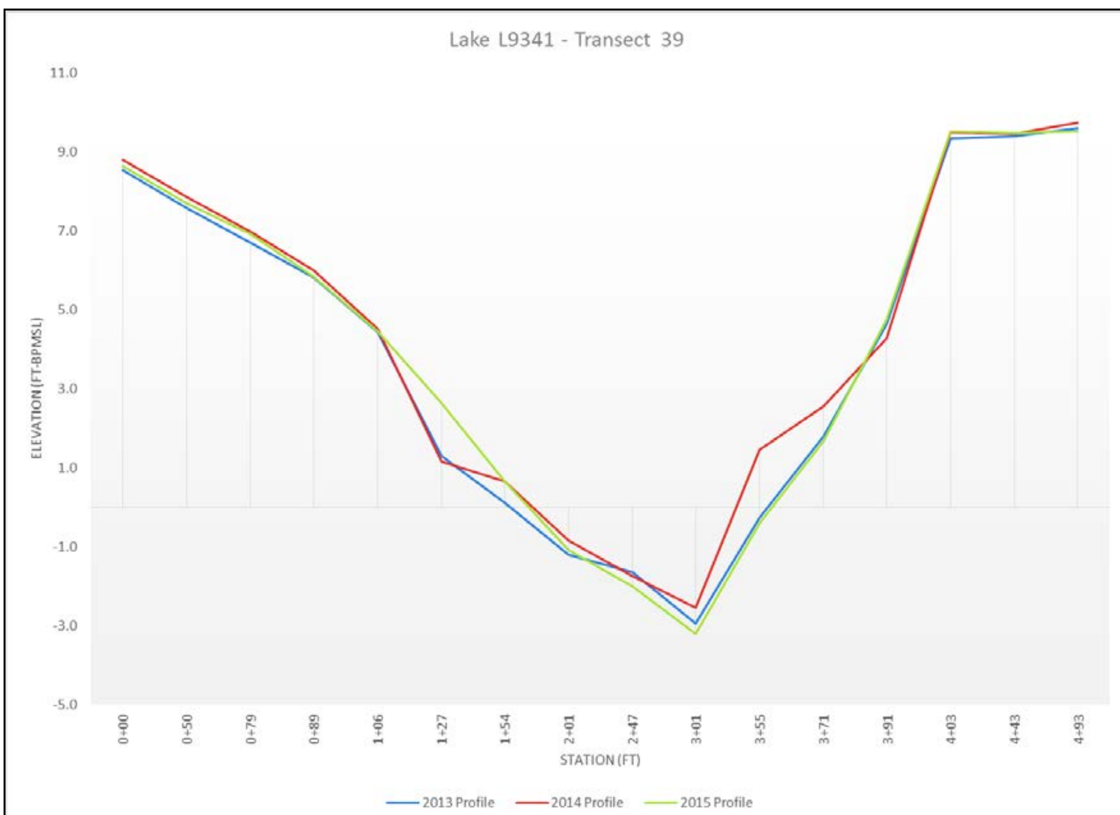
FORM: DSIZE

G.2 Lake L9341 Bridge






Lake L9341 - Transect 38
ELEVATION (FT-BPMSL)
11.0
9.0
7.0
5.0
3.0
1.0
-1.0
-3.0
-5.0
0+00
0+50
0+81
1+22
1+48
1+94
2+46
2+96
3+47
3+95
4+22
4+31
4+79
5+29
STATION (FT)
2013 Profile
2014 Profile
2015 Profile


Lake L9341 - Transect 39
ELEVATION (FT-BPMSL)
11.0
9.0
7.0
5.0
3.0
1.0
-1.0
-3.0
-5.0
0+00
0+50
0+79
0+89
1+06
1+27
1+54
2+01
2+47
3+01
3+55
3+71
3+91
4+03
4+43
4+93
STATION (FT)
2013 Profile
2014 Profile
2015 Profile

Calc'd By: TB
Date: 8/30/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	8.3	8.4	8.2	Ground Shot
0+50	8.0	8.2	8.0	Ground Shot
0+81	7.2	7.3	7.4	Ground Shot
1+17	7.2	7.2	7.2	Top of Bank
1+23	6.3	6.5	6.5	Edge of Vegetation
1+48	4.6	4.6	4.6	Edge of Water
1+52	4.0	2.0	4.4	River Bottom
1+89	0.8	1.5	2.1	River Bottom
2+20	-0.9	1.0	0.0	River Bottom
2+48	-1.7	-0.9	-1.8	River Bottom
2+95	-3.0	-2.8	-3.2	River Bottom
3+49	-2.1	-1.5	-1.5	River Bottom
3+78	1.7	1.5	2.5	River Bottom
3+90	2.5	2.2	4.1	River Bottom
3+96	4.8	4.7	4.8	Edge of Water
4+06	8.6	8.6	8.7	Top of Bank
5+03	9.5	9.6	9.5	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_36

Calc'd By: TB
Date: 8/30/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	8.0	8.1	8.5	Ground Shot
0+50	8.3	8.5	8.3	Ground Shot
0+92	7.0	7.1	7.2	Top of Bank
1+03	6.5	6.6	6.6	Edge of Vegetation
1+40	4.6	4.5	4.6	Edge of Water
1+59	2.2	1.7	3.1	River Bottom
2+01	0.5	1.1	0.0	River Bottom
2+48	-2.4	-2.5	-1.4	River Bottom
2+99	-2.9	-2.5	-2.6	River Bottom
3+45	-1.6	-1.3	-1.3	River Bottom
3+84	2.1	1.4	3.0	River Bottom
3+95	4.6	4.7	4.7	Edge of Water
4+04	9.1	9.1	9.1	Top of Bank
4+49	8.8	8.9	8.8	Ground Shot
4+99	9.5	9.6	9.5	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_37

Calc'd By: TB
Date: 8/30/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	8.1	8.4	7.8	Ground Shot
0+50	7.9	8.3	8.0	Ground Shot
0+81	7.3	7.3	7.4	Top of Bank
1+22	6.1	6.4	6.3	Edge of Vegetation
1+48	4.6	4.5	4.6	Edge of Water
1+94	1.4	1.6	2.4	River Bottom
2+46	0.4	0.4	0.0	River Bottom
2+96	-2.6	-2.2	-1.6	River Bottom
3+47	-2.8	-2.5	-3.2	River Bottom
3+95	0.8	1.5	1.0	River Bottom
4+22	4.7	3.7	5.0	Edge of Water
4+31	9.3	9.3	9.3	Top of Bank
4+79	9.0	9.1	9.0	Ground Shot
5+29	9.2	9.3	9.3	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_38

Calc'd By: TB
Date: 8/30/2015
RPT-CE-CD-114 REV3

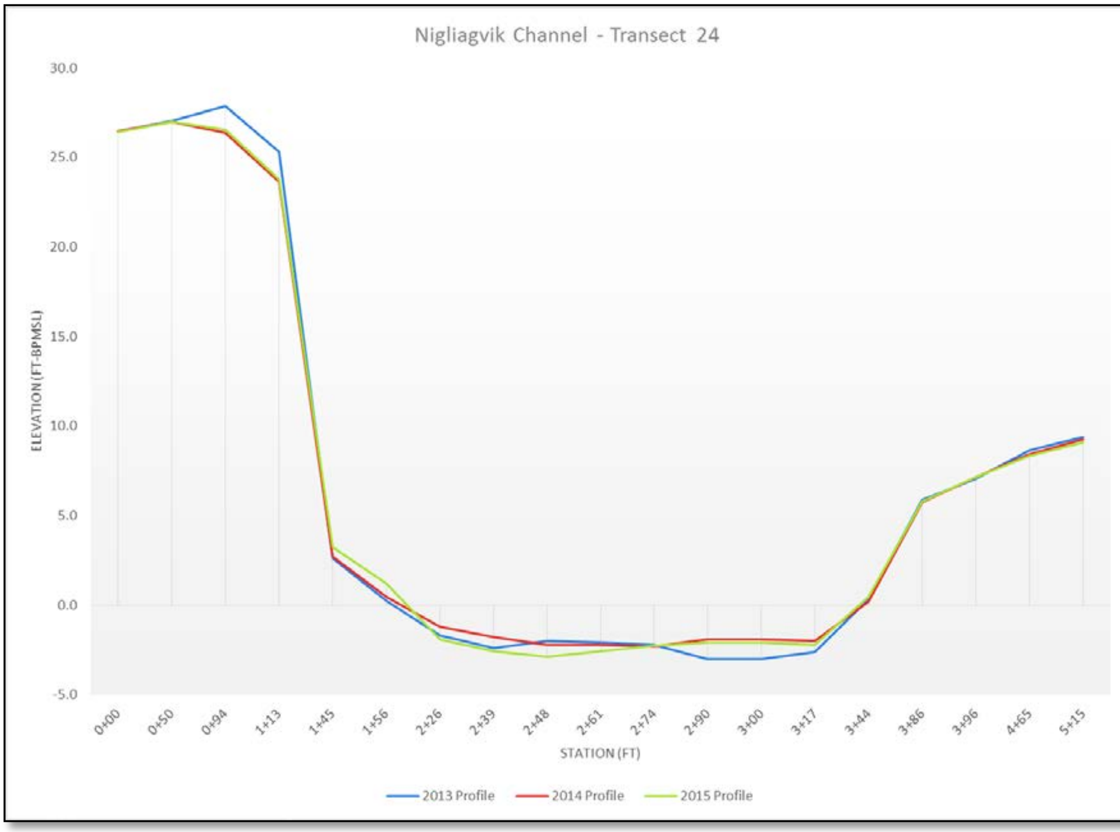
CD-5 Michael Baker
Bridge Transects

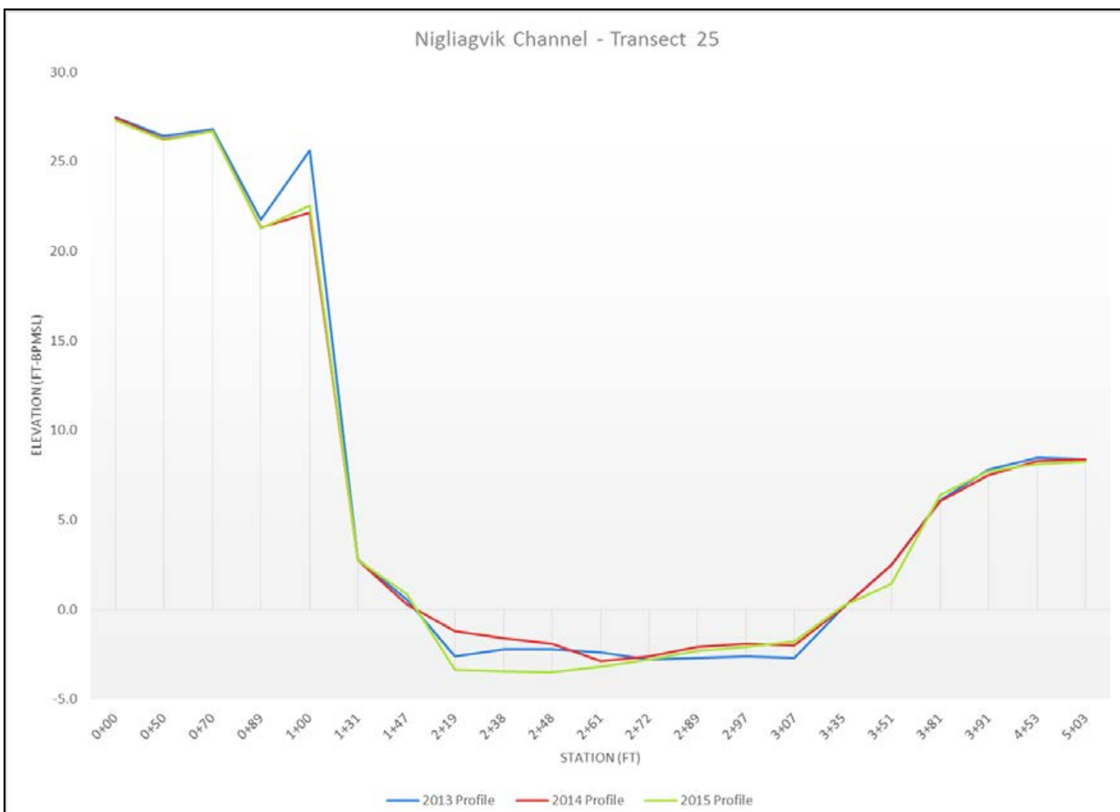
Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

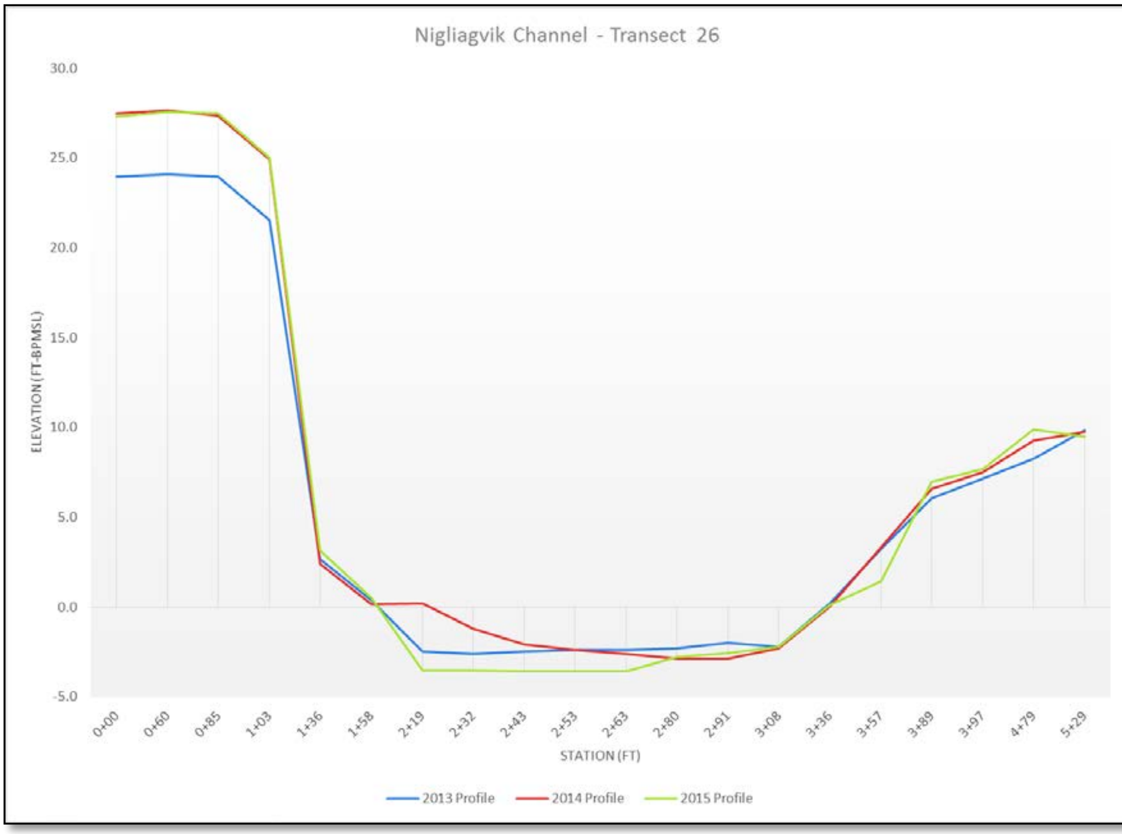
STA	2013	2014	2015	Description
0+00	8.5	8.8	8.6	Ground Shot
0+50	7.6	7.8	7.7	Ground Shot
0+79	6.7	7.0	6.9	Top of Bank
0+89	5.8	6.0	5.8	Edge of Vegetation
1+06	4.4	4.5	4.5	Edge of Water
1+27	1.3	1.2	2.6	River Bottom
1+54	0.1	0.7	0.6	River Bottom
2+01	-1.2	-0.8	-1.1	River Bottom
2+47	-1.7	-1.7	-2.0	River Bottom
3+01	-3.0	-2.5	-3.2	River Bottom
3+55	-0.3	1.5	-0.4	River Bottom
3+71	1.8	2.6	1.7	River Bottom
3+91	4.6	4.3	4.8	Edge of Water
4+03	9.3	9.5	9.5	Top of Bank
4+43	9.4	9.5	9.5	Ground Shot
4+93	9.6	9.7	9.5	Ground Shot

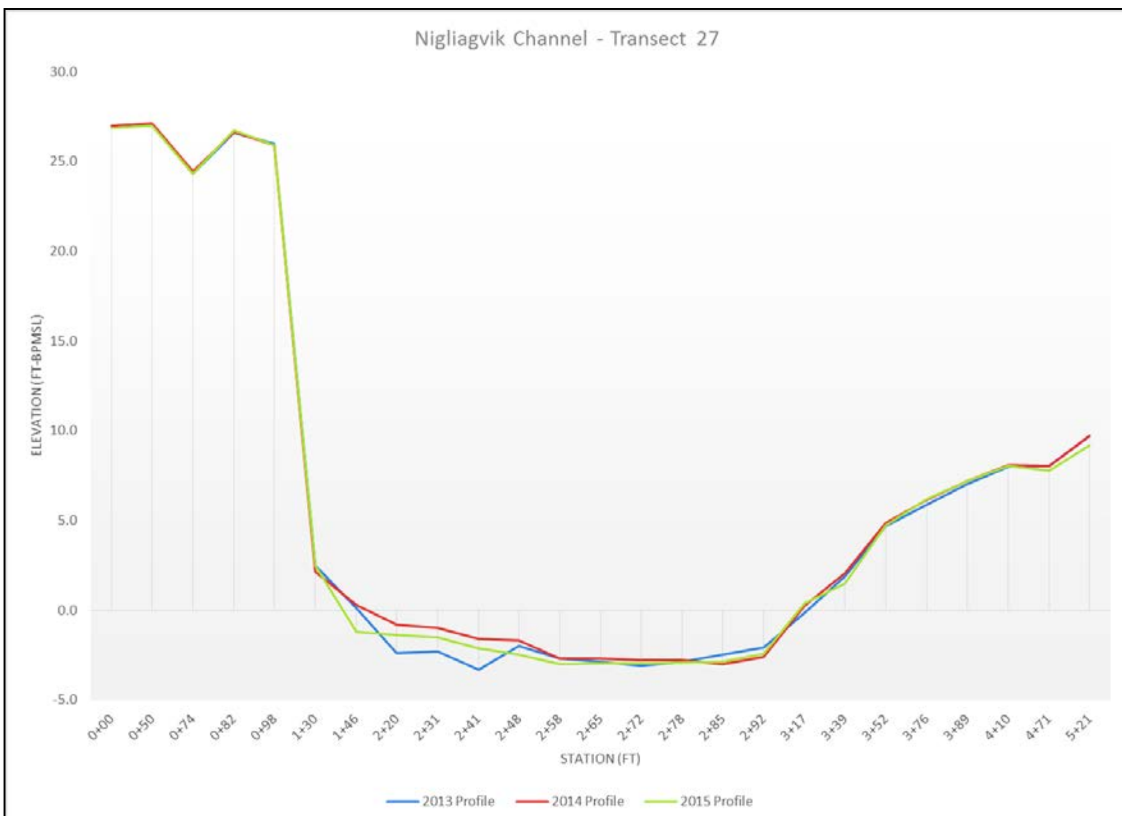
Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_39

G.3 Nigliagvik Bridge






Nigliagvik Channel - Transect 26
ELEVATION (FT-BPMSL)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
0+00
0+60
0+85
1+03
1+36
1+58
2+19
2+32
2+43
2+53
2+63
2+80
2+91
3+08
3+36
3+57
3+89
3+97
4+79
5+29
STATION (FT)
2013 Profile
2014 Profile
2015 Profile


Nigliagvik Channel - Transect 27
ELEVATION (FT-BPMSL)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
0+00
0+50
0+74
0+82
0+98
1+30
1+46
2+20
2+31
2+41
2+48
2+58
2+65
2+72
2+78
2+85
2+92
3+17
3+39
3+52
3+76
3+89
4+10
4+71
5+21
STATION (FT)
2013 Profile
2014 Profile
2015 Profile

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	26.5	26.5	26.4	Ground Shot
0+50	27.0	27.0	27.0	Ground Shot
0+94	27.9	26.4	26.5	Ground Shot
1+13	25.3	23.6	23.8	Top of Bank
1+45	2.6	2.7	3.2	Toe of Bank
1+56	0.2	0.5	1.2	Edge of Water
2+26	-1.7	-1.2	-1.9	River Bottom
2+39	-2.4	-1.8	-2.6	River Bottom
2+48	-2.0	-2.2	-2.9	River Bottom
2+61	-2.1	-2.2	-2.6	River Bottom
2+74	-2.2	-2.3	-2.3	River Bottom
2+90	-3.0	-1.9	-2.1	River Bottom
3+00	-3.0	-1.9	-2.1	River Bottom
3+17	-2.6	-2.0	-2.2	River Bottom
3+44	0.3	0.2	0.4	Edge of Water
3+86	5.9	5.7	5.8	Edge of Vegetation
3+96	7.1	7.2	7.2	Top of Bank
4+65	8.7	8.5	8.3	Ground Shot
5+15	9.4	9.2	9.1	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_24

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	27.5	27.4	27.3	Ground Shot
0+50	26.4	26.2	26.2	Ground Shot
0+70	26.8	26.7	26.7	Ground Shot
0+89	21.8	21.3	21.3	Grade Break
1+00	25.7	22.2	22.5	Top of Bank
1+31	2.8	2.8	2.7	Toe of Bank
1+47	0.6	0.3	0.9	Edge of Water
2+19	-2.6	-1.2	-3.4	River Bottom
2+38	-2.2	-1.6	-3.5	River Bottom
2+48	-2.2	-1.9	-3.5	River Bottom
2+61	-2.4	-2.9	-3.2	River Bottom
2+72	-2.8	-2.6	-2.8	River Bottom
2+89	-2.7	-2.1	-2.3	River Bottom
2+97	-2.6	-1.9	-2.1	River Bottom
3+07	-2.7	-2.0	-1.8	River Bottom
3+35	0.1	0.1	0.2	Edge of Water
3+51	2.5	2.5	1.5	Ground Shot
3+81	6.1	6.1	6.4	Edge of Vegetation
3+91	7.8	7.5	7.7	Top of Bank
4+53	8.5	8.3	8.1	Ground Shot
5+03	8.4	8.4	8.3	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_25

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	24.0	27.5	27.3	Ground Shot
0+60	24.1	27.7	27.6	Ground Shot
0+85	24.0	27.3	27.5	Ground Shot
1+03	21.5	24.9	25.0	Grade Break
1+36	2.7	2.4	3.1	Top of Bank
1+58	0.4	0.2	0.5	Toe of Bank
2+19	-2.5	0.2	-3.5	Edge of Water
2+32	-2.6	-1.2	-3.5	River Bottom
2+43	-2.5	-2.1	-3.6	River Bottom
2+53	-2.4	-2.4	-3.6	River Bottom
2+63	-2.4	-2.6	-3.6	River Bottom
2+80	-2.3	-2.9	-2.8	River Bottom
2+91	-2.0	-2.9	-2.6	River Bottom
3+08	-2.2	-2.3	-2.2	River Bottom
3+36	0.2	0.0	0.1	River Bottom
3+57	3.2	3.3	1.4	Edge of Water
3+89	6.1	6.6	7.0	Ground Shot
3+97	7.1	7.5	7.7	Edge of Vegetation
4+79	8.3	9.3	9.9	Top of Bank
5+29	9.8	9.8	9.5	Ground Shot
Station 4+79 falls in Slope of Gravel Road				

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_26

Calc'd By: TB
Date: 8/29/2015
RPT-CE-CD-114 REV3

CD-5 Michael Baker
Bridge Transects

Kuukpik/LCMF
Alpine Survey Office
DOC LCMF-156 REV3

STA	2013	2014	2015	Description
0+00	27.0	27.0	26.8	Ground Shot
0+50	27.1	27.1	27.0	Ground Shot
0+74	24.3	24.5	24.3	Grade Break
0+82	26.6	26.6	26.7	Grade Break
0+98	26.0	25.9	25.9	Top of Bank
1+30	2.5	2.1	2.5	Toe of Bank
1+46	0.1	0.3	-1.2	Edge of Water
2+20	-2.4	-0.8	-1.4	River Bottom
2+31	-2.3	-1.0	-1.5	River Bottom
2+41	-3.3	-1.6	-2.1	River Bottom
2+48	-2.0	-1.7	-2.5	River Bottom
2+58	-2.7	-2.7	-3.0	River Bottom
2+65	-2.9	-2.7	-3.0	River Bottom
2+72	-3.1	-2.8	-3.0	River Bottom
2+78	-2.9	-2.8	-2.9	River Bottom
2+85	-2.5	-3.0	-2.9	River Bottom
2+92	-2.1	-2.6	-2.4	River Bottom
3+17	-0.1	0.2	0.4	Edge of Water
3+39	1.9	2.0	1.5	Ground Shot
3+52	4.7	4.9	4.7	Ground Shot
3+76	5.9	6.1	6.2	Edge of Vegetation
3+89	7.0	7.2	7.2	Top of Bank
4+10	8.0	8.1	8.0	Ground Shot
4+71	8.0	8.0	7.8	Ground Shot
5+21	9.7	9.7	9.2	Ground Shot

Doc LCMF-156 CD5 Bridge Transects Rev3 Report Tables.xlsx 1 of 1 Transect_27

DRAWING NO:	SUB JOB NO:	JOB NO:
CE-CD50-1023	–	–

PIER 3
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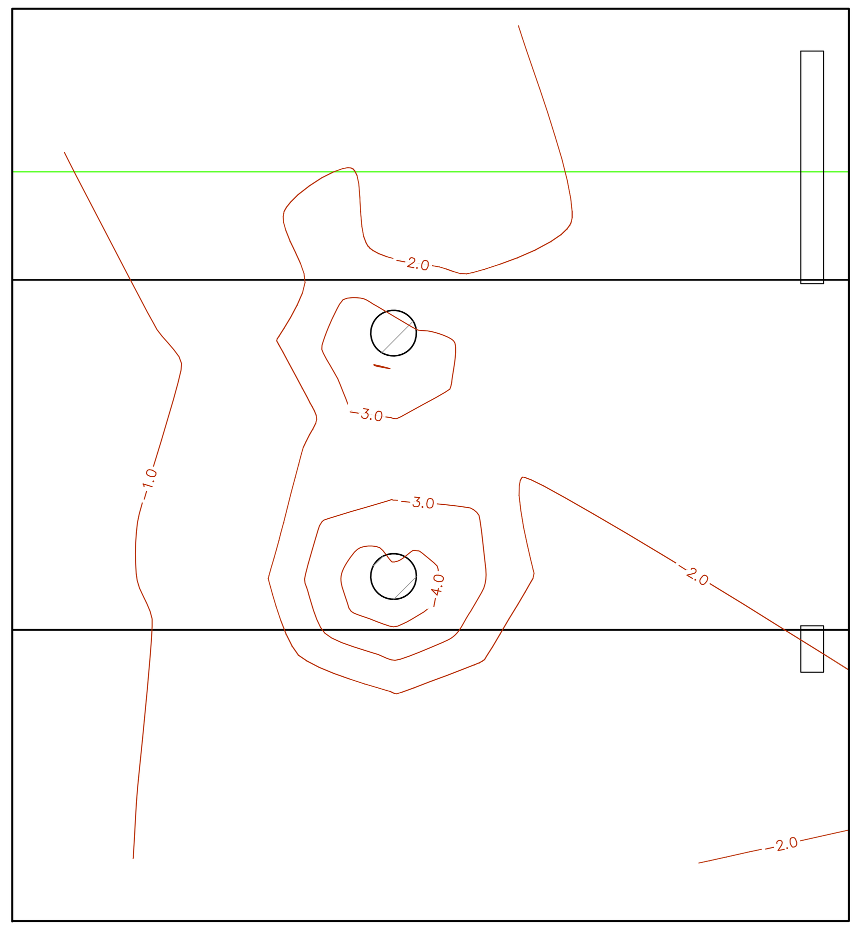
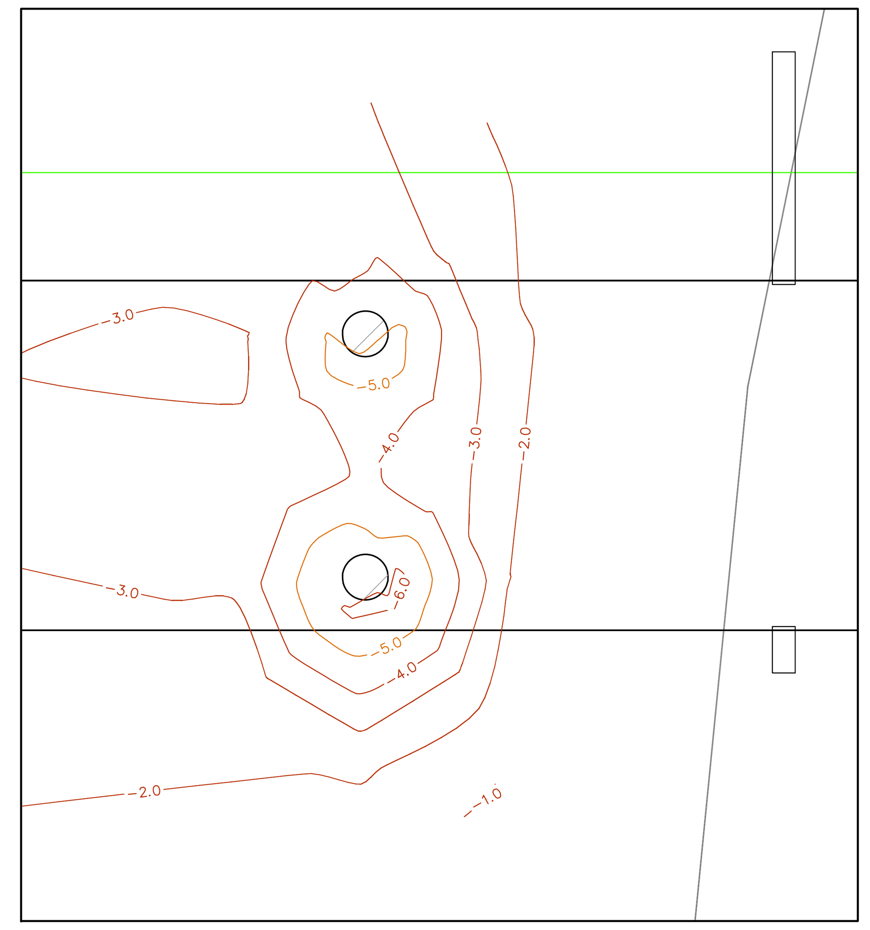
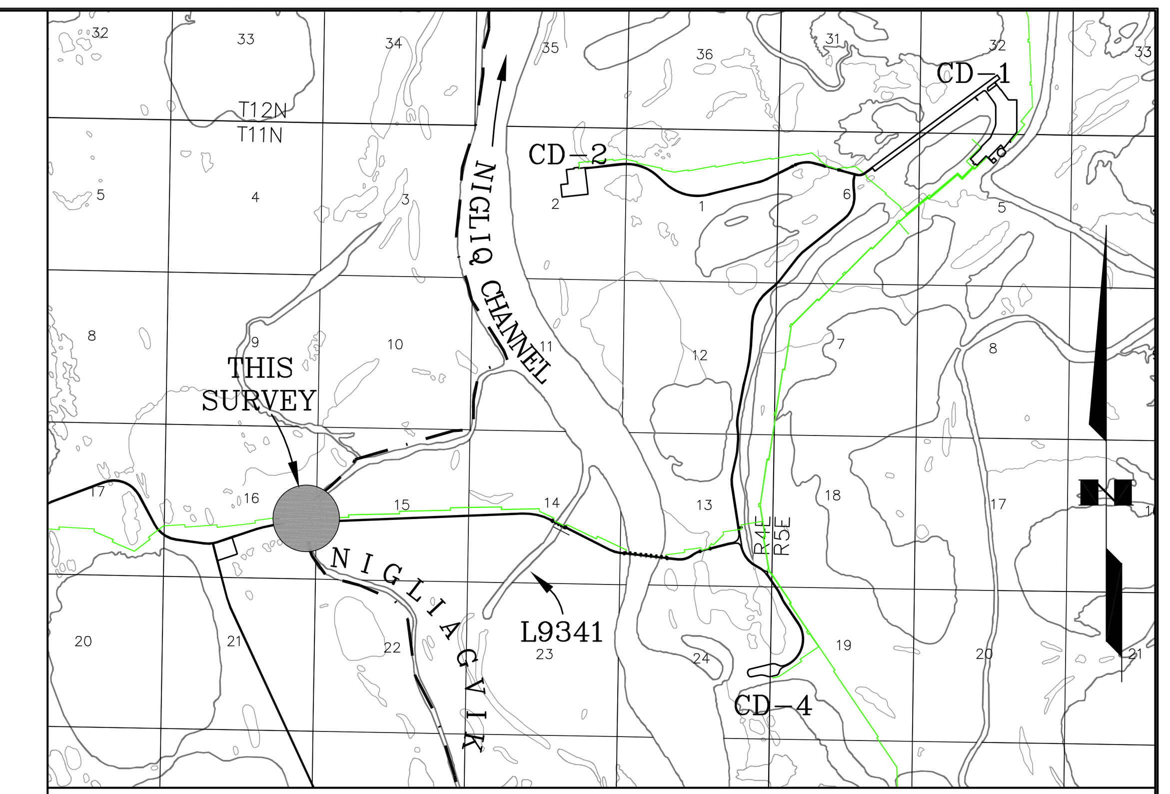


PIER 4
SCALE: 1" = 10'





VICINITY MAP

NOTES

1. DATE OF SURVEY: 8/21/14; 9/3/15.
2. REFERENCE FIELD BOOKS: LCMF2014-21, PG. 37; LCMF2015-19, PG. 14.
3. ELEVATIONS ARE BRITISH PETROLEUM MEAN SEAL LEVEL (B.P.M.S.L.)
4. HORIZONTAL DATUM IS NAD 83 ALASKA STATE PLANE ZONE 4,.

KUUKPIK LCMF LLC
Alpine Survey Office

ConocoPhillips
Alaska, Inc.

ALPINE MODULE: CD50 UNIT: CD

CD-5 ACCESS ROAD
NIGLIAGVIK BRIDGE
SCOUR MONITORING

REDRAWN FROM:
CONSTRUCTION SHEET OF

DO NOT SCALE — ABOVE SCALE FOR REFERENCE ONLY

FORM: DSIZE

REFERENCE DWG NO/SHT NO:

REV	DATE	REVISIONS	BY	CHK	JOB ENGR	PROJ ENGR	CUST APP
2	9/8/15	UPDATED PER 20968257ACS	CZ	DB			
1	08/25/14	ISSUED PER K140003ACS	CZ	GD			

DATE: 8/25/14	DRAWN: CZ	DESIGN: –	ECM NO: K140003ACS
	CHECKED: GD		CC NO: –
SCALE: 1" = 20'	APPROVAL: –		CADD FILE NO: 14-08-12-1CW
JOB NO: – / SUB JOB NO: –	DRAWING NO: CE-CD50-1023		PART: 1 OF 1 / REV: 2

G.3.1 NIGLIAGVIK CHANNEL REAL-TIME SCOUR MONITORING PROJECT NOTE

Status Report

Michael Baker INTERNATIONAL

Project:	2015 CD5 Bridge Real-Time Pier Scour Monitoring System Implementation	**Project No:** 145414	
To:	Conoco Phillips		
From:	Garrett Yager	**Date:** 05/14/2015	
Subject:	**System Testing and Nigliagvik Bridge Installation**		

Contents

Introduction

Michael Baker Jr., Inc. (Baker) is providing implementation and monitoring services for the CD5 Bridges Real-Time Pier Scour Monitoring System. This work supports the CD5 Monitoring Plan with Adaptive Management Strategy by providing real-time pier scour measurements during spring breakup flood events at piers most susceptible to scour. 2015 scour depths will be measured using a sonar system mounted on pier 3 of the Nigliagvik Bridge. In future years, the system will be expanded to include the Nigliq Bridge piers 2 through 5.

Equipment Acquisition and Pre-Deployment Testing

Two AS-3™ Sonar Scour Trackers were acquired from ETI Instrument Systems of Fort Collins, Colorado. The AS-3 systems consists of the following components (Photo 1):

- Sonar transducer(s) for sensing riverbed elevation at the base of the piers
- Datalogger for collecting, analyzing, and formatting sonar data
- Digital cellular modem providing communications via the Internet
- Remote unit (Nigliq system only)
- Wireless data link for connecting to remote unit (Nigliq system only)
- Fiberglass weatherproof electronics enclosure

Status Report

2015 CD5 Real-Time Pier Scour Monitoring System Implementation System Testing and Nigliagvik Bridge Installation

Photo 1: Electronics including the datalogger, cellular modem, and battery; May 2015

The sonar systems were equipped with 12-volt 18-amp hour sealed lead acid batteries and their functionality was tested prior to field deployment. A digital cellular modem account with a static IP address was set up through Verizon Wireless. For testing, the sonar transducers were wired to the dataloggers and submerged in a 6 foot column of water and depth measurements below the transducer were verified. A computer running Campbell Scientific LoggerNet software established communications via the Internet. The dataloggers were programmed to measure and store water depth every half hour and to email daily system status reports. The status reports confirm the system is operating and relay the current battery voltage.

The systems were powered on for approximately one week and data was downloaded frequently to check for issues. Edits were made to the datalogger programs until data was consistently recorded, saved, and transmitted.

Nigliagvik Installation and Field Testing

Steel pipe casing was installed by ConocoPhillips (CPAI) on pier 3 of the Nigliagvik Bridge to protect the sonar transducer and cable from ice impacts. The casing extends from the pile cap down to an elevation of approximately 1 foot BPMSL (Photo 2). Following the casing installation, the sonar system electronics and hardware were shipped to Alpine, Alaska.

Photo 2: Bottom of the protective steel casing after ice removal; May 2015

Prior to accessing the site, the field team coordinated with CD5 supervisors and Alpine Security. UMIAQ, LLC (LCMF) provided transportation and assisted in traffic control using signage and radio communication. A toolbox safety meeting was held and personal protective equipment was used including fall protection, hard hats, high visibility vest, and gloves A task hazard assessment was performed on-site prior to commencing work. The sonar transducer was mounted into a steel housing and the first 45 feet of cable was fed into flexible conduit (Photo 3). The transducer was placed into the steel casing from the bridge deck, then lowered, and aligned at the bottom. The sonar cable, approximately 200 feet long, was routed to the west abutment through hangers attached to the bridge rail bollard brackets (Photo 4 and Photo 5). The electronics enclosure was hung from the west abutment

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using hanging rods hooked onto the sheet pile freeboard above the gravel backfill. The sonar transducer cable was connected to the datalogger (Photo 6).

Photo 3: Nigliagvik Bridge steel housing; May 2015

Photo 4: Nigliagvik Bridge fiberglass electronics enclosure hanging from the west abutment sheet pile; May 2015

Photo 5: Nigliagvik Bridge sonar transducer cable routed through hangers from pier 3 to the west abutment; May 2015

Photo 6: Nigliagvik Bridge sonar transducer cable hanger detail; May 2015

Baker performed a survey to transfer BPMSL elevations from nearby vertical control to the bottom of the pipe casing. This elevation will be used to determine the elevation of the sonar transducer and subsequent elevation of the riverbed at the base of the pier. The sonar transducer elevation was entered into the datalogger program.

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Following installation, sonar communications were checked from CD1 and data transfer was confirmed. Following the field test, the electronics enclosure was removed; it will be reinstalled prior to breakup flooding.

During the breakup monitoring period, Baker personnel will review the daily data transmission and remotely login to the system to retrieve the riverbed elevations at the base of the pier two times per day. If scour approaches design elevations, CPAI will be notified following the same procedures used for reporting other breakup flooding events which include contacting Alpine Environmental Coordinators and Alpine Operations. Baker personnel will tend the batteries as needed. It is anticipated that routine battery replacement will occur every 5 days. The installation is temporary and, except for the steel casing, designed to be removed seasonally or to accommodate bridge traffic or maintenance.

2015 Colville River Delta Spring Breakup Monitoring and Hydrological Assessment