GEOMORPHOLOGY AND HYDROLOGY OF THE COLVILLE RIVER DELTA, ALASKA, 1993

Second Annual Report

Prepared for:

ARCO Alaska, Inc.
P.O. Box 100360
Anchorage, AK 99510

Prepared by:

M. Torre Jorgenson

Alaska Biological Research, Inc.
P.O. Box 81934
Fairbanks, AK 99708

and

James W. Aldrich
Carol J. Hammond

Shannon and Wilson, Inc.
2055 Hill Road
P.O. Box 70843
Fairbanks, AK 99707-0843

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Numerous individuals helped with the field work. Dave Dinkuhn helped with the discharge measurement. Tom DeLong arranged field logistics and coordinated services provided by Kuukpik Corporation.

Many villagers in Nuiqsut also contributed to this study. Clarence Ahnupkana performed ably as a boatman during long days. George Taalak helped monitor flood stage and maintain the field camp. Lanston Chinn, Manager of Kuukpik Corporation helped arrange field personnel and contractual arrangements.

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INTRODUCTION

The Colville River drains 29% of the North Slope of Alaska and its delta is the largest in arctic Alaska. The river's volume and heavy sediment load produces a dynamic deltaic system with diverse geomorphic, hydrologic, and ecological systems. Recognizing these characteristics and in preparation for exploration work on the Colville River Delta, ARCO Alaska, Inc., contracted Alaska Biological Research, along with Shannon and Wilson Consultants, to conduct both this study on geomorphology and hydrology and a companion study on wildlife. The geomorphology and hydrology studies were designed to provide information that is essential for designing of bridge and pipeline crossings and for locating roads and pads to minimize problems associated with flooding and terrain stability.

This report provides results from the second year of investigation of the geomorphology and hydrology of the Colville River Delta (CRD). In 1992, this project investigated the morphology of selected channels, mapped the distribution of terrain units, analyzed the flooding regime, and quantified the rate of landscape change (Jorgenson et al. 1993). In 1993, the project was limited to measuring peak discharge after snowmelt and mapping the distribution of floodwater within five small study areas. The data are intended to provide a long-term database upon which detailed engineering and facility planning analyses can be made.

The report is divided into two sections. Part I provides observations of spring breakup at the head of the delta, including observations of ice floes, an estimate of peak discharge, analysis of stage-velocity-discharge relationships, development of a flood hydrograph, and an analysis of flood-frequency relationships. Part II focuses on the distribution of flood waters by mapping flooding near peak stage and analyzing the distribution of flood water in relationship to integrated terrain units.

The remarkable environment of the CRD has been the subject of numerous studies conducted over the last four decades. Most information on the geomorphology and hydrology of the delta was gathered by Hugh Walker and his associates during the 1960s and 1970s (Walker 1983). Additional, major research efforts included the study of near-shore aquatic and marine environments by the University of Alaska (UAF 1972), the investigation of the coast and shelf of the Beaufort Sea by numerous organizations during the early 1970s (Reed and Sater 1974), and numerous multi-disciplinary studies conducted under the Outer Continental Shelf Environmental Assessment Program of the National Oceanic and Atmospheric Administration.

Despite the numerous studies conducted on the CRD, there still is no long-term record of discharge measurements and flood stages. Prior to this study, only a limited number of discharge measurements had been made at the head of the delta. Arnborg et al. (1966, 1967) collected stage-discharge information in 1962 and the U.S. Geological Survey (USGS) collected stage-discharge measurements in 1977 (USGS 1978). The USGS also collected occasional selected discharge measurements in 1977, 1979, 1980, and 1981 (USGS 1978, 1980, 1981, 1982).

In addition, attempts to characterize flooding in the delta have been limited. A small-scale map of the distribution of the floodwater across the delta on 3 June 1971 was developed by Walker (1974). Relative frequencies of flooding have been mapped on a small scale for the CRD by using geomorphic characteristics to delineate active and inactive portions of the floodplain (Cannon and Rawlinson 1981, Cannon and Mortensen 1982). However, these maps were not of sufficient detail to be useful to this project.

STUDY AREA

The Colville River is the largest river on Alaska's North Slope and is one of eight major rivers with significant freshwater input to the Arctic Ocean (Walker 1983). The Colville enters the Beaufort Sea just west of the Kuparuk Oilfield and midway between Barrow and Kaktovik. The native village of Nuiqsut, established in 1971, is near the head of the delta.

The Colville River drains about 20,700 mi^2 (29%) of the North Slope. Most of the watershed is situated in the foothills (64%), with smaller amounts situated in the Brooks Range (26%) and coastal plain (10%) (Walker 1976). The head of the CRD is located about 2 mi upstream from the mouth of the Itkillik River (Arnborg et al. 1966). The CRD is bounded on both sides by old alluvial terraces that are traceable from the coast to above the Itkillik River (Carter and Galloway 1982). Below the Itkillik River, the area encompassed by the floodplain of the CRD and water within the fringe of the delta covers 257 mi^2. Fossil wood collected at the base of exposures yielded ages of 48,000-50,600 ybp, suggesting that the terraces and underlying deposits of gravely sand were formed during the last interglacial period (Carter and Galloway 1982). Underlying these deposits is the Gubik Formation (Black 1964), a series of unconsolidated deposits that record a complex marine and alluvial history spanning ~3.5 million years (Carter et al. 1986). The terraces are capped by eolian silt derived from the delta. The surficial geology of the central Arctic Coastal Plain has been mapped (1:63,360) by Rawlinson (1993).

The CRD has two main distributaries, the Nechelik (western) Channel and the Colville (eastern) Channel (Figure 1). These two channels carry about 90% of the water through the delta during flooding and 99% during low water (Walker 1983). Smaller channels branching from the Colville Channel, include the Sakoonang, Tamayayak, and Elaktoveach channels. The delta also is characterized by numerous lakes and ponds, sandbars, mud flats, sand dunes, and low- and high-center polygons (Walker 1976). Most water bodies are shallow (< 6 ft deep) ponds that freeze to the bottom in winter and thaw by June. Lakes larger than 10 ac are common and cover 16% of the delta's surface (Walker 1978). Some of these lakes are deep (up to 33 ft) and freeze only in the upper 6 ft.

The CRD study area has a typical arctic maritime climate. Winters last about eight months and are generally cold and windy. Summers are cool, with temperatures ranging from 12°F in mid-May to 60°F in July and August (Simpson et al. 1982); summers also are characterized by low precipitation, overcast skies, fog, and persistent winds from the northeast. Occasional northwesterly storms usually bring storms, with high, wind-driven tides and rain (Walker 1964).

Integrated terrain unit maps (based on 1:18,000 scale photography) that classified and delineated landforms, surface-forms, vegetation, and hydrology components of the landscape were produced for the CRD by Jorgenson et al. (1993). In addition, land-cover maps (1:30,000 scale) of the CRD have been generated by the U.S. Fish and Wildlife Service [USFWS] (Rothe et al. 1983). Wetlands (1:63,360 scale) classified under the National Wetlands Inventory system also have been mapped by the USFWS. The North Slope Borough has mapped the delta for vegetation, surface form, and landforms (1:250,000 scale). Vegetation-soil-landform associations have been described for the Prudhoe Bay region east of the CRD (Walker et al. 1980).

The CRD has long been recognized as one of the most productive deltas for fish and wildlife on the Arctic Coast of Alaska (Gilliam and Lent 1982, Divoky 1983). The area is important for Tundra Swans, Brant, Yellow-billed Loons, and Greater White-fronted Geese (Rothe et al. 1983). Arctic and least cisco, overwinter in the delta (NOAA/OCSEAP 1983) and support the only commercial fishery on the North Slope. Caribou from both the Central Arctic Herd and the Teshekpuk Herd use the delta (Gilliam and Lent 1982). Finally, the area's resources are important to the subsistence economy of the Nuiqsut villagers.

Within the CRD, five areas representing different erosional and depositional regimes were chosen for study of flood distribution and patterns of landscape change (Figure 1). The Kupigruak and Kachemach Study Areas represent high-energy regimes and encompass active, braiding channels at the lower end of the delta. The Itkillik Study Area also is along the main channel but is at the head of the delta. The Tamayayak Study Area represents a low-energy environment that is dominated by thaw-lake processes. Finally, the Nechelik Study Area encompasses tidal flats along the western portion of the delta.

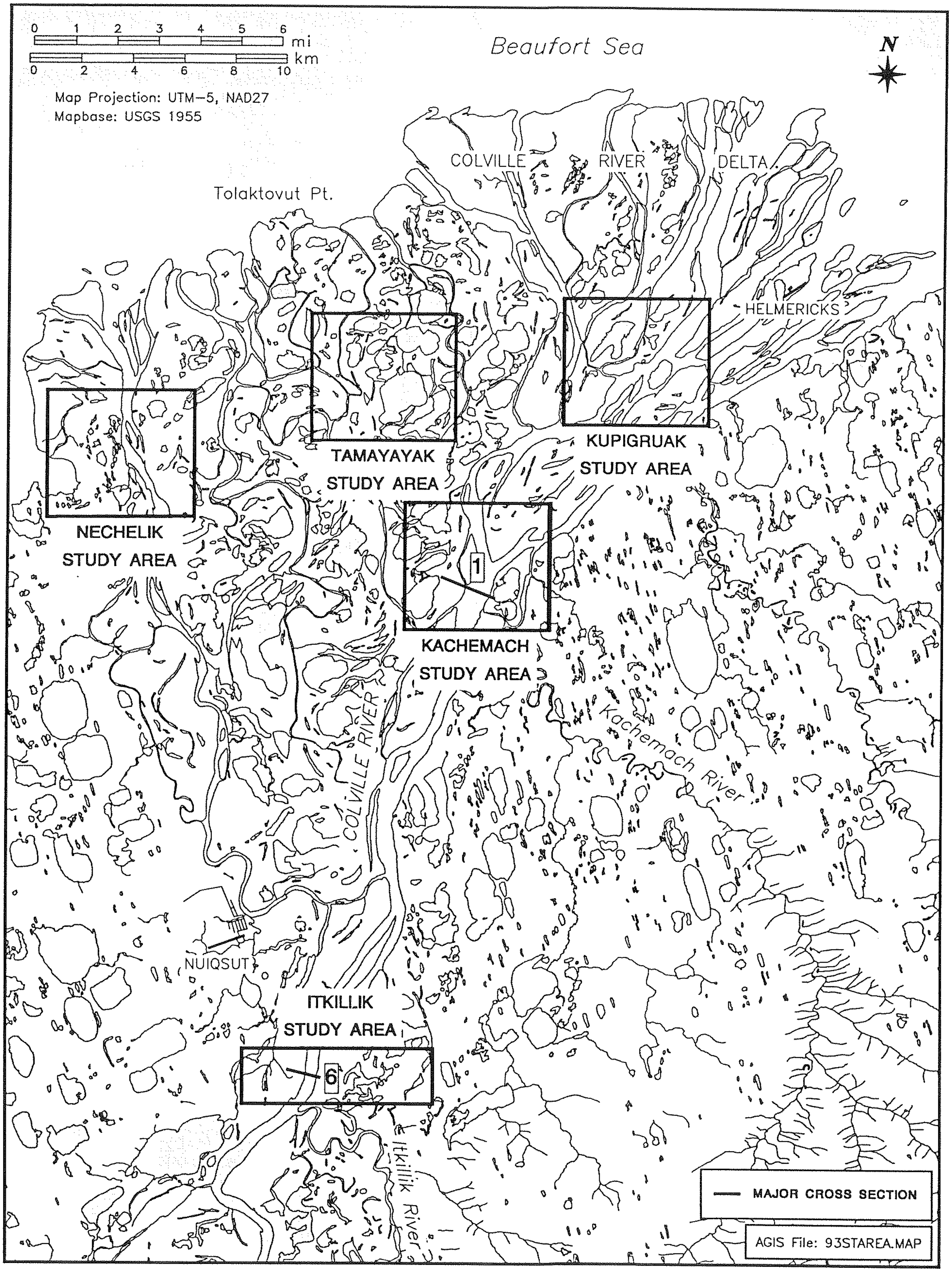

Figure 1. Map of study area showing locations of cross sections and flood distribution areas within the Colville River Delta, 1993.

PART I. SPRING BREAKUP OBSERVATIONS AT CROSS SECTION 6

INTRODUCTION

The purpose of this project was to estimate the peak discharge on the Colville River at Cross Section 6, during the 1993 spring flood. Cross Section 6 is located at the head of the delta, approximately 8.4 river miles upstream from the village of Nuiqsut.

The information obtained during spring breakup was also used to develop a flood hydrograph, and to revise the stage-discharge, velocity-discharge and the flood-frequency relationships established in 1992 (Jorgenson et al. 1993).

Observations of the size and velocity of ice floes, and the presence of ice jams were also made. In addition to observations at Cross Section 6, an aerial observation was made between Cross Sections 6 and Cross Section 1, which is located approximately 9.2 river miles downstream from Nuiqsut. The locations of the Cross Sections are shown in Figure 1.

METHODS

1993 PEAK DISCHARGE ESTIMATE

The peak discharge at Cross Section 6 (Figure 1) during the 1993 spring flood was estimated based on the peak water-surface elevation observed on 31 May and Manning's equation (Henderson, 1966). The parameters required to compute the peak discharge are the water-surface slope and water-surface elevation at the time of the peak discharge, the channel geometry, and the hydraulic roughness. The cross section surveyed in 1992 was used for the channel geometry.

WATER-SURFACE ELEVATION AND SLOPE

The water-surface elevation was recorded periodically on the west bank from 28 May to 3 June, 1993. The peak water-surface elevation was then computed by averaging the peak elevation observed on the west bank with the peak elevation estimated from high-water marks on the east bank.

The water-surface slope associated with the peak discharge was estimated by surveying the elevations of high-water marks between 622 ft upstream from Cross Section 6 and 2337 ft downstream from Cross Section 6 on the west bank.

The survey control point used to determine the water-surface elevations was a temporary benchmark (TBM) set in 1992 (TBM #1) at an elevation of 20.32 ft above mean sea level. The elevation at TBM #1 was determined by a level loop survey to the NOAA monument "KNIK" in 1992 (Jorgenson et al. 1993). The elevation of TBM #1 was assumed to be unchanged in 1993.

ESTIMATION OF HYDRAULIC ROUGHNESS

The hydraulic roughness values were computed from a discharge measurement made on 2 June 1993, approximately 53 hours after the peak water-surface elevation occurred. The measurement was made from a boat using a Price AA current meter suspended with a 75-pound weight. The horizontal position of the boat along the cross section was measured using a Leitz Set 6 total station. The water-surface elevation was recorded periodically during the discharge measurement on both the east and west banks of the river, and the average value was used as the water-surface elevation corresponding to the discharge measurement. The water-surface slope associated with the discharge measurement was obtained by a level survey of the water-surface elevation on the west bank between 3124 ft upstream and 2290 ft downstream of the cross section immediately after the discharge measurement.

The hydraulic roughness at the time of the discharge measurement was calculated using the measured discharge, and the associated water-surface elevation and slope. For computational purposes, the cross section was divided into two subsections based on the criteria presented in Davidian (1984). The two subsections were: 1) the gravel bar on the western half of the main channel, and 2) the low water channel comprising the eastern half of the main channel (Figure 2).

RESULTS AND DISCUSSION

BREAKUP OBSERVATIONS

Observations of the Colville River began on 28 May, 1993. On 28 May, the river stage (i.e., the water-surface elevation above mean sea level) was low (6.57 ft) and the sand bar on the west side of the main channel was exposed. River ice covered the

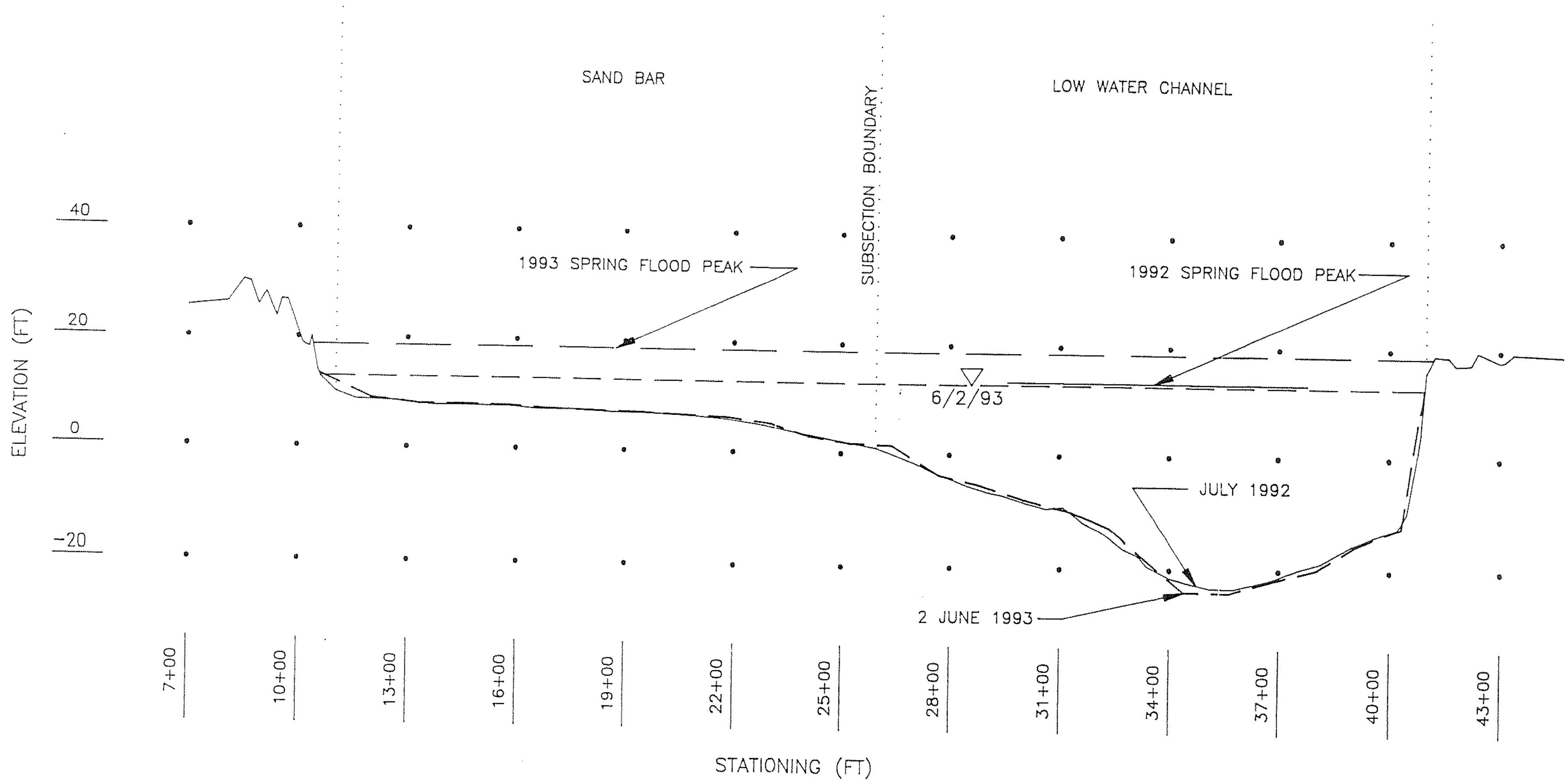

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Fig 2: Cross Section 6

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Date: 5 Oct 1993 File: 1225F2A.GRF

surface on the eastern third of the river, while meltwater had accumulated on the river ice on the remainder of the river (Figure 3a). The water level rose at a rate of about 3.3 feet per day, covering the sand bar by 29 May (Figure 3b). On 30 May, small ice floes occasionally were observed (Figure 3c).

The river ice began moving downstream sometime after midnight on 31 May, accompanied by a relatively rapid rise in the water level (Figure 3d). The water level on the west bank rose 5 feet in the 16.3 hours between 18:10 on 30 May and 10:30 on 31 May, and another foot during the next 6 hours to crest at 19.16 ft at 16:33 on 31 May (Figure 4). The water level dropped relatively rapidly after the peak stage occurred, falling nearly 3 feet in the first 18 hours. Between mid-morning on 1 June and early evening on 3 June, the water level dropped at a rate of 2.3 ft/day.

The high-water marks on the east bank indicated a peak water-surface elevation that was approximately one foot lower than that measured on the west bank. We considered the average of the two values (Figure 4) to be most representative of the peak water-surface elevation, and used the average value in the computation of the peak discharge.

ICE FLOE OBSERVATIONS

Although the river was covered from bank to bank with ice floes on 31 May, no ice jams were observed in the immediate vicinity of Cross Section 6. By early evening on 31 May, the river was relatively clear of ice floes from the west bank to the middle of the channel. However, the Nechelik Channel, which flows to Nuiqsut, was choked with ice about one-half mile upstream from the village.

By the morning of 1 June, the ice floes were limited to the low-water channel near the east bank, where the current is the fastest. In mid-afternoon on 1 June, an aerial observation was made of the ice floes between Cross Sections 6 and 1. An aerial view looking north (downstream) at Cross Section 6 shows that the channel is nearly free of ice by this time (Figure 5a).

At the time of the aerial observation on 1 June, the river was choked with ice in the vicinity of Cross Section 1 (Figure 5b), and water was flowing into distributaries on either side of the main channel. There did not appear to be a large drop in the water-surface elevation from the upstream side to the downstream side of the ice-choked reach. Thus, we assumed that backwater from this ice-choked reach did not significantly affect the discharge measurement made on 2 June 1993 at Cross Section 6. It is possible, however, that ice-choked areas occurred at other locations between Cross Sections 1 and 6 earlier in the breakup period.

On 4 June, the size of ice floes that had rafted on the east bank between Cross Section 6 and the Itkillik River were measured. Only floes greater than 2 ft thick and 5 ft across were recorded. The floes ranged in size from 7.5 to 13.5 ft wide, 12 to 26 ft long, and 2.5 to 5.5 ft thick. The floes were stacked 2 and 3 layers high in places. An example of one of the larger rafted floes is shown in Figure 6a.

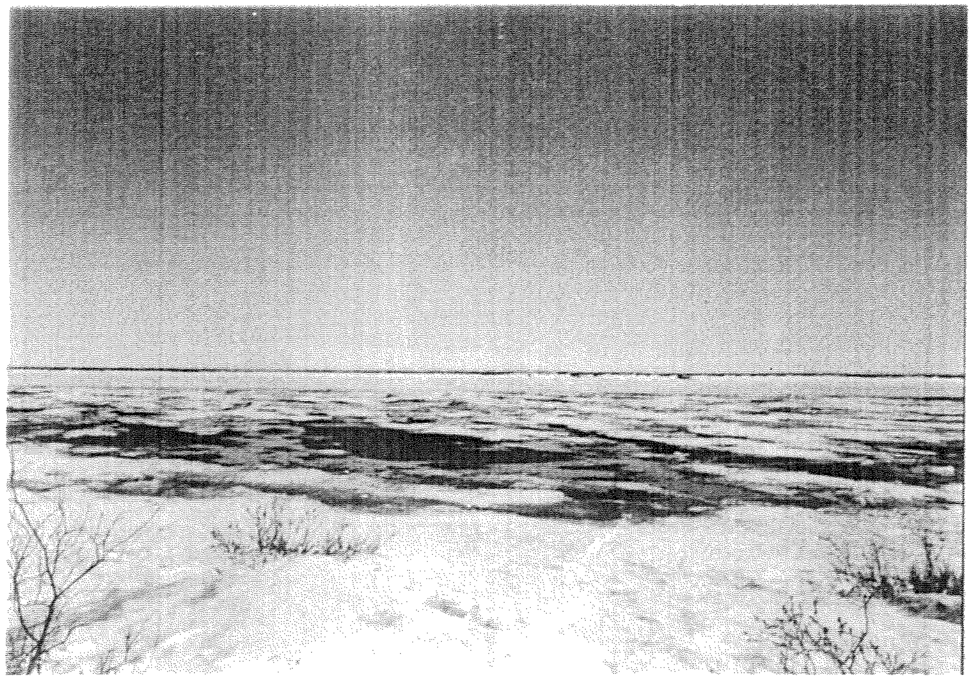
It is likely that the largest floes were not rafted, or that the larger floes may have broken when they were rafted. Larger floes were observed during breakup at Cross Section 6 and from the air at Cross Section 1 (Figure 6b). The largest floes at Cross Section 1 were estimated to be 80 to 118 ft wide, and 129 to 150 ft long.

1993 PEAK DISCHARGE ESTIMATE

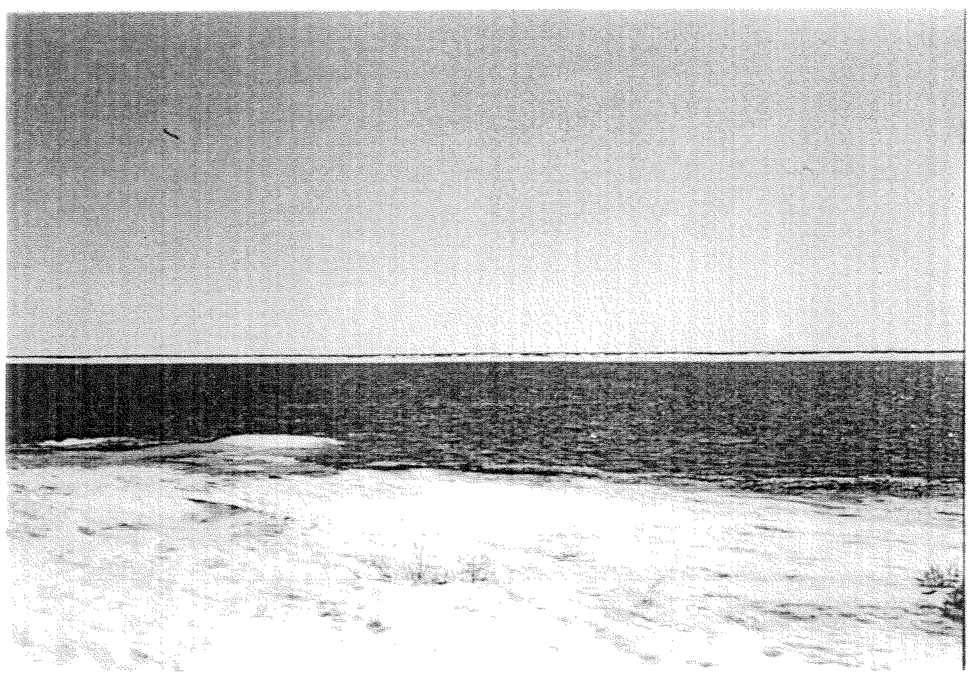
The peak discharge at Cross Section 6 was estimated to be 379,000 cubic feet per second (cfs), with an average main-channel velocity of 5.7 feet per second (fps). The average peak water-surface elevation corresponding to the peak discharge was estimated to be 18.69 ft. This water-surface elevation is close to the average bankfull stage along this reach of the river. The slope of the water during the peak discharge was estimated to be 1.11×10^{-4} ft/ft.

The computed hydraulic roughness values used to estimate the peak discharge were 0.0219 for the sand bar, and 0.02395 for the low water channel. These values were based on a measured discharge of 239,000 cfs on 2 June. The average water-surface elevation at the time of the discharge measurement was 12.86 ft, and the water-surface slope was 1.05×10^{4} ft/ft.

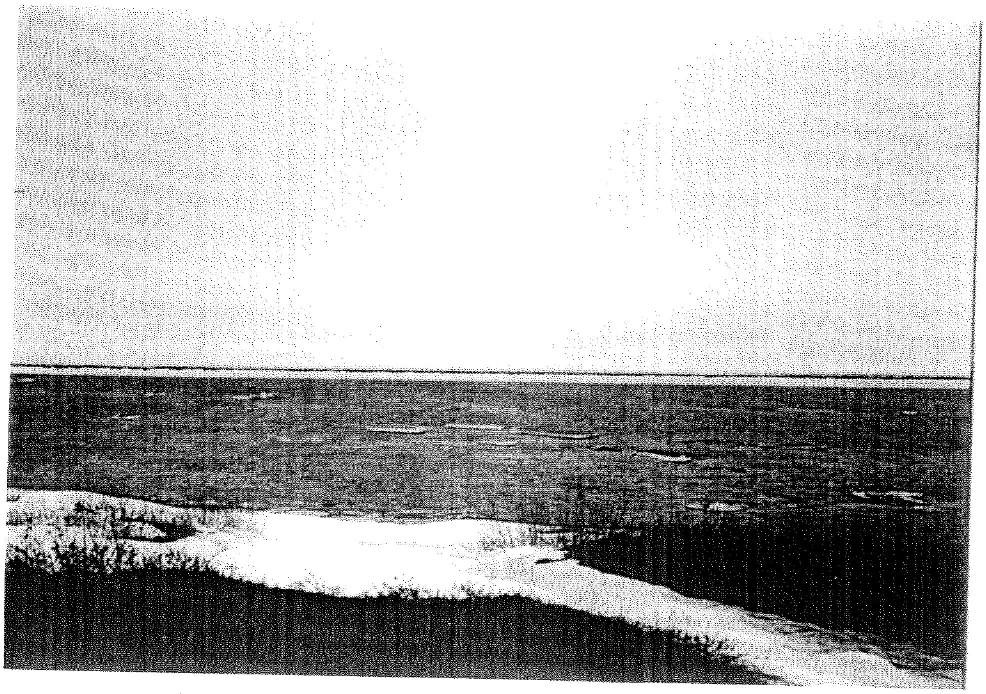
In computing the peak discharge, we assumed that the peak water-surface elevation was unaffected by ice in the river. Observations made of the velocity of the ice floes at the time of the peak water-surface elevation supported this assumption. The average ice floe velocity at approximately 500 and 1200 ft from the west bank was estimated to be 4.1 fps. This velocity was assumed to be representative of the velocity at a depth of 1.8 ft below the water-surface (i.e., the velocity at a depth approximately equal to



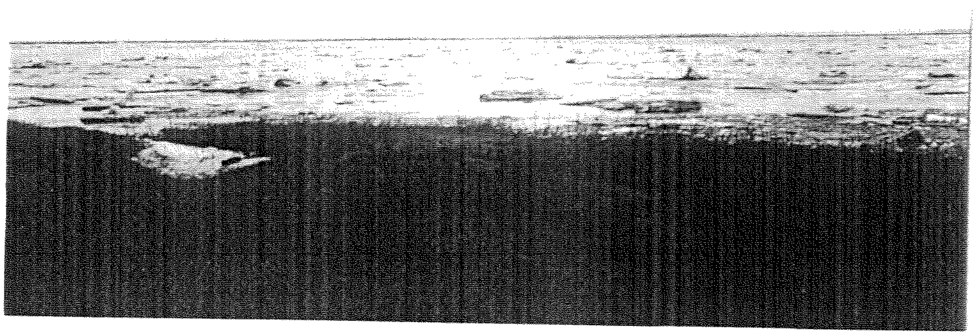
(a) 28 May. The sand bar is still exposed



(b) 29 May. The sand bar is flooded



[illegible] 10 May. A few [illegible] are present



[illegible] May. The [illegible] moving downstream

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[illegible] Breakup Observations [illegible]
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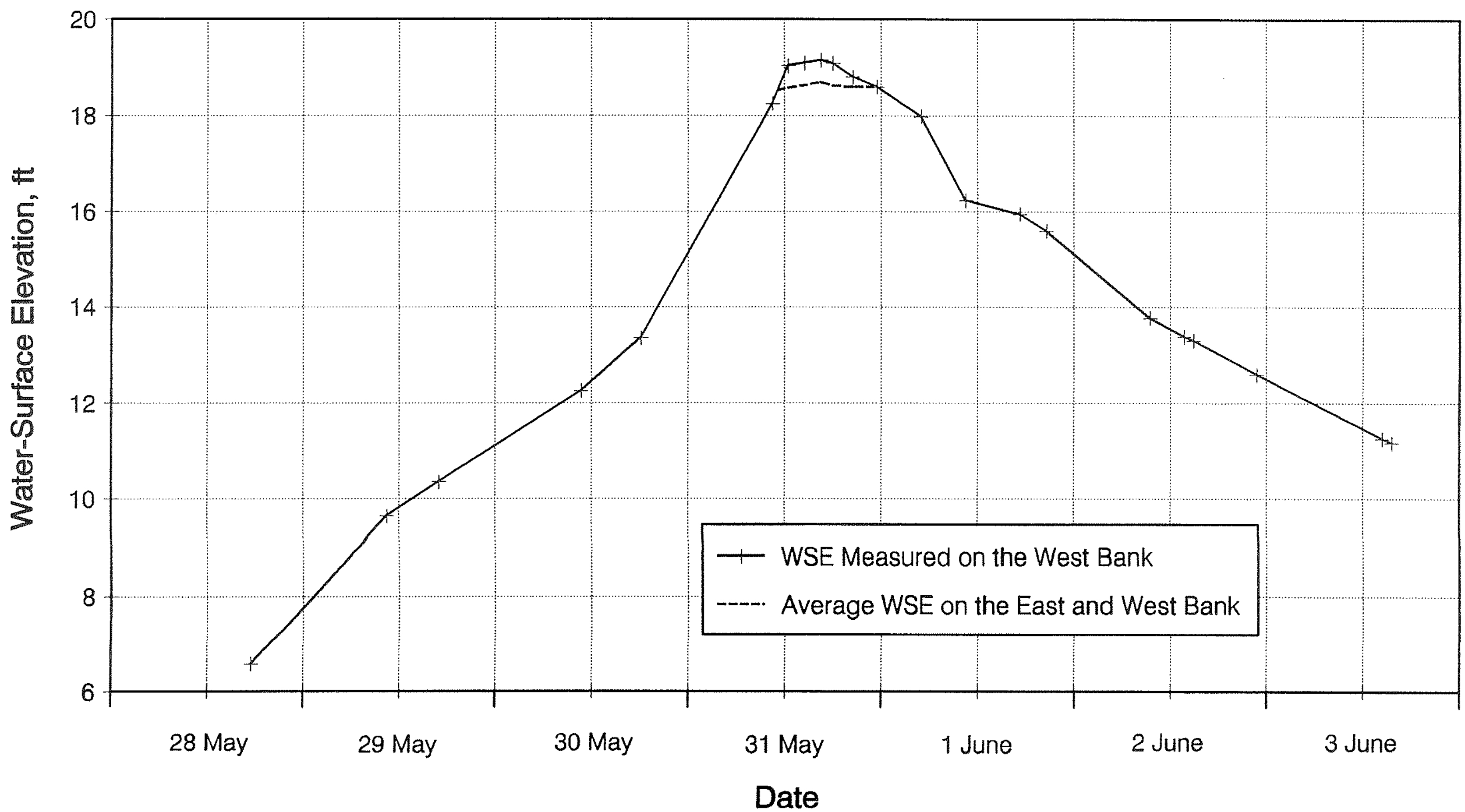

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Fig. 4: Water–Surface Elevations Over Time

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(a) Looking north at Cross Section 6. The river is nearly free of ice floes.

(b) Looking north toward Cross Section 1. The river is choked with ice.

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Fig. 5: Aerial Ice Floe Observations on 1 June 1993

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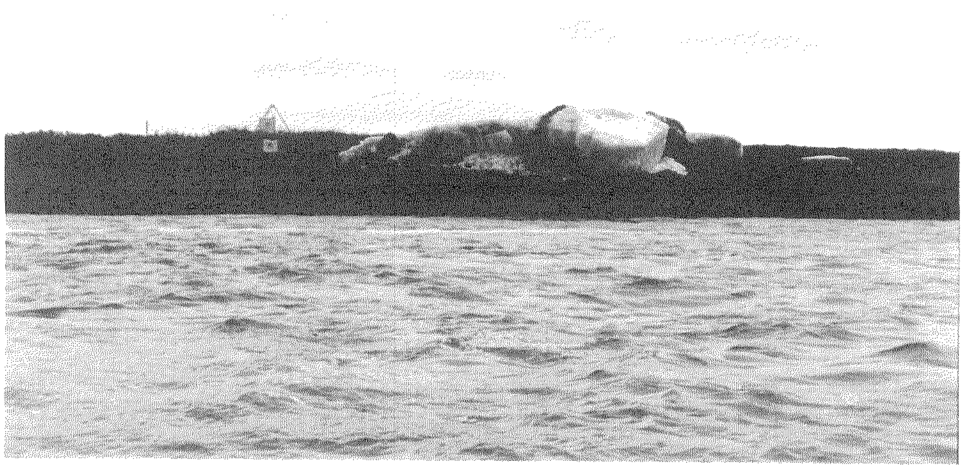

(a) A large rafted ice floe near Cross Section 6

(b) Large ice floes near Cross Section 1

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Fig. 6: Examples of Large Ice Floes

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one-half the average ice floe thickness). Based on this vicinity of the ice floes was estimated to be 3.6 fps, using the vertical-velocity curve presented in Buchanan and Somers (1969). This value compared closely to the computed average velocity of 3.7 fps, for the same channel section. If ice had affected the peak water-surface elevation, the observed ice floe velocity would be significantly less than the computed velocity.

BED STABILITY

The cross section geometry during the 1993 spring discharge measurement was nearly identical to that surveyed in July 1992 (Figure 1). This suggests that the channel at Cross Section 6 is relatively stable from year to year. In addition, the fact that the channel geometry during a relatively high discharge (239,000 cfs on 2 June 1993) was nearly identical to that during a low discharge (approximately 29,000 cfs in July 1992) suggests that the amount of scour during this year's flood event was probably small.

STAGE-DISCHARGE AND VELOCITY-DISCHARGE RELATIONSHIPS

The stage-discharge and velocity-discharge relationships developed in 1992 (Jorgenson et al. 1993) were revised based on the data obtained in 1993. Although the data point representing the 1993 measured stage and discharge fell close to the 1992 stage-discharge curve, the estimated 1993 peak discharge was somewhat above the curve. This portion of the curve was revised by computing discharges associated with several river stages using Manning's equation and the computed hydraulic roughness values. The water-surface slope at each stage was computed by linear interpolation between the slope corresponding to the discharge measurement and the slope corresponding to the peak discharge. The revised stage-discharge relationship is shown in Figure 7. For river stages greater than 13 ft, the revised curve yields slightly smaller discharges at a given stage than did the 1992 curve.

The upper portion of the velocity-discharge relationship developed in 1992 also was revised in 1993 (Figure 8). The revised curve bends downward, resulting in velocities that are, at most, 0.3 fps less than those given by the 1992 curve.

The bankfull discharge at Cross Section 6 in 1992 was estimated to be between 330,000 and assumption, the average cross sectional velocity in the 430,000 cfs. If the bankfull stage is taken as 19 ft, the revised stage-discharge curve suggests that the bankfull discharge is approximately 385,000 cfs.

Jorgenson et al. (1993) reported that the average main channel velocities obtained using the velocity-discharge curve can be multiplied by 1.4 to estimate the maximum average velocity at any location within the main channel. The maximum average velocity measured at any location within the main channel in 1993 was estimated to be 6.6 fps, which is 1.35 times the average main channel velocity of 4.92 fps. Thus, the 1993 data further support the relationship obtained in 1992.

1993 FLOOD HYDROGRAPH

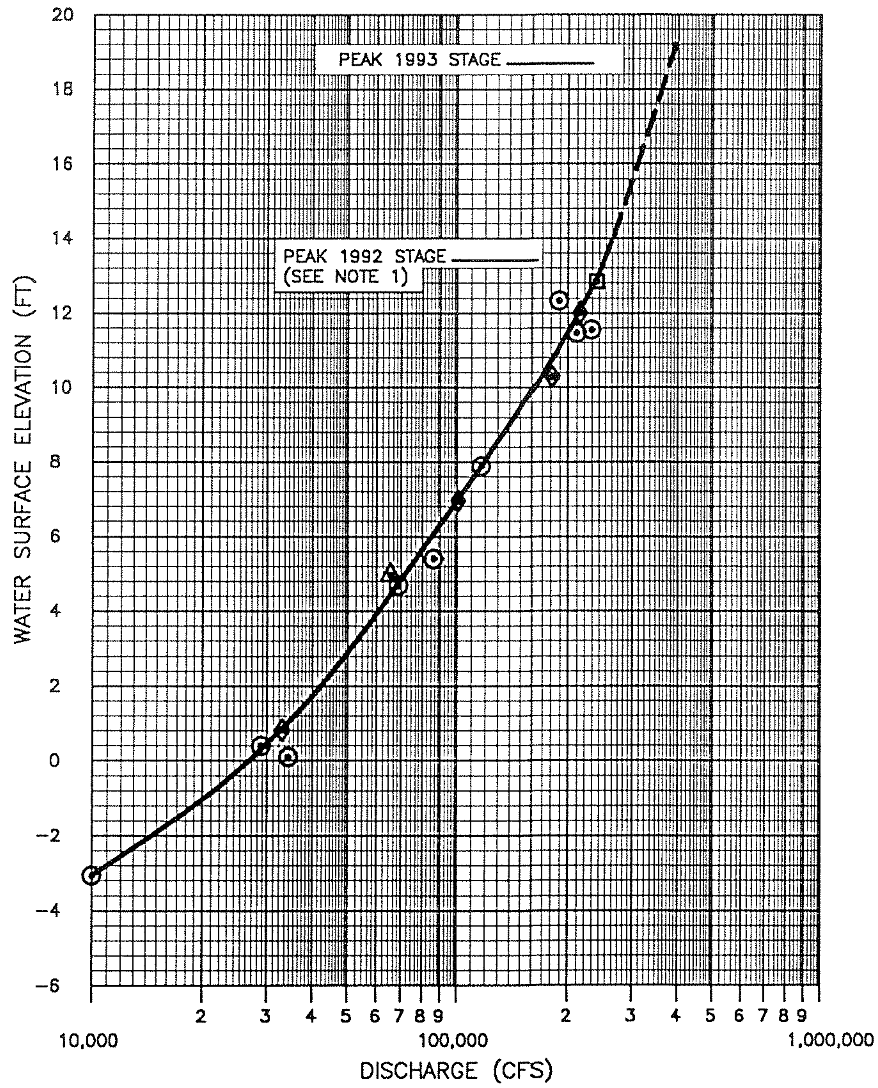
The flood hydrograph (Figure 9) was developed by estimating the discharge for each stage measurement made between 28 May and 3 June 1993. The discharges were estimated from the revised stage-discharge relationship (Figure 7).

SUMMARY OF MEASURED AND ESTIMATED PEAK DISCHARGES

To date, only one measurement and three estimates of the peak discharge on the Colville River have been made (Table 1). Based on these flood peak values, we estimated that the average annual or 2-yr peak discharge on the Colville River is 283,000 cfs. This value assumes that the spring peak discharge in each year in which it was measured or estimated, was the largest discharge that occurred during that year. This value is 13% greater than the estimate of the 2-yr peak discharge (250,000 cfs) made in 1992 (Jorgenson et al. 1993).

FLOOD-FREQUENCY RELATIONSHIPS

A flood-frequency relationship for the Colville River, at Cross Section 6, was developed in 1992. This relationship was revised in 1993 by passing the flood frequency curve (Figure 10) through the revised estimate for the 2-yr peak discharge (i.e., 283,000 cfs). The slope of the flood frequency curve was assumed to be the same as the slope of the 1992 flood-frequency curve, which was based on the slope of the flood-frequency curve developed from the Kuparuk River data (Jorgenson et al. 1993).



- ▣ BASED ON THE DISCHARGE MEASUREMENT MADE BY S&W ON 2 JUNE 1993.
- ⊙ BASED ON THE DISCHARGE MEASUREMENTS MADE BY THE USGS, IN THE VICINITY OF CROSS SECTION 6 BUT NOT NECESSARILY AT CROSS SECTION 6.
- △ BASED ON THE DISCHARGE MEASUREMENT MADE BY AHC ON 10 JUNE 1992.
- ◈ BASED ON THE DISCHARGE MEASUREMENTS MADE IN 1962 BY ARNBORG et al. (1966) IN THE VICINITY OF CROSS SECTION 6.

NOTES

1. THE PEAK 1992 STAGE WAS THOUGHT TO HAVE BEEN AFFECTED BY ICE. THUS, THE ESTIMATE FOR THE 1992 PEAK DISCHARGE (164,000 CFS) WAS LESS THAN WOULD BE SUGGESTED BY THIS CURVE.

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Fig. 7: Revised Stage-Discharge Relationship

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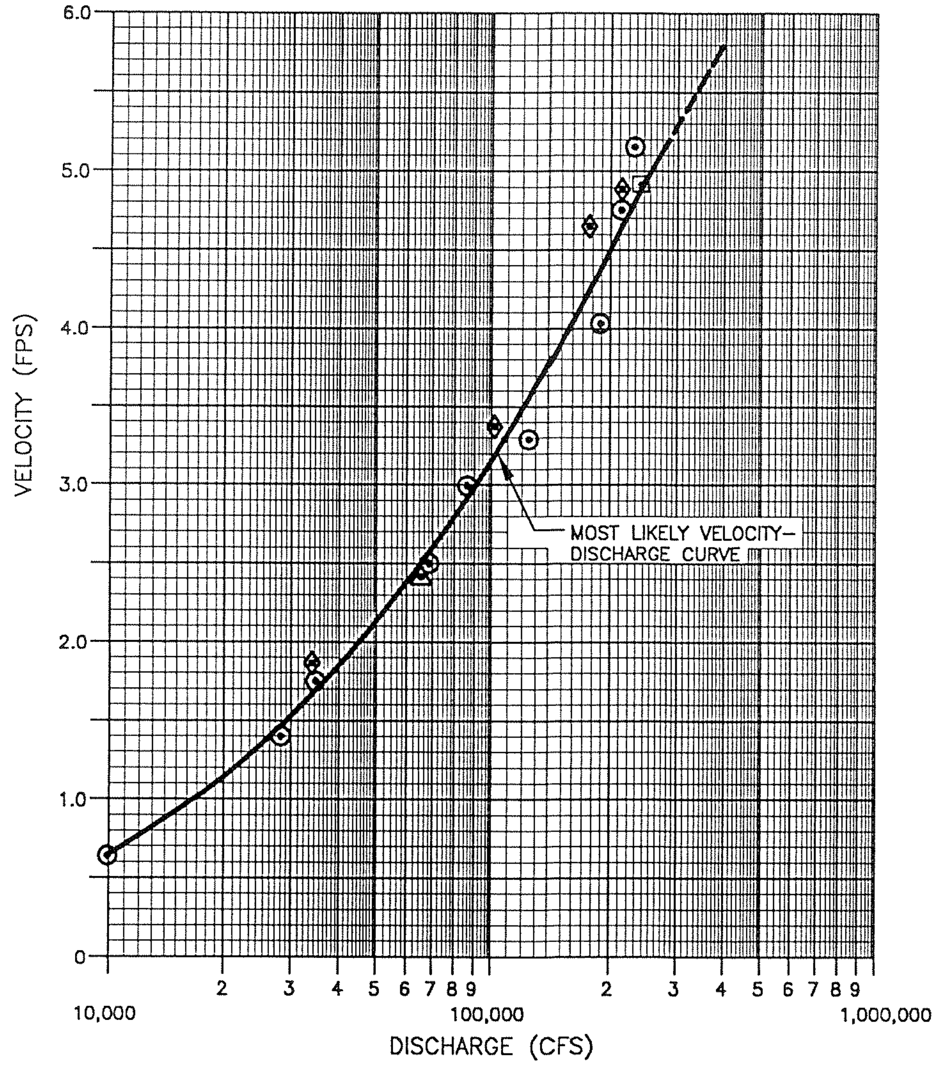

⊡ BASED ON THE DISCHARGE MEASUREMENT MADE BY S&W ON 2 JUNE 1993.

⊙ BASED ON THE DISCHARGE MEASUREMENTS MADE BY THE USGS IN THE VICINITY OF CROSS SECTION 6 BUT NOT NECESSARILY AT CROSS SECTION 6.

△ BASED ON THE DISCHARGE MEASUREMENT MADE BY AHC ON 10 JUNE 1992.

◈ BASED ON THE DISCHARGE MEASUREMENTS MADE IN 1962 BY ARNBORG et al. (1965) IN THE VICINITY OF CROSS SECTION 6.

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Fig. 8: Revised Velocity–Discharge Relationship

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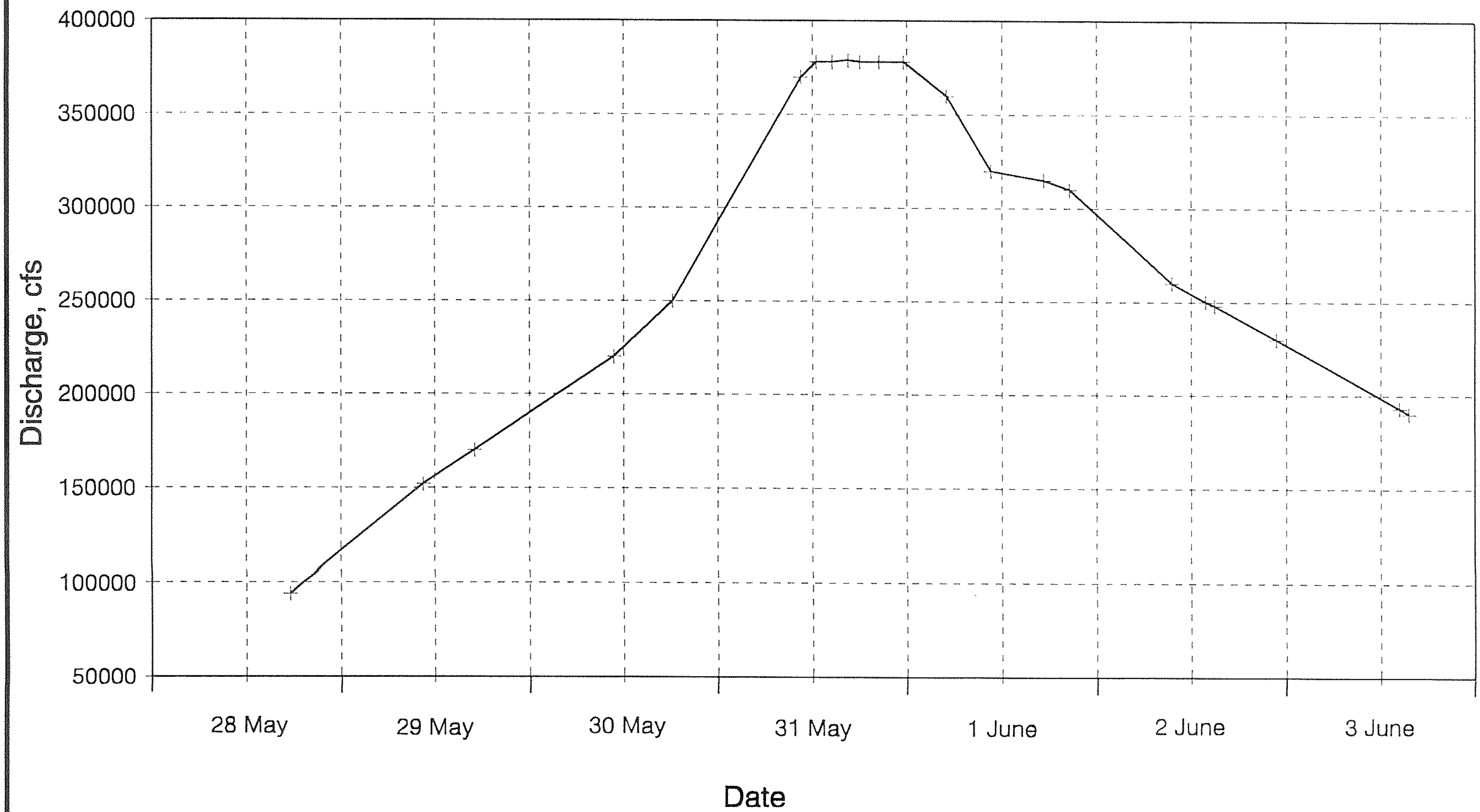

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Fig. 9: 1993 Spring Flood Hydrograph

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Table 1. Summary of measured and estimated peak discharges, Colville River Delta.

Year	Peak Discharge (cfs)	Source
1962	215,000	Arnborg et al. (1966)[a]
1977	374,000	USGS (1978)[b]
1992	164,000	Jorgenson et al. (1993)[b]
1993	379,000	This report[c]

[a] Measured on the day of the peak discharge.

[b] The peak discharge was estimated using data from 1962 to extrapolate to the peak discharge from the discharge measured two days after the peak. Additional information concerning the 1962, 1977 and 1992 peak discharges can be found in Jorgenson et al. (1993).

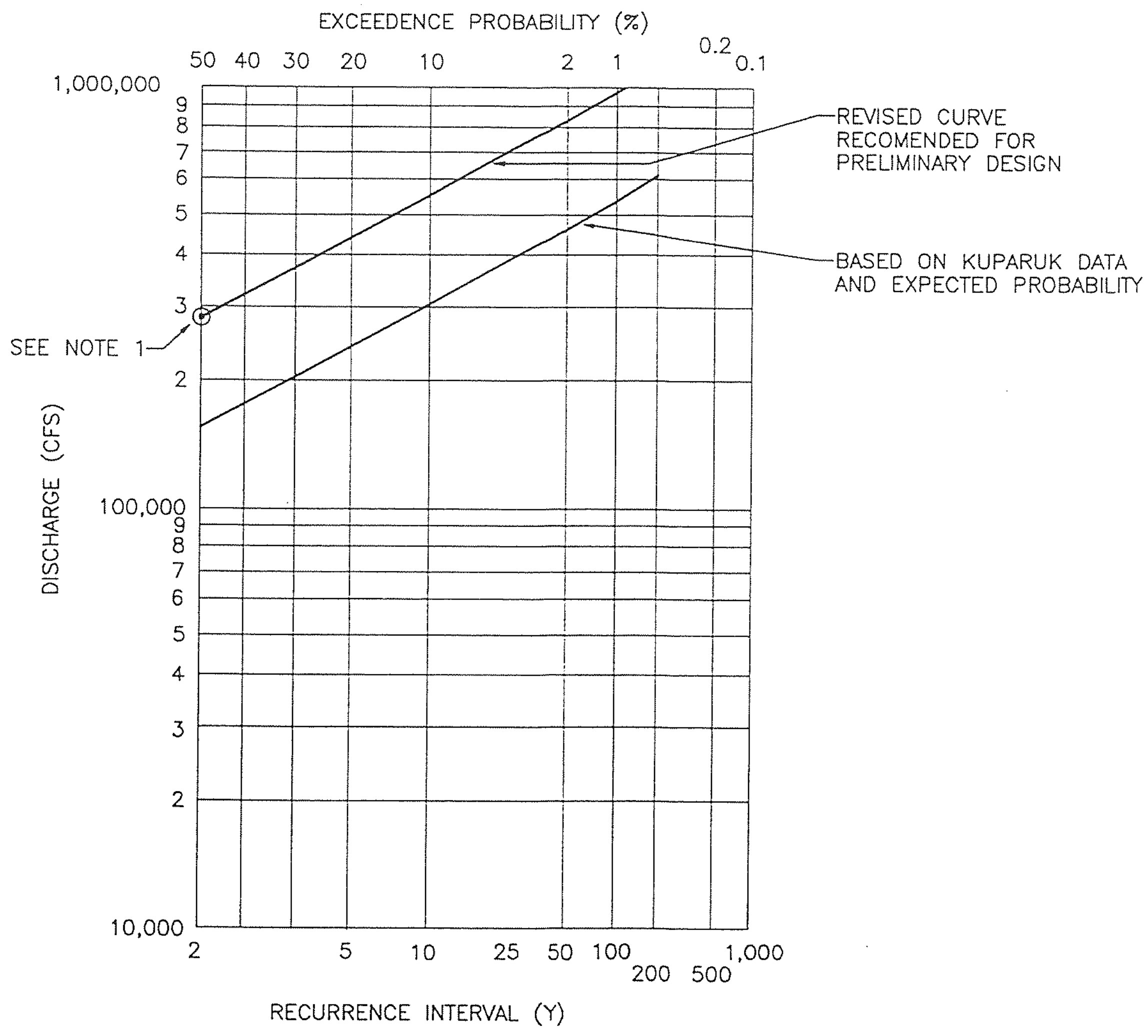
[c] This discharge was estimated using the measured peak water-surface elevation, the water-surface slope based on high-water marks, and the computed hydraulic roughness values.

Based on the revised flood-frequency relationship, the 1993 peak discharge has an estimated recurrence interval of 4 years. Additionally, the 50-year flood is estimated to be on the order of 820,000 cfs, and the 100-year flood is estimated to be on the order of 960,000 cfs. Because the database is limited, these values should be considered tenuous and should be refined with additional data prior to final design.

LIMITATIONS

The stage-discharge and velocity-discharge curves are based on site conditions as they existed at the time of the site inspection. If substantial time has elapsed between the submission of this report and their use in final design, or if conditions have changed because of natural or man-made causes, we recommend that this report be reviewed to determine the applicability of the conclusions.

The flood-frequency curve is considered preliminary and should be refined prior to it's use in final design.



NOTES

1. THIS POINT REPRESENTS AN ESTIMATE OF THE AVERAGE ANNUAL PEAK DISCHARGE, BASED ON THE AVERAGE OF THE PEAK DISCHARGES LISTED IN TABLE 1.

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Fig. 10: Revised Flood–Frequency Relationship

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Date: 5 Oct 1993	File: 1225F10A.DRW

PART II. FLOOD DISTRIBUTION

METHODS

In 1992, the extent of flood-water coverage was mapped within the Kupigruak, Tamayayak, and Nechelik study areas (Figure 1) by using aerial photography acquired on 4 and 8 June. Oblique photography was taken on 4 June, two days after the peak stage occurred at the head of the delta, with a 35-mm camera at 500 ft above ground level (agl), just below the cloud ceiling. On 8 June, when weather improved, color vertical photographs (1:17,000 scale) were taken at 11,000 ft agl with a Hasselblad 6 x 7-cm format camera. In 1992, complete coverage of the study areas was obtained on the 8 June flight.

In 1993, oblique aerial photography was obtained for four study areas on 1 June and for one area (Nechelik) on 2 June. Thus, most of the photography was acquired one day after peak stage occurred at the head of the delta. Photographs were taken with a 35-mm camera out the window of a Super Cub flying at 500-700 ft agl, just below the cloud ceiling. Due to poor weather, vertical photographs could not be obtained with a large format camera (6 x 7-cm Hasselblad). In 1993, the photography obtained along the flight lines was incomplete, covering approximately 20-30% of each study area.

The extent of flooding within the study areas in 1992 and 1993 was interpreted from the oblique photography and delineated on the CIR photography (1:18,000 scale) that was used to map integrated terrain units. Floodwater was identified by its light brown color caused by suspended sediments. In contrast, standing water from snowmelt in depressions and ponds typically had a clear or black appearance. Lakes and channels that had flood water around the ice margins were mapped as entirely flooded. In 1992, flood water in the three study areas was mapped entirely from the oblique aerial photography. In 1993, flood distribution was mapped in two phases because of the incomplete photographic coverage. First, flood water was delineated within the areas covered by the aerial photography for use in quantitative analysis of flood distribution. Second, for map presentation the flood distribution in the intervening gaps was delineated by extrapolating along integrated terrain unit (ITU) boundaries. The lines were digitized using a geographic information system (AtlasGIS, San Jose, CA) and rectified to the ITU map produced in 1992.

For analysis of flood distribution relative to the integrated terrain units, the flooding layer was overlain on the ITU map, and the percentage of each ITU covered by flood water was determined. In 1993, only the areas mapped directly with the aerial photography in the first phase of mapping were used for analysis. The data were summarized within each study area and for all areas combined.

RESULTS AND DISCUSSION

OVERALL FLOOD DISTRIBUTION

Overall, flooding on 8 June 1992 covered 43% of the study areas, but varied from 36% in the Tamayayak area (dominated by thaw lakes) to 42% in the Nechelik area (dominated by tidal flats) and 50% in the Kupigruak area (dominated by the main channel; Figures 11 and 12). Based on the stage-discharge relationship developed for the head of the delta, discharge (approximately 73,000 cfs) at the time when the photography was taken was substantially less than the flood peak on 2 June (approximately 164,000 cfs). The recurrence interval of the flood-peak discharge was probably less than 2 years.

In 1993, flooding on 1-2 June covered 58% of the study areas. The Tamayayak Study Area in the middle of the delta again showed the least flooding (44%), while the most flooded area was the Kachemach area (69%). Intermediate in flooding were the Kuprigruak (61%), Nechelik (62%), and Itkillik areas (51%). Peak discharge occurred on 31 May and was estimated at 379,000 cfs. The recurrence interval of the flood-peak discharge was estimated to be 4 years.

Although the 1993 photography was taken one day after peak stage at the head of the delta, the flood distribution that we mapped was probably near its maximal extent because 1) murky water persisted in polygonal basins and depressions on higher floodplain steps and was used to delineate floodwaters, and 2) there was a time lag between peak stage at the head of the delta versus the lower portions of the delta. However, the nature of that time lag and how flood stage in the lower delta is affected by floodwater flowing over sea ice is unknown and needs further study. A portion of the Tamayayak study area was photographed on both 1 and 2 June and there was almost no discernible difference in flood distribution.

RELATIONSHIP BETWEEN FLOODING AND INTEGRATED TERRAIN UNITS

In 1992, at a relatively low flood stage, flood water covered only barren, partially vegetated, and salt-marsh units on riverbed-sandbars, tidal flats, and thaw-lake deposits (Figure 13-18). Moderate-to-low amounts of flooding occurred in areas with riparian shrubs and salt-killed meadows that covered a wide range of landform deposits. Almost no flooding occurred on cover alluvium deposits supporting wet meadows.

In 1993, at an intermediate flood stage, ITUs that were almost entirely flooded included: barren (98%) and partially vegetated (74%) riverbed-sandbars; high water channels that were partially vegetated (96%); cover alluvium with salt-killed meadows (88%) and riparian shrubs (90%); barren (95%) and partially vegetated (84%) thaw lake deposits; and barren (100%) and partially vegetated (100%) tidal flats. ITUs that were intermediate in the amount of flooding included high-water channels with wet meadow (55%), riparian low-tall shrub (40%), and salt-marsh vegetation (40%); thaw lake deposits with various surface forms and wet-meadow and low-tall shrub vegetation (36-58%). The least flooded ITUs included loess (4%); vegetated sand dunes (6%); and cover alluvium with disjunct and low-centered polygons (8-20%).

In general, patterns in flood distribution were consistently related to ITU's. At low discharge (73,000 cfs), typically only riverbed and tidal flat deposits were covered and there was a sharp differentiation from other ITUs that were not flooded. At intermediate flooding (379,000 cfs), large portions of high-water channels and thaw lake deposits were covered, while higher floodplain steps with cover alluvium and wet-meadow vegetation were only slightly flooded. The few gaps in the data and small inconsistencies between 1992 and 1993 resulted from the addition of two new study areas in 1993 and the smaller sample size resulting from incomplete photographic coverage in 1993. In addition, a small error (estimated to be 1-3%) was associated with the mapping process.

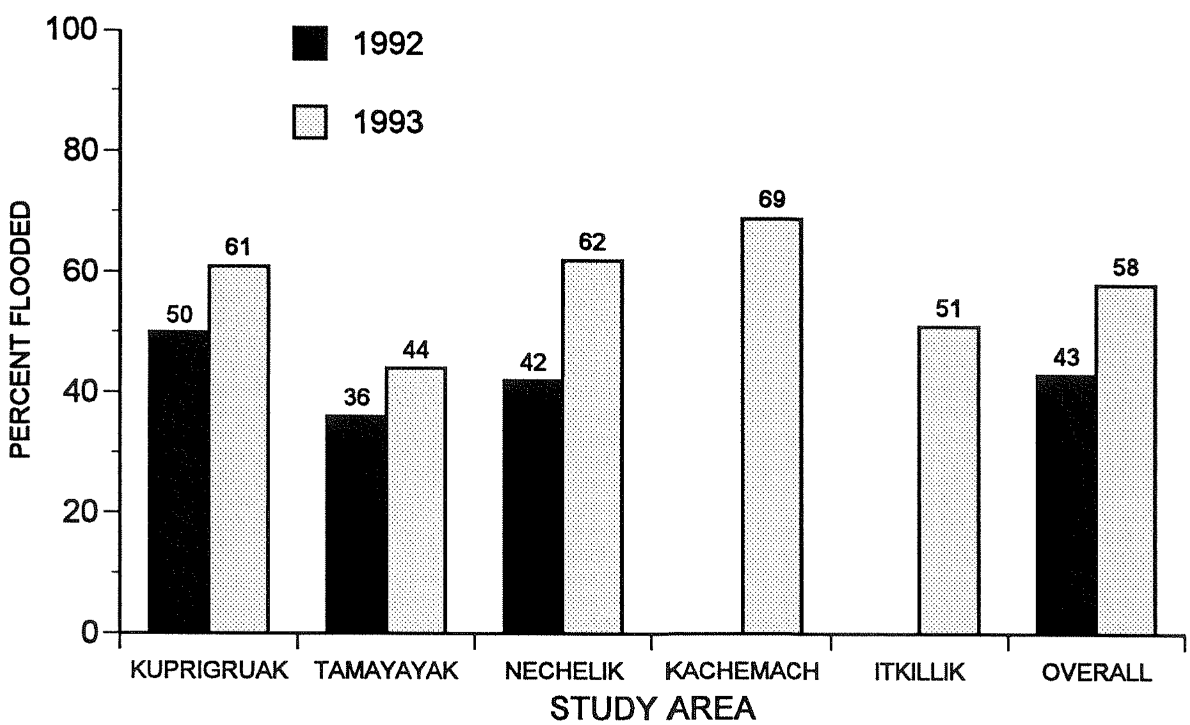

Figure 11. Percentage of total area covered by flood water in five study areas in the Colville River Delta, 1992-1993.

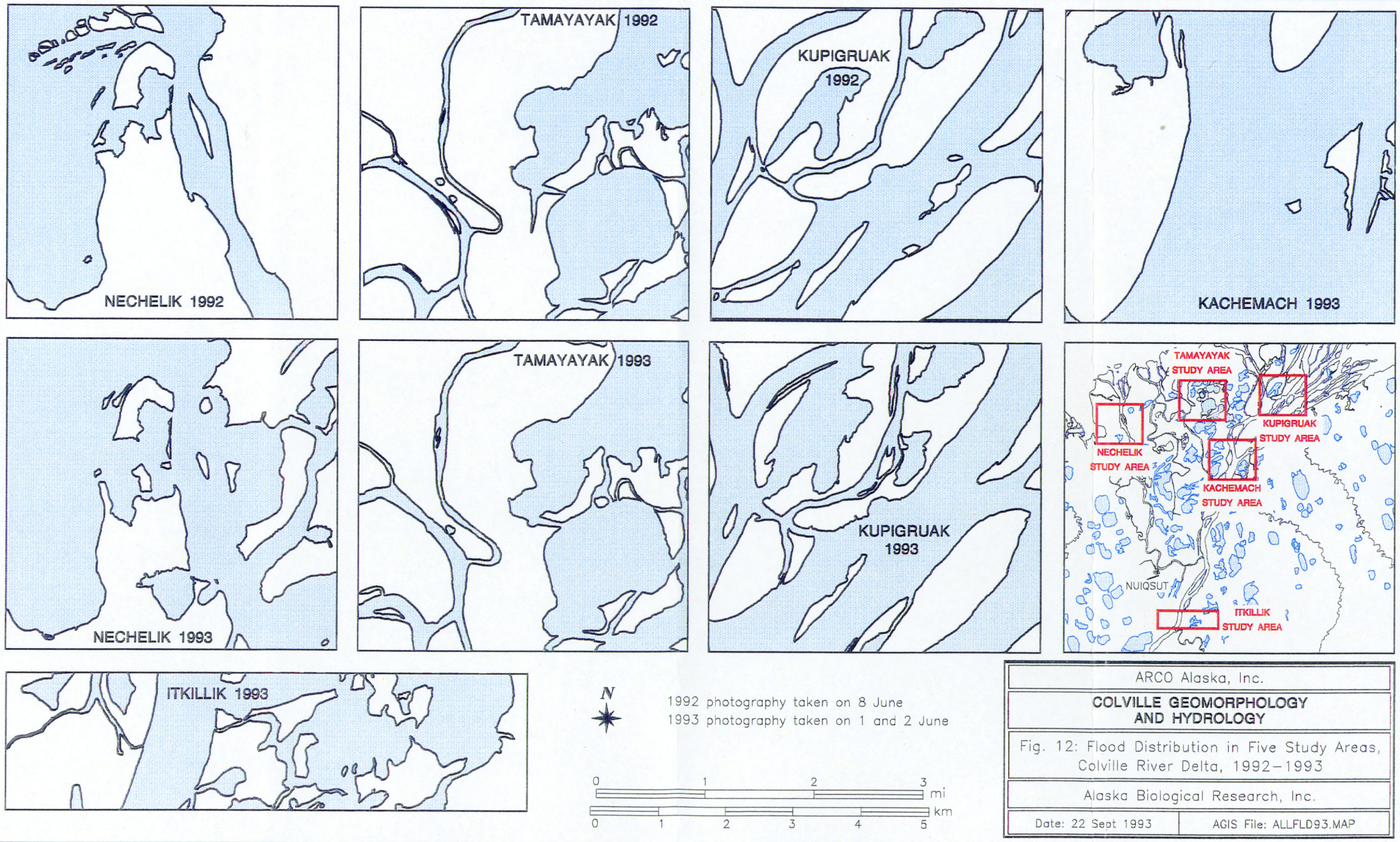

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Fig. 12: Flood Distribution in Five Study Areas, Colville River Delta, 1992–1993

Alaska Biological Research, Inc.

Date: 22 Sept 1993 | AGIS File: ALLFLD93.MAP

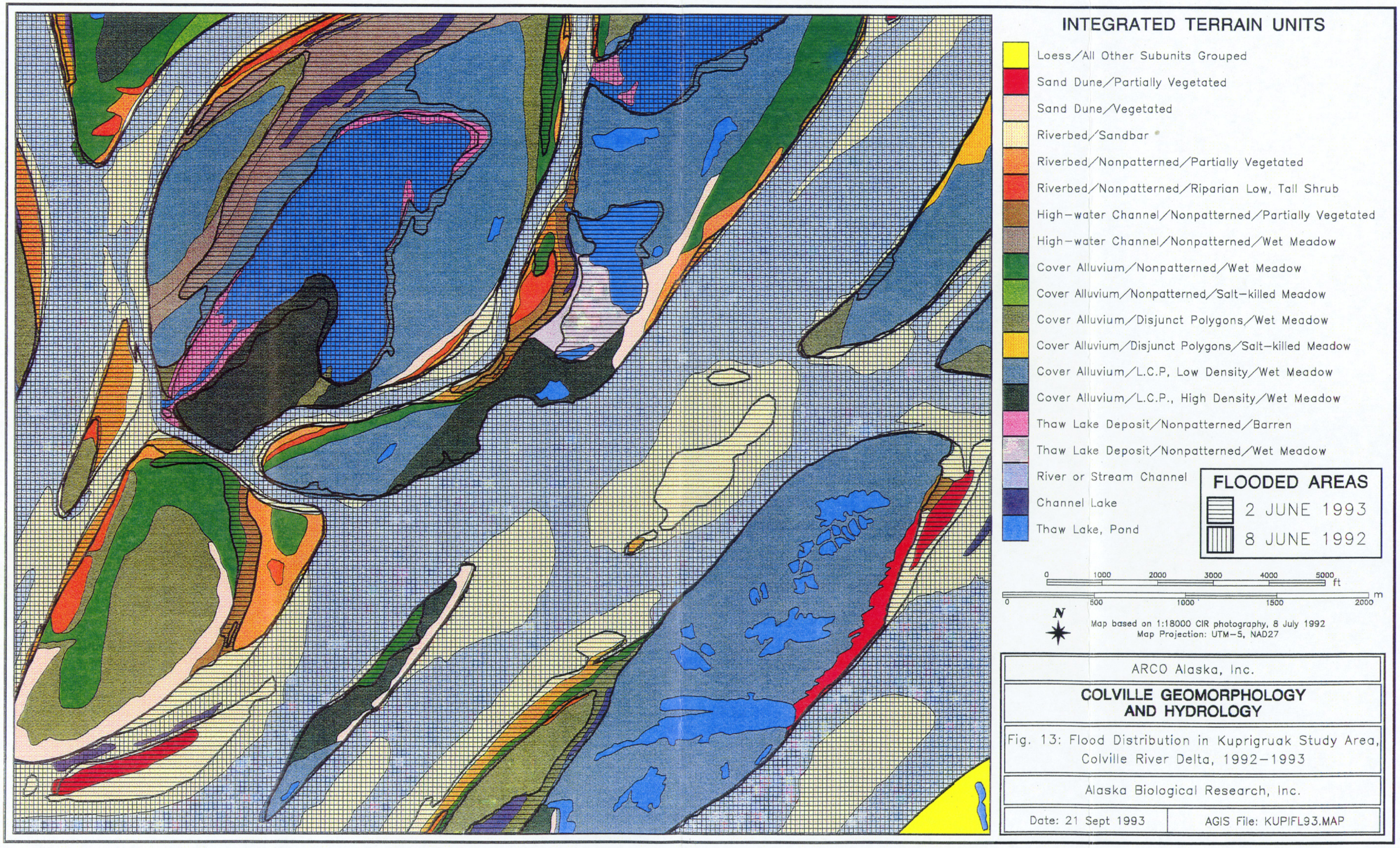

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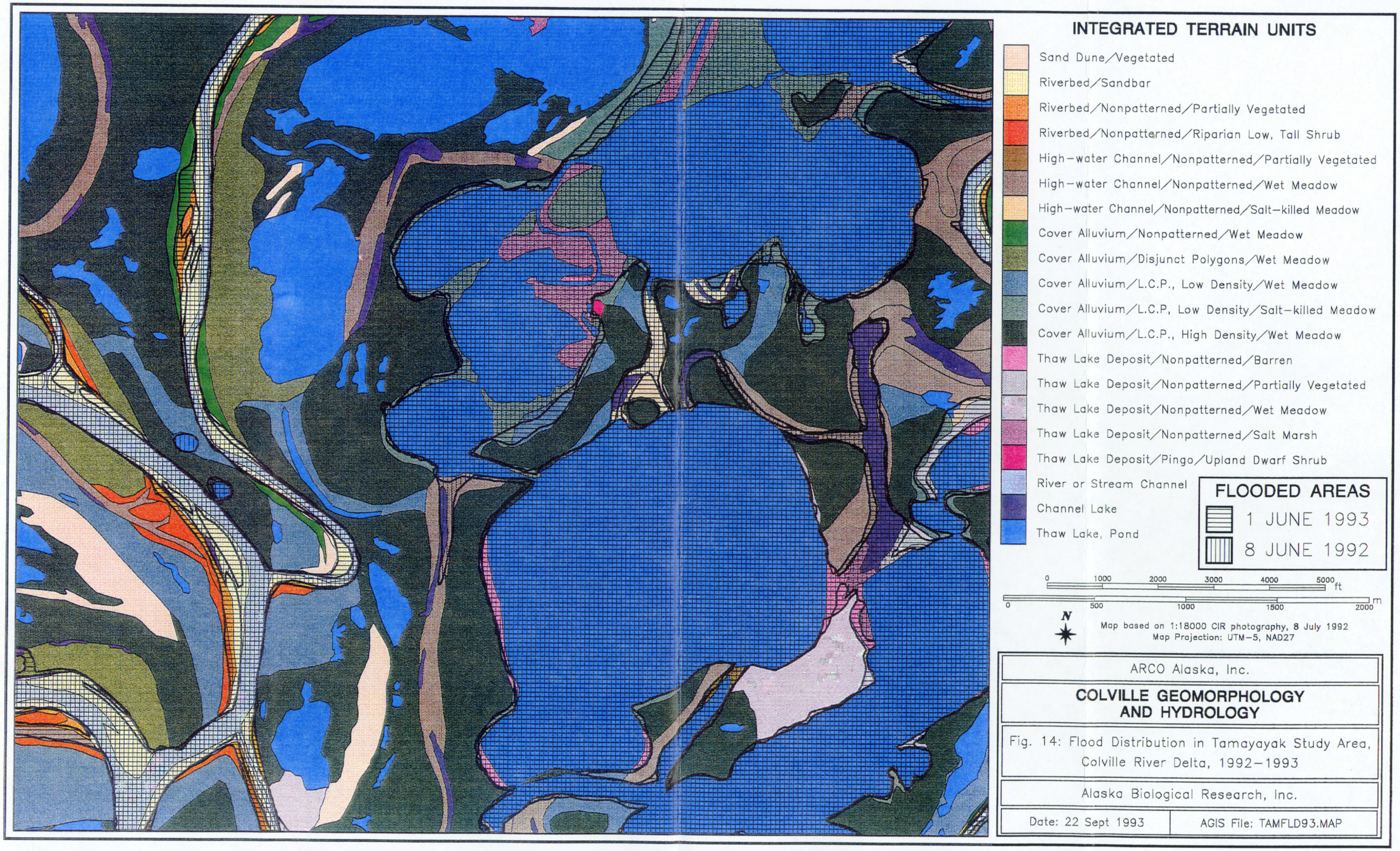
Fig. 13: Flood Distribution in Kuprigruak Study Area, Colville River Delta, 1992–1993

Alaska Biological Research, Inc.

Date: 21 Sept 1993	AGIS File: KUPIFL93.MAP



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COLVILLE GEOMORPHOLOGY AND HYDROLOGY

Fig. 14: Flood Distribution in Tamayayak Study Area, Colville River Delta, 1992–1993

Alaska Biological Research, Inc.

Date: 22 Sept 1993	AGIS File: TAMFLD93.MAP

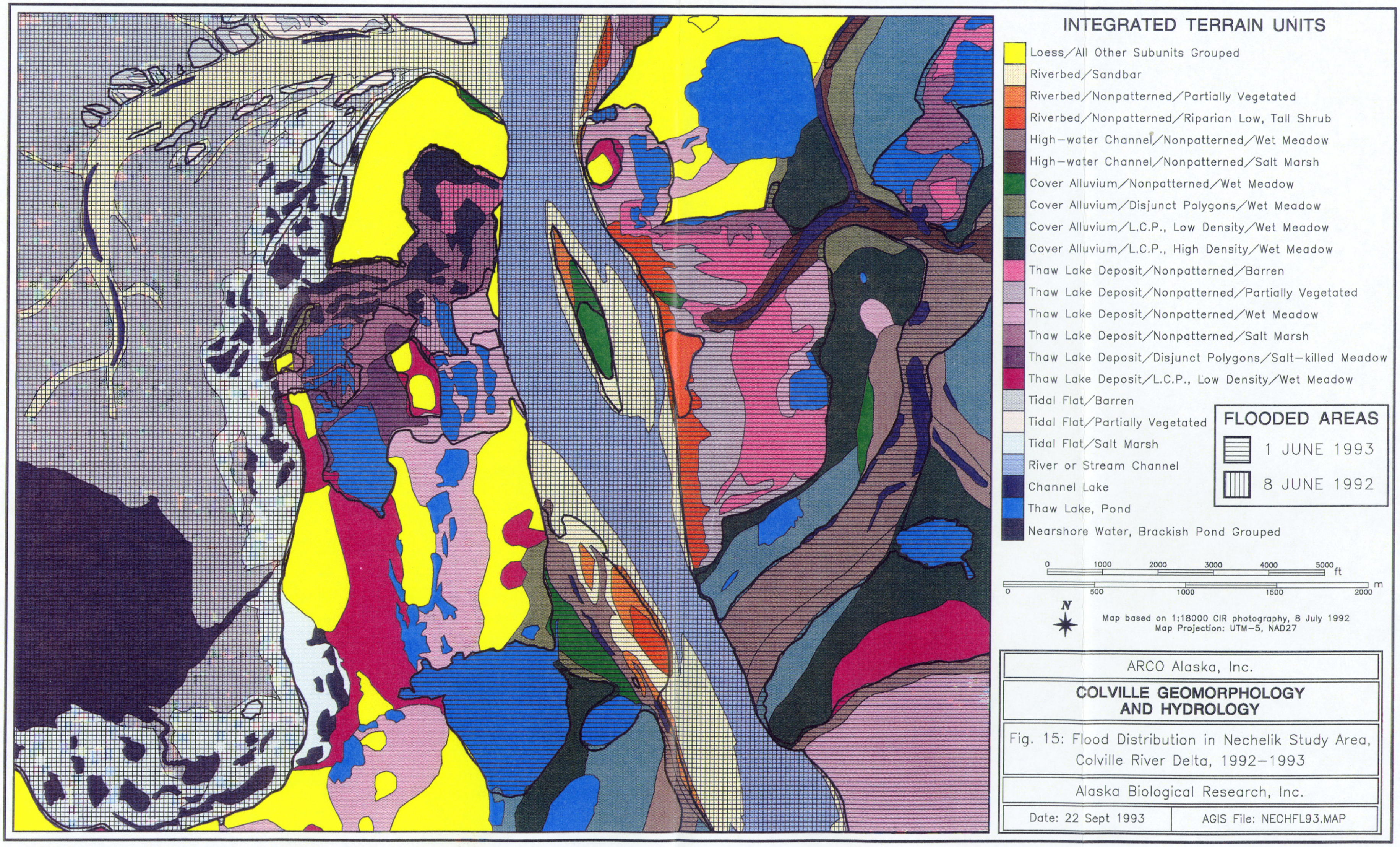

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Fig. 15: Flood Distribution in Nechelik Study Area, Colville River Delta, 1992–1993

Alaska Biological Research, Inc.

Date: 22 Sept 1993 | AGIS File: NECHFL93.MAP

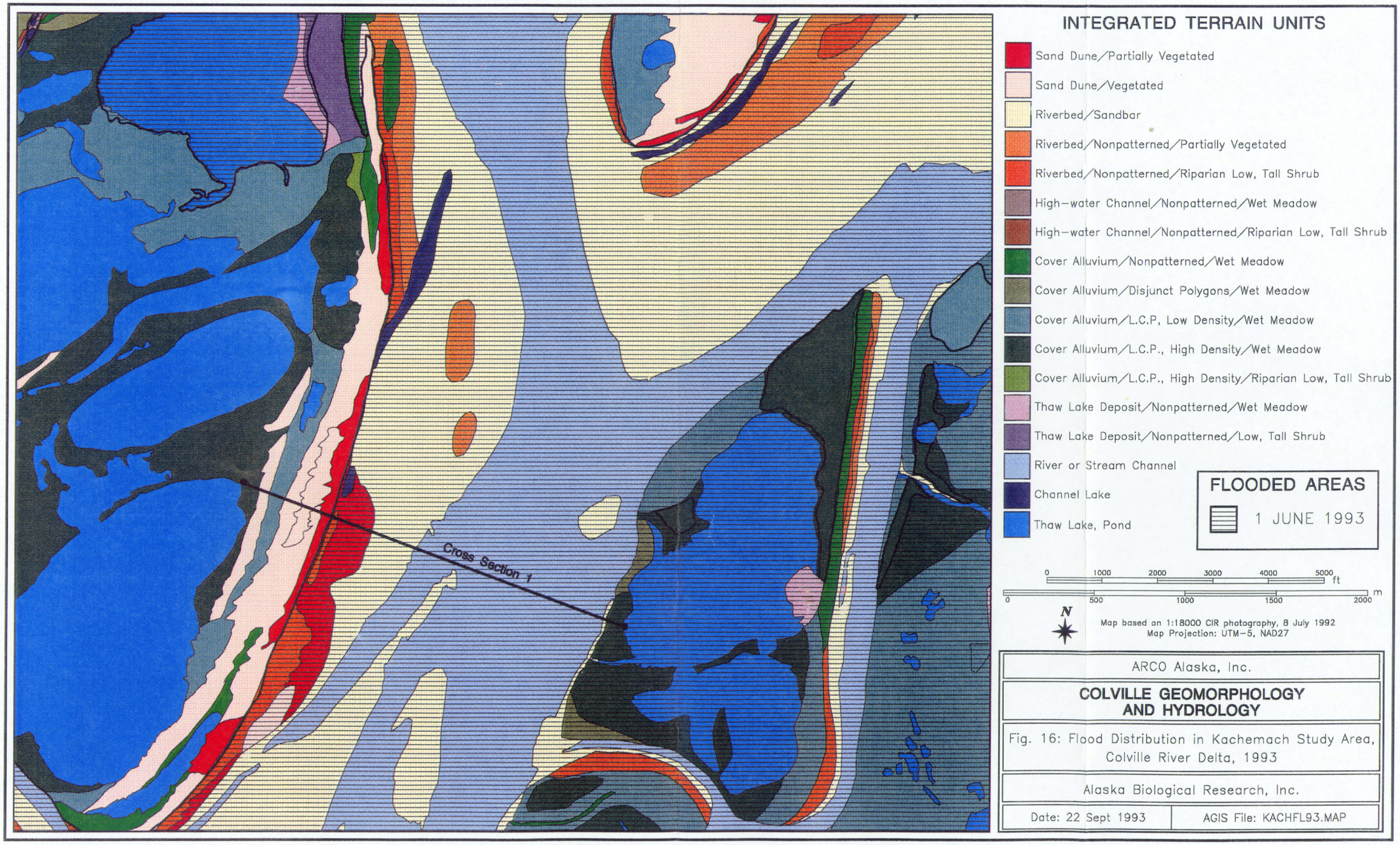
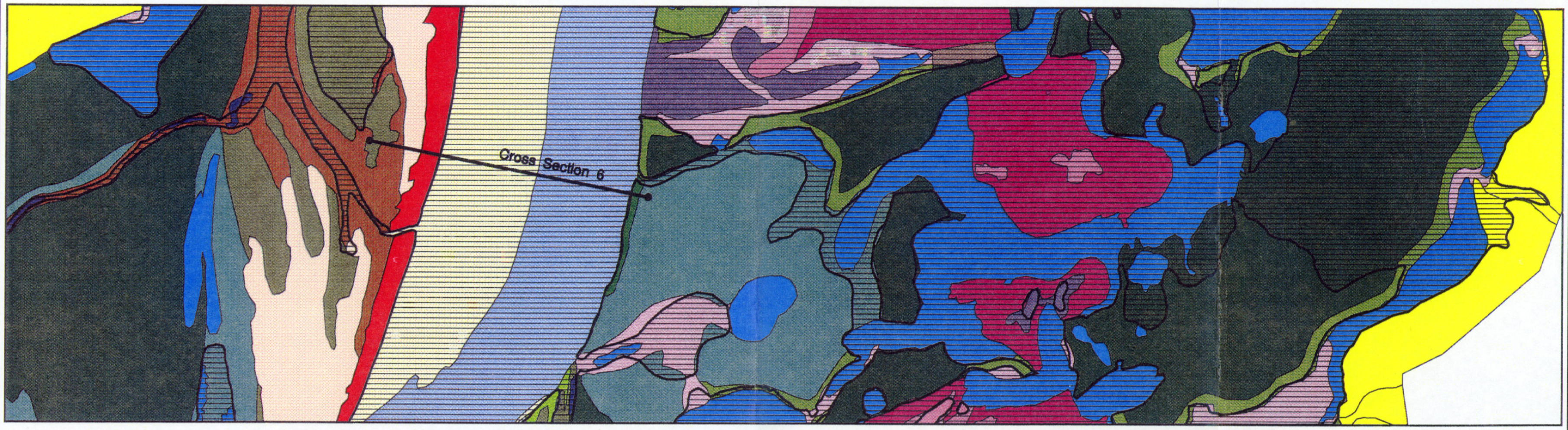


Fig. 16: Flood Distribution in Kachemach Study Area, Colville River Delta, 1993



INTEGRATED TERRAIN UNITS

- Loess/All Other Subunits Grouped
- Sand Dune/Partially Vegetated
- Sand Dune/Vegetated
- Riverbed/Sandbar
- High-water Channel/Nonpatterned/Wet Meadow
- High-water Channel/Nonpatterned/Riparian Low, Tall Shrub
- Cover Alluvium/Disjunct Polygons/Wet Meadow
- Cover Alluvium/Disjunct Polygons/Low, Tall Shrub
- Cover Alluvium/L.C.P., Low Density/Wet Meadow
- Cover Alluvium/L.C.P., Low Density/Riparian Low, Tall Shrub
- Cover Alluvium/L.C.P., High Density/Wet Meadow
- Cover Alluvium/L.C.P., High Density/Riparian Low, Tall Shrub
- Thaw Lake Deposit/Nonpatterned/Wet Meadow
- Thaw Lake Deposit/Nonpatterned/Low, Tall Shrub
- Thaw Lake Deposit/L.C.P., Low Density/Wet Meadow
- Thaw Lake Deposit/L.C.P., Low Density/Riparian Low, Tall Shrub
- River or Stream Channel
- Channel Lake
- Thaw Lake, Pond

FLOODED AREAS

1 JUNE 1993

N

0 1000 2000 3000 4000 5000 ft

0 500 1000 1500 2000 m

Map based on 1:18000 CIR photography, 8 July 1992
Map Projection: UTM-5, NAD27

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Fig. 17: Flood Distribution in Itkillik Study Area, Colville River Delta, 1993

Alaska Biological Research, Inc.

Date: 21 Sept 1993 | AGIS File: ITKIFL93.MAP

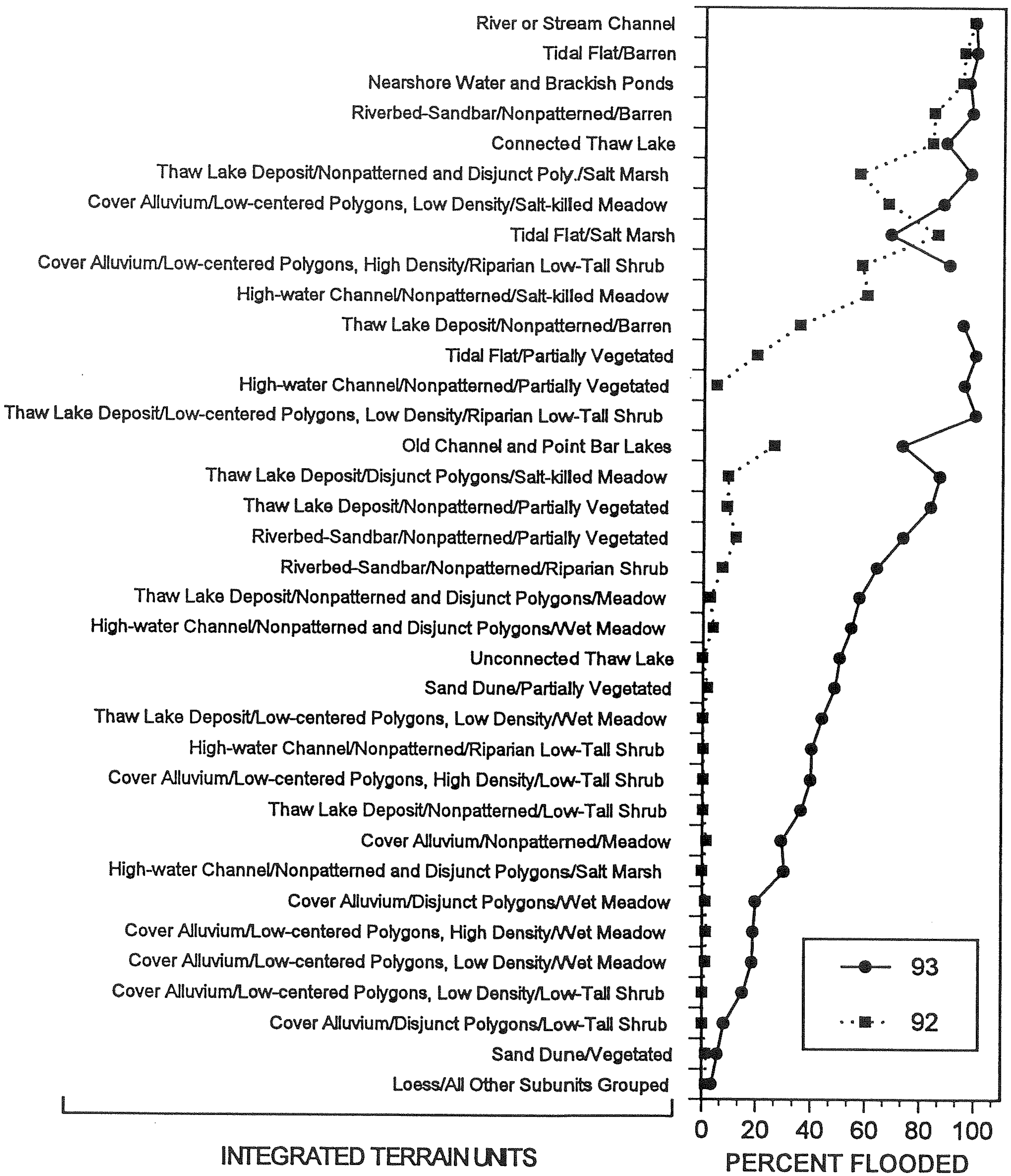

Figure 18. Percentage of each integrated terain unit covered by flood water in five study areas in the Colville River Delta, 1992-1993.

SUMMARY AND CONCLUSIONS

The timing of breakup in 1993 was typical of that reported in previous years (Walker 1983, Jorgenson et al. 1993). Water generally begins reaching the head of the delta between 23 and 30 May, with the river ice moving downstream between 30 May and 10 June. In 1993, the water level was rising by 29 May and the river ice moved downstream on 31 May. The water level rose initially at a rate of 3.3 ft/day, with a rapid rise of 6 ft occurring during the 22 hours preceding the peak stage. The average peak stage of 18.69 ft occurred on 31 May. After an initial drop of 3 ft during the first 18 hours after the peak, the water level dropped at a rate of 2.3 ft/day.

The spring peak discharge at Cross Section 6 in 1993 was estimated to be 379,000 cfs, with an estimated recurrence interval of 4 years. The peak water level was close to the bank full stage along this reach of river. The water-surface slope associated with the peak discharge was estimated to be 1.11×10^{-4} ft/ft.

The discharge measured on 2 June 1993 was estimated to be 239,000 cfs, at an average water-surface elevation of 12.86 ft. The water-surface slope associated with the discharge measurement was estimated to be 1.05×10^{-4} ft/ft. The hydraulic roughness computed for Cross Section 6, based on data from the discharge measurement, were 0.0219 for the sand bar and 0.02395 for the low water channel.

The stage-discharge and velocity-discharge curves for Cross Section 6 appear to be relatively stable. The similarity in the cross section geometry in 1993 to that surveyed in 1992 also suggests that the channel is stable at this location from year to year. Thus, the site appears to be an excellent location from which to continue collecting peak discharge information. Additional peak discharge information should be collected to refine the flood-frequency curve.

Flooding on 8 June 1992 covered 43% of the study areas, but varied from 36% in the Tamayayak area (dominated by thaw lakes) to 42% in the Nechelik area (dominated by tidal flats) and 50% in the Kupigruak area (situated in the main channel). Based on the stage-discharge relationship developed for the head of the delta, discharge at the time when the photography was taken (approximately 73,000 cfs) was substantially less than the flood peak on 2 June (approximately 164,000 cfs). The recurrence interval of the flood-peak discharge was probably less than 2 years.

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In general, there were consistent patterns in flood distribution related to ITUs. At low discharge (73,000 cfs), typically only riverbed and tidal flat deposits were covered while almost all other ITUs that were not flooded. At intermediate flooding (379,000 cfs), large portions of high-water channels and thaw lake deposits were covered, while higher floodplain steps with cover alluvium and wet-meadow vegetation were only slightly flooded. Loess deposits and vegetated sand dunes had very small areas of flooding.

In summary, stage, velocity, and discharge measurements during the last two years have contributed to a growing database from which preliminary estimates can be made for parameters required for the engineering design of bridge and pipeline crossings. Similarly, considerable knowledge has been gained on flood distribution across the delta that will be essential for siting and designing facilities.

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