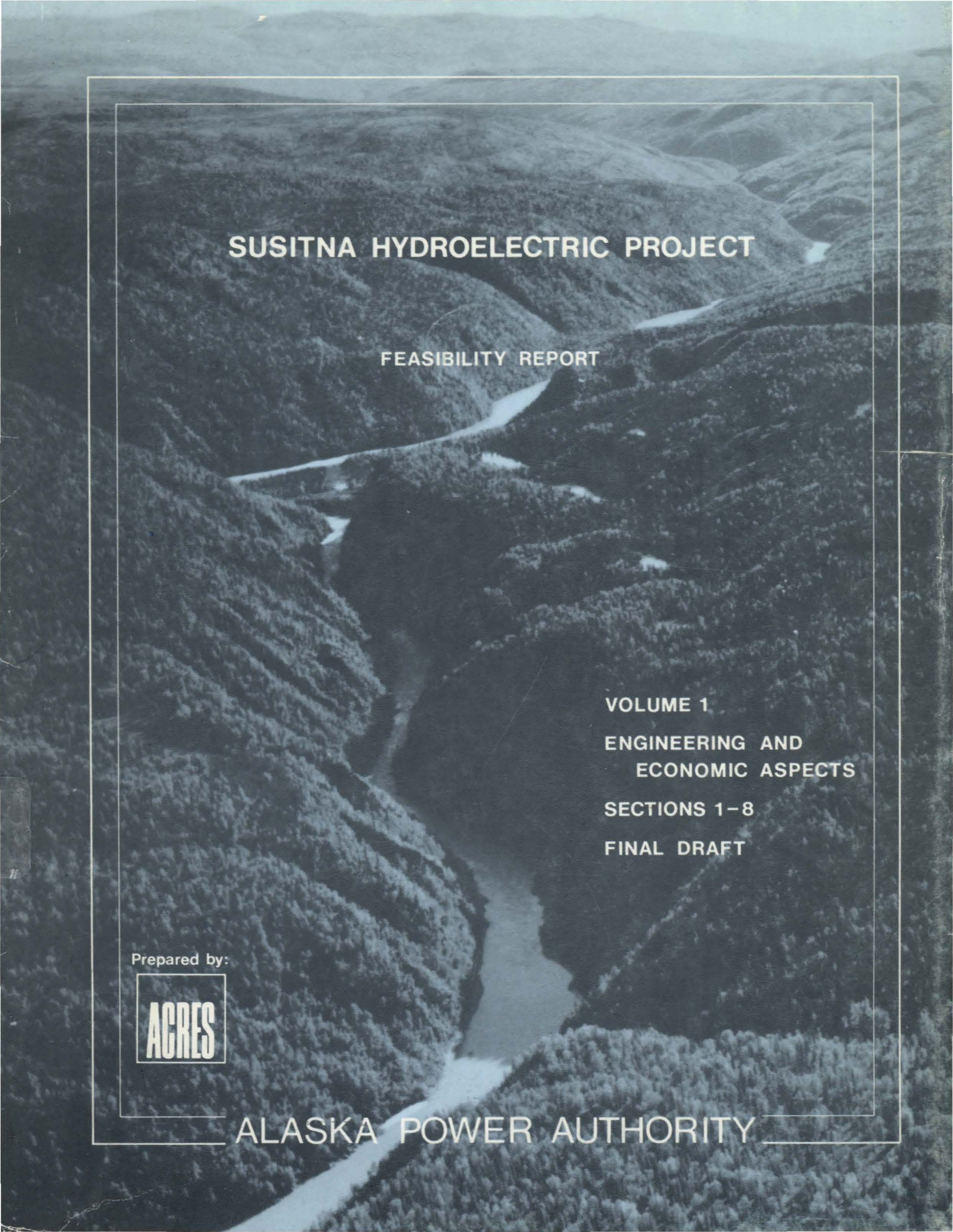

SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME 1

ENGINEERING AND ECONOMIC ASPECTS

SECTIONS 1–8

FINAL DRAFT

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME 1

ENGINEERING AND
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SECTIONS 1–8

FINAL DRAFT

ARLIS
Alaska Resources
Library & Information Services
Anchorage Alaska

Prepared by:

ACRES

ALASKA POWER AUTHORITY


WATANA


DEVIL CANYON

SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME 1 - ENGINEERING AND ECONOMIC ASPECTS PAGE

Note: Sections 9 to 19 are bound under separate cover.

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CONSTRUCTION SCHEDULES

LIST OF REFERENCE REPORTS

The following reports and documents were prepared during the course of the study program. Specific references in the text of the report are cited and listed separately by section; they should not be confused with the following list.

Number	Report	Prepared By
R1	Plan of Study	Acres
R2	Plan of Study, Revision 1	Acres
R3	Plan of Study, Revision 2	Acres
R4	Plan of Study, Revision 3	Acres
R5	Forecasting Peak Electrical Demands for Alaska's Railbelt	WCC
R6	Closeout Report, Review of ISER Work	Acres
R7	Task 1 Termination Report, September 1980	Acres
R8	Field Reconnaissance of Reservoir Area - Timber Report	R&M
R9	Marketability and Disposal Study for Reservoir Area	R&M
R10	Aerial Photography and Photogrammetric Mapping	R&M
R11	Control Network Survey Report	R&M
R12	Hydrographic Surveys	R&M
R13	Field Data Collection and Processing	R&M
R14	Glacier Studies	R&M/U. of Alaska
R15	Regional Flood Studies	R&M
R16	Hydraulic and Ice Studies	R&M/Acres
R17	Reservoir Sedimentation	R&M
R18	River Morphology	R&M
R19	Review of Available Materials	Acres
R20	Field Data Index	R&M
R21	Water Quality - Annual Report - 1980	R&M
R22	Water Quality - Annual Report - 1981	R&M
R23	Water Quality - Interpretation - 1981	R&M
R24	Ice Observations - 1980	R&M
R25	Processed Climatic Data for Six Weather Stations (6 volumes)	R&M
R26	Interim Report on Seismic Studies	WCC
R27	Final Report on Seismic Studies	WCC
R28	1980 Geotechnical Report (Superceded by R29)	Acres
R29	1980-81 Geotechnical Report	Acres
R30	OGP Data	Acres
R31	Development Selection Report	Acres
R32	Review of Previous Studies and Reports Closeout Report February 1981	Acres
R33	Tunnel Alternative Report July 1981	Acres
R34	Evaluation of Arch Dam at Devil Canyon Site	Acres
R35	1981 Upper Limit Capital Cost Estimate, July 1981	Acres
R36	Scour Hole Development Downstream of High Head Dams	Acres
R37	1980 Summary Environmental Report	TES

LIST OF REFERENCE REPORTS (Cont'd)

Number	Report	Prepared By
R38	Environmental Report - Fish Ecology - 1980	TES
R39	Environmental Report - Plant Ecology - 1980	TES
R40	Environmental Report - Big Game - 1980	TES
R41	Environmental Report - Birds and Non Game Mammals - 1980	TES
R42	Environmental Report - Furbearers - 1980	TES
R43	Environmental Report - Land Use Analysis - 1980	TES
R44	Environmental Report - Socioeconomics - 1980	TES
R45	Environmental Report - Cultural Resources - 1980	TES
R46	Fish and Wildlife Mitigation Policy - Revised	TES/Acres
R47	Instream Flow Study Plan	Acres
R48	Draft Fishery Mitigation Plan	TES
R49	Draft Wildlife Mitigation Plan	TES
R50	Phase 1 Report - Fish Ecology	ADF&G
R51	Phase 1 Report - Big Game	ADF&G
R52	Phase 1 Report - Plant Ecology	TES
R53	Phase 1 Report - Bird and Non-Game Mammals	TES
R54	Phase 1 Report - Furbearers	TES
R55	Phase 1 Report - Land Use	TES
R56	Phase 1 Report - Socioeconomics	TES
R57	Phase 1 Report - Cultural Resources	TES
R58	Phase 1 Report - Recreation	TES
R59	Sociocultural Report	Acres
R60	Environmental Analysis of Alternative Access Plan	TES
R61	Access Planning Study	R&M
R62	Access Route Selection Report	Acres
R63	Electric System Studies	Acres
R64	Transmission Line Corridor Screening Report	Acres
R65	Transmission Line Selected Route	Acres/TES
R66	Switching Stations and Substations - Single Line Diagrams	Acres
R67	Agency Consultation Report	Acres
R68	Initial Version Preliminary Licensing Documentation, April 1980	Acres
R69	Preliminary Licensing Documentation - 2nd Version November 1981	Acres
R70	Status of Susitna Basin Water Rights	Acres
R71	Project Overview Report, 2nd Draft	Acres
R72	Economic Marketing and Financial Evaluation	Acres
R73	Susitna Risk Analysis	Acres

1 - INTRODUCTION

This Feasibility Report has been prepared by Acres American Incorporated (Acres) for the Alaska Power Authority under the terms of an Agreement, dated December 19, 1979, to conduct a feasibility study and prepare a license application to the Federal Energy Regulatory Commission (FERC).

The feasibility study was undertaken in accordance with the Plan of Study (POS) for the Susitna Hydroelectric Project, which was first issued by the Power Authority for public review and comment on February 4, 1980. Three revisions to the POS were issued in September, 1980, December, 1981, and January, 1982 to take account of public, federal, and state agency comments and concerns. The POS 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, which is currently scheduled for September 30, 1982. The filing of the FERC license application is contingent upon acceptance of the findings of this report in terms of project feasibility and environmental acceptability by the state, and a decision to proceed with developmental efforts.

Studies by Acres through March, 1981 were mainly concerned with evaluation of the need for electric power in the Alaska Railbelt Region and preliminary consideration of the alternatives for meeting these power needs both with and without a Susitna Basin hydroelectric development. This work was undertaken in parallel with Railbelt power demand forecasting studies undertaken by the Institute for Social and Economic Research (ISER) for the State of Alaska. The results of these studies were presented in June, 1981, in a Development Selection Report which described these initial steps in the POS process and provided recommendations and justification for continuation of study of basin development at two sites, Watana and Devil Canyon.

Subsequent to selection of this basin development plan, engineering studies were continued to develop preliminary design and cost information for the Watana and Devil Canyon sites. These design development studies were updated in conjunction with an independent study of alternatives for meeting projected Railbelt electrical power requirements by Battelle Pacific Northwest Laboratories, undertaken for the State of Alaska. All of this information was used to establish definitive project arrangements for Watana and Devil Canyon as well as for the associated transmission facilities, to develop estimates of construction and operating costs, to undertake an economic and financial evaluation for the Susitna Hydroelectric Project, and to assess the environmental impact of the project and appropriate mitigation measures. The remainder of this section 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.

Meandering for the first 50 miles in a southerly direction across a broad alluvial fan and plateau, the river 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 to Cook Inlet, about 30 miles west of Anchorage. The vast hydroelectric potential of this river has been recognized and studied for more than 30 years. Strategically located in the heart of the South Central Railbelt, the Susitna Basin could be harnessed to produce about twice as much electrical energy per year as is now being consumed in the Railbelt region. The general location of the Susitna Basin within the Railbelt area is shown on Figure 1.1.

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. Freezing starts in October in the upper reaches of the basin; by late November, ice covers have formed on all but the most rapidly flowing stretches of the river. Breakup generally occurs during 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. Extensive studies are necessary to determine the total value of these wildlife resources, 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 1940s by agencies such as the U.S. Bureau of Reclamation (USBR), the Alaska Power Administration, and the US Army Corps of Engineers (COE), as well as H.H. Kaiser and Company. The more recent and most comprehensive of these studies was carried out by the COE. The optimum method of developing the hydroelectric potential of the basin was determined by the COE to comprise two major developments. The first of these would require a dam at the Watana site at approximately mile 184 up the Susitna River, and the second, a dam at the Devil Canyon site, approximately 31 miles downstream of Watana. The locations of these sites are shown on Figure 1.1. 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.

Development selection studies completed by Acres in 1981 confirmed that the preferred Susitna development plan should consist of two large hydroelectric dams at Watana and Devil Canyon. The Development Selection Report recommended further study of hydroelectric installations at these two sites. The preliminary studies indicated that an earthfill dam, roughly 880 feet maximum height, would be constructed at Watana first. The large reservoir volume created would provide adequate storage for seasonal regulation of the flow. Initially, approximately 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-foot maximum height double curvature concrete arch dam and incorporate a 400 MW powerhouse. The total average annual energy yield from this development was estimated as 6200 GWh. The Watana and Devil Canyon developments together comprise the Susitna Hydroelectric Project.

Design studies undertaken subsequent to the selection of the Susitna development plan confirmed that the optimum installed generating capacity for Watana should ultimately be 1020 MW, and that first power should be available in 1993. Devil Canyon would add 600 MW to the system by 2002. The most suitable access route to the site would involve a road from the Parks Highway southeast to Gold Creek, then along the south side of the Susitna River to Devil Canyon and along the north side of the river to Watana. The power from the two sites would be conveyed by five 345 kV transmission lines to the proposed Anchorage-Fairbanks intertie at Gold Creek. The connection to Fairbanks would finally consist of double 345 kV lines, and to Anchorage triple 345 kV lines via a cable crossing at Knik Arm near Point Mackenzie.

1.3 - Objectives and Scope of Current Studies

The assessment of feasibility of an undertaking as significant as the proposed Susitna Hydroelectric Project required an appropriately high level of effort in terms of field and office activities. Three primary objectives were first identified:

- To determine technical, economic and financial feasibility of the Susitna Project to meet future power needs of the Railbelt Region of the State of Alaska;

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

- To file a completed license application with the Federal Energy Regulatory Commission (FERC).

The scope of work was carefully structured to meet these objectives in the available time frame in a manner appropriate to the scale, variety, and complexity of the problems involved. The POS was originally prepared and revised three times to address in almost exhaustive detail the numerous work tasks and the many engineering, scientific, administrative, and associated supporting skills required.

A total of twelve major areas of study or tasks were identified:

- Task 1: Power Studies
- Task 2: Surveys and Site Facilities
- Task 3: Hydrology
- Task 4: Seismic Studies
- Task 5: Geotechnical Exploration
- Task 6: Design Development
- Task 7: Environmental Studies
- Task 8: Transmission
- Task 9: Construction Cost Estimates and Schedules
- Task 10: Licensing
- Task 11: Marketing and Financing
- Task 12: Public Participation Program

Two further tasks, 00 (Project Management) and 13 (Administration) were also established. These tasks were originally further subdivided into a total of 150 subtasks, ranging from five to 31 subtasks on a task-by-task basis. Revisions to the POS resulted in an additional 10 subtasks, the largest task then accounting for 39 subtasks.

Activities ranged from engineering and scientific data acquisitions, literature review, research, dam studies, design computations and analysis, to field surveys, hydraulic measurements, seismologic observations, geologic mapping, geotechnical exploration, environmental data gathering, and the necessary logistical support services. The study directly involved up to as many as 300 participants at one time and drew upon a broad cross-section of contributions from expert specialists to concerned citizens.

1.4 - Plan Formulation Selection Process

A key element in the studies undertaken was the process applied for formulation and comparison of development plans. Emphasis was placed on consideration of every important perspective which could influence the selection of a particular course of action from a number of possible alternatives. An essential component of this planning process involved a generalized multi-objective development selection methodology for guiding the planning decisions. A second important factor was 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 was developed to guide the various planning studies being conducted. Of the numerous planning decisions made in these studies, perhaps the most important were 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 involved 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 were eliminated on the basis of economic, environmental, social, and other prescribed criteria. Plans were then formulated which incorporated the shortlisted candidates individually or in appropriate combinations. Finally, a more detailed evaluation of the plans was carried out, again using prescribed criteria and aimed at selecting the best development plan. Figures 1.1, 1.2, and 1.3 illustrate this general process.

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

b) Economic Analyses

Since the proposed Susitna development is a public or state project, all planning studies described were carried out using economic parameters as a basis of evaluation. This ensured that the resulting investment decisions maximized benefits to the state as a whole rather than any individual group or groups of residents.

The economic analyses incorporated the following principles:

- Intra-state transfer payments such as taxes and subsidies were excluded.

- Opportunity values were used to establish the costs for coal, oil, and natural gas resources used for power generation in the alternatives considered. These opportunity costs were 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 ignored the existence of current term-contractual commitments which may exist, and which fix resource costs at values different from the opportunity costs.

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

- A 3 percent discount rate was used as the basis of the economic analysis. A lower value would tend to improve the relative economic position of capital intensive projects (such as hydro generation) versus high level cosumptive projects (such as thermal generation). A higher value would have the opposite effect.

1.5 - Organization of Report

The objective of this report is to describe the studies undertaken to establish the feasibility of the Susitna Hydroelectric Project.

In order to improve the continuity and clarity of the report, much of the detailed technical and environmental material is included in separate appendices. The report is organized as follows:

Volume 1 - Engineering and Economic Aspects

Section 1: Introduction

A brief summary of the background of the Feasibility Report is presented in this section.

Section 2: Summary

This section contains a complete summary of Sections 4 through 19 of Volume 1.

Section 3: Scope of Work

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

Section 4: Previous Studies

A brief summary of previous Susitna Basin studies undertaken by others is given in this section.

Section 5: Railbelt Load Forecasts

In this section, the results of the energy and load forecast studies undertaken by ISER, Woodward-Clyde Consultants, and Battelle 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 characteristics of the Susitna Basin including climatologic, hydrologic, geologic, seismic, and environmental aspects.

Section 8: Susitna Basin Development Selection

This section outlines the engineering and planning studies undertaken for formulation of Susitna Basin Development Plans and selection of the preferred plan. The selected plan is compared to alternative methods of generating Railbelt energy needs on the basis of technical, economic, environmental and social considerations.

Section 9: Selection of Watana General Arrangement

This section describes the evolution of the general arrangement of the Watana Project. The site topography, geology, and seismicity of the Watana site is outlined relative to the design and arrangement of the various site facilities. The process by which reservoir operating levels and the installed generating capacity of the power facilities were selected is presented, along with the selection of project design floods.

Section 10: Selection of Devil Canyon General Arrangement

The development of the general arrangement of the Devil Canyon Project is described in this section, in a manner similar to that outlined for Section 9.

Section 11: Selection of Main Access Plan

This section describes the process for selection of the main access plan, together with a discussion of the various economic, technical, environmental and socioeconomic factors which influenced the selection of the selected plan.

Section 12: Watana Development

The various structures, permanent equipment, and systems which comprise the Watana Development are described in this section.

Section 13: Devil Canyon Development

This section presents a description of the structures, permanent equipment, and systems which comprise the Devil Canyon Development.

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Section 14: Transmission Facilities

The studies undertaken to select a power delivery system from the Watana and Devil Canyon Developments to the major load centers in Anchorage and Fairbanks are described in this section.

Section 15: Project Operation

This section describes the proposed operation of the Watana and Devil Canyon developments within the framework of the various requirements of energy demand and physical and environmental restraints. The dependable capacity and annual energy production for both developments are presented, together with a description of operating and maintenance facilities and procedures and proposed performance monitoring of the various project structures.

Section 16: Estimates of Cost

This section summarizes construction costs, mitigation costs, operating, maintenance and replacement costs, as well as indirect costs such as engineering and administration costs, and allowance for funds used during construction.

Section 17: Development Schedule

The schedule for planning, licensing, design, procurement, construction, and startup of the Watana and Devil Canyon Developments, together with transmission facilities, is presented.

Section 18: Economic and Financial Evaluation

This section presents the economic and financial evaluation for the Susitna Hydroelectric Project. A discussion of power marketing options is also given.

Section 19: Conclusions and Recommendations

This section presents the main conclusions of the feasibility study, together with recommendations regarding further action which should be undertaken by the Power Authority.

Volume 2 - Environmental Aspects

This volume of the Feasibility Report describes the environmental resources of the Upper Susitna Basin with specific emphasis on the proposed Watana and Devil Canyon impoundment areas. Section 1 contains a general description of the locale. Sections 2 through 9 contain detailed information on water use and quality; fish, wildlife, and botanical resources; historic and archaeological resources; socioeconomic impacts; geological and soil resources; recreational and aesthetic resources; and land use. This information is then utilized to predict impacts of the construction and operation of the reservoirs, transmission lines, and access road on the natural resources and socioeconomic conditions in the project area. In Section 10, alternatives to the proposed project are discussed and evaluated from the environmental point of view. These alternatives include hydroelectric development within and outside the Upper Susitna Basin and thermal and tidal power development. A list of literature relative to the study is presented in Section 11.

Volume 3 - Plates

This volume contains all of the plates pertaining to the Feasibility Report.

Volume 4 - Appendix A - Hydrological Studies

This volume includes detailed supportive data for water resource studies and flood studies, reservoir hydraulic and thermal studies, and climatic studies for transmission lines.

Volume 5 - Appendix B - Design Development Studies

This volume contains background and supporting data for dam selection and design studies, project layout studies, power facilities selection studies, and power plant operation studies.

Volume 6 - Appendix C - Cost Estimates

Detailed cost estimates and supporting cost data are presented in this volume.

Volume 7 - Appendix D - Public Participation and Agency Consultation

This volume contains a list of agencies contacted and copies of correspondence from agencies relative to the study. It also explains the programs developed to ensure agency input into planning and decision making associated with the project. This volume also describes the public participation program and presents a summary of public participation meetings conducted during the study program.

1.6 - Principal Project Parameters

Table 1.1 sets out the principal project parameters for the proposed Watana and Devil Canyon projects as determined by the studies presented in this report.

TABLE 1.1: PRINCIPAL PROJECT PARAMETERS

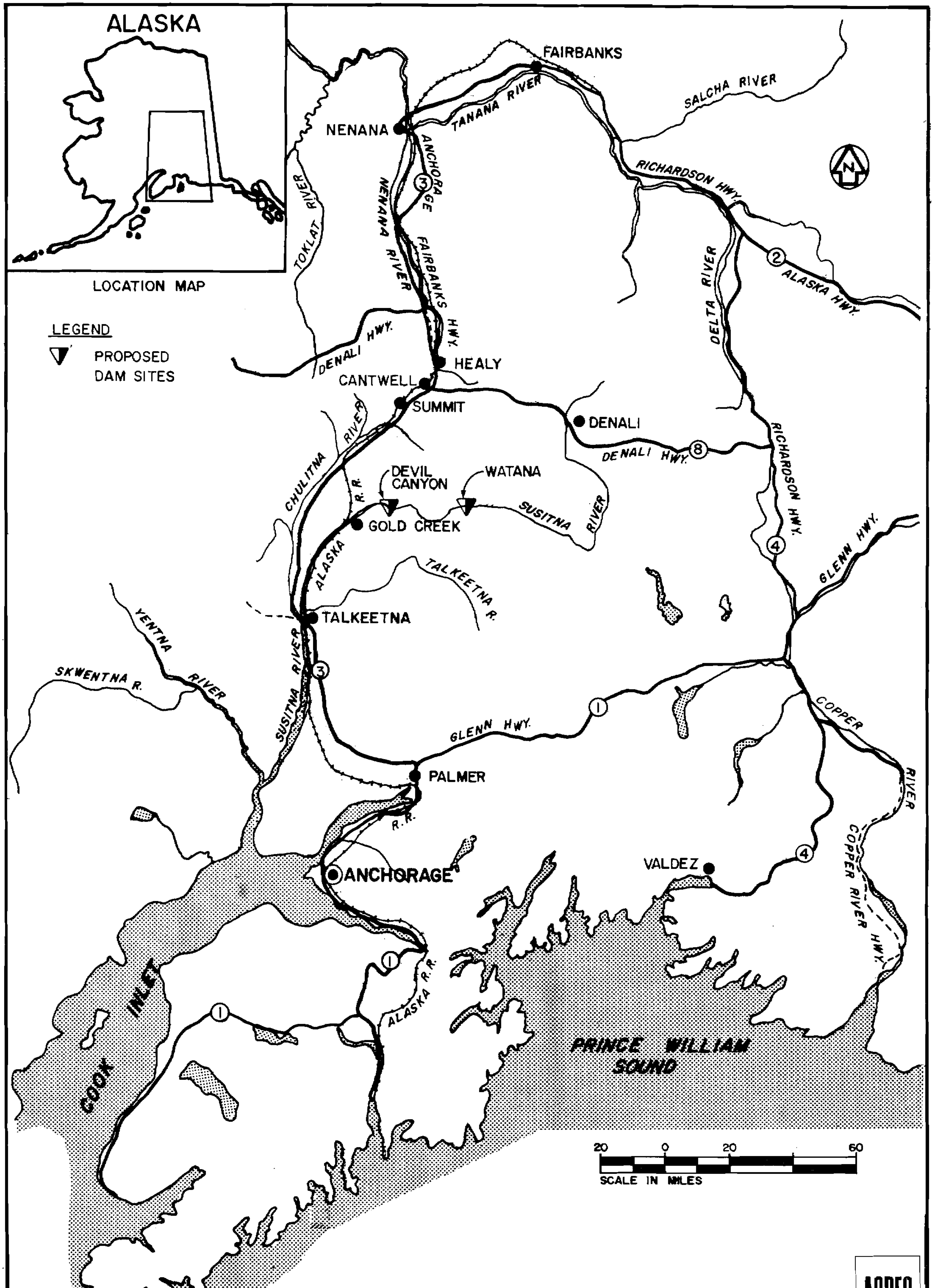
Item	Watana	Devil Canyon
Hydrology		
- Average River Flow (cfs)	7,940	9,040
- Peak Flood Inflows (cfs)		
. PMF	326,000	346,000
. 10,000 year	156,000	165,000
. 100 year	92,000	61,000
Reservoir Characteristics		
- Normal Maximum Operating Level (ft)	2,185	1,445
- Maximum Level, PMF (ft)	2,202	1,466
- Minimum Operating Level (ft)	2,045	1,405
- Area at NMOL (acres)	38,000	7,800
- Length (miles)	48	26
- Total Storage (acres/feet)	9.5×10^6	1.1×10^6
- Live Storage (acres/feet)	4.4×10^6	0.35×10^6
Project Outputs		
- Plant Design Capability (MW)	1,020	600
- Annual Generation (GWh)		
. Firm	2,630	2,770
. Average	3,450	3,340
Dams		
- Type	Earth/Rockfill, Central Core	Concrete Arch (Earth/Rockfill Saddle)
- Crest Elevation (ft)	2,210	1,463 (1472)
- Crest Length (ft)	4,100	1,650 (950)
- Height Above Foundation (ft)	885	646 (245)
- Crest Width (ft)	35	20 (35)
- Upstream Slope (H:V)	2.4:1	-(2.4:1)
- Downstream Slope (H:V)	2:1	-(2:1)
Diversion		
- Cofferdams		
. Type	Rockfill, Central Core	Rockfill, Central Core
. Upstream Crest Elevation (ft)	1,545	947
. Downstream Crest Elevation (ft)	1,472	898
. Maximum U/S Water Level (ft)	1,536	944
- Tunnels		
. Number/Type	2 - Circular, concrete-lined	1 - Horseshoe, concrete-lined
. Diameter (ft)	38	30
. Capacity (cfs)	80,500	36,000
Outlet Facilities		
- Central Structures	6-fixed cone valves	7-fixed cone valves
- Diameter (in)	78	4-102, 3-90
- Water Passage Diameter (ft)	28	8.5/7.5
- Capacity (cfs)	24,000	38,500

TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
Main Spillways		
- Capacity (cfs)	115,000	125,000
- Control Structure		
. Type	gated ogee	gated ogee
. Crest Elevation (ft)	2,148	1,404
. Gates (H x W, ft)	3-49 x 36	3-54 x 35
- Chute Width (ft)	144/80	122/65
- Energy Dissipation	Flip bucket	Flip bucket
Emergency Spillways		
- Capacity (cfs)	140,000	160,000
- Control Structure		
. Type	Open channel/ fuse plug	Open channel/ fuse plug
. Crest Elevation (ft)	2200/2201.5	1464/1465.5
- Chute Width (ft)	310/200	220
Power Intakes		
- Control Structures	Multi-level, gated	Single level, gated
- Gates (H x W, ft)	4-18 x 30	1-25 x 20
- Crest Elevation (ft)	2,012	1,364
- Maximum Drawdown (ft)	140	50
- Capacity, percent (cfs)	3,870	3,670
Penstocks		
- Number	6	4
- Type	Inclined/horizontal	Inclined/horizontal
- Diameter (ft)		
. Concrete-lined	17	20
. Steel-lined	15	15
Powerhouses		
- Type	Underground	Underground
- Cavern Size (L x W x H, ft)	455 x 74 x 126	360 x 74 x 126
- Turbine/Generator	6 Vertical Francis/ Synchr.	4 Vertical Francis/ Synchr.
- Speed (rpm)	225	225
- Design Unit Capability		
. Net head (ft)	652	542
. Flow (cfs)	3,510	3,710
. Output (MW)	170	150
- Rated Unit Capability		
. Net Head (ft)	680	575
. Full Gate Flow (cfs)	3,550	3,790
. Full Gate Output (MW)	1,089	656
. Best Gate Output (MW)	924	560
- Transformers		
. Location	Upstream gallery	Upstream gallery
. Cavern Size (L x W x H, ft)	314 x 45 x 40	446 x 43 x 40
. Number/Type	9 - single phase	12 - single phase
. Voltage (kV)	15/345	15/345
. Rating (MVA)	145	70

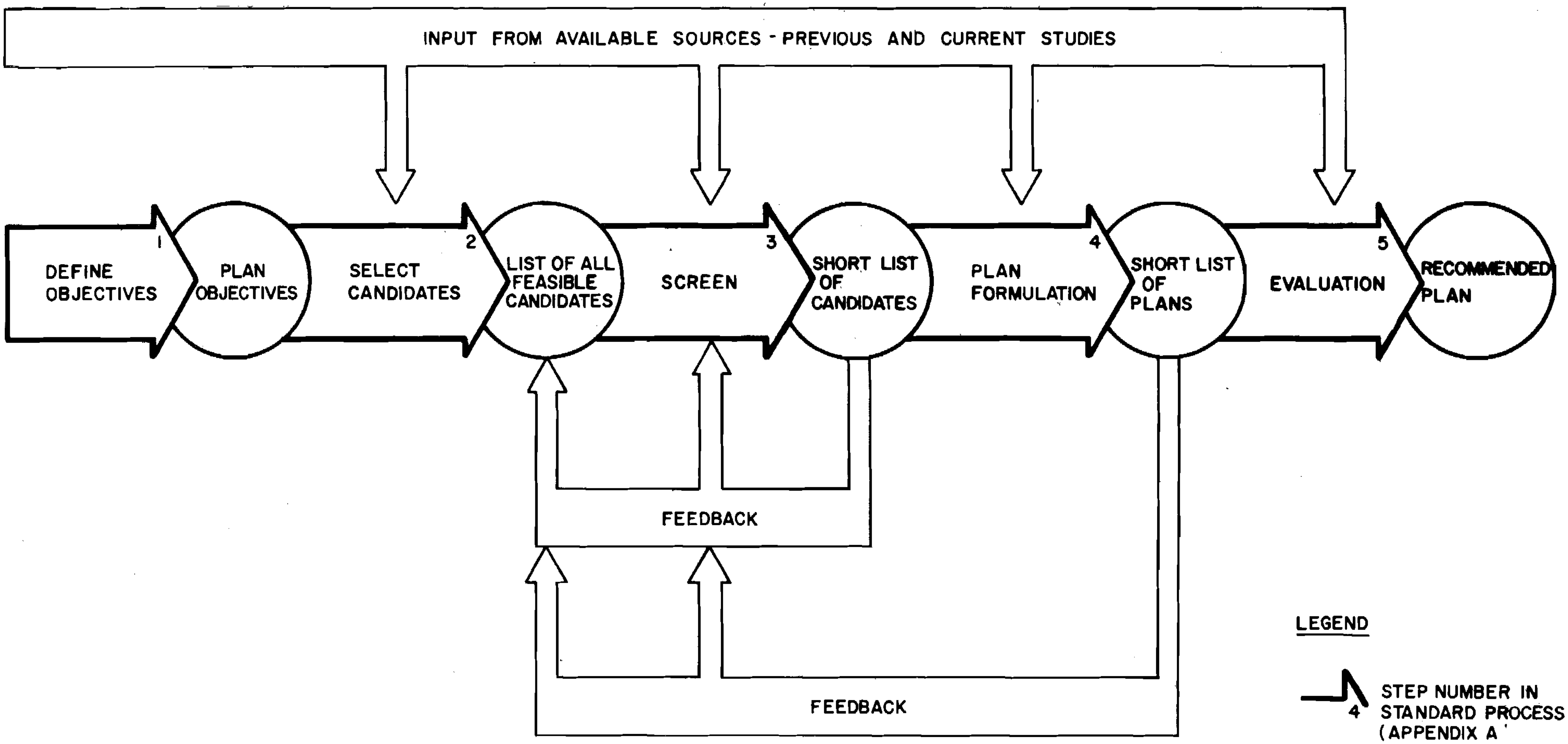
TABLE 1.1 (Cont'd)

Item	Watana	Devil Canyon
Tailrace Tunnels		
- Number/Type	2 - Horseshoe, concrete-lined	1 - Horseshoe concrete-lined
- Diameter (ft)	34	38
- Surge Chamber Size (L x W x H, ft)	350 x 50 x 150	300 x 75 x 190
- Capacity (cfs)	22,000	15,500



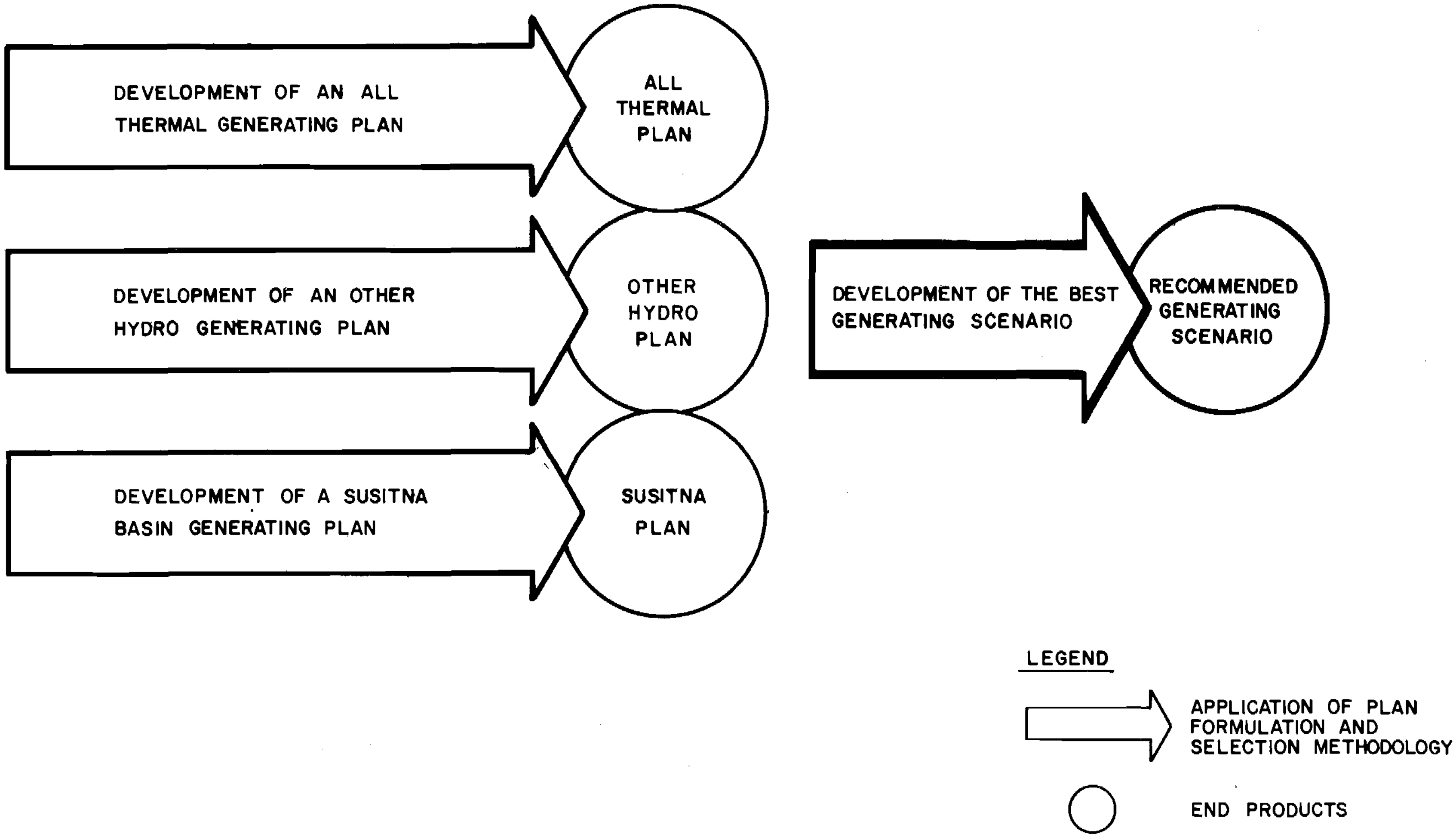
LOCATION MAP

FIGURE 1.1



PLAN FORMULATION AND SELECTION METHODOLOGY

FIGURE 1.2



PLANNING APPROACH

FIGURE 1.3

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2 - SUMMARY

This section presents a summary discussion of the contents of the feasibility report.

2.1 - Scope of Work

Activities under the Acres Plan of Study (POS) for the Susitna Project Feasibility assessment have been in progress from January 1980 to the present time. The study has involved detailed investigations of the numerous technical, economic, financial, environmental and institutional factors to be considered in an undertaking this large.

2.2 - Previous Studies

The hydroelectric potential of the Susitna River Basin has been the subject of numerous studies since shortly after World War II. An initial report on hydroelectric resources in Alaska, issued by the USBR in 1948 and updated in 1952, highlighted the development potential of the Susitna River. Subsequent studies and reports by the Department of the Interior (1961), the Alaska Power Administration (1974) and the Henry J. Kaiser Company (1974) confirmed the desirability of proceeding with hydroelectric development of the river at a number of different sites. Studies of the river basin by the COE in 1975 and 1979 culminated in the recommendation that development should proceed at the Watana and Devil Canyon sites.

2.3 - Railbelt Load Forecasts

Between 1940 and 1978, electricity sales in the Railbelt area grew at an average annual rate of 15.2 percent, about twice the national average. Between 1973 and 1978 the rate of growth fell to 10.9 percent. The two main reasons for these differences are the relatively higher growth rates in Alaska for both population and the proportion of households served by electric utilities.

Total utility sales in the Railbelt in 1980 reached 2,390 GWh, requiring 510 MW of generating capacity, at a load factor of 62.5 percent. Approximately 80 percent of these sales were consumed in the Anchorage area, about 19 percent in the Fairbanks area and the remainder in the Glenallen-Valdez area. In recent years approximately 47 percent of sales has been consumed by the residential sector, attributable mostly to space heating with smaller uses for lighting and domestic appliances such as refrigerators, water heaters and ranges. The remaining 53 percent has been accounted for by the commerical-industrial-government sectors. These proportions compare with national averages of 34 percent and 65 percent respectively.

Forecasts of Railbelt energy demand by Battelle Pacific Northwest Laboratories in December, 1981 range from 6,303 GWh to 11,435 GWh in the year 2010 for projected low and high growth scenarios. Railbelt generation planning studies undertaken for Susitna feasibility assessment are based on the Battelle December, 1981 forecast for a medium load growth scenario. In this case an energy demand of 7,791 GWh is forecast for 2010, requiring 1,537 MW of generating capacity at a projected load factor of 57.9 percent. This forecast is based on average annual growth rates from 1981 varying from 4.9 percent through 1990 to 3.5 percent overall. Sensitivity studies were also undertaken to test the low and high forecast scenarios and the potential impacts of energy conservation measures.

2.4 - Railbelt System and Future Power Generation Options

Planning of future electric power generation for the Railbelt Region must give careful consideration to economic necessity, acceptable environmental impacts, and social preferences. Development of the Susitna Basin could provide a major portion of the Railbelt Region energy needs well beyond the year 2000. However, this is but one of the available options for meeting Susitna Railbelt demand.

(a) Existing System

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. There are currently nine electric utilities, including the Alaska Power Administration, providing power and energy to the Railbelt system. In 1980, total Railbelt installed capacity of 984 MW consisted of two hydroelectric plants totaling 46 MW plus 938 MW of thermal generation units fired by oil, gas, or coal. An additional 12 MW of hydro has recently been commissioned by Copper Valley Electric Association at Solomon Gulch. Hydroelectric developments normally have a useful life of 50 years or more and thermal plants 20 to 35 years. Five more projects are currently expected to be added to the Railbelt system prior to 1990:

- Chugach Electric Association: Beluga No. 8 combined cycle, 178 MW (total plant), in progress; Bernice Lake No. 4 gas-turbine, 26.4 MW, 1982.

- Anchorage Municipal Light and Power Department: AMLPD No. 8 gas-turbine, 90 MW, 1982.

- Corps of Engineers: Bradley Lake hydroelectric, 90 MW, 1988.

- Alaska Power Authority: Grant Lake hydroelectric, 7 MW, 1988.

Engineering studies are currently in progress for construction of an intertie between the Anchorage and Fairbanks systems. These studies indicate that there is an economic benefit in having this intertie capability. As presently envisaged, the connection will involve a 345 kV transmission line between Willow and Healy scheduled for completion in 1984. The line will initially be operated at 138 kV with the capability for expansion as the loads grow in the load centers.

(b) Alternative Generating Sources

Current forecasts of Railbelt demand indicate that a significant amount of new generating capacity will be needed by 1993 in addition to that already planned. A number of alternatives exist for meeting these needs. A significant amount of non-Susitna hydroelectric potential identified in the Railbelt Region includes the following more attractive developments:

- Chakachamna (330 MW);
- Keetna (100 MW); and
- Snow (50 MW).

Although these sources would have generally stable energy costs once constructed, they would not alone be sufficient to meet projected demand, and they are relatively more costly than Susitna.

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 could be satisfied by all-thermal generation mix, but the continued rise in cost of fuels would lead to significant increases in long-term energy costs using these alternatives. The broader perspectives of other alternative resources and the relevant environmental, social, and other issues involved have been addressed in the Battelle Alternatives Study. Emphasis in the Acres study was placed in the following more likely alternative forms of thermal power generation:

- Coal-fired steam;
- Gas-fired combined-cycle;
- Gas-fired gas turbine; and
- Diesel.

(c) Coal-Fired Steam

There are currently two small coal-fired steam plants in operation in the Railbelt, as well as minor installations at military and university facilities. New coal-fired plants are likely to be sited at the undeveloped Beluga field or near Nenana, using Healy field coal, servicing the Fairbanks load center.

Estimated costs for a 10,000 BTU/kWh 200 MW plant range from $2242 to $2309 per kW in 1982, including provisions for meeting the national New Performance Standards, and interest during construction. A construction period of five to six years is required.

Fuel costs based on long-term opportunity values were set at \$1.43/MM BTU for Beluga field coal and \$1.75/MM BTU for Healy coal to be used at Nenana. Real escalation on these values was estimated as 2.3 to 2.6 percent through the year 2000, falling to 1.1 to 1.2 percent through 2010. O&M costs for coal-fired plants were estimated as \$16.83/kW-year and \$0.60/MWh.

(d) Combined Cycle

Combined cycle plants achieve higher efficiencies than conventional gas turbines. There are two combined cycle plants in Alaska at present, one operational and the other Beluga No. 9 unit owned by Chugach Electric Association, under construction. A 60 MW steam turbine will be added to the system sometime in 1982. Capital costs for a 8,000 BTU/kWh 200 MW unit in 1982 are estimated as \$1075 to \$1107 per kW. The combined cycle facilities would burn only gas with a domestic market value of \$3.00 per MM BTU, reflecting the equitable value of gas in Anchorage, assuming development of the export market. Currently, the local incremental gas market price is about one-third 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 2.5 percent (1982-2000) and 2 percent (2000-2010) was assumed. O&M costs were assumed at \$7.25/ kW-year and \$1.69/MWh.

(e) 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.

A 10,000 BTU/kWh, 75 MW gas-turbine plant would costs \$636 to \$627/kW and could be built over a two-year construction period. 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 \$6.50 per million BTU. The real annual growth rates in oil costs used were 2 percent for 1982-2000 and 1 percent for 2000-2010. O&M costs for gas turbines were assumed as \$2.70/kW-year and \$4.80/MWh.

(f) Diesel Power Generation

Most diesel plants in the Railbelt today are on standby status or are operated only for peak load service. About 65 MW of diesel plant capacity is currently available. The high cost of diesel fuel and relatively low capital cost of \$856 to \$869/kW 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. Diesel fuel costs and growth rates are the same as oil costs for gas turbines.

(g) Generation Scenarios Without Susitna

To assess economics of developing the Susitna project, the costs of meeting the Alaska Railbelt load forecast with and without the project have been compared. Thus, plans were developed using appropriate combinations of the alternative hydroelectric and thermal generating sources identified above. The resulting all-thermal and mixed hydro-thermal generating scenarios were used as a basis for comparison with appropriate Susitna-thermal generating scenarios developed to meet the projected Railbelt comparisons of a much broader range of possible types of generation were also made by Battelle in its alternatives study. These studies were made using economic parameters over a wide range of load forecasts, capital costs, interest (discount) rates, fuel cost and fuel escalation rates.

The results of Acres initial planning studies through early 1981 were documented in the June 1981 Development Selection Report. These studies concluded that Susitna showed promise of economic feasibility and was worthy of further study. Of the available non-Susitna alternatives the study showed that the all-thermal generation scenario was the most likely competitor. Confirmation of the without-Susitna generation scenario was possible using the results of the Battelle study for load forecasts, alternative plant and fuel costs and considering a range of project cost escalation rates. On this basis, the following plan has now been established as the non-Susitna Railbelt generation scenario:

- Existing system plus committed additions, as of January, 1993:

Coal-fired steam:	59 MW
Natural gas GT:	452 MW
Oil GT:	140 MW
Diesel:	67 MW
Natural gas CC:	317 MW
Hydropower:	155 MW
Total	1,190 MW

- System additions (1993-2009):

Coal-fired steam:	800 MW
Natural gas GT:	630 MW

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- System as of 2010 (accounting for retirements and additions):

Coal-fired steam:	813 MW
Natural gas GT:	746 MW
Oil GT:	0 MW
Diesel:	6 MW
Natural gas CC:	317 MW
Hydropower:	155 MW
Total	2,037 MW

The coal-fired steam additions assumed two 200 MW plants at Beluga in 1993-94, one 200 MW plant near Nenana in 1996, and a third 200 MW plant at Beluga in 2007. The costs associated with the Beluga development are based on the opening of that coal field for commercial development, which is by no means a certainty. A number of environmental problems require resolution before such development can take place.

Two alternatives which Battelle included in their base plan which have not been included in this plan are the Chakachamna and Allison Creek hydroelectric plants. The Chakachamna plant is currently the subject of a separate feasibility study by the Power Authority. The current plan would develop a 330 MW plant at a cost of $1.45 billion at January, 1982 price levels. Further sensitivity studies have confirmed that scenarios involving the Chakachamna development show some reduction in cost. However this alternative was not included in the non-Susitna plan due to environmental impact and cost uncertainties.

2.5 - Susitna Basin

An assessment of the physical and biological environment of the Susitna River Basin has been made on the basis of available information and studies conducted under the current study. The climate of the Susitna Basin is generally characterized by cold, dry winters and warm, moderately moist summers. The upper basin above Talkeetna is dominated by continental climatic conditions, the lower basin falling within a zone of transition between maritime and continental climatic influences.

(a) Hydrology

Precipitation in the basin varies from low to moderate amounts at lower elevations to heavy in the mountains. At Talkeetna Station, at elevation 345, the average annual precipitation is about 28 inches and average snowfall is about 106 inches. At elevations of about 3000 feet in the Talkeetna mountains, over 80 inches of precipitation are estimated. About 68 percent of Talkeetna precipitation occur during May through October. Mean daily temperatures at the Watana site during the study period varied from -36.7°C in December to 23.9°C in July.

The longest period of available Susitna River streamflow data is for the station at Gold Creek (32 years from 1949 to 1981). At other stations, record length varies from 6 to 23 years. Gaging was continued at all these stations as part of the current program. A gaging station was established at the Watana damsite in 1980, and streamflow records are available for the study period. Using the available records, average annual flows at the Watana and Devil Canyon damsites are computed as 7,943 cfs and 9,042 cfs, respectively.

Above its confluence with the Chulitna River, the Susitna contributes approximately 20 percent of the mean annual flow measured at Susitna Station near Cook Inlet. At Gold Creek, the average winter and summer flows are 2,100 and 20,250 cfs, respectively, i.e., a 1 to 10 ratio. Approximately 88 percent of the streamflow recorded at Gold Creek station occurs during the summer months. The lowest annual flow at Gold Creek was observed in the Water Year 1969 with an average flow of 5,560 cfs. The return period of such an event is estimated at about 1 in 10,000 years.

A monthly simulation of the proposed reservoirs and power development has been carried out to estimate energy potential of the proposed reservoirs. The critical low flow sequence for energy generation was observed to be the 32-month period between October, 1967 and May, 1970. The sequence comprises the lowest annual flow year described above and has a frequency of 1 in 300 years. The results of the analysis have been used to determine dependable energy potential of the proposed reservoirs.

(i) Floods

The most common causes of floods in the Susitna River Basin are snowmelt and/or rainfall over a large area. Annual maximum peak discharges generally occur between May and October, usually in June. Some 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.

For design of spillway facilities, a regional flood peak and volume frequency analysis was carried out using the recorded floods in the Susitna River and its principal tributaries. These analyses are also important for planning the design of cofferdams for river diversion during the construction phase of the project when ice jamming could also occur. Mean annual, 50-, 100-, and 10,000-year floods at Watana and Devil Canyon damsites range from 12,600 cfs to 165,000 cfs at Devil Canyon and from 48,000 cfs to 200,000 cfs at Watana.

The proposed reservoirs at Watana and Devil Canyon would be classified as "large" and with "high hazard potential" according to the guidelines for safety inspection of dams established by the COE. This would indicate the need for the probable maximum flood (PMF) to be considered in the evaluation of the proposed projects. Estimates of the PMF in the Susitna River at several locations, including the proposed damsites, were carried out by the COE. A reevaluation of the PMF in the basin was undertaken based on a more comprehensive climatological data base and refined basin modeling parameters resulting in peak inflows of 326,000 cfs at Watana and 366,000 cfs at Devil Canyon.

(ii) River Ice

The Susitna River usually starts to freeze by late October. River ice thickness and strength vary according to the river channel shape, slope and discharge. The maximum thicknesses observed at selected locations on the river vary from 3.2 feet at Gold Creek to 23.0 feet at Devil Canyon. Ice breakup in the river commences by late April or early May; ice jams occasionally occur at river constrictions, resulting in rises in the water level of up to 20 feet.

(iii) River Morphology and Sediment Yield

Suspended sediment data have been collected for several years by the USGS at 13 stations on the Susitna and its tributaries. At Gold Creek Station, 22 years of data are available. Most of the suspended sediment is transported in June through September. Bed load data for the river and its tributaries are extremely limited. Estimated annual transport of suspended materials at the Gold Creek gaging stations is 7.7 million tons. Trap efficiencies for the proposed reservoirs at Watana and Devil Canyon, based on literature surveys of worldwide experience under similar glacial river basins, are estimated at 70 to 100 percent. Estimated sediment deposition in the reservoirs is up to 472,000 acre feet in Watana in 100 years or 5 percent of gross reservoir volume, and up to 155,000 acre feet (14.2 percent) at Devil Canyon in 100 years.

Preliminary studies of the morphology of the river below the proposed dams have been made to evaluate potential changes caused by the post-project flow regime. The study indicates that significant changes in the lower river morphology are unlikely to be caused by the projects proposed.

(b) Regional Geology

The geologically complex Talkeetna Mountain area has a history of at least three periods of major tectonic deformation. The oldest rocks exposed in the region are volcanic flows and limestones (250 to 300 million years before present) which are overlain by sandstones and shales (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 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 and is still causing downcutting of streams and rivers, resulting in the 500-to-700 foot deep V-shaped canyons that are evident today, particularly at the Vee and Devil Canyon damsites. 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.

(c) Seismicity

A two year study of seismicity of the project area was undertaken to identify faults that have the potential for surface rupture within the project area and to provide a basis for estimates of earthquake ground motions to be considered for dam design. The project lies within the Talkeetna Terrain, a part of the North American Plate. The Terrain boundaries are denoted by the Denali-Totschunda fault to the north and east, the Castle Mountain fault to the south, a broad zone of deformation with volcanoes to the west, and the Benioff Zone at depth. The study has indicated that the Talkeetna Terrain is a relatively stable tectonic unit with major strain release occurring along its boundaries, but no evidence of faults with recent displacement within those boundaries.

The Talkeetna Terrain boundary faults were therefore identified as potential seismic sources. Because of their distance from the sites, these faults do not have the potential for rupture through the sites. A total of 13 features identified and investigated in some detail near the damsites as potential seismic sources, were found to show no evidence of recent displacement. These features, therefore, were not considered to be potential seismic sources that could cause seismic ground motions at the sites or surface rupture through the sites. There is considerable worldwide evidence that earthquakes up to a given magnitude could occur on faults at depth with no detectable evidence of recent displacement at the ground surface. Such earthquakes have been designated as "Terrain earthquakes" (or "detection level earthquakes"). The magnitude of the Terrain earthquake varies according to the degree of natural preservation of fault-related geomorphic features and from one tectonic environment to another.

To establish a basis for estimating ground motions at a specific site, and hence to design the structures to be built, estimates were made of magnitudes for the maximum earthquakes in the region associated with the potential earthquake sources. The maximum earthquake (ME) magnitude, closest approach and important mean peak ground accelerations were estimated for boundary faults and for the Terrain earthquake as follows:

Source	ME (M_S)	Devil Canyon miles	Devil Canyon accel. (g)	Watana miles	Watana accel. (g)
Castle Mountain	7-1/2	71	-	65	-
Denali Fault	8	40	0.2	43	0.2
Benioff Zone (interplate)	8-1/2	57	0.35	39	0.3
Benioff Zone (intraplate)	7-1/2	38	-	39	-
Terrain Earthquake	6-1/4	<6	0.55	<6	0.55

Work undertaken by Dr. L. Sykes of the Lamont Doherty Institute, New York, suggests that the magnitude of the Terrain earthquake could be as high as 6-1/4 to 6-1/2.

The studies concluded that there would be a high likelihood for reservoir induced earthquake as a result of impoundment. However, such an event is not expected to cause an earthquake larger than that which could occur in a given region "naturally."

(d) Water Use and Quality

Water rights in Alaska are administered by the Alaska Department of Natural Resources (DNR). The mainstem Susitna corridor encompasses 30 townships from the proposed impoundment area downstream to the estuary. Existing surface and ground water appropriations are primarily for single-family and multi-family homes, the greatest usage occurring during summer months for irrigating lawns, gardens, and crops. There are only five areas where water appropriations are located within one mile of the mainstem Susitna River. No surface water diversions are recorded that draw water directly from the Susitna River or its adjoining side channels and sloughs.

The Susitna River is a fast-flowing, cold-water stream of the calcium bicarbonate type containing soft-to-moderately hard water. The temperature remains at or near 32°F during winter, and in summer the maximum is 55°F. Dissolved oxygen concentrations typically remain near the saturation level, always exceeding 80 percent but averaging near 100 percent in the summer. Typically, pH values range between 7 and 8 and exhibit a wider range in the summer as compared to the winter. True color, resulting from tundra runoff, displays a wider range during summer than winter. The concentrations of many trace elements monitored in the river were low or within the range characteristic of natural waters with few exceptions, as were concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity.

(e) Fisheries Resources

Both resident and anadromous fish occur in the Susitna River system. Resident fish species are grayling, burbot, rainbow trout, Dolly Varden, three spined stickleback, lognose sucker, slimy sculpin, whitefish, and lampreys. Anadromous fish are sockeye, pink, coho, chinook, and chum salmon and eulachon. Arctic grayling and rainbow trout, the primary resident game species, occur near tributary mouths during the summer months and in the mainstem Susitna during winter. Both species use the mainstem of the Susitna as a migratory corridor for moving between rivers and streams. Spawning likely occurs in the clearer tributaries.

Salmon utilize the Susitna River and its tributaries below Devil Canyon as a spawning habitat. Data indicate that physical barriers prevent salmon from migrating upstream of Devil Canyon. Salmon migration begins in late spring and continues into the fall. Studies to date indicate that the run of chinook salmon through the area above the confluence of the Chulitna and Talkeetna Rivers begins around mid-June. Pink salmon arrive in this region during late July and chum salmon migrate through in August and early September. Sockeye salmon appear in July and August. Following deposition in the fall, the eggs hatch in the spring. The young salmon, depending on the species and a variety of unknown factors, either migrate to the sea within a few months or remain in the river for one or two years before migrating downstream.

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(f) Wildlife Resources

Species of big game which inhabit the upper Susitna basin are: black and brown bear, wolf and wolverine, Dall sheep, caribou, and moose.

Black bear distribution in Alaska coincides with the presence of forest habitat. Thus, within the Susitna basin most black bear are found in steep terrain along the river and its tributaries. Brown bear occur primarily in open tundra and grassland areas. Preliminary estimates of brown bear numbers in the study area is 1 bear per 19 mi^2, indicating 3 to 4 bears in the area to be flooded.

One known and 5 to 6 suspected wolf packs occur in the area that would be most directly affected by the 2 reservoirs. The estimated total population is between 40 and 80 animals. Wolf control operations have been conducted in the past, with the latest such activity occurring in 1978.

Wolverine are also present and are found in all habitat types. Their distribution appears to be related to prey availability, concentrating in hilly areas above treeline in the summer and fall, and in lower elevations during winter and early spring.

Three populations of Dall sheep occur in the Upper Susitna Basin: the Watana hills herd, Watana-Grebe Mountain herd and the Portage-Tsusena Creek herd. A mineral lick in the Jay Creek area appears to be an important area for the Watana hills herd. Sheep were frequently observed utilizing the lick, which will be partially inundated by the Watana reservoir.

The Nelchina caribou herd occupies an area of approximately 20,000 square miles in Alaska. This large range can be divided into 16 sub-ranges, including the Upper Susitna Basin. Portions of the Upper Susitna Basin have been consistently used throughout the years by large portions of the herd, with most use taking place in summer, fall, and late winter. During some years, the entire herd, currently numbering 20,000 animals, has used the Upper Basin. A small subherd of approximately 1,000 animals appears to be residing permanently in the upper portion of the basin.

Moose populations upstream from the proposed impoundment areas were studied in 1980 and 1981. Although the physical condition of the moose appeared to be deteriorating, the habitat is not believed to be at its carrying capacity. Moose generally moved to lower elevations during late spring and early summer, then back to higher elevations in late summer and winter. The majority of moose observed were in conifer and shrubland habitat. A winter census of the impoundment area showed 28 moose in the Devil Canyon impoundment and 42 within the Watana impoundment. This is believed to be lower than normal because of a mild winter. Moose are also present in the Susitna River Basin downstream from the Devil Canyon damsite, consisting of both resident and migratory populations. No specific calving areas were located during these studies, but it appears that females use river islands to calve. During winters of heavy snowfall, moose tend to migrate to the river bottoms.

The major furbearer species inhabiting the project area include red fox, coyote, lynx, mink, pine marten, river otter, short-tailed weasel, least weasel, muskrat and beaver. Red fox and pine marten are the most heavily trapped of the species; coyote and lynx are not common in the area.

A total of 132 species of birds were recorded in the Upper Susitna River Basin study area. The most abundant species are common redpoll, savannah sparrow, white crowned sparrow, lapland longspur, and tree sparrow. Fourteen species are rare in the region but are found in larger populations in other areas of Alaska.

Ten golden eagle, 6 bald eagle, and 4 common raven nests are located within the study area, while 2 bald eagle and 4 golden eagle nests occur within the impoundment zone. No endangered species (the bald eagle is not endangered in Alaska) are known to occur in the study area.

Sixteen species of small mammals are found in the upper Susitna Basin, the most abundant being the northern red-backed vole and the masked shrew. Arctic ground squirrels are abundant in well-drained tundra habitats throughout the high country. Collared pika and hoary marmots are relatively common in rock habitats above the treeline. Red squirrels and porcupine are found in forests and woodland habitats.

(g) Botanical Resources

The Upper Susitna River Basin is located in the Pacific Mountain physiographic division in south-central Alaska. Many areas along the river in the upper basin are steep and covered with coniferous, deciduous, and mixed coniferous and deciduous forests. Flat benches occur at the tops of these banks and usually contain low shurb or woodland conifer communities. Low mountains rise from these benches and are covered by sedge-grass tundra and mat and cushion tundra. The major vegetation/habitat types found in the upper river drainage are low-mixed shrub, woodland and open black spruce, sedge-grass tundra, mat and cushion tundra, and birch shrub.

Below Devil Canyon, vegetation/habitat consists primarily of mature and decadent cottonwood forests, birch-spruce forest, alder thickets, and willow-cottonwood shrub communities. The willow, cottonwood shrub and alder communities are the earliest to establish on new gravel bars, followed by cottonwood forests, and, eventually, birch-spruce forest. Wetland areas, ponds, and lakes are present only in limited amounts within the impoundment area.

No plant species occurring in Alaska are listed as endangered by federal or state authorities. None of the species under consideration for listing were found in the project area.

(h) Historic and Archaeological Resources

A total of 43 archaeological sites, and three historic sites are located within the area to be affected either directly or indirectly by the Watana Dam impoundment. The archaeological sites represent human occupation dating from approximately 10,000 B.C. in the following culture periods: American Paleoarctic, Northern Archaic Tradition, Arctic Small Tool Tradition, Late Prehistoric Athapaskan, and Historic. The historic sites are all cabins built in the 1920s.

The Devil Canyon impoundment area includes seven archaeological sites discovered during this study. These sites, representing various time periods in Alaska prehistory including the American Paleoarctic and the Northern Archaic Tradition. One historic site, also a cabin believed to be constructed in the 1930s, lies within the Devil Canyon impoundment area.

(i) Socioeconomics

The state of Alaska has experienced steadily increasing population since the 1940s, with accelerated growth during the 1970s. Current population is approximately 400,000, with approximately 50 percent located in the greater Anchorage area. The Railbelt region of Alaska contained 70 percent of the state's population, or approximately 285,000 people, in 1980. This is an increase from 200,230 in 1970. Employment in Alaska and the Railbelt rose dramatically during the construction of the Trans-Alaska Pipeline System and has since leveled off.

Increases in population between 1970 (6,500) and 1980 (18,000) in the Matanuska-Susitna Borough (175 percent) were far higher than the state average. Population levels stabilized as the Trans-Alaska Pipeline was completed. Most of these people reside in the southern quarter of the Borough. Palmer and Wasilla are the largest communities, with populations of approximately 2,100 and 1,550, respectively. Other population centers in the Borough are Big Lake, Eska-Sutton, Houston, and Talkeetna. Virtually all employment in the Mat-Su Borough is government, service, and support sector oriented. Total employment has risen steadily from 1,145 in 1979 to 3,078 in 1979, an increase of 169 percent. However, the Borough consistently has had high unemployment rates, often the highest in the state. The Borough is more dependent on seasonal employment than larger population centers such as Anchorage.

(j) Recreational Resources and Land Use

Recreational activities currently available in the Upper Susitna Basin are those associated with undeveloped facilities. Hunting, fishing, hiking, and camping are the primary recreational uses, along with boating on the lakes. There are no areas in the vicinity of the project that are included or designated for inclusion in the National Wild and Scenic River System, the National Trails System, or a federal or state wilderness area.

Existing land use in the area is typical for that of interior undeveloped Alaska. Broad expanses of wilderness areas are present with minimal man-made developments or structures, and access is severely restricted. A small number of inhabited structures are found near Portage Creek, High Lake, Gold Creek, Stephan Lake, Clarence Lake, and Big Lake. There is little land management in the area. Most land in the project area and directly south has been selected by native corporations under provisions of the Alaska Native Claims Settlement Act; lands to the north are generally managed by the U.S. Bureau of Land Management.

(k) Aesthetic Resources

The Upper Susitna River Basin is a wilderness region comprising a diverse landscape composite, roadless and relatively uninhabited. The combination of these factors creates a large region that is aesthetically renowned for its natural beauty. The deeply cut canyons and gorges of the Susitna River scenically exhibit the river's extraordinary power; the gorges are particularly striking at Devil and Vee Canyons where turbulent rapids, rock outcroppings and cliffs, and enclosed walls dominate the scene. Positioned between the two major population centers of Fairbanks and Anchorage, the area's aesthetic resources are important, but not outstanding compared with other areas in the state.

2.6 - Susitna Basin Development Selection

A number of engineering and planning studies were carried out during the early phases of the project feasibility assessment as a basis for formulation of Susitna Basin development plans and selection of the preferred plan. The recommended Watana/Devil Canyon dam project was compared to alternative methods of providing the Railbelt energy needs including thermal and other potential hydroelectric developments outside the Susitna Basin on the basis of technical, economic, environmental, and social aspects.

(a) Damsite Selection

In previous Susitna Basin studies, twelve damsites were identified in the upper portion of the basin, i.e., upstream from Gold Creek. Preliminary assessments of these sites, on the basis of published data, showed that three sites, Devil Canyon, High Devil Canyon, and Watana are potentially the most economic large energy producers in the basin. Sites such as Vee and Susitna III have only medium energy production, and are slightly more costly. 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.

A screening process was used to eliminate sites which would obviously not feature in the initial stages of a Susitna Basin development plan. This screening was based on consideration of environmental factors and the relative merits of each site in terms of economic energy contribution. The seven sites remaining after this screening were:

- Devil Canyon;
- High Devil Canyon (Susitna I);
- Watana;
- Susitna III;
- Vee;
- Maclaren; and
- Denali.

Preliminary construction cost estimates were developed for developments at each site. The relative cost differences between rockfill and concrete dams at the sites are generally marginal or greatly in favor of the rockfill. Rockfill dams were therefore assumed at all developments for general consistency. These estimates, together with energy production estimates, provided a basis for conceptualization of basin development plans.

(i) Devil Canyon

The Devil Canyon dam was assumed to consist of a rockfill dam, single spillway, power facilities incorporating an underground powerhouse, and a tunnel diversion located at the upper end of the canyon at its narrowest point. The 675-foot-high central core rockfill dam will rise above the valley on the left abutment and terminate in an adjoining saddle dam of similar construction. The gated overflow spillway structure will be located on the right bank together with a concrete-lined chute and intermediate and terminal stilling basins. The power facilities will be located underground on the right abutment. The massive

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intake structure will be founded within the rock at the end of a deep approach channel and will consist of four integrated units, each serving individual tunnel penstocks. The powerhouse will house four 150 MW turbine generators.

A staged powerhouse alternative was also investigated. The dam would be completed to its full height but with an initial plant installed capacity of 300 MW. The complete powerhouse would be constructed together with penstocks and a tailrace tunnel for the initial two 150 MW units, together with concrete foundations for the future units.

(ii) Watana

For initial comparative study purposes, the dam at Watana was assumed to be a 63-million-cubic-yard, central-core rockfill structure, 880 feet high, located on a similar alignment to that proposed in the previous COE studies. The right bank spillway will be similar in concept to that at Devil Canyon with an intermediate and terminal stilling basin. The underground power facilities located within the left abutment with similar intake, underground powerhouse, and water passage concepts to those at Devil Canyon will incorporate four 200 MW turbine/generator units giving a total output of 800 MW.

(iii) High Devil Canyon

This site is located between Devil Canyon and Watana. The 855-foot-high, 48-million-cubic-yard rockfill dam will be similar in design to Devil Canyon. The left bank spillway and the right bank powerhouse facilities will also be similar in concept to Devil Canyon, with an installed capacity of 800 MW.

(iv) Susitna III

The development will comprise a 55 million cubic yard rockfill dam with an impervious core approximately 670 feet high. A concrete-lined spillway chute and a single stilling basin and will be located on the right bank. A powerhouse of 350 MW capacity will be located underground and the two diversion tunnels on the left bank.

(v) Vee

A 610-foot-high, 10-million-cubic-yard rockfill dam was considered at this site together with a spillway utilizing a gated overflow structure, chute, and flip bucket. The 400-MW underground power facilities will be located in the left bank with a tailrace outlet well downstream from the main dam. A rockfill saddle dam will also be required. Two diversion tunnels will be provided on the right bank.

(vi) Maclaren

This development will consist of a 185-foot-high earthfill dam founded on pervious riverbed materials. The reservoir will essentially be used for regulating purposes. Diversion will be through three conduits located in an open cut on the left bank and floods will be discharged via a side chute spillway and stilling basin on the right bank.

(vii) Denali

Denali is similar in concept to Maclaren with no generating facilities. The dam will be 230 feet high and of earthfill construction. A combined diversion and spillway facility will be provided by twin concrete conduits founded in open cut excavation in the right bank and discharging into a common stilling basin.

(viii) Staged Developments

Staged developments were also considered at Devil Canyon, Watana, and High Devil Canyon. In these cases, initial partial completion of dam and power facilities was evaluated with later expansion to the complete development.

(c) Development Plan Formulation

Basin development plans involving appropriate combinations of the seven sites were formulated. A computer assisted screening process identified the plans that are most economic as those of Devil Canyon/Watana or High Devil Canyon/Vee. In addition to these two basic development plans, a tunnel/Watana dam scheme was introduced. This provides potential environmental advantages to the Devil Canyon/Watana scheme by replacing the Devil Canyon dam with a long power tunnel.

(i) Initial Screening

The most important conclusions drawn from this screening are as follows:

- For energy requirements of up to 1,750 GWh, the High Devil Canyon, Devil Canyon or the Watana sites individually provided the most economic energy.

- For energy requirements of between 1,750 and 3,500 GWh, the High Devil Canyon site is the most economic.

- For energy requirements of between 3,500 and 5,250 GWh the combinations of either Watana and Devil Canyon or High Devil Canyon and Vee are the most economic.

- 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 6,000 GWh range.

(ii) Tunnel Alternative

A scheme involving a long power tunnel could conceivably be used to replace the Devil Canyon dam as a second stage of the Watana/Devil Canyon development plan. It could develop comparable head for power generation and may provide some environmental advantages by avoiding inundation of Devil Canyon. 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 1,200 MW;

- A reregulation dam if the intake works are located downstream from Watana; and

- Arrangements for compensation flow in the bypassed river reach.

Of the tunnel schemes considered, an alternative was selected involving two 30-foot-diameter tunnels 13.5 miles long. This scheme, which includes a 245-foot high reregulating dam downstream from Watana, and a total installed capacity of 1,180 MW, is judged to be the environmentally and economically superior alternative.

(iii) Final Screening

The final plan screening process indicated that the Watana/Devil Canyon and the High Devil Canyon/Vee plans are clearly superior to all other dam combinations. In addition, plans involving the tunnel scheme as an alternative to the Devil Canyon dam and a plan combining a Watana/High Devil Canyon/Portage Creek combination were also formulated for more detailed evaluation. Four basic plans were established as a result of this process. 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.

(d) Development Plan Selection

Selection of the development plan was based on a final consideration of the economic, environmental, social and energy contribution attributes of each alternative. 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.

Some additional economic benefits are gained if the Chakachamna hydroelectric project is constructed instead of the Vee dam.

The results of the Watana tunnel comparison indicated that the tunnel scheme versus the Devil Canyon dam scheme adds approximately $680 million to the total system present worth cost. A sensitivity analysis made to determine the effect of halving the tunnel costs indicated that the tunnel scheme is still more costly then constructing the Devil Canyon dam.

The plans with the lowest present worth cost were also subjected to further sensitivity analyses to assess the economic impacts of various load growths. The results for low load forecasts illustrate that the most viable Susitna Basin development plan is the Watana-Devil Canyon plan with a capacity of 800 MW which has a present worth cost of $210 million less than its closest competitor, the High Devil Canyon-Vee plan. For the high load forecasts, the results indicated that the economic advantage of the Watana/Devil Canyon plan improves significantly.

For the remaining three Plans 1, 2, and 3 a final evaluation process was conducted in a series of steps. At each step, two plans are compared. The superior plan is then passed on to the next step for evaluation against a third plan, and so on.

(i) Devil Canyon Dam Versus Tunnel

The first step in the process involved the comparison of the Watana-Devil Canyon dam plan and the Watana-Tunnel plan. Since Watana is common to both plans, the evaluation was based on a comparison of the Devil Canyon dam and preferred tunnel alternative. From an economic point of view, the Watana-Devil Canyon dam scheme is superior. Consideration of the sensitivity of the basic economic evaluation to potential changes in capital cost estimate and other economic parameters did not change the basic economic superiority of the dam scheme over the tunnel scheme.

In the environmental comparison of the two schemes, the tunnel scheme was judged to be superior. In terms of impact on state and local economics and risks because of seismic exposure, the two schemes are rated equal. However, the dam scheme has a greater potential for energy production, develops a larger portion of the basin's potential, and displaces a larger amount of non-renewable energy resources.

Overall, the estimated cost saving of $680 million in favor of the dam scheme plus the additional energy produced are considered to outweigh the reduction in the overall environmental impact of the tunnel scheme. The dam scheme is therefore judged to be superior.

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

The second step in the development selection process involved an evaluation of the Watana-Devil Canyon and the High Devil Canyon-Vee development plans. In terms of the economic criteria the Watana-Devil Canyon plan is less costly by $520 million. Consideration of the sensitivity of this decision to potential changes in the various parameters considered did not change the basic superiority of the Watana-Devil Canyon Plan.

In assessing these plans environmentally, 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, the potential environmental impacts above the Vee Canyon dam with a High Devil Canyon-Vee development were judged to be more severe.

In terms of energy contribution criteria, the Watana-Devil Canyon scheme was assessed to be superior because of its higher energy potential and the fact that it develops a higher proportion of the basin's potential. In terms of the social criteria, the Watana-Devil Canyon plan was 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, the Watana-Devil Canyon plan is thus considered to be generally superior for all the evaluation criteria. This plan was therefore selected as the preferred Susitna

Basin development plan, as a basis for continuation of more detailed design optimization and environmental studies.

2.7 - Susitna Hydroelectric Development

The conclusion of the development selection studies was that the hydroelectric potential of the Susitna Basin should be tapped by installation of power plants and related facilities at the Watana and Devil Canyon sites. The Power Authority recommended to the governor in March 1981 that further study of these sites be undertaken.

As originally conceived the Watana project initially comprised an earthfill dam, crest elevation 2225 feet and 400 MW of generating capacity to commence operation in 1993. An additional 400 MW would be brought on-line in 1996. At Devil Canyon an additional 400 MW would be installed to commence operation in the year 2000. Detailed studies of each project have led to refinement and optimization of designs in terms of a number of key factors including updated load forecasts and economics. Geotechnical and environmental constraints identified as a result of continuing field work have also greatly influenced the currently recommended design concepts.

(a) Watana Project Formulation

The Watana Project as proposed in the recommended development selection has been further refined in the context of updated load forecasts and geotechnical and environmental investigations. The project will still comprise an earthfill dam with appropriately sized spillway, diversion, emergency release, and power generation facilities at the Watana site.

(i) Selection of Reservoir Level

The selected elevation of the Watana dam crest is based on considerations of the value of the hydroelectric energy produced from the associated reservoir, geotechnical constraints on reservoir levels, and freeboard requirements.

Economic comparisons of reservoir levels were made on the basis of firm and average annual energy produced by the Susitna development for a range of levels within appropriate drawdown and downstream flow constraints. These comparisons indicated total system costs to be relatively insensitive to dam height. From an economic standpoint, the optimum crest elevation could be considered as varying over a range of reservoir elevations from 2,140 to 2,220 feet with little effect on project economics. The governing factors in establishing the upper limit of dam height were consequently geotechnical considerations relative to the relict channel.

Geological conditions in the relict channel area are not fully known at this time. Nevertheless, reservoir levels above 2185 feet would lead to increased saturation of in situ materials and could give rise to potentially more severe settlement, seepage and seismic instability problems. Costly as any remedial measures might be, an element of uncertainty would still remain as to their effectiveness. It was therefore determined that with a normal reservoir level of 2185 and a small freeboard dike the following conditions should be met:

- For floods up to the 1:10,000-year occurrence there would be no danger of overtopping the lowest point in the relict channel.

- For the PMF a freeboard dike in the low area of up to 10 feet in height would provide adequate protection. This dike would be wetted only a few days during a PMF event.

- If seismic settlement or settlement because of permafrost melting were to occur, the combination of the 10-foot freeboard dike constructed on a suitable foundation plus a normal reservoir level of 2185 feet would ensure that breakthrough in the relict channel would not occur.

Within this approach, the Watana project will develop the maximum energy reasonably available without incurring the need for costly water retaining structures in the relict channel area. The normal maximum operating level of the reservoir was therefore set at Elevation 2185, which also maximizes the economic use of the Susitna resource.

(ii) Selection of Installed Capacity

The generating capacity to be installed at both Watana and Devil Canyon was determined on the basis of generation planning studies, together with appropriate consideration of the following:

- Available firm and average energy from Watana and Devil Canyon;

- The forecast energy demand and peak load demand of the system;

- Available firm and average energy from other existing and committed plants;

- Capital cost and annual operating costs for Watana and Devil Canyon;

- Capital cost and annual operating costs for alternative sources of energy and capacity;

- Environmental constraints on reservoir operation; and

- Turbine and generator operating characteristics.

The required total capacity at Watana in a wet year, based on the Battelle medium load forecast, varies between 800 MW in 1993 and 874 MW in the year 2000, excluding standby and spinning reserve capacity. With Devil Canyon on-line, the capacity requirement varies from 660 MW in 2002 to 900 MW in 2010. On the basis of this evaluation, the ultimate power generation capability at Watana was selected as 1020 MW for design purposes, to allow a margin for hydro spinning reserve and standby for forced outage. This installation also provides a low cost margin in the event that the load growth exceeds the Battelle medium load forecast. Considerations of improved plant efficiency and security of operation provided by a larger number of smaller capacity units led to adoption of a scheme incorporating six units each with a rated capacity of 170 MW

(iii) Selection of Spillway Design Floods

Normal design practice and applicable regulations for projects for this magnitude require that the project be capable of passing the PMF routed through the reservoir without endangering the dam. In addition to this requirement, the project should have sufficient spillway capacity to safely pass a major flood of lesser magnitude than the PMF without damaging the main dam or ancillary structures. The flood frequency analysis produced the following values:

Flood	Frequency	Inflow Peak
Probable Maximum	--	326,000 cfs
Spillway design	1:10,000	156,000 cfs

Additional capacity required to pass the PMF will be provided by an emergency spillway consisting of a fuse plug and rock channel cut on the right bank.

(b) Watana Scheme Development

A number of studies were undertaken to consider alternatives and select appropriate configurations for the Watana dam, diversion, spillway, and power facility arrangements.

(i) Main Dam Alternatives

Previous studies by the COE envisaged an embankment dam at Watana. Initial studies completed as part of this current evaluation included comparison of an earthfill dam with a concrete arch dam at the Watana site. The cost of the embankment dam was found to be somewhat lower than the arch dam, and there were no significant advantages to be gained in project layouts or schedule by constructing the concrete arch. The arch dam alternative was therefore eliminated from further consideration.

The Watana dam is the central and most costly component of this project. Selection of the configuration of the embankment dam cross-section required consideration of:

- The availability of suitable construction materials within economic haul distance, particularly core material;

- The requirement that the dam be capable of withstanding the effects of a significant earthquake shock as well as the static loads imposed by the reservoir and its own weight; and

- The relatively limited construction season available for placement of compacted fill materials.

Based on these considerations, the main dam will consist of a compacted central vertical core protected by fine and coarse filter zones both upstream and downstream. The upstream and downstream supporting fill zones will contain relatively free draining compacted gravel or rockfill, providing stability to the overall embankment structure. Alternative axes of the dam were investigated and optimized relative to overall project cost. The adopted axis has a slight curvature downstream at the right abutment. Upstream slopes of 2.75H:1V, 2.4H:1V, and 2.25H:1V were also examined from cost and stability perspectives. The 2.4H:1V slope was adopted for the recommended project layout. The downstream slope is 2H:1V.

(ii) Diversion Scheme Alternatives

The topography of the site generally dictates that diversion of the river during construction be accomplished using diversion tunnels with upstream and downstream cofferdams protecting the main construction area. The configuration of the river and rock conditions in the vicinity of the site favors location of the diversion tunnels on the right bank. The recurrence interval of the design flood for diversion is generally established based on the characteristics of the flow regime of the river, the length of the construction period for which diversion is required, and the probable consequences of overtopping of the cofferdams. A 50-year recurrence interval flood of 81,000 cfs was selected for Watana.

Selection of the arrangement and size of the component features of the diversion scheme included consideration of a number of alternatives. These included concrete-lined versus unlined tunnels, tunnel size, type of operation and elevation relative to cofferdam size, and the long-term use of diversion tunnels for provision of emergency flow-release facilities from the Watana reservoir. An important consideration in diversion scheme design is cofferdam closure. The selected combination of one lower level pressure tunnel and one free flow tunnel, each 38 feet in diameter, will permit initial diversion to be made using the lower pressure tunnel. This will simplify the critical closure operation and avoid potentially serious delays in the schedule.

(iii) Spillway Alternatives

The project has been designed to safely pass a 1:10,000-year flood discharge of 145,000 cfs and a PMF of 310,000 cfs. In the evaluation of alternative spillway arrangements, the potential for nitrogen supersaturation of spillway discharges was an important consideration. Nitrogen supersaturation is toxic to fish and could occur when aerated flows in deep plunge pools or large hydraulic jumps are subjected to pressures in excess of 30 to 40 feet. Alternatives considered to overcome this problem included cascade spillways in which flows are discharged over a series of relatively small steps excavated in rock and the use of discharge valves to release flood flows less than the 50-year flood.

Other alternatives considered were main spillway facilities in various locations, and appropriate combinations of gated ogee-type overflow structures, concrete-lined chutes, and flip buckets and stilling basin to discharge flows into the river downstream and for energy dissipation. Open channel emergency spillways with an erodible fuse plug were also considered for discharge of the PMF. Clearly the selected spillway type and location will greatly influence and be influenced by the selected project general arrangement. The proposed spillway configuration was selected on the basis of economics, technical feasibility, and environmental constraints. It comprises a 3-gated control structure, chute, and flip bucket in the right abutment designed to discharge 115,000 cfs, the remaining 30,000 cfs of the 10,000-year flood being handled through six fixed-cone valves located underneath the flip bucket.

An emergency spillway will also be located in the right abutment with a 30-foot-high erodible fuse plug which will be overtopped during a PMF, discharging into the Tsusena Creek area.

(iv) Power Facilities

Studies were undertaken during the development of conceptual project layouts at Watana to investigate both right and left bank and surface and underground locations for power facilities. The configuration of the site is such that left bank locations generally require longer penstock and/or tailrace tunnels in poorer quality rock than exists on the right abutment. Surface locations are also generally more expensive and subject to additional operation limitations because of climatic conditions. An underground powerhouse was therefore selected and located on the right bank such that the major openings lie between the two major shear features ("The Fins" and the "Fingerbuster").

It has been conservatively assumed that full concrete-lining of the penstocks and tailrace tunnels will be required. In practice, it may be possible for a large proportion of the tailrace tunnels to be unlined, depending on the actual rock quality encountered. For the design head and specific speed, Francis type turbines having a reasonably flat load-efficiency curve over a wide range of rated output, were selected. The final arrangement comprises six units producing 170 MW rated at maximum reservoir level in the peak demand month of December, at full gate. The unit output at best efficiency and a rated head of 680 feet is 181 MW. An underground transformer gallery has been selected for minimum total cost of transformers, cables, bus, and transformer losses. Single-phase transformers are required because of transport limitations on Alaskan roads and railways. The selected scheme is an economic grouping of nine transformers arranged so that each set of three transformers serves two turbine-generator units.

The power intake and approach channel are significant items in the cost of the overall power facilities arrangement. Studies of various configurations resulted in selection of a preferred penstock arrangement consisting of six individual 18-foot diameter penstocks. With this arrangement, no inlet valve is required in the powerhouse since penstock dewatering can be performed by using the control gate at the intake.

The preliminary design of the power facilities involves two tailrace tunnels leading from a common surge chamber.

Optimization studies were carried out for sizing of all water passages.

(v) Environmental Constraints

In addition to the potential for nitrogen supersaturation during spillway operation, major environmental constraints on the design of the power facilities are:

- Control of downstream river temperatures; and
- Control of downstream flows.

The power intake design is such that power plant flows may be drawn from the reservoir at four different levels throughout the anticipated range of reservoir drawdown for energy production. This allows control of downstream river temperatures within acceptable limits.

The Watana development is currently planned to provide maximum energy to the Railbelt as closely matched to demand as possible. For this purpose, the project will be operated as a daily peaking plant for load following. The actual extent of daily peaking will be dictated by unit availability, unit size, system demand, system stability, generating costs, etc. Flow releases during operation of the project will adversely impact the salmon spawning areas in some reaches of the river downstream during critical summer months. Appropriate mitigation measures to compensate for these impacts are currently under study.

(vi) Selection of Watana General Arrangement

Preliminary alternative arrangements of the Watana Project were developed and subjected to a comprehensive series of review and screening processes. The layouts selected from each screening process were developed in greater detail prior to the next review, and where necessary, additional layouts were prepared combining the features of two or more of the alternatives. Assumptions and criteria were evaluated at each stage and additional data incorporated as necessary. The final selection was accomplished on the basis of technical feasibility, economics, operational and environmental considerations.

(c) Devil Canyon Project Formulation

Development selection studies were initially based on a rockfill dam at Devil Canyon for general consistency of site comparisons. Studies of the concept of an arch dam at Devil Canyon, as originally proposed by the USBR and COE, indicated that construction of such a dam at this location was probably feasible. Formulation of project designs at Devil Canyon was therefore essentially based on this concept. Refinements in the context of updated load forecasts, geotechnical and environmental investigations and related spillway, diversion, and power facilities designs were further evaluated for this site.

(i) Selection of Reservoir Level

The selected normal maximum operating level at Devil Canyon is Elevation 1455, which corresponds to the tailwater level selected at the Watana site. Although the narrow configuration of the Devil Canyon site and the relatively low costs involved in increasing the dam height suggest that it might be economic to do so, it is clear that the upper economic limit of reservoir level at Devil Canyon is the Watana tailrace level.

(ii) Selection of Installed Capacity

Devil Canyon will be operated primarily as a base loaded plant for the following reasons:

- Daily peaking is more effectively performed at Watana than at Devil Canyon; and

- Excessive fluctuations in discharge have an undesirable impact on downstream fisheries.

Given this mode of operation, the required installed capacity at Devil Canyon has been determined as the maximum capacity needed to utilize the available energy from the hydrological flows of record, as modified by the reservoir operation rule curves.

The required total capacity at Devil Canyon in a wet year, based on the December 1981 Battelle medium load forecast, varies between 370 MW and 507 MW over the period 2002 through 2010, excluding standby and spinning reserve capacity. The total installed capacity at Devil Canyon has been established as 600 MW for design purposes. This will provide some margin for forced outage and possible accelerated growth in demand.

The major factors governing the selection of the unit size at Devil Canyon are the rate of growth of system demand, the minimum station output, and the requirement of standby capacity under forced outage conditions. The power facilities at Devil Canyon have been developed using four units at 150 MW each. This arrangement will provide for efficient station operation during low load periods as well as during peak December loads. It has been assumed that all units will be commissioned by 2002.

(iii) Selection of Spillway Design Floods

A flood frequency of 1:10,000 years equivalent to 165,000 cfs was selected for the spillway design on the same basis as Watana. An emergency spillway with an erodible fuse plug will also be provided to safely discharge the PMF of 366,000 cfs. The inflow flood peaks at Devil Canyon will be less than pre-project flood peaks because of routing through the Watana reservoir.

The avoidance of nitrogen supersaturation in downstream flows also will apply to Devil Canyon. Thus, the discharge of water possibly supersaturated with nitrogen from Devil Canyon will be limited to a recurrence period of not less than 1:50 years by the use of fixed-cone valves similar to Watana.

(d) Devil Canyon Scheme Development

Study of alternative scheme configurations at Devil Canyon was based on investigations of the dam, diversion, spillway, and power facility structures.

(i) Main Dam Alternatives

The location of the Devil Canyon damsite was examined during previous studies by the USBR and COE. These studies focused on the narrow entrance to the canyon and led to the recommendation of a concrete arch dam. Notwithstanding this initial appraisal, a comparative analysis was undertaken as part of this feasibility study to evaluate the relative merits of the following types of structures at the same location:

- Concrete gravity dam;
- Thick concrete arch;
- Thin concrete arch; and
- Fill embankment.

Preliminary comparisons of gravity, arch and rockfill dam alternatives indicated a trend in favor of the concrete arch dam alternatives. The assessment showed that a concrete gravity dam in the narrow gorge would be more expensive and tend to behave similarly to an arch dam, but would not have the flexibility of such a structure under severe seismic shaking conditions. Consideration of a central core rockfill dam at Devil Canyon indicated a trend in favor of a conservative arch dam cost estimate, based on a dam cross-section significantly thicker than the finally selected design.

Two types of arch dam were considered at the site, a thin arch and a thicker, gravity arch. Suitable sand and gravel for concrete aggregates are available in sufficient quantities close to the damsite. There are no geological or geotechnical concerns in regard to bedrock that would preclude either dam type from consideration. However, the studies showed that although the thin arch arrangement did not appear to have a distinct technical advantage compared to a thick arch dam, it would be less expensive because of the smaller volume of concrete needed. The thin arch alternative was therefore selected for detailed study.

(ii) Diversion Scheme Alternatives

The selection process for establishing the final general arrangement for diversion included examination of tunnel locations on both banks of the river. Rock conditions for tunneling did not favor one bank over the other. Access and ease of construction strongly favored the left bank.

The main dam could be subjected to overtopping during construction without causing serious damage, and the existence of the Watana facility upstream will offer considerable assistance in flow regulation in case of an emergency. These considerations led to the selection of a 25-year design flood of 37,800 cfs for this site. As at Watana, the considerable depth of riverbed alluvium at both cofferdam sites indicates that embankment type cofferdam structures would be the only technically and economically feasible alternative at Devil Canyon. Consideration of a number of alternative tunnel arrangements culiminated in selection of a single 30-foot diameter pressure tunnel arrangement. An upstream cofferdam 60 feet high, with a crest elevation of 945, was carried forward as part of the selected general arrangement.

(iii) Spillway Alternatives

The project spillways have been designed to safely pass a 1:10,000-year flood discharge of 165,000 cfs and a PMF of 365,000 cfs.

A number of alternatives were considered singly and in combination for Devil Canyon spillway facilities and locations. These included gated orifices in the main dam discharging into a plunge pool, right and left bank, chute or tunnel spillways with either a flip bucket or stilling basin for energy dissipation, and open channel spillways. The selected arrangement will comprise a gated spillway control structure and chute in the left bank with energy dissipation by a flip bucket which directs the spillway discharge in a free-fall jet into a plunge pool in the river. Restrictions with respect to nitrogen supersaturation have been applied in selecting acceptable spillway discharge structures. The main spillway is designed to pass 135,000 cfs, the remaining 30,000 cfs being discharged through seven fixed-cone valves in the dam. The selected emergency spillway is an open channel with erodible fuse plug in the left abutment of the dam.

(iv) Power Facilities Alternatives

A surface powerhouse at Devil Canyon would be located either at the downstream toe of the dam or along the side of the canyon wall. An underground arrangement was favored however because insufficient space is available in the steep-sided canyon for a surface powerhouse at the base of the dam. Provision of an extensive intake at the crest of the arch dam would also be detrimental to stress conditions in the arch dam particularly under earthquake loading. Underground powerhouse and related facilities have therefore been located on the right bank where topographic conditions are generally more favorable, and rock quality is superior at depth.

For the design head and specific speed, four Francis turbine units have been selected. These are rated to deliver 150 MW each at full gate opening and minimum reservoir level in December, the peak demand month. Six single-phase transformers will be installed underground to serve the 4 units, similar to Watana. For flexibility of operation, 4 individual penstocks are provided to each of the 4 units.

A single chamber and single tailrace tunnel with a length of 6,800 feet to develop 30 feet of additional head downstream from the dam has been incorporated in the design.

Detailed studies comparing construction cost to the value of energy lost or gained were carried out to determine the optimum diameter of the water passages.

(v) Environmental Constraints

In addition to potential nitrogen-saturation problems caused by spillway operation, the major impacts of the Devil Canyon power facilities development are:

- Changes in the temperature regime of the river; and
- Fluctuations in downstream river flows and levels.

Temperature modeling has indicated little benefit to be gained by constructing a multiple level intake design at

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Devil Canyon. The intake therefore incorporates a single level draw-off about 75 feet below maximum reservoir operating level. The Devil Canyon station will normally be operated as a base-loaded plant throughout the year, to satisfy the requirement of no significant daily variation in power flow.

(vi) Selection of Devil Canyon General Arrangement

Preliminary alternative arrangements of the Devil Canyon project were developed and a preferred arrangement selected. Topographic conditions at this site limited the development of reasonably feasible layouts, and initially, four schemes were developed and evaluated. During the final review, the selected layout was refined based on technical, operational, and environmental considerations identified during the preliminary review.

2.8 - Watana Development

The project site is located in a broad U-shaped valley at river mile 184, approximately 2.5 miles upstream of the confluence of Tsusena Creek with the Susitna River. The river at the site is relatively wide, although turbulent.

(a) Geologic Conditions

The site is generally characterized by up to 80 feet of overburden, consisting of talus, glacial silts, sands, gravels, and boulders. The riverbed consists of about 80 feet of alluvial sand, silt, coarse gravels, and boulders. Permafrost conditions exist generally on the north-facing slopes (left bank) of the damsite area and in sporadic areas of the north abutment.

The damsite is primarily underlain by an intrusive dioritic body which varies in composition from granodiorite to quartz diorite to diorite. The rock is hard, competent, and fresh except within shear zones, and has been intruded by mafic and felsic dikes which are generally only a few feet thick. The rock immediately downstream from the damsite is an andesite prophyry, containing quartz diorite inclusions.

The topography of the Watana reservoir and adjacent slopes is characterized by a narrow V-shaped stream-cut valley superimposed on a broad U-shaped glacial valley. The lower portions of the Watana reservoir are predominantly covered by a veneer of glacial till with scattered outwash deposits. The river valleys contain significant amounts of alluvial deposits and reworked outwash. The main structural feature of the Watana reservoir is the Talkeetna Thrust, an inactive fault which trends northeast-southwest, crossing the Susitna River approximately eight miles upstream from the damsite.

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(b) Geotechnical Design Considerations

Detailed investigations have been undertaken to evaluate the geotechnical aspects of design of the dam and other major structures at the Watana site.

The riverbed alluvium ranges up to approximately 100 feet in depth. The character of this material has not yet been well defined and its stability during a strong earthquake event is questionable. It will therefore be removed under the dam. The strength of the rock foundation is adequate to support the embankment and associated reservoir loads. Seepage under the dam will be controlled by the provision of a grout curtain cutoff combined with a downstream drainage system.

(i) Underground Structures

The rock conditions at the Watana site are suitable for the construction of tunnels and underground caverns. The orientation and location of rock discontinuities have been a major factor in selection of the alignments of the tunnels and major caverns to achieve maximum stability and minimum support requirement. Permafrost conditions will not have any major adverse impact except where thawing may be required for grouting. Conventional rock bolt support is generally considered adequate in most areas with spans less than 40 feet. For larger spans and in areas of poor quality rock, the support requirements have been determined on a case-by-case basis. Tunnel excavation can be performed using conventional drill and blast techniques or high production mechanical excavating equipment.

(ii) Relict Channel

A deep bedrock depression exists on the north bank of the river extending from about 2,500 feet west of Deadman Creek northwest toward Tsusena Creek. The depth to bedrock is as much as 400 feet below the surface and the reservoir level. The overburden consists of several sequences of glacial deposits, lake sediments, and alluvium varying in thickness and character, and containing some permafrost. With the proposed range of reservoir levels, these overburden deposits will become saturated, which may lead to potential design problems.

Additional investigations will be necessary to properly characterize the subsurface conditions in the area prior to construction.

(iii) Seismic Considerations

For earthquake engineering and design considerations, the project structures have been classified as either critical or non-critical structures. Critical structures will be designed to safely withstand the effect of the selected "Safety Evaluation Earthquake" (SEE) for the site. No significant damage to these structures will be accepted under these conditions. The design of non-critical structures for earthquake conditions is undertaken on the basis of conventional Uniform Building Code recommendations.

Two sources will be used for determination of the most severe SEE condition for design of structures at Watana, a Benioff Zone maximum earthquake of magnitude 8.5 at a distance of 40 miles from the site, and a Terrain maximum earthquake of magnitude 6.25 at a distance of less than 6 miles from the site.

Although the "Terrain" earthquake would result in more severe ground motions, the duration of these motions is relatively short and the likelihood of occurrence of such an event is extremely small. The design of the Watana dam has therefore been based on the projected time history for the Benioff event.

(c) General Arrangement

General arrangement drawings for Watana are presented in Volume 3 of this report.

The Watana dam will form a reservoir approximately 48 miles long, with a normal maximum operating elevation of 2185. The dam will be a 62 million cubic yard earthfill structure with a central impervious core. The crest elevation of the dam will be 2210, with a maximum height of 885 feet and a crest length of 4,100 feet. During construction, the river will be diverted around the main construction area by means of two 38-foot-diameter, concrete-lined diversion tunnels on the right bank of the river.

A power intake and approach channel will be located on the right bank, leading to a multilevel gated intake structure capable of operation over a 140-foot drawdown range. From the intake structure, six 17-foot-diameter penstocks will lead to an underground powerhouse complex housing six 170 MW Francis turbine-generator units. Access to the powerhouse complex will be by means of an unlined access tunnel. Turbine discharge will be conducted through six draft tube tunnels to a surge chamber downstream from the powerhouse, then by means of two 30-foot-diameter concrete-lined tailrace tunnels to the river downstream. A separate transformer gallery upstream from the powerhouse cavern will house nine single-phase 15/345 kV transformers. The transformers will be connected by 345 kV single-phase, oil-filled cable through two cable shafts to the switchyard at the surface. A tunnel outlet facility located on the right bank will discharge all flows resulting from floods having a return frequency of 1:50 years or less. This structure will be equipped with six fixed-cone valves at the downstream end to minimize undesirable nitrogen supersaturation in the river downstream from the dam during spillway operations. Flows resulting from floods with a frequency greater than 1:50 years but less than 1:10,000 years will be discharged by a main chute spillway also on the right bank. The spillway control structure at the upstream end will be controlled by three fixed wheel gates leading to a concrete-lined chute and flip bucket at the downstream end. An emergency spillway on the right bank will provide sufficient additional capacity to permit discharge of the PMF without overtopping the dam. An emergency release facility will allow lowering of the reservoir over a period of time to permit emergency inspection or repair.

(d) Site Access

Extensive studies were undertaken of a number of alternative access corridors to the sites. The selected route is considered to be the best compromise of the technical, economic, environmental, social and schedule factors involved. This route will be via a paved road starting near Hurricane on the Parks Highway from whence the route will proceed southeast to the vicinity of Gold Creek. A bridge will be constructed south of Gold Creek from which the road will be routed south of the Susitna River to a second low-level bridge upstream of the Devil Canyon site. From this point the road will be north of the river to Watana. In addition to the main access, several additional roads will be required to access the various site facilities and structures. The construction roads will be 40-foot wide gravel surfaced roads with small radius curves and grades limited to 10 percent. Major cut and fill work will be avoided. The completed main dam crest will provide permanent access across the Susitna River, and an access tunnel will be provided to the underground powerhouse.

A permanent 6,000 foot airstrip will be constructed approximately 2.5 miles north of the main construction camp. A temporary 2,500 foot airstrip will also be constructed to support the early phases of mobilization and construction.

(e) Site Facilities

The construction of the Watana development will require various support facilities throughout the construction period. Following construction, the operation of Watana will require other facilities to support the permanent operation and maintenance of the project. The site facilities, including housing, recreation, water supply, and sanitary facilities will be located on the north bank of the river about 2.5 miles northeast of the dam. It will be a combination camp and village which will accommodate up to 4,000 people during construction of the project. After construction is complete, it is planned to dismantle and demobilize the construction camp facility and to reclaim the area. Required permanent facilities will support a community of approximately 130 staff members and their families. Other permanent facility items will include a maintenance building for use during subsequent operation of the power plant.

During the first two years of construction, power supply will be provided by diesel generators. A single 345 kV transmission line will be constructed to service the site from 1987 onward. This line will be operated at 138 kV until commissioning and subsequently will be part of the permanent system supplying power to the interie at 345 kV.

(f) Main Dam

The main dam at Watana is 885 feet high and will be among the highest in the world. The Watana site is located in a seismically active area. The major design features of 24 embankment dams between 350 and 795 feet in height constructed in seismic areas compare favorably with the Watana design. These comparisons indicate that the proposed Watana design is generally conservative with respect to precedent design. However, some additional special features have also been incorporated in the Watana section to provide additional safeguards against seismic loading.

The embankment will consist of a central compacted core protected by fine and coarse filters on both sides. The downstream outer shell will consist of rock fill and alluvium gravel; and the upstream outer shell of clean alluvium gravel.

The proposed impervious material core is a combination of glacial outwash and tills with a wide grain size distribution. It is nonplastic and would tend to crack rather than deform under tensile stress. A central vertical core was chosen for the embankment rather then a sloping core based on a review of precedent design and the nature of the proposed impervious material.

Because of the apparent low plasticity of the impervious core material and the requirement for an earthquake resistant design, a number of special design features will be incorporated into the main dam cross-section. These include measures to withstand the effects of severe seismic shaking, such as widening of the core-foundation contact near the ends of the embankment to ensure seepage control, and careful attention in design of filters which will be self-healing in case of transverse cracks in the core. Compacted processed clean river alluvium gravel of high permeability will be used to construct the upstream outershell to minimize settlement displacement and to ensure rapid dissipation of any pore pressure buildup which may occur.

(g) Stability Analysis

Static and dynamic stability analyses have been performed to confirm the stability of the upstream and downstream slopes of the Watana dam. The analyses indicate stable slopes under all conditions for a 2.4H:1V upstream slope and 2H:1V vertical downstream slope.

The static analyses were used to determine the initial stresses in the dam during normal operating conditions. The dynamic analyses were made using a finite element model to incorporate strain dependent shear modulus and damping parameters. The design earthquake for the dynamic analyses was developed for a Benioff Zone event, magnitude 8.5 at a distance of 40 miles from the site.

The following conditions were analyzed under static conditions:

Condition	Required Minimum Factor of Safety	Calculated Factor of Safety U/S Slope	Calculated Factor of Safety D/S Slope
Construction	1.3	2.2 - 2.2	1.7
Normal Operating	1.5	2.0	1.7
Rapid Drawdown	1.0	1.8 - 2.0	1.7

The calculated factors of safety indicated no general slope stability problems under static loading.

In the dynamic analysis, estimated values were used for material properties such as shear modulus, based on published data. The analysis was based on a time history developed for the design earthquake, with a maximum acceleration of 0.55g; and a duration of strong motion of 45 seconds. The results of this analysis are dependent on the accuracy of the assumed material properties. However, they do indicate with some degree of confidence that the dam will safely withstand this seismic event, with minimal damage such as typical minor surface raveling.

(h) Relict Channel Treatment

The buried channel is located between the Susitna River gorge immediately upstream from the proposed damsite and Tsusena Creek, a distance of about 1.5 miles. The surface elevation of the lowest point of the saddle is approximately 2005 feet. Along the channel thalweg, the highest bedrock surface is some 450 feet below reservoir and the highest gradient along the buried channel from the edge of pool to Tsusena Creek is approximately 9 percent. Zones of permafrost have also been identified throughout the channel area. Potential problems associated with the buried channel are leakage, both surface and subsurface flows; piping at downstream outlets to Tsusena Creek; the impact of permafrost and the long-term effects as heat from the reservoir thaws the ground through the channel area; and instability of soil slopes on saturation, thawing, or seismic loading leading to a breach of the rim of the reservoir. The stability of the section of the buried channel forming the rim of the Watana reservoir is essential for the feasibility of the Watana development. Appropriate measures have therefore been provided in the design.

To eliminate these potential problems, the maximum operating level of the reservoir has been set at 2185 feet leaving a width of at least 1500 feet of "dry" ground at the saddle above this elevation. A low freeboard dike with a crest elevation of 2010 will also provide protection against extreme reservoir levels under PMF flood conditions. The potential for piping and erosion in the area of discharge into the Tsusena Creek will be controlled by placement of a filter blanket over the zones of emergence. Field investigation will be carried out to define critical areas, and only such areas will be treated since it may take many years for equilibrium with respect to the permafrost regime to become established in the buried channel area.

To guarantee the integrity of the reservoir rim through the channel area it is required that either:

- There is no potential for a liquefaction slide into the reservoir which could cut back and breach the rim; or

- If there is such potential, there is a sufficient volume of stable material at the critical section that even if the upstream materials were to slide into the reservoir, the failure zone could not cut back to the reservoir rim.

A better knowledge of the in situ materials in the relict channel will be possible with additional exploration. The potential for liquefaction can then be better defined. With the limited information currently available, in the worst case the most positive solution would be the replacement of the zones which may be subject to liquefacation with material that would not liquefy. This would involve, in effect, the rearrangement of the in-place materials to create an underground dam section founded on the dense till layer beneath the critical alluvium. The cost of such work is estimated to be about $100 million. The need of such expenditure is considered to be most unlikely and is deemed to be covered by the overall project cost contingency allowance.

(i) Reservoir

The Watana reservoir, at normal operating level of 2185 feet, will be approximately 48 miles long with a maximum width in the order of five miles. The minimum reservoir level will be 2045 feet during normal operation, resulting in a maximum drawdown of 140 feet. The reservoir will have a total capacity of 9,520,000 acre-feet of which 4,210,000 acre-feet will be live storage.

Prior to reservoir filling, the area below Elevation 2190, five feet above maximum operating level, will be cleared of all trees and brush. In the Watana reservoir area, an estimated 18,000,000 cubic feet of wood exists, of which approximately 87 percent are soft woods. Present market demand for the timber at Susitna is low; however, the worldwide demand for wood fluctuates considerably. It is anticipated that use of the harvested material would be limited to sale either as wood-waste products or as fuel. Slash material including brush and small trees, which will be unsuitable for either of the above uses, will be either burned in a carefully controlled manner consistent with applicable laws and regulations, or hauled to a disposal site in and adjacent to the reservoir. Material placed in disposal areas will be buried with an earthfill cover sufficient to prevent erosion and subsequent exposure.

2.9 - Devil Canyon Development

The Devil Canyon site is located at river mile 152 of the Susitna River, approximately 32 miles downstream from the Watana site, in a V-shaped section near the entrance to the canyon which is about two miles long. The river at this site is relatively narrow and extremely turbulent. The canyon is characterized by steep walls, particularly on the left bank which features overhanging cliffs and detached blocks of rock.

(a) Geologic Conditions

The valley walls are generally covered by a thin veneer of overburden consisting primarily of talus at the base. The flatter upland areas are covered by 5 to 35 feet of overburden of glacial origin. A topographic depression along the elongated lakes on the south bank has an overburden covering in excess of 85 feet of glacial materials. The overburden on the alluvial fan or point bar deposit at the Cheechako Creek confluence thickens from 100 feet to more than 300 feet over a distance of less than 400 feet. The river channel alluvium appears to be composed of cobbles, boulders, and detached blocks of rock and is inferred to be up to 30 feet thick. No permafrost was found in either the bedrock or surficial material at or around the damsite.

The bedrock at the Devil Canyon site is a low-grade metamorphosed sedimentary rock consisting predominantly of argillite with interbeds of graywacke. The argillite is a fresh, very thinly bedded, very fine grained argillaceous rock. The graywacke is generally a fresh, mainly fine-grained sandstone with an argillaceous matrix, interbedded with the argillite in beds generally less than six inches thick. The area has also been intruded by numerous felsic and mafic dikes ranging from 1 inch to 60 feet wide (averaging 20 feet). When closely fractured they are easily eroded and tend to form steep talus-filled gullies, some of which exhibit shearing with the host rock.

The Devil Canyon reservoir will be confined to a narrow canyon where the topography is controlled by bedrock. The overburden is thin to nonexistent, except in the upper reaches of the reservoir where alluvial deposits cover the valley floor. A large intrusive plutonic body composed predominantly of biotite granodiorite with local areas of quartz diorite and diorite underlies most of the reservoir and adjacent slopes. Argillite and graywacke are also present. The rock has been isoclinically folded into steeply dipping structures striking generally northeast-southwest. The argillite has been intruded by massive granodiorite, and as a result, large isolated roof pendants of the argillite and graywacke are found locally throughout the entire reservoir and surrounding areas.

(b) Geotechnical Design Considerations

The geotechnical investigations to date have been primarily directed toward the important geological features which may have significant impact on the feasibility of the project. The geologic and topographic conditions are favorable for an arch dam at the Devil Canyon site. The rock is principally hard, competent, and fresh with weathering limited to joints and shear zones. Intrusive mafic and felsic dikes, where present, are hard, the contact with the parent rock is tight, and they have no important adverse effect on the stability of the abutments. The stresses imposed by the arch dam will be well within acceptable limits for the rock. On the right abutment, the arch dam thrust block will be required to transfer the loads to competent rock. This thrust block will form an abutment to the saddle dam.

(i) Underground Structures

The rock conditions at the site are generally suitable for the construction of tunnels and underground caverns. For the most part, conventional rock bolt support has been assumed to be adequate for openings less than 40 feet in span. For larger spans, in areas of poor quality rock and where rock discontinuities are known to be adversely oriented, support requirements have been determined on a case-by-case basis.

(ii) Saddle Dam Foundation

The saddle dam on the south bank will be constructed across a buried channel where the thickness of overburden is up to 80 feet. The bedrock below (argillite and graywacke) the area is competent. The prominent shear zone or fault which was found in the saddle dam foundation, together with various shear and fracture zones, will require treatment by consolidation and curtain grouting under the core.

(iii) Seismic Considerations

As for Watana, critical structures at Devil Canyon, such as the arch dam, will be designed to safely withstand the effect of the "Safety Evaluation Earthquake" (SEE) for the site. No significant damage to these structures will be accepted under these conditions.

As at Watana, two earthquake sources have been considered for determination of the SEE for critical structures at Devil Canyon. For the arch dam and other critical concrete structures, a Terrain maximum earthquake of magnitude 6.25 at a distance of less than 6 miles from the site will be used as the basis for design. For the saddle dam, the projected time history for a Benioff Zone maximum earthquake of magnitude 8.5 at a distance of 57 miles from the site will be used.

(c) General Arrangement

Devil Canyon will form a reservoir approximately 26 miles long with a total volume of 1,092,000 acre-feet at a normal maximum operating elevation of 1455. The operating level of the Devil Canyon reservoir is controlled by the tailwater level of the upstream Watana development. During operation, the reservoir will be capable of being drawn down to a minimum elevation of 1405. The dam will be a thin arch concrete structure with a crest elevation of 1465 and maximum height of 645 feet. An earth- and rockfill saddle dam will provide closure to the left bank. The saddle dam will be a central core type generally similar in cross-section to the Watana dam. This dam will have a maximum height above foundation level of approximately 260 feet.

During construction, the reservoir will be diverted around the main construction area by means of a single concrete-lined diversion tunnel 30 feet in diameter on the left bank of the river. A power intake located at the right bank will comprise an approach channel in rock leading to a reinforced concrete gate structure. From the intake structure four penstocks, consisting of concrete-lined tunnels each 20 feet in diameter, will lead to an underground powerhouse complex housing four Francis turbine-generator units each with a rated capacity of 150 MW. Access to the powerhouse complex will be by means of an unlined access tunnel approximately 3,200 feet long, as well as a vertical access shaft about 950 feet deep. Turbine discharge will be conducted to the river by means of a single 39-foot-diameter tailrace tunnel leading from a surge chamber downstream from the powerhouse cavern. Compensation flow pumps at the power plant will ensure suitable flow in the river between the dam and tailrace tunnel outlet portal. A separate transformer gallery just upstream from the powerhouse cavern will house six single-phase 15/345 kV transformers. The transformers will be connected by 345-kV, single-phase, oil-filled cable through a cable shaft to the switchyard at the surface.

Seven individual outlet conduits will be located in the lower part of the main dam to discharge all floods with a frequency of 1:50 years or less. Each outlet conduit will have a fixed-cone valve similar to those provided at Watana to minimize undesirable nitrogen supersaturation in the flows downstream. Flows resulting from floods with a frequency greater than 1:50 years but less than 1:10,000 years will be discharged by a chute spillway on the right bank, also similar in design to that provided for Watana. An emergency spillway on the left bank will provide sufficient additional capacity to permit discharge of the PMF without overtopping the dam. An emergency-release, low-level outlet facility will allow lowering of the dam to permit emergency inspection or repair.

(d) Site Access

At Devil Canyon the main access road to the Watana site will enter the site from the south. The existing low-level bridge upstream from the dam will be used to cross the Susitna River during construction. After construction of the main dam is completed, the crest of the main dam will provide access across the Susitna River. The permanent airstrip located at the Watana site, approximately 30 miles west of the Devil Canyon site, will be used for the Devil Canyon development.

(e) Site Facilities

The construction of the Devil Canyon development will require various facilities to support the construction activities throughout the entire construction period. Following construction, the planned operation and maintenance of the development will be centered at the Watana development; therefore, minimum facilities at the site will be required to maintain the power facility.

A camp and construction village with water supply and sanitary facilities will be constructed and maintained approximately 2.5 miles west of the project site. The camp/village will provide housing and recreation facilities for up to 1,900 people during construction. Other site facilities include contractor's work areas, site power, services, and communications. Items such as power and communications and hospital services will be required for construction operations independent of camp operations. It is planned to dismantle and demobilize the facility upon completion of the project, after which the area will be reclaimed.

Since the Watana development will be in service during the construction period, electric power will be available. It is therefore planned to meet all heating requirements with electric heat.

(f) Arch Dam

The arch dam will be located at the upstream end of the canyon at its narrowest point. The height of the dam will be 645 feet, well within the range of heights of similar dams constructed elsewhere. The dam is designed to withstand dynamic loadings from seismic shaking. A number of other dams constructed throughout the world in seismically active areas have withstood earthquake loadings as high as 0.6g to 0.8g. Green Lake Dam is presently being constructed to a height of 210 feet in Sitka, Alaska.

The rock forming the right abutment rises several hundred feet above the dam crest but on the left side the rock surface rises only to Elevation 1400. It will be necessary to construct a mass concrete thrust block at this point to artificially form the bearing surface of the dam.

The dam will be founded on sound bedrock located 20 to 40 feet below the bedrock surface. The foundation will be excavated and trimmed beneath the dam so that no abrupt irregularities will occur at the foundations which could cause stress concentrations within the concrete.

(g) Design Analysis

The crown section at the center of the river will be of a double curved cupola shape inclined downstream. The static load from the reservoir will be taken primarily in the arches; the three-dimensional stress action of the structure will tend to induce tension in the downstream face of the cantilever. This will be offset by the gravity forces of the overhanging section, which also will counteract any loadings produced by downstream ground motion during an earthquake.

A two-center configuration will be adopted for the arches to counteract the slight assymetry of the valley and give a more uniform stress distribution across the dam. Stress analyses show that the structure will safely withstand the Terrain SEE, magnitude 6.25. For conservative structural design purposes, a mean spectral acceleration of 0.55g and 10 percent damping ratio has been adopted at the site.

Construction of the dam will be completed over a five-year period. Concrete will be placed by means of three highlines strung above the dam between the abutments. Construction will take place throughout the year with cooling coils built into the concrete to dissipate the heat of hydration and special heating and insulating precautions taken in the winter to prevent excessive cooling of concrete surfaces. Concrete aggregates will be obtained from the alluvial deposits in the terraces upstream from the dam.

(h) Saddle Dam

The design philosophy for the saddle dam at Devil Canyon is similar to that for the main dam at Watana. The most significant difference is the exclusive use of rockfill in the shells instead of river gravels used for the much higher Watana dam. The central vertical impervious core will be protected by fine and coarse filters on both upstream and downstream slopes and supported by rockfill shells. The wide filter zones will provide sufficient material for self-healing of any cracks which might occur in the core because of settlement or as the result of seismic disturbance. The saturated sections of both shells will be constructed of compacted clean rockfill, processed to remove fine material in order to minimize pore pressure generation and ensure rapid dissipation during and after a seismic event. Protection on the upstream slope will consist of a 10-foot layer of riprap.

No source of material suitable for the core of the saddle dam has been identified closer than the borrow areas at Watana (Sites D and H). Since access roads will be established to that area, the Site D source will be used for the Devil Canyon core. Investigations to date indicate that suitable material can be obtained from areas above the Watana reservoir level. The filter material will be obtained from the river deposits (Site G) immediately upstream from the main arch dam at Devil Canyon. This area will also be exploited for concrete aggregates. Rockfill for the saddle dam shells will be obtained primarily from the excavations for the spillway, tunnels, and powerhouse complex.

As at Watana, special precautions have been taken to ensure stability under earthquake loading by the use of processed free-draining rockfill in the saturated zones of the dam, the incorporation of very wide filter zones, and the removal of all unconsolidated natural material from beneath the dam. Static and dynamic stability analyses of the upstream slopes of the Watana dam have confirmed stable slopes under all conditions for 2.4H:1V upstream slope and a 2H:1V downstream slope. The Devil Canyon saddle dam is therefore also considered to be stable under such conditions.

(i) Reservoir

The Devil Canyon reservoir, at a normal operating level of 1455 feet, will be approximately 26 miles long with a maximum width in the order of 1/2-mile. The total surface area at normal operating level is 7,800 acres.

Present market demand for the timber at Susitna is low, however, the worldwide demand for wood fluctuates considerably. It is anticipated that use of the harvested material would be limited to sale either as wood-waste products or as fuel. Slash material including brush and small trees, which will be suitable for either of the above uses, will be either burned in a carefully controlled manner consistent with applicable laws and regulations, or hauled to a disposal site in and adjacent to the reservoir.

2.10 - Transmission Facilities

The project transmission facilities are required to provide a power delivery system from the Susitna River Basin generating plants to the major load centers in Anchorage and Fairbanks. This system will be comprised of transmission lines, substations, a dispatch center, and means of communications. Transmission planning criteria were developed and electric system studies undertaken to ensure the design of a reliable and economic electrical power system, with components rated to allow a smooth transition through early project stages to the ultimate developed potential. These criteria were essentially based on delivery of total power output of Susitna to one or two substations at Anchorage and one at Fairbanks.

Studies of alternative transmission voltages, hardware, and substation configurations resulted in selection of the following economic optimum arrangement for the Susitna development:

Line Section	Length (mi)	Number of Circuits	Voltage (kV)	Number and Size of Conductors (kcmil)
Watana to Devil Canyon	27	2	345	2 by 954
Devil Canyon to Fairbanks	189	2	345	2 by 795
Devil Canyon to Willow	90	3	345	2 by 954
Willow to Knik Arm	38	3	345	2 by 954
Knik Arm Crossing	4	3	345	Submarine cable
Knik Arm to University Substation	18	2	345	2 by 1351

Substations for this system will be located at each site and also at Esker (Fairbanks), Willow, Knik Arm (east shore), and University (Anchorage). The Esker substation will provide a connection of Susitna power to the GVEA system and the University substation to the CEA and AMLP systems. The segment of the system between Willow and Healy will

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incorporate the intertie which is currently being planned as a single line to be operated initially at 138 kV and subsequently upgraded to 345 kV.

Extensive studies were undertaken to select appropriate corridors and routes for the transmission lines. A number of alternative 3 to 5 mile wide corridors were investigated, and the selected corridor provided the optimum tradeoff of the technical, economic, and environmental factors involved. These studies were undertaken in parallel and coordinated with similar studies for the intertie. The selected corridors were subsequently subjected to a process of refinement and more detailed evaluation to identify the preferred 1/2-mile wide route in which to locate the transmission right-of-way. The required right-of-way will vary from 400 feet for 3 lines to 700 feet for 5 lines. This process was based on similar technical, economic, and environmental criteria to the corridor selection studies during the route selection phase. Particular emphasis was placed on satisfying regulatory and permit requirements, aesthetics, and avoidance of developed areas.

A hinged-guyed, two-legged steel X-tower was selected for all proposed transmission lines, including the intertie. Design features of these towers include hinged connections between the leg members and foundations and longitudinal guy systems which provide flexibility and stability. These are important considerations in the unique foundation and climate conditions in this area of Alaska. The selected design is considered to be a sound compromise of reliability, durability, economy, and aesthetics.

2.11 - Construction Cost Estimates and Schedules

Estimates of construction costs for the Watana and Devil Canyon developments have been prepared on a uniform January 1982 cost basis. These estimates are based on detailed construction schedules and quantity takeoffs for the designs developed for the entire project during the course of the study. Allowances have been made for unique construction conditions in Alaska where the remoteness of the project area and the severity of the climate will have significant effects.

(a) Estimate of Cost

The estimated costs of the project in January 1982 dollars, are as follows:

	$ x 10^6		
Category	Watana	Devil Canyon	Total
Production Plant	1,986	835	2,821
Transmission Plant	391	91	482
General Plant	5	5	10
Site Facilities	378	188	566
Subtotal	2,760	1,119	3,879
Contingency (17.5%)	482	196	678
Total Construction	3,242	1,315	4,557
Engineering & Administration (12.5%)	405	165	570
Project Total	3,647	1,480	5,127

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Of these costs, $112,775,000 at Watana and $36,303,000 at Devil Canyon are attributable to mitigation measures such as outlet facilities, restoration, multilevel intakes, etc., incorporated in the projects.

At current high levels of interest rates in the financial marketplace, allowance for funds used during construction (AFDC) will amount to a significant element of financing cost for the lengthy periods required for construction of the Watana and Devil Canyon projects. However, in economic evaluations of the Susitna project, the low real rates of interest assumed would have a much reduced impact on assumed project development costs. Furthermore, direct state involvement in financing of the Susitna project will also have a significant impact on the amount, if any, of AFDC. For purposes of the current feasibility study, therefore, the conventional practice of calculating AFDC as a separate line item for inclusion as part of project construction cost, has not been followed. Provisions for AFDC at appropriate rates of interest are made in the economic and financial analyses for the project.

(b) Construction Schedules

Construction schedules for the project are based on the system planning requirement of first power on-line at Watana in 1993 (680 MW) and at Devil Canyon in 2002 (600 MW). Assuming a FERC license to construct the project is received in late 1984, it is essential that mobilization for construction of diversion and site facilities at Watana be scheduled to commence in early 1985.

The critical construction activity at Watana is the 62 million cubic yard dam. Seasonal restrictions on placing embankment fill require a total of seven seasons for completion of this structure. Timely completion of the excavation and foundation is thus crucial in the first two years of construction. To insure that this work is not delayed, construction of a pioneer access road should begin in 1983, if necessary, prior to receipt of the FERC license. Construction of the remaining transmission, spillway, release, and power facilities and reservoir impoundment will be appropriately scheduled to ensure power generation capability in 1993.

Construction power will be obtained by installation of an initial transmission link from the intertie at Gold Creek to Watana within two years of commencement of construction. In the interim period diesel generators will be used at the site. To accomplish the desired schedule for construction of Watana, procurement contracts for site facilities, materials, and equipment should be appropriately scheduled over the 1983-84 period.

Construction of the Devil Canyon dam is currently scheduled to take five years. Thus, mobilization for diversion and site facilities is scheduled to begin in 1994. Completion of the remaining transmission, spillway and power facilities, and reservoir impoundment will be scheduled for the on-line power date of 2002.

2.12 - Environmental Impacts and Mitigation Measures

A number of measures have been incorporated into the design of the Susitna Project to mitigate some of the environmental impacts. Other measures are also being formulated where necessary in consultation with concerned agencies.

(a) Water Use and Water Quality

Examination of state agency files indicated the major, although small, users of surface water occur along the Kahiltna and Willow Creek township grids. Analysis of topographic maps and overlays showing the specific locations of the appropriations along the mainstream Susitna River Corridor indicated that neither surface water diversions from small tributaries nor shallow wells in the corridor area are likely to be affected by operation of the proposed project.

Impoundment of the Susitna River will change the water quality. The following parameters will exhibit reductions in values in the reservoir and downstream reaches as compared to the pre-project levels: suspended solids, turbidity, color, nutrients, iron, manganese and some trace elements. Both reservoirs will be heat exporters and the downstream reaches of the river will exhibit a reduced magnitude of seasonal temperature variation. An increase in downstream temperatures during the winter will result in open water downstream to Talkeetna, with some impact on fisheries. Dissolved oxygen concentrations will remain high, at or near saturation, in the upper levels of both reservoirs and downstream in the river. Although during initial years of operation the reservoir nutrient and trace element concentrations will be higher than at present, potential for eutrophication to develop in either reservoir is low.

Although water quality changes will be affected by the project, none of these changes will be significantly adverse and many changes may be beneficial. No mitigation measures are planned.

(b) Botanical Resources

The primary impacts to vegetation will be through inundation. The Watana impoundment, at maximum pool elevation, will inundate approximately 14,691 ha (36,750 acres), which represents 0.9 percent of the vegetated area of the upper basin. Woodlands, including open spruce stands and birch forests will be impacted relatively more than other habitat types. The Devil Canyon reservoir will flood approximately 3,214 ha (8,035 acres) which is less than 0.2 percent of the vegetation of the upper basin.

Construction of the dams, spillways, camps and utilization of the borrow areas will remove an additional 2,000 ha (5,000 acres). Preparation of the right-of-way for the access road will require the clearing of approximately 900 ha (2,250 acres). Some vegetation may be cleared during transmission line construction, but this will occur primarily only in areas of tower placement. In other areas, topping of trees may be required. Operation and maintenance of the reservoirs may cause minor slope instability and slumping of the banks.

Mitigation considerations have been incorporated into the planning process. Proposed construction camps and villages have been located in as compact a manner as possible, thereby reducing areas of vegetation effected. Transmission line routes have been identified which follow existing rights-of-ways and gentle terrain wherever possible. The transmission line and access route will utilize the same corridor for the majority of the way between Watana and the Parks Highway. Wherever possible, borrow areas have been located in the proposed impoundment zone, thereby reducing areas of disturbance outside this zone Clearing of the reservoir prior to inundation will insure use of the resource.

The major additional mitigation technique will be the restoration of borrow areas, temporary access roads and other areas that may be disturbed during construction. This will be accomplished through storing of topsoil, replacing it onto disturbed areas, contouring, seeding and fertilizing these areas to allow natural vegetation to regrow. These areas will be monitored and, if necessary, further mitigation techniques (water bars, terraces, mulching, etc.) implemented to insure erosion does not occur and vegetation is established.

(c) Wildlife Resources

Project impacts will occur on big game, furbearers, birds and non-game mammals.

(i) Big Game

The principal species of big game are moose, caribou, wolf and wolverine, bear and dall sheep.

- Moose

The Watana impoundment and associated facilities will result in loss of moose habitat and displacement of those moose whose home ranges occur primarily within the reservoir areas. It is estimated that approximately 400 moose at Watana and 100 moose at Devil Canyon will be directly impacted and as many as 800 at Watana and 200 at Devil Canyon indirectly affected. It is not known how many of these the surrounding habitat will be able to support.

Alterations of flows downstream of Devil Canyon has the potential to affect vegetative succession, thereby impacting moose. However, the amount of available browse in the Devil Canyon to Talkeetna area is minimal and is not expected to change significantly. Downstream of Talkeetna, the inflows of Susitna River tributaries and "dampening" of flow fluctuations will reduce the potential for changes in vegetation. However, with the reduction in peak floods, vegetative succession rates may increase. Without mitigation, this could result in a reduction in available browse for moose.

The primary method being explored to mitigate impacts to moose is management of habitats outside the impoundment zones. This management may involve burning of areas (stimulating browse growth on which moose feed), logging operations and other techniques to improve habitat values, thereby increasing moose populations. In addition, minimizing areas of disturbance, insuring hunting regulations are enforced and reclaiming borrow areas and other disturbed areas as described previously will all reduce impacts to moose.

- Caribou

The primary potential impact to caribou is through the intersection of the historically important migration route across the Susitna River between Deadman and Jay Creeks. This route is not currently being used; it is possible caribou will attempt to use it sometime during the life of the project. Although caribou are excellent swimmers, mud flats and ice conditions on the shore line of the impoundment which will be present during the spring migration to the calving grounds may impede their migration.

Insufficient evidence concerning caribou behavior exists to determine their reaction to the reservoir and the ice. It is anticipated that the caribou will attempt to cross (either successfully or with some injury or mortality); move along the reservoir to a point where a safer crossing is found or; turn back and bear their calves in a different area. It is considered most likely the caribou will cross the impoundment safely and impacts should not be significant.

Mitigation options are being considered. These involve the monitoring of the spring migration to determine if the caribou establish new calving grounds and, if so, insuring these areas are fully protected from human intrusion during the calving period. It is believed this measure will mitigate the impacts to caribou.

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- Wolf and Wolverine

Construction of the Watana and Devil Canyon reservoirs will impact wolves and wolverine primarily through loss of habitat and reduction in prey species. It is believed 6 or 7 wolf packs will be affected as territories of these packs include areas where moose populations will likely decline. Approximately 10 to 20 wolverines will be most directly affected.

The technique currently under consideration to alleviate these impacts is to insure an adequate food base for the wolf and wolverine population. This will be accomplished primarily through habitat management to increase moose populations in surrounding areas, as discussed previously.

- Brown and Black Bear

Brown bear will be primarily affected by the project by direct habitat loss and human disturbance. Although no bears' entire home range is within the impoundment zones, bears will be impacted. The loss of seasonal foraging areas, particularly in the spring, will likely result in a reduction of the brown bear population. No known dens will be flooded.

Black bear will be more severely affected. This species is closely associated with forest habitat, the majority of which in the project area is in the impoundment zone. Flooding of this forest and lack of suitable adjacent habitat will considerably reduce the black bear population. In addition, 9 known dens will be flooded by the Watana impoundment and 1 by Devil Canyon.

It is very difficult to mitigate these impacts to bears. Worker education and access restrictions are being considered as means to reduce human-caused disturbances. Habitat management for moose in areas outside the Susitna basin will be explored to determine if this could also be used to increase the values of the area as bear habitat. Presence of a healthy moose population will aid in providing a food source for bears.

- Dall Sheep

Of 3 sheep herds identified in the upper Susitna basin, only 1 will be potentially affected. The Watana herd utilizes a mineral lick on cliffs along Jay Creek. Portions of this lick will be inundated. However, the greatest portion of the lick will be exposed during the time of heaviest sheep use which is May and June. It is not known if the sheep will continue to use the lick following creation of the reservoir.

The Watana herd will be monitored. If use of the lick is discontinued, an artificial lick with similar chemical composition will be established.

(ii) Furbearers

Loss of habitat in the amount described previously and increased trapping and hunting pressure will be the primary impacts to furbearers. There is also the potential for alteration of downstream flows to effect downstream beavers.

Planning of facilities, location of borrow areas in the reservoir areas, location of the transmission lines and access roads in common corridors and other techniques as described previously have been utilized to reduce the areas disturbed and hence impacts to furbearers. Potential control of access and enforcement of hunting and trapping regulations will further reduce these impacts.

(iii) Birds and Non-Game Mammals

The Watana and Devil Canyon impoundment will inundate 43 km^2 (25 mi^2) of cliff habitat designated as high quality. In addition, 4 active and 4 inactive golden eagle nest sites, 2 active and 1 inactive bald eagle site and 2 inactive raven nest sites will be inundated. Approximately 95 km^2 (38 mi^2) of forest habitat, which includes the most productive avian habitat, will be inundated. Red squirrels, porcupines and other small mammals will also lose their habitat. None of these bird or mammal species are unusual and are present in other areas of Alaska.

The primary loss to be mitigated is that of the bald eagle nest sites. The creation of two large impoundments may result in an increase in the eagle population of the area. To increase chances of this happening, clumps of tall spruce trees will be left uncut at 1/2- to 1-mile intervals, thereby providing nest sites. If eagles do not use these, the possibility for erecting artificial nest sites will be explored. Loss of forest habitat for birds and small mammals will be mitigated by minimizing and reclaiming areas of disturbance as previously described.

(d) Fisheries

Avenues of impact to fisheries population could occur through creation of the impoundment and alteration of downstream flows.

The Watana impoundment will eliminate approximately 80 km (48 mi) of mainstream riverine habitat. In addition, a number of tributaries in both the Watana and Devil Canyon areas will be inundated. Inundation of the mainstream is not expected to adversely affect the fish populations present. The reservoir should provide new habitat for the existing populations of resident fishes. Furthermore, overwintering areas associated with clear water flows of the area tributaries will increase, providing habitat for grayling. Existing grayling habitat will be lost, but this may be compensated for by the production of new overwintering habitat.

Anadromous fish do not occur above Devil Canyon, therefore impacts to anadromous fish will be limited to those areas downstream of the proposed impoundment. The primary impact to anadromous fish will occur in the area between Devil Canyon and Talkeetna and will result mainly from a reduction in flows. This flow reduction may reduce the accessibility of sloughs and tributaries utilized by spawning salmon. The exact extent of this is not yet known. Preliminary estimates of worst case conditions without mitigation indicate impacts will be most severe to chum salmon and least severe to chinook salmon. Based on the size of the 1981 runs, preliminary estimates indicate approximately 14,000 sockeye could be lost annually from the harvest, 7,000-8,000 coho lost annually from the harvest, 68,000 chum salmon lost annually from the harvest, and 9,000-10,000 pink salmon (odd year), from an odd year harvest. Based on long term annual Cook Inlet harvests, the average annual post-project losses without mitigation would be approximately 2,300 sockeye for an average annual harvest of 1.2 million fish, 3,850 odd year pink for an average odd year harvest of 148,000 fish, 63,000 - 128,000 chum for an average annual harvest of 630,000 fish, and 12,900 coho for an average annual odd harvest of 231,000 fish. Data on chinook salmon are not available.

There may be some changes in the river temperature regime and water quality resulting from reservoir operation, but the impacts of these are not expected to be significant. Other potential impacts have been mitigated through site selection and design features, such as:

- The natural fish migration barrier of Devil Canyon precludes anadromous fish in the upper basin. Thus, the Susitna project will not block any migrating salmon or inundate spawning areas.

- Discharge facilities, capable of passing up to the 1:50-year flood have been designed with a cone type valve discharge. This type of discharge will significantly reduce the potential for nitrogen supersaturation, a condition which can be lethal to fish.

- A multilevel intake structure has been incorporated into the Watana dam to allow for partial control of discharge water temperature. This will permit release of water at a temperature closer to ambient than would normally occur downstream of the reservoir. This will reduce impacts to fish.

Other potential mitigation options being considered include: modification of operating procedures to increase flows downstream during critical times of the year; modification of the existing stream bed by excavating or adding gravel to build spawning areas; construction of a hatchery to replace any salmon lost through loss of spawning habitat.

In addition, controlled fueling areas and control of erosion as described previously by revegetation and restoration techniques will protect existing water quality and thereby reduce impacts to fish.

(e) Historic and Archeaological Resources

Field surveys revealed the following number of historic and archaeological sites will be affected:

- Watana Dam and Impoundment:

  Two historic and 24 archaeological sites directly affected and 1 historic and 23 archaeological sites indirectly affected;

- Devil Canyon Dam and Impoundment:

  One historical and 7 archaeological sites directly affected, 2 historic and 1 archaeological sites indirectly affected;

- Borrow Areas, Access Route, Transmission Lines:

  One historic site and 25 archaeological sites directly affected, no historic and 7 archaeological sites indirectly affected.

Historical sites consist primarily of trapper's cabins. Archaeological sites consisted primarily of remains from hunting activity, cache pits and house pits. These were largely seasonal camp sites. Potential impacts would result from disturbance by construction activities and increased access in the area. Mitigation of impacts to historic and cultural resources will be through avoidance, preservation or investigation (excavation).

Further studies of cultural resources will be conducted to locate additional sites that may occur in the area and to determine the significance (as based on the National Register of Historic Places criteria 36 CFR 60.6) of these sites. Final siting of access roads, transmission line towers and facilities associated with the dam will be done so as to avoid all sites possible. Sites avoided but subject to indirect impacts through increased access may be preserved through fencing, stabilization or patrolling. If sites are determined to be significant and cannot be avoided, excavation can be used to move the artifacts to a museum. A cultural resource mitigation plan is currently being developed and will be utilized to insure impacts to cultural resources are minimized.

(f) Socioeconomics

Impacts to the socioeconomics environment will result from increased populations, influx of workers and associated demands for schools, medical care, and public services. Peak work force will occur in the 1988-1992 period when approximately 3,500 people will be employed on the project, with up to 2,500 of these originating from within the Railbelt region. Peak payrolls during this period will contribute substantial benefits to the local community.

As a result of the project, the population is expected to increase over the baseline population forecast for the construction period. The majority of these people will live at the work camp and family village sites. During the peak work period, it is expected total population influx (including dependents) into communities outside of the work camp will be approximately 2,300. This includes direct and indirect work force. Up to 50 percent of this population increase will be in the Matanuska-Susitna borough with the remainder in Anchorage and Fairbanks. Demands for water supply, sewage treatment, solid waste, law enforcement, education, fire protection and health care will increase in general by less than 5 percent above baseline conditions projected for the period. This reflects the fact that population influx associated with the construction force will represent less than 3 percent of the borough population in 1989 and less than 2 percent in 1996.

Housing is projected to be available for the period of population influx. Talkeetna and Trapper Creek may experience a housing shortage unless additional homes are built. No businesses will be displaced by the project; one dwelling may be displaced by the transmission line in the northern section. Overall socioeconomic impacts should not be significant.

Socioeconomic impacts will be mitigated primarily through establishment of a fully contained construction camp and village at the site. This camp will provide living quarters for the workers, family living quarters for certain workers, a school, hospital, recreational facilities (halls, swimming pools, gymnasium, hockey rink, baseball field) bank, commissary and shopping center. Presence of a self-contained camp will reduce the need for travel to surrounding communities and reduce the demand for services from these communities. Consultation with these communities will occur as the project proceeds and measures taken to reduce the effects of the Susitna project on them.

(g) Geology and Soils

Some amount of slope instability will be generated in the Watana and Devil Canyon reservoirs as the result of reservoir filling.

These areas will be primarily in locations where the water level will be at an intermediate level relative to the valley depth.

Slope failure will be more common in the Watana reservoir because of the existence of permafrost throughout the reservoir. The Devil Canyon reservoir is generally in more stable rock, and the relatively thin overburden is unfrozen in the reach of the river upstream from the dam. Although skin flows, minor slides, and beaching will be common in parts of the reservoirs, they will present only a visual concern and pose no threat to the project. Many areas in which sliding does occur will stabilize into beaches with a steep backslope. Tree root systems left from reservoir clearing will tend to hold shallow surface slides and in cases where permafrost exists, may have a stabilizing influence, since the mat will hold the soil in place until excess pore pressure has dissipated. The primary method of mitigating these impacts will be through standard stabilization, reclamation and revegetation techniques.

All temporary access roads will be graded, recontoured and seeded following abandonment. Areas near streams and rivers where erosion may occur will be riprapped during the construction period and reseeded when construction is complete. Borrow areas will be excavated only as necessary and will either be regraded and seeded with appropriate species, or if excavation is deep enough, converted to ponds.

To insure success of restoration efforts, a comprehensive restoration and revegetation plan will be developed and implemented to prevent soil erosion. This plan will include the use of terraces (if necessary), mulch (hay and straw), mulch anchored with a light asphalt tack, and mats in areas of high erosion potential. Seeding mixtures will be developed to provide the most rapid recovery possible and include species adapted to all soil and light (shade, sun, etc.) conditions present at the site. Native seeds will be used where possible. Seed mixtures may be applied using the hydroseeding techniques which includes a mixture of fertilizer, lime and seeds. Restoration procedures will be monitored to insure their efficiency. Any areas showing erosion or where restoration is not effective will be restored with modified plans.

Rock excavated but not utilized in construction will be used as backfill in borrow areas or disposed of in areas which will be inundated by the reservoir.

(h) Land Use, Recreational, and Aesthetic Resources

The Susitna project will alter existing land use recreation and aesthetic conditions in the upper Susitna Basin. This will be due both to the presence of the structures and to increased access.

With increased access, certain land use and recreational activities are expected to become more intense than at present. Although the present low levels of riverine boating and rafting use will be displaced, there will be new opportunities for reservoir boating. Hunting and fishing preserves will increase as larger areas become available to more people; sightseeing, picnicking and camping will also increase.

Road access to the damsites from the Parks Highway will likely increase residential and commercial use of the land adjacent to those areas, resulting in an increase in land values. Presence of the two dams and reservoirs will modify existing scenery, contrasting with the natural landscape present. The access road and transmission lines will also be prominent features on the landscape. Planning during the design of the Susitna project will be the primary mechanism to insure impacts to land use, recreation and aesthetics are minimized. Recreational facilities currently proposed include camp grounds, picnic grounds, boat launches and hiking trails. Facilities for both primitive and modern camping will be provided. Commercial facilities such as service stations, lodging and boat rentals are being considered. All developments will be designed to blend into the landscape and be screened by vegetation. Scenic overlooks will be provided on the access road.

Aesthetic impacts were mitigated primarily in the planning process. Aesthetics was an evaluation factor in selecting the access route and the transmission line route. The powerhouse for generation is located underground, eliminating a surface facility. Flow will be maintained between the Devil Canyon dam and discharge outlet, providing an aesthetically pleasing continuous flow of water. Restoration and revegetation of borrow areas and other disturbed areas will also aid in reducing aesthetic impacts.

2.13 - Project Operation

In the year 2010, the projected Railbelt system, with the Susitna online and allowing for existing plant retirements and new additions, will comprise:

Coal-fired Steam:	13 MW
Natural Gas GT:	326 MW
Oil GT:	0 MW
Diesel:	6 MW
Natural Gas CC:	317 MW
Hydropower:	1440 MW
Total	2102 MW

Under current conditions in the Railbelt, a total of nine utilities share responsibility for generation and distribution of electric power, with limited interconnections. When constructed, the 1620 MW Susitna

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project will be the single most significant power source in the system. Careful consideration is therefore essential of the dispatch and distribution of power from all sources by the most economical and reliable means.

(a) Dispatch Control Center

It is likely that a single entity will be established to perform the dispatch control function. Such an entity will ensure the allocation of generating plant in the system on a short-term operation basis and in the long-term, to meet system load demand with the available generation at minimum cost consistent with the security of supply. A system Dispatch Control Center will be established for operation purposes near Willow.

One of the most important functions of the Control Center is the accurate forecasting of the load demands in the various areas of the system. Area demand forecasts up to 8 hours ahead of unit loading are based on regional short-range weather forecasts for an estimate of heating and lighting demands plus light or heavy industry loads. Short-term forecasting up to 1 or 2 hours ahead is more difficult and remains the key factor to the secure and economic operation of the system. Based on the demand, basic power transfers between areas and an allowance for reserve, the tentative amount of generating plant is determined, taking into consideration the reservoir regulation plans of the hydro plants.

The fastest response in system generation will come from the hydro units. The large hydro units at Watana and Devil Canyon on spinning reserve can respond in the turbining mode within 30 seconds. This is one of the particularly important advantages of the Susitna hydro units. A Watana Area Control Center will also be established. This will be equipped with a computer-aided control system, allowing a minimum of highly trained and skilled operators to perform the control and supervision of Watana and Devil Canyon plants from a single control room.

(b) Susitna Project Operation

Substantial seasonal as well as over-the-year regulation of the river flow is achieved with the two reservoirs. If the reservoirs are operated to produce maximum energy matched to Railbelt system demands, average energy potential of Watana development is 3,450 GWh, and that of Devil Canyon development is 3,340 GWh. These estimates are based on simulations using the 32-year period of flow records. Firm annual energy for the project, based on the FERC definition is 5,400 GWh, with an estimated recurrence frequency of 1 in 70 years. Expressed another way, the firm energy, as defined, may fall short of its value by about 5 percent once in 300 years. This is, again, a conservative interpretation of the FERC definition. The monthly distribution of firm annual energy as simulated in the reservoir operation has been used in system generation planning studies as a basis for reliability determinations.

(c) Downstream Flows

Minimum monthly flows that must be maintained in the river below the dam during filling were established in consultation with fisheries and other environmental study groups and agencies. With the minimum monthly flow that is considered acceptable for river maintenance and fisheries requirements during the filling period, it will take at least 2-1/2 years of average streamflow to fill the Watana reservoir. It may be noted that the placement of the fill dam critically controls the reservoir filling in average streamflow years and restricts earlier filling should wet years be experienced.

With Watana reservoir in operation, the filling of the Devil Canyon reservoir is relatively easily accomplished. Average monthly power flows from Watana in the months October through December in a single year will fill the reservoir while maintaining the minimum downstream flow requirements.

During operation of the project, average flows released in the critical summer salmon spawning periods are not considered to be sufficient to maintain the current spawning areas. Appropriate mitigation measures are proposed to compensate for these impacts on fisheries.

(d) Plant Operation and Maintenance

A comprehensive system of monitoring of performance of all project functions and structures will be instituted.

Watana and Devil Canyon power plants are each provided with workshops to facilitate the normal maintenance needs of each plant. The workshop block includes operations for fitting and machining, welding, electrical, and relay instrumentation, with adequate stores for tools and spare parts. The Watana power plant will be provided additionally with surface maintenance and central storage facilities to cater to the needs of both plants.

Maintenance operation planning of both plants are centralized at Watana. Staff wll be normally located at Watana and housed at the operators' village at Watana. With centralized control at Watana, the Devil Canyon plant will not have a resident operating and maintenance staff. Proper road and transport facilities should be maintained between Watana and Devil Canyon to facilitate movement of personnel and/or equipment between the plants.

2.14 - Economic and Financial Evaluation

The major factors in the economic evaluation of Susitna are the rate of real escalation for the fuels which are the main cost component of the thermal alternatives to Susitna. In broad conformity with other authoritative forecasts, the estimated escalation of coal, gas, and oil was taken as 2.6 percent, 2.5 percent, and 2.0 percent, respectively until 2000. From 2000 until 2010, the escalation for coal was taken as 1.2 percent and for gas and oil, 2.0 percent. Similarly in accordance with accepted authorities, the discount rate for evaluating future benefits and costs was taken as 3 percent in real terms.

Generation planning studies were conducted using a consistent set of fuel prices for thermal power generation alternatives and of capital and operation maintenance costs established for Susitna and alternative plant. A generation planning, model (OGP5), which is widely used for system studies of the type performed for Susitna, was employed to determine net economic benefits. These were modeled for the period to 2010 for systems scenarios "with" and "without" Susitna and the long-term increment in the estimated present worth was assessed to 2051.

The pattern of generation expansion investments was determined for a "with" Susitna plan involving 680 MW of capacity coming on-line at Watana with an addition of 600 MW at Devil Canyon in 2002. A later addition of 340 MW at Watana would be justified by standing and spinning reserve requirements. The comparable "without" Susitna plan calls for three 200 MW coal-fired plants fueled from Beluga installed in 1993, 1994, and 2007 and a single 200 MW plant at Nenana, using Healy coal, in 1996, together with 970 MW of gas-fired combustion turbines during the planning period.

The Probability Assessment analyzed the system costs of generation for the Railbelt on a "with" and "without" Susitna basis and concluded that the expected value of the net present worth savings from Susitna were $1.45 billion with a 36 percent probability of being less than $0.5 billion.

Risk Analyses which address the major natural, construction, and capital cost risks concluded that the probability that the project construction cost estimate would not be exceeded was 73 percent. The expected values of the actual costs are 90 percent of the project estimate for Watana and 92 percent for Devil Canyon. There is a 65 percent probability that the Watana stage of the project will be completed prior to schedule in 1993.

In the Marketing Assessment the problem of integrating the Susitna output into the Railbelt market as Watana comes on-stream in 1993 and Devil Canyon in 2002 was reviewed. The maximum "entry price" of the Watana energy was identified at 145 mills/kWh (in 1993) if it is to be competitive with the energy costs of generation from the best thermal option. When Watana comes on-line its output will displace existing generating capacity on the interconnected Railbelt utility system. While initially the avoided costs of the displaced energy generation will be relatively low, inflation and escalation strongly influence thermal power fuels and if the allowance is subsequently made for the investment costs arising from plant expansion to provide comparable alternative service to Susitna, the predominantly hydroelectric system can be shown to offer steadily increasing overall cost savings. The wholesale energy cost and marketability of Susitna output will be strongly influenced by the appropriations made by the State of Alaska through the "Power Development Fund".

On the assumption that residual revenue bond financing will be required to supplement state appropriations of funds for construction of Susitna, the tax-exempt status of the consumer utilities is a major consideration. This, combined with the need for sufficient financial robustness of the entities entering into contracts to support debt financing, suggests the need for financial restructuring of the Railbelt utilities.

It is recommended that the precontracts for the purchase of Susitna output at the wholesale energy price determined by legislation be arranged with the major Railbelt utilities as a precondition of proceeding with the construction of Susitna, and as a means of ensuring the least cost energy for the system as a whole.

In the Financial Evaluation the marketing and OGP5 analysis of the price at which Susitna energy would need to be marketed to be viable in establishes this as about 145 mills/kWh in 1993. The various financing options that would make this possible are considered. These range from a 100 percent state appropriation of the total capital cost ($5.1 billion in 1982 dollars) to a minimum level at which debt service cover and competitive energy pricing would be met. It is concluded that a state appropriation of $2.3 billion (in 1982 dollars) with residual financing from bonds would make Susitna output competitive with the price of 145 mills/kWh and ultimately produce very large subsequent savings to Alaskan consumers compared with the best thermal option. The long-term savings from Susitna are also such that the state appropriation could be recovered with a better than 10 percent rate of return.

In the Financial Risk Analysis the specific and aggregate financing risks are assessed. It is concluded in the $2.3 billion state appropriation case that the probability of the bond financing requirements exceeding $2.5 billion (compared with a forecast requirement of $1.7 billion) is less than 12 percent. The probability of the project not being able to meet fully its debt service cover in 1996 is 22 percent.

2.15 - Conclusions and Recommendations

The investigations presented in this report covering a comprehensive range of studies, in numerous and varied disciplines, in many different locations in the North America as well as Alaska, have allowed an objective evaluation to be made of the proposed Susitna Hydroelectric Project. The essential conclusions of this evaluation are that the project is technically feasible, and economically viable. The safety of the population in the vicinity of the project will not be impaired and the unavoidable impacts which this large project will cause on the environment will not be unduly severe and can be adequately mitigated. Financing of the project is also feasible with state assistance at acceptable risk to consumers in the Railbelt region.

It is recommended that the state authorize the filing of a FERC license application to construct the project and proceed with all permitting, environmental studies, and engineering activities necessary to maintain the project schedule. A decision to construct the Watana project should be periodically reviewed in light of additional engineering, cost, environmental and financial information generated during the design phase.

3 - SCOPE OF WORK

3.1 - Evolution of Plan of Study

The original Plan of Study (POS) for the Susitna Project Feasibility assessment was submitted by Acres on September 11, 1979 in response to the Request for Proposal issued on June 25, 1979, by Mr. Eric Yould, Executive Director of the Alaska Power Authority.

Acres initiated study planning activities in accordance with the original POS under the terms of a contract with the Power Authority dated December 19, 1979. In response to suggestions from interested citizens as well as public and private organizations and agencies, a number of revisions were made to the original POS. A revised POS was issued for further public review and comment on February 4, 1980, prior to commencement of major portions of the work (1). Further revisions to the POS were subsequently issued September, 1980 (Revision 1,[2]), December, 1981 (Revision 2, [3]) and February, 1982 (Revision 3, [4]).

(a) POS Revisions

The original Acres POS was prepared to include a wide range of comprehensive studies necessary to assess the technical and economic feasibility of the project and the environmental impacts which construction of such a project would cause. Details of the revised POS are presented in subsequent sections.

Revisions which were made to respond to questions and concerns raised by reviewers included:

- To ensure objectivity in Railbelt electric load forecasting and generation planning, the State of Alaska entered into separate contracts with the Institute of Social and Economic Research (ISER) to develop independent forecasts, and with Battelle Northwest to study alternatives for meeting future Railbelt electric energy requirements;

- Significant increases in the amount of effort devoted to fisheries and other environmental studies were introduced in response to comments from the Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service;

- To ensure objectivity in the conduct of the public participation program, it was decided that the public participation aspects of the study should be conducted under the direction of the Alaska Power Authority rather than by Acres;

- The level of effort associated with marketing and finance studies was reduced in the first phase of the study, thereby deferring certain financing subtasks until initial questions as to project viability and concept had been more thoroughly addressed;

- Some changes were made in logistical and administrative support efforts both to accommodate the increased level of environmental activity and to ensure efficiency and responsiveness as the study progressed;

- Additional effort was prescribed for in-stream flow studies downstream of Talkeetna in response to concerns expressed by the Alaska Department of Natural Resources; and

- License application preparation and submittal was postponed three months to allow additional data collection and analysis and additional opportunity for agency consultation in developing mitigation plans.

(b) Basis of POS

Prior to preparation of the Acres POS, numerous studies of the hydroelectric potential of the Susitna River Basin had culminated in a major pre-feasibility study by the U.S. Army Corps of Engineers (COE) which led to a recommendation in 1976 by the Chief of Engineers that the Susitna Project be authorized. The COE plan recommended two high dams, the first of which would be built as a massive earthfill gravity structure 810 feet in height at the Watana site. The second COE dam was to be a 635-foot-high thin arch concrete structure at the Devil Canyon gorge, more than 30 miles downstream.

By June 1978, the COE had prepared a plan of study describing a program leading to completion of a detailed feasibility study for the project (5). Further investigations by the COE confirmed the adequacy of the Watana site, though they did reveal that some design changes were required.

Data, analyses, and reports collected and prepared by the COE were used throughout the course of the work undertaken by Acres. The Acres POS comprised an initial series of tasks and subtasks, aimed at selecting an appropriate concept for development, if development were found appropriate, by the end of the first year of study. This was followed by a more detailed series of tasks and subtasks to prepare and assess the feasibility of designs for each site development.

(c) Specific Objectives of Study

As a basis for structuring the scope of work for the overall study, the three primary objectives of feasibility assessment, environmental evaluation and preparation of FERC license were further subdivided into a series of more specific objectives, as follows:

- Determine the future electric power and energy needs of the south-central Railbelt area, based upon independent analysis by ISER, and later Battelle;

- Assess alternative means of meeting the load requirements of the Railbelt area, consistent with independent analyses by Battelle;

- Prepare an optimal development plan for the Susitna Project wherein power costs and probable impacts are minimized, safety is enhanced, and financing is achievable;

- Establish a definitive estimate of the total cost of bringing power on-line, together with a statement of cash flow requirements;

- Evaluate the physical, economic, and financial risks of the Susitna Project and determine ways and means to avoid or minimize their consequences;

- Evaluate existing environmental and social factors as they now exist in the proposed project area, assess the impacts of the proposed project, enhance environmental values to the extent possible, and recommend mitigating measures;

- Estimate the annual system power costs in the Railbelt with and without the project, study the integration of Susitna power into the Railbelt utility system, and assess power marketability;

- Subject to confirmation of feasibility and State authorization to proceed, prepare a complete license application and file this with the Federal Energy Regulatory Commission;

- Ensure that the needs and desires of the public are known, keep interested parties and the public informed, and afford an opportunity for public participation in the study process; and

- Determine an optimal program for achieving financing, including resolution of issues regarding tax-exempt status of bonds which may later be offered.

In formulating a logical approach to the study of a major hydroelectric development in a relatively hostile climate and environmentally sensitive region, it was necessary to identify the particular problems to be addressed and to place these in proper perspective with the more routine elements of technical and economic feasibility assessment. To ensure an optimal development, it was essential to recognize and allow for all constraints imposed, and address such vital issues as environmental acceptability at the proper stage to allow it to be considered adequately through public participation and other processes to satisfy licensing procedures. The financial viability of the project is also a vitally important consideration which lies beyond the strict technical and economic parameters of the proposed development. The approach taken in the overall studies was such that a confident determination of the financibility of the project could be accomplished.

A summary of the activities undertaken in the twelve major tasks is presented in the following sections.

3.2 - Task 1: Power Studies

As conceived in the February, 1980 issue of the POS, the objectives of this Task were essentially defined as the determination of the need for power in the south-central Alaska Railbelt region and the development of a technically, economically and environmentally feasible plan to meet that need. Subsequent revisions to the POS resulted in significant modifications to these objectives and the corresponding scope of work.

(a) Demand Forecasts for Development Selection

The derivation of forecasts of demand for electric energy in the Railbelt was based on work performed for the Power Authority and the state in early 1980 by the ISER. Reviews of ISER's work were the subject of a report issued in December, 1980 (6), which formed the basis of initial Susitna development selection studies. This report dealt with energy forecasts alone. The determination of the corresponding peak load forecasts appropriate for use in generation planning studies was the subject of further studies culminating in a second report also issued in December, 1980 (7).

(b) POS Revision 1

As of June 6, 1980, following changes in State Legislation, all Task 1 work relating to study of Susitna alternatives by Acres was terminated, with the exception of the review of ISER work and derivation of peak load forecasts. Revision 1 to the POS to formalize these scope revisions, was issued in September, 1980 (2). A final Task 1 Closeout Report to document the results of partially completed studies of alternatives was issued in September, 1980 (8).

As a result of these legislative changes, the State of Alaska selected Battelle Pacific Northwest Laboratories to undertake an independent study of alternatives for meeting future Railbelt region demand for electricity. The scope of the Battelle study includes an update of the ISER forecast for electric energy demand as well as an independent assessment of peak load. The incorporation of the results of these studies into Susitna planning studies in late 1981, is discussed under Task 6.

3.3 - Task 2: Surveys and Site Facilities

The essential objective of Task 2 was to provide all necessary logistical support and other related services for successful accomplishment of field activities necessary for completion of the feasibility studies and license application preparation during the January, 1980 through June, 1982 period. Although the scope of this Task was expanded from time-to-time during the period of the study, the basic nature of the work did not significantly change.

These services included:

- Procurement, erection, and continued operation of camps with associated permitting requirements;

- Appropriate provisions for surface and air transportation, communications, and fuel supplies;

- Aerial, ground and hydrographic surveys;

- Access roads studies;

- Reservoir area reconnaissance, slope stability, and erosion studies; and

- Reservoir clearing and disposal studies.

(a) Field Accommodation

A 40-man camp supplied by Arctic Structures Inc. of Palmer, Alaska, was erected and placed in service by March, 1980. The camp building modules were designed in compliance with state ordinances and requirements for use in an arctic environment. The modules together with other equipment and materials necessary for camp construction were transported to the site by means of Catco Rolligon vehicles, in strict compliance with federal and state permit restrictions, during the winter months when there was adequate snow cover on the ground.

The camp comprised bedroom units, associated bathroom, kitchen/dining and recreation units, as well as fuel/materials storage facilities, and was used throughout the study period to house personnel engaged in numerous field activities. Self-contained water supply, electric power generation, sewage treatment, garbage disposal and helicopter landing facilities completed the installation. During peak activity periods, particularly during the summer months, personnel were also accommodated at three local hunting lodges and in more remote tent camps.

(b) Transportation Arrangements

With the exception of initial surface transportation of camp modules and construction equipment and materials, all transportation of personnel and resupply of materials to the study area was accomplished by means of helicopters and small fixed-wing aircraft. Contractual arrangements were made at various times during the conduct of the study with five different companies for the supply and operation of helicopters and fixed-wing aircraft. These aircraft operated mainly from Anchorage and Talkeetna, the fixed-wing aircraft utilizing existing landing strips at those locations together with existing strips in the project area and lakes. Helicopters used helicopter pads constructed at the camp and key working areas.

An effective system of radio and telephone communications was established to facilitate the operation of the aircraft and the camp itself. At peak periods, air transportation requirements for personnel traveling to numerous different locations on a daily basis, and for relocation of drilling and other heavy equipment, put a severe strain on logistical planning efforts. Particular attention was paid to safety and personnel security in all aircraft and helicopter operations.

(c) Surveys

Detailed topographic surveys were undertaken for the entire area of the project including reservoirs, damsites, access and transmission line corridors. Hydrographic surveys of important reaches of the Susitna River were also performed as a basis for Task 3 hydrologic and hydraulic design studies. These surveys were based on aerial photography and a comprehensive system of horizontal and vertical ground control which was established to complement USGS and Corps of Engineers mapping which already existed for parts of the project area.

The bulk of the field survey work was undertaken during the first 18 months of the study period. The processing and reduction of data for production of topographic maps was essentially completed by late 1981. The scheduling of field work and aerial photography was made particularly difficult by the need to avoid periods of snow cover and tree foliage. Susitna River hydrographic surveys were also hazardous, particularly at Devil Canyon. Detailed results of the mapping were provided to the National Geodetic Survey for incorporation into their overall data base for the State of Alaska, and were used as a basis for design and feasibility assessment of the Susitna project.

(d) Access Roads

A comprehensive design and feasibility assessment of alternative access corridors and routes was undertaken in Task 2. The objective of this study was to select an appropriate mode and route for access to the proposed Susitna development and a plan for implementation to meet the project schedule requirements. This work was undertaken in parallel with associated engineering, environmental, cost and scheduling studies in Tasks 6, 7, and 9.

The final product of this study is a report entitled "Access Planning Study" dated January, 1982 (9).

(e) Reservoir Studies

Reconnaissance of the Watana and Devil Canyon reservoir areas was undertaken first by means of aerial photography and overflying, and finally by on-the-ground inspection. The purpose of these studies was to identify areas of potential instability or susceptibility to erosion during filling and subsequent operation of the reservoirs.

Basic information acquired during this phase of the study was used as input to environmental studies of impacts of the reservoir impoundment. The information was also used as a basis for determination of requirements and costs for reservoir clearing and disposal of materials. A further activity undertaken during the course of the study was to identify the ownership and status of land in and adjoining the project and associated access and transmission corridors. This information was duly incorporated into the appropriate project planning and permitting processes.

3.4 - Task 3: Hydrology

The original objective and scope of Task 3, as proposed in the February 1980 POS, was to undertake all hydrologic, climatic, hydraulic and ice studies necessary to complete the feasibility assessment and designs for the Susitna Project as a basis for the FERC license application. Under Revision 2 of the POS, which was issued in December, 1981, the scope of Task 3 was expanded to include additional hydrologic and design studies in response to perceived public concerns. Work commenced in this Task early in 1980 with the initiation of data collection and monitoring and continued throughout the study period. Comprehensive results of Task 3 studies are presented in Appendix A to this report.

(a) Data Compilation

A comprehensive network of climatic and hydrologic data collection systems with appropriate processing and distribution arrangements were established early in 1980 and operated for the duration of the study period. These data provided a continuing basis of hydrologic and hydraulic studies and designs for assessment of project feasibility and environmental impact.

(b) Water Resources and Flood Studies

These studies involved the processing of available and newly acquired climatic and hydrologic data for purposes of determination of streamflow availability for hydroelectric generation, reservoir operation simulations, and estimates of flood frequency and magnitude. These studies then formed the basis of project economic planning analysis and spillway designs under Task 6. Under Revision 2 to the POS issued in December, 1981, in response to perceived public concerns, the scope of this activity was expanded. Additional activities included a re-evaluation of the probable maximum flood on the basis of more comprehensive data and the dam break analysis.

(c) Hydraulic and Ice Studies

The scope of these studies included the determination of water levels and ice cover conditions upstream and downstream from the project sites for pre- and post-project conditions, making use of available and newly acquired hydrologic and hydrographic survey data. These studies were used as a basis for establishment of reservoir freeboard and operating constraints, and pre- and post-project water temperature and quality conditions as input to fisheries and related studies under Task 7.

(d) Sedimentation and River Morphology

These studies were undertaken to determine the rate of sediment accumulation in the proposed reservoirs and prediction of the effects of project operation in the downstream river channel morphology from Devil Canyon to below Talkeetna. Appropriate river sampling procedures were established during the study period as a basis for these evaluations.

(e) Transmission and Access Studies

Climatic design criteria, including wind velocity and ice accumulation estimates, were developed on the basis of available climatic data and observations for transmission line designs together with evaluation of design flood requirements for access road stream crossings.

3.5 - Task 4: Seismic Studies

This Task involved 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. The original February, 1980 POS for Task 4 included a two-year program of activities for 1980 and 1981 to meet the study objectives. Some expansion of field activities in 1981 was made under Revision 2 of the POS.

(a) 1980 Studies

The essential purpose of the 1980 studies was to install and operate a microseismic network in the project area and to identify, from historical and available remote sensing imagery data, potential tectonic features to be considered in establishing the seismic setting of the project. The 1980 studies also included a preliminary geologic reconnaissance, an assessment of reservoir-induced seismicity, and preparation of a report (10).

(b) 1981 Studies

The 1981 studies involved a more detailed investigation and evaluation of a number of potential tectonic features identified in the 1980 studies. The work involved a large degree of field mapping of quaternary geology in the project area and trenching of significant features. Evaluation efforts included detailed studies of regional and similar worldwide earthquake characteristics, estimation of potential earthquake magnitudes and probability of occurrence associated with important tectonic features, an assessment of the corresponding potential ground motions, and the development of appropriate earthquake design criteria for use in design of project structures. A manual was also prepared for installation and continued operation of a permanent seismic monitoring system.

The results of the 1981 studies were incorporated into a comprehensive report (11).

3.6 - Task 5: Geotechnical Exploration

The objective of Task 5 as conceived in the February, 1980 POS was to determine the surface and subsurface geology and geotechnical conditions for the feasibility studies of the proposed Susitna Hydroelectric Project, including the access roads and the transmission lines. This was accomplished by a comprehensive program of field exploration, geotechnical evaluation, and dam studies over more than two years, commencing in early 1980. The scope of Task 5 was increased in 1982 in terms of additional field work under Revision 2 to the POS, to respond to concerns raised by the Power Authority's external review board.

(a) Field Work Programs

Programs of field work were developed and undertaken in summer and winter seasons in both 1980 and 1981, each of which culminated in a detailed report (12, 13). The field work was essentially designed to provide input to the Task 6 design studies and to provide support to the Task 4 studies.

A wide range of geotechnical exploration was undertaken at the Devil Canyon and Watana sites, reservoirs, and access roads and transmission line routes, together with comprehensive evaluation and documentation of the results. This work included preparation of:

- Geologic maps, both regional and site specific;
- Geologic sections;
- Descriptive and graphic borehole logs;
- Descriptive test trench logs;
- Field inspection borehole and test trench logs;
- Photogeologic maps;
- Borehole rock core photographs;

- Low level air photointerpretation;
- Seismic and resistivity bedrock profiles;
- Radar imagery interpretation maps;
- Geotechnical exploration program summaries for proposed structures and material borrow areas (1980, 1981, 1982);
- Data summaries for:
  - In-hole seismic testing.
  - Borehole camera studies.
  - Laboratory testing of construction materials.

(b) 1980 Program

The geotechnical exploration programs in the field were severely constrained by difficulties of access and maneuverability of equipment imposed by weather conditions and the requirements for environmental preservation.

The 1980 geotechnical exploration program was designed to identify and investigate in limited detail those geological and geotechnical conditions which were likely to significantly affect the feasibility of the proposed dam projects. Limited preplanning opportunities, requirements for permits from state regulatory agencies, and climatic constraints were such that investigations in 1980 were somewhat limited in scope, and the data limited in detail. Emphasis was therefore placed on identifying and investigating to the maximum extent the most adverse geotechnical conditions encountered.

(c) 1981 Program

The objectives of the 1981 geotechnical exploration program were to investigate in more detail those geological and geotechnical conditions, both general and adverse, which significantly affected the design and construction of the proposed dam projects, and to obtain the maximum amount of geotechnical design data possible in the time available. The scope of the exploratory work and the data produced in 1981 was by no means intended to be fully comprehensive for project designs, but rather to establish with reasonable confidence the feasibility and total cost of the project, access roads, and transmission lines. The exploratory programs in subsequent years will be yet more detailed, and aimed at providing greater certainty in the design of major dams and structures with a view towards further ensuring the safety of structures while minimizing potential project cost overruns because of unforeseen geotechnical design conditions.

3.7 - Task 6: Design Development

As originally conceived in the February, 1980 POS, this Task involved the initial planning studies and selection of an appropriate Susitna development, including the evaluation, analysis and review of all previous engineering studies related to hydroelectric development of the

Upper Susitna River Basin, and the development of preliminary engineering design and cost information for the selected Watana and Devil Canyon Dam projects with all associated intake, outlet works, spillways, and power facilities to allow preparation of the project feasibility report.

Further expansions of the scope of Task 6 studies were included in Revisions 1 and 2 to the POS to give added consideration to Railbelt region generation planning studies with and without the proposed Susitna project, and to develop additional estimates of project construction cost for planning purposes.

Activities under Task 6 were essentially divided into two phases. The first was devoted to consideration of alternatives and selection of an optimum plan for development of the Susitna River Basin, the second to preliminary design and assessment of the technical and economic feasibility of the selected development.

(a) Development Selection

The first phase of studies culminated in a recommended Susitna Basin development plan in March, 1981 (14). These studies involved consideration of development of all identifiable hydroelectric sites in the Susitna River Basin 80 as well as elsewhere in the Railbelt. Alternatives involving staged developments were also evaluated. Preliminary comparisons were undertaken on the basis of conceptual project designs at each site in terms of technical, economic, and environmental aspects.

Early consideration was given to the technical feasibility of construction of an arch dam at the Devil Canyon site, as proposed in earlier studies by the USBR and COE. Alternative Susitna developments, involving construction of tunnels up to 30 miles long in lieu of a Devil Canyon dam and reservoir, were also evaluated (15).

(b) Feasibility Assessments

The second phase of studies is essentially the subject matter of this report. The work undertaken involved a comprehensive evaluation of the project developments at the Watana and Devil Canyon sites. These studies included consideration and selection of optimum solutions for a variety of project arrangements as well as alternatives for major structures such as dams, spillways, power facilities, and river diversion schemes at each site, in terms of technical feasibility, cost, and environmental impact. Appropriate criteria were established for hydraulic seismic, geotechnical and structural designs on the basis of the data developed under other areas of the study. These designs were also intended to be used for inclusion in the FERC license application.

3.8 - Task 7: Environmental Studies

The overall objective of the environmental studies was to describe the existing environmental conditions, evaluate alternatives in light of the existing conditions and, for the selected alternatives, predict future conditions with and without the proposed project so that changes (impacts) caused by the project may be assessed.

(a) Basis of Studies

To accomplish the overall study objectives, the following activities were undertaken by the environmental study team:

- Participation with the design team in selection of the best alternatives for power generation, access road and site facility locations, and power transmission corridor based on the environmental impact of the proposed facility;

- Preparation of the exhibits required to support the FERC license application;

- Responses to inquiries from local, state, and federal agencies, and public participants at the request of the Power Authority;

- Appropriate execution and coordination of field and office activities for all environmental baseline studies and impact assessment;

- Monitoring of all field activities for environmental acceptability; and

- Development of environmental mitigation plan in consultation with the design team and external agencies.

Intensive baseline and impact-related investigations were performed over a two year period with the work progressing from general to specific as the project definition was developed. Because of the magnitude of the proposed action, the life cycle of some of the resources to be impacted, and the time required to evaluate alternatives and develop design specifications, it was recognized that some environmental studies should be continued beyond the time of license application. Thus, one important element of the early studies was to initiate baseline studies and to develop detailed plans of study for the further environmental impact analysis that will be completed after the license application submission, but prior to a final FERC decision on the license application.

(b) Studies Undertaken

The environmental program was primarily designed to evaluate the Susitna Hydroelectric Project and associated facilities, with respect to environmental impacts. To accomplish this, a comprehensive program of field and office studies was developed in the February, 1980 POS to address the following topics:

- Water Resources (Quality) Analysis:
- Socioecnomic Analysis;
- Cultural Resource Investigation;
- Land Use Analysis;
- Recreation Planning;
- Susitna Transmission Corridor Assessment;
- Fish Ecology Studies;
- Wildlife Ecology Studies;
- Plant Ecology Studies;
- Geological Analysis;
- Access Road Environmental Analysis; and
- Preparation of FERC License Application Environmental Exhibits.

The scope was also structured to provide appropriate coordination of the various environmental study topics and groups and to monitor field activities for environmental acceptability.

In response to concerns expressed by some agencies, the scope of work was further expanded in Revision 2 to the POS to provide for additional data collection and evaluation activities for geomorphology changes in the lower Susitna River, water quality, further quantification of project socioeconomic impacts, inclusion of sociocultural impact assessments, dissolved gas investigations, downstream river plant ecology assessments, and alternative access corridor environmental assessments.

Periodic progress reports summarizing the activities, results, and conclusions of the studies performed, were issued at appropriate stages of the major study topics. These reports formed the basis of submittals to various state and federal agencies, whose responses have been and will continue to be considered in formulation of Susitna project designs and in the FERC license application.

3.9 - Task 8: Transmission

The work undertaken under Task 8 was essentially to consider alternative transmission corridors, select the transmission route, and produce conceptual designs and cost estimates for the feasibility report and FERC license application for the following components of the Susitna Project:

- Transmission line linking the project damsites to Fairbanks and Anchorage, with potential intermediate substations to feed local communities;

- Substations, with particular reference to the two major terminals serving Fairbanks and Anchorage, together with a suitable design for intermediate load points; and

- Dispatch center and communications system.

The basic approach to the work in this task included review of earlier reports prepared by IECO and the COE with respect to their approach and their level of detail. Following this, more detailed study and conceptual design was undertaken up to a level appropriate for the FERC license submission and for assessment of basic technical and economic feasibility.

Included in this work was the utilization of geologic and climatologic field data obtained during the study period.

(a) Corridor Selection Studies

The main thrust of studies undertaken through early 1981 involved selection and evaluation of alternative transmission corridors for the proposed Susitna project (16). Associated with this work were studies related to transmission lines for power generation alternatives also under consideration, together with preliminary assessments of design requirements for the Susitna Transmission system.

(b) Transmission Line Design and System Studies

Subsequent studies involved transmission line route selection, transmission system analysis, and development of basic design information dealing with the following aspects:

- Transmission Line Voltage Level

  . Tower types;
  . Route map;
  . Conductor data;
  . Insulation levels;
  . Construction access;
  . Construction schedule; and
  . Cost estimates.

- Substations

  . Single-line diagrams for each main type of substation;
  . General arrangement drawings;
  . Transformer criteria;
  . Circuit-breaker criteria;
  . Outline of relay protection philosophy; and
  . Cost estimates.

- Dispatch Center and Communications

  . Location and size of center;
  . Level of automation proposed for remote stations;
  . Extent of real-time functions required;

- . Type of communication channel proposed together with appropriate data transmission rates;
- . Basic type of software; and
- . Man-Machine interface.

3.10 - Task 9: Construction Cost Estimates and Schedules

The basis of Task 9 was the development of comprehensive, contractor-type, construction cost estimates for each major element of the proposed Susitna Hydroelectric Project, detailed engineering and construction schedules, and an associated analysis of potential contingency constraints and impacts.

The development of these estimates and schedules took place in parallel with design development, and included assembly and preparation of:

- Cost and schedule data;
- Preliminary cost estimates;
- Cost estimate update;
- Engineering/construction schedule; and
- Contingency analysis.

The final products of this task were developed for the project as proposed in this report.

(a) Task Output

The primary outputs of Task 9 were the cost estimate summary reports and construction schedules appropriate for the assessment of feasibility of the selected Susitna project and for inclusion in FERC licensing documentation. These documents were also prepared to be suitable for continuous updating and/or modifications during the subsequent study period through commencement of construction. They are also appropriate for use in preparation of engineers' estimates during the construction and equipment supply contract bidding phases of the project.

(b) Description of Work

The work undertaken in Task 9 provides the basic framework for more detailed planning, marketing, and financing of the Susitna project to be undertaken during the period following submission of the FERC License Application through commencement of construction. This portion of the study was divided into two parts. During the initial part of Task 9 activities, the information systems and basic mechanisms necessary to develop the cost estimates and schedules were established as a basis for selection of the optimum Susitna development. The second part of Task 9 activities was devoted to the incorporation of more up-to-date information and appropriate revisions of the estimates and schedules for feasibility assessment of the project, prior to submission of the FERC License Application. For ongoing cost estimating and scheduling purposes, a continuous exchange of information was necessary with Task 2 - Surveys, Task 5 - Geotechnical Exploration, Task 6 - Design Development, Task 7 - Environmental Studies, and Task 8 - Transmission Activities.

3.11 - Task 10: Licensing

The overall basis for Task 10 and, in fact, the ultimate objective of the entire POS, was to provide for timely preparation and assembly of all documentation necessary for application for license to the FERC. Should the feasibility assessment addressed in this report be accepted by the State, the output from this task will be used as a basis for submission of a completed application for licensing the Susitna Hydroelectric Project.

(a) Basis of POS

As originally conceived in the February, 1980 POS, preparation of the license would have been based on the then-current FERC regulations which required submission of Exhibits A through W (less P and Q, which were not required for licensing a major hydroelectric project).

Assuming that technical and economic feasiblity of the project were established and that environmental impacts and proposed mitigatory actions were acceptable, the major target toward which all other work in the POS was aimed was the successful completion of a license application to FERC. Indeed, the entire POS was prepared in such a manner that only those tasks and subtasks considered to be the minimum necessary for acceptance by FERC of the license application were included in the first 30 months of effort. Although it was recognized that a significant amount of follow-on work would necessarily have to be accomplished prior to eventual project construction, the historically lengthy periods associated with federal processing of applications clearly suggested that the earliest possible submission was in the best interest of the Power Authority. It was decided entirely appropriate to file an application which meets minimum requirements for submission, while at the same time detailing plans for initiation or continuation of studies whose results may be required before the license itself was actually awarded.

(b) Revised FERC Regulations

The revision of the FERC requirements in late 1981 to five exhibits, A through E, did not effectively alter the scope or direction of the study. The revised regulations altered the format rather than the total content of the application. However, encouraging indications of a speed-up in the FERC licensing process and a desire to allow agencies additional time for constructive input to the project planning process led to revision 3 to the POS in February, 1982. In this revision, the scheduled date for the license submittal was postponed by three months to September 30, 1982. This also allowed for incorporation of additional environmental data into the application documents.

In accordance with FERC requirements, significant efforts have been made by the study team to assist the Power Authority in setting up a constructive Formal Agency Coordination process. This process is designed to allow federal, state, and local agencies the opportunity to participate in appropriate decision phases of the study and to ensure that acceptable mitigation measures are incorporated in the development of project designs where necessary.

3.12 - Task 11: Marketing and Financing

Activities to be undertaken in this Task were aimed at examining in some detail the potential Railbelt market for Susitna Power, the possible mechanisms through which the Power Authority might obtain adequate financing for this large undertaking, and an appropriate return on the investment. Direct state participation in the financial support of the Susitna and other hydroelectric developments in Alaska has been the subject of proposed and enacted state legislation over the period of the feasibility study. This, along with the inevitable uncertainty intrinsic to the financing of such large projects under current market conditions, has made it somewhat difficult to determine specific financing mechanisms. The scope of this task was the subject of a major modification under Revision 1 to the POS in September, 1980, and has been further modified from time to time during the feasibility study.

(a) Basis of Studies

The determination of power and energy outputs from the proposed project, the matching of this output with Railbelt demand over the life of the project, and the cash flow requirements for construction of the project were key products of the feasibility assessment which provided the basis of marketing and financing studies.

It was recognized that if the Susitna Project is selected as an appropriate element in the growth of generating capacity in the Railbelt region, it is likely to proceed on the basis of a partial or complete project financing. Essential to this is a reasonably accurate determination of revenues and properly established energy sales agreements. Furthermore, all project risks must be identified, their potential impact assessed, and appropriate contingency plans and provisions made.

(b) Risk Assessments

As the various elements of the project study reached the appropriate level of completion, a rigorous analysis of risk was applied as a basis for recommended contingency provisions. The approach used involved modern techniques of analysis and probability assessment and dealt with cost, schedule, technical, and other controlling elements of the project.

Risks assessed included those associated with the planning, design and construction of the project, as well as the financing of it. There were a number of basic project financing risks which were addressed, including:

- Cost overruns prior to completion;
- Late completion and non-completion;
- Partial or total post-completion outages;
- Customer failure to provide anticipated cash flows;
- Regulatory risks, particularly insofar as new regulations affect the operation (and, therefore, of course, the profitability and/or consumer costs); and
- Technological risks, particularly insofar as the extent to which new or relatively unproven technology may increase financing difficulties.

(c) Financing Plans

Initial review of financing plans for the project was based on conventional debt financing arrangements, and the level of early year operating deficits was established. A variety of alternatives have been suggested and analyzed in a continuing process of evolving a plan which matches the policies and legislation of the State regarding financing of hydroelectric projects. Financing plans incorporating legislative appropriations, subordinated debt financing, general obligation bonds, tax-exempt revenue bonds, and other financing investments have been examined. Financial risks were also assessed and analyzed.

3.13 - Task 12: Public Participation Program

The essential objective of the Public Participation Program was and is to keep the public fully informed of plans, progress, and findings associated with conduct of the detailed feasibility study. The program also provides a means whereby the public (including individuals, public and private organizations, and various government agencies) can influence the course of the work.

The program has been conducted effectively since commencement of the study and outputs have included:

- Records of the proceedings of public meetings, together with written comments and proposed action lists derived from public inputs;
- Periodic newsletters to address specific topics of public concern;
- Records of workshop meetings;
- Records of deliberations of external environmental and engineering boards;
- Written responses to individual letters of inquiry addressed to the project information office;

- Action lists, together with notes as to status of pending actions;
- News releases;
- Audio visual recordings; and
- Displays set up with periodic update.

The management of the Public Participation Program has been undertaken throughout the study by the Power Authority staff. Members of the study team participated in the program as necessary by attendance at meetings and preparation of appropriate information documents and responses to questions.

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(14) Acres American Incorporated, Susitna Hydroelectric Project, Development Selection Report, prepared for the Alaska Power Authority, June 1981.

(15) Acres American Incorporated, Susitna Hydroelectric Project, Tunnel Alternative Report, prepared for the Alaska Power Authority, July 1981.

(16) Acres American Incorporated, Susitna Hydroelectric Project, Transmission Line Corridor Screening Closeout Report, prepared for Alaska Power Authority, September 1981.

ACRES

4 - PREVIOUS STUDIES

In this section of the report a summary is presented of studies undertaken by 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 damsites 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 (an agency of the USBR) 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 1950s and 1960s, 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 1970s 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

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 damsites 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

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-foot-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 earth-fill 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

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

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 a height of 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 a site known as 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.

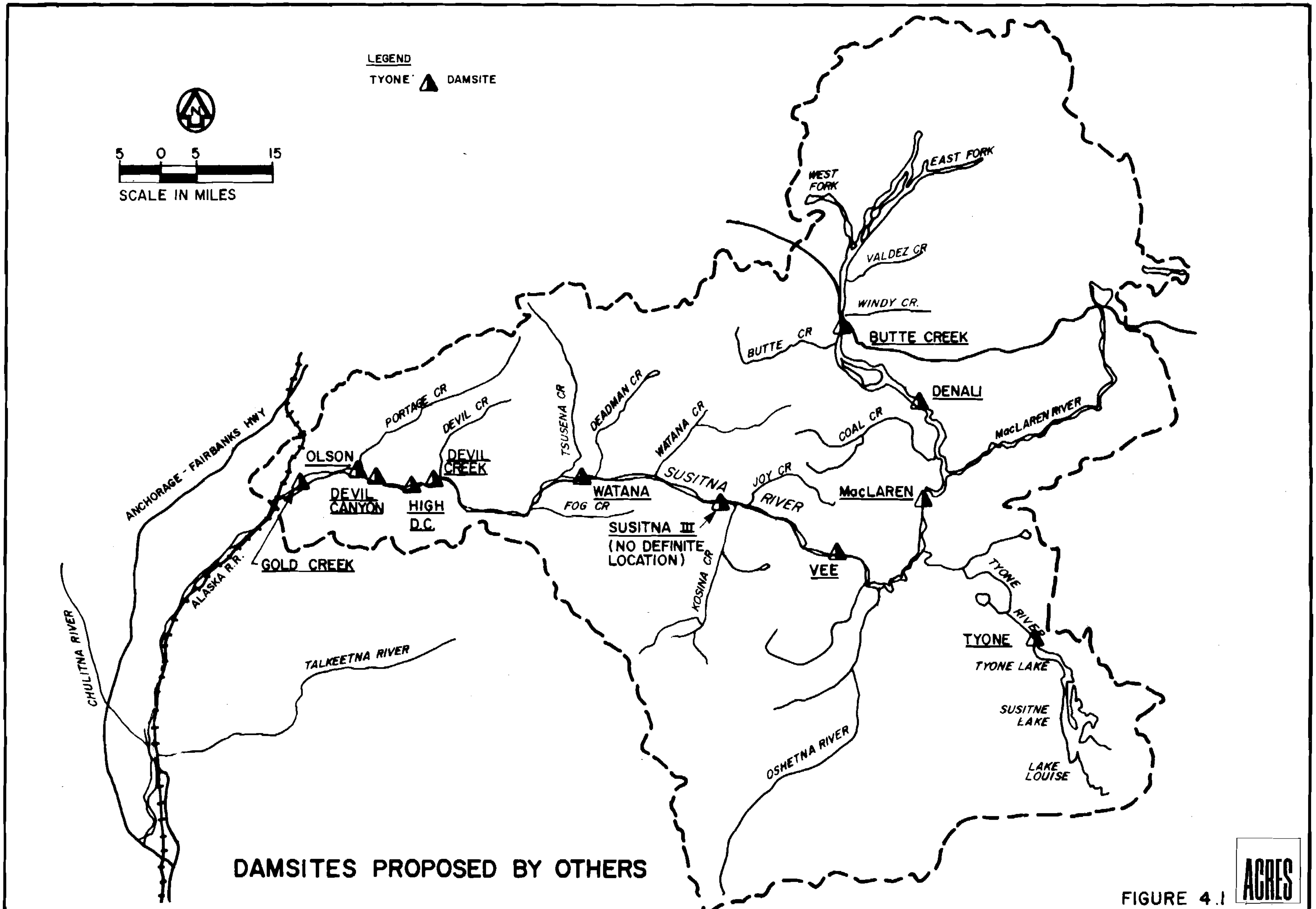
4.6 - U.S. Army Corps of Engineers - 1975 and 1979 Studies

The most comprehensive study of the Upper Susitna Basin prior to the current study 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 in 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

5 - RAILBELT LOAD FORECASTS

In this section of the report, the electrical demand forecasts for the Railbelt region are described. Historical and projected trends are identified and discussed, and the forecasts used in Susitna generation planning studies are presented.

The feasibility of a major hydroelectric project depends in part upon the extent 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, the Power Authority and the State of Alaska have authorized load forecasts for the Alaska Railbelt region to be prepared independently of the feasibility study.

5.1 - Scope of Studies

There have been two forecasts developed and used during the feasibility study. In 1980, the Institute for Social and Economic Research (ISER) prepared economic and accompanying end use energy demand projections for the Railbelt. The end use forecasts were further refined as part of the feasibility study to estimate capacity demands and demand patterns. Also estimated was the potential impact on these forecasts of additional load management and energy conservation efforts. These forecasts were used in several portions of the feasibility study, including the development selection study, initial economic, financial and sensitivity analyses. These forecasts are discussed in more detail in Section 5.2.

In December, 1981, Battelle Pacific Northwest Laboratories produced a series of revised load forecasts for the Railbelt. These forecasts were developed as a part of the Railbelt Alternatives Study, completed by Battelle under contract to the State of Alaska. Battelle's forecasts were a result of further updating of economic projections by ISER and some revised end-use models developed by Battelle, which took into account price sensitivity and several other factors not included in the 1980 projections. The December 1981 Battelle forecasts were used in this feasibility study for the final project staging, economic, financial and senstivity analyses presented in Section 18. The December 1981 Battelle forecasts are presented in Section 5.3.

5.2 - Electricity Demand Profiles

This section reviews the historical growth of electricity consumption in the Railbelt and compares it to the national trend. Earlier forecasts of Railbelt electricity consumption by ISER, which were used in Susitna development selection studies, are also described.

(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.

The distribution of electricity consumption between residential and commercial-industrial-government 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.

Historical 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.

(b) ISER Electricity Consumption Forecasts

The methodology used by ISER to estimate electric energy sales for the Railbelt is summarized in this section and the results obtained are discussed.

(i) 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.

(ii) 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. A short list of six future scenarios was selected. These concentrated around the mid-range or "base case" estimate the upper and lower and extremes (see Table 5.4).

(iii) Demand Forecasts

An important factor to be considered in generation planning studies is the peak power demand associated with a forecast of electric energy demand. 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 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 5.5 summarizes the total energy generation and the peak loads for each of the low, medium, and high ISER sales forecasts, assuming moderate government expenditure.

(iv) Adjusted ISER Forecasts

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

The electricity forecasts summarized in Table 5.5 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 5.6 and in Figure 5.2. The power and energy values given in Table 5.6 are those developed by ISER and used in the development selection 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.

5.3 - Battelle Load Forecasts

As part of its study of Alaska Railbelt Electric Energy Alternatives, Battelle did extensive work in reviewing the 1980 ISER forecasts, methodology, and data, and produced a new series of forecasts. These forecasts built on the base of information and modeling established by ISER's 1980 work and, with the assistance of ISER, developed new models for forecasting Railbelt economic activity and resulting electrical energy demands. The resulting forecasts were adopted directly for use in final generation planning studies under this feasibility study.

These revised forecasts included both an energy and peak capacity projection for each year of the study period (1982-2010). The projection left out portions of electrical demand which would be self-supplied, such as much of the military demand and some of the industrial demand. In addition, these forecasts took into account the conservation technology and market penetration likely to take place. Details of the Battelle forecasts and methodology are available in a report produced by Battelle in early 1982 (1).

The Battelle forecasts are based on energy sales, and have therefore been adjusted by an addition of an estimated 8 percent for transmission losses to arrive at the supply forecast to be used in generation planning. Table 5.7 presents the three Battelle forecasts which were prepared to bracket the range of electrical demand for the future.

The Battelle forecasts were used in second stage generation planning studies. The second stage studies focused on the economic and financial feasibility of the selected Susitna project and the sensitivity of the analyses to variation of key study assumptions. The differences between the earlier ISER forecasts used in development selection studies and the revised Battelle forecasts are not considered to be significant enough to have altered the conclusions of the earlier studies. The Railbelt generation planning studies undertaken for Susitna feasibility assessment were based on the Battelle medium forecast. The high and low Battelle forecasts were used as a basis for sensitivity testing.

No additional information on load patterns relative to monthly and daily shifting of load shapes was developed in the Battelle forecasts. Thus, the historical data developed to use with the 1980 ISER forecasts were also used with the Battelle forecasts.

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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	27	6.4	8.2	4.8	57.6	4.9
1978	77	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: 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 5.5: 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.

(2) All forecasts assume moderate government expenditure.

TABLE 5.6: ISER 1980 RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES FOR DEVELOPMENT SELECTION[5]

	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

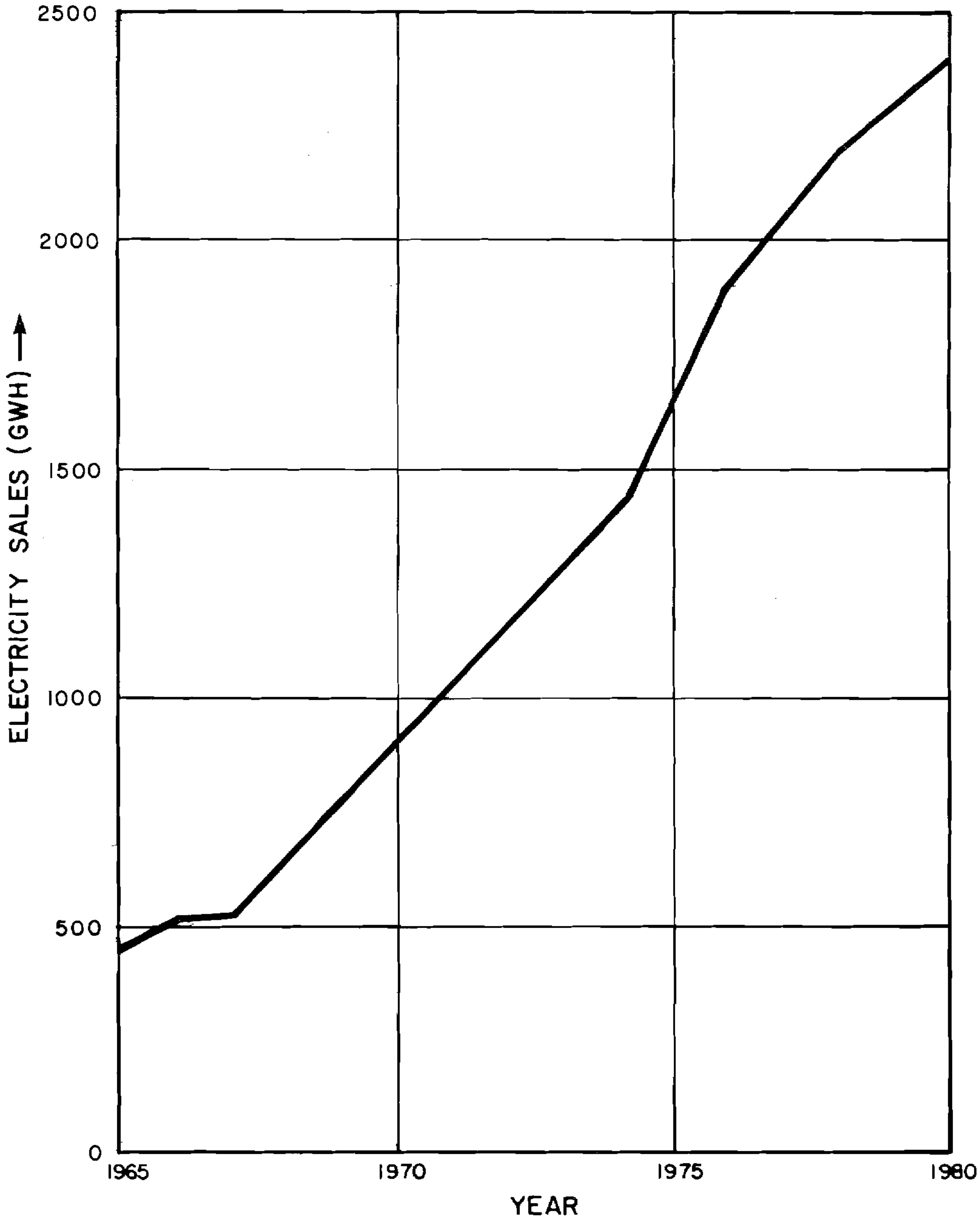
Notes:

(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.
(5) Excludes reserve requirements. Energy figures are for net generation.

TABLE 5.7: DECEMBER 1981 BATTELLE PNL RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

	LOAD CASE								
	Medium			Low			High		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1981	574	2893	57.5	568	2853	57.3	598	3053	58.3
1985	687	3431	57.8	642	3234	57.5	794	4231	60.8
1990	892	4456	57.0	802	3999	56.9	1098	5703	59.3
1995	983	4922	57.1	849	4240	57.0	1248	6464	59.1
2000	1084	5469	57.4	921	4641	57.4	1439	7457	59.0
2005	1270	6428	57.8	1066	5358	57.4	1769	9148	59.0
2010	1537	7791	57.9	1245	6303	57.8	2165	11,435	60.3
Average Annual Growth Rate(%)									
1981-1990	5.0	4.9		3.9	3.8		7.0	7.2	
1990-2000	2.0	2.1		1.4	1.5		2.7	2.7	
2001-2010	3.6	3.6		3.1	3.1		4.2	4.4	
1981-2010	3.5	3.5		2.7	2.8		4.5	4.6	

Note: Excludes reserve requirements. Energy figures are for net generation.



HISTORICAL TOTAL RAILBELT UTILITY SALES TO FINAL CUSTOMERS

FIGURE 5.1

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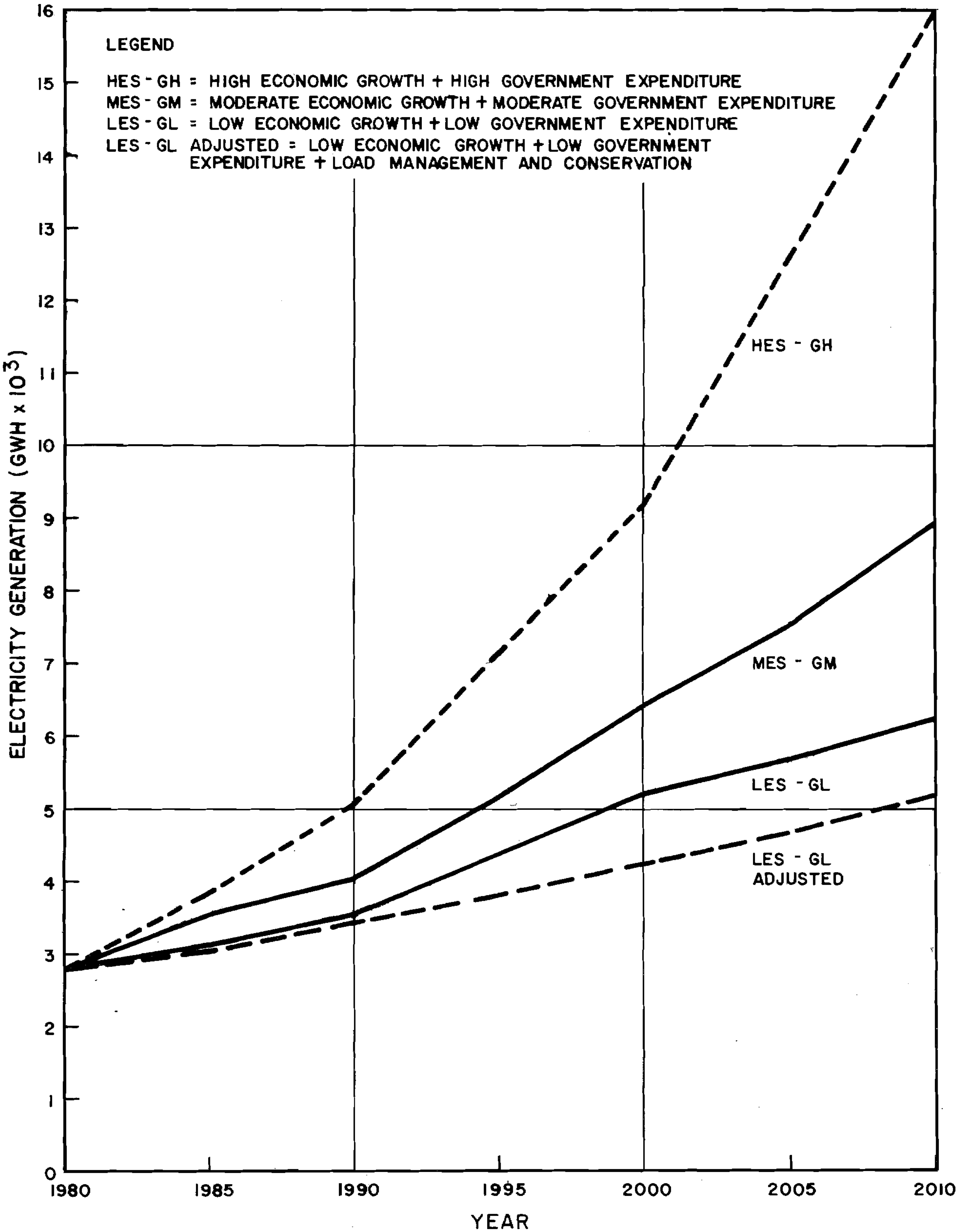

ISER 1980 ENERGY FORECASTS USED FOR DEVELOPMENT SELECTION STUDIES

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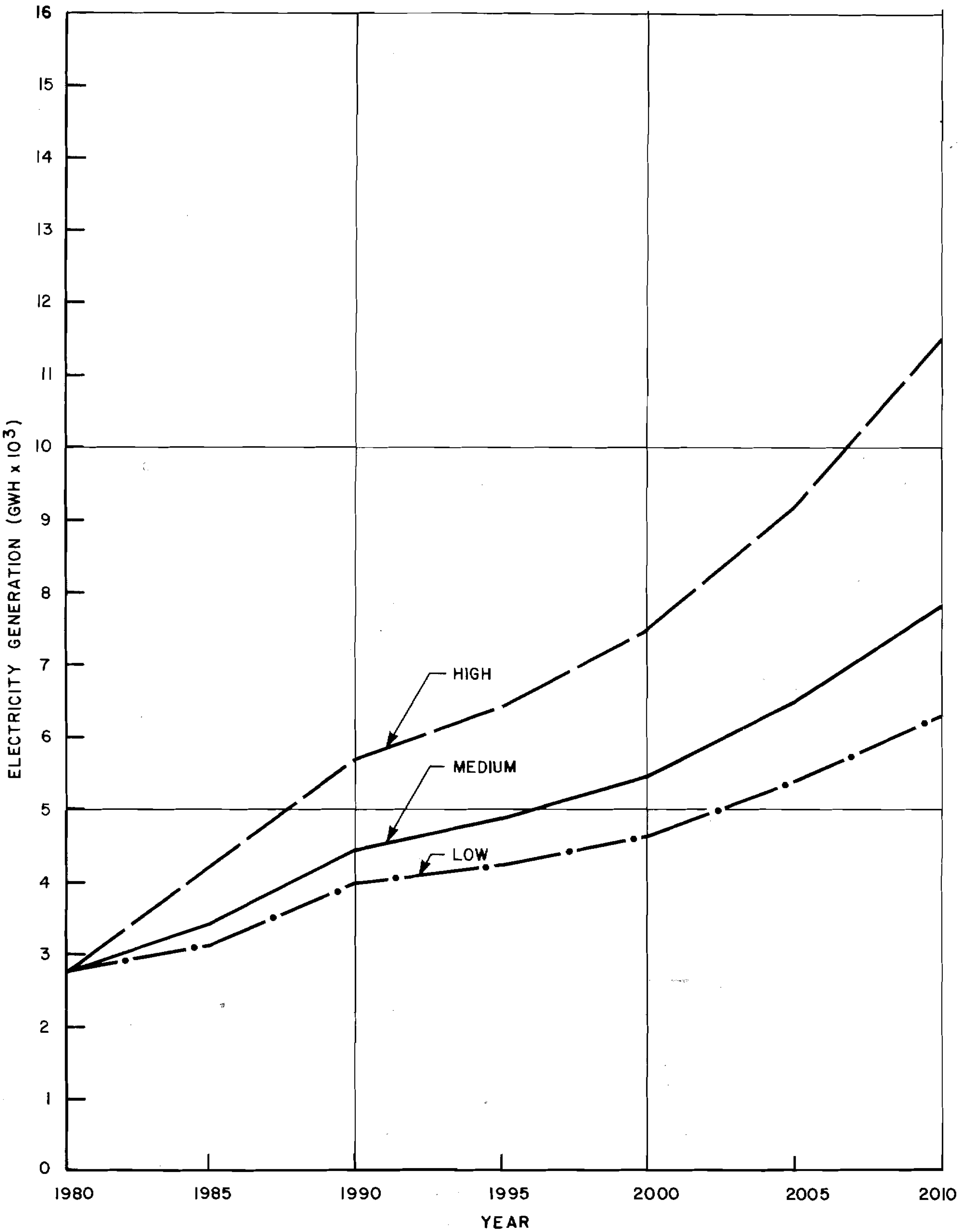
FIGURE 5.2



DECEMBER 1981 BATTELLE LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

FIGURE 5.3

6 - RAILBELT SYSTEM AND FUTURE POWER GENERATION OPTIONS

This section describes the process of assembling the information necessary to carry out the systemwide generation planning studies necessary for assessment of economic feasibility of the Susitna Project. Included is a discussion of the existing system characteristics, the planned Anchorage-Fairbanks intertie, and details of various generating options including hydroelectric and thermal. Performance and cost information required for the generation planning studies is presented for the hydroelectric and thermal generation options considered.

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. The generation planning studies for the Railbelt Region which were undertaken as part of the Susitna development selection process were an essential first step in the study process. These studies formed the basis for optimization of project components as well as the economic and financial feasibility assessment for this major development.

6.1 - Basis of Study

As with the load forecasts presented in Section 5, both a preliminary (1980) and final (1981) generation planning analysis were completed during the feasibility study. The initial set of data was developed in support of the development selection studies, as described in more detail in Section 8. These studies were completed in 1980 and reflected January price levels and supporting data available at that time. Emphasis in that study was placed on currently feasible, economic generating sources. Other options, including emerging technologies such as wind, solar, and bio-mass-fired generation were not considered. Also not considered were commercially unavailable technologies such as gasified coal combined cycle plants, or natural gas fuel cells.

The information developed during the second year of the feasibility study was used to support generation planning efforts which compared alternative developments at Watana and Devil Canyon, and project details such as dam height, installed capacity, tunnel diameters, and reservoir operating rules. The information on non-Susitna generation options was dealt with only in sufficient detail to develop representative performance and cost data for inclusion in the non-Susitna Railbelt system generation scenarios.

The detailed Susitna optimization studies and economic and financial feasibility and sensitivity assessments were based, to the maximum extent possible, on updated information. This information was made as consistent as possible with the Battelle Pacific Northwest Laboratories data derived in the concurrent study of Railbelt alternatives. Information used in Susitna generation planning studies was thus adjusted appropriately for general consistency with Battelle data for:

- Load forecasts;
- Capital costs of alternatives;
- Fuel costs and escalation; and
- Escalation of capital costs and O&M costs.

The final generation planning studies were thus based on somewhat different data and assumptions relative to new generation facilities from those used in the earlier development selection studies. However, a great deal of data relative to the composition of the existing generation mix in the Railbelt, the status of the Intertie, and the non-Susitna hydroelectric alternatives was not changed. The differences in data values used in the final analysis compared to the development selection studies are not considered to be large enough to have significantly affected the conclusions of those studies. Thus, the current Susitna feasibility assessment as presented in Section 18 is valid.

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. Table 6.1 summarizes the total generating capacity within the Railbelt System in 1980, based on information provided by Railbelt utilities and other sources. Table 6.2 presents the resulting detailed listing of units currently operating in the Railbelt, information on their performance characteristics, and their online and OIC use assumed retirement dates. The total Railbelt installed capacity of 984 MW as of 1980 consists of two hydroelectric plants totaling 46 MW plus 938 MW of thermal generation units fired by oil, gas, or coal, as summarized in Table 6.3.

(b) Retirement Schedule

In order to establish a retirement policy for the existing generating units, several sources were consulted, including the Power Authority's draft feasibility study guidelines, FERC guidelines, Battelle's study, and historical records. Utilities, particularly those in the Fairbanks area, were also consulted. Based on these sources, 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

Six new projects are currently expected to be added to the Railbelt system prior to 1990. The CEA is in the process of adding gas-fired combined-cycle capacity in Anchorage at a plant called Beluga No. 8. When complete, the total plant capacity will be 178 MW, but the plant will encompass existing Units 6 and 7. Chugach is also planning a 26.4 MW gas turbine rehabilitation at Bernice Lake No. 4 in 1982. For study purposes, this 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. The project would include between 90 and 135 MW of installed capacity and would produce an annual average energy of 350 Gwh. For study purposes, the project is assumed to come on line in 1988.

Three other units are also scheduled or have been added to the system since 1980. Anchorage Municipal Light and Power Department is adding a 90 MW gas turbine in 1982 called AMLPD No. 8. Copper Valley Electric Association is operating the new 12 MW Solomon Gulch Hydroelectric Project. Finally, the 7 MW Grant Lake hydroelectric project is undergoing planning for addition to the system in 1988 by the APA.

6.3 - Fairbanks - Anchorage Intertie

Engineering studies have been undertaken for construction of an intertie between the Anchorage and Fairbanks systems. As presently envisaged, this connection will involve a 345-kV transmission line between Willow and Healy scheduled for completion in 1984. The line will initially be operated at 138 kV with the capability for expansion as the loads grow in the load centers.

Based on these evaluations, it was concluded that an interconnected system should be assumed for the generation planning studies, and that the basic intertie facilities would be common to all generation scenarios considered.

Costs of additional transmission facilities were added to the scenarios as necessary for each unit added. In the "with Susitna" scenarios, the costs of adding circuits to the intertie corridor were added to the Susitna project cost. For the non-Susitna units, transmission costs were added as follows:

- No costs were added for combined-cycle or gas-turbine units, as they were assumed to have sufficient siting flexibility to be placed near the major transmission works;

- A multiple coal-fired unit development in the Beluga fields was estimated to have a transmission system with equal security to that planned for Susitna, costing $220 million. This system would take power from the bus back to the existing load center; and

- A single coal-fired unit development on the Nenana area, using coal mined in the Healy fields, would require a transmission system costing $117 million dollars.

With the addition of a unit in the Fairbanks area in the 1990s, no additions to the 345 kV line were considered necessary. Thus, no other transmission changes were made to the non-Susitna plans.

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 earlier in this section, feasibility assessment of the selected Susitna Basin Development Plan is based on comparisons of future Railbelt power generation scenarios with and without the Susitna Hydroelectric 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 applied in the development of Railbelt generation plans. Those plans which involve the Susitna Project are discussed in detail in Sections 7 and 8. Those plans which incorporate hydroelectric developments studied during the development selection phase other than Susitna are discussed in detail in the Development Selection Report.

The application of the five-step methodology for selection of non-Susitna plans which incorporate hydroelectric developments is summarized in this section. The analysis was completed in early 1981 and is based on January 1981 cost figure and all other parameters are contained in the Development Selection Report (1). 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 Power Administration report "Hydroelectric Alternatives for the Alaska Railbelt."

The screening of sites under Step 3 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. Figure 6.3 shows 49 of the sites which remained after the two initial screens.

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, listed in Table 6.4, 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 into the Step 5 evaluations.

Power and energy values for each of the developments were reevaluated in Step 5 utilizing monthly streamflow and a computer reservoir simulation model. The results of these calculations are summarized in Table 6.4.

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 is discussed in detail in Section 8. The criteria on which the preferred plan was finally selected in these activities were least present-worth cost based on economic parameters for development selection established in Section 8.

The selected potential non-Susitna Basin hydro developments (Table 6.4) 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, completed in early 1981, are summarized in Table 6.5 and illustrate that a minimum total system cost can be achieved by the introduction of the Chakachamna, Keetna, and Snow projects (See also Figure 6.4). Note that further studies of the Chakachamna project were initiated in mid-1981 by Bechtel under contract to the Power Authority. The Bechtel study is producing costs and project concepts different from the ones presented here.

6.5 - Thermal Options - Development Selection

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 could be satisfied by an all-thermal generation mix. In the following paragraphs, an outline is presented of the studies undertaken to determine an appropriate all-thermal generation scenario for comparison with the Susitna hydroelectric scenario.

(a) Assessment of Thermal Alternatives

The plan formulation and selection methodology discussed in Section 1 was adopted in a modified form to develop the necessary all-thermal generation plans (see Figure 6.5). The overall objective established for this selection process was the selection of an optimum all-thermal Railbelt generation plan for comparison with other plans.

Consideration was given to gas, coal, and oil-fired generation sources only from the standpoint of technical and economic feasibility. 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 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 types of thermal power generation units were considered:

- Coal-fired steam;
- Gas-fired combined-cycle;
- Gas-fired gas turbine; and
- 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.

During the first year of this study an all-termal, without Susitna plan, was developed. The plan was based on data for coal-fired steam plans, confined cycle plants, gas-turbine platns, and diesel power plants contained in the Development Selection Report (see Table 6.6). The resulting all thermal plan available in early 1981 was used in the Development Selection Report for comparison with the Susitna plan available at that time. The comparisons were made using economic parameters over a wide range of load forecasts, capital costs, interest (discount) rates, fuel cost and fuel escalation rates. The result of the 1980, early 1981 studies was the decision to continue with the Susitna feasibility study.

The following paragraphs present the thermal options used in developing the present without Susitna plan.

(b) Coal-Fired Steam

A coal-fired steam plant is one in which steam is generated by a coal-fired boiler and used to drive a steam-turbine generator. Cooling of these units is accomplished by steam condensation in cooling towers or by direct water cooling.

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 states and in Alaska.

(i) Capital Costs

A detailed cost study was done by Ebasco Services Incorporated as part of Battelle's Alternative study. The report found that it was feasible to site a plant at either the undeveloped Beluga field or near Nenana, using Healy field coal. The study produced costs and operating characteristics for both plants. All new coal units were estimated to have an average heat rate of 10,000 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 in Table 6.6.

It was found that, rather than develop solely at one field in the non-Susitna case, development would be likely to take place in both fields. Thus, one unit would be developed near Nenana to service the Fairbanks load center, with other units placed in the Beluga fields.

To satisfy the national New Performance Standards, 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

Fuel costs based on long-term opportunity values were set at $1.43/MM Btu for Beluga field coal and $1.75/MM Btu for Healy coal to be used at Nenana. Real escalation on these values was estimated as follows:

	1982-2000	2001-2010
Beluga/Coal	2.6%	1.2%
Healy Coal at Nenana	2.3%	1.1%

Details of the fuel cost information are included in Section 18 of this report.

(iii) Other Performance Characteristics

Annual operation and maintenance costs and representative forced outage rates are shown in Table 6.6.

(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 No. 9 unit owned by Chugach Electric Association (CEA). A 60-MW steam turbine will be added to the system sometime in 1982.

(i) Capital Costs

A new combined cycle plant unit size of 200-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 states and projected load increases in the Railbelt. A heat rate of 8,000 Btu/kWh was adopted based on the alternative study completed by Battelle.

The capital cost was estimated using the Battelle basis and is listed in Table 6.6.

(ii) Fuel Costs

The combined cycle facilities would burn only gas with a domestic market value of $3.00 per MM Btu 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 one-third 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 25 percent (1982-2000) and 2 percent (2000-2040) was used in the analysis.

(iii) Other Performance Characteristics

Annual operation and maintenance costs, along with a representative forced outage rate, are given in Table 6.6.

(d) Gas-Turbine

Gas turbines burn natural gas or oil in units similar to jet engines which are coupled to electric generators. These also require an appropriate water cooling arrangement.

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 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 10,000 Btu/kWh. The capital cost were again taken from the Battelle Alternatives study.

(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 $6.50 per million Btu. The real annual growth rates in oil costs used were 2 percent for 1982-2000 and 1 percent for 2000-2040.

(iii) Other Performance Characteristics

Annual operation and maintenance costs and forced outage rates are shown in Table 6.6.

(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 because of 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 6.6.

(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 6.6.

(f) Plan Formulation and Evaluation

The four candidate unit types and sizes were used to formulate plans for meeting future Railbelt power generation requirements. 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. The OGP5 generation planning model was utilized to develop a least cost scenario incorporating the necessary coal, oil, and gas-fired generating units.

6.6 - Without Susitna Plan

In order to analyze the economics of developing the Susitna project, it was necessary to analyze the costs of meeting the projected Alaska Railbelt load forecast with and without the project. Thus, a plan using the identified components in Section 6.5 was developed. The basic tool used in identifying this plan was a computerized generation planning model, Optimized Generation Planning (OGP), Version 5. The model simulates production costs of meeting electrical demand, given inputs of available generating resources, costs of fuel, characteristics of plants, and potential new plants.

Using the system model, a base case "without Susitna" plan was structured based on middle range projections. The base case input to the model included:

- Battelle's middle range forecast from Section 5.3;
- Fuel cost as specified in Section 6.5;
- Coal-fired steam and gas-fired combined-cycle and combustion turbine units as future additions to the system;
- Costs and characteristics of future additions as specified in Section 6.5 and Table 6.6;
- The existing system as specified in Section 6.2 and scheduled commitments listed in Table 6.3;
- Middle range fuel escalation as specified in Section 6.5;
- Economic parameters of three percent interest and zero percent general inflation;
- Real escalation on operation and maintenance and capital costs at a rate of 1.8 percent to 1992 and 2 percent thereafter; and
- Generation system reliability set to a loss of load probability of one day in ten years. This is a probabilistic measure of the inability of the generating system to meet projécted load. One day in ten years is a value generally accepted in the industry for planning generation systems.

The model was initially to be operated for a period from 1982-2000. It was found that, under the medium load forecast, the critical period for capacity addition to the system would be in the winter of 1992-1993. Until that time, the existing system, given the additions of the planned intertie and the planned units, appear to be sufficient to meet Railbelt demands. Given this information, the period of plan development using the model was set as 1993-2010.

The following was established as the non-Susitna Railbelt base plan (see Figure 6.6):

(a) System as of January 1993

Coal-fired steam:	59 MW
Natural gas GT:	452 MW
Oil GT:	140 MW
Diesel:	67 MW
Natural gas CC:	317 MW
Hydropower:	155 MW
Total (including committed conditions):	1190 MW

(b) System Additions

Year	Gas Fired Gas Turbine (MW)	Coal Fired Unit (MW)
1993		1 x 200 (Beluga Coal)
1994		1 x 200 (Beluga Coal)
1996		1 x 200 (Nenana/Healy Coal)
1997	1 x 70	
1998	1 x 70	
2001	1 x 70	
2003	1 x 70	
2004	1 x 70	
2005	2 x 70	
2006	1 x 70	
2007		1 x 200 (Beluga Coal)
2009	1 x 70	
Total	630	800

(c) System as of 2010

Coal-fired steam:	813 MW
Natural gas GT:	746 MW
Oil GT:	0 MW
Diesel:	6 MW
Natural gas CC:	317 MW
Hydropower:	155 MW
Total (accounting for retirements and additions)	2037 MW

The system costs attributable to this plan are discussed in Section 18.2. There is one particularly important assumption underlying the plan. The costs associated with the Beluga development are based on the opening of that coal field for commercial development. That development is not a certainty now and is somewhat beyond the control of the state, since the rights are in the hands of private interests. Even if the seam is mined for export, there will be environmental problems to overcome. The greatest problem will be the availability of cooling water for the units. The problem could be solved in the "worst" case by using the sea water from Cook Inlet as cooling water; however, this solution would add significantly to project costs.

Two alternatives which Battelle included in their base plan which have not been included in this plan are the Chakachamna and Allison Creek hydroelectric plants. The Chakachamna plant is currently the subject of a feasibility study by the Power Authority. The current plan would develop a 330 MW plant at a cost of $1.45 billion at January, 1982 price levels. The plant would produce nearly 1500 GWh on an average annual basis.

Due to some current questions regarding the feasibility of the Chakachamna plant, it has not been included in the non-Susitna plan. It has been checked, however, in the sensitivity analysis presented in Section 18.

The Allison Creek hydroelectric project was included on the non-Susitna base plan by Battelle. It has not been included in this base plan due to its high costs, $125/MWh (1981 dollars).

The thermal plan described above has been selected as representative of the generation scenario that would be pursued in the absence of Susitna. The selection has been confirmed by the Battelle results which show an almost identical plan to be the lowest cost of any non-Susitna plan.

LIST OF REFERENCES

(1) Acres American Incorporated. Susitna Hydroelectric Project Development Selection Report. Prepared for the Alaska Power Authority, December 1981.

TABLE 6.1: TOTAL GENERATING CAPACITY WITHIN THE RAILBELT SYSTEM

Abbreviations	Railbelt Utility	Installed Capacity[1]
AMLPD	Anchorage Municipal Light & Power Department	221.6
CEA	Chugach Electric Association	395.1
GVEA	Golden Valley Electric Association	221.6
FMUS	Fairbanks Municipal Utility System	68.5
CVEA	Copper Valley Electric Association	19.6
MEA	Matanuska Electric Association	0.9
HEA	Homer Electric Association	2.6
SES	Seward Electric System	5.5
APAd	Alaska Power Administration	30.0
U of A	University of Alaska	18.6
TOTAL		984.0

(1) Installed capacity as of 1980 at 0°F
(2) Excludes National Defense installed capacity of 46.5 MW

TABLE 6.2: GENERATING UNITS WITHIN THE RAILBELT - 1980

Railbelt Utility	Station Name	Unit No.	Unit Type	Installation Year	Heat Rate (Btu/kWh)	Installed Capacity (MW)	Fuel Type	Retirement Year
Anchorage Municipal	AMLPD	1	GT	1962	14,000	16.3	NG	1992
Light & Power	AMLPD	2	GT	1964	14,000	16.3	NG	1994
Department	AMLPD	3	GT	1968	14,000	18.0	NG	1998
	AMLPD	4	GT	1972	12,000	32.0	NG	2002
(AMLPD)	G.M. Sullivan	5,6,7	CC	1979	8,500	139.0	NG	2011
Chugach	Beluga	1	GT	1968	15,000	16.1	NG	1998
Electric	Beluga	2	GT	1968	15,000	16.1	NG	1998
Association (CEA)	Beluga	3	GT	1973	10,000	53.0	NG	2003
	Beluga	5	GT	1975	15,000	58.0	NG	2005
	Beluga	6	GT	1976	15,000	68.0	NG	2012
	Beluga	7	GT	1977	15,000	68.0	NG	2012
	Bernice Lake	1	GT	1963	23,440	8.6	NG	1993
		2	GT	1972	23,440	18.9	NG	2002
		3	GT	1978	23,440	26.4	NG	2008
	International Station	1	GT	1964	40,000	14.0	NG	1994
		2	GT	1965	--*	14.0	NG	1995
		3	GT	1970	--*	18.0	NG	2000
	Copper Lake	1	HY	1961	--*	16.0	--	2011
Golden Valley	Healy	1	ST	1967	11,808	25.0	Coal	2002
Electric		2	IC	1967	14,000	2.8	Oil	1997
Association	North Pole	1	GT	1976	13,000	65.0	Oil	1996
(GVEA)		2	GT	1977	13,500	65.0	Oil	1997
	Zehander	1	GT	1971	14,500	18.4	Oil	1991
		2	GT	1972	14,500	17.4	Oil	1992
		3	GT	1975	14,900	3.5	Oil	1995
		4	GT	1975	14,900	3.5	Oil	1995
		5	IC	1965	14,000	3.5	Oil	1995
		6	IC	1965	14,000	3.5	Oil	1995
		7	IC	1965	14,000	3.5	Oil	1995
		8	IC	1965	14,000	3.5	Oil	1995
		9	IC	1965	14,000	3.5	Oil	1995
		10	IC	1965	14,000	3.5	Oil	1995
Fairbanks	Chena	1	ST	1954	14,000	5.0	Coal	1989
Municipal		2	ST	1952	14,000	2.5	Coal	1987
Utility		3	ST	1952	14,000	1.5	Coal	1987
System (FMUS)		4	GT	1963	16,500	7.0	Oil	1993
		5	ST	1970	14,500	21.0	Coal	2005
		6	GT	1976	12,490	23.1	Oil	1997
	FMUS	1	IC	1967	11,000	2.8	Oil	1997
		2	IC	1968	11,000	2.8	Oil	1998
		3	IC	1968	11,000	2.8	Oil	1998

TABLE 6.2 (Continued)

Railbelt Utility	Station Name	Unit No.	Unit Type	Installation Year	Heat Rate (Btu/kWh)	Installed Capacity (MW)	Fuel Type	Retirement Year
Homer Electric Association (HEA)	Homer							
	Kenai	1	IC	1979	15,000	0.9	Oil	2009
	Pt. Graham	1	IC	1971	15,000	0.2	Oil	2001
	Seldovia	1	IC	1952	15,000	0.3	Oil	1982
		2	IC	1964	15,000	0.6	Oil	1994
		3	IC	1970	15,000	0.6	Oil	2000
University of Alaska (U of A)	University	1	ST	1980	12,000	1.5	Coal	2015
	University	2	ST	1980	12,000	1.5	Coal	2015
	University	3	ST	1980	12,000	10.0	Coal	2015
	University	1	IC	1980	10,500	2.8	Oil	2011
	University	2	IC	1980	10,500	2.8	Oil	2011
Copper Valley Electric Association (CVEA)	CVEA	1-3	IC	1963	10,500	1.2	Oil	1993
	CVEA	4-5	IC	1966	10,500	2.4	Oil	1996
	CVEA	6-7	IC	1976	10,500	5.2	Oil	2006
	CVEA	1-3	IC	1967	10,500	1.8	Oil	1997
	CVEA	4	IC	1972	10,500	1.9	Oil	2002
	CVEA	5	IC	1975	10,500	1.0	Oil	2005
	CVEA	6	IC	1975	10,500	2.6	Oil	2005
	CVEA	7	GT	1976	14,000	3.5	Oil	1996
Matanuska Elec. Association (MEA)	Talkeetna	1	IC	1967	15,000	0.9	Oil	1997
Seward Electric System (SES)	SES	1	IC	1965	15,000	1.5	Oil	1995
		2	IC	1965	15,000	1.5	Oil	1995
		3	IC	1965	15,000	2.5	Oil	1995
Alaska Power Administration (APAd)	Eklutna	-	HY	1955	--	30.0	--	2005
TOTAL						984.0		

Notes:

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

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

TABLE 6.3: SCHEDULE OF PLANNED UTILITY ADDITIONS (1980-1988)

Utility	Unit	Type	MW	Year	Avg. Energy (GWh)
CVEA	Solomon Gulch	HY	12	1981	55
CEA	Bernice Lake #4	GT	26.4	1982	--
AMLPD	AMLPD #8	GT	90.0	1982	--
CEA	Beluga #6,7,8	CC	42*	1982	--
COE	Bradley Lake	Hydro	90.0	1988	--
APA	Grant Lake	Hydro	7.0	1988	33
TOTAL			267.4		

* New Unit No. 8 will encompass Units 6 and 7, each rated at 68 MW. Total new station capacity will be 178 MW.

TABLE 6.4: OPERATING AND ECONOMIC PARAMETERS FOR SELECTED HYDROELECTRIC PLANTS

No.	Site	River	Max. Gross Head (ft)	Installed Capacity (MW)	Average Annual Energy (Gwh)	Plant Factor (%)	(1981 $) 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[3]	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 IDC, Insurance, Amortization, and Operation and Maintenance Costs.
(3) An indepedent study by Bechtel has proposed an installed capacity of 330 MW, 1500 GWh annually at a cost of $1,405 million (1982 dollars), including AFDC.

TABLE 6.5: 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 – ($10⁶)
All Thermal	No Renewals	Medium	LME1	900	801	50	144	1895	8130
Thermal Plus Alternative Hydro	No Renewals Plus: Chakachamna (500)[1]-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) Installed capacity.

TABLE 6.6: SUMMARY OF THERMAL GENERATING RESOURCE PLANT PARAMETERS/1982$

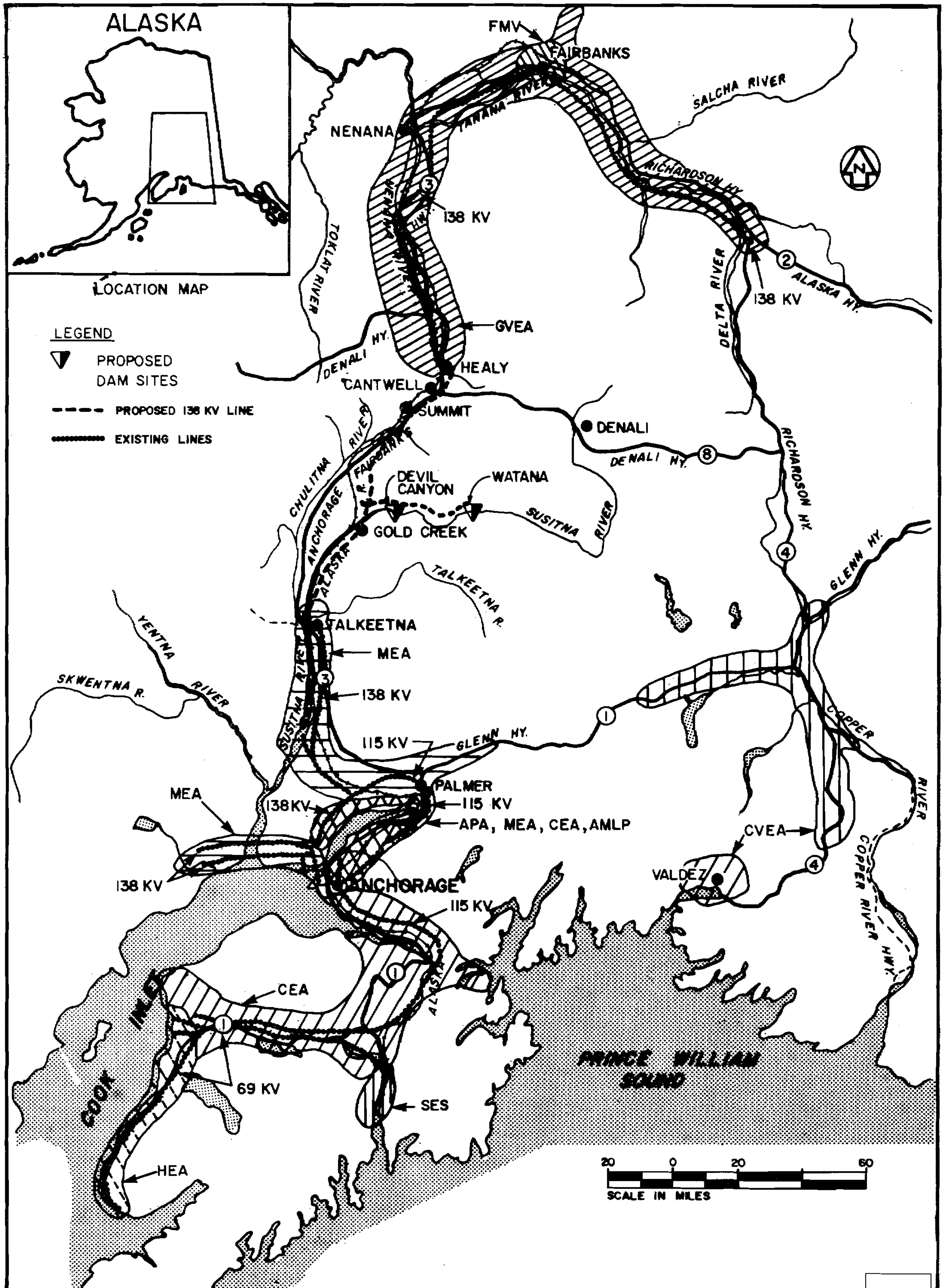
Parameter	200 MW	Combined Cycle 200 MW	Gas Turbine 70 MW	Diesel 10 MW
Heat Rate (Btu/kWh)	10,000	8,000	12,200	11,500
Earliest Availability	1989	1980	1984	1980
O&M Costs				
Fixed O&M ($/yr/kW)	16.83	7.25	2.7	0.55
Variable O&M (&/MWH)	0.6	1.69	4.8	5.38
Outages				
Planned Outages (%)	8	7	3.2	1
Forced Outages (%)	5.7	8	8	5
Construction Period (yrs)	6	2	1	1
Startup Time (yrs)	6	4	4	1
Unit Capital Cost ($/kW)[1]				
Railbelt	-	1,075	627	856
Beluga	2,061	-	-	-
Nenana	2,107	-	-	-
Unit Capital Cost ($/kW)[2]				
Railbelt	2,242	1,107	636	869
Beluga	-	-	-	-
Nenana	2,309	-	-	-

Notes:

(1) As estimated by Battelle/Ebasco without AFDC.
(2) Including IDC at 0 pecent escalation and 3 percent interest, assuming an S-shaped expenditure curve.
(3) Excludes transmission.

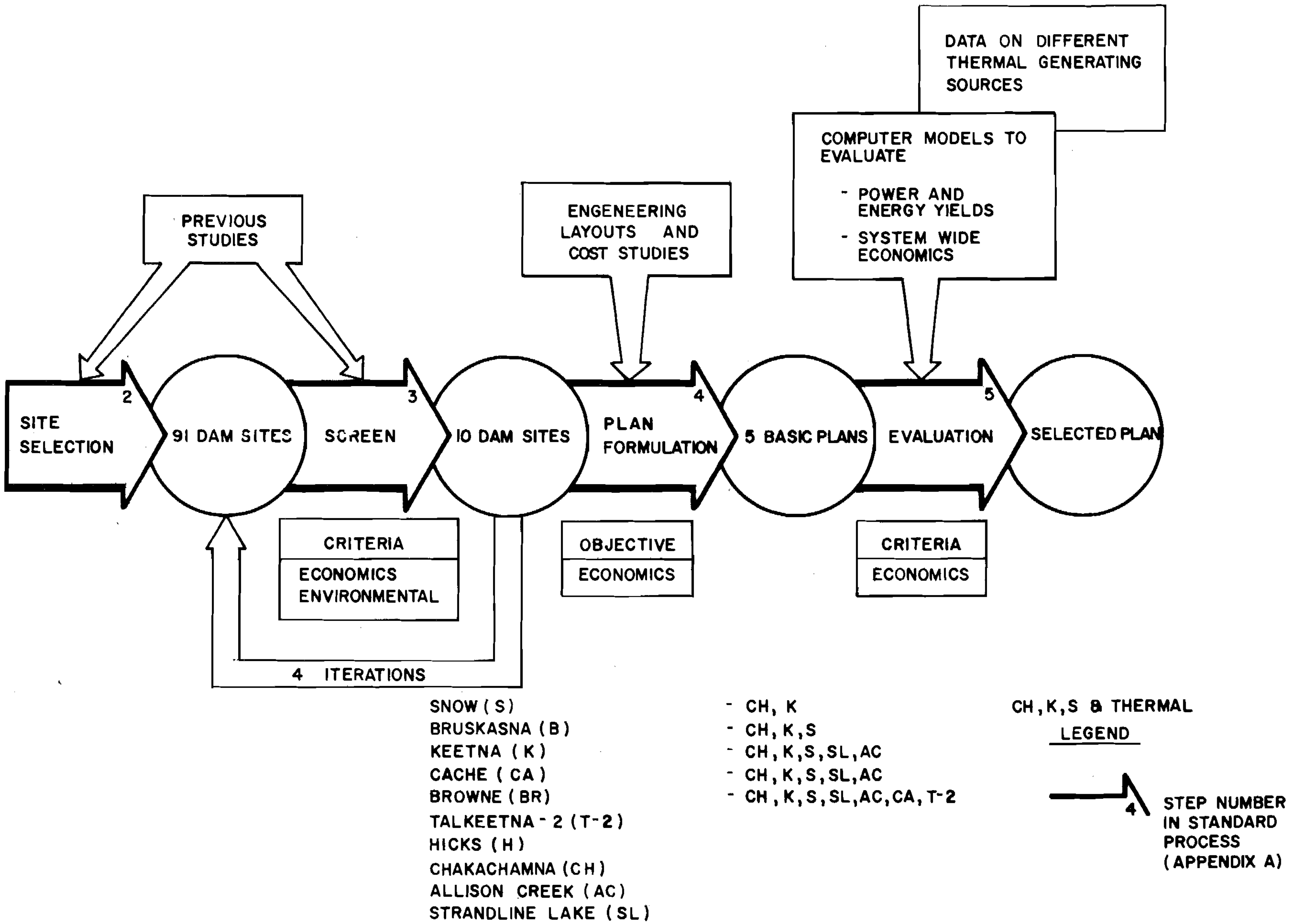
TABLE 6.7: ALASKAN FUEL RESERVES

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	--



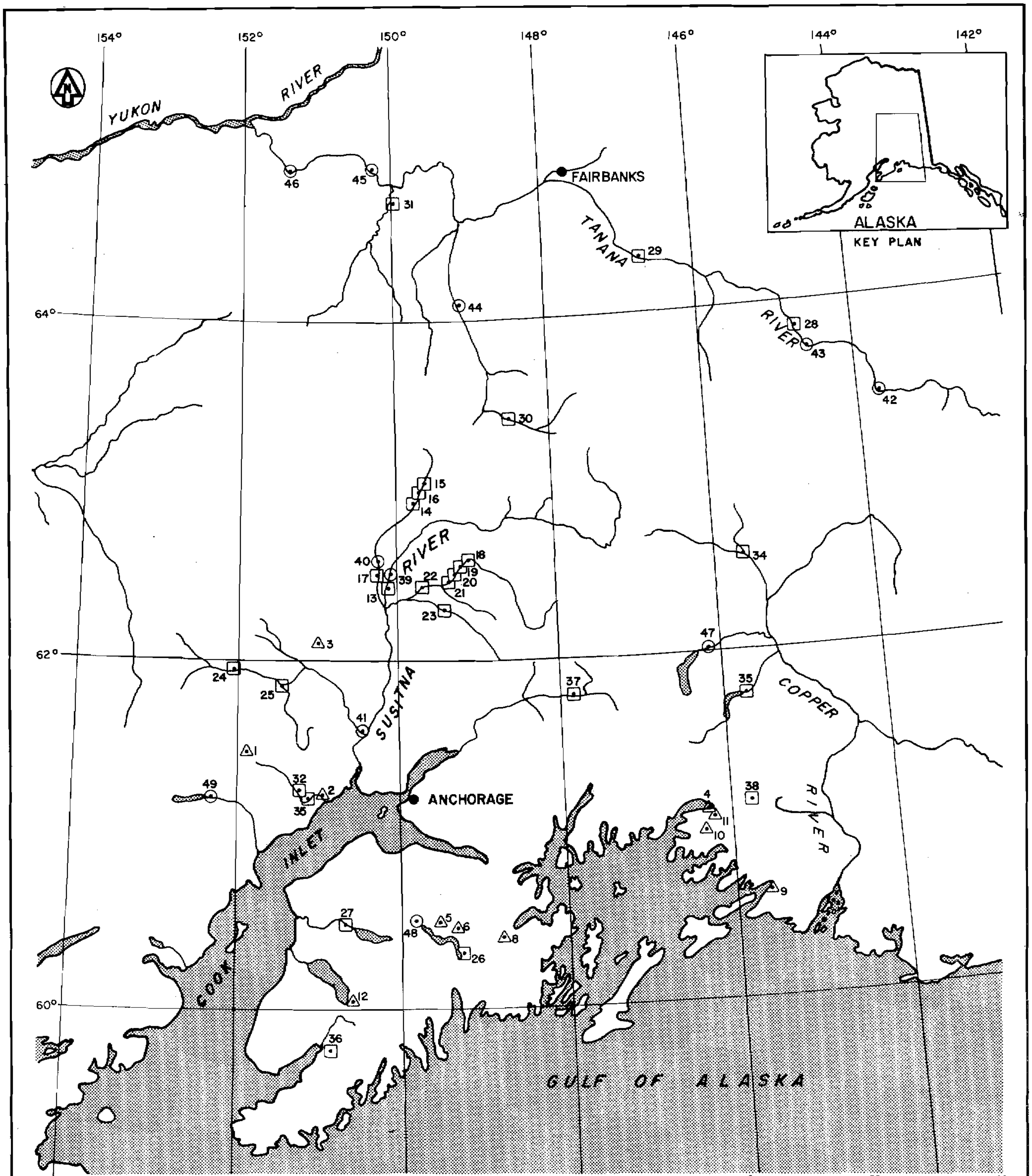
LOCATION MAP

FIGURE 6.1



FORMULATION OF PLANS INCORPORATING NON-SUSITNA HYDRO GENERATION

FIGURE 6.2



ALASKA RAILBELT REGION

SCALE- MILES
1 INCH EQUALS APPROXIMATELY 40 MILES

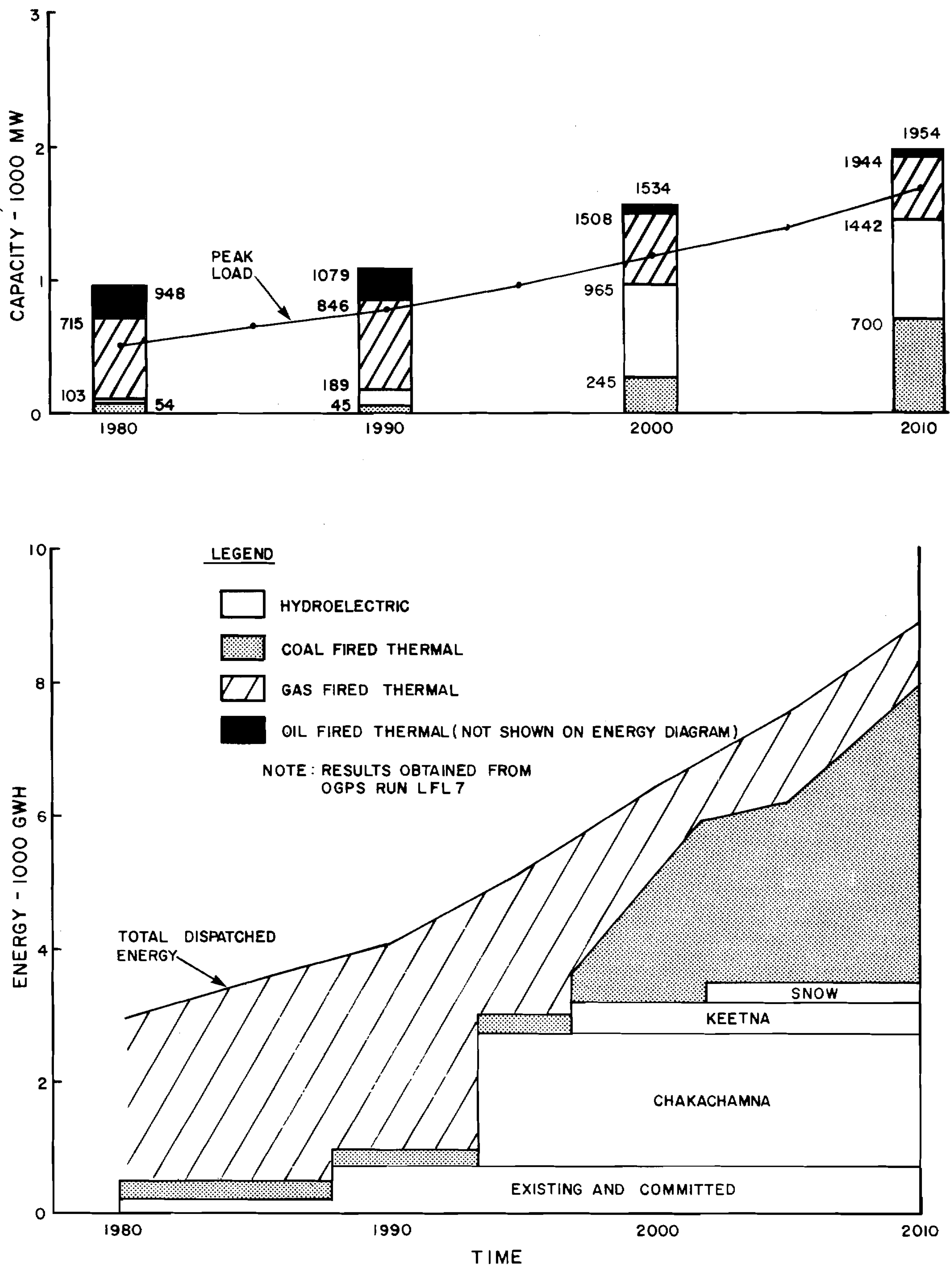
0 - 25 MW	25-100 MW	> 100 MW

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

SELECTED ALTERNATIVE HYDROELECTRIC SITES

FIGURE 6.3

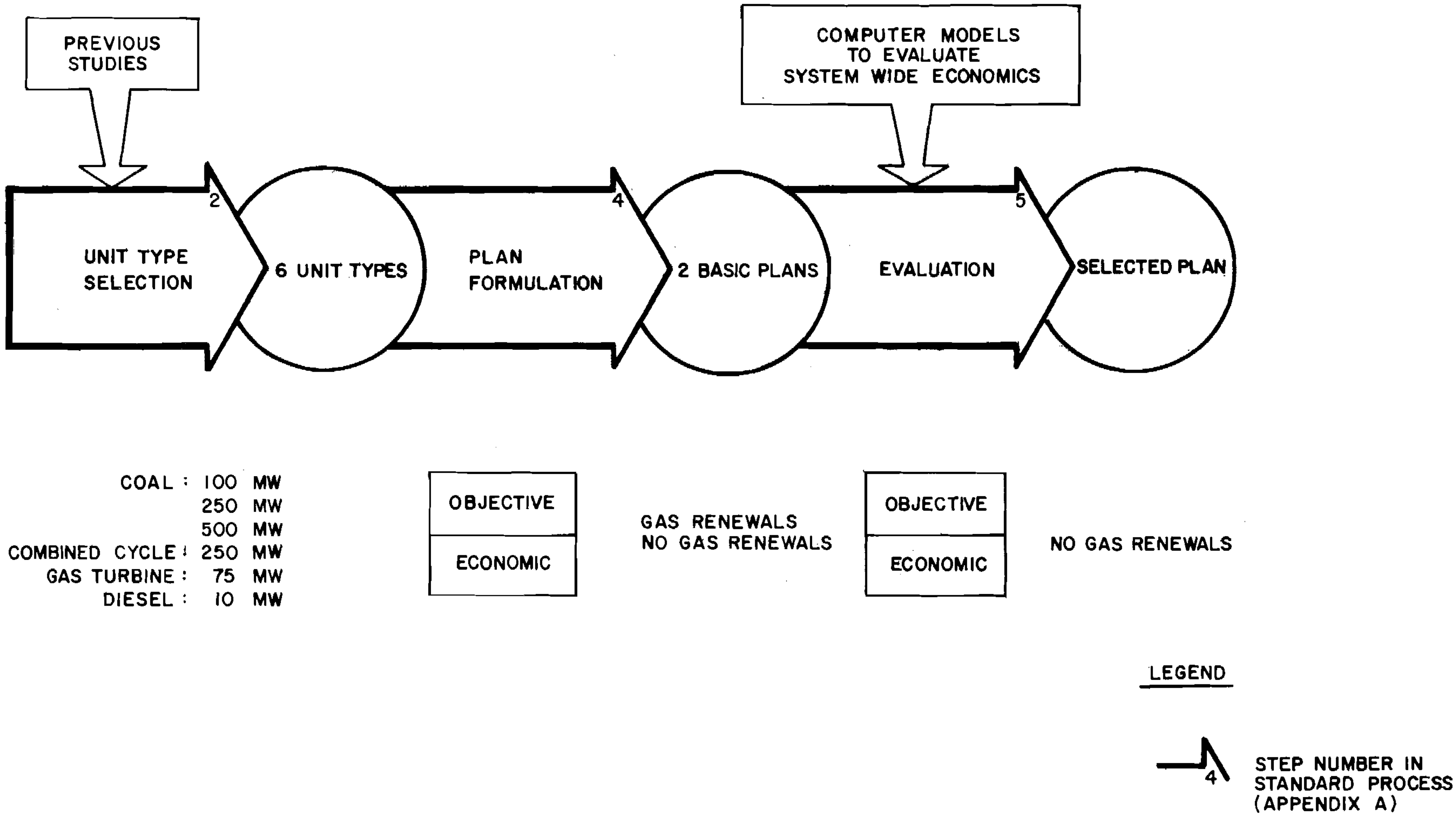
ACRES



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

FIGURE 6.4

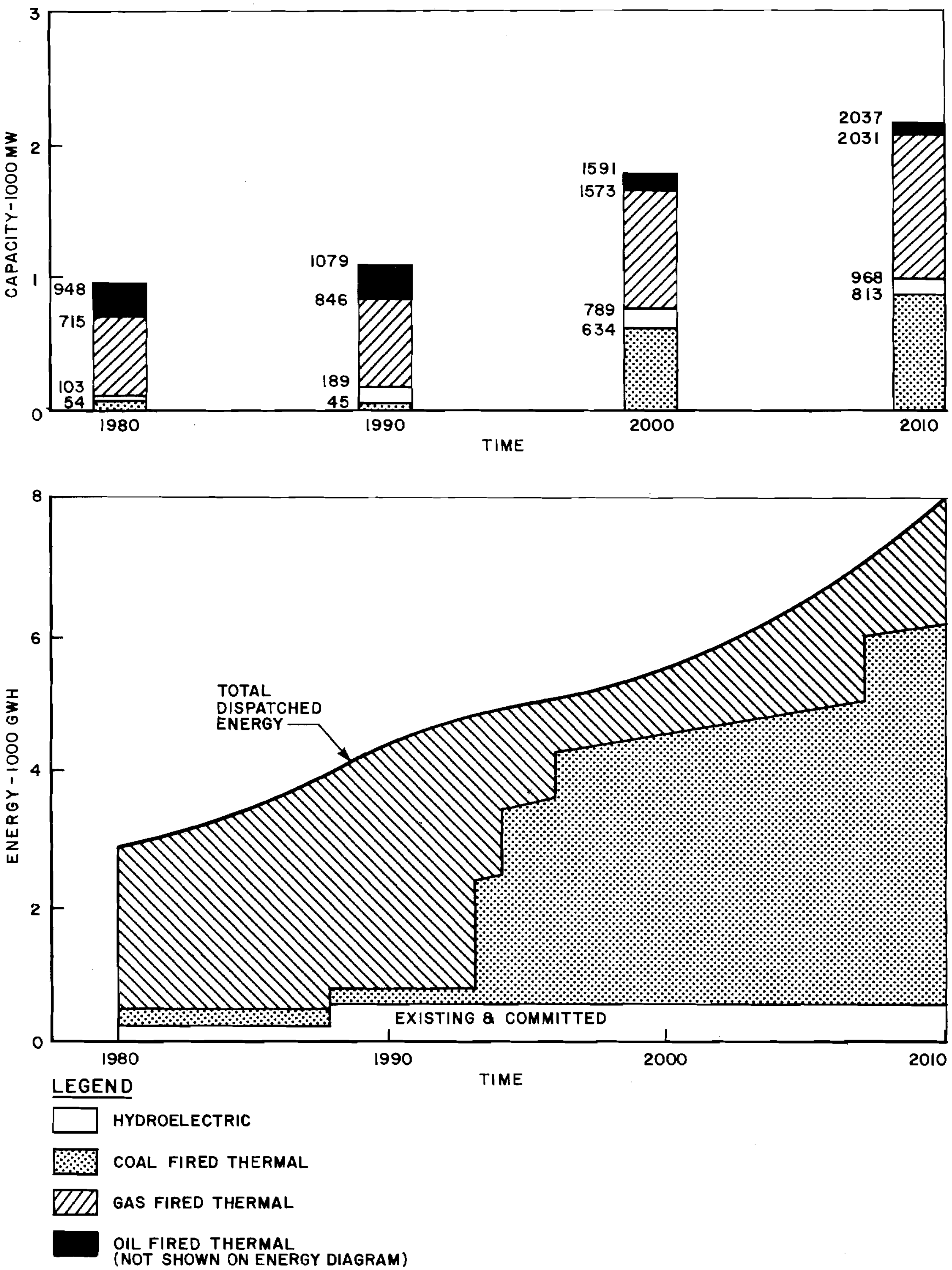
ACRES



FORMULATION OF PLANS INCORPORATING ALL-THERMAL GENERATION

FIGURE 6.5

ACRES



ALTERNATIVE GENERATION SCENARIO
BATTELLE MEDIUM LOAD FORECAST

FIGURE 6.6

ACRES

7 - SUSITNA BASIN

The purpose of this section is to describe briefly the physical, biological, and socioeconomic environment of the Susitna River Basin and vicinity, particularly in the area of the proposed development. This section was prepared utilizing existing literature, previous studies, and field studies conducted in 1980 and 1981, specifically for the Susitna Hydroelectric Project.

7.1 - Climatology

The climate of the Susitna Basin is generally characterized by cold, dry winters and warm, moderately moist summers. The upper basin above Talkeetna is dominated by continental climatic conditions, while the lower basin falls within a zone of transition between maritime and continental climatic influences. This section summarizes available historical climatic data for the basin and programs of field data collection and analysis undertaken during the study period.

(a) Climatic Data Records

Climatic data, including temperature, precipitation, wind, cloud cover, humdity, etc., have been collected by the National Oceanic and Atmospheric Administration (NOAA) at a number of stations in the southcentral region of Alaska since 1941. Prior to the current studies, there were no stations located within the Upper Susitna Basin above Talkeetna. The closest stations for which long-term climatic data are available are located, in relation to the upper basin, at Talkeetna to the south and Summit to the north. Typically, NOAA records are presented as annual summaries with comparative data for each station (see Table 7.1). Monthly summaries are available for most of the parameters presented on a daily basis, with selected parameters at three hour or one hour intervals.

Six climatic stations were established in the upper basin during 1980 to facilitate better definition and interpretation of the available historical data. The locations of the stations were finalized after careful evaluation of the basin characteristics, a reconnaissance field survey to ensure a good representation of basin climate and hydrologic characteristics, and to accommodate the climate data requirements of the Alaska Department of Fish and Game (ADF&G). The stations are located near the Watana camp, Devil Canyon damsite, Kosina Creek (ADF&G), Tyone River near the marshlands, at Denali, and adjacent to the Susitna Glacier, and are shown in Figure 7.1. Each station equipment comprises a microprocessor-based continuous weather monitoring system - Weather Wizard Model 5100; manufactured by Meteorology Research Inc. of California. The automatic recording system was selected in preference to conventional mechanical recording instruments due to ease of operation and savings in data processing costs. The data collected at these stations include air temperature, wind speed and direction, peak wind gust, relative humidity, precipitation, and solar radiation. Snowfall amounts are measured in a heated precipitation bucket at the Watana Station. Data are recorded at 30 minute intervals at the Susitna Glacier station and at 15 minute intervals at all the others. A typical monthly summary of the data for the Watana Station is presented in Table 7.2. Detailed summaries of data collected at the six stations are presented in a separate report (1).

(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 about 3,000 feet in the Talkeetna Mountains and the Alaskan Range, whereas at Talkeetna station, at Elevation 345, the average annual precipitation recorded is about 28 inches. The average precipitation lessens in a northerly direction as the continental climate starts to predominate. At Summit station (Elevation 2397), 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. Typical precipitation recorded at various NOAA stations is presented in Table 7.3.

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 3,000 feet; they 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). A program of data collection started in the winter of 1980 and will continue through the winter of 1981-82. Results of the snow surveys are being published by SCS in their monthly bulletins. Selected information was used in the reevaluation of the probable maximum flood studies (see Appendix A2).

(c) Temperature

Typical temperatures observed from historical records at the Talkeetna and Summit stations are presented in Table 7.4. It is expected that the temperatures at the damsites will be somewhere between the values observed at these stations. Typical values observed at Watana in 1981 are shown in Table 7.2. Three hourly and monthly summaries of data recorded at the six climatic stations are presented in a separate report (1).

(d) Evaporation

The closest stations to the Upper Susitna Basin where pan-evaporation data are collected are at the Matanuska Valley Agricultural Experiment Station near Palmer and the University Experiment Station in Fairbanks. The period of record for each station dates from 1944 to the present, with numerous gaps. Evaporation measurements are restricted to the summer months. A standard Weather Bureau Class A plan was installed near the Watana Camp, and daily observations were made during the summer of 1981. An estimate of potential monthly evaporation from the proposed reservoir surfaces was made from analysis of the historical data and measurements at Watana. Table 7.5 presents a comparative picture. Details of this analysis are presented in Appendix A1.

(e) Field Data Index

A Field Data Index (2) of all available climatic and hydrologic data for the Susitna Basin was compiled in June, 1980. Updates were made every six months to include data collected during the period of study. The latest update (January, 1982) may be consulted for a more detailed outline of available data. The Index served the purpose of a formal transmittal of information on data availability to study participants and agencies.

7.2 - Hydrology

Historical streamflow data are available for several gaging stations on the Susitna River and its main tributaries. Continuous gaging records were available for the following eight stations on the river and its tributaries: Maclaren River near Paxson, Denali, Cantwell, Gold Creek and Susitna stations on the Susitna River, Chulitna Station on the Chulitna River, Talkeetna on the Talkeetna River, and Skwentna on the Skwentna River. The longest period of record available is for the station at Gold Creek (32 years from 1949 to 1981). At other stations, record length varies from 6 to 23 years. Gaging was continued at all these stations as part of the current program, and continuous streamflow data are available for 1980 and 1981. A gaging station was established at the Watana damsite in 1980, and streamflow records are available for the study period. No historical streamflow data are available for the proposed damsites at Watana and Devil Canyon. Partial streamflow records are available at several other stations on the river for varying periods; the stations are shown in Figure 7.1. For details of available records at each station, see the Field Data Index (2).

(a) Water Resources

Above its confluence with the Chulitna River, the Susitna contributes approximately 20 percent of the mean annual flow measured at

Susitna Station near Cook Inlet. Figure 7.2 shows how the mean annual flow of the Susitna increases towards the mouth of the river at Cook Inlet.

Seasonal variation of flow in the river 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 2,100 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 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 (Elevation 4520), the average winter and summer flows are 144 and 2,100 cfs respectively, i.e. a 1 to 15 ratio. The monthly percent of annual discharge and mean monthly discharges for the Susitna River and tributaries at the gaging stations above the Chulitna confluence are given in Table 7.6.

Some 40 percent of the streamflow at Gold Creek originates above the Denali and Maclaren gages. This catchment generally comprises the glaciers and associated high mountains. A preliminary study of the glaciers was made to assess the effect of the glaciers on the available streamflow for power generation. Details of this study are presented in a separate report (3).

(b) Streamflow Extension

Acres' inhouse FILLIN computer program was used to fill in gaps in historical streamflow records at the eight continuous gaging stations. The 30 year record (up to 1979) at Gold Creek was used as the base record. The procedure adopted for filling in the data gaps uses a multi-site regression technique which analyzes monthly time-series data. Flow sequences for the 30-year period were generated at the remaining seven stations. Using these flows at Cantwell station and observed Gold Creek flows, 30-year monthly flow sequences at the Watana and Devil Canyon damsites were generated on the basis of prorated drainage areas. Table 7.7 shows recorded monthly flows at Gold Creek for the entire period of 32 years. Synthesized flows at the Watana and Devil Canyon damsites are presented in Tables 7.8 and 7.9. Flow duration curves based on these monthly estimates are presented for Watana and Devil Canyon damsites in Figures 7.4 and 7.5. Details of the regression analysis are presented in Appendix A1.

(c) Low Flow Frequency Duration Analysis

A frequency analysis of run-off volumes at low flow periods ranging from 1 to 10 years was carried out for recorded annual streamflows at Gold Creek. The lowest annual flow was observed in the Water Year 1969 with an average flow of 5,560 cfs. The return period of such an event is estimated at about 1 in 10,000 years (see Figure 7.6).

A monthly simulation of the proposed reservoirs and power development has been carried out to estimate energy potential of the proposed reservoirs. The critical low flow sequence for energy generation was observed to be the 32-month period between October, 1967 and May, 1970. The sequence comprises the lowest annual flow year described above and has a frequency of recurrence of 1 in 300 years.

The results of the analysis have been used to determine dependable energy potential of the proposed reservoirs (see Sections 9 and 10).

(d) 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. Table 7.10 presents selected flood peaks recorded at different gaging stations.

A regional flood peak and volume frequency analysis was carried out using the recorded floods in the Susitna River and its principal tributaries. These analyses were conducted for two different time periods. The first period, after the ice breakup and before freezeup (May through October), 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 (October through May). These floods, although smaller, can be accompanied by ice jamming and must be considered during the construction phase of the project in planning the design of cofferdams for river diversion.

A set of multiple linear regression equations were developed using physiographic basin parameters such as catchment area, stream length, precipitation, snowfall amounts, etc., to estimate flood peaks at ungaged sites in the basin. In conjunction with the analysis of shapes and volumes of recorded large floods at Gold Creek, a set of project design flood hydrographs of different recurrence intervals were developed (see Figures 7.7 and 7.8).

The results of the above analysis were used for estimating flood hydrographs at the damsites and ungaged streams and rivers along the access road alignments for design of spillways, culverts, etc. Table 7.11 lists mean annual, 50-, 100-, and 10,000-year floods at the Watana and Devil Canyon damsites and at the Gold Creek gage. Details of the regional flood frequency analysis are presented in a separate report (4).

The proposed reservoirs at Watana and Devil Canyon would be classified as "large" and with "high hazard potential" according to the guidelines for safety inspection of dams laid out by the Corps of Engineers. This would indicate the need for the probable maximum flood (PMF) to be considered in the evaluation of the proposed projects. Estimates of the PMF in the Susitna River at several locations, including the proposed damsites, were carried out by the Corps of Engineers (COE), Alaska District, in their 1975 study of the Susitna Basin Hydroelectric Developments. A detailed review of their work by Acres suggested that the PMF estimate made by the COE was sensitive to the three major parameters - probable maximum precipitation, available snow pack for melting, and the temperature sequence during the PMF event. A re-evaluation of the PMF in the basin was, therefore, undertaken based on a more comprehensive climatological data base and refined basin modeling parameters using the basin simulation program "Streamflow Synthesis and Reservoir Regulation" (SSARR) used by the COE in their study. The details of this study, including a review of the work undertaken by the COE, are presented in Appendix A2. Estimated peak discharges during the PMF at selected locations are included in Table 7.11, and the PMF hydrograph is presented in Figure 7.9.

(e) <u>River Ice</u>

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. The maximum thicknesses observed at selected locations on the river are given in Table 7.12. Ice breakup in the river commences by late April or early May; ice jams occasionally occur at river constrictions, resulting in rises in the water level of up to 20 feet.

Detailed field data collection programs and studies were undertaken to identify potential problem areas and to develop appropriate mitigation measures should the Susitna project be undertaken. The program included comprehensive aerial and ground reconnaissance and documentation of freezeup and break-up processes during the 1980-81 season. These data were used to calibrate computer models in order to predict the ice regime under post-project conditions in the proposed reservoirs and in the downstream river. Evaluations of the impacts of anticipated changes in ice conditions caused by the project have been made and mitigation measures proposed. Details of field investigation programs and the analysis are contained in references (1) and (5).

(f) River Morphology and Sediment Yield

(i) Available Data

Suspended sediment data have been collected by the USGS at 13 stations on the Susitna and its tributaries for periods ranging from one season at small tributaries is up to 22 years at Gold Creek Station. Figure 7.1 shows location of the stations. Generally, suspended sediment concentration, volume of transport and particle size data is collected by the USGS. Most of the suspended sediment is transported during the spring/summer months June through September. Except for a few samples collected by USGS at Denali in 1958, bed load data for the river and its tributaries are non-existent. Data coverage during high flow-high sediment discharge events was poor and consequently any estimate of total annual sediment yield has a high degree of uncertainty.

During the study period, several of the USGS sediment stations were revitalized and suspended sediment data collected. In addition, data was collected at Cantwell and Gold Creek Stations during specific events such as rising and falling limbs of flood hydrographs to fill gaps in historical information. During 1981, three bedload samples were collected at four stations - Susitna River at Gold Creek and Sunshine, Chulitna River near Talkeetna and Talkeetna River near Talkeetna to enable better understanding of river morphology below the damsites.

(ii) Estimate of Sediment Yield

Historical data and those collected during the study period were analysed to estimate sediment yield in the river at various locations and potential reservoirs sedimentation. Suspended sediment rating curves have been developed for stations on the Susitna at Gold Creek, Cantwell, Denali and at Paxson on Maclaren River (Figure 7.10). Estimated annual transport of suspended materials at selected gaging stations is presented in Table 7.13. Without adequate bedload measurements above the damsites, estimates had to be made based on earlier studies (1975) by the Corps of Engineers and data collected at Gold Creek for potential bedload movement into the reservoirs. Trap efficiencies for the proposed reservoirs at Watana and Devil Canyon were made based on literature surveys of worldwide experience under similar glacial river basins. Table 7.14 presents estimated sediment deposition in the reservoirs. Details of reservoirs sedimentation analysis may be found in (6).

(iii) Morphology of River Below Dams

Preliminary studies of the morphology of the river below the proposed dams have been made to evaluate potential changes caused by post-project flow regime. A detailed report (7) has been prepared on the subject. The study indicates that significant changes in the lower river morphology are unlikely to be caused by the projects proposed.

7.3 - Regional Geology

The regional geology of the Susitna Basin area has been extensively studied and is documented (8,9,10). 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 exposed in the region are volcanic flows and limestones which were formed 250 to 300 million years before present (m.y.b.p) 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 which has been identified in the literature, 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 7.11).

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 have intruded the pluton. 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 foot deep Vshaped canyons that are evident today, particularly at the Vee and Devil Canyon damsites. This erosion is believed to still be 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.

7.4 - Seismicity

A two year study of seismicity of the project area was undertaken by Woodward-Clyde Consultants (WCC) to identify faults that have the potential for surface rupture within the project area and to provide estimates of earthquake ground motions that could be used for dam design. Details of these studies are presented in referenced documents (1) and (2). The results of WCCs studies are summarized in this section.

(a) Seismic Setting

The project lies within the Talkeetna Terrain, a part of the North American Plate. The Terrain boundaries are denoted by the Denali-Totschunda fault to the north and east, the Castle Mountain fault to the south, a broad zone of deformation with volcanoes to the west, and the Benioff Zone at depth (Figure 7.12). With the exception of the western boundary, which is primarily a zone of uplift marked by Cenozoic age volcanoes, all of the boundaries are (or contain) faults with recent displacement.

The results of the WCC study suggest that the Talkeetna Terrain is a relatively stable tectonic unit with major strain release occurring along its boundaries. This conclusion is based on: the evidence for recent displacement along the Denali-Totschunda and Castle Mountain faults and the Benioff Zone; the absence of many major historical earthquakes within the Terrain; and the absence of faults with recent displacement within the Terrain.

(b) Potential Earthquake Sources

The guideline used in this study to define a fault with recent displacement was: any fault which has had surface displacement during the past 100,000 years. Faults for which evidence of recent displacement was found were evaluated during this study to estimate their potential affect on seismic design and their potential for surface rupture within six miles of the Watana and Devil Canyon damsites.

(i) Evidence of Recent Displacement

On the basis of WCCs study, the Talkeetna Terrain boundary faults were identified as potential seismic sources. These include: the Castle Mountain fault, the Denali fault, the Benioff interplate region, and the Benioff intraplate region (Figure 7.12). These faults are considered to be, or to contain, faults with recent displacement that could cause seismic ground motions at the damsites; however, because of their distance from the sites, these faults do not have the potential for rupture through the sites.

A total of 13 features which were identified and investigated in some detail near the damsite as potential seismic sources, were found to show no evidence of recent displacement. These features, therefore, were not considered to be potential seismic sources that could cause seismic ground motions at the sites or surface rupture through the sites.

(ii) Terrain Earthquake

Earthquakes up to a given magnitude could occur on faults with recent displacement that might not be detectable by the geotechnical investigations. Such earthquakes have been designated as "Terrain earthquakes" (or "detection level earthquakes" by WCC). The magnitude of the terrain earthquake varies according to the degree of natural preservation of fault-related geomorphic features and from one tectonic environment to another. The maximum terrain earthquake magnitude for consideration in project design was estimated by:

- Evaluating the dimensions of surface faulting associated with worldwide historical earthquakes in tectonic environments similar to the Talkeetna terrain;

- Identifying the threshold of surface faulting using a group of thoroughly studied earthquakes in California; and

- Evaluating the degree of preservation of fault-related geomorphic features in the Talkeetna Terrain.

For this project WCC estimated the terrain earthquake to be a magnitude (M_S) 6.

(iii) Benioff Zone Earthquakes

An evaluation was made by WCC of moderate to large historical earthquakes within or adjacent to the Talkeetna Terrain. This study showed that all earthquake events, (except one) larger than magnitude (M_S) 5.6 in the Talkeetna Terrain occurred on the Benioff Zone, adjacent to recognized faults with recent displacement (such as the Castle Mountain fault) or in the crust adjacent to the western boundary of the Terrain. The earthquake near the western boundary of the Terrain is the 1943 earthquake of magnitude (M_S) 7.3 which had a focal depth of 11 miles (17 km) and was located approximately 90 miles (145 km) southwest of the Project (Figure 7.13). Preliminary studies concluded that this event may be associated with several lineaments in that area, therefore, not be related to any features identified closer to the project locations.

Review of worldwide and Alaskan Benioff Zone seismicity resulted in a refined configuration of the Benioff Zone. The Benioff Zone in south-central Alaska is comprised of two regions. In the interplate region, earthquakes occur along the interface between the subducting Pacific Plate and the overlying North American plate (Figure 7.12). Relatively large earthquakes, such as the 1964 magnitude (M_S) 8.4 Prince William Sound earthquake, occur along this region. In the intraplate region, earthquakes occur within the subducting Pacific Plate where it is decoupled and dips beneath the North American Plate. The maximum earthquakes in this region of the Benioff Zone are of moderate to large size and are smaller than the maximum earthquakes in the interplate region.

(c) Maximum Earthquake (ME)

To establish a basis for estimating ground motions at a specific site, and hence to design the structures to be built, estimates were made by WCC of the maximum earthquakes in the region associated with the potential earthquake sources.

The maximum earthquake (ME) was estimated for each boundary fault (in the crust and in the Benioff Zone) and for the terrain earthquake. These are as follows:

		Closest Approach to Proposed Damsites			
	ME	Devil Canyon		Watana	
Source	(M_S)	miles	(km)	miles	(km)
Castle Mountain	7-1/2	71	(115)	65	(105)
Denali Fault	8	40	(64)	43	(70)
Benioff Zone (interplate)	8-1/2	57	(91)	40	(64)
Benioff Zone (intraplate)	7-1/2	38	(61)	31	(50)
Terrain Earthquake	6	<6	(<10)	<6	(<10)

Work undertaken by Dr. L. Sykes of the Lamont Doherty Institute, New York, suggests that the magnitude of the Terrain earthquake could be as high as (M_S) 6-1/4 to 6-1/2.

(d) Reservoir Induced Seismicity (RIS)

The studies concluded that there would be a high likelihood for reservoir induced earthquake as a result of impoundment. However, such an event is not expected to cause an earthquake larger than that which could occur in a given region "naturally."

(e) Ground Motion

Estimated mean peak horizontal ground accelerations and duration of strong shaking (significant duration) at the sites due to the governing maximum credible earthquake are the following:

Earthquake Source	Maximum Magnitude	Mean Peak Acceleration Watana Site	Mean Peak Acceleration Devil Canyon Site	Significant Duration (sec)
Benioff Zone	8-1/2	0.35g	0.3g	45
Denali Fault	8	0.2g	0.2g	35
Terrain Earthquake	6	0.5g	0.5g	6

The probabilities of exceedance of peak ground accelerations at the sites were estimated. The Benioff Zone was found to dominate the contributions to the probabilities of exceedance. Other sources of earthquakes, including the Denali Fault and the detection level earthquake contributed only slightly to the probabilities of exceedance.

These ground motions were used as a guideline in developing the engineering design criteria set forth in Sections 9 and 10.

7.5 - Water Use and Quality

(a) Water Use

Water rights in Alaska are administered by the Alaska Department of Natural Resources (DNR). The computer files of DNR's water management section were searched to determine the amount and type of water appropriations recorded for the Susitna River and surrounding area.

The mainstem Susitna corridor encompasses 30 townships from the proposed impoundment area downstream to the estuary. Existing surface and ground water appropriations are primarily for single-family and multi-family homes with approximately 50 acre feet per year, of surface water appropriated for all purposes. On a seasonal basis, the greatest usage occurs during summer months for irrigating lawns, gardens, and crops.

There are only five areas where water appropriations are located within one mile of the mainstem of the Susitna River (Table 7.15). No surface water diversions are recorded that draw water directly from the Susitna River or its adjoining side channels and sloughs.

(b) Water Quality

The wide seasonal fluctuations in river discharge and glacial character of the river have a significant effect on water quality.

Suspended sediment concentrations and turbidity levels are low during late fall and winter, but increase sharply at breakup and remain high throughout the summer. Dissolved solids concentrations and conductivity values are high during the low winter flow periods and low during the high summer flows.

The Susitna River is a fast-flowing, cold-water stream of the calcium bicarbonate type containing soft-to-moderately hard water during breakup and in the summer, and moderately hard water in the winter. Alkalinity cocentrations, with bicarbonate as the dominant anion, are low to moderate during summer, and moderate to high during winter. Nutrient concentrations, namely, nitrate and ortho-phosphate, exist in low to moderate concentrations. Dissolved oxygen concentrations typically remain near the saturation level, always exceeding 80 percent but averages near 100 percent in the summer; in the winter saturation levels decline slightly from the summer levels. Typically, pH values range between 7 and 8 and exhibit a wider range in the summer as compared to the winter. True color, resulting from tundra runoff, displays a wider range during summer than winter. Color levels in the vicinity of the damsites have been measured as high as 40 color units. The temperature remains at or near 32°F during winter, and in summer the maximum is 55°F.

The concentrations of many trace elements monitored in the river were low or within the range characteristic of natural waters. However, the concentrations of some trace elements exceeded water quality guidelines for the protection of freshwater aquatic organisms. These concentrations are the result of natural processes, since there are no man-induced sources of these elements in the Susitna River basin.

Concentrations of organic pesticides and herbicides, uranium, and gross alpha radioactivity were either less than their respective detection limits or were below levels considered to be potentially harmful.

7.6 - Fisheries Resources

Both resident and anadromous fish occur in the Susitna River system. Resident fish species present are grayling, burbot, rainbow trout, Dolly Varden, three spined stickleback, lognose sucker, slimy sculpin, whitefish, and lampreys; anadromous fish are sockeye, pink, coho, chinook, chum salmon and eulachon.

(a) Anadromous Fish

Salmon utilize the Susitna River and its tributaries below Devil Canyon as spawning habitat. Data indicate that physical barriers prevent salmon from migrating upstream from Devil Canyon.

Salmon migration begins in late spring and continues into the fall. Adult Chinook salmon enter the lower Susitna River in late May. The confluence of the Talkeetna, Chulitna and Susitna Rivers is thought to be a milling area for adult Chinooks. Spawning occurs in the tributaries to the Susitna, particularly Indian River, Deshka River and Willow, Clear, Peters and Portage Creeks. Spawning occurs in July and August.

Sockeye salmon enter the lower Susitna River in late spring. They were found spawning the sloughs of the river and in McKenzie Creek. Spawning occurs in late summer.

Pink salmon enter the lower Susitna River every year with even-year runs being substantially higher than odd-year runs. Peak spawning occurs in August in sloughs and tributaries, including Whisker, Chase, Lane, Skull, and Fourth of July Creeks.

(b) Resident Fish

Arctic grayling were found throughout the upper Susitna Basin. Downstream from Talkeetna, the spawning migration occurs in late April. It appears these fish spawn in the tributaries in early spring; no evidence of spawning was found between Devil Canyon and Cook Inlet in the mainstem.

Lake trout were found only in Sully and Deadman Lake. Rainbow trout were found at approximately the same number of habitat locations in all stretches of the river from Devil Canyon to Cook Inlet, with highest numbers occurring at habitat locations associated with tributary streams. These fish were consistently found at Anderson and Alexander Creeks and in the Deshka River.

Burbot were found upstream of Talkeetna during the winter, with the highest number near Curry. Downstream numbers were highest near the mouth of the Deshka River, Alexander Creek, and four mainstem sites.

The chum salmon migration begins during July and ends in September. Upstream from Talkeetna, the period from late July until the end of August was the peak migration period. Chum salmon were found to spawn in the mainstem of the Susitna, as well as Indian River and Whiskers, Chase, Lane, Lower, and Skull Creeks.

The coho salmon migration runs from July into October, the last spawn of Pacific salmon to migrate. Late July and August is the major migrational period upstream from Talkeetna. Cohos spawn in sloughs as well as tributaries, including Indian River, Whiskers, Chase, Lane, and Portage Creeks.

Following deposition in the fall, the eggs hatch in the spring. The young salmon, depending on the species and a variety of unknown factors, either migrate to the sea within a few months or remain in the river for one or two years before migrating downstream.

Juvenile Chinook salmon often spend one winter in fresh water before migrating to the sea. Juvenile sockeye, pink, and chums migrate in May and June, and cohos also out migrate in the spring.

Dolly Varden were found in the mainstem Susitna from Cook Inlet to Devil Canyon and in Indian River and upper Portage Creek. Higher numbers were found during July, perhaps due to higher availability of salmon eggs upon which Dolly Varden feed.

7.7 - Wildlife Resources

Information presented in the big game section below was taken from reports prepared for this project by the Alaska Department of Fish and Game.

(a) Big Game

Species of big game which inhabit the upper Susitna basin are: black bear, brown bear, wolverine, wolf, Dall sheep, caribou, and moose.

(i) Bears

Black bear distribution in Alaska coincide with the presence of forest habitat. Thus, within the Susitna basin most black bear are found in steep terrain along the river and its tributaries.

Studies indicate approximately 55 percent of the population is male. The average spring age is approximately 6-1/2 years for males and 8 years for females. The population appears to be healthy and producing. Dens utilized for overwintering were found primarily at an elevation of 1500 to 2500. Sixteen den sites were found in the vicinity of the proposed Devil Canyon impoundment (only one of which would be flooded) and 13 in the vicinity of the proposed Watana impoundment (9 of which would be flooded). Dens were also found downstream of the Devil Canyon site. Bears typically entered the dens from mid-September through mid-October and exited from April to mid-May.

Black bears are fairly abundant in Alaska and not heavily hunted. Within the upper Susitna basin, only an average of eight per year are harvested, primarily between the Talkeetna and Indian Rivers. This number is below the hunter inflicted mortality rate which the population could suffer and maintain its present population level, i.e., it is below the maximum sustainable yield for the population.

Brown bear occur primarily in open tundra and grassland areas of Alaska. Aerial observations of brown bear in the study area showed the highest percentage of sightings occurred in shrubland areas, followed by spruce and riparian habitats. Preliminary estimates of brown bear numbers in the study area is 70 animals or one bear per 19 mi^2 utilizing the same figure would indicated 3 to 4 bears in the area to be flooded. Females with cubs were not observed frequently in the proposed impoundment area but other bears were observed in their area, particularly during spring.

The brown bear population of the upper Susitna basin appears to have a 50:50 sex ratio. Average spring age is approximately 7-1/2 years for both males and females. The population is young and healthy, with litter sizes equivalent to know productive bear populations in other areas. Dens were found at elevations ranging from 2330 to 5150, with an average elevation of 4,181 feet. (Information on numbers of dens in area to be added, if available).

Harvest regulations for brown bears are more stringent than for black bears. Only an average of 15 per year are taken by hunters within the project area; this is believed to be below the maximum substainable yield.

(ii) Wolverine

Wolverine are present in the study area and are found in all habitat types. Their distribution appears to be related to prey availability, concentrating in hilly areas above treeline in the summer and fall and in lower elevations during winter and early spring.

Population density is estimated between 1 per 42 mi^2 and 1 per 56 mi^2 (1/56 mi^2). The entire impoundment area of both Watana and Devil Canyon is approximately 80 mi^2, indicating an area inhabited by two wolverines. Utilizing the same density figures, the entire upper Susitna basin population is estimated at 150. Harvest data suggest the wolverine population of the upper Susitna basin may be experiencing heavier trapping mortality than the population can sustain over a prolonged period.

(iii) Wolf

One known and five to six suspected wolf packs occur in the area that would be most directly effected by the two reservoirs (Figure 7.14).

The estimated population of these peaks combined is between 40 to 80 animals. Wolf control operations have been conducted in the past, with the latest such activity occurring in 1978.

Caribou and moose were found to be the most important prey items to the wolves, with caribou representing up to 30 percent of the diet. Wolves were estimated to consume from 11 to 13 percent of the study area moose with calf mortality ranging from 16 to 17 percent. Caribou mortality from wolf predation was estimated to vary between 2 and 13 percent.

Wolves are hunted and trapped in the area. Numbers removed annually from Game Management Unit 13 (Nelchina-Upper Susitna) during the past 10 years ranged from 40 to 110 and in Unit 13E, which contains the reservoir ares, 5 to 75.

(iv) Dall Sheep

Three populations of Dall Sheep occur in the Upper Susitna Basin: the Watana hills herd, Watana-Grebe Mountain herd and the Portage-Tsusena Creek herd. Population levels are not known but surveys conducted in 1980-1981 revealed 209 sheep in the Watana hills herd, 30 in the Watana-Grebe Mountain herd and 72 in the Portage-Tsusena Creek herd, for a total of 311. A total of 13 sheep were harvested by sport hunters in 1980 in the Upper Susitna Basin.

A mineral lick in the Jay Creek area appears to be an important area for the Watana hills herd. Sheep were frequently observed utilizing the lick, which is located at Elevation 2200 and will be partially inundated by the Watana reservoir.

(v) Caribou

The Nelchina caribou herd occupies an area of approximately 20,000 square miles in Alaska. This large range can be divided into 16 sub-ranges, including the Upper Susitna Basin (Figure 7.15). Portions of the Upper Susitna Basin have been consistently used throughout the years by large portions of the herd, with most use taking place in summer, fall, and late winter. During some years, the entire herd, currently numbering 20,000 animals, has used the Upper Basin. A small subherd of approximately 1,000 animals appear to be residing permanently in the upper portion of the basin.

During the spring migration, females moved from the Lake Louise Flat, foothills of the Alphabet hills and middle portions of the Gakona and Chistochina Rivers.

During the spring migration, females moved from the Lake Louise flats to the calving grounds in the eastern Talkeetna mountains. Migration occurred over a wide area, with some caribou utilizing the Susitna River in the upper area of the proposed Watana impoundment as a travel route. A small potion of the herd appears to cross between Deadman and Jay Creeks. None of the area utilized for calving will be flooded.

The fall dispersal and mating period occurred as the caribou moved out of the Talkeetna Mountains, across the Lake Louise flats and into the Alphabet hills and westward.

(vi) Moose

- Upstream Moose

Moose populations upstream from the proposed impoundment areas were studied in 1980 and 1981. The average age of adult cow moose was higher than other Alaskan moose population studied and pregnancy rates were lower. The physical condition of the moose appeared to be deteriorating, yet it was not believed the habitat was at its carrying capacity.

Moose generally moved to lower elevations during late spring and early summer, then back to higher elevations in late summer and winter. The majority of moose observed were in conifer and shrubland habitat.

A winter census of the impoundment area showed 28 moose in the Devil Canyon impoundment and 42 within the Watana impoundment. This was believed to be lower than normal because of a mild winter. Figure 7.16 depicts moose densities in the fall of 1980.

Studies of home range resulted in an estimated population of 2,400 moose, which either seasonally or year-round utilized an area within 5 miles of the proposed impoundment zones.

- Downstream Moose

Moose are also present in the Susitna River Basin downstream from the Devil Canyon damsite. There moose consist of both resident and migratory populations. No specific calving area were located during these studies, but it appears female use river islands to calve. During winters of heavy snowfall, moose tend to migrate to the river bottoms. Climax mixed birch/spruce habitat was utilized most frequently.

(b) Furbearers

The major furbearer species inhabiting the project area include red fox, coyote, lynx, mink, pine marten, river otter, short-tailed weasel, least weasel, muskrat and beaver. Red fox and pine marten are the most heavily trapped of the species; coyote and lynx are not common in the area.

Foxes were found to utilize the shores of the Susitna River and deltas of tributaries during summer and autumn, and alpine zones in the winter. All fox dens located were found above the area to be flooded by the proposed impoundment.

Pine marten are abundant in the study area. They utilize areas both inside and outside the impoundment zone, including closed forest areas and open white spruce forests.

Upstream from Gold Creek, most beaver and muskrat activity was found on plateaus between 2,000 and 2,400 feet above the river valley. No active beaver lodges or bank dens were found on the Susitna River upstream from Devil Canyon or on the lower reaches of the tributaries in this area. Furbearer activity increases progressively downstream from Devil Canyon. As the river becomes more braided, there is a marked increase in the number of beaver using the river, with the highest concentrations occurring south of Montana Creek.

Short-tailed weasels are common and locally abundant in the study area; little information is available on least weasels.

(c) Birds and Non-Game Mammals

A total of 132 species of birds were recorded in the Upper Susitna River Basin study area. The most abundant species are common red-poll, savannah sparrow, white crowned sparrow, lapland longspur, and tree sparrow. Fourteen species are rare in the region but are found in larger populations in other areas of Alaska.

Generally, the forest and woodland habitats support higher densities and/or biomass of birds than the shrub communities. Areas of upland cliffs and block-fields and of mat and cushion tundra have the lowest bird usage but support species not found in other habitats.

The ponds and lakes in the basin support relatively few water birds. The most abundant waterfowl species are scaup spp., American wigeon, goldeneye spp., mallards, and buffleheads. Trumpeter swans nest on a number of lakes, but none within the impoundment zone.

Ten golden eagle, six bald eagle, and four common ravin nests are located within the study area, while two bald eagle and four golden eagle nests occur within the impoundment zone. No endangered

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species (the bald eagle is not endangered in Alaska) are known to occur in the study area.

Sixteen species of small mammals are found in the upper Susitna Basin, the most abundant being the northern red-backed vole and the masked shrew.

Arctic ground squirrels are abundant in well-drained tundra habitats throughout the high country. Collared pika and hoary marmots are relatively common in rock habitats above the treeline. Red squirrels and porcupine are found in forests and woodland habitats.

7.8 - Botanical Resources

The Upper Susitna River Basin is located in the Pacific Mountain physiographic division in south-central Alaska. The Susitna River drains south slops of the Alaska Range on the north slopes of the Talkeetna Mountains on the south. Many areas along the river in the upper basin are steep and covered with coniferous, deciduous, and mixed coniferous and deciduous forests. Flat benches occur at the tops of these banks and usually contain low shurb or woodland conifer communities. Low mountains rise from these benches and are covered by sedge-grass tundra and mat and cushion tundra.

(a) Habitat Types

The vegetation/habitat types found in the upper basin (above Gold Creek) and floodplain downstream to Talkeetna are classified and mapped according to the Alaska Classification System.

The major vegetation/habitat types found in the upper river drainage are low-mixed shrub, woodland and open black spruce, sedge-grass tundra, mat and cushion tundra, and birch shrub. These vegetation types are typical of vast areas of interior Alaska and northern Canada, where plants exhibit slow or stunted growth in response to cold, wet, short growing seasons. Deciduous or mixed coniferous forests which, by contrast, have more robust growth characteristics, occupy less than 3 percent of the upper drainage area. These types occur at lower elevations, primarily along the Susitna River, where longer seasons of growth and better drained soils exist; they are more comparable to vegetation/habitat types occurring further downstream on the floodplain.

The downstream floodplain (below Devil Canyon) vegetation/habitat consists primarily of mature and decadent cottonwood forests, birch-spruce forest, alder thickets, and willow-cottonwood shrub communities. The willow cottonwood shrub and alder communities are the earliest to establish on new gravel bars, followed by cottonwood forests, and, eventually, birch-spruce forest. Wetland areas, ponds, and lakes are present only in limited amounts within the impoundment area.

Table 7.16 lists the area of each habitat type present in the Upper Susitna Basin. Of the total vegetated area of approximately 1.4 million hectares (3.5 million acres), approximately 22,160 hectares (55,400 acres) representing 1.6 percent of the vegetated area, will be removed by the impoundments, access routes, borrow areas, camps, and other facilities.

(b) Floristics

A total of 246 plant species in 130 genera and 55 families were found in the upper basin and floodplain areas. Families with the most species are Compositae, Salicaceae, Rosaceae, Grimineae, Cyperaceae and Eriecaceae.

(c) Endangered Species

No plant species occurring in Alaska are listed as endangered by federal or state authorities. None of the species under consideration for listing were found in the project area.

7.9 - Historic and Archaeological Resources

Surveys conducted located 43 archaeological sites within the area to be affected either directly or indirectly by the Watana Dam impoundment. These sites were found to represent human occupation dating from approximately 10,000 B.C. in the following culture periods: American Paleoarctic, Northern Archaic Tradition, Arctic Small Tool Tradition, Late Prehistoric Athapaskan, and Historic.

Three historic sites, all cabins built in the 1920s, occur in the Watana impoundment area.

The Devil Canyon impoundment area includes seven archaeological sites discovered during this study. These sites, representing various time periods in Alaska prehistory including the American Paleoarctic and the Northern Archaic Tradition.

One historic site, also a cabin believed to be constructed in the 1930s, lies within the Devil Canyon impoundment area.

7.10 - Socioeconomics

Three areas are discussed to depict the socioeconomic setting of the project. These areas, discussed in Volume 2, are:

- The state of Alaska;

- The Railbelt region which includes Anchorage, Kenai-Cook Inlet, Seward, Valdez-Chitina-Whittier, Matanuska-Susitna, southern Fairbanks, and the Yukon-Koyukuk census divisions; and

- The local region of the Matanuska-Susitna Borough and the Valdez-Chitina-Whittier census divisions, and selected adjacent communities.

Information on the state and the Railbelt region is presented in Volume 2; information on the local area is discussed briefly below.

(a) Local

Increases in population between 1970 and 1980 in the Mat-Su Borough (175 percent) and the Valdez-Chitina-Whittier census division (71 percent) were far higher than the state average. Population levels stabilized as the Trans-Alaska Pipeline was completed (Figure 7.17).

The Mat-Su Borough's population rose steadily from 6,500 people in 1970 to 18,000 in 1980. Most of these people reside in the southern quarter of the Borough. Palmer and Wasilla are the largest communities, with populations of approximately 2,100 and 1,550, respectively. Wasilla experienced an extraordinary growth rate of 510 percent during the past decade. Other population centers in the Borough are Big Lake, Eska-Sutton, Houston, and Talkeetna (Figure 7.18).

The Valdez-Chitina-Whittier census rose from 3,100 in 1970 to approximately 13,000 during 1976 as work on the TAPS pipeline peaked and then tapered off. The 1980 population was estimated at 6,225 (consistent demographic information is limited because of the alteration of this census division designation in 1980). Two trends are notable:

- Native population has represented a significant portion of total population (22 percent in 1970); and

- Population, along with economic activity in communities along the highways in this division, has declined since the opening of the Parks Highway in the early 1970s and the subsequent lessening of the traffic along the Richardson Highway.

Virtually all employment in the Mat-Su Borough is government, service, and support sector oriented. Total employment has risen steadily from 1,145 in 1970 to 3,078 in 1979, an increase of 169 percent. However, the Borough consistently has had high unemployment rates (20 percent in 1970 and 13.8 percent in 1979), often the highest in the state. Employment opportunities have not kept pace with the growth of the labor force. The Borough is more dependent on seasonal employment than larger population centers such as Anchorage.

Resident civilian employment in the Valdez-Chitina-Whittier census division also rose steadily in the 1970s from 831 in 1970 to 2,180 in 1979, an increase of 162 percent. State/local government and transportation/communications/utilities represent the largest sources of employment. The latter includes employment associated with operation and maintenance of the petroleum pipeline. This census division tends to have unemployment rates slightly higher than state averages.

Nominal personal income rose substantially in the 1970s, stabilizing as the TAPS pipeline was completed. In the Mat-Su Borough, per capita income rose from $3,957 in 1970 to $9,032 in 1977 and declined slightly to $8,878 in 1979. In the Valdez-Chitina-Whittier census division, the boom experience of the 1970s is even more prominent. In 1970 the per capita personal income of $3,822 was similar to the Mat-Su Borough level; with construction of the oil pipeline, per capita income jumped to $21,544 in 1976 and then fell dramatically over the next few years. In 1979, per capita income equalled $9,145.

The area of Palmer and Wasilla are suburban communities of Anchorage, with typical suburban lifestyles. Rural lifestyles are generally found in the more remote communities farther north. Hunting, trapping, and fishing provide not only recreation but seasonal income for a portion of the population. Partial or full self-sufficiency is characteristic of many households, living in an area with limited services and supplying their own heat, water and sewage disposal. Many of the people prefer the rural lifestyles in undeveloped areas and do not wish to see rapid growth. Others, primarily because of depressed economic conditions, hope for increases in development and population, thereby providing economic stimulus.

7.11 - Recreational Resources

Recreational activities currently available in the Upper Susitna Basin are those associated with undeveloped facilities. Hunting, fishing, hiking, and camping are the primary recreational uses, along with boating on the lakes.

There are no publicly developed recreation facilities in the project area. Private facilities include three lodges: Stephen Lake Lodge (10 structures); High Lake Lodge (9 structures); and Tsusena Lake Lodge. Those lodges are used as bases for fishing, hunting, skiing, boating, and hiking. Access is primarily by air.

There are no developed facilities in the impoundment areas, nor are there any areas in the vicinity of the project that are included or designated for inclusion in the National Wild and Scenic River System, the National Trails System, or a federal or state wilderness area.

7.12 - Aesthetic Resources

The Upper Susitna River Basin comprises a diverse landscape composite, roadless and relatively uninhabited. The combination of these factors creates a large region that is aesthetically renowned for its natural beauty, where, depending upon a viewer's location in the basin, a variety of visual groupings free from man-made structures are available. Compared with other areas in Alaska, the aesthetic resources of the project area are, typically, not seen as outstanding. Because the area is a wilderness region positioned between the two major population centers of Fairbanks and Anchorage, the aesthetic resources of the Upper Susitna Basin are important.

The Upper Susitna Basin offers aesthetic diversity created by the juxtaposition of vegetation, water, and topographical features. The landforms of the area are defined by three major elements: the deeply incised Susitna River Valley and its tributaries, the Northern Talkeetna and Chulitna Mountains, and the Northern Talkeetna Plateau. The area's dominating landform is the Plateau. Its features, textures and relief, northeast trending, rounded low mountains, and highlands of generally rolling terrain slope to meet adjacent landforms that are moderately rugged, higher, and more mountainous. The remaining landform types fall in the eastern project area and reflect the influence of the adjoining Copper River Basin. These landforms are characterized by lower mountains and hills widely spaced on the Plateau, and flat terrain interspersed with numerous ponds.

Vegetation is diverse and varies with elevation. A dense spruce- hardwood forest blankets the lower drainages and slopes, while vast meadows of tundra cover higher elevations. A variety of shrubs provides the transition between the two biomes, adding texture and color to the setting. This diversity of vegetation lends itself to the natural occurrence of edge effect found in the more scenic visual groupings.

Color enhances the scenic composite, particularly in autumn when the leaves of deciduous trees turn to golds and oranges, in direct contrast to the dominating dark spruce green. Also in the autumn, the tundra bursts into its brief bloom, adding color to the landscape.

The deeply cut canyons and gorges of the Susitna River scenically exhibit the river's extraordinary power; the gorges are particularly striking at Devil and Vee Canyons where turbulent rapids, rock outcroppings and cliffs, and enclosed walls dominate the scene. The clear, wild, and scenic mountain creeks are aesthetically stimulating; many of them rush over and through steep rocky embankments to form waterfalls. Lakes are numerous in the basin, ranging from small, irregularly shaped lakes in the midst of park-like woods and mountain peaks, to a complex of five finger-shaped lakes set in a black spruce and shrub wetland region.

Viewpoints overlooking the project and adjacent area which are found atop the the higher mountain peaks include Deadman, Devil, and Chulitna Buttes, the ridges above Vee Canyon, and Big Swimming Bear Lakes. On clear days, the scenery includes extensive views of the Central Talkeetna Mountains and the Alaska Range, focusing upon the often spectacular views of Mounts McKinley, Deborah, and Hess, and the Eldridge, West Fork, and Susitna glaciers.

7.13 - Land Use

Existing land use in the area is typical for that of interior undeveloped Alaska. Broad expanses of wilderness areas are present with minimal man-made developments or structures. Abandoned cabins and recreational lodges are the primary man-made structures (Figure 7.19). Significant concentrations of residences, cabins, and other structures occur near Portage Creek, High Lake, Gold Creek, Stephan Lake, Clarence Lake, and Big Lake. Dog sleds and all-terrain vehicles are used as modes of transportation into the area.

There is little land management in the area. Most land in the project area and directly south has been selected by native corporations under provisions of the Alaska Native Claims Settlement Act; lands to the north are generally managed by the U.S. Bureau of Land Management. Figure 7.20 depicts general land use aggregation in the area.

LIST OF REFERENCES

1. R&M Consultants, Susitna Hydroelectric Project, Field Data Collection and Processing, prepared for Acres American Incorporated, December, 1981.

2. R&M Consultants, Susitna Hydroelectric Project, Field Data Index, prepared for Acres American Incorporated, June 1980 (Revised January 1982).

3. R&M Consultants, University of Alaska, Susitna Hydroelectric Project, Glacier Studies, prepared for Acres American Incorporated, December 1981.

4. R&M Consultants, Susitna Hydroelectric Project, Regional Flood Studies, prepared for Acres American Incorporated, December 1981.

5. Acres American Incorporated and R&M Consultants, Susitna Hydroelectric Project, Hydraulic and Ice Studies, prepared for Acres American Incorporated, March 1982.

6. R&M Consultants, Susitna Hydroelectric Project, Reservoir Sedimentation, prepared for Acres American Incorporated, January 1982.

7. R&M Consultants, Susitna Hydroelectric Project, River Morphology, prepared for Acres American Incorporated, January 1982.

8. Woodward-Clyde Consultants, Interim Report on Seismic Studies for Susitna Hydroelectric Project, prepared for Acres American Incorporated, December 1980.

9. Woodward-Clyde Consultants, Final Report on Seismic Studies for Susitna Hydroelectric Project, prepared for Acres American Incorporated, February 1982.

10. Acres American Incorporated, Susitna Hydroelectric Project, 1980-81 Geotechnical Report, prepared for the Alaska Power Authority, February 1982.

TABLE 7.1: TYPICAL NOAA CLIMATE DATA RECORD

Meteorological Data For The Current Year

Station: SUMMIT, ALASKA # 26414 SUMMIT AIRPORT Standard time used: ALASKAN Latitude: 63° 20' N Longitude: 149° 08' W Elevation (ground): 2397 feet Year: 1976

Month	Temperature °F, Averages: Daily maximum	Daily minimum	Monthly	Temperature °F, Extremes: Highest	Date	Lowest	Date	Degree days Base 65 °F: Heating	Cooling	Precipitation in inches, Water equivalent: Total	Greatest in 24 hrs.	Date	Snow, Ice pellets: Total	Greatest in 24 hrs.	Date	Relative humidity, pct. Hour 02 (Local time)	Hour 08	Hour 14	Hour 20
JAN	9.0	-3.8	2.6	34	30	-26	9	1931	0	2.17	1.15	18-19	49.7	21.5	18-19	67	70	73	71
FEB	4.2	-10.4	-3.1	33	5	-28	11	1975	0	1.11	0.50	4	19.6	8.7	5-6		65	65	68
MAR	18.2	2.2	10.2	30	6	-14	15	1696	0	1.65	0.45	3-4	41.1	8.7	3		75	67	
APR	36.3	14.5	25.4	51	30	-3	15	1180	0	0.14	0.08	26	5.8	3.1	26		68		
MAY	43.6	29.4	36.5	54	2	17	7	878	0	2.98	1.90	8	8.7	2.6	8		69		
JUN	60.6	40.9	50.8	74	27	34	8	420	0	0.51	0.30	30	0.0	0.0			69		
JUL	62.1	43.6	52.9	76	23	33	6	368	0	1.05	0.33	23	0.0	0.0			81		
AUG	62.8	41.8	52.3	78	2	31	29	383	0	0.96	0.20	7	0.0	0.0			80		
SEP	49.8	31.7	40.8	59	14	16	30	718	0	1.59	0.48	9	0.4	0.3	20		76		
OCT																			
YEAR																			

Month	Wind, Resultant: Direction	Speed m.p.h.	Average speed m.p.h.	Fastest mile: Speed m.p.h.	Direction	Date	Percent of possible sunshine	Average sky cover, tenths, sunrise to sunset	Number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperature °F, Maximum (b): 90° and above	32° and below	Minimum: 32° and below	0° and below	Average station pressure mb, Elev. 2405 feet m.s.l.
JAN				28	23	30		6.0	11	4	16	12	7	0	2	0	29	31	20	
FEB				31	07	23		3.9	17	4	8	7	6	0	0	0	27	29	24	
MAR				35	07	17		8.0	4	4	23	11	8	0	0	0	31	31	15	
APR				20	08	14		6.2	8	8	14	3	2	0	0	0	8	30	2	
MAY				17	24	18		7.5	5	6	20	7	4	0	0	0	0	27	0	
JUN				18	22	17		6.9	6	8	16	4	0	0	0	3	0	0	0	
JUL				29	23	27		8.1	3	7	21	14	0	0	1	4	0	0	0	
AUG				20	26	7						13	0			5	0	1	0	
SEP				25	25	19		7.6	3	9	18	13	0	0	2	0	0	17	0	
OCT				20	08	12														
YEAR																				

Normals, Means, And Extremes - THROUGH 1975#

Month	Temperatures °F, Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches, Water equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs. $	Year
(a)				35		35					35		35		35	
J	7.9	-4.8	1.6	44	1945	-45	1971	1965	0	0.91	3.38	1948	0.09	1945	0.80	1948
F	13.5	-.4	6.6	45	1942	-45	1947	1635	0	1.23	4.31	1951	T	1950	2.79	1951
M	19.4	3.0	11.2	49	1961	-35	1971	1668	0	1.04	4.53	1946	0.07	1961	1.67	1946
A	32.9	14.1	23.5	57	1956	-30	1944	1245	0	0.67	4.45	1966	0.06	1944	0.97	1963
M	45.7	29.1	37.4	76	1960	-14	1945	856	0	0.77	2.66	1966	0.04	1949	0.96	1946
J	58.0	39.9	49.0	89	1961	25	1947	480	0	2.19	4.45	1949	0.41	1942	2.22	1967
J	60.2	43.8	52.0	81	1961	32	1970	403	0	3.09	5.58	1959	1.17	1955	1.95	1948
A	56.0	41.1	48.6	81	1968	20	1955	508	0	3.30	6.33	1955	0.70	1941	2.10	1944
S	47.1	32.6	39.9	75	1957	6	1956	753	0	2.81	6.13	1965	0.29	1969	2.07	1944
O	30.4	17.5	24.0	59	1969	-15	1975	1271	0	1.62	3.79	1952	0.12	1967	1.24	1963
N	15.7	3.7	9.7	44	1962	-29	1948	1659	0	1.23	4.85	1952	0.06	1963	1.30	1964
D	9.2	-3.4	2.9	42	1969	-43	1961	1925	0	1.20	4.63	1951	0.24	1945	1.09	1967
YR	33.0	18.0	25.5	89	JUN 1961	-45	JAN 1971	14368	0	20.06	6.74	AUG 1944	T	FEB 1950	2.79	FEB 1951

Month	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year	Relative humidity pct. Hour 02 (Local time)	Hour 08	Hour 14	Hour 20	Wind: Mean speed m.p.h. @	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset
(a)	34		35		5	7	7	6	8	5	7	7			7
J	64.8	1948	16.3	1973	68	68	69	68	15.1	NE	44	05	1968		5.2
F	44.5	1951	28.0	1964	76	75	75	76	11.9	NE	46	07	1974		7.0
M	59.1	1946	18.1	1946	76	76	70	73	11.1	NE	48	10	1971		6.2
A	28.7	1970	9.7	1963	80	75	65	75	7.6	NE	33	08	1971		7.2
M	17.4	1958	7.5	1946	83	70	58	67	7.7	W	28	07	1969		7.5
J	9.4	1974	8.7	1974	84	73	57	65	8.3	SW	29	22	1970		8.2
J	9.7	1970	9.7	1970	89	78	62	72	7.8	SW	30	23	1974		8.2
A	9.0	1955	6.0	1955	88	81	62	76	7.4	SW	31	22	1975		8.3
S	21.5	1958	14.0	1955	85	81	59	75	7.5	NE	32	23	1972		7.4
O	54.8	1970	12.6	1970	83	85	76	81	8.0	NE	35	23	1970		7.6
N	75.1	1967	21.9	1970	79	79	78	79	11.3	NE	39	25	1970		7.1
D	50.7	1970	27.4	1970	76	78	76	77	12.7	NE	44	11	1970		6.5
YR	75.1	NOV 1967	28.0	FEB 1964	81	76	67	74	9.7	NE	48	10	MAR 1971		7.2

Month	Mean number of days, Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more †	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F Max. (b): 90° and above	32° and below	Min.: 32° and below	0° and below	Average station pressure mb. Elev. 2405 feet m.s.l.
(a)	7	7	7	20	8	8	8	34	34	34	34	2
J	13	5	13	9	4	0	*	0	30	31	20	921.4
F	6	5	17	10	5	0	1	0	26	28	15	918.8
M	9	6	16	10	5	0	1	0	27	31	14	917.2
A	5	7	18	7	4	0	1	0	13	30	3	922.9
M	3	9	19	7	2	*	1	*	1	22	*	923.1
J	2	6	22	12	1	2	1	3	0	2	0	924.7
J	2	7	22	16	*	2	1	5	0	*	0	929.1
A	2	6	23	18	0	*	1	1	0	2	0	930.3
S	5	5	20	16	2	*	1	*	1	14	0	924.1
O	5	5	21	13	7	0	2	0	18	30	2	916.7
N	7	4	19	9	5	0	1	0	27	30	13	921.3
D	9	5	17	11	6	0	1	0	30	31	19	914.7
YR	68	70	227	138	41	5	12	9	173	251	86	922.0

NOTE: Due to less than full time operation on a variable schedule, manually recorded elements are from broken sequences in incomplete records. Daily temperature extremes and precipitation totals for portions of the record may be for other than a calendar day. The period of record for some elements is for other than consecutive years.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

$ For calendar day prior to 1968.
@ For the period 1950-1954 and January 1968 to date when available for full year.
† For the period 1942-1953 and January 1968 to date when available for full year.

\# Data for this station not available for archiving nor publication of summary effective October 1976.

TABLE 7.2: MONTHLY SUMMARY FOR WATANA WEATHER STATION DATA TAKEN DURING JANUARY 1981

Day	Max. Temp. Deg C	Min. Temp. Deg C	Mean Temp. Deg C	Res. Wind Dir. Deg	Res. Wind Spd. M/S	Avg. Wind Spd. M/S	Max. Gust Dir. M/S	Max. Gust Spd. Deg	P'Val Dir.	Mean RH %	Mean DP Deg C	Precip MM	Day's Solar Energy WH/SQM	Day
01	3.4	0.4	1.9	071	5.7	5.9	085	14.6	ENE	37	-11.7	0.0	***	01
02	2.2	-11.6	- 4.7	083	1.5	1.7	084	5.7	E	45	-15.6	0.0	***	02
03	- 2.4	-13.3	- 7.8	074	3.5	3.7	061	8.9	E	41	-18.3	0.0	***	03
04	- 4.3	- 9.0	- 6.7	058	2.5	2.6	058	7.0	NE	49	-15.0	0.0	***	04
05	- 5.8	-11.8	- 8.8	074	2.2	2.4	081	5.7	E	51	-18.3	0.0	***	05
06	- 3.6	-10.9	- 7.3	068	7.2	7.3	077	14.6	ENE	37	-18.0	0.0	***	06
07	1.2	- 4.8	- 1.8	064	5.0	5.3	076	12.7	ENE	33	-16.0	0.0	***	07
08	- 2.2	- 9.4	- 5.8	072	2.3	2.4	071	7.6	ENE	45	-15.9	0.0	***	08
09	- 1.5	- 6.7	- 4.1	059	5.2	5.3	077	12.1	ENE	30	-19.1	0.0	***	09
10	- 1.8	- 9.2	- 5.5	059	4.0	4.1	073	11.4	ENE	45	-14.8	0.2	***	10
11	- 1.1	- 5.1	- 3.1	062	4.8	4.9	075	10.8	ENE	47	-13.3	0.0	***	11
12	- 1.9	- 9.2	- 5.6	053	2.0	2.1	071	7.6	ENE	48	-14.1	0.0	***	12
13	- 1.2	- 9.9	- 5.6	049	3.8	4.2	099	12.7	ENE	33	-18.3	0.0	***	13
14	3.4	- 3.5	- 0.0	061	5.3	5.6	075	14.0	ENE	46	-10.8	0.0	***	14
15	3.5	- 0.9	1.3	079	3.2	4.1	081	12.7	ENE	51	- 7.3	0.2	***	15
16	0.1	- 5.7	- 2.8	050	2.9	3.2	071	12.1	ENE	45	-13.6	0.0	***	16
17	0.9	- 2.4	- 0.8	060	4.2	4.4	062	12.7	ENE	35	-15.1	0.0	***	17
18	0.9	- 3.6	- 1.3	068	4.8	5.0	074	14.0	ENE	35	-14.3	0.0	***	18
19	1.3	- 6.5	- 2.6	109	0.4	3.9	242	13.3	ENE	40	-14.2	0.8	***	19
20	- 5.8	-13.6	- 9.7	062	4.3	4.4	075	8.9	ENE	38	-20.3	0.0	***	20
21	- 4.8	-12.6	- 8.7	057	5.0	5.1	078	9.5	NE	35	-20.1	0.0	***	21
22	- 1.1	- 5.3	- 3.2	052	4.9	5.0	083	9.5	NE	34	-16.7	0.0	***	22
23	1.4	- 5.1	- 1.9	061	4.5	4.8	083	11.4	NE	40	-13.8	0.0	***	23
24	- 0.1	- 5.0	- 2.6	048	3.5	4.0	055	10.2	ENE	30	-18.3	0.0	***	24
25	1.6	- 3.9	- 1.2	067	4.6	5.0	090	12.1	ENE	23	-19.2	0.0	***	25
26	- 4.2	- 8.3	- 6.3	342	0.6	1.4	088	3.8	WSW	52	-14.3	0.2	***	26
27	- 6.2	-14.4	-10.3	062	1.0	1.2	059	3.2	ENE	51	-17.8	0.0	***	27
28	-11.3	-17.7	-14.5	065	4.5	4.6	065	14.6	ENE	44	-23.7	0.0	***	28
29	- 2.2	-12.3	- 7.3	058	6.2	6.4	070	13.3	NE	38	-19.7	0.0	***	29
30	1.7	- 3.2	- 0.7	068	5.7	5.8	075	12.1	ENE	26	-18.3	0.0	***	30
31	- 0.1	- 4.2	- 2.2	053	2.8	2.9	045	7.6	ENE	38	-14.7	0.2	***	31
MONTH	3.5	-17.7	- 4.5	062	3.8	4.2	085	14.6	ENE	40	-16.2	1.6	***	

Gust Vel. at Max. Gust Minus 2 Intervals	13.3
Gust Vel. at Max. Gust Minus 1 Interval	12.7
Gust Vel. at Max. Gust Plus 1 Interval	12.1
Gust Vel. at Max. Gust Plus 2 Intervals	12.7

TABLE 7.3: SUMMARY OF CLIMATOLOGICAL DATA

STATION	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL	PERIOD OF RECORD
MEAN MONTHLY PRECIPITATION IN INCHES														
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	1941 - 70
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	1941 - 70
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	1941 - 70
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	1951 - 75
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	1951 - 75
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	1951 - 75
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	1941 - 70
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		1941 - 70
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	1941 - 70
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	1941 - 70
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	1941 - 70
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	1951 - 75
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	1951 - 75
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	1951 - 75
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	1941 - 70

TABLE 7.4: 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 7.5: PAN EVAPORATION DATA

	Average Monthly Plan Evaporation, Inches					
	Matanuska Valley Agricultural Expansion Station		University Expansion Station		Watana Camp	
Month	Evaporation	Years Recorded	Evaporation	Years Recorded	Evaporation	Years Recorded
May	4.63	15	4.46	19	3.6	1
June	4.58	24	5.09	26	3.6	1
July	4.09	29	4.50	30	3.3	1
August	2.99	29	2.96	30	2.5	1
September	1.83	26	1.42	24	1.5	1
SUBTOTAL	18.12		18.43		14.3	

TABLE 7.6: AVERAGE ANNUAL AND MONTHLY FLOW AT GAGE IN THE SUSITNA BASIN*

	STATION (USGS Reference Number)							
	Susitna River at Gold Creek (2920)		Susitna River Near Cantwell (2915)		Susitna River Near Denali (2910)		Maclaren River Near Paxson (2912)	
MONTH Drainage Area sq. mi.	6160		4140		950		280	
	%	Mean(cfs)	%	Mean(cfs)	%	Mean(cfs)	%	Mean(cfs)
JANUARY	1	1,453	1	824	1	244	1	96
FEBRUARY	1	1,235	1	722	1	206	1	84
MARCH	1	1,114	1	692	1	188	1	76
APRIL	1	1,367	1	853	1	233	1	87
MAY	12	13,317	10	7,701	6	2,036	7	803
JUNE	24	27,928	26	19,326	22	7,285	25	2,920
JULY	21	23,853	23	16,892	28	9,350	27	3,181
AUGUST	19	21,478	20	14,658	24	8,050	22	2,573
SEPTEMBER	12	13,171	10	7,800	10	3,350	10	1,149
OCTOBER	5	5,639	4	3,033	3	1,122	3	409
NOVEMBER	2	2,467	2	1,449	2	490	1	177
DECEMBER	2	1,773	1	998	1	314	1	118
ANNUAL - cfs	100	9,566	100	6,246	100	2,739	100	973

Period of Record - Gold Creek - 1950-79
Cantwell - 1961-72
Denali - 1957-79
Maclaren - 1957-79

* Ref. USGS Streamflow Data

TABLE 7.7: GOLD CREEK NATURAL FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1950	6335.0	2583.0	1439.0	1027.0	788.0	726.0	870.0	11510.0	19600.0	22600.0	19880.0	8301.0	7971.6
1951	3848.0	1300.0	1100.0	960.0	820.0	740.0	1617.0	14090.0	20790.0	22570.0	19670.0	21240.0	9062.1
1952	5571.0	2744.0	1900.0	1600.0	1000.0	880.0	920.0	5419.0	32370.1	26390.0	20920.0	14480.0	9516.2
1953	8202.0	3497.0	1700.0	1100.0	820.0	820.0	1615.0	19270.0	27320.1	20200.0	20610.0	15270.0	10035.3
1954	5604.0	2100.0	1500.0	1300.0	1000.0	780.0	1235.0	17280.0	25250.0	20360.0	26100.0	12920.0	9619.1
1955	5370.0	2760.0	2045.0	1794.0	1400.0	1100.0	1200.0	9319.0	29860.0	27560.0	25750.0	14290.0	10204.0
1956	4951.0	1900.0	1300.0	980.0	970.0	940.0	950.0	17660.0	33340.0	31090.1	24530.0	18330.0	11411.8
1957	5806.0	3050.0	2142.0	1700.0	1500.0	1200.0	1200.0	13750.0	30160.0	23310.0	20540.0	19800.0	10346.5
1958	8212.0	3954.0	3264.0	1965.0	1307.0	1148.0	1533.0	12900.0	25700.0	22880.0	22540.0	7550.0	9412.8
1959	4811.0	2150.0	1513.0	1448.0	1307.0	980.0	1250.0	15990.0	23320.0	25000.0	31180.0	16920.0	10489.1
1960	6558.0	2850.0	2200.0	1845.0	1452.0	1197.0	1300.0	15780.0	15530.0	22980.0	23590.0	20510.0	9649.3
1961	7794.0	3000.0	2694.0	2452.0	1754.0	1810.0	2650.0	17360.0	29450.0	24570.0	22100.0	13370.0	10750.3
1962	5916.0	2700.0	2100.0	1900.0	1500.0	1400.0	1700.0	12590.0	43270.0	25850.0	23550.0	15890.0	11530.5
1963	6723.0	2800.0	2000.0	1600.0	1500.0	1000.0	830.0	19030.0	26000.0	34400.0	23670.0	12320.0	10989.4
1964	6449.0	2250.0	1494.0	1048.0	966.0	713.0	745.0	4307.0	50580.0	22950.0	16440.0	9571.0	9792.8
1965	6291.0	2799.0	1211.0	960.0	860.0	900.0	1360.0	12990.0	25720.0	27840.0	21120.0	19350.0	10116.8
1966	7205.0	2098.0	1631.0	1400.0	1300.0	1300.0	1775.0	9645.0	32950.0	19860.0	21830.0	11750.0	9395.3
1967	4163.0	1600.0	1500.0	1500.0	1400.0	1200.0	1167.0	15480.0	29510.0	26800.0	32620.0	16870.0	11150.8
1968	4900.0	2353.0	2055.0	1981.0	1900.0	1900.0	1910.0	16180.0	31550.0	26420.0	17170.0	8816.0	9761.3
1969	3822.0	1630.0	882.0	724.0	723.0	816.0	1510.0	11050.0	15500.0	16100.0	8879.0	5093.0	5560.8
1970	3124.0	1215.0	866.0	824.0	768.0	776.0	1080.0	11380.0	18630.0	22660.0	19980.0	9121.0	7535.3
1971	5288.0	3407.0	2290.0	1442.0	1036.0	950.0	1082.0	3745.0	32930.0	23950.0	31910.0	14440.0	10205.8
1972	5847.0	3093.0	2510.0	2239.0	2028.0	1823.0	1710.0	21890.0	34430.0	22770.0	19290.0	12400.0	10835.8
1973	4826.0	2253.0	1465.0	1200.0	1200.0	1000.0	1027.0	8235.0	27800.0	18250.0	20290.0	9074.0	8051.7
1974	3733.0	1523.0	1034.0	874.0	777.0	724.0	992.0	16180.0	17870.0	18800.0	16220.0	12250.0	7581.4
1975	3739.0	1700.0	1603.0	1516.0	1471.0	1400.0	1593.0	15350.0	32310.0	27720.0	18090.0	16310.0	10233.5
1976	7739.0	1993.0	1081.0	974.0	950.0	900.0	1373.0	12620.0	24380.0	18940.0	19800.0	6881.0	8135.9
1977	3874.0	2650.0	2403.0	1829.0	1618.0	1500.0	1680.0	12680.0	37970.0	22870.0	19240.0	12640.0	10079.5
1978	7571.0	3525.0	2589.0	2029.0	1668.0	1605.0	1702.0	11950.0	19050.0	21020.0	16390.0	8607.0	8142.2
1979	4907.0	2535.0	1681.0	1397.0	1286.0	1200.0	1450.0	13870.0	24690.0	28880.1	20460.0	10770.0	9427.2
1980	7311.0	4192.0	2416.0	1748.0	1466.0	1400.0	1670.0	12060.0	29080.0	32660.0	20960.0	13280.0	10686.9
1981	7725.0	3986.0	1773.1*	1453.6*	1235.6*	1114.3*	1367.5*	13316.7*	18143.0	32000.0	38538.0	13171.1*	11152.0
AVE	5756.7	2568.4	1793.2	1462.8	1242.8	1123.2	1377.0	13277.4	27657.9	24382.8	21995.5	13174.5	9651.0

*Long term average flows assumed

TABLE 7.8: WATANA ESTIMATED NATURAL FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1950	4719.9[1]	2083.6	1168.9	815.1	641.7	569.1	680.1	8655.9	16432.1	19193.4	16913.6	7320.4	6599.5
1951	3299.1	1107.3	906.2	808.0	673.0	619.8	1302.2	11649.8	18517.9	19786.6	16478.0	17205.5	7696.1
1952	4592.9	2170.1	1501.0	1274.5	841.0	735.0	803.9	4216.5	25773.4	22110.9	17356.3	11571.0	7745.5
1953	6285.7	2756.8	1281.2	818.9	611.7	670.7	1382.0	15037.2	21469.8	17355.3	16681.6	11513.5	7988.7
1954	4218.9	1599.6	1183.8	1087.8	803.1	638.2	942.6	11696.8	19476.7	16983.6	20420.6	9165.5	7351.4
1955	3859.2	2051.1	1549.5	1388.3	1050.5	886.1	940.8	6718.1	24881.4	23787.9	23537.0	13447.8	8674.8
1956	4102.3	1588.1	1038.6	816.9	754.8	694.4	718.3	12953.3	27171.8	25831.3	19153.4	13194.4	9001.5
1957	4208.0	2276.6	1707.0	1373.0	1189.0	935.0	945.1	10176.2	25275.0	19948.9	17317.7	14841.1	8349.4
1958	6034.9	2935.9	2258.5	1480.6	1041.7	973.5	1265.4	9957.8	22097.8	19752.7	18843.4	5978.7	7718.4
1959	3668.0	1729.5	1115.1	1081.0	949.0	694.0	885.7	10140.6	18329.6	20493.1	23940.4	12466.9	7957.7
1960	5165.5	2213.5	1672.3	1400.4	1138.9	961.1	1069.9	13044.2	13233.4	19506.1	19323.1	16085.6	7901.2
1961	6049.3	2327.8	1973.2	1779.9	1304.8	1331.0	1965.0	13637.9	22784.1	19839.8	19480.2	10146.2	8551.6
1962	4637.6	2263.4	1760.4	1608.9	1257.4	1176.8	1457.4	11333.5	36017.1	23443.7	19887.1	12746.2	9799.1
1963	5560.1	2508.9	1708.9	1308.9	1184.7	883.6	776.6	15299.2	20663.4	28767.4	21011.4	10800.0	9206.1
1964	5187.1	1789.1	1194.7	852.0	781.6	575.2	609.2	3578.8	42841.9	20082.8	14048.2	7524.2	8255.4
1965	4759.4	2368.2	1070.3	863.0	772.7	807.3	1232.4	10966.0	21213.0	23235.9	17394.1	16225.6	8409.0
1966	5221.2	1565.3	1203.6	1060.4	984.7	984.7	1338.4	7094.1	25939.6	16153.5	17390.9	9214.1	7345.9
1967	3269.8	1202.2	1121.6	1102.2	1031.3	889.5	849.7	12555.5	24711.9	21987.3	26104.5	13672.9	9041.5
1968	4019.0	1934.3	1704.2	1617.6	1560.4	1560.4	1576.7	12826.7	25704.0	22082.8	14147.5	7163.6	7991.4
1969	3135.0	1354.9	753.9	619.2	607.5	686.0	1261.6	9313.7	13962.1	14843.5	7771.9	4260.0	4880.8
1970	2403.1	1020.9	709.3	636.2	602.1	624.1	986.4	9536.4	14399.0	18410.1	16263.8	7224.1	6068.0
1971	3768.0	2496.4	1687.4	1097.1	777.4	717.1	813.7	2857.2	27612.8	21126.4	27446.6	12188.9	8549.1
1972	4979.1	2587.0	1957.4	1670.9	1491.4	1366.0	1305.4	15973.1	27429.3	19820.3	17509.5	10955.7	8920.4
1973	4301.2	1977.9	1246.5	1031.5	1000.2	873.9	914.1	7287.0	23859.3	16351.1	18016.7	8099.7	7079.9
1974	3056.5	1354.7	931.6	786.4	689.9	627.3	871.9	12889.0	14780.6	15971.9	13523.7	9786.2	6272.5
1975	3088.8	1474.4	1276.7	1215.8	1110.3	1041.4	1211.2	11672.2	26689.2	23430.4	15126.6	13075.3	8367.7
1976	5679.1	1601.1	876.2	757.8	743.2	690.7	1059.8	8938.8	19994.0	17015.3	18393.5	5711.5	6788.4
1977	2973.5	1926.7	1687.5	1348.7	1202.9	1110.8	1203.4	8569.4	31352.8	19707.3	16807.3	10613.1	8208.6
1978	5793.9	2645.3	1979.7	1577.9	1267.7	1256.7	1408.4	11231.5	17277.2	18385.2	13412.1	7132.6	6947.4
1979	3773.9	1944.9	1312.6	1136.8	1055.4	1101.2	1317.9	12369.3	22904.8	24911.7	16670.7	9096.7	8133.0
1980	6150.0[3]	3525.0[3]	2032.0[3]	1470.0[3]	1233.0[3]	1177.0[3]	1404.0[3]	10140.0[3]	23400.0[2]	26740.0[2]	18000.0[2]	11000.0[2]	8855.9
1981	6458.0[2]	3297.0[2]	1385.0[4]	1147.0[4]	971.0[4]	889.0[4]	1103.0[4]	10406.0[4]	17323.0[2]	27840.0[2]	31435.0[2]	12026.0[2]	9523.3
AVE	4513.1	2052.4	1404.8	1157.3	978.9	898.3	1112.6	10397.6	22922.4	20778.0	18431.4	10670.4	7943.1

Notes: (1) Discharges based on Cantwell and Gold Creek flows unless specified
(2) Watana observed flows
(3) Flows based on Gold Creek
(4) Watana long-term average flows assumed

TABLE 7.9: DEVIL CANYON ESTIMATED NATURAL FLOWS

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1950	5758.2	2404.7	1342.5	951.3	735.7	670.0	802.2	10490.7	18468.6	21383.4	18820.6	7950.8	7481.6
1951	3652.0	1231.2	1030.8	905.7	767.5	697.1	1504.6	13218.5	19978.5	21575.9	18530.0	19799.1	8574.2
1952	5221.7	2539.0	1757.5	1483.7	943.2	828.2	878.5	4989.5	30014.2	24861.7	19647.2	13441.1	8883.8
1953	7517.6	3232.6	1550.4	999.6	745.6	766.7	1531.8	17758.3	25230.7	19184.0	19207.0	13928.4	9304.4
1954	5109.3	1921.3	1387.1	1224.2	929.7	729.4	1130.6	15286.0	23188.1	19154.1	24071.6	11579.1	8809.2
1955	4830.4	2506.8	1868.0	1649.1	1275.2	1023.6	1107.4	8390.1	28081.9	26212.8	24959.6	13989.2	9657.8
1956	4647.9	1788.6	1206.6	921.7	893.1	852.3	867.3	15979.0	31137.1	29212.0	22609.8	16495.8	10550.9
1957	5235.3	2773.8	1986.6	1583.2	1388.9	1105.4	1109.0	12473.6	28415.4	22109.6	19389.2	18029.0	9633.3
1958	7434.5	3590.4	2904.9	1792.0	1212.2	1085.7	1437.4	11849.2	24413.5	21763.1	21219.8	6988.8	8807.6
1959	4402.8	1999.8	1370.9	1316.9	1179.1	877.9	1119.9	13900.9	21537.7	23390.4	28594.4	15329.6	9585.0
1960	6060.7	2622.7	2011.5	1686.2	1340.2	1112.8	1217.8	14802.9	14709.8	21739.3	22066.1	18929.9	9025.0
1961	7170.9	2759.9	2436.6	2212.0	1593.6	1638.9	2405.4	16030.7	27069.3	22880.6	21164.4	12218.6	9965.1
1962	5459.4	2544.1	1978.7	1796.0	1413.4	1320.3	1613.4	12141.2	40679.7	24990.6	22241.8	14767.2	10912.2
1963	6307.7	2696.0	1896.0	1496.0	1387.4	958.4	810.9	17697.6	24094.1	32388.4	22720.5	11777.2	10352.5
1964	5998.3	2085.4	1387.1	978.0	900.2	663.8	696.5	4046.9	47816.4	21926.0	15585.8	8840.0	9243.7
1965	5744.0	2645.1	1160.8	925.3	828.8	866.9	1314.4	12267.1	24110.3	26195.7	19789.3	18234.2	9506.8
1966	6496.5	1907.8	1478.4	1278.7	1187.4	1187.4	1619.1	8734.0	30446.3	18536.2	20244.6	10844.3	8663.4
1967	3844.0	1457.9	1364.9	1357.9	1268.3	1089.1	1053.7	14435.5	27796.4	25081.2	30293.0	15728.2	10397.5
1968	4585.3	2203.5	1929.7	1851.2	1778.7	1778.7	1791.0	14982.4	29462.1	24871.0	16090.5	8225.9	9129.2
1969	3576.7	1531.8	836.3	686.6	681.8	769.6	1421.3	10429.9	14950.7	15651.2	8483.6	4795.5	5317.9
1970	2866.5	1145.7	810.0	756.9	708.7	721.8	1046.6	10721.6	17118.9	21142.2	18652.8	8443.5	7011.3
1971	4745.2	3081.8	2074.8	1318.8	943.6	866.8	986.2	3427.9	31031.0	22941.6	30315.9	13636.0	9614.1
1972	5537.0	2912.3	2312.6	2036.1	1836.4	1659.8	1565.5	19776.8	31929.8	21716.5	18654.1	11884.2	10151.8
1973	4638.6	2154.8	1387.0	1139.8	1128.6	955.0	986.7	7896.4	26392.6	17571.8	19478.1	8726.0	7704.6
1974	3491.4	1462.9	997.4	842.7	745.9	689.5	949.1	15004.6	16766.7	17790.0	15257.0	11370.1	7113.9
1975	3506.8	1619.4	1486.5	1408.8	1342.2	1271.9	1456.7	14036.5	30302.6	26188.0	17031.6	15154.7	9567.1
1976	7003.3	1853.0	1007.9	896.8	876.2	825.2	1261.2	11305.3	22813.6	18252.6	19297.7	6463.3	7654.7
1977	3552.4	2391.7	2147.5	1657.4	1469.7	1361.0	1509.8	11211.9	35606.7	21740.5	18371.2	11916.1	9411.3
1978	6936.3	3210.8	2371.4	1867.9	1525.0	1480.6	1597.1	11693.4	18416.8	20079.0	15326.5	8080.4	7715.4
1979	4502.3	2324.3	1549.4	1304.1	1203.6	1164.7	1402.8	13334.0	24052.4	27462.8	19106.7	10172.4	8965.0
1980*	6900.0	3955.0	2279.0	1649.0	1383.0	1321.0	1575.0	11377.0	26255.0	30002.0	20196.0	12342.0	9936.2
1981*	7246.0	3699.0	1554.0	1287.0	1089.0	997.0	1238.0	11676.0	19436.0	31236.0	35270.0	13493.0	10685.1
AVE	5311.8	2382.9	1652.0	1351.9	1146.9	1041.8	1281.5	12230.2	25991.3	23100.9	20709.0	12299.2	9041.6

* Discharges based on Watana flows

TABLE 7.10: PEAK FLOWS OF RECORD

Gold Creek		Cantwell		Denali		Maclaren	
Date	Peak ft^3/s	Date	Peak ft^3/s	Date	Peak ft^3/s	Date	Peak ft^3/s
8/25/59	62,300	6/23/61	30,500	8/18/63	17,000	9/13/60	8,900
6/15/62	80,600	6/15/62	47,000	6/07/64	16,000	6/14/62	6,650
6/07/64	90,700	6/07/64	50,500	9/09/65	15,800	7/18/65	7,350
6/06/66	63,600	8/11/70	20,500	8/14/67	28,200	8/14/67	7,600
8/15/67	80,200	8/10/71	60,000	7/27/68	19,000	8/10/71	9,300
8/10/71	87,400	6/22/72	45,000	8/08/71	38,200	6/17/72	7,100

TABLE 7.11: ESTIMATED FLOOD PEAKS IN SUSITNA RIVER

Location	Peak Inflow in Cfs for Recurrence Interval in Years				
	1:2	1:50	1:100	1:10,000	PMF
Gold Creek	48,000	105,000	118,000	200,000	408,000
Watana Damsite	42,000	82,000	92,000	156,000	326,000
Devil Canyon Damsite (Routed Peak Inflow with Watana)	12,600	43,000	61,000	165,000	346,000

TABLE 7.12: MAXIMUM RECORDED ICE THICKNESS ON THE SUSITNA RIVER

	Historical Data			Current Program
	Maximum Ice Thickness		Year of	Maximum Ice Thickness
Location	Period of Record	(Feet)	Observation	Observed in 1980 (feet)
Maclaren River at Paxson	1960-68	5.2	1964	-
Susitna River at Cantwell	1962-70	5.3	1967	10.0
Susitna River at Gold Creek	1950-70	5.7	1963	3.2
Talkeetna River at Talkeetna	1966-71	3.3	1969	-
Chulitna River at Talkeetna	1961-72	5.3	1971	-
Watana Damsite	1980-81	NA	-	5.0
Devil Canyon	1980-81	NA	-	23.0*

* Ice shelf thickness - notice cover.

TABLE 7.13: SUSPENDED SEDIMENT TRANSPORT IN SUSITNA RIVER

Location	Average Annual Suspended Sediment load (tons/year)
Susitna River at Denali	2,965,000
Maclaren River near Paxson	543,000
Susitna River near Cantwell	6,898,000
Susitna River at Gold Creek	7,731,000

TABLE 7.14: ESTIMATED SEDIMENT DEPOSITION IN RESERVORS

Reservoir	Trap Efficiency %	Sediment Deposition: 50 - Year: Deposition ac - ft	50 - Year: % of Reservoir Gross Volume	100 - Year: Deposition ac - ft	100 - Year: % of Reservoir Gross Volume
Watana	100	240,000	2.5	472,000	5.0
	70	170,000	1.8	334,000	3.5
Devil Canyon (with Watana 100%)	100	8,600	0.8	16,800	1.5
	70	6,100	0.6	12,100	1.1
Devil Canyon (with Watana 70%)	100	79,000	7.2	155,000	14.2
	70	55,000	5.0	109,000	10.0

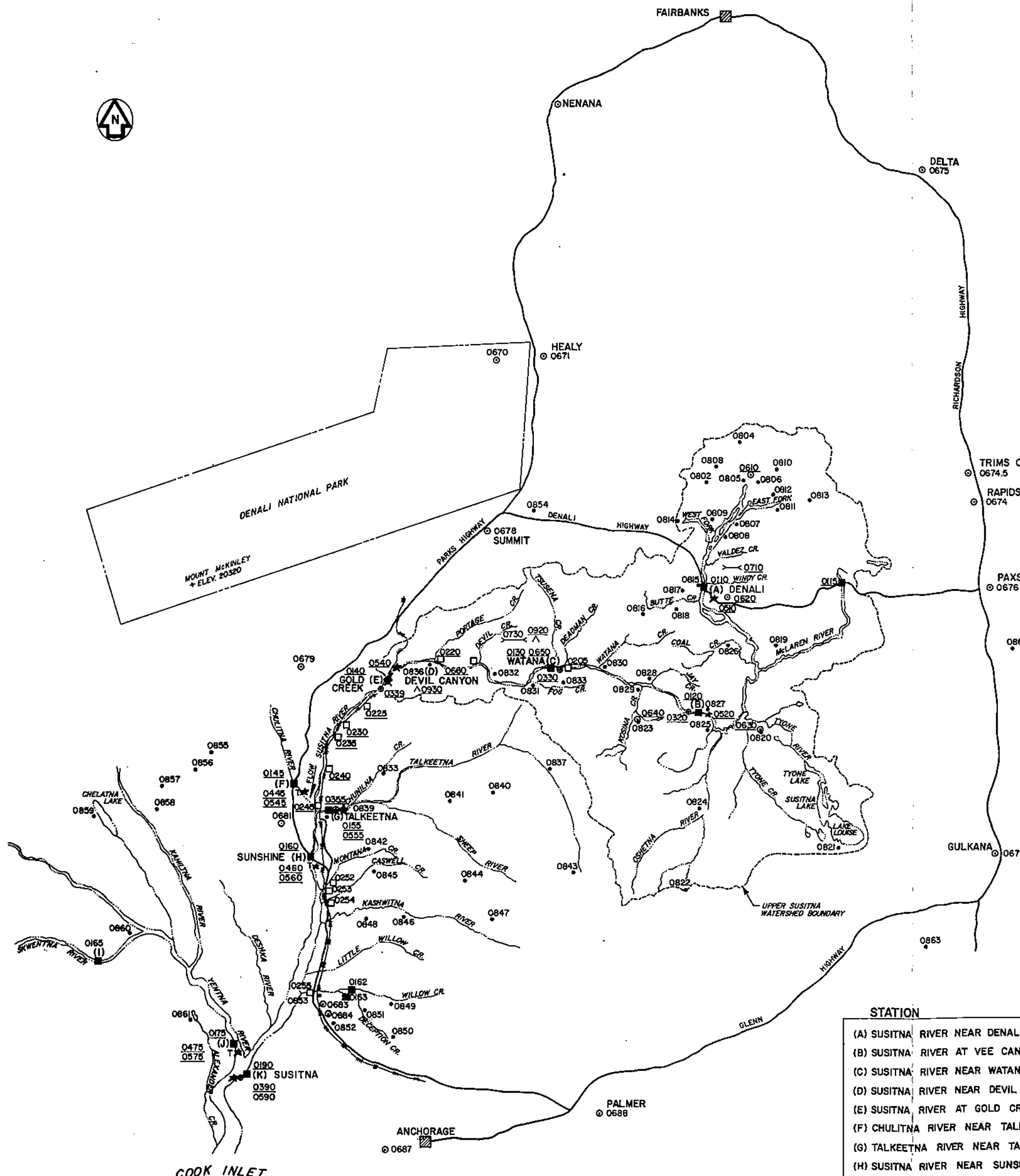
TABLE 7.15: WATER APPROPRIATIONS WITHIN ONE MILE OF THE SUSITNA RIVER

LOCATION*	ADDITIONAL NUMBER	TYPE	SOURCE (DEPTH)	AMOUNT	DAYS OF USE
CERTIFICATE					
T19N R5W	45156	Single-family dwelling	well (?)	650 gpd	365
		general crops	same source	0.5 ac-ft/yr	91
T25N R5W	43981	Single-family dwelling	well (90 ft)	500 gpd	365
T26N R5W	78895	Single-family dwelling	well (20 ft)	500 gpd	365
	200540	Grade school	well (27 ft)	910 gpd	334
	209233	Fire station	well (34 ft)	500 gpd	365
T27N R5W	200180	Single-family dwelling	unnamed stream	200 gpd	365
		Lawn & garden irrigation	same source	100 gpd	153
	200515	Single-family dwelling	unnamed lake	500 gpd	365
	206633	Single-family dwelling	unnamed lake	75 gpd	365
	206930	Single-family dwelling	unnamed lake	250 gpd	365
	206931	Single-family dwelling	unnamed lake	250 gpd	365
PERMIT					
	206929	General crops	unnamed creek	1 ac-ft/yr	153
T30N R3W	206735	Single-family dwelling	unnamed stream	250 gpd	365
PENDING					
	209866	Single-family dwelling	Sherman Creek	75 gpd	365
		Lawn & garden irrigation	same source	50 gpd	183

*All locations are within the Seward Meridian.

TABLE 7.16: HECTARES AND PERCENTAGE OF TOTAL AREA COVERED BY VEGETATION/HABITAT TYPES

	Hectares	Percent of Total Area
Total Vegetation	1,387,607	85.08
Forest	348,232	21.35
Conifer	307,586	18.86
Woodland spruce	188,391	11.55
Open spruce	118,873	7.29
Closed spruce	323	0.02
Deciduous	1,290	0.08
Open birch	968	0.06
Closed birch	323	0.02
Mixed	39,355	2.41
Open	23,387	1.43
Closed	15,968	0.98
Tundra	394,685	24.20
Wet sedge-grass	4,839	0.30
(Mesic) sedge-grass	184,358	11.30
Herbaceous alpine	807	0.05
Mat and cushion	65,001	3.99
Mat and cushion/sedge-grass	139,680	8.56
Shrubland	644,690	39.53
Tall shrub	129,035	7.91
Low shrub	515,655	31.62
Birch	33,549	2.06
Willow	10,645	0.65
Mixed	471,461	28.91
Unvegetated	243,392	14.92
Water	39,840	2.44
Lakes	25,162	1.54
Rivers	14,678	0.90
Rock	113,712	6.97
Snow and ice	89,841	5.51
Total Area	1,630,999	100.00



DATA COLLECTION STATIONS

DATA COLLECTED

	INDEX NUMBERING
■ STREAMFLOW - CONTINUOUS RECORD	0100
□ STREAMFLOW - PARTIAL RECORD	0200
⊕ WATER QUALITY	0300
T WATER TEMPERATURE	0400
★ SEDIMENT DISCHARGE	0500
⊙ CLIMATE	0600
⟼ FREEZING RAIN AND INCLOUD ICING	0700
• SNOW COURSE	0800
^ SNOW CREEP	0900

NOTES

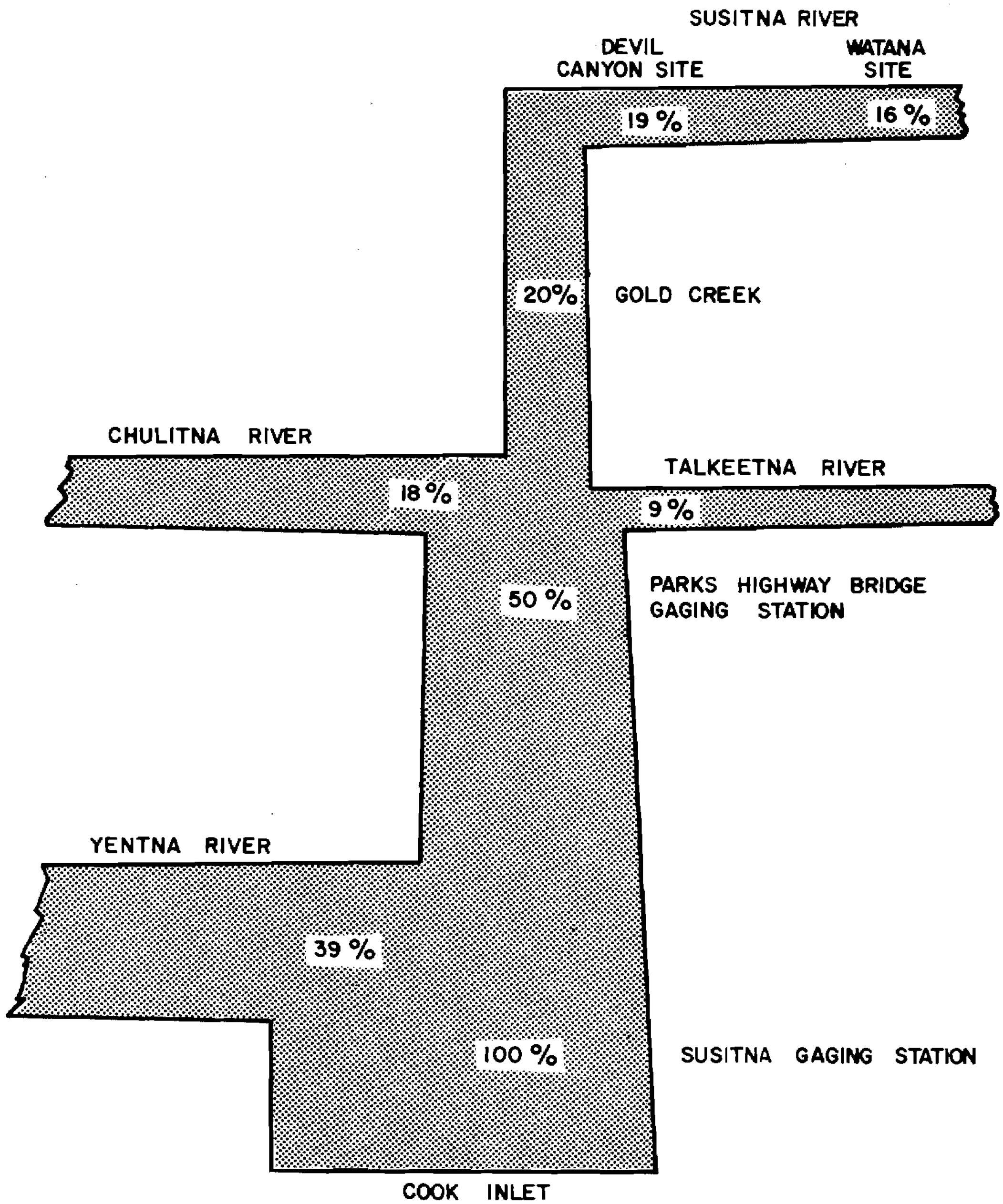
1. PARAMETERS MEASURED LISTED IN APPENDIX B1
2. CONTINUOUS WATER QUALITY MONITOR INSTALLED
3. DATA COLLECTION 1981 SEASON
4. THE LETTER BEFORE EACH STATION NAME IN THE TABLE IS USED ON THE MAP TO MARK THE APPROXIMATE LOCATION OF THE STATIONS.
5. STATION NUMBERS UNDERLINED INDICATES DATA COLLECTED BY STUDY TEAM IN 1980-82. SNOW COURSES MEASURED ARE NOT UNDERLINED FOR CLARITY.

STATION	STREAMFLOW GAGING	CREST STAGE GAGE	STAFF GAGE	WATER QUALITY (1)	WATER TEMPERATURE	SEDIMENT DISCHARGE	BEDLOAD SAMPLING (3)	CLIMATE	IN-CLOUD ICING	FREEZING RAIN	SNOW CREEP	PERIOD OF RECORD OF STREAMFLOW
(A) SUSITNA RIVER NEAR DENALI	X		X		X	X		X	X	X		1957 – PRESENT
(B) SUSITNA RIVER AT VEE CANYON	X		X	X	X	X						1961 – 1972 & 1980 – PRESENT
(C) SUSITNA RIVER NEAR WATANA DAMSITE	X	X		X[2]	X			X	X	X	X	1980 – PRESENT
(D) SUSITNA RIVER NEAR DEVIL CANYON		X	X					X			X	
(E) SUSITNA RIVER AT GOLD CREEK	X			X	X	X	X					1949 – PRESENT
(F) CHULITNA RIVER NEAR TALKEETNA	X				X	X	X					1958 – 1972 & 1980 – PRESENT
(G) TALKEETNA RIVER NEAR TALKEETNA	X			X	X	X	X					1964 – PRESENT
(H) SUSITNA RIVER NEAR SUNSHINE	X				X	X	X					1981 – PRESENT
(I) SKWENTNA RIVER NEAR SKWENTNA	X			X	X	X		X				1959 – 1980
(J) YENTNA RIVER NEAR SUSITNA STATION	X				X	X						1980 – PRESENT
(K) SUSITNA RIVER AT SUSITNA STATION	X			X	X	X						1974 – PRESENT

SCALE 0 10 20 MILES (APPROX.)

FIGURE 7.1

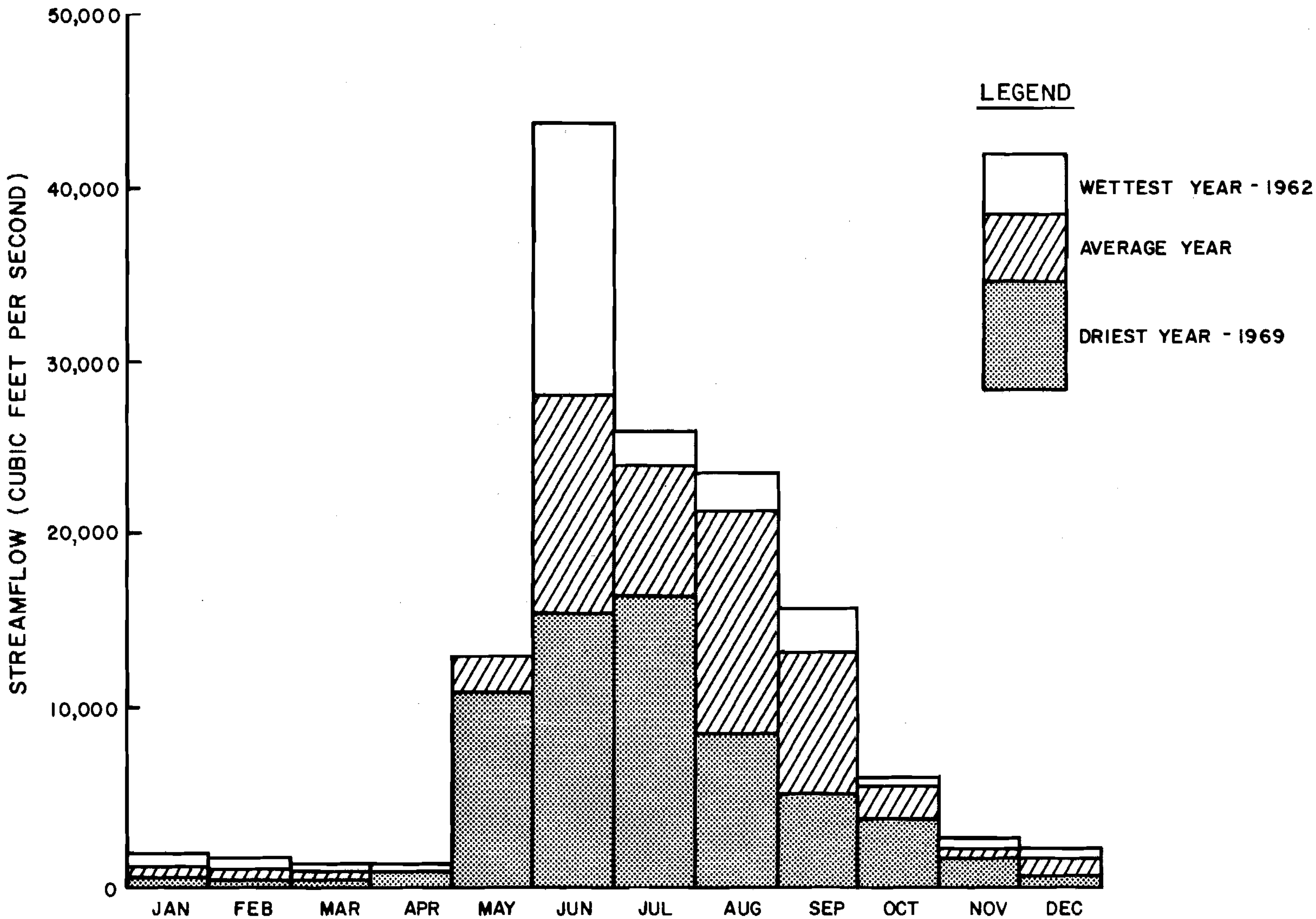
ACRES



AVERAGE ANNUAL FLOW DISTRIBUTION WITHIN THE SUSITNA RIVER BASIN

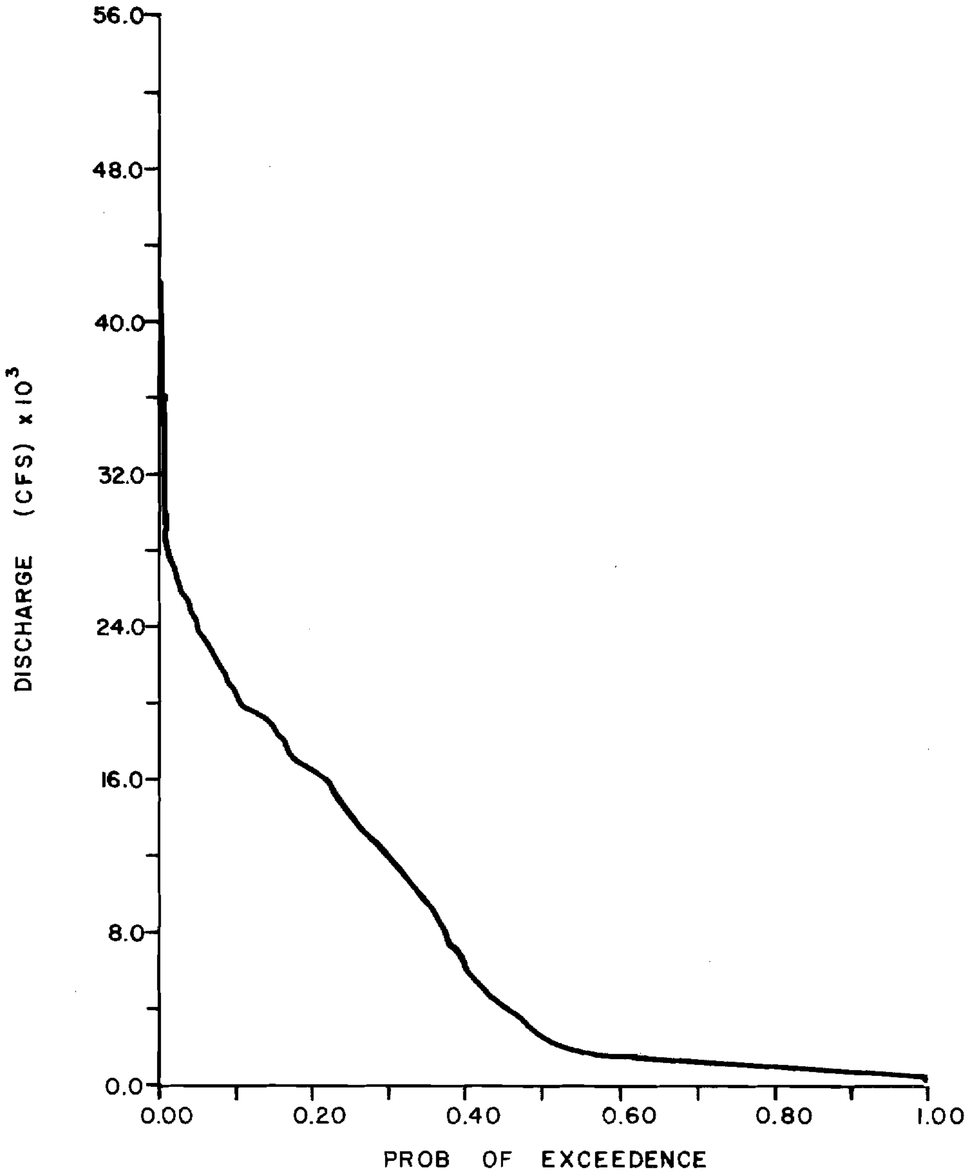
FIGURE 7.2

ACRES



MONTHLY AVERAGE FLOWS IN
THE SUSITNA RIVER AT GOLD CREEK

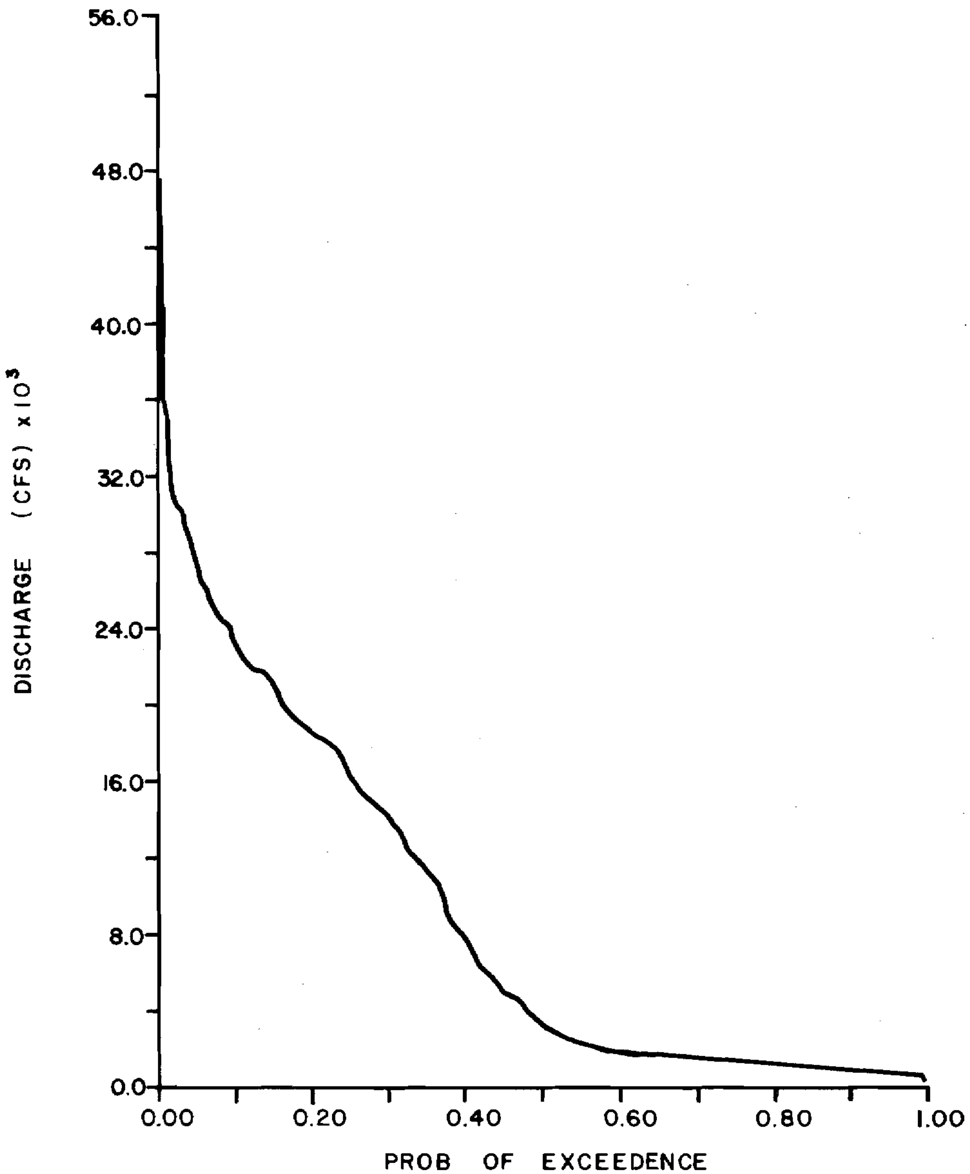
FIGURE 7.3



FLOW DURATION CURVE
MEAN MONTHLY INFLOW
AT WATANA
PRE-PROJECT

ACRES

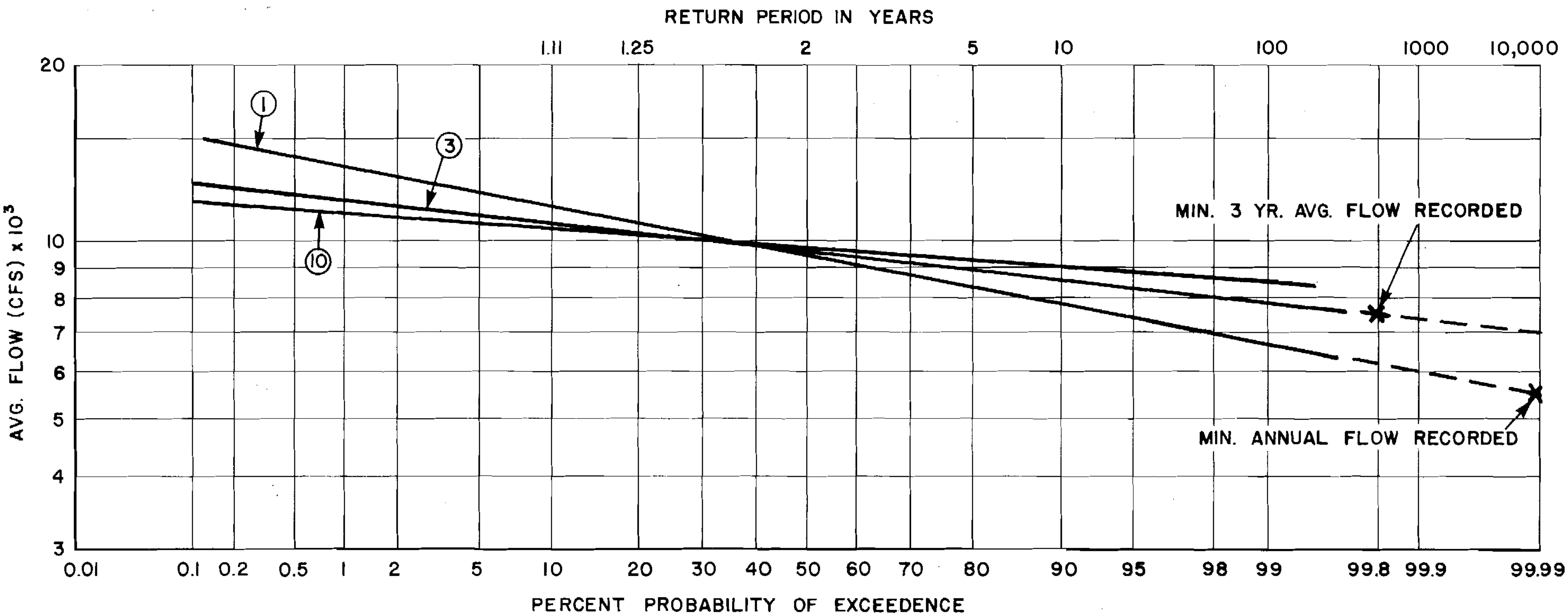
FIGURE 7.4



FLOW DURATION CURVE
MEAN MONTHLY INFLOW
AT DEVIL CANYON
PRE-PROJECT

ACRES

FIGURE 7.5

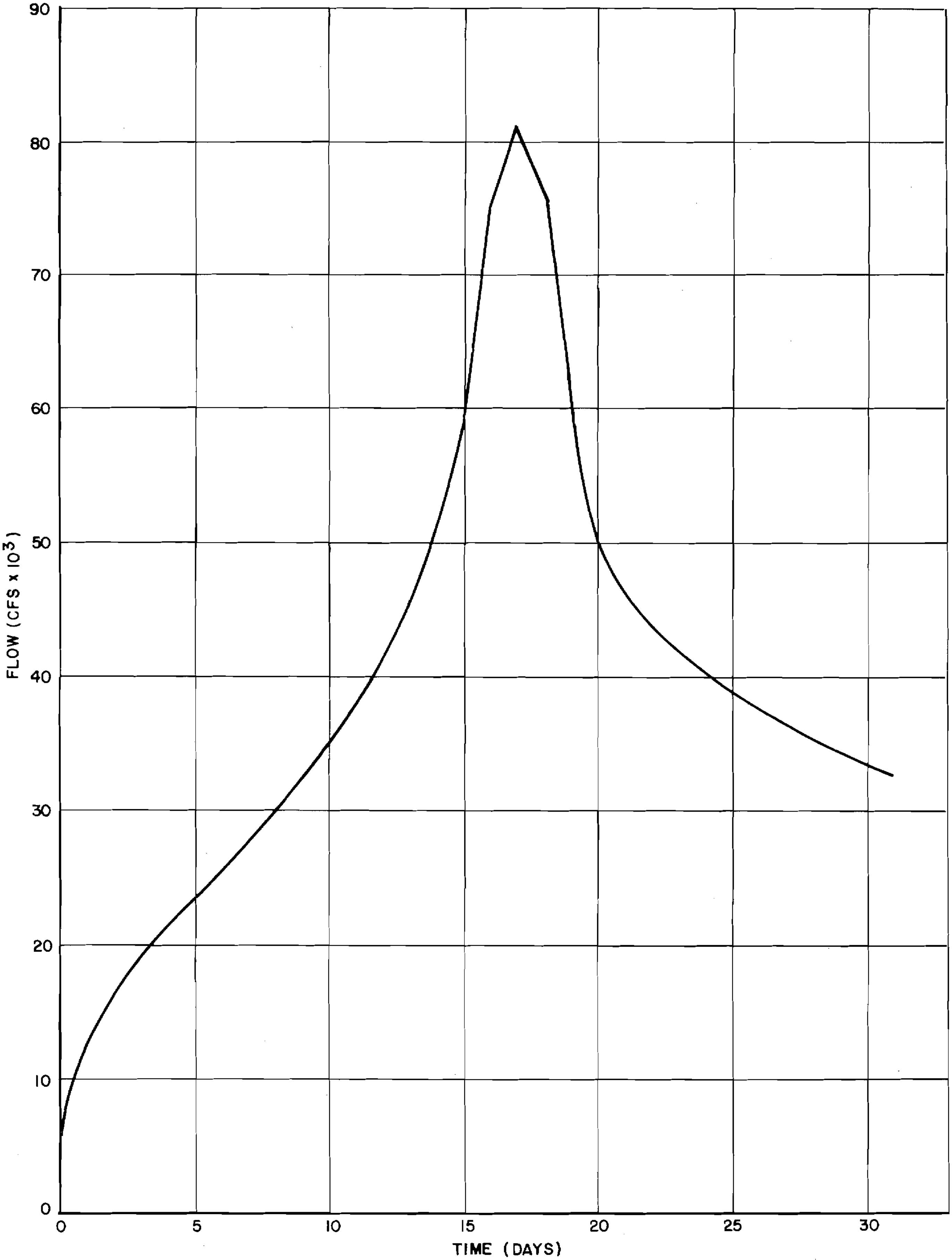


ANNUAL FLOW DURATION FREQUENCY CURVES
SUSITNA RIVER AT GOLD CREEK

3 INDICATES CURVE FOR 3-YR. AVERAGE FLOWS

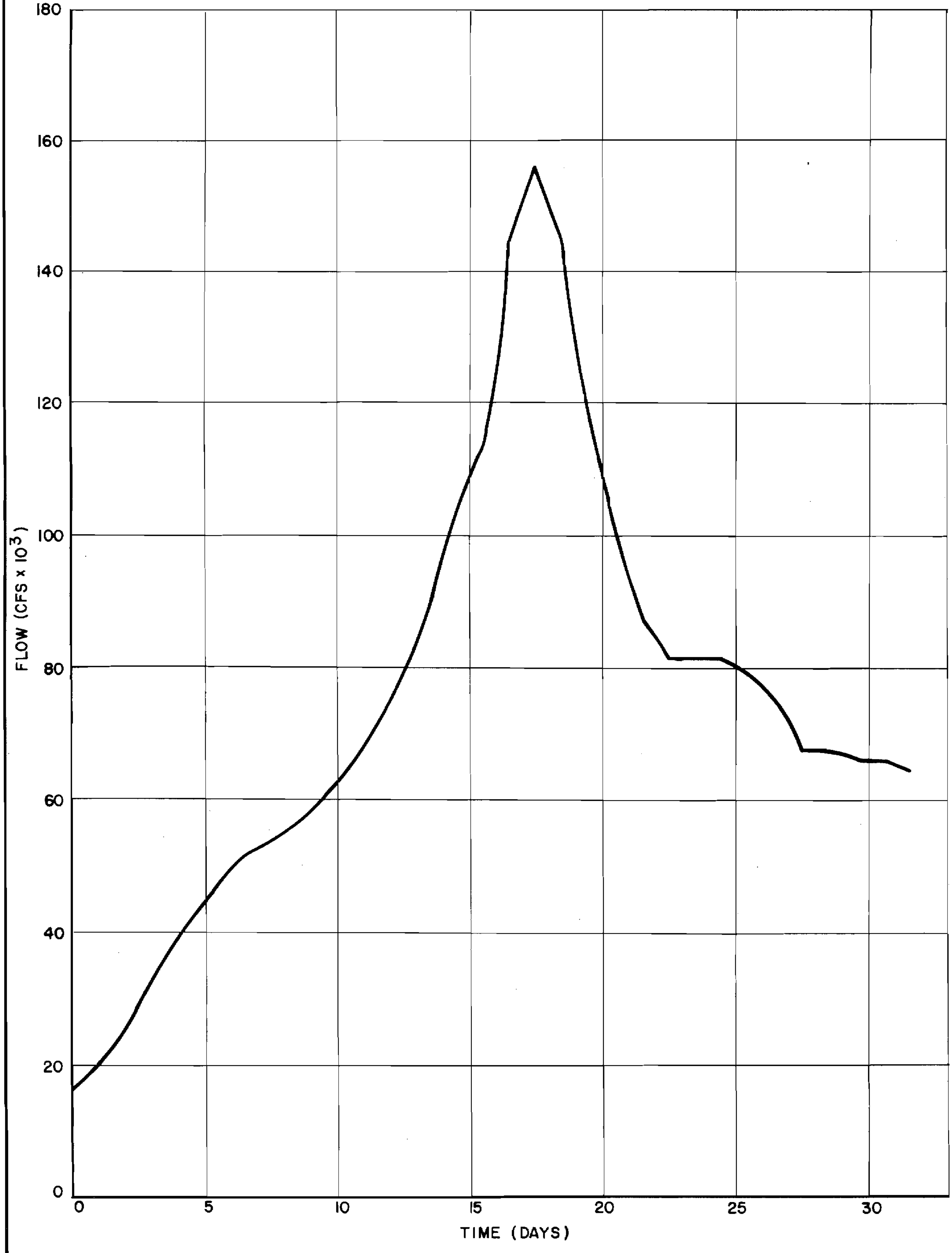
ACRES

FIGURE 7.6



1:50 YEAR ANNUAL FLOOD INFLOW HYDROGRAPH
SUSITNA RIVER AT WATANA DAM SITE

FIGURE 7.7



1:10000 YEAR FLOOD INFLOW HYDROGRAPH
SUSITNA RIVER AT WATANA DAM SITE

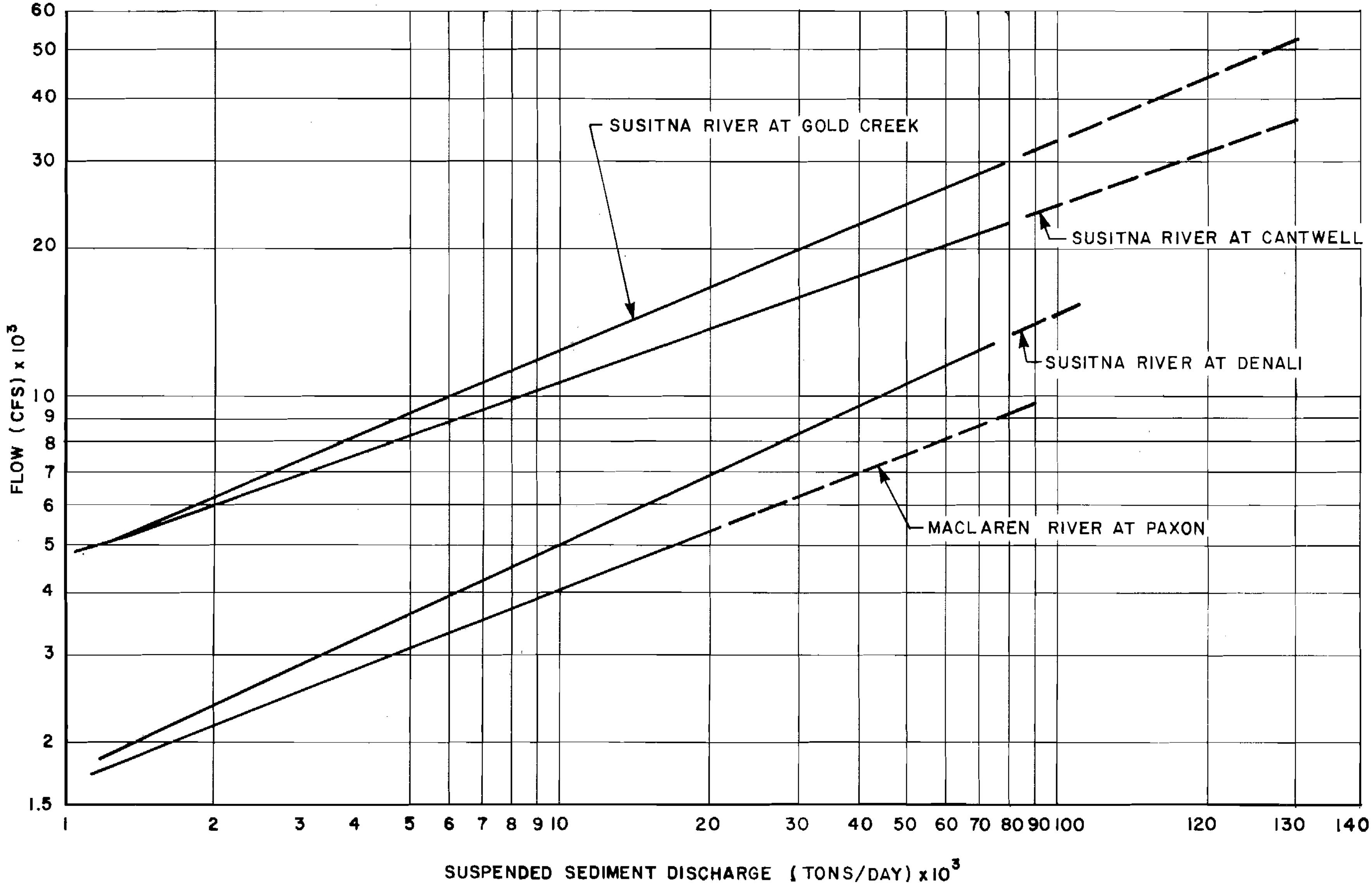
FIGURE 7.8

ACRES

PROBABLE MAXIMUM FLOOD INFLOW HYDROGRAPH
SUSITNA RIVER AT WATANA DAM SITE

FIGURE 7.9

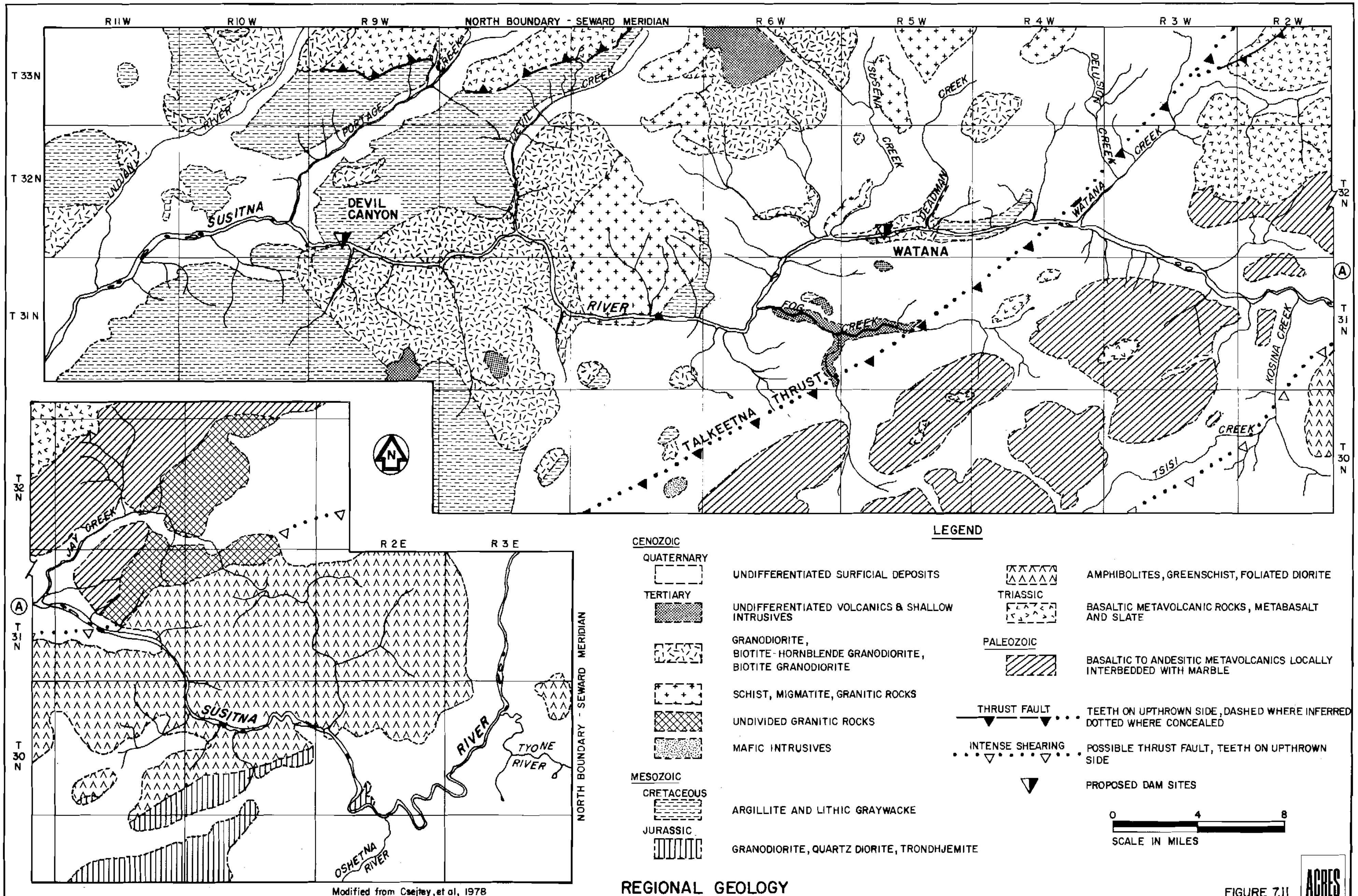
ACRES



SUSPENDED SEDIMENT TRANSPORT
SUSITNA RIVER AT SELECTED STATIONS

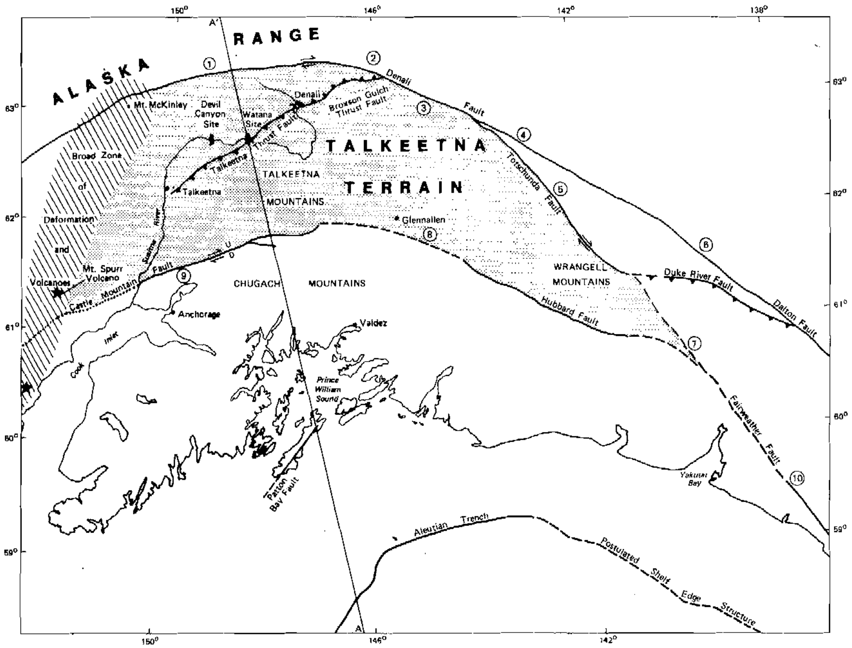
ACRES

FIGURE 7.10

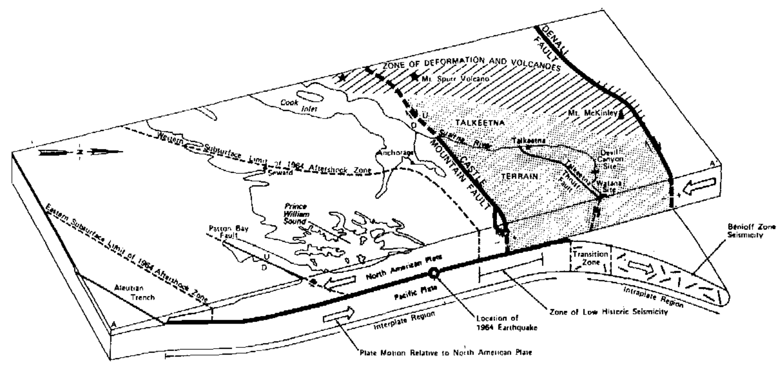


REGIONAL GEOLOGY

FIGURE 7.11



A. TALKEETNA TERRAIN MODEL



B. SCHEMATIC TALKEETNA TERRAIN SECTION

LEGEND

Mapped strike-slip fault, arrows show sense of horizontal displacement

U D Mapped strike-slip fault with dip slip component, letters show sense of vertical displacement: U is up; D is down.

Mapped fault, sense of horizontal displacement not defined

Inferred strike-slip fault

Mapped thrust fault, sawteeth on upper plate

NOTES

1. 0.9 – 2.0 cm/yr Hickman and Campbell (1973); and Page (1972).
2. 0.5 – 0.6 cm/yr Stout and others (1973).
3. 3.5 cm/yr Richter and Matson (1971).
4. 1.1 cm/yr, no Holocene activity farther east, Richter and Matson (1971).
5. 0.9 – 3.3 cm/yr Richter and Matson (1971).
6. Inferred connection with Dalton fault; Plafker and others (1978).
7. Inferred connection with Fairweather fault; Lahr and Plafker (1980).
8. Connection inferred for this report.
9. 0.1 – 1.1 cm/yr Detterman and others (1974); Bruhn (1979).
10. 5.8 cm/yr Lahr and Plafker (1980).
11. Aleutian Trench and Postulated Shelf Edge Structure after Guptill and others (1981).
12. Slip rates cited in notes 1 through 10 are Holocene slip rates.
13. All fault locations and sense of movement obtained from Beikman (1978; 1980).

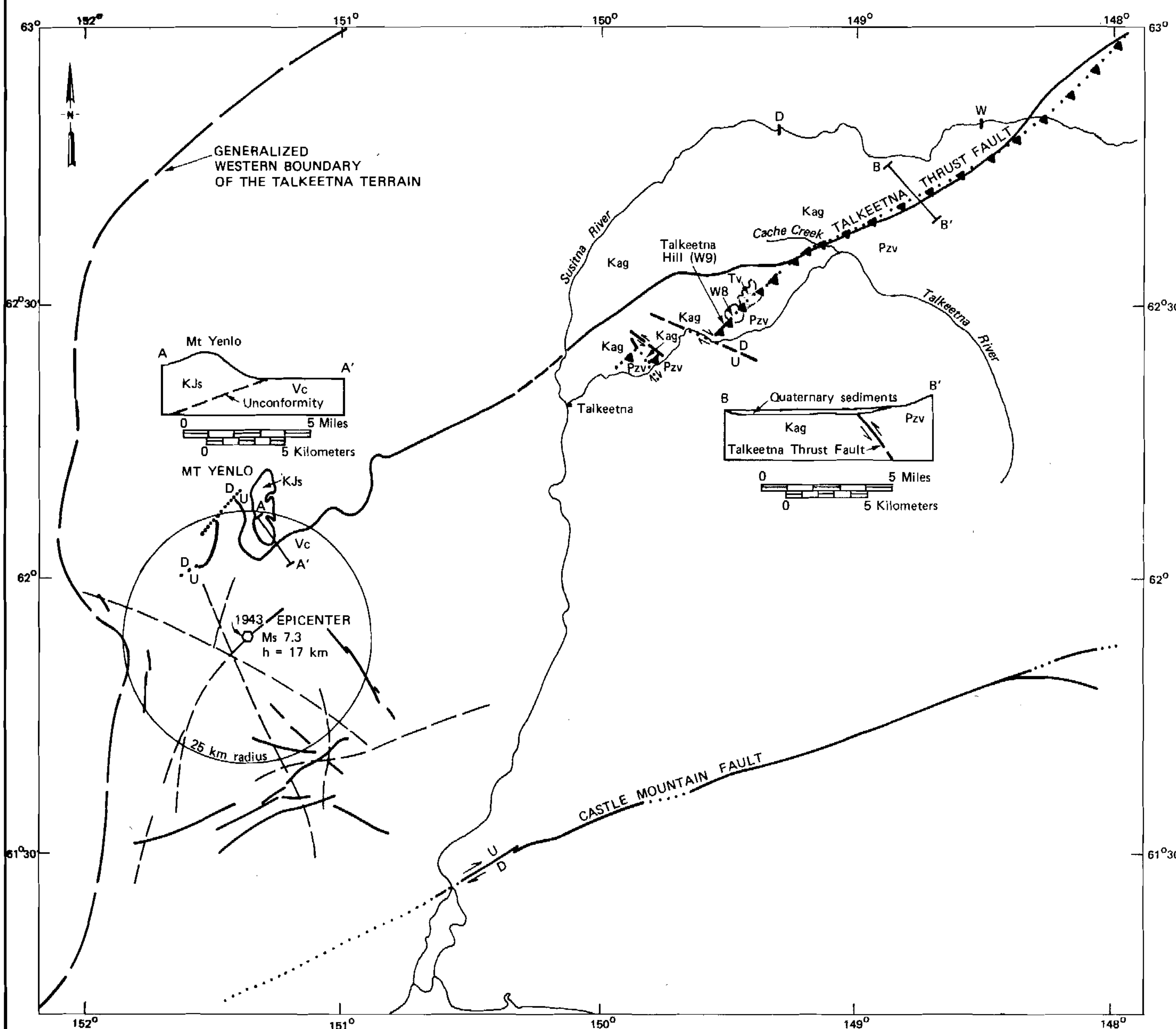
0 100 200 Miles

0 100 200 Kilometers

TALKEETNA TERRAIN MODEL AND SECTION

FIGURE 7.12

ACRES



LEGEND

Tv	Tertiary volcanic rocks
Kag	Cretaceous argillite and graywacke
KJs	Cretaceous - Jurassic marine sedimentary rocks, undivided
Vc	Paleozoic and Triassic rocks (inferred from aeromagnetic data)
Pzv	Paleozoic volcanic rocks
	Inferred lithologic contact
	Strike-slip fault with recent displacement, arrows show sense of horizontal displacement, letters show sense of vertical displacement: U is up; D is down, dotted where concealed
	Strike-slip fault without recent displacement, dashed where inferred, dotted where concealed.
	Thrust fault without recent displacement, dashed where inferred, dotted where concealed, sawteeth on upper plate
	Line separating aeromagnetically dissimilar terrain, dashed where indistinct
	U-2 lineament
	LANDSAT lineament
	Inferred fault from aeromagnetic data, letters show sense of vertical displacement, U is up; D is down
W8, W9	Locations studied during this investigation
W	Watana Site
D	Devil Canyon Site

NOTES

1. Line separating aeromagnetically dissimilar terrain and Mt Yenlo geology are shown by, or interpreted from Csejtey and others (1978) and Griscom (1979).
2. The Talkeetna thrust fault and adjacent geology are from Csejtey and others (1978).
3. Castle Mountain fault location is from Magoon and others (1976).
4. The 1943 epicenter location is from analysis conducted during this investigation (Section 5.1.3) and Tobin and Sykes (1966). h is the focal depth of this earthquake.
5. Locations W8 and W9 are shown in Figure 4-7 and discussed in Sections 4.4.1 and 5.1.3.

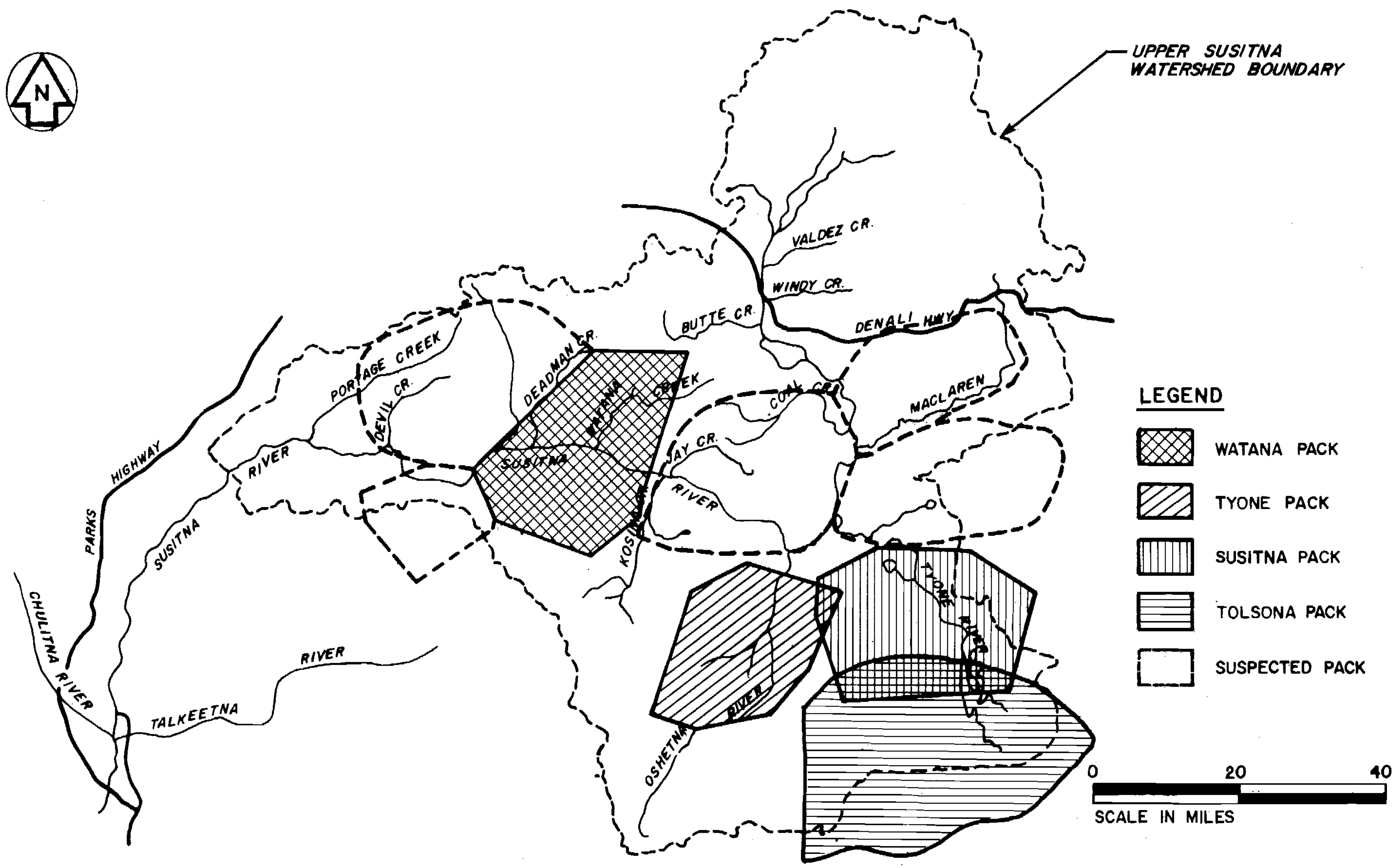
0 5 10 20 Miles
0 10 20 30 Kilometers

1943 EARTHQUAKE GEOLOGY MAP

FIGURE 7.13

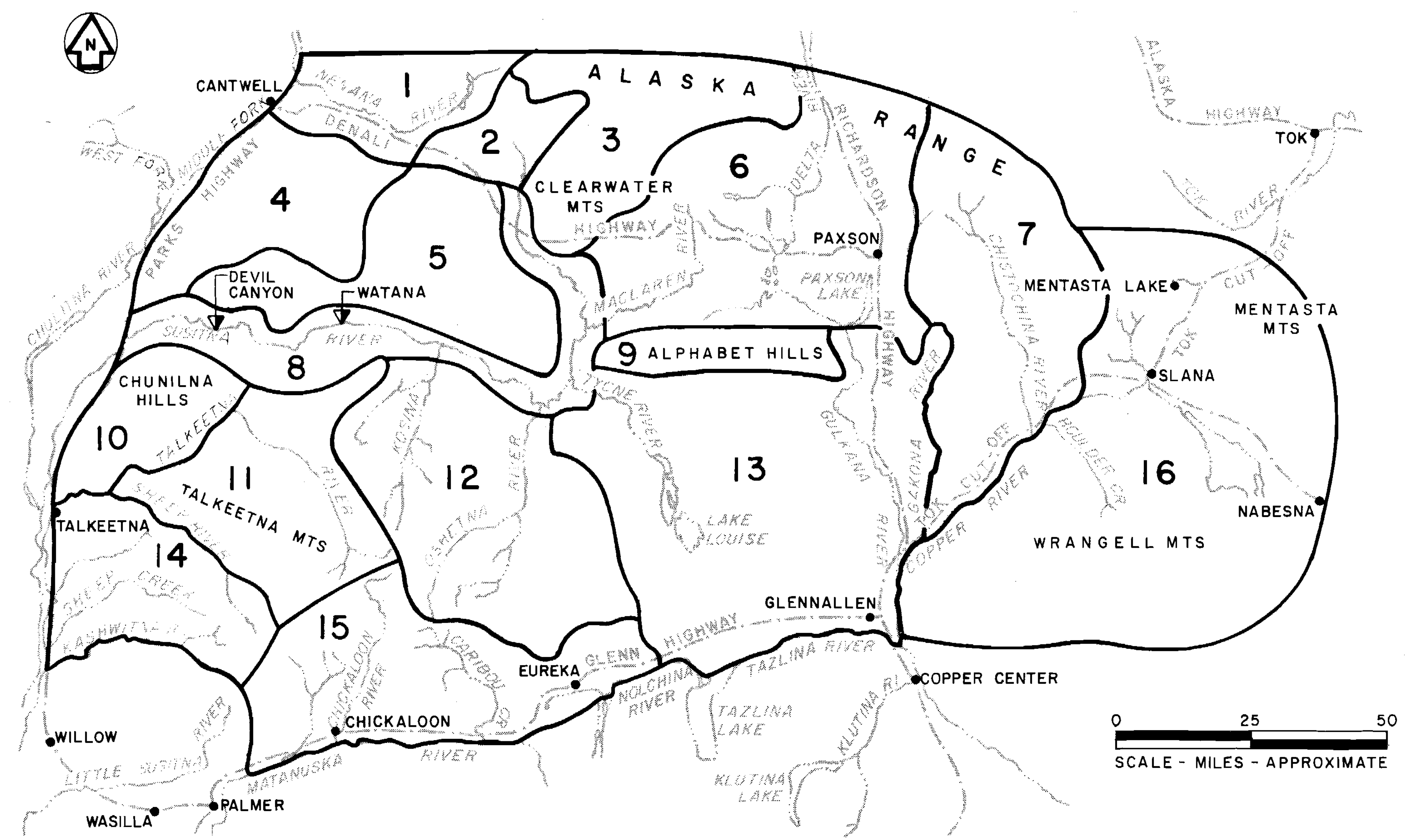
ACRES

WOODWARD-CLYDE CONSULTANTS 41410A February 1982



LOCATION AND TERRITORIAL BOUNDARIES OF WOLF PACKS - 1980

FIGURE 7.14

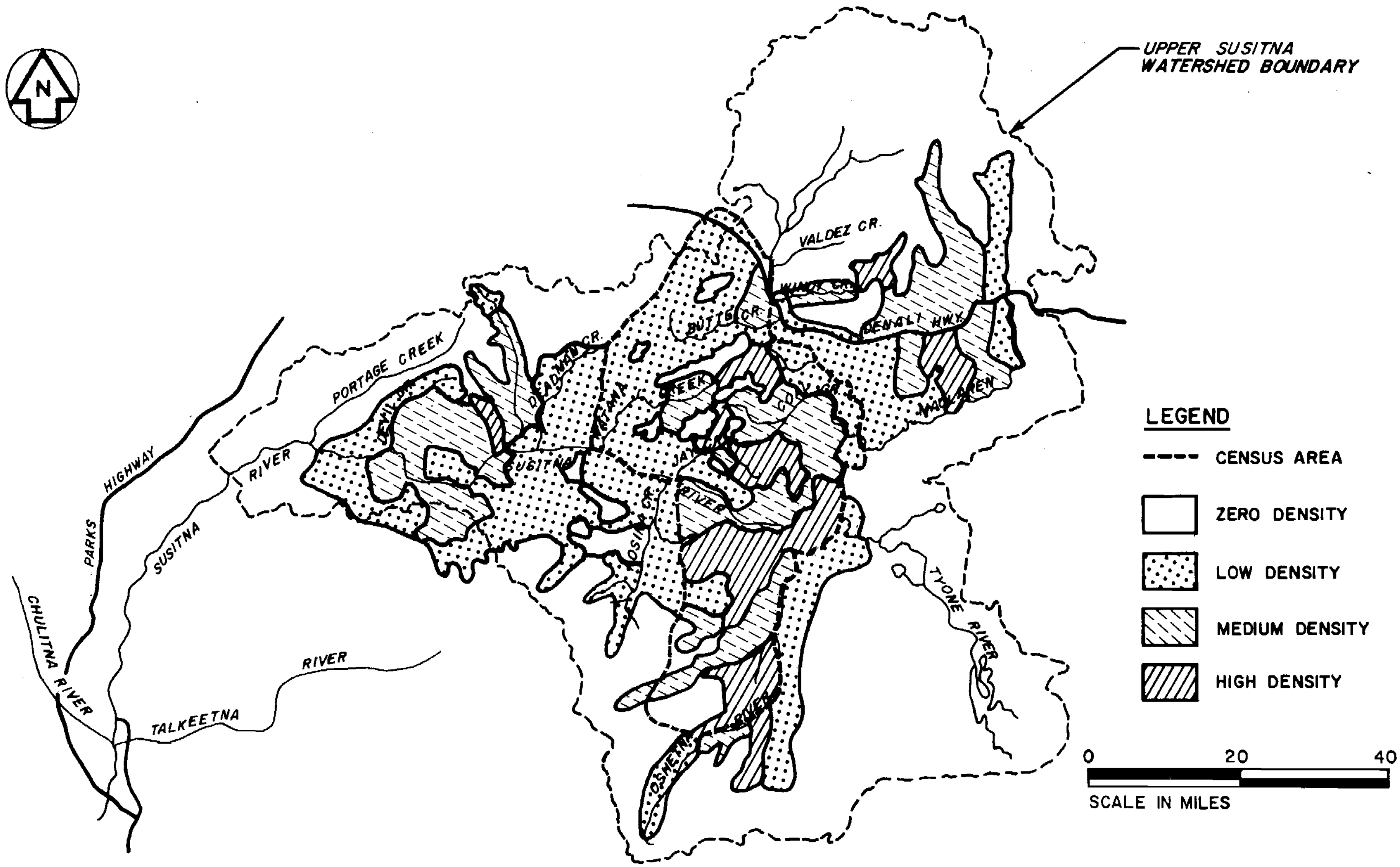


DIVISIONS OF NELCHINA CARIBOU HERD RANGES

(UNITS BASED UPON TOPOGRAPHY, VEGETATION AND USE)

MODIFIED FROM SKOOG 1968

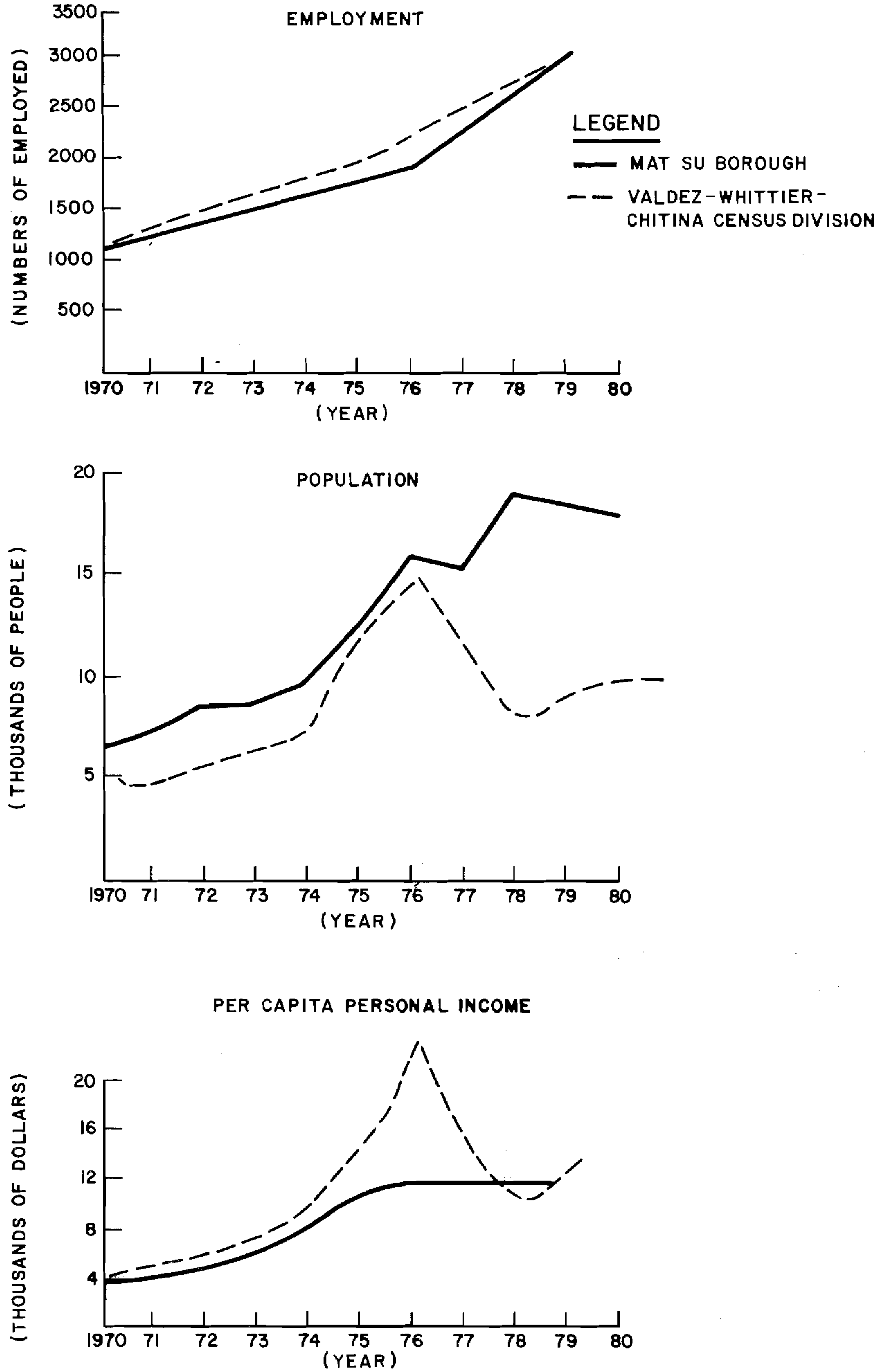
FIGURE 7.15



RELATIVE DENSITIES OF MOOSE - NOVEMBER, 1980

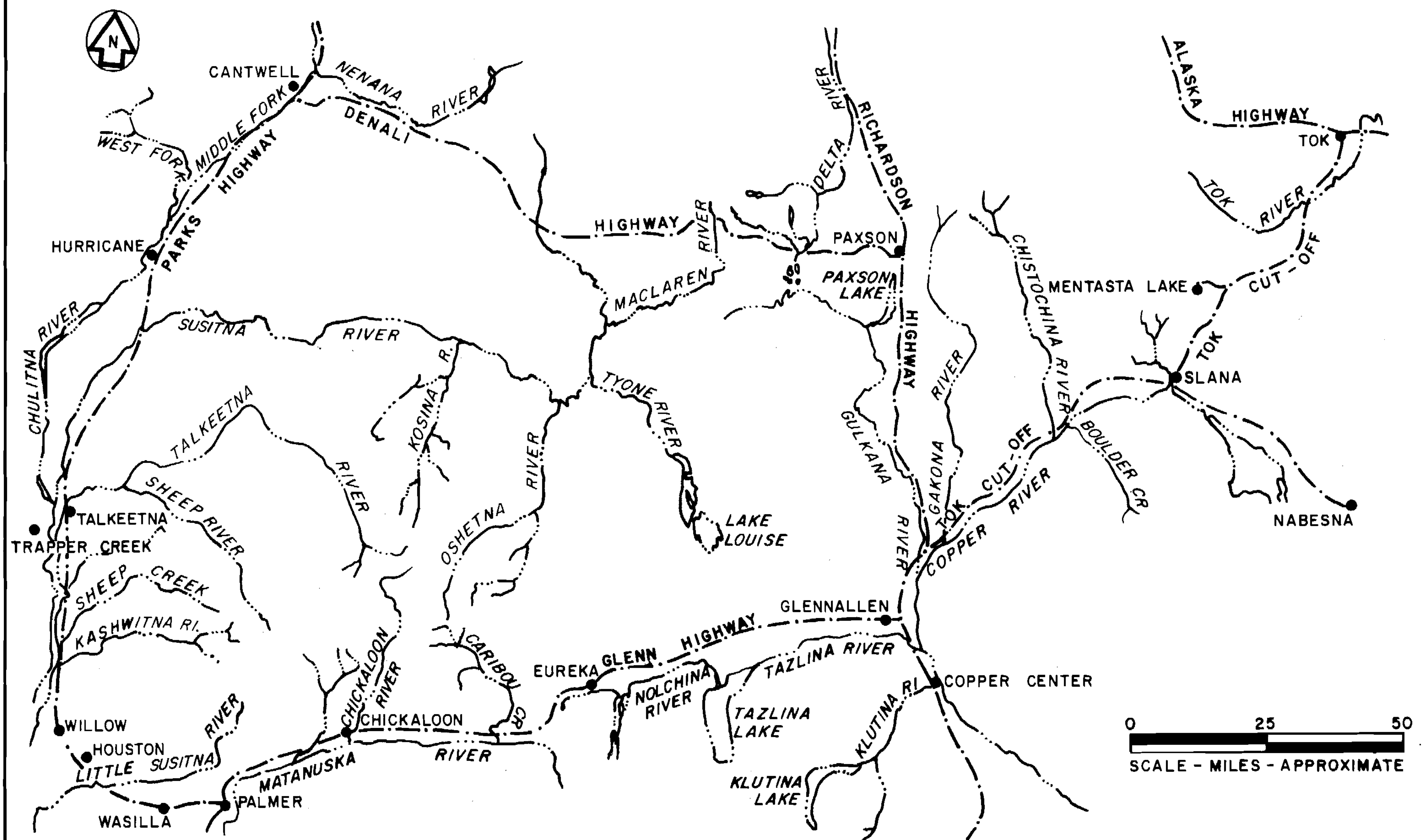
ACRES

FIGURE 7.16



EMPLOYMENT, POPULATION AND PER CAPITA PERSONAL INCOME IN THE MATANUSKA-SUSITNA BOROUGH AND VALDEZ-WHITTIER-CHITINA CENSUS DIVISION, 1970 - 1980

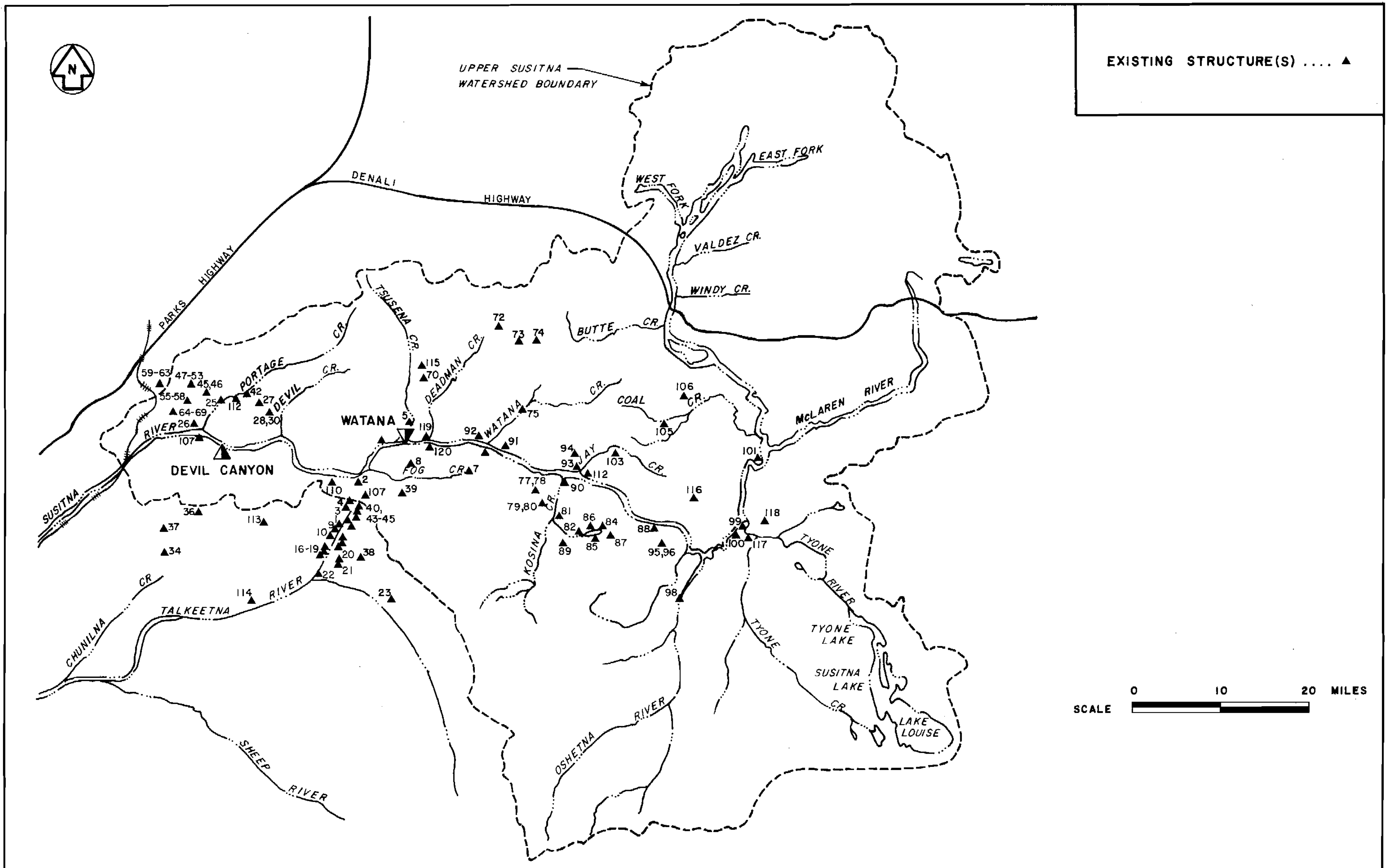
FIGURE 7.17



COMMUNITIES IN VICINITY OF SUSITNA BASIN

FIGURE 7.18

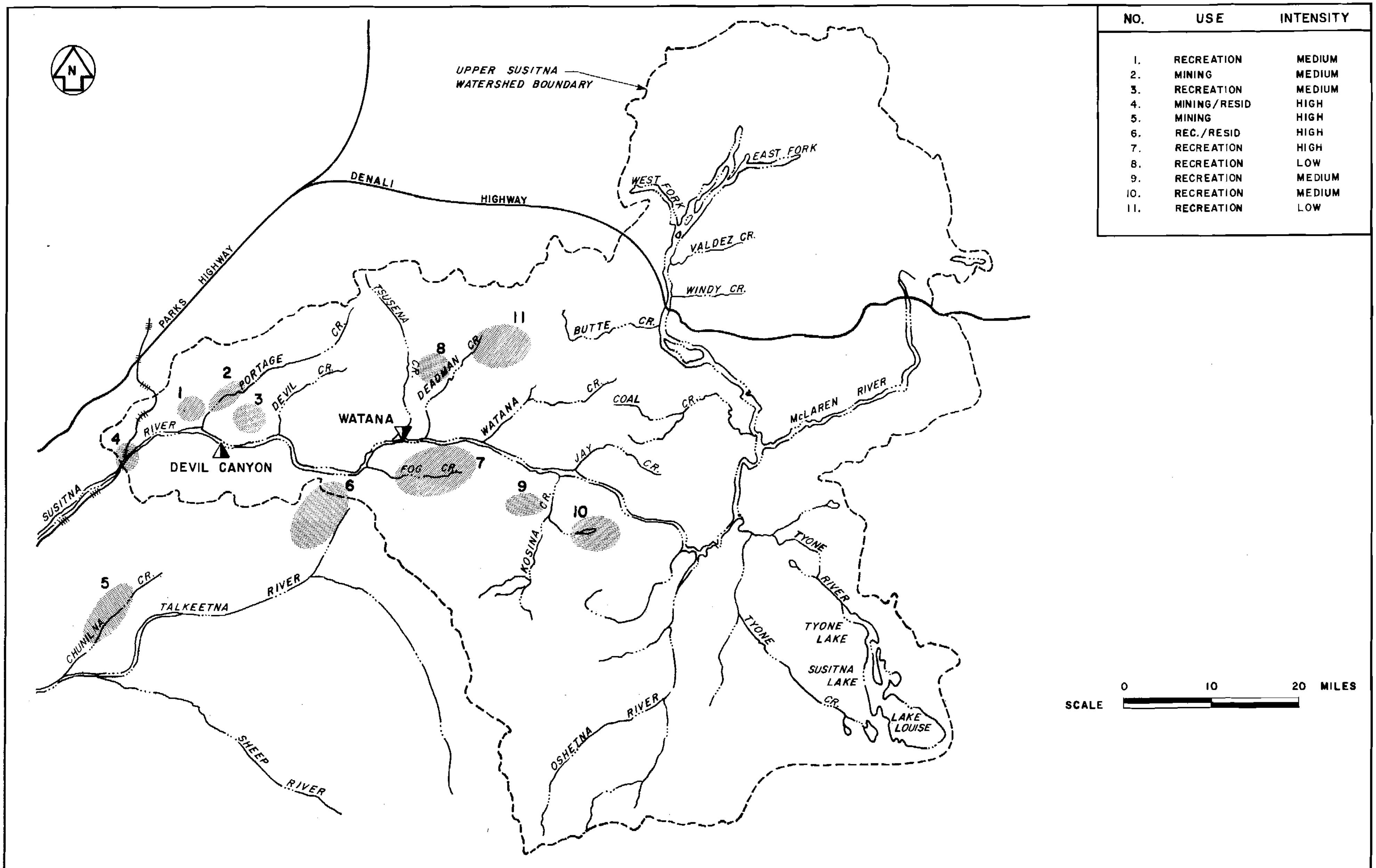
ACRES



EXISTING STRUCTURES

FIGURE 7.19

ACRES



NO.	USE	INTENSITY
1.	RECREATION	MEDIUM
2.	MINING	MEDIUM
3.	RECREATION	MEDIUM
4.	MINING/RESID	HIGH
5.	MINING	HIGH
6.	REC./RESID	HIGH
7.	RECREATION	HIGH
8.	RECREATION	LOW
9.	RECREATION	MEDIUM
10.	RECREATION	MEDIUM
11.	RECREATION	LOW

LAND USE AGGREGATIONS

FIGURE 7.20

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.

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) Damsite - An individual potential damsite in the Susitna Basin, referred to in the generic process as "candidate."

(b) Basin Development Plan - A plan for developing energy within the Upper Susitna 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.

(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 were developed for the comparative evaluations of Susitna Basin generation versus alternative methods of generation.

8.1 - Plan Formulation and Selection Methodology

In applying the generic plan formulation and selection methodology, five basic steps are required; defining the objectives, selecting candidates, screening, formulation of development plans, and, finally, a detailed evaluation of the plans (see Figure 8.1). The objective is to determine the optimum Susitna Basin development plan. The various steps required are outlined in subsections of this section.

Throughout the planning process, engineering layout studies were made to refine the cost estimates for power generation facilities or water storage development at several damsites within the basin. These data were fed into the screening and plan formulation and evaluation studies.

ACRES

The second objective, the detailed evaluation of the various plans, 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.

8.2 - Damsite Selection

In previous Susitna Basin studies (see Section 4), twelve damsites have been identified in the upper portion of the basin, i.e., upstream from Gold Creek. These sites are listed in Table 8.1 with relevant data concerning facilities, cost, capacity, and energy.

The longitudinal profile of the Susitna River and typical reservoir levels associated with these sites is shown in Figure 8.2. 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 capital costs were 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; 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 data presented 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 have only medium energy production, and are slightly more costly than the previously mentioned damsites. 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.

8.3 - Site Screening

The objective of this screening process was to eliminate sites which would obviously not feature in the initial stages of a Susitna Basin development plan and which, therefore, did not deserve further study at this stage. Three basic screening criteria were used: environmental, alternative sites, and energy contribution.

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 had some potential for upstream regulation. The results of this process, described in detail in the Development Selection Report (1), 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 insure that further study be directed toward determining the need and viability of providing flow regulation in the headwaters of the Susitna.

8.4 - Engineering Layouts

In order to obtain a uniform and reliable data base for studying the seven sites remaining, it was necessary to develop engineering layouts and reevaluate the costs. In addition, staged developments at several of the larger dams were studied.

The basic objective of these layout studies was 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, judgmental decisions had to be made on the appropriate foundation and abutment treatment. The accuracy of cost estimates made in these studies is of 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 was 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. 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 sites support this assumption. 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 unit costs compared to concrete unit costs at alternative sites.

(b) General Arrangements

A brief description of the general arrangements developed for the various sites is given below. Plates 8.1 to 8.7 illustrate the layout details. Table 8.2 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 8.1)

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

The rockfill dam will rise above the valley on the left abutment and terminate in an adjoining saddle dam of similar construction. The dam will be 675 feet above the lowest foundation level with a crest elevation of 1470 and a volume of 20 million cubic yards.

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

The power facilities will be located on the right abutment. The massive intake structure will be founded within the rock at the end of a deep approach channel and will consist of four integrated units, each serving individual tunnel penstocks. The powerhouse will house four 150-MW vertically mounted Francis type turbines driving overhead 165 MVA umbrella type generators.

As an alternative to the full power development in the first phase of construction, a staged powerhouse alternative was also investigated. The dam would be completed to its full height but with an initial plant installed capacity in 300-MW range. The complete powerhouse would be constructed together with penstocks and a tailrace tunnel for the initial two 150-MW units, together with concrete foundations for the future units.

(ii) Watana (Plates 8.2 and 8.3)

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 will be 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 will rise 880 feet from the lowest point on the foundation and have an overall volume of approximately 63 million cubic yards for a crest elevation of 2225.

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

The power facilities located within the left abutment with similar intake, underground powerhouse, and water passage concepts to those at Devil Canyon will incorporate 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 included 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 8.3.).

The powerhouse would be completely excavated to its final size during the first stage. 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 would be 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 would 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.

(iii) High Devil Canyon (Plate 8.4)

The development will be located between Devil Canyon and Watana. The 855 feet high rockfill dam will be similar in design to Devil Canyon, containing an estimated 48 million cubic yards of rockfill with a crest elevation of 1775. The left bank spillway and the right bank powerhouse facilities will also be similar in concept to Devil Canyon, with an installed capacity of 800-MW.

Two stages of 400-MW were envisaged in each which would be undertaken in the same manner as at Devil Canyon, with the dam initially constructed to its full height.

(iv) Susitna III (Plate 8.5)

The development will involve a rockfill dam with an impervious core approximately 670 feet high, a crest elevation of 2360, and a volume of approximately 55 million cubic yards. A concrete-lined spillway chute and a single stilling basin and will be located on the right bank. A powerhouse of 350-MW capacity will be located underground and the two diversion tunnels on the left bank.

(v) Vee (Plate 8.6)

A 610 feet high rockfill dam founded on bedrock with a crest elevation of 2350 and total volume of 10 million cubic yards was 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 was adopted.

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

(vi) Maclaren (Plate 8.7)

The development will consist of a 185 feet high earthfill dam founded on pervious riverbed materials. The crest elevation of the dam will be 2405. This reservoir will essentially be used for regulating purposes. Diversion will occur through three conduits located in an open cut on the left bank and floods will be discharged via a side chute spillway and stilling basin on the right bank.

(vii) Denali (Plate 8.7)

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

8.5 - 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.

The total capital costs developed are shown in Tables 8.1 and 8.3. It should be noted that the capital costs for Maclaren and Denali shown in Table 8.1 have been adjusted to incorporate the costs of generation plants with capacities of 55-MW and 60-MW, respectively.

8.6 - Formulation of Susitna Basin Development Plans

The results of the site screening process 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:

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

Supplementary upstream flow regulation could be provided by structures at:

- MacLaren; and
- Denali.

A computer assisted screening process identified the plans that are most economic as those of Devil Canyon/Watana or High Devil Canyon/Vee. In addition to these two basic development plans, a tunnel scheme which provides potential environmental advantages by replacing the Devil Canyon dam with a long power tunnel and a development plan involving Watana Dam was also introduced.

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

The results of the screening process are shown in Table 8.4. Because of the simplifying assumptions that were made in the screening model, the three best solutions from an economic point of view are included in the table.

The most important conclusions that can be drawn are as follows:

- For energy requirements of up to 1,750 Gwh, the High Devil Canyon, Devil Canyon or the Watana sites individually provided the most economic energy. The difference between the costs shown on Table 8.4 is around 10 percent, which is similar to the accuracy that can be expected from the screening model.

- For energy requirements of between 1,750 and 3,500 Gwh, the High Devil Canyon site is the most economic.

- For energy requirements of between 3,500 and 5,250 Gwh the combinations of either Watana and Devil Canyon or High Devil Canyon and Vee are the most economic.

- 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 6,000 Gwh range.

(a) Tunnel Alternative

A scheme involving a long power tunnel could conceivably be used to replace the Devil Canyon dam in the Watana/Devil Canyon development plan. It could develop similar head for power generation 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 1,200 MW;

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

- Arrangements for compensation flow in the bypassed river reach.

Four basic alternative schemes were developed and studied (see Figure 8.4). All schemes assumed an initial Watana development with full reservoir supply level at Elevation 2200 and the associated powerhouse with an installed capacity of 800 MW. Table 8.5 lists all the pertinent technical information. Table 8.6 lists the power and energy yields for the four schemes.

Based on the foregoing economic information, Scheme 3 (Plates 8.8 and 8.9) produces the lowest cost energy by almost a factor of 2.

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 almost 2 to 1 economic advantage, Scheme 3 was selected as the only scheme worth further study (see Development Selection Report fr detailed analysis). The capital cost estimate for Scheme 3 appears in Table 8.7. The estimates 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.

(b) 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 tunnel Scheme 3 as an alternative to the High Devil Canyon dam and a plan combining a Watana/High Devil Canyon/Portage Creek combination.

Associated with each of these plans are several options for staged development. For this more detailed analysis of these basic plans, a range of different aproaches to staging the developments were 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, was considered. The basic staging concepts adopted for these developments involved staging both dam and powerhouse construction, or alternatively just staging powerhouse construction. Powerhouse stages are considered in 400 MW increments.

Four basic plans and associated subplans 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.

8.7 - Evaluation of Basin Development Plans

The overall objective of this step in the evaluation process was 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.

In the process of initially evaluating the final four 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 8.8.

The plans listed in Table 8.8 were subjected to a more detailed analysis as described in the following section.

(a) 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), only economic criteria 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 is 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. Since 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 the optimum generation planning (OGP5) model described in Section 6.

The model 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. A summary of the input data to the model and a discussion of the results follows.

(i) Initial Economic Analyses

Table 8.9 lists the results of the first series of economic analyses undertaken for the basic Susitna Basin development plans listed in Table 8.8. The information provided includes the specified on-line dates for the various stages of the plans, the OGP5 run index number, the total installed capacity at year 2010 by category, and the total system present-worth cost in 1980 for the period 1980 to 2040. The OGP5 model is run for the period 1980-2010. Matching of the Susitna development to the load growth for Plans E1, E2, and E3 is shown in Figures 8.5, 8.6, and 8.7, respectively. After 2010, steady state conditions are assumed and the then-existing generation mix and annual costs for 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 simulated as operating for periods approaching their economic lives and that their full impact on the cost of the generation system is taken into account.

- 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 present worth advantage of not staging the dam amounts to $180 million in 1980 dollars.

The results indicate that, with the level of analysis performed, there is no discernible benefit in staging construction of the Watana powerhouse (Plans E1.1 and E1.3). However, Plan E1.4 results indicates that, should the powerhouse size at Watana be restricted to 400 MW, the overall system present worth would increase.

Additional runs performed for variations of Plan E1.3 indicated that system present worth would increase by $1,110 million if the Devil Canyon dam was not constructed. A five year delay in construction of the Watana dam would increase system present worth by $220 million.

- Plan E2 - High Devil Canyon/Vee

  . The results for Plan E2.3 indicate that the system present worth is $520 million more than Plan E1.3. Present worth increases also occur if the Vee dam stage is not constructed. A reduction in present worth of approximately $160 million is possible if the Chakachamna hydroelectric project is constructed instead of the Vee dam.

  . The results of Plan E2.1 indicate that total system present worth would increase by $250 million if the total capacity at High Devil Canyon were limited to 400 MW.

- Plan E3 - Watana/Tunnel

  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 present worth 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 then constructing the Devil Canyon dam.

- Plan E4 - Watana/High Devil Canyon/Portage Creek

  The results indicate that system present worth associated with Plan E4.1, excluding the Portage Creek site development, are $200 million more than the equivalent E1.3 plan. If the Portage Creek development is included, the present worth difference would be even greater.

(ii) Load Forecast Sensitivity Analyses

The plans with the lowest present-worth cost were subjected to further sensitivity analyses to assess the economic impacts of various load growths. These results are summarized in Table 8.10.

The results for low load forecasts illustrate that the most viable Susitna Basin development plan is the Watana-Devil Canyon plan with a capacity of 800 MW which has a present worth cost of $210 million less than its closest competitor, the High Devil Canyon-Vee plan.

For the high load forecasts, the results indicate that the Plan E1.3 has a present worth cost of $1040 million less than E2.3.

(b) Evaluation Criteria

The following criteria were used to evaluate the shortlisted basin development plans. These criteria generally contain the requirements of the generic process with the exception that an additional criterion, energy contribution, is added in order to ensure that full consideration is given to the total basin energy potential 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 Table 8.10.

(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 nonrenewable 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. The energy loss that is inherent to the plan and cannot easily be recovered by subsequent staged developments is of greatest concern.

(c) Results of Evaluation Process

The various attributes outlined above have been determined for each plan and are summarized in Tables 8.11 through 8.18. 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, 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 were relatively straightforward, and the decision-making process can, therefore, be regarded as effective and consistent. In addition, these trade-offs are clearly identified so the recorder can independently assess the judgment decisions made.

The overall evaluation process is conducted in a series of steps. At each step, only two plans are compared. The superior plan is then taken to the next step for evaluation against a third plan. This process continues until the best plan has been selected.

(i) Devil Canyon Dam Versus Tunnel

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

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 8.11. 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 Watana-Devil Canyon dam scheme is superior. As summarized in Tables 8.11 and 8.12, on a present worth basis the tunnel scheme is $680 million more expensive than the dam scheme. For a low demand growth rate, this cost difference would be reduced slightly to $650 million. Even if the tunnel scheme costs are halved, the total cost difference would still amount to $380 million. As highlighted in Table 8.12, 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 life 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 8.13. Overall, the tunnel scheme is judged to be superior because:

. 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;

. It would inundate 13 miles less of resident fisheries habitat in river and major tributaries;

. It has a lesser impact on wildlife habitat due to the less extensive inundation of habitat by the re-regulation dam;

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

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

- Energy Comparison

Table 8.15 summarizes the evaluation in terms of the energy 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 8.16. The estimated cost saving of $680 million in favor of the dam scheme plus the additional energy produced are 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 8.11 and 8.12) the Watana-Devil Canyon plan is less costly by $520 million. 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 8.17. 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 is judged that the potential environmental impacts which would occur above the Vee Canyon dam with a High Devil Canyon-Vee development are more severe in overall comparison.

Of the seven environmental factors considered in Table 8.17 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.

- Energy Comparison

The evaluation of the two plans in terms of energy contribution criteria is summarized in Table 8.18. The Watana-Devil Canyon scheme is assessed to be superior because of its higher energy potential and the fact that it develops a higher proportion of the basin's energy potential.

- Social Comparison

  Table 8.14 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 8.19 and indicates that the Watana-Devil Canyon plans are generally superior for all the evaluation criteria.

8.8 - Preferred Susitna Basin Development Plan

One on one 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 was therefore selected as the preferred Susitna Basin development plan, as a basis for continuation of more detailed design optimization and environmental studies.

LIST OF REFERENCES

(1) Acres American Incorporated, Susitna Hydroelectric Project, Development Selection Report, prepared for the Alaska Power Authority, December 1981.

ACRES

TABLE 8.1: POTENTIAL HYDROELECTRIC DEVELOPMENT

Site	Dam Proposed Type	Dam Height Ft.	Upstream Regulation	Capital Cost $ million (1980)	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 Yes	830 1,000	250 600	1,420 2,980	27 17	This Study "
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 and 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 damsites in perspective.
(4) Include estimated costs of power generation facility.

TABLE 8.2: 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 8.3: 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 & 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 8.4: RESULTS OF SCREENING MODEL

Run	Total Demand Cap. MW	Total Demand Energy GWh	Optimal Solution Site Names	Optimal Max. Water Level	Optimal Inst. Cap. MW	Optimal Total Cost $ million	First Suboptimal Solution Site Names	First Suboptimal Max. Water Level	First Suboptimal Inst. Cap. MW	First Suboptimal Total Cost $ million	Second Suboptimal Solution Site Names	Second Suboptimal Max. Water Level	Second Suboptimal Inst. Cap. MW	Second Suboptimal 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	NO ALTERNATIVE SOLUTION AVAILABLE							
			Devil Canyon	1450	660	1000								
			Total		1400	2770								

TABLE 8.5: 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 (cfs)	0	1,000	1,000	1,000	1,000
Reservoir Volume (1000 Acre-feet)	1,100	9.5	--	350	--
Dam Height (feet)	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 Reservoir (feet)	2	15	--	4	--

Notes:

[3] Estimated, above existing rock elevation.

TABLE 8.6: TUNNEL SCHEMES POWER OUTPUT AND AVERAGE ANNUAL ENERGY

Stage	Installed Capacity (MW)		Increase[1] in Installed Capacity (MW)	Tunnel Average Annual Energy (Gwh)	Increase[1] in Average Annual Energy (Gwh)
	Watana	Tunnel			
STAGE 1:					
Watana Dam	800	---	---	---	---
STAGE 2:					
Tunnel:					
- Scheme 1	800	550	550	2,050	2,050
- Scheme 2	70	1,150	420	4,750	1,900
- Scheme 3[2]	850	330	380	2,240	2,180
- Scheme 4	800	365	365	2,490	890

Notes:

(1) Increase over Watana, 800 MW development energy of 3,250 Gwh/yr.
(2) Includes power and energy produced at re-regulation dam.

TABLE 8.7: CAPITAL COST ESTIMATE SUMMARIES FOR SCHEME 3 TUNNEL ALTERNATIVE 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 8.8: SUSITNA ENVIRONMENTAL DEVELOPMENT PLANS

Plan	Stage	Construction	Stage/Incremental Data: Capital Cost $ Millions (1980 values)	Stage/Incremental Data: Earliest On-line Date[1]	Stage/Incremental Data: Reservoir Full Supply Level - ft	Stage/Incremental Data: Maximum Seasonal Draw-down-ft	Cumulative System Data: Annual Energy Production Firm GWH	Cumulative System Data: Annual Energy Production Avg GWH	Cumulative System Data: Plant Factor %
E1.1	1	Watana 2225 ft 800 MW & Re-Regulation Dam	1960	1993	2200	150	2670	3250	46
	2	Devil Canyon 1470 ft 400 MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200 MW	2860						
E1.2	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 & Re-Regulation Dam	230	1995	2200	150	2670	3250	46
	4	Devil Canyon 1470 ft 400 MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200 MW	3060						
E1.3	1	Watana 2225 ft 400 MW	1740	1993	2200	150	2670	2990	85
	2	Watana add 400 MW capacity & 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 1200 MW	2890						

TABLE 8.8 (Cont'd)

Plan	Stage	Construction	Stage/Incremental Data: Capital Cost $ Millions (1980 values)	Stage/Incremental Data: Earliest On-line Date[1]	Stage/Incremental Data: Reservoir Full Supply Level - ft	Stage/Incremental Data: Maximum Seasonal Draw-down-ft	Cumulative System Data: Annual Energy Production Firm GWH	Cumulative System Data: Annual Energy Production Avg GWH	Cumulative System Data: Plant Factor %
E1.4	1	Watana 2225 ft 400 MW	1740	1993	2200	150	2670	2990	85
	2	Devil Canyon 1470 ft 400 MW	900	1996	1450	100	5190	5670	81
		TOTAL SYSTEM 800 MW	2640						
E2.1	1	High Devil Canyon 1775 ft 800 MW and Re-Regulation Dam	1600	1994[3]	1750	150	2460	3400	49
	2	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2660						
E2.2	1	High Devil Canyon 1630 ft 400 MW	1140	1993[3]	1610	100	1770	2020	58
	2	High Devil Canyon raise dam to 1775 ft add 400 MW 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 1200 MW	2800						
E2.3	1	High Devil Canyon 1775 ft 400 MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400 MW capacity and Re-Regulation Dam	240	1995	1750	150	2460	3400	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	3870	4910	47
		TOTAL SYSTEM 1200 MW	2690						

TABLE 8.8 (Cont'd)

Plan	Stage	Construction	Stage/Incremental Data: 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	Avg GWH	Plant Factor %
E2.4	1	High Devil Canyon 1775 ft 400 MW	1390	1994[3]	1750	150	2400	2760	79
	2	High Devil Canyon add 400 MW capacity and Portage Creek Dam 150 ft	790	1995	1750	150	3170	4080	49
	3	Vee 2350 ft 400 MW	1060	1997	2330	150	4430	5540	47
		TOTAL SYSTEM	3240						
E3.2	1	Watana 2225 ft 400 MW	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 50 MW Tunnel Scheme 330 MW	1500	1995	1475	4	4890	5430	53
		TOTAL SYSTEM 1180 MW	3490						
E4.1	1	Watana 2225 ft 400 MW	1740	1995[3]	2200	150	2670	2990	85
	2	Watana add 400 MW capacity and Re-Regulation Dam	250	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	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, i.e., 2 years later than for the Watana/Devil Canyon Plan 1.

TABLE 8.9: RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS(1)

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(2)	Remarks Pertaining to the Susitna Basin Development Plan
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	State 3, Devil Canyon Dam
	1993	1996	--	--	L7W7	500	651	0	144	800	2095	6960	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.
E2.1	1994	2000	--	--	LB25	400	651	60	144	800	2055	6620	High Devil Canyon limited to 400 MW.
E2.3	1993	1996	2000	--	L601	300	651	20	144	1200	2315	6370	Stage 3, Vee Dam, not
	1993	1996	--	--	LE07	500	651	30	144	800	2125	6720	constructed.
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	
3.1S	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) These studies were completed in mid-1980 using ISERs 1980 energy demand forecasts.
(2) Present worth in 1980 dollars of system costs from 1980 to 2040.

TABLE 8.10: 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
LOW LOAD FORECAST													
E1.4	1993	2002	--	--	LC07	0	351	40	144	800	1335	4350	Watana limited to 400 MW.
	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.
3.1S	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.
3.1S	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	LBV7	800	651	60	144	1700	3355	10050	Chakachamna hydroelectric generating station (480 MW) brought online as a fourth stage.
E2.3	1993	1996	2000	--	LBV3	1300	951	90	144	1200	3685	11720	
Modified E2.3	1993	1996	2000	2003	LBY1	1000	876	10	144	1700	3730	11040	Chakachamna hydroelectric generating station (480 MW) brought online as a fourth stage.

TABLE 8.11: BASIC ECONOMIC DATA FOR EVALUATION OF PLANS

	Total Present Worth Cost for 1981 - 2040 Period $ Million (% Total)			
Parameter	Generation Plan With High Devil Canyon - Vee	Generation Plan With Watana - Devil Canyon Dam	Generation Plan With Watana - Tunnel	All Thermal Generation Plan
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 8.12: 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	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%			
- Fuel Cost	80% basic fuel cost	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 Escalation	0% fuel escalation 0% coal escalation			
- Economic Thermal Plant Life	50% extension 0% extension			

TABLE 8.13: 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. However, there are no current plans for such enhancement and feasibility is uncertain. Potential value is therefore not significant relative to additional cost of tunnel.	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.	Loss of habitat with dam scheme is less than 5% of total for Susitna main stem. This reach of river is therefore 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.	Moderate wildlife populations of moose, black bear, weasel, fox, wolverine, other small mammals and songbirds and some riparian cliff habitat for ravens and raptors, in 11 miles of river, would be lost with the dam scheme. Thus, 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.	Significant archeological sites, if identified, can probably be excavated. Additional costs could range from several hundreds to hundreds of thousands of dollars, but are still considerably less than the additional cost of the tunnel scheme. This concern is not considered a factor 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. However, current recreational uses of Devil Canyon are low due to limited access. Future possibilites include major recreational development with construction of restaurants, marinas, etc. Under such conditions, neither scheme would be more favorable.	X	

OVERALL EVALUATION: The tunnel scheme has overall a lower impact on the environment.

TABLE 8.14: 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 8.15: 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 of the 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 8.16: 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: The significant energy and economic advantage of dam scheme are judged to outweigh the reduced environmental impact associated with the tunnel scheme.

TABLE 8.17: 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 8.17 (Cont'd)

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 favor the W/DC plan.)

NOTES:

W = Watana Dam
DC = Devil Canyon Dam
HDC = High Devil Canyon Dam
V = Vee Dam

TABLE 8.18: ENERGY CONTRIBUTION EVALUATION OF THE WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

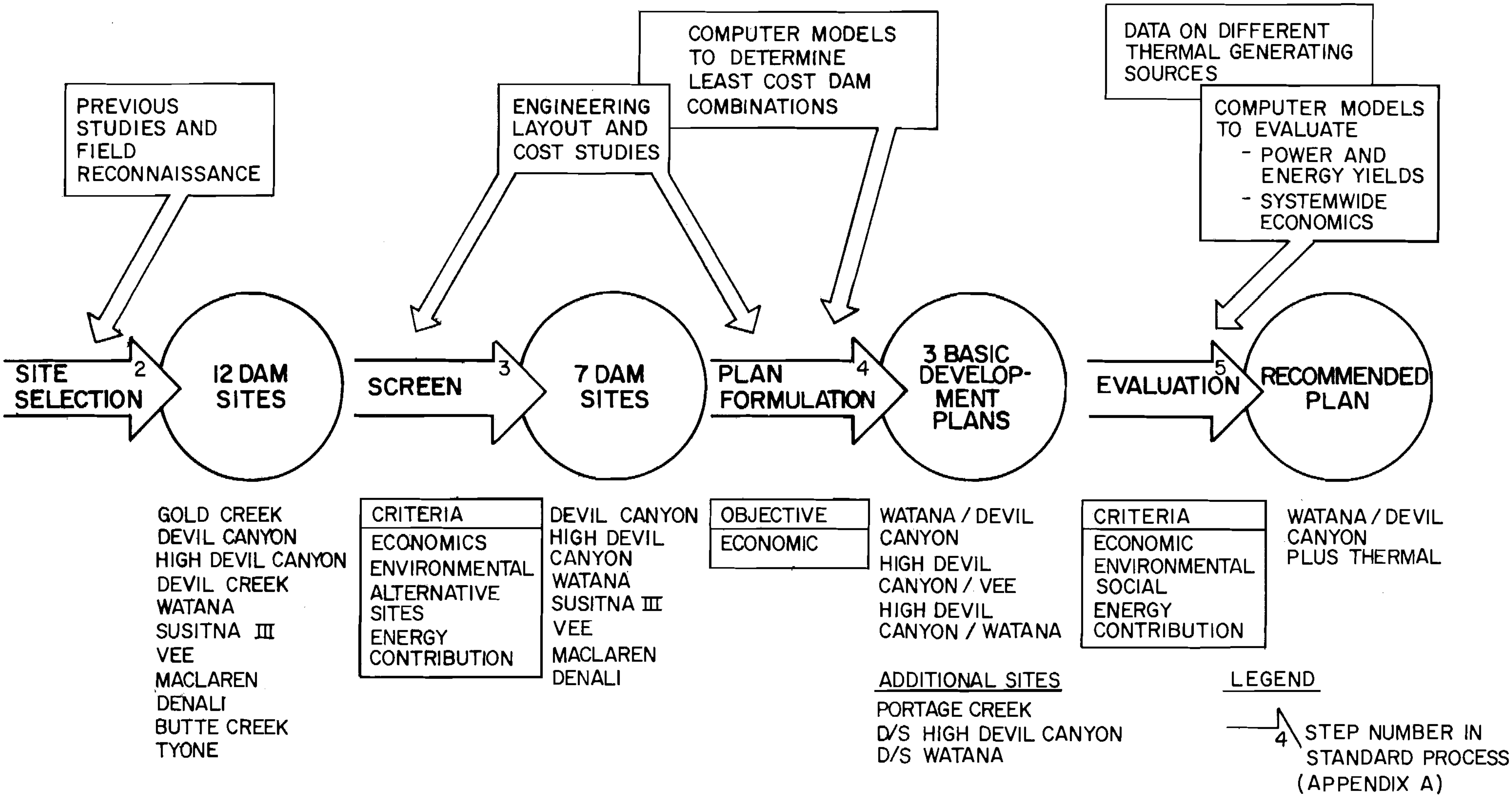
Parameter	Watana/ Devil Canyon	High Devil Canyon/Vee	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	6070	4910	Watana/Devil Canyon plan annually develops 1160 GWH and 1650 GWH more average and firm energy repectively than the High Devil Canyon/Vee Plan.
Firm Annual Energy GWH	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 conceived, the Watana/-Devil Canyon Plan does not develop 15 ft of the gross head between the Watana site and the Devil Canyon reservoir. The High Devil Canyon/Vee Plan does not develop 175 ft of the 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 8.19: OVERALL EVALUATION OF THE HIGH DEVIL CANYON/VEE AND WATANA/DEVIL CANYON DAM PLANS

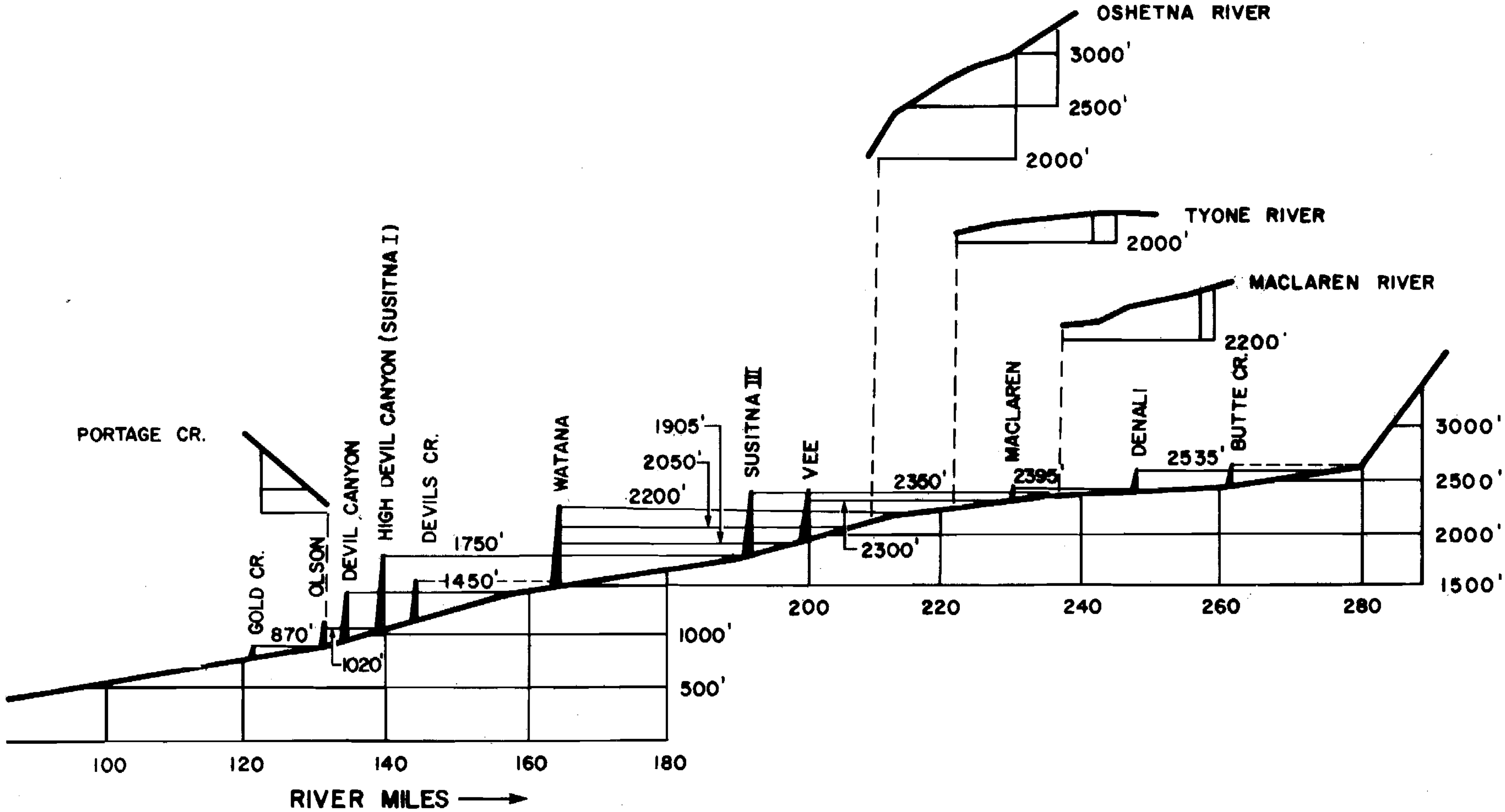
ATTRIBUTE	SUPERIOR PLAN
Economic	Watana/Devil Canyon
Energy Contribution	Watana/Devil Canyon
Environmental	Watana/Devil Canyon
Social	Watana/Devil Canyon (Marginal)
Overall Evaluation	Plan with Watana/Devil Canyon is superior Tradeoffs made: None



SUSITNA BASIN PLAN FORMULATION AND SELECTION PROCESS

ACRES

FIGURE 8.1



PROFILE THROUGH ALTERNATIVE SITES

FIGURE 8.2

ACRES

	GOLD CREEK	OLSON	DEVIL CANYON	HIGH DEVIL CANYON	DEVIL CREEK	WATANA	SUSITNA III	VEE	MACLAREN	DENALI	BUTTE CREEK	TYONE
GOLD CREEK												
OLSON			890 (50)									
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

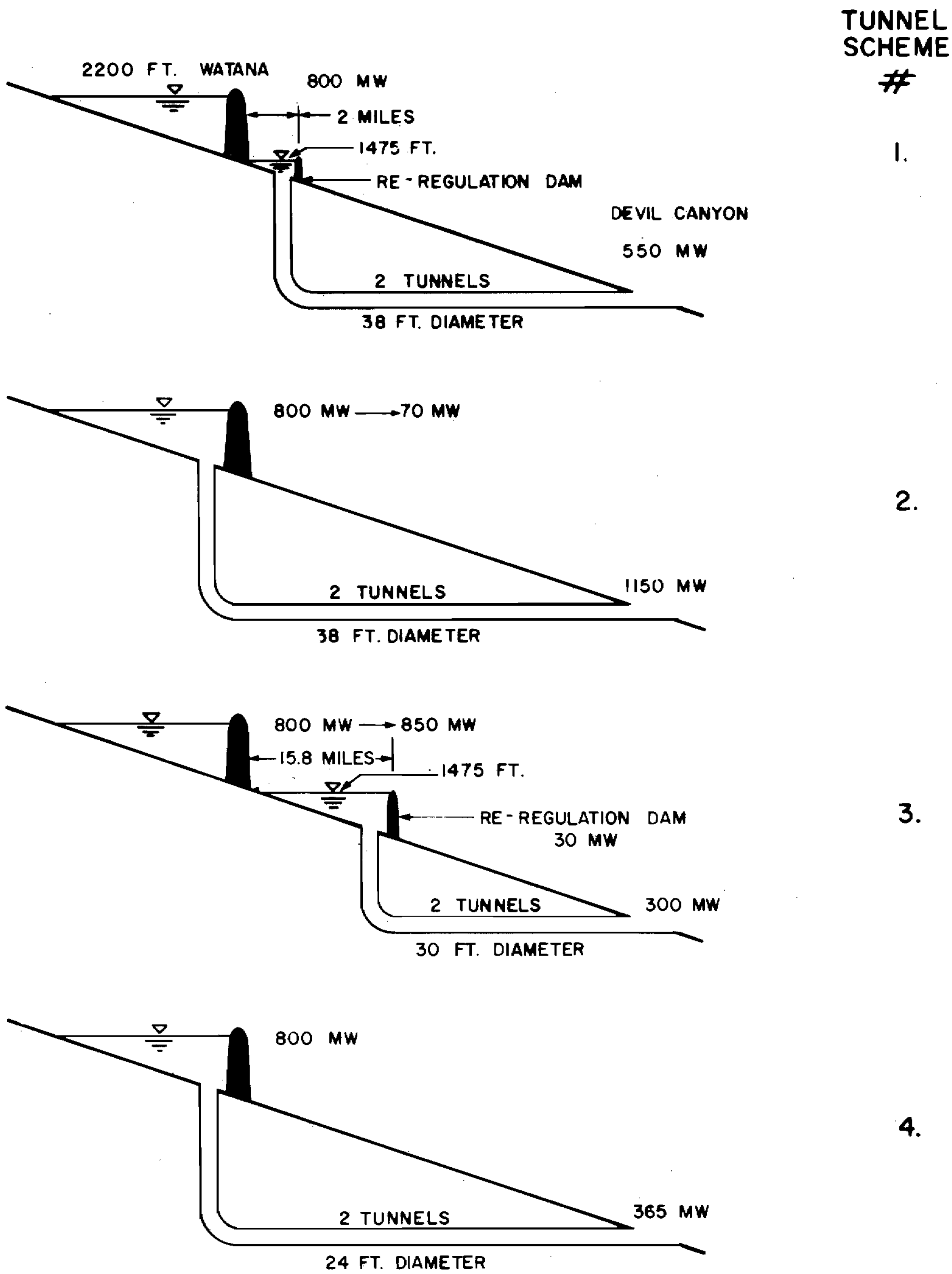
1465 (405) — DAM IN COLUMN IS MUTUALLY EXCLUSIVE IF FULL SUPPLY LEVEL OF DAM IN ROW EXCEEDS THIS VALUE - FT.

VALUE IN BRACKET REFERS TO APPROXIMATE DAM HEIGHT.

MUTUALLY EXCLUSIVE DEVELOPMENT ALTERNATIVES

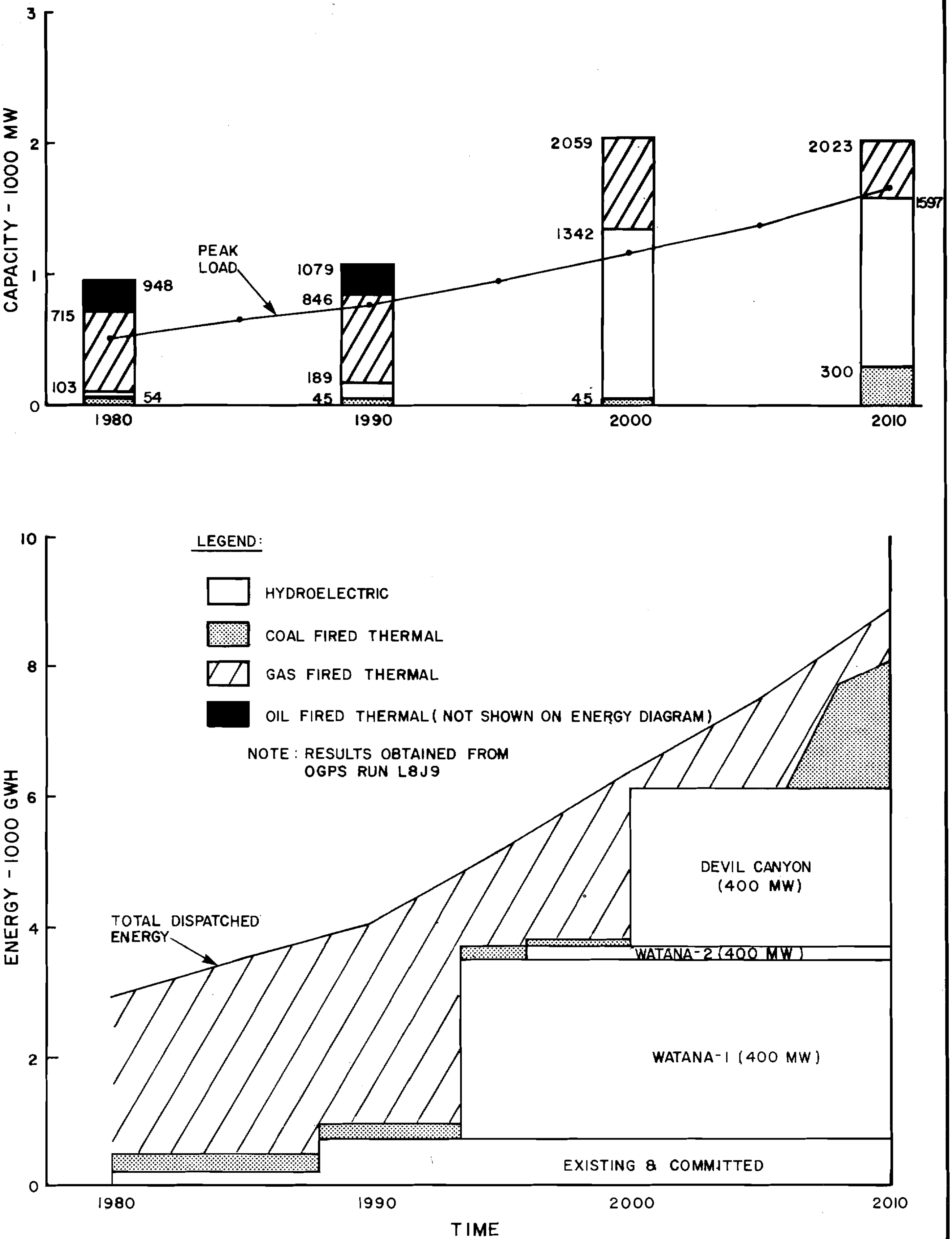
FIGURE 8.3

ACRES



SCHEMATIC REPRESENTATION
OF CONCEPTUAL TUNNEL SCHEMES

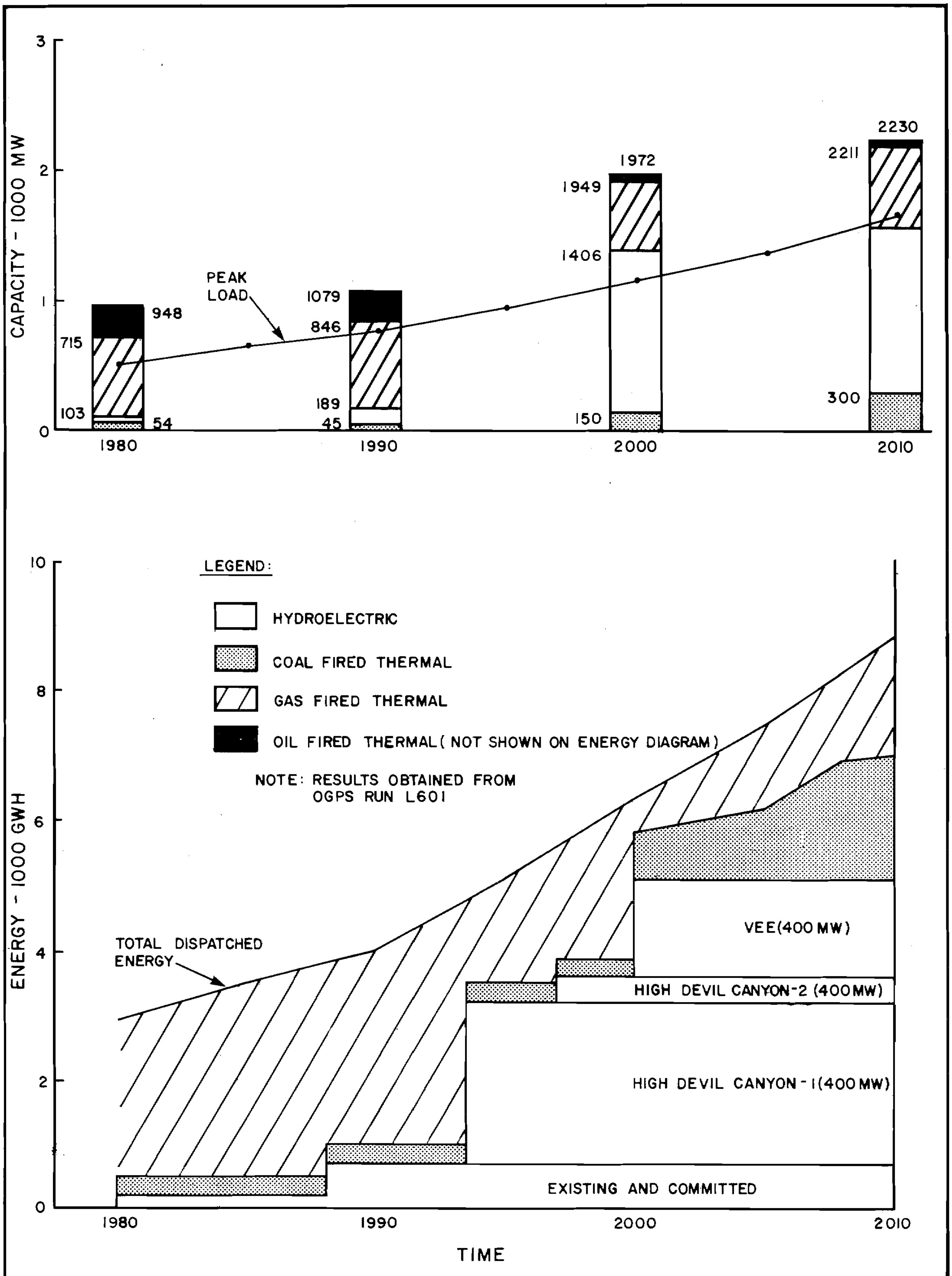
FIGURE 8.4



GENERATION SCENARIO WITH SUSITNA PLAN E1.3
-MEDIUM LOAD FORECAST-

ACRES

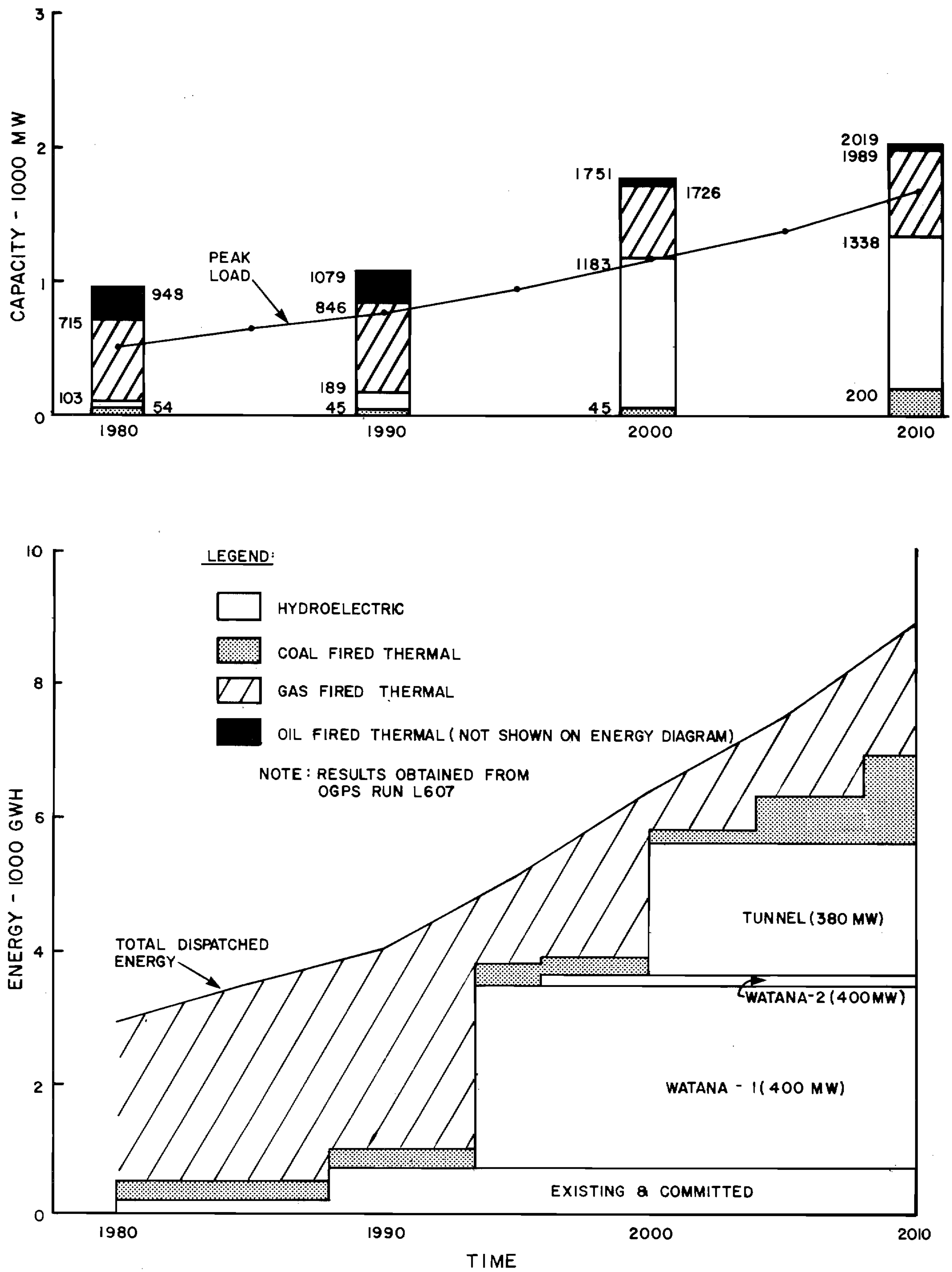
FIGURE 8.5



GENERATION SCENARIO WITH SUSITNA PLAN E 2.3
- MEDIUM LOAD FORECAST -

ACRES

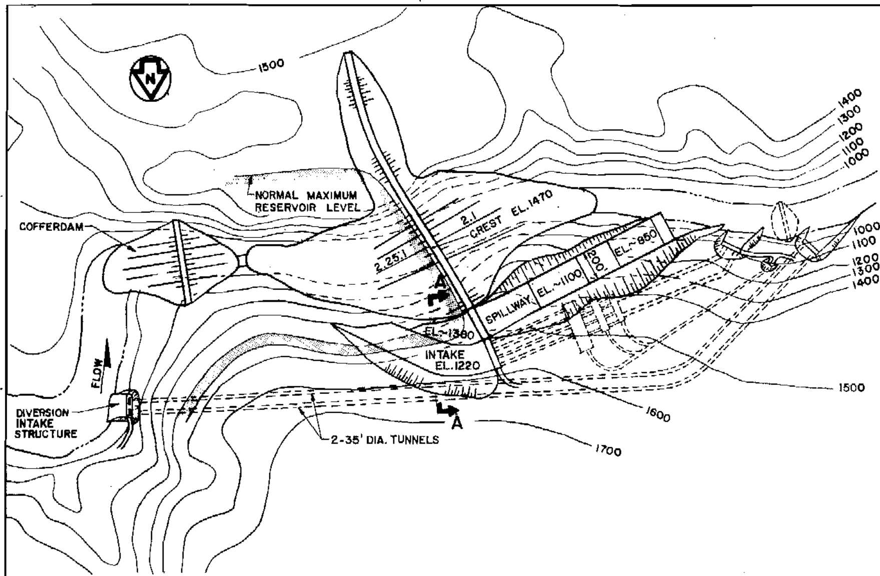
FIGURE 8.6



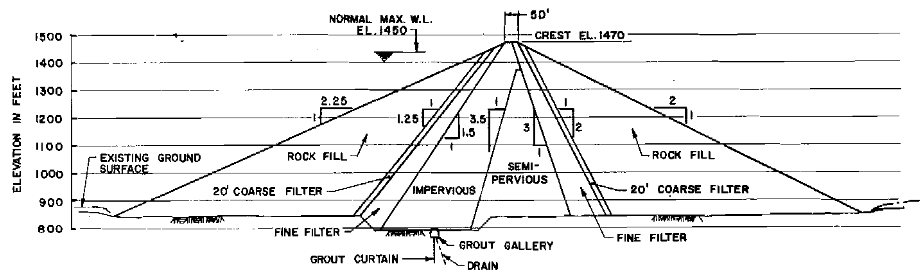
GENERATION SCENARIO WITH SUSITNA PLAN E3.1
- MEDIUM LOAD FORECAST -

ACRES

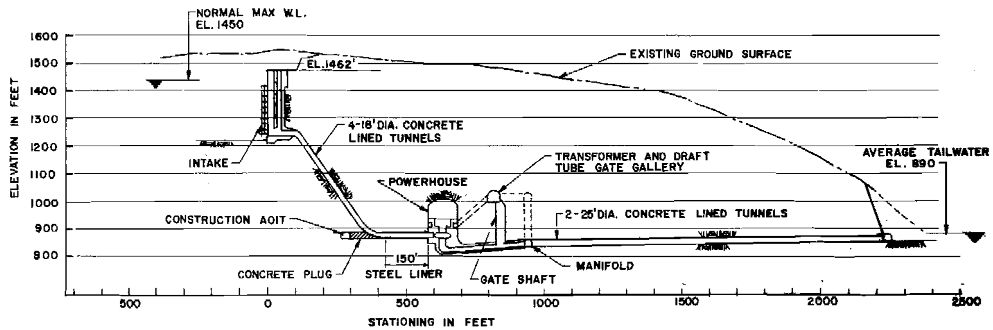
FIGURE 8.7



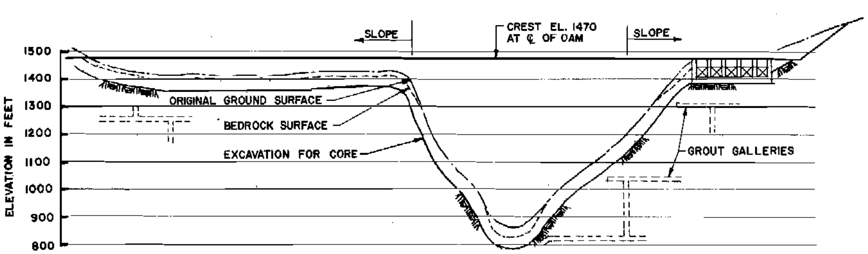
GENERAL ARRANGEMENT
SCALE: A



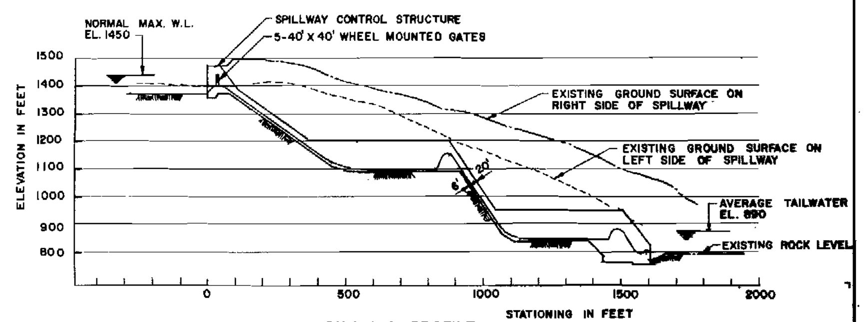
SECTION THRU DAM
SCALE: B



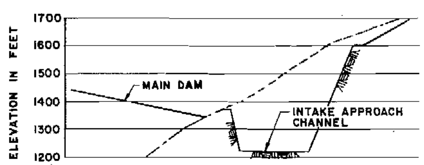
POWER FACILITIES PROFILE
SCALE: B



LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE: B



SPILLWAY PROFILE
SCALE: B



SECTION A-A
SCALE: B

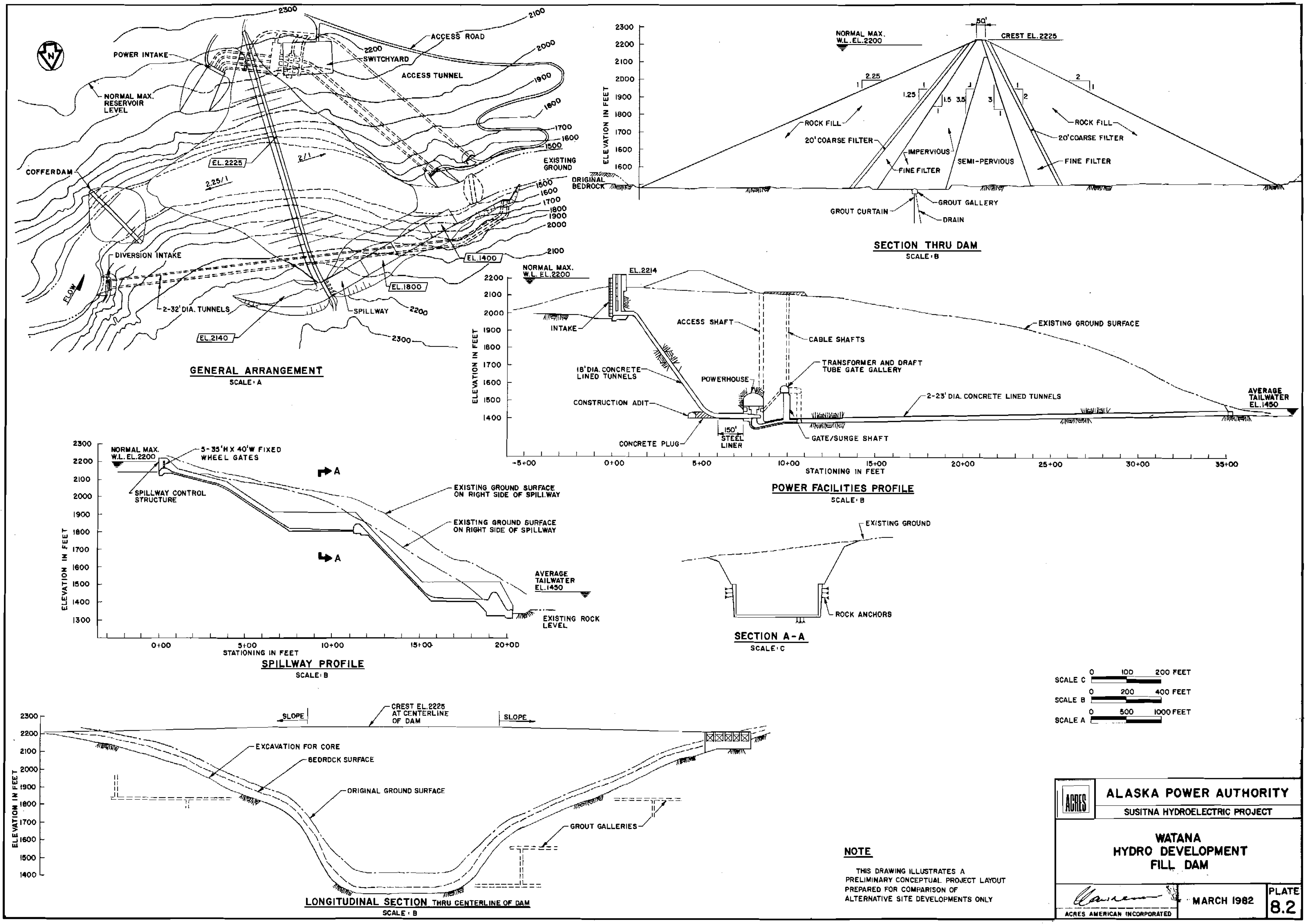
SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

NOTE

THIS DRAWING ILLUSTRATES A PRELIMINARY CONCEPTUAL PROJECT LAYOUT PREPARED FOR COMPARISON OF ALTERNATIVE SITE DEVELOPMENTS ONLY

ACRES	ALASKA POWER AUTHORITY
	SUSITNA HYDROELECTRIC PROJECT
	DEVIL CANYON HYDRO DEVELOPMENT FILL DAM
ACRES AMERICAN INCORPORATED	MARCH 1982
	PLATE 8.1


GENERAL ARRANGEMENT
SCALE: A
POWER INTAKE
SWITCHYARD
ACCESS ROAD
ACCESS TUNNEL
NORMAL MAX. RESERVOIR LEVEL
COFFERDAM
EL.2225
2.25/1
2/1
EXISTING GROUND
EL.1400
EL.1800
EL.2140
DIVERSION INTAKE
FLOW
2-32' DIA. TUNNELS
SPILLWAY
SECTION THRU DAM
SCALE: B
NORMAL MAX. W.L. EL.2200
CREST EL.2225
30'
ROCK FILL
20' COARSE FILTER
IMPERVIOUS
FINE FILTER
SEMI-PERVIOUS
ORIGINAL BEDROCK
GROUT CURTAIN
GROUT GALLERY
DRAIN
ELEVATION IN FEET
POWER FACILITIES PROFILE
SCALE: B
EL.2214
INTAKE
ACCESS SHAFT
CABLE SHAFTS
EXISTING GROUND SURFACE
18' DIA. CONCRETE LINED TUNNELS
POWERHOUSE
TRANSFORMER AND DRAFT TUBE GATE GALLERY
2-23' DIA. CONCRETE LINED TUNNELS
CONSTRUCTION ADIT
CONCRETE PLUG
150' STEEL LINER
GATE/SURGE SHAFT
AVERAGE TAILWATER EL.1450
STATIONING IN FEET
SPILLWAY PROFILE
SCALE: B
5-35'H X 40'W FIXED WHEEL GATES
SPILLWAY CONTROL STRUCTURE
EXISTING GROUND SURFACE ON RIGHT SIDE OF SPILLWAY
EXISTING GROUND SURFACE ON RIGHT SIDE OF SPILLWAY
EXISTING ROCK LEVEL
A
SECTION A-A
SCALE: C
EXISTING GROUND
ROCK ANCHORS
SCALE C 0 100 200 FEET
SCALE B 0 200 400 FEET
SCALE A 0 500 1000 FEET
LONGITUDINAL SECTION THRU CENTERLINE OF DAM
SCALE: B
CREST EL.2225 AT CENTERLINE OF DAM
SLOPE
EXCAVATION FOR CORE
BEDROCK SURFACE
ORIGINAL GROUND SURFACE
GROUT GALLERIES
NOTE
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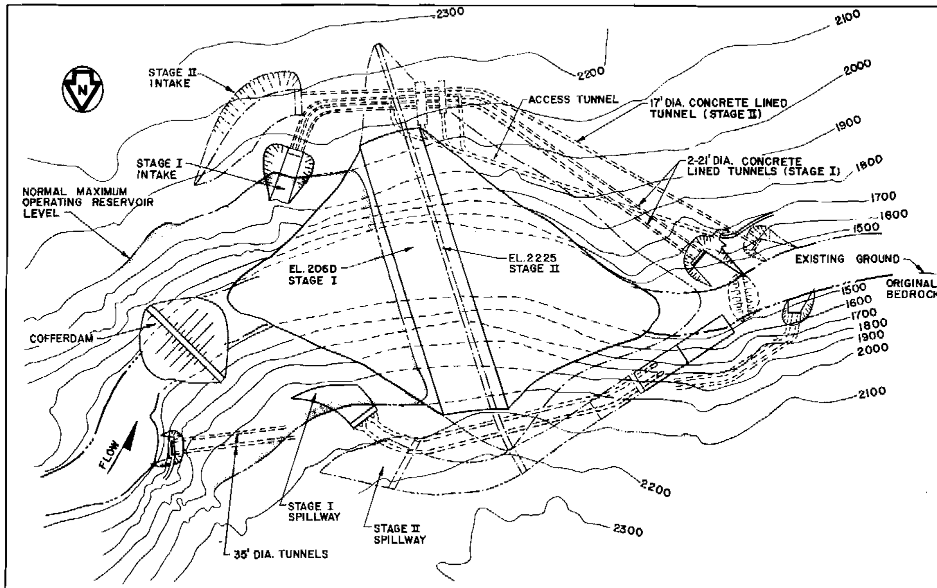
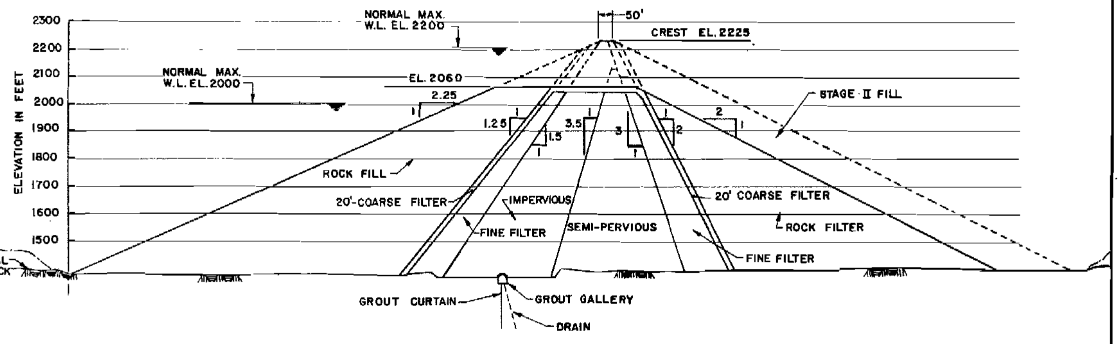
ACRES
ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT
WATANA HYDRO DEVELOPMENT FILL DAM
ACRES AMERICAN INCORPORATED
MARCH 1982
PLATE 8.2



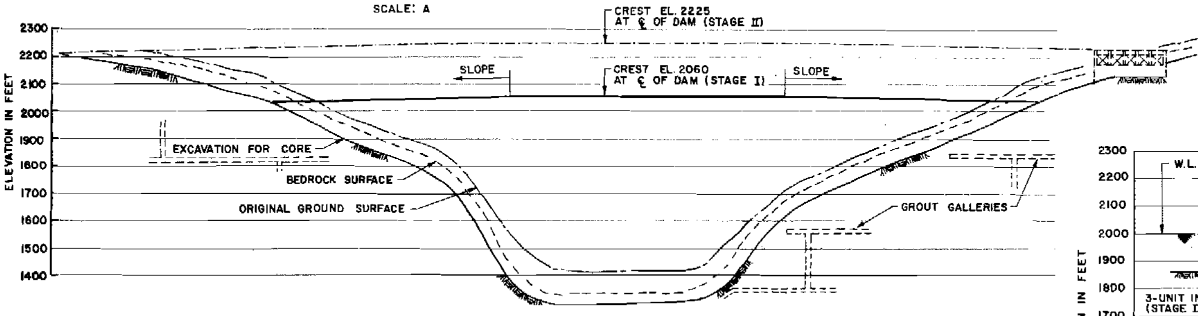
GENERAL ARRANGEMENT

SCALE: A



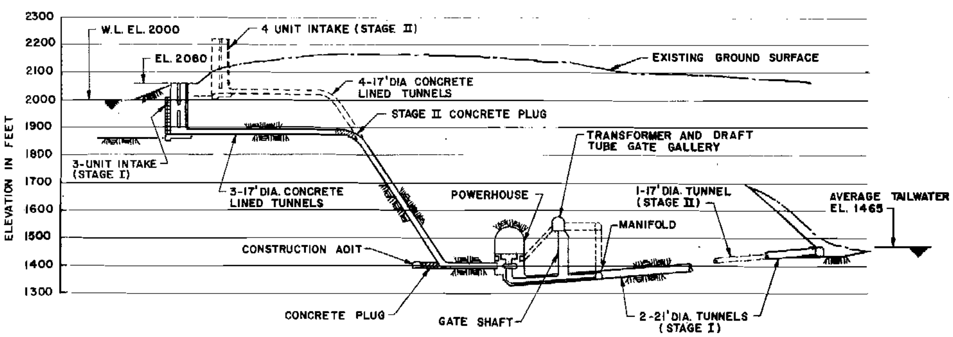
SECTION THRU DAM

SCALE: B



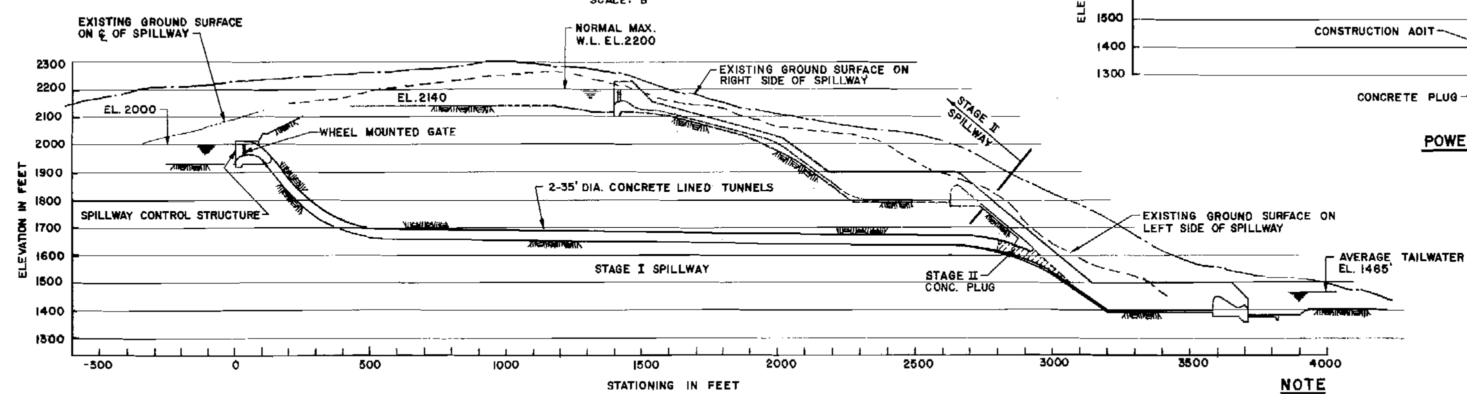
LONGITUDINAL SECTION THRU ℄ OF DAM

SCALE: B



POWER FACILITIES PROFILE

SCALE: B



SPILLWAY PROFILE

SCALE: B

SCALE B 0 200 400 FEET

SCALE A 0 500 1000 FEET

NOTE

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ACRES

ALASKA POWER AUTHORITY

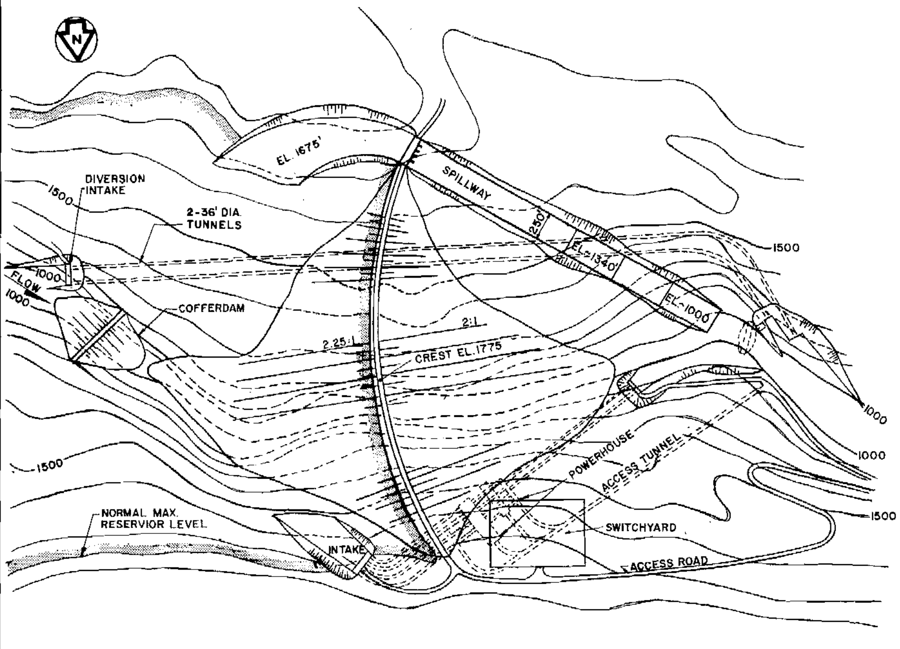
SUSITNA HYDROELECTRIC PROJECT

WATANA
STAGED FILL DAM

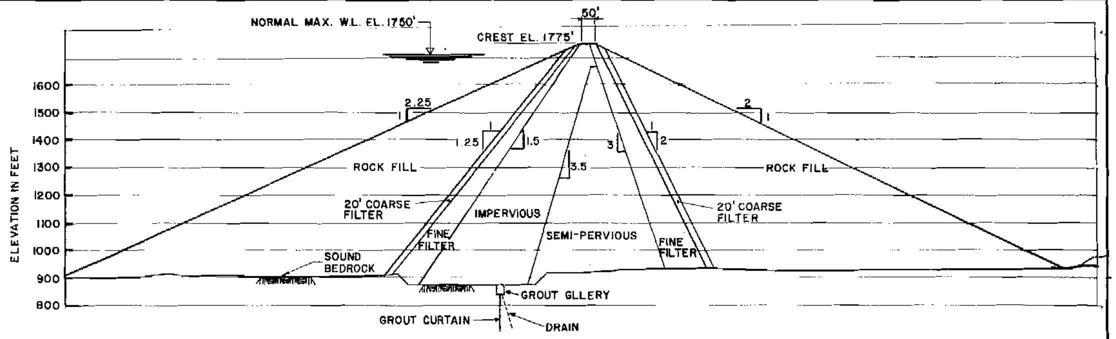
ACRES AMERICAN INCORPORATED

MARCH 1982

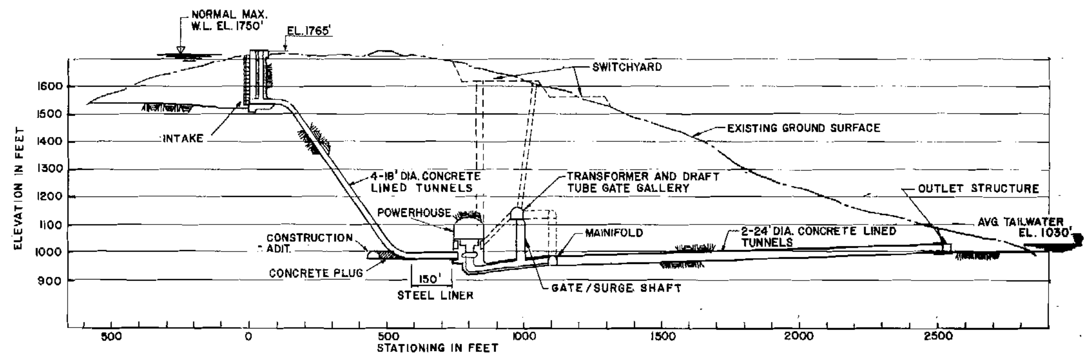
PLATE 8.3



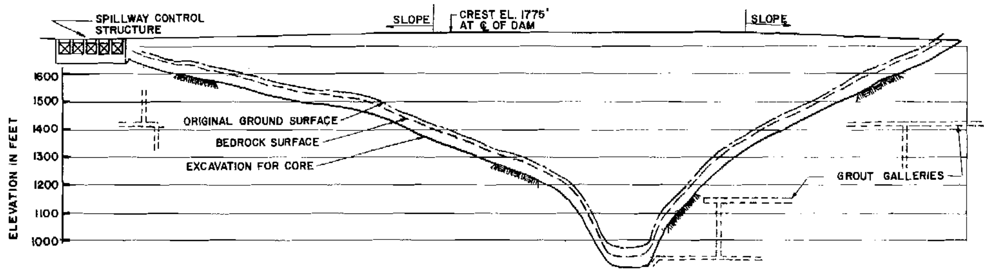
GENERAL ARRANGEMENT
SCALE : A



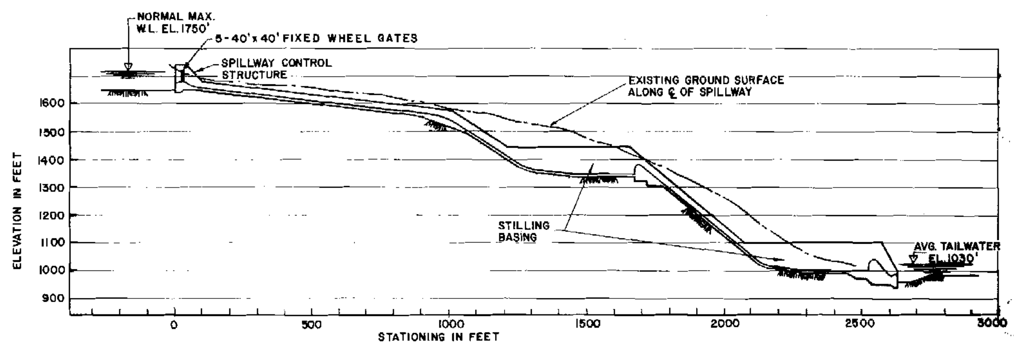
SECTION THRU DAM
SCALE : B



POWER FACILITIES PROFILE
SCALE : B



LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE : B



SPILLWAY PROFILES
SCALE : B

SCALE A 0 400 800 FEET

SCALE B 0 200 400 FEET

NOTE

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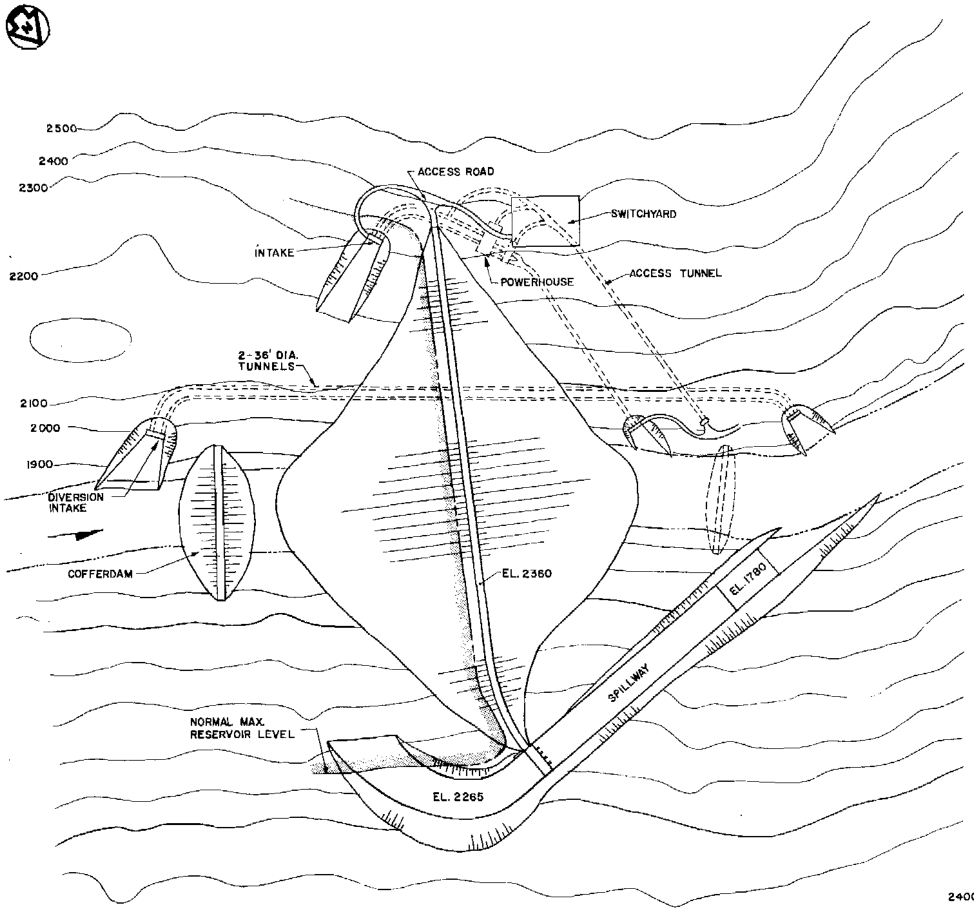
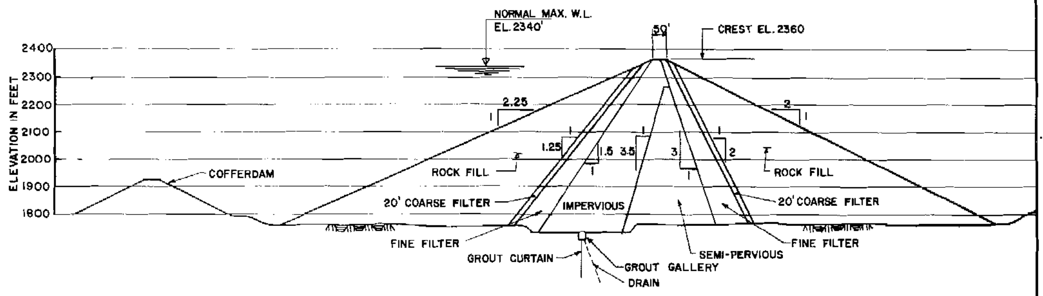
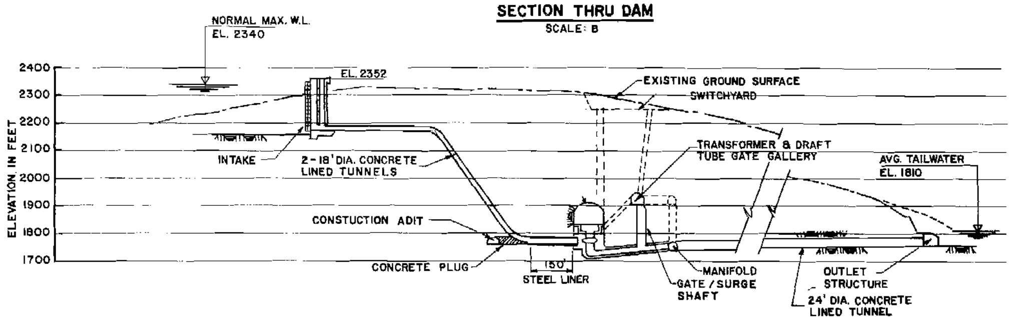
	SUSITNA HYDROELECTRIC PROJECT
HIGH DEVIL CANYON HYDRO DEVELOPMENT	
ACRES AMERICAN INCORPORATED	MARCH 1982
PLATE 8.4	



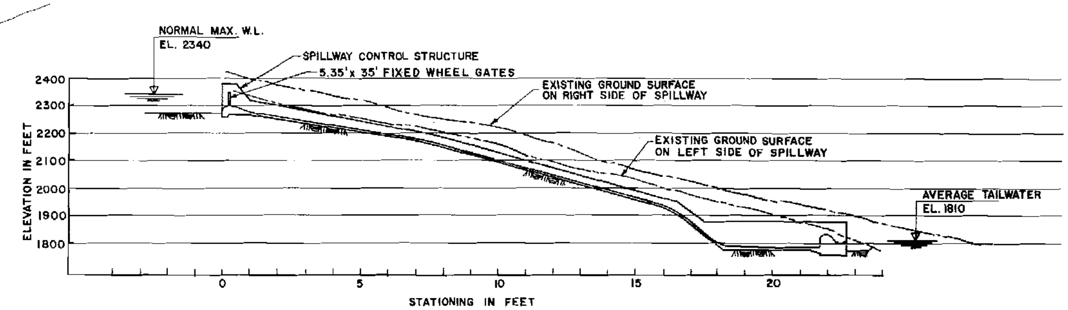
GENERAL ARRANGEMENT
SCALE: A



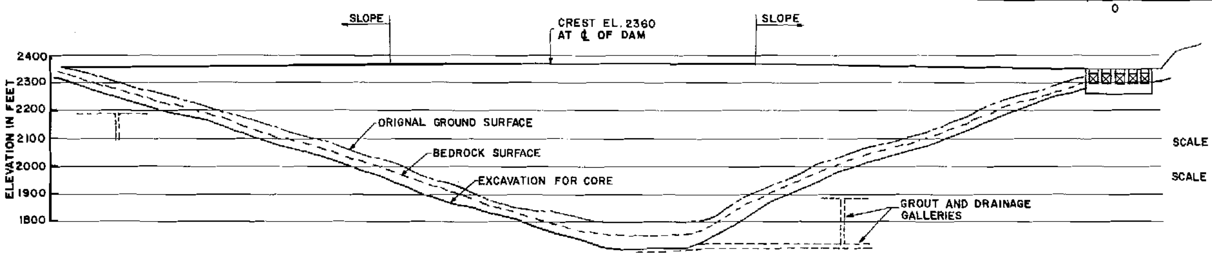
SECTION THRU DAM
SCALE: B



POWER FACILITIES PROFILE
SCALE: B



SPILLWAY PROFILE
SCALE: B



LONGITUDINAL SECTION THRU ℄ OF DAM
SCALE: B

SCALE A 0 400 800

SCALE B 0 200 400

NOTE

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ACRES

ALASKA POWER AUTHORITY

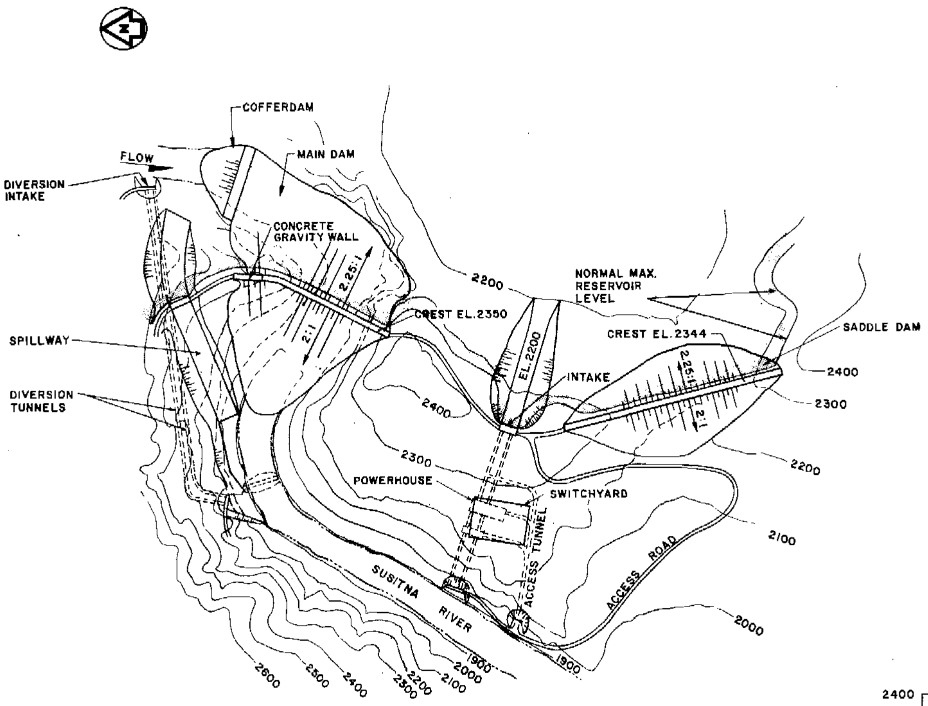
SUSITNA HYDROELECTRIC PROJECT

SUSITNA III
HYDRO DEVELOPMENT

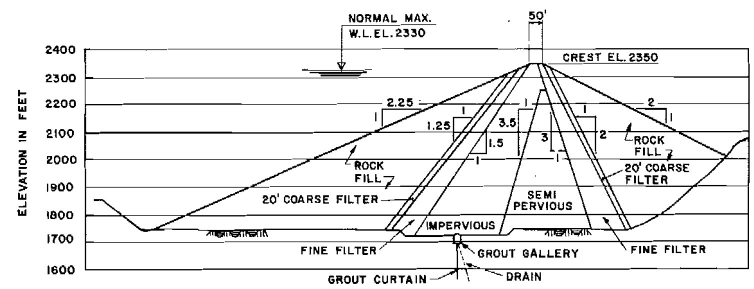
ACRES AMERICAN INCORPORATED

MARCH 1982

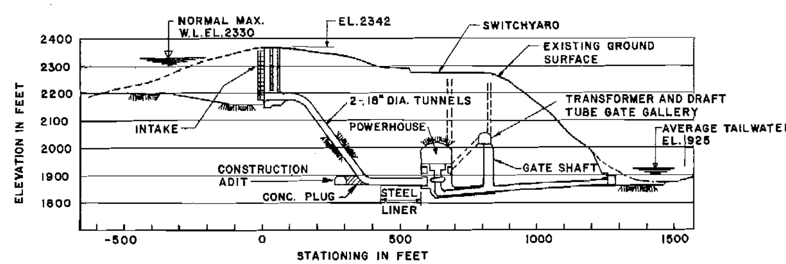
PLATE 8.5



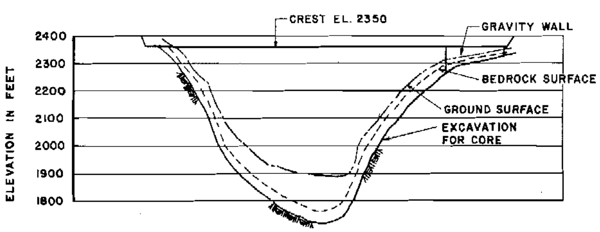
GENERAL ARRANGEMENT
SCALE A



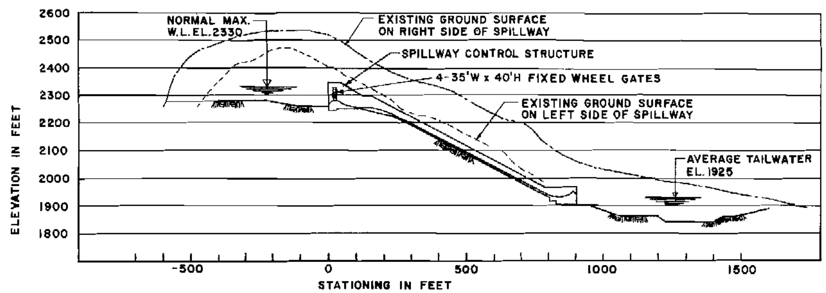
SECTION THRU DAM
SCALE B



POWER FACILITIES PROFILE
SCALE B



LONGITUDINAL SECTION THRU ℄ OF MAIN DAM
SCALE B



SPILLWAY PROFILE
SCALE B

SCALE B 0 200 400 FEET

SCALE A 0 400 800 FEET

NOTE

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ACRES

ALASKA POWER AUTHORITY

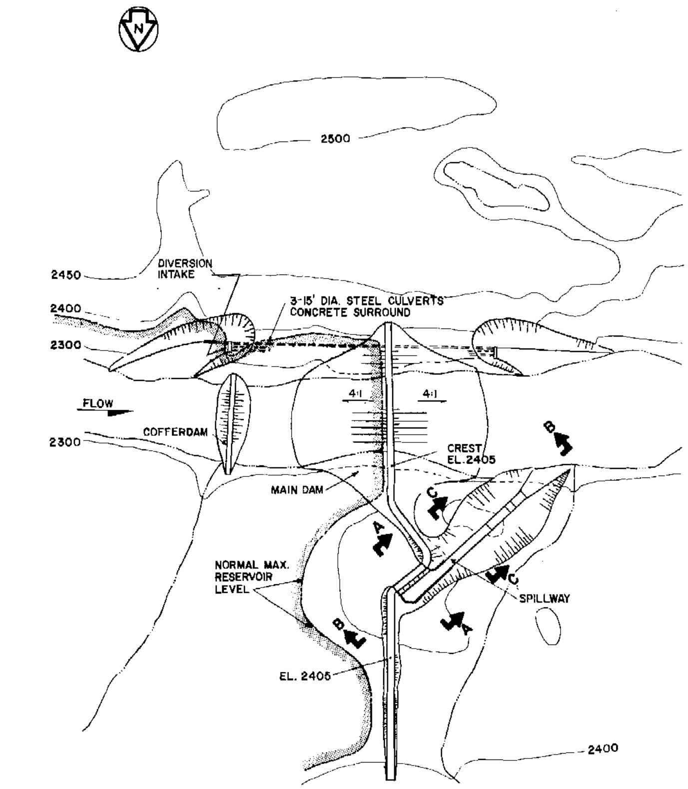
SUSITNA HYDROELECTRIC PROJECT

VEE
HYDRO DEVELOPMENT

ACRES AMERICAN INCORPORATED

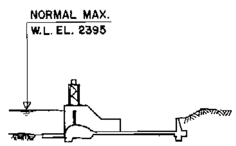
MARCH 1982

PLATE 8.6



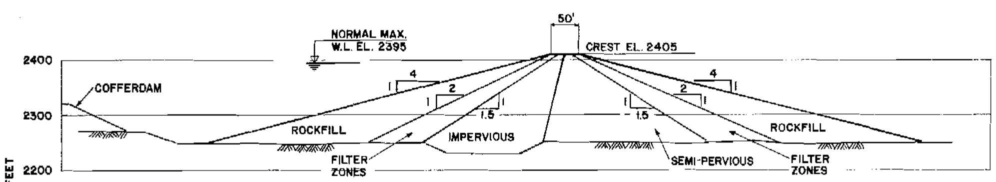
MACLAREN GENERAL ARRANGEMENT

SCALE: A



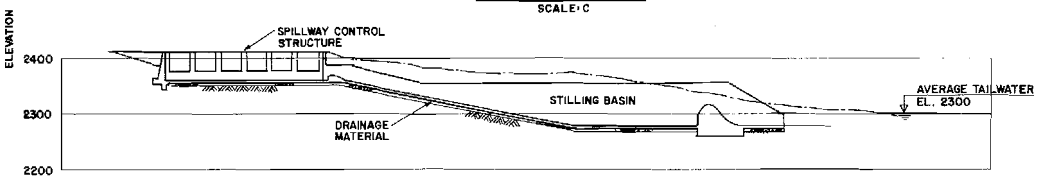
SECTION A-A

SECTION C-C



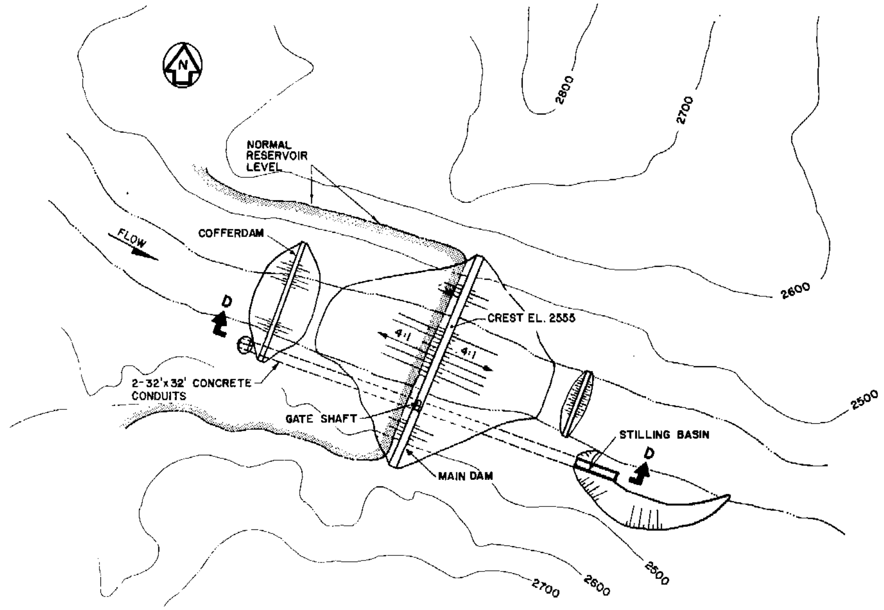
DAM CROSS SECTION

SCALE: C



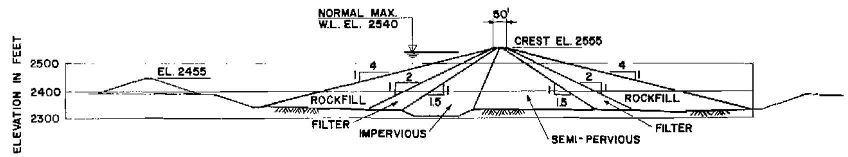
SECTION B-B

SCALE: C

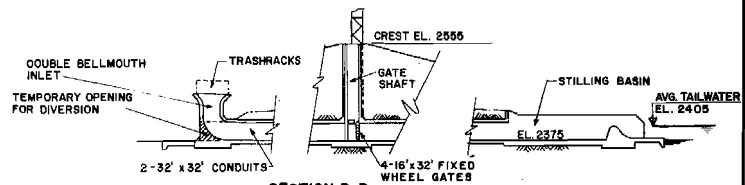


DENALI GENERAL ARRANGEMENT

SCALE: A



DAM CROSS SECTION



SECTION D-D

SCALE: C

SCALE: C 0 100 200 FEET

SCALE: B 0 200 400 FEET

SCALE: A 0 400 800 FEET

NOTE

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ALASKA POWER AUTHORITY

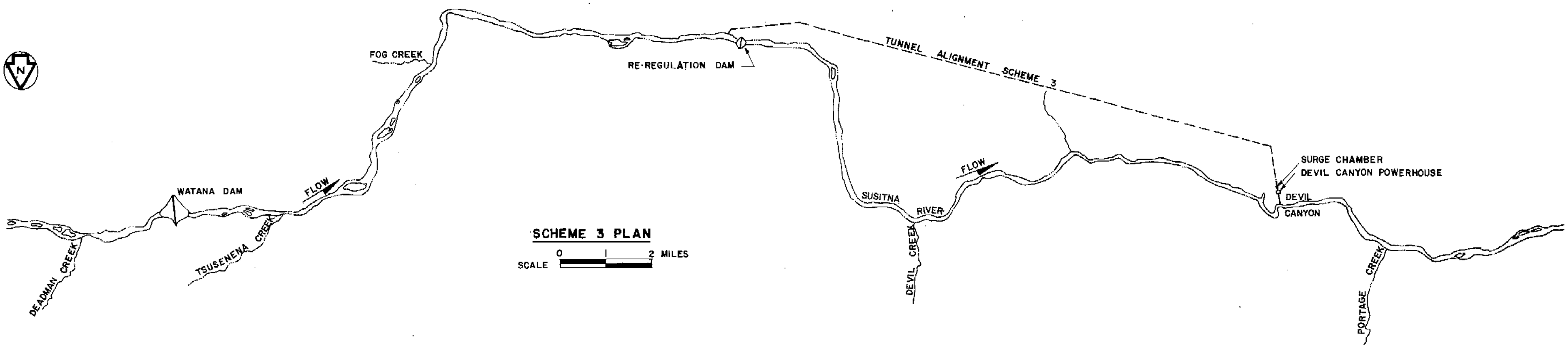
SUSITNA HYDROELECTRIC PROJECT

DENALI & MACLAREN HYDRO DEVELOPMENTS

ACRES AMERICAN INCORPORATED

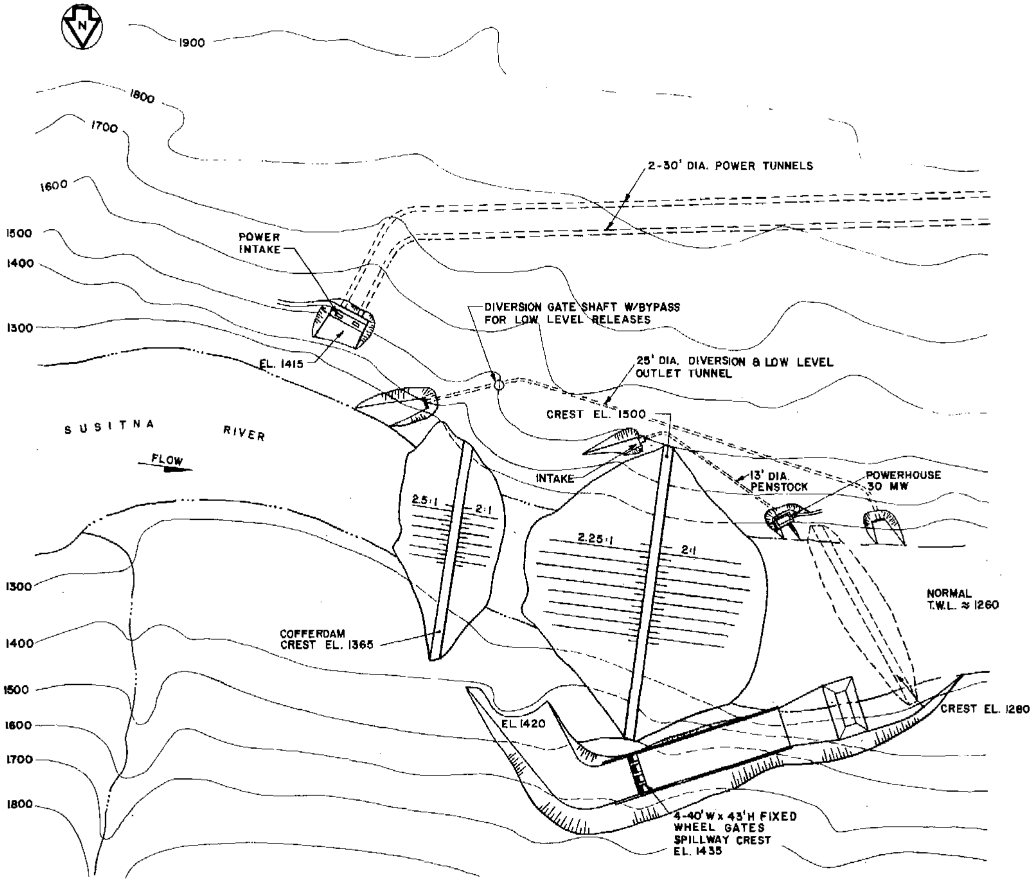
MARCH 1982

PLATE 8.7



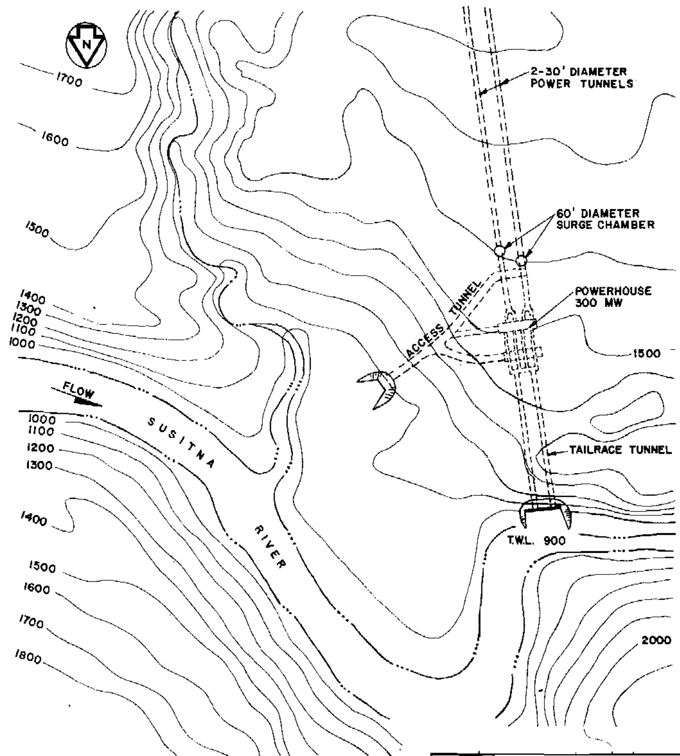
SCHEME 3 PLAN

SCALE 0 1 2 MILES



GENERAL ARRANGEMENT
RE-REGULATION DAM

SCALE 0 300 600 FEET



GENERAL ARRANGEMENT
DEVIL CANYON POWERHOUSE

SCALE 0 400 800 FEET

NOTE

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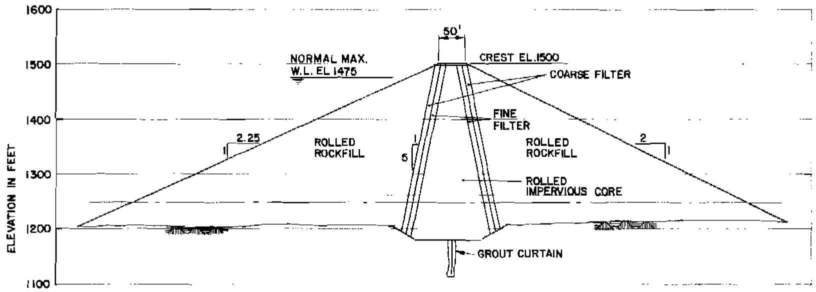
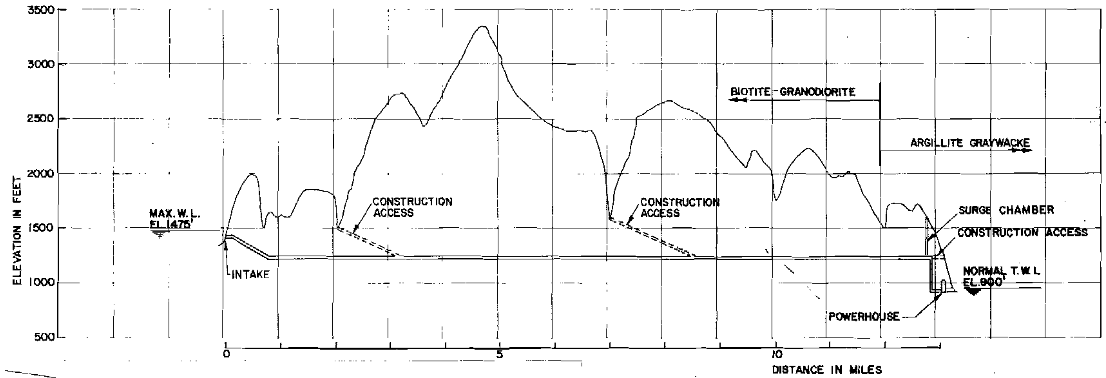
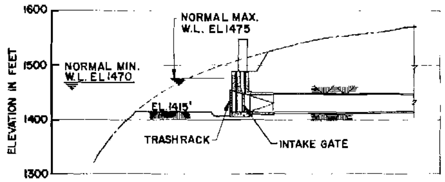
ACRES	ALASKA POWER AUTHORITY
	SUSITNA HYDROELECTRIC PROJECT
	PREFERRED TUNNEL SCHEME 3 PLAN VIEW
ACRES AMERICAN INCORPORATED	MARCH 1982	PLATE 8.8



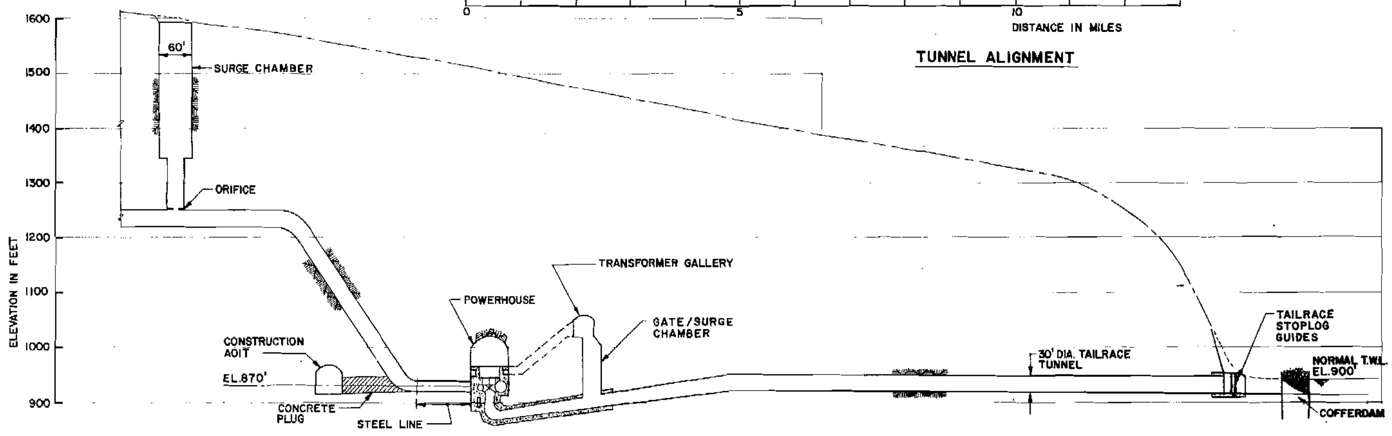
RE-REGULATION DAM TYPICAL SECTION
SCALE A



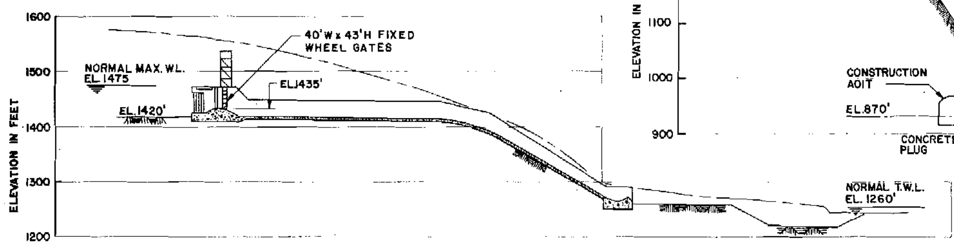
TUNNEL ALIGNMENT



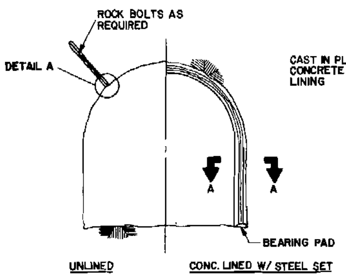
POWER TUNNEL INTAKE SECTION
SCALE A



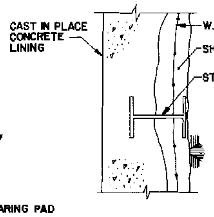
DEVIL CANYON POWER FACILITIES PROFILE
SCALE A



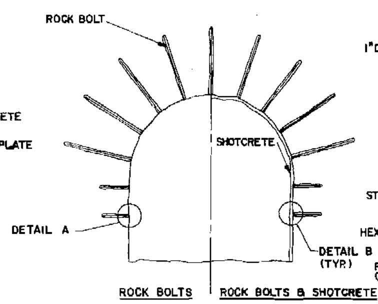
SPILLWAY PROFILE
SCALE A



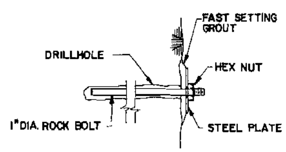
TYPICAL TUNNEL SECTIONS
(N.T.S.)



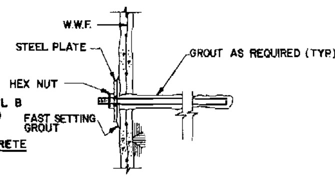
SECTION A



TYPICAL TUNNEL SECTIONS
(N.T.S.)



DETAIL A



DETAIL B

SCALE A 0 100 200 FEET

NOTE

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ACRES

ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

PREFERRED TUNNEL
SCHEME 3
SECTIONS

ACRES AMERICAN INCORPORATED

MARCH 1982

PLATE 8.9