SOUTHCENTRAL RAILBELT AREA ALASKA
UPPER SUSITNA RIVER BASIN

ERIM FEASIBILITY REPORT

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APPENDIX 1
PART 1

HYDROELECTRIC POWER

AND RELATED PURPOSES

U.S. ARMY · CORPS OF ENGINEERS · 1975 · BICENTENNIAL · 1775 · 200th

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UPPER SUSITNA RIVER BASIN

INTERIM FEASIBILITY REPORT

APPENDIX 1
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U.S. Army. Corps of Engineers. Alaska District.

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HYDROELECTRIC POWER

AND RELATED PURPOSES

U.S. ARMY · CORPS OF ENGINEERS · BICENTENNIAL · 1775 · 1975 · 200th

SECTION A

HYDROLOGY

SECTION A

HYDROLOGY

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HYDROLOGY

GENERAL

BASIN DESCRIPTION

The Upper Susitna River Basin contains several topographic features which provide a conglomerate streamflow heavily influenced by specific meteorological events. The basin was shaped by volcanism and diastrophism, subsidence and uplifting, block faulting and intrusion by batholiths, lateral slipping, glacial erosion, and marine deposition which provided the shells and sandstone. The basin is a fan-shaped area comprising about 6,160 square miles and is bordered by the Alaska Range to the north, the Talkeetna Mountains to the southeast, and flat, low-relief areas to the southwest.

Most of the basin has a well-defined dendritic stream pattern with a main channel emanating from glacial headwaters in the extreme northern segment of the divide. Below the glaciers, the braided channel traverses a high plateau deposited by aggraded alluvial sediment and then meanders several miles south to the confluence of the Oshetna River. It then takes a sharp turn to the west and flows through a steeply cut, degrading channel until it exits the basin at Gold Creek. The contributing glacial area comprises only four percent of the entire basin, but summer glacial melt provides a considerable portion of the total streamflow. By contrast, the flat, glacially carved Lake Louise area in the southeastern portion of the basin provides comparatively little flow from its 700-square-mile area.

The mountains within the basin reflect the influence of the Pleistocene Ice Age, during which glacial advancement over the topography planed the mountains and gave the basin surface a rounded and smoothed appearance. The highest elevation within the basin is 13,326 feet, and the lowest elevation is 740 feet. The hypsometric curve for the area above Gold Creek, Graph 1, shows that the basin has reached a mature stage of development. The basin relief implies a steep channel slope; however, variability of the slope compared to other mountain streams is somewhat reversed. The aggraded channel in the upper reaches of the basin has channel slopes in the range of only 4 to 7 feet per mile, while the lower basin channel drops as much as 37 feet per mile.

Main tributaries to the Susitna River have an even higher range of channel slopes, Graph 2. The deeply cut river channel below the Tyone River contrasts with the many traditional Alaskan U-shaped valleys, remnants of glacial advances. The absence of broad flood plains in the lower basin results in high stages during high runoff due to confined flow areas. The Susitna River alluvium has developed into a continuous effluent aquifer. Most of the tributary aquifers do not sustain winter flow.

STREAMFLOWS

The annual streamflow patterns of the upper Susitna River and most of its tributary streams are best described as providing perennial flow. The main tributaries of the Susitna River consist of the East and West Fork Susitna Rivers in the northern section of the drainage basin, the Maclaren River which originates in the northeastern portion of the basin, and the Tyone River which emanates from the southern reaches of the basin.

The flow regime of the Susitna River is seasonal, with the majority of the yearly streamflow occurring from May through September. Summer streamflow consists mainly of snow and glacial melt combined with surface runoff from rainfall. Winter flows are restricted almost entirely to groundwater inflow. Primary water sources for the Maclaren and East and West Fork Susitna Rivers are the numerous glaciers which rim the northern basin divide in the Alaska Range.

The Tyone River contribution is mostly reservoir outflow from the multitude of lakes located within its subbasin. Winter flows begin in early November and are composed of baseflow from subsurface storage. When breakup nears in March and April, subsurface storage is depleted to the extent that many small tributaries cease flowing, and the Susitna River flow shrinks to its seasonal minumum. Following breakup, flows increase rapidly with the onslaught of spring snowmelt. As summer temperatures increase, glacial flow accentuated by rainfall runoff becomes the predominant river source. The cycle repeats itself with winter freezeup.

The variability of streamflow within the basin is extreme. The following table represents average annual streamflow conditions for portions of the basin above the Gold Creek gaging station. Gaging station locations are shown on Plate 1.

Flow Variation in Upper Susitna River Basin

Gaging Station	Drainage Area (Sq Mi)	Percent of Gold Creek Drainage Area	Percent of Gold Creek Streamflow
Maclaren River near Paxson	280	4.5	10.0
Susitna River near Denali	950	15.4	27.6
Susitna River near Cantwell	4140	67.2	64.8
Susitna River at Gold Creek	6160	100.0	100.0

Nearly 38 percent of the Gold Creek streamflow originates from 20 percent of the area. This large percentage of streamflow is contributed by glaciers in the upper portion of the basin and by high precipitation runoff rates which result from impervious glaciers. In addition, it is suspected that the mountains form a geographic constraint, which causes excessive precipitation in this area in relation to the remainder of the basin.

By contrast, the Cantwell gaging station shows a runoff rate not consistent with that which could be expected below the glaciers, indicating that a large area below the Paxson and Denali stations contributes little annual streamflow. This large, low contributing area is believed to be the flat, 700-square-mile Lake Louise area. Flow percentage below the Cantwell station increases slightly to a more nearly normal area-discharge relationship for the basin.

CLIMATE OF THE BASIN

GENERAL DESCRIPTION

The climate of the upper Susitna basin is characterized by cold dry winters and warm but moderately moist summers. The yearly precipitation distribution shows that 64 percent of precipitation occurs from June through October. Within the Railbelt area, the climate is classified into three categories: (1) a zone dominated almost entirely by maritime influences; (2) a zone of transition from maritime to continental climate influences; and (3) a zone dominated by continental climatic conditions. The upper Susitna basin falls within the transitional zone. Climatological and stream gaging station locations are shown on Plate 1.

A compilation of mean monthly precipitation and temperature for locations bordering the basin is shown in Table 1. The record lengths are different for each station, but are for a period through the year 1970. No long-term records are available within the portion of the Susitna basin upstream from Talkeetna. Limited summer precipitation and temperature data gathered from the Gracious House station, located near the Denali Highway bridge, indicate that the climate of this area is similar to that of the Summit station.

The general Railbelt climate variations are presented in Table 2. The contrast between maritime-influenced areas of the southern Kenai Peninsula and continental conditions at Fairbanks is marked. Within the confines of the upper Susitna basin, the lack of moderating influence of maritime air results in greater temperature extremes than on the coast of the Gulf of Alaska. The extreme temperatures in the winter are caused by polar air masses which flow in from the north.

An extrapolation of these climatic conditions would imply that relatively severe winter temperatures contrasted by warm summers would occur within the basin. Mean annual precipitation in lower elevations of the basin would be expected to range between 18 to 22 inches, while precipitation in higher elevations, because of orographic effects, would be expected to reach 80 inches per year. Mean annual snowfall would range from 60 inches in the lowlands to as much as 400 inches in the high mountains. Freezeup in the highest reaches of the Susitna River starts in early October, and by the end of November, the lower regions of the river are icebound. The river breakup begins in early May, and within two weeks of breakup, the river tributaries are free of surface ice.

TEMPERATURE

Based on average climatological conditions reported at Gracious House and assuming that winter basin conditions are similar to those at the Summit station, the average annual basin temperature would be approximately 26°F. At Summit, the extreme temperatures recorded were minus 45°F in January 1967, and 81°F in July 1971. Based on the longer period of record of McKinley Park, the extremes could be expected to reach minus 54°F and 89°F. During the summer months when heating takes place over the interior, the average July temperature is about 52°F. The growing season averages about four months. Normally, the first freeze occurs early in September and the last freeze occurs in mid-May. Summertime temperature gradients follow the traditional pattern of decreasing temperatures with increasing altitude. During periods of extreme winter cold, however, a strong temperature inversion may exist in the lower layers of the atmosphere as a result of radiation cooling and cold air drainage from the surrounding mountains. Under these conditions, the temperature gradient will be reversed.

PRECIPITATION

Precipitation over the basin varies from moderate amounts in the low elevations to heavy in the mountains. Since the flow of moist air is generally from the southwest, the orographic effects from the Talkeetna Mountains and the Alaska Range insure heavy precipitation in the upper elevations of the basin and lower amounts in the lower basin. Storms are generally light in intensity, with few convective-type storms of cloudburst magnitude. Seasonal distribution of precipitation is similar for all stations surrounding the basin, with maximum monthly precipitation occurring in one of the four summer months, and minimum monthly precipitation occurring generally in the month of April. At Summit station, precipitation records show that 55 percent of the total annual precipitation occurs from June through September, while only 24 percent of the precipitation occurs in the 5 months of January through May.

SNOW

Absence of recorders within the basin makes it difficult to estimate average snowfall amounts. Average annual snowfall at Summit is approximately 120 inches; however, this is believed to be slightly high for the composite basin. The maximum annual snowfall observed at Summit was 187 inches in 1955. Snowfall is generally confined to October through April and comprises approximately 40 percent of the mean annual precipitation.

Snow course data for five stations within the basin are presented in the following tabulation. Also included is snow pack information from the Little Nelchina and Gulkana Glacier adjacent to the basin.

Upper Susitna Snow Course Data

Snow Course	Years of Record	Elevation	Average Water Content Per Month (Inches) — Average Date of Survey 1 Feb	1 March	1 April	1 May
Little Nelchina	6	4160	3.4	4.4	4.7	5.9
Clearwater Lake	9	3100	4.0	4.7	5.2	4.4
Fog Lakes	5	2250	4.6	6.0	6.7	6.8
Lake Louise	9	2400	3.0	3.6	4.0	3.4
Monahan Flat	9	2710	4.9	6.3	6.3	7.7
Oshetna Lake	9	2950	2.8	3.2	3.7	3.4
Gulkana Glacier	1	6360	68.5	---	---	---

The Hydrometeorological Branch of the National Weather Service estimates that the annual water equivalent of the Gulkana Glacier course, based on available data, is 94 inches. Locations for the five snow course stations within the basin are presented on Plate 1. Snow densities for the month of February generally range between .13 to .23, averaging about .16. The water content of the May snow mass provides a good index of expected spring runoff.

WIND

Wind data collected at Talkeetna, Summit, and Gulkana show that the most severe wind conditions which have been observed close to the study basin within the last eight years have occurred at Summit station. Although Talkeetna station provides a longer period of wind records, Summit station, presented below, is believed to be more representative of basin conditions.

SUMMIT WIND DATA

Measurement	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Speed (MPH)	16.3	14.6	12.0	9.4	8.7	9.8	9.3	8.5	8.3	10.4	13.3	13.7
Prevailing direction (Degrees Azimuth)	40	50	50	50	260	240	230	250	60	50	40	40

Maximum one minute velocity recorded at Summit station was 48 mph, but considerably higher winds are believed to occur. Prevailing wind direction at various times within the year shows a stark contrast between summer and winter. During the five summer months, May through August, mild southwestern winds carry maritime influences to the basin, while during winter northeast winds chill the basin and bring continental conditions.

WIND-DRIVEN WAVES

The orientation of the proposed dams and contiguous reservoirs provide good shielding against wind-driven waves. Maximum wind velocities observed at stations close to the basin have almost always occurred during three months, January through March, the period when the reservoir surfaces would be heavily laden with sheet ice. Although free surface reservoir conditions would prevail from May through October, maximum pool conditions at any reservoir other than Devil Canyon would occur only during the latter portion of this period. The critical situation for all proposed reservoirs should occur in October, when all reservoirs would be at full pool elevation with the prevailing wind from the northeast. Under these conditions, however, the orientation of the reservoirs being studied would provide very short effective fetch lengths.

If wind direction were to shift to the east, by assuming 60 mph velocity winds sustained for two hours, the Watana reservoir, with an effective fetch of 1.7 miles, could expect a significant wave height of 3.5 feet. Under these conditions, which would appear to be extreme circumstances, the maximum wave would be 5.8 feet.

ICE

River ice conditions in the basin are expected to vary according to channel slope and configuration. In general, depending on temperatures and snow cover, maximum ice thicknesses should range between two and five feet. Periodic measurements of ice thickness for the Susitna River at Gold Creek for the winters of 1961 through 1968 are shown below.

Susitna River at Gold Creek Ice Thicknesses

Observation Date	Ice Thickness (Feet)
15 March 1961	2.3
5 April 1963	4.7
19 February 1964	2.7
13 March 1964	3.2
12 January 1965	2.5
29 January 1966	4.1
11 January 1968	2.1

During spring breakup, ice jams can constrict the river, causing the water level to rise as much as 20 feet. This phenomenon replenishes adjacent sloughs and marshy areas necessary for certain aquatic wildlife. After creating Devil Canyon Dam and Watana reservoirs, the nature of breakup, both above and below, would be expected to change. As a result of heat trapped in the reservoirs, surface freezing within reservoirs would be expected to occur later than for surrounding rivers; for a few miles below Devil Canyon Dam, water would be open throughout the year. Breakup above Watana reservoir should occur on schedule, but breakup within the reservoirs would be late. This delay would probably create ice jams where rivers flow into the reservoirs; efforts should be taken to preclude development in these areas. No problems are anticipated below Devil Canyon Dam.

Although flow releases would increase monthly from October through January, previous studies conducted by the Missouri River Division, Corps of Engineers, have found that stage increases of up to seven feet, at a moderate rate, can be tolerated without premature ice breakup. Stage fluctuations below Devil Canyon Dam should be less than three feet during winter operation. During spring breakup, the dams should reduce damage from downstream flooding. Not only would the ice above the reservoirs be prevented from jamming below the dams, but the reservoir storage of spring runoff would reduce flood severity.

STREAMFLOW RECORDS

AVAILABLE RECORDS

Four gaging stations in the upper Susitna basin are or have been operated by the U.S. Geological Survey. At each station, records of discharge, chemical constituents, water temperature, and sediment content have been obtained. Recorded average monthly runoff for the period of record is shown in Tables 3, 4, 5, and 6.

The station, "Susitna River at Gold Creek," is located at the Alaska Railroad bridge and is approximately 15 miles downstream from the Devil Canyon damsite. At the gaging station, the drainage area is 6,160 square miles versus 5,810 square miles at the damsite. Records began in August 1949; for the 25 water years of 1949 through 1974, average annual runoff has been 7,037,000 acre-feet or 9,720 cubic feet per second. On the average, 64 percent of annual runoff occurs in June, July, and August; 22 percent in May and September; 5 percent in October; and only 9 percent in the 6 months from November through April.

The station, "Susitna River near Denali," is located at the Denali Highway bridge and is approximately 15 miles upstream from the Denali damsite. Drainage area above the station is 950 square miles versus 1,260 square miles at the damsite. Discharge records are available from May 1957 to September 1966 and from July 1968 to September 1974; for the 15 water years, annual runoff has averaged 1,942,000 acre-feet, or 2,682 cubic feet per second. About 5 percent of annual runoff occurs during 6 months, November through April.

The station, "Maclaren River near Paxson," began operating in June 1958. The gage is located at the Denali Highway bridge about 34 miles west of Paxson. Drainage area is 280 square miles, and average annual runoff is 705,000 acre-feet, or 974 cubic feet per second for the 16 years of streamflow records from 1958 through 1973.

The gaging station, "Susitna River near Cantwell," was placed in operation in May 1961 and was discontinued in September 1972. The station is located at the Vee damsite, 9 miles below the Oshetna River, 22 miles below the Tyone River, and about 65 miles southeast of Cantwell. Drainage area of the Susitna River at the gage is 4,140 square miles, and average annual runoff for the recorded 11 water years is 4,560,000 acre-feet, or 6,299 cubic feet per second.

EXTENSION OF STREAMFLOW RECORDS

Extension of monthly streamflow for Denali, Cantwell, and Maclaren gaging stations was performed by linear correlation of these stations with the Gold Creek station. In an attempt to observe visual relationships between the stations, the respective monthly streamflows for the three stations were plotted against the correlative Gold Creek monthly streamflows. Depending on the shapes of the relationships observed, the data were split into time groups ranging from a month to several months. After transformation, a linear regression analysis was performed for each data group, and, based on the correlation coefficients and standard errors of estimate, a relationship for each group of data was adopted for streamflow extension.

In general, good correlation was observed for the winter months of October through April, while summer correlations were less clearly defined. As could be expected, there was a high degree of correlation between Gold Creek and Cantwell, while the Denali and Maclaren stations, because of dissimilar hydrologic phenomena, showed marginal summer correlation with Gold Creek. A zero correlation coefficient was obtained for the July Denali-Gold Creek analysis. In order to improve the relationship, a multiple correlation analysis was attempted by introducing the Nenana monthly streamflow as an independent variable. Although the correlation improved slightly, it was not adequate to justify the more complex equation. In the case of Cantwell, a logarithmic transformation showed better correlation than that used, but once again the improvement was not sufficient when compared to no transformation.

The relationships derived for the three stations are as follows:

Susitna River near Cantwell

1. May through September
   $Q_c = 0.651Q_g - 39.0$ $\qquad \bar{R}^2 = 0.93$

2. October through April
   $Q_c = 0.544Q_g - 84.1$ $\qquad \bar{R}^2 = 0.92$

Maclaren River near Paxson

1. June through August
   $Q_m = 3.376Q_g^{0.667}$ $\qquad \bar{R}^2 = 0.59$

2. September
   $Q_m = 0.080Q_g^{1.011}$ $\qquad \bar{R}^2 = 0.88$

3. October through May
   $Q_m = 0.064Q_g^{0.994}$ $\qquad \bar{R}^2 = 0.87$

Susitna River near Denali

1. September through May

   $Qd = (-1.916 + .462Qg^{0.5})^2$ $\qquad \bar{R}^2 = 0.91$

2. June
   $Qd = 0.128Qg + 3889.5$ $\qquad \bar{R}^2 = 0.24$

3. July
   $Qd = 0.071Qg + 7574.6$ $\qquad \bar{R}^2 = 0.0$

4. August

   $Qd = 2.556Qg^{0.802}$ $\qquad \bar{R}^2 = 0.50$

Qg = Gold Creek monthly streamflow
Qc = Cantwell monthly streamflow
Qm = Maclaren monthly streamflow
Qd = Denali monthly streamflow

A plot of the various relationships are presented on Graphs 3 through 11.

ESTIMATED DAMSITE STREAMFLOWS

Interpolation of observed and estimated monthly streamflow records for the four damsites was accomplished by adopting linear drainage area relationships between stations and damsites. This approach assumes that the drainage areas above the various damsites are topographically and hydrologically similar to the drainage areas above the gaging stations. The geometric configuration of the four gaging stations within the basin provides adequate representation of the dissimilar portions of the overall basin for the linearity assumption to apply. The Vee damsite streamflows were assumed to be equal to those of the Susitna River at Cantwell gaging station, while the Watana and Devil Canyon streamflows were made proportional to the Gold Creek and Cantwell flows, based on the respective drainage areas.

Drainage area linearity for the Denali damsite could not be established. As shown in the table below, the flow contribution of the area between Cantwell and the glacially influenced stations of Denali and Maclaren is considerably lower than the unit flow from the remainder of the basin.

Localized Unit Flow

Local Flow Measured At:	Drainage Area (Sq Mi)	Annual Local Flow (Ac Ft)	Flow/Area (Ac-Ft/Sq Mi)
Susitna River near Denali	950	1,942,000	2044
Maclaren River near Paxson	280	705,000	2517
Susitna River near Cantwell	2910	1,913,000	657
Susitna River at Gold Creek	2020	2,480,000	1227
Total	6160	7,037,000	1126

The low local flow per unit area measured at the Cantwell station is believed to be a result of the Lake Louise area, which is not homogeneous with the topography between the Denali station and damsite. Therefore, because the local Denali damsite area is similar to that below Cantwell, the Denali damsite streamflow was related directly to local unit flows measured at the Gold Creek and Denali gages.

The following relationships were utilized to calculate the four damsite streamflow records:

$$Q_1 = \frac{A_1 - A_c}{A_g - A_c} \times (Q_g - Q_c) + Q_c$$

$$Q_2 = \frac{A_2 - A_c}{A_g - A_c} \times (Q_g - Q_c) + Q_c$$

$$Q_3 = Q_c$$

$$Q_4 = \frac{(Q_g - Q_c)}{(A_g - A_c)} \times (A_4 - A_d) + Q_d$$

Q_1 = Devil Canyon damsite monthly streamflow
Q_2 = Watana damsite monthly streamflow
Q_3 = Vee damsite monthly streamflow
Q_4 = Denali damsite monthly streamflow
A_1 = Drainage area above Devil Canyon damsite
A_g = Drainage area above Gold Creek gage
A_c = Drainage area above Cantwell gage
A_2 = Drainage area above Watana damsite
A_4 = Drainage area above Denali damsite
A_d = Drainage area above Denali gage

The calculated monthly streamflows for the four damsites are shown in Tables 7 through 10.

STREAMFLOW CHARACTERISTICS

FLOW DURATION

Daily flow duration curves for the four gaging stations within the Upper Susitna River Basin are presented on Graph 12. Curves represent respective periods of record for the stations, as shown on the legend. The general shapes of the curves are significant in similarity and in implications for reservoir development necessary to sustain power generation. The perennial nature of the streams is reflected in the lower end of the curves. Flows occurring within the 50- to 100-percent range are comprised of both winter subsurface flows and a summer combination of glacial melt and subsurface flow. The complete absence of zero flows implies a well developed flood plain alluvium with no apparent geological constrictions. The sharp reduction indicated in the Denali flow is believed to be erroneous data, as the period of record represented is termed "poor" and "affected by ice" by the U.S. Geological Survey. Higher flows which occur within the 10- to 40-percent range reflect influences of summer snowmelt and glacial melt, while upper portions of the curves illustrate the infrequency of high rainfall runoff.

The overall steep slope of the four curves indicates that to sustain high daily flows, storage control by reservoir is needed. Furthermore, average annual streamflow for the four stations is considerably higher than those flows which are exceeded 50 percent of the time. This means that a very large volume of the average annual flow emanates from high runoff events which occur with relatively low frequency. Conversely, low yield events occur with high regularity. Therefore, to fully regulate the river for maximum firm power output, reservoirs providing a high ratio of storage capacity to mean annual inflow are required. In fact, the power studies presented in Section C show that optimum reservoir development would require an active storage capability equal to the mean annual Devil Canyon streamflow volume.

LOW-FLOW FREQUENCY ANALYSIS

Power studies utilizing the 25 years of streamflow records (1950-1974) indicated that the 1969 water year was an extremely adverse water year. To demonstrate the severity of the 1969 low-flow year, an annual low-flow volume frequency study was conducted. The results of this analysis are plotted on Graph 13, which shows that for the 25 years of record, the 1969 water year runoff volume has an exceedence interval of over 1000 years. If the 1969 water year runoff volume is treated as an outlier and excluded from the statistical analysis, the exceedance interval is in excess of 10,000 years. Therefore, as suspected, the 1969 water year is an extremely adverse flow condition and its use in the power studies results in extremely conservative firm energy determinations. The critical period for the selected plan of development also includes the 1970 water year which is the second most adverse water year recorded. The fact that the two most adverse water years of record are in succession and within the critical period further demonstrates the severity of the flow conditions used to determine the firm energy generating capability of the plans of development studied.

The critical period for the selected plan of development was found to cover a 32 month period spanning October 1968 through May 1971, with a total Gold Creek runoff volume of 10,940,000 Ac. ft. In order to evaluate the exceedence frequency of the critical period, a synthetic 32-month duration low-flow frequency curve, Graph 14, was constructed for the Gold Creek gage. Four hundred years of monthly streamflow were generated based on the statistics of the 25 years of Gold Creek records and in accordance with the method outlined under "HEC-4, Monthly Streamflow Simulation." 1/ Consecutive 32-month periods were derived for the 400 years of synthetic streamflow, and a low-flow frequency curve was developed in accordance with procedures outlined under Chow's Handbook of Hydrology, Chapter 18. 2/ Superposition of the 32-month Gold Creek critical runoff reveals a return period in excess of 400 years.

FLOOD CHARACTERISTICS

Historic floods within the basin have resulted from snowmelt, rainfall runoff, or a combination. Compared to snowmelt floods, rainfall floods have exceptionally high flows of relatively short duration. Frozen ground conditions coupled with spring snowmelt and warm rain give both a high peak and a large runoff volume.

Graphs 15 through 18 show the minimum, maximum, and average daily streamflow conditions which have prevailed at the four gage sites. Maximum annual instantaneous flows are plotted to show time distribution of the events. Note the number of mean daily flows that were greater than many of the instantaneous annual peaks. Late summer peak flows were mainly short duration high peak rainfall events superimposed on glacial melt.

1/ "HEC-4, Monthly Streamflow Simulation," Generalized Computer Program 723-340, Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California, 1971.

2/ Handbook of Applied Hydrology, Ven Te Chow, Editor in Chief, McGraw Hill Book Company, New York, 1964.

Average daily flows for Gold Creek station show the initial springtime influence of the winter snow mass and the gradual recession of this source as higher land elevations shed their winter supply. Average daily flow at Denali and Maclaren stations depicts the summer influence of the sustained flow from mountain glaciers and snow mass. Since a large portion of the Upper Susitna River Basin is underlain with permafrost or temporary ice, infiltration losses are at a minimum, which increases flood flows from June through September.

PAST FLOODS

Major yearly peak flows for the two gaging stations are listed below. The maximum yearly peak flow at the Gold Creek station measured 90,700 cfs, and was a combination rainfall-snowmelt event. The primary constituent of the 38,200 cfs Denali streamflow event was rainfall runoff. Volumes for the two events were 1,683,000 and 347,000 acre-feet, respectively. The Gold Creek and Denali floods of 1971 were produced by a basinwide rainfall distribution which resulted in average runoff amounts of 1.37 inches and 3.5 inches, respectively. The time distribution of the peak flows is shown on Graphs 15 through 18.

Yearly Peak Flows of Record

Gold Creek		Cantwell		Denali		Maclaren	
Date	Peak CFS	Date	Peak CFS	Date	Peak CFS	Date	Peak CFS
8/25/59	62,300	6/23/61	30,500	8/18/63	17,000	9/13/60	8,900
6/15/62	80,600	6/15/62	47,000	6/7/64	16,000	6/14/62	6,650
6/7/64	90,700	6/7/64	50,500	9/9/65	15,800	7/18/65	7,350
6/6/66	63,600	8/11/70	20,500	8/14/67	28,200	8/14/67	7,600
8/15/67	80,200	8/10/71	60,000	7/27/68	19,000	8/10/71	9,300
8/10/71	87,400	6/22/72	45,000	8/8/71	38,200	6/17/72	7,100

FLOOD FREQUENCIES

Graphs 19 through 22 show peak flow frequency for the four gaging stations in the basin. Graphs 23 through 26 show volume frequencies of the four stations for the 1-day, 3-day, 7-day, 10-day, and 30-day volumes. Extension of peak flows for the Cantwell, Denali, and Maclaren stations was made through a regression analysis with peak flows from Gold Creek. Peak frequency curves for the three stations with short record were computed both for the extended period of record and for the respective periods of record for each station.

Both methods of computing frequency curves gave similar results, but the curves based on observed events gave slightly higher flows per respective return interval. As a result of the small difference in the peak frequency curves for the two methods of calculation, coupled with similar results for the volume frequency analysis, volume frequency curves shown represent data extended to match Gold Creek period of record. Observed values used in all curve computations were adjusted for skewness based on the extended Gold Creek period of record. No attempt has been made to extrapolate these curves to the four damsites; however, a weighted basin area approach should give adequate results.

The following tabulation shows peak discharges for the four gaging stations for various recurrence interval:

Upper Susitna River Basin Peak Discharges

	Peak Discharge--cfs			
Recurrence Interval (years)	Susitna at Gold Creek	Susitna near Cantwell	Susitna near Denali	Maclaren near Paxson
5	67,000	42,000	19,500	7,300
10	78,000	48,500	23,200	8,200
25	90,000	56,000	27,500	9,200
50	101,000	63,000	32,000	10,100
100	111,000	69,000	37,000	11,000

SEDIMENTATION

GENERAL

The U.S. Geological Survey has collected suspended sediment samples at the four gaging stations within the basin from 1952 to 1973. Results of their findings are published in U.S.G.S. water supply papers. The following table summarizes the available data and gives a range of flows for which samples were collected:

Suspended Sediment Data

Station	Number of Samples	Max. Flow Sampled (cfs)	Min. Flow Sampled (cfs)
Susitna at Gold Creek	59	53,000	920
Susitna near Cantwell	27	36,900	2,430
Susitna near Denali	22	12,000	950
Maclaren near Paxson	25	5,300	95

Although there are relatively few samples for low flows, the degree of error that would be imparted by incorrect relationships is extremely small. On the other hand, high runoff will heavily influence the calculation of sediment transport; hence, to collect additional data for high flows would be desirable. The relationships ultimately derived for sediment transport versus discharge are believed to be conservative. In addition to discharge concentration, the majority of the samples collected by the U.S. Geological Survey were analyzed for size distribution.

Of the sediment samples taken at the Denali gage, U.S.G.S. computed total sediment load for ten by use of the modified Einstein procedure. The bedload analysis was based on three bed material samples collected by U.S.G.S. in September 1958. No bed samples have been taken for the remaining three gaging stations.

SUSPENDED SEDIMENT

Suspended sediment rating curves were developed by a regression analysis in which both sediment, measured in tons per day, and flow were logarithmically transformed. Observation of the data revealed a good relationship from this method for the medium to high range flows. The low flow relationships were conservatively estimated. Correlation coefficients ($\bar{R}^2$) ranged from 0.72 for Gold Creek to 0.93 for Maclaren. The curves derived in this manner are shown on Graph 27.

Variability of suspended sediment transport was made a direct function of respective flow duration curves for each station, and annual sediment transport was calculated by the Flow-Duration, Sediment-Rating

Curve Method. Preliminary investigations showed that 98 percent of the annual sediment transport occurred from May through October; hence, no further attempt was made to derive seasonal flow-duration or rating curves. In order to determine the volume of sediment transported, the initial unit weight for each of seven sediment size ranges was estimated by using the Lara and Pemberton method. Fifty- and hundred-year unit weights were calculated by the Lane and Koelzer method as modified by Miller. The sediment size analysis curves shown on Graph 28 were developed for the four gaging stations from the data collected by the U.S.G.S.

Sediment transport for the four stations is shown below:

Suspended Sediment Transport

Station	Sediment Transport (Tons/year)	Initial Unit Weight (Lb/ft^3)
Susitna at Gold Creek	8,734,000	65.3
Susitna near Cantwell	5,129,000	70.6
Susitna near Denali	5,243,000	70.4
Maclaren near Paxson	614,000	68.6

BEDLOAD

The Denali gage bedload rating curve, presented on Graph 29, was established from the Einstein estimates provided by the Geological Survey. By using the flow-duration rating-curve method, the Denali bedload was found to be 1,588,000 tons per year, 30 percent of the yearly suspended sediment load. Lack of data precluded bedload estimates for the remaining three stations. Because of similarity between the Denali and Maclaren sites, the Maclaren bedload was also assumed to be 30 percent of the suspended load. Reconnaissance of the Cantwell gage site and the Watana and Devil Canyon damsites revealed that bed material at these locations is composed mostly of heavy boulders and cobbles; hence, the Cantwell and Gold Creek bedloads were estimated to be 10 percent of the respective suspended sediment loads. The unit weight of bedload material at the four stations was assumed to be 97 lb/ft^3.

RESERVOIR SEDIMENTATION

Complex topographic and erosion characteristics within the basin have complicated determining total reservoir deposition. Variation of sediment transport within the basin can be segregated into three topographic areas: (1) glacial areas; (2) well-drained topography as below the Cantwell station; and (3) low sediment yield areas as found in the Lake Louise basin. The combination of these three characteristic areas is readily apparent from the total sediment load at the four gaging stations.

Total Sediment Inflow

Station	Ratio Glacial Area to Basin Area	Average Basin Height (Ft.)	Yearly Sediment Production Rate (Tons/Sq. Miles)
Maclaren near Paxson	0.157	1,630	2,850
Susitna near Denali	0.233	1,927	7,191
Susitna near Cantwell	0.066	1,754	1,364
Susitna at Gold Creek	0.045	2,922	1,560

A strong relationship appears between the Glacial-area/Basin-area and the Production Rate (tons/sq. mi.). However, when these values are plotted on logarithmic paper, the Paxson, Denali, and Gold Creek stations fall on a straight line, with Cantwell considerably out of line. The Cantwell station is biased by the Lake Louise area. The bias can be eliminated, however, by introducing basin height as an erosion index. By plotting the Glacial-area/Basin-area versus Production Rate in tons per cubic mile of drainage basin, the relationship becomes considerably stronger, and a straight line can reasonably be fitted. Transformation of the relationship shows that a direct estimate of yearly sediment, measured in tons, can be obtained by the simple relationship of:

$$S = 89{,}144 \times H \times A_b^{-0.129} \times A_g^{1.129}$$

S = Sediment in tons per year
H = Average Basin height in miles
A_b = Basin Area (sq. mi.)
A_g = Glacial area within the basin (sq. mi.)

By using the basin rating curve shown on Graph 30, damsite sediment inflows for Devil Canyon and Watana reservoirs were based on the expected sediment at the actual damsites. Denali and Vee reservoir inflows, because of the aggrading nature of the stream, were based on expected inflow at the head of the reservoir plus local inflow from the tributaries. Estimates of local reservoir sediment for upstream reservoirs were computed by assuming both 100-percent entrapment at the upstream reservoir and production of local sediment inflow by the tributary load below the upstream reservoir. Tributary load below Vee damsite was computed by subtracting the Cantwell load from the Gold Creek load and dividing by the intervening area.

Tributary load estimates for the flat area between the Cantwell gage and the Maclaren and Denali gages were considerably more difficult to compute. The river channel is aggrading from the glacier snouts to the area below the confluence of the Susitna and Maclaren Rivers. Therefore, the sediment value recorded at Cantwell station, which represents a degrading condition, could not be subtracted from the value recorded at Denali station. Instead, the tributary load above Cantwell was based on inflow above the Cantwell station and below the confluence of the Maclaren and Susitna Rivers. Consequently, tributary load below the Cantwell station was calculated to be 1.125 Ac-ft./ Sq. Mi./Yr., while the production rate above Cantwell was estimated to be 0.31 Ac-ft./Sq.Mi./Yr.

Distribution of sediment within the reservoir was based on water temperature, sediment size, variation of inflow, and reservoir configuration. Fall velocities were based on data given in U.S. Inter-Agency Report, No. 7, and reservoir cross-sections were taken from U.S.G.S. contour maps. Although initial entrapment ratios of the reservoirs, based on full storage conditions, were found to range from 75 percent at Devil Canyon (because of the relatively minor amount of storage) to 100 percent at Denali, for the purpose of this study, all reservoirs were assumed to provide 10C-percent entrapment.

The area-capacity curves developed in this manner are shown on Graphs 31 through 36. A summary of total volume inflow to the reservoirs is shown in Table 11.

EVAPOTRANSPIRATION

EVAPORATION

Pan evaporation data for stations representative of the upper Susitna basin conditions have been collected for summer months at the Matanuska Valley Agricultural Experiment Station near Palmer and at the University Experiment Station near Fairbanks. The period of record for each station is from 1944 to the present; however, the number of continuous years for each month of data varies. The average monthly pan evaporations for the two stations are as follows:

Average Monthly Pan Evaporation, Inches

Month	Matanuska Valley Agr. Exp. Stn.		University Exp. Stn.	
	Evap.	Yrs. Rcd.	Evap.	Yrs. Rcd.
May	4.63	15	4.46	19
June	4.58	24	5.09	26
July	4.09	29	4.50	30
August	2.99	29	2.96	30
September	1.83	26	1.42	24
Subtotal	18.12		18.43	

More recent data collected at McKinley Park station, which would be more representative of basin losses, show that average summer pan evaporation is only 15 inches. However, the more conservative figures should be adequate for study purposes.

By averaging the two summer subtotals, applying a pan coefficient of 0.7, and assuming little evaporation during the winter months, a mean annual evaporation for the Susitna River basin of approximately 12.8 inches is reached. In reality, the spatial variation of surface evaporation within the basin is influenced heavily by orographic and physiographic variations throughout the basin; hence, the adopted average value is believed to be slightly high.

CONSUMPTIVE USE

Results from consumptive use experiments conducted in 1955 at Matanuska Valley Experiment Station are given in a Progress Report published in 1956. The report established that during the growing season, May through September, average monthly consumptive use amounts are as follows:

Average Consumptive Use

Month	Consumptive Use (Inches)
May	2.30
June	3.50
July	3.86
August	3.08
September	0.16
Total	12.90

Yearly consumptive use is consistent with free surface evaporation rates. This one-to-one relationship is valid as long as average annual precipitation far exceeds average annual evaporation. Consumptive use during the summer months occurs at maximum possible rate for the basin. If the true volume of runoff from glacial melt were known and if average annual basin precipitation could be established, basin consumptive use could be easily calculated.

WATER QUALITY

Evaluation of reservoir impacts on downstream water quality and subsequent effects on environmental cycles will require considerable future study and data acquisition. Absence of continually recorded water quality parameters makes it difficult to estimate post-project chemical and biological water constituents below the dams by applying mathematical models. Existing data include random samples collected at the four gaging stations within the basin, published by the U.S. Geological Survey, Water Resources Data for Alaska, see Table 18.

NATURAL CONDITIONS

The limnology of the Susitna River differs considerably from that of rivers in lower latitudes. During the summer, the river receives large quantities of cold, silty glacial melt and heavy runoff contributions from large, saturated muskeg areas. Biological growth flourishes both under long periods of solar radiation and from injection of high dissolved oxygen by the turbulent river flow.

Winter conditions are almost completely reversed. Winter flows consist almost entirely of groundwater supply; consequently, suspended sediment concentration is extremely low. Heavy ice cover, coupled with low solar energy and low temperatures, affect the photosynthetic and respiration rate of the river, resulting in low dissolved oxygen rates. Annual dissolved oxygen concentrations should approach saturation during spring breakup and fall freezeup when water temperatures are near freezing; slightly lower concentrations will occur during warm summer months, and minimum concentrations are expected in extreme cold periods of winter. For these reasons, chemical and nutrient cycles are expected to differ from those of streams in warmer regions.

RESERVOIR CONDITIONS

Chemical concentrations in the reservoirs are expected to be heavily influenced by the thermal stratification that naturally occurs in large bodies of water. Summer stratification will occur after ample warmth has been added to the top 50 feet of water. Unlike reservoirs in southern latitudes, winter stratification should result after average water temperature has dropped to $4^{o}C$ when lighter density, colder water is forced to the surface. This stratification, coupled with the long retention rate of the reservoirs, will result in a reduction of turbidity, silica, and coliform bacteria. Reservoir peripheries should increase algae growth. However, reduced dissolved oxygen in the lower portion of the reservoir, excessive hydrostatic pressures, reduced sunlight, and sediment buildup should reduce biological growth in deeper waters. Iron and manganese concentrations will increase significantly, as will dissolved solids and hardness.

DISSOLVED OXYGEN

A highly critical item in reservoirs of the size of those being contemplated is the dissolved oxygen (DO) content of impounded water. Normally, the DO content of impounded water drops with the greatest change taking place in deeper parts of the reservoir. Wave action and turbulence of the water are estimated to maintain an adequate DO content in the top 50 feet of the reservoir. Although powerhouse intake location would be too low for downstream utilization of this oxygen-rich water, artificial means can be employed to enhance downstream concentrations.

Although the turbulence of the river downstream of Devil Canyon would promote reoxygenation more rapidly than would occur in a placid stream, it is not possible to predict the actual flow distance required to restore DO to an acceptable level. Concurrent with construction, a monitoring system to determine the oxygen absorption rate in the torrential stretch below Devil Canyon should be established. Should natural reoxygenation not be sufficient, consideration should be given to mechanical means of increasing the DO content of the river.

SUSPENDED SEDIMENT AND TURBIDITY

By comparison with other natural and manmade glacially fed lakes within Alaska, suspended sediment concentrations within the reservoirs are expected to range between 15 and 35 mg/l. However, the distribution of concentrations within the reservoirs could vary according to the density of the inflowing water. Most of the sediment will be deposited in the upper reaches of the reservoirs, but that which remains in solution will seek an elevation compatible with the density of the reservoir stratification. Following breakup, sediment inflow should mix with all elevations of the reservoir, but as the upper portions warm throughout the summer, the dense inflow should seek the colder water below the anticipated thermocline.

The effect of reservoirs on downstream suspended sediment concentrations would be to reverse the normal annual trend, thereby increasing winter transport and decreasing summer movements. Natural stream transport measured at the Gold Creek gage amounts to roughly 10 million tons of sediment per year, with 95 percent of the load occurring from May through October. Summer concentrations are proportional to the volume of moving water; while winter rates are similarly related, the frozen nature of the basin restricts the amount of conveyable sediment. Consequently, winter sediment concentrations are extremely low. Suspended sediment concentrations measured at Gold Creek are shown in Table 12. Data have been arranged by season to show the cyclic trend in volume and concentration of sediment movement.

Dynamics of the reservoirs will cause an estimated 97 percent of the suspended sediment to settle in impoundments, but the retarding effect will allow winter releases to be considerably more turbid than those of the natural flow. Estimating sediment concentration of reservoir releases is difficult, but streams having existing flow characteristics analogous to those of the post-reservoir Susitna River should provide a reference which may help to determine concentrations. Several glacially fed, silt-laden streams drop their heavy sediment loads in lakes formed behind terminal glacial moraines. Winter releases from these large impoundments give sediment concentrations similar to those expected on the Susitna River. Data collected from these river-lake systems are presented in Tables 13 through 17.

Sediment concentrations collected above and below Long Lake near Juneau illustrate the entrapment effect of the natural reservoir. Although inflow concentrations were as high as 569 ppm, maximum release concentrations were only 8 ppm. Similar conditions are expected to prevail at the other rivers and lakes shown. It is extremely significant that while summer concentrations of glacially fed Alaskan streams range up to 5,000 ppm, depending on the basin production rates, winter releases from those streams which are retarded by lakes are very low in sediment concentrations. In fact, although milky in color, the Eklutna reservoir is presently being considered for municipal water use in the Anchorage area.

The change in seasonal distribution of sediment concentrations within the river would change the environment for fish as well, although it is difficult to anticipate the effect that the sediment change would produce. Resident fish and those anadromous species which winter in the Susitna River would have to contend with sediment concentrations higher than those that presently exist, but anadromous fish traveling to spawning beds would experience great reductions in the amount of sediment. At present, river hydraulic conditions do not permit migratory fish to travel above Devil Canyon.

Heavy sediment concentrations can result in death from lack of ability to see food and from metabolic agitation which can lead to fatal gill disease. Further problems may result from effects of heavy siltation on fertile eggs since oxygen depletion prior to hatching could occur. Although tolerance levels differ according to species, existing literature suggests that the anticipated winter concentrations below Devil Canyon are within the safe limits for fish habitation. One publication that deals with the subject is Fisheries Handbook of Engineering Requirements and Biologic Criteria, by Milo C. Bell, private consultant to the North Pacific Division, Corps of Engineers. After considerable research, Mr. Bell concludes that "streams with sediment loads averaging between 80 and 400 ppm should not be considered good areas for supporting freshwater fisheries; streams with less than 25 ppm may be expected to support good freshwater fisheries." To compare anticipated Susitna concentrations with those of U.S. West Coast streams, average monthly sediment concentrations for streams in Washington, Oregon, and California are extracted from this publication and are presented in Table 18.

Obviously, the question of sediment impact cannot be simply answered, and test programs to study the problem should be implemented. A program presently in progress has revealed good fish survival from the artificial stocking of Tustumena Lake. As mentioned, sediment concentrations below Tustumena are similar to those expected below Devil Canyon; if this program proves successful for fish enhancement, a similar success should be anticipated for development of the Susitna River.

DISSOLVED GAS

Of recent concern to salmon fisheries is the possibility of nitrogen supersaturation occurring below dams. Supersaturation can occur below dam spillways when air is drawn deep into the water, pressurized, and taken into solution. The combined high level regulating outlets and powerhouse capacities at the Watana Dam are adequate to accommodate floods with recurrence intervals up to approximately 50 years so spill will be very infrequent. At the Devil Canyon Dam the hydraulic capacity of the initial four generating units is approximately 25,000 cfs at normal maximum pool elevation of 1450 feet. The low level outlet works at Devil Canyon are not designed to operate at pool elevation 1450 feet. Plates 2 and 3 show the daily hydrograph of river discharges for the Susitna River at Gold Creek for the period of record (water years 1950-1974). Superimposed on the hydrograph are those daily streamflows which could have been expected to spill through the Devil Canyon spillway. Spills were considered to occur when both Devil Canyon and Watana reservoirs were filled in consonance with the power operation study, and when the hydraulic capacity of the Devil Canyon penstocks were exceeded (25,000 cfs at normal maximum pool elevation of 1450 feet). Of the 25 years of streamflow record, spills were estimated to occur in 11 of the operation years, with the average spill lasting 14 days with an average flow of 8,500 cfs. Spill durations will be for short periods and will occur only during the late summer months after reservoirs have filled.

Studies have shown that fish can tolerate high dissolved gas levels for short periods of time. It is also anticipated that the whitewater stretch of river below Devil Canyon will assist in the reduction of nitrogen supersaturation. The actual at-site Devil Canyon streamflow is roughly 7 percent less than that of Gold Creek, and hence, actual spillage would have been slightly less than that shown on Plates 2 and 3. In addition, a real time operation will allow for pool drawdown prior to flood events, and the frequency of spillage would be further reduced.

DATA COLLECTION AND ANALYSIS PROGRAM

Physical and chemical water quality data has been collected at stream gaging sites existing within the basin as discussed previously in this section. A data collection program designed to provide the additional information necessary to evaluate project effects on water quality and to provide information for design and operational criteria must be initiated immediately to permit compliance with the present design and construction schedule. Data collection is also required to permit design of hydraulic features such as diversion and regulating outlets and transmission facilities. Data requirements include:

a. Installation and operation of six additional stream gaging stations. Gages will be installed on the Tyone River near its mouth; on the Oshetna River near its mouth; on the Susitna River at the prior Cantwell gaging station; at the Watana damsite; the Devil Canyon damsite; and on the Susitna River at the Highway No. 3 bridge crossing below Talkeetna.

b. Measurement of physical and chemical water quality parameters. The principal parameters in addition to discharge are water temperature, dissolved oxygen, pH, BOD, alkalinity, nutrients, total sediment load, and turbidity.

c. Water surface profile determinations for a range of discharges at the Watana and Devil Canyon damsites. A recording gage, staff gages, and aerial photography will be utilized to obtain the required data.

d. Reservoir heat budget and selective withdrawal studies.

e. Soil, permafrost, and vegetation type mapping of the area to be inundated by the reservoirs. Photogrammetric techniques will be utilized extensively.

f. Clearly defined water quality management objectives in cooperation with appropriate Federal and State agencies.

g. Depth and duration of reservoir freeze determinations.

h. Observation of icing and breakup conditions on the Susitna River.

i. Wind and icing data acquisition at approximately 20 locations along the proposed transmission line location.

j. Establishment of a network of 20 precipitation and air temperature stations in the upper Susitna basin.

k. Biological measurements including a quantitative and qualitative assessment of bethnic invertebrates, periphyton, and phyoplankton.

l. Ecological modeling studies of the reservoirs.

Data collection and study costs are estimated for selected time periods in the following tabulation:

ITEM DESCRIPTION	PROGRAM COSTS ($1,000)		
	FY 76 & T Quarter	Phase 1 GDM	Phase 2 GDM
a. Stream Gage Installation and Operation	100	100	40
b. Physical and Chemical Water Quality Parameters	20	20	10
c. Water Surface Profile Determinations	100	50	30
d. Reservoir Heat Budget and Selective Withdrawal Studies	20	20	20
e. Soil, Permafrost, and Vegetation Type Maps	---	20	20
f. Depth and Duration of Reservoir Freezing	10	10	10
g. Icing and Breakup Conditions on the Susitna River	20	50	30
h. Biological Water Quality Baseline Study	---	50	50
i. Precipitation and Air Temperature Stations	---	60	20
j. Ecological Reservoir Modeling	---	20	20
	420	550	350

PROBABLE MAXIMUM FLOOD

GENERAL

This section describes the derivation of the Probable Maximum Flood for various locations along the Susitna River above Gold Creek. Design floods were used for spillway sizing and estimates of downstream impact for post system development. Flood hydrographs were computed by applying Probable Maximum Precipitation (PMP), as derived by the National Weather Service (NWS), to a mathematical computer model of the river basin. The established design flood represents spring snowmelt augmented by rainfall runoff.

STUDY METHODS AND CRITERIA

The mathematical model used for this study was the Streamflow Synthesis and Reservoir Regulation (SSARR) computer program developed by North Pacific Division, Corps of Engineers, Portland, Oregon. The model is a deterministic program which simulates portions of the hydrologic cycle in an attempt to generate long periods of daily or hourly streamflow. Comparison of synthetic streamflow with observed events was used for model calibration. By dividing the Upper Susitna River Basin into subbasins of similar hydrologic and physiographic characteristics, reconstitution of historic events measured at the four gaging stations revealed good model simulation. Composite hydrographs for each damsite were developed by combining channel routed flows with local inflow between the damsite and an upstream control point. The basin schematic diagram which was used for synthesis is shown in Plate 4. The primary data required for water budget by the model are precipitation and temperature; hydrologic processes simulated by the program are soil moisture, evapotranspiration, snow and glacial melt, depression storage, surface storage, subsurface storage, groundwater storage, infiltration and percolation into acquifers, and channel routing. The program is written generally so that it may be applied to almost any type of drainage basin.

The Hydrometeorological Branch of the National Weather Service developed a range of PMP values which could be expected for the study basin (see Appendix 2). Although a detailed study of the design storm is being performed by the Weather Service, for the purpose of this report, the preliminary values provided were used.

RIVER RECONSTITUTION

The SSARR watershed model for the Susitna River basin was verified by comparing computed and observed hydrographs for the four gaging stations: Susitna River at Gold Creek; Susitna River near Cantwell;

Susitna River near Denali; and Maclaren River near Paxson. Although the SSARR program is a water budget model capable of reconstituting many years of consecutive daily flow, lack of climatological data precluded this type of calibration. Instead, because the basin acts primarily as a precipitation catchment area for most of the year--with the only real depletions taking place during the four summer months--by using observed snow data for initial conditions, calibration was based on observed precipitation, temperatures, and discharges for the period May through August. Furthermore, because the model was to be calibrated for peak moisture conditions, basin linearity was ignored, and the model was verified based only on periods of high precipitation input. The following time periods were selected for reconstitution:

Reconstitution Periods

Period		Gold Creek Average Daily Flows (cfs) Observed	Calculated
1964	20 May-8 July	85,900	80,300
1967	1 Aug-30 Aug	76,000	73,500
1971	6 May-30 Aug	66,300	53,300
		77,700	78,500
1972	2 May-5 July	70,700	60,900

BASIN MODEL CHARACTERISTICS

In developing a mathematical model of a drainage basin, the theoretical procedure would entail development of mathematical equations that would accurately simulate portions of the hydrologic cycle. The composite result would then be a computed hydrograph which would very nearly equal the observed hydrograph. In a generalized computer model, however, only a limited set of relationships are available for process description, and to accurately define the basin without a complex sampling system is not possible. Therefore, assuming that the mathematical model is correct, calibration must be accomplished either by trial-and-error or by an iterative process in which variables and constants are changed to reduce error between observed and computed events. Given a logical range for each mathematical variable, the latter technique should give superior results; however, computer time required for complex models is too great for practical use. Therefore, in calibrating the SSARR model to the Upper Susitna River Basin, a trial-and-error process based on judgment was used. Realizing that the computed hydrograph could show good simulation with the observed hydrograph, but that the computed hydrograph could be composed of an unrealistic proportion of snowmelt, rainfall runoff, and ground water; the total hydrograph was split into components, and optimization was based on reconstitution of specific flow components as well as composite flow. A brief discussion of input data and basin variables is presented below.

Precipitation: Data from climatological stations in or near the basin were used as an index to moisture input. Stations provide marginal area coverage for low elevations and almost no representation for higher elevations. The stations were weighted, therefore, to make up for obvious discrepancies in hydrograph volumes. Gracious House station near Denali was found to give the best basin results, but Gulkana Glacier station was used as an index for the Maclaren and Denali sub-basins. Weighting factors ranged from 62 to 300 percent for precipitation.

Temperature: Basin temperatures were based on data gathered from Summit and Gracious House for low elevations and Gulkana Glacier and Trims Camp for high elevations. Melt rates for both snow and glacial ice were based on the average of maximum and minimum daily temperatures.

Snow: The amount of snow on the ground, measured in inches of water, at the beginning of each reconstitution period was estimated from existing snow course data and climatological data reports for stations within and surrounding the basin. Water equivalent data for lower elevations are good, but lack of information for higher mountains made depth-elevation estimates difficult. Gulkana Glacier station was used as an index for snow cover in higher basin elevations. After initial conditions were assumed, the depth-duration of snow on the ground was estimated by the model in accordance with snowmelt routine. Lack of sufficient data denied the use of the energy budget snowmelt routine which is an option of the model. Instead, the temperature index method was employed, and good results were obtained. With this method, the area-elevation curve of the basin is coupled with temperature for computation of volume-elevation moisture budgeting. A lapse rate of 3.3°F per thousand feet of elevation from the index station at 2400-foot elevation was used.

Runoff Relationship: Percentage of runoff relates directly to the amount of moisture contained in the soil horizon. Depletion of the soil reservoir is accomplished by evapotranspiration. The relationship of surface runoff to soil moisture is expressed in the form of a curve which is in turn developed into a table of values for computer adaptation. This is a rather flexible procedure, but the difficulty is in defining the relationship. Curve definition was accomplished by optimization procedures, and the results are consistent with relationships derived for Alaskan basins with physical and hydrological characteristics similar to those of the Susitna basin.

Evapotranspiration: The soil moisture index is used not only to indicate surface runoff, but also to estimate potential evapotranspiration. As in natural soil conditions, potential loss relates directly to the amount of moisture between saturation point and wilting point which is in the soil. Then, by considering average meteorological conditions, the model abstracts soil moisture by the estimated amount.

Base Flow: The percentage of runoff which becomes base flow depends on the base flow infiltration index and on glacial melt. The index is derived using the base flow infiltration index for the previous period, runoff generated in the current period, and a routing procedure which delays the buildup of the index. The base flow in the reconstitution studies ranged from 100 to 10 percent of total computed flow.

RECONSTITUTION RESULTS

Observed and computed hydrographs for the four gaging stations of the Upper Susitna River Basin are shown on Plates 5 through 12. With the exception of snowmelt rates, reconstitutions for all four years were based on one set of relationships, variables, and constants. The snowmelt rates ranged from 0.10 to 0.45 inches per degree day. The synthesized hydrographs follow general patterns and timing sufficiently well to justify application of the method to Probable Maximum Flood derivation. One noteworthy aspect of the reconstitutions is that the model was calibrated to give good reproduction of peak recorded events, yet it still gave good results for the events of more frequent occurrence. Rainfall data plotted on all hydrographs represent the observed amounts at climatological stations located near the basin.

PROBABLE MAXIMUM PRECIPITATION (PMP)

Preliminary PMP estimates were developed by the Hydrometeorological Branch, National Weather Service (NWS)(see Appendix 2) for four drainage basins areas on the Susitna River as follows:

Susitna Basin Tributary to	Drainage Area (sq mi)	72-Hr PMP (in)	24-Hr PMP (in)	6-Hr PMP (in)
Denali Site	1260	9-12	5.4-7.2	2.7-3.6
Vee Site	4140	7.5-10.5	4.5-6.3	2.3-3.2
Watana Site	5180	7-9	4.2-5.4	2.1-2.7
Devil Canyon Site	58.0	7-9	4.2-5.4	2.1-2.7

The estimates are for the months of August and September; the season of greatest rainfall potential. For the snowmelt season the precipitation estimates are less and are obtained by multiplying the above values by 0.7. Development of 6-hour increments of precipitation for the PMP storm was assumed to be as presented in NWS publication Hydrometeorological Report No. 43, Figure 6-1, Pattern c. Precipitation distribution for the summer 72-hour amount of 9.0 inches is as follows:

Hour	1st Day	2nd Day	3rd Day
0-6	.25	.6	.15
6-12	.50	1.2	.30
12-18	1.12	2.7	.67
18-24	.38	.9	.23
TOTALS	2.25	5.40	1.35

Precipitation distribution for the spring 72-hour amount was obtained by multiplying the above summer distribution by 0.70. Areal distribution of the precipitation amount to the subbasins of the drainage area is based on the distribution of the mean annual precipitation map presented in the NWS PMP derivation, Plate 14. This mean annual precipitation distribution is similar to information published in NOAA Technical Memorandum NWS AR-10, Mean Monthly and Annual Precipitation, Alaska.

An antecedent storm for the summer event consisting of the maximum 72-hour recorded precipitation, totaling 2.91 inches at the Summit FAA weather station, occurring 5 days prior to the PMP, was assumed. This event occurred in August 1944.

SNOWMELT

Snow and glacial melt for the PMF was computed by the SSARR program using the temperature index method. The split watershed snow cover depletion option was employed on subbasins contained glaciers. Use of the generalized snowmelt equation option was considered, but was determined to be impractical due to lack of adequate data. Approximately 9 years of snow course data are available for 14 locations in and surrounding the Susitna drainage. This information was utilized by the NWS to determine water equivalents of snow pack for the PMF derivation and are as shown on Plate 13. Average water equivalents on 1 May for subbasins ranged from 10.0 inches for the Lake Louise area to 35.5 inches for the Susitna River basin above the Denali Highway. Glacial areas were considered to have unlimited snow water equivalents for spring and summer PMF derivations.

TEMPERATURES

The National Weather Service Report (see Appendix 2) includes temperature information for seven days including the three-day PMP event and the preceeding four-day period. Mean daily temperatures adjusted to the 2400-foot elevation Summit FAA Weather Station for this seven-day period are as follows:

Date (June)	10	11	12	13	14	15	16
Mean Daily Temperature °F	57	54	52	51	49	50	48

Several combinations of antecedent temperature conditions were analyzed to allow determination of the most critical temperature-precipitation sequences. The maximum average daily temperatures for the Summit FAA Weather Station for duration of 3, 7, and 61 days were determined and are as shown on Graph 37. These curves were utilized as upper limits for the average daily temperature durations for the temperature sequence for the 1 June through 9 June period. Three different temperature sequences for this period were analyzed, as shown on Graph 36. The lowest temperature sequence resulted in the maximum peak discharges. The low temperature sequence resulted in a greater snowmelt runoff contribution during the PMP event which when combined with rainfall runoff exceeded the peak discharges from other assumed temperature sequences. May 1971 temperatures (below average) were used in all snowmelt analyses. A lapse rate of 3.3°F per thousand feet of elevation from the index station at 2400-foot elevation was used.

LOSSES

Losses during PMF runoff were simulated in the same manner as in the flood reconstitution.

BASE FLOW

Base flow during PMF runoff was simulated in the same manner as in the flood reconstitution.

PROBABLE MAXIMUM FLOOD HYDROGRAPHS

Probable Maximum Flood hydrographs are shown on Plates 15 and 16. Initial reservoir elevations were assumed to be normal maximum pool elevations of 1450 and 2200 feet for the Devil Canyon and Watana reservoirs, respectively. All outflow was assumed to be through the spillway and reservoirs were forced to surcharge when reservoir inflows exceeded spillway capacities at normal maximum pool elevations. Spillway discharge capacities are as shown on Plates B-5 and B-12 in Section B for the Watana and Devil Canyon projects, respectively. Devil Canyon spillway capacity was determined by routing the spring and summer Probable Maximum Floods through the Watana and Devil Canyon reservoirs. Maximum inflow, outflow, and water surface elevations are as follows:

Summer Probable Maximum Flood

Project	Maximum Inflow (cfs)	Maximum Outflow (cfs)	Maximum Reservoir Forebay Elevation (feet)
Watana	213,000	186,000	2204.3
Devil Canyon with Watana	223,000	218,000	1451.9

Spring Probable Maximum Flood

Project	Maximum Inflow (cfs)	Maximum Outflow (cfs)	Maximum Reservoir Forebay Elevation (feet)
Watana	233,000	192,000	2205.0
Devil Canyon with Watana	226,000	222,000	1452.5

FLOOD CONTROL REGULATION

Flood damages to the minor amount of development on the Susitna River flood plain below the Devil Canyon damsite are small compared to the benefits derived from the use of storage for power generation. Incidental flood control benefits are possible, however, and a seasonal upper flood control rule curve was established for the Watana reservoir as shown on Graph 38. Watana reservoir will be drafted during the winter low flow season each year to provide flow for power generation. By the end of April, a minimum of 2 million acre-feet of space is available which is adequate to provide complete regulation of all historical spring floods that have occurred during the 25 years of record. Optimum seasonal regulation requires that the Watana reservoir be gradually filled during the summer months so that the reservoir is at its normal maximum pool elevation of 2200 feet by 1 October. Summer flood control space is limited to the top 5 feet of the Watana pool range 2195 to 2200 feet during the month of August. No provision has been made for flood control space at the Devil Canyon reservoir because optimum regulation for power generation dictates that the Devil Canyon normal maximum pool elevation of 1450 feet be maintained.

CLIMATOLOGICAL DATA

MEAN MONTHLY PRECIPITATION - INCHES

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Matanuska Valley Agriculture Exp Stn	.90	.73	.43	.39	.74	1.30	2.24	2.90	2.39	1.59	1.01	.92	15.54
Talkeetna	1.76	1.72	1.46	.75	1.34	1.77	3.19	5.33	4.46	2.85	1.79	1.62	23.02
Summit	.88	1.31	1.21	.73	.81	2.24	3.15	3.27	2.90	1.72	1.37	1.34	20.93
Sheep Mountain	.55	.68	.62	.72	.56	1.97	2.43	1.24	1.41	1.13	.71	.56	12.58
McKinley Park	.83	.69	.37	.47	.68	1.93	2.59	2.81	1.54	.98	.75	.65	14.29
Gulkana	.68	.47	.36	.22	.60	1.40	1.92	1.58	1.85	.79	.60	.72	11.19

MEAN MONTHLY TEMPERATURE - ^0F

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Matanuska Valley Agriculture Exp Stn	12.1	18.8	24.6	37.1	47.2	55.4	57.7	55.4	47.7	35.6	21.9	13.2	35.6
Talkeetna	9.4	15.5	20.3	33.8	44.8	55.1	57.9	54.7	46.0	33.1	18.8	9.6	33.3
Summit	2.1	7.5	11.3	23.3	36.9	48.6	52.2	48.5	40.3	24.4	9.4	2.9	25.6
Sheep Mountain	5.1	9.5	15.7	27.8	41.0	53.3	52.9	51.0	42.4	28.0	12.7	5.1	28.8
McKinley Park	1.4	7.1	13.2	28.4	41.5	52.2	54.6	50.4	41.3	25.9	10.4	2.1	27.4
Gulkana	-1.3	2.8	14.5	29.5	43.1	53.3	56.6	52.5	43.4	27.7	6.8	-3.1	26.6

SUMMARY OF CLIMATOLOGICAL RECORDS

Station	Ground Elevation (Feet)	Years of Record*	Temperature (Degrees F.) Maximum	Minimum	Mean January	Mean July	Mean Annual	Average Annual Precipitation (Inches)	Average Annual Snowfall (Inches)	Average Length of Growing Season (Days)
Maritime Zone										
Seward	70	50	88	-20	24.7	55.5	39.5	67.35	81	134
Whittier	55	22	84	-29	24.5	56.9	39.0	173.73	260	148
Transition Zone										
Anchorage	114	51	86	-38	11.0	57.7	34.6	14.68	64	124
Homer	67	36	80	-21	22.6	52.4	36.4	23.08	56	100
Matanuska Agr. Exper. Station	150	49	91	-41	12.1	57.7	35.6	15.54	47	109
Talkeetna	345	52	91	-48	8.5	57.8	32.9	28.39	102	76
Continental Zone										
Big Delta	1268	30	92	-63	-5.9	59.4	27.0	11.37	41	114
Fairbanks	436	44	99	-66	-12.2	60.5	25.6	11.49	70	100
McKinley Park	2070	47	89	-54	1.4	54.6	27.4	14.29	76	62

*Years of record for maximum and minimum temperature data. Mean temperatures and other climatological parameters are generally based on shorter time intervals.

SUSITNA RIVER AT GOLD CREEK

Monthly Volumes in 1000's of Acre-Feet

Drainage Area - 6160 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
1950	390	154	88	63	44	45	52	708	1166	1390	1222	494	5316
1951	237	77	68	59	46	45	96	866	1237	1383	1210	1264	6593
1952	343	163	117	98	57	54	55	333	1926	1622	1286	862	6916
1953	504	208	105	68	45	50	96	1185	1626	1242	1267	909	7305
1954	344	135	92	80	56	48	73	1063	1502	1252	1605	769	7009
1955	330	164	126	110	78	63	71	573	1777	1694	1583	850	7424
1956	304	113	80	60	56	58	56	1036	1984	1912	1508	1091	9308
1957	357	182	132	104	83	74	71	846	1795	1433	1263	1178	7518
1958	505	235	201	121	73	71	91	793	1529	1407	1386	449	6861
1959	296	128	93	89	73	60	74	983	1383	1537	1917	1007	7645
1960	403	170	135	114	83	74	77	970	924	1413	1451	1220	7034
1961	479	179	166	151	97	111	158	1068	1753	1511	1359	796	7838
1962	364	161	129	117	83	86	101	774	2575	1590	1448	945	8313
1963	413	167	123	98	83	62	49	1170	1547	2115	1456	733	8016
1964	397	134	92	64	56	44	44	265	3010	1411	1011	5690	7096
1965	387	167	74	59	48	55	81	799	1530	1712	1298	1151	7362
1966	443	125	100	86	72	80	106	593	1961	1221	1342	699	6829
1967	256	95	92	92	78	74	69	952	1756	1648	2006	1004	8122
1968	301	140	126	123	109	117	114	995	1877	1625	1056	524	7106
1969	235	97	54	45	40	50	90	679	923	990	546	303	4052
1970	192	72	53	51	43	48	64	700	1109	1393	1228	543	5496
1971	325	203	141	89	58	58	64	230	1960	1473	1962	859	7421
1972	360	184	154	138	117	112	102	1346	2049	1400	1186	738	7885
1973	297	134	90	74	67	61	61	506	1654	1122	1248	540	5854
1974	230	91	64	54	43	45	59	995	1063	1156	997	816	5613
AVER.	347	147	108	88	68	66	79	817	1665	1466	1354	1017	7037

SUSITNA RIVER NEAR DENALI

Monthly Volumes in 1000's of Acre-Feet

Drainage Area - 950 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
									726	687	601	239	
1958	79	36	18	13	8	7	13	71	498	563	402	112	1820
1959	58	23	11	7	4	3	3	109	529	512	485	149	1893
1960	97	45	35	27	19	17	16	206	312	556	486	286	2102
1961	109	39	30	20	15	17	25	182	382	497	446	160	1922
1962	79	41	27	17	13	14	17	135	541	628	581	217	2310
1963	66	30	19	15	13	12	13	200	402	646	628	235	2279
1964	57	17	11	9	8	7	8	56	692	466	403	157	1890
1965	90	42	17	14	11	13	19	152	276	415	354	413	1817
1966	57	18	15	13	11	12	17	100	408	510	396	190	1745
1967													
1968										728	604	130	
1969	43	18	11	9	8	9	14	109	485	581	241	131	1658
1970	62	30	21	16	12	12	19	136	298	520	382	116	1624
1971	32	24	17	10	7	7	8	39	482	640	639	196	2101
1972	64	28	23	21	18	18	16	213	391	642	532	165	2132
1973	41	19	13	11	9	9	9	64	342	513	447	146	1623
1974	54	27	23	19	15	14	16	156	336	587	571	324	2216
AVER.	66	29	19	15	11	11	14	129	444	570	482	198	1942

SUSITNA RIVER NEAR CANTWELL

Monthly Volumes in 1000's of Acre-Feet

Drainage Area - 4140 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
1961								596	935	911	1027	400	
1962	202	107	86	80	56	58	71	615	1685	1284	983	560	5787
1963	266	131	86	62	47	47	43	697	892	1401	1118	547	5337
1964	237	77	54	40	34	26	28	173	2060	1048	707	319	4802
1965	193	114	57	47	38	44	65	542	978	1128	826	768	4799
1966	192	60	46	43	36	40	52	270	1101	751	779	388	3757
1967	143	46	44	42	36	34	31	581	1168	1038	1180	611	4954
1968	190	89	82	76	69	73	73	570	1160	1075	672	321	4451
1969	148	63	38	31	27	34	59	459	733	831	406	201	3031
1970	101	49	33	27	24	28	53	466	590	855	758	310	3293
1971	133	91	64	45	28	29	31	118	1307	1115	1396	583	4940
1972	250	122	84	66	53	54	52	596	1190	1026	960	561	5014
AVER.	187	86	61	51	41	42	51	474	1150	1039	901	464	4560

MACLAREN RIVER NEAR PAXSON

Monthly Volumes in 1000's of Acre-Feet

Drainage Area - 280 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	TOTAL
									210	217	166	47	
1959	23	7	8	8	5	4	5	36	171	165	128	51	611
1960	34	15	12	9	6	6	5	107	126	207	187	145	859
1961	42	12	9	7	5	6	9	76	159	207	203	70	805
1962	23	13	11	7	6	6	7	39	174	201	180	67	734
1963	24	12	8	6	5	5	5	131	185	286	193	72	932
1964	26	8	6	5	5	4	4	24	256	170	137	52	697
1965	23	9	3	3	2	3	4	60	135	198	148	125	712
1966	36	11	3	3	3	3	3	16	178	154	129	57	594
1967	23	6	4	4	3	3	3	63	216	200	221	84	831
1968	27	8	6	6	5	6	6	13	193	211	131	40	650
1969	16	7	4	4	3	4	6	52	156	165	60	28	504
1970	15	7	5	4	3	3	4	46	104	150	145	46	532
1971	19	11	8	5	3	3	4	22	203	216	225	69	791
1972	23	9	8	7	6	6	6	75	183	200	164	81	768
1973	34	14	8	5	4	3	3	35	173	176	140	49	644
1974	19	7	5	4	3	3	3	40	123	162	150	92	611
AVER.	25	10	7	5	4	4	5	52	173	193	159	69	705

DEVIL CANYON DAMSITE

Monthly Flow in Cubic Feet Per Second

Drainage Area - 5810 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1950	5998	2444	1360	970	744	685	822	10903	18837	21839	19151	7878
1951	3642	1229	1039	906	774	699	1529	13349	19961	21754	18950	20170
1952	5270	2596	1796	1512	945	831	869	5131	30886	25399	20144	13747
1953	7761	3309	1607	1039	774	774	1527	18259	26123	19583	19848	14498
1954	5336	1987	1418	1229	945	737	1167	16372	24170	19733	25088	12266
1955	5080	2612	1934	1698	1323	1039	1134	8827	28519	26498	24754	13567
1956	4683	1798	1229	926	916	888	897	16732	31800	29813	23590	17405
1957	5493	2886	2026	1607	1418	1134	1134	13026	29117	22644	19955	18804
1958	7743	3728	3062	1846	1227	1077	1442	12121	24678	22099	21595	7195
1959	4549	2027	1421	1357	1223	915	1167	15049	22492	24022	29764	16003
1960	6220	2709	2089	1749	1374	1133	1228	14965	14949	22184	22674	19525
1961	7386	2842	2543	2307	1652	1705	2498	16425	28004	23638	21280	12695
1962	5602	2563	1986	1789	1413	1319	1603	11896	41050	24972	22757	15101
1963	6341	2646	1884	1507	1413	944	786	18061	24855	33033	22937	11812
1964	6075	2117	1404	985	908	670	702	4093	48120	22054	15896	9140
1965	5964	2657	1146	908	814	851	1288	12313	24385	26572	20201	18619
1966	6780	1976	1536	1318	1224	1224	1673	9095	31309	19216	20885	11211
1967	3938	1514	1418	1418	1323	1134	1103	14672	28217	25801	30336	16013
1968	4635	2226	1943	1873	1797	1797	1806	15275	30103	25628	16800	8394
1969	3609	1544	832	683	682	769	1422	10451	15163	15819	8596	4922
1970	2978	1166	829	784	729	735	1027	10782	17788	21825	19171	8666
1971	4965	3204	2153	1355	973	892	1016	3550	31409	23239	30643	13731
1972	5521	2916	2365	2109	1910	1717	1611	20979	33158	22449	18997	11990
1973	4544	2122	1379	1129	1128	941	966	7882	26834	18008	19814	8790
1974	3552	1456	992	839	745	693	944	15258	17143	18327	15899	13231
AVER.	5347	2331	1656	1354	1135	1012	1254	12619	26763	23046	21189	13015

WATANA DAMSITE

Monthly Flow in Cubic Feet Per Second

Drainage Area - 5180 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1950	5067	2083	1174	847	657	607	722	9600	16527	19133	16791	6929
1951	3089	1064	904	793	682	619	1315	11757	17519	19057	16614	17759
1952	4457	2211	1540	1301	825	730	761	4511	27164	22280	17664	12100
1953	6548	2810	1381	904	682	682	1314	16085	22959	17138	17403	12762
1954	4512	1700	1223	1064	825	651	1012	14422	21234	17271	22015	10795
1955	4297	2225	1656	1457	1205	904	984	7770	25074	23251	21721	11941
1956	3964	1541	1064	809	801	777	785	15947	30237	28301	22370	16576
1957	4644	2455	1733	1381	1223	984	984	11472	25520	19808	17453	16555
1958	6538	3164	2608	1585	1064	938	1244	10700	21662	19363	18966	6319
1959	3851	1735	1227	1174	1062	803	1015	13282	19716	21081	26174	14104
1960	5251	2303	1784	1499	1185	983	1063	13178	13107	19441	19896	17179
1961	6230	2417	2168	1972	1420	1465	2131	14475	24653	20736	18662	11173
1962	4726	2275	1765	1605	1257	1176	1451	11181	36248	23432	20208	12954
1963	5581	2478	1701	1316	1201	875	761	15526	21137	29169	21146	10822
1964	5235	1809	1205	856	787	579	613	3607	43031	20162	14241	7711
1965	4896	2376	1061	852	801	797	1216	10995	21384	23470	17650	16465
1966	5398	1608	1239	1085	1007	1007	1372	7319	26477	16569	17790	9442
1967	3328	1237	1155	1140	1065	917	880	12703	24974	22436	26101	13850
1968	4050	1948	1713	1631	1572	1572	1586	13009	26103	22554	24589	7268
1969	3155	1363	751	617	608	686	1262	9327	14094	14948	7842	4339
1970	2472	1034	721	653	615	632	974	9574	14816	18835	16586	7363
1971	1750	2572	1736	1120	796	733	832	2933	27848	21312	27650	12248
1972	4969	2589	1990	1716	1537	1402	1334	16722	28194	20276	17723	11022
1973	3852	1815	1191	981	980	823	844	6915	23520	15679	17304	7687
1974	3010	1251	861	733	655	612	823	13459	15046	16012	13867	11590
AVER.	4435	2003	1422	1164	980	878	1091	11059	23530	20469	19137	11478

Appendix I
TABLE A-9
A-46

VEE DAMSITE

Monthly Flow in Cubic Feet Per Second

Drainage Area - 4140 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1950	3529	1489	867	643	513	479	557	7449	12713	14665	12895	5362
1951	2177	791	682	606	530	487	963	9128	13487	14606	12758	13780
1952	3114	1576	1117	954	628	563	584	3487	21021	17130	13572	9382
1953	4545	1986	1009	682	530	530	962	12498	17736	13103	13369	9896
1954	3151	1226	900	791	628	508	756	11203	16388	13207	16941	8367
1955	3004	1585	1196	1060	1009	682	737	6024	19388	17892	16714	9258
1956	2777	1117	791	617	612	595	601	11451	21652	20188	15920	11887
1957	3242	1743	1249	1009	900	737	737	8907	19583	15127	13324	12843
1958	4550	2234	1859	1153	795	708	918	8354	16682	14847	14626	4873
1959	2700	1253	907	871	795	617	764	10364	15133	16226	20247	10969
1960	3651	1634	1281	1087	874	735	791	10227	10065	14912	15309	13305
1961	4323	1716	1549	1418	1038	1068	1525	11256	19121	15946	14339	8660
1962	3281	1800	1400	1300	1000	940	1200	10000	28320	20890	16000	9410
1963	4326	2200	1400	1000	850	760	720	11340	15000	22790	18190	9187
1964	3848	1300	877	644	586	429	465	2806	34630	17040	11510	5352
1965	3134	1911	921	760	780	709	1097	8818	16430	18350	13440	12910
1966	3116	1000	750	700	650	650	875	4387	18500	12200	12680	6523
1967	2322	780	720	680	640	560	513	9452	19620	16880	19190	10280
1968	3084	1490	1332	1232	1200	1200	1223	9268	19500	17480	10940	5410
1969	2406	1063	618	508	485	548	998	7471	12330	13510	6597	3376
1970	1638	815	543	437	426	463	887	7580	9909	13900	12320	5211
1971	2155	1530	1048	731	503	470	529	1915	21970	18130	22710	9800
1972	4058	2050	1371	1068	922	881	876	9694	20000	16690	15620	9423
1973	2709	1309	881	737	737	628	643	5319	18048	11834	13161	5865
1974	2114	912	646	559	507	478	624	10488	11585	12190	10513	8880
AVER.	3158	1460	1037	850	726	657	822	8355	17952	15989	14515	8808

DENALI DAMSITE

Monthly Flow in Cubic Feet Per Second

Drainage Area - 1260 Square Miles

YEAR	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.
1950	1651	635	333	226	165	149	186	2903	7470	10406	8217	2029
1951	976	296	245	209	173	153	380	3573	7686	10396	8145	5442
1952	1443	679	454	375	219	188	198	1331	9798	10880	8570	3675
1953	2163	881	401	245	173	173	379	4926	8877	10106	8467	3881
1954	1462	507	348	296	219	163	279	4406	8500	10127	10294	3269
1955	1388	683	492	426	401	245	271	2335	9340	11027	10180	3625
1956	1274	454	296	214	212	204	206	4505	9975	11469	9778	4680
1957	1508	760	518	401	348	271	271	3485	13844	12442	10891	5098
1958	1846	877	506	345	230	188	306	1870	9769	10399	7766	2295
1959	1267	529	264	209	161	98	119	2657	10164	9697	9581	3423
1960	2029	949	718	562	411	347	344	4212	6087	10293	9197	5937
1961	2321	860	661	492	382	396	590	3908	8018	9419	8459	5233
1962	1700	820	549	373	318	292	358	2600	11411	10991	10628	4656
1963	1452	603	403	343	331	237	227	4448	8473	12305	11062	4436
1964	1329	438	281	203	199	154	174	1143	14109	8496	7318	3289
1965	1959	840	324	251	212	238	361	3113	6091	8231	6958	7956
1966	1556	471	377	319	301	301	420	2447	9096	9481	7852	4013
1967	1064	402	376	382	354	298	294	4026	9204	11012	12695	4400
1968	1208	1261	474	464	441	441	441	4308	9802	13230	10793	2721
1969	765	452	213	179	177	187	309	2324	8639	9848	4274	2480
1970	1233	563	389	325	274	242	349	2801	6369	9816	7407	2554
1971	1015	687	469	281	208	195	221	913	9803	11315	11830	4009
1972	1317	640	557	521	479	432	400	5364	8805	11395	9234	3241
1973	996	470	302	250	236	211	213	1495	7257	9343	8376	2944
1974	1128	557	426	359	313	273	319	3426	6620	10570	10179	6202
AVER.	1442	653	415	330	277	243	305	3141	9008	10508	9126	4060

RESERVOIR SEDIMENT INFLOW

	Upstream Development	Sediment Inflow 50-year Volume (Acre-Feet)	Sediment Inflow 100-year Volume (Acre-Feet)
Devil Canyon	None	252,000	497,000
	Denali	137,941	272,000
	Vee	94,000	186,000
	Watana	35,000	70,000
Watana	None	204,000	403,000
	Denali	102,000	202,000
	Vee	59,000	116,000
Vee (2300 ft. W.S.EL.)	None	162,000	320,000
	Denali	44,000	87,000
Denali (2535 ft. W.S.EL.)	None	290,000	572,000

Note: 50-year unit weight of sediment is 80 lbs/ft^3.

100-year unit weight of sediment is 81 lbs/ft^3.

SUSPENDED SEDIMENT CONCENTRATION
SUSITNA RIVER AT GOLD CREEK

DATE OF COLLECTION	DISCHARGE (CFS)	SEDIMENT CONCENTRATION (PPM)	SEDIMENT DISCHARGE (TONS/DAY)
Apr 24, 1953	1,060	3	8
May 6, 1953	22,400	954	57,700
May 21, 1953	30,300	1,330	109,000
May 29, 1953	20,800	314	17,600
May 24, 1956	31,300	661	55,900
May 25, 1956	28,800	703	54,700
Jun 5, 1953	32,200	1,010	87,800
Jun 22, 1953	24,300	1,060	69,500
Jun 23, 1953	25,000	1,090	73,600
Jun 24, 1953	24,200	1,070	69,900
Jun 3, 1955	33,600	491	44,500
Jun 23, 1955	28,200	920	70,000
Jun 3, 1957	33,400	1,433	---
Jun 20, 1957	29,300	2,965	---
Jun 12, 1958	8,770	2,620	62,000
Jun 16, 1962	52,000	1,400	196,000
Jul 2, 1953	20,400	2,080	115,000
Jul 16, 1953	21,700	1,610	94,300
Jul 7, 1955	28,200	920	70,000
Jul 14, 1955	22,400	637	38,500
Jul 28, 1955	29,000	2,690	211,000
Jul 2, 1957	25,500	4,191	---
Jul 10, 1957	20,200	1,709	---
Jul 21, 1958	8,360	2,480	56,000
Jul 6, 1962	25,200	852	58,000
Jul 16, 1962	13,200	334	11,900
Aug 6, 1953	21,800	1,880	111,000
Aug 15, 1953	17,800	775	37,200
Aug 8, 1955	19,100	797	41,100
Aug 18, 1955	13,500	257	9,370
Aug 31, 1955	23,000	422	26,200
Aug 7, 1956	30,600	917	75,800
Aug 21, 1956	21,000	742	42,100
Aug 8, 1957	17,700	3,660	---
Aug 17, 1957	21,600	3,310	---
Aug 29, 1957	23,500	2,778	---
Aug 28, 1958	4,170	832	9,370
Sep 28, 1953	10,200	61	1,680
Sep 28, 1955	10,100	33	900
Sep 6, 1957	16,700	2,100	---
Sep 24, 1958	1,920	244	1,260
Sep 11, 1962	14,400	107	4,160
Oct 15, 1952	9,200	36	894

Appendix I
TABLE A-12

KENAI RIVER BELOW SKILAK LAKE

Date	Temperature (Deg C)	Turbidity (JTU)	Discharge (cfs)	Sediment Concentration (ppm)	Sediment Discharge (Tons/Day)
Sept 2, 1967	20		21,900	45	2,700
Oct 22, 1967	4		4,570	35	430
Apr 2, 1968	1		1,440	15	58
May 17, 1968	7		2,480	37	250
Jun 19, 1968	10		9,150	22	540
Aug 2, 1968			12,300	27	900
Aug 21, 1968	11		13,640	30	1,100
Oct 23, 1968	2.0		2,090	11	62
Jan 15, 1969	0		1,190	28	90
Feb 27, 1969	0		1,880	41	208
Mar 19, 1969	0		1,530	4	17
May 5, 1969	5.0		1,480	11	44
Jun 25, 1969	8.0		14,200	58	2,220
Jul 31, 1969	13.0		11,000	16	475
Sept 9, 1969	9.0		5,450	4	59
Oct 16, 1969	6.0		26,000	103	7,230
Mar 5, 1970	0		1,810	5	24
Jun 24, 1970	9.0		9,050	12	293
Aug 9, 1970	10.0		14,000	22	832
Jan 28, 1971	0		1,300	3	11
Mar 24, 1971	0		1,130	1	3
Jul 14, 1971	12.0		16,700	151	6,810
Aug 26, 1971	10.0	2	15,300		
Oct 6, 1972	5.5	2	4,910		
Nov 22, 1973	2.0	3	2,150		
Jul 26, 1973	10.5	3	10,400		
Sept 5, 1973	10.5	1	8,190		

Note: Measurements taken at Soldotna gaging station.

KASILOF RIVER BELOW TUSTUMENA LAKE

Date	Temperature (Deg C)	Discharge (cfs)	Sediment Concentration (ppm)	Sediment Discharge (Tons/Day)
Sep 3, 1967	10	10,300	37	1,000
Oct 22, 1967	5	3,890	45	470
Mar 15, 1968	1	710	33	63
May 16, 1968	8	597	30	48

Note: Measurements taken at the Kasilof River gage.

EKLUTNA RIVER BELOW EKLUTNA LAKE

Date	Temperature (Deg C)	Turbidity (JTU)	Discharge (cfs)	Sediment Concentration (ppm)	Sediment Discharge (tons/day)
Oct 6, 1973	6.5	25	371	17	17
Dec 18, 1973	2.5	9	438	10	12
Feb 15, 1973	3.0	4	236	4	3
Apr 17, 1973	3.0	7	193	3	2
Jul 17, 1973	11.5	20	145	20	8
Jul 31, 1973	12.5	40	159	13	6
Aug 27, 1973	10.5	35	275	11	8
Sep 26, 1973	9.0	15	331	5	4

Note: Water samples were taken from the Eklutna Powerhouse outlet.

LONG RIVER - LONG LAKE SEDIMENT RATES

Date	Water Temperature °C	Discharge c.f.s.	Suspended Sediments mg/l	Suspended Sediments tons/day	Discharge c.f.s.	Suspended Sediments mg/l	Suspended Sediments tons/day
	Station 15-0310 Long River Above Long Lake				Station 15-0520 Long River Below Long Lake		
3 Oct 67	3.	36.	12	1.2			
19 Dec 67	1.	9.8	2	.05	111	3	.9
29 Mar 68	2.	8.8	2	.05			
29 Apr 68	2.	13.	1	.04			
22 Jul 68	5.	233.	96	60.	715	8	20.
1 Oct 68	3.	84.	14	3.2			
1 Apr 69	0.	2.3	2	.01			
1 May 69	1.	25.	2	.14	183	2	.99
29 May 69	2.	141.	8	3.0			
8 Jul 69		945.	569	1450.			
16 Jul 69	4.	155.	88	37.			
8 Aug 69	4.	241.	182	118.			
18 Sep 69	4.	67.	39	7.1			
18 Dec 69	.5	11.4	4	.12			
2 Mar 70		11.5	2	.06	6.6	1	.02
1 Apr 70	1.5	11.9	3	.10			
28 May 70	1.5	96.	7	1.8			
21 Jul 70	2.	205.	22	12.			
20 Oct 70	2.0	33.0	8	.72			
28 Apr 71	2.0	20.0	3	.16	95	5	1.3
14 Jul 71	2.5	237.0	32	20.0			
12 Jul 72	2.0	361	51	50.0			

SUSPENDED SEDIMENT CONCENTRATIONS IN PPM IN RIVERS OF CALIFORNIA, OREGON, AND WASHINGTON IN THE PERIOD 1906-1912.

State	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Coastal Rivers												
California	139	225	160	126	120	85	80	53	38	48	59	46
Oregon	27	16	9	8	10	8	20	5	6	3	12	6
Washington	12	7	19	18	14	12	6	4	7	16	28	13
Interior Rivers												
California	137	107	88	96	51	32	44	56	42	47	51	79
Oregon	94	107	58	113	107	194	81	74	62	33	37	13
Washington	6	24	47	41	26	14	16	17	13	14	19	14

MISCELLANEOUS ANALYSES OF STREAMS IN ALASKA

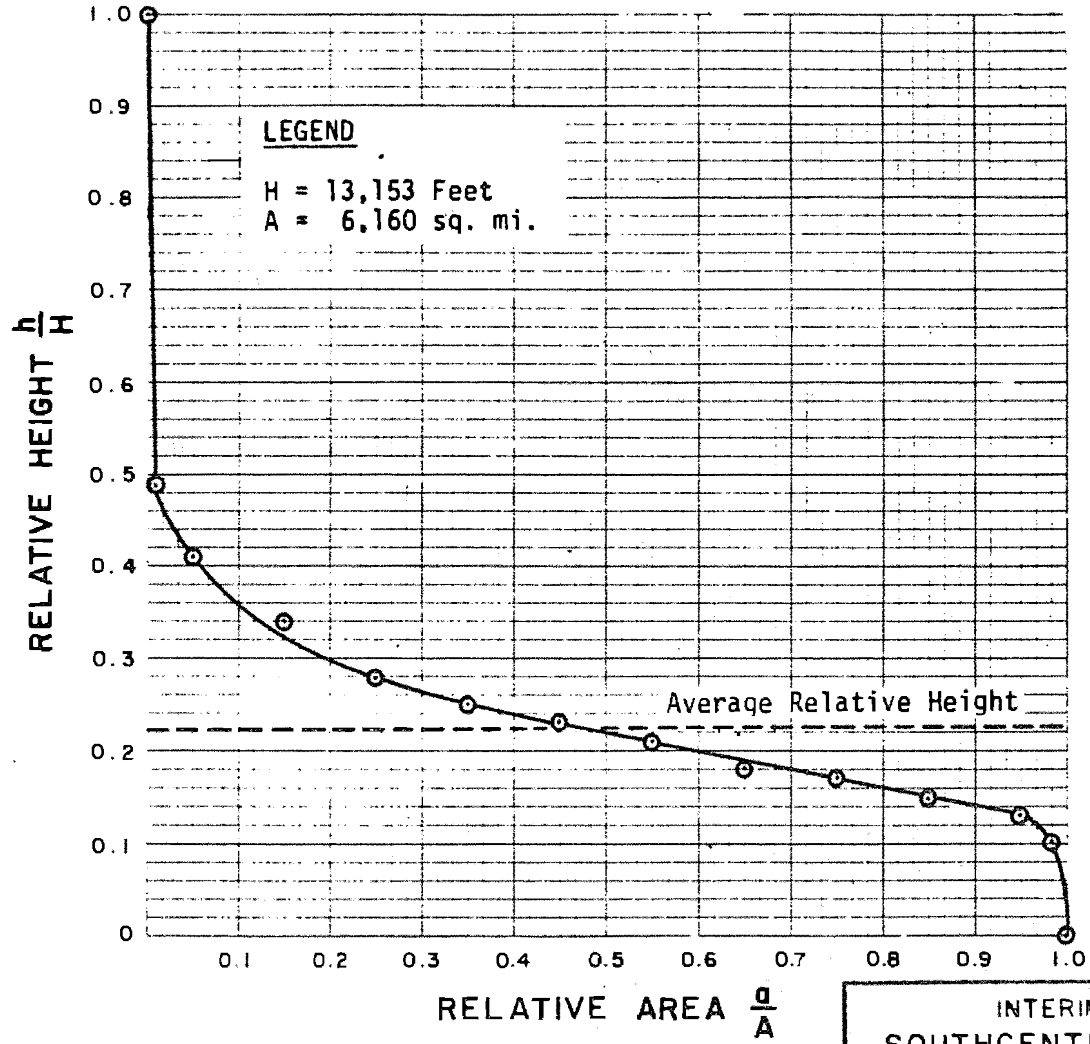
Chemical analyses, in parts per million

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
SUSITNA RIVER AT GOLD CREEK																		
22 Jun 1949		4.9		11	2.0	7.6		50	8.4	1.4		0.5	60	36	0	100	6.8	
3 Aug		7.8		15	2.4	5.5		50	11	4.5		.4	77	48	6	115	7.2	
31 Jul, 1-10 Aug 1950		6.6	0.40	20	2.6	7.1		70	12	4.2	0.1	.1	92	61	3	142	7.7	30
11-18 Aug		5.2	.19	24	2.3	8.7		80	15	4.8	.1	.1	102	69	4	170	7.5	20
6 Aug 1953	23,400	5.6	0.01	22	1.8	3.0	3.7	66	16	1.8	0.0	0.3	87	62	8	150	7.2	8
1953																		
9-20 Oct	6,350	11	0.02	29	5.4	8.6	1.8	85	29	12		1.0	145	95	25	231	7.7	0
21 Oct	4,350	13	.03	24	3.7	10	2.1	74	13	18			120	75	14	201	7.9	
22-26 Oct	4,210	12	.00	28	5.6	8.4	2.0	84	25	13		.7	142	93	24	228	8.0	0
27-31 Oct	2,830	11	.00	33	7.8	8.4	1.3	97	36	13		1.4	173	114	35	265	7.8	0
1-5 Nov	2,300	11	.00	31	6.6	9.6	1.6	94	30	15		1.0	158	104	27	257	8.1	0
7-13 Nov	2,300	11	.00	31	5.2	11	2.3	91	24	18		1.0	153	99	24	255	7.7	0
1954																		
11 Feb	1,160	13	.00	30	4.4	17	2.7	89	17	31	0.1	.7	160	93	20	282	7.2	
1955																		
24 Apr	1,060	11	.00	31	4.5	16	2.5	83	24	29		.2	159	96	28	211	8.0	
1-10 Jun	20,700	7.7	.12	13	1.5	4.3	1.0	43	8.5	4.0	.0	.7	62	39	3	101	7.2	40
11-20 Jun	34,400	5.9	.12	12	1.4	3.4	1.0	39	6.5	4.0	.0	.6	63	36	4	91	7.2	40
7 Jul	28,000	6.1	.11	16	2.0	3.5	2.1	53	14	4.8	.1	.4	75	48	5	122	7.7	10
11-20 Jul	24,800	7.1	.10	17	1.7	4.9	2.3	56	11	5.2	.0	.4	78	49	4	133	7.6	10
21-30 Jul	25,500	4.7	.08	23	1.9	3.5	3.5	68	16	4.0	.0	.2	90	65	10	161	7.4	5
31 Jul	23,000	5.4	.00	25	3.1	4.2	3.6	77	19	2.5	.0	.3	101	75	12	174	7.8	0
1-10 Aug	20,000	6.5	.00	22	3.2	4.6	2.4	67	16	5.0	.0	.2	93	68	13	156	7.8	5
11-20 Aug	20,890	6.9	.00	19	3.1	4.9	2.0	60	14	5.2	.0	.1	85	60	11	147	7.7	0
21-31 Aug	35,400	6.9	.00	21	5.7	3.5	1.3	66	21	3.2	.0	.8	96	76	22	156	7.7	8
1-10 Sep	19,400	7.5	.00	21	5.0	4.6	1.1	69	22	4.5	.0	.4	100	73	16	171	7.9	5
11-20 Sep	13,700	8.2	.00	23	5.0	4.8	1.3	68	22	5.0	.0	.4	103	78	22	176	7.8	5
1956																		
24 May	31,100	5.2	.00	13	.3	2.8	1.7	37	5.5	2.8	.1	.2	61	34	3	86	6.6	45
25 May	30,400	5.6	.00	12	1.4	2.9	1.7	39	5.5	1.8	.1	.2	62	36	4	91	7.0	50
26-31 May	23,300	5.5	.00	16	2.8	3.8	1.3	48	11	4.5	.0	.9	70	51	12	121	6.5	15
1-10 Jun	32,400	6.5	.00	16	2.3	3.5	1.4	49	9.9	3.5	.0	.5	68	49	9	115	6.6	8
11-20 Jun	39,000	6.0	.00	16	2.3	3.5	1.6	49	9.9	4.0	.0	.4	68	49	9	118	6.7	8
21-30 Jun	28,700	6.0	.00	17	1.5	3.5	1.7	50	11	4.0	.0	.5	70	49	8	116	6.9	10
1-2 Jul	27,900	10	.00	20	1.8	4.1	2.4	63	12	4.2	.1	.1	86	57	6	140	7.8	5
22 Aug 1967	29,400	7.1	.06	19	3.5	3.4	2.4	67	15	2.8	.1	.9	87	63	8	147	7.6	
11 Jan 1968	1,960	1.1	.19	34	4.5	11	2.4	98	12	29	.1	.5	152	38	0	277	8.0	5
SUSITNA RIVER NEAR DENALI																		
1957																		
9 Apr	164	12	0.00	51	6.8	15	6.5	163	37	19	0.2	0.3	228	155	22	382	7.5	5
27 Aug	a6,950	3.2	.04	23	6.2	3.8	3.6	70	31	3.8	.0	.0	109	84	26	194	7.4	5
17 Dec	190	12	0.06	41	8.0	18	6.3	137	36	21	0.1	0.2	210	135	23	351	7.6	0
1958																		
3 Apr	126	13	.02	46	16	23	6.6	196	39	30	.1	.0	270	181	20	467	7.1	5
12 Jun	a8,770	5.7	3.0	17	2.6	2.1	2.6	52	13	3.0	.0	.2	75	53	10	121	7.2	10
21 Jul	a8,360	4.5	.03	19	2.9	2.2	3.4	63	13	2.0	.1	.0	78	60	8	140	7.5	0
28 Aug	a3,860	5.4	.09	21	3.1	3.8	2.5	65	18	4.5	.2	.1	91	65	12	157	7.4	0
24 Sep	a1,400	6.9	.02	23	6.4	7.5	2.1	83	23	9.0	.3	.2	120	84	16	199	7.9	10
5 Jul 1960		7.3	.04	18	2.4	3.4	2.8	60	14	3.0	.1	.4	a81	55	6	129	7.8	0
23 May 1968	5,840	4.2	4.0	17	1.9	3.6	2.3	57	9.2	4.2	.1	.2	75	50	3	124	7.2	30
1 Oct 1968	963	7.4		29	3.6	10	2.1	92	20	11	.0	.0	130	87	12	226	7.8	5

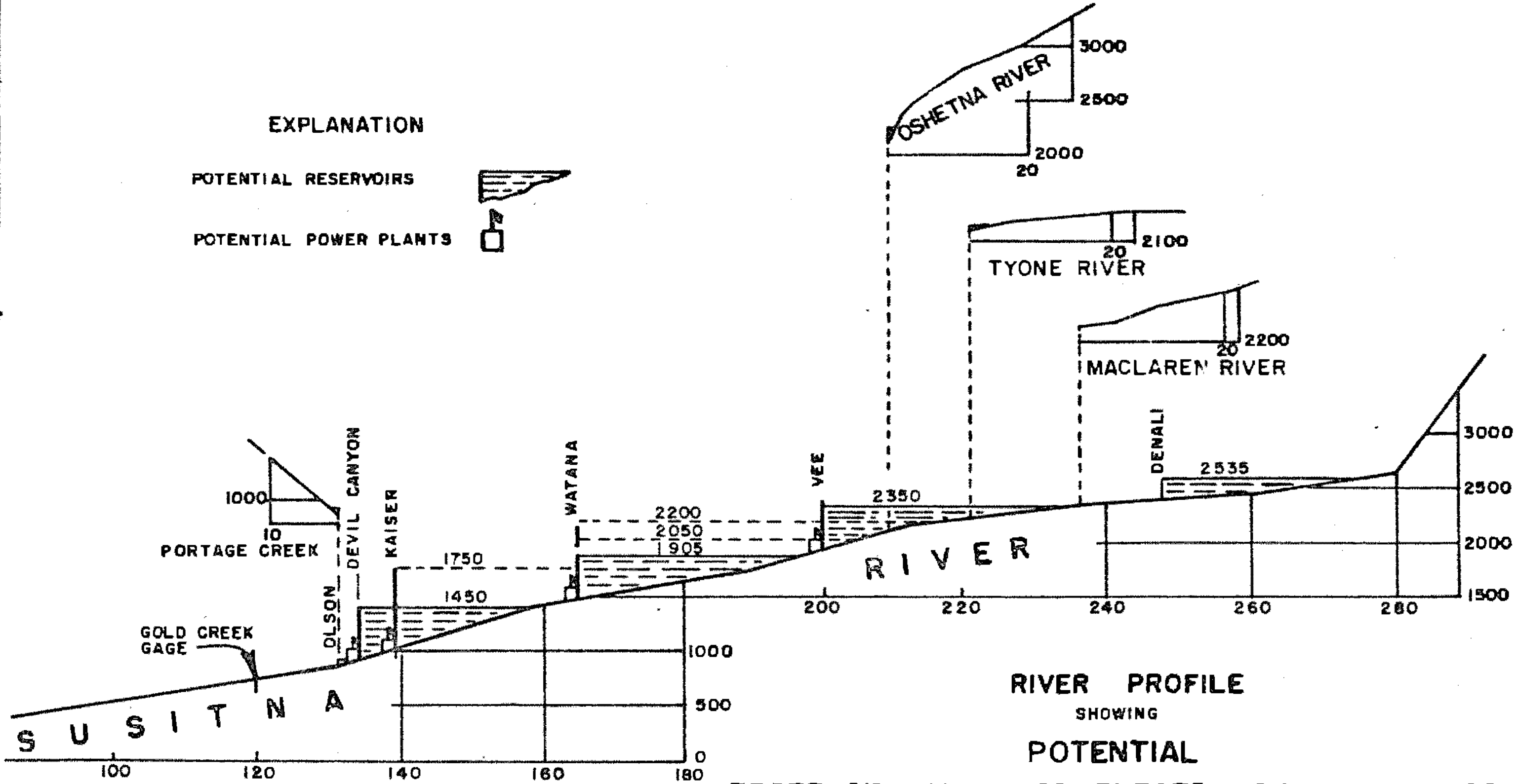
MISCELLANEOUS ANALYSES OF STREAMS IN ALASKA (Continued)
Chemical analyses, in parts per million

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$		Specific conductance (micromhos at 25°C)	pH	Color
								MACLAREN RIVER NEAR PAXSON										
12 Jun 1958	3.800	4.8	0.41	12	3.5	1.1	2.0	38	14	2.0	0.0	0.3	59	44	14	95	6.8	20
21 Jul	3,560	4.7	.02	12	3.7	1.4	2.2	42	15	.5	.0	.3	61	45	10	110	7.2	0
78 Aug	1,260	4.4	.12	15	4.1	1.6	2.1	46	19	1.5	.2	.0	71	54	17	130	7.2	0
24 Sept	692	6.7	.05	18	5.4	3.5	1.6	59	22	4.0	.2	.3	91	67	18	144	7.6	5
5 Jul 1960		5.0	.37	13	4.3	1.8	2.6	44	15	3.0	.2	.4	a 68	50	14	103	7.8	20
22 Jul 1967	4030	4.2	5.39	4.0	2.3	1.7	2.2	41	17	0.4	0.0	1.5	69	44	10	101	7.7	10
17 Aug	5320	4.8	.12	11	2.2	1.1	1.7	34	13	.7	.1	.9	53	36	8	84	7.6	5
20 Sep	936	5.3	.14	19	3.4	2.1	1.4	54	20	3.2	.0	.7	82	62	18	141	7.8	10
27 Mar 1968		8.5	.37	27	3.9	2.8	2.5	78	20	4.3	.0	.4	108	84	20	182	7.6	0
								SUSITNA RIVER NEAR CANTWELL										
23 Aug 1967	16100	6.1	0.10	20	2.6	3.2	2.8	63	16	2.5	0.2	0.7	85	61	9	142	7.7	10
21 Sep	7480	6.8	.87	20	3.2	4.8	1.4	64	10	7.4	.0	1.1	87	63	10	147	7.6	10
29 Sep	5750	7.6	.90	27	1.1	5.7	1.8	67	16	8.5	.3	3.9	106	70	15	174	7.2	10
8 Jun 1968	15,600	5.4	.66	14	1.8	2.2	7.3	48	7.5	3.5	.1	.1	66	42	3	105	7.4	40
24 Jul	18,200	4.4	7.9	23	2.2	2.1	3.0	67	16	3.0	.2	.6	95	66	11	148	7.9	10
20 Sep	4040	7.1	1.0	25	3.4	6.3	4.9	72	18	9.2	.3	.0	110	76	17	177	7.5	--
15 May 1969	8,670	2.7		17	2.4	4.8	2.8	54	12	7.4	.1	.7	77	54	10	136	7.6	30
24 Jun	15,800	4.6		18	4.4	2.1	5.2	64	14	2.1	.2	.2	95	62	10	145	8.0	5
17 Jul 1970	10,900	5.7	--	70	19	2.6	3.3	2.8	59	13								
18 Sept	7,040	6.3	--	50	24	3.0	4.6	2.2	70	16								

Susitna Drainage Basin Hypsometric Curve



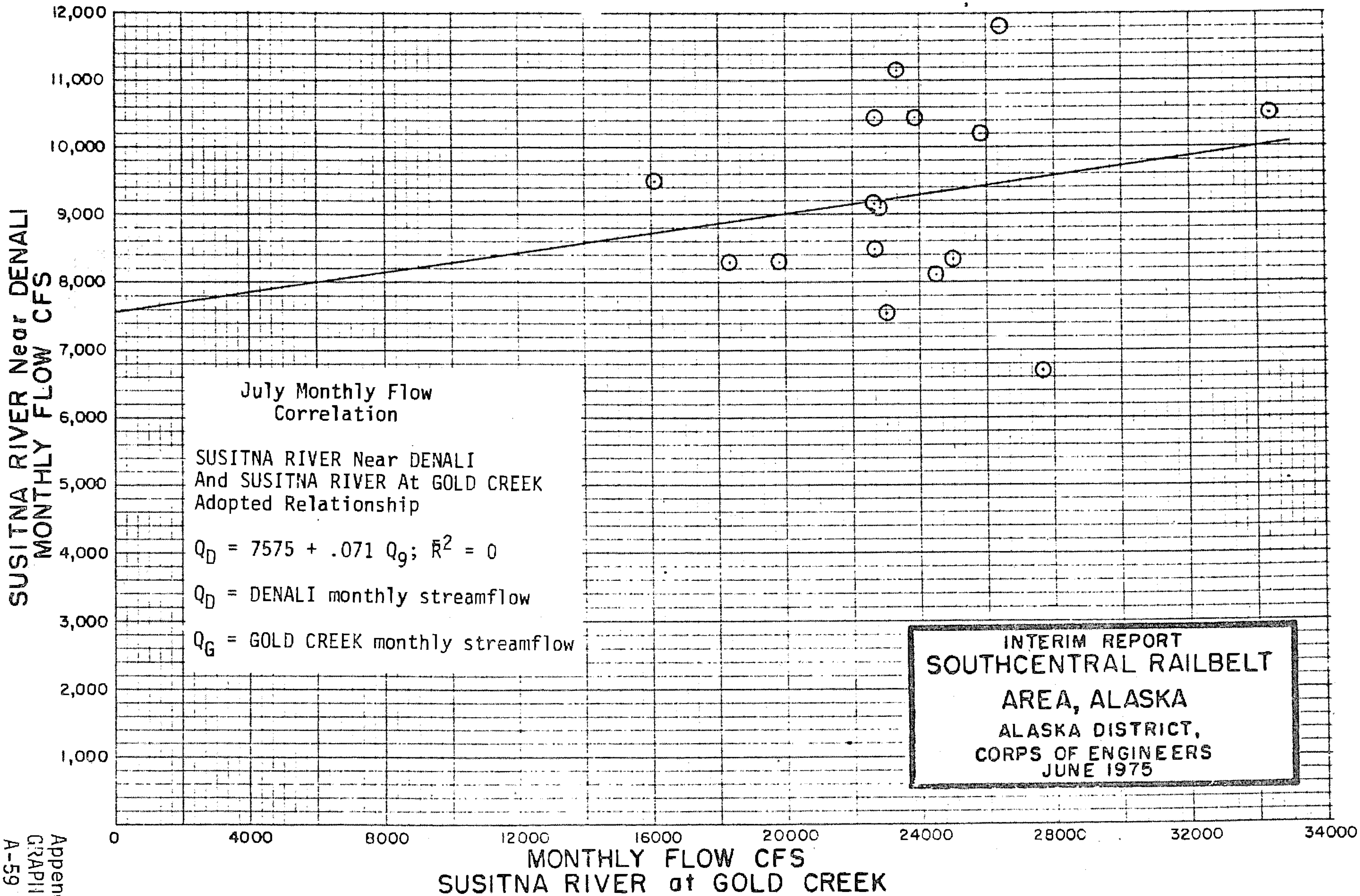
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

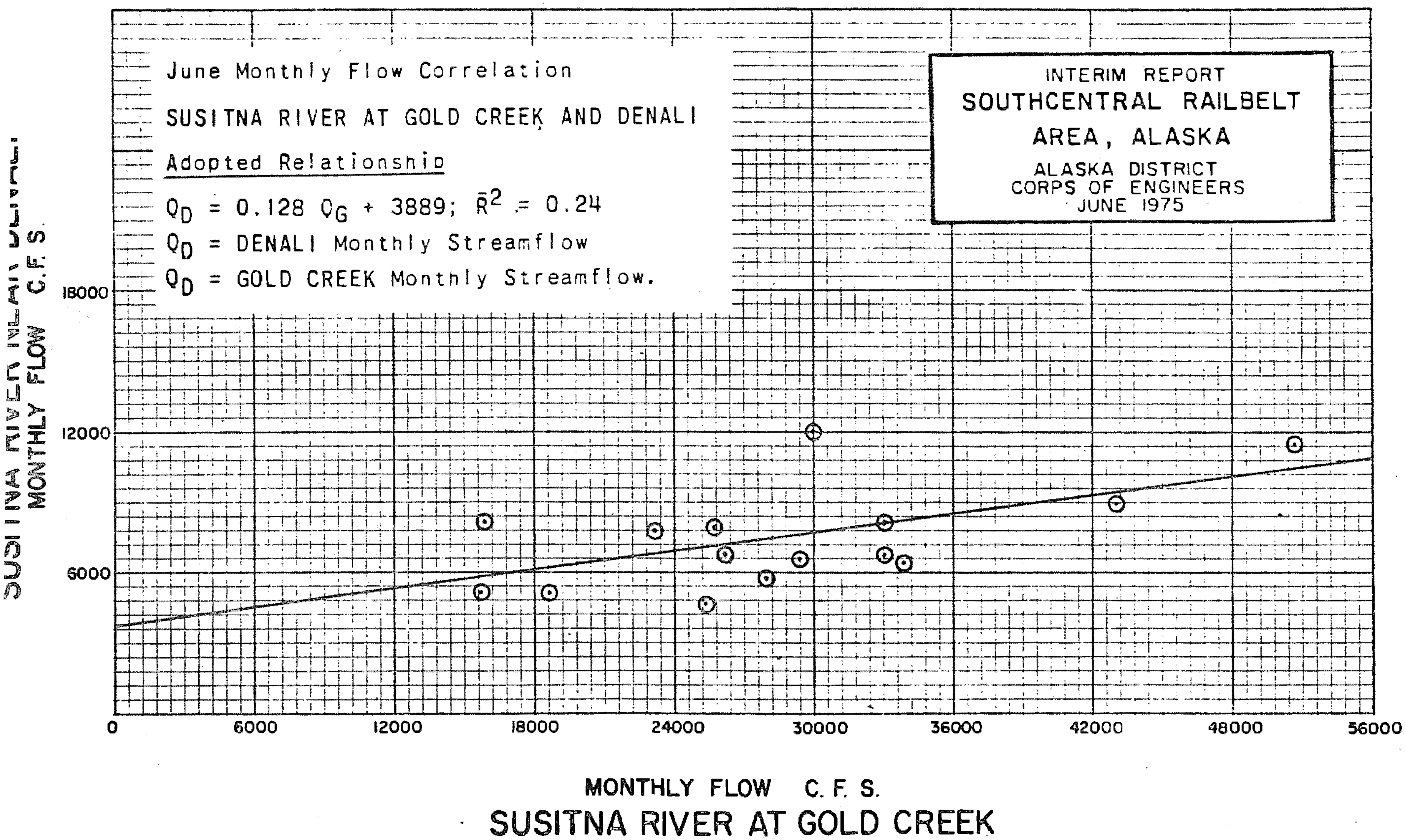


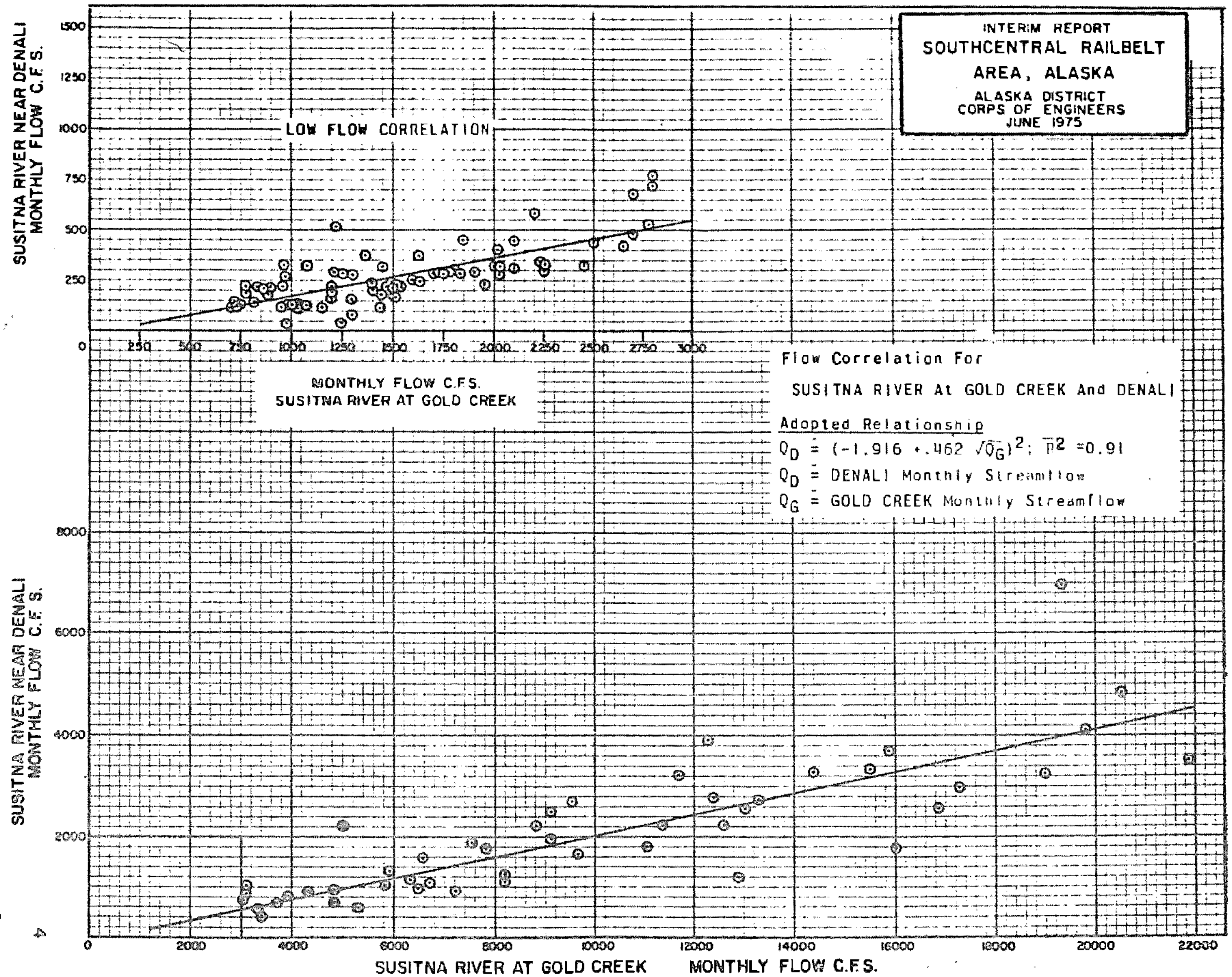
RIVER PROFILE
SHOWING
POTENTIAL
RESERVOIRS AND HYDROELECTRIC POWER PLANTS

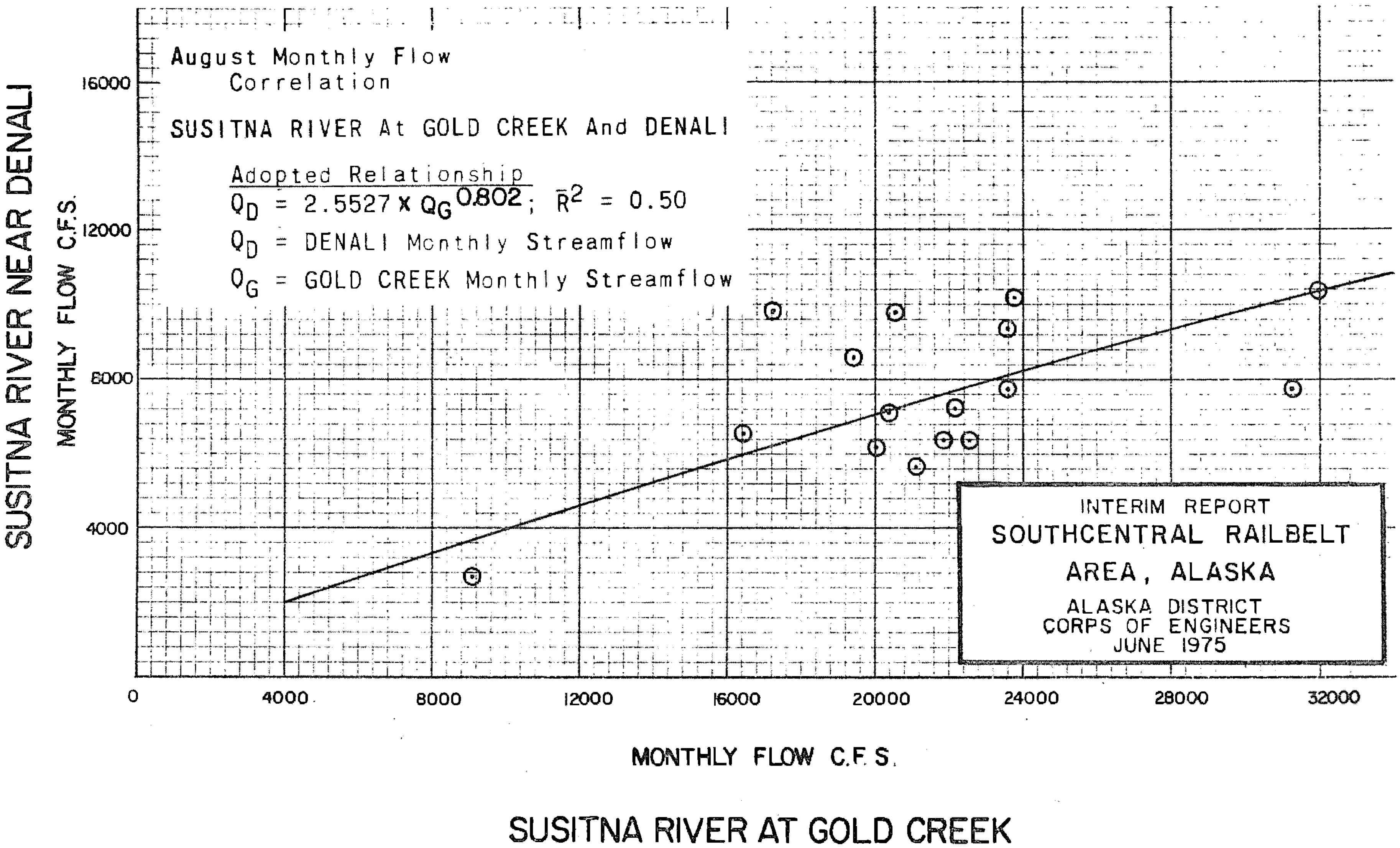
ALL DISTANCES SHOWN ARE IN MILES FROM THE MOUTH AT COOK INLET.
ALL ELEVATION ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.

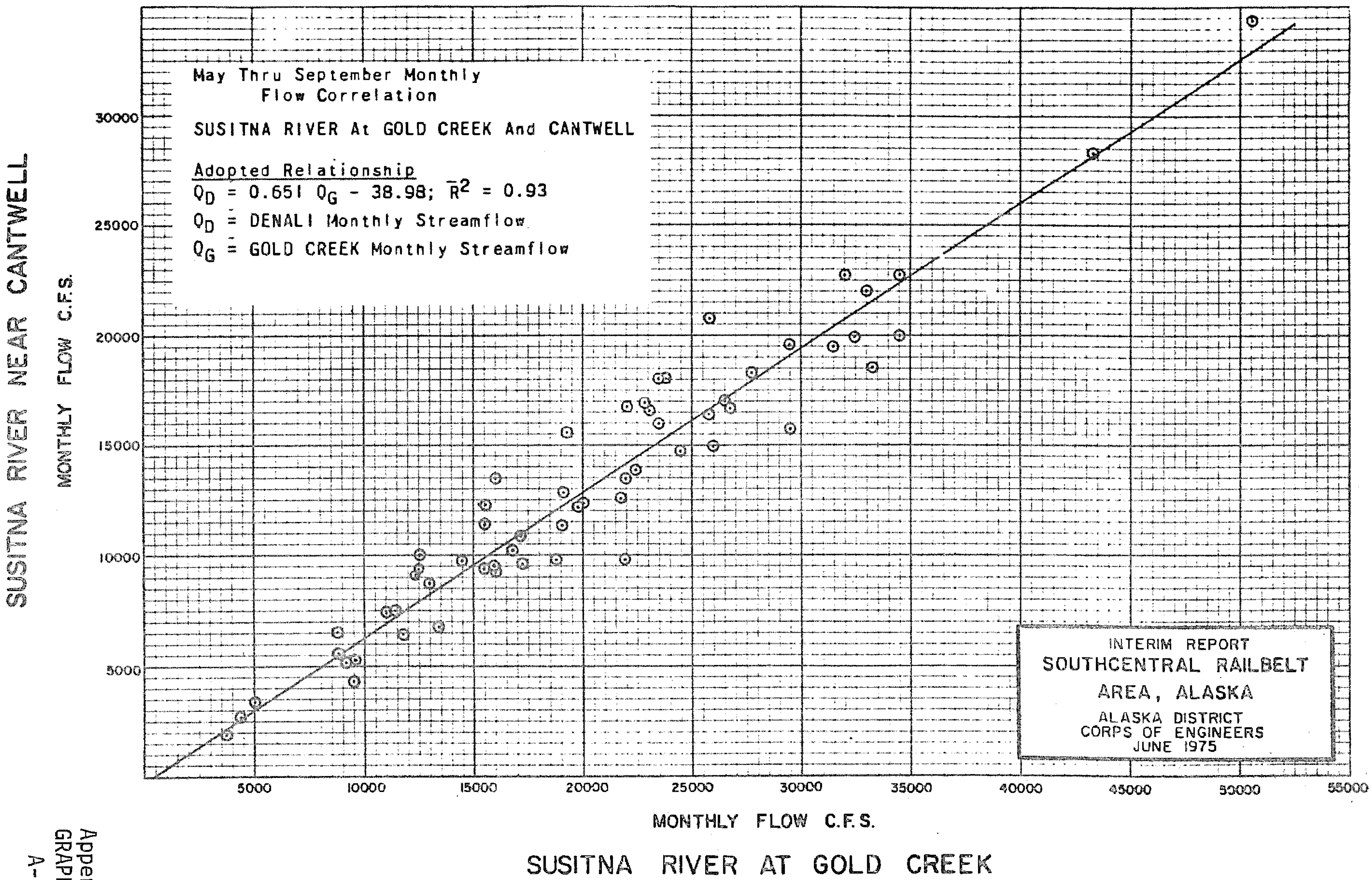
INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1975

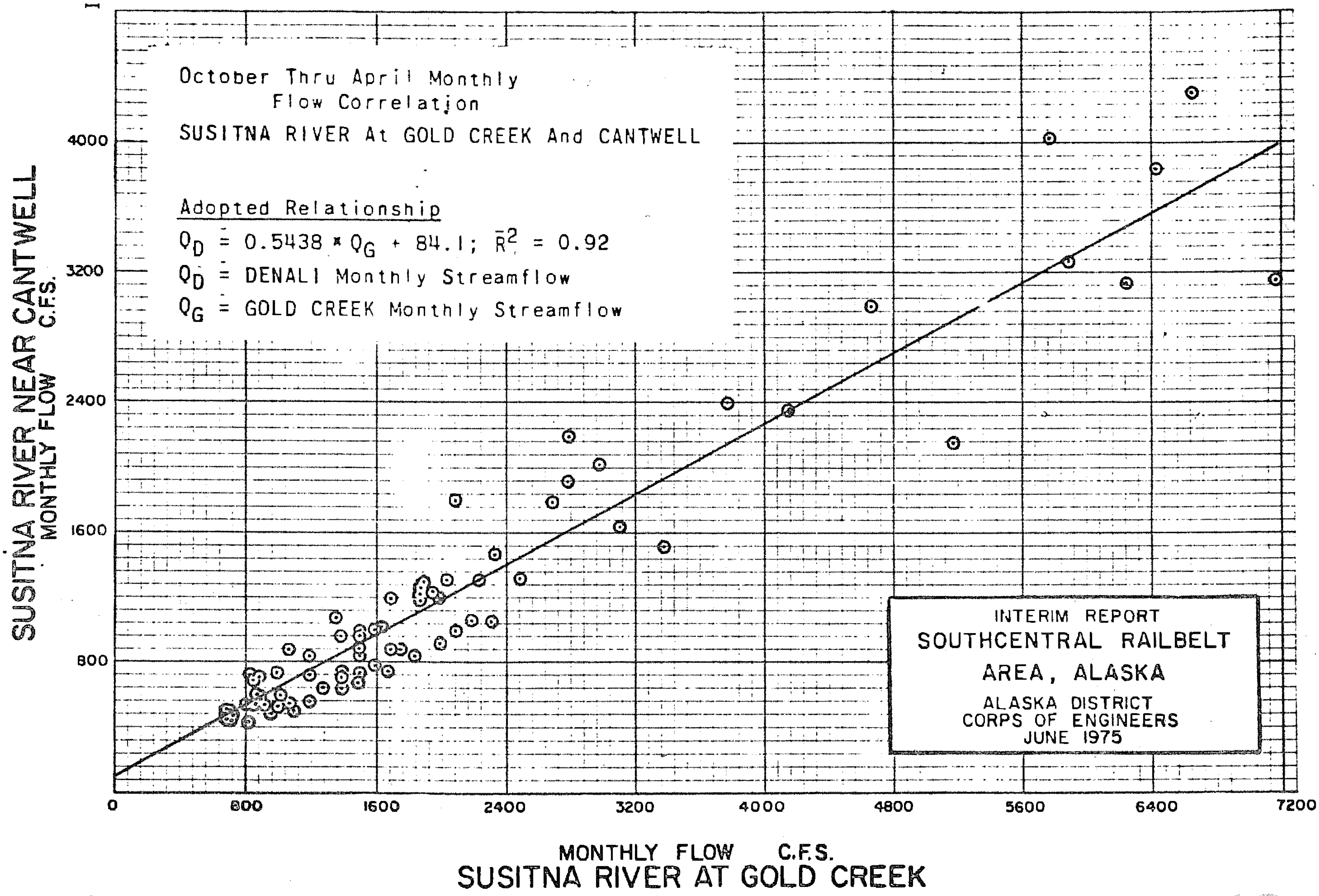

July Monthly Flow
Correlation
SUSITNA RIVER Near DENALI
And SUSITNA RIVER At GOLD CREEK
Adopted Relationship
$Q_D = 7575 + .071\ Q_g;\ \bar{R}^2 = 0$
Q_D = DENALI monthly streamflow
Q_G = GOLD CREEK monthly streamflow
SUSITNA RIVER Near DENALI
MONTHLY FLOW CFS
MONTHLY FLOW CFS
SUSITNA RIVER at GOLD CREEK
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
4000
8000
12000
16000
20000
24000
28000
32000
34000
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1975

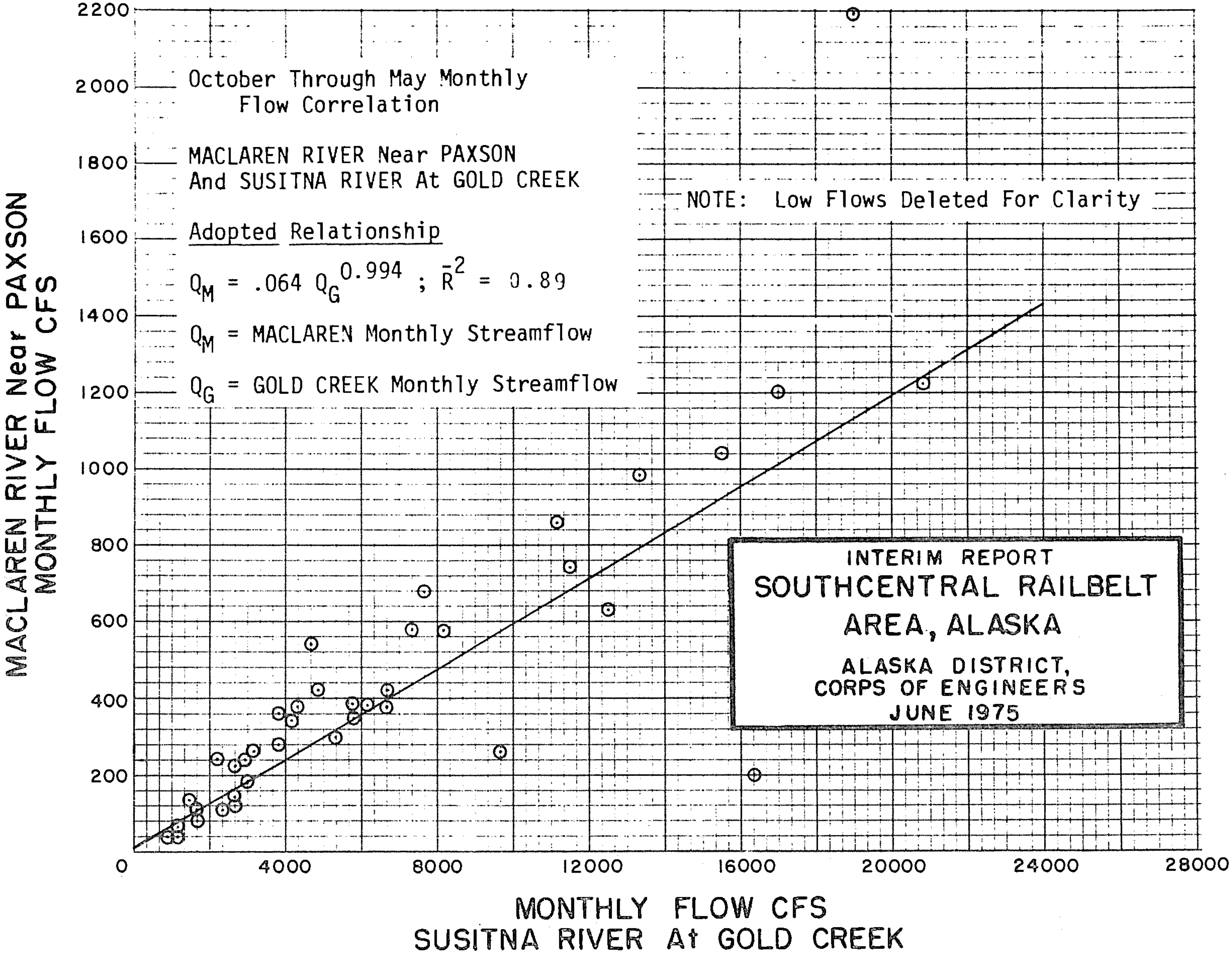

June Monthly Flow Correlation
SUSITNA RIVER AT GOLD CREEK AND DENALI
Adopted Relationship
$Q_D = 0.128\ Q_G + 3889;\ \bar{R}^2 = 0.24$
Q_D = DENALI Monthly Streamflow
Q_D = GOLD CREEK Monthly Streamflow.
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975
MONTHLY FLOW C.F.S.
18000
12000
6000
0
6000
12000
18000
24000
30000
36000
42000
48000
56000
MONTHLY FLOW C. F. S.
SUSITNA RIVER AT GOLD CREEK


INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975
LOW FLOW CORRELATION
SUSITNA RIVER NEAR DENALI
MONTHLY FLOW C.F.S.
1500
1250
1000
750
500
250
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
2750
3000
MONTHLY FLOW C.F.S.
SUSITNA RIVER AT GOLD CREEK
Flow Correlation For
SUSITNA RIVER At GOLD CREEK And DENALI
Adopted Relationship
$Q_D = (-1.916 + .462 \sqrt{Q_G})^2$; $\bar{R}^2 = 0.91$
Q_D = DENALI Monthly Streamflow
Q_G = GOLD CREEK Monthly Streamflow
SUSITNA RIVER NEAR DENALI
MONTHLY FLOW C.F.S.
8000
6000
4000
2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
SUSITNA RIVER AT GOLD CREEK
MONTHLY FLOW C.F.S.

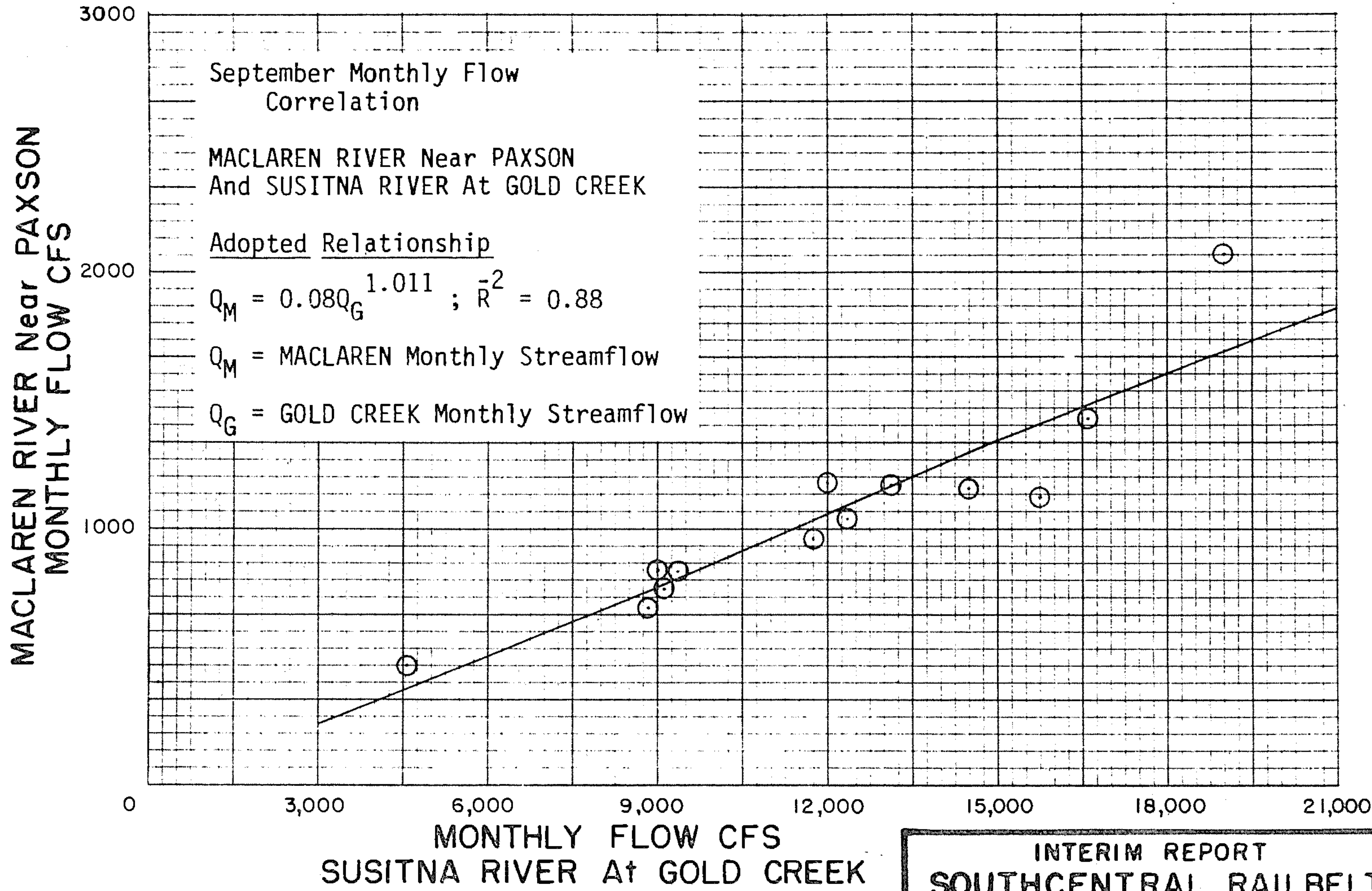

August Monthly Flow Correlation
SUSITNA RIVER At GOLD CREEK And DENALI
Adopted Relationship
$Q_D = 2.5527 \times Q_G^{0.802}$; $\bar{R}^2 = 0.50$
Q_D = DENALI Monthly Streamflow
Q_G = GOLD CREEK Monthly Streamflow
SUSITNA RIVER NEAR DENALI
MONTHLY FLOW C.F.S.
16000
12000
8000
4000
0
4000
8000
12000
16000
20000
24000
28000
32000
MONTHLY FLOW C.F.S.
SUSITNA RIVER AT GOLD CREEK
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975


May Thru September Monthly
Flow Correlation
SUSITNA RIVER At GOLD CREEK And CANTWELL
Adopted Relationship
$Q_D = 0.651\ Q_G - 38.98;\ \bar{R}^2 = 0.93$
Q_D = DENALI Monthly Streamflow
Q_G = GOLD CREEK Monthly Streamflow
SUSITNA RIVER NEAR CANTWELL
MONTHLY FLOW C.F.S.
30000
25000
20000
15000
10000
5000
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
MONTHLY FLOW C.F.S.
SUSITNA RIVER AT GOLD CREEK
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

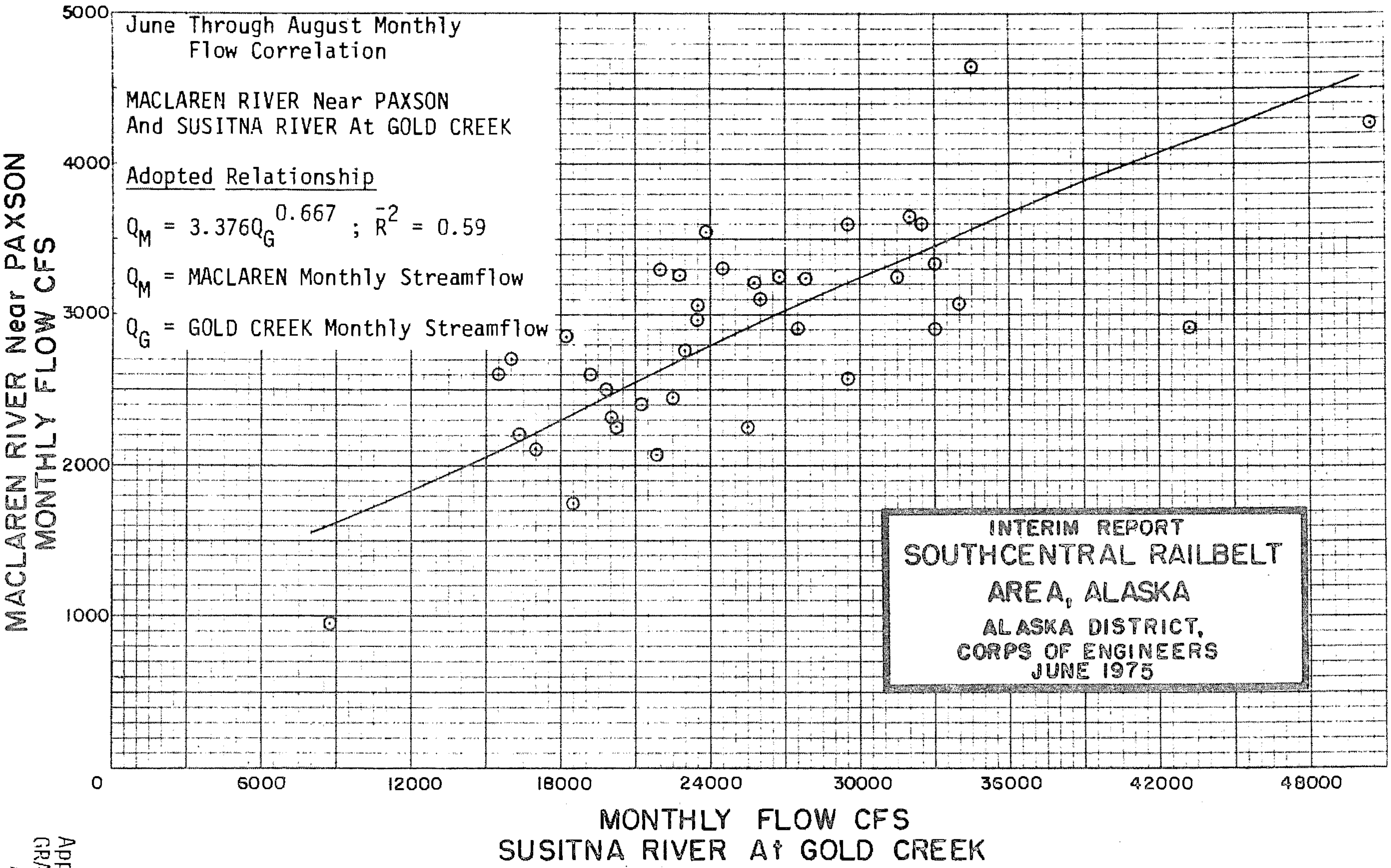

October Thru April Monthly
Flow Correlation
SUSITNA RIVER At GOLD CREEK And CANTWELL
Adopted Relationship
$Q_D = 0.5438 * Q_G + 84.1; \bar{R}^2 = 0.92$
Q_D = DENALI Monthly Streamflow
Q_G = GOLD CREEK Monthly Streamflow
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975
SUSITNA RIVER NEAR CANTWELL
MONTHLY FLOW C.F.S.
4000
3200
2400
1600
800
0
800
1600
2400
3200
4000
4800
5600
6400
7200
MONTHLY FLOW C.F.S.
SUSITNA RIVER AT GOLD CREEK



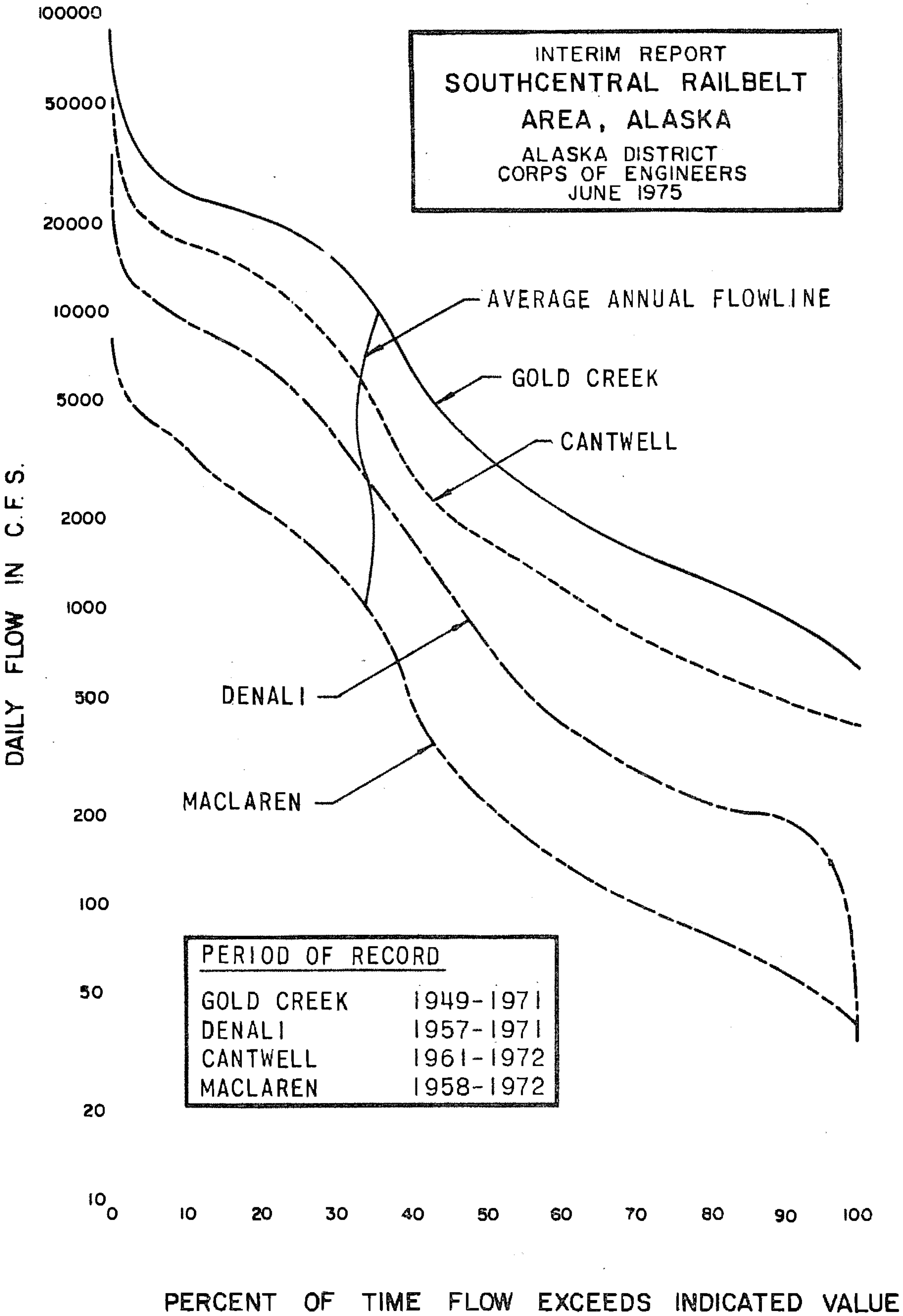
Appendix I
GRAPH A-9
A-65



INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT, CORPS OF ENGINEERS
JUNE 1975

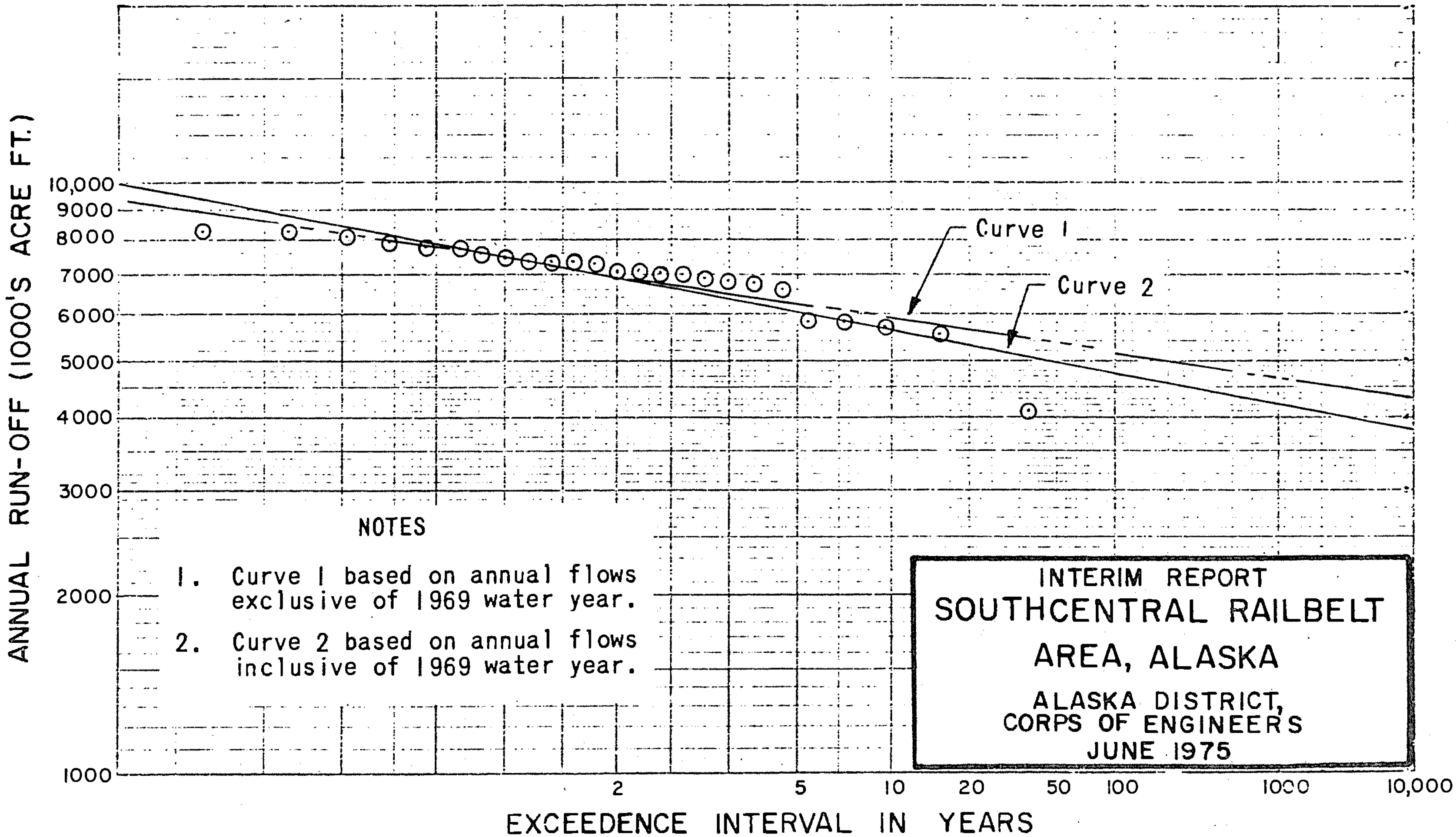

June Through August Monthly Flow Correlation
MACLAREN RIVER Near PAXSON And SUSITNA RIVER At GOLD CREEK
Adopted Relationship
$Q_M = 3.376 Q_G^{0.667}$; $\bar{R}^2 = 0.59$
Q_M = MACLAREN Monthly Streamflow
Q_G = GOLD CREEK Monthly Streamflow
INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT, CORPS OF ENGINEERS
JUNE 1975
MACLAREN RIVER Near PAXSON
MONTHLY FLOW CFS
5000
4000
3000
2000
1000
0
6000
12000
18000
24000
30000
36000
42000
48000
MONTHLY FLOW CFS
SUSITNA RIVER At GOLD CREEK

DAILY FLOW DURATION CURVES

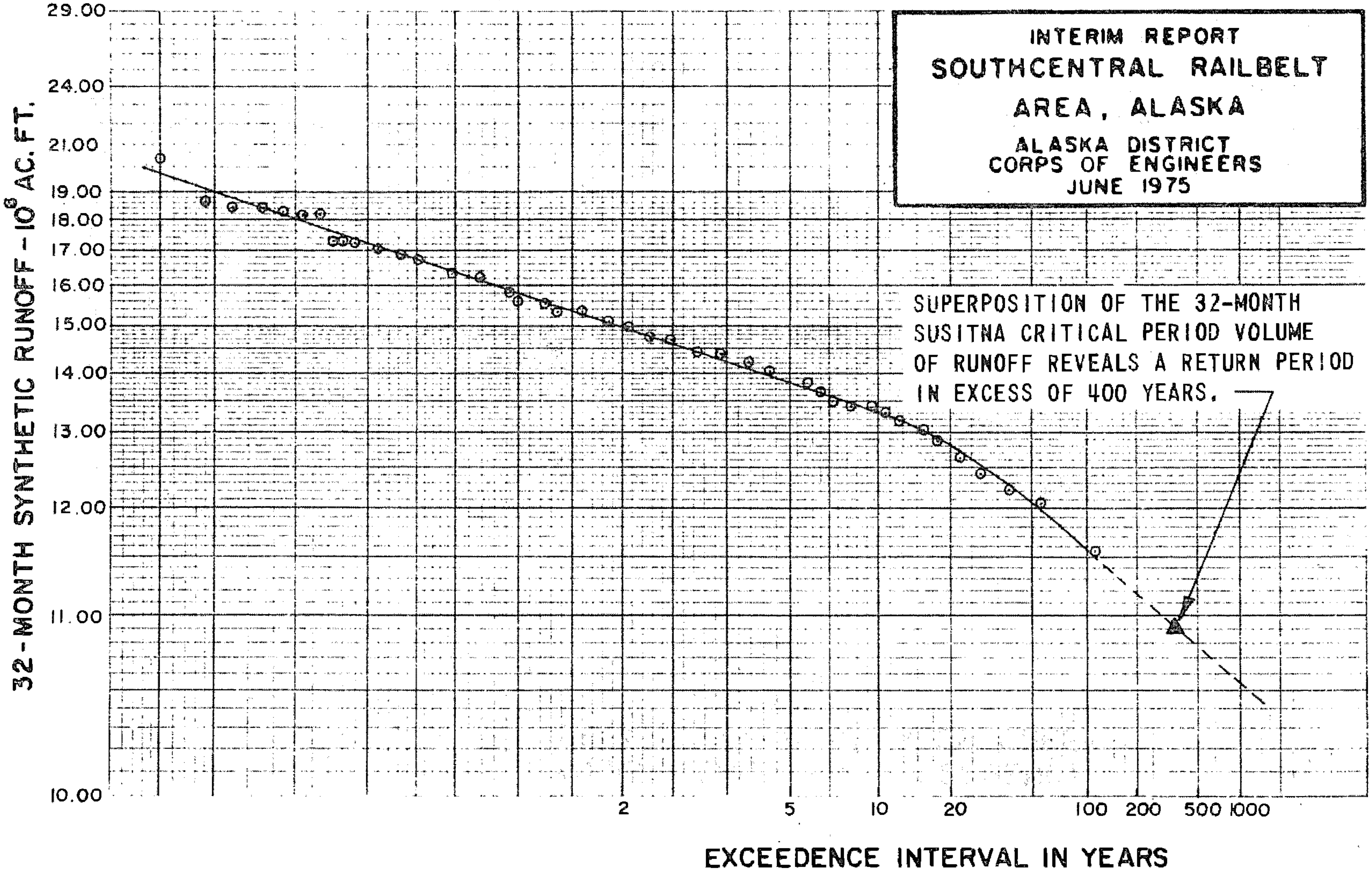


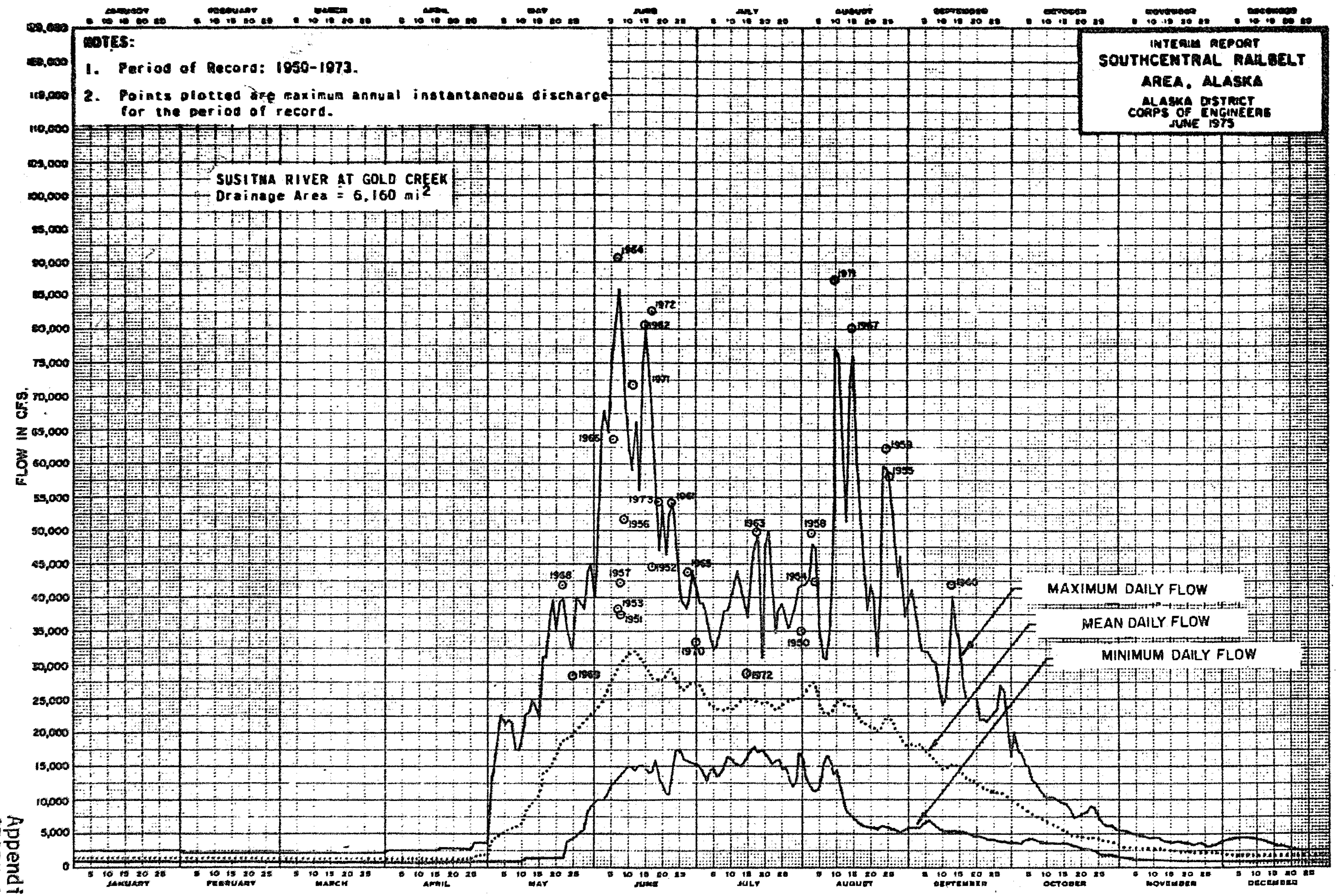
PERIOD OF RECORD	
GOLD CREEK	1949-1971
DENALI	1957-1971
CANTWELL	1961-1972
MACLAREN	1958-1972

ANNUAL LOW FLOW FREQUENCY
SUSITANA RIVER AT GOLD CREEK

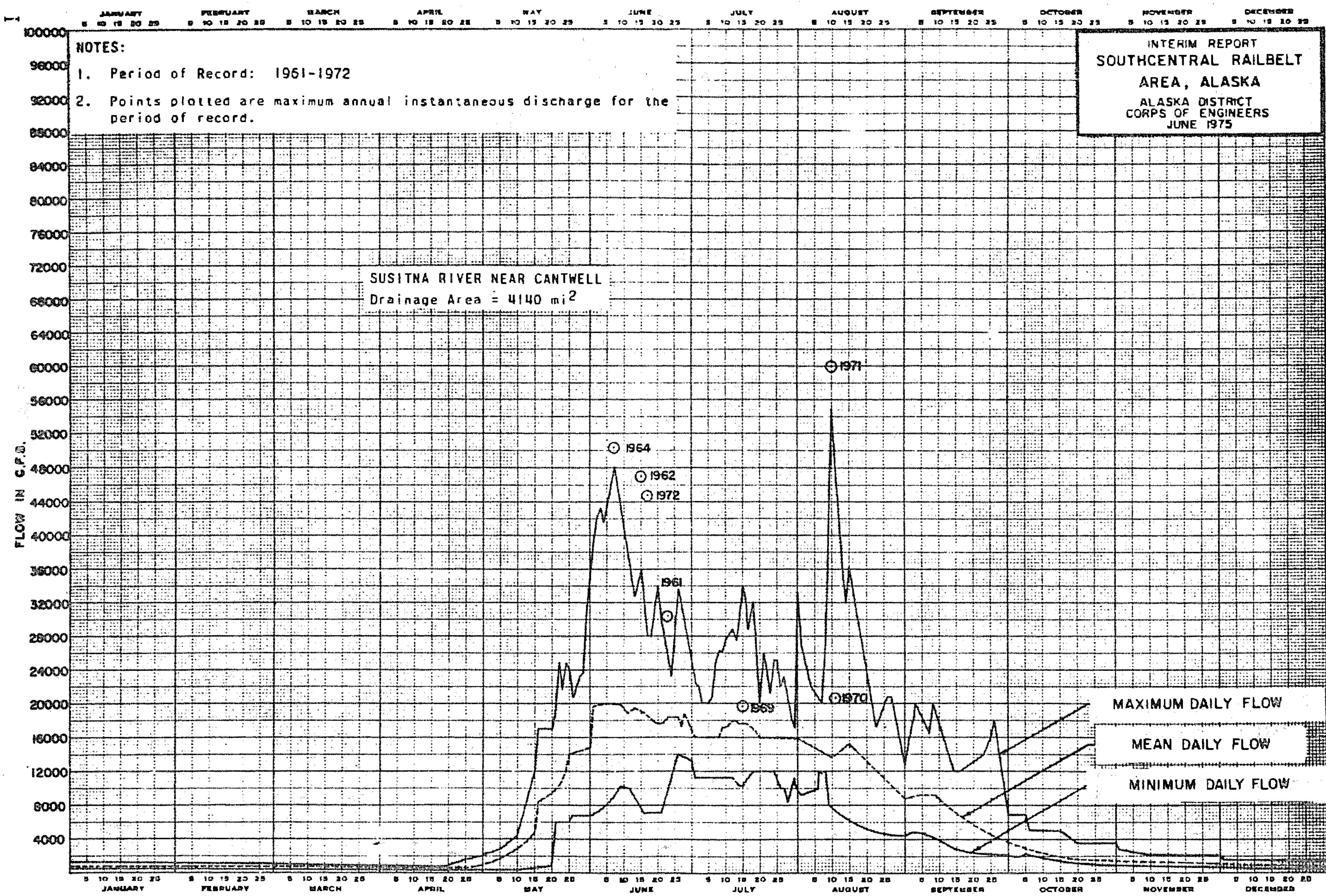


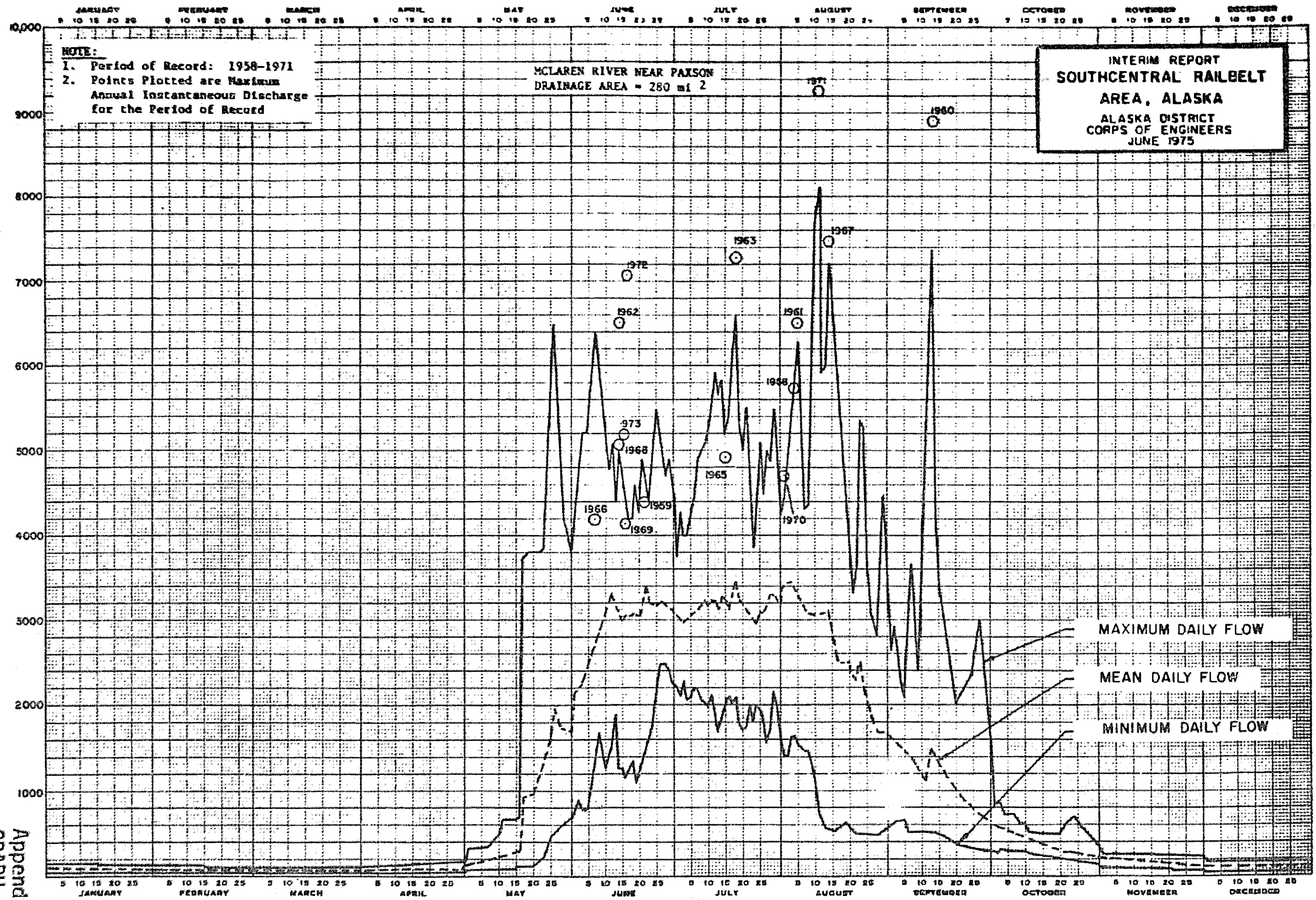
SYNTHETIC 32-MONTH LOW FLOW FREQUENCY
SUSITNA RIVER AT GOLD CREEK





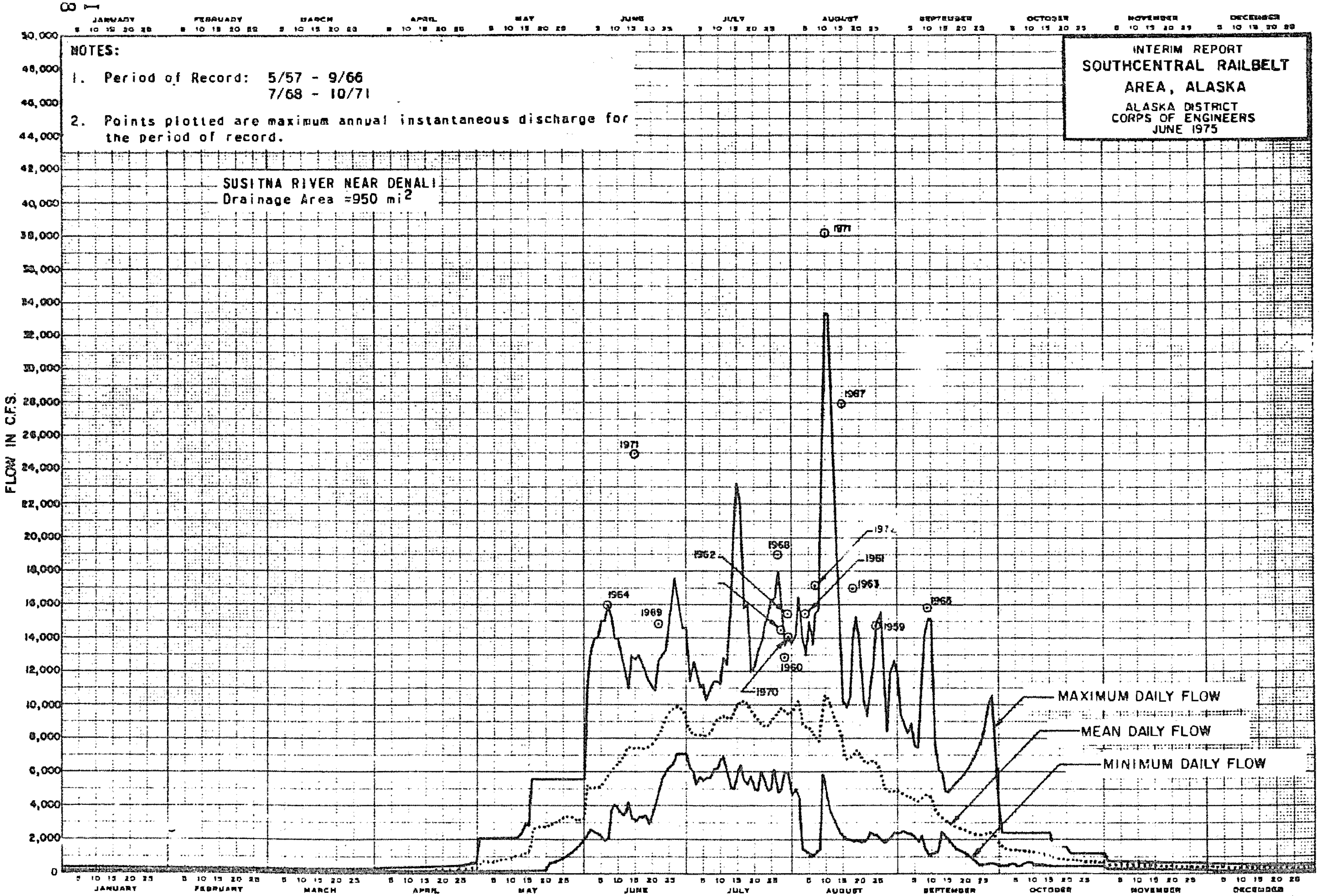
Appendix I
GRAPH A-15

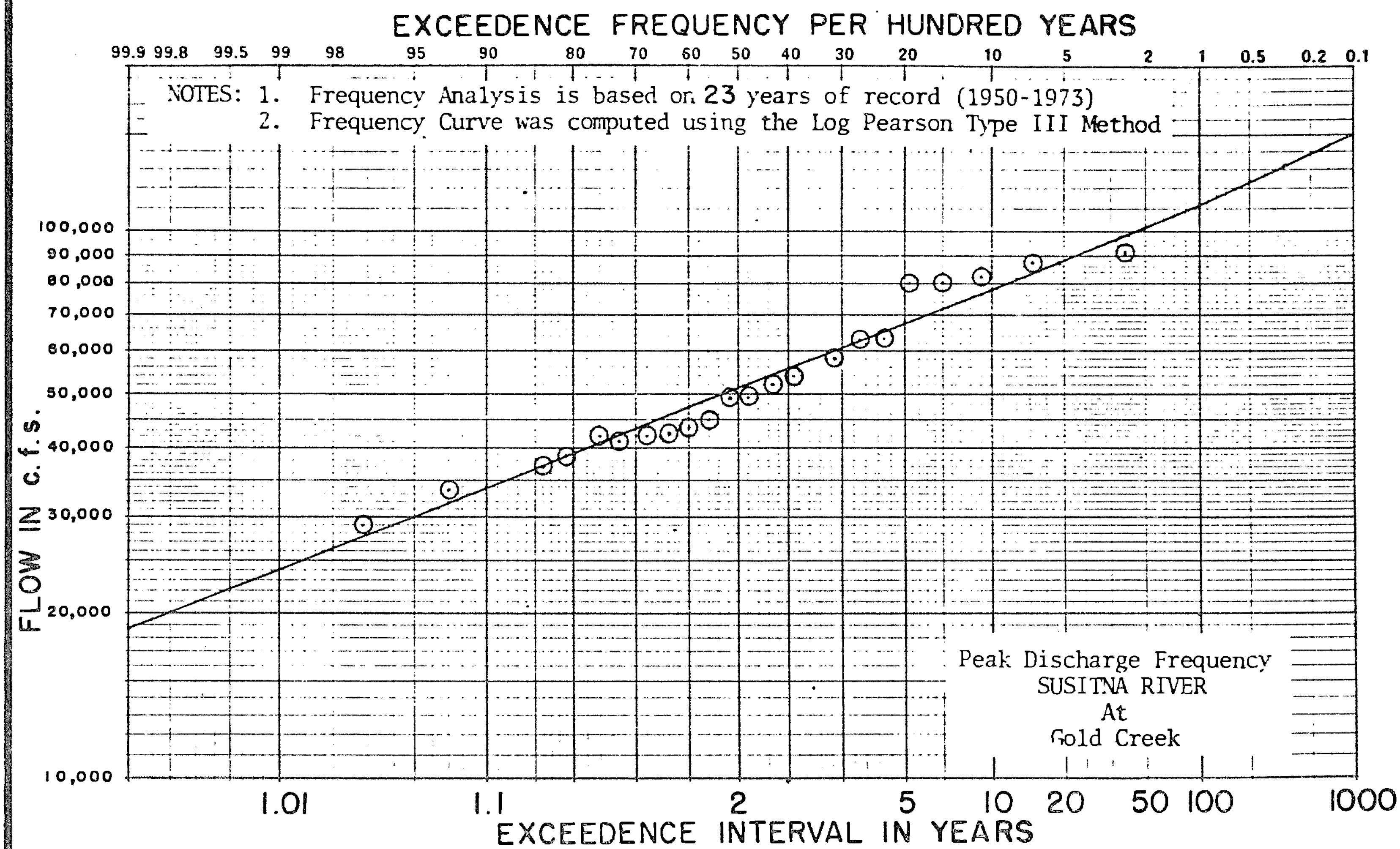

NOTES:
1. Period of Record: 1961-1972
2. Points plotted are maximum annual instantaneous discharge for the period of record.
INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975
SUSITNA RIVER NEAR CANTWELL
Drainage Area = 4140 mi²
FLOW IN C.F.S.
1964
1962
1972
1961
1969
1971
1970
MAXIMUM DAILY FLOW
MEAN DAILY FLOW
MINIMUM DAILY FLOW
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER



Appendix I
GRAPH A-17
A-73

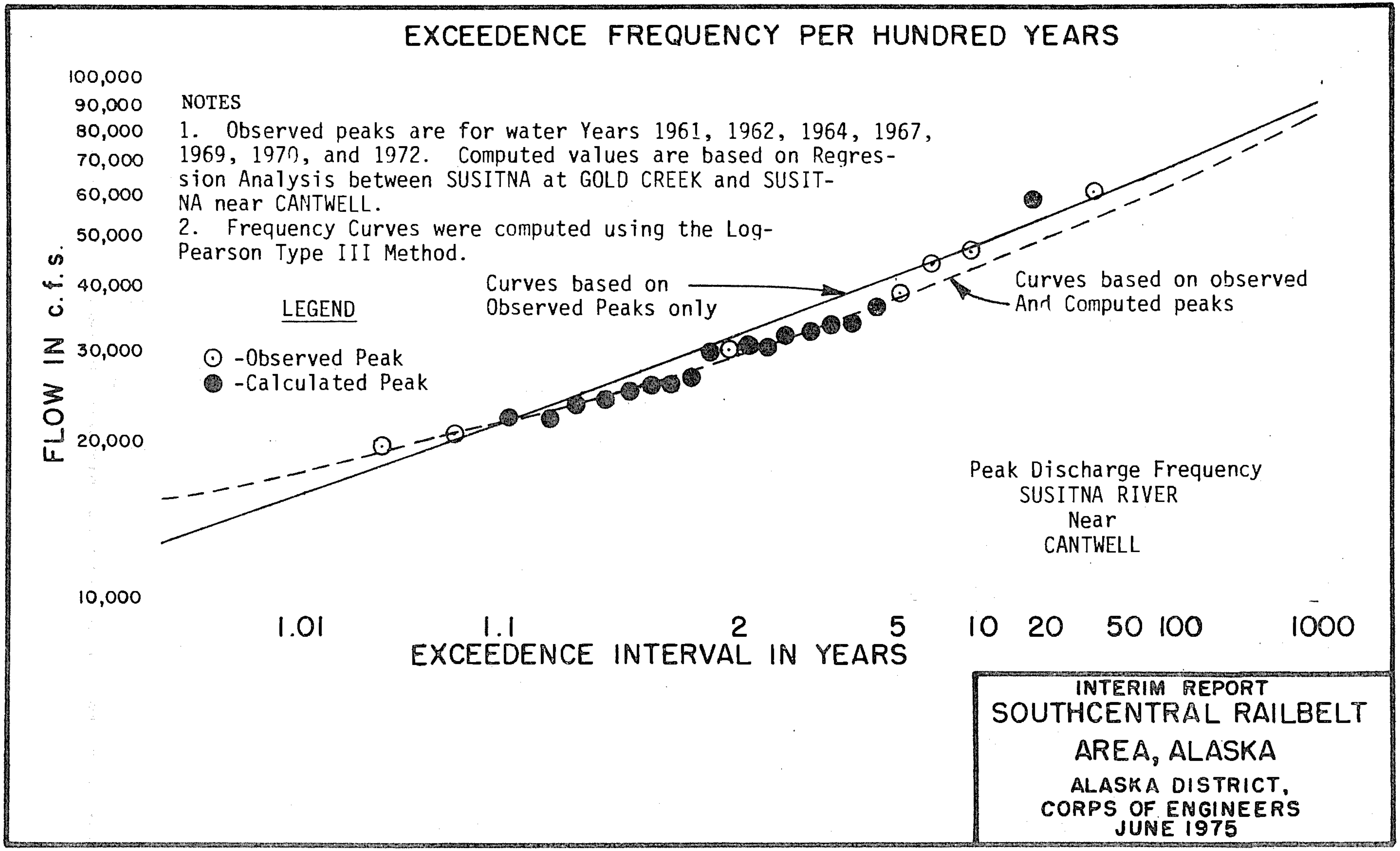
Appendix I
GRAPH A-18
A-74

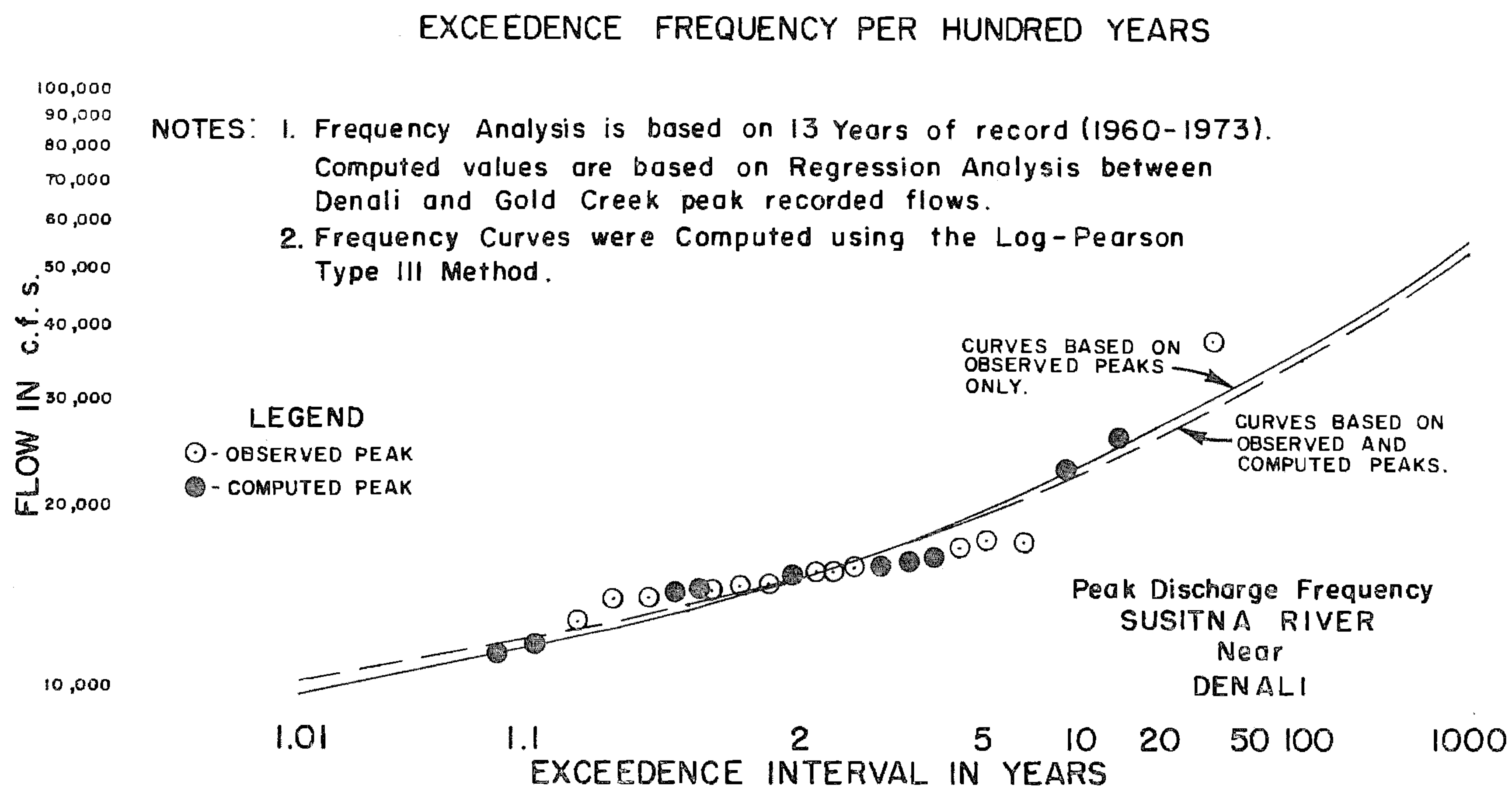




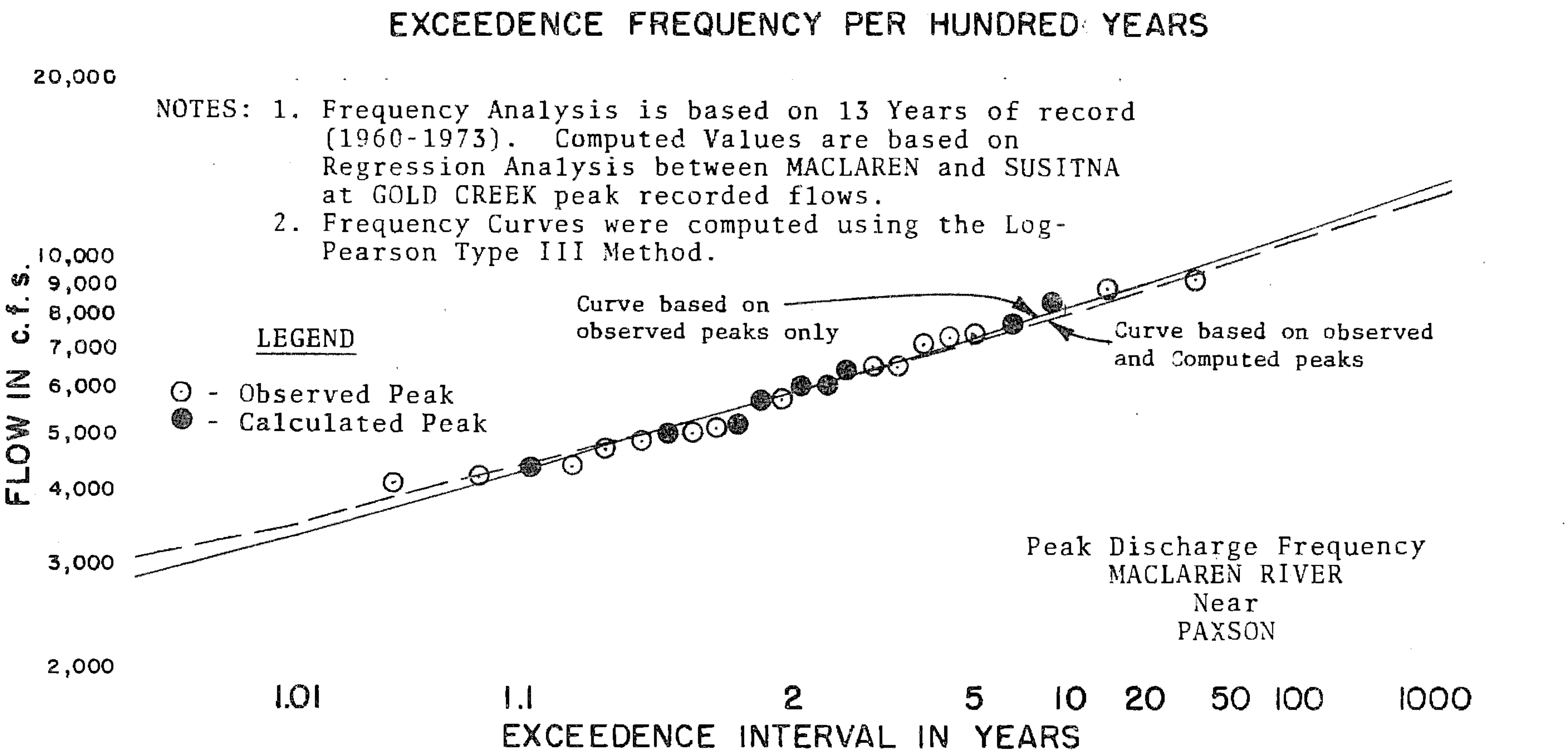
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1975

Appendix I
GRAPH A-19
A-75

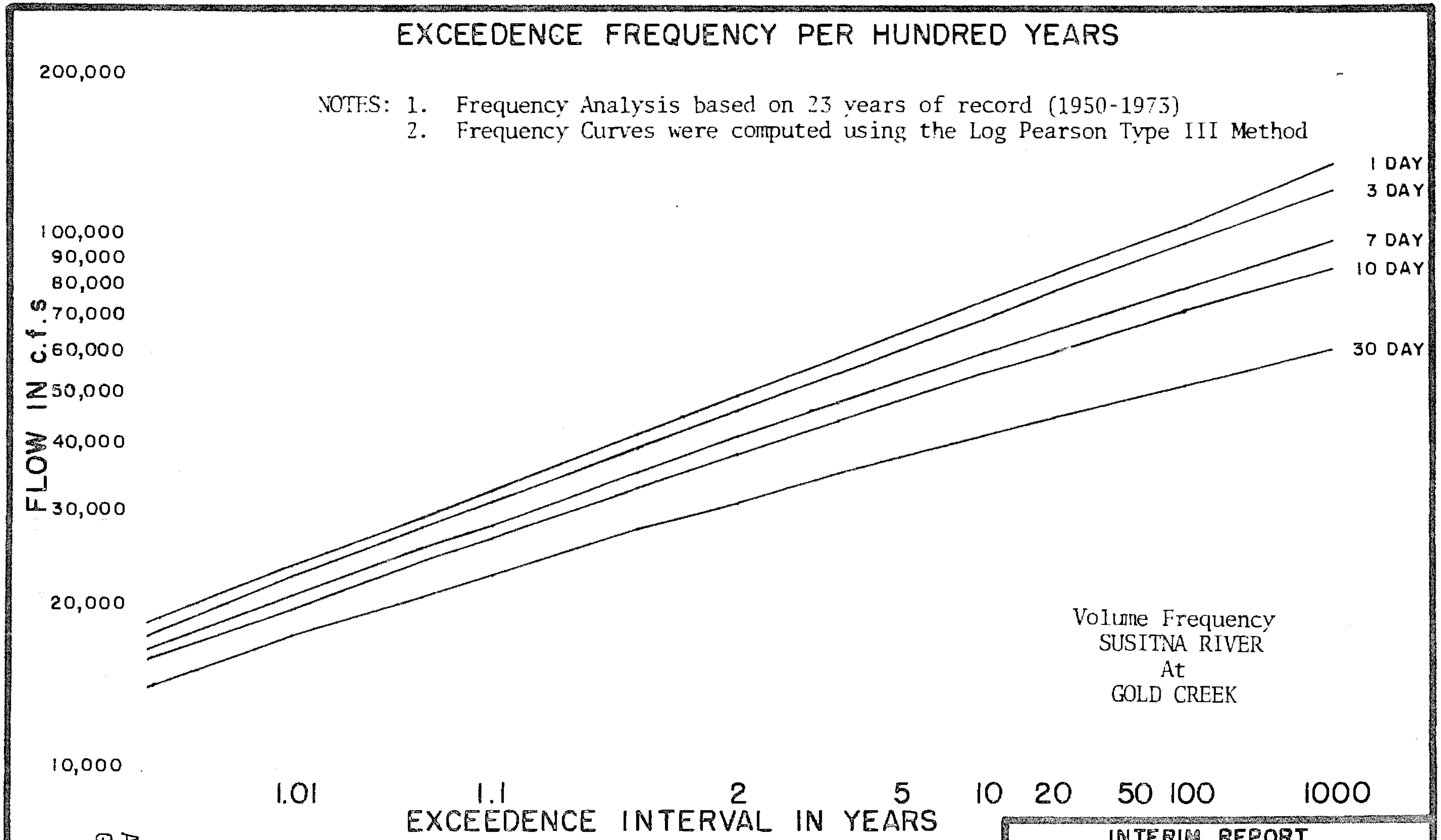

EXCEEDENCE FREQUENCY PER HUNDRED YEARS
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
FLOW IN c.f.s.
NOTES
1. Observed peaks are for water Years 1961, 1962, 1964, 1967, 1969, 1970, and 1972. Computed values are based on Regression Analysis between SUSITNA at GOLD CREEK and SUSITNA near CANTWELL.
2. Frequency Curves were computed using the Log-Pearson Type III Method.
LEGEND
-Observed Peak
-Calculated Peak
Curves based on Observed Peaks only
Curves based on observed And Computed peaks
Peak Discharge Frequency
SUSITNA RIVER
Near
CANTWELL
1.01
1.1
2
5
10
20
50
100
1000
EXCEEDENCE INTERVAL IN YEARS
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1975



INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT, CORPS OF ENGINEERS
JUNE 1975

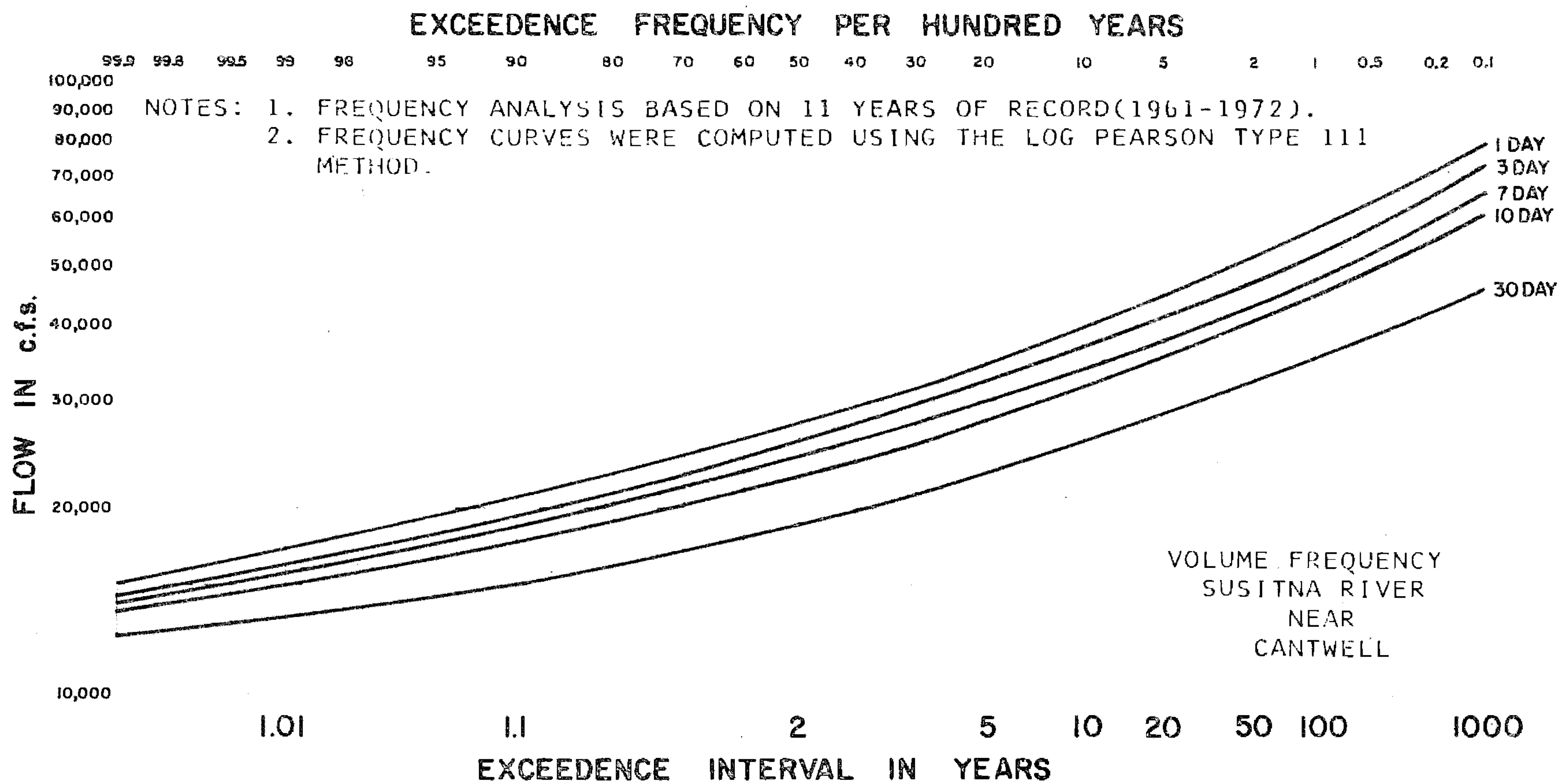


INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT, CORPS OF ENGINEERS
JUNE 1975

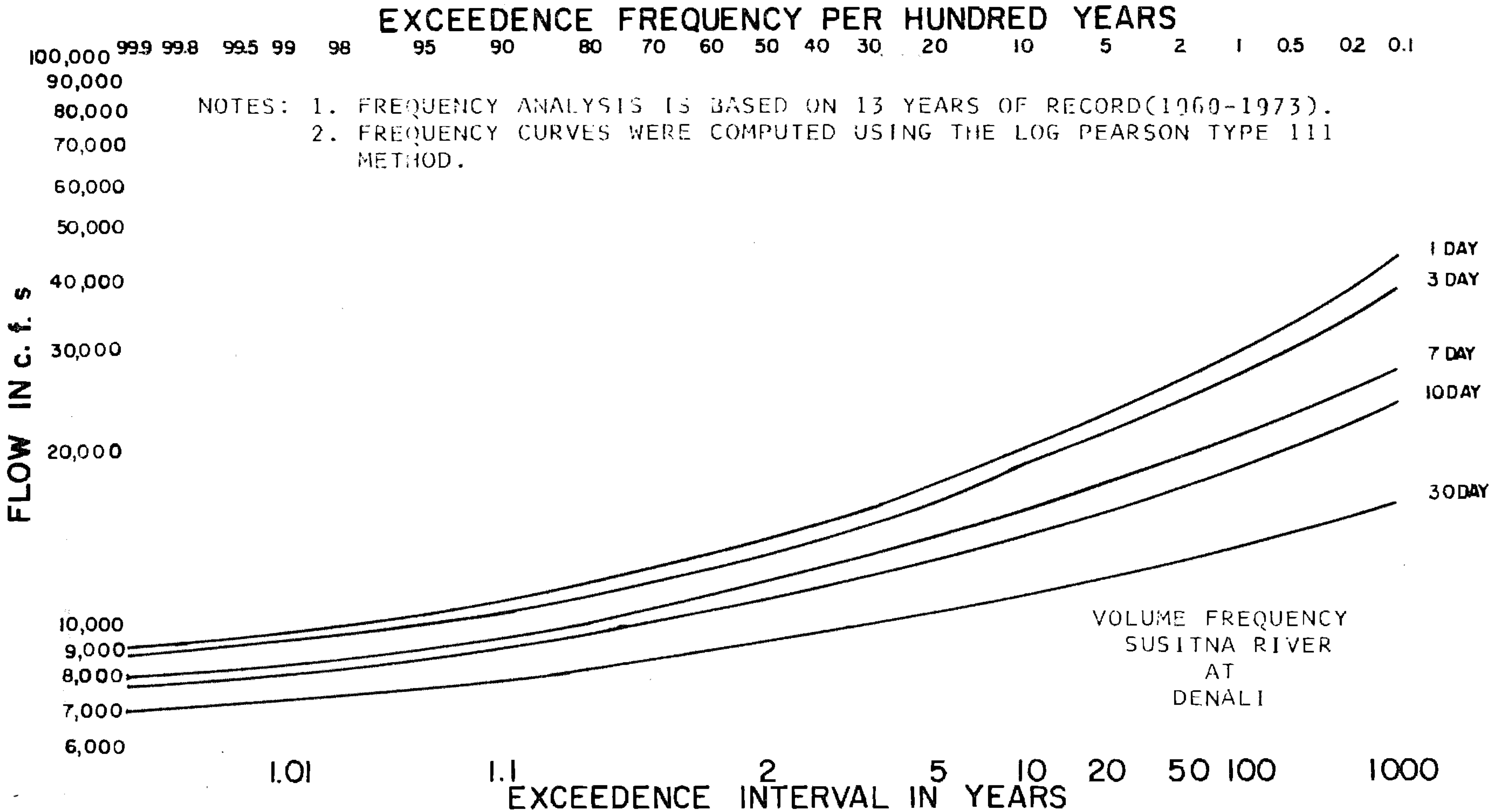


INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1975

Appendix I
GRAPH A-23
A-79

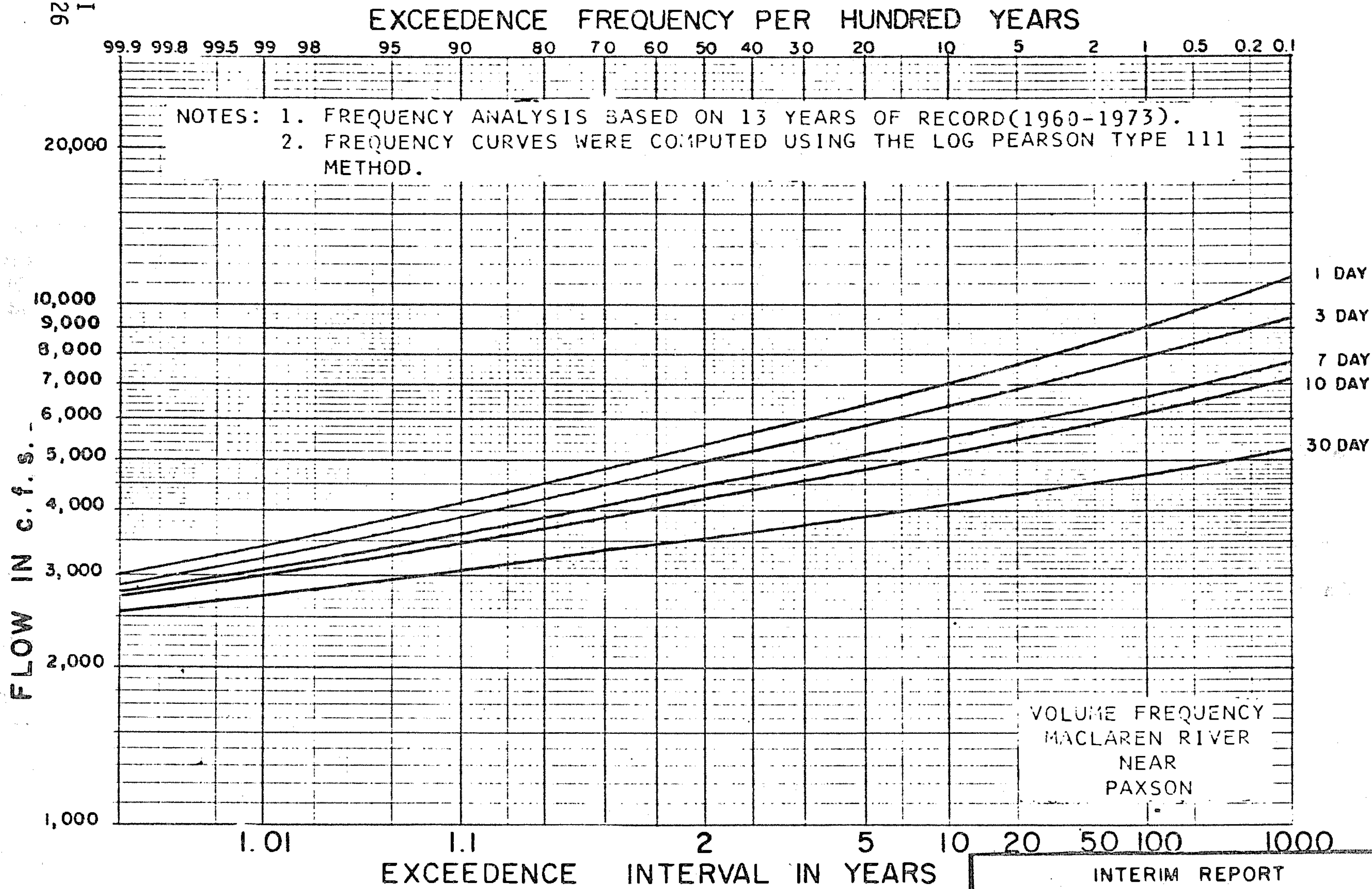


INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975



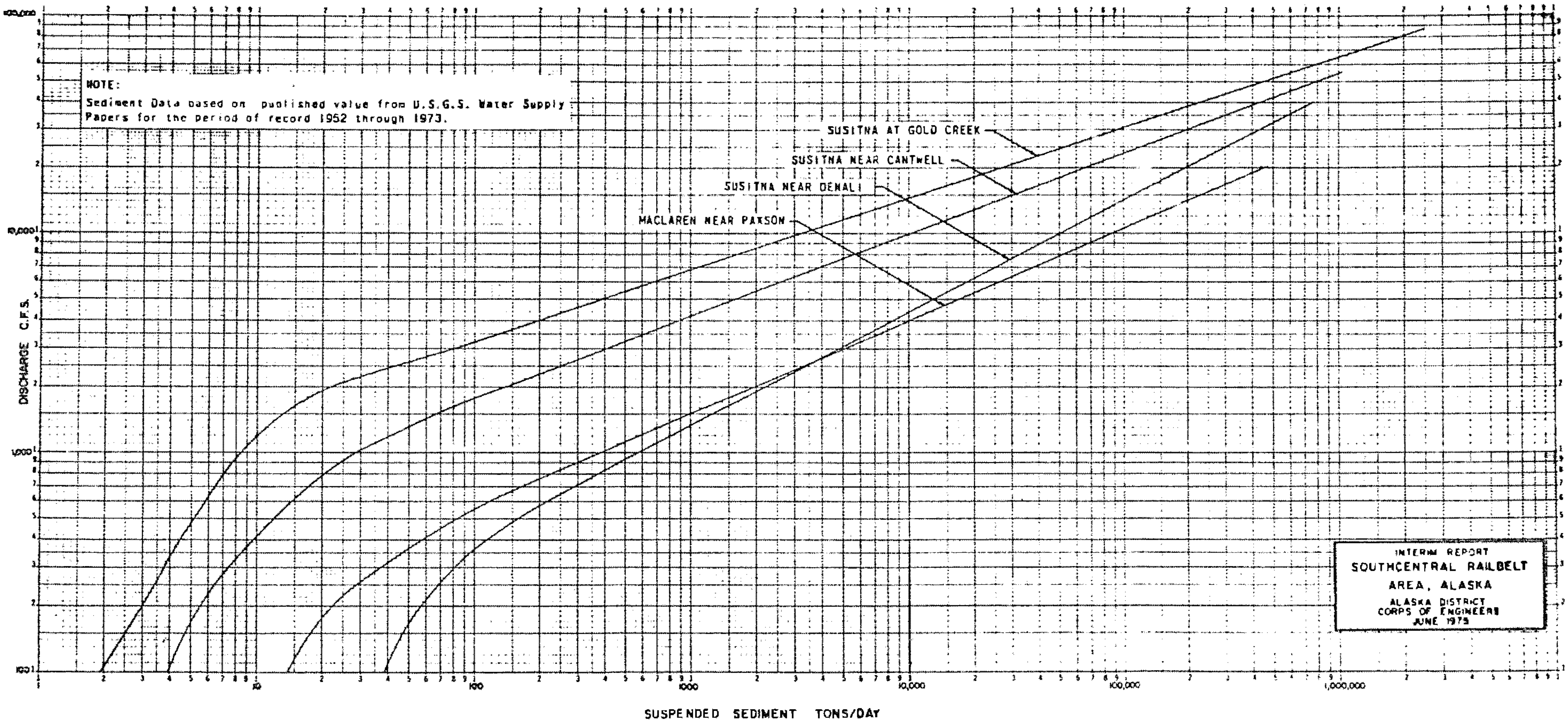
Appendix I
GRAPH A-25
A-81

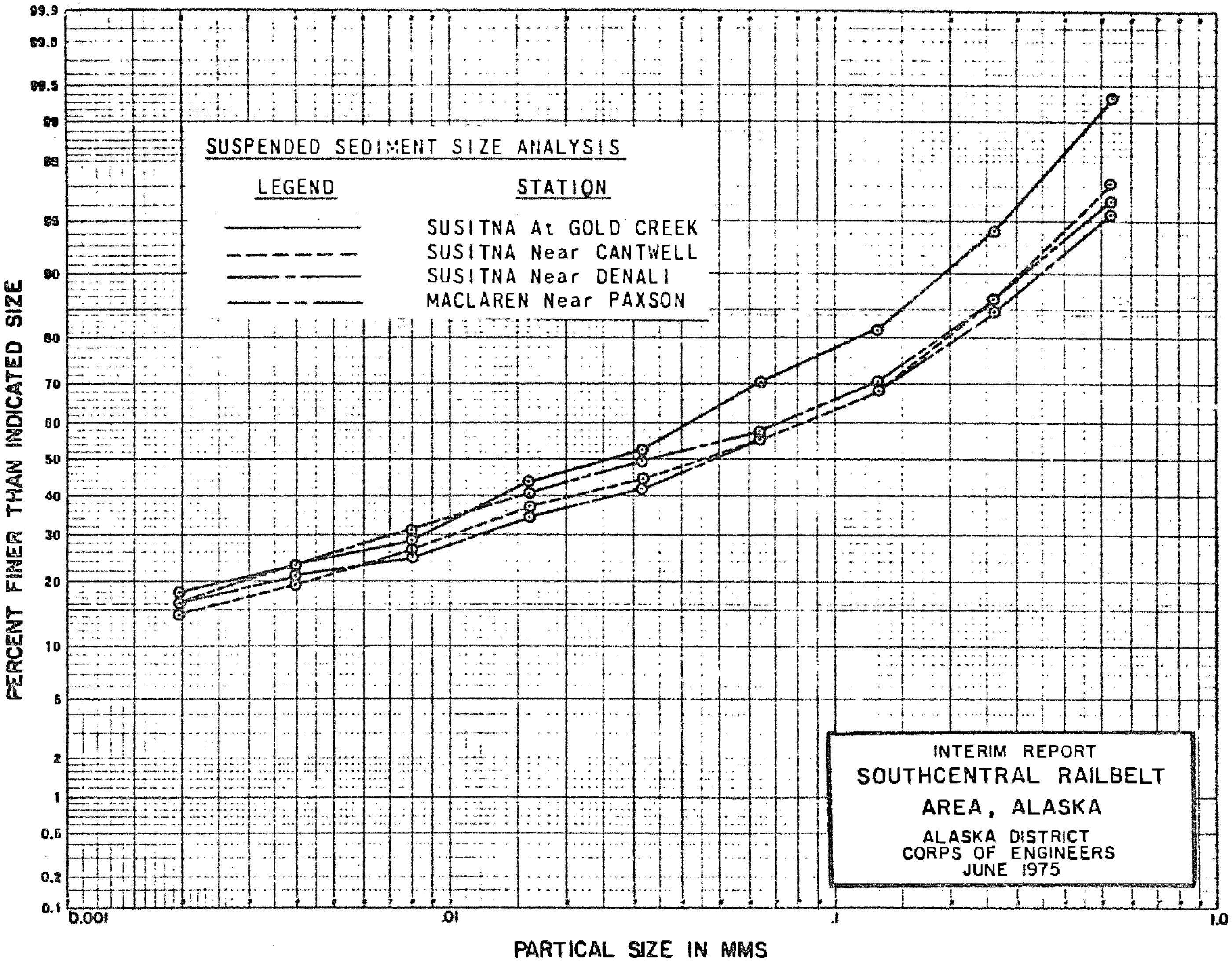
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

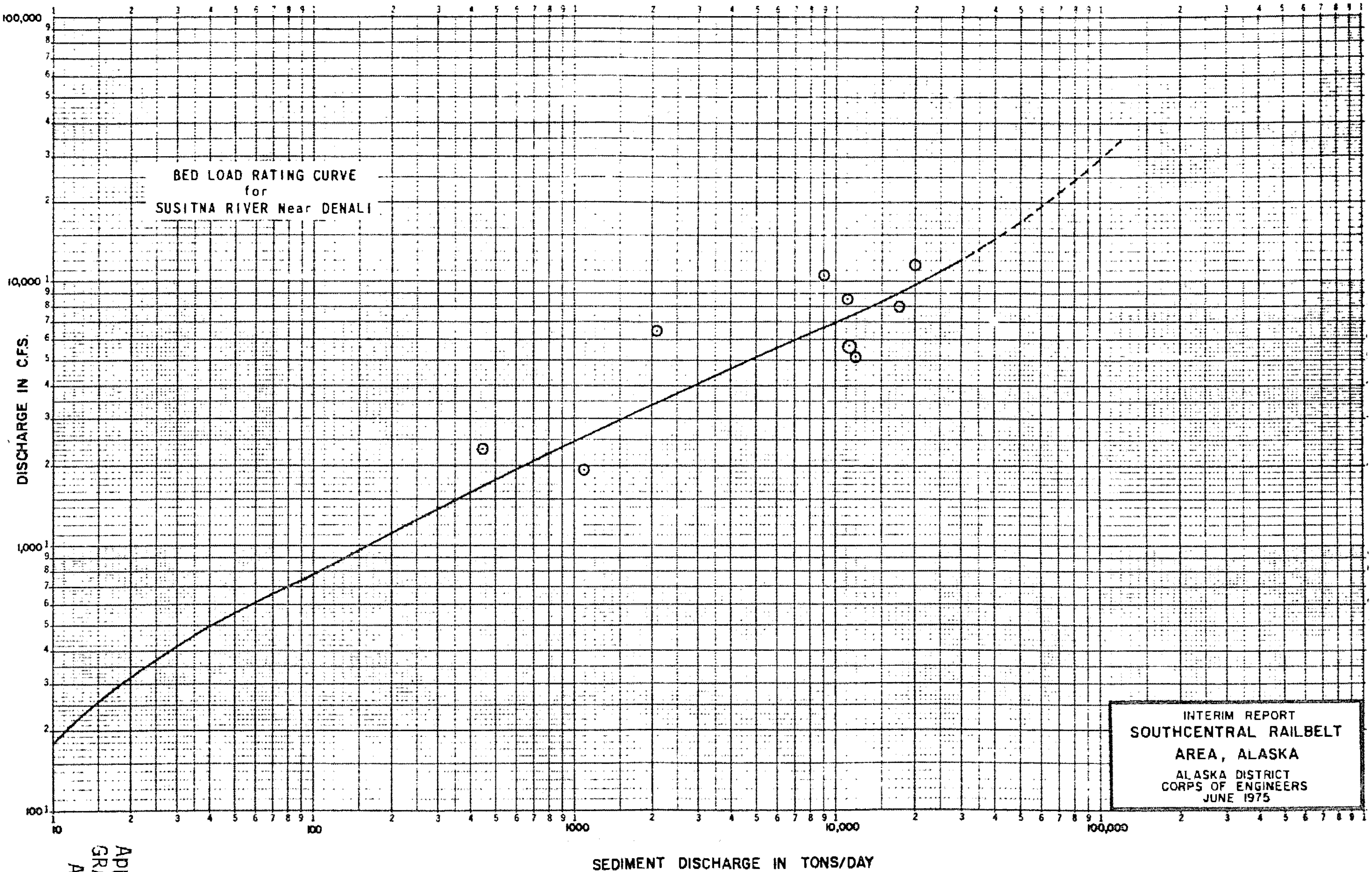


INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

SUSPENDED SEDIMENT RATING CURVES

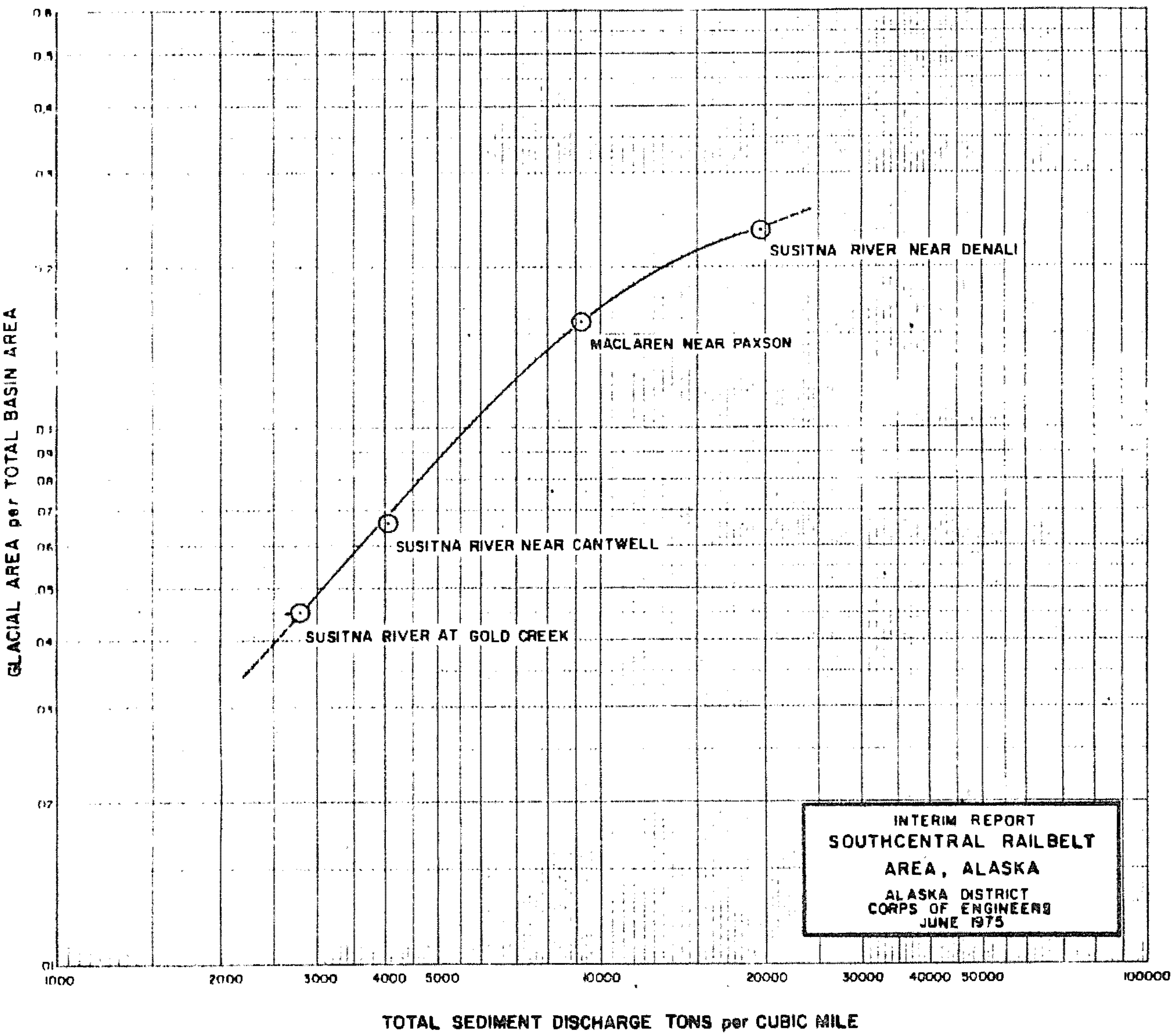



SUSPENDED SEDIMENT SIZE ANALYSIS
LEGEND
STATION
SUSITNA At GOLD CREEK
SUSITNA Near CANTWELL
SUSITNA Near DENALI
MACLAREN Near PAXSON
PERCENT FINER THAN INDICATED SIZE
99.9
99.8
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.001
.01
.1
1.0
PARTICAL SIZE IN MMS
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975



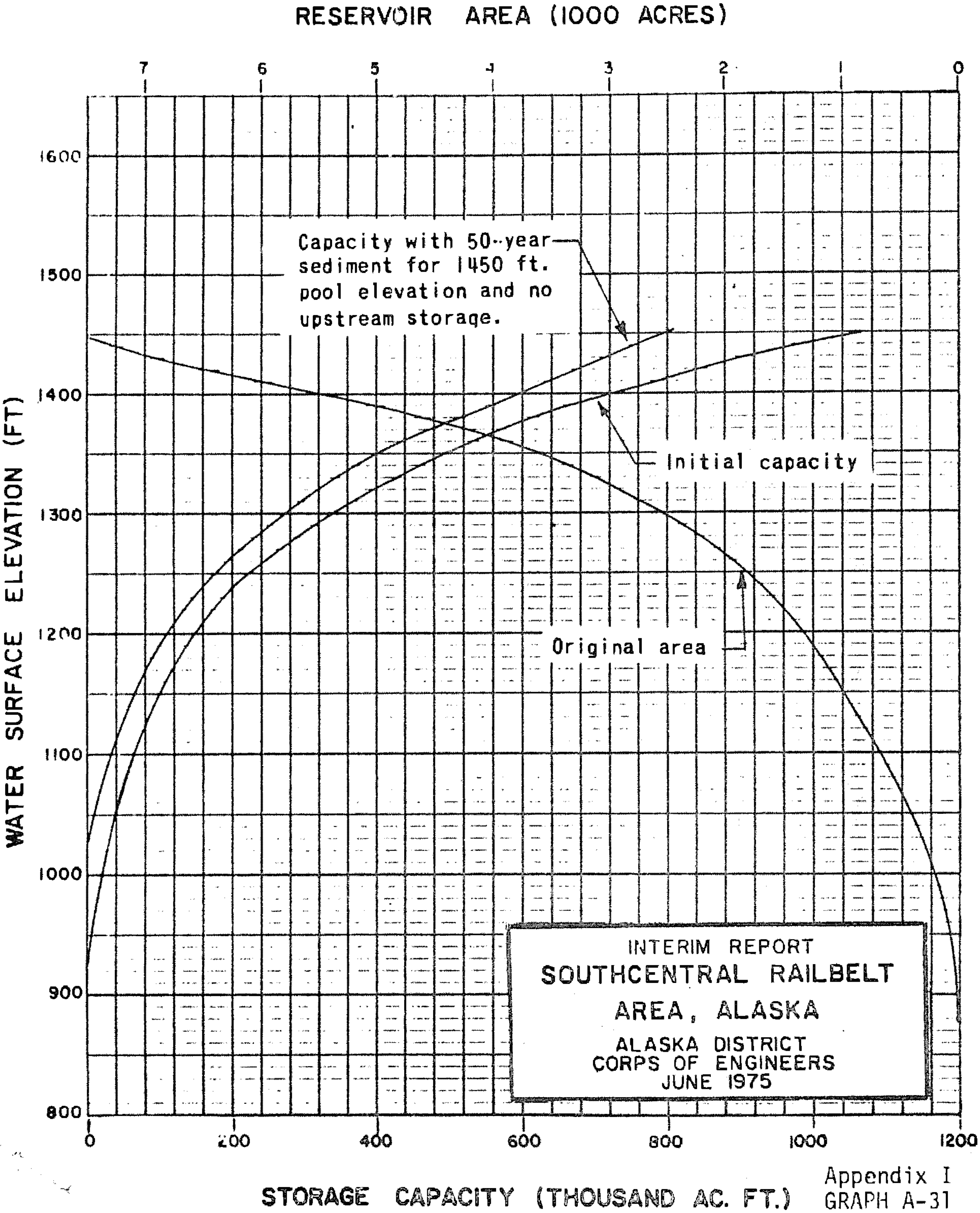
Appendix I
GRAPH A-29
A-85

TOTAL SEDIMENT RATING CURVE FOR SUSITNA BASIN ABOVE GOLD CREEK GAGE



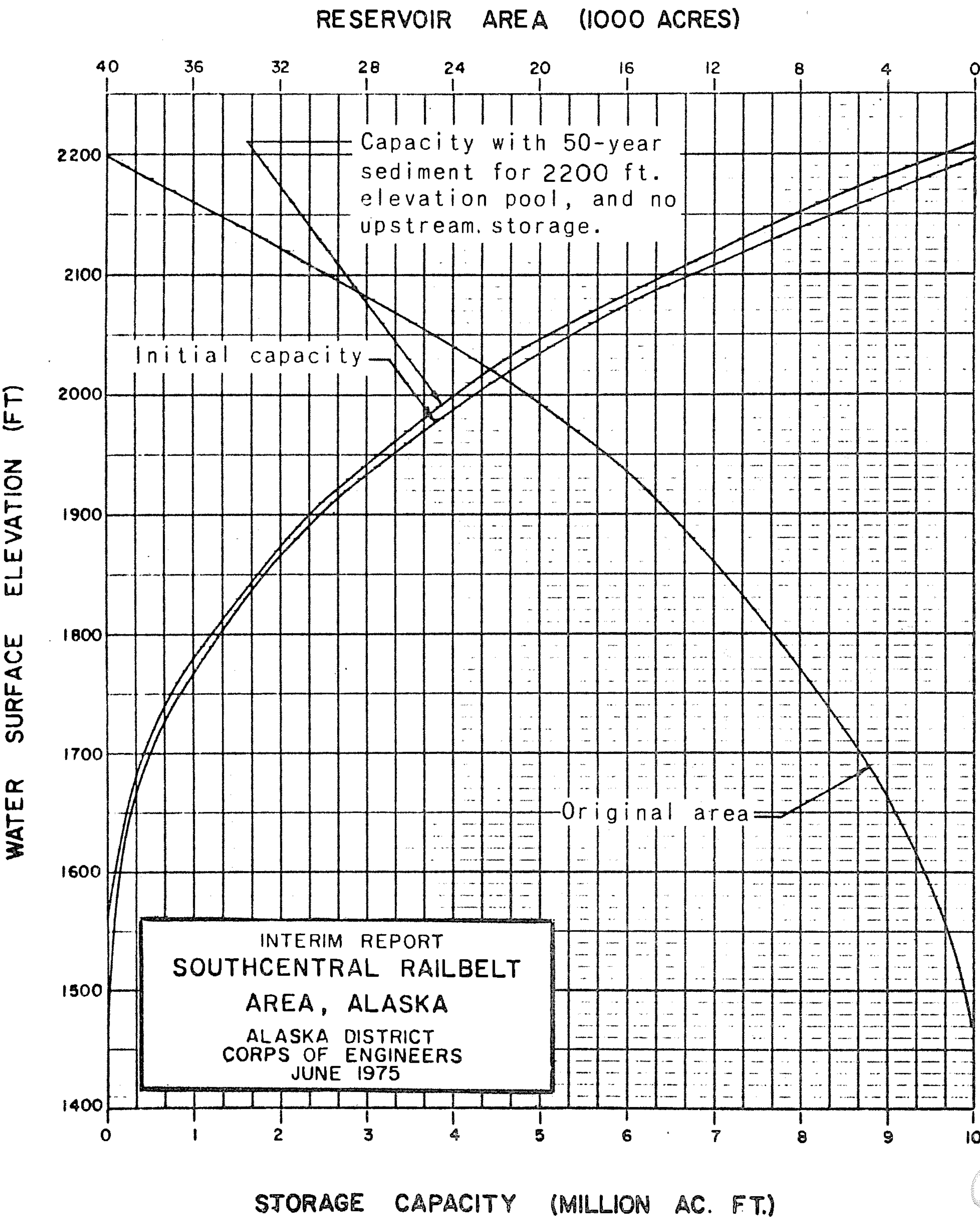
AREA AND CAPACITY CURVES

DEVIL CANYON RESERVOIR



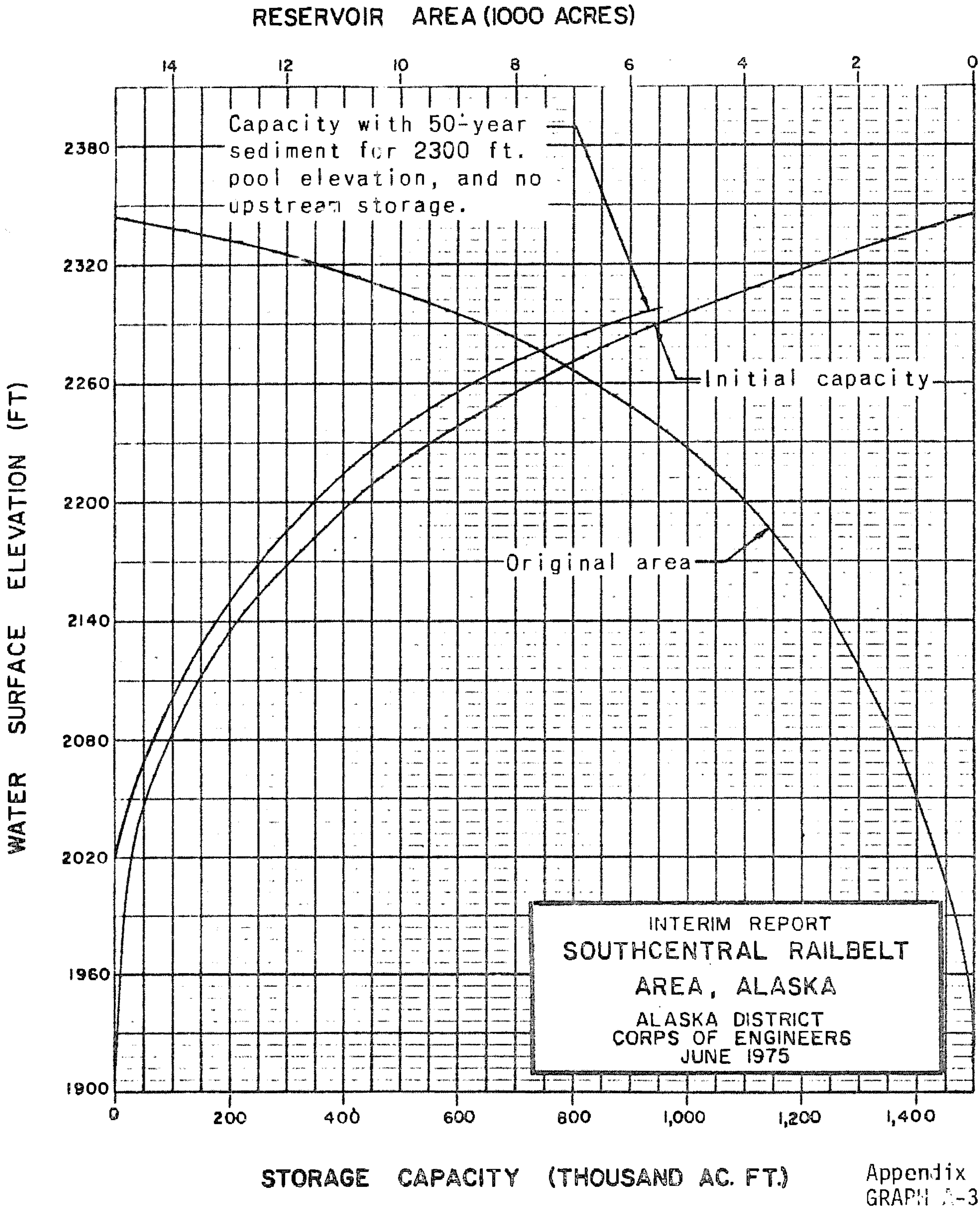
AREA AND CAPACITY CURVES

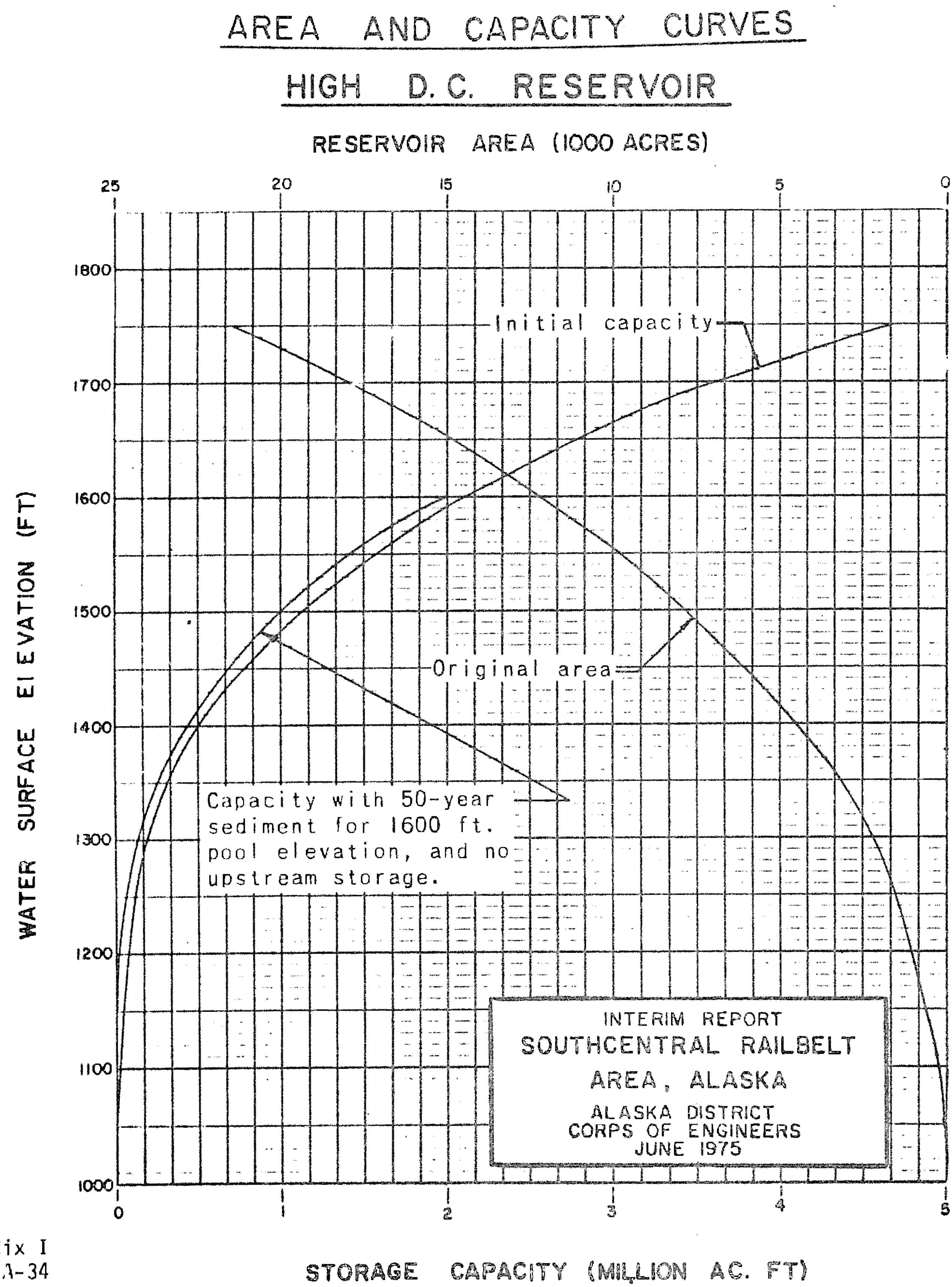
WATANA RESERVOIR



Appendix I
GRAPH A-32

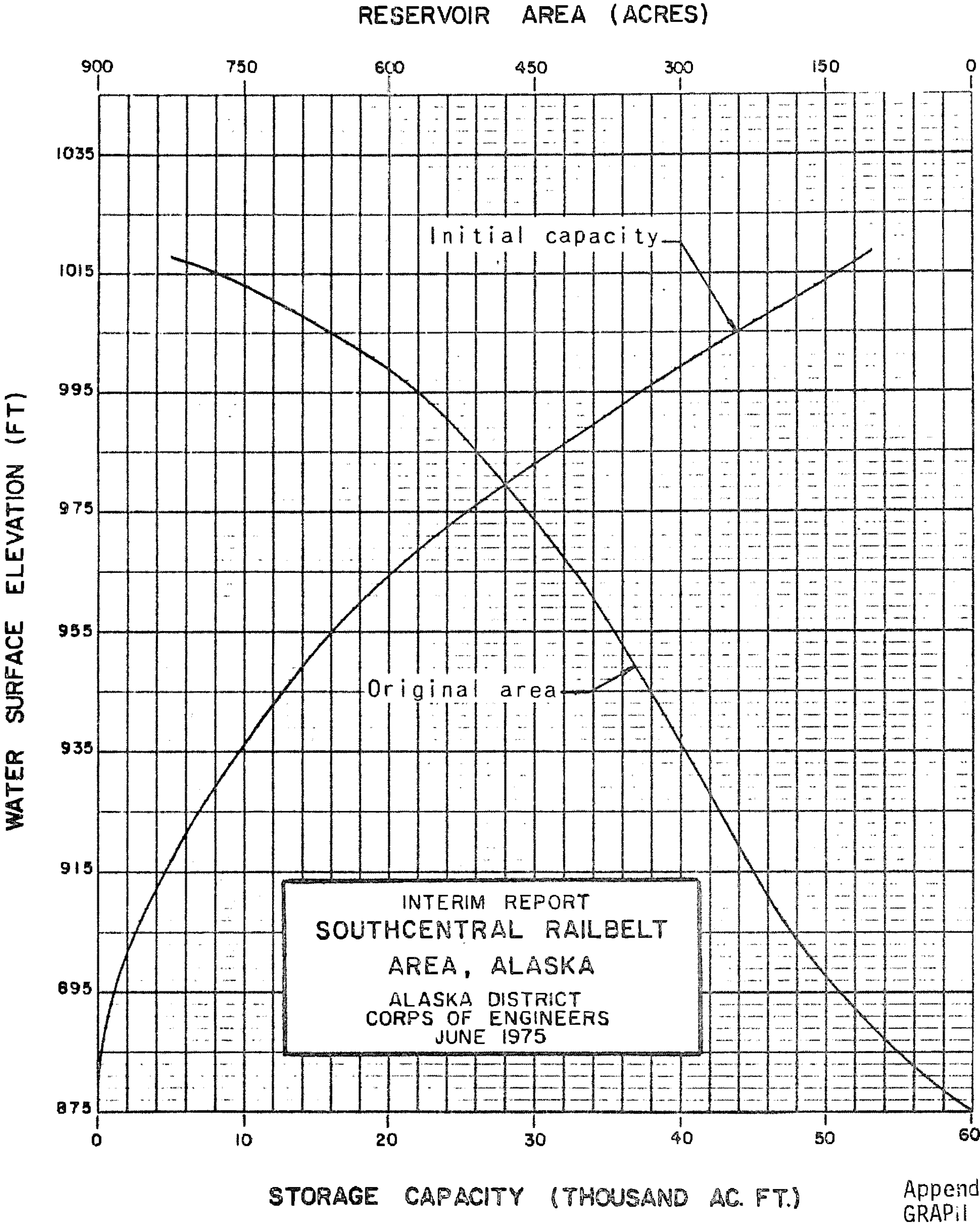
AREA AND CAPACITY CURVES
VEE RESERVOIR



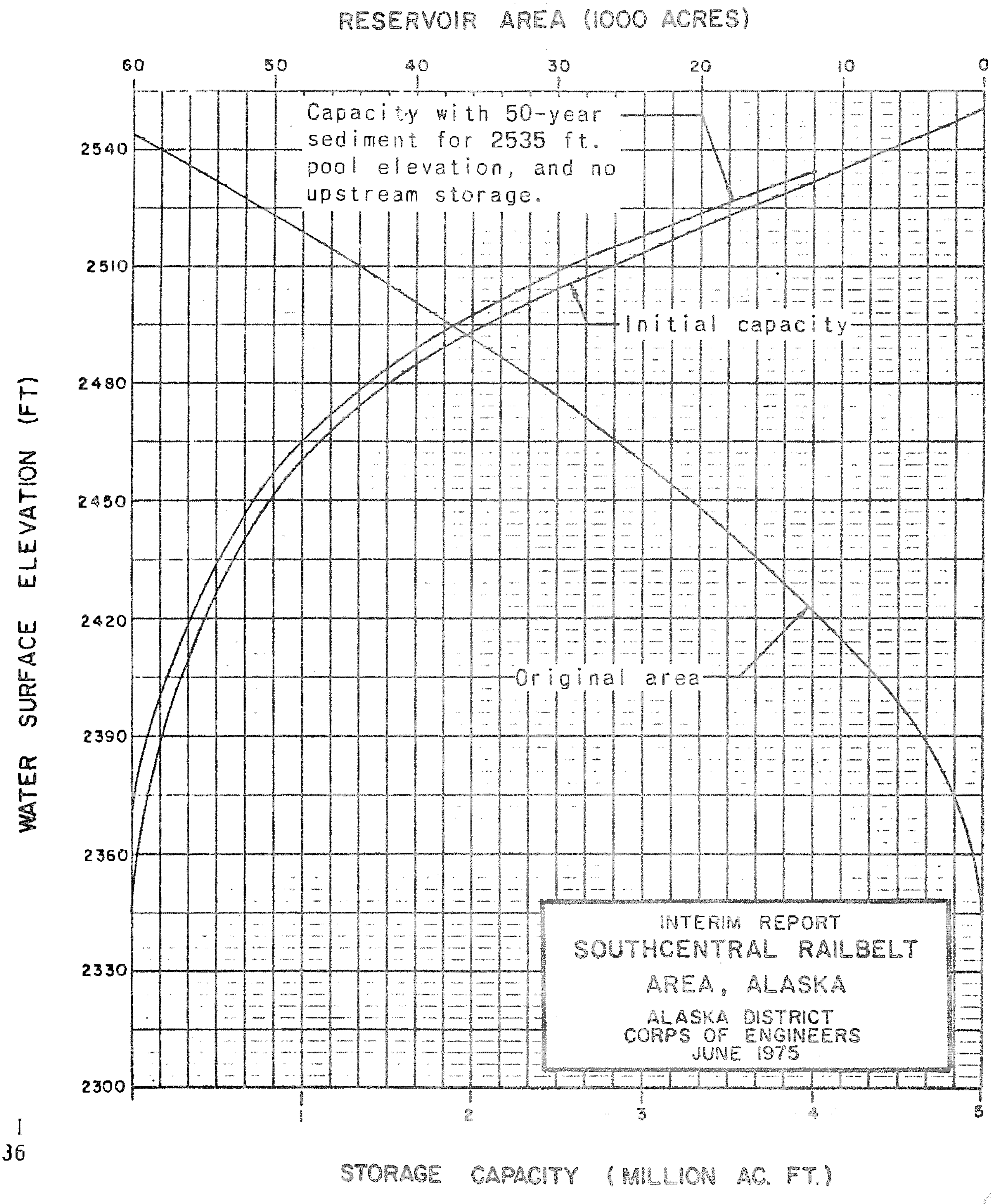

AREA AND CAPACITY CURVES
HIGH D.C. RESERVOIR
RESERVOIR AREA (1000 ACRES)
25
20
15
10
5
0
1800
1700
1600
1500
1400
1300
1200
1100
1000
Initial capacity
Original area
Capacity with 50-year sediment for 1600 ft. pool elevation, and no upstream storage.
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975
WATER SURFACE ELEVATION (FT)
0
1
2
3
4
5
STORAGE CAPACITY (MILLION AC. FT)

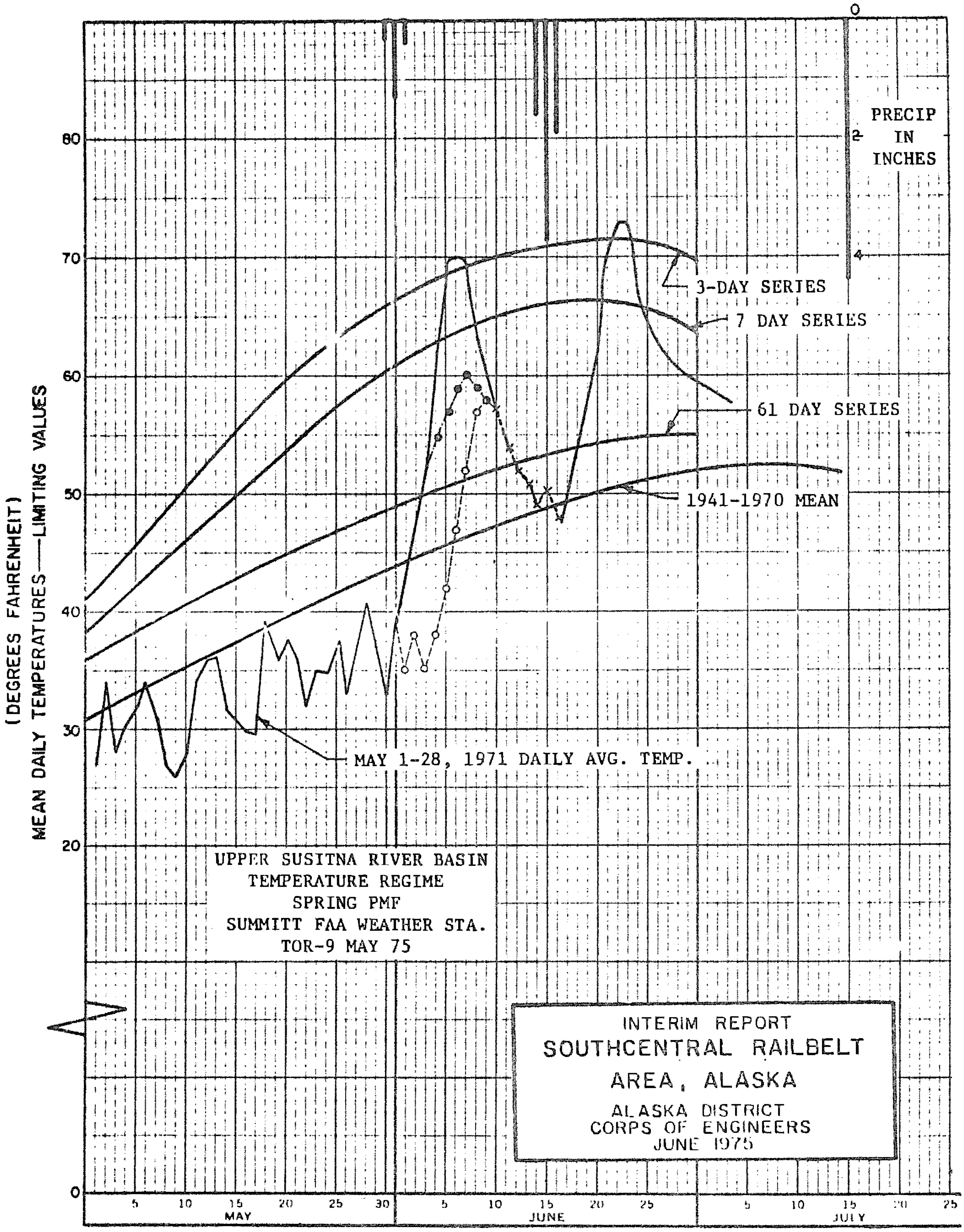
AREA AND CAPACITY CURVES

OLSON RESERVOIR



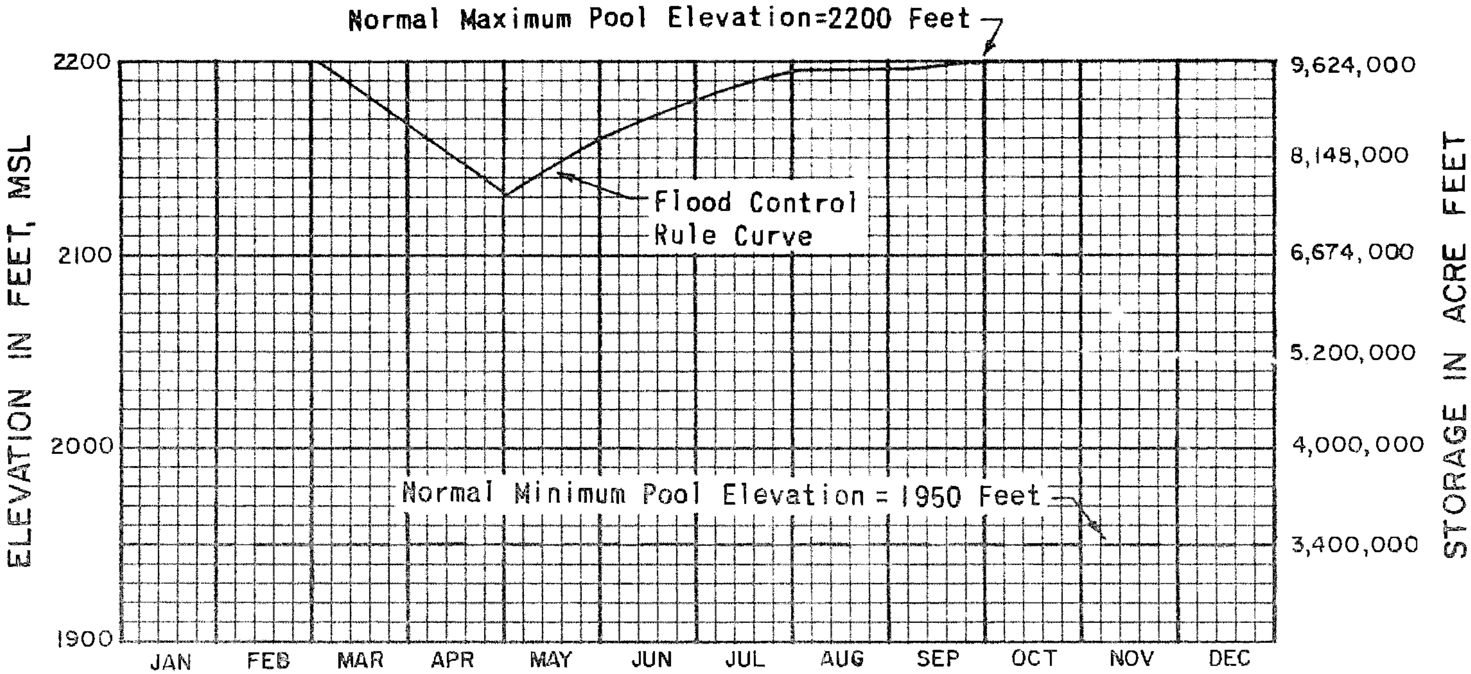
AREA AND CAPACITY CURVES
DENALI RESERVOIR





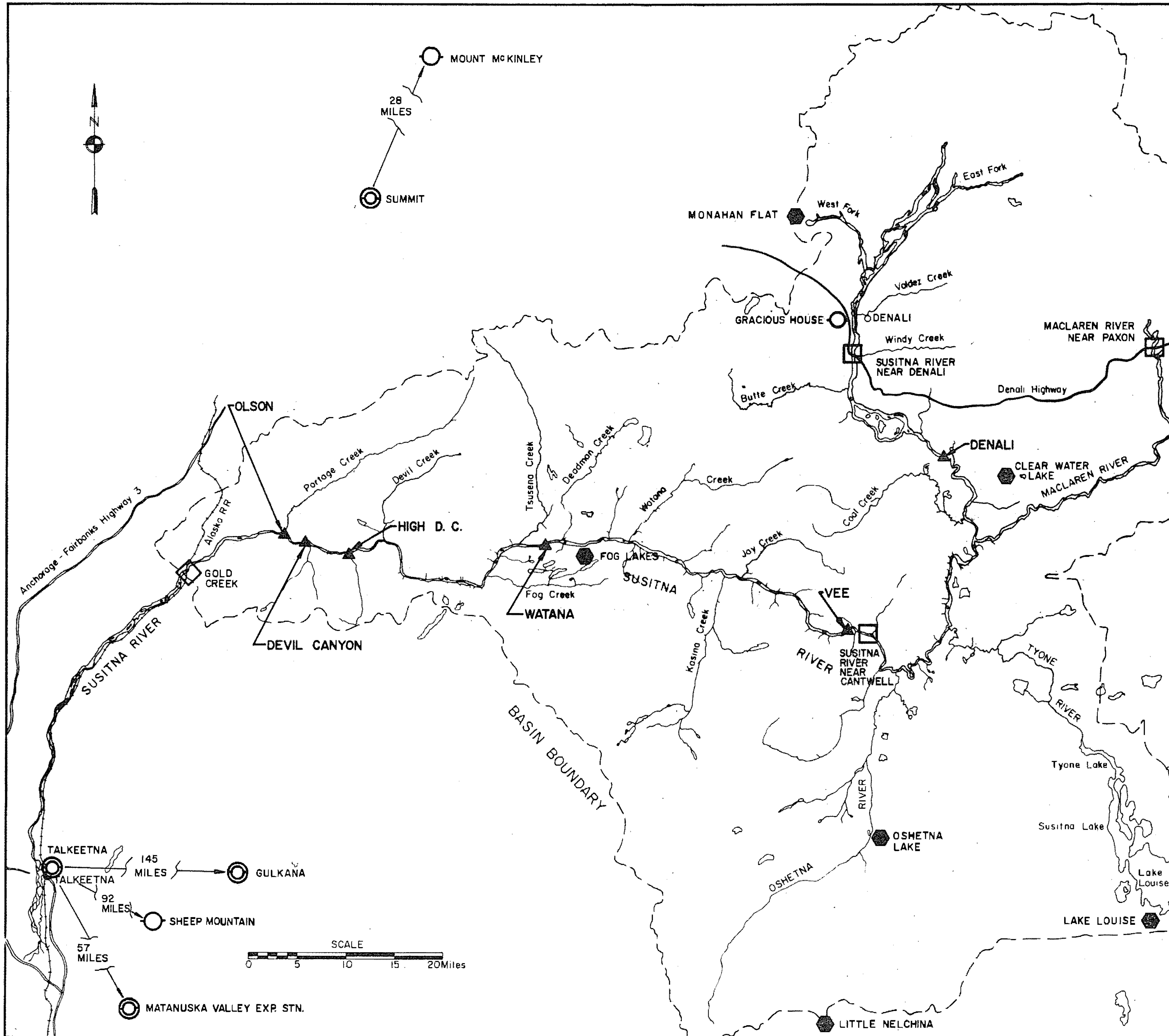
INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

Appendix I
GRAPH A-37



WATANA RESERVOIR
FLOOD CONTROL RULE CURVE

INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1975



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

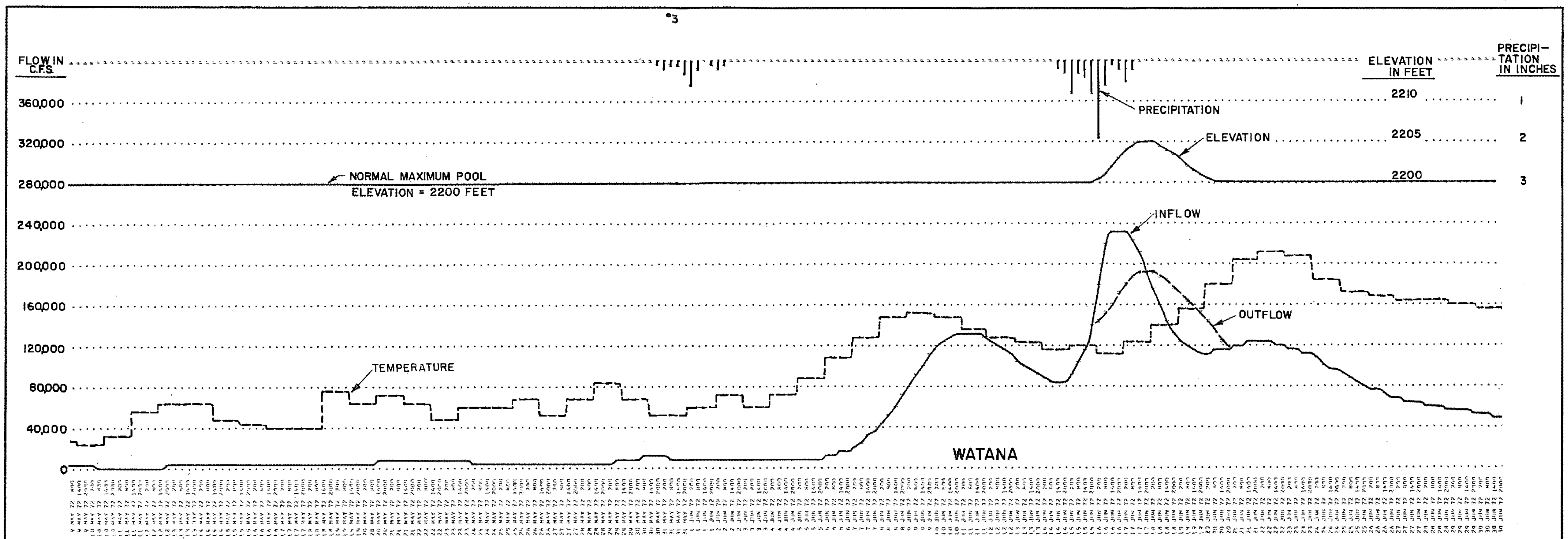
UPPER SUSITNA RIVER BASIN

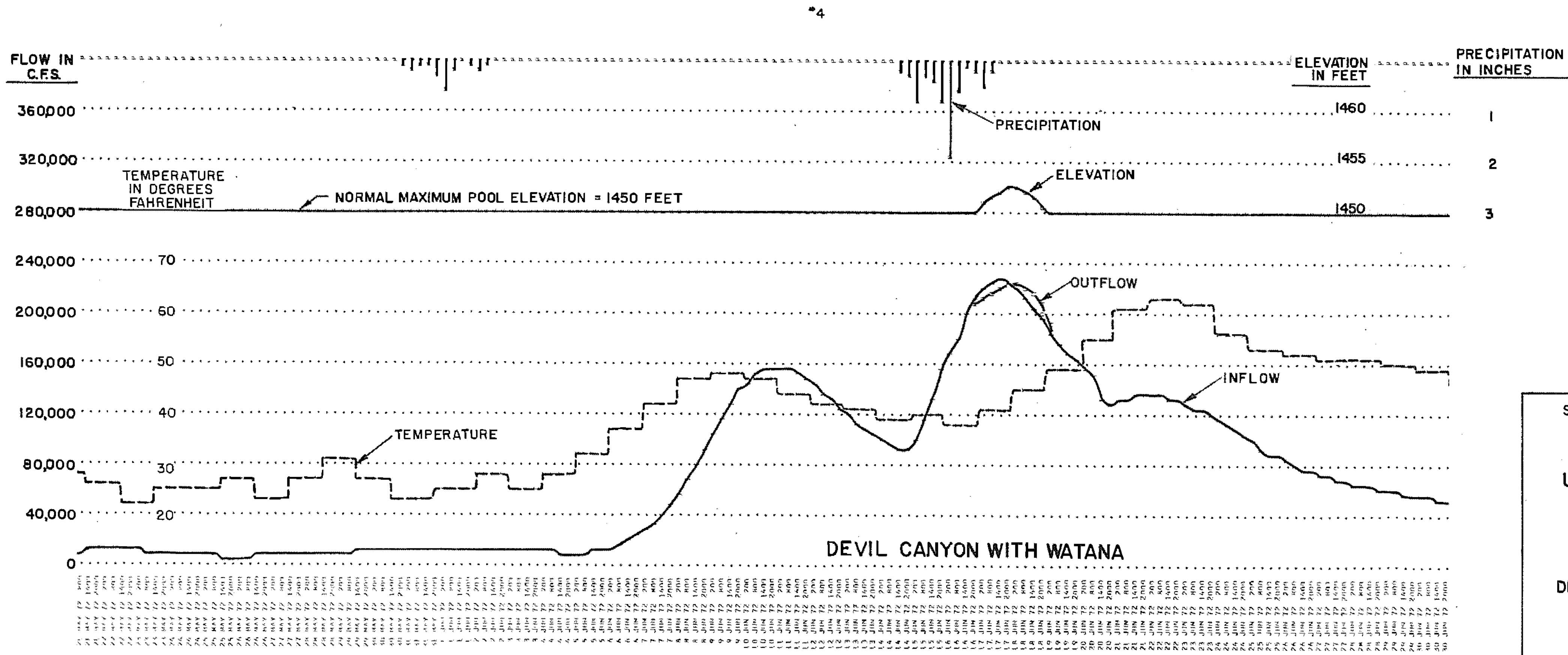
STUDY LOCATION MAP

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975





FILE NO. 2—SOU—92—04—01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

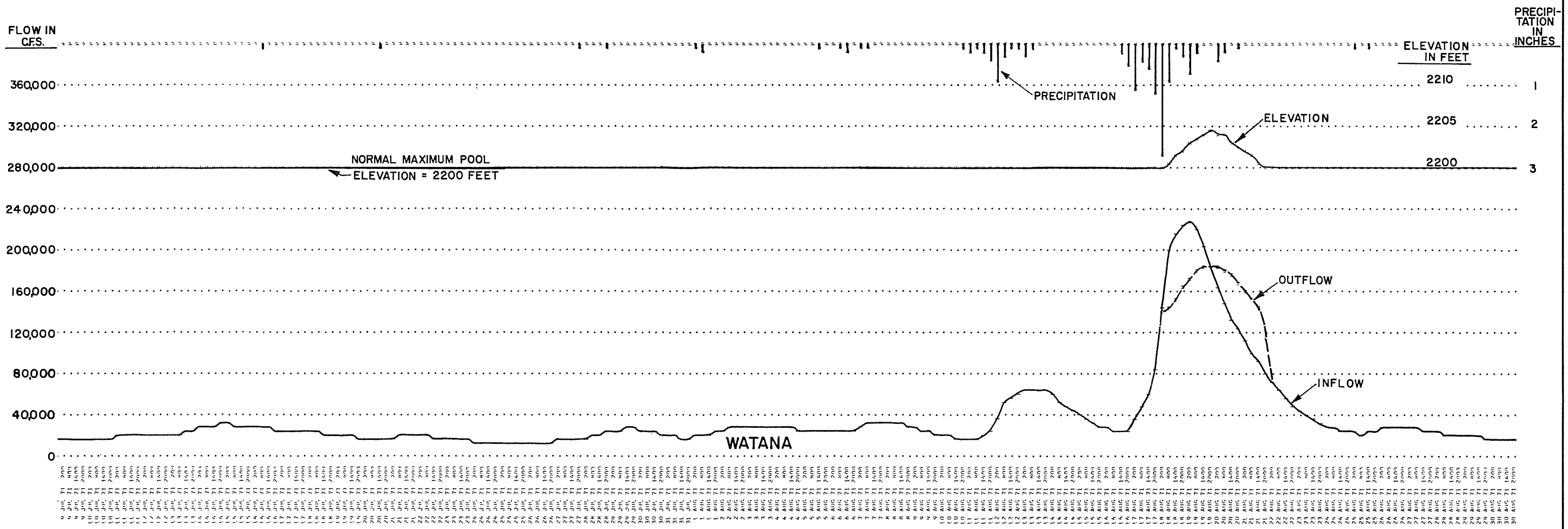
SPRING PROBABLE
MAXIMUM FLOOD
HYDROGRAPHS

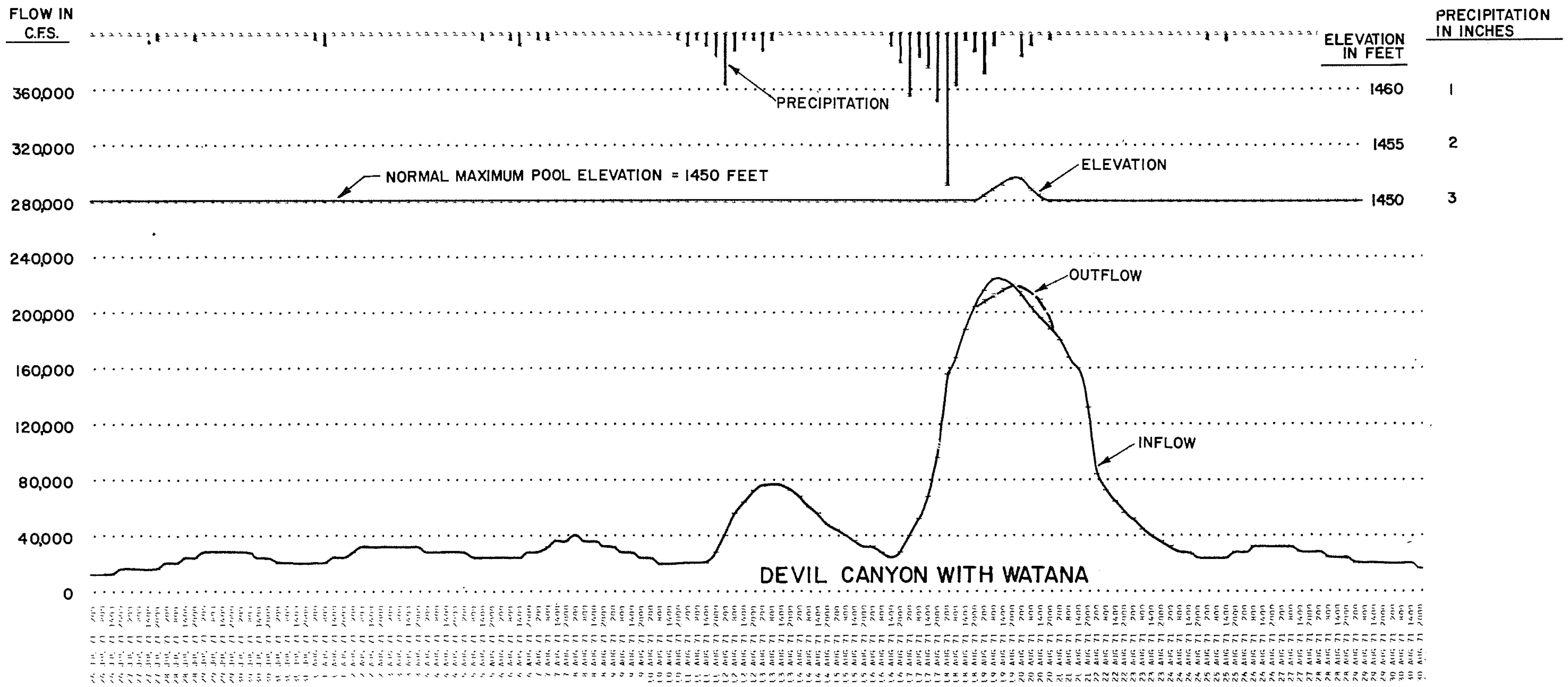
DEVIL CANYON AND WATANA PROJECTS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975





FILE NO. 2-SOU-92-04-01

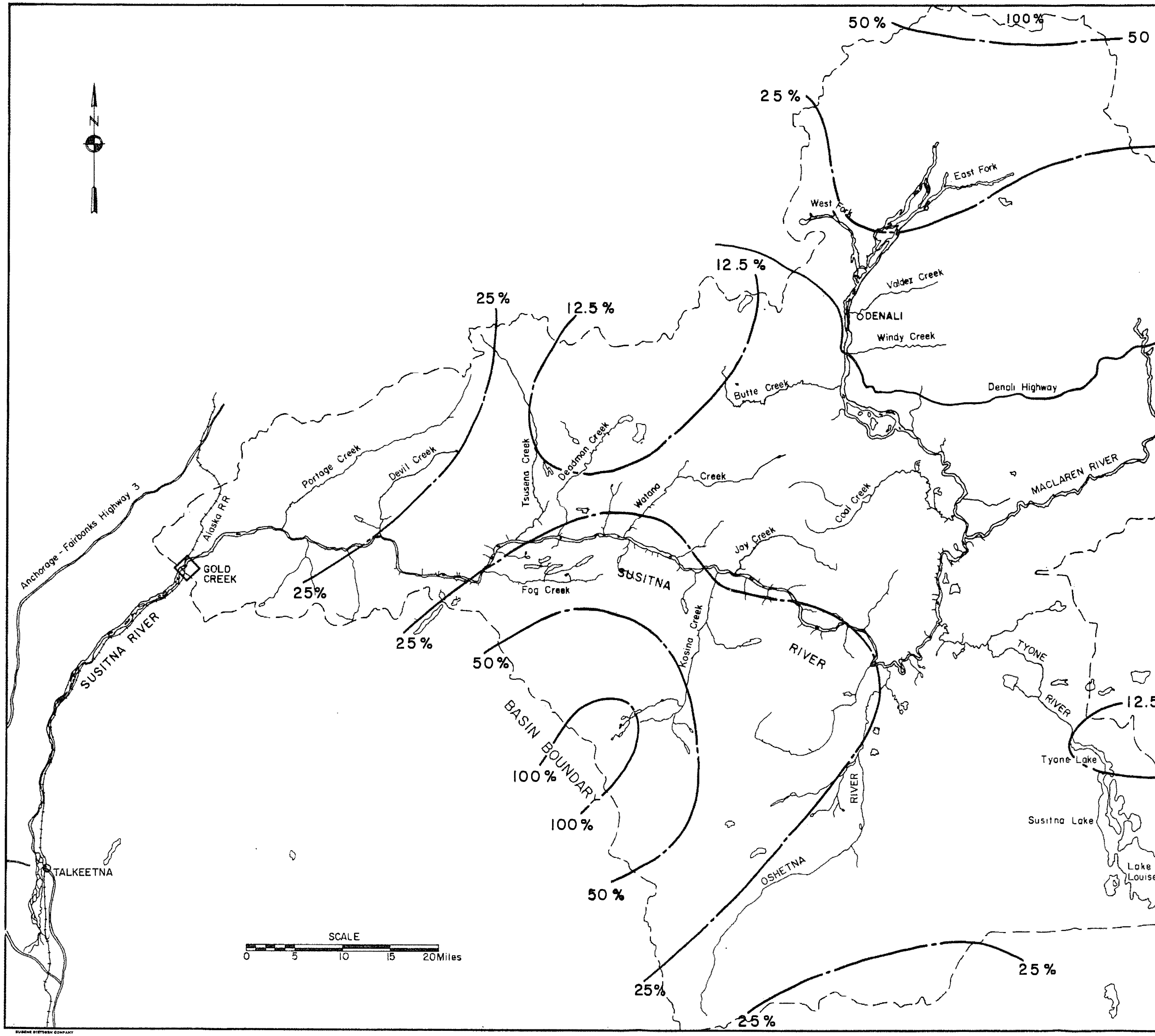
SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
SUMMER PROBABLE MAXIMUM FLOOD HYDROGRAPHS

DEVIL CANYON AND WATANA PROJECT

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975



FILE NO. 2—SOU-92-04-01

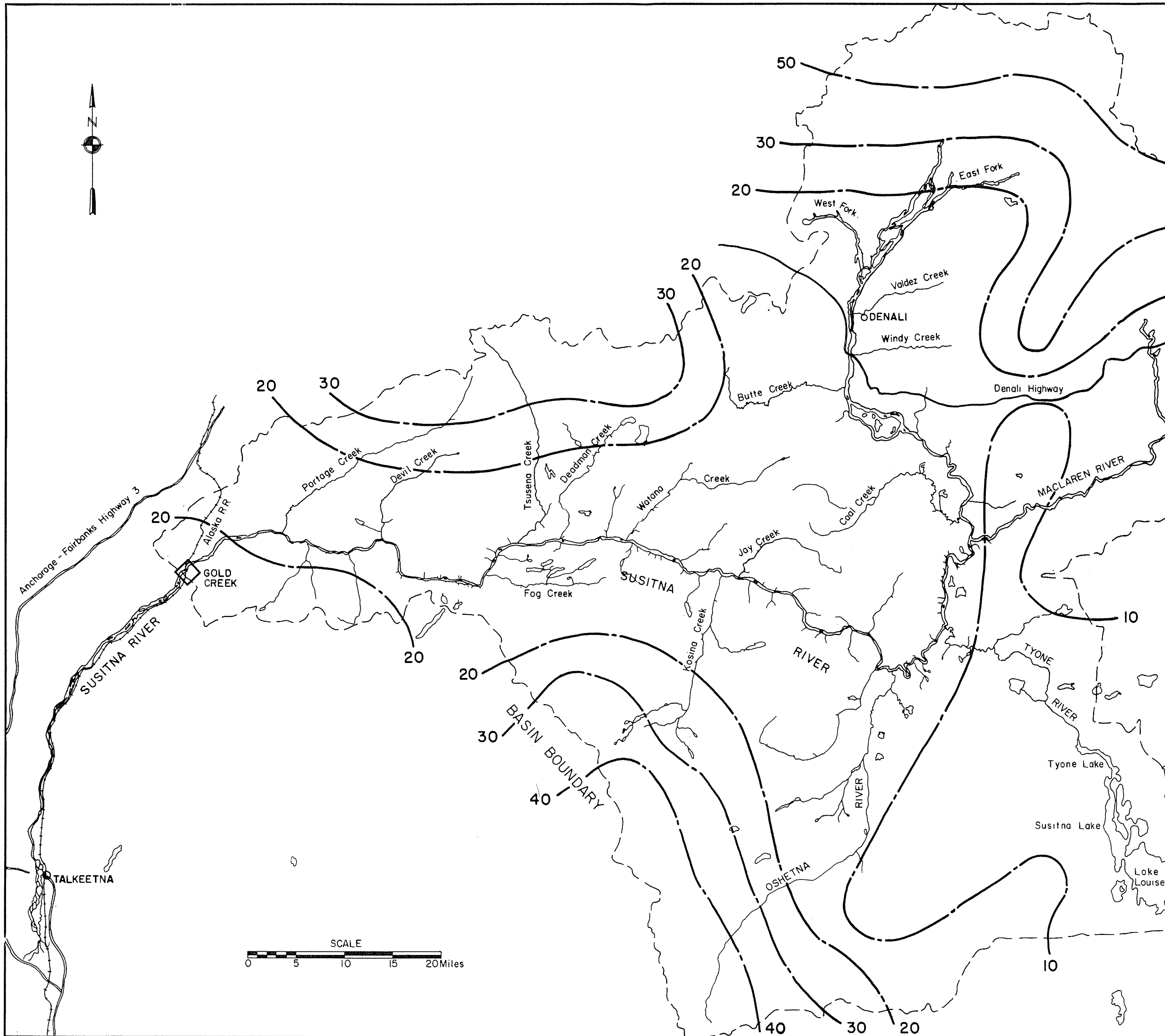
SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

ISOPERCENTAL PRECIPITATION VALUES

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975



FILE NO. 2—SOU—92—04—01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO I

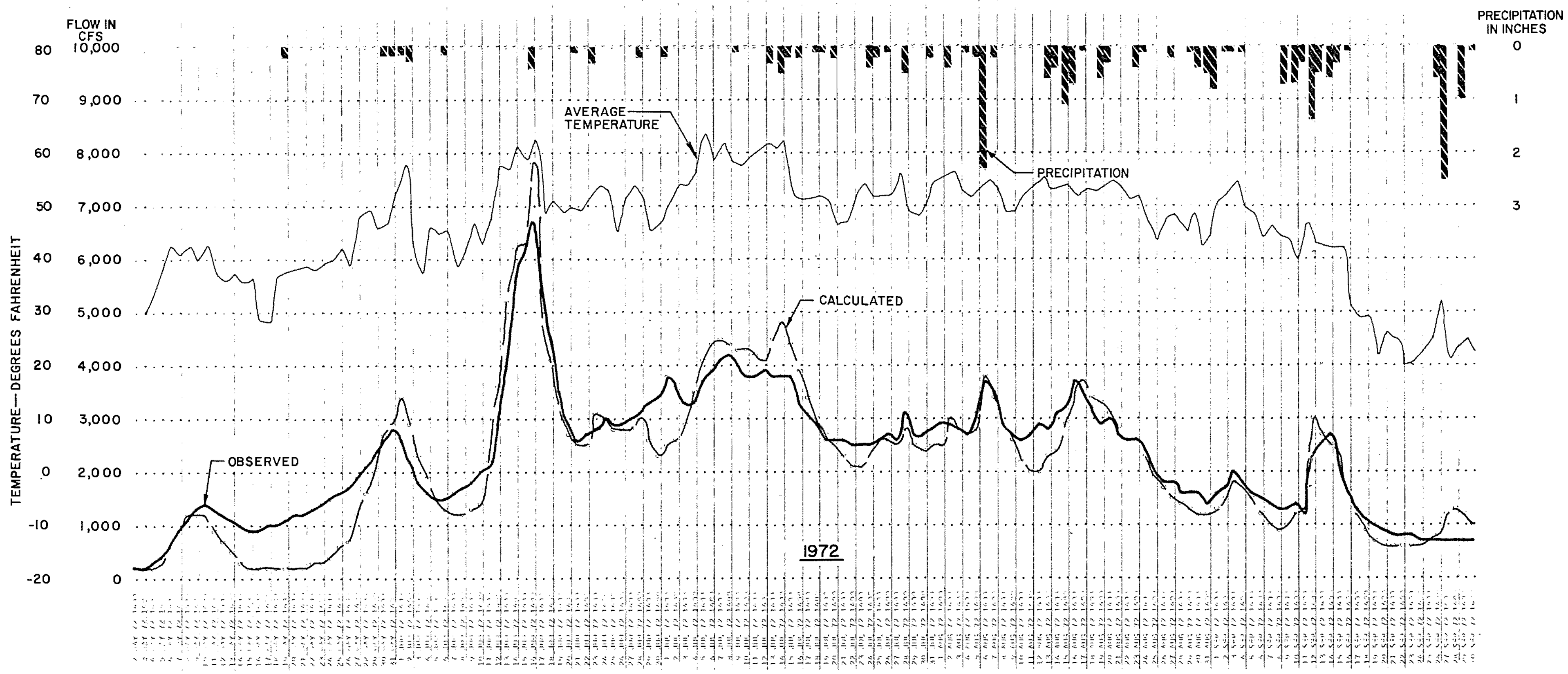
UPPER SUSITNA RIVER BASIN

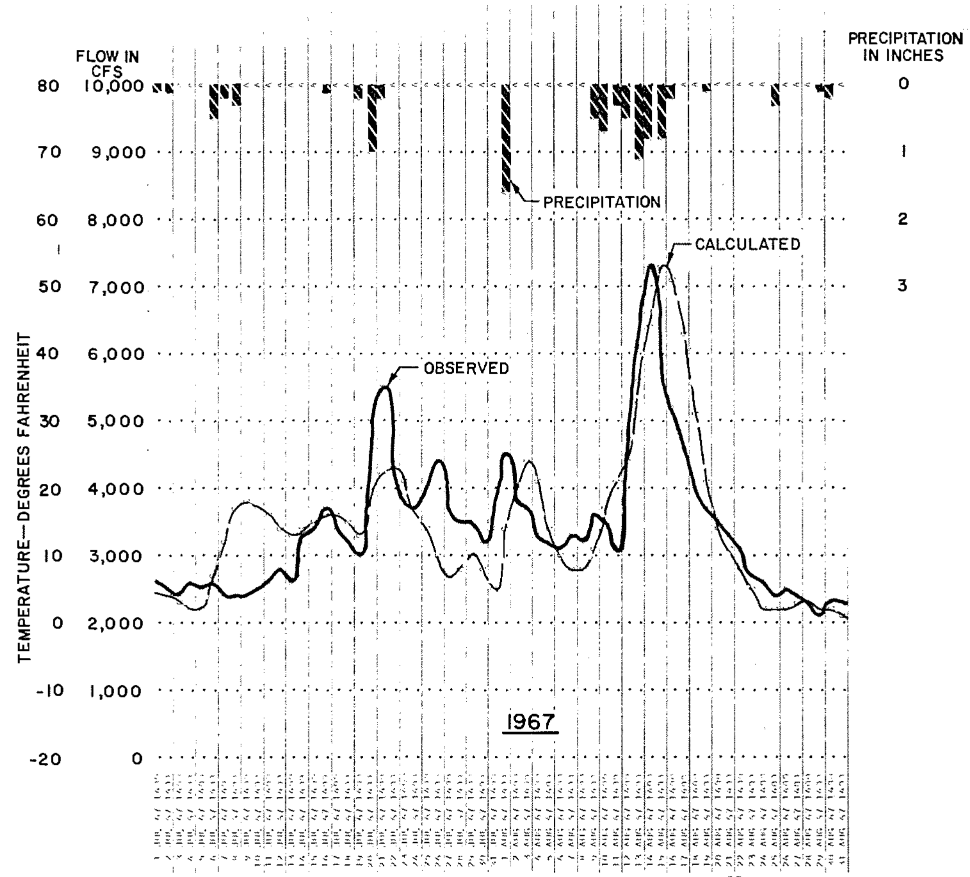
ASSUMED SNOW PACK, IN WATER EQUIVALENTS, FOR PMF DERIVATION

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975





FILE NO. 2—SOU—92—04—01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

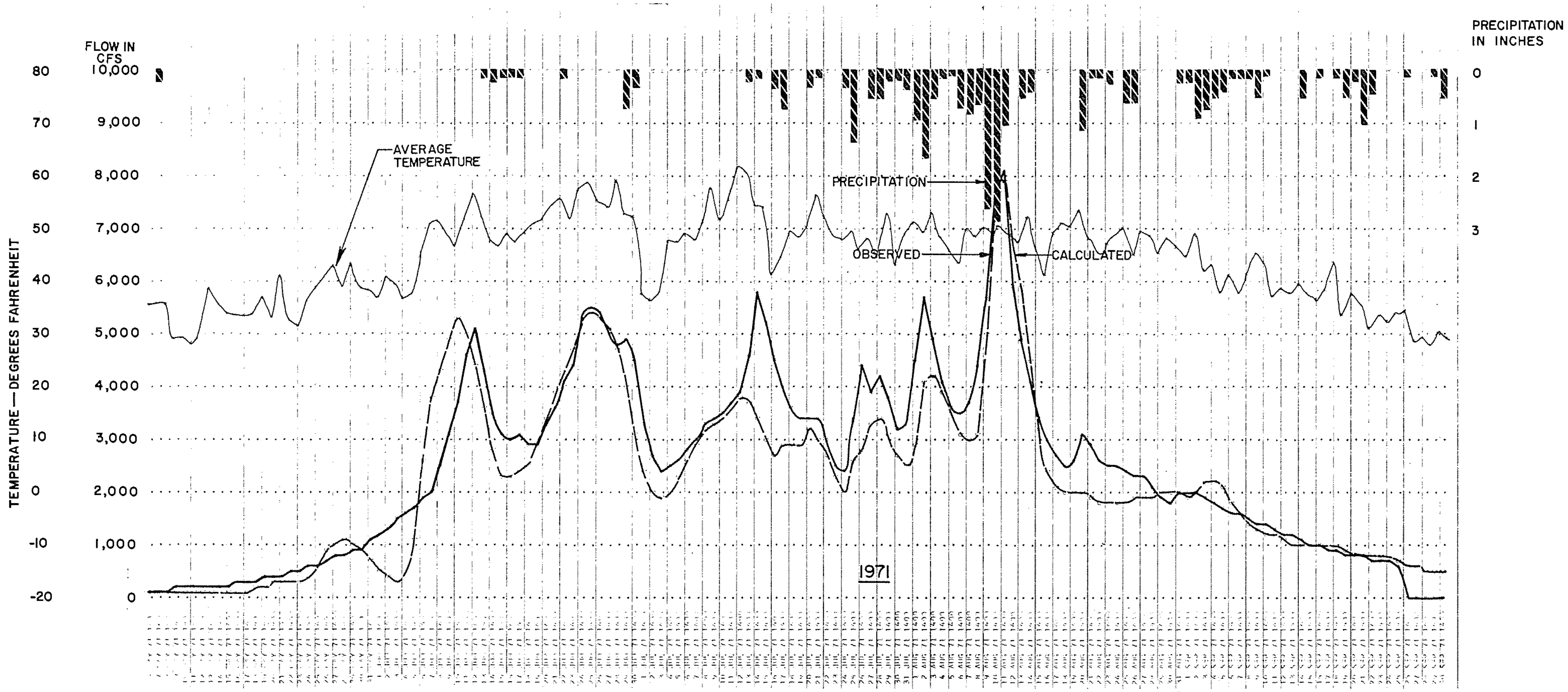
HYDROGRAPH RECONSTITUTION MACLAREN RIVER NEAR PAXSON

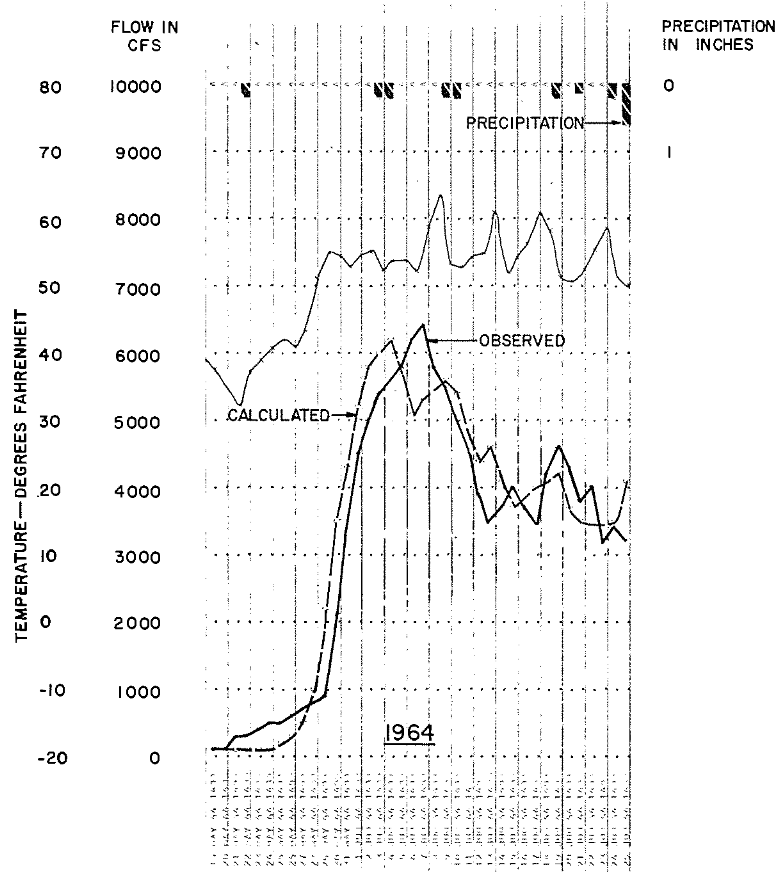
ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

APPENDIX I PLATE A-12





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SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

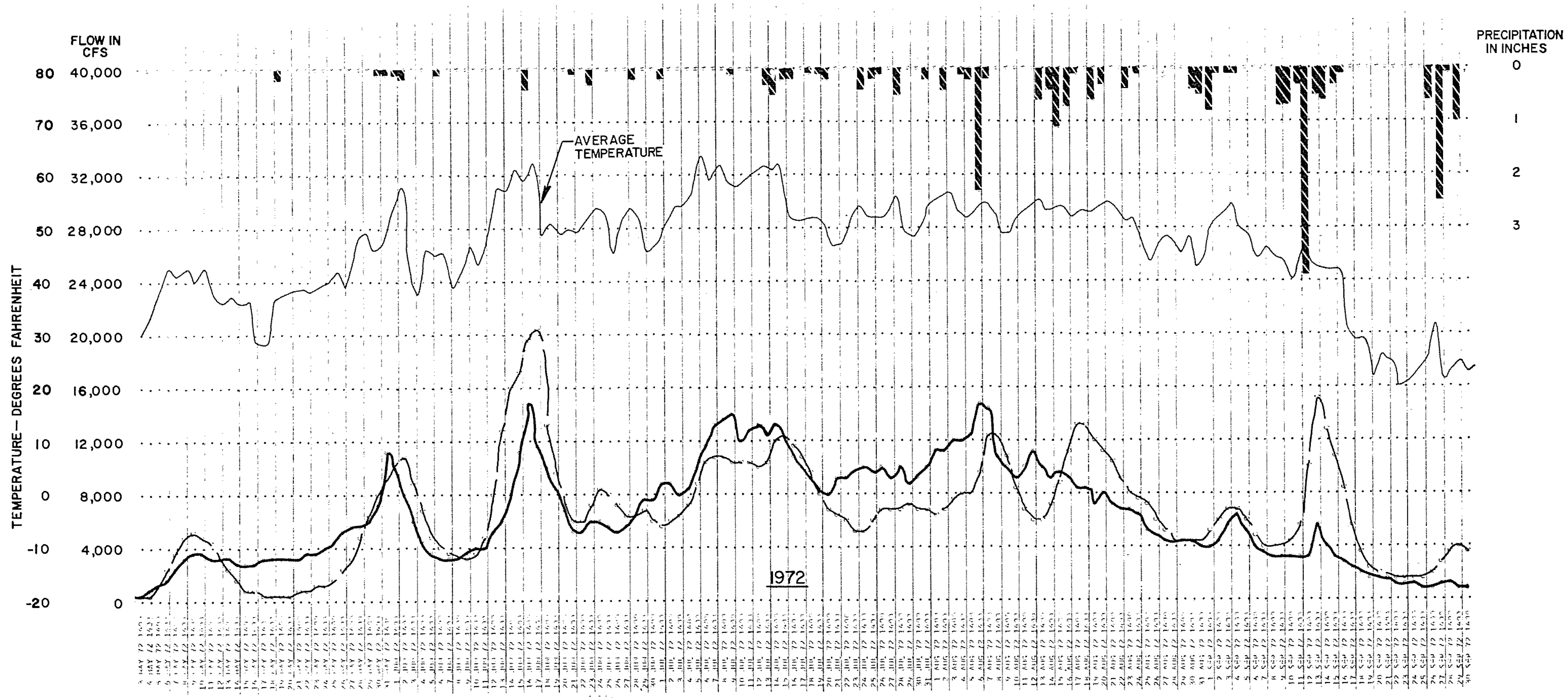
HYDROGRAPH RECONSTITUTION

MACLAREN RIVER
NEAR PAXSON

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

APPENDIX I PLATE A-11



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SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

HYDROGRAPH RECONSTITUTION

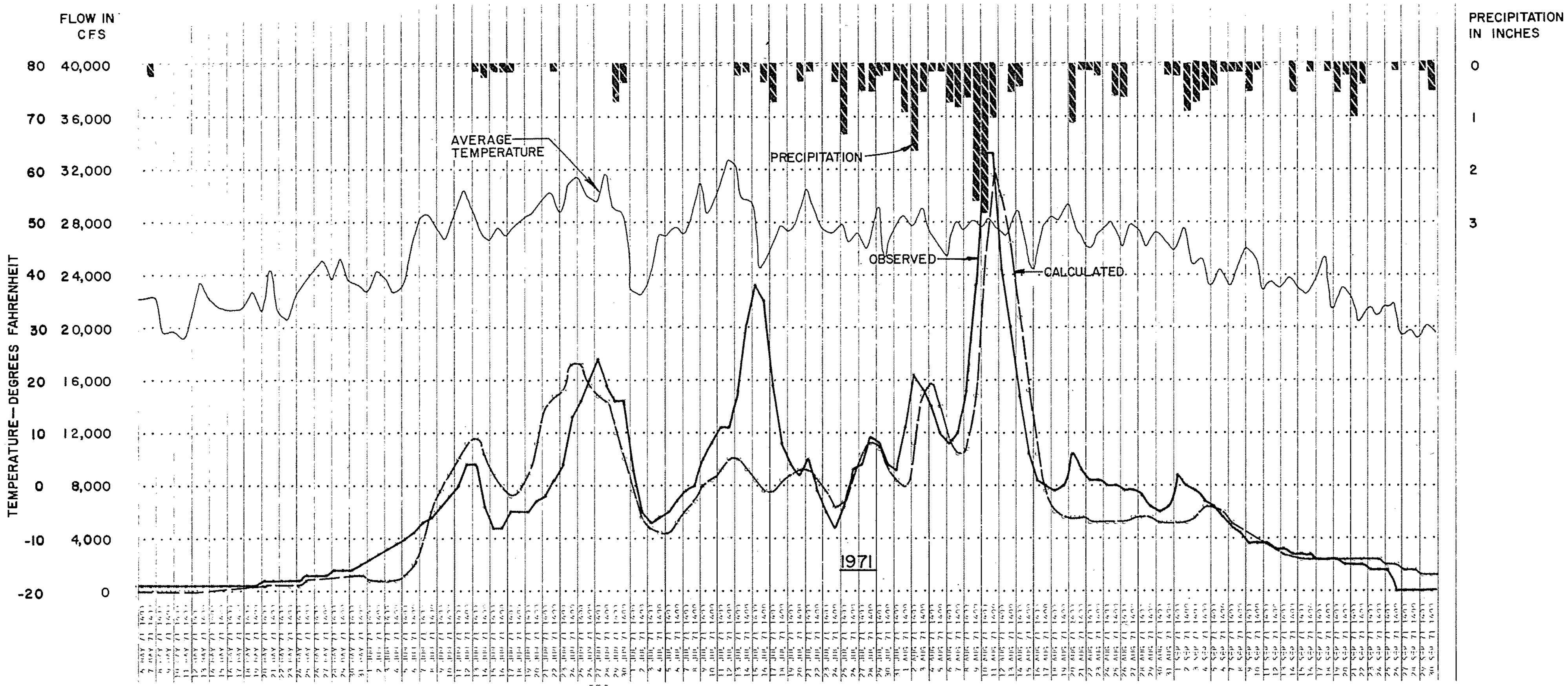
SUSITNA RIVER

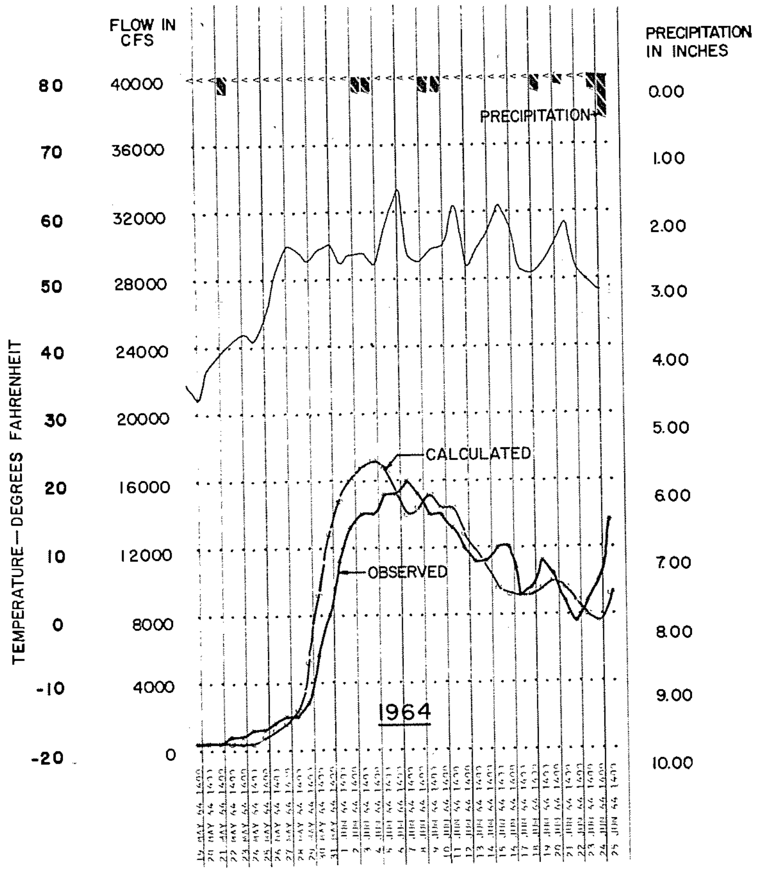
NEAR DENALI

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

APPENDIX I PLATE A-10





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SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

HYDROGRAPH RFCONSTITUTION

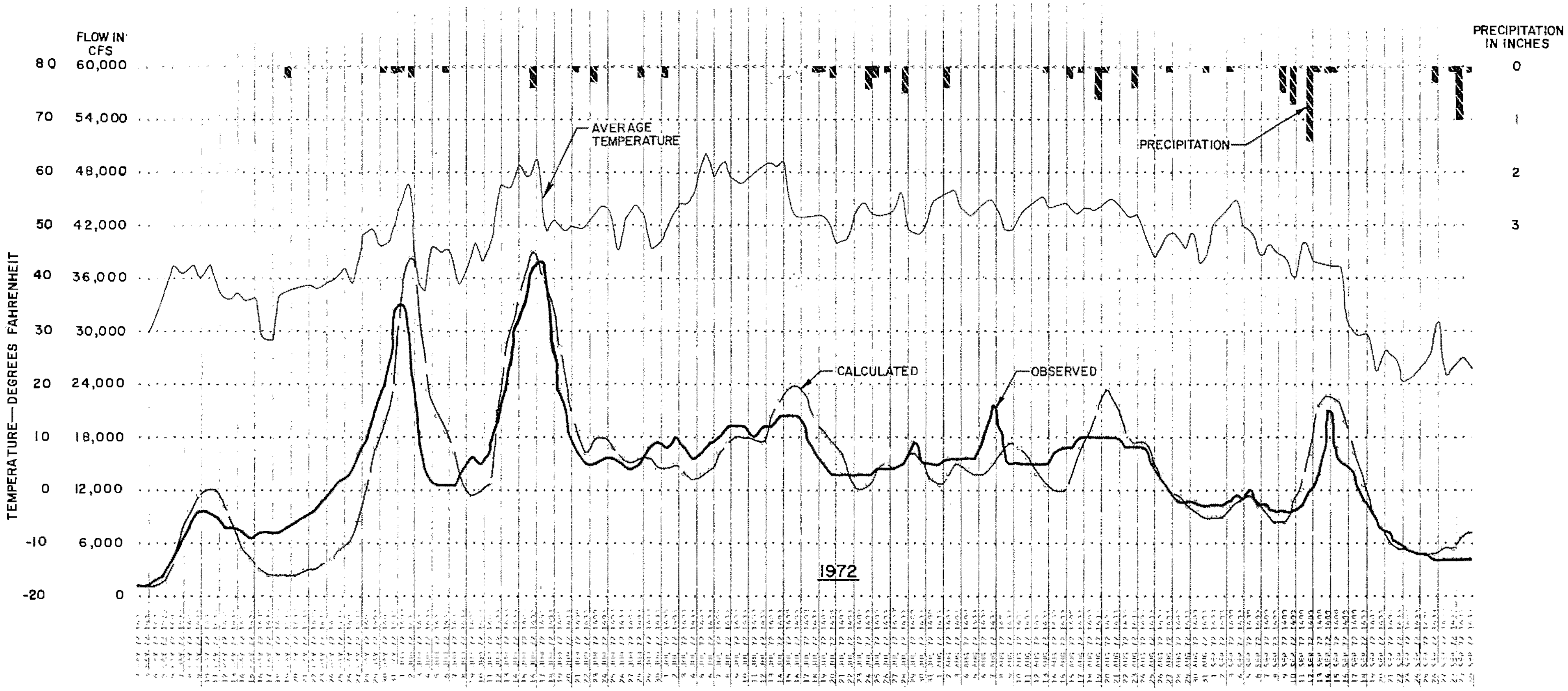
SUSITNA RIVER

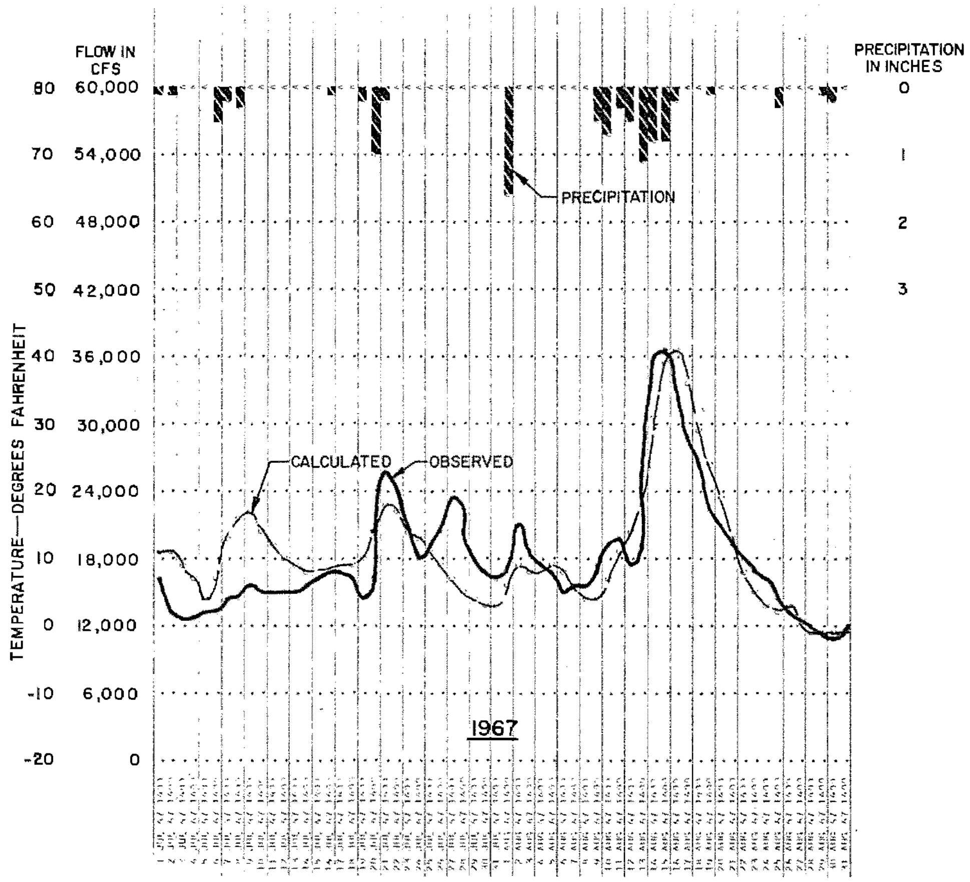
NEAR DENALI

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

APPENDIX I PLATE A-9





FILE NO. 2-SOU-92-04-01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

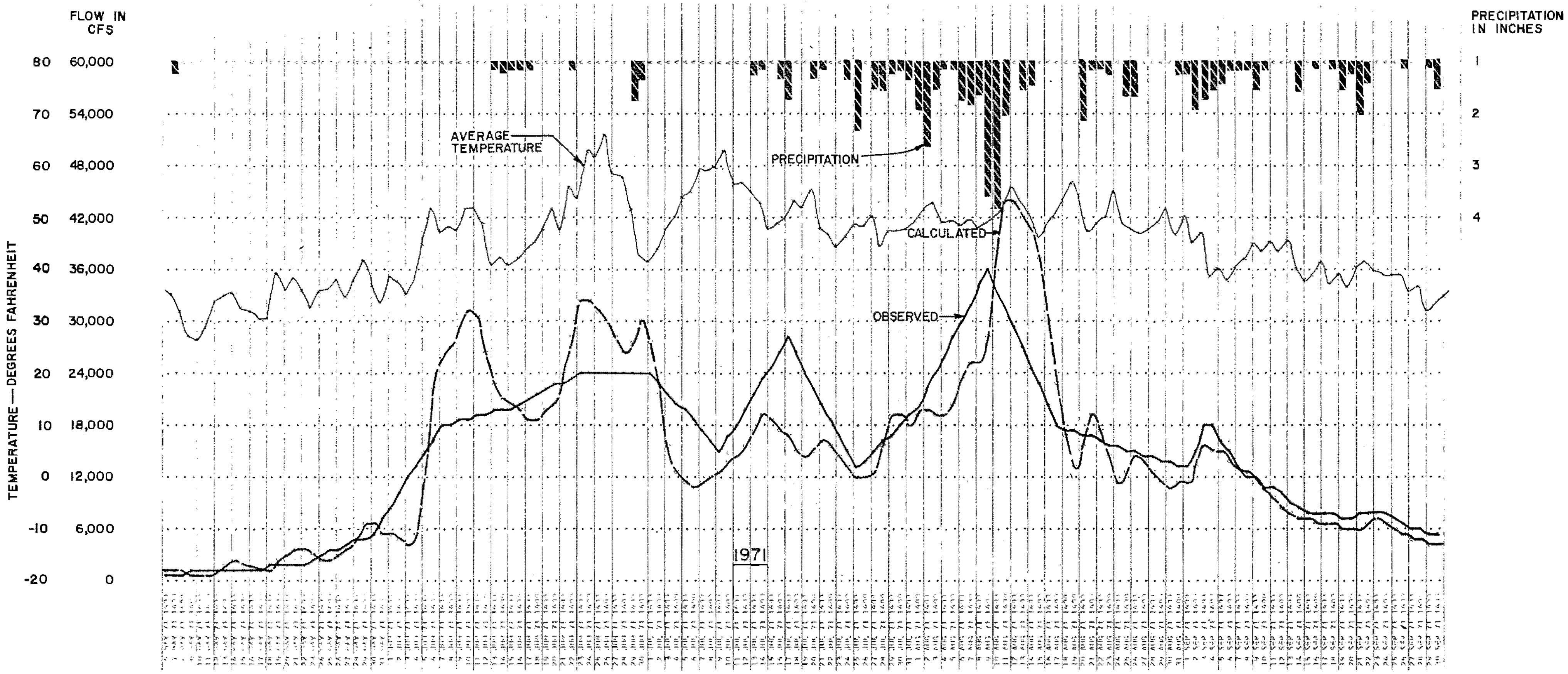
UPPER SUSITNA RIVER BASIN

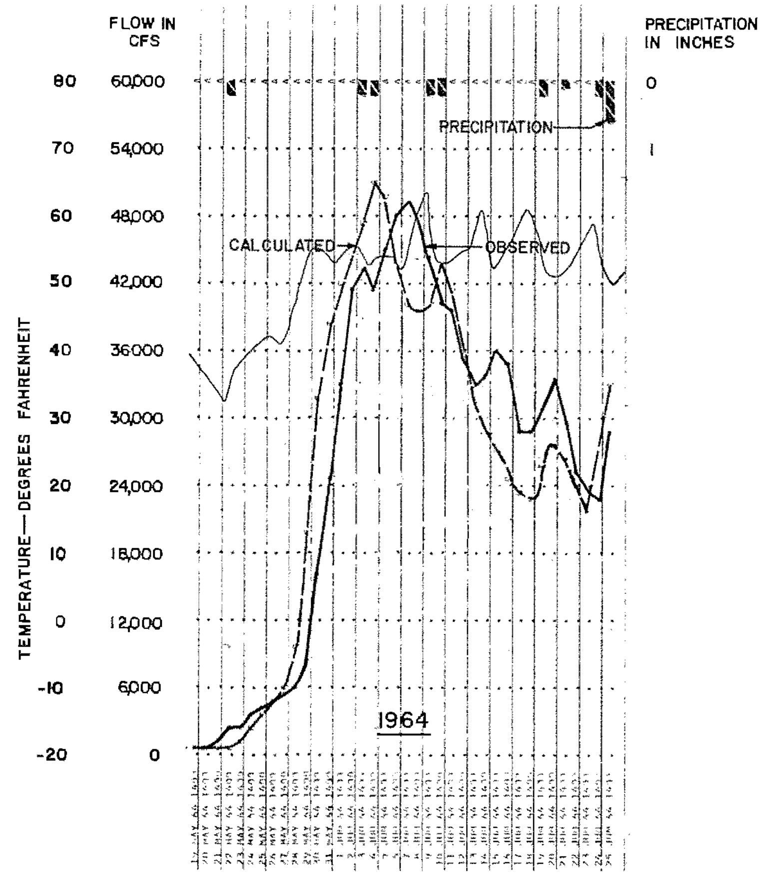
HYDROGRAPH RECONSTITUTION SUSITNA RIVER NEAR CANTWELL

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

APPENDIX I PLATE A-8





FILE NO. 2-SOU-92-04-01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

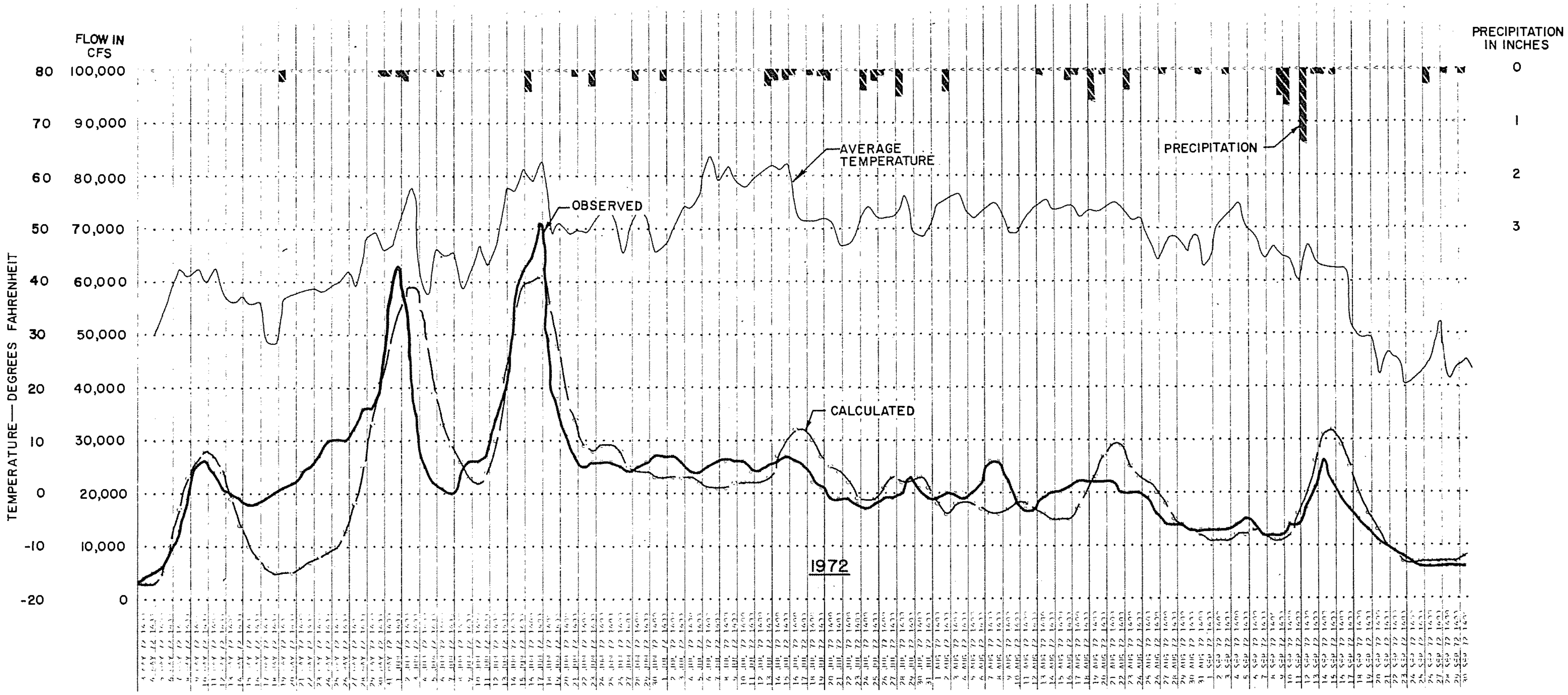
UPPER SUSITNA RIVER BASIN

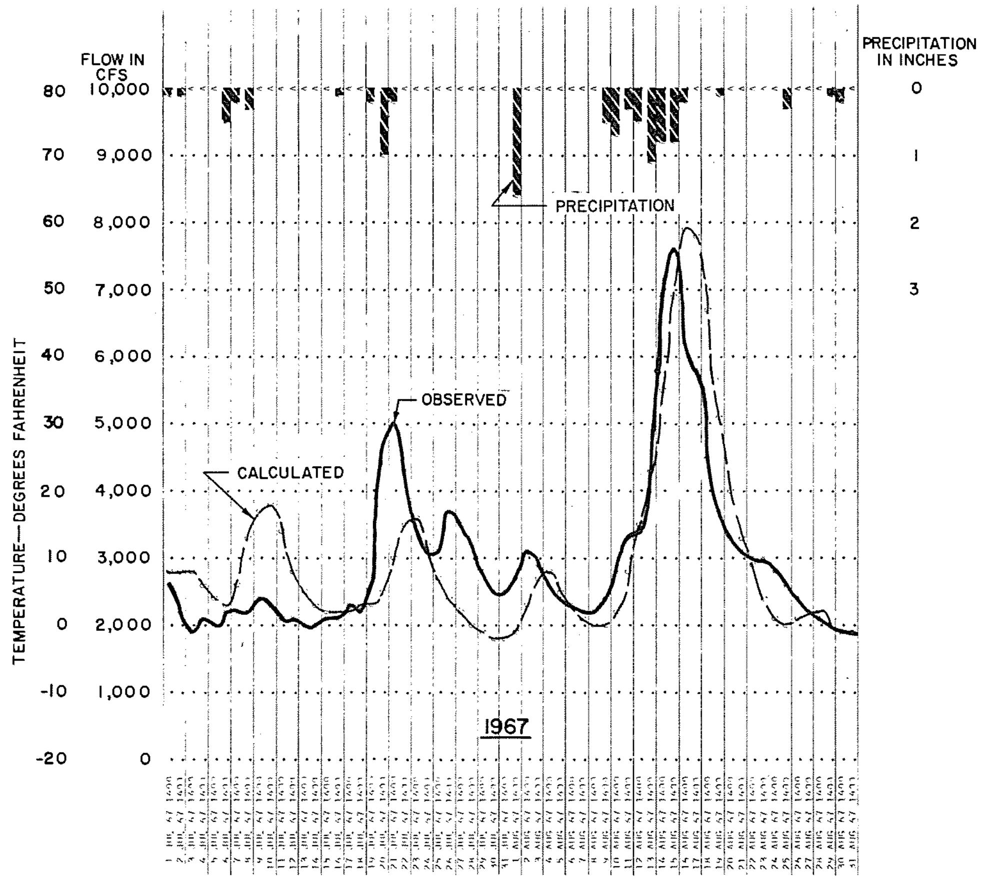
HYDROGRAPH RECONSTITUTION
SUSITNA RIVER
NEAR CANTWELL

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

APPENDIX I PLATE A-7





FILE NO. 2-SOU-92-04-01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

HYDROGRAPH RECONSTITUTION

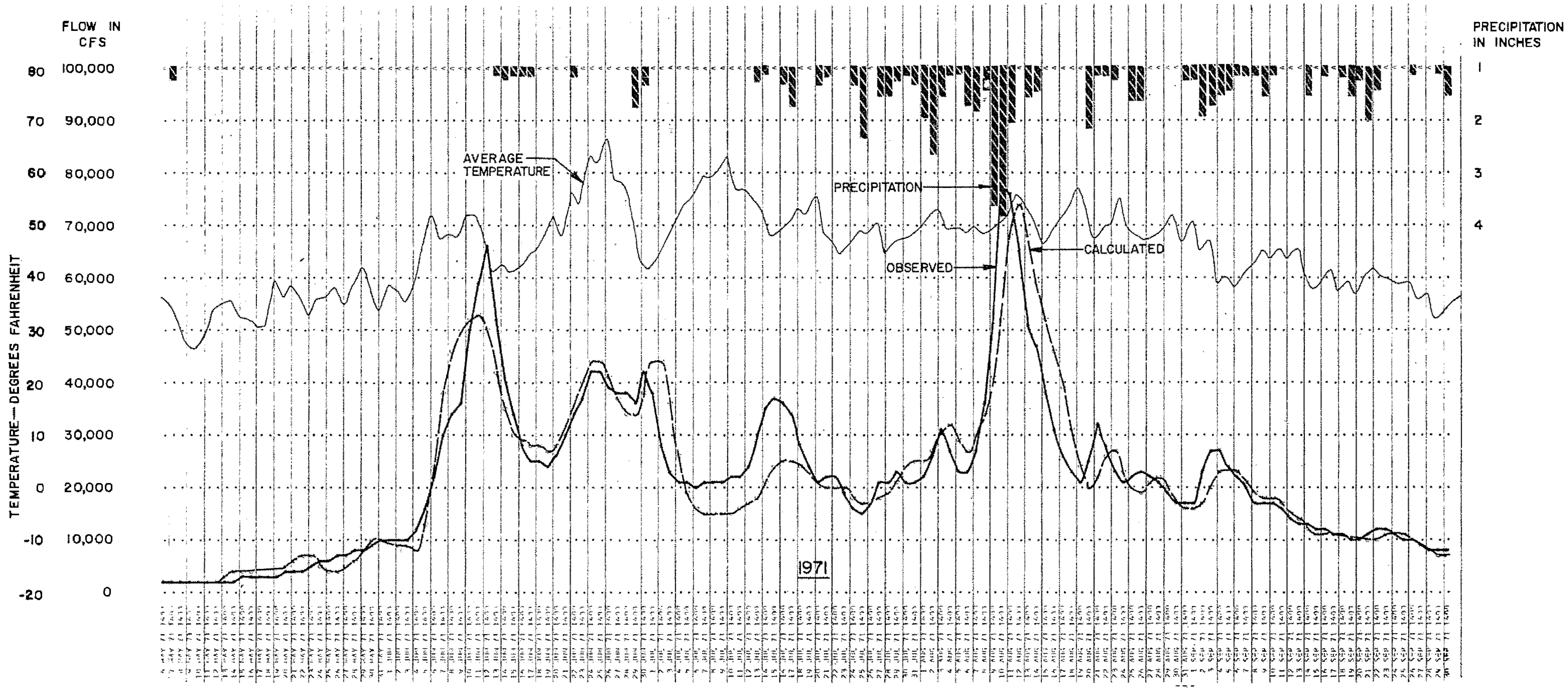
SUSITNA RIVER

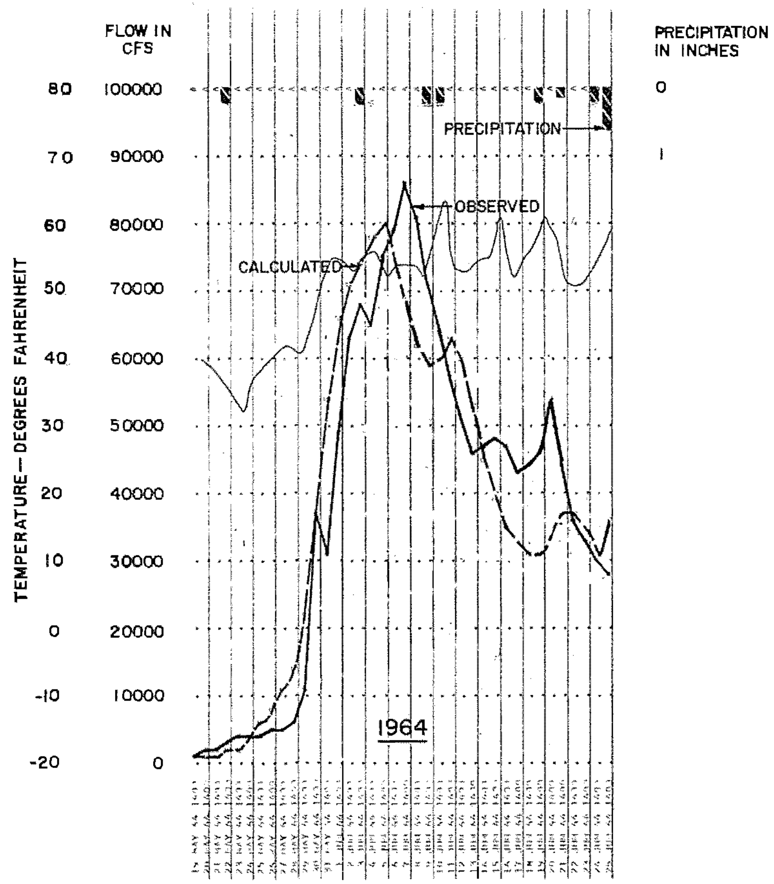
AT GOLD CREEK

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975 APPENDIX I PLATE A-6





FILE NO. 2-SOU-92-04-01

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

HYDROGRAPH RECONSTITUTION

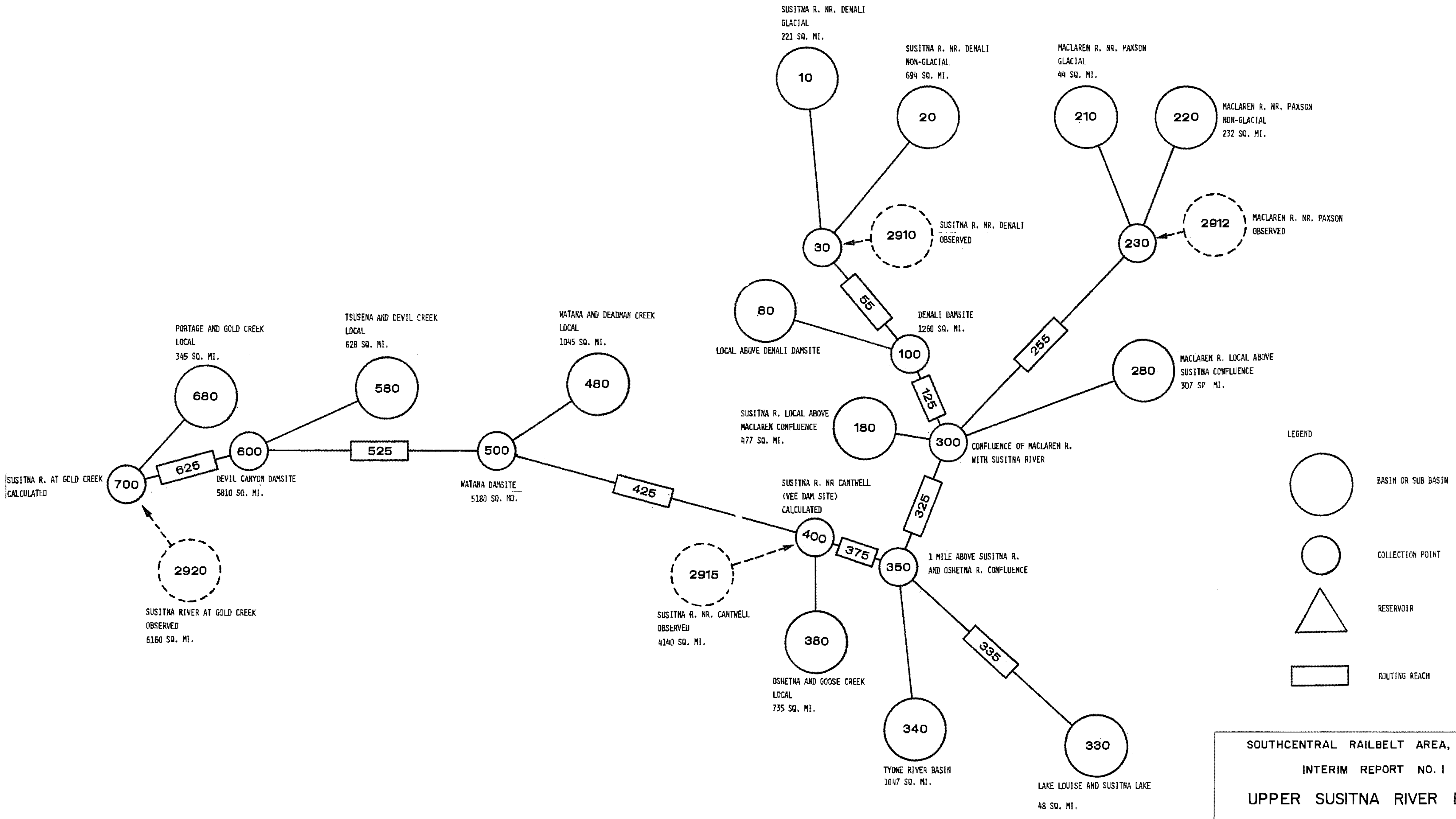
SUSITNA RIVER

AT GOLD CREEK

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975 APPENDIX I PLATE A-5



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

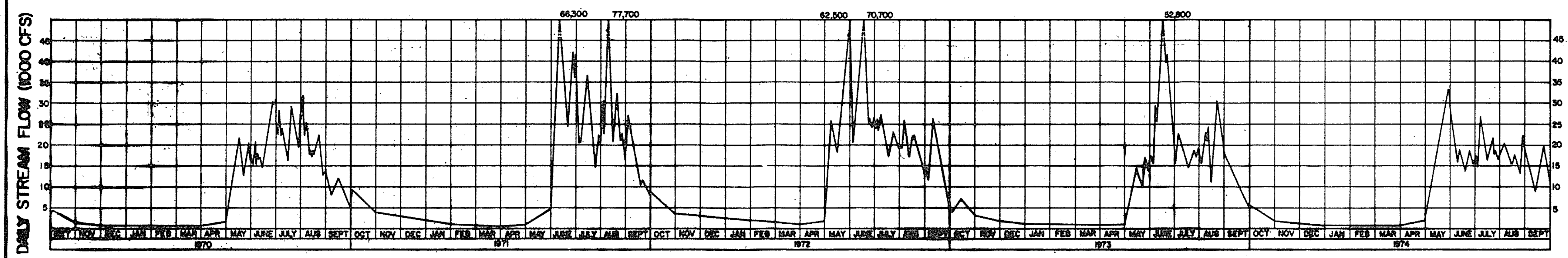
UPPER SUSITNA RIVER BASIN

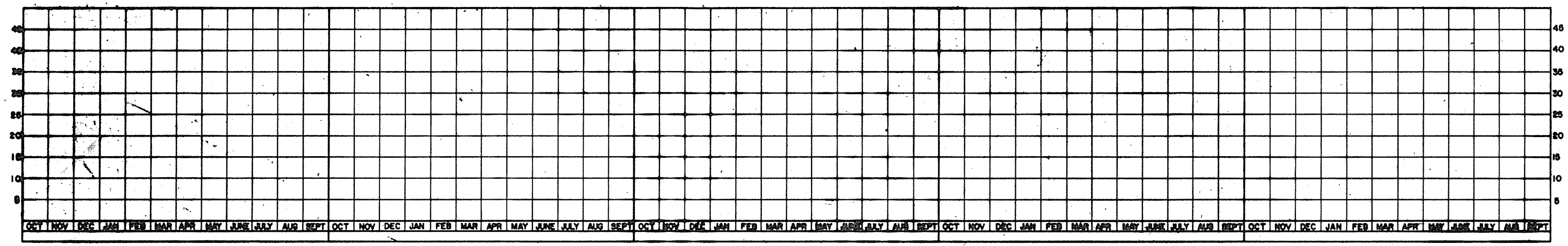
SCHEMATIC DIAGRAM OF SSARR COMPUTER MODEL

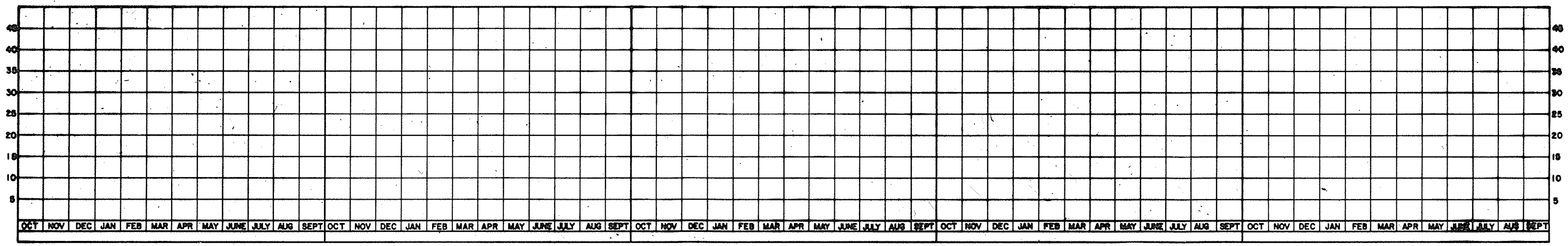
ALASKA DISTRICT, CORPS OF ENGINEERS

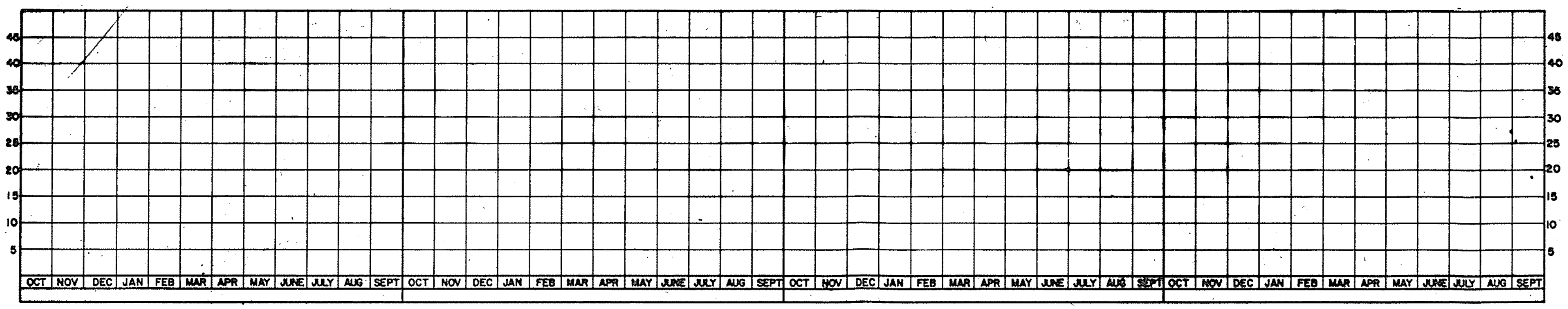
ANCHORAGE, ALASKA

DECEMBER 1975









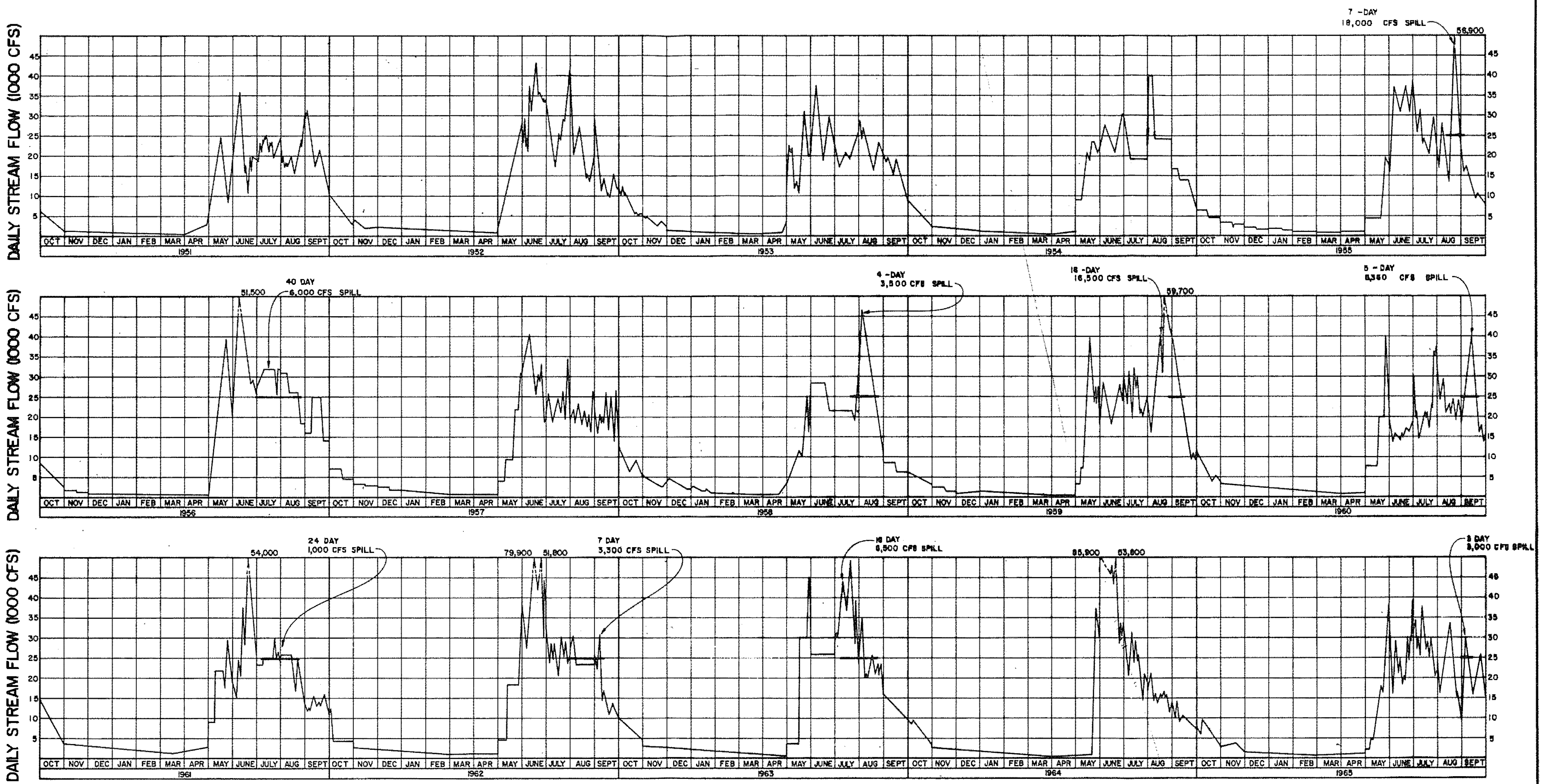
SOUTHCENTRAL RAILBELT AREA, ALASKA

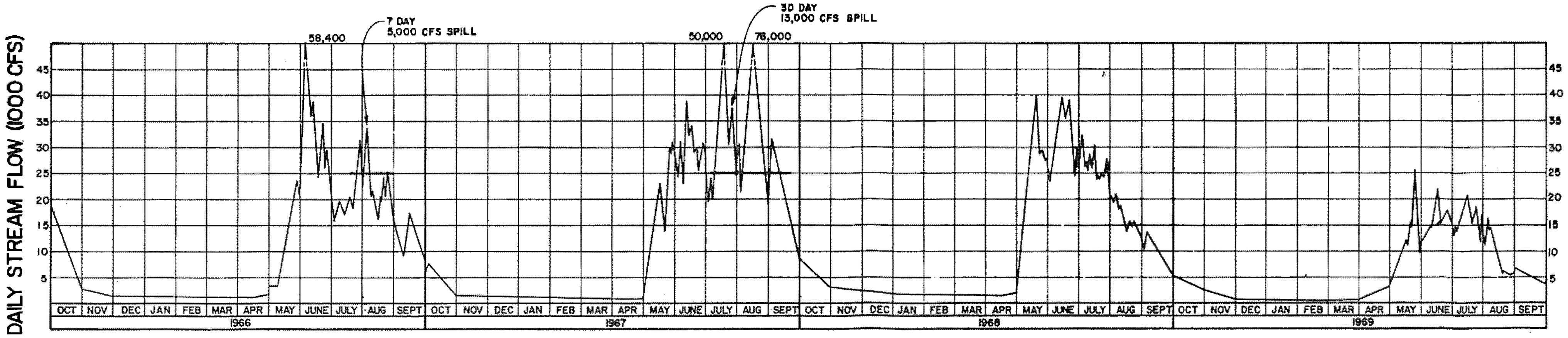
INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
SUSITNA RIVER AT GOLD CREEK DAILY FLOW
ESTIMATED DAILY SPILL RATE
FOR DEVIL CANYON AND WATANA (2200')
SYSTEM

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975





SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN
SUSITNA RIVER AT GOLD CREEK DAILY FLOW
ESTIMATED DAILY SPILL RATE
FOR DEVIL CANYON AND WATANA (2200) SYSTEM

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

SECTION B

PROJECT DESCRIPTION AND COST ESTIMATES

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TWO-DAM SELECTED PLAN

Pertinent Data

	Watana	Devil Canyon
Location	River Mile 165 (2 mi. upstream from DC pool head)	River Mile 134 (14.5 mi. from Gold Creek)
Type Construction	Earthfill	Concrete, thin-arch
Height, feet	810	635
Crest Elevation, feet, m.s.l.	2,210	1,455 at thin-arch section; 1,461 at earthfill section
Crest Length, feet	3,450	2,475
Design Earthquake, Richter Scale	8.5	8.5
Epicenter Distance, miles	40	40
Focal depth, miles	20	20
Water surface area (full pool), acres	43,000	7,550
Reservoir Storage (full pool), acre-feet	9,624,000	1,050,000
Full Pool Elevation, feet, m.s.l.	2,200	1,450
Average Annual Estimated Drawdown, feet	100	<5
Reservoir Length (river miles inundated)	54+	28
Powerplant	Three 264-mw units	Four 194-mw units
Firm Annual Energy (independent), Bkwhrs	3.1	0.9

Pertinent Data (Continued)

	Watana	Devil Canyon
Firm Annual Energy with Storage at Watana (combination), Bkwhrs	3.08	3.02
Secondary Production for 2-dam system, annually, Bkwhrs	0.44	0.36
Spillway Capacity, cfs	165,000	228,000
Normal Minimum Pool Level feet, m.s.l.	1,950	1,275
Maximum Design Flood Elevation, feet, m.s.l.	2,205	1,455
Outlet Works	High-level, two 10x14 gates, 25 ft. circular tunnel (Qmax. = 28,000 cfs) Low-level, two 10x14 gates, 25 ft. circular tunnel (Qmax. = 28,000 cfs)	Four 11x7-1/2 gated openings in dam (Qmax. = 47,000 cfs)
Diversion Facilities	Two 30 ft. horseshoe tunnels (72,000 cfs)	One 26 ft. horseshoe tunnel (21,000 cfs)
Access Road, miles	37	27
Construction Time, years	6	5
Reservoir Storage Loss-Sedimentation, per 100 years (combination)	4.2 percent	6.5 percent
	COSTS	
Total Project Costs	$1,088,000,000	$432,000,000
Benefit-to-cost Ratio (compared to coal, using 6-1/8 percent interest rate and 100-year life)	1.4 - Federal financing	

Pertinent Data (Continued)

	Watana		Devil Canyon
Annual Costs		$104,020,000	
Annual Benefits		$147,821,000	

TRANSMISSION SYSTEM

	To Anchorage		To Fairbanks
Two-single Circuit Lines	136 miles 345 kv		198 miles 230 kv
Route	Southern		Northern
	Devil Canyon Switchyard w. to--Gold Creek-- sw. along Susitna R., ARR-Talkeetna--e. bank Susitna R.--Nancy Lake area--s. to Pt. MacKenzie		Devil Canyon Switchyard w. to Gold Creek n. to Chulitna along Parks Hwy, ARR thru Broad Pass--Nenana Canyon-Healy, then along existing line--Gold Hill-Ester
Length	Devil Canyon-MacKenzie 140 mi.		Devil Canyon-Ester 200 mi.
Length		Devil Canyon-Watana 30 mi.	
	Devil Canyon-MacKenzie		Devil Canyon-Ester
Cleared Right-of-way	Varies		
Towers		Steel or aluminum	
Conductors (ACSR)	954		1272

PROJECT DESCRIPTION AND COST ESTIMATES

PLAN OF IMPROVEMENT

SELECTED PLAN LOCATION AND DESCRIPTION

The selected plan consists of a two-dam development on the upper Susitna River in the southcentral part of Alaska (see Plate B-1). The dams, in the sequence in which they will be constructed, are:

Watana Project: The project consists of an earthfill dam with saddle spillway that discharges into adjacent Tsusena Creek (see Plate B-5). The project's underground powerhouse has a capacity of three 264-MW generating units totaling 792-MW. The damsite is at river mile 165, about 45.5 miles upstream of Gold Creek, the closest point on the Alaska Railroad.

Devil Canyon Project: The project consists of a concrete thin-arch dam with a spillway through the left abutment (see Plate B-12). The project's underground powerhouse has a capacity of four 194-MW units totaling 776-MW. The damsite is at river mile 134, about 14.5 miles upstream of Gold Creek. The Devil Canyon reservoir will extend to within 2 miles of Watana Dam.

FEATURES OF THE SELECTED PLAN

This section describes in detail the features of the Watana and Devil Canyon projects.

Watana Features:

Main Dam: The main dam consists of an earthfill structure 810 feet high having a crest length of 3,450 feet at elevation 2,210 feet, m.s.l. The maximum section, shown on Plate B-6, has an upstream side slope of 1 vertical on 2.5 horizontal and a downstream side slope of 1 vertical on 2 horizontal.

A concrete gravity dam was considered; however, estimates (for a lower dam height) indicated dam and spillway costs were nearly double those for a comparable gravelfill dam and spillway. Processing of aggregate and cement costs were a major reason for the large difference in costs.

For the earthfill dam, a design earthquake of 8.5 Richter magnitude or equivalent is being used in stability analysis, as discussed in Section D of this appendix.

Spillway: Two different spillways were studied in detail for the Watana damsite, one a right bank spillway and the other a saddle spillway. Although the right bank spillway was found to be more economical, because of other considerations including the very limited space both upstream and downstream on the right abutment, the saddle spillway was selected.

The saddle spillway's 1,650-foot converging entrance channel slopes toward the reservoir pool, as shown on Plate B-8. The crest is a low ogee type with an elevation of 2,162 feet, m.s.l. The spillway is controlled with three 59-foot x 42-foot tainter gates. An access road to the spillway and saddle area is shown on Plate B-5. The channel downstream of the crest is concrete lined for a minimum distance of 150 feet and then transitions to sound natural rock. The channel diverges to 600 feet wide approximately 930 feet downstream and continues at that width for about 2,350 feet where it discharges into Tsusena Creek, approximately 2.6 miles upstream from its mouth. The channel daylights at about elevation 2,090 feet, m.s.l., and cascades down the remaining 410 feet to the creek at elevation 1,680 feet, m.s.l.

Routing of the design flood through the reservoir resulted in a maximum project design flood of 192,000 cfs at a reservoir pool elevation of 2,205 feet, m.s.l. The spillway can discharge 165,000 cfs and the remainder will pass through the high-level outlet works. The spillway and outlet works rating curves are shown on Plate B-5.

Outlet Works: The outlet works consist of two separate intakes and conduits, the high-level intake at elevation 1,925, and the low-level intake at elevation 1,725. The controlling criteria for these intakes are ER 1110-2-50 (the emergency drawdown requirement), and the maximum safe head for service gates of 250 feet. Although the ER requires evacuation of 90 percent of the reservoir volume in four months, a more extended drawdown time of eight months is proposed for the following reasons:

1. The large sectional width of the dam, once the water drops below the spillway crest, provides an inherently safer structure than a concrete dam of the same height.

2. The flood plain downstream is sparsely populated.

3. The cost differential between outlets necessary to provide a four-month drawdown and an eight-month drawdown is excessive, being in the order of $50 million.

A single outlet level was not chosen because the gates would have to operate under a maximum head of 480 feet and for a protracted 250-plus day period.

Under the proposed deviation from the ER requirements, the reservoir is drawn down to elevation 1,775, evacuating 90 percent of its volume, in 275 days. Drawdown time is plotted against reservoir elevation on Graph B-2. Rating curves for the outlets with 100-percent gate openings are shown on Plate B-5. Each outlet works consists of two 10x14 emergency slide gates and two 10x14 controlling tainter gates, a 25-foot, circular, steep conduit, and a 30-foot, horseshoe, flat conduit. The flat slope conduits are the downstream portions of the diversion tunnels. Profiles of the outlet works are shown on Plate B-7. Details of the intake are shown on Plate B-9.

Diversion Features and Operation: Diversion of the river flow through two 3,700 and 4,000-foot-long by 30-foot, straight-legged, horseshoe tunnels will dewater the damsite and tailrace portals. Gravelfill cofferdams about 100 feet high protect the area against all floods up to the 20-year design flood, 72,000 cfs. The cofferdams are incorporated in the main dam embankment. Each tunnel inlet is controlled by two 12.5-foot by 22-foot roller gates.

Sequences of construction and operation are as follows:

1. Sheet pile cofferdams isolate the upstream and downstream portals. Inlet and outlet structures are constructed, tunnels are driven and lined. See Plate B-9 for details.

2. After completion of diversion tunnel No. 1, the river is diverted into it. This will take place in the fall as soon as river discharge is low enough. The downstream portion of diversion tunnel No. 1 will eventually become part of the high-level outlet works. The downstream portion of diversion tunnel No. 2 will become part of the low-level outlet works. Upon river closure, construction of the cofferdams commences.

3. Construction of diversion tunnel No. 2 can continue until spring of the year following river closure. However, both tunnels must be ready for the high summer flows that year. The cofferdams must also be at or near their design elevation at this time. Construction of the inclined shaft of the low-level outlet works can continue in diversion tunnel No. 2 during the winter.

4. Once the low-level outlet works are complete, all river flow can be shifted to diversion tunnel No. 2 (in the winter season only), and the inclined shaft for the high-level outlet works can be completed.

5. In the fall of the year before pool filling commences, river flow is routed through tunnel No. 2. The filling valve and partial plug are then constructed in tunnel No. 1 (see Plate B-9). Pool is filled by closing and permanently plugging tunnel No. 2. Minimum river flows are maintained through fill valve in tunnel No. 1, and river rises to low-level outlet. By this time, plug-in tunnel No. 2 is in place and flow is allowed through low-level outlet and stopped through fill valve. The partial plug at the fill valve in tunnel No. 1 is completed and the reservoir continues to rise to power intakes. The system is designed to maintain minimum summer and winter releases of 5,000 cfs and 1,000 cfs, respectively.

Powerplant: The Watana powerplant is located in an underground chamber in the left abutment. Installation will consist of three 264-MW generating units being turned by three 362,000-horsepower Francis turbines.

The powerhouse chamber contains the generators and turbines, two 600-ton cranes, a machine shop, and all other necessary equipment, as shown on Plates B-10 and B-11. The three-phase transformers and circuit breakers are housed in a separate cavern upstream of the main powerhouse chamber, as shown in profile on Plate B-11. Vehicle access to the powerplant is provided by a service road 1.9 miles long, and includes a 2,100-foot tunnel, as shown on Plate B-5.

A cost comparison between an above ground and an underground powerplant at the Watana damsite showed that the underground plant is less expensive. Other factors, such as severe winter weather conditions, short construction seasons, higher above ground maintenance costs, and lack of good above-ground site locations, also favor the underground plant selection.

Penstocks and Waterways: A penstock and waterway profile is shown on Plate B-8. The penstock entrances are bell-mouth openings that transition into 18-foot and 25-foot- diameter conduits prior to leaving the intake structure. In the selective intake system, the penstock centerlines are placed in the intake structure at elevation 1,910 feet, m.s.l., and designed to select water at the desired elevation, which will help meet downstream water quality requirements. There are many advantages to having a selective withdrawal capability and it is especially important in projects with high heads. The penstocks drop from the intake structure to elevation 1,460 feet prior to passing through bonnetted, wheel-mounted gates installed in the gate chambers just upstream of the powerhouse. Surge chambers and draft tube bulkhead wells are placed in a common cavern downstream of the powerplant. The three draft tubes join to form a 60-foot horseshoe draft tube which returns the water to the natural river channel.

Model Studies: Model studies will include: a general model of the outflow from the diversion tunnels, the draft tubes, and the outlet works, and the inflow to the selective withdrawal tower; detailed models of the outlet works intake, tunnel, stilling basin, and downstream channel; and detailed model of the plug and fill valve.

Switchyard and Transmission System: The Watana switchyard is located on the left bank of the Susitna River just downstream of the dam, as shown on Plate B-5. The switchyard covers an area approximately 700 feet by 500 feet, at elevation 2,100 feet, m.s.l. The high-voltage cables pass through an access shaft to the switchyard above.

The transmission system involves approximately 30 miles of line to tie the Watana switchyard into the main system at the Devil Canyon switchyard. The 30-mile 230-kv system would consist of two single-circuit lines.

Lands and Reservoir Clearing: Some lands within the Watana reservoir area were withdrawn for power purposes in February 1958. However, access roads, transmis-ion corridors, and some other project features were not included in the withdrawal. There are no existing roads, railroads, or other improvements affected by the reservoir impoundment. The powersite withdrawal for Watana damsite, in effect, includes all lands below the 1,910-foot contour elevation. The additional lands required comprise an estimated 35,000 acres.

Watana reservoir, shown on Plate B-1, has a surface area of 43,000 acres at normal full pool elevation of 2,200 feet. The normal minimum pool level would be at elevation 1,950, while the maximum elevation produced by the inflow design flood would be 2,205 feet. The reservoir would extend about 54 miles upstream to a point approximately four miles below the confluence of the Tyone River with the Susitna.

Regulations require that the reservoir area, between minimum and maximum pool elevations, plus a vertical distance for safety reasons, be cleared in total. Therefore, it is planned that all floatable and other debris which might create public and wildlife health hazards, operational hazards, and navigational hazards be removed.

Access Road: Access to the Devil Canyon damsite from the Parks Highway would involve 27 miles of new road. Several routes were considered. The selected route is the most economical. This route, as shown on Plate B-1, begins at Highway 3 near Chulitna Station and winds south and east along the railroad until it meets the Susitna River. The road crosses the Susitna on a 650-foot bridge and parallels the river on the south bank for several miles. Then, climbs out of the Susitna River canyon, the road takes an easterly direction to the Devil Canyon damsite.

The access road to the Watana damsite from the Devil Canyon damsite involves an additional 37 miles of new road. The selected southern route, as shown on Plate B-1, was found to be the most economical. The route north of the Susitna River involved several major bridges. In the southern route, only one major bridge, a 500-foot structure crossing the reservoir where the Devil Canyon pool backs up into Cheechako Creek, is required. The access road then climbs to its highest pass (elevation 3,075 feet m.s.l.) as it winds southeast and then east. The road passes by the northern end of Stephan Lake, continues across Fog Creek, winds north around the Fog Lakes area, and ends at the Watana damsite.

The 24-foot-wide road, using American Association of State Highway Officials (AASHO) standards, is designed for a 30-mile-per-hour speed, with 275-foot minimum curve radius and maximum grades of 8 percent.

The Alaska Railroad siding at Gold Creek may be enlarged for a railhead and transfer point for trucking of heavy materials by access road to the project site. A small plane runway is planned for the Watana damsite.

Buildings, Grounds, and Utilities: The temporary construction camp, which is planned to be located at the damsite, consists of trailers and multidwelling units. Facilities used during construction of the Watana project may be relocated and used during construction of the Devil Canyon project. Operation and maintenance facilities at the damsite include a warehouse, a vehicle storage building, and permanent living quarters.

The visitor facilities at Watana are to be located near the left abutment of the dam and include a small visitor center building. The planned visitor center provides interpretive facilities and restrooms. The building, parking lot, and walks are to be designed and landscaped to blend harmoniously into the surrounding area. Parking spaces for visitors and administrative personnel provide for 30 vehicles, 10 with trailers, during the four-month recreational season, 15 May through 30 September. The parking facilities could also serve the Watana Creek trail system which begins on the right abutment at the Watana Dam. Five picnic units are located within this area.

Operating facilities at Watana reservoir are located approximately 2 to 3 miles upstream from the damsite on the south shore of the reservoir. The facilities include a paved boat ramp approximately 65 feet wide that serves a reservoir drawdown of about 50 feet. The ramp also has a one-lane, gravel- surfaced extension that can be used for reservoir maintenance purposes when drawdown is in excess of 50 feet. Related facilities include parking facilities for 28 vehicles, 20 with trailers, and 2 vault toilets. The facilities are to be designed and landscaped to blend harmoniously into the natural surroundings.

Permanent Operating Equipment: The permanent operating equipment for the Watana project consists of approximately 5 pieces of heavy equipment (e.g. D-8 dozer, lowboy, mobile crane) about 9 pieces of lighter equipment (e.g. pickups, sedans, small flatbeds), and approximately 4 pieces of other maintenance and emergency equipment (e.g. snow tractors, firetruck).

Project-owned operation and maintenance tools, such as shop, warehousing, and communications equipment are included in this feature. Water management activities require the installation of a data acquisition system (with its associated permanent operating equipment) to obtain data on rainfall, snowpack, and river and reservoir stages, water quality parameters and reservoir ice thickness. The major part of this system is required at an early date to provide capability for flood forecasting during construction and for the filling and operation of Watana reservoir.

Devil Canyon Features:

Main Dam: The main dam, as designed by the United States Bureau of Reclamation (USBR), consists of three integral sections: (1) a 635-foot-high concrete, double curvature, thin-arch right abutment section with a crest length of 1,370 feet; (2) a 110-foot-high concrete thrust block center section with a crest length of 155 feet; and (3) a 200-foot-high curved earth or gravelfill left abutment section with a 950-foot crest length. The crest elevation is 1,455 feet, m.s.l,. at the thin-arch section, and transitions to 1,461 feet, m.s.l. at the earthfill section.

Topographic conditions necessitate the left abutment thrust block. The foundation rock is predominantly fine-grained clastic or phyllite capable of withstanding the high loads imposed by the thin-arch dam design and accompanying reservoir. A pattern of shears that strike cross-river and dip nearly vertically requires remedial treatment where they are associated with the foundation of the dam; however, the amount of treatment involved is slight and is not a significant cost factor. A suitable borrow source for coarse and fine aggregates exists in a fan deposit (in the Cheechako Creek area) upstream from the dam axis on the left bank of the Susitna River. Foundation grouting is to be provided along the entire length of all three sections of the dam.

A complete stability analysis of the arch dam for earthquake design was made. The Maximum Credible Earthquake (MCE) used in the analysis had a magnitude of 8.5 on the Richter Scale at 40 miles from the dam and a focal depth of 20 miles. To compensate for above average tensile stresses produced by the MCE in the upper third of the central portion of the dam, a system of high strength steel strands is incorporated in the upstream face of the dam. A more detailed discussion of foundations, borrow source areas, and seismology can be found in Section D.

Spillway: The service spillway is located on the left abutment high ground between the arch dam thrust block and the earthfill auxiliary dam, and is intended to operate whenever reservoir outflow is needed in excess of the power plant discharge. A central spillway and plunge pool were analyzed but not selected, principally because of the plunge pool's proximity to the dam and the very great depths to which this type of pool can erode. Secondarily, nitrogen supersaturation problems are much greater with this type of overflow. Spillway design flood for Devil Canyon Dam, with the Watana project completed, is 222,000 cfs. The spillway is designed to pass this flow at a reservoir elevation of 1,452.5 feet, m.s.l. The ogee crest is at elevation 1,395. Two 64-foot-wide by 60-foot-high radial gates control flow and provide storage to maximum pool elevation. Elevation and sections are shown on Plate B-13.

The chute terminates at elevation 1,110 in a flip bucket with a superelevated floor which deflects the water into a trajectory parallel with and directly above the river. A spillway rating curve with both gates open is shown on Plate B-12.

Low-Level Outlet Works: Four 11-foot by 7-1/2-foot gated sluiceways at elevation 1,075 in the dam provide emergency drawdown capability to elevation 1,150 in accordance with the criterion established by ER 1110-2-50, dated 22 August 1975, which states that 90 percent of the reservoir volume must be evacuated within a four-month period during the high inflow season. Additional criteria are that the outlets should be at or above the 100-year sedimentation level and that operation heads on service gates cannot be over 250 feet, except that if the gates are used only in special or emergency situations, 350 feet can be used.

Inflow during the four-month drawdown period is computed at 18,550 cfs (average of four high months as per ER). Even assuming four units discharging at maximum capacity during drawdown with the reservoir at the spillway crest, this plant outflow is only 18,000 cfs. Therefore, additional drawdown capacity must come from the low-level outlets. An operating head of 350 feet measured below the spillway crest elevation (1,395) would indicate a minimum elevation of 1,045 for outlet; however, this elevation is well below the minimum consistent with the sedimentation criteria. (The four sluiceways with a minimum discharge of 21,000 cfs under 75 feet of head were selected.) As a compromise between a head consistent with flows great enough to achieve rapid drawdown and the sedimentation criterion, with 1,075 as the outlet elevation and opening the sluice gates with 350 feet of head, the reservoir can be drawn down to elevation 1,150 in 25 days. The spillway and four units in the powerhouse also discharge during the first part of the drawdown period. See Graph B-1 for the drawdown curve.

A rating curve for the outlet works is shown on Plate B-12. Each sluice has an emergency gate, a service gate, and facilities for injecting air around the periphery of the flow. A 30° lip on the downstream end of the sluice projects the water well away from the toe of the dam. Because of the infrequent use of the outlet, no plunge pool is provided. Details of the sluiceways are shown on Plate B-13.

Diversion Structure: Construction of the Watana project first provides flow regulation and substantially reduces the diversion effort at Devil Canyon. A 26-foot, lined, horseshoe diversion tunnel will be driven 1,150 feet through the left abutment. A cellular cofferdam will be constructed downstream of the diversion tunnel entrance to dewater the damsite. The dam will be high enough to allow a head of 50 feet on the tunnel entrance invert, enabling the tunnel to pass the output of three units from the Watana plant, about 20,000 cfs, under pressure flow. Up to 15,000 cfs, the tunnel flow is open channel. Two 12-1/2-foot by 22-foot intake gates will regulate flow during diversion. A cellular cofferdam, to be removed upon completion of the project, will also be constructed downstream from the draft tube outlets.

A gated bypass opening constructed either integrally with the intake structure or in one of the gates provides minimum downstream flows during initial reservoir filling only. A permanent concrete tunnel plug is constructed immediately after closure of the bypass valve.

Powerplant: The Devil Canyon powerplant is located in an underground chamber in the right abutment. Four 194-MW generating units with 266,000-horsepower Francis type turbines are installed.

The powerplant chamber houses the generators and turbines, two 425-ton cranes, service areas, and a machine shop for equipment maintenance and repair. The three-phase transformers and circuit breakers are housed in a separate cavern upstream of the main powerhouse chamber, as shown in plan on Plate B-14. Draft tube gate slots are provided in the powerplant chamber to minimize pumping for draft tube unwatering. Personnel access is provided through a divided tunnel from the dam. The other portion of the divided tunnel will carry the high-voltage cables from the powerplant to the dam. The high-voltage cables pass through the dam via a gallery and then to the 345-kv switchyard located on the left abutment.

Vehicle access to the powerplant is provided by a service road across the top of the dam and an all-weather road on the right bank of the river. The road is 2.3 miles long and includes 2,100 feet of tunnel (see Plate B-12).

Penstocks and Waterways: Penstocks are two 24-foot-diameter steel conduits through blocks 10 and 11 of the dam. Two inclined, semi-circular, metal trashracks, located on the upstream face of the dam, prevent debris from entering the penstocks. Guides that extend from the crest of the dam to the bottom of the intakes are provided to allow for installation of stoplogs and subsequent inspection of the selective gate intake system. Intake openings are at 50-foot intervals beginning at elevation 1,100 and ending at elevation 1,400. The selective withdrawal capability will help meet downstream water quality requirements for dissolved oxygen and temperature. Downstream from the dam, the steel conduits are installed in tunnels. The two 24-foot penstocks bifurcate into four 18-foot-diameter penstocks just before they enter the powerplant. Emergency gate regulation for all penstocks is provided by bonnetted, wheel-mounted gates installed in a gate chamber immediately upstream from the powerplant. Access from the gate chamber to the powerplant is provided by a tunnel sufficiently large to transport a wheel-mounted gate to the machine shop of the powerplant. The individual draft tubes from the four units join to form two large discharge tunnels to the river (see Plate B-12).

Model Studies: Anticipated hydraulic models for the Devil Canyon project are: (1) a general model showing spillway flow, outflow into the river channel from the diversion tunnels, the low-level outlets, and the powerplant and inflow into the selective withdrawal system; (2) a detail model of the low-level outlet works.

Switchyard and Transmission System: The Devil Canyon switchyard is located on the left bank of the river immediately downstream of the earthfill section of dam. The switchyard and transmission voltage is 345 kv. The switchyard and powerhouse is connected by high voltage cables which pass through a system of adits and galleries.

The transmission line from the switchyard to the Anchorage area consists of a 345-kv system with two single circuit 136-mile lines using 954 ACSR conductors. The transmission line north to the Fairbanks area consists of a 230-kv system with two single circuit 198-mile lines utilizing 1272 ACSR conductors. The transmission systems and their related corridors are discussed in Section H.

Lands and Reservoir Clearing: There are not roads, railroads, or other facilities affected by the reservoir impoundment. The Devil Canyon Dam powersite withdrawal, in effect, includes all lands below the 1,500-foot contour elevation. The additional lands required (by ER 405-2-150) comprise an estimated 1,840 acres. Devil Canyon reservoir would have a surface area of 7,550 acres at normal full pool elevation of 1,450 feet. The normal minimum pool level would be at elevation 1,275 while the elevation produced by routing the inflow design flood through the reservoir would be 1,452.5 feet. The reservoir would extend about 28 miles upstream to a point near the Watana damsite. The reservoir area, confined within the Susitna River canyon, would be relatively narrow, as shown on Plate B-1.

The reservoir area between minimum and maximum pool elevations plus the vertical distance required by safety regulations would be cleared in total. Also, all floatable and other debris that may create public and wildlife health hazards, operational hazards, or navigational hazards are to be removed. Achieving a pleasant general appearance is a planning objective in final reservoir clearing.

Buildings, Grounds, and Utilities: Tentative sites have been selected for construction of contractors' and government camps, as well as permanent housing for operating personnel. The temporary construction camps, located at the damsite, consist of trailers and multi-dwelling units. Permanent housing are to be completed for utilization by construction personnel prior to occupancy by the operating personnel. Operation and maintenance facilities are located on the left abutment, and include warehousing, vehicle storage, and permanent living quarters.

The visitor facilities at Devil Canyon are to be located near the left abutment of the dam. The planned facilities include a visitor center building with administration space, interpretive facilities, and restrooms. The building is to be designed and landscaped to blend harmoniously into the surrounding area, as will the walks and parking facilities. Parking spaces for visitors and administrative personnel provide for 40 vehicles, 15 with trailers. The visitor facilities will probably operate for a four-month period, 15 May through 15 September.

The parking area could also serve the downstream terminus of the Devil Canyon trail system. Six picnic units are located within this area.

The operating facilities at Devil Canyon reservoir include a paved boat ramp with a floating dock to serve a 10-foot reservoir drawdown. The boat ramp has a gravel surfaced one-lane service extension that could be used for reservoir maintenance purposes if drawdown ever exceeds 10 feet. The boat ramp location is between 1 and 3 miles upstream from the dam on the south shore of the reservoir. Related facilities include parking facilities for 40 vehicles, 30 with trailers, and 2 vault toilets. The facilities are to be designed and landscaped to blend harmoniously into the surrounding area.

Permanent Operating Equipment: The permanent operating equipment for the Devil Canyon project consists of approximately 2 pieces of heavy equipment, 4 pieces of lighter equipment, and 2 pieces of other maintenance and emergency equipment. With the main transmission tie located at Devil Canyon all line trucks, operation and maintenance tools and equipment associated with the transmission line are stationed at Devil Canyon or at two small line stations near Talkeetna and Healy.

The data acquisition system at Devil Canyon consists primarily of reservoir and tailwater gages, and instrumentation to measure reservoir water temperature at selected reservoir elevations. Facilities for measurement of other water quality parameters within the reservoir and downstream of the project are provided.

ALTERNATIVE HEIGHTS CONSIDERED FOR THE SELECTED DAMS

Maximization studies of the selected plan used design and cost estimates for one Devil Canyon reservoir pool elevation (1,450 feet) and four Watana reservoir pool elevations (1,905, 2,050, 2,200, and 2,250 feet). The following tabulation gives estimated project costs for the selected plan using various Watana Dam heights. The reduced Devil Canyon cost in Plans 3 and 4 is due to the construction sequence. Plans 1 and 2 were based on constructing Devil Canyon first while a reverse sequence was most desirable for Plans 3 and 4. With Watana constructed first, certain Devil Canyon costs either transferred to the Watana total or decreased.

Costs in $1,000,000

Plan	Devil Canyon	Watana	Total
1. Devil Canyon-Low Watana (1905)	714.0	420.0	1,134.0
2. Devil Canyon-Mid-Watana (2050)	714.0	628.0	1,342.0
3. Devil Canyon-High Watana (2200)	432.0	1,088.0	1,520.0
4. Devil Canyon-High Watana (2250)	432.0	1,153.0	1,585.0

Devil Canyon Dam: The Devil Canyon Dam height is limited to a maximum elevation of 1,455 because of topographic restraints at the left abutment.

The reservoir storage capacity at Devil Canyon is relatively small due to the narrow, steep-walled canyon. Decreasing the dam's height would decrease the power generating capability because of reduced head. For these reasons, the only normal pool elevation considered for Devil Canyon was elevation 1,450 feet, m.s.l. Refer to Tables B-2 and B-6 for summary and detailed cost estimates, respectively.

Watana Dam: The Watana Dam was estimated for the following four normal pool elevations: (1) Low Watana (1,905 feet elevation); (2) Mid-height Watana (2,050 feet elevation); (3) High Watana (2,200 feet elevation) and (4) High Watana (2250 feet elevation). The High Watana Dam (2200 feet) is part of the selected plan and has already been discussed in detail. Refer to Tables B-1 and B-5 for summary and detailed cost estimates, respectively. The site location for all four Watana structures is the same, Susitna River mile 165, as shown on Plate B-5.

Low Watana consists of a 515-foot (structural) high earthfill dam with 1 vertical and 2.5 horizontal upstream, and 1 vertical and 2 horizontal downstream side slopes. The dam would have an approximate crest length of 1,650 feet at elevation 1,915 feet, m.s.l. The spillway would pass through the right abutment and cascade down a chute, dropping more than 400 feet before returning to the natural river channel downstream of the dam. The low ogee crest would be at elevation 1,870 feet, m.s.l., have a crest length of 260 feet, and support four 57-foot x 42-foot tainter gates. The intake structure would be placed upstream on the left side with a bridge to connect the structure to the left bank access road. The intake structure would house the penstock entrances and their associated transition sections, in addition to containing the necessary elevator, machinery shaft, valve room, and other incorporated miscellaneous features. The diversion tunnels would be placed in the right bank of the Susitna River. The method used in cofferdamming, diverting, and unwatering for the estimated 3,000-foot tunnels would be as explained in the discussion of High Watana.

The powerplant would be underground with an estimated installed capacity of 420-MW. The location of the powerhouse chamber would be similar to that of High Watana's. The overall cost of the powerplant for Low Watana Dam were obtained from a method presented in Federal Power Commission (FPC) publication, 1968. Hydroelectric Power Evaluation using gross head and installed capacity of the proposed powerplant to obtain a cost-per-kilowatt value that was then equated to present Alaskan construction costs. This guide was applied to all projects in the study. It was checked against the Devil Canyon and High Watana powerplant costs that were estimated in detail using computed quantities. The comparison showed that the two values for each powerplant agreed within five percent, the FPC estimating method being fractionally higher for both Devil Canyon and High Watana. The switchyard and transmission system is similar for all three Watana projects.

A major portion of the lands within the low Watana reservoir area was withdrawn for powersite purposes; however, additional acres would be required (as per ER 405-2-150). Low Watana reservoir would have a surface area of 14,000 acres at normal full pool elevation of 1,905 feet. The normal minimum pool level would be at elevation 1,650, while the maximum elevation produced by the inflow design flood would be 1,910 feet. The pool would extend about 40 miles upstream to a point near the Vee damsite. The reservoir area, confined within the river canyon, would be relatively narrow, as shown on Plate B-3. The reservoir area would be cleared, as required by regulation. The access road is equivalent in scope and cost to that of High Watana, as are the buildings, grounds, and necessary utilities. A summary cost estimate for Low Watana is listed on Table B-7.

Mid-Watana dam consists of a 660-foot-high earthfill structure with upstream side slopes of 1 vertical and 2.5 horizontal, and downstream side slopes of 1 vertical and 2 horizontal. The dam would have an approximate crest length of 2,600 feet at elevation 2,060 feet, m.s.l. Mid-Watana would utilize the right bank saddle for its spillway location, as does High Watana. The ogee crest would be at elevation 2,005 feet, m.s.l., have a crest length of 210 feet, and support three 59-foot by 42-foot tainter gates. The overall dimensions would be similar to High Watana's spillway except that the approach channel would be longer as is the total length downstream of the crest. The intake structure location would be similar to the other Watana projects. The diversion would be by two 30-foot-diameter horseshoe tunnels, 3,800 feet in length, placed in the right bank of the Susitna River.

The Mid-Watana powerplant would be underground also, with an estimated installed capacity of just under 500-MW. Its location would be in a chamber on the left abutment centered approximately under the dam axis. The FPC cost estimating method, explained earlier, was applied to obtain overall powerplants costs.

A large portion of the lands within Mid-Watana reservoir are covered by the powersite withdrawal; however, additional acres would be required to meet acquisition regulations. Mid-Watana reservoir would have a surface area of 25,500 acres at normal full pool elevation of 2,050 feet. The normal minimum pool level would be at elevation 1,720, while the maximum elevation produced by the inflow design flood would be 2,055 feet. The pool would extend about 50 miles upstream to the confluence of the Oshetna River with the Susitna River. The reservoir area to be cleared, as per regulation, would be relatively narrow, as shown on Plate B-2. The access road, buildings, grounds, and necessary utilities are equivalent in all three Watana projects. A summary cost estimate for Mid-Watana Dam is given in Table B-7.

High Watana Dam (2250 feet) consists of an 860-foot-high earthfill structure that raises the dam to its topographic limit. This height was estimated for scoping purposes and it was found that while this

50 foot increase (from 2200-foot height) provided minimum power benefits it created large increases in construction costs. Dam embankment quantities increased significantly in the main dam alone. Also, the added 50 feet requires a major saddle dam and its associated seepage control measures in the are of the saddle spillway. Therefore, with large construction costs offsetting minor benefits gained this height Watana Dam (2250 feet) was no further considered.

ALTERNATIVE SYSTEMS STUDIED

PROJECTS USED IN SYSTEMS STUDIED

Three other projects that were considered in the alternative systems being studied were Vee, Denali, and High D.C. Dams. Summary cost estimates are included for Vee (at two heights), Denali, and High D.C. (Susitna I) Dams on Table B-7.

DIFFERENT SYSTEMS CONSIDERED

This section discusses total project costs for single-dam, two-dam, three-dam, and four-dam systems that were considered and later compared with their respective benefits in the power studies and economics section of this report.

Single-Dam Concept: The five dams considered as single projects are listed below, with their total project costs in millions of dollars.

Project (Normal Full Pool Elevation)	Cost
1. Devil Canyon (1450)	714.0
2. High D.C. (1750)	1,266.0
3. Low Watana (1905)	688.0
4. Mid-Watana (2050)	877.0
5. High Watana (2200)	1,088.0

Two-Dam Systems: The four combinations studied as two-dam systems are tabulated below, with their total system costs in millions of dollars.

System	Cost
1. Devil Canyon (1450)-Denali (2535)	1,054.0
2. Devil Canyon (1450)-Low Watana (1905)	1,100.0
3. Devil Canyon (1450)-Mid-Watana (2050)	1,309.0
4. Devil Canyon (1450)-High Watana (2200)	1,520.0

Three-Dam Systems: The five combinations used as three-dam systems are listed below, with their total system costs in millions of dollars.

System	Cost
1. Devil Canyon (1450)-Low Watana (1905)-Denali (2535)	1,440.0
2. Devil Canyon (1450)-Mid-Watana (2050)-Denali (2535)	1,649.0
3. Devil Canyon (1450)-High Watana (2200)-Denali (2535)	1,860.0
4. Devil Canyon (1450)-Low Watana (1905)-Vee (2300)	1,577.0
5. Devil Canyon (1450)-Low Watana (1905)-Vee (2350)	1,627.0

Four-Dam Systems: The three combinations studied as four-dam systems are tabulated below, with their respective total system costs in millions of dollars.

System	Cost
1. D.C. (1450)-Low Watana (1905)-Vee (2300)-Denali (2535)	1,917.0
2. D.C. (1450)-Low Watana (1905)-Vee (2350)-Denali (2535)	1,967.0
3. High D.C. (1750)-Olson (1020)-Vee (2300)-Denali (2535)	2,463.0

CONSTRUCTION SCHEDULE

CONSTRUCTION SEASON

The outdoor construction season at Devil Canyon and Watana damsites is about six months and could be extended by careful scheduling, planning, and the use of temporary, heated enclosures where construction situations would permit. Reservoir clearing operations would be conducted during the winter. Underground work would proceed on a year round basis.

PRECONSTRUCTION PLANNING FOR THE SELECTED PLAN

A period of about four years would be required for preconstruction planning for the selected plan. The work scheduled in this period includes an economic reanalysis, detailed environmental surveys, mapping, explorations and foundation investigations, a pioneer road to the Watana damsite, and acquisition of hydraulic data for the Devil Canyon and Watana projects.

CONSTRUCTION SCHEDULE FOR THE SELECTED PLAN

General: The construction period for the selected plan is 10 years, 6 years for Watana Dam and powerplant, and 5 years for Devil Canyon Dam and powerplant. Construction period for transmission facilities is 3 years. Over lapping construction will be required to complete the selected plan and to meet power-on-line schedules. The following paragraphs describe the sequence of construction for the selected plan's projects. A graphical schedule is shown on Graph B-3.

Access Roads: The completion of the access road to Highway No. 3 and the upgrading of the pioneer road to the Watana damsite is to be constructed during the first two plus years to allow heavy construction equipment into the project area. This road also provides access to the Devil Canyon damsite.

Diversion Plans: Construction of the diversion works for Watana is to start in the winter of the first year and the winter season of the fifth year for Devil Canyon Dam. The diversion works for each project is to be completed in two years.

Main Dams: Site clearing and foundation preparation starts in the third year with material placement scheduled from the fourth into the sixth year of construction for Watana Dam. The diversion tunnel is to be closed in June of the sixth year, and Watana reservoir filled to its normal full pool elevation by October to supply power-on-line the beginning of the seventh year.

Clearing and foundation preparation for Devil Canyon Dam is to start in the seventh year with material placement beginning in the eighth year and continuing into the tenth year of construction. The diversion tunnel is to be closed in June of the tenth year and Devil Canyon reservoir is to fill by October of the tenth year.

Powerhouses: Construction of underground powerhouses is concurrent with the main dams of both projects, and excavation and installation of mechanical and electrical equipment continues year round. Three generating units are to be installed in the Watana powerplant and four generating units in the Devil Canyon powerplant. Power-on-line (POL) for Watana is scheduled for 1986 and Devil Canyon POL is 1990.

COST ESTIMATES

The project costs are summarized in Tables B-1 through B-4 and in Table B-7 for eight individual major projects studied in this interim feasibility report. Table B-5 is the detailed cost estimate for Watana Dam, reservoir, and powerplant. Table B-6 is the detailed cost estimate for Devil Canyon Dam, reservoir, and powerplant. All estimates are based on January 1975 price levels. The contingency used for all projects studied was 20 percent. The costs for engineering and design and supervision and administration are consistent with the Chief of Engineers' (OCE) curves, published in EC 1110-2-144. The primary cost data were obtained from bid prices on recent major power projects in the Pacific northwest and adjusted to reflect current price levels, Alaska labor costs, and transportation costs for material and equipment to the sites. The estimates for transmission facilities were prepared by Alaska Power Administration (APA) and are discussed in Section H of this appendix.

The total estimated construction cost for the selected plan is $1,520,000,000.

SUMMARY COST ESTIMATE
JANUARY 1975 PRICE LEVEL

WATANA DAM AND RESERVOIR
2200 FEET NORMAL POOL ELEVATION
(FIRST-ADDED)

ACCOUNT NO.	ITEM		FEATURE COST ($1,000)
01	LANDS AND DAMAGES		16,392
03	RESERVOIR		9,180
04	DAMS		479,775
	Main Dam	194,172	
	Spillway	57,665	
	Outlet Works	44,544	
	Power Intake	123,298	
	Construction Facilities	60,096	
07	POWERPLANT		439,238
	Powerhouse	67,229	
	Turbines and Generators	50,649	
	Accessory Electrical and Powerplant Equipment	11,121	
	Tailrace	47,287	
	Switchyard	15,717	
	Transmission Facilities	219,600	
	Construction Facilities	27,635	
08	ROADS AND BRIDGES		48,875
14	RECREATIONAL FACILITIES		39
19	BUILDINGS, GROUNDS, AND UTILITIES		3,565
20	PERMANENT OPERATING EQUIPMENT		1,800
30	ENGINEERING AND DESIGN		39,638
31	SUPERVISION AND ADMINISTRATION		49,498
	TOTAL PROJECT COST		1,088,000

Table B-1

SUMMARY COST ESTIMATE
JANUARY 1975 PRICE LEVEL

DEVIL CANYON DAM AND RESERVOIR
1450 FEET NORMAL POOL ELEVATION
(SECOND-ADDED)

ACCOUNT NO.	ITEM		FEATURE COST ($1,000)
01	LANDS		1,444
03	RESERVOIRS		3,456
04	DAMS		219,543
	Main Dam	140,971	
	Spillway	19,792	
	Power Intakes	42,136	
	Auxiliary Dam	3,897	
	Construction Facilities	12,747	
07	POWERPLANT		147,977
	Powerhouse	42,702	
	Turbines and Generators	57,808	
	Accessory Electrical and Powerplant Equipment	10,475	
	Tailrace	13,921	
	Switchyard	19,518	
	Construction Facilities	3,553	
08	ROADS AND BRIDGES		8,528
14	RECREATIONAL FACILITIES		512
19	BUILDINGS, GROUNDS, AND UTILITIES		2,519
20	PERMANENT OPERATING EQUIPMENT		1,800
30	ENGINEERING AND DESIGN		26,962
31	SUPERVISION AND ADMINISTRATION		19,259
	TOTAL PROJECT COST		432,000

SUMMARY COST ESTIMATE
JANUARY 1975 PRICE LEVEL

WATANA DAM AND RESERVOIR
2200 FEET NORMAL POOL ELEVATION
(SECOND-ADDED)

ACCOUNT NO.	ITEM		FEATURE COST ($1,000)
01	LANDS AND DAMAGES		16,392
03	RESERVOIR		9,180
04	DAMS		479,775
	Main Dam	194,172	
	Spillway	57,665	
	Outlet Works	44,544	
	Power Intake	123,298	
	Construction Facilities	60,096	
07	POWERPLANT		232,305
	Powerhouse	67,229	
	Turbines and Generators	50,649	
	Accessory Electrical and Powerplant Equipment	11,121	
	Tailrace	47,287	
	Switchyard	15,717	
	Transmission Facilities	12,667	
	Construction Facilities	27,635	
08	ROADS AND BRIDGES		26,137
14	RECREATIONAL FACILITIES		39
19	BUILDINGS, GROUNDS, AND UTILITIES		3,565
20	PERMANENT OPERATING EQUIPMENT		1,800
30	ENGINEERING AND DESIGN		30,142
31	SUPERVISION AND ADMINISTRATION		37,665
	TOTAL PROJECT COST		837,000

SUMMARY COST ESTIMATE
JANUARY 1975 PRICE LEVEL

DEVIL CANYON DAM AND RESERVOIR
1450 FEET NORMAL POOL ELEVATION
(FIRST-ADDED)

ACCOUNT NO.	ITEM		FEATURE COST ($1,000)
01	LANDS		1,444
03	RESERVOIRS		3,456
04	DAMS		236,728
	Main Dam	140,971	
	Spillway	19,792	
	Power Intakes	42,136	
	Auxiliary Dam	3,897	
	Construction Facilities	29,932	
07	POWERPLANT		359,700
	Powerhouse	42,702	
	Turbines and Generators	57,808	
	Accessory Electrical and Powerplant Equipment	10,475	
	Tailrace	13,921	
	Switchyard	19,518	
	Transmission Facilities	206,933	
	Construction Facilities	8,343	
08	ROADS AND BRIDGES		31,266
14	RECREATIONAL FACILITIES		512
19	BUILDINGS, GROUNDS, AND UTILITIES		2,519
20	PERMANENT OPERATING EQUIPMENT		1,800
30	ENGINEERING AND DESIGN		44,648
31	SUPERVISION AND ADMINISTRATION		31,927
	TOTAL PROJECT COST		714,000

Table B-4

DETAILED COST ESTIMATE

WATANA DAM AND RESERVOIR ELEVATION 2200

JANUARY 1975 PRICE LEVEL

(FIRST-ADDED)

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
01	LANDS AND DAMAGES				
	Reservoir				
	Public domain	AC	18,600	323.00	(6,008)
	Private land	AC	30,000	317.00	9,510
	Site and other	AC	1,080	500.00	540
	Access road	AC	780	615.00	480
	Transmission facilities				
	Public domain	AC	4,400	300.00	(1,320)
	Private land	AC	3,795	620.00	2,352
	Recreation	AC	90	500.00	45
	Subtotal				20,255
	Contingencies 20%				4,051
	Government administrative costs				880
	TOTAL LANDS AND DAMAGES				(25,186)
	Construction cost				16,392
	Economic cost				(8,794)
03	RESERVOIR				
	Clearing	AC	5,100	1,500.00	7,650
	Contingencies 20%				1,530
	TOTAL, RESERVOIR				9,180
04	DAMS				
04.1	MAIN DAM				
	Mobilization and preparatory work	LS			23,000
	Clearing	AC	860	1,500.00	1,290
	Foundation preparation	SY	105,000	10.00	1,050
	Excavation				
	Foundation	CY	1,800,000	3.50	6,300
	Borrow and quarry areas	LS			3,000
	Embankment				
	Gravel fill	CY	39,200,000	1.65	64,680
	Sand filter	CY	1,100,000	8.00	8,800
	Second filter	CY	1,000,000	4.00	4,000
	Impervious core	CY	9,250,000	3.75	34,688
	Riprap	CY	280,000	10.00	2,800
	Select drain	CY	1,800,000	4.00	7,200

TABLE B-5 --DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.1	MAIN DAM (Cont'd)				
	Drilling and grouting	LF	145,000	18.75	2,719
	Drainage system	LS			283
	Right abutment seepage control	LS			2,000
	Subtotal				161,810
	Contingencies 20%				32,362
	TOTAL, MAIN DAM				194,172
04.2	SPILLWAY				
	Clearing and stripping	AC	150	1,500.00	225
	Foundation preparation	CY	8,500	16.00	136
	Excavation	CY	10,530,000	3.00	31,590
	Concrete				
	Mass	CY	97,000	50.00	4,850
	Structural	CY	15,100	325.00	4,908
	Cement	Cwt	240,000	4.00	960
	Reinforcing steel	Lbs	1,510,000	.60	906
	Anchor bars	Lbs	37,000	1.25	46
	Drilling and grouting	LF	6,200	21.50	133
	Drainage system	LS			250
	Tainter gates (3), complete	LS			3,250
	Stoplogs (1 set)	LS			300
	Electrical and mechanical work	LS			500
	Subtotal				48,054
	Contingencies 20%				9,611
	TOTAL, SPILLWAY				57,665
04.3	OUTLET WORKS				
	Intake structure				
	Excavation rock	CY	41,000	15.00	615
	Foundation preparation	SY	8,000	10.00	80
	Concrete				
	Mass	CY	20,400	50.00	1,020
	Structural	CY	18,500	325.00	6,013
	Cement	Cwt	82,000	4.00	328
	Reinforcing steel	Lbs	3,055,000	.60	1,833

TABLE B-5 -DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.3	OUTLET WORKS (Cont'd)				
	Electrical and mechanical work	LS			100
	Gate bonnets	EA	4	133,000.00	532
	Gate frames	EA	4	130,000.00	520
	Gates (slide)	EA	4	285,000.00	1,140
	Trash racks	EA	4	96,000.00	384
	Tainter gates	EA	4	395,000.00	1,580
	Excavation				
	Tunnels	CY	95,300	125.00	11,913
	Concrete	CY	21,700	300.00	6,510
	Cement	Cwt	100,000	4.00	400
	Reinforcing steel	Lbs	4,790,000	.60	2,874
	Elevator	LS	1		200
	Stairs	LS	1		100
	Steel sets & lagging	Lbs	349,000	1.00	349
	Rock bolts	EA	3,700	170.00	629
	Subtotal				37,120
	Contingencies 20%				7,424
	TOTAL, OUTLET WORKS				44,544
04.4	POWER INTAKE WORKS				
	Intake structure				
	Excavation	CY	222,000	15.00	3,330
	Foundation preparation	SY	3,700	10.00	37
	Mass concrete	CY	39,500	50.00	1,975
	Structural concrete	CY	69,200	325.00	22,490
	Cement	Cwt	376,000	4.00	1,504
	Resteel	Lbs	4,839,000	.60	2,904
	Emb. metal	Lbs	35,000	3.00	105
	Trash rack	LS	1		2,000
	Stairs	LS	1		75
	Elevator	LS	1		200
	Bulkhead gates	LS	1		1,500
	Stoplogs	LS	1		1,500
	Electrical and mechanical work	LS	1		1,600
	Truck crane	LS	1		225
	Bridge	LS	1		2,500
	Trash boom	LS	1		300
	Tunnel excavation	CY	79,000	125.00	9,875

TABLE B-5 --DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.4	POWER INTAKE WORKS (Cont'd)				
	Concrete	CY	16,650	300.00	4,995
	Cement	Cwt	84,000	4.00	336
	Resteel	Lbs	3,745,000	.60	2,247
	Steel liner	Lbs	21,000,000	2.00	42,000
	Bonnetted gates	LS			900
	Electrical and mechanical work	LS			150
	Subtotal				102,748
	Contingencies 20%				20,550
	TOTAL POWER INTAKE WORKS				123,298
	TOTAL DAMS				419,679
07	POWERPLANT				
07.1	POWERHOUSE				
	Mobilization and preparatory work	LS	1		3,500
	Excavation, rock	CY	202,000	110.00	22,220
	Concrete	CY	57,600	325.00	18,720
	Cement	Cwt	261,000	4.00	1,044
	Reinforcing steel	Lbs	5,228,000	.60	3,137
	Architectural features	LS			1,000
	Elevator	LS			200
	Mechanical and electrical work	LS			3,300
	Structural steel	Lbs	1,250,000	1.50	1,875
	Miscellaneous metalwork	Lbs	150,000	3.00	450
	Draft tube bulkhead gates	LS			380
	Rock bolts	EA	563	170.00	96
	Steel sets	Lbs	102,000	1.00	102
	Subtotal				56,024
	Contingencies 20%				11,205
	TOTAL, POWERHOUSE				67,229

TABLE B-5 --DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT (Cont'd)				
07.2	TURBINES AND GENERATORS				
	Turbines	LS			20,608
	Governors	LS			765
	Generators	LS			20,834
	Subtotal				42,207
	Contingencies 20%				8,442
	TOTAL, TURBINES AND GENERATORS				50,649
07.3	ACCESSORY ELECTRICAL EQUIPMENT				
	Accessory Electrical Equipment	LS			4,065
	Contingencies 20%				813
	TOTAL, ACCESSORY ELECTRICAL EQUIPMENT				4,878
07.4	MISCELLANEOUS POWERPLANT EQUIPMENT				
	Miscellaneous Powerplant Equipment	LS			5,202
	Contingencies				1,041
	TOTAL, MISCELLANEOUS POWERPLANT EQUIPMENT				6,243
07.5	TAILRACE				
	Excavation, tailrace tunnel	CY	223,000	125.00	27,875
	Concrete, tailrace tunnel lining	CY	21,000	300.00	6,300
	Cement	Cwt	104,000	4.00	416
	Reinforcing steel	Lbs	5,202,000	.60	3,122
	Rock bolts	EA	3,400	170.00	578
	Steel sets	Lbs	1,115,000	1.00	1,115
	Subtotal				39,406
	Contingencies 20%				7,181
	TOTAL, TAILRACE				47,287
07.6	SWITCHYARD				
	Transformers	LS			5,826
	Insulated cables	LS			1,030

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT				
07.6	SWITCHYARD (Cont'd)				
	Switchyard	LS			6,241
	Subtotal				13,097
	Contingencies 20%				2,620
	TOTAL, SWITCHYARD				15,717
07.8	TRANSMISSION FACILITIES				
	Transmission Facilities	LS			183,000
	Contingencies 20%				36,600
	TOTAL, TRANSMISSION FACILITIES				219,600
	TOTAL, POWERPLANT				411,603
08	ROADS AND BRIDGES				
	Permanent Access Road - 27 miles (Highway No. 3 to Devil Canyon)				
	Clearing	AC	135	1,500.00	203
	Excavation	CY	210,000	6.20	1,302
	Embankment	CY	885,000	2.00	1,770
	Riprap	CY	2,700	30.00	81
	Road surfacing (crushed)	CY	216,000	12.00	2,592
	Bridges	LS	1		10,000
	Culverts and guardrail	LS	1		3,000
	Permanent Access Road - 37 miles (Devil Canyon to Watana)				
	Clearing	AC	195	1,500.00	293
	Excavation	CY	360,000	6.20	2,232
	Embankment	CY	1,244,000	2.00	2,488
	Riprap	CY	3,800	30.00	114
	Road surfacing (crushed)	CY	304,000	12.00	3,648
	Bridges	LS			3,700
	Culverts and guardrail	LS	1		1,585
	Permanent on-site roads				
	Power plant access tunnel	LS	1		5,096
	Power plant access road	LS	1		1,515
	Dam crest road	LS	1		80

TABLE B-5 --DETAILED COST ESTIMATE--Continued

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
08	ROADS AND BRIDGES (Cont'd)				
	Spillway access road	LS	1		380
	Switch yard access road	LS	1		200
	Road to operating facility	LS	1		200
	Power intake structure access road	LS	1		250
	Subtotal				40,729
	Contingencies 20%				8,146
	TOTAL, ROADS AND BRIDGES				48,875
14	RECREATION FACILITIES				
	Site D				
	Camp units (tent camp)	EA	10	1,800.00	18
	Vault toilets	EA	2	2,000.00	4
	Subtotal				22
	Contingencies 15%				3
	Total Site D				25
	Site E				
	Trail system	MI	12	1,000.00	12
	Contingencies 15%				2
	Total Site E				14
	TOTAL, RECREATION FACILITIES				39
19	BUILDINGS, GROUNDS, AND UTILITIES				
	Living quarters and O&M facilities	LS			1,631
	Visitor facilities				
	Visitor building	LS			100
	Parking area	SF	12,000	3.00	36
	Boat ramp	LS			200
	Vault toilets	EA	2	2,000.00	4
	Runway facility	LS	1		1,000
	Subtotal				2,971
	Contingencies 20%				594
	TOTAL, BUILDINGS, GROUNDS, AND UTILITIES				3,565

WATANA DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
20	PERMANENT OPERATING EQUIPMENT				
	Operating Equipment and Facilities	LS	1		1,500
	Contingencies 20%				300
	TOTAL, PERMANENT OPERATING EQUIPMENT				1,800
50	CONSTRUCTION FACILITIES				
	Diversion tunnels				
	Excavation	CY	281,000	115.00	32,315
	Concrete	CY	48,750	275.00	13,407
	Cement	Cwt	244,000	4.00	976
	Resteel	Lbs	11,544,000	.60	6,927
	Steel sets and lagging	Lbs	1,404,000	1.00	1,404
	Rock bolts	EA	7,800	170.00	1,326
	Diversion outlet works				
	Excavation	CY	14,000	15.00	210
	Concrete	CY	7,500	325.00	2,438
	Cement	Cwt	30,000	4.00	120
	Resteel	Lbs	1,500,000	.60	900
	Anchors	LS	1		500
	Diversion inlet works				
	Excavation	CY	43,000	15.00	645
	Concrete	CY	16,500	325.00	5,363
	Cement	Cwt	58,000	4.00	232
	Resteel	Lbs	2,475,000	.60	1,485
	Gate frames and gates	LS	1		861
	Diversion tunnel plug	LS	1		3,000
	Care of water	LS	1		1,000
	Subtotal				73,109
	Contingencies 20%				14,622
	TOTAL, CONSTRUCTION FACILITIES				87,731
	TOTAL CONSTRUCTION COST				998,864
30	ENGINEERING AND DESIGN				39,638
31	SUPERVISION AND ADMINISTRATION				49,498
	TOTAL PROJECT COST WATANA DAM AND RESERVOIR ELEVATION 2200 (First-Added)				1,088,000

DETAILED COST ESTIMATE

DEVIL CANYON DAM AND RESERVOIR, ELEVATION 1450

JANUARY 1975 PRICE LEVEL

(SECOND-ADDED)

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
01	LANDS AND DAMAGES				
	Reservoir				
	Public domain	AC	8,350	300.00	(2,505)
	Private land	AC	850	300.00	255
	Site and other	AC	250	600.00	150
	Recreation	AC	740	600.00	440
	Subtotal				3,350
	Contingencies 20%				670
	Government administrative cost				430
	TOTAL, LANDS AND DAMAGES				(4,450)
	Construction cost				1,444
	Economic cost				(3,006)
03	RESERVOIR				
	Clearing	AC	1,920	1,500.00	2,880
	Contingencies 20%				576
	TOTAL, RESERVOIR				3,456
04	DAMS				
04.1	MAIN DAM				
	Mobilization and preparatory work	LS			24,300
	Prevention of water pollution	LS			500
	Scaling of canyon walls	CY	21,000	75.00	1,575
	Excavation				
	Exploratory tunnels	CY	3,500	190.00	665
	Dam	CY	327,000	15.00	4,905
	Foundation treatment	CY	3,000	60.00	180
	Drilling line holes for rock excavation	LF	34,000	4.60	156
	Drilling and grouting	LF	64,000	22.00	1,408
	Drainage holes	LF	29,570	15.30	452
	Concrete				
	Dam	CY	994,000	50.00	49,700
	Thrust block	CY	25,600	60.00	1,536
	Foundation treatment	CY	3,000	125.00	375

TABLE B-6 --DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.1	MAIN DAM (Cont'd)				
	Foundation, mass	CY	15,250	50.00	763
	Structural	CY	10,240	325.00	3,328
	Cooling concrete	LS			2,000
	Contraction joint and cooling system grouting	LS			1,135
	Cement	Cwt	3,779,000	4.00	15,116
	Pozzolan	Cwt	922,000	3.00	2,766
	Reinforcing steel	Lbs	1,200,000	.60	720
	Gates				
	Slide gates, frames, guides, and operators	EA	4	345,000.00	1,380
	Miscellaneous				
	High strength steel strands	Lbs	290,000	2.00	580
	Earthquake anchorages	LS			500
	Gantry crane	LS			385
	Gantry crane rails	Lbs	39,000	1.00	39
	Elevators	LS			280
	Stairways	Lbs	105,500	5.20	549
	Instrumentation	LS			115
	Rock bolts	LF	50,000	10.70	535
	Chain-link fence	LF	1,535	15.00	23
	Electrical and mechanical work	LS			1,000
	Miscellaneous metalwork	LS	170,000	3.00	510
	Subtotal				117,476
	Contingencies 20%				23,495
	TOTAL, MAIN DAM				140,971
04.2	SPILLWAY				
	Excavation, all classes	CY	239,000	15.00	3,585
	Foundation preparation	SY	7,520	10.00	75
	Drilling and grouting	LF	8,000	25.00	200
	Anchor bars	LF	48,000	1.25	60
	Drainage system	LS	1		500
	Concrete				
	Mass	CY	37,000	50.00	1,850
	Structural	CY	12,000	325.00	3,900
	Cement	Cwt	152,000	4.00	608

TABLE B-6 --DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.2	SPILLWAY (Cont'd)				
	Reinforcing steel	Lbs	1,191,000	.60	715
	Tainter gates and hoists, complete	EA	2	2,000,000.00	4,000
	Stoplogs, complete	Set	1		500
	Miscellaneous Electrical and mechanical work	LS			500
	Subtotal				16,493
	Contingencies 20%				3,299
	TOTAL, SPILLWAY				19,792
04.4	POWER INTAKE WORKS				
	Excavation				
	Open cut	CY	7,200	15.00	108
	Tunnels	CY	34,400	125.00	4,300
	Concrete				
	Mass	CY	7,300	55.00	402
	Structural and backfill	CY	10,430	325.00	3,390
	Cement	Cwt	74,000	4.00	296
	Reinforcing steel	Lbs	1,070,000	.60	642
	Penstocks	Lbs	8,175,000	2.00	16,350
	Bonnetted gates and controls	EA	5	1,375,000.00	6,875
	Stoplogs, complete	LS			914
	Trashracks	Lbs	1,224,000	1.50	1,836
	Subtotal				35,113
	Contingencies 20%				7,023
	TOTAL, POWER INTAKE WORKS				42,136
04.5	AUXILIARY DAM (EARTH FILL)				
	Excavation				
	Dam foundation	CY	110,000	3.50	385
	Foundation preparation	LS	1		40
	Dam embankment	CY	760,000	2.25	1,710
	Drilling and grouting	LF	8,800	46.60	410
	Concrete	CY	5,400	120.00	648

TABLE B-6 --DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
04	DAMS				
04.5	AUXILIARY DAM (EARTH FILL) Cont'd)				
	Cement	Cwt	13,500	4.00	54
	Subtotal				3,247
	Contingencies 20%				650
	TOTAL, AUXILIARY DAM				3,897
	TOTAL, DAMS				206,796
07	POWERPLANT				
07.1	POWERHOUSE				
	Mobilization and preparatory work	LS	1		5,000
	Excavation, rock	CY	120,000	110.00	13,200
	Concrete	CY	20,000	325.00	6,500
	Cement	Cwt	100,000	4.00	400
	Reinforcing steel	Lbs	4,600,000	.60	2,760
	Architectural features	LS			1,000
	Elevator	LS			75
	Mechanical and electrical work	LS			4,400
	Structural steel	Lbs	1,200,000	1.50	1,800
	Miscellaneous metalwork	Lbs	150,000	3.00	450
	Subtotal				35,585
	Contingencies 20%				7,117
	TOTAL, POWERHOUSE				42,702
07.2	TURBINES AND GENERATORS				
	Turbines	LS			22,575
	Governors	LS			2,546
	Generators	LS			23,052
	Subtotal				48,173
	Contingencies 20%				9,635
	TOTAL, TURBINES AND GENERATORS				57,808

TABLE B-6 --DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
07	POWERPLANT				
07.3	ACCESSORY ELECTRICAL EQUIPMENT				
	Accessory Electrical Equipment	LS			6,600
	Contingencies 20%				1,320
	TOTAL, ACCESSORY ELECTRICAL EQUIPMENT				7,920
07.4	MISCELLANEOUS POWERPLANT EQUIPMENT				
	Miscellaneous Powerplant Equipment	LS			2,129
	Contingencies 20%				426
	TOTAL, MISCELLANEOUS POWERPALNT EQUIPMENT				2,555
07.5	TAILRACE				
	Excavation tunnel	CY	37,000	125.00	4,625
	Concrete	CY	13,800	300.00	4,140
	Cement	Cwt	69,000	4.00	276
	Resteel	Lbs	3,163,000	.60	1,898
	Draft tube bulkhead gates	LS	1		378
	Draft tube stoplogs	LS	1		284
	Subtotal				11,601
	Contingencies 20%				2,320
	TOTAL, TAILRACE				13,921
07.6	SWITCHYARD				
	Transformers	LS			5,967
	Insulated cables	LS			1,372
	Switchyard	LS			8,926
	Subtotal				16,265
	Contingencies 20%				3,253
	TOTAL, SWITCHYARD				19,518
	TOTAL, POWERPLANT				144,424
08	ROADS AND BRIDGES				
	On-site road				
	Clearing and earthwork	Mile	2.3	200,000.00	460
	Paving	Mile	2.3	72,000.00	166

TABLE B-6 --DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
08	ROADS AND BRIDGES (Cont'd)				
	Culverts	LF	850	39.00	33
	Tunnel	LF	2,100	2,975.00	6,248
	Road to operating facility	Mile	2	100,000.00	200
	Subtotal				7,107
	Contingencies 20%				1,421
	TOTAL, ROADS AND BRIDGES				8,528
14	RECREATION FACILITIES				
	Site A				
	(Boat access only)				
	Boat dock	EA	1	25,000.00	25
	Camping units	EA	10	1,800.00	18
	Two-vault toilets	EA	2	2,000.00	4
	Subtotal				47
	Contingencies 15%				7
	Total Site A				54
	Site B				
	Access road	Mile	0.5	100,000.00	50
	Overnight camps	EA	50	2,500.00	125
	Comfort stations	EA	2	35,000.00	70
	Power	LS		25,000.00	25
	Sewerage	LS		50,000.00	50
	Subtotal				320
	Contingencies 15%				48
	Total Site B				368
	Site C				
	Trailhead picnic area access road	Mile	0.2	100,000.00	20
	Picnic units w/parking	EA	12	2,000.00	24
	Trail system	Mile	30	1,000.00	30
	Two-vault toilets	EA	2	2,000.00	4
	Subtotal				78
	Contingencies 15%				12
	Total Site C				90
	TOTAL, RECREATION FACILITIES				512

TABLE B-6 --DETAILED COST ESTIMATE--Continued

DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
19	BUILDINGS, GROUNDS, AND UTILITIES				
	Living quarters and O&M facilities	LS			1,700
	Visitor facilities				
	Visitor building	LS			200
	Parking area	SF	15,000	3.00	45
	Boat ramp	LS			150
	Vault toilets	EA	2	2,000.00	4
	Subtotal				2,099
	Contingencies 20%				420
	TOTAL, BUILDINGS, GROUNDS, AND UTILITIES				2,519
20	PERMANENT OPERATING EQUIPMENT				
	Operating Equipment and Facilities	LS	1		1,500
	Contingencies 20%				300
	TOTAL, PERMANENT OPERATING EQUIPMENT				1,800
50	CONSTRUCTION FACILITIES				
	Coffer dams				
	Sheet pile	Ton	1,024	1,000.00	1,024
	Earthfill	CY	38,000	5.00	190
	Diversion works				
	Tunnel				
	Excavation	CY	32,000	115.00	3,680
	Concrete	CY	5,750	275.00	1,582
	Cement	Cwt	29,000	4.00	116
	Resteel	Lbs	1,323,000	.60	794
	Steel sets	Lbs	157,000	1.25	197
	Rock bolts	EA	1,150	170.00	196
	Diversion intake structure				
	Rock excavation	CY	6,800	15.00	102
	Structural concrete	CY	3,800	325.00	1,235
	Cement	Cwt	150,000	4.00	60
	Resteel	Lbs	750,000	.60	450
	Gates and frames	LS	1		860
	Diversion outlet structure				
	Rock excavation	CY	6,800	15.00	102
	Concrete	CY	3,800	325.00	1,235
	Cement	Cwt	15,000	4.00	60

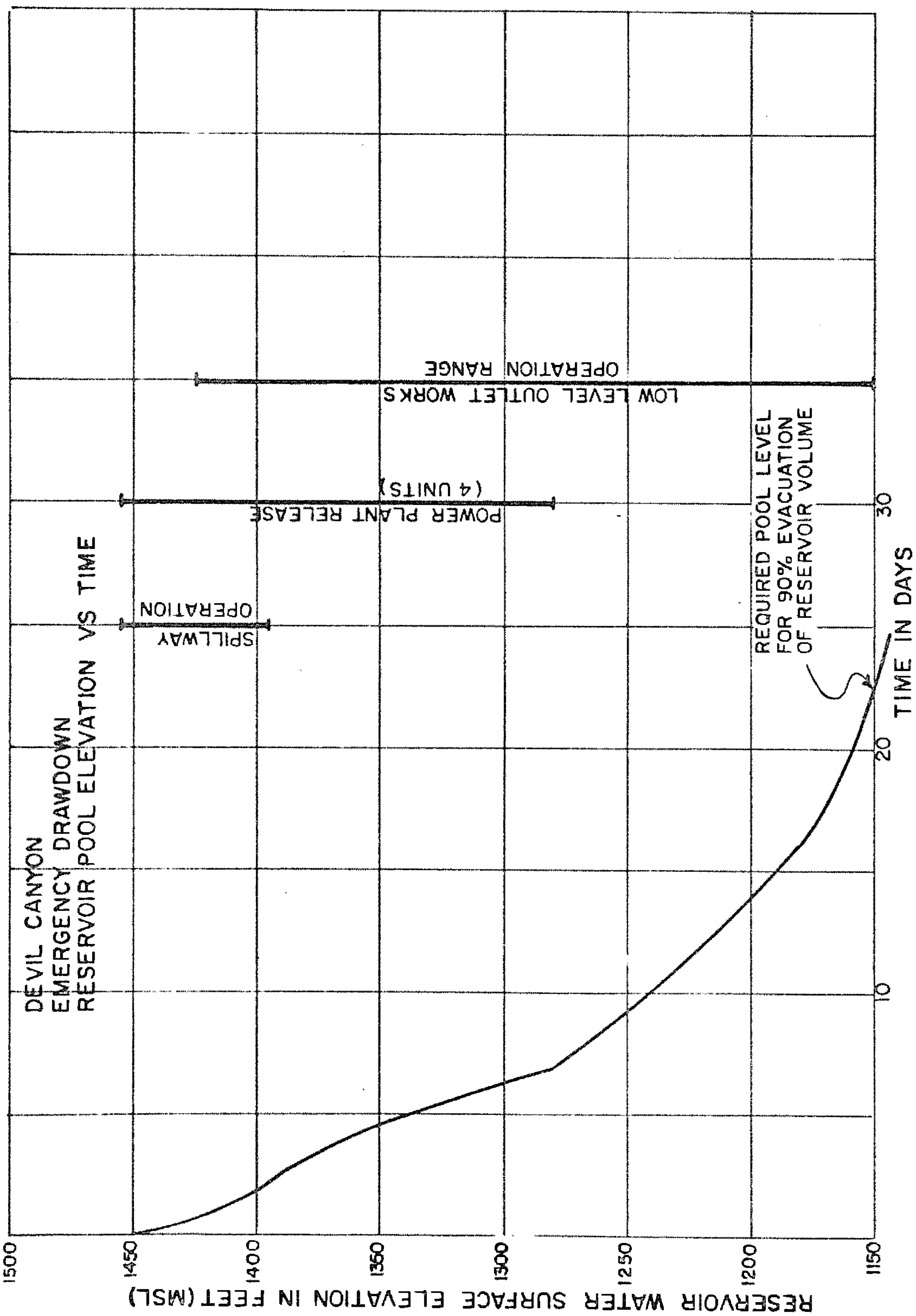
TABLE B-6 --DETAILED COST ESTIMATE--Continued

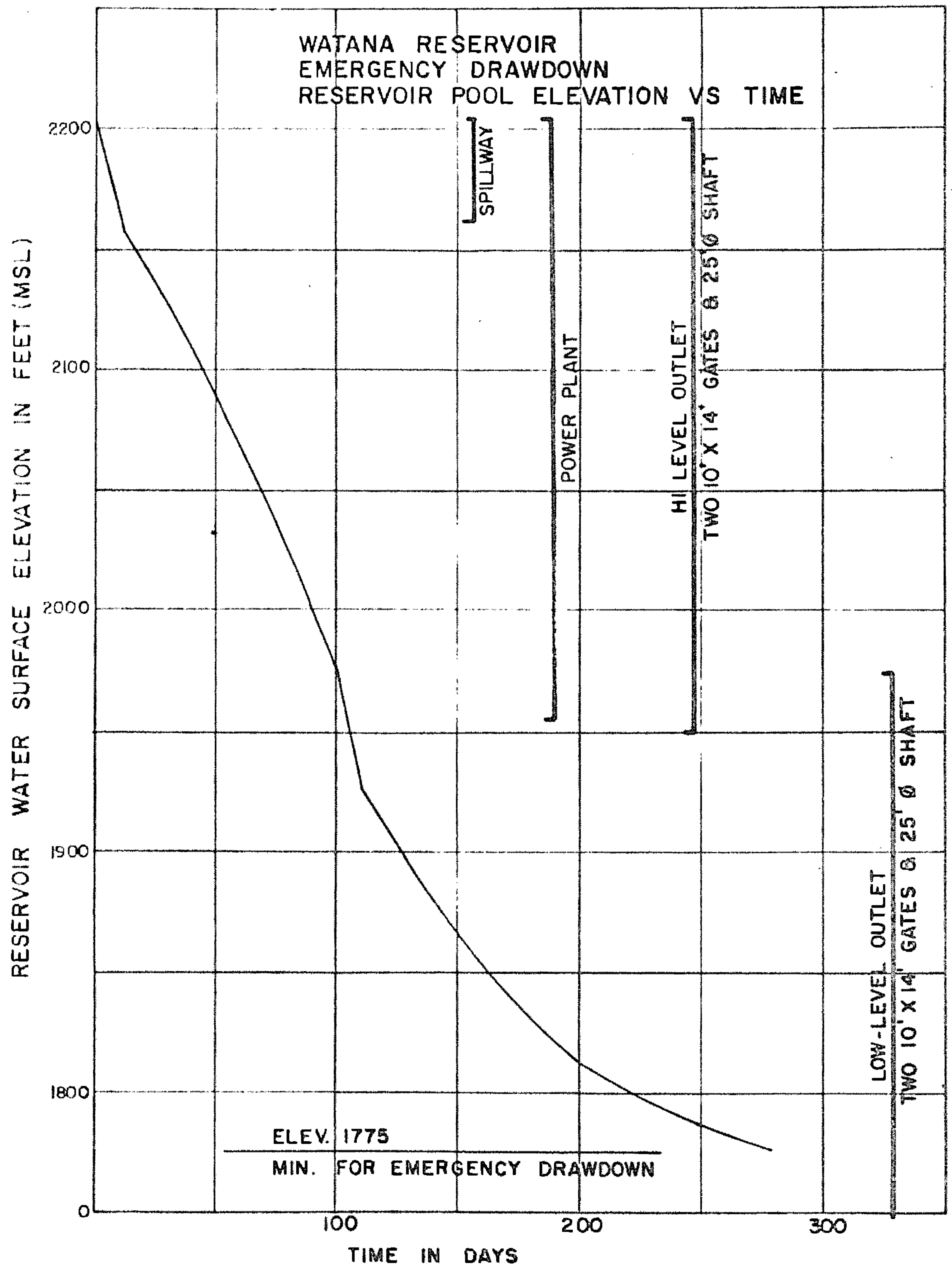
DEVIL CANYON DAM AND RESERVOIR

Cost Account Number	Description or Item	Unit	Quant	Unit Cost ($)	Total Cost ($1,000)
50	CONSTRUCTION FACILITIES (Cont'd)				
	Resteel	Lbs	750,000	.60	450
	Anchors	LS	1		250
	Care of water	LS	1		1,000
	Subtotal				13,583
	Contingencies 20%				2,717
	TOTAL, CONSTRUCTION FACILITIES				16,300
	TOTAL, CONSTRUCTION COST				385,779
30	ENGINEERING AND DESIGN				26,962
31	SUPERVISION AND ADMINISTRATION				19,259
	TOTAL PROJECT COST DEVIL CANYON DAM AND RESERVOIR ELEVATION 1450 (SECOND-ADDED)				432,000

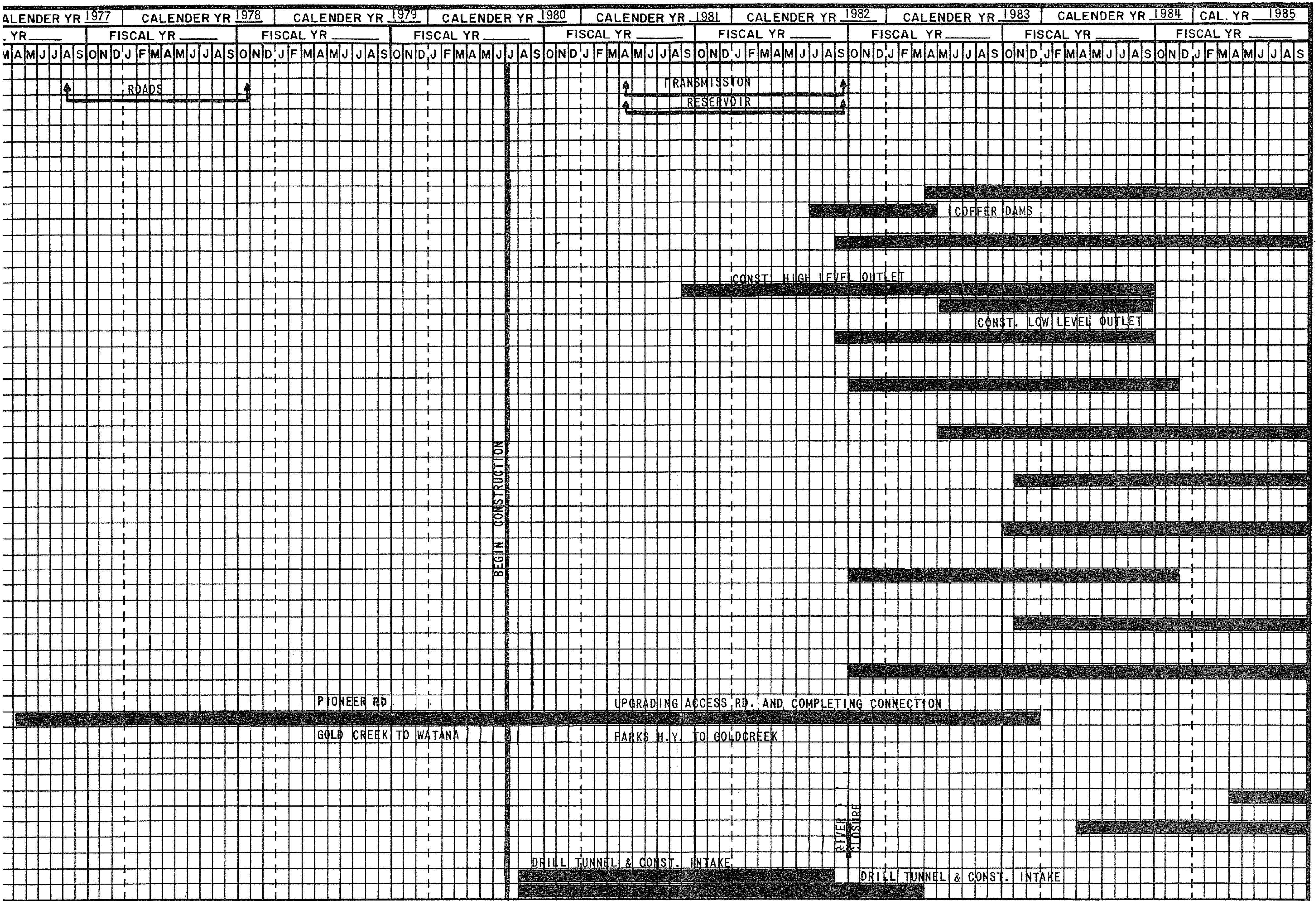
SUMMARY COST ESTIMATES--OTHER PROJECTS STUDIED
JANUARY 1975 PRICE LEVEL
(Costs in $1,000)

	PROJECT FULL POOL ELEV. (Ft., m.s.l.) CONST. SEQUENCE (Added)	DENALI 2535 (Second)	VEE 2300 (Second)	VEE 2350 (Second)	HIGH D.C. 1750 (First)	WATANA 1905 (First)	WATANA 1905 (Second)	WATANA 2050 (First)	WATANA 2050 (Second)
ACCOUNT NO.	PROJECT FEATURE								
01	LANDS AND DAMAGES	7,000	2,550	3,495	8,400	4,381	4,381	12,050	12,050
02	RELOCATIONS	13,000							
03	RESERVOIR	4,800	3,165	5,160	7,650	5,100	5,100	7,920	7,920
04	DAM	237,017	203,170	225,500	574,900	165,058	165,058	287,229	287,229
07	POWERPLANT		143,788	159,600	450,478	313,076	106,143	360,721	153,788
08	ROADS AND BRIDGES	1,500	19,968	20,748	34,511	47,587	24,849	48,231	25,493
14	RECREATIONAL FACILITIES	39	39	39	512	39	39	39	39
19	BUILDINGS, GROUNDS, AND UTILITIES	3,565	3,565	3,565	3,565	3,565	3,565	3,565	3,565
20	PERMANENT OPERATING EQUIPMENT	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
30-31	ENGINEERING AND DESIGN - SUPERVISION AND ADMINISTRATION	36,279	48,855	53,093	104,184	62,638	44,309	79,419	60,090
50	CONSTRUCTION FACILITIES	35,000	50,100	54,000	80,000	64,756	64,756	76,026	76,026
	TOTAL PROJECT COST	340,000	477,000	527,000	1,266,000	668,000	420,000	877,000	628,000


DEVIL CANYON
EMERGENCY DRAWDOWN
RESERVOIR POOL ELEVATION VS TIME
SPILLWAY
OPERATION
POWER PLANT RELEASE
(4 UNITS)
LOW LEVEL OUTLET WORKS
OPERATION RANGE
REQUIRED POOL LEVEL
FOR 90% EVACUATION
OF RESERVOIR VOLUME
TIME IN DAYS
10
20
30
1500
1450
1400
1350
1300
1250
1200
1150
RESERVOIR WATER SURFACE ELEVATION IN FEET (MSL)



Graph B-2
Appendix I
B-42



'E ACQUISITION

1 PROJECT

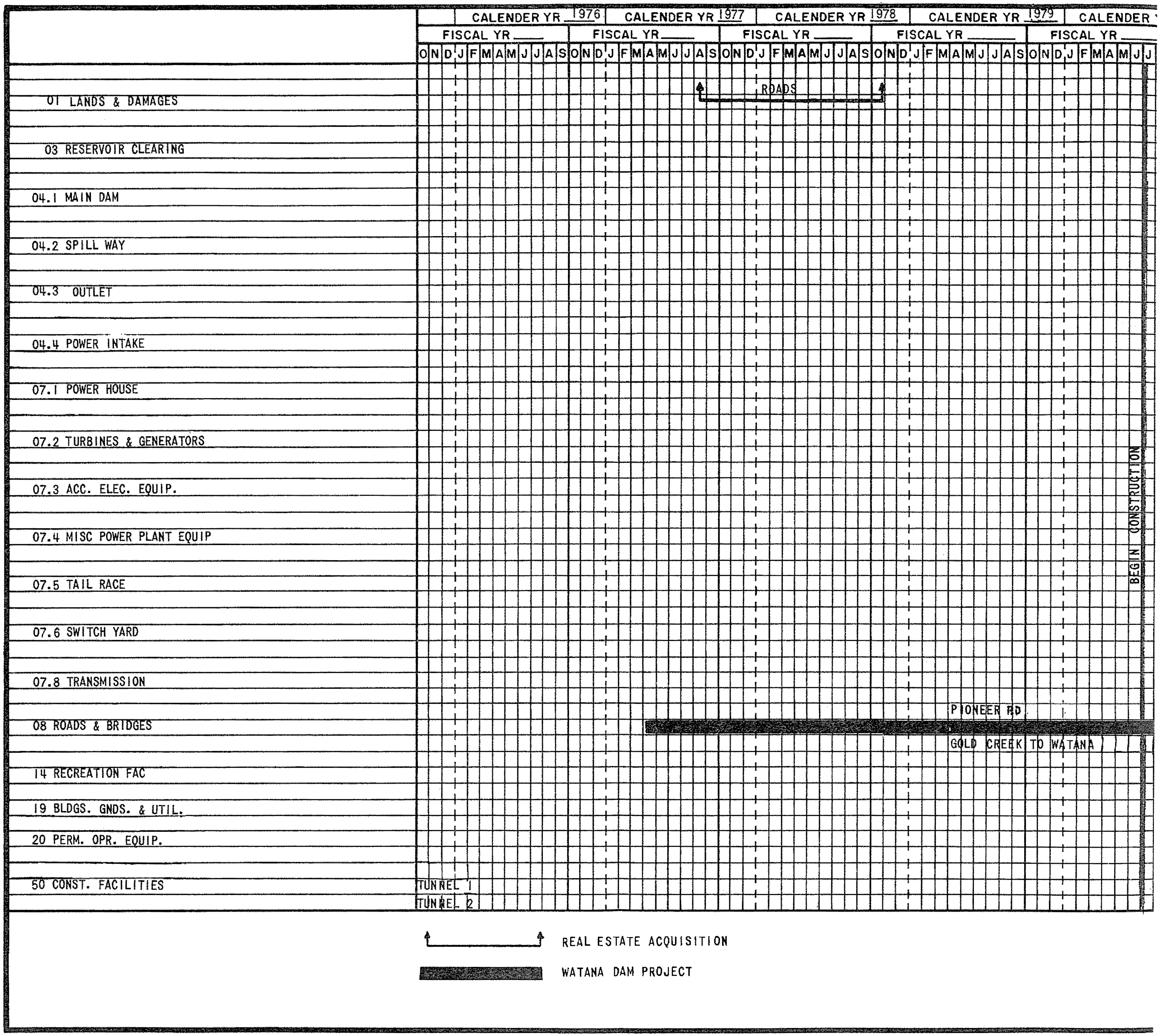
Appendix I
Graph B-3

DESIGN & CONSTRUCTION SCHEDULE

Sheet 1 of 2

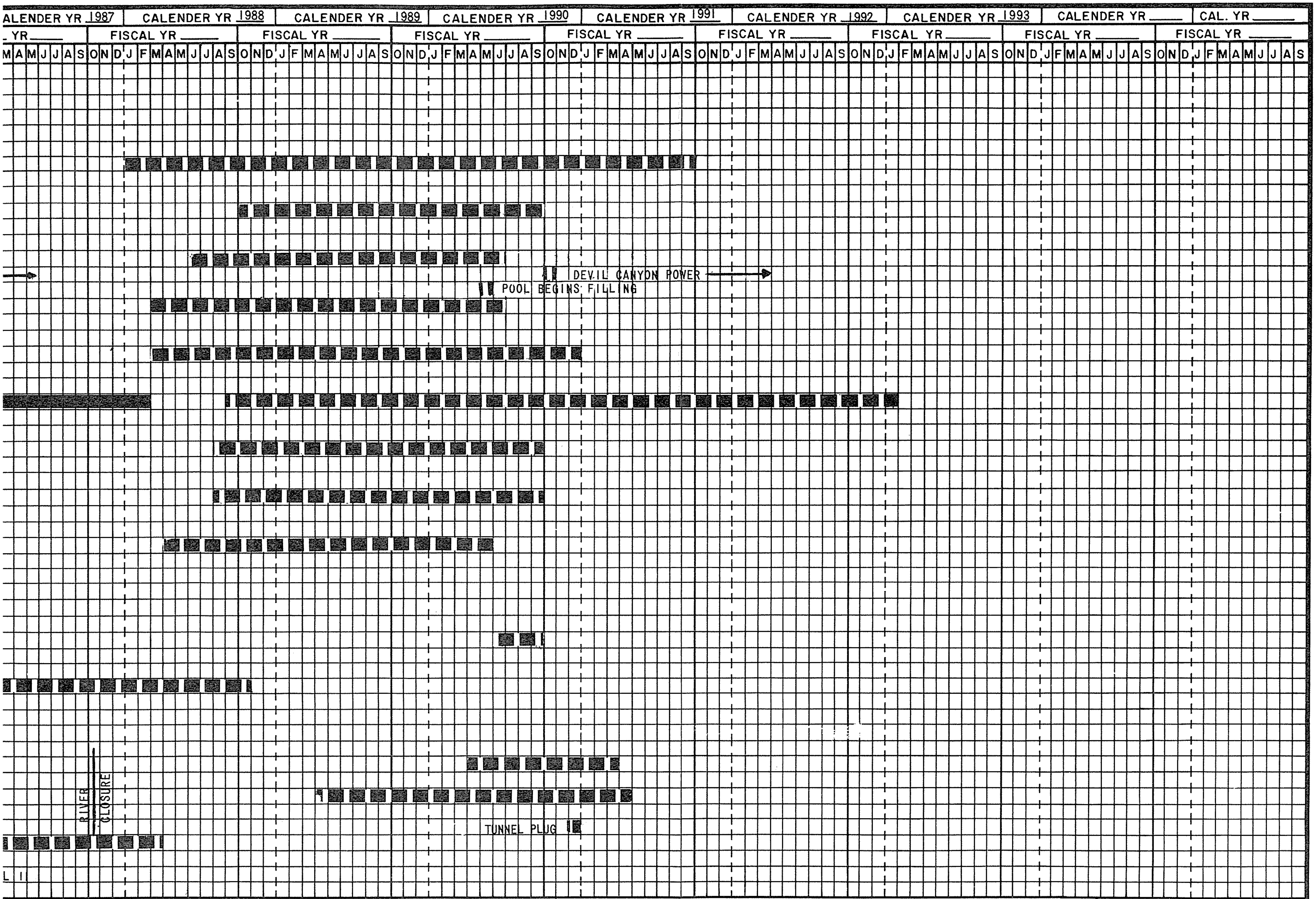
1539-76

CORPS OF ENGINEERS



NPA FORM 104
APR 75

U.S. ARMY



OJECT

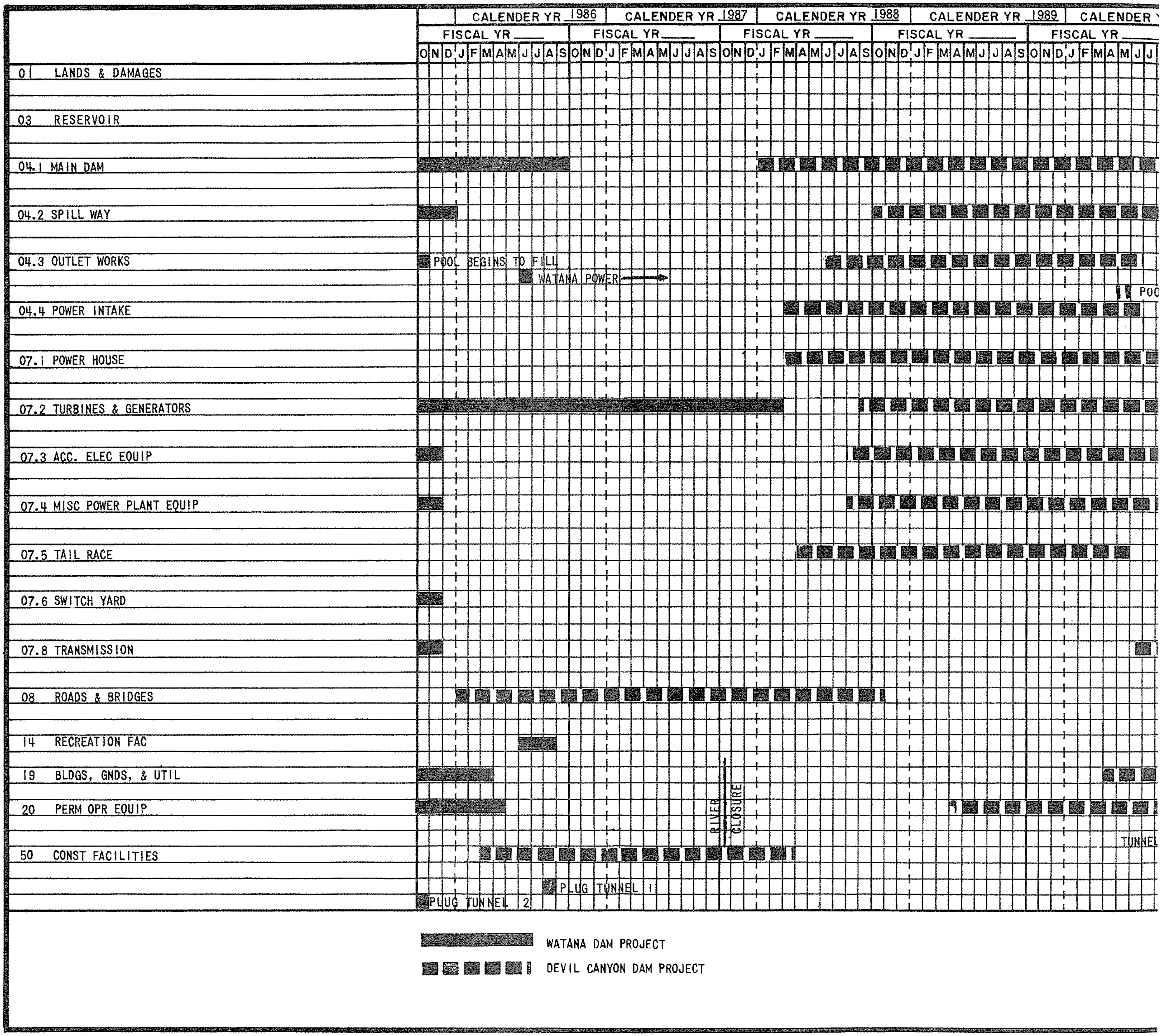
DAM PROJECT

Appendix I
Graph B-3

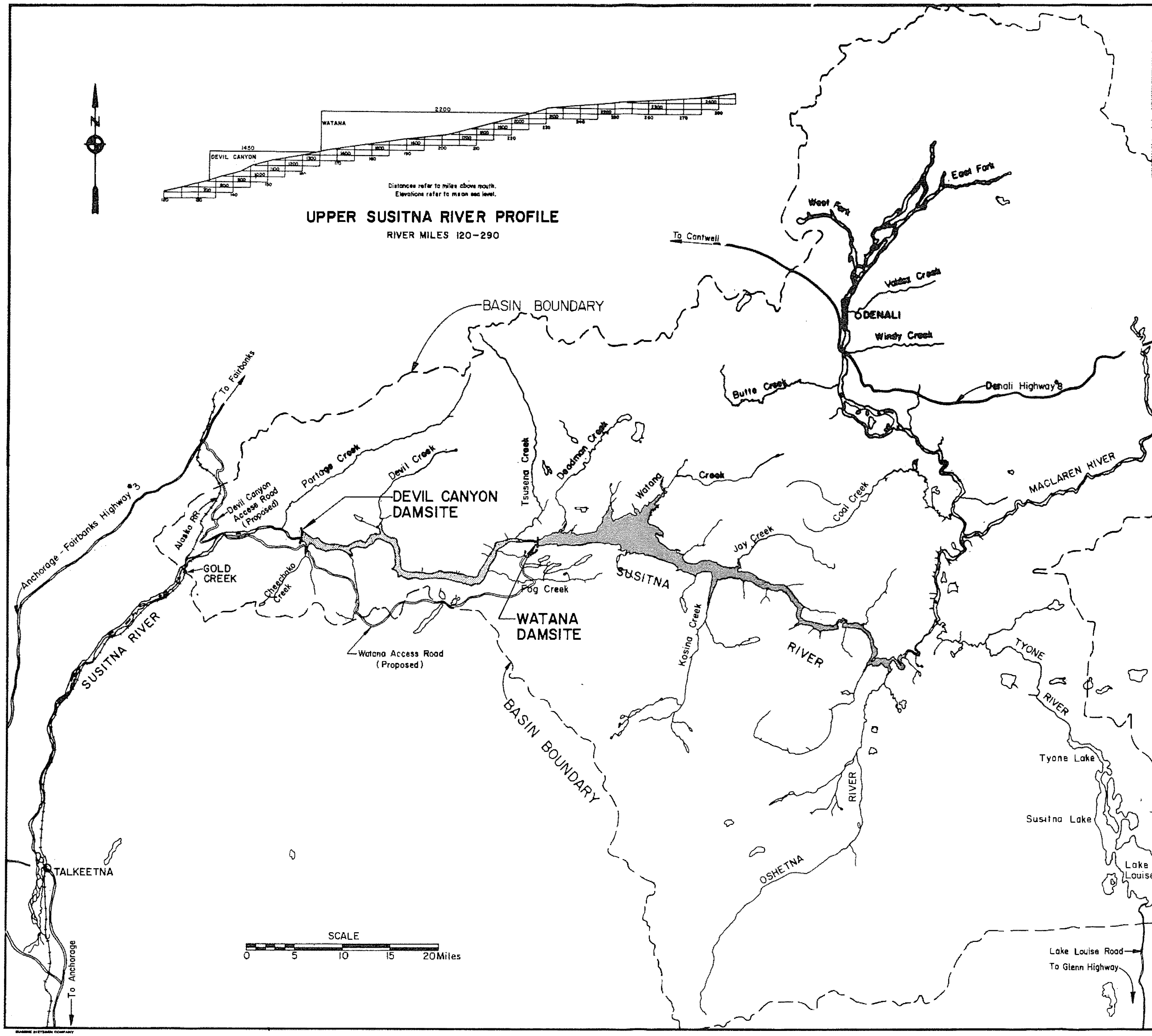
DESIGN & CONSTRUCTION SCHEDULE

Sheet 2 of 2

CORPS OF ENGINEERS



NPA FORM 104
APR 75



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

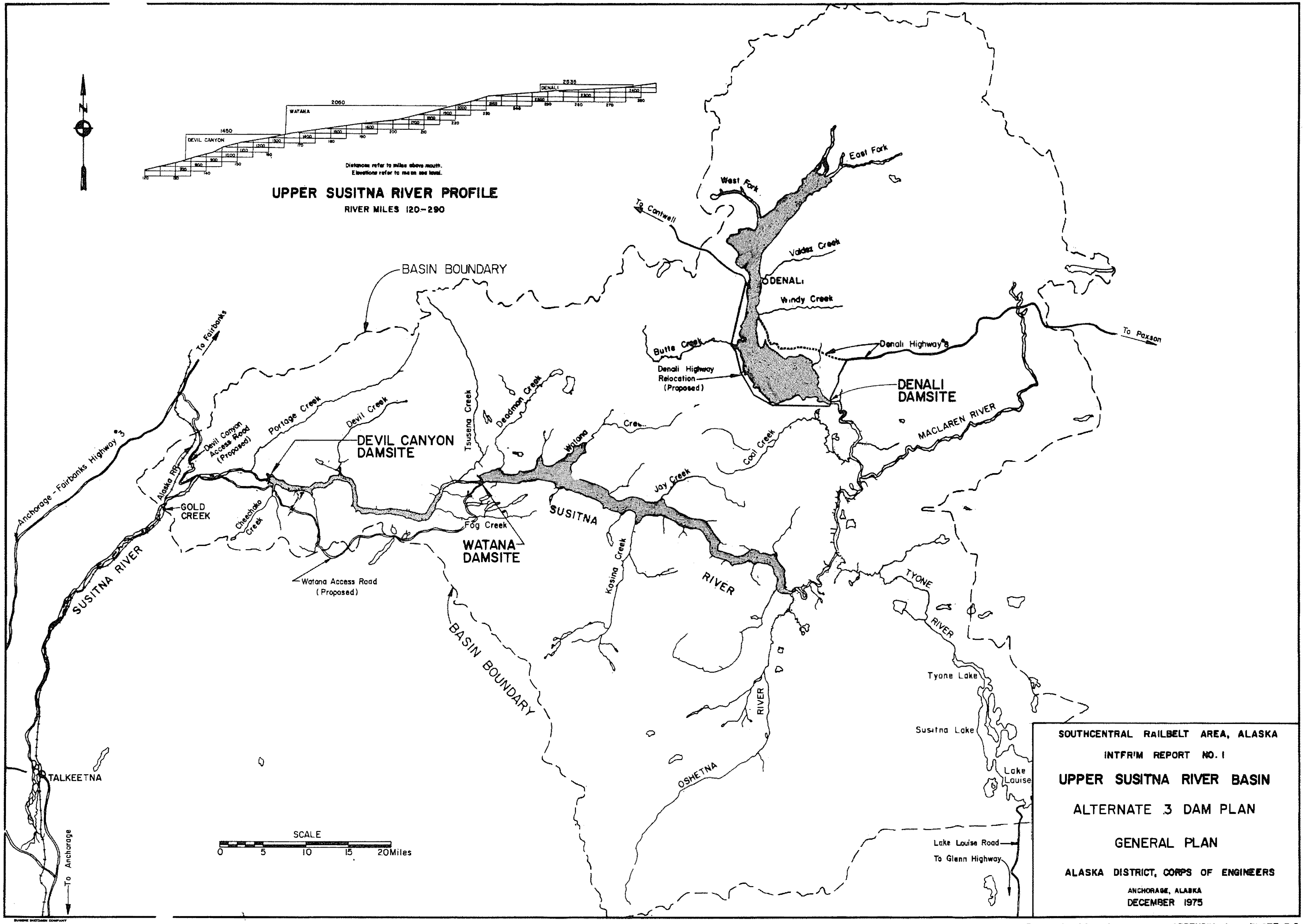
SELECTED 2 DAM PLAN

GENERAL PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

ALTERNATE 3 DAM PLAN

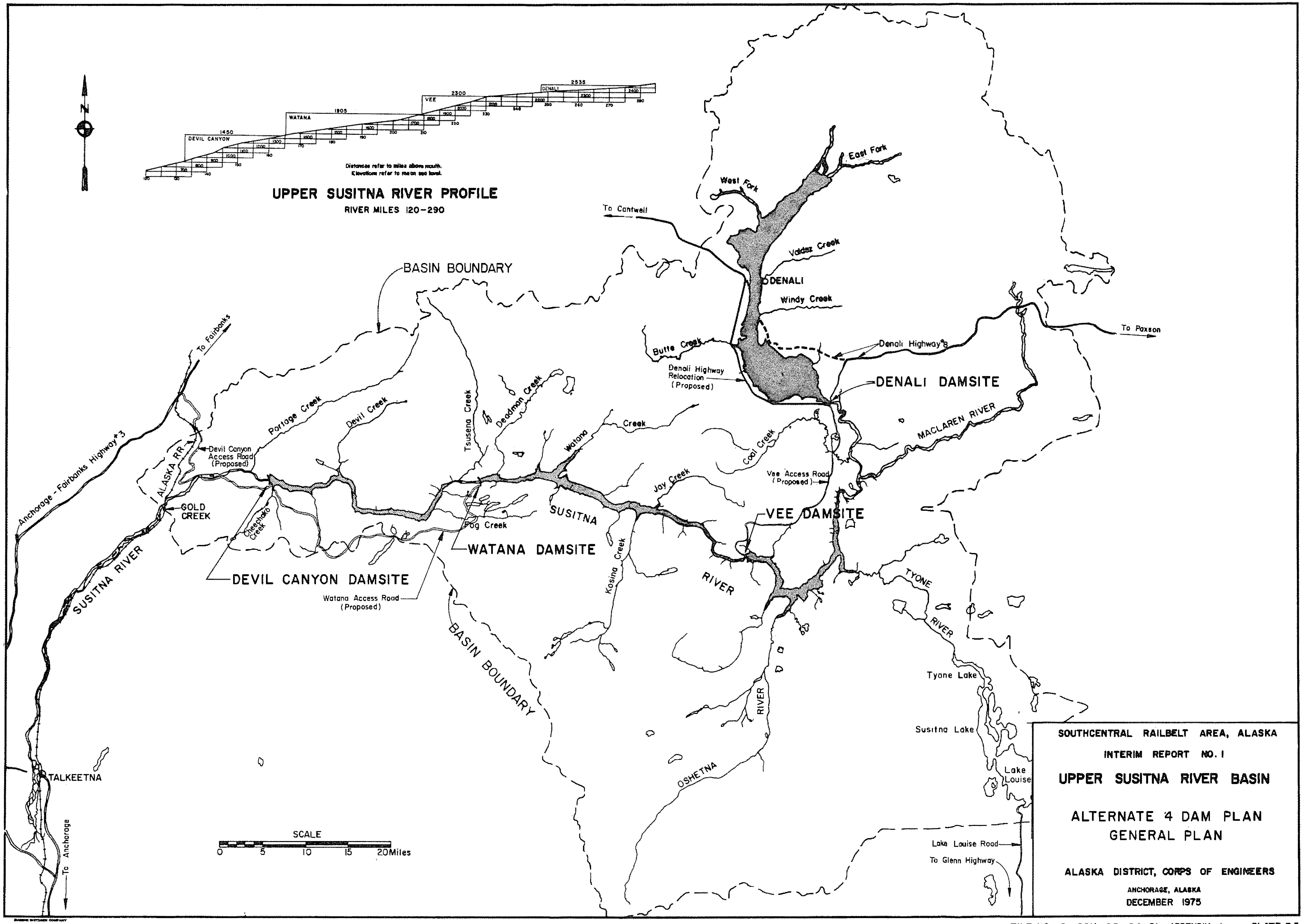
GENERAL PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

FILE NO. 2-SOU-92-04-01 APPENDIX 1 PLATE B-2



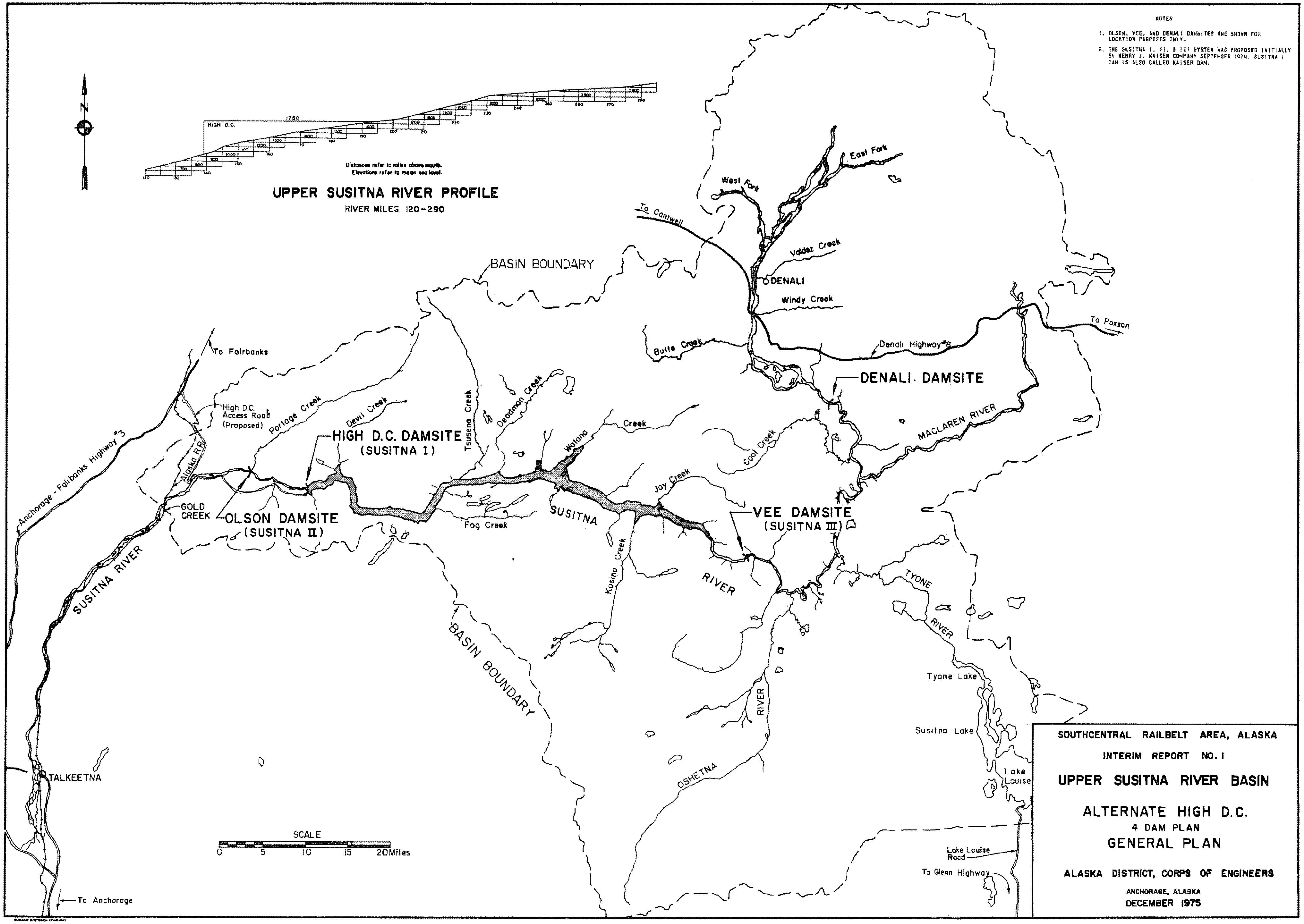
SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

ALTERNATE 4 DAM PLAN
GENERAL PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975



NOTES

1. OLSON, VEE, AND DENALI DAMSITES ARE SHOWN FOR LOCATION PURPOSES ONLY.
2. THE SUSITNA I, II, & III SYSTEM WAS PROPOSED INITIALLY BY HENRY J. KAISER COMPANY SEPTEMBER 1974. SUSITNA I DAM IS ALSO CALLED KAISER DAM.

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

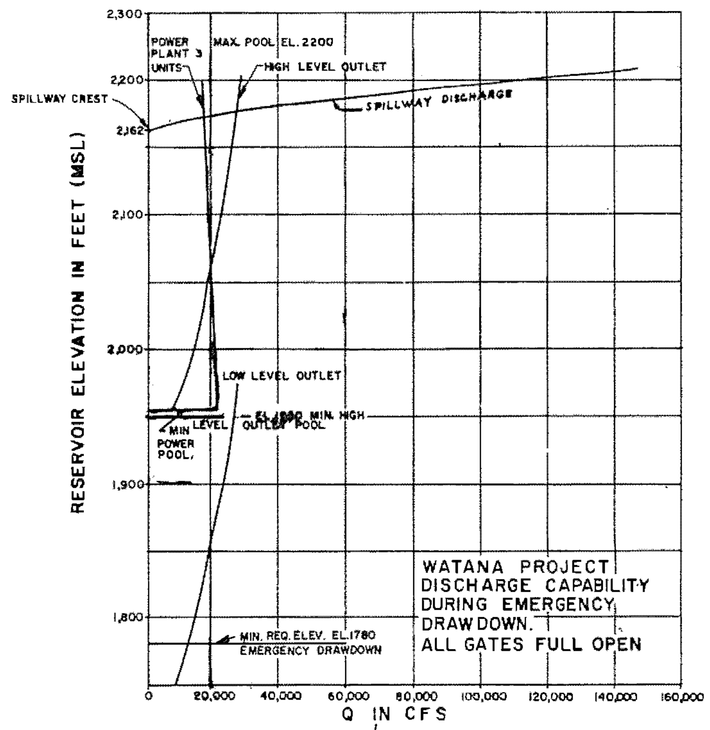
ALTERNATE HIGH D.C.
4 DAM PLAN
GENERAL PLAN

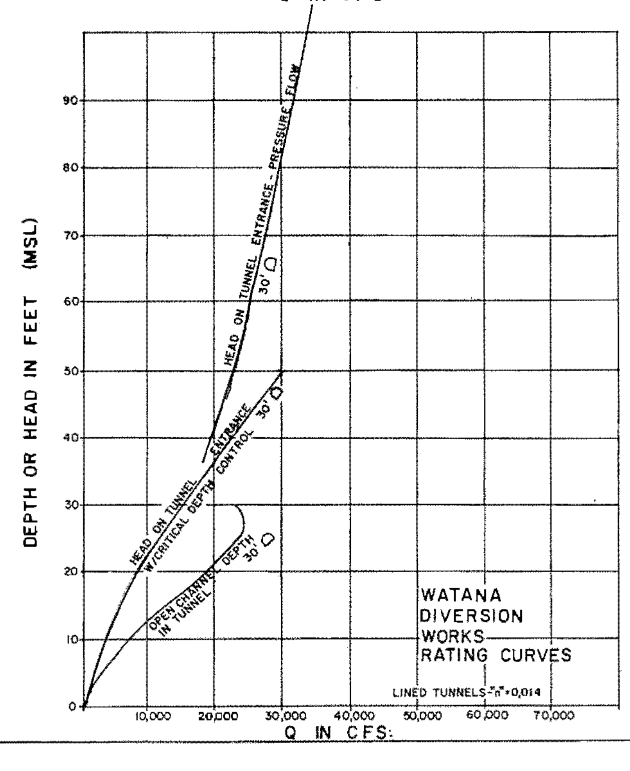
ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975

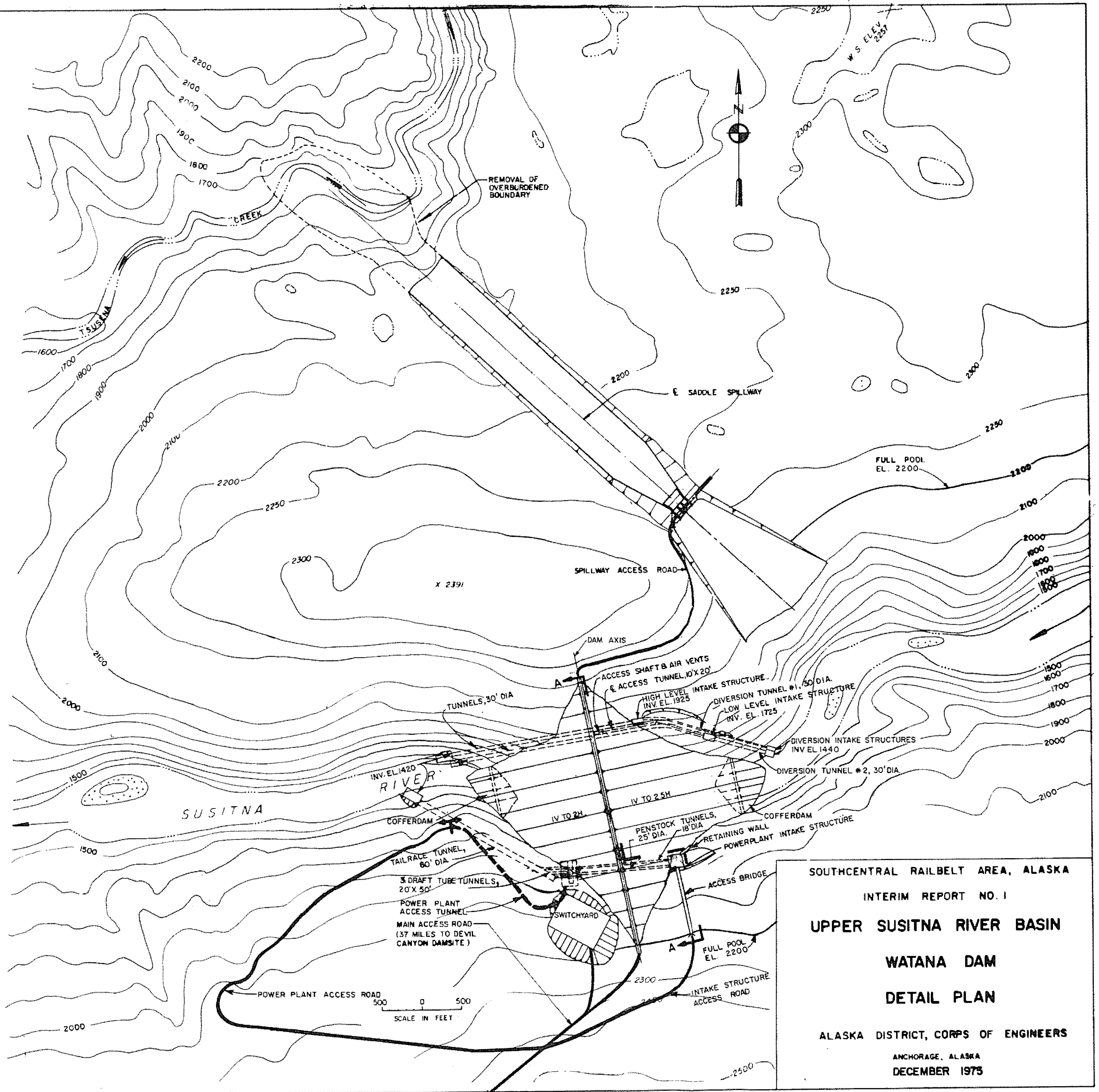
FILE NO. 2-SOU-92-04-01 APPENDIX I PLATE B-4

NOTES:

1. TOPOGRAPHIC CONTOURS WERE TAKEN FROM U.S.G.S. TOPOGRAPHY SCALE 1:63,360, TALKEETNA MOUNTAINS (D-4), ALASKA. VERTICAL DATUM IS MEAN SEA LEVEL (M.S.L.).
2. THERE ARE NO KNOWN EXISTING IMPROVEMENTS ON THIS PLATE.







SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

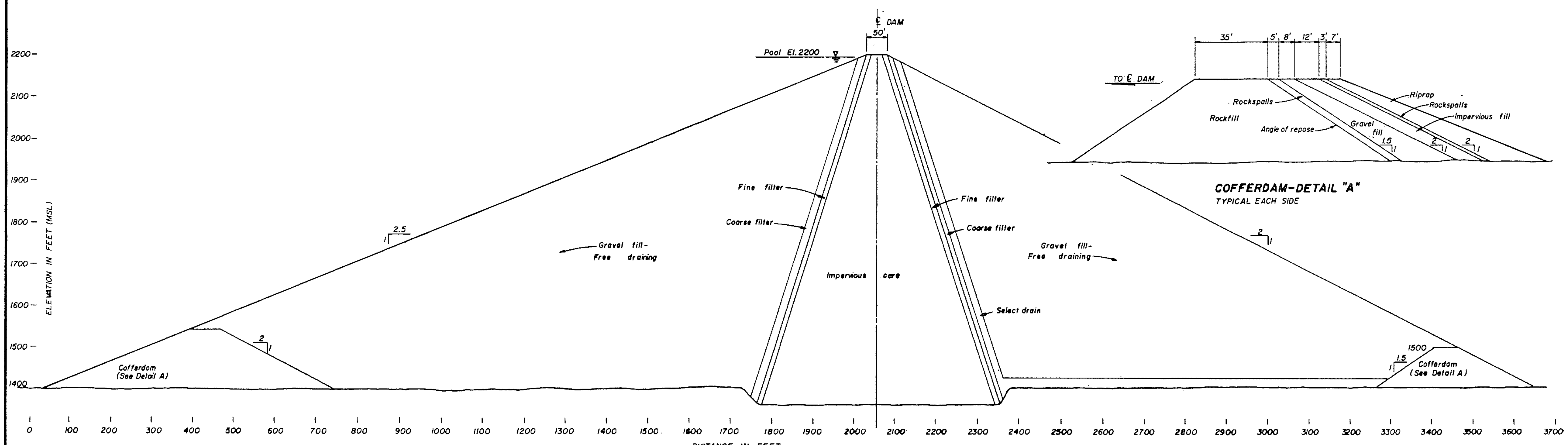
WATANA DAM

DETAIL PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS

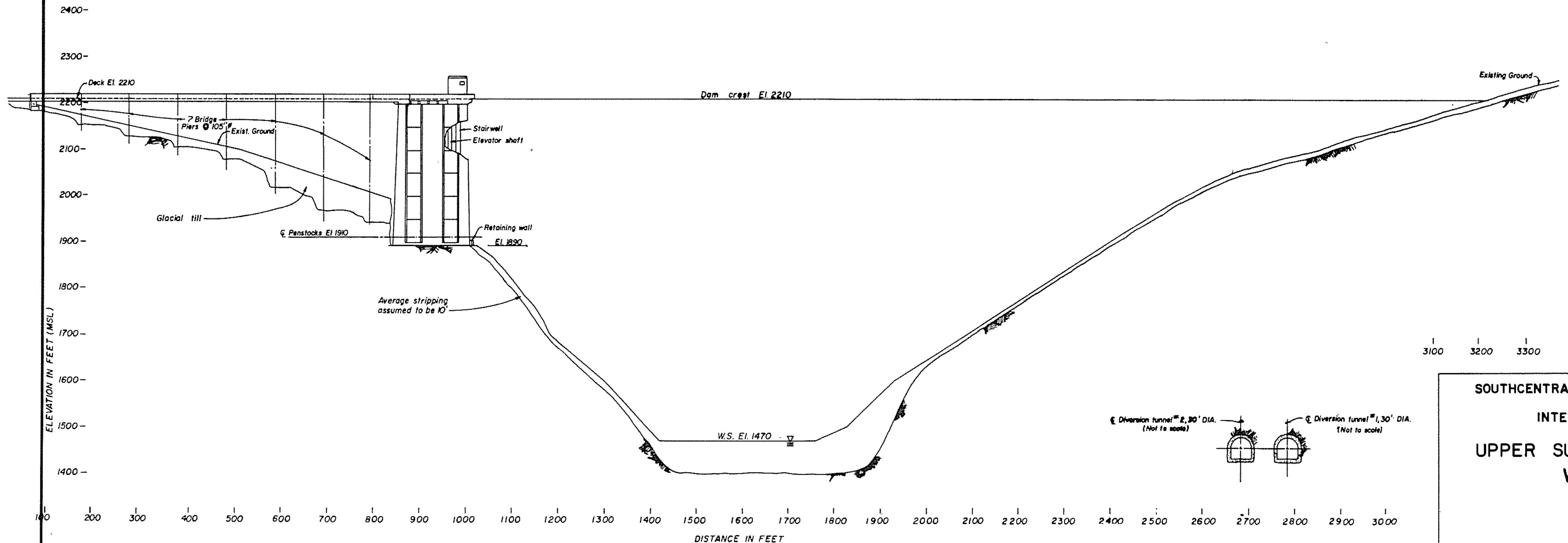
ANCHORAGE, ALASKA

DECEMBER 1975



MAXIMUM SECTION OF WATANA DAM

COFFERDAM-DETAIL "A"



WATANA DAM SECTION A-A (FROM B-8)
INTAKE STRUCTURE
LOOKING DOWNSTREAM

SOUTHCENTRAL RAILBELT AREA, ALASKA

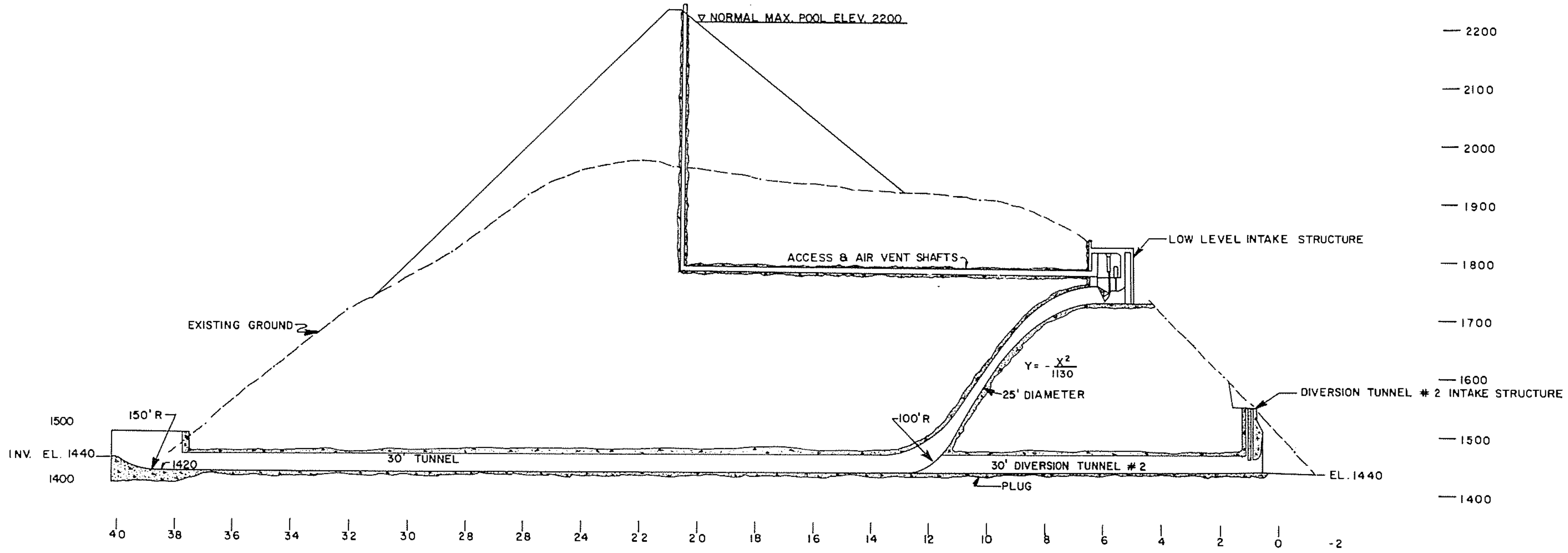
INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
WATANA DAM

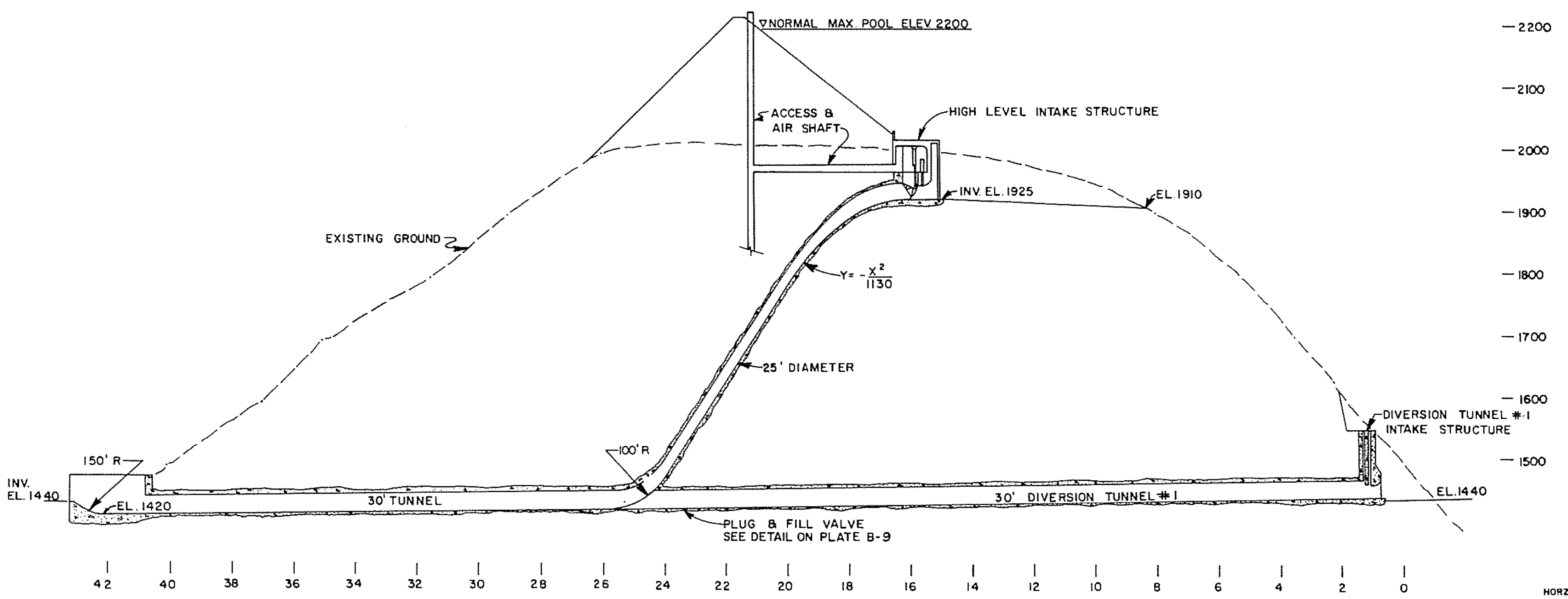
SECTIONS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975



PROFILE LOW LEVEL OUTLET & DIVERSION TUNNEL # 2



PROFILE HIGH LEVEL OUTLET & DIVERSION TUNNEL # 1

HORZ: GRAPHIC SCALE: IN FEET (0, 200, 400, 600)

VERT: GRAPHIC SCALE: IN FEET (0, 100, 200, 300)

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

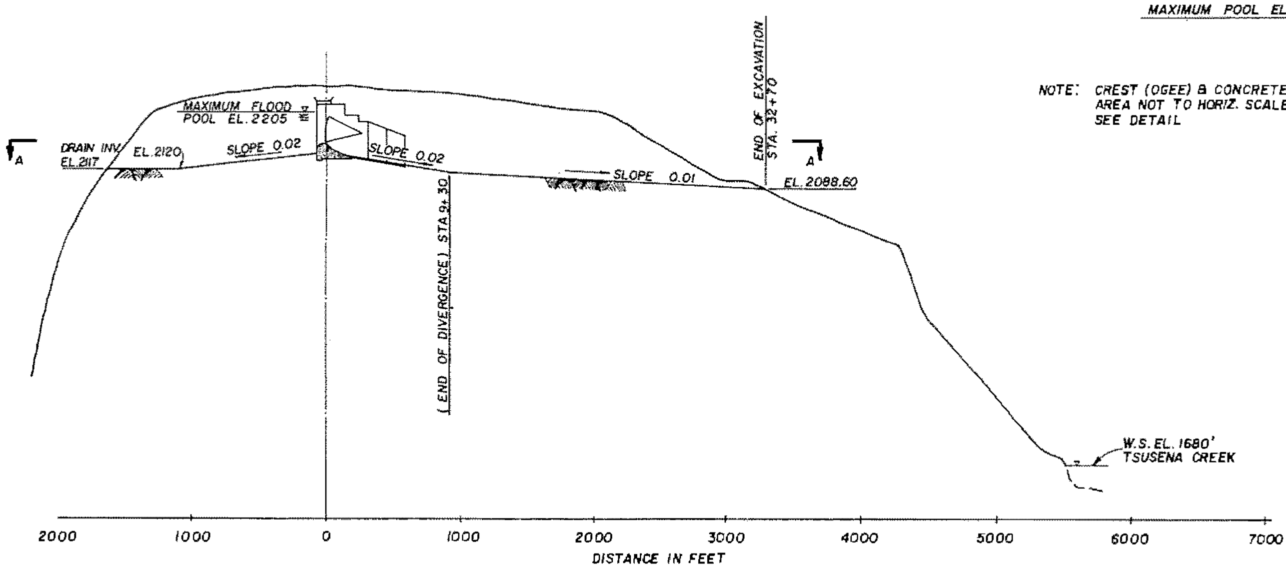
WATANA DAM

PROFILES

ALASKA DISTRICT, CORPS OF ENGINEERS

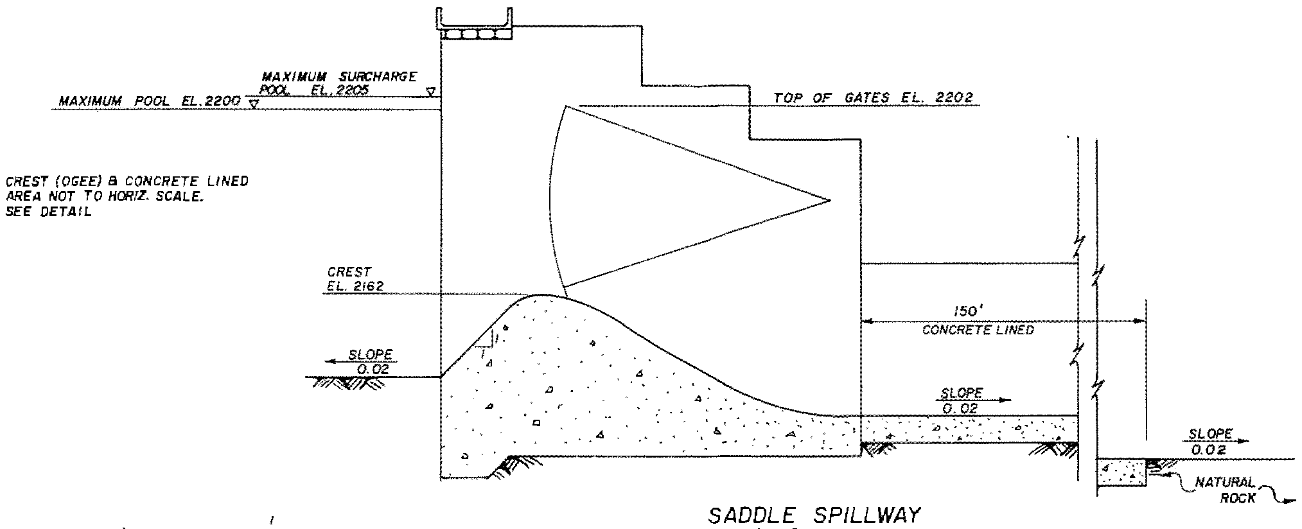
ANCHORAGE, ALASKA

DECEMBER 1975

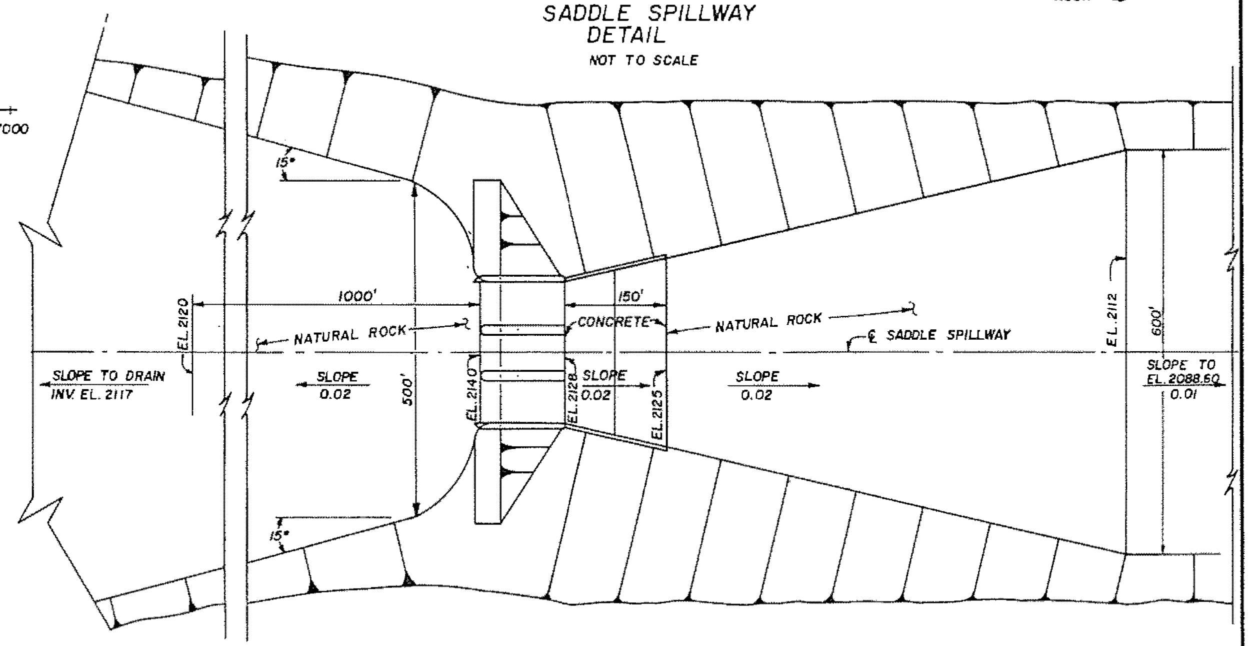


SADDLE SPILLWAY ℄ PROFILE
NOT TO SCALE

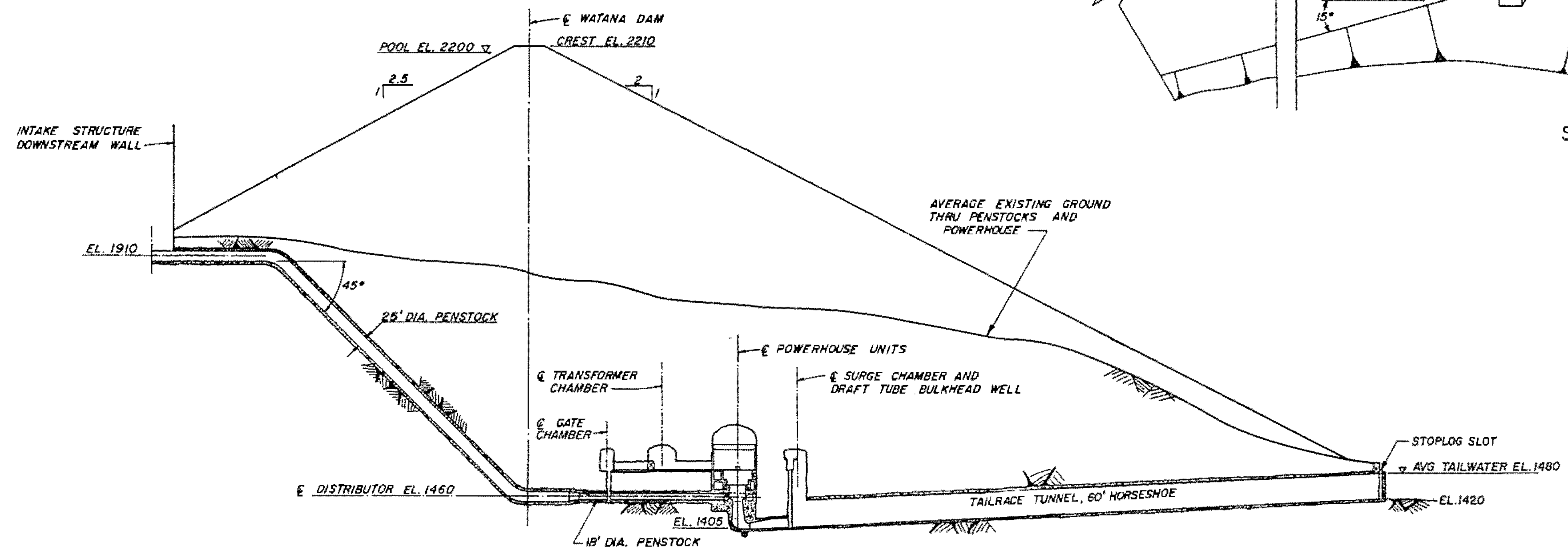
NOTE: CREST (OGEE) & CONCRETE LINED AREA NOT TO HORIZ. SCALE. SEE DETAIL



SADDLE SPILLWAY
DETAIL
NOT TO SCALE



SADDLE SPILLWAY
SECTION A-A
NOT TO SCALE



PENSTOCK ℄ PROFILE
NOT TO SCALE

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

WATANA DAM

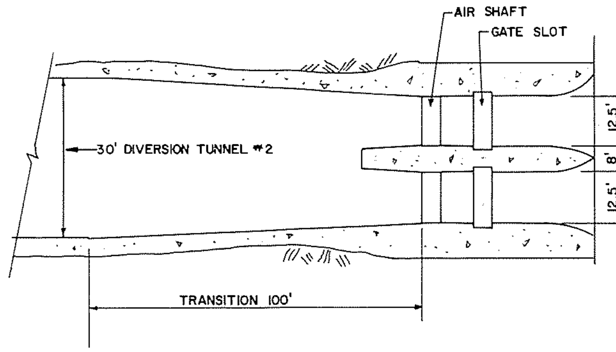
SADDLE SPILLWAY AND PENSTOCK

PROFILES, SECTIONS AND DETAILS

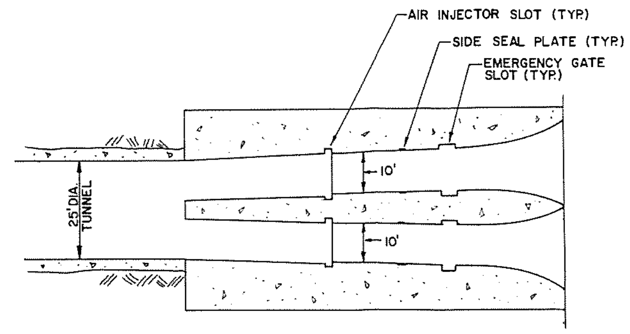
ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

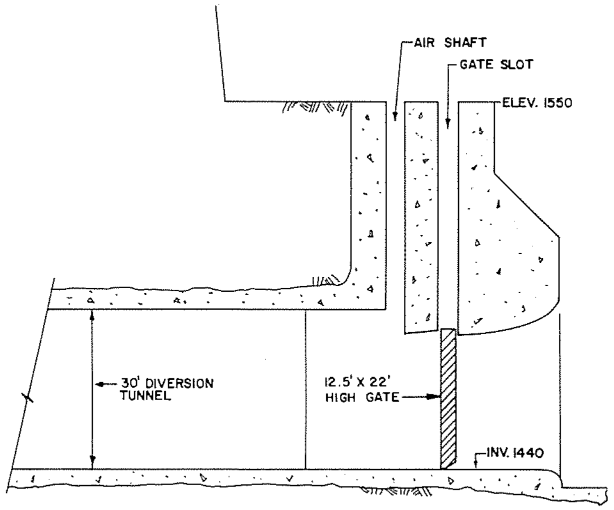
DECEMBER 1975



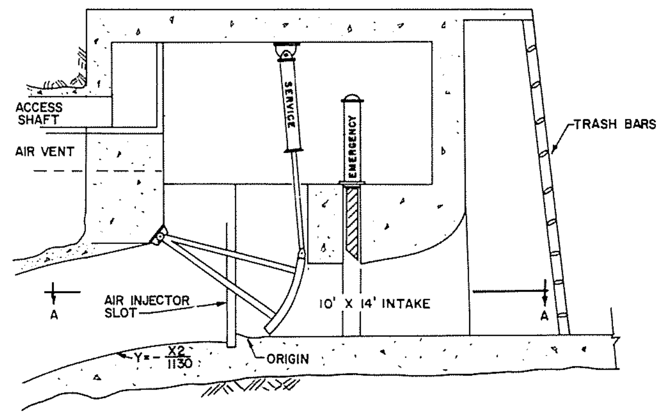
DIVERSION TUNNELS #1 AND #2 INTAKE STRUCTURE
PLAN @ EL. 1460



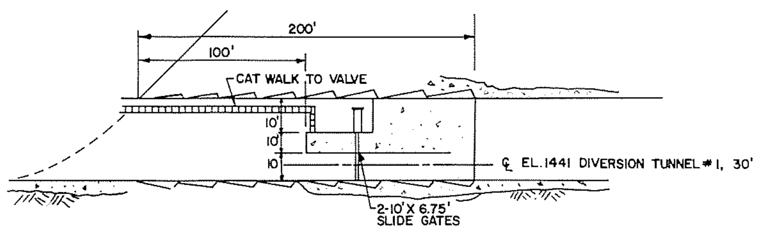
HIGH AND LOW LEVEL INTAKE
PLAN @ A-A



DIVERSION TUNNELS #1 AND #2 INTAKE STRUCTURE
SECTION



HIGH AND LOW LEVEL INTAKES
SECTION



PLUG AND FILL VALVE DETAIL
NOT TO SCALE

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

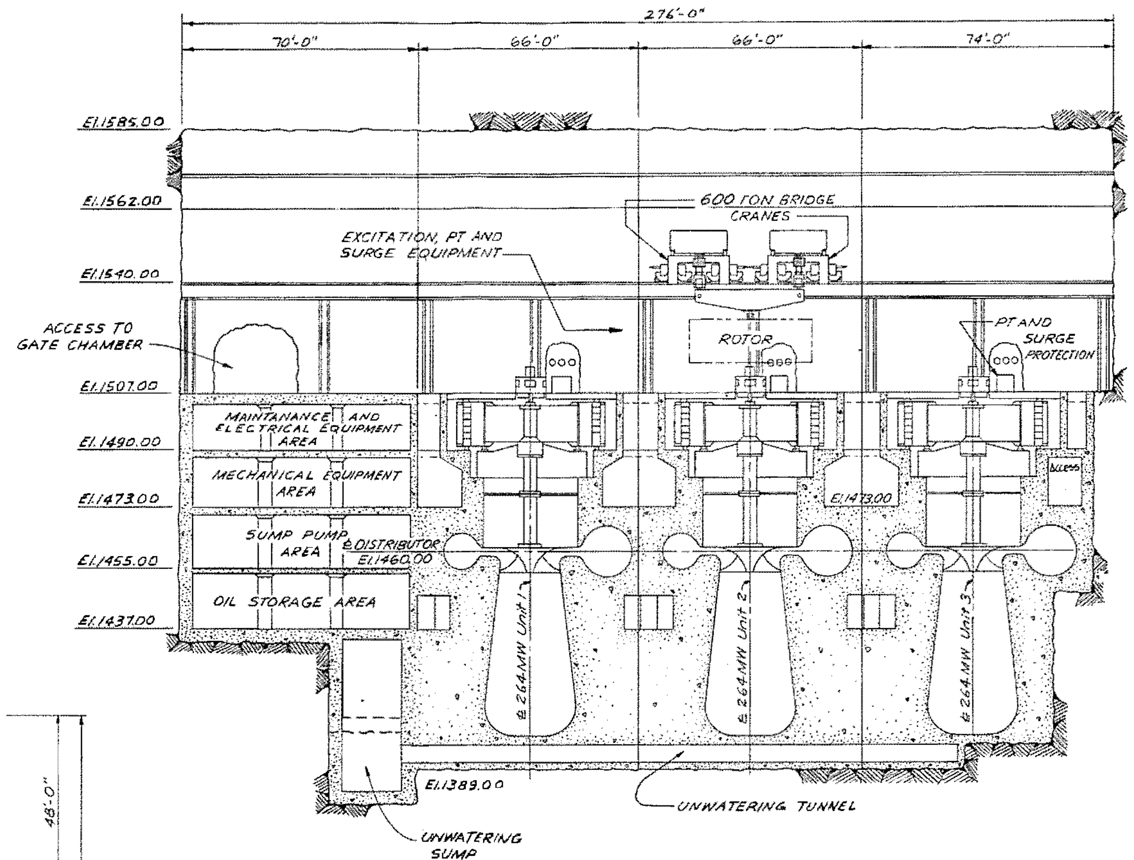
WATANA DAM

DETAILS

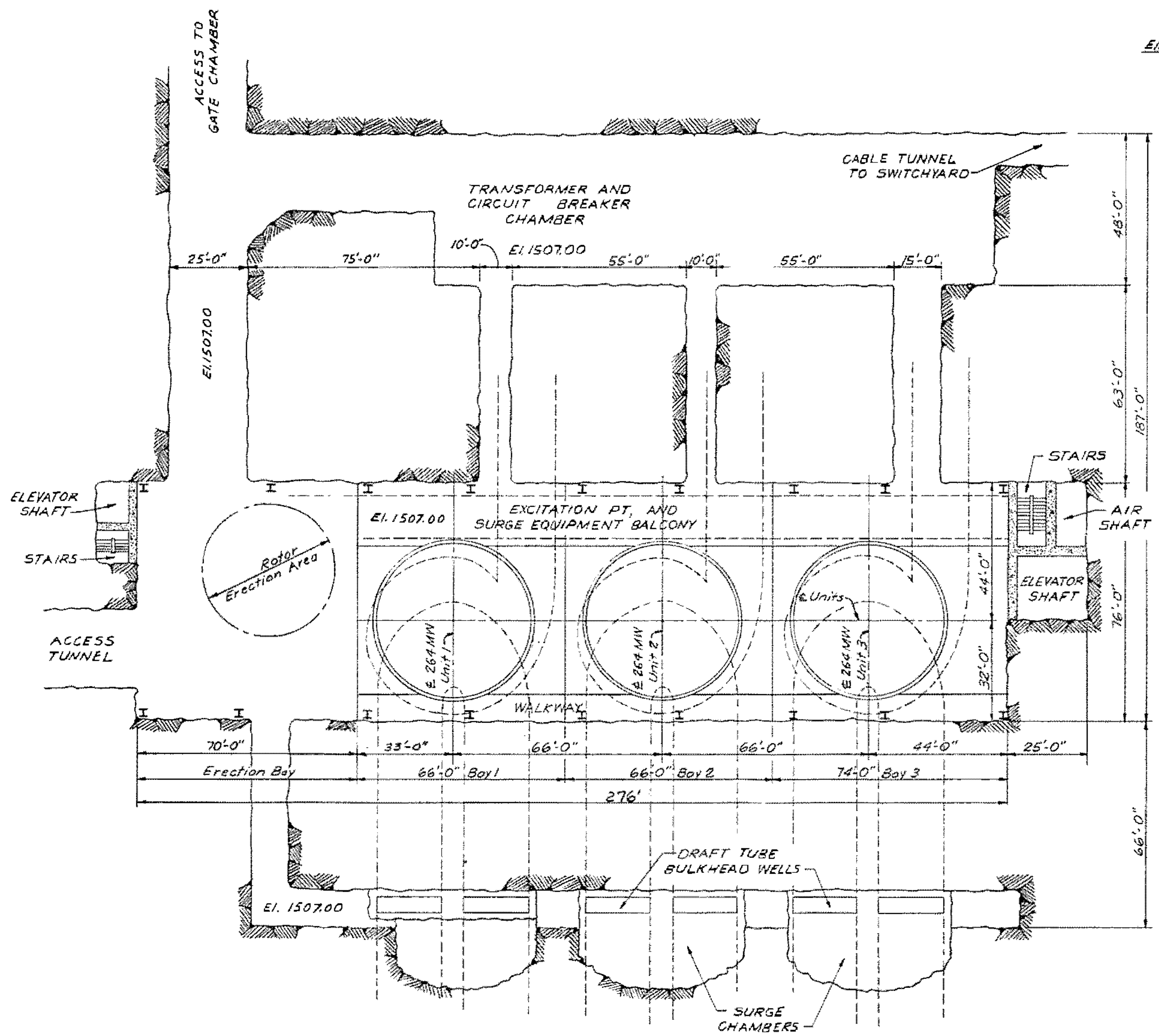
ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975



LONGITUDINAL SECTION
THRU ℄ UNITS



PLAN EL. 1507

POWER PLANT DATA (AT BEST GATE)
GENERATORS:
3 @ 264,000 KW EACH
TURBINES:
3 @ 352,000 HP EACH
CRITICAL HEAD:
580 FT.
DISCHARGE:
7,670 CFS EACH

SCALE IN FEET (APPROX.)

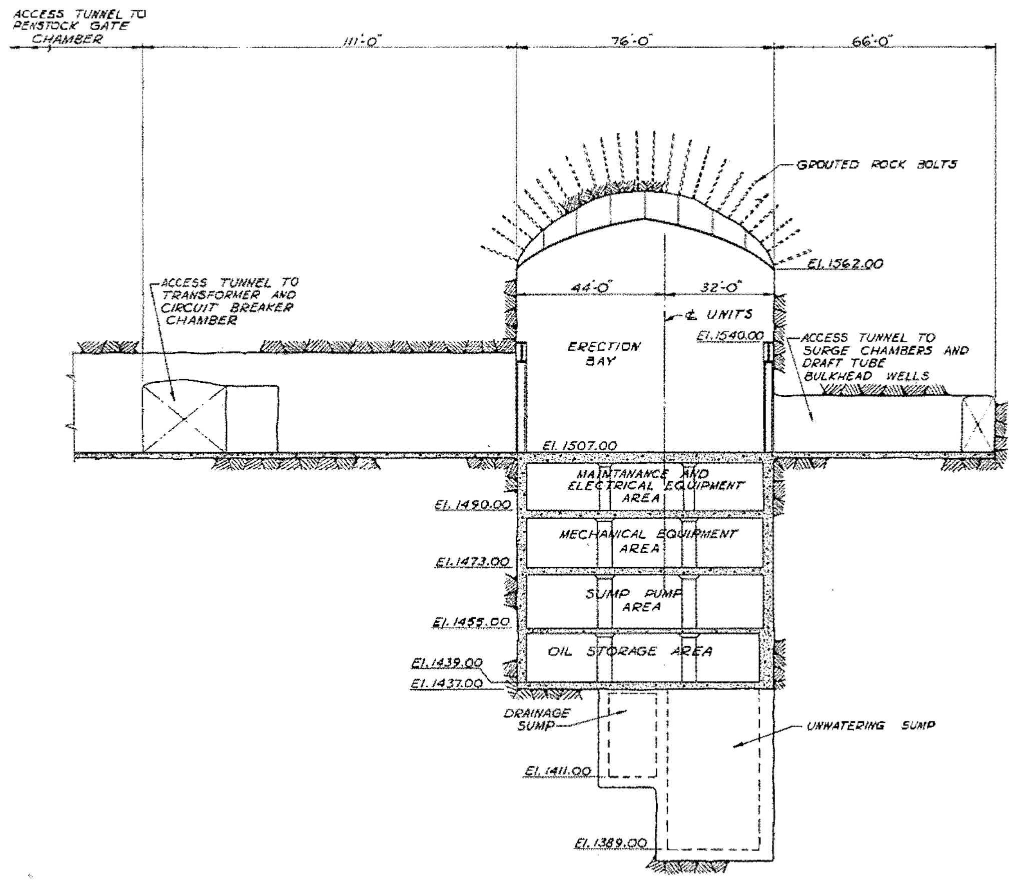
SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

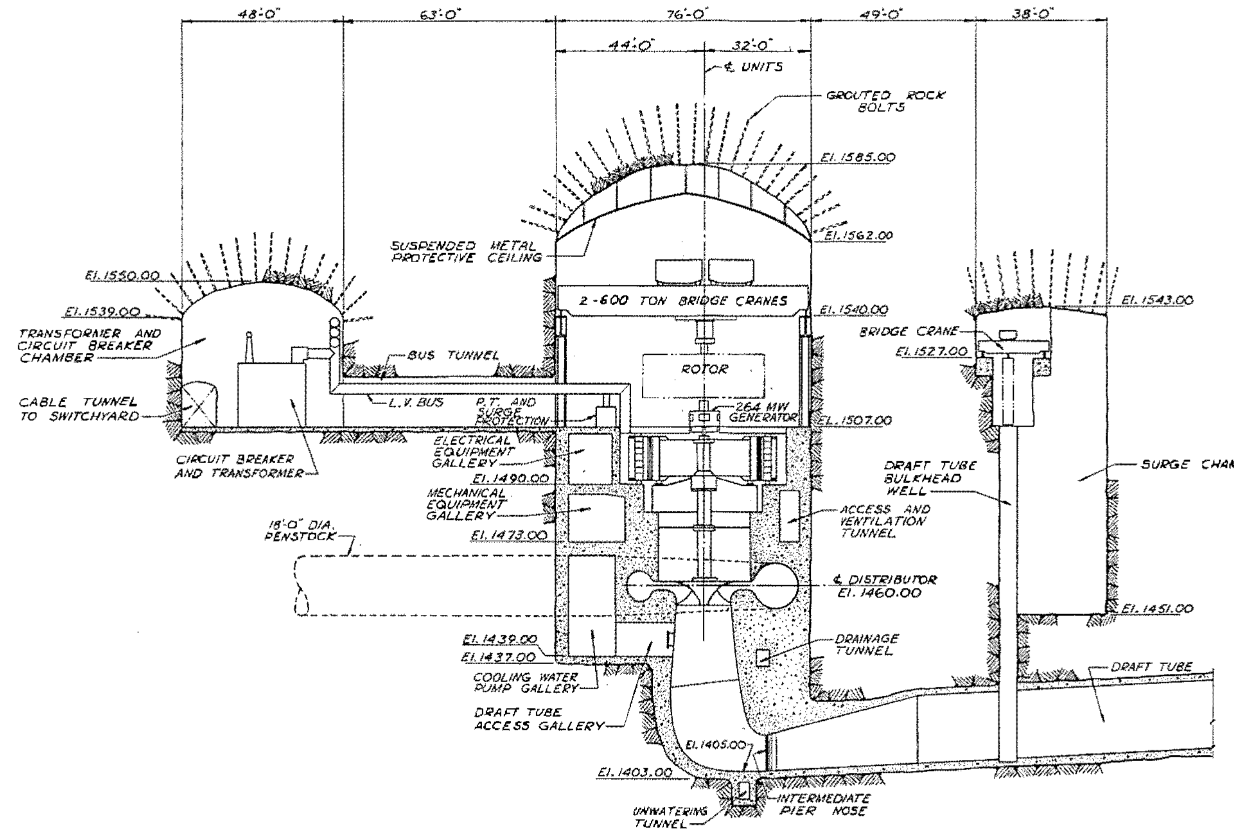
UPPER SUSITNA RIVER BASIN
WATANA DAM
POWERHOUSE

PLAN AND SECTION

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975



TRANSVERSE SECTION
THRU ERECTION BAY



TRANSVERSE SECTION
THRU GENERATOR BAY

GRAPHIC SCALE (APPROX.)

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

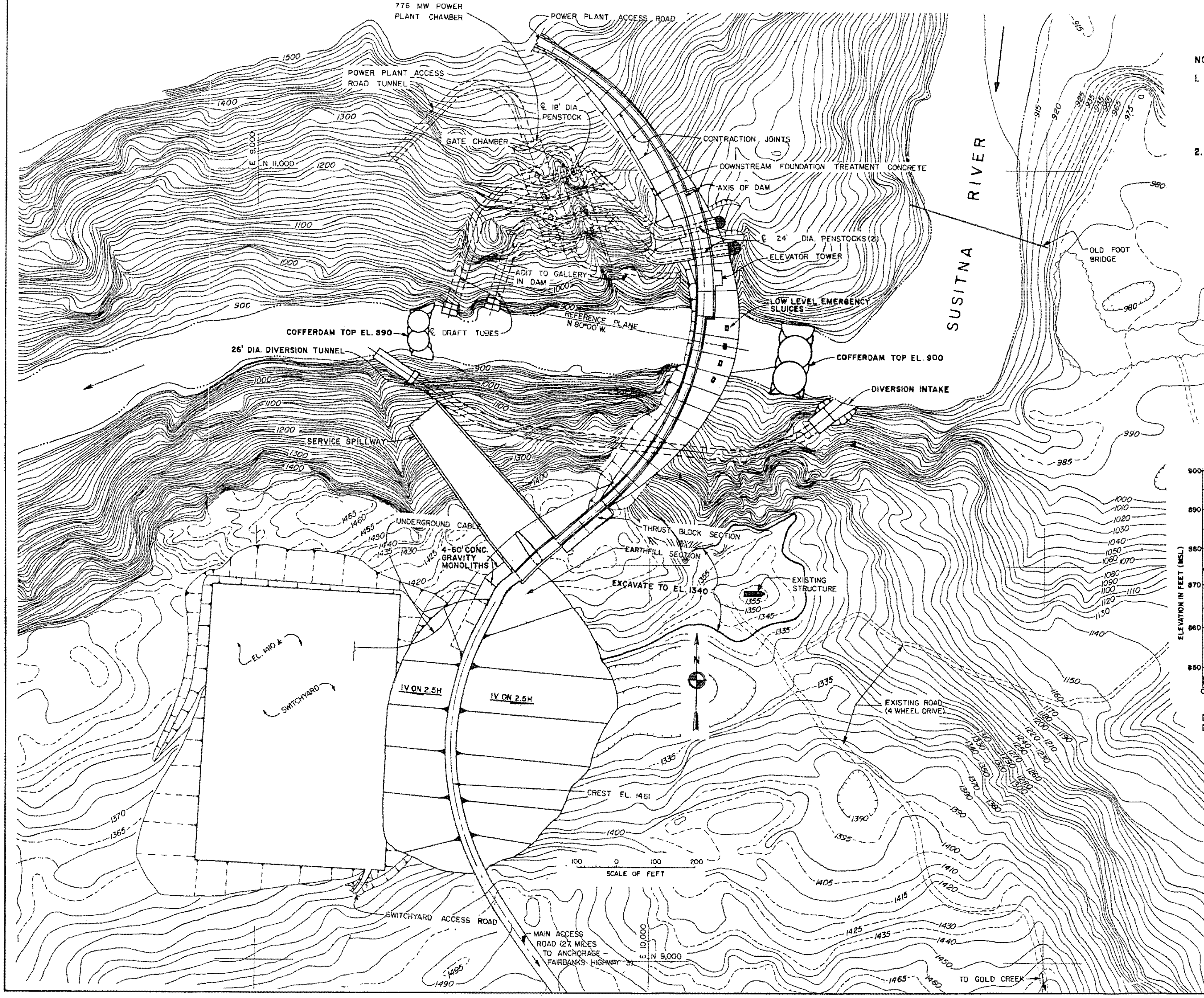
UPPER SUSITNA RIVER BASIN
WATANA DAM
POWERHOUSE

TRANSVERSE SECTIONS

ALASKA DISTRICT, CORPS OF ENGINEERS

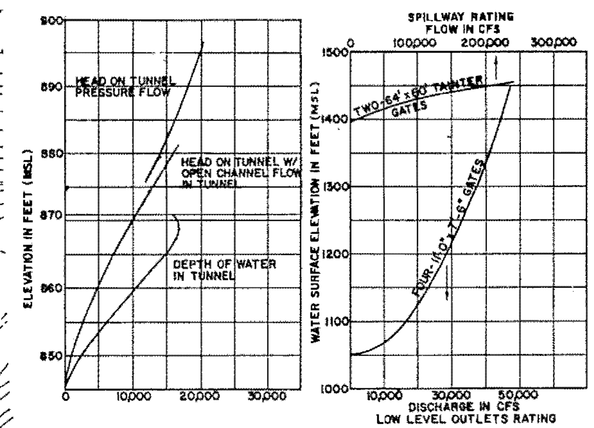
ANCHORAGE, ALASKA

DECEMBER 1975



NOTES:

1. TOPOGRAPHY WAS COMPILED FROM AERIAL PHOTOGRAPHY WITH GROUND CONTROL. VERTICAL DATUM IS MEAN SEA LEVEL, (m.s.l.).
2. EXISTING IMPROVEMENTS WERE CONSTRUCTED TO OBTAIN INFORMATION AND DATA FOR EARLIER STUDIES.



DEVIL CANYON 26' ⌂ DIVERSION TUNNEL

DEVIL CANYON RATING CURVES

SOUTHCENTRAL RAILBELT AREA, ALASKA

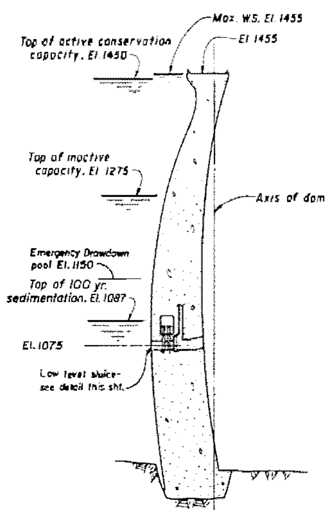
INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
DEVIL CANYON DAM
DETAIL PLAN

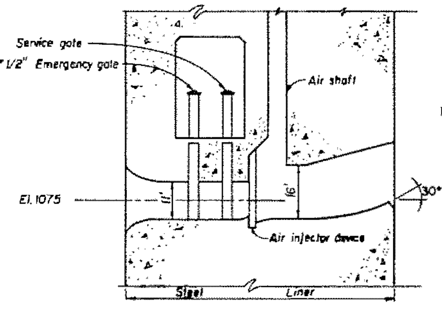
ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975



SECTION

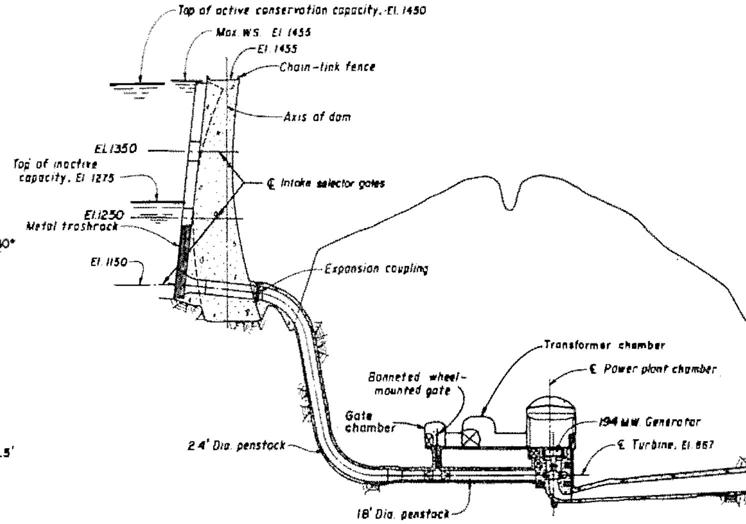


SECTION

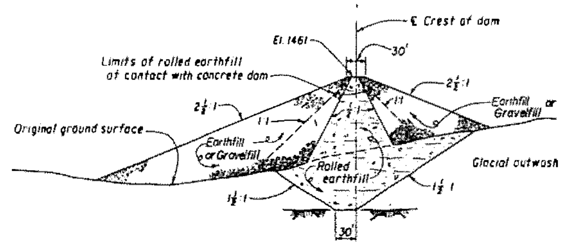
PLAN

LOW LEVEL SLUICE DETAIL

SCALE OF FEET

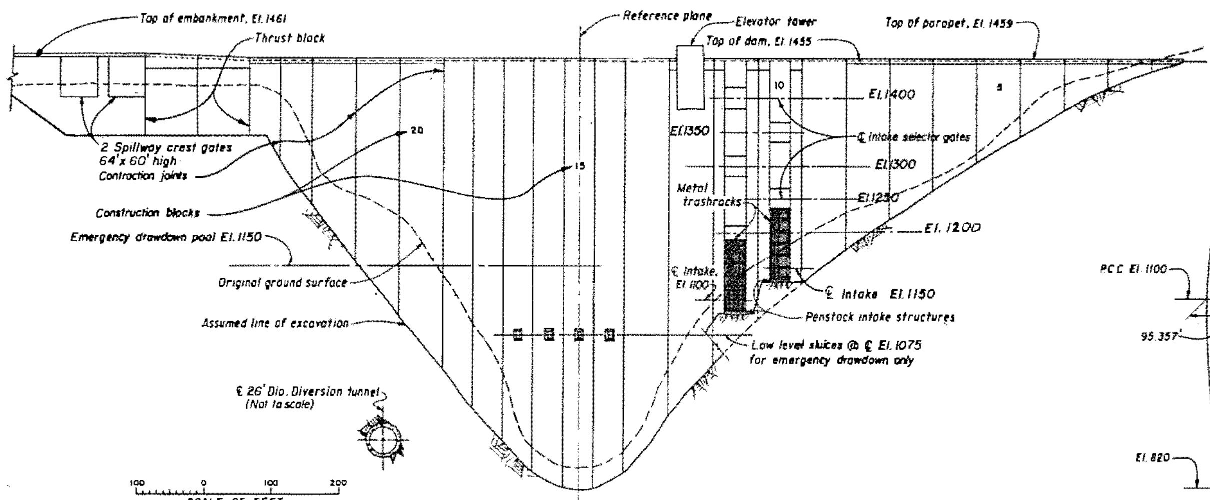


SECTION THRU PENSTOCK AND POWER PLANT



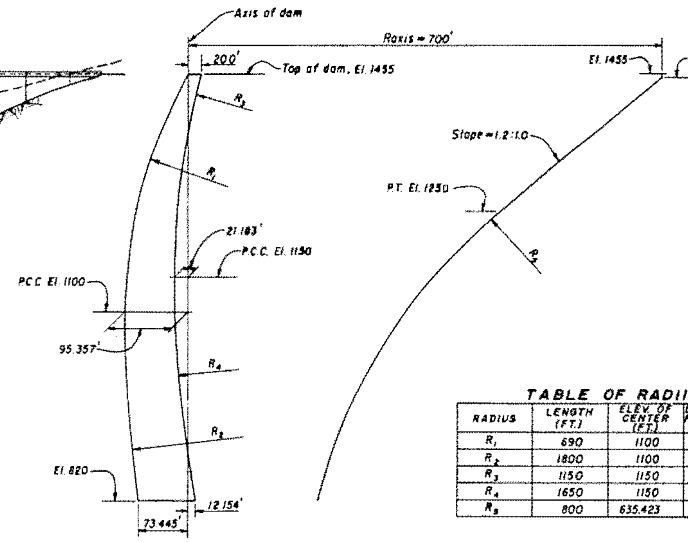
SECTION THRU EARTHFILL DAM

Scale: 1" = 100'



UPSTREAM ELEVATION

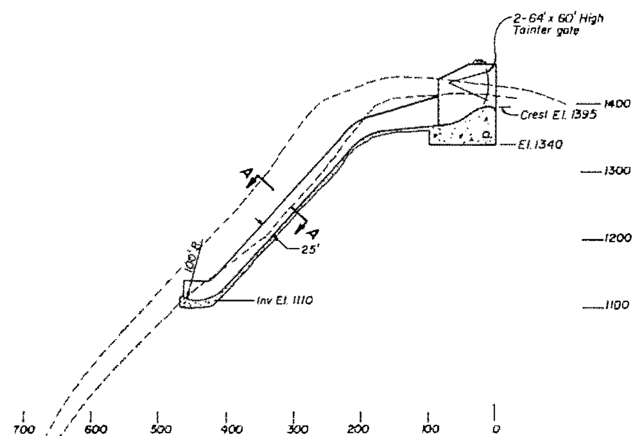
DEVELOPED ALONG AXIS OF DAM



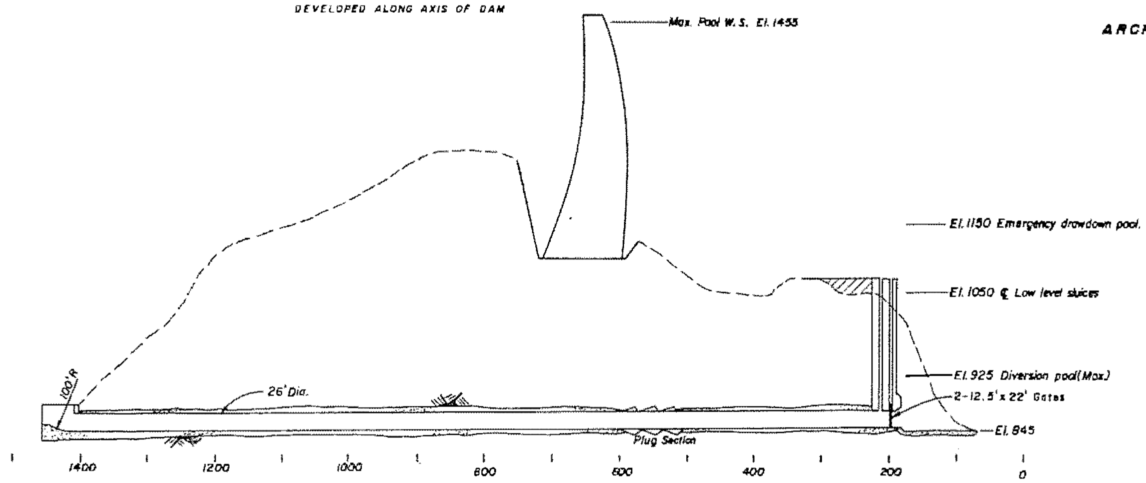
ARCH LAYOUT DATA

TABLE OF RADII

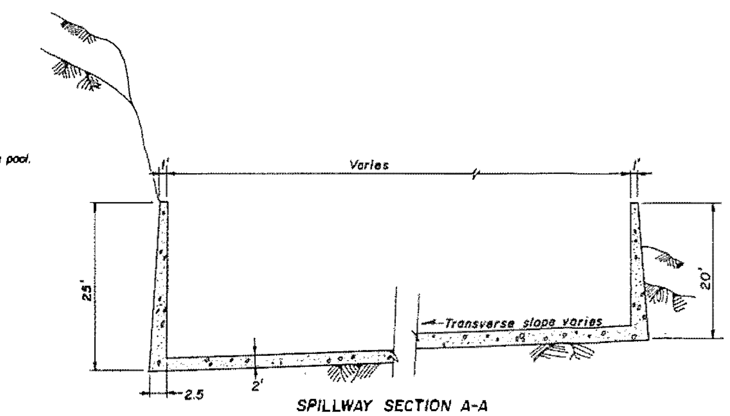
RADIUS	LENGTH (FT.)	ELEV. OF CENTER (FT.)	DIST. TO AXIS FROM CENTER (FT.)
R_1	690	1100	594.643
R_2	1800	1100	1704.643
R_3	1150	1150	1128.817
R_4	1650	1150	1628.817
R_5	800	635.423	972.148



SPILLWAY SECTION



DIVERSION TUNNEL PROFILE



SPILLWAY SECTION A-A

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

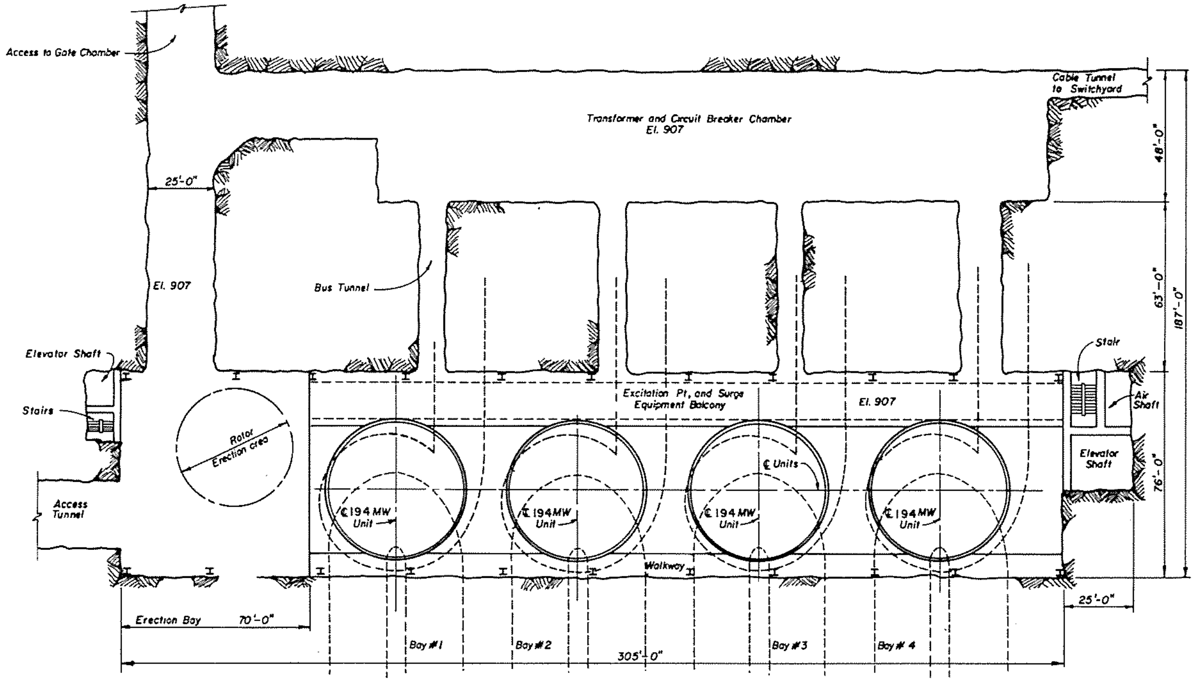
UPPER SUSITNA RIVER BASIN
DEVIL CANYON DAM

ELEVATION AND SECTIONS

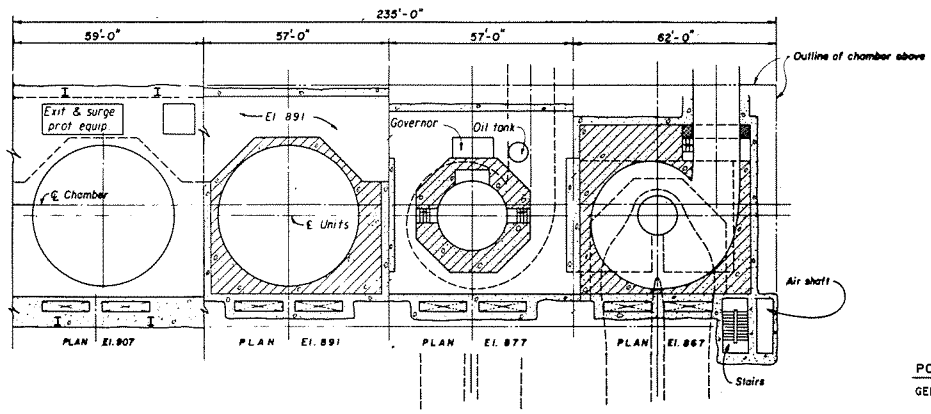
ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975



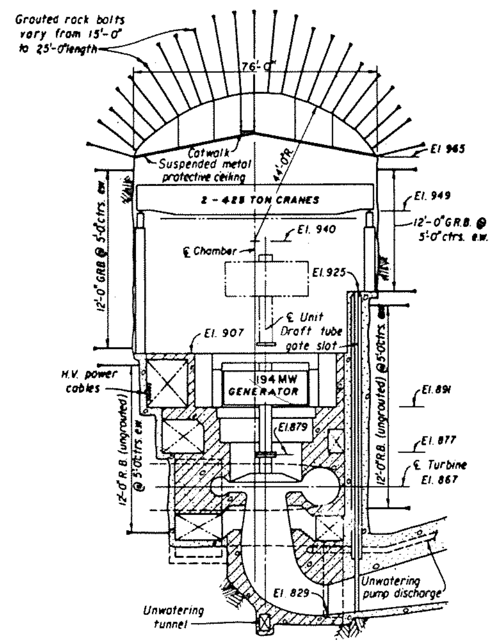
GENERAL PLAN EL. 907
Not to Scale



GENERAL PLANS
Not to Scale

POWER PLANT DATA (AT BEST GATE)

GENERATORS:
4 @ 194,000 KW EACH
TURBINE:
4 @ 266,000 HP EACH
CRITICAL HEAD:
520 FT.
DISCHARGE:
6,250 CFS. EACH



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SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

DEVIL CANYON DAM

POWERHOUSE

PLANS AND SECTIONS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

FILE NO. 2-SOU-92-04-01 APPENDIX I PLATE B-14

SECTION C

POWER STUDIES AND ECONOMICS

SECTION C

POWER STUDIES AND ECONOMICS

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POWER STUDIES AND ECONOMICS

PURPOSE AND SCOPE

This section serves as the basis for determining optimum power development for the Anchorage and Fairbanks population centers consistent with State and National objectives for fossil fuel conservation, National energy independence, and minimum environmental impact. The development of Alaskan natural resources coupled with high population growth rates have provided a State energy demand that is being met almost exclusively with fossil fuel. The depletion rate of useable petrochemicals and the subsequent rise in fuel costs have resulted in the increased economic attractiveness of alternative electrical power generation resources which could supplement or replace conventional fuel-fired generation plants.

The available alternatives can be broken down into three broad classes: those which can be implemented by altering existing consumption trends, specifically, conservation and controlled growth measures; those which entail developing fuel sources not in danger of immediate depletion; and those alternatives which entail the utilization of renewable resources. In addition to selecting the most economical and long-lasting power alternative, much consideration is given to developing the plan which will result in minimal environmental degradation. Therefore, this section will evaluate a broad range of energy resources, and through a screening process, select a plan which is not only economically attractive, but that which provides the least environmental impact in consonance with the objective of electrical power development. The overall purposes would be to develop power generating resources to maintain the Alaskan standard of living and to conserve fossil fuels for higher priority usage.

The section also discusses the economic climate of the Railbelt service area, past and estimated future power requirements, power values, and costs of comparably financed alternatives. Power benefits, project costs, benefit-to-cost ratios, and net benefits, based on January 1975 price levels, have been developed for practical alternatives. Environmental concerns are discussed in detail in the Environmental Assessment, Section E of this appendix. However, portions have been included here to help weigh the impact of various alternatives. Much of this section deals specifically with hydroelectric development of the Upper Susitna River Basin, as that plan for development appears to provide the most attractive solution to electrical power generation.

PREVIOUS STUDIES

A Reconnaissance Report on the Potential Development of Water Resources in the Territory of Alaska was published by the Bureau of Reclamation in December 1948. This report presented existing and projected Alaskan growth and identified a number of potential hydroelectric sites throughout the State. Contained in the report were 72 potential sites, of which 6 are located in the Susitna River basin.

Cook Inlet and Tributaries was published by the Corps of Engineers in 1950. The Chief of Engineers' report revealed the possibility of a three-dam development of the Upper Susitna River Basin from which an estimated 5.7 billion kilowatt-hours firm annual energy could be produced. The proposed damsites are in the locations similar to those studied in this report.

A Report on Potential Development of Water Resources in the Susitna River Basin of Alaska was published by the Bureau of Reclamation in June 1953. Within this report, the development of the total Susitna River basin entailed 12 damsites, 4 of which are in the Upper Susitna River Basin at the sites which are currently known as Devil Canyon, Watana, Vee, and Denali. The total installed capacity for the 12-dam system was estimated to be 1,249 megawatts.

Devil Canyon Project, Alaska, was published by the Bureau of Reclamation in March 1961. In this report, it was proposed that the Upper Susitna River Basin be developed by a four-dam system, with a first-stage development of Devil Canyon Dam, powerplant, reservoir, and transmission system, and a dam and storage reservoir at Denali. Based on the hydrologic data available at the time of the report, the estimated energy potential of the system and first-stage development was 7.0 and 2.9 billion kilowatt-hours, respectively.

Interim Report on Vee Project, Alaska, published in 1964, suggested that the Vee Dam be constructed as the second-stage development within the Upper Susitna River Basin, and that this dam be followed by the Watana Dam. This would give full-basin development with the normal maximum pool of each reservoir extending to the tailwater elevation of the next upstream power dam.

Devil Canyon Status Report was published in May 1974 by the Alaska Power Administration. This report updated the 1961 USBR report and included modifications to the Devil Canyon Dam and powerplant and the Denali Dam.

Reassessment Report on Upper Susitna River Hydroelectric Development for the State of Alaska was published in September 1974 by the Henry J. Kaiser Company, which was considering the development of a major energy-intensive industry within the Railbelt area, contingent upon the availability of large quantities of inexpensive energy. To meet this demand, Kaiser suggested a first-stage upper Susitna River development consisting of a single high dam five miles upstream from the USBR Devil Canyon damsite, and subsequent development to include power projects both up and downstream from the high dam. Although the high dam could produce 3.7 billion kilowatt-hours of average annual energy, Kaiser determined that the projected energy demand of the Railbelt area would soon absorb the initial hydro stage and would not leave sufficient surplus low cost energy for further consideration of the aluminum plant development.

STUDY AREA

The area that would benefit from the energy of the proposed development plan has been termed the "Railbelt" community, which, for the purpose of load growth, consists of portions of the southcentral and Yukon regions of Alaska. The main communities served would be those contiguous to the Alaska Railroad route connecting the Anchorage-Cook Inlet areas with the interior Fairbanks area; and, if a feasible transmission and marketing plan could be developed, service could be extended to communities along the pipeline route from Fairbanks to Valdez. The loop could be completed by a connecting line between Glennallen and Palmer. In 1972, the Railbelt utility loads totaled 80 percent of the statewide requirements for the year and 96 percent of the southcentral and Yukon demand.

COORDINATION WITH OTHER STATE AND FEDERAL AGENCIES

The power and economic studies of the Susitna project have been coordinated with the Federal Power Commission (FPC) and the Alaska Power Administration (APA) of the Department of Interior. An appraisal of power requirements for the State of Alaska, with projections to the year 2000, was published in the May 1974 report of the joint State-Federal Alaska Power Survey Technical Advisory Committee on Economic Analysis and Load Projections. The projected power demand contained in this report was used by FPC in the development of the power values and comparably financed alternative costs for the economic evaluation of the project. An evaluation of power marketability within the study area was provided by the APA. This information was used for powerplant sizing and stage development of the basin to meet projected demands. Also furnished by the APA were the design, associated cost, and tentative route of the transmission system that would link the project to the Railbelt load centers. Information obtained from the Federal Power Commission is presented in Appendix II. The APA reports on marketability of project power and the transmission system to serve the project are presented as Sections G and H of this appendix.

FORMULATION AND EVALUATION CRITERIA

National Economic Development (NED) and preservation and enhancement of Environmental Quality (EQ) were considered as equal objectives during the formulation studies. Impacts were measured in terms of contributions to Regional Development (RD) and Social Well-Being (SWB), as well as National Economic Development and Environmental Quality. In accordance with Principles and Standards, the development of the EQ plan was implemented after it was determined that an alternative power source was economically justified. The contributions to the NED and EQ accounts represent the overall beneficial and adverse impacts of the proposed action, and the net gains of the RD account are measured by the effect on regional income, employment, population, economic base, environment, and social development. Impact on the SWB account is measured by the regional effect on real income, security of life, health, and safety, education, cultural and recreational opportunities, and emergency preparedness.

Technical Criteria: The general guidelines which were followed during plan formulation entail three basic criteria: (1) That the growth in electrical power demand will be as projected by the Alaska Power Administration; (2) That the power generation development from any source or sources will satisfy projected needs; and (3) That a plan considered for development must be technically feasible. The APA load projections are based on a number of factors, one of which is population growth. In their analysis, APA utilized a number of population projections rather than adopting the Office of Business/Economic Research Science (OBERS) estimates per se. This was done because the OBERS projections to this time have proven unrepresentative of observed Alaskan growth. A more detailed discussion of the energy projections is presented in Section G of this appendix.

By assuming that power development would proceed to meet demand rather than exceed demand, the proposed system of development would require stage development to insure that excessive energy production would not stimulate the energy demand. In short, development was staged to meet the demand that could have been expected had conventional energy development proceeded under existing rates of growth.

Inherent in the NED objective is the criterion that the alternatives considered be technically feasible under existing engineering capabilities. This criterion is of particular importance when considering such alternatives as geothermal, hydro, solar, and wind power resources. If the technical capabilities of the alternatives considered are not presently adequate to complement or enhance the existing integrated energy system of the study area, little value was given to the potential of the resource to meet loads in the period of this analysis (1985-1995). Analysis in this manner assured economic feasibility consistent with known technology.

National Economic Development Criteria: The economic criterion used in evaluating technically feasible alternative plans is similar to that used in most feasibility reports submitted for Congressional review.

Tangible benefits must exceed total project economic costs, and each separable unit of work or purpose must provide benefits at least equal to its cost. Therefore, because the selected plan could provide incidental benefits in addition to those associated with electrical power generation, the cost of each benefit is allocated in proportion to individual benefits applied against the portion of the total cost which is shared by all benefit categories.

In analyzing the benefits and costs, it is imperative that the two values be expressed in comparable quantitative economic terms. The annual costs are based on a 100-year amortization period, an interest rate of 6-1/8 percent, and January 1975 price levels. The annual charges include the amortized construction and interest costs, and the estimated average annual operations, maintenance and replacement costs. Benefits are based on the present worth of the amortized revenue that would accrue over the 100-year economic life of the project. Power benefits represent the cost of providing the same energy by conventional thermal electric generation. The cost of alternative thermal generation is determined by the Federal Power Commission.

Finally, the scope of the plan is determined by the system of development which is technically feasible and which gives maximum net benefits.

Environmental Quality Criteria: The following criteria were considered in formulating the Environmental Quality Plan.

a. Conservation of esthetics, natural values, and other desirable environmental effects or features are considered to be basic EQ plan objectives.

b. A systematic approach was used to insure integration of the natural and social sciences and environmental design arts in planning and utilization.

c. An overall system assessment of operational effects was made, as well as consideration of the local project area.

d. Alternative courses of action were developed for any proposal which involved conflicts concerning uses of available resources.

e. All known environmental impacts of any proposed action were evaluated, including effects which cannot be avoided, alternatives to proposed actions, the relationship of local short-term uses and of long-term productivity, and a determination of any irreversible and irretrievable resource commitment.

f. Detrimental environmental effects were avoided to the extent possible, but where these are unavoidable, practicable mitigating features were included.

ECONOMIC BASE AND AREA NEEDS

THE STUDY AREA 1/

In keeping with the directive of Congress, the study area for this report encompasses the Southcentral Railbelt area of Alaska. This area includes Alaska's largest concentration of population and economic activity. Because of its great size and diversity, the study area is divided into three subregions for purposes of description. These are denoted as the Cook Inlet, Gulf of Alaska and Tanana subregions. Plate C-1 shows the study area in relation to the State of Alaska, and Plates C-2, C-3, and C-4 depict the individual subregions. The following discussion of the study area and its economy is designed to provide information on which to base judgment as to water resource development needs and impacts of any proposed solutions. For the purposes of this report, the population and employment projections of the Alaska Department of Labor have been used in lieu of OBERS projections. This course was taken because the observed population growth within the State has been considerably higher than that estimated by OBERS. The basis for deviating from OBERS is more thoroughly presented herein and in Section G of this appendix.

CLIMATE

Cook Inlet Subregion: At Anchorage, average annual precipitation is 14.7 inches with one-half to two-thirds falling during the period July through November. The mean daily January temperature is +12.1^{o}F and the mean July temperature is +58.2^{o}F. Record low and high temperatures at Anchorage are -38^{o}F and +86^{o}F. There are about 125 frost-free days per year with the last freeze in the spring occurring about 11 May, and the first fall freeze occurring about 18 September.

Gulf of Alaska Subregion: Inland of the Chugach Mountains is an area characterized by a semiarid climate with relatively clear skies and extreme temperatures. The mean annual temperature is generally about 29^{o}F. The southern flank of these mountains is somewhat warmer. The first freeze in the fall occurs around 14 September, and the last freeze in the spring usually occurs about 24 May, giving an annual average of about 110 frost-free days. Precipitation varies widely, as demonstrated by annual averages of 60 inches at Valdez, and 80 inches at Cordova, with 100-300 percent more precipitation in the mountains than in the lowlands. Earth tremors are common, especially along the southern portion of this subregion.

1/ Note: Most of the information in this section of the report has been taken from Resources of Alaska, compiled in July 1974 by the Resource Planning Team of the Joint Federal-State Land Use Planning Commission for Alaska. It is the most comprehensive and up-to-date compendium of resource information for the study area.

Tanana Subregion: The average annual precipitation is 11.3 inches at Fairbanks, and over one-half of the annual precipitation falls in the spring and summer months. At Fairbanks, record high and low temperatures are about 99°F and -65°F. The mean daily January temperature is about -16°F and the mean daily July temperature is about 60°F. Fairbanks averages 89 frost-free days per year.

TOPOGRAPHY AND HYDROLOGY

Cook Inlet Subregion: The subregion is characterized by rugged mountain ranges surrounding a central lowland and the ocean arm of Cook Inlet. Moderate precipitation, including the annual snow pack combined with glacial melt, generally provides a plentiful water supply. On the west side of Cook Inlet, the largest rivers are the Chakachatna and Beluga. To the north of Cook Inlet is the Susitna River, sixth largest river system in Alaska with a total drainage area of 19,400 square miles. This system includes the major tributaries: Yentna, Chulitna, Talkeetna, and Tyonek Rivers.

To the east of the Susitna are the drainages of the Matanuska (2,170 square miles), Knik, and Eagle Rivers. The rivers of the Kenai Peninsula are relatively small, with the largest being the Kenai River with a 2,000-square-mile drainage area.

The low ground area within the subregion is generally free of permafrost, while permanently frozen ground may exist in the higher elevations. The Kenai Mountains and the Aleutian and Alaska Ranges contain glaciers.

The Cook Inlet subregion contains Anchorage, Alaska's largest city, as well as the communities of Kenai, Soldotna, and Homer. It also contains one of Alaska's important farming areas in the Matanuska-Susitna valleys, with Palmer being the hub city. The subregion contains the "Railbelt," extending from the deep-water ports of Seward and Whittier through Anchorage to Fairbanks. A major share of the State's highway system is also here; however, large areas remain without road access.

Gulf of Alaska Subregion: This subregion includes parts of the Alaska Range, Wrangell and Chugach-Kenai Mountains, and the Copper River lowland. Massive mountains, rising in altitude to more than 16,000 feet in the Wrangells support the largest ice fields and glaciers in North America.

Principal watershed of the subregion is the Copper River system with a 24,400-square-mile drainage area. It drains the south slopes of the Alaska Range, south and west slopes of the Wrangell Mountains, most of the Chugach Range, the Copper River basin, and a small section of the Talkeetna Mountains. The land surface is largely rough and mountainous, with a narrow coastal plain along the Gulf and broad lake basins in the Gulkana area between the mountain systems.

The coastal portion of the subregion is generally free of permafrost, while the interior portion is underlain by discontinuous permafrost. Glaciers cover most of the higher peaks in the Wrangell Mountains and nearly all of the crest of the Kenai-Chugach Mountains, which separate the coastal area from the interior.

Most of the larger communities in this subregion are accessible by road. A notable exception is Cordova. Whittier is linked to Portage by rail and to Valdez by ferry.

Tanana Subregion: A broad level-to-rolling plain occupies the central and southwestern part of the subregion, flanked by mountains to the north and south. The entire subregion is drained by the Tanana River and its tributaries.

The Tanana subregion lies within the discontinuous permafrost zone of the State. Glaciers occur along most of the southern boundary of the area.

The Tanana subregion has one of the most developed surface transportation systems in Alaska. The Alaska Highway bisects the area; the Tok Cutoff and Richardson Highway both provide all-weather routes to Anchorage, as does the Parks Highway.

WILDLIFE--FISHERIES

Alaska is endowed with geographic characteristics that make possible a highly productive fishing region. Alaska's coast covers a broad geographical range in latitude and longitude, and includes every type of coastal system found in the Lower 48 States, with the exception of the tropical area. Coastal Alaska, with an extensive intertidal and littoral area, provides the environment necessary to sustain its fisheries production.

Following is a description of the fishery resources of the study area by subregion.

Cook Inlet Subregion: Pink salmon are the most abundant anadromous fish in the area with the greatest numbers arriving to spawn in even-numbered years. Red salmon are next in abundance and found primarily in the Kenai and Tustumena Lake drainages. Chum and silver salmon are found in most of the coastal streams, and king salmon are present in streams north of Anchor River on the east and Beluga River on the west.

Dolly Varden are found throughout the area; some remain in fresh water, others are anadromous. Rainbow trout inhabit some lakes and streams on the Kenai Peninsula and most of the Susitna River drainage.

Grayling are indigenous to the Susitna River drainage and other west side streams flowing into Cook Inlet, and they have been successfully introduced into freshwater lakes. Whitefish and lake trout are also found in the area.

Sport fisheries are intensively used in many waters of the subregion. This area contains over half the people of the State as well as a majority of the road network. Sport anglers use cars, airplanes, boats, and snowmachines to reach most parts of the area. Sport fish available are rainbow trout, arctic grayling, Dolly Varden, arctic char, lake trout, burbot, whitefish, black rockfish, and five species of salmon. Razor and other clam digging is pursued on the beaches of the Kenai Peninsula and west shores of Cook Inlet.

Freshwater sport fishing is available throughout the area. Saltwater fishing in Cook Inlet is confined mostly to Kachemak Bay and at the mouth of Deep Creek, south of Kenai. The numbers of fish and shellfish harvested by sport fishermen are unknown. Many lakes throughout the area are stocked with salmon, trout, or grayling.

Gulf of Alaska Subregion: Since much of the subregion is mountainous, the fisheries habitat is characterized by many short, steep coastal streams and the rather large drainage of the Copper River. The entire mountainous area is heavily glaciated, and many of the streams carry a high load of glacial sediment. There is a paucity of lakes for such a large area.

Pink and chum salmon utilize the short coastal streams. Silver salmon spawn and rear in somewhat larger streams where the young can survive for at least one year. Red salmon are found primarily in drainages that contain a lake or lakes, such as many lakes in the Copper River drainage. King salmon spawn in the upper reaches of the Copper River drainage. Dolly Varden are present throughout the coastal streams systems. Arctic grayling are confined to the clearwater systems in the upper portion of the Copper River drainage and have been successfully introduced in the Cordova area. Rainbow trout are present as well as lake trout, whitefish, and burbot.

Important marine fish and shellfish are herring, halibut, red snapper, black cod, king crab, tanner and Dungeness crab, shrimp, scallops, and razor clams.

The most sought-after sport fish are the five species of Pacific salmon, Dolly Varden, rainbow trout, Arctic grayling. lake trout, and burbot.

Tanana Subregion: Chum salmon spawn in a number of tributaries of the Tanana River. Silver salmon spawn and rear in the Chatanika and Salcha Rivers and Clearwater Creek. King salmon spawn and rear in the same streams as the silver salmon plus the Goodpaster, Delta, and Chena Rivers. Grayling, whitefish, and northern pike are present throughout the area. Lake trout, sheefish, and cisco are scattered in the various drainages.

Sport fishing is assisted by the extensive road system. The Tanana drainage receives the greatest angling pressure in the interior and arctic areas. Grayling receives more pressure than any other species. Other species sought are lake trout, sheefish, and whitefish.

WILDLIFE--BIRDS

Cook Inlet Subregion: Primary waterfowl habitat lies in the Matanuska-Susitna River glacial outwash plain and the Kenai lowland. Trumpeter swans are the most important breeding waterfowl; geese do not nest in appreciable numbers, and ducks are in lower numbers than in interior habitats. During migration, however, some areas become highly impacted with ducks and geese. As many as 70,000 have been estimated to be in the Susitna River Valley at one time.

Coastal areas support moderate populations of bald eagles and peregrine falcons. Rainy, Broad, and Windy Passes are migration routes for peregrines which move through the Susitna River Valley.

Golden eagles and gyrfalcons occupy the more upland areas. Great horned owls, great grey owls, and rough-legged hawks are some of the characteristic raptors of the spruce-birch forest of the more northern areas. Other raptors known to breed in this subregion include goshawks, sharp-shinned hawks, red-tailed hawks, Harlan's hawks, marsh hawks, ospreys, pigeon hawks, and short-eared owls.

Colonial nesting seabirds are not abundant; however, several colonies have been identified and others probably exist.

The marshes and lake shores support a host of shore and wading birds, and the entire subregion is host at one time or another to most of the passerine species that occur in Alaska.

Resident game birds of forest and other habitats are the spruce grouse and willow, rock and white-tailed ptarmigan.

Gulf of Alaska Subregion: Prince William Sound is an important migration route for many of waterfowl.

The Copper River delta and the Bering Glacier outwash plain contain about 15-18 townships of exceptional value to waterfowl. It is the principal nesting area for the world's population of dusky Canada geese, and may produce more ducks per square mile than any other known area in Alaska except the Yukon Flats. Trumpeter swans reach their greatest densities here. In spite of its unique nesting populations, the delta is probably most important as a staging and feeding area for migratory fowl bound to and from the arctic and subarctic nesting areas to the north.

At the confluence of the Bremner and Copper Rivers, 40 miles from the mouth of the latter, are several townships of trumpeter swan habitat, second only to the Copper River delta in importance.

The entire coastal area is habitat for seabirds of various species. At least 48 major seabird colonies have been identified in this subregion, and undoubtedly many more exist.

The nearly 200 square miles of tidal flats in Orca Inlet and the Copper River delta probably support one of the greatest remaining concentrations of birdlife in existence.

Resident game birds of forest, treeless, and other habitats are spruce, ruffed, and sharp-tailed grouse, willow, rock, and white-tailed ptarmigan.

Tanana Subregion: This subregion includes waterfowl habitat along the Tanana River and on tributary streams. Although it is primarily a production area, large numbers of ducks and geese utilize portions of the subregion as resting and foraging areas during migration. Primary species are trumpeter swans, white-fronted and lesser Canada geese, widgeon, scaup, pintail, green-winged teal, mallards, and canvasbacks. Nearly all major rivers of the interior regions have small intermittent areas of flood plains that are utilized extensively by nesting waterfowl.

Peregrine falcons, ospreys, and bald eagles are known to nest in the Tanana Valley. Other raptors present throughout the area include: goshawks and sharp-shinned hawks; great-horned, great gray, and boreal owls, generally in forested areas; and red-tailed, Harlan's, Swainson's, rough-legged, marsh, pigeon, and sparrow hawks and gyrfalcons (the latter usually above 2,500-foot elevation). Snowy and short-eared owls range over the open country.

The only seabirds likely to be found in this region are herring, mew, and Bonaparte's gulls, arctic terns, and long-tailed jaegers.

Resident game birds of forest and other habitats are spruce, ruffed, and sharp-tailed grouse, and willow, rock, and white-tailed ptarmigan.

WILDLIFE--MAMMALS

Cook Inlet Subregion: Some of Alaska's densest black bear populations live on the Kenai Peninsula, in the Susitna Valley, and in the mountains between Turnagain and Knik Arms. Density is lower in the interior regions.

The brown-grizzly bear is common throughout the subregion with lowest numbers in the Anchorage area and western Kenai Peninsula.

Wolves are most common in the interior and Susitna drainage portions of the subregion.

Wolverine are common throughout except in areas of high population. They are most abundant in the interior portions of the subregion.

Several herds of barren ground caribou use portions of the subregion: the Nelchina herd in the northeast section, the McKinley herd in the northcentral section, and the Kenai herd on the Kenai Peninsula.

Dall sheep are present throughout the Alaska Range, Talkeetna, Chugach, and Kenai Mountains. Populations fluctuate in response to weather, range condition, and susceptibility to predation.

Moose are abundant throughout the subregion except in the high mountains. The Susitna Valley supports an excellent population, but the premier area is the Kenai National Moose Range, which boasts the highest population per unit of area in the world.

Mountain goats are found in low numbers in the Talkeetna Mountains and in moderate numbers on the Kenai Peninsula Range within the subregion.

Marine mammals that inhabit the waters of lower Cook Inlet are harbor seal, sea lion, sea otter, and various whales.

Other smaller mammals present include lynx, red fox, land otter, mink, marten, short-tailed weasel, beaver, muskrat, and snowshoe hare.

Gulf of Alaska Subregion: Black bears live throughout the subregion. Population varies from relatively high levels along the coastal areas to moderate levels in the interior areas.

Brown-grizzly bears occur throughout the subregion; the bears are less common on the west side of Prince William Sound than on the east. They are more numerous in the interior than along the coast.

Wolves are relatively abundant in the interior portions of the subregion, but quite scarce along the Prince William Sound coast. The interior population numbers about 300.

Wolverines are abundant in the interior, but not as common along the coast.

Sitka black-tailed deer are primarily confined to islands of Prince William Sound, but some occur on the mainland in the Cordova area.

Barren ground caribou inhabit the interior portion of the subregion, which contains a sizable amount of the Nelchina caribou herd's winter range.

Two distinct bison herds, the Chitina and Copper River, exist in the subregion.

Some of the most important Dall sheep range in the State is contained in this subregion.

Moose occur in greatest concentrations in the interior portions of the subregion, but have suffered a severe decline in recent years.

Mountain goats are abundant in the mountains of Prince William Sound, but present only in low numbers in the Wrangell Mountains and interior portions of the Chugach Mountains.

After being nearly wiped out in the 19th century, sea otters have made an amazing recovery. There are now about 6,000 in the Gulf of Alaska. Harbor seal, steller sea lion, and various whales are in the Gulf.

Other smaller mammals present include lynx, red fox, land otter, mink, marten, short-tailed weasel, beaver, muskrat, and snowshoe hare.

Tanana Subregion: Black bears live throughout the area. Grizzly bears are usually found in alpine-subalpine areas and sporadically in lowlands.

Wolves range throughout the area even near Fairbanks. Population densities are generally high.

Wolverines occur throughout the area.

Barren ground caribou of the Delta, Fortymile, McKinley, Mentasta, and Chisana herds use portions of this subregion.

Sizeable Dall sheep populations are supported by habitat in the Alaska Range, Mentasta-Nutzotin Mountains, and Tanana Hills-White Mountains.

Moose are widely scattered and relatively abundant throughout the subregion.

The small mammal population is, in general, comprised of the same species as found in the other two subregions.

AGRICULTURE AND RANGE

Cook Inlet Subregion: There are approximately 2.6 million acres suitable for production of cultivated crops in the Cook Inlet-Susitna lowlands up to elevations of 1,500 feet. Roughly 30 percent is located on the west side of the Kenai Peninsula; the balance is located in the valleys of the Matanuska and Susitna Rivers and their tributaries, with a small part near the lower Beluga River. More than 70 percent of the State's current agricultural production is derived from these areas of the subregion.

In general, only the northern portions of the lowlands receive enough moisture for continued intensive use. Most of the area will require irrigation for best results. The growing season averages up to 110 days at lower elevations, adequate for all cool-weather crops, except in the northern parts where it drops to 87. The index of Growing Degree Days (accumulation of daily mean temperatures in excess of 40°F) varies from 1,355 in the south, to 1,940 in the mid-region and 1,785 in the north portions. This index decreases by about 300 for each thousand-foot increase in elevation. These factors impose limitations as to which crops may be produced successfully at different locations. At present, less than one percent of the land is in production, and gross income is less than $4 million.

The subregion's grazing season averages about five months. Limited grasslands occur on the lower Kenai Peninsula, stream deltas, higher slopes, and on burned-over forest lands. Woodland pastures are generally of marginal value. The short grazing season is a distinct disadvantage which may or may not be overcome by proximity of croplands.

Gulf of Alaska Subregion: Potential agricultural and range resources of the subregion are mainly along the Copper and Chitina River valleys. Narrow coastal strips and stream deltas along the coast might be grazed during the summers with removal of the animals imperative for the balance of the year.

Climate of the interior is continental in nature, with warm summers and cold winters. Elevation is generally 1,000 feet or more. The area lies in the "rain shadow" of high coastal mountains, and summer precipitation is typically below 10 inches. The proximity of very high mountains and downward flows of cold air combine to render the area susceptible to summer frosts and limit reliable agricultural production to gardens and forage crops.

In its natural forested state, the lower land area has relatively little range forage value.

Some 70 farms are located in the subregion, mostly active in the Kenny Lake area. None are operated on a full-time basis. With the long winter feeding period, it is unlikely that any extensive livestock industry will develop in the near future.

Tanana Subregion: Some 3.6 million acres are suitable for production of cultivated crops. The crop lands include approximately 810,000 acres which are lowlands of the Tanana and tributary rivers, another 840,000 acres located on the Yukon-Tanana uplands east of Nenana, and 860,000 acres of good upland soils located on the northern foothills of the Alaska Range and Kuskokwim Mountains, generally south and west of Nenana.

The Tanana and upper Yukon subregions share the greatest temperature extremes in the State. Higher elevations and lowlands with poor air drainage are subject to danger of summer frost. Aside from these local drawbacks, the subregion has the best record in the State for maturing hardy grains, normally the highest criterion for assessing northern agricultural potentials.

Fairbanks, approximately in the middle of the agricultural area, averages 1,996 growing degrees days, 57 days with temperatures 70°F or over, 89 frost-free days, and 8.06 inches of summer precipitation. This is both warmer and drier than either Tanana or Delta Junction, but the entire area is suitable for cool weather forages, vegetables, and hardy small grains. For sustained commercial production, fertilizers are necessary and irrigation is highly desirable.

There are no extensive grass range lands for a livestock economy. However, with improved range near crop lands, shelter, and hardy animals, the subregion could have a carrying capacity of approximately 650,000 animal units.

FORESTRY

Cook Inlet Subregion: Four forest ecosystems are represented in the subregion. The coastal Sitka spruce-western hemlock ecosystem is located on the Kenai Peninsula and the lands west of Cook Inlet. It covers 1,641,000 acres. The bottomland spruce-poplar forests cover 675,000 acres and are located primarily in the Susitna and Matanuska Valleys, where spruce and cottonwood are of important commercial value. The upland spruce-hardwood forest covers a large area of 3,570,000 acres, and has commercial forest stands on about one-fourth of the acreage, primarily in the Susitna Valley. The lowland spruce-hardwood forest ecosystem has a land area of 2,867,000 acres, and can be considered noncommercial. "Commercial" refers strictly to an annual volume growth rate, not to whether the timber is accessible, or has an economic commercial value or a market.

Of the 6,362,000 acres of inventoried forest land, commercial and subcommercial forests occupy 4,004,000 acres, and noncommercial forests 2,358,000 acres. The commercial forest land contains 7.0 billion board feet (International 1/4-inch rule) of sawtimber, of which 2.7 billion board feet are hardwood--primarily cottonwood, and 4.3 billion board feet are white and Sitka spruce. An additional 66.1 million board feet of dead but salvable timber could be added to the above.

The average volume is approximately 1,752 board feet/acre, but can range from 100 board feet/acre to about 25,000 board feet per acre. A general rule of thumb is 15 percent deduction for defect and cull. Stand stocking is generally not as high as it could be if the stands were fully regulated and managed. Regeneration appears to be adequate. In general, the trees reach maturity for harvesting in 80 to 100 years, depending on site and product to be manufactured. The total net growth volume is about 1.8 billion board feet.

The growth volume for the entire subregion is sufficient to supply several pulp mills, particle board mills, or large sawmills, if the forested lands were properly developed and managed for timber production. Presently, only a few small mills cut timber for various local use products. Some cants are produced for export to Japan for further processing. Some cottonwood logs have been exported to determine their suitability for paneling. Local markets exist and are expanding, and local and foreign demand for timber is increasing.

Gulf of Alaska Subregion: The interior forest of three different forest systems covers a total of 4,998,000 acres. The bottomland spruce-poplar forest ecosystem, 303,000 acres, is located primarily in the Copper and Chitina River valleys and can be considered essentially commercial forest land. The upland spruce-hardwood forest covers 2,211,000 acres and has local stands of commercial spruce and hardwoods.

Most of the forest stands in this ecosystem are noncommercial because of their slow growth due to poor site conditions. The lowland spruce-hardwood ecosystem covers 2,484,000 acres and is noncommercial throughout.

The best timber production land is in native village withdrawals and native regional deficiency areas. The major acreage of forested land lies in Federal control.

Two forest inventories were conducted in the subregion; an extensive inventory covering the entire basin, and a relatively intensive inventory covering the better bottomland forests. The following data are taken from the basinwide inventory, which lists 4,431,000 acres of total forest land for the Copper River basin, of which 1,178,000 acres are commercial and subcommercial timber, and 3,253,000 acres are noncommercial. Of the 2,064,000 acres of coastal forest, about 901,000 acres are considered commercial and subcommercial.

Total standing volume in the interior forests is 1.5 billion board feet (International 1/4-inch rule) consisting of 1.4 billion board feet of spruce and 52.5 million board feet of hardwoods, half of which is birch. Average volume per acre is 1,240 board feet and total annual volume growth is 28.5 million board feet. This volume can be considered the potential sustained yield for the entire Copper River basin.

The total volume of the coastal forests is about 19.8 billion board feet (International 1/4-inch rule), 67 percent of which is Sitka spruce, and 28 percent is western hemlock. The potential annual harvest on the Chugach National Forest lands is 103 million board feet (International 1/4-inch rule), plus an additional 20 million board feet from other lands.

Regeneration in both coastal and interior forest systems appears to be adequate, but could be improved with higher stocking density. Rotation ages for the interior forests are about 100 to 120 years, and 70 to 210 years in the coastal type.

Several sawmills operate in the subregion, some sporadically and others, like the mills at Seward and Whittier, on a full-time basis. The mills produce a variety of products for local markets and cants for export to Japan.

Tanana Subregion: The three interior forest ecosystems occupy a considerable area in this subregion. The bottomland spruce-poplar ecosystem (1.2 million acres) is found in the flood plains and on river terraces along all the major streams--primarily the Tanana River. This system can be considered commercial throughout its range.

The upland spruce-hardwood ecosystem has the greatest area, 7.3 million acres. It is partly commercial depending on the site. Much of the forest is noncommercial because the trees are very slow growing and occupy sites with thin soils, steep and dry hillsides, and northerly slopes.

The lowland spruce-hardwood ecosystem is found on poorly drained soils, usually in muskeg areas, and covers 5,184,000 acres. It should be considered noncommercial throughout its range due to small size of black spruce and hardwoods, and extremely slow growth rates. The term commercial refers to trees or forest stands adding volume growth in excess of 20 cubic feet per acre each year, and does not consider accessibility.

The total volume of commercial and subcommercial standing timber is about 6.2 billion board feet. About 5.2 billion board feet of this are spruce and about 1.0 billion board feet are hardwoods (primarily birch). The overall average gross volume is 1,265 board feet/acre, and the total annual volume growth is about 26.5 million board feet.

This growth can be used as an indicator of the potential annual harvest for the entire subregion. Regeneration appears adequate, but most timber stands are naturally understocked and could produce more volume if intensively managed. Although rotation rates have not been precisely determined, they are estimated at 90 to 120 years depending on the site.

Several mills are currently operating in the subregion, some sporadically and some full-time. Most of the mills are small size and saw products for local use.

MINERALS AND ENERGY

Cook Inlet Subregion: Mineral resources are abundant, and in the future will become more important to the Alaskan economy. Oil and gas produced from fields in the Cook Inlet basin have far exceeded other minerals in value.

The oil and gas-bearing sedimentary rocks of the Cook Inlet basin may be as much as 25,000 feet thick. Reserves of 2.6 billion barrels of oil and five trillion cubic feet of gas are estimated to exist in the upper Cook Inlet. Total projected resources from the Cook Inlet basin may be as much as 7.9 billion barrels of oil and 14.6 trillion cubic feet of gas. The resource estimates include both onshore and offshore areas.

Coal resources are large and exceed more than 2-1/2 billion short tons. Coal is present in the Broad Pass, Sustina, Matanuska, and Kenai Tertiary coal fields. Broad Pass coal ranges from subbituminous on Costello Creek to lignite at Broad Pass. Reserve estimates for the Broad Pass field are 64 million tons of indicated coal. The Susitna coal deposits are in the basins of Beluga and Chulitna Rivers, and are as much as 2.4 billion short tons less than 1,000 feet deep. The Matanuska coal is in the Chickaloon formation, ranging in beds up to 23 feet in thickness. It is high volatile bituminous in rank, and some have coking properties. The Anthracite Ridge contains semi-anthracite coal beds. The total resource estimates are 137 million short tons less than 2,000 feet deep. The Kenai field has at least 30 coal beds from three to seven feet in thickness, and ranging from subbituminous to lignite in rank. Estimated resources are about 318 million short tons less than 1,000 feet deep.

Geothermal potential is high in the south part of the Alaska Range, where a volcanic belt is locally surmounted by volcanoes and lava fields; some of the volcanoes are still active and indicate deep heat reservoirs.

Clay deposits which can be used for brick manufacturing occur at Point Woronzof in the Anchorage area, at Sheep Mountain in the upper Matanuska Valley, and near Homer on the Kenai Peninsula.

Gypsum deposits occur on Sheep Mountain, about 50 miles northeast of Palmer. Reserves are calculated at 310,800 tons of indicated and 348,000 tons of inferred gypsum rock averaging 25 to 30 percent gypsum.

Limestone deposits of nearly pure calcium carbonate occur in the drainage of the Kings River and in Foggy Pass near Cantwell.

The Cook Inlet subregion is traversed by numerous metal provinces. The subregion contains deposits of gold, silver, antimony, iron, chromite, molybdenum, copper, lead, and zinc. Like most of Alaska, past metallic production has been primarily gold, about one million ounces. In addition, nearly 300,000 tons of chromite ore and small amounts of copper ore have been produced.

Gulf of Alaska Subregion: High oil and gas potential exists in the coastal section within the Gulf of Alaska province. The many oil and gas seeps and petroliferous beds in sedimentary rocks, which exceed 25,000 feet in thickness, have attracted intensive exploration by industry. Interest has now shifted to the Outer Continental Shelf, where the presence of many folds, the possibility of reservoir rocks, and lack of intense deformation indicate high possibilities of petroleum deposits. The Copper River lowlands have low to moderate oil potential.

Coal-bearing rocks have been mapped over 50 square miles near Bering and Kushtaka Lakes in the Bering River coal field. Similar rocks appear in the Robinson Mountains east of Bering Glacier. The coal ranges upward from low volatile bituminous in the southwestern part. The beds are a few feet to 60 feet thick. The coal in part of the field has coking properties.

Geothermal energy potential is high. The Wrangell Mountains are the site of recent volcanic activity and provide a favorable environment for heat reservoirs.

Some potential for cement may exist in the limestone beds exposed near McCarthy. The beds are several hundred feet thick and quite extensive.

Sand and gravel deposits of economic significance occur in the Copper River lowlands, the Chitina Valley, and adjacent tributaries.

Metallic minerals occur in several districts. Lodes in many parts of the Copper River region contain copper, gold, silver, molybdenum, antimony, nickel, iron, lead, and zinc, but only gold, copper, and by-product silver were mined commercially. The Kennicott mines near McCarthy, and mines in the southwestern and northeastern parts of Prince William Sound, accounted for most of the 690,000 short tons of copper produced in Alaska. Two or three million dollars worth of gold and silver were produced from lodes and as by-products of copper mining in the Prince William Sound district. Gold placer deposits produced 35,000 ounces of gold and a few ounces of platinum from the Chistochina, Slana, and Nizina districts.

Gold and copper lodes are in the Seward district and eastern part of the Kenai Peninsula. Copper, gold, silver, and molybdenum lodes are between the Chitina River and the crest of the Wrangell Mountains. Other mineralized sites occur throughout the subregion.

Tanana Subregion: Low potential for oil and gas exist in the basins within the subregion. There may be potential for gas in connection with coal beds in the Tanana basin. The remainder of the subregion is underlain by rocks that are nonporous or too structurally complex for petroleum accumulation.

Large coal deposits exist in the young basins which flank the northern front of the Alaska Range. The coal deposits in the Nenana coal field have been mined since about 1918 and are presently producing about 700,000 tons per year. The coal is lignite to subbituminous, occurs in beds 2-1/2 feet to over 50 feet in thickness, has low sulfur content, and is used for power generation and domestic use in Fairbanks. Coal resources for all fields in this belt are estimated at nearly 7 billion tons located less than 3,000 feet deep.

Geothermal potential is present in the subregion.

Sand and gravel potential is high. Outwash deposits fronting the Alaska Range are economically significant. The Nenana gravel near Healy could be utilized. Other localities with potential for sand and gravel occur in the flood plains of the Tanana River and its major tributaries.

Limestone containing a high content of calcium suitable for cement occurs in outcrops at Windy Creek and Foggy Pass near Cantwell and the railroad. Other deposits of limestone are in the Minto Flats-Dugan Hills area west of Fairbanks.

Metallic minerals are present in a number of districts. The mineral potential of the Hot Springs district is moderate and contains silver, lead, minor amounts of gold, iron, copper, and other copper associated minerals. Chromite is found south of Boulder Creek. Nickel minerals are found in the vicinity of Hot Springs Dome.

Tolovana district lodes contain gold, silver, antimony, mercury, chromium, nickel, and iron.

Fairbanks district lodes have produced important amounts of gold and smaller quantities of silver, lead, tungsten, and antimony ore.

Delta River district lodes contain gold and silver, molybdenum, antimony, copper, lead, zinc, nickel, and chromium minerals.

The Chisana district is well known for its lode deposits of gold, copper, silver, lead, zinc, molybdenum, iron, and antimony. Lode production from the Nabesna mine was substantial and consisted of gold and subordinate copper and silver.

HUMAN RESOURCES

Population: Since 1930, Alaska's rate of population growth has exceeded that of the contiguous United States, and even that of the western States. This population growth has been characterized by a relatively high rate of natural increase, which accounted for 60 percent of the 1950 to 1960 population increase, and 81 percent of the growth between 1960 and 1970. Increases in military population were significant in Alaska's growth up to 1960, after which it has remained fairly stable at about 33,000 persons, accounting for about 9 percent of total population.

Earliest records indicate that Alaska's population, around 1740 to 1780, consisted of an estimated 74,500 native people. Of this total, 40,000 were Eskimos, 16,000 were Aleuts, 6,900 were Athabascan Indians, and 11,800 were Tlingit, Haida and Tsimpshean Indians. The native population declined from that time to the early 20th century, apparently the result of social disruption and disease. About 1920, improved economic and health conditions reversed the decline in the native population, which is now growing rapidly but has yet to reach the level of the late 1700's.

Table C-1 shows the proportion of native residents in the various census divisions of the study area.

Table C-1

Percent of Native Population in the Study Area By Census Division, 1970

Census Division	Population	% Native
Anchorage	124,542	3
Cordova-McCarthy	1,857	15
Fairbanks	45,864	4
Kenai-Cook Inlet	14,250	7
Matanuska-Susitna	6,509	4
Seward	2,336	11
Southeast Fairbanks	4,179	12
Valdez-Chitina-Whittier	3,098	23
Yukon-Koyukuk	4,752	46

Source: Adapted from information in the 1970 Census and from the University of Alaska, Institute of Social, Economic and Governmental Research, March 1972, Vol. IX, No. 1.

Published in: Alaska Statistical Review, Department of Economic Development, Dec. 1972.

A high rate of natural increase plus migration from the States boosted the population from 128,000 in 1950 to 227,000 in 1960. By 1970, the population had advanced to 302,000 and it is now estimated to be 386,000. Table C-2 shows Railbelt area population in relation to State totals.

Table C-2

Study Area Population As Percent of Total

Year	Total Alaska	Study Area 1/	Percent of Total
1880	33,426	6,920	21
1890	32,052	8,445	26
1900	63,592	15,600	25
1910	64,356	25,964	40
1920	55,036	19,137	35
1940	72,524	25,226	35
1950	128,643	73,101	57
1960	226,167	157,979	70
1970	302,173	220,271	73
1973	330,365	245,291	74

Source: Estimate from Alaska Regional Population and Employment, G. W. Rogers.

Source Note: Unless otherwise noted, all population statistics for 1960 and prior years are from G.W. Rogers and R. A. Cooley, Alaska's Population and Economy, all population statistics for 1970 are from the U.S. Census, and population estimates for 1971 are from the Alaska Department of Labor.

Published in: Alaska Statistical Review, Department of Economic Development, Dec. 1972.

1/ The boundaries of the study area do not coincide with census districts, and, therefore, population figures for the study area are approximate.

The Southcentral Railbelt area of Alaska contains the State's two largest population centers, Anchorage and Fairbanks, and almost three-fourths of the State's population. The Anchorage area alone has over half the residents in the State.

EMPLOYMENT

Alaska's civilian workforce amounted to 148,000 persons in 1974. The largest sector was government with 30 percent of the number employed. The next most important sector was trade followed by the service sector. Table C-3 provides a tabulation of Alaskan employment.

Labor Force Summary--1974

	Annual Average
TOTAL	148,900
Total Unemployment	14,900
Percent of Labor Force	10.0
Total Employment	134,000
TOTAL Non-Agriculture	128,200
Mining	3,000
Metal Mining	200
Oil & Gas	2,600
Other Mining	200
Contract Construction	14,100
Manufacturing	9,600
Food Processing	4,300
Logging-Lumber & Pulp	3,600
Other Manufacturing	1,700
Transp.-Comm. & Pub. Utilities	12,400
Trucking & Warehousing	2,200
Water Transportation	1,000
Air Transportation	4,000
Other Transportation	1,300
Comm. & Public Utilities	3,900
Trade	21,100
Wholesale	4,000
Retail	17,100
Gen. Mdse. & Apparel	4,100
Food Stores	2,000
Eating & Drinking Places	5,000
Other Retail	6,000
Finance-Ins. & Real Estate	4,900
Services	18,300
Hotel, Motels, & Lodges	2,500
Personal Services	800
Business Services	3,000
Medical Services	3,800
Other Services	8,200

Table C-3 (Continued)

Labor Force Summary--1974

	Annual Average
Government	43,800
Federal	18,000
State	14,200
Local	11,600
Misc. & Unclassified	1,000

Source: Alaska Department of Labor

Table C-4 provides location quotients for the various employment sectors. The location quotients compare the share of total personal income from an industry in Alaska to the share of total personal income arising from the same industry for the United States. A quotient greater than one indicates that Alaska is more dependent on that industry than the U.S. as a whole.

Table C-4

Location Quotients for Alaska
Vis-A-Vis United States (1960, 1971)

	1960	1971
Mining	1.6	3.7
Contract Construction	2.2	1.8
Manufacturing	.2	.2
Transportation, Communications and Public Utilities	1.3	1.5
Trade	.7	.8
Finance, Insurance, and Real Estate	.5	.6
Service	.7	.8
Government (Excludes Military)	2.8	2.3

Source: Derived from data in Survey of Current Business and Statistical Abstract of United States, both compiled by the U. S. Department of Commerce.

Published in: Alaska Statistical Review, Department of Economic Development, 1972 Edition.

Alaska has experienced unemployment rates consistently higher than the national average. In 1974, Anchorage and Fairbanks experienced an average unemployment rate of 8.6 percent, somewhat lower than the statewide 10 percent rate of unemployment.

INCOME

Table C-5 shows the per capita personal income for Alaska, Far West region, and U.S. average for 1970 through 1973. This table reduces Alaskan income by a 25 percent cost of living adjustment to show an estimated real per capita income relative to other parts of the United States.

Table C-5

Per Capita Personal Income for Alaska, Far West Regions, and U.S. Average

Year	Alaska	Alaska -25% COL	Percent of U.S. Average	Far West Region	U.S. Average
1970	$4,603	$3,452	87.6	$4,346	$3,943
1971	4,907	3,680	88.4	4,535	4,164
1972	5,141	3,856	85.8	4,866	4,492
1973	5,613	4,210	85.6	5,322	4,918

Source: Survey of Current Business

Published in: Alaska Statistical Review Department of Economic Development, Supplement to December 1972 edition.

EDUCATION

Enrollment in primary and secondary schools grew at a slightly faster rate than Alaska's total population over the period since statehood. As of 1970, a significantly higher share of personal income in Alaska went to education than for the nation, and Alaska's pupil-teacher ratio was slightly more favorable than the U.S. average.

ECONOMY OF THE STUDY AREA

The Southcentral Railbelt area of Alaska is the focus of continuing substantial growth in economic activity. Construction of the trans-Alaska oil pipeline is providing the primary impetus, with impacts being felt in virtually all sectors of the economy. A continued high level of Federal Government spending coupled with substantial State spending is supporting the growth. This expansion is expected to continue for at least five to seven years, supported largely by activities of, or relating to, the petroleum industry. Table C-6 provides an indication of these recent trends for the Alaskan economy.

TABLE C-6
ALASKAN ECONOMIC INDICATORS

		1970	1971	1972	1973	1974	1975*
	Total Resident Population	302.4	311.0	322.1	330.4	351.2	386.3
Thousands	Labor Force	108.2	115.9	122.9	129.6	148.9	176.5
	Total Employment	98.5	103.8	110.0	115.6	134.0	160.5
	Wage & Salary Employment	93.1	98.3	104.2	109.9	128.2	154.5
	Number Unemployed	9.7	12.1	12.9	13.9	14.9	16.0
	Percent Unemployed	9.0 %	10.4 %	10.5 %	10.7 %	10.0 %	9.1%
Millions of $	Wage & Salary Payments	$1,116.2	$1,283.7	$1,422.7	$1,546.8	$2,078.0	$3,100.0
	Total Personal Income	1,412.8	1,548.3	1,697.1	1,957.8	2,398.0	3,500.0
	Alaska Gross Product	2,196.4	2,354.7	2,508.3	2,756.3	3,790.0	5,800.0

*Estimates

Source: 1970-74 Personal Income from U.S. Department of Commerce; 1970-73 Gross Product from Man in the Arctic Program, ISEGR, University of Alaska; 1974 Gross Product by Division of Economic Enterprise; 1975 Projections by Division of Economic Enterprise.

Published in: The Alaskan Economy, Department of Commerce and Economic Development, Mid-Year Review, 1975.

Note: Unless otherwise noted, all tables and graphs in this section of the report are taken from The Alaskan Economy.

Mineral Production: Exploration and development activity in the mineral industry is increasing following a short slack period. A long-term trend of increasing value in mineral production continues, primarily reflecting increased product prices as shown in Table C-7.

TABLE C-7
MINERAL INDUSTRY INDICATORS
(Value in Thousands of Current Dollars)

Production		1971	1972	1973	1974 [P]
Petroleum:	Value	$257,562	$235,444	$261,877	$438,540
	Volume - 1,000 42 gal. barrels	79,494	72,893	72,323	71,540
Natural Gas.	Value	$ 17,878	$ 18,463	$ 19,483	$ 29,668
	Volume - MMCF	121,618	125,596	131,007	144,021
Sand & Gravel:	Value	$ 32,806	$ 15,214	$ 19,913	$ 24,936
	Volume - 1,000 short tons	23,817	14,187	14,999	18.740
Gold:	Value	$ 537	$ 506	$ 695	$ 1,318
	Volume - Troy ounces	13,012	8,639	7,107	8,185
Other Minerals:	Value	$ 14,040	$ 16,511	$ 26,821	$ 28,746
Total		$322,823	$286,038	$328,789	$523,208
Employment					
Petroleum Industry		2,090	1,792	1,671	2,586
All Other Minerals		340	321	296	390
Total Mining		2,430	2,113	1,967	2,976

[P] Preliminary

Source: U. S. Department of the Interior: Bureau of Mines, Alaska Department of Labor.

Oil production in the Cook Inlet reached its peak in 1970 and has been declining slowly since then. Continued development of proven fields is expected until completion of Alyeska's pipeline allows Prudhoe Bay oil to be produced, now projected for mid-1977. Copper, gold, and coal are the primary objectives of current hard mineral exploration activity. Despite the extensive mineral potential, the mining industry presently faces a proposed State severance tax on hard rock minerals, strict environmental constraints, and complicated land access problems linked to native land claims and Department of the Interior land withdrawals. New interest in steam coal, particularly by the Japanese, will attract investigation of coal fields in the Matanuska Valley and the Railbelt vicinity. Further exploration of the Beluga River coal fields is anticipated, accompanied by related research on refinement processes.

Fisheries: Of the world's 150 billion pound annual fish harvest, more than 4.5 billion pounds come from the waters adjacent to Alaska. Among the states, Alaska usually ranks first in value of fish products produced, and third or fourth in terms of volume. Salmon accounts for the largest portion of the Alaskan fishing industry and the catch tends to be cyclic from year to year, as suggested in Graph C-1.

GRAPH C-1

Value to Fisherman by Region
(1960 - 1971)

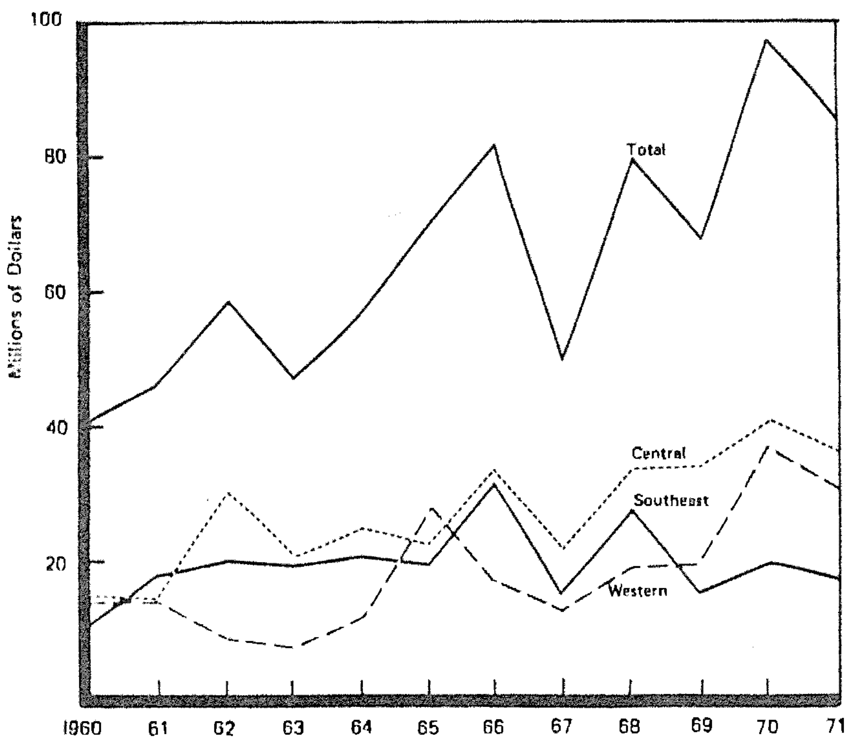


Table C-8 shows the size and value of the fish catch in the region that closely coincides with the study area.

TABLE C-8

CENTRAL ALASKA REGION CATCH AND GROSS VALUE TO THE FISHERMEN
1960 - 1972
(Catch in Millions of Lbs., Value in Thousands of Dollars)

Year	Salmon Lbs.	Salmon Value	Shellfish Lbs.	Shellfish Value	Other Fish Lbs.	Other Fish Value	Total Lbs.	Total Value
1960	84.2	$11,734	36.1	$ 2,789	6.1	$ 603	126.3	$15,126
1961	77.0	9,463	54.5	4,380	4.1	495	135.5	14,338
1962	144.8	21,851	63.5	5,663	9.4	2,502	217.7	30,015
1963	93.3	11,906	70.6	6,409	11.1	1,944	175.0	20,259
1964	146.4	16,958	64.7	6,147	8.2	1,314	219.3	24,419
1965	73.2	10,178	114.1	10,691	7.9	1,383	195.2	22,252
1966	116.6	17,163	144.3	13,142	15.6	3,117	276.6	33,421
1967	47.6	9,767	129.8	12,175	13.7	1,645	191.1	21,708
1968	111.8	17,680	90.8	14,492	12.7	1,546	215.3	33,719
1969	121.3	19,802	85.7	10,296	18.4	3,680	225.4	33,777
1970	140.1	23,774	13.6	12,025	15.6	4,882	269.3	40,681
1971	109.9	19,465	129.8	12,353	19.0	4,840	256.6	36,658
1972	73.3	16,344	140.9	17,049	19.6	9,380	233.8	44,773

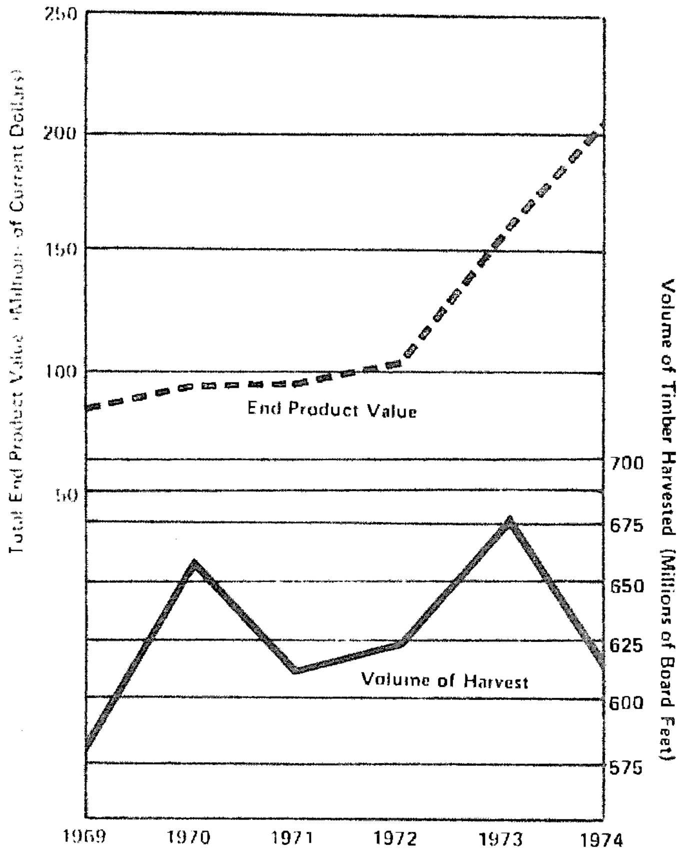
Source: Alaska Department of Fish and Game

More recently, the fishing industry has experienced several difficult and unstable years. The fishing industry was plagued by poor runs of pink salmon statewide and the continuing decline of the Bristol Bay fishery. Consequently, the total 1975 catch was at about the same level as the previous year's poor harvest. The current depressed condition of Alaska's salmon fisheries is considered a temporary phenomenon. Prospects for other fish varieties is mixed, dependent upon, among other things, the possible establishment of a 200-mile exclusive fisheries zone and harvesting at a rate that can be sustained. Alaska bottomfish potential appears to be high.

Forest Products: In general, Alaska's annual harvest of timber has increased steadily since 1959. National forest lands provided over 85 percent of total timber cut each year. About one-third of Alaska's 365 million acres supports forest cover of varying density, size, and type. One-fourth of this forested area is considered to have present or future commercial development potential. This includes present production within the study area on the west side of Cook Inlet, near Tyonek, and in the Chugach National Forest. In volume of timber processed, by far the greatest production is presently in the Tongass and Chugach National Forests. The major product of the timber harvest is wood pulp. A sharp decline in the timber harvest occurred in 1974 due primarily to a depressed market for sawn products in Japan. The unusually healthy pulp segment more than offset the poor performance of the lumber sector, however. Graph C-2 indicates recent industry trends. Despite the present slowdown, the Alaska Department of Economic Development predicts new markets in Japan and steady growth in Alaska's forest products industry.

GRAPH C-2

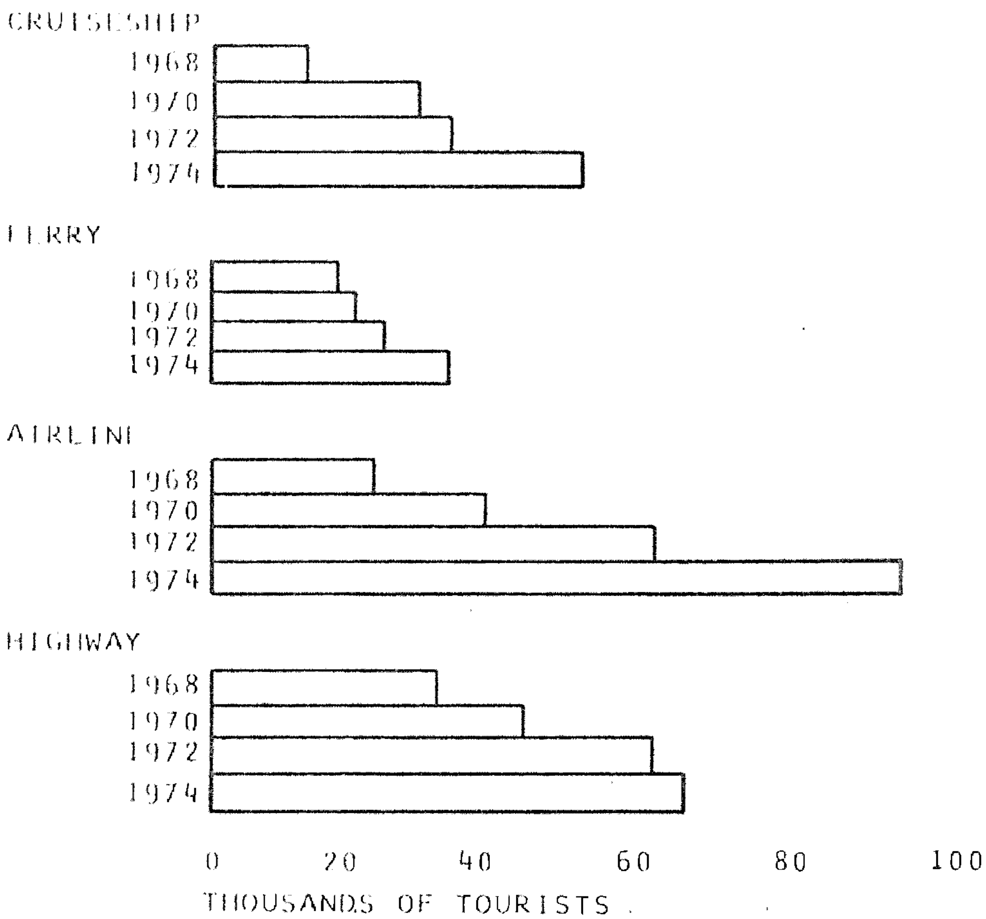
TIMBER HARVEST



Sources: U.S. Forest Service, Alaska Division of Lands, U.S. Bureau of Indian Affairs, U.S. Bureau of Land Management, and U.S. Department of Commerce.

Tourism: Tourism in Alaska is a major industry with tourist volume increasing at a rate of almost 15 percent per year since 1964. Approximately 240,000 non-resident pleasure travelers entered Alaska in 1974. Tourism should continue to grow as transportation and facilities are improved. Graph C-3 indicates recent trends. As the transportation hub of the bulk of Alaska, the Anchorage area will realize the major share of this activity.

GRAPH C-3
NUMBER OF TOURISTS ENTERING ALASKA



SOURCE: ALASKA DIVISION OF TOURISM.

Other Industries: Other industries have in general paralleled the growth in the primary industries. Contract construction is especially healthy due to pipeline construction activities, and the future would appear to depend on continued resource development in the State. Consistent growth over the last decade has occurred in the trade and service industries, while agricultural production has been relatively static. Recent changes to more efficient and larger farms have put Alaskan agriculture in a more solid position, and the amount of potentially tillable land is extensive. The government sector, already the largest contributor to the Alaskan economy, continues to grow rapidly.

PRESENT POWER REQUIREMENTS

To sustain the current population and level of economic activity in the Southcentral Railbelt area, power is provided by several utility systems as well as industrial and national defense power systems. Table C-9 provides a summary of existing generating capacity as of mid-1974.

TABLE C-9

SUMMARY OF EXISTING GENERATING CAPACITY

	Installed Capacity - 1000 kw				
	Hydro	Diesel IC	Gas Turbine	Steam Turbine	Total
Anchorage-Cook Inlet Area:					
Utility System	45.0	13.5	341.7	14.5	414.8
National Defense		9.3		49.5	58.8
Industrial System		10.1	2.3		12.4
Subtotal	45.0	32.9	344.0	64.0	486.0
Fairbanks-Tanana Valley Area:					
Utility System		32.1	42.1	53.5	127.7
National Defense		14.9	63.0		77.9
Subtotal		47.0	105.1	53.5	205.6
Valdez and Glennallen		6.2			6.2

Notes: The majority of the diesel generation is in standby status except at Valdez and Glennallen.

Source: 1974 Alaska Power Survey, Technical Advisory Report, Resources and Electric Power Generation, Appendix A, and Alaska Electric Power Statistics, 1960-1973, APA.

The Anchorage-Cook Inlet area had a total installed capacity of 414.8 MW in 1974. Natural gas-fired turbines were the predominant energy source with 341.7 MW of installed capacity. Hydroelectric capacity of 45 MW was available from two projects, Elkutna and Cooper Lakes. Steam turbines comprised 14.5 MW of capacity and diesel generation, mostly in standby service, and accounted for the remaining 13.5 MW.

The Fairbanks-Tanana Valley area utilities had a total installed capacity of 127.7 MW in 1974. Steam turbines provided the largest block of power in the area with an installed capacity of 53.5 MW. Gas turbine generation (oil-fired) provided 42.1 MW of power, and diesel generators contributed 32.1 MW to the area.

The energy needs of the Southcentral Railbelt area are estimated by the Alaska Power Administration to more than double by 1985 from the present 2 billion kilowatt-hours to 5.5 billion kilowatt-hours. By the year 2000, the energy requirement is estimated to reach 15 billion kilowatt-hours. The following section is a discussion of these energy need projections as well as of the energy use and development assumptions upon which they are based.

PROJECTED ENERGY NEEDS

In its marketability analysis, Alaska Power Administration prepared Railbelt area load projections for 1980, 1990, and 2000 under three different growth scenarios. These projections are based on the 1974 Alaska Power Survey, adjusted to account for more recent data, current regional and sectional trends in energy and power use, and to eliminate loads which would be too remote to be served from a Railbelt transmission system.

The use of a range of projections is necessitated by the wide variation possible in future population and economic growth in Alaska due to uncertainty regarding the controlling factors of cost, conservation technologies, available energy sources, types of Alaskan development, and national energy policy. All projections assume that saturation levels for many energy uses will be reached and that rates of increase for most individual uses will decline during the period of study. This reflects assumed effects of major efforts to increase efficiencies and conserve energy for all uses.

In accordance with APA's recommendations, the projections based on the mid-range growth scenario were adopted for this study. The mid-range projection is based on utility system growth rates of 12.4 percent for 1974-1980, 7 percent for 1980-1990, and 6 percent for 1990-2000. National defense requirements are based on a 1 percent growth rate and industrial requirements presume a gradual expansion of facilities.

Table C-10 summarizes the mid-range load projections for the Railbelt area.

Appendix I
TABLE C-10

ESTIMATED RAILBELT AREA POWER REQUIREMENTS - MID-RANGE GROWTH RATE

	1974 Actual		1980		1990		2000	
	Peak Demand 1000 kW	Annual Energy 10^6 kWh	Peak Demand 1000 kW	Annual Energy 10^6 kWh	Peak Demand 1000 kW	Annual Energy 10^6 kWh	Peak Demand 1000 kW	Annual Energy 10^6 kWh
Utilities								
Anchorage	284	1305	590	2580	1190	5210	2510	9420
Fairbanks	83	330	150	660	290	1270	510	2230
Total	367	1635	740	3240	1480	6480	2660	11,650
National Defense								
Anchorage	33	155	35	170	40	190	45	220
Fairbanks	41	197	45	220	50	240	55	260
Total	74	352	80	390	90	430	100	480
Industrial								
Anchorage	10	45	50	350	100	710	410	2870
Fairbanks 1/	--	--	--	---	---	---	---	----
Total	10	45	50	350	100	710	410	2870
Total								
Anchorage	327	1505	675	3100	1330	6110	2605	12,510
Fairbanks	124	527	195	880	340	1510	565	2,490
Total	451	2032	870	3980	1670	7620	3170	15,000

1/ Rounds to less than 10 MW for all years.

APA Power Requirement Projection Methodology: Several basic assumptions underlie Alaska Power Administration's analysis. It is assumed that boom conditions will give way to orderly expansion in the 1980's and 1990's, with an annual growth rate for electrical energy after 1980 similar to that experienced over the last decade in the rest of the country--between 6 and 7 percent. The presumption is also made that, barring major changes in technology that favor other forms of energy use, electrical power production will need to anticipate and keep pace with the overall growth in population and production.

APA's power requirement projections are a composite of three sectors which were analyzed separately. The first is composed of utility system requirements which includes residential, commercial, light industrial, and industrial support services requirements. The second sector examined is national defense requirements, and finally industrial requirements for resource extraction and processing, new energy-intensive industries, and heavy manufacturing are explored.

Utility System Requirements: Utility system load estimates were compiled for existing individual systems for the years 1980 and 1990; these were then extended through 1990 to the year 2000. The mid-range extends the growth rate to 1980 at about 12 percent, somewhat less than the past decade's historical rate of 14 percent for the Railbelt area. Higher and lower range utility load estimates for 1980 assume about 20 percent more and less growth respectively than the mid-range estimate. It is then assumed that somewhat lower growth rates would prevail in subsequent decades. Growth rates of 9 percent in the 1980's and 8 percent in the 1990's are considered to represent fairly rapid development of the Alaskan economy in those two decades. The lower range estimates are considered to represent fairly modest growth.

TABLE C-11

ASSUMED ANNUAL UTILITY GROWTH RATES IN PERCENT

ESTIMATE:	1974-1980	1980-1990	1990-2000
Higher Range	14	9	8
Likely Mid-range	12	7	6
Lower Range	11	6	4

National Defense Requirements: Future power requirements for national defense facilities were premised on the 1974 power use for the major bases and an assumed future growth of approximately 1 percent per year. These estimates are lower than presented in the 1974 Alaska Power Survey, which assumed a growth rate of 1.7 percent.

Industrial Requirements: Industrial use (as defined by APA for purposes of this analysis) accounts for about 2 percent of the Railbelt area's 1974 total power requirement and is expected to grow to 19 percent in 2000, according to the mid-range projection. This remains well below the industrial share nationwide. The industrial requirement is the most speculative aspect of the projection because it is very difficult to foresee the timing of new facilities.

The analysis assumes a high probability of major new mineral production and processing. Also expected are significant further developments in timber processing, and it is assumed that Alaska energy and the availability of other resources such as water, industrial sites, and port sites may attract energy-intensive industries. The primary data source for the industrial sector projections was a 1973 study by the Alaska Department of Economic Development. That study included review and estimates of power requirements for Alaska's fishery, forest products, petroleum, natural gas, coal, and other mineral industries, all premised on significant identified resource potentials and on power needs for similar developments elsewhere. Several qualifying assumptions were made by APA to adapt this study for use in the marketability analysis.

1. Power requirements for fish processing industries and support services for industrial development are not included, having already been addressed in the "utility requirement" portion of the analysis.

2. Estimated mineral industry loads (except for petroleum and related industry) for the year 2000 were adopted as APA's "higher range" estimate, with estimates for 1980 and 1990, reflecting anticipated minimum lead times for developing the resources involved. The mid-range estimate assumes a 10-year deferral of the Department of Economic Development's projected growth scenario, and the lower range estimate a 20-year deferral.

3. Power requirements assumed for Alaska petroleum and petrochemical industries are smaller than estimates in the reference study, based on expectations that most Alaska oil and gas production would be exported during the period of the survey. For example, the mid-range estimate assumes 7 percent of petroleum industry loads estimated in the reference study.

4. A somewhat slower pace of development was assumed for forest products industries.

All of the above qualifying assumptions, with the exception of No. 1 which had a neutral effect, were downward adjustments, decreasing the estimates of the basic study. Specific industrial development assumed for the study is presented in Appendix I, Part 2, Section G. Only planned expansions to existing facilities and realistically identifiable new industry closely tied to proven resource capabilities were assumed.

Summary: When combined, the composite annual growth rates for the projected power requirements are as indicated in the following table.

TABLE C-12

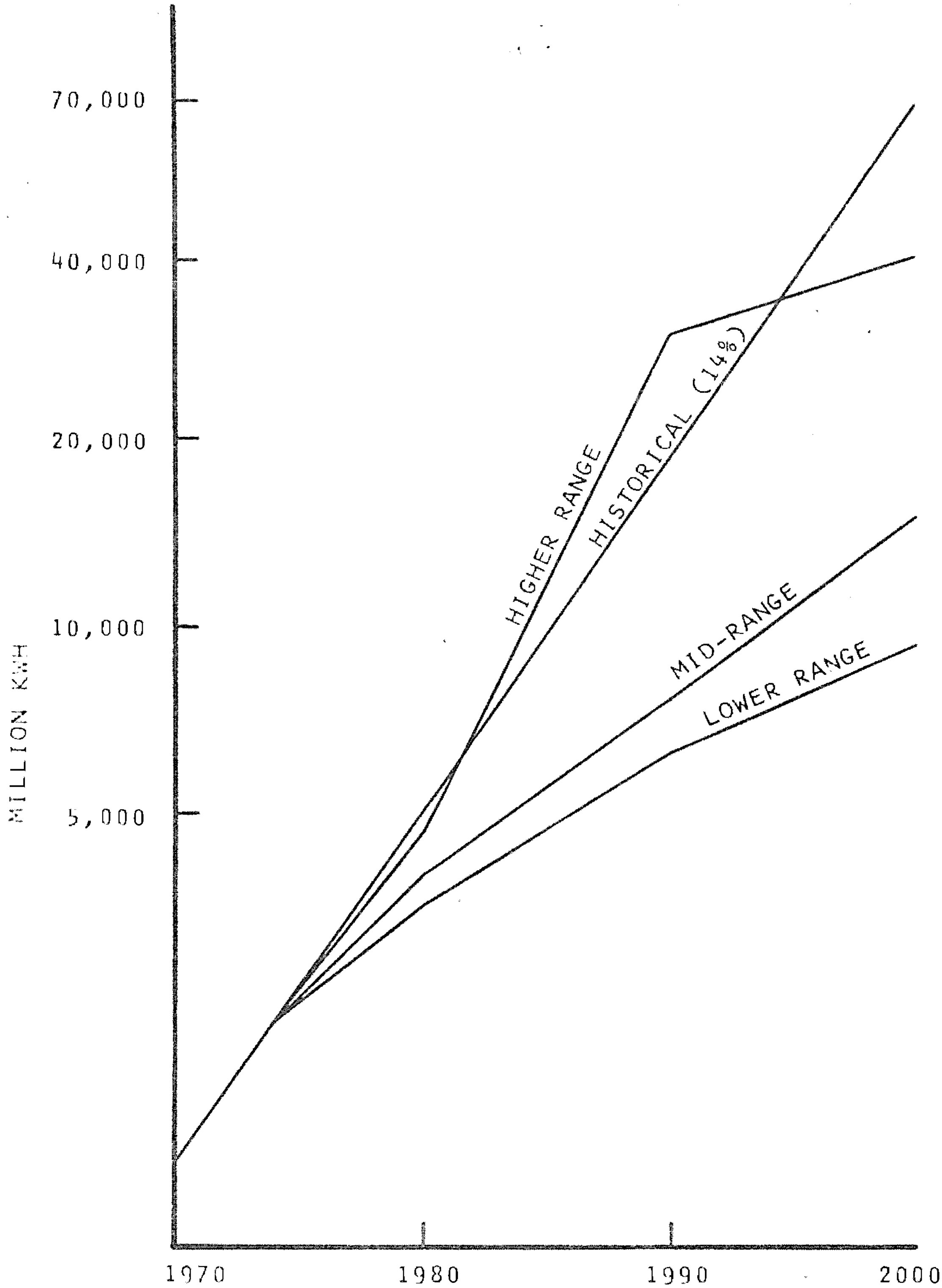
COMPOSITE ANNUAL GROWTH RATES FOR ELECTRIC POWER (PERCENT)

ESTIMATE:	1974-1980	1980-1990	1990-2000
Higher Range	12.4	20.2 1/	3.0
Likely Mid-range	9.6	6.7	7.0
Lower Range	7.5	5.8	4.0

1/ This high rate is caused by the assumed introduction of a 2500 MW nuclear fuel enrichment plant as an example of a possible large industrial load. Without this load, the 1980-1990 growth rate would be 9.3 percent and the following decade's would be 6.6 percent. No such load is assumed for the mid and lower range projections.

Table II of Section G, Appendix I, Part 2, provides the actual load projections under the three growth scenarios. These figures are displayed graphically in Graph C-4 and compared to the last decade's historical growth rate of 14 percent projected to the year 2000.

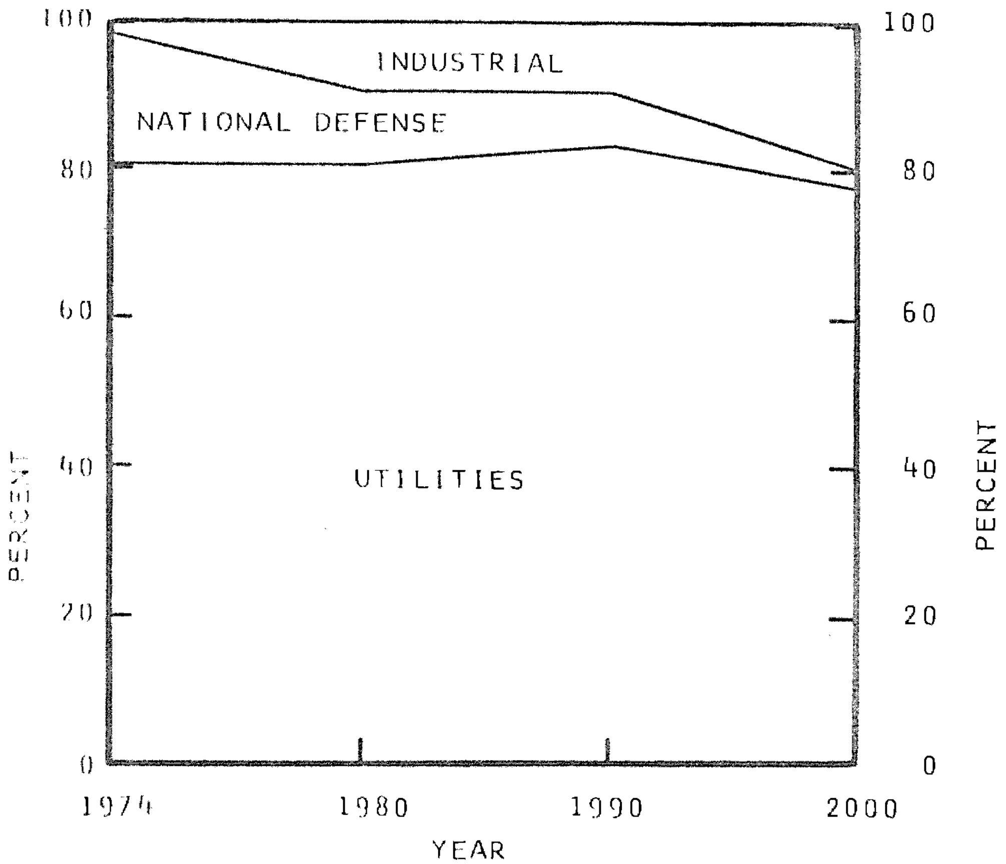
PROJECTED ENERGY DEMAND
SOUTHCENTRAL RAILBELT



Appendix I
GRAPH C-4

Graph C-5 depicts the relative shares through time of the three demand sectors analyzed by APA. Utility system requirements include residential, commercial, light industrial, and industrial support services needs. Industrial requirements are comprised of resource extraction and processing, new energy-intensive industries, and heavy manufacturing.

GRAPH C-5
COMPOSITION OF ENERGY REQUIREMENTS THROUGH TIME
(MID-RANGE ESTIMATES)



This graph clearly indicates that the prime determinants of future energy needs are expected to continue to be residential, commercial, and light industrial uses of energy. The energy use in these sectors is primarily determined by energy use habits, population, and economic activity.

Energy Use Assumptions: APA has assumed substantial savings in energy consumption due to increased efficiency and conservation in energy use. Both of these effects are expected to result from imminent and probable future increases in Alaska energy costs.

Population Assumptions: APA's population assumptions, based on a wide range of State and Federal agency, as well as financial and academic institution projections, tend to be somewhat conservative when compared to the most recent projections which more adequately incorporate existing economic realities. For instance, the Institute of Social, Economic, and Government Research of the University of Alaska, employing a recently formulated econometric model (the MAP model) and the most likely development scenario, predicts an annual population growth rate of about 5 percent for the Railbelt area through 1990. Current MAP model as well as National Bank of Alaska (NBA) population estimates both exceed those earlier projections that were cited in the 1974 Alaska Power Survey. Table C-13 compares population projections based on a continuation of 1960-1970 annual growth of 3 percent with MAP and OBERS estimates. OBERS projections are prepared by the U.S. Departments of Commerce and Agriculture for the U.S. Water Resources Council.

TABLE C-13

STATE POPULATION ESTIMATES (1000's)

	1960	1970	1975	1980	1990	2000
Actual	226	302	386 (est.)			
3 percent Growth (Alaska Power Survey)				410	550	740
MAP				471	738	
NBA				500		
OBERS (Series E)				333	391	438

OBERS projections are inappropriate for use in this study as a basis of population estimation in Alaska as evidenced by the fact that the actual 1975 Alaskan population almost equals the 1990 OBERS projection.

Economic Activity Assumptions: With regard to economic activity, the MAP model agrees with APA's assumption of steady economic growth following the present boom period. To 1980, gross product is projected by the MAP model to increase at an annual rate of 7.0 percent in the Anchorage-Fairbanks area, followed in the next decade by an annual growth rate of 6.0 percent. National Bank of Alaska considers this a somewhat conservative estimate.

Not all of the subregions will share equally in this growth. The Anchorage-Cook Inlet subregion has been the focal point for most of the State's growth in terms of population, business, services, and industry since World War II. Because of its central role in business, commerce, and government, the Anchorage area is directly influenced by economic activity elsewhere in the State. Present and proposed activities indicate a high probability of rapid growth in the Cook Inlet area for the foreseeable future. Much of this activity is related to oil and natural gas development to include expansion of refineries at Kenai, proposed LNG exports to the continental United States, and probable additional offshore oil and gas production. The area will continue to serve as the transportation hub for most of Alaska, and the proposed capital relocation would provide additional impetus for growth.

Fairbanks, in the Tanana subregion, is Alaska's second largest city, the trade center for much of Alaska's interior, service center for two major military bases and site of the University of Alaska. Currently, it is in the midst of a major boom connected with the construction of the Alyeska pipeline. It is generally felt that postpipeline growth in the Fairbanks area will be at a slower pace than that of the Cook Inlet subregion. Major future resource developments in the interior and north slope would have direct impact on the Fairbanks economy.

Like Fairbanks, the two major load centers of the Gulf of Alaska subregion, Valdez, and Glennallen are heavily impacted by pipeline construction. Longer range prospects indicate a more stable economy associated with pipeline and terminal operations and with recreation.

Institutional Considerations: Energy projections for Alaska are of necessity more speculative than those for more developed areas in the rest of the country. This is due to the present relatively small population and economic base and the very substantial influence that political decisions will have regarding development of Alaska. National energy policy, final land disposition, and capital relocation are examples of institutional constraints which may significantly alter future energy requirements. It is the effect of such influences that largely accounts for the wide range in energy projections.

Conclusions: The higher range projection provided by APA is comprised in the year 2000 of over 50 percent industrial use. This magnitude of heavy industrial development is deemed too speculative to serve as a basis for energy planning at this time. The lower range projection, on the other hand, incorporates a composite growth rate for the remainder of the 1970's too far removed from the present actual annual rate of increase to be accepted as a best estimate of future energy use. In general, the broad population and economic trends as well as the more specific energy use and economic development assumptions of the mid-range estimate reflect a realistic balancing of recent experience in Alaskan energy consumption growth with expected future development and more efficient use of energy. For these reasons, the mid-range energy requirement projection furnished by the Alaska Power Administration has been adopted as the basis for project planning.

It is recognized that by making assumptions about future population and economic growth and then providing energy sufficient to sustain such growth, the initial projections may become a self-fulfilling prophecy. By presuming that energy needs must be met, the opportunity to use the provision of power as a tool to direct growth toward socially desirable goals is foregone. In the absence, however, of any such generally accepted growth goals, it seems highly presumptuous to do otherwise than plan so as to satisfy the energy needs required to sustain that level of future development deemed most likely.

PROBLEMS AND NEEDS

Problems and needs of the Railbelt area which are associated with water and related land resource development cover a broad range of economic, environmental, and social concerns. Specific items identified from expressions of governmental agencies, of industry, of special interest organizations, and of private citizens include:

The projected need for increased supplies of electrical energy;

A need for reduction or prevention of flood damages;

A need for improved small boat and deep-draft navigation conditions;

A need for increased municipal water supply;

A need for future supplies of irrigation water;

A need for reduction and prevention of air pollution in Fairbanks and Anchorage;

The need to conserve and enhance fish and wildlife resources;

The need for additional recreational opportunities for the population;

The preservation and maintenance of the "Alaskan way of life;" including prevention of further population growth, prevention of additional industrialization, and cessation of expansion of urban areas;

The national desire to achieve energy independence from foreign sources; and

The national desire to conserve nonrenewable resources.

It would be highly presumptuous to assume that a specific water resources project could fulfill all of the desirable water related needs of a community; furthermore, although the potential for fulfilling specific needs may exist, the economics or social impact of attempting to use the water resource as a panacea for the needs may be detrimental. It is, therefore, necessary to evaluate individual needs to determine if they are in the best interest of State and National objectives, and if they can be reasonably fulfilled by a specific water resource development. In this respect, it may be desirable to fulfill specific objectives which may require incompatible water usage. Therefore, the extent to which desirable functions of a multipurpose project could be developed is highly dependent upon which various purposes are compatible. The economic, social, and technical implications of satisfying the above needs through water resource or land-related development is briefly discussed below.

Power Needs: Historically, most electrical generation in the Railbelt area has been through the firing of fossil fuel turbines; however, as pointed out earlier in this text, the abundance of available hydropower coupled with our ever-shrinking fuel supplies makes the demand for long-range power planning imperative. Recent power growth rates have been in the neighborhood of 14 percent annually, and although these rates are projected to decline to 7 percent beyond 1980, the year 2000 total Railbelt power requirements are estimated to be 15 million megawatt hours energy and 3,170 megawatts peaking capacity. The need for additional power was made apparent by the 1972 U.S. Senate Committee on Public Works resolution to study means for development of power resources within the Railbelt area. Electrical power development is obviously a need which could be satisfied by water resource development.

Flood Control: Development along the Susitna River consists of roads and bridges with some urban areas in the lower reaches of the major river system. Present damages occur from bank erosion in contrast to overbank flooding. With the upper reaches of the river controlled, greenbelt areas can be established which will support orderly development placed beyond the reach of flood or the threat of erosion.

From the standpoint of conventional flood protection, there has been little recorded historical flood damage to be prevented or eliminated by development. The major area where some benefits could be derived is in preventing occasional damage to the roadbed and bridges of the Alaska Railroad and the local road system. Benefits would accrue both from savings in repair costs and economic costs resulting from delays to traffic while repairs are underway.

Recreation: The steady growth of the tourist industry has been enhanced by the development of areas that were previously inaccessible by common transportation modes. One of the most popular tourist attractions within the entire State is the Mount McKinley National Park, which is within close proximity to both population centers and the Upper Susitna River Basin. As the population centers continue to grow, additional recreational facilities would be desirable to the tourist trade, and the road access and lake development of the upper Susitna River could enhance recreational potential.

Conservation of Natural Environment: Running counter to most development programs is the need to preserve a portion of our environment in its natural state. Of principal interest are areas having some unique scenic or environmental character, although it may be desirable to preserve other areas in their natural state as well. In evaluating the development of a stream such as the upper Susitna, it is necessary to determine if it has some unique character which possibly should be preserved and whether there will be adequate areas of a similar nature remaining undisturbed in this general geographic area. Development of the Susitna River would certainly alter a portion of the river from its original state. Associated human encroachment of the surrounding terrain could also be expected, and hence it should be anticipated that total conservation of the natural environment would not be possible. There are opportunities, however, to enhance portions of the environment through engineering measures and good land management. Furthermore, if one considers that virtually all development has an impact on the natural environment, then obviously there is a range of severity associated with the various forms of electrical development. Water resource development is generally a clean power source and while the natural environment may not be totally preserved, at least man would have the opportunity to view a terrain which had been previously inaccessible.

Navigation: Although the possibility for enhancing the navigability of the Susitna River exists, the associated requirements for channel improvements necessary for deep draft far outweigh the present benefits. Future development within the Railbelt may increase the desirability of the Susitna River as a transportation mode, but, in general, this purpose would not be considered compatible with the main and proven need for power production.

Irrigation: The need for irrigation water presumes a level of agricultural development which is not now planned or foreseeable. In addition, there are presently numerous opportunities for development of irrigation water which could be more economically feasible than upper Susitna River development.

Municipal Water Supply: The needs for municipal water supply can be more economically solved by other means. This need is not considered one which the recommended plan should attempt to address.

Preservation of "The Alaskan Way-of-Life": The "Alaskan way-of-life" is self-induced and is apparently defined by a specific date on which the lifestyle was very desirable. The lifestyle has changed considerably over the past few years with the general trend toward enhancement of standard of living. The regretable inability to gain quick access to wilderness appears to be a function of the growing population that desires this luxury. The best solution to this problem would be controlled growth. To preserve the Alaskan lifestyle by halting growth of all forms at the present level is beyond the authority of the Corps of Engineers and is, therefore, beyond the objectives of this study.

Air Pollution Reduction: Almost all energy resources which require some form of heat for electrical generation impart heat, water vapor, and chemical impurities to the surrounding air. The problem in Fairbanks has reached hazardous proportions and some form of relief is necessary. Both Anchorage and Fairbanks receive some forms of air pollution from existing electrical generating units. The conversion to hydroelectric could help diminish existing pollution levels in both cities, and could forestall the date when new thermal plants would be required to meet the ever-increasing energy demand.

Conservation of Nonrenewable Resources: The present national objective for conservation of nonrenewable resources could be partially met by the large abundance of Alaskan natural energy sources. One-third of the freshwater runoff of the entire United States is found in Alaska, as well as scores of untapped sources of hydroelectric power. In addition, Alaska has abundant potential for development of geothermal, wind, and tidal resources. Hydroelectric appears desirable for development when measured in terms of environmental impact, and economic feasibility as compared to conventional thermal generating plants presently in operation. Although the technology associated with the other sources of renewable energy is not at the present level as that of hydropower, these other energy sources may be a major source of electrical power in the near future.

National Energy Independence: Similar to conservation of nonrenewable resources, an enormous contribution toward the national objective of energy independence could be made by Alaska. The Prudhoe Bay gas and oil fields will contribute to this goal as will anticipated oil reserves from outer continental shelf oil explorations. Development of the renewable Alaskan energy sources could free additional fossil fuels for "Lower 48" use. It may even be feasible to transmit Alaskan hydropower via transmission lines to midwestern population centers. Development of renewable and nonrenewable Alaskan resources could have a profound effect on our need for national energy independence.

POSSIBLE SOLUTIONS

GENERAL

Solutions considered in this investigation to meet electrical needs in the Southcentral Railbelt area were grouped in three major categories: alternative sources of power; alternative hydropower sources in the Railbelt area; and alternative hydropower plans in the upper Susitna River Basin. The extent of study given to each potential solution was established by first screening each alternative for suitability, applicability, and economic merit in meeting needs. Each alternative was tested for physical, political, financial, institutional, economic, environmental, and social feasibility. Continuous coordination was maintained with area State and Federal agencies which have related interests. Alternative measures considered for power purposes are as follows:

Alternative Sources of Power

- No Growth
- Coal
- Natural Gas and Oil
- Nuclear Power
- Geothermal
- Solar
- Wind and Tidal
- Wood
- Intertie
- Solid Waste
- Hydropower

Alternative Hydrologic Basins in Southcentral Railbelt Area

- Yukon River - Rampart Dam
- Copper River - Wood Canyon Dam
- Chakachatna River - Chakachamna Dam
- Bradley River - Bradley Lake Dam
- Susitna River

Alternative Hydropower Plans in Upper Susitna River Basin

- Devil Canyon
- Watana
- High D.C. Dam (Henry J. Kaiser Company's Susitna I damsite)
- Devil Canyon - Denali
- Devil Canyon - Watana
- Devil Canyon - Watana - Denali
- Devil Canyon - Watana - Vee - Denali
- 4-Dam Kaiser Development

These alternatives were screened on the basis of preliminary estimates of response to the basic water resource planning objectives of NED (economic viability) and EQ (contributions to environmental quality). Within the NED considerations, in addition to the purely economic factors, such items as technical feasibility (Can it be done with existing technology?) and scale (Does it do too little or too much?) were considered important. Within the EQ considerations, in addition to positive contributions to environmental factors, a lack of adverse effects was considered significant. The intent and effect of this brief screening was to rule out impracticable and marginal alternatives leaving a small number of the better possible solutions to be studied and evaluated in detail. The following discussions summarize the preliminary evaluation.

ALTERNATIVE SOURCES OF POWER

No Growth: Restricting the growth in power demand and altering energy pricing policies are political decisions that cannot be addressed in this report with any authority. However, any adopted policy significantly reducing industrial consumption of energy would have to consider the living standard which depends on energy consumption. It would also be necessary for a policy to restrict population growth and to apply to all forms of energy to be effective. This alternative would achieve the maximum possible conservation of nonrenewable resources and have minimal adverse environmental effects. However, in the presence of the projected trends in population and energy consumption growth and in the absence of any indication of the required social and political atmosphere, the alternative is not considered realistic. Integral to any plan to restrict load growth would be a program to reduce waste and improve efficiency of electrical energy usage. However, this is a desirable and perhaps necessary measure regardless of what alternative is adopted. The Alaska Power Administration recognizes this in their load projections, assuming substantial demand savings through conservation programs and increased efficiency in use of energy.

Coal: Coal is the most abundant fossil fuel in the nation. Southcentral Alaska has two extensive deposits. The Beluga River area, northwest of Cook Inlet, contains coal reserves of at least 2.3 billion tons or, energy-wise, an equivalent of almost 6 billion barrels of oil. Development of Beluga coals would enhance possibilities for coal-fired power generation at reasonable cost. Coal resources in the Nenana Fields in the Southcentral Railbelt south of Fairbanks near Healy, Alaska, are even more extensive than the Beluga River reserves, totaling at least 7 billion tons.

In many cases, the major obstacle to increased coal usage is the problem of removing the high sulfur content in order to meet air quality standards when the coal is burned. Other problems include environmental impacts associated with strip mining, such as surface disturbance, waste material disposal, chemically active water discharge, post-mining restoration, and transportation of the coal. The Beluga coals have low amounts of sulfur but have high ash and water content. Considerable refining would be needed for use of this coal in power generation.

The coal alternative could be available on about the same time frame as other major new power sources such as hydropower and, possibly, nuclear power. Baseload thermal plants could probably be utilized in the Railbelt area by the 1980's. Coal-fired plants should also be given consideration in remote areas which could be supplied by water transportation.

In the absence of major hydro development or the discovery of additional gas reserves, the future Railbelt power system would probably shift from oil- and gas-fired power units to coal as their principal energy source. The coal plants would either be conventional steam or steam and gas turbine units located near the Beluga and Nenana coal fields. The use of coal as a source of energy is a viable alternative.

Natural Gas and Oil: Following the 1967 Department of Interior report, Alaska Natural Resources and the Rampart Project, most studies by Federal agencies and area utility companies focused on the Cook Inlet supplies of natural gas and, more recently, on pipeline fuels for Railbelt power.

Cook Inlet natural gas is a clean fuel. Few serious air pollution problems exist for gas-fired units; however, the extent of gas reserves is not known at this time. Gas turbine exhaust is noisy, although noise suppression equipment can reduce this impact at a price. Energy conservation aspects of gas-fired units may become significant because existing turbines have low efficiencies and give off visible water vapor emissions during the colder winter months. Also, nitrogen emissions could be of significant concern for the very large gas-fired plants which would be needed.

Existing plans for the Cook Inlet area include additional large, advanced-cycle gas turbine units at Beluga and additional turbines and waste-heat recovery units in Anchorage. The Fairbanks area utilities plan additional turbine units using pipeline fuels. Near future plans include a number of measures to increase efficiency of existing units, including use of the advanced-cycle and waste-heat-recovery units.

Cook Inlet natural gas has provided low-cost power benefits for the surrounding area in the recent past and, with substantial reserves under contract, should handle area power requirements for several more years. Also, additional reserves may be found in future exploration to meet future demands. To assume that there will be substantial increases in cost for future oil and gas supplies appears reasonable as United States domestic reserves decline, worldwide demand increases, and foreign oil prices remain high.

Planning of measures to meet future energy needs should factor in higher costs for fuels, especially for oil and gas, and should anticipate national efforts to develop alternative energy sources that limit the use of oil and gas for power generation. These factors invalidate many previous power planning studies which are premised on assumptions of cheap, long-range oil and gas fuel sources.

Alaska power systems now depend on oil and gas for about 60 percent of total energy production, and by 1980, about 90 percent of the State's electric energy will come from these fuels. Estimated 1972 fuel use for Alaska's power systems included 1.4 million barrels of oil and 16 billion cubic feet of natural gas. The use would increase to about 26 million barrels of oil and 134 billion cubic feet of natural gas annually (if available) by the year 2000 in meeting the midrange consumption level estimates.

A concentrated effort to develop alternatives for power generation such as coal, hydro, and eventually nuclear power could result in substantial reduction in demand for oil and natural gas. The lead times and large investments required to develop these alternatives reinforce the point that oil and natural gas must supply near future requirements.

The availability of oil and gas in Alaska could improve if more reserves and facilities are developed. However, there is no longer any reason to anticipate that Alaskan oil and gas will provide an abundant, cheap energy source for the long term. These fuels will be expensive, if for no other reason, because there will be pressures to export the resources to areas where higher prices can be obtained for their use in petrochemical industries. The present use of oil and natural gas as a source of electrical energy is viable for Alaska; however, a higher and better future use of these resources can be made and, in all probability will be. Therefore, oil and natural gas-fired generation is not considered to be a viable alternative.

Nuclear: The use of nuclear power as a commercial electrical energy source for the nation is expected to increase considerably by the year 1985. Adverse environmental impacts are associated with surface and subsurface mining of uranium, changes in land use, disposal of waste heat, risk of accidents, and disposal of highly radioactive wastes. In spite of these factors, more than 50 percent of the electrical power of the nation is expected to be generated by nuclear power by the year 2000. By that time, breeder plants, which produce additional fuel while they produce power, will hopefully be available to take over a larger share of the production of electricity. Possibly at some time in the next century, nuclear fission plants and proposed nuclear breeder plants will be replaced by nuclear fusion reactors.

Nuclear power should be considered a likely long-range source of baseload power for the Railbelt area, but is generally considered a distant option because of size of power markets, cost and environmental factors, and the availability of more favorable coal and hydro alternatives. The foreseeable future for nuclear power generation in Alaska should become materially more favorable only if there is a breakthrough in costs and technology of small-sized plants.

Geothermal: Geothermal resources may eventually provide significant power generation in Alaska; the Southcentral Railbelt area has substantial geothermal potential. Some of the possible problems associated with the generation of electrical power from geothermal resources include siting of facilities, brine disposal, corrosion, air pollution, thermal pollution, water pollution, land subsidence, and possible earth tremors. This resource could also provide usable side products such as heat, water, and chemicals. This source of energy is not considered a reasonable short-term alternative to other more proven types of power generation because of the relatively primitive level of present technological development and high costs.

Solar: The radiant heat of the sun is another renewable source of energy that has considerable potential for generating power in the nation and the world. Practical use of solar energy to produce electrical power on a large scale is primarily a question of developing the technology to generate and to store large amounts of electricity produced by the sun's radiation. A major disadvantage wherever such development is present is the large land area required for reflector installation to provide usable amounts of power and thus the large environmental disturbances inherent in such change in land use. During the winter, a second concern, especially in Alaska, is that when demand for electrical power is greatest, the sun is either absent from or at best a brief visitor to local skies. Solar power generation is not considered a feasible planning alternative for Alaskan power systems in the near future. Opportunities exist for utilizing solar heating systems as a supplementary source of energy for water and space heating. This could ultimately serve to reduce demand for other forms of energy, including electricity. However, it would not reduce the need for generating capacity because full power system peak loads would probably develop on days when solar energy could not contribute much usable energy and the full water and space heating needs would have to be met with electricity or other back-up systems.

Wind and Tidal: Research and development proposals for wind generators should improve future capabilities of wind-powered electrical generating systems. With increased diesel fuel costs, wind-generated electrical power is a possible alternative power source for remote areas with small loads. The alternative is not considered feasibile for provision of large amounts of energy at this time.

The Cook Inlet region of Alaska experiences one of the larger tidal ranges of the world, giving it a potential for the generation of electrical energy from a low head reversible hydro plant. Tidal power, however, in the absence of multiple storage reservoirs, is only available during lunar-solar tide peaks which do not coincide with the normal daily peaking requirements. Such an installation would require a low dam spanning the full width of the Inlet, a massive cost item in itself, as well as a deep draft lock system to allow commercial vessel access to the Anchorage port. The dam would change the entire flow regime of Cook Inlet with a significant potential for extensive adverse effects on major ecosystems. Additional major effects would include intensified ice pack conditions in the upstream pool with potential for significant adverse impacts on the Anchorage waterfront. Further study of either of these alternatives is not deemed justified for this report.

Wood: In parts of southeastern Alaska, wood is used to fire steam-generating power plants. Alaska does have vast forest reserves that could be used; however, these same trees have far higher and better alternative uses in wood, paper, and other industries. In addition, the esthetic, ecological, and environmental impacts of the large harvests necessary to allow production of large amounts of energy appear to be massive. Further study of this alternative is not deemed justified for the report.

Intertie: Instead of producing the required power in Alaska, excess power from Canada and/or the "Lower 48" could be imported by a transmission system interconnecting with the sources. However, there is no evident excess of power available to make such a development feasibile. Further study of this alternative is not deemed justified for this report.

Although interconnection with Canada or the contiguous United States is not presently justified, the possible benefits which would accrue by interconnecting the Anchorage and Fairbanks load centers will increase as the energy demand of the two areas increase. Interconnection of existing super load systems throughout the world have revealed a multitude of advantages including flexibility, economic potential and higher system reliability. Interconnection of the Anchorage and Fairbanks load centers could lead to cooperative long-range planning to allow efficient scheduling of additional generating plants. This in turn could lead to revenue savings through shared reserves and through inter-area energy sales to take advantage of the cost differential of producing energy in the two load centers. Side benefits which could be realized could include enhancement of total system reliability, added flexibility in scheduling facilities maintenance, and at least the capability to eliminate or minimize unnecessary duplication of staff facilities. Because short range investment requirements for interconnection of Anchorage and Fairbanks are relatively large in comparison to initial benefits, an area transmission intertie is not now suggested. However, if the two load centers were interconnected through the incidental development of a natural energy resource to be shared by the two load centers, then obviously some of the above mentioned benefits could be realized.

Solid Waste: The use of solid wastes was proposed by the Alaska Center for the Environment as an alternative source of energy at the public meeting held in Anchorage on 29 May 1975. There does not appear to be an adequate supply of solid waste products in the Railbelt area to produce enough energy to meet anticipated load growth. This alternative is not considered feasible to meet the full energy needs of the Railbelt area. However, it might serve as a source of supplemental energy and should be pursued further at the local level.

Hydropower: The reconnaissance report on potential development in the State of Alaska made in 1948 by the U.S. Bureau of Reclamation included hundreds of potential power development sites located throughout the five study regions of the State: Southeast, Southcentral, Yukon-Kuskokwim, Seward Peninsula, and Arctic. Many of these sites are located near the Fairbanks and Anchorage market areas. The large amount of the available renewable resource which could produce electric power has the potential to meet the energy needs of the Southcentral Railbelt area.

ALTERNATIVE HYDROELECTRIC POTENTIAL IN THE SOUTHCENTRAL RAILBELT AREA

Yukon River-Rampart Canyon Dam: The proposed site for the Rampart Canyon Dam is on the Yukon River, approximately 140 miles northwest of Fairbanks, Alaska. The project has one of the largest hydroelectric potentials in North America. The plan would include a reservoir with a water surface area of approximately 10,600 square miles, a maximum length of 280 miles, and a maximum width of about 80 miles. The project would provide firm annual energy of 34.2 billion kilowatt-hours (the energy equivalent of over 58 million barrels of oil per year). However, substantial adverse environmental impacts could result to fish and wildlife in the Yukon Flats area.

The tremendous financial investments, the large environmental impacts, the limited opportunities for marketing the enormous amounts of power, and availability of favorable, less costly alternatives are major considerations in evaluation of the Rampart project at this time. In view of these considerations, Rampart is not considered appropriate at this time.

Copper River-Wood Canyon Dam: The proposed site for the Wood Canyon Dam is about 85 miles above the mouth of the Copper River in the Chugach Mountains of southcentral Alaska. A "high dam" proposal would develop firm annual energy of 21.9 billion kilowatt-hours. A "low dam" plan would provide 10.3 billion kilowatt-hours of firm annual energy.

The construction of either dam at Wood Canyon would force relocation of two communities and would create serious environmental problems affecting both fish and wildlife values, especially to the large salmon runs on the Copper River. Unless the problem posed to migrating salmon could be solved satisfactorily, the project would have an extremely adverse effect on the major commercial fishing industry in a wide area of the Gulf of Alaska. This alternative is not considered feasible at this time.

Chakachatna River-Chakachamna Dam: The site for the proposed Chakachamna Dam is located on the Chakachatna River, which drains into the west side of Cook Inlet approximately 65 miles west of Anchorage. The facility would generate 1.6 billion kilowatt-hours of firm annual energy. The project would require the erection of additional transmission facilities over difficult terrain to tie into a Southcentral Railbelt transmission system and the construction of a costly 11-mile tunnel for power generation. The adverse environmental impact would be substantially less than from many proposed Alaskan hydroelectric projects; however, the low firm energy output and high costs compared to other available alternatives render this alternative economically unattractive at this time.

Bradley Lake: The site for this proposed hydroelectric project is at Bradley Lake on the Kenai Peninsula at the head of Kachemak Bay. The facility proposed would generate 0.4 billion kilowatt-hours of firm annual energy and could serve as a southern peaking installation for a Southcentral Railbelt power system. There would be a minimum of adverse environmental impacts associated with this proposed project. If an economically feasible plan can be developed for Bradley Lake, the project could be integrated with future development of the Susitna River basin. By itself, the alternative can produce only a small portion of the future energy requirements.

Susitna River: Surveys for potential hydropower development in the Susitna River basin were reported by the Corps of Engineers in 1950 and by the U.S. Bureau of Reclamation in 1948, 1952, 1961, and 1974. The 1952 USBR report indicated 12 potential hydropower sites in the basin; of these, the 5 damsites studied in the upper Susitna basin showed the highest potential. These studies showed the environmental impact from projects in the Upper Susitna River Basin would not be as severe as those from other basins, and the firm energy potential could contribute substantially to satisfying the needs of the Southcentral Railbelt area. A plan and profile of the potential damsites within this basin are shown on Plates C-5 and C-6.

ALTERNATIVE UPPER SUSITNA HYDROELECTRIC PLANS

Eight plans for hydroelectric development of the Susitna River basin were studied for this report. A brief narrative of each alternative plan follows.

Devil Canyon: The possibility of a single-dam development of the upper Susitna basin located at the Devil Canyon damsite was investigated. The proposed 635-foot-high thin-arch dam would have a water surface area of about 7,550 acres at the normal maximum pool elevation of 1,450 feet, m.s.l.

Watana: The proposed single-dam development of the upper Susitna basin located at the Watana site would be an earthfill dam with structural height of about 810 feet. The reservoir would have a normal maximum pool elevation of 2,200 feet, would have surface area of approximately 43,000 acres, and would extend about 54 river miles upstream to a point between the Oshetna and Tyone Rivers.

High D.C. Dam: In September 1974, Henry J. Kaiser Company prepared a reassessment report proposing an alternative hydroelectric development project on the upper Susitna River. The report proposes an initial project consisting of an 810-foot-high, concrete-faced, rockfill dam located about 5 miles upstream from the Devil Canyon site.

Devil Canyon-Denali: This alternative two-dam system would include the thin-arch concrete dam at Devil Canyon, and a 260-foot-high earthfill dam in the vicinity of Denali. The Denali dam would provide storage only and would have no powerplant.

Devil Canyon-Watana: This alternative two-dam system would include the concrete dam at Devil Canyon plus the earthfill dam at Watana. Both projects would have powerplants, and Watana would provide the seasonal storage for the system.

Devil Canyon-Watana-Denali: This plan is basically the same as the preceding one, but with the addition of the Denali storage project. Addition of Denali to the system would require an additional 54,000 acres of land for the reservoir.

Devil Canyon-Watana-Vee-Denali: This is the system proposed by the Bureau of Reclamation in its 1952 report on hydropower resources of the Upper Susitna River Basin. The USBR recommended initial development of Devil Canyon Dam plus the upstream storage reservoir at Denali; further development would include earthfill dams at the Watana and Vee Canyon sites between the two initial dams. In this system, the height of the Watana dam would be 515 feet and the height of the Vee dam would be 455 feet.

High D.C. (Susitna I)-Olson (Susitna II)-Vee (Susitna III)-Denali: The September 1974 Henry J. Kaiser Company's report also proposed a four-dam ultimate development plan for the Upper Susitna River Basin. The plan includes the 810-foot-high dam in Devil Canyon, a 195-foot concrete gravity dam at the Olson site, a 455-foot rockfill dam in the vicinity of Vee, and the 260-foot earthfill dam at Denali.

ALTERNATIVES CONSIDERED FURTHER

Of the 11 basic alternatives initially considered, only two--coal-fired thermal and hydropower--show promise of meeting increased Railbelt area load in the late 1980's and 1990's. Of the hydro alternatives, the upper Susitna River developments show the most promise. In the next two sections, an analysis will be made to evaluate the power potential of the eight proposed alternatives and to determine which are best from the standpoint of economics.

HYDROPOWER ANALYSIS

METHOD OF ANALYSIS

Scope: As discussed in the preceding section--Possible Solutions--several hydro projects in the upper Susitna basin were considered worthy of further study. Simulated operation studies were made to determine the power potential of these projects, both singly and in combination. In addition to power optimization, consideration was given to filling rate schedules and flow release requirements for fish, wildlife, and recreation. This section describes these studies and the basic assumptions that went into the studies.

Glossary: The following terms are defined.

Energy:

Average Energy: The average amount of energy produced each year by a hydro project over a specific period of operation or study.

Firm Energy: Electric energy which is required to be available at all times.

Prime Energy: The maximum energy expressed in average kilowatt-hours (or megawatt-hours) that can be produced at a hydro project during the most critical streamflow period. Prime energy would serve to meet firm energy loads.

Secondary Energy: Electric energy having limited availability. In good water years a hydro plant can generate energy in excess of its prime energy capability. This excess energy is classified as secondary energy because it is not available every year, and varies in magnitude in those years when it is available.

Usable Energy: The amount of energy generated by the hydro system for which there is an apparent market.

Capacity:

Installed Capacity: The rating of the generators at design head and best gate available for the production of saleable power.

Dependable Capacity: The assured peak load-carrying ability of a plant or system under adverse water conditions for the time interval and period specified when related to the characteristics of the load to be supplied, expressed in kilowatts (or megawatts).

Reserve Capacity: Capacity in excess of that required to carry peak load and which is available to meet unanticipated demands for power or to generate power in the event of scheduled or unscheduled outages.

Power Values:

Capacity Value: That part of the at-site or at-market value of electric power which is assigned to dependable capacity. This is based on the amortized investment costs and fixed operating costs of the most economical alternative power source.

Energy Value: That part of the at-site or at-market value of electric power which is assigned to energy. This is based largely on fuel and variable operating costs for the most economical alternative power source.

At-Market Value: The value of hydroelectric power at the market as measured by the cost of producing the equivalent power by the most economical means and delivering this power to the market.

At-Site Value: The value of power at the site of the generating station as measured by the at-market value minus the cost of transmission facilities and losses from generating station to market.

Head:

Critical Head: The head at which the nameplate installed capacity can be produced at full-gate opening.

Design Head: The head at which the turbine will operate to give the best overall efficiency under various operating conditions.

Rated Head: The head at which a turbine will deliver maximum generator capacity at full gate.

Reservoir Criteria:

Drawdown: The distance that the water surface of a reservoir is lowered from a given elevation as the result of the withdrawal of water.

Adverse Water Conditions: The most adverse sequence of flows from the standpoint of hydro system energy production. This sequence is a function of the amount of reservoir storage available and the power system load requirements and is usually determined by testing the full record of historical streamflow conditions.

Operating or Power Year: For purposes of this report a 12-month period beginning 1 October.

Critical Period: The interval of time when hydro energy production is limited by adverse water conditions. The period begins with reservoir(s) full and ends with reservoir(s) empty just prior to a sequence of flows which will refill the reservoir(s). Average energy produced during the critical period is called prime energy.

Critical Period Storage: The amount of water in storage which could be drafted to augment the low natural flows associated with the critical period.

Storage Refill Period: The period of time required to refill reservoir following the critical period draft.

Dead Storage: The amount of storage within the reservoir which lies below the minimum elevation to which the reservoir surface could be lowered. The minimum reservoir surface elevation is a function of the head range within which the turbines are designed to operate at greatest efficiency.

Usable Storage: The amount of reservoir storage which lies within the elevations above the dead storage pool and below the full reservoir pool. This storage is the water which is available to augment natural streamflow during the critical period.

Power Terms:

P.O.L.: Power-on-line date.

Load Shape: Daily and annual load curves reduced to a percentage factor of a specified load. For example, it is common to indicate the monthly loads for both energy and capacity in percentage of annual energy and annual peak loads.

Area Load Factor: The ratio of the average load over a designated period to the peak load occurring in that period, for an integrated load center.

Plant Factor: The load factor for a specific hydro project.

Load Center: A point at which a large share of the load of a given area is assumed to be concentrated.

Base Load: The minimum amount of load required 24 hours a day.

Peak Load: The maximum instantaneous load within a specified time.

Methodology: Power analysis of the study basin was based on the hydrologic data available from the various stream gaging stations within the basin above Gold Creek. The study period covered was the 25 years of record for the Gold Creek station for the years of 1950 through 1974. The three gaging stations with shorter periods of record were extended by correlation with the Gold Creek station, and damsite monthly flows were estimated by extrapolation of the observed and computed gaging station flows (see Section A of this Appendix). The analysis of the power output for a multitude of schemes within the basin was accomplished by analytical regulation using the "HEC-3 Reservoir System Analysis" computer program developed by the Hydrologic Engineering Center, Corps of Engineers, Davis, California. Final results were verified using the "Hydro System Seasonal Regulation" computer program developed by the North Pacific Division, Corps of Engineers, Portland, Oregon. The HEC-3 program was used because of the simplicity with which the system could be regulated and the ease with which the program could be adapted to the study conditions. Rule curves were established for maximum power output in accordance with hydrologic and system conditions. The projected energy load growth, the yearly energy demand shape, and the daily load factors were provided by the Alaska Power Administration. Additional information was provided by the Bureau of Reclamation.

Power Production Variables: Many variables were considered prior to commencement of the power study. A brief discussion of the assumptions and variables used is presented in the following text.

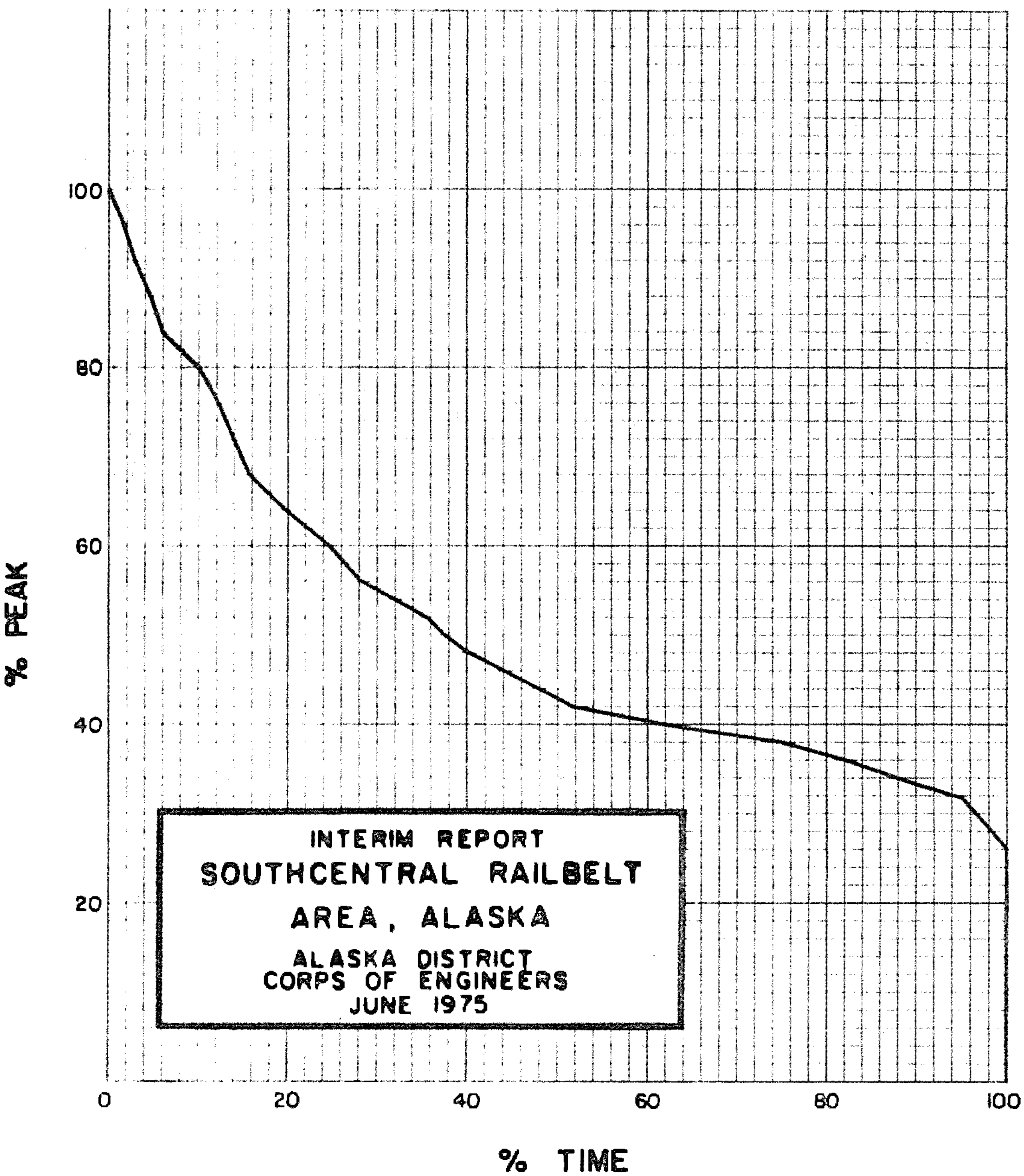
Free Surface Evaporation: Included in the Hydrology Section are rates of free surface evaporation and consumptive use. The figures show that the reservoir evaporation is very nearly equal to the consumptive use rate of the natural vegetation which would be inundated by the reservoir. Accordingly, no adjustments have been applied to account for evaporation and consumptive use.

Head Loss and Tailwater Elevation: Power head losses were confined to fluctuations in the tailwater elevations and to hydraulic losses through the tailrace, turbines, and penstocks. Although the HEC-3 program is sufficiently refined for a tailwater rating curve, absence of channel cross-sections did not permit the calculation of the damsite backwater. Penstock friction losses, although dependent upon discharge, averaged approximately one percent of the difference between pool elevation and tailwater. Consequently, the friction loss was assumed to be one percent of the maximum head, while the tailwater elevation was based on the average flow condition that could be expected. By adding the friction loss to the assumed tailwater elevation, the following average tailwater conditions were developed for use in the power studies.

Tailwater Elevations

Project	Tailwater Elevation (ft)
Devil Canyon	880
High D.C.	1030
Watana	1480
Vee	1925
Olson	875

ESTIMATED SOUTHCENTRAL AND YUKON PERCENT LOAD DURATION CURVE



Sedimentation: Impact from reservoir reduction caused by sediment entrapment is dependent on the system developed and sequence of construction. If Devil Canyon were built and no further upstream development were to occur, almost 55 percent of the initial total Devil Canyon storage capacity would be occupied by sediment at the end of 100 years. On the other hand, upstream development of the Watana project would result in negligible siltation in the Devil Canyon reservoir, and heavy buildup in the Watana reservoir. The percentage of volume reduction in the Watana reservoir is dependent on the volume of the reservoir selected for study. The 100-year volume reduction of the Watana reservoir that would accompany a maximum pool elevation of 2200 feet is estimated to be 4.2 percent; however, much of the reservoir volume that would be occupied by sediment is within the dead storage zone of the reservoir, and actual reduction in power generation caused by silt encroachment is small. As described in the Hydrology Section, the storage capacity curves for each of the six projects were adjusted to account for 50-year sedimentation and these curves were used for all operation studies.

Load Factors: Data presented by the Alaska Power Administration (Section G) indicate that the integrated annual load factor for the Railbelt area is close to 50 percent; for the purposes of analysis, a 50-percent load factor was used in the hydropower studies. It is assumed the hydro system will carry a proportional share of the total system load. The hydro plant generating installations were therefore based on a 50-percent plant factor.

Market area monthly load factors are uniformly high throughout the year, and range between 70 to 76 percent. Weekly load factors are anticipated to reach 80 percent, and daily load factors have ranged between 60 to 85 percent. Shown on Graph C-6 is the estimated percent hourly load duration curve for the year 1975.

The character of the projected demand profile assumes a steady industrial growth rate and a slight increase in the annual load factor. It is assumed, however, that while the hydro system may provide much of the baseload during the early years of operation, future thermal energy development would push the hydro system higher on the duration curve, lowering the hydro system plant factor. Therefore, although the market area load factor may increase during the economic life of the hydro project, its project load factor is expected to diminish. With the abundance of hydropower potential within the market area, it is possible that hydropower, in lieu of thermal energy, may provide the bulk of future Alaskan energy needs. If this were the case, the Susitna hydro system could remain at a fixed position on the load duration curve and the respective project plant factor would remain unchanged.

Throughout the rest of the country, hydropower utilization has followed the former course of development, and there is good chance it may eventually follow that pattern in Alaska also. To provide for this possibility, future studies should evaluate the feasibility for future installation of additional units to permit an ultimate plant factor less than 50 percent. If additional units are deemed appropriate, then skeleton bays should be provided during initial project construction.

Monthly Energy Distribution: The monthly energy distribution, as derived by the Alaska Power Administration, was developed in accordance with present energy trends projected to reflect industrial growth within the Railbelt area. Load distribution changes since 1961 have shown a steady increase in the requirements for the months of December and January, and a decrease in summertime loads. This reflects a utility load growth heavily influenced by the peaking requirements of the commercial and residential sectors. Any addition to the industrial base would tend to reverse this trend. Table C-14 shows the monthly load distribution indicated by recent Railbelt utility statistics. Also shown is the APA recommended distribution for the current study, which assumes a larger industrial load component. The shape of the load curve reflects the need for reservoir storage. Although nearly 65 percent of the energy produced is estimated to be utilized in the seven months of winter, between October through April, only 14 percent of the Susitna streamflow occurs during the same time period. In order to meet energy demand, the flow distribution of the river must be considerably altered, and the need for a large amount of storage to accomplish this flow control is apparent.

Flow Requirements: Downstream flow requirements for recreational use and fish and wildlife enhancement have been considered in selection of the most attractive first-stage development. Although minimum flow requirements necessary for environmental considerations below Devil Canyon are not presently known, assessment of firm power reduction as a result of varying release rates should be performed if minimum release rates are imposed. Also considered was need for maintaining static reservoir pool elevations for summer recreation and winter wildlife migration. In the studies, pool elevations at the downstream reservoirs were usually maintained steady for the compatible uses of power production, recreation usage, and wildlife migration. Upstream reservoirs used for storage releases were operated to fluctuate in accordance with power demand, regardless of recreation and wildlife needs.

Operation Procedure: Reservoir regulation was accomplished by allowing storage releases as established by monthly rule-curves for each reservoir. Six curves were developed for each reservoir, with each level in all reservoirs operating for a given downstream control point. The first rule-curve for each reservoir is minimum pool storage and the last is full reservoir. Intermediate levels are used as a means of controlling the distribution of storage within each reservoir. Reservoir regulation entailed routing the 25 years of monthly streamflows through the proposed hydro system in an attempt to meet an assumed firm load as per Table C-14. If the load could be met during each of the 300 monthly streamflow periods, a higher firm load was assumed, and another power run was made. This process was repeated until that load could be carried during all but the last month of the critical period, thus establishing the system's

RAILBELT ENERGY REQUIREMENTS AS PERCENT OF ANNUAL REQUIREMENTS

Months	1961 Devil Canyon 1/	1970-72 Utility Loads 2/	Recommended For Current Studies 3/
October	8.9	7.9	8.0
November	9.4	8.9	8.8
December	10.4	10.2	9.7
January	9.3	11.3	10.6
February	8.1	9.2	9.0
March	8.3	9.8	9.4
April	7.7	8.0	8.1
May	7.6	7.2	7.5
June	7.2	6.5	6.9
July	7.4	6.4	6.9
August	7.7	7.1	7.4
September	8.0	7.5	7.7
Total	100.0	100.0	100.0

1/ "Devil Canyon Project, Alaska," USBR feasibility report, March 1961.

2/ Combined loads of CEA, AML&P, GVEA, and FMUS for the period October 1970 through September 1972.

3/ Assumes total requirements consisting of 25 percent industrial loads and 75 percent the above combined loads for the four major utilities.

firm annual load-carrying capability. For the scoping analysis the installed plant capacity of each powerplant was then established based on the annual 50-percent plant factor and the project firm annual energy produced during the critical period. The selected plan installed capacity, however, is based on average annual energy and the 50-percent plant factor. It was decided not to use average annual energy as the basis for plant capacity in the scoping analysis because of the undue weight that this method would give to single projects with limited reservoir storage and high secondary energy. Average annual energy was based on the average energy produced by the selected generating capacity for the entire period of record. The critical period for each system studied was dependent on the storage capacity of the system and reservoir location.

POWER POTENTIAL OF ALTERNATIVE DEVELOPMENT

Alternatives Considered: Initial studies were based on determining the optimum plan for full development of the upper Susitna River above Gold Creek. Three plans were considered.

1. The USBR 4-dam plan: Devil Canyon-Watana-Vee-Denali

2. The High Watana 3-dam plan: Devil Canyon-High Watana-Denali

3. The Kaiser 4-dam plan: Olson-High D.C.-Vee-Denali

Difficult foundation conditions are present at both the Vee and Denali sites, and it was decided to evaluate alternative development plans without Vee, Denali, or both. This was done to permit recommendation of a first-stage development plan should it be considered desirable to defer consideration of the Vee and/or Denali sites, pending further evaluation of foundation problems.

Both single-dam and two-dam first-stage development were considered, including:

1. Devil Canyon

2. High D.C.

3. Low Watana

4. Mid-Height Watana

5. High Watana

6. Devil Canyon-Denali

7. Devil Canyon-Low Watana

8. Devil Canyon-Mid-Height Watana

9. Devil Canyon-High Watana

The various alternatives and their power potential are discussed in the following paragraphs. While power studies were made for all of the alternatives, full data is presented for only the most promising ones.

Full Basin Development:

Devil Canyon, Watana, Vee, Denali: The four-dam Bureau of Reclamation proposal consisting of Devil Canyon, Watana, Vee, and Denali, based on the 25-year flow record adopted for this study, could produce 6.25 billion kilowatt-hours of firm annual energy. A summary of the four-dam concept is shown on Table C-15 and a profile of the system is shown on Plate C-7. An addition to the system could include the low-head Olson Dam and powerplant three miles downstream from Devil Canyon damsite. Olson Dam and reservoir would serve both for at-site power generation and for reregulation of the daily releases from Devil Canyon. Olson Dam would be concrete gravity, rising approximately 50 feet above the riverbed, and it would have an energy-producing capability of 300 million kilowatt-hours firm annual energy.

Devil Canyon, Watana, Denali: A three-dam concept consisting of Devil Canyon, Watana, and Denali would make maximum use of potential storage at the Watana site and, with good foundation conditions, the height of the Watana Dam could be raised to an elevation that would allow utilization of all but 100 feet of the potential powerhead between the Vee and Devil Canyon damsites. As in the four-dam system, Olson reregulation would remain as a possible option. The three-dam system, with a maximum Watana pool elevation of 2200 feet, would have a firm annual energy capability of approximately 6.8 billion kilowatt-hours, slightly greater than the four-dam USBR proposal. With the addition of the generation capability of Olson, total system output of firm energy would be 7.1 billion kilowatt-hours. This is considered to be the ultimate practical basic development. Should economics indicate a lesser Watana Dam height, a 650-foot structural height Watana Dam would provide a system output of 5.9 billion kilowatt-hours. A profile of the three-dam concept is shown on Plate C-8, and a summary of power production data is shown on Table C-16.

Olson, High D.C., Vee, Denali: A third proposal (the Kaiser 4-dam plan) consists of a low-head dam (145 feet) and powerplant at the Olson damsite, a high-head dam (710 feet) and powerplant at the High D.C. damsite, five miles upstream from the Devil Canyon damsite, another high-head dam and powerplant at the backwater of the High D.C. reservoir, and a fourth dam at the Denali damsite. The success of the system is dependent not only on a high structure for the second upstream dam, but also confirmation of a suitable damsite for the third upstream structure. The Vee damsite is the only potential location for the third upstream dam, and this would result in nonutilization of approximately two miles of riverfall between the second and third upstream reservoirs. Because foundation conditions of the High D.C. damsite are unknown, its selection, based only on topographic limitations, must be considered optimistic. The High D.C. Dam can provide only half the storage capacity of the high Watana reservoir, although their heights are comparable. Consequently, power production for the High D.C. Dam is considerably less than that of the High Watana Dam. By integrating the High D.C. into the four-dam scheme mentioned earlier, the system has a firm annual capability of 5.9 billion kilowatt-hours. This is approximately 0.9 billion kilowatt-hours less than the three-dam system consisting of Devil Canyon, High Watana, and Denali. If the High D.C. Dam, because of bad foundation conditions, were lowered to a structural height of 650 feet, the energy capability of the system would be 5.0 billion kilowatt-hours. A profile of this four-dam concept is shown on Plate C-9, and Table C-17 summarizes power data for the system with a High D.C. elevation of 1750 feet (structural height: 810 feet).

First-Stage Development--Single Project Alternatives: Power production from a single dam first-stage development in the Upper Susitna River Basin is limited by a fluctuating powerhead and lack of adequate storage. A single-dam development would bear the total cost of the supporting network of roads, transmission systems, and logistical development, and would still be required to be economically attractive in the event that no further basin development were to occur. Under this criterion, the most feasible single dams in the Upper Susitna River Basin are those which are high enough to take advantage of the large storage potential of the broadening river valley in its upper reaches. Therefore, the elevations established for first-stage single-dam development were chosen for maximization of height consistent with technology, topography, and full basin development.

Devil Canyon: The Devil Canyon Dam normal maximum pool elevation was established by assuming that full basin development would include the Watana Dam. The power generating characteristics for Devil Canyon are shown below.

Devil Canyon Power Study

Project	Devil Canyon
Norm max res elev, ft.	1,450
Min power pool elev, ft.	1,275
Avg tailwater elev, ft.	880
Max generating head, ft.	570
Usable storage, Ac-ft.	810,000
Dead storage, Ac-ft.	290,000
Dependable capacity, mw	206
Firm annual energy, mw-yrs	103
Average energy, mw-yrs	170
Critical period, months	7

USBR FOUR-DAM SYSTEM

	Devil Canyon	Watana	Vee	Denali	Total
Normal Maximum Pool Elev. (ft)	1450	1905	2300	2535	---
Minimum Power Pool Elev. (ft)	1275	1650	2111	2368	---
Active Storage Capacity (Acft)	790,000	2,310,000	820,000	3,770,000	7,690,000
Dependable Capacity (MW)	702	425	300	---	1427
Adjusted Tailwater Elev. (ft)	880	1480	1925	---	---
Critical Period	October 1968 thru May 1971 (32 months)				
Firm Annual Energy (Billion kWh)	3.077	1.860	1.315	---	6.252
Average Annual Energy (Billion kWh)	3.382	2.031	1.468	---	6.881

HIGH WATANA THREE-DAM SYSTEM

	Devil Canyon	High Watana	Denali	Total
Normal Maximum Pool Elev. (ft)	1450	2200	2535	---
Minimum Power Pool Elev. (ft)	1275	1820	2368	---
Active Storage Capacity (Acft)	790,000	8,125,000	3,770,000	12,685,000
Dependable Capacity (MW)	785	767	---	1,552
Adjusted Tailwater Elev. (ft)	880	1,480	---	---
Critical Period	October 1968 thru April 1974 (67 months)			
Firm Annual Energy (Billion kWh)	3.440	3.360	---	6.800
Average Annual Energy (Billion kWh)	3.506	3.405	---	6.911

KAISER FOUR-DAM SYSTEM

	Olson	High D.C.	Vee	Denali	Total
Normal Maximum Pool Elev. (ft)	1018	1750	2300	2535	---
Minimum Power Pool Elev. (ft)	936	1430	2111	2368	---
Usable Storage Capacity (Acft)	43,000	3,930,000	820,000	3,770,000	8,563,000
Dependable Capacity (MW)	187	862	298	---	1347
Adjusted Tailwater Elev. (ft)	875	1030	1925	---	---
Critical Period	October 1968 thru May 1971 (32 months)				
Firm Annual Energy (Billion kWh)	0.821	3.775	1.304	---	5.900
Average Annual Energy (Billion kWh)	0.915	4.156	1.440	---	6.511

The Devil Canyon reservoir was operated strictly for power production, and the reservoir filled and spilled during each year of the study period including the year of critical flow. Average yearly pool fluctuation was 80 feet.

High D.C.: This proposal, located five miles upstream from the Devil Canyon damsite, provides increased storage for a single dam development but jeopardizes maximum basin development. The dam and reservoir virtually eliminate the Devil Canyon and Watana damsites and leave no opportunity for the devilopment of upstream storage capacity if Denali foundation conditions preclude its development. Ultimate system development could include projects at Vee and Denali, however, if foundation conditions permit. The potential of the High D.C. project is presented below.

D.C. High Power Study

Project	High D.C.
Norm max res elev, ft.	1,750
Min power pool elev, ft.	1,430
Avg tailwater elev, ft.	1,030
Max generating head, ft.	720
Usable storage, Ac-ft.	3,930,000
Dead storage, Ac-ft.	800,000
Dependable capacity, mw	600
Firm annual energy, mw-yrs	300
Average energy, mw-yrs	382
Critical period, months	32

Reservoir operation resulted in full pools by the end of October for each of the 25 years except 2 during the critical period. Average yearly head fluctuation was 110 feet, and spills occurred in 22 of the study years.

Watana Low Dam (1905 feet elevation): Selection of a normal maximum pool elevation at the Watana site is dependent upon the concept of full-basin development. By selecting a pool elevation of 1905 feet, the Vee damsite is available for a full-basin development consisting of four dams. At this elevation, however, reservoir storage control at Watana is not sufficient and upstream storage is required. This storage is available at the Denali site, assuming foundation conditions are determined to be satisfactory, and the four-dam concept would be a very attractive development. The Low Watana Dam could be considered for first-stage construction in such a plan. As shown in the following table, the generating head for the Low Watana Dam is less than that of Devil Canyon, but the larger storage volume at Watana allows production similar to that of Devil Canyon as a first-stage development.

Low Watana Power Study

Project	Watana (1905 ft.)
Norm max res elev, ft.	1,905
Min power pool elev, ft.	1,650
Avg tailwater elev, ft.	1,480
Max generating head, ft.	425
Usable storage, Ac-ft.	2,310,000
Dead storage, Ac-ft.	170,000
Dependable capacity, mw	252
Firm annual energy, mw-yrs	126
Average energy, mw-yrs	177
Critical period, months	7

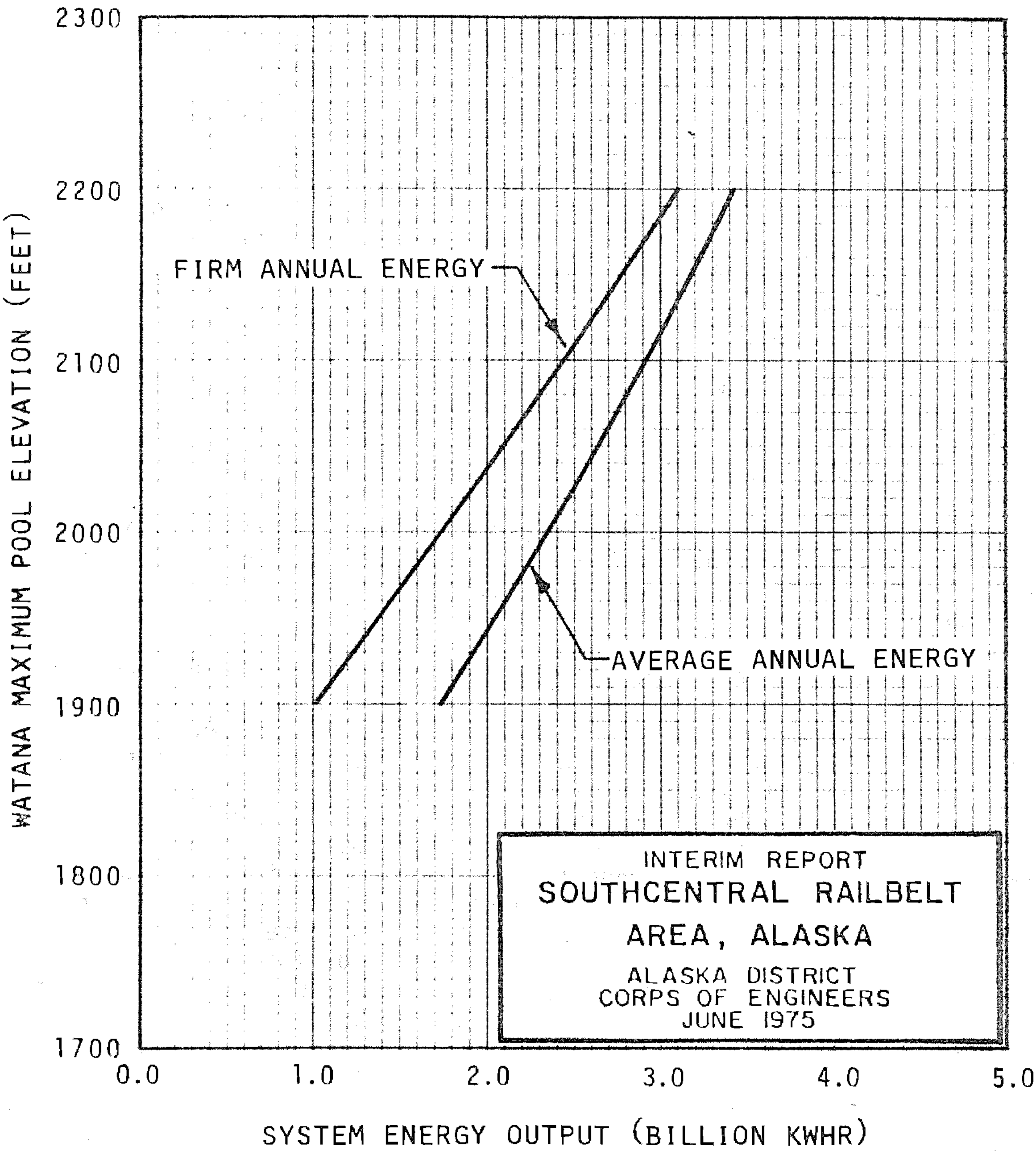
Energy produced for various Watana pool elevations is shown on Graph C-7. The power output from the Low Watana reservoir is very similar to that of Devil Canyon. The reservoir filled for each year of the study, and spills occurred in all years except the critical year. The average yearly head fluctuation was 95 feet.

Watana High Dam (2200 feet elevation): A normal maximum pool elevation of 2200 feet for the Watana Dam is possible since rock conditions at the Watana site are adequate for an 810-foot-high dam. The high Watana reservoir would flood the Vee damsite and thus preclude use of that dam system development. The study helped establish the elevation for which Watana either singularly or in conjunction with system development would optimize system development. A summary of the High Watana is given in the following table.

High Watana Power Study

Project	Watana
Norm max res elev, ft.	2,200
Min power pool elev, ft.	1,820
Avg tailwater elev, ft.	1,480
Max generating head, ft.	720
Usable storage, Ac-ft.	8,125,000
Dead storage, Ac-ft.	1,300,000
Dependable capacity, mw	686
Firm annual energy, mw-yrs	343
Average energy, mw-yrs	382
Critical period, months	32

SYSTEM ENERGY OUTPUT
WATANA



Watana Midrange Height (2050 feet elevation): The Watana Dam of medium elevation provides good storage potential, allows full-basin development in accompaniment with Devil Canyon and Denali, but again precludes use of Vee. If Denali could not be built for technical or economic reasons, a large percentage of the full-basin potential could still be produced by the Devil Canyon and Medium Watana Dams. The following table summarizes the results of the operation study.

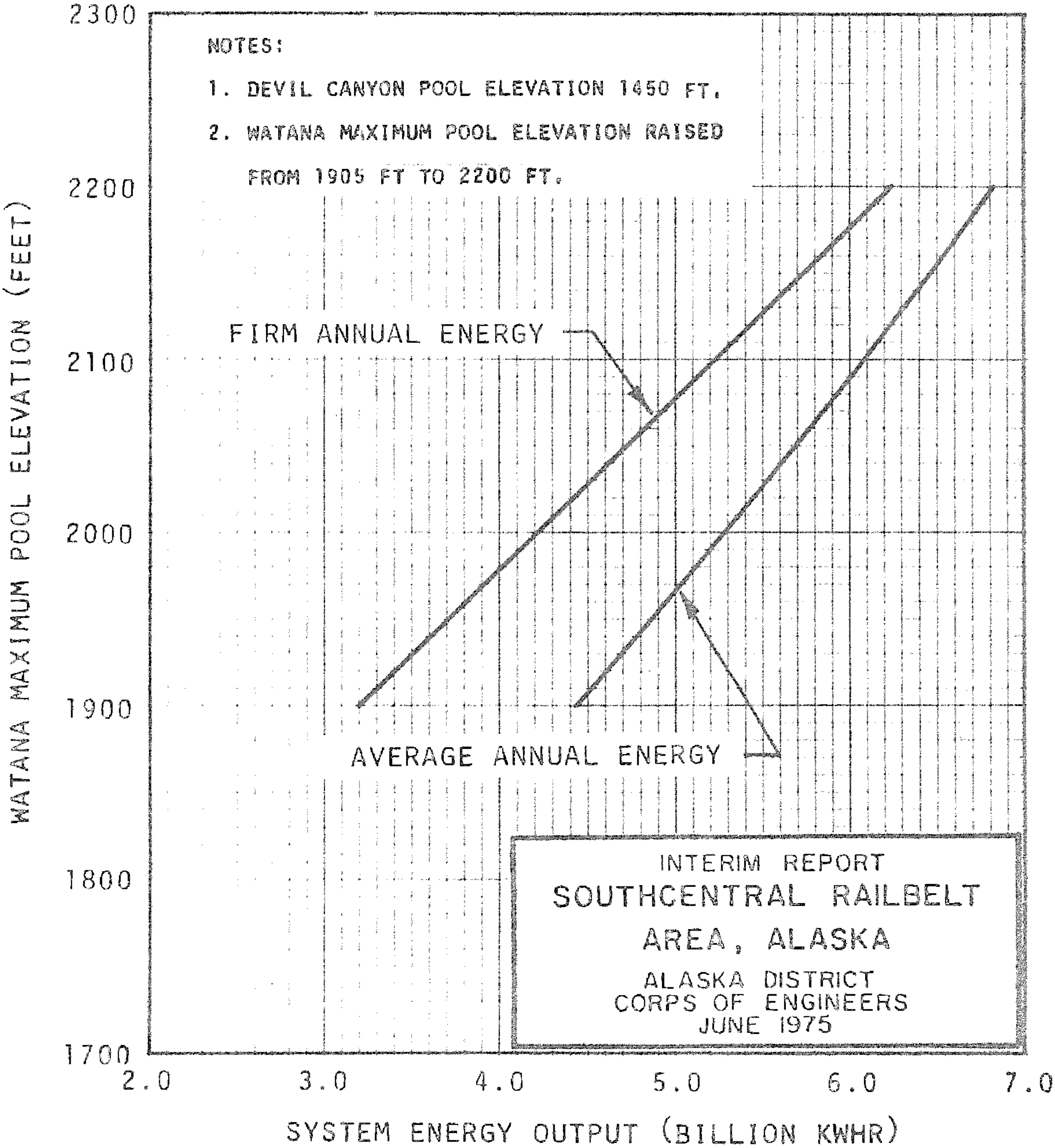
Medium Height Watana Power Study

Project	Watana
Norm max res elev, ft.	2,050
Min power pool elev, ft.	1,740
Avg tailwater elev, ft.	1,480
Max generating head, ft.	570
Usable storage, Ac-ft.	4,575,000
Dead storage, Ac-ft.	625,000
Dependable capacity, mw	457
Firm annual energy, mw-yrs	228
Average energy, mw-yrs	297
Critical period, months	32

The operation of the Watana reservoir revealed that the reservoir filled every year except during the 3-year critical period, and spills occurred in 19 of the years. Average yearly pool fluctuation was in the range of 100 feet.

First-Stage Development--Two-Dam Alternatives: Power production from a two-project first-stage development is a logical alternative toward full-basin development. The most feasible schemes studied were those consisting of a downstream project with a large power head coupled with an upstream project with a large storage capacity. Good power production was obtained from schemes consisting of either Devil Canyon, Watana, or Vee in conjunction with storage releases from Denali. As mentioned earlier, however, Denali foundation uncertainties exist, but for comparative purposes, the Devil Canyon-Denali system is presented for review. Consideration of other upstream reservoirs with large storage capacities were, therefore, limited to the Vee and Watana damsites. Good storage could be developed at the Vee damsite, but topographic constraints and backwater encroachment on the Lake Louise recreation area, as well as foundation conditions at the damsite, make this project unfeasible for large storage development at this time. The Watana project then becomes the logical choice for large storage development. This site could provide in excess of 11 million acre-feet of storage with a structural dam height of 860 feet. The reservoir would inundate less acreage than the Denali reservoir, but the storage capacity would be approximately three times as great as that of Denali.

SYSTEM ENERGY OUTPUT
DEVIL CANYON WITH WATANA



Presented below are power studies representing first-stage development of Devil Canyon-Denali and Devil Canyon-Watana. By assuming possible future development of the Denali damsite, the Devil Canyon-Watana scheme was studied with dam heights that would allow total basin development consisting of three or four projects.

Devil Canyon-Denali: The Devil Canyon Dam normal maximum reservoir elevation was established at the maximum height that would not encroach upon the tailwater of the upstream Watana damsite. The Denali Dam normal maximum reservoir elevation was optimized for the most feasible four-dam power output. By raising the Denali maximum pool elevation 15 feet, from elevation 2535 to elevation 2550, the resulting power production increase from the system was only four percent. The incremental cost increase was not recaptured by this proportional power benefit and, therefore, the Denali Dam with the lower pool elevation was used. The power analysis of this two-dam system was based on rule-curves that made maximum potential use of the active storage in both reservoirs. The Denali reservoir was heavily drafted during the months of low flow and it was allowed to refill during the four summer months of high inflow. Until the Denali reservoir filled, summer flow releases were held to the minimum flow release of 100 cfs. It was assumed that local inflow to the river below Denali combined with the 100 cfs release would be adequate for fish habitation. The Devil Canyon reservoir was drafted each spring to make room for storage of the summer runoff and to allow Denali to refill prior to the next winter.

Devil Canyon-Denali Power Study

Project	Devil Canyon	Denali	System
Norm max res elev, ft.	1,450	2,535	
Min power pool elev, ft.	1,275	---	
Avg tailwater elev, ft.	880	---	
Max generating head, ft.	570	---	---
Usable storage, Ac-ft.	740,000	3,770,000	4,510,000
Dead storage, Ac-ft.	260,000	80,000	340,000
Dependable capacity, mw	575	---	575
Firm annual energy, mw-yrs	285	---	285
Average energy, mw-yrs	377	---	377
Critical period, months			32

The Devil Canyon reservoir refilled each of the 25 years of study, and Denali refilled in 13 of the 25 years. Average annual Devil Canyon pool fluctuation was 175 feet, and the average annual Denali pool fluctuation was in the range of 40 feet.

Devil Canyon-Low Watana: The Devil Canyon-Watana combination was studied for the three Watana elevations mentioned under the previous section. A plot of the firm and average annual energy that can be obtained by increasing the Watana elevation for the Devil Canyon-Watana combination is shown on Graph C-8. The maximum pool elevation used under this power study, 1905 feet, allows for a full-basin development consisting of four dams. The system operation for the Devil Canyon-Low Watana is shown below.

Devil Canyon-Low Watana Power Study

Project	Devil Canyon	Watana	System
Norm max res elev, ft.	1,450	1,905	
Min power pool elev, ft.	1,275	1,650	
Avg tailwater elev, ft.	880	1,480	
Max generating head, ft.	570	425	---
Usable storage, Ac-ft.	790,000	2,310,000	3,100,000
Dead storage, Ac-ft.	260,000	170,000	430,000
Dependable capacity, mw	460	270	730
Firm annual energy, mw-yrs	230	135	365
Average energy, mw-yrs	322	190	512
Critical period, months			19

With the exception of the most critical year, both reservoirs filled to capacity each year. The severity of the Devil Canyon pool fluctuation has been drastically reduced. Although the Devil Canyon pool attained maximum fluctuation during the most critical year, average pool fluctuation during the remainder of the years was only 8 feet. The Watana pool had an average annual drawdown of 160 feet.

Devil Canyon-Midheight Watana: A summary of the Devil Canyon-Midheight Watana operation is presented below. Power produced from this system is 75 percent of that obtained from the four-dam system. The medium height Watana Dam is compatible with a three-dam full-basin development. The large storage potential of the Watana reservoir allowed Devil Canyon to maintain a full-pool elevation with the only fluctuations taking place during the critical period. Average annual Watana pool fluctuation is 125 feet.

Devil Canyon-Midheight Watana Power Study

Project	Devil Canyon	Watana	System
Norm max res elev, ft.	1,450	2,050	
Min power pool elev, ft.	1,275	1,740	
Avg tailwater elev, ft.	880	1,480	
Max generating head, ft.	570	570	
Usable storage, AC-ft.	790,000	4,550,000	5,340,000
Dead storage, AC-ft.	260,000	650,000	910,000
Dependable capacity, mw	594	468	1,062
Firm annual energy, mw-yrs	297	234	531
Average energy, mw-yrs	361	282	643
Critical period, months			32

Devil Canyon-High Watana: A summary of the Devil Canyon-High Watana system operation is shown below. The large storage capability of the High Watana reservoir provides almost 100 percent river control, and the consequential maximization of firm energy.

Devil Canyon-Watana Power Study

Project	Devil Canyon	Watana	System
Norm max res elev, ft.	1,450	2,200	
Min power pool elev, ft.	1,275	1,820	
Avg tailwater elev, ft.	880	1,480	
Max generating head, ft.	570	720	
Usable storage, Ac-ft.	790,000	8,125,000	8,915,000
Dead storage, Ac-ft.	260,000	1,300,000	1,560,000
Dependable capacity, mw	695	709	1,404
Firm annual energy, mw-yrs	348	354	702
Average energy, mw-yrs	388	394	782
Critical period, months			32

SYSTEM DEVELOPMENT EVALUATION

GENERAL

The purpose of this section is to outline the basic assumptions used in making the economic analysis and to reduce the large number of alternative Susitna River hydro development plans to a few of the more promising through a preliminary economic evaluation.

Evaluation of the upper Susitna River development was accomplished by comparing the total of the incremental benefits for each separate reservoir purpose to those of the accompanying costs. The benefit value of hydroelectric power is measured by the cost of providing the equivalent power from the most likely alternative source, as determined by the Federal Power Commission. Although alternative projects are assumed to be non-Federally financed, the coping analysis was made using the federal financing Power Values developed by FPC. Flood control, area redevelopment, and transmission intertie benefits were estimated by the Alaska District, Corps of Engineers, and recreational benefits were provided by a consultant. However, because power and AR benefits represent over 99 percent of total benefits, the preliminary scoping analysis was based entirely on these benefits. Project costs were based on the January 1975 Alaska Construction Index.

The feasibility test entailed the evaluation of maximization of net benefits consistent with engineering judgement.

The cost of providing equivalent power from the most likely alternative source, but based on financing comparable to the Federal project--the same interest rate and without taxes and insurance--is used in project formulation and scoping. This is in compliance with the methodology contained in Principles and Standards for planners, as published in Federal Register 1973, Volume 38, Section 134, which requires that projects meet the test that there is no more economical means, evaluated on a comparable basis, of providing project services.

PROJECT AND SYSTEM COSTS

Project Costs: Presented in Table C-18 is a summary of the project costs of the more feasible projects considered under the scoping analysis. A detailed cost estimate of the projects included in the selected plan is contained in Section B of the Appendix. In addition to the cost estimates shown, rough estimates were made for an Olson project with a 1020-foot maximum normal pool elevation, and a Vee storage project with a 2350-foot maximum normal pool elevation.

Interest During Construction (IDC): For the purpose of the scoping analysis, the construction period of the first project of each system

PROJECT COST ESTIMATES

Project	Pool Elevation (ft. MSL)	Construction Sequence	Construction Costs ($1000)
Watana	1905	1st Added	668,000
Watana	1905	2nd Added	420,000
Watana	2050	1st Added	877,000
Watana	2050	2nd Added	628,000
Watana	2200	1st Added	1,088,000
Watana	2200	2nd Added	837,000
Watana	2250	1st Added	1,153,000
Watana	2250	2nd Added	907,000
Devil Canyon	1450	1st Added	714,000
Devil Canyon	1450	2nd Added	432,000
Olson	1020	2nd Added	380,000 1/
High D.C.	1750	1st Added	1,266,000
Vee	2300	2nd Added	477,000
Vee	2350	2nd Added	527,000 1/
Denali	2535	2nd Added	340,000

1/ Reconnaissance grade estimates

analyzed was assumed to be five years, and IDC was based on the formula of simple interest applied to each increment of the averaged annual first cost.

System Annual Costs: The simple interest charge on money obligated during the construction period of any project is considered a logical cost of the construction phase and is added to first cost to establish the investment cost. This investment cost can then be transformed into an average annual fixed cost by applying the appropriate capital recovery factor associated with the 6-1/8-percent interest rate and 100-year economic project life. Average annual costs of projects brought on line beyond the initial power-on-line date are computed in this same manner, but the combined cost of the project and the interest during construction are first present worthed at the established interest rate back to the initial power-on-line date. This process is designed to give all phases of the system an equivalent value and the combined phases can then be reduced to a level annual payment. By adding operations, maintenance, and replacement costs, a total annual cost is established for the purpose of determining comparability and feasibility.

Operation, Maintenance, and Replacement Costs (OM&R): Annual OM&R costs were estimated by comparison of the system size and operation with those of existing hydro systems. For the preliminary scoping analysis, the basic amount of $1 million per power project and $0.2 million per non-power project was used for the estimated annual OM&R costs. The annual OM&R cost for the selected plan is based on the results of the APA study, which is contained in Section G.

Total Average Annual System Costs: The average annual costs for the various systems of development are shown on Table C-19. The figures are based on a 6-1/8-percent annual interest rate and a 100-year economic life. A more detailed discussion of the method of cost derivation is presented in Section B. The costs also reflect the sequence of project construction as shown, transmission facilities, access roads, land acquisition, replacement costs, annual operation and maintenance, and other associated project costs.

POWER BENEFITS

General: The benefit value of hydroelectric power is measured by the cost of providing the equivalent power from the most likely alternative source. The types of alternative power sources appropriate for the Railbelt area and the annual unit costs for those alternatives have been determined by the Federal Power Commission. The amount of power available from the various alternative hydro projects and systems was determined in the previous section, Hydropower Analysis. The energy and capacity-producing capabilities of these projects and systems were adjusted to account for transmission losses and marketability considerations.

AVERAGE ANNUAL ALTERNATIVE SYSTEM COSTS

SCOPING ANALYSIS

System of Development	Interest During Construction ($1,000)	Investment Cost ($1,000)	Average Annual Investment Cost ($1,000)	Average Annual OM&R ($1,000)	Total Average Annual Costs ($1,000)
Devil Canyon, Denali, Vee (2300), Watana (1905)	214,701	1,616,825	99,291	3,200	102,491
Devil Canyon, Denali, Vee (2350), Watana (1905)	218,927	1,648,651	101,245	3,200	104,445
High D. C., Olson, Denali, Vee (2300)	295,775	2,227,366	136,784	3,200	139,984
Devil Canyon, Watana (2200), Denali	233,297	1,756,868	107,891	2,200	110,091
Devil Canyon, Watana (2050), Denali	209,519	1,577,803	96,894	2,200	99,094
Devil Canyon, Watana (1905), Denali	185,855	1,399,595	85,950	2,200	88,150
Devil Canyon, Watana (2250)	212,522	1,600,423	102,336	2,000	104,336
Devil Canyon, Watana (2200)	204,558	1,540,449	94,600	2,000	96,600
Devil Canyon, Watana (2050)	180,780	1,361,384	83,604	2,000	85,604
Devil Canyon, Watana (1905)	157,116	1,183,176	72,660	2,000	74,660
Watana (2250), Devil Canyon	225,702	1,699,678	104,379	2,000	106,379
Watana (2200), Devil Canyon 4/	215,748	1,624,725	99,776	2,000	101,776
Watana (2250), Devil Canyon	183,440	1,381,416	84,834	2,000	86,834
Watana (1905), Devil Canyon	151,437	1,140,413	70,034	2,000	72,034
Devil Canyon, Denali	148,014	1,114,634	68,451	1,200	69,651
Devil Canyon	109,331	823,331	50,561	1,000	51,561
High D. C.	193,856	1,459,856	89,651	1,000	90,651
Watana (2200)	166,600	1,254,600	77,046	1,000	78,046
Watana (2050)	134,291	1,011,291	62,104	1,000	63,104
Watana (1905)	102,288	770,288	47,304	1,000	48,304

Notes:

1. Number in parenthesis represents the normal maximum pool elevation of that project.
2. Average Annual Investment Costs computed at 6-1/8 percent over 100 years.
3. Project staging in sequence as shown and each project was assumed to have a five-year construction time.
4. See Selected Plan for Final Cost Estimates.

Power Capabilities: Gross power generating capabilities of the various alternative projects and systems are summarized on Table C-20. The dependable capacity of each project and system evaluated was determined by dividing the firm energy by the appropriate plant factor (50 percent). Although the dependable capacity for the selected plan is based on a winter minimum head during the critical period, for system comparison it was assumed to be available at the absolute minimum drawdown.

Transmission Losses: Line losses for the Railbelt transmission system were estimated using data furnished by the Alaska Power Administration. In the preliminary analysis, all systems evaluated were assumed to incur four-percent losses for capacity, and one-percent losses for energy. More precise transmission losses were developed for the selected plan by the Alaska Power Administration, Section H. In both cases, the losses were subtracted from the energy and capacity capabilities of the system prior to derivation of benefits. The transmission losses established for the selected plan are given in the Selected Plan portion of this section.

Because some of the systems analyzed would have adequate capability to meet the projected load plus losses until the time that all capacity is needed to serve the load, transmission losses were not deducted for the concurrent period of time when capacity and energy were greater than demand.

Credit for Energy and Capacity: The analysis of usable energy and capacity is based largely on load estimates prepared by Alaska Power Administration and presented in their marketability analysis (Section G). Based on the projected energy requirement for the market area, if no existing utilities, facilities, or plants were displaced, all of the power output from full-basin development could be utilized within 13 years after the initial power-on-line date of 1985. Therefore, by the year 2000, full benefits would be realized from the capacity and energy of the Upper Susitna River Basin. Power from systems of less than full-basin development would of course be fully absorbed earlier.

However, opportunities do exist for displacing some energy which could theoretically be produced by existing thermal plants. If the cost of hydro energy is cheaper than the cost of producing energy at the existing thermal plants, it is to the utilities' advantage to shut down the thermal plants and purchase hydro energy. This would serve to conserve fossil fuel, which would otherwise be burned. The thermal plants would be held in reserve and would still be given full credit for their capacity. The amount of thermal energy that could be displaced is dependent on prevailing fuel costs.

Alaska Power Administration, in their marketability analysis, estimates that a substantial amount of thermal energy will be displaced.

POWER GENERATING CAPABILITY OF ALTERNATIVE HYDRO PROJECTS AND SYSTEMS UPPER SUSITNA RIVER

	At-Site Hydro Capabilities			At-Market Hydro Capabilities 1/		
	Dependable Capacity (MW)	Firm Energy (10^6 mwh)	Secondary Energy (10^6 mwh)	Dependable Capacity (MW)	Firm Energy (10^6 mwh)	Secondary Energy (10^6 mwh)
Total Basin Development						
USBR 4-Dam Plan	1427	6250	629	1370 2/	6188	623
High Watana 3-Dam Plan	1552	6800	111	1490 2/	6732	110
Kaiser 4-Dam Plan	1347	5900	611	1293	5841	605
First Stage-Single Dam						
Devil Canyon	205	900	750	197	891	743
High D.C.	594	2600	600	570	2574	594
Low Watana	228	1000	750	219	990	743
Mid Watana	479	2100	550	460	2079	545
High Watana	706	3100	350	678	3069	347
First Stage-Two Dam						
Devil Canyon - Denali	571	2500	700	548	2475	693
Devil Canyon - Low Watana	731	3200	1270	702	3168	1257
Devil Canyon - Mid Watana	1052	4650	1000	1019	4604	990
Devil Canyon - High Watana	1427	6250	550	1370 2/	6188	545

1/ Values include 4 percent capacity transmission losses and 1 percent energy transmission losses.

2/ See Table C-27 for power capabilities based on Average Annual Energy.

The total amount of firm energy which could be marketed, including both load growth and thermal displacement, is estimated to be 75 percent of the Railbelt utility load (Section G).

The marketability of secondary energy is less certain, particularly in the first five years of project life. The fact that it is available only in the low-load summer months limits its usability. If Devil Canyon were to be constructed first (or alone), the amount of secondary available during those summer months is relatively large (Plate C-10), and it would be difficult for the system to absorb that amount of energy in the early years. If a storage project is constructed first or added to a system including Devil Canyon, much of that secondary energy would be converted to firm energy and the magnitude of the remaining secondary would be such that it could be more readily absorbed (Plate C-11). Beyond 1990, the load growth is such that most of the secondary energy could be absorbed under any conditions. APA's marketability analysis indicates that a limited amount of secondary energy is marketable prior to 1990, and that the full amount is marketable following 1990 (except as limited by the restriction that the total energy marketable in any given year cannot exceed 75 percent of the Railbelt utility load).

To simplify analysis during the preliminary scoping studies, it was assumed that the full energy output (prime plus secondary) was marketable, in accordance with the APA projections of load growth and thermal energy displacement.

Federal Power Commission's estimate of how much capacity can be absorbed in the Railbelt area from 1985 through 1993 is contained in Appendix 2. This estimate assumes some retirement of old thermal, but assumesmuch of the thermal operating in 1985 will continue to be available. Alaska Power Administration estimates a larger percentage of the existing thermal will be retired or placed in cold reserve; their estimate of usable capacity again being up to 75 percent of the total Railbelt utility load. Table C-21 lists usable capacity estimates of both APA and FPC. In the economic analysis, the more conservative FPC estimate was used. However, for purposes of comparison, an analysis of the selected plan was alsomade using APA's estimate of usable capacity.

Power Values and Alternative Costs: The basic power values and alternative costs for the Susitna system were developed by the San Francisco Regional Office of the Federal Power Commission. Copies of their letters, dated 12 August 1975, and 20 August 1975, furnishing power values and alternative costs, are included in Appendix 2. Power values were divided into two components, the dependable capacity value and the energy value. Taxes and insurance costs, as applicable, are included in the power value. The method of analysis used by the FPC in developing power values is presented in Hydroelectric Power Evaluation, by the Federal Power Commission, dated March 1968.

USABILITY OF POWER FROM UPPER SUSITNA HYDRO PROJECTS

	Annual Energy, 10^6 kWh APA Estimate	Dependable Capacity, MW FPC Estimate	Dependable Capacity, MW APA Estimate
1985	3450	117	790
1986	3690	213	850
1987	3955	328	900
1988	4235	449	960
1989	4540	575	1030
1990	4860	765	1110
1991	5150	932	1170
1992	5470	1110	1240
1993	5800	1280 1/	1320
1994	6150	1450 1/	1400
1995	6510	1640 1/	1490

1/ FPC extended their estimate only to the point where 1233 MW could be absorbed. 1233 MW is the overload capacity of the Devil Canyon-Watana system that was being considered when FPC's estimate was made. In the analyses, usable capacity was estimated for years beyond 1993 by extrapolation.

It was assumed by FPC that output from the Susitna River hydro system would be utilized by the two major Railbelt area load centers in the ratio of 25 percent to Fairbanks-Tanana and 75 percent to Anchorage-Kenai-Cook Inlet. This allocation is based on load projections for the year 1985. In computing power values, it is assumed that without Susitna River hydropower, the loads of the Railbelt area would be met with separate thermal power installations to serve the two load centers.

Federally-financed thermal plant alternative costs were based on the 6-1/8-percent interest rate, and public non-Federally-financed alternative thermal plant costs were computed at 6.25-percent interest rate for the Anchorage-Kenai area and 5.95-percent interest rate for the Fairbanks area.

Selection of the most attractive alternative to hydroelectric power within the State of Alaska is a function of fuel availability, load requirements, and construction costs. Within Alaska, the large known reserves of coal and natural gas make these fuels relatively inexpensive for electric power production. Conversely, construction costs are extremely high.

Consideration of alternative projects in the contiguous United States would find nuclear plants being the most attractive alternatives for baseload projects, combined-cycle plants for the approximate annual capacity factor range of 10 to 30 percent, and combustion turbines for annual capacity factors below about 10 percent. However, because of the relatively high construction costs of nuclear plants compared to fossil-fuel plants and the fact that relatively small alternative thermal plants would be required to meet local area load growth, fossil-fuel thermal plants are a more economical source of baseload power in Alaska than nuclear plants. Since the annual plant factor of the Susitna project is estimated by APA to be 50 percent, the baseload fossil-fuel plants would be the most attractive alternative.

This is the system that has been chosen for the Fairbanks market area; however, the availability of natural gas within the Cook Inlet area makes the cost of combined-cycle gas plants the most economical alternative for the Anchorage load center at the present time.

Present FPC policy discourages utilizing natural gas plants as alternatives to hydro projects in the contiguous United States, but not in Alaska. FPC recognizes, however, that other Federal or State agencies may impose restrictions on the future usage of natural gas or oil for electric power generating purposes in Alaska. This, combined with limited natural gas reserves and possible fuel price deregulation, makes the future use of natural gas for electrical power generation tenuous. Therefore, in addition to power values based on gas-fired combined-cycle plants for the Anchorage area, FPC has also provided Anchorage area power values based on a coal-fired steamplant.

Power values based on coal-fired steamplants for electrical power generation in both the Anchorage and Fairbanks load centers have been adopted in this study for derivation of power benefits. The abundance of usable coal reserves within the Anchorage area, and the questionable future electrical power resource represented by the natural gas, make the coal power values an obvious selection. Worldwide shortages of energy have resulted in increased interest and competition for Cook Inlet natural gas. Of the 6.9 trillion cubic feet of known natural gas reserves in Cook Inlet, as of December 1974, 55 percent of that total had been committed to State, national, and international users. A summary of the known reserves, as compiled by the U.S. Bureau of Mines, and reported in Open File Report 35-74, is presented on Table C-22. Also shown are the committed reserves compiled by the Alaska State Department of Natural Resources. It is estimated that at the present use rate, the entire Cook Inlet natural gas reserve would be exhausted by 1996, and for electrical generation purposes, available reserves beyond the year 1984 would be insufficient for gas turbine capacity expansion. Furthermore, the use rate acceleration presently being experienced could further shorten the depletion time of known reserves: (1) the Philips Marathon liquification plant which presently transports Cook Inlet gas to Japan is now planning to sell additional gas to Northwest Natural Gas Company in Portland; (2) Pacific Alaska LNG Company has applied to FPC for a permit to liquify and transport gas to Los Angeles Harbor at a total project cost of approximately $1.2 billion. The use of Prudhoe Bay gas is years away, with wellhead prices estimated at not less than $0.50 per MCF, and transportation costs estimated at $1.05 per MCF at the Canadian border. The alternative to Alaska natural gas usage within the Anchorage load center is the power which could be generated from the Beluga coal field, which has an adequate supply of accessible coal to fuel Anchorage needs for at least the 100-year economic life of the proposed Susitna hydro system. The Beluga field is in the same location as the alternative gas generation plant.

In support of the assumption that coal will be the primary electrical energy fuel source within the Railbelt area beyond the year 1985 are public statements from representatives of two of the largest electric utilities within the State of Alaska. The manager of Chugach Electrical Association, Anchorage-based and largest electrical utility in Alaska, stated in a speech to the American Society of Military Engineers on 30 October 1975, Ft. Richardson, Alaska, that his company loods to the Beluga coal field as literally the sole fuel source for post-1985 electrical power generation. It was further revealed that Cook Inlet natural gas reserves allocated to Chugach Electrical Association could very possibly be exhausted by 1990. This, in the absence of new accessible gas discoveries, leads Chugach to its present state of planning for future Beluga coal development. Similarly, the Golden Valley Electrical Association (GVEA) foresees coal as the continuing electrical power generating fuel in the Fairbanks area. The position of GVEA was presented during the 8 October 1975 Fairbanks Public Meeting on Upper Susitna Hydropower Development in which their representative made the following statement, "If the Corps does not go ahead with the Devil Canyon-Watana project, very clearly, if their intent is not very clearly known by 1978, then Golden Valley Electrical Association will have to make a firm commitment to go to some alternative method. And, the only sensible alternative method that appears feasible at this time would be to go into the Nenana coal fields and build one, and then a second 84,000-kilowatt coal-fired steam generation unit."

The subsequent economic evaluation will be conducted using the power values derived from coal-fired steamplants for both the Anchorage and Fairbanks load centers. The scoping analysis, for comparability, will be based on both public non-Federally financed and Federally-financed alternative power values, and the final economic analysis of the selected plan will be based on public non-Federal financing. For the purpose of comparison, the benefits-to-cost ratio of the selected plan will be computed using both coal and gas power values for the Anchorage area.

Fairbanks Power Values: The at-market power value for the Fairbanks area is based on estimated cost of power from an alternative source described as follows: a coal-fired generating plant with 150-MW total capacity consisting of two 75-MW units; heat rate, 12,000 Btu/kWh; capital cost, $640 per kilowatt; service life, 35 years; and coal cost of $0.60 per Billion BTU. Also included in the power values is a 10 percent hydro-steam adjustment made to reflect the greater reliability and flexibility of hydro generation.

Anchorage-Kenai Power Values: The two alternative sets of at-site power values for the Anchorage-Kenai area are based on systems described as follows.

(1) Combined cycle generating plant with 450-MW total capacity consisting of four 112.5-MW units (one combustion turbine and one steam turbine per unit); heat rate, 8,500 Btu/kWh; capital cost, $235 per kilowatt; service life, 30 years; natural gas (operating) cost of $0.70 per million BTU; distillate oil (standby) cost of $1.75 per million BTU; and a five-percent hydro-steam adjustment.

(2) A coal-fired generating plant with 450-MW total capacity consisting of three 150-MW units; heat rate, 9,800 Btu/kWh, capital cost $585 per kilowatt; service life, 35 years; coal cost of $0.50 per million BTU; and a 10-percent hydro-steam adjustment.

The results of the computed power values are summarized as follows:

COOK INLET NATURAL GAS RESERVES AND COMMITTALS

11 December 1974

FIELD	RESERVES	COMMITTAL		UNCOMMITTED
Kenai	2,400,000 MMCF	440,000 MMCF	Alaska Pipeline	
		1,038,000 MMCF	Collier Chemical	
		400,000 MMCF	Socal-Arco	
		228,000 MMCF	LNG	
		2,106,000 MMCF		294,000 MMCF
North Cook Inlet	1,500,000 MMCF	532,000 MMCF	LNG	968,000 MMCF
McArthur River	800,000 MMCF	87,000 MMCF	Pacific Lighting	713,000 MMCF
Beluga River	973,000 MMCF	373,000 MMCF	Chugach Electric	
		600,000 MMCF	Pacific Lighting	
		973,000 MMCF		-0-
Beaver Creek	400,000 MMCF	113,000 MMCF	Pacific Lighting	287,000 MMCF
Swanson River	300,000 MMCF			300,000 MMCF
Sterling	200,000 MMCF			200,000 MMCF
Miscellaneous	395,000 MMCF			395,000 MMCF
TOTALS	6,968,000 MMCF	3,811,000 MMCF (55%)		3,157,000 MMCF (45%)

Pacific Lighting 800,000 MMCF Committal, 11% of Total Reserves

Value of Power

Market Area	Fuel	Public-Non-Federal 1/ Dependable Capacity ($/kW-Yr)	Public-Non-Federal 1/ Usable Energy (Mills/kWh)	Federal Dependable Capacity ($/kW-Yr)	Federal Usable Energy (Mills/kWh)
		Type of Financing (Price level of 1/1/75)			
45% Annual Capacity Factor					
Fairbanks		96.95	7.89	89.49	7.89
Anchorage-Kenai					
Coal-fired Alternative		86.15	5.42	75.78	5.42
Combined Cycle Alternative		46.89	6.43	41.93	6.43
51.8% Annual Capacity Factor					
Fairbanks		98.32	7.84	90.84	7.84
Anchorage-Kenai					
Coal-fired Alternative		87.13	5.36	76.77	5.36
Combined Cycle Alternative		47.78	6.37	42.79	6.37

1/ Composite REA and Municipal

Composite Power Values: By applying the FPC assumption that the power utilization of the hydro system would be distributed in the ratio of 75 percent to the Anchorage-Kenai area and 25 percent to the Fairbanks area, composite values were derived for both the energy and capacity values. The values determined in this manner are shown below.

Composite Value of Power

Market Area	Public-Non-Federal 1/ Dependable Capacity ($/kW-Yr)	Public-Non-Federal 1/ Usable Energy (Mills/kWh)	Federal Dependable Capacity ($/kW-Yr)	Federal Usable Energy (Mills/kWh)
	Type of Financing (Price level of 1/1/75)			
45% Annual Capacity Factor				
Coal-Fired Alternative	88.85	6.03	79.21	6.03
Combined Cycle Alternative	59.38	6.80	53.82	6.80
51.8% Annual Capacity Factor				
Coal-Fired Alternative	89.93	5.98	80.28	5.98
Combined Cycle Alternative	60.42	6.74	54.80	6.74

1/ Composite REA and Municipal

The FPC computed power values for the two plant factors, 45 percent and 51.8 percent. The 45-percent plant factor is the alternative to Devil Canyon without upstream storage and 51.8 percent for Devil Canyon-Watana. Since subsequent analyses have based installed capacities for all plants on a 50-percent plant factor, the closest FPC values, the 51.8-percent plant factor values, were used in all analyses.

Derivation of Power Benefits: Annual power benefits were computed for each of the systems, including both first-stage and full-basin development. Because in some systems the initial power-on-line is in excess of community needs, benefits during the early years of operation were limited by the Railbelt area capacity and energy growth rate (see previous discussion under Credit for Energy and Capacity). Therefore, benefits were computed for each year covering the 100-year life beginning with the 1985 power-on-line date. This was accomplished by present worthing each year's benefits to composite lifetime benefits that were then converted to an equivalent annual amount at the discount rate of 6-1/8 percent.

Detailed computations of benefits for the Devil Canyon, Denali, Vee, and Watana four-dam system are shown on Table C-23. Similar detailed computations for the remaining systems were performed; however, in order

Sample Power Benefit Calculations Scoping Analysis

DEVIL CANYON WITH DENALI AND VEE AND WATANA

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY (MW)	PRESENT WORTH OF CAPACITY (MW)	CAPACITY BENEFITS ($1000)	MARKETABLE FIRM ENERGY (MWYR)	PRESENT WORTH FIRM ENERGY (MWYR)	FIRM ENERGY BENEFITS ($1000)	MARKETABLE SECONDARY ENERGY (MWYR)	PRESENT WORTH SEC ENERGY (MWYR)	SECONDARY ENERGY BENEFITS ($1000)	PUMP CAPACITY BENEFITS ($1000)	TOTAL BENEFITS ($1000)
1985	0.9423	117.0	110.2	8851.8	102.0	96.1	5034.4	197.0	185.6	9723.3	0.0	23609.5
1986	0.8879	213.0	189.1	15194.7	102.0	90.6	4743.8	197.0	174.9	9162.1	0.0	29090.7
1987	0.8367	328.0	274.4	22033.5	102.0	85.3	4470.1	197.0	164.8	8633.3	0.0	35136.9
1988	0.7884	449.0	354.0	28420.9	102.0	80.4	4212.1	197.0	155.3	8135.1	0.0	40768.1
1989	0.7429	548.0	407.1	32685.5	102.0	75.8	3969.0	197.0	146.3	7665.6	0.0	44320.0
1990	0.7000	548.0	383.6	30799.1	283.0	198.1	10375.4	79.0	55.3	2896.6	0.0	44072.1
1991	0.6596	548.0	361.5	29021.5	283.0	186.7	9777.5	79.0	52.1	2729.4	0.0	41524.5
1992	0.6215	548.0	340.6	27346.5	283.0	175.9	9213.2	79.0	49.1	2571.9	0.0	39131.7
1993	0.5857	548.0	320.9	25768.2	283.0	165.7	8681.5	79.0	46.3	2423.5	0.0	36873.2
1994	0.5519	548.0	302.4	24281.1	283.0	156.2	8180.5	79.0	43.6	2283.6	0.0	34745.1
1995	0.5200	898.0	467.0	37492.6	463.0	240.8	12611.1	75.0	39.0	2042.8	0.0	52146.6
1996	0.4900	898.0	440.0	35328.8	463.0	226.9	11883.3	75.0	36.7	1924.9	0.0	49137.0
1997	0.4617	898.0	414.6	33289.8	463.0	213.8	11197.5	75.0	34.6	1813.8	0.0	46301.1
1998	0.4351	898.0	390.7	31368.5	463.0	201.4	10551.2	75.0	32.6	1709.2	0.0	43624.9
1999	0.4100	898.0	368.1	29558.1	463.0	189.8	9942.3	75.0	30.7	1610.5	0.0	41110.9
				411430.			124844.			65326.	0.	601600.
2000 2085	6.6504	1370.	9111.	731531.	706.	4695.	245935.	71.	472.	24733.	0.	1002199.
PRESENT WORTH BENEFITS				1142961.			370779.			93059.	0.	1603798.
CRF=	0.0614 AV ANN BENEFITS =			70190.			22770.			5531.	0.	98490.

CAPACITY VALUE = 80.28999
ENERGY VALUE = 52.37999
SECONDARY VALUE= 52.37999
INTEREST RATE = 0.06125

Appendix
TABLE C-2
C-93

to minimize the bulk of supporting material, they have not been included in this report.

OTHER BENEFITS

Recreation: Rationale for recreational benefits is contained within Section F of this Appendix. The analysis concluded that an estimated 77,000 recreation days could be anticipated for the power projects in the year 1985. Of these, 70 percent would be of generalized nature with an estimated rate of $2.00 per visitor day, and 30 percent would be for specialized recreation at a rate of $8.00 per visitor day. On the basis of these figures, the annual benefits for recreation have been developed in the amount of $300,000. (Rounded from $292,000.)

Area Redevelopment (AR): In accordance with Draft ER 1105-2-352, AR benefits are defined as beneficial contributions to the NED objective resulting from the use of otherwise unemployed manpower in construction and installation of a proposed project. Presented below are the steps taken in calculation of AR benefits for a system development of Devil Canyon and Watana (2200 feet). Similar calculations were made for all development plans but in order to reduce the bulk of supporting material these calculations were not included in this text. A summary of AR benefits for the plans under consideration is presented on Table C-24.

The labor area is defined to be the combined Anchorage and Fairbanks areas. The proposed project is to be constructed in a relatively unpopulated area and will necessarily draw heavily from these two population centers. The State of Alaska has been classified by the U.S. Department of Labor as an area of substantial and persistent unemployment.

The labor market was assessed to determine the present and prospective employment situation in the construction industry. Construction activity in Alaska is presently peaking at the height of pipeline construction, with a construction work force of approximately 20,000 out of a total civilian labor force of 190,000. Of the average 16,000 persons unemployed in Alaska, about 25 percent, or 4,000 are in the construction industry. Employment in construction is expected to remain at a high level after pipeline construction due to the increased need for houses, schools and other facilities caused by the increase in population. Additionally, a program of resource development throughout the State, the capitol relocation project, or a trans-Alaska gas pipeline would further help to maintain a fairly stable employment picture.

Estimated manpower required for construction of the Watana and Devil Canyon dams and the transmission line is as indicated in the following table:

AREA REDEVELOPMENT BENEFITS

System of Development	1985 AR Value ($1000)	Average Annual AR Value ($1000)
Devil Canyon, Denali, Vee (2300), Watana (1905)	178,686	10,971
Devil Canyon, Denali, Vee (2350), Watana (1905)	181,899	11,169
High D.C., Olson, Denali, Vee (2300)	209,956	12,891
Devil Canyon, Watana (2200), Denali	177,614	10,905
Devil Canyon, Watana (2050), Denali	156,624	9,617
Devil Canyon, Watana (1905), Denali	135,735	8,334
Devil Canyon, Watana (2250)	162,790	9,995
Devil Canyon, Watana (2200)	155,761	9,564
Devil Canyon, Watana (2050)	134,771	8,275
Devil Canyon, Watana (1905)	113,882	6,992
Watana (2250), Devil Canyon	159,175	9,773
Watana (2200), Devil Canyon	152,647	9,373
Watana (2050), Devil Canyon	131,458	8,072
Watana (1905), Devil Canyon	110,469	6,783
Devil Canyon, Denali	105,849	6,510
Devil Canyon	71,704	4,403
High D.C.	127,139	7,806
Watana (2200)	109,263	6,709
Watana (2050)	88,074	5,408
Watana (1905)	67,085	4,119

MANPOWER REQUIREMENTS BY BASIC SKILL

SKILLS	MAN-DAYS	PERCENT OF TOTAL
Operating Engineers	482,680	22%
Teamsters	131,640	6%
Laborers	482,680	22%
Cement Masons	87,760	4%
Carpenters	351,040	16%
Painters	65,820	3%
Iron Workers	241,340	11%
Electricians	131,640	6%
Pipe Fitters	153,580	7%
Sheet Metal Workers	43,880	2%
Technical Engineers	21,940	1%
	2,194,000	100%

Of this total, project planners estimate 20 percent to be in supervisory and managerial roles, giving 438,000 man-days of supervisory labor and 2,194,000 man-days as construction employment. It is estimated that 200 days of construction effort are possible each year given the circumstances of climate and project location. The construction period for the project is 10 years, allowing a calculation of the average number of men needed per year as shown in the following table:

MANPOWER NEEDS

	MAN-DAYS	MAN-YEARS	MEN PER YEAR
Total	2,194,000	10,970	1,097
Construction	1,756,000	8,780	878
Supervisory	438,000	2,190	219

Alyeska pipeline employment data indicates that 60 percent of the construction manpower needs are being met from within Alaska, 40 percent from outside the State. The existence of the pipeline project will ensure a sizeable skilled Alaskan workforce, which in turn will mean that a lesser proportion of manpower requirements will be imported into Alaska for future construction projects. With the presence of this large labor pool and assuming a stable, but somewhat reduced level of construction activity during the 1980's, a proposed Upper Susitna development is estimated to draw 80 percent of its construction manpower requirements from within Alaska; 20 percent will come from outside the State. The actual number to be employed from the resident labor force is thus 878 workers. It is further estimated that 50 percent or 439 of this local labor demand will be met out of the projected 4,000 construction workers who would otherwise be unemployed. The remaining 50 percent then is presumed to be part of the normal demand for construction employment and would come from already employed manpower resources of the State.

A weighted average hourly wage is calculated using 1975 Fairbanks vicinity wage rates for the various skill categories, supervisory levels and appropriate over-time. This composite wage rate of $17.40 when multiplied by the number of hours per day and 200 days per year gives $34,800. When applied to the 439 otherwise unemployed workers, an annual value of $15,262,770 results which over the 10 years of the construction period amounts to $152,627,700. This amount is approximately equivalent to the present value of this 10 year stream of benefits because the wage payments are fairly evenly distributed before and after the power-on-line date. Converted to an annual benefit over the 100-year project life at an interest rate of 6-1/8 percent, the rounded AR benefit amounts to $9,373,000.

Intertie Benefits: It was established under area needs that intertie benefits could be realized from shared reserves and from the transfer of energy between Anchorage and Fairbanks to take advantage of the differential cost of producing energy. Being interconnected also permits additional flexibility of operation. The Technical Advisory Committee on Coordinated Systems Development and Interconnection highlights further some of the possible intertie advantages in the 1974 Alaskan Power Survey.

Dollar quantification of incidental intertie benefits associated with the power lines which would connect the hydro projects to the two load centers is difficult, however, the value of shared reserves and energy transfer can be evaluated to some extent.

Shared Reserves: Reserve capacity within a load center can be described as the amount of generation required, beyond that necessary to meet load, Which would provide a predetermined degree of reliability against partial or total system failure. The required reserves is a function of the utility system makeup, maintenance schedule, and degree of interconnection. The System makeup is a multitude of generating units each with its own reliability in accordance with efficiency, age, fuel type, unit type, size, etc. Evaluation of reserve requirements is a complex procedure which attempts to determine statistically the probability of total or partial failure and the reserve requirements necessary to bolster the system to insure the predetermined reliability criteria. Therefore, intertie benefits through shared reserves of the two load centers could be established by first determining individual load center reserve requirements, and second, subsequent total reserve requirements if the two load centers were intertied and re-evaluated as a single load center. The reduction in reserve requirements could then be converted to a dollar value which when amortized would represent an average annual benefit.

As pointed out in the marketability section (Section G) Anchorage and Fairbanks peak load requirements are very nearly identical in terms of percent of total capacity required throughout the year. Therefore, while the system makeup of the two areas is presently quite different, the concurrent peaking requirements leave little opportunity for sharing reserves. Furthermore, since it is estimated that the Anchorage thermal units will shift from the present gas turbine mode to that of Beluga coal, then by the time that reserves could conceivably be shared, the combination of concurrent requirements and similar system makeups would leave scant possibilities for reserve sharing.

Energy Cost Differential: Based on FPC power values for coal fired steam plants in both Anchorage and Fairbanks the anticipated cost of producing energy in the Fairbanks market area is roughly eight mills higher than in Anchorage. Therefore, if Anchorage off-peak-month thermal energy could be sent to Fairbanks, a portion of the differential energy cost could be claimed as a benefit. The amount of energy which could be transferred in any month would be dependent on the transmission line capability, the amount of hydro energy being transmitted over each line, and the ability of Anchorage utilities to pursue this new market. The actual transfer of energy would entail a higher portion of the Susitna hydro being shifted to Fairbanks with the associated mill credit given to the Anchorage utilities. In analysing the maximum possible benefit that could be realized in this manner, the following monthly energy transfer capabilities are assumed for the two single circuit 230 KV transmission lines from Gold Creek to Fairbanks:

Month	Line Capacity (mw)	Hydro Capacity (mw)	Available Line Capacity (mw)	Maximum Energy Capacity (10^6 kwh)
January	358	358	0	0
February	358	358	0	0
March	358	273	85	63
April	358	244	114	82
May	358	219	139	103
June	358	206	152	109
July	358	200	158	118
August	358	215	143	106
September	358	232	126	94
October	358	232	126	94
November	358	264	94	68
December	358	282	76	57
			TOTAL	894

With an assumed hydro system firm generating capability of 6.1 billion kwh, the reserve transmission line capacity would not be required prior to 1995, and the full capacity could only be absorbed beyond the year 2005 based on mid-range energy projections. If it is assumed that the 894 million kilowatt hours per year are absorbed linearly between 1995 and the year 2005, then the following benefit calculations can be made based on a 1985 hydro power-on-line date and 8 mills at 6-1/8 percent.

Year	Energy Transferred	POL Present Worth of Energy	POL Dollar Worth of Energy
	(10^6 kwh)	(10^6 kwh)	(Dollars)
1996	89.4	43.8	$ 350,400
1997	178.8	82.6	660,800
1998	268.2	116.7	933,600
1999	357.6	146.6	1,172,800
2000	447.0	172.3	1,378,400
2001	536.4	195.2	1,561,600
2002	625.8	214.6	1,716,800
2003	715.2	231.2	1,849,600
2004	804.6	245.0	1,960,000
2005 thru 2086	894	4,406.9	35,255,200
	TOTAL	5,854.9	$46,839,200

The amortized value of the $46,839,200 benefit rounds to $2,900,000 based on the 100-year economic life of the hydro project.

The annual worth of the differential cost of energy is based on assumptions of the amount and time that energy could be transferred and the differential cost of energy in the two load centers.

Flood Control: Traditional flood control analysis involving the reduction of damage to real and personal property does not apply in the case of this project due to the lack of industrial and general urban growth downstream from the project. However, the Alaska Railroad has estimated that approximately $50,000 of annual maintenance of railroad bed could be eliminated by controlling the river flow.

ECONOMIC ANALYSIS OF ALTERNATIVE DEVELOPMENTS

The purpose of this analysis is to narrow down the alternative hydro plans to several of the best plans for analysis under Principles and Standards criteria. Since the combined flood control, recreational, and intertie benefits are small compared to the power and AR benefits, preliminary scoping of the upper Susitna hydro alternatives was done on the basis of power and AR benefits alone. However, flood control, recreation and transmission benefits are included in later stages of the analysis. Benefits estimated in this manner for the various systems of development are presented on Table C-25.

SYSTEM BENEFITS - SCOPING ANALYSIS

System of Development	Federal Financing Capacity BENEFITS ($1,000)	Prime Energy BENEFITS ($1,000)	Secondary Energy BENEFITS ($1,000)	AR BENEFITS ($1,000)	TOTAL BENEFITS ($1,000)
Devil Canyon, Denali, Vee (2300), Watana (1905)	70,190	22,770	5,531	10,971	109,461
Devil Canyon, Denali, Vee (2350), Watana (1905)	72,703	23,532	5,172	11,169	112,607
High D. C., Olson, Denali, Vee (2300)	73,037	23,931	3,795	12,891	113,654
Devil Canyon, Watana (2200), Denali	89,057	29,726	3,500	10,905	133,188
Devil Canyon, Watana (2050), Denali	78,359	25,903	4,735	9,617	118,615
Devil Canyon, Watana (1905), Denali	63,953	20,816	5,624	8,334	98,727
Devil Canyon, Watana (2250)	84,267	28,153	3,847	9,995	126,262
Devil Canyon, Watana (2200)	83,751	27,980	4,893	9,564	126,188
Devil Canyon, Watana (2050)	66,244	21,826	6,847	8,275	103,195
Devil Canyon, Watana (1905)	47,992	15,451	7,787	6,992	78,222
Watana (2250), Devil Canyon	84,223	31,051	2,100	9,773	127,147
Watana (2200), Devil Canyon	83,751	30,883	2,516	9,373	126,523
Watana (2050), Devil Canyon	65,823	23,688	4,964	8,072	102,547
Watana (1905), Devil Canyon	48,083	15,596	6,706	6,783	77,168
Devil Canyon, Denali	39,238	12,379	5,731	6,510	63,858
Devil Canyon	15,446	5,343	4,452	4,403	29,644
High D.C.	40,629	15,400	3,562	7,806	67,397
Watana (2200)	45,892	17,757	2,671	6,709	73,029
Watana (2050)	33,671	12,414	3,248	5,408	54,741
Watana (1905)	17,083	5,919	4,452	4,119	31,574

Notes:

1. Capacity Value: $80.29/Kw; Energy Value: $52.38/mw-yr. (Federal Financing)
2. Dependable capacity based on prime energy and 50% plant factor.
3. Interest rate at 6-1/8 percent over 100 years.

Presented on Table C-26 is a summary of the economic evaluation of the systems analyzed. The table gives information on benefits, costs, and net benefits.

Four alternatives were deemed worthy of further consideration. The USBR four-dam scheme appears quite a favorable project from an economic standpoint, as do the two- and three-dam schemes designed around a Watana project at a maximum pool elevation of approximately 2200 feet. The four-dam scheme consisting of Olson, High D.C., Vee, and Denali does not appear economically feasible, and therefore, this system was not included in subsequent analysis.

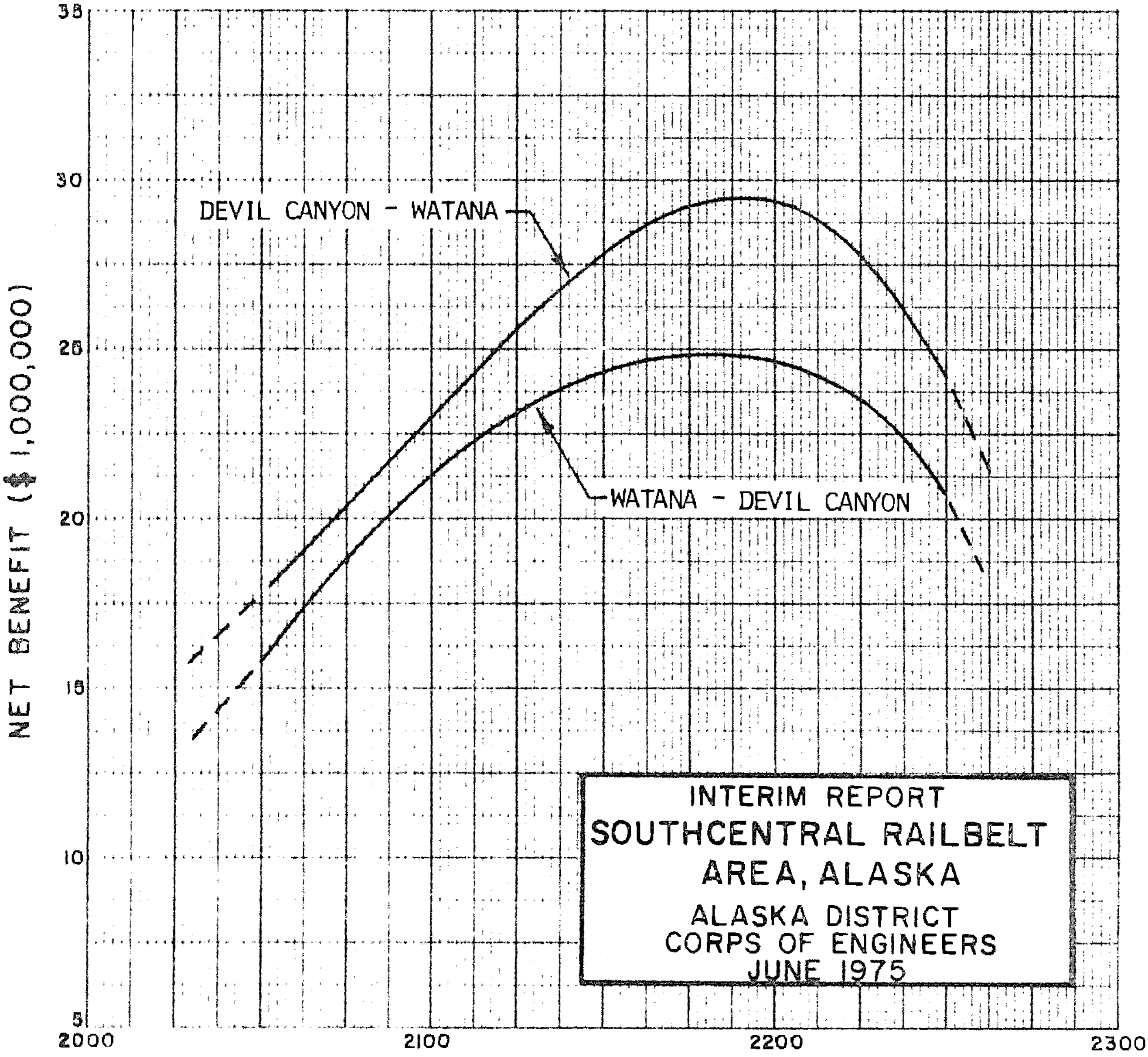
Of the single-dam alternatives, the Watana Dam with a pool elevation of 2200 feet appears most feasible. However, because the two-, three-, and four-dam alternatives are much more attractive economically, all single dam alternatives were eliminated from further consideration. The Devil Canyon-Denali combination was eliminated because it was economically marginal, and the power output of the system represents only a fraction of the basin potential.

In an attempt to maximize benefits from the USBR four-dam scheme, system benefits were computed based on two elevations for the Vee damsite. The analysis indicates that net benefits increased as the Vee maximum pool elevation increased above 2300 feet, and that maximum net benefits are obtained for a Vee pool elevation of 2350 feet, just 11 feet below Lake Louise water surface elevation. The power output from this system would be considerable, but the environmental impact could be the most sever of the systems analyzed. Therefore, the system inclusive of the lower (2300 feet) Vee project was selected for further consideration.

The Devil Canyon, Watana, and Denali system was analyzed for Watana pool elevations ranging between 1900 and 2200 feet. Analysis showed that based on power benefits, the most economical Watana three-dam scheme is a Watana pool built to an elevation of about 2200 feet. However, optimized net benefits from the three-dam scheme is not as great as those from the two-dam system consisting of Devil Canyon and the Watana project with a 2200-foot normal maximum pool elevation, Graph 9.

<u>NED Plan and Construction Sequence</u>: The two-dam Devil Canyon-Watana system was selected as the NED plan on the basis of maximization of net benefits. The sequence of construction influences the net benefits obtained from the NED plan is apparent as shown on Graph 9. A summary of the benefits and costs associated with the NED plan for both construction sequences is shown below:

NET BENEFIT SCOPING ANALYSIS
DEVIL CANYON-WATANA



SCOPING ECONOMIC ANALYSIS

System of Development	Total Average Annual Costs ($1,000)	Total Average Annual Benefits ($1,000)	NET BENEFITS ($1,000)
Devil Canyon, Denali, Vee (2300), Watana (1905)	102,491	109,461	6,970
Devil Canyon, Denali, Vee (2350), Watana (1905)	104,445	112,407	7,962
High D. C., Olson, Denali, Vee (2300)	139,984	113,654	- 26,330
Devil Canyon, Watana (2200), Denali	110,091	133,188	23,097
Devil Canyon, Watana (2050), Denali	99,094	118,615	19,521
Devil Canyon, Watana (1905), Denali	88,150	98,727	10,577
Devil Canyon, Watana (2250)	104,336	126,262	21,926
Devil Canyon, Watana (2200)	96,600	126,188	29,588
Devil Canyon, Watana (2050)	85,604	103,193	17,589
Devil Canyon, Watana (1905)	74,660	78,222	3,562
Watana (2250), Devil Canyon	106,379	127,147	20,768
Watana (2200), Devil Canyon	101,776 3/	126,523	24,747
Watana (2050), Devil Canyon	86,834	102,547	15,713
Watana (1905), Devil Canyon	72,034	77,168	5,134
Devil Canyon, Denali	69,651	63,858	- 5,793
Devil Canyon	51,561	29,644	- 21,917
High D. C.	90,651	67,397	- 23,254
Watana (2200)	78,046	73,029	- 5,017
Watana (2050)	63,104	54,741	- 8,363
Watana (1905)	48,304	31,574	- 16,730

1. Number in parenthesis represents the normal maximum pool elevation of the project.
2. Project staging in sequence as shown and each project was assumed to have a five-year construction time.
3. Six year Watana construction and IDC based on annual expenditures would have resulted in an Annual Cost of $103,920,000 (See Table 30).

SYSTEM COMPARABILITY

Construction Sequence	AR And Power Benefits ($1,000)	Annual Costs ($1,000)	B-C ($1,000)
Devil Canyon, Watana	126,188	96,600	29,588
Watana, Devil Canyon	126,523	101,776	24,747

The analysis shows the following:

1. Both sequences for system development are economically feasible.

2. The Devil Canyon followed by Watana stage construction appears to give the most economical sequence of construction.

Although maximum net benefits are realized for a system construction sequence of Devil Canyon followed by Watana, as mentioned earlier, the true market for the Susitna hydro is difficult to predict, and hence either construction sequence may prove equally feasible. The above figures do not take into account the intangible benefits that would be expected by specific construction sequence.

If the Devil Canyon project were first to be constructed, the following intangible benefits or adverse impacts could occur:

1. The firm energy producing capability of Devil Canyon project would be adequate to meet only two years of energy demand based on APA projections. This would result in a need for capital expenditures by utilities in the region prior to Watana's POL.

2. The spill rate of the Devil Canyon project during the five years preceeding the Watana POL date would be quite frequent and of relatively high magnitude. The adverse impacts from this operation have not been fully assessed.

3. If the Watana project were not built or if it was delayed a significant time, the resulting active storage sediment encroachment could further limit the prime energy producing capability of Devil Canyon.

If the Watana project were first to be constructed, the following intangible benefits or adverse impacts could occur:

1. The flow regulation provided by Watana would minimize the diversion structures required for the construction of Devil Canyon. This savings in construction costs has been estimated in the selected plan.

2. The frequency, duration, and magnitude of spills from Watana would be considerably less than those of Devil Canyon. Furthermore, the

operation studies reveal a very infrequent spill rate for the Watana spillway. This would minimize possible adverse impact from gas super-saturation of the river below the project.

3. The energy capability of the Watana project would be three times that of the Devil Canyon project without upstream storage.

4. Because of the large Watana reservoir capacity and the large dead storage, the Watana reservoir is not susceptible to significant sediment encroachment on the active storage.

By weighing the intangible benefits from the two projects and realizing that the economics of the system is influenced by a power market which is difficult to evaluate, the construction sequence that would provide Watana power first and Devil Canyon power second, appears the logical selection, and it is that sequence which has been chosen for further analysis.

Plans Considered Further: Principals and Standards require that alternatives displayed under the system of accounts be compared on an equal basis to the fullest possible extent. While the scoping analysis is adequate for determining the relative value of each system of development, it would be improper to compare the net worth of systems analyzed under the scoping analysis to that of net benefits derived for the selected plan, which is evaluated under slightly different criteria as outlined under the Selected Plan Section. Therefore, although the Devil Canyon and High Watana system was ultimately chosen as the selected plan for development, in order to compare this plan with the three and four-dam systems, it is necessary to apply the selected plan criteria to the three and four-dam alternatives. The rationale for the slightly different cirteria is presented under the Selected Plan Section. In short, the three and four dam alternatives were reanalyzed using the following criteria.

1. Transmission losses were limited to 3.2 percent capacity and 0.7 percent energy.

2. Minimum drawdown criteria for turbine efficiency reduced prime energy slightly.

3. Dependable capacity is based on average annual energy and a 50 percent plant factor.

4. Power benefits are based on non-Federal power values.

5. All benefits are used in computing net benefits and the benefits-to-cost ratio.

The subsequent at-market power which could be realized for the three alternative hydro developments is summarized on Table C-27.

Table C-27

	Prime Energy (10^6 kwh)	Secondary Energy (10^6 kwh)	Dependable Capacity (mw)
Two-Dam 1/	6,057	785	1,518
Three-Dam 2/	6,603	110	1,528
Four-Dam 3	6,107	724	1,520

1/ Watana (2200); Devil Canyon
2/ Watana (2200); Devil Canyon, Denali
3/ Devil Canyon, Denali, Vee (2300), Watana (1905)

Benefits are those which can be realized from power, flood control, recreation, area redevelopment, and transmission intertie. The following table summarizes the benefits for each project.

	Power ($1000)	Flood Control ($1000)	Recreation ($1000)	Intertie ($1000)	Area Redevelopment ($1000)	Total ($1000)
Two Dam	135,198	50	300	2,900	9,373	147,821
Three Dam	135,288	50	300	2,900	10,905	149,443
Four Dam	116,825	50	400	2,900	10,971	131,146

The economic comparison, therefore, for the system of accounts is shown on the table below. For a full explanation of how the benefits were calculated see the Selected Plan subsection of Section C, Appendix 1.

	Annual Const Cost ($1000)	Annual OM&R ($1000)	Total Annual Cost ($1000)	Annual Benefits ($1000)	Net Benefits ($1000)	B/C (Ratio)
Two Dam	101,520	2,500	104,020	147,821	44,658	1.42
Three Dam	113,066	2,600	115,666	149,252	33,777	1.29
Four Dam	99,291	3,200	102,491	131,146	28,655	1.28

These plans were selected because they are economically justified and they meet the objectives for meeting the load growth of the Railbelt community. The next section will analyze these three plans from an environmental standpoint in an attempt to develop an EQ plan. Development sequence for the two- and three-dam plans would have Watana constructed first and Devil Canyon second. The four-dam plan construction sequence would entail Devil Canyon's being built first followed in order by Denali, Vee, and Watana.

SELECTING A PLAN

ALTERNATIVES SELECTED FOR FURTHER STUDY

The preliminary screening disclosed four alternatives with economic justification, adequate scale, technical feasibility, and no adverse environmental effects of such obvious magnitude as to preclude plan implementation. These include one plan which depicts the most probable future if no Federal action is taken to meet the projected power needs of the Railbelt and three diverse hydroelectric plans for utilization of the power potential of the upper Susitna River. The four selected alternatives are:

Coal
Devil Canyon-Watana Dams
Devil Canyon-Watana-Denali Dams
Devil Canyon-Watana-Vee-Denali Dams.

EVALUATION OF ALTERNATIVES

Selection of the best plan from among the alternatives involves evaluation of their comparative performance in meeting the study objectives as measured against a set of evaluation criteria.

These criteria derive from law, regulations, and policies governi water resource planning and development. The following criteria were adopted for evaluating the alternatives.

Technical Criteria:

The growth in electrical power demand will be as projected by the Alaska Power Administration.

That power generation development, from any source or sources, will proceed to satisfy the projected needs.

A plan to be considered for initial development must be technically feasible.

National Economic Development Criteria:

Tangible benefits must exceed project economic costs;

Each separable unit of work or purpose must provide benefits at least equal to its cost;

The scope of the work is such as to provide the maximum net benefits.

The benefits and costs are expressed in comparable quantitative economic terms to the fullest extent possible. Annual costs are based on a 100-year amortization period, an interest rate of 6-1/8 percent, and January 1975 price levels. The annual charges include interest; amortization; and operation, maintenance, and replacement costs.

Power benefits are based on the difference in costs of providing the energy output of any plan as compared to providing the same energy by conventional coal-fired thermal generation.

Environmental Quality Criteria:

Conservation of esthetics, natural values, and other desirable environmental effects or features.

The use of a systematic approach to insure integration of the natural and social sciences and environmental design arts in planning and utilization.

The application of overall system assessment of operational effects as well as consideration of the local project area.

The study and development of recommended alternative courses of action to any proposal which involved conflicts concerning uses of available resources.

Evaluation of the environmental impacts of any proposed action, including effects which cannot be avoided, alternatives to proposed actions, the relationship of local short-term uses and of long-term productivity, and a determination of any irreversible and irretrievable resource commitment.

Avoidance of detrimental environmental effects, but where these are unavoidable, the inclusion of practicable mitigating features.

Social Well-Being and Regional Development Considerations:

In addition to the basic planning criteria, consideration was given to:

The possibility of enhancing or creating recreational values for the public;

The effects, both locally and regionally, on such items as income, employment, population, and business;

The effects on educational and cultural opportunities;

The conservation of nonrenewable resources.

Coal: This alternative is, effectively, the "without" condition, the probable future that would develop if no Federal action were taken to provide electrical power through a hydroelectric generation development. A coal-fired generation system could develop in a number of ways including piecemeal construction of plants at numerous locations with no intertie or overall grid being developed. For purposes of simplification and more direct comparability to the hydropower alternatives, a single large coal-fired complex located at the most favorable minemouth site (the Healy area) with a transmission system intertie between Anchorage and Fairbanks is analyzed. Plant construction would be staged to essentially duplicate the medium range power demand curve up to the energy levels achieved by the comparative hydropower plans.

This alternative is the economic standard against which each of the hydropower plans is tested. That is, the power benefits of a given hydro system represent the cost of producing the same amount of power by constructing and operating a conventional, state-of-the-art, generation system using coal as fuel. Included in all cases are the costs of the necessary transmission system to bring the power to the same load distribution centers in the Anchorage and Fairbanks areas. Thus, a benefit-to-cost ratio of greater than one (1.0) indicates that a hydro system is more economical than its coal competitor, while a ratio of less than unity indicates that it is economically inferior. Since the alternative values of electrical production and plant construction using coal as the fuel are the source of the energy and capacity benefits, respectively, for the hydropower plans, it follows that, for any given alternative coal system, the sum of the energy and capacity benefits is identical to the costs giving a benefit-to-cost (B/C) ratio of 1.0 and no net benefits. The projected energy cost to the distributors for this alternative is estimated to be 26.4 to 31.4 mills per kilowatt-hour.

The projected generating plant would require an area of approximately 40 acres for the buildings and grounds. An additional area of about 90 acres would be required for a 30-day stockpile of 500,000 tons of coal. The total annual coal requirement, based on a gross energy output of 6.88 to 6.91 billion kilowatt-hours (Kwh) annually and a fuel efficiency for coal of 1,181 Kwh/ton 1/ would be from 5.83 to 5.85 million tons. Over the 100-year analysis period, this would amount to 583 to 585 million tons total. No single district in the Nenana field has such reserves at a depth suitable for strip mining; however, the Heavy Creek district 2/ has reserves estimated at 535.7 million tons at depths less than 1,000 feet and seam thickness greater than 5 feet. Maximum use of this district is assumed with the deficit to be supplied by nearby reserves from Dry Creek and Savage River as needed.

1/ Alaska Electric Power Statistics, 1960-1973, APA, December 1974.
2/ Coal Resources of Alaska, Geological Survey Bulletin 1242-B, 1967.

To estimate the probable impacts of the strip mining, the following simplified mining operation was projected. A parallel strip technique with the overburden and wastes sidecast into windrows between two active working faces is projected since it requires the minimum land use. A maximum economic overburden of 200 feet is assumed, which with the coal running anywhere from the surface downward would mean an average overburden of 100 feet. It is further assumed that the coal lies in two 10-foot-thick seams with a 10-foot parting between. At the maximum, total excavation depth would be 230 feet, with 130 feet as the average. Ninety percent recovery of the coal is presumed. On this basis, each acre of mine would produce 209,733 cubic yards of material composed of 29,040 cubic yards of recovered coal and 180,693 cubic yards of mine wastes. Since the Nenana coals have an approximate specific gravity of 1.30 and a unit weight of 1,770 tons per acre-foot, the recovery rate means that a total of 183 to 184 acres of land annually would have to be mined. Over the 100-year life, a total acreage of 18,300 to 18,400 exclusive of roads or other subsidiary uses would be required. It should be emphasized that the disturbed acreage is based on a relatively favorable formation of coal seams that tend to minimize the land requirements. Actual field conditions could easily double or triple the strip mining acreage.

The Healy Creek Valley and most of the land westward to the Dry Creek-Savage River coal beds is covered by upland spruce-hardwood forest below 2,500 feet, m.s.l. The intervening lands are generally alpine tundra. As a result, the majority of the area is classified as fall and winter moose concentration area. 1/ Dall sheep range extends on both sides of the valley and along the southern rim of the westward area. The valley upstream of the 2,500-foot elevation and the Dry Creek-Savage River area are both winter range for caribou. The valley of the Nenana River running north-south between Healy Creek and the westward coal beds is listed as a nesting-moulting area for waterfowl and a major migration route (flyway). The Nenana River supports both resident and anadromous fish.

Thus, the destruction of the vegetative cover and land disturbance would be, acre for acre, destruction of important wildlife habitat. Revegetation over the long term would be possible, but for the active life of the mining operation, it is unlikely that any significant portion of the disturbed habitat would return to usefulness. In addition to the effects on wildlife habitat, the coal alternative would have a range of other environmental impacts. The mining and hauling of the coal could be expected to put considerable amounts of dust into the air in the project vicinity. Since the operations would, in general, be following natural water courses, there is a

1/ Alaska's Wildlife and Habitat, Alaska Department of Fish and Game, 1973.

strong probability that sediments could not be prevented from reaching the streams and being carried into the Nenana River where the increases in turbidity could be expected to have adverse effects on fish populations. Further, although the coal is low in sulfur content, ground water and runoff waters in contact with the beds and the uncovered coal residues could well experience chemical changes which in turn could have adverse effects on the Nenana River, its fish, and other aquatic biota.

The operation of the generating plant would have environmental impacts also. Even with pollution control devices to restrict and/or remove harmful substances, there would be some degradation of air quality from combustion products. These would include water vapor, carbon particles, sulfur compounds, and unburned gases to the limits permitted by air quality regulations. The characteristic odor of burning coal would be pervasive over a wide area including the Parks Highway and railroad which run beside the Nenana River through this region. Water, either from groundwater sources, or more likely, from the Nenana would be required to provide cooling for the steam condensers of the plant. This water would need to be returned to the river in exchange for cold waters to continue the function of system. This could effect a sharp change in the thermal regime of the river with possible adverse effects on its ecosystems. Alternatively, cooling towers or other artificial means could be installed to avoid thermal pollution, but at a substantial increase in the costs of the project. A third broad source of possible environmental impacts from the plant lies in the need for disposal of the solid combustion wastes such as fly ash and cinders. These could be added to the mine wastes, thus increasing the bulk of these spoil ridges or could be disposed on other lands. Either method would involve probable adverse effects in that the ash-cinders would tend to hinder efforts at revegetation of the mine wastes while dumping elsewhere would remove additional acreage from wildlife habitat or other beneficial use. The amount of waste, based on the coal content of noncombustibles, is estimated as up to 10 percent of the volume. Thus, a direct correlation to required mining acreage would give a disposal acreage of about 18 acres per year. Again, leaching of chemicals by surface waters could well cause water quality problems in the streams of the disposal area.

The Healy Creek vicinity has a long history of mining and mineral exploration which increases the probability that historic sites would be of above average occurrence within the area of project effects. The State Division of Parks considers the area to be extremely rich in archaeological potential. The Dry Creek area is being excavated while the area from Dry Creek to Savage River is being surveyed. Strip mining would tend to have adverse effects on preservation of historic sites while it could both encourage discovery and recovery of prehistoric artifacts and destroy sites for continued archaeological study.

This alternative would make no contribution to either flood control or recreation in the Railbelt area. In fact, the destruction of habitat and the widespread presence of human activities could be expected to reduce game animal and fish populations, both of which would reduce the present main recreational potential for hunting and fishing.

It is estimated that construction of the coal facility would impact on the regional economy in much the same way and magnitude as the alternative hydropower plans. However, because of the plant location, more of the effects would be felt in Fairbanks than Anchorage. These would include both employment of local labor, as well as a temporary influx of additional business activity from nonresident worker seeking recreation and services. It is probable that the year-by-year effects would be more evenly spread over a longer total construction period since construction would be in several stages as the power demand grew and would not be completed (to the output level of the hydropower alternatives) until about 1995. Permanent jobs arising from operation of the project are estimated to be 67 in the mining-hauling of the coal, and 35 in the actual powerplant operation and maintenance.

Response to Study Objectives: The response of the coal alternative to the study objectives is summarized as follows:

Power: Provides power equivalent to any other alternative (6.88 to 6.91 billion kilowatt-hours annually). Meets the projected demand until the mid-1990's.

Flood Control: Nonresponsive.

Air Pollution: Adverse response.

Fish and Wildlife: Direct loss of 18,000-20,000 acres of important moose and caribou habitat. Probable adverse effects on anadromous fish. No positive contributions.

Recreation: Nonresponsive.

Conservation of Nonrenewable Resources: Adverse response--expend 5.83-5.85 million tons of coal annually.

Energy Independence: Conserves equivalent of 112.5-112.9 billion cubic feet of natural gas annually, or 15.1-15.2 million barrels of oil.

Devil Canyon-Watana: This alternative would consist of a concrete thin-arch dam 635 feet high with a four-unit powerhouse and a switchyard at river mile 134 of the Susitna River, an earthfill dam 810 feet high with a three-unit powerhouse and a switchyard at river mile 165, an access road 64 miles long from the vicinity of Chulitna Station on the Alaska

Railroad and the Parks Highway, and 364 miles of transmission lines. Included in the permanent facilities would be living quarters for operating personnel, visitor centers at each dam, boat launching ramps, and a limited system of recreational facilities including camping spots and hiking trails. The first cost of the project is estimated as \$1.52 billion. Annual costs are estimated as \$104,020,000, including \$2,500,000 for operation, maintenance, and replacements. Average annual project benefits accrue as follows:

Power	\$138,098,000
Recreation	300,000
Flood Control	50,000
Area Redevelopment	9,373,000
Total	\$147,821,000

The benefit-to-cost (B/C) ratio is 1.4 to 1.
Net annual benefits are \$43,801,000.

The system would have an average annual energy output of 6.91 billion kilowatt-hours and a firm energy output of 6.10 billion kilowatt-hours from an installed capacity of 1,568 MW. The projected energy cost to the distributors would be 21.1 mills per kilowatt-hour.

Known and suspected project impacts for the proposed Devil Canyon-Watana hydroelectric project are discussed below.

River Flows: The natural average daily flows at Devil Canyon from the latter part of May through the latter part of August fluctuate in the range of 13,000 to 27,000 cubic feet per second (cfs). For November through April, the average daily flows range between 1,000 and 2,300 cfs. The river also carries a heavier load of glacial sediment during high runoff periods. During winter when low temperatures reduce water flows, the streams run practically silt free.

With a project, significant reductions of the late spring and early summer flows would occur and substantial increases of the winter flows. The average regulated downstream flows for this plan computed on a monthly basis are estimated between about 7,600 cfs in October to about 15,000 cfs in August. In extreme years, the monthly averages would range from about 6,500 cfs to over 28,000 cfs. The following table compares natural and regulated flows.

Month	Regulated cfs	Unregulated cfs
January	9,896	1,354
February	9,424	1,137
March	9.020	1,031
April	8,261	1,254
May	8,192	12,627
June	8,324	26,763
July	9,618	23,047
August	15,066	21,189
September	10,802	13,015
October	7,556	5,347
November	8,367	2,331
December	8,964	1,656

The high flows of the summer and fall plus unregulated flood flows of much higher magnitude presently require an average annual expenditure of $50,000 by the Alaska Railroad to prevent erosion of the roadbed. The regulated flows would make such protection unnecessary. The resulting savings is the source of the flood control benefit.

Water Quality: The heavier sediment material now carried by the river between Devil Canyon and the junction of the Chulitna and Talkeetna Rivers with the Susitna River during high runoff periods would be substantially reduced, and a year-round, somewhat milky-textured "glacial flour" (suspended glacial sediment) would be introduced into the controlled water releases below the dams. Preliminary studies indicate that the suspended materials in the releases below the dams would be in the range of 15 to 35 parts per million.

On occasions after the development of upstream storage, when spilling over Devil Canyon Dam would be necessary during periods of high flows, nitrogen supersaturation could be introduced into the river below the dam and would cause an adverse impact on fish for some distance downstream from the dam depending on the level and duration of the supersaturated condition. Fish exposed to this environment suffer gas bubble disease (like bends to a deep-sea diver) which is often fatal, particularly to juvenile salmon.

With the use of appropriate operational procedures, spilling would occur about every second year with an average annual duration of 14 days. Nitrogen supersaturation introduced by the spilling should be substantially reduced in the turbulent river section just downstream of the dam. The proposed spillway at the Watana Dam is not conducive to nitrogen supersaturation. Because of the flood storage capacity of this fluctuating impoundment and the large release capabilities of the outlet works and powerhouse, use of the spillway should be required only about once in 50 years.

Compared to natural conditions, temperature of the controlled releases of water from Devil Canyon Dam would tend to be cooler in the summer and warmer in the winter. Cooler summer water temperatures and warmer winter water temperatures could have both beneficial and adverse effects on migrating salmon, juvenile salmon, and resident fish populations, and will be investigated further in post-authorization studies.

Variations in water releases at Devil Canyon Dam would cause less than a one-foot daily fluctuation of downstream water levels in the river during the May through October period since the reservoir would not be used for peaking purposes. The regulated daily fluctuations during the winter months could range up to two feet under normal peaking conditions. According to U.S. Geological Survey studies, the natural normal daily fluctuations in the Susitna River below Devil Canyon range up to about one foot.

Stratification conditions within the reservoirs could cause some temperature and dissolved oxygen problems in the river for some distance downstream from the Devil Canyon Dam and within the reservoirs themselves. This could have an adverse impact on the downstream fishery and to fish within the reservoirs.

The multilevel intake structures at both dams provide for selective withdrawal of waters from varying depths within the reservoirs. This feature allows for considerable control of both downstream water temperature and dissolved oxygen content of the release waters. Because the lowest intake levels are well above the dead storage areas of the reservoirs, there should be no increase in passage of sediments even when the deepest intake levels are used.

General channel degradation caused by a river's attempt to replace the missing sediment load with material picked up from the riverbed is not expected to be a significant concern along the gravel bed reaches of the Susitna River between Talkeetna and Devil Canyon. There will undoubtedly be some degradation where bed conditions are favorable. It is expected that the river will channelize into a single deep watercourse during the winter months. However, because of the generally coarse nature of the surface materials of the riverbanks, no significant bank erosion is predicted.

Upstream from the dams the major environmental impacts would be caused by the reservoir impoundments. The reservoir behind the Devil Canyon Dam would remain essentially full throughout the year, while Watana reservoir would fluctuate between 95 and 120 feet below full pool during the average year.

Devil Canyon reservoir would cover about 7,550 acres in a steep-walled canyon will few known areas of big-game habitat and a minimal amount of resident fish habitat at the mouths of some of the tributaries that enter the Susitna River in the 28-mile section above the proposed damsite. The reservoir would, however, flood 9 of the 11 miles of the whitewater section known as Devil Canyon. These rapids are highly regarded by whitewater enthusiasts for their extreme violence and for their rarity, being rated as Class VI--cannot be attempted without risk of life to the most expert boatman. This very violence has, to date, limited recreational boating use of this section of the river to only a few highly expert individuals and/or parties. No significant future use by the general public, either for active boating or esthetic appreciation, seems likely considering the difficulty of access and the extreme danger of the waters. Construction of this alternative project would provide access to the canyon area and the remaining two miles of rapids below Devil Canyon Dam.

Watana reservoir would flood about 43,000 acres in a 54-mile section of the Susitna River that would reach upstream to the Oshetna River. Except in a few areas near the mouths of tributary creeks and most of the Watana Creek valley, the Watana reservoir would be contained within a fairly narrow canyon for much of its length.

Watana reservoir would flood areas used by migrating caribou in crossing the Susitna River and would also flood moose winter range in the river bottom. The reservoir would cover existing resident fish habitat at the mouths of some of the tributaries and possibly would create other fish habitat at higher elevations on these tributaries.

Fish: How some of the downstream river conditions caused by the proposed hydropower project would affect the anadromous and resident fish populations below the dams has not yet been fully determined, but past, ongoing, and future studies by State and Federal agencies coordinated by the U.S. Fish and Wildlife Service should provide the answers needed to further define adverse and beneficial impacts of the proposed project on fish and wildlife.

In a 1974 study by the Alaska Department of Fish and Game on surveys conducted to locate potential salmon rearing and spawning sloughs on the 50-mile section of the Susitna River between Portage Creek and the Chulitna River, 21 sloughs were found during the 23 July through 11 September study period. Salmon fry were observed in at least 15 of these 21 backwater areas. Adult salmon were present in 9 of the 21 sloughs. In 5 of the sloughs, the adult salmon were found in low numbers (6 to 7 average). In 4 other sloughs, large numbers were present (350 average).

During December 1974 and January and February 1975, the Alaska Department of Fish and Game investigated 16 of the 21 sloughs previously surveyed during the summer of 1974. Of the 16 sloughs, 5 indicated presence of coho salmon fry. Many of the 16 sloughs surveyed were appreciably dewatered from the summer/fall state. Also, a number of coho fry were captured in the Susitna River near Gold Creek, indicating that some coho salmon fry do overwinter in the main river.

It is reasonable to assume on the basis of existing data that there will be some changes in the relationship between the regulated river and access to existing salmon rearing and spawning sloughs and tributaries downstream from Devil Canyon Dam. It appears feasible to develop a program to improve fish access to and from some of the sloughs and tributaries in the Susitna River, if such is determined to be needed as a consequence of the project's stabilizing effect on summer flows. Such a program would be a project consideration.

Periodic flood conditions that presently destroy salmon eggs in this stretch of the river would be almost completely eliminated by regulation of the upper Susitna River flows.

Reduction in flows, turbidity, and water temperatures below Devil Canyon Dam might cause some disorientation of salmon migrating into the section of the Susitna River between Portage Creek and the Chulitna River during an initial period after construction of the dams.

According to a study discussed in the Journal of Fisheries Research Board of Canada--Volume 32, No. 1, January 1975, Ecological Consequences of the Proposed Moran Dam on the Fraser River, some of the beneficial downstream impacts of the dam could include the following:

The higher regulated winter flows might enhance the survival of salmon eggs in the river downstream from the dam. The increased flows could insure better coverage and better percolation through the gravel and presumably enhance egg and alevin survival.

An additional consequence of reduced turbidity below the dam might be a gradual reduction in the percentage of fine materials in the salmon spawning areas. This could also lead to improved percolation through the gravel in the streambed and possibly improve survival of eggs.

Reduced siltation during the summer months could prove beneficial for both anadromous and resident fish species in the 50-mile section of the Susitna River between the proposed Devil Canyon Dam and Talkeetna. With the almost total elimination of the heavier glacial sediment loads of the river, it is likely that the potential for recreational sport fishing would be improved in this section of the Susitna.

Upstream from the dams, the major impact on the resident fish populations would be caused by the reservoir impoundments. Devil Canyon reservoir would fluctuate very little. The steep-walled canyon of this reservoir might prove less than desirable to develop a resident fish population; however, some species of fish might adapt to this reservoir and provide sport fishing benefits.

Watana Dam would have a widely fluctuating reservoir and thus be generally detrimental to the development of resident fish populations. Suspended glacial sediment could be a factor in both of the reservoirs after the heavier glacial sediments have settled out; however, many natural lakes in Alaska such as Tustumena and Tazlina, with silt-laden inflows sustain fish populations under similar conditions.

Most resident fish populations, especially graying, utilize the clearwater tributaries of the Susitna River or areas near the mouths of these streams as they enter the glacially turbid main river during periods of high runoff. All of these tributaries, approximately 10 in number, would be flooded in their lower reaches by the proposed reservoir impoundments. Resident fish populations would be affected by the increased water levels in the proposed reservoirs. In about half of the areas, access to the less precipitous slopes of the upper tributaries would be improved by increased water elevations and could benefit resident fish populations.

Fish would experience extremely high mortality rates if they attempted to migrate downstream through turbines or outlet works at the proposed dams.

It appears highly unlikely that anadromous fish such as salmon could be introduced into the Upper Susitna River Basin. The related problems and costs of passing migrating fish over and through high dams appear infeasible. However, the introduction of a resident land-locked salmon species, such as sockeye (kokanee), to some waters of the upper Susitna basin might prove feasible.

Wildlife: Reservoir impoundments behind the proposed dams would have varying degrees of environmental impact on wildlife.

The Devil Canyon reservoir would be located within the confines of a narrow, steep-walled canyon with few areas of big-game habitat and no major migration routes for big-game animals. Based on observations of terrain slopes, and vegetation, it is estimated that about 100 acres of this reservoir might be favorable moose habitat. The reservoir would create about 65 miles of lake shoreline. Because the pool level would vary little, it is assumed that a fringe of water-oriented vegetation such as willow or alder would develop along the shore. Such a fringe zone could provide favorable habitat for a variety of small mammals and birds, and might provide replacement habitat for moose. A continuous fringing zone only 50 feet in width around the lake would represent 300-400 acres.

The proposed Watana Dam would be generally contained within a fairly deep and narrow river canyon. Watana reservoir would lie across one of the intermittent caribou migration routes between the north side of the Susitna River and the main calving area of the Nelchina caribou herd, located south of the river in the northeast foothills of the Talkeetna Mountains. Calving generally takes place during a month-long period starting in the middle of May. Ice-shelving conditions along the shoreline caused by winter drawdown on Watana reservoir or ice breakup conditions on the reservoir could cause problems for caribou migrating to the calving grounds. This reservoir would have a high water shoreline about 145 miles long. Development of a fringe habitat would be considerably less likely than for Devil Canyon because of the highly variable water level of the lake. Creation of beneficial habitat is doubtful.

As caribou are strong swimmers, they should have fewer problems crossing the narrow reservoir during July after calving than they would crossing the swollen glacial river during natural periods of high runoff. Caribou could migrate around the reservoir. Caribou migration patterns for the Nelchina herd are continually changing, as stated in Alaska Department of Fish and Game study reports. Under adverse ice conditions, the reservoirs could cause increased mortality in some segments of the herd, and some permanent changes in traditional herd movements.

A moose survey conducted in early June 1974 by the Alaska Department of Fish and Game indicated that, although spring counting conditions were less than ideal, a total of 356 moose were seen along the upper Susitna River and in the lower drainage areas of the major tributaries. A 1973 fall count in the same general area sighted a total of 1,796 moose. Of the 356 moose counted in the June 1974 survey, 13 were seen in the area of the proposed Watana reservoir. None were sighted within the proposed Devil Canyon reservoir impoundment. Based on visual observations and map studies of vegetation and terrain slopes, it is estimated that 2,000 to 3,000 acres, mostly in the lower reaches of Watana Creek, could be favorable moose habitat. Wildlife management agencies state that such habitat for moose should be considered as critical, especially as winter habitat. Further studies to delineate both the extent and value of the habitat would be required to determine the need and/or extent of mitigation.

The proposed reservoirs at Devil Canyon and Watana are located along a major flyway for waterfowl. Very few waterfowl appear to nest on the sections of the river that would be flooded by these reservoir proposals, but the reservoirs could provide suitable nesting areas not now available for waterfowl migrating through the basin.

The loss of habitat for bears, wolves, wolverines, Dall sheep, and other animals appears to be minimal. Other birds, including raptors, songbirds, shorebirds, and game birds, do not appear to be significantly affected by the reduction of habitat in the area of the proposed dams and reservoirs, although some habitat will be lost for all species of wildlife.

Road access to the two damsites could have a significant impact on fish and wildlife resources in areas opened to vehicle encroachment. Specific areas such as Stephan Lake, Fog Lakes, lower Deadman Creek, and the northern slopes of the Talkeetna Mountains could be greatly impacted by hunters, fishermen, and other recreationists as a result of the access road to Watana Dam. However, such an impact is properly a function of the establishment and enforcement of proper regulations by management authorities, not of the project.

The proposed reservoirs at Devil Canyon and Watana are located along a major flyway for waterfowl. Very few waterfowl appear to nest on the sections of the river that would be flooded by these reservoir proposals. On the other hand, the reservoirs would provide suitable resting areas for waterfowl migrating through the basin.

Migrating birds would possibly suffer some mortality from collisions with towers or lines, but such losses should be negligible. The line would generally parallel normal north-south migration routes. The cables would be large enough to have a high degree of visibility and would be widely enough spaced to be ineffective snares. Electrocution of birds is also unlikely since the distance between lines and between lines and ground would be great enough to make shorting out by birds almost impossible.

A transmission line per se will not have many impacts upon wildlife; most of the impacts will be as a result of construction and maintenance. Direct destruction will affect the less mobile animals such as the small mammals, whose territories may be small enough to be encompassed by the construction area. The significance of this impact to these animals is small in relation to their population in surrounding areas.

Recreation: Much of the Upper Susitna River Basin, except near the Denali Highway and Lake Louise vicinity, has little recreational activity at the present time. A combination of poor road access, rough terrain, and great distances limits the use of the 5,800-square-mile basin, especially the lands directly impacted by this alternative, to a few hunters, fishermen, and campers who utilize these lands for recreational purposes.

The construction of the proposed hydroelectric project would have an impact on a number of present and projected recreational activities both in the immediate dam and reservoir areas and downstream from the dams.

At the present time, the Susitna River upstream from Portage Creek to the Denali Highway bridge is a free-flowing river with few signs of man's activities. The construction of dams on the river would change sections of the river into a series of manmade lakes. The violent, whitewater section of the river through the area known as Devil Canyon would be substantially inundated by a dam at the Devil Canyon site. Other areas of the river would also be changed from river-oriented recreational opportunities to lake-oriented recreational activities.

Improved road access into some areas of the upper Susitna basin would substantially increase pressures on all the resources impacted by outdoor recreational activities within these areas.

The construction of project-oriented recreational facilities would substantially increase the recreational use of the areas around the proposed dams and reservoirs. These recreational facilities could include visitor facilities at the dams, boat launching facilities on the reservoirs, campgrounds, picnic areas, trail systems, and other related recreational facilities. Recreational facilities at Devil Canyon and Watana could also be developed to complement the 282,000-acre Denali State Park complex, which is located on the Parks Highway just west of the settlement of Gold Creek.

Few people reside within a 100-mile radius of the project area at the present time and day-use of the project by local residents would be minimal.

A project related recreational development program would involve cooperation between the Bureau of Land Management and the operating agency for maintenance of the developed recreational facil,ities. The projected recreational program would provide for an estimated 77,000 use days of recreation, mostly fishing, camping, hiking, and sightseeing. This is the source of the recreational benefit.

Historic and Archaeological Sites: The current National Register of Historic Places has been consulted, and no National Register properties will be affected by the project. A recently completed study for the Corps of Engineers, made by the Alaska Division of Parks, indicated 11 historic sites within the study portion of the upper Susitna basin, all of which are related to the discovery of gold. One known site (cabin) is in the proposed reservoir impoundment areas.

Only one archaeological site has been examined within the study area of the upper Susitna basin, and it has never been excavated. This is the Ratekin site, several miles east of the Susitna River near the Denali Highway. The Division of Parks survey projects a total of 40 zones of possible archaeological interest within the Devil Canyon and Watana impoundments.

Mining: The Susitna River basin in the proposed reservoir impoundment areas is generally favorable for various types of mineral deposits, but the area has never been mapped geologically. An extensive mineral examination program is expected to be necessary in the areas of proposed hydroelectric development, and this program would probably be funded to assess mineral resource potential.

Transmission System: Most of the power generated by hydroelectric development on the upper Susitna River would be utilized in the Fairbanks-Tanana Valley and Anchorage-Cook Inlet areas. For this study, a transmission system, consisting of two 230-kv single circuits from the project area to Fairbanks, and two single circuit 345-kv lines to the Anchorage area, is planned. All lines would generally parallel the Alaska Railroad, and would be connected to generation facilities at both Devil Canyon and Watana.

Most direct impacts of the transmission line upon vegetation would be relatively small with respect to the magnitude of surrounding unaffected land. Up to 6,100 of the approximately 8,200 acres of right-of-way would have to be cleared. The cleared right-of-way would have a major impact on scenic quality. Regrowth beyond a limited height would have to be prevented by maintenance so that cuts through forested areas would be permanently visible. In more open areas at higher elevations, such as Broad Pass, this effect would be as significant. However, in such areas the line itself would be visible.

Disposal of slash and debris has potentially adverse effects on remaining vegetation and other resources. Regardless of the method of disposal chosen, some impacts could be expected.

Roads: Permanent roads would be built to provide access from the Parks Highway to the Devil Canyon and Watana damsites. Permanent roads would also provide access to proposed recreational facilities within the project area. Temporary roads for project construction and reservoir clearing operations would also be constructed.

Resource values impacted by proposed roads include fish, wildlife, vegetation, recreation, scenery, water, and soils. Air and noise pollution related to road construction and dust generated by vehicle travel on unpaved roads could also be significant though temporary adverse environmental impacts.

Design, location, construction, rehabilitation, and maintenance of a project road system should give prime consideration to the utilization of good landscape management practices.

Construction Activities: Project related construction activities would include the building of the dams and related facilities; the clearing of reservoir areas; the construction of roads, electrical distribution systems, and recreational facilities; and the building of facilities for workers. The construction of the Devil Canyon and Watana project is estimated to take 10 years to complete, with an estimated 5 to 6 years required for construction at each of the two sites. The activities will overlap as simultaneous construction will occur in the final 1-2 years of the Watana project.

The activities themselves would cause varying degrees of physical pollution to the air, land, and water within the project area and to some areas outside the development area. Fish, wildlife, vegetation, visual resources, soils, and other resource values could be severely impacted by construction activities.

Roads and other facilities would be needed in order to obtain materials from borrow sources and quarry sites for the construction of the dams. Areas would also be needed to dispose of some materials and debris. All construction activities could be controlled to minimize or to eliminate adverse environmental impacts; environmental enhancement could be considered where feasible.

Workers' Facilities: No communities within commuting distance of the proposed project area could absorb the number of workers required for the construction of the dams and related facilities. Temporary construction camps with the necessary facilities would need to be provided during the construction periods. Permanent facilities would have be built for maintenance and operational personnel after completion of the construction phase.

The construction and operations of the workers' camps would have to meet State and Federal pollution control laws and standards, and all activities could be controlled to minimize the adverse environmental impacts presented by the camps.

Esthetics: The project would be located in areas that have practically no permanent signs of man's presence. The land between Portage Creek and the Denali Highway is an undisturbed scenic area.

The construction of a hydroelectric project would have a substantial impact on the existing natural scenic resource values within the project area. Any dam construction on the upper Susitna would change a free-flowing river into a series of manmade lakes. Devil Canyon reservoir would fluctuate up to 5 feet, while Watana reservoir could fluctuate up to 120 feet below full pool under normal operating conditions. The seasonal fluctuation of the Watana impoundment would not have a substantial scenic impact, inasmuch as the major drawdown would occur in the winter when public access was not possible, and the pool would be essentially refilled by the time access was restored. The whitewater section of the Susitna River through Devil Canyon would be substantially inundated by a dam at Devil Canyon. Roads and transmission lines would also impact the natural scenic resource values of the area.

After dam construction, many visitors could view the manmade structures and their reservoirs. It can be expected that a considerable number of tourists and State residents would visit the dams.

If consideration were given to minimizing the adverse impacts of construction activities, a great deal could be accomplished to maximize scenic resource values within the project area. Good landscape management practices would add substantially to the recreational experience of the project visitor.

Air Pollution: Most of the existing electrical power in the Southcentral Railbelt area is produced by gas, coal, and oil-fired generating units which cause varying degrees of air pollution.

Cook Inlet gas is a clean fuel that causes few serious air pollution problems at the present time. The existing gas turbines have very low efficiencies and give off visible water vapor emissions during the colder winter months. Also, nitrogen emissions could be of significant concern for any proposed larger gas-fired plants.

Hydroelectric energy could replace the burning of fossil fuels for electric power generation in much of the Fairbanks area and could help to alleviate winter ice fog and smoke problems, which are caused in part by coal-fired electrical plants in that area.

Hydroelectric projects provide a very clean source of power with practically no direct air pollution-related problems. This type of electrical power generation could reduce a substantial amount of future air pollution problems associated with the burning of gas, oil, and coal.

An ice-free stretch of warmer, open water below Devil Canyon Dam could cause ice-fog conditions in that area during periods of extreme cold weather.

Social:

Population: Substantial increases in population are expected within the Southcentral Railbelt area through the year 2000, and with the possible relocation of Alaska's State capital from Juneau to the Railbelt, an additional population impact can be expected in this area.

The population of the area will increase with or without the development of hydroelectric projects proposed for the Susitna River;

construction of the project is not expected to have any significant effect on overall population growth.

Economics: The proposed two-dam Devil Canyon-Watana hydroelectric development would have a minimal to moderate overall effect depending on various factors involved in the construction program itself. If the construction unit is brought in from outside Alaska to develop the project, the social and economic impact on the local system would be minimized, but if the project were constructed using substantial labor and material from the Anchorage-Fairbanks area, it would have a more moderate effect on local conditions during construction of the project and would help to stabilize economic conditions during that development period. It is projected that about 80 percent (878 out of 1,097 workers) of the labor force would be local and that half (439 workers) of that is labor that would otherwise be un- or underemployed. The resulting benefit to such labor is the source of Area Redevelopment benefit.

Various community, borough, State, and private facilities and agencies would be impacted to varying degrees by the workers involved in the construction of the proposed project. Workers' camps would be built in the vicinity of some of the various construction activities, but additional impacts would be created by the families of the construction workers living in various nearby communities, who would require additional facilities and services.

After the construction of the project, an estimated 45 permanent personnel would be required to operate and maintain the project and project-related facilities--these people would not create a significant overall socioeconomic impact on the Railbelt area.

Other Effects: The lands within the reservoir areas have sporadic occurrences of permafrost. The lakes would thaw such material to a considerable depth and increase the probability of earthslides and erosion of the material. However, the overburden depth to rock is quite shallow throughout most of the sharply incized canyon terrain of the two reservoirs and the quantities of materials which would be involved in such slides and/or erosion are thus not considered significant either in terms of reservoir sedimentation or in the creation of large waves of danger to the dams. It is estimated that of the 210 miles of combined shoreline, 40 miles could experience significant erosion, while the remaining 170 miles would be subject to only minor effects. The effects of even the severe erosion would be expected to last only a few years until the thawed and saturated slopes had attained equilibrium.

Response to Study Objectives: The response of the Devil Canyon-Watana hydropower alternative to the study objectives is summarized as follows:

Power: Provides 6.91 billion kilowatt-hours average annual energy. Meets the projected demand until the mid-1990's.

Flood Control: Provides minor flood control benefits.

Air Pollution: Provides partial air pollution abatement by displacing and or delaying increased use of coal in Railbelt area.

Fish and Wildlife: Direct loss of 50,550 acres of land including 2,100-3,100 acres of critical winter moose habitat. Possible adverse effect on caribou migration and anadronous fish. Probable creation of 300-400 acres of replacement moose habitat. Possible contribution to establishment of non-migration fish population. Provides 50,550 acres of possible waterfowl resting area.

Recreation: Provides light use recreational facilities equivalent to 77,000 visitor days. Adverse effect on 9 miles of whitewater boating potential.

Conservation of Nonrenewable Resources: Conserves equivalent of 5.85 million tons of coal annually.

Energy Independence: Conserves equivalent of 112.9 billion cubic feet of natural gas, or 15.2 million barrels of oil annually.

Devil Canyon-Watana-Denali: This alternative would be identical to the previous two-dam system except for the addition of a 260-foot-high earthfill dam at river mile 248 near Denali. This dam would provide an additional storage area of 54,000 acres, and would have no powerhouse. The first cost of the three-dam system is estimated as $1.89 billion. Annual costs are estimated as $115,566,000, including $2,600,000 for operation, maintenance, and replacements. Average annual project benefits accrue as follows:

Power	$138,188,000
Recreation	300,000
Flood Control	50,000
Area Redevelopment	10,905,000
Total	$149,443,000

The B/C ratio is 1.3 to 1.
Net annual benefits are $33,877,000.

The system would have an average annual energy output of 6.91 billion kilowatt-hours and a firm energy output of 6.80 billion kilowatt-hours from an installed capacity of 1578 MW. The project cost of energy to the distributors would be 21.0 mills per kilowatt-hour.

Project effects would be essentially identical to the two-dam project, except as follows:

River Flows: Average regulated downstream flows at Devil Canyon would range from about 8,900 cfs in October to 11,000 cfs in February. In extreme years, the flows would range from 7,800 cfs to 16,000 cfs. Overall, the effect would be to provide better river regulation. Flood control would remain essentially unchanged with flood control benefits identical.

Water Quality: Devil Canyon reservoir would remain unchanged. Watana reservoir would receive less heavy sediment, approximately 3.5 million tons per year rather than 7.1 million tons per year. Denali reservoir would have a high pool surface area of 54,000 acres and would fluctuate an average of 30 to 40 feet annually to a low surface area of 35,000 acres. The reservoir would be 34 miles long and 6 miles wide at high pool. The pool would force relocation of 19 miles of the Denali Highway.

Fish: Resident fish would be severely impacted by the fluctuating pool. Some might survive in the tributary streams at low pool, but many would be trapped in temporary pools and die during drawdown. Downstream effects on anadromous fish would be identical to the preceding plan. Adverse effects to resident fish in Watana reservoir could be increased marginally since the fluctuation of that reservoir would be increased from 95-120 feet annually to 110-140 feet, providing a less favorable environment. Stocking of Denali reservoir would probably be nonbeneficial in that the pool fluctuations would have the same adverse effects on these fish as on fish now resident to the tributary streams.

Wildlife: The impacts on wildlife would be increased greatly. Of the 54,000 acres inundated by Denali reservoir, an estimated 52,000 acres is moist tundra and pothole lakes which provide moderate habitat to moose and are highly significant as caribou habitat. In addition, the lakes, estimated to number about 400, provide significant resting and nesting for waterfowl. Effects at the two downstream dams would not be significantly changed. Human access, via the reservoir at full pool, would be improved to the headwater areas of the Susitna River. The major ecosystem in these areas, alpine tundra, is quite fragile and could be adversely impacted if access were not carefully regulated. The Denali reservoir would have a high water shoreline about 100 miles long. However, because of the frequent and rapid pool fluctuations, little beneficial habitat could be expected to develop.

Recreation: The Denali reservoir could have significant adverse impacts on present recreational uses made of the area. Moose and caribou hunting in this area now accessible by the Denali Highway provides a large part of the present recreational activity in the Upper Susitna River Basin. Establishment of the reservoir, by removing much of the suitable habitat of the game animals, would greatly reduce the hunting opportunities. Because of the fluctuations in the reservoir level and the resulting unfavorable conditions for fish, little if any replacement recreational opportunity would be provided to offset this loss. No recreational facilities would be provided at the reservoir in view of the unfavorable conditions.

Historic and Archaeological Sites: In addition to the single site of historic interest and 40 zones of archaeological interest contained in the two-dam system, the Denali reservoir would emcompass 20 archaeological zones of interest and 3 potential historical sites.

Mining: The area adjacent to the Denali reservoir has a long and continuing history of gold mining. Although no active mines would be inundated by the reservoir, further exploration and/or development within the confines of the impoundment would be hampered or precluded.

Transmission System: Because Denali Dam would have no generation capacity, no additional transmission lines or effects would result.

Roads: In addition to the effects of the two-dam system, there would be a required relocation of about 19 miles of the Denali Highway. The temporary construction access roads would, for the most part, be merged into the permanent road. The most significant effects of the relocation would be loss of about 200 additional acres of wildlife habitat and better access to the damsite vicinity, which could impose added pressures on wildlife.

Construction Activities: The general effects would be those listed for the two-dam system with the addition of an estimated three to four years of such activity at the Denali site.

Workers' Facilities: Construction of a Denali Dam would require a temporary camp for about 600 workers since the only nearby settlements, Denali and Paxson, do not have facilities which could absorb the workforce. The impacts and controls required would be the same as listed for the two-dam system.

Esthetics: The Denali Dam and reservoir, with the Denali Highway crossing the dam structure itself, would be highly visible to all motor traffic. The reservoir at less than full pool would have a definite adverse impact on the scenic values of the area. Because of the generally flat terrain within the reservoir, even a few feet of fluctuation in the pool level would create a wide "bathtub ring" of defoliated shore. At large drawdowns, the ring could be a mile or more in width.

No means of preventing or significantly lessening the impact of this feature is compatible with the power production objective which requires the drawdown.

Air Pollution: Except for the short-term effects of construction activities at Denali Dam, the effects of the three-dam system would be identical to the two-dam system.

Social: The effects would be the same as for the two-dam system except that additional employment would be provided. The increased Area Redevelopment benefits reflect the additional use of un- or under-employed labor in the construction of the additional dam and facilities. As previously stated, the addition of the Denali Dam would result in an increase of 4, from 45 to 49, in permanent jobs created in operation and maintenance of the dam system. The construction of permanent living quarters at the damsite might be foregone in favor of locating the personnel at Paxson.

Other Effects: The Denali reservoir area is underlain by permafrost. Inundation would cause a significant thawing of this material. Because of the very flat terrain, earthslides should not be of consequences. However, the materials are generally very fine-grained and when thawed and saturated could have poor structural integrity when subjected to earthquakes. As such, the materials pose a difficult technical problem in the design of a Denali Dam. The cost of adequate remedial foundation treatment for the structure is a significant factor in the overall cost of what would otherwise be a relatively small dam. Erosion of the thawed shoreline would not contribute significantly to sedimentation of the reservoir. It is estimated that all of the 100-mile shoreline could be subject to severe erosion until equilibrium was restored and vegetation reestablished.

Response to Study Objectives: The response of the Devil Canyon-Watana-Denali hydropower alternative to the study objectives is summarized as follows:

Power: Provides 6.91 billion kilowatt-hours average annual energy. Meets the projected demand until the mid-1990's.

Flood Control: Provides minor flood control benefit.

Air Pollution: Provides partial air pollution abatement by displacing and/or delaying increased use of coal in Railbelt area.

Fish and Wildlife: Direct loss of 104,550 acres of land, including 2,100-3,100 acres of critical winter moose habitat, and 52,000 acres of important caribou habitat and waterfowl nesting area. Possible adverse effects on caribou migration and anadromous fish. Probable creation of 300-400 acres of replacement moose habitat. Possible contribution to establishment of nonmigratory fish population. Provides 104,550 acres of possible waterfowl resting area.

Recreation: Provides light use recreational facilities equivalent to 77,000 visitor days. Adverse effect on 9 miles of whitewater boating potential. Probable adverse effect on recreational hunting and fishing in 54,000-acre Denali reservoir.

Conservation of Nonrenewable Resources: Conserves equivalent of 5.85 million tons of coal annually.

Energy Independence: Conserves equivalent of 112.9 billion cubic feet of natural gas, or 15.2 million barrels of oil annually.

Devil Canyon-Watana-Vee-Denali: This alternative would consist of the previously described dams at Devil Canyon and Denali with a lower (515 feet vs 810 feet) earthfill Watana Dam and a 455-foot-high earthfill dam in Vee Canyon at the extreme head of Watana reservoir at river mile 208. The three downstream dams would have powerhouses and switchyards. An additional 40 miles of access road would connect Vee Dam to Watana Dam. An additional 40 miles of transmission line would also be required to connect Vee Dam to the downstream system. The dam would have a visitor center, a boat ramp, and limited recreational facilities. The project first cost is estimated as $1.95 billion. Annual costs are estimated as $102,491,000, including $3,200,000 for operation, maintenance, and replacements. Average annual project benefits accrue as follows:

Power	$119,725,000
Recreation	400,000
Flood Control	50,000
Area Redevelopment	10,971,000
Total	$131,146,000

The B/C ratio is 1.3 to 1.
Net annual benefits are $28,655,000.

The system would have an average annual energy output of 6.88 billion kilowatt-hours and a firm energy output of 6.15 billion kilowatt-hours from an installed capacity of 1570 MW. The projected energy cost to the distributors would be 24.3 mills per kilowatt-hour.

Project impacts of the Devil Canyon, Watana, and Denali Dams would be essentially as described previously, except that Watana reservoir would have an area of only 14,000 acres. Because the most favorable wildlife habitat is in the vicinity of the stream-river confluences, there would be essentially the same losses of critical winter moose habitat as with the higher dam and larger reservoir. Vee reservoir, about 9,400 acres in extent, would impose the following additional impacts.

River Flows: Average regulated downstream flows at Devil Canyon would range from about 7,900 cfs in October to about 12,200 cfs in August. In extreme years, the flows would range from 5,800 cfs in October to 23,000 cfs in August. River regulation would be somewhat better than that of the two-dam system and not as good as that of the three-dam system. Flood control benefits would be identical in origin and value to the other plans.

Water Quality: Sediment entrapment at Watana reservoir would decrease further to 2.0 million tons per year from the 3.5 million tons per year of the three-dam system, the difference being the entrapment of Vee reservoir. All other downstream water quality effects would remain essentially unchanged.

Fish: The lower Watana reservoir level would offer less opportunity for allowing resident fish to get to the upper tributaries above the steep sections of these tributaries which now bar use of this possible habitat. In addition, Vee reservoir would flood the mouth of Tyone River with a fluctuating and turbid pool and would, in all likelihood, severely decrease the present resident fish population of this, the main clearwater tributary of the upper Susitna River. Fluctuations in Watana reservoir would be decreased to an average of 80-95 feet, which might offer potential for establishment of a lake-oriented fish populace by stocking. Simultaneously, fluctuation of Denali reservoir would increase to an average of 40-60 feet. No change would occur in effects on fish below the system of dams.

Wildlife: The addition of Vee reservoir to the system would have a significant impact on wildlife. About 7,000 acres of the 9,400-acre reservoir are lowland spruce-hardwood, which is prime moose habitat and favorable for smaller mammals because of its diverse vegetation. The inundated lands are much less precipitous than those of the Devil Canyon and Watana reservoirs and are not only more favorable for, but are much more heavily used by wildlife, especially by moose. In addition, if the reservoir systems should prove to be a barrier to traditional caribou migration routes, forcing the caribou to go around them, Vee reservoir would increase the detour mileage from 25 to 45 miles from the Kosina Creek-Jay Creek vicinity. The Vee reservoir would have a high-water shoreline about 100 miles long. Because of the large and frequent pool fluctuations, little beneficial habitat could be expected to develop.

Recreation: Vee reservoir would increase the recreational potential of Watana reservoir by reducing the fluctuation level of that impoundment. The Vee impoundment and the additional access provided by the necessary roads would provide added recreational opportunity in themselves, although the Vee reservoir would have an average drawdown of 90-100 feet. As with the two downstream reservoirs, low density fishing, boating, hiking, and camping use would be most in keeping with the land and location. An increase in use days to about 100,000 (from 77,000) would give recreational benefits estimated at $400,000 annually.

Improved access would also tend to increase hunting pressures in the area extending from Watana Dam to Vee reservoir. As a result, added pressures would also be placed on responsible agencies to insure proper resource management.

Historic and Archaeological Sites: The area at and around the mouth of Tyone River has a long history of occupation and use by man. Vee reservoir would affect 25 zones of potential archaeological interest, by far the most of any single reservoir studied. Representatives of the native people of the region have indicated that the Tyone River confluence with the Susitna River is a long-used and valued area which they would not care to see disturbed. Construction of the reservoir would benefit archaeological knowledge in that it would spur exploration of that area; however, it would adversely affect both the interests of the native peoples and future possible archaeological explorations.

Mining: The Vee reservoir would, in itself, have little probable effect on mining potential beyond that of the other impoundments of the system, especially Denali reservoir.

Transmission System: An additional 40 miles of transmission line to connect Vee Dam and powerhouse to the system downstream would be required. This would involve additional clearing and disturbance of approximately 900 acres. The effects of this would be the same as for the rest of the transmission route in type, but would be increased in proportion to the added line length.

Roads: An additional 40 miles of access road would also be required for the Vee Dam. This would require approximately 500 additional acres of habitat loss and disturbance of wildlife. This particular section of road would intersect the general caribou migration routes in the Kosina-Jay Creeks vicinity. Although the road should pose no bar to migration, there would be possible interference between the animals and humans inasmuch as the road would be open to vehicles during the summer when the northward movement of the herd could be expected.

Construction Activities: The type of effects would be the same as for Devil Canyon and Watana Dams. Vee Dam would prolong the period of effects by about five more years.

Workers' Facilities: As with the preceding systems, no existing communities could absorb the project workforce. Commuting distance from the nearest established camp facility, Watana Dam, would be too great for economical use of these facilities. Thus, a temporary camp would be required in the vicinity of the damsite. The effects would be identical and additive to those previously described for the two-and three-dam systems.

Esthetics: The previously discussed adverse visual impacts would be increased. The "bathtub ring" at Denali reservoir would be increased by the added drawdown. The Vee reservoir area, not so much the steep canyon sections downstream of Oshetna River, but the more gently sloped, rolling terrain in the Tyone River and upstream area, would acquire a similar ring of defoliated barren land which would decrease the scenic value drastically. These would be additions to the downstream effects described for the other systems.

Air Pollution: Except for the short-term effects during construction of Vee Dam, the effects of the four-dam system would be identical to the three-dam system.

Social: The effects would be the same as for the two- and three-dam systems except that additional employment would be provided. The Area Redevelopment benefits from this plan reflect the increase in use of un- or underemployed labor over the other plans. Facilities would have to be provided at the dam for permanent operating personnel. It is estimated that 10 additional permanent jobs would be created by construction of Vee Dam, raising the system total to 59.

Other Effects: The effects of the reservoir on underlying permafrost would be a combination of the effects at the downstream reservoirs and the Denali impoundment since the Vee reservoir would lie in part in steep canyons with shallow frozen overburden and in part in flatter terrain similar to the Denali area. No significant reservoir sedimentation or slide-caused waves would be expected. Significant shoreline erosion would be expected to affect about 35 miles of the shoreline for a few years until an equilibrium condition was reached.

Response to Study Objectives: The response of the Devil Canyon-Watana-Vee-Denali hydropower alternative to the study objectives is summarized as follows:

Power: Provides 6.88 billion kilowatt-hours average annual energy. Meets the projected demand until the mid-1990's.

Flood Control: Provides minor flood control benefits.

Air Pollution: Provides partial air pollution abatement by displacing and/or delaying increased use of coal in Railbelt area.

Fish and Wildlife: Direct loss of 84,950 acres of land including 9,100-10,100 acres of critical winter moose habitat, and 52,000 acres of important caribou habitat and waterfowl nesting area. Possible adverse effects on caribou migration and anadromous fish. Probable creation of 300-400 acres of replacement moose habitat. Possible contribution to establishment of non-migratory fish population. Provides 84,950 acres of possible waterfowl resting area.

Recreation: Provides light use recreational facilities equivalent to 100,000 visitor days. Adverse effect on 9 miles of whitewater boating potential. Probable adverse effect on present hunting-fishing use of Tyone River confluence.

Conservation of Nonrenewable Resources: Conserves equivalent of 5.83 million tons of coal annually.

Energy Independence: Conserves equivalent of 112.2 billion cubic feet of natural gas, or 15.1 million barrels of oil annually.

NED PLAN

From the preceding evaluations, it is concluded that the system comprised of dams at the Devil Canyon and Watana sites best accomplishes the objective of maximizing National Economic Development. The two-dam system has the highest B/C ratio at 1.4 and the maximum net benefits at $43,801,000 annually while producing electrical energy equal to any of the other plans.

EQ PLAN

From the preceding evaluations, it is evident that no means of producing a meaningful output of electrical energy was found to be free of significant adverse environmental effects. The plan which minimizes the unavoidable adverse impacts on fish and wildlife values while providing beneficial contributions to air and water quality and social well-being is considered to contribute most to the Environmental Quality objectives. On this basis, the system of two dams at Devil Canyon and Watana is also the EQ plan.

THE SELECTED PLAN

The two-dam Devil Canyon-Watana system is selected as the plan providing the best overall response to the study objectives. The following table displays a summary comparison of the significant facts and factors which guided formulation of the selected plan.

THE SELECTED PLAN

The plan which provides the most economical development of electrical power generation for the Railbelt communities at the least environmental impact is a hydroelectric alternative consisting of two high-head dams and accompanying powerplants located in the Upper Susitna River Basin. The two projects, Devil Canyon and Watana, would produce 6.1 billion kilowatt-hours firm annual energy (1/) with a dependable capacity of 1,568,000 kilowatts. Table C-28 gives a summary of the energy capability of the system.

The Devil Canyon project, located 14.5 miles upstream from the Gold Creek stream gage, would be a 635-foot thin-arch concrete dam with the powerhouse located underground. The reservoir would inundate 7,550 acres and 28 miles of natural river, thus giving 1,050,000 acre-feet of storage capacity. The multi-level intake structure would allow a maximum power pool drawdown of 175 feet, but when operated in conjunction with the upstream Watana reservoir, Devil Canyon annual drawdown would normally be less than 5 feet. Drafting of the Devil Canyon reservoir would occur only under the most adverse streamflow conditions, and only after complete drafting of the Watana usable storage. Normal maximum pool elevation would be at elevation 1450 feet, and the average tailwater elevation would be about 875 feet. The powerhouse would have four 194 MW Francis units. Hydraulic capacity of the four-unit installation would be about 25,000 cfs at critical head.

The Watana project located 32 miles upstream from the Devil Canyon project would contain an underground powerplant and an earthfill dam built to a structural height of approximately 810 feet. The large storage capacity of the Watana reservoir would provide flow augmentation during periods of naturally low streamflow. The reservoir would extend 54 miles upstream and have a surface area of 43,000 acres. The total storage capacity would be 9,624,000 acre-feet after 50 years of sediment inflow. The useable storage capacity would be contained in the top 250 feet of the reservoir and would total approximately 6,100,000 acre-feet. Normal maximum pool elevation would be 2200 feet and the average tailwater elevation would be approximately 1470 feet. The powerhouse would contain three 264 MW Francis units with a combined critical head hydraulic capability of about 23,000 cfs.

1/ Preliminary scoping studies gave the selected plan a firm annual energy capability of 6.25 billion kwh, but refinements in turbine sizing and reservoir regulation criteria reduced this to 6.1 billion kwh. Other systems studied under the scoping analysis would be similarly reduced for turbine sizing and reservoir regulation.

ACCOUNTS	Coding	PLAN A — WITHOUT CONDITION — Conventional Coal Thermal Plant	PLAN B — NATIONAL ECONOMIC DEVELOPMENT (NED) ENVIRONMENTAL QUALITY (EQ) PLANS — Devil Canyon-Watana Dams	PLAN C — MAXIMUM POWER DEVELOPMENT PLAN — Devil Canyon-Watana-Denali Dams	PLAN D — PREVIOUSLY RECOMMENDED PLAN — USBR Four-Dam System
1. NATIONAL ECONOMIC DEVELOPMENT					
a. Beneficial Impacts					
(1) Value of increased output of goods and services					
a) Power	1,6,0,9	$ 138,098,000	$ 138,098,000	$ 138,185,000	$ 119,725,000
* b) Recreation	1,5,0,10	0	300,000	300,000	400,000
c) Flood Control	1,6,0,9	0	50,000	50,000	50,000
d) Area Redevelopment	1,5,0,9	0	9,373,000	10,905,000	10,971,000
TOTAL BENEFICIAL		$ 138,098,000	$ 147,821,000	$ 149,443,000	$ 131,146,000
b. Adverse Impacts					
(1) Project costs ($1,000)					
a) Investment cost	1,6,0,9	$1,650,848,000	$1,653,136,000	$1,841,144,000	$1,616,825,000
b) Interest and amortization	1,6,0,9	$ 101,380,000	$ 101,520,000	$ 112,966,000	$ 99,291,000
c) Operation, maintenance, and replacements (OM&R)	1,5,0,9	$ 36,718,000	$ 2,500,000	$ 2,600,000	$ 3,200,000
TOTAL ADVERSE		$ 138,098,000	$ 104,020,000	$ 115,566,000	$ 102,491,000
c. NED Performance					
(1) Net NED benefits ($1,000)		0	$ 43,801,000	$ 33,877,000	$ 28,655,000
(2) Benefit-to-cost ratio		1.0	1.4	1.3	1.3
2. ENVIRONMENTAL QUALITY					
a. Environmental quality enhanced					
* (1) Reservoirs					
a) Number	1,6,0,9	0	2	3	4
b) Water acreage	1,6,0,9	0	50,550	104,550	84,950
c) Shoreline miles	1,6,0,9	0	210	310 (Includes widely fluctuating Denali pool)	400 (Includes Denali)
(2) Improved access for management of wilderness areas					
a) Access road miles	1,6,0,9	30-40	40-50	50-60	90-100
b) Accessible acreage	1,5,0,10	360,000 to 480,000	480,000 to 600,000	600,000 to 720,000	1,080,000 to 1,200,000
(3) Accelerated archaeological knowledge					
a) Potential investigation investment	1,4,0,10	0	$ 15,200,000	$ 18,900,000	$ 19,500,000
b) Number of zones investigated	1,4,0,10	(Unquantified-area has very high potential)	40	60	85
(4) Biological resources					
a) Expanded habit for idigenous fish	1,4,0,9	0	(Potential-low order of significance)	(Essentially identical to Plan B)	(Essentially identical to Plan B)
b) Introduction of new fish species	2,4,0,10	0	50,550 acres of potential habitat formed	50,550 acres of potential habitat formed (Excludes widely fluctuating Denali pool)	30,950 acres of potential habitat formed (excludes Denali)
c) Provision of waterfowl resting areas (acres)	1,5,0,9	0	50,550	50,550 to 104,550	30,950 to 84,950
d) Habitat diversity acreage provided by clearing utility corridors (above Gold Creek)	1,5,0,9	0	750	750	1,400
e) Improved moose feeding habitat acreage in downstream flood plain	2,4,0,9	0	50-100	50-100	50-100
* (5) Water quality (streams)					
a) Mileage affected	1,6,0,9	0	54	54	54
b) Suspended solids change	1,6,0,9	No effect	Reduction from 800 ppm to 35 ppm	Reduction from 800 ppm to 35 ppm	Reduction from 800 ppm to 35 ppm
c) Flow characteristics	1,6,0,9	No effect	6,500-28,000 cfs vs. unregulated 800-90,000 cfs	7,800-16,000 cfs vs. unregulated 800-90,000 cfs	5,800-23,000 cfs vs. unregulated 800-90,000 cfs
b. Environmental quality					
(1) Pristine areas					
a) Acreage inundated	1,6,0,9	0	50,550	104,550	84,950
b) Mileage altered by utility corridors (above Gold Creek)	1,5,0,9	0	44	44	80
c) Acreage altered by pool fluctuations	1,6,0,9	0	13,000	45,000	45,000
d) Downstream mileage altered	1,6,0,9	Not Applicable	54	54	54

Index of Coding

Timing

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3. Impact is expected in a longer time frame (15 or more years following implementation.

Uncertainty

4. The uncertainty associated with the impact is 50% or more.
5. The uncertainty is between 10% and 50%.
6. The uncertainty is less than 10%.

Exclusivity

7. Overlapping entry; fully monetized in NED account.
8. Overlapping entry; not fully monetized in NED account.

Actuality

9. Impact will occur with implementation.
10. Impact will occur only when specific additional actions are carried out during implementation.
11. Impact will not occur because necessary additional actions are lacking.

Section 122

* Items specifically required in Section 122 and ER 1105-2-105.

ACCOUNTS	Coding	PLAN A	PLAN B	PLAN C	PLAN D
		WITHOUT CONDITION	NATIONAL ECONOMIC DEVELOPMENT (NED) ENVIRONMENTAL QUALITY (EQ) PLANS	MAXIMUM POWER DEVELOPMENT PLAN	PREVIOUSLY RECOMMENDED PLAN
		Conventional Coal Thermal Plant	Devil Canyon-Watana Dams	Devil Canyon-Watana-Denali Dams	USBR Four-Dam System
2. ENVIRONMENTAL QUALITY (Cont.)					
b. Environmental quality degraded (Cont.)					
(2) Biological resources					
a) Caribou routes affected by reservoirs	1,4,0,9	0	1	1	2
b) Routes affected by transmission lines	1,4,0,9	1	1	1	1
c) Waterfowl nesting acreage affected by pool fluctuations	1,4,0,9	0	0	10,000	10,000
* (3) Water quality (streams)					
a) Mileage affected	1,6,0,9	70-80	54	54	54
b) Nutrient entrapment	1,4,0,9	0	Potential	Potential	Potential
c) Winter turbidity	1,5,0,9	Probable year-round increase	Increased from nil to 15-35 ppm	Increased from nil to 15-35 ppm	Increased from nil to 15-35 ppm
* (4) Air quality					
a) Construction	1,6,0,9	Temporary input of dust from construction equipment & smoke from burning of brush, trees stripped from construction site(s). Estimated duration 15 years.	Same impacts as Plan A except increased burning from reservoir clearing-probable shorter duration of effect 10-12 years.	Same as Plan B except increased clearing acreage. Duration estimated at 15-17 years.	Same as Plan C except slightly reduced clearing acreage-duration estimated at 20-22 years.
b) Operation	1,6,0,9	Long-term input of dust from strip-mining & transport of coal resource. Long-term input of smoke and pollutants from combustion of coal at powerplants-magnitude of probable effect significant.	Essentially zero	Essentially zero	Essentially zero
(5) Land quality					
a) Shoreline mileage subjected to severe erosion	2,4,0,9	0	40	140	175
b) Shoreline mileage subjected to moderate erosion	2,4,0,9	0	170	170	225
c) Cleared utility corridor acreage subject to erosion	2,4,0,9	250	250	250	500
d) Strip mining	1,6,0,9	20,000 acres	0	0	0
e) Permafrost subsidence	2,5,0,9	Minor effect if any	Moderate potential	High potential	High potential
c. Environmental quality destroyed					
(1) Freeflowing river					
a) Total mileage affected	1,6,0,9	0	99	162	162
b) Mileage inundated	1,6,0,9	0	82	116	138
c) Whitwater miles inundated	1,6,0,9	0	9	9	9
(2) Biological resources					
a) Upland spruce-hardwood forest destroyed	1,6,0,9	15,000 acres	47,000 acres	48,000 acres	21,000 acres
1) Moose habitat value		Highly sifnificant	Highly significant (2-3,000 acres)	Highly significant (2-3,000 acres)	Highly significant (9-10,000 acres)
2) Caribou habitat value		Insignificant	Insignificant	Insignificant	Insignificant
3) Waterfowl habitat value		Insignificant	Insignificant	Insignificant	Insignificant
b) Lowland spruce-hardwood forest destroyed	1,6,0,9	0	1,000 acres	1,000 acres	8,000 acres
1) Moose habitat value			Highly significant	Highly significant	Highly significant
2) Caribou habitat value			Insignificant	Insignificant	Insignificant
3) Waterfowl habitat value			Insignificant	Insignificant	Insignificant
c) Moist tundra destroyed	1,6,0,9	5,000 acres	0	52,000 acres	52,000 acres
1) Moose habitat value		Moderately significant		Moderately significant	Moderately significant
2) Caribou habitat value		Highly significant		Highly significant	Highly significant
3) Waterfowl habitat value		Insignificant		Moderately significant	Moderately significant
d) Aquatic areas inundated	1,6,0,9				
1) River miles		0	82	116	138
2) Number of pothole lakes		0	0	400	400

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ACCOUNTS	Coding	PLAN A	PLAN B	PLAN C	PLAN D
		WITHOUT CONDITION	NATIONAL ECONOMIC DEVELOPMENT (NED) ENVIRONMENTAL QUALITY (EQ) PLANS	MAXIMUM POWER DEVELOPMENT PLAN	PREVIOUSLY RECOMMENDED PLAN
		Conventional Coal Thermal Plant	Devil Canyon-Watana Dams	Devil Canyon-Watana-Denali Dams	USBR Four-Dam System
2. ENVIRONMENTAL QUALITY (Cont.)					
c. Environmental quality destroyed (Cont.)					
(3) Archaeological/ Historical areas inundated					
a) Zones of potential past human habitation or use	1,6,0,9	0	40	60	85
b) Known prehistoric sites	1,6,0,9	0	0	0	1
c) Known historic sites	1,6,0,9	0	1	4	4
3. SOCIAL WELL-BEING					
a. Beneficial impacts					
(1) Enhancement of quality of life, health and safety					
a) Power provided	1,6,0,9	6.9 billion kilowatt-hours annually	6.9 billion kilowatt-hours annually	6.9 billion kilowatt-hours annually	6.9 billion kilowatt-hours annually
b) Dependability (Fairbanks-Anchorage intertie)	1,6,0,9	Yes	Yes	Yes	Yes
(2) Educational, cultural, & recreational opportunities					
a) Camping, picnicing, & sightseeing	1,5,0,10	0	77,000 use days	77,000 use days	100,000 use days
b) Boating	1,6,0,9				
1) Lake acreage		0	50,550	50,550 to 104,550	30,450 to 84,950
2) River mileage		0	65	31	10
c) Fishing					
1) Lake acreage	1,5,0,10	0	50,550	50,580	30,950
2) River mileage	1,6,0,9	0	63	29	8
d) Access to remote areas					
1) Accessible acreage	1,5,0,10	360,000 to 480,000	480,000 to 600,000	600,000 to 720,000	1,080,000 to 1,200,000
2) Access road mileage	1,6,0,9	30-40	40-50	50-60	90-100
3) Acreage for float plane operation	1,6,0,9	0	50,550	50,550 to 104,550	30,950 to 84,950
e) Regional resource knowledge	1,4,0,10	No federal investment	Possible $15,200,000 archaeological investment	$ 18,900,000	$19,500,000
(3) Energy resources conserved					
* a) Tons per year of coal	1,6,0,9	0	$5,850,000	$ 5,850,000	$ 5,830,000
b. Adverse impacts					
(1) Deterioration in quality of life, health and safety					
a) Air quality	1,5,0,10	Significant potential	None	None	None
(2) Degraded educational, cultural, and recreational opportunities					
a) Archaeological zones precluded from study following project construction	1,6,0,9	Unquantified-area has very high potential	40	60	85
b) Boating	1,6,0,9	No effect	Reduced whitewater boating potential	Reduced whitewater boating potential	Reduced whitewater boating potential
c) Hunting	1,6,0,9	Potential reduced by habitat losses	Potential reduced by habitat losses	Potential reduced by habitat losses	Potential reduced by habitat losses
d) Stream fishing	1,5,0,9	Reduced present use from pollutions of Healy Creek-Nanana River	Essentially unchanged opportunity	Reduced use of Denali reservoir area tributaries: insignificant	Reduced present use of Denali -Vee reservoir area tributaries: moderately significant because of Tyone River sport fishing

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ACCOUNTS	Coding	PLAN A WITHOUT CONDITION Conventional Coal Thermal Plant	PLAN B NATIONAL ECONOMIC DEVELOPMENT (NED) ENVIRONMENTAL QUALITY (EQ) PLANS Devil Canyon-Watana Dams	PLAN C MAXIMUM POWER DEVELOPMENT PLAN Devil Canyon-Watana-Denali Dams	PLAN D PREVIOUSLY RECOMMENDED PLAN USBR Four-Dam System
4. REGIONAL DEVELOPMENT (RD)					
a. Beneficial impacts					
(1) Value of increased income					
a) Distribution of NED excess benefits					
1) Alaska	1,5,7,9	No excess benefits	0	0	0
2) Nation	1,5,7,9		$ 43,801,000	$ 33,877,000	$ 28,655,000
3) Total	1,6,7,9		$ 43,801,000	$ 33,877,000	$ 28,655,000
b) Cost of power to distributor (mills/kWh-hr)	1,5,7,10	26.4 - 31.4	21.1	21.0	24.3
* c) Induced economic activity	1,4,8,10	Moderate increase in tax revenues, disposable income	Moderate increase in tax revenues, disposable income	Moderate increase in tax revenues, disposable income	Moderate increase in tax revenues, disposable income
* (2) Quantity of increased employment					
a) Construction man-yrs.					
Alaska	1,4,7,9	11,000	8,800	10,700	11,200
Nation	1,4,7,9	0	2,200	2,700	2,800
Total	1,4,7,9	11,000	11,000	13,400	14,000
b) Operation-permanent jobs-Alaska only	1,4,7,10	102	45	49	59
* (3) Desirable population distribution	1,5,0,9	No effect	No effect	No effect	No effect
(4) Increased stability of regional economic growth	1,5,0,9	Minimal effect	Minimal effect	Minimal effect	Minimal effect
b. Adverse impacts					
(1) Economic					
a) Diversion of funds from other uses					
1) Alaska	1,6,7,9	$1,650,848,000	$ 572,000	$ 572,000	$ 743,000
2) Nation	1,6,7,9	0	$1,652,564,000	$1,840,572,000	$1,616,082,000
3) Total	1,6,7,9	$1,650,848,000	$1,653,136,000	$1,841,144,000	$1,616,825,000
(2) Undesirable population distribution	1,5,0,9	No effect	No effect	No effect	No effect

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At-Site
Selected Plan Power Capabilities

Month	Monthly Energy Requirement (Percent)	Critical Period Energy (MWHR)	Average Energy (MWHR)
October	8.0	488,000	488,800
November	8.8	536,800	536,800
December	9.7	591,700	591,700
January	10.6	646,600	646,600
February	9.0	549,000	549,000
March	9.4	573,400	573,400
April	8.1	494,100	494,100
May	7.5	457,500	457,500
June	6.9	420,900	420,900
July	6.9	420,900	510,000
August	7.4	451,400	865,200
September	7.7	469,700	756,000
Total	100.0	6,100,000	6,890,000

Power would be delivered to the Anchorage and Fairbanks load centers via a double circuit, double tower transmission system, which would consist of 136 miles of 345 kv circuits from the Devil Canyon switchyard to Anchorage and 198 miles of 230 kv line to Fairbanks.

POWER CAPABILITIES

Following is a tabulation of the power generating capabilities of the Devil Canyon and Watana projects.

At-Site Power Capabilities

	Devil Canyon	Watana	Total
Installed Capacity (MW)	776	792	1,568
Maximum Peaking Capacity (MW)	892	911	1,803
Dependable Capacity (MW)	776	792	1,568
Average Annual Energy, 10^6 kwh	3,410	3,480	6,890
Firm Annual Energy, 10^6 kwh	3,020	3,080	6,100
Secondary Energy, 10^6 kwh	390	400	790

Under the scoping analysis, dependable capacity was based on firm annual energy and a 50-percent plant factor. This method was adopted in order to minimize the relative importance that secondary energy would have on plant sizing. On the other hand, dependable capacity for the selected plan has been based on average annual energy. This method was employed because of the infrequency of a critical period as severe as the 32-month period on which firm energy is based. In order to evaluate the exceedence frequency of the critical period, a synthetic low flow frequency curve was constructed for the Gold Creek gaging stations for a 32-month flow duration. Four hundred years of monthly streamflow were randomly generated based on the statistics of the 25 years of recorded Gold Creek streamflow. And in accordance with the method outlined under "HEC-4, Monthly Streamflow Simulation." 1/ Consecutive 32-month periods were derived for the 400 years of synthesized monthly streamflow, and a low flow 32-month frequency curve was developed in accordance with procedures outlined under Chow's Handbook of Hydrology, Chapter 18. 2/ Superimposed on the frequency curve, graph A-14 is the 32-month Gold Creek selected plan critical period. The respective exceedence interval for the critical period is 400 years. On the basis of this rather infrequent return interval it appears appropriate to base dependable capacity not on firm energy, but rather on average annual energy.

1/ "HEC-4, Monthly Streamflow Simulation", Generalized Computer Program 723-340, Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California, February 1971.

2/ "Handbook of Applied Hydrology", Ven Te Chow, Editor-in-Chief, McGraw-Hill Book Company, New York, 1964.

Firm Annual Energy is based on average energy produced during the 32-month critical period. The Watana units are designed to produce dependable capacity with the head available in the February with the second greatest drawdown in the 25-year period of record (February 1970). February is assumed to be the most critical month considering both system loads and reservoir drawdown. The worst February (February 1971) has an extremely low probability of recurrence, so it was considered that the second worst February would be more appropriate for evaluating dependable capacity. The head duration curve for Watana is shown on Graph C-10. Coincidentally, the Watana critical head is the same as the February 1970 head, and therefore, the Installed Capacity equals dependable capacity. Because the Devil Canyon power pool would never be drafted during the period of peak load demand (February), design head for that project was established at full pool elevation, and consequently, installed nameplate capacity equals dependable capacity.

Nameplate capacity is based on the head available at average pool elevation. It is assumed that the units will generate rated capacity at most efficient gate opening at this head. It is further assumed that the units will generate rated capacity at full gate opening at critical head. The units would also be capable of generating 15 percent overload at full gate at average head. Assumed performance charts for the Devil Canyon and Watana units are shown on Graph C-11.

Alaska Power Administration has estimated transmission losses for the selected plan to be 3.2 percent on peak capacity and 0.7 percent on average energy (Section H). Following is a computation of the at-market power capabilities of the selected plan:

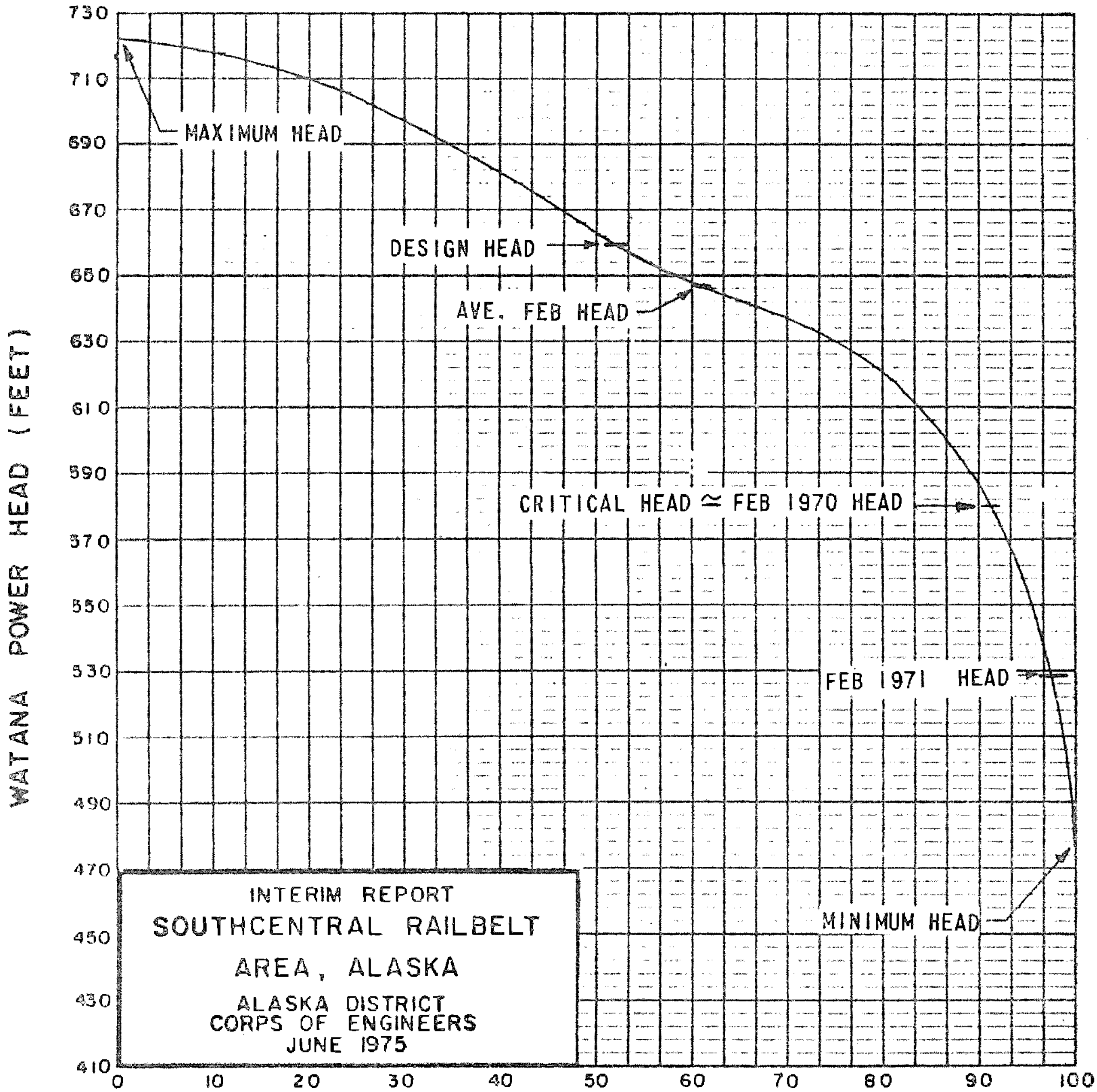
At Market Power Capability

	At-Site	Losses	At-Market
Dependable Capacity (MW)	1,568	50	1,518
Maximum Peaking Capacity (MW)	1,802	58	1,744
Average Annual Energy, 10^6 kwh	6,890	48	6,842
Firm Annual Energy, 10^6 kwh	6,100	43	6,057
Secondary Energy, 10^6 kwh	790	5	785

SEASONAL RESERVOIR OPERATION

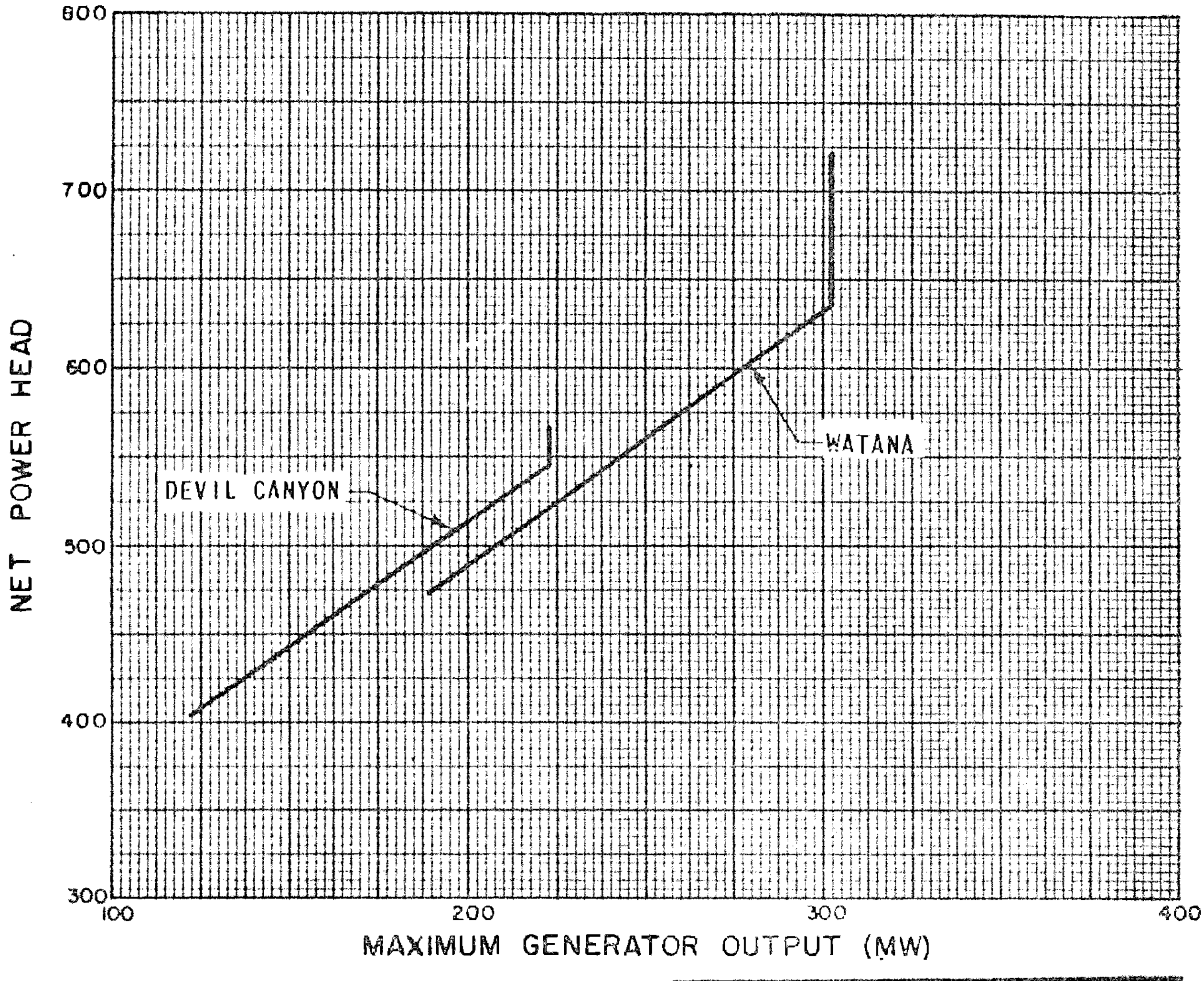
The basic reservoir operation consists of having the reservoirs full at the end of the summer high runoff season (May-September), with drawdown occurring through the fall, winter, and spring months as required to meet loads. Drawdown would be guided by rule curves which are based on a 32-month critical period. In actual operation, drawdown during late winter and spring would be adjusted in accordance with runoff forecasts, and this would permit better utilization of secondary energy than is shown by the simulated operation studies.

ANNUAL HEAD DURATION CURVE
WATANA RESERVOIR



PERCENT OF TIME HEAD IS GREATER THAN INDICATED VALUE

DEVIL CANYON AND WATANA UNIT MAXIMUM PERFORMANCES



INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT
CORPS OF ENGINEERS
JUNE 1975

Appendix I
GRAPH C-11

With both projects in operation, storage would normally be withdrawn from Watana, the upstream project, and Devil Canyon will be kept at or near full power to maximize generating head. The only condition under which Devil Canyon storage would be withdrawn would be in late spring at the end of the critical period, after Watana usable storage has been completely evacuated. The probability of this occurring is very small. The monthly regulated and unregulated damsite streamflows for the 25-year period of operation are shown on Tables C-29 and C-30.

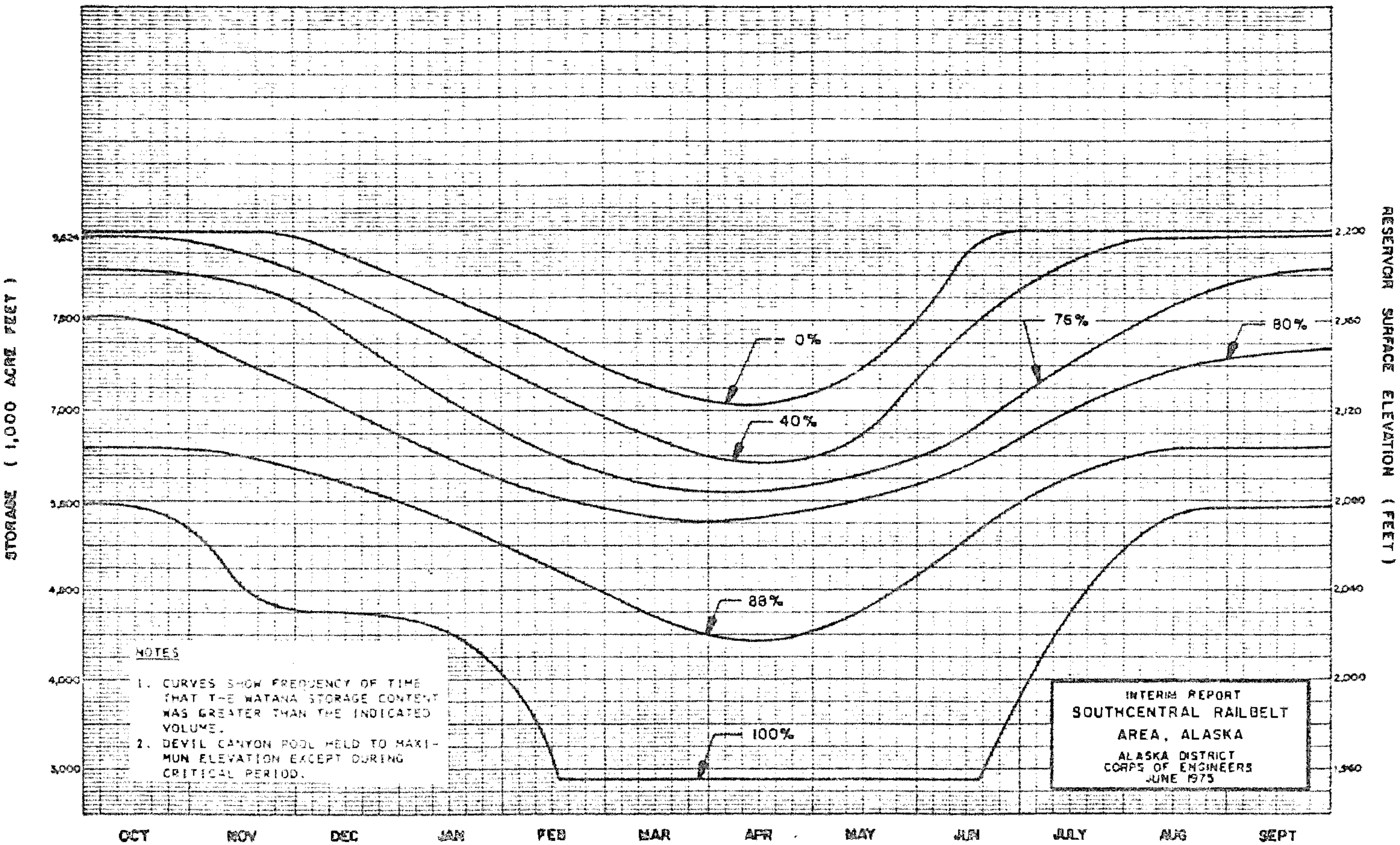
The Devil Canyon pool would normally be maintained at maximum pool elevation in order to develop maximum head and minimum flow. The Watana storage would be drafted to maintain flow requirements for both projects and, therefore, the average annual Watana drawdown would be about 100 feet. Power intake structures would be situated to limit the maximum drawdown to 35 percent of the maximum head at Watana and 30 percent at Devil Canyon. The operation study for the selected plan revealed that in 11 of the years of the 25-year study period, annual runoff was insufficient to refill the Watana reservoir. Five of the years had runoff volumes in excess of the combined capacity of Watana reservoir storage and turbine hydraulic capacity, and hence spills occurred. The magnitude of the spills was such that the outlet works could accommodate all flow without the use of the spillway. Plate C-11 illustrates the seasonal regulation of Devil Canyon and Watana through the 25-year period of record. Graph 12 shows frequency of drawdown by month for Watana.

A slightly different operation will be followed during the early years when only Watana is in operation. This will be necessary for flow control at the Devil Canyon damsite during construction of that project. It is not anticipated that the modified operations will alter the firm energy or dependable capacity of Watana during the Devil Canyon construction. Plate C-10 describes regulation of the Devil Canyon project without upstream storage over the 25-year period of record.

DAILY PROJECT OPERATION

The actual role of the Devil Canyon and Watana projects in meeting the system daily load will depend on the other types of generating plants in the Railbelt system and the prevailing fuel costs for fossil fuel-fired plants. It will also depend on the relative magnitude of the load on any given day and the amount of secondary energy which could be generated in addition to firm. Under some conditions it can be expected that both plants will be baseloaded, with the result that discharge fluctuations will be minimal. In other situations, Devil Canyon and Watana may be relied on for "peaking," thus following the daily fluctuations in system load. If operated in the peaking mode, fluctuations in discharge will occur.

WATANA MONTHLY STORAGE FREQUENCY FOR THE DEVIL CANYON AND WATANA SYSTEM



Appendix I
TABLE C-29
C-148

Estimated Regulated Streamflow at Devil Canyon and Watana Damsites

10 WATANA RESERVOIR

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
1950	7386.	7915.	8630.	9501.	9156.	8750.	7416.	6666.	5616.	5053.	5573.	5694.	AVG
1951	6982.	8136.	8805.	9784.	9266.	8893.	7958.	6517.	5517.	5121.	6626.	6025.	7378.
1952	6871.	7967.	8663.	9524.	9201.	8769.	7882.	5881.	5033.	4810.	5656.	9865.	7384.
1953	6548.	7816.	8559.	9534.	9092.	8593.	7755.	5994.	5065.	4978.	16696.	10678.	7563.
1954	6679.	7966.	8623.	9577.	9133.	8747.	7779.	6193.	5219.	5035.	13723.	8711.	8635.
1955	6700.	7900.	8578.	9526.	9112.	8598.	7756.	6563.	5073.	6663.	18513.	9857.	8113.
1956	6732.	7966.	8569.	9517.	9155.	8753.	7908.	6674.	5826.	15517.	22370.	14692.	8586.
1957	6667.	7876.	8562.	9572.	9066.	9580.	7745.	6373.	4895.	4820.	15960.	14471.	10320.
1958	6538.	7783.	8666.	9666.	9019.	8625.	7732.	6348.	5153.	4872.	14485.	6583.	8716.
1959	6867.	7983.	8669.	9621.	9161.	8758.	7819.	6307.	5293.	4895.	14254.	12020.	9092.
1960	6697.	7877.	8669.	9501.	9058.	8566.	7778.	6193.	5669.	5015.	8176.	15995.	8635.
1961	6515.	7856.	8698.	9632.	9033.	8588.	7551.	6070.	4953.	11572.	18662.	9089.	8165.
1962	6665.	7937.	8596.	9542.	9083.	8631.	7734.	6769.	4328.	17922.	20208.	10870.	9008.
1963	6698.	7978.	8599.	9526.	9048.	9708.	7800.	5874.	4817.	13350.	21146.	8738.	9890.
1964	6665.	7926.	8609.	9581.	9123.	8735.	7808.	5879.	4320.	10242.	14241.	6301.	9382.
1965	6651.	7946.	8568.	9525.	9193.	8752.	7817.	6510.	5296.	4755.	12420.	14381.	8382.
1966	6421.	7896.	8551.	9527.	9057.	8551.	7578.	6217.	4416.	4945.	9976.	7359.	8484.
1967	6787.	7969.	8619.	9555.	9095.	8705.	7764.	6203.	5085.	4601.	24145.	11766.	7556.
1968	6791.	7956.	8609.	9535.	9057.	8553.	7706.	6020.	4691.	9156.	14589.	6443.	9203.
1969	6947.	8031.	8725.	9589.	9225.	8761.	7859.	6603.	6228.	6021.	6491.	7099.	8278.
1970	7238.	8510.	9195.	10238.	9753.	9663.	8551.	7240.	5839.	5380.	5939.	6991.	7631.
1971	7163.	8688.	9349.	10528.	10217.	9876.	6562.	2933.	13492.	7362.	5838.	6852.	7859.
1972	7301.	8566.	9227.	10292.	9837.	9555.	8631.	5746.	4600.	5568.	6263.	6903.	8198.
1973	7086.	8410.	9026.	10083.	9584.	9226.	8392.	7177.	5454.	5554.	5833.	6878.	7696.
1974	7283.	8555.	9302.	10348.	9937.	9571.	8742.	7031.	6325.	5777.	6291.	5944.	7715.
AVERAGE	6828.	8047.	8733.	9714.	9256.	8883.	7855.	6311.	5528.	7079.	12667.	9243.	8005.
													8347.

20 DEVIL CANYON RESERVOIR

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
1950	6687.	8277.	8816.	9724.	9243.	8838.	8007.	7814.	7858.	7816.	7955.	7651.	AVG
1951	7372.	8299.	8944.	9901.	9430.	8989.	8173.	8026.	8057.	7877.	8050.	8446.	8219.
1952	7478.	8352.	8919.	9839.	9321.	9904.	8042.	7522.	8523.	8035.	7991.	11325.	8458.
1953	7761.	8315.	8786.	9569.	9184.	8795.	7968.	8168.	8229.	7586.	18777.	12414.	9687.
1954	7573.	8231.	8818.	9742.	9253.	8833.	8025.	8055.	8155.	7552.	16642.	10182.	9645.
1955	7483.	8287.	8856.	9767.	9230.	8833.	7997.	7564.	8381.	8063.	21393.	11483.	9264.
1956	7451.	8223.	8814.	9734.	9270.	8854.	8031.	7552.	7389.	17047.	23590.	15321.	9799.
1957	7516.	8305.	8855.	9749.	9251.	8830.	7986.	7835.	8492.	7813.	18305.	16720.	10967.
1958	7743.	8347.	8698.	9705.	9192.	8765.	7930.	7769.	8169.	7764.	18958.	7627.	9974.
1959	7383.	8275.	8863.	9803.	9322.	8980.	8060.	7988.	8153.	7897.	19691.	13919.	9252.
1960	7576.	8283.	8854.	9751.	9247.	8915.	7943.	7980.	7563.	7762.	10802.	17441.	9860.
1961	7671.	8279.	8873.	9757.	9235.	8828.	8018.	8020.	8304.	14474.	21280.	10611.	9333.
1962	7530.	8275.	8817.	9726.	9239.	8824.	7984.	7390.	9130.	19462.	22757.	13017.	10305.
1963	7458.	8146.	8782.	9717.	9250.	8777.	7913.	8325.	8535.	17214.	22937.	9728.	11038.
1964	7505.	8232.	8808.	9710.	9244.	8827.	7982.	7418.	9259.	12134.	15896.	7899.	10598.
1965	7557.	8227.	8753.	9681.	9196.	8816.	7981.	7739.	8229.	7990.	14816.	16535.	9423.
1966	7803.	8262.	8858.	9760.	9284.	8878.	8077.	8034.	9196.	7745.	12917.	9127.	9623.
1967	7397.	8246.	8882.	9833.	9353.	8922.	8076.	8086.	8328.	8111.	28234.	13929.	8989.
1968	7376.	8232.	8839.	9777.	9292.	8878.	8026.	8190.	8691.	12228.	16800.	7737.	10637.
1969	7238.	8212.	8806.	9755.	9299.	8899.	8069.	7753.	7311.	6905.	7252.	7683.	9522.
1970	7688.	8601.	9306.	10298.	9867.	9576.	8714.	8448.	8811.	8370.	8524.	8301.	8092.
1971	8242.	9141.	9719.	10763.	10394.	10033.	11229.	12059.	6452.	6784.	8747.	8369.	8870.
1972	7937.	8859.	9570.	10632.	10210.	9871.	8908.	10003.	9564.	7741.	7677.	7886.	9325.
1973	7761.	8591.	9269.	10198.	9766.	9292.	8514.	8144.	8768.	7883.	8343.	8121.	9065.
1974	7803.	8738.	9389.	10406.	10027.	9752.	8863.	8830.	8422.	8092.	8323.	8585.	8713.
AVERAGE	7556.	8367.	8964.	9896.	9424.	9020.	8261.	8192.	8326.	9618.	15066.	10802.	8930.
													9464.

Estimated Unregulated Streamflows at Devil Canyon and Watana Damsites

19 WATANA RESERVOIR

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
1950	[illegible]	[illegible]	1174.	947.	657.	517.	722.	9503.	15527.	19133.	16791.	6929.	AVG
1951	[illegible]	[illegible]	[illegible]	793.	725.	514.	1315.	11757.	17519.	19057.	16614.	17759.	6729.
1952	4467.	2211.	1943.	1301.	825.	733.	761.	4511.	27154.	22243.	17444.	12101.	7438.
1953	[illegible]	2410.	1341.	906.	592.	582.	1314.	15035.	22959.	17134.	17403.	12742.	7992.
1954	5512.	1700.	1273.	1054.	825.	551.	1012.	14422.	21234.	17271.	22015.	13745.	8435.
1955	4347.	2225.	1454.	1457.	1235.	914.	944.	7773.	25074.	23351.	21721.	11941.	8113.
1956	3944.	1561.	1054.	939.	801.	777.	745.	15967.	30237.	24301.	22377.	16576.	8584.
1957	[illegible]	2455.	1733.	1381.	1223.	484.	484.	11472.	25520.	19908.	17453.	15555.	10320.
1958	6543.	3154.	2404.	1585.	1064.	438.	1244.	17703.	21462.	14343.	13944.	6319.	8716.
1959	3941.	1735.	1227.	1174.	1052.	433.	1315.	13242.	14715.	21361.	25174.	14104.	7649.
1960	5261.	2373.	1744.	1444.	1135.	1455.	1363.	13179.	13107.	19441.	19806.	17179.	8824.
1961	6233.	2417.	2158.	1972.	1420.	1455.	2131.	14475.	[illegible]	20735.	18552.	11173.	8165.
1962	4724.	2275.	1765.	1505.	1257.	1175.	1451.	11181.	36248.	23432.	20208.	12954.	9004.
1963	5541.	2478.	1791.	1315.	1201.	875.	761.	15525.	21137.	29169.	21145.	10422.	9890.
1964	5235.	1809.	1205.	855.	787.	579.	513.	3607.	43031.	20162.	14241.	7711.	9342.
1965	4846.	2376.	1061.	852.	801.	795.	1216.	10995.	21384.	23470.	17650.	16465.	8327.
1966	5358.	1608.	1239.	1085.	1007.	1007.	1372.	7319.	25477.	15569.	17790.	9442.	8540.
1967	3328.	1237.	1155.	1140.	1065.	917.	980.	12703.	24974.	22436.	26101.	13850.	7556.
1968	4050.	1948.	1713.	1631.	1572.	1572.	1585.	13009.	26173.	22554.	14589.	7268.	9203.
1969	3155.	1353.	751.	617.	608.	585.	1252.	9327.	14094.	14448.	7842.	4339.	8175.
1970	2472.	1034.	721.	653.	612.	632.	974.	9674.	14815.	18835.	15586.	7363.	4948.
1971	3905.	2572.	1735.	1120.	796.	733.	332.	2933.	27848.	21312.	27650.	12248.	6237.
1972	4964.	2589.	1490.	1716.	1537.	1402.	1334.	16722.	28194.	20276.	17723.	11022.	8680.
1973	3852.	1815.	1191.	981.	980.	823.	844.	6915.	23520.	15579.	17304.	7687.	9167.
1974	3010.	1251.	561.	733.	655.	512.	823.	13459.	15046.	15012.	13867.	11590.	6829.
AVERAGE	4521.	2003.	1422.	1164.	982.	897.	1091.	11059.	23530.	20469.	18737.	11478.	5534.
													8156.

20 DEVIL CANYON RESERVOIR

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
1950	5997.	2444.	1360.	970.	744.	585.	822.	10903.	18837.	21839.	19151.	7878.	AVG
1951	3642.	1229.	1039.	906.	817.	599.	1529.	13349.	19951.	21754.	18950.	20170.	7494.
1952	5270.	2596.	1796.	1512.	945.	831.	859.	5131.	30886.	25399.	20144.	13748.	8712.
1953	7761.	3379.	1607.	1039.	774.	774.	1527.	14259.	24123.	19583.	19846.	14494.	9129.
1954	5335.	1947.	1618.	1229.	945.	737.	1157.	15372.	24170.	19733.	25088.	12266.	9645.
1955	5940.	2412.	1934.	1599.	1323.	1039.	1134.	8827.	28519.	26498.	24754.	13567.	9264.
1956	4643.	1798.	1229.	925.	916.	838.	847.	15937.	31800.	29831.	23590.	17405.	9799.
1957	5443.	2887.	2026.	1607.	1418.	1134.	1134.	13025.	29117.	22544.	19955.	18804.	10967.
1958	7763.	3728.	3062.	1845.	1227.	1077.	1442.	17121.	24578.	22099.	21595.	7195.	9974.
1959	4549.	2027.	1421.	1357.	1223.	915.	1157.	15049.	22492.	24022.	29764.	16003.	9045.
1960	6220.	2709.	2089.	1749.	1374.	1595.	1228.	14965.	14949.	22184.	22674.	19525.	10067.
1961	7386.	2842.	2543.	2307.	1652.	1705.	2498.	15425.	28004.	23438.	21280.	12695.	9333.
1962	5502.	2553.	1985.	1789.	1413.	1319.	1503.	11895.	41050.	24972.	22757.	15101.	10305.
1963	6341.	2546.	1884.	1507.	1413.	944.	786.	18061.	24855.	33033.	22937.	11812.	11038.
1964	6075.	2117.	1404.	985.	908.	570.	702.	4093.	48120.	22054.	15896.	9140.	10598.
1965	5944.	2657.	1145.	908.	814.	849.	1288.	12313.	24385.	25572.	20201.	18619.	9354.
1966	6740.	1976.	1535.	1318.	1224.	1224.	1673.	9095.	31309.	19216.	20885.	11211.	9693.
1967	3938.	1514.	1418.	1418.	1323.	1134.	1103.	14672.	28217.	25801.	30336.	16013.	8989.
1968	4635.	2226.	1943.	1873.	1797.	1797.	1806.	15275.	30103.	25628.	15800.	8394.	10637.
1969	3609.	1544.	832.	583.	682.	769.	1422.	10451.	15153.	15819.	8596.	4922.	9435.
1970	2978.	1166.	829.	784.	726.	745.	1027.	10782.	17788.	21825.	19171.	8666.	5409.
1971	4965.	3204.	2153.	1355.	973.	892.	1016.	3550.	31409.	23239.	30643.	13731.	7261.
1972	5521.	2916.	2365.	2109.	1910.	1717.	1611.	20979.	33158.	22449.	18997.	11990.	9805.
1973	4544.	2122.	1379.	1129.	1128.	941.	966.	7882.	26834.	18008.	19814.	8790.	10526.
1974	3552.	1456.	992.	839.	745.	693.	944.	15258.	17143.	18327.	15899.	13231.	7829.
AVERAGE	5347.	2331.	1655.	1354.	1137.	1031.	1254.	12627.	25763.	23047.	21189.	13015.	7470.
													9278.

Most of the time it can be expected that the Devil Canyon-Watana system will be required to generate a combination of baseload and peaking power. In this situation, it is planned to carry as much of the peaking load as possible at Watana and operate Devil Canyon at near baseload generation. This would minimize fluctuations in the open river below Devil Canyon. Graphs C-13 and C-14 illustrate this type of operation. The portion of the load served by each project is shown on Graph C-13, the resulting streamflow is presented on Graph C-14. Also included is the stage-discharge relationship for the Gold Creek gage 15 miles downstream from Devil Canyon. Although the river width is different for the Devil Canyon and Gold Creek stations, the steep channel slope at Devil Canyon should compensate for the Gold Creek width which would in turn make the Gold Creek stage fluctuation representative of Devil Canyon.

However, during periods of high power demand or when forced thermal outages make other generating resources unavailable, the full peaking capability of both Devil Canyon and Watana may be required to meet system load. It is anticipated that this will occur infrequently. The most extreme condition with both projects peaking would occur in winter. However, under unusual circumstances, high peaking demands could be placed on both Devil Canyon and Watana at other times of the year.

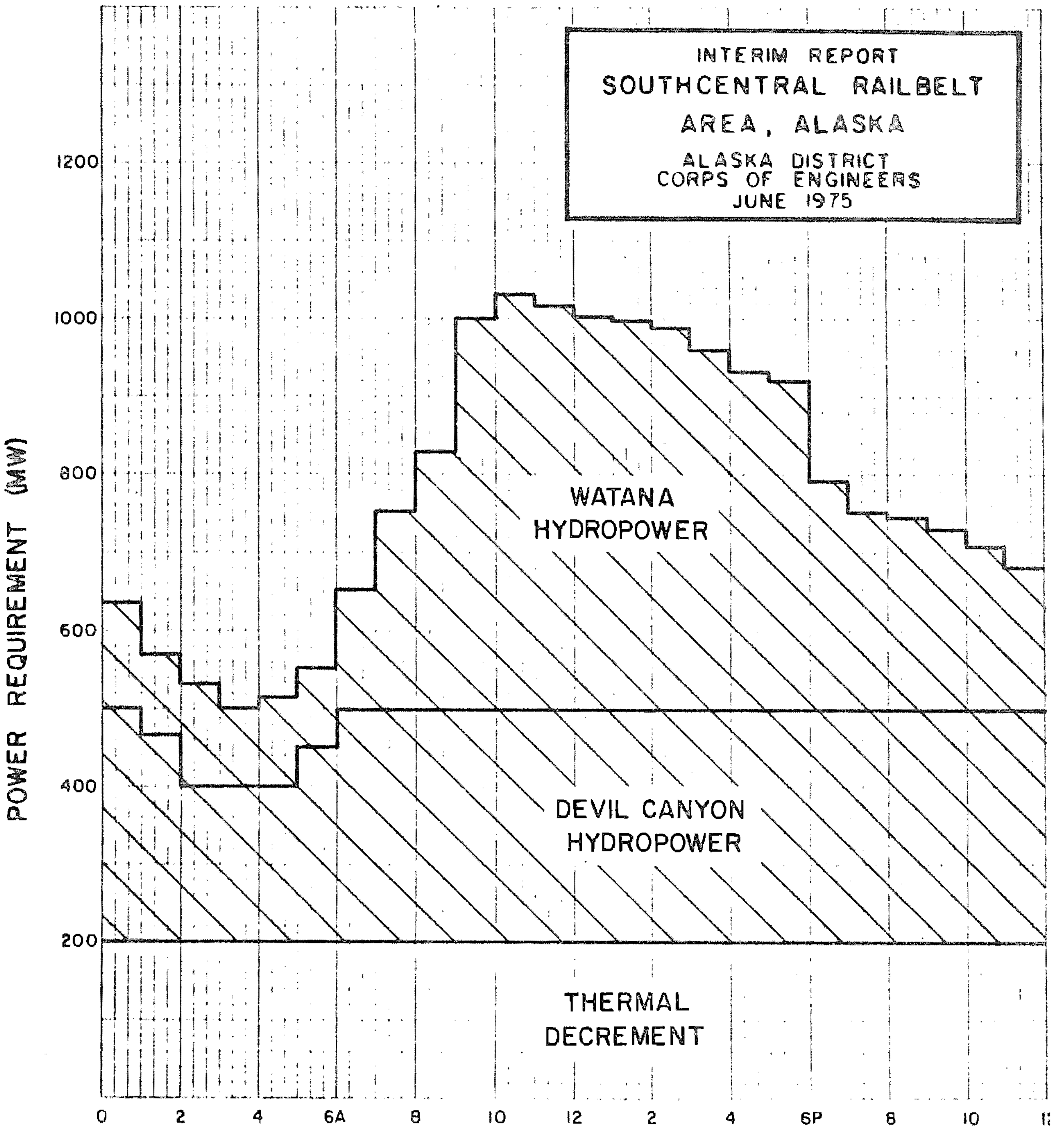
Graphs C-15 and C-16 illustrate a possible operation on a high load day in the winter of 1995. Although the daily load factor of the system demand is 81 percent, the hydro system has been assigned to operate under a 62 percent daily load factor. In order to meet the demand, but still provide some of the system's reserve requirements, all three of the Watana installed generators would be required, and three of the four Devil Canyon units would be used. The minimum generator load was assumed to be 40 percent of nameplate capacity. Under these extreme conditions, the daily fluctuation at Gold Creek would approach three feet. If the full peaking capability at Devil Canyon were required, the fluctuations could approach four feet. However, most of the time the daily fluctuations would not exceed two feet.

During the latter part of summer when both Devil Canyon and Watana reservoirs are filled, both of the reservoirs would be releasing constant streamflow amounts that would match the natural streamflow hydrographs for the two locations. The river stage for both locations would then match the stages that would have occurred under natural conditions.

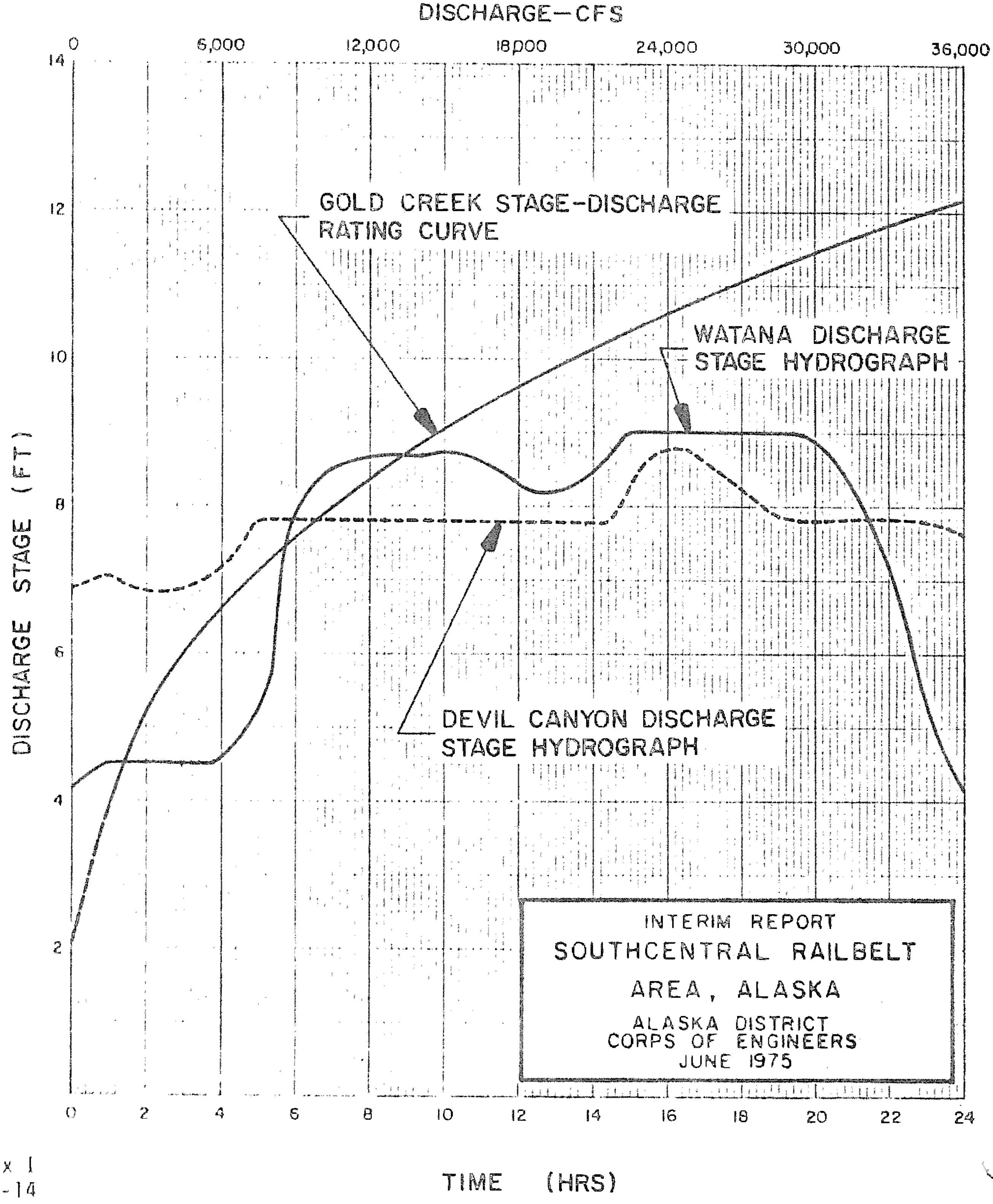
FUTURE GENERATING UNITS AND REREGULATION

If power system development in the Railbelt area follows the same course as systems elsewhere, large baseload thermal plants will eventually be built to handle increasing baseload power demands. Hydro systems such as Devil Canyon and Watana would then move up in the load duration curve to handle peaking demands almost exclusively. However, in order to provide the peaking capacity, additional generating units would be required.

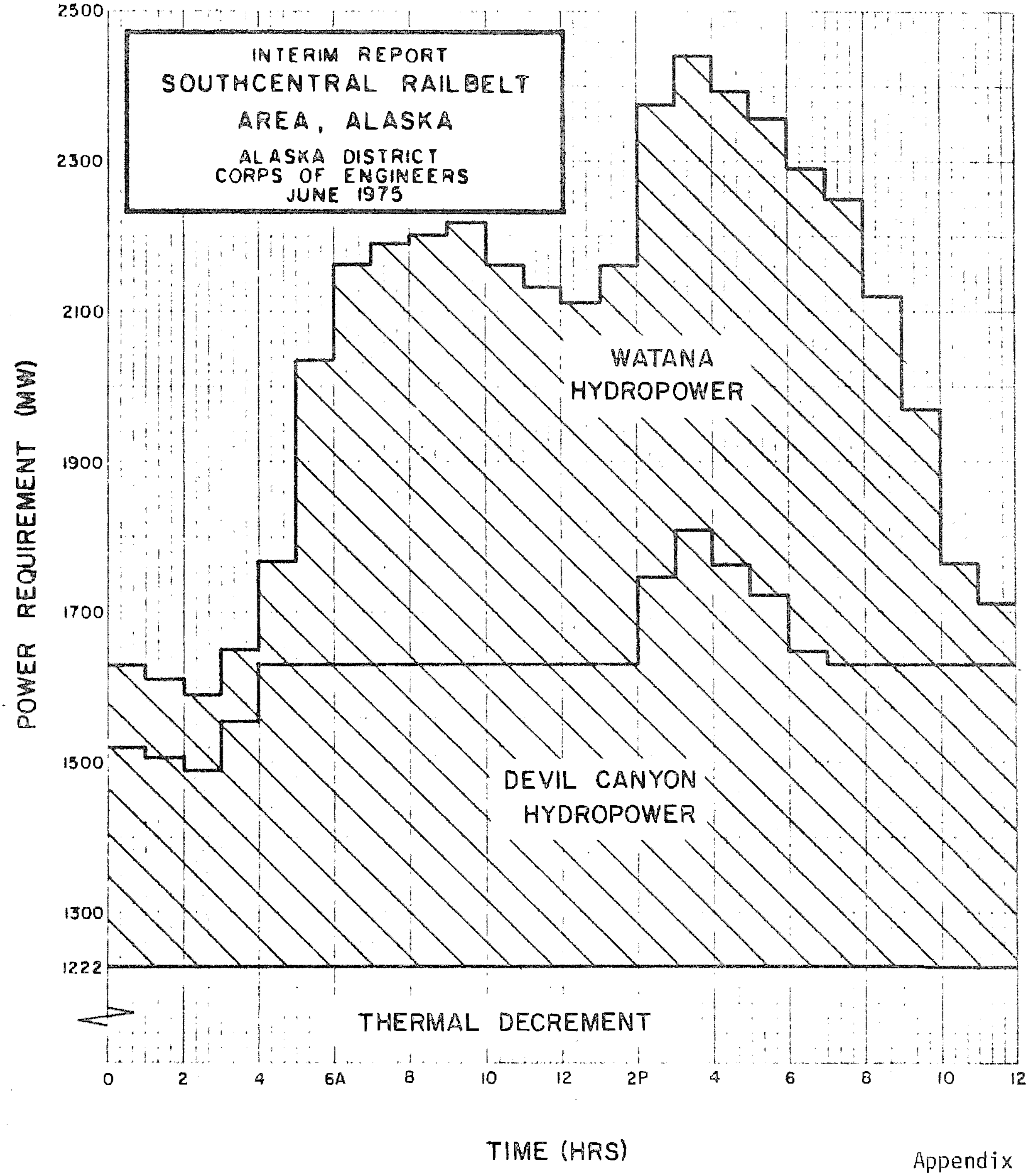
INTEGRATED RAILBELT SUMMER DAY POWER COMPOSITION



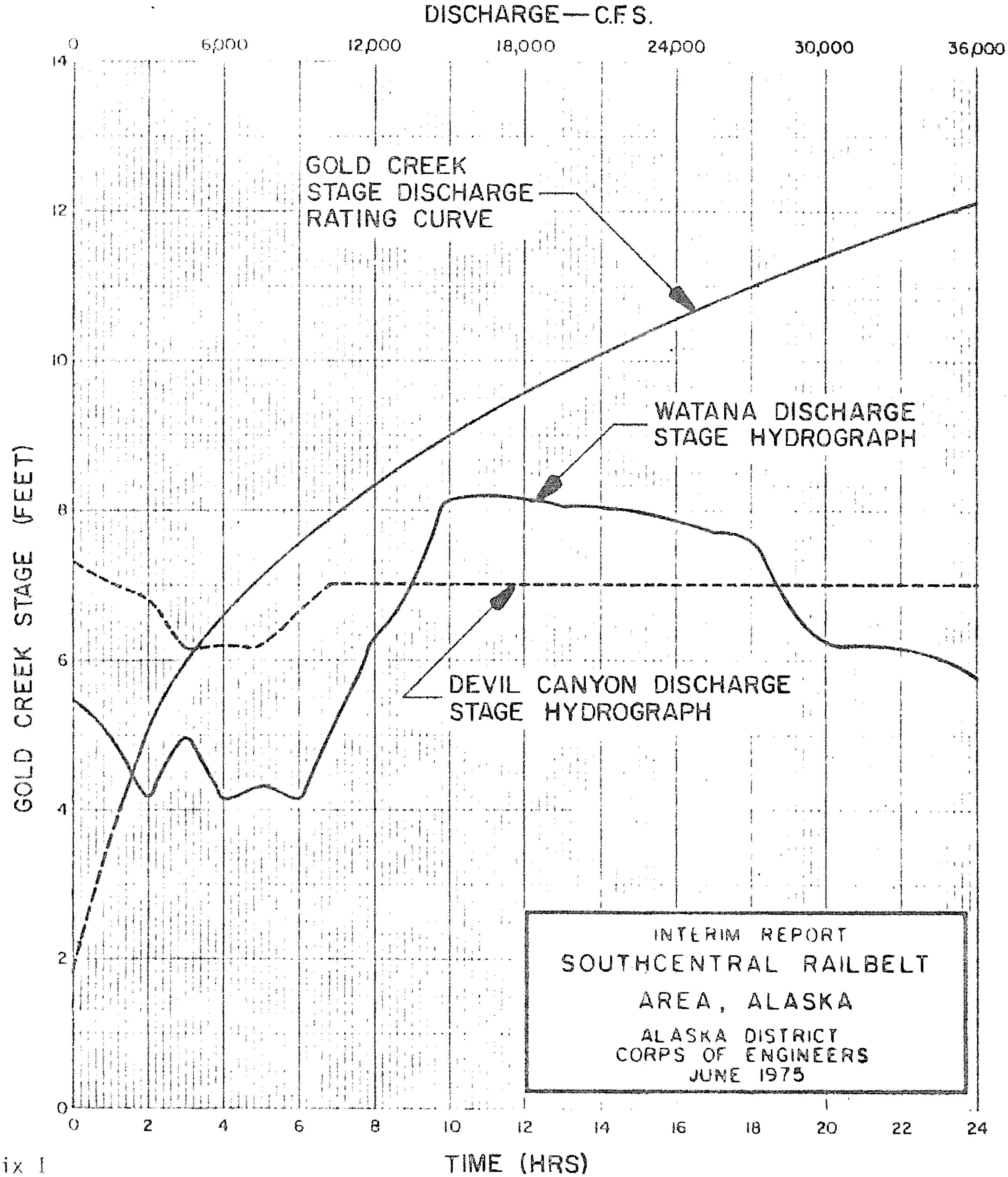
DAILY RELEASE FOR PEAK POWER PRODUCTION CONDITION



INTEGRATED RAILBELT PEAK DAY POWER COMPOSITION



DAILY STREAMFLOW FOR TYPICAL SUMMER POWER PRODUCTION



If no provisions are made for future units at Devil Canyon and Watana, the cost of installing them at a later date would be very high because of the underground powerhouse construction and additional tunnel requirements. However, minimum facilities could be included in the initial construction phase at relatively low cost. Under the existing plan of development, it is technically feasible to include at least two additional units at each plant, thus lowering the annual hydro load factor to 32 percent. More detailed studies of future system requirements may ultimately show that even more units would be needed. Therefore, although the present plan does not make provisions for skeleton bays, their inclusion during initial construction should be carefully considered under GDM Phase One should the project be authorized.

In addition, consideration should also be given to altering the number of units in each project. It may prove desirable to utilize the Devil Canyon units strictly for baseload power, and the Watana units for all peaking power. This operation would require an increase in units in the Watana powerplant, and a decrease in number of units in the Devil Canyon powerplant. Devil Canyon would then provide reregulation for Watana peaking operations.

However, if additional units are installed at Devil Canyon a reregulating dam downstream to minimize the impact of the increased flow fluctuations resulting from peaking operations may be required. The cost of the reregulating dam could be partially defrayed by at-site power generation of baseload electricity. While no detailed site selection studies have been made for a reregulating dam, suitable sites appear to be available as a possible future element of the selected plan.

ECONOMIC ANALYSIS

Costs: The detailed construction costs for the two projects and connecting transmission systems are presented in Section B of this Appendix. Also shown is the construction timetable and the estimated construction costs to be expended during each year of the construction period. It is anticipated that construction would begin in 1980, Watana would be completed in 1986, and Devil Canyon would be finished by 1990. The total estimated first cost of the Devil Canyon and Watana projects and transmission system is $1,520,000,000 based on January 1975 price levels.

Interest During Construction (IDC) computations were based on each year's estimated expenditure. Simple interest was calculated at 6-1/8 percent for each of the annual expenditures. Expenditure and IDC accruing beyond the 1986 POL date of the Watana project were present-worthed back to 1986. The resultant investment cost was then amortized over 100 years at 6-1/8 percent to give the annual interest and amortization cost. The IDC, investment and annual interest and amortization cost computations are summarized on Table C-31.

INTEREST DURING CONSTRUCTION AND AVERAGE ANNUAL CONSTRUCTION COSTS FOR PROJECT AND SYSTEM DEVELOPMENT

Year	SELECTED PLAN WATANA PHASE: Annual Construction Cost ($1,000)	Accumulated Construction Cost ($1,000)	Interest During Construction ($1,000)	SELECTED PLAN DEVIL CANYON PHASE: Annual Construction Cost ($1,000)	Accumulated Construction Cost ($1,000)	Interest During Construction ($1,000)	Percent of Construct Costs (%)
1977	5,659		173				0.4
1978	6,200	5,659	537				0.4
1979	17,919	11,859	1,275				1.2
1980	17,919	29,778	2,373				1.2
1981	46,453	47,697	4,344				3.0
1982	92,852	94,150	8,611				6.1
1983	202,090	187,002	17,643	5,390		165	13.5
1984	347,421	389,092	34,472	5,390	5,390	495	23.0
1985	219,893	736,513	51,845	9,840	10,780	961	15.0
1986	120,890	956,406	62,282	15,170	20,620	1,728	8.9
1987	19,498	1,077,296	- 1,125 [1]	16,186	35,790	2,688	2.3
1988	1,096,794	1,096,794	182,430	101,596	51,976	6,295	6.7
1989				148,784	153,572	13,963	9.7
1990				90,359	302,356	21,286	5.9
1991				35,531	392,715	25,142	2.3
1992				6,760	428,246	26,437	0.4
				435,006	435,006	99,160	100.0
1986 Present Worth				(304,501)		(69,411)	

	Selected Plan Watana Phase		Selected Plan Devil Canyon Phase
Construction Cost (PW)[2]	$1,096,794,000	Construction Cost (PW)	$1,401,295,000
Interest During Const. (PW)	182,430,000	Interest During Const. (PW)	251,841,000
Investment Cost	$1,279,224,000	Investment Cost	$1,653,136,000
Average Annual Cost	$ 78,544,000	Average Annual Cost	$ 101,520,000

1. The 1987 expenditure is discounted one year to the POL date.
2. "PW" in this and later tables indicates that figure has been discounted to the October 1986 power-on-line date.

Annual Operations, Maintenance, and Repair (OM&R) costs estimated by the Alaska Power Administration, Section G, were added to the average annual interest and amortization cost to obtain the total average annual cost. The OM&R breakout for the selected plan is shown on table 37. The total OM&R annual cost is $2,500,000 including $100,000 for recreation OM&R.

Hydropower Benefits: The basic procedure for deriving hydropower benefits in the scoping analysis was discussed in the section on System Development Evaluation under "Credit for Energy and Capacity". The same basic criteria were used in evaluation of the selected plan, but with slight modifications as follows:

1. Firm energy is fully useable up to 75 percent of the total Anchorage and Fairbanks utility load.

2. Dependable capacity is based on average annual energy divided by the 50 percent load factor. The reason for basing dependable capacity on average annual energy rather than firm energy was presented in the above-mentioned section.

3. Credit for Dependable Capacity is limited to the annual values estimated by FPC (Appendix 2).

4. Transmission losses were estimated at 3.2 percent for capacity and 0.7 percent energy.

5. Watana construction time was assumed to be six years rather than the 5 years followed under the scoping analysis.

6. Useable reservoir strorage is limited by turbine design considerations which limit the maximum permissible head drawdown to 35 percent of maximum head for Watana units and 30 percent of maximum head for Devil Canyon Units. This has the effect of slightly decreasing the firm energy capability of the projects.

7. Dependable Capacity must be available under the second worst February drawdown in the period of study (see subsection on Power Capabilities under Selected Plan). The estimated annual construction costs for the two single projects and for the combination of projects are summarized below.

Total Average Annual Costs

Development	Interest and Amort. Costs ($1000)	Annual OM&R ($1000)	Total Avg. Annual Cost ($1000)
Watana 1/	78,544	1,300	79,844
Devil Canyon	22,976	1,200	24,176
Watana plus Devil Canyon	101,520	2,500	104,020

1/ Includes total transmission cost and the majority of roadworks and supporting facilities.

Benefits and Alternative Costs: The benefits for the Upper Susitna River Project are predominantly derived from hydroelectric power generation with lesser benefits credited to Area Redevelopment, Transmission Intertie, Recreation, and Flood Control.

Flood control, recreation,and area redevelopment benefits were discussed earlier in this section, but power benefits developed in the scoping analysis were refined to more accurately reflect the actual useability of the project power during early years, before the system is able to absorb the full output of the projects.

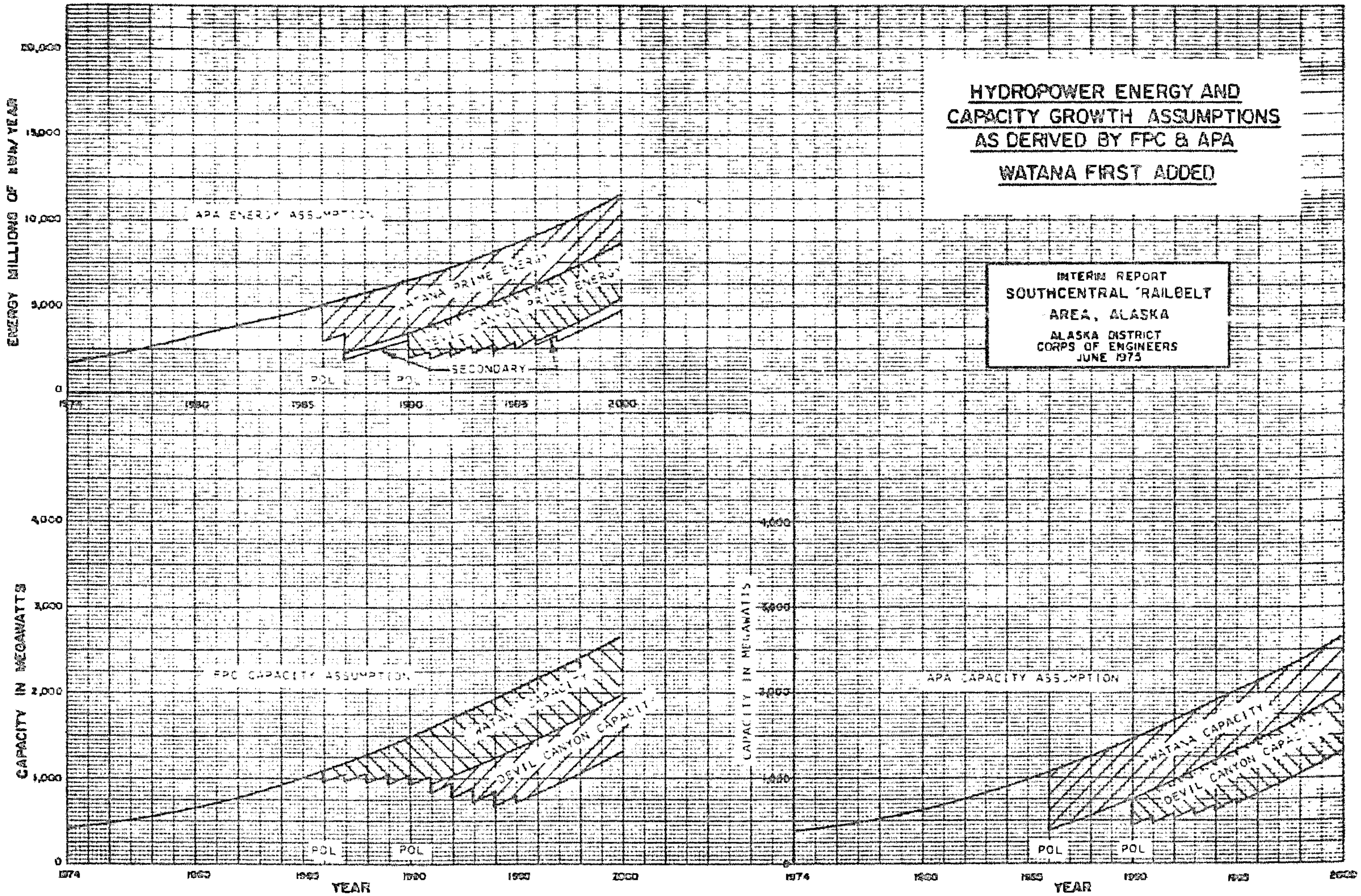
Because the last two criteria are related to power generating capability of the projects, a new reservoir regulation study was performed to reflect these additional constraints, and the power benefits are based on the energy output shown by that study.

Table C-32 shows the creditable energy and capacity claimed year by year for the two projects in accordance with criteria outlined above. Graph C-17 also shows how the power is assimilated into the railbelt area energy and capacity loads as estimated by both FPC and APA.

Power benefits are based on the composite at-market energy and capacity values discussed earlier in this section. These power values are based on non-Federal financing and a 51.8 percent plant factor. In computing the benefits, it was assumed that Watana, the first project constructed, would have a 100-year life. Table C-33 shows the computation of power benefits based on the creditable energy and capacity values derived in Table C-32, and a summary of the average annual power benefits for the selected plan is as follows:

	Watana	Watana Plus Devil Canyon
Capacity Benefit ($1,000)	$58,659	$101,380
Firm Energy Benefit ($1,000)	17,911	30,903
Secondary Energy Benefit ($1,000)	2,220	2,915
Total Power Benefits ($1,000)	$78,790	$135,198

Total Benefits: Total tangible project and system benefits for the Susitna hydro development are the sum of average annual benefits accrued from power, recreation, flood control, area redevelopment, and the transmission intertie. The following table summarizes the estimated benefits for the Watana project and for the selected plan.



HYDROPOWER ENERGY AND CAPACITY GROWTH ASSUMPTIONS AS DERIVED BY FPC & APA
WATANA FIRST ADDED
INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA
ALASKA DISTRICT CORPS OF ENGINEERS JUNE 1975
ENERGY MILLIONS OF KWH/YEAR
APA ENERGY ASSUMPTION
WATANA PRIME ENERGY
DEVIL CANYON PRIME ENERGY
SECONDARY
POL
CAPACITY IN MEGAWATTS
FPC CAPACITY ASSUMPTION
APA CAPACITY ASSUMPTION
WATANA CAPACITY
DEVIL CANYON CAPACITY
YEAR

INTEGRATED RAILBELT UTILITY MAKE-UP WITH SUSITNA HYDRO ELECTRIC

		NOTE	UNIT	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1.	Est. Capacity Requirement (Utility)	APA	MW	1120	1210	1300	1380	1480	1570	1670	1770	1880	2000	2110	2220
2.	Incremental Hydro Load Market	FPC	"	117	213	328	449	575	765	932	1110	1280	1450	1640	1730
3.	Watana Dependable Capacity	COE	"	264	528	767	767	767	767	767	767	767	767	767	767
4.	Useable Watana Dependable Capacity	≤col 2	"	117	213	328	449	575	765	767	767	767	767	767	767
5.	Devil Canyon Dependable Capacity	COE	"					388	582	751	751	751	751	751	751
6.	Useable Devil Canyon Dependable Capacity	4+5≤2	"							165	343	513	683	751	751
7.	Hydro System Dependable Capacity	3+5	"	264	528	767	767	961	1155	1349	1518	1518	1518	1518	1518
8.	Useable Hydro System Dependable Capacity	4+6	"	117	213	328	449	575	765	932	1110	1280	1450	1518	1518
9.	Market Area Capacity Deficit	2-8	"	0	0	0	0	0	0	0	0	0	0	122	212
10.	Est. Energy Requirement (Utility)	APA	10^6 Kwh	4910	5280	5650	6050	6480	6900	7300	7750	8200	8700	9250	9600
11.	Maximum Useable Hydro Energy	APA	"	3450	3690	3955	4235	4540	4860	5150	5470	5800	6150	6510	7000
12.	Existing Thermal	10-21	"	2905	1825	2195	2595	1940	2040	2150	2280	2400	2550	2740	2758
13.	Watana Prime Energy	COE	"	2005	3058	3058	3058	3058	3058	3058	3058	3058	3058	3058	3058
14.	Watana Secondary Energy	COE	"		397	397	397		397	397	397	397	397	397	397
15.	Devil Canyon Prime Energy	COE	"					2999	2999	2999	2999	2999	2999	2999	2999
16.	Devil Canyon Secondary Energy	COE	"						386	386	386	386	386	386	386
17.	Hydro System Prime Energy	13+15	"	2005	3058	3058	3058	6057	6057	6057	6057	6057	6057	6057	6057
18.	Hydro System Secondary Energy	14+16	"		397	397	397		785	785	785	785	785	785	785
19.	Useable Hydro System Prime Energy	17≤11	"	2005	3058	3058	3058	4540	4860	5150	5470	5800	6057	6057	6057
20.	Useable Hydro System Secondary Energy	18≤11-17	"		397	397	397						93	453	785
21.	Total Useable Hydro	19+20	"	2005	3455	3455	3455	4540	4860	5150	5470	5800	6150	6510	6842
22.	Market Firm Energy Deficit	10-12-21	"	0	0	0	0	0	0	0	0	0	0	0	0

COE - Corps of Engineers
APA - Alaska Power Administration
FPC - Federal Power Commission

Selected Plan Power Benefit Calculations

WATANA-2200 AND DEVIL CANYON   AVERAGE ANNUAL CAPACITY

YEAR	PRESENT WORTH FACTOR	MARKETABLE CAPACITY	PRESENT WORTH OF CAPACITY	CAPACITY BENEFITS	MARKETABLE FIRM ENERGY	PRESENT WORTH FIRM ENERGY	FIRM ENERGY BENEFITS	MARKETABLE SECONDARY ENERGY	PRESENT WORTH SEC ENERGY	SECONDARY ENERGY BENEFITS	DUMP CAPACITY BENEFITS	TOTAL BENEFITS
		(MW)	(MW)	($1000)	(MWYR)	(MWYR)	($1000)	(MWYR)	(MWYR)	($1000)	($1000)	($1000)
1986	0.9423	117.0	110.2	9914.5	229.0	215.8	11302.7	0.0	0.0	0.0	0.0	21217.3
1987	0.8879	213.0	189.1	17007.8	349.0	309.9	15231.4	45.0	40.0	2092.9	0.0	34332.1
1988	0.8367	328.0	274.4	24678.9	349.0	292.0	15294.6	45.0	37.6	1972.1	0.0	41945.6
1989	0.7884	449.0	354.0	31833.3	349.0	275.1	14411.9	45.0	35.5	1858.3	0.0	48103.4
1990	0.7429	575.0	427.2	38413.6	518.0	384.8	20156.2	0.0	0.0	0.0	0.0	58569.8
1991	0.7000	765.0	535.5	48157.2	555.0	388.5	20349.5	0.0	0.0	0.0	0.0	68506.7
1992	0.6596	932.0	614.7	55283.9	588.0	387.8	20315.2	0.0	0.0	0.0	0.0	75599.1
1993	0.6215	1110.0	599.9	62042.3	624.0	387.8	20314.7	0.0	0.0	0.0	0.0	82357.0
1994	0.5857	1280.0	749.5	67415.1	662.0	387.7	20308.0	0.0	0.0	0.0	0.0	87723.1
1995	0.5519	1450.0	800.2	71961.1	691.0	381.3	19974.2	11.0	6.1	318.0	0.0	92253.2
1996	0.5200	1518.0	789.4	70987.9	691.0	359.3	18821.4	52.0	27.0	1416.4	0.0	91225.6
				497696.			197489.			7658.	0.	702833.
1997 2086	8.4472	1518.	12823.	1153155.	691.	5837.	305742.	90.	760.	39822.	0.	1498717.
PRESENT WORTH BENEFITS				1650850.			503221.			47479.	0.	2201549.
CRF=	0.0614 AV ANN BENEFITS =			101380.			30903.			2916.	0.	135198.

CAPACITY VALUE = 89.92999
ENERGY VALUE = 52.37999
SECONDARY VALUE= 52.37999
INTEREST RATE = 0.06125

Total Average Annual Benefits

	Watana ($1000)	Watana plus Devil Canyon ($1000)
Power	$78,790	$135,198
Flood Control	50	50
Recreation	100	300
Area Redevelopment	6,709	9,373
Transmission Intertie		2,900
TOTAL	$85,649	$147,821

System Justification: The benefits-to-cost ratio, net benefits, and incremental increase in net benefits from the last project are as follows:

System Justification

	Watana	Watana plus Devil Canyon	Devil Canyon Last Added
Annual Cost ($1000)	$79,844	$104,020	$24,176
Annual Benefits ($1000)	85,649	147,821	62,172
Net Benefits ($1000)	5,805	43,801	37,996
B/C Ratio	1.1	1.4	2.5

The above analysis shows the following:

1. The Watana-Devil Canyon system is economically feasible.

2. The Watana project is economically feasible by itself.

3. Devil Canyon is incrementally justified on a last added basis.

Comparability Test: Principles and Standards require that a proposed project also be justifiable when benefits and costs are computed on a fully comparable basis in terms of financing, taxes, etc. Power benefits were recomputed for the selected plan of development using thermal plant alternative costs based on Federal financing at 6-1/8 percent in lieu of the non-Federal power values. Derivation of the alternative costs are discussed earlier in this section, under "Power Values and Alternative Costs". Using the alternative costs, the average annual power benefits for the selected plan are $124,331,000. The costs and non-power benefits, which are already based on financing comparable to costs, remain unchanged. The total benefits, costs, and justification ratio for the selected plan are as follows:

Average Annual Benefits ($1000)	$136,954
Average Annual Costs ($1000)	104,020
Justification Ratio	1.3

Sensitivity Tests: The following sensitivity tests are included to demonstrate the relative effect that different assumptions could have on the final economic outcome of the Selected Plan. Each of the tests was conducted under the same criteria outlined earlier in this subsection, but with the specific changes cited below. None of the tests were combined.

Gas-Fired Power Values: FPC provided two sets of power values for the Anchorage load center: one set based on a coal-fired steamplant and one set based on a gas-fired combined cycle plant. By combining both sets of values with the Fairbanks coal power value, the resulting non-Federal power values are as presented under the System Development Evaluation Subsection. It has been demonstrated earlier that the coal-fired power values are most representative of the future alternative power source in the absence of hydro development. For the sake of comparison, however, the selected plan was reanalyzed using the gas power values for the Anchorage area. The average annual power benefit was estimated to be \$106,231,000. By combining this benefit with those of flood control, area redevelopment, intertie and recreation, the total Project Benefits amount to \$118,854,000. When compared to the \$104,020,000 Average Annual Project costs, the benefits-to-cost ratio becomes 1.13.

Low-load Growth Assumption: The selected plan economic analysis was based on Alaska Power Administration's "mid-range" estimate of load growth for the railbelt area. This is considered to be a reasonable estimate of what might occur, based on present knowledge. However, in response to the concern that the present use of energy is excessive, and that measures must and will be taken to improve efficiency of use and thereby reduce load growth, it was considered appropriate to evaluate the feasibility of the project using APA's lower rate of load growth. However, regardless of what measures are imposed and how successful they are, some generation will be required. It was assumed that Watana would come on-line in 1986, but that Devil Canyon would not be required until 1992. Using the coal-fired power values and the same procedures as outlined earlier, but using revised costs based on delay of Devil Canyon and revised benefits based on the longer period required for the system to fully absorb the power from the projects, the total annual benefits drop to \$134,283,000, and the average annual costs change to \$100,595,000 giving a benefit-to-cost ratio of 1.30. An even lower load growth rate could further reduce the net benefits, but the project would remain feasible.

APA Capacity Assumptions: Alaska Power Administration in their marketability analysis determined that a much greater share of the Selected Plan capacity could be absorbed during the early years of operation. After reviewing existing and projected railbelt capacity, it was determined that by 1985 some of the older steam-fired plants would be at or near the end of their useful life and would therefore, be replaced by Susitna hydro. Furthermore, it was assumed that because fuel costs would continue to grow disproportionately high (at least two to three times that estimated by FPC based on 1975 prices), that it would be desirable to place much of the gas turbine equipment in cold reserve except for limited operation in the peak sharing mode. This is also very true for oil-fired equipment. Under these assumptions, it is assumed that firm demand for Susitna hydro would develop very rapidly in the early years. It was therefore concluded by APA that as much as 75 percent of the Railbelt utility load could be displaced by Susitna hydro capacity. This position is supported by the Corps, but it was decided to use the less controversial capacity assumption developed by FPC.

For the purpose of comparison, power benefits were computed using APA's somewhat higher estimates of what quantity of capacity could be absorbed into the system during the early years (see Section G). Using these estimates, the power benefit becomes $146,147,000. By combining the power benefit with those of flood control, recreation and area redevelopment, and comparing again the benefits to costs, the benefits-to-cost ratio becomes 1.51. This value would increase if even more capacity were claimed in the early years.

Various Interest Rates: Interest rates for Civil Works Projects are established by Congress annually. Furthermore, the interest rate is applied not only to project costs, but also to project benefits. It is possible that if the project is authorized, that post-authorization economic analysis will be conducted using a different interest rate than the 6-1/8 percent used in this report.

It is not possible to fully assess the impact that various interest rates would have on the project unless new power values based on the different interest rates were derived. However, in order to determine the relative effect that interest rates could have on the project, two separate analyses were made using interest rates of 5 percent and 8 percent. Under the 5 percent interest rate, costs went down, and benefits went up. The trend was reversed for the 8 percent interest rate, but under both situations, benefits exceeded costs. If new power values had been derived based on the different interest rates, the 5 percent interest rate would have resulted in a decreased benefit, and the 8 percent rate would have shown an increased benefit. Under the changed power values it is anticipated that the project would still remain favorable. Interest rate changes have shown only a 1/4 percent maximum increase from one year to the next and, therefore, it is not anticipated that future rate changes will have a significant effect on the project economics.

COST ALLOCATION

Project Costs: The estimated construction cost of the selected plan is $1,520,000,000, which includes $572,000 in non-Federal recreational costs. The $11,800,000 value of public domain transferred without cost added to the construction cost gives a total project cost of $1,531,800,000. The project costs, along with appropriate interest charges and operation, maintenance, and replacement costs, are to be allocated to the three project purposes of power, recreation, and flood control.

The specific power features of the plan consist of the powerhouses, switchyards, transmission line, power intakes (exclusive of the multilevel selection facility for downstream water temperature control), and accompanying construction facilities. The specific recreational features are comprised of lands and facilities for the five recreational sites. There are no specific flood control features, and all other costs are considered joint costs, as itemized in Tables C-34 and C-35 and summarized below.

Specific power features	$ 674,189,000
Specific recreational features	1,051,000
Specific flood control features	0
Joint features	856,560,000
Project Cost	$1,531,800,000

Interest during construction is computed as simple interest on project costs from the estimated date of expenditure to the appropriate power-on-line date. Interest during construction is estimated separately for specific feature costs. The construction costs and interest during construction for the second dam are discounted to the Watana power-on-line date of October 1986. These calculations are shown in Tables C-31 and C-36.

The investment cost to be allocated is the construction cost plus interest during construction, both discounted to the 1986 power-on-line date.

Construction cost (Present Worth)	$1,401,295,000
Interest during construction (PW)	251,841,000
Investment cost	$1,653,136,000

SUMMARY OF CONSTRUCTION COSTS--WATANA ($1,000)

Feature	Specific Power	Specific Recreation	Specific Flood Control	Joint Use	Total
Federal Costs					
01 LANDS AND DAMAGES 1/					
Reservoir, Site, Roads				20,882	20,882
Recreation		47			47
Transmission Line	4,257				4,257
03 RESERVOIR				9,180	9,180
04 DAM					
Dam				296,381	296,381
Power Intake 2/	61,649			61,649	123,298
07 POWERPLANT	411,603				411,603
08 ROADS AND BRIDGES				48,875	48,875
14 RECREATION FACILITIES		39			39
19 BUILDINGS, GROUNDS, AND UTILITIES				3,565	3,565
20 PERMANENT OPERATING EQUIPMENT				1,800	1,800
30 ENGINEERING AND DESIGN				39,638	39,638
31 SUPERVISION AND ADMINISTRATION				49,498	49,498
50 CONSTRUCTION FACILITIES	27,635			60,096	87,731
CONSTRUCTION COST	505,144	86	0	591,564	1,096,794

1/ Included is the value of lands transferred without cost. Figures differ from detailed cost estimate due to inclusion of appropriate share of contingency and administrative costs.

2/ One-half the cost of the intake is estimated to be the direct result of the multilevel nature of the intake.

SUMMARY OF CONSTRUCTION COSTS--DEVIL CANYON ($1,000)

Feature	Specific Power	Specific Recreation	Specific Flood Control	Joint Use	Total
Federal Costs					
01 LANDS AND DAMAGES 1/					
Reservoir, Site				3,993	3,993
Recreation		453			453
03 RESERVOIR				3,456	3,456
04 DAM					
Dam				164,660	164,660
Power Intake 2/	21,068			21,068	42,136
07 POWERPLANT	144,424				144,424
08 ROADS AND BRIDGES				8,528	8,528
14 RECREATION FACILITIES		512			512
19 BUILDINGS, GROUNDS, AND UTILITIES				2,519	2,519
20 PERMANENT OPERATING EQUIPMENT				1,800	1,800
30 ENGINEERING AND DESIGN				26,962	26,962
31 SUPERVISION AND ADMINISTRATION				19,259	19,259
50 CONSTRUCTION FACILITIES	3,553			12,747	16,300
CONSTRUCTION COST	169,045	965	0	264,996	435,006
(PRESENT WORTH)	(118,330)	(761)	(0)	(185,410)	(304,501)

1/ Included is the value of lands transferred without cost. Figures differ from detailed cost estimate due to inclusion of appropriate share of contingency and administrative costs.

2/ One-half the cost of the intake is estimated to be the direct result of the multilevel nature of the intake.

INTEREST DURING CONSTRUCTION FOR SPECIFIC FEATURES

	Power ($1,000)			Recreation ($1,000)		
Year	Expenditure	Accumulated Expenditure	IDC	Expenditure	Accumulated Expenditure	IDC
	Watana			Watana		
1981	3,000	0	92	47	0	1
1982	2,879	3,000	272		47	3
1983	96,283	5,879	3,309		47	3
1984	194,112	102,162	12,202		47	3
1985	123,404	296,274	21,926		47	3
1986	66,718	419,678	27,748	39	47	4
1987	18,748	486,396	-1,082 1/			
	505,144		64,467	86		17
	Devil	Canyon		Devil	Canyon	
1985				453	0	14
1986					453	28
1987					453	28
1988	42,524	0	1,302		453	28
1989	79,430	42,524	5,038		453	28
1990	35,530	121,954	8,558	512	453	44
1991	5,781	157,484	9,823			
1992	5,780	163,265	10,177			
	169,045		34,898	965		170
(PW)	(118,330)		(24,428)	(761)		(134)

	Power	Recreation
CONSTRUCTION COST (PW)	$623,474	$847
INTEREST COST (PW)	88,895	151
INVESTMENT COST	$712,369	$998

Summary ($1,000)	Construction Cost (PW)	Interest Cost (PW)
Total Cost	1,401,295	251,841
Specific Power	623,474	88,895
Specific Recreation	847	847
Specific Flood Control	0	0
Total Specific	624,321	89,046
Joint Use	776,974	162,795

1/ The 1987 expenditure is discounted one year to the power-on-line date.

The estimated average annual operation and maintenance cost over the 100-year life of the proposed plan is $1,928,000. The breakdown to specific and joint use facilities is shown in Table C-37 and summarized as follows:

Annual Operation and Maintenance Costs

Specific power	$1,117,000
Specific recreation	45,000
Specific flood control	0
Joint use	766,000
Total	$1,928,000

Annual costs for replacement of mechanical equipment and other items which normally have a useful life less than the 100-year project life are estimated at $572,000. Replacement costs were assigned to features, as shown in Table C-37 and summarized as follows:

Annual Replacement Costs

Specific power	$517,000
Specific recreation	55,000
Specific flood control	0
Joint use	0
Total	$572,000

Table C-38 summarizes the construction, investment, and average annual costs for the proposed plan. Average annual costs include estimated annual operation and maintenance costs, estimated annual replacement costs, and interest and amortization on the project investment, computed at an interest rate of 6-1/8 percent over a 100-year project life.

Project Benefits: Project benefits have been discussed earlier in Section C and are summarized as follows:

Average Annual Benefits

Power	$135,198,000
Recreation	292,000 3/
Flood control	50,000
Area redevelopment 1/	9,373,000
Intertie 2/	2,900,000
Total	$147,813,000

1/ Not included in cost allocation.
2/ Included as a power benefit for purposes of cost allocation.
3/ Whereas in previous discussion of recreation benefits a value of $300,000 is used, for purposes of cost allocation the actual estimate of $292,000 is used.

SUMMARY OF ANNUAL OPERATION, MAINTENANCE, AND REPLACEMENT COSTS 1/

	Operation and Maintenance	Replacement
Specific Power (Powerplant, Transmission Line, Switchyards, Marketing)	$1,117,000	$517,000
Specific Recreation	45,000	55,000
Specific Flood Control	0	0
Joint Use (Overall Project Supervision, Administration and Maintenance)	766,000	0
Total	$1,928,000	$572,000

1/ For purposes of this study, O,M&R costs are treated as if Devil Canyon project went on line in 1986.

SUMMARY OF COSTS AND CHARGES ($1,000)

Cost Category	Specific Power	Specific Recreation	Specific Flood Control	Joint Use	Total Cost
Project Cost (Present Worth - 1986)	$623,474	$ 847	0	$ 776,974	$ 1,401,295
Watana	(505,144)	(86)		(591,564)	(1,096,794)
Devil Canyon	(118,330)	(761)		(185,410)	(304,501)
Interest During Construction (PW)	$ 88,895	$ 151	0	$ 162,795	$ 251,841
Watana	(64,467)	(17)		(117,946)	(182,430)
Devil Canyon	(24,428)	(134)		(44,849)	(69,411)
Total Investment Cost	$712,369	$ 998	0	$ 939,769	$ 1,653,136
Project First Cost	$674,189	$1,051	0	$ 856,560	$ 1,531,800
Watana	(505,144)	(86)		(591,564)	(1,096,794)
Devil Canyon	(169,045)	(965)		(264,996)	(435,006)
Interest During Construction	$ 99,365	$ 187	0	$ 182,038	$ 281,590
Watana	(64,467)	(17)		(117,946)	(182,430)
Devil Canyon	(34,898)	(170)		(64,092)	(99,160)
Annual Charges					
Interest and Amortization 1/	$ 43,747	$ 61	0	$ 57,712	$ 101,520
Operation and Maintenance	1,117	45	0	766	1,928
Replacement	517	55	0	0	572
Total Annual Cost	$ 45,381	$ 161	0	$ 58,478	$ 104,020

1/ Based on total investment cost.

Alternative Projects: The least-cost single-purpose alternative power project would be the recommended plan without any facilities for recreation. Such a project would cost $103,859,000 annually.

For recreation, the least-cost alternative would be a public recreational plan which could produce an equivalent type and amount of recreational opportunity in the same general location. Exact cost estimates have not been developed for such a plan since simply providing ground access would necessitate costs well in excess of the recreational benefit.

The least cost alternative flood control project to achieve an equivalent amount of flood protection would require approximately 7.5 miles of bank revetment work along the river downstream from the dam and adjacent to the endangered railroad bed at $633,500 per mile for an alternative cost of $4,750,000, or $292,000 annually.

Allocation of Costs:

Allocation Method: The Alternative Justifiable Expenditure (AJE) method has been used herein to allocate plan costs. This method serves as a reasonable approximation of the normally preferred Separable Costs-Remaining Benefits (SCRB) method and is allowable when necessary basic data to determine separable costs are not available. In this instance, the separable costs of power are not readily identifiable. The costs of developing a plan without power which would provide the same recreational and flood control output as the multipurpose project has not been estimated. First appraisals indicate an at-site dam and reservoir project would be so costly compared to benefits as to preclude its being considered. Later stage formulation will address other possible ways of providing the recreational and flood control output with more reasonable investments. Meanwhile, the AJE method has been used following the same general procedures and principles as the SCRB method. These principles are as follows:

(1) Costs allocated to any purpose should not exceed the corresponding benefit or least costly alternative method of obtaining the benefit.

(2) Each purpose must carry at least its separable (specific in this case) cost.

(3) The remaining or joint costs are distributed in such a manner that each purpose shares proportionately in the savings resulting from the multipurpose plan.

Allocation Results: Results of the allocation are derived in Table C-39 and are summarized below:

Purpose	Percent of Joint-Use Costs
Power	99.69
Recreation	0.22
Flood control	0.09

ALLOCATION OF ANNUAL COSTS ($1,000)
(ALTERNATIVE JUSTIFIABLE EXPENDITURE METHOD)

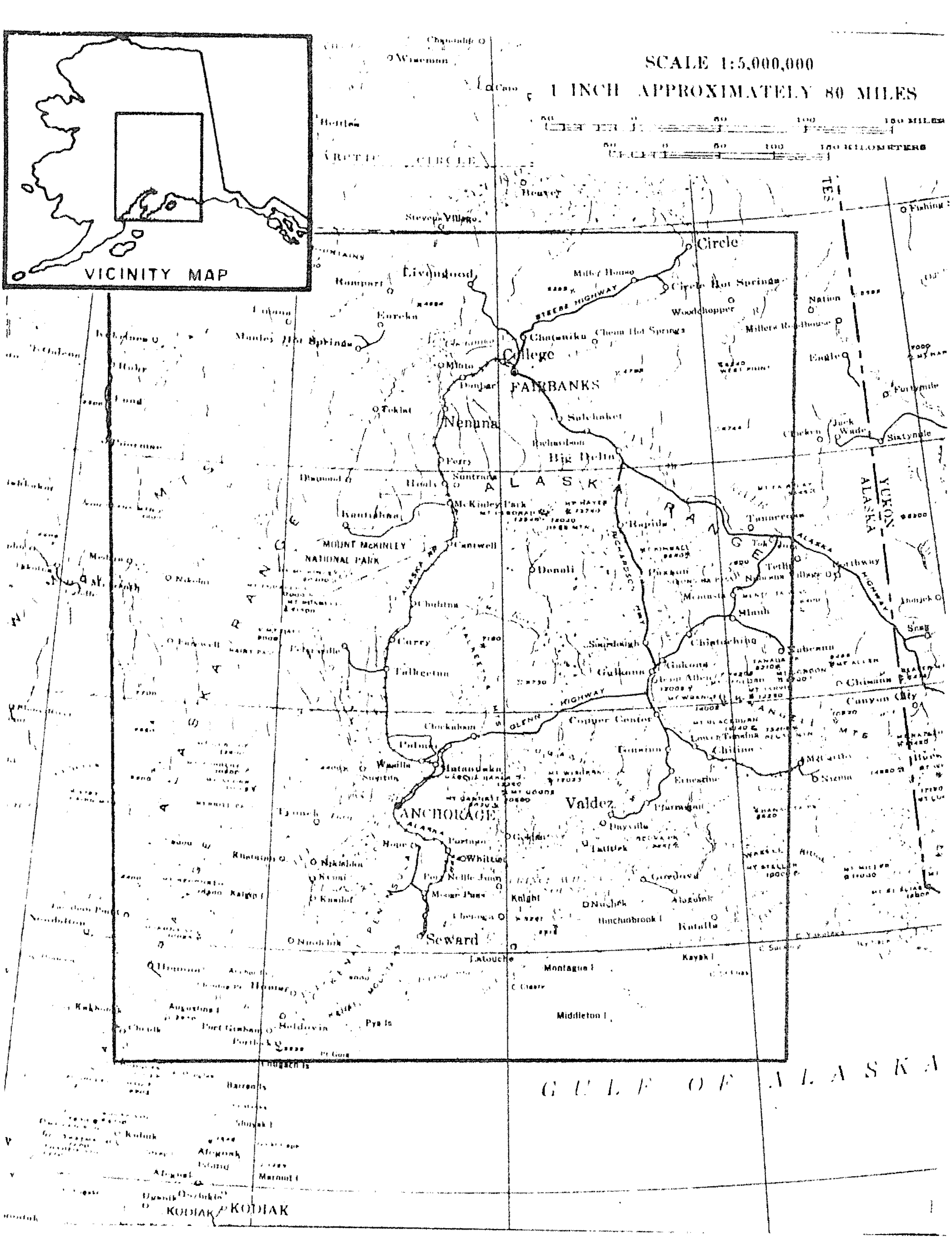
Item	Power	Recreation	Flood Control	Total
1. ALLOCATION OF ANNUAL COSTS:				
a. Benefits	138,098 1/	292	50	138,440 2/
b. Least Cost Single Purpose Alternative Cost	103,859	3/	292	
c. Benefits Limited by Alternative Cost	103,859	292	50	
d. Specific Costs	45,381	161	0	45,542
e. Remaining Benefits	58,478	131	50	58,659
f. Percent Remaining Benefits	(99.692%)	0.223%)	(0.085%)	
g. Allocated Joint Costs	58,298	130	50	58,478
h. Total Allocation	103,679	291	50	104,020
2. ALLOCATION OF ANNUAL OPERATION AND MAINTENANCE:				
a. Specific Costs	1,117	45	0	1,162
b. Allocated Joint Costs	763	2	1	766
c. Total O&M Allocation	1,880	47	1	1,928
3. ALLOCATION OF ANNUAL REPLACEMENT COSTS:				
a. Specific Costs	517	55	0	572
4. ALLOCATION OF CAPITAL INVESTMENT:				
a. Annual Investment Costs	101,282	189	49	101,520
b. Percent Annual Investment	(99.76%)	(0.19%)	(0.05%)	
c. Allocated Investment	1,649,259	3,079	798	1,653,136

ALLOCATION OF ANNUAL COSTS ($1,000) (Continued)

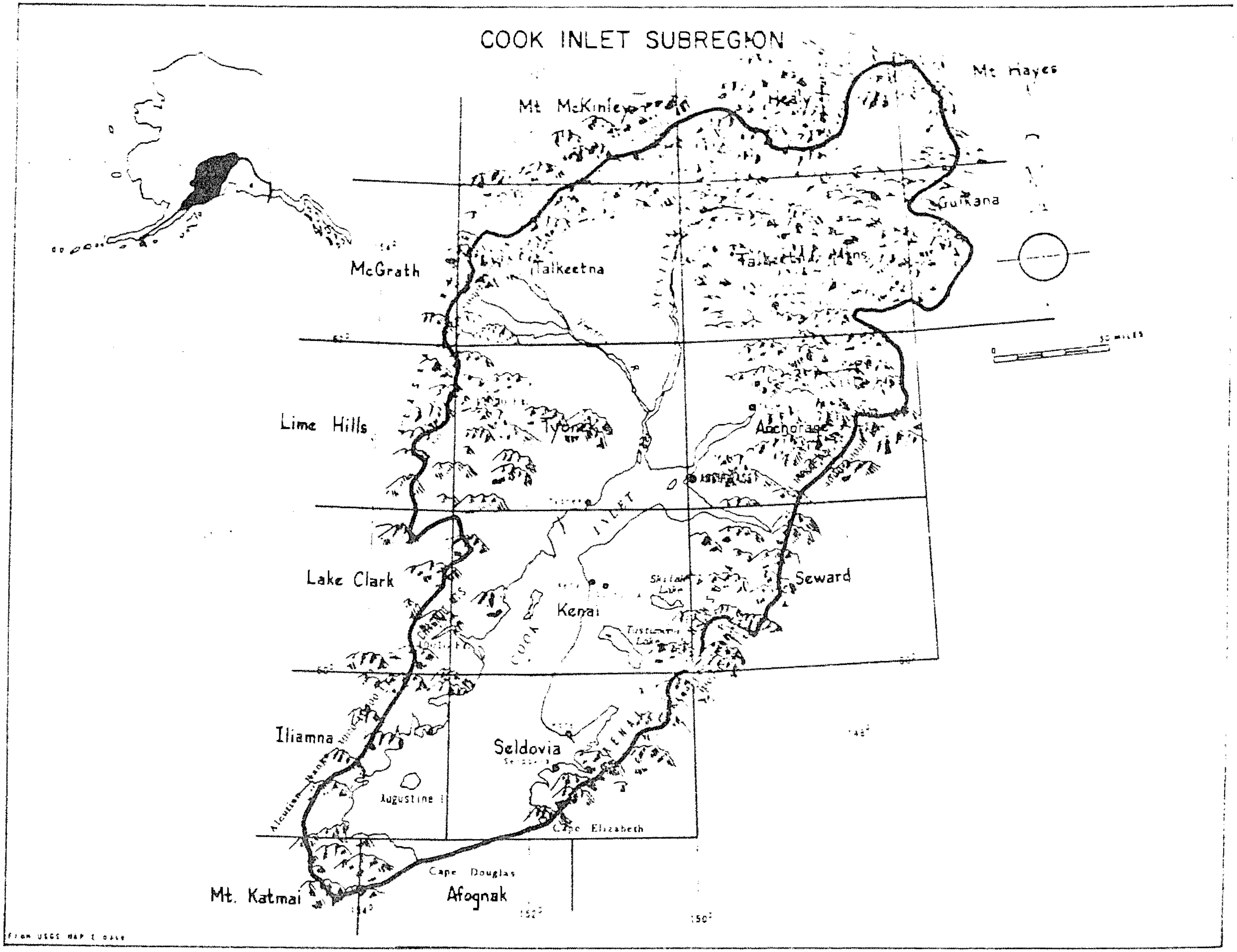
Item	Power	Recreation	Flood Control	Total
5. ALLOCATION OF PROJECT COSTS:				
a. Specific Investment	712,369	998	0	713,367
b. Investment, Joint Use	936,890	2,081	798	939,769
c. Interest during Construction, Joint Use	162,294	363	138	162,795 4/
d. Project Cost, Joint Use (PW)	774,596	1,718	660	776,974
e. Percent Project Cost, Joint Use	(99.69%)	(0.22%)	(0.09%)	
f. Project Cost, Specific Facilities (PW)	623,474	847	0	754,826
g. Total Project Cost (PW)	1,398,070	2,565	660	1,401,295
6. ALLOCATION OF CONSTRUCTION FIRST COSTS (w/o Public Domain Value):				
a. Specific Construction Costs (w/o Public Domain Value)	672,869	1,051	0	673,920
b. Allocated Joint-Use Costs 5/	843,457	1,861	762	846,080
c. Total Allocation of Construction First Costs	1,516,326	2,912	762	1,520,000
7. ALLOCATION OF PUBLIC DOMAIN VALUE				
a. Specific Public Domain Costs	1,320	0	0	1,320
b. Allocated Joint-Use Public Domain Costs 5/	10,448	23	9	10,480
c. Total Allocation of Public Domain Value	11,768	23	9	11,800
8. ALLOCATION OF INTEREST DURING CONSTRUCTION:				
a. Specific Interest during Construction	99,365	187	0	99,552
b. Allocated IDC, Joint Use 5/	181,474	400	164	182,038
c. Total Allocation of IDC	280,839	587	164	281,590

1/ Includes $2,900,000 intertie benefit.
2/ Does not include $9,373,000 Area Redevelopment benefit.
3/ No cost estimate available, but annual cost known to exceed the annual recreational benefit.
4/ IDC allocated on basis of percent remaining benefits.
5/ Allocated on basis of percent project cost, joint use (5e).

THE STUDY AREA

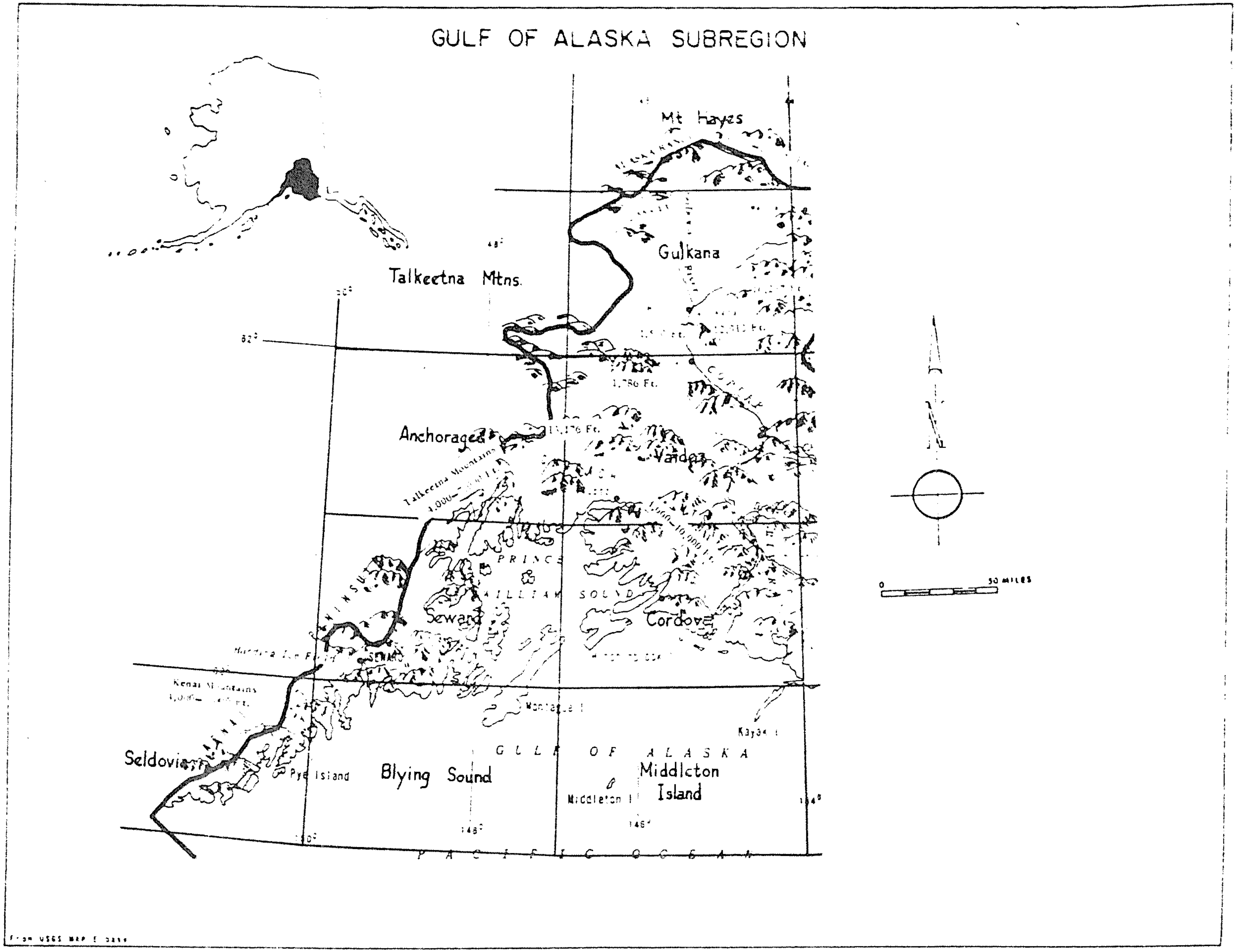


APPENDIX I
PLATE 1

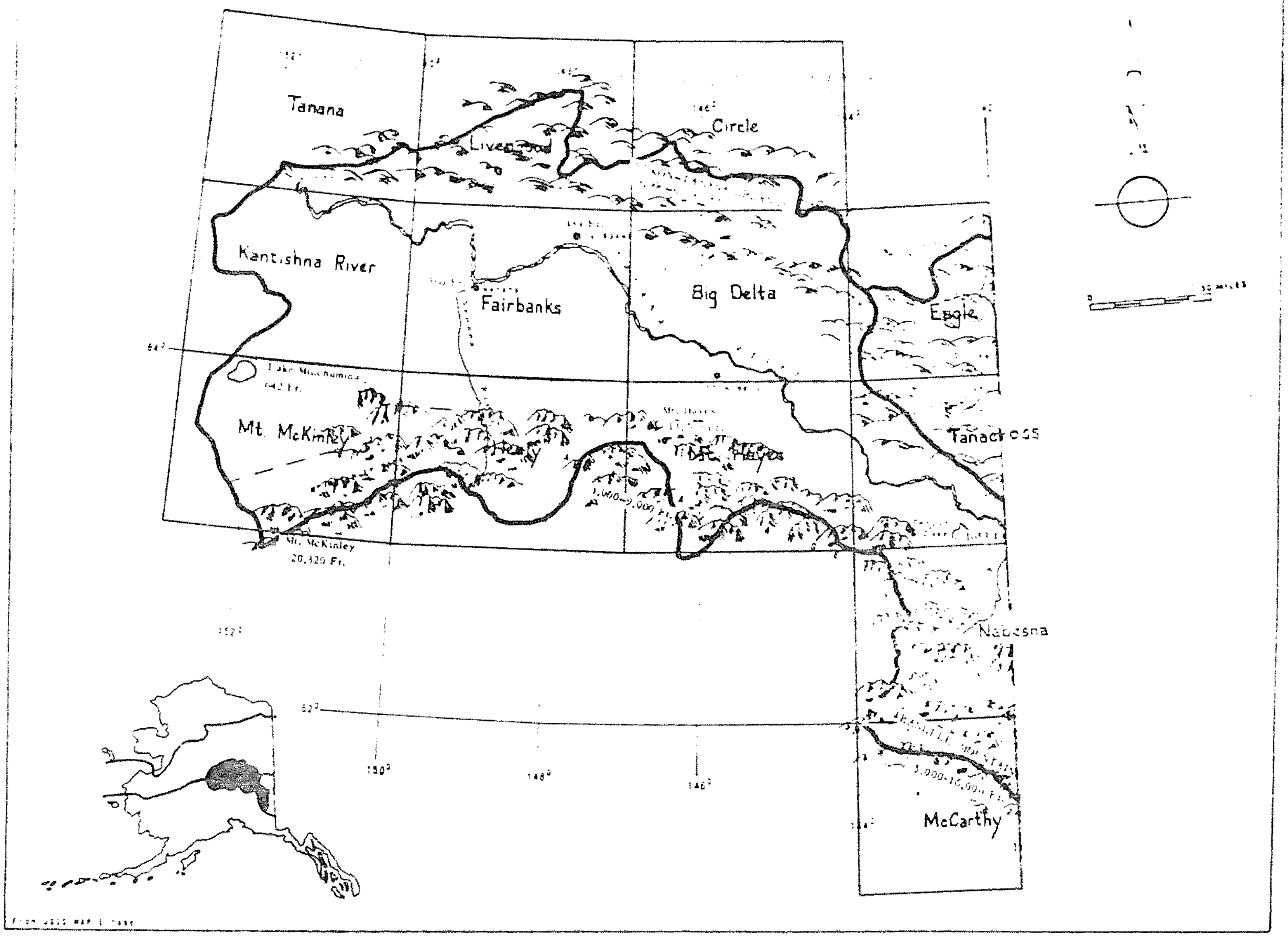


APPENDIX I
PLATE 2

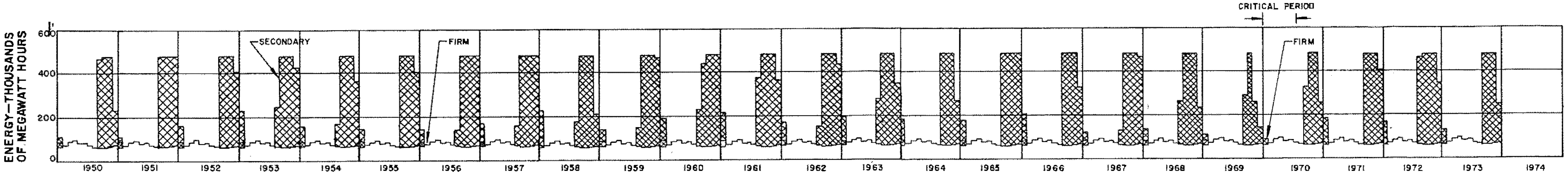
APPENDIX I
PLATE 3



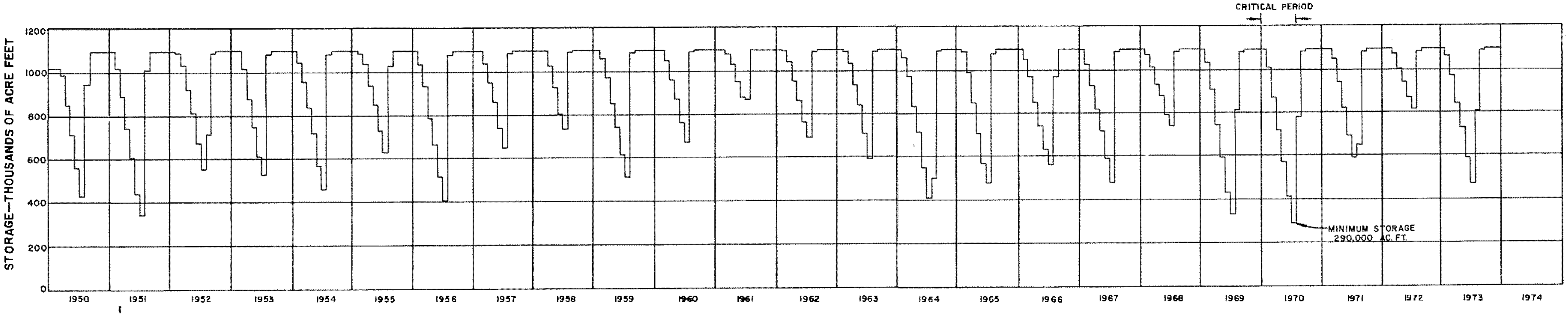
TANANA SUBREGION



APPENDIX I
PLATE 4



DEVIL CANYON AVERAGE MONTHLY OUTPUT



DEVIL CANYON STORAGE CONTENT

SOUTHCENTRAL RAILBELT AREA, ALASKA

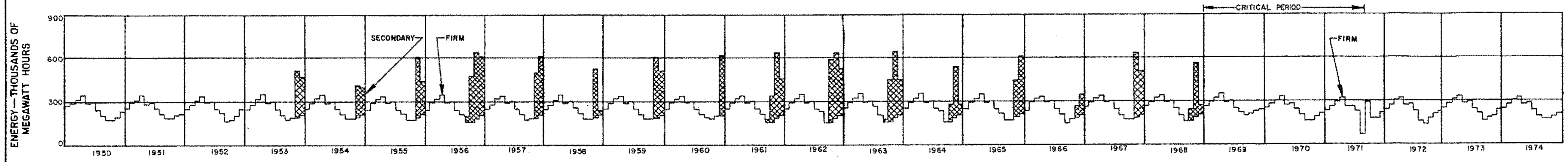
INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

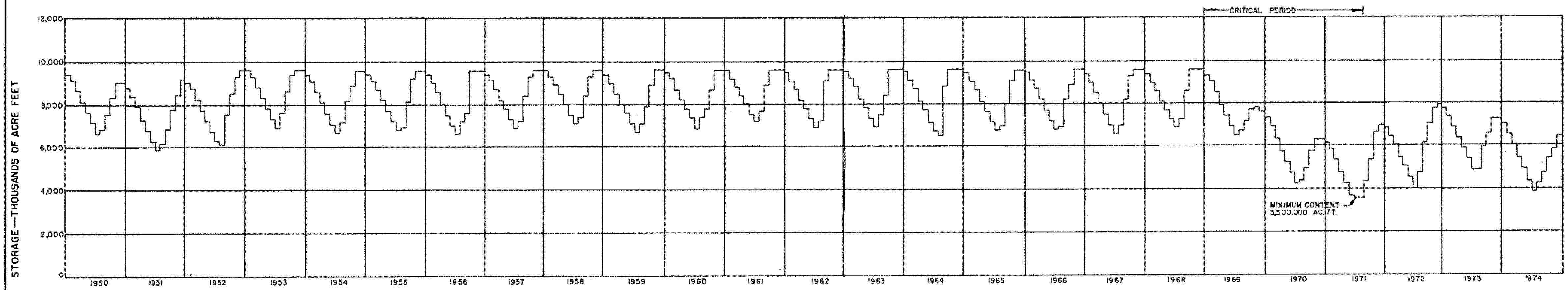
RESERVOIR OPERATIONS AND
ENERGY OUTPUT FOR
DEVIL CANYON SYSTEM

ALASKA DISTRICT, CORPS OF ENGINEERS

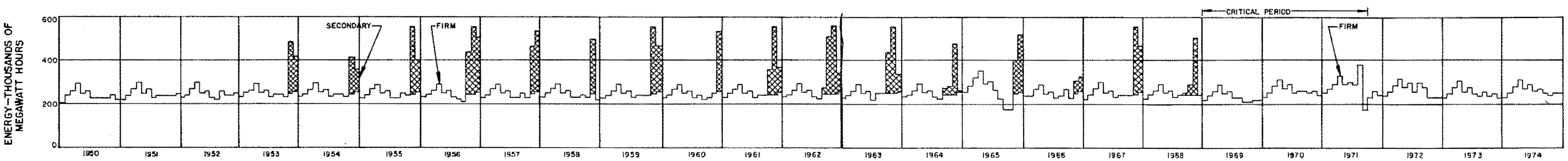
ANCHORAGE, ALASKA
DECEMBER 1975



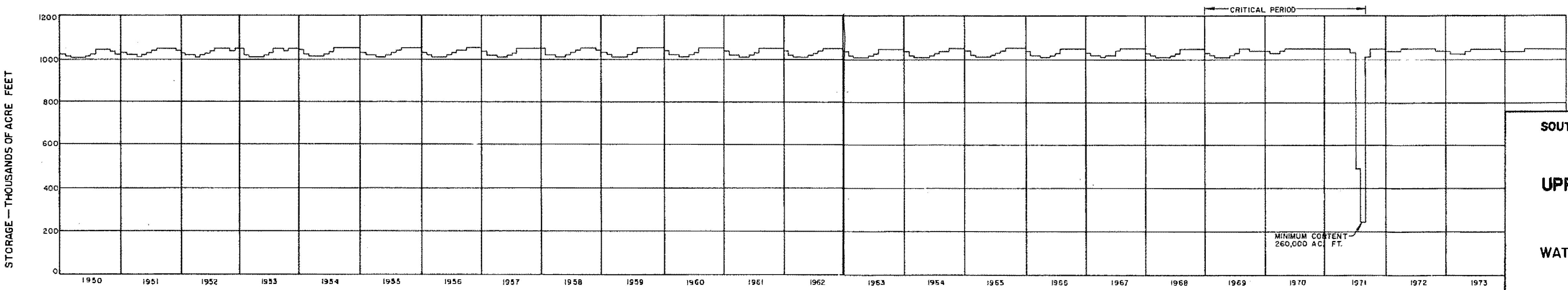
WATANA (2200') AVERAGE MONTHLY OUTPUT



WATANA (2200') STORAGE CONTENT



DEVIL CANYON AVERAGE MONTHLY OUTPUT



DEVIL CANYON STORAGE CONTENT

SOUTHCENTRAL RAILBELT AREA, ALASKA

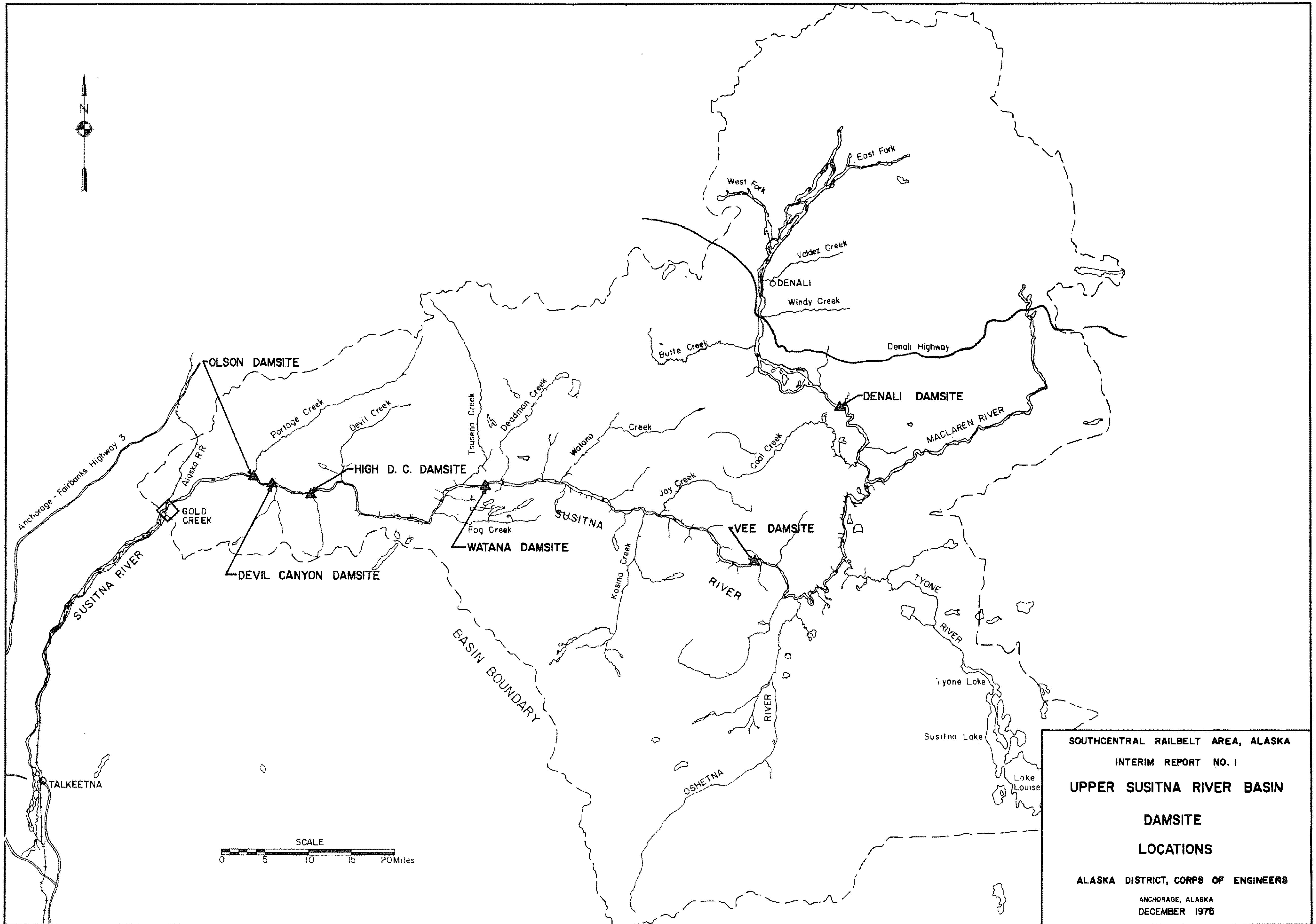
INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

RESERVOIR OPERATION AND ENERGY OUTPUT FOR WATANA (2200') AND DEVIL CANYON SYSTEMS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

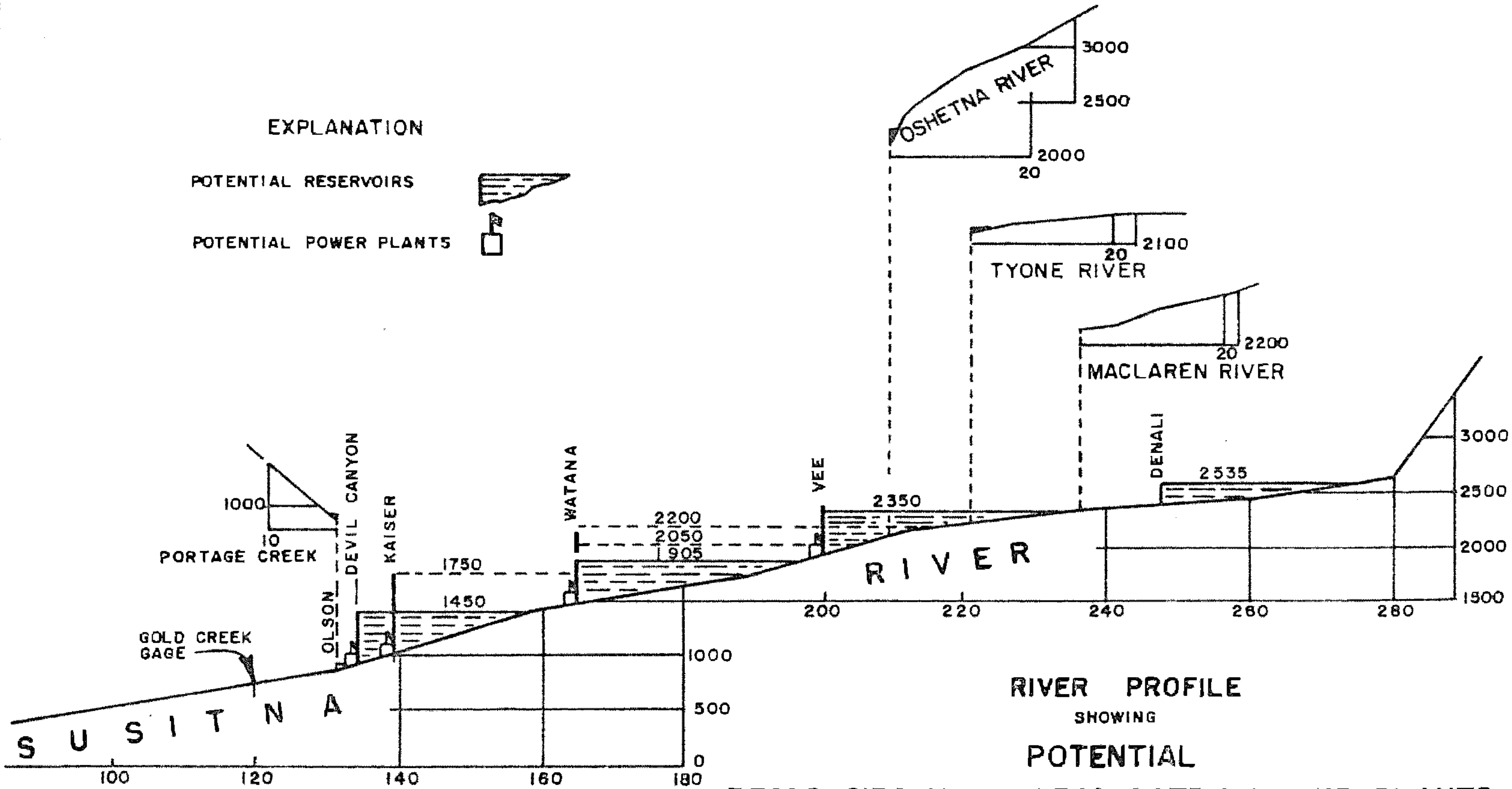
UPPER SUSITNA RIVER BASIN

DAMSITE LOCATIONS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1976



RIVER PROFILE
SHOWING
POTENTIAL
RESERVOIRS AND HYDROELECTRIC POWER PLANTS

ALL DISTANCES SHOWN ARE IN MILES FROM THE MOUTH AT COOK INLET.
ALL ELEVATION ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.

INTERIM REPORT
SOUTHCENTRAL RAILBELT AREA, ALASKA

ALASKA DISTRICT,
CORPS OF ENGINEERS
JUNE 1976

APPENDIX I
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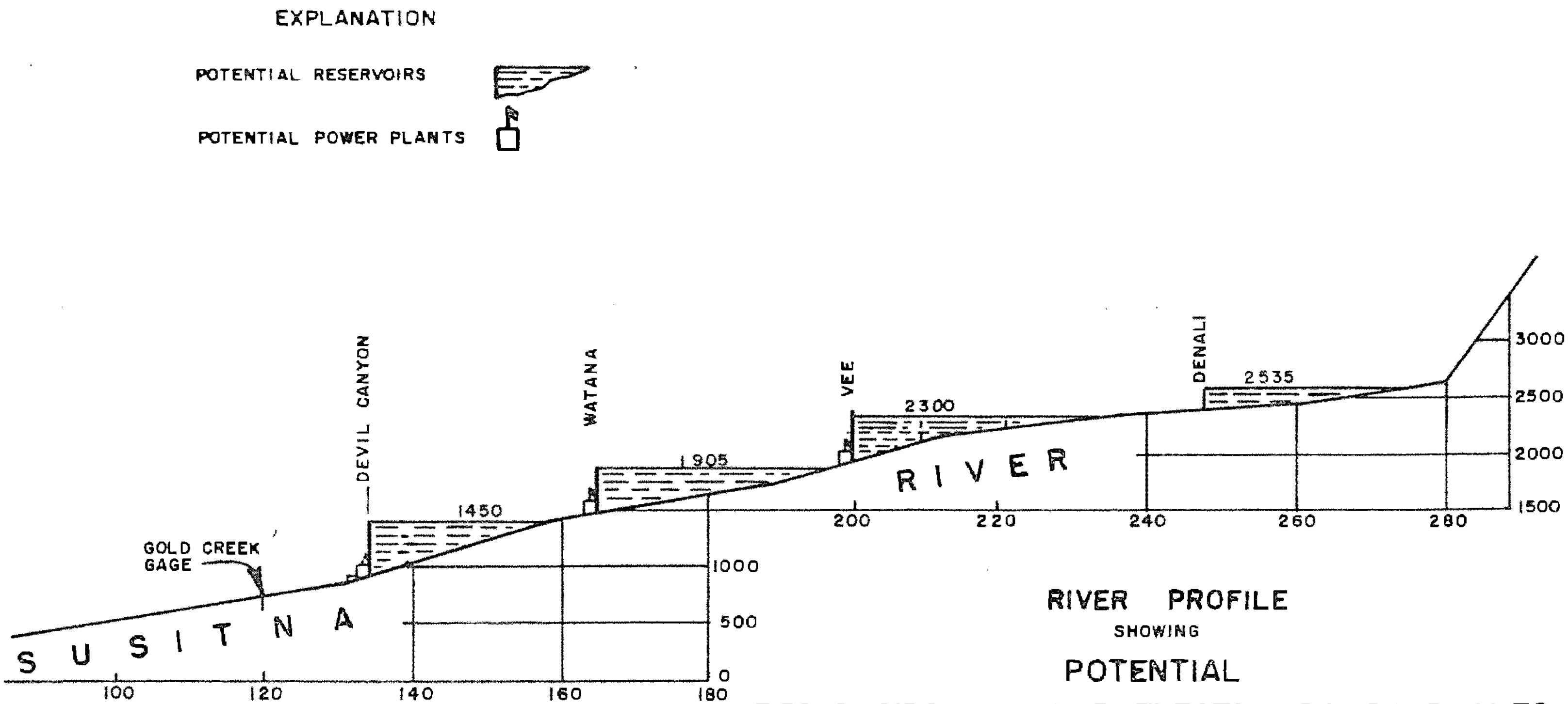


RIVER PROFILE
SHOWING
POTENTIAL
RESERVOIRS AND HYDROELECTRIC POWER PLANTS

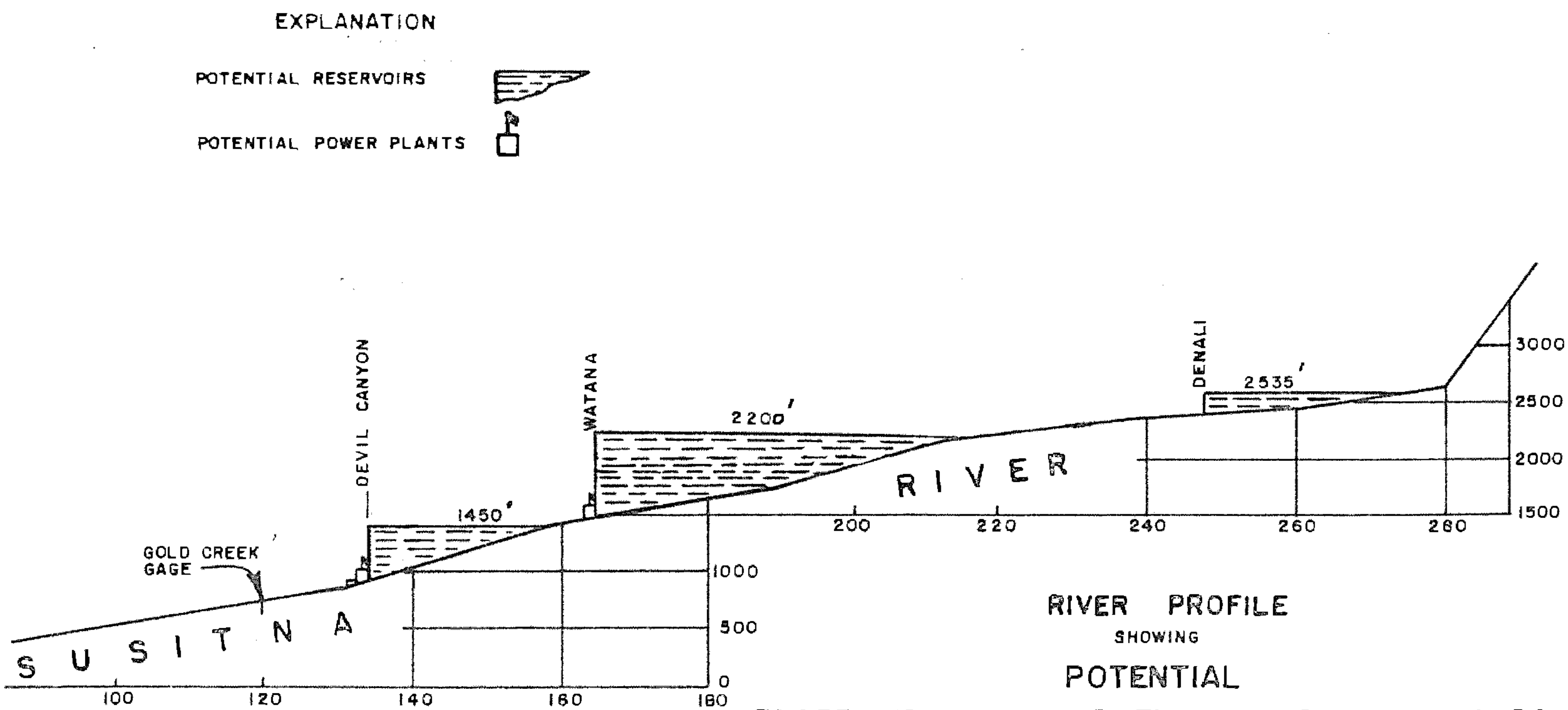
ALL DISTANCES SHOWN ARE IN MILES FROM THE MOUTH AT COOK INLET.
ALL ELEVATION ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.

U.S. BUREAU OF RECLAMATION (4-DAM PROPOSAL)

FIRM ANNUAL ENERGY: 6.25 BILLION Kw HOURS

INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA
ALASKA DISTRICT,
CORPS OF ENGINEERS
MAY 1975

APPENDIX I
PLATE 7



RIVER PROFILE
SHOWING
POTENTIAL
RESERVOIRS AND HYDROELECTRIC POWER PLANTS

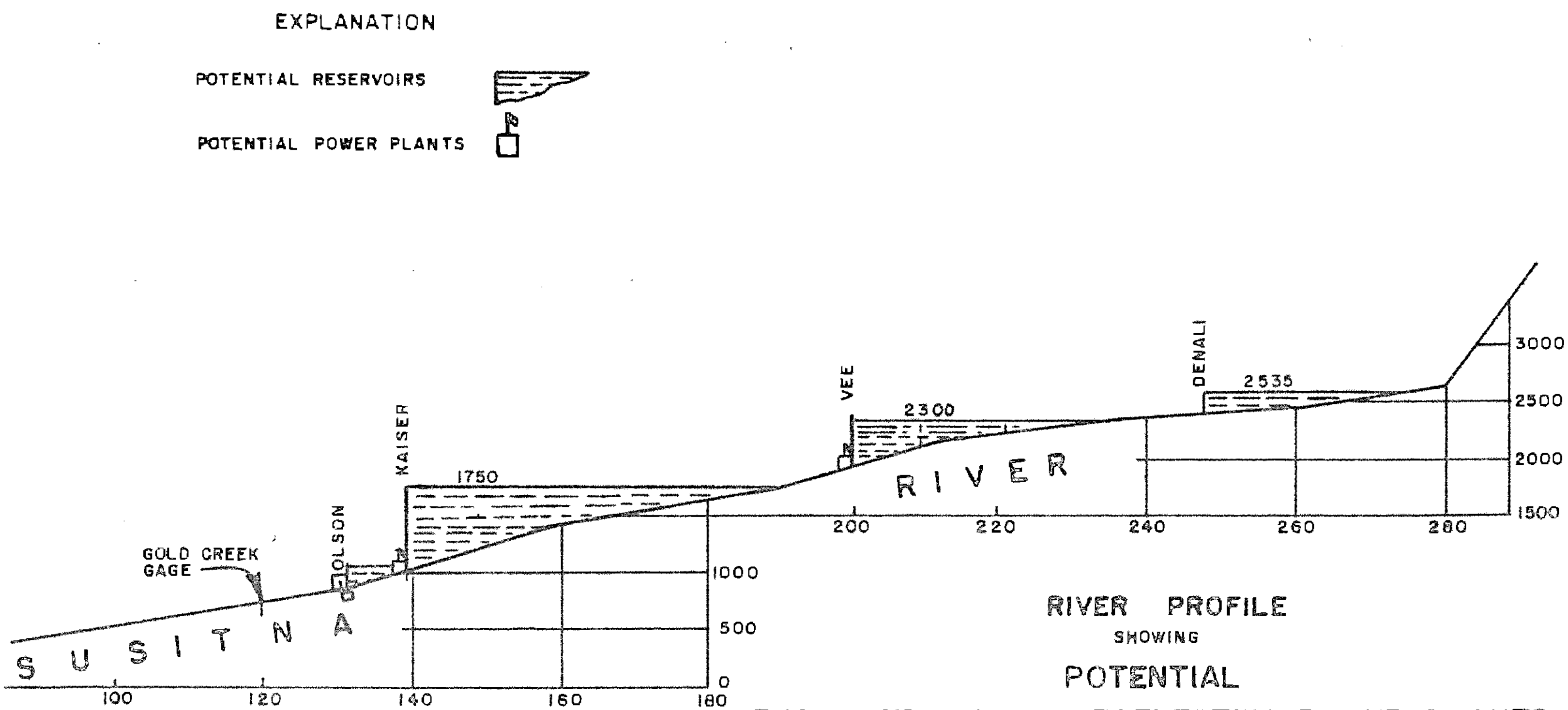
ALL DISTANCES SHOWN ARE IN MILES FROM THE MOUTH AT COOK INLET.
ALL ELEVATION ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.

CORPS 3-DAM PROPOSAL WITH MED. HEIGHT WATANA - (810')
FIRM ANNUAL ENERGY: 6.8 BILLION KW HRS.

INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA

ALASKA DISTRICT,
CORPS OF ENGINEERS
MAY 1975

APPENDIX
PLATE 8



RIVER PROFILE
SHOWING
POTENTIAL
RESERVOIRS AND HYDROELECTRIC POWER PLANTS

ALL DISTANCES SHOWN ARE IN MILES FROM THE MOUTH AT COOK INLET.
ALL ELEVATION ARE IN FEET AND REFER TO MEAN SEA LEVEL DATUM.

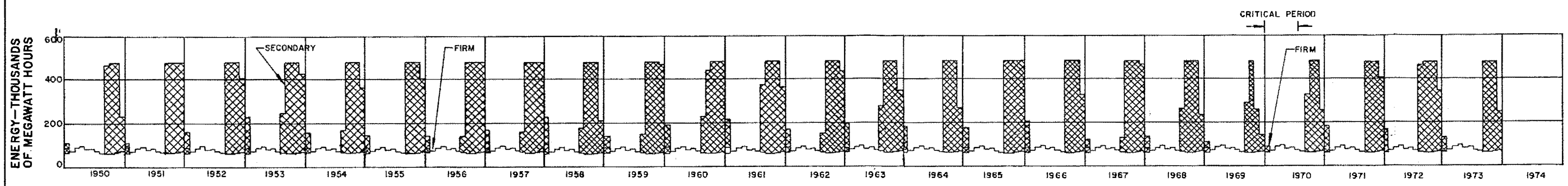
PROPOSAL (4-DAMS)

FIRM ANNUAL ENERGY: 5.9 BILLION Kw HOURS

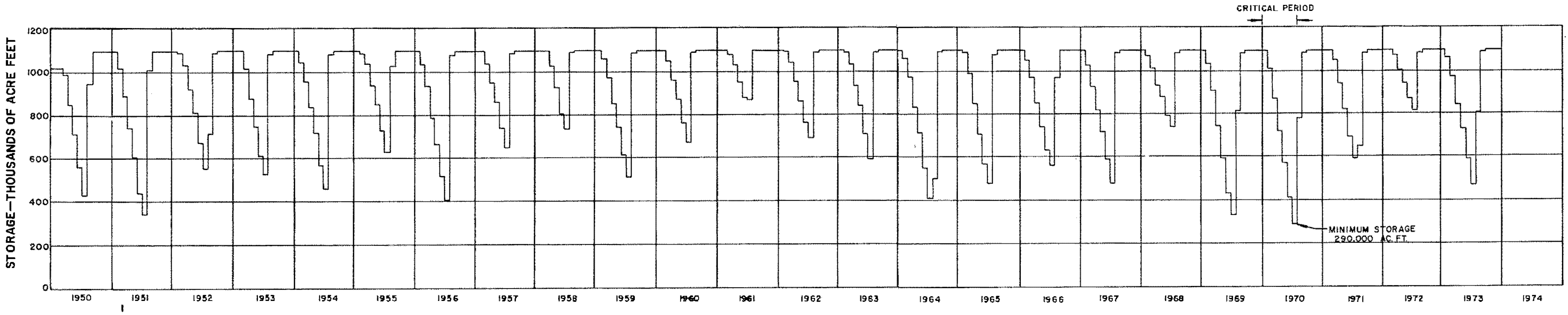
INTERIM REPORT
SOUTHCENTRAL RAILBELT
AREA, ALASKA

ALASKA DISTRICT,
CORPS OF ENGINEERS
MAY 1975

APPENDIX I
PLATE 9



DEVIL CANYON AVERAGE MONTHLY OUTPUT



DEVIL CANYON STORAGE CONTENT

SOUTHCENTRAL RAILBELT AREA, ALASKA

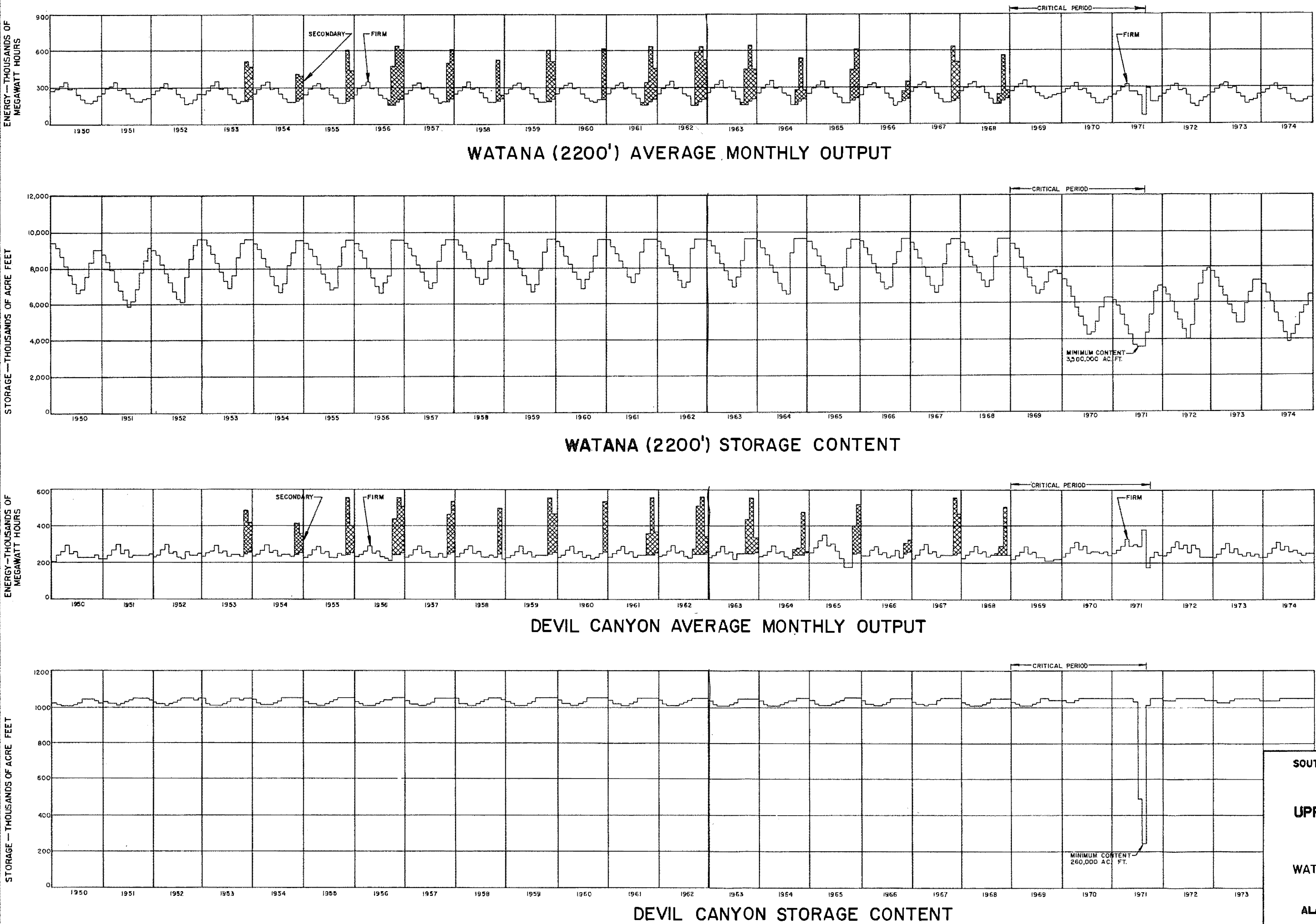
INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

RESERVOIR OPERATIONS AND
ENERGY OUTPUT FOR
DEVIL CANYON SYSTEM

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

RESERVOIR OPERATION AND ENERGY OUTPUT FOR WATANA (2200') AND DEVIL CANYON SYSTEMS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SECTION D

FOUNDATIONS AND MATERIALS

SECTION D

FOUNDATIONS AND MATERIALS

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LIST OF EXHIBITS

FOUNDATIONS AND MATERIALS

REGIONAL GEOLOGY

INFERRED GEOLOGIC HISTORY

The upper Susitna River lies in middle ground between older rocks (pre-Cambrian to Devonian) north of the Denali Fault and younger rocks (Jurassic and Cretaceous) south of the Susitna. The oldest known rocks of this area are Pennsylvanian and Permian volcanics and volcaniclastics. These are the basement terrane or strata upon which the regional sequences have been built.

The area received marine deposition, probably in a transitional shelf/trench environment, through the Middle and Late Triassic and continuing through the Early Jurassic. This deposition was contemporaneous with the massive outpouring of subareal lavas in the eastern Alaska Range, resulting in regional subsidence (Richter and Jones, 1973). Marine sediments, or clastics, are evident today as sandstones and shales interbedded with volcanic flows and sediments.

Batholithic intrusions, beginning in the Middle Jurassic, are probably responsible for much of the regional uplift and deformation. This uplift and metamorphism of the clastics continued through the end of the Cretaceous and into Tertiary time. These metamorphosed clastics, predominantly phyllite, are well exposed in the canyon walls at Devil Canyon and along the slopes of Valdez Creek.

Sometime during the Cretaceous, the Susitna River must have begun to form. The Late Cretaceous and Tertiary periods are marked by severe erosion which must have required a developed drainage system. Block faulting, differential uplift, and batholithic intrusive forces make it entirely possible that the upper Susitna River, particularly the apparently more youthful east-west segment, has changed its course and direction of flow many times since Cretaceous time. Paleozoic rocks exposed at the surface in the central upper Susitna region reflect the significant degree of erosion which has taken place. This area may also represent a locally high block which was subsequently subjected to greater erosion.

The Tertiary period was primarily dominated by continuing uplift and erosion while deposition was limited to localized non-marine sedimentation in fault block basins. Both intrusive and extrusive volcanics have been noted during this period. The post-Pliocene epoch was a period of great orogenic activity, involving substantial uplift and faulting (Payne, 1955). Many of the faults in the upper Susitna region are probably related to the post-Pliocene orogeny, though a positive date is unknown.

During the Caribou Hills/Mt. Susitna and Eklutna glaciations of the Pleistocene epoch, the entire area was covered with ice. Subsequent glaciations (Knik and Naptowne) were not as extensive as the earlier ones and only the northern and western portions of the area were subjected to glacial scouring and carving, leaving the central and eastern portions to be occupied by a tremendous proglacial lake--a lake formed at the boundary of a glacier--(Alaska Glacial Map Committee, 1965). Proglacial lake deposits cover a large portion of the area today.

PHYSIOGRAPHY

The area of study is located within the Coastal Trough Province of southcentral Alaska. The Susitna River drains an area of nearly 6,000 square miles between the southern slopes of the Alaska Range, where it heads from several glaciers, and Gold Creek bridge, where it emerges from the Talkeetna Mountains. The river then flows by way of a continuously widening valley to the tidewaters of Cook Inlet. Within this reach of approximately 200 river miles, the Susitna passes through a variety of land forms related to the lithology and geology of the region. From its proglacial channel in the Alaska Range, it passes through a broad, glaciated, intermontane valley characterized by knob and kettle topography and by braided river channels. Swinging westward along the northern edge of the Copper River lowlands, the Susitna enters a deep V-shaped valley and picks its way through the Talkeetna Mountains, emerging once more into a conventional channel and broad valley which it follows to the sea.

GEOLOGY

The geology of the upper Susitna River region reflects the complex processes which make up its geologic history. It has undergone subsidence, marine deposition, volcanic intrusion, mountain building, glacial planing, and erosion. In the upper reaches of the river, the valley floor is composed of reworked glacial moraine and lakebed deposits, which are thought to be approximately 200 feet thick. Materials range in size from silt to boulders. Adjacent mountains are composed of metavolcanics and metasediments, and the bedrock beneath the valley floor is also assumed to be a metamorphic complex of rocks. In the midsection of the upper Susitna, massive intrusions of granitic rock have warped and uplifted the region. Subsequent vigorous tectonic movement resulted in the building of the Talkeetna Mountains. Throughout this area the metavolcanics and metasediments are warped and twisted, and medium-grained granite intrusives are exposed intermittently along the valley walls. At the lower end of the drainage, glacial action is evidenced in the absence of overburden materials at higher elevations and the scouring and planing of the underlying bedrock.

REGIONAL TECTONICS

Two major earth tectonic features bracket the upper Susitna region. The Denali Fault, active during Holocene (Recent) time, is one of the earth's major fractures. It lies approximately 43 miles north of the proposed Devil Canyon damsite. A second arcuate fracture, the Castle Mountain Fault, lies some 75 miles to the south of the river basin. Bisecting the region in a north-east, south-west direction and truncated by the Denali Fault, lies the Susitna Fault, approximately 2.5 miles west of the proposed Watana Dam. Large prominent lineaments pass through the region trending north-east, south-west, and the river valley is controlled by many of these features.

SEISMOLOGY

Located as it is in an area of major faults, it is to be expected that the upper Susitna basin would lie in a zone of major seismic activity. During the period of record, through the end of 1970, 262 earthquakes had been recorded within a radius of 150 miles of the proposed Devil Canyon site (Kachadoorian 1974). Of these, 229 had a magnitude on the Richter scale of less than 5.3, 20 were between 5.3 and 7.0, 11 were between 7.0 and 7.75, and 2 were greater than 7.75. An evaluation of the potential exposure of the upper Susitna damsites to seismic activity was made by the Bureau of Reclamation. Their conclusions led to a Maximum Credible Earthquake (MCE) of 8.5 Magnitude for both Devil Canyon and Denali sites. It is probable that Watana and Vee sites would use the same MCE since they are between the other two sites and are approximately the same distance from Denali Fault, the most likely source of a seismic event of this magnitude. However, Susitna Fault is also under investigation to determine its seismic potential in relation to Watana Dam. It is expected that due to its relatively short length, the Maximum Credible Earthquake for this fault will be in the order of 6.

INSTRUMENTATION

The immediate requirement for instrumentation at the Devil Canyon and Watana damsite areas is to establish a high gain seismic net supplemented by a strong motion instrument at each site. This type of seismic instrumentation will provide the necessary data for design of the structures. In addition, instruments will be installed during construction to monitor pore pressures, settlement, and deformation within the structures and the foundations.

SCOPE OF INVESTIGATIONS

The potential of the Susitna River basin for hydroelectric development has been recognized for many years. Early investigations were begun by the Bureau of Reclamation in 1950, and a reconnaissance report was published in 1953 on the development of water resources in the basin. This report was followed by field surveys, geologic mapping, and subsurface investigations at the Devil Canyon site, and an Engineering Geology Report-Feasibility Stage, Devil Canyon Dam was presented in 1960. Limited explorations were also conducted at the Denali site in 1958-1959, and detailed studies of the Vee site were made in 1960-1962.

To date, on-site investigation by the Corps of Engineers has been limited to a reconnaissance of the four-dam area with particular emphasis on Watana to insure the feasibility of Watana as a damsite. The work done by the Bureau of Reclamation is considered to be adequate to insure the feasibility of Devil Canyon damsite. Their work at Denali revealed potentially troublesome strata of fine sands and areas of permafrost in the foundation.

DEVIL CANYON SITE

SCOPE OF INVESTIGATIONS

In the spring of 1957, an exploratory program was initiated at Devil Canyon by the Bureau of Reclamation. Their objective was to explore the area in sufficient depth to provide adequate information for a feasibility report. Accordingly, 22 diamond-drill borings were drilled during the summers of 1957 and 1958. Additionally, 19 trenches and test pits were excavated to locate possible sources of concrete aggregate and embankment materials. Geologic mapping was done in 1957 by Mr. Kachadoorian from the U.S. Geological Survey. Mr. Kachadoorian also assisted in logging core and preparing the geologic report presented in 1958. Location of explorations are shown on Plate D-1 and logs of explorations are shown on Plates D-7 through D-10.

SITE GEOLOGY

The rocks which form the abutments at the Devil Canyon site are predominantly dark grey to black, fine-grained clastics of Middle Jurassic to Late Cretaceous age. These phyllites are massive with prominent cleavage, and contain numerous quartz stringers. Calcite filling in the incipient fractures is common and assemblages of other rocks and minerals may occasionally be seen. The river is deeply entrenched in a narrow canyon with nearly vertical walls. Bedding of the country rock dips 56 to 70 degrees to the south. There are three sets of joints in the damsite area, one of which is well developed, with an average strike of N25^{O}W and a dip varying from vertical to 80^{O}E. Average spacing of these joints is four to five feet. The other two joint sets are poorly developed and tight. Several narrow faults can be seen in the canyon walls, some gouge filled. However, the frequency and magnitude of these zones is not considered to be a critical factor in the evaluation of the site.

GEOLOGY OF FEATURES

Main Dam: The rock competency at Devil Canyon damsite generally is favorable for the construction of a high concrete arch dam. The exact rockline underneath the river has not been established, but it is believed that approximately 35 feet of alluvial materials overlie bedrock in the channel area. Angle holes drilled from both sides of the river have revealed no major geologic problems, but dental work will be required in the shear zones that interlace both abutments, and grouting will be required to effectively seal the foundation.

Powerhouse: Topographic, geologic, and climatic conditions all favor an underground powerhouse. Geologic conditions indicating desirability of an underground structure include the restricted topography, the need for extensive scaling, and protection from future rockfalls if an external powerhouse were constructed, and the unusual competency of the rock. This high quality of the abutment rock will greatly reduce the amount of roof and wall support required; however, certain faults and fractures will require remedial treatment, such as rock bolts and mine ties. Explorations for the underground workings will require deep drilling and the possible use of a pilot tunnel to completely investigate the potential roof and wall support as well as any latent geologic problems.

Left Abutment: The most critical geologic problems occur on the south side of the canyon wall. The overhanging cliff formed by the southerly dipping beds has, in some cases, resulted in large blocks separating from the adjacent bedrock. Minor faulting has resulted in zones of sheared and broken rock. The sheared rock is not well healed, and extensive fracturing with open crevices is common. However, pressure tests in exploratory drill holes did not, in general, result in heavy water losses. It is estimated that between 35 and 50 feet of loose and weathered rock will have to be removed before firm rock is reached. It will not be possible to obtain a smooth excavation surface because of the blocky and overhanging nature of the formation; therefore, extensive dental work may be required. Tendons may also be required to anchor the thrust block to the foundation rock.

Left Abutment Saddle Dam: Drill holes in the area of the earth and rockfill saddle dam at the left abutment have disclosed a deep buried channel striking east and west. The maximum depth of the valley fill in this channel is approximately 90 feet. The fill material is composed primarily of well consolidated outwash, and continuous strata of pervious materials are probably present. Approximately 10 feet of moraine covers the outwash material and may form a moderately impervious blanket. However, it will be necessary to effectively seal the foundation materials under the saddle dam or excavate the outwash and carry the impervious section of the dam to bedrock.

Right Abutment: The structural attitude of the bedding planes on the right abutment is approximately N70°E in strike and 60°E in dip. This attitude is favorable to shaping for the arch dam. However, the configuration of bedding attitude and canyon alinement may result in the bedding planes corresponding rather closely to the theoretical shearing plane formed by the arch thrust at the abutment. To compensate for this condition, the arch should be keyed deeper into the abutment rock, and rock reinforcement may be required. The abutment is intersected by shear zones striking almost normal to the stream, but only thin seams of gouge are evident, and the joints on this side of the canyon appear well healed. Considerable scaling may be required to protect the excavation from rockfalls.

Penstock, Tailrace, and Diversion Tunnels: As presently planned, the underground powerhouse, penstocks, and tailrace tunnels will be located in the right abutment. Drilling done in this area indicates that the rock tightens with depth and that fracturing decreases. Prior to final design, extensive drilling will be required to determine extent of jointing and fracturing, and areas requiring steel supports or rock bolting. The diversion tunnel will be located in the left abutment. Because of the several well-developed shears on this side of the river, the tunnel will be concrete lined.

SEISMOLOGY

As previously noted, 262 earthquakes have been recorded within 150 miles of Devil Canyon damsite. Of these, two have been greater than 7.75 M.; one occurred in 1928 about 100 miles south of the damsite, and the other was the Alaska earthquake of 1964, whose epicenter was located approximately 130 miles southeast of Devil Canyon. There were 42 earthquakes with epicenters within 50 miles of the damsite; 39 had a magnitude of less than 5.3; 2 were between 5.3 and 5.9, and the other was above 6 M. Eleven earthquake epicenters have been located within 25 miles of the damsite. Of these, nine had magnitudes less than 5.3; one was between 5.3 and 5.9, and on 3 July 1929, one occurred on the Talkeetna River, 25 miles from the damsite, with a magnitude of 6.25. Hypothetical earthquakes considered for Devil Canyon by the Bureau of Reclamation in selecting a Maximum Probable Earthquake were a magnitude 8.5 earthquake at 40 miles, and a magnitude 7.0 earthquake at 10 miles. The 8.5 M. at 40 miles was determined to be the MCE (Maximum Credible Earthquake).

CONSTRUCTION MATERIALS

Material Requirements: Concrete:

Aggregate Sources: Material requirements for Devil Canyon Dam are based on the Bureau of Reclamation's proposed double curvature thin-arch dam and underground powerplant. In this scheme, approximately 1.1 million cubic yards will be mass concrete in the dam, and 100,000 cubic yards will be structural concrete in the appurtenant structures, including the powerplant. With some allowances for stockpile loss, this amount of concrete will require approximately 1.25 million cubic yards of processed aggregate.

The Bureau of Reclamation located an extensive deposit of material which will yield concrete aggregate of adequate quality in a fan approximately 1,000 feet upstream of the proposed dam axis. The fan was formed at the confluence of Cheechako Creek and the Susitna River. The lower portion of this fan, up to about elevation 1,000, is relatively level, except for steep banks along the river's edge. Above elevation 1,000, the level ground breaks into a series of benches and ridges with hummocky surfaces.

Thirteen test pits and trenches were completed in the fan area by Bureau of Reclamation personnel in 1957. Of the 13 test pits, 5 were logged and 4 were sampled. A total of 1,262 pounds of minus-3-inch material was shipped to the Bureau of Reclamation, Division of Engineering Laboratories, Concrete Laboratory Branch (since changed to Division of General Research, Concrete and Structural Branch), for basic aggregate suitability studies. An additional 200 pounds of material has since been obtained by Corps of Engineers personnel for additional testing to confirm suitability.

Additional granular materials can be obtained in the Cheechako Creek terraces. The Cheechako Creek fan and adjacent terraces should yield an ample quantity of aggregate for a thin-arch dam, underground powerplant, and appurtenant structures.

Results of Investigations: The area sampled by the test pits is estimated to contain approximately 6 million cubic yards of material of which approximately 50 percent is smaller than 6 inches. This quantity is based on excavation of material to the present river level; therefore, placement of the coffer dam and the capacity of the diversion tunnel will ultimately affect the exploitation of the fan area as an aggregate source. The locations of test pits are shown on Plate D-1, and the detailed logs of test pits K-6, K-19, K-21, K-93, and K-94 can be found in the U. S. Bureau of Reclamation's Alaska Geologic Report No. 7, Devil Canyon Project, dated March 1960. The results of laboratory investigations of the aggregate samples were reported in Report No. C-932 by the Concrete Laboratory Branch (now the Concrete and Structural Branch), dated 31 December 1959.

Tests were run on a composite sample from trench K-6 and K-19, and a second composite sample from trench K-21 and K-93. Depths of overburden on these trench locations ranged up to 2-1/2 feet. The ground surface in the fan area is covered with scrub spruce and brush.

The gravels in the fan are composed of quartz diorites, diorites, granites, andesites, dacites, metavolcanic rocks, aplites, breccias, schists, phyllites, argillites, and amphibolites. The sands are composed primarily of the same rock types present in the gravel. The gravel particles are stream worn and generally rounded in shape. The sand grains vary from nearly rounded to sharply angular in shape, averaging subangular.

These aggregates meet usual specifications requirements for physical properties and soundness. However, the freeze-thaw resistance of concrete containing this aggregate was considered marginal by Bureau of Reclamation criteria for use in severe climates.

The general conclusion is that serviceable concrete can be manufactured from the fan aggregate source if air content and gradation are closely controlled.

Material Requirements: Embankment:

Material Sources: Approximately 900,000 cubic yards of embankment materials will be required for the left abutment saddle dam. This will include impervious core materials, sand and gravel filters, gravel or rockfill shell materials, and riprap for slope protection. Sand and gravel for filters can be obtained by selective processing of the moraine and outwash deposits. If design considerations favor the use of gravel rather than rock for the shell sections, adequate quantities are available in the deposits previously discussed. Rockfill and riprap in the quantities required can be obtained from abutment preparation, diversion tunnel, penstock tunnels, and powerhouse excavation, or from extensive talus deposits which exist along the river's edge. Considerable boulder-size material is also to be found in the outwash deposits. The required impervious core material will be obtained from moraine deposits at the higher elevations or by blending the silts stripped from the aggregate source with sandy gravels.

WATANA SITE

SCOPE OF INVESTIGATIONS

Initial investigation at Watana damsite was limited to field reconnaissance by personnel of the Bureau of Reclamation during the period between 1950 and 1953. This reconnaissance was undertaken as a part of the investigation of the Susitna River and the formulation of an ultimate development plan as presented in the report Potential Development of Water Resources in the Susitna River Basin of Alaska, August 1952. At the time the site was examined, a profile of the dam centerline, as proposed, was made by transit-stadia methods, and an estimated geologic section was drawn to indicate probable excavation requirements. The Bureau's report was favorable and indicated that no adverse conditions were observed. Studies of recent aerial photographs and field reconnaissance supported this view, and it was felt that the knowledge of regional and site geology was adequate to warrant recommendation of Watana as a favorable site. To insure that this recommendation was founded on a broad base of professional experience, corroborative opinions were sought from a team of engineers consisting of personnel from the Soils and Geology Branch of OCE, the Soils and Geology Section of North Pacific Division, and the Foundation and Materials Branch of the Alaska District, Corps of Engineers. They visited the site in June 1975, and their findings served to verify the Bureau's opinion that the site is a viable damsite. However, an area on the right bank, approximately 1/2-mile upstream of the dam, may require remedial treatment due to the existence of a deep glacial deposit. The extent of the deposit was explored under a seismic exploration contract during the fall of 1975. The work was accomplished by Dames and Moore, Consultants in Environmental and Applied Earth Sciences, and their report is included as Exhibit D-1 of this section.

SITE GEOLOGY

The proposed site for the Watana Dam is located at river mile 165 in an area where the river has eroded a channel through a sound, hard, coarse-grained granitic formation. The river valley has been carved to form a rather broad U-shaped canyon with fairly steep walls. Though no subsurface explorations have been done at this site as yet, it has been carefully examined surficially, as discussed in the previous paragraph, and is considered to be an excellent choice from a geologic point of view. The characteristic weathering of the granite will necessitate removal of sufficient material to expose sound foundation rock, but no serious structural defects have been observed at the dam axis. The depth of weathering is estimated to vary from 0 to 10 feet on the canyon walls. Depth to bedrock in the river channel is in the order of 60 to 70 feet. The country rock is broken by numerous near-vertical fractures which trend N30^{o}W. These dominant features can be seen in the canyon walls. They tend to break the area into large monolithic fins, some 20 to 70 feet thick. No zones of fault breccia or gouge have been observed; however, topographic expression indicates such zones should occasionally be expected.

GEOLOGY OF FEATURES

Powerhouse: Subarctic weather and environmental concerns favor the use of an underground powerhouse. The narrow Susitna canyon with its steep walls lends itself well to this type of structure. The granitic rock is expected to be competent at the depths of the underground features. Seismic velocities tend to confirm this conclusion. Probably the most important geologic feature at the site is the fracture pattern which trends N30^{o}W. Insofar as it is possible, the powerhouse will be oriented to minimize the impact of the fracture system. Pattern rock bolting is planned for the crown of the chamber. Use of remedial concrete is anticipated in some areas where fallout may occur or in fracture zones having a substantial width of crushed rock. Minor fracturing will require occasional use of rock bolts, mine ties, and wire mesh.

Spillway: Approximately 1/2-mile upstream of the damsite, a relatively low saddle between the north valley wall and Tsusena Creek provides a favorable location for a channel-type spillway. Extending northward from this saddle to the foot of Tsusena Butte is a terrace composed of glacial till, some of which has been reworked by alluvial action. An impervious cutoff may be necessary in this area to insure positive protection against seepage. Cost of this remedial work is included in the estimates for the project.

Access Road: Approximately 64 miles of access road will be required between the existing Parks Highway and Watana damsite. This road will pass through the Devil Canyon damsite area and will subsequently serve as an access road for exploration and construction at Devil Canyon. Foundation materials will include stretches of bedrock and high terrace deposits, as well as swamp and muskeg. The latter will require removal and replacement, or other special techniques, and should, in general, be avoided where possible. Steep north-facing slopes along the canyon rims should also be avoided since permafrost would be encountered in the area and would undoubtedly create stability problems. Every attempt should be made to locate the road, insofar as it is possible to do so, on bedrock or granular materials to minimize problems of frost heave, settlement from degrading permafrost and ice lenses, and slope instability. Several bridges will be required, but excellent foundation conditions are expected since bedrock is usually exposed on the walls of the steep gorges.

Reservoir: Watana reservoir includes areas of intermittent permafrost. This is particularly true of north-facing slopes and, where present, the permafrosted overburden mantle assumes a steeper angle of repose than would normally exist. It is to be expected that as the reservoir is filled and the permafrost degrades, some slumping of natural slopes will occur. These slumps or slides will be minimal in their effect on the reservoir. The lower elevations of the canyon where slumping would occur are characterized by very light overburden covers. Above these rocky walls, the valley flattens abruptly into the high terraces of glacial deposits where stable slopes generally exist.

SEISMOLOGY

Seismic conditions at Watana are very similar to those at Devil Canyon. The Denali Fault to the north is equidistant from Devil Canyon and Watana, and is probably of major significance in selection of a Maximum Credible Earthquake for Watana site. However, the Susitna Fault is only 2-1/2 miles to the west, and must be considered as a source of seismic activity. Its influence, due to its proximity, might, on examination, prove to be more critical to the site than the more active but more distant Denali Fault. Studies are presently being conducted with the assistance of the USGS and the University of Alaska Geophysical Instutute to further define the seismic characteristics of the Susitna Fault to establish a MCE for the Watana site. A preliminary report by USGS is included as Exhibit D-2 of this section.

CONSTRUCTION MATERIALS

Material Requirements: Concrete:

Aggregate Sources: Concrete quantities for Watana Dam will range from 200,000 cubic yards or less, if the proposed earth or rockfill dam is used, to approximately 6.5 million cubic yards for a concrete gravity structure. Information on the quantities and quality of possible aggregate sources is very limited. In a report dated 1952, the U.S. Bureau of Reclamation mentioned the availability of hard, dense, and durable concrete aggregate in the form of stream gravels both upstream and downstream of the proposed damsite. During the June 1975 field reconnaissance by Corps of Engineers personnel, the gravel deposits were examined, and samples were taken to confirm their suitability. If a concrete gravity structure is recommended, a processing plant can be constructed in the reservoir area for processing the required aggregates.

Material Requirements: Embankment: Approximately 52,630,000 cubic yards of embankment materials will be required to construct an earthfill dam at the Watana site. Of this amount, approximately 42,000,000 cubic yards will be required for the main shell sections of the dam. These shell sections can be built from the clean gravels on the terrace along Deadman Creek and from channel excavation. Riprap can be obtained from spillway excavation and rock spalls, and rock drain material can be obtained from excavation of the diversion tunnel and underground features of the dam. Sand and gravel filters and select drain material can be obtained by processing terrace deposits or gravel bars within the river channel. Impervious core material can be obtained by selecting and processing glacial till deposits found along the upper levels of the south valley wall.

During the reconnaissance of the Watana area in June 1975, 500 pounds of samples were taken for testing from these recommended sources.

VEE CANYON SITE

SCOPE OF INVESTIGATIONS

During the period from 1960 to 1962, the Bureau of Reclamation conducted field studies at Vee Canyon. In all, 13 holes were drilled for a total footage of 1,646 feet. Sixteen dozer trenches were made in the area to evaluate in-place materials. Locations of explorations are shown on Plate D-4, and logs of explorations are shown on Plates D-11 through D-14.

SITE GEOLOGY

Vee Canyon site is located in the extreme northeastern section of the Talkeetna Mountains. The Susitna River has cut down through the overlying sediments and eroded a deep, steep-walled, V-shaped canyon into hard crystalline rock. The canyon walls rise some 800 feet above the river, and the exposed rocks are predominantly fine to medium-grained gneiss with some schistose zones. The gneiss is thought to be the result of contact metamorphism after the intrusion of the great granitic batholith which formed the Talkeetna Mountains. The rocks are, in general, fresh to lightly weathered, and highly to moderately jointed.

GEOLOGY OF FEATURES

Main Dam: On the right abutment near the proposed axis, the rock outcrops rise from the river (elevation 1895), to a maximum elevation of approximately 2600 feet. The rockline gradually drops in elevation both upstream and downstream. Rock quality is good, but large quantities of loose rock and extensive talus at the base of the canyon wall will require removal. Foliation is roughly east-west, and oversteepening or undercutting foliation planes could result in slides along shear zones which are generally parallel to the foliation. Deposits in the bottom of the river channel are estimated to be 125 feet deep.

Left Abutment Saddle Dam: Near Vee Canyon, the glaciation formed a broad U-shaped valley about 6,000 feet wide. Glacial outwash and stream sediments from adjacent mountain areas filled the valley with drift which was once on the order of 800 feet thick. Subsequent stream erosion generally has followed the old valley and has removed much of the drift. At Vee Canyon, the river has left the old channel and is now entrenched for a distance of 7500 feet in hard metamorphic rock at the north side of the partially "buried" glacial valley. In the area where the left abutment saddle dam crosses this old buried valley, the ancient thalweg (or valley axis line) is at a lower elevation than the rock beneath the Susitna River in its present channel. Construction problems at the saddle damsite would be directly related to the buried channel.

Partially frozen, stratified drift estimated to be in the order of 400 feet thick underlies the saddle dam. Silts and sands are most common with lesser amounts of gravel and clay. Part of the foundation upstream may rest on terrace material of crudely stratified cobbles, gravel, and sand. Permafrost is present with the temperatures in the frozen mass so close to the melting point that stripping of the muskeg cover promotes thawing and mudflows. However, where drainage is provided by ditches, the material will drain and stabilize. Extensive foundation excavation or other measures to prevent seepage beneath the saddle dam would be required.

Underground Powerhouse: Present proposals for a dam at Vee Canyon include an underground powerhouse, as well as power and spillway tunnels, in the left abutment. It is anticipated that much of the excavation would be in sheared and highly jointed rock, and that steel supports would be required throughout. Where conditions are favorable, systematic rock bolting in conjunction with wire mesh may be used instead of the steel supports.

CONSTRUCTION MATERIALS

Material Requirements: Concrete:

Aggregate Sources: Concrete quantities for Vee Canyon Dam are based on a rockfill dam with concrete spillway and outlet works to include intake structures, stilling basins, and control structures. Concrete quantities are estimated at 100,000 to 150,000 cubic yards, most of which will be structural concrete.

Concrete aggregates may be obtained from the river channel deposits and sand and gravel bars of the Susitna River. The alluvium in the channel and bars contains stream-worn boulder- to sand-size detritus. The detritus is unsorted, subrounded to subangular, and mostly in the 2- to 12-inch size range. Cobbles and boulders to 4 feet in diameter were observed in the river channel during periods when the silt content was at a minimum. Rock varieties include coarse- to fine-grained granitic types, greenstone, gneissic metamorphics, and other dense, fine-grained metamorphics. The sand content is clean and is composed of angular, medium- to fine-grained quartz, and gray to black lithic grains. A second possible source of concrete aggregate lies in two distinct river-cut terraces in the reservoir area about 2000 feet east of the saddle dike site. Three trenches were cut across the banks of these terraces, and exposed crudely stratified pervious cobble gravel and sand with some boulders. The maximum boulder size is 1-1/2 feet, with about 20 percent being larger than 6 inches. An estimated 50 percent is between 6-inch to 1/4-inch size and the remaining 30 percent is less than 1/4-inch. The material is generally well graded and composed of subangular to subrounded metamorphic and igneous rock types. The sand tends to be heavy in the medium- to coarse-grain sizes and is partly silty and clayey. Permafrost may be encountered in the main body of the terraces. The amount of available material was conservatively estimated to be 2 million cubic yards by Bureau of Reclamation personnel.

Scope of Investigations: Material in the river-cut terraces and adjacent glacial valley on the left abutment was sampled by dozer trenches and by a number of random hand-dug pits three feet deep. The material encountered in the glacial valley is silty sand, with some gravelly sand, with gravels ranging to 2-inch maximum size. Materials from these areas were forwarded to the U.S. Army, Corps of Engineers, Alaska District, for an elementary petrographic description. The materials were found to be predominately quartz, feldspar, mica, and other materials, with weathering and alteration ranging from moderate to advanced. No other aggregate suitability tests were run.

Material Requirements: Embankment: Impervious core materials as well as sand and gravel filters may be obtained by selection from the glacio-fluvial deposits in the proposed reservoir area and on the slopes of the glacial valley south of the saddle damsite. Three general areas were sampled and the materials were tested in the Bureau of Reclamation laboratory at Denver, Colorado. Complete test results are available in the Bureau report, Engineering Geology of the Vee Canyon Damsite, November 1962. While explorations were not sufficiently complete to delineate specific borrow areas, the exploratory work and the test results showed that very large quantities of pervious to semi-pervious material can be obtained close to the damsite and in the reservoir area to the east. Rockfill and riprap may be quarried from selected zones in the gneiss upstream from the damsite. Rock from required excavation can also be incorporated into the fills.

DENALI SITE

SCOPE OF INVESTIGATIONS

During the summer of 1958, an engineering geology study of the Denali damsite area was conducted by the Bureau of Reclamation. The primary purpose was to make a surficial geologic map and to report on the character and properties of the materials. During the fall of 1958 and the summer of 1959, 5 holes were drilled on the damsite, and 14 test pits and trenches were excavated at the site and in potential borrow areas within reasonable haul distances. Samples from the test pits, outcrops, and talus deposits were shipped to Denver for testing. Location of the explorations and logs is shown on Plate D-5, and detailed logs are shown on Plates D-15 and D-16.

GENERAL GEOLOGY

The Denali damsite lies in a broad glaciated valley some 40 miles downstream of the glaciers at the headwaters of the Susitna River. The advances and recessions of these glaciers in geologic history have filled the valley to an unknown depth with glacial debris. Except for the mountains north of the Paxson-Cantwell Highway, the only rock outcrop in the area is in a small knob approximately 8000 feet downstream from the investigated site.

SITE GEOLOGY

Present Site: The most critical geological factors at the present damsite are: (a) permafrost in both abutments; (b) pervious sand and gravel strata in the right abutment; (c) low density fine-grained sands in the river section, which may be subject to liquifaction; (d) occasional layers of compressible silts in both abutments. Melting of permafrosted materials following reservoir impoundment could lead to instability of abutments and foundations. In addition, the severe design earthquake (magnitude 8.5 at 40 miles) could liquefy the unfrozen abutment and foundation materials. Because of the suspect stability, both static and dynamic, of the site, it is not considered to be a feasible damsite at this time.

Alternative Site: The alternative site mentioned by the Bureau of Reclamation in their report was examined by the Corps of Engineers during the reconnaissance trip of June 1975. Particular attention was directed toward the right abutment, which appeared to present the more serious problems. No signs of rock outcrops could be found, but evidence of deep permanently-frozen sands and glacial deposits was abundant. It was the opinion of the group that serious foundation problems existed at both sites; however, the original site explored by the Bureau was the better of the two sites.

CONSTRUCTION MATERIALS

Material Requirements: Concrete:

Aggregate Sources: Concrete quantities for Denali Dam are based on an earthfill dam with concrete spillway and outlet works to include intake structures, stilling basins, and control structures. U.S. Bureau of Reclamation estimates for Denali Dam include approximately 125,000 cubic yards of concrete. Concrete aggregates may be obtained from end moraine deposits and gravel alluvium. These materials are all available in the vicinity of the damsite and in the bed of Corset Creek, which flows into the Susitna River, approximately 6,000 feet downstream of the present damsite and 2,000 feet upstream of the rock outcrop, which is considered the most likely location for an alternative damsite.

Scope of Investigations: Test pits and trenches were excavated in the end moraine material at the presently explored damsite and along the approximately 8-mile-long access road from the damsite to the Denali Highway. These test pits revealed a material consisting of sandy till with unsorted rocks. The till is composed of less than 10 percent silt, 50 to 70 percent sand, and about 30 percent pebbles, cobbles, and boulders. Occasionally, the rock fragments may constitute 50 percent of the deposit.

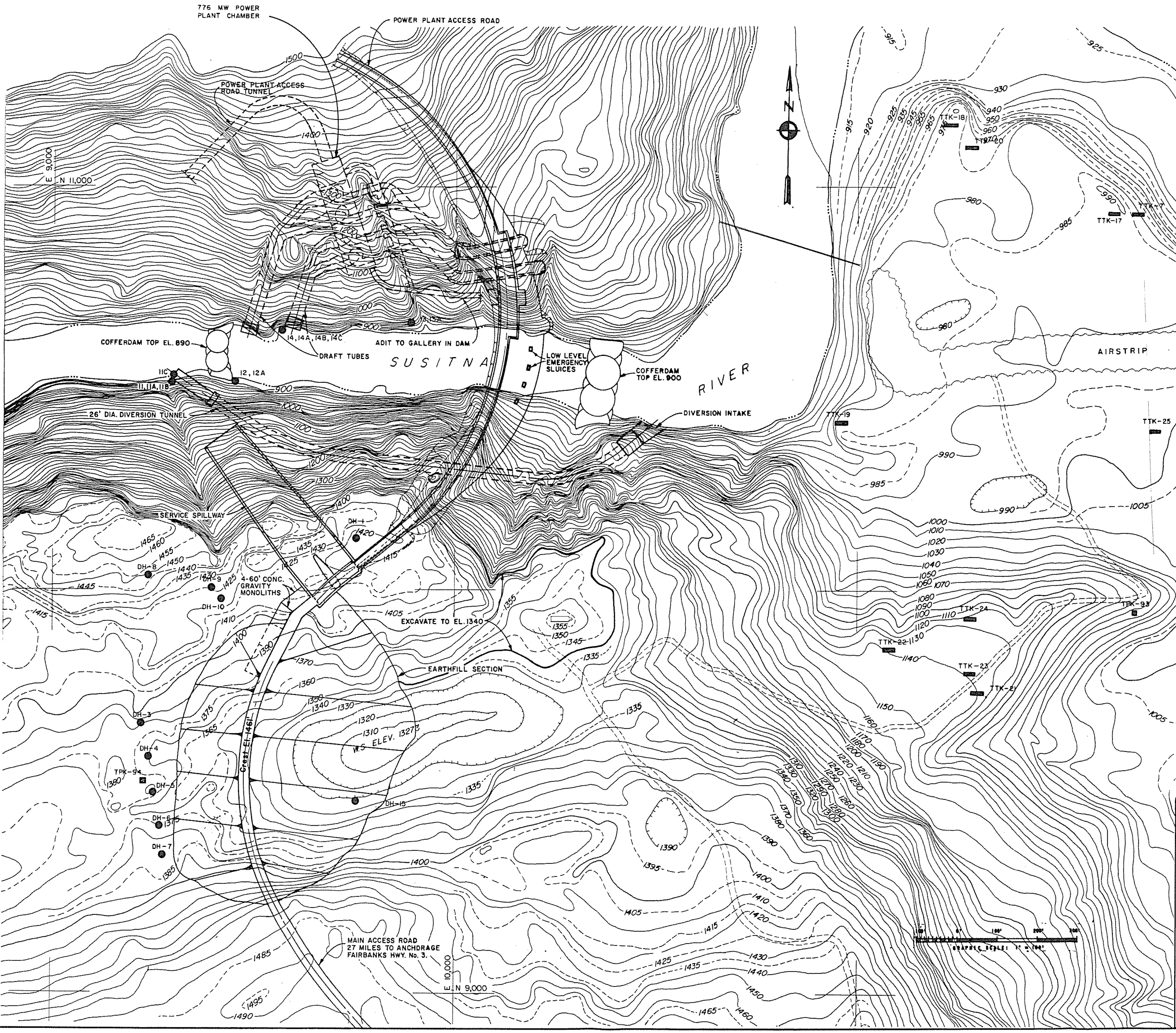
Terrace deposits along the shores of the Susitna River and Corset Creek primarily consist of rounded to subrounded pebbles and cobbles up to 6 inches in diameter in a matrix of coarse sand.

Gravel alluvium underlies the channel and flood plain of Corset Creek. The deposits are composed of interfingering lenses of clean pebble-cobble gravel, sandy pebble-cobble gravel, and minor amounts of sand and silt. The average grain size decreases with increasing distance from the foothills or from the end moraine complex. The surface commonly is mantled with a few inches to one foot of silt. Samples from the test pits in the end moraine were tested in the U.S. Bureau of Reclamation's Denver Soils Laboratory for suitability as fill. A possible source of riprap located downstream of the present damsite was examined and sampled. Petrographic examinations were completed on samples of the end moraine and the riprap sources.

Results of Investigations: Petrographic examinations of the sands in the end moraine from two of the test pits show the material to be composed of phyllites, argillites, shale, and a few altered andesites and basalts. Very small amounts of quartzite, chert, and opal were also found. The sands sampled would produce concrete aggregates of fair to poor quality.

The sample of the rock outcrop near the mouth of Corset Creek was examined petrographically and found to be a meta-andesite of satisfactory quality for use as coarse concrete aggregate.

Material Requirements: Embankment: Approximately 12,000,000 cubic yards of embankment materials would be required for Denali Dam. In general, there appear to be sufficient and suitable pervious embankment materials available in moraine and outwash deposits near the site. Also large terrace deposits are available for pervious embankment materials. Filter materials may also be obtained by selection and processing of terrace deposits. The primary difficulty will be to locate suitable and adequate quantities of impervious material for the dam core. Very little clay occurs, and many of the fine-grained deposits have a high moisture content and are permafrosted. If the morainal deposits are processed for pervious material, costs will be high. However, some of the oversize material recovered would be suitable as riprap. The additional riprap required could be obtained from excavation of the rock outcrop near Corset Creek or from talus deposits near the Denali Highway.



NOTES:

DH – COMBINATION CORE & DRIVE SAMPLE HOLE.
TTK – DOZER TRENCHES FOR MATERIAL EXPLORATION.
TPK – HAND DUG TEST PITS

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

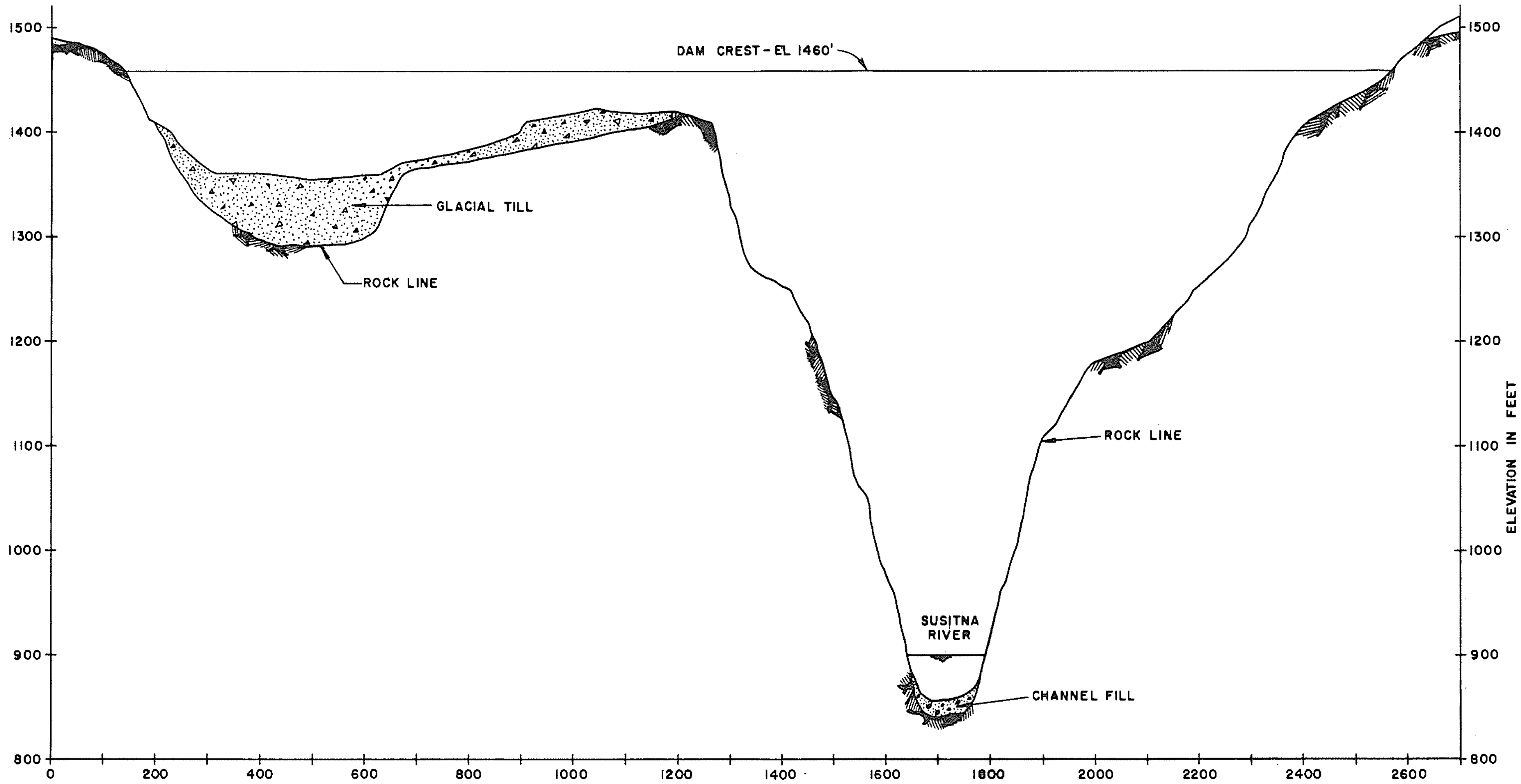
DEVIL CANYON

SITE PLAN & EXPLORATIONS

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975



CROSS SECTION - DEVIL CANYON

LOOKING DOWNSTREAM

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

DEVIL CANYON

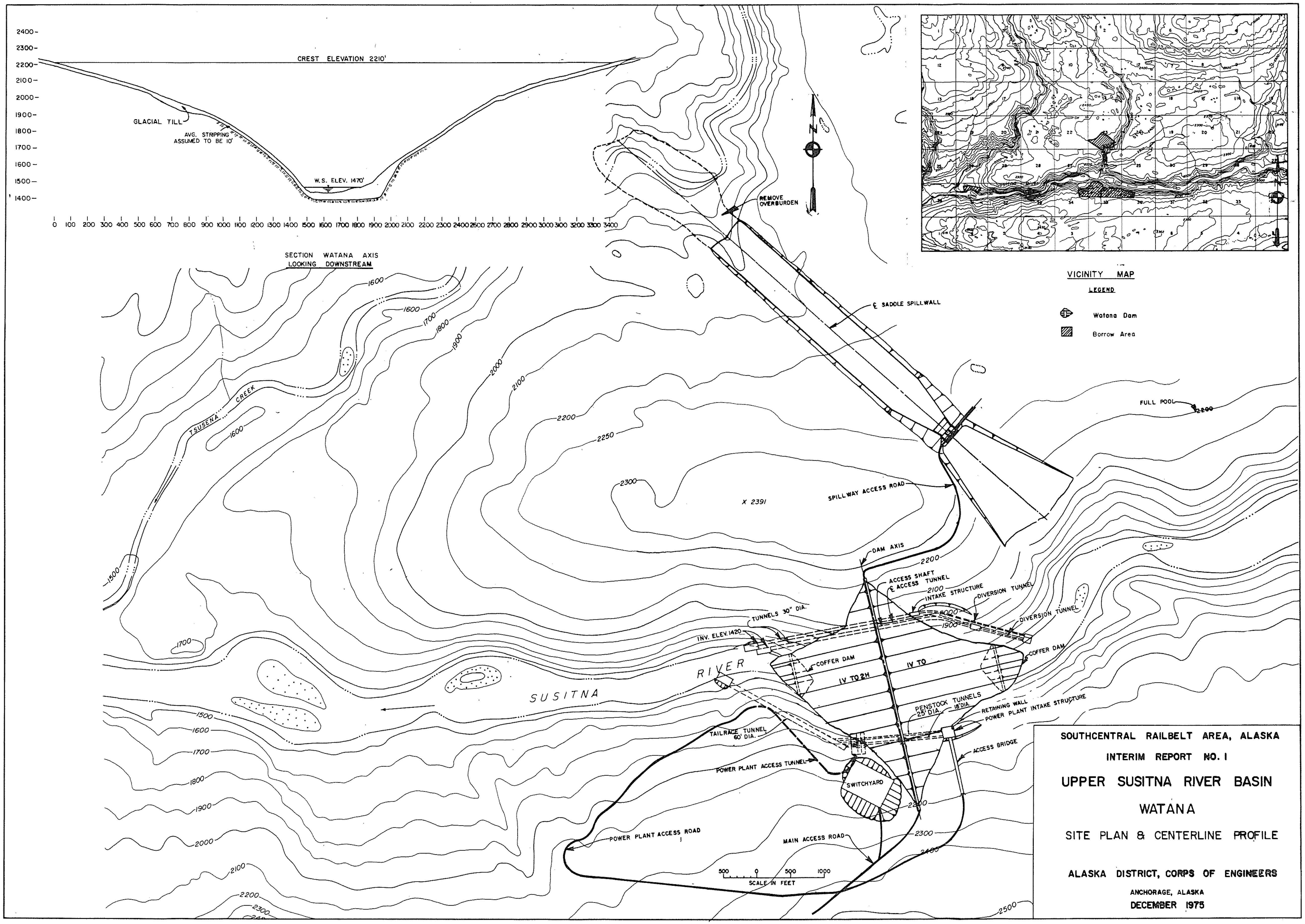
CENTERLINE PROFILE

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

FILE NO. 2-SOU-92-04-01 APPENDIX I PLATE D-2



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

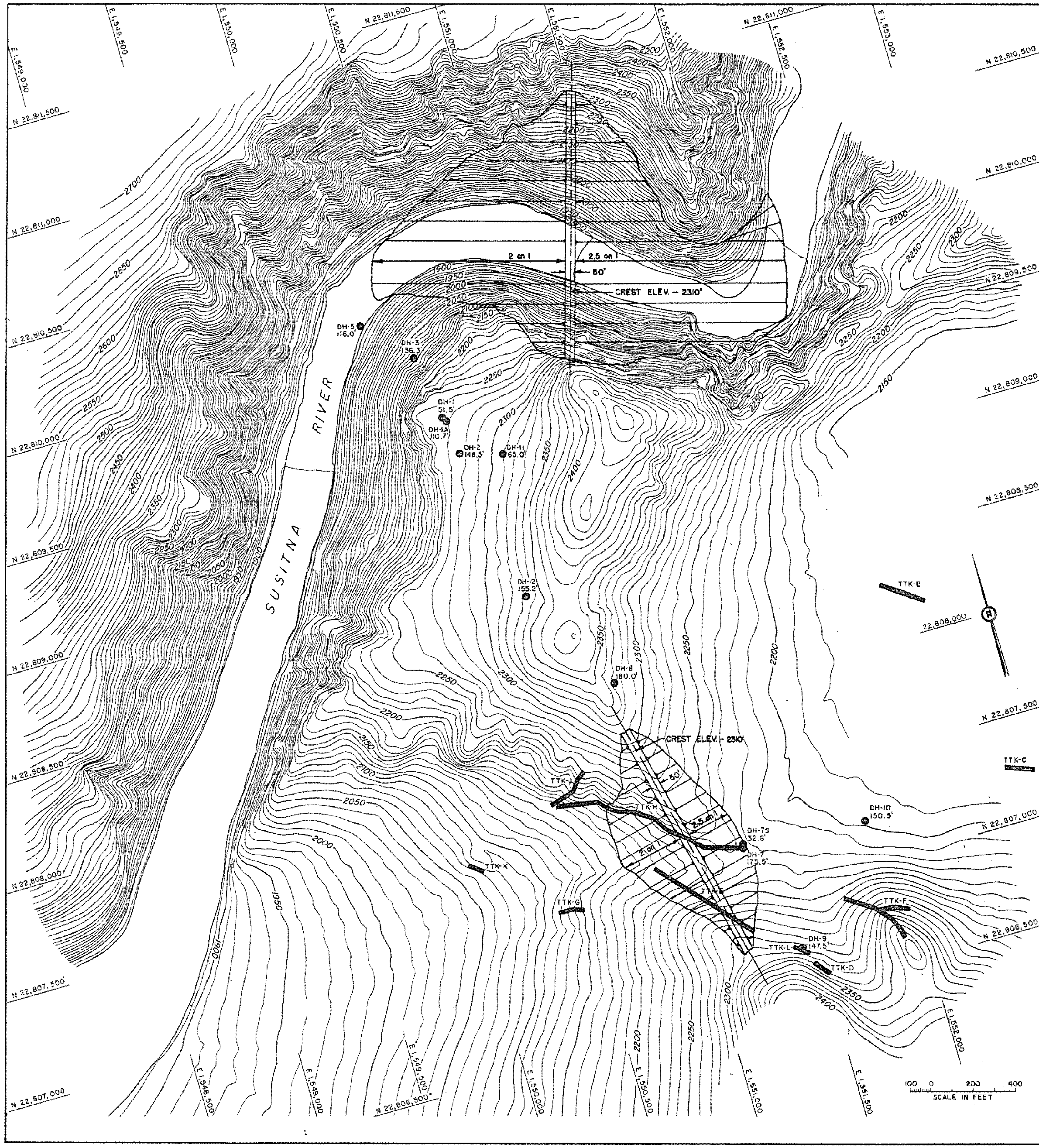
WATANA

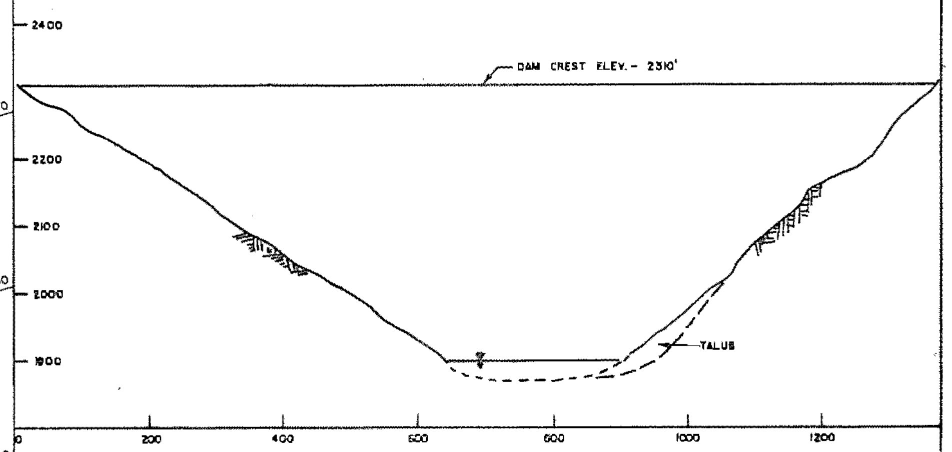
SITE PLAN & CENTERLINE PROFILE

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975





CENTERLINE PROFILE

LEGEND

DH-2 175.5' — DRILL HOLE AND DEPTH

TTK-H — DOZER TRENCH

NOTES

1. CONTOUR INTERVAL 10'

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN

VEE CANYON

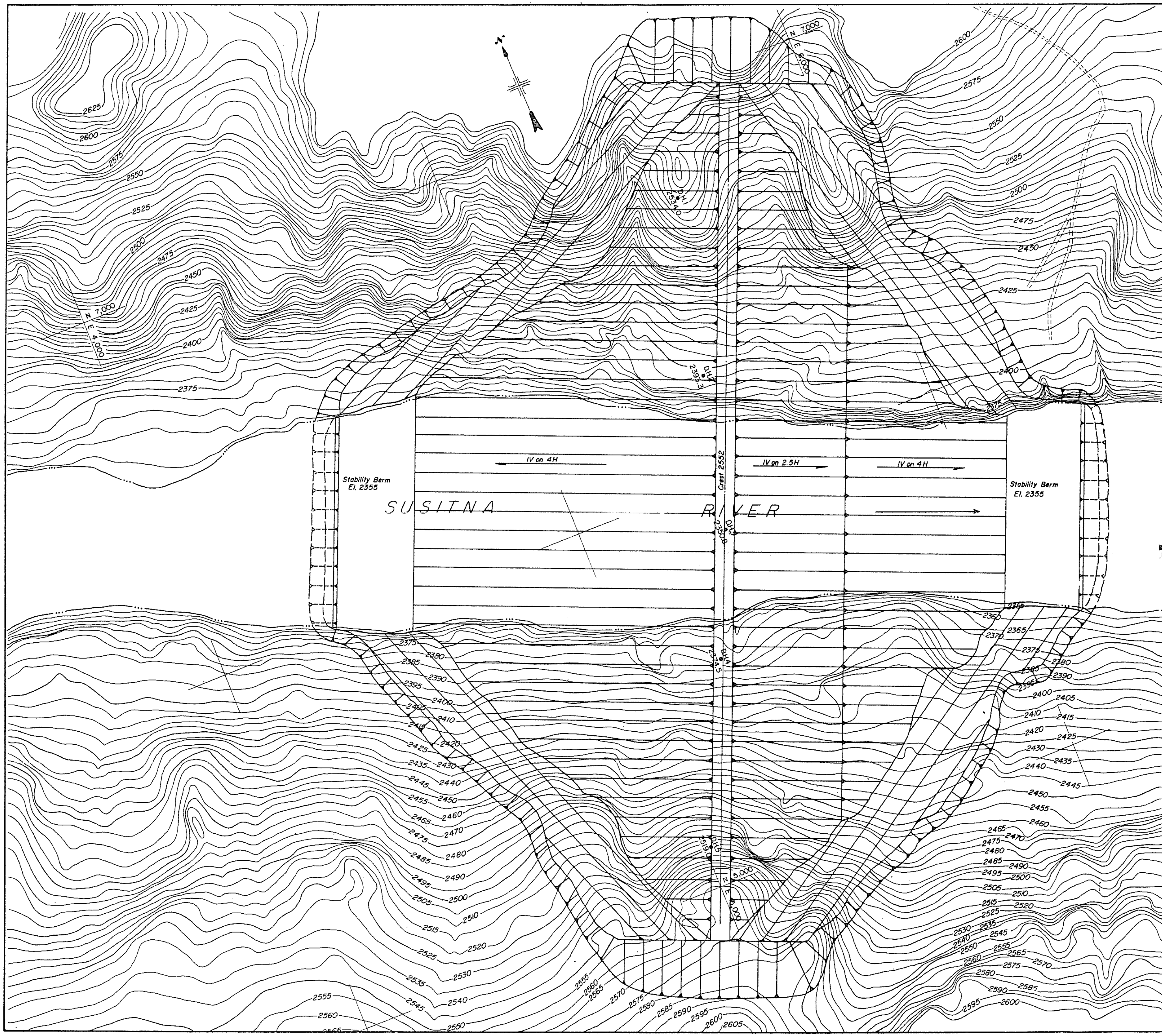
SITE PLAN & CENTERLINE PROFILE

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

FILE NO. 2-SOU-92-04-01 APPENDIX I PLATE 04



SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

DENALI — UPPER SITE

SITE PLAN

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SUMMARY LOG — HOLE NO. 1 (SHEET 1 OF 2)

SUMMARY LOG HOLE NO. 1	N 10,138.1 / E 9,734.4	SHEET 1 OF 2 / SURFACE ELEV. 1419.7
PROJECT Devil Canyon	DRILL DATES: START 4 Jun 57	COMP. 18 Jun 57
DEPTH OF HOLE 117.3'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX
ROCK DRILLED 117.3'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 157°30'	COMPILED BY, DATE
DISTANCES: VERTICAL, 82.9'; HORIZONTAL, 82.9'		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1419.7	0		Phyllite		Not Cored
			Phyllite, moderately weathered, considerable staining on joints, high quartz content		Pressure Tests: 5.2' to 15.2' 15.0 gpm loss @ 50 psi 24.0 gpm loss @ 100 psi 14.2' to 24.2' 22.0 gpm @ 50 psi 27.0 gpm @ 100 psi 17.0'
140 .7			Phyllite, lightly weathered, high quartz content		25.9' to 35.9' 7.5 gpm @ 50 psi 11.0 gpm @ 100 psi
					35.2' to 45.2' 11.0 gpm @ 50 psi 16.0 gpm @ 100 psi
					45.0' to 55.0' 15.5 gpm @ 50 psi 20.5 gpm @ 100 psi
			Very little quartz 61.7' to 94.1'		56.7' to 66.7' 15.5 gpm @ 50 psi 22.5 gpm @ 100 psi
					65.5' to 75.5' 18.75 gpm @ 50 psi 21.0 gpm @ 100 psi
					74.1' to 84.1' 21.0 gpm @ 50 psi 27.5 gpm @ 100 psi
			94.1' to 111.5' Highly jointed, considerable staining with gouge.		84.1' to 94.1' 14.5 gpm @ 50 psi 18.75 gpm @ 100 psi
13 9.0	100				

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 1

SUMMARY LOG — HOLE NO. 1 (SHEET 2 OF 2)

SUMMARY LOG HOLE NO. 1	N 10,138.1 / E 9,734.4	SHEET 2 OF 2 / SURFACE ELEV. 1419.7
PROJECT Devil Canyon	DRILL DATES: START 4 Jun 57	COMP. 18 Jun 57
DEPTH OF HOLE 117.3'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX
ROCK DRILLED 117.3'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 157°30'	COMPILED BY, DATE
DISTANCES: VERTICAL, 82.9'; HORIZONTAL, 82.9'		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
13 9.0	100		Phyllite Highly broken 101.1' to 111.5' Water table 104.5' Core to 2.3' 111.5' to 117.3'		Pressure Tests: 96.2' to 106.2' 7.25 gpm @ 50 psi 10.5 gpm @ 100 psi 103.8' to 113.8' 7.25 gpm @ 50 psi 11.25 gpm @ 100 psi 107.3' to 117.3' 0.55 gpm @ 50 psi 0.85 gpm @ 100 psi
1336.9	120				117.3'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 1

SUMMARY LOG — HOLE NO. 3 (SHEET 1 OF 1)

SUMMARY LOG HOLE NO. 3	N 9,667.0 / E 9,223.6	SHEET 1 OF 1 / SURFACE ELEV. 1381.1
PROJECT Devil Canyon	DRILL DATES: START	COMP.
DEPTH OF HOLE N/A	DEPTH OF OVERBURDEN N/A	DIAM. OF HOLE N/A
ROCK DRILLED None	CORE RECOVERED None	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
			Hole was trenched for 15' north and south to expose phyllite at 1380 elev.		

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 3

SUMMARY LOG — HOLE NO. 4 (SHEET 1 OF 1)

SUMMARY LOG HOLE NO. 4	N 9,590.5 / E 9,236.0	SHEET 1 OF 1 / SURFACE ELEV. 1375.7
PROJECT Devil Canyon	DRILL DATES: START 10 Sep 57	COMP. 21 Sep 57
DEPTH OF HOLE 52.5'	DEPTH OF OVERBURDEN 24.7'	DIAM. OF HOLE NX
ROCK DRILLED 27.8'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1375.7			Overburden, reworked glacial till granite origin. Sandy till 17' to 21'. Highly compacted.		24.7' Cores to 1.0'
1351.0			Phyllite, lightly weathered. Jointing parallels bedding		Pressure Tests: 31.6' to 41.6' 0.55 gpm loss @ 25 psi 0.6 gpm loss @ 50 psi 42.5' to 52.5' 0.8 gpm loss @ 25 psi 0.95 gpm loss @ 50 psi 36.8'
			Meta-sandstone (?)		38.7'
	40		Phyllite, fine grained, dark grey to black, moderately hard. Bedding 45° to core axis.		Core to 2.0'
1323.2					52.5'

NPA Form 7(Text) APR. 66 — PROJECT Devil Canyon — HOLE NO. 4

SUMMARY LOG — HOLE NO. 5 (SHEET 1 OF 1)

SUMMARY LOG HOLE NO. 5	N 9,508.4 / E 9,248.5	SHEET 1 OF 1 / SURFACE ELEV. 1373.9
PROJECT Devil Canyon	DRILL DATES: START 25 Jul 57	COMP. 9 Aug 57
DEPTH OF HOLE 86.2'	DEPTH OF OVERBURDEN 55.5'	DIAM. OF HOLE NX
ROCK DRILLED 30.7'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1373.9			Overburden, Glacial Till. Wash Samples: 30.0' to 30.5' Medium sub-angular sand 75% quartz, 25% lithic fragments. 40.0' to 40.5' Medium sub-angular sand 75% quartz, 25% lithic fragments. 50.0' to 50.5' Medium to very coarse sub-angular sand 70% quartz, 30% lithic fragments		No Coring 55.5'
1318.4			Phyllitic quartzite (sic), medium dark grey, coarse grained (elongated parallel to bedding), moderately jointed		55.5' to 61.8' (?) slump block. 61.8' to 64.1' no core
			Phyllite, light to dark grey, banded moderately hard, fine grained 77.6' to 78.6'. Quartz vein 30° to axis, 85.0' to 85.4'. Partings along bedding avg. 1.0' 78.6' to 86.2'		Pressure Tests: 66.2' to 86.2' 1.05 gpm loss @ 50 psi 1.4 gpm loss @ 100 psi
1287.7					86.2'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 5

SUMMARY LOG — HOLE NO. 6 (SHEET 1 OF 2)

SUMMARY LOG HOLE NO. 6	N 9,426 / E 9,261	SHEET 1 OF 2 / SURFACE ELEV. 1370.1
PROJECT Devil Canyon	DRILL DATES: START 10 Aug 57	COMP. 26 Aug 57
DEPTH OF HOLE 107.3'	DEPTH OF OVERBURDEN 86.9'	DIAM. OF HOLE NX
ROCK DRILLED 20.4'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1370.1			Overburden. Glacial Till		
	20		20.0' to 21.0', sand poorly sorted, very coarse grained sub-angular. 50% quartz, 50% lithic and mafic fragement		
			30.0' to 30.5', Sand, well sorted, fine to medium grained, sub-angular to sub-rounded. 70% quartz, 30% lithic and mafic fragments.		
			40.0' to 50.0' Sand, same as 30.0' to 30.5'		
	40		50.0' to 50.2' Sand, poorly sorted, medium to coarse grained, sub-angular to sub-rounded. 60% quartz, 40% lithic and mafic fragments.		
			52.0' to 60.0' Sand, poorly sorted, coarse grained to granular (sic), angular to sub-rounded. 30% angular phyllite fragments, 30% sub-angular quartz, 40% phyllite granular fragments.		
	60		60.0' to 60.6', Sandy gravel, 40% sand, same material as 52.0' to 60.0'		
			60.6' to 63.0', Gravel, 10% sand, 70% sub-angular phyllite, 30% other sub-angular lithic fragments.		
			63.0' to 65.0'-phyllite boulders		
	70		65.0' to 68.0' Sand, poorly sorted, 60% quartz, 40% mafic and lithic fragments.		
			68.0' to 70.0' Gravel. Same as 60.6' to 63.0'		
	80		70.0' to 79.2' Sand, same as 65.0' to 68.0'		
			79.2' to 79.8' Fine grained granite boulder.		
			79.8' to 86.9' Sub-angular sand, gravel and talus.		86.9'
1283.2	90		Phyllite, dark grey, highly fractured, moderately hard w/gouge		
1270.1	100				

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 6

SUMMARY LOG — HOLE NO. 6 (SHEET 2 OF 2)

SUMMARY LOG HOLE NO. 6	N 9,426 / E 9,261	SHEET 2 OF 2 / SURFACE ELEV. 1370.1
PROJECT Devil Canyon	DRILL DATES: START 10 Aug 57	COMP. 26 Aug 57
DEPTH OF HOLE 107.3'	DEPTH OF OVERBURDEN 86.9'	DIAM. OF HOLE NX
ROCK DRILLED 20.4'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1270.1	100		1010		
1262.8					107.3'
	110				

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 6

SUMMARY LOG — HOLE NO. 7 (SHEET 1 OF 1)

SUMMARY LOG HOLE NO. 7	N 9,344.3 / E 9,273.3	SHEET 1 OF 1 / SURFACE ELEV. 1376.6
PROJECT Devil Canyon	DRILL DATES: START 27 Aug 57	COMP. 9 Sep 57
DEPTH OF HOLE 59.5'	DEPTH OF OVERBURDEN 33.9'	DIAM. OF HOLE NX
ROCK DRILLED 25.6'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1376.6			Overburden, Reworked glacial till Gravel and boulders usually granitic. Strong stratification and semi-indurated		No Samples ▽ 11.9' 9 Sep 57 33.9'
1342.7	40		Phyllite, moderately to highly fractured, stained. Numerous quartz veins. 47.2'– 0.4' crack		Pressure Test: 39.7' to 49.7' 0.3 gpm loss @ 25 psi 0.5 gpm loss @ 50 psi 51.0'
1325.6	50		Phyllite, lightly weathered, dark grey to black, lightly fractured		49.5' to 59.5' 0.1 gpm loss @ 50 psi 0.15 gpm loss @ 75 psi
1317.1	60				59.5'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 7

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

LOGS OF EXPLORATIONS DEVIL CANYON

HOLES I THRU 7

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SUMMARY LOG — HOLE NO. 8 (SHEET 1 OF 2)

N 10,031	E 7,25	SURFACE ELEV. 1448.3
PROJECT Devil Canyon	DRILL DATES: START 20 Jun 57	COMP. 3 Jul 57
DEPTH OF HOLE 150.4'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX
ROCK DRILLED 150.4'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 60°	AZIMUTH FROM NORTH 351°	COMPILED BY, DATE
DISTANCES: VERTICAL, 75.2'	HORIZONTAL, 130.3'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1448.3				Casing bit; no core 2.0'
		Phyllite, medium grey, highly fractured, moderately weathered. 8.6'-11.9' Numerous vuggy quartz veins Greyish-black 12.0'-15.9' Medium grey 15.9'-22.0' Calcite joint filler 22.0'-70.8'		Pressure Tests: (Sampling-not all entered) 5.9' to 15.9' 17.0 gpm loss @ 25 psi 23.7 gpm loss @ 75 psi 35.4' to 45.4' 18.9 gpm loss @ 25 psi 26.3 gpm loss @ 75 psi Lost drill water @ 40.3' 55.4' to 65.4' 16.1 gpm loss @ 25 psi 21.7 gpm loss @ 75 psi
1412.9	70			70.8'
		Phyllite, lightly weathered, lightly jointed, light grey. Pyrite in joint @ 72.5' Medium grey w/vuggy quartz veins 74.5'-90.9'		77.4' to 87.4' 2.35 gpm loss @ 50 psi 4.45 gpm loss @ 100 psi
1402.8	90			90.9'
		Phyllite, lightly weathered, moderately jointed, brownish grey. Quartz disseminated and in vuggy veins through out.		
1398.3				

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 8

SUMMARY LOG — HOLE NO. 8 (SHEET 2 OF 2)

N 10031	E 7258	SURFACE ELEV. 1448.3
PROJECT Devil Canyon	DRILL DATES: START 20 Jun 57	COMP. 3 Jul 57
DEPTH OF HOLE 150.4'	DEPTH OF OVERBURDEN	DIAM. OF HOLE NX
ROCK DRILLED 150.4'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 60°	AZIMUTH FROM NORTH 351°	COMPILED BY, DATE
DISTANCES: VERTICAL, 75.2'	HORIZONTAL, 130.3'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1398.3	100	IBID		107.6' to 117.6' 19.0 gpm loss @ 50 psi 24.4 gpm loss @ 100". 125.6' to 135.6' 0.8 gpm loss @ 50 psi 1.2 gpm loss @ 100 psi
1378.2	140	Gouge 140.0' - 140.1'		140.2'
		Phyllite, lightly weathered, moderately jointed, medium grey w/vuggy quartz veins throughout		140.4' to 150.4' 0.2 gpm loss @ 50 psi 0.3 gpm loss @ 100 psi
1373.1	150			150.4'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 8

SUMMARY LOG — HOLE NO. 9 (SHEET 1 OF 1)

N 9994	E 9424	SURFACE ELEV. 1424.1
PROJECT Devil Canyon	DRILL DATES: START 8 Jul 1957	COMP. 12 Jul 1957
DEPTH OF HOLE 87.0'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX
ROCK DRILLED 87.0'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 360°	COMPILED BY, DATE
DISTANCES: VERTICAL, 61.5'	HORIZONTAL, 61.5'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1424.1		Phyllite, lightly to moderately weathered, dark grey, moderate to high fracture with occasional gouge, quartz veins and secondary mineralization.		Pressure tests (Sampling - not all recorded) 7.8' to 17.8' 2.1 gpm loss @ 50 psi 5.6 gpm loss @ 100 psi
	30	Joints iron stained to 60.5'		35.2' to 45.2' 9.0 gpm loss @ 25 psi 11.2 gpm loss @ 50 psi
	60	61.4' to 74.7' Joints contain quartz, iron staining, pyrite, calcite and arseno pyrite and amethyst.		70.3 to 80.3' 2.3 gpm loss @ 25 psi 3.1 gpm loss @ 50 psi
		74.7' to 75.5' Shear		
1362.6				87.0'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 9

SUMMARY LOG — HOLE NO. 10 (SHEET 1 OF 2)

N 9991	E 9424.65	SURFACE ELEV. 1425.1
PROJECT Devil Canyon	DRILL DATES: START 13 Jul 1957	COMP. 24 Jul 1952
DEPTH OF HOLE 121.7'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX
ROCK DRILLED 121.7'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 38°	AZIMUTH FROM NORTH 065°	COMPILED BY, DATE
DISTANCES: VERTICAL, 95.9'	HORIZONTAL, 74.9'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1425.1	0	Phyllite, dark grey, medium hard moderately fractured, joints have iron staining; quartz veins throughout.		
1346.1	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 10

SUMMARY LOG — HOLE NO. 10 (SHEET 2 OF 2)

N 9,991.0	E 9,424.65	SURFACE ELEV. 1425.1
PROJECT Devil Canyon	DRILL DATES: START 30 Jul 1957	COMP. 2 Aug 1957
DEPTH OF HOLE 121.7'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE X
ROCK DRILLED 121.7	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 33°	AZIMUTH FROM NORTH 065°	COMPILED BY, DATE
DISTANCES: VERTICAL, 95.9'	HORIZONTAL, 74.9'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1345.2	100	IBID		101.4'
		Shear zone, fragments, gouge. Minor pyrite and arsenopyrite mineralization.		116.9'
1333.0		Phyllite, IBID		
1329.2	120			121.7'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 10

SUMMARY LOG — HOLE NO. 11 (SHEET 1 OF 1)

N 10517.6	E 9302.0	SURFACE ELEV. 893.5
PROJECT Devil Canyon	DRILL DATES: START 30 Jul 1957	COMP. 2 Aug 1957
DEPTH OF HOLE 30.5'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX
ROCK DRILLED 30.5'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 355°	COMPILED BY, DATE
DISTANCES: VERTICAL, 20.4'	HORIZONTAL, 22.7'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
893.5		Phyllite, fine grained, dark grey, light to moderate fracture, joints locally healed with calcite or quartz		Pressure tests. 7.0' to 17.0' 16.0 gpm loss @ 10 psi 16.6' to 26.6' 16.0 gpm loss @ 9 psi 20.5' to 30.5' 16.1 gpm loss @ 5 psi
873.1	30	Hole day lighted @ 30.5'		30.5'
		Susitna River		

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 11

SUMMARY LOG — HOLE NO. 11A (SHEET 1 OF 1)

N 10517.6	E 9302.2	SURFACE ELEV. 893.5
PROJECT Devil Canyon	DRILL DATES: START 3 Aug 1957	COMP. 7 Aug 1957
DEPTH OF HOLE 29.1'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX
ROCK DRILLED 29.1'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 355°	COMPILED BY, DATE
DISTANCES: VERTICAL, 20.6'	HORIZONTAL, 20.6'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
893.5		Phyllite, same as Hole #11		Pressure Tests: 7.7' to 17.7' 15.7 gpm loss @ 15 psi 16.7' to 26.7' 16.3 gpm loss @ 9 psi
872.9		Hole day lighted at 29.1'		29.1'
	30	Susitna River		

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 11A

SUMMARY LOG — HOLE NO. 11B (SHEET 1 OF 1)

N 10517.6	E 9302.3	SURFACE ELEV. 893.5
PROJECT Devil Canyon	DRILL DATES: START 8 Aug 1957	COMP. 11 Aug 1957
DEPTH OF HOLE 33.9'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX
ROCK DRILLED 33.9'	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. 39°	AZIMUTH FROM NORTH 355°	COMPILED BY, DATE
DISTANCES: VERTICAL, 26.3'	HORIZONTAL, 21.3'	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
893.5	0	Phyllite, same as holes #11 & 11A		Pressure Tests: 4.1' to 14.1' 15.1 gpm loss @ 50 psi 13.8' to 23.8' 5.4 gpm loss @ 50 psi 11.9 gpm loss @ 100 psi 23.6' to 33.6' 16.2 gpm loss @ 5 psi
867.2		Hole day lighted at 33.9'		33.9'
		Susitna River		

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 11B

SOUTHCENTRAL RAILBELT AREA, ALASKA
INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
LOGS OF EXPLORATIONS
DEVIL CANYON
HOLES 8 THRU 11B

ALASKA DISTRICT, CORPS OF ENGINEERS
ANCHORAGE, ALASKA
DECEMBER 1975

SUMMARY LOG — HOLE NO. 11C (Sheet 1 of 2)

N 10526.8	E 9302	SHEET 1 OF 2	SURFACE ELEV. 892.7
PROJECT Devil Canyon	DRILL DATES: START 13 Aug 1957	COMP. 14 Sep 1957	
DEPTH OF HOLE 150.1'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX	
ROCK DRILLED 150.1'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 33°	AZIMUTH FROM NORTH 355°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 125.9'	HORIZONTAL, 81.8'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
892.7	0	Phyllite, lightly to moderately weathered, light to moderate fracture, dark grey to black, fine grained with minor stain on joints		Pressure Tests: (Sampling - not all recorded) 6.1' to 16.1' 14.3 gpm loss @ 50 psi 41.0 gpm loss @ 100 psi
	20			26.0' to 36.0' 78.3 gpm loss @ 5 psi
				36.8' to 46.8' 79.5 gpm loss @ 3 psi
	30			58.5' to 60.5' 9.0 gpm loss @ 50 psi 9.6 gpm loss @ 100 psi
849 848	50	Sand and Gravel 52.0' to 53.1' (day lighted into Susitna River)		
	80			80.8' to 90.8' 3.0 gpm loss @ 50 psi 4.3 gpm loss @ 100 psi
808.8	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 11C

SUMMARY LOG — HOLE NO. 11C (Sheet 2 of 2)

N 10,526.8	E 9,302.0	SHEET 2 OF 2	SURFACE ELEV. 892.7
PROJECT Devil Canyon	DRILL DATES: START 13 Aug. 57	COMP. 14 Sep 57	
DEPTH OF HOLE 150.1'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX	
ROCK DRILLED 150.1'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 33°	AZIMUTH FROM NORTH 355°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 125.9'	HORIZONTAL, 81.8'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
808.8	100	IBID		
	110	Moderate to high fracture 100.0' to 123.5'		103.9' to 118.9' 3.0 gpm loss at 50 psi 3.3 gpm loss at 100 psi
	120			123.5'
789.1	130	Phyllite, moderately fractured, light grey to reddish brown, medium hard. High quartz injection 134.0' to 135.0'		128.5' to 138.5' 6.0 gpm loss at 50 psi 6.5 gpm loss at 100 psi
766.8	150			150.1'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 11C

SUMMARY LOG — HOLE NO. 12 (Sheet 1 of 2)

N Power Plant	E Foundation	SHEET 1 OF 2	SURFACE ELEV. —
PROJECT Devil Canyon	DRILL DATES: START 16 Sep 1957	COMP. 26 Sep 1957	
DEPTH OF HOLE 127.5'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX	
ROCK DRILLED 127.5'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 045°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 110.4'	HORIZONTAL, 63.8'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	0	Phyllite, moderately weathered		2.0'
	10	Phyllite, lightly weathered, moderately fractured, medium hard, dark grey to black. Joints 45° to axis healed with quartz; 30° to axis healed with calcareous material		85'
	90	Ibid, color light reddish brown		
	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 12

SUMMARY LOG — HOLE NO. 12 (Sheet 2 of 2)

N Powerhouse	E Foundation	SHEET 2 OF 2	SURFACE ELEV. —
PROJECT Devil Canyon	DRILL DATES: START 16 Sep 1957	COMP. 26 Sep 1957	
DEPTH OF HOLE 127.5'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX	
ROCK DRILLED 127.5'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH 045°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 110.4'	HORIZONTAL, 63.8'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
	100	IBID		117.3'
	120	Phyllite, dark grey to black, lightly weathered, medium hard, moderately fractured.		127.5'
	130			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 12

SUMMARY LOG — HOLE NO. 12A (Sheet 1 of 2)

N Downstream of	E Axis	SHEET 1 OF 2	SURFACE ELEV. 896
PROJECT Devil Canyon	DRILL DATES: START 1 Oct 1957	COMP. 12 Oct 1957	
DEPTH OF HOLE 149.3'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE BX	
ROCK DRILLED 149.3'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 045°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 105.6'	HORIZONTAL, 105.6'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
896	0	Phyllite, medium hard, dark grey to black, moderately fractured		Pressure Tests: (Sampling not all recorded) 15.3' to 25.3' 2.3 gpm loss @ 50 psi 3.4 gpm loss @ 100 psi
	40			37.8' to 47.8' 2.8 gpm loss @ 50 psi 3.2 gpm loss @ 100 psi
	60			65.7' to 75.7' 3.7 gpm loss @ 50 psi 3.0 (sic) loss @ 100 psi
	80			85.7' to 95.7' 1.5 gpm loss @ 50 psi 1.8 gpm loss @ 100 psi
797	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 12A

SUMMARY LOG — HOLE NO. 12A (Sheet 2 of 2)

N Downstream of	E Axis	SHEET 2 OF 2	SURFACE ELEV. 896
PROJECT Devil Canyon	DRILL DATES: START 1 Oct 1957	COMP. 12 Oct 1957	
DEPTH OF HOLE 149.3'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX	
ROCK DRILLED 149.3'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 045°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 105.6'	HORIZONTAL, 105.6'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
797	100	IBID		106.8' to 116.8' 3.5 gpm loss @ 50 psi 3.4 (sic) gpm loss @ 100 psi
	120			126.2' to 136.2' 2.1 gpm loss at 50 psi 1.9 (sic) loss at 100 psi
	140			140'
		Phyllite, medium hard to hard, alternating light & dark banding, moderately fractured.		139.3' to 149.3' 3.3 gpm loss @ 50 psi 2.6 (sic) loss @ 100 psi 149.3'
750	150			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 12A

SUMMARY LOG — HOLE NO. 13 (Sheet 1 of 2)

N 10668.25	E 9891.24	SHEET 1 OF 2	SURFACE ELEV. 912.3
PROJECT Devil Canyon	DRILL DATES: START 22 Jul 1957	COMP. 1 Aug 1957	
DEPTH OF HOLE 137'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX	
ROCK DRILLED 137'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 162°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 96.9'	HORIZONTAL, 96.9'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
912.3	0	Phyllite, light to moderate weathering, medium hard, moderate to high fracture, slight iron stain, dark grey		Pressure tests Sampling-not all recorded 7.2'
907.2	10	Phyllite, moderate weathered dark grey, moderate to high fracture. Broken with slicks & gouge 16.6' to 17.4'		Pressure Tests 7.4' to 17.4' 25.3 gpm loss @ 25 psi 31.5 gpm loss @ 50 psi 75.3 gpm loss @ 100 psi 17.4'
900.0	20	Phyllite, highly weathered, broken with slicks and gouge		27.7' to 37.7' 53.5 gpm loss @ 25 psi 66.3 gpm loss @ 50 psi 99.8 gpm loss @ 100 psi
	30	17.4' to 63.9' Fault zone		Hole caving 34.7' to 86.3'
	50			48.8' to 58.8' 6.3 gpm loss @ 25 psi 8.8 gpm loss @ 50 psi 13.0 gpm loss @ 100 psi
	60	Fault 61.5' to 63.9'		63.9'
867.1	70	Phyllite, lightly weathered moderately fracture, medium to dark grey. Quartz nodules, calcite throughout.		70.4' to 80.4' No loss @ 25,50 & 100 psi 81.4'
854.7	80	Quartzite (sic), moderately to highly weathered, moderate to high fracture		88.6'
849.7		Phyllite, moderately to highly weathered, moderate to highly fractured with slicks & gouge. Gouge 93.9' - 94.9'		
841.6	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 13

SUMMARY LOG — HOLE NO. 13 (Sheet 2 of 2)

N 10668.25	E 9891.24	SHEET 2 OF 2	SURFACE ELEV. 912.3
PROJECT Devil Canyon	DRILL DATES: START 22 Jul 1957	COMP. 1 Aug 1957	
DEPTH OF HOLE 137'	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX	
ROCK DRILLED 137'	CORE RECOVERED	% RECOVERY	
ANGLE FROM VERT. 45°	AZIMUTH FROM NORTH 162°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 96.9'	HORIZONTAL, 96.9'		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
841.6	100	IBID		Packer would not seal 105.8' to 137' No pressure tests.
	110	Slickensides 105.8 to 114.6'		Lost 6' core 105.8 to 114.6'
	130	Slickensides 124.7 to 137'		
815.4	140	Hole appears to have been drilled in a fault zone		

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 13

SUMMARY LOG — HOLE NO. 13-A (Sheet 1 of 1)

N 10668.25	E 9871.25	SHEET 1 OF 1	SURFACE ELEV. 912
PROJECT Devil Canyon	DRILL DATES: START 2 Aug 1958	COMP. 5 Aug 1958	
DEPTH OF HOLE 80.7 ft.	DEPTH OF OVERBURDEN 0.0'	DIAM. OF HOLE NX	
ROCK DRILLED 80.7 ft.	CORE RECOVERED	% RECOVERY 100	
ANGLE FROM VERT. 53°	AZIMUTH FROM NORTH 162°	COMPILED BY, DATE	
DISTANCES: VERTICAL, 48.6 ft.	HORIZONTAL, 64.4 ft.		

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
912	0	Phyllite, moderately to highly weathered, highly fractured, light to dark grey. Slicken sides common. Shear 8.9 ft to 9.5 ft.		Pressure Tests. Original illegible. Several appear to be 80+ gpm loss @ 25 psi. 36.1 ft.
	40	Phyllite, moderately to lightly weathered, moderately fractured.		66.9 ft.
	70	Phyllite/Quartzite (sic), highly fractured with slicken sides. Shear 71.8 ft. to 80.7 ft Gouge 76.7 ft. to 78.0 ft.		80.7 ft.
863	80			
	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 13-A

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN
LOGS OF EXPLORATIONS
DEVIL CANYON
HOLES IIC THRU I3A

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA
DECEMBER 1975

SUMMARY LOG — HOLE NO. 14

N 10645 | E 9567 | SHEET 1 OF 1 | SURFACE ELEV. 903.1

PROJECT Devil Canyon | DRILL DATES: START 5 Jun 1958 COMP. 10 Jun '58

DEPTH OF HOLE 50 ft. | DEPTH OF OVERBURDEN 0.0' | DIAM. OF HOLE BX

ROCK DRILLED 50 ft. | CORE RECOVERED 50 ft. | % RECOVERY 100

ANGLE FROM VERT. 45° | AZIMUTH FROM NORTH 225° | COMPILED BY, DATE

DISTANCES: VERTICAL, 35.6 ft.; HORIZONTAL, 35.6 ft.

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
903.1	0	Phyllite, moderately weathered, light to dark grey, moderately to highly fractured with slicken sides. Disseminated pyrite Xls throughout. Drilled through fault 0.0 ft to 4.5 ft.		Pressure Tests (Sampling - not all recorded) 6.7 ft. to 16.7 ft. 14.8 gpm loss @ 25 psi 27.3 gpm loss @ 50 psi; 26.2 ft. to 36.2 ft. No loss @ 25 and 50 psi; 35.0 ft. to 45.0 ft. 6.5 gpm loss @ 25 psi 7.3 gpm loss @ 50 psi
867.5	50	Daylighted in river.		50 ft.

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 14

SUMMARY LOG — HOLE NO. 14A

N 10643 | E 9567 | SHEET 1 OF 2 | SURFACE ELEV. 903.0

PROJECT Devil Canyon | DRILL DATES: START 10 Jun 1958 COMP. 7 Jul 1958

DEPTH OF HOLE 130.4' | DEPTH OF OVERBURDEN 0.0' | DIAM. OF HOLE BX/AX

ROCK DRILLED 130.4' | CORE RECOVERED | % RECOVERY

ANGLE FROM VERT. 37° | AZIMUTH FROM NORTH 225° | COMPILED BY, DATE

DISTANCES: VERTICAL, 104.1'; HORIZONTAL, 78.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
903.0	0	Phyllite, moderately weathered light to medium grey, moderately to highly fractured, disseminated and Xln pyrite throughout. Calcite and quartz common on jointing. Slickensides common in shears. Shattered 1.1' - 1.6' & 2.4' - 2.8' Slicks 4.2' - 4.6' Shear 6.9' - 7.5' Shatter w/slicks 10.6' - 11.8' & 17.4' - 18.9'; Shattered w/slicks 25.9' - 26.7'; Lightly weathered below 36.5'; Small shear 45.2' High pyrite concentration 46.2' - 46.7'		BX Core to 56.1' Pressure tests (Sampling — not all recorded). 18.6' to 28.6' 7.5 gpm loss @ 25 psi, 9.8 gpm loss @ 50; 37.5' to 47.5' 15.0 gpm loss @ 25 psi 24.3 gpm loss @ 50 psi 53.8 gpm loss @ 100 psi; 56.1'
858.2		Susitna River		59.8'
855.2	60	Phyllite, lightly weathered. Occasional biotite & chlorite in joints - only after passing through river. Small shear 66.3'; Slicks 84.5'		AX core 59.8' to 130.4'; 66.3' to 75.5' 10.3 gpm loss @ 25 psi 13.0 gpm loss @ 50 psi 15.3 gpm loss @ 100 psi; 78.5' to 87.7' 40.5 gpm loss @ 25 psi 65.8 gpm loss @ 50 psi 87.3 gpm loss @ 100 psi Possible leaking packer; 89.7' tn 98.9' 1.8 gpm loss @ 25 psi 2.0 gpm loss @ 50 psi 2.3 gpm loss @ 100 psi
823.1	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO.14A

SUMMARY LOG — HOLE NO.14A

N 10643 | E 9567 | SHEET 2 OF 2 | SURFACE ELEV. 903.0

PROJECT Devil Canyon | DRILL DATES: START 10 Jan 1958 COMP. 7 Jul 1958

DEPTH OF HOLE 130.4' | DEPTH OF OVERBURDEN | DIAM. OF HOLE BX/AX

ROCK DRILLED 130.4' | CORE RECOVERED | % RECOVERY

ANGLE FROM VERT. 37° | AZIMUTH FROM NORTH 225° | COMPILED BY, DATE

DISTANCES: VERTICAL, 104.1'; HORIZONTAL, 78.5'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
823.1	100	Ibid		
798.9	130	Shattered 129.4' - 130.4'		130.4'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO.14A

SUMMARY LOG — HOLE NO. 14B

N 10645 | E 9567 | SHEET 1 OF 2 | SURFACE ELEV 901.5

PROJECT Devil Canyon | DRILL DATES: START 12 Jun 1958 COMP. 23 Jun 1958

DEPTH OF HOLE 146.2' | DEPTH OF OVERBURDEN 0.0' | DIAM. OF HOLE BX

ROCK DRILLED 146.2' | CORE RECOVERED | % RECOVERY

ANGLE FROM VERT. 30° | AZIMUTH FROM NORTH 225° | COMPILED BY, DATE

DISTANCES: VERTICAL, 126.6'; HORIZONTAL, 73.1'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
901.5	0	Phyllite, lightly to moderately weathered, moderately to highly fractured, medium to dark grey. Pyrite common, slicks & gouge in shears Lightly weathered below 7.9'; Highly weathered shear 14.5' - 17.2'; Shear 22.4' to 23.4'; Shear 27.0' 29.1'; Shear 32.0' - 34.0'; Shear 40.1' - 40.8'; Shear 45.6' - 49.5'; Shear 61.8' - 65.7'; Small shear 84.3'; Slicks 97.0'		Pressure tests: (sampling - not all recorded) 4.5' to 14.5' 4.5 gpm loss @ 25 psi; 24.2' to 34.2' 49 gpm loss @ 25 psi 58.3 gpm loss @ 50 psi 67.6 gpm loss @ 100 psi; 35.7' to 45.7' 5.3 gpm loss @ 25 psi 6.8 gpm loss @ 50 gpm 7.3 gpm loss @ 100 gpm; 66.3' to 76.3' 45.0 gpm loss @ 25 psi 54 gpm loss @ 50 psi 67.3 gpm loss @ 100 psi; 87.2' to 97.2' 29.5 gpm loss @ 25 psi 31.0 gpm loss @ 50 psi 37.3 gpm loss @ 100 psi
814.9	100			

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 14B

SUMMARY LOG — HOLE NO. 14B

N 10645 | E 9567 | SHEET 2 OF 2 | SURFACE ELEV. 901.5

PROJECT Devil Canyon | DRILL DATES: START 12 Jun 1958 COMP. 23 Jun 1958

DEPTH OF HOLE 146.2' | DEPTH OF OVERBURDEN 0.0' | DIAM. OF HOLE BX

ROCK DRILLED 146.2' | CORE RECOVERED | % RECOVERY

ANGLE FROM VERT. 30° | AZIMUTH FROM NORTH 225° | COMPILED BY, DATE

DISTANCES: VERTICAL, 126.6'; HORIZONTAL, 73.1'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
814.9	100	Shear 103.8' - 104.7'; Shear 112.7' - 113.5'; Shear 114.8' - 115.8'; Shear 124.8 - 126.6'		108.1' to 118.1' 7.8 gpm loss @ 25 psi 8.5 gpm loss @ 50 psi 10.9 gpm loss @ 100; 136.2' to 146.2' 9.0 gpm loss @ 25 psi 12.3 gpm loss @ 50 psi 14.5 gpm loss @ 100 psi
774.9				146.2'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 14B

SUMMARY LOG — HOLE NO. 14C

N 10643 | E 9567 | SHEET 1 OF 1 | SURFACE ELEV. 902.8

PROJECT Devil Canyon | DRILL DATES: START 25 Jun 1958 COMP. 28 Jun 1958

DEPTH OF HOLE 82.0' | DEPTH OF OVERBURDEN 0.0' | DIAM. OF HOLE BX

ROCK DRILLED 82.0' | CORE RECOVERED — | % RECOVERY

ANGLE FROM VERT. 35° | AZIMUTH FROM NORTH 171° | COMPILED BY, DATE

DISTANCES: VERTICAL, 67.2'; HORIZONTAL, 47.0'

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
902.8	0	Phyllite, light to medium grey, moderately weathered, highly fractured, iron stained throughout, occasional slickensides. Lightly weathered from 43.9'; Shear 58.0' - 58.9' Slicken sides to 82.0'; Fragments; Fragments — Shear zone; Fragments		Pressure tests 14.4' to 24.4' 31.3 gpm loss @ 25 psi 41.5 gpm loss @ 50 psi 81.0 gpm loss @ 100 psi 24.1' to 34.1' 46.5 gpm loss @ 25 psi 65.0 gpm loss @ 50 psi 91.0 gpm loss @ 100 psi; 42.3' to 52.3' 28.3 gpm loss @ 25 psi 32.3 gpm loss @ 50 psi 50.5 gpm loss @ 100 psi; 61.8' to 71.8' 3.0 gpm loss @ 25 psi 2.0 (sic) loss @ 50 psi 3.25 gpm loss @ 100 psi
835.6	80			82.0'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 14C

SUMMARY LOG — HOLE NO. 15

N 9483 | E 9277 | SHEET 1 OF 1 | SURFACE ELEV. 1329.1

PROJECT Devil Canyon | DRILL DATES: START 24 Sept 1957 COMP. 3 Oct 1957

DEPTH OF HOLE 68.3' | DEPTH OF OVERBURDEN 47.6' | DIAM. OF HOLE NX/BX

ROCK DRILLED 20.7' | CORE RECOVERED | % RECOVERY

ANGLE FROM VERT. | AZIMUTH FROM NORTH | COMPILED BY, DATE

DISTANCES: VERTICAL, ; HORIZONTAL,

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1329.1	0	Overburden, 0.0' - 7.0' Brown silt with minor gravel. 7.0' - 12.2' Brown to light green reworked fill 12.2' - 29.5' Brown to green sand 29.5' - 40.0' Brown to green till Lenticular gravel beds with minor sand. Firm, highly compacted 40.0' - 41.1' Boulder, granite (Erratic?) 41.1 - 47.6' Brown to light green till, gravel with some sand, soft to hard.		NX casing to 46.7'
1281.5				47.6'
	50	Phyllite, highly weathered, shattered. Drilled in fault parallel to river.		BX core from 47.6' to 68.3' Pressure test 58.0' to 68.3' 3.8 gpm loss @ 50 psi 4.5 gpm loss @ 100 psi
1260.8				68.3'

NPA Form 7(Test) APR. 66 — PROJECT Devil Canyon — HOLE NO. 15

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

LOGS OF EXPLORATIONS

DEVIL CANYON

HOLES 14 AND 15

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

FILE NO. 2-SOU-92-04-01 APPENDIX I PLATE D-9

SUMMARY LOG — HOLE NO. DH-1

N 22,809,616.2 / E 1,550,485.9	SHEET 1 OF 1	SURFACE ELEV. 2264
PROJECT Vee Canyon	DRILL DATES: START 8/12/61	COMP. 8/30/61
DEPTH OF HOLE 52	DEPTH OF OVERBURDEN 48	DIAM. OF HOLE NX
ROCK DRILLED 4	CORE RECOVERED 47%	% RECOVERY
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH N25W	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2264	Silt, clayey and organic, olive gray contains some fine sand and scattered rounded gravels, frozen ice lenses.	-	Drill: Knight & Stone. Hole advanced by chop and wash methods; samples recovered by NX and BX core barrels. Generally fair water return.
	No recovery.		
	Cobbles and sand, fresh, sound gneissic fragments and core to 1.0' long.		
	Clayey gravel		47' Water return poor.
2223			Start NX Core
2219	Gneiss bedrock, dark gray to black fine grained, gneisose structure.	50	51.5 Drive shoe lost in hole
	Bottom of Hole 2212' Depth of Hole 52' Thickness of O.B. 48' Rock Drilled 4'		
2177			

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-1

SUMMARY LOG — HOLE NO. DH-1A

N 22,809,594.6 / E 1,550,499.0	SHEET 1 OF 1	SURFACE ELEV. 2265
PROJECT Vee Canyon	DRILL DATES: START 8/31/61	COMP. 9/8/61
DEPTH OF HOLE 111	DEPTH OF OVERBURDEN 53	DIAM. OF HOLE NX
ROCK DRILLED 58	CORE RECOVERED 31-100%	% RECOVERY
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH N25W	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2177	Silt, clayey and organic, olive gray, contains some fine sand and scattered rounded gravels, frozen ice lenses common.		Drill: Knight & Stone. Hole advanced by chop and wash methods; samples recovered by core barrels: NX to 12' BX to 111' Water return generally good.
			Start NX core.
	Gneiss light to dark gray, fine grained, mod hard.	96	
		90	Core lengths up to 3 in.
	Foliation dips 40° to core axis.	31	
		86	
		66	Lost core.
		80	
		80	
		100	Core lengths 0.1' to 0.4'
	Qtz, epidote and garnets.	100	
		92	
2069	Bottom of Hole El. 2154		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-1A

SUMMARY LOG — HOLE NO. DH-2 (Sheet 1)

N 22,809,428.0 / E 1,550,513.8	SHEET 1 OF 2	SURFACE ELEV. 2275
PROJECT Vee Canyon	DRILL DATES: START 8/7/61	COMP. 8/12/61
DEPTH OF HOLE 149	DEPTH OF OVERBURDEN 17	DIAM. OF HOLE NX
ROCK DRILLED 132	CORE RECOVERED 72-100%	% RECOVERY
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH N25W	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2275	Silt, clayey and organic. Olive gray, contains some fine sand, and occasional rounded gravels, frozen.		Drill: Knight & Stone Hole advanced by chopping. Good water.
2260			Start NX Core.
	Gneiss with intercalated mica schist dark gray to black, fine grained, mod. hard, foliation dips 30° to 50° to core axis.	97	Core lengths 0.1' to 0.3'
	Shear - brecciated, Qtz healed	100	Core lengths 0.1' to 0.3'
	Broken rock, soft friable fragments	92	
		82	
		97	
		100	Core lengths to 0.3'
	Shear - soft, green core pieces	95	
		72	
		94	
		84	
	Brecciated, Qtz healed slickensides.	86	
		100	Core lengths to 0.5'
2188		90	

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-2

SUMMARY LOG — HOLE NO. DH-2 (Sheet 2)

N 22,809,428.0 / E 1,550,513.8	SHEET 2 OF 2	SURFACE ELEV. 2275
PROJECT Vee Canyon	DRILL DATES: START 8/7/61	COMP. 8/12/61
DEPTH OF HOLE 149	DEPTH OF OVERBURDEN 17	DIAM. OF HOLE NX
ROCK DRILLED 132	CORE RECOVERED 72-100%	% RECOVERY
ANGLE FROM VERT. 30°	AZIMUTH FROM NORTH N25W	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2188	Idem	90	Core lengths to 0.3'
	Shear	94	
		81	
		66	
	Shear	100	Core lengths 0.1' to 0.4'
		93	
		100	
		95	Core lengths 0.1' to 0.4'
		86	
	Shear	82	
	Bottom of Hole El. 2126' Depth of Hole 149' Thickness of O.B. 17' Rock Drilled 132'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-2

SUMMARY LOG — HOLE NO. DH-3 (Sheet 1)

N 22,809,921.6 / E 1,550,432.0	SHEET 1 OF 2	SURFACE ELEV. 2085
PROJECT Vee Canyon	DRILL DATES: START 9/23/61	COMP. 9/30/61
DEPTH OF HOLE 136	DEPTH OF OVERBURDEN 35	DIAM. OF HOLE NX
ROCK DRILLED 101	CORE RECOVERED 41-100%	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2085	Talus. Blocks, gravel and sand, blocks are loose, angular gneissic fragments up to 5' across. Gravel and sand is glaciofluvial material washed in from above.		Drill: Knight & Stone Hole advanced by chopping. Good water return. Start NX core.
	Talus, gneiss blocks.	80	
		100	Start BX core.
	Garnet gneiss light gray to black fine grained, mod hard, foliation dips 60° + to axis.	78	Core lengths 0.1' to 0.7'
		91	
	Jts. dip 40 to 65°	56	Core is closely broken due to blockage.
	Jt. surfaces are rust stained.	100	Core length 0.1' to 0.5'
		84	
		58	
1985		41	

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-3

SUMMARY LOG — HOLE NO. DH-3 (Sheet 2)

N 22,809,921.6 / E 1,550,432.0	SHEET 2 OF 2	SURFACE ELEV. 2085
PROJECT Vee Canyon	DRILL DATES: START 9/23/61	COMP. 9/30/61
DEPTH OF HOLE 136	DEPTH OF OVERBURDEN 35	DIAM. OF HOLE NX
ROCK DRILLED 101	CORE RECOVERED 41-100%	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1985	Idem	41	Core lengths 0.2' to 1.5'
	Jt. surfaces are rust stained	79	
		100	
		95	
		92	
		100	
	Bottom of Hole El. 1949' Depth of Hole 136' Thickness of O.B. 35' Rock Drilled 101'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-3

SUMMARY LOG — HOLE NO. DH-5

N 22,810,135.0 / E 1,550,237.0	SHEET 1 OF 1	SURFACE ELEV. 1901
PROJECT Vee Canyon	DRILL DATES: START 3/15/62	COMP. 4/2/62
DEPTH OF HOLE 116	DEPTH OF OVERBURDEN 74	DIAM. OF HOLE NX
ROCK DRILLED 42	CORE RECOVERED 27-100%	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
1901	Ice and Water		Drill: Knight & Stone Drill was set up on the ice in the Susitna River; surface elevation shown is top of ice. Hole advanced by chop wash and blast, samples recovered by NX and BX core barrels. Generally good water return.
	River channel deposits; boulders, cobbles, gravel and sand, some core lengths to 14".		
	Fine gravel, some sand, dark gray.		
	Fine sand and silt, brownish gray.		
	Cobbles, fine gravel.		
	Fine sand and gravel.		
	Schist boulder or cobbles.		
	Fine sand and fine gravel, gray to black.		
	Schist boulder, dark gray.		
	Fine sand, occasional fine gravel, dark gray.		Start NX core.
	Gneiss, light gray to gray, med. grain, mod. hard.	86	
		89	Core lengths are 0.1' to 1.2'.
	Foliation dip ranges between 45° to nearly vertical.	80	
		100	
1801	Bottom of Hole El. 1785'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-5

SUMMARY LOG — HOLE NO. DH-7 (Sheet 1)

N 22,807,245.0 / E 1,551,289.0	SHEET 1 OF 2	SURFACE ELEV. 2228
PROJECT Vee Canyon	DRILL DATES: START	COMP.
DEPTH OF HOLE 176	DEPTH OF OVERBURDEN 176	DIAM. OF HOLE NX
ROCK DRILLED 0	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2228	Sand, buff, medium, loose, dry Sand, silty gray, fine to silt sized, moist to wet, loose, thin ice lenses, some clay lenses less than 1/4" thick.		Drill: Knight & Stone Hole advanced by chopping bit, samples recovered with 2" split spoon sampler. Good water return.
	Silt, gray, very wet, loose, frozen. Clay, fat, gray, sticky, frozen, ice lenses 1/4" thick, grades to silty clay.		
	Silt, partly clayey, gray, stratified, frozen, loose when thawed, some ice lenses.		
	Clay, lean, gray, moderate plasticity, not frozen, moist firm.		
	Silt, gray, slight plasticity, firm, drains rapidly.		
	Clay, fat, gray, very soft high plasticity, wet, drains slowly, squeezes into hole and binds sampling tube.		
	Clay, lean, silty, gray, firm, moist, few silt lenses, drains rapidly, medium dry strength.		
2128			

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-7S

SUMMARY LOG — HOLE NO. DH-7 (Sheet 2)

N 22,807,245.0 / E 1,551,28 .0	SHEET 2 OF 2	SURFACE ELEV. 2228
PROJECT Vee Canyon	DRILL DATES: START	COMP.
DEPTH OF HOLE 176	DEPTH OF OVERBURDEN 176	DIAM. OF HOLE NX
ROCK DRILLED 0	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2128	Possible clay, lean, silty, gray, firm, moist, few silt lenses.		
	Clay, fat, some silt as 2" layers or thin lenses, clay is hard, dark gray, contains claystone nodules. Some gravel lenses.		
2052	Bottom of Hole El. 2052' Depth of Hole 176' Depth of O.B. 176'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-7

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN LOGS OF EXPLORATIONS VEE CANYON

HOLES I THRU 7

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SUMMARY LOG — HOLE NO. DH-7S

N 22,807,767.6	E 1,551,296.5	SHEET 1 OF 1
SURFACE ELEV. 2230	PROJECT Vee Canyon	DRILL DATES: START 7-1-61 COMP. 7-7-61
DEPTH OF HOLE 33	DEPTH OF OVERBURDEN 33	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2230	0	Sand, silty with some stratified gravel, partially frozen		Drill: Knight & Stone Hole advanced by chopping Hole drilled to obtain thin-wall drive samples no success due to tube crumpling in frozen soil.
		Sand, silty, some stratified clay, gray, frozen		
		Bottom of Hole El. 2197' Depth of Hole 33' Depth of O. B. 33'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-7S

SUMMARY LOG — HOLE NO. DH-8

N 22,808,168.0	E 1,550,925.8	SHEET 1 OF 2
SURFACE ELEV. 2333	PROJECT Vee Canyon	DRILL DATES: START 8-1-61 COMP. 8-5-61
DEPTH OF HOLE 180	DEPTH OF OVERBURDEN 180	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2333	0	Silt, frozen, stratified, contains laminations (possible varves), some layers contain very fine sand, some ice lenses 1/16" to 1/2" noted, gray, some yellowish layers, gradational change to clayey silt with depth.		Drill: Knight & Stone Hole advanced with chopping bit, samples recovered with 1 1/2" split-tube sampler.
		Clay, silty, gradation change from clayey silt, gray, firm, laminations or varves, very sticky, moderate to high plasticity.		
		Silt, frozen, dark gray, moist, soft when thawed, no plasticity, quick dilatancy, stratified.		
		Sand, silty, fine		
		Gravel and sand Sand, well graded, angular, clean		
		Sand, silty to clean, fine to very fine, gray uncemented, stratified, occasional gravels.		
2233	100			

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-8

SUMMARY LOG — HOLE NO. DH-8

N 22,808,168.0	E 1,550,925.8	SHEET 2 OF 2
SURFACE ELEV. 2333	PROJECT Vee Canyon	DRILL DATES: START COMP.
DEPTH OF HOLE 180	DEPTH OF OVERBURDEN 180	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2233	100	Idem		
		Bottom of Hole El. 2158' Depth of Hole 175' Depth of O. B. 175'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-8

SUMMARY LOG — HOLE NO. DH-9

N 22,806,714.4	E 1,551,438.4	SHEET 1 OF 2
SURFACE ELEV. 2307	PROJECT Vee Canyon	DRILL DATES: START 7-25-61 COMP. 7-29-61
DEPTH OF HOLE 148	DEPTH OF OVERBURDEN 148	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2307	0	Gravel and sand, loose, igneous and metamorphic rock types, gravels grade from coarse near the surface to fine and sandy near bottom of section.		Drill: Knight & Stone Hole [illegible] with cho[illegible] samples recovered [illegible] 1 1/2" split-tube sampler
		Sand, fine to medium, fairly well graded, occasional small gravel, loose		
		Sand, gray, very fine, silty grades to gravelly sand with depth		
		Gravel and sand, coarse sand to 1/4"		
		Sand, fairly well graded, lacks coarse grains, occasional 1/4" gravel		
		Sand and gravel well graded, considerable 1/4" gravel		
		Sand and silt		
2207	100			

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-9

SUMMARY LOG — HOLE NO. DH-9

N 22,806,714.4	E 1,551,438.4	SHEET 2 OF 2
SURFACE ELEV. 2307	PROJECT Vee Canyon	DRILL DATES: START 7-25-61 COMP. 7-29-61
DEPTH OF HOLE 148	DEPTH OF OVERBURDEN 148	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, Vert	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2207	100	Silt, olive gray, slightly plastic slightly clayey, moist to wet, very soft, quick dilatancy, hard to drive, probably frozen, but thawed when recovered.		
		Sand, clayey, gray, very hard, probably frozen, coarse some gravel		
		Silt, gray, soft, non-plastic, moist, frozen lenses, some ice lenses.		
		Bottom of Hole El 2159' Depth of Hole 148' Depth of O. B. 148'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. 148

SUMMARY LOG — HOLE NO. DH-10

N 22,807,208.2	E 1,551,883.6	SHEET 1 OF 2
SURFACE ELEV. 2199	PROJECT Vee Canyon	DRILL DATES: START 7-8-61 COMP. 7-24-61
DEPTH OF HOLE 151	DEPTH OF OVERBURDEN 151	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2199	0	Muskeg, some coarse silty sand and ice		Drill: Knight & Stone Hole advanced by chop, wash and blast methods. Sampled with 1 1/2" split-spoon sampler.
		Gravel and coarse sand, clean, coarse gravels, probably frozen		
		Sand and gravel, coarse sand, dark, metamorphic and some granitic, fine gravel, clean		
		Cobbles, boulders, gravel & sand		
		Sand and gravel		
	100	Silt, partly clayey, olive gray, some fine sand and soft clay layers		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-10

SUMMARY LOG — HOLE NO. DH-10

N 22,807,208.2	E 1,551,883.6	SHEET 2 OF2
SURFACE ELEV. 2199	PROJECT Vee Canyon	DRILL DATES: START 7-8-61 COMP. 7-24-61
DEPTH OF HOLE 151	DEPTH OF OVERBURDEN 151	DIAM. OF HOLE NX
ROCK DRILLED	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2207	100	Id m, transitions to clay below 135.0'		
		Clay, gray, moist firm, crumbles in hand, breaks along irregular, glossy planes		
2156	150			
		Bottom of Hole El. 2207' Depth of Hole 151' Depth of O. B. 151'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-10

SUMMARY LOG — HOLE NO. DH-11

N 22,809,357.6	E 1,550,716.4	SHEET 1 OF 1
SURFACE ELEV. 2305	PROJECT Vee C anyon	DRILL DATES: START 9-9-61 COMP. 9-12-61
DEPTH OF HOLE 65	DEPTH OF OVERBURDEN 31	DIAM. OF HOLE NX
ROCK DRILLED 34	CORE RECOVERED 77-100%	% RECOVERY
ANGLE FROM VERT.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2305	0	Silt, clayey, organic, olive gray, some fine sand, frozen, icelenses Silt and sand, frozen Sand and gravel, frozen		Drill- Knight & Stone Good water return Hole advanced with chopping bit Start NX Core
		Gneiss, lt to dark gray, med grain mod. hard Shear zone-Core is fragmented sandy	100 77 92	Core lengths o.1'to 0.4'
		Gneiss, white to Lt. gray schistose structure is very prominant	100 90 100	Core lengths o.1' to 0.4'. Core is broken parallel to foliation planes
		Bottom of Hole El. 2240' Depth of Hole 65' Depth of O. B. 31' Depth of Rock 34'		

NPA Form 7(Test) APR. 66 — PROJECT Vee Canyon — HOLE NO. DH-11

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN
LOGS OF EXPLORATIONS
VEE · CANYON

HOLES 7S THRU II

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SUMMARY LOG — HOLE NO. DH-12 (Sheet 1 of 2)

SUMMARY LOG HOLE NO. DH-12	N 22,808,684.5 E 1,550,631.1	SHEET 1 OF 2 SURFACE ELEV. 2331
PROJECT Vee Canyon	DRILL DATES: START 9-13-61	COMP. 9-19-61
DEPTH OF HOLE 155	DEPTH OF OVERBURDEN 125	DIAM. OF HOLE NX
ROCK DRILLED 30	CORE RECOVERED 50-100%	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2331			Silt clayey, organic, some fine sand and occasional gravels, frozen, ice lenses		
			Silt and fine sand, frozen		
	10				
	20				
	30		Gravel and Sand, frozen, from 39' to 42' grades to clay and silts		
	40		Clay and silt, frozen, ice lens at 59', transitions to sand		
	50				
	60				
	70		Sand, olive gray, fine to very fine, clean, loose, moist, not frozen, some silt layers, some gravel		
	80		Sand, mostly quartzose grains, frozen		
	90				
2231	100				

KPA Form APR. 66 7(Test) — PROJECT Vee Canyon — HOLE NO. DH-12

SUMMARY LOG — HOLE NO. DH-12 (Sheet 2 of 2)

SUMMARY LOG HOLE NO. DH-12	N 22,808,684.5 E 1,550,631.1	SHEET 2 OF 2 SURFACE ELEV. 2331
PROJECT Vee Canyon	DRILL DATES: START 9-13-61	COMP. 9-19-61
DEPTH OF HOLE 155	DEPTH OF OVERBURDEN 125	DIAM. OF HOLE NX
ROCK DRILLED 30	CORE RECOVERED 50-100%	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	GRAPHIC LOG	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2231			Idem		
	110				
	120		Gravel and Sand, gneissic, weathered granite and quartzite		
					Start NX Core
	130		Gneiss, gray, fine to med grain mod. hard. Foliation dip ranges between 45° to near vertical	50	Core lengths 0.1' to 0.6'
				78	
	140		Jt dip 45° - 70°.	100	
				95	
	150			100	
2176			Bottom of Hole El. 2176' Depth of Hole 155' Depth of O. B. 125' Depth of Rock 30'		
	160				
	170				
	180				
	190				
	200				

KPA Form APR. 66 7(Test) — PROJECT Vee Canyon — HOLE NO. DH-12

LOG OF TEST PIT OR AUGER HOLE — Trench B

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature ____ Project Vee Canyon, Alaska Hole No. Trench B
Area Designation Upper Terrace Coordinates ____ Ground Elevation ____ Depth To Ground Water Level* ____
Method of Excavation D.7 Dozer Approximate Dimensions of Hole 225' long, 2'-3' deep Dates of Excavation 7/22/61 Hole Logged By R. J. Farina

Classification Symbol	Size and Type of Sample Taken	Classification and Description of Material
ML	75 lb. sack samples, Sack B 1 of 2, Sack B 2 of 2. Removed about 40% +3" material.	Muskeg cover - 1 to 1½' organic, clayey silt, dark olive brown, moderate to high plasticity, quick dilatancy; contains considerable pebbles and cobbles, (ML).
GW		Gravel and sand - Estimated sizes: +0.5' 20% 0.5' - ¼" 50% -¼" 30% Maximum size noted 1.5'; fairly uniform, crudely stratified, cobble gravel, well graded, subangular hard, durable, metamorphic rocks. Some layers are clean, others are silty and clayey. Sand fraction tends to be heavy in medium to coarse grain sizes; loose, angular to subangular grains, (GW). Not frozen.

REMARKS: Photos 3.14, 3.15, 3.17
Elevation difference, top to bottom of trench, is about 50'.

LOG OF TEST PIT OR AUGER HOLE — Trench C

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature ____ Project Vee Canyon, Alaska Hole No. Trench C
Area Designation Upper Terrace Coordinates ____ Ground Elevation ____ Depth To Ground Water Level* ____
Method of Excavation D.7 Dozer Approximate Dimensions of Hole 140' long, 4' deep Dates of Excavation 7/27/61 Hole Logged By R. J. Farina

Classification Symbol	Size and Type of Sample Taken	Classification and Description of Material
ML	75 lb. sack sample, Sack C. Removed about 40% + 3" material.	Muskeg cover - 1 to 1½' organic, clayey silt, dark olive brown, moderate to high plasticity, quick dilatancy; contains considerable pebbles and cobbles, (ML).
GW		Gravel and sand - Estimated sizes: +0.5' 20% 0.5' - ¼" 50% -¼" 30% Maximum size noted 1.5'; fairly uniform, crudely stratified, cobble gravel, well graded, subangular, hard, durable, metamorphic rocks. Some layers are clean, others are silty and clayey. Sand fraction tends to be heavy in medium to coarse grain sizes; loose, angular to subangular grains, (GW). Some ice lenses and frozen gravel and sand were noted during dozing of Trench C.

REMARKS: Photo 3.13 Elevation difference, top to bottom of trench, is about 30'.

LOG OF TEST PIT OR AUGER HOLE — Trench D

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Saddle Dike Project Vee Canyon, Alaska Hole No. Trench D
Area Designation Left Abutment Coordinates ____ Ground Elevation ____ Depth To Ground Water Level* ____
Method of Excavation D.7 Dozer Approximate Dimensions of Hole 90' long, 5' deep Dates of Excavation 7/19/61 Hole Logged By R. J. Farina

Classification Symbol	Classification and Description of Material
ML	Muskeg cover - ½' organic silt, moss and shrubs, few scattered small trees, (ML)
SM	Silty sand, fine grain, silty, gray, crudely stratified, Frozen. Contains some beds of well graded clean sand with lenses of frozen fine, sandy gravel. Very difficult to excavate since dozer tracks slide on ice. Becomes muddy when thawed, (SM).

REMARKS: Photos 1.1, 1.2, 1.3, 1.4, 1.36, 1.37.

LOG OF TEST PIT OR AUGER HOLE — Trench E

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Saddle Dike Project Vee Canyon, Alaska Hole No. Trench E
Area Designation Left Abutment Coordinates ____ Ground Elevation ____ Depth To Ground Water Level* ____
Method of Excavation D.7 Dozer Approximate Dimensions of Hole 550' long, 1'-2' deep Dates of Excavation 7/28/61 Hole Logged By R. J. Farina

The muskeg cover, 1 to 2 feet thick, was stripped off and almost continuous frozen ground was exposed. Some of the cut exposed clear ice lenses estimated to be up to 6" thick or more. Other parts of the cut contain surficial, frozen, silty to clayey silt soil and frozen moss and other organic matter. It is not possible to cut deeper as the dozer has no traction on the ice.

REMARKS: Photo 2.19.

LOG OF TEST PIT OR AUGER HOLE — Trench F

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Saddle Dike Project Vee Canyon, Alaska Hole No. Trench F
Area Designation Left Abutment Coordinates ____ Ground Elevation ____ Depth To Ground Water Level* ____
Method of Excavation D.7 Dozer Approximate Dimensions of Hole 250' long, 1'-5' deep Dates of Excavation 8/1/61 Hole Logged By R. J. Farina

Classification Symbol	Size and Type of Sample Taken	Classification and Description of Material
SW	75 lb. Sack F1 El 2375-2345	El 2375-2320 Sand, clean, angular, granitic detritus; Primarily buff, with some gray beds which tend to be silty. Loose, mostly clean, crude stratifications 1"-3" thick, gradations between beds are extremely variable. Some beds are very coarse to medium grain; others are medium to fine and a few beds are fine to silty. When mixed, the deposit would probably be a fairly well graded, pervious sand, (SW). Not frozen.
SM	75 lb. Sack F2 2345-2320	El 2320-2280 Sand, crudely stratified buff and gray, beds ½" to 3" thick; angular granitic detritus, (SM). More fine grain, silty sand and silt than above elevation 2320. Irregular dip, estimated less than 10° to the west. The east end of the trench was stopped due to frozen sand.
SW	75 lb. Sack F3 2320-2290	El 2290-2265 Sand, brown, well graded, angular granitic detritus. Frozen, (SW).

REMARKS: Photos 2.20, 3.0, 3.1, 3.2.

LOG OF TEST PIT OR AUGER HOLE — Trench G

FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature Saddle Dike Project Vee Canyon, Alaska Hole No. Trench G
Area Designation Downstream Coordinates ____ Ground Elevation ____ Depth To Ground Water Level* ____
Method of Excavation D.7 Dozer Approximate Dimensions of Hole 120' long, 2' deep Dates of Excavation 8/1/61 Hole Logged By R. J. Farina

Classification Symbol	Classification and Description of Material
SM	Sand silty, gray, fine to very fine loose sand with some fine sandy, gravel lenses up to 6" thick. Crudely stratified, probably pervious. Top of trench is Frozen; not frozen for the most part, (SM).

REMARKS: Photo 3.3 Elevation difference, top to bottom of trench, is about 60'.

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN

LOGS OF EXPLORATIONS VEE CANYON

HOLE 12 & TEST PITS "B" THRU "G"

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

FILE NO. 2-SOU-92-04-01 APPENDIX I PLATE D-12

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Page 1 of 2

Feature: Saddle Dike — Project: Vee Canyon, Alaska — Hole No. Trench H
Area Designation: Right Abutment, Downstream
Method of Excavation: D.7 Dozer — Approximate Dimensions of Hole: 900' long, 2'-12' deep — Dates of Excavation: 8/1/61 — Hole Logged By: R. J. Farina

Classification Symbol (Letter)	Classification and Description of Material
SP	DH 7 to J 1, cut 3-4', Sand Crudely stratified, buff, lenticular beds, generally poorly graded - lacking coarse size; medium to very fine, some silty; loose, pervious sand, Not frozen. Contains some fine subrounded gravel lenses. Beds are variable and range from 1" to 6", (SP).
SM	J 1 to J 2, cut 2½', Sand Silty Gray, medium to fine, loose, pervious. Similar to sand in anchor pit at DH 7. Contains some scattered subrounded gravel to 2" maximum. Sand is crudely stratified 1" to 3" thick; contains occassional lenses of medium or coarse sorted sand. Partly frozen, (SM).
SM	J 2 to J 3, cut 2-5', Sand As at J 1 - J 2. The deposits appear to dip to the S.W., estimated dip on crude stratifications is less than 10°. Not frozen, except near J 3, (SM).
ML	Gully near J 3 - Frozen ground occurs about 30' E and 20' W of J3. Clayey silt with ice lenses. Gully area is not well exposed. The clayey silt appears to be restricted to the gully and is probably washed down from higher elevations, (ML).

Remarks: Photos 3.4, 3.5, 3.6

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Page 2 of 2

Feature: Saddle Dike — Project: Vee Canyon, Alaska — Hole No. Trench H
Area Designation: Right Abutment, Downstream
Method of Excavation: D 7 Dozer — Approximate Dimensions of Hole: 900' long, 2'-12' deep — Dates of Excavation: 8/1/61 — Hole Logged By: R. J. Farina

Classification Symbol (Letter)	Classification and Description of Material
SM	J 3 to J 4, cut 4'-12', Silty Sand, gray, medium to fine with beds of gray, loose, silt. These silty beds apparently dip beneath Trench J as they cannot be seen there, (SM).

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature: Saddle Dike — Project: Vee Canyon, Alaska — Hole No. Trench J
Area Designation: Northeast of Camp
Method of Excavation: D 7 Dozer — Approximate Dimensions of Hole: 200' long, 3' deep — Dates of Excavation: 8/1/61 — Hole Logged By: R. J. Farina

Classification Symbol (Letter)	Classification and Description of Material
ML	El 2250-2243 Silt, gray, clayey. Trench is not clean, poor exposure, gentle slope, (ML).
GW	El 2243-2220 Gravel and sand channel partly frozen. Well graded, loose gravel-sand mixture; maximum size about 3", occassional cobbles to 6". Overall color is gray-brown with some prominent limonite stained lenses which are weakly cemented and friable. Gravels are subangular to subrounded; generally sound igneous and metamorphic types with some decomposed granite. Very steep slope, (GW).
SW	El 2220-2160 Sand-tan, crudely stratified, some beds are coarse, others medium to fine. In general, fairly well graded, clean, loose sand with scattered, subrounded to subangular gravel to 2". Sand is mostly quartz and feldspar with lithic (black) grains - salt and pepper appearance, steep slope, (SW). Not frozen.
	Below 2160 the slope flattens out and is frozen clayey silt.

Remarks: Photos 3.8, 3.9, 3.10.

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature: Saddle Dike — Project: Vee Canyon, Alaska — Hole No. Trench K
Area Designation: 50' south of Camp
Method of Excavation: D 7 Dozer — Approximate Dimensions of Hole: 80' long, 4' deep — Dates of Excavation: 8/5/61 — Hole Logged By: R. J. Farina

Classification Symbol (Letter)	Classification and Description of Material
SM-SW	Sand, gray, loose, crudely stratified, medium to fine, some beds of silty fine sand and some well graded beds. Contains scattered fine gravel, subrounded, (SM-SW).

Remarks: Photo 3.7

LOG OF TEST PIT OR AUGER HOLE
FOR BORROW AND FOUNDATION INVESTIGATIONS

Feature: SADDLE DIKE — Project: VEE CANYON, ALASKA — Hole No. Trench L (Cut at DH 9)
Area Designation: 10' south of D.H. 9
Method of Excavation: D 7 Dozer — Approximate Dimensions of Hole: 80' long, 15' deep — Dates of Excavation: 7/19/61 — Hole Logged By: R. J. Farina

Classification Symbol (Letter)	Size and Type of Sample Taken	Classification and Description of Material
ML		Muskeg cover -- 1 ft. organic, silty brown soil; supports moss and shrubs but only a few small trees. Not frozen, (ML).
GW	75 lb. sack -- cut at DH 9	Sand -- fairly well-graded, gray, clean, loose, pervious, crudely stratified. Angular granitic detritus; contains some scattered subangular to subrounded gravel generally less than 1", some gravels to 3". Not frozen, (GW).
		Some sandy gravel noted at bottom of cut.

Remarks: Photo 2.1

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
LOGS OF EXPLORATIONS VEE CANYON

TEST PITS "H" THRU "L"

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SUMMARY LOG — HOLE NO. 1 — SHEET 1 OF 2

N 6,720	E 5,572	SURFACE ELEV. 2534.
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 193	DEPTH OF OVERBURDEN 193	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2534.		Very fine sand ranging to sandy silt loose to compact, light green to grey.		Hole drilled dry to 129' - water table not encountered at this depth. Hole completed using drilling mud, water table not measured.
	10	Silt with small amount of clay, sand fine, fairly compact, occasional pebble, green gray.		
	20	Silt with small amount of clay, some sand and occasional pebble, some Fe stains, fairly compact.		
	30	Silt, with broken granite fragments to 1" diameter, also pebbles to 1" diameter.		
	40	Silt with sand and pebbles, occasional rock to 1-1/4" diameter, damp at 44', iron stains at 51-52', firm to compact, green.		
	50	Silt with very fine sand, iron stained, frozen 54.6-54.9', green		
	60	Silt with occasional pebble, iron stained, frozen 57.5' to 58.1', firm, green.		
		Silt with fine to coarse sand, occasional rock to 1-1/2" diameter, compact, iron stained, green buff.		
	70			
	80	Silt with gravel dispersed throughout, compact, green buff.		
	90			
2533	100	Silt, iron stained, color change to grey at 93', compact, dry.		

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 1

SUMMARY LOG — HOLE NO. 1 — SHEET 2 OF 2

N 6,720	E 5,572	SURFACE ELEV. 2534
PROJECT	DRILL DATES: START	COMP.
DEPTH OF HOLE 193	DEPTH OF OVERBURDEN 193	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2533		Silt with few sand grains, few pebbles, fairly dry, compact, green, buff.		
	110	Silty sand, few pebbles, loose dry, gray.		
	120	Sand, trace of silt, fine to coarse, fairly well graded, loose, very dry, gray.		
		Silty sand, fine to coarse, dry, loose, gray.		
	130			
	140	Sand, fine, occasional rock to 1-1/2" dia. few thin layers of silt, ranging from loose to compact, sand gray, silt green.		
	150			
	160	Silt with fine sand, few pebbles.		
		Sand, fine to very fine, clean, firm to hard packed, gray.		
	170			
	180			
2347	190			
		Bottom of Hole 2341 Depth of Hole 193		

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 1

SUMMARY LOG — HOLE NO. 2 — SHEET 1 OF 3

N 6,266	E 5,456	SURFACE ELEV. 2393.3
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 210'	DEPTH OF OVERBURDEN 210'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE
2393.3		Silt with some fine sand, frozen at 1.5'	
	10	Fine sand, hard packed, dark gray	
		Sand, fine, hard packed, gray	
	20	Sand, fine with thin layers of coarse sand.	
		Sand, fine with thin layers of silt coarse sand and gravel, firm.	
	30	Sand, fine, with thin layers of silt, coarse sand and fine gravel, firm, gray.	
	40	Silt with fine sand, firm, blue-grn.	
		Sand, fine, very small amount of silt, hard packed, gray.	
		Silt, with thin layers of fine sand.	
	50	Silt, with little or no sand.	
	60	Sand, fine to medium, small amount of silt, gray.	
		Silt, with some fine sand, soft, blue	
	70	Sand, fine to medium, small amount of silt, blue gray.	
		Sand, fine to coarse, small amount of silt, few pebbles, soft.	
	80	Sand, fine to medium, firmly packed, gray.	
	90	Sand, fine ranging to medium, varying from loose to firm, small amount of silt, dark gray.	
2293.3	100		

REMARKS:

Depth to Water Table	Hole at Depth	Date
3.05'	45'	7/23/59
42.2'	75'	7/24/59
42.3'	81.7'	7/27/59

Silt from 125' to 200' appears to be lake bed deposit

Temperature Readings

Depth (ft)	Temp (°C)
10	4.0
20	.9
30	.85
40	.88
50	2.05
60	2.53
70	2.80
80	2.80
90	3.08
100	3.10
110	3.03
120	3.05
127.7	3.00

Above readings taken 8/4/59 with Whitney

Thermocouple, may require corrections after instrument is checked.

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 2

SUMMARY LOG — HOLE NO. 2 — SHEET 2 OF 3

N 6,266	E 5,456	SURFACE ELEV. 2393.3
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 210'	DEPTH OF OVERBURDEN 210'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE
2293.3		Sand, fine to medium, varying from loose to firm, small amount of silt, dark gray.	
	110	Very fine sand, loose to firm, dark gray	
	120	Very fine sand, firm, dark gray	
		Silt, soft to firm, w/small amount of clay, forms thread when rolled.	
	130	Silt, soft to firm, with few very thin layers of fine sand, dark gray.	
	140	Silt, soft to firm, some clay will form good thread, shine test, medium, dark gray.	
	150		
	160	Silt, soft to firm, little too rocky dark gray.	
	170	Silt, small amount clay, few thin layers very fine sand, gray.	
	180	Silt, some clay, forms good thread, shine medium bright, thin layers of very fine sand, soft to firm.	
	190	Silt, firm to hard, few thin layers of fine sand, dark gray.	
2193.3	200		

REMARKS:

Temperature readings made on 8/4/59 using Bureau of Reclamation Thermocouples.

Depth (ft)	Temp (°F)
10	36.3
20	26.6
30	26.4
40	27.1
50	28.4
60	28.9
70	29.6
80	29.6
90	29.6
100	30.1
110	30.1
120	30.1
127	30.1

Drill was cased to 127 ft. and allowed to stand 3 days to permit hole temperature to return to normal before taking temperature readings.

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 2

SUMMARY LOG — HOLE NO. 2 — SHEET 3 OF 3

N 6,266	E 5,456	SURFACE ELEV. 2393.3
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 210'	DEPTH OF OVERBURDEN 210'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2193.3		Fine sand, hard packed, some pyrite, mica flakes, very hard at 205		
		Very fine sand, hard packed, gray.		
2183.3		Bottom of Hole 2183.3 Depth of Hole 210'		

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 2

SUMMARY LOG — HOLE NO. 3 — SHEET 1 OF 2

N 5,865	E 5,362	SURFACE ELEV. 2350.8
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 176.3'	DEPTH OF OVERBURDEN 176.3'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE
2350.8		No core-barge deck to water surface.	
		Very fine sand, clean, sharp, loose, gray	
		Fine sand and gravel, loose to firm, gray.	
	10	Fine sand ranging to gravel with some pieces to 1-1/4" dia hard packed, brown to gray.	
	20	Very fine to fine sand, lenses of med. to coarse sand, mica and pyrite flakes throughout, loose, gray.	
		Very fine sand, trace of silt.	
	30	Very fine to fine sand, mica and pyrite loose, blue gray.	
	40		
	50	Sand, gravel, boulders	
		Very fine to med. sand, few coarse grains, few very thin layers of silt, soft, gray.	
	60	Fine sand, silt, with small amount gravel mixed throughout.	
	70	Silt	
		Layers of sand and silt, sand predominant.	
	80	Silt, gray.	
		Layers of sand, silt, sand layers about 1' thick, silt layers slightly thicker, firm, gray.	
	90	Silt, soft, sticky, blue gray.	
2250.8	100	Sand and silt, soft, contains artesian water, flowed to surface.	

REMARKS:

Ft. to Water	Date	Depth of Hole
5.7	9/12/59	11.5'
1.7	9/14/59	52.5'
6.6	9/15/59	103.4'
9.1	9/16/59	163.7'

Small artesian flow back thru drill rods from 98' to 101'

Artesian flow through drill rods from 163.7'. Flowed at rate 8 GPM. Rate of flow did not change in 30 minute test period.

Artesian flow at 8 GPM from 175.1' to 176.3'.

Water flowing from hole at completion. No temperature readings taken.

Silts, sands from about 55' to 140'. Maybe lake bed deposits.

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 3

SUMMARY LOG — HOLE NO. 3 — SHEET 2 OF 2

N 5,865	E 5,362	SURFACE ELEV. 2350.8
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 176.3'	DEPTH OF OVERBURDEN 176.3'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL,	; HORIZONTAL,	

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	% CORE	REMARKS
2250.8		Sand and silt, soft contains artesian water, flowed to surface.		
		Silt, with very fine sand, forms fair thread, soft, blue-gray.		
	110	Very fine sand, trace of silt, forms weak thread, soft, gray.		
		Silt, with very fine sand, soft to firm, forms good thread, blue-gray.		
	120	Very fine sand with some silt, soft forms weak thread.		
		Silt, soft to firm, forms good thread, gray.		
	130	Fine sand, little to no silt, soft, from 146' to 153' drill rods and casing dropped through formation under own weight without chopping or driving.		
	140			
	150			
	160	Fine sand, gravel, little to no silt Artesian aquifer, flowed to surface, rate 8 GPM.		
	170	Fine to coarse sand, well graded, with silt and clay, mica and pyrite flakes throughout, gravel to 1" dia. good thread, firm, gray.		
2174'		Fine sand, coarse gravel, boulders mica and pyrite flakes, packed, gray Artesian, rate 8 GPM.		
	180	Bottom of Hole 2174.5' Depth of Hole 176.3'		

NPA Form APR. 66 7(Test) — PROJECT Denali Damsite — HOLE NO. 3

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. I

UPPER SUSITNA RIVER BASIN
LOGS OF EXPLORATIONS
DEŃALI

HOLES I THRU 3

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

SUMMARY LOG — HOLE NO. 4 — SHEET 1 OF 2

SUMMARY LOG HOLE NO. 4	N 5,552 / E 5,226	SHEET 1 OF 2 / SURFACE ELEV. 2374.5
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 200.5'	DEPTH OF OVERBURDEN 200.5'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV. 2374.5 (top); 2275 (at depth 100)

DESCRIPTION OF MATERIALS	% CORE
Silt with considerable fine sand, mica flakes, frozen, some ice crystals, brown to gray.	
Gravel, small boulders, hard packed frozen.	
Fine sand, slight amount gravel, frozen.	
Fine sand with layers of clear ice, trace of silt, frozen.	
Sand and gravel, fine sand at 28', hard, frozen.	
Very fine to fine sand, few medium grains, mica and pyrite flakes, compact and hard, gray.	
Fine sand, with some gravel inter mixed.	
Hard packed gravel, few shall boulders	
Fine to medium sand, pyrite and mica flakes, loose to firm.	
Very fine to fine sand, silt mica and pyrite, silt in thin layers firm blue gray.	
Silt with very fine sand, fair thread, soft to firm, blue gray.	
Silt with considerable clay, good thread, soft, gray.	
Silt, compact, possible frozen.	

REMARKS

Water Table

Depth to Water	Date	Hole
0.9	8/31/59	28.3'
20.8	9/1/59	68.3'
26.1	9/2/59	130.2'
22.5	9/4/59	200.5'

Silt from 80.0' to 200' may be lake bed deposits.

NX casing to 89'

BX casing to 129.4'

AX casing to 192.8'

AX installed to hold hole open for temperature readings.

NPA Form 7(Test) APR. 66 — PROJECT Denali Damsite — HOLE NO. 4

SUMMARY LOG — HOLE NO. 4 — SHEET 2 OF 2

SUMMARY LOG HOLE NO. 4	N 5,552 / E 5,226	SHEET 2 OF 2 / SURFACE ELEV. 2374.5
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 200.5'	DEPTH OF OVERBURDEN 200.5'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV. 2274.5 (top); 2174 (at depth 200)

DESCRIPTION OF MATERIALS	% CORE
Silt, possible frozen, compact.	
Silt with some clay, good thread, soft, blue gray.	
Silt, compact, possible frozen	
Silt, alt. from soft to compact layers, with gravel and small boulders inter mixed, hard 166' to 170'	
Silt with fine to coarse sand, mica and pyrite flakes, soft to hard layers, blue gray.	
Silt with fine to coarse sand, mica and pyrite flakes, sand sharp, soft to hard layers, blue gray.	
Silt, compact, with coarse gravel	
Bottom of Hole 2174' / Depth of Hole 200.5'	

REMARKS

Used drill mud in hole from 131' to 200'

Hole caved-166.4' Filled hole to 168' on each run.

NPA Form 7(Test) APR. 66 — PROJECT Denali Damsite — HOLE NO. 4

SUMMARY LOG — HOLE NO. 5 — SHEET 1 OF 2

SUMMARY LOG HOLE NO. 5	N 5,105.5 / E 5,013.6	SHEET 1 OF 2 / SURFACE ELEV. 2519.0
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 203'	DEPTH OF OVERBURDEN 203'	DIAM. OF HOLE 3
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV. 2519.0 (top)

DESCRIPTION OF MATERIALS	% CORE
Very fine sand, trace of silt, frozen, ice crystals, dark gray	
Fine to very fine sand, clean, loose, gray.	
Very fine sand, trace silt, gray.	
Very fine to coarse sand, loose to firm, lenticular, brown gray.	
Fine sand, loose to compact, brown.	
Fine to medium sand, loose to compact, brown	
Very fine to fine sand, compact to hard, brown.	
Fine to very fine sand, thin layers of silt, compact to hard, brown to gray.	
Gravel Boulders	
Fine sand and clay "sticky"	
Fine sand and silt	

REMARKS

Water Table

Feet of Water	Date	Depth of Hole
6.1	8/17/59	35.2
21.6	8/18/59	90.4
17.7	8/19/59	113.4
31.6	8/20/59	150.9
102.0	8/22/59	203.
102.0	8/24/59	203.

NX casing to 89'

BX casing to 169.3'

NPA Form 7(Test) APR. 66 — PROJECT Denali Damsite — HOLE NO. 5

SUMMARY LOG — HOLE NO. 5 — SHEET 2 OF 2

SUMMARY LOG HOLE NO. 5	N 5,105.5 / E 5,013.6	SHEET 2 OF 2 / SURFACE ELEV. 2519.0
PROJECT Denali Damsite	DRILL DATES: START	COMP.
DEPTH OF HOLE 203'	DEPTH OF OVERBURDEN 203'	DIAM. OF HOLE 3"
ROCK DRILLED None	CORE RECOVERED	% RECOVERY
ANGLE FROM VERT. Vert.	AZIMUTH FROM NORTH	COMPILED BY, DATE
DISTANCES: VERTICAL, ; HORIZONTAL,		

ELEV. 2419.0 (top)

DESCRIPTION OF MATERIALS	% CORE
Fine sand and silt.	
Silt with gravel, hard packed.	
Fine to medium sand, pyrite flakes hard to compact, gray.	
Fine sand with some silt, compact to hard, blue gray.	
Sand with small amount silt and fine gravel, gray.	
Fine to medium sand, trace of silt, compact, gray.	
Fine to medium sand, some coarse sand with gravel, gray	
Fine gravel, sand, hard packed.	
Gravel, sand and silt in layers too 2' thick	
Sand and gravel trace of silt in layers, compact, gray.	
Fine sand, and gravel to 203'	

REMARKS

Hole caved badly from 170' to 200'

Bottom of Hole 2316'
Depth of Hole 203'

NPA Form 7(Test) APR. 66 — PROJECT Denali Damsite — HOLE NO. 5

SOUTHCENTRAL RAILBELT AREA, ALASKA

INTERIM REPORT NO. 1

UPPER SUSITNA RIVER BASIN
LOGS OF EXPLORATIONS
DENALI

HOLES 4 AND 5

ALASKA DISTRICT, CORPS OF ENGINEERS

ANCHORAGE, ALASKA

DECEMBER 1975

REPORT

SUBSURFACE GEOPHYSICAL EXPLORATION
PROPOSED WATANA DAMSITE ON THE SUSITNA
RIVER, ALASKA for
DEPARTMENT OF THE ARMY
ALASKA DISTRICT, CORPS OF ENGINEERS
CONTRACT NO. DACW85-76-C-0004

EO
AN

DAMES & MOORE
JOB NO. 3221-011-20

APPENDIX I
EXHIBIT D-1

Anchorage, Alaska
September 25, 1975

District Engineer
Alaska District, Corps of Engineers
Department of the Army
P. O. Box 7002
Anchorage, Alaska 99510

Gentlemen:

Report
Subsurface Geophysical Exploration
Proposed Watana Damsite on the Susitna River, Alaska for
Department of the Army
Alaska District, Corps of Engineers
Contract No. DACW85-76-C-0004

In compliance with your request and as authorized by your contract number DACW85-76-C-0004, we are pleased to submit five copies of our report, "Subsurface Geophysical Exploration, Proposed Watana Damsite on the Susitna River, Alaska for Department of the Army, Alaska District, Corps of Engineers." We also submit reproducable copies of all recordings, plans, and cross-sections.

The accompanying report presents our conclusions concerning the nature of the overburden and bedrock, and the depth to the top of bedrock as interpreted from the seismic refraction data.

The horizontal and vertical scales used for the cross-sections have been modified from those originally requested, as authorized by Mr. Glenn Greeley.

In the event that you have any questions, or desire clarification of any part of this report, please contact us at your convenience. It has been a pleasure to assist you on this project.

Very truly yours,

DAMES & MOORE

Sukhmander Singh
Associate

Forrest D. Peters
Senior Geophysicist

SS:FDP:sed
Attachments

REPORT

SUBSURFACE GEOPHYSICAL EXPLORATION

PROPOSED WATANA DAMSITE ON THE SUSITNA RIVER, ALASKA

FOR

DEPARTMENT OF THE ARMY

ALASKA DISTRICT, CORPS OF ENGINEERS

CONTRACT NO. DACW85-76-C-0004

INTRODUCTION

This report contains the results of a subsurface geophysical survey performed during August and September 1975 at the proposed Watana damsite on the Susitna River, Alaska. The proposed dam would be a rock-fill, impervious-core dam approximately 650 to 850 feet high with a water-pool elevation of between 2,050 and 2,200 feet MSL.

The site is located in T32N, R5E, Seward Meridian, and is approximately 125 miles NNE from Anchorage, Alaska. The location of the site is illustrated on Plate 1, Plot Plan.

PURPOSE OF THE SURVEY

The purpose of the geophysical survey was to obtain additional information concerning this site, for use in evaluating the feasibility of the dam, and for use in planning what further exploration may be necessary at the site.

SCOPE OF WORK

The geophysical survey consisted of 22,000 lineal feet of seismic refraction line on the upper right abutment area of the proposed dam, and approximately 500 feet of seismic refraction line across the Susitna River in the vicinity of the proposed axis of the dam. The locations and details of these refraction lines are illustrated on Plate 1.

These refraction lines were used to determine the nature and thickness of the overburden and the depth to the top of bedrock along the lines. In addition, the refraction data was interpreted to obtain any indications of major structural, tectonic, or lithologic features which may exist within the bedrock. The specific purpose of the geophysical work on the right abutment area of the proposed dam, was to determine if one or more buried, abandoned river channels exist through this abutment of the damsite.

FIELD WORK AND RESULTANT DATA

Details of the field work are described in Appendix A. The seismic refraction records which were obtained during this work, are reproduced on Plates 5 and 6. The time vs. distance plots of the refraction data and the subsurface cross-sections which were interpreted from this data are presented on Plates 2 through 4.

DISCUSSION

The results of this geophysical survey are of a preliminary reconaissance nature, due to the fact that no other subsurface information is available concerning this site. The seismic refraction method of investigation is an indirect method, which is by itself, non-definitive concerning many aspects of the geology of the bedrock and the characteristics of the overburden materials. The results derived from refraction data became progressively more definitive with the incorporation of more and more surface and subsurface information into the interpretation process. The conclusions discussed in this report should, therefore, be re-evaluated in the light of any additional surface and subsurface information which may become available at a later date.

UPPER RIGHT ABUTMENT AREA

Topography

Station 0+00 was used as a local elevation datum for seismic lines A and B with an assumed elevation of 1,000 feet. The actual elevation of this station is approximately 2,300 feet MSL as estimated from the USGS topographic sheet Talkeetna Mountains D-4. The subsurface cross-sections on Plates 2 and 3 can; therefore, be viewed with respect to possible pool-elevations behind the dam with this possible MSL elevation as a reference.

The topography along lines A and B is gently rolling with some relatively sharp topographic breaks about 10 to 15 feet high. Surface drainage throughout this area is generally poor such that most of the near-surface soils are wet or fully saturated except close to the sharper topographic breaks.

Surface Geology

There are no known bedrock outcrops along lines A and B. Igneous bedrock does outcrop southwest of station -4+00 on the higher ground in this direction, and on portions of the slopes leading down to the Susitna River.

The surficial materials observed at the ground surface and in the borings drilled for shotholes (maximum depth of 9 feet, usual depths of about 4 feet), are with one exception, generally of coarse glacial till/glacial outwash origin. Large boulders and cobble-sized fragments of igneous rock are characteristic of the surficial materials and form boulder pavements in many areas. These boulder pavements have little or no interstitial materials in many cases. The rest of the surficial materials consist of a heterogeneous mixture of silt to boulder sized clastics with a very high proportion of boulders.

The only observed occurrences of clay along lines A and B were in the shotholes at stations 119+50 and 132+00. Approximately 4 feet of clay was penetrated in the shothole at station 119+50 and similar clay was observed at the bottom of the shothole at station 132+00. The origin and extent of this clayey material is unknown, although it would presumably be of lacustrine origin. A sample of this material was given to the Corps of Engineers representative on the site.

Depth to Bedrock and Thickness of Overburden

The depth of bedrock and the thickness of overburden as interpreted from the refraction data are shown on the cross-sections on Plates 2 and 3. The overburden thickness varies from approximately 15 feet to approximately 420 feet along lines A and B. These depths to bedrock are considered to be accurate to approximately plus or minus 20 percent of the calculated depths. This low order of accuracy is caused by highly variable overburden characteristics, strong changes in the bedrock surface and variable bedrock velocity. The question of the accuracy of the interpretations derived from the refraction data is addressed more fully in Appendix B. The interpretation of the data between stations 0+00 and 53+50 (Plate 2) is considered less accurate than on the rest of the refraction line because of a combination of overlapping anomalous conditions in the bedrock and overburden.

Bedrock Velocities

The velocities of the bedrock obtained from this survey range between 10,000 to 18,000 feet per second. A value of 18,000 feet per second was obtained on line C in the river bottom as will be discussed later. This velocity is considered representative of igneous bedrock which does not have any appreciable open fractures caused by near-surface stress relief.

The bedrock velocities obtained from lines A and B have a highest value of approximately 16,000 feet per second. This velocity is found from station 0+00 to 3+00 and from station 198+00 to 220+00. It is considered to be representative of probable igneous bedrock which has been stress relieved to depths of at least one or two hundred feet.

Most of the area between stations 3+00 and 198+00 has a bedrock velocity in the vicinity of 14,000 - 15,000 feet per second. The velocity contrast between this and 16,000 feet per second is considered significant and real, however, the cause of this velocity change is open to question. The bedrock in this area could be igneous rock with a slightly lower velocity, or it could be of a different lithology (metamorphic or volcanic rocks).

The two low velocity zones in the bedrock (station 5+00 to 11+50 and station 161+00 to 178+50) have velocities between 10,000 and 12,000 feet per second. These low velocity zones must be caused by a significant change in either lithology or internal structure of the bedrock in these areas. The location and orientation of a highly fractured zone in the bedrock exposed in the river-canyon wall south-southeast of stations 5+00 through 11+50, suggests that this low velocity zone may represent a shear zone. However, this low velocity zone could also be caused by lithologic differences. The low velocity zone between stations 161+00 and 178+50 could also be caused by either a shear zone or different lithology.

Overburden Velocities

The overburden velocities range between approximately 1,200 feet per second and 9,000 feet per second. The low overburden velocities between 1,200 and 2,000 feet per second are indicative of loose, partially saturated near-surface overburden. Intermediate velocities between 2,000 and 5,500 feet per second are probably the result of velocity averaging between the near-surface materials and water saturated materials below them, but may also represent nearly saturated materials in some areas.

The velocities between 5,500 and 9,000 feet per second represent fully saturated overburden. The range of 5,500 to 6,500 feet per second is the normal velocity for fully saturated alluvium/glacial outwash material. Velocities between 6,500 and 9,000 feet per second must represent other than alluvial/glacial outwash conditions in the overburden. There are three possibilities:

(1) Ground moraine overriden by relatively thick glacial ice can have velocities in this range.

(2) Permafrost conditions in otherwise normal velocity materials can have velocities in this range.

(3) Overburden containing a very high percentage of boulders and cobbles, which have good contact with each other can have velocities in this range. Note that a zone of shattered bedrock will also fit this description.

It is impossible to determine from the velocity data alone, which of these three types of conditions are causing velocities within the 6,500 to 9,000 feet per second range.

The area between 15+00 and 31+50 (Plate 2) contains overburden velocities of 7,500 to 9,000 feet per second. This zone of high overburden velocity is unusual and is part of the reason for interpretation problems in this portion of the line. This zone appears to contain a relatively thin (50 to 100 foot thick) zone of high velocity near the ground surface. Overburden with normal velocity appears to be present below this high velocity zone.

This interpretation is supported by unusual high frequencies of the 9,000 foot per second arrivals from shotpoints at 22+00 and 31+50 which is indicative of relatively thin-bed refraction arrivals. This interpretation is also supported by the large offsets in the time-distance plots in the vicinity of the critical distance of the refractor. This thin bedded high velocity zone may be due to a very high concentration of boulders in the near-surface, or perhaps by near-surface permafrost. Other interpretations of the refraction data are possible in this vicinity, but the interpretation given is considered to be the most probable subsurface configuration.

The other areas with overburden velocities above 6,500 feet per second do not have any distinct peculiarities within the refraction data that will aid us in making educated guesses between the alternatives given for this velocity range.

RIVER BOTTOM (LINE C)

Topography

The northern monument of line C (0+00) was used for a datum with an assumed elevation of 100 feet. The water level in the river on September 7, 1975 was approximately 55.0 feet using this elevation datum.

Surface Geology

Igneous bedrock outcrops in a vertical cliff on the south side of the river about 15 feet behind the spruce tree used for the southern monument of the refraction line. There were no observed bedrock outcrops near the northern portion of the refraction line. The slope between stations 1+00 and 0+00 and north of 0+00 consists predominantly of large-sized talus boulders with little or no interstitial material. The materials on the gravel bar and in the river consist of a heterogeneous mixture of silt to cobble sized clastics with a large percentage of cobbles.

Depth to Bedrock and Thickness of Overburden

The quality of the refraction records for line C varies from excellent to very poor. The land geophones gave excellent arrival information while the hydrophones gave very poor arrival information due to the very great noise generated by the river current. The accuracy of the depth to bedrock shown on Plate 4 is considered to be plus or minus 15 percent of the calculated depths, except under the hydrophone portion of the line where the accuracy is less than this.

Bedrock Velocity

The bedrock velocity in the river bottom is approximately 18,000 feet per second. As discussed previously, this velocity is considered to be representative of the velocity of the igneous rock which has no appreciable open fractures induced by stress relief.

Overburden Velocities

The velocity of 7,000 feet per second observed on the northern end of line C is the velocity of the talus boulders, or is a combination of arrivals through these boulders and through bedrock due to the effect of the steep slope on the bedrock surface at this end of the line.

The water-saturated velocity of the alluvium in the bottom of the river was obtained from a short refraction line run with a Bison Seismograph. The observed velocity from this line was 6,100 feet per second and is in the normal range for water saturated alluvium with a high percentage of large clastics.

SUMMARY AND CONCLUSIONS

The subsurface cross-sections shown on Plates 2 through 4 contain our best estimates concerning the probable depths to bedrock along the refraction line in the upper right abutment area, and in the vicinity of the proposed dam axis. These cross-sections can not be taken at face-value, but must be considered in context with the discussion of the results given in the main body of this report, and the dicussion of accuracy given in Appendix B. Additional subsurface information would provide more definitive interpretations concerning the geology of this area.

There is a considerable portion of line A where the bedrock surface is apparently below the potential pool elevations of either 2,050 or 2,200 feet MSL. The area between stations 20+50 and 41+50 has a bedrock surface appreciably below an elevation of 2,050 feet if we accept the estimate given in this report of a true elevation of 2,300 feet for station 0+00. The area between stations 1+50 and 59+00 has a bedrock surface appreciably below an elevation of 2,200 feet, if we accept this same elevation estimate.

This area with relatively deep bedrock may or may not contain an abandoned, buried river channel as such. It is possible that this area may be due solely to preferential excavation of metamorphic bedrock by glacial action rather than erosion of a river channel. The overburden may therefore consist of normal glacial till with or without highly permeable river or glacial outwash materials. If this is the case, no firm conclusions can be drawn concerning the lateral extent of this low bedrock area, and the bedrock along the water's edge of the reservoir may lie above or below the possible pool elevations.

The presence of boulder pavements on the surface of this area and the possible existance of a relatively thick boulder zone between stations 21+00 and 53+50 could present large water loss problems if these extend to the edge of the proposed reservoir below pool elevation. However, the high near-surface velocities between these stations could be due to the presence of permafrost rather than a boulder zone.

The clayey material observed in the shotholes at stations 119+50 and 132+00 may indicate a possible borrow area for impervious core material.

The two low velocity zones within the bedrock (station 5+00 to 11+50, and station 161+00 to 178+50) may be caused by a high degree of fracturing within the bedrock (shear zone), or by a lithologic change within the bedrock. The strongly fractured zone in the bedrock exposed in the river bluff SSE of stations 5+00 to 11+50, appears to trend toward this portion of line A, and may therefore be related to this low velocity zone.

The bedrock along the rest of lines A and B may be wholly igneous, or may be a combination of igneous and metamorphic rocks.

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The following plates and appendicies are attached and complete this report:

Plate 1	Plot Plan
Plate 2	Seismic Refraction Line A
Plate 3	Seismic Refraction Line B
Plate 4	Seismic Refraction Line C
Plate 5	Seismic Refraction Records Line A
Plate 6	Seismic Refraction Records Lines B and C

Appendix A   Field Work

Appendix B   Accuracy of Results

Respectfully submitted,

DAMES & MOORE

Sukhmander Singh
Associate

Forrest D. Peters
Senior Geophysicist

SS:FDP:sed

APPENDIX A

FIELD WORK

The geophysical field work for this report was performed between August 28 and September 8, 1975 at the Watana damsite. The field crew consisted of three Dames & Moore geophysicists, two licensed powdermen, two surveyors, a helicopter pilot, and several technicians. The Corps of Engineers sent a representative to the site for the duration of the field work.

The survey consisted of one 22,000 foot seismic refraction line utilizing geophone spacings of 25, 50, and 100 feet. One 545-foot refraction line was conducted perpendicular to the Susitna River near the axis of the proposed dam. In addition, a short 100-foot long, hammer refraction survey was conducted in the river bottom. Total footage for the survey was 22,645 lineal feet.

The site was located (Plate 1) approximately five miles from Tsusena Lodge where the field crew was lodged. Tranpsortation from Anchorage to the lodge and back was provided by float planes and transportation from the lodge to the site was provided by a 206B Jet Ranger helicopter. The above facilities and services were provided by Sea Airmotive, Inc. All transport of equipment and personnel along the refraction lines was by helicopter. Surveying services were provided by F. M. Lindsey and Associates. Powder and blasting services were provided by X-Demex Corporation. All subcontractors are based in Anchorage.

The seismic lines were located at the direction of the Corps of Engineer's representative at the site. The seismic refraction line was brushed and staked at 100-foot intervals. Elevations were measured to the nearest tenth of a foot, at every stake. Permanent monuments, Labeled PTA, PTB, and PTC shown on Plate 1, were placed at stations 0+00, 110+00, and 220+00.

The seismic energy used for the survey was produced by detonation of explosive charges (Kinemetrics K1 2-component explosives) placed into shallow shotholes. The shotholes were drilled with a two-man power auger or poled down with a crowbar. Shotholes were not less than three feet deep. At all shotpoints the required poundage, which varied from 4 to 12 pounds, was achieved by loading a pattern of shotholes positioned within a five-foot radius of the shotpoint. All charges were stemmed and tamped with material from the shothole.

The energy released by the detonation of the explosive charges was detected by vertically oriented, 14-hertz geophones. The geophones were coupled to the earth by burial in a hole 6 to 10 inches deep.

A basic geophone and cable layout (profile) of 2,200 feet was used for the main refraction line as shown on Plate 1. A total of five shots were recorded into each geophone profile. The seismic energy detected by each geophone was input into a 24 channel SIE RA 44 Seismic Amplifier, and recorded on an SIE R-6 Recording Oscillograph.

The field work for the river line was performed on September 7 and 8, 1975. Total length of the line was 545 feet of which 275 feet was in the Susitna River. To span this segment of the river, a continuous loop of aircraft stress cable (diameter 5/32 inches) was extended over the river to the opposite bank. Slack was taken up to the point where the stress cable extended across the river at an average height of 10 feet.

A hydrophone cable and shot line was then attached to the stress cable. The hydrophones were spaced at intervals of 25 feet and secured to cable crimps fastened to the stress cable to prevent any slippage. Ten vertically oriented land geophones were spaced at intervals of 25 feet on the dry ground of the north bank of the river. Shotpoints for the river line were positioned at both ends and 282 feet downstream from station 1+80.

To supplement the river survey, a 100-foot long hammer refraction survey was conducted in the river bottom. This survey consisted of recording first arrivals from hammer blows located at various positions along the line into a single channel Bison Seismograph. This refraction line was not long enough to obtain refracted arrivals from the bedrock, therefore the data from this line is not presented in this report.

APPENDIX B

ACCURACY OF RESULTS

Accuracy of Calculated Depths to Bedrock

The low order of accuracy for the results obtained from seismic refraction data is quite common for this method of exploration when no other type of subsurface information is available. Accuracies of plus or minus 15 and 20 percent of the calculated depth to bedrock are quoted in this report. If the calculated depth to top of bedrock is shown on the cross-section at 100 feet below the surface, a quoted accuracy of ± 20 percent means that the true bedrock surface could be anywhere between 80 and 120 feet below the ground surface (i.e. ± 20 percent of 100 feet). Quoted accuracies of this type have a very special meaning which must be explained.

The quoted accuracy is a qualitative estimate made by the geophysicist who interprets the refraction data, and represents his best estimate of the effect of a large number of factors on the calculated depths. The major factors which affect accuracy are the following:

(1) Small scale irregularities on the bedrock surface. The seismic refraction method tends to average (smooth) the bedrock surface. A boring may penetrate bedrock on a high or low point of the bedrock surface which is not observed in the refraction data. However, a large number of borings along the refraction line will show that the average depth to bedrock is very close to that calculated from the refraction data. The average accuracy of the calculated depth to bedrock will, there-

fore, be much better than the quoted value (for example, ± 10 percent or even ± 5 percent instead of ± 20 percent).

(2) Hidden layers or blind zones. These types of subsurface conditions cannot be observed directly in the refraction data, but are the major cause for large differences between calculated depths and the actual depths found by borings. Near-surface high velocities underlain by lower velocities, and buried high velocity zones which do not appear in the refraction data as first arrivals, are the major types of subsurface geometries which are referred to as hidden, or blind zones. The quoted accuracy for calculated depths contains a large factor to account for such possible subsurface conditions. One or more borings which penetrate bedrock along the refraction line, will permit recalculation of the depth to bedrock to remove the effect of such hidden or blind layers. The accuracy of the recalculated cross-section will then become ± 10 percent or even ± 5 percent.

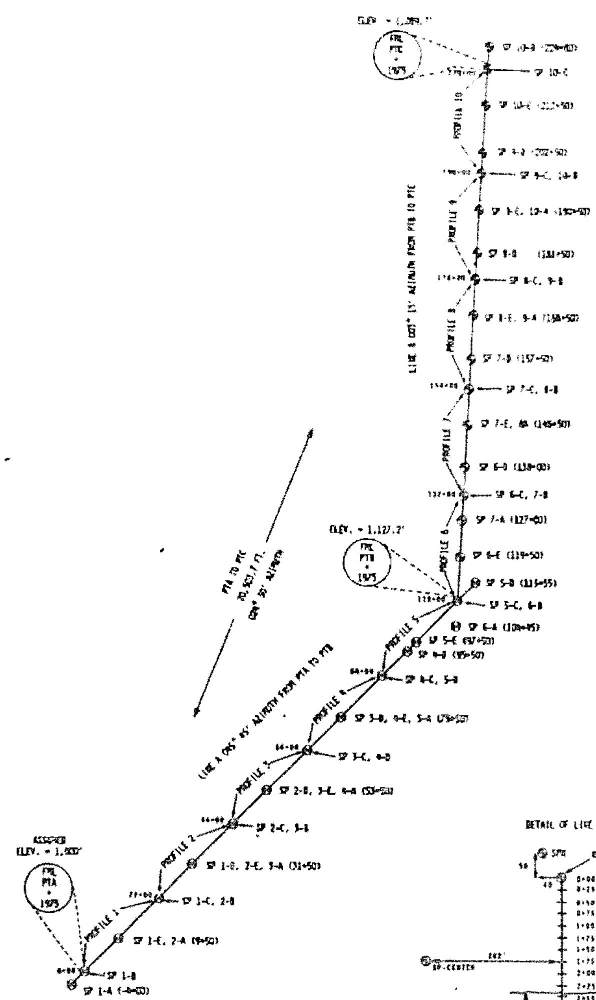
(3) Highly irregular subsurface conditions and overlapping subsurface anomalies: The refraction data between stations 0+00 and 53+50 on line A is an example of this type of accuracy problem. The bedrock surface in this area is irregular with some areas of strong relief. The bedrock velocity in this area is not constant. The near-surface arrivals indicate the possibility of a surface high velocity layer which is underlain by lower velocities. All of these anomalies occur together and overlap each other to such an extent that it becomes difficult

if not impossible to interpret the refraction data properly. One or more borings in this area would help in the interpretation of the data by providing definitive subsurface information which can be used to sort out the overlapping effects of the various types of anomalies.

ACCURACY OF CALCULATED VELOCITIES

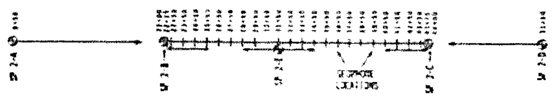
The quoted accuracies for the refraction data do not refer to the velocity values given on the time-distance and cross-section plots. The accuracy of the calculated velocities are dependent primarily on the inherent timing accuracy of the seismic records. The calculated velocities are accurate to within $\pm$ 5 percent. Small-scale variations of seismic velocity within the bedrock and overburden do affect the calculated velocities, but this type of inaccuracy is included within the above quoted accuracy for the seismic velocities.

The velocities shown on the time-distance plots are not necessarily the real velocities of bedrock or overburden. These plots contain the effects of subsurface conditions and the geometry of the seismic wave systems. These calculated velocities are therefore called apparent velocities. The apparent velocity from one direction on a geophone profile is directly related to the apparent velocity from the other direction. The combination of these two apparent velocities is related to the true velocities and these true velocities are given on the subsurface cross-sections.



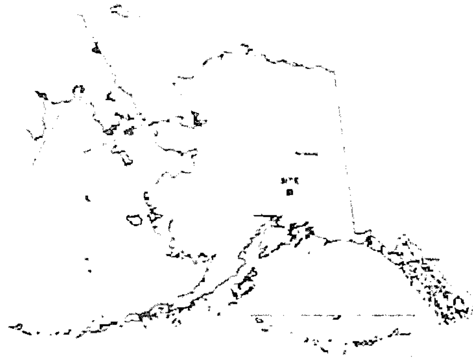
DETAILS OF GEOPHONE AND SHOTPOINT LAYOUTS
FOR EACH PROFILE OF LINES A AND B

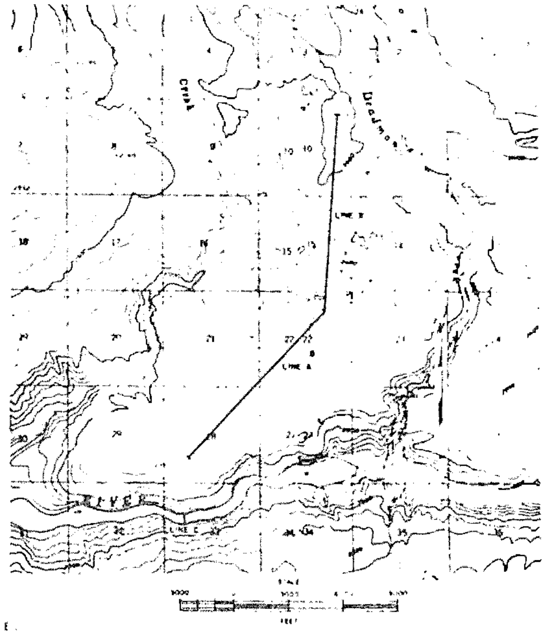
GEOPHONE PROFILE 2



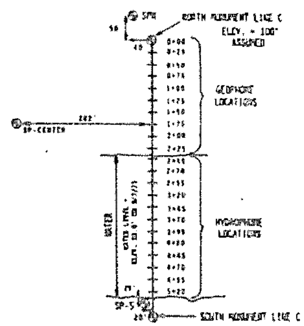
BASIC GEOPHONE INTERVAL = 100 FT. EXCEPT NEAR ENDS OF PROFILE WHERE GEOPHONES WERE MOVED BACK FROM STATION 22+00 TO 22+25 AND FROM 44+00 TO 43+75 WHEN SHOT POINT 2-B and 2-C WERE DETONATED, RESPECTIVELY.

BASIC SHOTPOINT PATTERN CONSISTED OF 5 SHOTS INTO EACH GEOPHONE PROFILE (SP 2-A, 2-B, 2-C, 2-D AND 2-E). EACH SHOTPOINT WAS OFFSET FROM THE LINE IF REQUIRED BY THE PRESENCE OF GEOPHONES AND CABLES.





DETAIL OF LINE C



I LINE C
(SEE SHEET FOR DETAILS OF LINE C)

NOTES: 1) THE NORTHERN END OF LINE C IS APPROXIMATELY 7900 FEET SOUTH OF STATION 0+00 ON LINE A. THIS RELATIVE LOCATION WAS ESTIMATED FROM THE APPROXIMATE POSITIONS OF LINES A AND C AS PLOTTED ON THE TALKEETNA MOUNTAINS D-4 TOPOGRAPHIC SHEET.

2) LOCATION AND DESCRIPTION OF PERMANENT MONUMENTS

a) PTA 0+00 LINE A. A COPPER ROD EXTENDING 4 INCHES ABOVE THE TOP OF A PROMINENT ROCK APPROXIMATELY 8 FEET HIGH. COPPER ROD HAS A SCREW CAP MARKED AS SHOWN ON PLOT PLAN.

b) PTB 110+00 INTERSECTION OF LINES A AND B. A COPPER ROD EXTENDING 1 FOOT OUT OF GROUND 0.47 FEET SOUTHWEST OF TRUE STATION 110+00. COPPER ROD HAS A SCREW CAP MARKED AS SHOWN ON PLOT PLAN.

c) PTC 220+00 END OF LINE B. A COPPER ROD EXTENDING 4 INCHES ABOVE GROUND SURFACE WITH A SCREW CAP MARKED AS SHOWN ON PLOT PLAN.

d) NORTH MONUMENT 0+00 LINE C ON RIVER: NAIL ON TOP OF 7-INCH BIRCH STUMP.

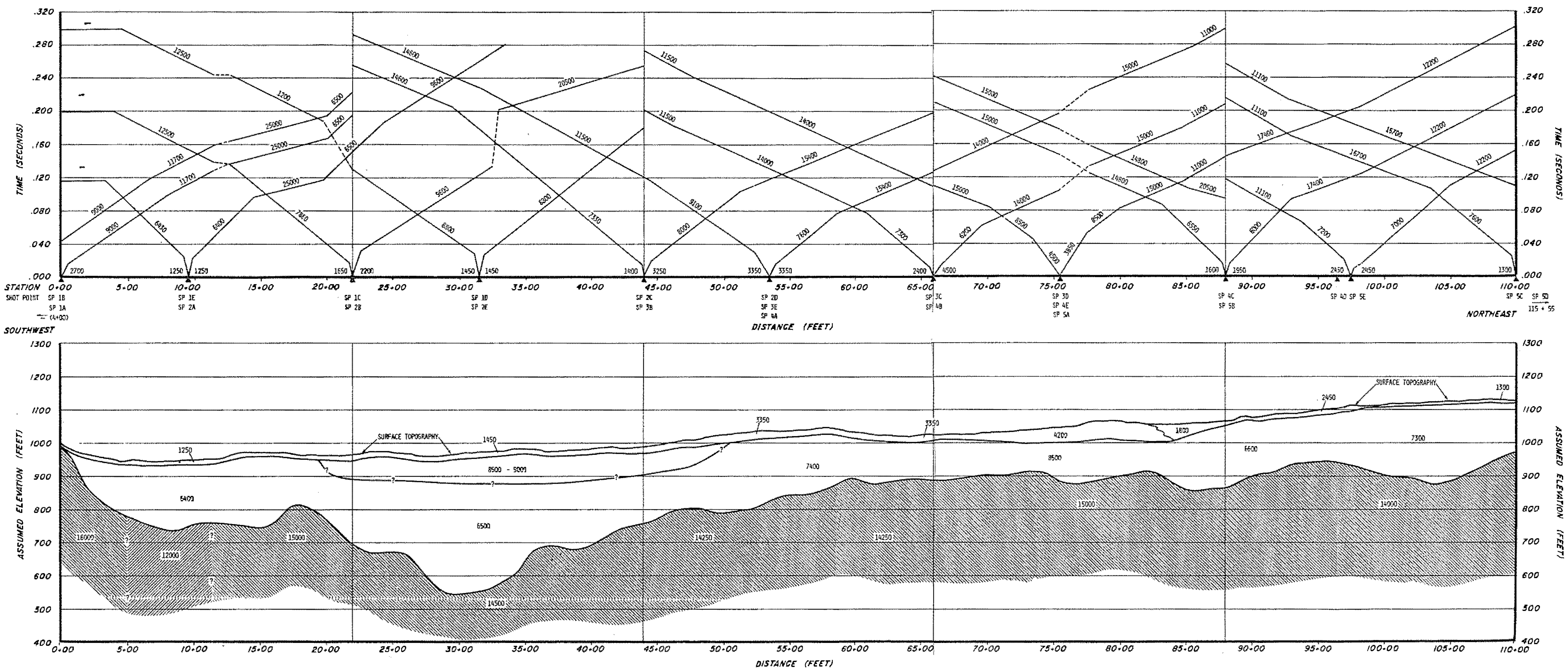
e) SOUTH MONUMENT 5+66.5 LINE C: NAIL ABOUT 5 FEET HIGH ON NORTHWEST SIDE OF 8-INCH SPRUCE TREE.

REFERENCE.
U.S. GEOLOGICAL SURVEY 1:63,360 TOPOGRAPHIC MAPS, TALKEETNA MOUNTAINS (D-5) AND (D-4), ALASKA.

PLOT PLAN

SHOWING LOCATIONS AND DETAILS OF SEISMIC REFRACTION LINES AND SURVEYING INFORMATION

PLATE I



NOTES:

TIME-DISTANCE PLOTS REFLECT INFORMATION COLLECTED FROM SHOT POINTS ESTABLISHED AT SEVERAL LOCATIONS ALONG A SEISMIC LINE. FOR CLARIFICATION, THE FOLLOWING PLOT SYMBOL HAS BEEN USED:

▲ SHOT POINT LOCATION

THE SUBSURFACE SECTION SHOWN REPRESENTS OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATIONS OF PRESENTLY AVAILABLE GEOPHYSICAL DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

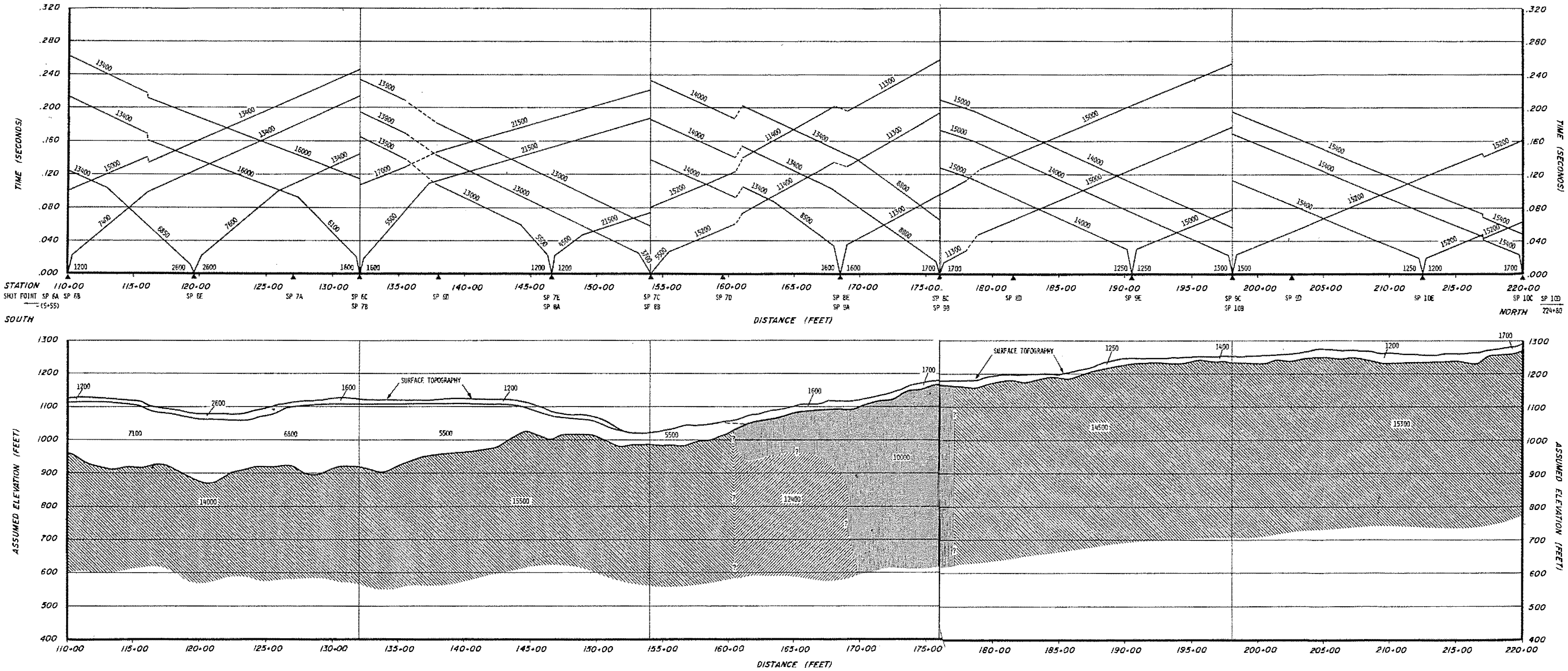
ALL OF THE COMPRESSIONAL WAVE VELOCITIES SHOWN ON THE TIME-DISTANCE PLOTS ARE APPARENT VELOCITIES. THESE VELOCITIES HAVE BEEN DETERMINED DIRECTLY FROM THE PLOTS. WHEN THE APPARENT COMPRESSIONAL WAVE VELOCITIES HAVE BEEN CORRECTED FOR SUBSURFACE VARIATIONS, THE TRUE COMPRESSIONAL WAVE VELOCITY RESULTS, AS SHOWN IN THE SUBSURFACE CROSS-SECTIONS.

ALL ELEVATIONS ARE RELATIVE TO AN ASSUMED ELEVATION OF 1000 FEET AT STATION 0+00.

SEISMIC REFRACTION
LINE A
STATIONS 0+00 TO 110+00

DAMES & MOORE

PLATE 2



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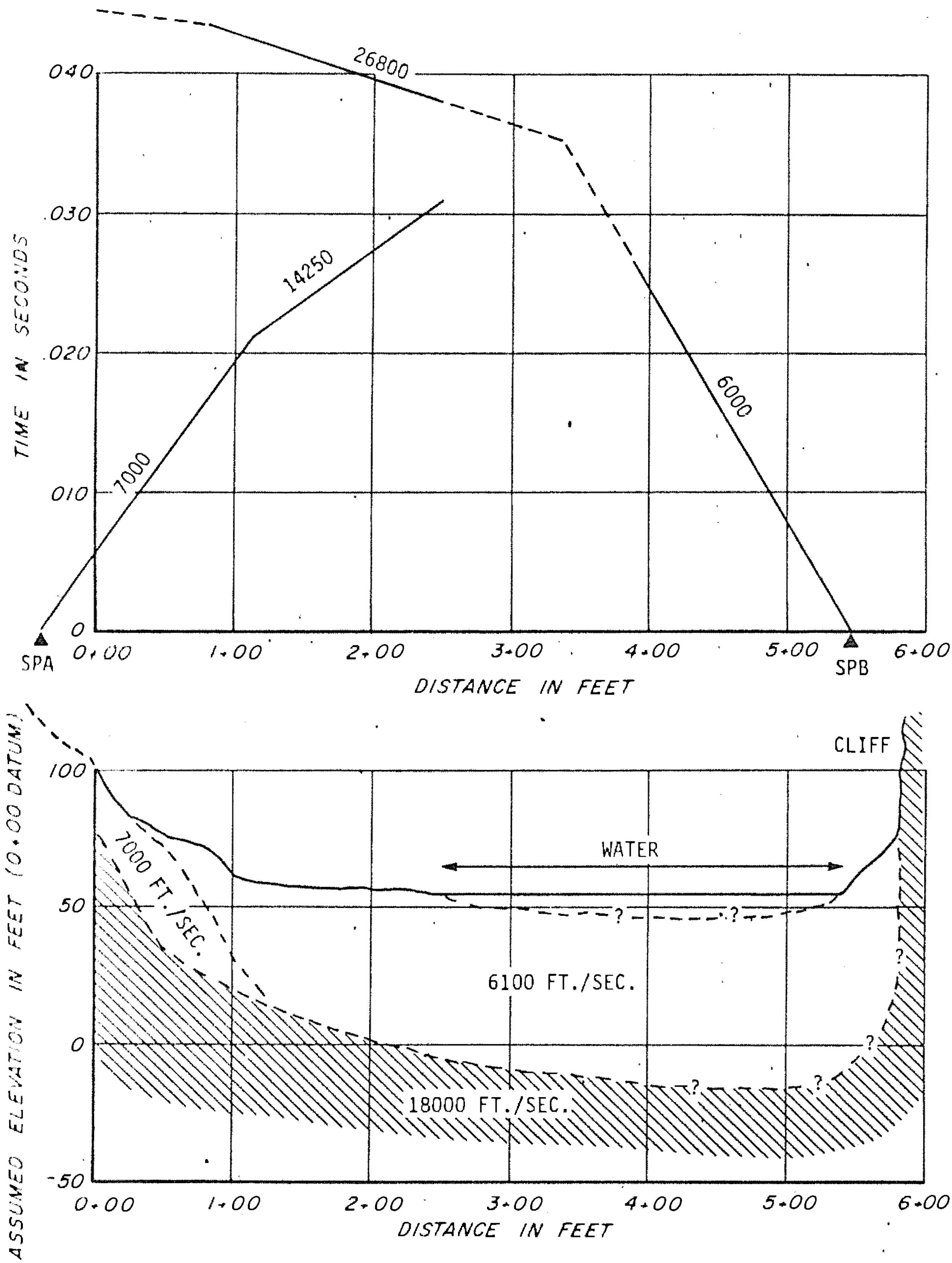
ALL ELEVATIONS ARE RELATIVE TO AN ASSUMED ELEVATION OF 1000 FEET STATION 0+00

SEISMIC REFRACTION
LINE B
STATIONS 110+00 TO 220+00

DAMES & MOORE

PLATE 3



SEISMIC REFRACTION
LINE C

DAMES & MOORE

PLATE 4

PLATE 5

SEISMIC REFRACTION RECORDS

LINE A

STATIONS 0+00 TO 110+00

UNREADABLE AT REDUCED SCALE

NOT REPRODUCED FOR THIS EXHIBIT

PLATE 6

SEISMIC REFRACTION RECORDS

LINE A

STATIONS 110+00 TO 220+00

LINE C

(RIVER LINE)

UNREADABLE AT REDUCED SCALE

NOT REPRODUCED FOR THIS EXHIBIT

PRELIMINARY GEOLOGIC AND SEISMIC EVALUATION OF THE PROPOSED DEVIL CANYON AND WATANA RESERVOIR AREAS, SUSITNA RIVER, ALASKA

by

John C. Lahr and Reuben Kachadoorian

This report is prelminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

Appendix 1
Exhibit D-2

CONTENTS

ILLUSTRATIONS

INTRODUCTION

The Alaska District, Corps of Engineers, requested the U.S. Geological Survey to conduct preliminary geotechnical evaluation of the proposed Devil Canyon and Watana Reservoir areas, Susitna River, Alaska. The Alaska District, CE, requested (1) a brief study of the potential for seismic events caused by reservoir loading and fault lubrication, (2) a brief study of major mass movement potential in the reservoirs with emphasis on possible catastrophic events, and (3) recommendations for remote instrumention to evaluate items 1 and 2 above.

In view of the limited time for response, this report consists of a brief discussion of potential geologic and seismic hazards and recommendations for detailed studies of potential hazards that should be undertaken in the Devil Canyon and Watana Reservoir areas. This response is based on a literature search, discussions with colleagues, examination of vertical aerial photographs, and a prior geologic investigation of the Devil Canyon Damsite for the Bureau of Reclamation (Kachadoorian, 1974).

The proposed Devil Canyon and Watana dams are located on the Susitna River in the Talkeetna Mountains, south central Alaska (Figure 1). The Devil Canyon site is located about 18 miles (29 kilometers) upstream from Gold Creek, which is on the Alaska Railroad. The proposed dam is 635 feet (193 meters) high and the reservoir formed would have a maximum water elevation of 1,450 feet (441 meters) above sea level and would extend upstream for about 28 miles (45 kilometers) to the Watana damsite. The height of the proposed Watana dam is 810 feet (247 meters). The reservoir produced would have a maximum water elevation of 2,200 feet (670 meters) above sea level and would extend upstream for 54 miles (87 kilometers).

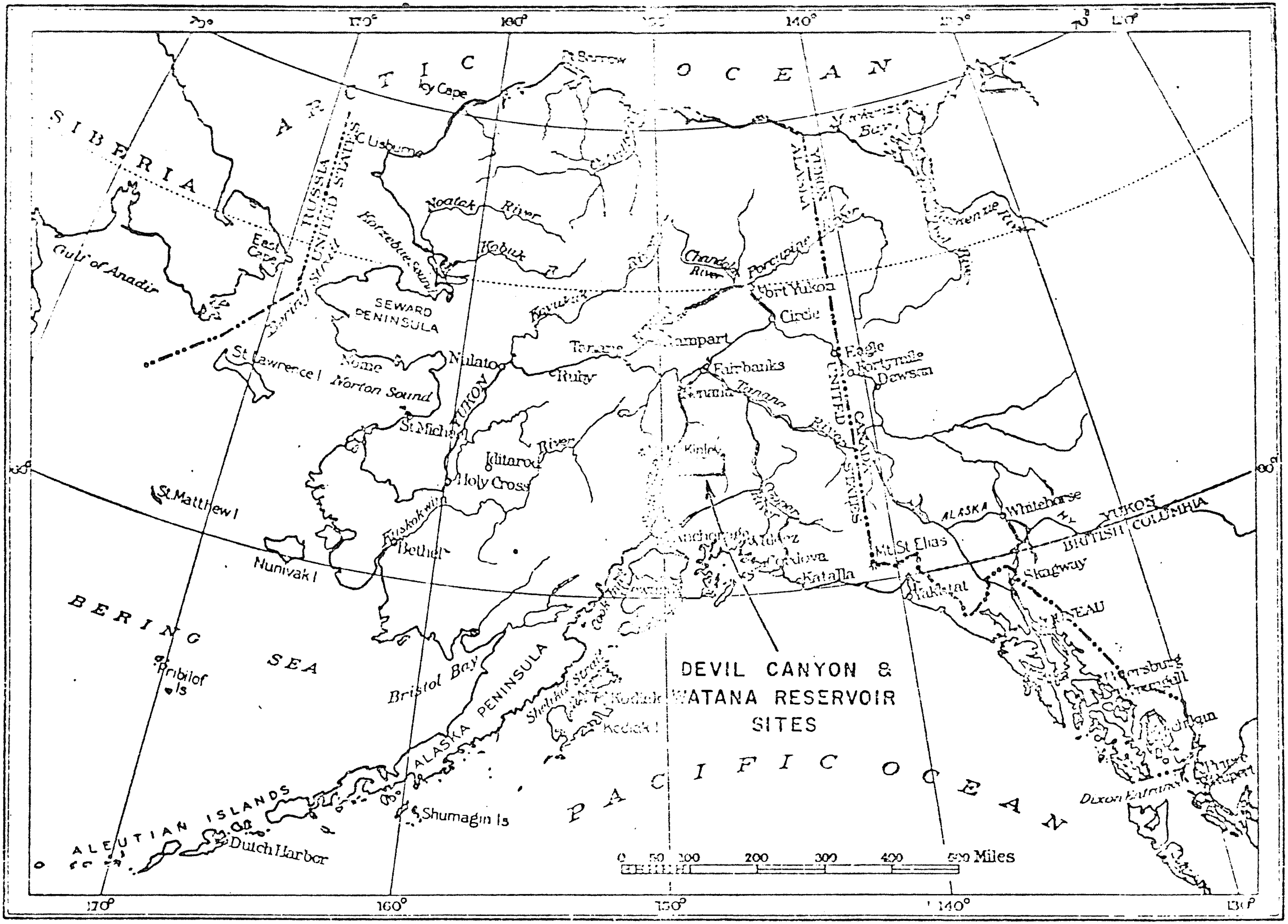


FIGURE I : INDEX MAP SHOWING LOCATIONS OF PROPOSED DEVIL CANYON AND WATANA RESERVOIR SITES , SUSITNA RIVER , ALASKA

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GEOLOGIC SETTING

Devil Canyon Site

Geology.-- The proposed Devil Canyon damsite is underlain by argillite and graywacke of Cretaceous age. The rock is exposed in the canyon walls of the Susitna River and in scattered outcrops throughout the area. It is hard, generally massive, medium- to dark-gray metamorphosed fine-grained sediments that contain numerous stringers and vugs of quartz (Kachadoorian, 1974). The reservoir of the proposed Devil Canyon dam is underlain chiefly by argillite, graywacke, granite, and unconsolidated sediments of glacial and non-glacial origin.

Structure.--The following discussion of structure is taken from Kachadoorian (1974). There are three joint sets in the Devil Canyon dam site area, one well-developed and two poorly developed. The strike of the well-developed or master joint set varies from N. 45° W. to N. 10° W. and averages N. 25° W. The dip of the joints ranges from vertical to 75° E. and averages 80° E. The average spacing of these joints is 4 to 5 ft. Locally, however, they are as close as 2 in. and as far as 15 ft apart. The joints, with few exceptions, are tight. Many of these joints are filled with quartz containing finely disseminated pyrite.

The two poorly developed joint sets consist of a generally tight set striking parallel or subparallel to the bedding but generally dipping north instead of south, and an eastward-striking, nearly horizontal set. The first set has a spacing of 3 in. to 15 ft. It is locally well developed and its joints contain some quartz. The second set has a spacing from 3 in. to 30 ft. With few exceptions, the joints in this set are tight. They dip from 15° N. to 15° S., but more commonly the dip is horizontal.

Well-developed shear zones, spaced from 50 to 800 ft apart, have been observed in the bedrock walls of Devil Canyon. Many of the larger shear zones contain gouge as much as 2 ft thick. The shear zones with gouge are much tighter than those without.

The shear zones appear to have developed parallel to or along the same trend as the master joint system, which is probably older than the shear zones. The strike of the shear zones is N. 25° W. and the dip is 80° E. This attitude is comparable to the average strike and dip of the master joint set discussed earlier in this report. The variation in the attitudes of the shear zones is of the same order of magnitude as the variation in attitudes of the master joint set.

Watana Site

Geology.-- The proposed Watana damsite is underlain by granitic rock which has intruded the Cretacous argillite and graywacke. Therefore, the granitic rocks ~~is~~ are late Cretaceous to Tertiary in age. The rock underlying the damsite is sound, hard, and coarse-grained. The reservoir of the Watana dam is underlain chiefly by granite, argillite, graywacke, greenstone, and unconsolidated sediments of glacial and non-glacial origin.

Structure.-- We have no information on the joint and shear zone pattern at the proposed Watana damsite.

Regional Faulting

Except for the detailed work of Kachadoorian (1974) around the Devil Canyon damsite there has only been limited geologic work, mostly of a reconnaissance nature, done in this region. Plate 1 shows the location of regional faults (Beikman, 1974; Csejtey, personal communication, 1975). Faults that are questionable are queried on the plate.

TECTONIC SETTING

The proposed Devil Canyon and Watana Reservoir region is located in the tectonic zone which extends along the entire margin of the Pacific "plate". According to the tenets of plate tectonics the lithosphere of the earth is made up of several large mobile plates. The Pacific plate is moving northwestward with respect to the North American plate and is being thrust under Alaska at the Aleutian trench. The seismicity associated with this process may generally be divided into three groups: earthquakes, such as the 1964 Alaska earthquake, which occur on the surface of contact between the Pacific plate and the North American plate in order to accommodate their relative motion; earthquakes which occur in the North American plate in response to stresses produced by interaction with the Pacific plate; and earthquakes occurring in that portion of the Pacific plate which has been thrust below Alaska. The latter events define a region called the Benioff zone.

A major complication in the tectonics of Alaska which is not well understood is the transition from underthrusting along the Aleutian trench to strike slip motion on the Fairweather fault.

The present trench extends eastward only to about 145°W., more than 200 km from the Fairweather fault. Therefore there appears to be a "transition" zone in southern Alaska between the eastern limit of underthrusting and the strike slip Fairweather fault, and in this zone Alaska may be largely coupled to the Pacific plate (Richter and Matsen, 1971). Richter and Matsen (1971) present this explanation for the Holocene and Quaternary faulting observed along the Denali fault system and it probably influences the tectonics throughout the reservoir region.

It is within this tectonic framework that the regional seismicity will be reviewed.

SEISMICITY

Devil Canyon and Watana Reservoir Region

In order to access the ambient seismicity of this region seismic data compiled in the USGS (formerly NOAA) Earthquake Data File for January 1900 through February 1975 was searched for events located from 146.5°W to 151.5°W and from 62°N to 63.7°N. This data set was used to plot the epicenters shown on Plate 2.

The accuracy of these epicenters is highly dependent upon the number and distribution of seismograph stations used in their location. Previous to 1935, when the College, Alaska station was installed, the nearest data was recorded at Sitka, Alaska. Five events are from this early time period. They are all rather large events with magnitudes of from 5.6 to 6.25. They have been assigned 0.0 km depth due to lack of depth control and their epicentral coordinates have an accuracy of approximately 100 km. Earthquakes recorded from 1935 to 1960 have an epicentral accuracy of approximately 50 km and errors in depth as great at 100 km. In this data file the only magnitude assigned during the 1935 to 1960 interval was 6.25 for an event in 1948. The remaining 22 events were probably of magnitude 4.5 or greater in order to be recorded by enough stations for a location to be determined. With the establishment of the World Wide Standard Seismograph Network (WWSSN) in the 1960's and the use of computer techniques for earthquake location the probable errors were again reduced. From 1960 through 1966 two events of magnitude class 6 occurred, both below 70 km depth. Five events of class 5 were located and three of these had depth of 50 km or less.

Further improvement in accuracy and a decrease in the magnitude of the smallest locatable earthquake occurred when the Palmer Observatory of NOAA and the University of Alaska established seismograph networks in 1967. Since that time the accuracy has been typically 10-15 km for epicenter and 25 km for depth although errors may be much larger on occasion.

The seismicity in the region of the proposed reservoirs ranges in depth from less than 10 km to greater than 175 km. In order to emphasize the more reliable earthquakes not associated with the Benioff zone, the events shallower than 50 km and occurring since January 1967 are indicated by solid symbols. Events at 33 km depth are not included, however, because this depth is assigned to those earthquakes which lack depth control and they may, in fact, be deeper than 50 km. The five largest events with reliably determined depth of 50 km or less and located since 1967 have magnitudes ranging from 4.1 to 4.6. In addition four magnitude class 4 events are assigned a depth of 33 km. The closest of these eight events to the damsites occurred in 1970 and was located about 72 km south of the proposed Watana damsite, at a depth of 44 km. Fifty-four magnitude class 3 earthquakes with depth of 50 km or less were located since 1967. Seven of the 28 events with a reliable depth estimate were located within 50 km of one or both of the proposed damsites.

The tectonics of this region are too poorly known at this time to reliably predict the location and magnitude of future crustal earthquakes. The Denali fault, which lies less than 80 km north of the proposed damsites, Plate 1, is a major strike-slip fault with geologic evidence for a 3 cm/yr average Holocene slip rate. This fault could sustain a magnitude 8.0 event. The activity of the other faults shown on Plate 1 is uncertain, and the shallow seismicity is too scattered to reliably associate it with individual faults.

Benioff Zone.-- The seismic activity deeper than about 50 km depth is believed to be associated with the Benioff zone of the underthrust Pacific plate. PDE hypocenters have been used to determine the extent and configuration of the Benioff zone (Lahr, 1975), as shown in Figures 2, 3, and 4. Portions of cross-sections F, G, and H pass through the reservoir region as noted on Plate 2. Reference to Figures 3 and 4 shows that the upper limit of the Benioff zone lies at a depth of approximately 50 to 80 km below the proposed reservoirs.

Since 1967 there have been 58 Benioff zone events of magnitude class 3, thirty-one of class 4, and five of class 5. This is a substantially higher rate of activity than in the upper 50 kilometers. Subcrustal activity at a depth of 50 km or more below the damsite and possibly as large as magnitude class 7 should be considered for its shaking hazard in designing the dams, but faulting associated with deep events would not extend into the crust.

GEOLOGIC AND SEISMIC HAZARDS

Mass Movement

The proposed Devil Canyon and Watana damsites are located in narrow, steep-walled canyons of the Susitna River. At the left abutment of the Devil Canyon site there are some overhanging cliffs formed by the southerly dipping beds. The overhanging cliffs have resulted in large blocks, that, in some cases, are distinctly separated from the adjacent bedrock. Some of these blocks are as much as 25 feet across and 50 feet high. These blocks could be shaken loose during a major seismic event and if they fell into the reservoir could generate waves or if they were to fall upon the dam they could damage the structure. It is unknown whether such large blocks occur in the Devil Canyon and Watana reservoir areas or at the Watana damsite.

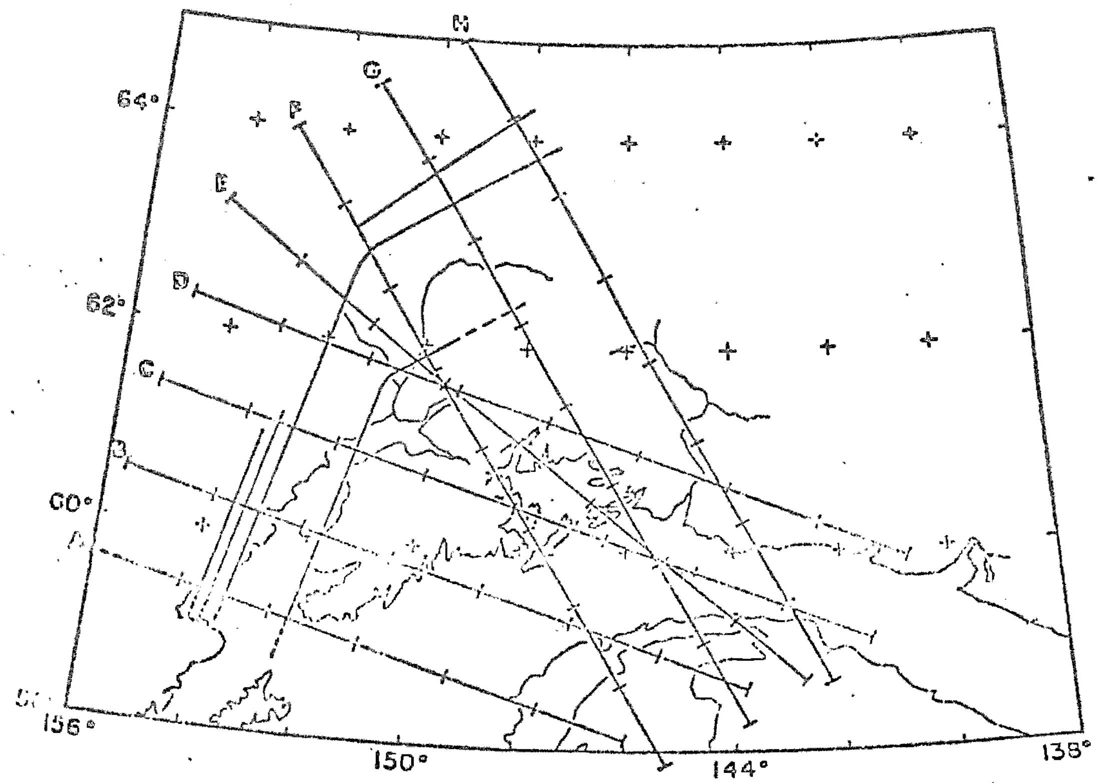

Figure 2. Index map showing the location of the 4 vertical cross-sections shown in Fig. 3. Each cross-section includes the epicenters within a 100 km wide zone centered on the corresponding line. Tick marks are spaced at 100 km intervals along each line. After Lahr (1975).

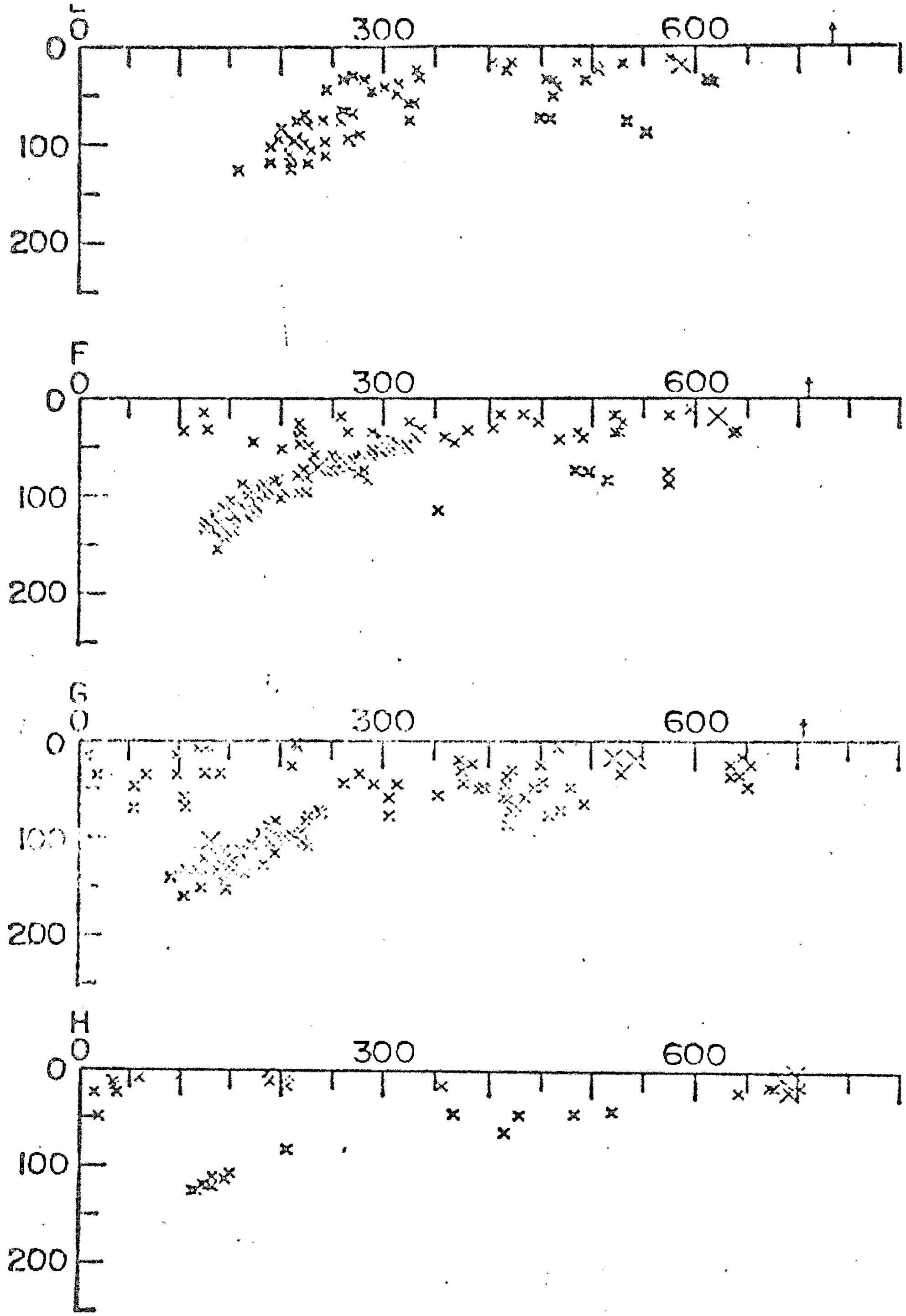

Figure 3. Vertical cross-sections of PDE data for Jan. 1970 - May 1973. Location given in Fig. 2. Small and large X's correspond to 10-49 and 50 or greater stations used in location; a t is plotted above Aleutian Trench crossings. After Lahr (1975).

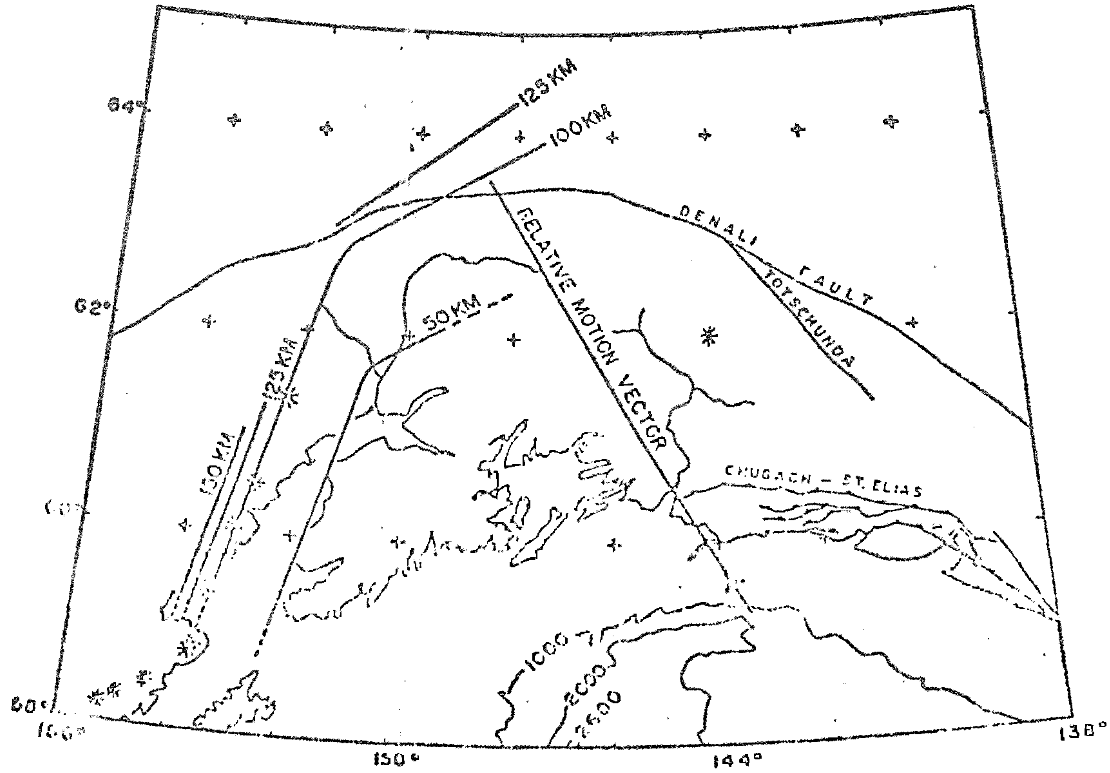

Figure 4. Map of south central Alaska region showing the extent of the underthrust Pacific plate. 50, 100, 125 and 150 km contours are given for the upper surface of the Benioff zone. The Denali and Totschunda faults are shown (after Richter and Matson, 1971). The thrust faults, sawteeth on upper plate, are after Plafker (1967). Depth contours are in fathoms. Relative motion vector shown is portion of small circle about pole at 54°N and 61°W. After Lahr (1975).

Approximately 1/2 mile (1 kilometer) upstream from the proposed Watana damsite a study of aerial photographs indicates that there may be a large landslide on the south wall of the canyon that has reached the Susitna River. Small landslides were noted on Watana Creek about 1 mile (1.6 kilometers) from its confluence with the Susitna River. It is unknown whether these landslides are the result of seismic activity. However, studies have shown that numerous landslides occur during a seismic event. Therefore, one must assume that the proposed Devil Canyon and Watana reservoirs could be subjected to earthquake generated landslides.

There are numerous unconsolidated sediments consisting of glacial debris and alluvial fan deposits that are plastered on the walls of the canyon high above the river. These unconsolidated sediments will be inundated when the Devil Canyon and Watana reservoirs are filled. During a major seismic event these sediments may slide and generate waves in the reservoir.

The highest runups of waves generated by overhanging blocks falling into the reservoir and subaerial and subaqueous landslides will occur at the landslide site and on the opposite wall of the reservoir. Waves generated by landslides at a bend in the reservoir could be oriented primarily along the axis of the reservoir. If such waves do occur, they would runup higher along the face of the proposed earthfill Watana dam than the proposed concrete arch Devil Canyon dam.

Seiches

Seiches that develop in lakes and reservoirs during earthquakes generally do not have high crests and probably would not cause significant damage, however, this possibility does exist. In the Hebgen Lake, Montana earthquake of 1959 subsidence of portions of the lake caused great surges of water, as high as 10 feet above the previous static water level, that overtopped the dam three or four times (Myers and Hamilton, 1964).

Earthquakes Induced by Reservoir Filling

Table 1 summarizes some of the cases in which there is an apparent relationship between reservoir filling and seismic activity. Many other large reservoirs have evidenced no recognized increase in seismic activity. This induced activity generally dies out a few years after the reservoir is filled. There is not a consensus as to the mechanism for inducing seismicity. The most widely accepted theory, however, is that increased fluid pressure in the earth effectively reduces friction and allows abrupt faulting to relieve pre-existing stresses. The modification of the pre-existing stresses by the weight of the impounded water may also be involved.

Based upon the reservoir heights listed in Table 1, as compared with the height proposed reservoirs, some induced activity might be expected, and the largest event could be of magnitude class 6. Since the induced faulting would be more likely to reactivate a pre-existing fault or joint system than to rupture virgin rock, it is preferable to place the dams away from faulted and jointed areas.

TABLE 1

SUMMARY OF SEISMIC ACTIVITY THAT MAY BE RELATED TO RESERVOIR FILLING

RESERVOIR	YEAR COMPLETED	YEAR OF FIRST EARTHQUAKE	MAGNITUDE OF FIRST EARTHQUAKE	APPROXIMATE WATER HEIGHT (m)	APPROXIMATE WATER VOLUME ($10^9 m^3$)	TYPE OF DAM
Oued Fadda, Algeria	1932	1933	Unknown			
L. Mead, U.S.	1935	1936	5.0	118	35.	Arch
L. Kariba, Rhodesia-Zambi	1958	1961	6.1	125	175.	Arch
Hsifengkiang, China	1959	1959	6.1	105	11.5	Buttress
Cajura, Brazil	1959	1970	4.8	30	.12	
L. Grandvad, France	1959	1961	V(Intensity)	78	292.	
Kurobe, Japan	1960	1962	4.9	180		Arch
L. Monteyard, France	1962	1963	4.9	130	275.	Arch
Koyna, India	1962	1963	6.4	103	2.8	Concrete-Gravity
Vogarno, Switzerland	1964	1965	Unknown			
L. Kremasta, Greece	1965	1965	6.3	120	4.8	Earth
Mangla, Pakistan	1968	1968	Unknown			
Hendrik Verwoerd	1970	1971	2.0	66	5.	Arched Wal
Talbingo, Australia	1971	1971	2.4	151		Earth & Ro
Grancarevo, Yugoslavia			4.	121	1.3	Arch
Vajont, Italy	A landslide in 1965 killed 2600 people					
Nuryek, U.S.S.R.	1971	1971	5.5	120		Earth & Ro

CONCLUSIONS

The Devil Canyon and Watana damsites lie in a region of high seismicity between two major tectonic structures which could sustain earthquakes in the magnitude 8 range -- the Aleutian subduction zone along the southern coast of Alaska and the Denali fault system in the Alaska Range to the north. The earthquake history of the reservoir area has not been studied in detail, nor has the level and spatial distribution of current seismicity. Within the present limits of knowledge, it should be assumed that the proposed dam will be subject to potentially serious earthquake hazards. Surface faulting, if it occurs at the damsites, is a potential hazard; however, it may be minimized by careful investigation of surface faulting prior to the final selection of the damsites. Strong ground shaking from nearby earthquakes is a hazard that is not easily avoided by selection of alternative damsites. Accordingly, ground shaking is likely to be a more significant hazard. Strong shaking may cause damage to structures directly and may also trigger slope failures and seiching of water in the reservoirs. In addition to the naturally occurring earthquake activity in the region, there is also the hazard that filling of a reservoir will trigger potentially damaging earthquakes (as large as magnitude 6 or greater) in the immediate vicinity of the damsites. All these hazards should be carefully assessed in the siting and design of the proposed dams.

RECOMMENDATIONS

The impetus for the following recommendations is three fold:

1) To provide the geophysical and geologic data necessary to pick the optimum damsite locations and to design the dams to accomodate potential environmental hazards.

2) Once the dams are constructed, to monitor the tectonic processes

in the region and if possible to warn of impending damage to the dams by earthquakes and earthquake-induced landslides.

3) To further the understanding of the mechanism of reservoir-induced seismicity in order to improve the prospects for predicting or controlling both induced and natural earthquakes.

The Introduction and and Recommendations of a publication entitled Earthquakes Related to Reservoir Filling by the Joint Panel on Problems Concerning Seismology and Rock Mechanics to the NAS-NAE (1972) is appended for reference. Their recommendations, aimed at the third category, are excellent and have influenced the recommendations proposed herein.

Geologic Studies

In addition to the detailed geologic maps that will no doubt be prepared for the area around the foundations of the proposed Devil Canyon and Watana Dams, geologic mapping should be carried out for the entire area of the reservoirs. Although great detail may not be required, special attention should be given to the patterns of faulting, the competency of bedrock and the extent and nature of the unconsolidated sediments in the reservoir areas.

Geologic studies should be conducted to evaluate the faults that are queried on Plate 1 and to determine whether other faults exist in the proposed Devil Canyon and Watana reservoir areas. Emphasis should be placed on the age and sense of the most recent fault movement, in order to assess the potential for future seismic activity and to improve our understanding of the tectonic regime. The stability of the perched unconsolidated sediments and large overhanging blocks of bedrock should be examined.

Geophysical Studies

Because the damsites lie in a region of high, but poorly understood seismicity, comprehensive earthquake investigations are recommended including:

a) Operation of a network of sensitive seismograph stations to record earthquake data necessary for determining in detail the pattern and level of current seismicity, for identifying active faults, and for determining the orientation of tectonic stress in the region through focal mechanisms. Long term seismic monitoring should be initiated as soon as possible.

b) Critical review and detailed reassessment of locations and focal mechanisms of historic earthquakes occurring within 100 km of the reservoir area. Foci of historic earthquakes should be relocated by special computer techniques to minimize the uncertainties in existing published locations. The improved locations would aid in the delineation of active faults.

c) Strong motion instruments placed near each of the proposed damsites to record free-field ground shaking in the advent of potentially damaging local earthquakes.

For purposes of earthquake forewarning, it is recommended that tilting of the reservoir be monitored by installing continuously-recording water-level gauges at the east end, center and west end of each reservoir. At Tasu Reservoir in China premonitory water level changes, attributed to tilt, occurred prior to a large local earthquake (B. Raleigh, personal communication, 1975).

Gravity studies in the proposed reservoir region show a major NE trending discontinuity in gravity. These data should be reviewed and additional data possibly obtained to increase our understanding of the structure and tectonics of the region.

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APPENDIX

INTRODUCTION

There is evidence that local seismic activity, including earthquakes of moderate magnitude (up to Richter magnitude 6.4), some of them quite destructive, has occurred in association with the impounding of water in large reservoirs in several countries. For many other large reservoirs, there is no evidence of earthquakes related to filling.

As populations have continued to increase and the demand for water has grown correspondingly, this phenomenon has generated a considerable amount of international interest. Though reservoir-related earthquakes have not thus far caused loss of life or notable damage in the United States, in at least three foreign areas such earthquakes have had quite serious, even disastrous, effects—at Koyna Reservoir in India, at Kremasta Lake in Greece, and at lake Kariba in the Zambia-Rhodesia boundary region. In the past, such earthquakes were not given sufficient scientific attention to permit a comprehensive evaluation of the associated hazards. It now seems wise to review all aspects of the problem to determine the types and amounts of additional information needed to evaluate these hazards. Of equal importance, perhaps, to the question of why these earthquakes occurred in these places is the question of why no increase in seismicity has been observed with the filling of other, equally large, reservoirs in other places (for example, the Aswan Dam in Egypt).

This report summarizes the history of recorded correlations between seismic activity and the filling of large reservoirs, discusses scientific considerations, and provides background for the recommendations on the following pages. It is important to consider that for a relatively small increase in the investment of manpower, effort, and equipment called for in the recommended monitoring and study program, very large benefits might be realized in terms of greatly improved understanding of the mechanisms of much larger, potentially catastrophic, natural events and in the prospects for predicting and controlling such events or for modifying their effects.

RECOMMENDATIONS

The Panel offers the following recommendations, whose purpose is to provide an improved understanding of the relationship between earthquakes and the impoundment of large reservoirs*—of whether there is, indeed, a cause-and-effect relationship in some cases; of the triggering mechanism, or mechanisms, if such a relationship is clearly shown; and of what we might do to mitigate or prevent such earthquakes. Ultimately, this knowledge would also provide the basis for consideration of the question of what constitutes "acceptable risk"—a question that will have to be faced increasingly in the future as man's needs, with growing frequency, come into conflict with risks associated with his efforts to satisfy those needs.

Geologic Studies

In addition to the detailed geological maps usually prepared for the area around the foundation of a proposed dam, geologic mapping must be carried out for the entire area of the reservoir. Although great detail may not be required, special attention should be given to patterns of faulting and the competency of the rock

*A "large reservoir" is defined empirically, in this study, as one with a volume of one million acre-feet or more, usually impounded behind a dam 300 feet or greater in height. Although earthquakes have also been reported in association with the filling of some smaller reservoirs the damaging quakes of relatively large magnitudes have occurred near large reservoirs as defined above.

in the reservoir area. A clearer understanding of the hydrologic regime, particularly as related to the faulting, is required. If large faults are present, and especially if these show evidence of recent movement, a complete re-evaluation of the chosen site, and of possible alternative sites, should be made before construction is begun. In any case, the orientations and positions at depth of such faults should be determined. Such information would be extremely important in subsequent geological and seismological considerations of the area.

Geodetic Studies

The question of whether earthquakes occurring in the vicinity of large reservoirs might be triggered by increased fluid pressure or by crustal loading, or both, remains to be resolved. Geodetic studies before and after reservoir filling, with special emphasis given to vertical measurements, would help to answer this question. Such studies are being conducted in conjunction with seismic investigations at the Libby Reservoir in Montana and should be included in the planning for all future large reservoirs.

It has been shown at Lake Kariba that the crust behaved in an elastic manner when subjected to reservoir loads and that the elastic-strain energy induced was approximately equivalent to the seismic energy released. The most useful data in this study were from long level-lines run before and after filling. An additional check on the response of the crust to loading could be obtained by trilateration using electro-optical measuring devices.

Crucial information about elastic deformations at dam sites can be obtained from long geodetic level-lines established before construction has begun and repeated after the dam has been completed. An important addition to such geodetic measurements could be made by some form of continuously recording strain meter. Tiltmeters for emplacement in boreholes have been developed recently. These instruments should be installed in at least three widely spaced boreholes prior to filling of a reservoir and recorded on a time base comparable to that of the seismic recording. If the response of the reservoir to loading takes place in discontinuous steps, when earthquakes occur, rather than smoothly as the reservoir is filled, the tiltmeters will be able to resolve these strain steps. However, it should be emphasized that the continuously recording strain-meter-type measurement is not a substitute for the long level-lines.

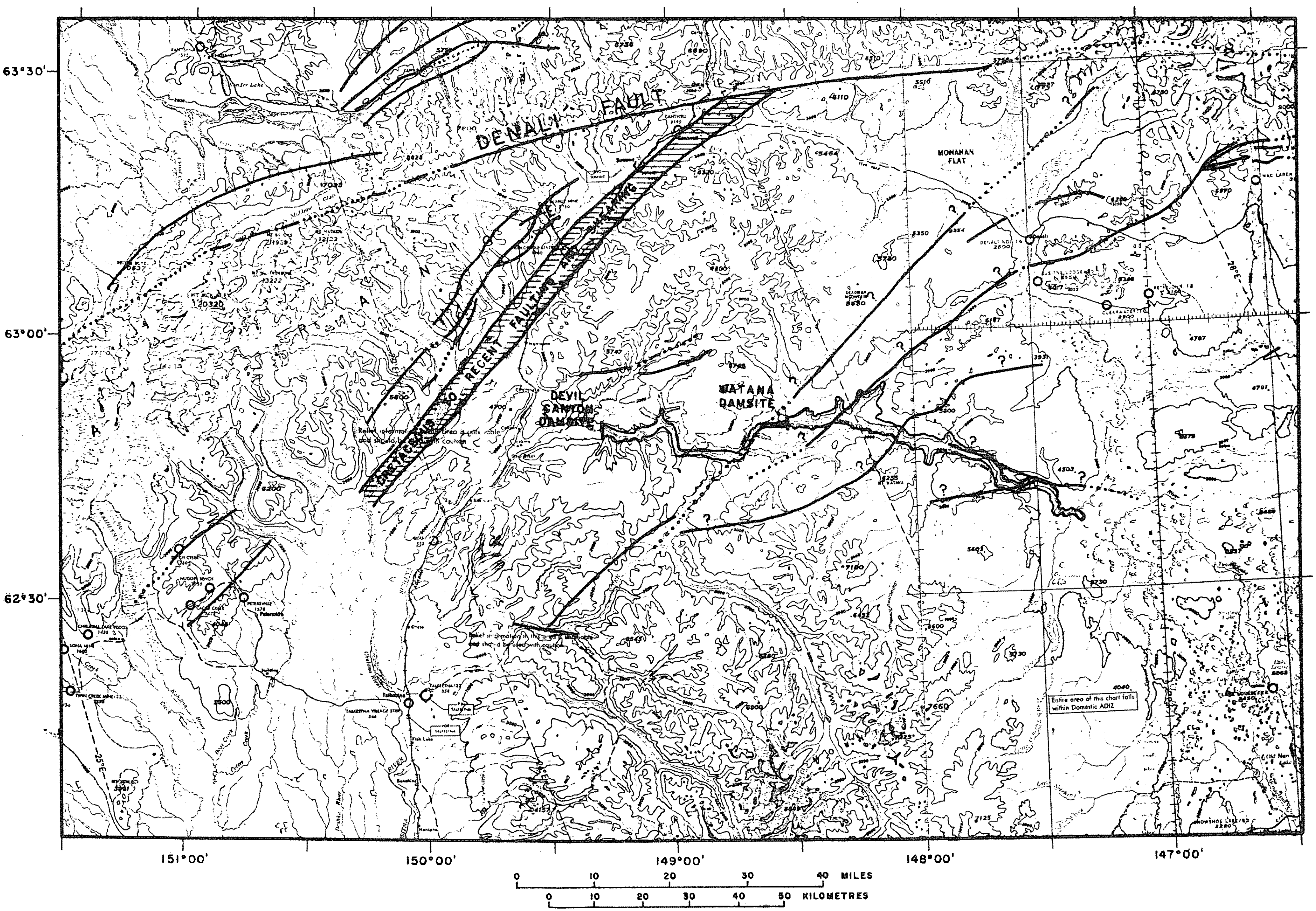
Seismic Studies

Comprehensive and continuing seismic studies should be carried out before, during, and after reservoir filling. Five years before filling, a tripartite network of seismographs should be installed. These will serve to give approximate locations of earthquakes that may occur prior to filling and to provide a reasonable record of their frequency of occurrence. If the pattern of seismicity changes as the reservoir is filled, the network should be expanded to the number of stations needed to provide good coverage of the entire reservoir area. Experience has shown that at least 10 high-gain, short-period stations are required for accurate locations of microearthquakes and determination of their focal mechanisms. Strong-motion instruments should also be placed within and near the dam to monitor the larger quakes and the response of the structure to large motions.

The proposed dam site and the surrounding area should be examined critically for geologic faults using microearthquake-detection techniques and other methods. If faults exist, an evaluation should be made of the degree of hazard associated with the planned reservoir and, as recommended above, alternative sites should be considered.

U.S. DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

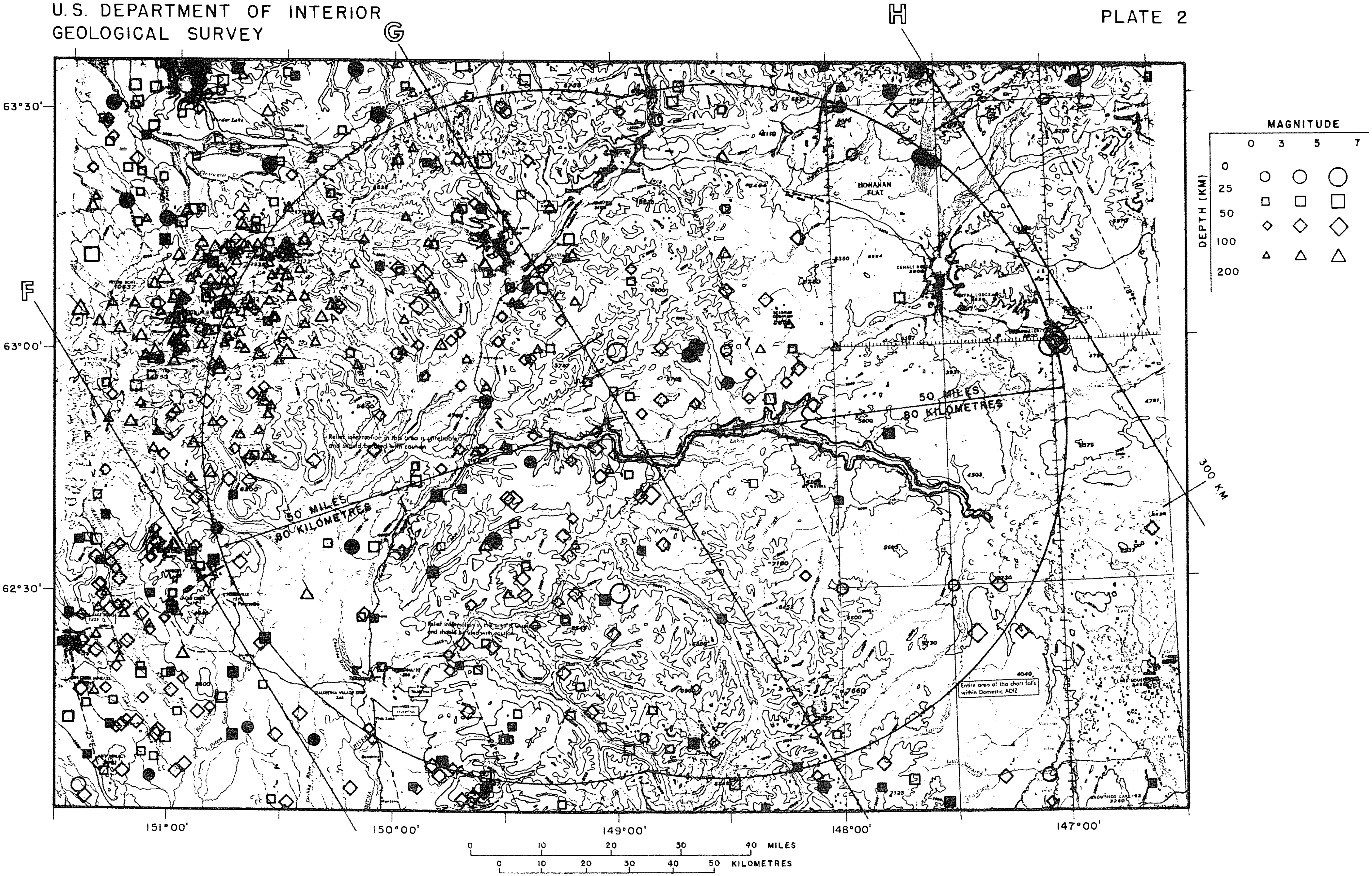
PLATE I



MAP SHOWING FAULTS IN THE AREA OF PROPOSED DEVIL CANYON AND WATANA DAMSITES, SUSITNA RIVER, ALASKA

U.S. DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY

PLATE 2



MAP SHOWING LOCATIONS OF EPICENTERS IN THE AREA OF PROPOSED DEVIL CANYON AND WATANA DAMSITES, SUSITNA RIVER, ALASKA

SECTION E

ENVIRONMENTAL ASSESSMENT

SECTION E

ENVIRONMENTAL ASSESSMENT

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ALTERNATIVE SOURCES OF POWER

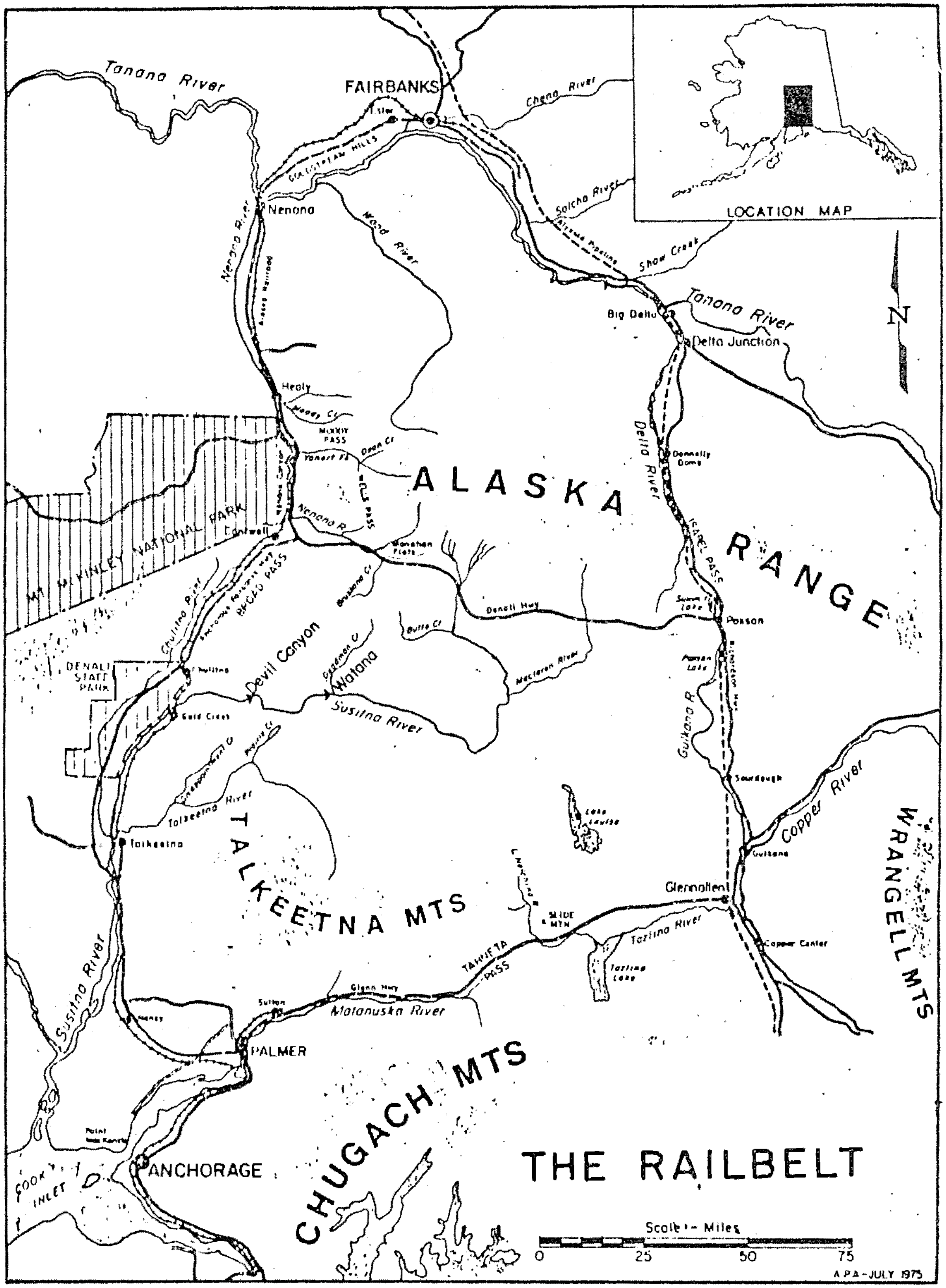
GENERAL

Alaska has a wide variety of energy alternatives to produce electricity. Each of the major energy resources--oil, coal, natural gas, and hydroelectric potential could easily meet projected power requirements well beyond the year 2000. The nuclear energy alternative is also available, and geothermal resources could be significant in some parts of the State. Present energy generation systems depend heavily on fuel oils and natural gas with smaller amounts of electrical energy coming from hydro powerplants and coal. Major power resources, both hydroelectric and fossil fuel, and the greatest power demands are in the Southcentral Railbelt area. This area of Alaska extends from Cook Inlet and the Gulf of Alaska on the south to the foothills of the brooks Range on the north (see Figure 1). Containing about 75 percent of the population of the state, this region is served by the Alaska Railroad, and is commonly referred to as the "Railbelt."

It has been determined that hydroelectric power in the Southcentral Railbelt Area could be operational by 1986 with the completion of a dam and powerplant; thus economic and financial feasibility should be assessed in terms of realistic alternatives that could be made available in about the same time frame. Such alternatives include power from Cook Inlet oil and natural gas, coal resources in the Beluga and Nenana fields, oil from the Alyeska pipeline, natural gas from the North Slope, other hydro resources, nuclear power, and geothermal power.

Public Law 93-577 passed by the Congress on 31 December 1974 has emphasized the conservation of nonrenewable resources and the utilization of renewable resources where possible. The construction of hydroelectric dams is a feasible project that utilizes a renewable resource to generate electrical power while helping to conserve the use of nonrenewable resources such as oil and natural gas. Present Alaskan power systems have a significant environmental impact on urban environments, but a relatively small environmental impact outside the urban areas. Substantial increases in Southcentral Railbelt power requirements will involve the development of future electric power systems,larger facilities, and some alternatives that have very important environmental implications.

Future power systems will also require approaches that include full consideration of environmental values and alternatives and must anticipate that Alaska and the nation will attach increasing importance to



Appendix I
FIGURE E-1
E-2

environmental protection, energy conservation, and conservation of non-renewable resources. Additional requirements must be anticipated for long-range advance planning and site selection, public participation, and full consideration of the environment in planning, design, construction, and operation of power facilities.

The significant environmental impacts of the various proposed alternatives would vary depending on the location, design, construction, and operation of the facilities for each of the alternatives.

Solutions considered in this investigation to meet electrical needs of the Southcentral Railbelt area were grouped in three major categories: alternative sources of power; alternative hydropower sources in the entire Railbelt area; and alternative hydropower sources in the Upper Susitna River Basin. The amount of study given to each potential solution was established by first screening each alternative for suitability, applicability, and economic merit in meeting needs. Each alternative was tested for physical, political, financial, institutional, economic, environmental, and social feasibility. Continuous coordination was maintained with area State and Federal agencies which have related interests.

ALTERNATIVE HYDROPOWER SOURCES IN THE RAILBELT AREA

RAMPART CANYON

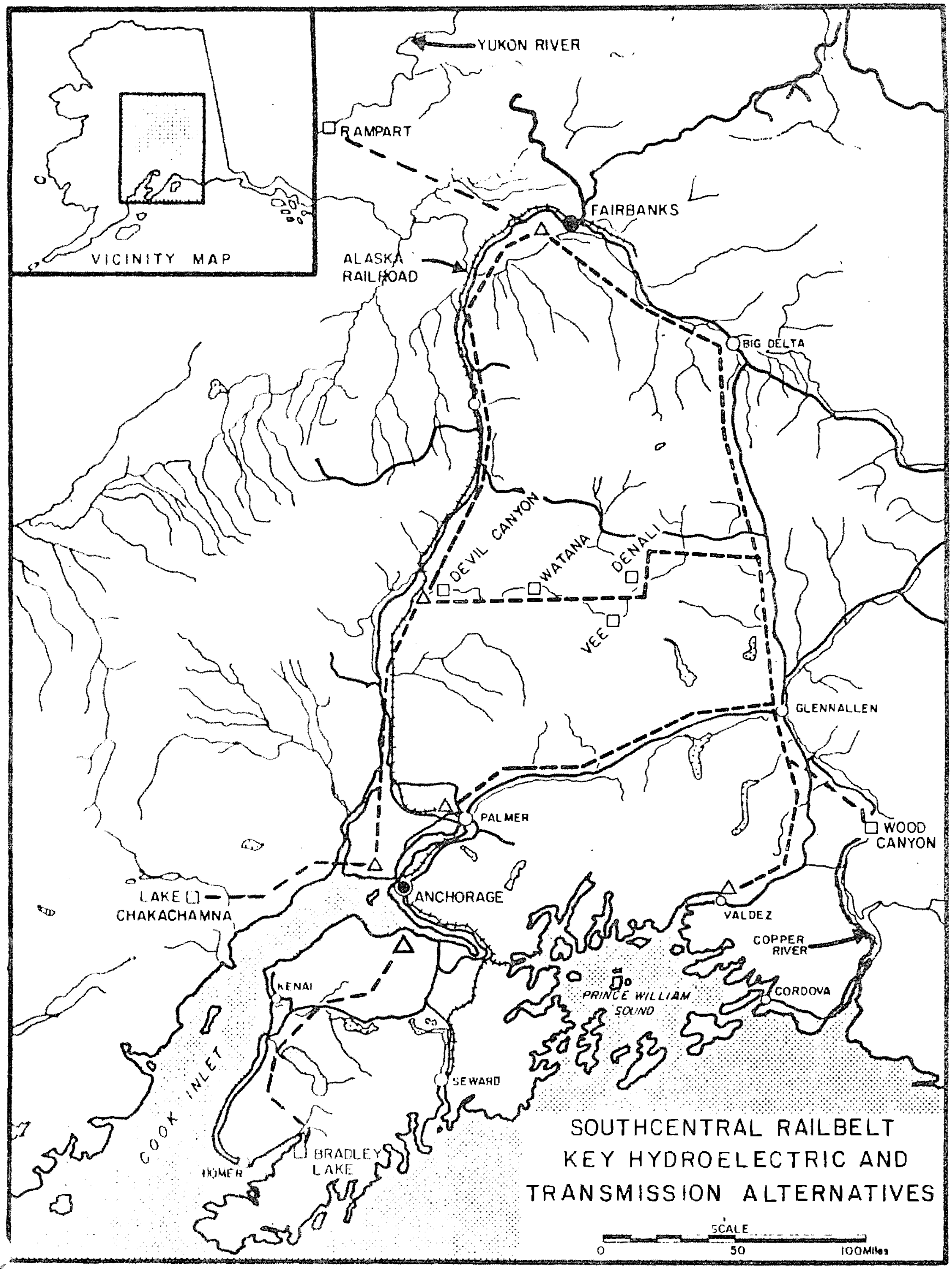
Considerable study has been made of the possibility of developing hydroelectric power in the Upper Yukon Basin, with a dam located in Rampart Canyon (see Figure 2). The site for this dam is on the Yukon River approximately 140 miles northwest of Fairbanks, Alaska. The project has one of the greatest hydroelectric potentials in North America. The proposal would create a reservoir with a water surface area of approximately 10,600 square miles, with a maximum length of 280 miles and a maximum width of about 80 miles. The project would provide firm annual energy of 34.2 billion kilowatt-hours (the energy equivalent of over 74 million barrels of oil per year). However, the impacts on fish and wildlife resources in the Yukon Flats would be highly damaging. Implemention of such a project would also be extremely controversial.

Rampart is engineeringly feasible, and the proposed project would provide enough excess energy to encourage further industrial development in Alaska, but it would introduce a number of secondary impacts not associated with the recommended alternative. Excess energy could also be transmitted to the "Lower 48" through an intertie system. However, this would be a major action not directly applicable to energy needs of the Railbelt Area. Justification would have to be based on a nationwide plan which included Rampart as a recommended alternative to the development of other energy sources. Within the time-frame criteria established for fulfillment of projected growth needs in the Railbelt Area, this is not considered a viable alternative.

The tremendous financial investments, the substantial environmental impacts, the limited opportunities for marketing the enormous amounts of power, and the availability of more favorable, less costly alternatives preclude recommending construction of the Rampart project at this time. Rampart Dam could be developed if future national needs recommend the project's construction.

WOOD CANYON

Another possible location for significant hydroelectric power development is Wood Canyon on the Copper River. The dam would be located about 85 miles above the mouth of the Copper River in the Chugach Mountains of southcentral Alaska. A "high dam" would develop firm annual energy of 21.9 billion kilowatt-hours. A "low dam" would provide 10.3 billion kilowatt-hours of firm annual energy.



Appendix I
FIGURE E-2

The construction of a dam at Wood Canyon would force relocation of two communities and would create serious environmental problems affecting both fish and wildlife resources, especially the large salmon runs on the Copper River. Unless the problem posed to migrating salmon could be solved satisfactorily, the project would have an extremely adverse effect on the major commercial fishing industry in a wide area of the Gulf of Alaska. This alternative is not considered feasible at this time.

CHAKACHAMNA LAKE

The possibility of developing hydroelectric power from Chakachamna Lake was investigated. The lake is located on the Chakachamna River which empties into the west side of Cook Inlet approximately 65 miles west of Anchorage. The facility would generate 1.6 billion kilowatt-hours of firm annual energy. The project would require the erection of tramsmission facilities over difficult terrain to tie into a South-central Railbelt transmission System and the construction of a high-cost 11-mile tunnel for power generation. The adverse environmental impact would be substantially less than for many proposed Alaskan hydroelectric projects. However, the low energy output and the high costs render this alternative infeasible at this time.

BRADLEY LAKE

The site for this authorized hydroelectric project is at Bradley Lake on the Kenai Peninsula at the head of Kachemak Bay near Homer, Alaska. The proposal would generate 0.4 billion kilowatt-hours of firm annual energy and could serve as a southern peaking installation for a Southcentral Railbelt power system. Adverse environmental impacts of this proposed project would be relatively minor compared to the other hydroelectric development alternatives which were considered. If an economically feasible plan can be developed for Bradley Lake, the project could be integrated with future development of the Susitna River basin. By itself, this project would fulfill only a small portion of the projected electrical needs of the Railbelt area.

UPPER SUSITNA RIVER BASIN

Surveys for potential hydropower development in the Susitna River basin were reported by the Corps of Engineers in 1950 and by the U.S. Bureau of Reclamation in 1948, 1952, 1961, and 1974. The 1952 USBR report indicated 12 potential hydropower sites in the basin; of these, the five damsites studied in the upper Susitna basin showed the highest potential. These studies showed the environmental impact from projects in the Upper Susitna River Basin would not be as severe as those from other basins, and the firm energy potential could contribute substantially to satisfying the needs of the Southcentral Railbelt area. Therefore, the Upper Susitna River Basin was determined to be the most feasible location for hydroelectric development necessary to satisfy a significant portion of the projected needs of the Southcentral Railbelt Area prior to the year 2000. Following is a detailed description of the basin study area along with other pertinent environmental data, as a basis for evaluating impacts attributable to various hydroelectric development schemes

ALTERNATIVES FOR HYDROPOWER IN THE UPPER SUITNA RIVER BASIN

ENVIRONMENTAL SETTING

Physical Characteristics:

Description of the Area: The Susitna River, with an overall drainage area of about 19,400 square miles, is the largest stream discharging into Cook Inlet. The Susitna River basin is bordered on the south by the waters of Cook Inlet and the Talkeetna Mountains, on the east by the Copper River plateau and the Talkeetna Mountains, and on the west and north by the towering mountains of the Alaska Range. The upper Susitna River upstream from the proposed Devil Canyon damsite drains an area of approximately 5,810 square miles (see Figure 3).

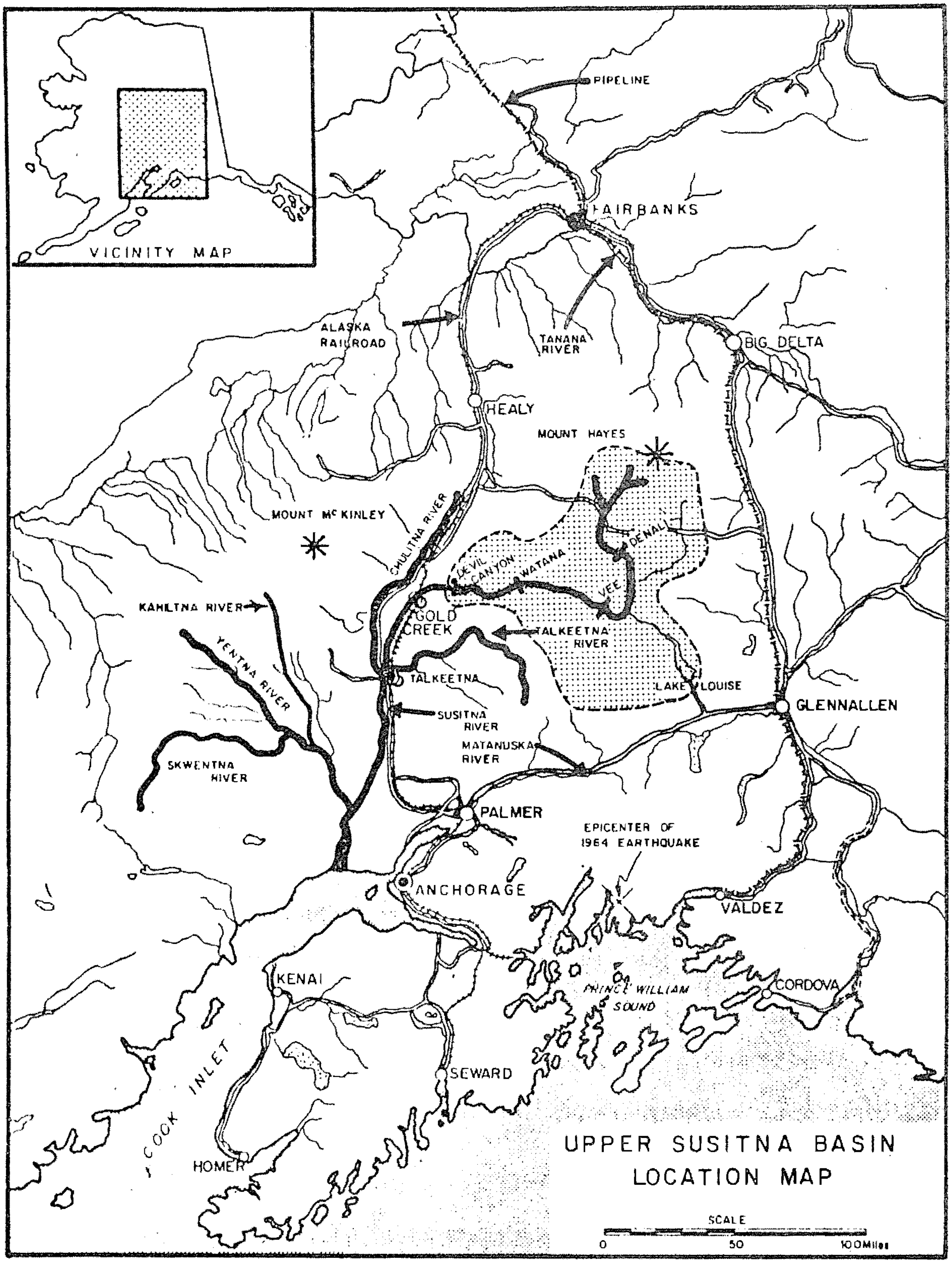
Three glaciers flow down the southern flanks of the Alaska Range near 13,832-foot Mount Hayes to form the three forks of the upper Susitna River. These forks join to flow southward for about 50 miles through a network of channels over a wide gravel flood plain composed of the coarse debris discharged by the retreating glaciers. The cold, swift, silt-laden river then curves toward the west where it winds through a single deep channel, some 130 miles through uninhabited country, until it reaches the Alaska Railroad at the small settlement of Gold Creek.

After the Susitna escapes the confinement of Devil Canyon, the river's gradient flattens. The river then turns south past Gold Creek, where it flows for about 120 miles through a broad silt and gravel-filled valley into Cook Inlet near Anchorage, almost 300 miles from its source.

Principal tributaries of the lower Susitna basin also originate in the glaciers of the surrounding mountain ranges. These streams are generally turbulent in the upper reaches and slower flowing in the lower regions. Most of the larger tributaries carry heavy loads of glacial silt during the warmer summer months.

The Yentna River, one of the Susitna's largest tributaries, begins in the high glaciers of the Alaska Range, flows in a general south-easterly direction for approximately 95 miles and enters the Susitna 24 miles upstream from its mouth.

The Talkeetna River originates in the Talkeetna Mountains on the southeastern part of the basin, flows in a westerly direction, and discharges into the Susitna River 80 miles upstream from Cook Inlet and just north of the community of Talkeetna.



Appendix I
FIGURE E-3

The Chulitna River heads on the southern slopes of Mount McKinley, the highest point in North America, with an elevation of 20,320 feet. The river flows in a southerly direction, joining the Susitna River near Talkeetna.

The principal tributaries of the upper Susitna basin are the silt-laden Maclaren, the less turbid Oshetna, and the clear-flowing Tyone (Figure 4). Numerous other smaller tributaries generally run clear. Streamflow in the Susitna River basin is characterized by a high rate of discharge from May through September and by low flows from October through April.

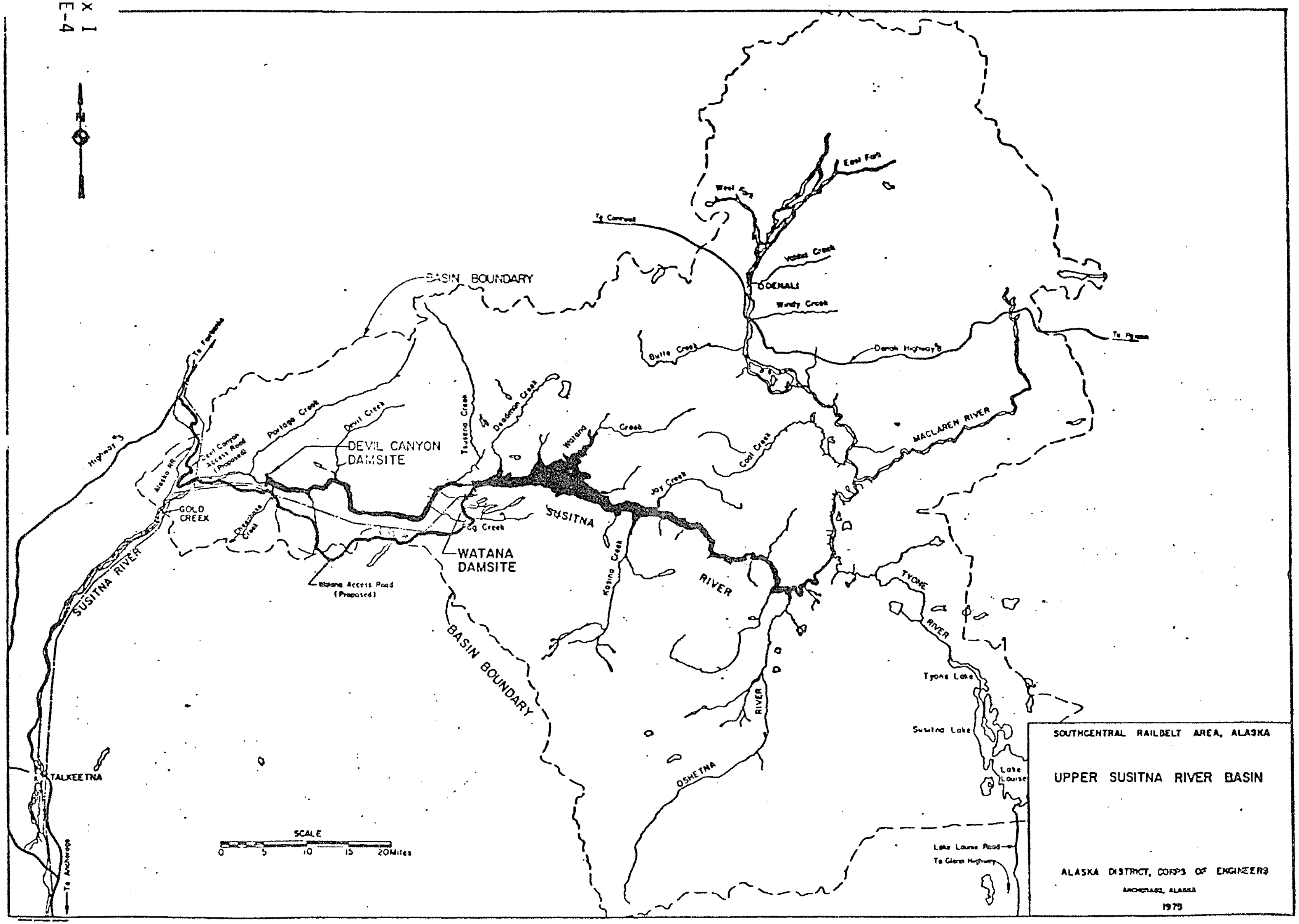
Most of the Upper Susitna River Basin is underlain by discontinuous permafrost. Permafrost is defined as a thickness of soil, or other surficial deposit, or of bedrock beneath the ground surface in which a temperature below 32°F has existed continuously for two years or more. Such permanently frozen ground is found throughout much of Alaska.

The area above and below the Maclaren River junction with the Susitna is generally underlain by thin to moderately thick permafrost. Maximum depth to the base of permafrost in this area is about 600 feet. Around the larger water bodies, such as lakes, permafrost is generally absent. In some areas of the lower section of the upper Susitna basin, permafrost is not present. Additional data is required before permafrost areas can be specifically identified upstream from Devil Canyon.

River Characteristics: The upper Susitna River is a scenic, free-flowing river with very few signs of man's presence. The extreme upper and lower reaches of the Susitna occupy broad, glacially scoured valleys. However, the middle section of the river, between the Denali Highway and Gold Creek, occupies a stream-cut valley with spectacular rapids in Devil Canyon that are extremely violent.

The Susitna, the Bremner in the southcentral region, and the Alsek in the southeast are the three major whitewater rivers in Alaska. All three are Class VI (on a scale of I to VI) boating rivers, at the upper limit of navigability, and cannot be attempted without risk of life. Few kayakers have completed the dangerous 11-mile run through Devil Canyon.

Appendix I
FIGURE E-4



The Susitna was one of the Alaskan rivers recommended for detailed study as possible additions to the National Wild and Scenic Rivers System in 1973, but was not one of the 20 rivers recommended for inclusion in the system by the Secretary of the Interior in 1974. The Susitna River has not yet been studied as recommended.

About 86 percent of the total annual flow of the upper Susitna occurs from May through September, with the mean daily average flow from late May through late August in the range of 20,000 to 32,000 cubic feet per second. In the November through April period, the mean average daily flow of the river is in the range of 1,000 to 2,500 cubic feet per second. On 7 June 1964, the recording station at Gold Creek measured a flow slightly in excess of 90,000 cubic feet per second, which was the highest flow recorded for the upper Susitna River since recording started in 1950.

High summer discharges are caused by snowmelt, rainfall, and glacial melt. The main streams carry a heavy load of glacial silt during the high runoff periods. During the winter when low temperatures retard water flows, streams run relatively silt-free.

Cook Inlet: All of the major water courses which flow into Cook Inlet either originate from glaciers or flow through erosive soils; either type of stream carries a high suspended-solids load. The natural high flow period in streams tributary to Cook Inlet occurs during the summer months of May to September, the main period when sediment is transported to the Inlet.

Freshwater runoff into the upper Inlet is an important source of nutrients and sediments. Large quantities of nitrate, silicate, and surface-suspended sediment with particulate organic carbon enter the Inlet with fresh water. Concentrations are especially high in the initial runoff each spring and summer. These additions decrease in concentration down the Inlet upon subsequent mixing with saline oceanic water and with tidal action. The large input of fresh water dilutes and tends to reduce salinity and phosphate concentration around river mouths and in the upper reaches of Cook Inlet.

Geology/Topography:

General: The Railbelt area is characterized by three lowland areas separated by three major mountain areas. To the north is the

Tanana-Kuskokwim Lowland, which is delineated by the Alaska Range to the south. The Susitna Lowland is to the southwest, bounded to the north by the Alaska Range, and to the east by the Talkeetna and Chugach Mountains. The Copper River Lowland in the east is bounded on the north by the Alaska Range, and the west by the Talkeetna Mountains. Each basin is underlain by quaternary rocks surfaced with glacial debris, alluvium, and eolian deposits. The mountains are primarily metamorphic and sedimentary rocks of the Mesozoic, with several areas of intrusive granitic rocks in the Talkeetna Mountains and the Alaska Range, and Mesozoic volcanic rocks in the Talkeetna Mountains. Figure 5 delineates the major features.

Susitna Basin: The Alaska Range to the west and north and the Talkeetna Mountains to the east make up the high perimeter of the Lower Susitna River Basin. The Alaska Range is made up of Paleozoic and Mesozoic sediments, some of which have been metamorphosed in varying degrees and intruded by granitic masses. The Talkeetna Mountain Range, with peaks up to 8,850 feet, is made up of a granitic batholith rimmed on the Susitna basin side by graywackes, argellites, and phyllites. Much of the interior portion of the basin is fluvial-glacial overburden deposits. Glaciers, in turn, carved the broad U-shaped valleys. Glacial overburden covers the bedrock, which is composed mainly of shale and sandstone with interbedded coals, Paleozoic and Mesozoic sediments, and lava flows.

The Upper Susitna River Basin is predominantly mountainous, bordered on the west and south by the Talkeetna Mountains, on the north by the summits of the Alaska Range, and on the south and east by the flat Copper River plateau. Valleys are floored with a thick fill of glacial moraines and gravels.

Seismic Areas: The southcentral area of Alaska is one of the world's most active seismic zones. In this century, 9 Alaskan earthquakes have equalled or exceeded a magnitude of 8.0 on the Richter Scale, and more than 60 quakes have exceeded a magnitude of 7.0. Several major and minor fault systems either border or cross the Susitna River basin. The March 1964 Alaska earthquake, with a magnitude of 8.4, which struck southcentral Alaska, was one of the strongest earthquakes ever recorded.

Much of southcentral Alaska falls within seismic zone 4 (on a scale of 0 to 4) where structural damage caused by earthquakes is generally the greatest. This area of Alaska and the adjoining Aleutian chain are just part of the vast, almost continuous seismically and volcanically active belt that circumscribes the entire Pacific Ocean Basin.

LEGEND

SEDIMENTARY AND METAMORPHIC ROCKS

QUATERNARY
Surficial deposits, alluvium, glacial debris, eolian sand and silt

TERTIARY
Sandstone, conglomerate, shale, mudstone; nonmarine and marine

MESOZOIC
Sandstone and shale; marine and nonmarine; includes some metamorphic rocks

PALEOZOIC AND PRECAMBRIAN
Sandstone, shale, limestone; mostly marine; includes some early Mesozoic rocks

PALEOZOIC AND PRECAMBRIAN
Metamorphic rocks: schist, gneiss, etc.; mainly Paleozoic

IGNEOUS ROCKS

Quaternary and Tertiary volcanic rocks

Mesozoic intrusive rocks; mainly granitic

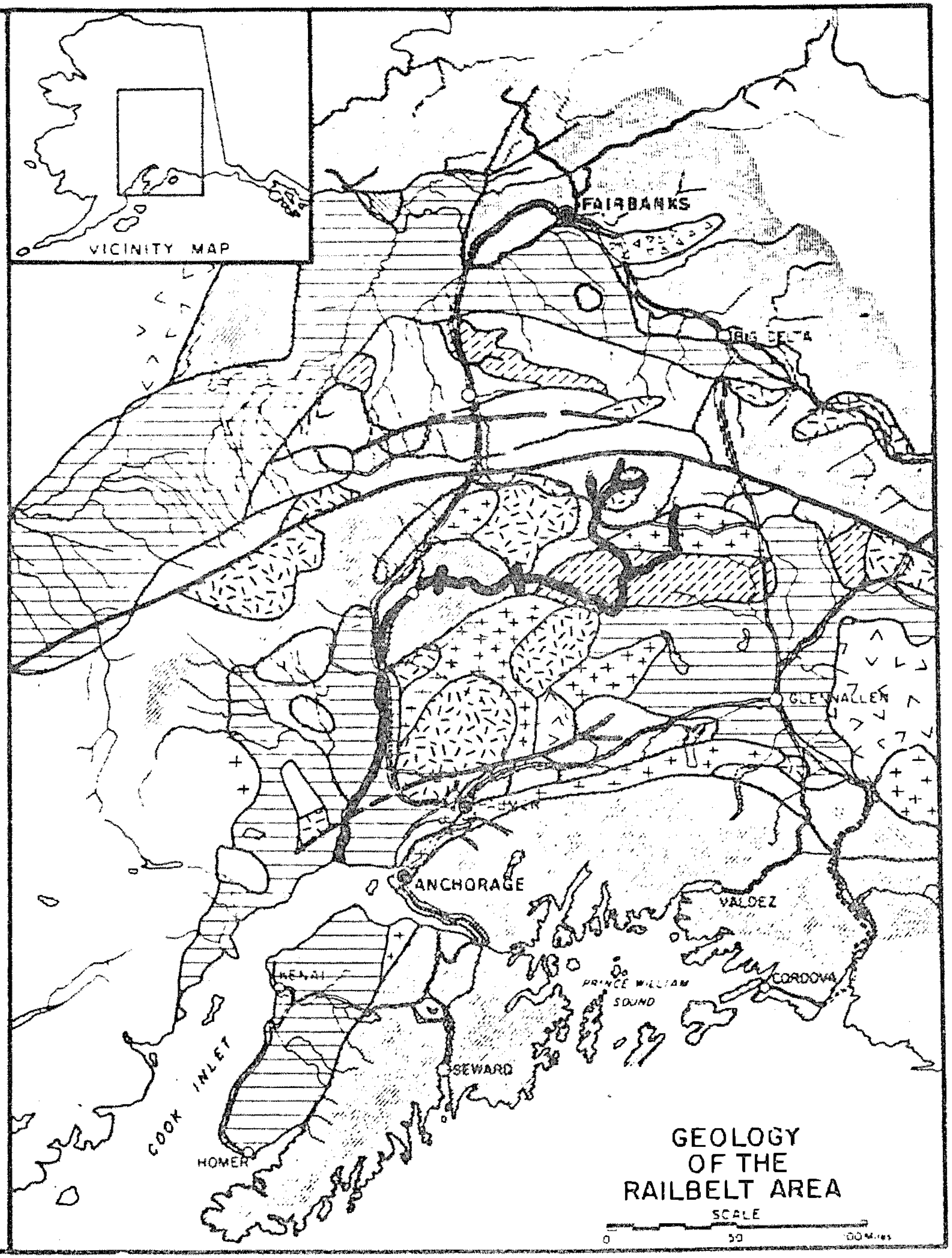
Mesozoic volcanic rocks

Paleozoic volcanic rocks

Paleozoic intrusive rocks; granitic and ultramafic

Fault
(Dashed where inferred)

Source: U.S.G.S.
APA-1975



GEOLOGY OF THE RAILBELT AREA

Minerals: Most of the Susitna basin above Devil Canyon is considered to be highly favorable for deposits of copper or molybdenum and for contact or vein deposits of gold and silver. One known deposit of copper of near-commercial size and grade is near Denali. Also, the Valdez Creek gold placer district, from which there has been some production, is within the proposed project watershed.

Though a number of mineral occurrences are known and the area is considered favorable for discovery of additional deposits, much of the drainage basin has never been geologically mapped. Thus, geologically, the basin constitutes one of the least known areas in the State except for a few areas in the vicinity of Denali where some geologic mapping has been done.

Geologic information for the project area is not detailed enough to assess mineral resource potential within the proposed reservoir impoundment areas.

The Alaska State Department of Natural Resources states that there are "active" and "non-active" mining claims in the upper Susitna River drainage area between Devil Canyon and the Oshetna River. Many of these claims are in upper Watana Creek above the maximum reservoir pool elevation, and in the surrounding drainage areas where copper activity is moderately extensive.

Climate: The Susitna basin has a diversified climate. The latitude of the region gives it long winters and short summers, with great variation in the length of daylight between winter and summer. The lower Susitna basin owes its relatively moderate climate to the warm waters of the Pacific on the south, the barrier effect of the Alaska Range on the west and north, and the Talkeetna Range on the east. The summers are characterized by moderate temperatures, cloudy days, and gentle rains. The winters are cold and the snowfall is fairly heavy. At Talkeetna, at an elevation of 345 feet, which is representative of the lower basin, the normal summer temperature ranges between 44^{o} and 68^{o}F, with winter temperatures ranging between 0^{o} and 40^{o}F. The extreme temperature range is between -48^{o} and 91^{o}F. The average annual precipitation is about 29 inches, including about 102 inches of snowfall.

The upper Susitna basin, separated from the lower basin by mountains, has a somewhat colder climate and an average overall annual precipitation rate of approximately 30 inches.

Biological Characteristics:

Fish:

Anadromous Fish: Fish inhabiting the Susitna basin are divided into two major groups: resident and anadromous. The anadromous fish spends a portion of its life cycle in salt water, returning to the freshwater streams to spawn. In this group are included five species of Pacific salmon: sockeye (red); coho (silver); chinook (king); pink (humpback); and chum (dog) salmon. All five species of salmon die soon after spawning. Dolly Varden, a char, is widely distributed in the streams of Cook Inlet and is present in the Lower Susitna River Basin, with both anadromous and resident populations. Smelt runs are known to occur in the Susitna River as far upstream as the Deshka River about 40 miles from Cook Inlet.

Salmon spawn in varying numbers in some of the sloughs and tributaries of the Susitna River below Devil Canyon. Salmon surveys and inventories of the lower Susitna River and its tributaries have been made over a number of years, resulting in considerable distribution data; however, population studies and additional resource studies are needed. The surveys indicate that salmon are unable to ascend the turbulent Devil Canyon, and, thus, are prevented from migrating into the Upper Susitna River Basin.

The 14 million pounds of commercial salmon caught in Cook Inlet during 1973 comprised about 10 percent of the 136.5 million pounds of salmon harvested in Alaska during the year. Chum, red, and pink salmon totaled about 94 percent of the salmon catch for Cook Inlet during 1973. (1973 Catch and Production--Commercial Fisheries Statistics--Leaflet #26, State of Alaska Department of Fish and Game).

The 1973 commercial catch figures do not approach the maximum sustained yields for Cook Inlet, but do present the latest available commercial catch information, and except for chinook salmon, are representative of the last several years of commercial salmon fishing. Sport and subsistence fishing for salmon in Cook Inlet and in the Susitna basin are also important considerations.

According to the Alaska Department of Fish and Game, a significant percentage of the Cook Inlet salmon run migrates into the Susitna River Basin. Indications are that although all salmon stocks are important, only a small percentage of the Susitna basin salmon migrate as far upstream as the 50-mile section of the Susitna between Devil Canyon damsite and the confluence of the Chulitna River, to spawn in the river's clearwater sloughs and tributaries. A 1974 assessment study, by the Alaska Department of Fish and Game, of anadromous fish populations in the Susitna River watershed estimated 24,000 chum, 5,200 pink, 1,000 red, and between 4,000 and 9,000 coho salmon migrated up the Susitna River above the river's confluence with the Chulitna River during the 7-week study period from 23 July through 11 September when most of the salmon were migrating up the river. The report indicated that chinook salmon were also present.

A minimum of 1,036 pink, 2,753 chum, 307 coho, and 104 sockeye salmon spawned during the August and September spawning period in the streams and sloughs of the Susitna River between the Chulitna River tributary and Portage Creek as determined from peak slough and stream index escapement counts, according to the study. The assessment also indicated that a portion of the pink salmon spawn in the study area may have been destroyed by a late August-early September flood.

Chinook (King Salmon): The king salmon spends from one to three years in fresh water before migrating to sea. It is not unusual for this species to attain a weight of over 40 pounds. The maximum age is 8 years. In 1973, over 5,000 kings were caught in Cook Inlet; the total commercial catch comprised about 1.5 percent of the total weight of salmon caught in this area. The 1973 catch figures for king salmon were very low when compared to the average yearly catch for this species.

Sockeye Salmon (Red): The sockeye salmon averages between 6 and 8 pounds, with a range of from 2 to 12 pounds. This species spends from 1 to 3 years in a river system in which there are connecting lakes. The maximum age attained by this salmon is 7 years, but most return to spawn at 4 or 5 years of age. The landlocked variety of this species is called a kokanee and usually attains a length of from 12 to 15 inches. In 1973, almost 700,000 sockeye were caught in Cook Inlet, with a total weight of over 5 million pounds, or 37.0 percent of the total weight of the Cook Inlet commercial salmon catch. About 14.5 percent of the sockeye salmon catch in Alaska occurred in Cook Inlet.

Coho Salmon (Silver): The coho or silver salmon spends from 1 to 2 years in fresh water and returns from the ocean to spawn at 3 or 4 years of age. Mature coho average about 10 pounds; some reach weights of over 30 pounds. The 106,000 cohos caught in Cook Inlet during 1973 weighed just over 648,000 pounds and comprised about 4.5 percent of the total commercial salmon catch for the area.

Pink Salmon (Humpback): The pink salmon migrates to sea immediately after hatching and returns to spawn at 2 years of age. The average weight of a mature pink is 3 to 4 pounds, with some pinks weighing up to 10 pounds. The 624,000 pink salmon caught in Cook Inlet during 1973 weighed over 2,260,000 pounds and comprised about 16.2 percent of the total weight of the commercial salmon catch in the area. Historically, odd-year catches of pink salmon are poor. Even-numbered year catches average about 2 million pinks.

Chum (Dog Salmon): Chum salmon attain weights of up to 30 pounds, with an average mature weight of 8 to 9 pounds. This species migrates to sea immediately after hatching and matures between 3 and 6 years of age. The 742,000 chums caught in Cook Inlet during 1973 weighed almost 5,800,000 pounds and made up over 41.0 percent of the total commercial salmon catch for the area, the largest percentage of any of the 5 species of Pacific salmon. About 12.5 percent of the 1973 Alaskan chum salmon catch occurred in Cook Inlet.

Salmon eggs hatch in late winter or early spring following the summer and fall spawning periods. The eggs incubate in gravelly streambeds and cannot tolerate high levels of siltation or low flows that dewater the streambeds during the incubation or alevin (pre-emergent) stages.

Resident Fish: Grayling, rainbow trout, lake trout, Dolly Varden, whitefish, sucker, sculpin, and burbot (ling) comprise the principal resident fish population of the Susitna River basin. Although distribution studies have been made in the past, the magnitude of resident fish populations in the Susitna drainage is largely unknown.

During the warmer months of the year, when the Susitna River is silt laden, sport fishing is limited to clearwater tributaries and to areas in the main Susitna River near the mouths of these tributaries.

Resident fish, especially grayling, apparently inhabit the mouths of some of the clearwater streams on the Susitna River between Devil Canyon and the Oshetna River; however, most of the tributaries are too steep to support significant fish populations. Some of the upper sections of these clearwater tributaries, such as Deadman Creek, support grayling populations. Lake trout are also prominent in many of the terrace and upland lakes of the area.

Birds:

Waterfowl: The east-west stretch of the Susitna River between the Tyone River and Gold Creek is a major flyway for waterfowl. The majority of the waterfowl nesting areas in the Upper Susitna River Basin are on the nearby lakes of the Copper River Lowland region, on the Tyone River and surrounding drainage areas, and on the ponds and lakes of the wide flood plain in the Denali area.

The Upper Susitna River Basin has a moderate amount of use by waterfowl when compared with the Lower Susitna River Basin. The lower basin has a substantially greater amount of waterfowl habitat, and a greater number and variety of waterfowl seasonally use the thousands of lakes and ponds in this area to nest and to raise their young. Large numbers of migrant birds also use the Susitna River basin for feeding and resting during spring and fall flights to and from Alaska's interior and north slope. Distribution and density of waterfowl habitat within the Railbelt area is shown on Figure 6.

Raptors: Raptors, including golden eagles, bald eagles, and various species of hawks, owls, and falcons, occur throughout the entire Susitna River basin but in smaller numbers in the river canyon between Portage Creek and the Oshetna River. A June 1974 survey of cliff-nesting raptors conducted by the U.S. Fish and Wildlife Service, determined that the population densities of these birds between Devil Canyon and the Oshetna River are low and that no endangered species of peregrine falcons, American or arctic, appear to nest along the upper Susitna River. Peregrines have occasionally been sighted within the area of the upper Susitna basin and along migration routes through the Broad Pass area of the upper Chulitna River.

On the basis of the 1974 U.S. Fish and Wildlife Service findings, other raptor populations in the canyon area of the upper Susitna River were determined to be minor, although minimal data were acquired on the tree-nesting raptors. Several nesting pairs of bald eagles and gyrfalcons were observed in or near the canyons of this area, and golden eagles frequently occupied upland cliffs in the vicinity of Coal Creek.

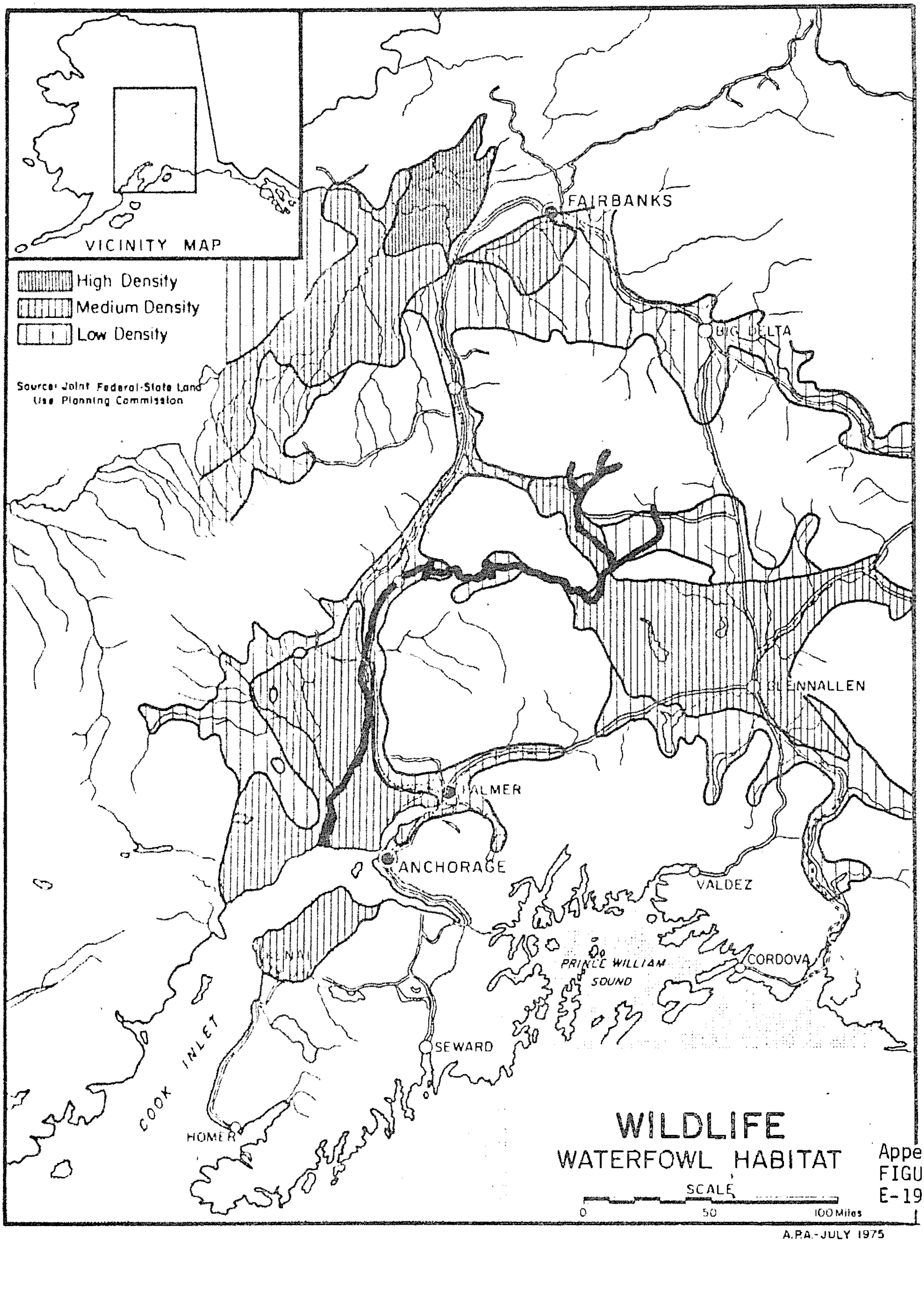
Substantial populations of ravens were found in reaches of the Susitna River above Gold Creek. The nests of this large bird are often used by raptors, including peregrines and gyrfalcons. However, there was no evidence that the nests observed were being used by raptors.

Other Birds: Unknown numbers of game birds, such as spruce grouse and willow ptarmigan, inhabit the Upper Susitna River Basin. Some incidental hunting takes place along the Denali Highway, but hunting pressures are practically nonexistent in most of the area.

Various other species of birds including songbirds, shorebirds, and other small birds are found throughout the Upper Susitna River Basin in varying numbers.

Mammals:

Caribou: One of the most significant wildlife resources of the Upper Susitna River Basin is the wide-ranging Nelchina caribou herd. This herd, a major recreational and subsistence resource in the south-central region, declined from a population high of about 71,000 in 1962 to a low of between 6,500 and 8,100 animals in 1972. This spectacular



Appendix
FIGURE E-
E-19

decline has been attributed to various factors, including migration to other areas, bad weather, predation, and overhunting. Motorized all-terrain vehicle access to the backcountry has improved hunting success even in the face of a rapidly declining caribou population.

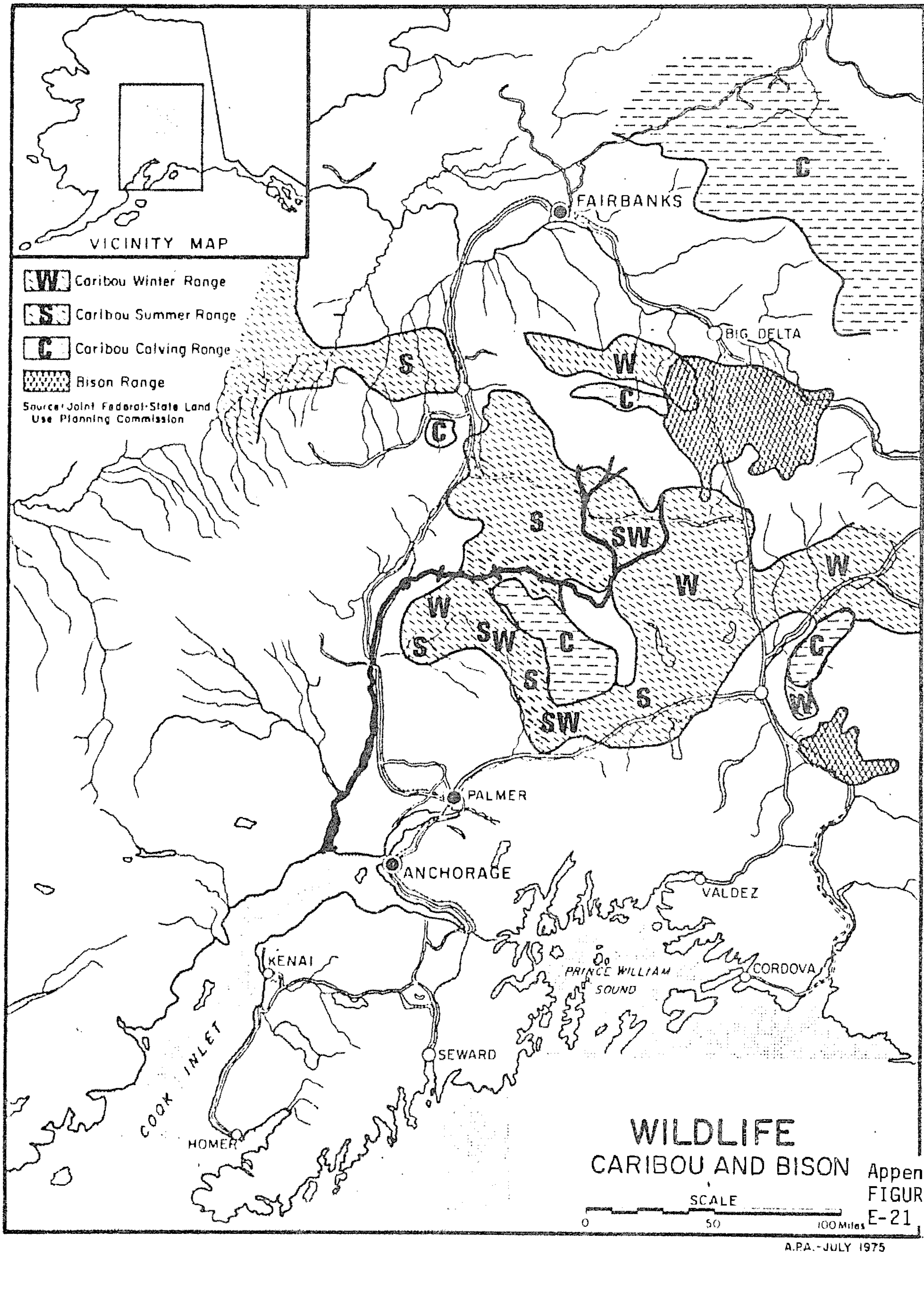
Segments of the Nelchina herd periodically range throughout much of the Upper Susitna River Basin (see Figure 7). The major calving area for the herd is on the northeast slopes of the Talkeetna Mountains on the upper reaches of the Kosina Creek, Oshetna River, and Little Nelchina River drainages. Calving generally takes place between mid-May and mid-June. Except for intermittent seasonal migration routes across the Susitna River in areas upstream from Tsusena Creek, caribou are not resident to the main Susitna River canyon between Devil Canyon and the Oshetna River.

Caribou depend upon climax range, especially for winter forage; any alteration of the vegetation, especially of sedges and lichens, has a detrimental impact upon their distribution and numbers. A trait of the Nelchina herd is an almost constant change of winter ranges, a phenomenon that has undoubtedly characterized Alaska's caribou populations for centuries.

The Alaska Department of Fish and Game considers the Nelchina herd to be one of the State's most important caribou populations. Several thousand hunters from Anchorage and Fairbanks participate in the annual hunting of this species. Additional thousands of non-hunting recreationists view the migrations of caribou as they cross the State's major highways. In addition, the herd provides sustenance to predators and scavengers such as wolves, grizzly bears, black bears, wolverines, lynx, and various species of birds.

Moose: Moose range throughout much of the Upper Susitna River Basin (Figure 8). Wide fluctuations of populations have occurred over the years. A 1973 Alaska Department of Fish and Game fall aerial count resulted in sighting of approximately 1,800 moose in the upper Susitna River drainage. The numbers of moose in the southcentral region of Alaska have been reduced in recent years due mainly to weather conditions, hunting pressures, wolf predation, unbalanced age-sex ratios, and elimination of habitat.

Much of the Upper Susitna River Basin is at or above timberline, resulting in large amounts of "edge" at timberline, which produces considerable quantities of willow, an important winter forage for moose. Successional vegetation changes following fire also contribute heavily to areas favoring moose habitat.



Appendix I
FIGURE E-7

Limited numbers of moose inhabit the Susitna River bottom between Devil Canyon and the Oshetna River, because of a restricted amount of suitable habitat. However, the available habitat provides critical winter range for moose that do utilize this area.

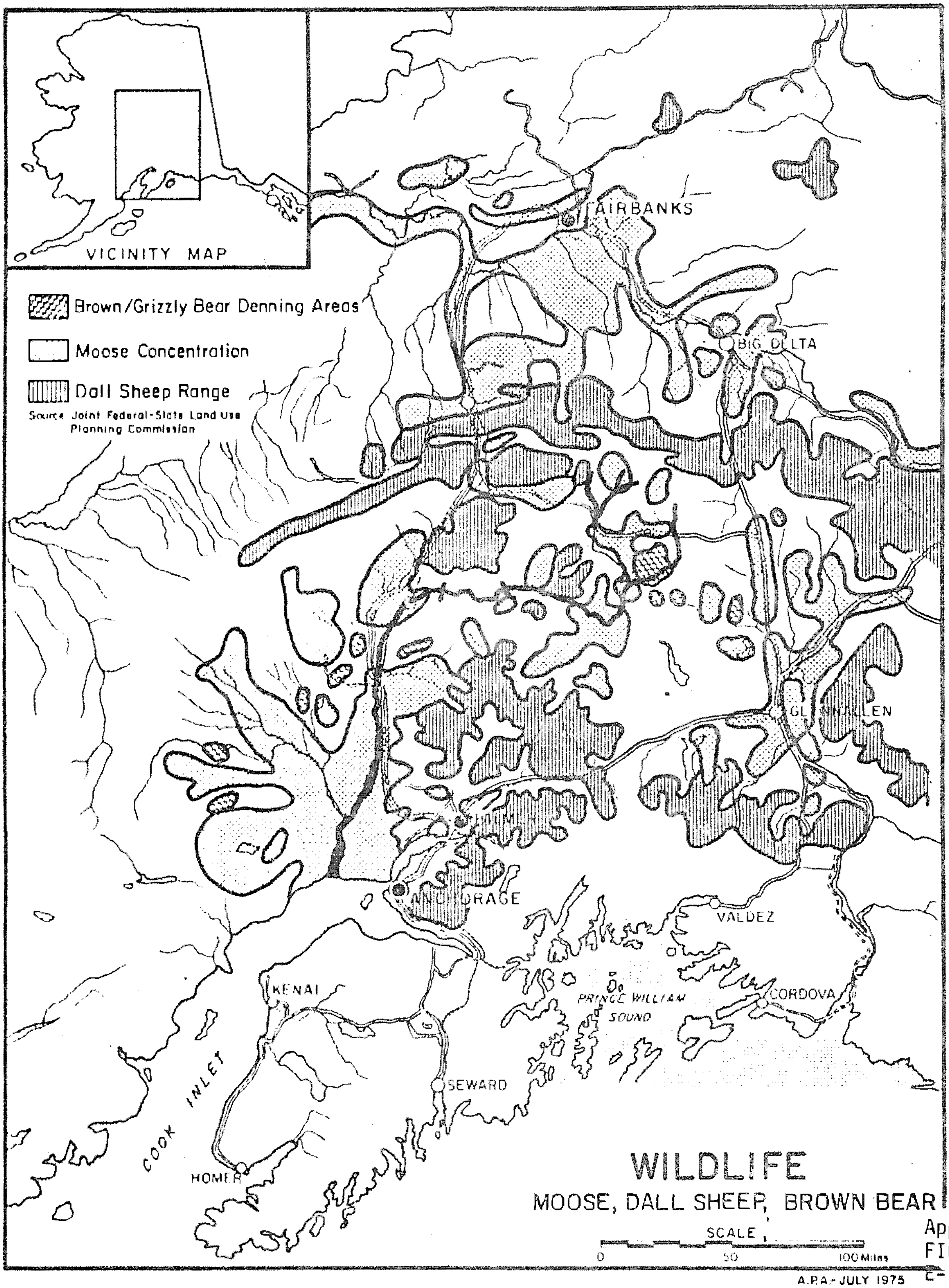
Grizzly/Brown Bears: Grizzlies, also referred to as brown bears in Alaska, are common throughout the Susitna River drainage and are fairly numerous in the upper Susitna despite the absence of salmon. Alpine and subalpine zones are the habitats most frequently used by grizzlies, although the more timbered areas are seasonally important. Denning begins in October, and all bears are in dens by mid-November (see Figure 8). Bears usually reappear during May, depending on weather conditions. Important spring foods include grasses, sedges, horsetails, other herbaceous plants, and carrion when available. On occasion, moose or caribou calves are taken. Berries--lowbush and highbush cranberries, blueberries, and bearberries--provide major summer food supplements. A prime consideration for grizzly bears is to minimize direct conflict with humans, as the grizzly is adversely affected by contact with man.

Hunting for grizzly bears in this area often occurs incidentally to other hunting during the short fall open season.

Black Bears: The Upper Susitna River Basin supports fair black bear densities. The larger populations are in semi-open forested areas with readily accessible alpine-subalpine berry crops. River bottoms, lake shores, and marshy lowlands are favorite spring black bear areas. Black bears generally eat many of the same types of food as are eaten by grizzlies. Denning habits are also somewhat similar to the grizzly bear's.

Natural fires generally benefit black bears, especially when dense mature spruce stands are burned. Most other land uses do not seriously affect bear numbers in this area, and black bears are not as adversely affected by contact with man as are grizzlies.

Dall Sheep: These sheep are present in many areas of the Alaska Range, Talkeetna Mountains, and in the higher elevations of the Susitna River basin (Figure 8). The greatest concentrations of Dall sheep in the Susitna basin occur in the southern portions of the Talkeetnas; herds become scattered on the northern portion of the range, where parts of the mountains are uninhabited by sheep. Dall sheep are also found in the Watana Hills. Because of the relatively gentle nature of much of the Talkeetna Mountains and Watana Hills, predation in this area has more effect on sheep numbers than in more rugged habitats. Sheep have always furnished some of the diet of wolves and other carnivores in this area.



Appendix
FIGURE E-23

Hunting pressure for rams is fairly heavy due to relatively good access from highways, by air, and by ATVs (all-terrain vehicles). Nevertheless, as is true elsewhere in the State, ram-only hunting seems to have little effect on overall numbers. Sheep populations are almost entirely controlled by natural factors such as habitat, weather conditions, predation, and disease. Conflicts between man's activities and critical sheep habitat, such as lambing or wintering areas, can adversely impact Dall sheep populations.

Mountain Goats: Goats occur in low numbers in various areas of the Talkeetna Mountains and in the Watana Hills area, and do not provide a significant amount of hunting in the upper Susitna basin. The goats generally inhabit rougher terrain than do Dall sheep, and are thus less susceptible to man's activities.

Wolves: Wolves occur throughout most of the Upper Susitna River Basin. Populations are subject to rapid fluctuations, and estimates should be viewed with extreme caution. Wolf numbers have been estimated from a low of 13 in 1943, after predator control efforts, to a high of 400 to 450 in 1965. Currently an estimated 300 wolves populate the area encompassing the upper Susitna, the Talkeetna Mountains, and the upper Copper River drainage area. The wolf has been removed from predator classification and is now classified as a game animal in Alaska.

Alaska Department of Fish and Game management studies concluded that, from 1957 to 1967, wolf predation neither adversely affected other game populations, nor reduced hunting success for sportsmen. However, absolute conclusions were uncertain since moose and caribou populations may have reached their highs during this period. The study proved that wolves and men can often coexist while competing for game animals, but that at times man must accept reduction of available game by wolves.

Wolverines: This area of Alaska has consistently produced more wolverines than any other area of comparable size in the State. Wolverines are seen regularly throughout the area, and it is not unusual for a hunter returning to a kill site to find a wolverine feeding on his moose or caribou. Wolverines have withstood human encroachment and trapping without any noticeable reduction in numbers or range.

Other Mammals: Fur animal species of the upper Susitna in addition to wolf and wolverine include beaver, muskrat, otter, mink, Canada lynx, fox, marten, and weasel. Found in varying populations throughout much of the Upper Susitna River Basin and transmission corridor, each of these species has its own unique habitat requirements. However, except for a limited number of beaver, the river canyon area between Devil Canyon and the mouth of the Oshetna River is not considered good quality fur animal habitat for most of these species.

Other mammals found in this area include coyotes, snowshoe hares, ground squirrels, tree squirrels, pikas, marmots, and several species of voles, shrews, and mice. As with other animals, the populations of the various species vary as adverse or beneficial factors are encountered. Some populations fluctuate greatly while others remain fairly stable.

Threatened Wildlife of the United States: The only species in the U.S. Fish and Wildlife Services publication, Threatened Wildlife of the United States, that might be resident in or migrate through the Upper Susitna River Basin are the two subspecies of the peregrine falcon: *Falco peregrines anatum* (American) and *Falco peregrines tundrius* (arctic). Although no peregrines appear to be nesting along the upper Susitna River at present, there have been occasional sightings within the area and along known migration routes for this species as they move through the Broad Pass area on the upper Chulitna River. These migrating peregrines are occasionally reported to include members of the two endangered subspecies.

Several species of wildlife that are considered threatened or depleted in the Lower 48 States have substantial populations within Alaska. Such species include the American bald eagle, the wolf, and the grizzly bear.

Vegetation: The major ecosystems of Alaska are divided into marine and land groupings, with the land group divided into fresh-water, tundra, and coniferous systems. The freshwater system includes glaciers and ice fields, lakes, and riverine ecosystems; the tundra system is subdivided into moist, wet, and alpine tundras; and the coniferous system is divided into six plant-related classifications.

The Upper Susitna River Basin includes the following four broad land ecosystem classifications: moist tundra; alpine tundra; upland spruce-hardwood forest; and lowland spruce-hardwood forest. The largest percentage of the basin is classified as moist or alpine tundra with most of the area in and adjacent to the main river channel below the Maclaren River classified as either upland or lowland spruce-hardwood forest.

At Gold Creek, the bottomland forest of white spruce and black cottonwoood is very much in evidence on well drained banks. Ascending the river, balsam poplar replaces the cottonwoods around Fog and Tsusena Creeks. Thin hardwoods and white spruce become less and less in evidence but still occur in small stands on well drained river bars and tributary fans upstream to Butte Creek. Above this tributary, only scattered stands of black spruce occur, growing up to the glaciers. The lower hillsides have a low brush cover with moist tundra in the lower areas. The periodically flooded river flats are in willow, sedges-high brush, and wet tundra. Since much of the drainage basin is uplands, alpine tundra is one of the most prominent vegetation types.

Alpine tundra is composed of low mat plants, both herbaceous and shrubby. Moist tundra usually forms a complete ground cover and is very productive during the growing season. Plant types vary from almost continuous cottongrass with a sparse growth of sedges and dwarf shrubs to stands where dwarf shrubs dominate. Tundra ecosystems are especially fragile and are very susceptible to long-term damage or destruction from overuse. Regeneration is extremely slow, with some lichens requiring more than 60 years to recover.

Most of the timber ecosystems in the upper Susitna basin are located adjacent to the river and tributaries on the canyon slopes and on the surrounding benchlands. The major timber species include birch, balsam poplar, black cottonwood, white spruce, and black spruce. Overall, the timber quality in this area is not good, with a wide variety of sizes, mostly smaller and noncommercial. Much of the birch and spruce is more suitable for pulp than for sawtimber; however, a fair yield of sawlogs could be obtained from stands of black cottonwood and balsam poplar.

Cultural Characteristics:

Population: The Southcentral Railbelt area of Alaska contains the State's two largest population centers, Anchorage and Fairbanks, and almost three-fourths of the State's total population. The Anchorage area alone has over half the residents in the State. Recently revised estimates for 1975 indicate over 386,000 people will be in Alaska by the end of the year, compared to slightly over 302,000 counted in the 1970 census, an increase of about 28 percent in that period. Other estimates by the Alaska Department of Labor indicate an expected State population of almost 450,000 for the year 1980, an additional 16 percent increase over 1975, and a population increase of nearly 50 percent in 10 years. The largest growth in the State has been in the Southcentral Railbelt area, and this trend is expected to continue. With the possible relocation of Alaska's capital from Juneau to the Railbelt area, an additional population impact will be exerted on this area of the State.

At the present time, only a few small settlements are located along the Parks Highway between Anchorage and Fairbanks and the Alaska Railroad in the Susitna River valley. Except for the small settlement at Denali, there are few, if any, permanent full-time residents in the Upper Susitna River Basin above Devil Canyon.

Economics: The southcentral region of Alaska includes the Kodiak-Shelikof area, the Cook Inlet area, and the Copper River-Gulf of Alaska area. The Southcentral Railbelt area is that portion of the southcentral and Yukon subregions that is served by the Alaska Railroad. Both Anchorage and Fairbanks are regional economic centers for the Southcentral Railbelt area. Government, trade, and services comprise the major portion of the area's total employment. Construction and transportation are also important. Making relatively less significant contributions are the financing, mining, and manufacturing industries, while agriculture, forestry, and fisheries contribute less than one percent of the employment dollar to the economy of the Railbelt area. In 1972 the wages and salaries for the southcentral region of Alaska amounted to more than $704,000,000.

In the government groups, employment is divided more or less equally between Federal, State, and local sectors. The area's major Federal employer is the Department of Defense, with most of its employees concentrated in four military installations. State and local government employment includes employees from agencies of the State of Alaska and the cities and boroughs within the area.

After government, the two groups having the largest employment are trade and services. Their importance as sources of employment for the Railbelt area residents is a further manifestation of the region's two relatively concentrated population centers and of the high degree of economic diversity, as well as levels of demand for goods and services, which are substantially higher than in most other parts of Alaska. The importance of construction is largely due to the high level of expansion experienced by the Anchorage and Fairbanks areas since 1968. This growth can partly be attributed to the Trans-Alaska pipeline project, which is encouraging much new construction in both public and private sectors.

High levels of employment in the region's transportation industry reflect the positions of Anchorage and Fairbanks as major transportation centers, not only for the Southcentral Railbelt area but for the rest of the State as well. The Port of Anchorage handles most of the waterborne freight moving into southcentral and northern Alaska. International airports at Anchorage and Fairbanks serve as hubs for commercial air traffic throughout Alaska and are important stopovers for 37 major international air carriers. Anchorage also serves as the transfer point for goods brought into the area by air and water, which are then distributed by air transport, truck or by Alaska Railroad to more remote areas.

Although exerting relatively little direct impact on total employment, mining, finance, insurance, and real estate play important roles in terms of the secondary employment they generate in the region. Most people employed in mining engage in activities relating to petroleum extraction from fields in Cook Inlet and the Kenai Peninsula. A substantial portion of the royalties and taxes collected by the State as a result of oil production in the area is returned to the area in the form of jobs in State government and through revenue sharing with various local governments. The total value of oil and gas production in the southcentral region for 1972 was almost $240 million. Similarly, the Anchorage financial sector, in spite of its small employment, exerts considerable economic leverage as the banking center for Alaska.

Most agricultural activities in the Southcentral Railbelt area take place in the Matanuska, Susitna, and Tanana Valleys. The potential for agriculture in these areas of Alaska is considered favorable, although development of the industry has not been extensive.

Commercial fisheries activity is the oldest cash-based industry of major importance within the region. The industry has changed substantially during the past 20 years and continues to be modified as a result of both biologic and economic stimuli. The salmon industry has always been a major component of the industry in terms of volume and value. Since 1955, the king crab, shrimp, and Tanner crab fisheries have undergone major development. The total wholesale value of commercial fish and shellfish for the southcentral region of Alaska in 1972 was just over $100 million including a catch of almost 110 million pounds of salmon, with a wholesale value of nearly $38 million.

The region's timber output is less than 10 percent of the total timber harvested commercially in Alaska. The timber industry is shifting from supplying the local market to production aimed at the export market. Stumpage value of timber cut from State and National forest lands in the whole southcentral region during 1972 was about $130,000.

The tourist industry plays an increasingly important role in the economy of the region. Precise data on tourism are not available, but the numbers of Alaskan visitors have increased from about 130,000 in 1971 to approximately 216,000 in 1973. A forecast by the Division of Tourism in 1973 estimated 288,000 people would visit Alaska in 1975 and about 554,000 in 1980.

With population trend projections showing a substantial increase in the number of future residents in the State and especially in the Southcentral Railbelt area, there will be a related increase in the demand for jobs, goods, energy, and services. Alaska has a wealth of reserves in renewable and nonrenewable resources that will have to be addressed in the very near future.

The world consumption of nonrenewable resources for energy production, such as oil and gas, has reached or will soon reach a critical point in time where alternative means to produce energy must be developed. The need for the development and utilization of those renewable resources must be weighed against the adverse effects that these developments would have on an ever-decreasing regime of natural environment.

Transportation:

Rail: The Alaska Railroad runs from Seward on the Gulf of Alaska, past Anchorage, up the Susitna Valley, past Mount McKinley National Park, and to Fairbanks, a distance of 483 miles. The Federally constructed and operated Alaska Railroad was built between 1914 and 1923.

Roads: Paved roads in the Railbelt area include: the 227-mile Sterling-Seward Highway between Homer and Anchorage, with a 27-mile side spur to Seward; the newly-constructed 358-mile Parks Highway between Anchorage and Fairbanks; a 205-mile section of the Alaska Highway that connects Tok Junction with Fairbanks; the 328-mile Glenn Highway connecting Anchorage with Tok Junction; and the 266-mile Richardson Highway from Valdez, on Prince William Sound, to a junction with the Alaska Highway at Delta Junction, 97 miles southeast of Fairbanks.

The only road access through the upper Susitna basin is the 135-mile gravel Denali Highway between Paxson on the Richardson Highway and Cantwell on the Parks Highway, and the 20-mile gravel road from the Glenn Highway to Lake Louise. The Denali Highway is not open for use during the winter months.

Air: In addition to major airlines within Alaska, there are numerous small commercial operators plus the highest per capita ratio of private aircraft in the nation. Many small remote landing strips are scattered throughout the Susitna basin, and float planes utilize many lakes and streams to ferry freight and passengers to the remote back-country areas. In many areas of the State, the only access is provided by the airplane.

Other Forms of Transportation: ATVs and other types of off-road vehicles provide transportation into areas in the upper Susitna basin where there are no developed roads. Several developed trails are shown on maps of the upper basin. Trails are utilized by ATVs, trail bikes, hikers, horseback riders, and winter travelers.

Shallow-draft river boats, small boats, canoes, rubber rafts, and kayaks utilize sections of the upper Susitna River, a few tributary streams, and some of the lakes for recreation purposes. Except for these few areas, boating use is practically nonexistent within much of the upper basin.

Recreation:

Access: The greatest constraint on recreational activities for most of the 5,800-square-mile Upper Susitna River Basin is the shortage of road access. Except for a 20-mile gravel road from the Glenn Highway to the southern shores of Lake Louise on the upper drainage of the Tyone River, the main access to the area is by way of the gravel Denali Highway through the upper part of the basin.

Float planes are used to fly in hunters, fishermen, and other recreationists to various areas within the basin, but, except for a few larger isolated lakes, this form of access is relatively minor. All-terrain vehicles and snowmobiles also provide off-road access to areas within the upper Susitna basin. Boats are used to some extent to provide access on the Tyone River drainage and to areas of the Susitna River between the Denali Highway and Devil Canyon.

Much of the Upper Susitna River Basin has very little recreational activity at the present time. Great distances, rough or wet terrain, and lack of roads limit use of most of this area to a few hardy souls who enter these wild lands for recreational purposes.

Hunting: A major recreational use of the upper Susitna area is big-game hunting and associated recreational activities. The greatest hunting pressures are exerted from a few fly-in camps, and from areas along the Denali Highway. Most wolves and bears harvested are taken while hunting caribou or moose. The increased use of ATVs to provide access and to haul big game is a significant factor in improved hunting success, even in the face of declining game populations. The mechanized ATV can penetrate deeply into previously inaccessible country, leaving few areas that provide havens for the reduced numbers of caribou and moose. It appears that the use of ATVs for hunting, already prohibited in some areas, may have to be further controlled.

The hunting of Dall sheep, mountain goats, and waterfowl is minimal in the upper basin even in areas of road access such as the Denali Highway.

Fishing: Access is again the major factor in determining areas that are utilized in fishing for grayling, rainbow trout, whitefish, and lake trout. The Susitna and Maclaren Rivers are silt laden throughout their entire courses during the warmer months of the year. Therefore, sport fishing is limited to lakes, clearwater tributaries, and to areas in the main Susitna near the mouths of these tributaries.

Sport fishing pressure in the upper Susitna basin is light. Many lakes and some areas of the river afford landing sites for float-equipped aircraft. A few areas along the main Susitna and some tributaries, such as the Tyone River and Lake Louise, have some pressure from boat fishermen. An increasing number of hunters use ATVs to get into and out of the back country, exerting incidental fishing pressure in some areas.

As previously stated, salmon do not migrate into the upper Susitna River above Devil Canyon so are not a factor in the sport fishery of this area.

Boating: A minor amount of recreational boating occurs in the waters of the upper Susitna basin. Some lakes such as Lake Louise have a heavier amount of boating activity, and some rivers such as the Tyone and the Susitna have a lighter amount of boating activity. Some kayakers utilize portions of the main Susitna River, but very few have braved the violent waters of the Susitna through the area known as Devil Canyon.

Camping: Most camping use in this area is incidental to other recreational activities such as hunting, fishing, boating, and highway travel. Some developed campground facilities are located at Lake Louise and at three campgrounds along the Denali Highway outside the upper Susitna basin. Tourism during the summer months involving the use of campers, trailers, and similar recreational vehicles is increasing at a dramatic rate in Alaska. Many of these vehicles camp along the roads where adequate facilities do not exist and where these activities are creating ever-increasing adverse impacts upon the land.

Other Outdoor Recreational Activities: Most other recreational activities in the Upper Susitna River Basin exert varying environmental impacts on the area. Many activities such as hiking, backpacking, and photography take place incidentally to other recreational pursuits such as hunting, fishing, boating, camping, and driving for pleasure. Trail bikes, snowmobiles, four-wheel-drive vehicles, and other mechanical equipment can cause extreme adverse environmental damage to the fragile ecosystems of the basin when used in a careless, uncontrolled manner.

At the present time, recreation is one of the major uses of the upper Susitna River drainage area, but the overall utilization of this area by humans remains comparatively light.

Historic Resources: A historical-archaeological study recently completed for the Corps of Engineers by the Alaska Division of Parks (Heritage Resources Along the Upper Susitna River, August 1975) indicates 11 historic sites within the study portion of the upper Susitna basin. These are all essentially related to the discovery of gold. Most of the early mining activity occurred on Valdez Creek, where the town of Denali was established. Nine of the sites are located in that general area. Two sites, both designated as cabins, are located on Kosina Creek, one near its mouth, and one about six miles upstream. The apparent dearth of historical locations between Devil Canyon and the Maclaren River is explained by the following excerpt from the Alaska Division of Parks' report (in discussing the first mapping of the area in 1912): "Except for a few prospects on the Oshetna River, the USGS never received any reports of gold being found on the Susitna between Devil Canyon and the Maclaren in significant quantities. Though the Tanaina and Ahtna Indians did a great deal of hunting and fishing on the river in this area, the white man found little gold, an almost unnavigable river, and no reason to settle anywhere near the 'Devil's Canyon'."

In 1920 the Alaska Railroad was completed, giving general access to Mount McKinley National Park. Highways followed in the 1940's and 1950's, and the primary use of the area became recreational. The road approach to Mount McKinley Park was by way of the gravel Denali Highway until the recent completion of the Parks Highway between Anchorage and Fairbanks.

Archaeological Resources: Only one archaeological site has been examined within the study area portion of the upper Susitna basin, and it has never been excavated. This is the Ratekin Site, located near the Denali Highway several miles east of the Susitna River. Three other late prehistoric archaeological sites have been reported, one on upper Valdez Creek, and two on the Tyone River. Very little information is presently available on the aboriginal uses of the Upper Susitna River Basin. Based upon the knowledge of the prehistory of contiguous areas, the Alaska Division of Parks' report concludes that the Upper Susitna River Basin was likely inhabited as early as 10,000 years ago, during Late Pleistocene/Early Holocene times, with use continuing in intensity during Late Prehistoric/Early Historic times.

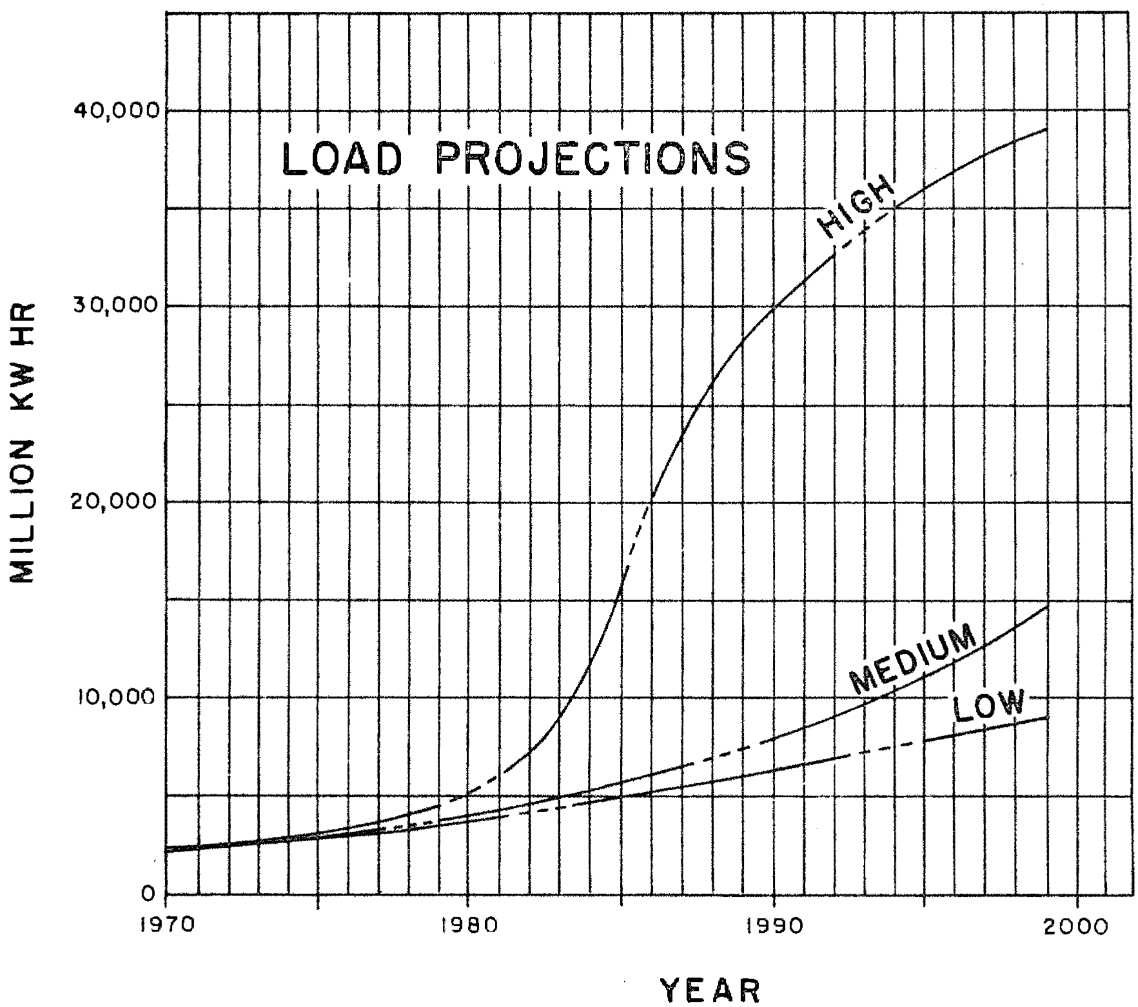
Extensive archaeological remains have been found in the Tangle Lakes area outside the Upper Susitna River Basin near the Maclaren River drainage, and the area has been entered on the National Register of Historic Places. The remains are apparently associated with a large proglacial lake (a lake formed at the outer limit of a glacier) that existed during and after the last period of glaciation, dating back some 10,000 to 12,000 years. It is reasonable to expect further remains to be found around the lakebed margins when more detailed investigations are made.

Energy Needs:

Power requirements for the Railbelt are increasing rapidly, and substantial amounts of new generating capacity and additional transmission system development will be needed in the near future. The Railbelt now derives most of its power from oil and natural gas. Past planning has contemplated that natural gas and, eventually, fuels from the Alyeska Pipeline would continue as long-range energy sources for Railbelt power systems. However, recent changes in the national and international energy situation indicate that other alternatives such as the abundant coal and hydro resources of the Railbelt should be reconsidered.

The energy demand curve used in the hydropower study is based on 1975 projections provided by the Alaska Power Administration. The curve represents the combined demand of the areas that could be served directly from an interconnected Railbelt system, and is premised upon assumed growth rates after 1980 that are substantially below existing trends. These growth rates assume substantial savings through increased efficiency in use of energy and through conservation programs.

The load projection used in the hydropower study is depicted in Figure 9 along with the other estimates provided in APA's 1975 analysis. The "higher" range anticipates significant new energy and mineral developments from among those that appear most promising, along with an annual growth rate in residential, commercial, and light industrial uses that remains throughout the study period somewhat above recent electrical energy consumption growth rates in the U.S. The "lower" range presumes minimal industrial development, a load growth rate for the remainder of this decade well below current actual rates of increase, and energy growth over the next twenty years that barely matches the latest population growth rate projections for that period. This lower estimate generally assumes a significant slackening of the pace of development almost immediately and continuing throughout the period of study. The "mid-range" appears to be a reasonably conservative estimate, with annual rates of increase in power requirements less than 7 percent after 1980 as compared to an historical annual growth rate of 14 percent during the period 1960 to 1971. This adopted "mid-range" projection assumes steady but moderate growth after the present boom period coupled with more efficient energy use.



PROJECTED
ENERGY DEMAND
SOUTHCENTRAL RAILBELT

Appendix I
FIGURE E-9

Because of lead time needed for coal and hydroelectric development, immediate needs for the next decade will have to be handled by additional oil and gas-fired units. However, the opportunity exists for hydro and coal to become the main energy sources for Railbelt power by about 1985, if priority is attached to these resources.

Studies by the advisory committees for the current Alaska Power Survey provide estimates of costs for alternative power supplies from coal, natural gas, and oil-fired plants. Indications are that power from Susitna hydroelectric development would be comparable in cost to present gas-fired generation in the Cook Inlet area and would be less expensive than alternatives available to other Southcentral Railbelt power markets.

There are many questions concerning future availability and costs of natural gas and oil for power production. Oil prices have increased dramatically in the past few years, and there are many pressures to raise natural gas prices. There are also arguments that natural gas reserves are needed for petrochemical industries and for other non-power uses. Many people in Government and industry question the use of natural gas and oil for long-range power system fuels.

On 31 December 1974 the Congress enacted Public Law 93-577. This act established a national program for research and development in non-nuclear energy sources. One of the sections of the law stipulated that heavy emphasis should be given to those technologies which utilize renewable or essentially inexhaustible energy sources.

UPPER SUSITNA RIVER BASIN DAM ALTERNATIVES

General:

Eight technically feasible plans for hydroelectric development of the Upper Susitna River Basin were studied as follows:

Devil Canyon:

The possibility of a single dam development in the Upper Susitna Basin located at the Devil Canyon damsite (river mile 134) was investigated. The proposed thin-arch dam would have a structural height of 635 feet and a water surface area of 7,550 acres at a normal maximum pool elevation of 1,450 feet. The reservoir would extend approximately 28 river miles upstream and would be confined within the narrow Susitna River Canyon. The project would produce 0.9 billion kilowatt-hours of firm annual energy from an installed capacity of 220 megawatts. Because of the very limited storage capacity, the project has a low firm energy capability and a high secondary energy capacity.

Watana:

This single dam development of the Upper Susitna Basin located at the Watana site (river mile 165) would be an earthfill dam with structural height of about 810 feet. The reservoir would have a normal maximum pool elevation of 2,200 feet, would have a surface area of approximately 43,000 acres, and would extend about 54 river miles upstream to a point between the Oshetna and Tyone Rivers. The annual firm electrical production of Watana would be 3.1 billion kilowatt-hours from an installed capacity of 792 megawatts. The project would develop less than half of the basin potential.

Devil Canyon-Denali:

This alternative two-dam system would include the thin-arch concrete dam at Devil Canyon and a 260-foot-high earthfill dam in the vicinity of Denali (river mile 247). The Denali Dam would provide storage only and would have no powerhouse. This system would generate 2.5 billion kilowatt-hours of firm annual energy from an installed capacity of 575 megawatts at Devil Canyon Dam. The surface acres flooded would total about 62,000 acres (Devil Canyon, 7,550; Denali 54,000). The plan would entail significant environmental impacts on waterfowl nesting areas, moose range, and archaeological/historical values in the Denali reservoir area.

Devil Canyon-Watana:

This two-dam system would include the previously mentioned 635-foot thin-arch dam at Devil Canyon and the 810-foot earthfill dam at Watana. This proposed plan would inundate about 82 miles of the upper Susitna River and approximately 50,550 surface acres. A total of 6.1 billion kilowatt hours of firm annual energy would be produced by the combined Devil Canyon-Watana system.

The construction period for this two-dam proposal is estimated to be 10 years. This plan is economically feasible and has less adverse environmental impact than any of the other multi-dam proposals.

The adverse environmental effects of this proposal would include the permanent loss of all vegetation within the reservoir pools.

Water released from the reservoirs may be slightly turbid throughout the year, whereas under existing conditions the stream normally runs clear from late fall until early spring breakup. Studies to date indicate that the sediment in suspension would not be high, ranging probably from 15-35 ppm. On the other hand, heavy sediment loads now carried by the stream during the warmer months of spring through early fall would be significantly reduced.

Downstream water quality problems related to temperature, dissolved oxygen, and supersaturated nitrogen could occur. These would be held to minimal, and possibly insignificant levels by spillway design and the incorporation of multiple-level water withdrawal structures.

Approximately 9 miles of the existing 11-mile whitewater reach through Devil Canyon would be lost through inundation.

The lower 2.5 miles of Tsusena Creek, which would be utilized as a spillway for excess river flows (this would occur rarely, if ever, during periods of excessive late summer flood conditions), will suffer adverse impacts to fish and on-shore vegetation during such periods.

Some moose habitat on the canyon floor and adjacent slopes would be inundated by the reservoirs. Most of the present use is upstream from Tsusena Creek; thus the greatest impact to moose would result from the Watana reservoir. The amount of good habitat is limited, but its loss would be permanent.

The reservoirs would lie between the spring calving grounds and portions of the summer range of the wide-ranging Nelchina caribou herd. Increased mortality to caribou attempting to cross the reservoirs between these two areas could result from ice-shelving conditions which might occur, particularly on Watana reservoir, and other difficulties which might be encountered in swimming both reservoirs. The reservoirs could conceivably alter historical herd movement and distribution, although the animals do not exhibit any readily definable patterns, other than in the broadest of terms, at the present time.

Although other major wildlife species, such as bears, wolves, wolverines, and Dall sheep are not expected to be directly affected by the project to a significant extent, there will inevitably be some secondary impacts resulting from disruption of existing predator-prey relationships. Overall, terrestrial wildlife habitat will be reduced. Small animals resident to inundated areas will be lost.

Resident fish populations above Devil Canyon Dam (there are no anadromous fish under existing conditions above this point) could be adversely affected to some extent by the change from a riverine to lake environment within the reservoir pools. The resident sport fishery is not believed to be significant within the main river channel. Primary impacts would occur near the mouths of a few clearwater tributaries which provide some known grayling habitat. The intricate changes expected to occur downstream from Devil Canyon will result in both beneficial and adverse impacts to resident and anadromous fishes. Adverse impacts could result from possible reduction in nutrients and primary productivity, cutting, and erosion of existing streambed configuration, increased turbidity during the winter months, and changes in the hydraulic and biological regime of salmon rearing and spawning sloughs. (As pointed out in the section titled <u>Environment Impacts of The Devil Canyon-Watana Hydropower Plan</u>, many of the anticipated changes downstream from Devil Canyon Dam could prove beneficial to both the anadromous and resident fishery. Determinations as to the offsetting effects of these changes are the subject of on-going studies.)

Roads required for project construction, operation, and maintenance would impair visual quality and permit general public access to a largely pristine area. This would increase pressure on existing game populations through hunting, trapping, and general disturbance and harassment. This in turn would require intensified game management and law enforcement practices and preventive measures for the control of wildfire. Another harmful effect would be the impact of some of the roads themselves where delicate ecosystems are traversed. Some of the inevitable consequences of road construction are destruction of vegetation and wildlife habitat, reduced insulation of frozen soils, and settling from permafrost degradation, resulting in both erosion and alteration of the groundwater regime.

Degradation of visual quality in general would be a major adverse effect of project construction. This would be attributable primarily to roads, dam construction, right-of-way clearing for the transmission line, and the obtrusiveness of the transmission line itself. Although care would be taken to minimize these impacts to the greatest possible extent, the overall natural setting and scenic quality of the damsites and transmission line corridor would be permanently impaired.

Devil Canyon High Dam:

In September 1974, Henry J. Kaiser Company prepared a report proposing an alternative hydroelectric development project on the upper Susitna River. The report states that preliminary investigations indicated that an 810-foot-high, concrete-faced rockfill dam located about 5 miles upstream from the other Devil Canyon site would provide 3.7 billion kilowatts of average annual energy, or 2.6 billion kilowatt-hours of firm annual energy (figures converted to standard Corps of Engineers evaluation parameters). This dam would inundate about 58 miles of the Susitna River with a reservoir of approximately 24,000 surface acres at a full pool elevation of 1,750 feet.

This project would be located in much the same area of the Susitna River canyon as the proposed Devil Canyon-Watana project and would have similar environmental impacts with some exceptions. Whereas the Devil Canyon reservoir in the two-dam proposal would remain nearly full all year, the Kaiser reservoir would fluctuate substantially.

Kaiser's proposed Devil Canyon High Dam, located about 25 miles downstream from the Watana site, would have proportionately fewer miles of permanent roads and transmission lines than the Devil Canyon-Watana two-dam project, therefore less environmental impact on resources affected by these facilities.

The recreational opportunities would be fewer for the one-dam proposal. The substantial fluctuation of the reservoir would reduce some recreation potential and reduce resident fish populations while increasing the adverse visual impact associated with reservoir drawdown. The plan was found to lack economic feasibility.

Three-Dam System:

A three-dam Devil Canyon-Watana-Denali hydroelectric development on the upper Susitna River could be build as an extension of the two-dam Devil Canyon-Watana project if the Denali storage site proved feasible. Such a dam system would provide a total of 6.8 billion kilowatt-hours of firm annual energy.

If a three-dam Devil Canyon-Watana-Denali project were constructed, it would include Devil Canyon and Watana dams previously described, and a 260-foot storage dam at Denali. This three-dam system would inundate approximately 104,550 acres and would take 13 to 17 years to construct. With a three-dam system, the 100-year storage capacity in Watana reservoir would be reduced by less than 3 percent due to sedimentation.

Environmentally, this plan would result in the adverse impacts associated with the Devil Canyon-Watana two-dam system, plus the added impact of inundating significant additional moose range and waterfowl nesting areas. There are also some archaeological and historical values within a proposed Denali impoundment.

This alternative has significantly greater total adverse environmental impacts than the Devil Canyon-Watana development.

Four-Dam System:

In May 1974, the Alaska Power Administration updated a March 1961 report of the Bureau of Reclamation which proposed development of the hydroelectric resources of the Upper Susitna River Basin. The report proposed an initial plan to build the Devil Canyon Dam and powerplant and an upstream storage dam and reservoir at Denali. Subsequent development of a four-dam system would include dams at both the Watana and Vee sites. The four-dam system would generate a total of 6.2 billion kilowatts of firm annual electrical energy. The Watana Dam under this plan would be about 300 feet lower than in the Devil Canyon-Watana two-dam proposal, and the Vee dam would be about 55 feet lower than in the original Bureau of Reclamation 4-dam plan.

Initial development of the four-dam system, Devil Canyon-Watana-Vee-Denali, would include only the construction of the hydroelectric dam at Devil Canyon and the storage dam at Denali. This combination of two dams would produce 2.5 billion kilowatt-hours of firm annual energy. This initial two-dam stystem would also be compatible with the three-dam Devil Canyon-Watana-Denali, alternative proposal.

The four reservoirs considered in this development would inundate approximately 85,000 acres of land and river in the upper Susitna basin, compared with about 50,550 acres flooded in the two-dam proposal.

In a four-dam plan, the two reservoirs proposed in the lower section of the upper Susitna River would have substantially fewer known adverse environmental impacts than the two upper area reservoirs at the Vee and Denali. Generally the further upstream a reservoir is located in the four-dam system, the greater the overall adverse environmental impact would be on fish, wildlife, and esthetic resources.

Watana reservoir, in this plan, would be lower. It would cover a surface area of about 14,000 acres behind a 515-foot-high dam with a pool elevation of 1,905 feet. The reservoir would extend over 40 miles upstream from the damsite and would be contained in the narrow canyon for most of its length.

Under either Watana alternative, the reservoir would flood areas used by migrating caribou and would flood some moose winter range in the river bottom. It would also cover existing resident fish habitat at the mouths of some of the tributaries in this section of the river and possibly would create additional stream habitat at higher elevations.

The 455-foot-high Vee Dam would be built only under the four-dam plan in conjunction with the lower height Watana Dam. Vee reservoir would inundate about 32 miles of glacial river and would have a pool elevation of 2,300 feet with a surface area of approximately 9,400 acres. The reservoir would flood a substantial amount of moose habitat on the main Susitna and on the lower reaches of the Oshetna and Tyone Rivers. Caribou migration routes along the south bank of the Susitna River would also be affected as would some waterfowl habitat of minor significance. Present resident fish habitat, especially grayling, would be flooded at the mouths of many of the clearwater tributaries in the area covered by the Vee reservoir.

Any road to the Vee damsite would open up large areas of wild lands that are prime wildlife habitat and escapement areas (inaccessible to man) for caribou, bear, and moose, and would have a significant impact on these and other fish and wildlife resources within these areas.

Denali Dam, with a structural height of 260 feet, would form a 54,000-acre storage reservoir with a pool elevation of 2,535 feet. Large areas of wildlife habitat, especially for moose and waterfowl, would be inundated in an area between 2 to 6 miles wide and approximately 34 miles long. Many clearwater streams entering the Susitna River in this area have varying populations of arctic grayling; how the fluctuating reservoir would affect this fishery is generally unknown at this time. Substantial areas of lands would be exposed during the seasonal drawdowns of this storage reservoir. From an esthetic standpoint, this would be a substantial adverse environmental impact, especially when viewed from the well-traveled Denali Highway during the earlier summer months when the reservoir would be low.

The relocation of 19 miles of the Denali Highway necessary with the construction of a dam at the Denali site would provide additional access to this area with increasing pressures on the fish and wildlife resources in Coal Creek, Clearwater Creek, lower Maclaren River, Butte Creek, and the eastern slopes of the Watana Hills. There would be substantially less developed recreational potential at the Vee and Denali sites than at Devil Canyon because of travel distances involved and reservoir drawdown, especially at the Denali damsite.

It is expected that construction of the Vee project would take 5 to 6 years, while the Denali dam and reservoir would take between 3 and 5 years to construct. The construction period of the four-dam system would be between 18 and 23 years, if the dams were constructed in sequence. The magnitude of environmental impacts resulting from a four-dam system in the Upper Susitna River Basin clearly makes this a less desirable alternative than the one-, two-, or three-dam plans.

Kaiser Four-Dam System:

An additional study of a four-dam system was made by the Corps of Engineers utilizing the Kaiser Devil Canyon High Dam as the main component in an upper Susitna basin system. This alternative included both the Vee and Denali Dams and a low reregulating dam just below the confluence of Portage Creek with the Susitna. This four-dam system could provide an estimated 5.6 billion kilowatt-hours of firm annual energy.

The environmental impacts of this four-dam system are a combination of the impacts of the Kaiser Devil Canyon High Dam, the Vee and Denali damsites, and a low reregulating dam downstream from Devil Canyon just below Portage Creek. The system would inundate about 88,250 acres. One of the major additional impacts would include anadromous and resident fishery impacts caused by the 200-foot high Olson reregulating dam just below Portage Creek.

Summary:

The Devil Canyon-Watana two-dam system, with a total of 6.1 billion kilowatt hours of firm annual energy, develops almost 90% of the 6.8 billion kilowatt hours projected from the Devil Canyon-Watana-Denali alternative, which would produce the highest amount of electrical energy of any of the proposed Upper Susitna Basin alternatives.

The Devil Canyon-Watana alternative would inundate about 50,550 acres compared to about 104,550 acres with the three-dam plan, and substantially less area than any of the other multi-dam alternatives as shown on Table I.

DATA ON THE PROPOSED PROJECT AND SELECTED SUSITNA ALTERNATIVES

	Type of Construction	Structural Height	Normal Full Pool Elevation	Surface Acres	Total Storage Acre-Feet	Miles of River Inundated	Billion Kilowa Hours of Firm Annual Energy
Selected Plan:							
Devil Canyon	Concrete, thin-arch	635'	1450'	7,550	1,050,000	28	
Watana	Earthfill	810'	2200'	43,000	9,400,000	54	
Totals				50,550			6.1
Alternatives:							
Kaiser's High Devil Canyon	Earthfill	810'	1750'	24,000	4,700,000	58	(2.6)
Olson	Concrete, gravity	200'±	1020'	1,000	83,000	8	
Vee	Earthfill	455'	2300'	9,400	920,000	32	
Denali	Earthfill	260'	2535'	54,000	3,850,000	34	
Totals				88,400			5.6
Devil Canyon	Concrete, thin-arch	635'	1450'	7,550	1,050,000	28	
Watana	Earthfill	810'	2200'	43,000	9,400,000	54	
Denali	Earthfill	260'	2535'	54,000	3,850,000	34	
Totals				104,550			6.8
Devil Canyon	Concrete, thin-arch	635'	1450'	7,550	1,050,000	28	
Watana	Earthfill	515'	1905'	14,000	2,420,000	40	
Vee	Earthfill	455'	2300'	9,400	920,000	32	
Denali	Earthfill	260'	2535'	54,000	3,850,000	34	

In addition to the smaller number of surface acres inundated in the Devil Canyon-Watana two-dam system, there would be substantially less overall adverse environmental impact with the two-dam proposal as compared to any of the other multi-dam proposals. The Vee and Denali proposals would inundate a significant amount of moose, caribou and waterfowl habitat whereas the Devil Canyon and Watana proposals would affect a minimal number of big game animals and waterfowl nesting areas. The two upstream dam proposals would also have a greater adverse effect on fish, wildlife, and esthetic resources.

Under the 4-dam Kaiser proposal a reregulating dam at the Olson site would be a project requirement--this reregulating dam would be constructed just downstream from the Portage Creek confluence with the Susitna and could be a significant impact on the migration of salmon to Portage Creek.

The Devil Canyon-Watana hydroelectric development proposal has the highest benefit-to-cost ratio of any of the Upper Susitna River Basin alternative plans and also has significantly less adverse environmental impact than any of the alternative multi-dam proposals.

DEVIL CANYON-WATANA HYDROPOWER PLAN

DESCRIPTION OF THE DEVIL CANYON-WATANA PLAN

The recommended plan consists of construction of dams and powerplants on the upper Susitna River at Watana and Devil Canyon, and construction of electric transmission facilities to the Railbelt load centers, with access roads, permanent operating facilities, and other project related features.

A subsidiary purpose in the construction of the electric transmission line will be the interconnection of the two largest electrical power distribution grids in the State of Alaska, which will result in increased reliability of service and lower cost of power generation.

The proposed plan for the Watana site (figure 4) would include the construction of an earthfill dam with a structural height of 810 feet at river mile 165 on the Susitna River. The reservoir at normal full pool would have an elevation of 2,200 feet and a crest elevation of 2,210 feet, have a surface area of approximately 43,000 acres, and would extend about 54 river miles upstream from the damsite to about 4 miles above the confluence of the Oshetna River with the Susitna.

Development of the Devil Canyon site includes the construction of a concrete, thin-arch dam with a maximum structural height of 635 feet and with a crest elevation of 1,455 feet. The dam would be located at river mile 134 on the Susitna River. Devil Canyon reservoir would have a water surface area of about 7,550 acres at the normal full pool elevation of 1,450 feet. The reservoir would extend about 28 river miles upstream to a point near the Watana damsite, and would be confined within the narrow Susitna River canyon.

The generating facilities for Watana would include three Francis reaction turbines with a capacity of 264 MW (megawatts) per unit, and a maximum unit hydraulic capacity of 7,790 cfs (cubic feet per second). The firm annual production of electrical power at Watana would be 3.1 billion kilowatt-hours.

The generating facilities for Devil Canyon would include four Francis reaction turbines with a capacity of 194 MW per unit and a maximum unit hydraulic capacity of 6,250 cfs. The firm annual energy provided at Devil Canyon would be 3.0 billion kilowatt-hours.

A total of 6.1 billion kilowatt-hours of firm annual energy would be produced by the combined Devil Canyon-Watana system. Secondary annual average energy production from this two-dam system includes an additional 0.8 billion kilowatt-hours per year. The 6.9 billion kilowatts of firm and secondary annual energy would be the energy equivalent of about 15 million barrels of oil per year, or about 112 billion cubic feet of natural gas per year, or about 1.5 billion barrels of oil over a 100-year project-life period.

Most of the generated electrical power would be utilized in the Fairbanks-Tanana Valley and the Anchorage-Kenai Peninsula areas. The proposed transmission system would consist of two 198-mile, 230 kv single circuit lines from Devil Canyon to Fairbanks (called the Nenana corridor), and two 136-mile, 345 kv single circuit lines from Devil Canyon to the Anchorage area (called the Susitna corridor). Both lines would generally parallel the Alaska Railroad. Power would be carried from Watana to Devil Canyon via two single circuit transmission lines, a distance of 30 miles. Total length of the transmission lines would be 364 miles. The general locations of the transmission lines are shown on Figure 10.

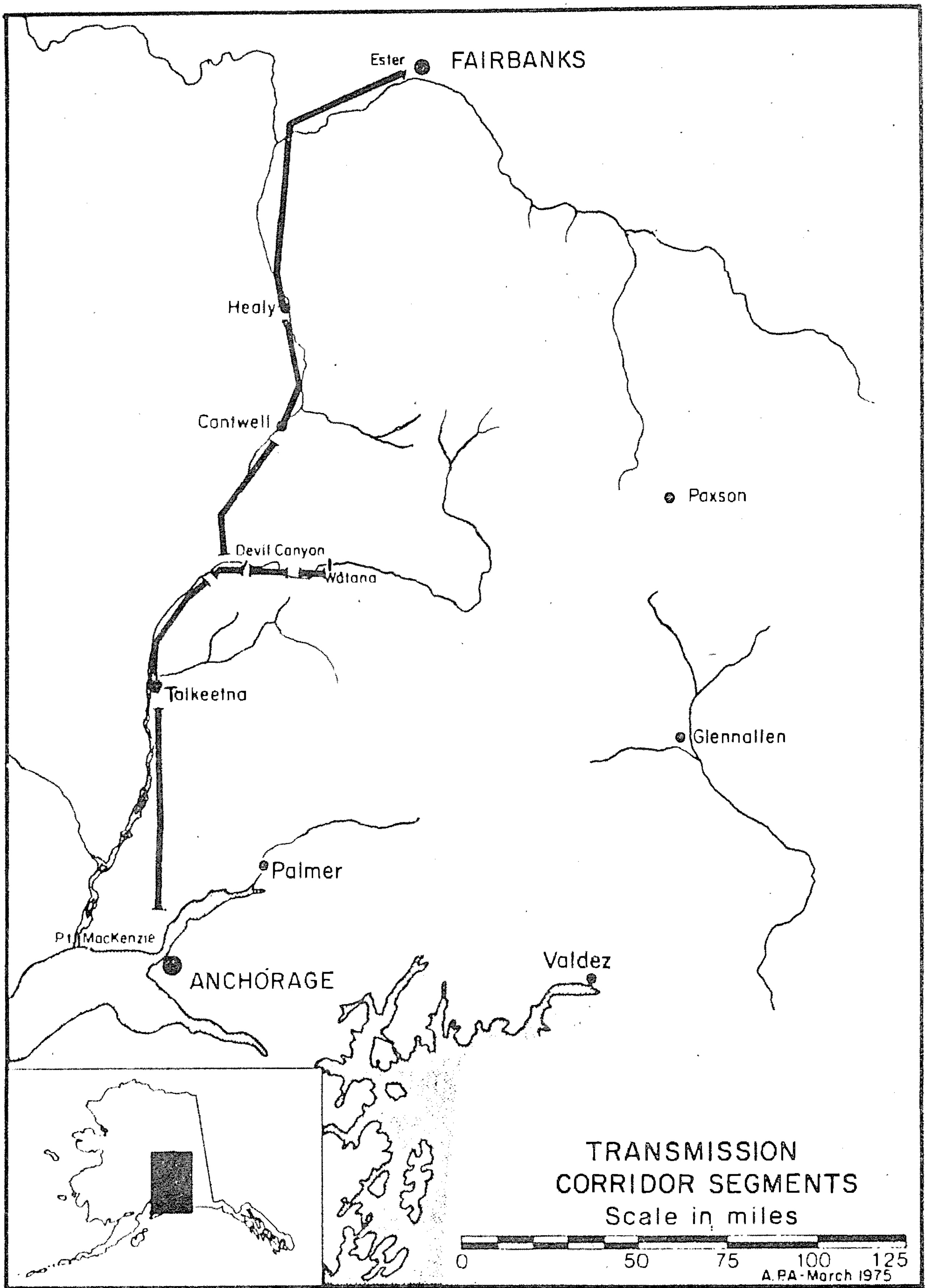
Access to the Devil Canyon and Watana sites would be determined by siting studies that would include consideration of the environmental impacts for roads and transmission lines. Preliminary studies recommend an access road approximately 64 miles in length to connect the Watana site with the Parks Highway via Devil Canyon. A factor considered in location and design of access roads would be their subsequent use for public recreational purposes.

Project-oriented recreational facilities would include visitor centers at the dams, boat launching ramps, campgrounds, picnic areas, and trail systems.

The total first costs of the proposed hydroelectric project, based on January 1975 prices, are estimated at $1.52 billion, including the transmission system. Overall, Devil Canyon costs are estimated at $432,000,000, and Watana at $1,088,000,000. Watana Dam would be constructed first and Watana's costs would include the total cost of the transmission system.

The benefit-to-cost ratio compared to the coal alternative at 6-1/8 percent interest rate and 100-year project life is 1.4 using Federal financing.

Various studies, reports and articles provided background data and information for this assessment (see BIBLIOGRAPHY).



Appendix I
FIGURE E-10

General environmental studies are continuing. Inventory and evaluation studies of fish and wildlife resources affected by the project are being conducted by the Alaska Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. As these ongoing studies identify specific areas of concern, they will be selected for more intensive investigation during detailed design studies, should Congress authorize advancement to that stage. Examples of problems expected to be addressed during the detailed design study phase include identification of significant adverse impacts to important fish and wildlife species, and specific actions which should be taken to prevent, ameliorate, or mitigate these impacts.

HYDROLOGY AND WATER QUALITY

About 86 percent of the total annual flow of the upper Susitna River occurs from May through September. Average daily flows from the latter part of May through the latter part of August fluctuate in the range of 20,000 to 32,000 cubic feet per second (cfs). November through April the average daily flows range between 1,000 and 2,500 cfs. The river also carries a heavy load of glacial sediment during the high runoff periods. During the winter when low temperatures reduce water flows the streams run practically silt-free.

Some of the impacts that could be caused by the project downstream from Devil Canyon Dam are discussed below.

Significant reductions of the late spring and early summer flows of the river and substantial increases of the winter flows would occur. The flow of the river during the period 1950 through 1974 averaged about 9,280 cfs. The projected average regulated downstream flows for a Devil Canyon-Watana system computed on a monthly basis would range between about 7,560 cfs in October to about 15,100 cfs in August. In extreme years, the monthly averages would range from about 6,000 cfs to nearly 32,000 cfs. The average monthly regulated flows compared to the average unregulated flows based on the period from 1950 through 1974 are as follows:

TABLE II

Month	Regulated cfs	Unregulated cfs
January	9,905	1,354
February	9,429	1,137
March	9,026	1,031
April	8,278	1,254
May	8,158	12,627
June	8,329	26,763
July	9,604	23,047
August	15,091	21,189
September	10,800	13,015
October	7,560	5,347
November	8,369	2,331
December	8,968	1,656

The heavier sediment material now carried by the river during high runoff periods between Devil Canyon and the junction of the Chulitna and Talkeetna Rivers with the Susitna River would be substantially reduced, and a year-round, somewhat milky-textured "glacial flour" (suspended glacial sediment) would be introduced into the controlled water releases below the dam. Preliminary studies indicate that the suspended sediment in releases at Devil Canyon Dam would be at low levels (15-35 ppm). According to fishery investigations during the winter of 1974-75 by the Division of Commercial Fisheries of the Alaska Department of Fish and Game on the Susitna River between Portage Creek and the Chulitna River, suspended solid samples of river water at Gold Creek, Chase and the Parks Highway bridge indicated a range of from 4 to 228 ppm, and indicated that these suspended solids are within anadromus fish tolerances. Although the average sed.ment load in summer months is less than 1000 ppm, loads sometimes reach a maximum of 5000 ppm in the unregulated river. Reduction of existing summer sedimentation peaks should have a beneficial effect on anadromous and resident fish populations for some distance downstream from Devil Canyon Dam.

When spilling water over Devil Canyon Dam would be necessary during some periods of extreme high flows, nitrogen supersaturation could be introduced into the river below the dam. Fish exposed to high levels of this condition can suffer gas-bubble disease (like bends to a deep-sea diver) which can be fatal.

With appropriate operational procedures, it is estimated that spilling excess flows at Devil Canyon would occur on the frequency of once every 2 years with an average duration of 14 days. However, any nitrogen supersaturation and dissolved oxygen thus introduced should be reduced substantially in the turbulent river section just downstream from the dam. The proposed spillway at Watana Dam is not conducive to high levels of nitrogen or oxygen supersaturation, and spills would occur seldom, and under extreme flooding conditions in late summer. Few fish, under existing conditions, are believed to occupy the 2½ mile section of Susitna River between the proposed Devil Canyon damsite and the mouth of Portage Creek. This situation could change with a decrease in regulated flows during the summer months.

Temperature of the water released from Devil Canyon Dam would be adjusted to approach the natural river water temperatures. This would be made possible by the proposed incorporation of selective withdrawl outlets into the dam structure.

Variations in water releases at Devil Canyon Dam would cause less than a one-foot daily fluctuation of downstream water levels in the river during the May through October period since the reservoir would not be used for peaking purposes. The regulated daily fluctuations during the winter months could range up to one foot under normal operating conditions. According to U.S. Geological Survey studies, the natural normal daily fluctuations in the Susitna River below Devil Canyon range up to about one foot.

Stratification conditions within the reservoirs could cause some temperature and dissolved oxygen problems in the river for some distance downstream from the Devil Canyon Dam and within the reservoirs themselves. These conditions could have an adverse impact on the downstream fishery. However, this problem can be minimized by multiple-level water release structures which are proposed for incorporation into both dams. This would provide the capability of selective withdrawal of water from any level within the reservoir to moderate release temperatures and dissolved oxygen content. Spillway designs will also be considered to reduce supersaturation of downstream water flows with atmospheric gases.

There would be a period of channel stablization in the 50-mile section of the Susitna River below Devil Canyon Dam in which the river would tend to adjust to the stabilized flow with low sediment levels, but general channel degradation caused by a river's attempt to replace the missing sediment load with material picked up from the riverbed is not expected to be a significant concern along the coarse gravel bed reaches of the Susitna River between Talkeetna and Devil Canyon. However, this phenomenon would be the subject of future detailed studies to determine the distance at which sediment loads would become reestablished.

Upstream from the dams the major environmental impacts would be caused by the reservoir impoundments. Under the proposed two-dam system, the reservoir behind the Devil Canyon Dam would fluctuate up to 5 feet during the year, while Watana reservoir would fluctuate between 80 and 125 feet during the year under normal operating conditions. The maximum daily fluctuation at Devil Canyon reservoir under normal operating conditions would be less than two feet.

Devil Canyon reservoir would cover about 7,550 acres in a narrow steep-walled canyon (1/4 to 3/4-mile-wide) with few areas of big game habitat and a minimal amount of resident fish habitat at the mouths of a few of the tributaries that enter the Susitna River in the 28-mile section above the proposed damsite. The reservoir would also flood approximately 9 miles of the 11-mile, whitewater section of Devil Canyon.

Watana reservoir, with a structural height of 810 feet and a pool elevation of 2,200 feet, would flood about 43,000 acres in a 54-mile section of the Susitna River that would reach upstream to about 4 miles above the Oshetna River confluence. Except in a few areas near the mouths of tributaries such as Deadman Creek, Watana Creek, Jay Creek, and Kosina Creek, the Watana reservoir would be contained within a fairly narrow canyon 1/3-mile to 1 mile in width for much of its length.

The spillway design at Watana diverts the excess river flows into the Tsusena Creek drainage approximately 2.5 miles above the creek's confluence with the Susitna River. On the rare occasions when it would be necessary to divert excess river flows over the spillway, the adverse environmental impact on fish and vegetation resources in lower Tsusena Creek could be significant.

Watana reservoir would flood reaches of the Susitna River upstream from Tsusena Creek that are sometimes used as caribou crossings. It would also flood some moose winter range in the river bottom. The reservoir would also cover existing resident fish habitat at the mouths of some of the tributaries in this section of the river and possibly would create other fish habitat at higher elevations on these tributaries.

Fish:

One of the environmental impacts caused by the proposed Devil Canyon-Watana project would be the substantial reduction of natural river flows during the latter part of June and the early part of July when salmon start migrating up the Susitna River. The projected average monthly regulated flows during periods in August and September, when the majority of the salmon are spawning, approach the average natural flows of the river during this period (see Table I, page 43).

In a 1974 study by the Alaska Department of Fish and Game on surveys conducted to locate potential salmon rearing and spawning sloughs on the 50-mile section of the Susitna River between Portage Creek and the Chulitna River, 21 sloughs were found during the 23 July through 11 September study period. Salmon fry were observed in at least 15 of these 21 backwater areas. Adult salmon were present in 9 of the 21 sloughs. In 5 of the sloughs the adult salmon were found in low numbers (from 1 to 24 with an average between 6 and 7). In 4 other sloughs large numbers were present (from 107 to 681 with an average of just over 350).

During December 1974 and January and February 1975, the Alaska Department of Fish and Game investigated 16 of the 21 sloughs previously surveyed during the summer of 1974. Of the 16 sloughs, 5 indicated presence of coho salmon fry. The numbers of fry captured in the 5 sloughs at various times ranged from 1 to 21 with an average of 5. Many of the 16 sloughs surveyed were appreciably dewatered from the summer/fall state.

The report also stated that a number of coho fry were captured in the Susitna River near Gold Creek, indicating that some coho salmon fry do overwinter in the main river.

The winter investigations indicated that the Susitna River between Devil Canyon and Talkeetna was transporting suspended solid loads ranging from 4 ppm to 228 ppm.

It may be reasonable to assume that one of the most critical factors in salmon spawning is the dewatering of areas in which the salmon have spawned. If winter flows are insufficient to cover the spawning beds it would be of little consequence if high summer flows allowed salmon to spawn in some of the sloughs that are dewatered during the egg incubation or alevin stages. According to a Hydrologic Reconnaissanc of the Susitna River Below Devil's Canyon, October 1974, by the National Marine Fisheries Service when comparing regulated flows to natural flows (see Table 1, page 43), "It is reasonable to conclude that during the months of October through March spring flows may be enhanced in the river valley bottom, during the months of May through mid-September these springflows may be depressed".

It is logical to assume on the basis of existing data that there will be some changes in the relationship between the regulated river and access to existing salmon rearing and spawning sloughs and tributaries downstream from Devil Canyon Dam. It appears feasible to develop a program to improve fish access to and from some of the sloughs and tributaries in the Susitna River as a consequence of the project's stabilizing effect on summer flows. Such a program would be a project consideration.

Periodic flood conditions that presently destroy salmon eggs in this stretch of the river would be almost completely eliminated by regulation of the upper Susitna River flows.

Reduction in flows and turbidity below Devil Canyon Dam might cause some disorientation of salmon migrating into the section of the Susitna River between Portage Creek and the Chulitna River during an initial period after construction of the dams and until future salmon stocks readjusted to the change in regulated river conditions.

During periods of construction, river flows will be diverted through tunnels in the canyon walls and past the construction areas at the damsites with minimal changes in existing water quality.

During the period in which the newly-constructed reservoirs would be filling with water, downstream flow maintenance would be coordinated with the fish and wildlife agencies to prevent unnecessary damage to downstream fishery resources. It is proposed to construct Watana Dam first starting in about 1981, and Devil Canyon approximately five years later.

According to a study discussed in the Journal of Fisheries Research Board of Canada--Volume 32, No. 1, January 1975, Ecological Consequences of the Proposed Moran Dam on the Fraser River--some of the beneficial downstream impacts of the dam could include the following:

The higher regulated winter flows might increase the survival of salmon eggs in the sloughs and backwater areas of the river downstream from the dam. The increased flows could also insure better coverage and better percolation through the gravel and presumably increase egg and alevin survival. (Salmon alevin are young fish with attached egg-sacs that remain in the gravel beds until they emerge as fry.)

An additional consequence of reduced turbidity below the dam might be a gradual reduction in the percentage of fine materials in the salmon spawning areas near the mouths of sloughs and tributaries as they enter the Susitna River. This could also lead to improved percolation through the gravel in the streambed and possibly improve survival of eggs.

Reduced siltation during the summer months should prove beneficial for both anadromous and resident fish species for some distance downstream from the proposed Devil Canyon Dam. It is also reasonable to expect that some additional salmon spawning and rearing habitat would develop within some sections of the Susitna River between Devil Canyon and Talkeetna.

Other hydrologic factors previously discussed would also affect the fishery resource downstream from the dams. These and other changes could also influence the food and life cycles for fish in this section of the river. Biological and physical changes likely to occur are the subjects of ongoing studies by State and Federal agencies under the direction of the U.S. Fish and Wildlife Service. Results of these studies will be used in determining needs for more detailed final design phase studies, feasible project modification, and mitigative or ameliorative measures.

Upstream from the dams, the major impact on the resident fish populations would be caused by the reservoir impoundments. Under the proposed plan, Devil Canyon reservoir would fluctuate very little. Even though the steep-walled canyon of this reservoir might prove less than desirable for a program to develop a resident fish population, some species of fish might be able to adapt to this reservoir and provide some future sport fishing benefits.

Watana Dam would have a widely fluctuating reservoir which would generally prove detrimental to the development of resident fish populations. Suspended glacial sediment could be a factor in both of the reservoirs after the heavier glacial sediments have settled out; however, many natural lakes in Alaska such as Tustumena and Tazlina, with heavy inflows of glacial debris sustain fish populations under similar conditions, so to develop populations of fish under related conditions may be feasible.

Most resident fish populations, especially grayling, utilize some of the clearwater tributaries of the Susitna River or areas near the mouths of these streams as they enter the glacially turbid main river channel during periods of high runoff. Many of these tributaries would be flooded in their lower reaches by the proposed reservoir impoundments. The resident fish populations would be affected by the increased water levels in the proposed reservoirs; but in some areas, access to tributaries for resident fish may be improved by increased water elevations.

It appears highly unlikely that anadromous fish such as salmon could be successfully introduced into the Upper Susitna River Basin. With the succession of very high dams and the related problems and costs of passing migrating fish over and through these dams, such a program would be infeasible (Report, Ecological Consequences of the Proposed Moran Dam on the Fraser River). This report states in reference to high dams: "The choice is clearly between upstream salmon stocks or dams." However, the introduction of a resident salmon species, such as sockeye (kokanee) or others to some waters of the upper Susitna basin might prove feasible with further studies.

Other problems related to the introduction of anadromous fish into the Upper Susitna River Basin would include the following: Fish would experience high mortality rates if they attempted to move downstream through turbines or outlet works in the proposed series of high-head dams. According to Corps of Engineers studies, a 35 percent mortality rate could be expected on fish such as young salmon at each dam. Perhaps even more significant than turbine loss is the experience-background that juvenile salmonids will generally not migrate out of large storage-type reservoirs. Reverse currents, temperature stratification, etc., apparently disorient the migrants and cause them to lose their migrational motivation. As a result many never even reach the dam and they spend their lives as residuals in the reservoir (Example: Brownlee Reservoir, Snake River, Idaho and Oregon).

Wildlife:

Reservoir impoundments, transmission line corridors, and access roads would have varying degrees of environmental impact on wildlife.

The Devil Canyon reservoir would be located within the confines of a narrow, steep-walled canyon with few areas of big-game habitat and no major migration routes for big-game animals. In some cases, animals such as moose and caribou may find it easier to cross the narrow reservoir than they would the present fast-moving river at the bottom of a deep, steep-sided canyon.

The proposed Watana Dam would be generally contained within a fairly deep and narrow river canyon. Watana reservoir would lie across one of the intermittent seasonal caribou migration routes between the main calving area of the Nelchina caribou herd, located south of the river in the northeast foothills of the Talkeetna Mountains, and some caribou summer range on the north side of the Susitna River. Calving generally takes place during a month-long period starting in the middle of May.

Ice-shelving conditions caused by winter drawdown on Watana reservoir or spring ice breakup conditions on the reservoir could cause problems for caribou, moose, or other animals if they attempt to cross this reservoir when these adverse conditions exist. Warmer weather and a rapidly filling reservoir should eliminate any adverse ice conditions at Watana during the month of May. As caribou are strong swimmers, they should have fewer problems crossing the narrow reservoir in the historic crossing areas near Kosina and Jay Creeks during July after calving than they would crossing the 2/3-to 1-mile-wide section of the swollen glacial river during periods of high runoff. Some caribou could also migrate around the upper reaches of the proposed Watana reservoir area as indicated in existing spring migration patterns. Caribou migration patterns for the Nelchina herd are continually changing, as stated in Alaska Department of Fish and Game study reports. Their studies also indicated that the use of the Watana reservoir site by Nelchina caribou for grazing and crossing was minimal during the period November 1974 through April 1975. Under adverse ice conditions, the reservoirs could result in increased problems for some segments of the herd. Also, there could be some permanent changes in historical herd movement patterns.

Within the transmission line corridor system, impacts to caribou would be limited to the 136-mile segment extending north from Cantwell. There is no significant caribou use of areas to the south. Although the transmission line and related access roads would not impose a physical barrier to migration of caribou, construction and maintenance work during certain seasons may inhibit herd movement. Since caribou are primarily confined to the west bank of the Nenana River, they will not be significantly affected in this area if the line runs along the east bank. Although physical destruction of caribou habitat will not be a significant impact of power line construction, there are indirect consequences which could be significant. Increase of fires resulting from manmade causes could destroy tundra lichen which is their prime source of winter food. It is estimated that approximately 50 years are required for a burned area to recover a usable cover of lichen for caribou. Noise generated by the transmission lines could also modify normal behavior, as could public accessibility provided by transmission line roads.

A moose survey conducted in early June 1974 by the Alaska Department of Fish and Game indicated that, although spring counting conditions were less than ideal, a total of 356 moose were seen along the upper Susitna River and in the lower drainage areas of the major tributaries. A 1973 fall count in the same general area sighted a total of 1,796 moose.

Of the 356 moose counted in the June 1974 survey, 13 were seen in or near the area of the proposed Watana reservoir below Vee Canyon. None were sighted within the proposed Devil Canyon reservoir impoundment.

Although moose habitat does exist within the pool areas of the proposed Devil Canyon and Watana reservoirs, the overall loss of preferred or critical winter forage areas would affect only a small percentage of the upper Susitna moose population.

During the June 1974 Alaska Department of Fish and Game survey period, one grizzly was sighted on the upper Oshetna and one on the Maclaren River. Five black bears were sighted on the Susitna River. A total of 56 caribou were sighted in the survey area.

The proposed reservoirs at Devil Canyon and Watana are located along a major flyway for waterfowl. Very few waterfowl appear to nest on the sections of the river that would be flooded by these reservoir proposals. On the other hand, the reservoirs would provide suitable resting areas for waterfowl migrating through the basin.

The loss of habitat for bears, wolves, wolverines, Dall sheep, and other animals also appears to be minimal. However, losses to any significant element of the food web will affect consumers. Thus, losses to moose or caribou would impact upon predator species. Other birds, including raptors, songbirds, shorebirds, and game birds, do not appear to be significantly affected by the reduction of habitat in the area of the proposed dams and reservoirs and on the transmission line corridor, although some habitat will be lost for all species of wildlife that utilize the affected areas.

Road access to the two damsites and to the transmission line would have a significant impact on fish and wildlife resources in areas opened to vehicle encroachment. Specific areas such as Stephan Lake, Fog Lakes, lower Deadman Creek, and the northern slopes of the Talkeetna Mountains could be significantly impacted by hunters, fishermen, and other recreationists by an access road to the Watana Dam. The same would be true along various segments of the transmission line. State game management policies could control some of the adverse impacts on fish and wildlife in these areas. However, this increase in public accessibility would significantly increase the necessity for intensified law enforcement and fire prevention measures.

Recreation:

Much of the Upper Susitna River Basin has little or, in many areas, no recreational activity at the present time. A combination of poor road access, rough terrain, and great distances presently limit the use of the 5,800-square-mile basin, especially the lands directly impacted by the proposed project, to a few hunters, fishermen, and other hardy souls who utilize these wild lands for recreational purposes.

The construction of the proposed hydroelectric project would have an impact on a number of present and projected recreational activities both in the immediate dam and reservoir areas and downstream from the dams.

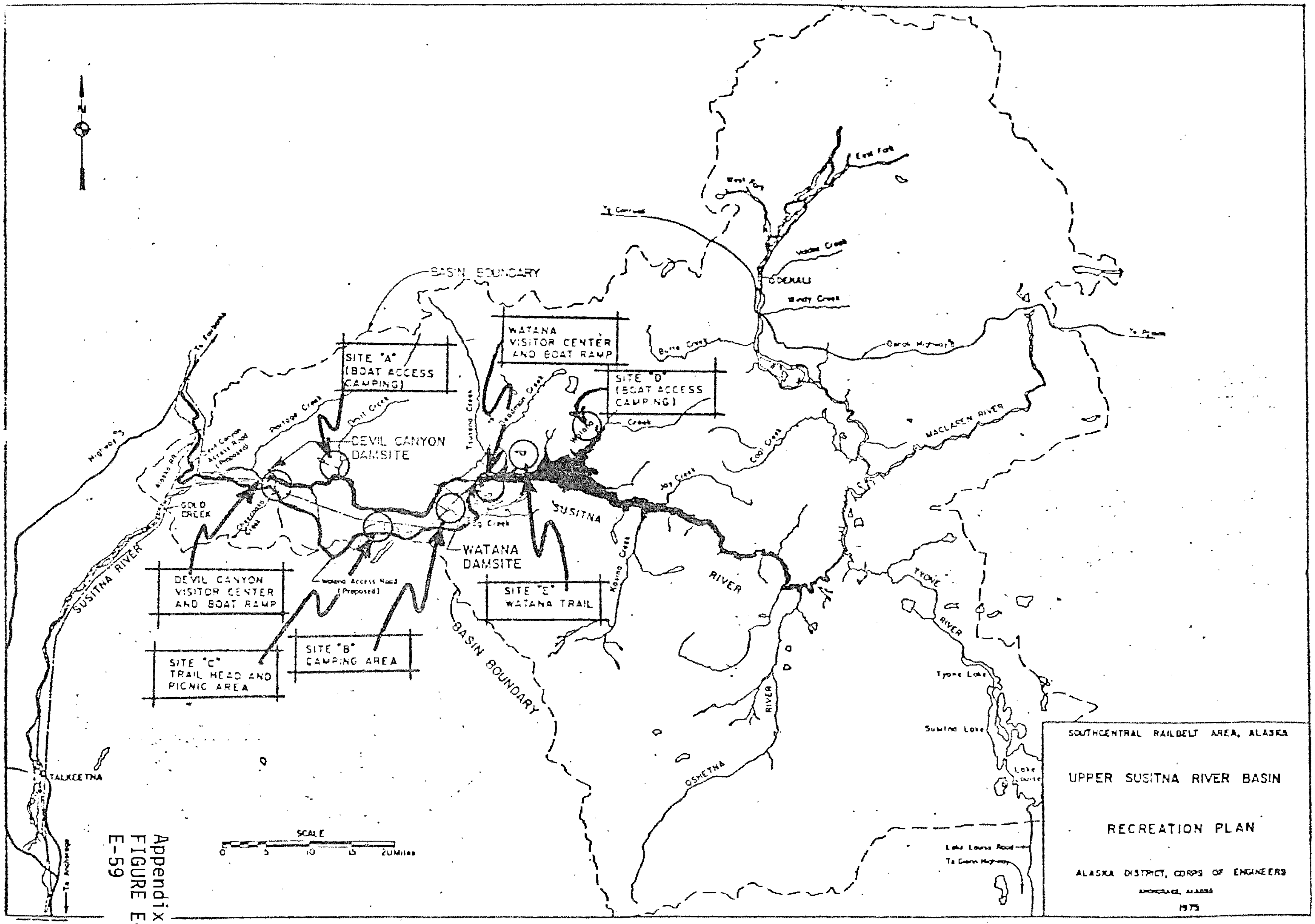
At the present time, the Susitna River upstream from Portage Creek to the Denali Highway bridge is a free-flowing river with few signs of man's activities and minimal public use. The project would significantly change both the present riverine setting and human use of the area. Improved road access into the upper Susitna basin would substantially increase pressures on all the resources impacted by outdoor recreation activities within these areas. Along with a potential increase in hunting pressure, the construction of project-oriented recreational facilities would further increase public use in the immediate vicinity of the proposed dams and reservoirs. These recreational developments would eventually include visitor centers at the dams, boat launching ramps on the reservoirs, campgrounds, picnic areas, trail systems, and other related developments, as shown in Figure 11. It is estimated that with the recommended development plan, the initial annual visitation to the project area would be about 77,000 people.

The possible relocation of the state capital to the Lower Susitna River Basin could have a substantial impact on the extent of development of recreational facilities within the Devil Canyon-Watana project area. At the present time, few people reside within a 100-mile radius of the project area, and day-use of the project by local residents would be minimal under existing growth conditions.

Any project-related recreational development program would involve cooperation between the appropriate Federal, State, and local interests and would require State or local sponsorship, sharing of costs for construction, and maintenance of the developed recreational facilities by the appropriate State or local sponsor. The State of Alaska (Division of Parks) has indicated an interest in sponsoring a program of recreational development in the area of the proposed project.

Historical Resources:

Although a preliminary investigation by the Alaska Division of Parks (Heritage Resources along the Upper Susitna River, August 1975) indicates the location of 11 historic sites within the upper Susitna basin hydropower study area, only one of these would be directly affected by the currently proposed two-dam development. This site is located near the mouth of Kosina Creek and would be inundated by the Watana reservoir. The significance of this site, a cabin, is not disclosed in the State report. However, on the basis of the limited early modern



Appendix I
FIGURE E-11
E-59

history associated with the upper Susitna basin, particularly the downstream portion above Devil Canyon, it is most likely that the site is related to early exploratory mining in the area. The Knik historical site, although located in the vicinity of the transmission line would not be affected by the transmission line corridor.

Archaeological Resources:

Of the four presently known archaeological sites in the upper Susitna basin, all lie upstream from the influence of the Watana Dam and reservoir, according to the Alaska Division of Parks report of August 1975. On the basis of probable highest game diversity in early times, this report selects areas most likely to have been inhabited by people, and thus identifies sites for potential archaeological exploration. These sites are usually designated as being near the confluence of streams where habitat diversity was likely highest. The report concludes that "--the entire river system should be regarded as an area of extremely high archaeological potential." The report further states: "While it is difficult to measure the amount of adverse impact each of the four dam complexes will have on heritage resources, it is possible to ascertain that the Devil Canyon Dam will have the least effect. The Watana Dam will have the second lowest adverse impact, followed by Denali Dam. The construction of the Vee Dam site will have the most adverse impact on significant heritage resources." (The Vee and Denali Dams are not in the proposed plan of development.)

More intensive reconnaissance of the affected areas will be necessary following project authorization to determine the actual existence and locations of sites.

The Dry Creek archaeological site is located in the vicinity of the proposed transmission line corridor. The site will not be affected by development within the proposed route.

Vegetation:

All of the vegetation within the pools of the proposed reservoirs and in the proposed road locations would be eliminated if the dams were constructed. Trees would also be cleared in areas within transmission line corridors. Most of the trees and shrubs would be cleared during construction operations, and some of the commercial timber would probably be marketed. Most of the residue slash material and debris would be burned or buried.

Much of the existing tree and shrub cover in the Upper Susitna River Basin is located in the river and creek bottoms and on the steep canyon slopes above the streams and would be lost during dam construction. The operations to clear the vegetation within the reservoir impoundments and other areas would require a network of temporary roads and work areas for personnel, equipment, and vehicles within and around the areas to be cleared. Controls over the clearing and related operations would include provisions to reduce or prevent many of the adverse environmental impacts of these activities including the possibility of uncontrolled fires.

The major ecosystems of the upper Susitna basin include the upland and lowland spruce-hardwood forest systems and the moist and alpine tundra systems. All these ecosystems are susceptible to long-term damage or destruction; the predominant tundra systems are especially vulnerable. Particular care would have to be taken to protect the land and the vegetation from unnecessary damage, and remedial actions (where feasible) would also need to be taken to repair whatever damage should occur. Except for the river itself the area within the proposed reservoir pool is dominated by the upland spruce-hardwood forest ecosystem.

The disposal of slash and debris, whether by burning, burying, chipping, or stacking has potentially adverse effects upon remaining vegetation and other resources. Although stacked or dispersed slash may provide habitat for small animals, there is a high potential that slash may result in increased fire hazard and increases in insect populations which could damage surrounding forests. Chipping is very expensive and requires more machinery to travel along the right-of-way. Disposal of chips is a problem because they should be dispersed to prevent killing the plants on the ground. Since decomposition rates are slow, chips may not revert to humus for quite some time. With proper precautionary measures, burning would probably be the most desirable method of slash and debris disposal from an environmental viewpoint.

Mining:

The U.S. Department of Interior, Bureau of Mines office in Juneau, Alaska, has stated that the Susitna River basin in the proposed reservoir impoundment areas is generally favorable for various types of mineral deposits, but much of the area has never been mapped geologically.

Agriculture:

No project benefits are anticipated for irrigation at this time, and except for providing reasonably priced electrical power to farms and agricultural activities, no other major impacts on agriculture are expected.

Presently most agricultural activity in the State, from crop farming to dairy farming, occurs in the Cook Inlet subregion. Of the 2.5 million acres of land that have soil characteristics conducive to the production of cultivated crops in the Cook Inlet-Susitna Lowlands, about 70 percent lies in the valleys of the Matanuska and the Susitna Rivers and their tributaries. Most of this land is still undeveloped.

Roads:

Permanent roads would be built to provide access from the Parks Highway to the Devil Canyon and Watana damsites and some segments of the transmission line. Permanent roads would also provide access to proposed recreation facilities within the project area. Temporary roads for project construction and reservoir clearing operations would also be constructed. No permanent roads would be constructed upstream from the vicinity of Watana Dam.

The impact of road access to areas within the proposed hydroelectric developments would be significant; also, the roads themselves would have a definite impact upon the land. Resource values impacted by proposed roads include fish, wildlife, vegetation, recreation, scenery, water, and soils. Air and noise pollution related to road construction and dust generated by vehicle travel on unpaved roads could also be significant adverse environmental impacts.

Proposed right-of-way restoration after construction includes removal of temporary structures and temporary roads, disposal of slash and refuse, and where necessary, revegetation.

Design, location, construction, rehabilitation, and maintenance of a project road system will be given prime consideration with the utilization of good landscape management practices.

It is also expected that helipads and possibly an aircraft landing strip would be provided within the project area for air evacuation of injured workers and for the convenience of reduced travel time; any temporary aircraft landing facilities would be rehabilitated after project construction.

Construction Activities:

Proposed project-related construction activities include the building of the dams and their related facilities; the clearing of reservoir areas; the construction of roads, electrical distribution systems, and recreation facilities; and the building of facilities for workers. The construction of the entire Devil Canyon-Watana project is estimated to take 10 years to complete, 6 years for Watana and 5 for Devil Canyon, with one year when both dams would be under construction at the same time.

The impact of these construction activities on the existing environment would be significant. The activities themselves would cause varying degrees of physical pollution to the air, land, and water within the project area and to some areas outside the development area. Fish, wildlife, vegetation, visual resources, soils, and other resource values would be adversely impacted by construction activities within the project area. General construction activities would intrude on existing fish and wildlife habitat, cause soil erosion problems with related reduction of water quality, clear areas of vegetation, cause noise and dust problems, intrude on natural visual resource values, introduce air pollutants into the atmosphere by burning slash and debris, and cause other related environmental impacts. For instance, breaking the surface mat of vegetation and disruption of surface drainage can result in wind and water erosion, and melting of permafrost, resulting in subsidence and disruption of groundwater tables, which in turn results in erosion.

To obtain materials from borrow sources and quarry sites for the construction of the dams, roads and other facilities would be necessary. Borrow areas would be located within the proposed reservoir pool areas where feasible. Any borrow or quarry sites necessary outside of the pool area would be rehabilitated. Areas will also be needed to dispose of some materials and debris. All construction activities would be controlled to minimize or to prevent adverse environmental impacts.

Workers' Facilities:

No communities within commuting distance of the proposed project area could absorb the number of workers required for the construction of the dams and related facilities. Some type of temporary construction camps with the necessary facilities would need to be provided during the construction periods, and permanent facilities would need to be built for maintenance and operational personnel after completion of the construction phase.

The construction and operations of the workers' camps would have to comply with State and Federal pollution control laws and standards, and all activities would be controlled to minimize adverse environmental impacts presented by the camps. Lands used for operating the temporary camp areas would be rehabilitated when the project work was completed.

Esthetics:

The proposed project would be located in areas that presently have practically no permanent signs of man's presence. The land between Portage Creek and the Denali Highway is a natural and scenic area that would probably qualify for wilderness classification under most definitions of the term.

The construction of the proposed hydroelectric project would have a significant impact on the existing natural scenic resource values within the project area. Any dam construction on the upper Susitna would change a segment of what is now a natural, free-flowing river into a manmade impoundment. Within a 12-month period, Devil Canyon reservoir could fluctuate up to 5 feet while Watana reservoir would fluctuate up to 125 feet under normal operating conditions. The proposed Watana impoundment is located in a narrow, steep, isolated canyon where the seasonal fluctuation would not have a substantial scenic impact. The violent, whitewater section of the Susitna River through Devil Canyon would be substantially inundated by a dam at Devil Canyon. Roads and transmission lines would also impact the natural scenic resource values of the area.

Since it is expected that a considerable number of tourists and State residents would visit the damsites, every effort would be given to minimizing the adverse visual impacts of construction activities. A great deal can be accomplished to maximize scenic resource values that will remain after construction. Good landscape management practices would add substantially to the recreational experience of the project visitor with facilities that are well planned and well maintained.

Earthquakes:

Several major and minor fault systems either border or cross the Upper Susitna River Basin, and the southcentral area of Alaska is in one of the world's most active seismic zones. One of the strongest earthquakes in recorded history struck southcentral Alaska in March of 1964; the magnitude of the quake was 8.4 on the Richter Scale. The quake was centered just north of the Prince William Sound area, approximately 120 miles from the proposed damsites.

Devil Canyon and Watana Dams will be designed to withstand a Maximum Credible Earthquake of 8.5 magnitude with an epicenter of 40 miles at a focal depth of 20 miles, which is the approximate distance of both damsites to the Denali Fault system, and is the most likely source of a seismic event of this magnitude. The Susitna Fault, truncated by the Denali Fault, bisects the region in a northeast to southwest direction approximately 2.5 miles west of the Watana damsite. Due to the relatively short length of the Susitna fault, a maximum credible earthquake of a magnitude of 6.0 is considered reasonable. This possible seismic event has also been considered in the design of Watana and Devil Canyon dams.

Sedimentation:

Reservoir sediment inflow would vary at each reservoir. Under the proposed system, Devil Canyon reservoir would lose approximately 6.5 percent of its total storage area to sedimentation during a 100-year period. Watana reservoir would have a 100-year sediment inflow that would equal about 3.6 percent of the reservoir's storage capacity.

Both proposed reservoirs have a dead storage area that is not utilized for power production; therefore, much of the initial 100-year sedimentation for the reservoirs would be contained within this "dead storage space," which would not have any significant effect on reservoir operations. Much of the heavier sediment deposited in Watana reservoir would collect at the head of the 54-mile-long reservoir. Even though the project-life is computed on a 100-year period for economic reasons, with adequate maintenance, the useful life of the proposed project is estimated to be in excess of 500 years. If at some future time a feasible program of sediment removal were developed, the useful life period could be extended.

Climatic Conditions:

The severe climatic conditions in the Upper Susitna River Basin could have a substantial environmental impact on the design, construction, and operation of the proposed hydroelectric development. Permafrost conditions, extreme cold winter temperatures, a long period of cold weather, and ice conditions on the reservoir and river are some of the significant climatic conditions that would have to be considered.

The Upper Susitna River Basin is underlain by discontinuous permafrost, so some project areas will have to contend with permafrost and other areas will not.

Extremely cold winter temperatures and long periods of cold weather will place substantial restrictions on many project construction activities and increase the time needed to complete the construction of the project to a total of 10 years.

Icing conditions on the reservoirs and the river may cause a wide range of adverse impacts both on project construction activities and on project operations. An ice-free stretch of warmer, open water below Devil Canyon Dam could cause ice-fog conditions in that area during periods of extremely cold weather. Regulations of winter flows are not expected to have any significant effects on river ice conditions necessary for the continued use of the stream for winter travel downstream from Talkeetna.

Air Pollution:

Most of the existing electrical power in the Southcentral Railbelt area is produced by gas, coal, and oil-fired generating units which cause varying degrees of air pollution.

Cook Inlet gas is a clean fuel that causes few serious air pollution problems at the present time. The existing gas turbines have very low efficiencies and emit visible water vapor during the colder winter months. Also, nitrogen emissions could be of significant concern for any proposed larger gas-fired plants.

Hydroelectric energy could replace the burning of fossil fuels for electric power generation in much of the Fairbanks area and could help to alleviate the severe winter ice fog and smoke problems in that area.

Hydroelectric projects provide a very clean source of power, with practically no direct air pollution-related problems. This type of electrical power generation could reduce a substantial number of future air pollution problems associated with the burning of gas, oil, and coal. It would be necessary to burn some of the residue slash material and debris during project construction and clearing operations, and fires would be controlled as necessary.

Social:

Population: Substantial increases in population are expected within the Southcentral Railbelt area through the year 2000 and, with the possible relocation of Alaska's State capital from Juneau to the Railbelt, an additional population impact can be expected in this area.

The population of the area will increase with or without the development of hydroelectric projects proposed for the Susitna River; construction of the project is not expected to have any significant long-range effect on overall population growth. Thus the total amount of power generated by the proposed Susitna hydroelectric project would generally be an alternative source, which would have as one of its major considerations a renewable energy source, rather than being an additional power source. Projected power requirements based on mid-range estimates show that the proposed Susitna hydroelectric development program could supply a substantial portion of the Railbelt's projected electric power needs starting in about 1985. The proposed upper Susitna River hydro projects would not create large blocks of excess electric power for heavy energy-consuming industries. If larger amounts of electric energy should be needed for a program of heavy industrial development, additional energy-producing sources will have to be constructed. In summary, the project would serve projected population needs--not stimulate population growth as a consequence of industries which would be attracted by large blocks of excess electrical energy.

A 10-year Devil Canyon-Watana hydroelectric development program would have an economic impact on the Southcentral Railbelt area that would be largely felt during the construction phase of project development.

It is expected that this proposed project would have some stabilizing influence on the overall economy of the Railbelt area during the period of construction starting in about 1980, since construction would be initiated several years after the Alaskan oil pipeline has been built and about the time the proposed gas pipeline is scheduled for completion. The number of men required to construct this project is estimated to be about 1,100 during the peak construction period.

Various community, borough, state, and private facilities and agencies would be impacted to varying degrees by the workers involved in the construction of the proposed project. Workers' camps would be constructed in the vicinity of some of the various construction activities, but additional impacts would be created by the families of the construction workers living in various nearby communities who would require additional facilities and services. It is also expected that due to adverse climatic conditions, much of the construction on the project facilities would be restricted to the warmer months of the year--probably April through October. The seasonal nature of the construction work would have an adverse impact on the local economy during the winter months.

After the construction of the project, a small number of people would be required to operate and maintain the project and project-related facilities--these people would not create a significant social or economic impact on the railbelt area.

RELATIONSHIP OF THE PROPOSED DEVELOPMENT TO LAND USE PLANS

PRESENT LAND STATUS

Lands in the general project area of the proposed Upper Susitna River Basin hydroelectric development at Devil Canyon and Watana are under Federal jurisdiction and administered by the U.S. Bureau of Land Management. These lands have been classified as power sites by Power Site Classification Number 443, dated 13 February 1958. The project areas are designated in the Power Site Classification by approximate damsite locations and contour designations as follows:

Devil Canyon:

This area begins approximately 1.4 miles upstream from the mouth of Portage Creek and includes all lands upstream from this point below the 1500-foot contour.

Watana:

This area begins approximately 1.5 miles upstream from Tsusena Creek and includes all lands upstream from Tsusena Creek and from this point below the 1,910-foot contour.

ALASKA NATIVE CLAIMS SETTLEMENT ACT

The Power Site Classification withdrawals and the surrounding lands in the proposed project area are in an area designated under the Alaska Native Claims Settlement Act (Public Law 92-203) for village deficiency withdrawals: lands which can be selected by native village corporations who cannot meet their selection entitlement from the withdrawals in their regions.

The U.S. Department of Interior, Bureau of Land Management, stated in correspondence of 13 March 1975: "The land within the power site reserve is segregated from a deficiency withdrawal under ANCSA because it is 'reserved public land' and Congress did not give the Secretary (Interior) the authority to make deficiency withdrawals from reserved lands."

UTILITY CORRIDORS

The U.S. Bureau of Land Management has prepared a report suggesting a Primary Corridor System for the State of Alaska. The report was prepared in accordance with the provisions of Section 17 (b)(3) of the Alaska Native Claims Settlement Act (Public Law 92-203).

The Primary Corridor System is defined as a network of corridors intended for the systematic transport of high-value, energy-related resources from their point of origin to processing or transshipment points in other regions of the State. The network is intended to identify transportation routes for resources of national or statewide significance and is analogous to the transportation network that already exists in conterminous states consisting of navigation, highway, railroad, and pipeline systems.

The Susitna project is one of the hydroelectric power developments sufficiently advanced in the planning phase to warrant corridor consideration for high-voltage power transmission lines. The transmission lines from the proposed Susitna project have been identified in the suggested Primary Corridor System.

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SECTION F

RECREATIONAL ASSESSMENT

SECTION F

RECREATIONAL ASSESSMENT

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LIST OF EXHIBITS

RECREATIONAL ASSESSMENT

INTRODUCTION

RECREATIONAL AND FISH AND WILDLIFE ENHANCEMENT

Projects authorized subsequent to passage of Public Law 89-72, Federal Water Project Recreation Act, July 1965, are subject to the provisions of that act. The act establishes development of recreational and fish and wildlife potential at Federal water resource projects as full project purposes whenever a project may serve them consistently within the act. Specifically, the act provides:

a. Benefits for recreation may be included in the economics of a contemplated project, provided that non-Federal public entities agree (letter of intent) to participate in recreational development.

b. The non-Federal entity must assume:

(1) At least one-half of the separable first costs for recreational facilities and lands specifically required for recreation;

(2) All costs of operation, maintenance, replacement, and management of recreational areas and facilities.

c. Lacking an agreement on non-Federal participation prior to initiation of construction, separable lands to preserve the future recreational potential may be acquired at Federal expense and held for 10 years.

d. The basic act specifies the same conditions of cost-sharing in b(1) and (2) above for fish and wildlife enhancement. The Water Resource Development Act of 1974, Section 77, amends PL 89-72, however, by stipulating that the non-Federal entity must assume 25 percent of the separable costs, and that the Federal Government will assume 75 percent of the costs for fish and wildlife enhancement.

PURPOSE

Stage 1, Interim Report on the feasibility of hydroelectric power development in the Upper Susitna River Basin indicates that the Devil Canyon and Watana projects offer the best initial combination for developing the hydroelectric potential of the area. This section will identify recreational and collateral resources of these two projects, will present public use projections, and will indicate the level of development needed to accommodate this use.

SCOPE

Coverage of this section will be limited to information required to insure an understanding of basic recreational and environmental resources related to the development of Devil Canyon and Watana projects. Typically, as a preauthorization study, a general plan of development, including land requirements, will be recommended to assure utilization of the recreational potential. Detailed site planning which would be accomplished as a post-authorization activity will not be included. Levels of development will be based on the provisions of PL 89-72; namely, minimum development for health and safety by the Federal Government in the absence of cost sharing and that level of development for which non-Federal interests have expressed intent to participate. Facilities necessary to accommodate visitors at project structures which are provided at Federal cost will also be recommended.

BACKGROUND

Various existing studies and reports provide background data and information used in this section, including:

a. U.S. Department of Interior, Alaska Power Administration, Juneau, Alaska, Devil Canyon Project Status Report, May 1974;

b. Upper Susitna River, Alaska, An Inventory and Evaluation of the Environmental, Aesthetic and Recreation Resources, U.S. Corps of Engineers, January 1975;

c. Alaska Outdoor Recreation Plan, in four volumes, February 1970, with information updated in 1971, 1972, and 1973, Outdoor Recreation and Historic Preservation in Alaska, prepared by Division of Parks, Department of Natural Resources, State of Alaska.

GENERAL

Few places in the world offer the variety of outdoor recreational resources available in Alaska. Both residents and visitors alike have unexcelled opportunities for recreational activities among a profusion of beautiful lakes, rivers, and mountains, largely untouched by modern civilization. From the fiords and rain forests of southeastern Alaska to the summer marshlands of the interior and the tundra lands of the north, the land is largely in its primitive state, with some areas still unexplored. For more than 1,000 miles from Ketchikan to Barrow and 2,000 miles from Barter Island to Attu, elevations ranging from low hills to the continent's highest mountains define Alaska's landscape. Within this broad expanse are over 3,000,000 lakes and over 10,000 rivers and streams, 6 of which are over 400 miles long. Variety and abundance in fish and wildlife resources provide unusual big-game species and fish. Fishing and hunting are not only important recreational resources but also provide significant economic returns.

Access to all this splendor is limited; these resources are not where people reside and are relatively inaccessible to the majority of the people. Total highway and road mileage is very low; air transportation costs are high; many ports and rivers freeze over in the winter; and only two rail lines serve the entire population. Despite deficient access systems, tourism increases and will become a more and more important factor in Alaska's economy.

RECREATIONAL MARKET AREA

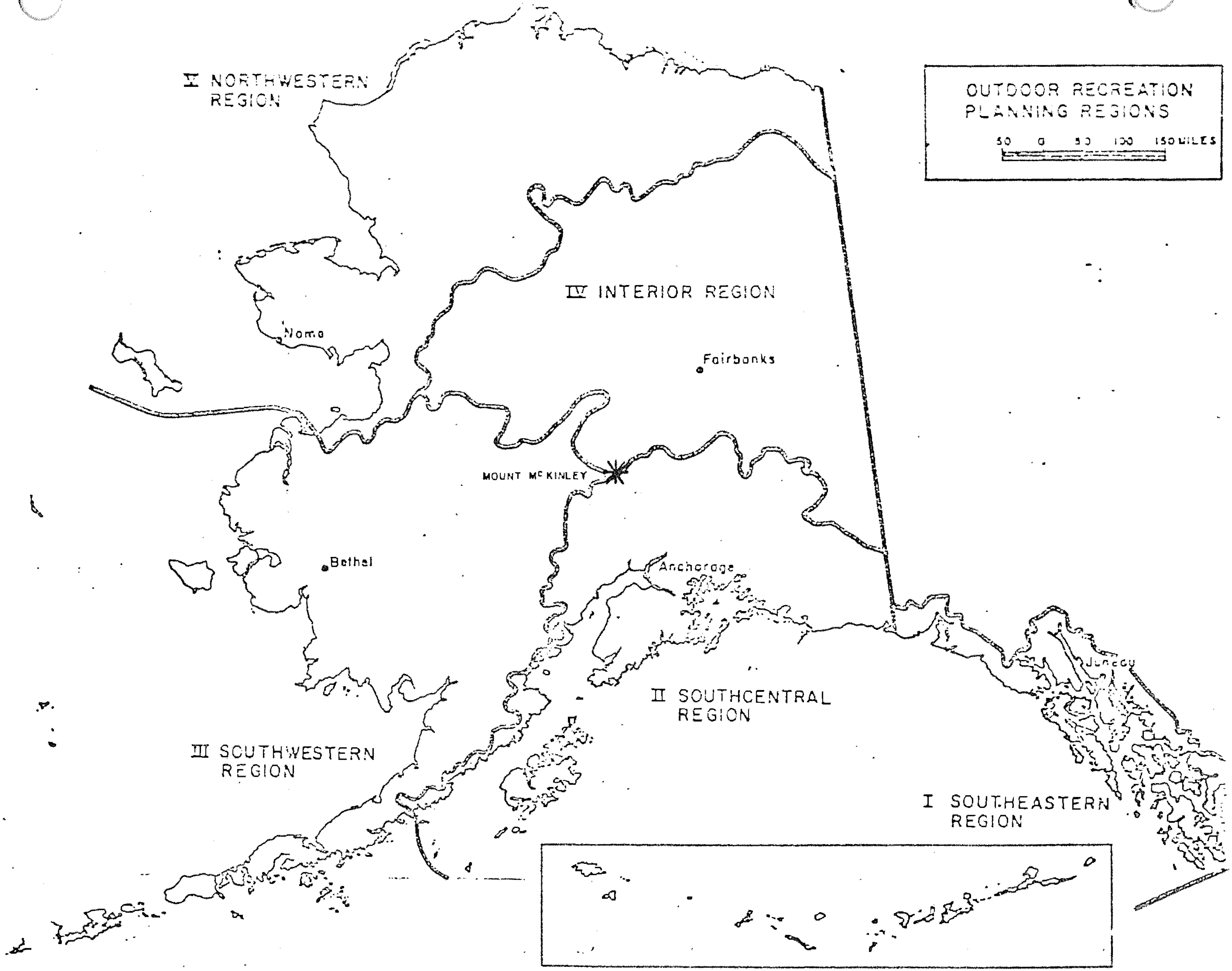
MARKET AREA

Zone of Influence: The study area, lying east of the Parks Highway and south of the Denali Highway, is located 150 to 200 miles from both Fairbanks and Anchorage. By far, the greatest source of recreational usage will be these two cities. Resident population outside these metropolitan areas is sparse. Except those in the small settlement at Denali, there are few permanent residents in the upper Susitna basin above Devil Canyon. Thus, the project areas lack a "day-use" market in the sense that ordinary travel distance limitations would apply. Normally, that area from which 80 percent of a reservoir's recreational day-use originates is less than 75 miles away and not more than 100 miles. Except for sightseeing in the vicinity of project structures (interest only in viewing the dam and appurtenances), major recreational use of the study area is expected to be of the weekend or overnight type. Tourist use is anticipated in about the same proportion as that experienced within the Alaska State Park System.

In defining a market area for the Devil Canyon and Watana projects, there is no consistent similarity to existing projects in the Lower 48 States. Thus, the similar projects approach to analysis of market area and use prediction prescribed in ER 1120-2-403 is not appropriate for use in this study. Having no definable day-use zone, the market area is assumed to include the metropolitan areas served by the Parks Highway and the Alaska Railroad. The area served roughly coincides with the Southcentral Railbelt area and the Southcentral and Interior Planning Regions established by the Statewide Comprehensive Outdoor Recreation Plan (SCORP), as shown in the following sketch. Data on population, recreational supply and demand, and use projections for this area are obtained from SCORP, updated, and revised hereinafter as indicated. There is also a relationship of use between the study area and the Denali State Park, the eastern boundary of which lies approximately 14 miles downstream from Devil Canyon damsite. Recent master plan studies for the State park provide data appropriate to this study. The Denali study recognizes both possible downstream effects of regulated flows from Devil Canyon on water-associated recreation within the park and the potential that exists to enhance the existing State park attraction with nearby, but more remote, reservoir-related recreational experience.

SOCIOECONOMIC CHARACTERISTICS

Economic activity in Alaska is as diverse as its people, topography, and climate. Within this vast area reside Eskimos, Aleuts, and Athabascan, Tlingit, Haida, Tshimsian, and Eyak Indians, many of whom subsist by hunting and fishing in much the same manner as did their ancestors.


OUTDOOR RECREATION
PLANNING REGIONS
50 0 50 100 150 MILES
V NORTHWESTERN
REGION
IV INTERIOR REGION
Nome
Fairbanks
MOUNT McKINLEY
Bethel
Anchorage
Juneau
II SOUTHCENTRAL
REGION
III SOUTHWESTERN
REGION
I SOUTHEASTERN
REGION

Most of the other residents of the State, including military personnel, live in metropolitan areas. Thus, two sharply diverse cultures exist within the State's boundaries: one engaged in subsistence economy involving little use of money, where primary work activity is related to procurement of food and shelter; and another which includes most residents of the established market area, where dollars are earned to purchase necessary goods and services.

The study area's zone of influence contains approximately three-fourths of the State's residents. According to the 1970 Census, 54 percent of the State's population resides in southcentral Alaska; the majority live within the Anchorage area. Most of the rest of the State's population, with the exception of urban centers in southeastern Alaska, reside in approximately 170 bush communities of less than 1,000 people. Of this bush population, more than half are Eskimos, Indians, and Aleuts.

LAND USE

Land use patterns, particularly in the study area, have yet to evolve. However, land withdrawals made and pending under the terms of the Alaska Native Claims Settlement Act (ANCSA) and under provisions of the Alaska Statehood Act will result in large-scale transfer of title and more definable land use. Pending completion of these selections, lands within the study area remain under interim management jurisdiction of the Bureau of Land Management (BLM). The reservoirs and damsites are withdrawn under Power Site Classification No. 443, dated 13 February 1958. The study area overall, however, is classified as Regional Deficiency Lands under ANCSA. Final date for selection of Regional Deficiency Lands is 18 December 1975. These lands, with potential access afforded through project construction, will have potential for recreational use, mineral extraction, harvesting of forest products, and settlement.

<u>Power Site Classifications</u>: The project areas are designated in the Power Site Classification by approximate damsite location and contour designations as follows:

<u>Devil Canyon</u>: This area begins approximately 1.4 miles upstream from the mouth of Portage Creek and includes all lands upstream from this point below the 1500-foot contour.

<u>Watana</u>: This area begins approximately 1.5 miles upstream from Tsusena Creek and includes all lands upstream from Tsusena Creek and from this point below the 1,910-foot contour.

<u>Alaska Native Claims Settlement Act</u>: The Power Site Classification withdrawals are in an area designated under the Alaska Native Claims Settlement Act (Public Law 92-203) for regional deficiency withdrawals, where lands can be selected by Native Regional Corporations which cannot meet their selection entitlement from the withdrawals in their regions.

According to officials of Cook Inlet Regional Corporation, most lands with proximity to the Devil Canyon and Watana projects will have been tentatively selected prior to December 1975. This report recognizes the indeterminate status of final lands jurisdiction, but assumes that lands necessary for all project purposes will be acquired through exercise of power-site withdrawals and through acquisition in fee, or by land exchange, as required. While the proposed recreational program is based on Alaska State Park operation, the possibility that cost-sharing agreements may be made with the Cook Inlet Native Corporation, should it qualify as an administering agency under Public Law 89-72, is also considered. However, this study assumes the more likely occurrence of concession-type operations by native elements for such self-liquidating activities as marinas, boat excursions, and lodges, rather than public outdoor recreational facilities normally provided by governmental entities.

POPULATION AND GROWTH PATTERNS

According to the 1970 Census, Alaska's statewide population was 300,382. Of this total, 218,145 resided within the established market area.

SCORP projections for the market area (Southcentral and Interior Planning Regions) are as follows:

Region	1975	1980	2000
Southcentral	176,000	199,000	334,000
Interior	58,000	63,000	86,000
TOTAL	234,000	262,000	420,000

Population growth in Alaska is difficult to forecast with certainty because of the small base for the forecast, past erratic growth patterns, and uncertainties in the rate of development of the State's resources. However, oil industry activities, coupled with an increased national interest in Alaska as the last remaining frontier, portend significant and sharp upward trends in population.

OUT-OF-STATE VISITATION

Projections of the number of tourists expected to visit Alaska are taken from SCORP as follows:

1975	287,800
1980	553,800

Tourists are not only expected to increase in numbers of visits, as shown above, but their length of stay in the State and the number of days they will devote to outdoor recreational activity are also expected to increase sharply. This analysis is based on current trends reflecting more leisure time, more expendable income, and the prospect of improved means of transportation and access.

INVENTORY OF FEDERAL/STATE, LOCAL, AND PRIVATE RECREATIONAL ACREAGE AND FACILITIES

Alaska's recreational resource inventory is on the threshold of great change. As a result of the Alaska Native Claims Settlement Act, 40 million acres, or 11 percent of the State, may be selected by native villages and regional corporations, and approximately 80 million acres, or 22 percent of the State, may be added to four Federal systems (Parks, Wildlife Refuges, Wild and Scenic Rivers, National Forests); the State can continue to select and to receive patent to approximately 105.5 million acres, or 29 percent of the State, under the terms of the Statehood Act.

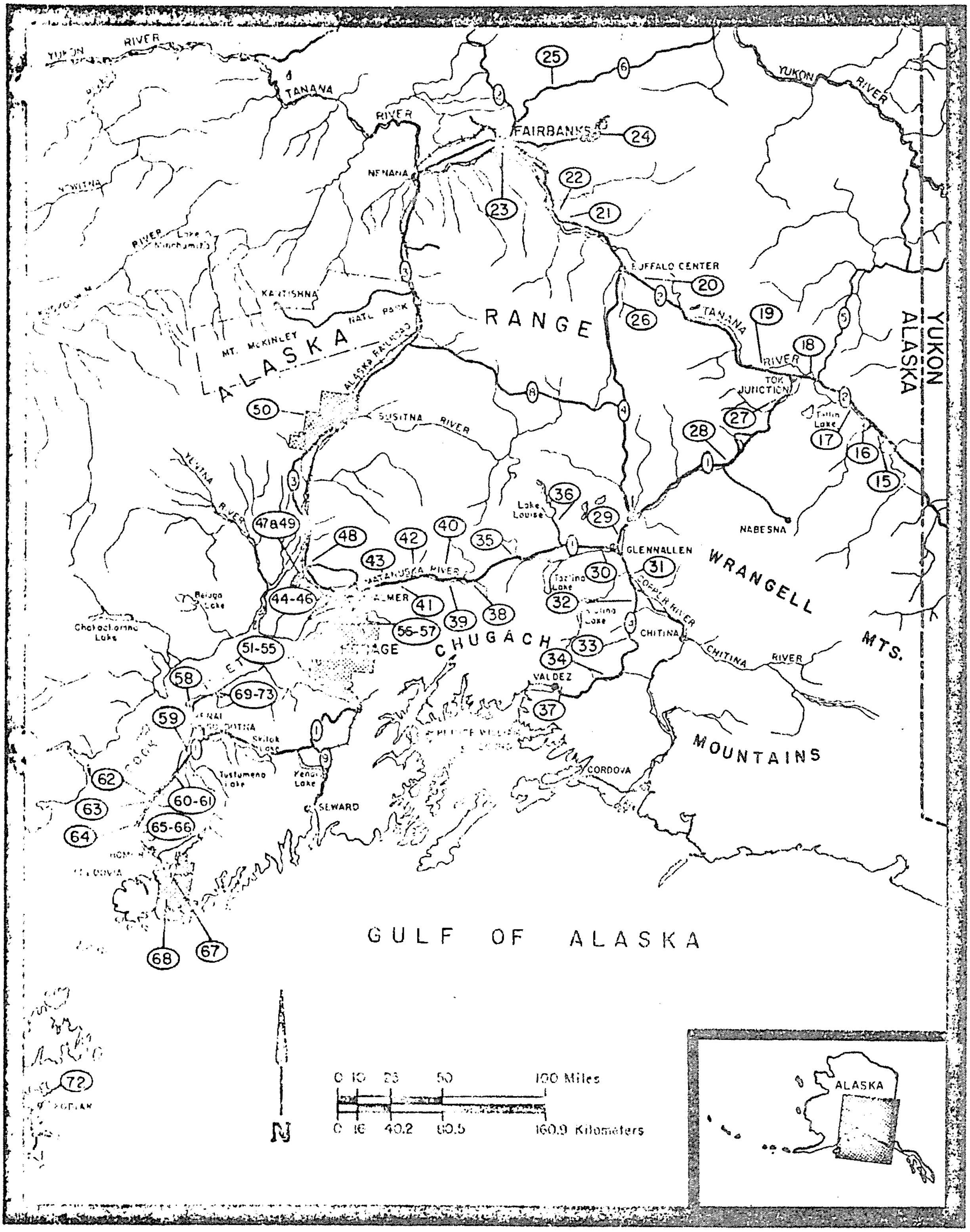
Currently 8 percent of Alaska's 365,481,000 acres are dedicated for park and recreational purposes. Recreational opportunities are available on the multiple-use lands under jurisdiction of BLM, U.S. Forest Service, and the State's Division of Lands, which combined, manage about 90 percent of the State's land area. The future availability of recreational opportunities on these lands will be reduced as title reverts to other management entities (e.g., 40 million acres to native regional and village corporations) and as timber sales and other uses of National forests and State lands materialize.

Within the market area, the State Park System's Recreation Guide lists 60 areas; two large parks, Kachemak Bay State Park and Kachemak Wilderness Park, remain undeveloped. The other sites, ranging from State parks, such as Denali and Chugach, to small campgrounds, day-use areas, and waysides, all have varying degrees of development. Many of these waysides are located at small lakes which offer facilities similar to those which could be developed in the Devil Canyon and Watana project areas. The following sketch and table show location and facilities available at each site. Mount McKinley National Park is also within the market area.

Use and demand statistics within the market area are significant. The Denali State Park Master Plan, updated in 1975, shows the following:

In 1972, 372,614 visits were recorded for units of the State Park System. In 1973 this figure increased to 712,791, nearly double the use of State park units. A more modest increase for 1974 was recorded in a visitation of 751,892. Interior and southcentral units (market area) received nearly 70 percent, or 504,656, of the total 1974 visitation.

STATE RECREATIONAL FACILITIES



STATE RECREATIONAL FACILITIES

	ACREAGE	CAMP UNITS	CAMPING LIMIT	PICNIC UNITS	TOILETS	DRINKING WATER	SHELTER	TRAILS	HISTORIC	BOAT LAUNCH	CANOEING	FISHING	SWIMMING	NO. ON MAP	nearest community
DISTRICT II															
Chugach State Park	495,204														
Eklutna Basin		30	15		•			•						51	Eagle River
Thunderbird Falls				6	•			•						52	Eagle River
Eagle River		36	4	12	•	•					•	•		53	Eagle River
McHugh Creek				30	•			•						54	Anchorage
Bird Creek		25	7	14	•	•	•					•		55	Anchorage
Mirror Lake Wayside	90			30	•	•	•			•	•	•	•	56	Eagle River
Peters Creek Wayside	52	32	4		•	•						•		57	Eagle River
DISTRICT III															
Bernice Lake Wayside	7	11	15		•	•				•	•	•	•	58	Kenai
Kasilof River Wayside	47	10	15	5	•	•						•		59	Soldotna
Johnson Lake Wayside	56	20	15		•					•	•	•	•	60	Soldotna
Clam Gulch Picnic	36			20	•	•	•					•		61	Soldotna
Ninilchik Wayside	13	15	15		•									62	Ninilchik
Deep Creek Wayside	44			10	•					•	•	•		63	Ninilchik
Starisky Wayside	30	12	15		•	•	•							64	Anchor Point
Silver King Wayside	174	40	15		•	•		•				•		65	Anchor Point
Anchor River Wayside	57	7	15									•		66	Anchor Point
Kachemak Bay State Park	119,970				undeveloped							•		67	Seldovia
Kachemak Wilderness Park	208,320				undeveloped							•		68	Seldovia
Captain Cook Recreation Area	3,620														Kenai
Discovery Campground		57	15		•	•								69	Kenai
Discovery Picnic Area				28	•	•								70	Kenai
Swanson River Canoe Landing					•						•	•		71	Kenai
Stormy Lake		10	15	40	•	•	•	•		•	•	•	•	72	Kenai
Bishop Creek		15	15		•	•		•						73	Kenai
Fort Abercrombie	183	7	15	5	•				•			•	•	74	Kodiak
DISTRICT VI															
Gordiner Creek Wayside	10	6	15		•							•		15	Tok
Deadman Lake Wayside	20	16	15		•					•	•	•	•	16	Tok
Lakeview Wayside	415	8	15		•					•	•	•	•	17	Tok
Tok River Wayside	4	10	15		•	•								18	Tok
Moon Lake Wayside	92	15	15		•					•	•		•	19	Tok
Clearwater Wayside	29	12	15		•	•				•	•	•		20	Delta Junction
Harding Lake Recreation Area	95	89	15	52	•	•	•			•	•	•	•	21	North Pole
Salcha River Picnic Wayside	59			20	•	•				•	•	•		22	North Pole
Chena River Wayside	27	62	5	39	•	•	•			•	•			23	Fairbanks
Chena River Recreation Area	15,360										•	•		24	Fairbanks
Chatanika River Wayside	73	25	15		•	•				•	•	•		25	Fairbanks
Donnelly Creek Wayside	20	12	15		•									26	Delta Junction
Eagle Trail Wayside	640	40	15	4	•	•	•	•				•		27	Tok
DISTRICT V															
Porcupine Creek Wayside	240	12	15		•	•		•						28	Tok
Dry Creek Wayside	128	13	15		•							•		29	Glennallen
Tolsona Creek Wayside		5	15		•									30	Glennallen
Squirrel Creek Wayside		7	15		•	•						•		31	Copper Center
Little Tonsina Wayside	102	6	15		•	•						•		32	Copper Center
Worthington Glacier Wayside	113	6	15		•									33	Valdez
Blueberry Lake Wayside	192	6	15		•		•					•		34	Valdez
Little Nelchina Wayside	22	6	15		•									35	Glennallen
Lake Louise Wayside	50	5	15		•						•	•		36	Glennallen
Valdez Glacier Wayside	226	101	15		•	•								37	Valdez
DISTRICT I															
Matanuska Glacier Wayside	231	6	15		•			•				•		38	Palmer
Long Lake Wayside	372	8	15		•	•				•	•	•		39	Palmer
Bonnie Lake Wayside	31	8	15		•					•	•	•		40	Palmer
King Mountain Wayside	20	22	15		•	•	•							41	Palmer
Mouse Creek Wayside	40	8	15		•	•								42	Palmer
Finger Lake Wayside	47	36	15		•	•		•		•	•	•		43	Palmer
Big Lake (South) Wayside	16	13	15	6	•	•				•	•	•		44	Wasilla
Big Lake (East) Wayside	19	14	15		•	•				•	•		•	45	Wasilla
Rocky Lake Wayside	48	10	15		•	•				•	•			46	Wasilla
Nancy Lake Wayside	35	30	15	30	•	•				•	•	•		47	Willow
Willow Creek Wayside	90	17	15		•							•		48	Willow
Nancy Lake Recreation Area	22,685										•			49	Willow
South Rolly Lake Campground		106	15	20	•	•					•	•			Willow
Denali State Park	282,000				•	•								50	Cantwell
Byers Lake Campground		100	15		•	•		•			•	•	•		Cantwell

Mount McKinley National Park visitation increased from 58,300 in 1971 to 137,418 in 1973. The primary reason for this 135 percent increase was the completion of the Parks Highway between Anchorage and Fairbanks.

The Denali Master Plan forecasts increases in total annual demand for various outdoor recreational activities. The following is a percentage increase of the 1967 demand base for uses anticipated in the study area as indicated in the Denali Plan:

Demand For Selected Outdoor Recreational Activities in Alaska

Activity	Percent of 1967 1970	1975	1980
Trail-related Activities	129	147	249
Sightseeing	146	175	385
Picnicking	132	162	235
Fishing	134	155	268
Camping	156	197	516
Boating	134	169	343

In the 1973 revision of the Alaska Outdoor Recreation Plan, deficits of facilities for several popular activities were projected. Listed by region, three recreational pursuits applicable to Denali State Park are presented below:

Region	Projected 1975 Supply	As Percent of Need
	-Picnic Units-	
Southcentral	1,037	32%
Interior	492	43%
	-Camp Units-	
Southcentral	3,825	67%
Interior	1,256	63%
	-Trail Mileage-	
Southcentral	587.7	28%
Interior	88.2	16%

The projected deficits, as a factor of supply and demand, are severe. Development of recreational capability of the study area has the potential to alleviate a portion of these shortages through construction of appropriate facilities at Devil Canyon and Watana projects.

DETERMINATION OF OUTDOOR RECREATIONAL ATTENDANCE

BASIC ASSUMPTIONS

The State Division of Parks plans to operate and to manage the recreational program presented for Devil Canyon and Watana projects so that they would be complementary to Denali State Park; that is, supplement Denali's facilities and accommodate increased use generated because it is nearby. The total system is to be interrelated and developed on a phased basis, consistent with needs identified in the Denali Master Plan. Attendance projections will necessarily be related to use potential of an agreed-upon program.

The initial year of recreational use of the study area is estimated to be 1986.

USE PROJECTIONS

Development of use projections for the study area is complicated because no similar project exists from which data can be utilized. No current market area surveys or reliable activity participation data are available, and economic and social factors of the market area are extremely fluid. In the final analysis, it is necessary to rely upon informed judgment when assessing behavioral patterns which influence recreational use of the area.

Population and Use Trends: Census data for the market area for 1970 show a population of 218,145. Statewide Comprehensive Outdoor Recreation Plan (SCORP) projections for the year 2000 indicate a possible doubling of this figure, with an average annual increase of approximately 7 percent.

Out-of-state visitation over the same period was estimated to increase over 400 percent, an average annual increase of approximately 14 percent.

State parks visitation within the market area totalled 668,716 for fiscal year 1973, almost doubling over a 3-year period. This attendance is expected to increase at a slower rate, leveling off to an annual increase of approximately 10 percent.

National Park Service statistics for Mount McKinley National Park show usage increased from 58,300 in 1971 to 137,418 in 1973. This 135 percent increase was influenced by completion of the Parks Highway. Future attendance is expected to level off at a rate approximating State park usage.

Methodology:

Method 1 (sampling of market area usage): Visitation to public recreational areas during fiscal year 1973 was reported by the 1973 revision to SCORP as follows:

Southcentral Region

Federal	2,656,858
State	541,021
Local	2,173,165
	5,371,044

Interior Region

Federal	2,704,100
State	127,695
Local	174,000
	3,005,795

Total for Market Area: 8,376,839

Assuming continuation of present use patterns exhibited within the market area, total recreational visits by 1985 are estimated to approximate 18,000,000. At least 0.5 percent of this total, or 90,000 of these visitors, may reasonably be expected to visit Denali State Park and the Devil Canyon and Watana project areas.

Method 2 (sampling of vicinity activity): Alaska State Department of Highways, utilizing a traffic counter at East Fork Chulitna River bridge (16 miles north of Denali State Park), recorded an average of 578 vehicles per day from June through September 1973. Based on an average of 2.6 passengers per vehicle, nearly 180,400 persons drove through Denali State Park during the summer. Updated projections to 1985 indicate that approximately 1,366 vehicles per day can be expected during the 4-month summer period, a total of 426,192 persons. Since Mount McKinley and Denali State Park (including the study area) will be major recreational attractions and will be a convenient stop between Anchorage and Fairbanks, at least an estimated one of every 10 through-passengers will visit the Devil Canyon area, approximately 27 miles off the Parks Highway. Total visitation from this source is estimated to be 42,600.

The Alaska Railroad estimates 75,000 passengers were transported between Anchorage and McKinley Park Station during the summer of 1974. This use is projected to approximately 87,000 for the year 1985. Assuming that shuttle bus transport will probably be placed in service to transport rail passengers to Mount McKinley Park, an estimated 20 percent of these visitors will desire to visit Devil Canyon as part of a total tour package, resulting in possibly 17,400 visitations.

No statistics are available on possible fly-in use of the project areas or on possible access by ATV vehicles. By the year 1985, such access might result in an additional 3,000 annual visitations.

Total predicted usage from the above sources is:

Highway	42,600
Railroad	17,400
Off-road	3,000
Total	63,000

USE PREDICTIONS (STUDY AREA)

Initial with Development (Cost-sharing): Assuming that a recreational development program will be provided as proposed, the estimated initial annual attendance at Devil Canyon and Watana projects is projected by averaging the results of Methods 1 and 2 above for a total of approximately 77,000 persons.

Initial with Recreational Development: With only minimum facilities provided at road ends at Devil Canyon and Watana damsites, the estimated annual attendance may be approximately 15,000, most of which would be sightseeing use at Devil Canyon damsite.

Future:

With Development: To predict the extent of future phased development, at this time, is not feasible without full analysis of development and programming for Denali State Park. However, it is anticipated that project recreational use will increase at an average annual rate of approximately 10 percent until the year 2000, when it will level off to an average annual visitation of approximately 190,000. This analysis assumes that phased future expansion will be governed by demonstrated need and use pressure as affecting the Denali State Park System.

Without Cost-shared Development: Without formal development, aside from sightseeing use and boating use of available project launching ramps, project areas will have minimal attraction for outdoor recreational activity. Continued lack of development would probably maintain usage near the initial level of 15,000.

REAL ESTATE REQUIREMENTS

Lands specifically required to accommodate the proposed recreational program over and above lands included within the normal taking line are estimated to approximate 830 acres.

In the absence of a formal cost-sharing agreement, Public Law 89-72 permits acquisition of lands necessary to preserve recreational potential, and permits retention of such lands for a period of 10 years. Considering the political aspects of the Alaska Native Claims Settlement Act and the circumstances of native possession, setting aside such land does not appear judicious unless affected landowners are willing to convey these lands. Current philosophy, reflected by the Cook Inlet Native Corporation, is that selling such lands in fee will be strongly resisted. A possibility exists that suitable lands held elsewhere by the State or by BLM could be considered in exchange for lands considered to be necessary to utilize or to preserve recreational potential.

RECOMMENDED PLAN OF DEVELOPMENT

INITIAL AND FUTURE DEVELOPMENT

The location of the Devil Canyon and Watana projects, in relation to Mount McKinley National Park and Denali State Park, lends specific character to and influences the nature of proposed developments. In addition to giving people an opportunity to look at dam structures, the two projects would offer reservoir-related experiences in a remote setting. These would include trail use, boating, picnicking, and overnight camping. As demand develops, the possibility exists of providing concessionary facilities such as lodges, marinas, and boat excursion trips.

DEVELOPMENT PROPOSED (See reservoir map on the following page.)

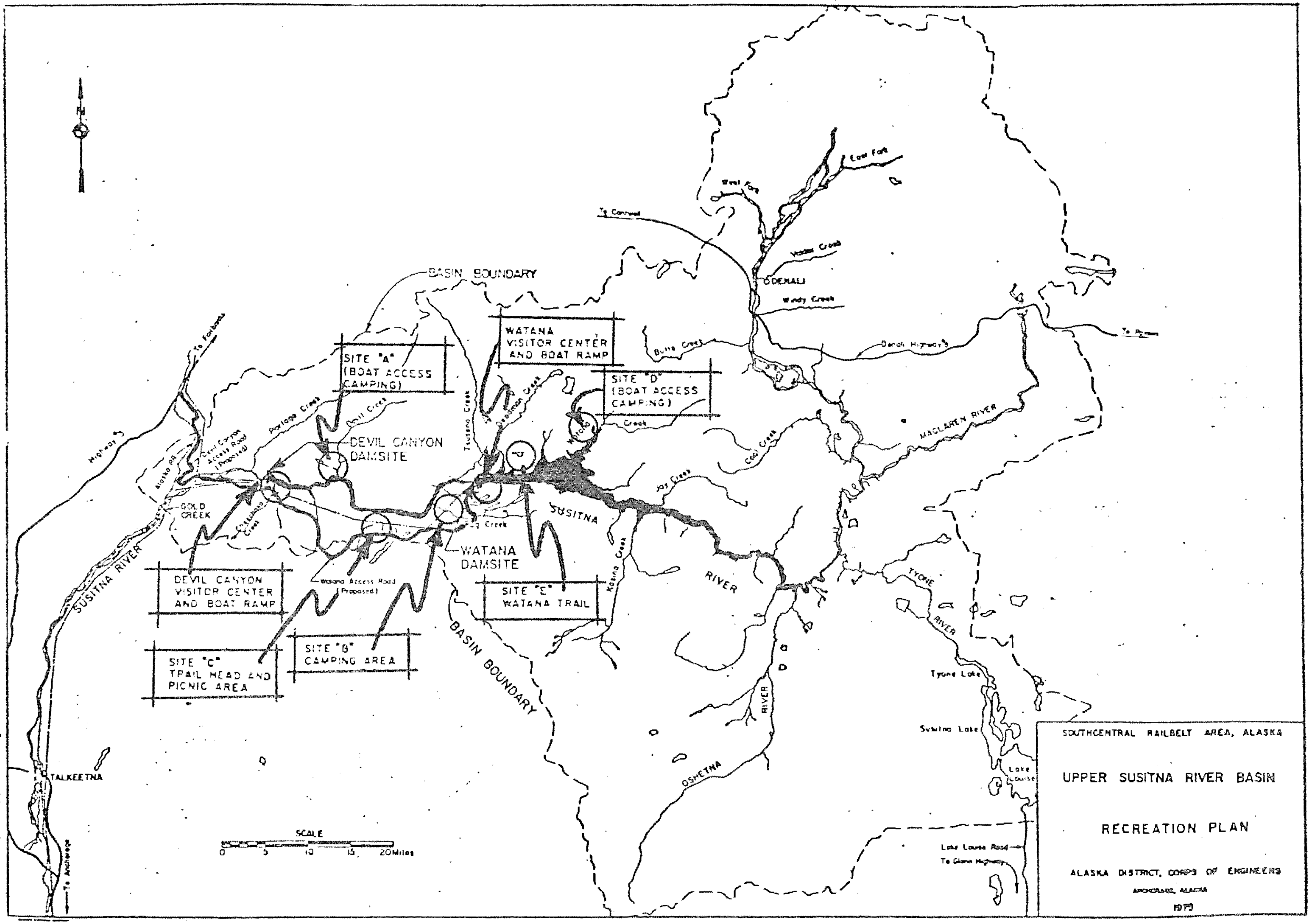
Developments proposed initially are considered in two categories:

Visitor Accommodations at Project Structures: These would be facilities for sightseers who visit the dam and appurtenant structures, and, except for sightseeing, would not be reservoir-recreation oriented. Such facilities would include visitor buildings, interpretive facilities, parking, and sanitary facilities. Cost-sharing is not required.

Reservoir-Related Outdoor Recreation: Based on a fully coordinated cost-sharing program, proposed developments will include a picnic area, an all-purpose camping and day-use area, a boat-access-only campsite, and a reservoir-oriented trail system for Devil Canyon; boating access, boat-access-only camping, and trails for the Watana area.

Future Development: It is anticipated that future development will consist principally of expansion of initial areas and provision of self-liquidating concessionary developments by others. Because of the nature of cost-sharing involved, no attempt is made here to define a future program, as this would necessarily have to be integrated with the Denali State Park program.

Minimum Development: In the event a cost-sharing program cannot be implemented prior to expenditure of project construction funds, minimum facility development consisting of a launching ramp facility with minimum parking (mainly for operation and maintenance activities) and minimum sanitary facilities will be provided in the immediate vicinity of both Devil Canyon and Watana Dams where road access terminates for project construction activity.



Appendix I
E-17

ACTIVITY MIX

This projection of initial activity mix is based upon anticipated participation rates, adjusted to the use considered to be commensurate with the study area's role as related to the Denali Park System.

Activity	Percent
Sightseeing	65
Camping	30
Trail-related activities 1/	25
Boating	15
Picnicking	10
Fishing	7
Hunting	8
Water sports activity 2/	2
Total	162 3/

1/ May include such activities as hiking, snowmobiling, motorcycling, snowshoeing, dry-sledding, cross-country skiing, and nature study.

2/ Includes swimming and waterskiing.

3/ Percentage is based on a single visit with participation in one or more activities.

INITIAL FACILITY LOAD CRITERIA

Based upon estimated attendance projections and participation rates used for the project, a project design load (peak day attendance) and specific facility design loads are calculated as follows:

Project Design Load

$DL = AA \times P \times E \div D$

Where: AA = Annual Attendance
P = % of annual attendance during peak month
E = % of peak month use expected on weekends
D = Average number of weekend days during peak month

$DL = 77{,}000 \times .20 \times 55 \div 9 = 940$ persons

Specific Design Load By Activity		Sight-seeing	Camping	Trail-Related Activities	Boating	Picnicking
SDL = (PR) x (DL) ÷ TxA						
Where:	PR = Participation rate (%)	65	30	25	15	10
	DL = Design load	940	940	940	940	940
	T = Turnover factor	2	1	1	1	2
	A = Average group size	3	4	4	3	4

Sightseeing

$$SDL = \frac{.65 \times 940}{2 \times 3} = 102 \text{ cars}$$

An estimated 60 percent of sightseeing activity will occur at project structures, resulting in the need for 60 parking spaces. Assuming there will be shuttle bus service, space requirements should be further reduced by approximately 20 percent for an overall total of 48 parking spaces divided between Devil Canyon and Watana Dams.

Camping

$$SDL = \frac{.30 \times 940}{4} = 70 \text{ campsites}$$

Trails

$$SDL = \frac{.25 \times 940}{4} = 60 \text{ trail-related activities on peak day}$$

Boating

$$SDL = \frac{.15 \times 940}{3} = 47 \text{ boats}$$

Assuming 30 launches and haul-outs/day/per lane, 2 launching lanes would be required. Because of limitations of access points, at least 3 one-lane launching sites should be provided, 2 on Devil Canyon and 1 on Watana. Approximately 15 car and trailer parking spaces should be provided at each site.

Picnicking

$$SDL = \frac{.10 \times 940}{2 \times 4} = 12 \text{ picnic units}$$

Fishing and Hunting - No specific additional facilities other than those provided at developed areas are anticipated.

Water Sports Activity - Very limited swimming activity is anticipated because of water conditions and generally steep shorelines. A small beach area may be possible at the proposed overnight campsite on Devil Canyon below Watana Dam.

FISH AND WILDLIFE CONSERVATION AND ENHANCEMENT

Since the project study is currently in the feasibility stage, this report does not include a detailed evaluation of fish and wildlife impacts, nor specific recommendations for fish and wildlife conservation and enhancement. If the project is authorized by Congress, currently on-going and future study results will be used to determine what actions should be taken to conserve and enhance fish and wildlife resources.

COORDINATION WITH OTHER AGENCIES

FEDERAL

Bureau of Outdoor Recreation: Both the Seattle Regional Office and the Anchorage Office have cooperated by furnishing data and guidance in the preparation of this report.

National Park Service: The Pacific Northwest Region has been informed about archaeological investigations being carried out under authority of Public Law 93-291. Continuous coordination will be maintained as required under provisions of that Act.

Bureau of Land Management: BLM has interim jurisdiction over most of the lands within the study area and has been requested to furnish an Impact Report. If the lands surrounding the project remain under public ownership, the recreational facilities would be developed and operated by the Bureau of Land Management. The response from BLM is inclosed as Exhibit A.

Alaska Power Administration: Since this agency would operate the project after construction, it has been kept informed on study progress.

STATE

Continuous coordination has been carried out with the State of Alaska, Department of Natural Resources, Division of Parks. Representatives of that agency have participated in planning and have expressed intent to participate in the recreational development and management program, as required under Public Law 89-72. A copy of the Letter of Intent is inclosed as Exhibit B.

LOCAL INTERESTS

The projects are within an area designated as Regional Deficiency Lands under the Alaska Native Claims Settlement Act. Coordination has been maintained with the Cook Inlet Regional Corporation as the responsible entity in this matter.

MANAGEMENT AND COST-SHARING

FEDERAL RESPONSIBILITIES

The Alaska Power Administration will be responsible for operation and maintenance of Devil Canyon and Watana Dams and appurtenant structures, including the operation of reservoirs for the authorized project purposes. To provide for health and safety of the visiting public during and after construction, visitor facilities--including a visitor building, interpretive facilities, sightseeing overlooks, protective fencing, sanitary facilities, and parking at damsites--will be developed at full Federal cost.

RESPONSIBILITIES OF OTHERS

The State of Alaska's Division of Parks, as local sponsor, will be responsible for administration and management of public outdoor recreational areas. Park sites do not include custodial residences or maintenance buildings. In view of the high percentage of sightseeing activity estimated at project structures, an interpretive program will be developed cooperatively between Federal and State entities. Administrative headquarters for park management forces will be maintained at proposed visitor centers.

COST-SHARING

By letter dated 4 April 1975, the State of Alaska indicated its intent to sponsor the initial recreational development proposed herein at an estimated cost of $1,144,600. The State's share of the cost of the facilities would be approximately $572,300.

ENVIRONMENTAL QUALITY

GENERAL

Carefully prepared, creative development plans will be required to enhance, conserve, and maintain both the environmental quality and the esthetics of project areas. Emphasis will be placed on composition and space relationship for human purposes consistent with the type of activity involved.

The access road to both dams will be designed to cause minimum impact on the environm.nt with emphasis on preserving the roadside, the viewscape, and the esthetic character. Where possible, alinement should take advantage of views to lend interest and variety to the driving experience.

COST ESTIMATES

Cost estimates are presented in the following table for three categories:

a. Visitor facilities at project structures (no cost-sharing);

b. Minimum recreational development--permitted under PL 89-72 in the absence of a cost-sharing sponsor;

c. Cost-shared recreational program (as agreed to by sponsor).

Operating facilities (boat ramps) and visitor facilities which are provided at project structures for public safety and convenience are project costs and are charged to Feature Account No. 19, Buildings and Grounds. Because of terrain limitations and access road construction limitations, operating facility development will be located within a 2-mile distance of proposed main access roads. The launching ramps, which will also be used for operational purposes, will have separate vault-type toilets to accommodate boaters.

Recreational facilities are charged to Feature Account No. 14 and are to be cost-shared.

SUMMARY OF COST ESTIMATES

	Feature Account	Total Cost Initial Development	Cost-Sharing Federal	Cost-Sharing Non-Federal
VISITOR FACILITIES:				
Devil Canyon	19	$ 294,000	$294,000	0
Watana	19	$ 163,000	$163,000	0
Total		$ 457,000	$457,000	
OPERATING FACILITIES:				
Devil Canyon	19	$ 185,000	$185,000	0
Watana	19	$ 245,000	$245,000	0
		$ 430,000	$430,000	
Total		$ 887,000	$887,000	
COST-SHARED RECREATION UNDER PL 89-72:				
SITE A	14	$ 63,200	$ 31,600	$ 31,600
SITE B	14	$ 430,600	$215,300	$215,300
SITE C	14	$ 105,000	$ 52,500	$ 52,500
SITE D	14	$ 29,600	$ 14,800	$ 14,800
SITE E	14	$ 16,200	$ 8,100	$ 8,100
Lands (830 Acres)	14	$ 500,000	$250,000	$250,000
TOTAL COST-SHARED DEVELOPMENT:		$1,144,600	$572,300	$572,300

Table F-1
Appendix I

DETAILED COST ESTIMATES

	Account Number	Quantity	Unit	Unit Price	Initial Total Cost
A. VISITOR FACILITIES:					
Devil Canyon					
Visitor Building with Interpretive Facilities and Admin. Space	19	1	ea	LS	$200,000
Parking Area, Visitor and Admin-25 Car Spaces 15 Car & Trailer Spaces	19	15,000	SF	$3.00	$ 45,000
		Total			$245,000
		Contingency - 20%			$ 49,000
		Total Direct Cost			$294,000
Watana					
Visitor Building with Interpretive Facilities and Admin. Spaces	19	1	ea	LS	$100,000
Parking, 20 Cars and 10 Car & Trailer Spaces	19	12,000	SF	$3.00	$ 36,000
		Total Visitor Facilities			$136,000
		Contingency - 20%			$ 27,000
		Total Direct Cost			$163,000
		Total Visitor Facilities			$457,000
B. OPERATING FACILITIES:					
Devil Canyon					
Launch Site with Parking and Launch Ramp w/Dock	19	LS		$150,000	$150,000
2-Vault Toilets	19	2	ea	$ 2,000	$ 4,000
		Total			$154,000
		Contingency - 20%			$ 31,000
		Total Direct Cost			$185,000
Watana					
Launch Site w/Parking & Launch Ramp w/Dock	19	LS		$200,000	$200,000
2-Vault Toilets	19	2	ea	$ 2,000	$ 4,000
		Total			$204,000
		Contingency - 20%			$ 41,000
		Total Direct Cost			$245,000
	TOTAL OPERATING FACILITIES:				$430,000

Table F-2
Appendix I

TABLE II (Continued)
DETAILED COST ESTIMATES

	Account Number	Quantity	Unit	Unit Price	Initial Total Cost
C. COST-SHARED RECREATION:					
Devil Canyon - Site A (Boat Access Only)					
Boat Dock	14	1	ea	$ 25,000	$ 25,000
Camping Units	14	10	ea	$ 1,800	$ 18,000
2-Vault Toilets	14	2	ea	$ 2,000	$ 4,000
		Total			$ 47,000
		Contingency - 15%			$ 7,000
		Total Direct Cost			$ 54,000
		*E&D - 10%			$ 5,400
		**S&A - 7%			$ 3,800
				Total	$ 63,200
Devil Canyon - Site B					
Access Road	14	0.5	mi	$100,000	$ 50,000
Overnight Camps	14	50	ea	$ 2,500	$125,000
Comfort Stations	14	2	ea	$ 35,000	$ 70,000
Power	14	LS		$ 25,000	$ 25,000
Sewerage	14	LS		$ 50,000	$ 50,000
		Total			$320,000
		Contingency - 15%			$ 48,000
		Total Direct Cost			$368,000
		E&D - 10%			$ 36,800
		S&A - 7%			$ 25,800
				Total	$430,600
Devil Canyon - Site C Trailhead Picnic Area					
Access Road	14	0.2	mi	$100,000	$ 20,000
Picnic Units w/Parking	14	12	ea	$ 2,000	$ 24,000
Trail System	14	30	mi	$ 1,000	$ 30,000
2-Vault Toilets	14	2	ea	$ 2,000	$ 4,000
		Total			$ 78,000
		Contingency - 15%			$ 11,700
		Total Direct Cost			$ 90,000
		E&D - 10%			$ 9,000
		S&A - 7%			$ 6,000
				Total	$105,000

* Engineering and Design
** Supervision and Administration

TABLE II (Continued)
DETAILED COST ESTIMATE

	Account Number	Quantity	Unit	Unit Price	Initial Total Cost
C. COST-SHARED RECREATION					
Watana - Site D (Watana Creek - Access by Boat & Trail Only)					
Camp Units (Tent Camp)	14	10	ea	$ 1,800	$ 18,000
2-Vault Toilets	14	2	ea	$ 2,000	$ 4,000
		Total			$ 22,000
		Contingency - 15%			$ 3,000
		Total Direct Cost			$ 25,000
		E&D - 10%			$ 2,600
		S&A - 7%			$ 2,000
				Total	$ 29,600
Trail System - Site E					
Watana Dam Site to Watana Creek	14	12	mi	$ 1,000	$ 12,000
		Contingency - 15%			$ 2,000
		Total Direct Cost			$ 14,000
		E&D - 10%			$ 1,300
		S&A - 7%			$ 900
				Total	$ 16,200

LANDS:

(Separate cost for recreation over and above joint-cost lands for project)

	Acres	Unit Cost	Total
SITE A	40	$600	$ 24,000
SITE B	600	$600	$360,000
SITE C	100	$600	$ 60,000
SITE D	40	$500	$ 20,000
SITE E (Trail System)	50	$500	$ 25,000
Administration Costs	--	L.S.	$ 11,000
TOTALS	830		$500,000

BENEFITS

STANDARDS

The Water Resource Council's revised evaluation standards published in the Federal Register, Vol. 38, No. 174, 10 September 1973, require that in determining benefits for recreation, a single-unit value be assigned per recreational day. The value assigned should reflect both the quality and variety of activities offered. This value represents benefit of the activity to the individual, based somewhat on difficulty and expense of the activity (e.g., big-game hunting would be assigned a higher value than hiking). Two classifications for an outdoor recreational day are given for evaluation purposes:

Type	Range of Unit Values
General	\$ 0.75 to \$2.25
Specialized	3.00 to 9.00

General activities would be such things as viewing the sites, visiting the information center, and walking short distances; more specialized activities, camping, boating, use of trails, etc.

INITIAL BENEFITS FOR RECREATION

In this study area a variety of general and specialized recreational values are possible, given facilities and access by road, trail, and water to both pools; and facilities for camping, picnicking, sightseeing, boating, hiking, and other trail-related activities. The specialized values are enhanced opportunities to gain access to back country for hunting, fishing, photography, or viewing the scenery. Value of a recreational day within the study area is estimated as follows:

General Recreation: Seventy percent of the total annual visitation is considered to be of general nature and is valued at \$2.00/day.

Specialized Recreation: The remaining 30 percent is classed as specialized, with an estimated value of \$8.00/day.

Thus annual recreational benefits based on initial visitation are:

$$\begin{aligned} 77{,}000 \times .70 \times 2.00 &= 107{,}800 \\ 77{,}000 \times .30 \times 8.00 &= \underline{184{,}800} \\ \text{Total} \quad & \$292{,}600 \end{aligned}$$

Fish, wildlife, and other recreational benefits have not yet been fully evaluated. When the project is authorized by Congress, additional studies will further evaluate these resources as a basis for determining losses and gains to fish and wildlife and other recreational resources.

RECREATIONAL BENEFIT/COST ANALYSIS

CONSTRUCTION COSTS

Recreational costs for the selected plan consist of those for recreational facilities, recreational land, and land-related administration, as shown in the following table.

ITEM	WATANA	DEVIL CANYON	TOTAL
Facilities 1/	$45,750	$ 598,850	$ 644,600
Land	45,000	444,000	489,000
Administration	2,000	9,000	11,000
Total	$92,750	$1,051,850	$1,144,600

1/ Includes E&D and S&A.

Interest during construction is computed as simple interest on construction costs from the estimated date of expenditures to the appropriate project completion date. The construction costs and interest during construction for post-1986 expenditures are discounted to the Watana completion date of October 1986. The appropriately discounted construction and interest costs are summed to give the recreational-related investment cost, as shown below.

WATANA

YEAR	EXPENDITURE	ACCUMULATED EXPENDITURE	INTEREST
1981	$47,000	0	$ 1,440
1982		$47,000	2,880
1983		47,000	2,880
1984		47,000	2,880
1985		47,000	2,800
1986	46,000	47,000	4,290
	$93,000		$17,250

DEVIL CANYON

YEAR	EXPENDITURE	ACCUMULATED EXPENDITURE	INTEREST
1985	$ 453,000	0	$ 13,870
1986		$ 453,000	27,740
1987		453,000	27,740
1988		453,000	27,740
1989		453,000	27,740
1990	$ 599,000	453,000	46,080
1991		1,052,000	64,440
	$1,052,000		$235,350
(PW)	($ 781,500)		($174,830)

Construction Cost (PW--Present Worth)	$ 874,500
Interest during Construction (PW)	192,080
Recreation Investment Cost	$1,066,580

OPERATION, MAINTENANCE, AND REPLACEMENT

Annual operation and maintenance costs for the recreational facilities are estimated to be $45,000, while the cost of replacement of recreational facilities over the 100-year project life is estimated at $55,000 annually.

ANNUAL COST SUMMARY FOR RECREATIONAL FACILITIES

Interest and Amortization	$ 65,000
Operation and Maintenance	45,000
Replacement	55,000
Total Annual Cost	$165,000

BENEFIT-TO-COST RATIO

Based on annual costs of $165,000 and annual benefits of $300,000 (rounded), the B/C ratio for recreation is 1.8 to 1.

EXHIBITS

IN REPLY REFER TO:

United States Department of the Interior 1780 (110)

BUREAU OF LAND MANAGEMENT

Anchorage District Office
4700 East 72nd Avenue
Anchorage, Alaska 99507

JUL 15 1975

Mr. Henry Nakamura
Department of the Army
Alaska District
Corps of Engineers
P.O. Box 7002
Elmendorf AFB, Alaska 99510

Dear Mr. Nakamura:

Impacts of the proposed Devils Canyon, Watana Creek and Denali hydroelectric power project on BLM lands, resources and programs is difficult to access. The information necessary to do a thorough analysis of these projects, simply isn't available. The reports of the impacts on the various resources drafted by our staff, briefly summarizes the basic data that is available, recognizing that more detailed information is necessary.

Management of the recreation activities which would be generated by development of the proposed projects will also be an important consideration. If the lands adjoining the future reservoirs go into private ownership, the on-the-ground recreation management responsibilities may better be handled by an agency other than the BLM; the State may be a good choice. However, in order to insure public access, it is strongly recommended that the BLM, through whatever means possible, retain ownership of public access points to the lake. The actual management, operation and/or ultimate ownership could rest with another public agency after a more detailed cost effectiveness analysis were undertaken. Naturally, if the adjacent lands remain in Federal administration, we would be interested in developing and managing a recreation program. With the present land status situation, it is impossible to determine whether or not the adjoining lands will remain in public ownership.

A more thorough analysis will be made during the impact statement review process.

Sincerely,

Donovan Yingst

Donovan Yingst
Acting District Manager

STATE OF ALASKA

JAY S. HAMMOND, Governor

DEPARTMENT OF NATURAL RESOURCES
DIVISION OF PARKS

323 E. 4TH AVENUE
ANCHORAGE 99501

April 4, 1975

RE: 2425

Colonel Charles A. Debelius
Corps of Engineers, Alaska District
Department of the Army
P. O. Box 7002
Anchorage, AK 99510

Dear Colonel Debelius:

Reference is made to your letter of March 18, 1975 and our response dated March 19, 1975 concerning the cooperative aspects of the planning and development of a recreation program for the proposed Devil's Canyon Hydroelectric Project and related impoundments. This letter will serve as a declaration of intent on our part to provide the necessary local participation at said project, as required under the Federal Water Project Recreation Act, Public Law 89-72, to the extent set forth hereafter: The State of Alaska would:

1. Administer project land and water areas for recreational purposes.

2. With legislative approval, contribute in kind, pay, or repay with interest, 1/2 of the separable cost for recreation facilities and specific recreation lands, in accordance with the Federal Water Project Recreation Act of 1965.

3. Operate and maintain said recreation facilities.

At this very preliminary stage of planning, we recognize that the proposed projects have the potential for fulfilling a portion of the significant deficits of recreation facilities within the Southcentral and Interior regions of Alaska. Furthermore, we recognize the very general and tentative nature of the recreation program identified here with respect to congressional authorization for further study and funding, and the capability of future state budgets to support such endeavors.

It is our understanding that more definitive recreation area and site planning would follow project authorization by congress, and based on this, formal contract agreement could become possible between our respective agencies. Furthermore, it is our understanding that this letter of intent does not bind the State of Alaska to any future formal contract agreement with the Corps of Engineers.

Due to the very limited staff of the Division of Parks, we can provide only limited comment and input during this pre-authorization stage of planning. However, if authorized, the project will be of great interest to the state and at that time we would wish to discuss a formal recreation contract agreement.

Sincerely,

for William A. Sacheck
Director

cc: Guy R. Martin, Commissioner
Department of Natural Resources

NCJ:krm