Flood Hazard Potential of Five Selected Arctic Rivers Arctic Coastal Plain, Alaska

Completed for North Slope Borough Coastal Management Program

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ALASKA
COASTAL MANAGEMENT PROGRAM

February, 1982

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ABSTRACT

The relative flooding frequencies and potential flooding hazards of five Arctic rivers were mapped utilizing the geomorphic characteristics of each floodplain to delineate the present active and inactive floodplain units. The floodplain geomorphology of the Canning, Shaviovik, Sagavanirktok, Kuparuk and Colville Rivers was interpreted from the stereo viewing of color infrared and black and white aerial photography.

Field verification of the relative flooding frequency and the geomorphic description of each floodplain unit was accomplished in the summer of 1981. The flooding potentials of each river were then derived and mapped after the flooding parameter of each geomorphic unit was determined.

The rivers of Arctic Alaska are unique and must be treated as a special case for floodplain mapping. The flooding which occurs at the spring breakup may be the largest flooding event, but may have little physical effect because the active layer is predominantly frozen at that time.

Engineering formulas used to determine flooding frequencies in more temperate rivers cannot be applied to the Arctic rivers, due to the presence of aufeis and ice damming.

The floodplain geomorphology may be used to delineate potential flooding levels, provided that the possible changes of the geomorphology/flooding relationships along a particular drainage are considered.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

INTRODUCTION AND OBJECTIVES

The major objective of this study was to map the extent of the active and inactive floodplains of five Arctic rivers. Other objectivs were to determine the potential flooding hazards, and the geomorphic features of the rivers (Table 1). An attempt was also made to establish the relative flooding frequencies. This study produced eight maps that show the extent of the floodplains (in pocket) of the following rivers (Figure 1):

Canning River
Shaviovik River
Sagavanirktok River
Kuparuk River
Colville River.

The maps that were produced from this study delineate the following:

1) active floodplains
2) standard project floodplains
3) abandoned or inactive floodplains
4) active channels
5) field verification sites
6) the estimated relative flood frequency and flood magnitude for each mapping unit
7) major floodplain geomorphic features
8) major non-floodplain geomorphic features.

Table 1 **Generalized relationships between similar floodplain geomorphology units of the study rivers.**

Colville	Kuparuk	Sagavanirktok	Shaviovik	Canning
Fpi2				Fpi2
Fpi1	Fpi1	Fpi2		Fpi1
Fpa4	Fpa4	Fpi1	Fpi1	Fpa4
Fpa3	Fpa3	Fpa3	Fpa3	Fpa3
Fpa2	Fpa2	Fpa2	Fpa2	Fpa2
Fpa1	Fpa1	Fpa1	Fpa1	Fpa1

Fpa is defined as an active floodplain geomorphic unit that may be inundated by floodwaters.

Fpi is defined as an inactive floodplain geomorphic unit that is not inundated by floodwaters.

Using the Colville River as an example, Fpa1 is the active river channel. Fpa4 is the geomorphic unit of the highest elevation above the adjacent active river channel (Fpa1) that lies within the river's active floodplain. Fpi1 is the lowest and Fpi2 the highest inactive geomorphic unit that lies within the river's floodplain.

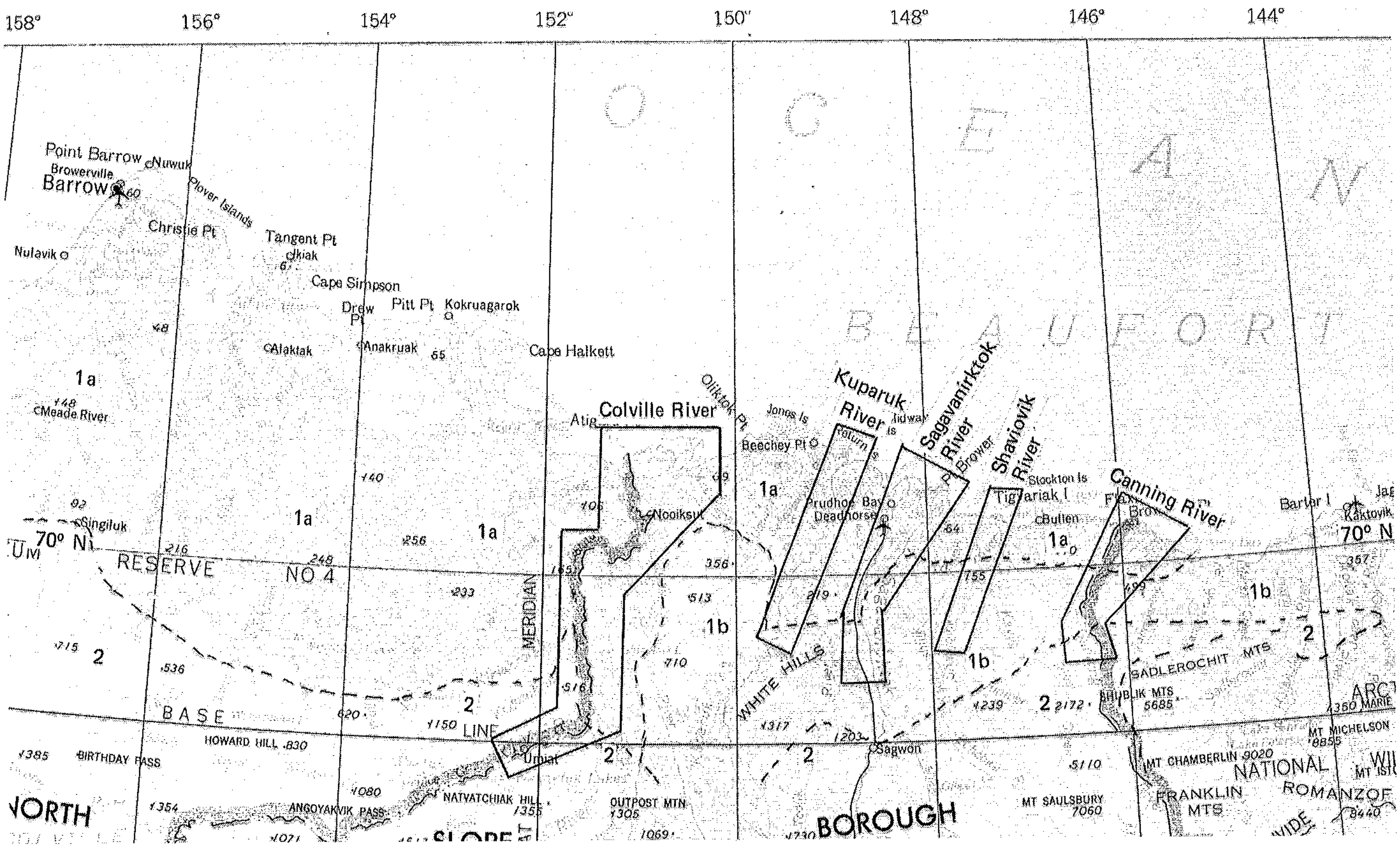


Figure 1
Location map of the study area. Scale; 1:2,500,000.

RATIONALE AND METHODS OF DATA COLLECTION

The data was collected and the preliminary geomorphic mapping of the study rivers was done under the assumption that similar floodplain geomorphic units along a particular river drainage may indicate different floodplain topographic levels, hence the extent of similar flooding levels along that drainage.

The basic geomorphic information of the floodplains was derived from U.S.G.S. topographic maps (Appendices A and B) and from the stereo viewing of both color infrared and black and white aerial photography (Appendix B).

Unpublished geomorphology maps (S.E. Rawlinson, 1980) were also utilized to aid in the preliminary geomorphology mapping of the floodplains (Appendix B).

Low altitude aerial reconnaissance of the rivers was done with a Cessna 172 in late May 1981 to observe and photograph the magnitude of flooding during the spring breakup.

Descriptions of the preliminary geomorphic units and their flooding characteristics were determined by field reconnaissance in July/August 1981 using a Bell 206 helicopter (Appendix C).

The observed ground evidence of flooding includes:

1) Presence of silts, sands and gravels that have recently undergone active transport.
2) Driftwood, especially when found on tundra-covered floodplain units.
3) Fine sand/silt layers on tundra-covered floodplain units.
4) Ice block gouging of tundra-mat during spring breakup.

The flooding potential maps (in pocket) were derived from the preliminary geomorphology maps and the field reconnaissance data.

An important point to realize about this study is that all flood stage magnitudes and frequency intervals are relative estimates for each particular drainage. Due to the consistent lack of accurate hydrologic data for the study rivers, no attempt was made to estimate flood stage magnitudes as discharge rates over time, or the flood frequency as standard reoccurrence intervals.

LOCATION AND DESCRIPTION OF THE STUDY AREA

Physical Description of Each Area Mapped

The extent of floodplain mapping of each of the rivers is as follows:

The Canning River is mapped from sea level to the 350 ft. contour, with a total channel length of 35 miles. The total floodplain area mapped is 152.3 square miles, including the Staines River (Map 1, in pocket).

The Shaviovik River is mapped from sea level to the 275 ft. contour, with a total channel length of 49 miles, including 9 miles of the Kavik River. The total floodplain area mapped is 56.5 square miles (Map 2, in pocket).

The Sagavanirktok River is mapped from sea level to the 350 ft. contour, with a total channel length of 54 miles. The total floodplain area mapped is 285.2 square miles (Map 3, in pocket).

The Kuparuk River is mapped from sea level to the 250 ft. contour, with a total channel length of 89 miles, including 7 miles of the Toolik River. The total floodplain area mapped is 137.4 square miles (Maps 4a and 4b, in pocket).

The Colville River is mapped from sea level to the 275 ft. contour, with a total channel length of 142.5 square miles, including 18 miles of the Anaktuvik, Chandler and the Itkillik Rivers. The total floodplain area mapped is 596 square miles (Maps 5a, 5b and 5c, in pocket).

For all five of the study rivers, the total channel length mapped is 369.5 miles, and the total floodplain area mapped is 1227.4 square miles.

Physiography

Two of the major physiographic features of North America extend into Arctic Alaska; the Interior Plains and the North America Cordillera. The Arctic Coastal Plain is the only continuation of the Interior Plains in Alaska (Wahrhaftig, 1965).

Arctic Coastal Plain

General topography. The Arctic Coastal Plain is a smooth plain rising from the Arctic Ocean to a maximum altitude of 600 ft. at its southern margin. The coastline makes little break in the profile of the coastal plain and shelf, and the shore is generally only 1-10 ft. above the ocean; the highest coastal cliffs are only 50 ft. high. The Arctic Coastal Plain province is divided into the Teshekpuk (1a) and White Hills (1b) sections (Figure 1). Scattered groups of low hills rise above the plain in the White Hills section; the Teshekpuk section is flat. Locally, an abrupt scarp 50-200 ft. high separates the coastal plain from the Arctic Foothills. Locally, pingos are sufficiently abundant to give an undulatory skyline. The part of the coastal plain between the Kuk and Colville Rivers has scattered longitudinal sand dunes 10-20 ft. high trending N. 55^{o} - 75^{o} E.

Drainage. The Arctic Coastal Plain is very poorly drained and consequently is very marshy in the summer. It is crossed by rivers which head in highlands to the south. Rivers west of the Colville River meander sluggishly in valleys incised 50-300 ft.; those east of the Colville cross the plain in braided or braided-meandering channels.

Lakes. The Teshekpuk Lake section of the Arctic Coastal Plain province is covered by elongated thaw lakes oriented N. 15° W.; these range from a few feet to 9 miles long, are from 2 to 20 ft. deep, and are oval or rectangular in shape.

Glaciers and permafrost. There are no glaciers. The entire land area is underlain by permafrost at least 1,000 ft. thick. The permafrost table (depth of the active layer) is 0.5 - 4 ft. below the surface. A network of polygons covers the coastal plain (Wahrhaftig, 1965).

Arctic Foothills

General topography. The Arctic Foothills consist of rolling plateaus and low linear mountains; they are divided into two sections. The northern section (2), which is included in the study area (Figure 1), rises from an altitude of 600 ft. on the north to 1,200 ft. on the south and has broad east-trending ridges, dominated locally by mesa-like mountains.

Drainage. The Arctic Foothills are crossed by north-flowing rivers from sources in the Brooks Range. The Colville River, the largest stream, has an anomalous east-trending course for more than 220 miles along the boundary between the northern and southern sections of the Arctic Foothills Province. Most streams have swift, braided courses across broad gravel flats that are locally covered in winter with extensive sheets of aufeis.

Lakes. A few thaw (talik) lakes are present in the river valleys and on some divides. The upper valleys of major rivers from the Brooks Range contain many morainal lakes.

Glaciers and permafrost. There are no glaciers. The entire province is underlain by permafrost. Ice wedges, stone stripes, polygonal ground, and other features of a periglacial climate are common (Wahrhaftig, 1965).

Tectonic and Depositional History of the Arctic Coastal Plain

During the Precambrian and the early Paleozoic, the Arctic (Innuitian) fold belt was located in and northward of the present Brooks Range. This was probably a separate mobile belt that existed prior to Mississippian time, and is more logically equated with the Innuitian fold belt than with the Cordilleran (Lathram, 1973).

During the late Paleozoic (Permian) and Mesozoic, miogeosynclinal sediments associated with the Yukon geosyncline to the south were deposited from the present Brooks Range northward (Brosge, 1973).

From the early Jurassic through the early Cretaceous, deposition of interbedded marine and non-marine clastic rocks into the Colville geosyncline occurred. The clastic rocks were clearly from a southern source, and become finer grained, more shaly, and more marine in character to the north, losing distinction as a unit north of the coastline (Detterman, 1973 and 1975).

Cenozoic Stratigraphy

In the Tertiary, the tectonics of the mostly marine Sagavanirktok Basin was controlled by the older Mesozoic structures. The Sagavanirktok Basin is superimposed on deposits of the Colville Basin and is the farthest northeast in a series of sequential foredeep basins that migrated northeastward from the rising and northward thrusting Brooks Range (Lathram, 1973).

The Tertiary Sagavanirktok Formation is composed of shallow-water marine clastic rocks and beach type sediments, including sands, conglomerates, silts and clays, all poorly consolidated with a few lignitic coals and carbonaceous shales. The Pleistocene Gubic Formation contains unconsolidated sands, gravels, clays and silts that are probably not more than several hundred feet thick in the vicinity of the Colville River, and possibly thinner to the east.

The Sagavanirktok and Gubik Formations overlie the Colville Group sedimentary rocks with a slight angular unconformity. The Gubic deposits are widespread west of the Colville River, and overlie or interfinger with the Sagavanirktok deposits east of the Colville River (Detterman, 1975).

The coastal plain unconsolidated deposits are within the geographic zone of continuously frozen ground. The most conspicuous geomorphic features of the coastal plain, polygons and talik lakes, are a consequence of their location within this zone. A tundra-mat, which averages less than a meter in thickness, overlies the unconsolidated deposits over most of the coastal plain (Cannon, 1981a).

Climatological Summary of the Arctic Coastal Plain

The climate of the Arctic Coastal Plain is determined by the amount of open, ice-free water of the Arctic Ocean to the north and the lack of natural topographic wind barriers across the Coastal Plain from the Arctic Ocean south 65 to 80 miles to the Brooks Range.

During long Arctic nights, temperatures along the Arctic coast do not drop to the extreme low readings reached in the Central Interior of Alaska. The modifying effect of the adjacent ocean, although frozen during the winter months, is one of the factors preventing extremely low temperatures. During the warmest months of the summer, the open water surface is still more effective in modifying the warming effects of a continuous period of possible sunshine, which lasts almost from the middle of May to the end of July.

There are no major topographic features from the Arctic Ocean coast south to the Brooks Range. Thus, during the winter, there are no natural wind barriers to assist in stilling the wind, permitting the lowering of temperatures by radiation, and no down-slope drainage areas to aid the flow of cold air to lower levels. Consequently, temperature inversions in the lower levels of the atmosphere are not as marked as those of the Central Interior of Alaska.

At Barter Island, located on the Arctic coast 47 miles east of the Canning River, high temperature readings reaching 70°F or above have occurred on only seven days during the 27 year period of continuous weather records; these were in July 1953, 1967, 1969, 1974 and August 1957. Freezing temperatures are reached, on the average, during all months of the year. Snow covers the ground about eight months of the year, and snow usually falls every month of the year. The mean annual precipitation at Barter Island is 6.51 inches (Local Climatological Data, Barter Island, AK, 1979).

Diurnal temperature ranges are confined within relatively narrow limits, reaching monthly maxima of around 17°F in April, and diminish to their minima of slightly less than 8°F in June during the period of continuous daylight. The mean average temperature of Barter Island is 9.8°F.

Temperatures at Barrow, located 158 miles west northwest of the

Colville River, remain below the freezing point through most of the year, with the daily maxima reaching higher than 32°F on an average of only 109 days a year (Local Climatological Data, Barrow, AK, 1979). Daily minima drop below the freezing point 324 days of the year, and freezing temperatures have been observed every month of the year. February is generally the coldest month, and the lowest temperature at the station on record is -56°F, reached in February 1924. March temperatures are but little higher than those observed in the winter months. In April, temperatures begin a general upward trend, with May becoming the definite transitional period from winter to the summer season. During May, an average of five daily maximum temperatures climb above the freezing point. July is the warmest month of the year, and the frequency of minimum temperatures of 32°F or lower average about one day out of two for July and August. During late July or early August, the Arctic Ocean is generally ice-free for the first time in summer. The end of the short summer is reached in September. By November, about half of the daily mean temperatures are zero or below. Variation of wind speed during the year is small, with the fall months being windiest. Extreme winds in the upper forties and low fifties have been recorded for all months.

At 12:50 p.m. on November 18, the sun dips below the horizon and is not seen again until 11:51 a.m. on January 24. Then the amount of possible sunshine each day increases by never less than 9 minutes per day. By 1:06 a.m. on the 10th of May, the possible sunshine has increased to 24 hours per day. The sun remains visible from that time to August 2, when it again sets for 1 hour and 25 minutes. The decrease in hours of sunshine is as rapid as the increase, and at 12:50 p.m. on November 18, the sky is once again continuously dark (Local Climatological Data, Barrow, AK, 1979).

The amount of sunshine appears to have a direct relationship to the occurrence of cloudiness, precipitation and heavy fog. All three build up to a maximum along with the hours of sunshine. Maximum cloudiness does continue into the fall months, although the amount of sunshine, precipitation and fog are on the decrease.

The mean annual precipitation at Barrow from 1940 to 1979 is 4.4 inches. The mean average temperature at Barrow from 1940 to 1979 is 9.6°F (Local Climatological Data, Barrow, AK, 1979).

Arctic Streams

The Arctic coast year can be divided into four major periods; the ice-locked winter, spring breakup, the ice-free summer, and freezeup. The four periods are of unequal length, with the ice-locked winter being the longest. The ice-free summer is the second longest period. Freezeup is the shortest period, taking three to five weeks. The processes associated with breakup span a longer length of time than that concerned just with the retreat of ice from adjacent sea and lagoons. The processes of breakup can begin in April and extend until the middle of July.

During breakup, the streams begin to flow on the surface before the sea ice melts. The streams have their maximum discharge at this time and run out over the sea ice where the pre-polynya water ponds up and deposits a layer of fine material on top of the ice (Figure 2). The water drains off

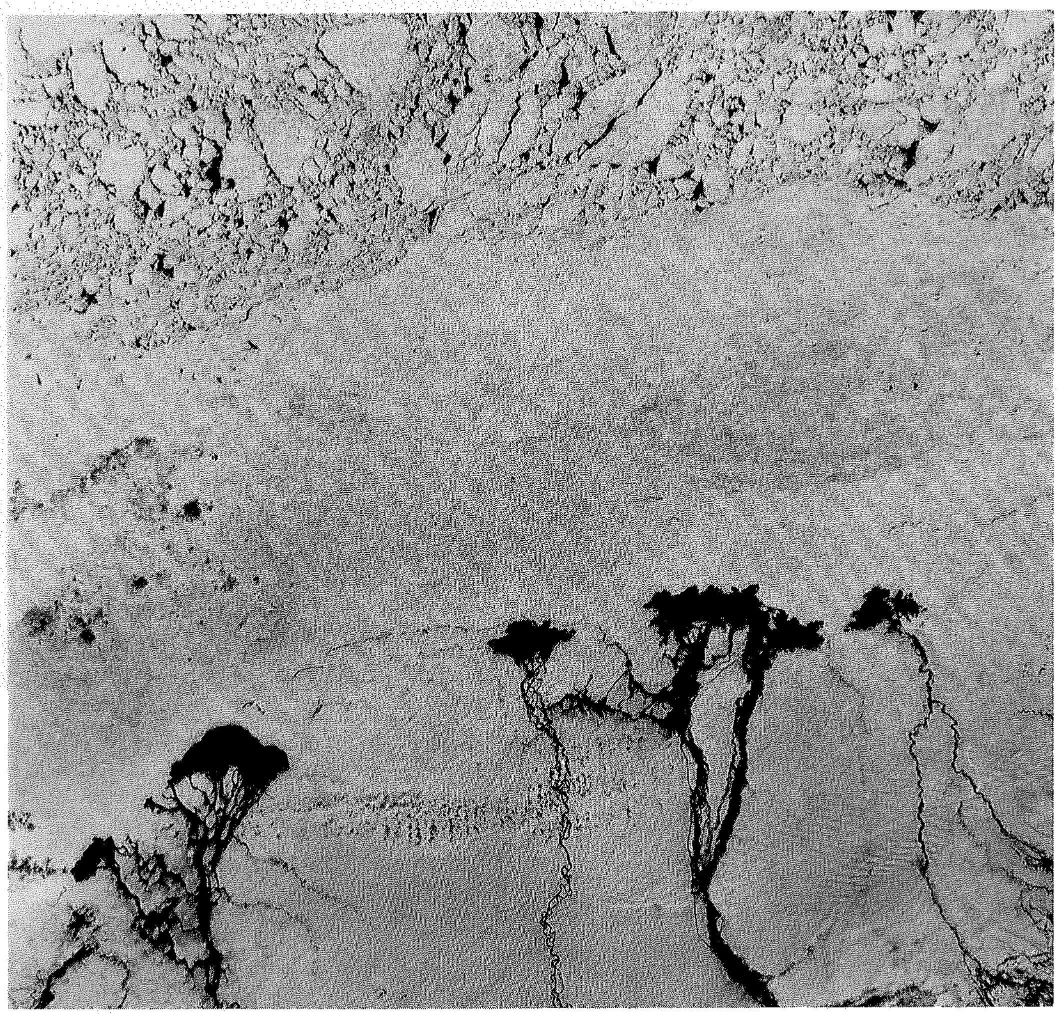


Figure 2
Landsat image E-2501-21051-7 (6 June 1976) showing the spring breakup flood waters of the Colville, Kuparuk, Sagavanirktok, and Shaviovik Rivers fanning out over the near shore Arctic Ocean ice as pre-polynya water. The scene is 185 km. across.

through cracks and features called strudle holes in the ice itself, leaving the layer of block material behind. The ice under this layer melts before the adjacent sea ice does, forming a large open space at the mouth of the river called a polynya (Figure 3). The materials transported by the stream during breakup are dumped on the delta front and pro-delta through the polynya. This material dumped on the delta front through the polynya is picked up and transported by the long-shore currents during the ice-free summer.

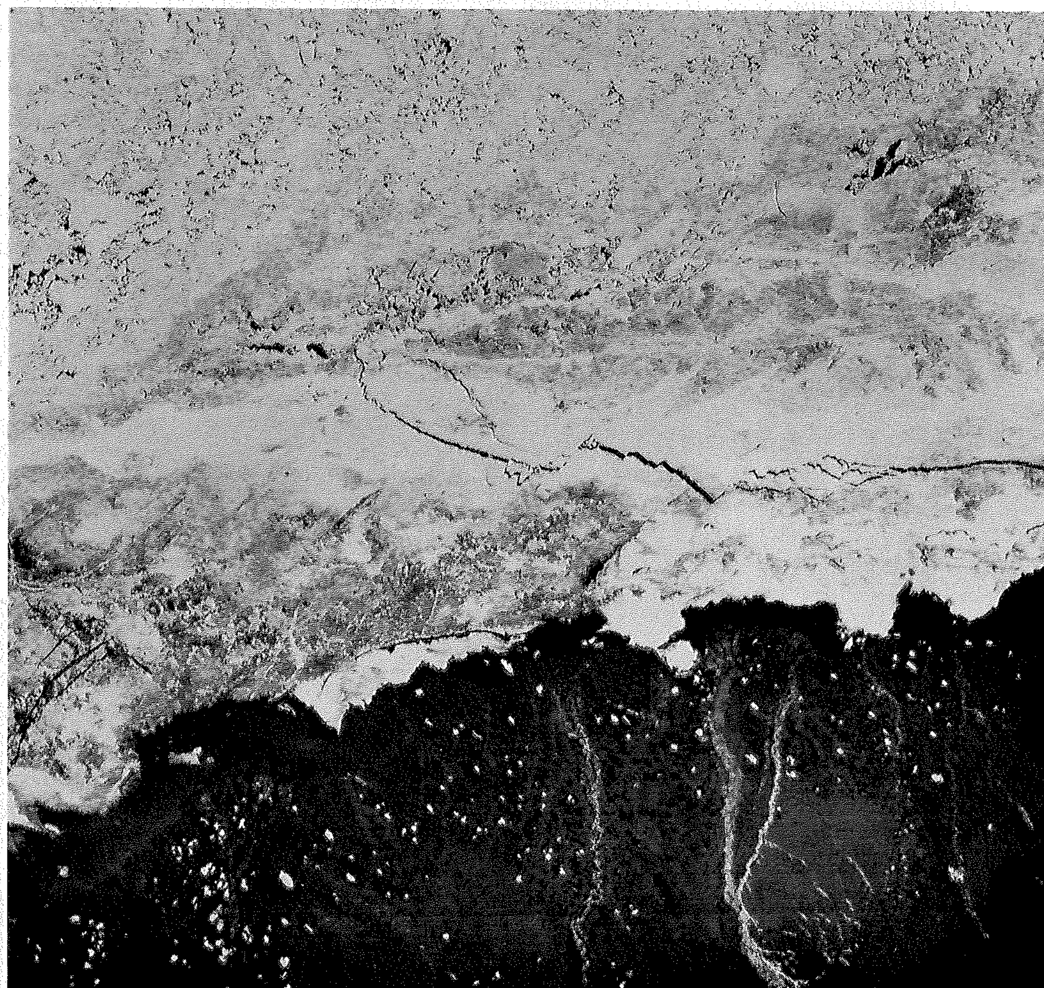


Figure 3
Landsat image E-2897-20493-5 (7 July 1977). The polynias are opening in the near shore Arctic Ocean ice at the mouths of the Colville, Kuparuk, Sagavanirktok, and Shaviovik Rivers. Notice the sediment plume at the Colville River delta. Some of the talik lakes are still ice covered. The scene is 185 km. across.

During the ice-free summer, plumes of turbid water can be observed on remote sensing data extending from the delta fronts of the major streams and along the coast. This material, in transit by the longshore currents, is fine-grain clays, silts and organic materials. The remote sensing data further indicates that, at this time, the water from the streams has a suspension load much less than that of the longshore currents (Figure 4). Wave action is picking up materials from the delta fronts which were deposited there before the ice-free summer during breakup.

During spring breakup, the presence of aufeis in the river channels and the temporary damming of the channel by in-transit ice blocks may cause localized flooding along the river.

Processes and Landforms

The most important landforming process in the area is the loss of ground ice. The natural stability of the landforms is directly related to the rates at which ground ice is lost. All the major landforms of the area, including barrier islands, lagoons, streams, lakes and deltas, are shaped or influenced by the loss of ground ice. Hence, there is an important interrelationship between the major landforms; a landform changes at the expense of another, or it evolves into another landform (Cannon, 1979).

Figure 4
Landsat image E-2915-20483-5 (25 July 1977). This scene shows the Colville, Kuparuk, Sagavanirktok, and the Shaviovik Rivers. A wide lead has now opened up along the coast, and the talik lakes are free of ice. Notice the sediment plumes at the Colville and Sagavanirktok deltas. The exposed active channels of the rivers are easily recognized by their high reflectance. The scene is 185 km. across (Figure 2, Figure 3).

There are two types of islands which make up the Barrier Island chains. One is composed of tundra-covered, frozen coastal plain material which has been left behind as the coastline has retreated due to the loss of ground ice (Table 2). The other is composed of non-frozen gravel materials derived from the destruction of tundra islands or coastal promontories (Cannon, 1979). Most of the islands have a recurved, umbrella shape. The islands are not true barrier islands like those found along other coasts, because the materials of the island are not being derived from the streams on the coastal plain and transported hundreds of kilometers by a dominant longshore current. The umbrella shape of the islands is due to the effects of two alternating longshore current directions (Cannon, 1979).

Since the coastal plain slopes toward the coastline, the bluffs along the beach should become higher as the coastline retreats. However, the bluffs appear to have maintained a low height of 1-3 meters. If coastline retreat had started just at the island, the coastal bluffs should be over 10 meters in height. From this, it appears that vertical subsidence of the surface due to loss of ground ice is occurring along with the horizontal retreat of the coastline (Cannon, 1979).

The coastline along the Beaufort Sea shows a range of morphologies. Typically, there is about a 2 meter bluff along the back of a narrow beach. However, in some areas, the tundra surface slopes to the back of the beach with no break or bluff. In these areas, the beach consists of a berm of sand and gravel on top of tundra. The tundra continues out from under the beach berm and under the water of the adjacent lagoon. This bluffless shoreline attests to the vertical subsidence of the coastal plain. The conclusion drawn from the bluff to bluffless shoreline range is that the rates of vertical subsidence vary between areas. A bluff forms where the rate of horizontal retreat is significantly greater than the rate of vertical subsidence. There is no bluff where the rate of vertical change keeps pace with the horizontal component of change.

Table 2 Average horizontal rates of retreat due to loss of ground ice (after Cannon, 1979).

Location	Average Rate
Tundra Islands, Simpson Lagoon	1.6 m/yr.
Coastline, Simpson Lagoon	1.2 m/yr.
Seaward shoreline, Flaxman Island	2.1 m/yr.
Lagoon shoreline, Flaxman Island	1.1 m/yr.
Total Flaxman Island shoreline	1.4 m/yr.
Coastline, Point Thomson to Brownlow Point	0.8 m/yr.
Total Prudhoe Bay shoreline	1.9 m/yr.
Total coastal plain-talik lake shorelines	0.4 m/yr.
Total Sagavanirktok River bank	0.7 m/yr.
Total coastline, Camden Bay	1.9 m/yr.

The shorelines of the lakes show the same range of morphologies as the coastline. Some lakes have bluffs at the shoreline, while others have no bluffs and the tundra slopes to the edge of the water and continues below the lake surface. In general, large lakes have bluffs and small lakes are bluffless.

Many of the streams show this same bluff phenomenon as the lake shorelines. In small stream channels, tundra often slopes down the banks and under the stream, and in larger stream channels, in-transit gravels may be seen on top of tundra. The largest streams have bluffs or a bluff only on one side of the channel. These stream channels are not being created or rapidly enlarged by mechanical erosion of bank and bed materials, but rather by loss of ground ice. This explains why some streams show very intense meandering without any meandering scars, point bars, chutes or chute cutoffs. Meandering in streams, where mechanical erosion is the major process, always shows scars of erosion and features of deposition.

The development of these stream channels begins during breakup, with water flowing overland in vast sheets. Channels begin by the melting of near surface ground ice. As channel flow increases, the melting of ground ice increases, and the tundra-mat subsides. Thus, the original material which is removed to make the channels is ground ice, and not soil or rock materials. As the channels are deepened by the melting of ground ice, the tundra mat is stretched until it breaks, at which time blocks of tundra-mat and underlying peat are dropped into the stream and transported. This rupture of the tundra-mat produces a bluff in which the rock materials of the coastal plain are exposed. With availability of rock materials, the stream begins to carry sand and gravel. When the volume of transported materials reaches a critical amount, the construction of a delta begins at the stream's mouth.

Although not extensive on the coastal plain, the deltas are perhaps the most important landforms in the ecosystem. The deltas are the sources of detritus, which is picked up and transported throughout the barrier island/lagoon system for most of the ice-free season (Cannon, 1979). The major landforms of the coastal plain are listed in Table 3.

Table 3 Landforms of the Beaufort Sea Coastal Plain (modified after Cannon, 1979).

Beaches	Narrow strips of gravel with minor amounts of sand along the shores of the islands and coastline.
Coastal Plain	A gently sloping, tundra-covered plain. It is poorly drained and covered with talik lakes and polygonal ground patterns.
Deltas	Broad, fan-shaped areas of very fine sediment at the mouths of the largest streams. Some small deltas occur at the mouths of streams which run into drained lakes.
Gravel Islands	Shoestring gravel bars derived from the destruction of tundra islands. Wave action slowly works the gravels towards the coast, and disperses the gravels on to the seafloor.
Lagoons	Shallow bodies of sea water protected by a seaward barrier of gravel and/or tundra islands. The lagoons are formed by

Table 3 continued on next page

Table 3 continued

	the coalescing of talik lakes which are breached by the retreating shoreline.
Sand Dunes	Minor features of sand derived from large streams, or from beach materials on some tundra islands. There are no sand dunes on the gravel islands and there are no islands composed only of sand.
Spits	Gravel bars extending from the ends of tundra islands and coastal promontories, which are the gravel sources. The spits are often reworked extensively during storms.
Streams	Channels which begin by the loss of ground ice. The larger channels transport materials derived from their banks.
Talik Lakes	Shallow lakes on the coastal plain formed by the loss of ground ice.
Tundra Islands	Tundra-covered remnants of the coastal plain.

GENERAL THEORY OF FLUVIAL PROCESSES AND GEOMORPHOLOGY

Channel Patterns

The channel pattern is the planimetric or map view of a stream. The channel patterns that are recognized are meandering, braided, and straight. Rivers are seldom straight through a distance greater than about ten channel widths, so the designation of a straight channel may imply irregular, sinuous, or non-meandering. There is no sharp distinction between any of these patterns. Many rivers exhibit each of these three channel patterns somewhere along their lengths, with the pattern being a continuum from one extreme to another (Leopold et al., 1964).

River patterns represent an additional mechanism of channel adjustment which is related to the channel gradient and cross section. The pattern itself affects the resistance to flow, and the existence of a particular pattern is closely related to the river's load and discharge (Ruhe, 1975).

Meandering Channels

A stream is considered to be meandering if the sinuousity (ratio of the talweg length to the down-valley distance) is 1.5 or greater. The sinuousity relates to the kind of sediment at the perimeter of the channel (Schumm, 1963), with meandering streams generally leaving a high amount of silt and clay in their banks and beds. Meanders occur in alluvium. If the stream is entrenched in bedrock or other material, such a bend is an entrenched meander.

Most meandering river bends have proportional sizes with consistent relations between wave length, channel width, and radius of curvature (Leopold et al., 1964). The wave length and meander-belt width relate to mean annual discharge as a power function (Carlston, 1965; Schumm, 1967).

Braided Channels

The separate channels of a braided stream are divided by islands or bars. The bars which divide the stream into separate channels at low flow are often submerged at high flow.

A braided stream is characterized by the general instability of the bars and channelways and by caving of the channel walls. Once an initial channel island is formed, the process of division goes on and another bar is formed in one or both of the divided channels. The profile is similar to that of a straight or meandering reach, with pools and shoals (Morisawa, 1968).

Braided streams are common in semiarid regions, where a large sediment load is supplied to the channel, and in meltwater streams from glaciers (Ruhe, 1975).

Braiding occurs in channel reaches where the slope may be oversteepened. In general, braided and straight channels relate to steeper slopes, meandering channels to gentler slopes (Leopold and Wolman, 1957).

Braiding is also caused by the inability of a stream to carry the total load supplied to it. If a local change in the velocity occurs, the sediment is deposited as bank or bed accretion.

Misfit Streams

A misfit stream is one whose meanders do not fit the size of the valley in which the stream is presently flowing.

A misfit or underfit condition commonly results from drainage changes effected by stream diversion (piracy) or derangement. Changes in runoff volumes could also be accounted for by the disappearance of the Pleistocene glaciers (Thornbury, 1969).

Floodplain Deposits

The principal types of alluvial floodplain sediments are channel, channel-margin, and overbank deposits.

Channel Deposits

These are lateral accretion deposits that include transitory channel deposits which are the bed loads temporarily at rest. Their surface forms include ripples, waves, dunes, anti-dunes, and longitudinal or crossing bars. All of these features may move rapidly in the channel, but some of them may persist in varying stages of flow. Bars in the channel are bed accretions, bars along the banks are bank accretions. Channel-lag deposits are formed by the removal of finer or lighter particles, leaving behind larger and heavier particles. Coarse gravel or boulder beds at the bottom of valley sediments are lag concentrations. Channel-fill deposits result from a general aggrading condition in the stream. These sediments may fill the channel nearly to bank level (Ruhe, 1975).

Channel-margin sediments are lateral accretion deposits, which form on the convex sides of bends as point bars.

There are two kinds of overbank deposits, vertical accretion deposits and flood plain splays. Vertical accretion deposits form by deposition of suspended load during overbank flooding. The thickest and coarsest particles are deposited bordering the channel, forming low ridges or natural levees. Away from the channel, finer grained sediment is deposited in the backlands, where they build up vertically. Floodplain splays are relatively coarse sediments that spill through a breach along the channel bank and form in a fanlike pattern over finer sediment of the floodplain.

The identification of channel, channel-margin and overbank deposits is difficult unless they are specifically associated with a well-defined feature (Ruhe, 1975).

Floodplain Morphology

The floodplain is the part of the valley floor adjacent to the stream that is built of fluvial sediments. The floodplain slopes down valley, but perpendicular to the stream; a floodplain is not flat, but essentially horizontal (Ruhe, 1975).

A typical floodplain will include most of the following features:

1) The river channel.
2) Oxbows or oxbow lakes, representing the cutoff portion of meander bends.
3) Point bars, loci of deposition on the convex side of river curves.

4) Meander scrolls, depressions and rises on the convex side of bends formed as the channel migrated laterally down valley and toward the concave bank.
5) Sloughs, areas of dead water, formed both in meander-scroll depressions and along the valley walls as flood flows move directly down valley, scouring adjacent to the valley walls.
6) Natural levees, raised berms or crests above the floodplain surface adjacent to the channel, usually containing coarser materials deposited as flood flows over the top of the channel banks. Where most of the load in transit is fine-grained, natural levees may be absent or nearly imperceptible.
7) Backswamp deposits, overbank deposits of finer sediments deposited in slack water ponded between the natural levees and the valley wall or terrace riser.
8) Sand splays, deposits of flood debris usually of coarser sand particles in the form of splays or scattered debris.
9) Terraces, either paired or unpaired (Leopold, 1964).

Fluvial Terraces

Fluvial terraces are topographic steps in river valleys that usually represent former levels of the active channel. Terraces may be located at a more or less constant elevation above the present active channel. The line of the terrace across the valley is similar to the transverse profile of the floodplain and is essentially horizontal but not necessarily flat. The individual terraces are usually separated by low bluffs or scarps. Terraces may have relic floodplain features such as abandoned channels, scrolls, levees and backswamps.

The floodplain of a given time is related to the river's base level. Terraces reflect variations in base level and stream energy; two parameters which may change independently or together.

There are two fundamental categories of fluvial terraces; erosional and depositional. The erosional terrace may be eroded in bedrock or in a former sedimentary fill. The depositional terrace is a result of the infilling of the valley floor by the deposition of alluvium (Ruhe, 1975).

River terraces are produced by surges of erosion along river valleys and represent periods of rejuvenation which have affected the streams. River terraces may be classified as either cyclic or non-cyclic. Cyclic terraces represent former valley floors formed during periods when valley deepening had largely stopped and lateral erosion had become dominant. The distinguishing feature of cyclic terraces is that, for any set of terraces, remnants on opposite sides of the valley will be paired or will correspond in altitude along any particular valley stretch. Non-cyclic terraces imply that there was continued downcutting accompanied by lateral erosion, resulting from continued slow uplift of the land or other changes that would have a similar effect upon a stream (Thornbury, 1969).

In mapping terraces, it is important to realize that the geomorphic terrace is a landform surface and must be mapped as a physiographic type, while the terrace alluvium is mapped as a stratigraphic unit (Fairbridge, 1968).

Flood Frequency and Flooding Potential

The magnitude and frequency of flooding may be predicted where sufficient discharge data for a river exists.

For a particular river, the flood of the greatest recorded discharge is designated as number one, the flood of the second greatest discharge as number two, etc. Since there may be more than one flood of a given discharge, a flood recurrence interval (RI) is calculated:

$$RI = \frac{N-1}{M}$$

where N is the number of years that a flood of a given discharge recurs and M is the number assigned in listing flood discharge.

The recurrence interval is the number of years, on the average, until a given flood will be equaled or exceeded one time. It is inversely related to the probability that a given flood will be equaled or exceeded in any one year. (A 25-year flood would have one chance in 25, or a 50-year flood one chance in 50, of being equaled or exceeded in any one year).

The data may be extrapolated to predict a flood magnitude with a recurrence interval that is greater than the length of continuous records. Prediction beyond the measured data should be done with caution (Ruhe, 1975).

Predicting flood frequency and discharge magnitudes by this method is not applicable to the Arctic rivers, primarily due to the lack of recorded flooding data. The presence of aufeis in the active river channels, and temporary ice block damming during spring breakup affects the magnitude of localized flooding along a drainage. Alterations of the river channel may also cause flooding. An example of this is the localized flooding caused by the Kuparuk River Bridge during the spring breakup flooding in May 1981.

As flooding along a drainage rises vertically above the active channel, there is also a horizontal component of flooding as the floodplain farther from the active channel is inundated. Because of the horizontal component of flooding, doubling the discharge does not necessarily double the vertical height of the flood water. The relationship of flooding discharge to the height of the flood water (not considering the effects of aufeis or ice block damming) is not a linear relationship. For the highest flood stage possible for a particular drainage it approaches a logarithmic function.

FLOODPLAIN GEOMORPHOLOGY AND FLOODING POTENTIAL OF THE STUDY RIVERS

Introduction

Active floodplain units are those geomorphic features along a river which may be covered by water at various flood stages. There are two extreme events in the consideration of relative stages of flooding. The common extreme is the lesser event of high frequency and low magnitude. This is the low water flooding which most often occurs. The other extreme is the low water flooding which most often occurs. The other extreme is the low frequency-high magnitude event. This is the maximum flooding event which rarely occurs. Geomorphic features indicate the limits or boundaries of these extremes and in some cases indicate the intermediate flooding levels. The low frequency-high magnitude flood can be equated to the standard project flood for planning and management purposes. The standard project flood is the high water stage expected from the most severe combination of meteorologic and hydrologic conditions that are considered possible for the river and its watershed.

According to Ruhe, a floodplain level that has been flooded during the present stream regimen should not be considered a terrace. Thus, the true floodplain must be separated from the lowest terrace in a valley. The levels subject to flooding should be called flood-plain steps (Ruhe, 1975 p. 79). According to this definition, all Fpa geomorphic units above Fpa1 would become floodplain steps, and all the Fpi geomorphic units would become terraces (Table 4). I prefer the use of 'terrace' as a term describing only the physical configuration of a floodplain feature, with no relation to its susceptibility to flooding (Table 5).

Table 4 Description of geomorphic units mapped and their corresponding map symbols.

Fpa1	-	Floodplain active, level one (active channels).
Fpa2	-	Floodplain active, level two.
Fpa3	-	Floodplain active, level three.
Fpa4	-	Floodplain active, level four. The highest floodplain geomorphic unit above the active channel that is inundated by flood water.
Fpi1	-	Floodplain inactive, level one. The lowest floodplain geomorphic unit above the active channel that is not inundated by flood water.
Fpi2	-	Floodplain inactive, level two. The highest floodplain geomorphic unit above the active channel that is not inundated by flood water.
Fp	-	Floodplain, undifferentiated.
L	-	Lake.
Lt	-	Talik lake
Lo	-	Lake formed by oxbow or chute cutoff.

Table 4 continued on next page

Table 4 continued

Cpt1	-	Coastal plain deposits with talik lakes.
Cpau	-	Coastal plain, alluvial uplands.
Al	-	Alluvium.
Sd	-	Eolian sand dune.
Sdv	-	Vegetated oelian sand dune.
Tf	-	Tidal flats.

The above units are mapped on Maps 1, 2, 3, 4a, 4b, 5a, 5b and 5c.

Canning River

On the Canning River there were 11 field verification sites visited using a Bell 206 helicopter on 22 August 1981. Low altitude aerial reconnaissance of spring breakup was done with a Cessna 172 on 25 May 1981 (Appendix C).

The Canning River channel pattern is braided-distributary from sea level to the 325 ft. contour, and is meandering from the 325 ft. contour to the end of the mapping at the 350 ft. contour (Table A-1).

The floodplain geomorphic units of the Canning River are cyclic terraces. The term terrace used here describes only the physical unit, it does not infer an active or inactive floodplain unit (Tables 5 and 6, Figures 5 and 6).

The flooding unit is the relative magnitude of flood waters needed to inundate a specific geomorphic unit or units. Example: an F3 flood stage on the Canning River would inundate the geomorphic units Fpa3, Fpa2 and Fpa1, but not Fpa4 or Fpi1 (Table 5, Map 1).

Table 5 Canning River flooding unit/geomorphic unit relationships.

Flooding Units	Geomorphic Units
F1	Fpa1
F2	Fpa2
F3	Fpa3
F4	Fpa4
F5 (non-flooding)	Fpi1

Cpt1 and Cpau units are non-flooding.
Flooding units are from Map 1.

Table 6 Generalized relationships between the floodplain geomorphology and flooding units of the study rivers.

Colville	Kuparuk	Sagavanirktok	Shaviovik	Canning
F6, Fpi2				Fpi2
F5, Fpi1	F5, Fpi1	F6, Fpi2		F5, Fpi1
F4, Fpa4	F4, Fpa4	F5, Fpi1	F4, Fpi1	F4, Fpa4
F3, Fpa3	F3, Fpa3	F4, Fpa3	F3, Fpa3	F3, Fpa3
F2, Fpa2	F2, Fpa2	F2, F3, Fpa2	F2, Fpa2	F2, Fpa2
F1, Fpa1	F1, Fpa1	F1, Fpa1	F1, Fpa1	F1, Fpa1

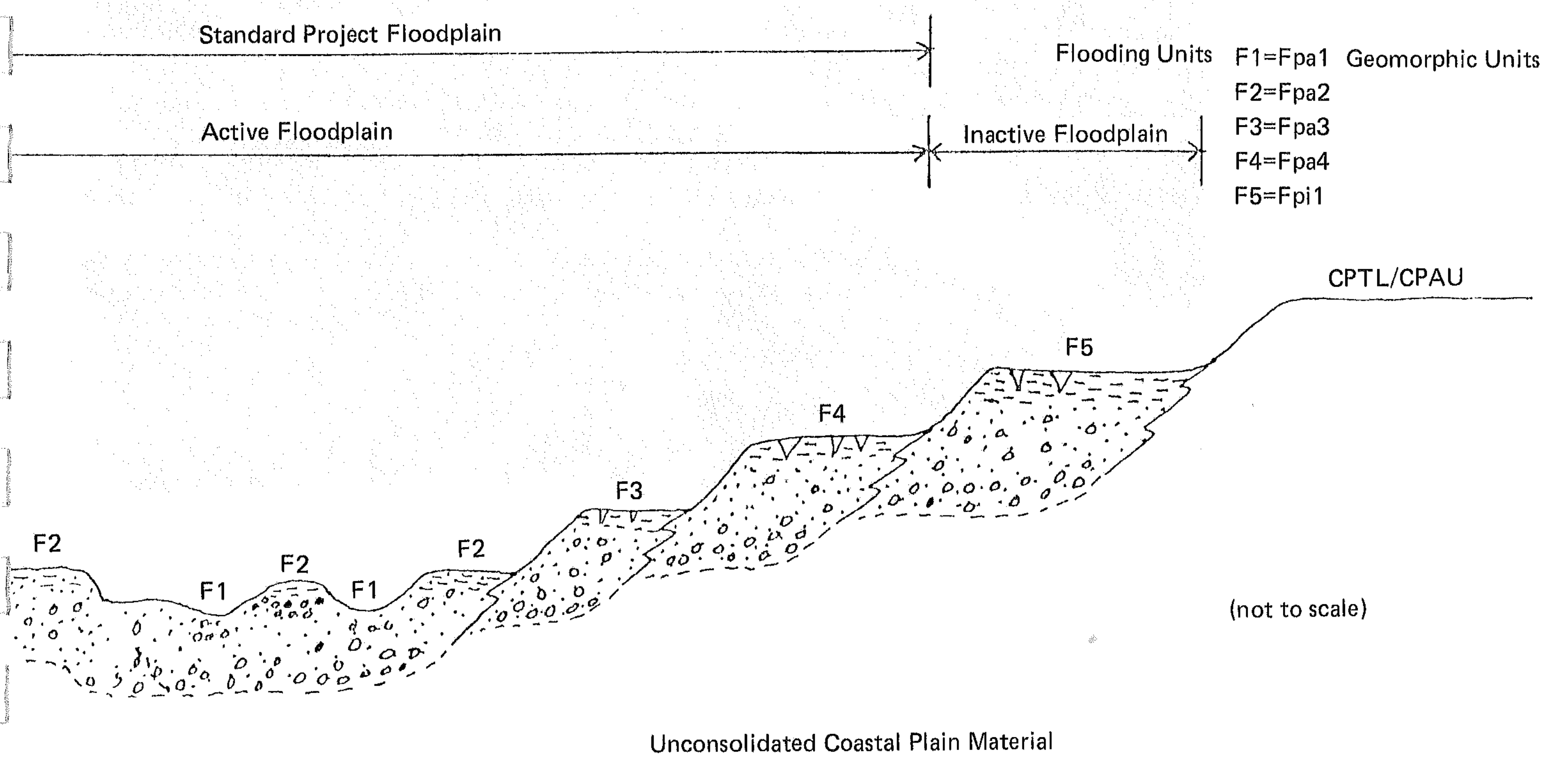
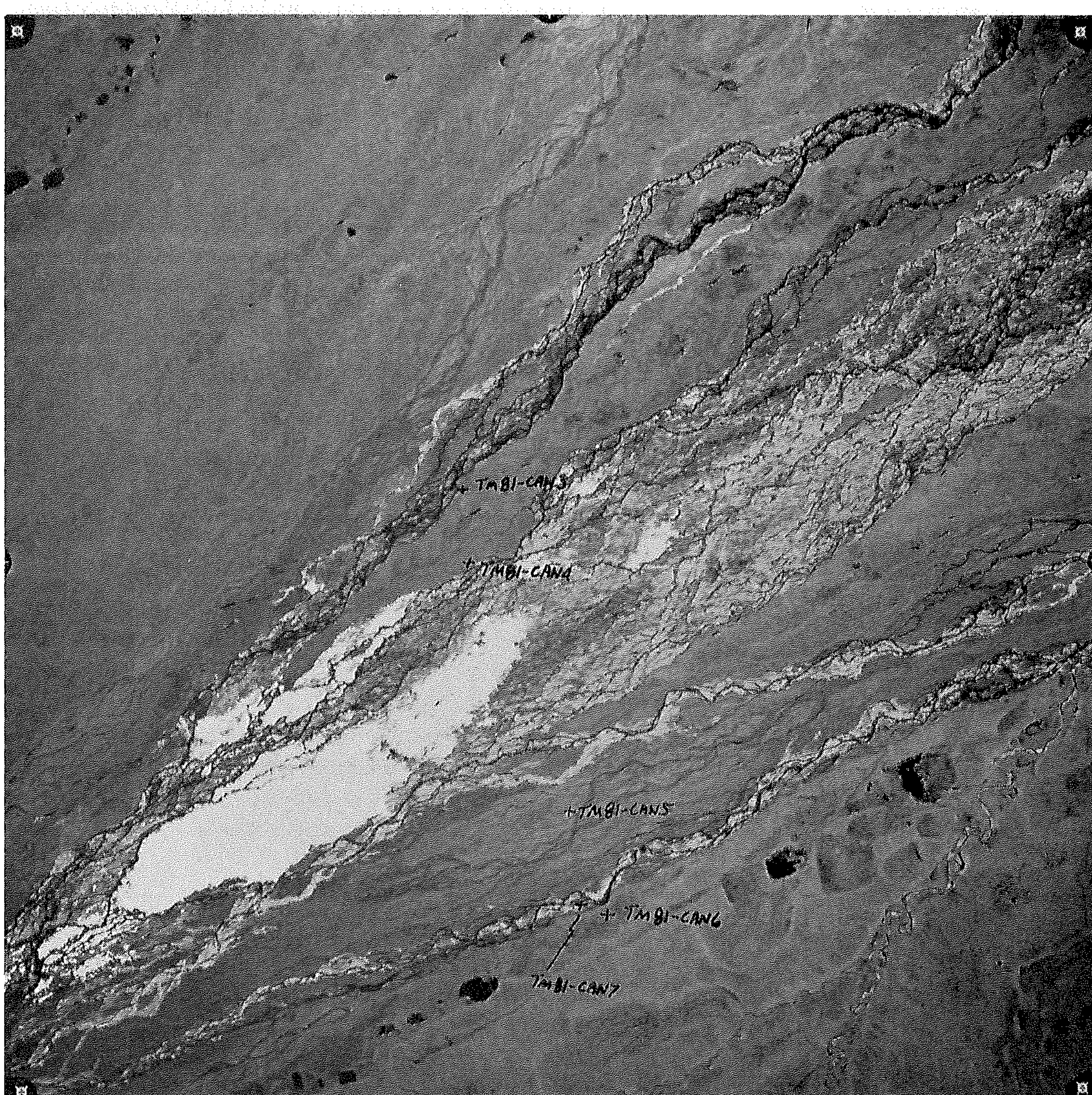


Figure 5
Generalized cross-section of the Canning River geomorphology/flooding relationships. By author.



NASA U-2 infrared aerial photograph of the Canning River. Note the extensive aufeis in the active channel. Notations on the photograph indicate field verification sites. The scene is 9 miles across. Flight line 20, frame number 2407, July 1979.

The evidence for flooding on the Canning River was the presence of driftwood and recently transported silts, sands and gravels.

The presence of large aufeis fields in the active channels of the Canning River affects the magnitude of localized spring breakup flooding (Figure 6).

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage, the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

> *Active channels* are braided floodplain deposits of sand and gravel, may contain small amounts of silt and organic matter, no vegetation, subject to aufeis, perennially unfrozen.

Tidal flats are deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be present. These deposits are north of the limit of tidal influence.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage, the geomorphic units that are inundated by water are grouped under the category Fpa2, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel or associated with channel bars of tidal flat units.

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick. Moss, grass and low-brush vegetation. Active layer to 1 m thick, continuously frozen.

F3 defines active floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa3.

Fpa3; silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and indistinct polygonal ground, generally bounded by well-defined scarps. Active eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate ice content.

F4 defines active floodplain areas that undergo very low frequency-very high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa4. The flooding in this unit may be caused by local aufeis conditions.

Fpa4; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons; pingos and small thaw lakes may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

F5 defines an inactive floodplain unit, not subject to inundation by streams. It is equal to the geomorphic unit Fpi1.

Fpi1; higher above the active channel than Fpa4. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show modified meander and braiding scars and polygons. Stabilized dunes, pingos and small thaw lakes may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

The other geomorphic features mapped are:

Cpt1; coastal plain deposits with talik lakes.

Cpau; coastal plain, alluvial uplands.

Lt; talik lake.

Shaviovik River

On the Shaviovik River there were 6 field verification sites visited using a Bell 206 helicopter on 20 August 1981. Aerial reconnaissance of spring breakup was done using a Cessna 172 on 25 May 1981. Additional aerial reconnaissance of the Shaviovik River Delta was done using a Bell 206 helicopter on 22 August 1981 (Appendix C).

The Shaviovik River channel pattern is braided-meandering from sea level to the end of the mapping at the 275 ft. contour (Table A-2, Figure 31).

The floodplain geomorphic units of the Shaviovik River are cyclic terraces. The term terrace used here describes only the physical unit, it does not infer an active or inactive floodplain unit (Tables 6 and 7, Figures 11 and 12).

The flooding unit is the relative magnitude of flood waters needed to inundate a specific geomorphic unit or units. Example: an F2 flood stage on the Shaviovik River would inundate the geomorphic units Fpa2 and Fpa1, but not Fpa3 or Fpi1 (Table 7, Map 2).

The evidence for flooding on the Shaviovik River was the presence of driftwood and recently transported silts, sands and gravels.

The presence of aufeis in the active channel affects the magnitude of localized spring breakup flooding.

The Shaviovik River, like the Sagavanirktok River, has only three geomorphic units that are inundated by flood waters (Table 8). The fluvial regime of the Shaviovik River north (downstream) of the Kavik River junction can best be compared to the fluvial regime of the Kuparuk River, south (upstream) of the Toolik River junction, which also has only three geomorphic units that flood (Table 9).

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this floodstage the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

Table 7 Shaviovik River flooding unit/geomorphic unit relationships.

North (downstream) of the Kavik River Junction

Flooding Units	Geomorphic Units
F1	Fpa1
F2	Fpa2
F3	Fpa3
F4 (non-flooding)	Fpi1

Table 7 continued on next page

Table 7 continued

South (upstream) of the Kavik River Junction

Flooding Units	Geomorphic Units
F1	Fpa1
F2, F3	Fpa2
F4 (non-flooding)	Fpi1, Fpi2

Cpt1 is non-flooding.
Flooding units are from Map 2.
Geomorphic units are from Map II.

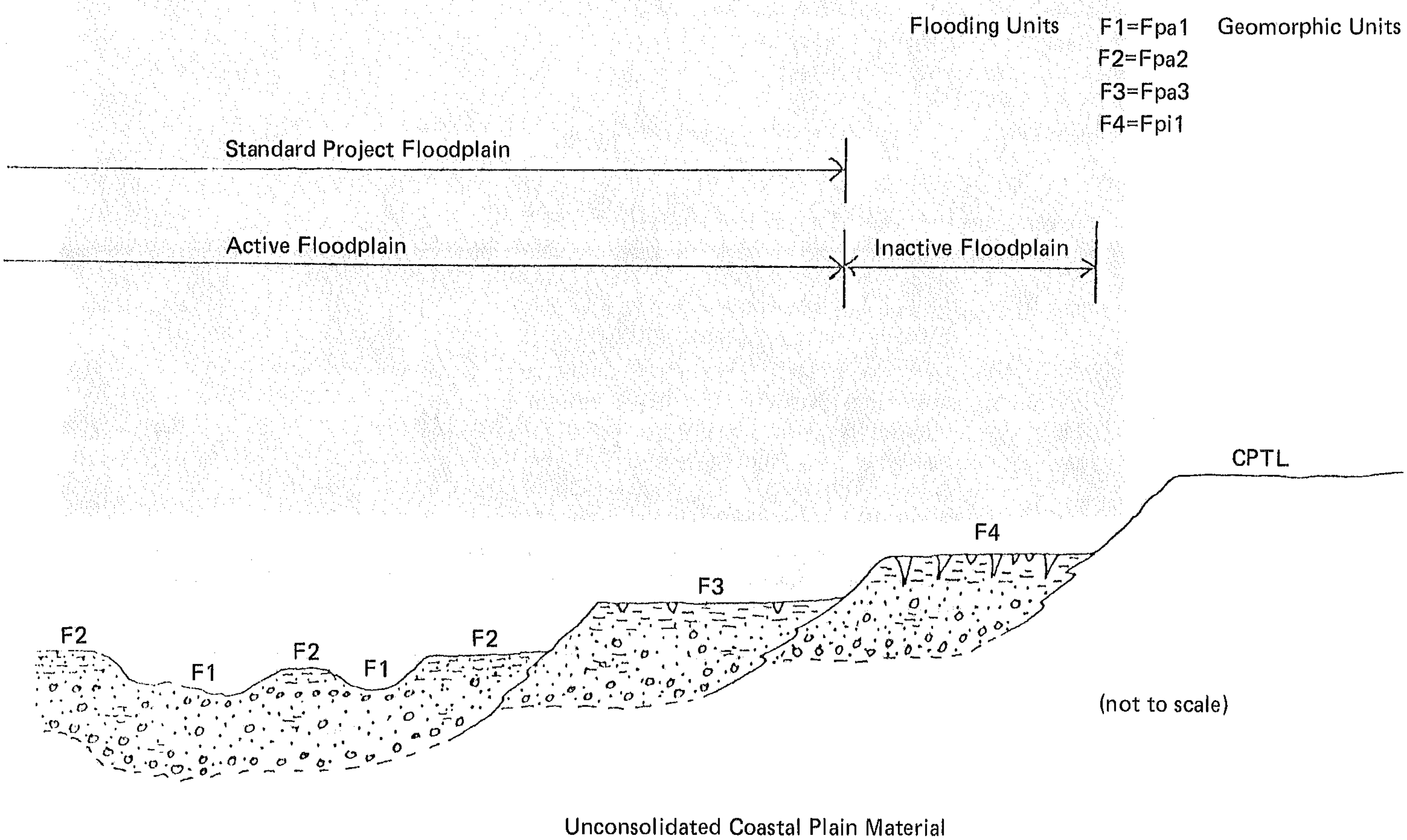
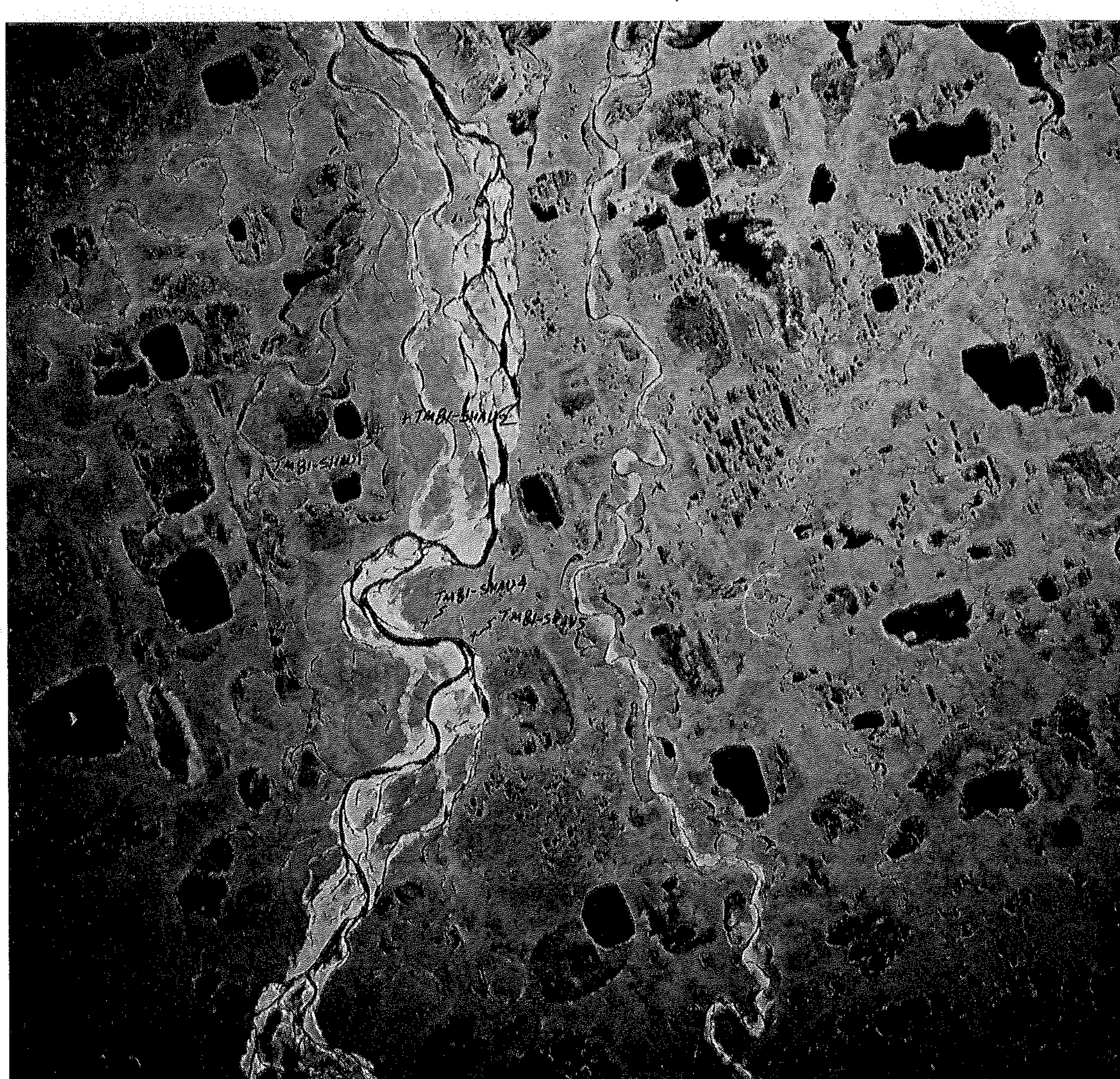


Figure 11
Generalized cross-section of the Shaviovik River geomorphology/flooding relationships. By author.



NASA U-2 infrared aerial photograph of the Shaviovik River. Notations on the photograph indicate field verification sites. The scene is 9 miles across. Flight line 19, frame number 2496, July 1979.

Table 8 Sagavanirktok River flooding unit/geomorphic unit relationships.

Flooding Units	Geomorphic Units
F1	Fpa1
F2, F3	Fpa2
F4	Fpa3
F5 (non-flooding)	Fpi1
F6 (non-flooding)	Fpi2

Cpt1 and Cpau units are non-flooding.
Flooding units are from Map 3.

Table 9 Kuparuk River flooding unit/geomorphic unit relationships.

From sea level to the Toolik River junction	
Flooding Units	**Geomorphic Units**
F1	Fpa1
F2	Fpa2
F3	Fpa3
F4	Fpa4
F5 (non-flooding)	Fpi1

From the Toolik River junction to the 250 ft. contour	
Flooding Units	**Geomorphic Units**
F1	Fpa1
F2	Fpa2
F3, F4	Fpa3
F5 (non-flooding)	Fpi1

Cpt1 and Cpau units are non-flooding.
Flooding units are from Maps 4a and 4b.

Active channels are braided-meandering floodplain deposits of sand and gravel that may contain small amounts of silt and organic matter. No vegetation, and perennially unfrozen.

Tidal flats are deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be present. These deposits are north of the limit of tidal influence.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa2, as follows:

Channel bar, vegetated; refers to channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel or associated with channel bar or tidal flat units.

Braided floodplain deposits, vegetated; refers to sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick; with moss, grass and low-brush vegetation. Active layer to 1 m thick, continuously frozen.

F3 defines active floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa3.

Fpa3; silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and indistinct polygonal ground. Active eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen, with moderate ice content.

F4 defines an inactive floodplain, not subject to inundation by streams. It is equal to the geomorphic unit Fpi1.

Fpi1; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

South (upstream) of the Shaviovik River-Kavik River junction, the fluvial regime of the river changes. Here, flooding unit F4 is equal to the descriptions of geomorphic units Fpa3 and Fpi1, as they are found north of the Shaviovik-Kavik junction. Geomorphic unit Fpi2 is higher above the active channel than Fpi1, with the same geomorphic description as Fpi1.

Other geomorphic features mapped are:

Cpt1; coastal plain deposits with talik lakes.

Lt; talik lake.

Lo; lake formed by oxbow or chute cutoff.

Sagavanirktok River

On the Sagavanirktok River, there where 12 field verification sites visited using a Bell 206 helicopter on 1 August and 29 August 1981. Low altitude aerial reconnaissance of spring breakup was done with a Cessna 172 on 25-26 May 1981. Additional aerial reconnaissance was done using a Bell 206 helicopter on 20 August and 22 August 1981 (Appendix C).

The Sagavanirktok River channel pattern is a braided-meandering distributary channel from sea level to the 200 ft. contour, and is braided-meandering from the 200 ft. contour to the end of mapping at the 350 ft. contour (Table A-3, Figure 31).

The floodplain geomorphic units of the Sagavanirktok River are cyclic terraces. The term 'terrace' used here describes only the physical unit, it does not infer an active or inactive floodplain unit (Tables 6 and 8, Figures 15 and 16).

The flooding unit is the relative magnitude of flood waters needed to inundate a specific geomorphic unit or units. Example: an F3 flood stage on the Sagavanirktok River would inundate the geomorphic units Fpa2 and

Pfa1, but not Fpa3, Fpi1 or Fpi2 (Table 8, Map 3).

The evidence of flooding on the Sagavanirktok River was the presence of driftwood, and recently transported silts, sands and gravels.

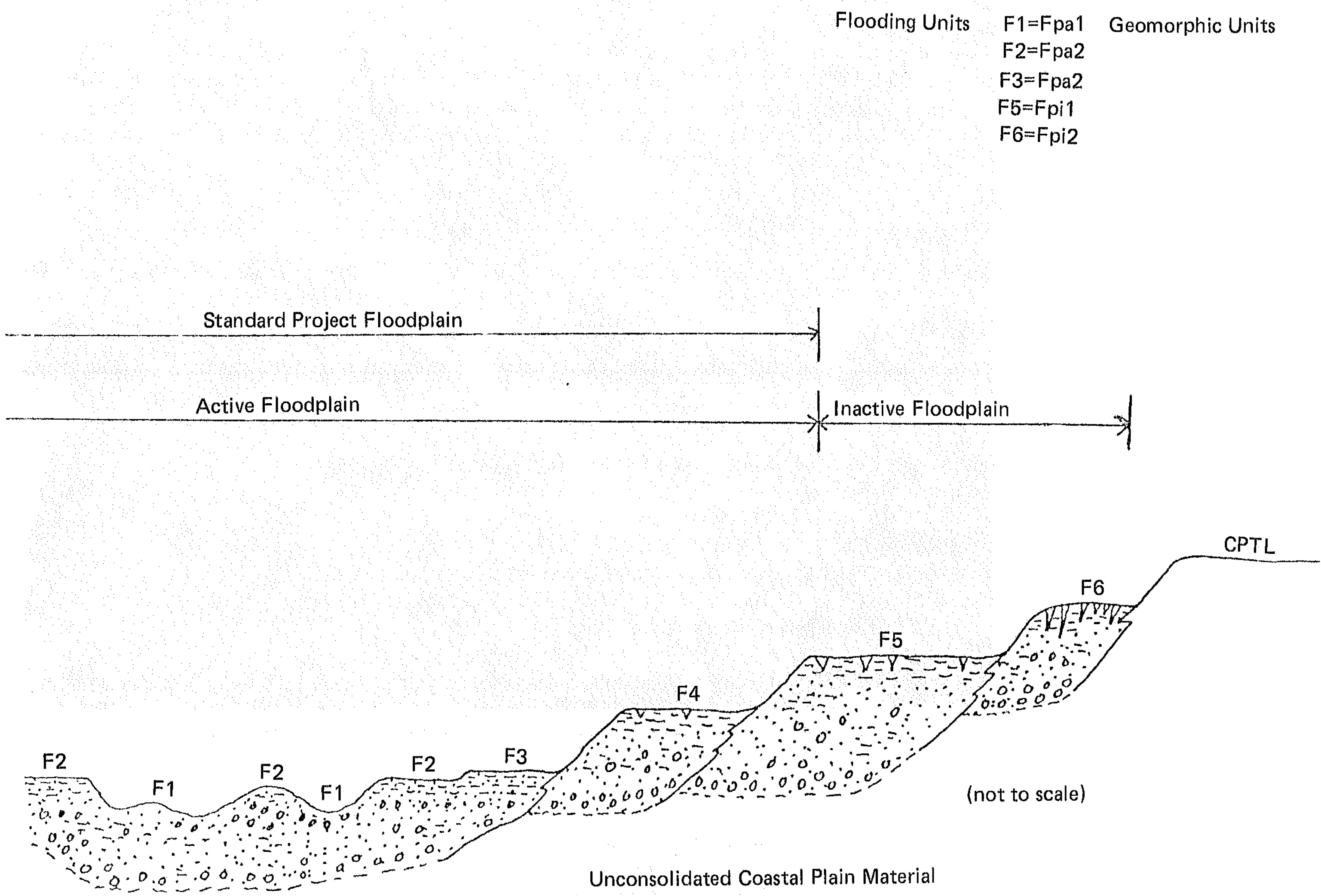
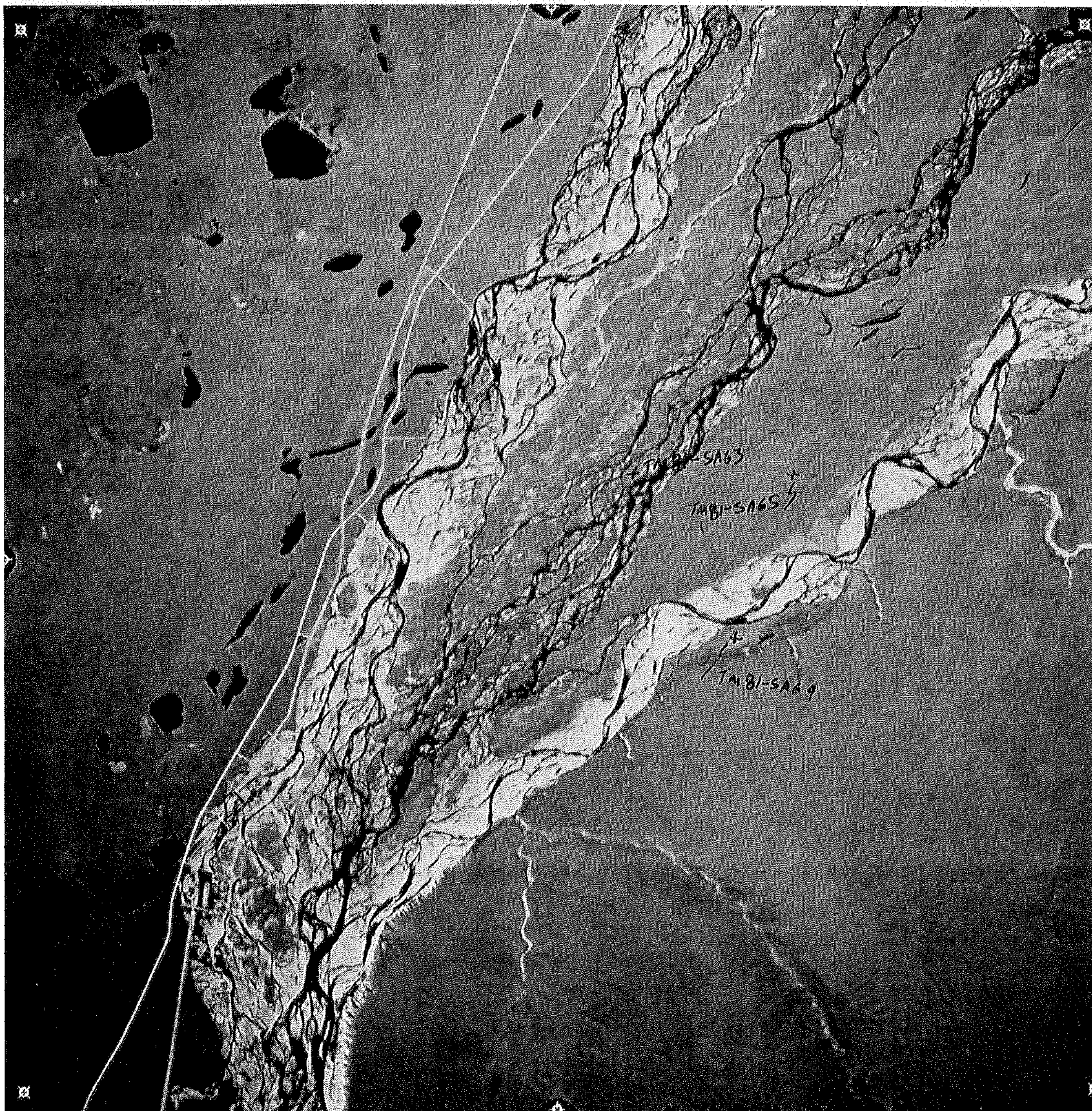


Figure 15
Generalized cross-section of the Sagavanirktok River geomorphology/flooding relationships. By author.



NASA U-2 infrared aerial photograph of the Sagavanirktok River. Notations indicate field verification sites. The scene is 9 miles across. Flight line 20, frame number 2422, July, 1979.

The presence of aufeis in the active channels affects the magnitude of localized spring breakup flooding.

The Sagavanirktok River is a misfit or underfit stream, in that the discharge of the river is small when compared to its floodplain. The Sagavanirktok River has only three geomorphic units that are inundated by floodwaters, and two geomorphic units that do not flood (Map 3). The river today has a smaller discharge than when it inundated the present Fpi1 (inactive floodplain) unit, which is geomorphically equivalent to the Fpa4 (active floodplain) units of the Colville, Kuparuk and Canning Rivers (Table 6).

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

Active channels are braided-meandering floodplain deposits of sand and gravel that may contain small amounts of silt and organic matter. No vegetation, subject to aufeis, and perennially unfrozen.

Tidal flats are deposits of fine sand and smaller amounts of silt, with some clay. Organic matter may also be present. These deposits are north of the limit of tidal influence.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa2, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel or associated with channel bar or tidal flat units.

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick. Moss, grass and low brush vegetation. Active layer to 1 m thick, continuously frozen.

F3 defines active floodplain. A sub-unit of F2, with a slightly higher flooding level. It is equal to geomorphic unit Fpa2.

F4 defines action floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa3.

Fpa3; silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and indistinct polygonal ground. Generally bounded by well-defined scarps. Active eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate ice content.

F5 defines an inactive floodplain unit, not subject to inundation by streams. It is equal to the geomorphic unit Fpi1.

Fpi1; higher above the active channel that Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick. Continuously frozen with moderate to high ice content.

F6 defines an inactive floodplain unit. Not subject to inundation by streams, it is equal to the geomorphic unit Fpi2.

Fpi2; higher above the active channel that Fpi1. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show modified meander and braiding scars and ice-wedge polygons. Stabilized dunes, pingos and small lakes may be present. Tundra vegetation. Active layer to 1 m thick, continously frozen with moderate to high ice content.

The other geomorphic features mapped are:

Cpt1; coastal plain deposits with talik lakes.

Cpau; coastal plain, alluvial deposits.

Lt; talik lake.

Lo; lake formed by oxbow or chute cutoff.

Al; alluvium.

Kuparuk River

On the Kuparuk River there were 26 field verification sites visited using a Bell 206 helicopter on 1 August, 20 August and 29 August 1981. Field sites were also checked on foot near the Kuparuk River Bridge on 31 July 1981. Low altitude aerial reconnaissance of spring breakup was done with a Cessna 172 on 25-26 May 1981 (Appendix C).

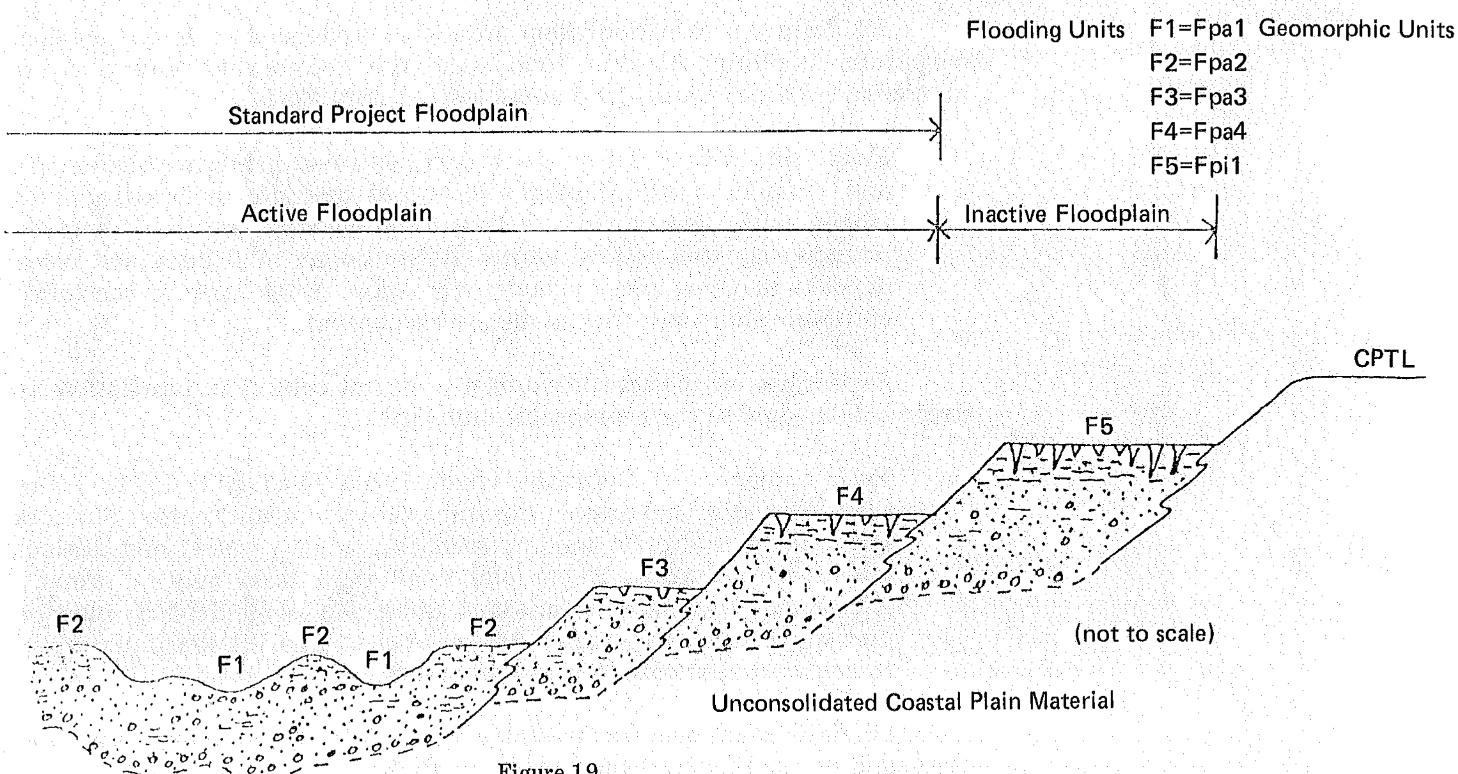


Figure 19
Generalized cross-section of the Kuparuk River geomorphology/flooding relationships. By author.

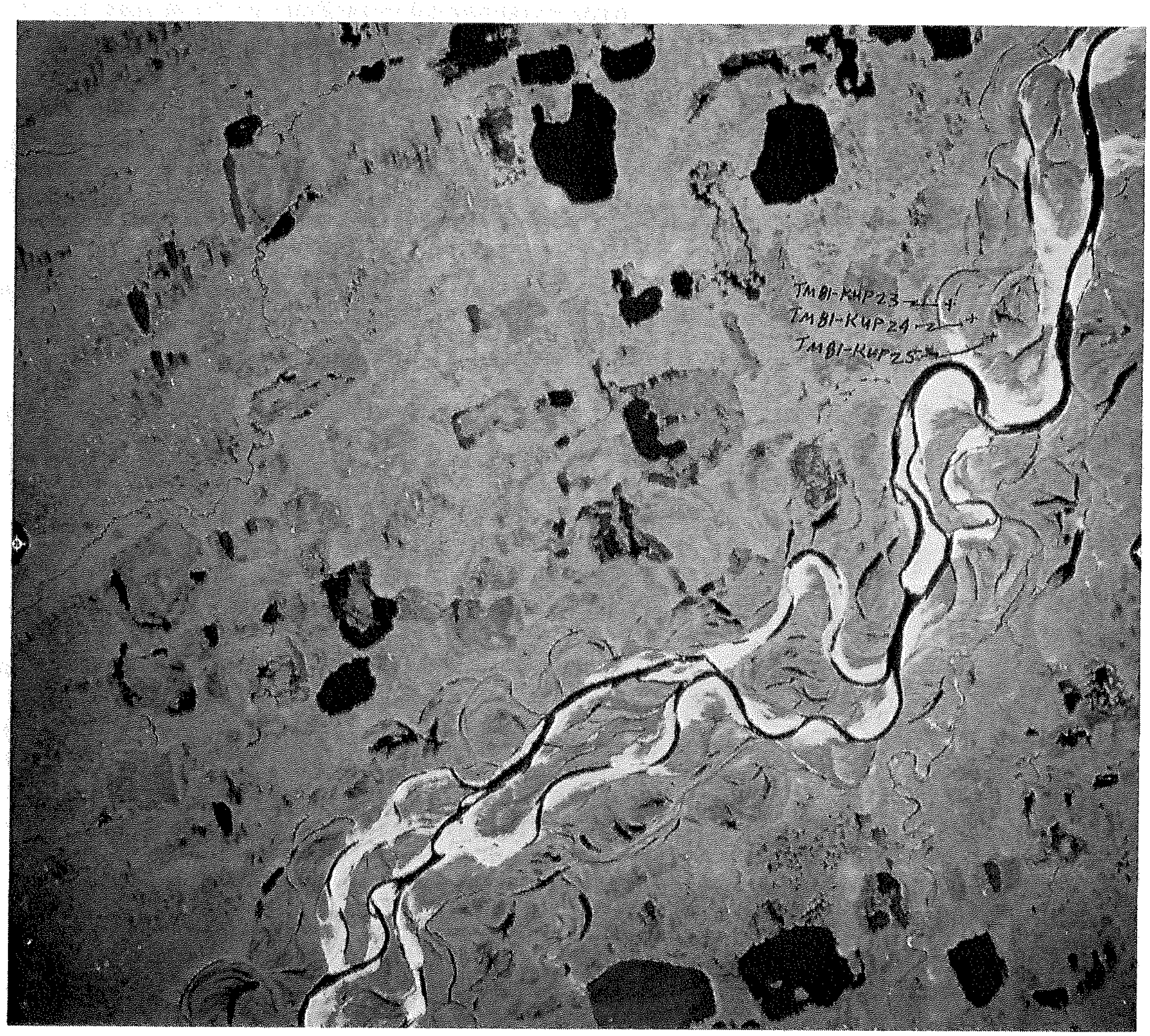
The Kuparuk River channel pattern is braided-meandering from sea level to the 175 ft. contour, and meandering from the 175 ft. contour to the end of mapping at the 250 ft. contour (Table A-4, Figure 31).

The floodplain geomorphic units of the Kuparuk River are cyclic terraces. The term 'terrace' used here describes only the physical unit, it does not infer an active or inactive floodplain unit (Tables 6 and 9, Figures 19 and 20).

The flooding unit is the relative magnitude of flood waters needed to inundate a specific geomorphic unit or units. Example: an F3 flood stage on the Kuparuk River would inundate the geomorphic units Fpa3, Fpa2 and Fpa1, but not Fpa4 or Fpi1 (Table 9, Maps 4a and 4b).

The evidence for flooding on the Kuparuk was the presence of driftwood and recently transported silts, sands and gravels.

The presence of aufeis in the active channel affects the magnitude of localized spring breakup flooding.



NASA U-2 infrared aerial photograph of the Kuparuk River. Notations indicate field verification sites. The scene is 9 miles across. Flight line 19, frame number 2483, July, 1979.

Kuparuk River Delta

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

Active channels are braided-meandering distributary floodplain deposits of sand and gravel, may contain small amounts of silt and organic matter. No vegetation, perennially unfrozen.

Tidal flats are deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be present. These deposits are north of the limit of tidal influence.

Salt marshes are areas north of the limit of tidal influence, with lag and accumulated deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be intercalated. These areas were once one type of Fpa3 or Fpa4 unit that has been denuded by inundation of saline waters. Vegetation is restricted to salt resistant grasses.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa2, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel or associated with channel bar or tidal flat units.

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick. Moss, grass and low brush vegetation. Active layer to 1 m thick, continuously frozen.

Tidal flats, vegetated; deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be present.

Fluvial, low deltaic terrace deposits; fine sand and silt with low to moderate amounts of organic matter. Surfaces show old meander scars (some with water) and indistinct polygonal ground. This unit is generally bounded by well-defined scarps. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate ice content.

F3 defines active floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa3.

Fpa3; fine sand and silt with low to moderate amounts of organic matter. Surfaces show old meander scars (some with water) and indistinct polygonal ground. This unit is generally bounded by well-defined scarps. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick. Continuously frozen with moderate ice content.

F4 defines active floodplain areas that undergo very low frequency-very high magnitude flooding. At this flood stage the geomorphic units that inundated by water are grouped under the category Fpa4.

Fpa4; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander and braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

F5 defines an inactive floodplain unit not subject to inundation by streams. It is equal to the geomorphic unit Fpi1.

Fpi1; higher above the active channel than Fpa4. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show modified meander and braiding scars with polygons. Stabilized dunes, pingos and small thaw lakes may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

Kuparuk River from north (downstream) of the Kuparuk River-Toolik River junction to the Kuparuk River Delta

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

Active channels are braided-meandering floodplain deposits of sand and gravel, and may contain small amounts of silt and organic matter. No vegetation, perennially unfrozen.

F2 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel or associated with channel bar or tidal flat units.

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick.

Moss, grass and low brush vegetation. Active layer to 1 m thick, continuously frozen.

F3 defines active floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa3.

Fpa3; fine sand and silt with low to moderate amounts of organic matter. Surfaces show old meander scars (some with water) and indistinct polygonal ground. This unit is generally bounded by well-defined scarps. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate ice content.

F4 defines active floodplain areas that undergo very low frequency-very high magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa4.

Fpa4; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander and braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

F5 defines an inactive floodplain unit not subject to inundation by streams. It is equal to the geomorphic unit Fpi1.

Fpi1; higher above the active channel than Fpa4. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show modified meander and braiding scars with polygons. Stabilized dunes, pingos and small thaw lakes may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

Kuparuk River south (upstream) of the Kuparuk River-Toolik River junction

Flooding unit F4 is equal to the Kuparuk River geomorphic unit Fpa3.

Flooding unit F5 (inactive floodplain) is equal to the Kuparuk River geomorphic unit Fpa4. For this section of the river, Fpa4 is redefined as Fpi1.

The other geomorphic features mapped are:

Cpt1; coastal plain deposits with talik lakes.

Cpau; coastal plain, alluvial uplands.

Lt; talik lake.

Lo; lake formed by oxbow or chute cutoff.

Colville River

On the Colville River there were 84 field verification sites visited using a Bell 206 helicopter on 21 August and 29 August 1981. Low altitude aerial reconnaissance of spring breakup was done with a Cessna 172 on 25 May 1981 (Appendix C).

The Colville River channel pattern is distributary from sea level to four miles north (downstream) of the Itkillik River junction, meandering from four miles north (downstream) of the Itkillik River junction to the 50 ft. contour, and braided-meandering from the 50 ft. contour to the end of mapping at the 275 ft. contour (Table A-5).

The floodplain geomorphic units of the Colville River are cyclic terraces. The term 'terrace' used here describes only the physical unit, it does not infer an active or inactive floodplain unit (Tables 6 and 10, Figures 23 and 24).

The presence of aufeis in the active channel affects the magnitude of localized spring breakup flooding.

Table 10 Colville River flooding unit/geomorphic unit relationships.

From sea level to 4 miles north (downstream) of the Itkillik River junction

Flooding Units	Geomorphic Units
F1	Fpa1
F2	Fpa2
F3	Fpa3, Fpa4
F4	Fpa4
F5 (non-flooding)	Fpi1
F6 (non-flooding)	Fpi2

From 4 miles north (downstream) of the Itkillik River junction south (upstream) to the Chandler River-Anaktuvik River junctions

Flooding Units	Geomorphic Units
F1	Fpa1
F2	Fpa2
F3	Fpa3
F4	Fpa4
F5 (non-flooding)	Fpi1

Table 10 continued on next page

Table 10 continued

From the Chandler River and Anaktuvik River junction west (upstream) to the end of mapping at the 275 ft. contour

Flooding Units	Geomorphic Units
F1	Fpa1
F2, F3	Fpa2
F4	Fpa3
F5 (non-flooding)	Fpi1

Cpt1 and Cpau units are non-flooding.
Flooding units are from Maps 5a, 5b and 5c.
Geomorphic units are from Map V.

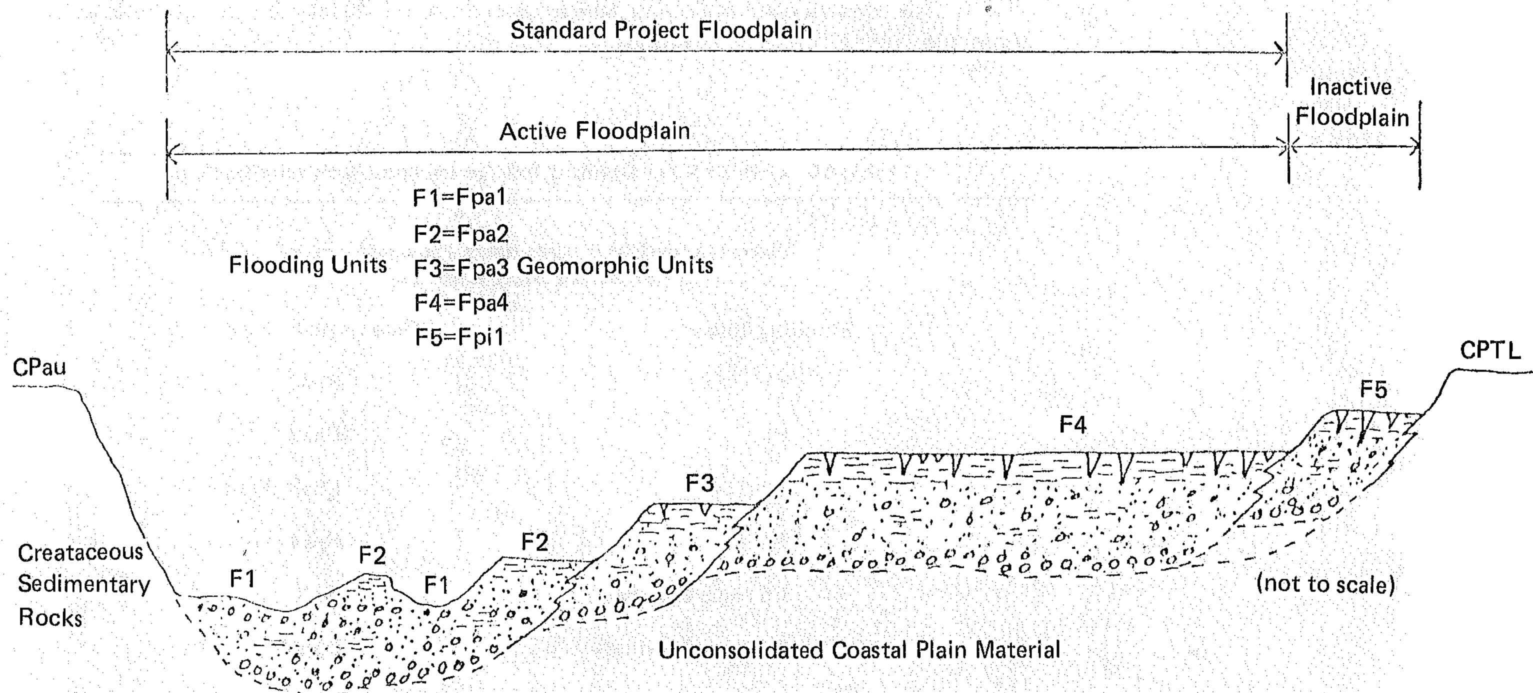


Figure 23
Generalized cross-section of the Colville River geomorphology/flooding relationships. By author.

The flooding unit is the relative magnitude of flood waters needed to inundate a specific geomorphic unit or units. Example: an F3 flood stage in the north half of the Colville River Delta would inundate the geomorphic units Fpa4, Fpa3, Fpa2 and Fpa1, but not Fpi1 or Fpi2 (Table 10, Map 5a). A flood of this magnitude would place the entire north half of the Colville River Delta under flood waters, while an F3 flood stage occurring on the Colville River between the Itkillic and the Anaktuvik Rivers would inundate the geomorphic units Fpa3, Fpa2 and Fpa1, but not Fpa4 or Fpi1 (Table 10, Map 5b).

The evidence for flooding on the Colville River Delta was ice block gouging of the tundra, the presence of driftwood and recently transported silts, sands and gravels. The evidence for flooding on the Colville River was the presence of driftwood and recently transported silts, sands and gravels.

Colville River Delta

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa1, as follows:

> *Active channels* are braided-meandering distributary floodplain channel deposits of sand and gravel, may contain small amounts of silt and organic matter. No vegetation, perennially unfrozen.

NASA U-2 infrared aerial photograph of the Colville River delta. Notations on the photograph indicate field verification sites. The scene is 9 miles across. Flight line 16, frame number 3368, July 1979.

Tidal flats are deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be present. These deposits are north of the limit of tidal influence.

Salt marshes are areas within the zone of tidal influence with lag and accumulated deposits of fine sand and smaller amounts of silt with some clay. Organic matter may also be intercalated.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa2, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel or associated with channel bar or tidal flat units.

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick. Moss, grass and low brush vegetation. Active layer to 1 m thick, continuously frozen.

Tidal flats, vegetated; deposits of fine sand and smaller amounts of silt with some clay. Organic matter may be present. These deposits are north of the limit of tidal influence.

F3 defines active floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage, in the north half of the Colville River Delta the geomorphic units that are inundated by water are grouped under the categories Fpa3 and Fpa4.

Fpa3; silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and indistinct polygonal ground. Generally bounded by well-defined scarps. Active eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate ice content.

Fpa4; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons. Pingos may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

The F3 flood unit in the north half of the delta may include some areas that are actually F4 flood units, and some F5 non-flood units.

F4 defines active floodplain areas that undergo very low frequency-very high magnitude flooding. From the south half of the Colville River Delta to the Colville River-Chandler River junction, the geomorphic units that are inundated by this flood stage are grouped under the category Fpa4.

Fpa4; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1m thick, continuously frozen with moderate to high ice content.

The flooding in the F4 unit may result from temporary ice block damming during spring breakup. The flooding in this unit appears to be localized and associated with the main and side channels within the Fpa4 units. Flood unit F4 may contain areas that are actually F3 flood units and F5 non-flood units.

F5 defines an inactive floodplain unit, not subject to inundation by streams. From the south half of the Colville River Delta to the Colville River-Chandler River junction the geomorphic units are equal to Fpi1.

Fpi1; higher above the active channel than Fpa4. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show modified meander and braiding scars and polygons. Stabilized dunes. Pingos and small thaw lakes may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

F6 defines an inactive floodplain unit, not subject to inundation by streams. It is equal to the geomorphic unit Fpi2.

Fpi2; higher above the active channel than Fpi1, with the same geomorphic description.

Colville River from north (downstream) of the Colville River-Chandler River junction to 4 miles north of the Itkillik River

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic unit that is inundated by water is Fpa1, as follows:

Active channels are braided-meandering and meandering floodplain channel deposits of sand and gravel that may contain small amounts of silt and organic matter. No vegetation, perennially unfrozen.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage the geomorphic units that are inundated by water are grouped under the category Fpa2, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel deposits.

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick. Moss, grass and low brush vegetation. Active layer to 1 m thick, continuously frozen.

F3 defines active floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic unit that is inundated by water is Fpa3.

Fpa3; silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and indistinct polygonal ground. Generally bounded by well-defined scarps. Active eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen with moderate ice content.

F4 defines active floodplain areas that undergo very low frequency-very high magnitude flooding. The geomorphic unit that is inundated by water at this flood stage is Fpa4.

Fpa4; higher above the active channel than Fpa3. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Active and stabilized eolian sand dune and cover deposits may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen, with moderate to high ice content.

The flooding in the F4 unit may result from temporary ice block damming during spring breakup. The flooding in this unit appears to be localized and associated with the main and side channels within the Fpa4 units. Flood unit F4 may contain areas that are actually F3 flood units and F5 non-flood units.

F5 defines an inactive floodplain unit, not subject to inundation by streams. It is equal to the geomorphic unit Fpi1.

Fpi1; higher above the active channel than Fpa4. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show modified meander and braiding scars and polygons. Stabilized dunes. Pingos and small thaw lakes may be present. Tundra vegetation. Active layer to 1 m thick, continuously frozen, with moderate to high ice content.

Colville River from the Colville River-Chandler River junction, upstream to the end of mapping at the 275 ft. contour line

F1 defines active floodplain areas that undergo high frequency-low magnitude flooding. At this flood stage the geomorphic unit that is inundated by water is Fpa1, as follows:

Active channels are braided-meandering floodplain channel deposits of sand and gravel. May contain small amounts of silt and organic matter. No vegetation. Perennially unfrozen.

F2 defines active floodplain areas that undergo intermediate frequency-intermediate magnitude flooding. At this flood stage the geomorphic unit that is inundated by water is Fpa2, as follows:

Channel bar, vegetated; channel bars of fine to medium sand with grass and/or low shrub vegetation. These units are in-channel deposits.

F3 defines floodplain areas that undergo low frequency-high magnitude flooding. At this flood stage the geomorphic unit that is inundated by water is defined as Fpa2, as follows:

Braided floodplain deposits, vegetated; sand and gravel with some silt and organic matter, with silt cover generally less than 1 m thick. Moss, grass and low brush vegetation. Active layer to 1 m thick, continuously frozen.

F4 defines active floodplain areas that undergo very low frequency-very high magnitude flooding. At this flood stage the geomorphic unit that is inundated by water is defined as Fpa3.

Fpa3; higher above the active channel than Fpa2. Silts 1.0 to 1.5 m thick over sand and gravel with some silt and organic matter. Surfaces show old meander or braiding scars (some with water) and distinct low-center polygons. Pingos and small thaw lakes may be present. Active layer to 1 m thick, continuously frozen with moderate to high ice content.

F5 defines an inactive floodplain unit, not subject to inundation by streams. At this location of the Colville River drainage, it is defined as geomorphic unit Fpi1. Its geomorphic description is equal to geomorphic units Fpa4 and Fpi1 as described for the Colville River from the Colville-Chandler junction, to 4 miles north of the Itkillik River.

The other geomorphic features mapped are:

Cpt1; coastal plan deposits with talik lakes.

Cpau; coastal plain, alluvial uplands.

L; lake.

Lt; talik lake.

Lo; lake formed by oxbow or chute cutoff.

Fp; floodplain deposits, undifferentiated.

SUMMARY OF CONCLUSIONS

The rivers of Arctic Alaska are unique and must be treated as a special case for floodplain mapping. The five rivers of this study cannot be directly compared to temperate rivers. All of the study rivers differ significantly from each other in overall morphology, even though they run across similar geology, erode similar materials (frozen sands and gravels), exist in a similar climate, and have roughly the same gradients. The morphologic differences between the study rivers reflect differences in the geomorphic processes affecting them. These processes include:

1) The amount and location of channel aufeis.

2) The loss of ground ice.

3) The geomorphic history of each river.

Flooding which occurs at breakup may be the largest flooding event, but may have the least Physical effect, because the ground is still largely frozen at that time. Recurrence intervals used to determine flooding frequencies in other areas cannot be applied to the Arctic rivers, because of the presence of ice and frozen materials.

Floodplain geomorphology may be used to delineate flooding levels of Arctic rivers, as long as the possible changes of the geomorphology/flooding relationships along a particular drainage are accounted for (Table 6).

The general lack of overbank deposits in areas of high frequency flooding (as would be expected along a temperate river system with similar gradients) leads me to conclude that very small amounts of sand/silt sized materials are transported by the study rivers during flood stage.

As proposed by previous research (Cannon, 1979), this study supports the theory that the Sagavanirktok River is presently a misfit stream; the present discharge of the river cannot account for the extent of the floodplain it occupies.

The flooding potential maps produced from this study do not predict the probability of flooding. Accurate, long-term hydrologic records of each river are necessary before the map units designating the flooding potential can be converted to flooding probabilities.

The role that channel aufeis conditions and temporary ice damming play in the spring breakup flooding of Arctic rivers is not fully understood. I therefore recommend that further research should concentrate in this area. I suggest that, along with visual observations, radar imagery should be taken of each river during the spring breakup. Radar imagery would provide high resolution coverage of the rivers during breakup and would not be hampered by the low clouds that are common across the Arctic Coastal Plain at this time of year. Radar coverage should be obtained during spring break-up for a period of several years.

Table A-1 Canning River channel profile data from U.S. Geological Survey topographic maps (Appendix B and Figure 31).

Channel Distance (miles)	Change in Distance	Feet above Sea Level	Change in Elevation	Gradient (feet per mile)	Channel Pattern
10.0	10.0	25	25	2.5	braided
11.5	1.5	50	25	16.7	braided
14.5	3.0	75	25	8.3	braided
17.5	3.0	100	25	8.3	braided
21.0	3.5	125	25	7.1	braided
22.0	1.0	150	25	25.0	braided
23.5	1.5	175	25	16.7	braided
25.0	1.5	200	25	16.7	braided
27.0	2.0	225	25	12.5	braided
28.5	1.5	250	25	16.7	braided
29.5	1.0	275	25	25.0	braided
30.5	1.0	300	25	25.0	braided
32.0	1.5	325	25	16.7	meandering
34.5	2.5	350	25	10.0	meandering

Table A-2 Shaviovik River channel profile data from U.S. Geological Survey topographic maps (Appendix B and Figure 31).

Channel Distance (miles)	Change in Distance	Feet above Sea Level	Change in Elevation	Gradient (feet per mile)	Channel Pattern
12.5	12.5	25	25	2.0	braided-meandering
16.5	4.0	50	25	6.3	braided-meandering
19.0	2.5	75	25	10.0	braided-meandering
25.0	6.0	100	25	4.2	braided-meandering

Table A-2 continued on next page

Table A-2 continued

26.0	1.0	125	25	33.3	braided-meandering
29.5	3.5	150	25	7.1	braided-meandering
30.5	1.0	175	25	25.0	braided-meandering
33.5	3.0	200	25	8.3	braided-meandering
36.5	3.0	225	25	8.3	braided-meandering
38.0	1.0	250	25	16.7	braided-meandering
40.0	2.0	275	25	12.5	braided-meandering

Table A-3 Sagavanirktok River channel profile data from U.S. Geological Survey topographic maps (Appendix B and Figure 31).

Channel Distance (miles)	Change in Distance	Feet above Sea Level	Change in Elevation	Gradient (feet per mile)	Channel Pattern
15.0	15.0	25	25	1.7	braided-meandering
23.0	8.0	50	25	3.1	braided-meandering
24.5	1.5	75	25	16.7	braided-meandering
29.0	4.5	100	25	5.6	braided-meandering
30.5	1.5	125	25	16.7	braided-meandering
34.5	4.0	150	25	6.3	braided-meandering
37.0	2.5	175	25	10.0	braided-meandering
39.0	2.5	200	25	10.0	braided-meandering
40.5	1.5	225	25	16.7	braided-meandering
46.5	6.0	250	25	4.2	braided-meandering

Table A-3 continued on next page

Table A-3 continued

48.5	2.0	275	25	12.5	braided-meandering
50.0	1.5	300	25	16.7	braided-meandering
53.0	3.0	325	25	8.3	braided-meandering
56.0	3.0	350	25	8.3	braided-meandering

Table A-4 Kuparuk River channel profile data from U.S. Geological Survey topographic maps (Appendix B and Figure 31).

Channel Distance (miles)	Change in Distance	Feet above Sea Level	Change in Elevation	Gradient (feet per mile)	Channel Pattern
14.5	14.5	25	25	1.7	braided-meandering
19.0	4.5	50	25	5.6	braided-meandering
27.0	8.0	75	25	3.1	braided-meandering
34.0	7.0	100	25	3.6	braided-meandering
4.1	7.0	125	25	3.6	braided-meandering
47.5	6.5	150	25	3.8	braided-meandering
52.0	4.5	175	25	5.6	meandering
60.5	8.5	200	25	2.9	meandering
66.5	6.0	225	25	4.2	meandering
82.0	15.5	250	25	1.6	meandering

Table A-5 Colville River channel profile data from U.S. Geological Survey topographic maps (Appendix B and Figure 31).

Channel Distance (miles)	Change in Distance	Feet above Sea Level	Change in Elevation	Gradient (feet per mile)	Channel Pattern
43.5	43.5	25	25	0.6	meandering
68.5	25.0	50	25	1.0	braided-meandering
74.5	6.0	75	25	4.2	braided-meandering
87.0	12.5	100	25	2.0	braided-meandering
90.5	3.5	125	25	7.1	braided-meandering
103.5	13.0	150	25	1.9	braided-meandering
114.0	10.5	200	50	4.8	braided-meandering
120.5	6.5	250	50	7.7	braided-meandering
134.0	13.5	300	50	3.7	braided-meandering

APPENDIX B
SOURCES OF MAPPING DATA

Table B-1 Canning River mapping data.

Aerial photography	-	NASA color infrared U-2 photography	
		Flight Lines	**Frame Numbers**
		19	2503-2507
		20	2405-2408
		21	320-325
		22	289-290
Landsat Imagery	-	E-21597-20522-7 (7 June, 1979)	
U.S.G.S. topographic maps	-	Flaxman Island (1955) A-3, A-4 Mt. Michelson (1955) C-4, D-4, D-5	

Table B-2 Shaviovik River mapping data.

Aerial photography	-	NASA color infrared U-2 photography		
		Flight Lines		**Frame Numbers**
		19		2495-2496
		20		2414-2415
		U.S.G.S. 1955 mapping photography		
		Mission	**Roll**	**Frame Numbers**
		36	62	7495-7498
Landsat Imagery	-	E-2501-21051-7 (6 June, 1976) E-2897-20493-5 (7 July, 1977) E-2915-20483-5 (25 July, 1977)		
U.S.G.S. topographic maps	-	Beechey Point (1955) A-1 Sagavanirktok (1955) D-1, D-2		

Table B-3 Sagavanirktok River mapping data.

Aerial photography	-	NASA color infrared U-2 photography	
		Flight Lines	**Frame Numbers**
		19	2487-2491
		20	2420-2423
		21	2364-2365
		22	2294-2296
Landsat Imagery	-	E-2501-21051-7 (6 June, 1976) E-2897-20493-5 (7 July, 1977) E-2915-20483-5 (25 July, 1977)	
U.S.G.S. topographic maps	-	Beechey Point (1955) A-2, A-3, B2, B-3, D-3 Beechey Point (1971) B-3, C-3	

Table B-4 Kuparuk River mapping data.

Aerial photography	-	NASA color infrared U-2 photography		
		Flight Lines		**Frame Numbers**
		16		3378-3380
		19		2482-2485
		20		2426-2428
		21		2359-2360
		22		2300-2301
		U.S.G.S. 1955 mapping photography		
		Mission	**Roll**	**Frame Numbers**
		37	64	7750-7751
		37	64	7692-7693
		37	64	7781-7782
		37	66	8166-8167
Landsat Imagery	-	E-2501-21051-7 (6 June, 1976) E-2897-20493-5 (7 July, 1977) E-2915-20483-5 (25 July, 1977)		
U.S.G.S. topographic maps	-	Beechey Point (1955) A-4, A-5, B-4 Sagavanirktok (1955) C-5, D-4, D-5		

Table B-5 Colville River mapping data.

Aerial photography	-	NASA color infrared U-2 photography	
		Flight Lines	**Frame Numbers**
		15	3249-3252
		16	3365-3371
		19	2468-2474
		20	2437-2441
		21	2345-2348
		22	2311-2314
		23	8281-8285
		24	2281-2284
		25	2273-2276
		26	8322-8328
Landsat Imagery	-	E-30130-21225-D (13 July, 1978) E-30130-21225-B (13 July, 1978) E-2501-21051-7 (6 June, 1976) E-2897-20493-5 (7 July, 1977) E-2915-20483-5 (25 July, 1977)	
U.S.G.S. topographic maps	-	Harrison Bay (1955) A-2, A-3, B-1, B-2 Umiat (1955) B-3, B-4, C-3, D-3	

APPENDIX C
FIELD SITE LOCATIONS

Canning River - 11 field verification sites. On 22 August, 1981, field verification sites TM81-CAN1 to TM81-CAN10 were visited.

Shaviovik River - 6 field verification sites. On 20 August, 1981, field verification sites TM81-SHAV1 to TM81-SHAV6 were visited.

Sagavanirktok River - 14 field verification sites. On 1 August, 1981, field verification sites TM81-SAG3 to TM81-SAG10 were visited. On 29 August, 1981, field verification sites TM81-SAG11 and TM81-SAG12 were visited.

Kuparuk River - 28 field verification sites. On 31 July, 1981, field verification sites TM81-KUP10 and TM81-KUP13 to TM81-KUP15 were visited. On 1 August, 1981, field verification sites TM81-KUP6 to TM81-KUP11 and TM81-KUP16 were visited. On 20 August, 1981, field verification sites TM81-KUP1 to TM81-KUP4 were visited. On 30 August, 1981, field verification sites TM81-KUP17 to TM81-KUP30 were visited.

Colville River - 84 field verification sites. On 21 August, 1981, field verification sites TM81-COL1 to TM81-COL9 were visited. On 29 August, 1981, 75 field sites were checked using very low altitude and ground observations with a Bell 206 helicopter. These field sites are not individually numbered. Their location is designated by TM81-COL.

For all five of the study rivers, there were 143 field verification sites visited, 138 of them using helicopter transportation. Low altitude aerial reconnaissance of spring breakup flooding of all the study rivers was done with a Cessna 172 on 25-26 May 1981.

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