SUSITNA HYDROELECTRIC PROJECT

DEVELOPMENT SELECTION REPORT

TASK 6 – DESIGN DEVELOPMENT

DECEMBER 1981

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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SUSITNA HYDROELECTRIC PROJECT

TASK 6 - DEVELOPMENT SELECTION

SUBTASK 6.05
DEVELOPMENT SELECTION REPORT

FINAL REPORT

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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

SUSITNA BASIN DEVELOPMENT SELECTION

VOLUME I - MAIN REPORT

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1 - INTRODUCTION

This report has been prepared by Acres American Incorporated (Acres) on behalf of the Alaska Power Authority (APA). The report essentially represents a milestone in the Plan of Study (POS) for the Susitna Hydroelectric Project currently being undertaken by Acres under the terms of an Agreement with APA dated December 19, 1979. The Susitna POS was first issued in February 1980 and subsequently revised in September 1980. It describes in detail the many and complex studies to be undertaken from January 1980 through June 1982 to assess the feasibility and the environmental impact of the proposed Susitna Project. The POS also addresses the requirements for filing a FERC license application should project feasibility and environmental acceptability be established.

Studies through March 1981 have mainly been concerned with evaluation of the need for electric power in the Alaska Railbelt Region and consideration of the alternatives for meeting these power needs both with and without a Susitna Basin hydroelectric development. This Development Selection Report presents the results of this initial step in the POS process, and provides recommendations and justification for continuation of study of a specific basin development.

The remainder of Section 1 of this report deals with a description of the study area and the proposed Susitna development and a summary of the objectives and scope of the current studies.

1.1 - The Study Area

The main stream of the Susitna River originates about 90 miles south of Fairbanks where melting glaciers contribute much of its summer flow (see Figure 1.1). Meandering for the first 50 miles in a southerly direction across a broad alluvial fan and plateau, it turns westward and begins a 75 mile plunge between essentially continuous canyon walls before it changes course to the southwest and flows for another 125 miles in a broad lowland. For more than 30 years, the vast hydroelectric potential of this river has been recognized and studied. Strategically located in the heart of the South Central Railbelt, the Susitna could be harnessed to produce about twice as much electrical energy per year as is now being consumed in the Railbelt.

The Susitna River system, with a drainage area of more than 19,000 square miles, is the sixth largest in Alaska. Major tributaries include the Yentna, Chulitna, Talkeetna, and Tyone rivers. A substantial portion of the total annual streamflow occurs during spring and summer and is generated by glacial melt and rainfall runoff. The water during this period is turbid. Winter flows consist almost entirely of ground water supply and are generally free of sediment. Freezeup starts in October in the upper reaches of the basin, and by late November ice covers have formed on all but the most rapidly flowing stretches of the river. Breakup generally occurs around early May.

The Susitna River and its tributaries are important components of Alaska's highly prolific fishery resource. Salmon, Dolly Varden trout, grayling, and whitefish are found within the Basin. Waterfowl habitat in the glacial outwash plain supports trumpeter swan and migratory fowl. Bear, moose, and caribou thrive there. In short, wildlife resources are plentiful. Extensive studies are necessary both to determine their total value, the impacts which any development may have upon them, and the nature of mitigative measures which might be taken to eliminate or offset negative environmental consequences of hydroelectric development.

1.2 - Project Description

The Susitna Basin has been under study since the mid-forties by agencies such as the Water Resources and Power Services (WRPS, formerly the USBR), the Alaska Power Administration, and the US Army Corps of Engineers (COE), as well as H.J. Kaiser and Company. The more recent and most comprehensive of these studies were carried out by the COE. The optimum method of developing the basin's potential was determined by the COE to comprise two major hydroelectric developments. The first of these would require a dam at Watana and the second, a dam at Devil Canyon. This development was found to be economically viable and would provide the Railbelt area with a long-term supply of relatively cheap and reliable energy.

Studies completed by Acres to date have confirmed that the preferred development should consist of two large hydroelectric dams at Watana and Devil Canyon (see Figure 1.1). The Watana dam would be constructed first. It would involve a fill dam roughly 880 feet maximum height, and because of the large reservoir volume created would provide adequate storage for seasonal regulation of the flow. Initially, 400 MW of generating capacity would be installed at this site. This would later be expanded to around 800 MW to allow for additional peaking capacity. The Devil Canyon dam would be the next stage of the development. It would involve a 675 feet maximum height double curvature concrete arch dam and incorporate a 400 MW powerhouse. The total average annual energy yield from this development amounts to 6200 GWh.

The power from the total development would be conveyed to the Railbelt system by as many as four 345 kV transmission lines running from the project sites to the proposed Anchorage-Fairbanks intertie in the vicinity of Gold Creek. The capacity of the currently envisaged intertie would ultimately be increased to a total transmission capability of two 345 kV lines from Anchorage to Fairbanks.

Access to the project site is still under study. Alternative routes being considered include a road access from the east via the Denali Highway, and rail and road access from the west via the Parks Highway, and the railroad passing through Gold Creek. It is envisaged that substantial air support would be required during the construction of the project and an airstrip would be constructed near the Watana site.

The current schedule calls for the first 400 MW at Watana to be on-line by 1993. The additional 400 MW at Watana would be commissioned as required and probably be brought on-line in 1996. The Devil Canyon development would be brought on-line in the year 2000.

1.3 - Objectives and Scope of Current Studies

The primary objectives of the studies are:

- To establish technical, economic, and financial feasibility of the Susitna project to meet future power needs of the Railbelt region;

- To evaluate the environmental consequences of designing and constructing the Susitna project;

- File a completed license application with the Federal Regulatory Commission in June 1982.

The overall scope of work involves a broad range of comprehensive field and office studies over a 30 month period from January 1980 to June 1982. These have been divided into specific tasks and are discussed briefly below. The major portion of the work is being conducted by Acres with the support of several subcontractors.

(a) Task 1 - Power Studies

These studies involve the development of a range of power and energy projections for the Railbelt area. The energy forecast work has been undertaken by the Institute for Social and Economic Research (ISER) under contract to APA. Woodward Clyde Consultants (WCC), under subcontract to Acres, produced the associated load duration curves and power forecasts.

(b) Task 2 - Surveys and Site Facilities

This task includes the construction and maintenance of a 40 man field camp located at the Watana site and the provision of aircraft and helicopter support to the field teams. The camp construction and maintenance is being undertaken by Cook Inlet Region, Inc. (CIRI), and Holmes and Narver, Inc. (H&N) under subcontract to Acres. Local aircraft companies are providing fixed wing and helicopter support also under subcontract to Acres. Also included in this task is an extensive range of survey and mapping work being undertaken by R&M Consultants, Inc. for Acres and ancillary studies dealing with site access, land status, and reservoir clearing studies.

(c) Task 3 - Hydrology

This task incorporates an extensive field data collection program being conducted by R&M and associated office studies required for the project which are being conducted jointly by R&M and Acres.

(d) Task 4 - Seismic Studies

This work incorporates a wide range of field and office studies aimed at developing an understanding of the seismic setting and potential earthquake mechanisms of the region and determining the seismic design criteria for the structures to be built. Most of this work is being conducted by WCC under subcontract to Acres.

(e) Task 5 - Geotechnical Exploration

This task incorporates all the geotechnical exploration field work conducted at the Watana and Devil Canyon dam sites. Much of the field work is being carried out by R&M under subcontract to Acres.

(f) Task 6 - Design Development

This task incorporates the planning and engineering studies for selecting the most appropriate Susitna Basin development plan and for producing the conceptual engineering designs for the selected development. This work can be divided into two stages:

(i) Stage 1 - Development Selection

This phase of the work encompasses the river basin planning and Railbelt system generation planning work aimed at determining the most appropriate basin development plan.

(ii) Stage 2 - Feasibility Design

This phase includes the more detailed engineering studies aimed at optimizing the selected project and producing the conceptual designs for inclusion in the FERC license.

(g) Task 7 - Environmental Studies

These studies encompass a broad range of field and office studies aimed at determining potential environmental impacts due to the project and developing appropriate mitigating measures. Much of this work is being conducted under subcontract for Acres by Terrestrial Environmental Specialists (TES). The large game and fisheries studies are being conducted by The Alaska Department of Fish and Game (ADF&G) under a reimbursable service agreement with APA.

(h) Task 8 - Transmission

This task includes the studies necessary to develop conceptual designs for the transmission system required to convey Susitna power into the Railbelt system. This work is being conducted by Acres with some support from R.W. Retherford and Associates (RWRA), a division of International Engineering Company (IECO).

(i) Task 9 - Construction Cost Estimate and Schedules

This work involves the production of detailed construction type cost estimates and construction schedules of the project and is being conducted by Acres with some assistance from F. Moolin and Associates (FMA).

(j) Task 10 - Licensing

This task covers the work required to produce the FERC license documents and is being carried out by Acres.

(k) Task 11 - Marketing and Financing

This task includes support studies dealing with the risk and financial aspects associated with the project. These studies are requried to identify and secure the necessary funding for the project and are being carried out by Acres with support from specialist consultants.

(l) Task 12 - Public Participation Program

APA is conducting an extensive public participation program to keep the public informed on the progress and findings of the study and to obtain feedback from them on issues they believe are critical to the successful implementation of the project. Acres and the subcontractors support APA in these activities on an as required basis.

(m) Task 13 - Administration

This task deals with the Acres administration of the entire study effort.

1.4 - Plan Formulation and Selection Process

A key element in the studies being undertaken is the process which is being applied for formulation and comparison of development plans. Much emphasis is being placed on consideration of every important perspective which may influence the selection of a particular course of action from a number of possible alternatives. A description of the generic plan formulation and selection methodology is presented in Appendix A. An essential component of this planning process is a generalized multi-objective development selection methodology for guiding the planning decisions. A second important factor is the formulation of a consistent and rational approach to the economic analyses undertaken by the studies.

(a) Planning Methodology

A generalized plan formulation and selection process has been developed to guide the various planning studies being conducted. Of numerous planning decisions to be made in these studies, perhaps the most important are the selection of the preferred Susitna Basin development plan (Task 6), and appropriate access and transmission line routes (Tasks 2 and 8).

The basic approach involves the identification of feasible candidates and courses of action, followed by the development and application of an appropriate screening process. In the screening process, less favorable candidates are eliminated on the basis of economic, environmental, social and other prescribed criteria. Plans are then formulated which incorporate the shortlisted candidates individually or in appropriate combinations. Finally, a more detailed evaluation of the plans is carried out, again using prescribed criteria and aimed at selecting the best development plan. Figure 1.2 illustrates this general process.

In the final evaluation, no attempt is made to quantify all the attributes used and to combine these into an overall numerical evaluation. Instead, the plans are compared utilizing both quantitative and qualitive attributes, and where necessary, judgemental tradeoffs between the two types are made and highlighted. This allows reviewers of the planning process to quickly focus on the key tradeoffs that effect the outcome of the decisions. To facilitate this procedure, a paired comparison technique is used so that at any one step in the planning process, only two plans are being evaluated.

The studies aimed at selecting the best Susitna Basin development plan involve consideration of a large number of alternative courses of action. The selection process has been used in three parallel applications in an attempt to simplify the procedure. Two Railbelt generating scenarios, one involving only thermal generating units and a second involving a mix of thermal and other potential (non-Susitna) hydro developments were evaluated separately, as well as a Susitna/thermal scenario. Information on these alternative generating scenarios is necessary to make a preliminary assessment of the feasibility of the "with Susitna" generating scenario by means of a comparison of the three different scenarios.

Figure 1.3 graphically illustrates the overall planning process. Steps 1 to 5 of the formulation and selection methodology are applied to developing a plan incorporating all-thermal generation and a plan incorporating non-Susitna hydro generation. These studies are outlined in Section 6 of this report. The same five steps are also applied to the development of the best "with Susitna" generating scenario as outlined in Section 8. The final comparison or evaluation of the three scenarios is carried out using a compressed format of the methodology as a guideline to yield the required preliminary feasibility assessment. This aspect of the study is covered at the end of Section 8.

(b) Economic Analyses

As the proposed Susitna development is a public or State project, all planning studies described are being carried out using economic parameters as a basis of evaluation. This ensures that the resulting investment decisions maximize benefits to the State as a whole rather than any individual group or groups of residents.

The economic analyses incorporate the following principles:

(i) Intra-state transfer payments such as taxes and subsidies are excluded;

(ii) Opportunity values are used to establish the costs for coal, oil and natural gas resources used for power generation in the alternatives considered. These opportunity costs are based on what the open market is prepared to pay for these resources. They therefore reflect the true value of these resources to the State. These analyses ignore the existence of current term-contractual commitments which may exist, and which fix resource costs at values different from the opportunity costs;

(iii) The analyses are conducted using "real" or inflation adjusted parameters. This means that the interest or discount rate used equals the assessed market rate minus the general rate of inflation. Similarly, the fuel and construction cost escalation rates are adjusted to reflect the rate over or under the general inflation rate;

(iv) The major impact caused by the use of these inflation adjusted parameters is to improve the relative economics of capital intensive projects (such as hydro generation) versus the high fuel consumption projects (such as thermal generation). It also leads to the selection of larger economic optimum sizes of the capital intensive projects. These shifts towards the capital intensive projects are consistent with maximizing total benefits to the State.

1.5 - Organization of Report

The objective of this report is to describe the results of Susitna Basin development selection studies, i.e. Task 6, Stage 1. It also briefly outlines the results of some of the early Task 6, Stage 2 engineering studies aimed at refining the project's general arrangements.

In order to improve readibility of the report, much of the detailed technical material as well as the review of the status of technical support studies is included in a separate volume of appendices. The report is organized as follows:

Volume 1 - Main Report

Section 1: Introduction

Section 2: Summary

This section contains a complete summary of Sections 4 through 10 of the main report.

Section 3: Scope of Work

This section outlines the scope of work associated with the results presented in this report.

Section 4: Previous Studies

This section briefly summarizes previous Susitna Basin studies by others.

Section 5: Railbelt Load Forecasts

In this section, the results of the energy and load forecast studies undertaken by ISER and WCC are summarized. It concludes with a discussion of the range of load forecasts used in the Susitna Basin planning studies.

Section 6: Railbelt System and Future Power Generating Options

This section describes currently feasible alternatives considered in this study for generating electrical energy to meet future Railbelt needs. It incorporates data on the performance and costs of the facilities.

Section 7: Susitna Basin

This section provides a description of the physical attributes of the Susitna Basin including climatologic, hydrologic, geologic, seismic, and environmental aspects.

Section 8: Susitna Basin Development Selection

The Susitna Basin planning studies and the Railbelt system generation planning work carried out are discussed in this section. It includes a description of the Susitna Basin development selection process and preliminary assessment of the economic and environmental feasibility of the selected Watana/Devil Canyon hydropower development.

Section 9: Susitna Hydroelectric Development

This section describes, in more detail, the selected Watana/Devil Canyon project and includes a discussion of the results of the preliminary operational studies and a summary environmental review of the project. The project general arrangements described result from initial Task 6, Stage 2 engineering studies and therefore present a more up-to-date picture than the arrangements described in Section 8.

Section 10: Conclusions and Recommendations

In this section recommendations are made for the Susitna Basin development plan considered by Acres to merit further study. It also deals with tentative conclusions with respect to the project's technical, environmental, and economic feasibility.

Volume 2 - Appendices

A: Plan Formulation and Selection Process

A description of the generic approach to site scenarios, plan formulation and plan evaluation is presented.

B: Thermal Generating Sources

This appendix outines the detailed backup to the thermal generating unit performance and cost information presented in Section 6 of the main report.

C: Alternative Hydro Generating Sources

The studies undertaken to produce the shortlist of alternative hydro developments discussed in Section 6, i.e. those outside the Susitna Basin, are described in this appendix.

D: Engineering Layout Design Assumptions

This appendix describes the design assumptions that were made in order to develop the engineering layouts for potential power development projects at the Devil Canyon, High Devil Canyon, Watana, Susitna III, Vee, Maclaren, and Denali sites.

E: Susitna Basin Screening Model

Here a description is presented of the computer model used to screen out uneconomic basin development plans, as discussed in Section 8.

F: Single and Multi-Reservoir Hydropower Simulation Studies

The computer model used to simulate the monthly energy yield from the various Susitna development plans is described in this appendix. Details are presented on the average monthly firm and average yields for the development plans discussed in Section 8 of the main report.

G: Systemwide Economic Evaluation (OGP5)

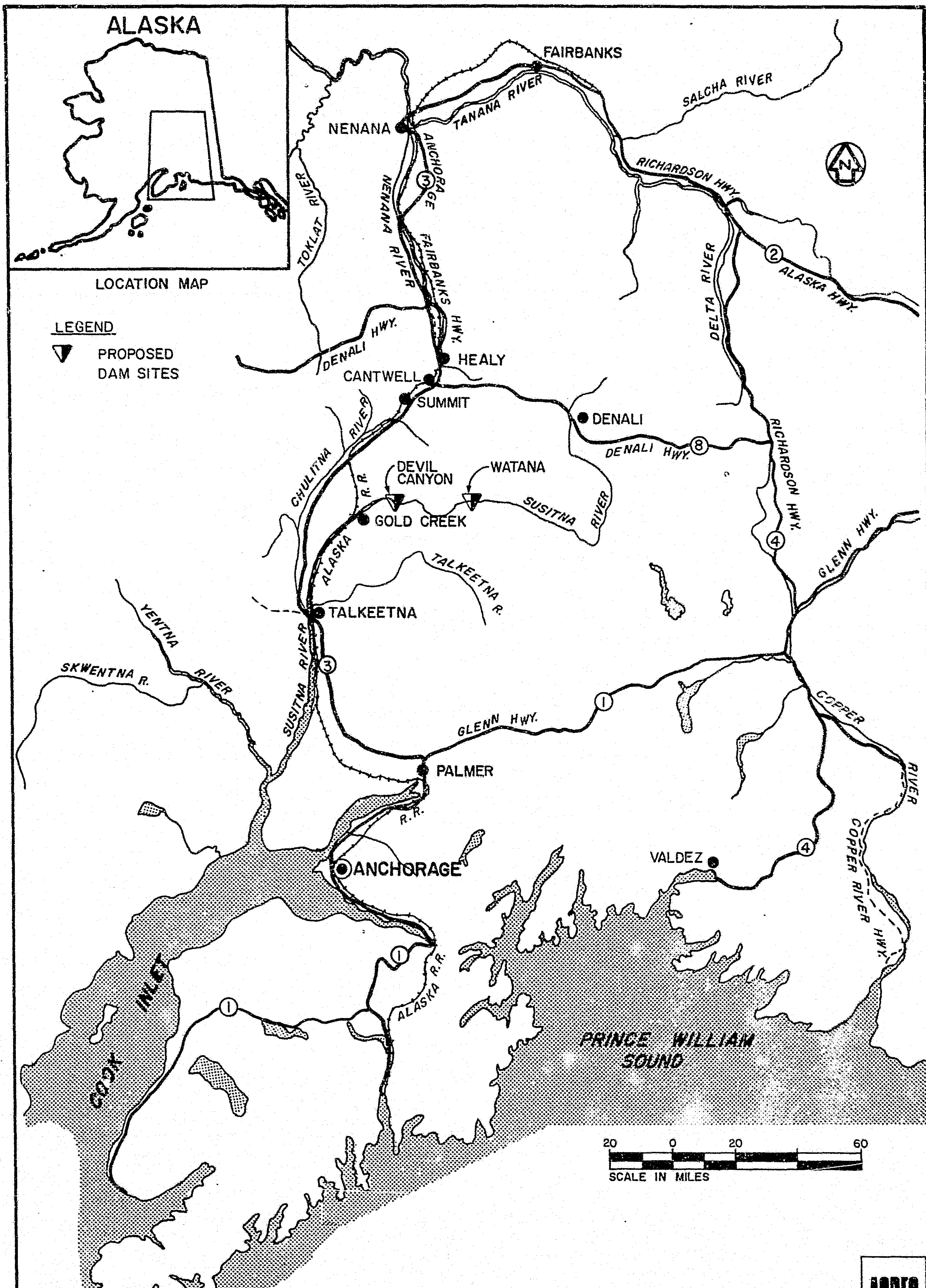
This appendix contains the detailed backup information to the computer model runs used in the economic evaluation of the various generating scenarios considered in the planning studies.

H: Engineering Studies

The backup studies to the project general arrangements described in Section 9 of the main report are presented in this appendix.

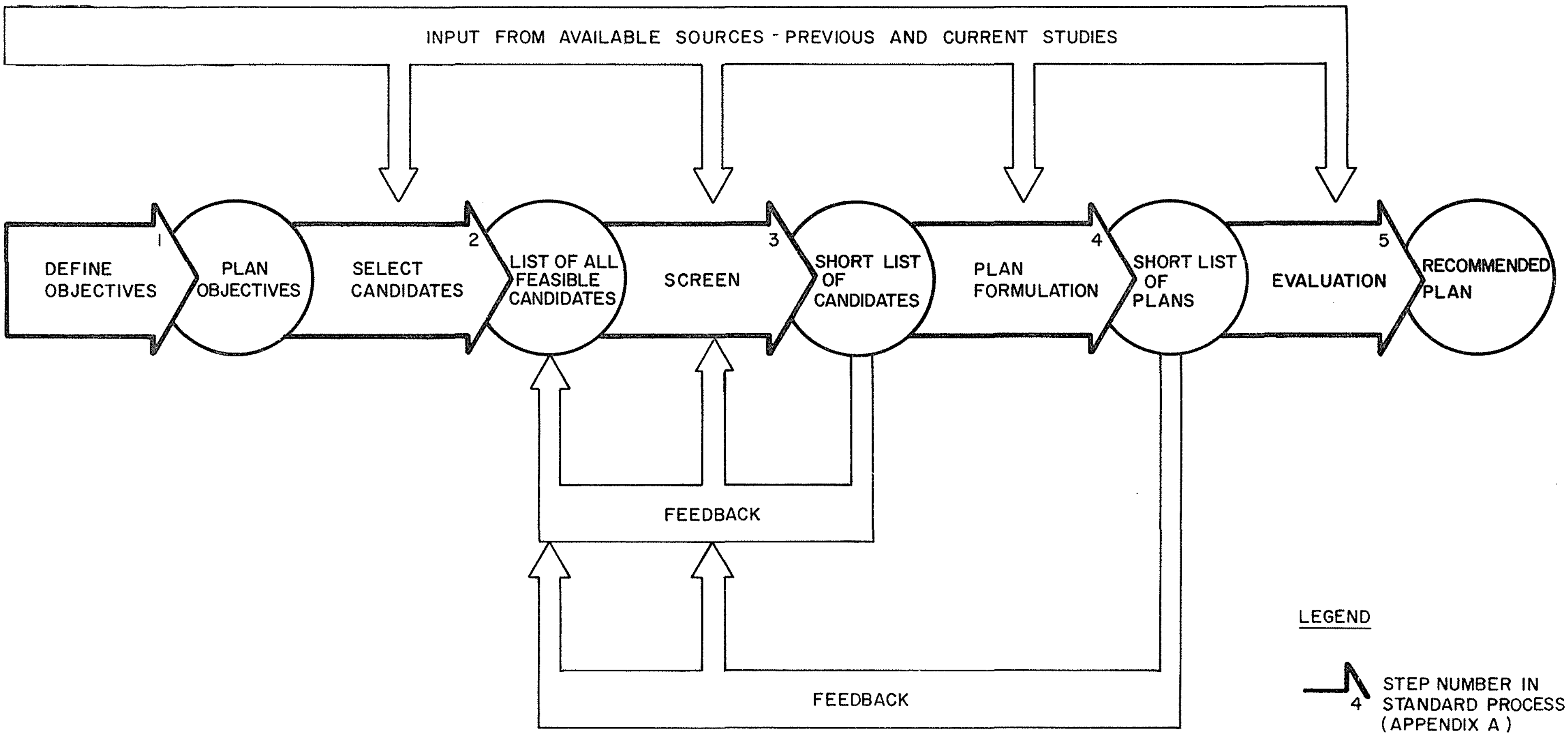
I: Environmental Studies

This appendix contains the detailed backup data on environmental aspects gathered by Acres during the course of investigations and by the various subcontractors.



LOCATION MAP

FIGURE 1.1



PLAN FORMULATION AND SELECTION METHODOLOGY

FIGURE 1.2

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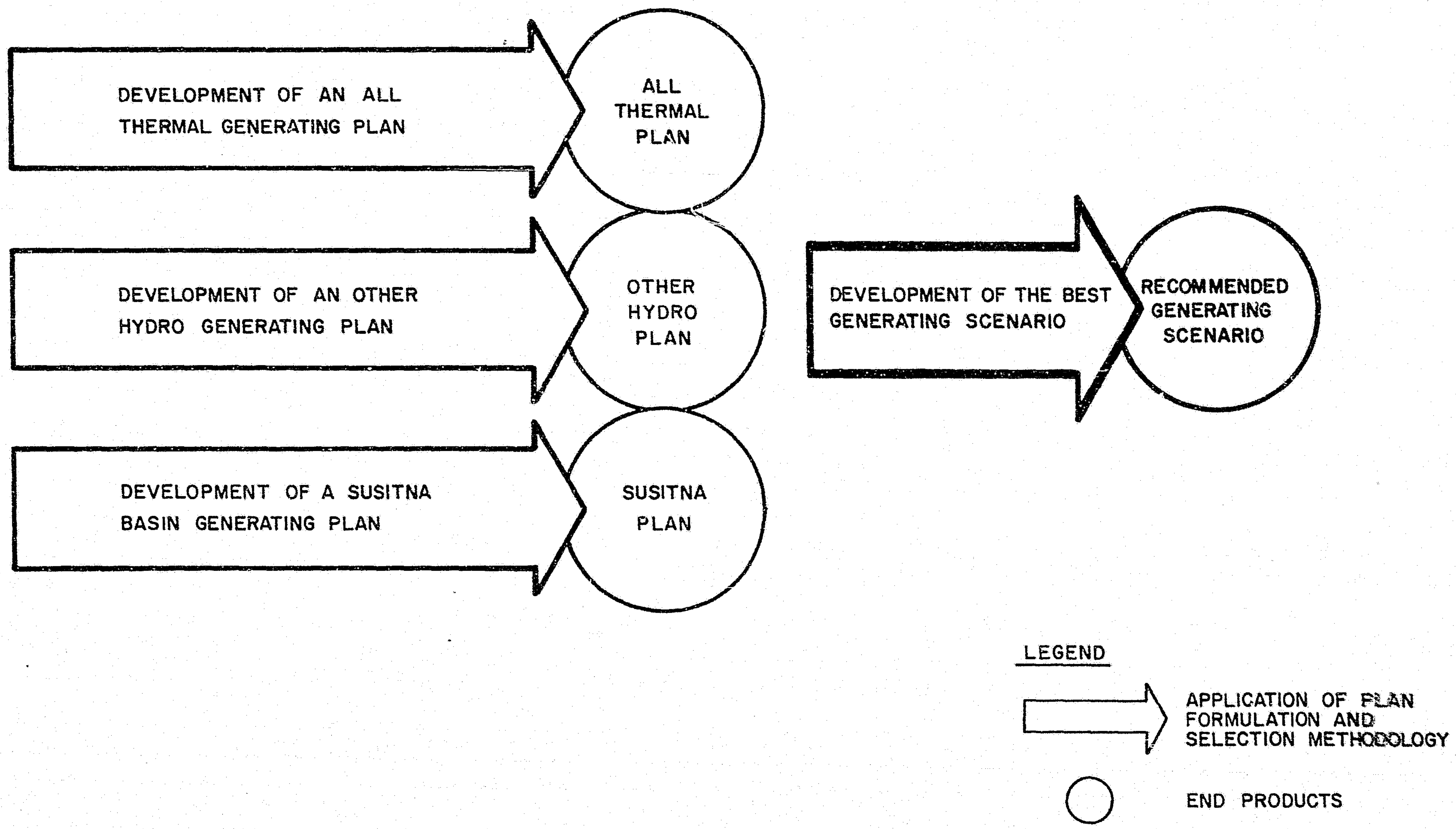


PLANNING APPROACH

FIGURE 1.3

2 - SUMMARY

2.1 - Scope of Work

The Scope of Work discussed in the Development Selection Report includes the development selection studies and preliminary engineering studies aimed at refining the general arrangements of the selected Watana and Devil Canyon dam projects.

The development selection studies constitute Stage 1 of the Task 6 design studies as described in the Acres POS, and include the following:

(a) Review of Previous Studies and Reports (Subtask 6.01)
(b) Investigate Tunnel Alternatives (Subtask 6.02)
(c) Evaluate Alternative Susitna Developments (Subtask 6.03)
(d) Watana and Devil Canyon Staged Development (Subtask 6.06)
(e) Thermal Generating Resources (Subtask 6.32)
(f) Hydroelectric Generating Sources (Subtask 6.33)
(g) Environmental Analysis (Subtask 6.34)
(h) Load Management and Conservation (Subtask 6.35)
(i) Generation Planning (Subtask 6.36)
(j) Development Selection Report (Subtask 6.05)

As the development selection studies were finalized work continued on engineering design studies aimed at refining the general arrangements at the Devil Canyon and Watana sites. These studies involved the production of alternative general arrangements incorporating earth/rockfill and concrete arch dams at both Watana and Devil Canyon. These arrangements were costed and evaluated to determine which is the most appropriate. Design work is being carried out on the proposed thin arch dam at Devil Canyon to ensure that such a structure can safely withstand the anticipated seismic loading. Extensive use was made of computer stress analyses in the design studies.

2.2 - Previous Studies

Shortly after World War II had ended, the USBR conducted an initial investigation of hydroelectric potential in Alaska, reporting its results in 1948. Responding to a recommendation in 1949 by the nineteenth Alaska territorial legislature that Alaska be included in the Bureau of Reclamation program, the Secretary of Interior provided funds to update the 1948 work. The resulting report, issued in 1952, recognized the vast hydroelectric potential within the territory. Particular emphasis was placed on the strategic location of the Susitna River between Anchorage and Fairbanks as well as its proximity to the connecting Railbelt (see Figure 1.1).

A series of studies was commissioned over the years to identify dam sites and conduct geotechnical investigations. By 1961, the Department of the Interior proposed authorization of the two dam power system involving the Devil Canyon and the Denali sites. The definitive 1961 report was subsequently updated by the Alaska Power Administration (at that time an agency of the Bureau of Reclamation) in 1974, at which time the desirability of proceeding with hydroelectric development was reaffirmed.

The COE was also active in hydropower investigations in Alaska during the 1950's and 1960's, but focused its attention on a more ambitious development at Rampart on the Yukon River. This project was capable of generating five times as much electric energy as Susitna annually. The sheer size and the technological challenges associated with Rampart captured the imagination of supporters and effectively diverted attention from the Susitna Basin for more than a decade. The Rampart report was finally shelved in the early 1970's because of strong environmental concerns and uncertainty of marketing prospects for so much energy, particularly in light of abundant natural gas which had been discovered and developed in Cook Inlet.

The energy crisis occasioned by the OPEC oil boycott in 1973 provided some further impetus for seeking development of renewable resources. Federal funding was made available to complete the Alaska Power Administration's update report on Susitna in 1974 and to launch a prefeasibility investigation by the COE. The State of Alaska itself commissioned a reassessment of the Susitna Project by the Henry J. Kaiser Company in 1974.

Although the gestation period for a possible Susitna Project has been long, Federal, State, and private organizations have been virtually unanimous over the years in recommending that the project proceed.

2.3 - Railbelt Load Forecasts

The feasibility of a major hydroelectric project depends in part upon the extent to which the available capacity and energy are consistent with the needs of the market to be served by the time the project comes on line. Attempting to forecast future energy demand is a difficult process at best. It is therefore particularly important that this exercise be accomplished in an objective manner. For this reason APA and the State of Alaska jointly awarded a separate contract to ISER to prepare appropriate projections for the Alaska Railbelt region.

(a) Electricity Demand Profiles

Between 1940 and 1978, electricity sales in the Railbelt grew at an average annual rate of 15.2 percent. This growth was roughly twice that for the nation as a whole. National and Alaskan annual growth rates for different periods between 1940 and 1978, and the historical growth of Railbelt utility sales from 1965 consistently exceeded the national average. However, the gap has been narrowing due to the gradual maturing of the Alaskan economy. Growth in the Railbelt has exceeded the national average for two reasons; the population growth in the Railbelt has been higher than the national rate, and the proportion of Alaskan households served by electric utilities was lower than the U.S. average so that some growth in the number of customers occurred independently of population growth.

(b) ISER Electricity Consumption Forecasts

The ISER electricity demand forecasting model conceptualized in computer logic the linkage between economic growth secnarios and electricity consumption. The output from the model is in the form of projected values of electricity consumption for each of the three geographical areas of the

Railbelt (Greater Anchorage, Greater Fairbanks and Glennallen-Valdez) and is classified by final use (i.e., heating, washing, cooling, etc.) and consuming sector (commercial, residential, etc). The model produces output on a five-year time basis from 1985 to 2010, inclusive.

The ISER model consists of several submodels linked by key variables and driven by policy and technical assumptions and state and national trends. These submodels are grouped into four economic models which forecast future levels of economic activity and four electricity consumption models which forecast the associated electricity requirements by consuming sectors. For two of the consuming sectors it was not possible to set up computer models; therefore simplifying assumptions were made.

The overall approach to derivation of the peak demand forecasts for the Railbelt Region was to examine the available historical data with regard to the generation of electrical energy and to apply the observed generation patterns to existing sales forecasts. Information routinely supplied by the Railbelt utilities to the Federal Energy Regulatory Commission was utilized to determine these load patterns.

The analysis of load patterns emphasized the identification of average patterns over the 10-year period from 1970 to 1979 and did not consider trends or changes in the patterns with time. Generally, the use of average values was preferred as it reduced the impact of yearly variations due to variable weather conditions and outages. In any event, it was not possible to detect any consistent patterns in the available data.

The average hourly distribution of generation for the first weeks of April, August and December was used to determine the typical average load pattern for the various utilities. As a result of the relatively limited data base, the calculated load duration curve would be expected to show less variation than one computed from a more complete data base, resulting in an overestimation of the load factor. In addition, hourly data also tend to average out actual peak demands occurring within a time interval of less than one hour. This could also lead to overestimation of the load factor. It is, however, considered that the accuracy achieved is adequate for these studies, particularly in light of the relatively much greater uncertainties associated with the load forecasts.

(c) Load Forecasts Used for Generation Planning Studies

Three ISER energy forecasts were considered in generation planning studies. These include the base case (MES-GM) or medium forecast, a low and a high forecast. The low forecast is that corresponding to the low economic growth as proposed by ISER with an adjustment for low government expenditure (LES-GL). The high forecast corresponds to the ISER high economic growth scenario with an adjustment for high government expenditure (HES-GH).

Electricity forecasts derived in this study represent total utility generation and include projections for self-supplied industrial and military generation sectors. Included in these forecasts are transmission and distribution losses in the range of between 9 and 13 percent, depending upon the generation scenario assumed. These forecasts, ranging from 2.71 to 4.76 percent average annual growth, were adjusted for use in generation planning studies.

The low forecast case assumed above incorporates an annual growth rate of 2.71 percent. This rate would be reduced with enforcement of energy conservation measures more intensive than those presently in use in the State. An annual growth rate of 2.1 percent was judged to be a reasonable lower limit for electrical demand for purposes of this study. This represents a 23 percent reduction in growth rate which is similar to the reduction developed in an independent study authorized by the State.

The implementation of load management measures would result in an additional reduction in peak load demand. The residential sector demand is the most sensitive to a shift of load from the peak period to the off-peak period. Over the 1980-2010 period, an annual peak load growth rate of 2.73 percent was used in the low forecast case. With load management measures such as rate reform and load controls, this growth rate could be reduced to an estimated 2.1 percent. The annual load factor for year 2010 would be increased from 62.2 percent in the low forecast to 64.4 percent in the lowest case.

2.4 - Railbelt System and Future Power Generation Options

If constructed, the Susitna Basin development plan would provide a major portion of the Railbelt Region energy needs well beyond the year 2000. It is clearly important to determine the most economic basin development plan which clearly defines details such as dam heights, installed generating capacities, reservoir operating rules, dam and powerhouse staging concepts, and construction schedules. To accomplish this, it is first necessary to evaluate in economic terms the plan in the context of the entire Railbelt generating system. This requires that economic analyses be undertaken of expansion alternatives for the total Railbelt system containing several different types of generating sources. These sources include both thermal and hydropower generating facilities capable of satisfying a specified load forecast. Economic analyses of scenarios containing alternative Susitna Basin development plans being investigated would then reveal which is the most economic basin development plan. This process and the comparison of other factors such as environmental impacts and social preferences essentially falls within the purview of "generation planning".

These systemwide generation planning studies require a comprehensive process of assembling the necessary information. This information includes an assessment of the existing system characteristics, the planned Anchorage-Fairbanks intertie, and details of various generating options including hydroelectric and thermal. The implications of the Fuel Use Act (FUA), and consideration of other options such as tidal and geothermal energy generation are also important factors. Performance and cost information required for the generation planning studies have been developed for the hydroelectric and thermal generation options but not for the tidal and geothermal options. Preliminary indications are that these options are as yet not competitive with the more conventional options considered.

The two major load centers of the Railbelt Region are the Anchorage-Cook Inlet area and the Fairbanks-Tanana Valley area. At present, these two areas operate independently. The existing transmission system between Anchorage and Willow consists of a network of 115 kV and 138 kV lines with interconnection to Palmer.

Fairbanks is primarily served by a 138 kV line from the 28 MW coal-fired plant at Healy. Communities between Willow and Healy are served by local distribution.

There are currently nine electric utilities (including the Alaska Power Administration) providing power and energy to the Railbelt system. With the exception of two hydroelectric plants, the total Railbelt installed capacity of 944 MW as of 1980 consists of fifty-one thermal generation units fired by oil, gas or coal.

Engineering studies are currently being undertaken for construction of an intertie between the Anchorage and Fairbanks systems. As presently envisaged, this connection will involve a 138 kV transmission line between Willow and Healy and would provide capability for transferring 50 MW of capacity at any time. It is scheduled for completion in 1984. Current intertie studies indicate that it is economic to construct this intertie such that it can be upgraded to the 375 kV Susitna transmission capability when Watana comes on line.

It was concluded that a fully interconnected system should be assumed for all the generation planning studies outlined in this report, and that the intertie facilities would be common to all generation scenarios considered. In the preliminary comparisons of alternative generation scenarios, the cost of such intertie facilities was also assumed to be common. However, in final comparisons of a lesser number of preferred alternative scenarios, appropriate consideration was given to relative intertie costs. The cost of transmitting energy from a particular generating source to the interconnected system is included in all cases.

Selection of non-Susitna plans which incorporate hydroelectric developments was accomplished by the application of a five-step methodology (Figure 1.2). Step 1 of this process essentially established the overall objective of the exercise as the selection of an optimum Railbelt generation plan which incorporated the proposed non-Susitna hydroelectric developments, for comparison with other plans. Under Step 2 of the selection process, all feasible candidate sites were identified for inclusion in the subsequent screening exercise. A total of 91 potential sites were obtained from inventories of potential sites published in the COE National Hydropower Study and the APA report "Hydroelectric Alternatives for the Alaska Railbelt". From these 91 sites, 10 were selected for further study on the basis of economic and environmental superiority after a four-iteration screening process.

2.5 - Susitna Basin

Information presented herein on the climatological, physical and environmental characteristics of the Susitna River Basin has been obtained both from previous studies and the field programs and office studies initiated during 1980 under Tasks 3, 4, 5 and 7.

(a) Climatology and Hydrology

The climate of the Susitna Basin upstream from Talkeetna is generally characterized by cold, dry winters and warm, moderately moist summers. The upper basin is dominated by continental climatic conditions while the lower basin falls within a zone of transition between maritime and continental climatic influences.

The Susitna River usually starts to freeze by late October. River ice conditions such as thickness and strength vary according to the river channel shape and slope, and more importantly, with river discharge. Periodic measurements of ice thickness at several locations in the river have been carried out during the winters of 1961 through 1972. Ice breakup in the river commences by late April or early May and ice jams occasionally occur at river constrictions, resulting in rises in water level of up to 20 feet.

Seasonal variation of flows is extreme and ranges from very low values in winter (October to April) to high summer values (May to September). For the Susitna River at Gold Creek the average winter and summer flows are 2100 and 20,250 cfs respectively, i.e. a 1 to 10 ratio. On the average, approximately 88 percent of the streamflow recorded at Gold Creek station occurs during the summer months. At higher elevations in the basin the distribution of flows is concentrated even more in the summer months. For the Maclaren River near Paxson (El 4520 feet) the average winter and summer flows are 144 and 2100 cfs respectively, i.e. a 1 to 15 ratio.

The most common causes of flood peaks in the Susitna Basin are snowmelt or a combination of snowmelt and rainfall over a large area. Annual maximum peak discharges generally occur between May and October with the majority, approximately 60 percent, occurring in June. Some of the annual maximum flood peaks have also occurred in August or later and are the result of heavy rains over large areas augmented by significant snowmelt from higher elevations and glacial runoff.

(b) Regional Geology

The upper Susitna Basin lies within what is geologically called the Talkeetna Mountains area. This area is geologically complex and has a history of at least three periods of major tectonic deformation. The oldest rocks (250 to 300 m.y.b.p.*) exposed in the region are volcanic flows and limestones which are overlain by sandstones and shales dated approximately 150 to 200 m.y.b.p. A tectonic event approximately 135 to 180 m.y.b.p. resulted in the intrusion of large diorite and granite plutons, which caused intense thermal metamorphism. This was followed by marine deposition of silts and clays. The argillites and phyllites which predominate at Devil Canyon were formed from the silts and clays during faulting and folding of the Talkeetna Mountains area in the Late Cretaceous period (65 to 100 m.y.b.p.). As a result of this faulting and uplift, the eastern portion of the area was elevated, and the oldest volcanics and sediments were thrust over the younger metamorphics and sediments. The major area of deformation during this period of activity was southeast of Devil Canyon and included the Watana area. The Talkeetna Thrust Fault, a well-known tectonic feature, trends northwest through this region. This fault was one of the major mechanisms of this overthrusting from southeast to northwest. The Devil Canyon area was probably deformed and subjected to tectonic stress during the same period, but no major deformations are evident at the site.

*m.y.b.p.: million years before present

The diorite pluton that forms the bedrock of the Watana site was intruded into sediments and volcanics about 65 m.y.b.p. The andesite and basalt flows near the site may have been formed immediately after this plutonic intrusion, or after a period of erosion and minor deposition.

During the Tertiary period (20 to 40 m.y.b.p.) the area surrounding the sites was again uplifted by as much as 3,000 feet. Since then widespread erosion has removed much of the older sedimentary and volcanic rocks. During the last several million years at least two alpine glaciations have carved the Talkeetna Mountains into the ridges, peaks, and broad glacial plateaus seen today. Postglacial uplift has induced downcutting of streams and rivers, resulting in the 500 to 700 feet deep V-shaped canyons that are evident today, particularly at the Vee and Devil Canyon dam sites. This erosion is believed to be still occurring and virtually all streams and rivers in the region are considered to be actively downcutting. This continuing erosion has removed much of the glacial debris at higher elevations but very little alluvial deposition has occurred. The resulting landscape consists of barren bedrock mountains, glacial till-covered plains, and exposed bedrock cliffs in canyons and along streams. The arctic climate has retarded development of topsoil.

Further geologic mapping of the project area and geotechnical investigation of the proposed dam sites was initiated under the current study in 1980, and will continue through early 1982.

The Talkeetna Mountains region of south-central Alaska lies within the Talkeetna Terrain. This term is the designation given to the immediate region of south-central Alaska that includes the upper Susitna River basin. The region is bounded on the north by the Denali Fault, and on the west by the Alaska Peninsula features that make up the Central Alaska Range. South of the Talkeetna Mountains, the Talkeetna Terrain is separated from the Chugach Mountains by the Castle Mountain Fault. The proposed Susitna Hydroelectric Project dam sites are located in the western half of the Talkeetna Terrain. The eastern half of the region includes the relatively inactive, ancient zone of sediments under the Copper River Basin and is bounded on the east by the Totschunda section of the Denali Fault and the volcanic Wrangell Mountains.

(c) Seismic Aspects

Regional earthquake activity in the project area is closely related to the plate tectonics of Alaska. The Pacific Plate is underthrusting the North American Plate in this region. The major earthquakes of Alaska, including the Good Friday earthquake of 1964, have primarily occurred along the boundary between these plates.

The historical seismicity in the vicinity of the dam sites is associated with crustal earthquakes within the North American Plate and the shallow and deep earthquakes generated within the Benioff Zone, which underlies the project area. Historical data reveal that the major source of earthquakes in the site region is in the deep portion of the Benioff Zone, with depths ranging between 24 to 36 miles below the surface. Several moderate size earthquakes have been reported at these depths. The crustal seismicity within the Talkeetna Terrain is very low based on historical records. Most of the recorded earthquakes in the area are reported to be related to the Denali-Toschunda Fault, the Castle Mountain Fault or the Benioff Zone.

(d) Environmental Aspects

Numerous studies of the environmental characteristics of the Susitna River Basin have been undertaken in the past. The current studies were initiated in early 1980 and are planned to continue indefinitely. These studies constitute the most comprehensive and detailed examination of the Susitna Basin ever undertaken, and possibly of any comparable resource.

The Susitna basin is inhabited by resident and anadromous fish. The anadromous group includes five species of Pacific salmon: sockeye (red); coho (silver); chinook (king); pink (humpback); and chum (dog) salmon. Dolly Varden are also present in the lower Susitna Basin with both resident and anadromous populations. Anadromous smelt are known to run up the Susitna River as far as the Deshka River about 40 miles from Cook Inlet.

The project area is known to support species of caribou, moose, bear, wolves, wolverine and Dall sheep.

Furbearers in the Upper Susitna Basin include red fox, coyote, lynx, mink, pine marten, river otter, short-tailed weasel, least weasel, muskrat and beaver. Direct innundation, construction activities and access can be expected to generally have minimal impact on these species.

One hundred and fifteen species of birds were recorded in the study area during the 1980 field season, the most abundant being Scaup and Common Redpoll. Ten active raptor/raven nests have been recorded and of these, two Bald Eagle nests and at least four Golden Eagle nests would be flooded by the proposed reservoirs, as would about three currently inactive raptor/raven nest sites. Preliminary observations indicate a low population of waterbirds on the lakes in the region; however, Trumpeter Swans nested on a number of lakes between the Oshetna and Tyone Rivers.

Flooding would destroy a large percentage of the riparian cliff habitat and forest habitats upriver of Devil Canyon dam. Raptors and ravens using the cliffs would be expected to find alternate nesting sites in the surrounding mountains, but the forest inhabitants are relatively common breeders in forests in adjacent regions. Lesser amounts of lowland meadows and of fluviatile shorelines and alluvia, each important to a few species, will also be lost. None of the waterbodies that appear to be important to waterfowl will be flooded, nor will the important prey species of the upland tundra areas be affected. Impacts of other types of habitat alteration will depend on the type of alteration. Potential impacts can be lessened through avoidance of sensitive areas.

Thirteen small mammal species were found during 1980, and the presence of three others was suspected. During the fall survey, red-backed voles and masked shrews were the most abundant species trapped; and these, plus the dusky shrew, appeared to be habitat generalists, occupying a wide range of vegetation types. Meadow voles and pygmy shrews were least abundant and the most restricted in their habitat use, the former occupying only meadows and the latter forests.

The Susitna River drains parts of the Alaska Range on the north and parts of the Talkeetna Mountains on the south. Many areas along the east-west portion of the river, between the confluences of Portage Creek and the

Oshetna River, are steep and covered with conifer, deciduous and mixed conifer, and deciduous forests. Flat benches occur at the tops of these banks and usually contain low shrub or woodland conifer communities. Low mountains rise from these benches and contain sedge-grass tundra and mat and cushion tundra.

The 1980 archaeological reconnaissance in the Susitna Hydroelectric Project area located and documented 40 prehistoric sites and one historic site. It is expected that continuous reconnaissance surveys in 1981 will locate additional sites. Sites are also documented adjacent to the study area near Stephan Lake, Fog Lakes, Lakes Susitna, Tyone and Louise, and along the Tyone River. Determinations of significance of sites will be based on the intensive testing data collected during the summer of 1981 and national register criteria which determine eligibility for the national register of historic places.

Commercial fisheries constitute the oldest cash-based industry of major importance within the region. The industry has changed substantially during the past 20 years and continues to be modified as a result of both biologic and economic stimuli. The salmon industry has always been a major component of the industry in terms of volume and value. Since 1955, the king crab, shrimp, and Tanner crab fisheries have undergone major development, and halibut landings have increased substantially in recent years. The total wholesale value of commercial fish and shell-fish for the domestic fishery of Alaska in 1979 was just over $1.2 billion including a catch of 459 million pounds of salmon with a wholesale value of just over $700 million.

Existing land use in the Susitna Project area is characterized by broad expanses of open wilderness areas. Those areas where development has occurred often included small clusters of several cabins or other residences. There are also many single cabin settlements throughout the basin.

There are approximately 109 structures within 18 miles of the Susitna River between Gold Creek and the Tyone River. These include four lodges involving some 21 structures. A significant concentration of residence cabins or other structures are found near the Otter Lake area, Portage Creek, High Lake, Gold Creek, Chunila Creek, Stephan Lake, Fog Lake, Tsusena Lake, Watana Lake, Clarence Lake, and Big Lake.

2.6 - Susitna Basin Development Selection

A comprehensive series of engineering and planning studies were carried out as a basis for formulation of Susitna Basin development plans and selection of the preferred plan. The selection process used is consistent with the generic plan formulation and selection methodology discussed in Section 1. The recommended plan, the Watana/Devil Canyon dam project, is compared to alternative methods of generating Railbelt energy needs including thermal and other potential hydroelectric developments outside the Susitna Basin on the basis of technical, economic, environmental and social aspects.

As outlined in the description of the generic plan formulation and selection methodology (Section 1.4) five basic steps are required. These essentially consist of defining the objectives, selecting candidates, screening, formulation of development plans and finally, a detailed evaluation of the plans.

The objectives of these studies are essentially twofold; the first is to determine the optimum Susitna Basin development plan and the second to undertake a preliminary assessment of the feasibility of the selected plan by comparison with alternative methods of generating energy.

Throughout this planning process, engineering layout studies were conducted to refine the cost estimates for power or water storage development at several dam sites within the basin. As they became available, these data were fed into the screening and plan formulation and evaluation studies.

The results of the site screening exercise indicate that the Susitna Basin development plan should incorporate a combination of several major dams and powerhouses located at one or more of the following sites:

- Devil Canyon
- High Devil Canyon
- Watana
- Susitna III
- Vee

In addition, the following two sites are to be considered as candidates for supplementary upstream flow regulation:

- Maclaren
- Denali

To establish the likely optimum combination of dams, a computer screening model was used to directly identify the types of plans that are most economic. Results of these runs indicate that the Devil Canyon/Watana or the High Devil Canyon/Vee combinations are the most economic. In addition to these two basic development plans, a tunnel scheme was also introduced. This alternative provides potential environmental advantages by replacing the Devil Canyon dam by a long power tunnel. A further alternative development plan involving the two most economic dam sites, High Devil Canyon and Watana, was also considered.

The main criterion used in the initial selection of Susitna Basin development plans, is that of economics. Environmental considerations are incorporated into the assessment of the plans finally selected. The results of the final screening process indicate that the Watana/Devil Canyon and the High Devil Canyon/Vee plans warrant further, more detailed study. In addition, it was decided to study further the tunnel scheme and the Watana/High Devil Canyon plan.

Four basin plans are considered. Plan 1 deals with the Watana/Devil Canyon sites, Plan 2 with the High Devil Canyon/Vee sites, Plan 3 with the Watana tunnel concept, and Plan 4 with the Watana/High Devil Canyon sites. In assessing these plans, a reach-by-reach comparison was made for the section of the Susitna River between Portage Creek and the Tyone River. The Watana/Devil Canyon scheme would create more potential environmental impacts in the Watana Creek area. However, it was judged that this was more than compensated for by avoiding the even greater potential environmental impacts in the upper reaches of the river, which would result from a High Devil Canyon/Vee development.

From a fisheries' perspective, both schemes would have a similar effect on the downstream anadromous fisheries although the High Devil Canyon/Vee scheme would produce a slightly greater impact on the resident fisheries in the Upper Susitna Basin.

Except for the increased loss of river valley, bird, and black bear habitat, the Watana/Devil Canyon development plan was judged to be more environmentally acceptable than the High Devil Canyon/Vee plan. Although the Watana/Devil Canyon plan is considered to be the more environmentally compatible Upper Susitna development plan, the actual degree of acceptability is a question being addressed as part of ongoing studies.

The two plans in were also evaluated and compared in terms of energy contribution criteria. The Watana/Devil Canyon is assessed to be superior due to its higher energy potential and the fact that it develops a higher proportion of the basin's potential. In terms of social criteria, as in the case of the dam versus tunnel comparison, the Watana/Devil Canyon plan is judged to have a slight advantage over the High Devil Canyon/Vee plan because of the higher potential for displacing nonrenewable resources.

The overall evaluation indicates that the Watana/Devil Canyon plans are generally superior for all the evaluation criteria considered. Thus, the Watana/Devil Canyon plan is judged to be the best Susitna Basin development plan.

2.7 - Susitna Hydroelectric Development

The studies discussed in this report conclude that, on the basis of the analyses to date, the future development of Railbelt electric power generation sources should include a Susitna Hydroelectric Project. However, further work is required to fully establish the technical and economic feasibility of the Susitna project and to refine its design.

The selected basin development plan involves the construction of the Watana dam to a crest elevation currently estimated as 2225 feet, with a 400 MW powerhouse scheduled to commence operation by 1993. This date is the earliest that a project of this magnitude can be brought on-line. A delay in this date would mean that additional thermal units would have to be brought on line to meet the projected demand, resulting in an increase in the cost of power to the consumer. This first stage would be followed by expansion of the powerhouse capacity to 800 MW by 1996 and possibly the construction of a re-regulation dam downstream to allow daily peaking operations. More detailed environmental studies are required to firm up the requirement for this re-regulation dam; it may be possible to incorporate it in the Devil Canyon dam diversion facilities. The final stage involves the construction of the Devil Canyon dam to a crest elevation of 1465 feet with an installed capacity of 400 MW by the year 2000.

Should the load growth occur at a lower rate than the current medium forecast, then consideration should be given to postponing the capacity expansion proposed at Watana, and the construction of the Devil Canyon dam to the year 2002, or possibly even 2005. These latter two dates correspond respectively to the low forecast and the extreme low forecast incorporating an increased level of load management and conservation. For actual load growth rates higher than the medium load forecasts, construction of the Devil Canyon dam could be advanced to 1998.

Although it has been demonstrated that this development plan is extremely economic for a wide range of possible future energy growth rates, the actual scheduling for the various stages should be continuously reassessed on perhaps a five year basis. It should also be stressed that the dam heights and installed capacities quoted above are preliminary and subject to modification as the more detailed project optimization studies are conducted in 1981. The dam type selected for the Devil Canyon dam site has been revised from the rockfill alternative assumed in the initial Basin development studies, to a thin doublecurvature concrete arch dam. More detailed engineering studies carried out subsequent to the planning studies described have indicated this dam type to be more appropriate to the site conditions and slightly more cost effective.

At this stage of the study, a preliminary assessment of the construction schedules for the Watana and Devil Canyon dams has been made, mainly to provide a reasonable estimate of on-line dates for the generation planning studies. More detailed construction schedules will be developed during the 1981 studies.

In developing these preliminary schedules, roughly 70 major construction activities were identified and the applicable quantities such as excavation, borrow and concrete volumes were determined. Construction durations were then estimated using historical records as backup and the expertise of senior scheduler-planners, estimators and design staff. A critical path logic diagram was developed from those activities and the project duration was determined. The critical or new critical activity durations were further reviewed and refined as needed. These construction logic diagrams are coded so that they may be incorporated into a computerized system for the more detailed studies to be conducted during 1981.

2.8 - Conclusions and Recommendations

(a) Conclusions

A standard methodology has been adopted to guide the Susitna Basin development selection process described in this report. It incorporates a series of screening steps and concludes with plan formulation and evaluation procedures. Both the screening and plan evaluation procedures incorporate criteria relating to technical feasibility, environmental and socioeconomic aspects, and economic viability.

The economic analyses are required to assist the State in allocating funds optimally and are therefore conducted using a real (i.e., inflation adjusted) interest rate of 3 percent and a corresponding general inflation rate of zero percent. Fuel costs are assumed to escalate at specified amounts above the general inflation rate. Analyses based on the foregoing assumptions have allowed certain conclusions to be made for future Railbelt generation planning purposes.

Previous studies over the past 30 years have thoroughly investigated the potential of the basin, and the most recent studies conducted by the COE have concluded that the Watana-Devil Canyon development plan is the preferred option. However, review of these studies has indicated that a certain amount of revision is appropriate. These revisions are necessary both to develop a more uniform level of detail for all the alternative sites considered, and to reassess the earlier planning decisions in the light of current load projections, which are generally lower than those used in the earlier studies.

The current (1980) Railbelt System annual energy requirement is estimated to be 2790 Gwh and the peak demand 515 MW. Near future demands can be satisfied by the existing generating system, the committed expansion at Bradley Lake (hydroelectric) and the combined cycle (gas-fired) plant at Anchorage. These will meet the demand until 1993 provided an Anchorage-Fairbanks intertie of adequate capacity is constructed.

A range of technically feasible options capable of meeting future energy and capacity demands have been identified and include the following:

- Thermal Units

  . Coal-fired steam generation: 100, 250, and 500 MW
  . Combined cycle generation: 250 MW
  . Gas turbine generation: 75 MW
  . Diesel generation: 10 MW

- Hydroelectric Options

  . Alternative development plans for the Susitna Basin capable of providing up to 1200 to 1400 MW capacity and an average energy yield of approximately 6000 Gwh.

  . Ten additional potential hydroelectric developments located outside the Susitna Basin and ranging from 8 to 480 MW in capacity and 33 to 1925 Gwh annual energy yield.

Indications are that the utilities will be subject to the prohibitions of the Fuel Use Act and that the use of natural gas in new facilities will be restricted to peak load application only.

The Susitna Basin development selection studies indicated that the 1200 MW Watana-Devil Canyon dam scheme is the optimum basin development plan from an economic, environmental, and social point of view. It involves an 880 feet high fill dam at Watana with an ultimate installed capacity of 800 MW, and a 675 feet high concrete arch dam at Devil Canyon with a 400 MW powerhouse. This project will develop approximately 91 percent of the total basin potential.

Should only one dam site be developed in the basin, then the High Devil Canyon dam, which develops 53 percent of the basin potential, provides the most economical energy. This project, however, is not compatible with the Watana-Devil Canyon development plan as the site would be inundated by the Devil Canyon development.

Comparison of the Railbelt system generation scenario incorporating the Watana-Devil Canyon Susitna development and the all-thermal option reveals that the scenario "with Susitna" is economically superior and reduces the total system present worth cost by $2280 million. An overall evaluation of these two scenarios based on economic, environmental, and social criteria indicates that the "with Susitna" scenario is the preferred option.

The "with Susitna" scenario remains the most economic for a wide range load forecast and parameters such as interest rate, fuel costs and fuel escalation rates. For real interest rates above 8 percent or fuel escalation rates below zero, the all thermal generating scenario becomes more economic. However, it is not likely that such high interest rates or low fuel escalation rates would prevail during the foreseeable future.

Economic comparisons of the generating scenarios "with Susitna" and the scenario incorporating alternative hydro options indicate that the present worth cost of the "with Susitna" scenario is $1190 million less.

Prelimary engineering studies indicate that the preferred dam type at Watana is a rockfill alternative, while a double curvature thin arch concrete dam is the most appropriate type for the Devil Canyon site.

(b) Recommendations

The recommendations outlined in this section pertain to the continuing studies under Task 6 - Design and Development. It is assumed that the necessary hydrologic, seismic, geotechnical, environmental, and tranmission system studies will also continue to provide the necessary support data for completion of the Feasibility Report.

Project planning and engineering studies should continue on the selected Susitna Basin Watana-Devil Canyon development plan. These studies should encompass the following:

- Additional optimization studies to define in more detail the Watana-Devil Canyon development plan. These studies should be aimed at refining:

  . Dam heights.

  . Installed capacities. As part of this task consideration should also be given to locating the tailrace of the Devil Canyon powerhouse closer to Portage Creek in order to make use of the additional head estimated to amount to 55 feet.

  . Reservoir operating rule curves.

  . Project scheduling and staging concepts. A more detailed analysis of the staging concept should be undertaken. This should include a reevaluation of the powerhouse stage sizes and the construction schedules. In addition, an assessment should be made of the technical, environmental and economic feasibility of bringing the Devil Canyon dam and powerhouse on-line before the Watana development.

This may be an attractive alternative from a scheduling point of view as it allows Susitna power to be brought on-line at an earlier date due to the shorter construction period associated with the Devil Canyon dam.

The general procedure established during this study for site selection and plan formulation as outined in Appendix A should be adhered to in undertaking the above optimization studies.

The engineering studies outlined in Subtasks 6.07 through 6.31 of the POS should continue as originally planned in order to finalize the project general arrangements and details, and to firm up technical feasibility of the proposed development.

As outlined in the original Task 6.37 study effort, the generation scenario planning studies should be refined once more definitive project data are obtained from the studies outlined above and the Railbelt generation alternatives study is completed. The objective of these studies should be to refine the assessment of the economic, environmental, and social feasibility of the proposed Susitna Basin development.

3 - SCOPE OF WORK

The Scope of Work discussed in this section of the Development Selection Report includes the development selection studies and preliminary engineering studies aimed at refining the general arrangements of the selected Watana and Devil Canyon dam projects.

Further details of the Scope of Work may be found in the Acres' POS (1,2).

3.1 - Development Selection Studies

These studies constitute Stage 1 of the Task 6 design studies and include the following:

(a) Review of Previous Studies and Reports (Subtask 6.01)

These activities involve assembling and reviewing all available engineering data pertaining to Susitna Basin hydropower development. The results of this work are summarized in Section 4 and are also reported separately in Reference (3).

(b) Investigate Tunnel Alternatives (Subtask 6.02)

In this subtask conceptual engineering designs of a long power tunnel alternative to the Devil Canyon dam are produced and evaluated in terms of economic and environmental impact. This work is summarized in Section 8 and is reported in detail in Reference (4).

(c) Evaluate Alternative Susitna Developments (Subtask 6.03)

This subtask incorporates studies aimed at developing engineering, cost and environmental impact data at all potential sites within the Susitna Basin and a series of screening and evaluation exercises to produce a shortlist of preferred Susitna Basin development options. These studies include the development of engineering layouts at several candidate sites within the basin in order to improve the accuracy of capital cost estimates. Computer models are used to screen out non-economic development plans and to evaluate power and energy yields of the more promising dam schemes.

This work is described in Section 8. Detailed results are contained in Appendices D, E, and F.

(d) Watana and Devil Canyon Staged Development (Subtask 6.06)

As an extension to the engineering layout work described above, several additional layout studies have been undertaken to investigate the feasibility of staging dam construction at the larger damsites such as Watana and High Devil Canyon. Consideration is also given to methods of staging the mechanical equipment. The results of these studies are included in Section 8.

(e) Thermal Generating Resources (Subtask 6.32)

Economic benefits of proposed Susitna Basin developments are evaluated in terms of the economic impact on the entire Railbelt electrical generating system. It is therefore necessary to develop cost and performance figures for alternative energy generating resources including thermal and other potential hydro sites located outside the Susitna Basin. The subtask involves studies undertaken to develop performance and cost data for a range of feasible thermal generating options including coal fired steam, gas turbine, combined cycle and diesel plants.

The results of this subtask are reported in Section 6 and Appendix B.

(f) Hydroelectric Generating Source (Subtask 6.33)

This subtask involves an extensive screening exercise incorporating economic and environmental criteria. The aim of this exercise is to shortlist several potential hydroelectric developments located outside the Susitna Basin which could supply the railbelt with energy. Conceptual sketch layouts are produced for the shortlist developments in order to estimate the capital costs more accurately. Computer models are used to indicate the power and energy yields.

The result of this work are reported in Section 6 and Appendices C and F.

(g) Environmental Analysis (Subtask 6.34)

This subtask includes the environmental studies necessary to screen the potential hydroelectric developments outlined in (f) above and to provide general information on the potential environmental impacts associated with the thermal generating resources.

The results of these studies are outlined in Sections 6 and 8 and in Appendices A and C.

(h) Load Management and Conservation (Subtask 6.35)

In order to thoroughly assess the economics of the proposed Susitna development plan for a wide range of projected load forecasts it is necessary to assess the potential impact of possible future local management and conservation practices. A brief study is undertaken to determine the impact of a feasible load management and conservation scenario and appropriate adjustments are made to energy and load forecasts for use in the generation planning studies discussed in Section 5.

(i) Generation Planning (Subtask 6.36)

This subtask involves the systemwide economic analyses undertaken to determine the economic benefits of various Susitna Basin development plans and alternative all-thermal and thermal-plus-other-hydro generating scenarios. These latter two scenarios are studied in order to assess the economic benefit associated with developing the Susitna Basin. A computer generation planning model is used to undertake these analyses.

Section 8 and Appendix G outline the results of this work.

(j) Development Selection Report (Subtask 6.05)

This subtask deals with the production of the report. It also includes a summary of the load projections prepared by ISER and the power projections provided by WCC in Section 5.

Additional study work is also carried out to formalize the project development selection process, i.e. to integrate the results of the studies outlined above to provide a comprehensive selection process incorporating economic, environmental and other considerations.

3.2 - Continued Engineering Studies

As the development selection studies were finalized work continued on engineering design studies aimed at refining the general arrangements at the Devil Canyon and Watana sites. These studies involve the production of alternative general arrangements incorporating rockfill and concrete arch dams at Watana and several alternative concrete arch dams at Devil Canyon. These arrangements are costed and evaluated to determine which is the most appropriate. Design work is carried out on the proposed thin arch dam at Devil Canyon to ensure that such a structure can safely withstand the anticipated seismic loading. Extensive use is made of computer stress analysis techniques in the design studies.

These studies are scoped in Subtasks 6.04, 6.07, and 6.08 and the results are summarized in Section 9 and Appendix H.

LIST OF REFERENCES

(1) Acres American Incorporated, Susitna Hydroelectric Project - Plan of Study, Prepared for the Alaska Power Authority, February, 1980.

(2) Acres American Incorporated, Susitna Hydroelectric Project - Plan of Study, Revision 1, Prepared for the Alaska Power Authority, September, 1981.

(3) Acres American Incorporated, Susitna Hydroelectric Project - Review of Previous Studies and Reports, Prepared for the Alaska Power Authority, February, 1981.

(4) Acres American Incorporated, Susitna Hydroelectric Project - Investigate Tunnel Alternative, Closeout Report prepared for the Alaska Power Authority, April, 1981.

4 - PREVIOUS STUDIES

In this section of the report a summary is presented of studies undertaken by the WRPS (formerly the USBR), the COE and others over the period 1948 through 1979.

4.1 - Early Studies of Hydroelectric Potential

Shortly after World War II ended the USBR conducted an initial investigation of hydroelectric potential in Alaska, and issued a report of the results in 1948. Responding to a recommendation made in 1949 by the nineteenth Alaska territorial legislature that Alaska be included in the Bureau of Reclamation program, the Secretary of Interior provided funds to update the 1948 work. The resulting report, issued in 1952, recognized the vast hydroelectric potential within the territory and placed particular emphasis on the strategic location of the Susitna River between Anchorage and Fairbanks as well as its proximity to the connecting Railbelt (See Figures 1.1 and 4.1).

A series of studies was commissioned over the years to identify dam sites and conduct geotechnical investigations. By 1961, the Department of the Interior proposed authorization of a two dam power system involving the Devil Canyon and the Denali sites (Figure 4.1). The definitive 1961 report was subsequently updated by the Alaska Power Administration (at that time an agency of the Bureau of Reclamation) in 1974, at which time the desirability of proceeding with hydroelectric development was reaffirmed.

The COE was also active in hydropower investigations in Alaska during the 1950's and 1960's, but focused its attention on a more ambitious development at Rampart on the Yukon River. This project was capable of generating five times as much electric energy as Susitna annually. The sheer size and the technological challenges associated with Rampart captured the imagination of supporters and effectively diverted attention from the Susitna Basin for more than a decade. The Rampart report was finally shelved in the early 1970's because of strong environmental concerns and the uncertainty of marketing prospects for so much energy, particularly in light of abundant natural gas which had been discovered and developed in Cook Inlet.

The energy crisis precipitated by the OPEC oil boycott in 1973 provided some further impetus for seeking development of renewable resources. Federal funding was made available both to complete the Alaska Power Administration's update report on Susitna in 1974 and to launch a prefeasibility investigation by the COE. The State of Alaska itself commissioned a reassessment of the Susitna Project by the Henry J. Kaiser Company in 1974.

Although the gestation period for a possible Susitna Project has been lengthy, Federal, State, and private organizations have been virtually unanimous over the years in recommending that the project proceed. Salient features of the various reports to date are outlined in the following sections.

4.2 - U.S. Bureau of Reclamation - 1953 Study (1)

The USBR 1952 report to the Congress on Alaska's overall hydroelectric potential was followed shortly by the first major study of the Susitna Basin in 1953. Ten dam sites were identified above the railroad crossing at Gold Creek (see also Figure 4-1):

- Gold Creek
- Olson
- Devil Canyon
- Devil Creek
- Watana
- Vee
- Maclaren
- Denali
- Butte Creek
- Tyone (on the Tyone River)

Fifteen more sites were considered below Gold Creek. However, more attention has been focused over the years on the Upper Susitna Basin where the topography is better suited to dam construction and where less impact on anadromous fisheries is expected. Field reconnaissance eliminated half the original Upper Basin list and further USBR consideration centered on Olson, Devil Canyon, Watana, Vee and Denali. All of the USBR studies since 1953 have regarded these sites as the most appropriate for further investigation.

4.3 - U.S. Bureau of Reclamation - 1961 Study (2)

In 1961 a more detailed feasibility study resulted in a recommended five stage development plan to match the load growth curve as it was then projected. Devil Canyon was to be the first development--a 635 feet high arch dam with an installed capacity of about 220 MW. The reservoir formed by the Devil Canyon dam alone would not store enough water to permit higher capacities to be economically installed since long periods of relatively low flow occur in the winter months. The second stage would have increased storage capacity by adding an earthfill dam at Denali in the upper reaches of the basin. Subsequent stages involved adding generating capacity to the Devil Canyon dam. Geotechnical investigations at Devil Canyon were more thorough than at Denali. At Denali, test pits were dug, but no drilling occurred.

4.4 - Alaska Power Administration - 1974 (3)

Little change from the basic USBR-1961 five stage concept appeared in the 1974 report by the Alaska Power Administration. This later effort offered a more sophisticated design, provided new cost and schedule estimates, and addressed marketing, economics, and environmental considerations.

4.5 - Kaiser Proposal for Development (4)

The Kaiser study, commissioned by the Office of the Governor in 1974, proposed that the initial Susitna development consist of a single dam known as High Devil Canyon (See Figure 4.1). No field investigations were made to confirm the technical feasibility of the High Devil Canyon location because the funding level was insufficient for such efforts. Visual observations suggested the site was probably favorable. The USBR had always been uneasy about foundation conditions at Denali, but had to rely upon the Denali reservoir to provide storage during long periods of low flow. Kaiser chose to avoid the perceived uncertainty at Denali by proposing to build a rockfill dam at High Devil Canyon which, at 810 feet, would create a large enough reservoir to overcome the storage problem. Although the selected sites were different, the COE reached a similar conclusion when it later chose the high dam at Watana as the first to be constructed.

Subsequent developments suggested by Kaiser included a downstream dam at the Olson Site and an upstream dam at Susitna III (see Figure 4.1). The information developed for these additional dams was confined to estimating energy potential. As in the COE study, future development of Denali remained a possibility if foundation conditions were found to be adequate and if the value of additional firm energy provided economic justification at some later date.

Kaiser did not regard the development of an energy consumptive aluminum plant as necessary to economically justify its proposed project.

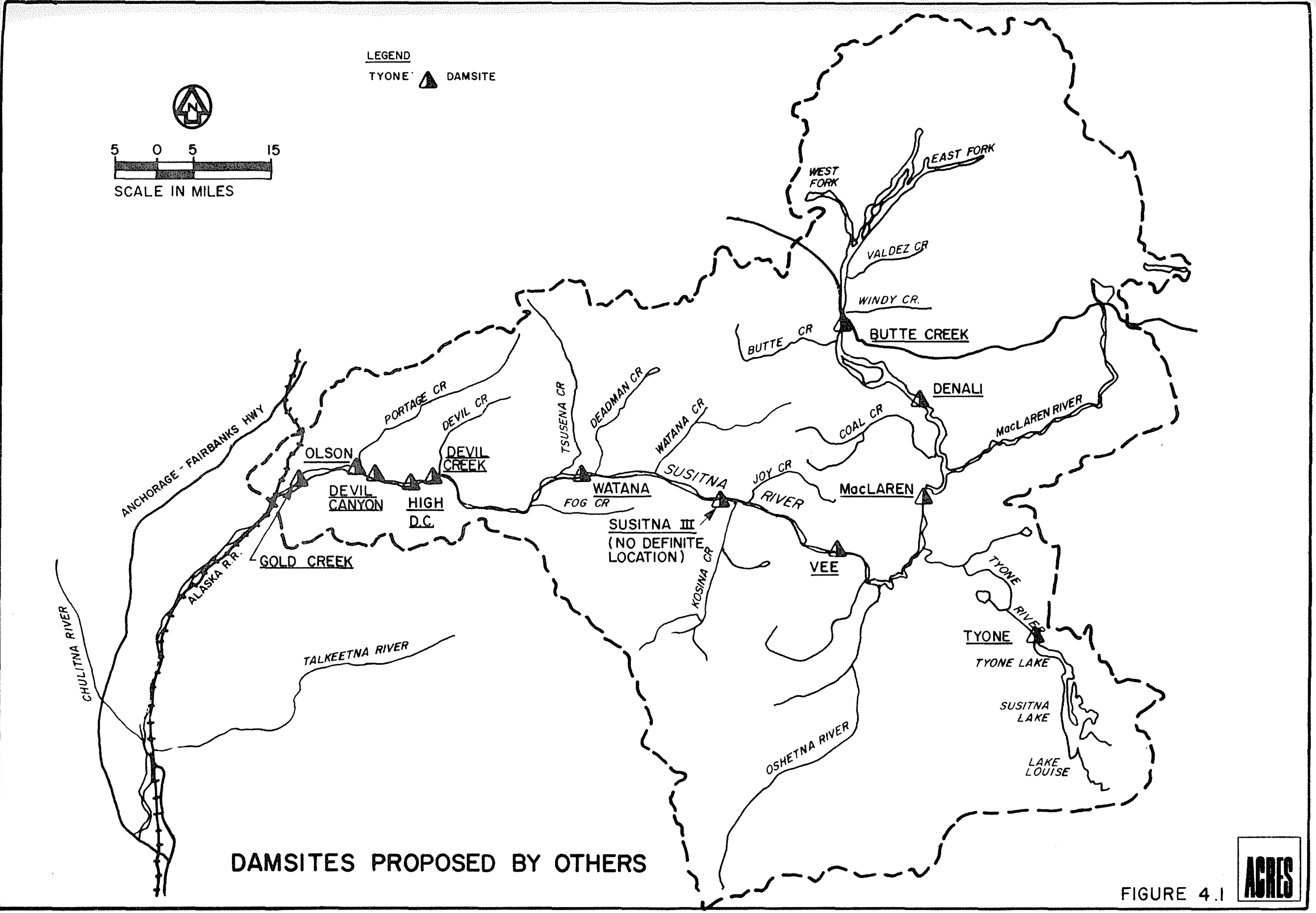
4.6 - U.S. Army Corps of Engineers - 1975 and 1979 Studies (5,6)

The most comprehensive study of the Upper Susitna Basin to date was completed in 1975 by the COE. A total of 23 alternative developments were analyzed, including those proposed by the USBR as well as consideration of coal as the primary energy source for Railbelt electrical needs. The COE agreed that an arch dam at Devil Canyon was appropriate, but found that a high dam at the Watana site would form a large enough reservoir for seasonal storage and would permit continued generation during low flow periods.

The COE recommended an earthfill dam at Watana with a height of 810 feet. In the longer term, development of the Denali site remained a possibility which, if constructed, would increase the amount of firm energy available, even in very dry years.

An ad-hoc task force was created by Governor Jay Hammond upon completion of the 1975 COE Study. This task force recommended endorsement of the COE request for Congressional authorization, but pointed out that extensive further studies, particularly those dealing with environmental and socioeconomic questions, were necessary before any construction decision could be made.

At the Federal level, concern was expressed at the Office of Management and Budget regarding the adequacy of geotechnical data at the Watana site as well as the validity of the economics. The apparent ambitiousness of the schedule and the feasibility of a thin arch dam at Devil Canyon were also questioned. Further investigations were funded and the COE produced an updated report in 1979. Devil Canyon and Watana were reaffirmed as appropriate sites, but alternative dam types were investigated. A concrete gravity dam was analyzed as an alternative for the thin arch dam at Devil Canyon and the Watana dam was changed from earthfill to rockfill. Subsequent cost and schedule estimates still indicated economic justification for the project.



DAMSITES PROPOSED BY OTHERS

FIGURE 4.1

LIST OF REFERENCES

(1) U.S. Department of the Interior, Bureau of Reclamation (Alaska District), District Manager's Reconnaissance Report of August, 1952 on Susitna River Basin: A Report on the Potential Development of Water Resources in the Susitna River Basin of Alaska, 1952.

(2) U.S. Department of the Interior, Bureau of Reclamation (Alaska District), Devil Canyon Project, Alaska: Report of the Commissioner of Reclamation and Supporting Reports, 1960.

(3) Alaska Power Administration, Devil Canyon Status Report, Juneau, Alaska, May, 1974.

(4) H. J. Kaiser & Company, Reassessment Report on Upper Susitna River Hydroelectric Development for the State of Alaska, September, 1974.

(5) U.S. Department of the Army, Corps of Engineers (Alaska District), Hydroelectric Power and Related Purposes: Southcentral Railbelt Area, Alaska, Upper Susitna River Basin - Interim Feasibility Report, Anchorage, Alaska, 1975.

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

5 - RAILBELT LOAD FORECASTS

5.1 - Introduction

The feasibility of a major hydroelectric project depends in part upon the extent which the available capacity and energy are consistent with the needs of the market to be served by the time the project comes on line. Attempting to forecast future energy demand is a difficult process at best; it is therefore particularly important that this exercise be accomplished in an objective manner. For this reason APA and the State of Alaska jointly awarded a separate contract to ISER to prepare appropriate projections for the Alaska Railbelt region. Section 5 presents a review of the economic scenarios upon which the ISER forecasts were based and a discussion of the forecasts developed for use in generation planning studies.

5.2 - Electricity Demand Profiles

This section reviews the historical growth of electricity consumption in the Railbelt and compares it to the national trend. Railbelt electricity consumption is then disaggregated by regions and by end-use sectors to clarify past usage patterns.

(a) Historical Trends

Between 1940 and 1978, electricity sales in the Railbelt grew at an average annual rate of 15.2 percent. This growth was roughly twice that for the nation as a whole. Table 5.1 shows U.S. and Alaskan annual growth rates for different periods between 1940 and 1978. The historical growth of Railbelt utility sales from 1965 is illustrated in Figure 5.1.

Although the Railbelt growth rates consistently exceeded the national average, the gap has been narrowing in later years due to the gradual maturing of the Alaskan economy. Growth in the Railbelt has exceeded the national average for two reasons: population growth in the Railbelt has been higher than the national rate, and the proportion of Alaskan households served by electric utilities was lower than the U.S. average so that some growth in the number of customers occurred independently of population growth. Table 5.2 compares U.S. and Alaskan growth rates in the residential and commercial sectors.

(b) Regional Demand

Electricity demand in the Railbelt, disaggregated by regions, is shown in Table 5.3. During the period from 1965 to 1978, Greater Anchorage accounted for about 75 percent of Railbelt electricity consumption followed by Greater Fairbanks with 24 percent and Glennallen-Valdez with 1 percent. The pattern of regional sharing during this period has been quite stable and no discernible trend in regional shift has emerged. This is mainly a result of the uniform rate of economic development in the Alaskan Railbelt.

(c) End-Use Consumption

Railbelt electricity consumption by major end-use sector is shown in Table 5.4. In the residential sector, electricity consumption is largely attributed to space heating; utilities such as refrigerators, water heaters, lights and cooking ranges rank next in order of usage. In the commercial-industrial-government sector, end-use consumption is less clear because of a lack of data; however, it is reasonable to assume that electricity is used mainly for lighting, space heating, cooling and water heating. Consumption in the miscellaneous sector is attributed mainly to street lighting and usage in second homes.

The distribution of electricity consumption in these end-use sectors has been fairly stable. By 1978, the commercial-industrial-government and residential sectors accounted for 52 percent and 47 percent respectively. In contrast, the 1978 nationwide shares were 65 percent and 34 percent respectively(1).

5.3 - ISER Electricity Consumption Forecasts

As outlined in Section 3, the electricity consumption forecasts were undertaken by ISER(1). This section briefly discusses the methodology used by ISER to estimate electric energy sales for the Railbelt, and summarizes the results obtained.

(a) Methodology

The ISER electricity demand forecasting model conceptualized in computer logic the linkage between economic growth scenarios and electricity consumption. The output from the model is in the form of projected values of electricity consumption for each of the three geographical areas of the Railbelt (Greater Anchorage, Greater Fairbanks and Glennallen-Valdez) and is classified by final use (i.e., heating, washing, cooling, etc.) and consuming sector (commercial, residential, etc). The model produces output on a five-year time basis from 1985 to 2010, inclusive.

The ISER model consists of several submodels linked by key variables and driven by policy and technical assumptions and state and national trends. These submodels are grouped into four economic models which forecast future levels of economic activity and four electricity consumption models which forecast the associated electricity requirements by consuming sectors. For two of the consuming sectors it was not possible to set up computer models and simplifying assumptions were made. The models and assumptions are described below.

(i) Economic Submodels

- The MAP Econometric Model

MAP is an econometric model based on forecasted or assumed levels of national economic trends, State government activity, and developments in the Alaska resource sector. These economic indicators are translated into forecasted levels of statewide population by age and sex, employment by industrial sector, and income.

- The Household Formation Model

  The household formation model groups individuals into household units on the basis of national and state demographic trends. The output is the forecast number of household heads by age and sex, which is in turn an input to the housing stock and electricity consumption models.

- Regional Allocation Model

  This model disaggregates MAP's projections of population and employment into regions of the Railbelt. The model uses econometric techniques to structure regional shares of state population, the support sector, and government employment.

- Housing Stock Model

  The housing stock model utilizes the output from the household formation model, the regional population information from the regional allocation model, and the results of an independent survey on housing choice. These outputs are combined to produce the number of housing units by type (e.g. single family, duplex, multifamily, etc.) and by region for each of the forecast years.

(ii) Electricity Consumption Submodels

These submodels are structured to determine electricity requirements for various demand components:

- Residential Non-space Heating Electricity Requirements

  This model estimates electricity requirements for household appliances utilizing the following information:

  . number of households
  . appliance saturation rate
  . fuel mode split
  . average annual consumption of appliance
  . average household size

  Residential non-space heating electricity requirements are obtained by summing the electricity requirements of all appliances.

- Residential Space Heating

  This model estimates space heating electricity requirements for four types of dwelling units: single family, duplex, multifamily, and mobile home. The space heating electricity requirement for each type of dwelling unit is calculated as the product of the number of dwelling units, fuel mode split and specified average levels of consumption.

- Commercial-Industrial-Government

  Total electricity requirements for the commercial-industrial-government sector are defined as the product of non-agricultural wage and salary employment and average electricity consumption per employee. Electricity consumption per employee is a function of time and application of conservation standards. This implies that new electricity users in this sector will have different electricity requirements than previous customers.

- Miscellaneous

  This model estimates two remaining sectors of electricity consumption: i.e. street lighting and recreational homes.

(iii) Consumption Sectors Not Modeled

Electricity requirements were not modeled for two sectors of demand:

- Military

  For many reasons, including a lack of historical data, no model is included to correlate military electricity consumption with causal factors. Hence, future electricity requirements for the military are assumed to be the same as the current level.

- Self-Supplied Industrial

  No model is included to project future self-generated electricity for industry. Existing users are identified and current electricity consumption determined for APA sources. New users and future consumption levels are identified from economic scenarios.

(b) Assumptions

To make these models operational, a number of additional assumptions are incorporated:

- The electricity market is presently in a state of relative equilibrium except for Fairbanks where a shift away from electric space heating is underway. This equilibrium is expected to remain in effect throughout the forecast period because of relatively constant fuel price ratios.

- The price of energy relative to other goods and services will continue to rise.

- Rising real incomes will act to increase the demand for electricity.

- Federal policies will be effective in the area of appliance energy conservation, but will have a much smaller impact on building stock thermal efficiencies.

- No State conservation policies directed exclusively toward electricity will be implemented.

- No significant State policies designed to alter the price or availability of alternative fuels will be implemented.

- No new electricity technologies will be introduced.

- In terms of residential appliances:

  . Saturation rates will follow national trends;
  . For some appliances, reduced household size will act to reduce average electricity requirements;
  . Consumption is a function of the appliance scrapping rate as the average age affects efficiency;
  . Unspecified appliance consumption will increase to accommodate the Possibility of new domestic electricity applications.

- In terms of residential space heating:

  . A slight trend toward single family homes is projected;
  . Average housing unit size will continue to grow;
  . Natural gas availability will not significantly increase;
  . Space heating alternatives such as oil, wood or coal will not greatly affect aggregate space heating demand;
  . No significant increase in the number of heat pumps will occur.

- In terms of commercial-industrial-government use:

  . Employment will grow more rapidly than the population;
  . No major energy conservation measures are anticipated;
  . The distribution of electricity end-uses will not shift significantly.

- Miscellaneous utility sales (street lighting and second home use) will grow at rates consistent with predicted total utility sales.

(c) Forecasting Uncertainty

To adequately address the uncertainty associated with the prediction of future demands, a number of different economic growth scenarios were considered. These were formulated by alternatively combining high, moderate and low growth rates in the area of special projects and industry with State government fiscal policies aimed at stimulating either high, moderate or low growth. This resulted in a total of nine potential growth scenarios for the State. In addition to these scenarios, ISER also considered the potential impact of a price reduced shift towards increased electricity demand. As outlined below, a short list of six future scenarios was selected. These concentrated around the mid-range or "most likely" estimate and the upper and lower extremes.

(d) Forecast Results

(i) Base Case

The ISER forecast which incorporates the combination of moderate economic growth and moderate government expenditure is considered to be the "most likely" load forecast. This has been identified for the purpose of this study as the "Base Case Forecast". The results of this forecast are presented in Table 5.5 and indicate that utility sales for the Railbelt will grow from the 1980 level of 2390 GWh to 7952 GWh in 2010, representing an average annual growth rate of 4.09 percent. Over the period of the forecast, the highest growth rate occurs from 1990 to 2000 at 4.76 percent, followed by a decline to 3.33 percent during the 2000 to 2010 period.

(ii) Range of Forecasts

In addition to the base case, the ISER results incorporate a higher and lower rate of economic growth coupled with moderate government expenditure, and they also incorporate the case where a shift to electricity takes place. These forecasts do not provide a complete envelope of potential growth scenarios because the impacts of high industrial growth/high government expenditure and low industrial growth/low government expenditure on electricity demand have not been included. Estimates of these impacts have been computed by the method of proportionality as approximations to the model runs. A summary of aggregate Railbelt electricity growth for the range of scenarios is presented in Table 5.6 and in Figure 5.2. The medium growth rate of 4.1 percent is shown to be bounded by lower and upper limits of 2.8 percent and 6.1 percent respectively. In comparison, historical electricity demand in the Railbelt has increased by 11 percent.

5.4 - Past Projections of Railbelt Electricity Demand

A number of electricity projections have been developed in the past. The discussion here is confined to work conducted since 1975 in order to compare ISER's forecasts with previous work and to rationalize any differences that occur.

Forecasts of electric power requirements developed since 1975 (excluding ISER's latest forecast) are summarized in Table 5.7. A cursory examination indicates that differences which occur in the early years progressively increase within the forecast period. The performance of these forecasts can be ascertained by comparing them to 1980 utility sales. Table 5.8 shows the percent error in the forecasted growth rate to 1980. As can be seen, all of the forecasts significantly overestimated 1980 consumption.

These forecasts are also significantly different from those developed recently by ISER; the differences are mainly attributed to assumptions concerning economic growth and electricity consumption rates. Although the economic growth assumptions incorporated in previous studies have varied widely, they have been generally more optimistic with respect to the type, size and timing of projects and other economic events. This has consequently resulted in higher projections of economic activity compared to the recent ISER study.

Electricity consumption rates in the ISER studies are generally lower than those in previous studies. This is essentially because ISER has been the first to incorporate estimates of appliance saturation rates, end-use patterns and conservation measures.

5.5 - Demand Forecasts

(a) Approach

The overall approach to derivation of the peak demand forecasts for the Railbelt Region was to examine the available historical data with regard to the generation of electrical energy and to apply the observed generation patterns to existing sales forecasts. Information routinely supplied by the Railbelt utilities to the Federal Energy Regulatory Commission was utilized to determine these load patterns.

(b) Load Patterns

The analysis of load patterns emphasized the identification of average patterns over the 10-year period from 1970 to 1979 and did not consider trends or changes in the patterns with time. Generally, the use of average values was preferred as it reduced the impact of yearly variations due to variable weather conditions and outages. In any event, it was not possible to detect any patterns in the available data.

The average hourly distribution of generation for the first weeks of April, August and December was used to determine the typical average load pattern for the various utilities. As a result of the relatively limited data base, the calculated load duration curve would be expected to show less variation than one computed from a more complete data base resulting in an overestimation of the load factor. In addition, hourly data also tend to average out actual peak demands occurring within a time interval of less than one hour. This could also lead to overestimation of the load factor. It is, however, believed that the accuracy achieved is adequate for these studies, particularly in light of the relatively much greater uncertainties associated with the load forecasts.

(c) Sales Allocation

Although the above load data are available by utility, the kWh sales forecasts are based on service area alone. The kWh sales data were allocated to the individual utilities utilizing a predicted mix of consumer categories in the area and the current mix of sales by consumer category for the utilities serving the area.

(d) Peak Loads

The two data sets were combined to determine composite peak loads for the Railbelt area.

The first step involved an adjustment to the allocated sales to reflect losses and energy unaccounted for. The adjustment was made by increasing the energy allocated to each utility by a factor computed from historical sales and generation levels. This resulted in a gross energy generation for each utility.

The factors determined for the monthly distribution of total annual generation were then used to distribute the gross generation for each year. The resulting hourly loads for each utility were added together to obtain the total Railbelt system load pattern for each forecast year. Table 5.9 summarizes the total energy generation and the peak loads for each of the low, medium, and high ISER sales forecasts, assuming moderate government expenditure.

The load factors computed in this study average seven percentage points higher than the average load factors observed in the four utilities over the 10-year period.

5.6 - Potential for Load Management and Energy Conservation

Utilities nationwide are currently paying increasing attention to the implementation of load management and conservation measures in an attempt to reduce or shift peak load and to reduce energy demand. Load management is defined as the "shifting" and corresponding reduction of peak demands and the alteration of daily load shapes by means of appropriate measures. Although some load management techniques can result in a slight increase in daily energy demand, the objective is essentially to accomplish a reduction of peak demand with no significant difference in total energy demand. Load management may generally be achieved by one of two methods: direct control, in which the utility controls the end-use devices; or indirect control, in which price incentives are used to motivate load shifting by the consumer. Conservation is defined as a net reduction in energy demand by means of appropriate measures, with a corresponding reduction in peak demand.

The potential benefits of power demand control and reduction measures require careful evaluation before implementation on a major scale. A considerable amount of research and development work has been undertaken in the Lower 48 to develop methods and cost strategies, and to assess the potential impact of such strategies on demand. As a result of this work, load management and energy conservation concepts have either been implemented or are being planned by many utilities. The anticipated effects on the growth of future peak load and energy consumption in the utility systems have been included in their forecasts. Currently in Alaska, one utility, Anchorage Municipal Light and Power, has instituted an experimental time-of-day rate for electricity.

Although conservation is essentially accomplished by a reduction in demand, it may also be regarded as a means of diverting available energy to other uses, or creating a "new" source of energy. A recent study by the Alaska Center for Policy Studies (2) indicated that conservation was the most economically attractive source of new energy available to the Railbelt area. This conclusion was based on evidence from existing weatherization programs and projections from the Alaska Federation for Community Self Reliance in Fairbanks. However, the total amount of energy that can be made available by such means is relatively small compared to the total Railbelt system energy demand up to the year 2010.

The ISER forecasts incorporated the impacts of certain energy conservation measures, but did not include any load management. In this study, opportunities for implementation of additional programs of intensified conservation and load management measures are considered in the generation planning studies. These are discussed in more detail in the following section.

5.7 - Load Forecasts Used for Generation Planning Studies

This section outlines the adjustments that were made to produce the total Railbelt system electricity forecasts to be used in the generation planning studies described in Section 8.

(a) Adjusted ISER Forecasts

Three ISER energy forecasts were considered in generation planning studies (see Table 5.6). These include the base case (MES-GM) or medium forecast, a low and a high forecast. The low forecast is that corresponding to the low economic growth as proposed by ISER with an adjustment for low government expenditure (LES-GL). The high forecast corresponds to the ISER high economic growth scenario with an adjustment for high government expenditure (HES-GH).

The electricity forecasts summarized in Table 5.9 represent total utility generation and include projections for self-supplied industrial and military generation sectors. Included in these forecasts are transmission and distribution losses in the range of 9 to 13 percent depending upon the generation scenario assumed. These forecasts, ranging from 2.71 to 4.76 percent average annual growth, were adjusted for use in generation planning studies.

The self-supplied industrial energy primarily involves drilling and offshore operations and other activities which are not likely to be connected into the Railbelt supply system. This component, which varies depending upon generation scenario, was therefore omitted from the forecasts used for planning purposes.

The military is likely to continue purchasing energy from the general market as long as it remains economic. However, much of their generating capacity is tied to district heating systems which would presumably continue operation. For study purposes, it was therefore assumed that 30 percent of the estimated military generation would be supplied from the grid system.

The adjustments made to power and energy forecasts for use in self-supplied industrial and military sectors are reflected in Table 5.10 and in Figure 5.3 The power and energy values given in Table 5.10 are those used in the generation planning studies. Annual growth rates range from 1.99 to 5.96 percent for very low and high forecasts with a medium generation forecast of 3.96 percent.

(b) Forecast Incorporating Load Management and Conservation

In order to evaluate generation plans under extremely low projected energy growth rates, the low forecast was further adjusted downward to account for additional load management and energy conservation. The results of this scenario also appear on Table 5.10.

- ISER Conservation Assumptions

For the residential sector, ISER assumed the federally-mandated efficiency standards for electrical home appliances would be enforced from 1981 to 1985 but that target efficiencies would be reduced by 10 percent. Energy saving due to retrofitting of homes was assumed to be confined to single family residences and to occur between 1980 and 1985. Heating energy consumption was assumed to be reduced by 4 percent in Fairbanks, 2 percent in Anchorage and between 2 and 4 percent in the Glennallen-Valdez area. Enforcement of mandatory construction or performance standards for new housing was assumed in 1981 with a reduction of the heat load for new permanent home construction by 5 percent.

In the commercial-industrial-government sector, it was assumed by ISER that electricity requirements for new construction would be reduced by 5 percent between 1985 and 1990 and by 10 percent during the period 1990 to 2000. It was assumed that retrofitting measures would have no impact.

- Impacts of Recent Legislation

The National Energy Conservation Policy Act includes a variety of incentives and mandates for energy conservation and alternative energy use by individuals, state government and business. The new programs consist of energy audits of residential customers and public buildings, insulation and retrofitting of homes through loan and grant programs, improvement of energy efficiency of schools and hospitals, and use of solar energy.

The Public Utilities Regulatory Policies Act (PURPA) of November 9, 1978, requires state public utility commissions to consider certain rate-making standards for utilities if they have sales in excess of 500 million kilowatt hours. The established standards to be considered are:

. Rates to reflect cost of service;
. Abolition of declining block rates;
. Time-of-day rates;
. Seasonal rates.

Both Chugach Electric (CEA) and Anchorage Municipal Light and Power Department (AMLPD) are affected by the provisions of PURPA regarding rate and service standards for electric utilities. According to the report by the Alaska Center for Policy Studies (2), the Alaska Public Utilities Commission (APUC) intends to deal with the rate and load management considerations called for by PURPA in 1981.

- Study Assumptions

The programs of energy conservation and load management measures that could be implemented in addition to those included in the ISER forecast are the following:

- Energy programs provided for in the recent state energy conservation legislation;

- Load management concepts now tested by utilities, including rate reform, to reflect incremental cost of service and load controls.

These measures could decrease the growth rate of energy and winter peak projected in the ISER forecast and the forecasts used in generation planning. The impacts would be mainly in the residential sector.

The impact of state energy conservation legislation has been evaluated in a study by Energy Probe (3) which indicated that it could reduce the amount of electricity needed for space heating by 47 percent. The total growth rate in electricity demand over the 1980-2010 period would drop from an average of 3.98 percent per annum (projected by ISER in the MES-GM forecast), to 3.49 percent per annum. Energy Probe indicated that the electrical energy growth rate could be reduced even further to 2.70 percent per annum with a conservation program more stringent than that presently contemplated by the State legislature.

The low forecast case assumed above incorporates an annual growth rate of 2.71 percent. This rate would be reduced with enforcement of energy conservation measures more intensive than those presently in the State legislature. An annual growth rate of 2.1 percent was judged to be a reasonable lower limit for electrical demand for purposes of this study. This represents a 23 percent reduction in growth rate which is similar to the reduction developed in the Energy Probe study.

The implementation of load management measures would result in an additional reduction in peak load demand. The residential sector demand is the most sensitive to a shift of load from the peak period to the off-peak period. Over the 1980-2010 period, an annual growth rate for peak load of 2.73 percent was used in the low forecast case. With load management measures such as rate reform and load controls, this growth rate could be reduced to an estimated 2.1 percent. The annual load factor for year 2010 would be increased from 62.2 percent in the low forecast to 64.4 in the lowest case.

TABLE 5.1 - HISTORICAL ANNUAL GROWTH RATES OF ELECTRIC UTILITY SALES

Period	U.S.	Anchorage and Fairbanks Areas
1940 - 1950	8.8%	20.5%
1950 - 1960	8.7%	15.3%
1960 - 1970	7.3%	12.9%
1970 - 1978	4.6%	11.7%
1970 - 1973	6.7%	13.1%
1973 - 1978	3.5%	10.9%
1940 - 1978	7.3%	15.2%

TABLE 5.2 - ANNUAL GROWTH RATES IN UTILITY CUSTOMERS AND CONSUMPTION PER CUSTOMER

	Greater Anchorage		Greater Fairbanks		U.S.	
	Customers (Thousands)	Consumption per Customer (MWh)	Customers (Thousands)	Consumption per Customer (MWh)	Customers (Millions)	Consumption per Customer (MWh)
Residential						
1965	2.7	6.4	8.2	4.8	57.6	4.9
1978	7.7	10.9	17.5	10.2	77.8	8.8
Annual Growth Rate (%)	8.4	4.2	6.0	6.0	2.3	4.6
Commercial						
1965	4.0	-	1.3	-	7.4	-
1978	10.2	-	2.9	-	9.1	
Annual Growth Rate (%)	7.5	-	6.4	-	1.6	-

TABLE 5.3 - UTILITY SALES BY RAILBELT REGIONS

Year	Greater Anchorage Sales GWh	Greater Anchorage Sales Regional Share	Greater Anchorage No. of Customers[1] (Thousands)	Greater Fairbanks Sales GWh	Greater Fairbanks Sales Regional Share	Greater Fairbanks No. of Customers[1] (Thousands)	Glennallen-Valdez Sales GWh	Glennallen-Valdez Sales Regional Share	Glennallen-Valdez No. of Customers[1] (Thousands)	Railbelt Total Sales GWh	Railbelt Total No. of Customers[1] (Thousands)
1965	369	78%	31.0	98	21%	9.5	6	1%	.6	473	41.1
1966	415		32.2	108		9.6	NA		NA	523	41.8
1967	461		34.4	66		NA	NA		NA	527	34.4
1968	519		39.2	141		10.8	NA		NA	661	30.0
1969	587		42.8	170		11.6	NA		NA	758	54.4
1970	684	75%	46.9	213	24%	12.6	9	1%	.8	907	60.3
1971	797		49.5	251		13.1	10		.9	1059	63.5
1972	906		54.1	262		13.5	6		.4	1174	68.0
1973	1010		56.1	290		13.9	11		1.0	1311	71.0
1974	1086		61.8	322		15.5	14		1.3	1422	78.6
1975	1270	75%	66.1	413	24%	16.2	24	1%	1.9	1707	84.2
1976	1463		71.2	423		17.9	33		2.2	1920	91.3
1977	1603		81.1	447		20.0	42		2.1	2092	103.2
1978	1747	79%	87.2	432	19%	20.4	38	2%	2.0	2217	109.6
Annual Growth	12.7%		8.2%	12.1%		6.1%	13.9%		9.7%	12.6%	7.8%

NOTES:

(1) Includes residential and commercial users only, but not miscellaneous users.
Source: Federal Energy Regulatory Commission, Power System Statement (_).
NA: Not Available.

TABLE 5.4 - RAILBELT ELECTRICITY END-USE CONSUMPTION (GWh)

Year	Residential	Commercial-Industrial - Government	Miscellaneous
1965	214	248	9
1966	241	275	8
1967	208	241	8
1968	294	355	11
1969	339	407	12
1970	402	489	14
1971	478	555	25
1972	542	613	17
1973	592	698	19
1974	651	749	20
1975	790	886	28
1976	879	1012	26
1977	948	1117	21
1978	1029	1156	27
Average Annual Growth	12.8%	12.6%	8.8%
% of Annual Consumption			
1965	45%	53%	2%
1970	44%	54%	2%
1975	46%	52%	2%
1978	47%	52%	1%

TABLE 5.5 - BASE CASE FORECAST (MES-GM)[1] (GWh)

	Utility Sales to All Consuming Sectors			Sales	Military	Self-Supplied
Year	Anchorage	Fairbanks	Glennallen-Valdez	Total Utility	Net Generation	Industry Net Generation
1980	1907	446	37	2390	334	414
1985	2438	669	64	3171	334	571
1990	2782	742	75	3599	334	571
1995	3564	949	88	4601	334	571
2000	4451	1177	102	5730	334	571
2005	5226	1397	119	6742	334	571
2010	6141	1671	140	7952	334	571
Average Annual Growth Rate (%)						
1980-1990	3.85	5.22	7.32	4.18	0.0	3.27
1990-2000	4.81	4.72	3.12	4.76	0.0	0.0
2000-2010	3.27	3.57	3.22	3.33	0.0	0.0
1980-2010	3.85	4.50	4.54	4.09	0.0	1.08

NOTES:

(1) Reproduced from ISER's (_) Medium Economic Growth/Moderate Government Expenditure Scenario (without price induced shift to electricity).

TABLE 5.6 - SUMMARY OF RAILBELT ELECTRICITY PROJECTIONS

	Utility Sales to All Consuming Sectors (GWh)						Military Net Generation (GWh)	Self-Supplied Industry Net Generation (GWh)			
Year	LES-GL[1] Bound	LES-GM	MES-GM (Base Case)	MES-GM with Price Induced Shift	HES-GM	HES-GH[1] Bound	MES-GM (Base Case)	LES-GM	MES-GM (Base Case)	MES-GM with Price Induced Shift	HES-GM
1980	2390	2390	2390	2390	2390	2390	334	414	414	414	414
1985	2798	2921	3171	3171	3561	3707	334	414	571	571	847
1990	3041	3236	3599	3599	4282	4443	334	414	571	571	981
1995	3640	3976	4601	4617	5789	6317	334	414	571	571	981
2000	4468	5101	5730	6525	7192	8010	334	414	571	571	981
2005	4912	5617	6742	8219	9177	10596	334	414	571	571	981
2010	5442	6179	7952	10142	11736	14009	334	414	571	571	981
Average Annual Growth Rate (%)											
1980-1990	2.44	3.08	4.18	4.18	6.00	6.40	0.0	0.0	3.27	3.27	9.0
1990-2000	3.92	4.66	4.76	6.13	5.32	6.07	0.0	0.0	0.0	0.0	0.0
2000-2010	1.99	1.94	3.33	4.51	5.02	5.75	0.0	0.0	0.0	0.0	0.0
1980-2010	2.78	3.22	4.09	4.94	5.45	6.07	0.0	0.0	1.08	1.08	2.92

NOTES:

Lower Bound = Estimates for LES-GL
Upper Bound = Estimates for HES-GH

LES = Low Economic Growth
MES = Medium Economic Growth
HES = High Economic Growth
GL = Low Government Expenditure
GM = Moderate Government Expenditure
GH = High Government Expenditure

(1) Results generated by Acres, all others by ISER (_).

TABLE 5.7 - SUMMARY OF RECENT PROJECTIONS OF RAILBELT ELECTRIC POWER REQUIREMENTS (GWh)

Study Number/Source	1980			1990			1995			2000			2025		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1. South Central Railbelt Area, Alaska Interim Feasibility Report: Hydro-electric Power and Related Purposes for the Upper Susitna River Basin, Alaska District Corps of Engineers, Department of the Army, 1975.(_)	3020	3240	3550	5470	6480	8540	6656	8688	12576	8100	11650	18520			
2. Electric Power in Alaska 1976-1995 Institute of Social and Economic Research, University of Alaska, 1976.(_)	2478	-	3877	5415	-	12706	8092	-	20984						
3. Alaska Electric Power: An Analysis of Future Requirements and Supply Alternatives for the Railbelt Region, Battelle Pacific Northwest Laboratories, 1978.(_)	2600	-	3400	8500	-	10800	10341	-	17552	16000	-	22500			
4. Upper Susitna River Project Power Market Analyses, U.S. Department of Energy, Alaska Power Administration, 1979; South Central Railbelt Area, Alaska, Upper Susitna River Basin, Supplemental Feasibility Report, Corps of Engineers, 1979 (_) and Phase I Technical Memorandum: Electric Power Needs Assessment, South Central Alaska Water Resources Committee, 1979 (_)	2920	3155	3410	4550	6110	8200	5672	8175	11778	7070	10940	16920	8110	17770	38020

TABLE 5.8 - PERFORMANCE OF PAST PROJECTIONS
RAILBELT ELECTRIC POWER REQUIREMENTS[1]

Study Number[2]	Year of Publication	Net Energy (GWh) Year of Forecast	Net Energy (GWh) Forecast for 1980	Annual Growth Rate of Net Energy Between Forecast Year & 1980: Forecast	Annual Growth Rate of Net Energy Between Forecast Year & 1980: Actual[3]	Percent Error[4] in Forecast of Growth Rate to 1980 (%)
1	1975	1851	3240	11.9	7.3	+ 63
2	1976	2093	2985	9.3	5.9	+ 58
3	1978	2397	3000	11.9	4.8	+ 148
4	1979	2469	3155	27.8	6.5	+ 328

NOTES:

(1) Net Energy figures calculated from sales plus 10 percent for losses
(2) Corresponds to Table 5.7.
(3) Assuming 1980 Net Energy consisting of 2390 of sales plus 10 percent losses.
(4) Indicates overestimation.

TABLE 5.9 - FORECAST TOTAL GENERATION AND PEAK LOADS - TOTAL RAILBELT REGION[1]

	ISER Low (LES-GM)[2]		ISER Medium (MES-GM)		ISER High (HES-GM)	
Year	Generation (GWh)	Peak Load (MW)	Generation (GWh)	Peak Load (MW)	Generation (GWh)	Peak Load (MW)
1978	3323	606	3323	606	3323	606
1980	3522	643	3522	643	4135	753
1985	4141	757	4429	808	5528	995
1990	4503	824	4922	898	6336	1146
1995	5331	977	6050	1105	8013	1456
2000	6599	1210	7327	1341	9598	1750
2005	7188	1319	8471	1551	11843	2158
2010	7822	1435	9838	1800	14730	2683
Percent Growth/Yr. 1978-2010	2.71	2.73	3.45	3.46	4.76	4.76

NOTES:

(1) Includes net generation from military and self-supplied industry sources.
Source: Reference ( )

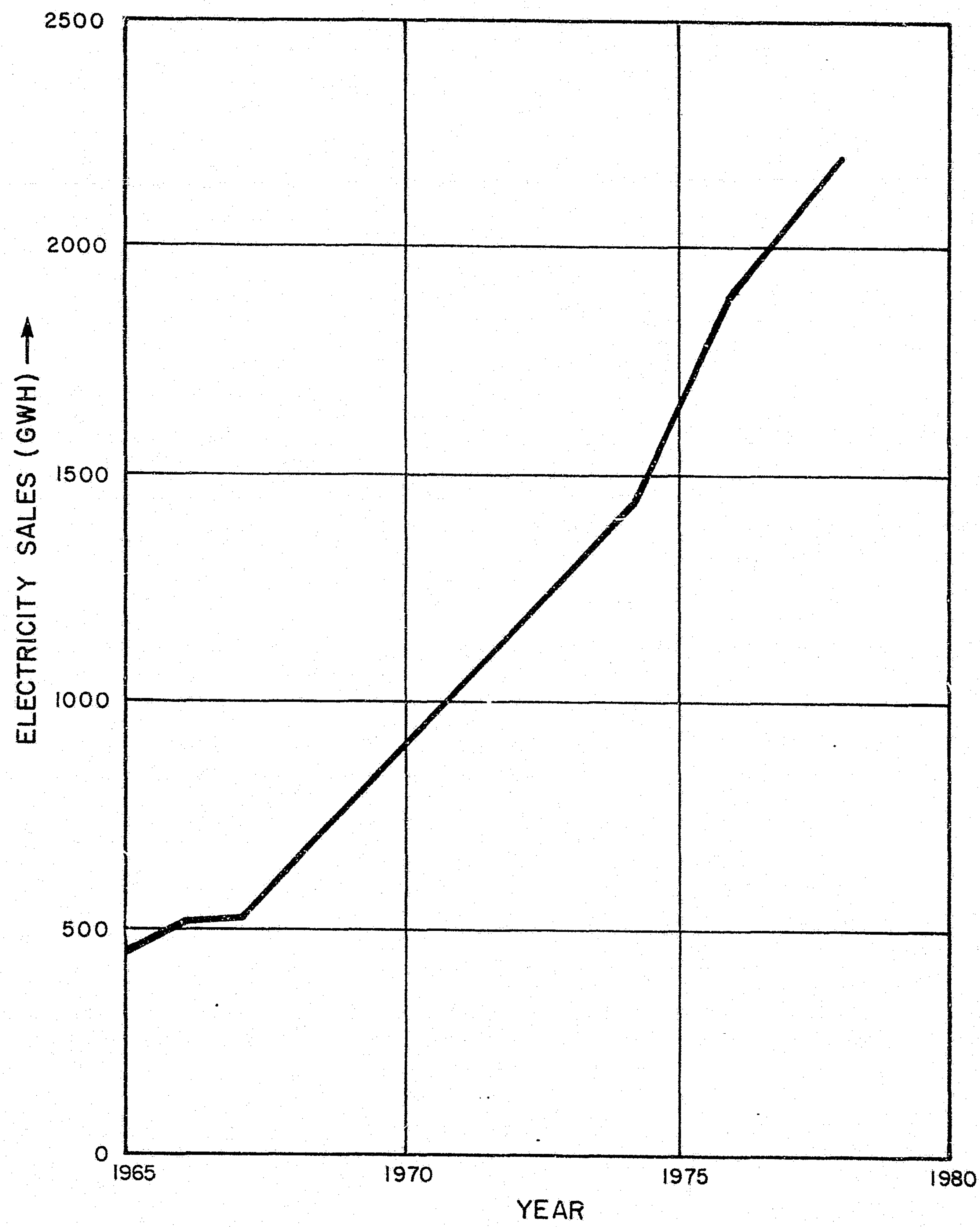
(2) All forecasts assume moderate government expenditure.

TABLE 5.10 - RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

	LOAD CASE											
	Low Plus Load Management and Conservation (LES-GL Adjusted)[1]			Low (LES-GL)[2]			Medium (MES-GM)[3]			High (HES-GH)[4]		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1980	510	2790	62.5	510	2790	62.4	510	2790	62.4	510	2790	62.4
1985	560	3090	62.8	580	3160	62.4	650	3570	62.6	695	3860	63.4
1990	620	3430	63.2	640	3505	62.4	735	4030	62.6	920	5090	63.1
1995	685	3810	63.5	795	4350	62.3	945	5170	62.5	1295	7120	62.8
2000	755	4240	63.8	950	5210	62.3	1175	6430	62.4	1670	9170	62.6
2005	835	4690	64.1	1045	5700	62.2	1380	7530	62.3	2285	12540	62.6
2010	920	5200	64.4	1140	6220	62.2	1635	8940	62.4	2900	15930	62.7

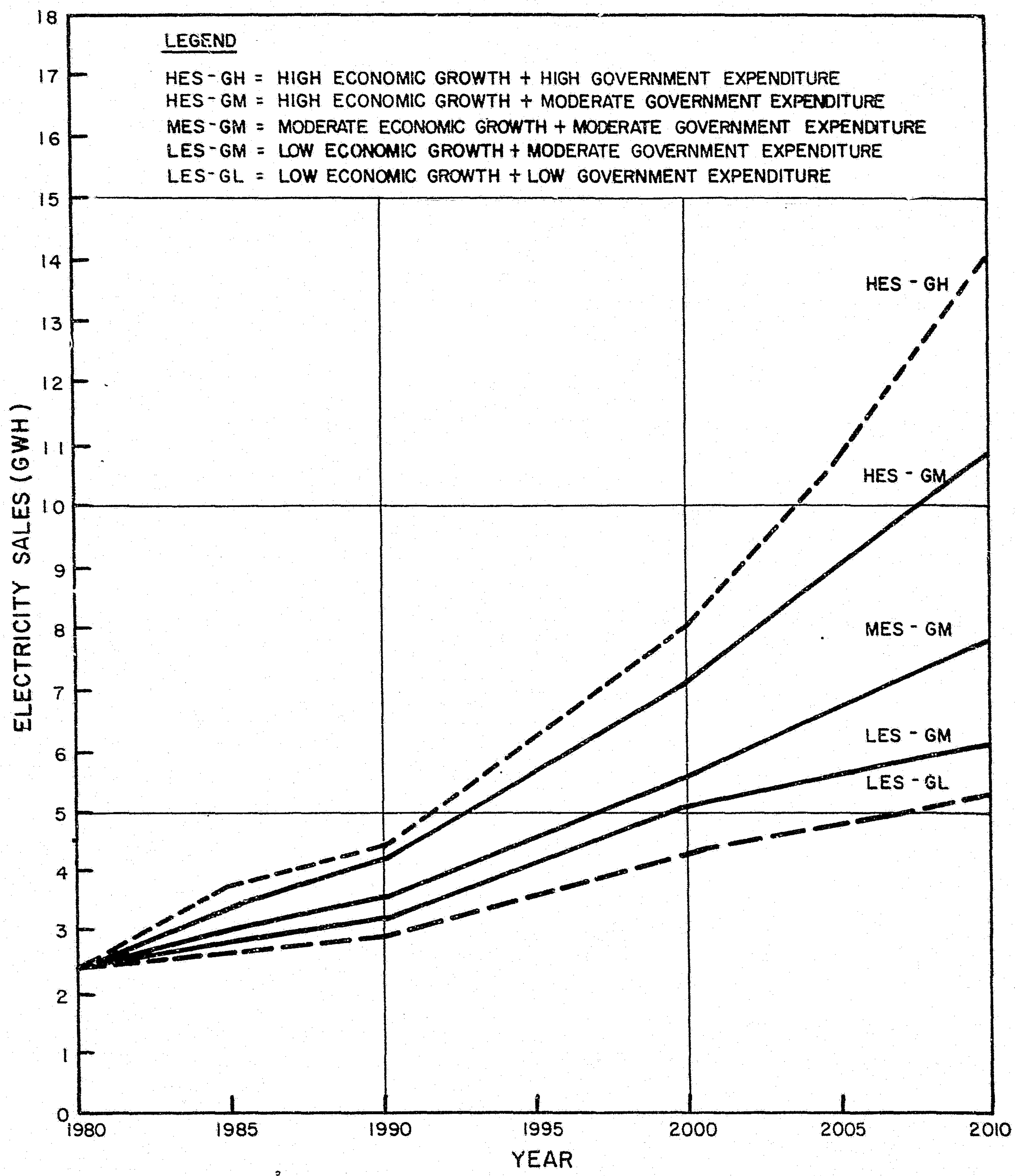
Notes:

(1) LES-GL: Low economic growth/low government expenditure with load management and conservation.
(2) LES-GL: Low economic growth/low government expenditure.
(3) MES-GM: Medium economic growth/moderate government expenditure.
(4) HES-GH: High economic growth/high government expenditure.



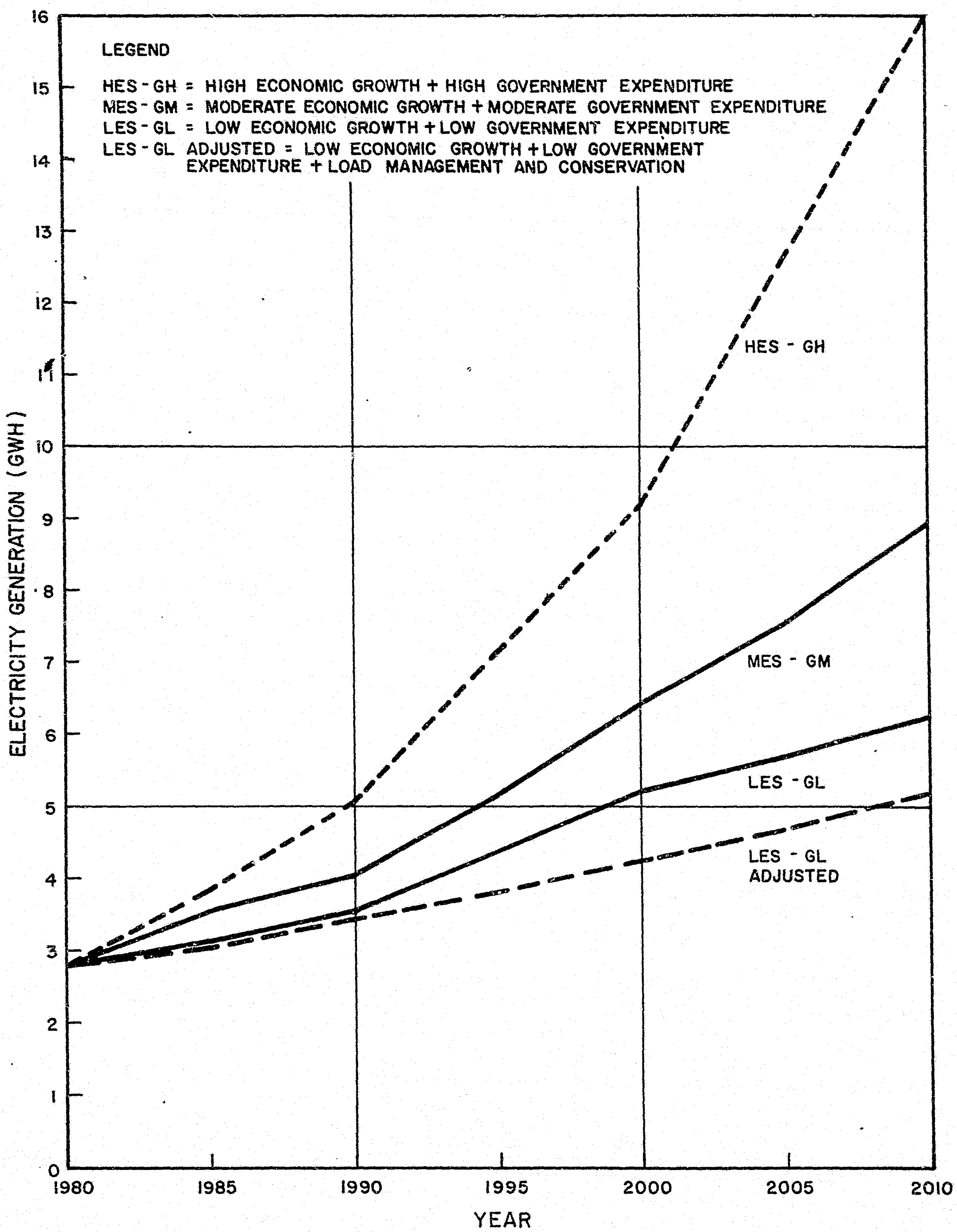
HISTORICAL TOTAL RAILBELT UTILITY SALES TO FINAL CUSTOMERS

FIGURE 5.1



FORECAST ALTERNATIVE TOTAL RAILBELT UTILITY SALES

FIGURE 5.2



ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

FIGURE 5.3

LIST OF REFERENCES

(1) Institute of Social and Economic Research, Electric Power Requirements for the Railbelt, June, 1980.

(2) Alaska Center for Policy Studies, Energy Alternatives for the Railbelt - Study of End-Use Structure, Energy Conservation Potential, Alternative Energy Resources and Related Public Policy Issues, August, 1980.

(3) Energy Probe, An Evaluation of the ISER Electricity Demand Forecast, July, 1980.

6 - RAILBELT SYSTEM AND FUTURE POWER GENERATION OPTIONS

6.1 - Introduction

Effective planning of future electric power generation sources to meet the projected needs of the Railbelt Region must address a number of concerns. Apart from the obvious goal of planning to meet projected power and energy needs of the region, careful consideration must be given to the trade-offs which will be required in satisfying those needs within the constraints of technical feasibility, economic necessity, acceptable environmental impacts and social preferences. The hydroelectric potential in the Susitna River Basin is but one of the available options for meeting future Railbelt demand.

If constructed, the Susitna Basin development plan would provide a major portion of the Railbelt Region energy needs well beyond the year 2000. In order to accurately determine the most economic basin development plan which clearly defines details such as dam heights, installed generating capacities, reservoir operating rules, dam and powerhouse staging concepts, and construction schedules, it is first necessary to evaluate in economic terms the plan in the context of the entire Railbelt generating system. This requires that economic analyses be undertaken of expansion alternatives for the total Railbelt system containing several different types of generating sources. These sources include both thermal and hydropower generating facilities capable of satisfying a specified load forecast. Economic analyses of scenarios containing alternative Susitna Basin development plans being investigated would then reveal which is the most economic basin development plan. This process and the comparison of other factors such as environmental impacts and social preferences, essentially falls within the purview of "generation planning". These studies are discussed in more detail in Section 8.

This section describes the process of assembling the information necessary to carry out these systemwide generation planning studies. Included is a discussion of the existing system characteristics, the planned Anchorage-Fairbanks intertie, and details of various generating options including hydroelectric and thermal, a discussion of the implications of the Fuel Use Act (FUA), and a brief outline of other options such as tidal and geothermal energy generation. Performance and cost information required for the generation planning studies is presented for the hydroelectric and thermal generation options but not for the tidal and geothermal options. Preliminary indications are that these options are as yet not competitive with the more conventional options considered.

Emphasis is placed on currently feasible and economic generating sources. Other options such as wind, solar and biomass-fired generation are not considered in this study. An independent study currently being undertaken for the State of Alaska by Battelle Pacific Northwest Laboratories addresses all such options. It should be stressed that the non-Susitna generation options have only been dealt with in sufficient detail to develop representative performance and cost data for inclusion in the alternative Railbelt system generation scenarios. The primary objective is to carry out a preliminary assessment of the feasibility of the selected Susitna Basin development plan by comparing the costs and benefits of the "with Susitna scenario" with selected "without Susitna scenarios".

6.2 - Existing System Characteristics

(a) System Description

The two major load centers of the Railbelt Region are the Anchorage-Cook Inlet area and the Fairbanks-Tanana Valley area (see Figure 6.1). At present, these two areas operate independently. The existing transmission system between Anchorage and Willow consists of a network of 115 kV and 138 kV lines with interconnection to Palmer. Fairbanks is primarily served by a 138 kV line from the 28 MW coal fired plant at Healy. Communities between Willow and Healy are served by local distribution.

There are currently nine electric utilities (including the Alaska Power Administration) providing power and energy to the Railbelt system (See Table 6.1). In order to obtain information on the current (1980) installed generation capability of these utilities, the following sources were consulted:

(i) Published Documents

- WCC Report, "Forecasting Peak Electrical Demand for Alaska's Railbelt", September, 1980 (1).
- IECO Transmission Report for the Railbelt, 1978 (2).
- U.S. DOE, "Inventory of Power Plants in the U.S.," April 1979 (3).
- Electrical World Directory of Public Utilities 1979 - 1980 Edition (4).
- Williams Brothers Engineering Company, 1978 Report on FMUS and GVEA Systems (5).
- FERC Form 12A for the following utilities:
  - Anchorage Municipal Light & Power Department (AMLPD)
  - Chugach Electric Association (CEA)
  - Homer Electric Association (HEA)
  - Fairbanks Municipal Utility System (FMUS)

(ii) Discussions With:

- Anchorage Municipal Light and Power Department (AMLPD)
- Fairbanks Municipal Utility System (FMUS)
- Copper Valley Electric Association (CVEA)
- Alaska Power Administration (APAd)

Table 6.1 summarizes the information received from these sources. Some discrepancies are apparent especially with respect to AMLPD and CVEA. The ACRES column lists the installed capacity data used in the generating planning studies described in this report and represents a resolution of discrepancies in data collected.

Table 6.2 includes a detailed listing of units currently operating in the Railbelt, information on their performance characteristics, and their on-line and assumed retirement dates.

With the exception of two hydroelectric plants, the total Railbelt installed capacity of 944 MW as of 1980 consists of fifty-one thermal generation units fired by oil, gas or coal, as summarized in Table 6.3.

(b) Schedule Retirements

In order to establish a retirement policy for the existing generating units, several references were consulted including the APA draft feasibility study guidelines (6), FERC guidelines, and historical records. Utilities, particularly those in the Fairbanks area, were also consulted. Based on the above, the following retirement periods of operation were adopted for use in this study:

- Large Coal-Fired Steam Turbines (> 100 MW):	30 years
- Small Coal-Fired Steam Turbines (< 100 MW):	35 years
- Oil-Fired Gas Turbines:	20 years
- Natural Gas-Fired Gas Turbines:	30 years
- Diesels:	30 years
- Combined Cycle Units:	30 years
- Conventional Hydro:	50 years

Table 6.2 lists the retirement dates for each of the current generating units based on the above retirement policy.

(c) Schedule of Additions

Only two new projects are currently to be committed within the Railbelt system. The CEA is in the process of adding 60 MW of gas fired combined cycle capacity in Anchorage. The plant will be called Beluga No. 8. For study purposes, the plant is assumed to come on-line in January 1982.

The COE is currently in the post-authorization planning phase for the Bradley Lake hydroelectric project located on the Kenai Peninsula. As currently envisaged, the project includes 94 MW of installed capacity and would produce an annual average energy of 420 Gwh. For study purposes, the project is assumed to come on-line in 1988.

6.3 - Fairbanks - Anchorage Intertie

Engineering studies are currently being undertaken for construction of an intertie between the Anchorage and Fairbanks systems. As presently envisaged, this connection will involve a 138 kV transmission line between Willow and Healy and would provide capability for transferring 50 MW of capacity at any time. It is scheduled for completion in 1984. Current intertie studies indicate that it is economic to construct this intertie such that it can be upgraded to the 345 kV Susitna transmission capability when Watana comes on-line.

A brief study was undertaken to check the validity of the assumption that a fully interconnected system should be maintained as the total system capacity increases over the next 30 years. A simplified analysis was carried out in which the economics of two alternative all-thermal generating scenarios was evaluated for the ISER medium load forecast. The first scenario, called the "intertie scenario", allows for additional transmission to be added as needed, with increased capacity requirements being met by the most economic generating units constructed in optimum geographic locations. The second scenario restricts the intertie to 138 kV and assumes that increased capacity requirements will be met by separate developments in the Anchorage and Fairbanks areas.

Both scenarios incorporate the committed CEA combined cycle 60 MW plant in 1982 and the 94 MW Bradley Lake hydro plant in 1988. After 1992, in either scenario, additional generating facilities will be required in both Anchorage and Fairbanks. The preliminary economic comparison was therefore only carried out for the period 1980 to 1992.

The intertie scenario requires upgrading of the existing 138 kV line to 230 kV and new 230 kV lines from Anchorage to Willow and from Healy to Fairbanks in 1986. No additional capacity is necessary. The second scenario requires 75 MW of gas turbine generation to meet the reserve requirements in the Anchorage area in 1988, and a 100 MW coal-fired unit to supplement the generation capacity in the Fairbanks region in 1986. The total present worth cost in 1980 dollars of the second scenario exceeds that of the first by just over $300 million.

The analysis clearly indicates that it is extremely economic to construct and maintain a fully integrated system. This conclusion is conservative as it does not incorporate the benefits to be derived for a fully interconnected system in terms of load sharing and economy energy transfers after the year 1992. The actual benefit of the interconnected system could be somewhat higher than estimated.

Based on these evaluations, it was concluded that a fully interconnected system should be assumed for all the generation planning studies outlined in this report, and that the intertie facilities would be common to all generation scenarios considered. In the preliminary comparisons of alternative generation scenarios, the cost of such intertie facilities were also assumed to be common. However, in final comparisons of a lesser number of preferred alternative scenarios, appropriate consideration was given to relative intertie costs. The cost of transmitting energy from a particular generating source to the interconnected system is included in all cases.

6.4 - Hydroelectric Options

Numerous studies of hydroelectric potential in Alaska have been undertaken. These date as far back as 1947, and were performed by various agencies including the then Federal Power Commission, the COE, the USBR, the USGS and the State of Alaska. A significant amount of the identified potential is located in the Railbelt Region, including several sites in the Susitna River Basin.

As discussed in Section 6.1, feasibility assessment of the selected Susitna Basin development plan is based on comparisons of future Railbelt power generation scenarios with and without the project. An obvious "without Susitna" scenario is one which includes hydroelectric developments outside the Sustina Basin. The plan formulation and selection methodology discussed in Section 1.4 and Appendix A has been applied in the development of Railbelt generation plans which include and exclude Susitna. Those plans which involve the Susitna Project are discussed in detail in Sections 7 and 8. Those plans which incorporate hydroelectric developments other than Susitna are discussed in this Section.

(a) Assessment of Hydro Alternatives

The application of the five-step methodology (Figure 1.2) for selection of non-Susitna plans which incorporate hydroelectric developments, is presented in detail in Appendix C. This process is summarized in this section and Figure 6.2. Step 1 of this process essentially established the overall objective of the exercise as the selection of an optimum Railbelt generation plan which incorporated the proposed non-Susitna hydroelectric developments, for comparison with other plans.

Under Step 2 of the selection process, all feasible candidate sites were identified for inclusion in the subsequent screening exercise. A total of 91 potential sites (Figure 6.3) were obtained from inventories of potential sites published in the COE National Hydropower Study (7) and the APAd report "Hydroelectric Alternatives for the Alaska Railbelt"(8).

(b) Screening of Candidate Sites

The screening of sites required a total of four successive iterations to reduce the number of alternatives to a manageable short list. The overall objective of this process was defined as the selection of approximately 10 sites for consideration in plan formulation, essentially on the basis of published data on the sites and appropriately defined criteria. The first iteration in this process was based on a coarse screen in which sites which were considered technically infeasible or not economically viable were rejected. For this purpose, economic viability for a site was defined as energy production costs less than 50 mills per kWh, based on economic parameters. This value was considered to be a reasonable upper limit consistent with Susitna Basin alternatives (See Section 8).

Energy production costs were derived for each site considered, using the capital cost data published in the cited reports, updated to 1980 levels, and using published cost escalation data and an appropriate contingency allowance. As discussed in Section 8, annual costs were derived on the basis of a 3 percent cost of money, net of general inflation. Allowances for operation and maintenance costs were also included in these estimates. For this initial screening process, the reported energy yield data for each site were then used as a basis for estimating annual energy production costs in mills per kWh.

As a result of this screen, 26 sites were rejected and the remaining 65 sites were subjected to a second iteration of screening. The additional criteria established for this screening were environmental in nature. Based on data published in the COE and APAd reports, (7, 8) rejection of sites occurred if:

(i) They would cause significant impacts within the boundaries of an existing National Park or a proclaimed National Monument area;

(ii) They were located on a river in which:

- anadromous fish are known to exist;
- the annual passage of fish at the site exceeds 50,000;
- a confluence with a tributary occurs, upstream of the site, in which a major spawning or fishing area is located.

As a result of this screen, 19 sites were rejected and the remaining 46 sites were subjected to a third iteration of economic and environmental screening. At this stage in the selection process, adjustments were made to capital and energy production costs for each site to take account of transmission line costs to link each site to the Anchorage-Fairbanks intertie. A representative list of 28 sites was thus derived by judgemental elimination of the more obviously uneconomic or less environmentally acceptable sites. These sites were then categorized into sizes as follows:

- less than 25 MW: 5 sites
- 25 MW to 100 MW: 15 sites
- greater than 100 MW: 8 sites

The fourth and final screen was then performed in which a more detailed numerical environmental assessment was made. Eight evaluation criteria were utilized:

- Impact on big game
- Impact on agricultural potential
- Impact on waterfowl, raptors and endangered species
- Impact on anadromous fish
- Restricted land uses
- Impact on wilderness areas
- Impact on cultural, recreational and scientific resources
- Impact generated by access

The above environmental ranking criteria were assigned numerical weights, and scale ratings for each site and each criterion were developed using available data. Total scores were then calculated for each site by summing the products of the weight and scale ratings.

This process allowed the number of sites to be reduced to the ten sites listed in Table 6.3.

(c) Plan Formulation and Evaluation

In Step 4 of the plan selection process, the ten sites shortlisted under Step 3 were further refined as a basis for formulation of Railbelt generation plans. Engineering sketch-type layouts were produced for each of the sites, and quantities and capital costs were evaluated. These costs are also listed in Table 6.3 and incorporate a 20 percent allowance for contingencies and 10 percent for engineering and owner's administration. A total of five plans were formulated incorporating various combinations of these sites as input to the Step 5 evaluations.

Power and energy values for each of the developments were re-evaluated in Step 5 utilizing monthly streamflow and a computer reservoir simulation model. Details of these calculations are given in Appendix F and the results are summarized in Table 6.3.

The essential objective of Step 5 was established as the derivation of the optimum plan for the future Railbelt generation incorporating non-Susitna hydro generation as well as required thermal generation. The methodology used in evaluation of alternative generation scenarios for the Railbelt are discussed in detail in Section 8. The criteria on which the preferred plan was finally selected in these activities was least present worth cost based on economic parameters established in Section 8.

The selected potential non-Susitna Basin hydro developments (Table 6.3) were ranked in terms of their economic cost of energy. They were then introduced into the all thermal generating scenario during the planning analyses (See Section 6.5), in groups of two or three. The most economic schemes were introduced first and were followed by the less economic schemes.

The results of these analyses are summarized in Table 6.4 and illustrate that a minimum total system cost of $7040 million can be achieved by the introduction of the Chakachamna, Keetna, and Snow projects (See also Figure 6.4).

Additional sites such as Strandline, Allison Creek and Talkeetna-2 can also be introduced without significantly changing the economics, and would be beneficial in terms of displacing non-renewable energy resource consumption.

6.5 - Thermal Options

As discussed earlier in this Section, the major portion of generating capability in the Railbelt is currently thermal, principally natural gas with some coal and oil-fired installations. There is no doubt that the future electric energy demand in the Railbelt would technically be satisfied by an all-thermal generation mix. In the following paragraphs an outline is presented of studies undertaken to determine an appropriate all-thermal generation scenario for comparison with other scenarios in Section 8. A more detailed description of these studies may be found in Appendix B of this report.

(a) Assessment of Thermal Alternatives

The plan formulation and selection methodology discussed in Section 1.4 and Appendix A, has been adopted in a modified form to develop the necessary all-thermal generation plans (see Figure 6.5). The overall objective established in Step 1 is the selection of an optimum all-thermal Railbelt generation plan for comparison with other plans.

In Step 2 of the selection process, consideration was given to gas, coal and oil-fired generation sources only, from the standpoint of technical and economic feasibility alone. The broader perspectives of other alternative resources and the relevant environmental, social and other issues involved are being addressed in the Battelle alternatives study.

This being the case, the Step 3 screening process was therefore considered unnecessary in this study and emphasis was placed on selection of unit sizes appropriate for inclusion in the generation planning exercise. Thus for study purposes, the following five types of thermal power generation units were considered:

- Coal-fired steam
- Gas-fired combined-cycle
- Gas-fired gas turbine
- Diesel

To formulate plans incorporating these alternatives it was necessary to develop capital cost and fuel cost data for these units and other related operational characteristics.

(b) Coal-Fired Steam

Aside from the military power plant at Fort Wainwright and the self-supplied generation at the University of Alaska, there are currently two coal-fired steam plants in operation in the Railbelt (see Table 6.1). These plants are small in comparison with new units under consideration in the Lower 48 and in Alaska.

(i) Capital Costs

Based on the general magnitude of the Railbelt load requirements, three coal-fired unit sizes were chosen for potential capacity additions: 100, 250 and 500 MW. All new coal units are estimated to have an average heat rate of 10,500 Btu/kWh, and involve an average construction period of five to six years. Capital costs and operating parameters are defined for coal and other thermal generating plants on Table 6.5. These costs include a 16 percent contingency, a 10 percent allowance for construction facilities and utilities and 12 percent for engineering and owner's administration. The costs were developed using published data for the Lower 48 (9) and appropriate Alaska scaling factors based on studies conducted by Battelle (10). It is unlikely that a 500 MW plant will be proposed in the Fairbanks region because forecasted demand there is insufficient to justify placing this much capacity on line at one time. Therefore, costs for such a plant at Fairbanks are not included.

To satisfy the national New Performance Standards (11), the capital costs incorporate provision for installation of flue gas desulfurization for sulphur control, highly efficient combustion technology for control of nitrogen acids and baghouses for particulate removal.

(ii) Fuel Costs

The total estimated coal reserves in Alaska are shown on Table 6.6. Projected opportunity costs for Alaskan coal range from $1.00 to $1.33 per million Btu. A cost of $1.15 was selected as the base coal cost for generation planning (see Table 6.7). The market price for coal is currently within the same general cost range as the indicated opportunity cost.

Real growth rates in coal costs (excluding general price inflation) are based on fuel escalation rates developed by the Department of Energy (DOE) (12) in the mid-term Energy Forecasting System for DOE Region 10 which includes the states of Alaska, Washington, Oregon and Idaho. Specified price escalation rates pertaining to the industrial sector was selected to reflect the bulk purchasing advantage of utilities more accurately than equivalent rates pertaining to the commercial and residential sectors. A composite annual escalation rate of 2.93 percent has been computed for the period 1980 to 1995 from the five yearly values given by the DOE. This composite rate has been assumed to apply to the 1995-2005 period as suggested by the DOE. Beyond 2005, zero real growth in the coal price is assumed.

(iii) Other Performance Characteristics

Annual operation and maintenance costs and representative forced outage rates are shown on Table 6.5.

(c) Combined Cycle

A combined cycle plant is one in which electricity is generated partly in a gas turbine and partly in a steam turbine cycle. Combined cycle plants achieve higher efficiencies than conventional gas turbines. There are two combined cycle plants in Alaska at present. One is operational and the other is under construction (See Table 6.1). The plant under construction is the Beluga #9 unit owned by Chugach Electric Association (CEA). It will add a 60 MW steam turbine to the system sometime in 1982.

(i) Capital Costs

A new combined cycle plant unit size of 250 MW capacity was considered to be representative of future additions to generating capability in the Anchorage area. This is based on economic sizing for plants in the Lower 48 and projected load increases in the Railbelt. A heat rate of 8500 Btu/kWh was adopted based on technical publications issued by the Electric Power Research Institute (13).

The capital cost was estimated using the same basis and data sources as for the coal-fired steam plants and is listed in Table 6.5.

(ii) Fuel Costs

The combined cycle facilities would burn only gas with the opportunity value ranging from $1.08 to $2.92 per million Btu. A gas cost of $2.00 was chosen to reflect the equitable value of gas in Anchorage, assuming development of the export market. Currently, the local incremental gas market price is about half of this amount due to the relatively light local demands and limited facilities for export.

Using an approach similar to that used for coal costs, a real annual growth rate in gas costs of 3.98 percent was obtained from the DOE studies for 1980 to 2005. Zero percent was assumed thereafter.

(iii) Other Performance Characteristics

Annual operation and maintenance costs and a representative forced outage rate are given in Table 6.5.

(d) Gas-Turbine

Gas turbines are by far the main source of thermal power generating resources in the Railbelt area at present. There are 470 MW of installed gas turbines operating on natural gas in the Anchorage area and approximately 168 MW of oil-fired gas turbines supplying the Fairbanks area. (See Table 6.1). Their low initial cost, simplicity of construction and operation, and relatively short implementation lead time have made them attractive as a Railbelt generating alternative. The extremely low cost contract gas in the Anchorage area also has made this type of generating facility cost-effective for the Anchorage load center.

(i) Capital Costs

A unit size of 75 MW was considered to be representative of a modern gas turbine plant addition in the Railbelt region. However, the possibility of installing gas turbine units at Beluga was not considered, since the Beluga development is at this time primarily being considered for coal.

Gas turbine plants can be built over a two-year construction period and have an average heat rate of approximately 12,000 Btu/kWh. The capital cost was evaluated using the same data source as for the coal-fired plants and incorporates a 10 percent allowance for construction facilities and 14 percent for engineering and owner's administration. This cost includes provision for wet control of air emissions.

(ii) Fuel Costs

Gas turbine units can be operated on oil as well as natural gas. The opportunity value and market cost for oil are considered to be equal, at $4.00 per million Btu. Real annual growth rates in oil costs were developed as described above and amounted to 3.58 percent for the 1980-2005 period and zero percent thereafter.

(iii) Other Performance Characteristics

Annual operation and maintenance costs and forced outage rates are shown in Table 6.5.

(e) Diesel Power Generation

Most diesel plants in the Railbelt today are on standby status or are operated only for peak load service. Nearly all the continuous duty units were retired in the past several years due to high fuel prices. About 65 MW of diesel plant capacity is currently available.

(i) Capital Costs

The high cost of diesel fuel and low capital cost makes new diesel plants most effective for emergency use or in remote areas where small loads exist. A unit size of 10 MW was selected as appropriate for this type of facility. The capital cost was derived from the same source as given in Table 6.5 and includes provision for a fuel injection system to minimize air pollution.

(ii) Fuel Costs

Diesel fuel costs and growth rates are the same as oil costs for gas turbines.

(iii) Other Performance Characteristics

Annual operation and maintenance and the forced outage rate is given in Table 6.5.

(f) Plan Formulation and Evaluation

The six candidate unit types and sizes developed under Step 2 were used to formulate plans for meeting future Railbelt power generation requirements in Step 4. The objective of this exercise was defined as the formulation of appropriate plans for meeting the project Railbelt demand on the basis of economic preferences.

Two different cases of natural gas consumption policy were considered in formulating plans. The first, called the "renewal" policy allowed for the renewal of natural gas turbines at the end of their economic lives, anticipating the possible exemptions that utilities may obtain from the FUA. The second policy, called the "no renewals" policy assumed that the utilities would not be allowed to reconstruct plants as they are retired and that they would only be allowed to construct new plants with not more than 1500 hours of annual operation (see Condition 9 of the FUA as discussed in Section 6.6).

In the subsequent Step 5 evaluation of the two basic plans, the OGP5 generation planning model was utilized to develop a least cost scenario incorporating the necessary coal, oil, and gas fired generating units. The results for the very low, low, medium, and high load forecasts are summarized in Table 6.4. They indicate that for the medium forecast the total system present worth cost is slightly higher than $8,100 million.

As illustrated by the results displayed in Table 6.4, these two policies have very similar economic impacts. The difference in present worth costs for the medium forecast amounts to only $20 million. For purposes of this study, therefore, it is assumed that the "no renewals" policy is more appropriate and is used to be representative of the all thermal generation scenario.

Figure 6.6 illustrates this all thermal generating scenario graphically.

6.6 - Impact of the Fuel Use Act

(a) Background

The "Power Plant and Industrial Fuel Use Act of 1978" (FUA), Public Law 95-620, regulates the use of natural gas and petroleum to reduce imports and conserve scarce non-renewable resources. It is, therefore, essential to understand the implications of this act and to incorporate important aspects in the generation planning studies.

Section 201 of the FUA prohibits the use of petroleum or natural gas as a primary energy source in any new electric power plant and precludes the construction of any new power plant without the capability to use an alternate fuel as a primary energy source. There are, however, twelve different exemption categories incorporated in the Act. Plants which can be included in any of these categories may qualify for a permanent exemption.

These exemption catagories are:

(1) Cogeneration
(2) Fuel mixture
(3) Emergency purposes
(4) Maintenance of reliability of service (short development lead time)
(5) Inability to obtain adequate capital
(6) State or local requirements
(7) Inability to comply with applicable environmental requirements
(8) Site limitations
(9) Peak load power plants
(10) Intermediate load power plants
(11) Lack of alternative fuel supply for the first ten years of useful life
(12) Lack of alternative fuel supply at a cost which does not substantially exceed the cost of using imported petroleum.

(b) FUA and the Railbelt

The two Anchorage utilities, Chugach Electric Association (CEA) and Anchorage Municipal Light and Power Department (AMLPD) have been able to maintain relatively low electric rates to their customers by the use of natural gas from the Cook Inlet region. As reported to the DOE in June of 1980, CEA paid an average of \$0.32/Million Btu (MMBtu) for gas, with its cheapest contract supplying its largest plant with gas at \$0.24/MMBtu. Compared to the U.S. average price of over \$2.00/MMBtu, this situation represents an obvious incentive for the continued use of natural gas for electric generation by CEA. AMLPD reports that its cost for gas is approximately \$1.00/MMBtu, which is still below the national average utility price. The price differences exist because CEA holds certain long term contracts at favorable rates.

In spite of the low gas prices currently enjoyed in Anchorage, it is assumed that the cost of natural gas will rise rapidly as soon as suitable export facilities now under consideration are developed. Thus, the "opportunity" cost of \$2.00/MMBtu discussed earlier is considered appropriate for future system comparisons and relevent to the discussion on the FUA presented here.

It can also be argued that the Cook Inlet reserves are sufficiently large and the cost of delivery to potential markets in the Lower 48 is low enough to make export to these states feasible.

Assuming that new gas-fired generation would be either a gas turbine or gas-fired boiler located in the Anchorage area, there would be no particular capital or time planning constraints and the unit would be actively used to meet the anticipated load. Under these assumptions, the exemption categories 1 through 5 would not apply.

Categories 6 and 7 require the existence of some state, local or environmental requirement which would preclude the development of the plant using an alternative fuel. As no such constraint is foreseen, it is likely that these categories would apply.

To obtain an exemption under category 8, it must be shown that alternative fuels are inaccessible due to physical limitations, and that transportation, handling and storage, and waste disposal facilities are unavailable or other physical limitations exist. It is not anticipated that generation facilities, including coal, are inaccessible and is therefore not likely that this category would apply.

To qualify for exemption 9 for peak load power, a petitioner must certify that the plant will be operated solely as a peak load plant. In addition, the EPA or appropriate state administrator must also certify that alternative fuel use (other than natural gas) will contribute to concentration of a pollutant which would exceed a national air quality standard. However, due to the shift in concern regarding the use of gas as compared to oil, this requirement appears to be liberally interpreted. If this certification could be obtained, any plant would still be limited in output to only 1500 hours of generation per year at design capacity.

Exemption 10 for intermediate load power plants is available only when petroleum is used as the primary energy source. This exemption category would therefore not apply.

To obtain exemption 11, the petitioner must demonstrate an effort has been made to obtain an adequate and reliable supply of an alternate fuel and show that such a supply will not be available for 10 years of the useful plant life. The petitioner must also prove that the earliest possible online date for the alternative is not soon enough to prevent reserve capacity margins becoming unacceptably low. It is not anticipated that exemptions would be granted under this category.

Exemption 12 requires that the alternative source is at least 30 percent more costly than similar plant operating on imported oil before an exemption is granted. The actual cost of natural gas does not directly enter into the decision. Results of the studies outlined in this report indicate that there are coal-fired and hydro alternatives which can produce energy at prices well below that associated with imported oil. It is, therefore, also unlikely that this exemption is applicable.

(c) Conclusions

The Anchorage utilities are subject to the prohibitions of the FUA for the development of new sources of power generation. Existing facilities may continue to use gas, but the use of gas in new facilities will apparently be restricted to peak load applications only.

6.7 - Other Options

The more exotic types of electric utility generating stations, such as wind, biomass, solar, tidal and geothermal are being investigated for application to the Railbelt in the Battelle alternatives study. These could provide a portion of the Railbelt's generating needs in a conjunction with a thermal or thermal/hydroelectric generation plan. It is recognized that these options could be incorporated into the generation plan, however a cursory review of the two of these resources which are most likely to be developed (geothermal and tidal) would indicate that their contribution would be ancillary to the principal alternatives described in the previous sections.

(a) Geothermal

Of the numerous geothermal sites identified in the state, only a few are located in the South Central Region encompassing the Railbelt (14). Of these, all but one are low temperature sources (100-200°F) and therefore feasible only for building or process heating. The high temperature Klawasi site, located east of Glennallen, has been recently investigated for electric power generation potential (14). Although a study has been made for the development of this site, it has not been funded. No potential consumer for the energy has been identified, mainly because it is remoteness from any existing or planned major transmission connection from the site vicinity to populated areas to the south or west. As suggested by this study, this type of energy would possibly be feasible if the Alaska pipeline corridor becomes populated since the geothermal site is near the route of the line.

Based upon available data, a potential site capacity on the order of several hundred MW may exist, although only a 25 MW development is discussed. Unless a transmission loop paralleling Alaska Highway Routes 2 and 4 or 1 is constructed, the likelihood of a geothermal development at this location economically supplying any of the Railbelt needs is remote. Geothermal sources have therefore not been considered further in this study.

(b) Tidal Power

The Cook Inlet area has long been recognized as having some of the highest tidal ranges in the world, with mean tides ranges of more than 30 feet at Sunrise, on Turnagain Arm, 26 feet at Anchorage, and decreasing towards the lower reaches of Cook Inlet to 15 feet or so near Seldovia. Initial studies of Cook Inlet tidal power development (15) have concluded that generation from tide fluctuation is technically feasible and numerous conceptual schemes ranging in estimated capacity of 50 MW to 25,900 MW have been developed. Preliminary studies indicate that the tidal power would require some type of retiming of energy production to be useful in the Railbelt electrical system. The earliest estimate of on-line data for a tidal plant would be the mid 1990's.

Studies are currently underway to develop more specific information on how much and which portion of the Railbelt energy needs this type of generation could supply and what the cost would be. This information is not available for consideration in this phase of the generation planning studies.

Table 6.1 - TOTAL GENERATING CAPACITY WITHIN THE RAILBELT SYSTEM

Railbelt Utility		Installed Capacity (MW)				
Abbreviations	Name	WCC(__) 1980	IECO(__) 1978	DOE(__) 1979	ELEC.WO.(__) 1979	ACRES 1980
AMLPD	Anchorage Municipal Light & Power Department	184.0	130.5	148.0	108.9	215.4
CEA	Chugach Electric Association	420.0	411.0	402.2	410.9	411.0
GVEA	Golden Valley Electric Association	211.0	218.6	230.0	211.0	211.0
FMUS	Fairbanks Municipal Utility System	67.0	65.5	68.2	67.4	67.2
CVEA	Copper Valley Electric Association	18.0	--	13.0	--	--
MEA	Matanuska Electric Association	0.9	0.6	3.0	0.9	0.9
HEA	Homer Electric Association	2.6	9.2	1.7	3.5	2.6
SES	Seward Electric System	5.5	5.5	5.5	5.5	5.5
APAd	Alaska Power Administration	--	30.0	30.0	30.0	30.0
TOTAL		909.0	870.9	901.6	838.0	943.6

Table 6.2 - GENERATING UNITS WITHIN THE RAILBELT - 1980

Railbelt Utility	Station Name	Unit #	Unit Type	Installation Year	Heat Rate (BTU/kWH)	Installed Capacity (MW)	Minimum Capacity (MW)	Maximum Capacity (MW)	Fuel Type	Retirement Year
Anchorage	AMLPD	1	GT	1962	15,000	14	2	15	NG	1992
Municipal	AMLPD	2	GT	1964	15,000	14	2	15	NG	1994
Light & Power	AMLPD	3	GT	1968	14,000	15	2	20	NG	1998
Department	AMLPD	4	GT	1972	12,000	28.5	2	35	NG	2002
(AMLPD)	G.M. Sullivan	5,6,7	CC	1979	8,500	140.9	NA	NA	NG	2009
Chugach	Beluga	1	GT	1969	13,742	15.1	NA	NA	NG	1998
Electric	Beluga	2	GT	1968	13,742	15.1	NA	NA	NG	1998
Association	Beluga	3	GT	1973	13,742	53.5	NA	NA	NG	2003
(CEA)	Beluga	4	GT	1976	13,742	9.3	NA	NA	NG	2006
	Beluga	5	GT	1975	13,742	53.5	NA	NA	NG	2005
	Beluga	6	GT	1976	13,742	67.8	NA	NA	NG	2006
	Beluga	7	GT	1978	13,742	67.8	NA	NA	NG	2008
	Bernice Lake	1	GT	1963	23,440	8.2	NA	NA	NG	1993
		2	GT	1972	23,440	19.6	NA	NA	NG	2002
		3	GT	1978	23,440	24.0	NA	NA	NG	2008
	International Station	1	GT	1965	39,973[1]	14.5	NA	NA	NG	1995
		2	GT	1975	39,973[1]	14.5	NA	NA	NG	1995
		3	GT	1971	39,973[1]	18.6	NA	NA	NG	2001
	Knik Arm	1	GT	1952	28,264	14.5	NA	NA	NG	1985
	Copper Lake	1	HY	1961	--	15.0	NA	NA	--	2011
Golden Valley	Healy	1	ST	1967	11,808	25.0	7	27	Coal	2002
Electric		2	IC	1967	14,000	2.7	2	3	Oil	1997
Association	North Pole	2	GT	1976	13,500	64.0	5	64	Oil	1996
(GVEA)		2	GT	1977	13,000	64.0	25	64	Oil	1997
	Zehander	1	GT	1971	14,500	17.65	10	20	Oil	1991
		2	GT	1972	14,500	17.65	10	20	Oil	1992
		3	GT	1975	14,900	2.5	1	3	Oil	1995
		4	GT	1975	14,900	2.5	1	3	Oil	1995
		5	IC	1970	14,000	2.5	1	3	Oil	2000
		6	IC	1970	14,000	2.5	1	3	Oil	2000
		7	IC	1970	14,000	2.5	1	3	Oil	2000
		8	IC	1970	14,000	2.5	1	3	Oil	2000
		9	IC	1970	14,000	2.5	1	3	Oil	2000
		10	IC	1970	14,000	2.5	1	3	Oil	2000

Table 6.2 (Continued)

Railbelt Utility	Station Name	Unit #	Unit Type	Installation Year	Heat Rate (BTU/kWH)	Installed Capacity (MW)	Minimum Capacity (MW)	Maximum Capacity (MW)	Fuel Type	Retirement Year
Fairbanks Municipal Utiltiy System (FMUS)	Chena	1	ST	1954	14,000	5.0	2	5	Coal	1989
		2	ST	1952	14,000	2.5	1	2	Coal	1987
		3	ST	1952	14,000	1.5	1	1.5	Coal	1987
		4	GT	1963	16,500	7.0	2	7	Oil	1993
		5	ST	1970	14,500	20.0	5	20	Coal	2005
		6	GT	1976	12,490	23.1	10	29	Oil	2006
	FMUS	1	IC	1967	11,000	2.7	1	3	Oil	1997
		2	IC	1968	11,000	2.7	1	3	Oil	1998
		3	IC	1968	11,000	2.7	1	3	Oil	1998
Homer Elec. Association (HEA)	Homer= Kenai	1	IC	1979	15,000	0.9	NA	NA	Oil	2009
	Pt. Graham	1	IC	1971	15,000	0.2	NA	NA	Oil	2001
	Seldovia	1	IC	1952	15,000	0.3	NA	NA	Oil	1982
		2	IC	1964	15,000	0.6	NA	NA	Oil	1994
		3	IC	1970	15,000	0.6	NA	NA	Oil	2000
Matanuska Elec. Assoc. (MEA)	Talkeetna	1	IC	1967	15,000	0.9	NA	NA	Oil	1997
Seward Electric System (SES)	SES	1	IC	1965	15,000	1.5	NA	NA	Oil	1995
		2	IC	1965	15,000	1.5	NA	NA	Oil	1995
Alaska Power Administration (APAd)	Eklutna	-	HY	1955	--	30.0	NA	NA	--	2005
TOTAL						943.6				

Notes:

GT = Gas turbine
CC = Combined cycle
HY = Conventional hydro
IC = Internal Combustion
ST = Steam turbine
NG = Natural gas
NA = Not available

(1) This value judged to be unrealistic for large range planning and therefore is adjusted to 15,000 for generation planning studies.

Table 6.3 - OPERATING AND ECONOMIC PARAMETERS FOR SELECTED HYDROELECTRIC PLANTS

No.	Site	River	Max. Gross Head Ft.	Installed Capacity (MW)	Average Annual Energy (Gwh)	Plant Factor (%)	Capital Cost[1] ($10^6)	Economic[2] Cost of Energy ($/1000 Kwh)
1	Snow	Snow	690	50	220	50	255	45
2	Bruskasna	Nenana	235	30	140	53	238	113
3	Keetna	Talkeetna	330	100	395	45	463	73
4	Cache	Talkeetna	310	50	220	51	564	100
5	Browne	Nenana	195	100	410	47	625	59
6	Talkeetna-2	Talkeetna	350	50	215	50	500	90
7	Hicks	Matanuska	275	60	245	46	529	84
8	Chakachamna	Chakachatna	945	500	1925	44	1480	30
9	Allison	Allison Creek	1270	8	33	47	54	125
10	Strandline Lake	Beluga	810	20	85	49	126	115

NOTES:
(1) Including engineering and owner's administrative costs but excluding AFDC.
(2) Including AFDC, Insurance, Amortization, and Operation and Maintenance Costs.

Table 6.4 - RESULTS OF ECONOMIC ANALYSES OF ALTERNATIVE GENERATION SCENARIOS

Generation Scenario Type	Generation Scenario Description	Load Forecast	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010: Thermal: Coal	Thermal: Gas	Thermal: Oil	Hydro	Total System Installed Capacity in 2010 (MW)	Total System Present Worth Cost (10^6)
All Thermal	No Renewals	Very Low[1]	LBT7	500	426	90	144	1160	4930
	No Renewals	Low	L7E1	700	300	40	144	1385	5920
	With Renewals	Low	L2C7	600	657	30	144	1431	5910
	No Renewals	Medium	LME1	900	801	50	144	1895	8130
	With Renewals	Medium	LME3	900	807	40	144	1891	8110
	No Renewals	High	L7F7	2000	1176	50	144	3370	13520
	With Renewals	High	L2E9	2000	576	130	144	3306	13630
	No Renewals	Probabilistic	LOF3	1100	1176	100	144	3120	8320
Thermal Plus Alternative Hydro	No Renewals Plus: Chakachamna (500)[2]-1993 Keetna (100)-1997	Medium	L7W1	600	576	70	744	1990	7080
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1997 Snow (50)-2002	Medium	LFL7	700	501	10	894	2005	7040
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1996 Strandline (20), Allison Creek (8), Snow (50)-1998	Medium	LWP7	500	576	60	822	1958	7064
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1996 Strandline (20), Allison Creek (8), Snow (50)-2002	Medium	LXF1	700	426	30	822	1978	7041
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1996 Snow (50), Cache (50), Allison Creek (8), Talkeetna-2 (50), Strandline (20)-2002	Medium	L403	500	576	30	922	2028	7088

Notes:

(1) Incorporating load management and conservation
(2) Installed capacity

Table 6.5 - SUMMARY OF THERMAL GENERATING RESOURCE PLANT PARAMETERS

Parameter	PLANT TYPE: COAL-FIRED STEAM 500 MW	COAL-FIRED STEAM 250 MW	COAL-FIRED STEAM 100 MW	COMBINED CYCLE 250 MW	GAS TURBINE 75 MW	DIESEL 10 MW
Heat Rate (Btu/kWh)	10,500	10,500	10,500	8,500	12,000	11,500
O&M Costs						
Fixed O&M ($/yr/kW)	0.50	1.05	1.30	2.75	2.75	0.50
Variable O&M ($/MWH)	1.40	1.80	2.20	0.30	0.30	5.00
Outages						
Planned Outages (%)	11	11	11	14	11	1
Forced Outages (%)	5	5	5	6	3.8	5
Construction Period (yrs)	6	6	5	3	2	1
Start-up Time (yrs)	6	6	6	4	4	1
Total Capital Cost ($ million)						
Railbelt:	-	-	-	175	26	7.7
Beluga:	1,130	630	290	-	-	-
Unit Capital Cost ($/kW)[1]						
Railbelt:	-	-	-	728	250	778
Beluga:	2473	2744	3102	-	-	-

Notes:

(1) Including AFDC at 0 percent escalation and 3 percent interest.

Table 6.4 - RESULTS OF ECONOMIC ANALYSES OF ALTERNATIVE GENERATION SCENARIOS

Generation Scenario: Type	Generation Scenario: Description	Load Forecast	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010: Thermal: Coal	Thermal: Gas	Thermal: Oil	Hydro	Total System Installed Capacity in 2010 (MW)	Total System Present Worth Cost - ($$10^6$)
All Thermal	No Renewals	Very Low[1]	LBT7	500	426	90	144	1160	4930
	No Renewals	Low	L7E1	700	300	40	144	1385	5920
	With Renewals	Low	L2C7	600	657	30	144	1431	5910
	No Renewals	Medium	LME1	900	801	50	144	1895	8130
	With Renewals	Medium	LME3	900	807	40	144	1891	8110
	No Renewals	High	L7F7	2000	1176	50	144	3370	13520
	With Renewals	High	L2E9	2000	576	130	144	3306	13630
	No Renewals	Probabilistic	LOF3	1100	1176	100	144	3120	8320
Thermal Plus Alternative Hydro	No Renewals Plus: Chakachamna (500)[2]-1993 Keetna (100)-1997	Medium	L7W1	600	576	70	744	1990	7080
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1997 Snow (50)-2002	Medium	LFL7	700	501	10	894	2005	7040
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1996 Strandline (20), Allison Creek (8), Snow (50)-1998	Medium	LWP7	500	576	60	822	1958	7064
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1996 Strandline (20), Allison Creek (8), Snow (50)-2002	Medium	LXF1	700	426	30	822	1978	7041
	No Renewals Plus: Chakachamna (500)-1993 Keetna (100)-1996 Snow (50), Cache (50), Allison Creek (8), Talkeetna-2 (50), Strandline (20)-2002	Medium	L403	500	576	30	922	2028	7088

Notes:

(1) Incorporating load management and conservation
(2) Installed capacity

Table 6.5 - SUMMARY OF THERMAL GENERATING RESOURCE PLANT PARAMETERS

Parameter	PLANT TYPE					
	COAL-FIRED STEAM			COMBINED CYCLE	GAS TURBINE	DIESEL
	500 MW	250 MW	100 MW	250 MW	75 MW	10 MW
Heat Rate (Btu/kWh)	10,500	10,500	10,500	8,500	12,000	11,500
O&M Costs						
Fixed O&M ($/yr/kW)	0.50	1.05	1.30	2.75	2.75	0.50
Variable O&M ($/MWH)	1.40	1.80	2.20	0.30	0.30	5.00
Outages						
Planned Outages (%)	11	11	11	14	11	1
Forced Outages (%)	5	5	5	6	3.8	5
Construction Period (yrs)	6	6	5	3	2	1
Start-up Time (yrs)	6	6	6	4	4	1
Total Capital Cost ($ million)						
Railbelt:	-	-	-	175	26	7.7
Beluga:	1,130	630	290	-	-	-
Unit Capital Cost ($/kW)[1]						
Railbelt:	-	-	-	728	250	778
Beluga:	2473	2744	3102	-	-	-

Notes:

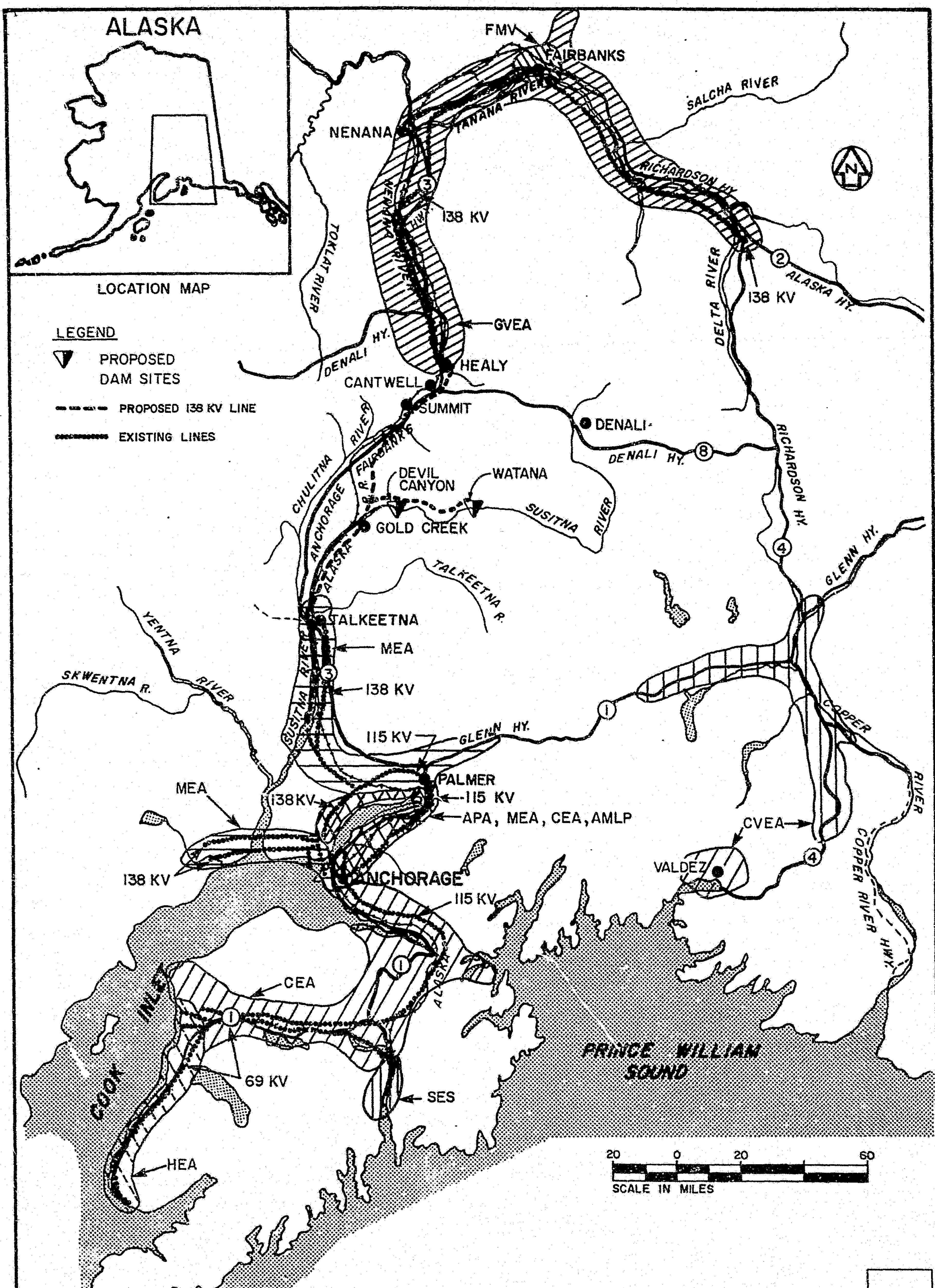
(1) Including AFDC at 0 percent escalation and 3 percent interest.

Table 6.6 - ALASKAN FUEL RESERVES

Reserve	Field	Approximate Reserve	Heating Value Btu/lb
Coal (million tons)	Buluga	2400	7200 - 8900
	Nenana	2000	7500 - 9400
	Kenai	300	6500 - 8500
	Matanuska	100	10300 - 14000
Gas (billion cubic feet)	North Slope	29000 plus	--
	Cook Inlet	4200 plus	--
Oil (billion cubic feet)	North Slope	8400 plus	--
	Cook Inlet	200	--

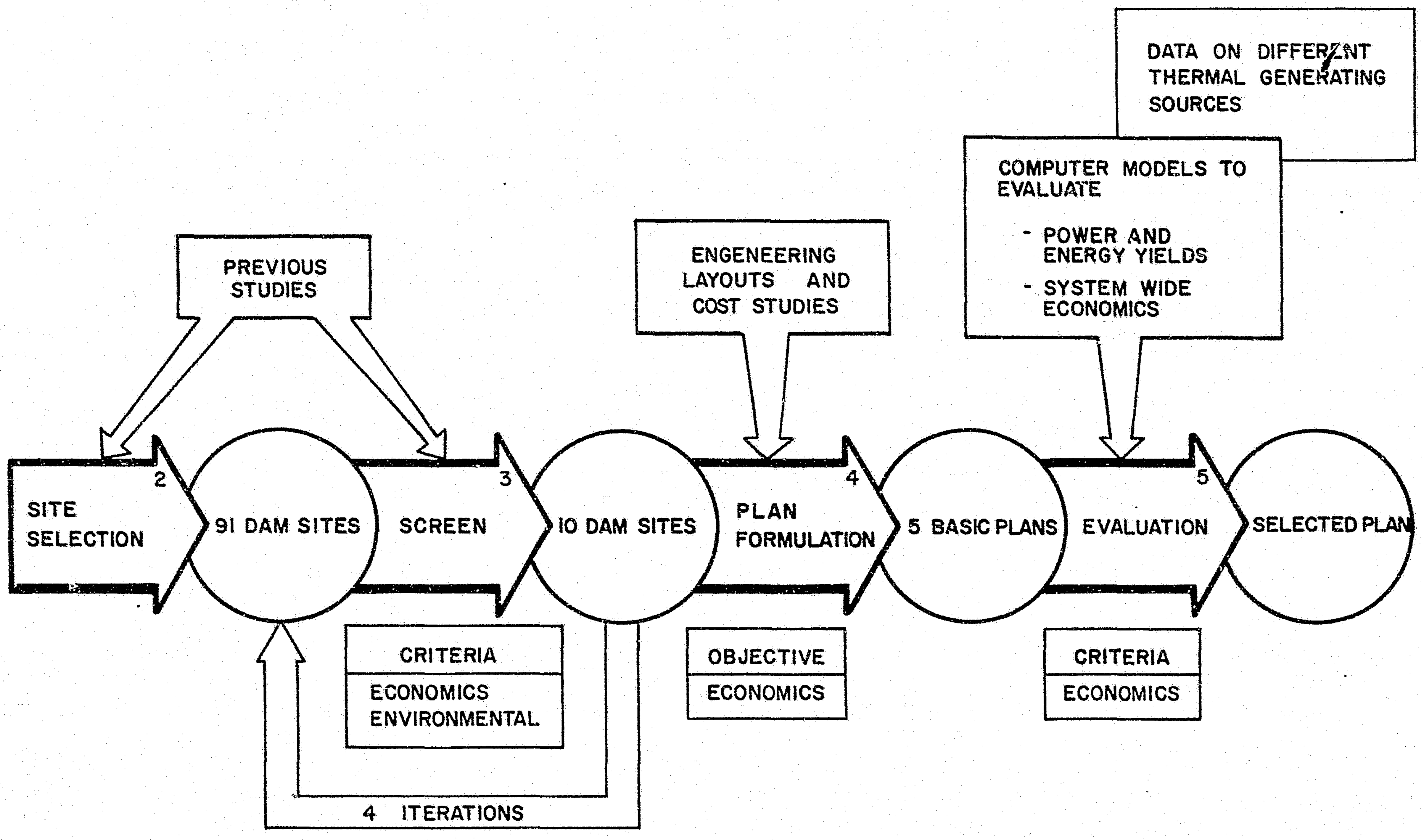
Table 6.7 - FUEL COSTS AND ESCALATION RATES SELECTED FOR GENERATION PLANNING STUDIES

Parameter	Fuel Type		
	Natural Gas	Coal	Oil
Economic Cost - $/Million BTU	2.00	1.15	4.00
Annual Escalation Rate - %			
Period: 1980 - 2005	3.98	2.93	3.58
2006 - 2010	0	0	0



LOCATION MAP

FIGURE 6.1



SNOW (S)
BRUSKASNA (B)
KEETNA (K)
CACHE (CA)
BROWNE (BR)
TALKEETNA - 2 (T-2)
HICKS (H)
CHAKACHAMNA (CH)
ALLISON CREEK (AC)
STRANDLINE LAKE (SL)

- CH, K
- CH, K, S
- CH, K, S, SL, AC
- CH, K, S, SL, AC
- CH, K, S, SL, AC, CA, T-2

CH, K, S & THERMAL

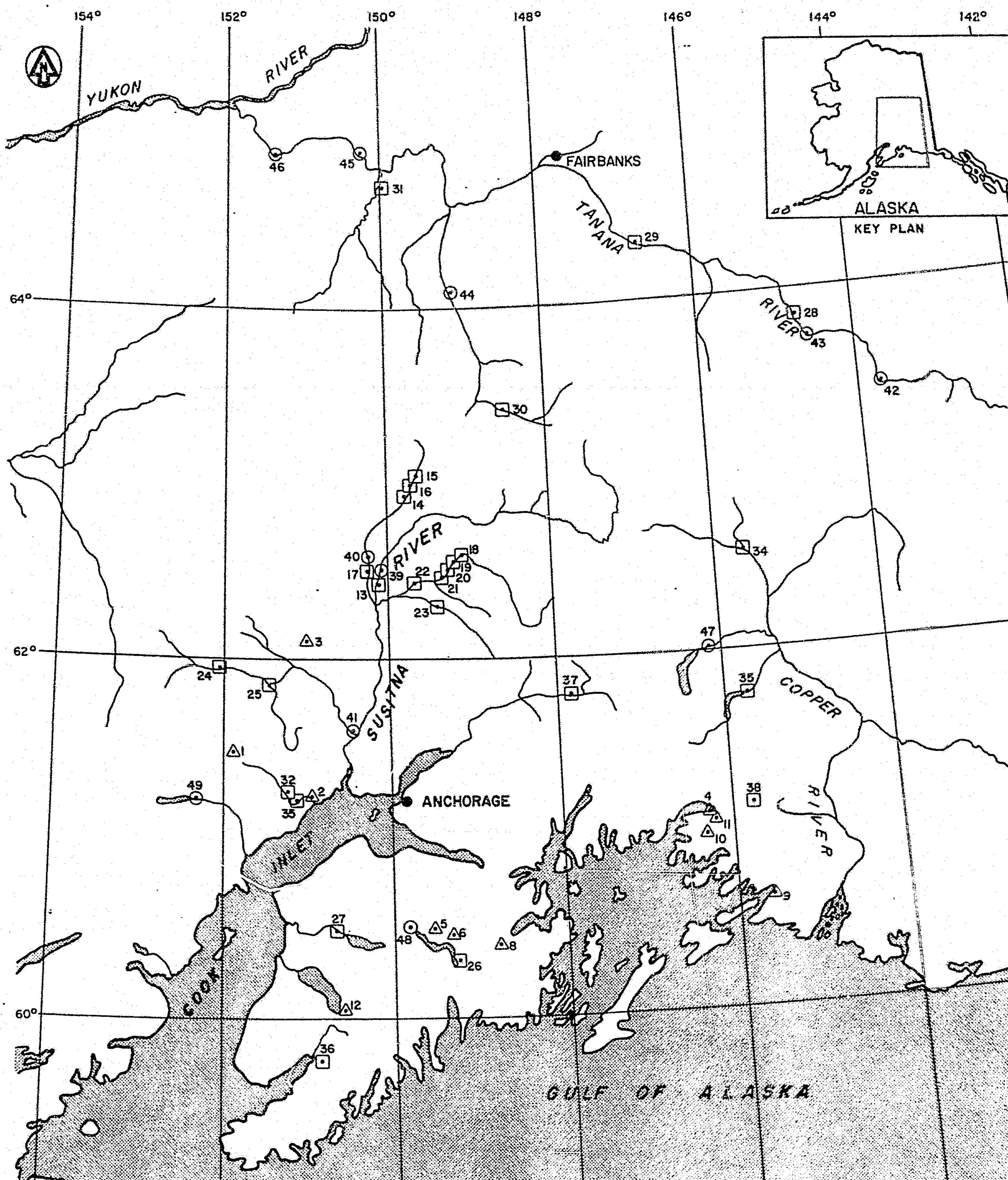
LEGEND

4 STEP NUMBER IN STANDARD PROCESS (APPENDIX A)

FORMULATION OF PLANS INCORPORATING NON-SUSITNA HYDRO GENERATION

FIGURE 6.2

ACRES



ALASKA RAILBELT REGION

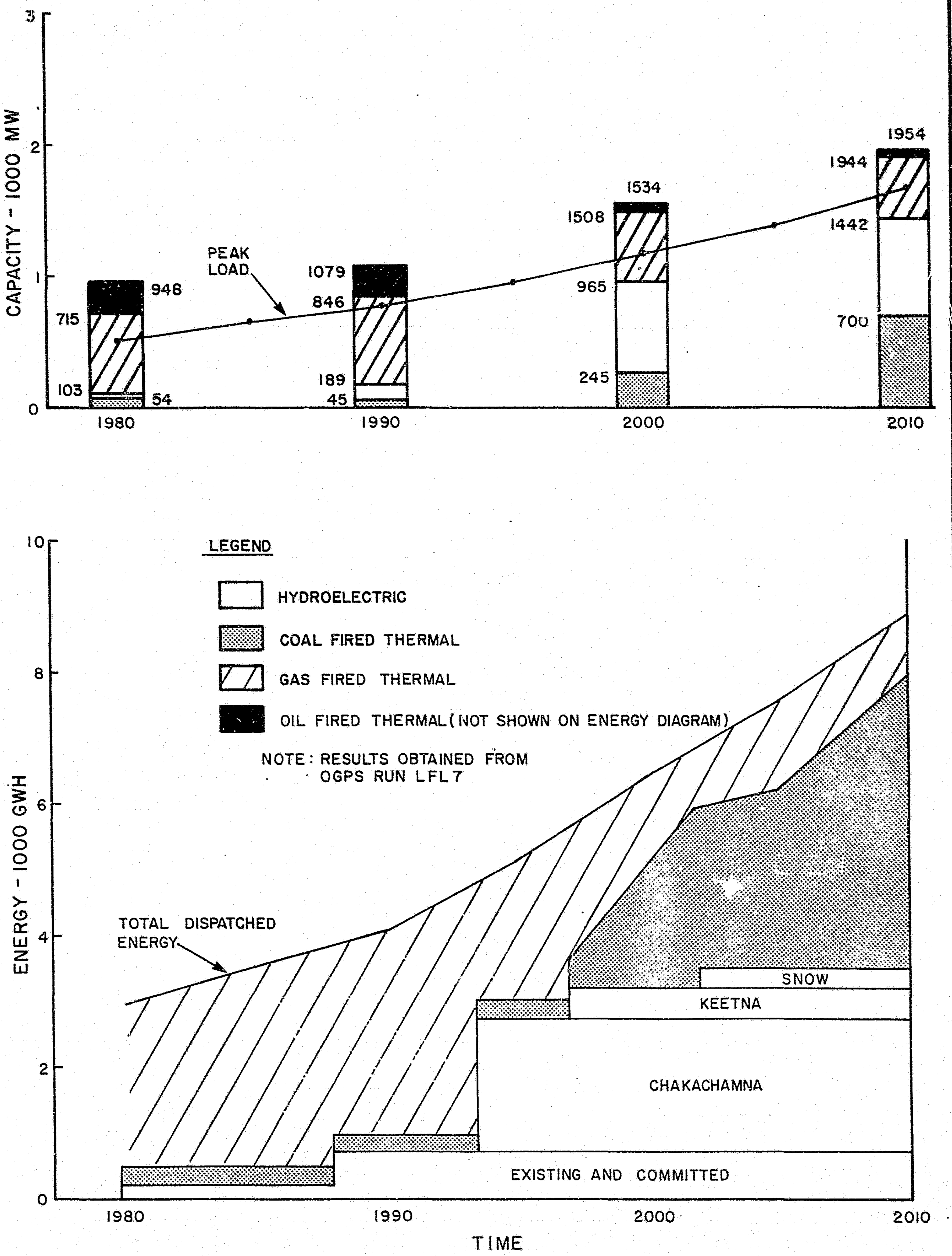
0 50 100
SCALE- MILES
1 INCH EQUALS APPROXIMATELY 40 MILES

0 - 25 MW		25-100 MW		> 100 MW	
1. STRANDLINE L.	13. WHISKERS	26. SNOW	39. LANE		
2. LOWER BELUGA	14. COAL	27. KENAI LOWER	40. TOKICHITNA		
3. LOWER LAKE CR.	15. CHULITNA	28. GERSTLE	41. YENTNA		
4. ALLISON CR.	16. OHIO	29. TANANA R.	42. CATHEDRAL BLUFFS		
5. CRESCENT LAKE 2	17. LOWER CHULITNA	30. BRUSKASNA	43. JOHNSON		
6. GRANT LAKE	18. CACHE	31. KANTISHNA R.	44. BROWNE		
7. McCLURE BAY	19. GREENSTONE	32. UPPER BELUGA	45. JUNCTION IS.		
8. UPPER NELLIE JUAN	20. TALKEETNA 2	33. COFFEE	46. VACHON IS		
9. POWER CREEK	21. GRANITE GORGE	34. GULKANA R.	47. TAZILNA		
10. SILVER LAKE	22. KEETNA	35. KLUTINA	48. KENAI LAKE		
11. SOLOMON GULCH	23. SHEEP CREEK	36. BRADLEY LAKE	49. CHAKACHAMNA		
12. TUSTUMENA	24. SKWENTNA	37. HICK'S SITE			
	25. TALACHULITNA	38. LOWE			

SELECTED ALTERNATIVE HYDROELECTRIC SITES

FIGURE 63

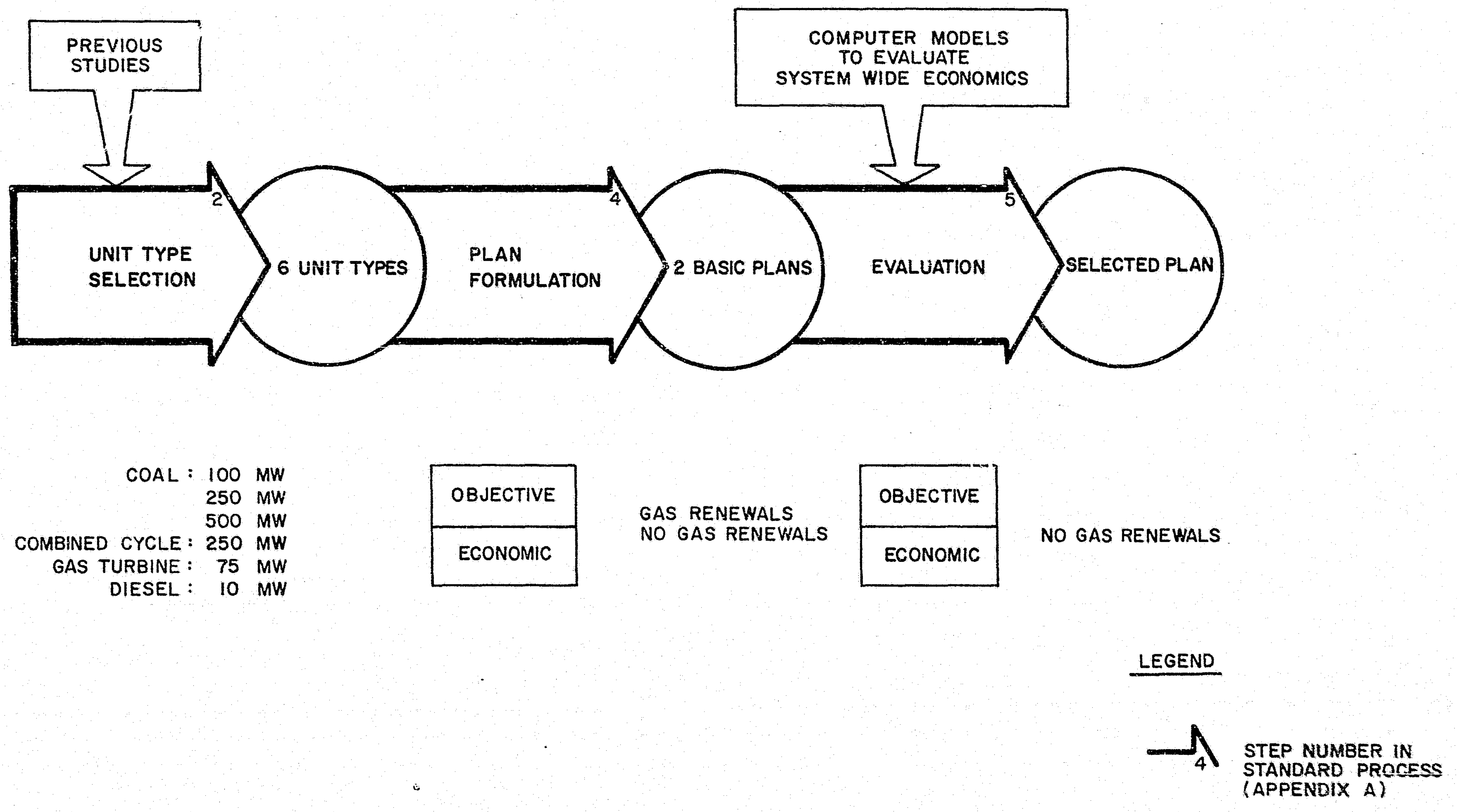
ACRES



GENERATION SCENARIO INCORPORATING THERMAL AND ALTERNATIVE HYDROPOWER DEVELOPMENTS - MEDIUM LOAD FORECAST -

FIGURE 6.4

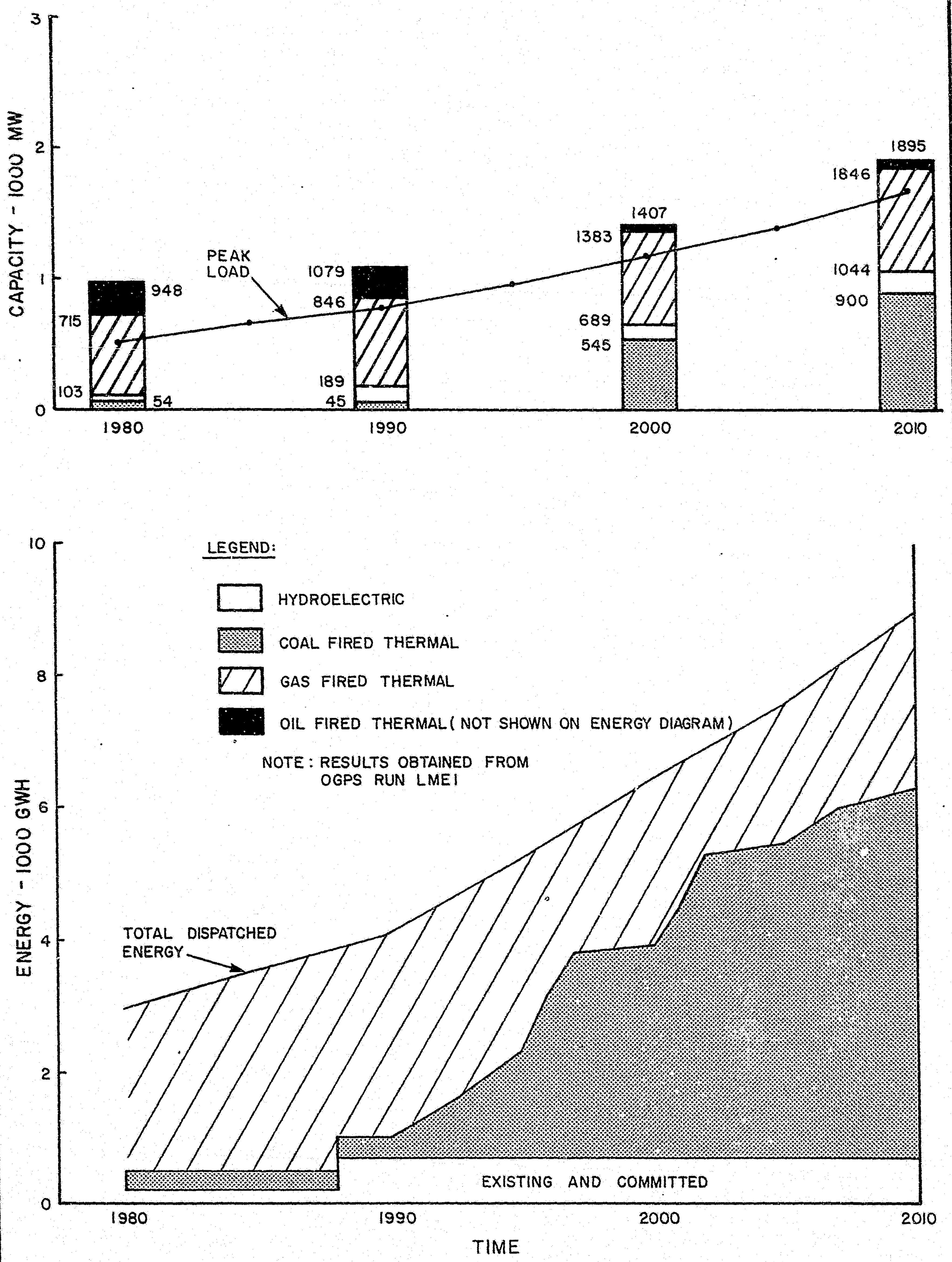
ACRES



FORMULATION OF PLANS INCORPORATING ALL-THERMAL GENERATION

FIGURE 6.5

ACRES



ALL THERMAL GENERATION SCENARIO
- MEDIUM LOAD FORECAST -

FIGURE 6.6

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7 - SUSITNA BASIN

7.1 - Introduction

The purpose of this section is to describe climatological, physical and environmental characteristics of the Susitna River Basin and to briefly acquaint the reader with some of the ongoing studies being undertaken to augment previously recorded data. It deals with general descriptions of the climatology, hydrology and geology, and seismic considerations and outlines the environmental aspects. The information presented has been obtained both from previous studies and the field programs and office studies initiated during 1980 under Tasks 3, 4, 5 and 7.

7.2 - Climatology and Hydrology

The climate of the Susitna Basin upstream from Talkeetna is generally characterized by cold, dry winters and warm, moderately moist summers. The upper basin is dominated by continental climatic conditions while the lower basin falls within a zone of transition between maritime and continental climatic influences.

(a) Climatic Data Records

Data on precipitation, temperature and other climatic parameters have been collected by NOAA at several stations in the south central region of Alaska since 1941. Prior to the current studies, there were no stations located within the Susitna basin upstream from Talkeetna. The closest stations where long-term climate data is available are at Talkeetna to the south and Summit to the north. A summary of the precipitation and temperature data available in the vicinity of the basin is presented in Table 7.1.

Six automatic climate stations were established in the upper basin during 1980 (see Figure 7.1). The data currently being collected at these stations includes air temperature, average wind speed, wind direction, peak wind gust, relative humidity, precipitation, and solar radiation. Snowfall amounts are being measured in a heated precipitation bucket at the Watana station. Data are recorded at thirty minute intervals at the Susitna Glacier station and at fifteen minute intervals at all other stations.

(b) Precipitation

Precipitation in the basin varies from low to moderate amounts in the lower elevations to heavy in the mountains. Mean annual precipitation of over 80 inches is estimated to occur at elevations above 3000 feet in the Talkeetna Mountains and the Alaskan Range whereas at Talkeetna station, at elevation 345 feet, the average annual precipitation recorded is about 28 inches. The average precipitation reduces in a northerly direction as the continental climate starts to predominate. At Summit station, at elevation 2397 feet, the average annual precipitation is only 18 inches. The seasonal distribution of precipitation is similar for all the stations in and surrounding the basin. At Talkeetna, records show that 68 percent of the total precipitation occurs during the warmer months, May through October, while only 32 percent is recorded in the winter months. Average recorded snowfall at Talkeetna is about 106 inches. Generally, snowfall is restricted to the months of October through April with some 82 percent snowfall recorded in the period November to March.

The U.S. Soil Conservation Service (SCS) operates a network of snow course stations in the basin and records of snow depths and water content are available as far back as 1964. The stations within the Upper Susitna Basin are generally located at elevations below 3000 feet and indicate that annual snow accumulations are around 20 to 40 inches and that peak depths occur in late March. There are no historical data for the higher elevations. The basic network was expanded during 1980 with the addition of three new snow courses on the Susitna glacier (see Figure 7.1). Arrangements have been made with SCS for continuing the collection of information from the expanded network during the study period.

(c) Temperature

Typical temperatures observed from historical records at the Talkeetna and Summit stations are presented in Table 7.2. It is expected that the temperatures at the dam sites will be somewhere between the values observed at these stations.

(d) River Ice

The Susitna River usually starts to freeze up by late October. River ice conditions such as thickness and strength vary according to the river channel shape and slope, and more importantly, with river discharge. Periodic measurements of ice thickness at several locations in the river have been carried out during the winters of 1961 through 1972. The maximum thicknesses observed at selected locations on the river are given in Table 7.3. Ice breakup in the river commences by late April or early May and ice jams occasionally occur at river constrictions resulting in rises in water level of up to 20 feet.

Detailed field data collection programs and studies are underway to identify potential problem areas should the Susitna Project be undertaken, and to develop appropriate mitigation measures. The program includes comprehensive aerial and ground reconnaissance and documentation of freeze-up and break-up processes. This data will be used to calibrate computer models which can be used to predict the ice cover regime under post project conditions. It will then be possible to evaluate the impacts of anticipated changes in ice conditions caused by the project and any proposed mitigation measures.

(e) Water Resources

Streamflow data has been recorded by the USGS for a number of years at a total of 12 gaging stations on the Susitna River and its tributaries (see Figure 7.1). The length of these records varies from 30 years at Gold Creek to about five years at the Susitna station. There are no historical records of streamflow at any of the proposed dam sites. For current study purposes, available streamflow records have been extended to cover the full 30 year period using a multisite correlation technique to fill the gaps in flow data at each of the stations. Flow sequences at the dam sites have subsequently been generated for the same 30 year period by extrapolation on the basis of drainage basin areas.

A gaging station was established at the Watana dam site in June 1980 and continuous river stage data is beir, collected. It is proposed to develop a rating curve at the station with streamflow measurements taken during the 1980 and 1981 seasons. River flows will be calculated and used to check the extrapolated streamflow data at the Watana site.

Seasonal variation of flows is extreme and ranges from very low values in winter (October to April) to high summer values (May to September). For the Susitna River at Gold Creek the average winter and summer flows are 2100 and 20,250 cfs respectively, i.e. a 1 to 10 ratio. The monthly average flows in the Susitna River at Gold Creek are given in Figure 7.3. On average, approximately 88 percent of the streamflow recorded at Gold Creek station occurs during the summer months. At higher elevations in the basin the distribution of flows is concentrated even more in the summer months. For the Maclaren River near Paxson (El 4520 ft) the average winter and summer flows are 144 and 2100 cfs respectively, i.e. a 1 to 15 ratio. The monthly percent of annual discharge and mean monthly discharges for the Susitna River at the gaging stations are given in Table 7.4.

The Susitna River above the confluence with the Chulitna River contributes only approximately 20 percent of the mean annual flow measured near Cook Inlet (at Susitna station). Figure 7.2 shows how the mean annual flow of the Susitna increases towards the mouth of the river at Cook Inlet.

(f) Floods

The most common causes of flood peaks in the Susitna River Basin are snowmelt or a combination of snowmelt and rainfall over a large area. Annual maximum peak discharges generally occur between May and October with the majority, approximately 60 percent, occurring in June. Some of the annual maximum flood peaks have also occurred in August or later and are the result of heavy rains over large areas augmented by significant snowmelt from higher elevations and glacial runoff.

A regional flood frequency analysis has been carried out using the recorded floods in the Susitna River and its principle tributaries, as well as the Copper, Matanuska and Tosina Rivers. These analyses have been conducted for two different time periods within the year. The first period selected is the open water period, i.e. after the ice breakup and before freezeup. This period contains the largest floods which must be accommodated by the project. The second period represents that portion of time during which ice conditions occur in the river. These floods, although smaller, can be accompanied by ice jamming, and must be considered during the construction phase of the project in planning and design of coffer dams for river diversion.

The results of these frequency analyses will be used for estimating floods in ungaged rivers and streams. They will also be used to check the accuracy of the Gold Creek Station rating curve which is important in determining spillway design floods for the proposed Susitna River projects. Multiple regression equations have been developed using physiographic parameters of the basin such as catchment area, stream length, mean annual precipitation, etc. to assess flood peaks at the dam sites and intermediate points of interest in the river. Table 7.5 lists mean annual, 100 and 10,000 year flood peaks as well as the 50 year flood peaks under water and under ice cover conditions. These latter flood peaks are included as they are representative of the flood conditions for which the construction diversion facilities must be designed.

Estimates of the probable maximum floods in the Susitna Basin were made by COE in their 1975 study (PMF). A river basin computer simulation model (SSARR) was used for that purpose. A detailed review of the input data to the model has been undertaken and discussions held with COE engineers to improve understanding of the model parameters used. A series of computer runs with the model have been undertaken to study the effects of likely changes in the timing and magnitude of three important parameters, i.e. probable maximum precipitation, snow pack and temperature. These studies have indicated that the PMF is extremely sensitive to certain of these parameters and that additional refinement of the flood estimation technique is warranted.

(g) River Sediment

Periodic suspended sediment samples have been collected by the USGS at the four gaging stations upstream from Gold Creek (see Figure 7.1) for varying periods between 1952 and 1979. Except for three samples collected at Denali in 1958, no bed load sampling has been undertaken at any stations. Data coverage during high-flow, high sediment events is poor and consequently any estimate of total annual sediment yield has a high degree of uncertainty.

The most comprehensive analysis of sediment load in the river to date is that undertaken by the COE in 1975. Table 7.6 gives the COE estimates of sediment transport at the gaging stations.

7.3 - Regional Geology

The regional geology of the area in which the Susitna Basin is located has been extensively studied and documented (1, 2). The Upper Susitna Basin lies within what is geologically called the Talkeetna Mountains area. This area is geologically complex and has a history of at least three periods of major tectonic deformation. The oldest rocks (250 to 300 m.y.b.p.)* exposed in the region are volcanic flows and limestones which are overlain by sandstones and shales dated approximately 150 to 200 m.y.b.p. A tectonic event approximately 135 to 180 m.y.b.p. resulted in the instrusion of large diorite and granite plutons, which caused intense thermal metamorphism. This was followed by marine deposition of silts and clays. The argillites and phyllites which predominate at Devil Canyon were formed from the silts and clays during faulting and folding of the Talkeetna Mountains area in the Late Cretaceous

*m.y.b.p.: million years before present

period (65 to 100 m.y.b.p.). As a result of this faulting and uplift, the eastern portion of the area was elevated, and the oldest volcanics and sediments were thrust over the younger metamorphics and sediments. The major area of deformation during this period of activity was southeast of Devil Canyon and included the Watana area. The Talkeetna Thrust Fault, a well-known tectonic feature which has been identified in the literature (note WCC report), trends northwest through this region. This fault was one of the major mechanisms of this overthrusting from southeast to northwest. The Devil Canyon area was probably deformed and subjected to tectonic stress during the same period, but no major deformations are evident at the site (Figure 7.4).

The diorite pluton that forms the bedrock of the Watana site was intruded into sediments and volcanics about 65 m.y.b.p. The andesite and basalt flows near the site may have been formed immediately after this plutonic intrusion, or after a period of erosion and minor deposition.

During the Tertiary period (20 to 40 m.y.b.p.) the area surrounding the sites was again uplifted by as much as 3,000 feet. Since then widespread erosion has removed much of the older sedimentary and volcanic rocks. During the last several million years at least two alpine glaciations have carved the Talkeetna Mountains into the ridges, peaks, and broad glacial plateaus seen today. Post-glacial uplift has induced downcutting of streams and rivers, resulting in the 500 to 700 feet deep V-shaped canyons that are evident today, particularly at the Vee and Devil Canyon dam sites. This erosion is believed to be still occurring and virtually all streams and rivers in the region are considered to be actively downcutting. This continuing erosion has removed much of the glacial debris at higher elevations but very little alluvial deposition has occurred. The resulting landscape consists of barren bedrock mountains, glacial till covered plains, and exposed bedrock cliffs in canyons and along streams. The arctic climate has retarded development of topsoil.

Further geologic mapping of the project area and geotechnical investigation of the proposed dam sites was initiated under the current study in 1980, and will continue through early 1982.

7.4 - Seismic Aspects

Relatively little detailed investigation of the seismology of the Susitna Basin area had been undertaken prior to the current studies. A comprehensive program of field work and investigation of seismicity was initiated in 1980.

The seismic studies referred to in the following sections were specifically aimed at developing design criteria for the Devil Canyon and Watana dam sites. However, much of the discussion is pertinent to all dam sites in the Susitna Basin and is therefore included in this section.

(a) Seismic Geology

The Talkeetna Mountains region of south-central Alaska lies within the Talkeetna Terrain. This term is the designation given to the immediate region of south-central Alaska that includes the upper Susitna River basin (as shown on Figure 7.4). The region is bounded on the north by the Denali Fault, and on the west by the Alaska Peninsula features that make up the Central Alaska Range. South of the Talkeetna Mountains, the Talkeetna Terrain is separated from the Chugach Mountains by the Castle Mountain

Fault. The proposed Susitna Hydroelectric Project dam sites are located in the western half of the Talkeetna Terrain. The eastern half of the region includes the relatively inactive, ancient zone of sediments under the Copper River Basin and is bounded on the east by the Totschunda section of the Denali Fault and the volcanic Wrangell Mountains.

Regional earthquake activity in the project area is closely related to the plate tectonics of Alaska. The Pacific Plate is underthrusting the North American Plate in this region. The major earthquakes of Alaska, including the Good Friday earthquake of 1964, have primarily occurred along the boundary between these plates.

The historical seismicity in the vicinity of the dam sites is associated with crustal earthquakes within the North American Plate and the shallow and deep earthquakes generated within the Benioff Zone, which underlies the project area. Historical data reveals that the major source of earthquakes in the site region is in the deep portion of the Benioff Zone, with depths ranging between 24 to 36 miles below the surface. Several moderate size earthquakes have been reported to have been generated at these depths. The crustal seismicity within the Talkeetna Terrain is very low based on historical records. Most of the recorded earthquakes in the area are reported to be related to the Denali-Toschunda Fault, the Castle Mountain Fault or the Benioff Zone.

(b) Field Investigations

For project design purposes, it is important to identify the surface expressions of potential seismic activity. Within the Talkeetna Terrain, numerous lineaments and features were investigated as part of the 1980 seismic studies. Utilizing available air photos, satellite imagery and airborne remote sensing data, a catalog of reported and observable discontinuities and linear features (lineaments) was compiled. After elimination of those features that were judged to have been caused by glaciation, bedding, river processes, or man's impact, the 216 remaining features were screened. The 48 significant features passing the screen were then classified as either being features that could positively be identified as faults, or features which could possibly be faults but for which a definitive origin could not be identified.

The following criteria were used in the screening process:

- All lineaments or faults that have been subjected to recent displacement are retained for further study.

- All lineaments located within 6 miles of project structures, or having a branch that is suspected of passing through a structure is retained for further study unless there is evidence that they have not experienced displacement in the last 100,000 years.

- All features identified as faults which have experienced movement in the last 100,000 years are retained.

These guidelines were formulated after review of regulatory requirements of the WPRS, COE, U.S. Nuclear Regulatory Commission, Federal Energy Regulatory Commission, and several state regulations.

Of the 48 candidate features, only 13 features were judged to be significant for the design of the project. These 13 features include four features at the Watana site (including the Talkeetna Fault and the Susitna feature) and nine features at the Devil Canyon site. It is worth noting that no evidence of a surface expression was observed in the vicinity of the so-called Susitna feature during the 1980 studies. These thirteen features will be further investigated during 1981 to establish their potential impact on the project design.

(c) Microseismic Monitoring

To support the identification of potential faults in the project area, a short-term microseismic monitoring network was installed and operated for three months. The objective of this exercise was to collect microearthquake data as a basis for studying the types of faulting and stress orientation within the crust, the correlation of microearthquakes with surface faults and lineaments, and seismic wave propagation characteristics. A total of 265 earthquakes with sensitivity approaching magnitude zero were recorded. Of these events, 170 were recorded at shallow depths, the largest being magnitude 2.8 (Richter Scale). Ninety-eight events were related to the Benioff Zone, the largest being magnitude 3.7. None of the microearthquakes recorded at shallow depths were found to be related to any surface feature or lineament within the Talkeetna Terrain, including the Talkeetna Fault. The depth of the Benioff Zone was distinctly defined by this data as being 36 miles below the Devil Canyon site and 39 miles below the Watana site.

(d) Reservoir Induced Seismicity

The subject of Reservoir Induced Seismicity (RIS) was studied for the proposed project area on a preliminary basis using worldwide RIS data and site specific information. The phenomenon of RIS has been observed at numerous large reservoirs where seismic tremors under or immediately adjacent to the reservoir have been correlated to periods of high filling rate. In recent years, this subject has drawn considerable attention within the engineering and seismic community. It is thought that RIS may be caused by the increased weight of the water in the reservoir or by increased pore pressures migrating through and "lubricating" joints in the rock and acting hydraulically upon highly stressed rock. Studies indicate that for a reservoir system to trigger a significant earthquake, a pre-existing fault with recent displacement must be under or very near to the reservoir. The presence of a fault with recent displacement has not been confirmed at either site.

The analysis of previously reported cases indicated a high probability of RIS for the proposed Susitna reservior on the basis of its depth and volume, if faults with recent displacement exist nearby. Most RIS recorded events are believed to be due to an early release of stored energy in a fault. Thus, in serving as a mechanism for energy release, the resultant earthquakes are likely to be smaller than if full energy buildup had occurred. In no case studied has an RIS event exceeded the estimated maximum credible earthquake on a related fault. Therefore, RIS of itself will not control the design earthquake determination and is considered only for purposes of estimating recurrence intervals of potential events.

(e) Preliminary Ground Motion Evaluations

On the basis of the geologic and seismic studies, three main sources of potential earthquakes have been identified at this time. These sources are the Denali Fault located roughly 40 miles north of the sites, Castle Mountain Fault less than 60 miles south of the sites and the Benioff Zone 30 to 36 miles below the surface. No evidence has yet been found to indicate that any of the features and lineaments identified to date could be regarded as surface expressions of faults that have experienced displacement during recent geologic times. Thus, for current study purposes, no attempt is made to assign potential earthquake magnitudes to the 13 features identified as warranting further study. Further field studies will be conducted on these features during 1981 to ensure that eliminating them from consideration is justified.

For preliminary project design puroses, very conservative assumptions have been made for anticipated ground motions which would be caused by possible earthquakes occurring on the three faults. The Denali Fault has been assigned a preliminary conservative maximum credible earthquake value of magnitude 8.5. This earthquake, when attenuated to the sites, is postulated to generate a mean peak acceleration of 0.21g at both the Watana and Devil Canyon sites. The Castle Mountain Fault has been assigned a preliminary conservative value of magnitude 7.4, which would generate a mean peak acceleration in the 0.05g to 0.06g range at the sites. The Benioff Zone has been assigned an upper bound conservative value of magnitude 8.5, which would generate a mean peak acceleration of 0.41g at the Watana site and 0.37g at the Devil Canyon site. The duration of potential strong motion earthquakes for both the Denali and Benioff Zones is conservatively estimated to be 45 seconds. It is evident that of these three potential sources, the Benioff Zone will govern the design. Further studies will be undertaken to finalize these maximum credible earthquake magnitudes and to further evaluate the features identified within the Talkeetna Terrain. There is every indication that further study will lead to a reduction in the design earthquake magnitudes for the three known faults. Due to their distant locations, none of these faults have any potential for causing ground rupture at the sites.

Numerous large dams have been designed to accommodate ground motions from relatively large earthquakes located close to the dam. In California, dams are routinely designed to withstand ground motions from magnitude 7.5 to 8.5 earthquakes at distances of 12 miles. Dams have also been designed to accommodate up to 20 feet of horizontal displacement and three feet of vertical displacement. All of these conditions are more severe than those anticipated at the Susitna sites. Oroville Dam in central California was designed to withstand severe seismic loadings and has been progressively analyzed as new data and methods become available. Current evaluations indicate that the dam, which is comparable in size to Watana, could withstand seismic loadings comparable to those postulated for the Watana and Devil Canyon sites.

7.5 - Environmental Aspects

Numerous studies of the environmental characteristics of the Susitna River Basin have been undertaken in the past. The current studies were initiated in early 1980 and are planned to continue indefinitely. These studies constitute the most comprehensive and detailed examination of the Susitna Basin ever undertaken, and possibly of any comparable resource. In this section, descriptions of ambient biological and vegetation conditions are presented. These descriptions are based on reviews of the literature as well as the preliminary results of on-going studies.

(a) Biological

(i) Fisheries

The Susitna basin is inhabited by resident and anadromous fish. The anadromous group includes five species of Pacific salmon: sockeye (red); coho (silver); chinook (king); pink (humpback); and chum (dog) salmon. Dolly Varden are also present in the lower Susitna Basin with both resident and anadromous populations. Anadromous smelt are known to run up the Susitna River as far as the Deshka River about 40 miles from Cook Inlet.

Salmon are known to migrate up the Susitna River to spawn in tributary streams. Surveys to date indicate that salmon are unable to migrate through Devil Canyon into the Upper Susitna River Basin. To varying degrees spawning is also known to occur in freshwater sloughs and side channels. For a number of years in the past, distribution data has been collected for the lower Susitna River and tributaries. As part of the ongoing studies, additional resource and population information is being collected.

Principal resident fish in the basin include grayling, rainbow trout, lake trout, whitefish, sucker, sculpin, burbot and Dolly Varden.

Since the Susitna is a glacial fed stream the waters are silt laden during the summer months. This tends to restrict sport fishing to clearwater tributaries and to areas in the Susitna near the mouth of these tributaries.

In the Upper Susitna Basin grayling populations occur at the mouths and in the upper sections of clear water tributaries. Between Devil Canyon and the Oshetna Rivers most tributaries are too steep to support significant fish populations. Many terrace and upland lakes in the area support lake trout and grayling populations.

(ii) Big Game

The project area is known to support species of caribou, moose, bear, wolves, wolverine and Dall sheep.

- Caribou: The Nelchina caribou herd which occupies a range of about 20,000 square miles in southcentral Alaska has been important to hunters because of its size and proximity to population centers. The herd has been studied continuously since 1948. The population declined from a high of about 71,000 in 1962 to a low of between 6,500 and 8,100 animals in 1972. From October 1980 estimates, the Nelchina caribou herd contained approximately 18,500 animals composed of 49 percent cows, 30 percent bulls and 21 percent calves.

During the late winter of 1980, the caribou were distributed in the Chistochina-Gakona River drainages, the western foothills of the Alphabet Hills and the Lake Louise Flat. There were two main migration routes to the northern foothills of the Talkeetna Mountains. The first route was across the Lake Louise Flat to the calving area via the lower Oshetna River, and the second was across the Susitna River in the area from Deadman Creek to the "big bend" of the Susitna. Calving occurred between the Oshetna River and Kosina Creek between the 3,000 to 4,500 feet elevations. The main summering concentration of caribou occurred in the northern and eastern slopes of the Talkeetna Mountains between Tsisi Creek and Crooked Creek, primarily between 4,000 and 6,000 feet. Most caribou were located on the Lake Louise Flat during the rut. During early winter the herd was split in two groups. One group was located in the Slide Mountain- Little Nelchina River area and the other was spread from the Chistochina River west to the Gakona River through the Alphabet Hills to the MacLaren River.

It appears that at least two small subherds with separate calving areas also existed, one in the upper Talkeetna River and one in the upper Nenana-Susitna drainages.

The proposed impoundments would inundate a very small portion of apparent low quality caribou habitat. Concern has been expressed that the impoundments and associated development might serve as barriers to caribou movement, increase mortality, decrease use of nearby areas and tend to isolate subherds.

- Moose: Moose are distributed throughout the Upper Susitna Basin. Population estimates for November 1980 in census areas 6, 7 and 14 (Fig. 7.5) were approximately 830 and 3,000 respectively. Winter distributions are shown on Figure 7.5.

  Studies to date suggest that the areas to be inundated are utilized by moose primarily during the winter and spring. The loss of their habitat could reduce the moose population for the area. The areas do not appear to be important for calving or breeding purposes, however they do provide a winter range that could be critical during severe winters. In addition to direct losses, displaced moose could create a lower capacity for the animals in surrounding areas.

- Bear: Black bear and brown bear populations in the vicinity of the proposed reservoirs appear to be healthy and productive. Brown bears are ubiquitous throughout the study area while black bears appear largely confined to a finger of forested habitat along the Susitna River.

The proposed impoundments are likely to have little impact on the availability of adequate brown bear den sites, however the extent and utility of habitats utilized in the spring following emergence from the dens may be reduced. The number of brown bears in the 3,500 square mile study area is approximately 70.

Black bear distribution appears to be largely confined to or near the forests found in the vicinity of the Susitna River and the major tributaries. Utilization of the forest habitat appears most prevalent in the early spring. In the late summer black bears tend to move into the more open shrublands adjacent to the spruce forest due to the greater prevalence of berries in these areas.

Most of the known active dens in the Devil Canyon area will not be inundated although several known dens will be inundated by the Watana Resevoir.

- Wolf: Five known and four to five suspected wolf packs have been identified in the Upper Susitna Basin (Fig. 7.6) (3). Territory sizes for the five studied wolf packs averaged 452 to 821 square miles. Known wolf territories are eventually non-overlapping during any particular year. A minimum of 40 wolves were known to inhabit the study area in the spring of 1980. By fall the packs had increased to an estimated 77 wolves.

  Impacts on wolves could occur indirectly due to reduction in prey density, particularly moose. Temporary increases could occur in the project area due to displacement of prey from the impoundment areas. Direct inundation of den and rendezvous sites may decrease wolf densities. Potential for increased hunting and trapping pressure could also act to increase wolf mortality.

- Wolverine: Wolverines occur throughout the study area although they show a preference towards upland shrub habitats on southerly and westerly slopes. Potential impacts would relate to direct loss of habitat, construction disturbance and increased competition for prey.

- Dall Sheep: Dall sheep are known to occupy all portions of the Upper Susitna River Basin which contains extensive areas of habitat above 4,000 feet elevation. Three such areas in the proximity of the project area include the Portage-Tsusena Creek drainages, the Watana Creek Hills and Mount Watana.

  Since Dall sheep are usually found at elevations above 3,000 feet, impacts will likely be restricted to potential indirect disturbance from construction activities and access.

(iii) Furbearers

Furbearers in the Upper Susitna Basin include red fox, coyote, lynx, mink, pine marten, river otter, short-tailed weasel, least weasel, muskrat and beaver. Direct innundation, construction activities and access can be expected to generally have minimal impact on these species.

(iv) Birds and Non-Game Mammals

One hundred and fifteen species of birds were recorded in the study area during the 1980 field season, the most abundant being Scaup and Common Redpoll. Ten active raptor/raven nests have been recorded and of these, two Bald Eagle nests and at least four Golden Eagle nests would be flooded by the proposed reservoirs, as would about three currently inactive raptor/raven nest sites. Preliminary observations indicate a low populaiton of waterbirds on the lakes in the region; however, Trumpeter Swans nested on a number of lakes between the Oshetna and Tyone Rivers.

Flooding would destroy a large percentage of the riparian cliff habitat and forest habitats upriver of Devil Canyon dam. Raptors and ravens using the cliffs could be expected to find alternate nesting sites in the surrounding mountains, and the forest inhabitants are relatively common breeders in forests in adjacent regions. Lesser amounts of lowland meadows and of fluviatile shorelines and alluvia, each important to a few species, will also be lost. None of the waterbodies that appear to be important to waterfowl will be flooded, nor will the important prey species of the upland tundra areas be affected. Impacts of other types of habitat alteration will depend on the type of alteration. Potential impacts can be lessened through avoidance of sensitive areas.

Thirteen small mammal species were found during 1980, and the presence of three others was suspected. During the fall survey, red-backed voles and masked shrews were the most abundant species trapped; and these, plus the dusky shrew, appeared to be habitat generalists, occupying a wide range of vegetation types. Meadow voles and pygmy shrews were least abundant and the most restricted in their habitat use, the former occurring only in meadows and the latter in forests.

(b) Vegetation

The Upper Susitna River Basin is located in the Pacific Mountain physiographic division in southcentral Alaska (Joint Federal-State Land Use Planning Commission for Alaska 1973). The Susitna River drains parts of the Alaska Range on the north and parts of the Talkeetna Mountains on the south. Many areas along the east-west portion of the river, between the confluences of Portage Creek and the Oshetna River, are steep and covered with conifer, deciduous and mixed conifer, and deciduous forests. Flat benches occur at the tops of these banks and usually contain low shrub or woodland conifer communities. Low mountains rise from these benches and contain sedge-grass tundra and mat and cushion tundra.

The southeastern portion of the study area between the Susitna River and Lake Louise is characterized by extensive flat areas covered with low shrubland and woodland conifer communities. These are often intermixed and difficult to distinguish in the field or on aerial photographs because of intergradations. The area between the Maclaren River and the Denali Highway along the Susitna River is covered with woodland and open spruce stands. Farther east, the area has more low shrubland cover. The

Clear Mountains north of the Denali Highway have extensive tundra vegetation. The floodplain of the Susitna River north of the Denali Highway has woodland spruce and willow stands. The Alaska Range contains most of the permanent snowfields and glaciers in the study area.

If proposed maximum pool elevations are required, the Devil Canyon (mapped at the 1500 ft elevation) and Watana (mapped at the 2200 ft elevation) reservoirs will inundate approximately 3603 and 15,885 ha of area respectively; 2753 and 13,669 ha, respectively, are vegetated (Table 7.7). A total of 18,109 ha of vegetation will be lost if all borrow areas (outside the impoundment areas) are also totally utilized. Borrow sites may eventually be revegetated, however. The 18,109 ha of impacted vegetation represents roughly 1.2 percent of the total vegetated area in the Upper Susitna River Basin.

Assuming maximum impact in the impoundment and borrow areas, the vegetation/habitat types which will be lost (and the apparent percent each is of the total available in the entire basin) are presented in Table 7.7. Problems created by comparing maps of two different scales resulted in apparent percentages of overlap which are highly inflated for the comparison of birch forests in the impact areas with that of their availability of the overall basin. However, it can safely be said that birch forests will be substantially impacted by the project, relatively more so than any other vegetation/habitat type. The only other types which would recieve relatively substantial impact are open and closed conifer-deciduous forests and open and closed balsam poplar stands.

The access road or railroad will destroy an additional 150 to 300 ha of vegetation, depending of the route selected, and assuming access is from one direction only and a 30 m wide roadbed is utilized. Three-hundred hectares is roughly equal to 0.02 percent of the vegetation in the entire basin. The primary vegetation types to be affected are mat and cushion tundra, sedge-grass tundra, birch shrubland and woodland spruce. Preliminary observations indicate that the impoundments and alternative routes are well below the elevation where potential threatened or endangered species might occur.

c) Cultural Resources

The archeological study presently being conducted as part of the Susitna Hydroelectric program is the only intensive archeological survey to have been conducted in the Upper Susitna Basin. The archeological data gathered from this study will greatly add information and understanding of prehistoric native populations in central Alaska.

The 1980 archeological reconnaissance, in the Susitna Hydroelectric Project area, located and documented 40 prehistoric sites and one historic site. It is expected that continued reconnaissance surveys in 1981 will locate additional sites. Sites are also documented adjacent to the study area near Stephan Lake, Fog Lakes, Lakes Susitna, Tyone and Louise, and along the Tyone River. Determinations of significance of sites will be based on the intensive testing data collected during the summer of 1981 and national register criteria which determine eligibility for the national register of historic places.

Geological studies generated data that were used in selecting archeological survey locals. Data concerning surficial geological deposits and glacial events of the last glaciation were compiled and provided limiting dates for the earliest possible human occupation of the Upper Susitna Valley. This is the first time this type of study has been done in this area.

Paleontological studies were conducted that identified the Watana Creek area as a tertiary basin with a fossil bearing deposit. A tertiary basin is unique in the region thereby making this basin a significant site for obtaining data on regional tertiary flora and fauna.

Impacts on cultural resources will vary in relation to the type of activities that occur on or near them. Within the Devil Canyon, Watana Dam study area it is expected that with the development of this scheme approximately half of the cultural resource sites would receive direct impact and the other half indirect impacts. The Watana Creek tertiary basin would also be inundated.

Since few reconnaissance surveys have been conducted outside the Devil Canyon/Watana Dam study area, the precise number of sites that would be impacted by a High Devil Canyon/Vee Scheme cannot be listed at this time. However, preliminary data analyses indicate a clear number of archeological sites toward the east end of the study area. In addition, there is a high potential for many more sites along the lakes, streams and rivers in this easterly region of the Upper Susitna River Basin. Additional sites could be expected near caribou crossings of the Oshetna River. In summary, a preliminary assessment of available information suggests that there perhaps could be a greater number of archeological sites associated with High Devil Canyon/Vee Scheme than the Watana/Devil Canyon Scheme.

(d) Socioeconomics

As part of the Susitna Hydroelectric program a socioeconomic program has been implemented to identify the socioeconomic factors that will be affected and to determine the extent to which they will be impacted. The results of this study will also provide input into the selection of the type and location of certain project facilities.

(i) Population

The Southcentral Railbelt area of Alaska contains the State's two largest population centers, Anchorage and Fairbanks. Preliminary 1980 census figures indicate the Railbelt contained 280,511 people, 71 percent of the state population of 400,331. The state population has increased approximately 30 percent since 1970. The Mat-Su borrow area had a 1980 population of 17,938 and Valdez-Cordova - 8,546.

Housing in the Mat-Su Burrow is primarily single family year round units. Vacancy rates for Mat-Su Borough, Fairbanks, and Anchorage were 5.5% (289 units) 9.1% (1,072 units) and 10.2% (5,729 units) respectively. In addition to year round units, Mat-Su Borough has 1,141 recreational units.

(ii) Economics

Both Anchorage and Fairbanks are regional economic centers for the Southcentral Railbelt area. Government, trade, and services comprise the major portion of the area's total employment. Construction and transportation are also important. Making relatively less significant contributions are the financing, mining, and manufacturing industries, while agriculture, forestry, and fisheries contribute even less.

After government, the two groups having the largest employment are trade and services. Their importance as sources of employment for the Railbelt area residents is a further manifestation of the region's two relatively concentrated population centers and of the high degree of economic diversity, as well as levels of demand for goods and services, which are substantially higher than in most other parts of Alaska. The importance of construction is largely due to the high level of expansion experienced by the Anchorage and Fairbanks areas since 1968. This growth was partly attributable to the trans-Alaska pipeline project. Consideration of additional natural resource exploitation projects is continuing to encourage increased construction activities.

High levels of employment in the region's transportation industry reflect the positions of Anchorage and Fairbanks as major transportation centers, not only for the Southcentral Railbelt area but for the rest of the State as well. The Port of Anchorage handles most of the waterborne freight moving into southcentral and northern Alaska. International airports at Anchorage and Fairbanks serve as hubs for commercial air traffic throughout Alaska and are important stopovers for major international air carriers. Anchorage also serves as the transfer point for goods brought in the area by air and water, which are then distributed by air transport, truck or by Alaska Railroad to more remote areas.

Valdez is the states largest port handling an annual tonnage of 60 million tons. Ninety-seven percent of this involves the shipment of crude petroleum from the pipeline. The ports of Anchorage and Valdez handle 2.2 million tons and 0.4 million tons respectively.

Although exerting relatively little direct impact on total employment, mining, finance, insurance, and real estate play important roles in terms of the secondary employment they generate in the region.

Most agricultural activities in the Southcentral Railbelt area take place in the Matanuska, Susitna, and Tanana Valleys. The potential for agricultural in these areas of Alaska is considered favorable, although development of the industry has not been extensive.

Commercial fisheries activity is the oldest cash-based industry of major importance within the region. The industry has changed substantially during the past 20 years and continues to be modified as a result of both biologic and economic stimuli. The salmon industry has always been a major component of the industry in terms of volume and value. Since 1955, the king crab, shrimp, and Tanner crab fisheries have undergone major development, and halibut landings have increased substantially in recent years. The total wholesale value of commercial fish and shell-fish for the domestic fishery of Alaska in 1979 was just over $1.2 billion including a catch of 459 million pounds of salmon with a wholesale value of just over $700 million.

The tourist industry plans an increasingly important role in the economy of Alaska. In 1977 approximately 504,000 people visited Alaska spending a total of $374 million.

(e) Transportation

(i) Rail. The Alaska Railroad runs from Seward on the Gulf of Alaska, past Anchorage, up the Susitna Valley, past Mount McKinley National Park, and down to Fairbanks on the Tanana River, a distance of 483 miles. The Federally constructed and operated Alaska Railroad was built between 1914 and 1923. Annual traffic volume varies between 1.8 and 2.3 million tons. Coal and gravel account for 75% of this. The system is operating at only 20% of its capacity.

(ii) Roads. Paved roads in the Railbelt area include: the 227-mile Sterling-Seward Highway between Homer and Anchorage, with a 27-mile side spur to Seward; the newly-constructed 358-mile Parks Highway between Anchorage and Fairbanks; a 205-mile section of the Alaska Highway that connects Tok Junction with Fairbanks; the 328-mile Glenn Highway connecting Anchorage with Tok Junction; and the 226-mile Richardson Highway from Valdez, on Prince William Sound, to its junction with the Alaska Highway at Delta Junction, 97 miles southeast of Fairbanks.

The only road access through the upper Susitna basin is the 135-mile gravel Denali Highway between Paxson on the Richardson Highway and Cantwell on the Parks Highway, and the 20-mile gravel road from the Glenn Highway to Lake Louise. The Denali Highway is not open for use during the winter months.

(iii) Air. In addition to major airlines within Alaska, there are numerous small commerical operators plus the highest per capita ratio of private aircraft in the nation. Many small remote landing strips are scattered throughout the Susitna basin, and float planes utilize many lakes and streams to ferry freight and passengers to the remote back-country areas. In many areas of the State, the only access is provided by the airplane.

(iv) Other Forms of Transportation. ATVs and other types of off-road vehicles provide transportation into areas in the upper Susitna basin where there are no developed roads. Several developed trails are shown on maps of the upper basin. Trails are utilized by ATVs, trail bikes, hikers, horseback riders, and winter travelers.

Shallow-draft river boats, small boats, canoes, rubber rafts, and kayaks utilize sections of the upper Susitna River, a few tributary streams, Lake Louise, and some of the other lakes for recreation purposes. Except for these few areas, boating use is practically nonexistent within much of the upper basin.

(f) Land Use

Existing land use in the Susitna Project area is characterized by broad expanses of open wilderness areas. Those areas where development has occurred often included small clusters of several cabins or other residences. There are also many single cabin settlements throughout the basin.

Most of the existing structures are related to historical development of the area involving initially, hunting, mining, and trapping and later guiding activities associated with hunting and to a lesser extent fishing. Today there are a few lodges mostly used by hunters and other recreationalists. Many lakes in the area also included small clusters of private year round or recreational cabins.

There are apprximately 109 structures within 18 miles of the Susitna River between Gold Creek and the Tyone River. These included 4 lodges involving some 21 structures. A significant concentration of residences, cabins or other structures are found near the Otter lake area, Portage Creek, High Lake, Gold Creek, Chunila Creek, Stephan Lake, Fog Lake, Tsusena Lake, Watana Lake, Clarence Lake and Big Lake.

Perhaps the most significant use activity for the past 40 years has been the study of the Susitna River for potential hydro development. Hunting, boating, and other forms of recreation are also important uses. There are numerous trails throughout the basin used by dog sled, snowmobile and ATV's. Air use is significant for many lakes providing landing areas for planes on floats.

There has been little land management activity for the area. However, Federal and State agencies, native corporations and the private sector have been involved heavily in the selection and transfer of land ownership under the Alaska Statehood and the Alaska Native Claims settlement Act. Most of the lands in the project area and on the south side of the river have been selected by the native corporation. Lands to the north are generally federal and managed by BLM.

TABLE 7.1 - SUMMARY OF CLIMATOLOGICAL DATA

	MEAN MONTHLY PRECIPITATION IN INCHES												
STATION	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
Anchorage	0.84	0.56	0.56	0.56	0.59	1.07	2.07	2.32	2.37	1.43	1.02	1.07	
Big Delta	0.36	0.27	0.33	0.31	0.94	2.20	2.49	1.92	1.23	0.56	0.41	0.42	11.44
Fairbanks	0.60	0.53	0.48	0.33	0.65	1.42	1.90	2.19	1.08	0.73	0.66	0.65	11.22
Gulkana	0.58	0.47	0.34	0.22	0.63	1.34	1.84	1.58	1.72	0.88	0.75	0.76	11.11
Matanuska Agr. Exp. Station	0.79	0.63	0.52	0.62	0.75	1.61	2.40	2.62	2.31	1.39	0.93	0.93	15.49
McKinley Park	0.68	0.61	0.60	0.38	0.82	2.51	3.25	2.48	1.43	0.42	0.90	0.96	15.54
Summit WSO	0.89	1.19	0.86	0.72	0.60	2.18	2.97	3.09	2.56	1.57	1.29	1.11	19.03
Talkeetna	1.63	1.79	1.54	1.12	1.46	2.17	3.48	4.89	4.52	2.54	1.79	1.71	28.64
	MEAN MONTHLY TEMPERATURES												
Anchorage	11.8	17.8	23.7	35.3	46.2	54.6	57.9	55.9	48.1	34.8	21.1	13.0	
Big Delta	- 4.9	4.3	12.3	29.4	46.3	57.1	59.4	54.8	43.6	25.2	6.9	- 4.2	27.5
Fairbanks	-11.9	- 2.5	9.5	28.9	47.3	59.0	60.7	55.4	44.4	25.2	2.8	-10.4	25.7
Gulkana	- 7.3	3.9	14.5	30.2	43.8	54.2	56.9	53.2	43.6	26.8	6.1	- 5.1	26.8
Matanuska Agr. Exp. Station	9.9	17.8	23.6	36.2	46.8	54.8	57.8	55.3	47.6	33.8	20.3	12.5	34.7
McKinley Park	- 2.7	4.8	11.5	26.4	40.8	51.5	54.2	50.2	40.8	23.0	8.9	- 0.10	25.8
Summit WSO	- 0.6	5.5	9.7	23.5	37.5	48.7	52.1	48.7	39.6	23.0	9.8	3.0	25.0
Talkeetna	9.4	15.3	20.0	32.6	44.7	55.0	57.9	54.6	46.1	32.1	17.5	9.0	32.8

Source:

Reference 4

TABLE 7.2 - RECORDED AIR TEMPERATURES AT TALKEETNA AND SUMMIT IN °F

	STATION					
	Talkeetna			Summit		
Month	Daily Max.	Daily Min.	Monthly Average	Daily Max.	Daily Min.	Monthly Average
Jan	19.1	- 0.4	9.4	5.7	- 6.8	- 0.6
Feb	25.8	4.7	15.3	12.5	- 1.4	5.5
Mar	32.8	7.1	20.0	18.0	1.3	9.7
Apr	44.0	21.2	32.6	32.5	14.4	23.5
May	56.1	33.2	44.7	45.6	29.3	37.5
June	65.7	44.3	55.0	52.4	39.8	48.7
Jul	67.5	48.2	57.9	60.2	43.4	52.1
Aug	64.1	45.0	54.6	56.0	41.2	48.7
Sept	55.6	36.6	46.1	46.9	32.2	39.6
Oct	40.6	23.6	32.1	29.4	16.5	23.0
Nov	26.1	8.8	17.5	15.6	4.0	9.8
Dec	18.0	- 0.1	9.0	9.2	- 3.3	3.0
Annual Average			32.8			25.0

TABLE 7.3 - MAXIMUM RECORDED ICE THICKNESS ON THE SUSITNA RIVER

Location	Maximum Ice Thickness (Feet)
Susitna River at Gold Creek	5.7
Susitna River at Cantwell	5.3
Talkeetna River at Talkeetna	3.3
Chulitna River at Talkeetna	5.3
Maclaren River at Paxson	5.2

TABLE 7.4 - AVERAGE ANNUAL AND MONTHLY FLOW AT GAGE IN THE SUSITNA BASIN

MONTH	Susitna River at Gold Creek (2920)		Susitna River Near Cantwell (2915)		Susitna River Near Denali (2910)		Maclaren River Near Paxson (2912)	
	%	Mean(cfs)	%	Mean(cfs)	%	Mean(cfs)	%	Mean(cfs)
JANUARY	1	1,438	1	824	1	245	1	90
FEBRUARY	1	1,213	1	722	1	204	1	78
MARCH	1	1,085	1	692	1	187	1	71
APRIL	1	1,339	1	853	1	233	1	82
MAY	12	13,400	10	7,701	6	2,063	7	845
JUNE	24	28,150	26	19,330	23	7,431	25	2,926
JULY	21	23,990	23	16,890	29	9,428	27	3,171
AUGUST	19	21,950	20	14,660	24	7,813	22	2,557
SEPTEMBER	12	13,770	10	7,800	10	3,343	10	1,184
OCTOBER	5	5,580	4	3,033	3	1,138	3	407
NOVEMBER	2	2,435	2	1,449	2	502	1	168
DECEMBER	2	1,748	1	998	1	318	1	111
ANNUAL - cfs	--	9,610	--	6,300	--	2,720	--	975

TABLE 7.5 - FLOOD PEAKS AT SELECTED GAGING STATIONS ON THE SUSITNA RIVER

Station (USGS No.)	Drainage Area-mile^2	Annual Flood Peaks - cfs			Open Water Season 50 Year Flood Peaks - cfs
		Mean Annual	1:100 yr	1:10,000 yr	
Gold Creek Gage (2920)	6,160	53,000	118,000	185,000	106,000
Cantwell Gage (2915)	4,140	33,700	68,000	118,000	61,700
Denali Gage (2910)	950	17,800	43,600	63,000	36,600

TABLE 7.6 - SUSPENDED SEDIMENT TRANSPORT

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

TABLE 7.7 - DIFFERENT VEGETATION TYPES FOUND IN THE SUSITNA BASIN

Hectares of vegetation types to be impacted compared with total hectares of those types.

	Impoundments		Borrow Areas					
	Devil Canyon	Watana	A	C	D	F	H	Upper Susitna River Basin
Woodland spruce	162 (0.09)[1]	4766 (2.53)	228 (0.12)	77 (0.04)	15 (0.01)		227 (0.12)	188,391
Open spruce	862 (0.73)	3854 (3.24)	48 (0.04)	7 (0.01)			125 (0.11)	118,873
Open birch	73 (0.73)	318 (2.85)						968
Closed birch	470[2]	491[2]			1[2]			323
Open conifer-deciduous	300 (1.28)	1329 (5.68)			19 (0.08)	9 (0.04)	94 (0.40)	23,387
Closed conifer-deciduous	758 (4.75)	869 (5.44)			2 (0.01)			15,969
Open balsam poplar	7[3]							
Closed balsam poplar	10[3]	2[3]						
Wet sedge grass	12 (0.25)	100 (2.07)	6 (0.12)		1 (0.02)			4,839
and cushion tundra			78 (0.12)					65,001[3 4]
Tall shrub	19 (0.01)	580 (0.45)	18 (0.01)	23 (0.22)	8 (0.01)			129,035
Birch shrub	58 (0.17)	474 (1.41)	18 (0.05)	92 (0.27)	73 (0.22)			33,549
Willow	16 (0.015)	55 (0.52)					7 (0.07)	10,645
Low mixed shrub	6 (+)	785 (0.15)	101 (0.02)	113 (0.02)	109 (0.02)	55 (0.01)	46 (0.01)	471,461
Lakes	1 (+)	47 (0.22)	3 (0.01)			1 (+)		21,162
Rivers	835 (5.69)	2106 (14.35)		10 (0.07)		6 (0.04)		14,678
Rock	14 (0.01)	63 (0.06)			1 (+)			113,712
Total Areas	3603 (0.22)	15839 (0.97)	500 (0.03)	322 (0.03)	228 (0.01)	71 (+)	499 (0.03)	1,211,992

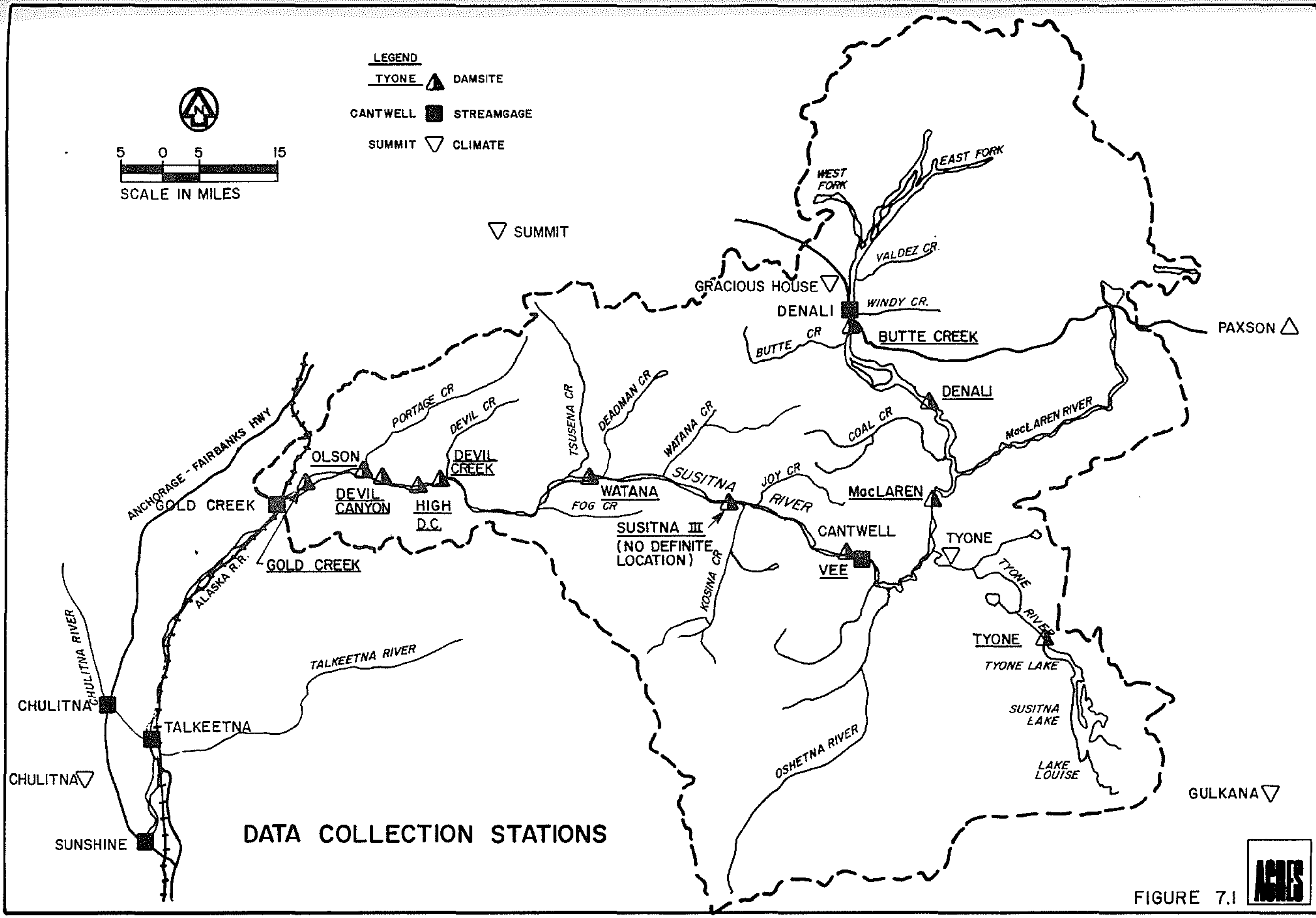
NOTES:

(1) Numbers in parentheses are the percent of the vegetation as found in the entire Upper Susitna Basin.

(2) Hectares of closed birch are apparently greater in the impact areas (mapped at a scale of 1:24,000) than for the entire basin (mapped at a scale of 1:250,000), because the basin was mapped at a much smaller scale, and many of the closed birch stands did not appear at that scale.

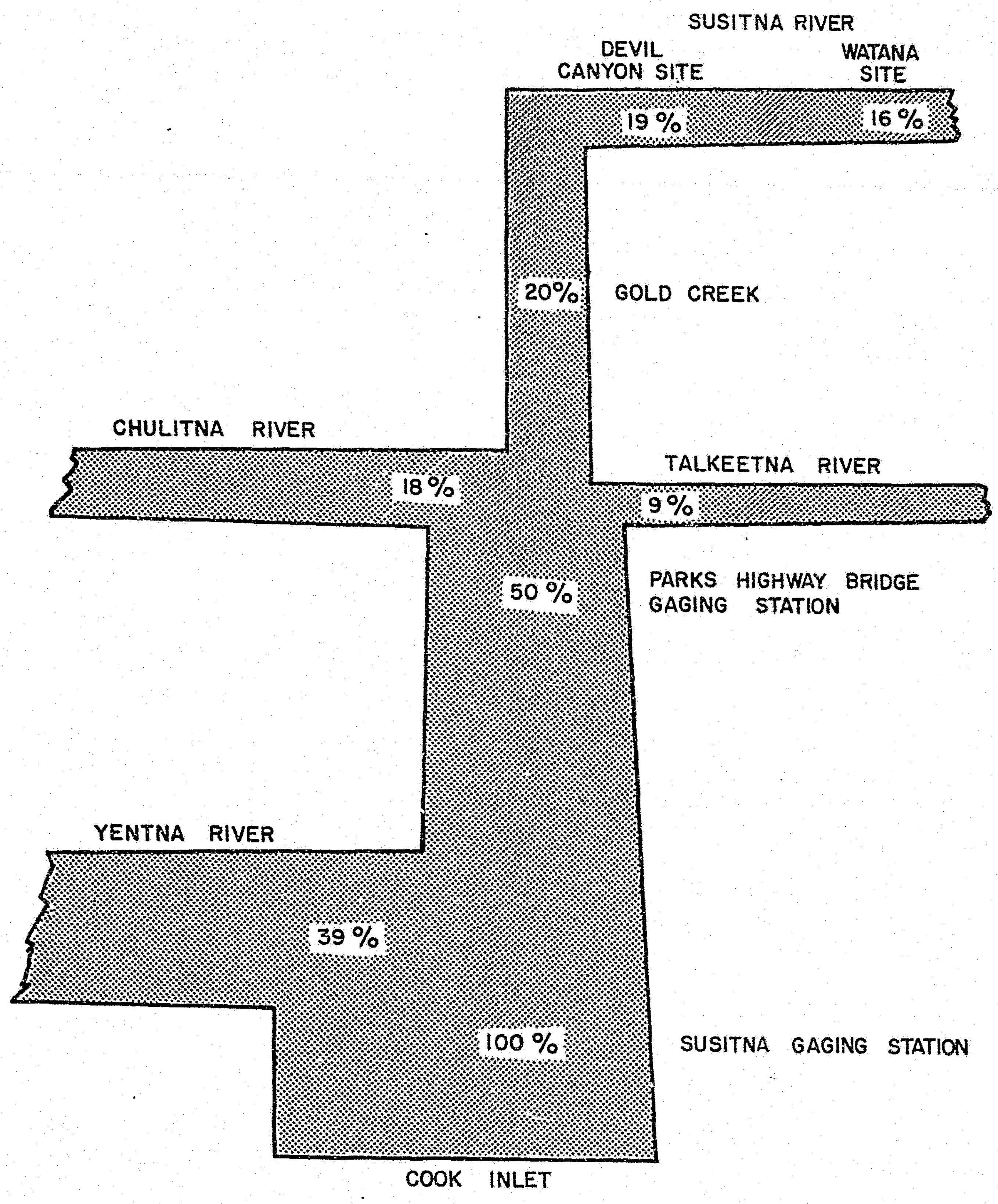
(3) Balsam poplar stands were too small to be mapped at the scale of which the Upper Susitna River Basin was mapped.

(4) Total hectares of mat and cushion tundra are much greater than this, but many hectares were mapped as a complex with sedge-grass tundra.



DATA COLLECTION STATIONS

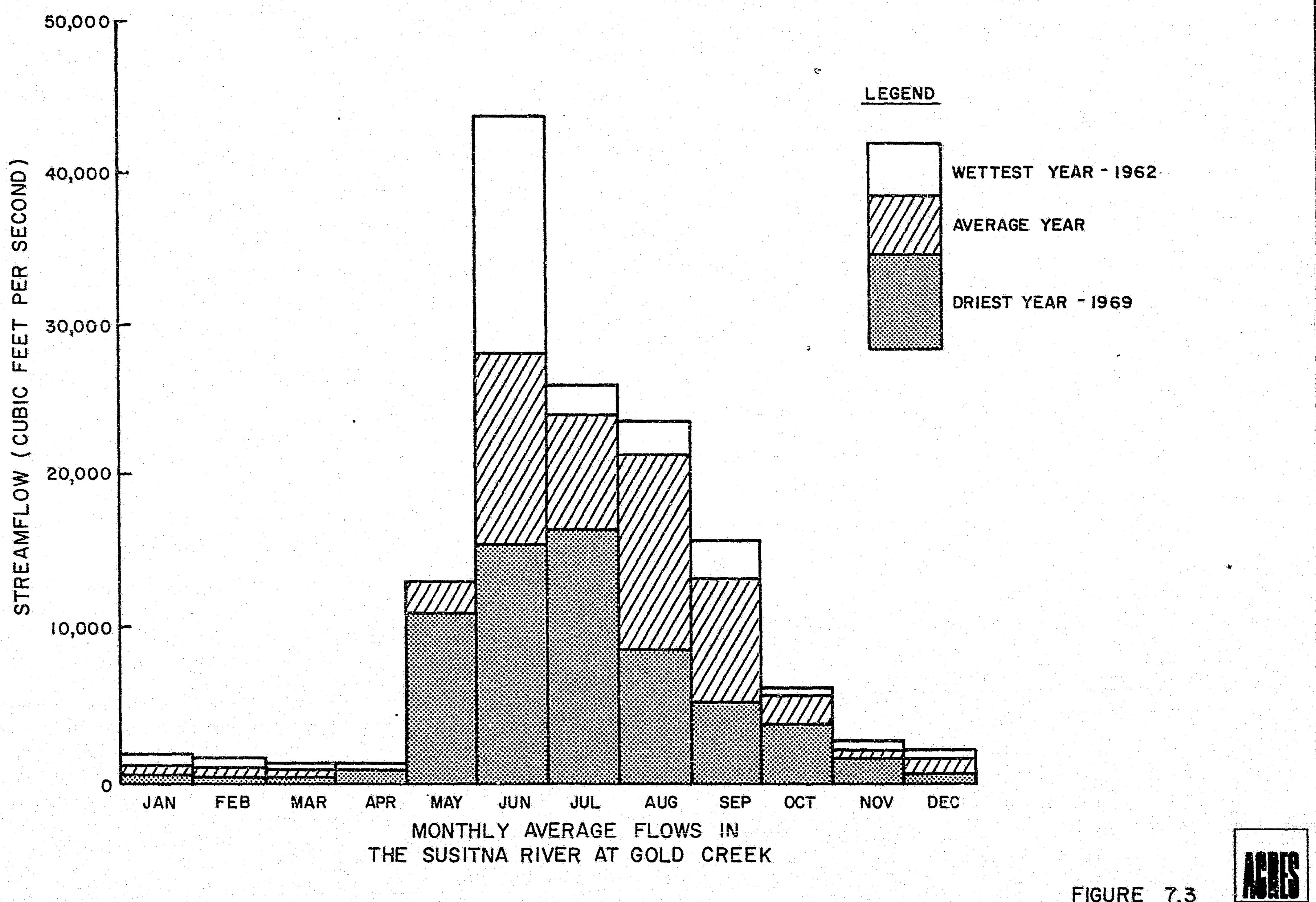
FIGURE 7.1



AVERAGE ANNUAL FLOW DISTRIBUTION WITHIN THE SUSITNA RIVER BASIN

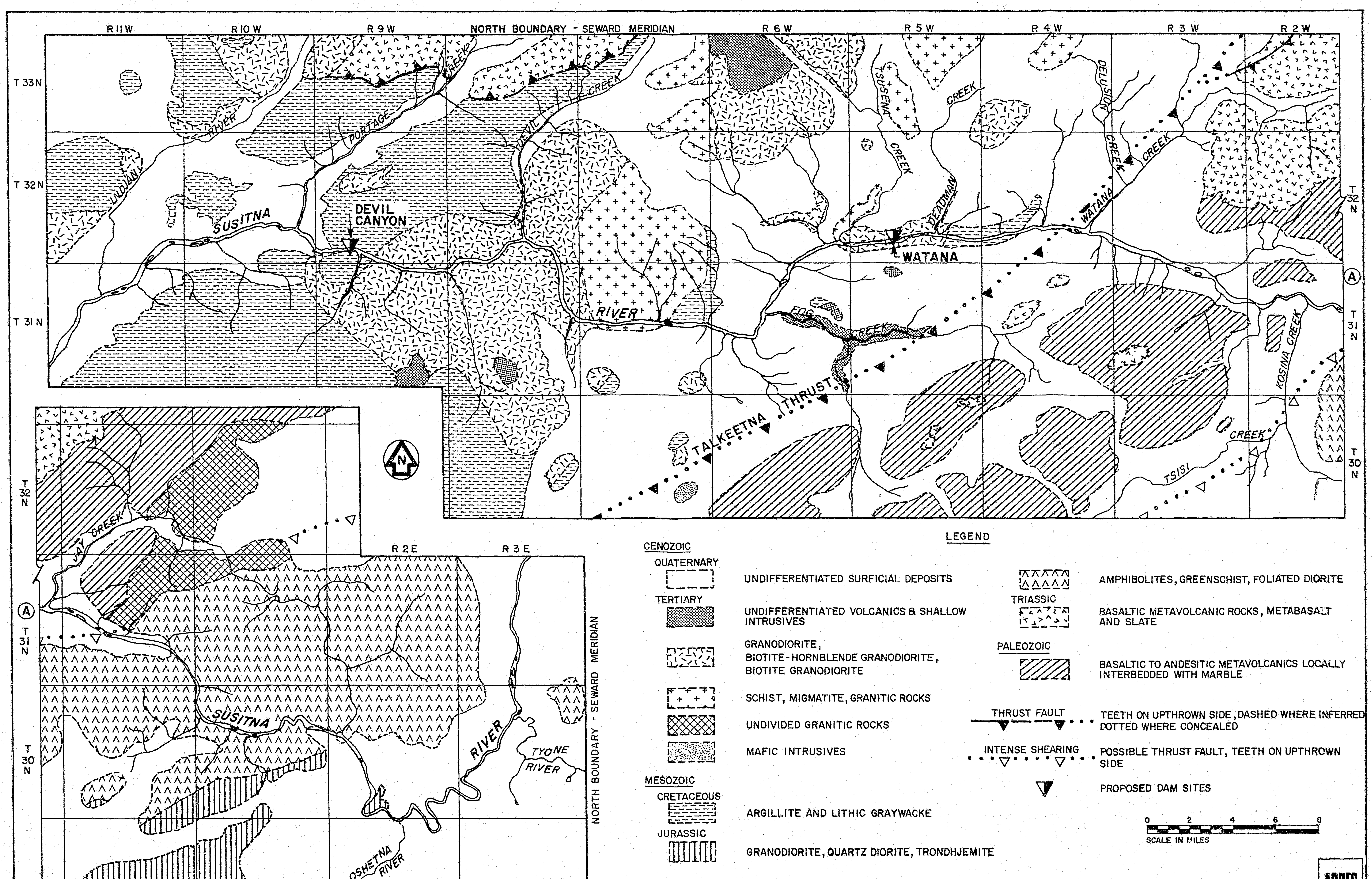
FIGURE 7.2

ACRES



MONTHLY AVERAGE FLOWS IN
THE SUSITNA RIVER AT GOLD CREEK

FIGURE 7.3



Modified from Csejtey, et al, 1978

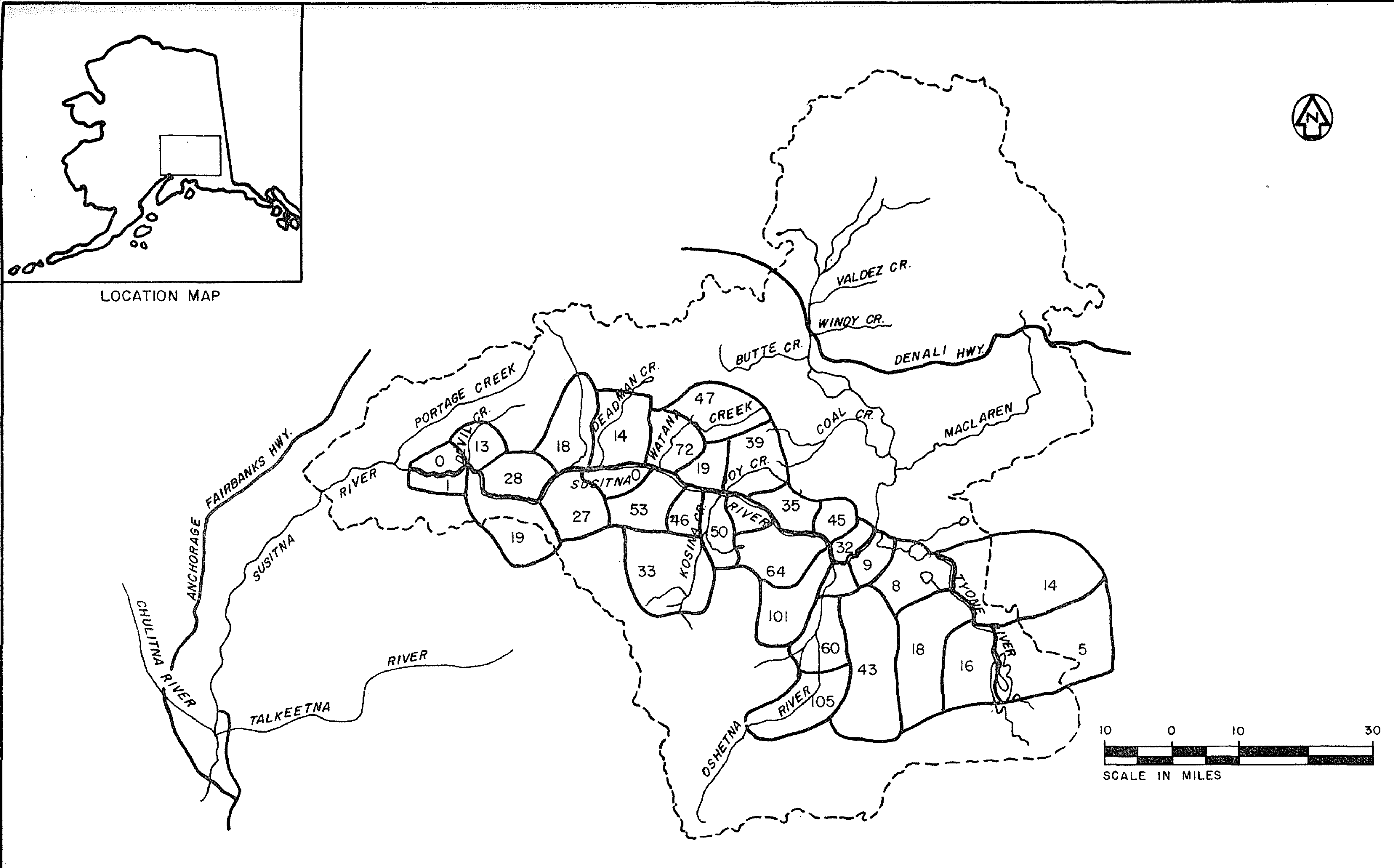
REGIONAL GEOLOGY

FIGURE 7.4

ACRES

RELATIVE DENSITIES OF MOOSE - NOVEMBER, 1980

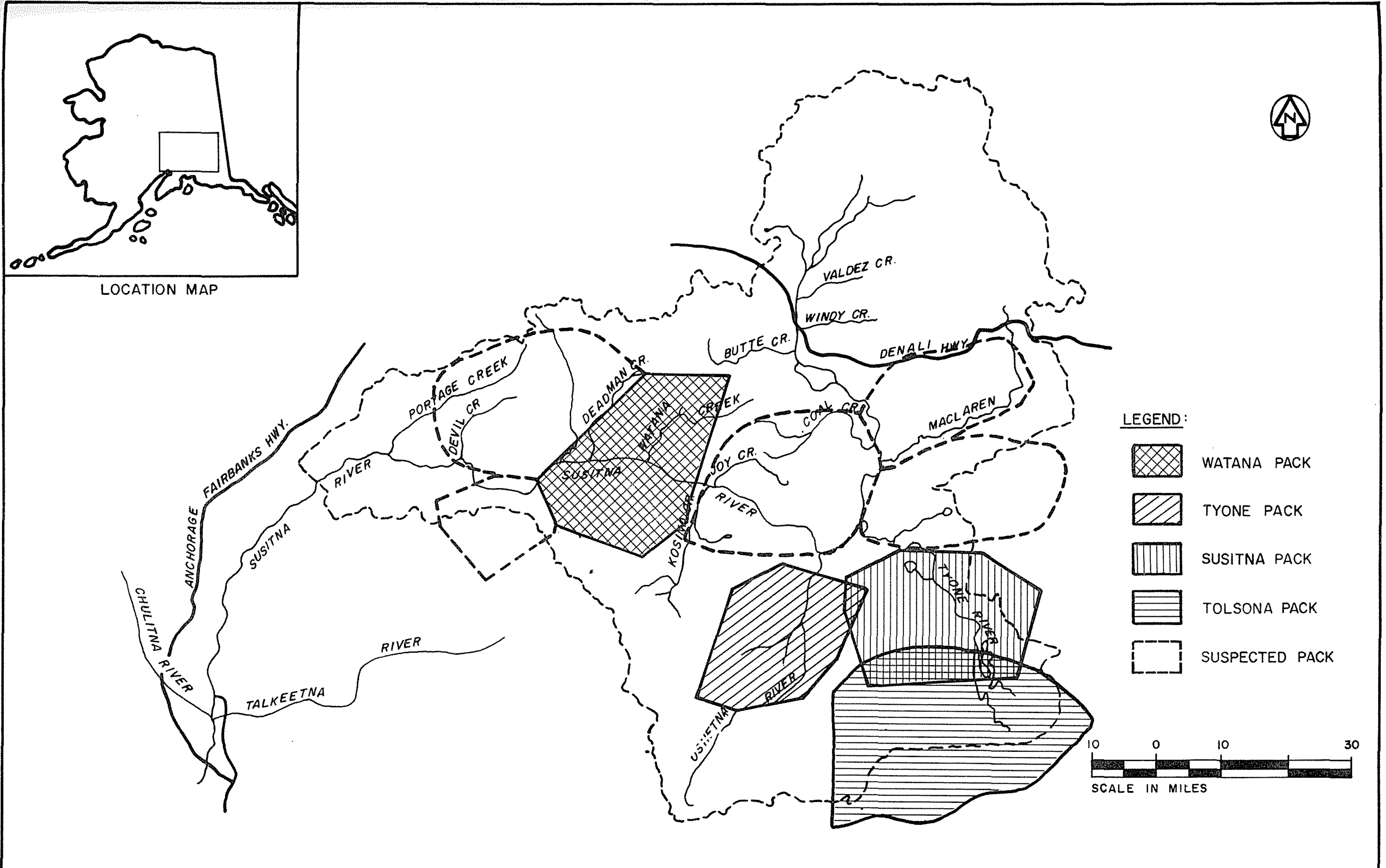
FIGURE 7.5



MODIFIED FROM REFERENCE ( )

WINTER DISTRIBUTION OF MOOSE - MARCH, 1980

FIGURE 7.6



LOCATION AND TERRITORIAL BOUNDARIES OF WOLF PACKS - 1980

FIGURE 7.7

ACRES

LIST OF REFERENCES

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(2) Csejtey, B. Jr., et al. "Reconnaissance Geology Map and Geochronology, Talkeetna Mountain Quadrangle, Northern Part of Anchorage Quadrangle, and Southwest Corner of Healy Quadrangle, Alaska", U.S. Geological Survey, Open File Report, 78-558A.

(3) Alaska Department of Fish and Game, 1980 Draft Annual Report.

(4) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Section, Local Climatological Data.

8 - SUSITNA BASIN DEVELOPMENT SELECTION

This section of the report outlines the engineering and planning studies carried out as a basis for formulation of Susitna Basin development plans and selection of the preferred plan. The selection process used is consistent with the generic plan formulation and selection methodology discussed in Section 1.4 and Appendix A. The recommended plan, the Watana/Devil Canyon dam project, is compared to alternative methods of generating Railbelt energy needs including thermal and other potential hydroelectric developments outside the Susitna Basin on the basis of technical, economic, environmental and social aspects.

8.1 - Terminology

In the description of the planning process, certain plan components and processes are frequently discussed. It is appropriate that three particular terms be clearly defined:

(a) Dam Site - An individual potential dam site in the Susitna Basin, equivalent to "alternative" and referred to in the generic process as "candidate".

(b) Basin Development Plan - A plan for developing energy within the basin involving one or more dams, each of specified height, and corresponding power plants of specified capacity. Each plan is identified by a plan number and subnumber indicating the staging sequence to be followed in developing the full potential of the plan over a period of time. These are equivalent to the "plans" referred to in Appendix A.

(c) Generation Scenario - A specified sequence of implementation of power generation sources capable of providing sufficient power and energy to satisfy an electric load growth forecast for the 1980-2010 period in the Railbelt area. This sequence may include different types of generation sources such as hydroelectric and coal, gas or oil-fired thermal. These generation scenarios are required for the comparative evaluations of Susitna Basin generation versus alternative methods of generation.

8.2 - Plan Formulation and Selection Methodology

As outlined in the description of the generic plan formulation and selection methodology (Appendix A) five basic steps are required. These essentially consist of defining the objectives, selecting candidates, screening, formulation of development plans and finally, a detailed evaluation of the plans.

The objectives of the studies outlined in this section are essentially twofold.

The first is to determine the optimum Susitna Basin development plan, and the second is to undertake a preliminary assessment of the feasibility of the selected plan by comparison with alternative methods of generating energy.

Studies carried out to meet the first objective follow the prescribed methodology and are outlined in the following subsections. Step 2 of the methodology, which calls for the selection of candidate dam sites, is outlined in Section 8.3. Step 3, screening, is discussed in 8.4 while Subsection 8.6 deals with Step 4, plan formulation. The final step, plan evaluation, is dealt with in Subsection 8.6. Figure 8.1 illustrates the process and highlights the data sources and techniques used for plan formulation and evaluation.

Throughout this planning process, engineering layout studies were conducted to refine the cost estimates for power or water storage development at several dam sites within the basin (Section 8.5). As they became available, these data were fed into the screening and plan formulation and evaluation studies.

The second objective is satisfied by comparing generation scenarios that include the selected Susitna Basin development plan with alternative generation scenarios including all-thermal and a mix of thermal plus alternative hydropower developments. The selection and screening of alternative hydropower thermal units and developments is discussed in Sections 6.4 and 6.5 respectively. The plan formulation step which involves developing the alternative generating scenarios is outlined in Section 8.7 below. The final evaluation of the plans is also discussed in Section 8.7.

8.3 - Dam Site Selection

In the previous Susitna Basin studies discussed in Section 4, twelve dam sites were identified in the upper portion of the basin, i.e. upstream from Gold Creek (see Figure 4.1). These sites are listed below:

- Gold Creek
- Olson (alternative name: Susitna II)
- Devil Canyon
- High Devil Canyon (alternative name: Susitna I)
- Devil Creek
- Watana
- Susitna III
- Vee
- Maclaren

- Denali

- Butte Creek

- Tyone

Figure 8.2 shows a longitudinal profile of the Susitna River and typical reservoir levels associated with these sites. Figure 8.3 illustrates which sites are mutually exclusive, i.e. those which cannot be developed jointly since the downstream site would inundate the upstream site.

All relevant data concerning dam type, capital cost, power, and energy output were assembled and are summarized in Table 8.1. For the Devil Canyon, High Devil Canyon, Watana, Susitna III, Vee, Maclaren and Denali sites conceptual engineering layouts were produced and the capital cost estimated based on calculated quantities and unit rates. Detailed analyses were also undertaken to assess the power capability and energy yields. At the Gold Creek, Devil Creek, Maclaren, Butte Creek, and Tyone sites, no detailed engineering or energy studies were undertaken and data from previous studies were used with capital cost estimates updated to 1980 levels. Approximate estimates of the potential average energy yield at the Butte Creek and Tyone sites were undertaken to assess the relative importance of these sites as energy producers.

The results in Table 8.1 show that Devil Canyon, High Devil Canyon, and Watana are the most economic large energy producers in the basin. Sites such as Vee and Susitna III are medium energy producers, although slightly more costly than the previously mentioned dam sites. Other sites such as Olson and Gold Creek are competitive provided they have additional upstream regulation. Sites such as Denali and Maclaren produce substantially higher cost energy than the other sites but can also be used to increase regulation of flow for downstream use.

For comparative purposes the capital cost estimates developed in recent previous studies, updated to 1980 values, are listed alongside the costs developed for the current studies (Table 8.2). These results show that the current estimates are generally slightly higher than previous estimates and, except in the case of Vee, differences are within 15 percent.

At Devil Canyon current total development costs are similar to the 1978 COE estimates. Although the estimates involve different dam types, current studies have indicated that at a conceptual level the cost of development at this site is not very sensitive to dam type. The results in Table 8.2, therefore, indicate relative agreement. Costs developed for the High Devil Canyon dam site are very close while those at Watana exceed previous estimates by about 15 percent. A major difference occurs at Vee where current estimates exceed those developed by the COE by 40 percent. A large portion of this difference can be ascribed to the greater level of detail incorporated in the current studies as compared to the previous work and the more extensive foundation excavation and treatment that have been assumed. This additional foundation work is consistent with a standard set of design assumptions used for developing all the site layouts reported here. Section 8.4 and Appendix D discuss these aspects in more detail.

8.4 - Site Screening

The objective of this screening exercise is to eliminate sites which would obviously not feature the initial stages of a Susitna Basin development plan and which, therefore, do not require any further study at this stage. Three basic screening criteria are used; these include environmental, alternative sites, and energy contribution.

(a) Screening Criteria

(i) Environmental

The potential impact on the environment of a reservoir located at each of the sites was assessed and catagorized as being relatively unacceptable, significant or moderate.

- Unacceptable Sites

Sites in this category are classified as unacceptable because either their impact on the environment would be extremely severe or there are obviously better alternatives available. Under the current circumstances, it is expected that it would not be possible to obtain the necessary agency approval, permits, and licenses to develop these sites.

The Gold Creek and Olson sites both fall into this category. As salmon are known to migrate up Portage Creek, a development at either of these sites would obstruct this migration and inundate spawning grounds. Available information indicates that salmon do not migrate through Devil Canyon to the river reaches beyond because of the steep fall and high flow velocities.

Development of the mid reaches of the Tyone River would result in the inundation of sensitive big game and waterfowl areas, provide access to a large expanse of wilderness area, and contribute only a small amount of storage and energy to any Susitna development. Since more acceptable alternatives are obviously available, the Tyone site is also considered unacceptable.

- Sites With Significant Impact

Between Devil Canyon and the Oshetna River the Susitna River is confined to a relatively steep river valley. Upstream of the Oshetna River the surrounding topography flattens and any development in this area has the potential of flooding large areas even for relatively low dams. Although the Denali Highway is relatively close by, this area is not as isolated as the Upper Tyone River Basin. It is still very sensitive in terms of potential impact on big game and waterfowl. The sites at Butte Creek, Denali, Maclaren, and, to a lesser extent Vee, fit into this category.

- Sites With Moderate Impact

  Sites between Devil Canyon and the Oshetna River have a lower potential environmental impact. These sites include the Devil Canyon, High Devil Canyon, Devil Creek, Watana and Susitna sites, and, to a lesser extent, the Vee site.

(ii) Alternative Sites

Sites which are close to each other and can be regarded as alternative dam locations can be treated as one site for project definition study purposes. The two sites which fall into this category are Devil Creek, which can be regarded as an alternative to the High Devil Canyon site, and Butte Creek, which is an alternative to the Denali site.

(iii) Energy Contribution

The total Susitna Basin Potential has been assessed at 6700 GWh. As outlined on Table 5.11, additional future energy requirements for the period 1980 to 2010 are forecast to range from 2400 to 13,100 GWh. It was therefore decided to limit the minimum size of any power development in the Susitna Basin to an average annual energy production in the range of 500 to 1000 GWh. The upstream sites such as Maclaren, Denali, Butte Creek, and Tyone do not meet this minimum energy generation criterion.

(b) Screening Process

The screening process involved eliminating all sites falling in the unacceptable environmental impact and alternative site categories. Those failing to meet the energy contribution criteria were also eliminated unless they have some potential for upstream regulation. The results of this process are as follows:

- The "unacceptable site" environmental category eliminated the Gold Creek, Olson, and Tyone sites.

- The alternative sites category eliminated the Devil Creek and Butte Creek sites.

- No additional sites were eliminated for failing to meet the energy contribution criteria. The remaining sites upstream from Vee, i.e. Maclaren and Denali, were retained to ensure that further study be directed toward determining the need and viability of providing flow regulation in the headwaters of the Susitna.

8.5 - Engineering Layout and Cost Studies

In order to obtain a more uniform and reliable data base for studying the seven sites remaining, it was necessary to develop engineering layouts for these sites and re-evaluate the costs. In addition, it was also necessary to study staged developments at several of the larger dams.

The basic objective of these layout studies is to establish a uniform and consistent development cost for each site. These layouts are consequently conceptual in nature and do not necessarily represent optimum project arrangements at the sites. Also, because of the lack of geotechnical information at several of the sites, judgemental decisions had to be made on the appropriate foundation and abutment treatment. The accuracy of cost estimates made in these studies is probably in the order of plus or minus 30 percent.

(a) Design Assumptions

In order to maximize standardization of the layouts, a set of basic design assumptions were developed. These assumptions covered geotechnical, hydrologic, hydraulic, civil, mechanical, and electrical considerations and were used as guidelines to determine the type and size of the various components within the overall project layouts. They are described in detail in Appendix D. As stated previously, other than at Watana, Devil Canyon, and Denali, little information regarding site conditions was available. Broad assumptions were made on the basis of the limited data, and those assumptions and the interpretation of data have been conservative.

It was assumed that the relative cost differences between rockfill and concrete dams at the sites would either be marginal or greatly in favor of the rockfill. The more detailed studies carried out subsequently for the Watana and Devil Canyon site support this assumption (see Appendix H). Therefore, a rockfill dam has been assumed at all developments in order to eliminate different cost discrepancies that might result from a consideration of dam fill rates compared to concrete rates at alternative sites.

(b) General Arrangements

A brief description of the general arrangements developed for the various sites is given below. Plates 1 to 7 illustrate the layout details. Table 8.3 summarizes the crest levels and dam heights considered.

In laying out the developments, conservative arrangements have been adopted, and whenever possible there has been a general standardization of the component structures.

(i) Devil Canyon (Plate 1)

- Standard Arrangement

The development at Devil Canyon is located at the upper end of the canyon at its narrowest point. It consists of a rockfill dam, single spillway, power facilities incorporating an underground powerhouse, and a tunnel diversion.

The rockfill dam rises above the valley on the left abutment and terminates in an adjoining saddle dam of similar construction. The dam rises 675 feet above the lowest foundation level with a crest elevation of 1470 feet and a volume of 20 million cubic yards. It consists of an inclined impervious core, filter zones, and an overlying rockfill shell. Part of tne shell will come from excavation at the site but the majority will be blast rock from local quarries. It is anticipated that core and filter materials will also be available locally. The core is founded on sound bedrock, and full foundation treatment is allowed for in the form of contact grouting, curtain grouting, and drainage via a network of shafts and galleries. All alluvium and overburden material are removed from the shell foundation area.

Diversion is effected by two concrete-lined tunnels driven within the rock on the right abutment. Upstream and downstream rockfill cofferdams with aqueous trench cutoffs are founded on the river alluvium and are separated from the main dam. Final closure is achieved by lowering vertical lift sliding gates housed in an upstream structure followed by construction of a solid concrete plug within the tunnel in line with the main dam grout curtain. Subsequent controlled downstream releases occur via a small tunnel bypass located at the gate structure and a Howell Bunger valve housed within the concrete plug.

The spillway is located on the right bank and consists of a gated overflow structure and a concrete-lined chute linking the overflow structure with an intermediate and terminal stilling basins. Sufficient spillway capacity is provided to pass the Probable Maximum Flood safely.

The power facilities are located on the right abutment. The massive intake structure is founded within the rock at the end of a deep approach channel and consists of four integrated units, each serving individual tunnel penstocks. Each unit has three outlets at different levels allowing for various levels of drawoff and corresponding temperature control of releases from the seasonally fluctuating reservoir. Each outlet is controlled by a pair of vertical lift wheeled gates and incorporates provision for upstream guard gates.

The penstocks are concrete-lined over their full length except for the section just upstream of the powerhouse which is steel-lined to prevent seepage into the powerhouse area. The rock in this vicinity is generally badly fractured by blasting operations during powerhouse cavern construction activity.

The powerhouse houses four 100 MW (or 150 MW) vertically mounted Francis type turbines driving overhead 110/165 MVa umbrella type generators. These are serviced by two overhead cranes running the length of the main power hall and an adjacent service bay. The main power transformers are housed in an underground gallery located above the draft tubes. This gallery also houses a gentry crane for operating the draft tube gates required to isolate the individual draft tubes from the common downstream manifold and tailrace tunnels during maintenance. The control room and offices are situated at the surface adjacent to a surface switchyard.

- Staged Powerhouse

As an alternative to the full power development, a staged powerhouse alternative was also investigated. The dam would be completed to its full height but with an initial plant installed capacity in the 200 to 300 MW range. The complete powerhouse would be constructed together with concrete foundations for the future units, penstocks and tailrace tunnel for the initial 2-100 MW (or 150 MW) units. The complete intake would be constructed except for gates and trashracks required for the second stage. The second stage would include installation of the remaining gates and racks and construction of the corresponding penstocks and tailrace tunnel for two new 100 MW (or 150 MW) units. Civil, electrical, and mechanical installation for these units would also be completed within the powerhouse area, together with the enlargement of the surface switchyard, during the second stage.

(ii) Watana (Plates 2 and 3)

- Standard Arrangement (see Plate 3)

For initial comparative study purposes, the dam at Watana is assumed to be a rockfill structure located on a similar alignment to that proposed in the previous COE studies. It is similar in construction to the dam at Devil Canyon with an impervious core founded on sound bedrock and an outer shell composed of blasted rock excavated from a single quarry located on the left abutment. The dam rises 880 feet from the lowest point on the foundation and has an overall volume of approximately 63 million cubic yards. The crest elevation is 2225 feet.

The diversion consists of twin concrete-lined tunnels located within the rock of the right abutment. Rockfill cofferdams, also with impervious cores and appropriate cutoffs, are founded on the alluvium and are separated from the main dam. Diversion closure and facilities for downstream releases are provided for in a manner similar to that at Devil Canyon.

The spillway is located on the right bank and is similar in concept to that at Devil Canyon with an intermediate and terminal stilling basin.

The power facilities are located within the left abutment with similar intake, underground powerhouse and water passage concepts to those at Devil Canyon. The power facilities consist of four 200 MW turbine/generator units giving a total output of 800 MW.

- Staging Concepts

As an alternative to initial full development at Watana, staging alternatives were investigated. These include staging of both dam and powerhouse construction. Staging of the powerhouse would be similar to that at Devil Canyon, with a Stage I installation of 400 MW and a further 400 MW in Stage II.

In order to study the alternative dam staging concept it has been assumed that the dam would be constructed for a maximum operating water surface elevation some 200 feet lower than that in the final stage. (See Plate 3).

The first stage powerhouse would be completely excavated to its final size. Three oversized 135 MW units would be installed together with base concrete for an additional unit. A low level control structure and twin concrete-lined tunnels leading into a downstream stilling basin would form the first stage spillway.

For the second stage, the dam would be completed to its full height, the impervious core would be appropriately raised and additional rockfill would be placed on the downstream face. It is assumed that before construction commences the top 40 feet of the first stage dam is removed to ensure the complete integrity of the impervious core for the raised dam. A second spillway control structure would be constructed at a higher level and incorporate a downstream chute leading to the Stage I spillway structure. The original spillway tunnels would be closed with concrete plugs. A new intake structure would be constructed utilizing existing gates and hoists, and new penstocks would be driven to connect with the existing ones. The existing intake would be sealed off. One additional 200 MW unit would be installed and the required additional penstock and tailrace tunnel constructed. The existing 135 MW units would be upgraded to 200 MW. This can be accomplished as described below.

- <u>Staging Generating Equipment</u>

Turbine-generator equipment operates at one particular speed and usually performs at maximum efficiency for a relatively small range of head variation. If the head varies significantly, the turbine efficiency is reduced, and unit operation may be rougher with increased potential for cavitation.

The options available for selection of turbine-generator equipment for staged dam construction are consequently fairly restricted. In general, these options would include:

- Selection of the turbine and generator so that the equipment will operate satisfactorily at one intermediate head with some loss of efficiency during both the initial and final stages;
- Modification of the turbine-generator rotational speed for the final stage of operation;
- Replacement of the turbine runner for the final stage of operation;
- Replacement of the runner and modification of turbine-generator speed for the final stage of operation.

The first option is the simplest alternative from an equipment point of view. However, the change in head will result in an efficiency penalty in one or perhaps both stages of operation. Unless the head change is relatively small, the energy loss due to reduction in efficiency would outweigh the additional capital expenditure associated with the other alternatives for staging.

The second option involves increasing the generator speed when the reservoir level is raised so as to maintain turbine operation at or near the best efficiency point during both stages of operation. For first stage operation, the unit speed may be selected slightly lower than normal to avoid excessive speed for the higher head operation. The generator speed change can be accomplished by changing the stator winding connections and also changing the rim and rotor winding electrical connections to reduce the number of poles. A change in generator speed would result in a marginal reduction in generator efficiency.

The third approach involves installing a new runner with a higher optimum operating head once the dam is completed to its full height. Such an option has been used on other projects. For very large changes in head however, the shape and dimensions of the initial and final runners vary considerably. This may result in difficulties in designing the turbine distributor to accommodate both runners without a sacrifice in turbine efficiency.

The fourth method is essentially a combination of the second and third options, resulting in a change both in the turbine runner and the unit speed after the dam is raised to its full height. Such an approach would be suitable for a staging scheme involving a significant increase in head.

In addition to the above considerations it should be noted that the generators, transformers, circuit breakers, bus bars, power transmission cable and ancillary equipment must be selected to accommodate the higher capacity which will be available in the final stage of operation.

For the staged dam construction at Watana, maximum operating head would increase from about 520 feet to 720 feet. The units would be required to operate for part of the time under substantial drawdown conditions under both stages. Option one would not in this case be appropriate because of the large range in head involved. Option four on the other hand is not warranted because it is designed to cope with much larger head changes than are currently envisaged at Watana. Preliminary analyses indicate that of the two options remaining, the third would provide the more cost effective solution for Watana. However, should staged development appear economic, more detailed studies would be required for the selection of generating equipment. This refinement is not expected to significantly affect the overall economics of the staging concept, and therefore is not considered necessary for this phase of the study.

(iii) High Devil Canyon (Plate 4)

The development is located between Devil Canyon and Watana. The dam is an 855 feet high rockfill dam similar in design to Devil Canyon, containing an estimated 48 million cubic yards of rockfill with a crest elevation of 1775 feet. The left bank spillway and the right bank powerhouse facilities are also similar in concept to Devil Canyon. The installed capacity is 800 MW. The left bank diversion system is formed by upstream and downstream earth/rockfill cofferdams and twin concrete-lined tunnels with typical cutoff and downstream release facilities.

Staging is envisaged as two stages of 400 MW each in the same manner as at Devil Canyon with the dam initially constructed to its full height.

(iv) Susitna III (Plate 5)

The development is comprised of a rockfill dam with an impervious core approximately 670 feet high. The dam would have a volume of approximately 55 million cubic yards and a crest elevation of 2360 feet.

The spillway consists of a concrete-lined chute and a single stilling basin and is located on the right bank.

A powerhouse of 350 MW capacity is located underground and the two diversion tunnels are located on the left bank.

(v) Vee (Plate 6)

A 610 feet high rockfill dam founded on bedrock with a crest elevation of 2350 feet and total volume of 10 million cubic yards, has been considered.

Since Vee is located further upstream than the other major sites the flood flows are correspondingly lower, thus allowing for a reduction in size of the spillway facilities. A spillway utilizing a gated overflow structure, chute, and flip bucket has been adopted and is located within the ridge forming the right abutment of the dam.

The power facilities consist of a 400 MW underground powerhouse located in the left bank with a tailrace outlet well downstream of the main dam. The intake is founded in a rock shoulder to the left of the dam. A secondary rockfill dam is also required in this vicinity to seal off a low point. Two diversion tunnels are provided on the right bank.

(vi) Maclaren (Plate 7)

The development consists of a 185 feet high earthfill dam founded on pervious riverbed materials. Crest elevation is 2405 feet. This reservoir would essentially be used for regulating purposes. Although generating capacity could be provided a powerhouse has not been shown in the proposed layout. Diversion is through three conduits located in an open cut on the left bank and floods are discharged via a side chute spillway and stilling basin on the right bank.

(vii) Denali (Plate 7)

Denali is similar in concept to Maclaren. The dam is 230 feet high, of earthfill construction, and has a crest elevation of 2555 feet. As for Maclaren, no generating capacity is shown. A combined diversion and spillway facility is provided by twin concrete conduits founded in open cut excavation in the right bank and discharging into a common stilling basin.

(c) Capital Cost

For purposes of initial comparisons of alternatives, construction quantities were determined for items comprising the major works and structures at the sites. Where detail or data were not sufficient for certain work, quantity estimates have been made based on previous Acres' experience and the general knowledge of site conditions reported in the literature. In order to determine total capital costs for various structures, unit costs have been developed for the items measured. These have been estimated on the basis of reviews of rates used in previous studies, and of rates used on similar works in Alaska and elsewhere. Where applicable, adjustment factors based on geography, climate, manpower and accessibility were used. Technical publications have also been reviewed for basic rates and escalation factors.

An overall mobilization cost of 5 percent has been assumed and camp and catering costs have been based on a preliminary review of construction manpower and schedules. An annual construction period of 6 months has been assumed for placement of fill materials and 8 months for all other operations. Night work has been assumed throughout.

A 20 percent allowance for non-predictable contingencies has been added as a lump sum together with a typical allowance for large projects of 12 percent for engineering and administration costs.

The total capital costs developed are shown in Tables 8.1, 8.2, and 8.4 . It should be noted that the capital costs for Maclaren and Denali shown in Table 8.1 and 8.2 have been adjusted to incorporate the costs of 55 MW and 60 MW plants respectively.

8.6 - Formulation of Susitna Basin Development Plans

The results of the site screening exercise described in Section 8.3 indicate that the Susitna Basin development plan should incorporate a combination of several major dams and powerhouses located at one or more of the following sites:

- Devil Canyon.
- High Devil Canyon.
- Watana.
- Susitna III.
- Vee.

In addition, the following two sites should be considered as candidates for supplementary upstream flow regulation:

- MacLaren
- Denali

To establish very quickly the likely optimum combination of dams, a computer screening model was used to directly identify the types of plans that are most economic. Results of these runs indicate that the Devil Canyon/Watana or the High Devil Canyon/Vee combinations are the most economic. In addition to these two basic development plans, a tunnel scheme which provides potential environmental advantages by replacing the Devil Canyon dam by a long power tunnel and a development plan involving the two most economic dam sites, High Devil Canyon and Watana, were also introduced. These studies are outlined in more detail below.

The criteria used at this stage of the process for selection of preferred Susitna Basin development plans are mainly economic (see Figure 8.1). As discussed below, environmental considerations are incorporated into the further assessment of the plans finally selected.

(a) Application of Screening Model

Basically, this computer model compares basin development plans for a given total basin power and energy demand and selects the sites, approximate dam heights, and installed capacities on a least cost basis.

The model incorporates a standard Mixed Integer Programming (MIP) algorithm for determining the optimum or least cost solution. Inputs essentially comprise basic hydrologic data, dam volume-cost curves for each site, an indication of which sites are mutually exclusive, and a total power demand required from the basin. A time period by time period energy simulation process for individual sites and groups of sites is incorporated into the model. The model then systematically searches out the least cost system of reservoirs and selects installed capacities to meet the specified power and energy demand.

A detailed description of the model as well as the input and output data are given in Appendix E. A summary of this information is presented below:

(i) Input Data

Input data to the model take the following form:

- Streamflow: In order to reduce the complexity of the model, a year is divided into two periods, summer and winter, and flows are specified for each. For the smaller dam sites such as Denali, Maclaren, Vee, and Devil Canyon, which have little or no overyear storage capability, only two typical years of hydrology are input. These correspond to a dry year (90 percent probability of exceedence) and an average year (50 percent probability of exceedence). For the other larger sites, the full thirty years of historical summer and winter flows are specified.

- Site Characteristics: For each site, storage capacity versus cost curves are provided. These curves were developed from the engineering layouts presented in Section 8.4. Utilizing these layouts as a basis, the quantities for lower level dam heights were determined and used to estimate the costs associated with these lower levels. Figures 8.4 to 8.6 depict the curves used in the model runs. These curves incorporate the cost of the appropriate generating equipment except for the Denali and Maclaren reservoirs, which are treated solely as storage facilities.

- Basin Characteristics: The model is supplied with information on the mutually exclusive sites as outlined in Figures 8.4 to 8.6.

- Power and Energy Demand: The model is supplied with a power and energy demand. This is achieved by specifying a total generating capacity required from the river basin and an associated annual plant factor which is then used to calculate the annual energy demand.

(ii) Model Runs and Results

A review of the energy forecasts discussed in Section 5 reveals that between the earliest time a Susitna project could come on line (in early 1993) and the end of the planning period (2010), approximately 2200, 4250, and 9570 Gwh of additional energy would be required for the low, medium, and high energy forecasts, respectively. In terms of capacity, these values represent 400, 780, and 1750 MW. Based on these figures, it was decided to run the screening model for the following total capacity and energy values:

- Run 1: 400 MW - 1750 Gwh.
- Run 2: 800 MW - 3500 Gwh.
- Run 3: 1200 MW - 5250 Gwh.
- Run 4: 1400 MW - 6150 Gwh.

The results of these runs are shown in Table 8.5. Because of the simplifying assumptions that are made in the screening model, the three best solutions from an economic point of view are presented.

The most important conclusions that can be drawn from the results shown in Table 8.5 are as follows:

- For energy requirements of up to 1750 Gwh, the High Devil Canyon, Devil Canyon or the Watana sites individually provide the most economic energy. The difference between the costs shown on Table 8.5 is around 10 percent, which is similar to the accuracy that can be expected from the screening model.

- For energy requirements of between 1750 and 3500 Gwh, the High Devil Canyon site is the most economic. Developments at Watana and Devil Canyon are 20 to 25 percent more costly.

- For energy requirements of between 3500 and 5250 Gwh the combinations of either Watana and Devil Canyon or High Devil Canyon and Vee are the most economic. The High Devil/Susitna III combination is also competitive. Its cost exceeds the Watana/Devil Canyon option by 11 percent which is within the accuracy of the model.

- The total energy production capability of the Watana/Devil Canyon developments is considerably larger than that of the High Devil Canyon/Vee alternative and is the only plan capable of meeting energy demands in the 6000 Gwh range.

The reasons why this screening process rejected the other sites is as follows:

Except for the one case, Susitna III is rejected due to its high capital cost. The cost of energy production at this site is high in comparison with Vee, even allowing for the 150 feet of the system head that is lost between the headwaters of High Devil Canyon and the tailwater of Vee.

Maclaren and Denali have a very small impact on the system's energy production capability and are relatively costly.

(b) Tunnel Scheme

A scheme involving a long power tunnel could conceivably be used to replace the Devil Canyon dam in the Watana/Devil Canyon Susitna development plan. It could develop similar head for power generation at costs comparable to the Devil Canyon dam development, and may provide some environmental advantages by avoiding inundation of Devil Canyon. Obviously, because of the low winter flows in the river, a tunnel alternative could be considered only as a second stage to the Watana development.

Conceptually, the tunnel alternatives would comprise the following major components in some combination, in addition to the Watana dam reservoir and associated powerhouse:

- Power tunnel intake works.

- One or two power tunnels of up to forty feet in diameter and up to thirty miles in length.

- A surface or underground powerhouse with a capacity of up to 1200 MW.

- A re-regulation dam if the intake works are located downstream from Watana.

- Arrangements for compensation for loss of flow in the bypassed river reach.

Four basic alternative schemes were developed and studied. All schemes assume an initial Watana development with full reservoir supply level at elevation 2200 feet and the associated powerhouse with an installed capacity of 800 MW. Figure 8.7 is a schematic illustration of these schemes.

- Scheme 1: This scheme comprises a small re-regulation dam about 75 feet high, downstream of Watana, with power tunnels leading to a second powerhouse at the end of the tunnel near Devil Canyon. This power station would operate in series with the one at Watana since the storage behind the re-regulation dam is small. Essentially, the re-regulation dam provides for constant head on the tunnel and deals with surges in operation at Watana. The two powerhouses would operate as peaking stations resulting in flow and level fluctuations downstream from Devil Canyon.

- Scheme 2: This proposal also provides for peaking operation of the two powerhouses except that the tunnel intake works are located in the Watana reservoir. Initially, the powerhouse at Watana would have 800 MW installed capacity which would then be reduced to some 70 MW after the tunnels are completed. This capacity would take advantage of the required minimum flow from the Watana reservoir. The power flow would be diverted through the tunnels to the powerhouse at Devil Canyon with an installed capacity of about 1150 MW. Daily fluctuations of water level downstream would be similar to those in Scheme 1 for peaking operations.

- Schemes 3 and 4: These schemes provide for base load operation at Devil Canyon powerhouse and peaking at Watana. In Scheme 3, the tunnel develops only the Devil Canyon dam head and includes a 245 feet high re-regulation dam and reservoir with the capacity to regulate diurnal fluctuations due to peaking operation at Watana. The site for the re-regulation dam was chosen by means of a map study to provide sufficient re-regulation storage, and is located at what appears to be a suitable dam site. In Scheme 4, the tunnel intakes are located in the Watana reservoir. The Watana powerhouse installed capacity for this scheme is 800 MW, as for the Watana-Devil Canyon development, and is used to supply peaking demand.

Table 8.6 lists all the pertinent technical information and Table 8.7, the energy yields and costs associated with these four schemes.

In general, development costs are based on the same unit costs as those used in other Susitna developments. Little geotechnical information is available for much of the proposed tunnel routes. Nevertheless, on the basis of precedent, tunnel construction costs are estimated on the assumption that excavation will be done by conventional drill and blast operations and that the entire length may not have to be lined. Tentative assumptions as to the extent of lining and support are as follows:

- 31 percent unlined.
- 34 percent shotcrete-lined.
- 26 percent concrete-lined.
- 9 percent lined with steel sets and concrete.

Based on the foregoing economic information, Scheme 3 produces the lowest cost energy.

A review of the environmental impacts associated with the four tunnel schemes indicates that Scheme 3 would have the least impact, primarily because it offers the best opportunities for regulating daily flows downstream from the project. Based on this assessment, and because of its economic advantage, Scheme 3 was selected as the most appropriate. More detailed general arrangement drawings for this alternative were produced (Plates 8 and 9) and costed. The capital cost estimate appears in Table 8.8. It should be noted that the cost estimates in this table differ slightly from those in Table 8.5 and reflect the additional level of detail. They also incorporate single and double tunnel options. For purposes of these studies, the double tunnel option has been selected because of its superior reliability. It should also be recognized that the cost estimates associated with the tunnels are probably subject to more variation than those associated with the dam schemes due to geotechnical uncertainties. In an attempt to compensate for these uncertainties, economic sensitivity analyses using both higher and lower tunnel costs have been conducted.

(c) Additional Basin Development Plan

As noted above, the Watana and High Devil Canyon dam sites appear to be individually superior in economic terms to all others. An additional plan was therefore developed to assess the potential for developing these two sites together. For this scheme, the Watana dam would be developed to its full potential. However, the High Devil Canyon dam would be constructed to a crest elevation of 1470 feet to fully utilize the head downstream from Watana.

Costs for the lower level High Devil Canyon dam were developed by assuming the same general arrangement as for the higher version shown in Plate 4 and appropriately adjusting the quantities involved.

(d) Selected Basin Development Plans

The essential objective of this step in the development selection process is defined as the identification of those plans which appear to warrant further, more detailed evaluation. The results of the final screening process indicate that the Watana/Devil Canyon and the High Devil Canyon/Vee plans are clearly superior to all other dam combinations. In addition, it was decided to study further the tunnel scheme as an alternative to the Watana/High Devil Canyon plan.

Associated with each of these plans are several options for staged development, including staged construction of the dams and/or the power generation facilities. For this more detailed analysis of these basic plans, a range of different aproaches to staging the developments are considered. In order to keep the total options to a reasonable number and also to maintain reasonably large staging steps consistent with the total development size, staging of only the two larger developments, i.e. Watana and High Devil Canyon, is considered. The basic staging concepts adopted for these developments involve staging both dam and powerhouse construction or alternatively just staging powerhouse construction. Powerhouse stages are considered in 400 MW increments.

Four basic plans are considered. These are summarized in Table 8.9 and are briefly described below. Plan 1 involves the Watana-Devil Canyon sites, Plan 2 the High Devil Canyon-Vee sites, Plan 3 the Watana-tunnel concept and Plan 4 the Watana-High Devil Canyon sites.

Under each plan several alternative subplans are identified, each involving a different staging concept.

(i) Plan 1

- Subplan 1.1: The first stage involves constructing Watana dam to its full height and installing 800 MW. Stage 2 involves constructing Devil Canyon dam and installing 600 MW.

- Subplan 1.2: For this Subplan, construction of the Watana dam is staged from a crest elevation of 2060 feet to 2225 feet. The powerhouse is also staged from 400 MW to 800 MW. As for Subplan 1.1, the final stage involves Devil Canyon with an installed capacity of 600 MW.

- Subplan 1.3: This Subplan is similar to Subplan 1.2 except that only the powerhouse and not the dam at Watana is staged.

(ii) Plan 2

- Subplan 2.1: This Subplan involves constructing the High Devil Canyon dam first with an installed capacity of 800 MW. The second stage involves constructing the Vee dam with an installed capacity of 400 MW.

- Subplan 2.2: For this Subplan, the construction of High Devil Canyon dam is staged from a crest elevation of 1630 to 1775 feet. The installed capacity is also staged from 400 to 800 MW. As for Subplan 2.1, Vee follows with 400 MW of installed capacity.

- Subplan 2.3: This Subplan is similar to Subplan 2.2 except that only the powerhouse and not the dam at High Devil Canyon is staged.

(iii) Plan 3

- Subplan 3.1: This Subplan involves initial construction of Watana and installation of 800 MW of capacity. The next stage involves the construction of the downstream re-regulation dam to a crest elevation of 1500 feet and a 15 mile long tunnel. A total of 300 MW would be installed at the end of the tunnel and a further 30 MW at the re-regulation dam. An additional 50 MW of capacity would be installed at the Watana powerhouse to facilitate peaking operations.

- Subplan 3.2: This Subplan is essentially the same as Subplan 3.1 except that construction of the initial 800 MW powerhouse at Watana is staged.

(iv) Plan 4

This single plan was developed to evaluate the development of the two most economic dam sites, Watana and High Devil Canyon, jointly. Stage 1 involves constructing Watana to its full height with an installed capacity of 400 MW. Stage 2 involves increasing the capacity at Watana to 800 MW. Stage 3 involves constructing High Devil Canyon to a crest elevation of 1470 feet so that the reservoir extends to just downstream of Watana. In order to develop the full head between Watana and Portage Creek, an additional smaller dam is added downstream of High Devil Canyon. This dam would be located just upstream from Portage Creek so as not to interfere with the anadromous fisheries and would have a crest elevation of 1030 feet and an installed capacity of 150 MW. For purposes of these studies, this site is referred to as the Portage Creek site.

8.7 - Evaluation of Basin Development Plans

The overall objective of this step in the evaluation process is to select the preferred basin development plan. A preliminary evaluation of plans was initially undertaken to determine broad comparisons of the available alternatives. This was followed by appropriate adjustments to the plans and a more detailed evaluation and comparison.

(a) Preliminary Evaluations

Table 8.9 lists pertinent details such as capital costs, construction periods and energy yields associated with the selected plans. The cost information was obtained from the engineering layout studies described in Section 8.4. The energy yield information was developed using a multireservoir computer model. This model simulates, on a monthly basis, the energy production from a given system of reservoirs for the 30-year period for which streamflow data is available. It incorporates daily peaking operations if these are required to generate the necessary peak capacity. All the model runs incorporate preliminary environmental constraints. Seasonal reservoir drawdowns are limited to 150 feet for the larger and 100 feet for the smaller reservoirs; daily drawdowns for daily peaking operations are limited to 5 feet and minimum discharges from each reservoir are maintained at all times to ensure all river reaches remain watered. These minimum discharges were set approximately equal to the seasonal average natural low flows at the dam sites.

The model is driven by an energy demand which follows a distribution corresponding to the seasonal distribution of the total system load as outlined in Section 5, Table 5.10.

The model was used to evaluate for each stage of the plans described above the average and firm energy and the installed capacity for a specified plant factor. This usually required a series of iterative runs to ensure that the number of reservoir failures in the 30-year period were limited to one year. The firm power was assumed equal to that delivered during the second lowest annual energy yield in the simulation period. This corresponds approximately to the 95 percent level of assurance.

A more detailed description of the model, the model runs, and the average monthly energy yields associated with the development plans is given in Appendix F.

A range of sensitivity runs was conducted to explore the effect of the reservoir drawdown limitation on the energy yield. The results of these runs are summarized in Table 8.10. They indicate that the drawdown limitations currently imposed reduce the firm energy yield for Watana development by approximately 6 percent.

(b) Plan Modifications

In the process of evaluating the schemes, it became apparent that there would be environmental problems associated with allowing daily peaking operations from the most downstream reservoir in each of the plans described above. In order to avoid these potential problems while still maintaining operational flexibility to peak on a daily basis, re-regulation facilities were incorporated in the four basic plans. These facilities incorporate both structural measures such as re-regulation dams and modified operational procedures. Details of these modified plans, referred to as E1 to E4, are listed in Table 8.11.

A brief description of the changes that were made follows:

(i) E1 Plans

For Subplans 1.1 to 1.3 a low temporary re-regulation dam is constructed downstream from Watana during the stage in which the generating capacity is increased to 800 MW. This dam would re-regulate the outflows from Watana and allow daily peaking operations. It has been assumed that it would be possible to incorporate this dam with the diversion works at the Devil Canyon site, and an allowance of $100 million has been made to cover any additional costs associated with this approach.

In the final stage, only 400 MW of capacity is added to the dam at Devil Canyon instead of the original 600 MW. Reservoir operating rules are changed so that Devil Canyon dam acts as the re-regulation dam for Watana.

(ii) E2 Plans

For Subplans 2.1 to 2.3 a permanent re-regulation dam is located downstream from the High Devil Canyon site at the same time the generating capacity is increased to 800 MW. An allowance of $140 million has been made to cover the costs of such a dam.

An additional Subplan E2.4 was established. This plan is similar to E2.3 except that the re-regulation dam is utilized for power production. The dam site is located at the Portage Creek site with a crest level set so as to utilize the full head. A 150 MW powerhouse is installed. As this dam is to serve as a re-regulating facility, it is constructed at the same time as the capacity of High Devil Canyon is increased to 800 MW, i.e. during Stage 2.

(iii) E3 Plan

The Watana tunnel development plan already incorporates an adequate degree of re-regulation and the E3.1 plan is, therefore, identical to to the 3.1 plan.

(iv) E4 Plans

As for the E1 Plans, the E4.1 plan incorporates a re-regulation dam downstream from Watana during Stage 2. As for the E1 plans, it has been assumed that it would be possible to incorporate this dam as part of the diversion arrangements at the High Devil Canyon site, and an allowance of $100 million has been made to cover the costs.

The energy and cost information presented in Table 8.11 is graphically displayed in Figure 8.8 which shows plots of average annual energy production versus total capital costs for all the plans. Although these curves do not represent accurate economic analyses, they do give an indication of the relative economics of the schemes. These evaluations basically reinforce the results of the screening model; for a total energy production capability of up to approximately 4000 Gwh, Plan E2 (High Devil Canyon) provides the most economic energy while for capabilities in the range of 6000 Gwh, Plan E1 (Watana-Devil Canyon) is the most economic.

The plans listed in Table 8.11 are subjected to a more detailed analysis in the following section.

(c) Evaluation Criteria and Methodology

The approach to evaluating the various basin development plans described above is twofold:

- For determining the optimum staging concept associated with each basic plan (i.e. the optimum subplan) economic criteria only are used and the least cost staging concept is adopted.

- For assessing which plan is the most appropriate, a more detailed evaluation process incorporating economic, environmental, social, and energy contribution aspects are taken into account.

Economic evaluation of any Susitna Basin development plan requires that the impact of the plan on the cost of energy to the railbelt area consumer be assessed on a systemwide basis. As the consumer is supplied by a large number of different generating sources, it is necessary to determine the total Railbelt system cost in each case to compare the various Susitna Basin development options. The basic tool used to determine the system costs is a computer simulation/ planning model (called OGP5) of the entire generating system. Input to this model includes the following:

- Load forecast over a specified period of time (as contained in Section 5, Table 5.10).

- Load duration curves (as outlined in Section 5.5).

- Details of the existing generating system (Section 6.2).

- A list of all potential future thermal generating sources with associated annualized costs, installed capacities, fuel consumption rates, etc. (as outlined in Section 6.5).

- Fuel prices (as outlined in Section 6.5).

- A specified hydroelectric development plan, i.e. the annualized costs, on-line dates, installed capacities, and energy production capability of the various stages of the plan (as outlined in Sections 6.4 and 8.5).

- System reliability criteria. For current study purposes, a loss of load probability, (LOLP) of .1 day/year is used.

Utilizing the above information, the program simulates the performance of the system, incorporates the hydroelectric development as specified, and adds thermal generating resources as necessary to meet the load growth and to satisfy the reliability criteria. The thermal plants are selected so that the present worth of the total generation cost is minimized.

A summary of the input data to the model and a discussion of the results follows. A more detailed description of the model runs is presented in Appendix G.

As discussed in Section 1.4, the basic economic analyses undertaken in this study incorporate "real" discount and escalation rates. The parameters used are summarized in Table 8.12. The economic lives listed in this table are the same as the assumed economic lives outlined in Section 6.2.

(d) Initial Economic Analyses

s

Table 8.13 lists the results of the first series of economic analyses undertaken for the basic Susitna Basin development plans listed in Table 8.11. The information in Table 8.13 includes the specified on-line dates for the various stages of the plans, the OGP5 run index number, the total installed capacity at the year 2010 by category, and the total system present worth cost in 1980. The present worth cost is evaluated for the period 1980 to 2040, i.e. 60 years. The OGP5 model is run for the period 1980-2010; thereafter steady state conditions are assumed and the generation mix and annual costs of 2010 are applied to the years 2011 to 2040. This extended period of time is necessary to ensure that the hydroelectric options being studied, many of which only come on-line around 2000, are operated for periods approaching their economic lives and that their full impact on the cost of the generation system are taken into account.

The highlights of the results in Table 8.13 can be summarized as follows:

(i) Plan E1 - Watana-Devil Canyon

- Staging the dam at Watana (Plan E1.2) is not as economic as constructing it to its full height (Plans E1.1 and E1.3). The economic advantage of not staging the dam amounts to $180 million in 1980.

- The results indicate that to the level of analysis performed, there is no discernible benefit in staging construction of the Watana powerhouse (Plans E1.1 and E1.3). It is considered likely, however, that some degree of staged powerhouse construction will ultimately be incorporated due to economic considerations and also because it provides maximum flexibility. For current planning purposes, it is therefore assumed that the staged powerhouse concept, i.e Plan E1.3, is the most appropriate Watana-Devil Canyon development plan.

Additional runs performed for variations of Plan E1.3 indicate that system costs would increase by $1,110 million if the Devil Canyon dam stage were not constructed. Furthermore, a five year delay in construction of the Watana dam would increase system costs by $220 million. These increases are due to additional higher cost thermal units which must be brought on line to meet the forecast demand in the early 1990's.

- Plan E1.4 indicates that should the powerhouse size at Watana be restricted to 400 MW the overall system cost would increase by $40 million.

(ii) Plan E2 - High Devil Canyon-Vee

- Plans E2.1 and E2.2 were not analyzed as these are similar to E1.1 and E1.2 and similar results can be expected.

- The results for Plan E2.3 indicate it is $520 million more costly than Plan E1.3. Cost increases also occur if the Vee dam stage is not constructed. A cost reduction of approximately $160 million is possible if the Chakachamna hydroelectric project is constructed instead of the Vee dam.

- The results of Plan E2.5 indicate that total system generating costs would go up by $160 million if the total capacity at High Devil Canyon were limited to 400 MW.

(iii) Plan E3

The results for Plan E3.1 illustrate that the tunnel scheme versus the Devil Canyon dam scheme (E1.3) adds approximately $680 million to the total system cost. The availability of reliable geotechnical data would undoubtedly have improved the accuracy of the cost estimates for the tunnel alternative. For this reason, a sensitivity analysis was made as a check to determine the effect of halving the tunnel costs. This analysis indicates that the tunnel scheme is still more costly by $380 million.

(iv) Plan E4

The results indicate that system costs associated with Plan E4.1 excluding the Portage Creek site development are $200 million more than the equivalent E1 plan. If the Portage Creek development is included, a greater increase in cost would result.

(e) Economic Sensitivity Analyses

Plans E1, E2, and E3 were subjected to further sensitivity analyses to assess the economic impacts of various loadgrowths. These results are summarized in Table 8.14.

The results for low load forecasts illustrate that the most viable Susitna Basin development plans include the 800 MW plans, i.e. Plan E1.5 and E2.5. Of these two, the Watana-Devil Canyon plan is less costly than the High Devil Canyon-Vee plan by $210 million. Higher system costs are involved if only the first stage dam is constructed, i.e. either Watana or High Devil Canyon. In this case, the Watana only plan is $90 million more costly than the High Devil Canyon plan.

Plan E3 variations are more costly than both Plans E1 and E2.

For the high load forecasts, the results indicate that the Plan E1.3 is $1040 million less costly than E2.3. The costs of both plans can be reduced by $630 and $680 million respectively by the addition of the Chakachamna development as a fourth stage.

No further analyses were conducted on Plan E4. As envisaged, this plan is similar to Plan E1 with the exception that the lower main dam site is moved from Devil Canyon upstream to High Devil Canyon. The initial analyses outlined in Table 8.13 indicate this scheme to be more expensive.

(f) Evaluation Criteria

As outlined in the generic methodology (Section 1.4 and Appendix A), the final evaluation of the development plans is to be undertaken by a perceived comparision process on the basis of appropriate criteria. The following criteria are used to evaluate the shortlisted basin development plans. They generally contain the requirements of the generic process with the exception that an additional criterion, energy contribution, is added. The objective of including this criterion is to ensure that full consideration is given to the total basin energy potential that is developed by the various plans.

(i) Economic:

The parameter used is the total present worth cost of the total Railbelt generating system for the period 1980 to 2040 as listed in Tables 8.14 and 8.15.

(ii) Environmental:

A qualitative assessment of the environmental impact on the ecological, cultural, and aesthetic resources is undertaken for each plan. Emphasis is placed on identifying major concerns so that these could be combined with the other evaluation attributes in an overall assessment of the plan.

(iii) Social:

This attribute includes determination of the potential non-renewable resource displacement, the impact on the state and local economy, and the risks and consequences of major structural failures due to seismic events. Impacts on the economy refer to the effects of an investment plan on economic variables.

(iv) Energy Contribution:

The parameter used is the total amount of energy produced from the specific development plan. An assessment of the energy development foregone is also undertaken. This energy loss is inherent to the plan and cannot easily be recovered by subsequent staged developments.

(g) Results of Evaluation Process

The various attributes outlined above have been determined for each plan and are summarized in Tables 8.16 through 8.24. Some of the attributes are quantitative while others are qualitative. Overall evaluation is based on a comparison of similar types of attributes for each plan. In cases where the attributes associated with one plan all indicate equality or superiority with respect to another plan, the decision as to the best plan is clear cut. In other cases where some attributes indicate superiority and others inferiority, these differences are highlighted and trade-off decisions are made to determine the preferred development plan. In cases where these trade-offs have had to be made, they are relatively convincing and the decision making process can, therefore, be regarded as fairly robust. In addition, these trade-offs are clearly identified so the recorder can independently answer the judgement decisions made.

The overall evaluation process is conducted in a series of steps. At each step, only a pair of plans is evaluated. The superior plan is then passed on to the next step for evaluation against an alternative plan.

(i) Devil Canyon Dam Versus Tunnel

The first step in the process involves the evaluation of the Watana-Devil Canyon dam plan (E1.3) and the Watana tunnel plan (E3.1). As Watana is common to both plans, the evaluation is based on a comparison of the Devil Canyon dam and tunnel schemes.

In order to assist in the evaluation in terms of economic criteria, additional information obtained by analyzing the results of the OGP5 computer runs is shown in Table 8.16. This information illustrates the breakdown of the total system present worth cost in terms of capital investment, fuel and operation and maintenance costs.

- Economic Comparison

From an economic point of view, the Devil Canyon dam scheme is superior. As summarized in Tables 8.16 and 8.17, on a present worth basis, the tunnel scheme is $680 million or about 12 percent more expensive than the dam scheme. For a low demand growth rate, this cost difference would be reduced slightly to $610 million. Even if the tunnel scheme costs are halved, the total cost difference would still amount to $380 million. As highlighted in Table 8.17, consideration of the sensitivity of the basic economic evaluation to potential changes in capital cost estimate, the period of economic analysis, the discount rate, fuel costs, fuel cost escalation, and economic plant lives do not change the basic economic superiority of the dam scheme over the tunnel scheme.

- Environmental Comparison

The environmental comparison of the two schemes is summarized in Table 8.18. Overall, the tunnel scheme is judged to be superior because:

- o It offers the potential for enhancing anadromous fish populations downstream of the re-regulation dam due to the more uniform flow distribution that will be achieved in this reach;

- o It inundates 13 miles less of resident fisheries habitat in river and major tributaries;

- o It has a lower impact on wildlife habitat due to the smaller inundation of habitat by the re-regulation dam;

- o It has a lower potential for inundating archeological sites due to the smaller reservoir involved;

- o It would preserve much of the characteristics of the Devil Canyon gorge which is considered to be an aesthetic and recreational resource.

- Social Comparison

Table 8.19 summarizes the evaluation in terms of the social criteria of the two schemes. In terms of impact on state and local economics and risks due to seismic exposure, the two schemes are rated equally. However, the dam scheme has, due to its higher energy yield, more potential for displacing nonrenewable energy resources, and therefore scores a slight overall plus in terms of the social evaluation criteria.

- Energy Comparison

Table 8.20 summarizes the evaluation in terms of the energsy contribution criteria. The results shown that the dam scheme has a greater potential for energy production and develops a larger portion of the basin's potential. The dam scheme is therefore judged to be superior from the energy contribution standpoint.

- Overall Comparison

The overall evaluation of the two schemes is summarized in Table 8.21. The estimated cost saving of $680 million in favor of the dam scheme is considered to outweigh the reduction in the overall environmental impact of the tunnel scheme. The dam scheme is therefore judged to be superior overall.

(ii) Watana-Devil Canyon Versus High Devil Canyon-Vee

The second step in the development selection process involves an evaluation of the Watana-Devil Canyon (E1.3) and the High Devil Canyon-Vee (E2.3) development plans.

- Economic Comparison

In terms of the economic criteria (see Tables 8.16 and 8.17) the Watana-Devil Canyon plan is less costly by $520 million. As for the dam-tunnel evaluation discussed above, consideration of the sensitivity of this decision to potential changes in the various parameters considered (i.e. load forecast, discount rates, etc.) does not change the basic superiority of the Watana-Devil Canyon Plan.

- Environmental Comparison

The evaluation in terms of the environmental criteria is summarized in Table 8.22. In assessing these plans, a reach by reach comparison is made for the section of the Susitna River between Portage Creek and the Tyone River. The Watana-Devil Canyon scheme would create more potential environmental impacts in the Watana Creek area. However, it is judged that the potential environmental impacts which would occur in the upper reaches of the river with a High Devil Canyon-Vee development are more severe in comparison overall.

From a fisheries perspective, both schemes would have a similar effect on the downstream anadromous fisheries although the High Devil Canyon-Vee scheme would produce a slightly greater impact on the resident fisheries in the Upper Susitna Basin.

The High Devil Canyon-Vee scheme would inundate approximately 14 percent (15 miles) more critical winter river bottom moose habitat than the Watana-Devil Canyon scheme. The High Devil Canyon-Vee scheme would inundate a large area upstream of the Vee site utilized by three subpopulation of moose that range in the northeast section of the basin. The Watana-Devil Canyon scheme would avoid the potential impacts on moose in the upper section of the river; however, a larger percentage of the Watana Creek basin would be inundated.

The condition of the subpopulation of moose utilizing this Watana Creek Basin and the quality of the habitat appears to be decreasing. Habitat manipulation measures could be implemented in this area to improve the moose habitat. Nevertheless, it is considered that the upstream moose habitat losses associated with the High Devil Canyon-Vee scheme would probably be greater than the Watana Creek losses associated with the Watana-Devil Canyon scheme.

A major factor to be considered in comparing the two development plans is the potential effects on caribou in the region. It is judged that the increased length of river flooded, especially upstream from the Vee dam site, would result in the High Devil Canyon-Vee plan creating a greater potential diversion of the Nelchina herd's range. In addition, a larger area of caribou range would be directly inundated by the Vee reservoir.

The area flooded by the Vee reservoir is also considered important to some key furbearers, particularly red fox. In a comparison of this area with the Watana Creek area that would be inundated with the Watana-Devil Canyon scheme, the area upstream of Vee is judged to be more important for furbearers.

As previously mentioned, the area between Devil Canyon and the Oshetna River on the Susitna River is confined to a relatively steep river valley. Along these valley slopes are habitats important to birds and black bears. As the Watana reservoir would flood the river section between the Watana Dam site and the Oshetna River to a higher elevation than would the High Devil Canyon reservoir (2200 feet as compared to 1750 feet) the High Devil Canyon-Vee plan would retain the integrity of more of this river valley slope habitat.

From the archeological studies done to date, there tends to be an increase in site intensity as one progresses towards the northeast section of the Upper Susitna Basin. The High Devil Canyon-Vee plan would result in more extensive inundation and increased access to the northeasterly section of the basin. This plan is therefore judged to have a greater potential for directly or indirectly affecting archeological sites.

Due to the wilderness nature of the Upper Susitna Basin, the creation of increased access associated with project development could have a significant influence on future uses and management of the area. The High Devil Canyon-Vee plan would involve the construction of a dam at the Vee site and the creation of a reservoir in the more northeasterly section of the basin. This plan would thus create inherent access to more wilderness than would the Watana-Devil Canyon scheme. As it is easier to extend access than to limit it, inherent access requirements are considered detrimental and the Watana-Devil Canyon scheme is judged to be more acceptable in this regard.

Except for the increased loss of river valley, bird, and black bear habitat the Watana-Devil Canyon development plan is judged to be more environmentally acceptable than the High Devil Canyon-Vee plan. Although the Watana-Devil Canyon plan is considered to be the more environmentally compatible Upper Susitna development plan, the actual degree of acceptability is a question being addressed as part of ongoing studies.

- Energy Comparison

  The evaluation of the two plans in terms of energy contribution criteria is summarized in Table 8.23. The Watana-Devil Canyon scheme is assessed to be superior due to its higher energy potential and the fact that it develops a higher proportion of the basin's potential.

- Social Comparison

Table 8.19 summarizes the evaluation in terms of the social criteria. As in the case of the dam versus tunnel comparison, the Watana-Devil Canyon plan is judged to have a slight advantage over the High Devil Canyon-Vee plan. This is because of its greater potential for displacing nonrenewable resources.

- Overall Comparison

The overall evaluation is summarized in Table 8.24 and indicates that the Watana-Devil Canyon plans are generally superior for all the evaluation criteria.

(iii) Preferred Susitna Basin Development Plan

Comparisons of the Watana-Devil Canyon plan with the Watana-tunnel plan and the High Devil Canyon-Vee plans are judged to favor the Watana-Devil Canyon plan in each case.

The Watana-Devil Canyon plan is therefore selected as the preferred Susitna Basin development plan, as a basis for continuation of more detailed design optimization and environmental studies.

8.8 - Comparison of Generation Scenarios With and Without the Susitna Basin Development Plan

This section outlines the results of the preliminary studies undertaken to compare the preferred Railbelt generation scenario incorporating the selected Watana-Devil Canyon dam development plan, with alternative generation scenarios. These studies are not intended to develop comprehensive and detailed alternative generating scenarios but merely to obtain a preliminary assessment of the feasibility of the Susitna plan in terms of economic, environmental, and social criteria.

The main alternative generating scenario considered is the all-thermal option, and a detailed evaluation of the "with Susitna" and the all-thermal generation scenarios is carried out. In addition to this, a less detailed assessment of the generating scenarios incorporating non-Susitna Basin hydro development is also conducted. The objective of the latter evaluation is to assess the economics of developing alternative and generally smaller hydro projects. A more comprehensive comparison would require more detailed analyses of the environmental and technical aspects at each of the sites which are not being undertaken under the current studies.

(a) "Without Susitna" Generation Scenarios

The development and evaluation of Railbelt generation plans incorporating all-thermal and thermal plus non-Susitna hydroelectric alternatives, is discussed in Section 6. Results of all-thermal and thermal with Susitna alternatives are given in Table 6.4.

(b) Comparison of All-Thermal and "With Susitna" Generation Scenarios

(i) Economic Comparison

In terms of economic criteria, the "with Susitna" scenario is $2280 million less costly than the all-thermal option. In order to explore the sensitivity of this comparison in more detail, several additional runs were carried out with the OGP5 model. For these runs, parameters such as projected load growth, interest rates, fuel costs and escalation rates, economic lives, and capital costs were varied and the impact on the overall system costs assessed. The detailed results are presented in Table 8.25 and are summarized in Table 8.26. A brief outline of these results follows.

The economic advantage of the "with Susitna" scenario decreases with decreasing load growth but still amounts to $1280 million for the very low forecast. A lower limit thermal plant capital cost estimate was also considered. The cost estimate was based on the minimum Alaska cost factor adjustment reported in the literature rather than the average factor used for the standard cost estimates which appear in Table 6.4. Even though this results in a 72 percent reduction in the thermal capital cost, the "with Susitna" scenario is still $1850 million more economic. The second type of capital cost sensitivity run involved increasing the Susitna Basin hydro development cost by 50 percent to represent an extreme upper limit. Even with this cost adjustment, the "with Susitna" generating scenario costs are still less than the all-thermal scenario by $1320 million.

As shown in Table 8.26, shortening the period of economic analysis from 60 to 30 years (i.e. to 1980-2010) reduces the net benefit to $960 million. The interest rate sensitivity run results indicate that the "with Susitna" scenario is more economic for real interest rates of zero to eight percent. At rates above this, the thermal scenario becomes more economic. A fuel cost sensitivity run using an assumed 20 percent reduction to the estimated cost of fuel reduces the cost difference to $1810 million.

Fuel cost escalation is an important parameter and the sensitivity analyses show that for zero percent escalation on all fuels the difference in total system costs reduces to $200 million. A zero percent escalation rate for coal-only reduces this difference to $1330 million.

The final sensitivity runs assumed the economic lives of all-thermal units is extended by 50 percent. This reduces the cost difference to $1800 million.

The above results indicate that the "with Susitna" scenario remains the more economic plan for a wide range of parameters. At real interest rates exceeding 8 percent, the all-thermal option becomes more attractive. It is, however, unlikely that such high rates would ever materialize. Although the net economic advantage of the "with Susitna" scenario is significantly reduced, a zero fuel cost escalation rate still results in a more expensive all-thermal generation scenario.

(ii) Social Comparison

The evaluation in terms of social criteria is summarized in Table 8.27. The "with Susitna" scenario provides greater potential for non-renewable resource conservation and is, therefore, regarded as superior from this point of view.

There is insufficient information available at this time to fully evaluate the impact on the state and local economics. The pattern of power investment expenditures will probably tend to be more regular with the all-thermal plan and hence there is potentially a more gradual impact than with the Susitna-inclusive generation plan. The timing of the Susitna type investment is probably more disruptive in relation to other large scale Alaskan projects. However, this could result in countercyclical investment that would tend to reduce such disruptions.

(iii) Environmental Comparison

Table 8.28 broadly summarizes the environmental impacts associated with the two scenarios. As indicated, both hydro and thermal development have potential for environmental impact. However, the extent to which the potential impacts are realized is very site specific. As specific information on potential future coal-fired generating sources is not available at this time, the overall comparison is generic rather than site specific.

(iv) Overall Comparison

An overall evaluation is summarized in Table 8.29. This indicates that the "with Susitna" scenario is clearly superior with regard to the economic criteria and suggests that there is not a distinguishable difference between the evaluations based on environmental and social criteria. It is therefore concluded that the scenario incorporating the Watana-Devil Canyon plan is superior to the all-thermal scenario.

(c) Comparison of the "With Susitna" and Alternative Hydro Generating Scenarios

Comparison of the "with-Susitna" and alternative hydro Railbelt generation scenarios have been made only on the basis of economics. Although preliminary screening of the alternative hydroelectric developments is made as described in Section 6, the absence of immediate site-specific data prevents a more detailed assessment of non-economic aspects.

The "with-Susitna" scenario is generally $1190 million more economic than the scenario incorporating the alternative hydro developments. Although development of the Susitna Basin is more economic than developing alternative hydro, this does not imply that alternative hydro should be neglected. In fact, as several of the combination runs involving both Susitna and non-Susitna hydro alternatives indicate, it may be economically advantageous to consider development of several alternative hydro sites in conjunction with Susitna.

TABLE 8.1 - POTENTIAL HYDROELECTRIC DEVELOPMENT

Site	Dam: Proposed Type	Dam: Height Ft.	Upstream Regulation	Capital Cost $ million	Installed Capacity (MW)	Average Annual Energy Gwh	Economic[1] Cost of Energy $/1000 kWh	Source of Data
Gold Creek[2]	Fill	190	Yes	900	260	1,140	37	USBR 1953
Olson (Susitna II)	Concrete	160	Yes	600	200	915	31	USBR 1953 KAISER 1974 COE 1975
Devil Canyon	Concrete	675	No	830	250	1,420	27	This Study
			Yes	1,000	600	2,980	17	"
High Devil Canyon (Susitna I)	Fill	855	No	1,500	800	3,540	21	" "
Devil Creek[2]	Fill	Approx 850	No	-	-	-	-	-
Watana	Fill	880	No	1,860	800	3,250	28	"
Susitna III	Fill	670	No	1,390	350	1,580	41	"
Vee	Fill	610	No	1,060	400	1,370	37	"
Maclaren[2]	Fill	185	No	530[4]	55	180	124	"
Denali	Fill	230	No	480[4]	60	245	81	"
Butte Creek[2]	Fill	Approx 150	No	-	40	130[3]	-	USBR 1953
Tyone[2]	Fill	Approx 60	No	-	6	22[3]	-	USBR 1953

Notes:

(1) Includes AFDC, Insurance, Amortization, and Operation & Maintenance Costs.
(2) No detailed engineering or energy studies undertaken as part of this study.
(3) These are approximate estimates and serve only to represent the potential of these two dam sites in perspective.
(4) Include estimated costs of power generation facility.

TABLE 8.2 - COST COMPARISONS

DAM		Capital Cost Estimate[2] (1980 $)				
		ACRES 1980		OTHERS		
Site	Type	Installed Capacity - MW	Capital Cost $ million	Installed Capacity - MW	Capital Cost $ million	Source and Date of Data
Gold Creek	Fill	-	-	260[1]	890	USRB 1968
Olson (Susitna II)	Concrete	-	-	190[1]	550	COE 1975
Devil Canyon	Fill	600	1,000	-	-	-
	Concrete Arch	-	-	776	630	COE 1975
	Concrete Gravity	-	-	776	910	COE 1978
High Devil Canyon (Susitna I)	Fill	800	1,500	700	1,480	COE 1975
Devil Creek	Fill	-	-	-	-	-
Watana	Fill	800	1,860	792	1,630	COE 1978
Susitna III	Fill	350	1,390	445	-	KAISER 1974
Vee	Fill	400	1,060	-	770	COE 1975
Maclaren	Fill	55	530	-		-
Denali	Fill	60	480	None	500	COE 1975

Notes:

(1) Dependable Capacity
(2) Excluding Anchorage/Fairbanks transmission intertie, but including local access and transmission.

TABLE 8.3 - DAM CREST AND FULL SUPPLY LEVELS

Site	Staged Dam Construction	Full Supply Level - Ft.	Dam Crest Level - Ft.	Average Tailwater Level - ft.	Dam Height[1] ft.
Gold Creek	No	870	880	680	290
Olson	No	1,020	1,030	810	310
Portage Creek	No	1,020	1,030	870	250
Devil Canyon - intermediate height	No	1,250	1,270	890	465
Devil Canyon - full height	No	1,450	1,470	890	675
High Devil Canyon	No	1,610	1,630	1,030	710
	No	1,750	1,775	1,030	855
Watana	Yes	2,000	2,060	1,465	680
	Stage 2	2,200	2,225	1,465	880
Susitna III	No	2,340	2,360	1,810	670
Vee	No	2,330	2,350	1,925	610
Maclaren	No	2,395	2,405	2,300	185
Denali	No	2,540	2,555	2,405	230

Notes:

(1) To foundation level.

TABLE 8.4 - CAPITAL COST ESTIMATE SUMMARIES
SUSITNA BASIN DAM SCHEMES
COST IN $MILLION 1980

Item	Devil Canyon 1470 ft Crest 600 MW	High Devil Canyon 1775 ft Crest 800 MW	Watana 2225 ft Crest 800 MW	Susitna III 2360 ft Crest 330 MW	Vee 2350 ft Crest 400 MW	Maclaren 2405 ft Crest No power	Denali 2250 ft Crest No power
1) Lands, Damages & Reservoirs	26	11	46	13	22	25	38
2) Diversion Works	50	48	71	88	37	118	112
3) Main Dam	166	432	536	398	183	106	100
4) Auxiliary Dam	0	0	0	0	40	0	0
5) Power System	195	232	244	140	175	0	0
6) Spillway System	130	141	165	121	74	0	0
7) Roads and Bridges	45	68	96	70	80	57	14
8) Transmission Line	10	10	26	40	49	0	0
9) Camp Facilities and Support	97	140	160	130	100	53	50
10) Miscellaneous[1]	8	8	8	8	8	5	5
11) Mobilization and Preparation	30	47	57	45	35	15	14
Subtotal	757	1137	1409	1053	803	379	333
Contingency (20%)	152	227	282	211	161	76	67
Engineering and Owner's Administration (12%)	91	136	169	126	96	45	40
TOTAL	1000	1500	1860	1390	1060	500	440

Notes:

(1) Includes recreational facilities, buildings and grounds and permanent operating equipment.

TABLE 8.5 - RESULTS OF SCREENING MODEL

	Total Demand		Optimal Solution				First Suboptimal Solution				Second Suboptimal Soultion			
Run	Cap. MW	Energy GWh	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million
1	400	1750	High Devil Canyon	1580	400	885	Devil Canyon	1450	400	970	Watana	1950	400	980
2	800	3500	High Devil Canyon	1750	800	1500	Watana	1900	450	1130	Watana	2200	800	1860
							Devil Canyon	1250	350	710				
							TOTAL		800	1840				
3	1200	5250	Watana	2110	700	1690	High Devil Canyon	1750	800	1500	High Devil Canyon	1750	820	1500
			Devil Canyon	1350	500	800	Vee	2350	400	1060	Susitna III	2300	380	1260
			TOTAL		1200	2490	TOTAL		1200	2560	TOTAL		1200	2760
4	1400	6150	Watana	2150	740	1770	N O S O L U T I O N				N O S O L U T I O N			
			Devil Canyon	1450	660	1000								

TABLE 8.6 - INFORMATION ON THE DEVIL CANYON DAM AND TUNNEL SCHEMES

Item	Devil Canyon Dam	Tunnel Scheme 1	Tunnel Scheme 2	Tunnel Scheme 3	Tunnel Scheme 4
Reservoir Area (Acres)	7,500	320	0	3,900	0
River Miles Flooded	31.6	2.0	0	15.8	0
Tunnel Length (Miles)	0	27	29	13.5	29
Tunnel Volume (1000 Yd^3)	0	11,976	12,863	3,732	5,131
Compensating Flow Release from Watana (cfs)	0	1,000	1,000	500[1]	1,000
Downstream[2] Reservoir Volume (1000 Acre-feet)	1,100	9.5	--	350	--
Downstream Dam Height (feet)[3]	625	75	--	245	--
Typical Daily Range of Discharge From Devil Canyon Powerhouse (cfs)	6,000 to 13,000	4,000 to 14,000	4,000 to 14,000	8,300 to 8,900	3,900 to 4,200
Approximate Maximum Daily Fluctuations in Downstream Reservoir (feet)	2	15	--	4	--

Notes:

1 1,000 cfs compensating flow release from the re-regulation dam.
2 Downstream from Watana.
3 Estimated, above existing rock elevation.

TABLE 8.7 - DEVIL CANYON TUNNEL SCHEMES
COSTS, POWER OUTPUT AND AVERAGE ANNUAL ENERGY

Stage	Installed Capacity (MW) Watana	Installed Capacity (MW) Devil Canyon Tunnel	Increase[1] in Installed Capacity (MW)	Devil Canyon Average Annual Energy (Gwh)	Increase[1] in Average Annual Energy (Gwh)	Tunnel Scheme Total Project Costs $ Million	Cost[3] of Additional Energy[1] (mills/kWh)
STAGE 1:							
Watana Dam	800	---	---	---	---	---	---
STAGE 2:							
Tunnel:							
- Scheme 1	800	550	550	2,050	2,050	1980	42.6
- Scheme 2	70	1,150	420	4,750	1,900	2320	52.9
- Scheme 3[2]	850	330	380	2,240	2,180	1220	24.9
- Scheme 4	800	365	365	2,490	890	1490	73.6

Notes:

(1) Increase over single Watana, 800 MW development 3250 Gwh/yr
(2) Includes power and energy produced at re-regulation dam
(3) Energy cost is based on an economic analysis (i.e. using 3 percent interest rate)

TABLE 8.8 - CAPITAL COST ESTIMATE SUMMARIES
TUNNEL SCHEMES
COSTS IN $MILLION 1980

Item		Two 30 ft dia tunnels		One 40 ft dia tunnel
Land and damages, reservoir clearing		14		14
Diversion works		35		35
Re-regulation dam		102		102
Power system		680		576
(a) Main tunnels	557		453	
(b) Intake, powerhouse, tailrace and switchyard	123		123	
Secondary power station		21		21
Spillway system		42		42
Roads and bridges		42		42
Transmission lines		15		15
Camp facilities and support		131		117
Miscellaneous*		8		8
Mobilization and preparation		47		47
TOTAL CONSTRUCTION COST		1,137		1,015
Contingencies (20%)		227		203
Engineering, and Owner's Administration		136		122
TOTAL PROJECT COST		1,500		1,340

TABLE 8.9. SUSITNA DEVELOPMENT PLANS

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft	Annual Energy Production Firm GWH	Avg. GWH.	Plant Factor %
1.1	1	Watana 2225 ft 800MW	1860	1993	2200	150	2670	3250	46
	2	Devil Canyon 1470 ft 600 MW	1000	1996	1450	100	5500	6230	51
		TOTAL SYSTEM 1400 MW	2860						
1.2	1	Watana 2060 ft 400 MW	1570	1992	2000	100	1710	2110	60
	2	Watana raise to 2225 ft	360	1995	2200	150	2670	2990	85
	3	Watana add 400 MW capacity	130[2]	1995	2200	150	2670	3250	46
	4	Devil Canyon 1470 ft 600 MW	1000	1996	1450	100	5500	6230	51
		TOTAL SYSTEM 1400 MW	3060						
1.3	1	Watana 2225 ft 400 MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity	150	1993	2200	150	2670	3250	46
	3	Devil Canyon 1470 ft 600 MW	1000	1996	1450	100	5500	6230	51
		TOTAL SYSTEM 1400 MW	2890						

TABLE 8.9 (Continued)

Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Annual Energy Production Avg. GWH	Plant Factor %
			Stage/Incremental Data				Cumulative System Data		
2.1	1	High Devil Canyon							
		1775 ft 800 MW	1500	1994[3]	1750	150	2460	3400	49
	2	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2560						
2.2	1	High Devil Canyon							
		1630 ft 400 MW	1140	1993[3]	1610	100	1770	2020	58
	2	High Devil Canyon add 400 MW Capacity raise dam to 1775 ft	500	1996	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2700						
2.3	1	High Devil Canyon							
		1775 ft 400 MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400 MW capacity	140	1994	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2590						
3.1	1	Watana 2225 ft 800 MW	1860	1993	2200	150	2670	3250	46
	2	Watana add 50 MW tunnel 330 MW	1500	1995	1475	4	4890	5430	53
		TOTAL SYSTEM 1180 MW	3360						

TABLE 8.9 (Continued)

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Avg. GWH	Plant Factor %
3.2	1	Watana 2225 ft 400 MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity	150	1994	2200	150	2670	3250	46
	3	Tunnel 330 MW add 50 MW to Watana	1500	1995	1475	4	4890	5430	53
			3390						
4.1	1	Watana 2225 ft 400 MW	1740	1995[3]	2200	150	2670	2990	85
	2	Watana add 400 MW capacity	150	1996	2200	150	2670	3250	46
	3	High Devil Canyon 1470 ft 400 MW	860	1998	1450	100	4520	5280	50
	4	Portage Creek 1030 ft 150 MW	650	2000	1020	50	5110	6000	51
		TOTAL SYSTEM 1350 MW	3400						

NOTES:

(1) Allowing for a 3 year overlap construction period between major dams.
(2) Plan 1.2 Stage 3 is less expensive than Plan 1.3 Stage 2 due to lower mobilization costs.
(3) Assumes FERC license can be filed by June 1984, ie. 2 years later than for the Watana/Devil Canyon Plan 1.

TABLE 8.10 - ENERGY SIMULATION SENSITIVITY

Development	Installed Capacity MW	Reservoir Full Supply Level Feet	Maximum Reservoir Drawdown Feet	Annual Energy-Gwh Firm[1]	(%)	Average	(%)	Plant Factor %
Watana 2225 Feet	800	2200	100	2510	(89)	3210	(101)	45.8
	800	2200	150	2670	(94)	3250	(103)	46.4
	800	2200	175	2770	(98)	3200	(101)	45.7
	800	2200	Unlimited	2830	(100)	3170	(100)	45.2

Notes:

(1) Second lowest energy generated during simulation period.

TABLE 8.11. SUSITNA ENVIRONMENTAL DEVELOPMENT PLANS

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft	Annual Energy Production Firm GWH	Avg. GWH.	Plant Factor %
E1.1	1	Watana 2225 ft 800MW and Re-Regulation Dam	1960	1993	2200	150	2670	3250	46
	2	Devil Canyon 1470 ft 400MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200MW	2860						
E1.2	1	Watana 2060 ft 400MW	1570	1992	2000	100	1710	2110	60
	2	Watana raise to 2225 ft	360	1995	2200	150	2670	2990	85
	3	Watana add 400MW capacity and Re-Regulation Dam	230[2]	1995	2200	150	2670	3250	46
	4	Devil Canyon 1470 ft 400MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200MW	3060						
E1.3	1	Watana 2225 ft 400MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400MW capacity and Re-Regulation Dam	250	1993	2200	150	2670	3250	46
	3	Devil Canyon 1470 ft 400 MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200MW	2890						

TABLE 8.11 (Continued)

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Avg. GWH	Plant Factor %
E1.4	1	Watana 2225 ft 400MW	1740	1993	2200	150	2670	2990	85
	2	Devil Canyon 1470 ft 400MW	900	1996	1450	100	5190	5670	81
		TOTAL SYSTEM 800MW	2640						
E2.1	1	High Devil Canyon 1775 ft 800MW and Re-Regulation Dam	1600	1994[3]	1750	150	2460	3400	49
	2	Vee 2350ft 400MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200MW	2660						
E2.2	1	High Devil Canyon 1630 ft 400MW	1140	1993[3]	1610	100	1770	2020	58
	2	High Devil Canyon raise dam to 1775 ft add 400MW and Re-Regulation Dam	600	1996	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200MW	2800						
E2.3	1	High Devil Canyon 1775 ft 400MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400MW capacity and Re-Regulation Dam	240	1995	1750	150	2460	3400	49
	3	Vee 2350 ft 400MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200	2690						

TABLE 8.11 (Continued)

Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Cumulative System Data: Annual Energy Production Firm GWH	Annual Energy Production Avg. GWH	Plant Factor %
			Stage/Incremental Data						
E2.4	1	High Devil Canyon 1755 ft 400MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400MW capacity and Portage Creek Dam 150 ft	790	1995	1750	150	3170	4080	49
	3	Vee 2350 ft 400MW	1060	1997	2330	150	4430	5540	47
		TOTAL SYSTEM	3240						
E3.2	1	Watana 2225 ft 400MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity and Re-Regulation Dam	250	1994	2200	150	2670	3250	46
	3	Watana add 50MW Tunnel Scheme 330MW	1500	1995	1475	4	4890	5430	53
		TOTAL SYSTEM 1180MW	3490						
E4.1	1	Watana 2225 ft 400MW	1740	1995[3]	2200	150	2670	2990	85
	2	Watana add 400MW capacity and Re-Regulation Dam	250	1996	2200	150	2670	3250	46
	3	High Devil Canyon 1470 ft 400MW	860	1998	1450	100	4520	5280	50
	4	Portage Creek 1030 ft 150MW	650	2000	1020	50	5110	6000	51
		TOTAL SYSTEM 1350 MW	3500						

NOTES:
(1) Allowing for a 3 year overlap construction period between major dams.
(2) Plan 1.2 Stage 3 is less expensive than Plan 1.3 Stage 2 due to lower mobilization costs.
(3) Assumes FERC license can be filed by June 1984, ie. 2 years later than for the Watana/Devil Canyon Plan 1.

TABLE 8.12 - ANNUAL FIXED CARRYING CHARGES

Project Type	Economic Life - Years	Economic Parameters: Cost of Money %	Amortization %	Insurance %	Total Annual Fixed Cost %
Thermal - Gas Turbine (Oil Fired)	20	3.00	3.72	0.25	6.97
- Diesel, Gas Turbine (Gas Fired) and Large Steam Turbine	30	3.00	2.10	0.25	5.35
- Small Steam Turbine	35	3.00	1.65	0.25	4.90
Hydropower	50	3.00	0.89	0.10	3.99

TABLE 8.13 - RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS - MEDIUM LOAD FORECAST

Susitna Development Plan Inc.	Online Dates					Installed Capacity (MW) by Category in 2010					Total System Installed Capacity In 2010-MW	Total System Present Worth Cost $ Million[1]	Remarks Pertaining to the Susitna Basin Development Plan
Plan No.	Stages				OGP5 Run Id. No.	Thermal			Hydro				
	1	2	3	4		Coal	Gas	Oil	Other	Susitna			
E1.1	1993	2000	--	--	LXE7	300	426	0	144	1200	2070	5850	
E1.2	1992	1995	1997	2002	L5Y9	200	501	0	144	1200	2045	6030	
E1.3	1993	1996	2000	--	L8J9	300	426	0	144	1200	2070	5850	
	1993	1996	--	--	L7W7	500	651	0	144	800	2095	6960	Stage 3, Devil Canyon Dam not constructed
	1998	2001	2005	--	LAD7	400	276	30	144	1200	2050	6070	Delayed implementation schedule
E1.4	1993	2000	--	--	LCK5	200	726	50	144	800	1920	5890	Total development limited to 800 MW
Modified E2.1	1994	2000	--	--	LB25	400	651	60	144	800	2055	6620	High Devil Canyon limited to 400 MW
E2.3[1]	1993	1996	2000	--	L601	300	651	20	144	1200	2315	6370	
	1993	1996	--	--	LE07	500	651	30	144	800	2125	6720	Stage 3, Vee Dam, not constructed
Modified E2.3	1993	1996	2000		LEB3	300	726	220	144	1300	2690	6210	Vee dam replaced by Chakachamna dam
3.1	1993	1996	2000	--	L607	200	651	30	144	1180	2205	6530	
Special 3.1	1993	1996	2000	--	L615	200	651	30	144	1180	2205	6230	Capital cost of tunnel reduced by 50 percent
E4.1	1995	1996	1998	--	LTZ5	200	576	30	144	1200	2150	6050	Stage 4 not constructed

NOTES:

(1) Adjusted to incorporate cost of re-regulation dam

TABLE 8.14 - RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS - LOW AND HIGH LOAD FORECAST

Plan No.	Susitna Development Plan Inc. Online Dates Stages 1	2	3	4	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010 Thermal Coal	Gas	Oil	Hydro Other	Susitna	Total System Installed Capacity In 2010-MW	Total System Present Worth Cost $ Million	Remarks Pertaining to the Susitna Basin Development Plan
VERY LOW FORECAST[1]													
E1.4	1997	2005	--	--	L7B7	0	651	50	144	800	1645	3650	
LOW LOAD FORECAST													
E1.3	1993	1996	2000	--	--	--	--	--	--	--	--	--	Low energy demand does not warrant plan capacities
E1.4	1993	2002	--	--	LC07	0	351	40	144	800	1335	4350	
	1993	--	--	--	LBK7	200	501	80	144	400	1325	4940	Stage 2, Devil Canyon Dam, not constructed
E2.1	1993	2002	--	--	LG09	100	426	30	144	800	1500	4560	High Devil Canyon limited to 400 MW
	1993	--	--	--	LBU1	400	501	0	144	400	1445	4850	Stage 2, Vee Dam, not constructed
E2.3	1993	1996	2000	--	--	--	--	--	--	--	--	--	Low energy demand does not warrant plan capacities
Special 3.1	1993	1996	2000	--	L613	0	576	20	144	780	1520	4730	Capital cost of tunnel reduced by 50 percent
3.2	1993	2002	--	--	L609	0	576	20	144	780	1520	5000	Stage 2, 400 MW addition to Watana, not constructed
HIGH LOAD FORECAST													
E1.3	1993	1996	2000	--	LA73	1000	951	0	144	1200	3295	10680	
Modified E1.3	1993	1996	2000	2005[2]	LBV7	800	651	60	144	1700	3355	10050	Chakachamna hydroelectric generating station (480 MW) brought on line as a fourth stage
E2.3	1993	1996	2000	--	LBV3	1300	951	90	144	1200	3685	11720	
Modified E2.3	1993	1996	2000	2003[2]	LBY1	1000	876	10	144	1700	3730	11040	Chakachamna hydroelectric generating station (480 MW) brought on line as a fourth stage

NOTE:

(1) Incorporating load management and conservation

TABLE 8.15 - RESULTS OF ECONOMIC SENSITIVITY ANALYSES FOR GENERATION SCENARIO INCORPORATING SUSITNA BASIN DEVELOPMENT PLAN E1.3 - MEDIUM FORECAST

Description Parameter Varied	Parameter Values	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010: Thermal: Coal	Thermal: Gas	Thermal: Oil	Hydro: Other	Hydro: Susitna	Total System Installed Capacity In 2010 MW	Total System Present Worth Cost $ Million	Remarks
Interest Rate	5%	LF85	300	426	0	144	1200	2070	4230	
	9%	LF87	300	426	0	144	1200	2070	2690	
Fuel Cost ($ million Btu, natural gas/coal/oil)	1.60/0.92/3.20	L533	100	576	20	144	1200	2040	5260	20% fuel cost reduction
Fuel Cost Escalation (%, natural gas/coal/oil)	0/0/0	L557	0	651	30	144	1200	2025	4360	Zero escalation
	3.98/0/3.58	L563	300	426	0	144	1200	2070	5590	Zero coal cost escalation
Economic Life of Thermal Plants (year, natural gas/coal/oil)	45/45/30	L585	45	367	233	144	1200	1989	6100	Economic lives increased by 50%
Thermal Plant Capital Cost ($/kW, natural gas/coal/oil)	350/2135/778	LED7	300	426	0	144	1200	2070	5740	Coal capital cost reduced by 22%
Watana/Devil Canyon Capital Cost[2] ($ million, Watana/Devil Canyon)	1990/1110	L5G1	300	426	0	144	1200	2070	6210	Capital cost for Devil Canyon Dam increased by 23%
	2976/1350	LD75	300	426	0	144	1200	2070	6810	Capital cost for both dams increased by 50%
Probabilistic Load Forecast		L8T5	200	1476	140	144	1200	3160	6290	

NOTES:

(1) Alaskan cost adjustment factor reduced from 1.8 to 1.4
(2) Excluding AFDC

TABLE 8.16 - ECONOMIC BACKUP DATA FOR EVALUATION OF PLANS

Parameter	Total Present Worth Cost for 1981 - 2040 Period $ Million (% Total) Generation Plan With High Devil Canyon - Vee	Generation Plan With Watana - Devil Canyon Dam	Generation Plan With Watana - Tunnel	All Thermal Generation Plans
Capital Investment	2800 (44)	2740 (47)	3170 (49)	2520 (31)
Fuel	3220 (50)	2780 (47)	3020 (46)	5240 (64)
Operation and Maintenance	350 (6)	330 (6)	340 (5)	370 (5)
TOTAL:	6370 (100)	5850 (100)	6530 (100)	8130 (100)

TABLE 8.17 - ECONOMIC EVALUATION OF DEVIL CANYON DAM AND TUNNEL SCHEMES AND WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

		Present worth of Net Benefit ($ million) of total generation system costs for the: Devil Canyon Dam over the Tunnel Scheme	Present worth of Net Benefit ($ million) of total generation system costs for the: Watana/Devil Canyon Dams over the High Devil Canyon/Vee Dams	Remarks
ECONOMIC EVALUATION: - Base Case		680	520	Economic ranking: Devil Canyon dam scheme is superior to Tunnel scheme. Watana/Devil Canyon dam plan is superior to the High Devil Canyon dam/Vee dam plan.
SENSITIVITY ANALYSES:				
- Load Growth	Low High	650 N.A.	210 1040	The net benefit of the Watana/Devil Canyon plan remains positive for the range of load forecasts considered. No change in ranking.
- Capital Cost Estimate		Higher uncertainty associated with tunnel scheme.	Higher uncertainty associated with H.D.C./Vee plan.	Higher cost uncertainties associated with higher cost schemes/plans. Cost uncertainty therefore does not affect economic ranking.
- Period of Economic Analysis	Period shortened to (1980 - 2010)	230	160	Shorter period of evaluation decreases economic differences. Ranking remains unchanged.
- Discount Rate	5% 8% (interpolated) 9%	As both the capital and fuel costs associated with the tunnel scheme and H.D.C./Vee Plan are higher than for Watana/Devil Canyon plan any changes to these parameters cannot reduce the Devil Canyon or Watana/Devil Canyon net benefit to below zero.		Ranking remains unchanged.
- Fuel Cost	80% basic fuel cost			
- Fuel Cost Escalation	0% fuel escalation 0% coal escalation			
- Economic Thermal Plant Life	50% extension 0% extension			

TABLE 8.18 - ENVIRONMENTAL EVALUATION OF DEVIL CANYON DAM AND TUNNEL SCHEME

Environmental Attribute	Concerns	Appraisal (Differences in impact of two schemes)	Identification of difference	Appraisal Judgement	Scheme judged to have the least potential impact: Tunnel	Scheme judged to have the least potential impact: DC
Ecological:						
- Downstream Fisheries and Wildlife	Effects resulting from changes in water quantity and quality.	No significant difference between schemes regarding effects downstream of Devil Canyon.	---	Not a factor in evaluation of scheme.		
		Difference in reach between Devil Canyon dam and tunnel re-regulation dam.	With the tunnel scheme controlled flows between regulation dam and downstream powerhouse offers potential for anadromous fisheries enhancement in this 11 mile reach of the river.	If fisheries enhancement opportunity can be realized the tunnel scheme offers a positive mitigation measure not available with the Devil Canyon dam scheme. This opportunity is considered moderate and favors the tunnel scheme.	X	
Resident Fisheries:	Loss of resident fisheries habitat.	Minimal differences between schemes.	Devil Canyon dam would inundate 27 miles of the Susitna River and approximately 2 miles of Devil Creek. The tunnel scheme would inundate 16 miles of the Susitna River.	This reach of river is not considered to be highly significant for resident fisheries and thus the difference between the schemes is minor and favors the tunnel scheme.	X	
Wildlife:	Loss of wildlife habitat.	Minimal differences between schemes.	The most sensitive wildlife habitat in this reach is upstream of the tunnel re-regulation dam where there is no significant difference between the schemes. The Devil Canyon dam scheme in addition inundates the river valley between the two dam sites resulting in a moderate increase in impacts to wildlife.	The difference in loss of wildlife habitat is considered moderate and favors the tunnel scheme.	X	
Cultural:	Inundation of archeological sites.	Potential differences between schemes.	Due to the larger area inundated the probability of inundating archeological sites is increased.	A significant archeological site, if identified, can probably be excavated. This concern is not considered a factor in in scheme evaluation.	-	-
Land Use:	Inundation of Devil Canyon.	Significant difference between schemes.	The Devil Canyon is considered a unique resource, 80 percent of which would be inundated by the Devil Canyon dam scheme. This would result in a loss of both an aesthetic value plus the potential for white water recreation.	The aesthetic and to some extent the recreational losses associated with the development of the Devil Canyon dam is the main aspect favoring the tunnel scheme.	X	

OVERALL EVALUATION: The tunnel scheme has overall a lower impact on the environment.

TABLE 8.19 - SOCIAL EVALUATION OF SUSITNA BASIN DEVELOPMENT SCHEMES/PLANS

Social Aspect	Parameter	Tunnel Scheme	Devil Canyon Dam Scheme	High Devil Canyon/ Vee Plan	Watana/Devil Canyon Plan	Remarks
Potential non-renewable resource displacement	Million tons Beluga coal over 50 years	80	110	170	210	Devil Canyon dam scheme potential higher than tunnel scheme. Watana/ Devil Canyon plan higher than High Devil Canyon/ Vee plan.
Impact on state economy	--	All projects would have similar impacts on the state and local economy.				Essentially no difference between plans/schemes.
Impact on local economy	--					
Seismic exposure	Risk of major structural failure	All projects designed to similar levels of safety.				
	Potential impact of failure on human life.	Any dam failures would effect the same downstream population.				
Overall Evaluation	1. Devil Canyon dam superior to tunnel. 2. Watana/Devil Canyon superior to High Devil Canyon/Vee plan.					

TABLE 8.20 - ENERGY CONTRIBUTION EVALUATION OF THE DEVIL CANYON DAM AND TUNNEL SCHEMES

Parameter	Dam	Tunnel	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	2850	2240	Devil Canyon dam annually develops 610 GWH and 540 GWH more average and firm energy respectively than the Tunnel scheme.
Firm Annual Energy GWH	2590	2050	
% Basin Potential Developed[1]	43	32	Devil Canyon schemes develops more of the basin potential.
Energy Potential Not Developed GWH	60	380	As currently envisaged, the Devil Canyon dam does not develop 15 ft gross head between the Watana site and the Devil Canyon reservsoir. The tunnel scheme incorporates additional friction losses in tunnels. Also the compensation flow released from re-regulation dam is not used in conjunction with head between re-regulation dam and Devil Canyon.

Notes:

(1) Based on annual average energy. Full potential based on USBR four dam scheme.

TABLE 8.21 - OVERALL EVALUATION OF TUNNEL SCHEME AND DEVIL CANYON DAM SCHEME

ATTRIBUTE	SUPERIOR PLAN
Economic	Devil Canyon Dam
Energy Contribution	Devil Canyon Dam
Environmental	Tunnel
Social	Devil Canyon Dam (Marginal)
Overall Evaluation	Devil Canyon dam scheme is superior
	Tradeoffs made:
	Economic advantage of dam scheme is judged to outweigh the reduced environmental impact associated with the tunnel scheme.

TABLE 8.22 - ENVIRONMENTAL EVALUATION OF WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE DEVELOPMENT PLANS

Environmental Attribute	Plan Comparison	Appraisal Judgement	Plan judged to have the least potential impact HDC/V	W/DC
Ecological: 1) Fisheries	No significant difference in effects on downstream anadromous fisheries. HDC/V would inundate approximately 95 miles of the Susitna River and 28 miles of tributary streams, including the Tyone River. W/DC would inundate approximately 84 miles of the Susitna River and 24 miles of tributary streams, including Watana Creek.	Due to the avoidance of the Tyone River, lesser inundation of resident fisheries habitat and no significant difference in the effects on anadromous fisheries, the W/DC plan is judged to have less impact.		X
2) Wildlife a) Moose	HDC/V would inundate 123 miles of critical winter river bottom habitat. W/DC would inundate 108 miles of this river bottom habitat. HDC/V would inundate a large area upstream of Vee utilized by three sub-populations of moose that range in the northeast section of the basin. W/DC would inundate the Watana Creek area utilized by moose. The condition of this sub-population of moose and the quality of the habitat they are using appears to be decreasing.	Due to the lower potential for direct impact on moose populations within the Susitna, the W/DC plan is judged superior.		X
b) Caribou	The increased length of river flooded, especially upstream from the Vee dam site, would result in the HDC/V plan creating a greater potential division of the Nelchina herd's range. In addition, an increase in range would be directly inundated by the Vee reservoir.	Due to the potential for a greater impact on the Nelchina caribou herd, the HDC/V scheme is considered inferior.		X
c) Furbearers	The area flooded by the Vee reservoir is considered important to some key furbearers, particularly red fox. This area is judged to be more important than the Watana Creek area that would be inundated by the W/DC plan.	Due to the lesser potential for impact on furbearers the W/DC is judged to be superior.		X
d) Birds and Bears	Forest habitat, important for birds and black bears, exist along the valley slopes. The loss of this habitat would be greater with the W/DC plan.	The HDC/V plan is judged superior.	X	
Cultural:	There is a high potential for discovery of archeological sites in the easterly region of the Upper Susitna Basin. The HDC/V plan has a greater potential of affecting these sites. For other reaches of the river the difference between plans is considered minimal.	The W/DC plan is judged to have a lower potential effect on archeological sites.		X

TABLE 8.22 (Continued)

Environmental Attribute	Plan Comparison	Appraisal Judgement	Plan judged to have the least potential impact HDC/V	W/DC
Aesthetic/ Land Use				
	With either scheme, the aesthetic quality of both Devil Canyon and Vee Canyon would be impaired. The HDC/V plan would also inundate Tsusena Falls.	Both plans impact the valley aesthetics. The difference is considered minimal.	-	-
	Due to construction at Vee Dam site and the size of the Vee Reservoir, the HDC/V plan would inherently create access to more wilderness area than would the W/DC plan.	As it is easier to extend access than to limit it, inherent access requirements were considered detrimental and the W/DC plan is judged superior. The ecological sensitivity of the area opened by the HDC/V plan reinforces this judgement.		X

OVERALL EVALUATION: The W/DC plan is judged to be superior to the HDC/V plan. (The lower impact on birds and bears associated with HDC/V plan is considered to be outweighed by all the other impacts which favour the W/DC plan.)

NOTES:

W = Watana Dam
DC = Devil Canyon Dam
HDC = High Devil Canyon Dam
V = Vee Dam

TABLE 8.23 - ENERGY CONTRIBUTION EVALUATION OF THE WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

Parameter	Watana/ Devil Canyon	High Devil Canyon/Vee	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	6070	4910	Watana/Devil Canyon plan annually devel- ops 1160 GWH and 1650 GWH more average and firm energy re- pectively than the High Devil Canyon/Vee Plan.
Firm Annual Energy GWH	5520	3870	
% Basin Potential Developed (1)	91	81	Watana/Devil Canyon plan develops more of the basin potential
Energy Potential Not Developed GWH (2)	60	650	As currently con- ceived, the Watana/- Devil Canyon Plan does not develop 15 ft of gross head between the Watana site and the Devil Canyon reservoir. The High Devil Canyon/Vee Plan does not develop 175 ft gross head between Vee site and High Devil reservoir.

Notes:

(1) Based on annual average energy. Full potential based on USBR four dam schemes.
(2) Includes losses due to unutilized head.

TABLE 8.24 - OVERALL EVALUATION OF THE HIGH DEVIL CANYON/VEE AND WATANA/DEVIL CANYON DAM PLANS

ATTRIBUTE	SUPERIOR PLAN
Economic	Watana/Devil Canyon
Energy Contribution	Watana/Devil Canyon
Environmental	Watana/Devil Canyon
Social	Watana/Devil Canyon (Marginal)
Overall Evaluation	Plan with Watana/Devil Canyon is superior Tradeoffs made: None

TABLE 8.25 - RESULTS OF ECONOMIC ANALYSES FOR GENERATION SCENARIO INCORPORATING THERMAL DEVELOPMENT PLAN - MEDIUM FORECAST

Description Parameter Varied	Parameter Value	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010 Thermal Coal	Gas	Oil	Hydro	Total System Installed Capacity In 2010 Total MW	Total System Present Worth Cost $ Million	Remarks
Interest Rate	5%	LEA9	900	800	50	144	1895	5170	
	9%	LEB1	900	801	50	144	1895	2610	
Fuel Cost ($ million Btu, natural gas/coal/oil)	1.60/0.92/3.20	L1K7	800	876	70	144	1890	7070	20% fuel cost reduction
Fuel Cost Escalation (%, natural gas/coal/oil)	0/0/0	L547	0	1701	10	144	1855	4560	Zero escalation
	3.98/0/3.58	L561	1100	726	10	144	1980	6920	Zero coal cost escalation
Economic Life of Thermal Plants (year, natural gas/coal/oil)	45/45/30	L583	1145	667	51	144	2007	7850	Economic life increased 50%
Thermal Plant Capital Cost ($/kW, natural gas/ coal/oil)	350/2135/778	LAL9	1100	726	10	144	1980	7590	Coal capital cost reduced by 22%

TABLE 8.26 - ECONOMIC SENSITIVITY OF COMPARISON OF GENERATION PLAN WITH WATANA/DEVIL CANYON AND THE ALL THERMAL PLAN

Present worth of Net Benefit ($ million) of total generation system costs for the Watana/Devil Canyon plan over the all thermal plan.

Parameters	Sensitivity Analyses	Present worth ($ million)	Remarks
LOAD GROWTH	Very low	1280	The net benefit of the Watana/Devil Canyon Plan remains positive for the range of load forecasts considered.
	Low	1570	
	Medium	2280	
	High	2840	
CAPITAL COST ESTIMATE	Low Thermal Cost[2]	1850	System costs relatively insensitive. Capital cost estimating uncertainty does not effect economic ranking.
	High Hydroelectric Cost[3]	1320	
PERIOD OF ECONOMIC ANALYSIS	1980 - 2040	2280	Shorter period of evaluation decreases economic differences. Ranking remains unchanged.
	1980 - 2010	960	
DISCOUNT RATE	3%	2280	Below discount rate of 8% the Watana/Devil Canyon plan is economically superior.
	5%	940	
	8% (interpolated)	0	
	9%	-80	
FUEL COST	Low[4]	1810	
FUEL COST ESCALATION[5]	0% escalation for all fuels	200	Watana/Devil Canyon plan remains economically superior for wide range of fuel prices and escalation rates.
	0% escalation for coal only	1330	
ECONOMIC THERMAL PLANT LIFE	50% extension to all thermal plant life	1800	Economic benefit for Watana/Devil Canyon plan relatively insensitive to extended thermal plan economic life.

Notes:

(1) All parameters, except load growth, tested using medium load forecast.
(2) Thermal capital cost decreased by 22%.
(3) Estimated Susitna cost increased by 50%.
(4) All fuel costs reduced by 20%. Base case costs $/million Btu: Coal 1.15, Gas 2.00, Oil 4.00
(5) Base case escalation: Coal 2.93%, Gas 3.98%, Oil 3.58%.

TABLE 8.27 - SOCIAL COMPARISON OF SYSTEM GENERATION PLAN WITH WATANA/DEVIL CANYON AND THE ALL THERMAL PLAN

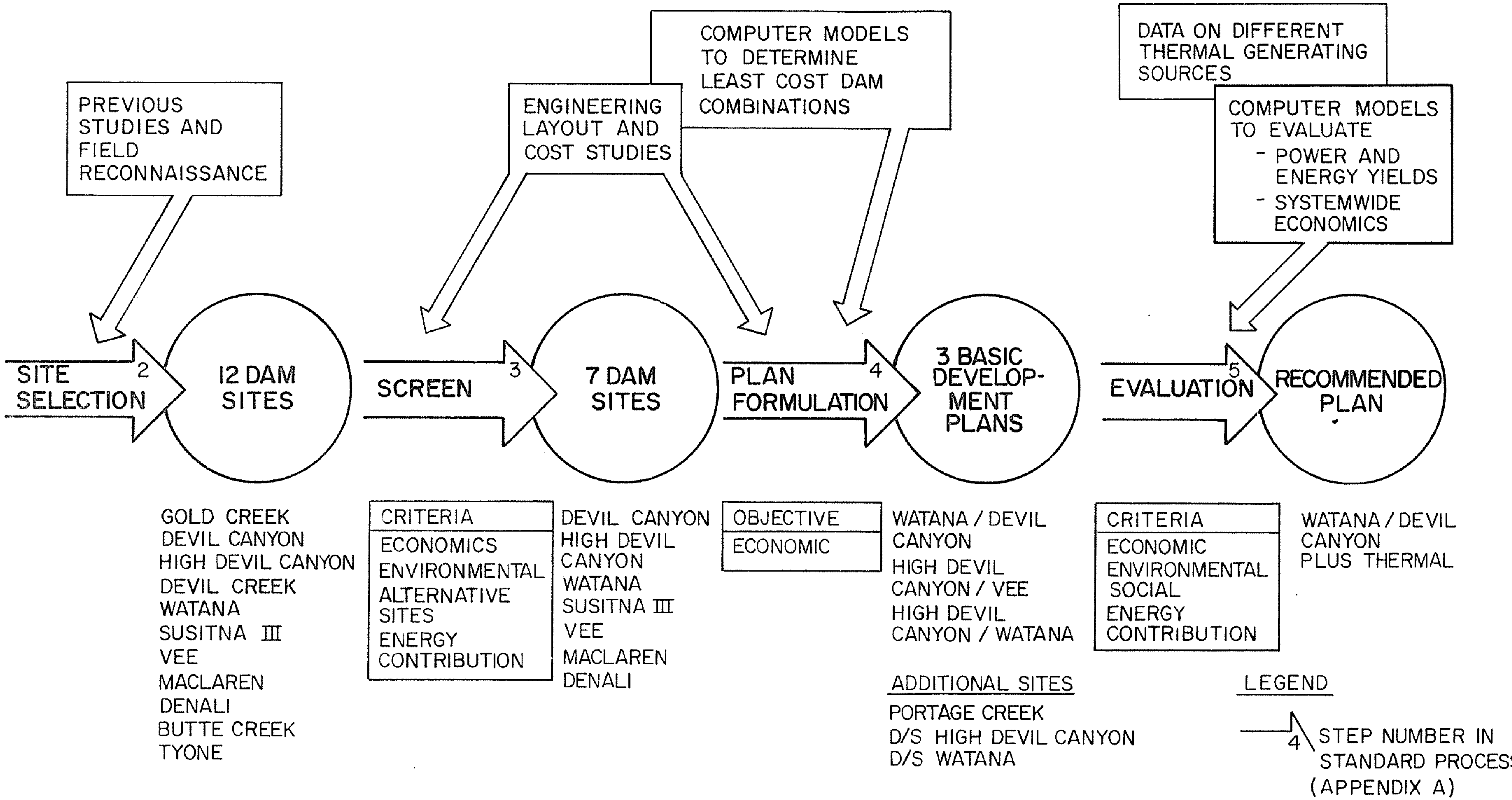
Social Aspect	Parameter	All Thermal Generation Plan	Generation Plan with Watana/Devil Canyon	Remarks
Potential non-renewable resource displacement	Million tons of Beluga coal, over 50 years	--	210	With Watana/Devil Canyon plan is superior.
Impact on state economy	Direct & Indirect employment and income.	Gradually, continuously growing impact.	Potentially more disruptive impact on economics.	Available information insufficient to draw definite conclusions.
Impact on local economy	Business investment.			
Seismic exposure	Risk of major structural failure	All projects designed to similar levels of safety.		Both scenarios judged to be equal.
	Potential impact of failure on human life.	Failure would effect only operating personnel. Forecast of failure would be impossible.	Failure would effect larger number of people located downstream, however, some degree of forecasting dam failure would be impossible.	
Overall Comparison	No significant difference in terms of overall assessment of plans.			

TABLE 8.28 - GENERIC COMPARISON OF ENVIRONMENTAL IMPACTS OF A SUSITNA BASIN HYDRO DEVELOPMENT VERSUS COAL FIRED THERMAL GENERATION IN THE BELUGA COAL FIELDS

Environmental Attributes	Concerns: Susitna Basin Development	Thermal Generation
Ecological:	Potential impact on fisheries due to alteration of downsteam flow distribution and water quality. Inundation of Moose and furbearer habitat and potential impact on Caribou migration. No major air quality problems, only minor microclimatic changes would occur.	Potential for impact on fisheries resulting from water quality impairment of local streams and local habitat destruction due to surface disturbances both at mine and generating facilities. Impact on air quality due to emission of particulates SO_2, NO_x, trace metals and water vapours from generating facilities.
Cultural:	Inundation of archeological sites.	Potential destruction of archeological sites.
Aesthetic/ Land Use:	Inundation of large area and surface disturbance in construction area. Creates additional access to wilderness areas, reduces river recreation but increases lake recreational activities.	Surface disturbance of large areas associated with coal mining and thermal generation facilities. Creates additional access and may restrict land use activities.

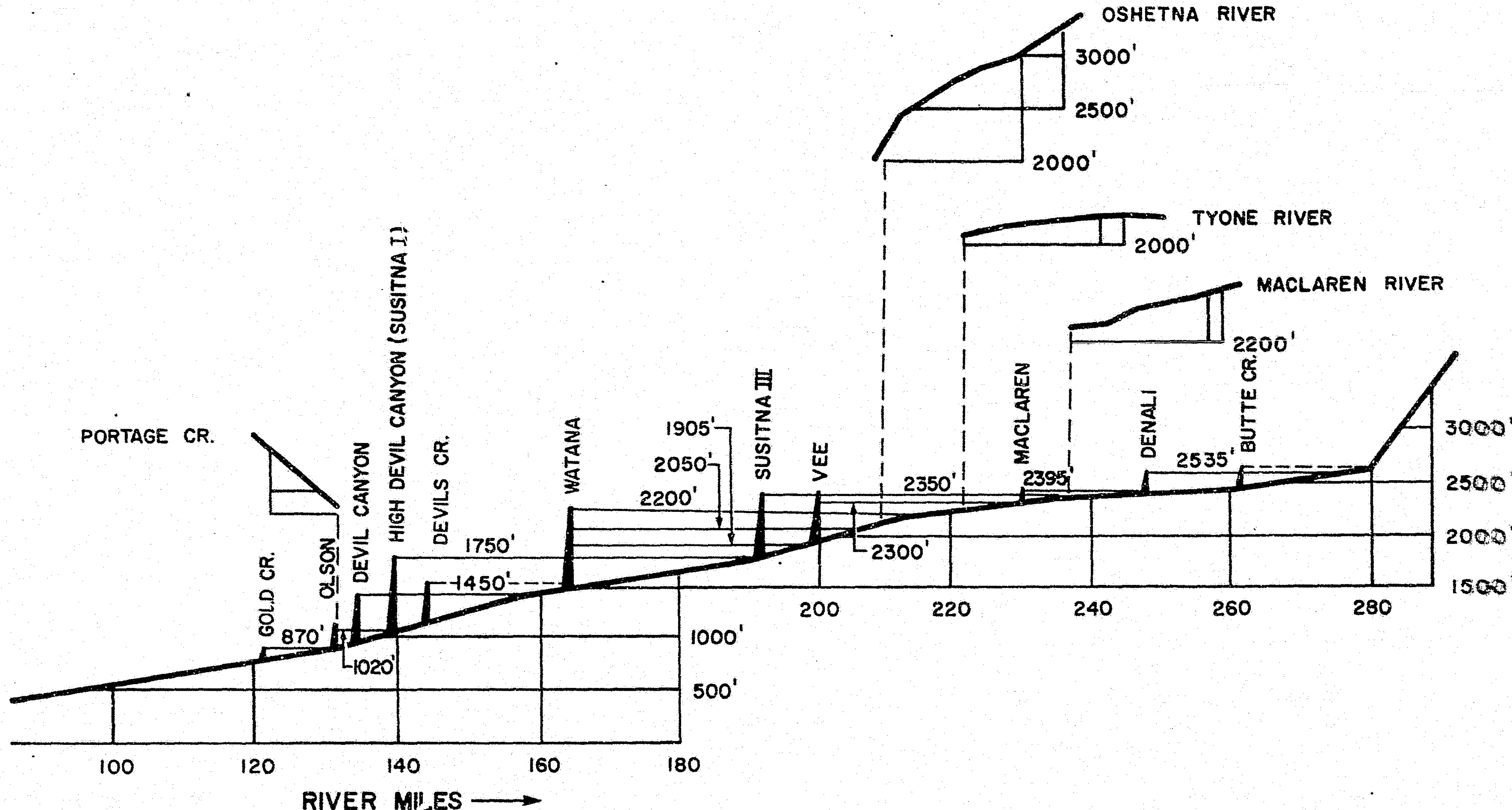
TABLE 8.29 - OVERALL EVALUATION OF ALL THERMAL GENERATION PLANS WITH THE GENERATION PLAN INCORPORATING WATANA/DEVIL CANYON DAMS

ATTRIBUTE	SUPERIOR PLAN
Economic	With Watana/Devil Canyon
Environmental	Unable to distinguish difference in this study due to site specific nature of impacts
Social	No significant overall difference
Overall	Plan with Watana/Devil Canyon is judged to be superior
Evaluation	Tradeoffs made: Not fully explored



SUSITNA BASIN PLAN FORMULATION AND SELECTION PROCESS

FIGURE 8.1



PROFILE THROUGH ALTERNATIVE SITES

FIGURE 8.2

	GOLD CREEK	OLSON	DEVIL CANYON	HIGH DEVIL CANYON	DEVIL CREEK	WATANA	SUSITNA III	VEE	MACLAREN	DENALI	BUTTE CREEK	TYONE
GOLD CREEK												
OLSON			890 (30)									
DEVIL CANYON				1030 (160)	1070 (200)							
HIGH DEVIL CANYON						1465 (445)						
DEVIL CREEK						1465 (405)						
WATANA							1810 (355)	1925 (470)				
SUSITNA III								1925 (125)	2320 (520)			
VEE									2320 (405)			
MACLAREN												
DENALI												
BUTTE CREEK												
TYONE												

LEGEND

COMPATIBLE ALTERNATIVES

MUTUALLY EXCLUSIVE ALTERNATIVES

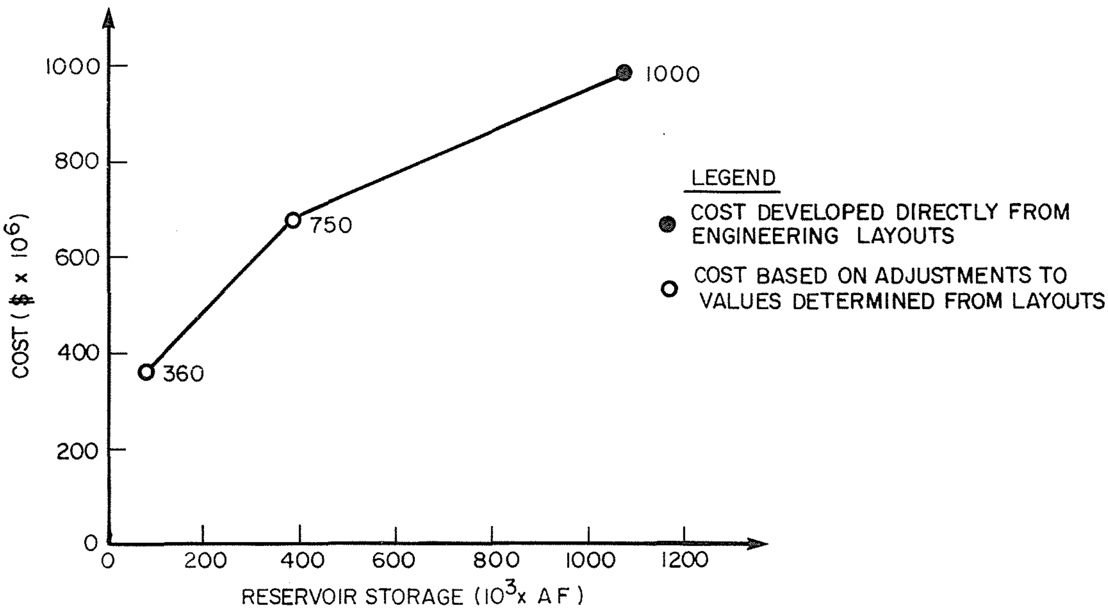
1465 (405) — DAM IN COLUMN IS MUTUALLY EXCLUSIVE IF FULL SUPPLY LEVEL OF DAM IN ROW EXCEEDS THIS VALUE - FT.

VALUE IN BRACKET REFERS TO APPROXIMATE DAM HEIGHT.

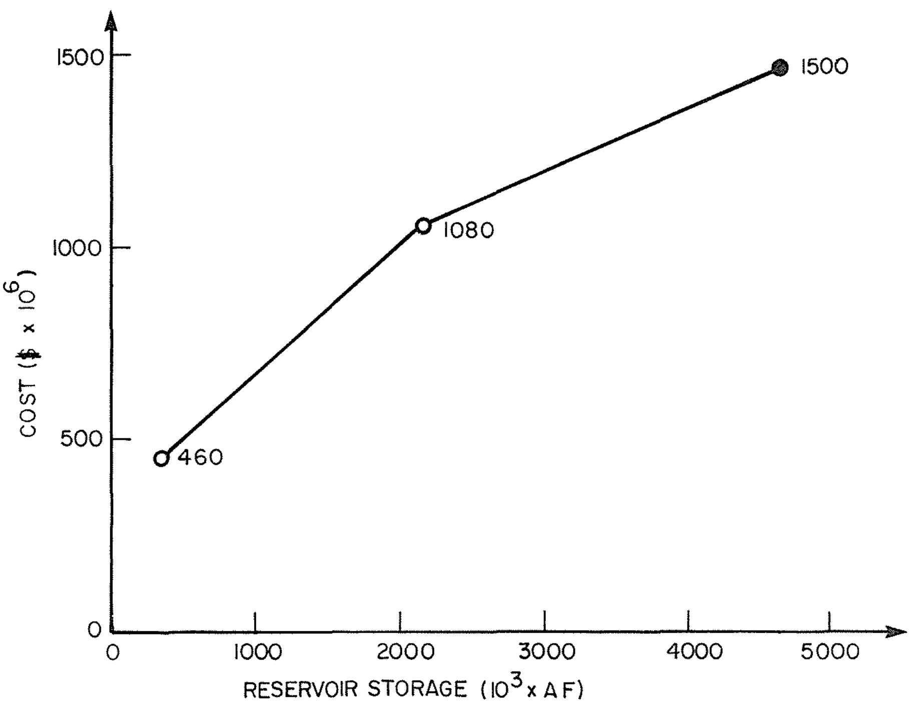
MUTUALLY EXCLUSIVE DEVELOPMENT ALTERNATIVES

FIGURE 8.3

ACRES



DEVIL CANYON

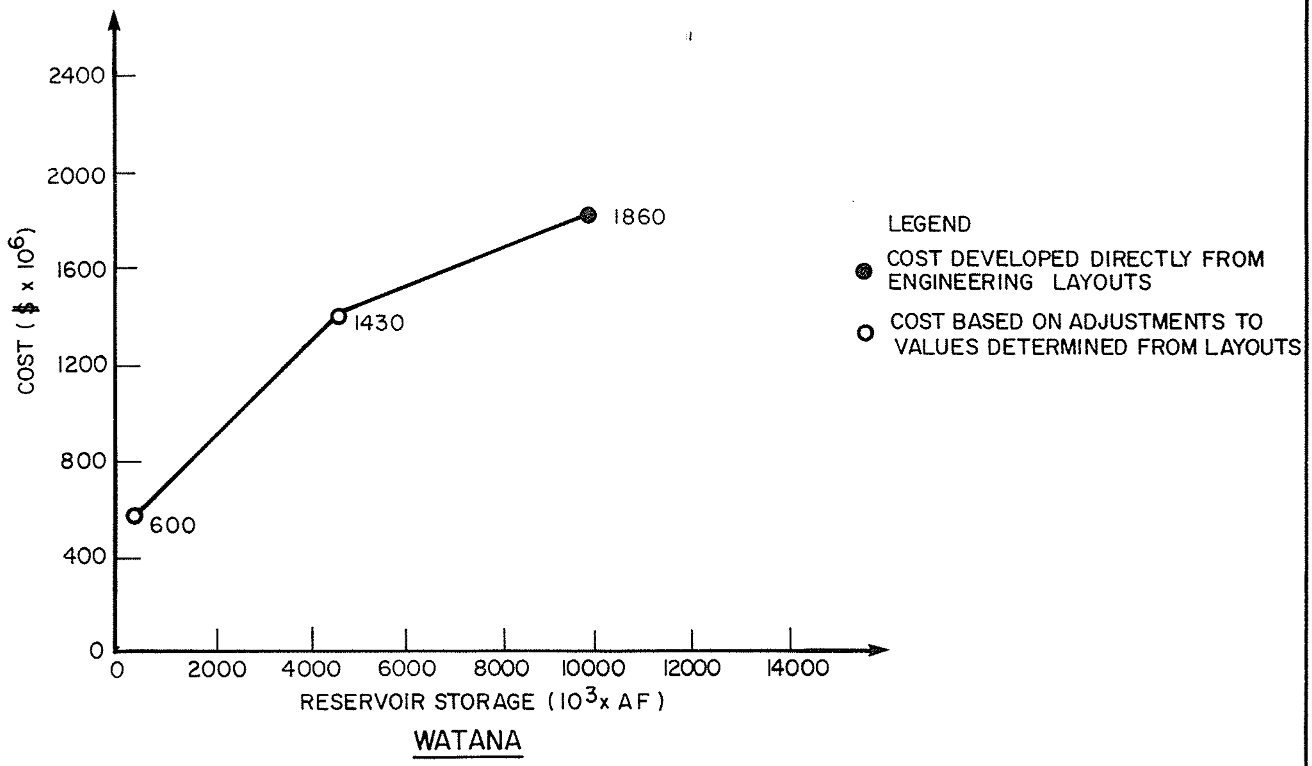


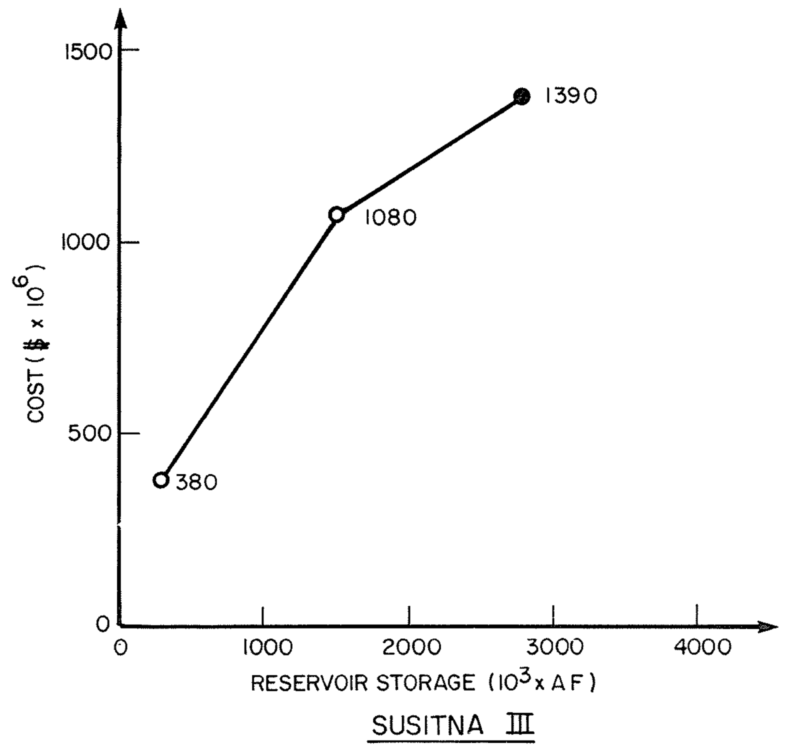
HIGH DEVIL CANYON

DAMSITE COST VS RESERVOIR STORAGE CURVES

ACRES

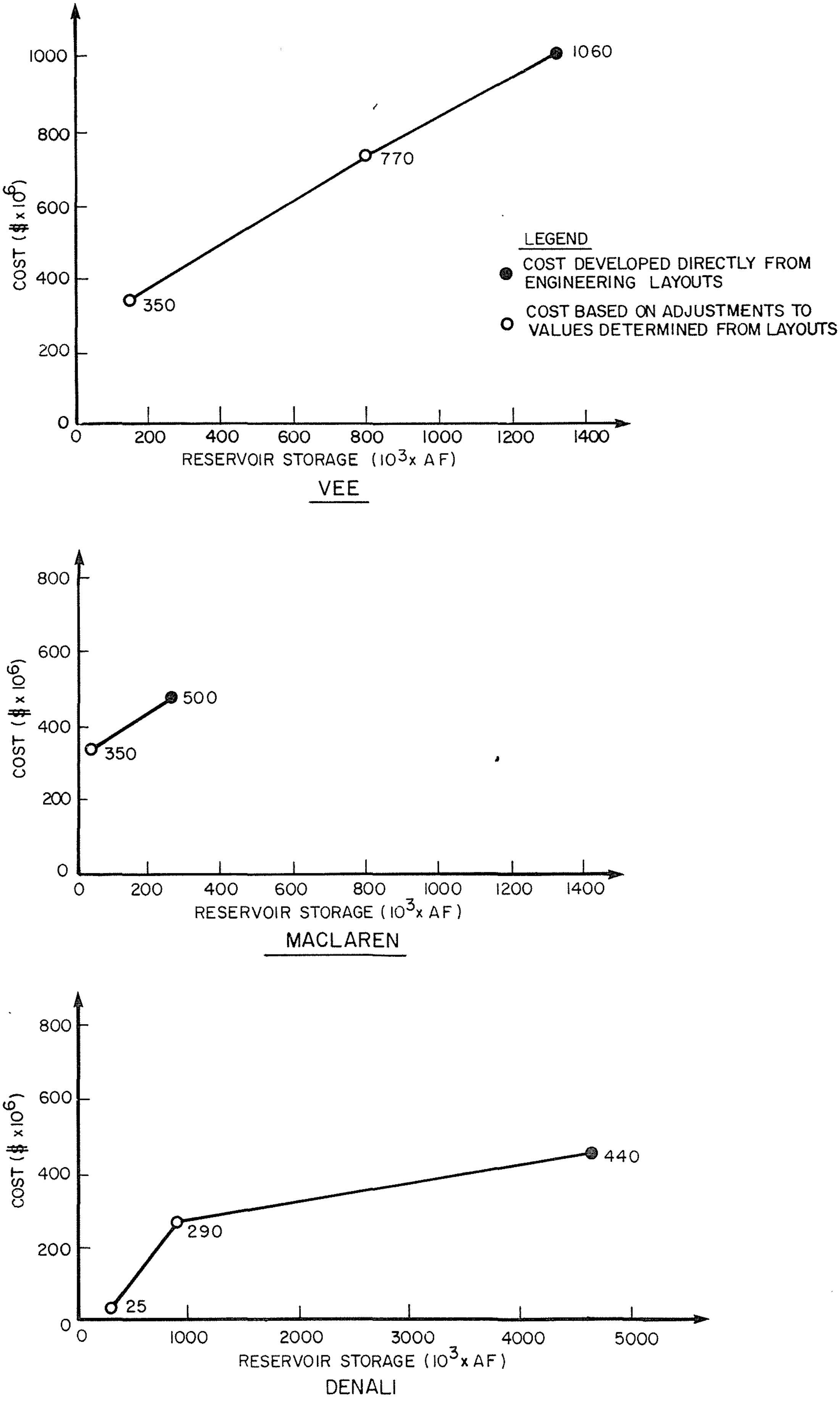
FIGURE 8.4





DAMSITE COST VS RESERVOIR STORAGE CURVES

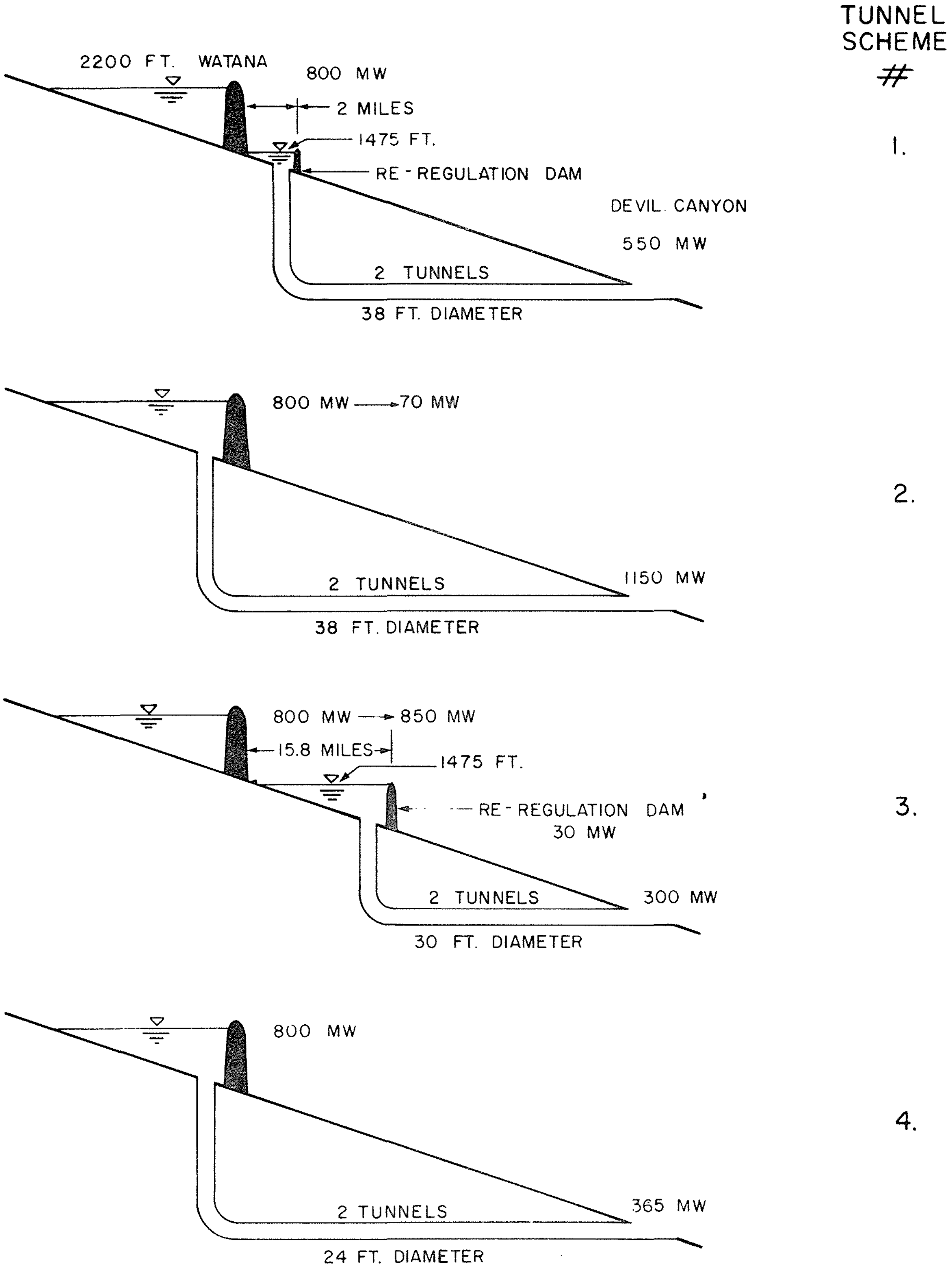
FIGURE 8.5



DAMSITE COST VS RESERVOIR STORAGE CURVES

ACRES

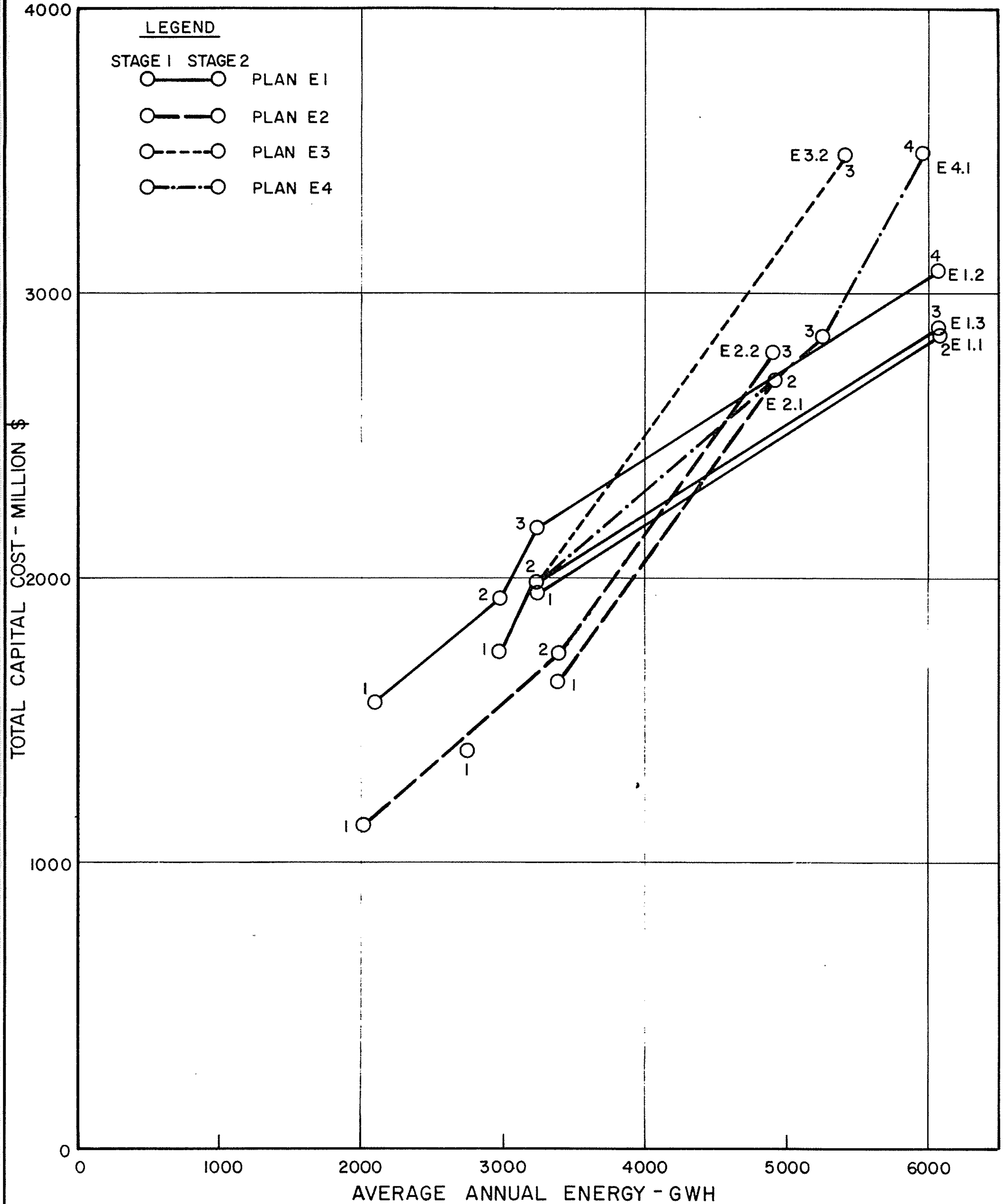
FIGURE 8.6



SCHEMATIC REPRESENTATION
OF CONCEPTUAL TUNNEL SCHEMES

ACRES

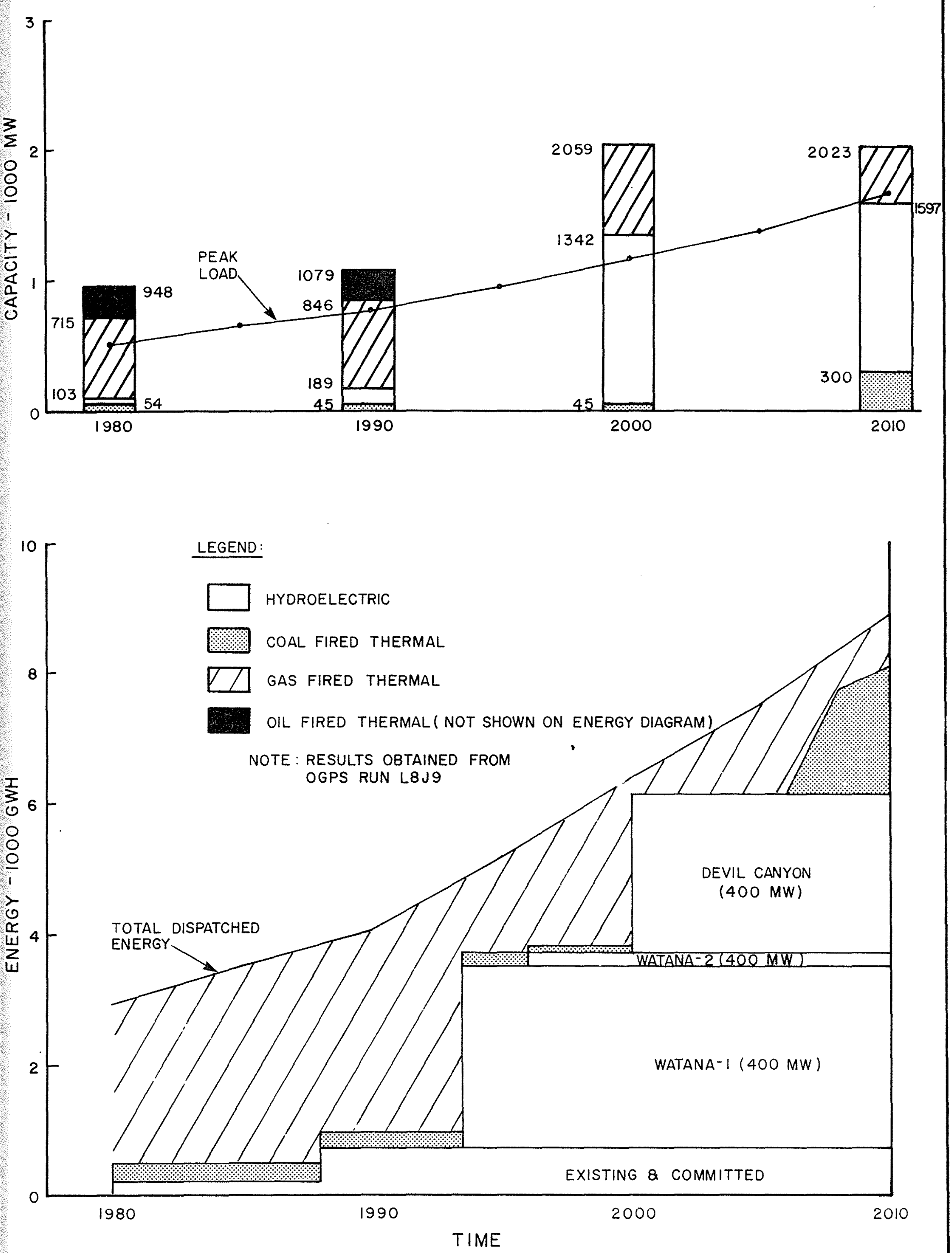
FIGURE 8.7



CAPITAL COST VERSUS ENERGY PLOTS
FOR ENVIRONMENTAL SUSITNA BASIN PLANS

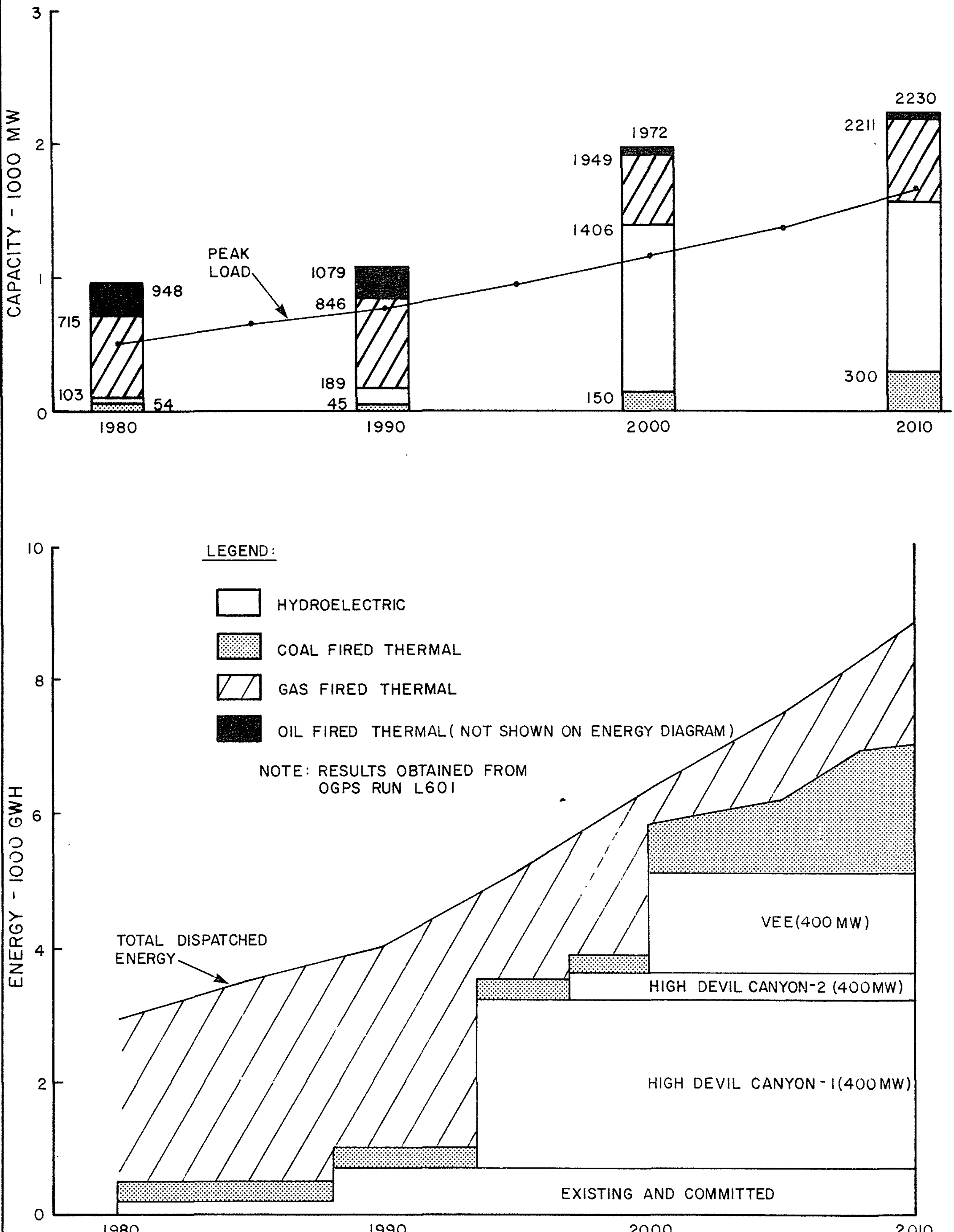
ACRES

FIGURE 8.8



GENERATION SCENARIO WITH SUSITNA PLAN E1.3
-MEDIUM LOAD FORECAST-

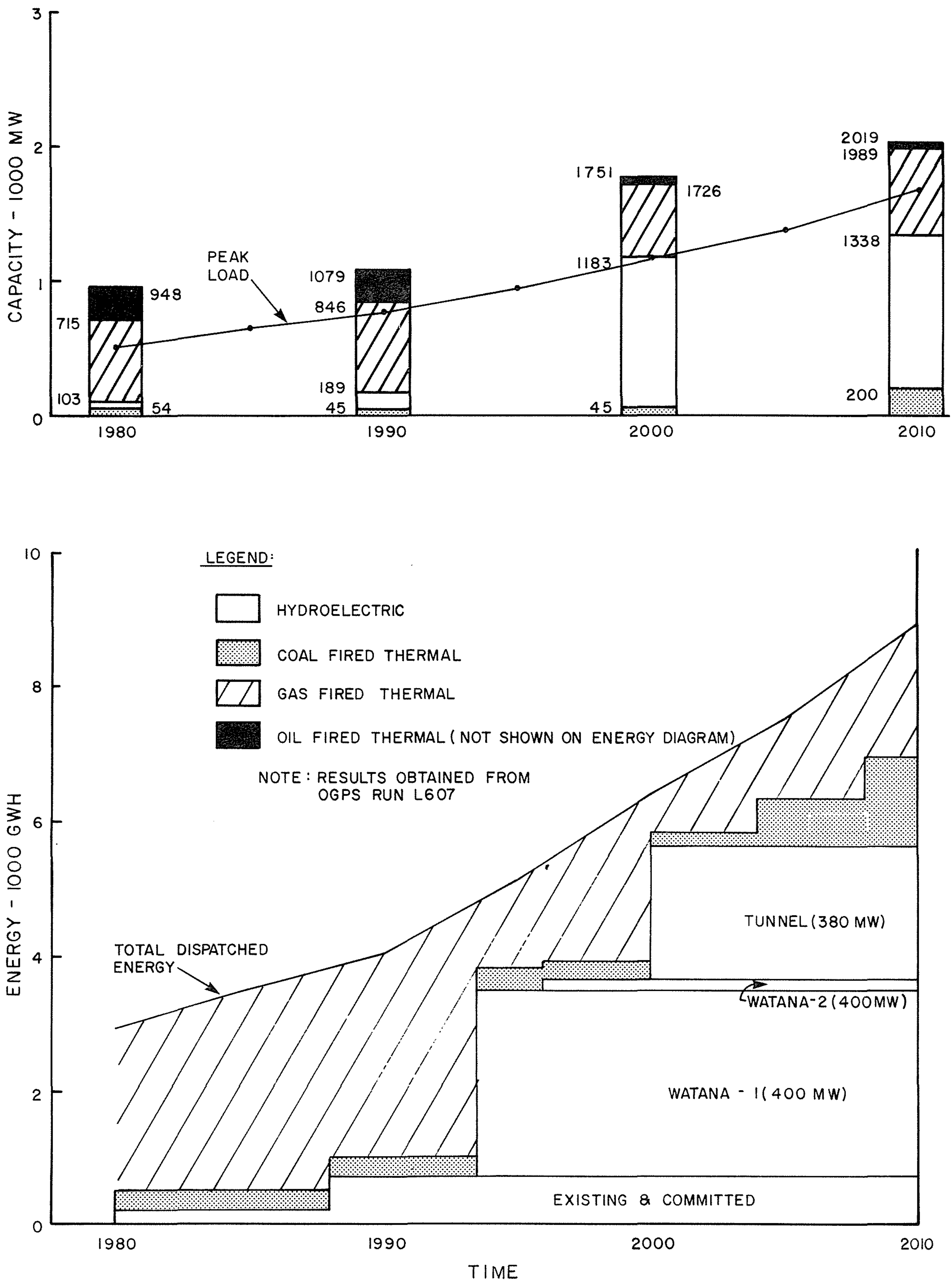
FIGURE 8.9



GENERATION SCENARIO WITH SUSITNA PLAN E 2.3
- MEDIUM LOAD FORECAST -

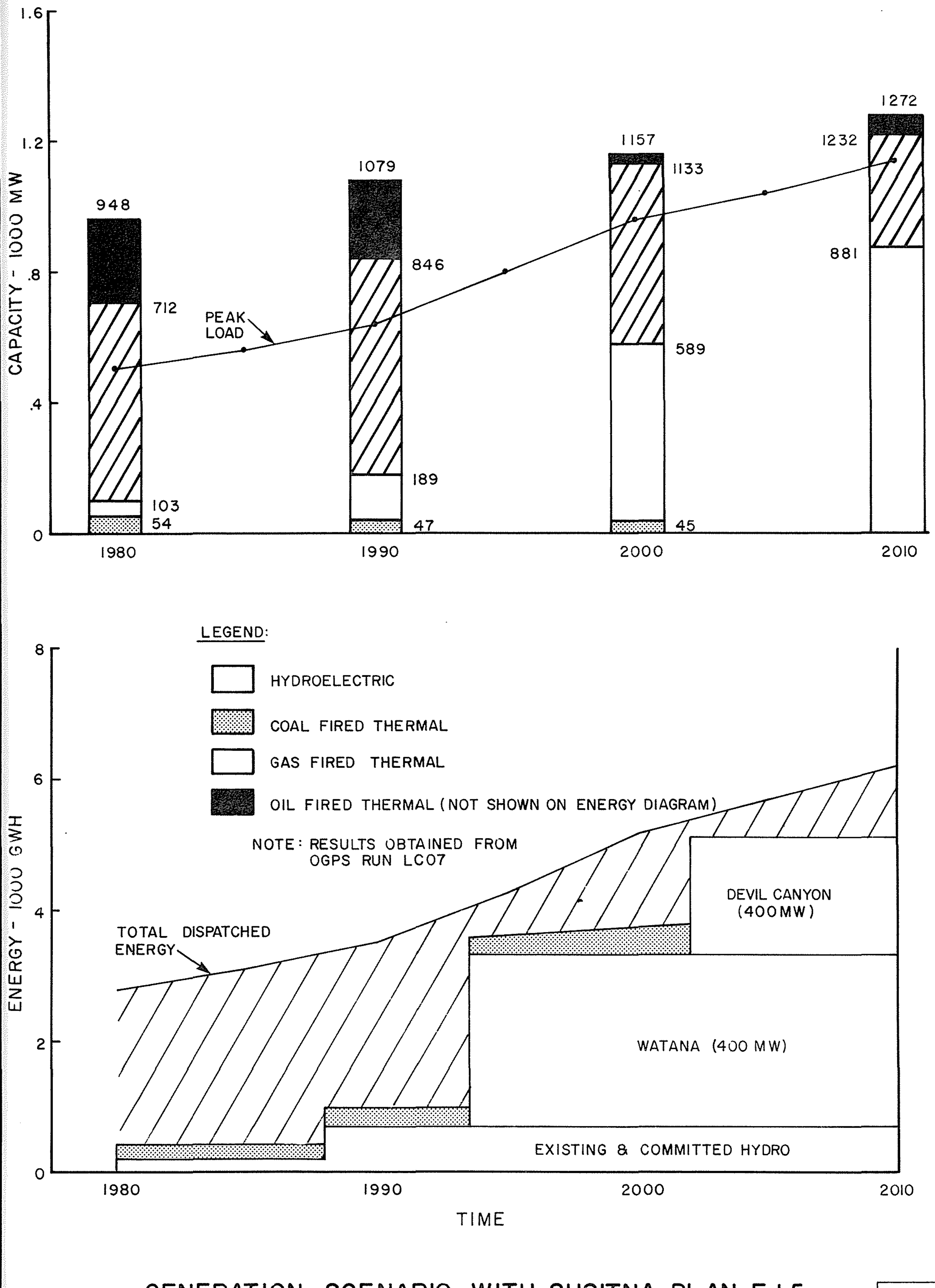
FIGURE 8.10

ACRES



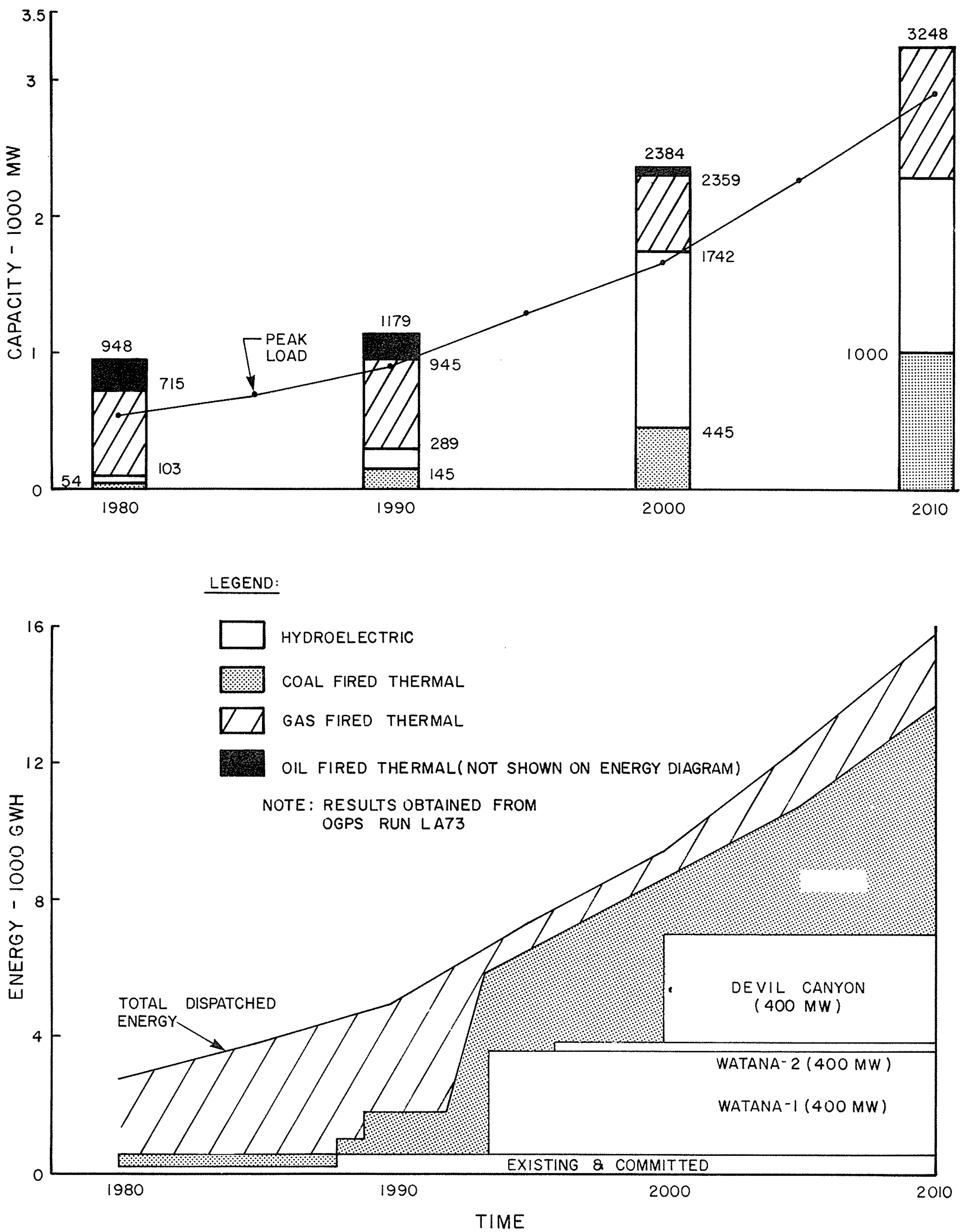
GENERATION SCENARIO WITH SUSITNA PLAN E3.1
- MEDIUM LOAD FORECAST -

FIGURE 8.11



GENERATION SCENARIO WITH SUSITNA PLAN E 1.5
- LOW LOAD FORECAST -

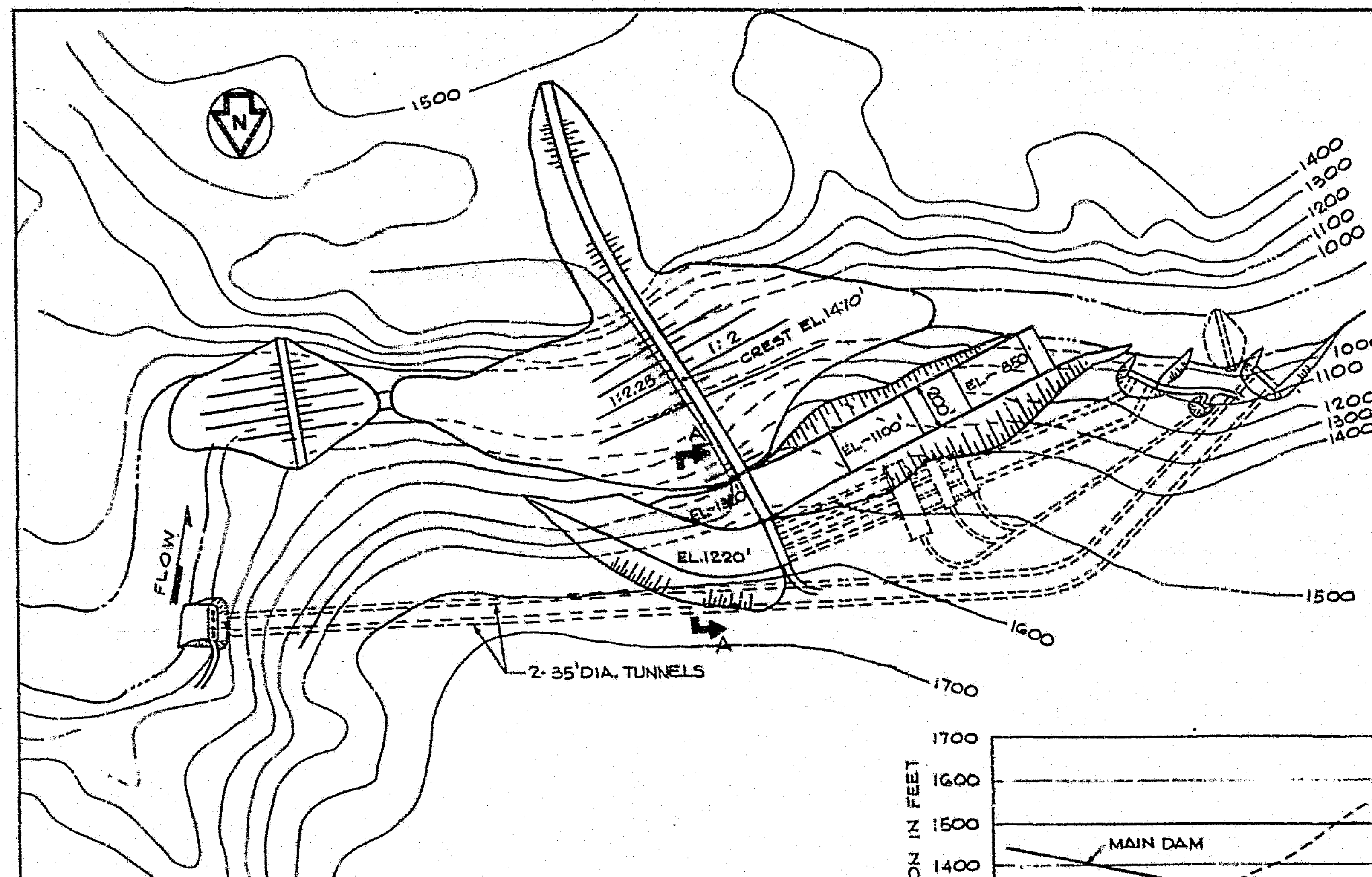
FIGURE 8.12



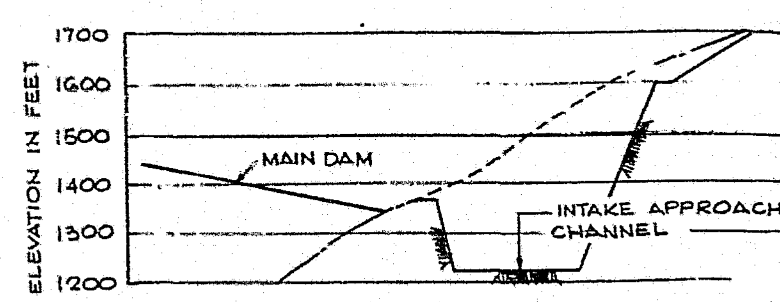
GENERATION SCENARIO WITH SUSITNA PLAN E1.3
HIGH LOAD FORECAST

FIGURE 8.13

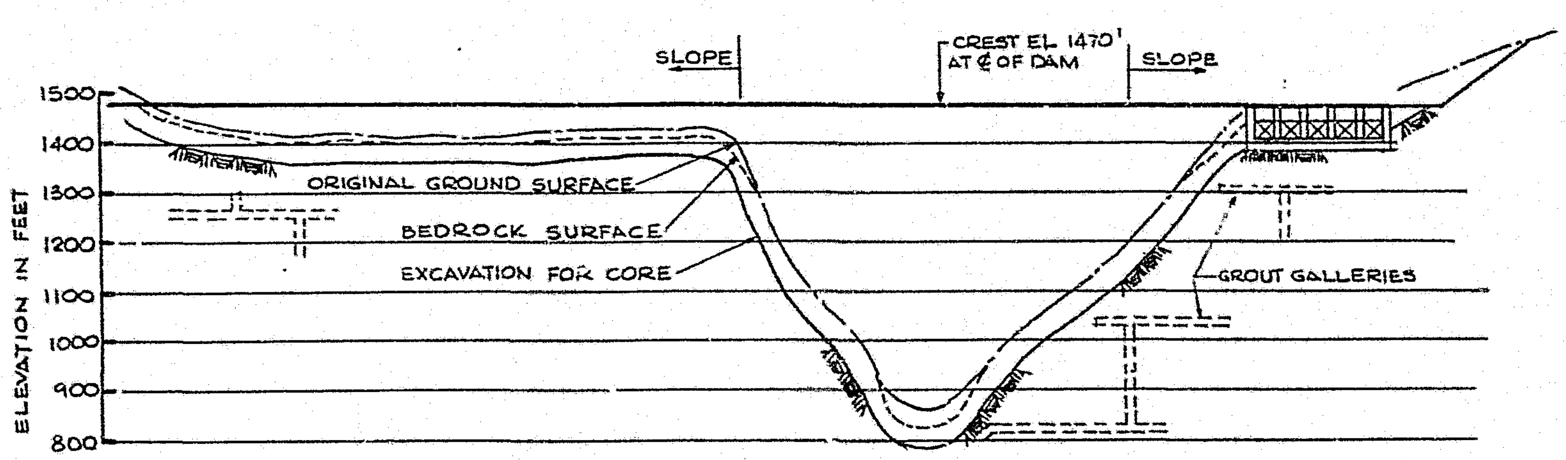
ACRES



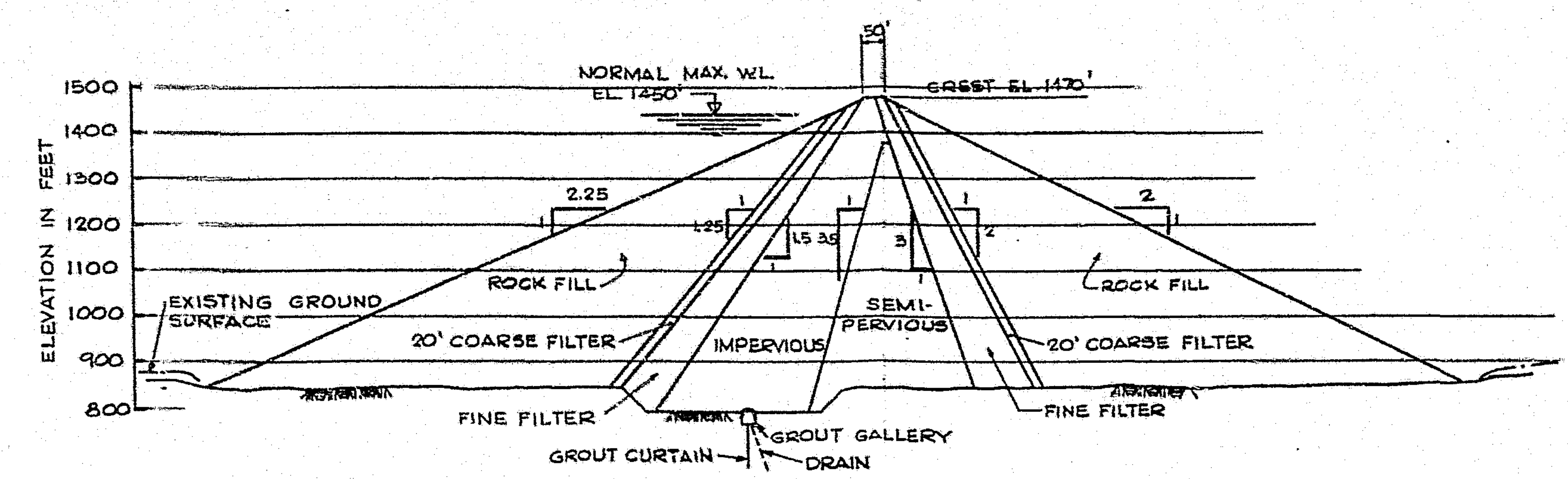
GENERAL ARRANGEMENT
SCALE: A



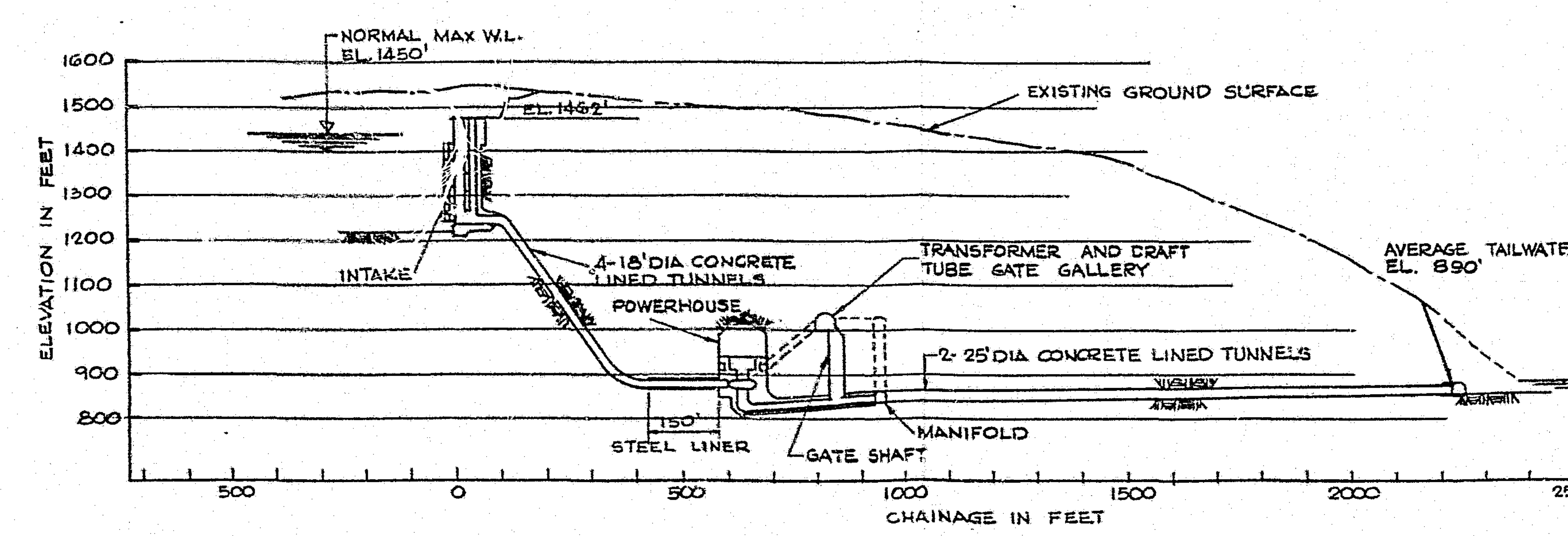
SECTION A-A
SCALE: B



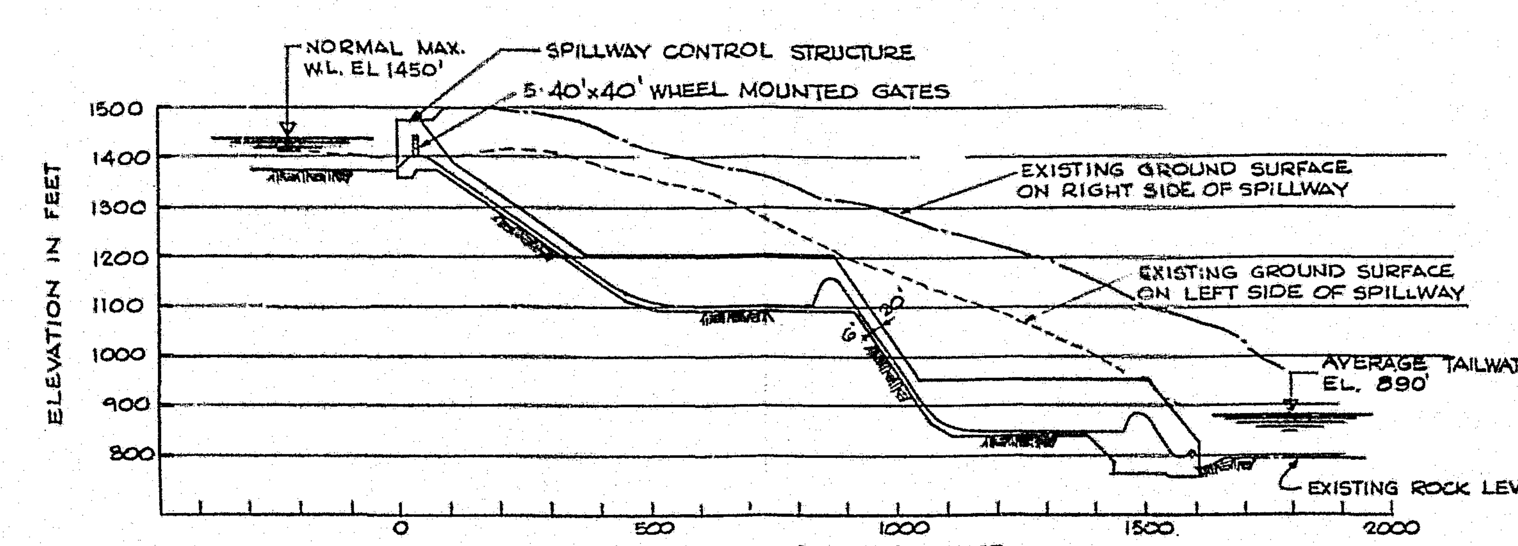
LONGITUDINAL SECTION THRU ¢ OF DAM
SCALE : B



SECTION THRU DAM
SCALE: B



POWER FACILITIES PROFILE
SCALE: B



SPILLWAY PROFILE
SCALE: B

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

PLATE I

ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
HYDRO DEVELOPMENT
FILL DAM

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED

DATE DEC. 1981

DEPARTMENT

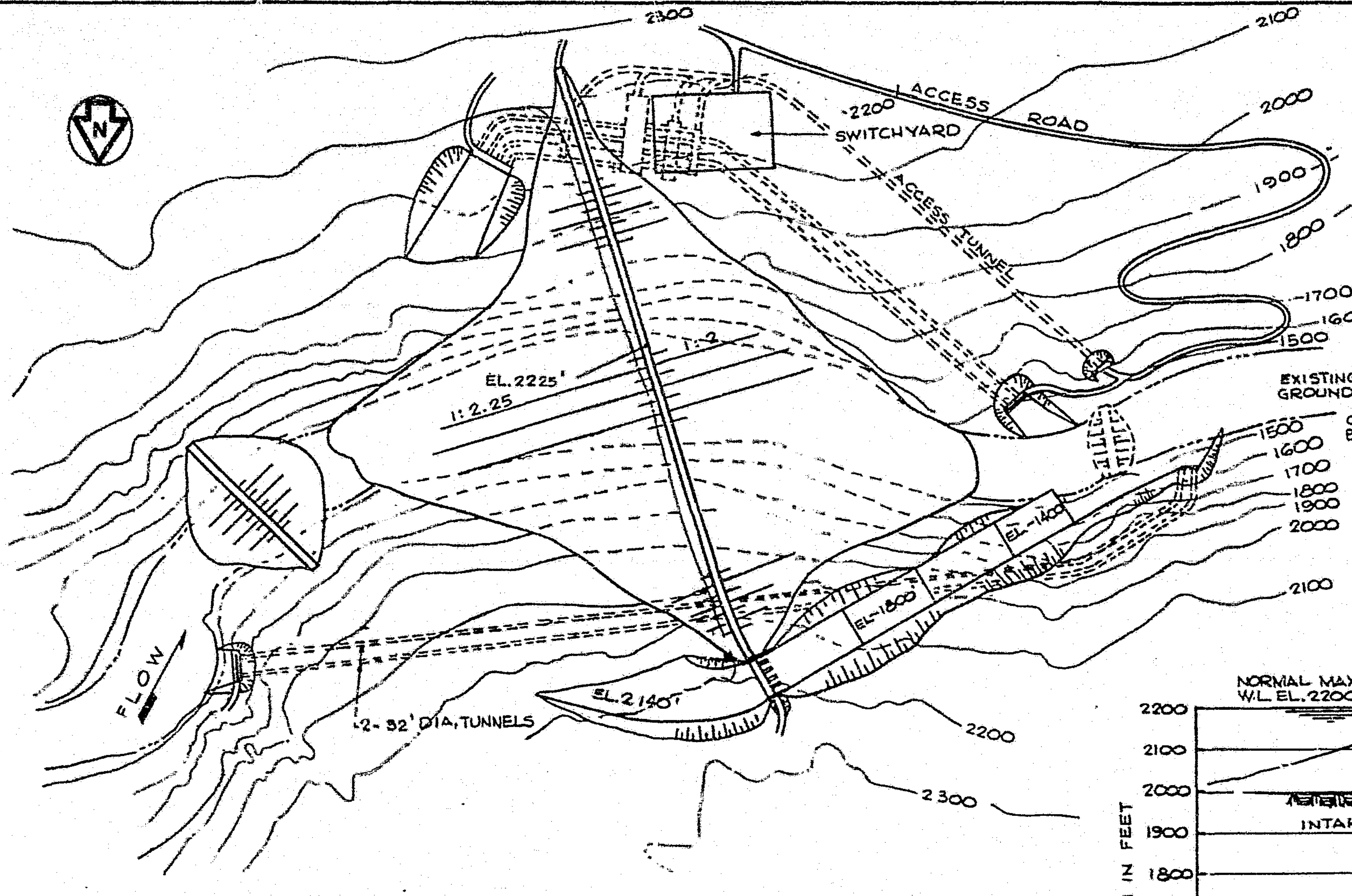
PROJECT

SCALE AS SHOWN

DRAWING NO. SK-5700-CG-102

SHEET OF

REV.



GENERAL ARRANGEMENT
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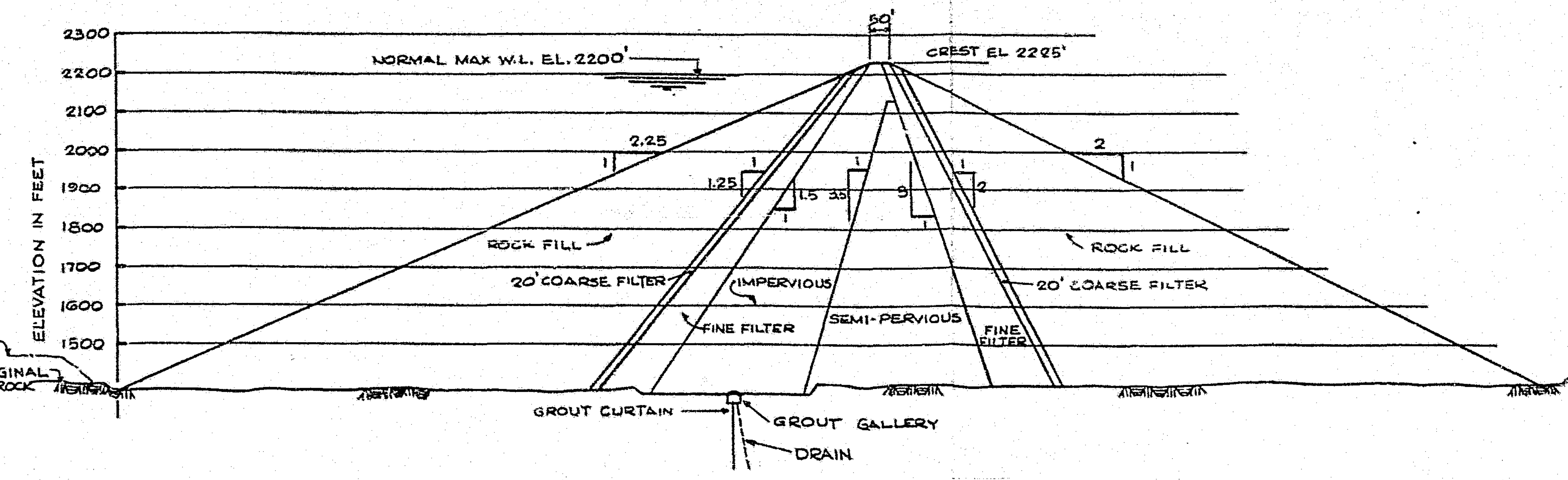

SECTION THRU DAM
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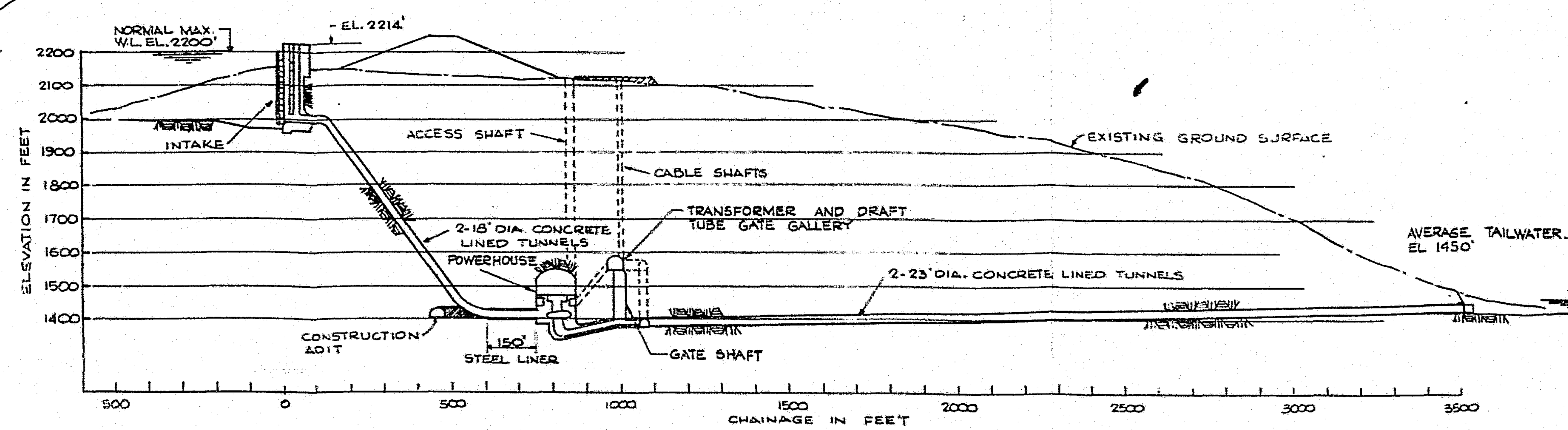
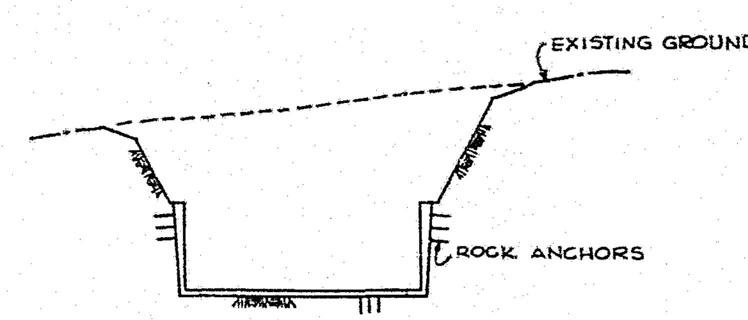
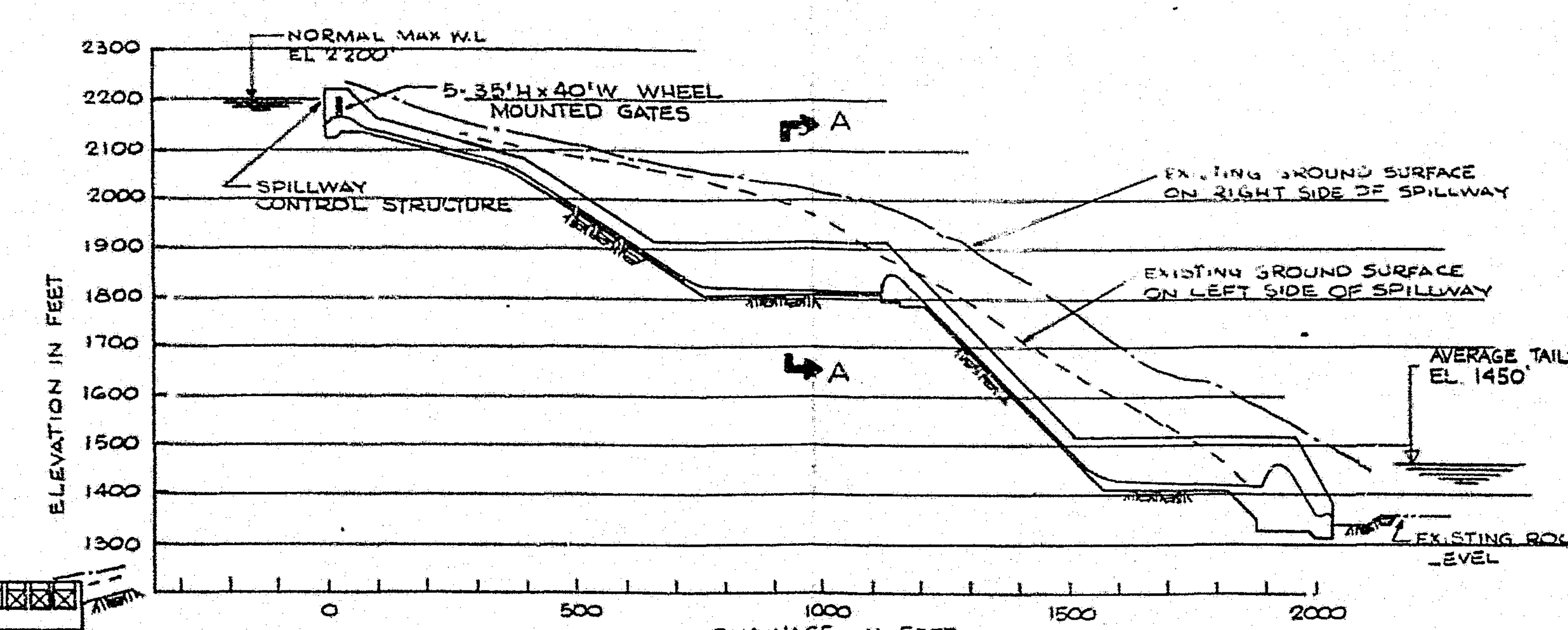


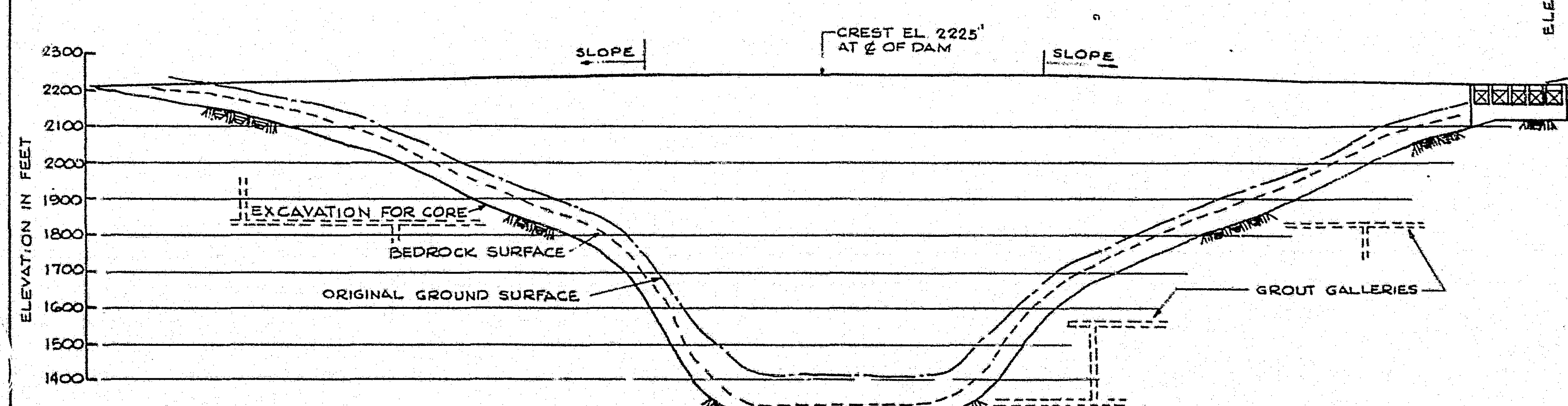
POWER FACILITIES PROFILE
SCALE: B



SECTION A-A
SCALE: C



SPILLWAY PROFILE
SCALE: B



LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE: B

SCALE A 0 500 1000 FEET

SCALE B 0 200 400 FEET

SCALE C 0 100 200 FEET

PLATE 2

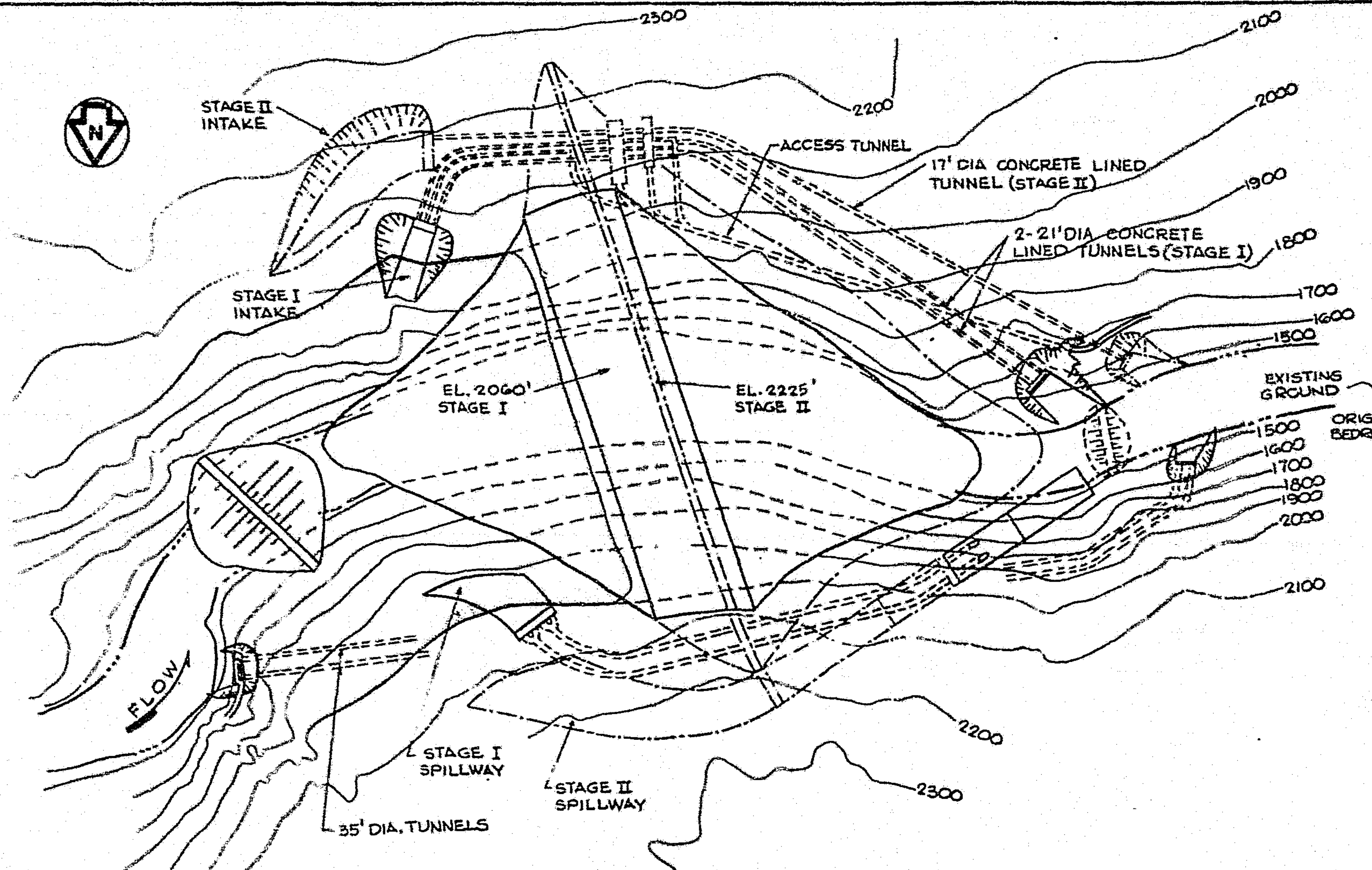
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

WATANA
HYDRO DEVELOPMENT
FILL DAM

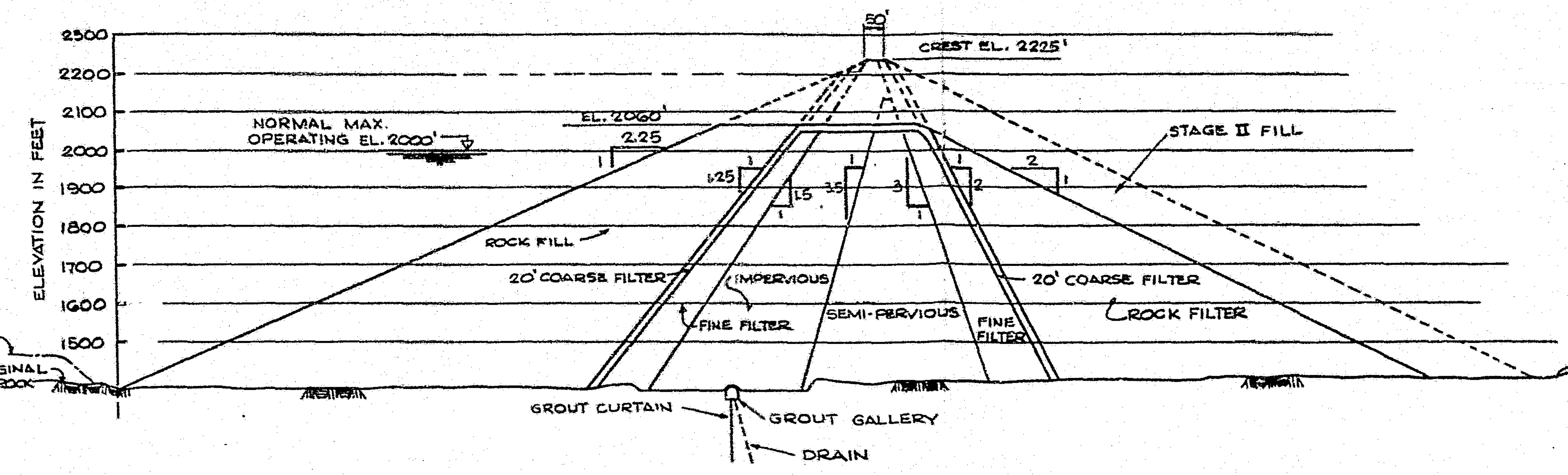
DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED

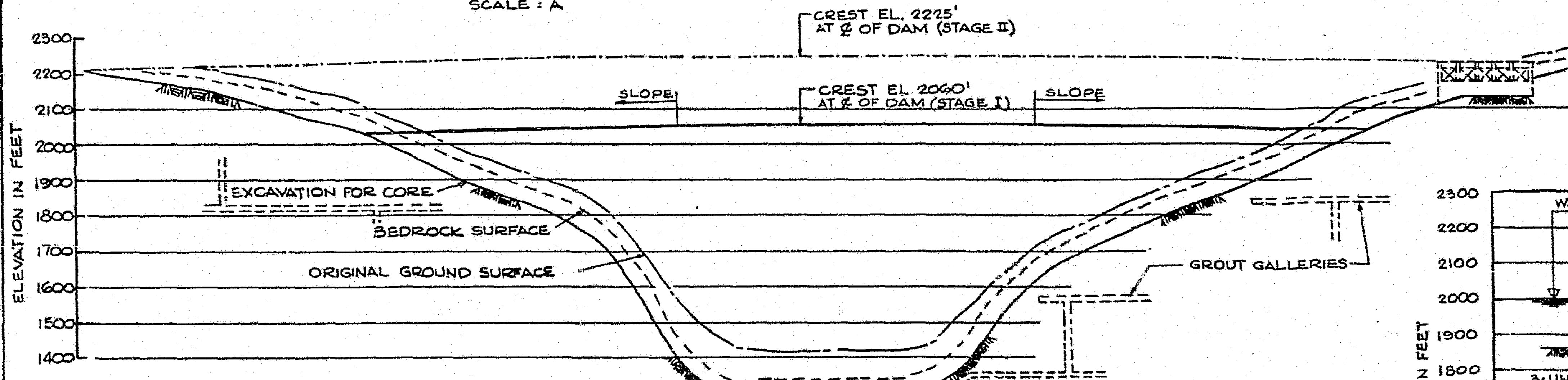
DATE DEC. 1981 | SCALE AS SHOWN
DEPARTMENT | DRAWING NO. SK-5700-C6-103
PROJECT | SHEET OF



GENERAL ARRANGEMENT
SCALE : A



SECTION THRU DAM
SCALE: B



LONGITUDINAL SECTION THRU ℄ OF DAM
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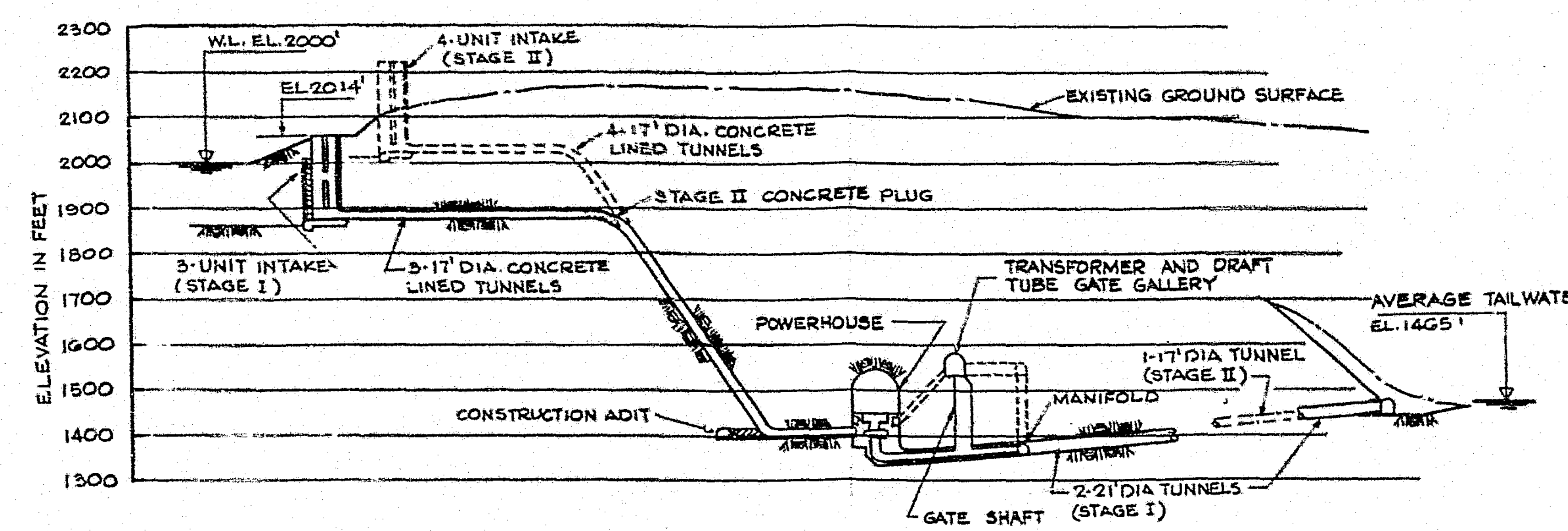
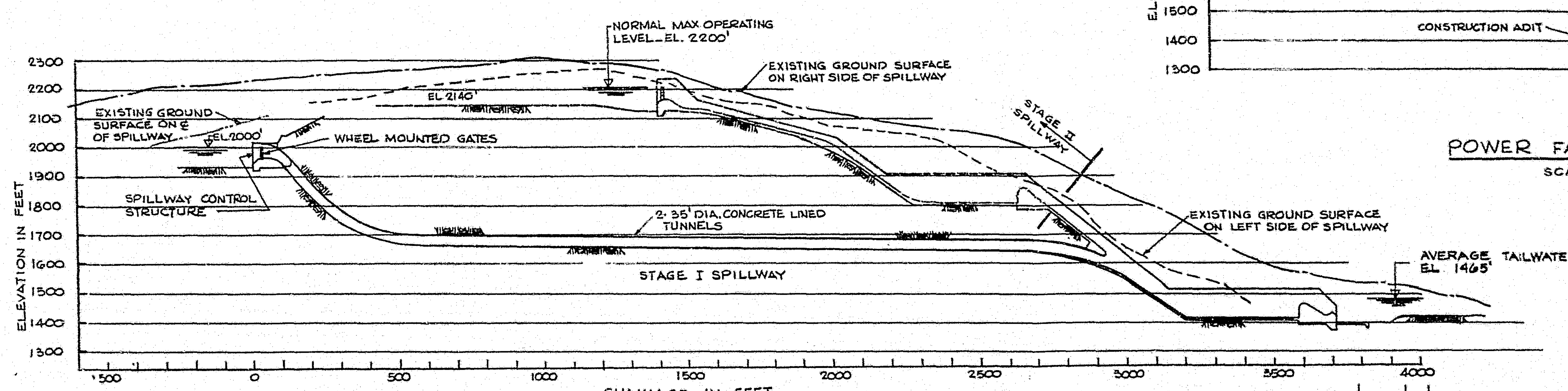


POWER FACILITIES PROFILE
SCALE: B



SPILLWAY PROFILE
SCALE: B

SCALE A 0 500 1000 FEET

SCALE B 0 200 400 FEET

PLATE 3

ACRES

ALASKA POWER AUTHORITY

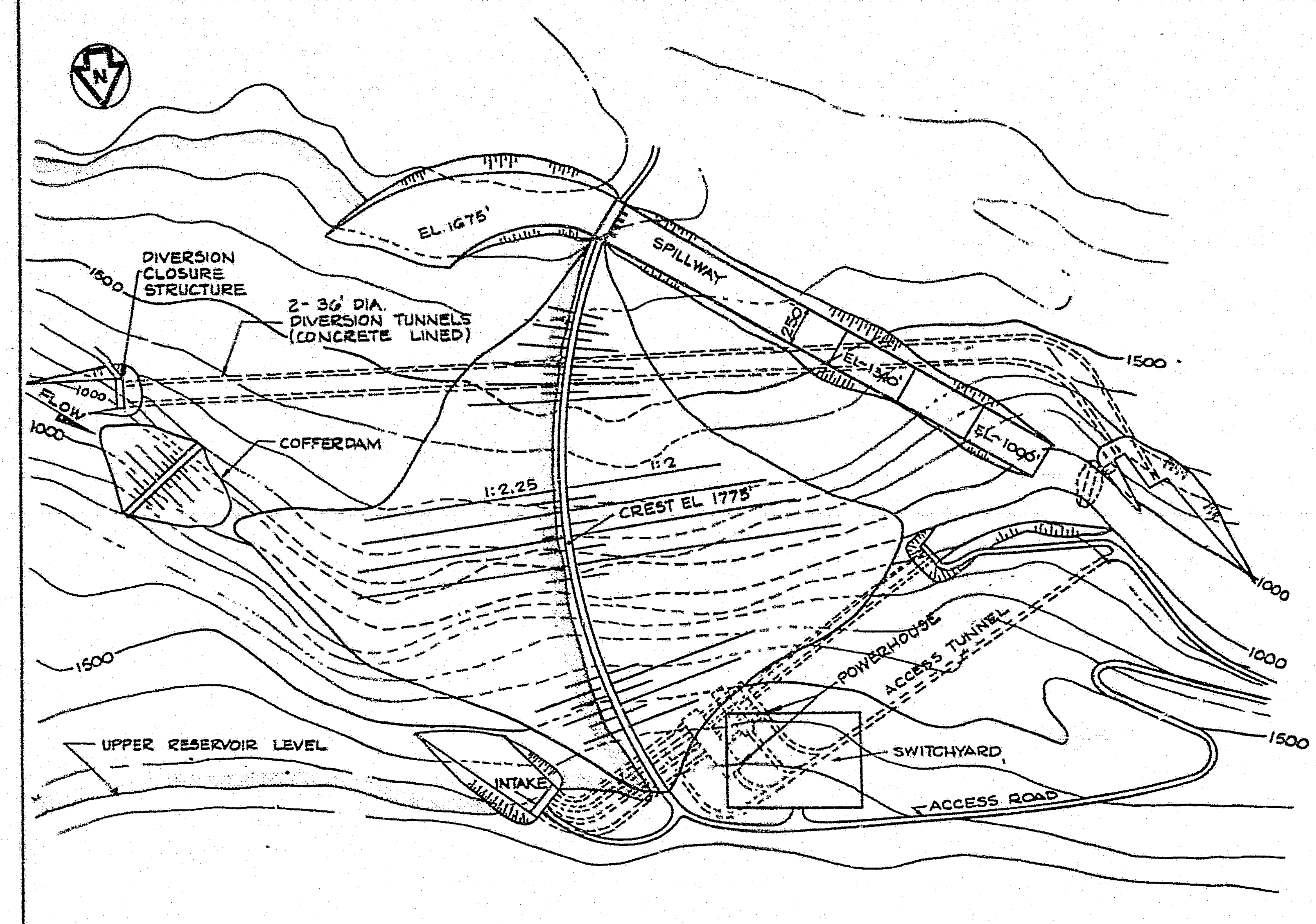
SUSITNA HYDROELECTRIC PROJECT

WATANA
STAGED FILL DAM

DATE	NO.	REVISIONS	CH.	APP.	APP.

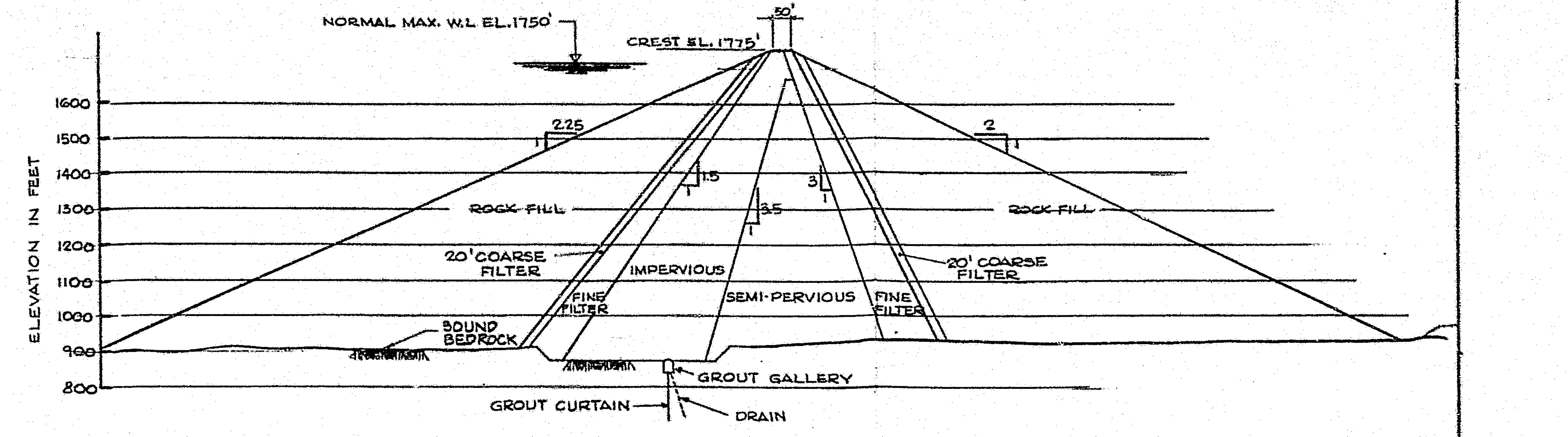
ACRES AMERICAN INCORPORATED

DATE DEC. 1981 | SCALE AS SHOWN
DEPARTMENT | DRAWING NO. SK-5700-C8-104 | REV. A
PROJECT | SHEET OF



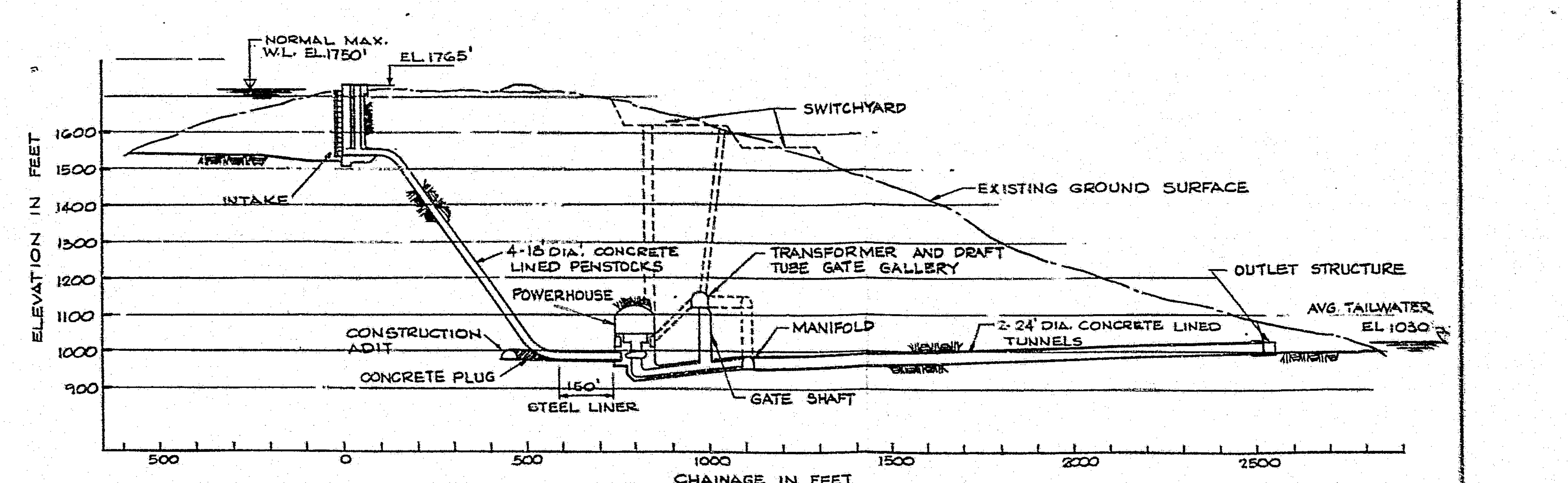
GENERAL ARRANGEMENT

SCALE: A



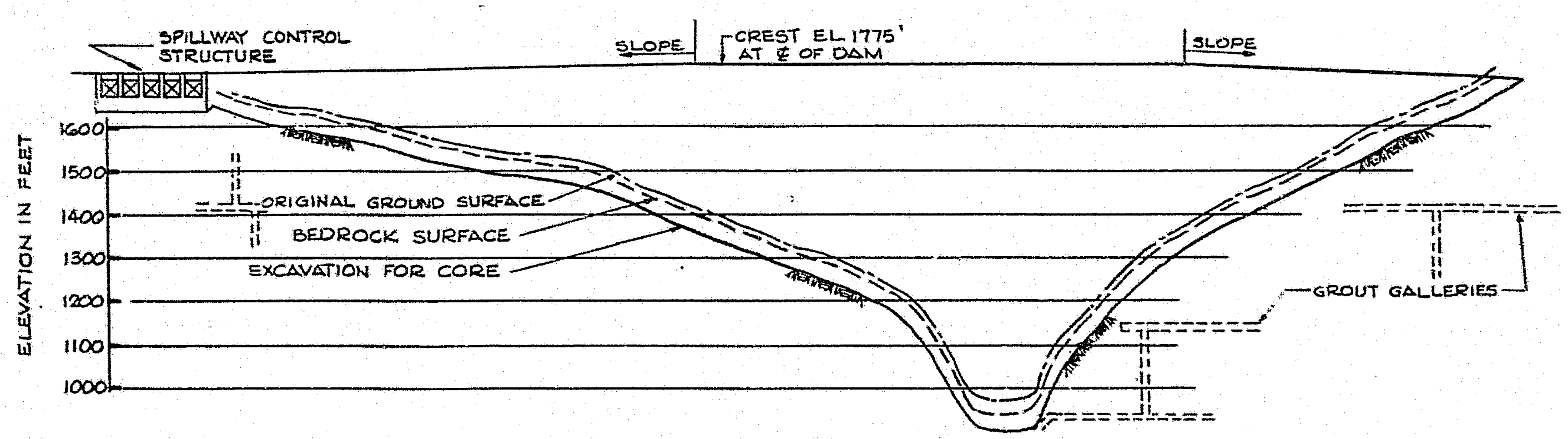
SECTION THRU DAM

SCALE: B



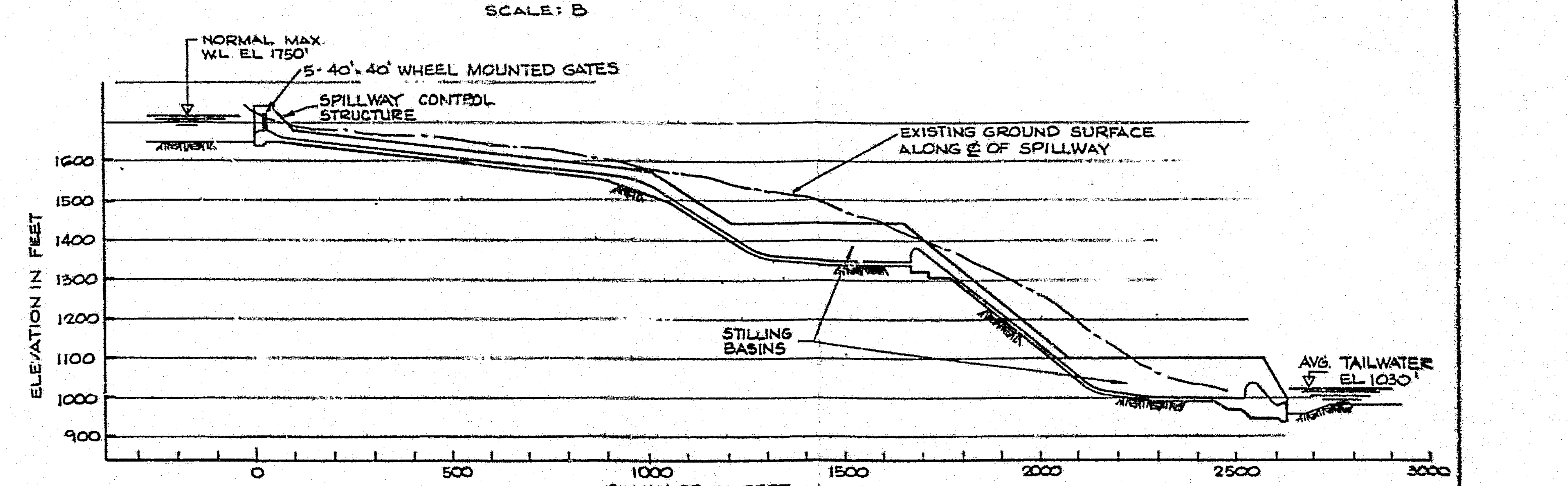
POWER FACILITIES PROFILE

SCALE: B



LONGITUDINAL SECTION THRU ℄ OF DAM

SCALE: B



SPILLWAY PROFILE

SCALE: B

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

PLATE 4

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

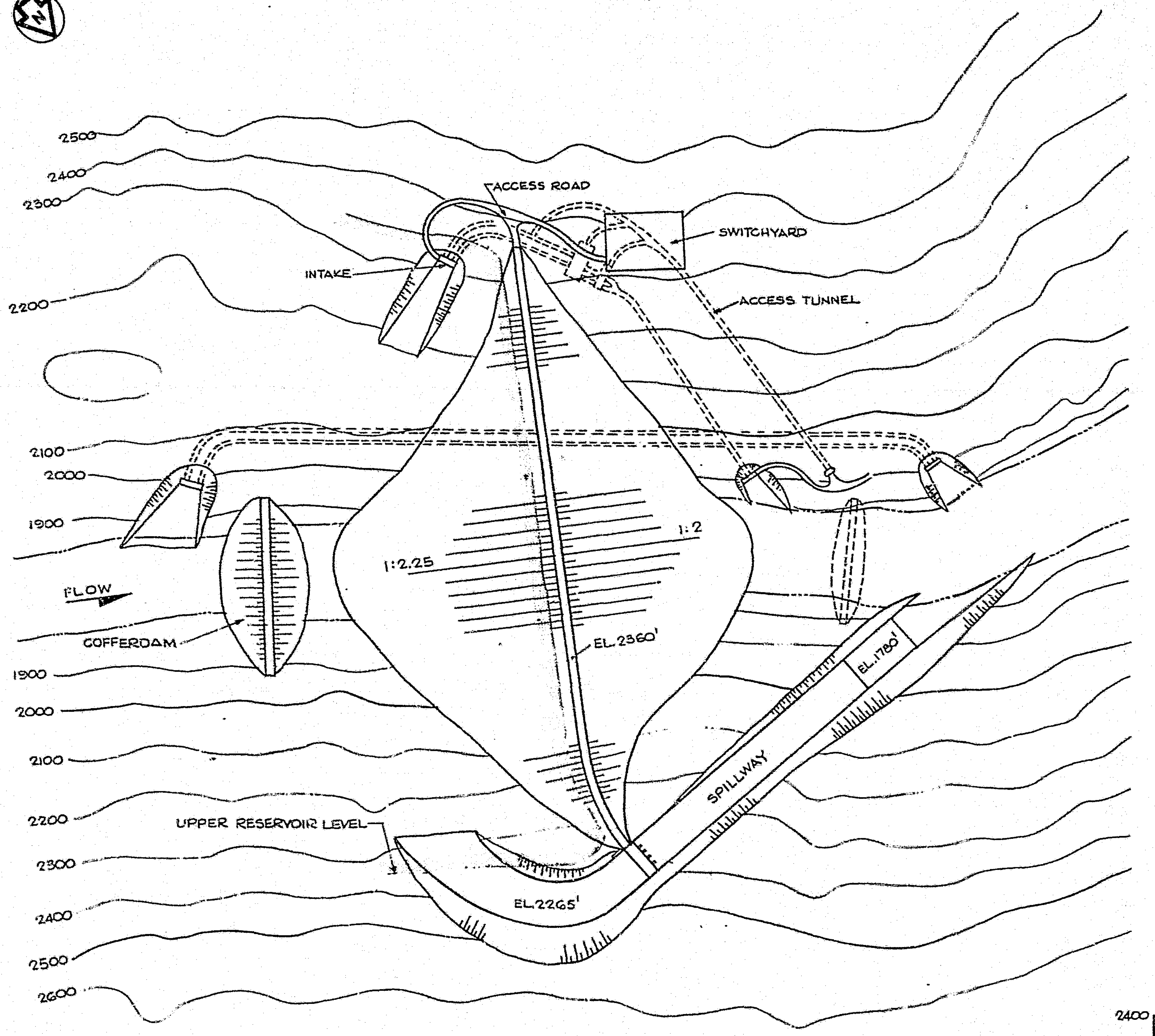
HIGH DEVIL CANYON HYDRO DEVELOPMENT

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED

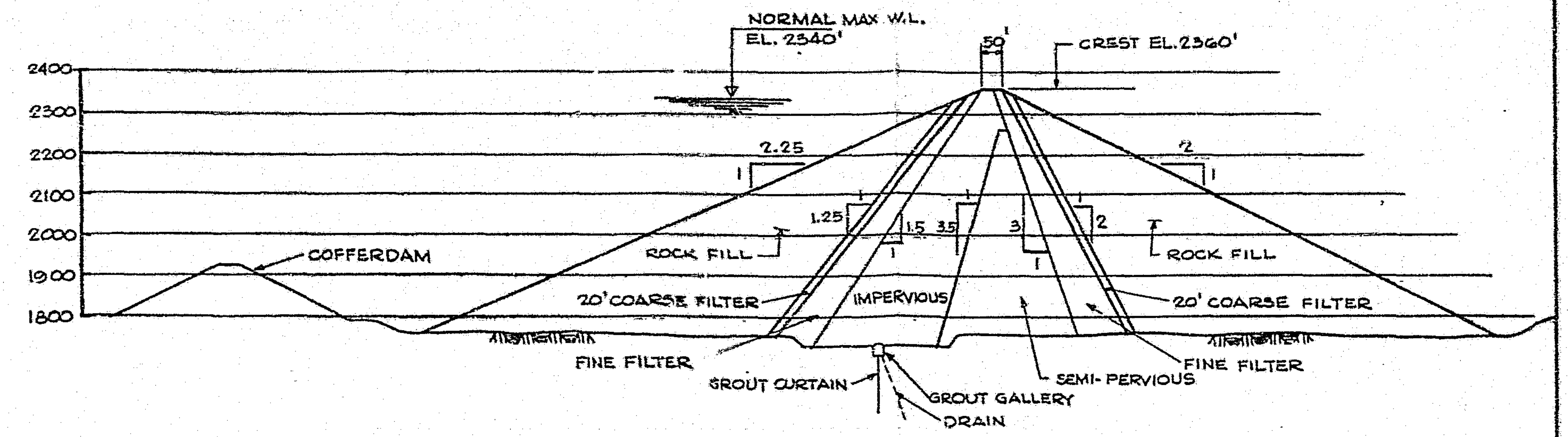
DATE DEC. 1981 | SCALE AS SHOWN | DRAWING NO. 8K-5700-C8-101 | REV. A

DEPARTMENT | PROJECT | SHEET OF



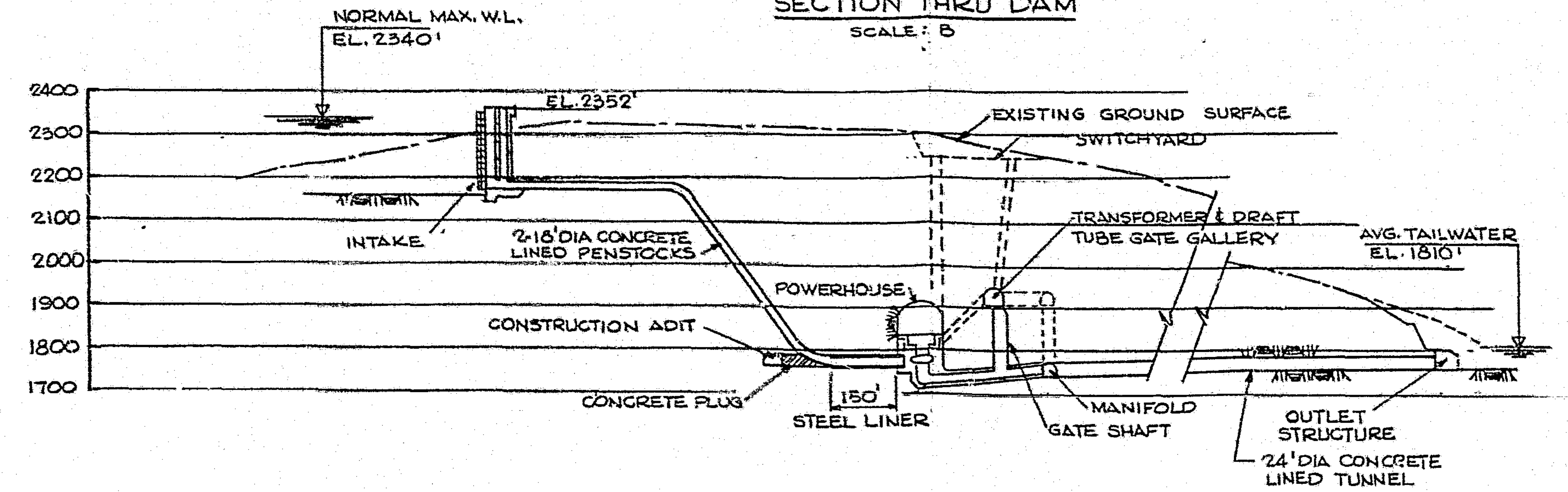
GENERAL ARRANGEMENT

SCALE: A



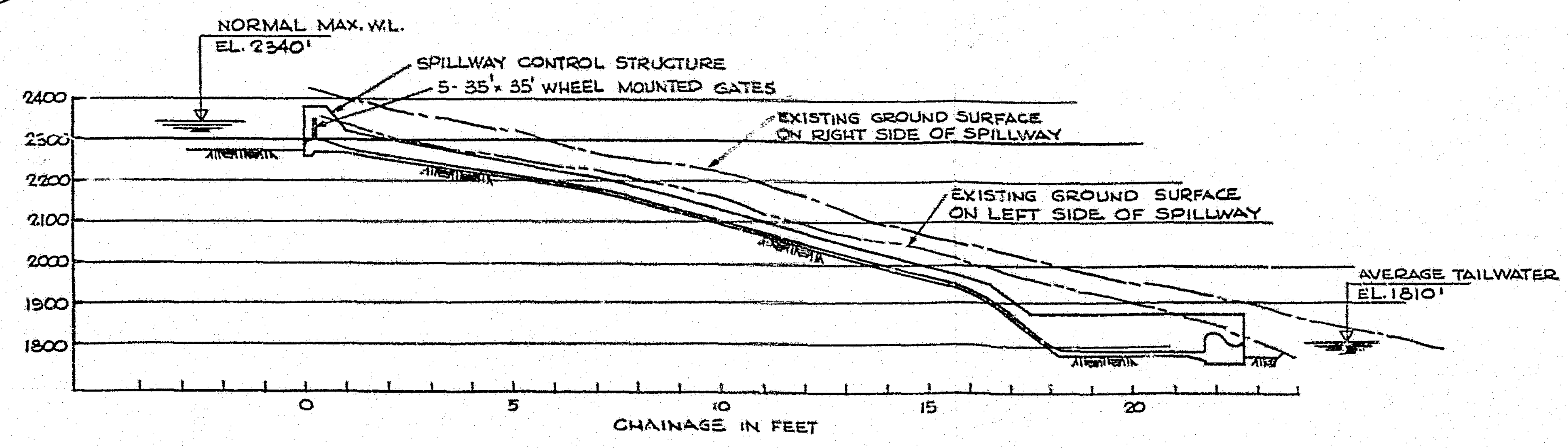
SECTION THRU DAM

SCALE: B



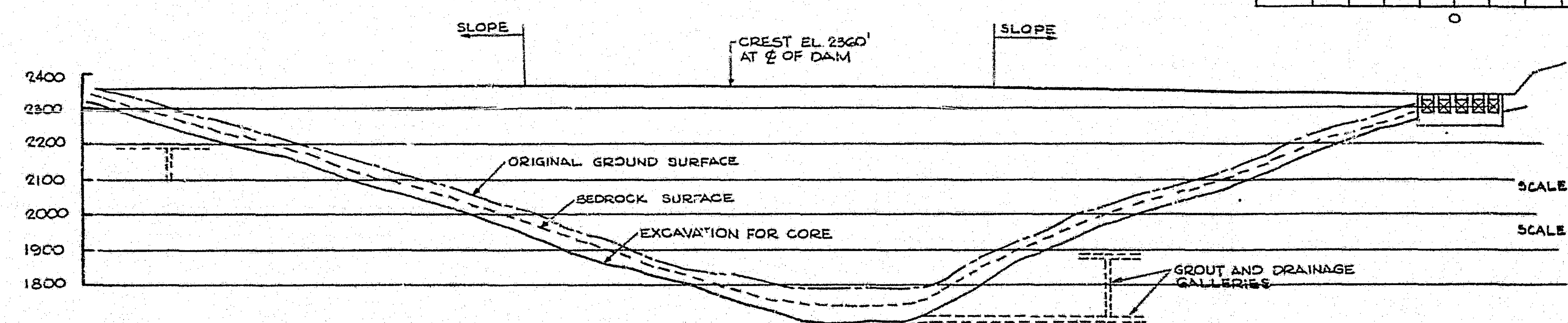
POWER FACILITES PROFILE

SCALE: B



SPILLWAY PROFILE

SCALE: B



LONGITUDINAL SECTION THRU ℄ OF DAM

SCALE: B

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

PLATE 5

ALASKA POWER AUTHORITY

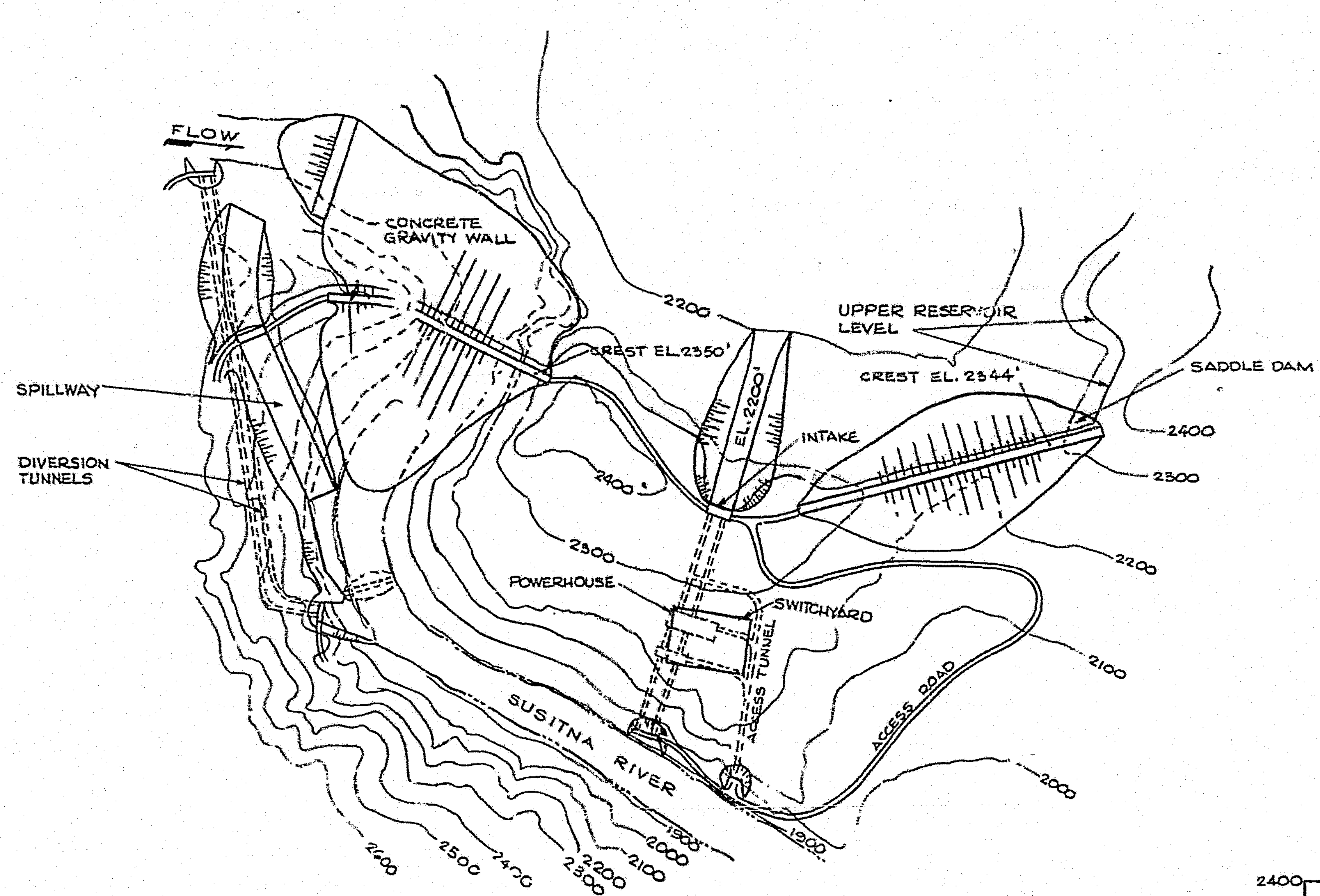
SUSITNA HYDROELECTRIC PROJECT

SUSITNA III
HYDRO DEVELOPMENT

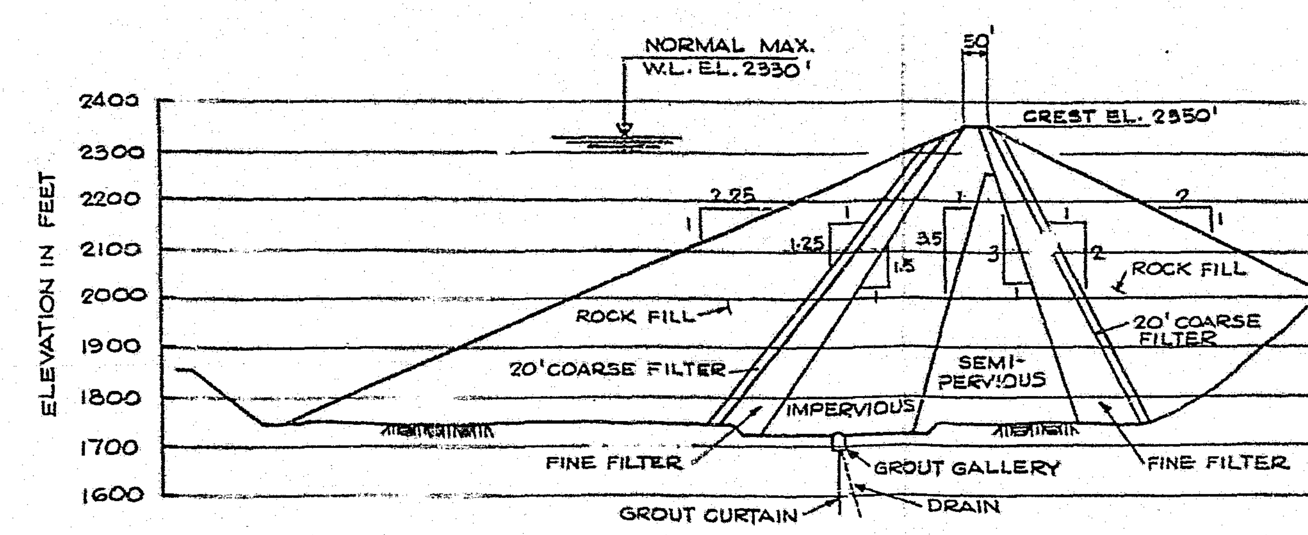
DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED

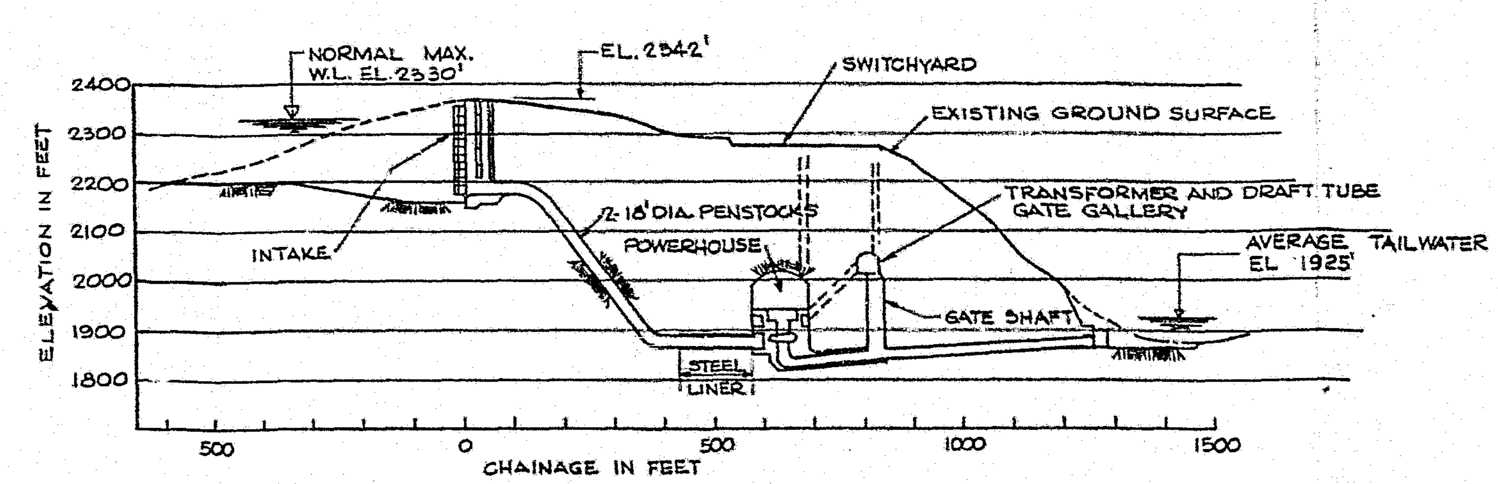
DATE DEC. 1981 | SCALE AS SHOWN | DRAWING NO. SK-5700-C6-109



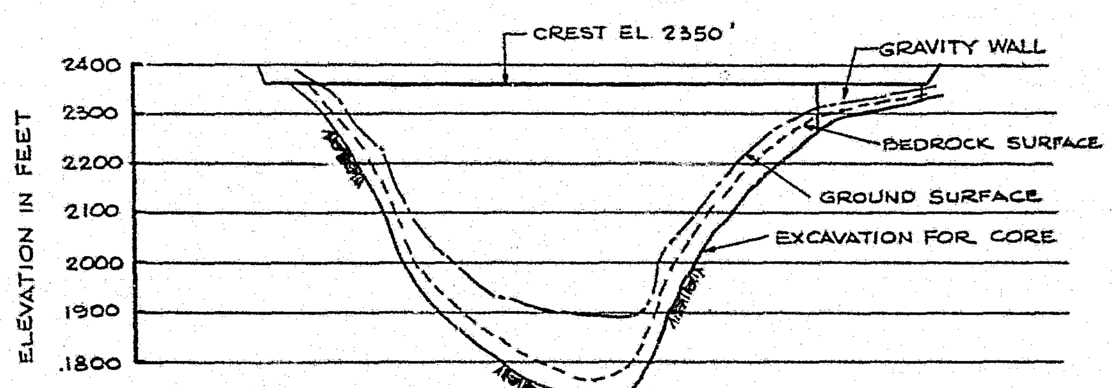
GENERAL ARRANGEMENT
SCALE: A



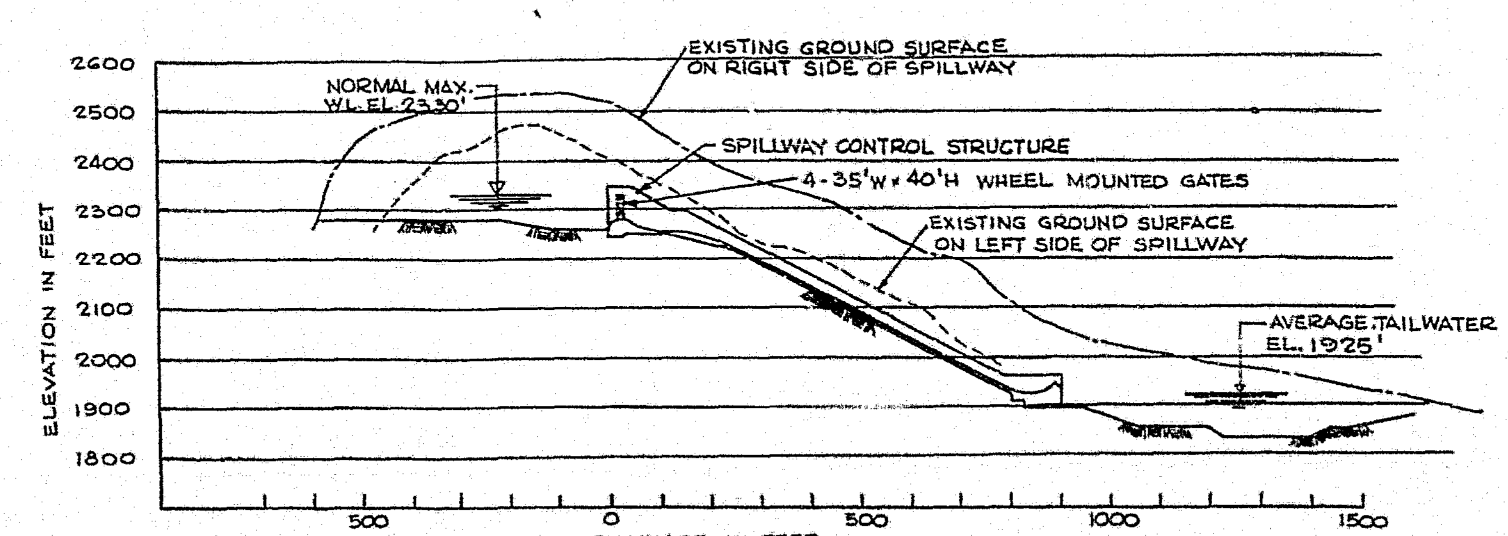
SECTION THRU MAIN DAM
SCALE: B



POWER FACILITIES PROFILE
SCALE: B



LONGITUDINAL SECTION THRU ℄ OF MAIN DAM
SCALE: B



SPILLWAY PROFILE
SCALE: B

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

PLATE 6

ALASKA POWER AUTHORITY

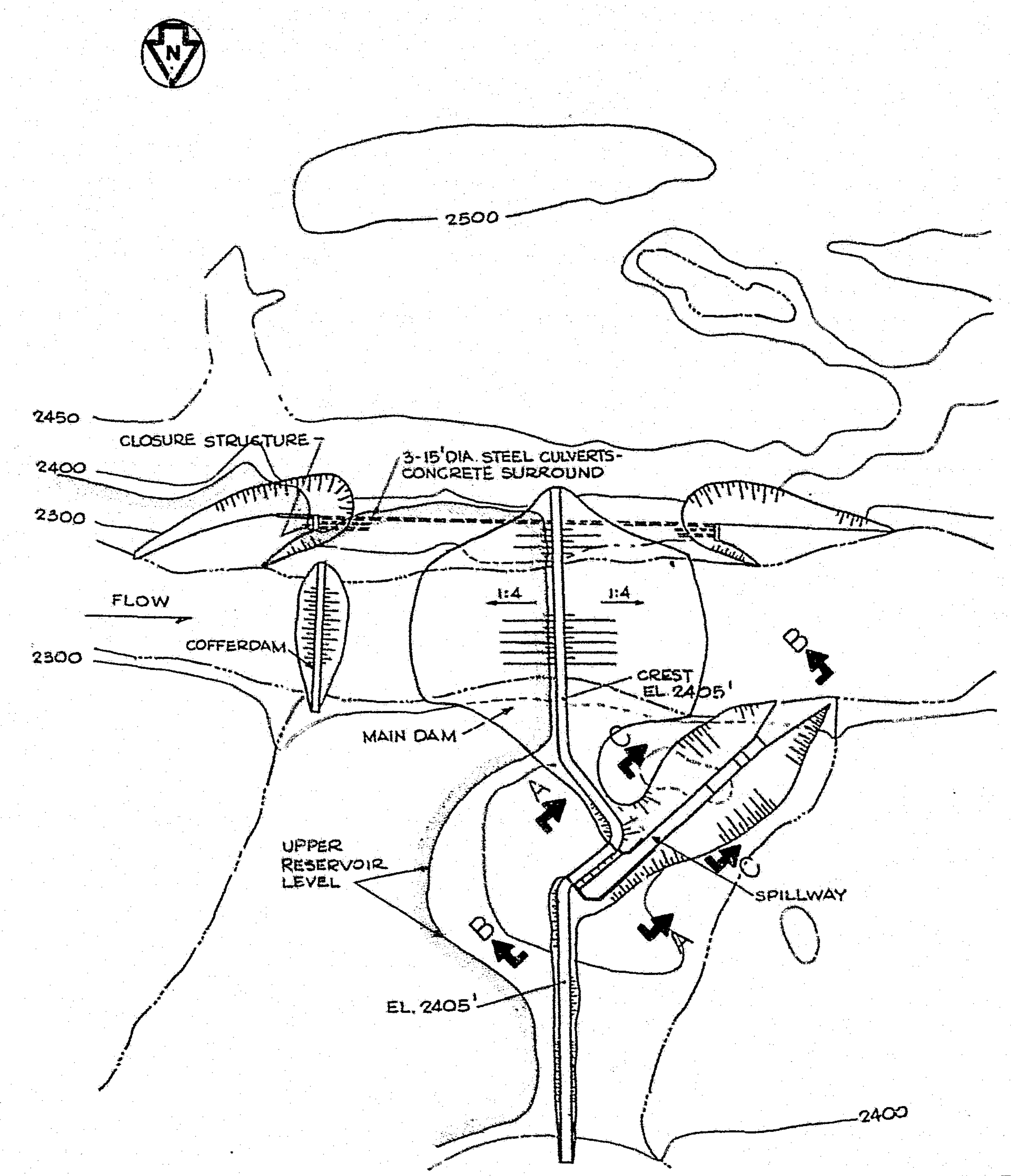
SUSITNA HYDROELECTRIC PROJECT

VEE
HYDRO DEVELOPMENT

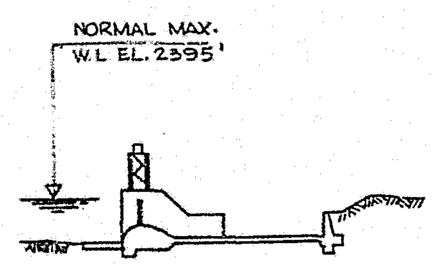
DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED

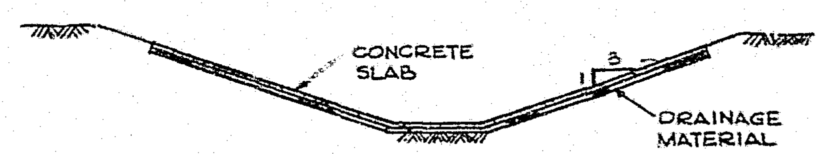
DATE DEC. 1981 | SCALE AS SHOWN
DEPARTMENT | DRAWING NO. SK-5700-C6-107 | REV.
PROJECT | SHEET OF



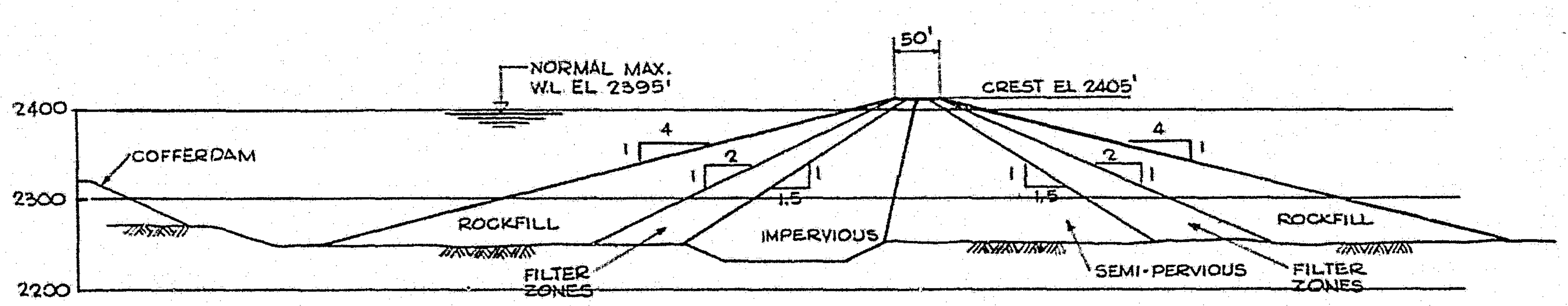
MACLAREN
GENERAL ARRANGEMENT
SCALE: A



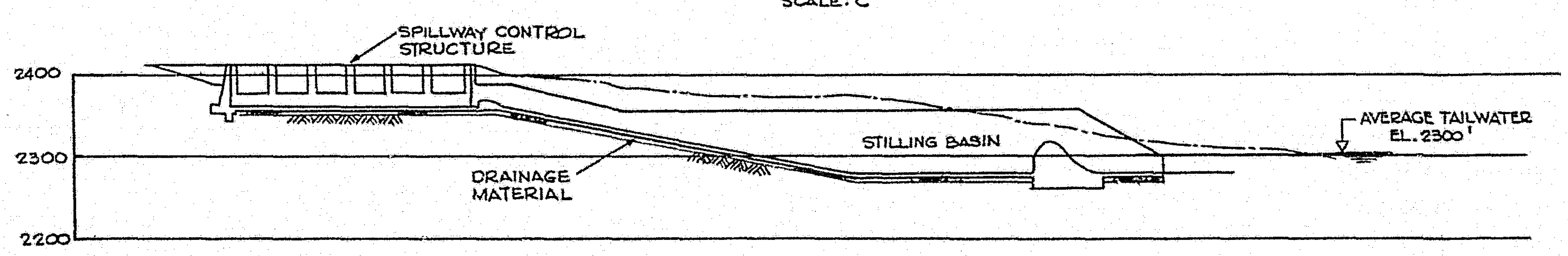
SECTION A-A



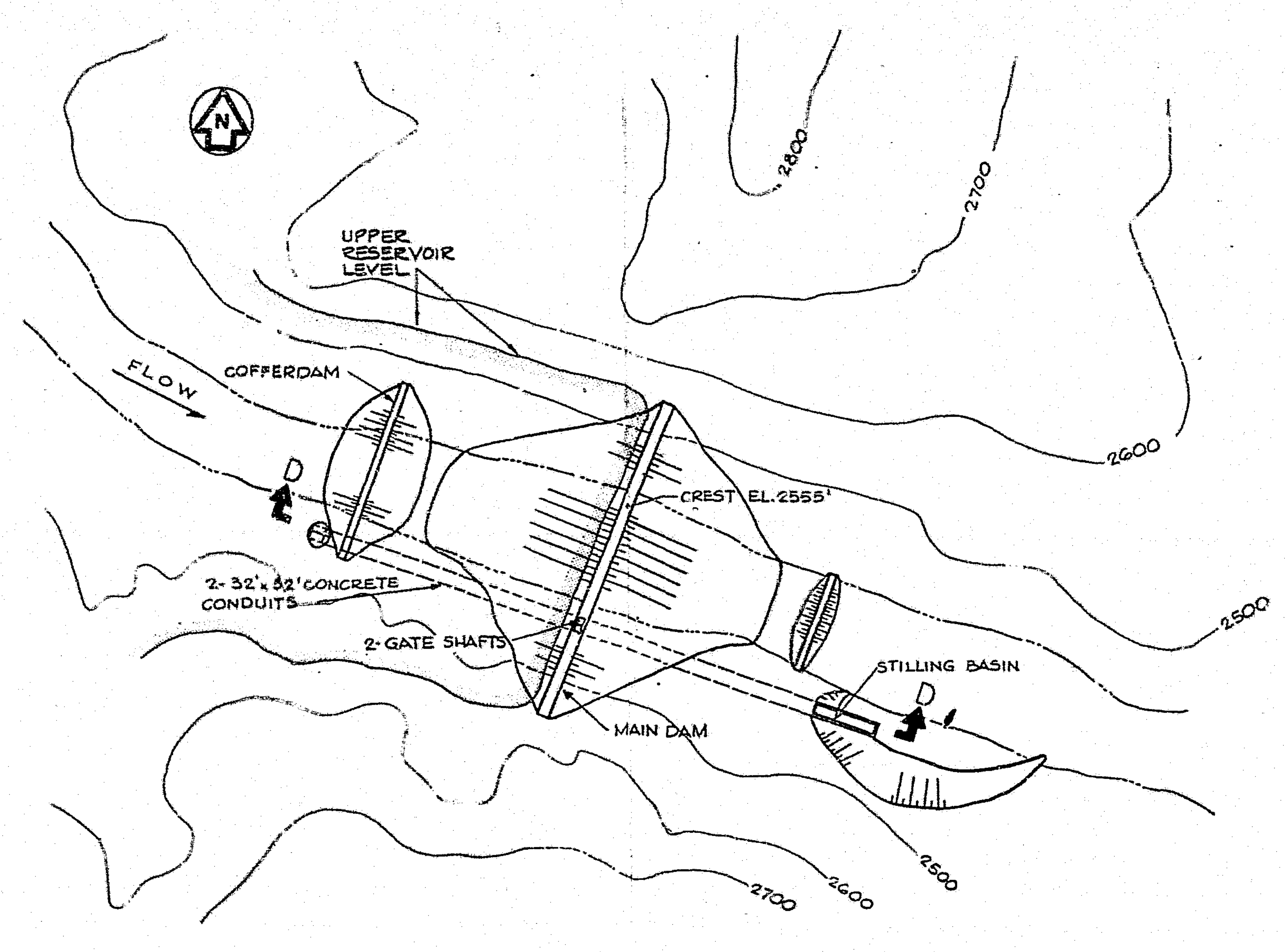
SECTION C-C



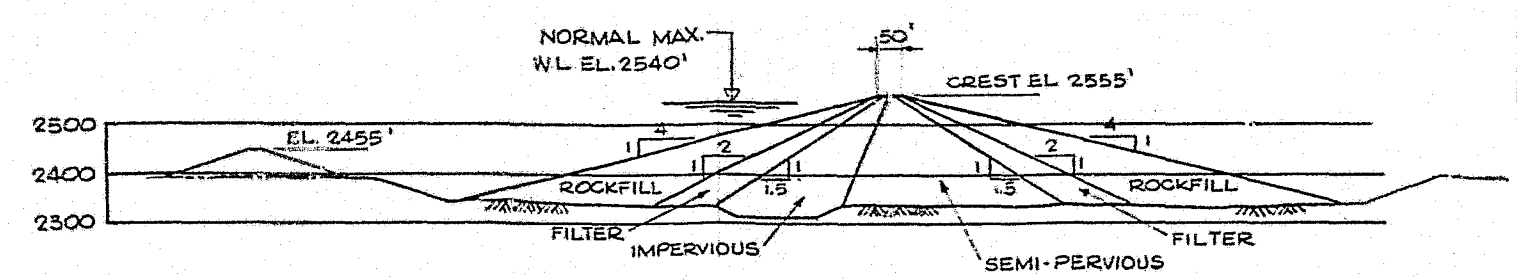
DAM CROSS SECTION
SCALE: C



SECTION B-B
SCALE: C



DENALI
GENERAL ARRANGEMENT
SCALE: A.



DAM CROSS SECTION
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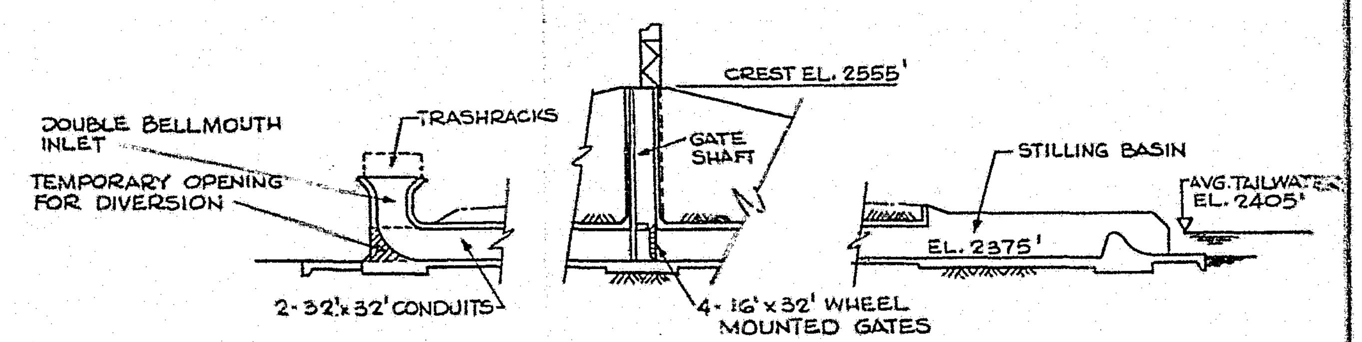


SECTION D-D
SCALE: C

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

SCALE C 0 100 200 FEET

PLATE 7

ALASKA POWER AUTHORITY

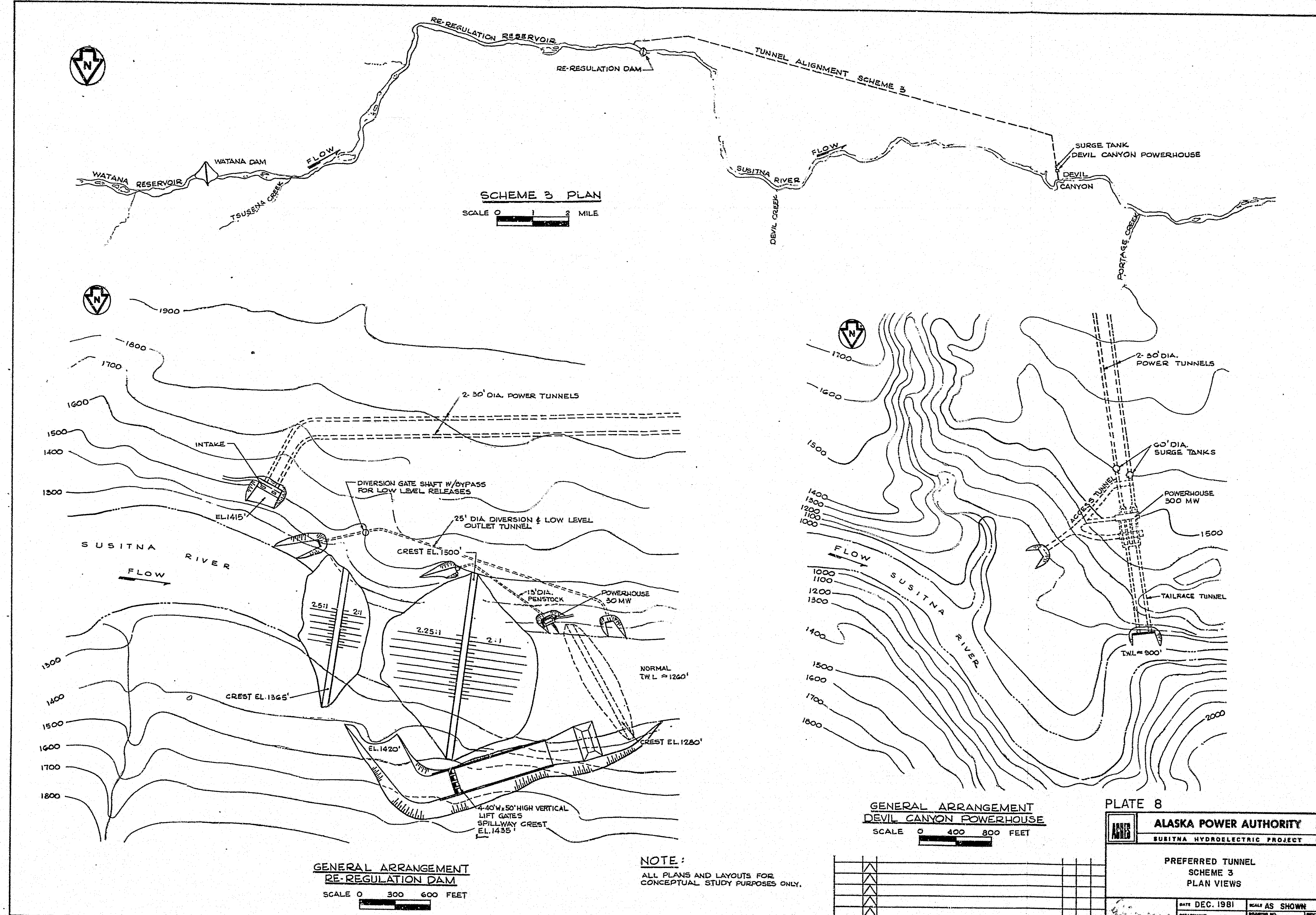
SUSITNA HYDROELECTRIC PROJECT

DENALI & MACLAREN
HYDRO DEVELOPMENTS

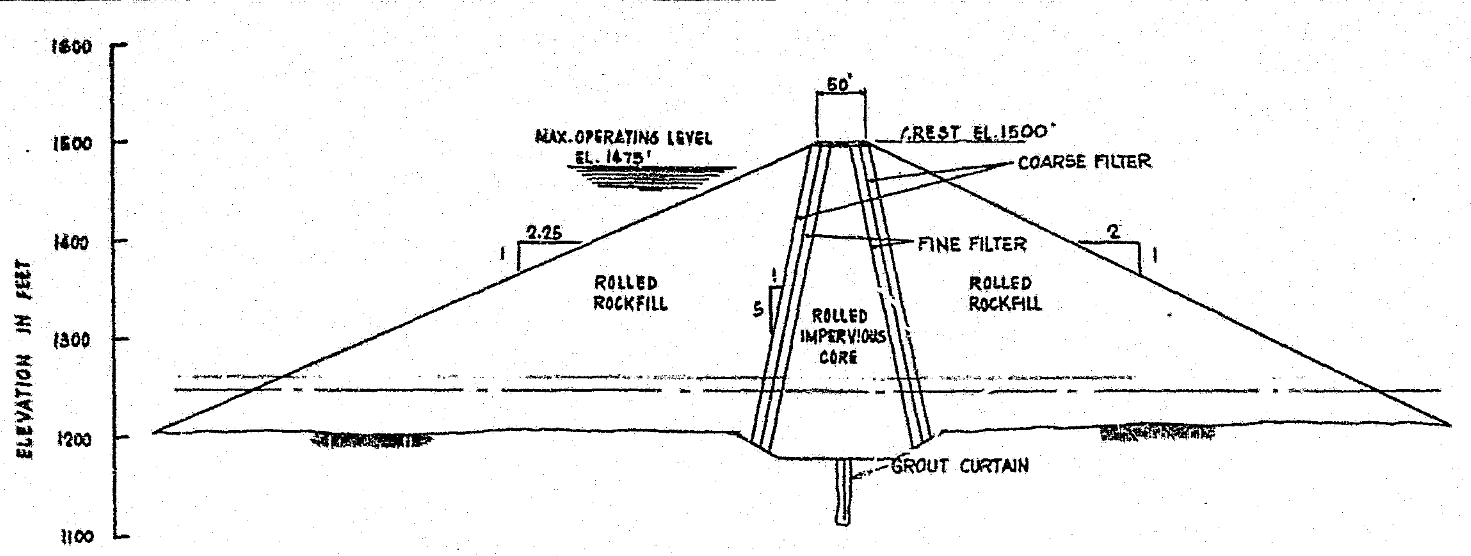
DATE DEC. 1981 | SCALE AS SHOWN

DRAWING NO. SK-5700-C6-106

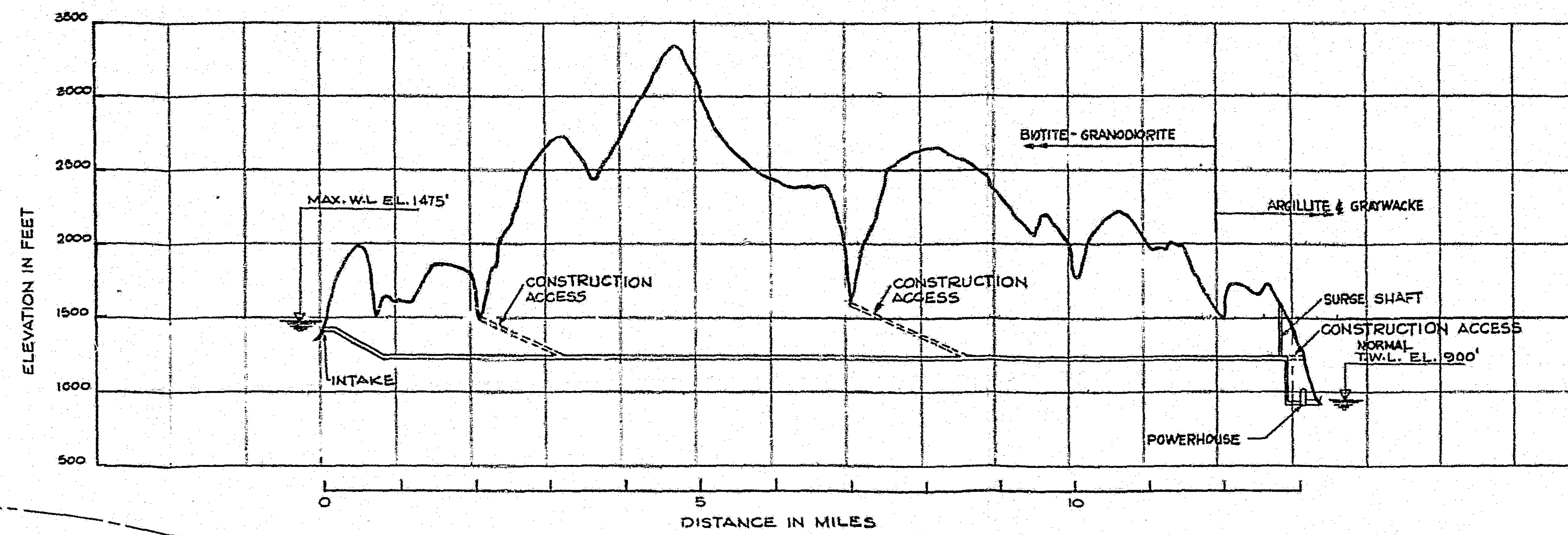
DATE | NO. | REVISIONS | CH. | APP. | APP. | ACRES AMERICAN INCORPORATED | PROJECT



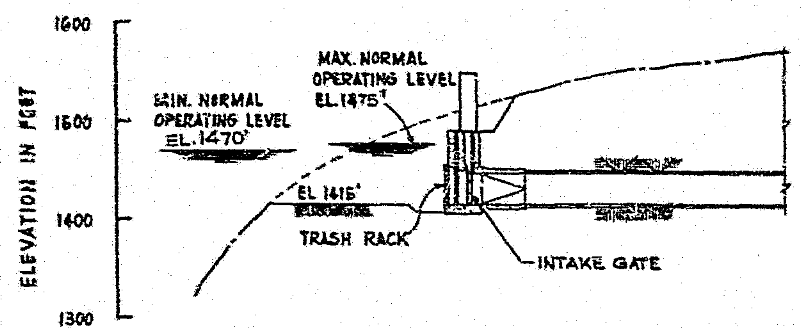
RE-REGULATION RESERVOIR
RE-REGULATION DAM
TUNNEL ALIGNMENT SCHEME 3
WATANA DAM
FLOW
WATANA RESERVOIR
TSUSENA CREEK
SUSITNA RIVER
DEVIL CREEK
SURGE TANK
DEVIL CANYON POWERHOUSE
DEVIL CANYON
PORTAGE CREEK
SCHEME 3 PLAN
SCALE 0 1 2 MILE
2-30' DIA. POWER TUNNELS
INTAKE
EL.1415'
DIVERSION GATE SHAFT W/BYPASS FOR LOW LEVEL RELEASES
25' DIA DIVERSION & LOW LEVEL OUTLET TUNNEL
CREST EL.1500'
13' DIA. PENSTOCK
POWERHOUSE 30 MW
NORMAL T.W.L ≈1260'
CREST EL.1365'
CREST EL.1280'
EL.1420'
2.5:1
2:1
2.25:1
2:1
4-40'W x 50' HIGH VERTICAL LIFT GATES
SPILLWAY CREST EL.1435'
GENERAL ARRANGEMENT RE-REGULATION DAM
SCALE 0 300 600 FEET
NOTE:
ALL PLANS AND LAYOUTS FOR CONCEPTUAL STUDY PURPOSES ONLY.
2-30' DIA. POWER TUNNELS
60' DIA. SURGE TANKS
ACCESS TUNNEL
POWERHOUSE 300 MW
TAILRACE TUNNEL
T.W.L ≈900'
GENERAL ARRANGEMENT DEVIL CANYON POWERHOUSE
SCALE 0 400 800 FEET
PLATE 8
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
PREFERRED TUNNEL
SCHEME 3
PLAN VIEWS
DATE DEC. 1981
SCALE AS SHOWN
SK-8700-C6-M2
DATE NO. REVISIONS CH. APP. APP.
ACRES AMERICAN INCORPORATED



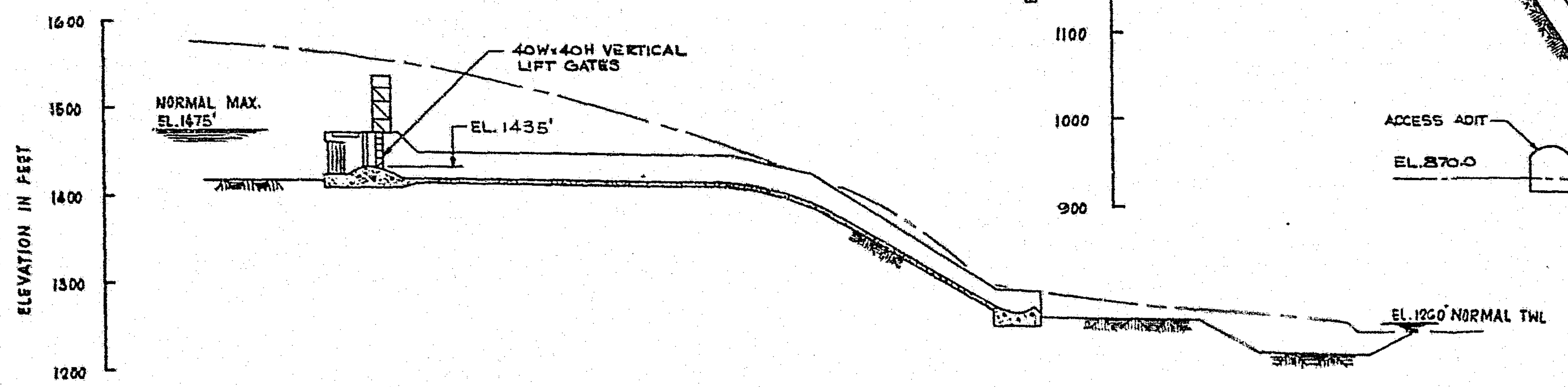
RE-REGULATION DAM TYPICAL SECTION
SCALE: A



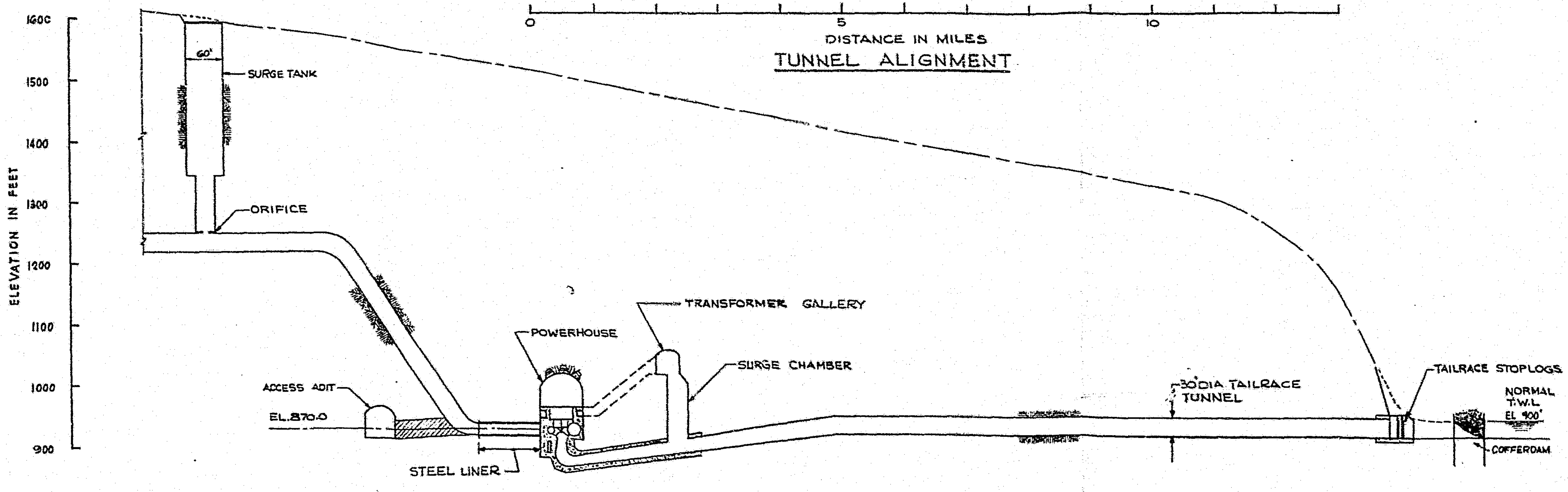
TUNNEL ALIGNMENT



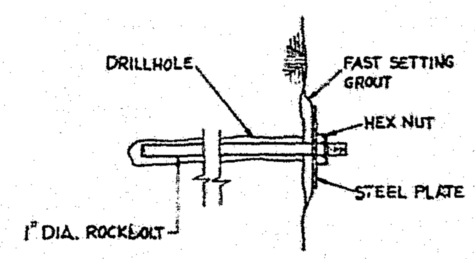
POWER TUNNEL INTAKE SECTION
SCALE: A



SPILLWAY PROFILE
SCALE: A

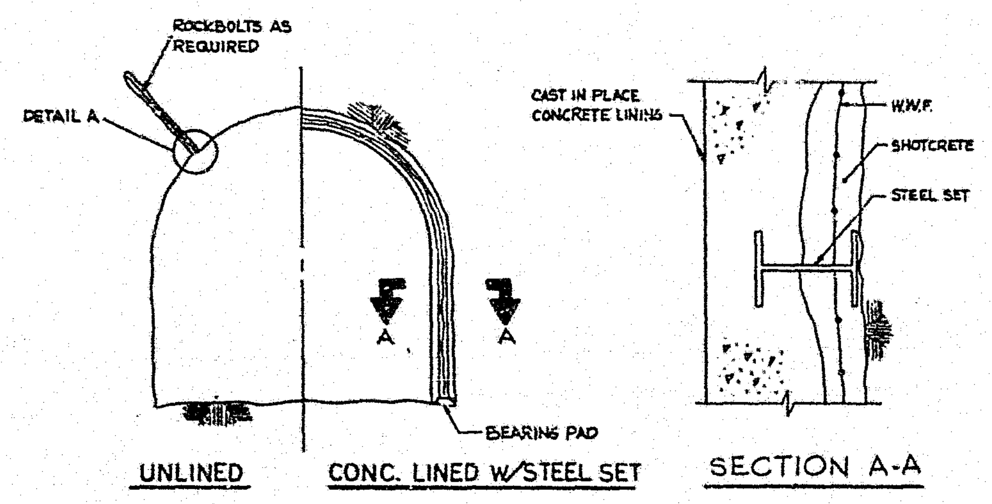


DEVIL CANYON POWER FACILITIES PROFILE
SCALE: A

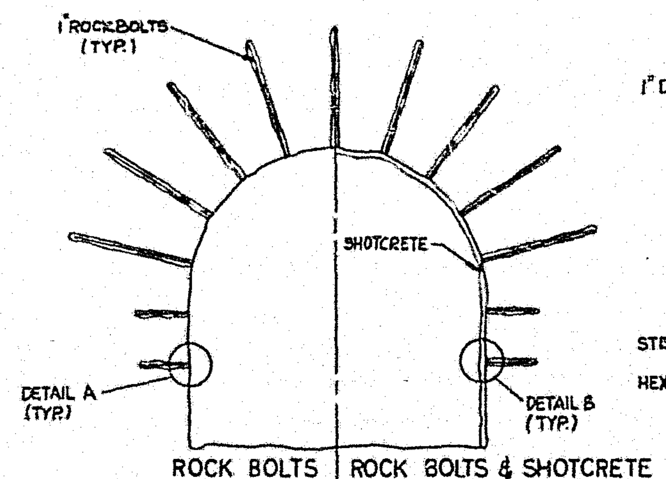


DETAIL "A"

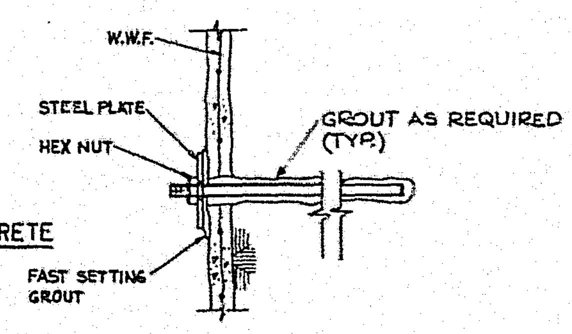
NOTE:
ALL STRUCTURAL AND SUPPORT DETAILS ARE CONCEPTUAL AND FOR STUDY PURPOSES ONLY.



TYPICAL TUNNEL SECTIONS (NOT TO SCALE)



TYPICAL TUNNEL SECTIONS
(NOT TO SCALE)



DETAIL "B"

SCALE A 0 100 200 FEET

PLATE 9

ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

PREFERRED TUNNEL
SCHEME 3
SECTIONS

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED
DATE DEC. 1981
SCALE AS SHOWN
DRAWING NO. SK-5700-C6-113

9 - SUSITNA HYDROELECTRIC DEVELOPMENT

The studies discussed in previous sections of this report conclude that, on the basis of the analyses to date, the future development of Railbelt electric power generation sources should include a Susitna Hydroelectric Project. Further work is required to fully establish the technical and economic feasibility of the Susitna project and to refine its design. The project as currently conceived is described in this section.

9.1 - Selected Plan

As described in Section 8, the selected Susitna Basin development plan involves the construction of the Watana dam to a crest elevation of 2225 feet with a 400 MW powerhouse scheduled to commence operation by 1993. This date is the earliest that a project of this magnitude can be brought on-line. A delay in this date would mean that additional thermal units would have to be brought on-line resulting in an increase in the cost of power to the consumer. This first stage would be followed by expanding the powerhouse capacity to 800 MW by 1996 and possibly the construction of a re-regulation dam downstream to allow daily peaking operations. More detailed environmental studies are required to confirm the requirement for this re-regulation dam and it may be possible to incorporate it in the Devil Canyon dam diversion facilities. The final stage involves the construction of the Devil Canyon dam to a crest elevation of 1465 feet with an installed capacity of 400 MW by the year 2000.

Should the load growth occur at a lower rate than the current medium forecast, then consideration should be given to postponing the capacity expansion proposed at Watana and the construction of the Devil Canyon dam to the year 2002 or possibly even 2005. These latter two dates correspond respectively to the low load forecast and the extreme low forecast incorporating an increased level of load management and conservation. For actual load growth rates higher than the medium load forecasts, construction of the Devil Canyon dam could be advanced to 1998.

Although it has been determined that this development plan is extremely economic for a wide range of possible future energy growth rates, the actual scheduling for the various stages should be continuously reassessed on, say, a five year basis. It should also be stressed that the dam heights and installed capacities quoted above are essentially representative orders of magnitude at this stage of project planning. These key parameters are subject to modification as the more detailed project optimization studies are conducted during 1981. The dam type selected for the Devil Canyon dam site has currently been revised from the rockfill alternative described in Section 8 to a thin double-curvature concrete arch dam. More detailed engineering studies carried out subsequent to the planning studies described have indicated this dam type to be more appropriate to the site conditions as well as slightly more cost effective. The results of these engineering studies are contained in Appendix H.

9.2 - Project Description

At this stage in the development of optimum project designs, various alternative project layouts are being produced for both the Watana and Devil Canyon sites. These layouts are being compared from both technical and economic viewpoints and this comparison will lead to the selection of possibly two or three basic layouts at each site for study in more detail.

At this early stage certain layouts are discerned to be more attractive than their counterparts. Of these, a single layout at each of the Watana and Devil Canyon sites has been selected as representative of the possible final development, and is described in this section.

These layouts are indicative of the present stage of the study. Much field work is still planned together with design and refinement studies, and these layouts should on no account be regarded as the final developments at this time.

(a) Watana (Plates 12 and 13)

(i) Site Geology

The dam site at Watana is underlain by a dioritic intrusion (pluton). The site has a favorable configuration because the river has cut down through the intrusion, resulting in a narrow canyon. The pluton is bounded at the upstream and downstream edges by sedimentary rocks that show evidence of being deformed and arched upwards by the plutonic intrusion (Figure 7.4). The evidence to date indicates that the sedimentary rock has been eroded from the top of the pluton at the immediate site. Following intrusion, at intervals that have not yet been determined, volcanics erupted into the area. These volcanics form the basalt flows exposed in the canyon near Fog Creek downstream of the site, and the andesite flows over the pluton at the dam site. There is no indication of basalt flows within the immediate dam site, but the andesite has been detected in several borings in the western portion of the site. The nature and characteristics of the diorite-andesite contact will be further investigated in the 1981 program.

The surficial material at the dam site is predominantly talus and very thin glacial sediments on the abutments, with limited deposits of river alluvium and lake clay at isolated locations. The river channel is filled with up to 80 feet of alluvial deposits derived from till and talus material. The drilling and seismic lines indicate that the bedrock weathering averages ten to twenty feet, with a very distinct gradation from weathered to unweathered rock. The surficial weathering processes seem to be primarily physical rather than chemical. Bedrock quality below 60 feet is uniform to the maximum depths drilled. The pattern of sound, unweathered rock zones are separated by shear zones of rock altered by injection of felsite and andesite dikes, with subsequent deterioration of the broken rock by groundwater. The basic conditions are favorable to construction of both surface and underground structures, with remedial treatment likely to be limited to shear zones.

(ii) Geotechnical Aspects

The Watana dam site lies predominantly on sound diorite while some portions of the downstream shell overlay andesite. The upper 10 to 40 feet of rock is weathered. The seismic considerations for the site, as discussed in Section 7, indicate that the relatively uncompacted alluvium (up to 80 feet in depth) would have to be removed from underneath most of the dam. In addition, it is assumed that up to 40 feet of rock excavation will be required under the impervious core and the supporting filters to found the dam on sound competent rock. This type of foundation preparation is considered normal for large dams of comparable size. Shear zones and joints within the rock foundation have been located and will require consolidation and curtain grouting. These features may also necessitate the inclusion of drainage features within the foundation and the abutments as indicated in the present arrangement. Permafrost is present on the left abutment and may also be present under the river channel. The data indicates that this is "warm" permafrost and can be economically thawed for grouting.

A deep relict channel exists on the right bank upstream of the dam. The overburden within this relict channel contains a sequence of glacial till and outwash interlayered with silts and clays of glacial origin. The top of rock under the relict channel area will be below the reservoir level. Further investigations will be undertaken to precisely define the characteristics of the channel. However, the data collected to date does not indicate that it will have any major impact on the feasibility of the site.

The rock conditions in the left bank, where the underground powerhouse is currently proposed, are favorable, and the powerhouse cavern will require only nominal support. However, additional investigations will be conducted to determine the exact location and orientation of the features, so as to minimize the impact of joints and any possible unfavorable stress orientation.

Materials for construction of a fill dam and related concrete structures are available within economic distances. Impervious and semipervious core and filter materials are available within three miles upstream of the site, (Figure 7.4) and a good source of filter material and concrete aggregate is available at the mouth of Tsusena Creek just downstream of the dam. Rockfill is available from a quarry source immediately adjacent to left abutment of the dam and from structure excavations. There is also a possibility of using rounded riverbed material for the dam shells if adequate quantities are available. Further investigations will be conducted to better define the quantity and characteristics of material in each source area and the relative economics of each borrow location.

(iii) Dam

The main dam is an earth/rockfill structure with the majority of the materials excavated from selected borrow areas, but with a small portion derived from excavation for the structures at the project site. The compacted impervious till core is protected upstream and downstream by gravel filter and transition zones and supported by shells formed from compacted layers of blasted rock and gravel materials. The maximum height of the dam above the foundation is approximately 880 feet, the crest elevation is 2,225 feet and the developed crest length is 5400 feet. The crest width is 80 feet, the upstream and downstream slopes are 1:2.75 and 1:2 respectively and the overall volume of the dam is currently estimated as approximately

63 million cubic yards. The dam is founded on sound bedrock. Upstream and downstream cofferdams are founded on the river alluvium and integrated with the main dam.

A low lying area above the right abutment is closed with an approximately 25 foot high impervious fill saddle dam.

(iv) Diversion

During construction, the river is diverted through two concrete-lined tunnels driven within the rock of the left abutment. The tunnels are set low and will flow full at all times. Upstream control structures at the tunnel inlets will regulate flows to maintain a near constant water level in the reservoir and allow formation of a stable ice cover and to prevent ice buildup within the tunnel inlets. Control will be affected by vertical fixed well gates housed within the upstream structures. These will also be utilized for final closure together with mass concrete plugs constructed within the tunnels in alignment with the dam grout curtain.

The river will be diverted upstream by means of a rock/earthfill cofferdam founded on the riverbed alluvium. Cutoff beneath the cofferdam is formed by a slurry trench to rock.

(v) Spillway

The spillway is located on the right bank and designed to pass the routed 1:10,000 year frequency design flood of approximately 115,000 cfs without damage to any of the project structures. The spillway is also capable of passing flows of up to 230,000 cfs corresponding to the probably maximum flood at Watana. This would require a reservoir surcharge up to 5 feet below the dam crest level. During passage of this major flood some damage to the spillway chute and discharge structures and some downstream erosion within the river valley would be accepted.

The spillway consists of a gate structure, with three vertical fixed wheel control gates, a concrete lined chute and a flip bucket, similar to that at Devil Canyon (Section 9.2(b)), discharging into a downstream plunge pool excavated from the alluvium within the riverbed.

(vi) Power Facilities

- Intake

The intake is situated upstream of the right abutment of the dam. It is set deep within the rock and is similar in structure to the Devil Canyon intake with provision for drawing off water at different levels within the fluctuating reservoir.

- Penstocks

Four concrete-lined tunnel penstocks descend at an inclination of 55° and terminate in steel liners at the powerhouse feeding the high pressure turbines.

- Powerhouse

The powerhouse complex is similar to that for Devil Canyon with separate powerhouse and transformer bay caverns. The main cavern houses four 200 MW turbine/generator units consisting of vertically mounted Francis turbines driving overhead umbrella type generators serviced by the main overhead crane. Major offices and the control room are incorporated in the administration building at the surface. An elevator descends from this building to provide personnel access to the powerhouse. Vehicle access to the powerhouse and transformer gallery is by unlined rock tunnel leading from the bottom of the valley.

- Tailrace

The turbine draft tube tunnels lead from the powerhouse to a common manifold supplying a single partly-lined tailrace tunnel which emerges, below river level, downstream of the main dam.

(vii) Downstream Releases

At the present time there is provision made for emergency drawdown of the Watana reservoir. This will take the form of an intermediate level reservoir outlet. Flows are controlled by high pressure gates located in an underground chamber, and a concrete-lined tunnel discharges into the diversion tunnel, downstream of the concrete plug. Small releases, during shutdown of the generating plant, are made via a small diversion incorporated with the underground control structure.

(b) Devil Canyon (Plates 10 and 11)

(i) Site Geology

Devil Canyon is a very narrow V-shaped canyon cut through relatively homogeneous argillite and graywacke. This rock was formed by low-grade metamorphism of marine shales, mudstones, and clayey sand-stones. The bedding strikes about 15° northeast of the river alignment through the canyon and dips at about 65° to the southwest. The rock has been deformed and moderately sheared by the northwest acting regional tectonic forces, causing shearing and jointing parallel to this force (Figure 7.4). The glaciation of the past few million years apparently preceded the erosion of the canyon by the river. Glacial deposits blanket the valley above the V-shaped canyon, while deposits in the canyon itself are limited to a large gravel bar just upstream of the canyon entrance, and boulder and talus deposits at the base of the canyon walls.

Bedrock conditions at Devil Canyon vary within a limited range due to changes of lithology, but the rock is basically sound and fairly durable. Jointing and shears are frequently quite open at the surface, but there is a general tightening of such openings with depth. The major joint set strikes about North 30° West across the canyon, and may be an indication of shear zones in this direction. Two minor sets strike roughly North 60-90° East, with dips of about 50-60° south and 15° south. The orientation of the joints, and particularly the shear zones, is not well defined. Further field mapping in 1981 should clarify this.

(ii) Geotechnical Aspects

The Devil Canyon dam site lies on argillite and graywacke exhibiting significant jointing and frequent shear zones. The nature of the rock is such that numerous zones of gouge, alteration, and fractured rock were caused during the major tectonic events of the past, in addition to the folding and internal slippage during lithification and metamorphism. Consequently, zones of deep weathering and alteration can be expected in the foundation. Excavation of up to 40 feet of rock will expose sound foundation rock, and consolidation grouting and dental excavation of badly crushed and altered rock will be necessary to provide adequate bearing surfaces for the dam. Overburden within the narrow V-section of the valley is minimal.

The left bank plateau, which is the location of a saddle dam, has a buried river channel paralleling the river. The overburden reaches 90 feet under a small lake in this area and construction of the saddle dam will require excavation of considerable amounts of till and lake deposits or construction of a cutoff extending down to bedrock. Seepage control will be effected by two methods: first, by general contact and consolidation grouting to control flow at the dam foundation contact, and second by a deep grout curtain with corresponding drainage curtain to limit downstream flow through the foundation. Permafrost has not been detected at the site but, if it does exist, it is not expected to be substantial or widespread. A thawing program can be incorporated in conjunction with the grouting if necessary.

Construction materials are available in the large gravel bar immediately upstream of the dam site. The materials in this bar are estimated to be adequate in quantity for all material needs of the concrete dam. The lakebed and till deposits in Cheechako Creek (approximately 0.25 miles upstream), may be sources of a substantial portion of impervious material for the earthfill saddle dam.

(iii) Dam

The main dam is currently proposed as a thin concrete arch structure with an overall height of 650 feet and developed crest length of 1,230 feet. The crest width is 20 feet and the base width at the crown cantilever is 90 feet. The geometry of the arch corresponds to a two center configuration which is compatible with the assymetric transverse profile of the valley.

The central section of the dam rests on a massive concrete plug, founded deep within the valley floor and the upper arches terminate in thrust blocks located high on the abutments. A concrete wall extends 4 feet above the upstream edge of the crest to allow additional surcharge during passage of the probable maximum flood.

A low lying area on the left abutment is filled by a saddle dam. The saddle dam is a rockfill structure with an impervious core. It abuts and surrounds the concrete thrust block with the core wrapping the concrete to provide a seal. Overburden will be excavated to allow the core to be founded on the deep underlying bedrock.

A continuous grout curtain and drainage system is provided beneath the main and saddle dams linking with similar systems upstream of the powerhouse and beneath the main spillway. Grout and drainage holes are driven from a series of interconnecting shafts and galleries which will allow continued access beneath the foundations of the dam.

(iv) Diversion

River diversion during construction is similar to diversion for Watana with twin concrete-lined tunnels and upstream control structures. Cofferdams are as described previously. Full use of storage at Watana will be used to safeguard construction at Devil Canyon.

(v) Spillways

The main service spillway is located on the right abutment and is designed for flows of up to 90,000 cfs. Discharges are controlled by three vertical fixed wheel gates housed in a concrete overflow structure incorporated in a right thrust block. Flows are routed down a steeply inclined concrete lined chute, founded within sound bedrock, and discharge over a flip bucket into the river. The flip bucket is a massive concrete structure contiguous with the chute. It imparts a vertical velocity component to the discharges, training them along a uniformly curved invert and ejecting them in a broad shallow jet into the river well downstream of the dam. Alluvium within the river is removed to bedrock in the vicinity of the area of impact of the discharge jet.

A secondary spillway system designed to discharge 40,000 cfs is provided within the dam in the form of four submerged orifices high in its center section. These orifices are controlled by 15 feet x 15 feet vertical lift gates and discharges are thrown clear of the dam into a downstream plunge pool excavated in the rock beneath the existing riverbed.

The combination of the above spillways is sufficient to pass the routed 1:10,000 year frequency design flood of 130,000 cfs. Greater discharges are possible by allowing surcharge of the reservoir to the level of the dam crest wave wall.

Beyond the rockfill saddle dam on the left abutment a channel is excavated in the rock and runs approximately 1,400 feet downstream discharging into a tributary valley to the main river. The channel is closed by an impervious fill fuse plug which can be overtopped during excessive floods and will wash out, probably after some local excavation has been carried out, to the full section of the rock channel. Discharge down this channel plus surcharge over the main spillways will allow for passing of the full probable maximum flood in the unlikely event that this should ever take place.

(vi) Power Facilities

- Intake

The intake is located upstream of the right abutment of the dam. It is a massive concrete structure set deep in the bedrock at the end of a short upstream power canal. The intake is formed of four adjacent units, each with the capability of drawing off water at levels throughout and below a 150 feet range of drawdown within the reservoir. These levels are controlled by large vertical shutters operating in two sets of guides set one behind the other. By raising and lowering the shutters, openings can be created by varying levels over the height of the structure. These shutters will not operate under pressure as closure of the intakes will be performed by vertical fixed wheel gates set downstream of the shutters.

- Penstocks

Four concrete lined tunnel penstocks lead from the intake and descend at an angle of inclination of 55° to horizontal to the underground powerhouse. Just upstream of the powerhouse the lining changes to steel in order to prevent seepage into the main power cavern and to contain the high internal pressures in the vicinity of the fractured rock caused by blasting the powerhouse excavation.

- Powerhouse

The powerhouse complex consists of two main excavations; the main power cavern housing the generating units service bay and maintenance areas, and the transformer and draft tube gate gallery.

The main cavern houses four 100 MW turbine/generator units. The turbines are vertically mounted Francis type units driving overhead umbrella type generators serviced by an overhead crane travelling the length of the powerhall and end service bay. Switchgear, minor offices, service areas and a workshop are housed in this area. Upstream bus duct galleries are inclined from generator floor level at the power cavern to the transformer gallery running the length of the powerhouse and set above the penstocks. Vertical shafts are raised from the draft tubes to the downstream side of the powerhouse and these incorporate vertical guides for the operation of closure gates within the draft tubes and function as surge shafts during changes of flow within the tailrace.

Cable shafts rise from the transformer gallery to the surface and the power lines are carried from these across the dam to the switchyard on the left abutment. The control room and main administration building is located at the surface.

Vehicle access to the powerhouse is via an inclined rock tunnel driven from the bottom of the river gorge. Personnel access is by means of an elevator operating between the powerhouse cavern and the administration building.

- Tailrace

Downstream of the gates, the draft tubes merge into a single concrete lined tailrace tunnel which will be set below river level and will flow full at all times.

(vii) Downstream Releases

Releases downstream during shutdown of the power plant will be made through Howell Bunger valves set close to the base of the dam and discharging freely into the river valley.

9.3 - Construction Schedules

At this stage of the study, a preliminary assessment of the construction schedules for the Watana and Devil Canyon dams has been made. The main objective has been to provide a reasonable estimate of on-line dates for the generation planning studies described in Section 8. More detailed construction schedules will be developed during the 1981 studies.

In developing these preliminary schedules, roughly 70 major construction activities were identified and the applicable quantities such as excavation, borrow and concrete volumes were determined. Construction durations were then estimated using historical records as backup and the expertise of senior scheduler-planners, estimators and design staff. A critical path logic diagram was developed from those activities and the project duration was determined. The critical or near critical activity durations were further reviewed and refined as needed. These construction logic diagrams are coded so that they may be incorporated into a computerized system for the more detailed studies to be conducted during 1981.

The schedules developed are described below:

(a) Watana Rockfill Dam

As shown in Figure 9.1, it is expected to take approximately 11 years to complete construction of the Watana dam from the start of an access road to the testing and commissioning of all the generating units. Principal components of the schedule include approximately 3 years of site and local access, 1-1/2 years for river diversion and most of the remaining time for foundation preparation and embankment placement. This period compares to 15 years estimated in the COE 1979 report. The most important differences that the COE provided for a 4-1/2 year period of access road construction prior to any work being done at the site. In this study, because of the economic advantage to be gained from an early on-line date, a "fast track" approach has been adopted during the early stages of construction. This involves overland winter access and extensive aircraft support to the early activities associated with construction of the diversion system and abutment excavation for the main dam.

Only about six months per year can be used for fill placement due to snow and temperature conditions. Fill placement rates have been estimated at between 2.5 and 3.0 million cubic yards per month. This is somewhat higher than the 1979 COE figure of 2.4 million cubic yards per month placement over a five-month annual placement period. It has been judged that the early on-line date would justify the implementation of construction systems with higher production rates. It is expected that the river can be impounded as construction proceeds so as to minimize the time lag between the completion of the dam embankment and the testing and commissioning of the first power unit.

The schedule shows the earliest date power production from the Watana dam could start would be January 1993. This is based on starting construction of access roads in early 1985 as soon as the FERC license is received.

(b) Devil Canyon Thin Arch Dam

As shown in Figure 9.2, it will take approximately 9 years to complete the dam from the start of constructing access to the site to the testing and commissioning of the power units. As far as construction of the dam is concerned this schedule agrees with that developed by the COE. It does, however, incorporate an additional 1-1/2 years for construction of a main access road from the Watana site.

The key elements in determining the overall schedule are the construction of diversion tunnels, cofferdams, the excavation and preparation of the foundation and the placement of the concrete dam. For purposes of estimating activity durations, it is assumed that embankment and curtain grouting will be done through vertical access shafts on each embankment.

(c) Interpretation of Schedules

The attached figures represent an "early start" schedule and the majority of the study effort to date has been expended in determining the "critical path" which controls project duration. During the continuing 1981 studies the "non-critical" items will be scheduled to take into account resource availability and financial and climatic aspects. This will result in the "non-critical" items being more rigidly scheduled than is shown in the attached figures.

9.4 - Operational Aspects

Section 8 outlines the results of the power and energy evaluations for the selected plan. This section supplements the information and illustrates some of the monthly reservoir simulation results and highlights the downstream flow characteristics which are important from an environmental point of view.

Figures 9.3 through 9.5 illustrate the operation of the reservoirs for a typical 30 year period. Figure 9.1 shows the monthly energy production, inflow, outflows, and water levels for the Stage 1 Watana 400 MW development. Figures 9.4 and 9.5 illustrate similar results for the final fully developed two dam scheme.

The reservoirs have been assumed to be operated to produce monthly energy production that follows the same general shape as the seasonal pattern of the total Railbelt electricity demand. During the summer months, particularly during late summer when the reservoirs tend to be full, additional or secondary energy is generated in order to utilize some of the water that would otherwise be spilled. The secondary energy production and spillage is clearly illustrated.

The figures indicate that during Stage 1 the Watana spillway would be operated 8 out of every 10 years and that in 7 of these years, flow would be discharged for 2 or more months. Once the total development is completed, the spillways would only be operated for roughly 2-1/2 years out of 10 and most of the time for a period of less than a month in a given year. At this stage of development, the Devil Canyon spillway would be operated 7 out of 10 years, and during 3 of these years spill would occur for 2 or more months.

Tables 9.1 to 9.3 summarize typical outflows from the downstream dam in the preferred development. These flows include water coming from the turbines and water passing over the spillway. It will be noted that daily fluctuations are kept to a minimum for the Watana 400 MW development. Outflows from the Devil Canyon dam in the full development plan also show limited fluctuations. However, for the Stage 2 400 MW capacity addition at Watana substantial daily fluctuations do occur and may require downstream regulation.

9.5 - Environmental Review

The environmental input into the Susitna studies has two major components; mitigation planning and impact identification. Mitigation planning includes avoidance, reduction, and compensation. In participating in the Susitna development selection, our objective was to identify what development scheme(s) was most environmentally compatable, thus, avoiding many potential impacts. In addition, design features were recommended to reduce potential impacts even if the most compatable sites were selected. Identifying compensation measures and the actual prediction of environmental impacts are the subject of ongoing studies. The results of these studies will be included in our 1982 feasibility report to be available prior to making the decision as to whether or not to proceed with FERC licensing.

(a) Environmental Aspects

The Upper Susitna Basin has been considered as a potential hydroelectric development site not only because of the economics and energy potential but also because of its relative compatability with the environment. Compared to other potential large hydro development sites (e.g. Rampart on the Yukon River or Million Dollar on the Copper River). The Upper Susitna has less potential environmental impact. A comparison of alternatives to Susitna is outside the realm of these studies, however, they are being fully assessed in a parallel study being conducted by Batelle.

As with any type of major development, hydroelectric projects can cause and have elsewhere caused significant environmental impacts. In regard to reducing or eliminating environmental impacts, probably the most important factor is the selection of a development plan that is basically as inherently compatible with the environment as possible. Retrofit type mitigation measures which are often of minimal success and usually very costly are undesirable.

Development characteristics that have caused problems on other hydro projects that are not inherent to Susitna include:

- The diversion of major rivers.

- The direct blockage of anadromous fish migration due to the barrier created by the dam.

- The amplification of flow regulation problems caused by having a series of reservoirs with minimal storage and poor spillway design.

- Inundation of large areas of prime wildlife habitat.

Thus, although the Susitna Hydroelectric Project still has the potential of creating environmental impacts, many of the major potential impacts often associated with hydroelectric developments are avoided by the selection of the Upper Susitna Basin.

For studies within the Susitna Basin it is still important that environmental input still be provided into the decision making process. To date, the major environmental input into the Susitna studies has been directed towards evaluation of alternatives, recommendation of design features, establishment of operating limits for planning purposes, and the collection of baseline data. The major environmental objectives are to (1) ensure that environmental compatibility is incorporated as a principle factor in development selection and design, and (2) to present a clear picture of the environmental consequences of developing the final selected scheme. Parts of objective (1) are presented in this report where an environmental comparison of alternative Susitna developments is presented. The product of objective (2) will be contained in the environmental section of the feasibility report prepared at the end of Phase I studies.

It must be noted that although environmental compatibility has been incorporated as a desirable objective, it is not a sole factor in the decision making process. The interrogation of economic viability, technical feasibility, and environmental acceptability have necessitated judgements and tradeoffs. To facilitate a rational assessment, these judgements and tradeoffs have been defined as clearly as possible. In some instances, economic and environmental preferences recommended similar action; an example being the Watana/Devil Canyon plan where the reservoirs are basically confined to the river valley. In other instances a specific decision has been made that an economic expenditure is required to retain environmental compatibility; examples being multilevel intake structures to allow for some temperature control of discharge water and the provision for downstream daily re-regulation of flows. In still other instances, the economic expenditure was not considered warranted to reduce or avoid resultant environmental impacts; an example being a tunnel scheme at a cost of $680 million to avoid the inundation of the upstream portion of Devil Canyon. As design studies progress, continued environmental impact assessments will be incorporated. An environmental assessment of the selected scheme will be incorporated into the final feasibility report. This report will be made available for government agency and public review prior to making a decision as to whether or not to proceed with FERC license application.

In 1975 (updated in 1979) the COE produced an Environmental Impact Statement on the Watana/Devil Canyon Development. The information gathered by the COE in this study is being enhanced by insight obtained from the 1980 studies and in areas where study effort is continuing as part of the present study.

(b) Hydrology

Under existing conditions seasonal variation of flows in the Susitna is extreme. At Gold Creek the average winter and summer flows are 2,100 and 20,250 cfs respectively, a 1 to 10 ratio. With regulated discharge resulting from a hydroelectric development, downstream flows between Devil Canyon and the confluence of the Talkeetna/Chulitna rivers will be relatively constant. Figures 9.3 - 9.5 show the differences between inflows and outflows and the occurrence of spilling with the project at various stages of development. These changes in flow will be attenuated downstream due to the unaltered inflow from tributaries. Percent contribution from these tributary streams under existing conditions is shown in Figure 7.5.

The monthly flow and resulting stage at Gold Creek, Sunshine and Susitna Station with and without the project are shown in Figures 9.6 to 9.8.

Under existing conditions the level of suspended sediment is very high in the summer months (23 to 2620 ppm) and relatively low in the winter months (4 to 228 ppm, ADF&G 1975). With the project, a glacial flow will result year round with suspended solids in the releases at Devil Canyon Dam projected to be in the 15-35 ppm range.

Changes in dissolved gasses, specifically nitrogen, will be dependent on the spillage occurrence and the design of the spillways. Although it is considered that the majority of potential nitrogen supersaturation problems can be avoided (or minimized) through design and operation, sufficient study has yet to be conducted to confirm this.

Temperature of the discharge waters will be adjusted to approach the natural river water temperatures through the incorporation of multilevel intake structures. Even so, slight changes in discharge temperatures can be expected at certain times of the year, the extent to be predicted by means of a reservoir computer model presently being developed.

Although it is essential to alter seasonal flows in order to produce adequate power during the winter when the demand is highest, it is possible to avoid or dampen daily fluctuations in flow by means of operating the downstream powerhouse as a base load plant or incorporating a re-regulation dam. As this constraint has been incorporated into the proposed Watana/Devil Canyon development, potential impacts associated with daily fluctuations due to peaking operations are avoided.

(c) Mitigating Measures

In developing the detailed project design a range of mitigating measures required to minimize the impact on the environment will be incorporated. This is achieved by involving the environmental studies coordinator as a member of the engineering design team. This procedure ensures constant interaction between the engineers and environmentalists and facilitates the identification and design of all necessary mitigation measures.

There are two basic types of mitigation measures that are being developed: Those which are incorporated in the project design and those which are included in the reservoir operating rules. These are briefly discussed below.

(i) Design Features

The two major design features currently incorporated include multilevel power intake structures to allow some temperature control of released water and provision of a downstream re-regulation dam to assist in damping the downstream discharge and water level fluctuations induced by power peaking operations at the dam. During the 1981 studies these two features will be designed in more detail and other features incorporated as necessary. Of particular importance will be the design of the spillways to minimize the impact of nitrogen supersaturation in the downstream river reaches. Consideration will also be given to developing mitigation measures to limit the impact on the environment during the project construction period. The access roads, transmission lines, and construction and permanent camp facilities will also be designed to incorporate mitigation measures as required.

(ii) Operating Rules

As outlined in Chapter 7, limitations on seasonal and daily reservoir level drawdown, as well as on downstream minimum flow conditions, have been imposed. During 1981 more detailed studies will be undertaken to refine these current constraints and to look at detailed operational requirements to adequately control downstream water level fluctuations, water temperature, and sediment concentration.

TABLE 9.1 - OUTFLOWS FROM WATANA/DEVIL CANYON DEVELOPMENT
STAGE 1 WATANA 400 MW

Month	Average Monthly Inflow (cfs)	Outflow (cfs)[1]			Average Monthly Spills (cfs)
		Average Monthly	Average Daily		
			Peak	Offpeak	
JAN	1147	7699	7834	7603	-
FEB	971	7409	7538	7316	-
MAR	889	6758	6873	6676	-
APR	1103	6168	6264	6100	-
MAY	10406	5689	5699	5682	-
JUN	23093	5571	5571	5571	-
JUL	20344	8227	8227	8227	1779
AUG	18012	14263	14263	14263	6582
SEP	10614	10299	10299	10298	2744
OCT	4394	6503	6523	6498	-
NOV	1962	7497	7578	7439	-
DEC	1385	8237	8369	8143	-

Note:

(1) Total outflow includes powerhouse flows, compensation flows and spills.

TABLE 9.2 - OUTFLOWS FROM WATANA/DEVIL CANYON DEVELOPMENT
STAGE 2 WATANA 800 MW

Month	Average Monthly Inflow (cfs)	OUTFLOW (cfs)[1] Average Monthly	Average Daily Peak	Average Daily Offpeak	Average Monthly Spills (cfs)
JAN	1147	7699	15663	2011	-
FEB	971	7409	14979	2001	-
MAR	889	6758	13419	2000	-
APR	1103	6168	12003	2000	-
MAY	10406	5689	10703	2108	-
JUN	23093	5571	10524	2033	-
JUL	20344	8227	11337	6006	134
AUG	18012	14263	15224	13576	431
SEP	10614	10299	12358	8827	-
OCT	4394	6503	12783	2017	-
NOV	1962	7497	15139	2039	-
DEC	1385	8237	16737	2166	-

Note:

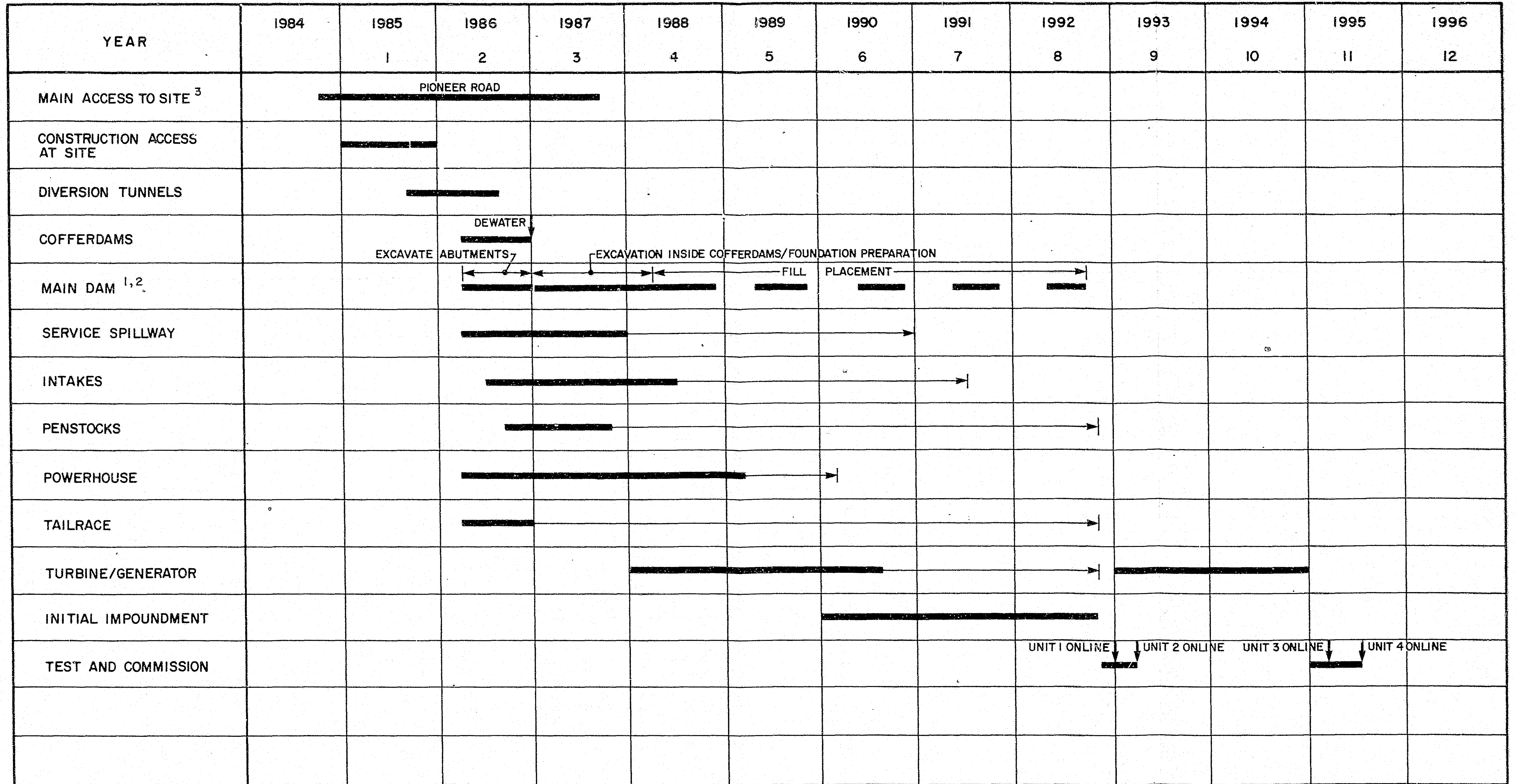
(1) Total outflow includes powerhouse flows, compensation flows and spills.

TABLE 9.3 - OUTFLOWS FROM WATANA/DEVIL CANYON DEVELOPMENT STAGE 3 DEVIL CANYON 400 MW[1]

Month	Average Monthly Inflow (cfs)	Average Monthly Outflow (cfs)[2]	Average Monthly Spills (cfs)
JAN	8595	8666	-
FEB	8280	9216	-
MAR	7576	7394	-
APR	6988	6833	-
MAY	8235	7806	-
JUN	9294	8796	24
JUL	9524	8967	958
AUG	13534	16239	7129
SEP	11188	13491	4180
OCT	7838	7950	-
NOV	8462	8889	-
DEC	9211	9383	-

Notes:

(1) Operated as a base load plant. Minimal daily fluctuations.
(2) Total outflow includes powerhouse flows, compensation flows and spills.



LEGEND

CRITICAL ACTIVITIES

OTHER ACTIVITIES

KEY

EARLIEST START OF ACTIVITY

EARLIEST FINISH OF ACTIVITY

LATEST FINISH OF ACTIVITY

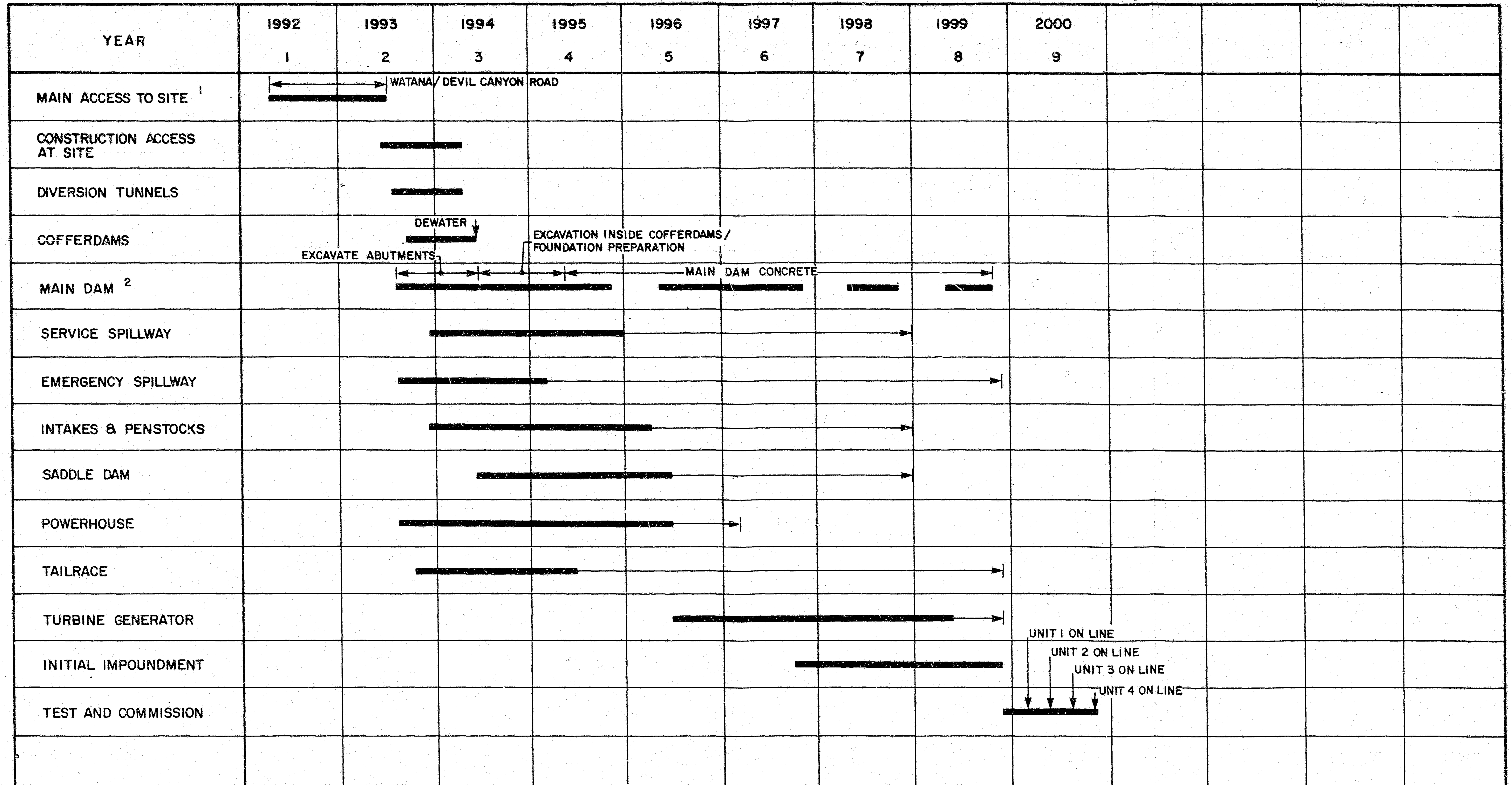
NOTES

1. MAIN DAM SCHEDULE BASED ON FILL PLACEMENT RATES OF 2.5 TO 3.0 MILLION CUBIC YARDS PER MONTH.
2. FIVE TO SIX MONTH FILL PLACEMENT SEASON ASSUMED.
3. BASED ON ACCESS FROM DENALI HIGHWAY AND ASSUMES OVERLAND WINTER ACCESS AND AIRCRAFT SUPPORT DURING 1985.

WATANA FILL DAM
PRELIMINARY CONSTRUCTION SCHEDULE

FIGURE 9.1

ACRES



LEGEND

CRITICAL ACTIVITIES
OTHER ACTIVITIES

KEY

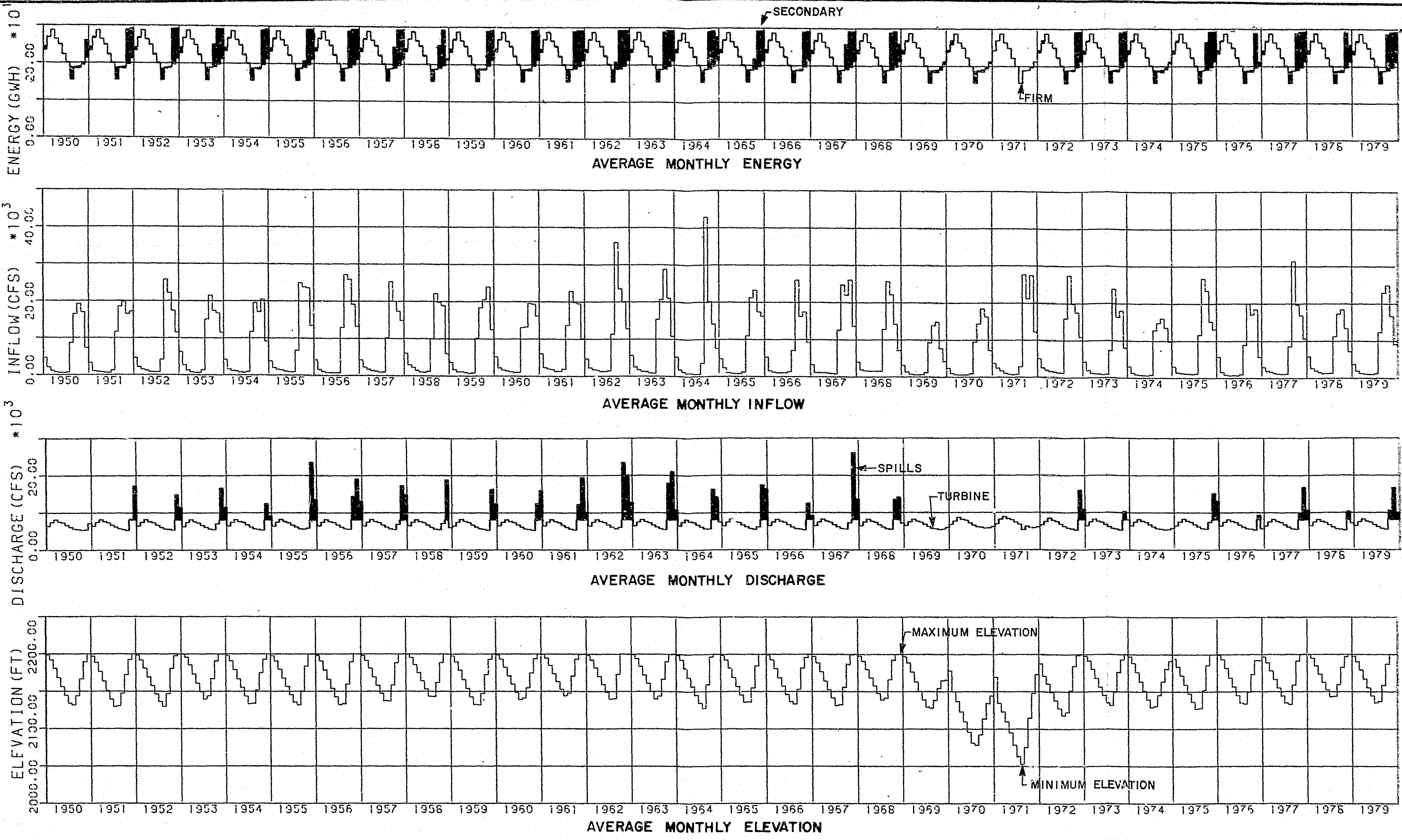
EARLIEST START OF ACTIVITY
EARLIEST FINISH OF ACTIVITY
LATEST FINISH OF ACTIVITY

NOTES

1. SCHEDULE ASSUMES DENALI - WATANA HIGHWAY ALREADY AVAILABLE.
2. BASED UPON SIX MONTH CONCRETE PLACEMENT SEASON.

DEVIL CANYON THIN ARCH DAM
PRELIMINARY CONSTRUCTION SCHEDULE

FIGURE 9.2



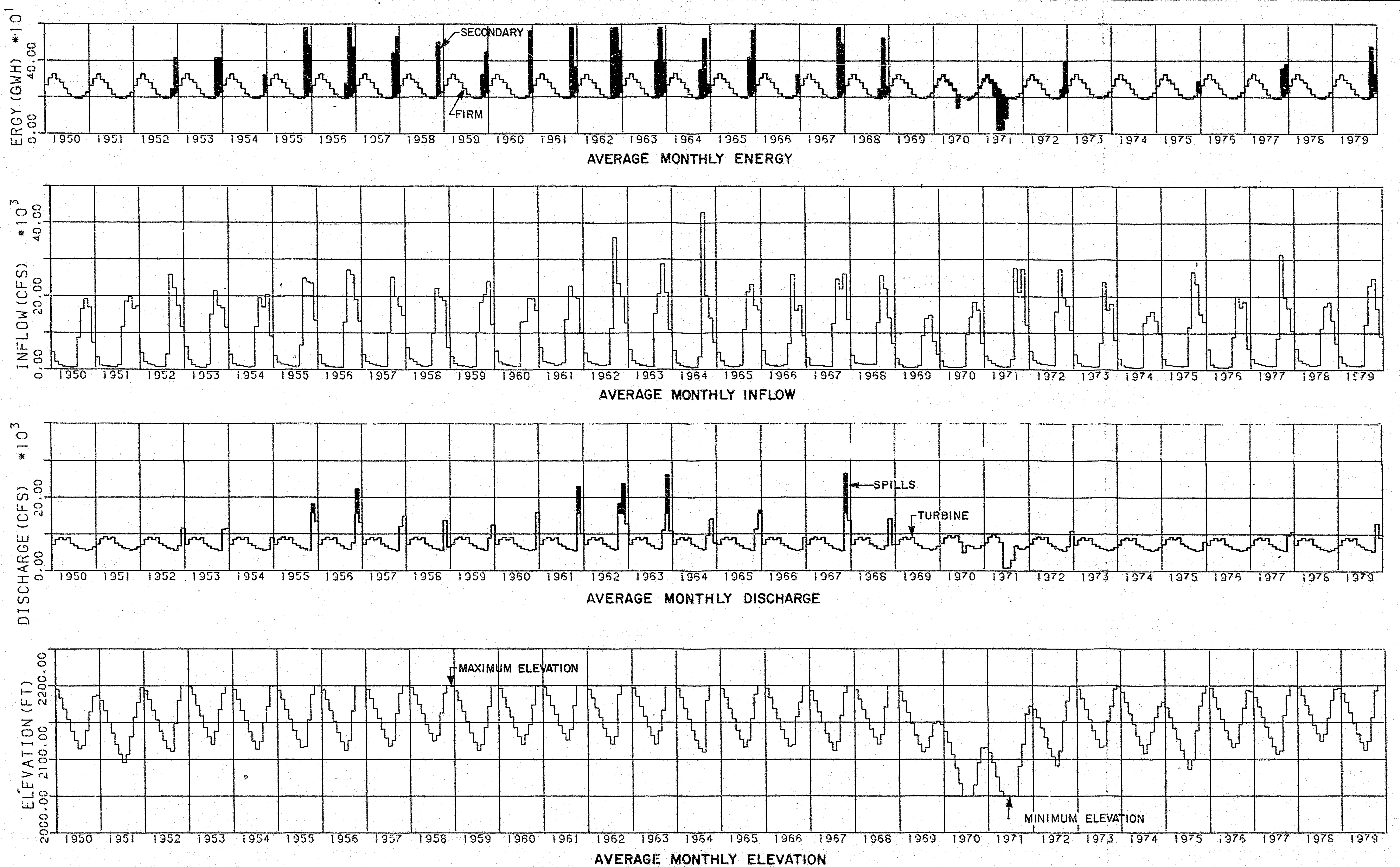
NOTE : WATER YEAR OCT.–SEPT.

STAGE I - WATANA RESERVOIR (400 MW)

OPERATION OF THE WATANA / DEVIL CANYON DEVELOPMENT PLAN E 1.3

FIGURE 9.3

ACRES

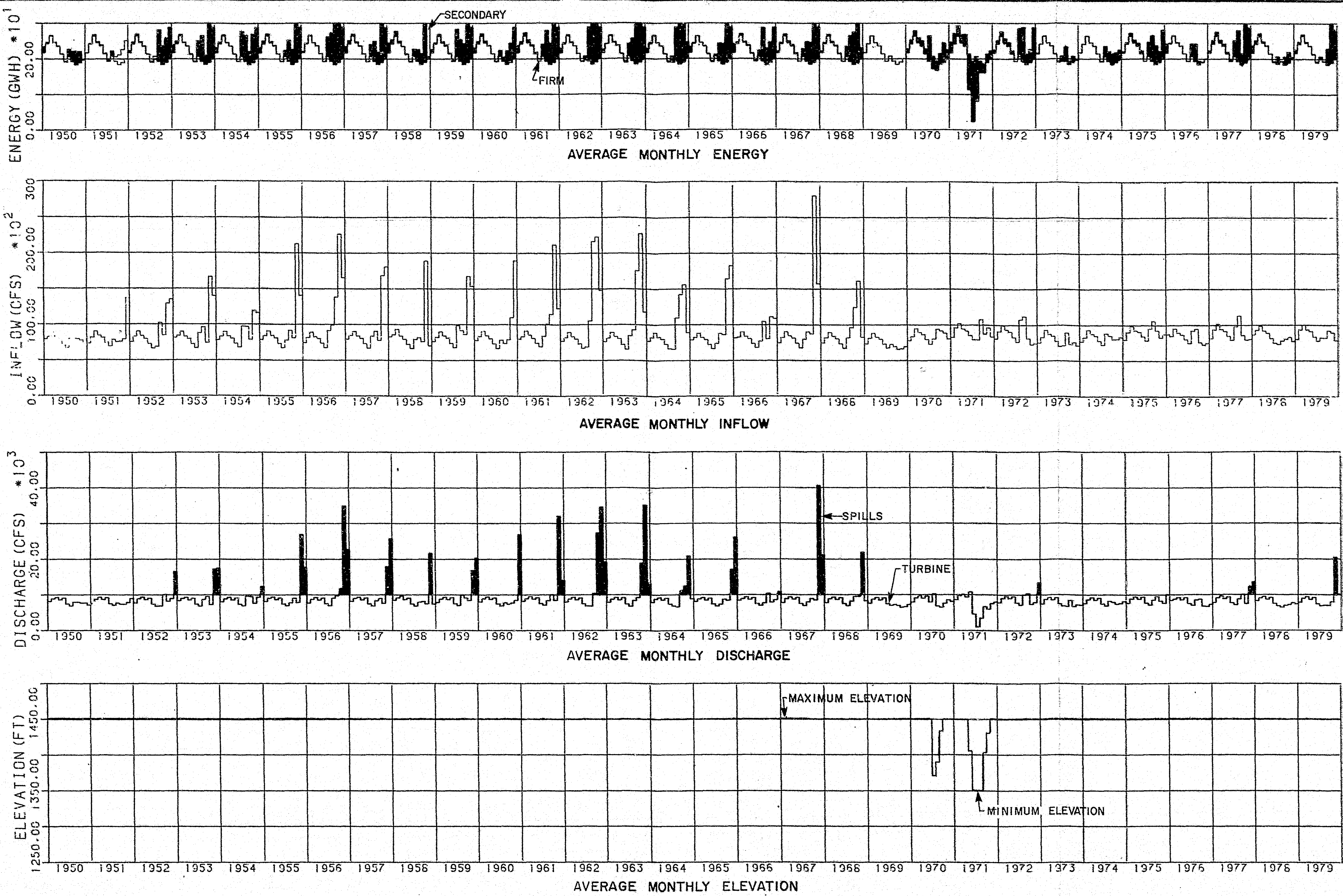


NOTE: WATER YEAR OCT.–SEPT.

STAGE 3 - WATANA RESERVOIR (800 MW)

OPERATION OF THE WATANA / DEVIL CANYON DEVELOPMENT PLAN E1.3

FIGURE 9.4

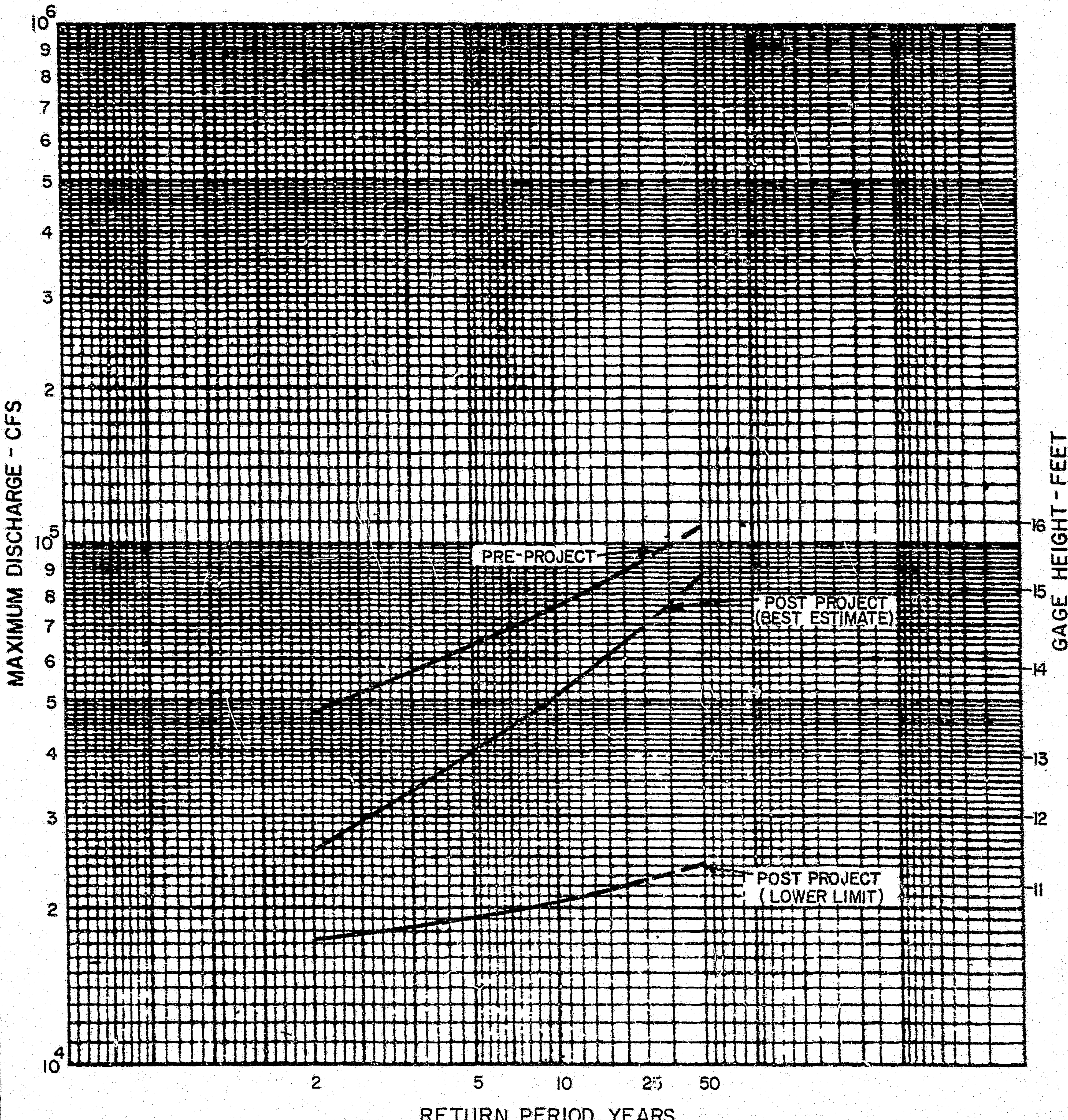


NOTE: WATER YEAR OCT.-SEPT.

STAGE 3 - DEVIL CANYON RESERVOIR (400 MW)

OPERATION OF THE WATANA/DEVIL CANYON DEVELOPMENT PLAN E1.3

FIGURE 9.5

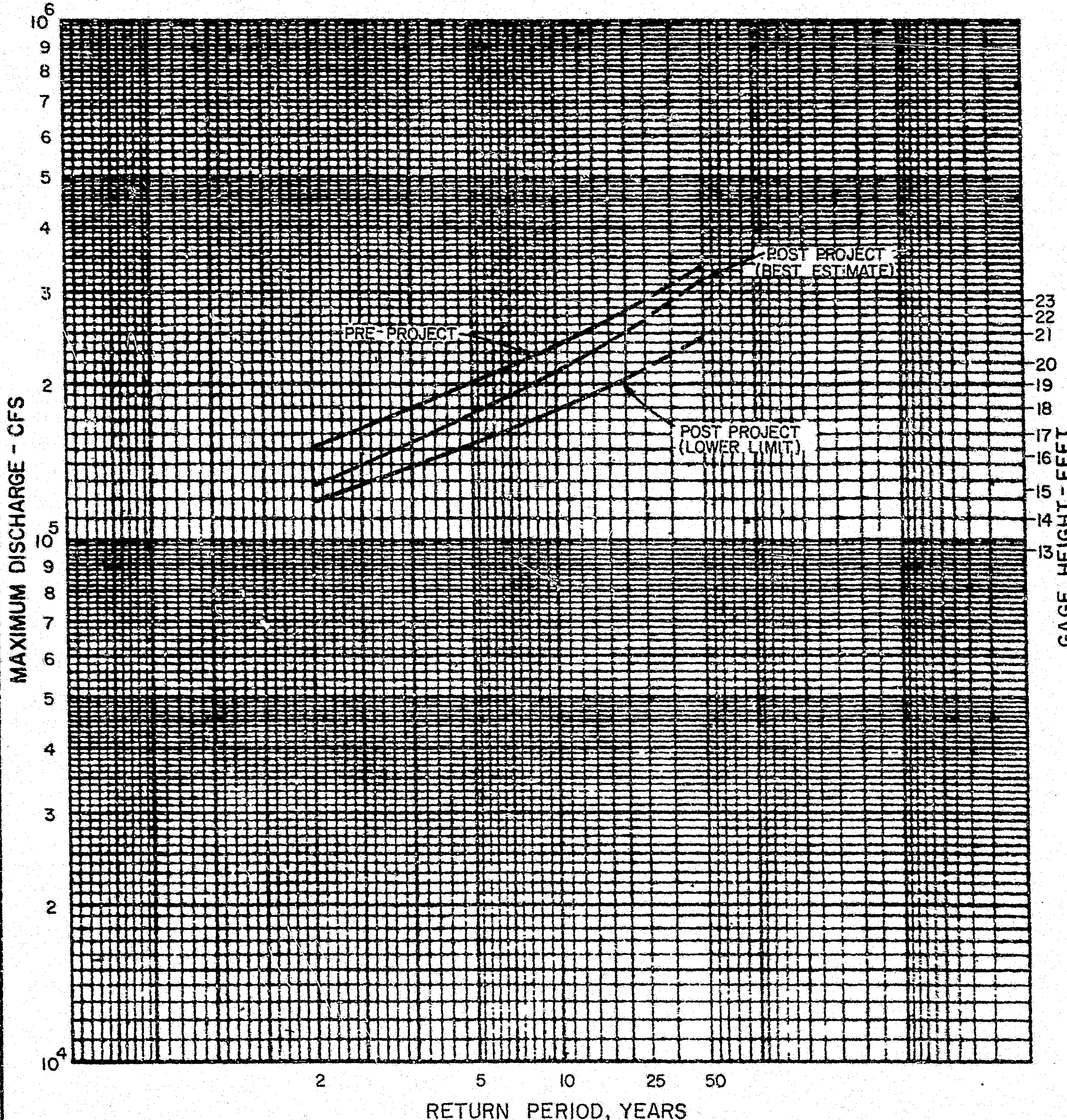


DISCHARGE - STAGE FREQUENCY CURVE
SUSITNA RIVER AT GOLD CREEK

NOTE: BASED ON PRELIMINARY DATA, SUBJECT TO REVISION

FIGURE 9.6

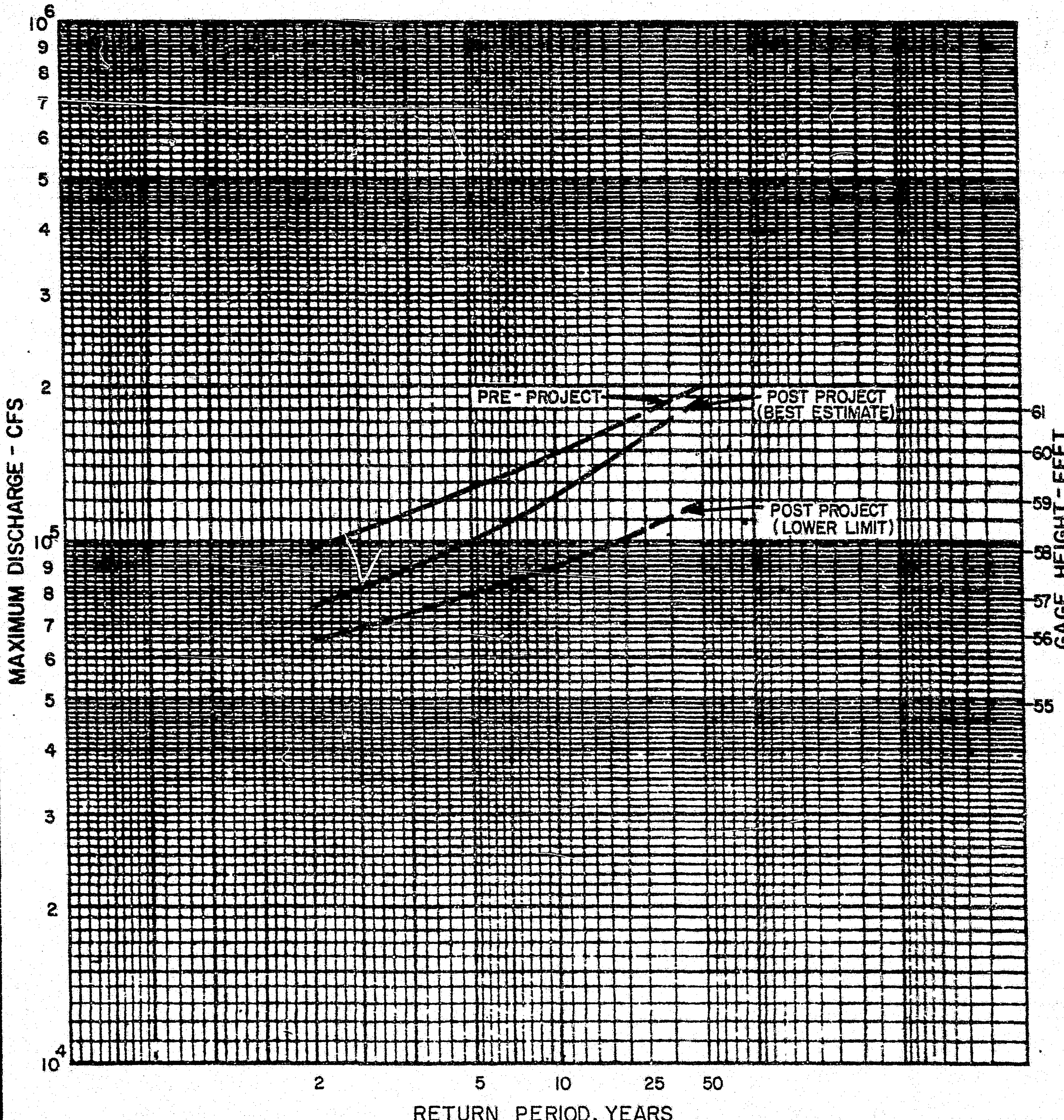
ACRES



DISCHARGE - STAGE FREQUENCY CURVE
SUSITNA RIVER AT SUSITNA STATION

NOTE: BASED ON PRELIMARY DATA, SUBJECT TO REVISION

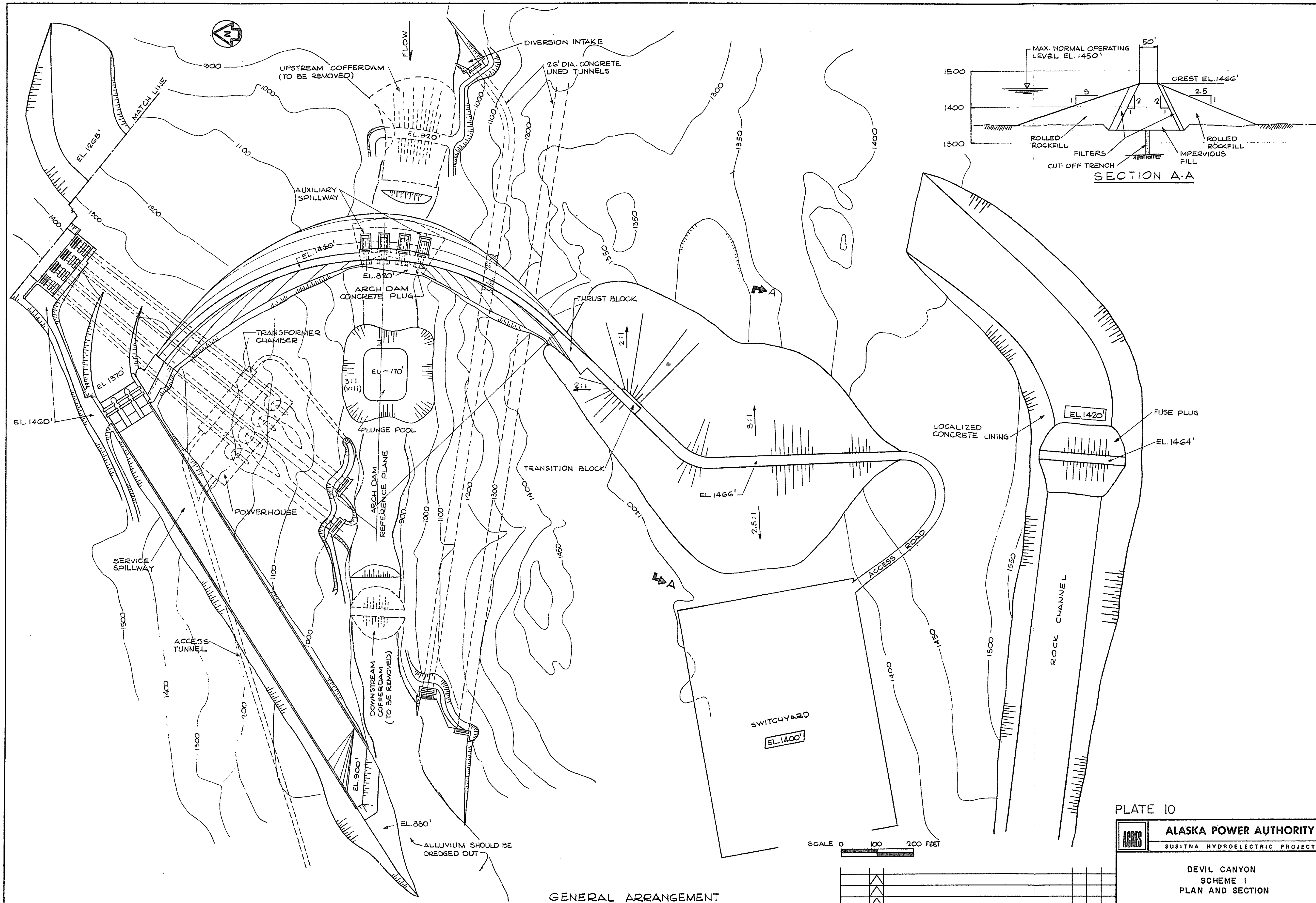
FIGURE 9.7



DISCHARGE - STAGE FREQUENCY CURVE
SUSITNA RIVER AT SUNSHINE

NOTE: BASED ON PRELIMINARY DATA SUBJECT TO RETURN

FIGURE 9.8

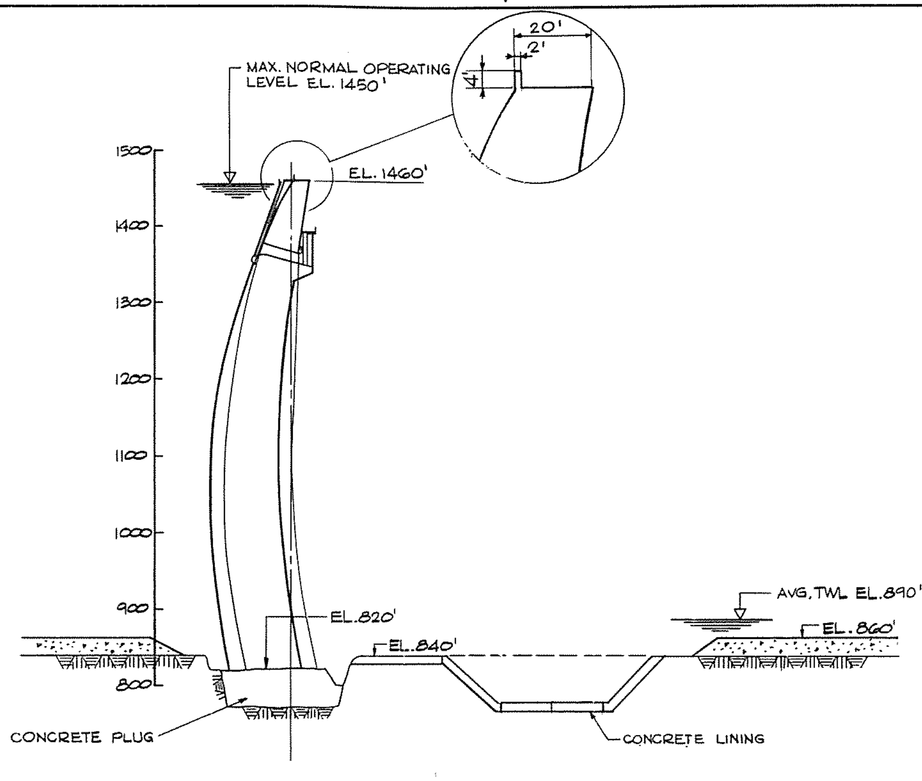


GENERAL ARRANGEMENT

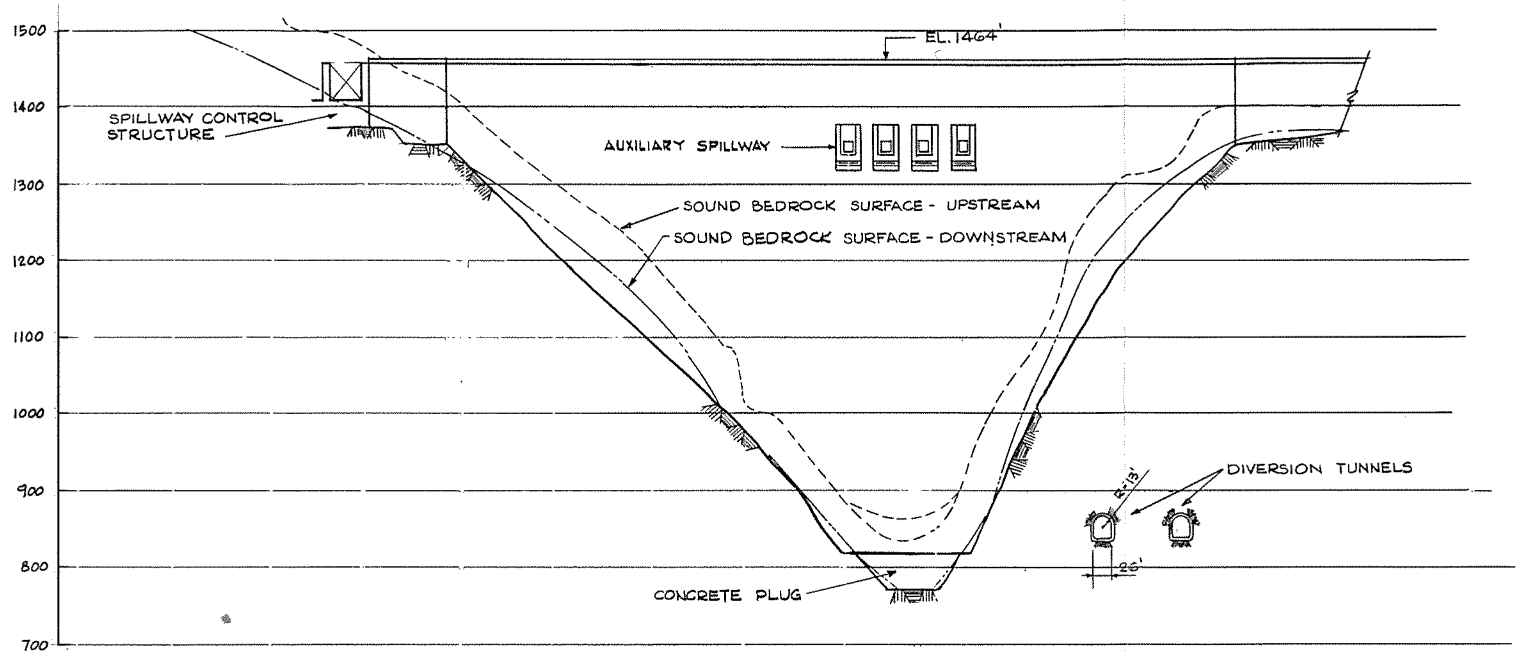
PLATE 10

ACRES	ALASKA POWER AUTHORITY
	SUSITNA HYDROELECTRIC PROJECT
	DEVIL CANYON SCHEME I PLAN AND SECTION
DATE DEC. 1981	SCALE 1" = 100'
ACRES AMERICAN INCORPORATED	DRAWING NO. SK-5700-C6-30B

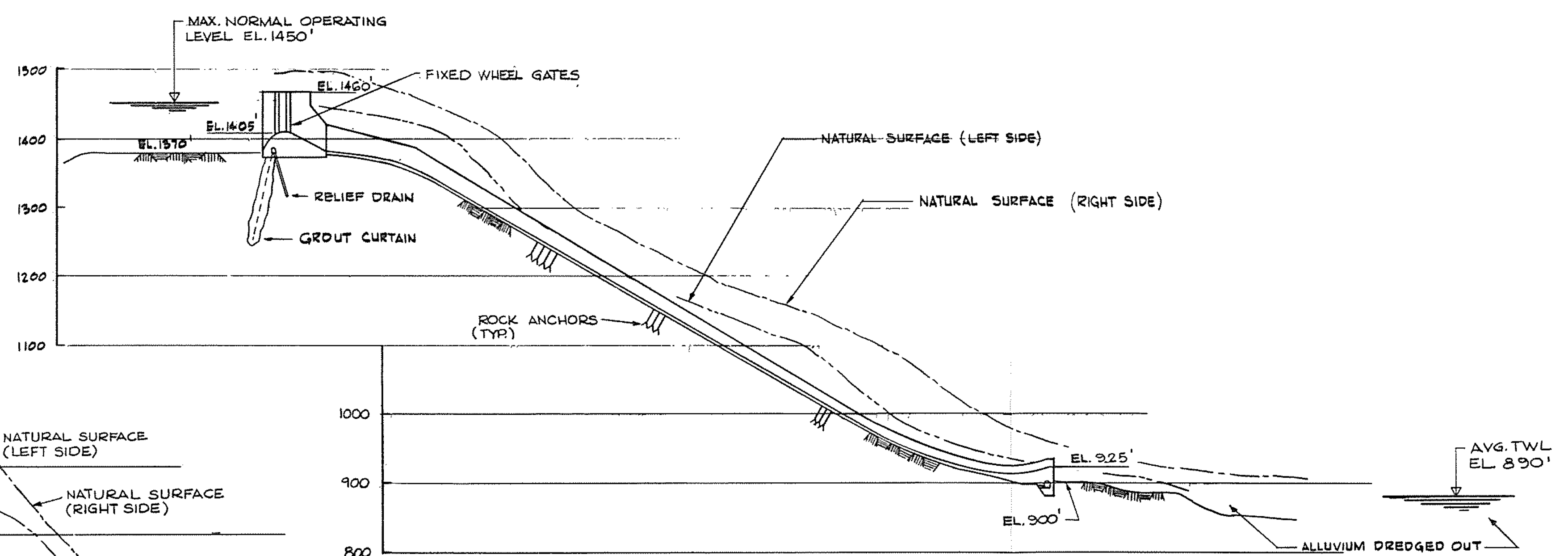
DATE	NO.	REVISIONS	CH.	APP.	APP.



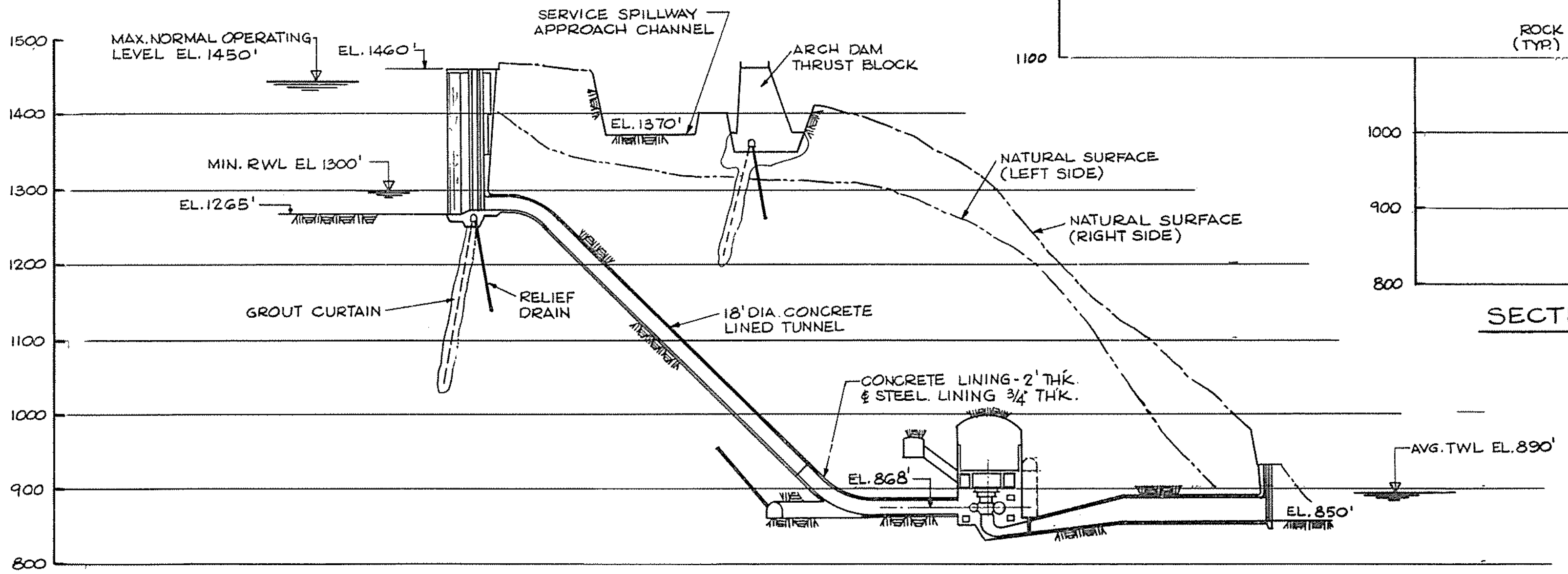
CROWN SECTION



DAM PROFILE (LOOKING UPSTREAM)



SECTION THRU SPILLWAY



SECTION THRU POWER FACILITIES

SCALE 0 100 200 FEET

PLATE 11

ACRES

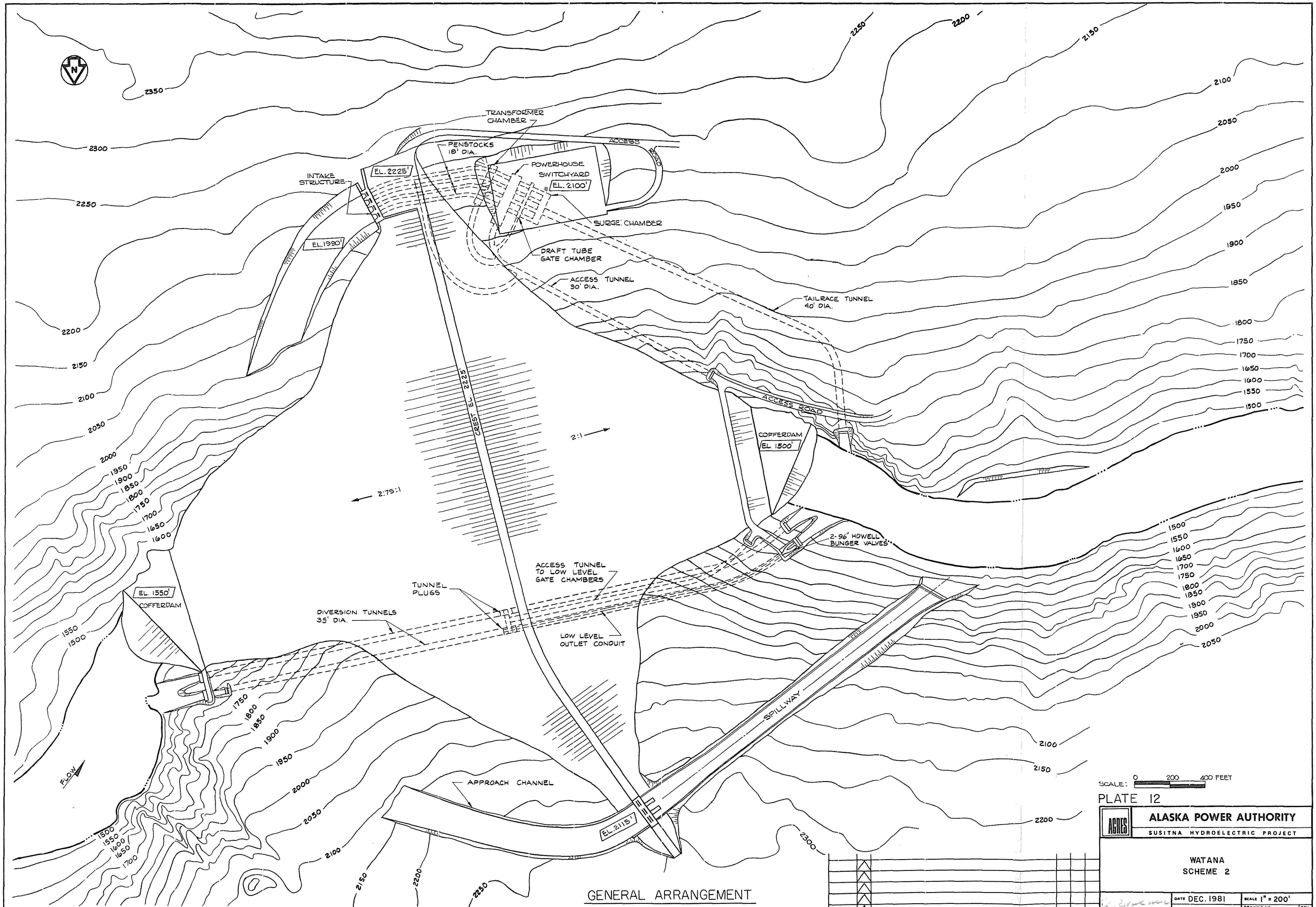
ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

DEVIL CANYON
SCHEME I
SECTIONS

ACRES AMERICAN INCORPORATED	DATE DEC. 1981	SCALE 1" = 100'	
	DEPARTMENT	DRAWING NO. SK-5700-C6-307	REV.
	PROJECT	SHEET OF	

DATE	NO.	REVISIONS	CH.	APP.	APP.



GENERAL ARRANGEMENT

PLATE 12

ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

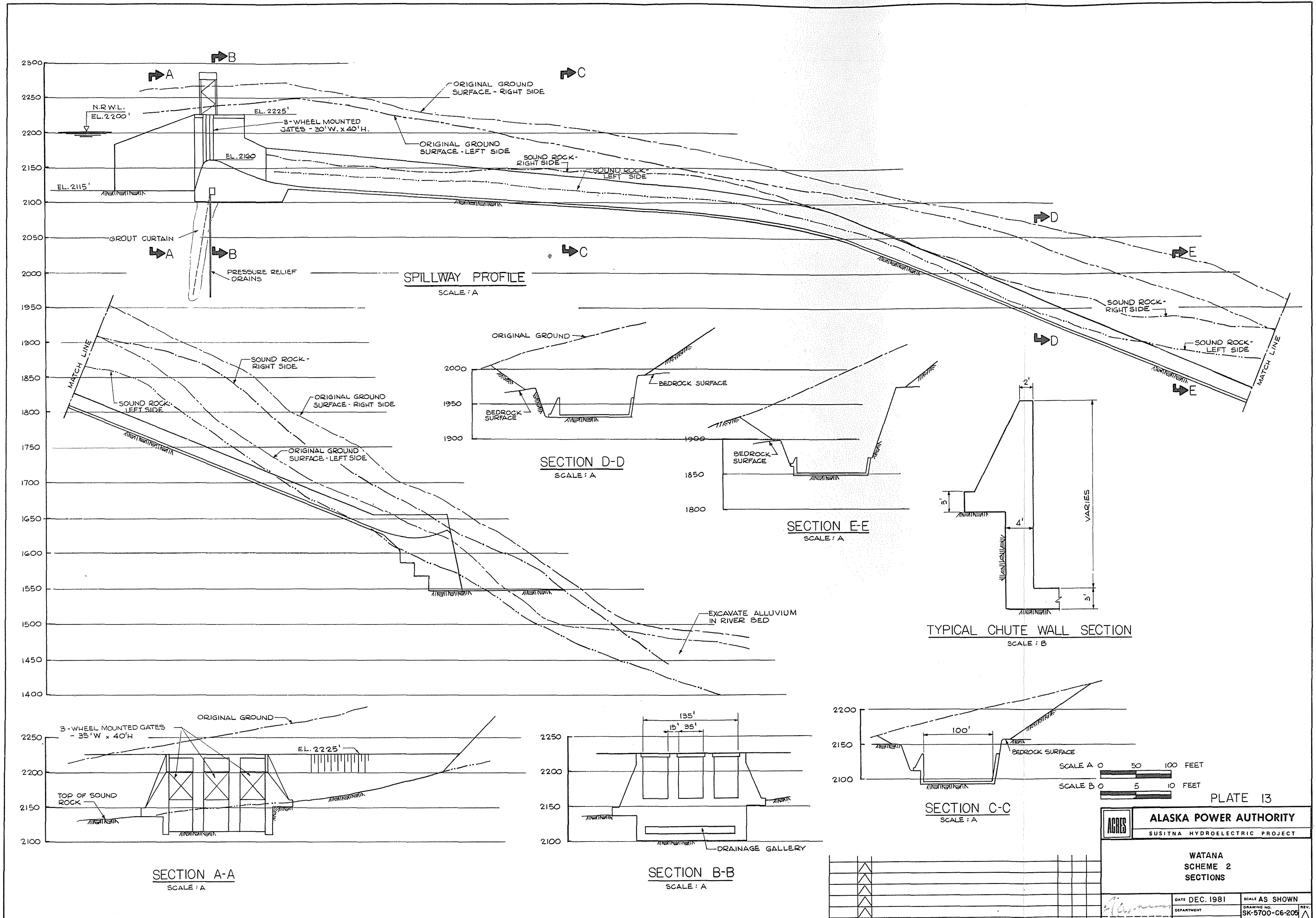
WATANA
SCHEME 2

DATE	NO.	REVISIONS	CH.	APP.	APP.

ACRES AMERICAN INCORPORATED

DATE DEC. 1981 | SCALE 1" = 200'

DRAWING NO. SK-5700-C6-204


SPILLWAY PROFILE
SCALE : A
ORIGINAL GROUND SURFACE - RIGHT SIDE
ORIGINAL GROUND SURFACE - LEFT SIDE
N.R.W.L. EL.2200'
EL. 2225'
3-WHEEL MOUNTED GATES - 30'W. x 40'H.
EL. 2160
EL. 2115'
SOUND ROCK - RIGHT SIDE
SOUND ROCK - LEFT SIDE
GROUT CURTAIN
PRESSURE RELIEF DRAINS
MATCH LINE
EXCAVATE ALLUVIUM IN RIVER BED
SECTION D-D
SCALE : A
ORIGINAL GROUND
BEDROCK SURFACE
SECTION E-E
SCALE : A
TYPICAL CHUTE WALL SECTION
SCALE : B
2'
3'
4'
VARIES
SECTION A-A
SCALE : A
3 - WHEEL MOUNTED GATES - 35'W x 40'H
TOP OF SOUND ROCK
EL. 2225'
SECTION B-B
SCALE : A
135'
15' 35'
DRAINAGE GALLERY
SECTION C-C
SCALE : A
100'
SCALE A 0 50 100 FEET
SCALE B 0 5 10 FEET
PLATE 13
ACRES
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA
SCHEME 2
SECTIONS
DATE DEC. 1981
SCALE AS SHOWN
DRAWING NO. SK-5700-C6-205
ACRES AMERICAN INCORPORATED
DATE
NO.
REVISIONS
CH.
APP.
APP.

10 - CONCLUSIONS AND RECOMMENDATIONS

10.1 - Conclusions

(a) A standard methodology has been adopted to guide the Susitna Basin development selection process described in this report. It incorporates a series of screening steps and concludes with plan formulation and evaluation procedures. Both the screening and plan evaluation procedures incorporate criteria relating to technical feasibility, environmental and socioeconomic aspects, and economic viability.

(b) The economic analyses are required to assist the State in allocating funds optimally and are therefore conducted using a real (i.e. inflation adjusted) interest rate of 3 percent and a corresponding general inflation rate of zero percent. Fuel costs are assumed to escalate at specified amounts above the general inflation rate.

(c) Previous studies over the past 30 years have thoroughly investigated the potential of the basin and the most recent studies conducted by the COE have concluded that the Watana-Devil Canyon development plan is the preferred option. However, review of these studies has indicated that a certain amount of revision is appropriate, both to develop a more uniform level of detail for all the alternative sites considered and to reassess the earlier planning decisions in the light of current load projections which are generally lower than those used in the earlier studies.

(d) The current (1980) Railbelt System annual energy requirement is estimated to be 2790 Gwh and the peak demand 515 MW. Near future demands can be satisfied by the existing generating system plus the committed expansion at Bradley Lake (hydroelectric) and the combined cycle (gas fired) plant at Anchorage till 1993 provided an Anchorage-Fairbanks intertie of adequate capacity is constructed.

(e) Energy and capacity forecasts for the year 2010 can be summarized as in Table 10.1.

(f) A range of technically feasible options capable of meeting future energy and capacity demands have been identified and include the following:

- Thermal Units

  - Coal fired steam generation: 100, 250, and 500 MW
  - Combined cycle generation: 250 MW
  - Gas turbine generation: 75 MW
  - Diesel generation: 10 MW

- Hydroelectric Options

  - Alternative development plans for the Susitna Basin capable of providing up to 1200 to 1400 MW capacity and an average energy yield of approximately 6000 Gwh.

Ten additional potential hydroelectric developments located outside the Susitna Basin and ranging from 8 to 480 MW in capacity and 33 to 1925 Gwh annual energy yield.

(g) Indications are that the utilities will be subject to the prohibitions of the Fuel Use Act and that the use of natural gas in new facilities will be restricted to peak load application only.

(h) The Susitna Basin development selection studies indicated that the 1200 MW Watana-Devil Canyon dam scheme is the optimum basin development plan from an economic, environmental, and social point of view. It involves a 880 feet high fill dam at Watana with an ultimate installed capacity of 800 MW and a 675 feet high concrete arch dam at Devil Canyon with a 400 MW powerhouse, and develops approximately 91 percent of the total basin potential.

Should only one dam site be developed in the basin, then the High Devil Canyon dam which develops 53 percent of the basin potential provides the most economical energy. This project, however, is not compatible with the Watana-Devil Canyon development plan as the site would be inundated by the Devil Canyon development.

(i) Comparison of the Railbelt system generation scenario incorporating the Watana-Devil Canyon Susitna development and the all thermal option reveals that the scenario "with Susitna" is economically superior and reduces the total system present worth cost by $2280 million. An overall evaluation of these two scenarios based on economic, environmental, and social criteria indicates that the "with Susitna" scenario is the preferred option.

The "with Susitna" scenario remains the most economic for a wide range load forecast and parameters such as interest rate, fuel costs and fuel escalation rates. For real interest rates above 8 percent or fuel escalation rates below zero, the all thermal generating scenario becomes more economic. However, it is not likely that such high interest rates or low fuel escalation rates would prevail during the foreseeable future.

(j) Economic comparisons of the generating scenarios "with Susitna" and the scenario incorporating alternative hydro options indicate that the present worth cost of the "with Susitna" scenario is $1190 million less.

(k) Preliminary engineering studies indicate that the preferred dam type at Watana is a rockfill alternative while a double curvature thin arch concrete dam is the most appropriate type for the Devil Canyon site.

10.2 - Recommendations

The recommendations outlined in this section pertain to the continuing studies under Task 6 Design Development. It is assumed that the necessary hydrologic, seismic, geotechnical, environmental, and tranmission system studies will also continue to provide the necessary support data for completion of the Feasibility Report.

Project planning and engineering studies should continue on the selected Susitna Basin Watana-Devil Canyon development plan. These studies should encompass the following:

(a) Project Planning

Additional optimization studies should be conducted to define in more detail, the Watana-Devil Canyon development plan. These studies should be aimed at refining:

- Dam heights

- Installed capacities: as part of this task consideration should also be given to locating the tailrace of the Devil Canyon powerhouse closer to Portage Creek in order to make use of the additional head estimated to amount to 55 feet.

- Reservoir operating rule curves

- Project scheduling and staging concepts: a more detailed analysis of the staging concept should be undertaken. This should include a re-evaluation of the powerhouse stage sizes and the construction schedules. In addition, an assessment should be made of the technical, environmental and economic feasibility of bringing the Devil Canyon dam and powerhouse online before the Wantana development. This may be an attractive alternative from a scheduling point of view as it allows Susitna power to be brought online at an earlier date due to the shorter construction period associated with the Devil Canyon dam.

The general procedure established during this study for site selection and plan formulation as outlined in Appendix A should be adhered to in undertaking the above optimization studies.

(b) Project Engineering Studies

The engineering studies outlined in Subtasks 6.07 through 6.31 should continue as originally planned in order to finalize the project general arrangements and details, and to firm up technical feasibility of the proposed development.

(c) Generation Planning

As outlined in the original Task 6.37 study effort, the generation scenario planning studies should be refined once the more definitive project data is obtained from the studies outlined in Sections (a) and (b) above and the Railbelt generation alternatives study is completed. The objective of these studies should be to refine the assessment of the economic, environmental, and social feasibility of the proposed Susitna Basin development.

TABLE 10.1 - ENERGY AND CAPACITY FORECASTS FOR 2010

Load Growth	Project Annual Energy Demand Gwh	Equivalent Annual Rate of Increase	Peak Demand MW
Very low (i.e. incorporating additional load management and conservation measures)	5,200	2.1%	920
Low	6,220	2.7%	1,140
Medium	8,940	4.0%	1,635
High	15,930	6.0%	2,900