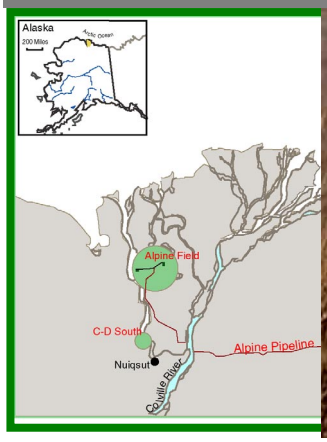
# CD-South Development Project

# 2001 Spring Breakup and Hydrologic Assessment










Submitted to

PHILLIPS Alaska, Inc.
A Subsidiary of PHILLIPS PETROLEUM COMPANY

By

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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 ensure a high level of safety 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-South satellite development. Field data for CD-South was collected in conjunction with the existing Alpine Development hydrologic breakup study.

The report is divided into three main sections. Section 2 provides data, observations, and analysis related to the Colville River at Monument 01, an area typically referred to as the head of the Delta and observations that pertain to the Delta as a whole. Section 3 presents data, observations, and analysis related specifically to CD-South.

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 after the text at the end of that section.

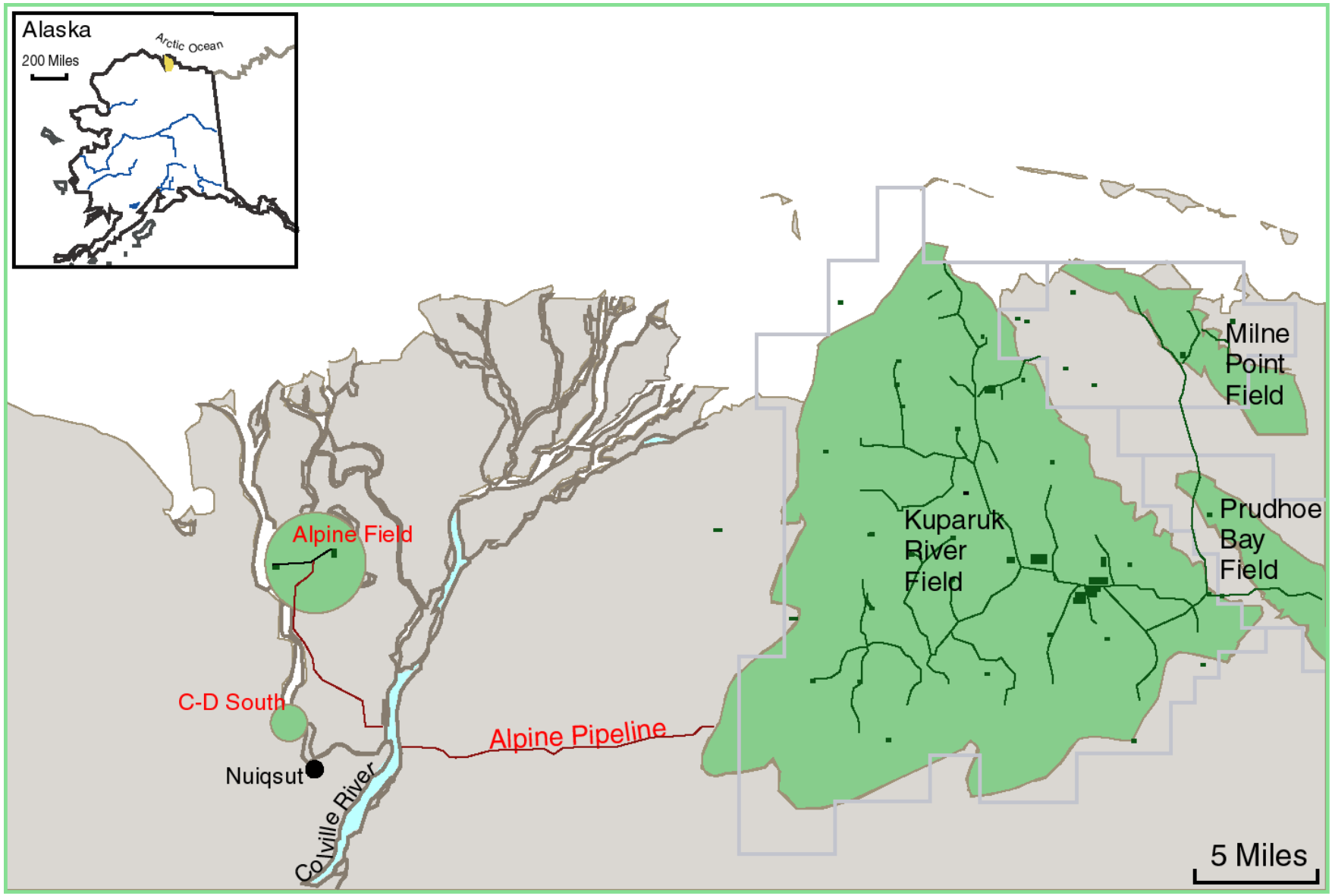



**Figure 1-1. Project Location**

# 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, at 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 all temporary staff gages in the Delta, including those 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, at which time 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 2-5 show conditions at the cross sections during the period 6 June through 10 June 2001.

## 2.2 Peak Water Surface Elevation and Peak Discharge in the Colville River Delta

The peak water surface elevation at Monument 01 occurred on the morning of 10 June, at an elevation of 17.37 feet (Photo 2-7). Discharge at the time of the peak water surface elevation was 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 mostly intact (however floating). 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 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.

**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.

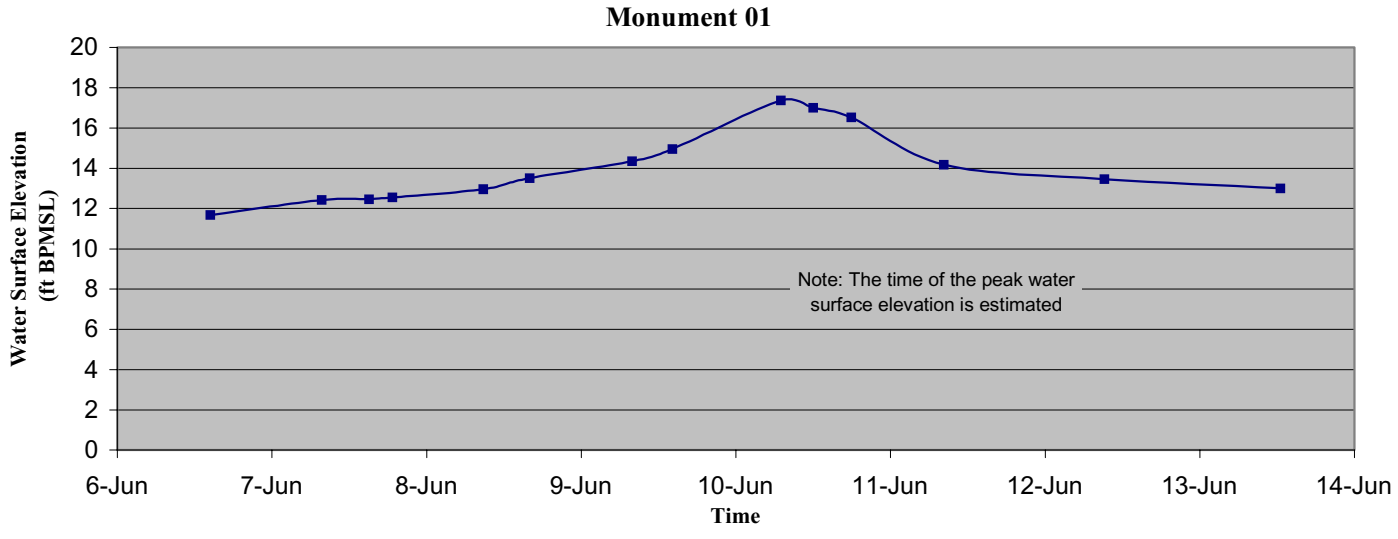


**Table 2-2. Temporary Benchmark 01U, Water Surface Elevations and Observations**

| 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.

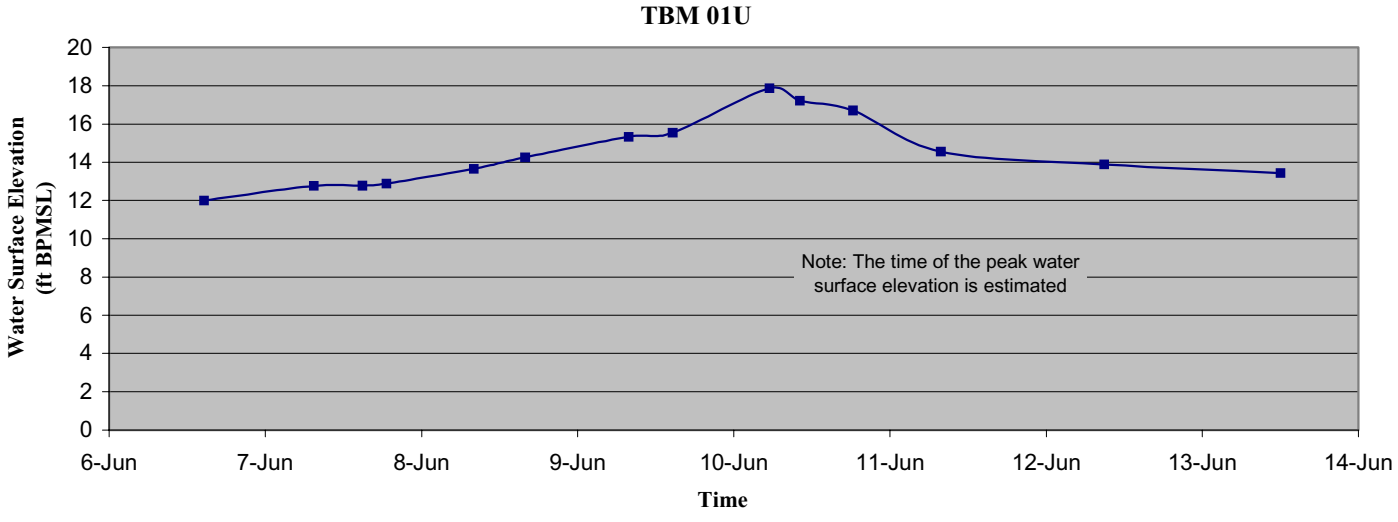
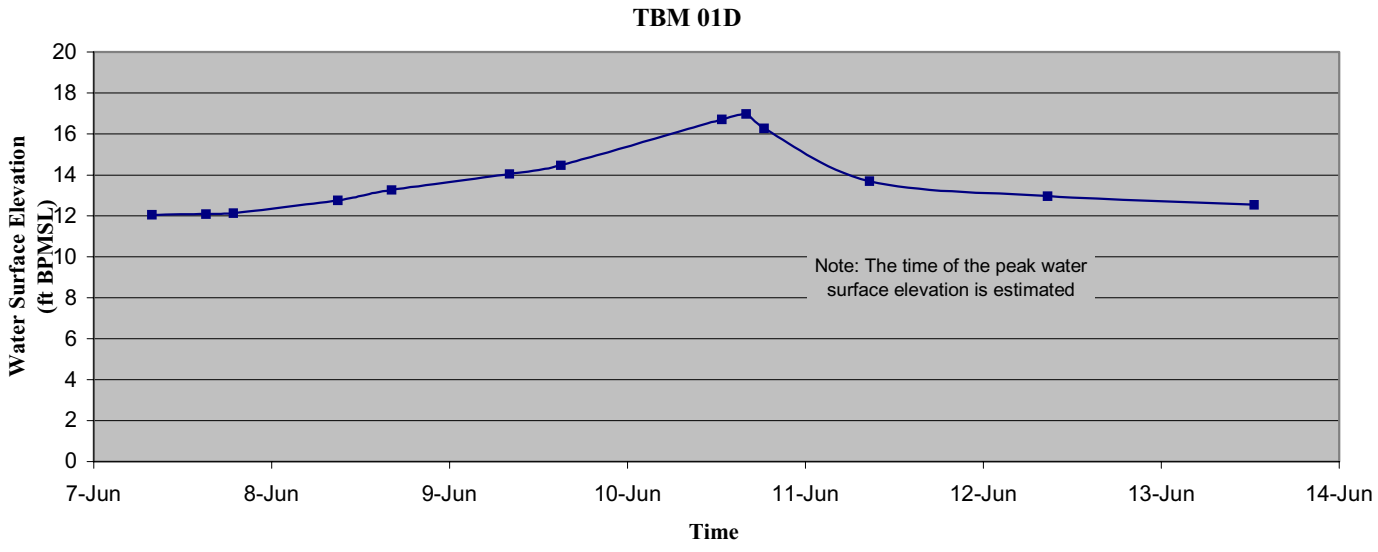


**Table 2-3. Temporary Benchmark 01D, Water Surface Elevations and Observations**

| 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°10'26.6" W150°056'01.6" (NAD 27) as obtained by a Garmin II Plus handheld GPS.



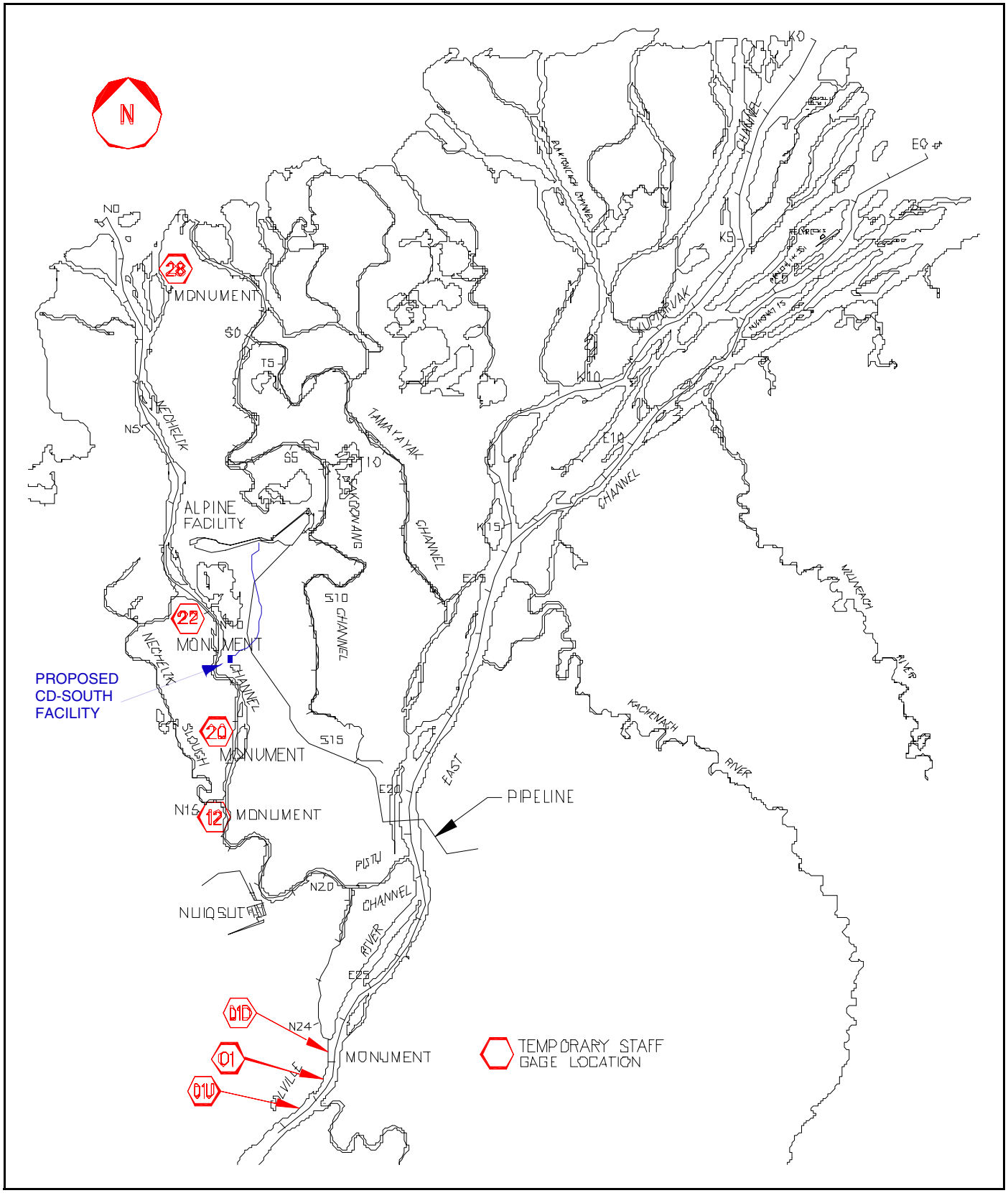



**Figure 2-1. Temporary Staff Gage and Monument Locations**

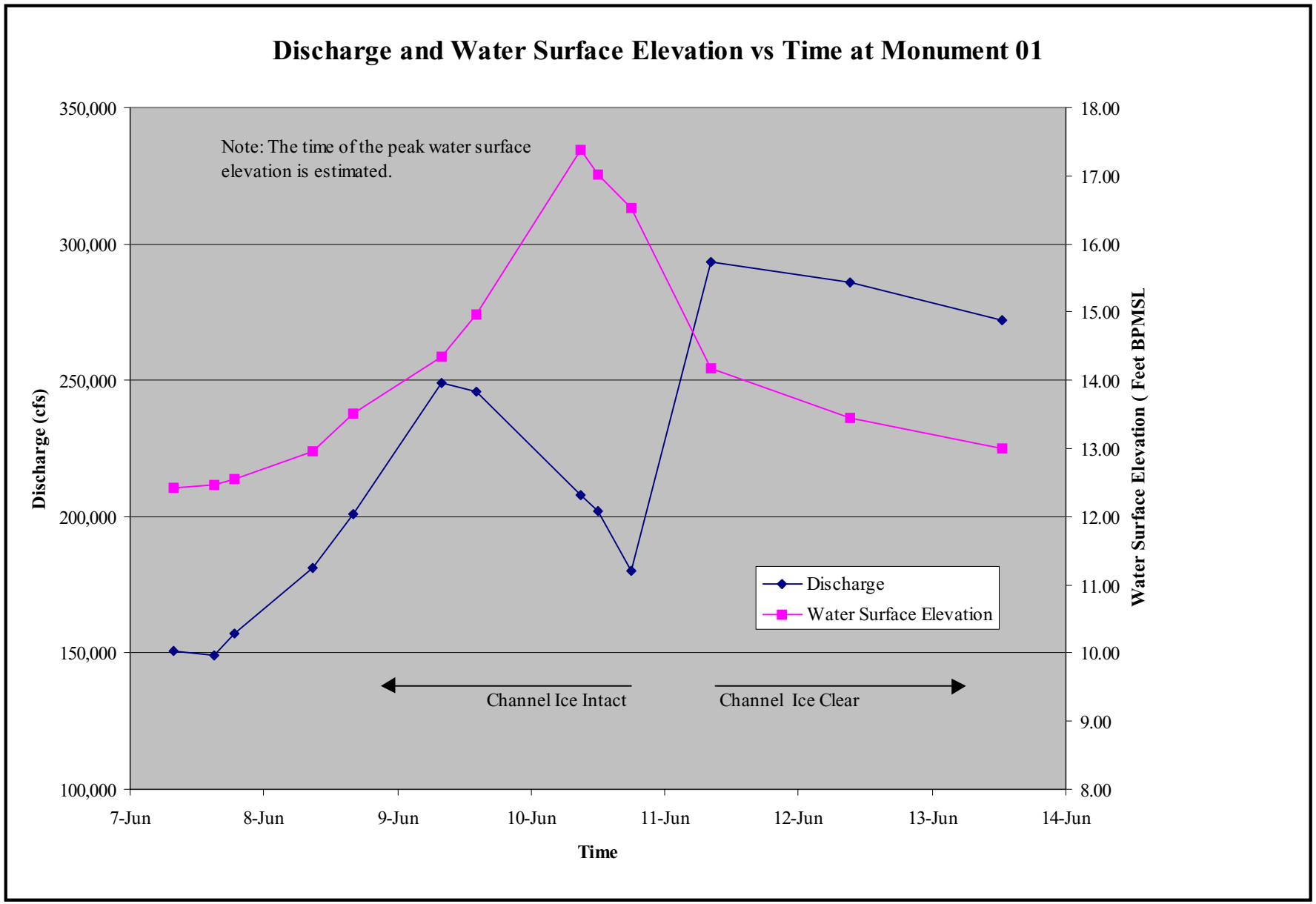



**Figure 2-2. Stage/Discharge Hydrograph**

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

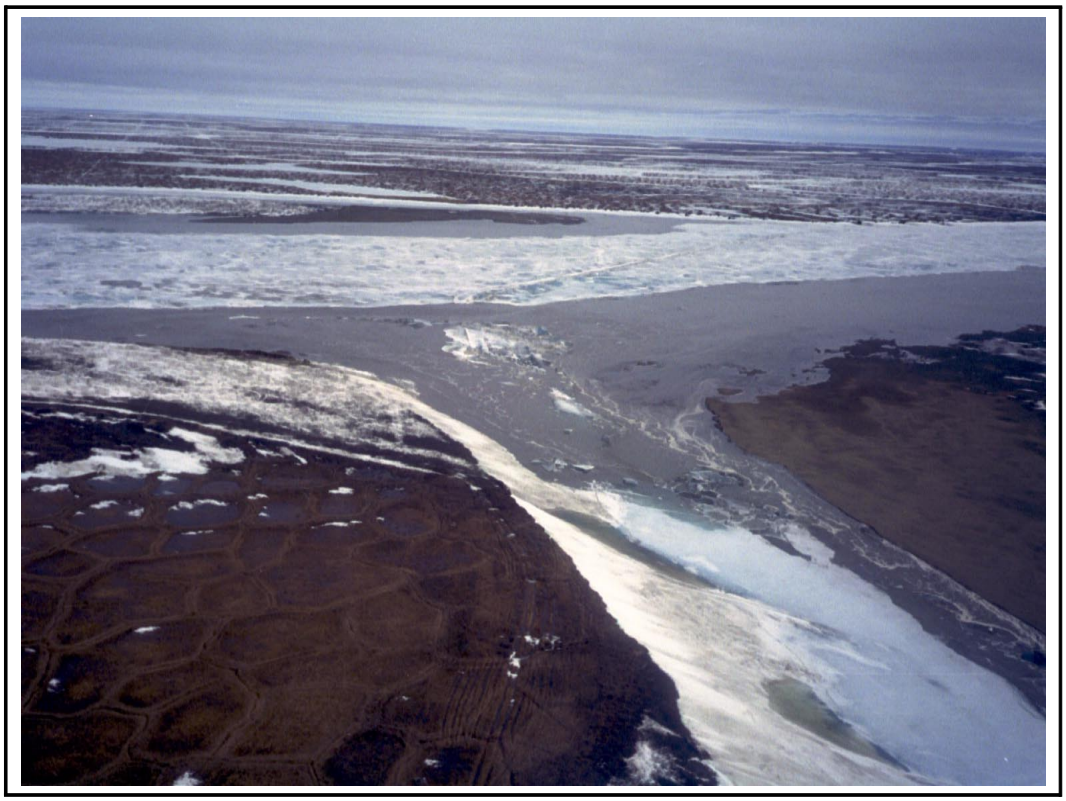


**Photo 2-2. Looking East at the Divergence of the East Channel and Putu Channel, 5 June 2001. Note flow entering Putu Channel.**

**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-South

## 3.1 Water Surface Elevations and Observations

Water surface elevations were monitored along the Nigliq Channel at survey Monuments 12, 22, 28, and at a temporary benchmark established adjacent to the CD-South proposed pad location, approximately 1 mile downstream from Monument 20 and designated TBM 20N (Figure 2-1). Measurements began on 6 June, the day after flowing water was first observed near Monument 01, and continued until 13 June when all temporary staff gages were removed. Water surface elevation and observation records for CD-South are presented in Tables 3-1 through 3-4.

In the Nigliq Channel near Monument 12 and TBM 20N, the peak water surface elevations occurred sometime during the afternoon of 10 June at elevations of 11.94 and 10.16 feet, respectively. The peak water surface elevation near Monument 22 likely occurred the evening of 10 June at an elevation of approximately 8.8 feet. Definitive high water marks were not available at Monument 22 and the peak water surface elevation presented was estimated. The highest recorded water surface elevation at Monument 28 was 3.83 feet. The temporary staff gages at Monument 28 were destroyed by ice and high water marks were not available. However, based on the time of measurement on 11 June and the observed peak at other locations in the Delta, the measurement of 3.83 feet is likely close to the peak water surface elevation.

## 3.2 Channel Ice Observations

Channel ice surveys began on 5 June when water was first observed flowing on the 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 channel ice clearing and ice jamming is shown on a series of figures presented in Appendix A.

Large areas of intact floating channel ice characterized the early stages of breakup in the main channels of the delta. On 5 and 6 June, floating channel ice on the East Channel appeared to be diverting a large percentage of flow into the upper Nigliq Channel. As breakup progressed and water levels rose, the influence of ice in the East Channel appeared to lessen. Channel ice in the

East channel remained relatively intact until the evening of 10 June when much of the channel ice cleared. Approximately 90 percent of the East Channel channel ice had cleared by the morning of 11 June.

Channel ice in the Nigliq channel adjacent to the proposed CD-South facility remained intact until 8 June. On 9 June, ice chunks began moving through open water areas near the CD-South pad site, and by 10 June, channel ice in this section of river had broken into large floes. On the morning of 11 June, channel ice upstream of TBM 20N had cleared; however, an ice jam had formed adjacent to the proposed pad location, at the bend in the channel just below TBM 20N. The location of this ice jam is one of the areas identified by traditional knowledge (Phillips Alaska, Inc., and Anadarko Petroleum Corp., 2001) as being prone to annual grounded ice jamming., The observed ice jam, however, appeared to be a surface ice jam rather than a grounded ice jam and did not appear to cause significant backwater, blockage, or diversion of flow. Intact channel ice remained downstream of the ice jam, suggesting that the presence of the jam might have slowed the clearing of ice downstream from the proposed facility location.

Also on 11 June, grounded ice chunks that had been deposited by high water were noted on the channel bank adjacent to the proposed facility location. Ice chunks varied in size; however, the larger ice chunks were estimated to be approximately 100 foot in diameter and 4-5 feet thick. By 12 June, the ice jam in the bend downstream of TBM 20N (west of the proposed facility) had cleared, as had the Nigliq Channel as a whole.

## 3.3 Proposed CD-South Road Alignment

### 3.3.1 Field Observations

The proposed CD-South road alignment was monitored to document cross-flow during the 2001 spring breakup and to assess the potential for cross-flow during subsequent flood events. Daily aerial surveys were completed; in addition, two ground reconnaissance walks of the proposed alignment were completed on 7 June (3-4 days before the peak water surface elevations) and on 18 June (7-8 days after peak water surface elevations). A representative from the Alaska Department of Fish & Game accompanied Baker on the 18 June reconnaissance.

During both investigations, the road alignment was partially staked. In those portions without staking, aerial photographs depicting the route layout were used by the field team to identify their position on the alignment.

Two road alignments (original and new) are shown on Figure 3-1. The preferred alignment during the breakup studies is labeled original. The preferred alignment at the time of this writing is the new alignment.

Cross-flow was observed at two locations along the origianl alignment. On 11 June during aerial reconnaissance, flow across the alignment was observed south of Lake L93-23 in the paleochannel that connects Lake L93-24 to Lake L93-23 (Figure 3-2, Location D and Photos 3-8, 3-9, and 3-10). A breach in the shoreline of Lake L93-24 was allowing water to flow from the lake into the paleochannel. The width of flow was visually estimated to be between 50 and 100 feet wide. Flow was confined to the base of the ridge, which forms the left bank of the paleochannel, and by 12 June had decreased such that, from the air, it no longer appeared to be continuous. During the 18 June alignment investigation, wet tundra and bent grass, as well as a high water mark on the surface ice of Lake L93-23, confirmed that flow in this area had occurred. The width of the flow was estimated at 150 feet based on visual observations of the ground conditions. Silty water on the edge of Lake L93-23 verified that this flow was caused by inundation of water from the Sakoonang Channel.

On 11 June, flow across the original alignment was observed north of Lake L9323 in the paleochannel that connects Lake L93-23 and Lake M95-25 (Figure 3-2, Location E). The width of flow was visually estimated at 100-200 feet. During the 18 June alignment investigation, flow through the grass was observed at this location; however, depths were very shallow and flow velocity was barely discernible. No cross-flow was observed east of Lake L93-23.

After crossing the paleochannel north of Lake L93-23, the proposed road alignment climbs onto a ridge that runs north towards the existing Alpine Development. No evidence of cross-flow was observed from this point north. The ridge that the proposed road alignment follows is relatively high ground that will likely see cross-flow only during large flood events. Wet tundra caused by local snowmelt was the only source of surface water noted in this area.

A prominent break in the ridge was noted during both field reconnaissance trips. The approximate location of the break is 2,000 feet north of Nanuq Lake at coordinates N70°19'24.1", W150°59'34.8" (Figure 3-2, Location F and Photo 3-12). The break was estimated to be approximately 145 feet wide, and there was no indication of flow through this break this year.

No evidence of flow was observed across the proposed roadway alignment immediately south of the Alpine airstrip and to the east of the Alpine swale area. Low polygon channels and undulations in the surface terrain that collected local snowmelt were noted; however, there were no indications that cross-flow occurred in the area.

The area east of the proposed alignment was recharged by two breaches in the Sakoonang Channel. The first breach was located east of Lake M95-25 where the Sakoonang Channel begins a "U" shaped bend (Figure 3-2, location A and Photo 3-7) and appeared to be the primary recharge mechanism to those areas east of the proposed alignment. The second breach was located east of the southernmost portion of Lake L93-24 (Figure 3-2, Location B) at the 90° channel bend. Recharge contributions from this breach were negligible compared to the contributions observed from the breach east of Lake M95-25.

The area west of the proposed alignment was recharged by a breach in the Nigliq Channel. The breach was located west of Nanuq Lake (Figure 3-2, Location C) and was the primary mechanism for recharge to those areas west of the proposed alignment.

### 3.3.2 Hydrologic Assessment

- Based on field reconnaissance and observations made during the Spring 2001 breakup program, the proposed CD-South road is located such that it will result in minimal impact to hydrologic systems in the vicinity of the project. Hydrologically, the proposed CD-South road is fundamentally different from the existing Alpine road in that the proposed CD-South road is aligned such that it is parallel to flow while the Alpine road is perpendicular to flow.

- Based on field observations, it appears that cross-flow over the proposed CD-South alignment is relatively infrequent. During Spring 2001 breakup, recharge to the system east of the

alignment was from the Sakoonang Channel (via Figure 3-2, Location A) and recharge to west of the alignment was from the Nigliq Channel (via Figure 3-2, Location C). The proposed road alignment essentially follows a ridge that forms a natural divide between these two systems.

## 3.4 Proposed CD-South Pad Location

### 3.4.1 Field Observations

The proposed location of the gravel pad was not impacted by either high water or grounded ice during the 2001 breakup. The lowest ground surface elevation in the vicinity of the pad is approximately 10.5 feet and the peak water surface elevation recorded at TBM 20N (adjacent to the proposed pad site) was 10.16 feet. Wet tundra caused by snowmelt was the only source of surface water noted in the immediate vicinity of the pad location.

During the spring field program it appeared that the proposed CD-South pad site might be vulnerable to ice floes from the Nigliq Channel during a large flood event. On 16 June, a reconnaissance of the proposed pad site was conducted to assess whether the pad location should remain in the currently proposed site, or whether it could be relocated to the east to reduce the risk of ice damage.

During the 16 June site visit, it was apparent that ground surface elevations between the Nigliq Channel and the paleochannel connecting Lakes L93-24 and L93-23 gradually increase from west to east. High water marks were identified within 30 feet of the existing ice pad (approximately the same location as the proposed pad). Stranded ice floes remained along the right bank and in the channel meander adjacent to the proposed site. In addition, the right bank of the outside meander showed significant slumping, evidence of erosion from high water and/or ice scour.

### 3.4.2 Hydrologic Assessment

- Field observations were compared to the results of the two-dimensional surface water model developed for the Colville River Delta (Michael Baker Jr., Inc., 2001, 1998; and Shannon & Wilson, 1998). After further analysis, it appears that from a hydrologic perspective, there is little difference between the proposed pad location and moving the pad to the east. Preliminary

modeling indicates that during the 200-year design event, water surface elevations and velocities are essentially the same at each location. Ground surface elevations are approximately 10.0 feet and 12.0 feet for the proposed site and to the east, respectively. Assuming the pad height remains the same, water depths will decrease approximately 2 feet by moving the pad to the east. During a 200-year flood event, a 5-foot thick ice floe will be able to impact the pad at either location and there is little benefit for moving to the east based on the 200-year design event. The pad will require protection from ice floes regardless of which site is selected. However, a pad moved to the east will offer more protection from ice floes during flood-events smaller than the 200-year, where the two additional feet of ground surface will act as a natural barrier to ice floes.

**Table 3-1. Monument 12, Water Surface Elevations and Observations**

| Date | Time | Water Surface Elevation (ft BPMSL) | Observations |
|---|---|---|---|
| 6/6/01 | 15:22 | 7.81 | Channel ice still intact. |
| 6/7/01 | 8:00 | 8.38 | Channel ice intact along left bank. Small amount of ice chunks floating in channel. |
| 6/8/01 | 9:06 | 8.86 | Channel ice intact on opposite bank. No visible floating ice chunks. |
| 6/9/01 | 8:20 | 9.80 | Channel ice intact on opposite bank. No visible floating ice chunks. |
| 6/9/01 | 15:26 | 10.05 | Channel ice intact on opposite bank. No visible floating ice chunks. |
| 6/10/01 | 13:36 | 11.36 | Water has risen two-hundreths in 10 minutes. Large floes overiding eachother in the channel. Snow on east bank completely saturated. |
| High Water Mark | | 11.94 | The peak water surface elevation likely occurred on the afternoon of 10 June. |
| 6/11/01 | 9:05 | 10.52 | Lots of standed ice chunks on bank. Channel ice has cleared. |
| 6/12/01 | 9:55 | 8.54 | Ice chunks up to 30' in diameter and 5' thick stranded on bank. |
| 6/13/01 | 13:55 | 7.80 | |

Notes:
1. Elevations are based on an elevation of 14.60 feet BPMSL for Monument 12, established by Lounsbury & Assoc. in 1996.
2. Coordinates for Monument 12 are N70°14'58.3" W151°01'23.5" (NAD 27) as surveyed by Lounsbury & Associates.
3. Staff gages were set on opposite bank from Monument 12.

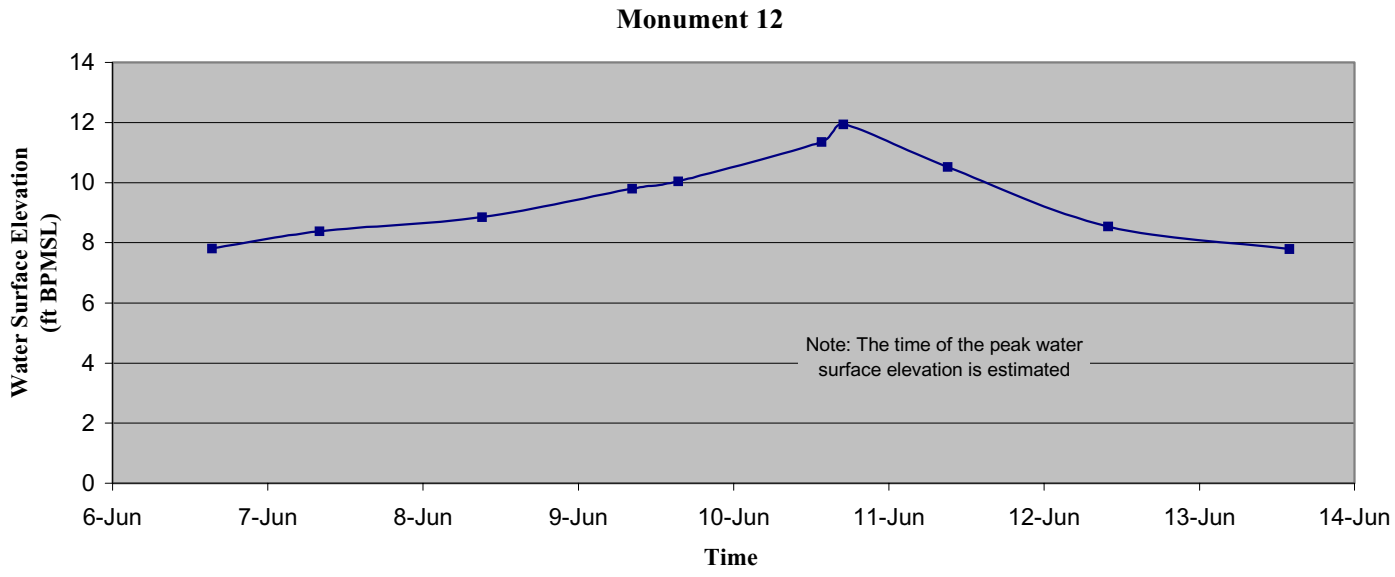


**Table 3-2. Temporary Benchmark 20N, Water Surface Elevations and Observations**

| Date | Time | Water Surface Elevation (ft BPMSL) | Observations |
|---|---|---|---|
| 6/6/01 | 15:39 | 5.69 | Channel ice intact. |
| 6/7/01 | 8:11 | 6.83 | Channel ice intact. Water is filling low channel along east bank. |
| 6/8/01 | 9:18 | 7.54 | Channel ice intact. |
| 6/9/01 | 8:44 | 8.47 | Ice chunks in reach. |
| 6/9/01 | 15:42 | 8.67 | Ice chunks in reach. |
| 6/10/01 | 13:58 | 8.99 | Large ice floes floating past and through reach. |
| High Water Mark | | 10.16 | The peak water surface elevation likely occurred on the afternoon of 10 June. |
| 6/11/01 | 9:14 | 9.54 | Grounded ice upstream and downstream. Snow on east bank gone. |
| 6/12/01 | 10:16 | 7.59 | Grounded ice chunks. |
| 6/13/01 | 14:15 | 6.48 | |

Notes:
1. Elevations are based on an elevation of 19.17 feet BPMSL for Monument 20, established by Lounsbury & Assoc. in 1996.
2. Coordinates for TBM 20N are N70°17'29.0" W150°59'57.8" (NAD 27) as surveyed by Lounsbury & Associates.
3. Gages were set on opposite bank and approximately 1 mile downstream (north) from Monument 20.

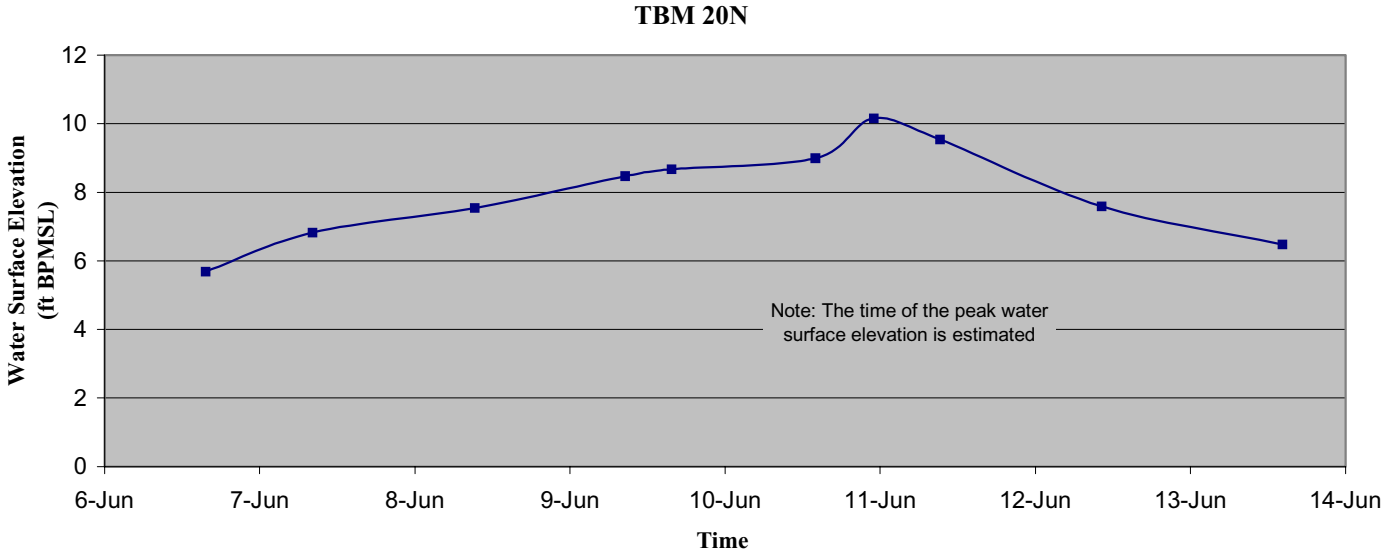


**Table 3-3. Monument 22, Water Surface Elevations and Observations**

| Date | Time | Water Surface Elevation (ft BPMSL) | Observations |
|---|---|---|---|
| 6/6/01 | 9:54 | 4.30 | |
| 6/6/01 | 15:49 | 4.72 | Channel ice intact on right bank. |
| 6/7/01 | 8:20 | 5.83 | Channel ice intact on right bank. |
| 6/8/01 | 8:20 | 6.40 | Channel ice intact on right bank. |
| High Water Mark | | 8.80 | Estimated high water. See Note 3. |
| 6/11/01 | 9:32 | 7.83 | Channel is open. Ice chunks floating through reach. |
| 6/12/01 | 10:24 | 6.31 | Channel clear of ice. |

Notes:
1. Elevations are based on an elevation of 10.13 feet BPMSL for Monument 22, established by Lounsbury & Assoc. in 1996.
2. Coordinates for Monument 22 are N70°19'06.3" W151°00'10.4" (NAD 27) as surveyed by Lounsbury & Associates.
3. Definitive high water marks were not available at Monument 22. Peak water surface elevation shown is an estimate.

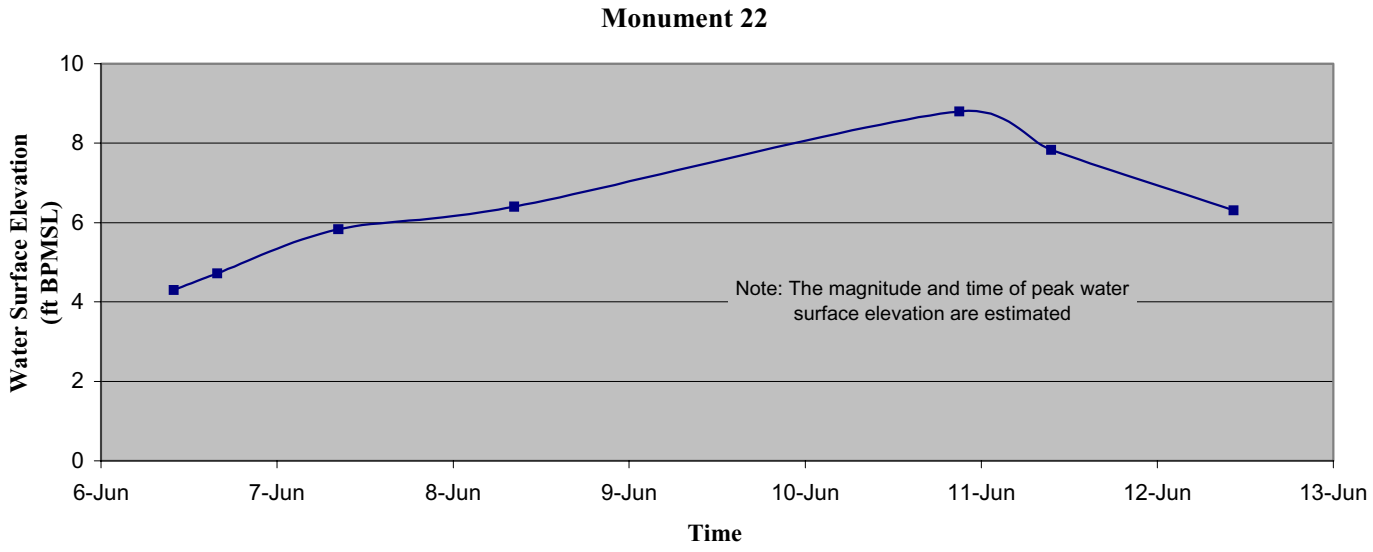
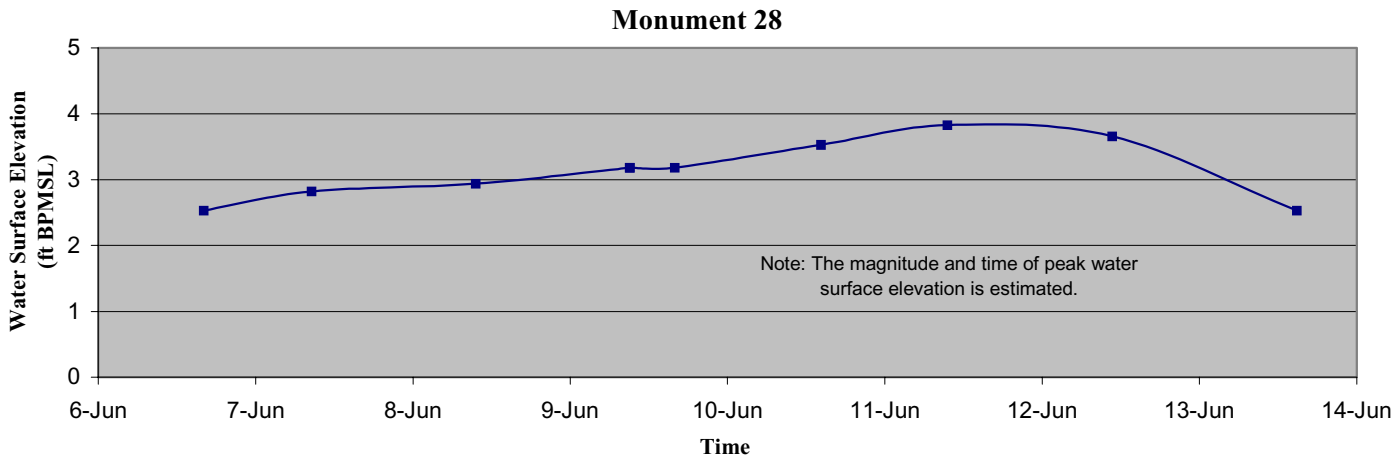


**Table 3-4. Monument 28, Water Surface Elevations and Observations**

| Date | Time | Water Surface Elevation (ft BPMSL) | Observations |
|---|---|---|---|
| 6/6/01 | 16:04 | 2.53 | Some floating ice. |
| 6/7/01 | 8:33 | 2.82 | Very little floating ice observed in channel. |
| 6/8/01 | 9:34 | 2.94 | Channel ice is clear. |
| 6/9/01 | 9:02 | 3.18 | Channel ice is clear. |
| 6/9/01 | 15:56 | 3.18 | |
| 6/10/01 | 14:14 | 3.53 | |
| 6/11/01 | 9:43 | 3.83 | |
| 6/12/01 | 10:43 | 3.66 | |
| 6/13/01 | 14:50 | 2.53 | |

Notes:
1. Elevations are based on an elevation of 3.66 feet BPMSL for Monument 28, established by Lounsbury & Assoc. in 1998.
2. Coordinates for Mon 28 are N70°23'33.2" W151°03'49.6" (NAD 27) as surveyed by Lounsbury & Associates.
3. Gages destroyed on evening of 10 June, no high water mark available. Elevations on 11, 12, 13 June surveyed from Mon 28.



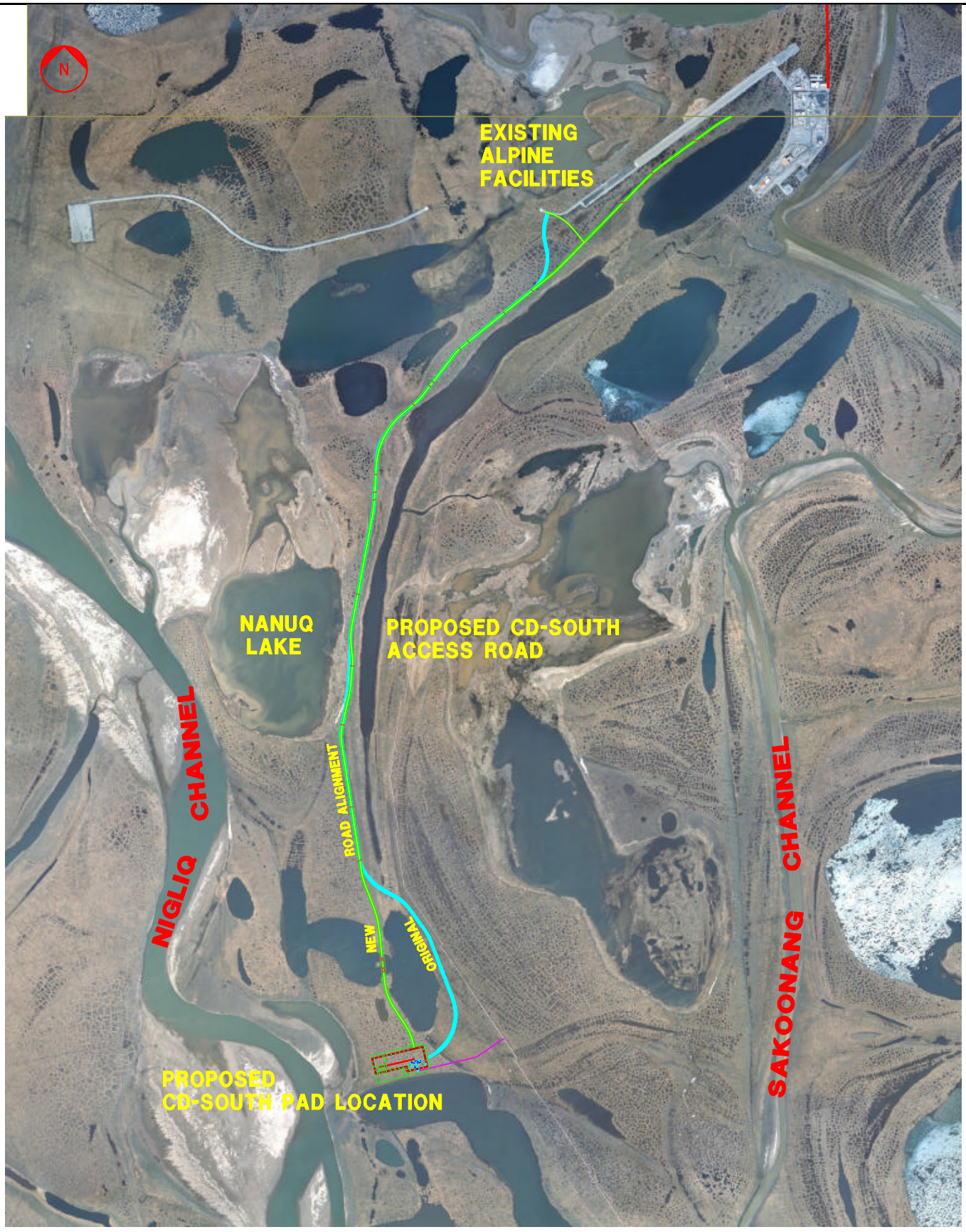



**Figure 3-1. CD-South Project Location**

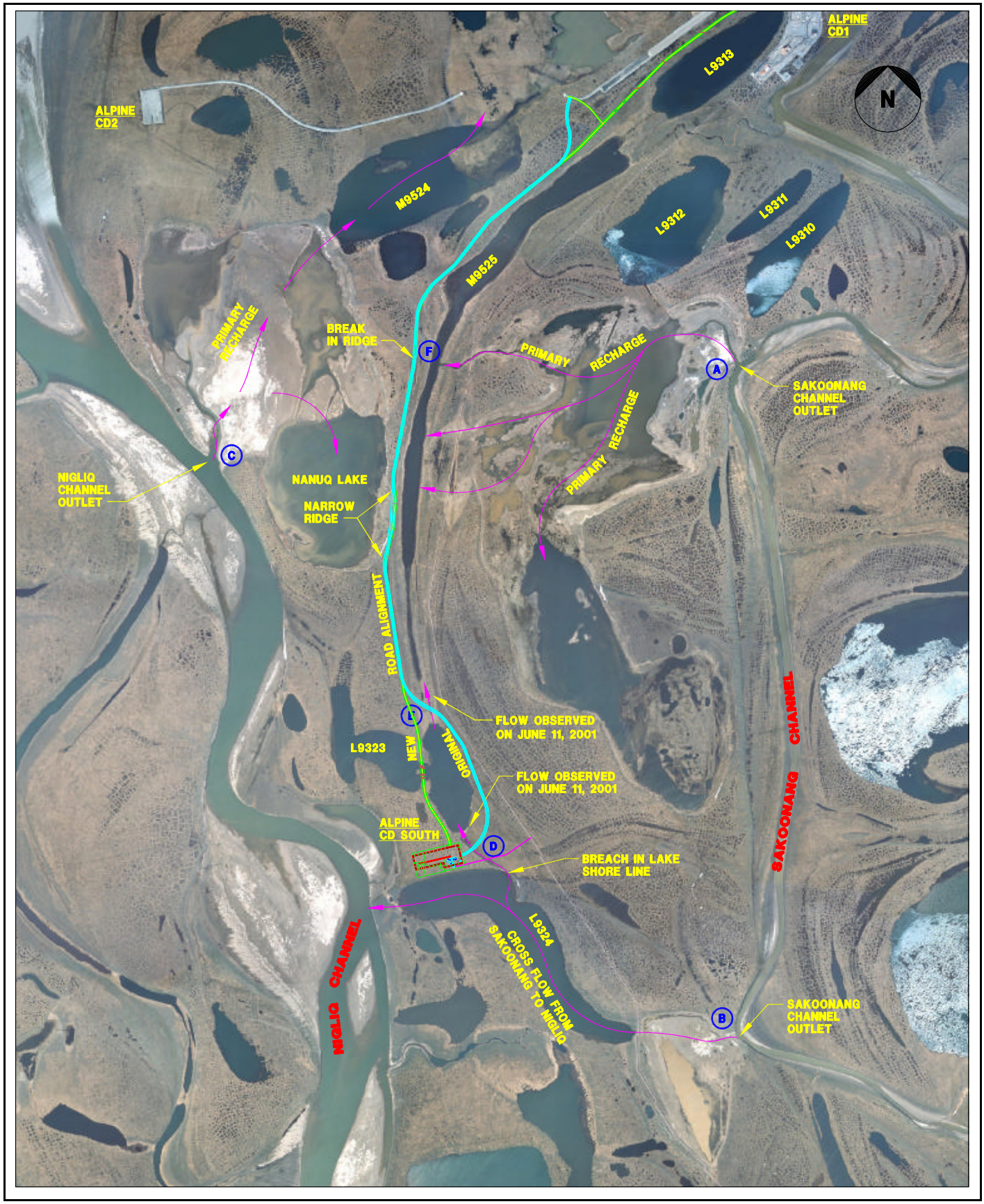



**Figure 3-2. CD-South Road Alignment Breakup Flooding 2001**

**Photo 3-1. Monument 12, J June 2001. Looking west across the Nigliq Channel.**

**Photo 3-2. Temporary Benchmark 20N, 6 June 2001. Looking west across the Nigliq Channel.**

**Photo 3-3. Temporary Benchmark 20N, 7 June 2001. Looking southwest across the Nigliq Channel.**

**Photo 3-4. Temporary Benchmark 20N, 8 June 2001. Looking west at the Nigliq Channel.**

**Photo 3-5. Temporary Benchmark 20N, 9 June 2001. Looking west at the Nigliq Channel.**

**Photo 3-6. Monument 22, 6 June 2001. Looking west across the Nigliq Channel.**

**Photo 3-7. Monument 28, 7 June 2001. Looking west across Nigliq Channel.**

**Photo 3-8. Cross-Section at Monument 28, 9 June 2001. Looking west across Nigliq Channel.**

**Photo 3-9. Ice Jam on Nigliq Channel, 11 June 2001. Looking north at the west of the proposed CD-South facility.**

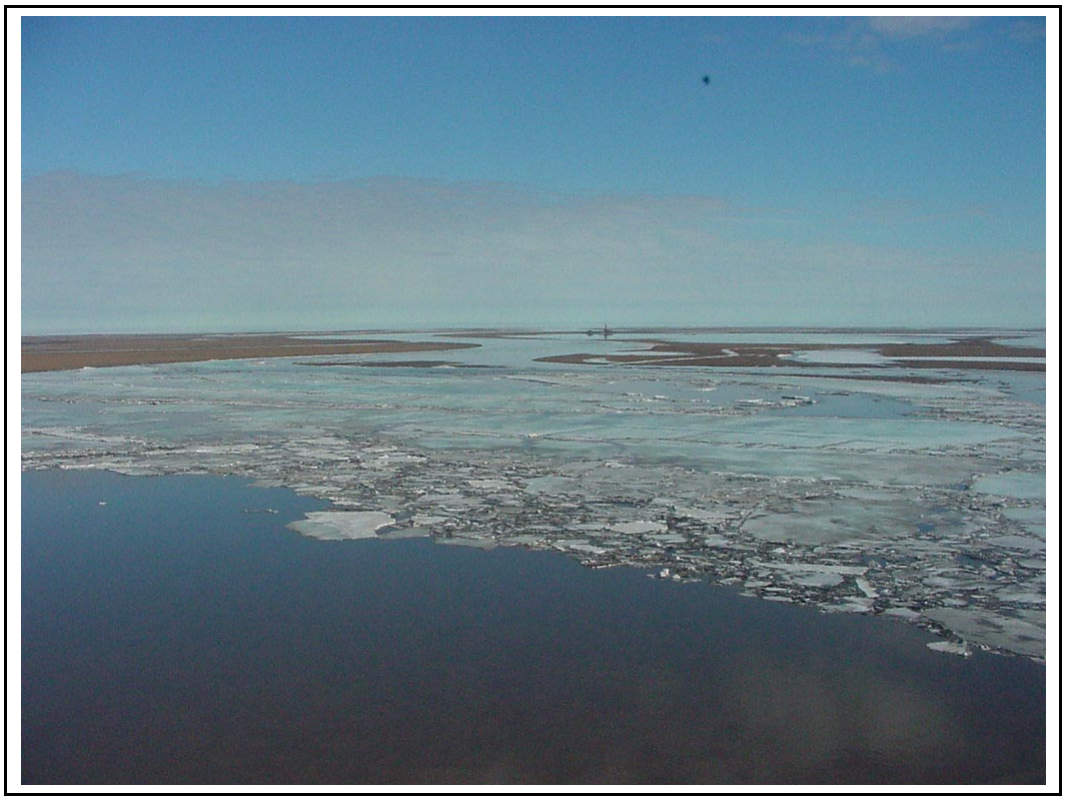


**Photo 3-10. Ice Jam on Nigliq Channel, 11 June 2001. Looking northwest just west of the proposed CD-South facility.**

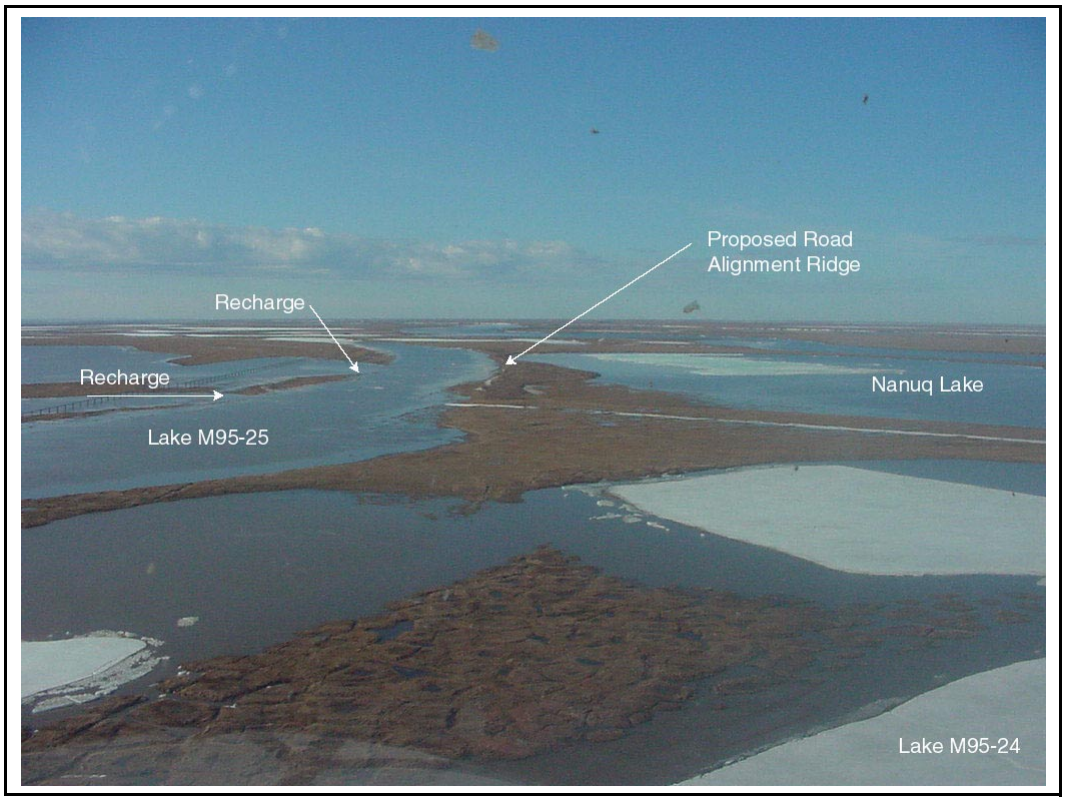



**Photo 3-11. Looking South from Alpine Swale Area, 12 June 2001.**

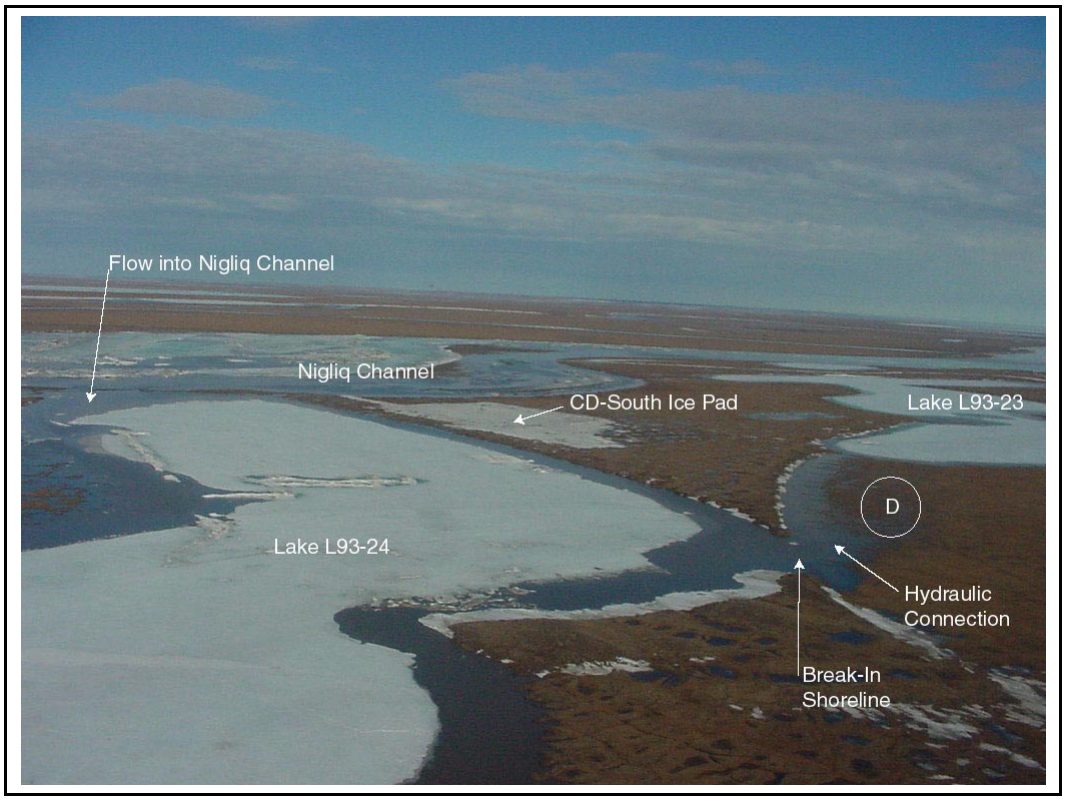



**Photo 3-12. Looking West towards CD-South Pad Location, 11 June 2001.**

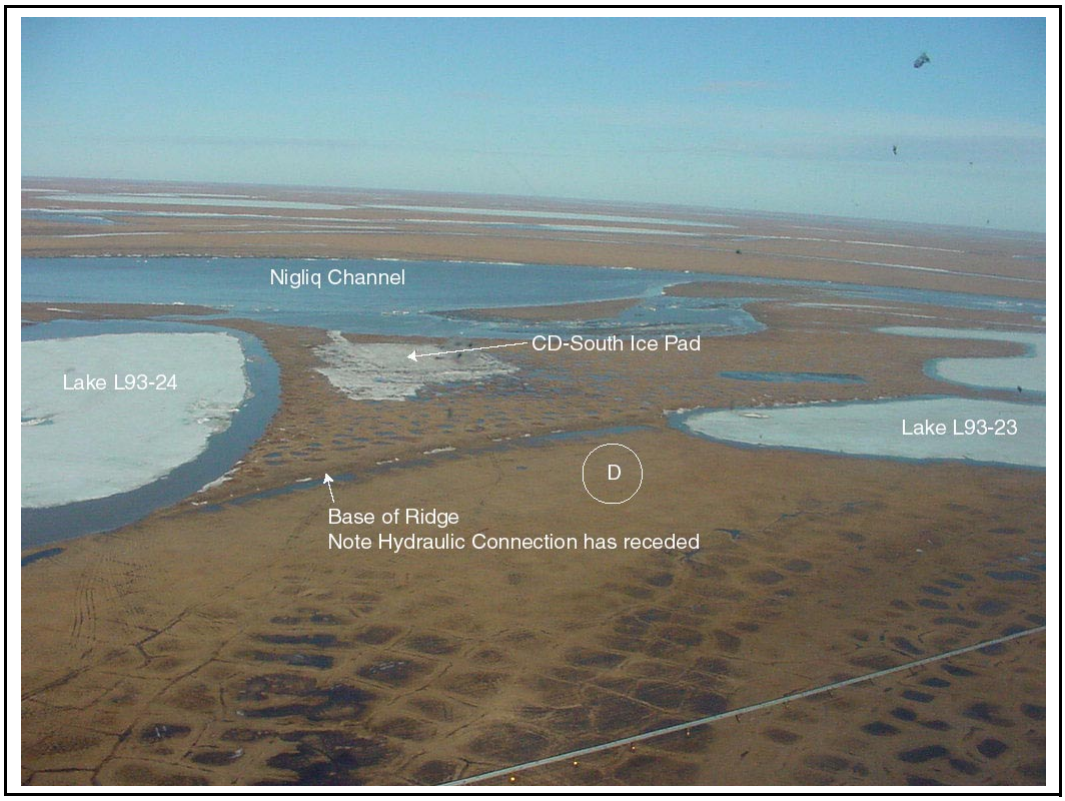



**Photo 3-13. Looking West towards CD-South Pad Location, 12 June 2001.**

**Photo 3-14. Looking South from the South End of Lake L93-23, 18 June 2001. Looking at the paleochannel that connects Lakes L93-23 and L93-24.**

**Photo 3-15. Looking North from the North End of Lake L93-23, 18 June 2001. Standing in the paleochannel that connects Lakes L93-23 and M95-25.**

**Photo 3-16. Looking North at the Prominent Break in the Ridge. Ridge is located approximately 2,000 feet north of Nanuq Lake.**

# 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

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

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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

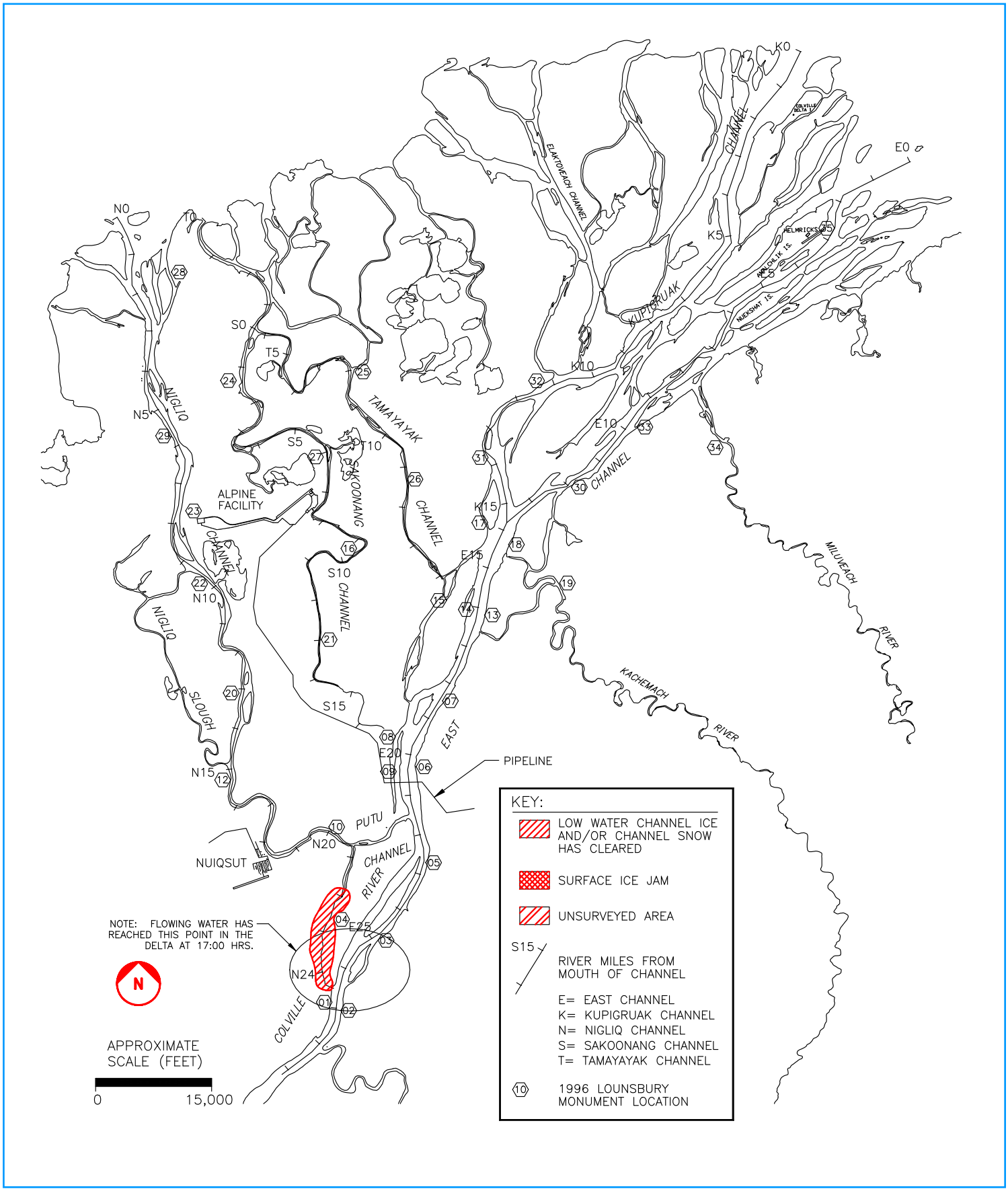


**Figure A-1. Low Water Channel Ice Survey, June 5, 2001**

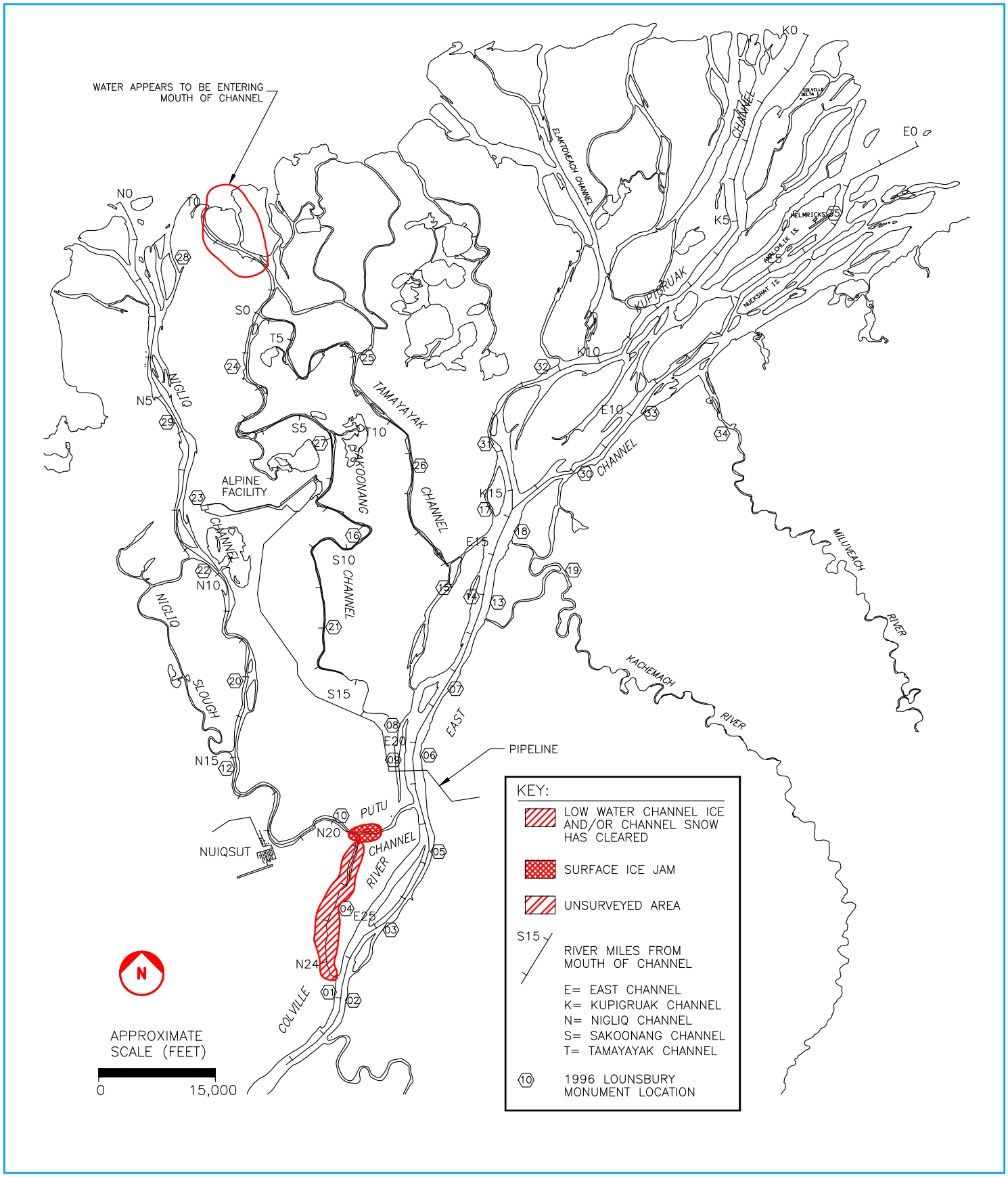


**Figure A-2. Low Water Channel Ice Survey, June 6, 2001**

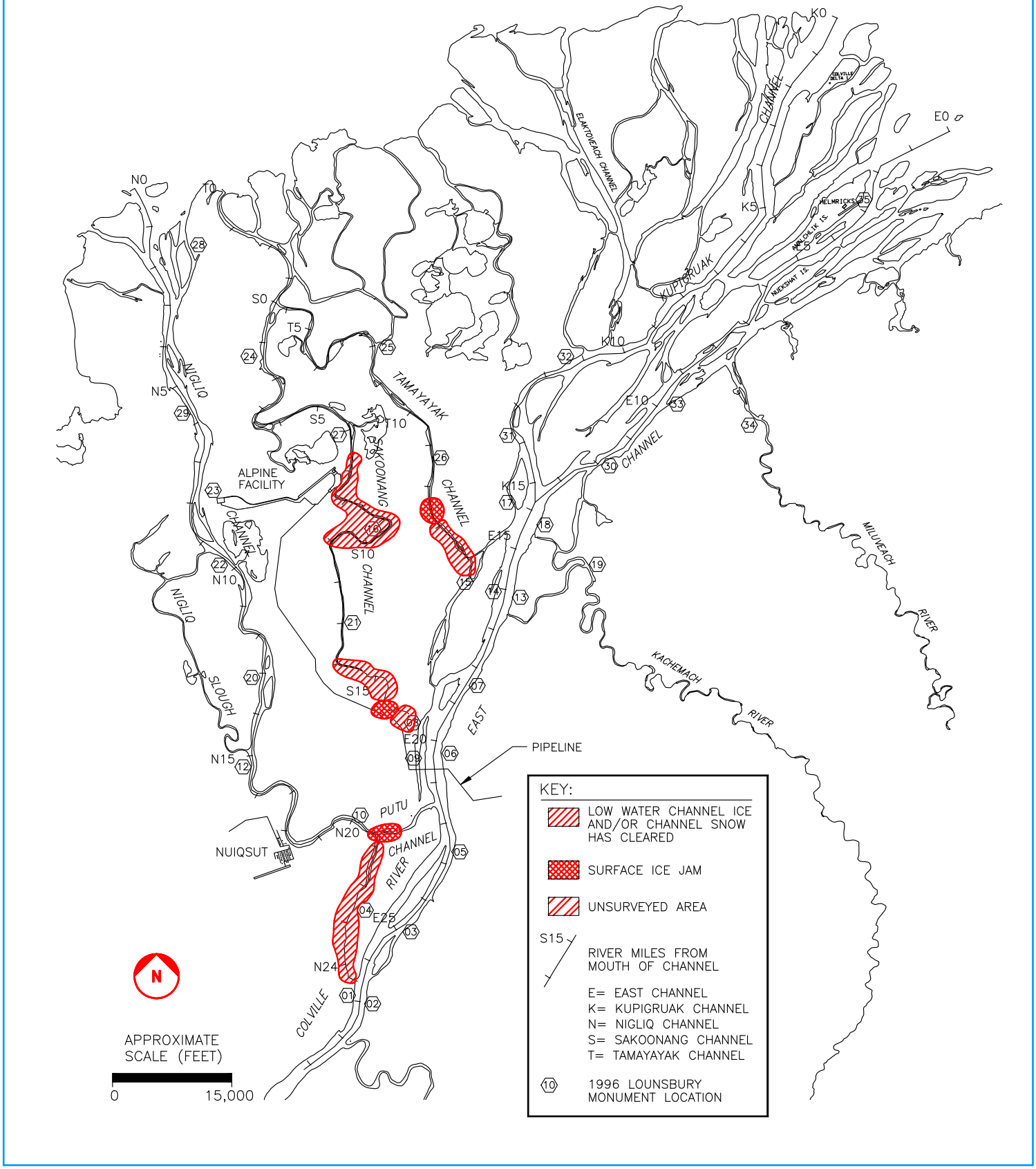


**Figure A-3. Low Water Channel Ice Survey, June 7, 2001**

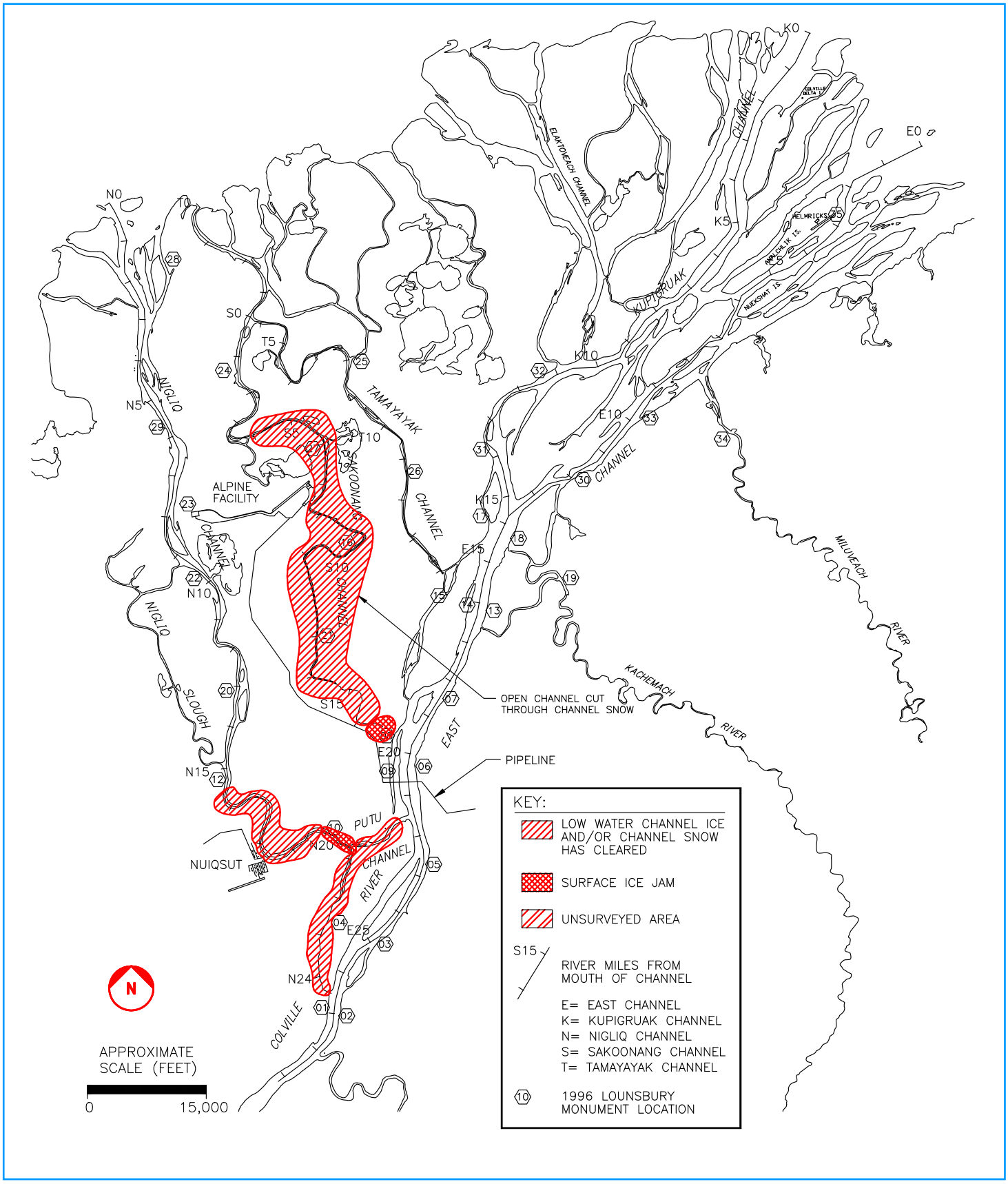


**Figure A-4. Low Water Channel Ice Survey, June 8, 2001**

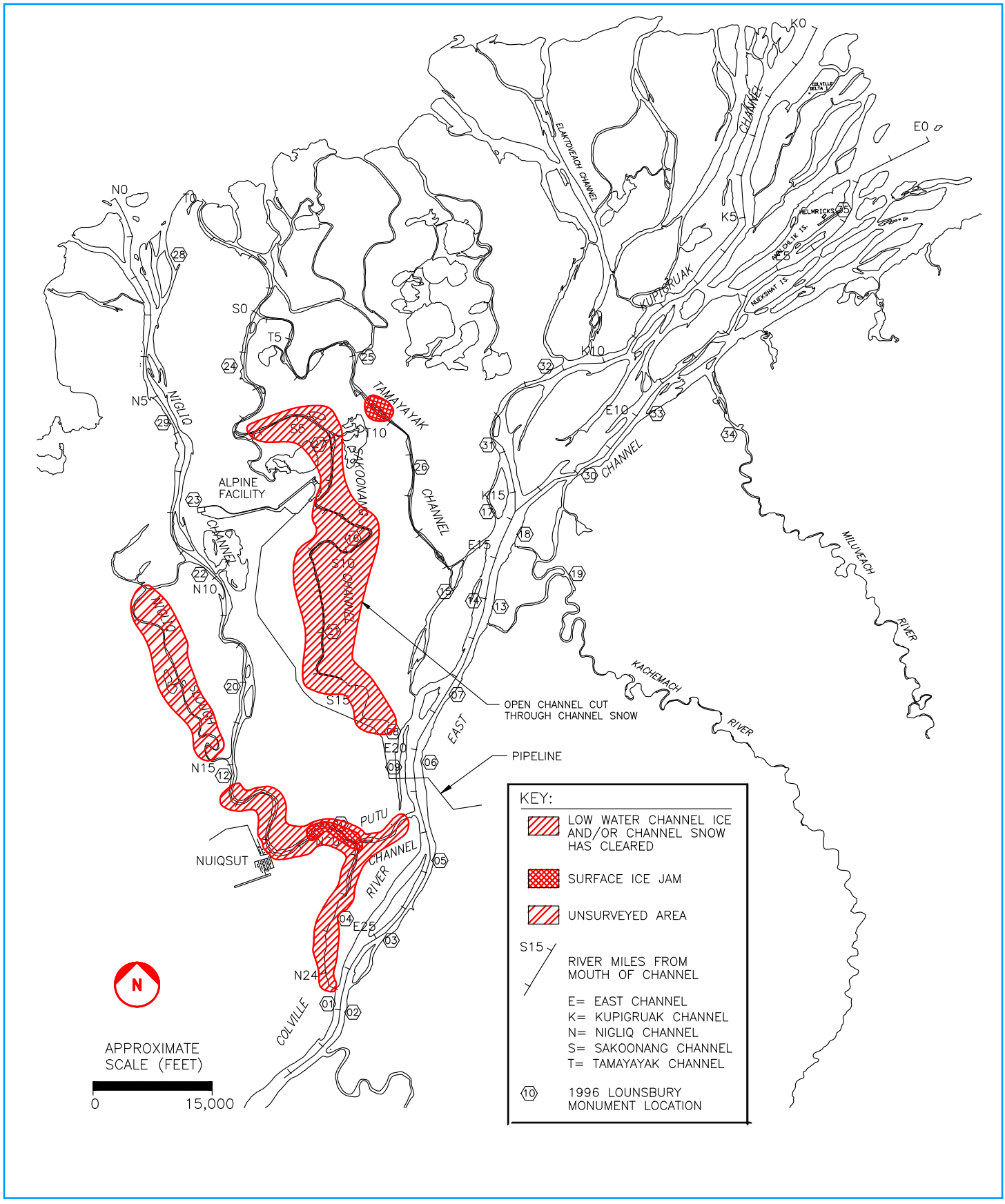


**Figure A-5. Low Water Channel Ice Survey, June 9, 2001**

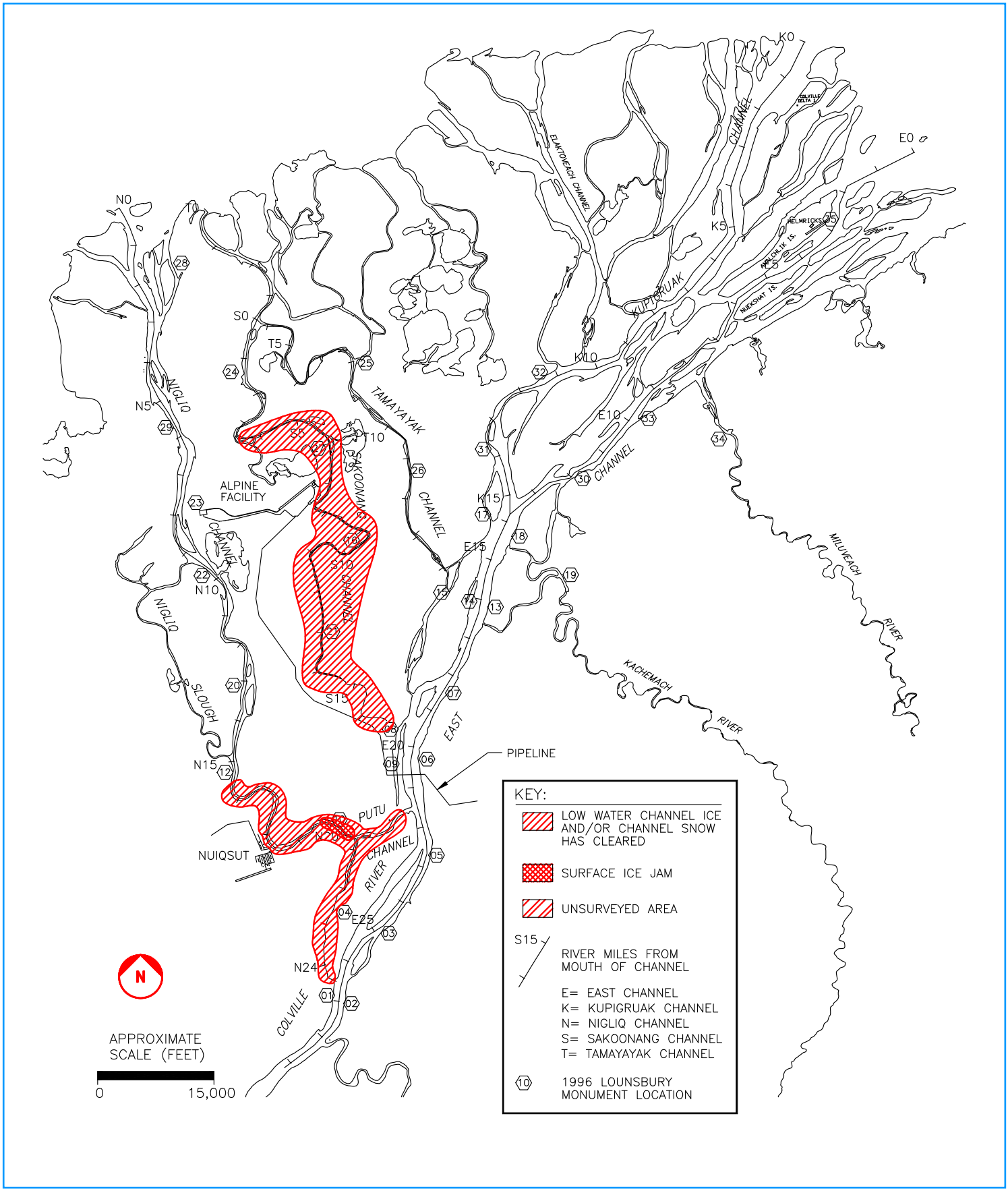


**Figure A-6. Low Water Channel Ice Survey, June 10, 2001**

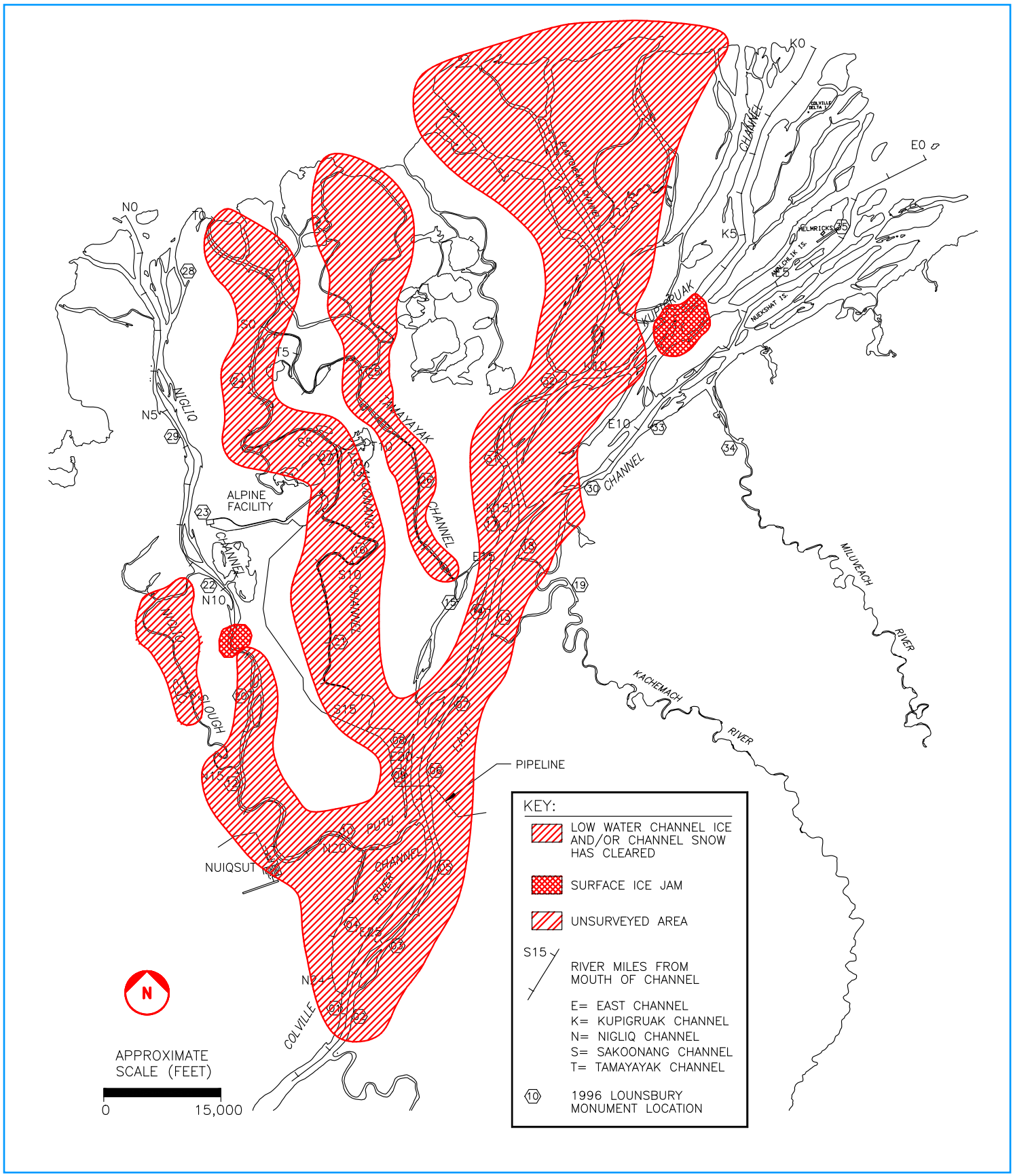


**Figure A-7. Low Water Channel Ice Survey, June 11, 2001**

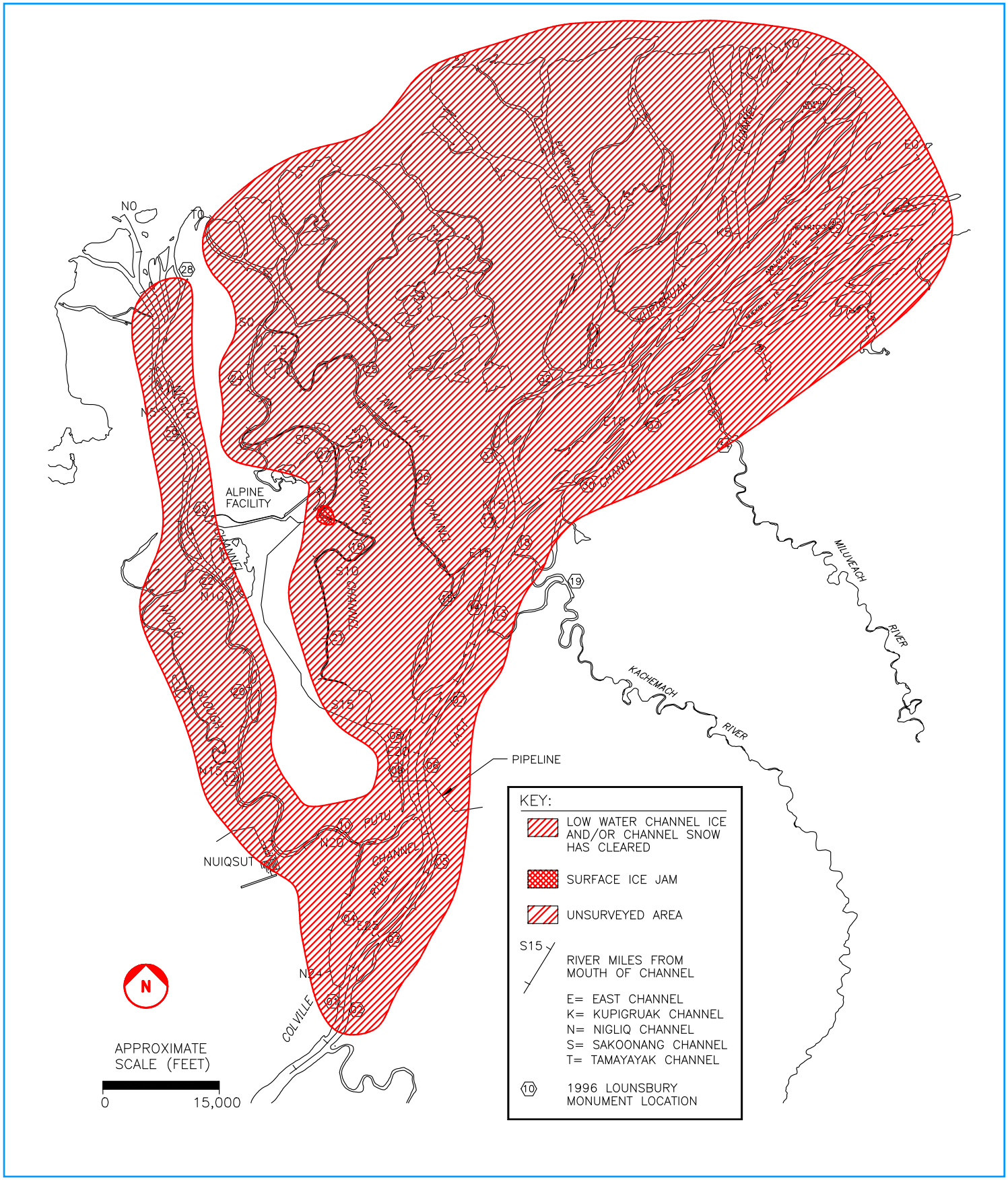


**Figure A-8. Low Water Channel Ice Survey, June 12, 2001.**