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Subtask 6.01 Closeout Report
Final December 80

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SUSITNA HYDROELECTRIC PROJECT

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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUBTASK 6.01 CLOSEOUT REPORT
DESIGN DEVELOPMENT
REVIEW OF PREVIOUS STUDIES AND REPORTS

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1 - INTRODUCTION

1.1 - Background

The development of hydropower in the Susitna Basin has been under study for the past 30 years. The objective of subtask 6.01, as stated in the Plan of Study is to "Assemble and review all available engineering data, siting, and economic studies relating to the Susitna hydropower development and to alternative potential sites". Alternative potential sites have been assumed to include only sites in the Susitna River Basin upstream from Gold Creek. For purposes of this study, this area is referred to as the Upper Susitna River Basin

Other sites and developments both on the lower Susitna and other rivers are included in Subtask 6.33 - Hydroelectric Generation Resources. Collection of geotechnical and hydrological data is dealt with separately in the Subtask 5.01 and 3.01 closeout reports.

1.2 - Report Contents

This report contains a brief review of the previous studies pertaining to hydroelectric development in the Uupper Susitna River Basin and sumarizes the significant findings.

Section 2 contains a summary of the report and Section 3 outlines the disccusion and conclusions. Section 4 outlines the scope of work associated with Subtask 6.01. A chronological review of the previous studies is dealt with in Section 5. Section 6 outlines the civil, hydrological, geotechnical, environmental, hydropower and planning parameters associated with each of the previously identified sites. Cost comparison between alternatives is given in Section 7.

2 - SUMMARY

2.1 - Previous Studies

The major engineering studies conducted during the past 30 years are briefly discussed below:

A 1953 study by the USBR(1) identified a total of 10 sites in the Susitna Basin upstream from Gold Creek. Preliminary schemes of development including dam types and heights were presented for seven of the sites. Based on these studies the USBR proposed that the ultimate development consist of dams at Olson, Devil Canyon, Watana, Vee and Denali with a total installed capacity of 1010 MW.

The first stage of this USBR proposal was the subject of the 1961 follow-up study (3) of the Devil Canyon Project. In this study designs for the Devil Canyon Dam and the Denali Dam were developed. Devil Canyon was to have an installed capacity of 580 MW and Denali was to be used for flow regulation purposes only.

In 1974 the Alaska Power Administration, Department of Interior, issued a report on the status of the Devil Canyon Project.(5) This involved an update of information in the 1961 USBR study and included some minor design changes.

A report issued by Kaiser Engineers in 1974 (6) suggested the construction of a dam approximately five miles upstream from the Devil Canyon site known as Susitna I (or High Devil Canyon as an alternative to the Devil Canyon Project. Unlike Devil Canyon, this site has the advantage that sufficient storage is available for utilization of the maximum power potential without an additional upstream reservoir. Ultimately this scheme called for three other dams to be constructed for full basin development.

To date, the Interim and Supplemental Feasibility Studies by the Corps of Engineers issued in 1975 and 1979 respectively (7 & 11) represent the most extensive studies on development of hydropower on the Upper Susitna river. Several different schemes involving six dam sites were considered. A scheme including dams at Watana and Devil Canyon was selected as being the most economical development as well as the best from an environmental viewpoint. It was shown that the Benefit Cost Ratio for this scheme was 1.4 using alternative coal-fired energy to assess project benefits (1979 value).

The above studies identified a total of eleven sites upstream from Gold Creek (see Figure 1). Figure 2 illustrates the river profile, indicates heights and shows which site would be eliminated by development at other sites.

Other studies that have been conducted have dealt more specifically with environmental issues and geotechnical investigations.

2.2 - Design Parameters

The design parameters associated with the various developments are discussed in Section 6. Tables 5 to 10 summarize the civil, hydrological, mechanical and hydropower parameters contained in the previous studies. Table 11 summarizes the environmental data pertaining to various reaches of the Upper Susitna River.

2.3 - Cost Comparisons

The most extensive cost information for alternative developments is contained in the 1975 Corps of Engineers Interim Feasibility Report[7]. The unit prices used were based on bid prices from the Pacific Northwest and Canada. They were adjusted to reflect 1975 prices, Alaska labor rates, and additional transportation costs to the sites. Cost data extracted from the Corps of Engineers 1975 report is given in Appendix C.

For purposes of this report these costs as well as cost information from other reports were excalated to 1980 price levels using the Handy-Whitman Index. Table 13 lists updated total costs as well as capacity and energy costs.

3 - DISCUSSION AND CONCLUSIONS

The following major items were identified in this review of previous studies:

(a) The level of detail on the potential development at each site varies significantly. Standardization of this information and some upgrading of information pertaining to the less intensively studied sites would facilitate a more formal and convincing site selection study.

(b) The Devil Canyon and Watana sites appear to be the most economic combination. The Devil Canyon site requires upstream regulation for economic power generation.

(c) The Kaiser plan proposed a dam located in the vicinity of Devil Creek (High Devil Canyon). It provides both a high head and storage and consideration should be given to studying it in more detail.

(d) The economics of the project as proposed by the US Corps is very dependent on the assumed rate of retirement of existing plants and, to a lesser degree, on the rate of load growth. The validity of their assumptions with respect to these aspects should therefore be carefully reviewed in any further studies.

4 - SCOPE

The references listed at the end of this report were reviewed. Discussions were held with the engineering staff of the US Corps in Alaska. Data was collected from the reports and from material such as working files and drawings obtained from the US Corps. The type of information obtained ranges from detailed layouts to merely an identification of a potential site. Table 4 lists what data is available in terms of engineering layouts, topographic mapping, geotechnical field drilling, and air photos. The available engineering layouts are included in Appendix A.

5 - PREVIOUS STUDIES

The earliest studies were undertaken by the Corps of Engineers in 1950 and identified several potential sites for hydroelectric power development in the Susitna River Basin as part of a reconnaissance level survey of Cook Inlet and tributaries. A second study; the Bureau of Reclamation "Reconnaissance Study or the Potential Development of Water Resources in Alaska" was completed in January 1952.

Subsequently, the feasibility of hydropower development of the Susitna River has been the subject of several more detailed studies. The most significant of these were conducted by the following agencies (or company):

(a) U.S. Bureau of Reclamation - 1953[1]
(b) U.S. Bureau of Reclamation - 1961[3]
(c) Alaska Power Administration - 1974[5]
(d) Kaiser Engineers - 1974[6]
(e) U.S. Corps of Engineers - 1975[7]
(f) U.S. Corps of Engineers - 1979[11

The above studies are discussed in more detail in the following sections.

5.1 - U.S. Bureau of Reclamation - 1953

This represented the first major study and was completed in 1953. The following ten sites were identified above the railroad crossing at Gold Creek (see also Figure 1):

(a) Gold Creek
(b) Olson
(c) Devil Canyon
(d) Devil Creek
(e) Watana
(f) Vee

(g) Maclaren
(h) Denali
(i) Butte Creek
(j) Tyone (on the Tyone river)

An additional 15 dam sites were identified within the remainder of the Susitna Basin downstream of the Gold Creek railroad crossing.

The sites at Butte Creek, Devil Creek, and Gold Creek were eliminated from detailed study on the basis of field reconnaissance. The other sites were inlcuded in desk studies involving the development of conceptual engineering layouts and costs. Selection of the development plan was based on maximizing energy output for the least cost. This plan included the development of the following sites:

(a) Olsen:	Max. pool eleva. = 920 ft.	Installed capacity =	50MW
(b) Devil Caynon:	= 1,417 ft.		= 390MW
(c) Watana:	= 1,900 ft.		= 310MW
(d) Vee:	= 2,330 ft.		= 260MW
(e) Denali:	= 2,590 ft.	No power generation facilities	

The first stage of development involved a dam at Devil Caynon with an initial installation of 195 MW of generating capacity. To meet subsequent increases in demand the dam at Denali would be built. This would provide sufficient regulation to allow doubling the capacity at Devils Canyon to 390 MW. The sequence of construction for the remaining developments would depend on future load growth.

It should be emphasized that this USBR study was very preliminary in nature. At the time of the study, limited mapping and geotechnical information as well as only two or three years of hydrological records were available.

5.2 - U.S. Bureau of Reclamation - 1961

In 1961 a more detailed feasibility study dealing specifically with the Devil Canyon-Denali development was completed. It recommended a five-stage construction scheme be used to match the load growth curve. The first stage would consist of a 635 ft high arch dam constructed at Devil Canyon. Initially, 3 units totaling 217.5 MW were to be installed. The second stage involved building an earthfill dam without a power house at Denali to increase the dependable energy at Devil Canyon. Stages 3 and 4 each involved adding two units and stage 5 one unit, to the Devil Canyon powerhouse, leading to a total installed capacity of 580 MW.

The increase in installed capacity over the value derived in the previous study resulted from the greater level of detail to which the development at Devil Caynon was studied. The full pool elevation of the Devil Canyon Reservoir was increased by 33 ft to 1,450 feet. The larger period of streamflow data (10 year vs. 2 years) allowed a more accurate determination of the mean annual flow which was 12% higher than the previous estimate. The proposed development was also sized for a lower plant factor.

5.3 - Alaska Power Administration - 1974

The status of the Devil Canyon Project was reviewed in a report which was essentially an update of the USBR 1961 report. One major change from the 1961 report on Devil Canyon Dam was the change from a single curvature arch to a double curvature thin arch dam. Revised load forecasts as well as revised cost estimates and schedules were included in this report.

5.4 - Kaiser Engineers - 1974

This study suggested an alternative to the USBR scheme of development. It was proposed that the initial development consist of a single dam known as Susitna I* located at at site approximately five miles upstream from the USBR Devil Canyon site. A 810 ft high rockfill dam at this site with a pool elevation of

* Note: Subsequently this name has been changed to High Devil Canyon.

1,750 feet would provide sufficient storage for 600 MW of dependable capacity without an additional upstream reservoir. Because of the perception that foundation conditions at Denali are questionable, this scheme was preferred to the USBR Devil Canyon-Denali scheme.

Kaiser suggested the ultimate development would incorporate Susitna II located downstream at approximately the same location as to the USBR Olson Site, and Susitna III located at the upstream end of the Susitna I reservoir. The exact location of the Susitna III site was not identified but it was determined that a head of 600 feet could be obtained. Information developed for the Susitna II and III site was limited to an estimate of the energy potential. The report also mentioned that the future addition of Denali, if foundation conditions proved to be adequate, would increase the energy generation potential of the other three sites.

5.5 - U.S. Corps of Engineers - 1975

The most comprehensive study of the hydroelectric potential of the Upper Susitna Basin was completed in 1975 by the Corps of Engineers. In this study several schemes of development were considered including combinations of dams of various heights at the following sites:

(a) Olsen;
(b) Devil Canyon;
(c) High Devil Canyon (Susitna I from the Kaiser Plan);
(d) Watana;
(e) Vee; and
(f) Denali

A total of 23 alternative developments were identified and evaluated using a "scoping type" economic analysis. The results are shown in Table 1. Alternatives were selected for final evaluation based on "maximizing net benefits consistant with engineering judgement". The more promising of these alternatives are listed in Table 2 together with their respective firm annual energy, dependable capacity values, and comments relating to further study.

The four most promising alternatives for meeting the future power needs of the Railbelt Area were selected for futher studies. These were:

(a) Coal (considered to be the "without" Susitna condition or the base case);
(b) Devil Canyon (1450) Watana (2200);
(c) Devil Canyon (1450) Watana (2200) - Denali (2535); and
(d) Devil Canyon (1450) Watana (1905) - Vee (2300) - Denali (2535)

Note: The numbers in brackets refer to the maximum pool elevation in feet.

Each of these alternatives were evaluated using the following four criteria (See Appendix B for a more detailed definition of the terms).

(a) Technical Criteria;
(b) National economic development (NED);
(c) Environmental quality criteria (EQ); and
(d) Social well-being and regional development

Table 3 gives a summary comparison of the four alternatives in terms of the above criteria.

The scheme finally selected by the U.S. Corps was the Devil Canyon (1450) - Watana (2200) option. It maximized the National Economic Development and also minimized enviornmental effects. The scheme involved the first stage construction of an earthfill dam at the Watana site with a height of 810 feet. Three 264 MW units would be installed giving a total capacity of 792 MW. The second stage involved a 635 high thin arch dam at Devil Canyon and would be constructed to meet future local growth. The Devil Canyon site would have an installed capacity of 776 MW. Firm annual energy was estimated as 3.0×10^9 kW-hr for Watana and 3.2×10^9 kW-hr for Devil Canyon. The benefit-cost ratio for the total development was computed as 1.3 with power benefits based on the cost of the coal alternative.

5.6 - U.S. Corps of Engineers - 1979

In 1977 the Office Management and Budget (OMB) questioned the economic justification of the project. Concerns expressed were that the cost estimates for Watana were not based on any geotechnical investigations. Also the construction schedule required higher construction rates than had ever been achieved. These concerns, as well as several other comments, were addressed in 1979 in a "Supplementary Feasibility Report". Highlights of this later study include:

(a) At the Devil Caynon site, the thin arch dam was replaced by a concrete gravity dam. This was done to provide a more conservative basis for economic evaluation in the event that subsequent more detailed field data collection and engineering design studies proved an arch dam to be technically infeasible.

(b) Results of additional geotechnical exploratic. at the Watana site performed in 1978 were incorporated. As a result, the Watana dam was changed from earthfill to rockfill.

(c) The total consruction period for both dams was increased to more accurately reflect historical construction rates.

(d) New cost estimates were developed and the economic analyses redone. The revised benefit-cost ratio was found to have increased to 1.4 because the value of power, as assessed by the coal thermal alternative, had increased more in the five year period than the construction costs.

(e) Sensitivity analyses were carried out to determine the effect of different rates of local growth on the economics of the proposed scheme. These revealed that the local growth rate would have to fall below 0.8% annually before project costs exceed benefits. This lack of sensitivity was due in-part to a large number of fossil-fuel plants which were specified to have planned retirements close to the proposed on-line dates for the Susitna development and should therefore be interpreted with caution.

6 - DESIGN PARAMETERS

6.1 - General

For each of the twelve sites identified in the basin (Figure 1), information has been gathered and tabulated. At several sites various heights have been studied, although, not always to the same degree of detail. At other sites, such as the Susitna III site, very little information is available. Table 4 summarizes available topographic, engineering layout, subsurface investigation and air photo information for each site and the source of such information.

In the sections that follow, some of the more pertinent parameters assocaited with the various sites are discussed in more detail.

6.2 - Civil Engineering Parameters

Preliminary engineering layouts are available for the following dam alternatives:

Site	Max. pool Elevation	Dam Type
Devil Canyon	1417	Concrete Arch
Devil Canyon	1450	Concrete Thin Arch
Devil Canyon	1450	Concrete Gravity
High Devil Canyon (Susitna I)	1750	Concrete Faced Rock-fill
Watana	2200	Earthfill
Watana	2185	Rockfill
Vee	2300	Earthfill
Denali	2535	Earthfill
Denali	2552	Earthfill

Copies of these drawings are included in Appendix A.

, or other levels of development, and dams at the other seven sites, information is limited to descriptions in the text of the reports.

Civil detailed design parameters such as dam type, height, length, length-to-height ratio, reservoir area, gross storage, spillway type and provision for a low level outlet are listed in Table 5. A brief description of the more important aspects associated with dams at each site follows:

6.2.1 - Gold Creek

A 135 feet high earthfill dam constructed at this site would cause water to back-up to the Olson site. A spillway and power plant could be constructed on either abutment.

Diversion of the Chulitna River (by two tunnels) and of the Indian River into the reservoir would considerably increase the energy generating potential of this site.

6.2.2 - Olson

A concrete gravity dam at the Olson site would raise the water level 50 feet without encroaching on the tailwater level at the High Devil Canyon site. The spillway could be a gated overflow section in the center of the dam.

6.2.3 - Devil Caynon

At the Devil Canyon site, three dam designs have been proposed. Each of these designs has a maximum pool elevation of 1450 feet with a dam height of approximately 650 feet. These designs each consist of a main concrete section and an earthfill embankment 200 feet high and 950 feet long at the south end of the main dam.

As proposed by the USBR in 1961, the main concrete section is a single curvature arch dam. The Devil Canyon Project Status Report prepared by the Alaska Power Administration in 1974 included an updated design of the dam using a double curvative thin arch section. This design was also utilized by the Corps in their 1975 Interim Feasibility Study. In the 1979 report, the Corps changed the design to a concrete gravity section as it was considered less sensitive to foundation conditions and lead to a considerably higher cost estimate. It was pointed out that further geotechnical investigations would be required to firm up the feasibility of an arch dam.

The USBR design includes a tunnel spillway through the north abutment. The thin arch dam design has a chute-type spillway with a flip bucket located on the south canyon wall. For the gravity dam option the spillway is incorporated in the center of the dam.

6.2.4. - High Devil Canyon (Susitna I)

A 810 foot high concrete-faced rock fill dam was proposed for the High Devil Canyon site. The crest elevation was set at 1755 feet giving a maximum pool elevation of 1,750 feet. Upstream and downstream slopes of the rockfill dam were 1.4 and 1.3 to 1 respectively. On preliminary examination it appears that these slopes may be too steep for this type of dam in the area; particularly because of the high seismicity.

The spillway is located on the south abutment. It is a channel type and incorporates a series of steps excavated in the rock to form a cascade.

6.2.5 - Devil Creek

Located just below the mouth of Devil Creek, the Devil Creek site appears sutiable for the Construction of a low dam. The maximum height would be limited to 350 feet by the right abutment. No layouts are available for this site.

6.2.5 - Watana

Rockfill dams of various heights have been proposed at the Watana site. The most recent Watana Dam design presented in the Corps of Engineers 1979 report is a rockfill dam with a crest elevation of 2,195 feet and a maximum water pool elevation of 2,185 feet. This is essentially the same dam as proposed in 1975 which has a maximum pool elevation of 2,200 feet. The discrepancy was due to corrections in topography made during field investigations. The dam is 810 feet high and incorporates a sloping impervious core.

A saddle spillway is provided across the left abutment discharging into the Tsusena Creek. Twin diversion tunnels are also located in the left abutment. These tunnels would be converted to a high and low level outlets before completion of the project. The powerhouse is located underground below the right abutment.

6.2.7 - Susitna III

The Susitna III site is defined by the H.J. Kaiser Company as a point above the headwaters of the High Devil Canyon (Susitna I) reservoir where a head of 600 feet could be obtained. There is no engineering information available at this site.

6.2.8 - Vee

At the Vee site, any structure higher than 250 feet requires a saddle dam. Above height 480 feet water starts to spill into the Copper River Basin to the south. The USBR originally proposed a gravity-arch concrete structure with a crest elevation of 2,340 feet. Further work by the USBR, and the Corps of Engineers which included some site investigation, resulted in an earthfill dam being selected with a height of 410 feet and a maximum pool elevation of 2,300 feet. No reference has been found detailing the rationale for this design. A geotechnical investigation report[A] for the Vee Canyon site refers to a tunnel type spillway; however, this is not shown on the available plan.

6.2.9 - Maclaren

In the initial USBR studies, a concrete dam with a height of not more than 100 feet flanked by earth embankments was considered. The concrete river section incorporated an overflow spillway. No engineering layouts are available.

6.2.10 - Denali

The primary purpose of the Denali reservoir was considered to be the provision of storage for regulating releases to downstream power facilities. As the mode of operation for this type of reservoir involves no downstream water release for several months each year, it was not considered feasible to install a powerhouse at this site. A 260 foot high earthfill dam was proposed. The spillway is a 19 foot diameter Glory Hole type with the outlet conduit passing through the embankment.

6.2.11 - Butte Creek

A dam at the Butte Creek site was considered by the USBR. A field reconnaissance led to the rejection of this site in favor of the Denali site which was found to have better foundation conditions. No engineering layouts are available.

6.3. - Hydrology

The following USGS gaging stations have been operated by the USGS:

USGS Gaging Stations	Period of Record
Gold Creek	1949 - present
Vee	1961 - 1972
Denali	1957 - present
Maclaren	1958 - present
Talkeetna	1964 - present

Obviously, the earlier studies were based on very limited flow records. In particular, the initial USBR studies had at most, two years of record. Extended flow estimates were obtained by correlation with long term rainfall records at Talkeetna.

The most comprehensive study in which hydrological parameters are given for the various site is the 1975 Corps of Engineers report. Monthly flow data for the Devil Canyon and Watana sites were generally prorated from the Gold Creek using factors based on drainage basin areas. Flood estimates were derived both from frequency analyses of recorded flood flows and by utilizing the SSARR computer model to develop Probable Maximum Flood values. Table 6 lists pertinent hydrological parameters such as annual and monthly flow rates, spillway design floods and reservoir volumes for each of the sites.

Detailed hydrological information is contained in the Subtask 3.01 Close-out Report.

6.4 - Geotechnical

Geotechnical investigations at the sites have ranged from aerial reconnaissance to drilling programs at Watana, Devil Canyon, Vee and Denali. Available geological and geotechnical information is discussed in the Subtask 5.01 - Close-out Report. However for the sake of completeness a brief review of geotechnical aspects pertaining to each site is included in this report.

6.4.1 - Gold Creek

Available information is very limited. It is known that a very deep cut-off wall of the order of 70 feet will be required and that construction material suitable for the earthfill dam may be difficult to obtain.

6.4.2 - Olson

Available information is very limited. The abutments appear to be very good and consist of a rounded, hard, sound graywacke formation.

6.4.3 - Devil Canyon

Exploration performed by the Bureau of Reclamation in 1957 consisted of 22 borings, 19 trenches and test pits and geologic mapping. The Corps of Engineers did a limited amount of additional seismic work in 1979. The significant aspects resulting from these investigations include:

- About 35 feet of alluvium overlying bedrock in the channel;
- The abutments will require extensive dental work;
- The foundation will require grouting;
- Shear zones exist in both abutments;
- A buried stream channel or shear zone exists near the saddle dam location (to the south of the main dam);
- The maximum Credible Earthquake was estimated to be 8.5 Richter magnitude at 40 miles or 7.0 at 10 miles;
- Materials for a concrete dam are available in sufficent quantity but the aggregate shows marginal freeze-thaw resistance; and
- Sporadic permafrost may exist in the left (south) abutment.

6.4.4 - Watana

Exploration of Watana has taken place as follows:

Date	Agency	Scope
1950 - 1953	Bureau of Reclamation	Reconnaissance
1974	USGS	Reconnaissance and mapping
1975	Corps of Engineers	Reconnaissance
1975	Dames and Moore	Right abutment seismic
1978	Corps of Engineers	28 borings, 27 test pits. 18 auger holes
1978	Shannon & Wilson	Seismic

The significant aspects resulting from these investigations include:

- Overburden thickness varies from 40 to 80 feet in the valley bottom and 10 feet to 20 feet on the abutments.
- The river channel alluvium thickness varies from 50 feet to 80.
- It is suspected that a buried stream channel incorporating an aquifer under artesian pressure occurs near the spillway location.
- A possible slide block exists on the right abutment.
- The "Finger Buster" and "Finns" are pronounced shear zones located just upstream and downstream of the dam on the right abutment.
- Deep permafrost occurs in the left abutment.
- Sufficient borrow material is available but engineering properties of the fine-grained materials are very sensitive to water content.
- Once the reservoir is filled the "Warm" permafrost which occurs in the reservoir banks may slump after thawing.
- A possible fault, tentatively named the Susitna fault, is located about 2.5 miles to the west of the site.

6.4.5 - Susitna III

The location of this site has not been firmly fixed and therefore no geotechnical information is available.

6.4.6 - Vee

Investigations consisting of thirteen borings and 16 dozer trenches were performed by the USR during 1960 - 1962.

- Deposits in the river bottom are approximately 125 feet deep.
- A buried streambed located at the site of the saddle dam is expected to be deeper than the present Susitna River channel.
- Considerable amounts of talus and loose rock must be removed from abutment areas to expose good quality rock.
- Permafrost is present at the saddle dam location.

6.4.7 - Maclaren

Bedrock outcrops indicate a good dam site.

6.4.8 - Denali

In 1958 - 1959 the USBR performed investigations consisting of five borings and 14 test pits. Significant features include:

- Deep permafrost occurs in both abutments;
- Pervious sand and gravel occurs in the right abutment;
- Low density, potentially liquifiable, fine grained sands occur in the river bottom;
- Layers of compressible silt are found in both abutments;
- Maximum Credible Earthquake is estimated as a Richter Scale of 8.5 at 40 miles;
- A deep cutoff excavation and extensive foundation treatment will be required; and
- Impervious materials may be difficult to obtain.

6.4.9 - Butte Creek

Limited information is available. Glacial silts occur on the right abutment and will require removal for dam construction.

6.4.10 - Tyone

No information available.

6.5 - Mechanical

Preliminary project layouts showing the major mechanical equipment were developed in the recent studies by the Corp of Engineers (7 and 11), and also to a lesser extent in the studies by the Alaska Power Administration(5) and the USBR(3).

The Major mechanical equipment is summarized in Tables 7, 8, and 9 and a brief description of the arrangements is presented below.

6.5.1 - Devil Canyon

The underground power house has four 194 MW units with Francis turbines (520 ft head). Access to the powerhouse is by a 550 ft. vertical shaft. The units have bonnetted fixed wheel intake gates located in a separate gallery upstream of the powerhouse cavern. Two penstocks are provided and the intake has three stoplog slots with provision to place stoplags at various elevations to permit water to be taken from different levels.

The spillway has radial crest gates and bonnetted slide type low level outlet gates. Wheeled bulkend gates are provided for closure in the single diversion tunnel.

6.5.2 - Watana

The underground powerhouse has three 264 MW units with Francis turbines (580 ft head). The units have bonnetted fixed wheel intake gates located in a separate gallery upstream of the powerhouse cavern. Two penstocks are provided, one supplying water to two units, the other for the third unit.

The spillway has radial crest gates. A high and low level outlet each with two radial control gates and two bonnetted slide type emergency gates are incorporated in the spillway. The outlets are provided at two levels to reduce the operating head on the control gate.

Wheeled bulkhead gates are provided for diversion closure. Two slide gates are also provided in a temporary plug in one of the diversion tunnels. These are used for final closure of the second diversion tunnel.

6.5.3 - Denali Dam

Denali Dam, described in the USBR March 1961 report[3], has a morning glory type spillway with no gates, as well as a single outlet works tunnel with radial control gates and vertical lift emergency gates.

6.6 - Hydropower

Table 10 lists available hydropower parameters for each of the sites as well as the parameters for the multi-site schemes developed by the Corps of Engineers in 1975. As hydroelectric potential at a given site is not only dependent upon the site characteristics but also upon the degree of upstream regulation, the hydropower parameters are related to specific schemes of development.

6.7 - Environmental

The majority of baseline environmental information for the Upper Susitna River was acquired from U.S. Corps of Engineers Environmental Impact Statement Report [12] and the Jones and Jones March 1975 Report[8].

To facilitate synthesis and presentation of the environmental information in this report the river is divided into 6 study reaches starting with reach A at the downstream end and finishing with reach F located upstream of Denali (Figure 2). Within each of these reaches the environmental aspects can be assumed to be constant for the general level of study at this stage. Major environmental features for each of these reaches are tabulated in Table 11 and are summarized below.

(a) Reach A - Talkeetna To Devil Canyon

Under existing conditions, salmon mirgrate as far as Devil Canyon, utilizing Portage Creek and Indian River for spawning (Figure 1). The development of any dam downstream of Devil's Canyon would thus result in a direct loss of salmon habitat. It can therefore be anticipated that approval for such schemes would be extremely difficult to acquire.

(b) Reach B - Devil Canyon to Watana

The concerns associated with development in this section of the river relate mainly to the inundation of Devil Canyon which is considered a unique scenic and white water reach of the river, and dam safety aspects associated with the occurrence of major geological faults. In addition, the Nelchina caribou heard has a general migration crossing in the area of Fog Creek (Figure 1).

(c) Reach C - Watana to Vee

There are concerns which relate to the loss of some moose habitat in the Watana Creek area and the inundation of sections of Deadman and Kosina Creeks.

Other aspects include the effect on caribou crossing in the Jay Creek area, and the potential for extensive reservoir shoreline erosion and dam safety because of the possibility of geological faults.

(d) Reach D - Vee to Maclaren

Inundation of moose winter range, waterfowl breeding areas, the scenic Vee Canyon and the downstream portions of the Oshetna and Tyone Rivers are all potential environmental impacts associated with this reach of the river. In addition, caribou crossing occurs in the area of the Oshetna River. The area surrounding this section of the river is relatively inaccessable and development would open large areas to hunters.

(e) Reach E - Maclaren to Denali

Environmentally, this area appears to be more sensitive than Reaches B and C. Inundation could affect Grizzly bear denning areas, moose habitat, waterfowl breeding areas and moist alpine tundra vegetation. Improved access would open wilderness areas to hunters.

(f) Reach F - Upstream of Denali

This area is similiar to Reach E with the exception of Grizzly bear denning areas. Human access to this area would not impact to the same extent as in Section D and F, however due to the proximity to the Denali highway, the inflow of people could be greater.

In an attempt to put the above information in perspective, the reaches were ranked relative to each other in terms of biological, social and physical impact potential. This is summarized in Table 12.

6.8 - Generation Planning

A substantial portion of each of the previous studies has been devoted to generation planning studies and the consideration of how the Susitna development would fit into the total electrical system. The initial USBR report showed that Susitna power would be required to meet load growth in the 1960's. As the Susitna project was delayed, fossil fuel plants were built to meet the demand.

In 1970 the Corps of Engineers showed the need for Watana in 1994 followed by Devil Canyon in 1998. Figures 3 and 4 demonstrate how the proposed development was to fit into the total system subject to medium and low load growth rates.

As can been seen from these figures, the retirement of the existing plants has a pronounced effect on the timing of introducing Susitna power. By assuming the relatively rapid retirement rates shown, the U.S. Corps found that for load growth rates as low as 0.8 percent annually, the Susitna development would still be economical. Preliminary sensitivity calculations as part of Subtask 6.01 indicate that without any planned retirement of existing plants, admittedly an extreme case, the benefit-cost ratio for the low range growth curve would reduce to 0.75 as opposed to 1.4 with the planned reitrement shown.

7 - CONSTRUCTION COST INFORMATION

7.1 - Available Data

The cost of development at a particular site is dependent on whether that site is the first to be developed in the basin or whether it constitutes a second or third stage of development. The initial development is usually burdened with the major proportion of the access and transmission costs and with higher flood diversion costs. For this reason the available cost data is referred to as being applicable to either an initial or a subsequent stage of development.

The most recent cost estimates for development of the Susitna were performed in October 1978 by the Corps of Engineers.(11) Detailed engineering type estimates were developed for the Watana (2200) and the Devil Canyon Concrete Gravity (1450) alternative only.

More comprehensive cost information is incorporated in the 1975 Corps of Engineers report.(7) This includes detailed quanities and unit costs for the Watana (2200) and Devil Canyon thin arch dam (1450) alternativs constructed in that order. Also included are summaries of cost estimates performed on a similar basis for the following developments:

- Olson (1020) Subsequent stage.
- Devil Canyon (1450) Initial stage.
- High Devil Canyon (1702)[2] Initial stage.
- Low Watana (1905) Initial stage.
- Low Watana (1905) Subsequent stage.
- Mid Watana (2050) Initial stage.
- Mid Watana (2050) Subsequent stage.
- High Watana (2200) Subsequent stage.
- Vee (2300) Subsequent stage.
- Vee (2350) Subsequent stage.
- Denali (2535) Subsequent stage.

Except for Olson these costs are given as summary costs for individual accounts such as Lands and Damages, Reservoir, Dams, Power-Plant, Roads and Bridges, Recreational Facilities, Buildings, Grounds and Utilities, Permanent Operating Equipment, Engineering and Design, and Supervision and Administration.

Since the 1975 data incorporates the most complete set of alternatives, this information is included in Appendix C. For information the summary sheets for the 1978 estimates are also included.

Some limited cost information is available for developments at other sites. It is based on relatively crude estimates performed between 1953 and 1968 and is not included in this report.

7.2 - Basis of Cost Estimates

Both the 1975 and 1978 Corps of Engineers estimates used unit prices derived from bid prices of other major hydroelectric projects in the Pacific Northwest and Canada. These bid prices were adjusted to reflect the following:

(a) Current price levels;
(b) Alaska labor costs; and
(c) Transportation costs for material and equipment to the site.

7.3 - Preliminary Ranking of Sites

All estimates have been brought to a 1980 basis using the Handy-Whitman Index. Table 13 lists the costs for the various alternative developments as well as the years of the original estimate. It also includes costs per kilowatt and costs per kilowatt hour.

This data is briefly summarized below. The sites have been ranked in ascending order of energy costs.

Rank	Dam Site (Maximum pool elevation)	Capital Cost ($ x 10^6)	Cost (4) per kW Dependable Capacity	Cost ($)/1000 kWh Energy*
1	High Watana (2200)	1587	2300	71
2	Mid Watana (2050)	1279	2800	74
3	High Devil Canyon (1750)	1216	3100	83
4	Low Watana (1905)	975	3900	94
5	Devil Canyon (1450)	1042	5000	105

The ranking of dams for subsequent development stage is as follows:

1	Devil Canyon (1450)	630	900	28
2	Mid Watana (2050)	915	2000	53
3	High Watana (2200)	1221	1800	55
4	Low Watana (1905)	613	2400	59
5	Vee (2300)	696	2300	72

* Based on an assumed annual cost factor of 15% of Capital Cost.

The above results should be regarded merely as an economic ranking of currently proposed developments and not necessarily as being indicative of the most economic schemes to meet future load demands. To accomplish the latter requires additional studies aimed at assessing the best methods of staging development to meet a range of possible future load forecasts. Such a study should also incorporate a review of the potential at sites for which currently very little information is available and should incorporate the environmental impacts associated with the various developments.

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2. Alaska Power Administration, Inventory Type Calculations for Some Potential Hydroelectric Projects in Alaska (Working File).

3. U.S. Department of the Interior, Bureau of Reclamation (Alaska District), Devil Canyon Project, Alaska: Report of the Commissioner of Reclamation and Supporting Reports, Juneau, Alaska, March 1961. (Reprinted March 1974).

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5. Alaska Power Administration, Devil Canyon Status Report, Juneau, Alaska, May, 1974.

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8. Jones and Jones, An Inventory and Evaluation of the Environmental, Aesthetic and Recreational Resources of the Upper Susitna River, Alaska, (Final Report prepared for Dept. of Army, Alaska District, Corps of Engineers), Seattle, Washington, March 1975.

9. U.S. Department of the Army, Corps of Engineers (Alaska District), Final Enrironmental Impact Statement, Hydroelectric Power Development, Upper Susitna River Basin, Southcentral Railbelt area, Alaska, Anchorage, Alaska, 1977.

10. U.S. Federal Power Commission, The 1976 Alaska Power Survey, 3 vol., 1976.

11. U.S. Department of the Army, Corps of Engineers (Alaska District), Hydroelectric Power and Related Purposes: Southcentral Railbelt Area, Alaska Upper Susitna River Basin - Supplimentarty Feasibility Report ... 1979.

12. U.S. Department of the Army, Corps of Engineers (Alaska District), Revised Draft Environmental Impact Statement, Hydroelectric Power Development, Upper Susitna River Basin, Southcentral Railbelt Area, Alaska, Anchorage, Alaska, 1977.

13. The Federal Power Commission, The 1976 Alaska Power Survey, 1976

FIGURES

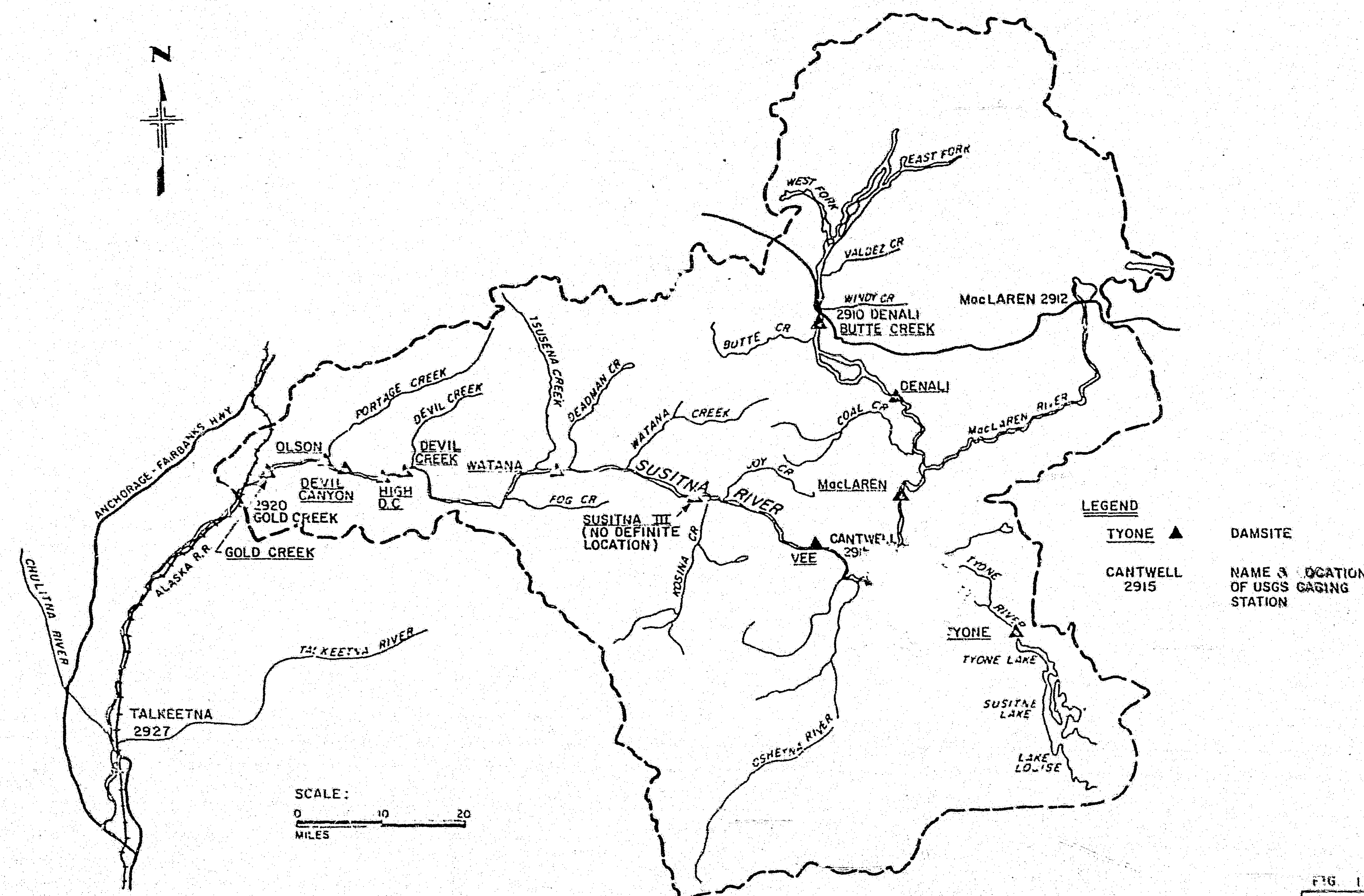


FIG. 1

SUSITNA HYDROELECTRIC PROJECT
DESIGN DEVELOPMENT

LOCATION OF DAMSITES PROPOSED BY OTHERS

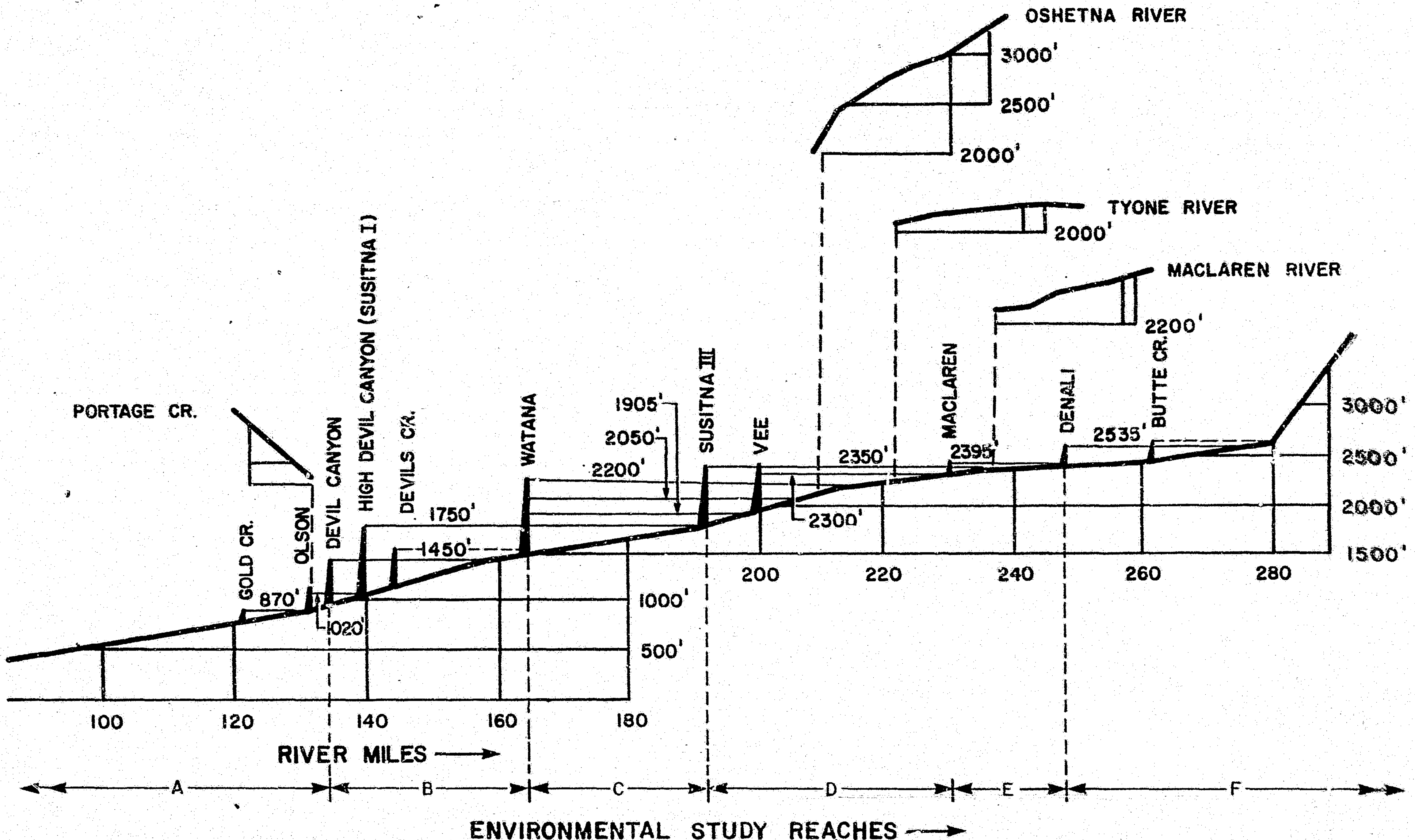


FIG.2

SUSITNA HYDROELECTRIC PROJECT
DESIGN DEVELOPMENT

PROFILE THROUGH ALTERNATIVE SITES

ACRES

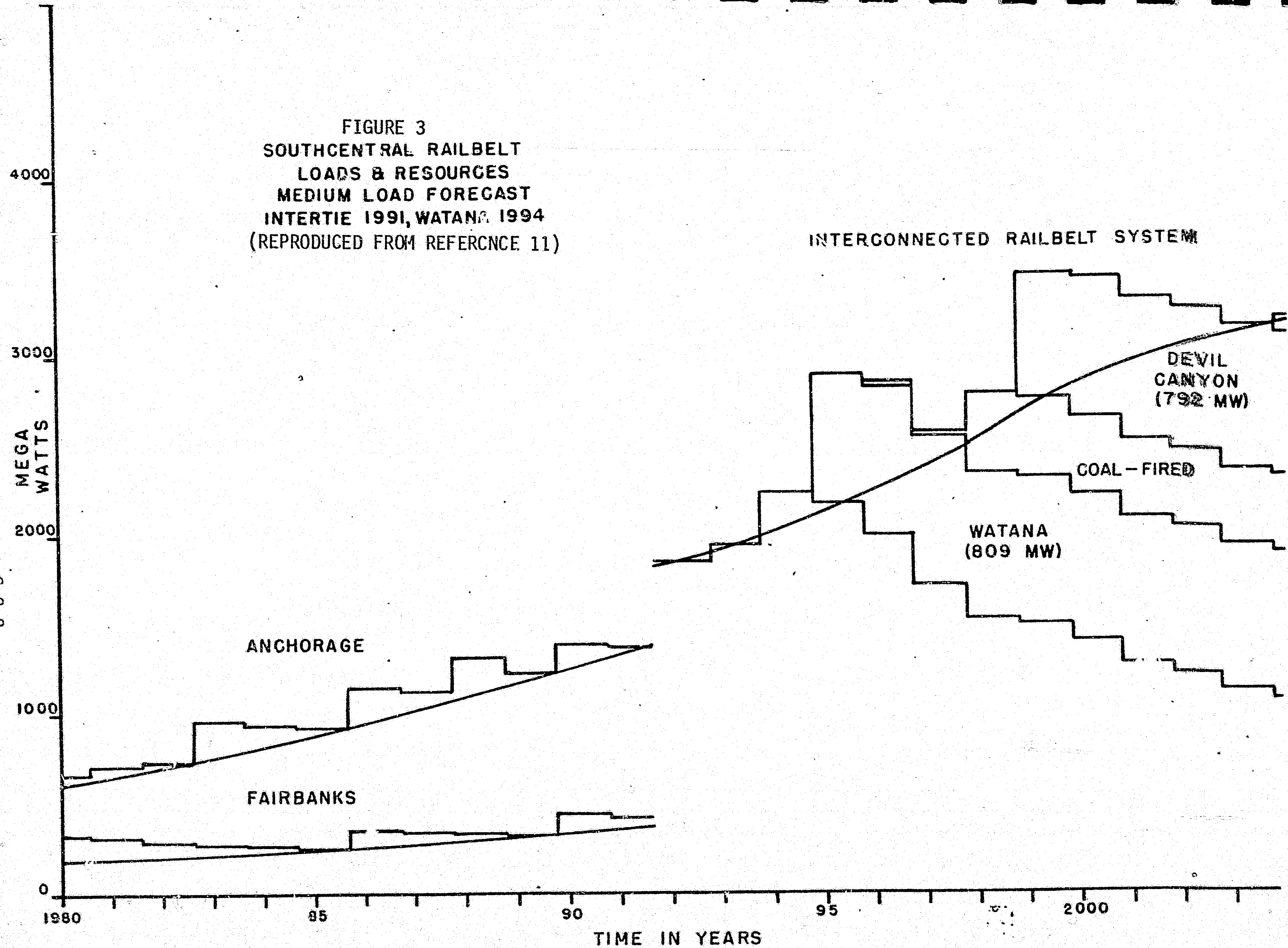


FIGURE 3
SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
MEDIUM LOAD FORECAST
INTERTIE 1991, WATANA 1994
(REPRODUCED FROM REFERCNCE 11)

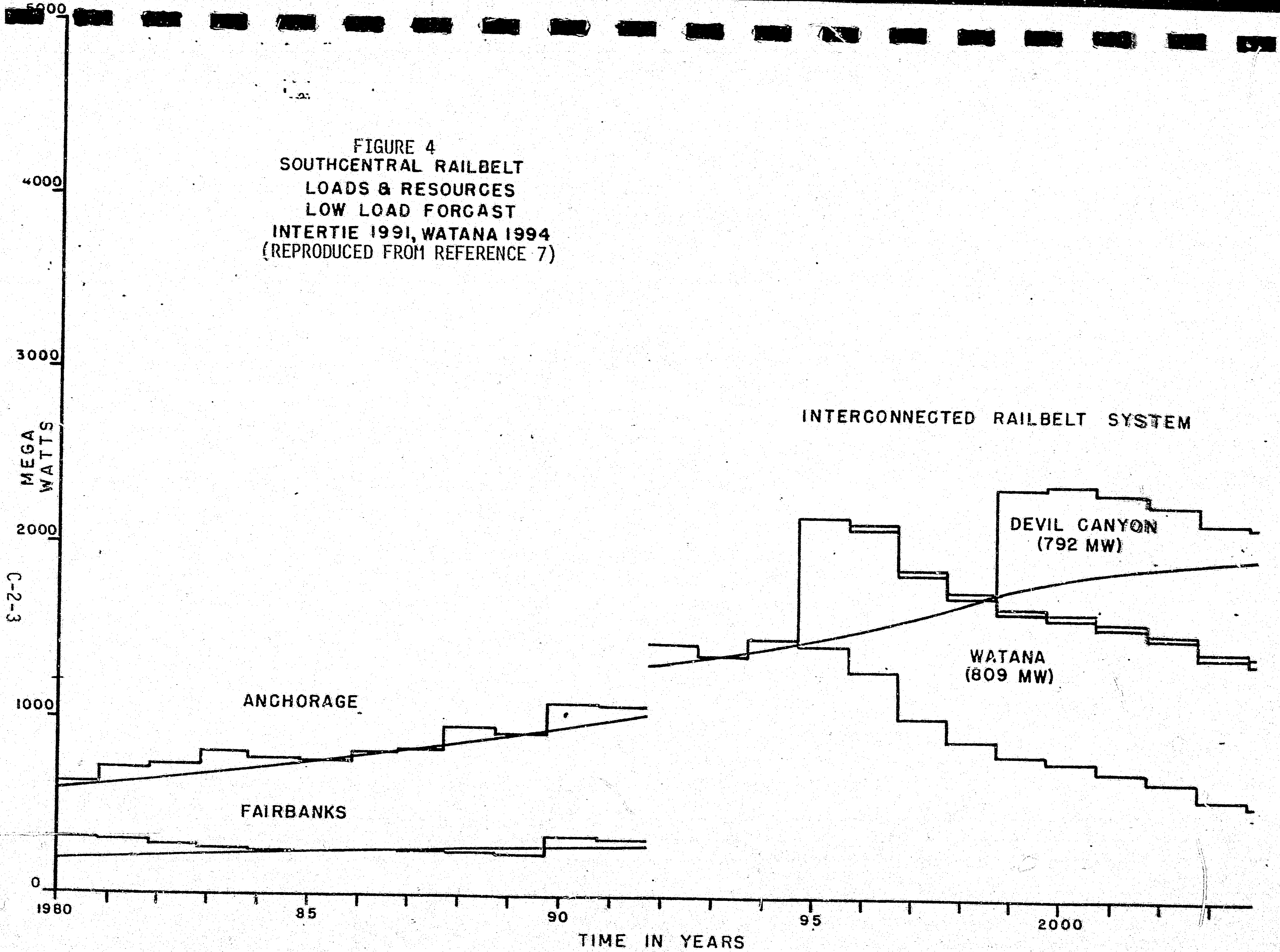


FIGURE 4
SOUTHCENTRAL RAILBELT
LOADS & RESOURCES
LOW LOAD FORCAST
INTERTIE 1991, WATANA 1994
(REPRODUCED FROM REFERENCE 7)

TABLES

Table 1

CORPS OF ENGINEERS - "SCOPING ECONOMIC ANALYSIS"

(Reproduced from Reference 7)

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).

Table 2

CORPS OF ENGINEERS
DATA PERTAINING TO PROMISING SUSITNA DEVELOPMENTS

(Data obtained from Reference 7)

	Firm Annual Energy-kWH	Dependable Capaciy-MW	CORPS OF ENGINEERS COMMENTS
Devil Canyon	0.9×10^9 kW-hr	205	Not economic by itself
High Devil Canyon	2.6×10^9 kW-hr		Not economic by itself
Watana	3.1×10^9 kW-hr	706	Economic, however, same environmental impact as project twice its size.
Devil Canyon - Denali	2.5×10^9 kW-hr	571	Not economically feasible
Devil Canyon - High Watana	6.1×10^9 kW-hr	1,568	Economic - should be studied further
Devil Canyon - High Watana - Denali	6.8×10^9 kW-hr	1,578	Economic - environmental affects greater than Devil Canyon - Watana - should be studied further
Devil Canyon - Low Watana - Vee - Denali	6.1×10^9 kW-hr	1,570	
High Devil Canyon - Olson - Vee - Denali	5.9×10^9 kW-hr		Develops less than basin potential - Not economically justified

Table 3

CORPS OF ENGINEERS - EVALUATION OF ALTERNATIVES (Reproduced from Reference 7)

	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
A. PLAN DESCRIPTION	Non-Federal financing of a 370-MW coal-fired generating plant at Healy and a 1,200-MW coal-fired plant at Beluga. The plants would have 35-year service lives. Project would include costs for coal mining and separate Healy-to-Fairbanks and Beluga-to-Anchorage transmission systems.	Federal financing of the total system to include a thin-arch dam and underground powerplant at the Devil Canyon site, and an earthfill dam and underground powerplant at the Watana site. Both projects would provide baseload generation. Watana would provide the seasonal storage for the system. Plan would also include transmission system between projects and to the Anchorage and Fairbanks load centers.	This plan is basically the same as the Plan B, with the addition of the Denali dam. [illegible] would be used only for low flow augmentation of the two downstream projects.	This is the system proposed by the Bureau of Reclamation in its 1952 report on hydropower resources of the Upper Susitna River Basin. Federal financing of the total system to include a thin-arch dam and powerplant at the Devil Canyon site, a low, earthfill dam and powerplant at the Watana site, an earthfill dam and powerplant at the Vee site, and a fill structure at Denali site. Plan would also include transmission system between projects and to the two load centers.
1. Dam Heights	No Dams	1. Devil Canyon - 635 feet 2. Watana - 810 feet	1. Devil Canyon - 635 feet 2. Watana - 810 feet 3. Denali - 260 feet	1. Devil Canyon - 635 feet 2. Watana - 575 feet 3. Vee - 455 feet 4. Denali - 260 feet
2. Dependable Capacity	1,570,000 kilowatts	1,394,000 kilowatts	1,552,000 kilowatts	1,404,000 kilowatts
B. SIGNIFICANT IMPACTS	(Included in Relationship to Four Accounts)	(Included in Relationship to Four Accounts)	(Included in Relationship to Four Accounts)	(Included in Relationship to Four Accounts)
C. PLAN EVALUATION				
1. Contribution to Planning Objective				
a. Firm Annual Energy	5,800,000,000 kilowatt-hours	6,100,000,000 kilowatt-hours	6,300,000,000 kilowatt-hours	6,150,000,000 kilowatt-hours
b. Average Annual Energy	5,910,000,000 kilowatt-hours	6,910,000,000 kilowatt-hours	6,910,000,000 kilowatt-hours	6,390,000,000 kilowatt-hours
c. Percent of Basin Potential	Not Applicable	96%	99%	95%
d. System Dependability	No grid intertie of major load centers. Reduced dependability.	Provides grid intertie of major load centers.	Provides grid intertie of major load centers.	Provides grid intertie of major load centers.
2. Relationship to Four Accounts				
a. National Economic Development (NED)				
NET NED BENEFITS	0	$33,355,000	$23,5[illegible],000	$16,735,000
BENEFIT-TO-COST RATIO	1.0	1.3	[illegible]	[illegible].2
b. Environmental Quality (EQ)				
Acreage Inundated or Destroyed	20,000	50,550	104,550	84,350
Drawdown Zone Acreage	0	13,000	45,000	45,000
Stream Mileage Inundated or Degraded	110-120	82	115	138
Whitewater Mileage Inundated	0	9	9	9
Major Ecosystems, Acreage Inundated or Destroyed				
Important Moose Habitat	18,000	4,000	4,000	10,000
Important Caribou Habitat	2,000	0	52,000	52,000
Important Waterfowl Habitat	2,000 acres	0	400	400
Number of Pothole Lakes				
Archaeological Zones Precluded from Post-Construction Studies	Unquantified area has very high potential	40	50	35
Prehistoric Sites Inundated or Destroyed	0	0	0	[illegible]
Historic Sites Inundated or Destroyed	0	[illegible]	4	4
c. Social Well-Being (SWB)				
Energy Resources Conserved in Tons per Year		5,850,000	6,550,000	6,830,000
d. Regional Development and Cost of Power in Mills/kWh	25.4 - 31.4	21.[illegible]	21.0	24.3
3. Plan Response to Associated Evaluation Criteria				
a. Acceptability	This plan is the worst from the standpoint of conservation of nonrenewable resources. It has large adverse EQ effects in that it requires strip-mining of 20,000 acres of important wildlife habitat, it degrades water quality by chemical inputs and suspended sediments, and it degrades air quality by inputs of particulates and chemical pollutants. Its NED performance is acceptable. It provides no flood control or recreational opportunity.	Maximum beneficial impacts of options studied in NED and EQ accounts. Supported by consensus of most publics. Plan has drawn some concern because of possibility for induced population growth associated with initial power on line, as well as the adverse impact on fish and wildlife values. Would provide flood control and recreation potential.	Greater adverse EQ effects than in recommended plan. Ranks second to the recommended plan in the NED account. Would provide maximum firm power of hydro development plans. Would provide flood control and recreation potential.	Beneficial impacts in NED, SWB, and RD accounts. Has good potential for stage development of hydro projects and is plan favored by Alaska Power Administration. Ranks low in the EQ account in comparison to other alternatives. Would provide flood control and recreation potential.

	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
C. PLAN EVALUATION (Cont.)				
3. Plan Response to Associated Evaluation Criteria (Cont.)				
b. Certainty	This appears to be an implementable plan which could be pursued to meet energy needs for the near and long range future. It is the most flexible plan in terms of incremental development and operation potentials.	Foundation conditions appear adequate for construction of both projects. Transmission system is within the means of present technology. Least flexible of alternatives to changes in projected power demand.	Same evaluation as for Plan B except for storage control project at Denali site. Additional explorational required before this structure could be recommended. More flexible than Plan B.	Same evaluation as for Plan C except for the power project at the Vee site. Additional exploration of abutment material required before this dam could be recommended for the structure height stated above. Most flexible of hydro alternatives.
c. Completeness	Could match the energy output of any plans evaluated herein as long as fuel source is available.	Provides adequate power to satisfy projected demand growth until mid-1990's. Little potential for expansion. Demand beyond the project capability will have to be met by other development.	Provides adequate power to satisfy projected demand growth until mid-1990's. Little potential for expansion. Demand beyond the project capability will have to be met by other development.	Provides adequate power to satisfy projected demand growth until mid-1990's. Little potential for expansion. Demand beyond the project capability will have to be met by other development.
d. Effectiveness	Could be expanded indefinitely to limits of fuel.	Would develop 95 percent of basin development potential.	Develops greatest firm power - equal to Plan B in average annual power.	Would develop 95 percent of basin development potential.
D. IMPLEMENTATION RESPONSIBILITY				
1. Financial Responsibility	Private and/or semi-public entities coordinated with Federal and State regulatory agencies.	Federal Government with power marketed through the Alaska Power Administration.	Federal Government with power marketed through the Alaska Power Administration.	Federal Government with power marketed through the Alaska Power Administration.
2. Recreation Sponsorship	None	State of Alaska	State of Alaska	State of Alaska

Table 4

DATA AVAILABLE FOR ALTERNATIVE HYDROELECTRIC DEVELOPMENT SCHEMES

SITE (Pool El.)	TOPOGRAPHIC MAPPING**	ENGINEERING LAYOUTS (Date)	SUBSURFACE INVESTIGATION	AIR PHOTOS
Gold Creek	--	--	--	--
Olson (920)	--	--	--	--
Olson (1020)	--	N - COE (1975)	--	--
Devil Canyon (1417/ 1450)	Y - COE*	Y - USBR (1961) Y - APAd (1974) Y - COE (1975) Y - COE (1979)*	Y - USBR	1:30,000 B&W
High Devil Canyon (1750)	--	Y - Ka (1974) N - COE (1975)	--	1:30,000 B&W
Devil Creek	--	--	--	1:30,000 B&W
Low Watana (1905)	Y - COE*	N - COE (1975)	Y - COE	1:30,000 B&W
Mid Watana (2050)	Y - COE*	N - COE (1975)		
High Watana (2185/ 2200)	Y - COE*	Y - COE (1975) Y - COE (1979)*		
Susitna III	--	--	--	--
Vee (2300)	N - COE	Y - COE (1975)	Y - USBR	--
Vee (2350)	N - COE	N - COE (1975)		
Maclaren	--	--	--	--
Denali (2535)	--	Y - COE (1975)	Y - USBR	
Denali (2552)	--	Y - USBR (1961)		
Denali (2590)				
Butte Creek	--	--	--	--
Tyone	--	--	--	--

KEY:

--	No information available
N:	This information may be available, but could not be traced.
Y:	Information obtained
APAd:	Alaska Power Administration
COE:	Corps of Engineers
USBR:	United States Bureau of Reclamation
Ka:	Kaiser Engineers
*:	Reproducible drawings
**:	Other than USGS 1 inch to the mile with 50 or 100 ft contours.

Table 5

CIVIL DESIGN PARAMETERS

Site (Pool El.)	Dam Type		Height (ft)	Length (ft)	Length / Height	Reservoir Area (acres)	Gross Storage 10^6 Ac-ft	Spillway Type	Low Level Outlet
Gold Creek	Earthfill		135	4,900	36	--	--	--	--
Olson (920)	Concrete Gravity		50	400	7	--	.01	Overflow section of dam	--
Olson (1020)	Concrete Gravity		145	--	--	--	--	--	--
Devil Canyon (1450)	75 US Corps	Thin Arch	635	1,370	2	7,550	1.1	Chute & flip	
	Alternative	Thrust Block	110	155	1.4	--	--	bucket	Yes
		Earthfill	200	950	4.2	--	--	--	--
	79 US Corps	Gravity &	650	1,590	2.4	7,550	1.1	Center section	
	Alternative	Earthfill	200	720	3.6	--	--	of dam	Yes
High Devil Canyon (1750)	Concrete-faced Rockfill		810	3,050	3.8	24,200	4.7	Channel cut into south abutment	--
Devil Creek	Concrete		350 Max	--	--	--	--	--	--
Low Watana (1905)	Earthfill		515	1,650	3.2	--	2.5	Channel cut in saddle discharging to Tsusena Creek	--
Mid Watana (2050)	Earthfill		660	2,600	3.9	--	5.2	" " "	--
High Watana (2200)	Earthfill		810	3,450	4.3	43,000	9.4	" " "	--
Susitna III	--		--	--	--	--	--	--	--
Vee (2300)	Earthfill		455	--	--	--	3.4	--	--
Vee (2350)	Earthfill		--	--	--	--	--	--	--
Maclaren (2395)	Earthfill with Concrete		100	2,300	23	--	0.2	--	--
Denali (2535)	Earthfill		260	--	--	--	3.9	19' Dia. Glory Hole & conduit through embankment	--
Denali (2552)	Earthfill		219*	2,050	9.4	51,000	5.4	--	--
Denali (2590)	Earthfill		205*	1,900	9.3	--	5.7	--	--
Butte Creek	--		100	500	5	--	--	--	--
Tyone	Earthfill with Concrete		35	500	14		--	--	--

*Discrepancy probably due to better information in the 1961 study (Denali - 2552) than in the 1953 study (Denali - 2590)

Table 6

HYDROLOGICAL DESIGN PARAMETERS

Site (Pool El.)	Mean Annual In-Flow (Ac-ft/year) ((cfs))	Min. Avg. Monthly In-Flow (March)* (cfs)	Max. Avg. Monthly In-Flow (June)* (cfs)	Spillway Design Flood (cfs)	Reservoir Storage Total (Ac-ft)	Reservoir Storage Usable (Ac-ft)	Data Sources (Ref. No.)
Gold Creek	6,965,000 (9620)	710	50,580	-	--	-	
Olson (920/1020)	6,815,000** (9410)	690	49,600	-	6,600	NIL	USBR (1)
Devil Canyon (1450)	6,682,000** (9230)	660	47,800	228,000	1,050,000	790,000	U.S. Corps (7)
High D.C. (1750)	6,617,000** (9,140)	650	47,600		4,730,00	3,930,00	U.S. Corps (7)
Devil Creek	6,487,000** (8,960)	640	46,600	-	-	-	
Watana (1905)	5,893,000** (8,160)	570	42,800	-	2,480,000	2,310,000	U.S. Corps (7)
Watana (2050)	5,893,000 (8,160)	570	42,800	-	5,300,000	4,575,000	U.S. Corps (7)
Watana (2200)	5,893,000 (8,160)	570	42,000	165,000	9,425,000	8,125,000	U.S. Corps (7)
Susitna III	4,590,000** (6,350)	446	35,300	-	--	-	-
Vee (2300)	4,481,000 (6,190)	430	34,630	-	1,000,000	820,000	U.S. Corps (7)
Maclaren	3,150,000*** (4,360)	70	18,000	-	210,000	158,000	USBR (1)

Table 6 (Cont'd)

HYDROLOGICAL DESIGN PARAMETERS

Site (Pool El.)	Mean Annual In-Flow (Ac-ft/year) ((cfs))	Min. Avg. Monthly In-Flow (March)* (cfs)	Max. Avg. Monthly In-Flow (June)* (cfs)	Spillway Design Flood (cfs)	Reservoir Storage Total (Ac-ft)	Reservoir Storage Usable (Ac-ft)	Data Sources (Ref. No.)
Denali (2535)	2,386,000*** (3,290)	55	14,110	-	4,250,000	3,770,000	U.S. Corps (7)
Denali (2552)	2,386,000* (3,290)	55	14,110	-	5,400,000	5,300,000	USBR (3)
Denali (2590)	2,386,000 (3,290)	55	14,110	-	6,700,000	5,700,000	USBR (1)
Butte Creek	2,064,000 (2,850)	44	12,200	-	-	-	-
Tyone (2385)	222,000 (300)	Proration not appropriate		-	700,000	700,000	USBR (1)

NOTES

The mean annual, minimum and maximum average monthly inflows were calculated as part of subtask 6.01 by prorating available streamflow records

* Unregulated

** Inflows prorated from gaged flow at Gold Creek using drainage basin area ratios.

*** Inflows prorated from gaged flow at Denali using drainage basin area ratios.

TABLE 7

DEVIL CANYON PROJECT

MECHANICAL EQUIPMENT

	USBR March 1961*	Alaska Power Administration May 1974**	Corps of Engineers 1979***
1. GENERAL			
Capacity	580 MW	600 MW	776 MW
Total Head	530 ft	550 ft	520 ft
Powerhouse type	surface	underground	underground
Number of units	8	4	4
2. HYDRAULIC CONDITIONS			
Headwater level			
- maximum	EL 1455	EL 1455	EL 1455
- normal	EL 1450	-	EL 1450
- minimum	EL 1275	EL 1275	EL 1275
Tailwater level			
- maximum	EL 897	EL 924	EL 924
- normal	EL 875	-	-
- minimum	EL 870	EL 878	EL 878
Gross Head			
- maximum	585 ft	577 ft	577 ft
- minimum	405 ft	351 ft	351 ft
Net Head			
- maximum	570 ft	-	-
- rated	530 ft	550 ft	520 ft
- minimum	395 ft	-	-
3. TURBINES			
Type	vertical Francis	vertical Francis	vertical Francis
Rated power (each)	100,000 hp	205,000 hp	265,000 hp (best gate)
Rated net head	530 ft	550 ft	520 ft
Centerline distributor	EL 881	EL 867	EL 867
Submergence (minimum)	- 11 ft	11 ft	11 ft
4. GENERATORS			
Type	vertical synchronous	vertical synchronous	vertical synchoronous
Rated power	72.5 MW	150 MW	194 MW

*Reference No. 3
**Reference No. 5
***Reference No. 11

TABLE 7 (Cont'd)

	USBR March 1961	Alaska Power Administration May 1974	Corps of Engineers 1979
5. POWERHOUSE CRANES			
Type	overhead travelling bridge		
Number	-	2	2
Capacity (each)..........	350 tons	225 tons	425
Span	-	68 ft	72 ft
6. PENSTOCK VALVES			
Number	eight	none	none
Type	butterfly	-	-
Diameter	11.5 ft	-	-
Head to centerline	355 ft	-	-
7. INTAKE GATES			
Number	2	4	4
Type	fixed wheel	bonneted fixed wheel	bonneted fixed wheel
Width	26 ft (approx)	15	18
Height	26 ft (approx)	15	18
Head to centerline........	210 feet	588 ft.	588 ft.
Hoist....................	hydraulic	hydraulic	hydraulic
8. INTAKE BULKHEAD GATES	none	-	3 sets of slots with several sets of stoplogs to premit water to be drawn from various elevations.
9. TRASHRACKS			
Number	2	2	2
Configuration	sloping, semi-circular	vertical, semi-vertical	vertical, semi-circular
10. DRAFT TUBE GATES			
Number of openings per turbine..................	3	2	2
Type of gate.............	bulkhead	bulkhead	bulkhead
Handling	5 ton gantry crane (outside)	powerhouse crane	powerhouse crane
11. TAILRACE TUNNEL STOPLOGS	None		
Number of openings........	-	2	2
Sill beam	-	El 850	El 850
Stoplog handling..........	-	-	-

TABLE 7 (Cont'd)

	USBR March 1961	Alaska Power Administration May 1974	Corps of Engineers 1979
12. SPILLWAY CREST GATES			
Number	2	none	2
Type	radial	-	radial
Width	-	-	64 ft (approx)
Height	64 ft.	-	42.5 ft
Hoist	wire rope	-	wire rope
13. LOW LEVEL OUTLETS (Main Gates)			
Number	none	6	4
Type	-	vertical fixed wheel	bonnetted slide
Width	-	-	7.5
Height...................	-	-	11 ft
Head to centerline	-	70	380 ft
Hoist....................	-	-	hydraulic
14. LOW LEVEL OUTLETS (Emergency Gates)			
Number	none	none	4
Type	-	-	as per main gate
15. LOW LEVEL OUTLET TRASHRACKS	none	none	none
16. OUTLET VALVES			
Number	1	1	none
Type	hollow jet	jet flow	-
Diameter.................	66	-	-
Head to centerline.......	575 ft	-	-
17. OUTLET VALUE CLOSURE GATE			
Type	ring follower gate	ring follower gate	-
Size	66 in.	-	-
Head to centerline.......	575 ft.	-	-
18. OUTLET VALVE TRASHRACKS			
Number of sets	1	1	none
Configuration............	vertical semi-circular	vertical semi-circular	-
19. DIVERSION CLOSURE GATES			
Number...................	2	2	1 set
Type.....................	vertical	vertical	wheeled bulkhead
Width....................		-	26 ft
Height		-	36 ft approx
Head to centerline:		-	
- during closure			18 ft approx
- after closure		-	594

TABLE 8

WATANA PROJECT

MECHANICAL EQUIPMENT

	Corps of Engineers 1979*
1. GENERAL	
Total Capacity	792 MW
Head	580
Powerhouse type	underground
Number of units	3
2. HYDRAULIC CONDITIONS	
Headwater level:	
- maximum	EL 2190
- normal	EL 2185
- minimum	EL 1940
Tailwater level:	
- normal	EL 1465
Gross head:	
- maximum	725 ft (approx)
- minimum	475 ft (approx)
Rated net Lead	580 ft
3. TURBINES	
Type	vertical Francis
Rated power (each)	362,000 hp (best gate)
Rated net Lead	580 ft.
Centerline distributor	1460
Submergence (average)	5 ft.
4. GENERATORS	
Type	vertical synchronous
Rater power	264 MW
5. POWERHOUSE CRANES	
Type	overhead travelling bridge
Number	2
Capacity (each)	600 tons
Span	72 ft
6. PENSTOCK VALVES	None

*Reference 11

TABLE 8 (Cont'd)

7. INTAKE GATES

Number	3
Type	bonnetted fixed wheel
Width	18 ft.
Height	18 ft.
Head to centerline	730 ft.
Hoist	hydraulic

8. INTAKE BULKHEAD GATES --

9. TRASHRACKS

Number	2
Configuration	vertical semi-circular

10. DRAFT TUBE GATES

Number of Openings per turbine	2
Type of Gate	bulkhead
Handling	overhead travelling case

11. TAILRACE TUNNEL STOPLOGS

Number of openings	1
Sill beam	EL 1405

12. SPILLWAY CREST GATES

Number	3
Type	radial
Width	55 ft.
Height	45 ft.
Head to sill	44 ft.
Hoist	wire rope

13. SPILLWAY STOPLOGS

Number of sets of guides	3
Number of sets of stoplogs	1
Sill beam	EL 2147
Width	55 ft.
Height	46 ft.

TABLE 8 (Cont'd)

	High Level	Low Level
14. OUTLETS (Main Gate)		
Number	2	2
Type	radial	radial
Width	10 ft	10 ft
Height	14 ft	14 ft
Head to centerline	250 ft	490 ft
Hoist	hydraulic	hydraulic
15. OUTLETS (Emergency Gate)		
Number	2	2
Type	bonnetted slide gate	bonnetted slide gate
Width	10 ft	10 ft
Height	14 ft	14 ft
Head to centerline	250 ft	490 ft
Hoist	hydraulic	hydraulic

16. OUTLET TRASHRACKS

Number of sets	2
Configuration	flat, slightly sloping

17. DIVERSION CLOSURE GATES

Number	1 set
Type	wheeled bulkhead
Width	30 ft
Height	38 ft (approx)
Head to centerline	239 ft

18. DIVERSION PLUG SLIDE GATES

Type	bonneted slide gate
Number	2
Width	6.75 ft
Height	10 ft
Head to centerline:	
- for control	255 ft
- after closure	730 ft
Hoist	hydraulic

TABLE 9

DEVIL CANYON PROJECT

DENALI DAM - MECHANICAL EQUIPMENT

	USBR March 1961*
OUTLET WORKS CONTROL GATES	
Number	3
Type	radial
Width	10
Height	12
Head to Centerline	210 ft.
Hoist	hydraulic
OUTLET WORKS EMERGENCY GATES	
Number	3
Type	bonnetted slide gates
Width	10
Height	16
Head to centerline	208 ft
Hoist	hydraulic

*Reference No. 3

Table 10

HYDROPOWER PARAMETERS

Site/Scheme (Pool El. ft.	Approx Max Head (ft)	Installed Capacity (MW)	Dependable Capacity (MW)	Average Annual Energy ($x10^9$ kWh)	Firm Energy ($x10^9$ kWh)	% of River Potential*	Remarks
Gold Creek	190	260			1.139	17%	Referred to as Gold Site in Reference 13
Olson (920)	45						
Olson (1020)	145		187	0.915	0.821	13%	With U/S Regulation
Devil Canyon(1450)	570		206	1.489	0.900	21%	
High D.C. (1750)	720	700	600	3.346	2,628	47%	
Devil Creek							
Low Watana (1905)	425	420	252	1.550	1.104	22%	
Mid Watana (2050)	570	500	457	2.601	1.997	36%	
High Watana (2200)	720	792	686	3.346	3.004	47%	
Susitna III	600	445			1.840	28%	Reference
Vee (2300)	375		300	1.450	1.310	20%	With U/S Regulation
Vee (2350)	425						
Maclaren							
Denali (2535)	----------------	----------------	----------------	NO POWER GENERATION	----------------	----------------	----------------
Butte Creek							
Tyone							
Devil Canyon (1450) Denali (2535)	570	-	575	3.300	2.500	46%	
Devil Canyon (1450) Low Watana (1905)	995	-	730	4.485	3.200	62%	
Devil Canyon (1450) Mid Watana (2050)	1140	-	1,062	5.630	4.650	78%	
Devil Canyon (1450) High Watana (2200)	1290	1568	1,404	6.850	6.150	95%	

Table 10 (Cont'd)

HYDROPOWER PARAMETERS

Site (Poll El.)	Approx Max Head (ft)	Installed Capacity (MW)	Dependable Capacity (MW)	Average Annual Engrgy ($x10^9$ kWh)	Firm Energy ($x10^9$ kWh)	% of River Potential*	Remarks
Devil Canyon (1450) High Watana (2200) Denali (2535)	1290		1,552	6.911	6.800	96%	
Susitna I Susitna II Susitna III	1455	1,308		6.309		88%	Reference 6
Devil Canyon (1450) Low Watana (1905) Vee (2300) Denali (2535)	1370		1,427	6.881	6.252	96%	USBR four dam proposal
Olson (1018) High Devil Canyon (1750) Vee (2300) Denali (2535)	1238		1,347	6.511	[illegible].900	91%	Kaiser four dam proposal
Devil Canyon Watana Vee Denali Olson				7.181+	6.552	100%	

NOTES:

All data obtained from US Corps 1975 Study (7) unless otherwise indicated.

* Percent of Average Annual Energy with Devil Canyon, Watana, Vee, Denali; Olson assumed to 100%

TABLE 11
UPPER SUSITNA ENVIRONMENTAL DATA BASE FOR INPUT INTO THE SELECTION OF DEVELOPMENT SITES
(Includes only information that varies between reaches)

	Talkeetna to Devil Canyon (Reach A)	Devil Canyon to Watana (Reach B)	Watana to Vee (Reach C)	Vee to Maclaren (Reach D)	Maclaren to Denali (Reach E)	Upstream from Denali (Reach F)
Biological						
Fisheries	- Resident & migratory salmon - Provides salmon access to Portage Creek and Indian River	- No anadromous fish	- Inundation of part of Deadman & Kosina Creek	- Inundation of part of Oshetna and Tyone River		
Wildlife	- Moose habitat in river valley downstream of Portage Creek	Nelchina Caribou herd - Summer range north of Susitna River - Summer & winter range south of Susitna River - Migration in the area of Fog Creek	Caribou - Calving area south of Susitna River in the area of Kosina Creek - Migration in the Jay Creek area - Ranges as stated for Reach B	- Inundation of posible moose winter range - Medium waterfowl density - Caribou migration in the area of Oshetna River	- Brown Grizzly bear denning adjacent to reservoir area - Good moose habitat - Medium water-fowl density	- Water fowl nesting area - Good moose habitat - Medium waterfowl density
Vegetation	- Mainly upland or lowland spruce-hardwood forest	-	- Moose habitat Watana Creek	-	- Fragile moist & alpine tundra	- Fragile moist & al-pine tundra
Social						
Aesthetic	-	- Unique Devil Canyon	-	- Moderately unique Vee Canyon	-	-
Recreation	-	- White water kayaking Class IV Devil Canyon	-	-	-	-
Access	- Access road would open up minimal area of wilderness	- Access road would open up moderate area of wilderness	- Access road would open up moderate area of wilderness	- Access road would open up large areas of wilder-ness presently inaccessible	- Access road would open up large areas of wilderness presently inaccessible	- Reservoir could have access from the Denali Highway, therefore impact on wilderness area minimal

Table 12

ENVIRONMENTAL RANKING OF SITES

River Section	Type of Develop.	Biological		Social		Institutional	Overall
		Fish	Wildlife	Local	Reg.		
Gold Creek	a b	M	M	M	L	X	M-H
Olson (Susitna II)	a b	M	M	M	L	X	M-H
Devil Canyon	a b	L	L	M-H	M-H	M	M-L
Devil Canyon (Susitna I)	a b	L	M	M-H	M-H	M	M-M
Devil Creek	a b	L	M	M-H	M	M	M-M
Watana	a b	L	M-H	M-H	L-M	M	M-M
Susitna III	a b	L-M	M-H	M-H	M-H	M-H	M-M
Vee	a b	L-M	M-H	M	M-H	M-H	M-H
McLaren	a b	L-M	M-H	L-M	L-M	M-H	M-L
Denali	a	L	M-H	L-M	M	M-H	M-L
Butte Creek	a	L	M-H	L-M	L-M	M	M
Tyone	a	L	M-H	L-M	H	M-H	M-H

Type of development: a) independent development
b) development with upstream regulation

Type of impact: L: Potential for Low Impact; H: Potential for High Impact; M: Potential for Moderate Impact; X: Potentially Unacceptable

Table 13

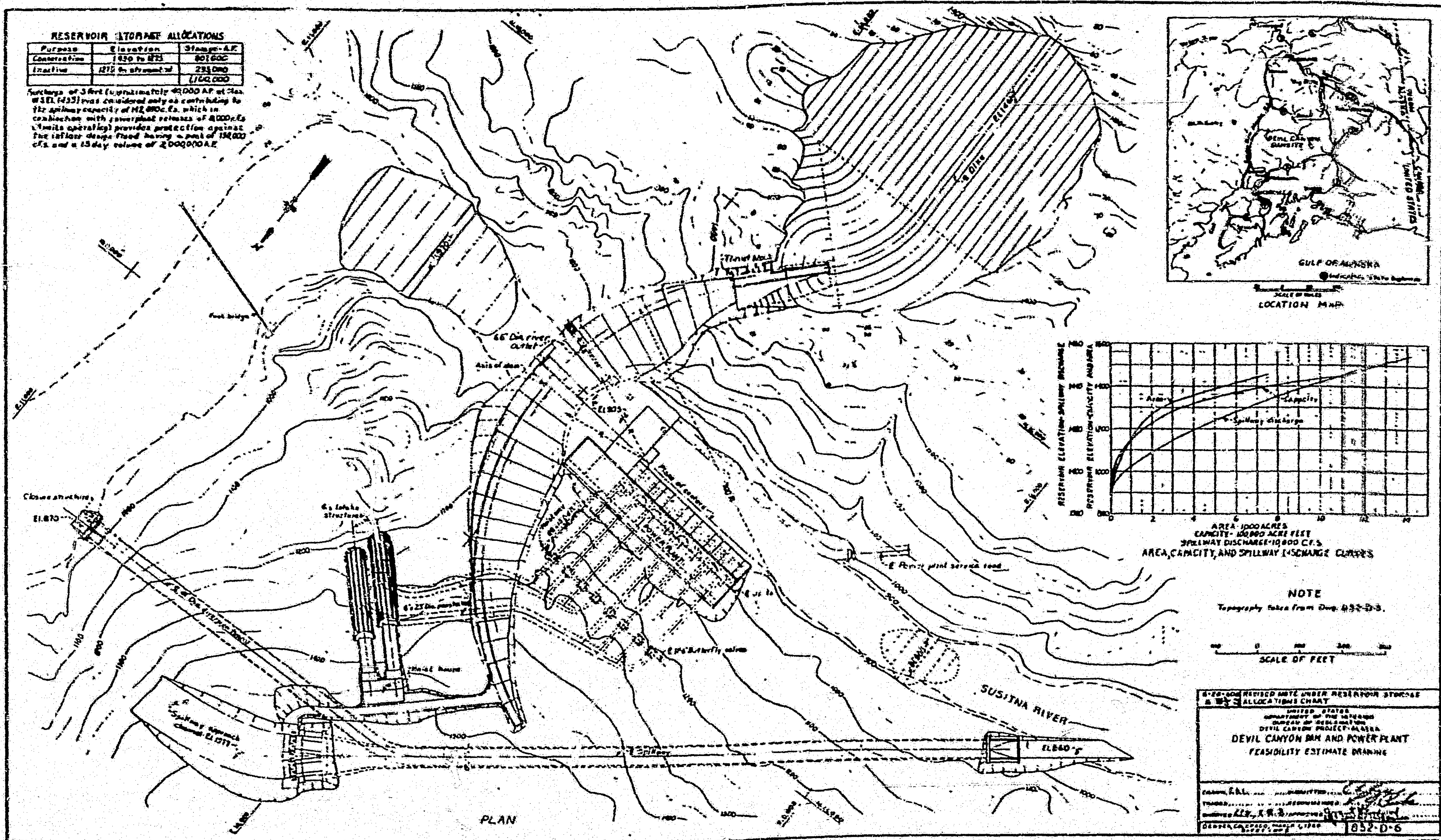
COST COMPARISON

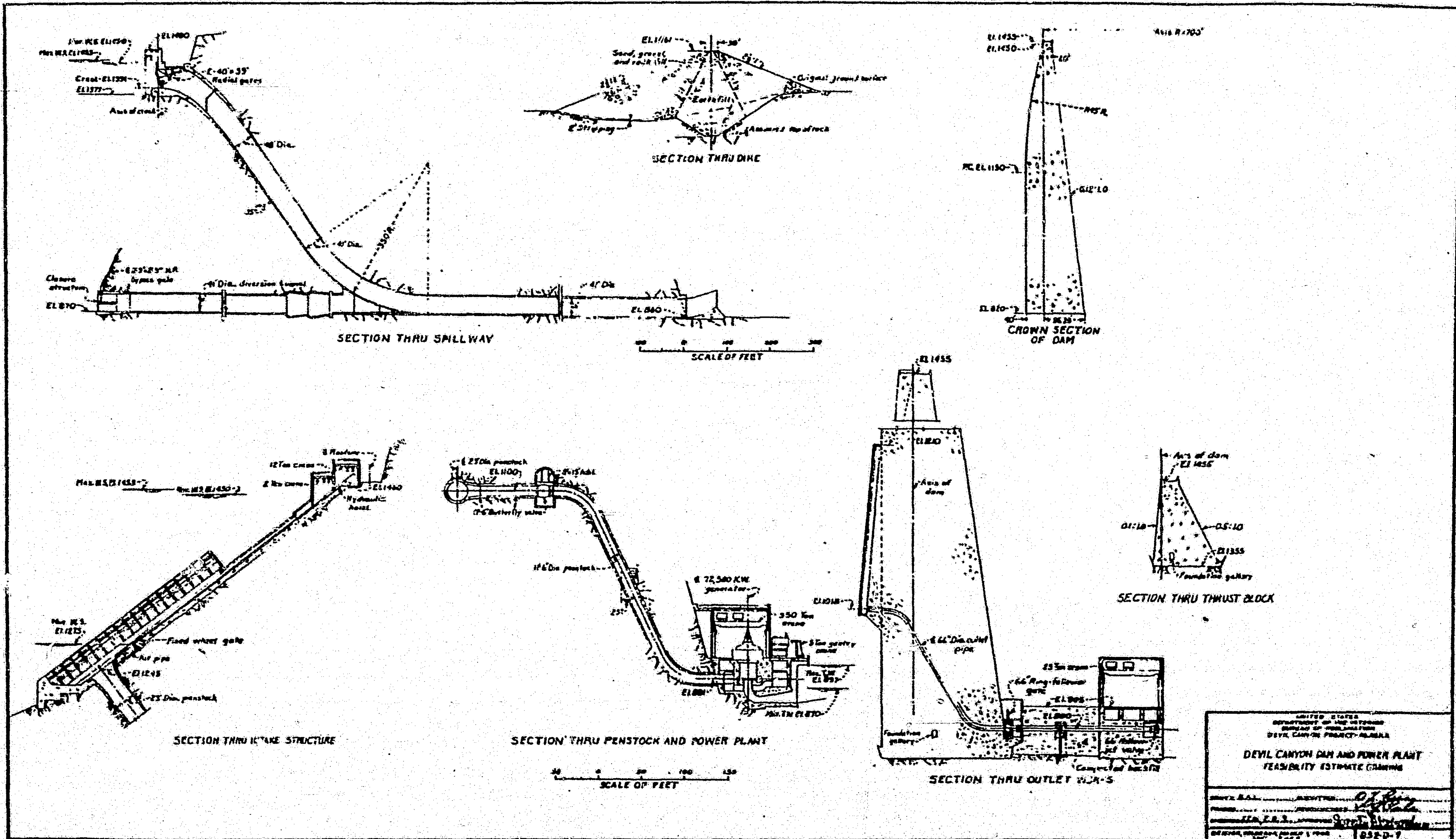
Site (Pool El.)	Estimated Cost (1) ($ x 10^6)	Year of Estimate	Escalation Factor (Whitman Index)	1980 Cost (x10^6$)	Dependable Capacity (MW)	Cost/ kW ($)	Avg. Annual Energy (10^6 kWh)	Cost/Avg. Energy Cost Cost (9) ($/1000Wh)	Notes
Gold Creek	338	1968	550/210	885	260 (4)	3,404	1,139 (5)	117	(3)(6)
Olson (920)	-	-	-	-	-	-	-	-	-
Olson (1020)	380	1975	550/377	554	187	2,964	915	91	*(3)(6)
Devil Canyon Arch (1450)	714	1975	550/377	1,042	206	5,056	1,489	105	*(2)
	432	1975	550/377	630	695	906	3,340	28	*(3)(6) with H. Watana
	463	1975	550/377	675	206	3,277	1,489	68	*(8)
Devil Canyon Gravity (1450)	535	1975	550/377	780	206	3,286	1,489	79	*(7)
	535	1975	550/377	780	695	1,122	3,340	35	*(7)(6)(3)
	823	1978	550/495	914	695	1,315	3,340	41	(3)(6) with H. Watana
High Devil Canyon (1750)	1,266	1975	550/377	1,846	600	3,078	3,346	83	*(2)
	1,015	1975	550/377	1,481	600	2,470	3,346	67	*(8)
Devil Creek	-	-	-	-	-	-	-	-	-
Low Watana (1905)	668	1975	550/377	975	252	3,868	1,550	94	*(2)
	420	1975	550/377	613	252	2,431	1,550	59	*(3)
Mid Watana (2050)	877	1975	550/377	1,279	457	2,800	2,601	74	*(2)
	628	1975	550/377	916	457	2,004	2,601	53	*(3)
High Watana (2200)	1,088	1975	550/377	1,587	686	2,313	3,346	71	*(2)
	837	1975	550/377	1,221	686	1,780	3,346	55	*(3)
	1,765	1978	550/495	1,961	686	2,859	3,346	88	*(2) Revised Estimate
Susitna III	---	---	------	----	---	-----	-----	--	-
Vee (2300)	477	1975	550/377	696	300	2,320	1,450	72	*(3)(6)
Vee (2350)	527	1975	550/377	769					*(3)
Maclaren	-	-	-	-	-	-	-	-	-
Denali (2335)	340	1975	550/377	496	None		None		*(3)
Denali (2552)	134	1960	550/170	433	None		None		
Denali (2590)	80	1953	550/122	331	None		None		
Butte Creek	-	-	-	-	-	-	-	-	-
Tyone	-	-	-	-	-	-	-	-	-

* Estimated in same base year therefore best for comparison purposes
(1) Generally includes contingencies but not IDC
(2) Constructed first (i.e. includes main access road and transmission line)
(3) Subsequent development
(4) Installed capacity
(5) Firm energy
(6) With U/S Regulation
(7) 1978 cost adjusted back to 1975 using relative costs of Arch Dam and Gravity Dam, Page B-9, Corps 1979 Report (7) and escalted to 1980 costs
(8) Constructed first but excludes common costs of transmission lines and roads ($251,000,000 - 1975 $'s)
(9) Based on annual cost equal to 15% of Capital Cost.

APPENDIX - A

PROJECT LAYOUTS

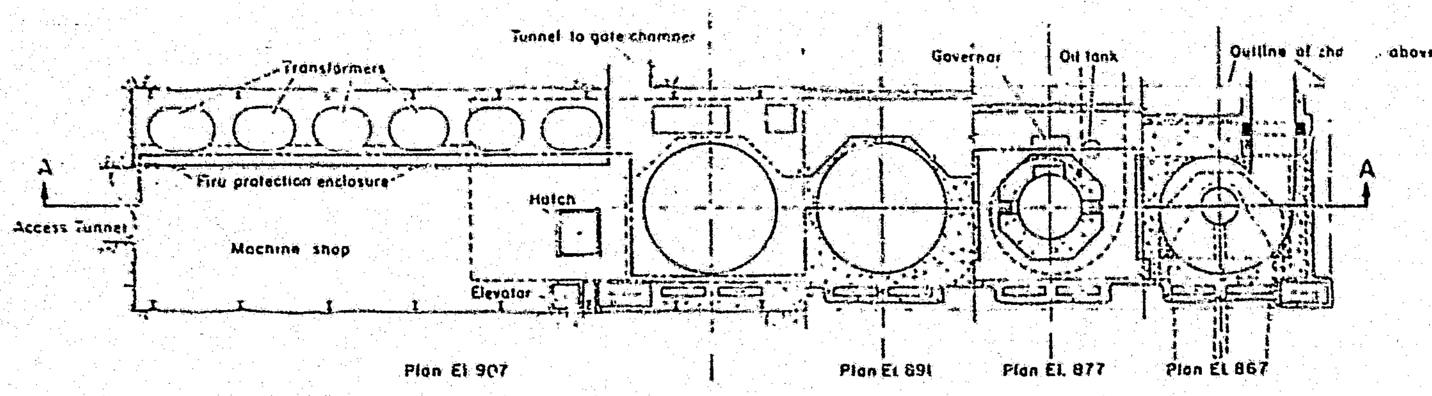

RESERVOIR STORAGE ALLOCATIONS
Purpose
Elevation
LOCATION MAP
GULF OF ALASKA
AREA, CAPACITY, AND SPILLWAY DISCHARGE CURVES
NOTE
SCALE OF FEET
SUSITNA RIVER
PLAN
Closure structure
Hoist house
DEVIL CANYON DAM AND POWER PLANT
FEASIBILITY ESTIMATE DRAWING
852-D-6


SECTION THRU SPILLWAY
SECTION THRU DIKE
CROWN SECTION OF DAM
SCALE OF FEET
SECTION THRU INTAKE STRUCTURE
SECTION THRU PENSTOCK AND POWER PLANT
SECTION THRU OUTLET WORKS
SECTION THRU THRUST BLOCK
SCALE OF FEET
Radial gates
Original ground surface
Earthfill
Foundation gallery
Fixed wheel gate
Air pipe
25' Dia. penstock
Hydraulic hoist
350 Ton crane
Compacted backfill
DEVIL CANYON DAM AND POWER PLANT
FEASIBILITY ESTIMATE DRAWING
952-D-9

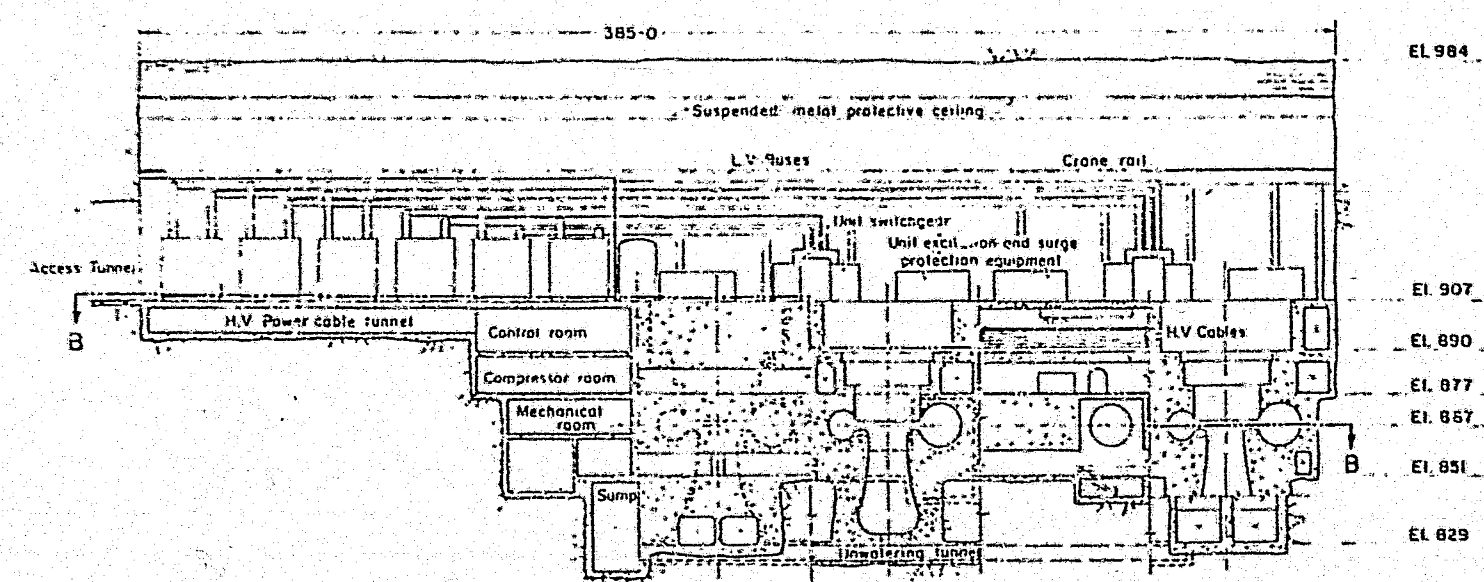
DEVIL CANYON DAM AND POWERPLANT

POWERPLANT PLAN AND SECTIONS

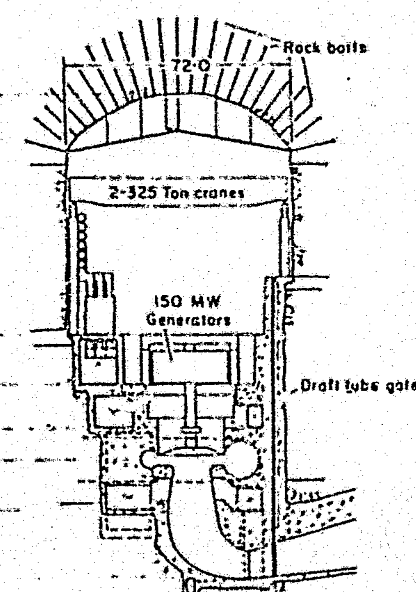
SCALE
0 20 40 60 80 100 120 FT



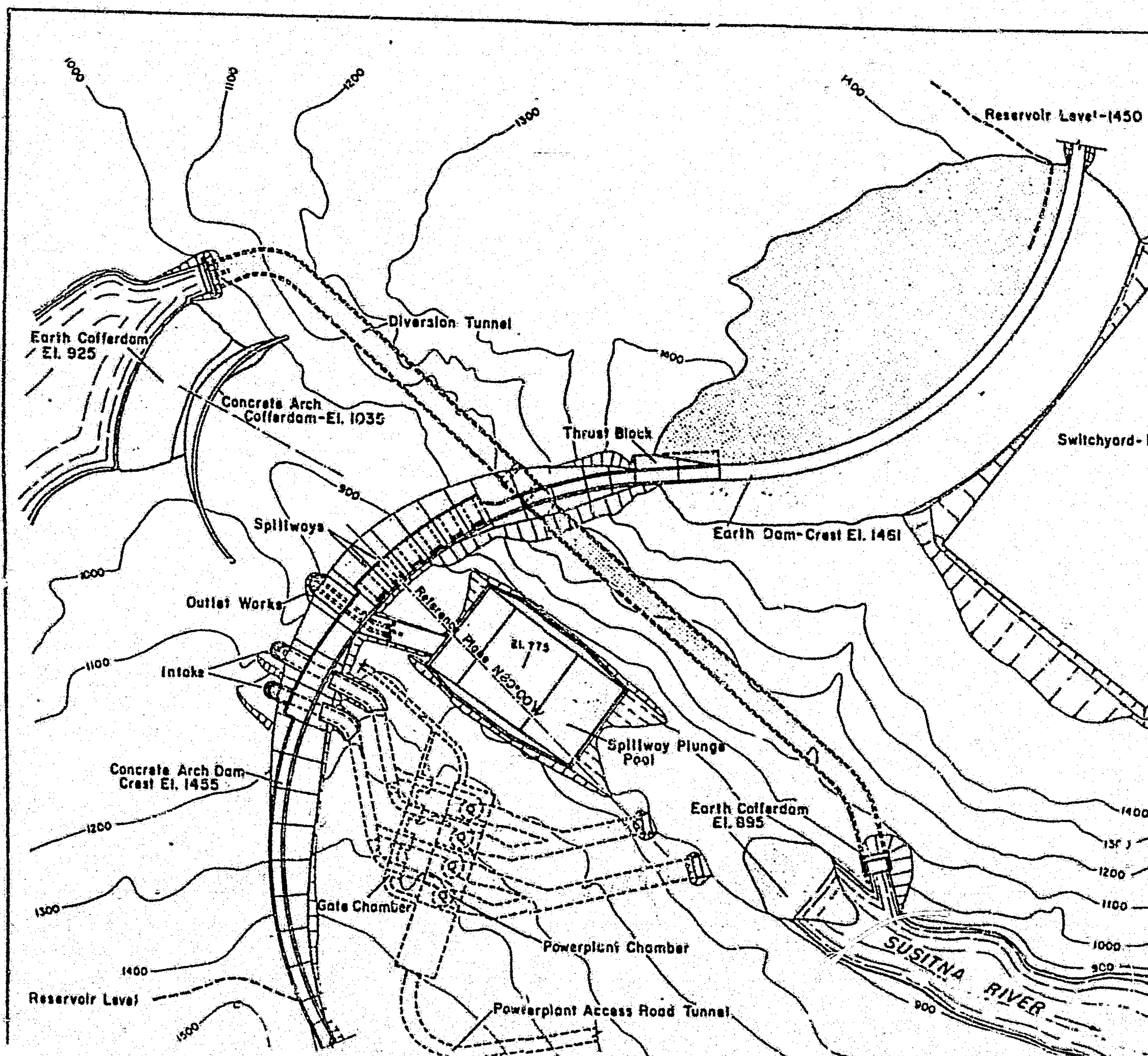
General plan
Section B-B



Longitudinal section
Section A-A



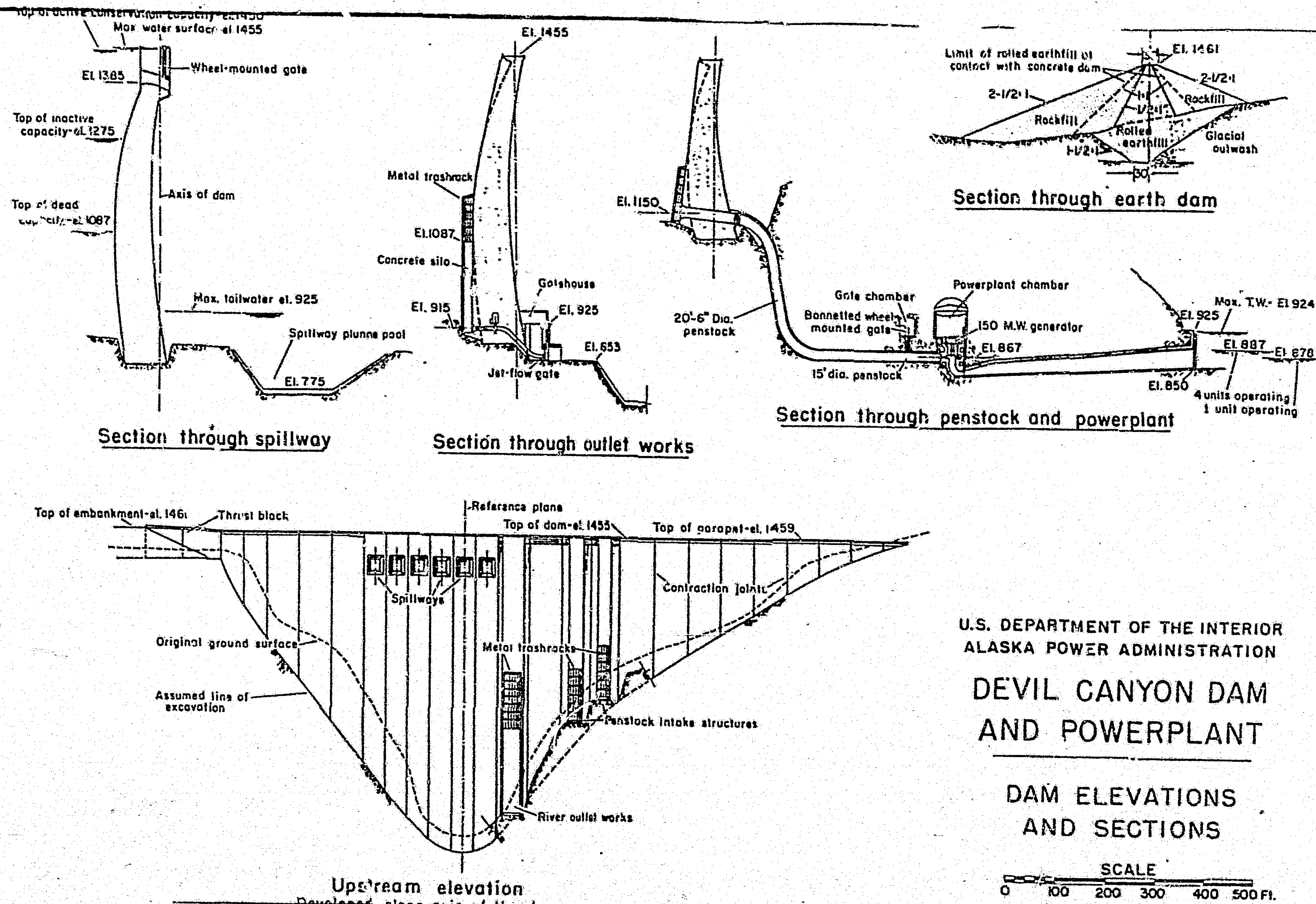
Transverse section
through ℄ of units



U.S. DEPARTMENT OF THE INTERIOR
ALASKA POWER ADMINISTRATION

DEVIL CANYON DAM AND POWERPLANT

GENERAL DAMSITE LAYOUT

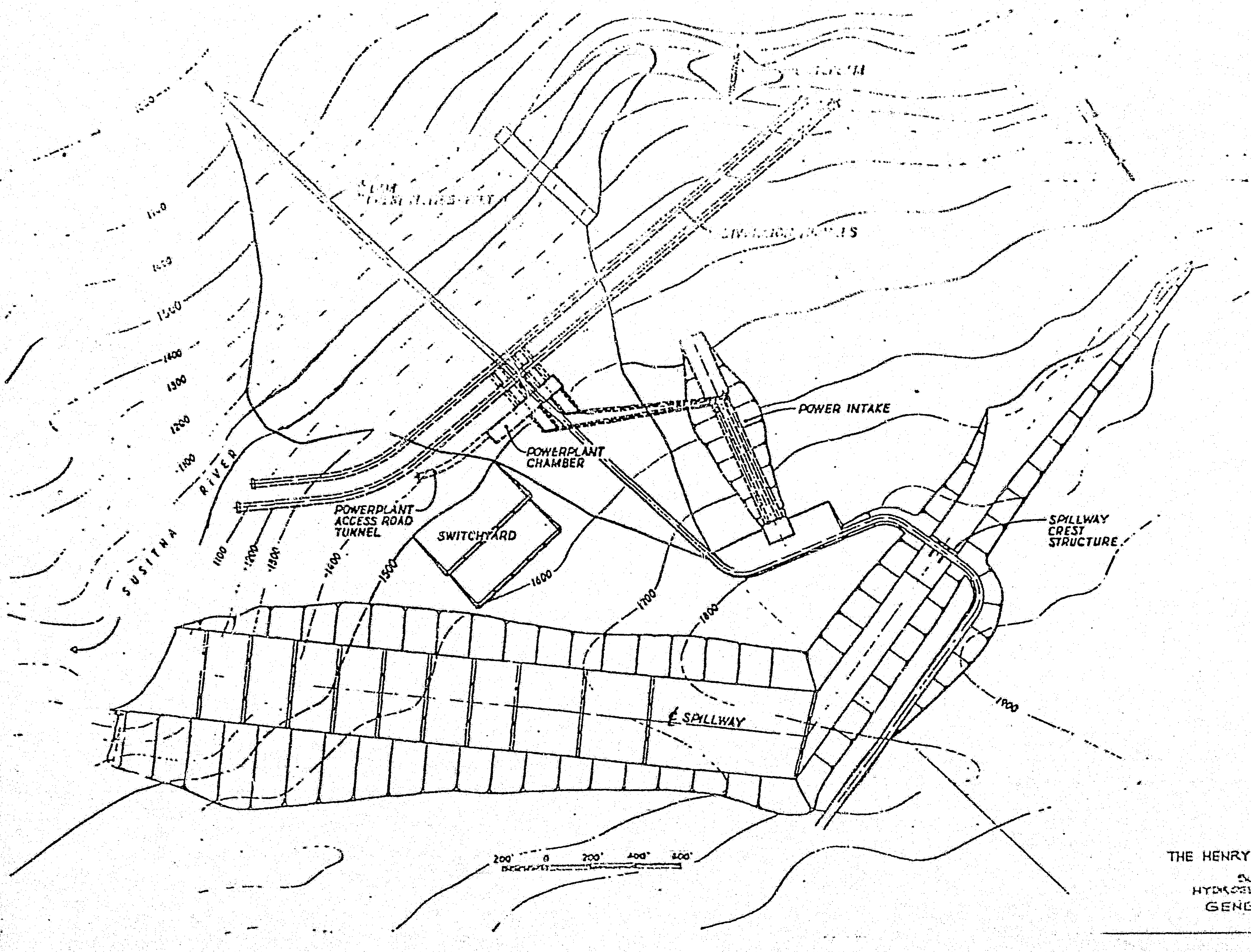


U.S. DEPARTMENT OF THE INTERIOR
ALASKA POWER ADMINISTRATION

DEVIL CANYON DAM AND POWERPLANT

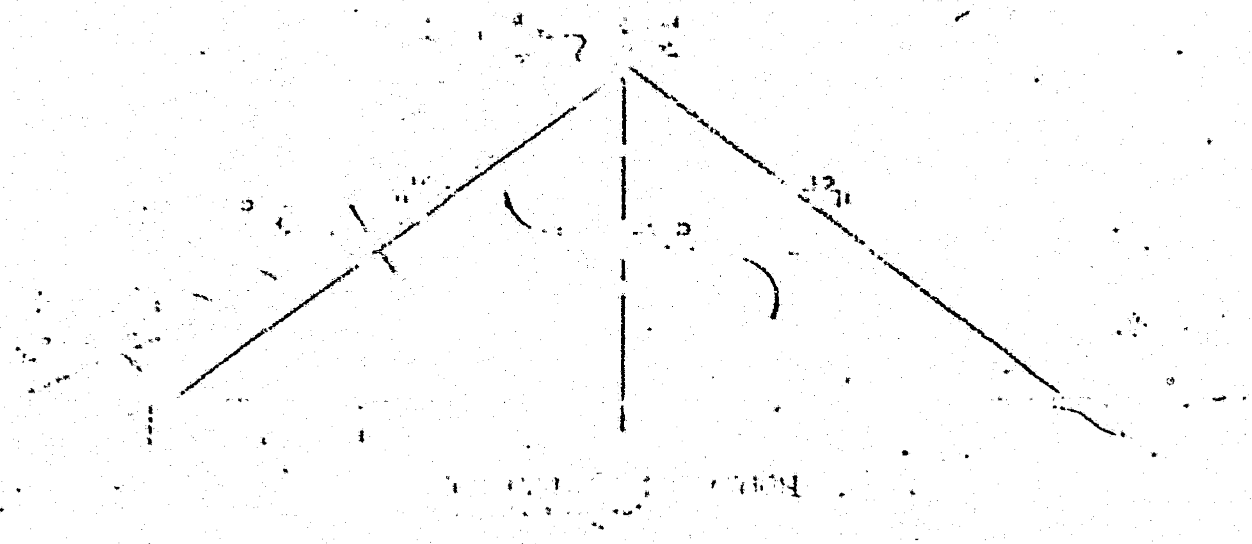
DAM ELEVATIONS AND SECTIONS

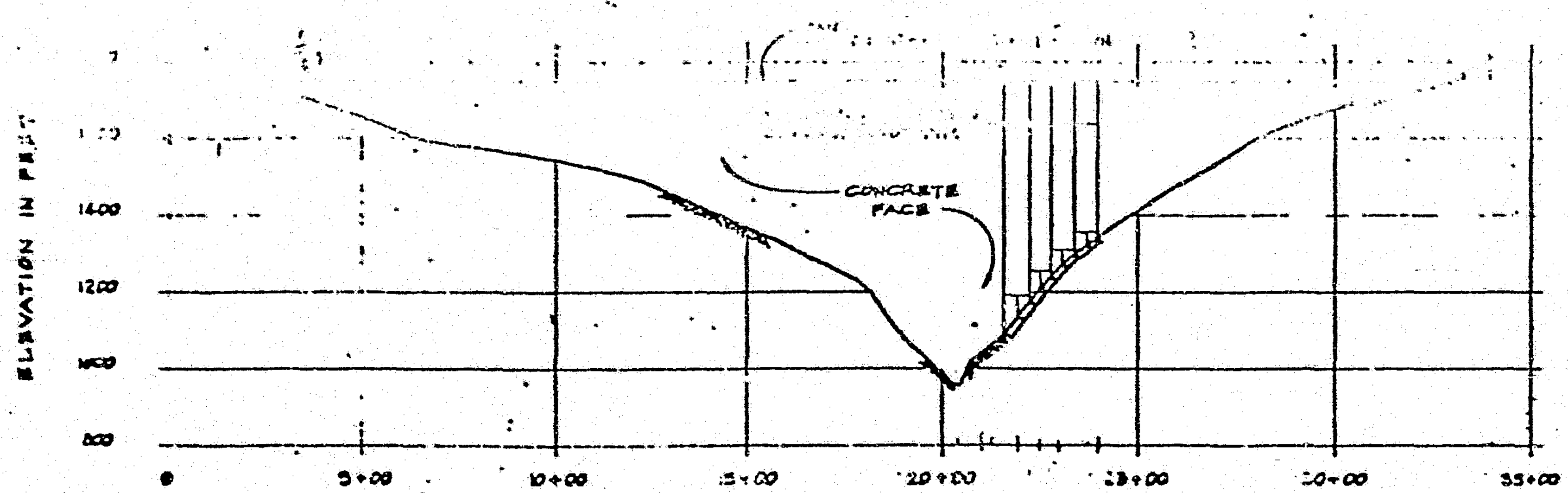
SCALE
0 100 200 300 400 500 Ft.



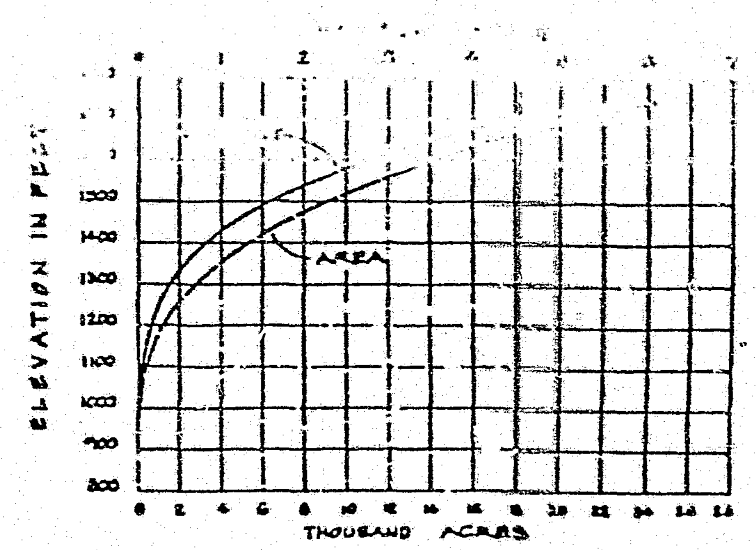
THE HENRY J. KAISER COMPANY

SUSITNA I
HYDROELECTRIC PROJECT
GENERAL LAYOUT

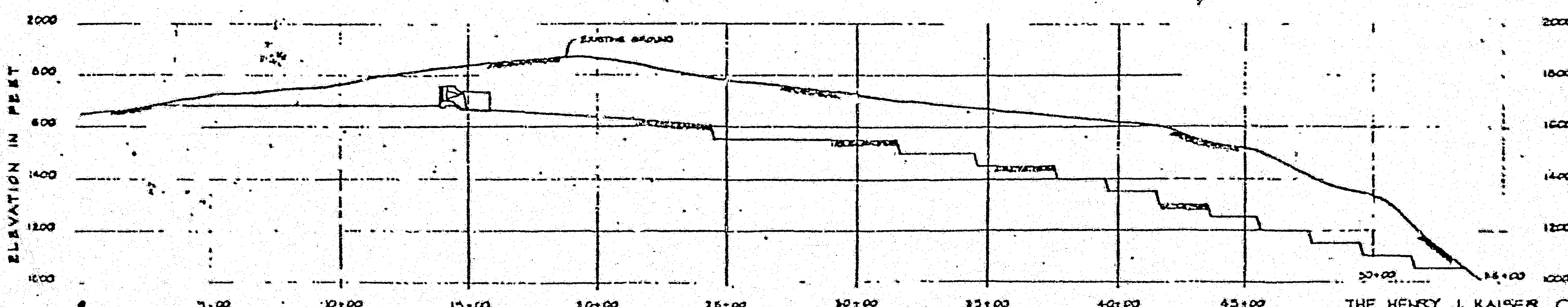




UPSTREAM ELEVATION OF DAM
SCALE 1" = 200' HORIZONTAL & VERTICAL



RESERVOIR AREA-CAPACITY CURVE



SPILLWAY & PROFILE
SCALE 1" = 200' HORIZONTAL & VERTICAL

THE HENRY J. KAISER COMPY.
SUSITNA I
HYDROELECTRIC PROJECT
SECTIONS

FIGURE VII

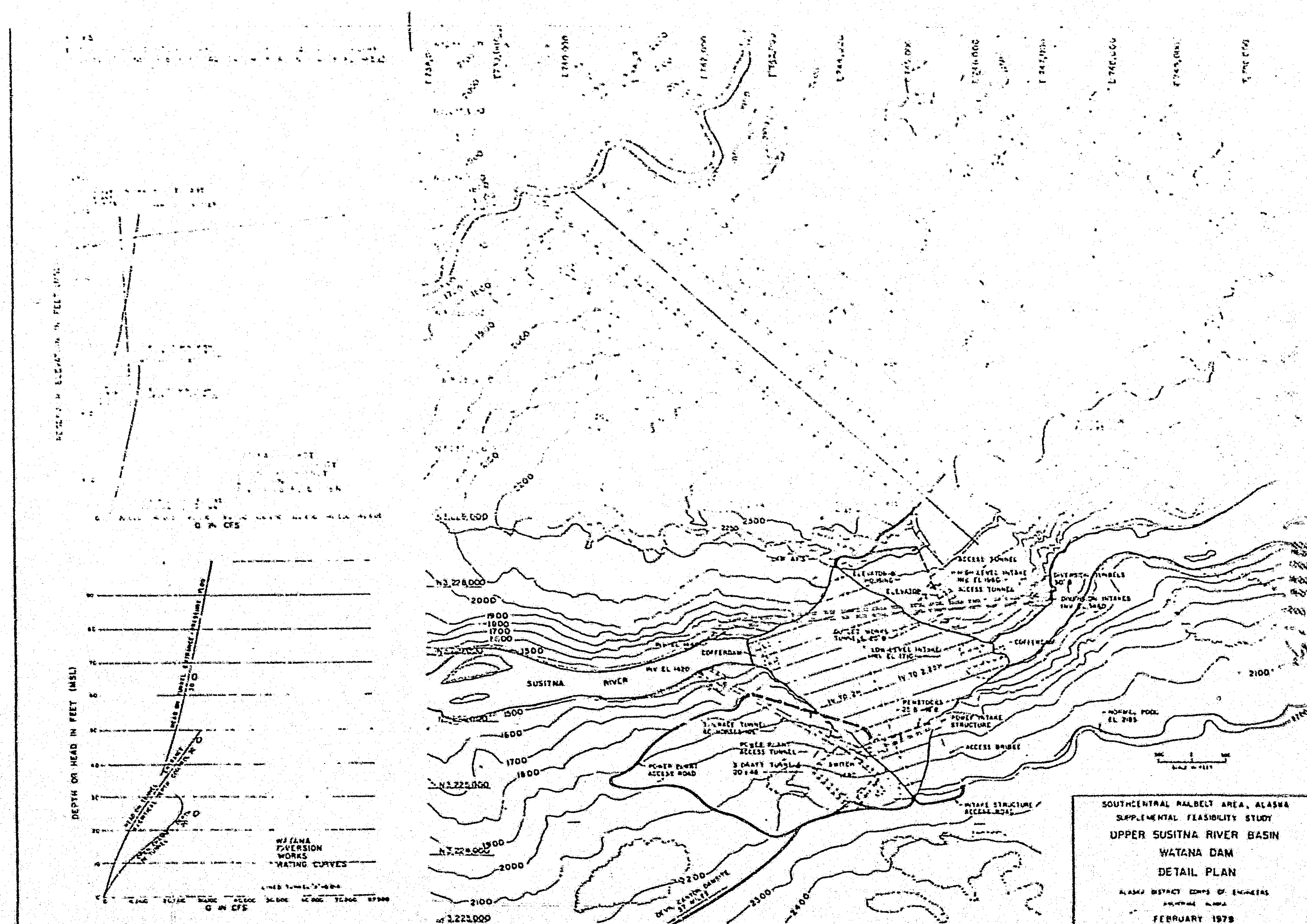

Q IN CFS
DEPTH OR HEAD IN FEET (MSL)
WATANA DIVERSION WORKS RATING CURVES
Q IN CFS
SUSITNA RIVER
ACCESS TUNNEL
COFFERDAM
PENSTOCKS
ACCESS BRIDGE
NORMAL POOL EL 2185
POWER PLANT ACCESS TUNNEL
POWER PLANT ACCESS ROAD
INTAKE STRUCTURE / ACCESS ROAD
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
DETAIL PLAN
ALASKA DISTRICT CORPS OF ENGINEERS
FEBRUARY 1979

PLATE B-2

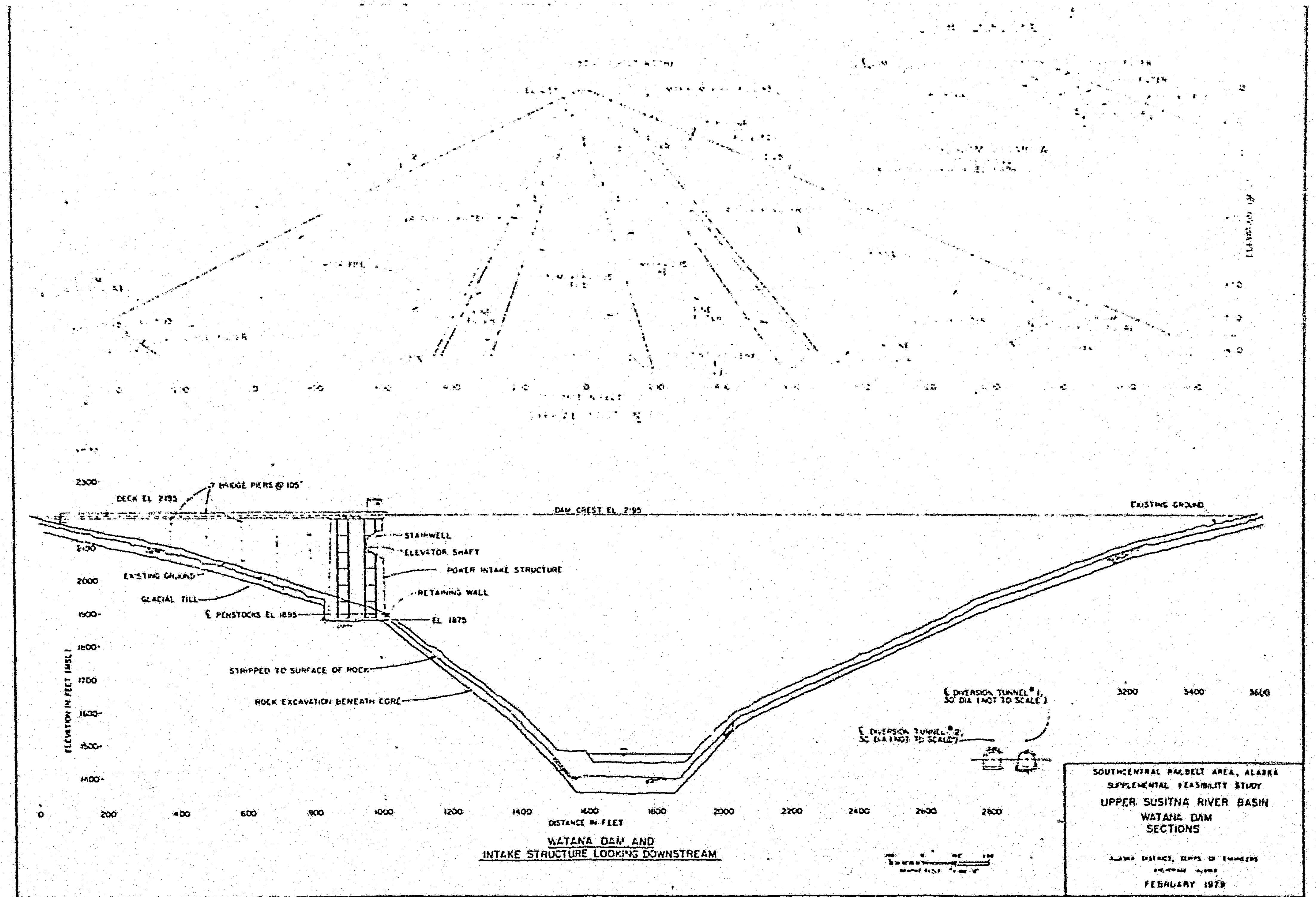
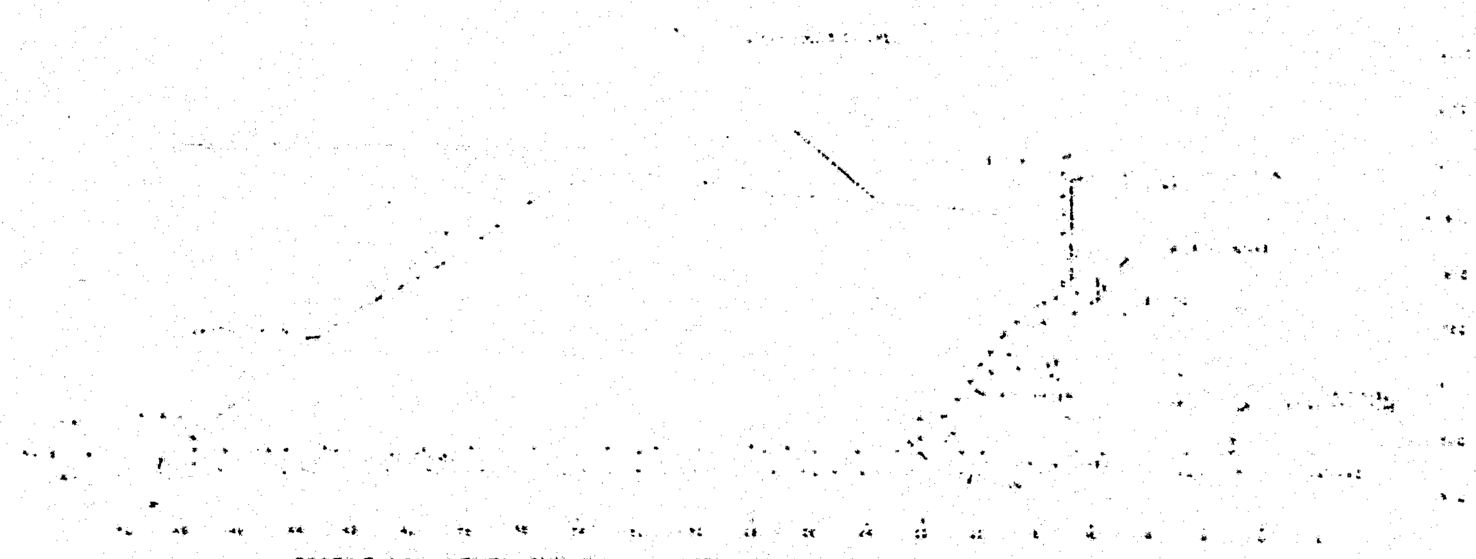
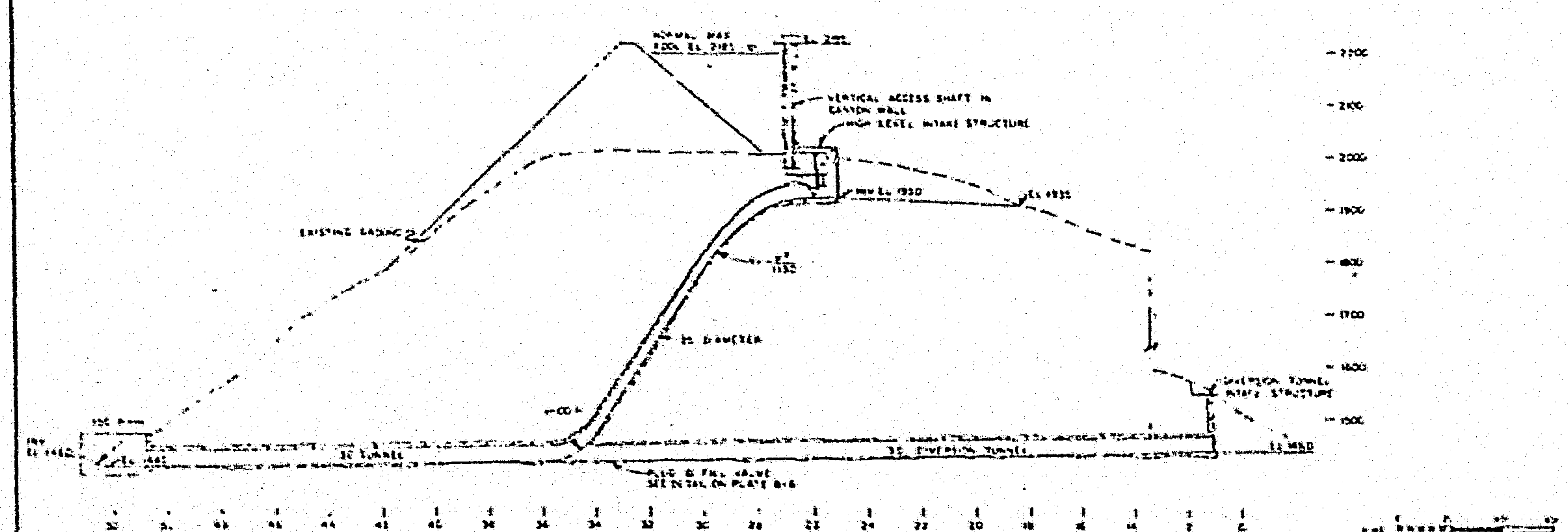

7 BRIDGE PIERS @ 105'
DECK EL 2195
DAM CREST EL 2195
EXISTING GROUND
STAIRWELL
ELEVATOR SHAFT
POWER INTAKE STRUCTURE
RETAINING WALL
EXISTING GROUND
GLACIAL TILL
℄ PENSTOCKS EL 1895
EL 1875
STRIPPED TO SURFACE OF ROCK
ROCK EXCAVATION BENEATH CORE
℄ DIVERSION TUNNEL # 1, 30' DIA (NOT TO SCALE)
℄ DIVERSION TUNNEL # 2, 30' DIA (NOT TO SCALE)
ELEVATION IN FEET (MSL)
DISTANCE IN FEET
WATANA DAM AND INTAKE STRUCTURE LOOKING DOWNSTREAM
SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
SECTIONS
FEBRUARY 1979

PLATE B-3



PROFILE LOW LEVEL OUTLET & DIVERSION TUNNEL #2



PROFILE HIGH LEVEL OUTLET & DIVERSION TUNNEL #1

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY

UPPER SUSITNA RIVER BASIN

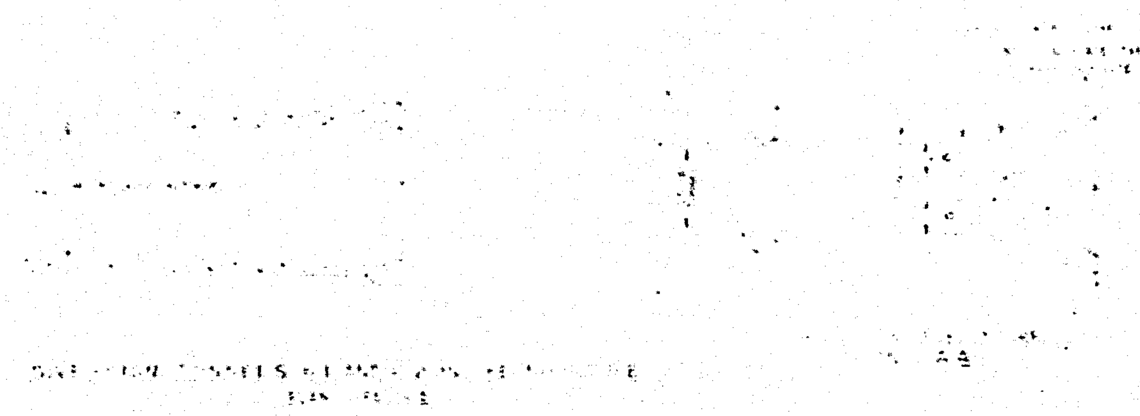
WATANA DAM

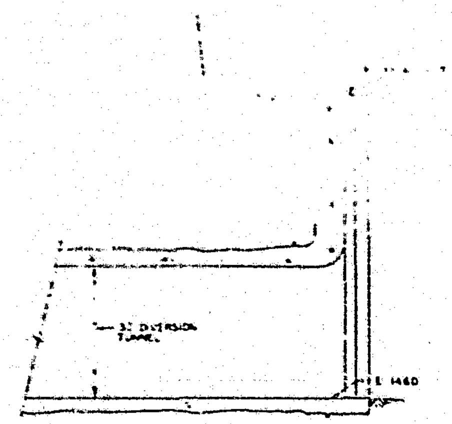
PROFILES

ALASKA DISTRICT, CORPS OF ENGINEERS

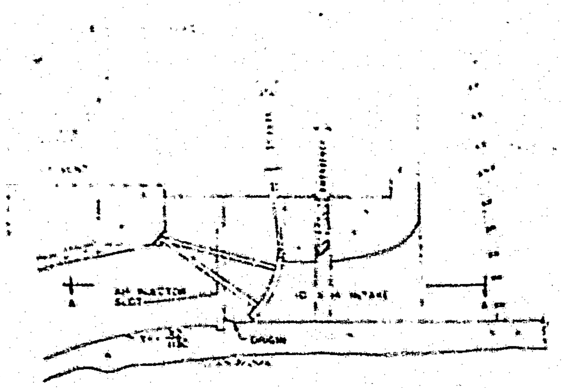
FEBRUARY 1979

PLATE B-4

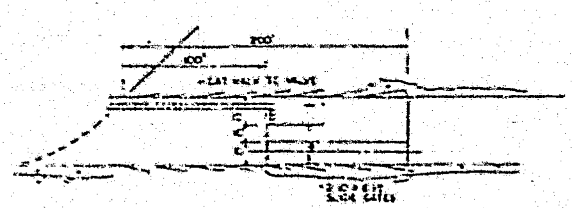




DIVERSION TUNNELS #1 AND #2 INTAKE STRUCTURE
SECTION



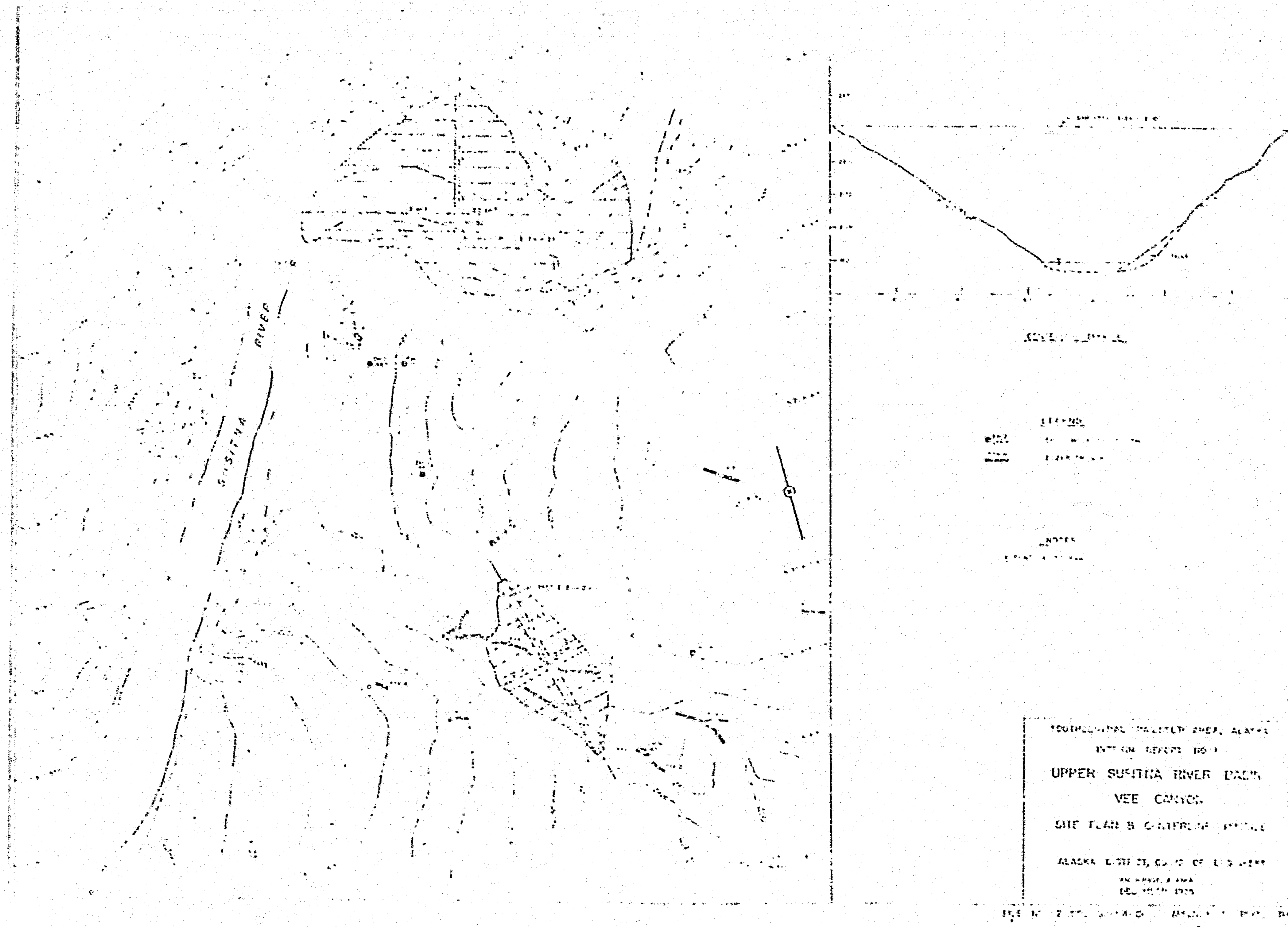
HIGH AND LOW LEVEL INTAKES
SECTION

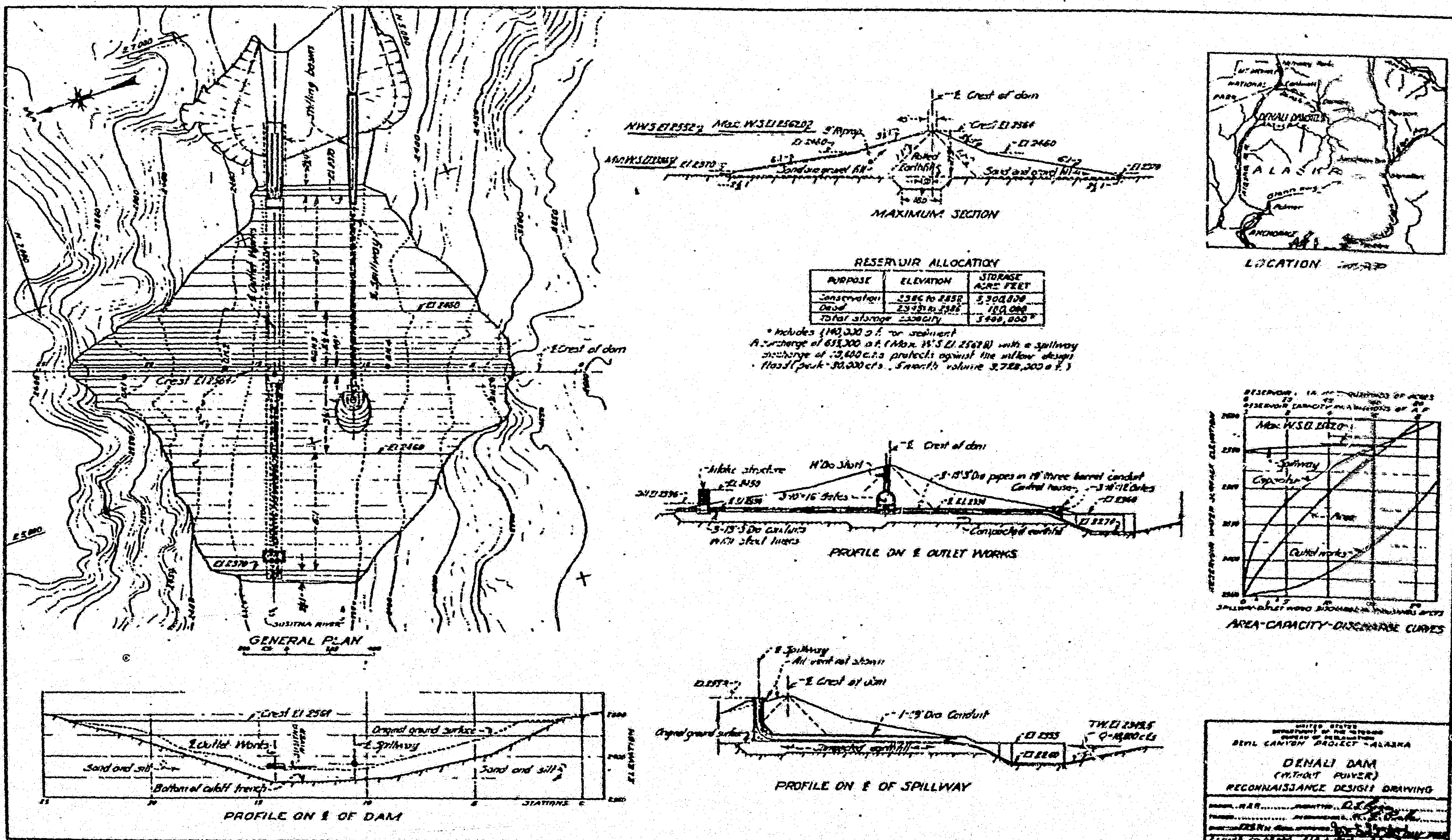


PLUG AND FILL VALVE DETAIL

SOUTHCENTRAL RAILBELT AREA, ALASKA
SUPPLEMENTAL FEASIBILITY STUDY
UPPER SUSITNA RIVER BASIN
WATANA DAM
DETAILS

FEBRUARY 1979


SUSITNA RIVER
UPPER SUSITNA RIVER
VEE CANYON



RESERVOIR ALLOCATION

PURPOSE	ELEVATION	STORAGE ACRE FEET
Conservation	2386 to 2552	3,300,000
Dead	2345 to 2386	100,000
Total storage capacity		3,400,000*

* Includes 140,000 a.f. for sediment
A surcharge of 655,000 a.f. (Max. W.S. El. 2562.0) with a spillway discharge of 13,600 c.f.s. protects against the inflow design flood (peak 30,000 c.f.s., 5 month volume 3,728,000 a.f.)

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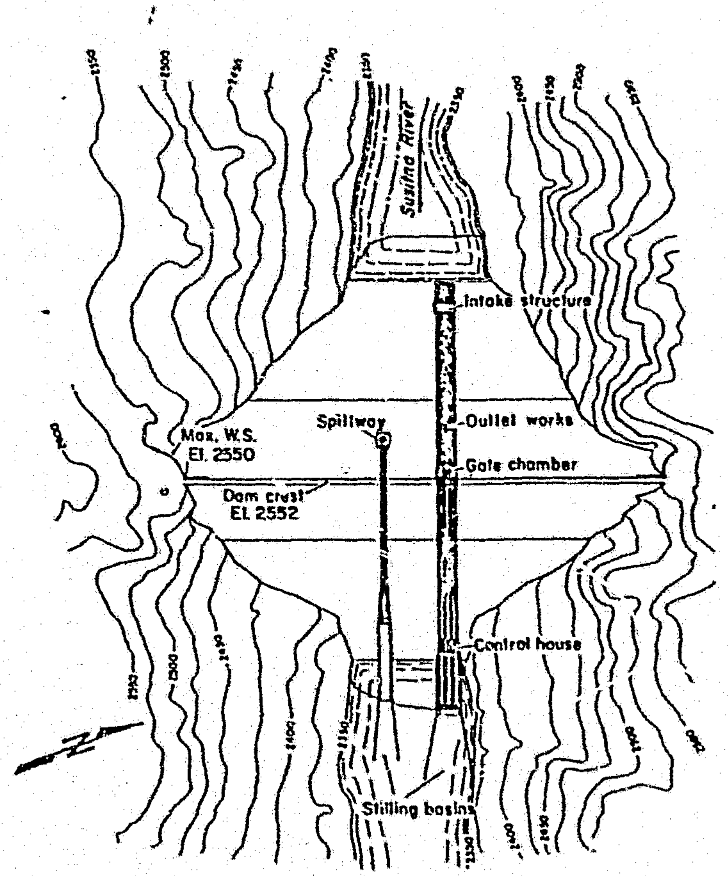
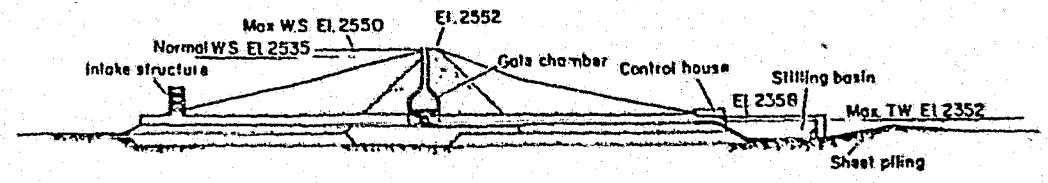


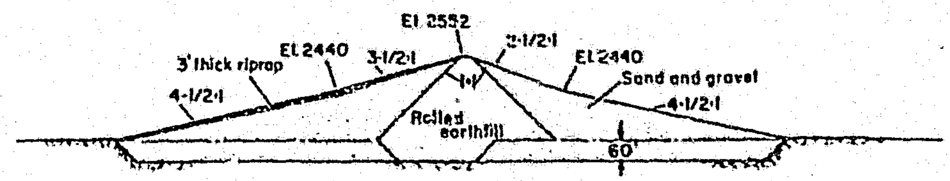
General damsite plan

Scale

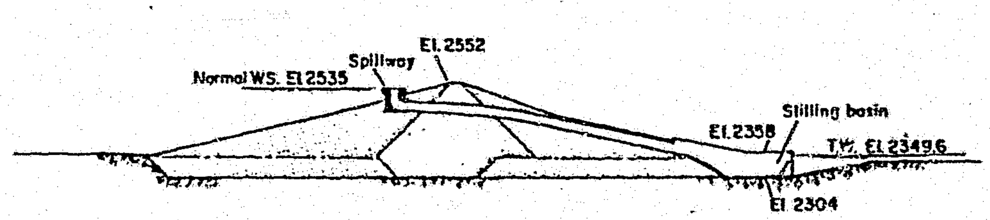
0 200 600 1200 Feet



Section through outlet works



Maximum section



Section through spillway

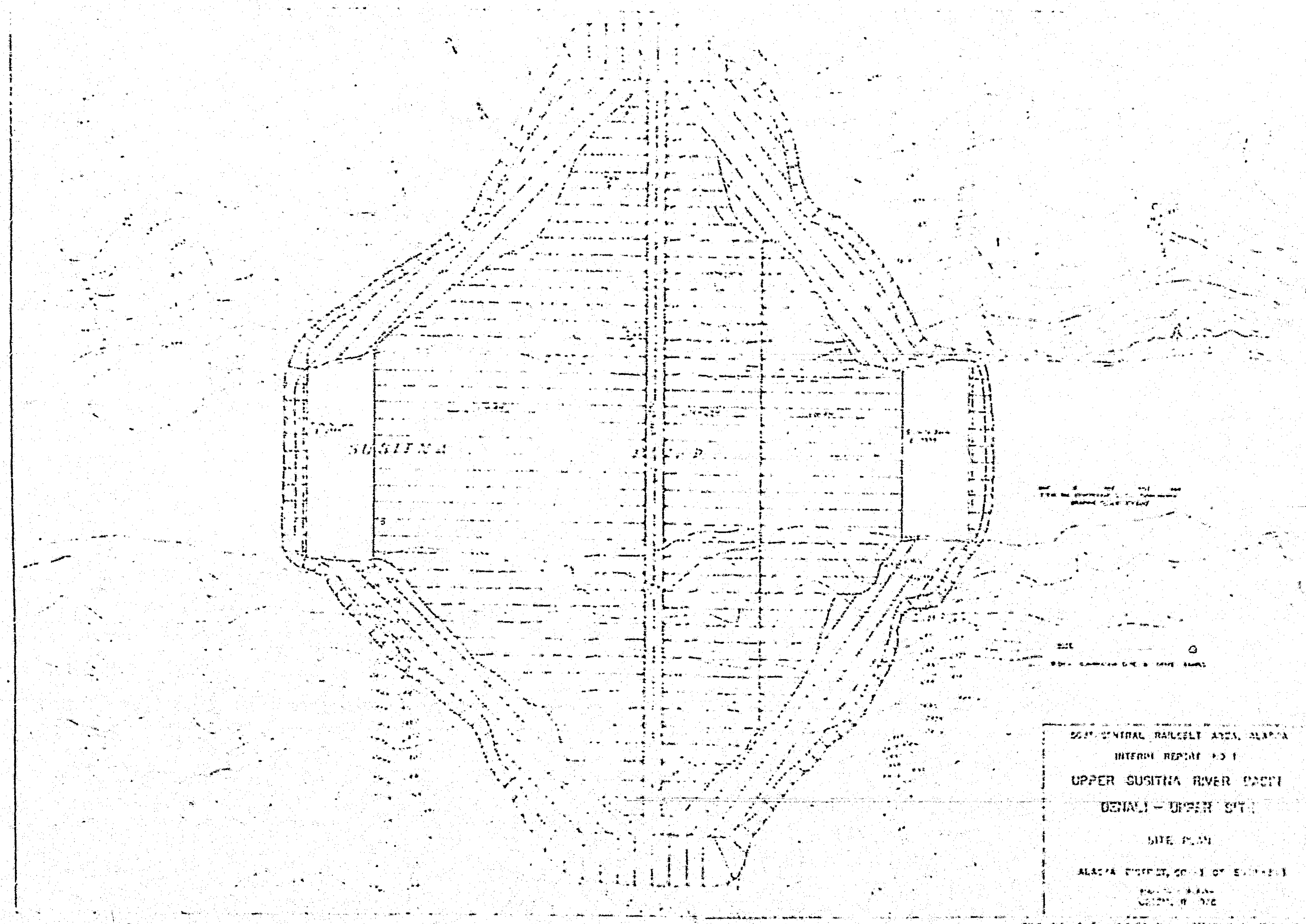
Section scale

0 100 200 400 600 800 1000 Feet

U.S. DEPARTMENT OF THE INTERIOR
ALASKA POWER ADMINISTRATION

DENALI DAM

PLAN & SECTIONS


SUSITNA
UPPER SUSITNA RIVER
DENALI – UPPER SITE
SITE PLAN

APPENDIX - B

CORPS OF ENGINEERS
CRITERIA FOR EVALUATION OF ALTERNATIVES

(REPRODUCED FROM REFERENCE 7)

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 governing 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 costs of providing the energy output of any plan 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.

APPENDIX C -

CORPS OF ENGINEERS
COST DATA FROM 1975 INTERIM FEASIBILITY REPORT

(REFERENCE 7)

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

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		26,952
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

Table B-3

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

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

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

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				
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

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)
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
	Sealing 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	[illegible]ES AND GENERATORS				
	[illegible]s	LS			22,575
	[illegible]rs	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	[illegible]	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

Table B-7
Appendix I
B-40

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