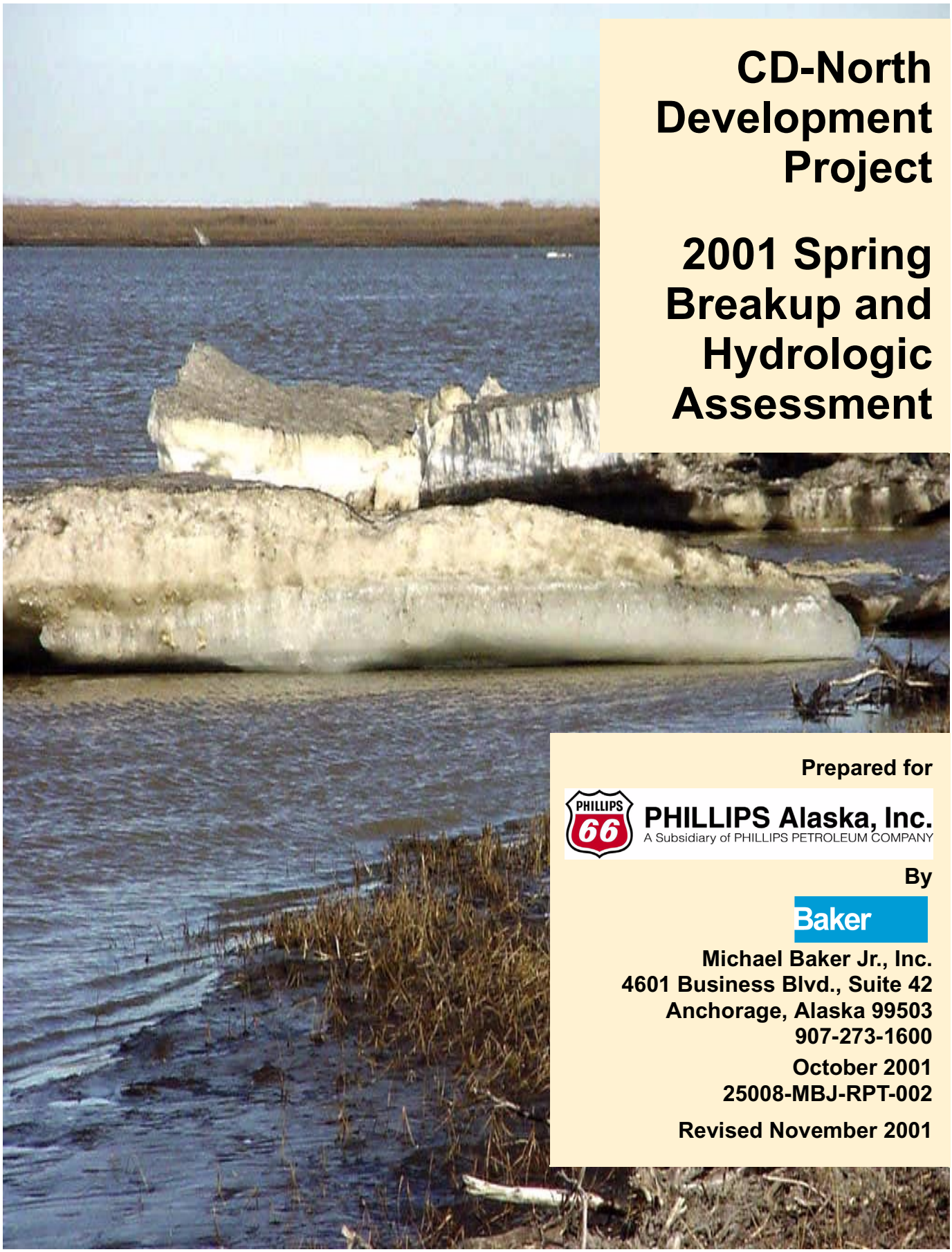

CD-North Development Project

2001 Spring Breakup and Hydrologic Assessment

Prepared for

PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

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Section 1. Introduction

Since 1992, breakup studies have been conducted on the Colville River Delta to further the understanding of the hydrologic characteristics associated with spring breakup flooding events. Historic data for the Colville River Delta and its region are limited. A continued monitoring effort is required to provide the necessary information to design oil field facilities that are safe during a large flood event.

This report summarizes the observations and measurements made during the 2001 spring breakup of the Colville River Delta and its impact on the proposed CD-North satellite development (Figure-1-1). Field data for CD-North was collected in conjunction with the existing Alpine Development hydrologic breakup study .

Provided in Section 2 of this report are data, observations, and analysis related to the head of the delta and observations that pertain to the delta as a whole. Presented in Section 3 are data, observations, and analysis related specifically to CD-North.

All elevations presented in this report are in feet and are referenced to British Petroleum Mean Sea Level (BPMSL) datum unless otherwise noted. All tables, figures, and photographs referenced within a given section are located at the end of that section.

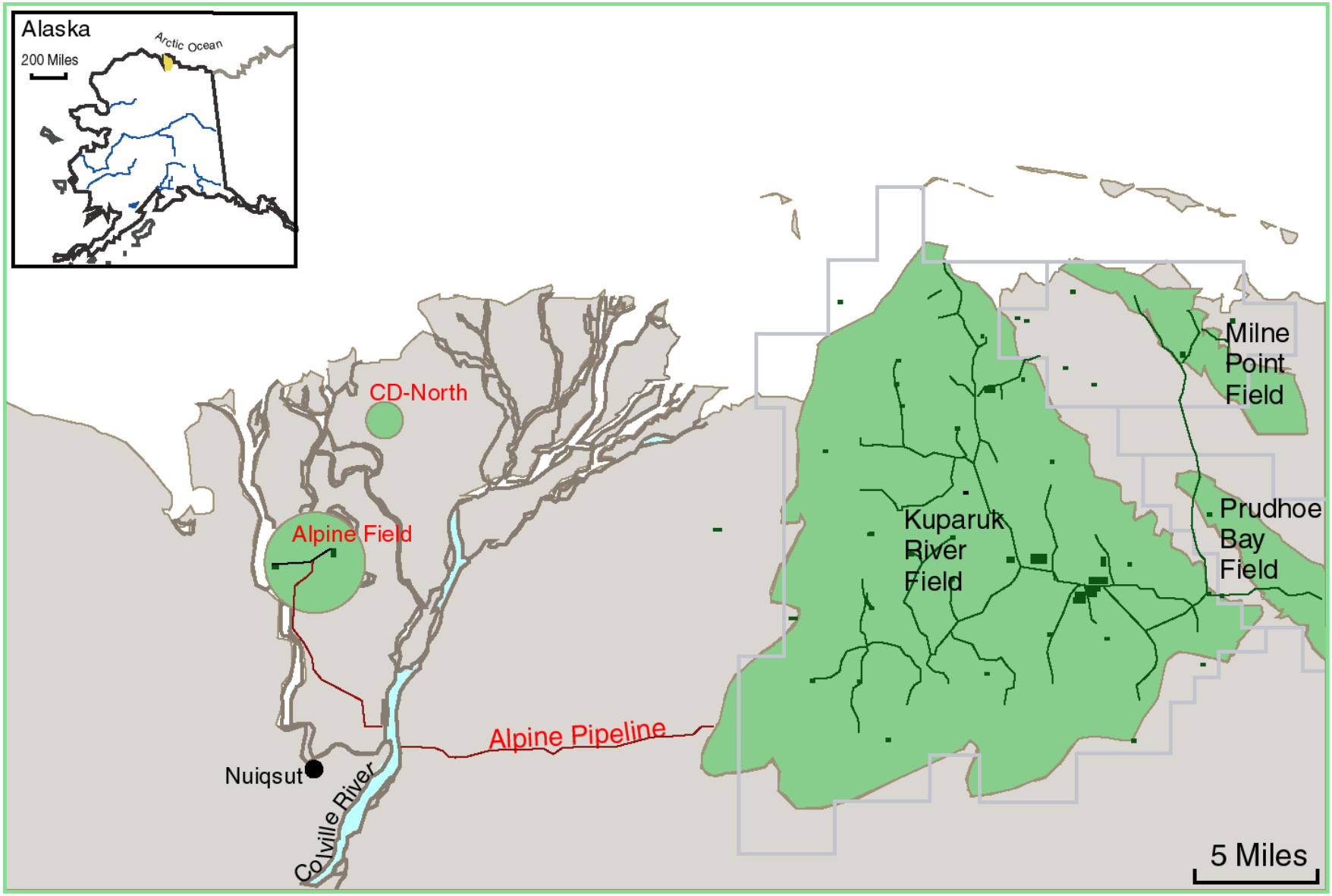


Figure 1-1. Colville Delta North (Cd-North) Satellite Development Location

Section 2. Colville River

2.1 Water Surface Elevations and Observations at the Head of the Delta

Water surface elevations were monitored at the head of the Colville River Delta at three monitoring sites, Monument 01, temporary benchmark (TBM) 01U, and TBM 01D. TBM 01U and TBM 01D are located approximately ½-mile upstream and downstream from Monument 01, respectively. Figure 2-1 shows the locations of the temporary staff gages at the head of the delta. Measurements began on 6 June, the day after flowing water was first observed near Monument 01. Measurements continued until 13 June, when all temporary staff gages were removed. Water surface elevation and observation records for the temporary staff gages at the head of the delta are presented in Tables 2-1 through 2-3. Photographs 2-1 through 2-7 show conditions at the cross sections during the period 6 June through 10 June 2001.

2.2 Peak Water Surface Elevation and Discharge

The peak water surface elevation at Monument 01 occurred on the morning of 10 June at an elevation of 17.37 feet. Discharge at the time of the peak water surface elevation is estimated to have been 208,000 cubic feet per second (cfs). At the time of the peak water surface elevation, the low water channel ice on both the East and Nigliq Channels was floating and was mostly intact. In addition, the Sakoonang and other channels in the lower portions of the delta were blocked with snow, or contained intact low water channel ice.

Measured peak water surface elevations at Monument 01 were compared to water surface elevations predicted by the two-dimensional surface water model developed for the Colville River Delta (Michael Baker Jr., Inc., 2001, 1998; and Shannon & Wilson, Inc., 1997). Based on a linear interpolation between the water surface elevations predicted for the 2- and 10-year open water floods, it is estimated that the peak water surface elevations observed this spring at Monument 01 will likely be equaled or exceeded, on average, about once every 7 years.

Normal depth computations were used to estimate the peak spring discharge in the Colville River. Water surface elevation and slope data were obtained from the measurements made at the head of the delta. Cross section geometry was based on a 1996-surveyed cross section at Monument 01

(Shannon & Wilson, 1996). Hydraulic roughness values were estimated based on a 1993 discharge measurement (Alaska Biological Research and Shannon & Wilson, 1994). The peak discharge at the head of the Colville River Delta is estimated to have been 300,000 cfs and to have occurred early on the morning of 11 June (approximately 24 hours after the peak water surface elevation). It is estimated that this discharge will be equaled or exceeded, on average, approximately once every 4 years (Michael Baker Jr., Inc. et. al., 1998).

The peak discharge coincided with a period of significant clearing of ice and snow in the channels. During the evening of 10 June and the early morning of 11 June, much of the low water channel ice in the East Channel and the upper Nigliq Channel had cleared. At the time the peak discharge is estimated to have occurred, the channel at Monument 01 was likely clear of low water channel ice and the channel ice downstream in the delta was clearing. Most of the snow that was blocking flow in the Sakoonang and other channels of the lower delta had cleared by the morning of 11 June. To a large degree, the clearing of the intact channel ice, especially in the Nigliq and East channels, resulted in the increase in discharge and the accompanying decrease in water surface elevation observed at Monument 01 between 10 and 11 June. A hydrograph of water surface elevation and discharge vs. time is presented on Figure 2-2.

Observations at the time of the peak water surface elevation indicate that low water channel ice was intact in the major channels of the delta and that many of the smaller channels were blocked with snow. The two-dimensional surface water model assumes open water conditions and does not take into account channel ice or ice jams. At the time the model was constructed, it was assumed that during a large flood (such as the 50-, 100- and 200-year events for which the model was constructed), the presence of an ice sheet or ice jams would have little effect on the water surface elevation. However, channel ice and ice jams will restrict flow and cause increases in water surface elevation during smaller flood events when the flow is mainly confined within the channel banks. Thus, the water surface elevation predictions of the two-dimensional model will generally under-predict water surface elevations during small flood events when channel ice or ice jams are occurring in the delta. It is for this reason that the return period estimated from predicted water surface elevations is higher than the return period estimated from discharge at the head of the delta.

Table 2-1. Monument 01, Water Surface Elevations and Observations

Date	Time	Water Surface Elevation (ft BPMSL)	Observations
6/6/01	14:26	11.67	Channel ice intact along right bank. Small ice chunks floating in water near left bank.
6/7/01	7:42	12.43	Channel ice intact on right bank. Snow on left bank at water surface becoming saturated. Ice chunks floating in channel near gages.
6/7/01	15:02	12.46	Channel ice intact on right bank. Snow on left bank at water surface becoming saturated. Ice chunks floating in channel near gages.
6/7/01	18:44	12.55	Channel ice intact on right bank. Some floating ice chunks.
6/8/01	8:49	12.96	Channel ice intact along right bank.
6/8/01	16:02	13.51	Channel ice intact along right bank.
6/9/01	7:56	14.34	Channel ice intact along right bank.
6/9/01	14:10	14.96	Ice chunks floating among gages.
High Water Mark		17.37	The peak water surface elevation probably occurred the morning of 10 June
6/10/01	12:00	17.01	
6/10/01	17:55	16.52	
6/11/01	8:17	14.18	Channel ice has cleared. Ice chunks floating through section.
6/12/01	9:13	13.45	Ice chunks floating through section.
6/13/01	12:30	13.00	

Notes:
1. Elevations are based on an elevation of 27.74 feet BPMSL for Monument 01, established by Lounsbury & Assoc. in 1996.
2. The distance from TBM 01U to Monument 01 is 2901 feet. The distance from Monument 01 to TBM 01D is 2928 feet.
3. Coordinates for Monument 01 are N70°09'50.3" W150°056'12.7" (NAD 27) as surveyed by Lounsbury & Associates.

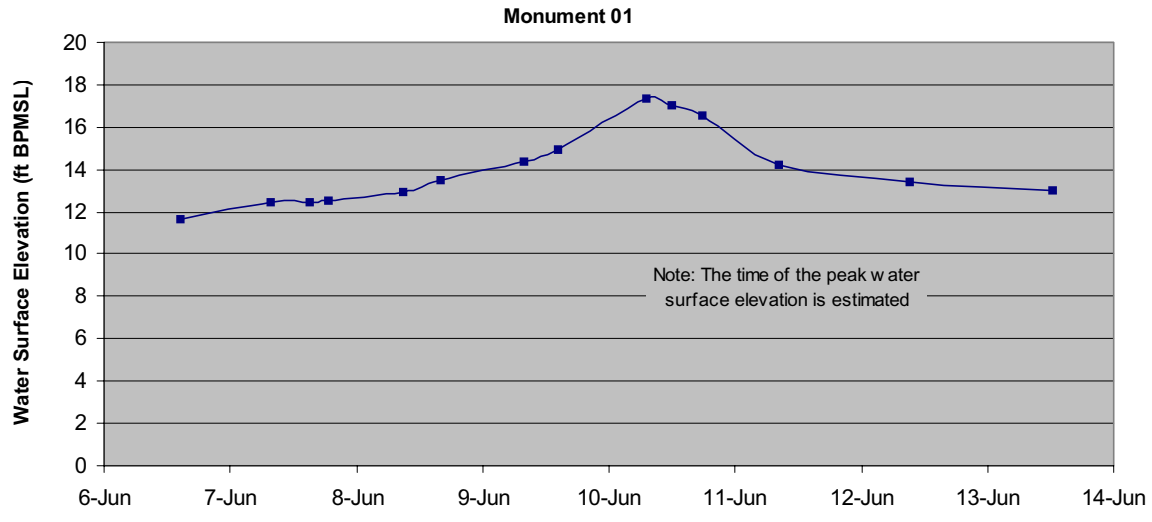


Table 2-2. Temporary Benchmark 01U, Water Surface Elevations and Observations

Date	Time	Water Surface Elevation (ft BPMSL)	Observations
6/6/01	14:34	12.01	Channel ice still intact along right bank. Small ice chunks floating in water near left bank.
6/7/01	7:28	12.76	Channel ice intact on right bank. Snow on left bank at water surface becoming saturated. Ice chunks floating in channel near gages.
6/7/01	14:55	12.78	Channel ice intact on right bank. Snow on left bank at water surface becoming saturated. Ice chunks floating in channel near gages.
6/7/01	18:38	12.89	Channel ice intact on right bank. Some floating ice chunks.
6/8/01	8:00	13.66	Channel ice intact along right bank.
6/8/01	15:56	14.26	Channel ice intact along right bank.
6/9/01	7:51	15.34	Channel ice intact along right bank.
6/9/01	14:35	15.54	Ice chunks floating in channel. Channel ice intact along right bank.
High Water Mark		17.88	The peak water surface elevation probably occurred the morning of 10 June
6/10/01	10:10	17.22	Channel ice along right bank breaking up. Appears peak may have occurred, good high water indicators.
6/10/01	18:18	16.71	Water apparently receding. Less floating chunks of ice.
6/11/01	7:49	14.56	Channel ice has cleared. Ice chunks floating through section. Some grounded ice along left bank.
6/12/01	8:55	13.89	Ice chunks floating through section.
6/13/01	12:00	13.44	

Notes:
1. Elevations are based on an elevation of 27.74 feet BPMSL for Monument 01, established by Lounsbury & Assoc. in 1996.
2. The distance from TBM 01U to Monument 01 is 2901 feet.
3. Coordinates for TBM 01U are N70°09'31.4" W150°56'36.7" (NAD 27) as obtained by a Garmin II Plus handheld GPS.

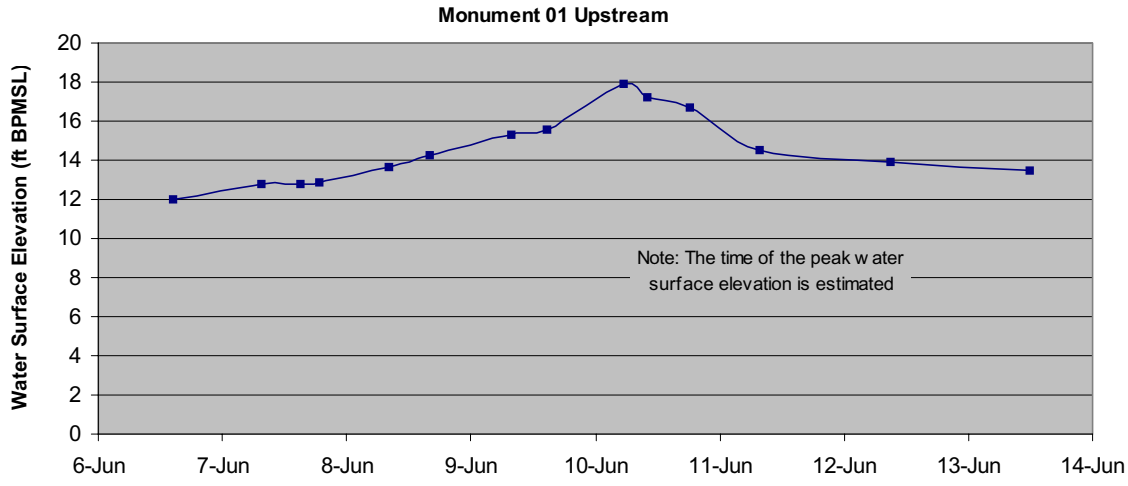
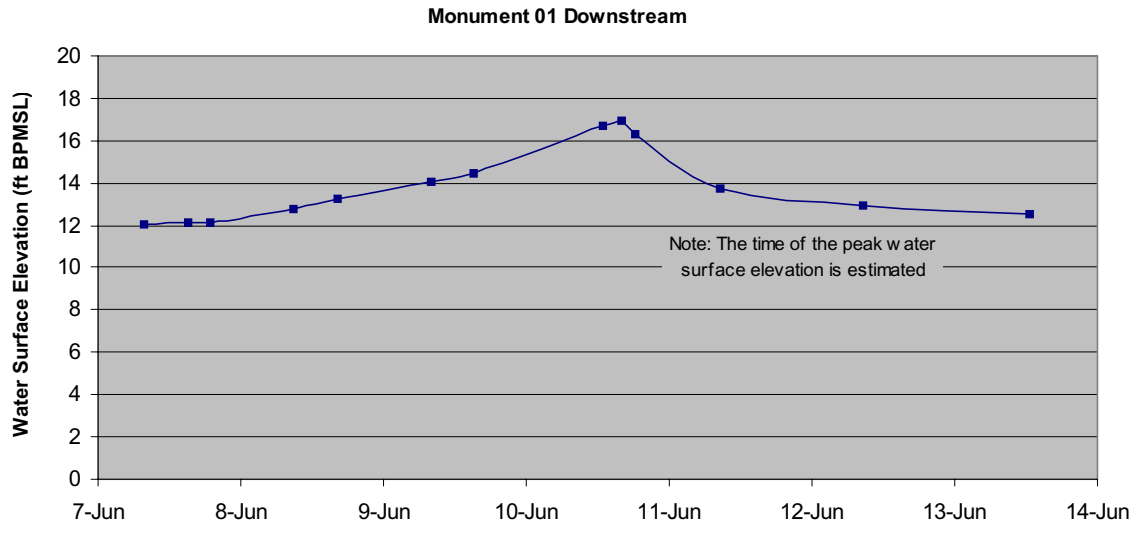


Table 2-3. Temporary Benchmark 01D, Water Surface Elevations and Observations

Date	Time	Water Surface Elevation (ft BPMSL)	Observations
6/7/01	7:49	12.05	Channel ice intact on right bank. Snow on left bank at water surface becoming saturated. Ice chunks floating in channel near gages.
6/7/01	15:07	12.09	Channel ice intact on right bank. Snow on left bank at water surface becoming saturated. Ice chunks floating in channel near gages.
6/7/01	18:48	12.14	Channel ice intact on right bank. Some floating ice chunks.
6/8/01	8:55	12.76	Channel ice intact along right bank.
6/8/01	16:10	13.27	Channel ice intact along right bank.
6/9/01	8:05	14.05	Channel ice intact along right bank.
6/9/01	15:00	14.47	Ice chunks floating through gages.
High Water Mark		16.98	The peak water surface elevation probably occurred the morning of 10 June
6/10/01	12:44	16.72	Channel ice along right bank breaking up. Appears peak may have occurred, good high water marks on shoreline.
6/10/01	18:25	16.28	
6/11/01	8:39	13.70	Channel ice has cleared. Ice chunks floating through section.
6/12/01	9:38	12.97	
6/13/01	12:30	12.54	

Notes:
1. Elevations are based on an elevation of 27.74 feet BPMSL for Monument 01, established by Lounsbury & Assoc. in 1996.
2. The distance from Monument 01 to TBM 01D is 2928 feet.
3. Coordinates for TBM 01D are N70°01'26.6" W150°056'01.6" (NAD 27) as obtained by a Garmin II Plus handheld GPS.



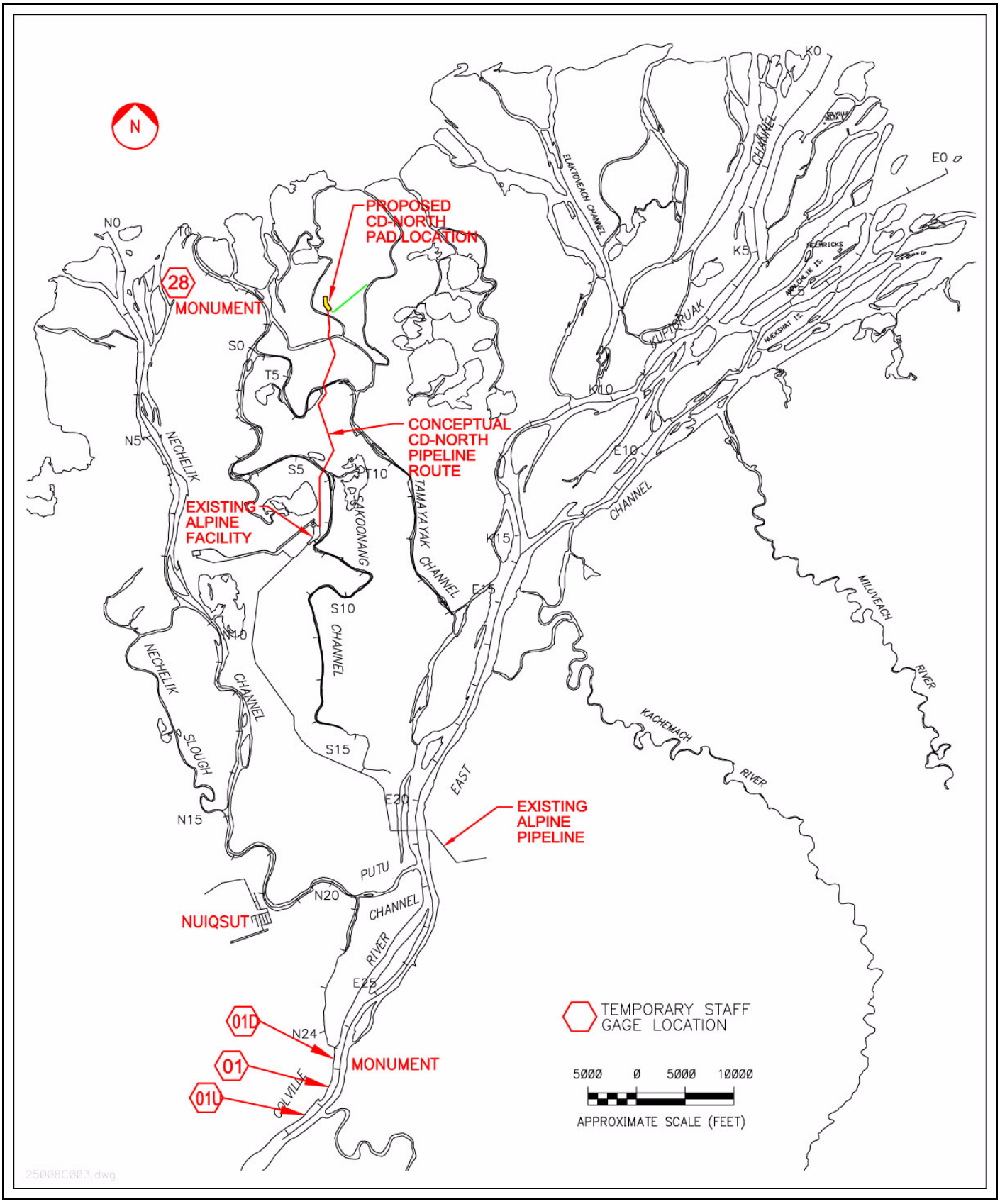


Figure 2-1. Temporary Staff Gage and Monument Locations

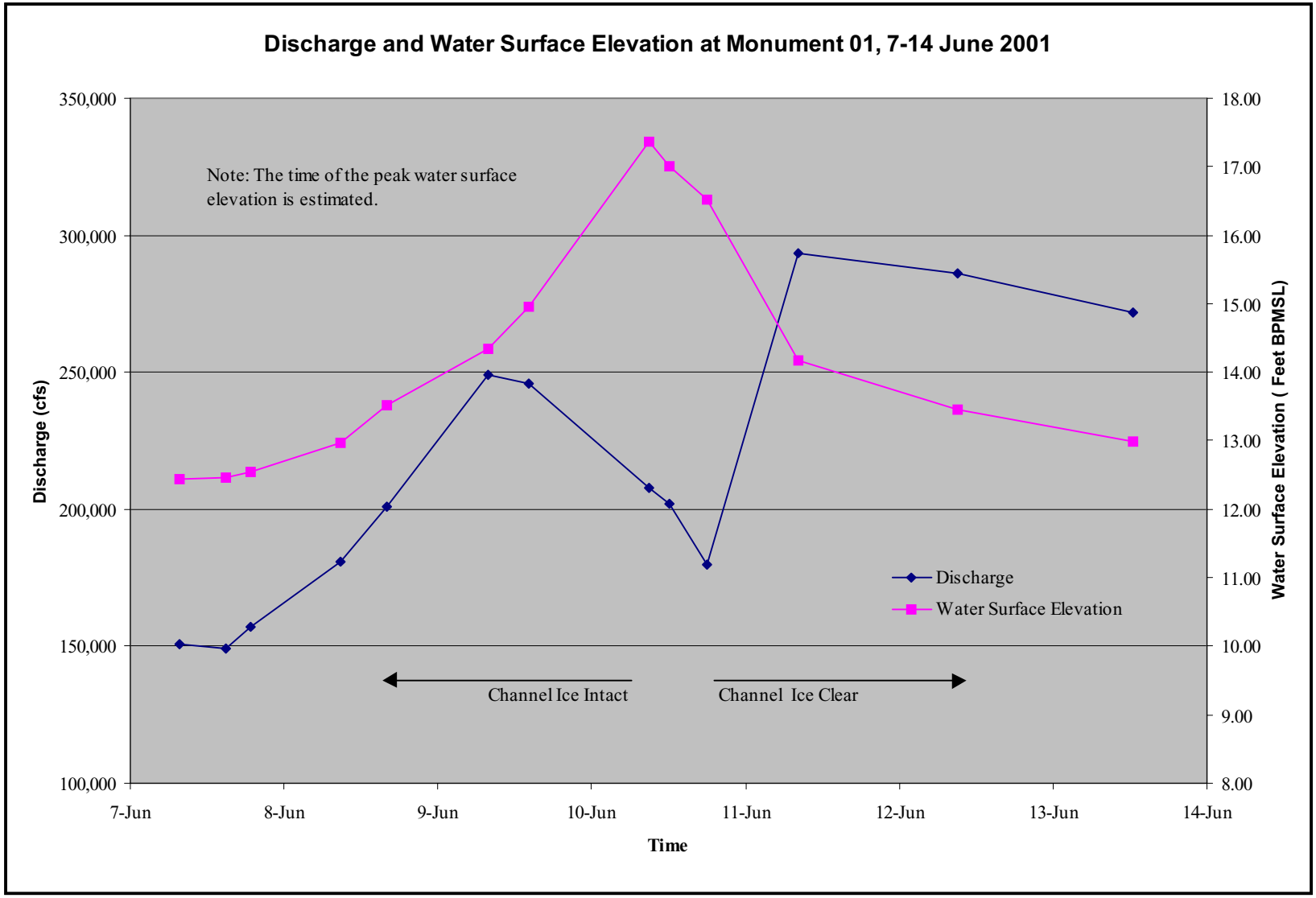


Figure 2-2. Discharge and Water Surface Elevation at Monument 01, 7-14 June 2001

Photo 2-1. Looking North at the Divergence of the East Channel and Nigliq Channel, 5 June 2001. Note flow entering Nigliq on left.

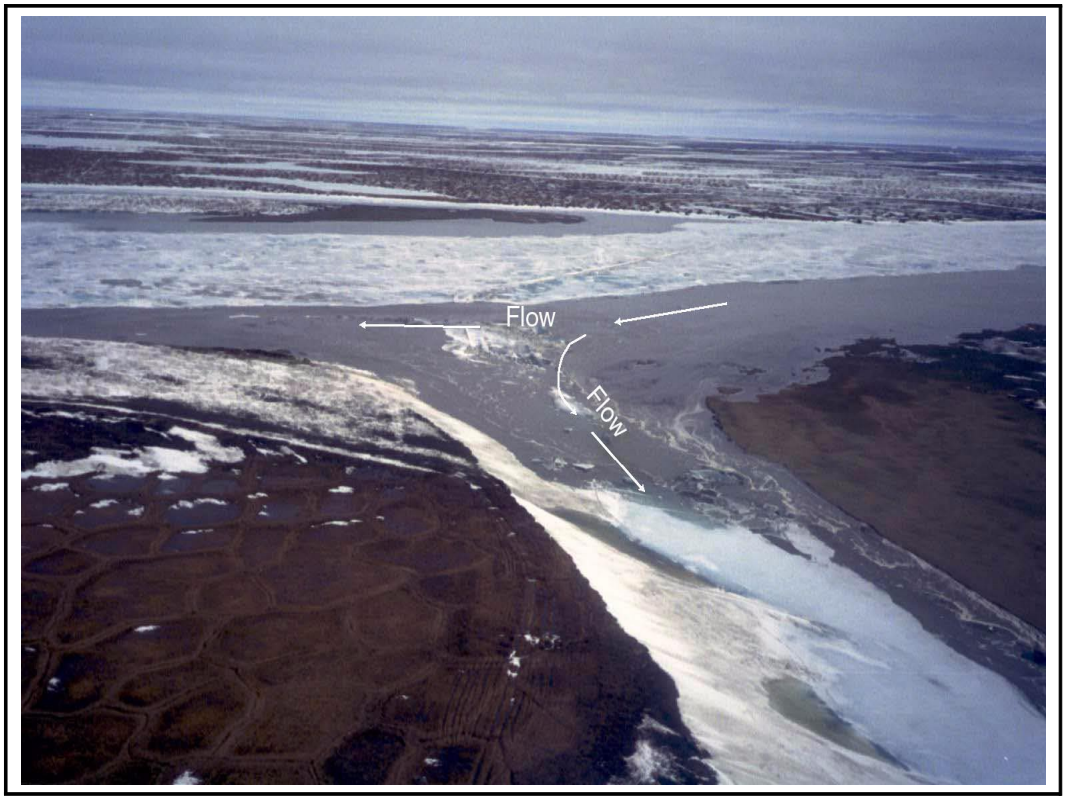


Photo 2-2. Looking East at the Divergence of the East Channel and Putu Channel, 5 June 2001. Note flow entering Putu Channel.

Photo 2-3. Temporary Benchmark 01U, 6 June 2001. Looking east across the Colville River.

Photo 2-4. Monument 01, 6 June 2001. Looking east across the Colville River.

Photo 2-5. Temporary Benchmark 01U, 7 June 2001. Looking south (upstream).

Photo 2-6. Temporary Benchmark 01D, 9 June 2001. Looking east across the Colville River.

Photo 2-7. Temporary Benchmark 01U, 10 June 2001. Looking east at conditions in the Colville River at Temporary Benchmark 01U approximately 3 - 4 hours after the peak water surface elevation occurred.

Section 3. CD-North

CD-North is a proposed Colville Delta satellite development located between the West and East Ulamnigiaq Channels of the Colville River approximately 5 miles north of existing Alpine facilities. CD-North is proposed as a roadless development that will have a facilities gravel pad and airstrip. A pipeline connecting CD-North to Alpine is proposed. The location of the proposed gravel structures and two conceptual pipeline routes are presented on Figure-3-1. At the time of the breakup studies, Alternate 1 was the preferred pipeline route.

To monitor water surface elevations in the CD-North project area, temporary staff gages were installed on the Sakoonang, Tamayagiaq, Ulamnigiaq, West Ulamnigiaq, and East Ulamnigiaq Channels (see Figure-3-2). Staff gages were installed at each of the pipeline crossing locations and in the vicinity of the proposed gravel structures.

Water surface elevation measurements began on 7 June 2001 when flowing water was first observed and continued until 13 June when all staff gages were removed. In addition to water surface elevation measurements, a channel cross section was identified on each channel crossed by the proposed pipeline routes and surveyed by Kuukpik/LCMF Incorporated. Cross section locations are shown on Figure-3-2 and each of the cross sections are presented on Figures 3-3 through 3-7. Site specific water surface elevations and observations for each of the channels monitored is discussed in the following sections. A summary of channel conditions at the time of the peak water surface elevation is shown on Table 3-1.

3.1 Sakoonang Channel

The Sakoonang Channel is asymmetrical and generally trapezoidal in shape in the vicinity of the proposed pipeline crossing. During 2001 spring breakup, flow was confined entirely to the active channel. At the time of the peak water surface elevation, the top width of flow was 460 feet, average depth was 6.6 feet, and the maximum depth was 12.1 feet. The Sakoonang Channel at the proposed pipeline crossing is shown in cross section in Figure-3-3.

Water was first observed on the Sakoonang Channel staff gages on 7 June. Water surface elevations peaked at 7.32 feet and 6.76 feet at the upstream and downstream monitoring sites, respectively. In the vicinity of the proposed pipeline crossing, the peak water surface elevation was estimated to be 7.1 feet. Peak water surface elevations occurred on the morning on 11 June. No visible channel ice or snow remained intact, or was observed floating in the channel during the afternoon of 11 June.

Based on normal depth calculations, it was estimated that at the time the peak water surface elevation occurred, discharge on the Sakoonang Channel at the proposed pipeline crossing was approximately 14,500 cubic feet per second (cfs) with an average velocity of 3.8 feet per second (ft/sec). Water surface elevations and observations for the Sakoonang Channel are summarized in Table 3-2. Photos 3-1 and 3-2 show the Sakoonang Channel on 7 and 9 June, respectively.

Between 7 and 10 June, negative water surface slopes (downstream water surface elevation higher than upstream water surface elevation) were observed on the Sakoonang Channel indicating flow was entering the channel downstream from the monitoring sites and flowing upstream. This is consistent with observations of the upper reaches of the Sakoonang Channel (south of Alpine), during the same period, when the channel was blocked with snow and no flowing water was observed. Water from both the Nigliq and Tamayagiaq Channels was observed flowing onto the sea ice and back into the mouth of the Sakoonang Channel.

By the afternoon of 11 June, snow blockages in the upper reaches of the Sakoonang Channel had cleared and water was entering the Sakoonang Channel from the East Channel and flowing downstream. The clearing of the snow blockages in the Sakoonang Channel coincided with the peak discharge estimated at the head of the delta.

Based on visual observations, the streambed material of the active channel was composed of fine sand and silt, and was relatively free of dunes and other bedforms. The bank-to-bank width of the channel was approximately 470 feet. The left (looking downstream) overflow bank was relatively smooth and covered with sedge and sparse willow. The right overflow bank consisted of rough polygon formations and dense sedge. Manning roughness coefficients, *n*, estimated for the

Sakoonang Channel crossing were 0.050 for the left overflow bank, 0.021 for the active channel, and 0.060 for the right overflow bank. Selection of Manning's *n* at all cross sections was based on the procedures outlined in Arcement & Schneider, 1989.

3.2 Tamayagiaq Channel

The Tamayagiaq Channel is asymmetrical and generally trapezoidal in shape in the vicinity of the proposed pipeline crossing. At the time of the peak water surface elevation, the top width of water was approximately 1,180 feet, and water was flowing on both the right and left overbanks. The average depth was 5.8 feet, and the maximum depth was 14.8 feet at the time of the peak water surface elevation. The Tamayagiaq Channel at the proposed pipeline crossing is shown in cross section in Figure-3-4.

In the Tamayagiaq Channel, flowing water was first observed on 7 June. Water surface elevations peaked at 9.13 feet and 8.60 feet at the upstream and downstream monitoring sites, respectively. In the vicinity of the proposed pipeline crossing the peak water surface elevation was estimated to be 9.1 feet. Peak water surface elevations occurred on the morning on 11 June and no intact channel ice or snow was visible; however, ice floes up to 30 feet across and 4 feet thick were observed. Based on normal depth calculations, it was estimated that at the time the peak water surface elevation occurred, peak discharge on the Tamayagiaq Channel at the proposed pipeline crossing was approximately 21,500 cfs with an average velocity of 3.2 ft/sec. Water surface elevation and observations for the Tamayagiaq Channel are summarized in Table 3-3. Photos 3-3, 3-4, and 3-5 show the Tamayagiaq Channel on 6 and 11 June, respectively.

Based on visual observation, the streambed material of the active channel was composed of fine silt and was relatively smooth and free of bedforms. The bank-to-bank width of the channel is approximately 640 feet. The left overflow bank was covered with dense grasses and sparse willow. The right overflow bank area consisted of dense grasses and rough polygon formations with relief of up to 2 feet. Manning roughness coefficients, *n*, estimated for the Tamayagiaq crossing were 0.058 for the left overflow bank, 0.021 for the active channel, and 0.065 for the right overflow bank area.

3.3 Ulamnigiaq Channel

The Ulamnigiaq Channel is asymmetrical and generally trapezoidal in shape in the vicinity of the pipeline crossing. At the time of the peak water surface elevation, the top width of water was approximately 600 feet, average depth was 8.4 feet, and the maximum depth was 20.4 feet. The Ulamnigiaq Channel at the proposed pipeline crossing is shown in cross section in Figure-3-5.

Flowing water was first observed on the Ulamnigiaq Channel on 7 June. Water surface elevations peaked between the evening of 10 June and the morning of 11 June, at an estimated 7.4 feet[1] at the upstream monitoring site and 6.92 feet at the downstream monitoring site. In the vicinity of the proposed pipeline crossing the peak water surface elevation was estimated to be 7.3 feet. On the afternoon of 11 June, no intact channel ice or snow was observed, however, ice floes up to 30 feet across and 4 feet thick were observed stranded in the channel and on the banks.

Based on normal depth calculations it was estimated that at the time the peak water surface elevation occurred, peak discharge on the Ulamnigiaq Channel at the proposed pipeline crossing was approximately 14,200 cfs with an average velocity of 3.2 ft/sec. Water surface elevation and observations for the Ulamnigiaq Channel are summarized in Table 3-4. Photos 3-6 and 3-7 show conditions at the Ulamnigiaq Channel on 6 and 11 June, respectively.

Based on visual observations, the streambed material of the active channel was composed of fine silt. The channel bed was irregular, but was relatively smooth and free of bedforms. The bank-to-bank width of the channel was approximately 620 feet. The left overflow bank was relatively smooth and covered with dense grasses. The right overflow bank area consisted of rough ground with as much as 2 feet of relief and was covered with dense grasses. Manning roughness coefficients, *n*, estimated for the Ulamnigiaq crossing were 0.050 and 0.040 for the left overflow bank, 0.023 for the active channel, and 0.060 for the right overflow bank area.

1. The data does not appear to support an accurate measurement of the peak water surface elevation and the value presented is estimated based on the available data.

Alternate Ulamnigiaq Channel Pipeline Crossing

An alternate pipeline crossing location was identified on the Ulamnigiaq Channel that could conceivably eliminate the necessity of a crossing on the West Ulamnigiaq Channel. The alternate crossing was approximately one-quarter mile upstream from the divergence of the West Ulamnigiaq Channel from the Ulamnigiaq Channel (Figure-3-2). The alternate Ulamnigiaq Channel crossing is shown in cross section in Figure-3-6. The main channel at the alternate crossing was generally trapezoidal in shape. A relatively shallow paleochannel was noted approximately 700 feet south of the active channel.

The bank-to-bank width of the active channel was approximately 700 feet. The right overflow bank was relatively smooth and covered with dense grasses to 0.4 feet in height. Manning roughness coefficients, *n*, estimated for the alternate Ulamnigiaq crossing were 0.045 for the paleochannel, 0.042 and 0.043 for the left and right overflow banks, respectively, and 0.022 for the active channel. Temporary staff gages were not established at the alternate crossing; however, a peak water surface elevation of 7.76 feet was estimated based on water surface slopes and peak water surface elevations measured downstream at the Ulamnigiaq monitoring sites. At the time of the peak water surface elevation, the top width of water was approximately 700 feet based on the channel cross section survey and the estimated peak water.

Based on visual observations, the streambed material of the active channel was composed of fine silt and the active channel bed was irregular. The left overflow bank between the active channel and the paleochannel was relatively smooth ground with dense grasses up to approximately 0.5 feet in height. The paleochannel proper was relatively smooth ground with grasses up to 0.8 feet in height. Low sand dunes were noted on the left bank of the paleochannel.

3.4 West Ulamnigiaq Channel

The West Ulamnigiaq Channel at the pipeline crossing is asymmetrical and generally trapezoidal in shape. At the time of the peak water surface elevation, the top width of water was approximately 270 feet, the average depth was 4.8 feet, and the maximum depth was 9.5 feet. The West Ulamnigiaq Channel at the proposed pipeline crossing is shown in cross section in Figure-3-7.

Flowing water was not observed on the West Ulamnigiaq Channel until 10 June. Until that time, the channel was filled with snow that blocked flow from the Ulamnigiaq Channel. By 11 June, the channel snow had cleared, and ice chunks up to 25 feet in diameter were observed stranded in the channel.

Water surface elevations peaked at 7.57 feet and 7.08 feet at the upstream and downstream monitoring sites, respectively. In the vicinity of the proposed pipeline crossing, the peak water surface elevation was estimated to be 7.3 feet. Peak water surface elevations occurred between the evening of 10 June and the morning of 11 June.

Based on normal depth calculations, it was estimated that at the time the peak water surface elevation occurred, peak discharge on the West Ulamnigiaq Channel at the proposed pipeline crossing was approximately 12,200 cfs with an average velocity of 2.82 ft/sec. Water surface elevations and observations for the West Ulamnigiaq Channel are summarized in Table 3-5. Photos 3-8 and 3-9 shows snow conditions in the West Ulamnigiaq Channel on 7 and 9 June, respectively.

Based on visual observation, the streambed material of the active channel was composed of fine silt and the channel bed was smooth and free of bedforms. The bank-to-bank width of the channel was approximately 160 feet. The left and right overflow banks were relatively smooth and covered with dense grasses. Manning roughness coefficients, n, estimated for the West Ulamnigiaq crossing were 0.045 for the left and right overflow banks and 0.021 for the active channel.

3.5 Proposed CD-North Gravel Structures Location

The proposed location of the gravel pad was not impacted by either high water or floating ice during the 2001 breakup. River water was not observed at any time on the floodplain in the vicinity of the proposed gravel pad or in the paleochannel that is crossed by the proposed runway. In addition, ground observations showed no evidence of inundation by river water.

Peak water surface elevations in the vicinity of the proposed CD-North gravel structures occurred between the evening of 10 June and the morning of 11 June. Water surface elevations were monitored on two channels in the vicinity of the CD-North pad location. As previously discussed,

the water surface elevation in the West Ulamnigiaq Channel (adjacent and to the west of the proposed pad location) peaked at 7.57 feet. In the East Ulamnigiaq Channel (adjacent and to the east of the proposed pad location) the water surface elevation peaked at 7.43 feet. Channel and snow conditions in the East Ulamnigiaq Channel were similar to the conditions observed in the West Ulamnigiaq Channel. Photos 3-10 and 3-11 show conditions in the East Ulamnigiaq Channel on 7 and 9 June, respectively.

3.6 Channel Ice Observations

Channel ice surveys began on 5 June when water was first observed flowing at the head of the Colville River Delta. Channel ice surveys were performed daily until 12 June when all the major channels of the delta were clear of channel ice and ice jams. The progression of the ice clearing and ice jamming is shown on figures in Appendix A.

Discontinuous floating channel ice beneath deep and drifted snow was typical of pre-breakup conditions in the smaller channels in the vicinity of the proposed CD-North facility. On 7 and 8 June as breakup progressed, flow began to erode the snow in the smaller channels. In many cases, flow was observed over the top of or cutting through the snow (Photo 3-10). By 9 June, the Ulamnigiaq, Tamayagiaq, and Sakoonang Channels were up to 90 percent free of ice and snow while the East and West Ulamnigiaq Channels remained blocked with snow (Photo 3-9). On 9 June, an ice jam was noted on the Tamayagiaq Channel approximately 3 miles upstream of the proposed pipeline crossing. The ice jam appeared to be floating rather than grounded, and did not appear to cause significant backwater, blockage, or diversion of flow. Clearing of channel ice continued throughout the day on 10 June and by 11 June, all of the major channels south of the proposed CD-North facility were free of ice and snow with the exception of occasional floating or stranded ice chunks. Grounded ice blocks and chunks that had been stranded on the banks by receding water and occasional floating chunks were noted at most CD-North gage locations on 11 June, and by 13 June the channels were entirely ice free.

3.7 Sea Ice Observations

A temporary staff gage was installed on the sea ice and tied to the BPMSL datum via Monument 28 on 5 June. The temporary staff gage was located approximately 200-250 feet north of the coastline and due north of Monument 28. The gage was placed on what appeared to be a small gravel bar visible in the offshore sea ice. On 5 June, the average elevation of the sea ice was 2.33 feet based on 10 surveyed points.

On 7 June, water from the Nigliq Channel was observed flowing over the sea ice near the temporary staff gage. The entire area was inundated and the water surface elevation was 3.75 feet. On 8 June, the temporary staff gage could not be located and was presumed destroyed.

During breakup, the sea ice is generally shore fast and water flows on top of the sea ice as it leaves the delta. Observations made during 2001 and previous breakup investigations on the Colville River Delta support this finding. Thus, the presence and elevation of the sea ice will likely affect water levels in channels near the coast. The effects of the sea ice will vary from year to year, but will likely have greater effects in years when the flood peak discharge is smaller.

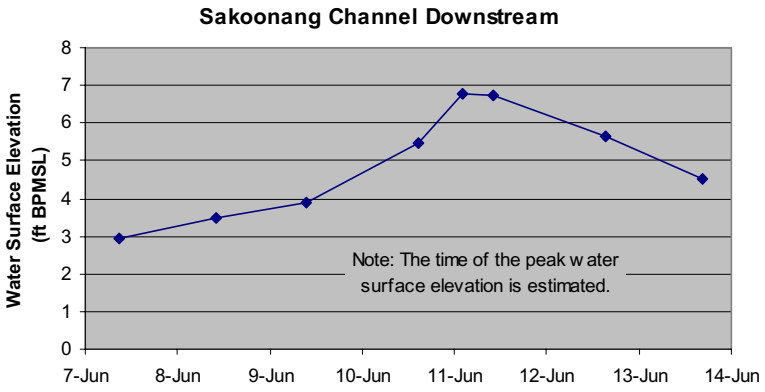
Table 3-1. Summary of Channel Conditions at Peak Flow

Channel	Estimated Time of Peak Water Surface Elevations	Estimated Discharge at Peak Water Surface Elevation (cfs)	Width of Flow at Peak Water Surface Elevation (feet)	Average Depth at Peak Water Surface Elevation (feet)	Maximum Depth at Peak Water Surface Elevation (feet)	Average Velocity at Peak Water Surface Elevation (ft/sec)
Sakoonang	Morning of 11 June	14,500	460	6.6	12.1	3.8
Tamayagiaq	Morning of 11 June	21,500	1,180	5.8	14.8	3.2
Ulamnigiaq	Morning of 11 June	14,200	600	8.4	20.4	3.2
West Ulamnigiaq	Morning of 11 June	12,200	270	4.80	9.5	2.8

Table 3-2. Sakoonang Channel, Water Surface Elevations and Observations

	Downstream Monitoring Site			Upstream Monitoring Site			
Date	Time	Water Surface Elevation (ft BPMSL)	Observations	Time	Water Surface Elevation (ft BPMSL)	Observations	Water Surface Slope
6/7/01	9:01	2.92	Snow around gage. Channel shoveled to open water. Very windy, could not verify flowing water.	8:55	2.73	Snow around gage. Channel shoveled to open water. Very windy, could not verify flowing water.	-0.19
6/8/01	9:52	3.49	Water on gage, but does not appear to be flowing. Surface ice extends approx. 150 feet from left	9:57	3.36	Surface ice on bank at gage.	-0.13
6/9/01	9:25	3.88	Channel is 90% clear of ice.	9:34	3.73	Channel is 90% clear of ice.	-0.15
6/10/01	14:30	5.48		14:35	5.37		-0.11
High Water Mark		6.76	Peak water surface elevation likely occurred on the morning of 11 June	High Water	7.32	Peak water surface elevation likely occurred on the morning of 11 June	0.56
6/11/01	10:13	6.74	All visible channel ice gone.	10:18	6.77	Large, wide hydraulic connection to lake across from gage. No visible ice in channel.	0.03
6/12/01	15:21	5.64	Channel is ice-free except occasional chunks, both floating and grounded	15:26	5.84	Channel is ice-free except occasional chunks, both floating and grounded	0.20
6/13/01	16:41	4.51	Channel is ice-free except occasional chunks, both floating and grounded	16:54	4.69	Channel is ice-free except occasional chunks, both floating and grounded	0.18

Notes:
1. Elevations are based on an elevation of 11.12 feet BPMSL for Monument 27, established by Lounsbury & Associates in 1998.
2. The distance along the flow path from the upstream site to the downstream site is 3300 feet.
3. Coordinates for the upstream and downstream cross sections are N70°21'43.7" W150°54'40.3" and N70°22'04.3" W150°55'47.9", respectively as determined with a Garmin II Plus handheld global positioning system.



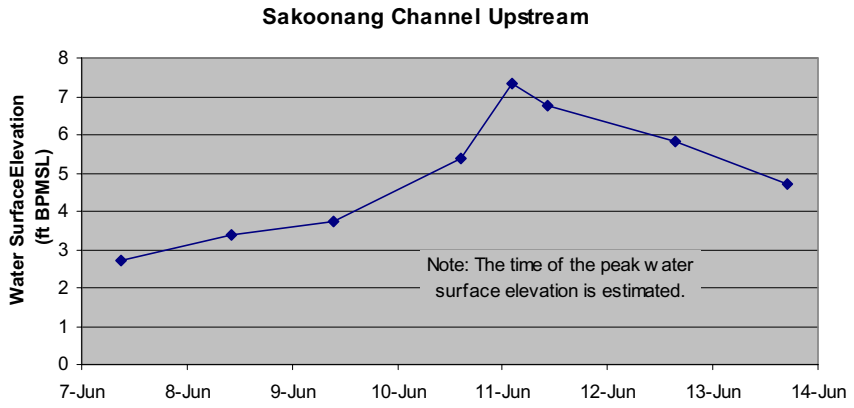
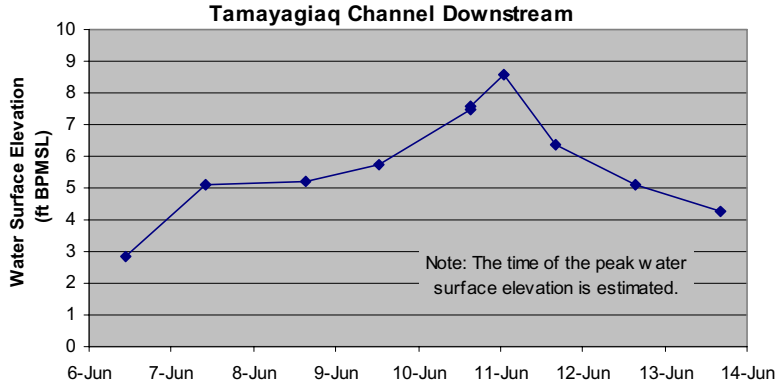


Table 3-3. Tamayagiaq Channel, Water Surface Elevations and Observation

	Downstream Monitoring Site			Upstream Monitoring Site			
Date	Time	Water Surface Elevation (ft BPMSL)	Observations	Time	Water Surface Elevation (ft BPMSL)	Observations	Water Surface Slope
6/6/01	10:50	2.86	Localized melting only.	10:40	3.26	Localized melting only.	
6/7/01	9:48	5.09	Channel ice grounded on right bank, approximately 1/3 the width of channel.	9:25	5.30		0.21
6/8/01	15:07	5.20		15:02	5.49		0.29
6/9/01	12:45	5.72	Some surface ice in the reach.	12:15	6.09	Channel is ice-free. Small ice floe on opposite bank.	0.37
6/10/01	15:25	7.49		15:37	7.92		0.43
6/10/01	15:26	7.57					
High Water Mark		8.60	Peak water surface elevation likely occurred on the morning of 11 June	High Water	9.13	Peak water surface elevation likely occurred on the morning of 11 June	0.53
6/11/01	16:10	6.37	Ice chunks up to 30' across and 4' thick stranded on bank.	15:49	6.61		0.24
6/12/01	15:35	5.13	Channel is ice-free with the exception of occasional grounded chunks.	15:50	5.33	Channel is ice-free with the exception of occasional grounded chunks.	0.20
6/13/01	16:05	4.27	Channel is ice-free with the exception of occasional grounded chunks.	16:21	4.58	Channel is ice-free with the exception of occasional grounded chunks.	0.31

Notes:
1. Elevations are based on an elevation of 10.46 feet BPMSL for Monument 25, established by Lounsbury & Associates in 1996.
2. The distance along the flow path from the upstream site to the downstream site is 5100 feet.
3. Coordinates for the upstream and downstream cross sections are N70°23'30.9" W150°54'17.1" and N70°23'00.8" W150°55'43.8", respectively as determined with a Garmin II Plus handheld global positioning system.



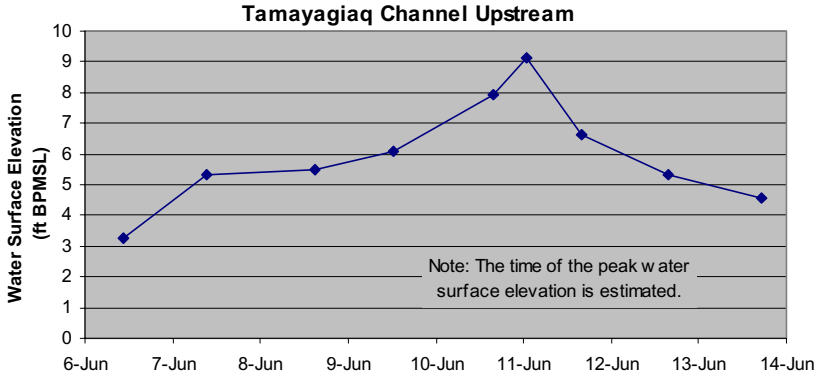
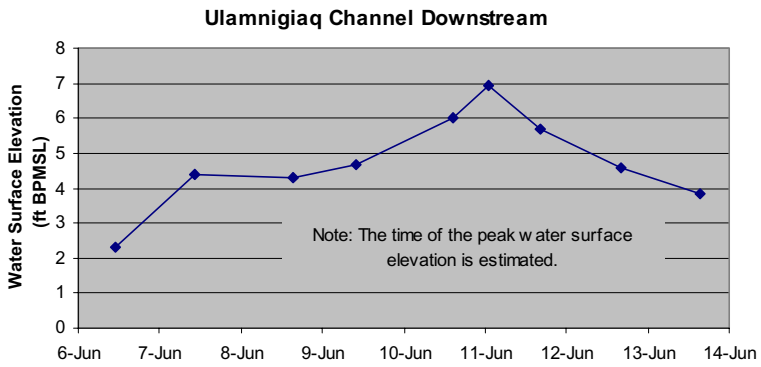


Table 3-4. Ulamnigiaq Channel, Water Surface Elevations and Observations

	Downstream Monitoring Site			Upstream Monitoring Site			
Date	Time	Water Surface Elevation (ft BPMSL)	Observations	Time	Water Surface Elevation (ft BPMSL)	Observations	Water Surface Slope
6/6/01	11:10	2.29	Snow and ice blocking channel, localized ponding.	11:00	2.85	Snow and ice blocking channel, localized ponding.	
6/7/01	10:25	4.40	Channel is approx. 70% clear	10:00	4.53	Channel is approx. 70% clear	0.13
6/8/01	15:16	4.31	Channel ice remaining on opposite bank.				
6/9/01	9:45	4.67	Channel is 90% clear, some mid-channel ice.	9:55	5.6	Channel is 90% clear, some ice on far bank.	0.93
6/10/01	14:41	6.02		15:00	6.62		0.60
6/10/01				15:44	6.85		
High Water Mark		6.92	Peak water surface elevation likely occurred on the morning of 11 June	High Water	7.4	Peak water surface elevation likely occurred on the morning of 11 June. See Note 4.	0.48
6/11/01	16:28	5.71		16:38	6.04	Stranded ice on bank.	0.33
6/12/01	16:04	4.57	Channel is ice-free with the exception of occasional grounded chunks.	16:10	4.94	Channel is ice-free with the exception of occasional grounded chunks.	0.37
6/13/01	15:19	3.85	Channel is ice-free with the exception of occasional grounded chunks.	15:40	4.25	Channel is ice-free with the exception of occasional grounded chunks.	0.40

Notes:
1. Elevations are based on an elevation of 10.46 feet BPMSL for Monument 25, established by Lounsbury & Associates in 1996.
2. The distance along the flow path from the upstream site to the downstream site is 4100 feet.
3. Coordinates for the upstream and downstream cross sections are N70°24'29.9" W150°53'5.74" and N70°24'17.8" W150°55'52.6", respectively as determined with a Garmin II Plus handheld global positioning system.
4. Definitive high water marks were not available at the upstream monitoring site, thus the high water elevation was estimated, based on water surface slopes before and of the high water.



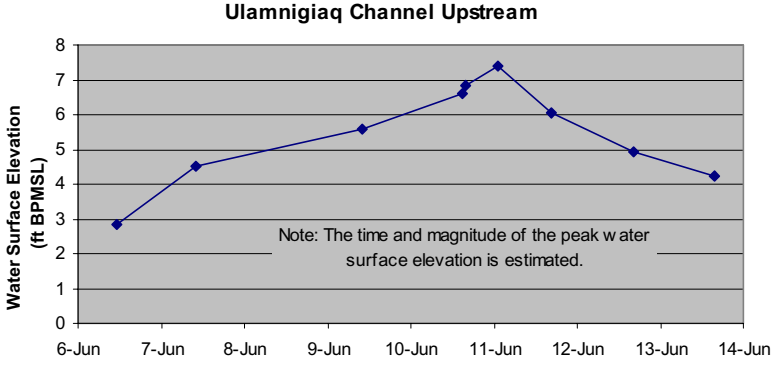
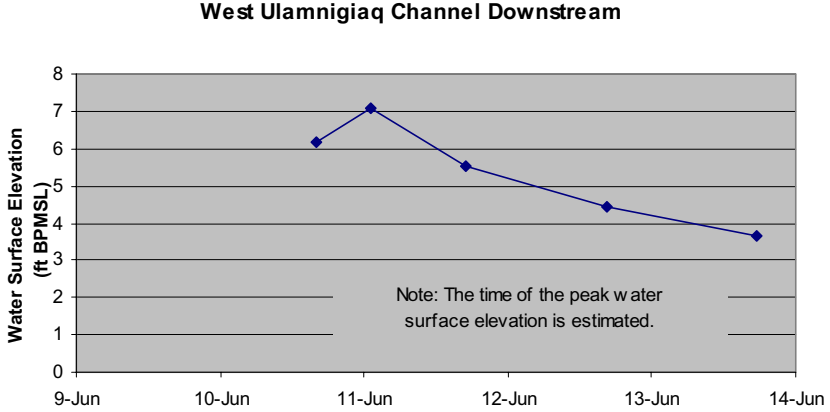


Table 3-5. West Ulamnigiaq Channel, Water Surface Elevations and Observations

	Downstream Monitoring Site			Upstream Monitoring Site			
Date	Time	Water Surface Elevation (ft BPMSL)	Observations	Time	Water Surface Elevation (ft BPMSL)	Observations	Water Surface Slope
6/7/01				12:15	4.36	Localized melting only.	
6/7/01	12:51		Channel completely blocked with snow. No visual flow in channel.	12:26		Channel completely blocked with snow. No visual flow in channel.	
6/8/01	15:25		Channel completely blocked with snow. No visual flow in channel.	15:25		Channel completely blocked with snow. No visual flow in channel.	
6/9/01	13:20		Snow & ice covers 100% of channel.	13:14	4.46	Local melting only. Snow & ice covers 90% of channel.	
6/10/01	15:54	6.18		15:47	6.76		0.58
High Water Mark		7.08	Peak water surface elevation likely occurred on the morning of 11 June	High Water	7.57	Peak water surface elevation likely occurred on the morning of 11 June	0.49
6/11/01	17:05	5.53	Stranded ice chunk in channel. Ice chunks up to 25' in diameter stranded on right bank.	16:58	5.86	No visible indication of flow into paleochannel at CD-North	0.33
6/12/01	16:30	4.42	Channel is ice-free.	16:20	4.58	Channel is ice-free.	0.16
6/13/01	17:34	3.65	Channel is ice-free.				

Notes:
1. Elevations are based on an elevation of 10.46 feet BPMSL for Monument 25, established by Lounsbury & Associates in 1996.
2. The distance along the flow path from the upstream site to the downstream site is 3800 feet.
3. Coordinates for the upstream and downstream cross sections are N70°24'48.0" W150°53'28.7" and N70°25'7.4" W150°54'59.7", respectively as determined with a Garmin II Plus handheld global positioning system.



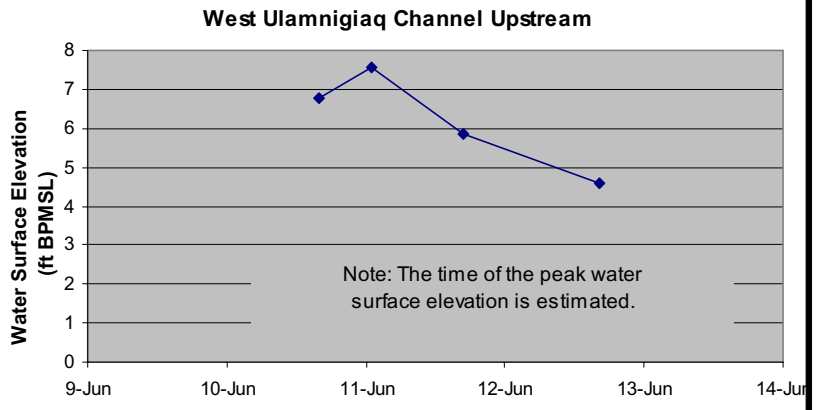
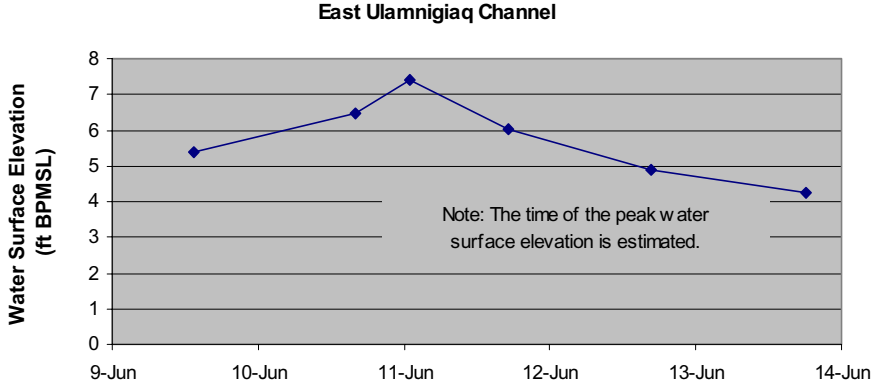


Table 3-6. East Ulamnigiaq Channel, Water Surface Elevations and Observations

Date	Time	Water Surface Elevation (ft BPMSL)	Observations
6/7/01	13:04		Channel completely blocked with snow. No visual flow in channel.
6/8/01	15:25		Channel filled with snow. Flow beginning to be visible on top of snow. Water not yet on gages.
6/9/01	13:30	5.36	Both banks ice-bound.
6/10/01	16:00	6.49	
High Water Mark		7.43	Peak water surface elevation likely occurred on the morning of 11 June
6/11/01	17:13	6.01	Ice chunk up to 30' in diameter in channel during survey. Stranded ice chunks in channel.
6/12/01	16:45	4.91	Channel is clear.
6/13/01	18:00	4.24	Channel is clear.

Notes:
1. Elevations are based on an elevation of 10.46 feet BPMSL for Monument 25, established by by Lounsbury & Associates in 1996.
2. Coordinates for the cross section are N70°24'32.7" W150°52'18.1" as determined with a Garmin II Plus handheld global positioning system.



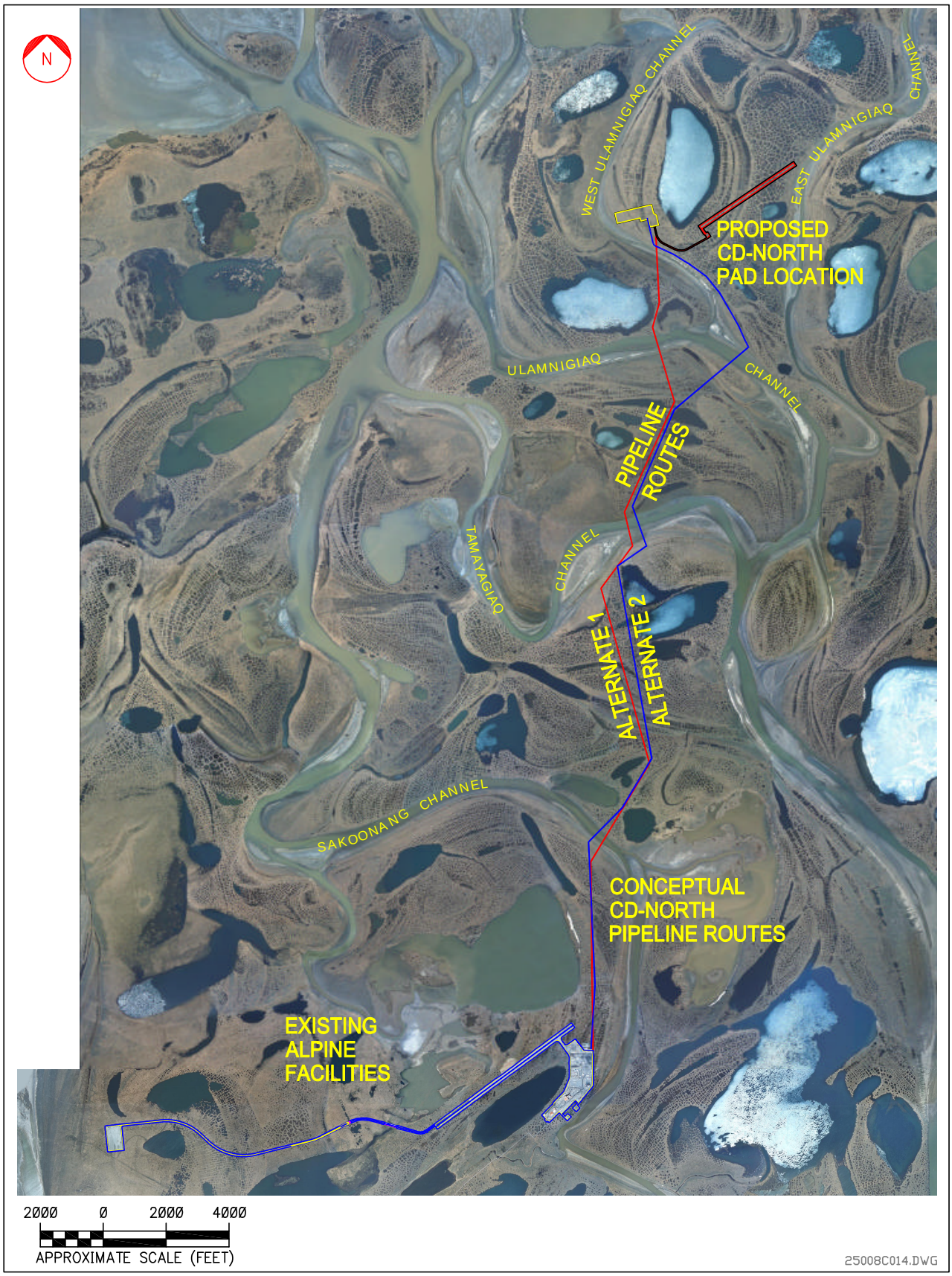


Figure 3-1. CD-North Project Location

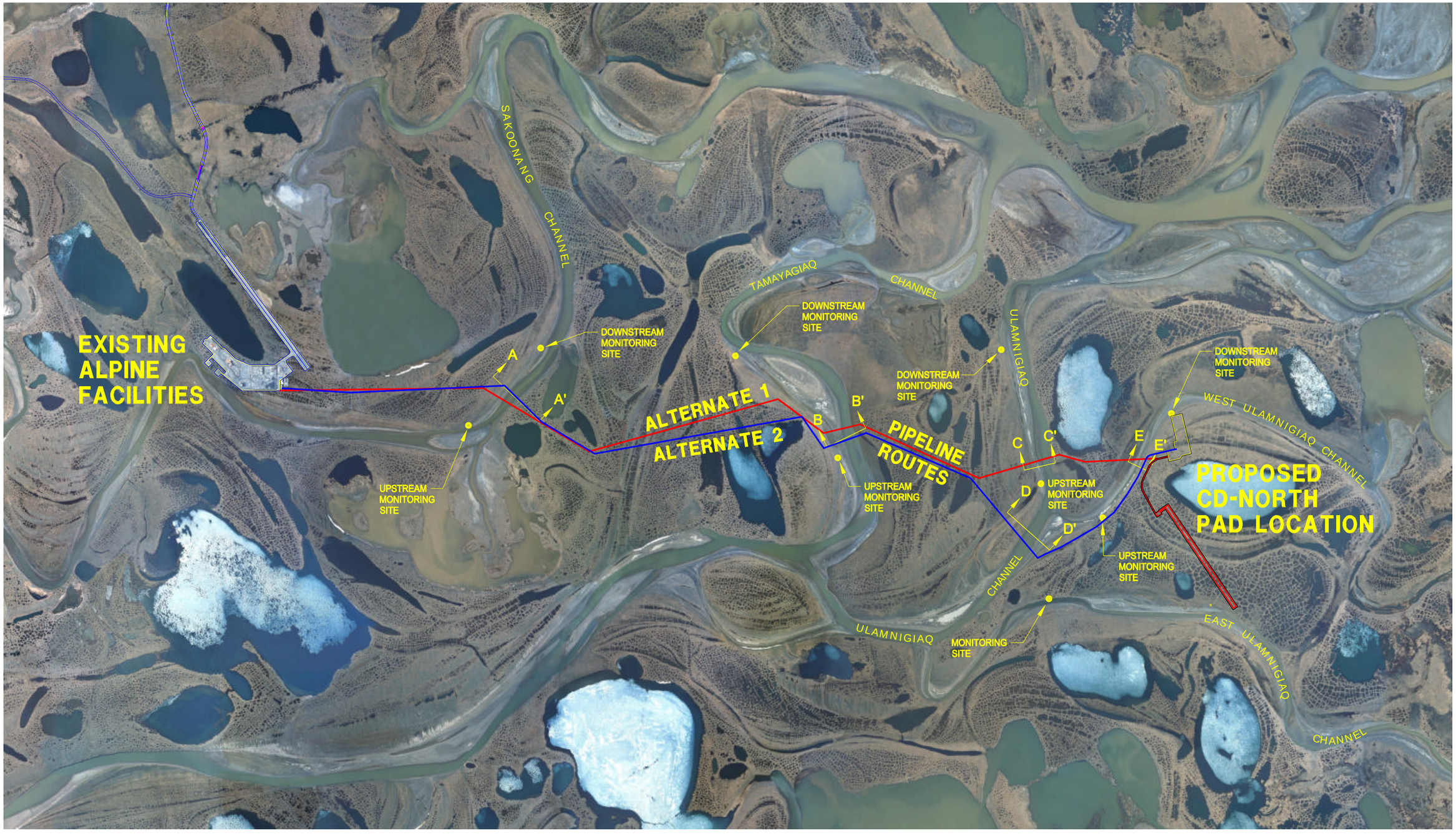


Figure 3-2. CD-North Reaches and Cross Sections

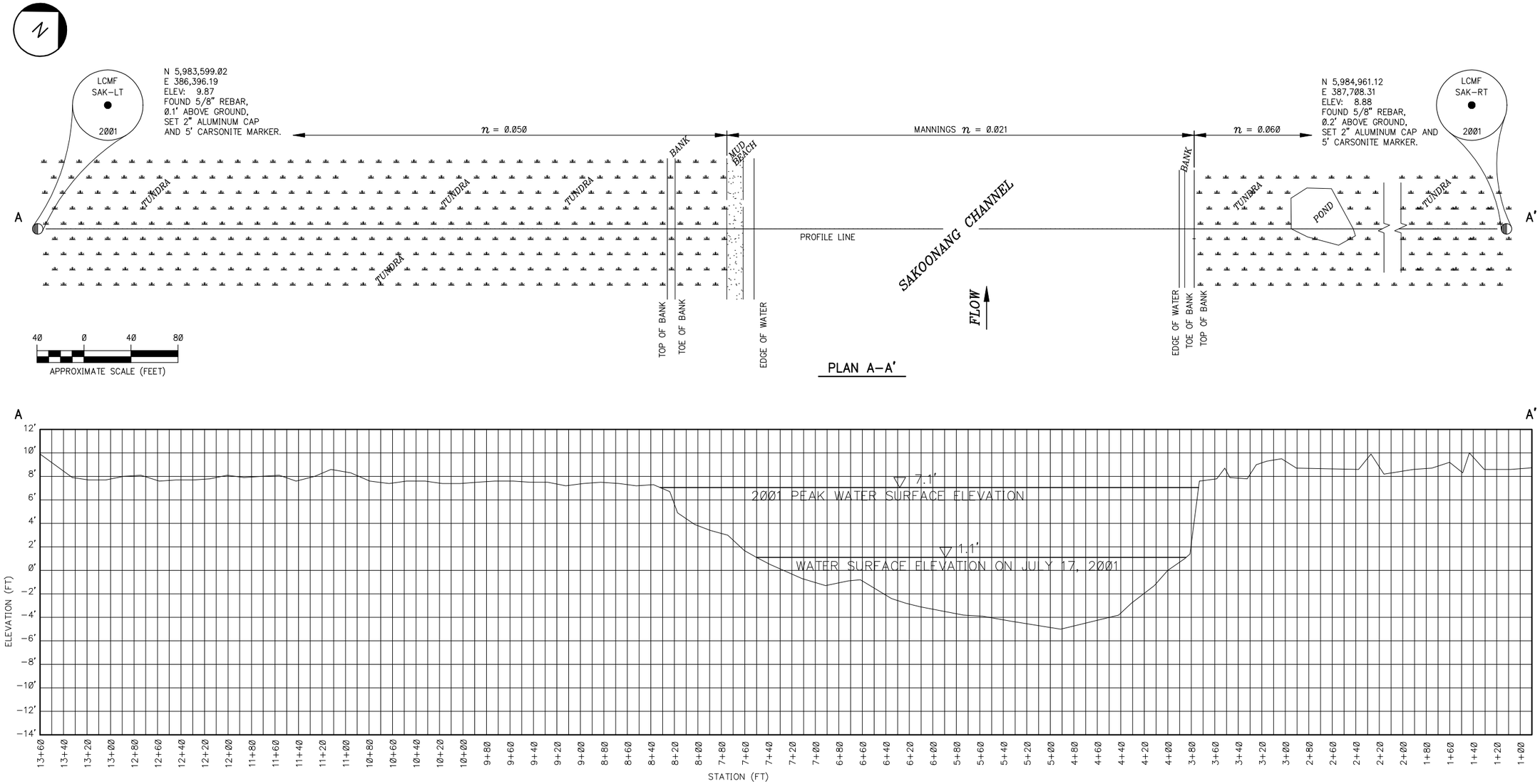


Figure 3-3. Sakoonang Channel

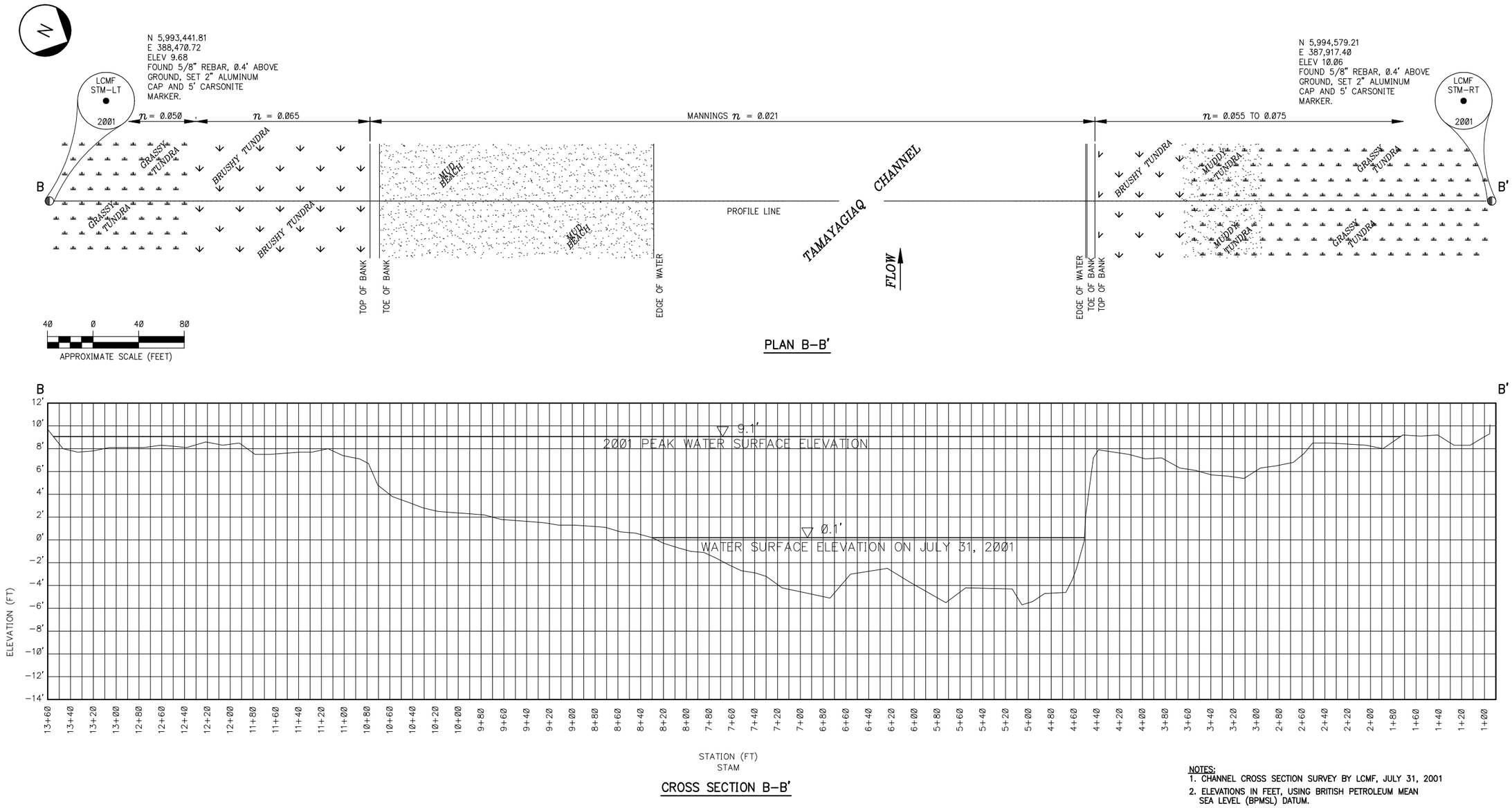
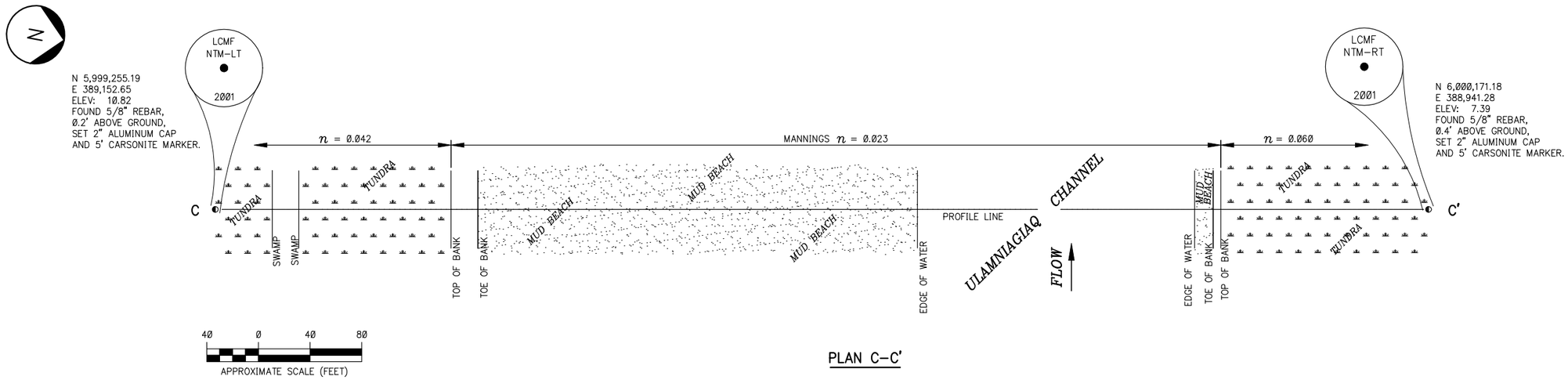
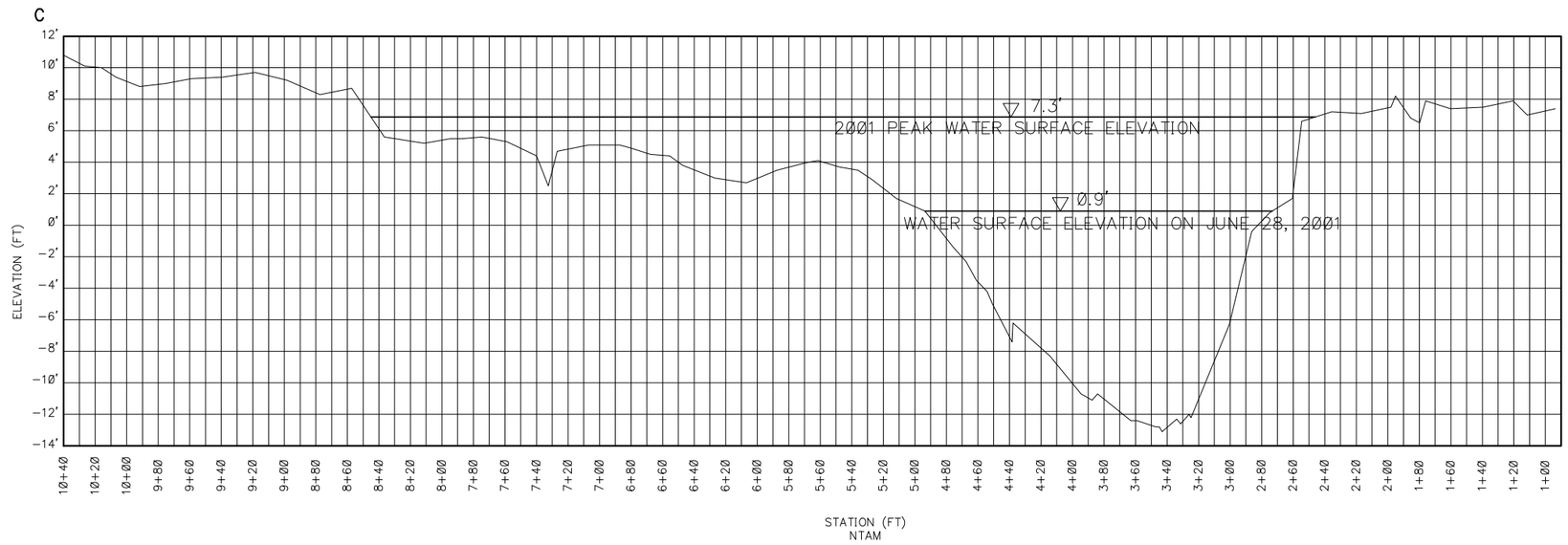


Figure 3-4. Tamayagiaq Channel



PLAN C–C'



CROSS SECTION C–C'

NOTES:
1. CHANNEL CROSS SECTION SURVEY BY LCMF, JUNE 28 AND AUGUST 6, 2001
2. ELEVATIONS IN FEET, USING BRITISH PETROLEUM MEAN SEA LEVEL (BPMSL) DATUM.
3. HORIZONTAL DATUM IS NAD 27 ALASKA STATE PLANE COORDINATES, ZONE 4, RELATIVE TO THE ALPINE CONTROL NETWORK.
4. THE 2001 PEAK WATER SURFACE ELEVATION IS AN ESTIMATE BASED ON READINGS FROM THE WEST ULAMNIGIAQ UPSTREAM AND DOWNSTREAM MONITORING SITES, SEE FIGURE 3–2.

Figure 3-5. Ulamnigiaq Channel

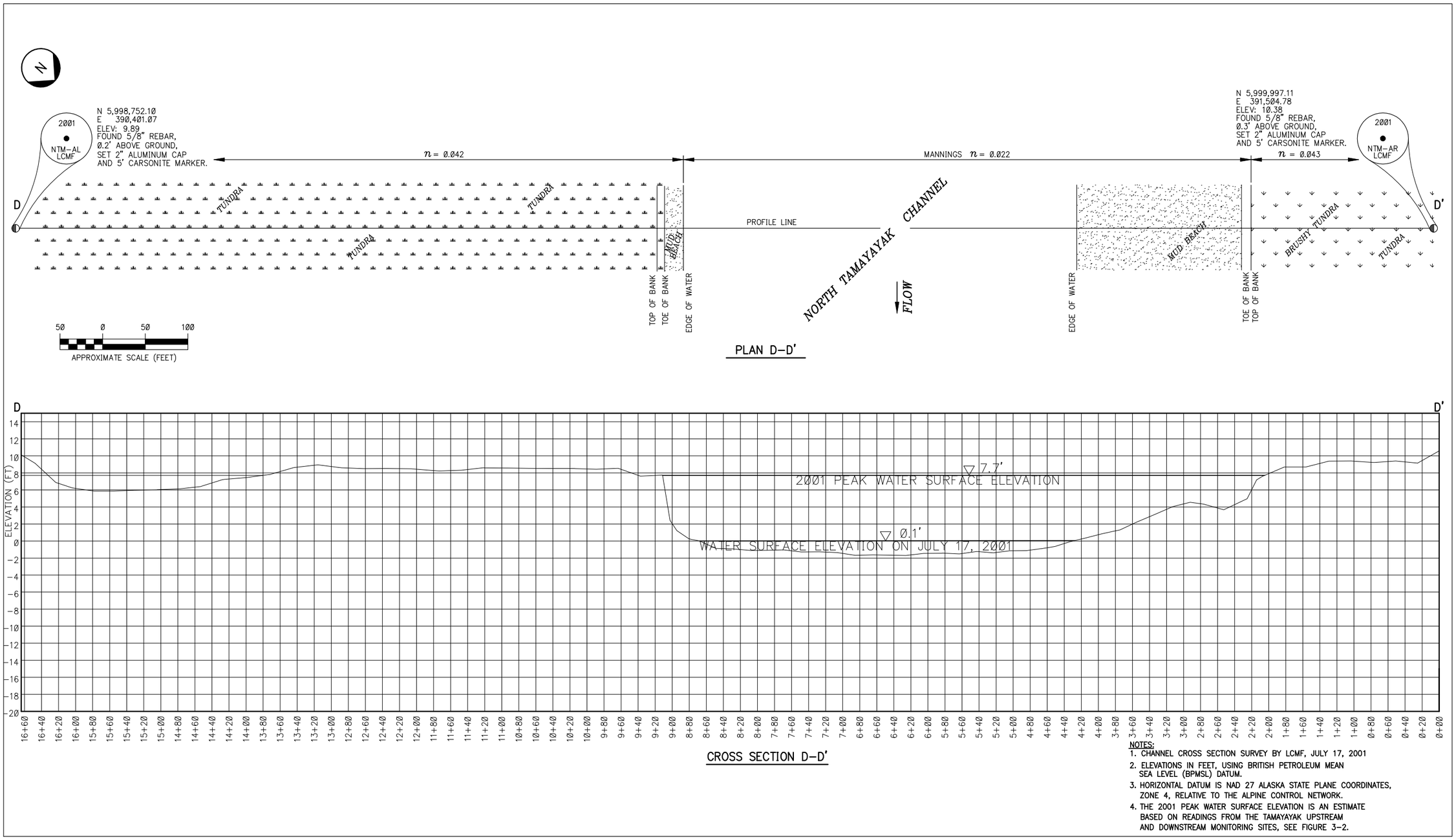


Figure 3-6. Ulamnigiaq Channel, Alternate

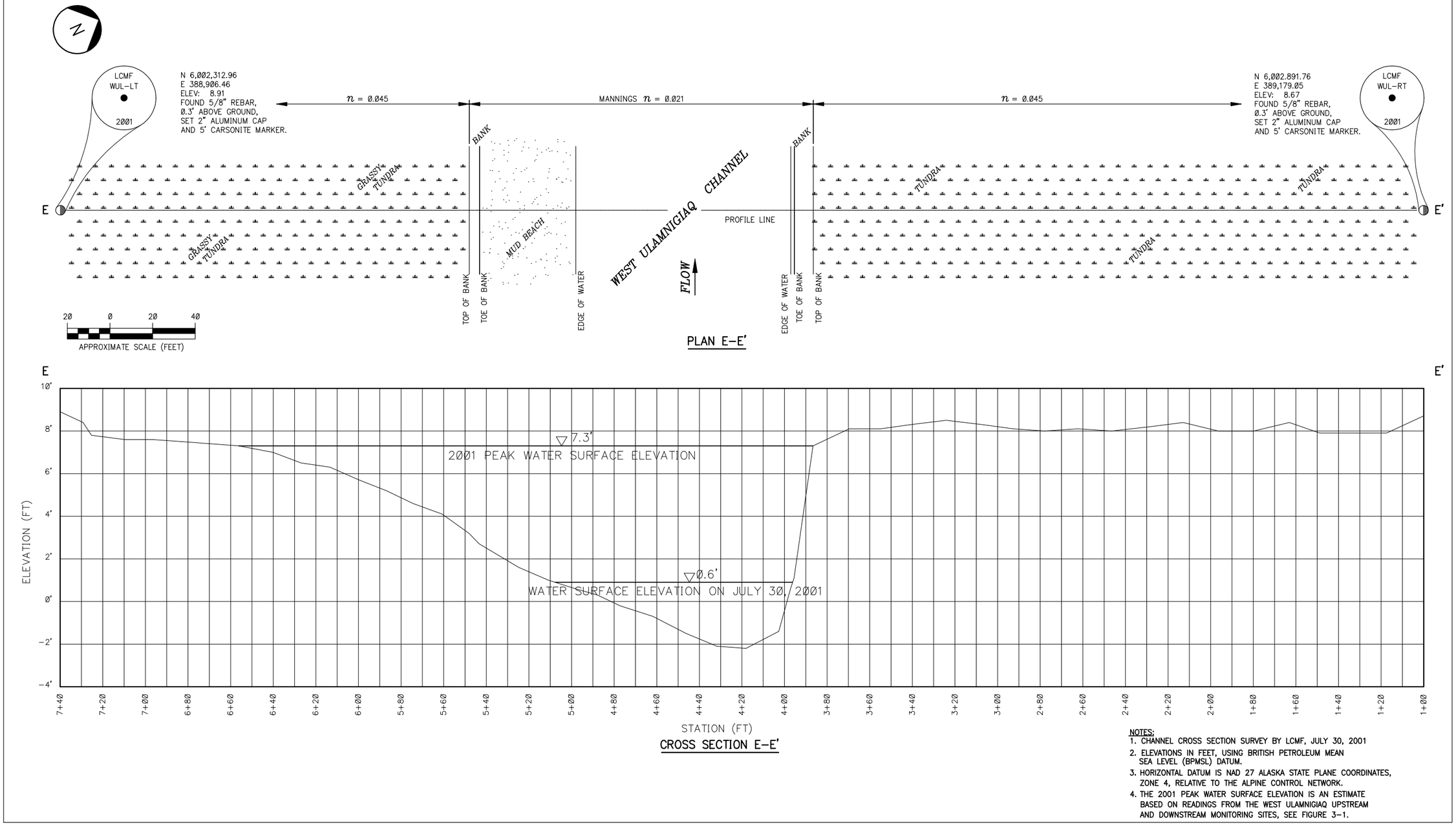


Figure 3-7. West Ulamnigiaq Channel

Photo 3-1. Sakoonang Channel, 7 June 2001. Looking north across the channel from the downstream gages.

Photo 3-2. Sakoonang Channel, 9 June 2001. Looking north across the channel from the downstream gages.

Photo 3-3. Tamayagiaq Channel, 6 June 2001. Looking north across the channel from the downstream gages.

Photo 3-4. Tamayagiaq Channel, 11 June 2001. Looking west across the channel from the downstream gages.

Photo 3-5. Tamayagiaq Channel, 11 June 2001. Looking southwest from the downstream gages. Note the grounded ice chunks behind helicopter.

Photo 3-6. Ulamnigiaq Channel, 6 June 2001. Looking northeast across channel from the downstream gages.

Photo 3-7. Ulamnigiaq Channel, 11 June 2001. Looking east across the channel from the upstream gages.

Photo 3-8. West Ulamnigiaq Channel, 7 June 2001. Looking west across the channel from the upstream cross section.

Photo 3-9. West Ulamnigiaq Channel, 9 June 2001. Looking west across the channel from the upstream cross section.

Photo 3-10. East Ulamnigiaq Channel, 7 June 2001. Looking east across the channel from the gages.

Photo 3-11. East Ulamnigiaq Channel, 9 June 2001. Looking east across the channel from the gages.

Section 4. References

Alaska Biological Research and Shannon & Wilson, 1994. *Geomorphology and Hydrology of the Colville River Delta, Alaska, 1993*. Prepared for ARCO Alaska, Inc., Anchorage, Alaska.

Arcement, G.J. & Schneider. 1989. *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains.* U.S. Geological Survey Water Supply Paper 2339. U.S. Government Printing Office, Denver, Colorado.

Michael Baker Jr., Inc. 1998. *Colville River Delta Two-Dimensional Surface Water Model, Project Update.* Prepared for: ARCO Alaska, Inc., Anchorage. *[Ongoing work to be published in 2001.]*

Michael Baker Jr., Inc. and Shannon Wilson, Inc. 1998. *Colville River Flood Frequency Analysis, North Slope Alaska.* Prepared for: ARCO Alaska, Inc., Anchorage.

Michael Baker Jr., Inc. 2000. *Alpine Facilities Spring 2000 Breakup Monitoring and Hydrologic Assessment.* Prepared for: Phillips Alaska, Inc., Anchorage.

Michael Baker Jr., Inc. 2001. *Alpine Facilities 2001 Spring Breakup and Hydrologic Assessment.* Prepared for: Phillips Alaska, Inc., Anchorage.

Phillips Alaska, Inc., & Anadarko Petroleum Corp. 2001. *Colville River Unit, Satellite Development, Draft Environmental Evaluation Document*, February 2001.

Shannon & Wilson, 1996 *1996 Colville River Delta, Channel Assessment, Colville River Delta North Slope, Alaska*, Prepared for Michael Baker Jr. Inc., Anchorage, Alaska.

Appendix A. Channel Ice Survey Sheets

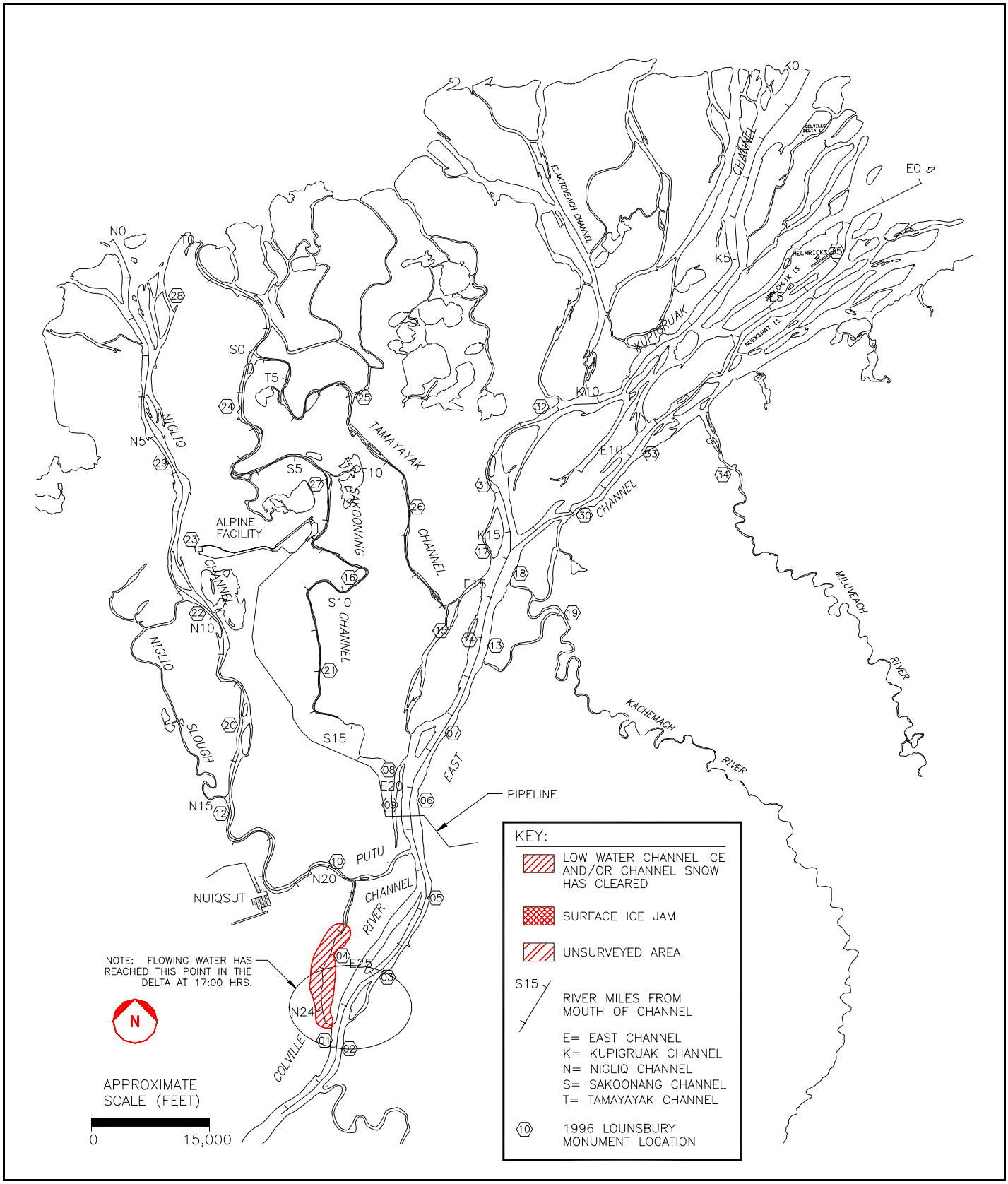


Figure A-1. Low Water Channel Ice Survey, June 5, 2001

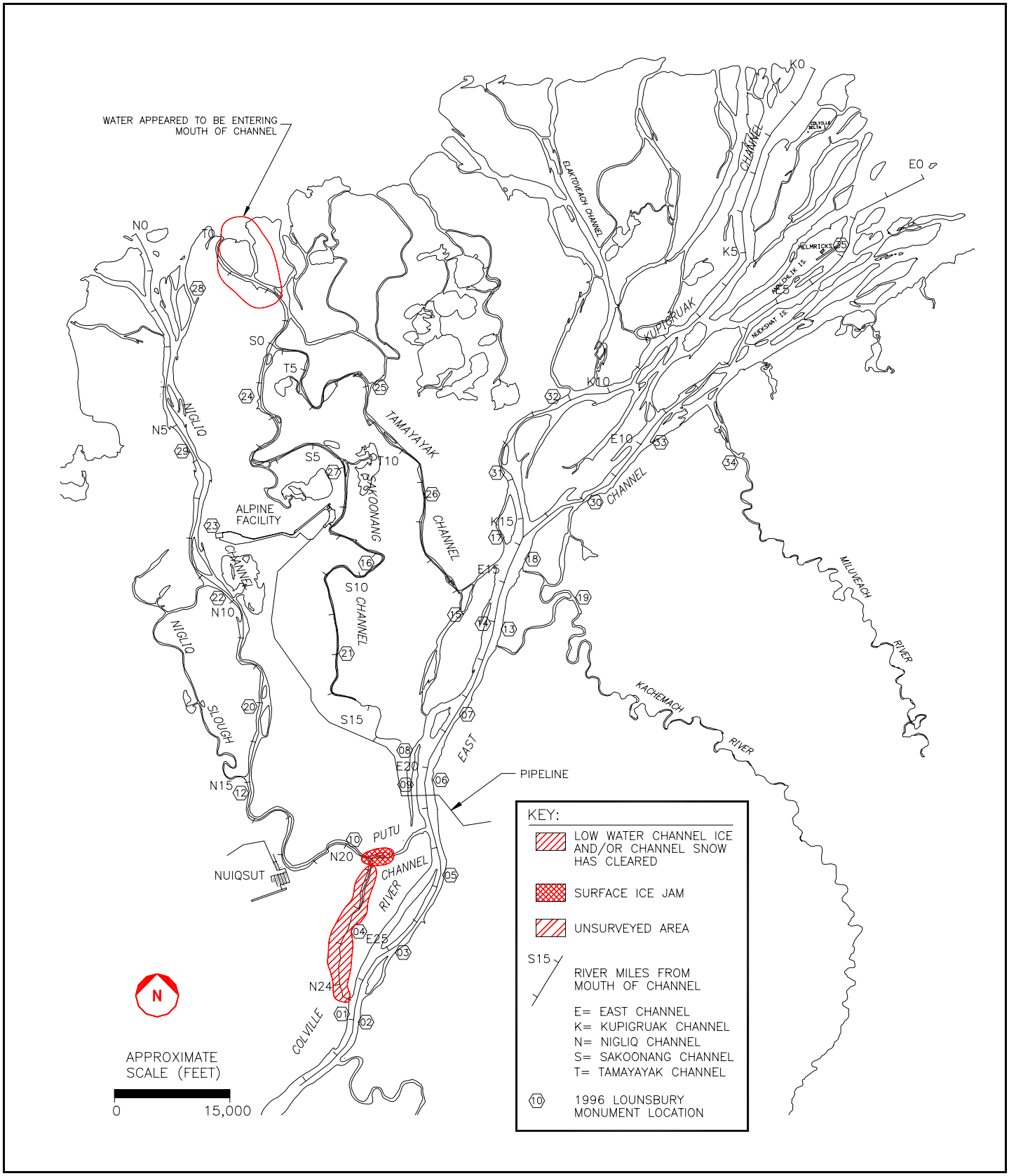


Figure A-2. Low Water Channel Ice Survey, June 6, 2001

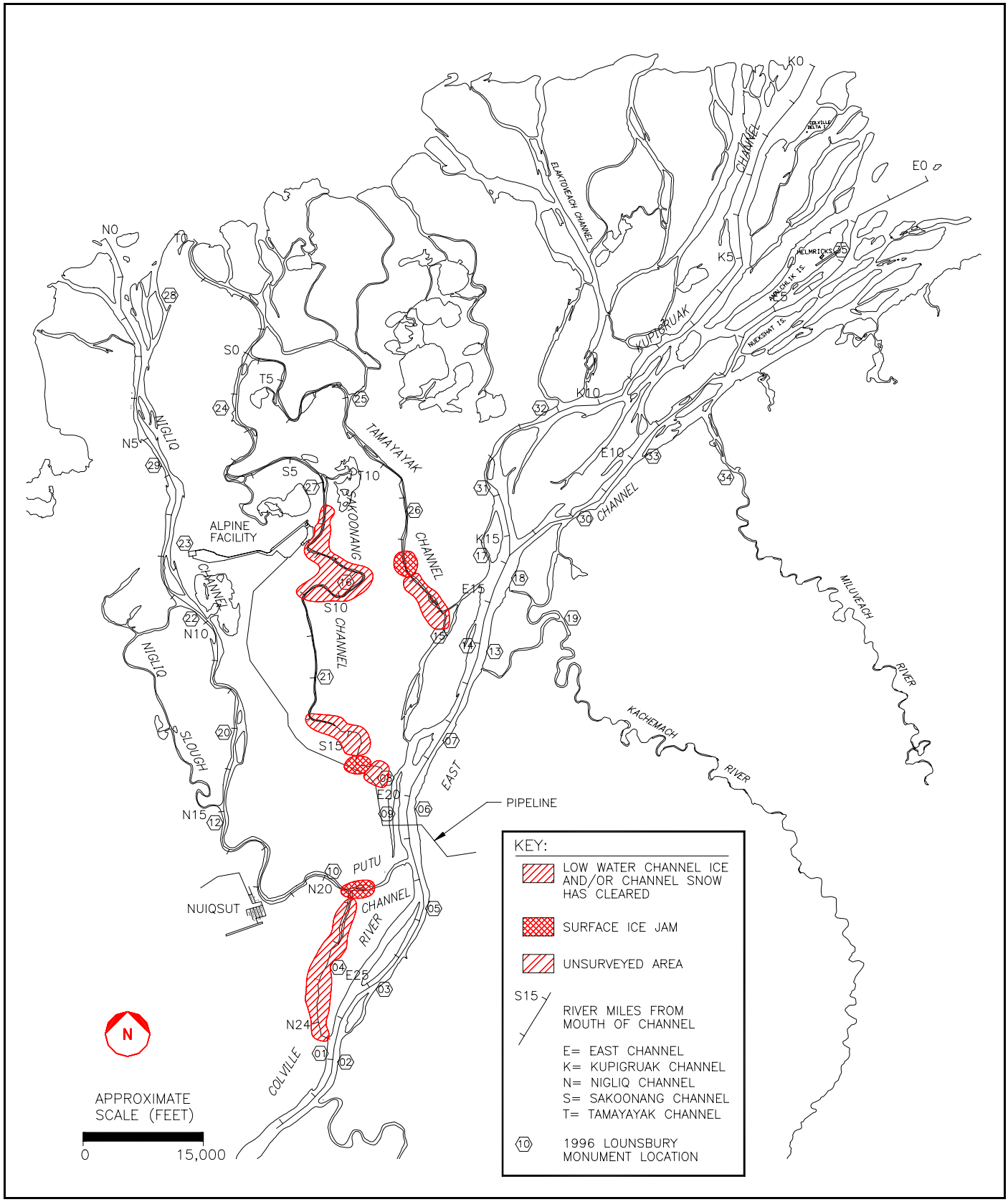


Figure A-3. Low Water Channel Ice Survey, June 7, 2001

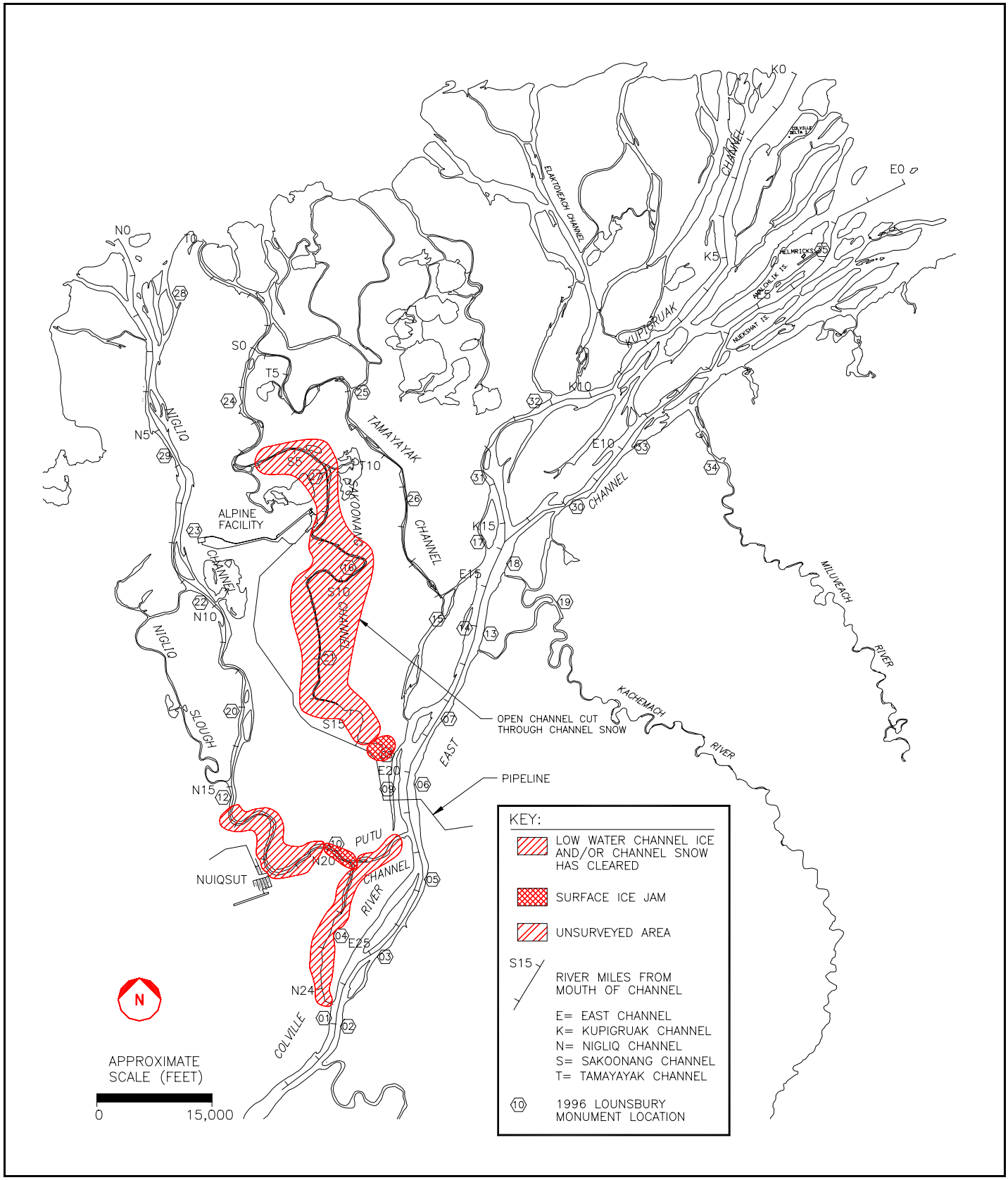


Figure A-4. Low Water Channel Ice Survey, June 8, 2001

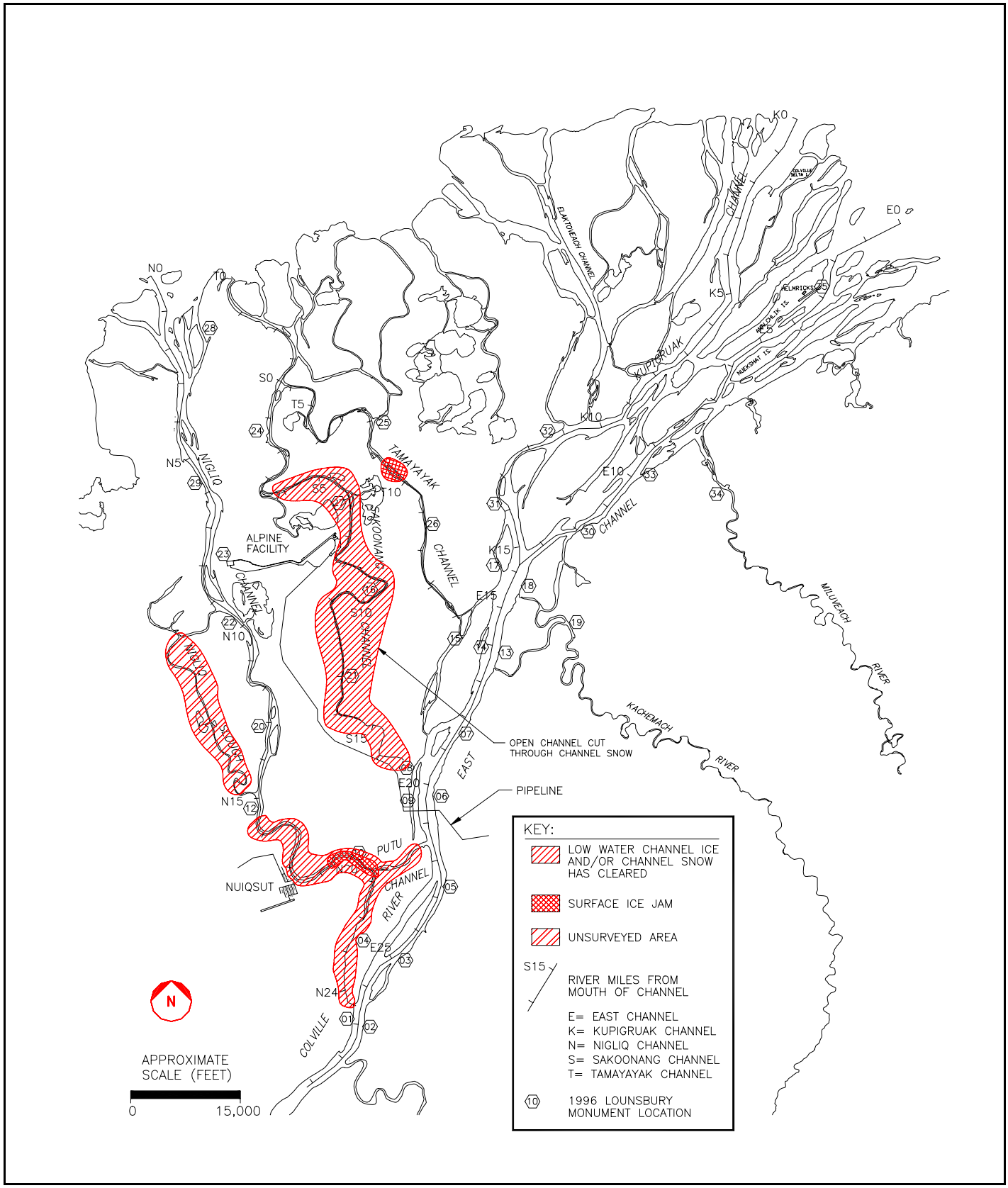


Figure A-5. Low Water Channel Ice Survey, June 9, 2001

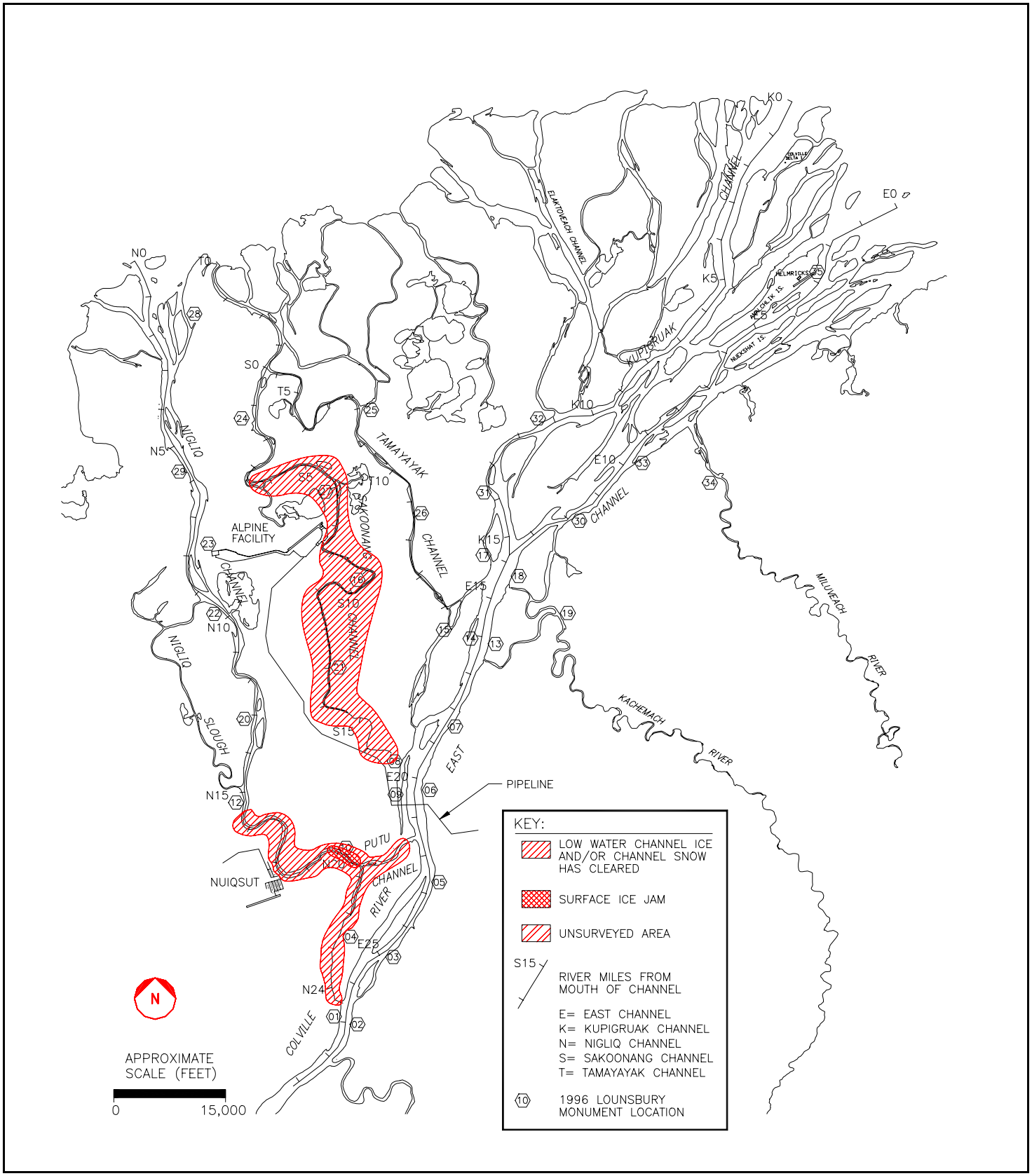


Figure A-6. Low Water Channel Ice Survey, June 10, 2001

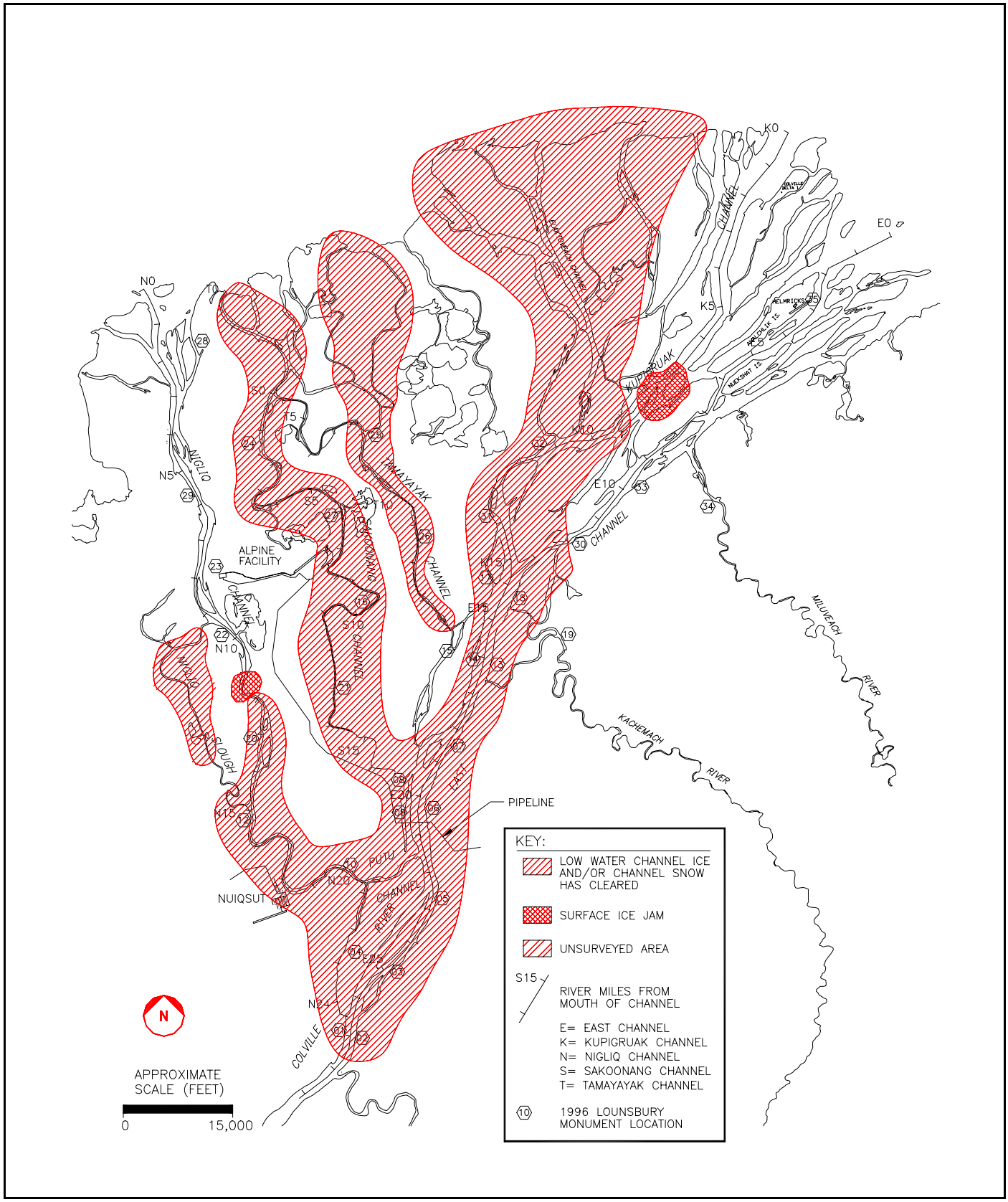


Figure A-7. Low Water Channel Ice Survey, June 11, 2001

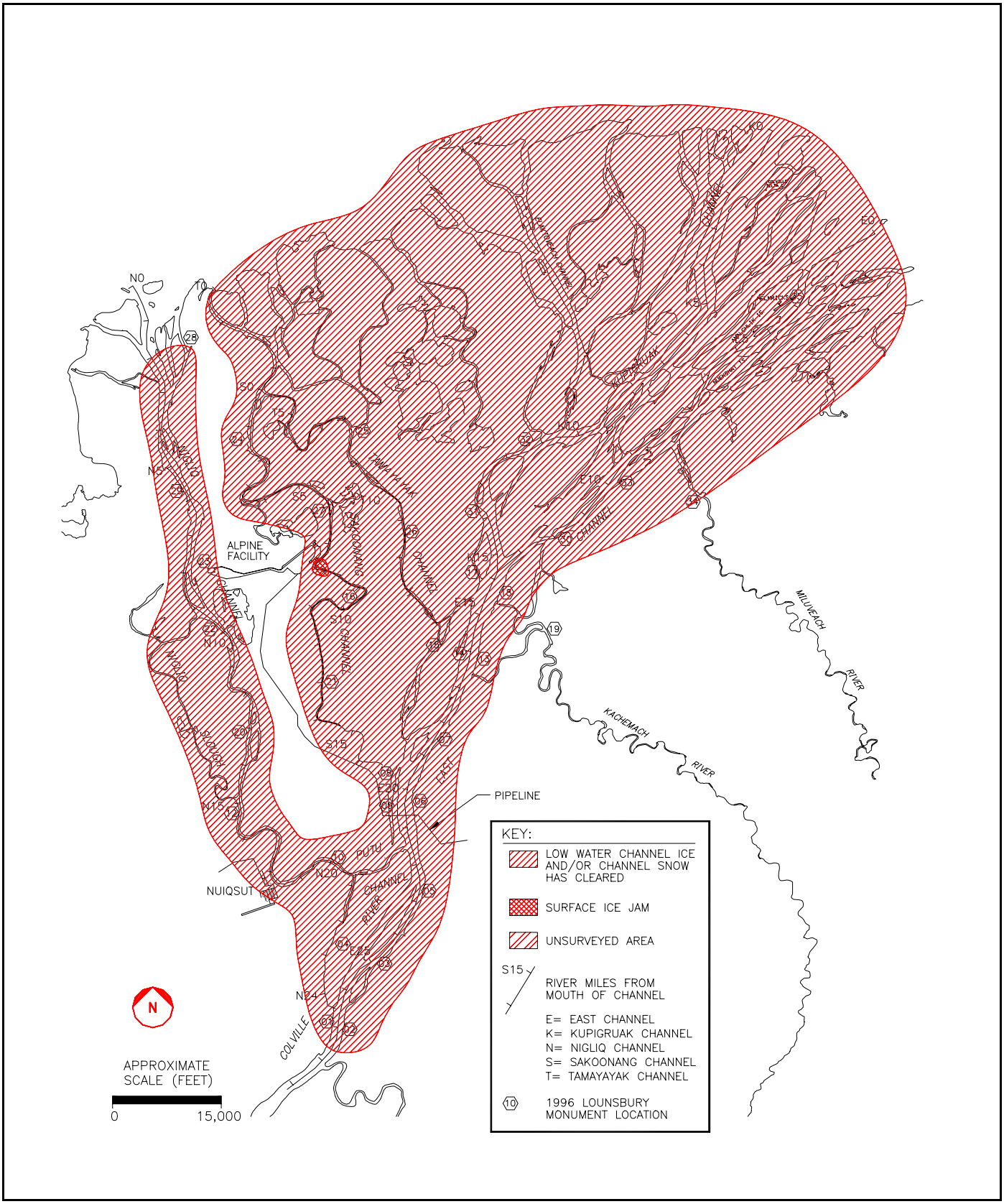


Figure A-8. Low Water Channel Ice Survey, June 12, 2001.