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SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME 1

FIRST DRAFT

SECTIONS 1 - 8

Prepared by:

ACRES

ALASKA POWER AUTHORITY

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SUSITNA HYDROELECTRIC PROJECT
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ALASKA POWER AUTHORITY
SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

VOLUME 1 - ENGINEERING AND ECONOMIC ASPECTS

FIRST DRAFT

FEBRUARY, 1982

SUSITNA HYDROELECTRIC PROJECT

FEASIBILITY REPORT

PRELIMINARY OUTLINE

VOLUME 1 - ENGINEERING AND ECONOMIC ASPECTS

List of Plates

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List of Plates (cont'd)

1 - INTRODUCTION

This Feasibility Report has been prepared by Acres American Incorporated (Acres) for the Alaska Power Authority (APA) 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 APA 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 construction of the development.

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 performed concurrently with ongoing site surveys and investigations, and environmental studies were updated in conjunction with an independent study of alternatives for meeting project Railbelt electric power requirements by Battelle Pacific Northwest, and also 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 appropiate 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 Plate 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 early May.

The Susitna River and its tributaries are important components of Alaska's highly prolific fishery resource. Salmon, Dolly Varden trout, grayling, and whitefish are found within the Basin. Waterfowl habitat in the glacial outwash plain supports trumpeter swan and migratory fowl. Bear, moose, and caribou thrive there. Extensive studies are necessary to determine the total value of these extensive 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 183 of 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 Plate 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 west 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 each of the two sites would be conveyed by double 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. The economic evaluation confirmed that the project would have a favorable benefit-cost relationship over a range of probable economic and financial conditions, and that the necessary financing and power marketing arrangements were feasible.

1.3 - Objectives and Scope of Current Studies

The assessment of feasibility of an undertaking as important and 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 establish 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.

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 resolved in an additional 10 subtasks, the largest task then accounting for 39 subtasks.

Activities ranged from engineering and scientific data acquistions, 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 the ordinary person.

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 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. Figure 1.1 illustrates 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 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.

- The major impact caused by the use of these inflation adjusted parameters was the improvement of the relative economics of capital intensive projects (such as hydro generation) versus the high fuel consumption projects (such as thermal generation). It also led to the selection of larger economic optimum sizes of the capital intensive projects. These shifts toward the capital intensive projects were consistent with maximizing total benefits to the state.

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 clarify 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 operatings levels and the installed generating capacity of the power facilities 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 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.

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 APA.

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 comparises 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 - Electrical Supply and Demand Studies

This volume contains the OGP data used to support and develop the electrical supply and demand studies.

Volume 5 - Hydrological Studies

This volume includes detailed hydrological and meteorolcgical data, supportive data for water resource studies and flood studies, ice studies, sediment yield and river morphology studies, climatic studies for transmission lines, and lower Susitna River studies.

Volume 6 - Project Land Studies

This volume contains land status information, an inventory of private and public lands required for the project, and marketability and disposal studies for the reservoir areas.

Volume 7 - Design Development Studies

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

Volume 8 - Transmission Line Studies

This volume includes electric systems studies, a report on transmission line corridor screening, and maps of the transmission line route.

Volume 9 - Cost Estimates

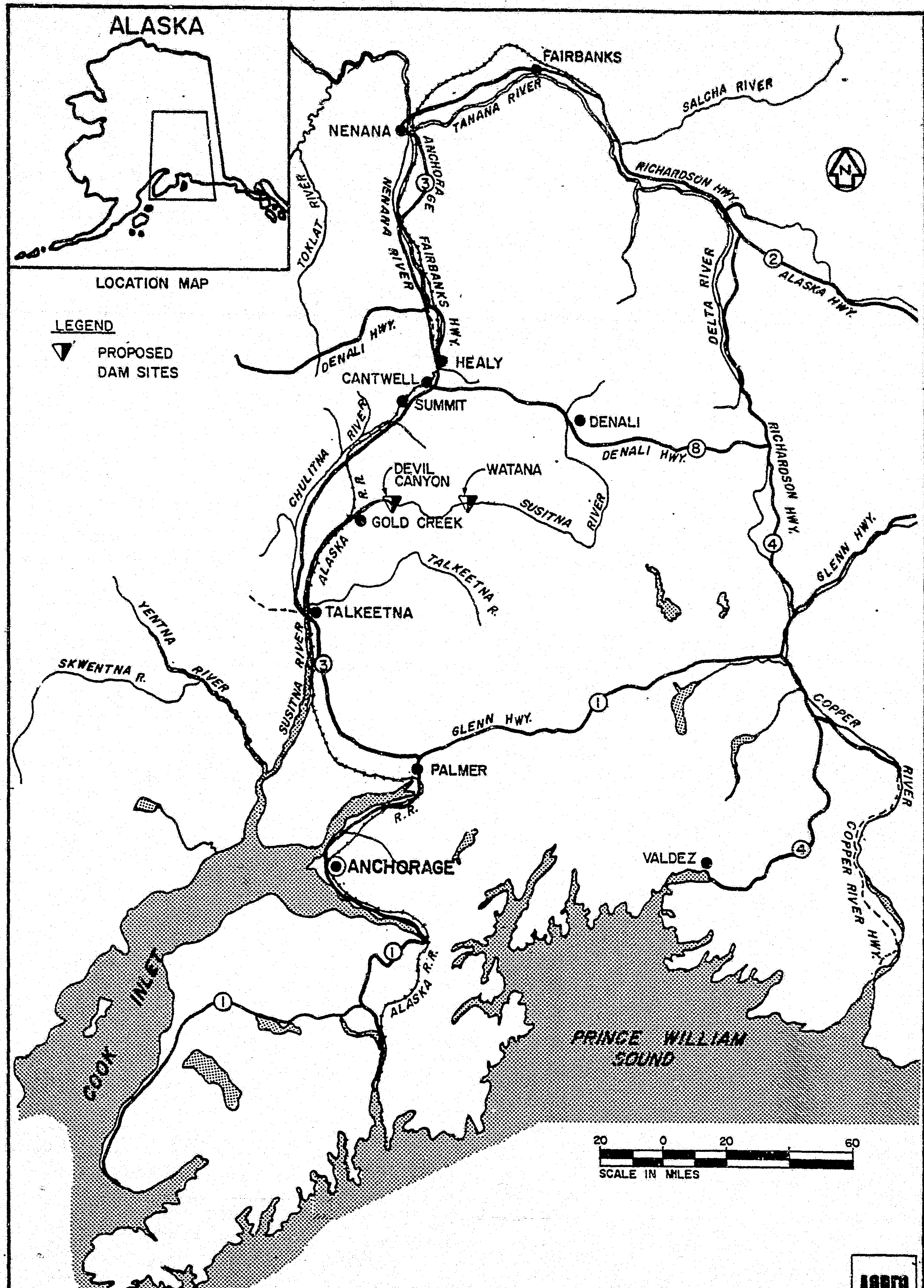
Detailed cost estimates and supporting cost data are presented in this volume.

Volume 10 - 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.

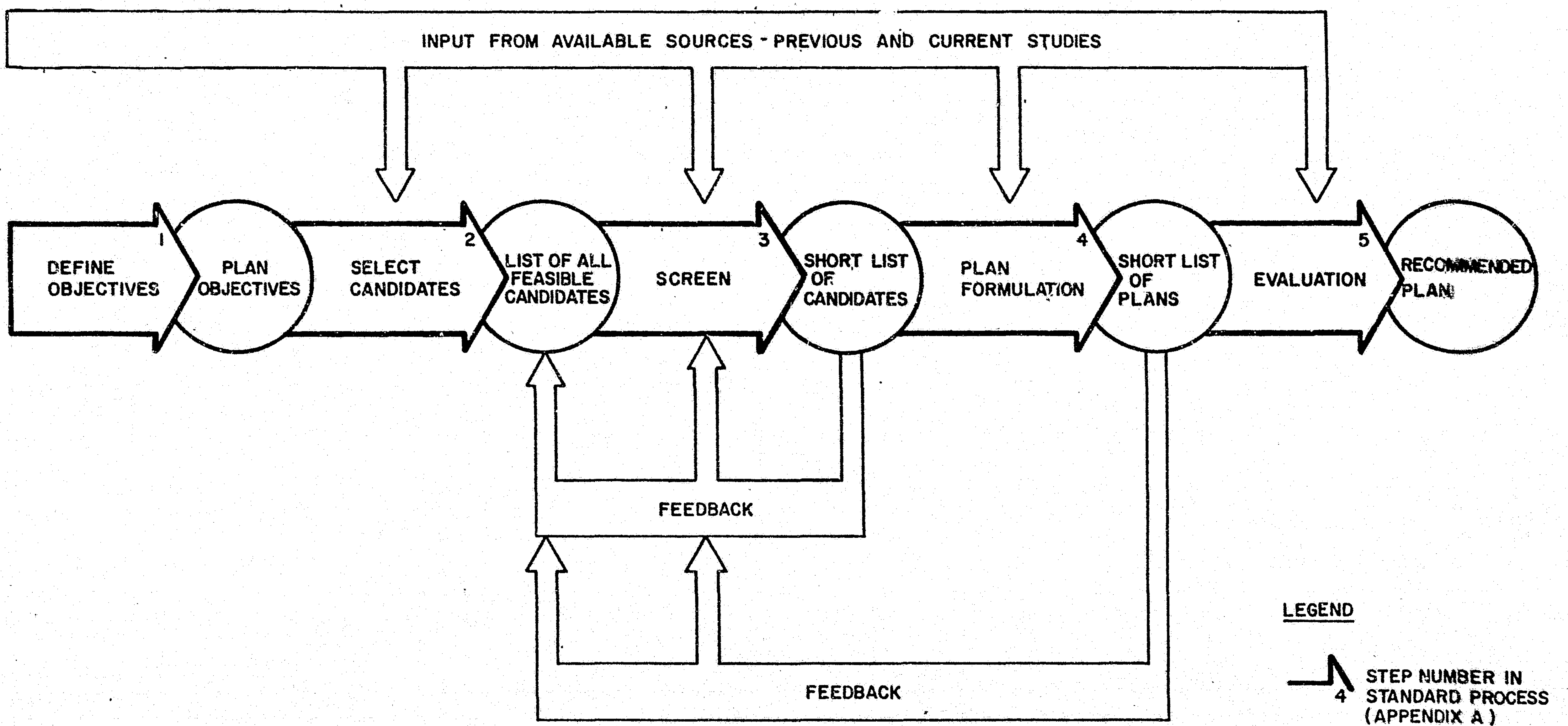
Volume 11 - Coordination and Public Participation

This volume describes the public participation program and presents a summary of public participation meetings conducted during the study program.



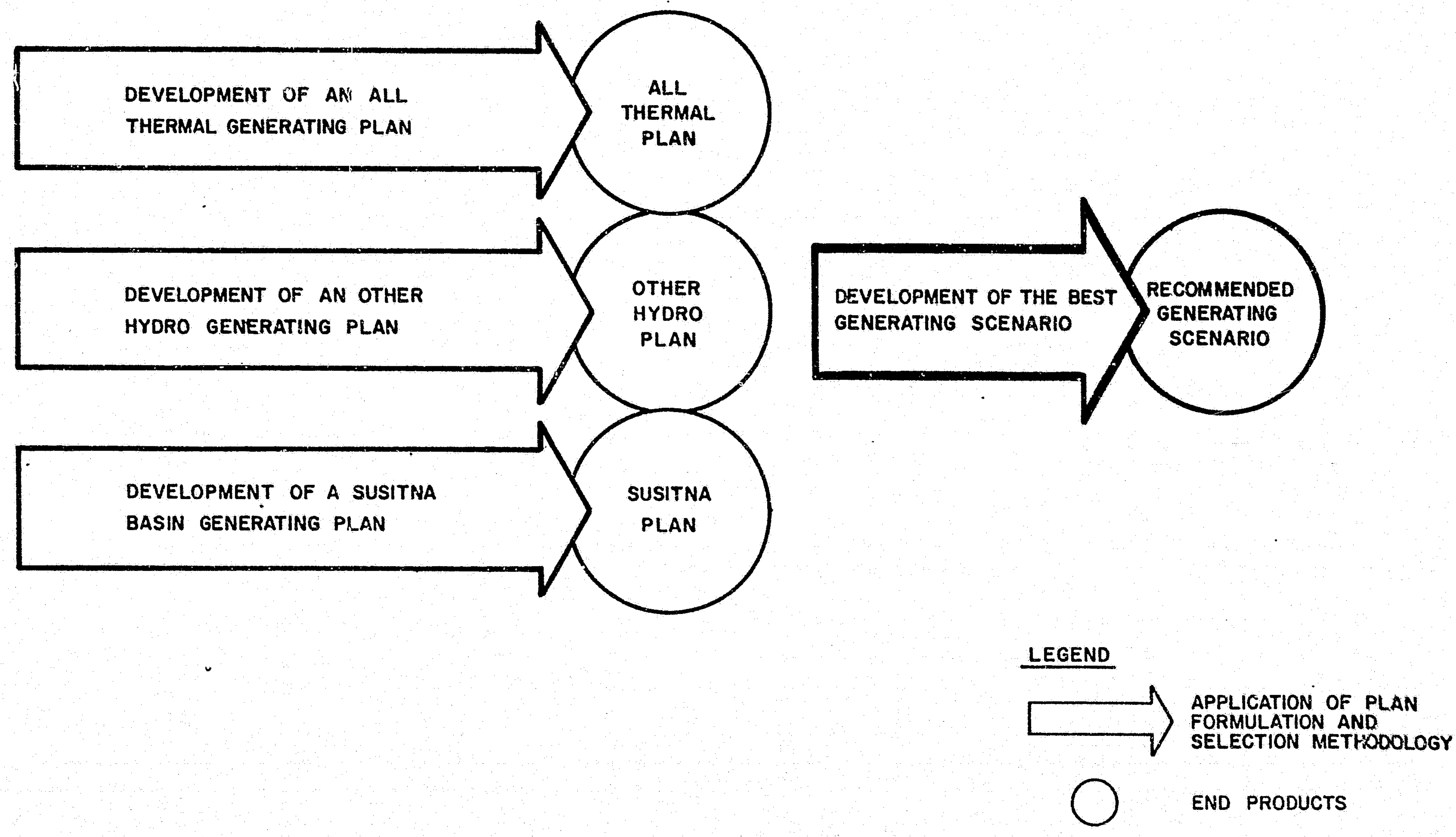
LOCATION MAP

FIGURE 1.1



PLAN FORMULATION AND SELECTION METHODOLOGY

FIGURE 1.2



PLANNING APPROACH

FIGURE 1.3

ACRES

2 - SUMMARY

- To Follow

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 APA 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 an 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]), August, 1981 (Revision 2, [3]) and January, 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; and

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

(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 prefeasibility study by the U.S. Army Corps of Engineers which led to a recommendation in 1976 by the Chief of Engineers that the Susitna Project be authorized. The Corps 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 Corps 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 Corps of Engineers 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 Corps 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 Corps of Engineers 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;

- 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 south-central 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 APA and the state in early 1980 by the

Institute for Social and Economic Research (ISER). Reviews of this 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 complete activities in 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 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 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 and associated bathroom, kitchen/dining, recreation and 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, lakes, and 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 surveys were also hazardous, particularly at Devil Canyon. Detailed results of the mapping were provided to the USGS 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 Task 7, 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 B 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 sutdy 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 steam 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 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. Revision 2 of the POS increased the extent of the trenching work. 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 as 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 base line 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.

As a resource 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 sediment data for the lower Susitna River, water quality, further quantification of project socioeconomic impacts, inclusion of sociocultural impact assessments, fish ecology 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 Federal Energy Regulatory Commission (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 is postponed by three months to September 30, 1982. This also allows 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 a number 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 input 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 basis 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.

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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(12) Acres Amercian Incorporated, Susitna Hydroelectric Project, 1980 Geotechnical Report, prepared for the Alaska Power Authority, June 1981.

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

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

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(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.

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 dam sites and conduct geotechnical investigations. By 1961, the Department of the Interior proposed authorization of a two dam power system involving the Devil Canyon and the Denali sites (Figure 4.1). The definitive 1961 report was subsequently updated by the Alaska Power Administration (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 1950's and 1960's, but focused its attention on a more ambitious development at Rampart on the Yukon River. This project was capable of generating five times as much electric energy as Susitna annually. The sheer size and the technological challenges associated with Rampart captured the imagination of supporters and effectively diverted attention from the Susitna Basin for more than a decade. The Rampart Report was finally shelved in the early 1970's because of strong environmental concerns and the uncertainty of marketing prospects for so much energy, particularly in light of abundant natural gas which had been discovered and developed in Cook Inlet.

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

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

4.2 - U.S. Bureau of Reclamation - 1953 Study

The USBR 1952 report to the Congress on Alaska's overall hydroelectric potential was followed shortly by the first major study of the Susitna Basin in 1953. Ten dam sites were identified above the railroad crossing at Gold Creek (see also Figure 4.1):

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

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

4.3 - U.S. Bureau of Reclamation - 1961 Study

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

4.4 - Alaska Power Administration - 1974

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 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.

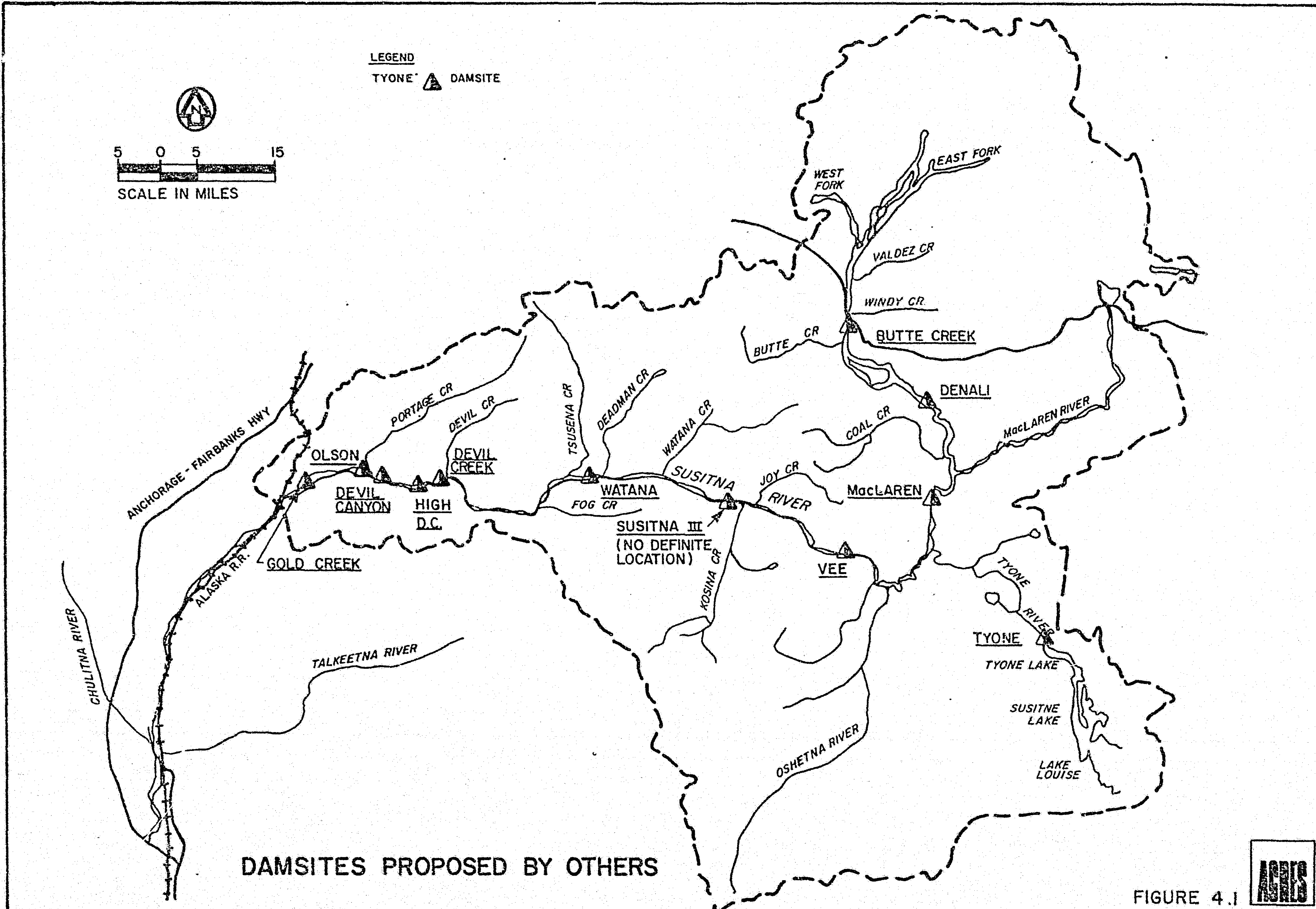
4.6 - U.S. Army Corps of Engineers - 1975 and 1979 Studies

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, even in very dry years.

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

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



DAMSITES PROPOSED BY OTHERS

FIGURE 4.1

5 - RAILBELT LOAD FORECASTS

In this section of the report, the process of development of electrical demand forecasts for the Railbelt region is described. Historical and projected trends in the factors which influence such demand are identified and discussed, and the basis of forecasts used in Susitna generation planning studies is 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 APA 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 and financial analysis, sensitivity analyses, and capacity staging. These forecasts are discussed in more detail in Sections 5.2 to 5.7.

In December, 1981, Battelle Pacific Northwest Laboratory produced a revised series of load forecasts for the Railbelt. These forecasts were developed as a part of the Railbelt Alternatives Study, done 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 concerns not included in the 1980 projections. The 1981 Battelle forecasts were used in this feasibility study for the final economic and financial analyses presented in Section 18, as well as for reviewing the project staging. The Battelle forecasts are presented in Section 5.8.

5.2 - Electricity Demand Profiles

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

(a) Historical Trends

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

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

(b) Regional Demand

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

(c) End-Use Consumption

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

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

5.3 - ISER Electricity Consumption Forecasts

This section briefly discusses the methodology used by ISER to estimate electric energy sales for the Railbelt, and summarizes the results obtained.

(a) Methodology

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

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

(i) Economic Submodels

- The MAP Econometric Model

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

- The Household Formation Model

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

- Regional Allocation Model

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

- Housing Stock Model

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

(ii) Electricity Consumption Submodels

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

- Residential Non-space Heating Electricity Requirements

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

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

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

- Residential Space Heating

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

- Commercial-Industrial-Government

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

- Miscellaneous

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

(iii) Consumption Sectors Not Modeled

Electricity requirements were not modeled for two sectors of demand:

- Military

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

- Self-Supplied Industrial

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

(b) Assumptions

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

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

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

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

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

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

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

- No new electricity technologies will be introduced.

- In terms of residential appliances:

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

- In terms of residential space heating:

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

- In terms of commercial-industrial-government use:

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

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

(c) Forecasting Uncertainty

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

(d) Initial ISER Forecast Results

The results of the ISER forecasts prepared in 1980, which were used as the basis of Susitna development selection studies, were as follows:

(i) Base Case

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

(ii) Range of Forecasts

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

5.4 - Past Projections of Railbelt Electricity Demand

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

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

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

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

5.5 - Demand Forecasts

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.

(a) Load Patterns

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

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

(b) Sales Allocation

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

(c) Peak Loads

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

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

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

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

5.6 - Potential for Load Management and Energy Conservation

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

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

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

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

5.7 - Load Forecasts Used for Development Selection Studies

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

(a) Adjusted ISER Forecasts

Three of the initial ISER energy forecasts were considered in generation planning studies for development selection studies (see Table 5.6). 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 5.9 represent total utility generation and include projections for self-supplied industrial and military generation sectors. Included in these forecasts are transmission and distribution losses in the range of 9 to 13 percent depending upon the generation scenario assumed. These forecasts, ranging from 2.71 to 4.76 percent average annual growth, were adjusted for use in generation planning studies.

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

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

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

(b) Forecast Incorporating Load Management and Conservation

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

- ISER Conservation Assumptions

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

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

- Impacts of Recent Legislation

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

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

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

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

- Study Assumptions

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

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

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

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

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

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

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

5.8 - 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 series of reports produced by Battelle in early 1982.

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 5.11 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 those studies. The Railbelt generation planning studies undertaken for Susitna feasibility assessment were therefore 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.

TABLE 5.1: HISTORICAL ANNUAL GROWTH RATES OF ELECTRIC UTILITY SALES

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

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

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

TABLE 5.3: UTILITY SALES BY RAILBELT REGIONS

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

NOTES:

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

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

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

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

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

NOTES:

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

TABLE 5.6: SUMMARY OF RAILBELT ELECTRICITY PROJECTIONS

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

NOTES:

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

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

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

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

Study Number/Source	1980			1990			1995			2000			2025		
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
1. South Central Railbelt Area, Alaska Interim Feasibility Report: Hydroelectric Power and Related Purposes for the Upper Susitna River Basin, Alaska District Corps of Engineers, Department of the Army, 1975.	3020	3240	3550	5470	6480	8540	6656	8688	12576	8100	11650	18520			
2. Electric Power in Alaska 1976-1995 Institute of Social and Economic Research, University of Alaska, 1976.	2478	-	3877	5415	-	12706	8092	-	22784						
3. Alaska Electric Power: An Analysis of Future Requirements and Supply Alternatives for the Railbelt Region, Battelle Pacific Northwest Laboratories, 1978.	2600	-	3400	8500	-	10800	10341	-	17552	16000	-	22500			
4. Upper Susitna River Project Power Market Analyses, U.S. Department of Energy, Alaska Power Administration, 1979; South Central Railbelt Area, Alaska, Upper Susitna River Basin, Supplemental Feasibility Report, Corps of Engineers, 1979 and Phase I Technical Memorandum: Electric Power Needs Assessment, South Central Alaska Water Resources Committee, 1979.	2920	3155	3410	4550	6110	8200	5672	8175	11778	7070	10940	16920	8110	17770	39020

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

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

NOTES:

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

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

Year	ISER Low (LES-GM)[2]		ISER Medium (MES-GM)		ISER High (HES-GM)	
	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 5.10: 1980 RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES FOR DEVELOPMENT SELECTION

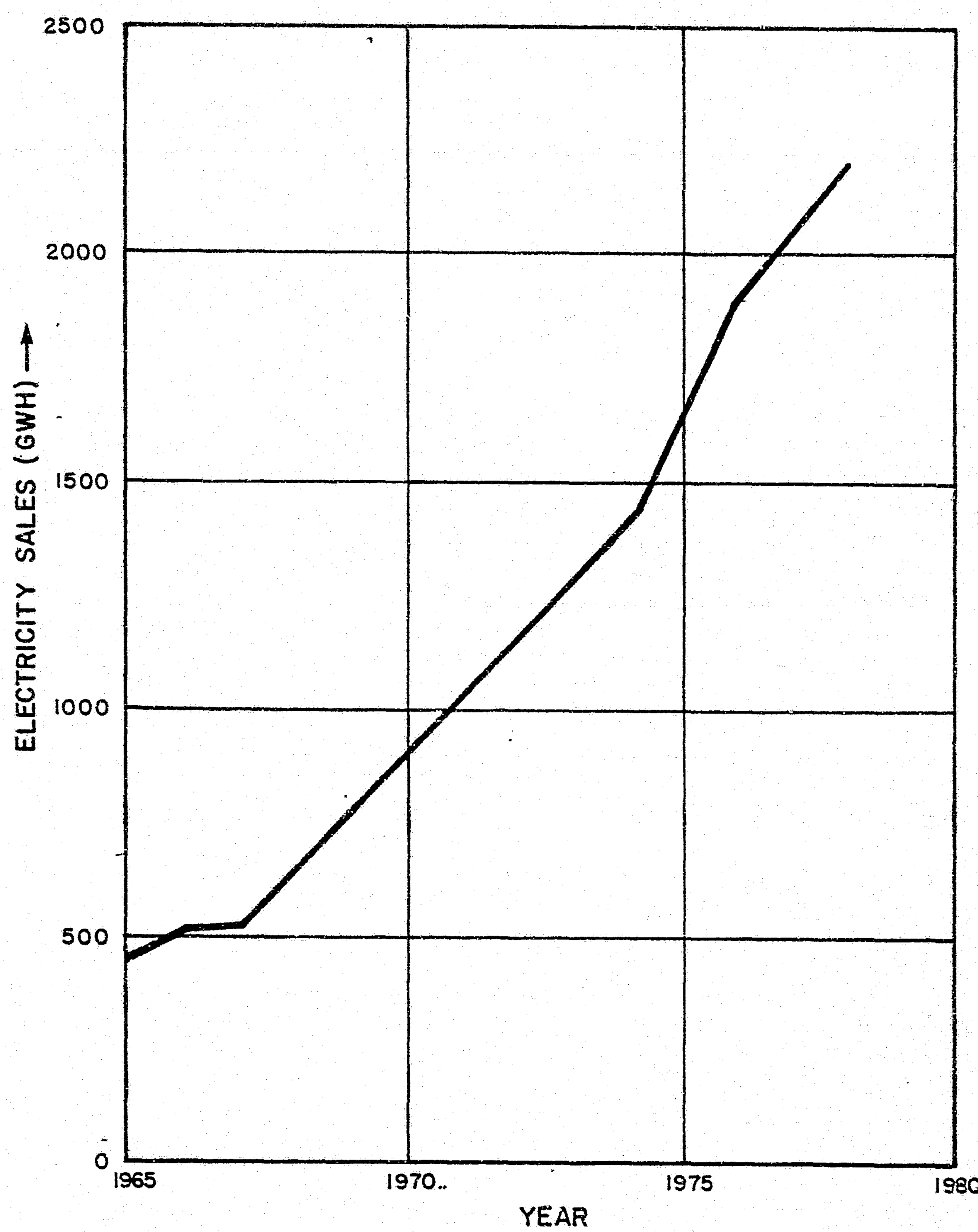
	LOAD CASE											
	Low Plus Load Management and Conservation (LES-GL Adjusted)[1]			Low (LES-GL)[2]			Medium (MES-GM)[3]			High (HES-GH)[4]		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1980	510	2790	62.5	510	2790	62.4	510	2790	62.4	510	2790	62.4
1985	560	3090	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.

TABLE 5.11: 1981 BATTELLE PNL RAILBELT REGION LOAD AND ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES -- ECONOMIC ANALYSIS AND SENSITIVITY ANALYSIS

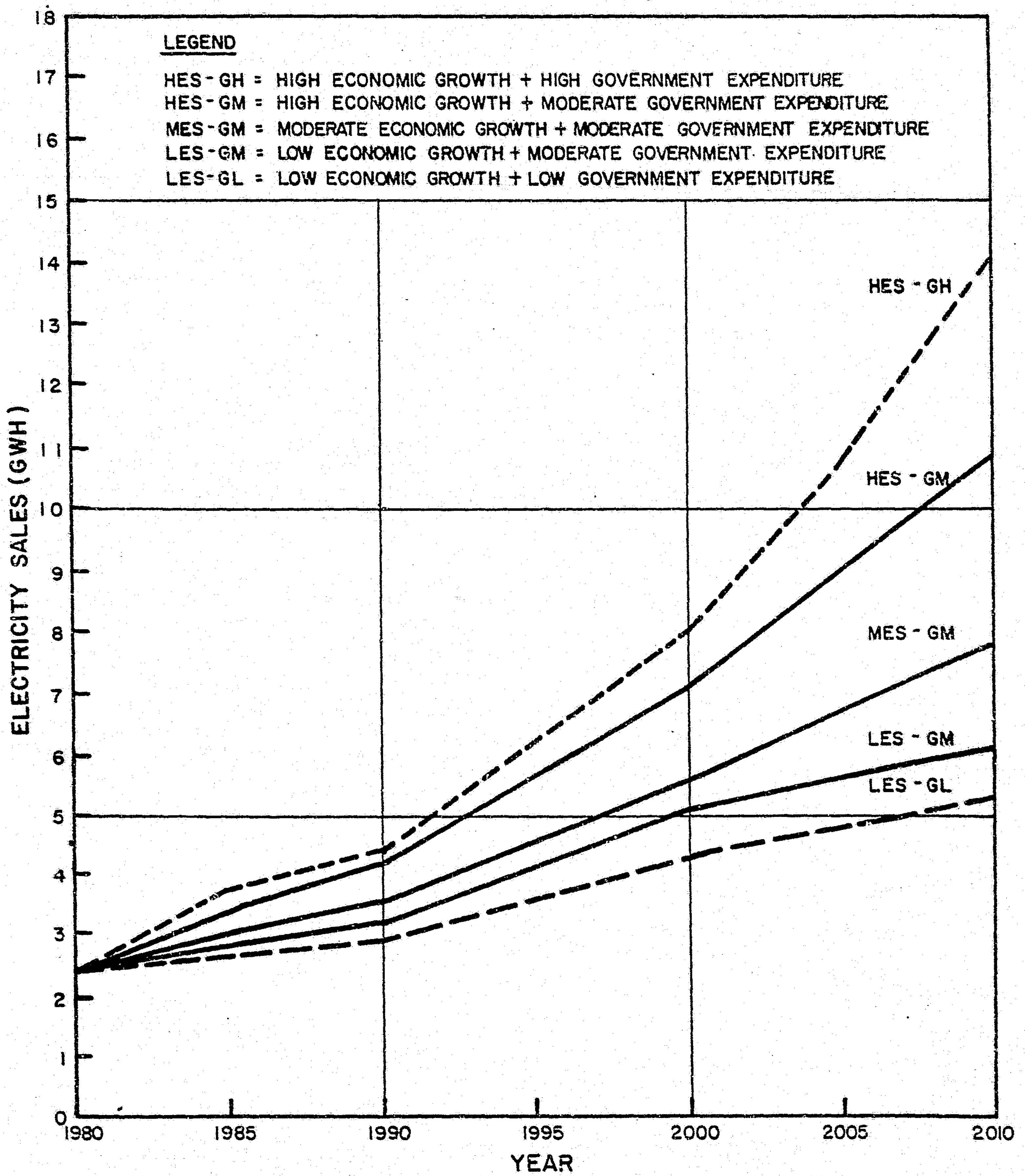
	LOAD CASE								
	Medium			Low			High		
Year	MW	GWh	Load Factor	MW	GWh	Load Factor	MW	GWh	Load Factor
1981	574	2893	57.5	568	2853	57.3	598	3053	58.3
1985	687	3431	57.8	642	3234	57.5	794	4231	60.8
1990	892	4456	57.0	802	3999	56.9	1098	5703	59.3
1995	983	4922	57.1	849	4240	57.0	1248	6464	59.1
2000	1084	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	



HISTORICAL TOTAL RAILBELT UTILITY SALES TO FINAL CUSTOMERS

FIGURE 5.1

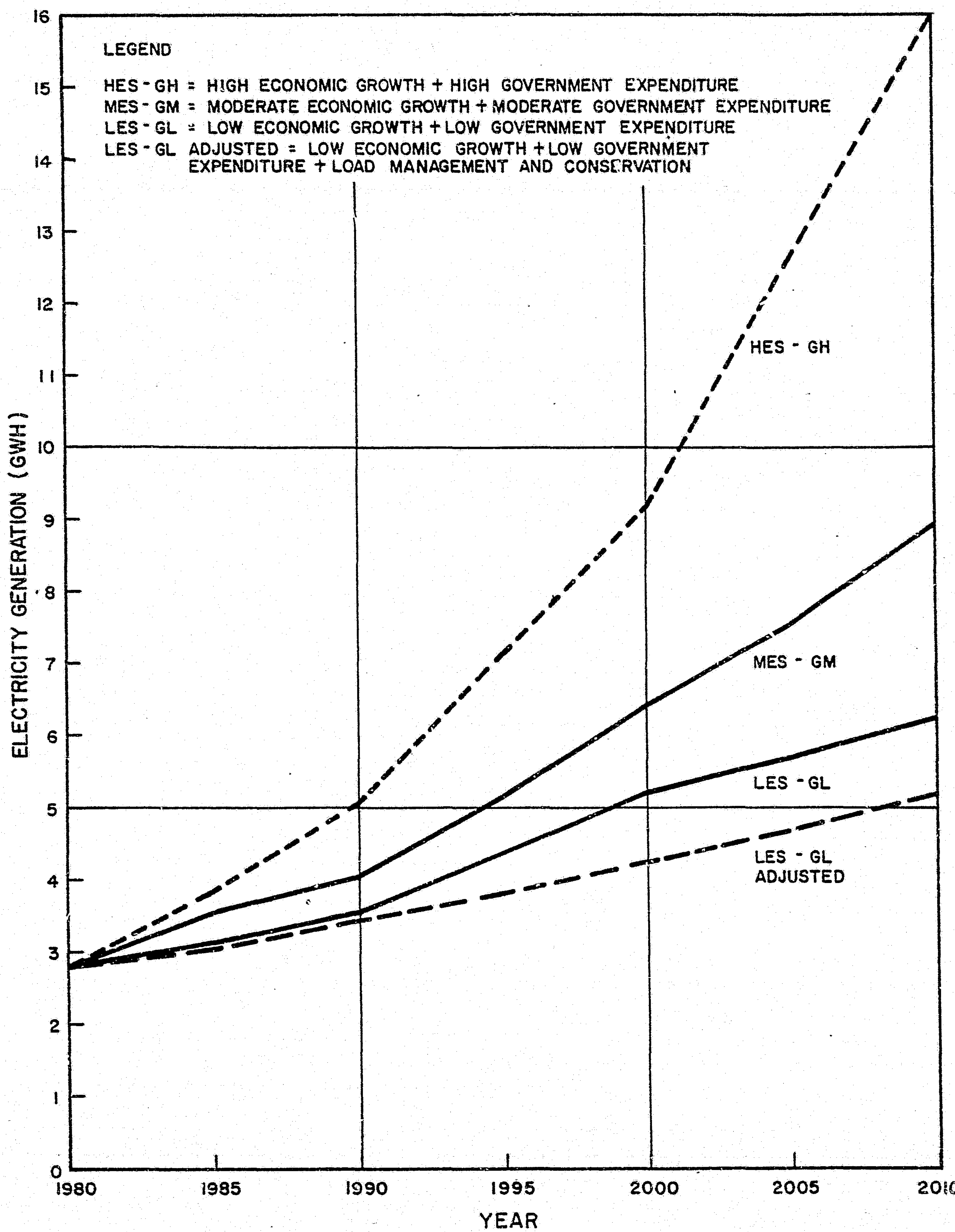
ACRES



FORECAST ALTERNATIVE TOTAL RAILBELT UTILITY SALES

FIGURE 5.2

ACRES



ENERGY FORECASTS USED FOR GENERATION PLANNING STUDIES

ACRES

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, two sets of data were available 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 a price level estimated at January, 1981 and data available at that time. Emphasis in that study was placed on currently feasible, economic generating sources. Other options, including emergency technologies of 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 in the subsequent feasibility study was used to support generation planning efforts which compared alternative developments in the Susitna Basin, 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 has been dealt with only in sufficient detail to develop representative performance and cost data for inclusion in the alternative Railbelt system generation scenarios.

The detailed Susitna optimization studies and economic and financial feasibility and sensitivity assessments, described in Section 18 of this report, 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 and O&M costs.

In addition to this, Susitna capital costs were adjusted to reflect most recent estimates prepared under Task 9. Generation planning studies were thus, in some cases, based on somewhat different basic data and assumptions from those used in the earlier development selection studies. On the other hand, a great deal of significant data is common to both evaluations: for example, the composition of the existing generation mix in the Railbelt, the status of the Intertie, data for the non-Susitna hydroelectric alternatives, and the selected non-Susitna thermal alternatives. The differences in data values used in 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 also considered to be 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 then reliable sources. This information has been subjected to minor adjustments compared with that used in the development selection studies so as to maintain consistency with Battelle alternatives study data.

Table 6.2 presents the resulting detailed listing of units currently operating in the Railbelt, information on their performance characteristics, and their online and assumed retirement dates.

With the exception of two hydroelectric plants, the total Railbelt installed capacity of 984 MW as of 1980 consists of 938 MW of thermal generation units fired by oil, gas, or coal, as summarized in Table 6.3.

(b) Schedule Retirements

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

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

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

(c) Schedule of Additions

Six new projects are currently expected to be committed within the Railbelt system. 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. As currently envisaged, the project includes 90 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 Bernice Lake No. 4. 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 continually 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 all the generation planning studies outlined in this report, and that the basic intertie facilities would be common to all generation scenarios considered.

From this point, costs of 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 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 has been applied in the development of Railbelt generation plans which include and exclude Susitna. Those plans which involve the Susitna Project are discussed in detail in Sections 7 and 8. Those plans which incorporate hydroelectric developments studied during the development selection phase other than Susitna are discussed in this section.

(a) Assessment of Hydro Alternatives

The application of the five-step methodology for selection of non-Susitna plans which incorporate hydroelectric developments is summarized in this section. Step 1 of this process essentially established the overall objective of the exercise as the selection of an optimum Railbelt generation plan which incorporated the proposed non-Susitna hydroelectric developments for comparison with other plans.

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

(b) Screening of Candidate Sites

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

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

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

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

- They were located on a river in which:

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

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

- Less than 25 MW: 5 sites;
- 25 MW to 100 MW: 15 sites; and
- Greater than 100 MW: 8 sites.

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

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

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

This process allowed the number of sites to be reduced to the ten sites listed in Table 6.4.

(c) Plan Formulation and Evaluation

In Step 4 of the plan selection process, the ten sites shortlisted under Step 3 were further refined as a basis for formulation of Railbelt generation plans. Engineering sketch-type layouts were produced for each of the sites, and quantities and capital costs were evaluated. These costs, 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 are summarized in Table 6.5 and illustrate that a minimum total system cost of $7040 million can be achieved by the introduction of the Chakachamna, Keetna, and Snow projects (See also Figure 6.4). Note that further studies of the Chakachamna project were initiated in mid-1981 by Bechtel under contract to the APA. This study is producing costs and project concepts different from the ones presented here.

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

6.5 - Thermal Options - 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 would technically be satisfied by an all-thermal generation mix. In the following paragraphs, an outline is presented of studies undertaken to determine an appropriate all-thermal generation scenario for comparison with other scenarios in Section 8. These comparisons were used in selecting the Susitna development and in establishing preliminary economic feasibility. Information developed during later studies by Battelle and Acres used for economic analysis is presented in Section 6.5.

(a) Assessment of Thermal Alternatives

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

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

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

(b) Coal-Fired Steam

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

(i) Capital Costs

Based on the general magnitude of the Railbelt load requirements, three coal-fired unit sizes were chosen for potential capacity additions: 100, 250, and 500 MW. All new coal units were estimated to have an average heat rate of 10,500 Btu/kWh and involve an average construction period of five to six years. Capital costs and operating parameters are defined for coal and other thermal generating plants in Table 6.6. These costs include a 16 percent contingency, a 10 percent allowance for construction facilities and utilities, and 12 percent for engineering and owner's administration. The costs were developed using published data for the lower 48 states and appropriate Alaska scaling factors based on studies conducted by Battelle. It is unlikely that a 500-MW plant will be proposed in the Fairbanks region because forecasted demand there is insufficient to justify placing this much capacity online at one time. Therefore, costs for such a plant at Fairbanks are not included.

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

The total estimated coal reserves in Alaska are shown in Table 6.7. Projected opportunity costs for Alaskan coal range from $1.00 to $1.33 per million Btu. A cost of $1.15 was selected as the base coal cost for generation planning (see Table 6.8). The market price for coal is currently within the same general cost range as the indicated opportunity cost.

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

(iii) Other Performance Characteristics

Annual operation and maintenance costs and representative forced outage rates are shown 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 #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 250-MW capacity was considered to be representative of future additions to generating capability in the Anchorage area. This is based on economic sizing for plants in the lower 48 states and projected load increases in the Railbelt. A heat rate of 8,500 Btu/kWh was adopted based on technical publications issued by the Electric Power Research Institute (EPRI).

The capital cost was estimated using the same basis and data sources as for the coal-fired steam plants and is listed in Table 6.6.

(ii) Fuel Costs

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

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

(iii) Other Performance Characteristics

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

(d) Gas-Turbine

Gas turbines are by far the main source of thermal power generating resources in the Railbelt area at present. There are 470 MW of installed gas turbines operating on natural gas in the Anchorage area and approximately 168 MW of oil-fired gas turbines supplying the Fairbanks area (see Table 6.1). Their low initial cost, simplicity of construction and

and operation, and relatively short implementation lead time have made them attractive as a Railbelt generating alternative. The extremely low-cost contract gas in the Anchorage area also has made this type of generating facility cost-effective for the Anchorage load center.

(i) Capital Costs

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

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

(ii) Fuel Costs

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

(iii) Other Performance Characteristics

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

(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 and includes provision for a fuel injection system to minimize air pollution.

(ii) Fuel Costs

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

(iii) Other Performance Characteristics

Annual operation and maintenance and the forced outage rate is given in Table 6.6.

(f) Plan Formulation and Evaluation

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

Two different cases of natural gas consumption policy were considered in formulating plans. The first, called the "renewal" policy, allowed for the renewal of natural gas turbines at the end of their economic lives, anticipating the possible exemptions that utilities may obtain from the Fuel Use Act (FUA). The second policy, called the "no renewals" policy, assumed that the utilities would not be allowed to reconstruct plants as they are retired and that they would only be allowed to construct new plants with not more than 1,500 hours of annual operation.

In the subsequent Step 5 evaluation of the two basic plans, the OGP5 generation planning model was utilized to develop a least cost scenario incorporating the necessary coal, oil, and gas-fired generating units. The results for the very low, low, medium, and high load forecasts are summarized in Table 6.5. They indicate that for the medium forecast the total system present worth cost is slightly higher than $8,100 million.

As illustrated by the results displayed in Table 6.5, these two policies have very similar economic impacts. The difference in present-worth costs for the medium forecast amounts to only $20 million. For purposes of this study, therefore, it is assumed that the "no renewals" policy is more appropriate and is used to be representative of the all-thermal generation scenario. Figure 6.6 illustrates this all-thermal generating scenario graphically. These results were used as a comparison for development selection as described in Section 8.

6.6 - Thermal Options - Economic Analysis

During the final stage of study, a revised set of data was available for the selected Susitna project analysis. Much of these data was taken directly from the Battelle Pacific Northwest Laboratories independent Railbelt Alternatives study. The findings of this study are reasonably consistent with the findings of the preliminary studies presented in Section 6.4. The information presented in this section is in support of the non-Susitna option presented in Section 6.6.

As a result of the Battelle study, it was found that in their base case, the most likely thermal generating opportunities would be coal-fired steam electric plants, natural gas-fired combined-cycle plants, and gas-fired combustion turbines. In addition, there are several hydropower plants which would be possible.

(a) Coal-Fired Steam Plants

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. Unit size was set at 200 MW. Details of the units are listed 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.

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 16 of this report.

(b) Combined Cycle and Gas Turbines

The Battelle study also produced a cost estimate for combined cycle plants which would be located near the Railbelt gas reserves near Cook Inlet. The combined cycle plant would be similar to that envisaged by the preliminary Acres study, but would have a heat rate of 8,000 Btu/kWh (as compared to 8,500 Btu/kWh). The estimated capital costs were significantly higher.

Gas turbines, like combined-cycle plants, had higher costs in the Battelle study than the Acres study, but lower heat rates (10,000 as compared to 10,500 Btu/kWh).

6.7 - Without Susitna Plan

In order to analyze the economics of developing the Susitna project, it is 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. Details on the model are presented in Appendix A.

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 5.6;
- Fuel cost as specified in Section 18.1;
- 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;
- The existing system as specified in Section 6.1 and scheduled commitments of Table 6.3;
- Middle range fuel escalation as specified in Section 18.1;
- 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 projected load. One day in ten years is a value generally accepted in the industry for V 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 plan was established as the non-Susitna Railbelt base plan:

Existing System as of January, 1993:
Remainder of Existing System Plus Committed Additions: 1190 MW

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

System additions:

1993:	First 200 MW coal-fired plan at Beluga field
1994:	Second 200 MW coal-fired plant at Beluga field
1996:	200 MW coal-fired plant near Nenana using Healy coal
1997:	70 MW gas-fired gas turbine
1998:	70 MW gas-fired gas turbine
2001:	70 MW gas-fired gas turbine
2003:	70 MW gas-fired gas turbine
2004:	70 MW gas-fired gas turbine
2005:	Two 70 MW gas-fired gas turbines
2006:	One 70 MW gas-fired gas turbine
2007:	Third 200 MW coal-fired unit at Beluga
2009:	One 70 MW gas-fired gas turbine
Total system additions:	800 MW coal-fired steam electric plants 630 MW gas-fired combustion turbines

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	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 may be some environmental problems to overcome. The greatest problem will be the availability of cooling water for the units. This problem would be particularly severe with the development of several units. The problem could be solved in the "worst" case by using the sea water from Cook Inlet as cooling water. 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 APA. 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, on the sensitivity analysis presented in Section 16.2.

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).

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	30.5
U of A	University of Alaska	18.6
TOTAL		984.0

(1) Installed capacity as of 1980 at 0°F

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 IDC.

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

Notes:

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

TABLE 6.6: SUMMARY OF THERMAL GENERATING RESOURCE PLANT PARAMETERS USED IN DEVELOPMENT SELECTION STUDIES - JANUARY 1981 PRICE LEVEL

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

Notes:

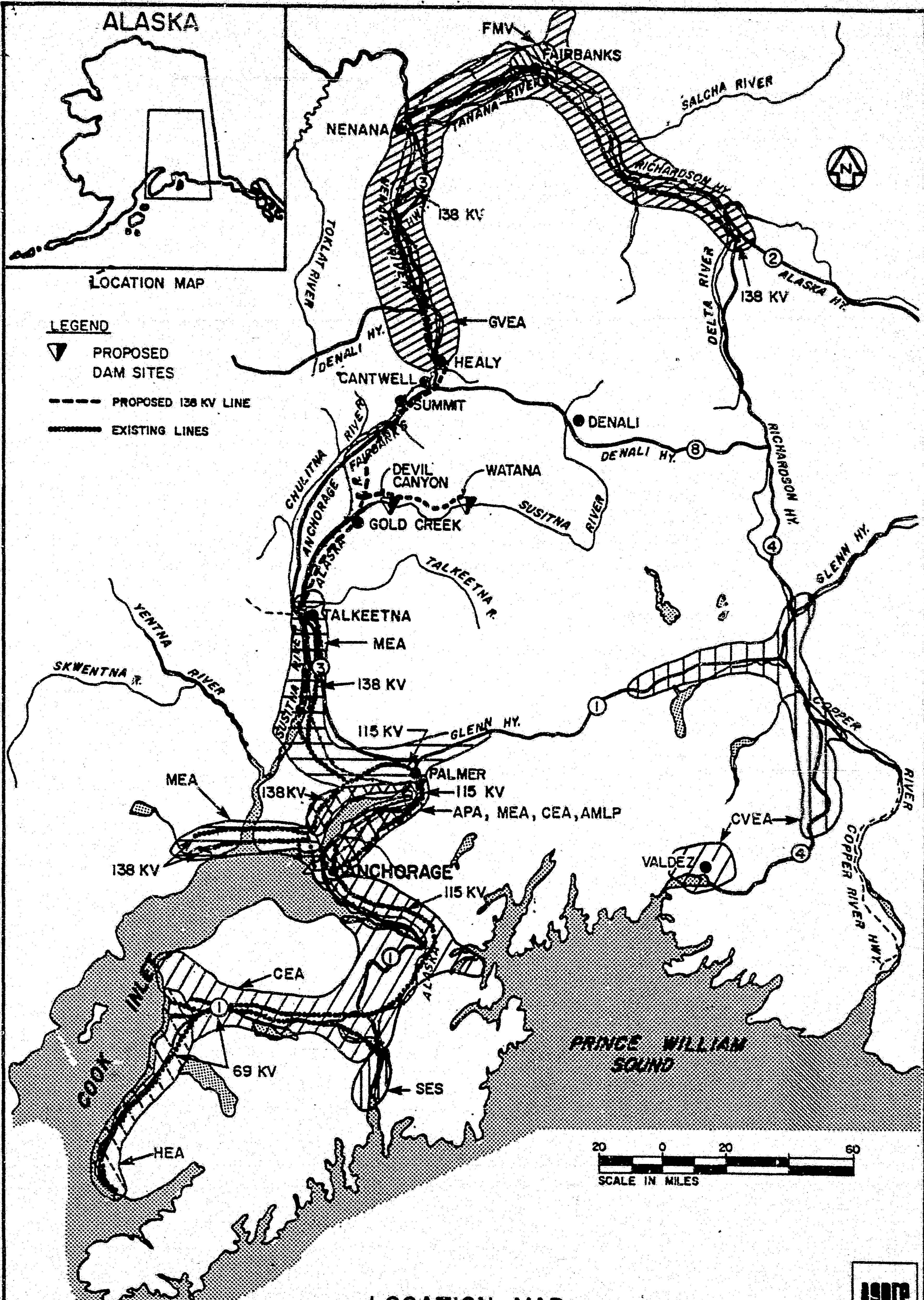
(1) Including AFDC at 0 percent escalation and 3 percent interest.

TABLE 6.7: 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	--

TABLE 6.8: FUEL COSTS AND ESCALATION RATES SELECTED FOR GENERATION PLANNING STUDIES

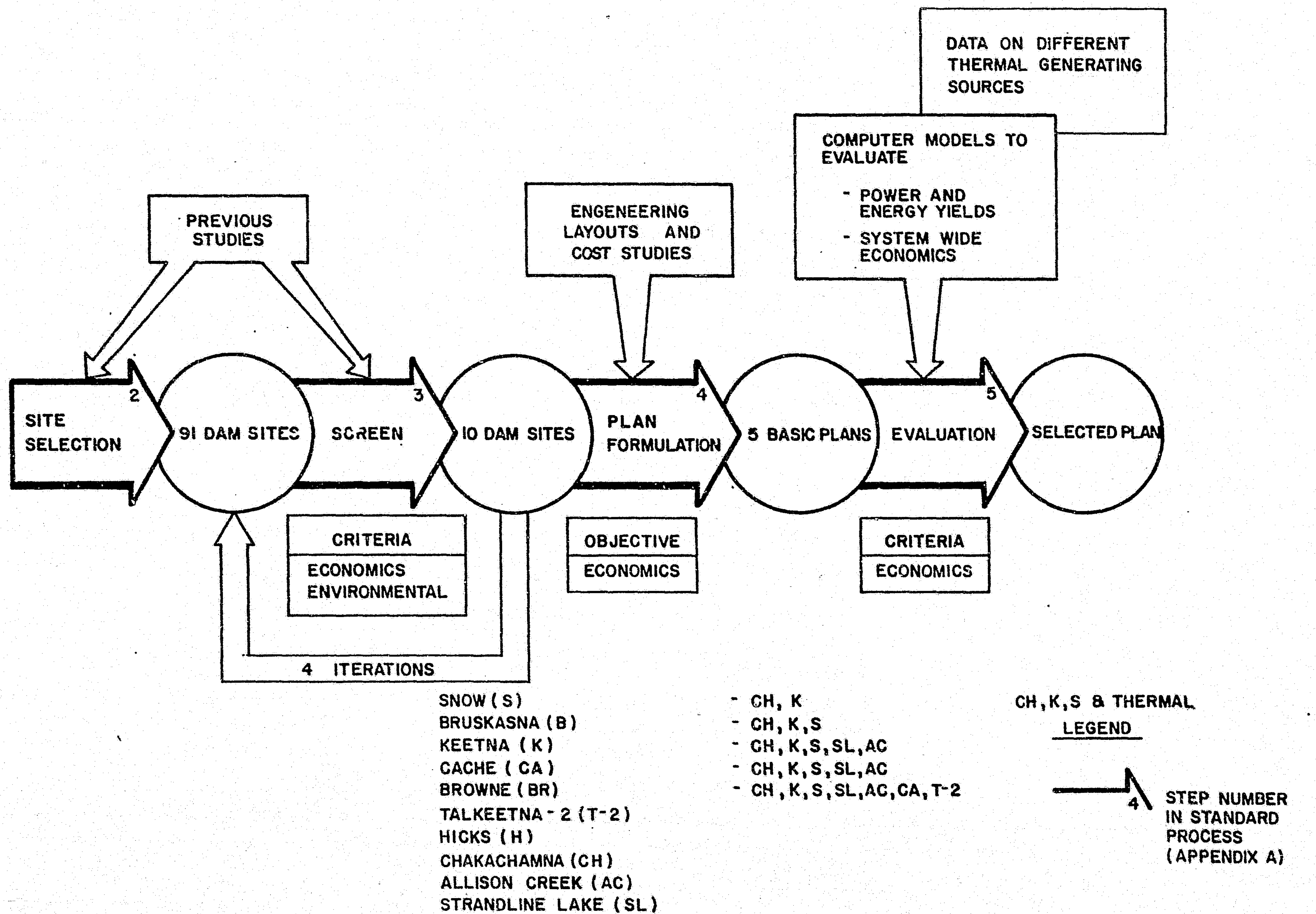
Parameter	Fuel Type		
	Natural Gas	Coal	Oil
Economic Cost - $/Million BTU	2.00	1.15	4.00
Annual Escalation Rate - %			
Period: 1980 - 2005	3.98	2.93	3.58
2006 - 2010	0	0	0



LOCATION MAP

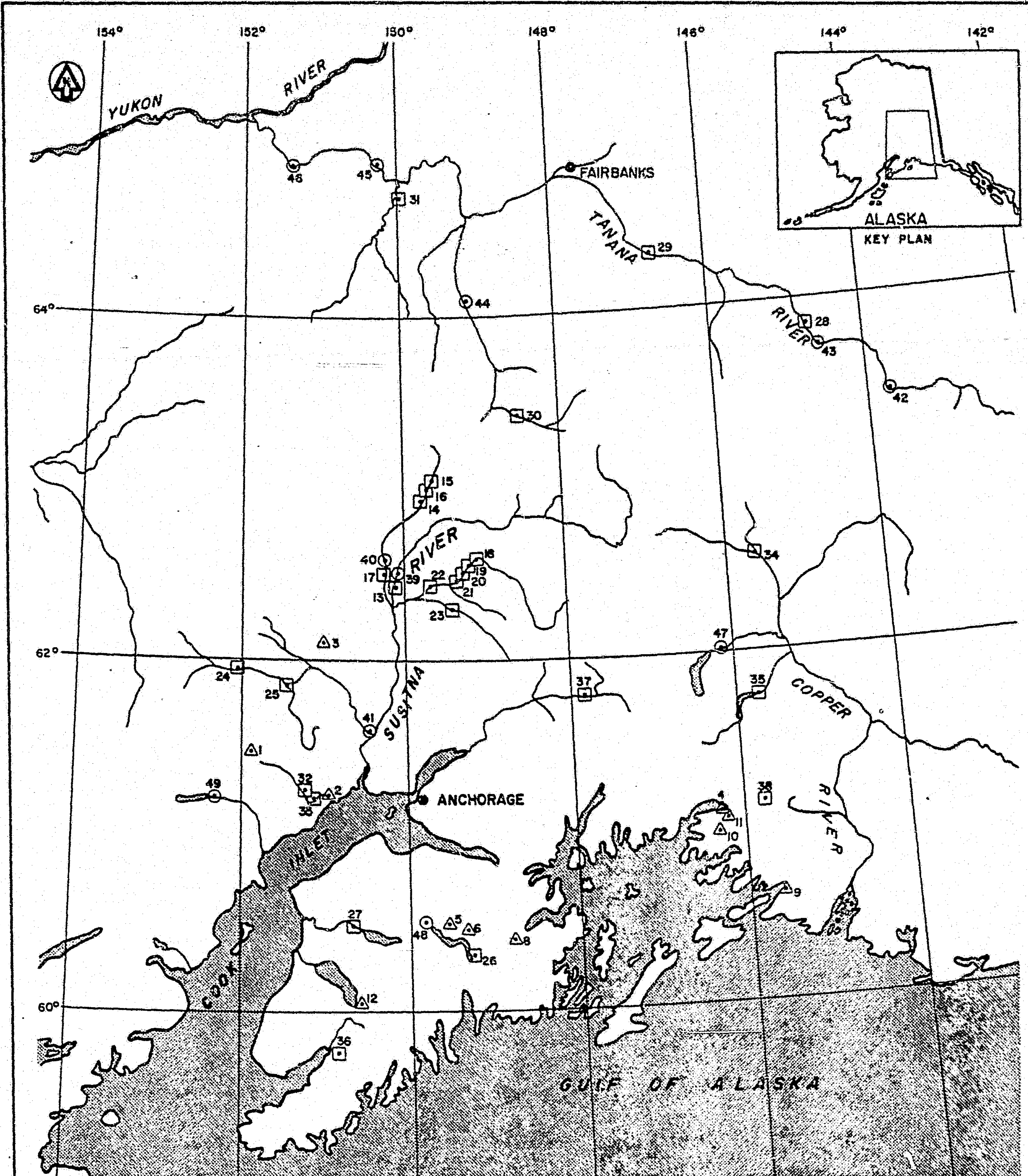
FIGURE 6.1

ACRES



FORMULATION OF PLANS INCORPORATING NON-SUSITNA HYDRO GENERATION

FIGURE 6.2



ALASKA RAILBELT REGION

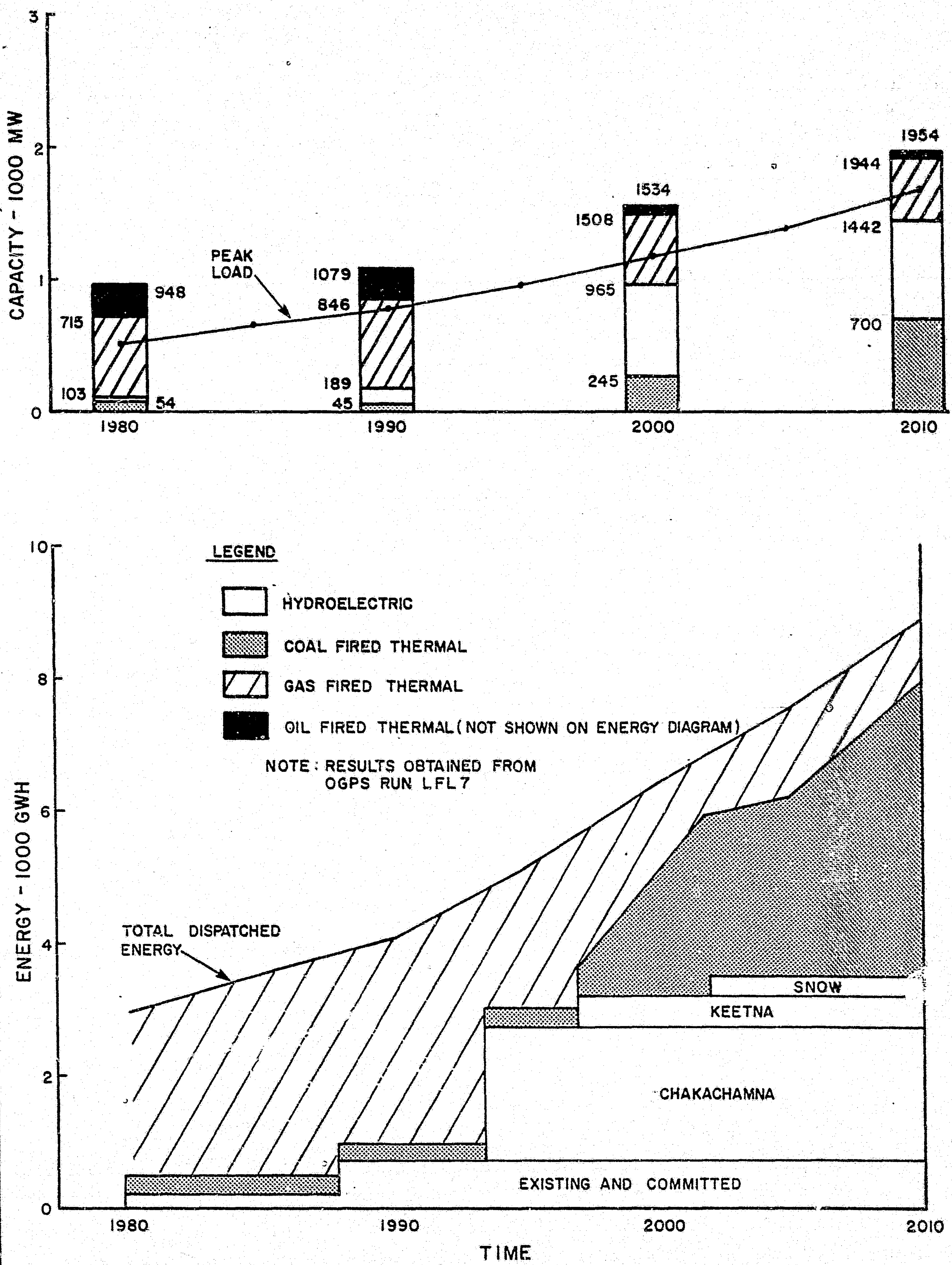
SCALE- MILES 0 50 100
1 INCH EQUALS APPROXIMATELY 40 MILES

△ 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

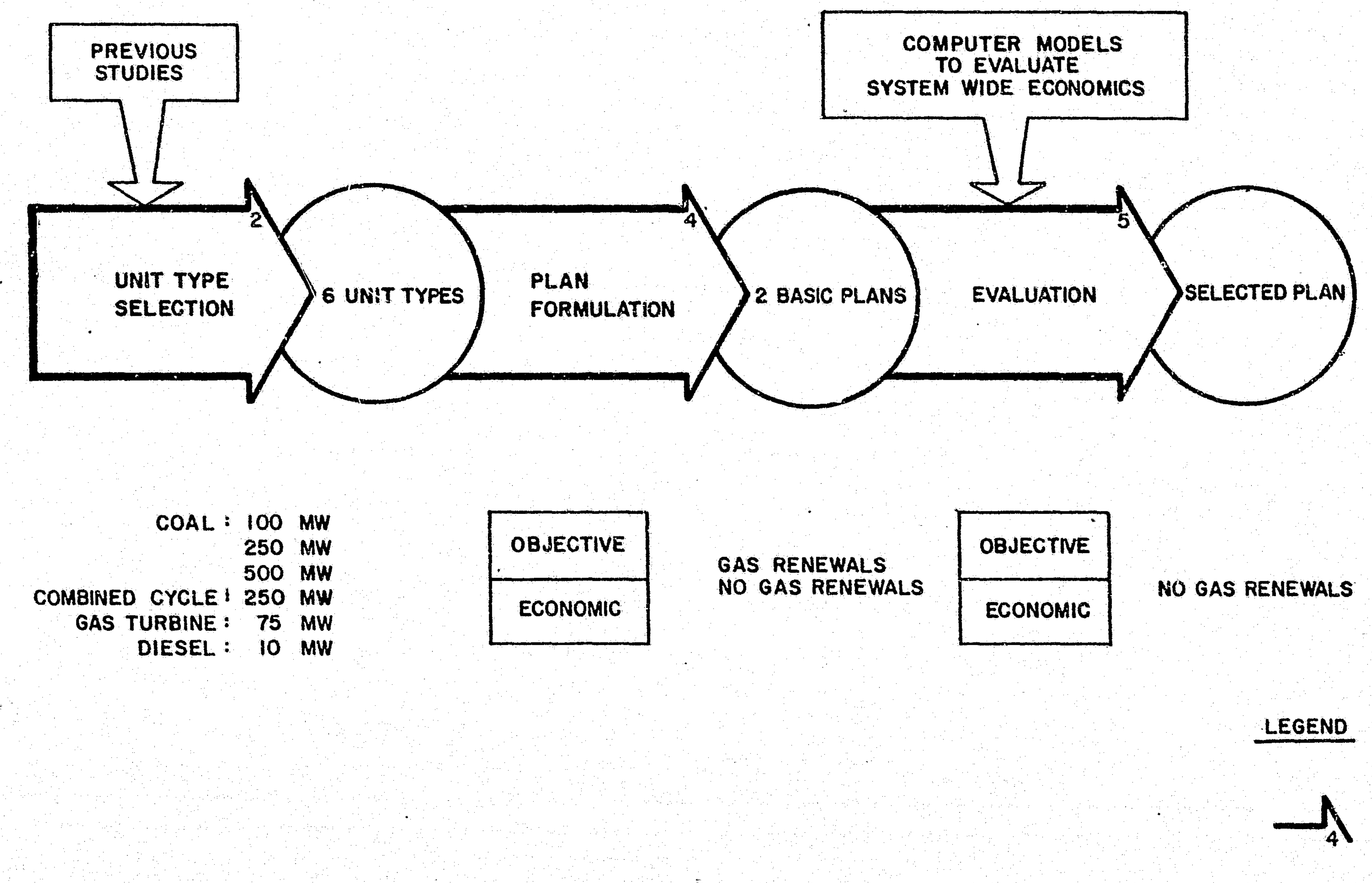
FIGURE 63



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

7 - SUSITNA BASIN

The purpose of this section is to describe briefly the physical and biological environment of the Susitna River Basin, 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 seccion 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 and 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 considerable 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 Appendix B1.

(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 re-evaluation of the probable maximum flood studies (see Appendix B5).

(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 Appendix B1.

(d) Evaporation

The closest stations to the Upper Susitna Basin where pan-evaporation data are collected are at the Matanushka 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 B2.

(e) Field Data Index

A Field Data Index 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 is available for the station at Gold Creek (30 years from 1949 to 1970). 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 an additional two years (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 Field Data Index (Reference 1).

(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.

(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 the filling-in of 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 B2.

(c) Low Flow Frequency Duration Analysis

A frequency analysis of run-off volumes at low flow periods of durations 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 7.4).

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 (see Figure 7.6).

The results of the analysis have been used to determine dependable energy potential of the proposed reservoirs (see Section 15.6).

(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, as well as the Copper, Matanuska, and Tosina rivers. 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 Appendix B4.

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 extremely sensitive to the three major parameters - probable maximum precipitation, available snow pack for melting, and the temperature sequence during the PMF event. A reevaluation 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 B5. 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) River Ice

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 freeze-up 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. For details of field investigation programs and the analysis, see Appendices B1 and B7.

(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 upto 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.

(ii) Field Investigations

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 damsites.

(iii) 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 (see

River (see 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 Appendix B8.

(iv) 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 has been prepared on the subject and is presented as Appendix B9. 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 (1,2,3). 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 may have been formed immediately after this plutonic intrusion, or after a period of erosion and minor deposition.

During the Tertiary period (20 to 40 m.y.b.p.) the area surrounding the sites was again uplifted by as much as 3,000 feet. Since then, widespread erosion has removed much of the older sedimentary and volcanic rocks. During the last several million years, at least two alpine glaciations have carved the Talkeetna Mountains into the ridges, peaks, and broad glacial plateaus seen today. Post-glacial uplift has induced downcutting of streams and rivers, resulting in the 500-to-700 foot deep V-shaped 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) General

The Talkeetna Mountains region of south-central Alaska is considered to be highly seismic with numerous reported earthquakes of moderate-to-large magnitude. Therefore, in order to assess the risk of seismic exposure of the Susitna Basin development and to define the earthquake design parameters for the critical project structures, a comprehensive study was undertaken as a part of the feasibility study. A brief summary of this study is presented in this section. Details of the study are contained in References 1 and 2.

The scope of the study was developed to identify and evaluate all potential sources of earthquakes with magnitudes larger than 5 on the Richter scale, to determine the maximum credible earthquake (MCE) for each source and the ground motions associated with the MCE at the project site, and to assess the potential of ground surface rupture near the project structures that could affect the safety and/or integrity of the structures. In addition, sufficient geologic and seismologic studies were performed to evaluate the probability of Reservoir-Induced Seismicity (RIS) and its impact on the project design. A seismic monitoring network plan was also developed to monitor both micro-earthquake and strong earthquake activities within the Susitna Basin prior to and during the construction of the project and for a period of approximately 15 years after the project is completed and the reservoirs are flooded.

(b) Regional Seismicity and Tectonics

Recent concepts of plate tectonics have been a major influence in the interpretation of the current tectonics of Alaska. The earthquake activity in central and southern Alaska is caused by the subduction of the Pacific Plate under the North American Plate at the Aleutian Trench (Figure 7.12). The Pacific Plate spreads northward at a rate of approximately 2.4 inches/year relative to the North American Plate. This movement in the Gulf of Alaska is expressed as three styles of deformations: right lateral slip along the Queen Charlotte and Fairweather Faults, underthrusting of the oceanic Pacific Plate beneath the continental block of Alaska, and the complex transition zone of oblique thrust faulting near the eastern end of the Aleutian Trench. This subducting plate dips gently under the Upper Susitna River region.

Historically, major earthquakes in Alaska have occurred primarily along the interplate boundary between the Pacific and the North American Plate. For example, three great earthquakes of September, 1899 (estimated magnitudes 8.5, 8.4 and 8.1) were felt near Yakulat Bay. Similarly, an earthquake of magnitude 7.7 in Lituya Bay in 1958, one of magnitude 7.6 in 1972 near Sitka, and the devastating 1964 Alaskan earthquake occurred along the plate contact. Nevertheless, the overlying North American Plate is also disrupted by the compressional and tensional forces caused by the interplate movements (approximately 2.4 inches/year). The strain buildup and release caused by this movement within the crust takes place along a series of faults and also generates earthquakes of small-to-moderately large magnitude within the crust with no surface expressions. Available information suggests that the sum of the rates of displacement along faults in southern Alaska is less than the rate of convergence of the Pacific Plate relative to the North American plate and that a significant portion of that unaccounted-for convergence is transmitted northward. This has resulted in broad folds and reverse faults, northward thrusting of the Alaska Range northern front, and the overall uplift of the Alaska Range.

The site region of interest for the Susitna Basin development lies between the Aleutian Trench and the Alaska Range and has been termed the Talkeetna Terrain.

(c) <u>Tectonic Model of Talkeetna Terrain</u>

The Talkeetna Terrain is a subunit of the larger tectonic unit, the Wrangell Block (Figure 7.13). The terrain is defined by the McKinley strand of the Denali Fault on the north, the Denali-Totschunda Fault system on the east, the Castle Mountain Fault on the south, and a zone of deformation on the west extending from the Aleutian volcanic chain to Mt. Denali (formerly Mt. McKinley - Figure 7.13). The north, south, and east boundary faults are faults with recent displacements, and the western boundary is primarily a zone of uplift marked by Cenozoic volcanos. The subducting Pacific Plate, called the Benioff Zone, bounds the base of the Talkeetna Terrain. At the southern boundary of the Talkeetna Terrain, the Benioff Zone is decoupled from the North American Plate. Most of the deformation in the Talkeetna Terrain caused by the converging plates appears along the boundaries; the interior region is relatively stable. A schematic section showing these boundaries is presented in Figure 7.14.

Much of the interplate convergence, in the form of strike-slip faults, is believed to lie within a broad area of deformation extending from Montague Island east to Pamploma Ridge in the Gulf of Alaska. A small amount of movement occurs within the Castle Mountain Fault, which is decoupled from the Benioff Zone in the site region. This fault is a right-lateral, strike-slip fault with a significant component of the northside up reverse component. The Denali and the Totschunda faults are right-lateral, strike-slip faults that exhibit progressively lower slip rates northward and westward. Within the Talkeetna Terrain, two major geologic structures, the Broxson-Gulch Fault and the Talkeetna Thrust Fault, are present. The Talkeetna Thrust Fault is an old geologic feature with no signs of recent movements. The Broxson-Gulch Fault, although considered to be active in accommodating some of the movement along the Denali-Totschunda Fault, is outside the area of study and is not considered significant for the project studies.

Most of the moderate-to-large earthquakes and all the large earthquakes within the Talkeetna Terrain are associated with either the Benioff Zone or the boundary faults. The terrain itself is relatively stable with no brittle deformation related to the current stress conditions.

(d) Historical Seismicity

Within 200 miles of the project site, the earthquakes generally originate from three sources: the shallow Benioff Zone, the deep Benioff Zone, and the crustal seismic zone within the North American Plate.

The shallow Benioff Zone is a major source of earthquake activities. The major 1964 earthquake of magnitude 8.5 occurred on this source. Several additional large earthquakes have been reported in the same vicinity during the twentieth century. The focal depth of these earthquakes is generally 15 to 28 miles.

The deeper Benioff Zone dips gently under the North American plate and reaches a depth of approximately 31 miles beneath the Watana site and 37 miles beneath the Devil Canyon site. Moderate-to-large size earthquakes have been reported on this source within the site region. The largest reported event within the 60-mile radius has been magnitude 6.1. The crustal seismicity is related to the Talkeetna Terrain boundary faults; namely, the Denali and the Castle Mountain Faults and the strain release within the crust with no surface faults. Moderate-to-large earthquakes have been reported along the two faults. Within the terrain, numerous moderate-size earthquakes with a largest reported magnitude of 5.6 have been reported.

(e) Identification and Screening of Faults

The project site is remotely located and the area had not been studied in detail for hydroelectric developmen prior to this study program. Therefore, a systematic and comprehensive study was undertaken to identify faults in the area. A fault-screening methodology was developed to direct efforts in studying significant features (Figure 7.15).

All lineaments within 62 miles of either site were reviewed using this methodology. All available literature and remotely sensed data was researched and reviewed. More than 400 features were identified from this review and were further screened using a length-distance criteria. All features within 6 miles of either project site were identified for their potential for surface rupture and during an earthquake. This first step resulted in a list of 216 features that required further study. Throughout this screening process, the following criteria were used in identifying and studying the faults with recent displacement:

- All features identified as faults that have experienced movement in the last 100,000 years were considered to have had recent displacement. All faults with recent displacement were considered as potential sources for ground motion and surface displacement.

- All lineaments or faults that have been defined by the geology and seismology community as having experienced recent displacement were included for further study in assessing the seismic design criteria for the project.

- If a lineament existed within 6 miles of the damsite, or if a branch of more distant lineament was suspected of passing through a damsite, then a more detailed investigation was made to establish whether the feature was a fault, whether or not it was recently displaced, and whether the potential for displacement in the dam foundation existed.

- Lineaments farther than 6 miles from the damsites for which deterministic estimates of ground motion at the site may control the design of a dam were investigated to determine if the lineament was a fault and if it had recently undergone displacement.

- Therefore, at a distance of less than 6 miles from the damsite, all faults or lineaments with a length of 3 miles or more were selected for field study. A fault of this length has a potential for an earthquake with a magnitude of 5 or greater. All faults or lineaments 6 miles or longer at a distance of 6 to 31 miles, and 31 miles or longer at a distance of 31 to 93 miles, were also selected for field study. This process resulted in a list of 216 features that were identified for field study on a reconnaissance level.

(f) Field Reconnaissance Studies

The 216 features were further studied in the field during the summer of 1980. Aerial and ground reconnaissance work was conducted for all these features by experienced teams of geologists. Flights were made along these lineaments in both directions looking for morphologic features. The features were photographed at key locations for later studies and documentation. For some long faults or lineaments, the feature was examined in detail on the ground.

A systematic method was again used to identify significant features. Lineaments that could be related to glacial or fluvial processes were eliminated from further considerations. This resulted in a group of 106 features for further screening (see Table 7.15) using the following criteria:

- Any feature less than 3 miles in length (potential a magnitude for 5-or-less earthquake) was not studied any further unless that features was within 6 miles of the project site.

- Features that would generate a peak acceleration of 0.15g or less if they were faults were eliminated. This acceleration is less than the acceleration caused by a Denali Fault earthquake of magnitude 8.5 at 40 miles from either damsite. The Denali Fault was recognized as an active fault and therefore a source of earthquake concern.

- Two features, KC 4-27 at the Watana site and KC 5-43 at the Devil Canyon site, were less than 3 miles long; however, they were retained for further studies because of their proximity to the damsites and associated potential ground rupture.

With this process, 58 features were eliminated, leaving 48 features for further consideration. These 48 features were evaluated in greater detail on the basis of their potential impact on the design of the project and the likelihood of a feature being a fault on the basis of field reconnaissance. This evaluation resulted in identification of 13 significant features that could potentially impact the design of the project. These features and the boundary faults are listed in Table 7.16 and were studied in detail during the 1981 summer season. The four features located near the Watana site are shown in Figures 7.16 and 7.17. The remaining nine features were near the Devil Canyon site and are shown in Figures 7.18 and 7.19.

(g) Detailed Field Studies

The significant features identified during 1980 were studied in much more detail during 1981. The approach used to guide the field studies was to:

- Study the bedrock along each feature to assess whether or not the feature was a fault; and

- Examine the surficial units along the features to evaluate when the displacement occurred.

The detectability of faults with recent displacement is dependent on the age of sediments overlying the fault, the amount of displacement at the surface during an earthquake, how often the earthquakes and the displacements occur, the type of displacement, the length of fault that experienced displacement, and the time that the displaced features are preserved. On the basis of the site fault morphology, review of a select group of worldwide data and a review of moderate-to-large historical earthquakes in Figure 7.16 shows the boundary faults, Talkeetna Thrust Fault and the Susitna feature. In California (where the studies are much more complete), it was judged that any fault which has experienced displacement for a length of 9 miles or longer and a scarp height of 2 to 3 feet would be recognized during the field studies. It was recognized that recent displacement along a fault could go unrecognized if the length of displacement was less than 9 miles and the scarp height was less than 2 to 3 feet or both; however, such a displacement would be associated with a magnitude of 6 or less earthquake.

The first step in this investigation consisted of quaternary geology mapping in the site region to determine or estimate the age of surficial sediments and geomorphic surfaces near the 13 features. The extent, magnitude, and chronology of the repeated glacial events affecting the Talkeetna Terrain was reconstructed using stratigraphic and morphologic relationships and relative and radiometric age dating techniques. The results of air photo interpretation of stereographic aerial photographs, published works by other investigators, and field mapping were used supplemented by age determination of soil samples from selected locations.

The geologic setting of the Talkeetna Terrain is largely one of crystalline bedrock and bedrock overlain by thin glacial cover. No deep Neogene subbasins exist that could conceal faults and the effects of recent displacements. Thus the incidence of recognizing faults is rather high.

The Quaternary geology and bedrock geology studies were performed along these 13 features using low level aerial reconnaissance and ground techniques. The data were integrated with the results of historical seismicity and microseismic network data and ground mapping was conducted at 300 locations. Two trenches were excavated across the inferred location of the Talkeetna Thrust Fault and one trench across the inferred location of the Susitna feature (see Figure 7.13). In addition, magnetic surveys were performed at locations across the Talkeetna Thrust Fault, locations across the Susitna features, and locations on other features. During the ground examination, 28 samples were collected from 15 different locations for age dating, and five test pits were dug with a backhoe for relative age dating. In addition, low sun angle photographs were taken of selected features to improve the level of resolution. A ten seismograph station microseismic network was operated during the period from June 25, 1980 to September 28, 1980 around the Watana and Devil Canyon sites. The location of the network stations is shown in Figures 7.20 and 7.21. The objective of this network was to collect a large quantity of microearthquake data within a relatively short period of time. A total of 268 earthquakes were recorded during the periods, 98 of which occurred below a depth of 19 miles (in the Benioff Zone); the remaining 170 occurred within the crust. The largest magnitude recorded was 3.68 for the deep earthquakes and 2.8 for the shallow earthquakes. The locations of the shallow earthquakes are shown in Figure 7.20, and the deep earthquakes in Figure 7.21. The results of this microseismic network were used in conjunction with geologic and seismologic studies to determine current activity along known/inferred faults, to determine the Benioff Zone depth in the site region, and to develop frequency - magnitude relationships for the study area. A cross-section through the site, showing the shallow and deep earthquakes recorded during this period, is presented in Figure 7.22. The results of these studies were used to assess the recency of displacement along faults or features, with the following results:

- From the 13 features selected for the study, only four features were determined to be faults: the Talkeetna Thrust Fault and the Fins at the Watana site, and KC5-5 and KD5-2 at the Devil Canyon site. The remaining nine features were determined not to be faults.

- The features that are not faults were not considered to be significant in the design of the project under earthquake conditions.

- The four features that were determined to be faults did not meet the guidelines for a fault with recent displacement. Therefore, these are not considered to be possible sources of earthquake activity for the project.

- The only known sources of earthquake activity are the Denali Fault, the Castle Mountain Fault, the Benioff Zone, and a fault within the crust with no detectable surface trace.

- The Benioff Zone under the site is decoupled from the crust. The approximate depth to the upper boundary of this zone is estimated to be ___ miles under the Watana site and ____ miles under the Devil Canyon site.

- There is a seismic belt of low seismic activity between the crust in the site region and the shallow Benioff Zone.

- No microearthquake activity was found to be related to the Talkeetna Fault or any other feature.

(h) Sources of Earthquakes in Susitna Basin

Based on the studies conducted to date, four sources of earthquakes have been identified for the design of the project. These sources and the associated maximum credible earthquakes are summarized in Table 7.17 and briefly discussed in Sections 9 and 10.

(i) Denali Fault System

This strike-slip fault system lies to the north of the site region and connects with the Totschunda and the Fairweather Fault system to the east and the southeast. One section of this fault could be as long as 670 miles; this fault is considered capable of causing a magnitude 8 earthquake.

(ii) Castle Mountain Fault

This strike-slip fault lies outside the limits of the area studied and forms the southern boundary of the Talkeetna Terrain. It is approximately 295 miles long and capable of generating a magnitude 7.5 earthquake.

(iii) Benioff Zone

This is the most dominant of all sources. The Benioff Zone is divided two discrete segments for earthquake considerations; the Interplate Zone and the Intraplate Zone. These zones are separated by a transition zone of relatively low seismic activity.

- Interplate Zone: This zone represents the interface between the Pacific Plate and the North American Plate. The depth of this zone is estimated to be less than 35 km. The maximum credible earthquake for the source is estimated to be 8.5 magnitude at the closest distance of 63 km from the Watana site and 90 km from the Devil Canyon site. This magnitude is similar to that of the 1964 Alaska earthquake.

- Intraplate Zone: This portion of the Benioff Zone is detached from the North American Plate Crust and dips beneath the crust. The earthquakes occur within the subducting plate. The maximum credible earthquake that can be generated by this intraplate zone within the site region is estimated to be magnitude 7.5. The closest this earthquake can occur to the Watana and Devil Canyon sites is 48 km and 58 km, respectively.

(iv) Random Terrain Earthquake

As discussed earlier, the studies indicate that earthquakes do occur in the crust without causing recognizable surface faulting. The magnitude of these earthquakes in similar seismic environment is moderate and the location is difficult to identify prior to the actual earthquake. For conservative design purposes, it is assumed that these earthquakes can occur very close to the site. For the Susitna Hydroelectric Project, it has been conservatively selected to consider, at the most, a magnitude 6 earthquake to occur within a few kilometers of either project site.

(i) Reservoir Induced Seismicity (RIS)

During the past few decades, it has been accepted that the impoundment of large reservoirs affects the seismicity of the region. This phenomenon was first recognized during a study of Hoover Dam in the United States in the early 1940s. Since then similar relationships have been reported for 63 other reservoirs around the world, of which 55 cases have been accepted as either RIS or questionable cases of RIS (see Figure 7.23). Several RIS events have exceeded magnitude 6.

Recent studies have suggested that RIS is influenced by several considerations; the most prominent ones are water depth and reservoir volume (see Figure 7.23), geologic setting and faulting (see Figure 7.24), and the state of tectonic stress (Figure 7.25) in the shallow crust beneath the reservoir.

The study of RIS suggests that the impoundment of water acts as a triggering mechanism for the seismic events that would occur at some point in time under natural states of stress. Therefore, reservoirs do not reactivate inactive faults or create new faults, but merely accelerate the release of stored tectonic strains. This hypothesis forms the basis of statement that RIS is an important consideration only in those areas where active faults, whether identified or not, exist. It also suggests that the largest event caused by RIS would be less than or equal to the maximum credible event on the fault. Further, it is recognized that RIS events occur mostly within the first ten years of impoundment; after ten years the micro as well as macro seismicity return to their natural state after that.

Mathematical models have been developed to assess the probability of RIS under a given set of conditions. For the purpose of this study it has been assumed that both the Watana and Devil Canyon reservoirs act as one hydrologic regime. Using this assumption and the results of geologic and seismologic studies, it has been estimated that there is a 90 percent probability of an RIS event of some magnitude occurring. The largest RIS event that could occur is estimated to be magnitude 6, which is the same as the maximum credible earthquake with no recognizable trace of faulting at the surface. This estimate is based on the finding that there are no active faults present within the hydrologic regime of the combined reservoirs.

(j) Long-Term Seismic Monitoring Network

A seismic monitoring network will be installed at the Susitna Hydroelectric project to monitor the seismic activity in the region on a long term basis. This network will be separate from the seismic instrumentation that may be installed in the dam and other structures, although some components of the network may be integrated and may become part of the permanent instrumentation. This system will be operated during the design and construction of the project and for a period of 10 to 15 years after the reservoirs are filled.

The major objectives of this network will be to monitor the natural seismic activities within the region (both microearthquakes and strong motion), to monitor the seismic activity after the reservoirs are filled (to study and document any change in seismic activity caused by the project), and to calibrate source-distance attenuation curves for this region for a proper ground motion attenuation. The key requirements of this network will be to:

- Provide reasonably accurate hypocentral locations of 3 earthquakes within 15 to 20 km of the two reservoirs;

- Effect good control on the depth and local mechanism of earthquakes; and

- Provide a reasonably accurate magnitude of both small and large earthquakes.

For maintenance and operation consideration, a system which provides continuous monitoring, quality data, and requires the least possible maintenance and repair in this environment will be provided.

Such a network, as envisioned at this point, will include 11 vertical component seismometers and two three-component seismometers. Six of the eleven component seismometers will be strong motion instruments. The locations of these siesmometers (conceptual) are shown in Figure 7.16; they were selected to provide the optimum coverage within a region of 15 to 20 km of the reservoir limits. This network will provide good constraint on the hypocentral locations of all earthquakes that occur within 20 km of the reservoirs with a focal depth of greater than 5 km. The data from these stations will be collected at a central location at the Watana site and transmitted by VHF radio or hard wire line. A central recording facility will be located at the Watana site. The data will be compiled and processed by a microcomputer which will continuously scrutinize incoming signals and store them on disc. When a seismic event is detected, the digitized data will be copied from disc to tape for permanent storage. Data from selected stations will also be recorded asanolog paper records. These data will be accessible via a telephone telemetry link for rapid transmittal of data to distant locations. Preliminary data analysis performed by microcomputers will allow quick and timely decision making.

The instrument locations will be selected in the field and proper protective measures will be designed to mitigate the effects of weather and wild habitat. The number of stations included in the network will provide a sufficient degree of redundency in the network. Although, the instruments and the system selected will require minimum maintenance and repair, a well-planned regular maintenance and repair program will be developed to assure long term, uninterrupted data gathering.

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 at Devil Canyon downstream to the estuary. Existing surface and ground water appropriations are primarily for single-family and multi-family homes (Table 7.18). A small amount of water is used year-round for watering livestock. Only 0.153 cfs, or 50 acre feet per year, of surface water has been appropriated for all purposes (Table 7.19). Water appropriations in other areas are even less significant. On a seasonal basis, the greatest usage occurs during summer months for irrigating lawns, gardens, and crops. The largest single use of surface water is for placer gold operations.

There are only five areas where water appropriations are located within one mile of the mainstem Susitna River (Table 7.20). No surface water diversions are recorded that draw water directly from the Susitna River or its adjoining side channels and sloughs. Immediately downstream from the Delta Islands, on the west bank of the Susitna River, a single-family dwelling has a certificate for 650 gpd of ground water from a well of unlisted depth. About six miles below Talkeetna and 0.25 miles inland from the west bank of the Susitna River, a single-family dwelling has a certificate for 500 gpd of ground water from a 90-foot deep well. In Talkeetna, ground water from three shallow wells has been appropriated for a single-family dwelling (500 gpd), the grade school (910 gpd), and the fire station (500 gpd). Near Chase, several unnamed streams, lakes, and creeks have been appropriated for single-family dwellings (1,250 gpd), lawn and garden irrigation (100 gpd), and crops (1 acre foot per year). Near Sherman, an unnamed stream and Sherman Creek have been appropriated for two single-family dwellings (325 gpd) and lawn and garden irrigation (50 gpd).

(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 summer during the glacial melt period. Dissolved solids concentrations and conductivity values are high during low 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. Nutrient concentrations, namely, nitrate and ortho-phosphate, exist in low to moderate concentrations. Dissolved oxygen concentrations typically remain high, averaging about 12 mg/l during the summer and 13 mg/l during winter. Percentage saturation of dissolved oxygen always exceeds 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. During summer, pH occasionally drops below 7, which can be attributed to tundra runoff. True color, also 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. Alkalinity concentrations, with bicarbonate as the dominant anion, are low to moderate during summer, and moderate to high during winter. The buffering capacity of the river is relatively low on occasion.

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.

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 to the upstream part 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 here 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.

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. (Information on habitats, home range, population levels, density to be added).

Studies indicate approximately 55 percent of the population is males. 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 9only 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 (Information or habitats, home range, density to be added). Preliminary estimates of brown bear numbers in the study area is 70 animals or one bear per 50 km^2 utilizing the same figure would indicated 3 to 4 bears in the area to be flooded.

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, 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 109 km^2 (1/42 mi^2) and 1 per 144 km^2 (1/56 mi^2). The entire impoundment area of both Watana and Devil Canyon is approximately 206 km^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

(To be written following receipt of report from ADF&G).

(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-Orebe 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 7.28). Portions of the 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 this area. A small subherd of approximately 1,000 animals appear to be residing permanently in this portion of the basin.

During winter, caribou were found primarily on 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

(To be written following receipt of report from ADF&G)

(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 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.

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 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 parts of the Alaska Range on the north and parts 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, and 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. 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 7.21 lists the area of each habitat type present in the Upper Susitna Basin. Table 7.22 lists the area of each habitat type within the impoundment zones and borrow areas.

(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. All of these sites are believed to be eligible for the National Register of Historic Places.

Three historic sites, all cabins built in the 1920s, occur in the Watana impoundment area. All three appear to be eligible for inclusion in the National Register.

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, are all believed to be eligible for the National Register.

One historic site, also a cabin believed to be constructed in the 1930s, lies within the Devil Canyon impoundment area. This cabin is believed to be eligible for the National Register.

7.10 - Socioeconomics

Three areas are discussed to depict the socioeconomic settling of the project. These areas 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.

(a) State

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 (Figure 7.30).

Employment in Alaska rose dramatically during the construction of the Trans-Alaska Pipeline System and has since leveled off; employment in 1979 equaled 166,400. Government is the largest employer in the state, responsible for 33 percent of all jobs in 1979. Service industry employment has increased recently, as has employment in transportation, communication, utilities, retail trade, finance, insurance, and real estate. Unemployment is typically higher in Alaska than in the lower 48 states; the highest rate is associated with the native populations (Figure 7.30).

Per capita personal income in Alaska rose from $4,638 in 1970 to $10,254 in 1976, and then rose more slowly to $11,150 in 1979 (Figure 7.30).

(b) Region

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 (Figure 7.30).

Employment trends in the Railbelt region have been similar to overall trends, but there has been a higher share of employment in the services and support sector and a lower share in producing sections of the economy (Figure 7.30).

Per capita personal income rose from $4,940 in 1970 to $11,245 in 1976, then stabilized. 1978 per capita personal income in the Railbelt region was $11,522 (Figure 7.30).

(c) 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.

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, EskaSutton, Houston, and Talkeetna.

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 (Figure 7.31).

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 (Figure 7.31).

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 (Figure 7.31).

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, but 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. Significant concentrations of residences, cabins, and other structures occur near other lakes, 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 in 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.

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	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	1.19	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	63	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	43.4	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: 90° and above (b)	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	1633	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	1936	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	1945
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	1965	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
(a)	34		35		5	7	7	6	8	5	7	7	
J	64.8	1948	16.3	1973	68	68	69	68	15.1	NE	44	05	1968
F	44.5	1951	28.0	1964	76	75	75	76	11.9	NE	46	07	1974
M	59.1	1946	18.1	1946	76	76	70	73	11.1	NE	48	10	1971
A	28.7	1970	9.7	1963	80	75	65	75	7.6	NE	33	08	1971
M	17.4	1958	7.5	1946	83	70	58	67	7.7	W	28	07	1969
J	9.4	1974	8.7	1974	84	73	57	65	8.3	SW	29	22	1970
J	9.7	1970	9.7	1970	89	78	62	72	7.8	SW	30	23	1974
A	9.0	1954	6.0	1955	88	81	62	76	7.4	SW	31	22	1975
S	21.5	1958	14.0	1955	85	81	59	75	7.5	NE	32	23	1972
O	54.8	1970	12.6	1970	83	85	76	81	8.0	NE	35	23	1970
N	75.1	1967	21.9	1970	79	79	78	79	11.3	NE	39	25	1970
D	50.7	1970	27.4	1970	76	78	76	77	12.7	NE	44	11	1970
YR	75.1	NOV 1967	28.0	FEB 1964	81	76	67	74	9.7	NE	48	10	MAR 1971

Month	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	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.: 90° and above (b)	32° and below	Min.: 32° and below	0° and below	Average station pressure mb. Elev. 2405 feet m.s.l.
(a)		7	7	7	7	20	8	8	8	34	34	34	34	2
J		5.2	13	5	13	9	4	0	*	0	30	31	20	921.4
F		7.0	6	5	17	10	5	0	1	0	26	28	15	918.8
M		6.2	9	6	16	10	5	0	1	0	27	31	14	917.2
A		7.2	5	7	18	7	4	0	1	0	13	30	3	922.9
M		7.5	3	9	19	7	2	*	1	*	1	22	0	923.1
J		8.2	2	6	22	12	1	2	1	3	0	2	0	924.7
J		8.2	2	7	22	16	*	2	1	5	0	*	0	929.1
A		8.3	2	6	23	18	0	*	1	1	0	2	0	930.3
S		7.4	5	5	20	16	2	*	1	*	1	14	0	924.1
O		7.6	5	5	21	13	7	0	2	0	18	30	2	916.7
N		7.1	7	4	19	9	5	0	1	0	27	30	13	921.3
D		6.5	9	5	17	11	6	0	1	0	30	31	19	914.7
YR		7.2	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

Month	Matanuska Valley Agricultural Expansion Station		University Expansion Station		Watana Camp	
	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*

MONTH	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)	
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	26740.0	18000.0	11000.0	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	366,000

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: LENGTH-DISTANCE CRITERIA FOR IDENTIFICATION OF FAULTS AND LINEAMENTS FOR PRELIMINARY FIELD RECONNAISSANCE

Distance from damsite Alignment (km)	Distance from damsite Alignment (miles)	Minimum Length of Fault of Lineament (km)	Minimum Length of Fault of Lineament (miles)
0 to 10	(0 to 6)	5	(3)
10 to 50	(6 to 31)	10	(6)
50 to 150	(31 to 93)	50	(31)

TABLE 7.16: SUMMARY OF BOUNDARY FAULTS AND SIGNIFICANT FEATURES

Feature No.	Feature Name	Fault (F) or Linea-ment (L)	Length (km)	Distance (km) from Devil Canyon	Distance (km) from Watana
BOUNDARY FAULTS					
AD5-1	Castle Mountain Fault	F	200	500	115
-	Benioff Zone	F	-	60	50
HB4-1	Denali Fault	F	2000	70	64
WATANA SIGNIFICANT FEATURES					
KC4-1	Talkeetna Thrust	F	354	25	6.5
KD3-3	Susitna Feature	F	153	25	3.2
KD3-7	--	L	50	35	0.0
KD4-27	Fins Feature	F	3.2	37	0.0
DEVIL CANYON SIGNIFICANT FEATURES					
KC5-5	--	L	20	7	31
KD5-2	--	F	5	5.6	38
KD5-3	--	L	82	5.8	23
KD5-9	--	L	5	1.6	39
KD5-12	--	L	24	2.4	28
KD5-42	--	L	5	0.8	35
KD5-43	--	L	2.4	0.0	38
KD5-44	--	L	34	0.5	37
KD5-45	--	L	31	1.3	41

TABLE 7.17: SUMMARY OF EARTHQUAKE SOURCES CONSIDERED IN GROUND MOTION STUDIES

Earthquake Source	Maximum Magnitude (M_s)	Closest Distance to Dam Sites (km)	
		Watana	Devil Canyon
Benioff Zone:			
- Interplate	8-1/2	63	90
- Intraplate	7-1/2	48	58
Denali Fault	8	70	64
Castle Mountain Fault	7-1/2	105	115
Talkeetna Terrain	6	within a few km of either site	

TABLE 7.18: WATER APPROPRIATIONS WITHIN THE SUSITNA TOWNSHIP GRID

TYPE	SURFACE WATER APPROPRIATIONS cfs	SURFACE WATER APPROPRIATIONS gpd	SURFACE WATER APPROPRIATIONS ac-ft/yr	DAYS OF USE	GROUND WATER APPROPRIATIONS cfs	GROUND WATER APPROPRIATIONS gpd	GROUND WATER APPROPRIATIONS ac-ft/yr	DAYS OF USE
Certificates								
Single-family dwelling		4,500		365		5,440		365
		75		214				
2 to 4 unit housing						1,200		365
Grade Schools						910		334
Fire protection						500		365
Animals		63.5		365		94		365
Lawn and garden irrigation		200		184				
		100		153			0.5	60
General Crops			12.5	153			5.5	91
Total		4,938.5	12.5			8,144	6.0	
Permits								
Single-family dwelling		2[illegible]		365				
Vegetables			1	153				
Total		250	1					
Pending								
Single-family dwelling		75		365		1,000		365
						250		214
Lawn and garden irrigation		50		183				
Placer gold	0.1			184				
Total	0.[illegible]	125				1,250		
TOTAL	0.1	5,313.5	13.5			9,394	6.0	

TABLE 7.19: SUMMARY OF WATER APPROPRIATION*

TOWNSHIP GRID	SURFACE WATER EQUIVALENT cfs	SURFACE WATER EQUIVALENT ac-ft/yr	GROUND WATER EQUIVALENT cfs	GROUND WATER EQUIVALENT ac-ft/yr
Susitna	.153	50.0	.0498	16.3
Fish Creek	.000116	.021	.003	2.24
Willow Creek	18.3	5,660	.153	128
Little Willow Creek	.00613	1.42	.00190	1.37
Montana Creek	.0196	7.85	.366	264
Chulina	.00322	.797	.000831	.601
Susitna Reservoir	.00465	3.36		
Chulitna			.00329	2.38
Kroto-Trapper Creek	.0564	10.7		
Kahiltna	125	37,000		
Yentna	.00155	.565		
Skwentna	.00551	1.90	.000775	5.60

* Figures from Table 7.18 all converted to cfs and ac-ft/yr equivalents as follows:

1 gpd = .00000155 cfs
1 cfs = 1.98 ac-ft/day

TABLE 7.20: 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 7.21: HECTARES AND PERCENTAGE OF TOTAL AREA COVERED BY VEGETATION/HABITAT TYPES ON 1:250,000 SCALE MAP

	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

TABLE 7.22: HECTARES OF DIFFERENT VEGETATION TYPES TO BE IMPACTED COMPARED WITH TOTAL HECTARES OF THOSE TYPES IN THE ENTIRE UPPER SUSITNA RIVER BASIN

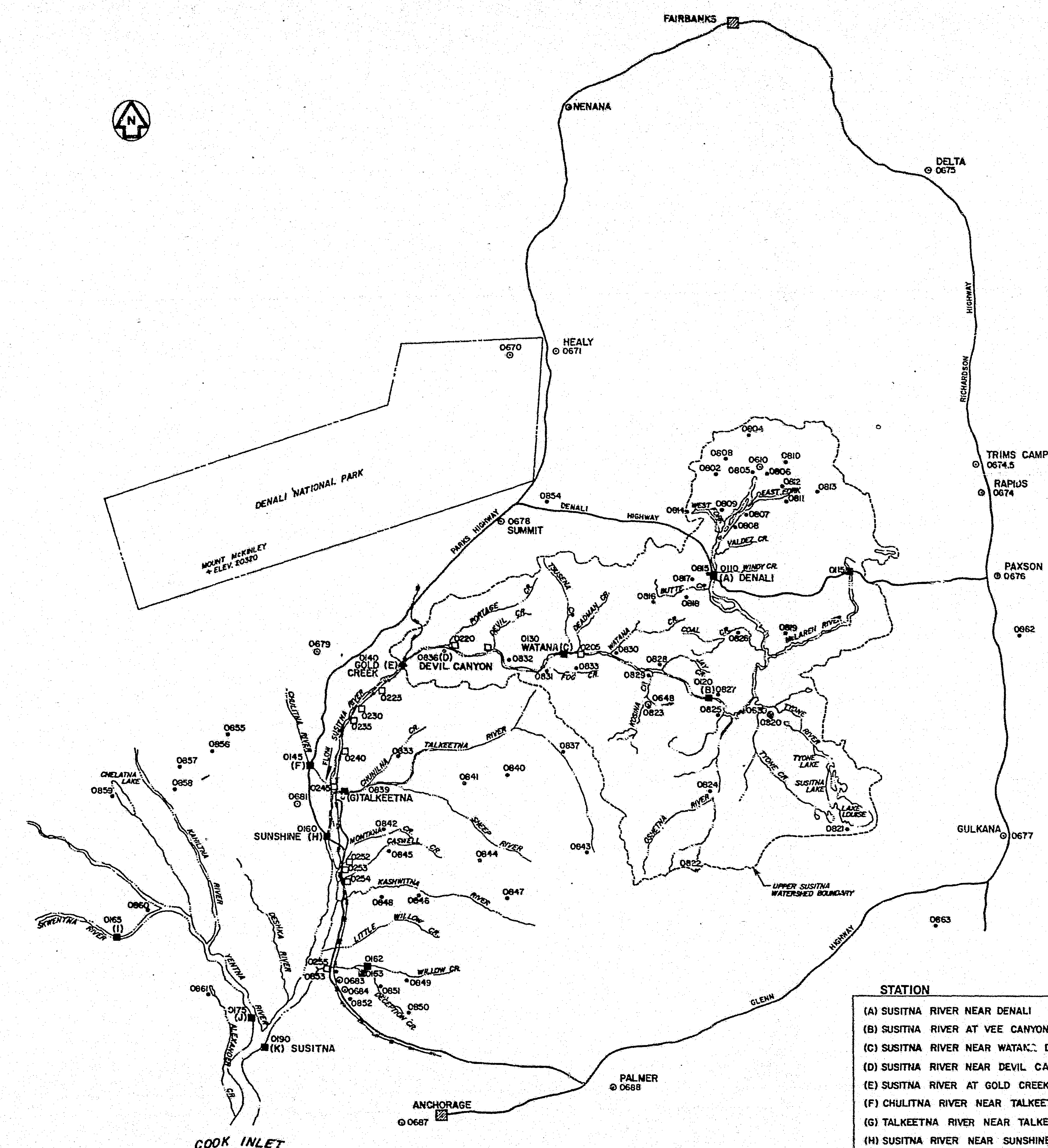
(Number in parentheses is the percent of the vegetation types as found in the entire Upper Basin)

	Impoundments		Borrow Areas					Upper Susitna River Basin
	Devil Canyon	Watana	A	C	D	F	H	
Woodland spruce	162 (0.09)	4766 (2.53)	228 (0.12)	77 (0.04)	15 (0.01)		227 (0.12)	188,391
Open spruce	862 (0.73)	3854 (3.24)	48 (0.04)	7 (0.01)			125 (0.11)	118,873
Open birch	73 (7.54)	318 (32.85)						968
Closed birch	470[(a)]	491[(a)]			1[(a)]			523
Open conifer-deciduous	300 (1.28)	1329 (5.68)			19 (0.08)	9 (0.04)	94 (0.40)	23,387
Closed conifer-deciduous	758 (4.75)	869 (5.44)			2 (0.01)			15,968
Open balsam popular	7[(b)]							
Closed balsam popular	10[(b)]	2[(b)]						
Wet sedge-grass	12 (0.25)	100 (2.07)	6 (0.12)		1 (0.02)			4,839
Mat and cushion tundra			78 (0.12)					65,001[(c)]
Tall shrub	19 (0.01)	580 (0.45)	18 (0.01)	23 (0.02)	8 (0.01)			129,035
Birch shrub	58 (0.17)	474 (1.41)	18 (0.05)	92 (0.27)	73 (0.22)			33,549
Willow	16 (0.15)	55 (0.52)					7 (0.07)	10,645
Low mixed shrub	6 (+)	785 (0.15)	101 (0.02)	113 (0.02)	109 (0.02)	55 (0.01)	46 (0.01)	471,461
Lakes	1 (+)	47 (0.22)	3 (0.01)			1 (+)		21,162
Rivers	835 (5.69)	2106 (14.35)		10 (0.07)		6 (0.04)		14,678
Rock	14 (0.01)	63 (0.06)			1 (+)			113,712
Total Areas	3603 (0.22)	15839 (0.97)	500 (0.03)	322 (0.03)	228 (0.01)	71 (+)	499 (0.03)	1,211,992

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

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

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



DATA COLLECTED

	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
ʌ	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.

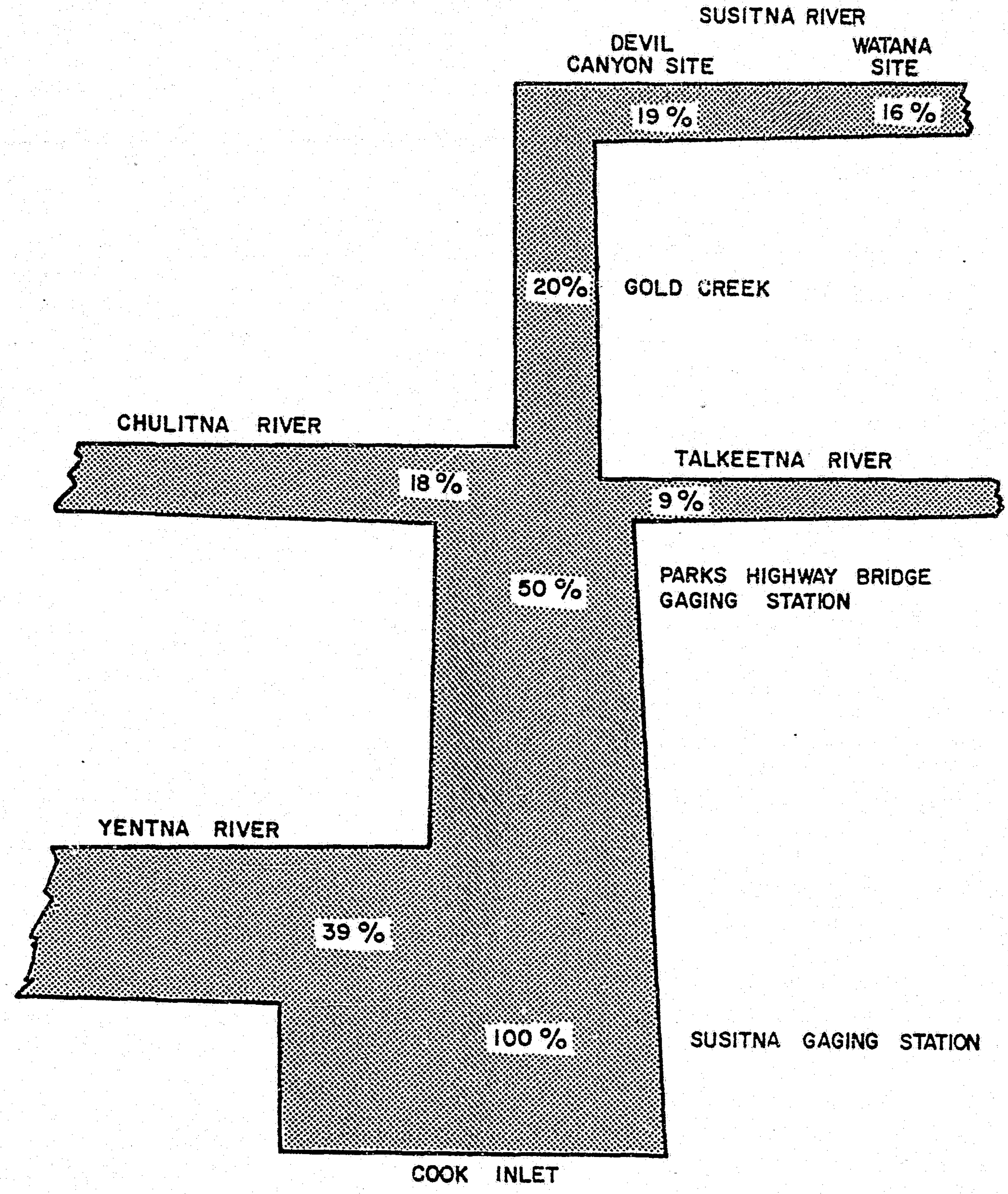
STATION	STREAMFLOW GAGING	CREST STAGE GAGE	STAFF GAGE	WATER QUALITY (1)	WATER TEMPERATURE	SEDIMENT DISCHARGE	BEDLOAD SAMPLING (3)	CLIMATE	IN-CLOUD ICING	FREEZING RAIN	SNOW CREEP	PERIOD OF RECORD OF STREAMFLOW
(A) SUSITNA RIVER NEAR DENALI	X		X		X	X		X	X	X		1957–PRESENT
(B) SUSITNA RIVER AT VEE CANYON	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.)

DATA COLLECTION STATIONS

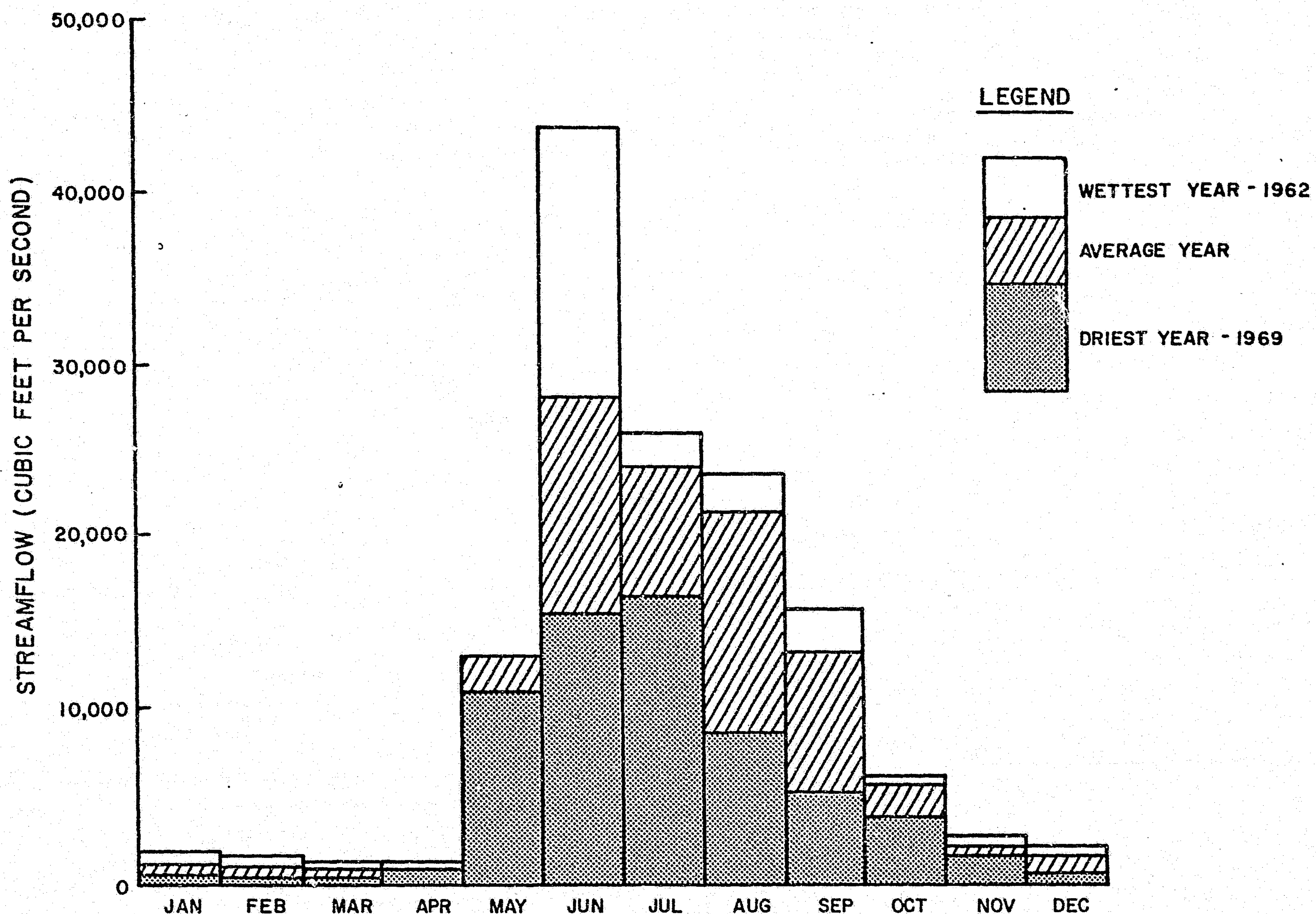
FIGURE 7.1

ACRES



AVERAGE ANNUAL FLOW DISTRIBUTION
WITHIN THE SUSITNA RIVER BASIN

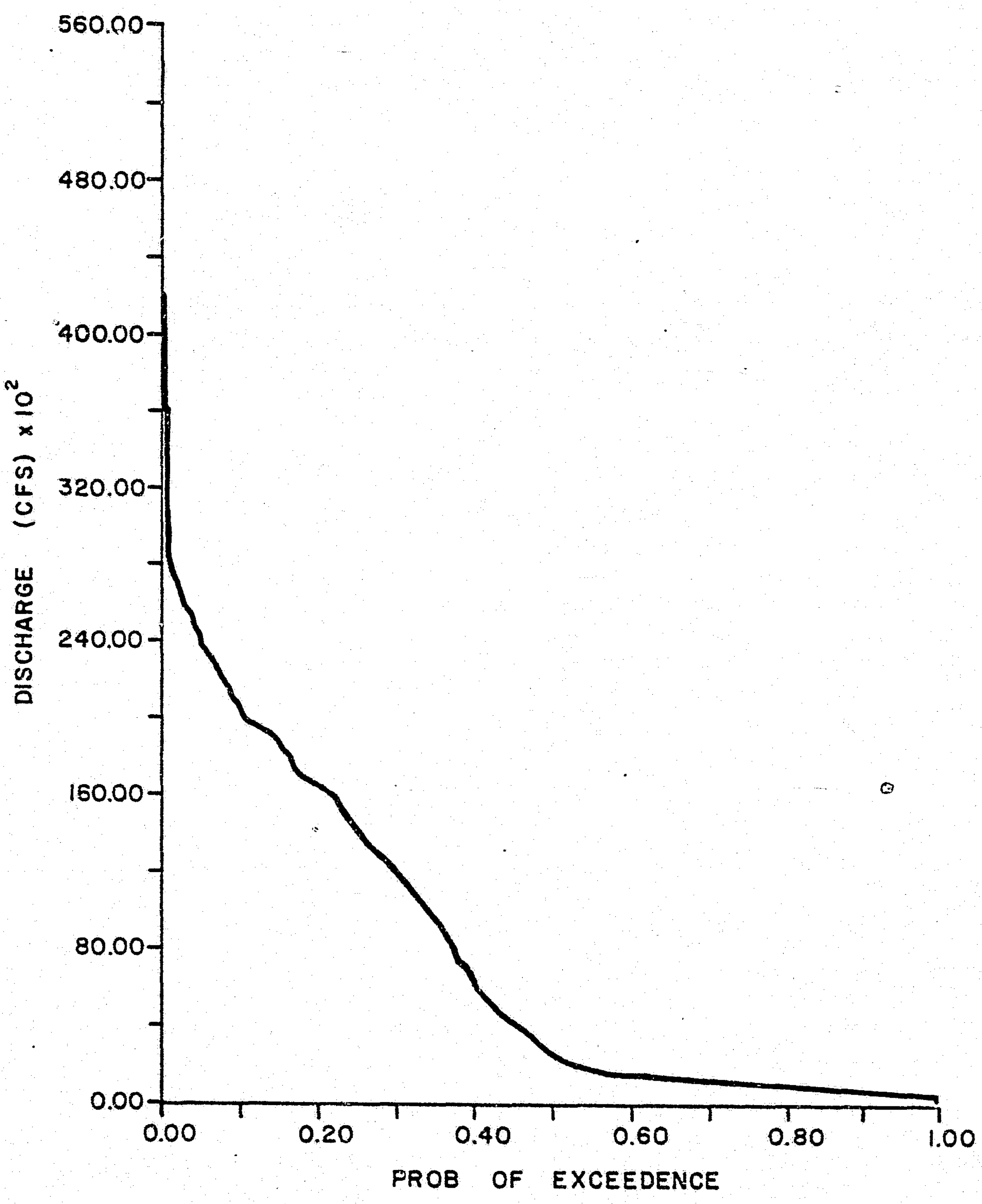
FIGURE 7.2



MONTHLY AVERAGE FLOWS IN
THE SUSITNA RIVER AT GOLD CREEK

FIGURE 7.3

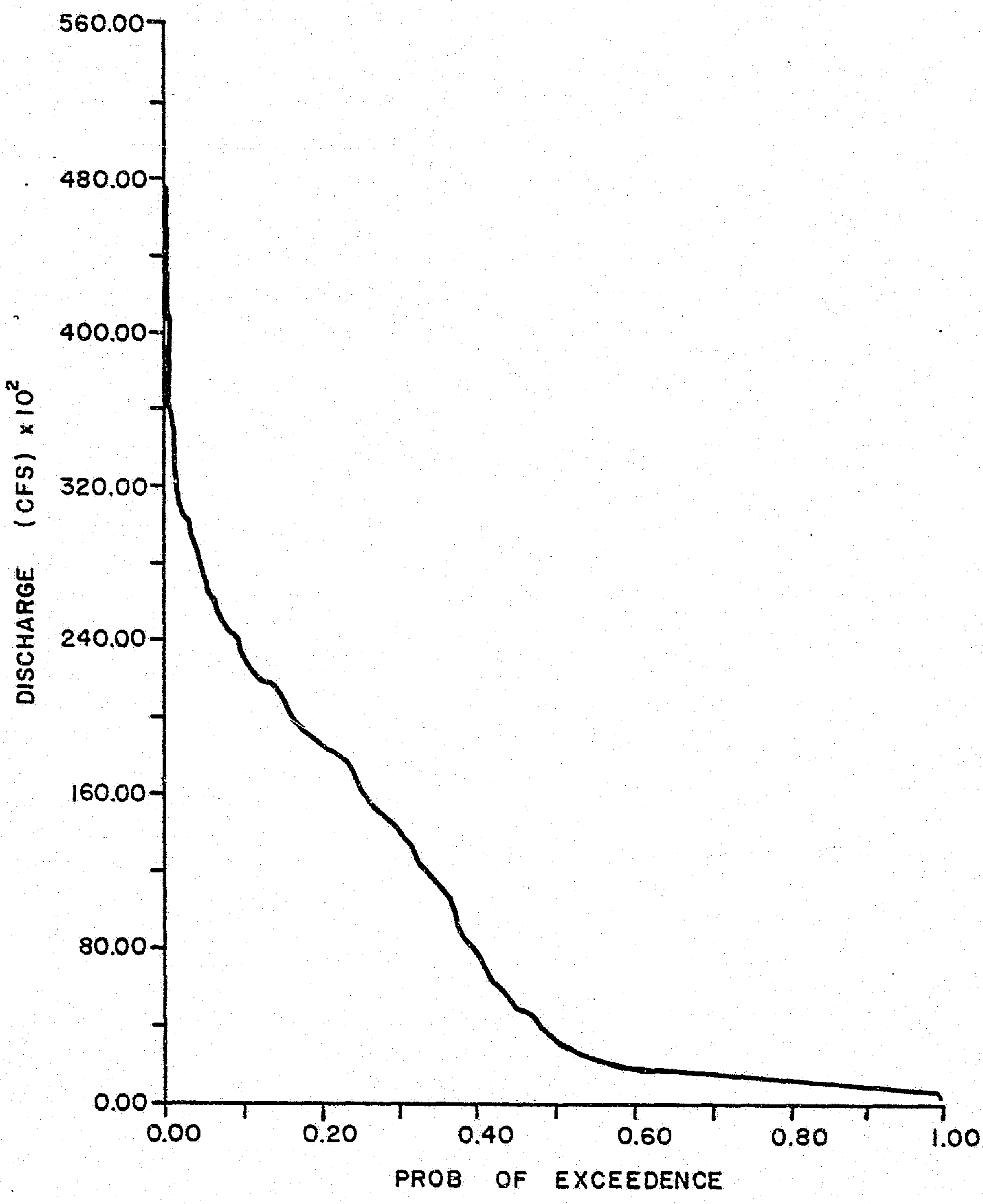
ACRES



FLOW DURATION CURVE
MEAN MONTHLY INFLOW
AT WATANA
PRE / POST PROJECT

ACRES

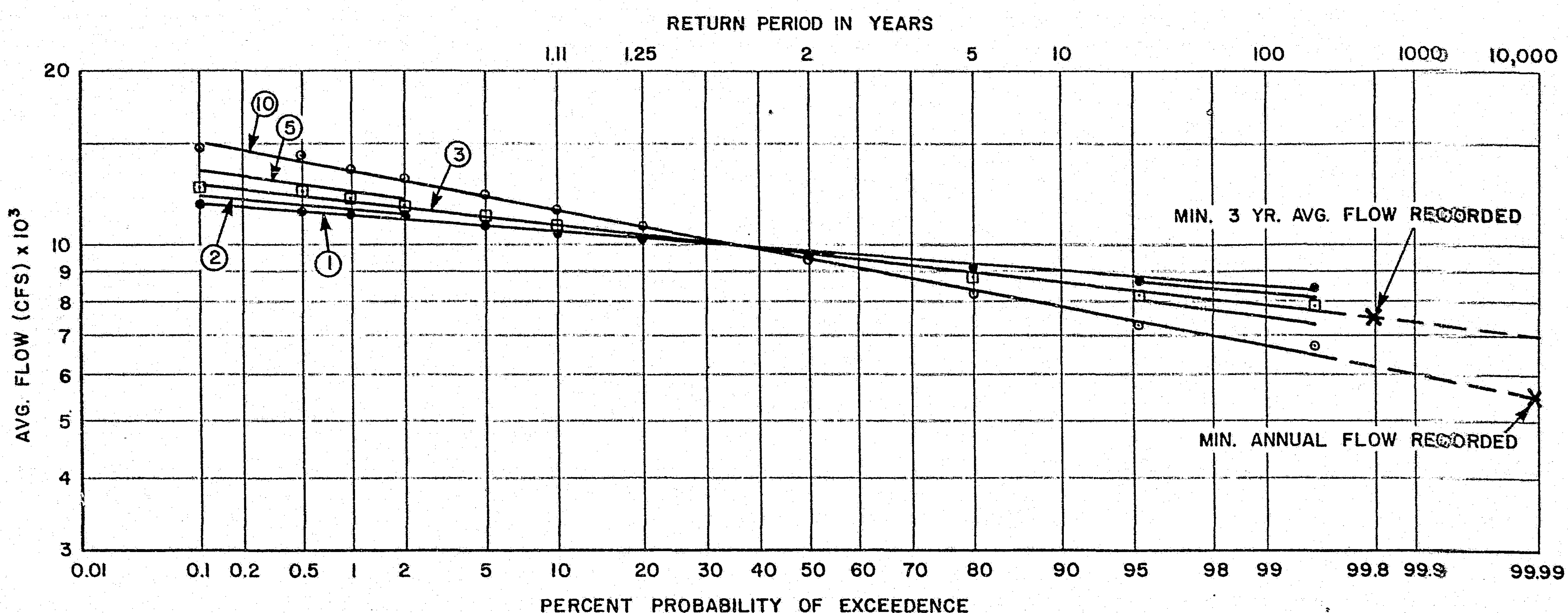
FIGURE 7.4



FLOW DURATION CURVE
MEAN MONTHLY INFLOW
AT DEVIL CANYON
PRE-PROJECT

ACRES

FIGURE 7.5

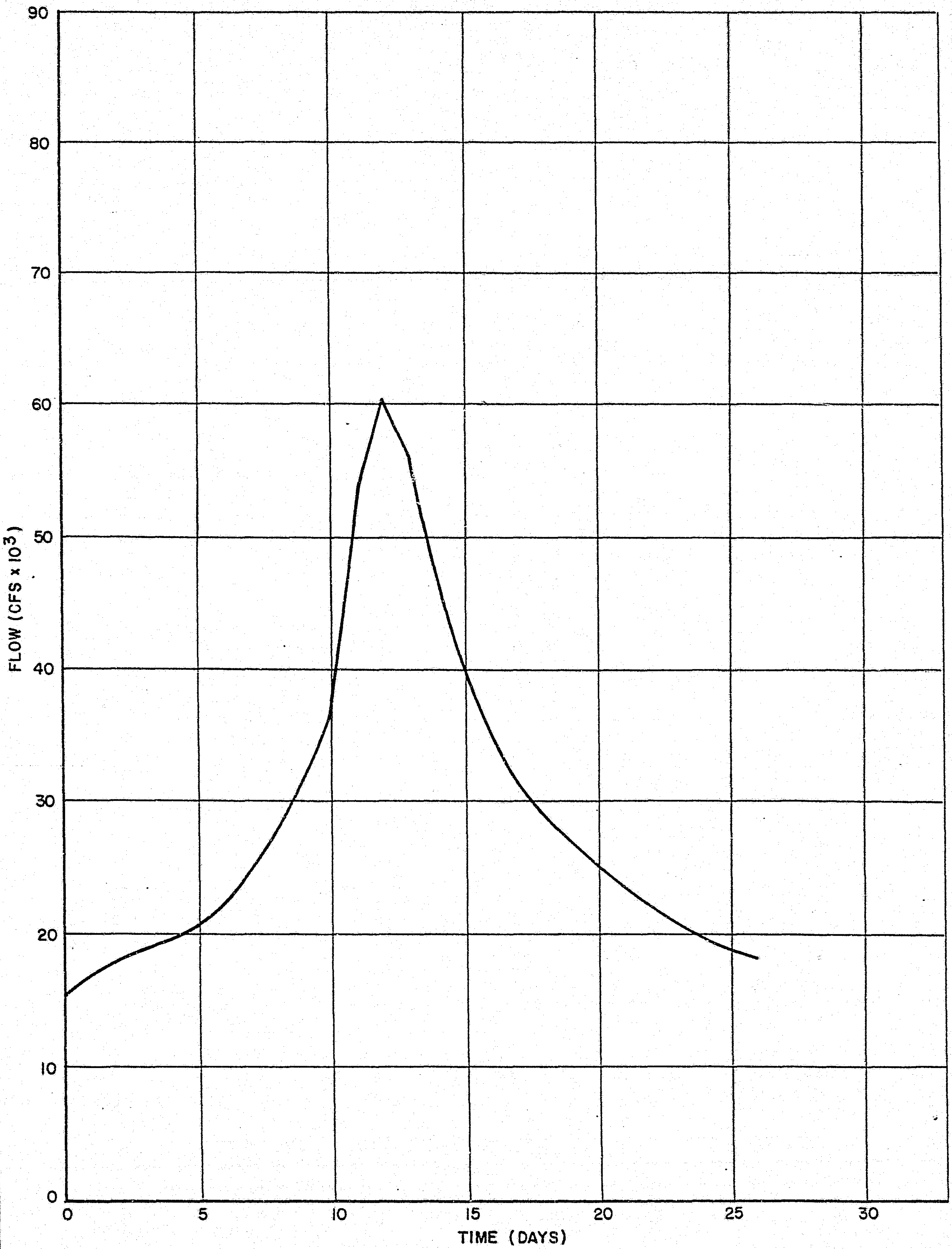


ANNUAL FLOW DURATION FREQUENCY CURVES
SUSITNA RIVER AT GOLD CREEK

② INDICATES CURVE FOR 2-YR. AVERAGE FLOWS

FIGURE 7.6

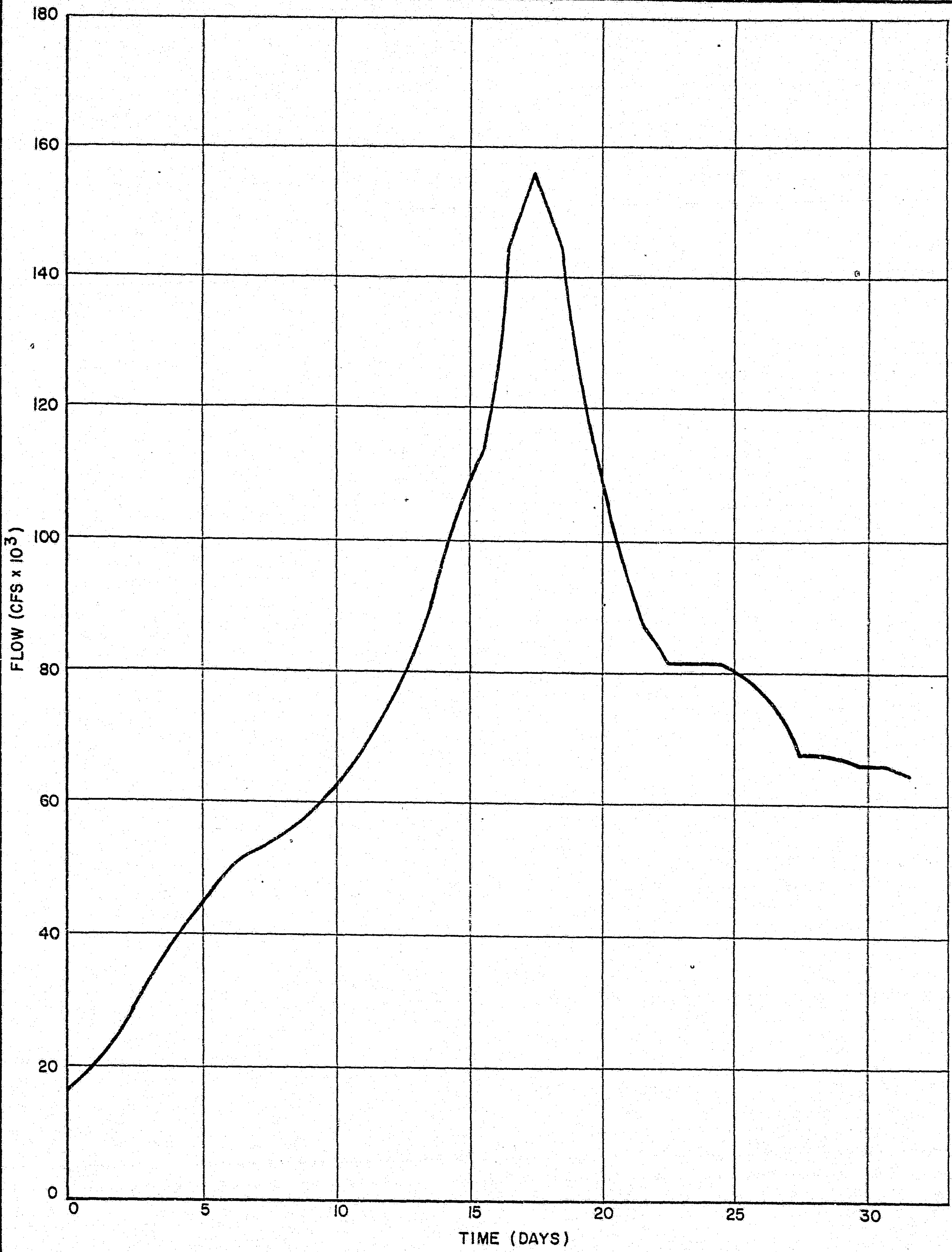
ACRES



1:50 YEAR FLOOD INFLOW HYDROGRAPH
SUSITNA RIVER AT WATANA DAM SITE

FIGURE 7.7

ACRES



1:10000 YEAR FLOOD INFLOW HYDROGRAPH
SUSITNA RIVER AT WATANA DAM SITE

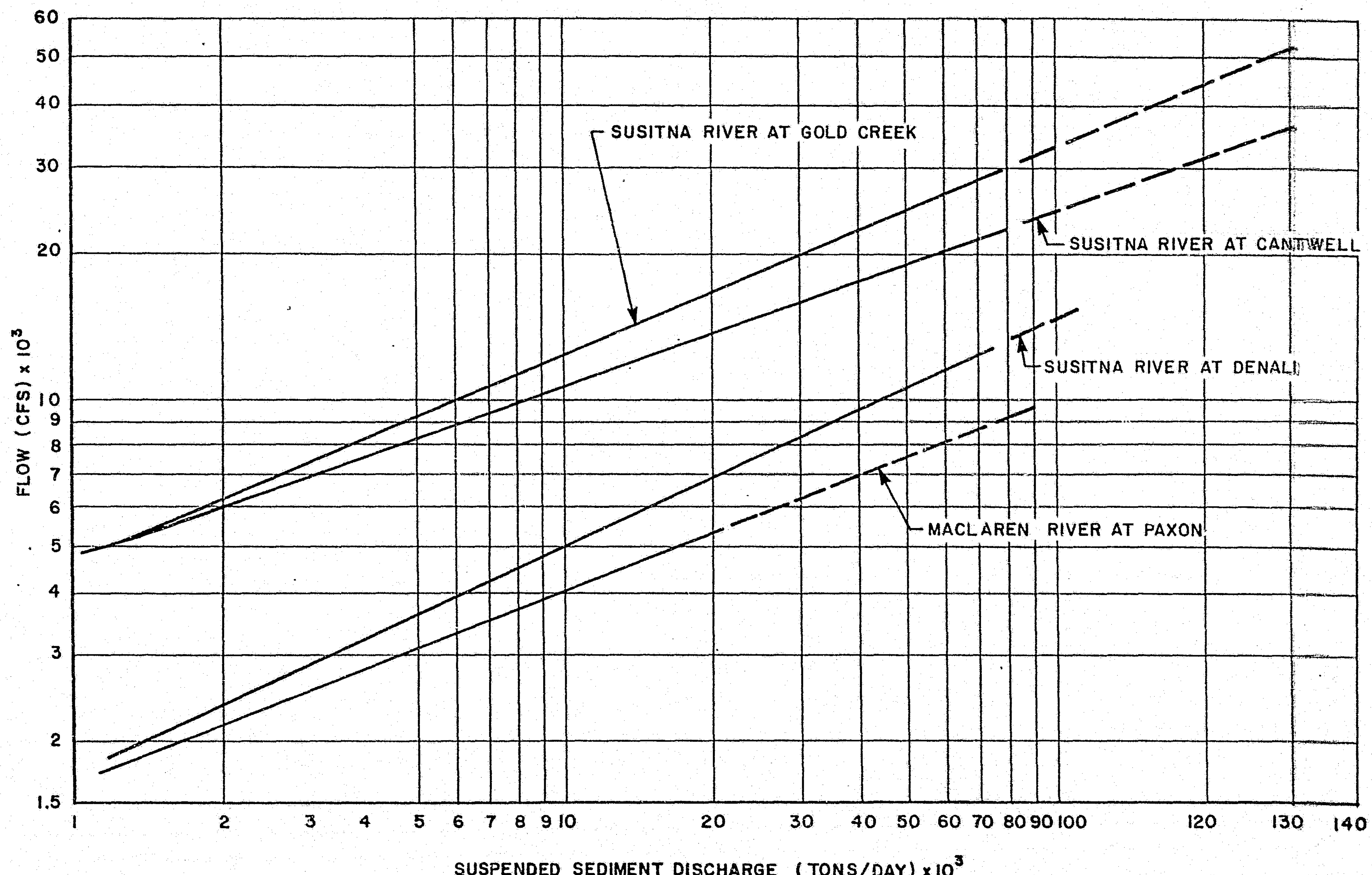
ACRES

FIGURE 7.8

PROBABLE MAXIMUM FLOOD INFLOW HYDROGRAPH
SUSITNA RIVER AT WATANA DAM SITE

FIGURE 7.9

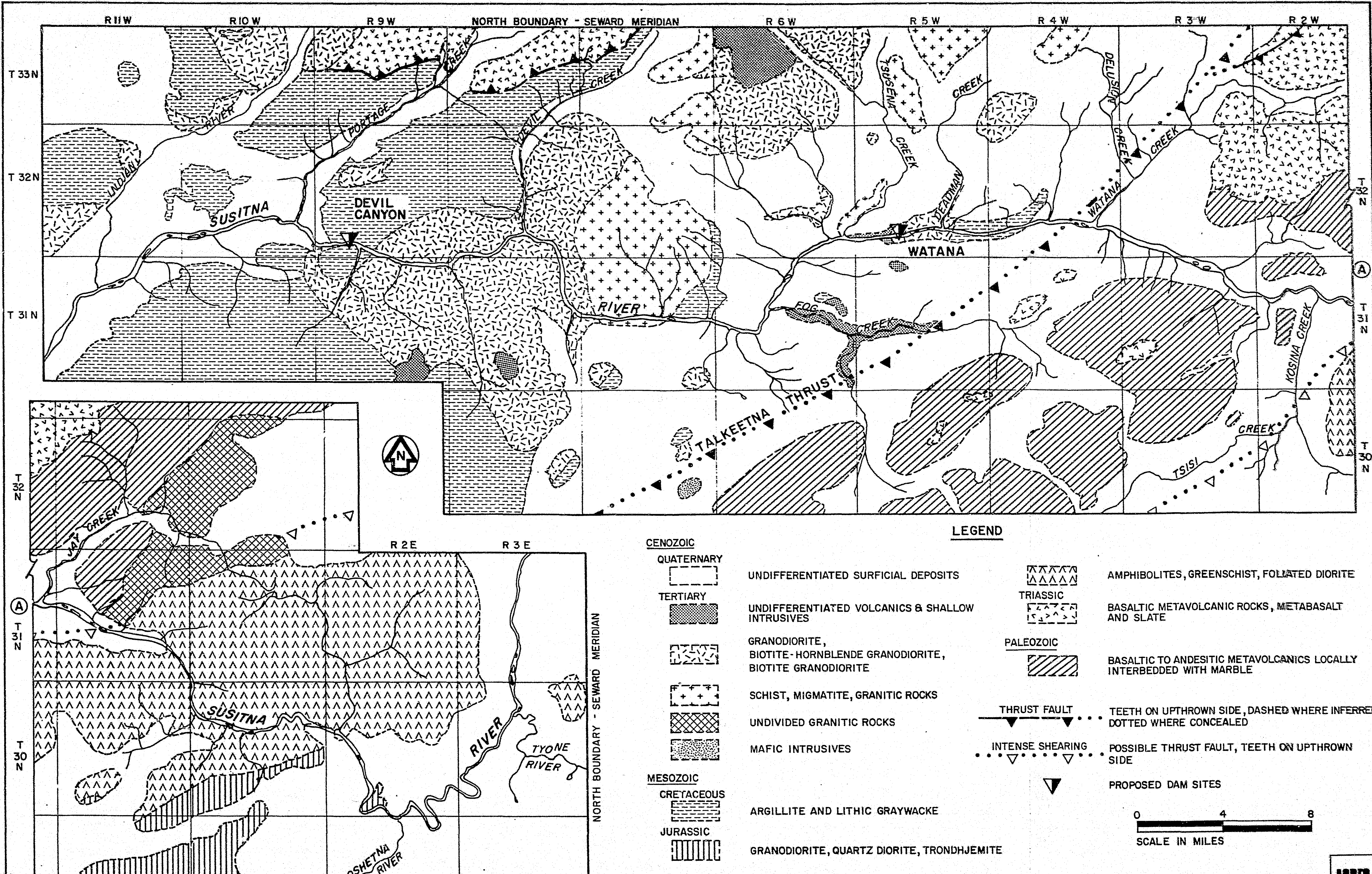
ACRES



SUSPENDED SEDIMENT TRANSPORT
SUSITNA RIVER AT SELECTED STATIONS

FIGURE 7.10

ACRES



REGIONAL GEOLOGY

FIGURE 7.11

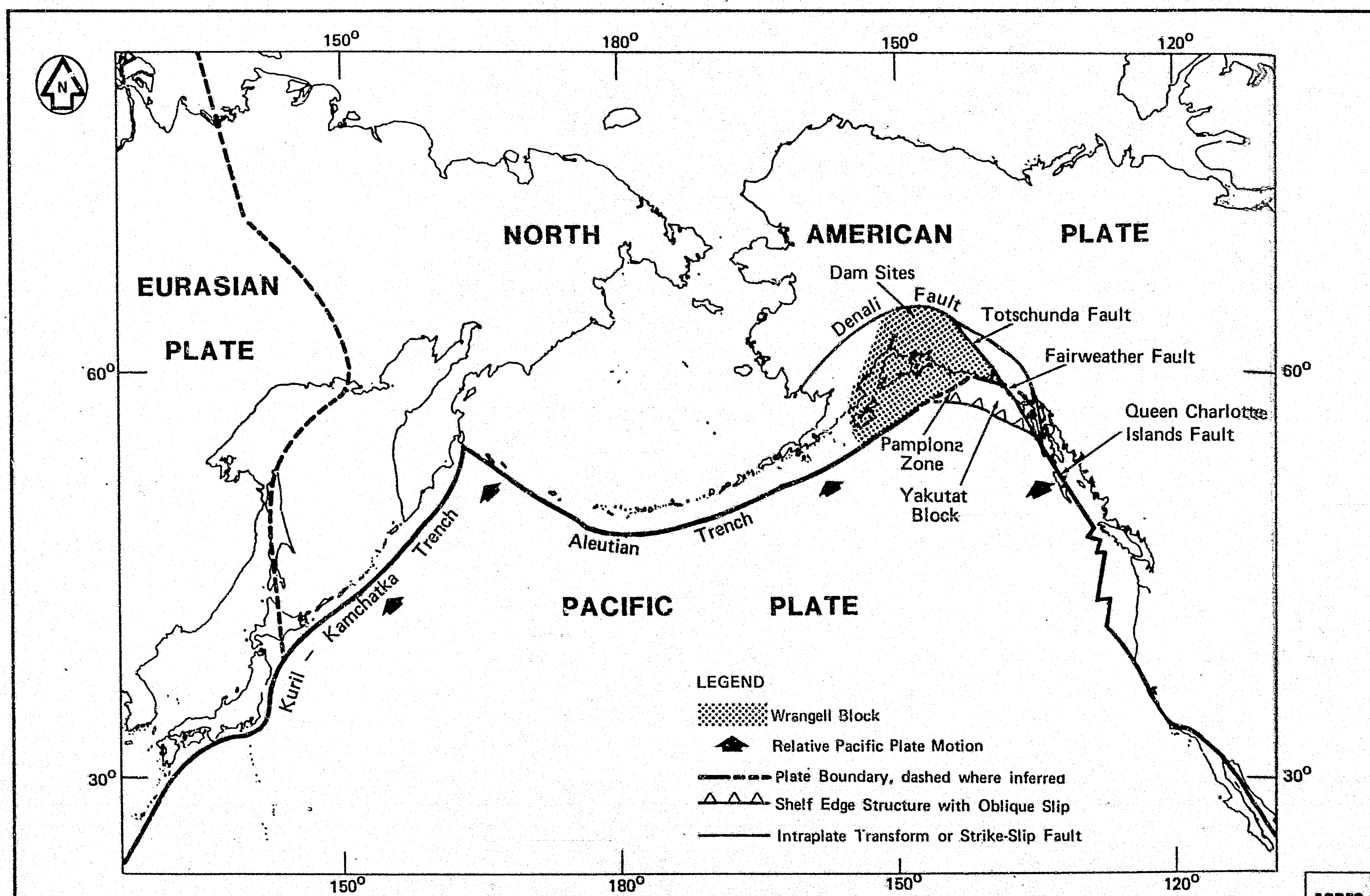
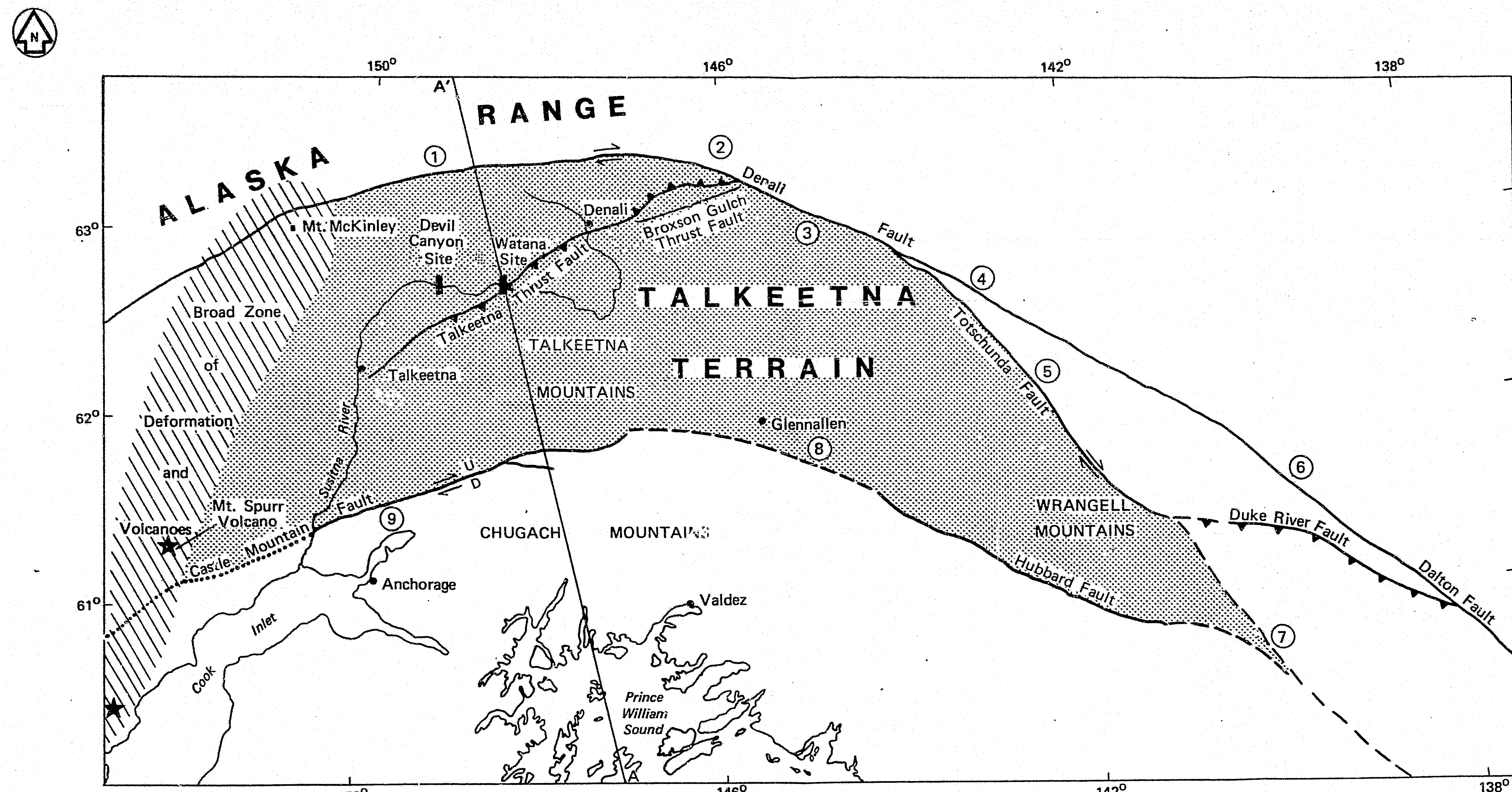


PLATE TECTONIC MAP

FIGURE 7.12

ACRES

WOODWARD - CLYDE CONSULTANTS 14658 A DECEMBER 1980



LEGEND

- Mapped strike-slip fault with dip slip component (U / D)
- Mapped strike-slip fault, arrows show sense of displacement
- Mapped fault, sense of displacement not defined
- Inferred strike-slip fault
- Mapped thrust fault, teeth indicate upthrown side of block, dashed where inferred
- Mapped thrust fault, teeth indicate inferred upthrown side of block

NOTES

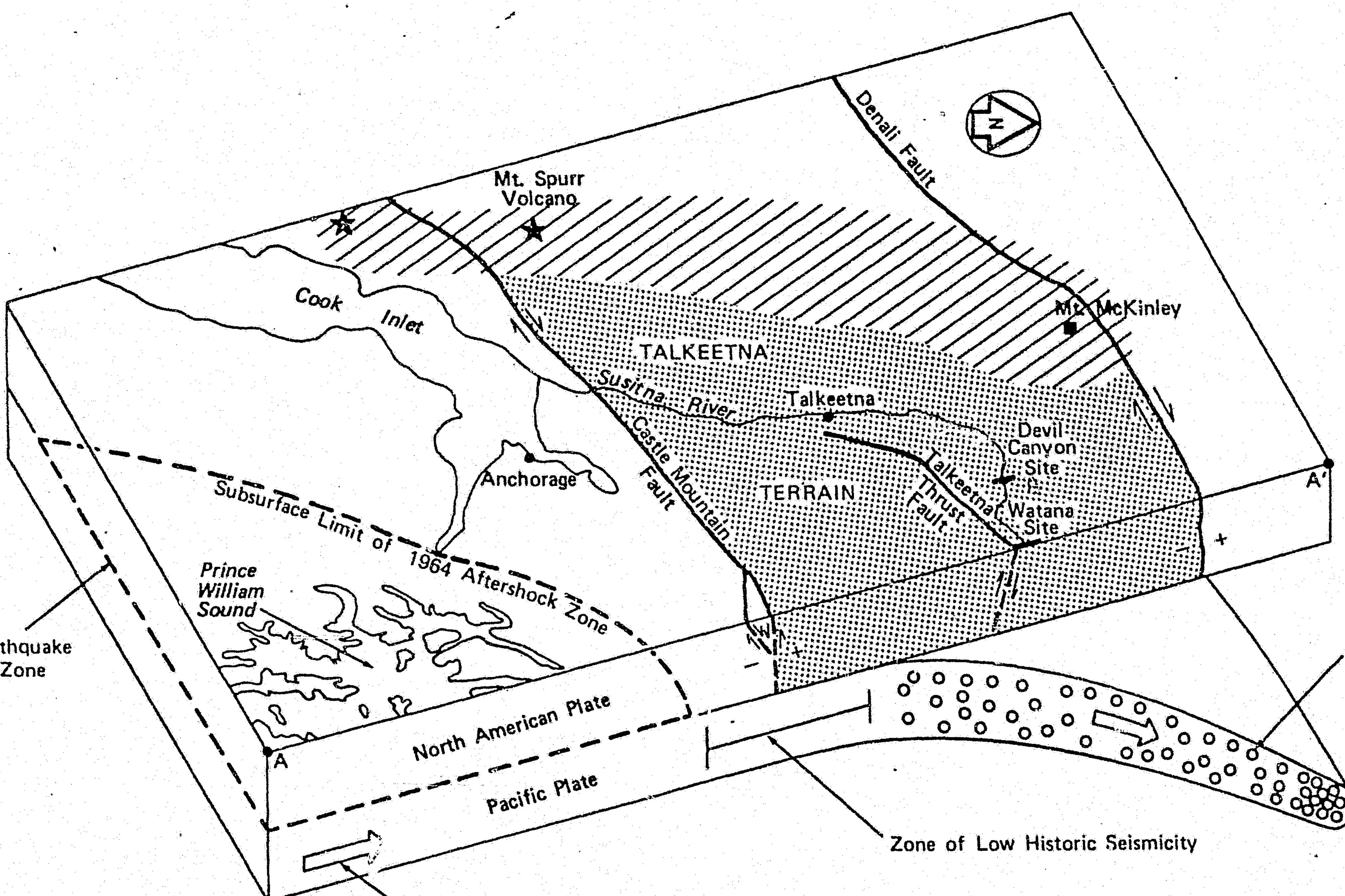
① 0.9 - 2.0 cm/yr Hickman and Campbell, (1973); and Page, (1972).
② 0.5 - 0.6 cm/yr Stout and others, (1973).
③ 3.5 cm/yr Richter and Matson, (1971).
④ 1.1 cm/yr, no Holocene activity farther east, Richter and Matson, (1971).
⑤ 0.9 -3.3 cm/yr Richter and Matson, (1971)
⑥ Inferred connection with Dalton 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. Slip rates cited in notes ① through ⑨ are Holocene slip rates.
11. All fault locations and sense of movement obtained from Beikman, (1978).
12. Figure 7.14 presents Section A—A'.

SCALE 0 20 40 MILES

TALKEETNA TERRAIN MODEL

ACRES

FIGURE 7.13



NOTES

1. Location of Section A–A' is shown in Figure 5-1.

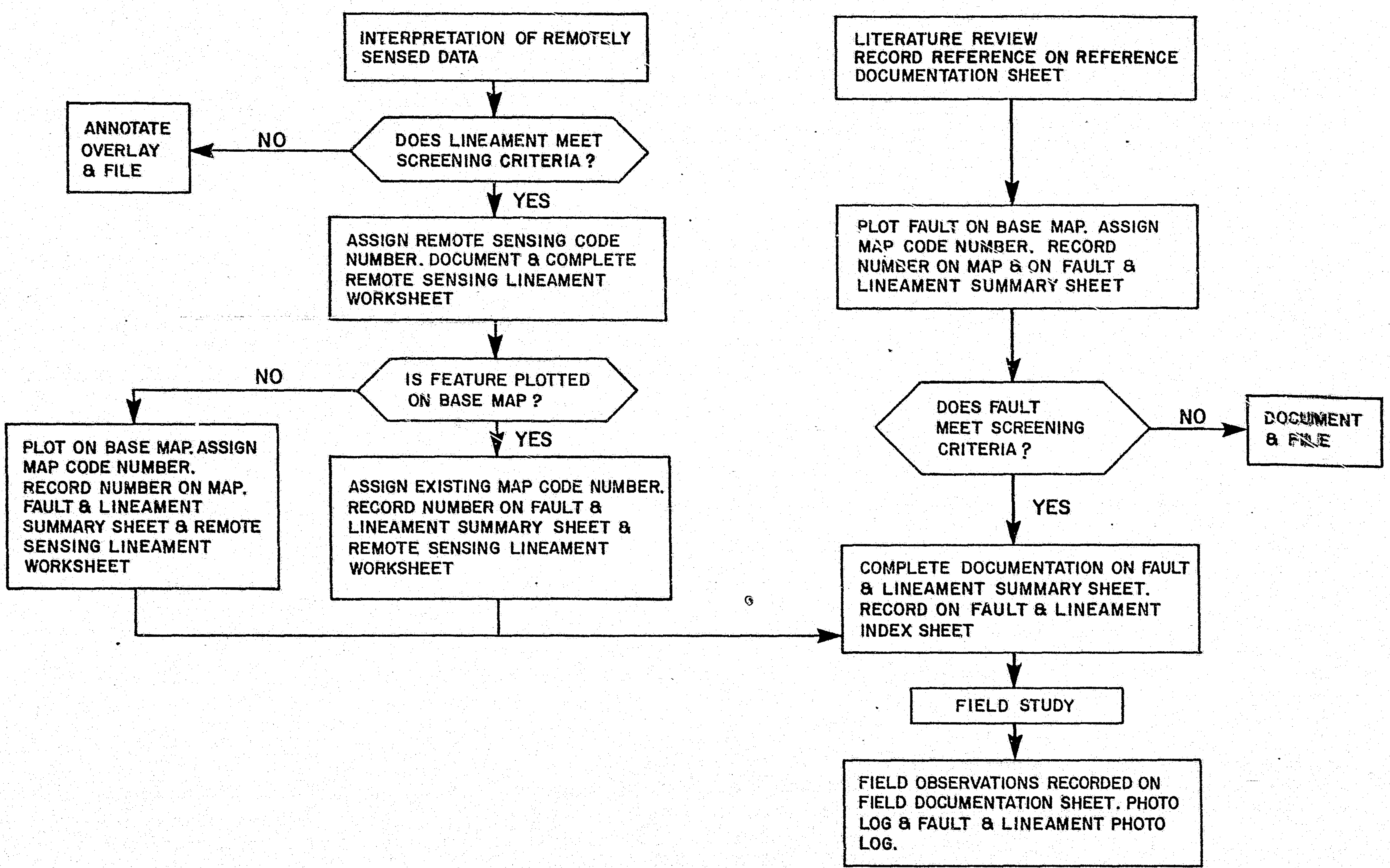
SCALE 0 40 80 MILES

SCHEMATIC TALKEETNA TERRAIN SECTION

FIGURE 7.14

ACRES

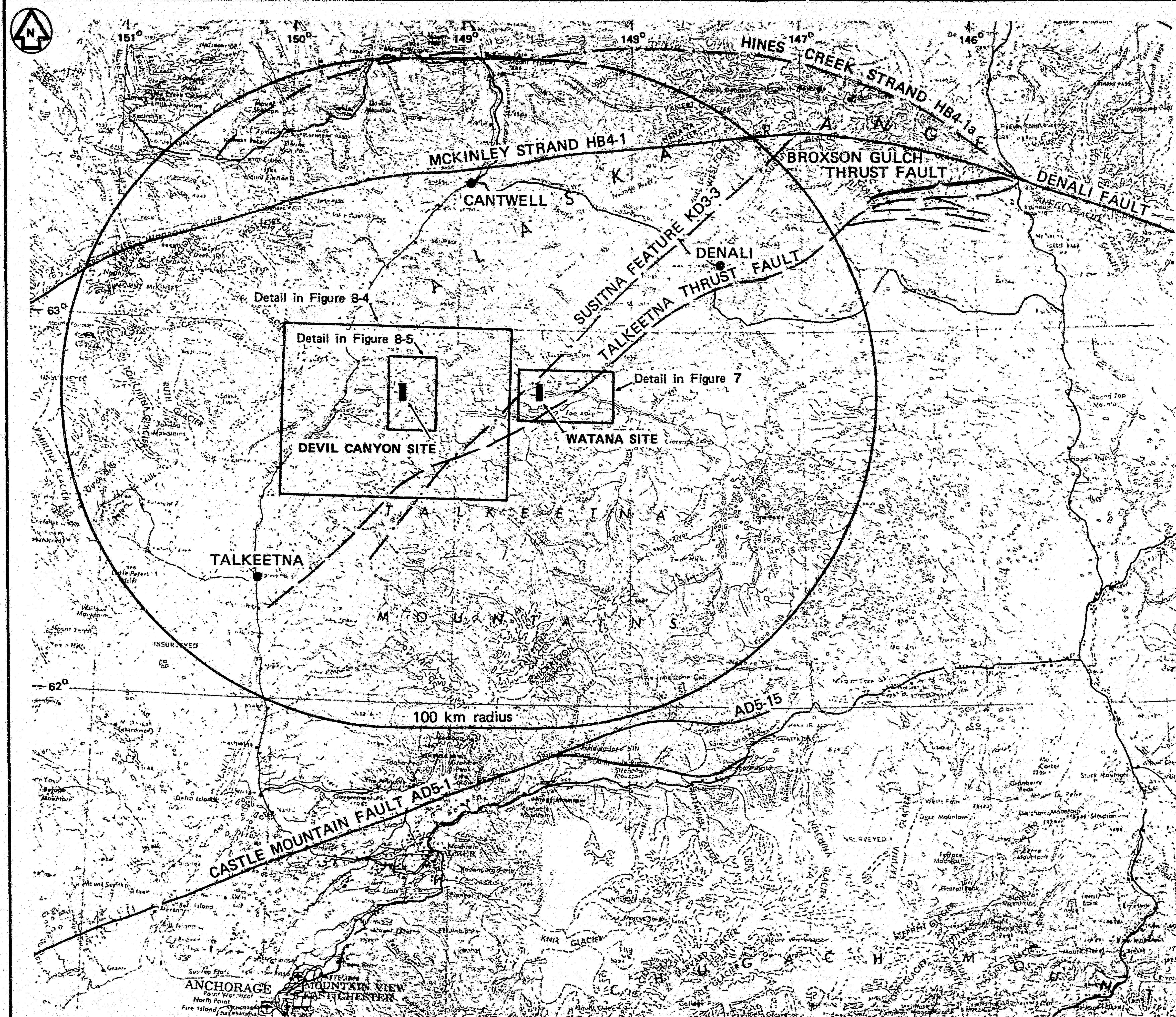
WOODWARD - CLYDE CONSULTANTS 14658 A DECEMBER 1980



FLOW DIAGRAM OF DOCUMENTATION PROCEDURES

FIGURE 7.15

ACRES



LEGEND

BOUNDARY FAULTS

Faults with recent displacement

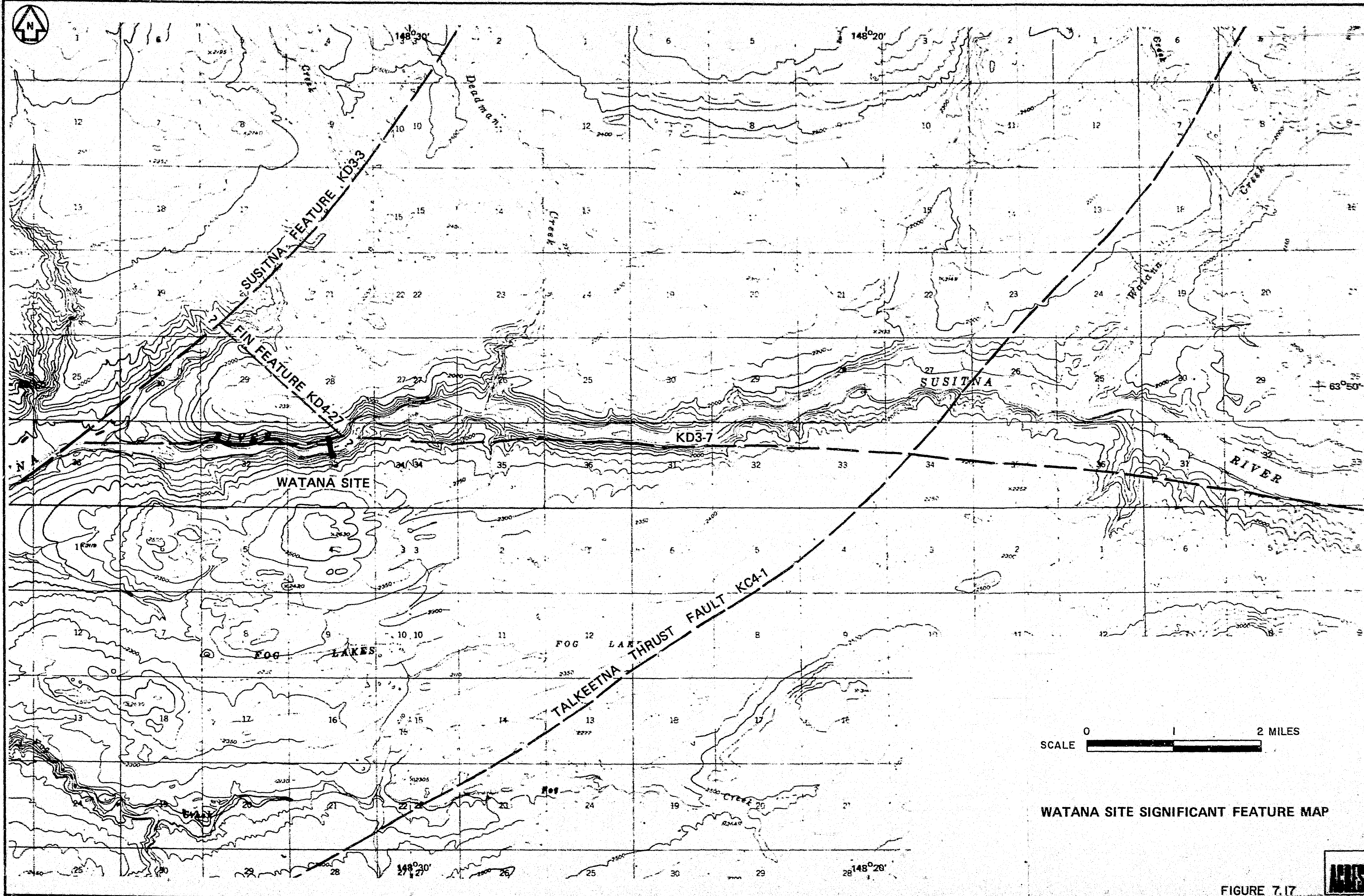
SCALE 0 20 40 MILES

BOUNDARY FAULT AND SIGNIFICANT FEATURE MAP FOR THE SITE REGION

FIGURE 7.16

ACRES

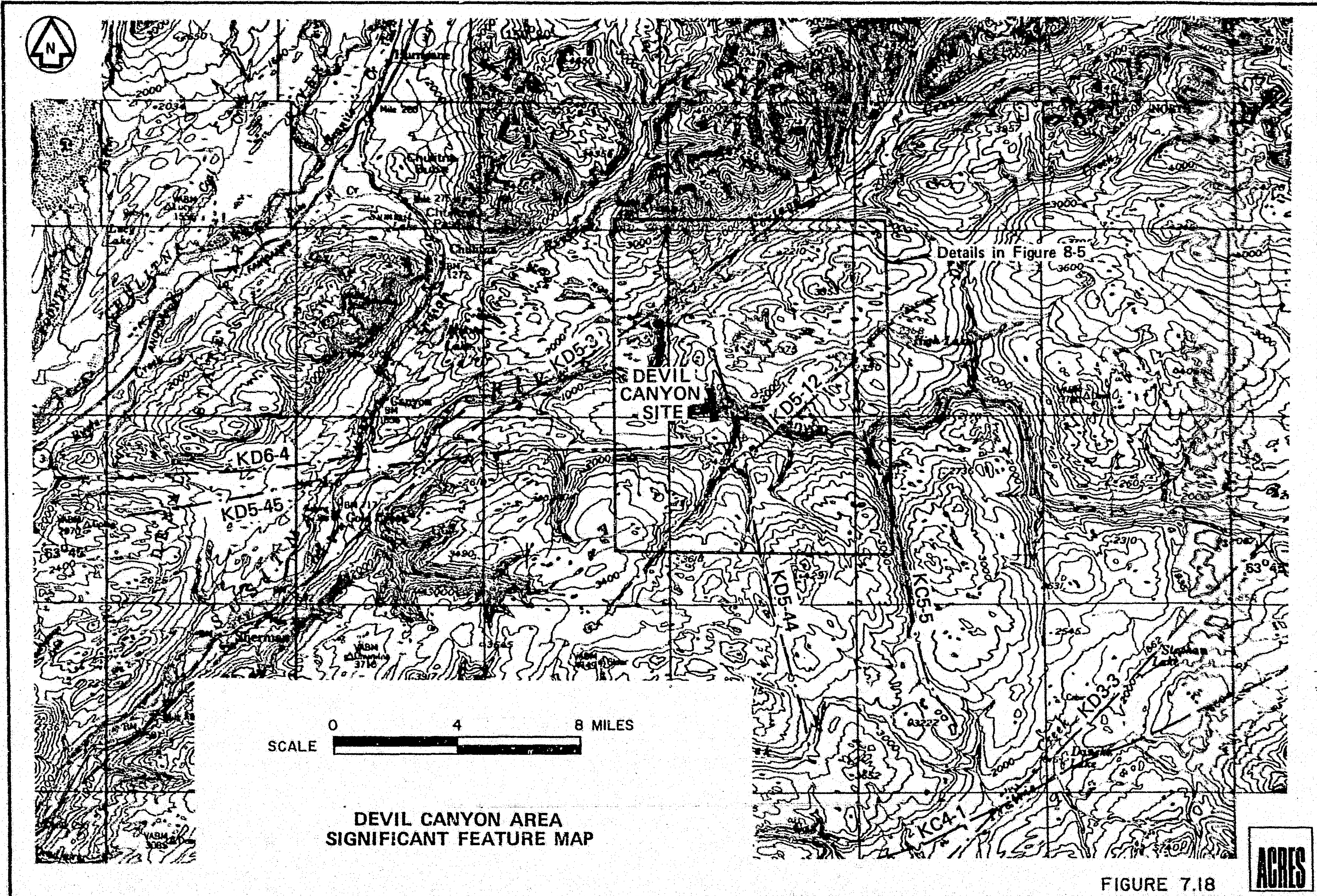
WOODWARD - CLYDE CONSULTANTS 14658A DECEMBER 1980



WATANA SITE SIGNIFICANT FEATURE MAP

FIGURE 7.17

WOODWARD - CLYDE CONSULTANTS 14658A DECEMBER 1980

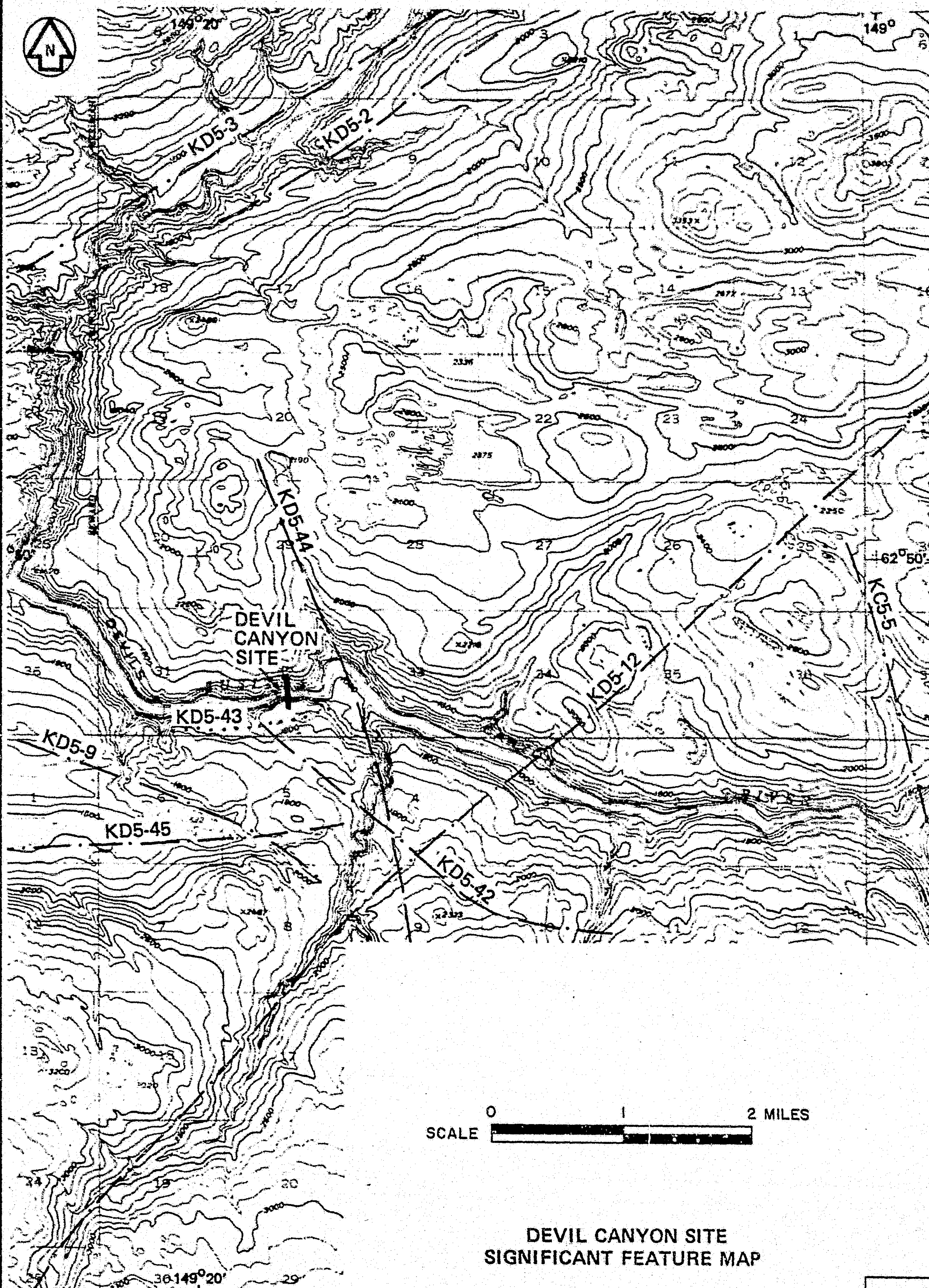


DEVIL CANYON AREA
SIGNIFICANT FEATURE MAP

FIGURE 7.18

ACRES

WOODWARD - CLYDE CONSULTANTS 14658 A DECEMBER 1980

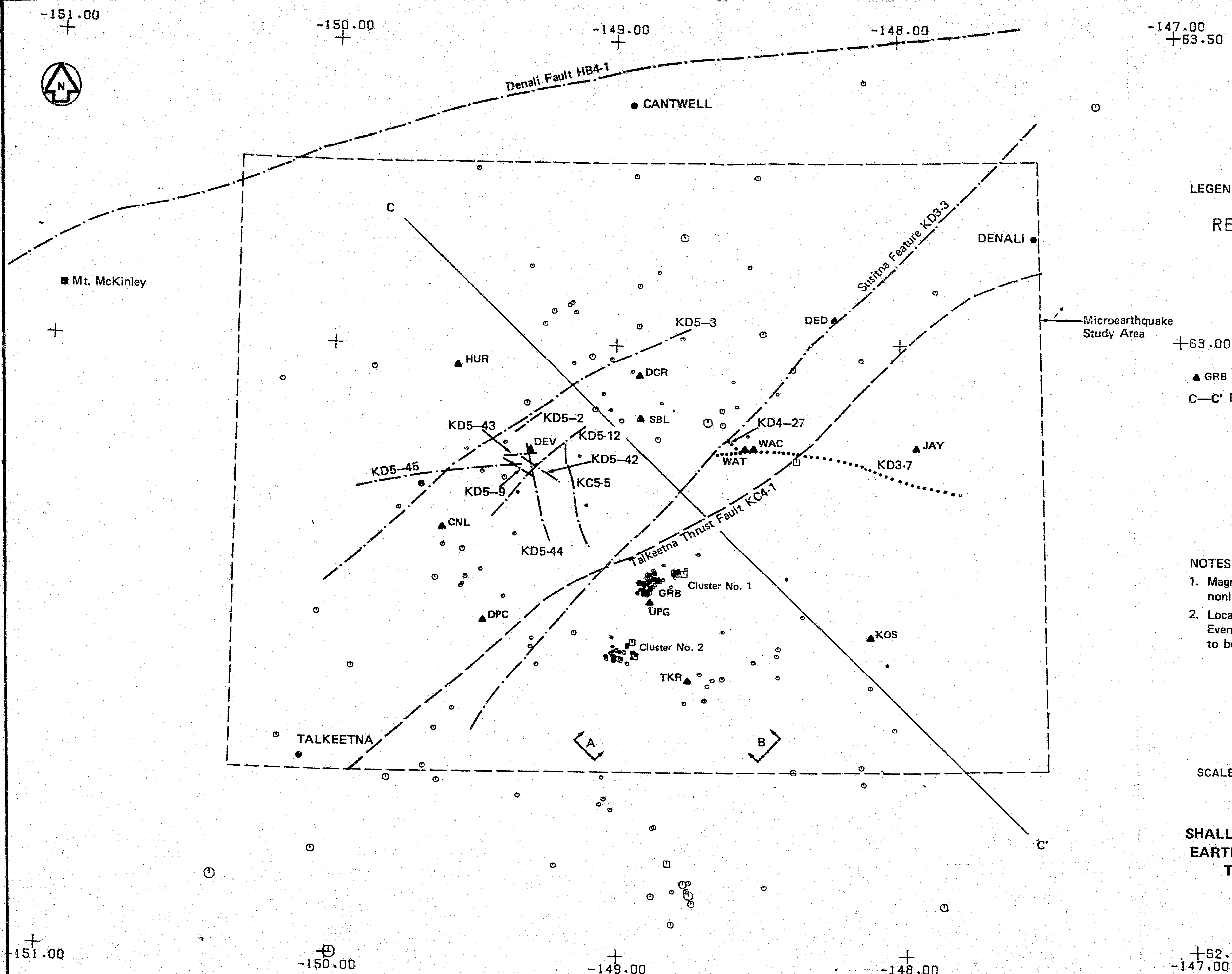


DEVIL CANYON SITE
SIGNIFICANT FEATURE MAP

ACRES

FIGURE 7.19

WOODWARD - CLYDE CONSULTANTS 14658 A DECEMBER 1980



LEGEND

REPORTED MAGNITUDE

4.0
3.0
2.0
1.0

▲ GRB Station location and name used for this study

C—C' Projection for cross-section is shown in Figure 7.19

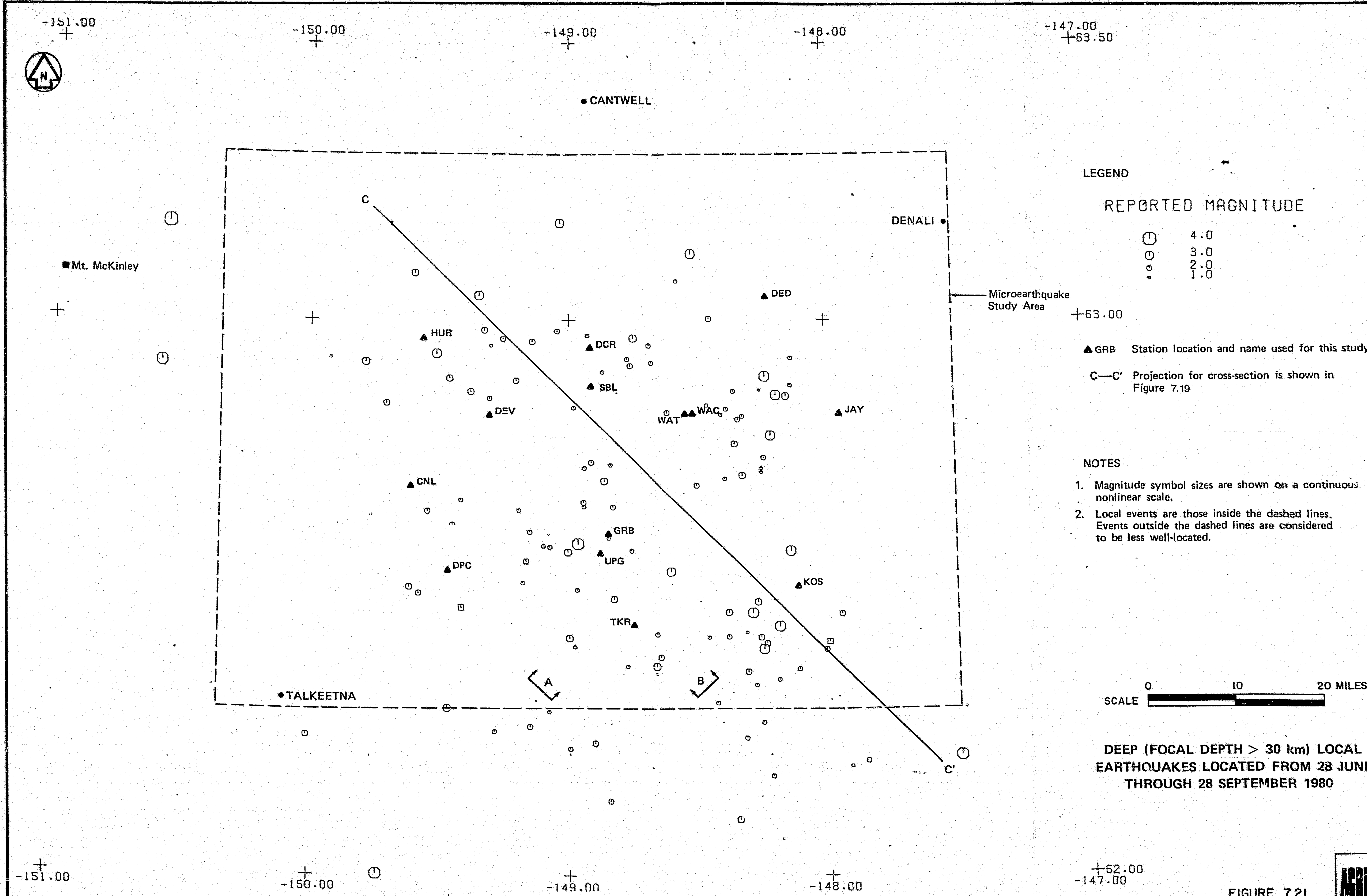
NOTES

1. Magnitude symbol sizes are shown on a continuous nonlinear scale.
2. Local events are those inside the dashed lines. Events outside the dashed lines are considered to be less well-located.

SCALE 0 10 20 MILES

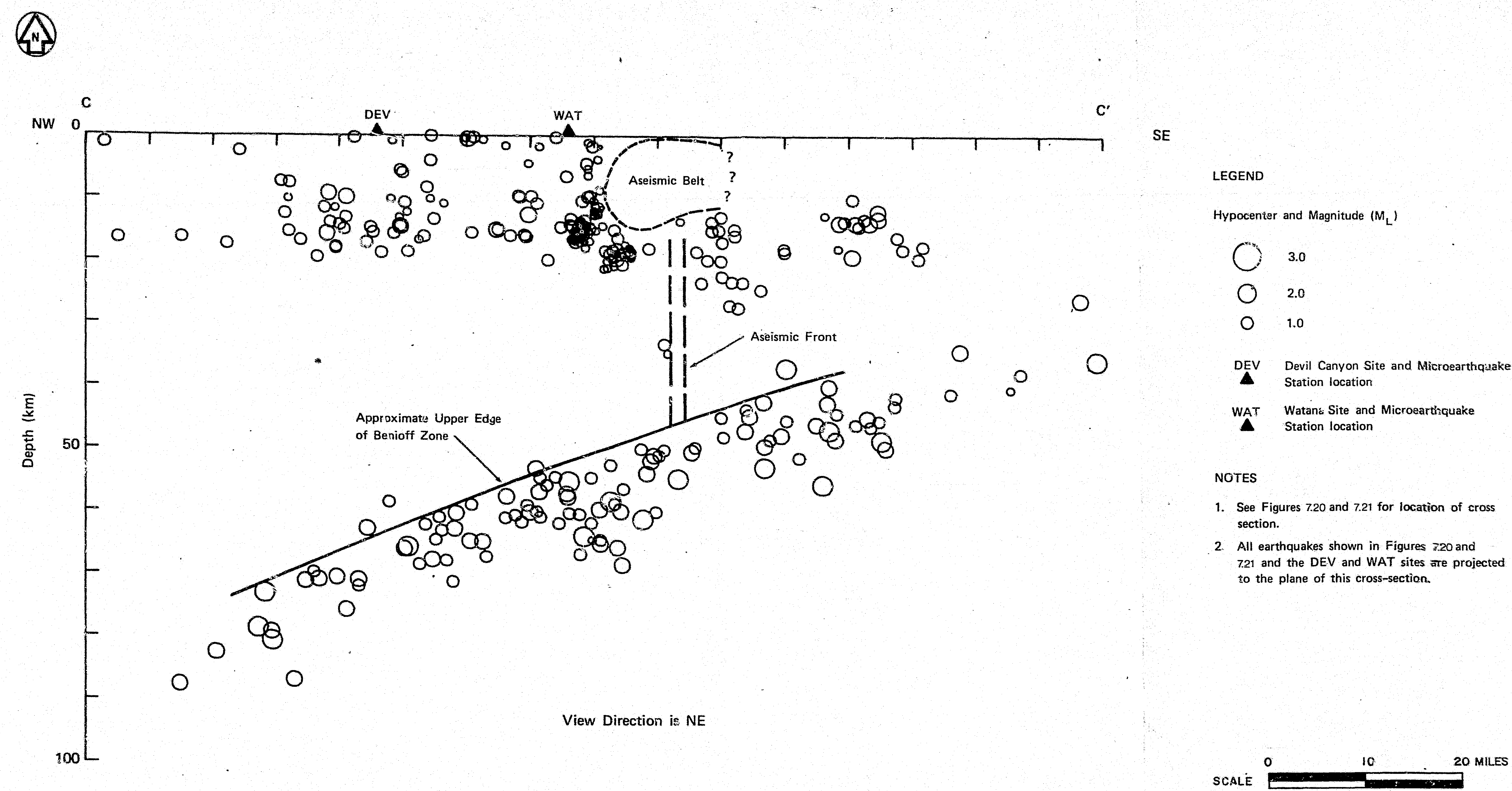
SHALLOW (FOCAL DEPTH < 30 km) LOCAL EARTHQUAKES LOCATED FROM 28 JUNE THROUGH 28 SEPTEMBER 1980

FIGURE 7.20



DEEP (FOCAL DEPTH > 30 km) LOCAL EARTHQUAKES LOCATED FROM 28 JUNE THROUGH 28 SEPTEMBER 1980

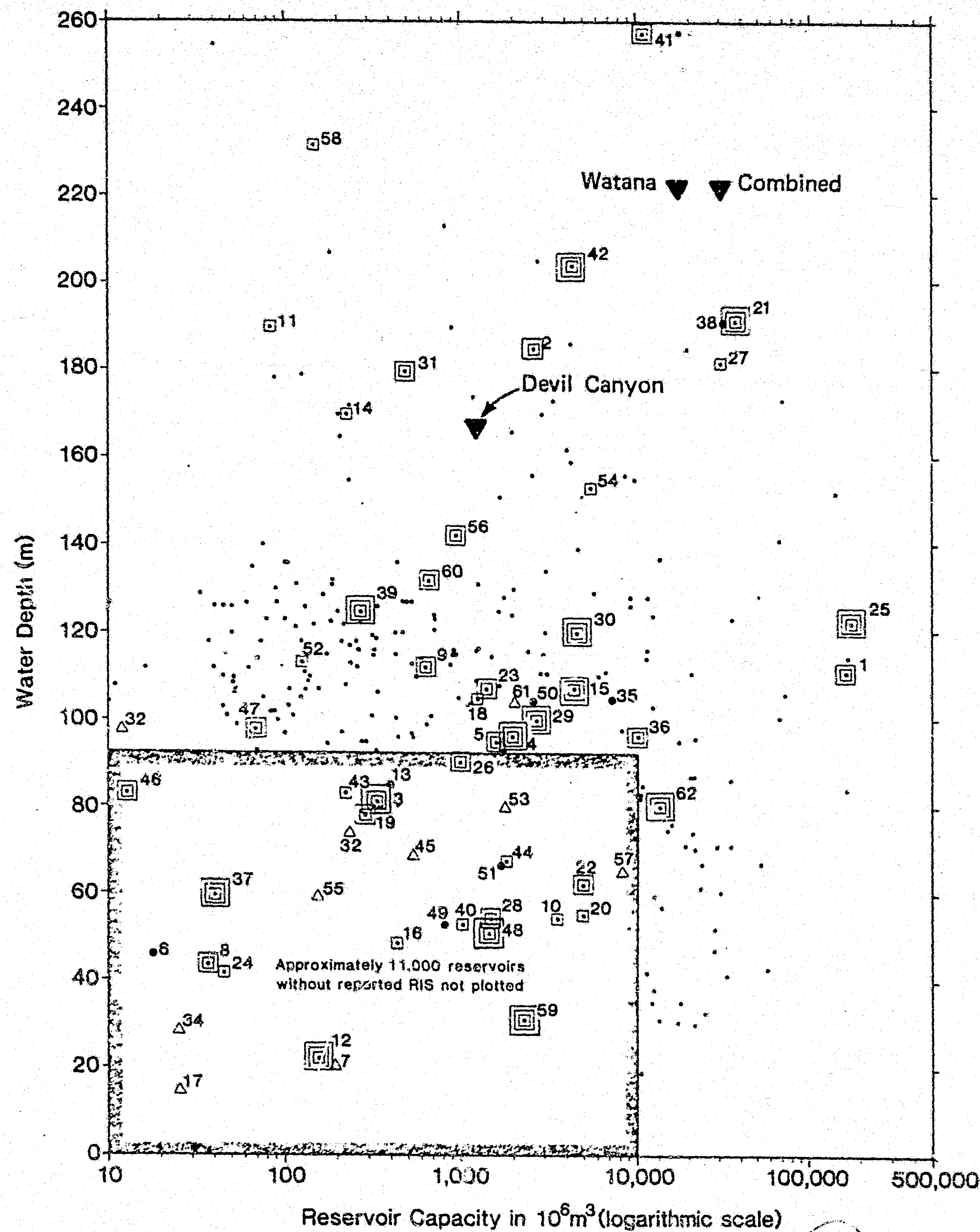
FIGURE 7.21



CROSS-SECTION OF CRUSTAL AND BENIOFF ZONE MICROEARTHQUAKES LOCATED WITHIN THE NETWORK

FIGURE 7.22

WOODWARD-CLYDE CONSULTANTS 14658A DECEMBER 1980



Note: The following reservoirs were not plotted because of insufficient data: Kinarsani, Sharavathi.

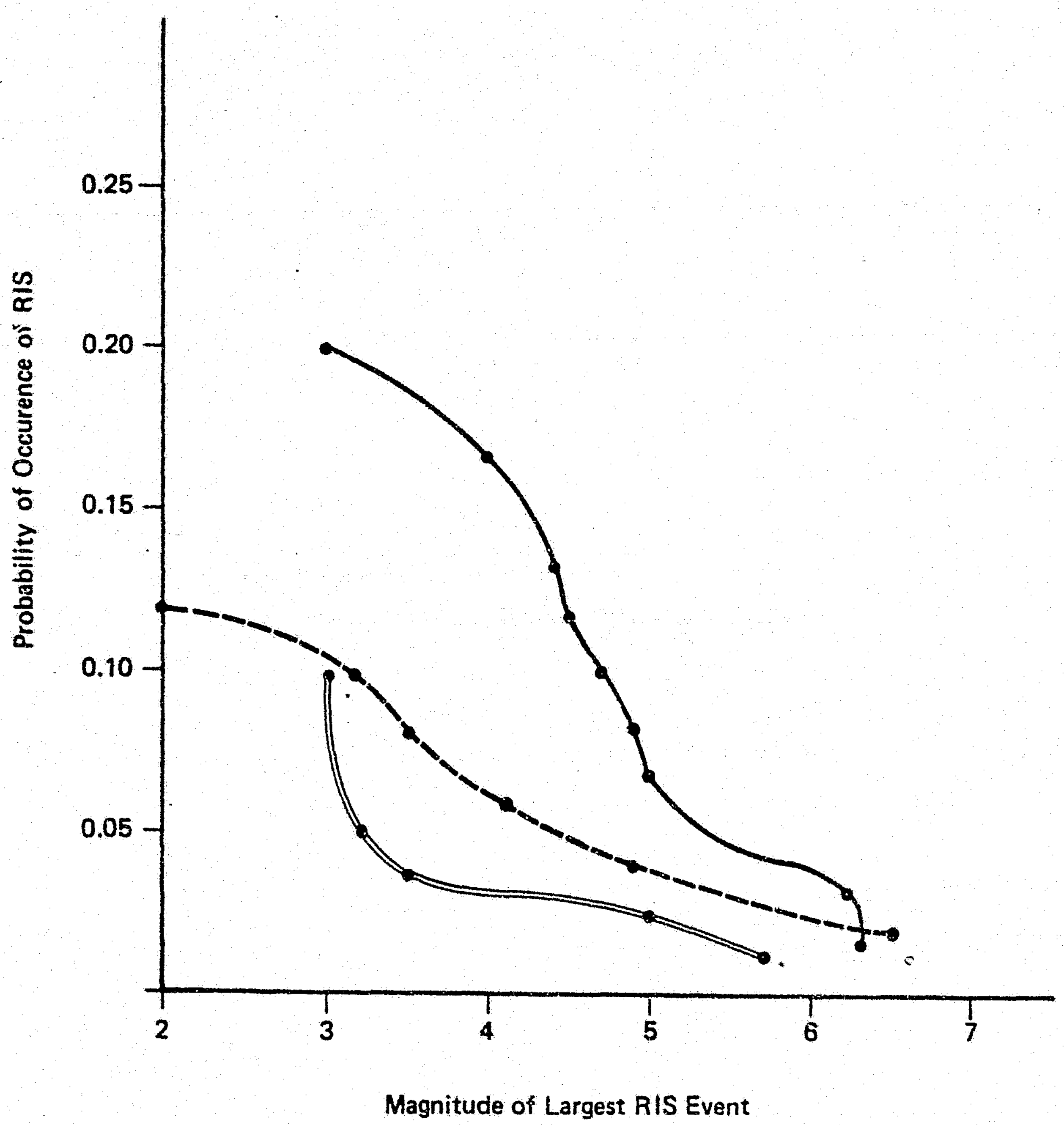
*41 - Nurek (USSR) depth is in excess of 283 m.

LEGEND

- • Deep and/or very large reservoir
- Accepted case of RIS, maximum magnitude ≥ 5
- Accepted case of RIS, maximum magnitude 3-5
- Accepted case of RIS, maximum magnitude ≤ 3
- △ Questionable case of RIS
- ● Not RIS

PLOT OF WATER DEPTH AND VOLUME FOR WORLDWIDE RESERVOIRS AND REPORTED CASES OF RIS

FIGURE 7.23



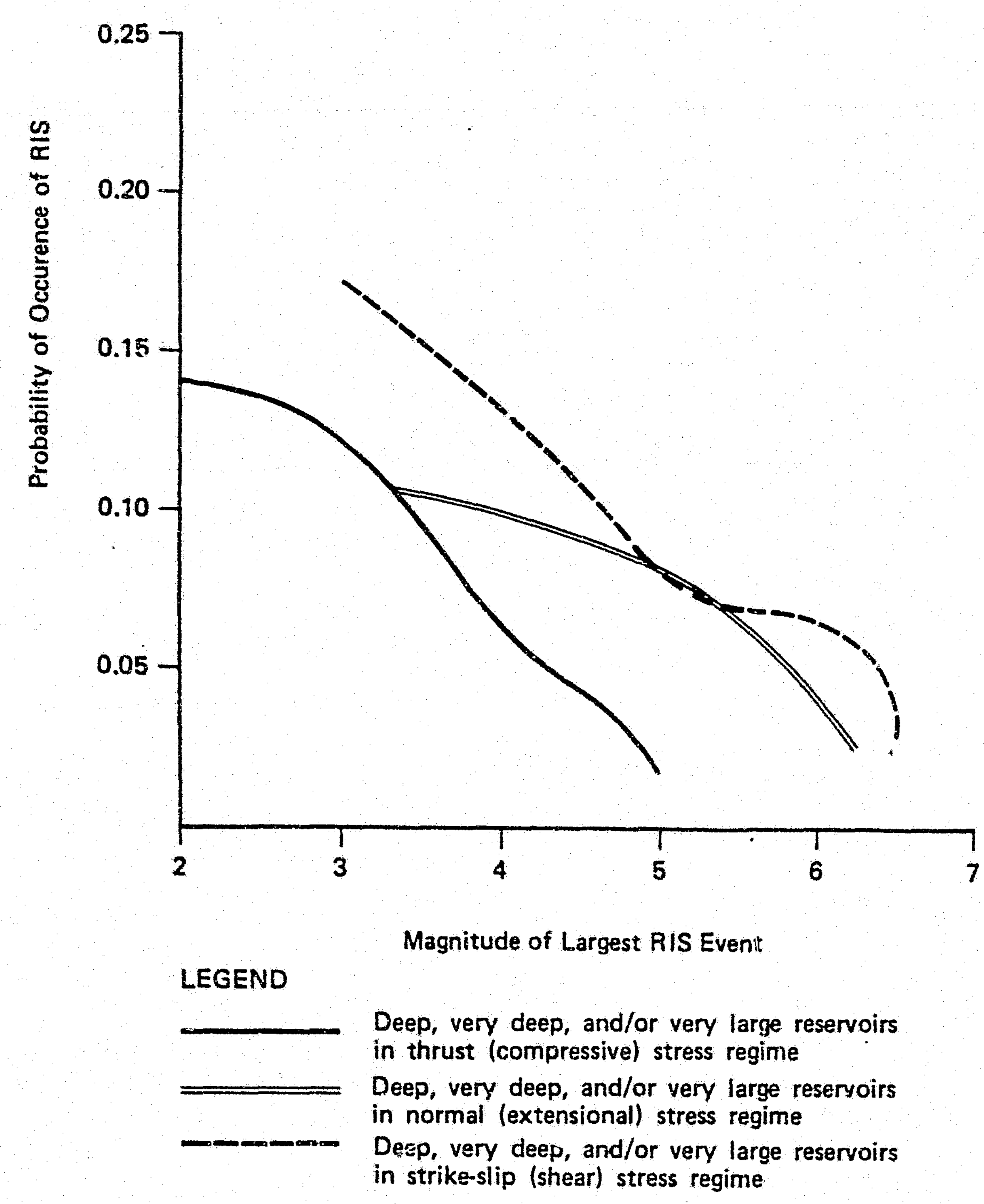
LEGEND

- (solid line) Deep, very deep, and/or very large reservoirs with sedimentary geology
- (dashed line) Deep, very deep, and/or very large reservoirs with igneous geology
- (double line) Deep, very deep, and/or very large reservoirs with metamorphic geology

PLOT OF VARIATION OF RIS PROBABILITY WITH DIFFERENT GEOLOGIC SETTINGS FOR DEEP, VERY DEEP, AND/OR VERY LARGE RESERVOIRS

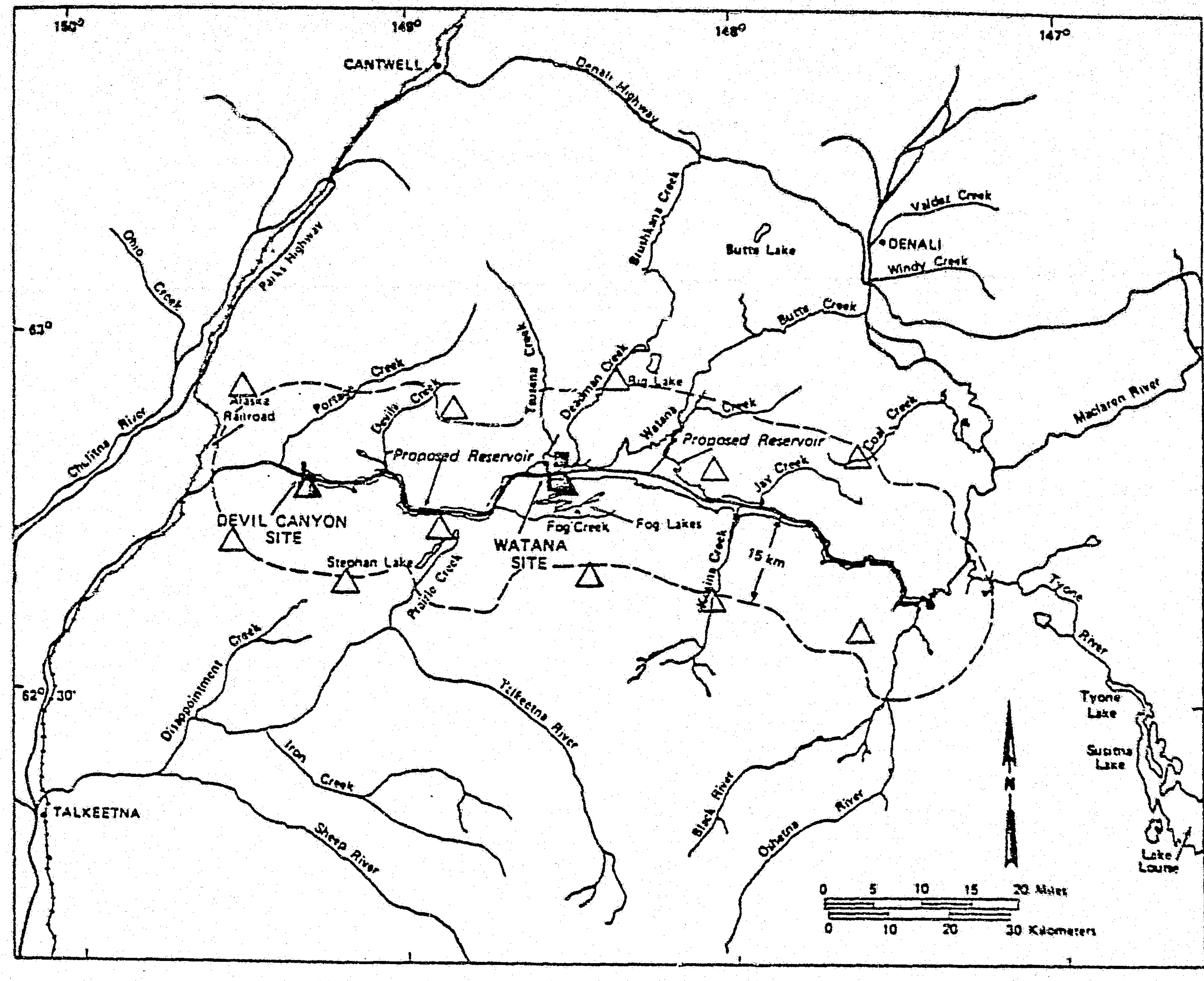
FIGURE 7.24

ACRES



PLOT OF VARIATION OF RIS PROBABILITY WITH DIFFERENT STRESS REGIMES FOR DEEP, VERY DEEP, AND/OR VERY LARGE RESERVOIRS

FIGURE 7.25



LEGEND

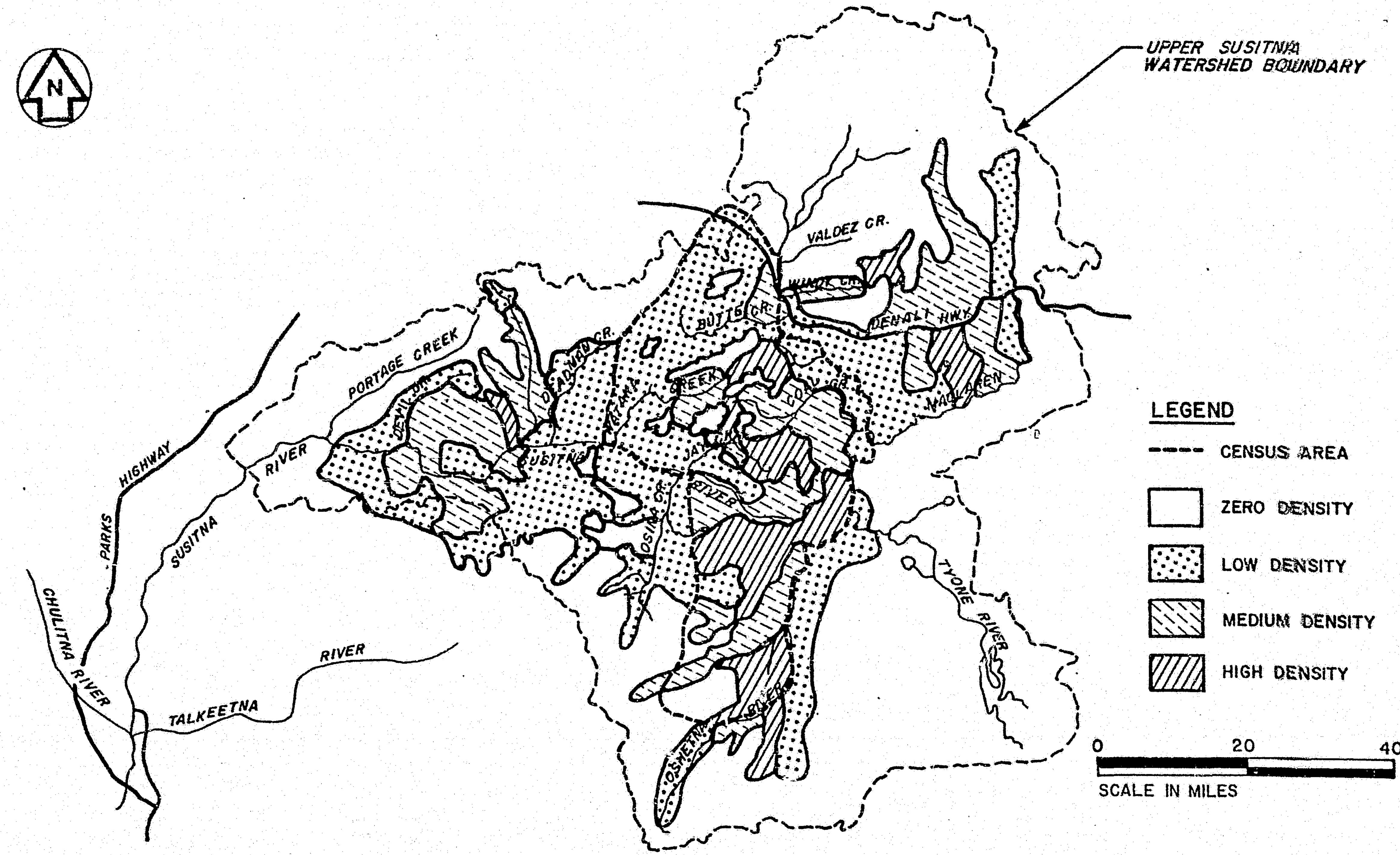
- △ Vertical-component, short-period, telemetered station
- Three-component, short-period, telemetered station
- ▲ Three-component, broad-band station
- ■ Central recording facility
- - - - 15 km zone around reservoir system

DRAFT

GENERAL CONFIGURATION OF THE PROPOSED LONG TERM SEISMIC NETWORK

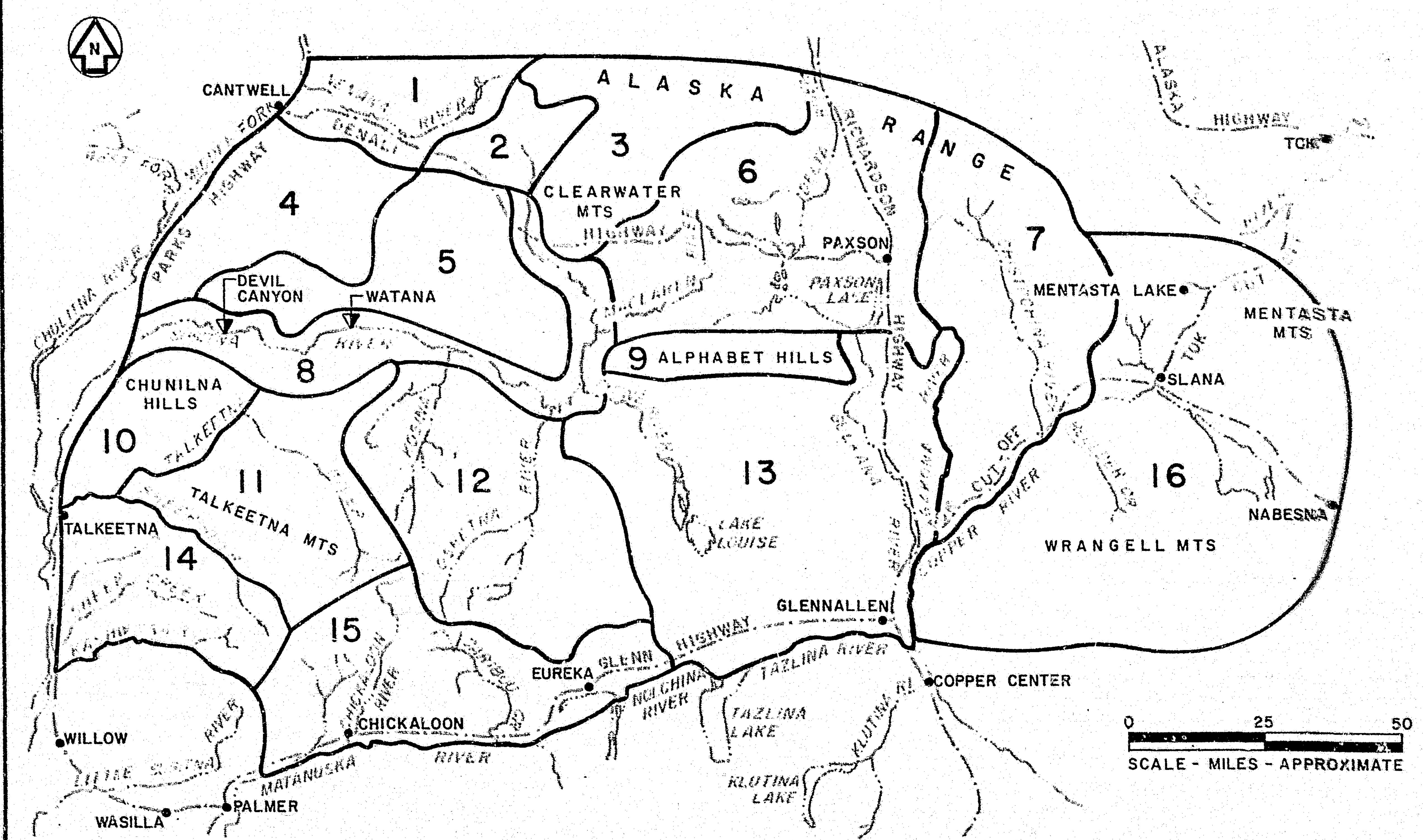
ACRES

FIGURE 7.26



RELATIVE DENSITIES OF MOOSE - NOVEMBER, 1980

FIGURE 7.27



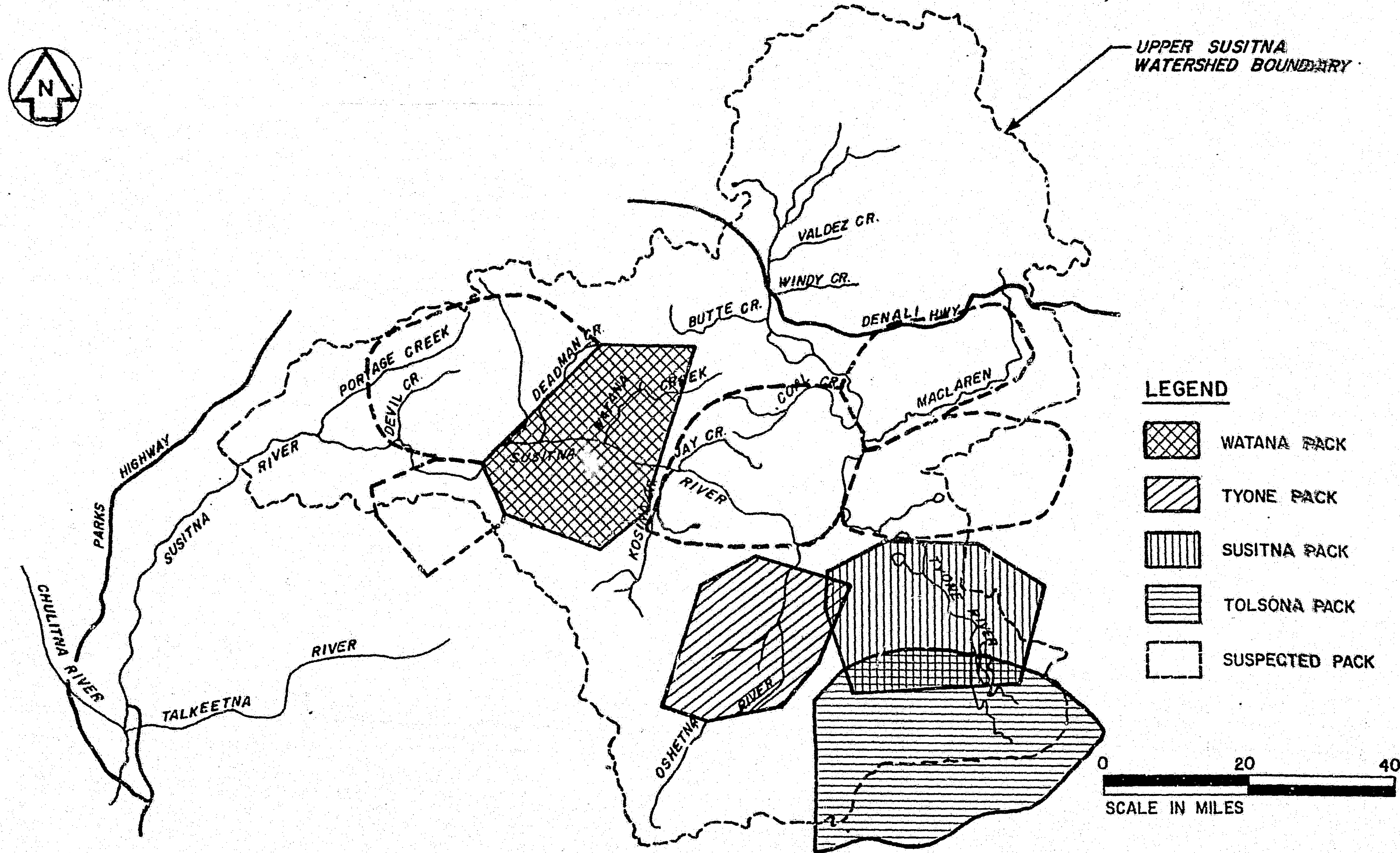
DIVISIONS OF NELCHINA CARIBOU HERD RANGES

(UNITS BASED UPON TOPOGRAPHY, VEGETATION AND USE)

MODIFIED FROM SKOOG 1968

FIGURE 7.28

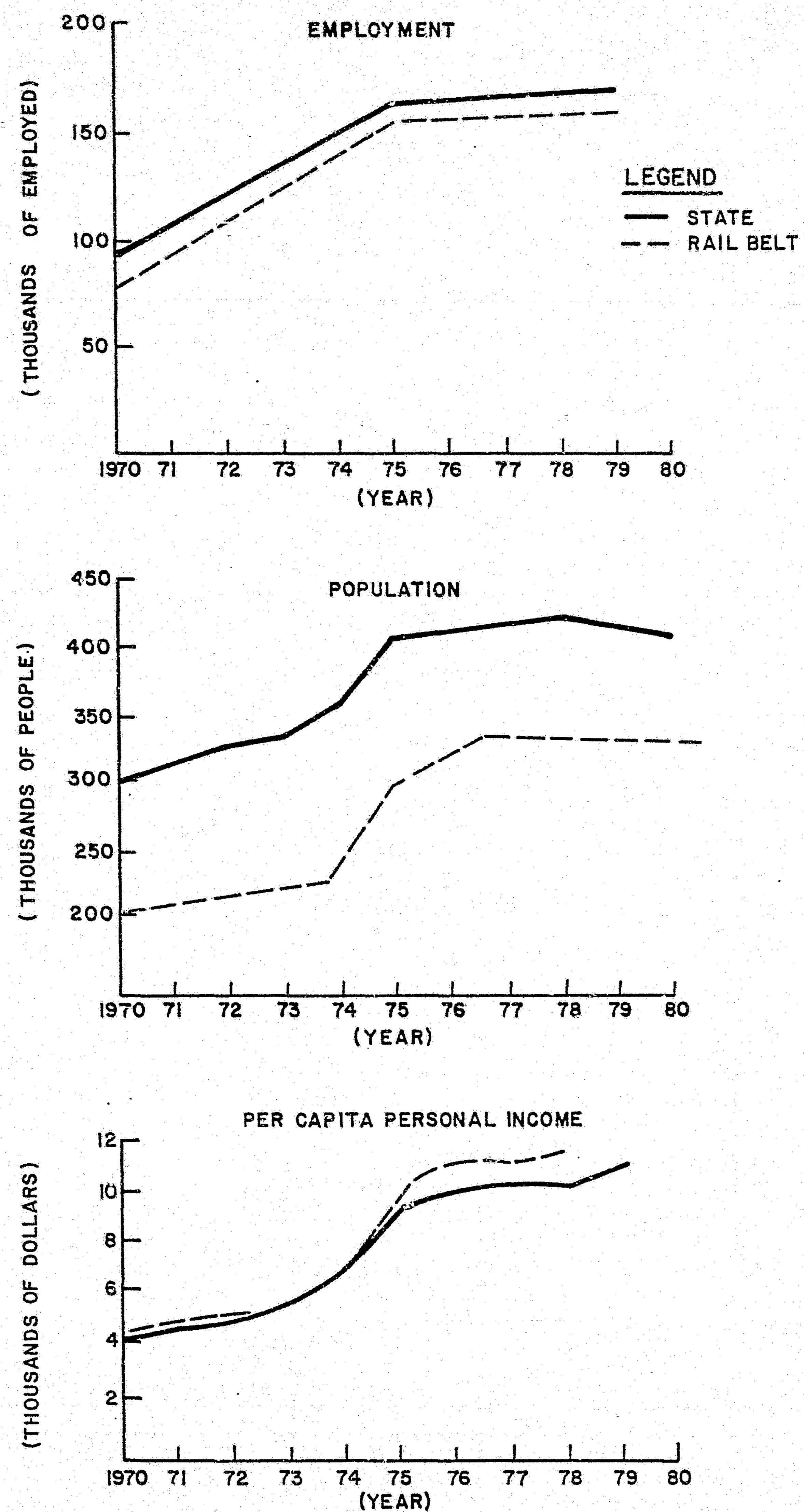
ACRES



LOCATION AND TERRITORIAL BOUNDARIES OF WOLF PACKS - 1980

FIGURE 7.29

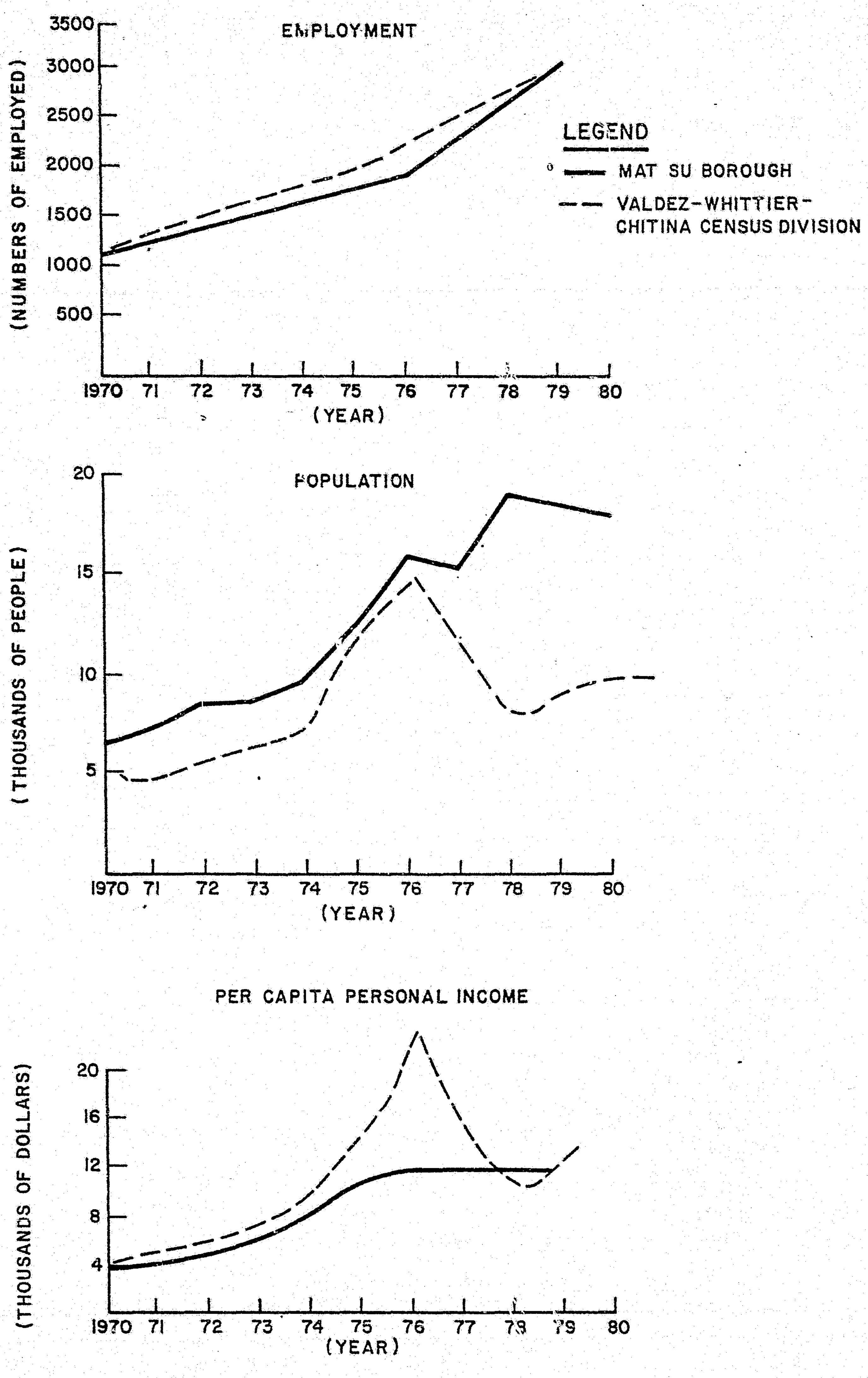
ACRES



EMPLOYMENT, POPULATION AND PER CAPITA PERSONAL INCOME IN THE STATE OF ALASKA AND RAIL BELT REGION, 1970-1980

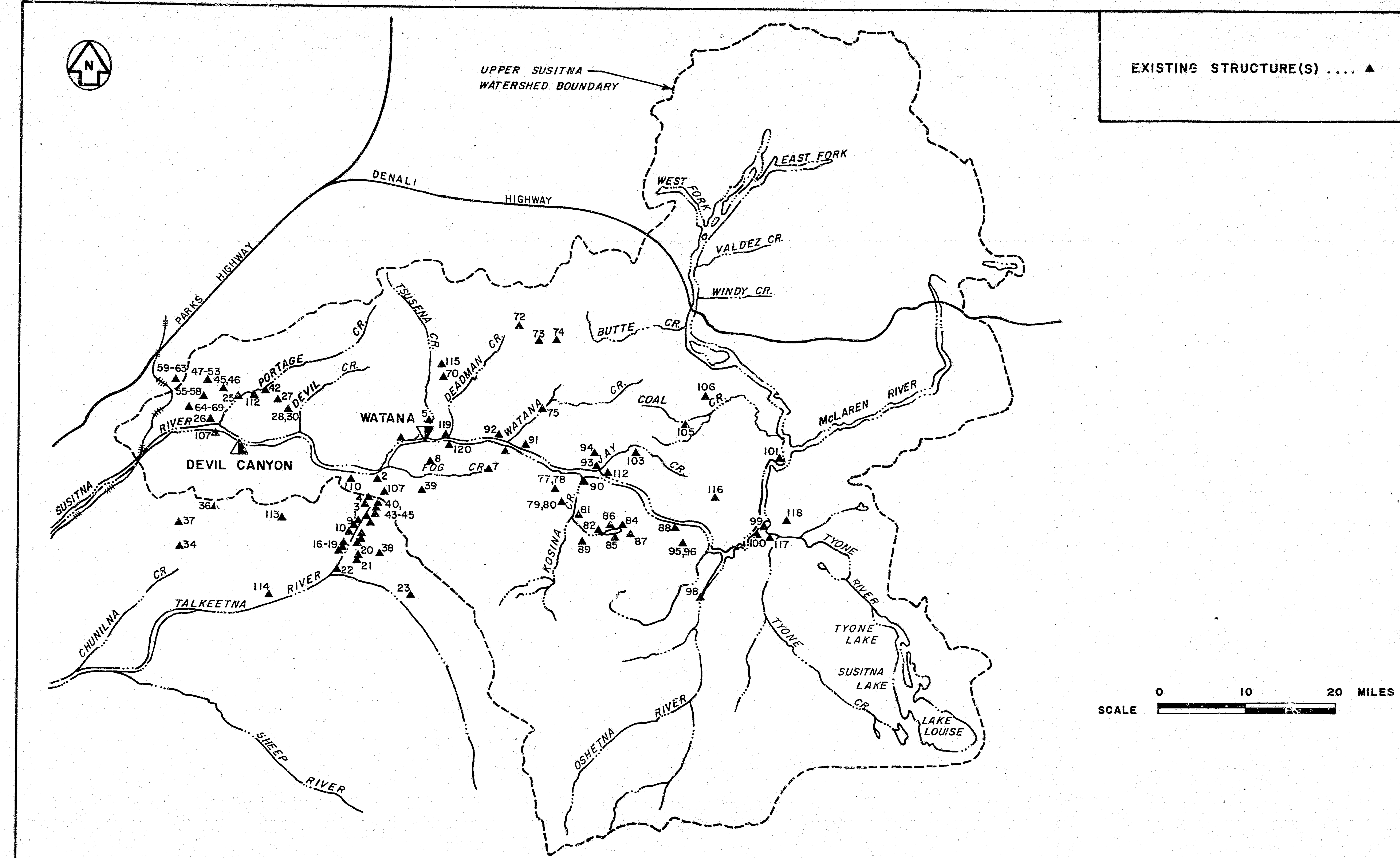
FIGURE 7.30

ACRES



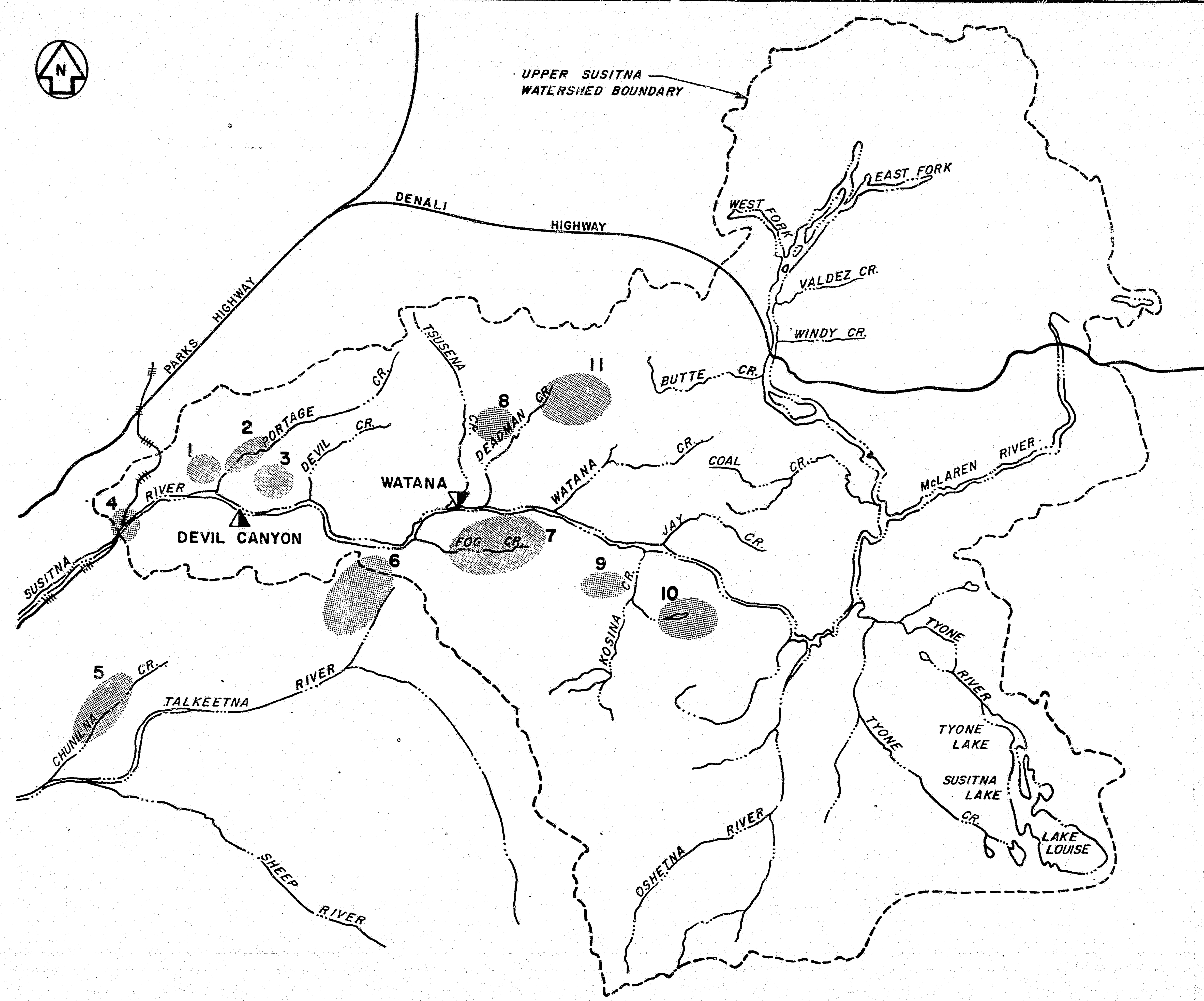
EMPLOYMENT, POPULATION AND PER CAPITA PERSONAL INCOME IN THE MATANUSKA-SUSITNA BOROUGH AND VALDEZ-WHITTIER-CHITINA CENSUS DIVISION, 1970 - 1980

FIGURE 7.31



EXISTING STRUCTURES

FIGURE 7.32



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

SCALE 0 10 20 MILES

LAND USE AGGREGATIONS

FIGURE 7.33

8 - SUSITNA BASIN DEVELOPMENT SELECTION

This section of the report outlines the engineering and planning studies carried out as a basis for formulation of Susitna Basin development plans and selection of the preferred plan. The recommended plan, the Watana/Devil Canyon dam project, is 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.

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, equivalent to "alternative" and referred to in the generic process as "candidate."

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

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

8.1 - Plan Formulation and Selection Methodology

In the formulation of the generic plan 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. The objectives are essentially twofold.

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

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, 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.

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

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

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.

(a) Screening Criteria

(i) Environmental

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

- Unacceptable Sites

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

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

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

- Sites With Significant Impact

  Between Devil Canyon and the Oshetna River, the Susitna River is confined to a relatively steep river valley. Upstream from the Oshetna River the surrounding topography flattens, and any development in this area has the potential of flooding large areas, even with relatively low dams. The area is very sensitive in terms of potential impact on big game and waterfowl. The sites at Butte Creek, Denali, Maclaren, and, to a lesser extent Vee, fit into this category.

- Sites With Moderate Impact

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

(ii) Alternative Sites

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

(iii) Energy Contribution

The total Susitna Basin potential energy production has been assessed at 6,700 GWh. Forecast future energy requirements within the Railbelt region for the period 1980 to 2010 range from 2,400 to 13,100 GWh. It was therefore decided to limit the minimum size of any power development in the Susitna Basin to an average annual energy production in the range of 500 to 1,000 GWh. The upstream sites such as Maclaren, Denali, Butte Creek, and Tyone do not meet this minimum energy generation criterion.

(b) Screening Process

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

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

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

- No additional sites were eliminated for failing to meet the energy contribution criteria. The remaining sites upstream from Vee, i.e., Maclaren and Denali, were retained to 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 probably 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 site 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 rates compared to concrete rates at alternative sites.

(b) General Arrangements

A brief description of the general arrangements developed for the various sites is given below. Plates 2 to 8 illustrate the layout details. Table 8.3 summarizes the crest levels and dam heights considered.

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

(i) Devil Canyon (Plate 2)

- Standard Arrangement

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 involving an inclined impervious core, filter zones, and an overlying rockfill shell. It is anticipated that the shell core and filter materials will be available locally. Contact grouting, curtain grouting, and drainage via a network of shafts and galleries was allowed for, and all alluvium and overburden material will be removed from the shell foundation area.

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

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. Each unit has three outlets at different levels allowing for various levels of drawoff and corresponding temperature control of releases from the seasonally fluctuating reservoir.

The penstocks will be concrete-lined over their full length except for the section just upstream from the powerhouse which will be steel-lined to prevent seepage into the powerhouse area.

The powerhouse will house four 100-MW (or 150-MW) vertically mounted Francis type turbines driving overhead 110 (165 MVA) umbrella type generators. The main power transformers will be housed in an underground gallery located above the draft tubes. The control room and offices will be situated at the surface adjacent to a surface switchyard.

- Staged Powerhouse

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 the 200- to 300-MW range. The complete powerhouse would be constructed together with penstocks and a tailrace tunnel for the initial two 100-MW (or 150-MW) units, together with concrete foundations for the future units.

(ii) Watana (Plates 3 and 4)

- Standard Arrangement (see Plate 3)

For initial comparative study purposes, the dam at Watana is assumed to be a rockfill structure located on a similar alignment to that proposed in the previous COE studies. It 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 diversion will consist of twin, concrete-lined tunnels located within the rock of the right abutment. Rockfill cofferdams, also with impervious cores and appropriate cutoffs, will be founded on the alluvium and separated from the main dam. Diversion closure and facilities for downstream releases will be provided for in a manner similar to that at Devil Canyon.

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.

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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 the 200- to 300-MW range. The complete powerhouse would be constructed together with penstocks and a tailrace tunnel for the initial two 100-MW (or 150-MW) units, together with concrete foundations for the future units.

(ii) Watana (Plates 3 and 4)

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

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 4).

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

For the second stage, the dam would be completed to its full height, the impervious core would be appropriately raised and additional rockfill would be placed on the downstream face. It is assumed that before construction commences the top 40 feet of the first stage dam 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 5)

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 6)

The development will be comprised of 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 7)

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)

The development will consist of a 185 feet high earthfill dam founded on pervious riverbed materials. Crest elevation 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)

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.

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

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

The total capital costs developed are shown in Tables 8.1, 8.2, and 8.4 . It should be noted that the capital costs for Maclaren and Denali shown in Tables 8.1 and 8.2 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 exercise described in Section 8.3 indicate that the Susitna Basin development plan should incorporate a combination of several major dams and powerhouses located at one or more of the following sites:

- Devil Canyon;
- High Devil Canyon;
- Watana;
- Susitna III; 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 the two most economic damsites, High Devil Canyon and Watana, were 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 8.5. Because of the simplifying assumptions that were made in the screening model, the three best solutions from an economic point of view are presented here.

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 8.5 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. Developments at Watana and Devil Canyon are 20 to 25 percent more costly.

- 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 High Devil/Susitna III combination is also competitive. Its cost exceeds the Watana/Devil Canyon option by 11 percent, which is within the accuracy of the model.

- The total energy production capability of the Watana/Devil Canyon developments is considerably larger than that of the High Devil Canyon/Vee alternative and is the only plan capable of meeting energy demands in the 6,000 Gwh range.

(a) Tunnel Scheme

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

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

- Power tunnel intake works;
- One or two power tunnels of up to forty feet in diameter and up to thirty miles in length;
- A surface or underground powerhouse with a capacity of up to 1,200 MW;
- A re-regulation dam if the intake works are located downstream from Watana; and
- Arrangements for compensation for loss of flow in the bypassed river reach.

Four basic alternative schemes were developed and studied. All schemes assume an initial Watana development with full reservoir supply level at Elevation 2200 and the associated powerhouse with an installed capacity of 800 MW.

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

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

A review of the environmental impacts associated with the four tunnel schemes indicates that Scheme 3 would have the least impact, primarily because it offers the best opportunities for regulating daily flows downstream from the project. Based on this assessment, and because of its economic advantage, Scheme 3 was selected as the most appropriate. The capital cost estimate appears in Table 8.8. 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) Additional Basin Development Plan

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

(c) Selected Basin Development Plans

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

Associated with each of these plans are several options for staged development, including staged construction of the dams and/or the power generation facilities. For this more detailed analysis of these basic plans, a range of different aproaches to staging the developments 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 summarized in Table 8.9 and are briefly described below. Plan 1 involves the Watana-Devil Canyon sites, Plan 2 the High Devil Canyon-Vee sites, Plan 3 the Watana-tunnel concept, and Plan 4 the Watana-High Devil Canyon sites.

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.

(a) Preliminary Evaluations

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

The model is driven by an energy demand which follows a distribution corresponding to the seasonal distribution of the total system load.

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

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

(b) Plan Modifications

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

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

(c) Evaluation Criteria and Methodology

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

- For determining the optimum staging concept associated with each basic plan (i.e. the optimum subplan), 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 a computer simulation/ planning model of the entire generating system, General Electric's Optimized Generation Planning Model (OGP5). Input to this model includes the following:

- Load forecast over a specified period of time;

- Load duration curves;

- Details of the existing generating system;

- A list of all potential future thermal generating sources with associated annualized costs, installed capacities, fuel consumption rates, etc.;

- Fuel prices;

- A specified hydroelectric development plan, i.e. the annualized costs, on-line dates, installed capacities, and energy production capability of the various stages of the plan; and

- System reliability criteria. For current study purposes, a loss of load probability (LOLP) of 0.1 day/year is used.

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

The basic economic analyses undertaken in this study incorporated "real" discount and escalation rates, and the parameters used are summarized in Table 8.12.

A summary of the input data to the model and a discussion of the results follows.

(d) Initial Economic Analyses

Table 8.13 lists the results of the first series of economic analyses undertaken for the basic Susitna Basin development plans listed in Table 8.11. The information provided includes the specified online dates for the various stages of the plans, the OGP5 run index number, the total installed capacity at the year 2010 by category, and the total system present worth cost in 1980. A present worth cost is evaluated for the period 1980 to 2040. The OGP5 model is run for the period 1980-2010; thereafter steady state conditions are assumed and the then-existing generation mix and annual costs of 2010 are applied to the years 2011 to 2040. This extended period of time is necessary to ensure that the hydroelectric options being studied, many of which only come online 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.

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

(i) Plan E1 - Watana-Devil Canyon

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

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

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

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

(ii) Plan E2 - High Devil Canyon-Vee

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

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

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

(iii) Plan E3

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

(iv) Plan E4

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

(e) Economic Sensitivity Analyses

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

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

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

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

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

(f) Evaluation Criteria

The following criteria were used to evaluate the shortlisted basin development plans. They generally contain the requirements of the generic process with the exception that an additional criterion, energy contribution, is added 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 Tables 8.14 and 8.15.

(ii) Environmental

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

(iii) Social

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

(iv) Energy Contribution

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

(g) Results of Evaluation Process

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

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

(i) Devil Canyon Dam Versus Tunnel

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

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

- Economic Comparison

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

- Environmental Comparison

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

- 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 inundates 13 miles less of resident fisheries habitat in river and major tributaries;
- It has a lower impact on wildlife habitat due to the smaller 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 8.19 summarizes the evaluation in terms of the social criteria of the two schemes. In terms of impact on state and local economics and risks due to seismic exposure, the two schemes are rated equally. However, the dam scheme has, due to its higher energy yield, more potential for displacing nonrenewable energy resources, and therefore scores a slight overall plus in terms of the social evaluation criteria.

- Energy Comparison

Table 8.20 summarizes the evaluation in terms of the 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 8.21. The estimated cost saving of $680 million in favor of the dam scheme is considered to outweigh the reduction in the overall environmental impact of the tunnel scheme. The dam scheme is therefore judged to be superior overall.

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

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

- Economic Comparison

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

- Environmental Comparison

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

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

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

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

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

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

As previously mentioned, the area between Devil Canyon and the Oshetna River on the Susitna River is confined to a relatively steep river valley. Along these valley slopes are habitats important to birds and black bears. Since the Watana reservoir would flood the river section between the Watana Dam site and the Oshetna River to a higher elevation than would the High Devil Canyon reservoir (2,200 feet as compared to 1,750 feet), the High Devil Canyon- Vee plan would retain the integrity of more of this river valley slope habitat.

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

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

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

- <u>Energy Comparison</u>

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

- <u>Social Comparison</u>

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

- <u>Overall Comparison</u>

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

(iii) <u>Preferred Susitna Basin Development Plan</u>

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

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

8.8 - On-Line Schedule

The project schedules have been developed to allow substantial power production capability at Watana by December 1993 and complete capability at Devil Canyon by October 2002.

TABLE 8.1: POTENTIAL HYDROELECTRIC DEVELOPMENT

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

Notes:

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

TABLE 8.2: COST COMPARISONS

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

Notes:

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

TABLE 8.3: DAM CREST AND FULL SUPPLY LEVELS

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

Notes:

(1) To foundation level.

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

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

Notes:

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

TABLE 8.5: RESULTS OF SCREENING MODEL

	Total Demand		Optimal Solution				First Suboptimal Solution				Second Suboptimal Soultion			
Run	Cap. MW	Energy GWh	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million	Site Names	Max. Water Level	Inst. Cap. MW	Total Cost $ million
1	400	1750	High Devil Canyon	1580	400	885	Devil Canyon	1450	400	970	Watana	1950	400	980
2	800	3500	High Devil Canyon	1750	800	1500	Watana	1900	450	1130	Watana	2200	800	1860
							Devil Canyon	1250	350	710				
							TOTAL		800	1840				
3	1200	5250	Watana	2110	700	1690	High Devil Canyon	1750	800	1500	High Devil Canyon	1750	820	1500
			Devil Canyon	1350	500	800	Vee	2350	400	1060	Susitna III	2300	380	1260
			TOTAL		1200	2490	TOTAL		1200	2560	TOTAL		1200	2760
4	1400	6150	Watana	2150	740	1770	NO SOLUTION				NO SOLUTION			
			Devil Canyon	1450	660	1000								

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

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

Notes:

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

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

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

Notes:

(1) Increase over single Watana, 800 MW development 3,250 Gwh/yr
(2) Includes power and energy produced at re-regulation dam
(3) Energy cost is based on an economic analysis (i.e. using 3 percent interest rate)

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

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

TABLE 8.9: SUSITNA DEVELOPMENT PLANS

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

TABLE 8.9 (Continued)

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

TABLE 8.9 (Continued)

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

NOTES:

(1) Allowing for a 3 year overlap construction period between major dams.
(2) Plan 1.2 Stage 3 is less expensive than Plan 1.3 Stage 2 due to lower mobilization costs.
(3) Assumes FERC license can be filed by June 1984, i.e., 2 years later than for the Watana/Devil Canyon Plan 1.

TABLE 8.10: ENERGY SIMULATION SENSITIVITY

Development	Installed Capacity MW	Reservoir Full Supply Level Feet	Maximum Reservoir Drawdown Feet	Annual Energy-Gwh Firm[1] (%)		Annual Energy-Gwh Average (%)		Plant Factor %
Watana 2225 Feet	800	2200	100	2510	(89)	3210	(101)	45.8
	800	2200	150	2670	(94)	3250	(103)	46.4
	800	2200	175	2770	(98)	3200	(101)	45.7
	800	2200	Unlimited	2830	(100)	3170	(100)	45.2

Notes:

(1) Second lowest energy generated during simulation period.

TABLE 8.11: SUSITNA ENVIRONMENTAL DEVELOPMENT PLANS

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft	Annual Energy Production Firm GWH	Avg. GWH.	Plant Factor %
E1.1	1	Watana 2225 ft 800 MW and 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 and Re-Regulation Dam	230[2]	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 and Re-Regulation Dam	250	1993	2200	150	2670	3250	46
	3	Devil Canyon 1470 ft 400 MW	900	1996	1450	100	5520	6070	58
		TOTAL SYSTEM 1200 MW	2890						

TABLE 8.11 (Continued)

			Stage/Incremental Data				Cumulative System Data		
Plan	Stage	Construction	Capital Cost $ Millions (1980 values)	Earliest On-line Date[1]	Reservoir Full Supply Level - ft.	Maximum Seasonal Draw-down-ft.	Annual Energy Production Firm GWH	Avg. GWH	Plant Factor %
E1.4	1	Watana 2225 ft 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 2350ft 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 8.11 (Continued)

Plan	Stage	Construction	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 %
E2.4	1	High Devil Canyon 1755 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 400MW 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 8.12: ANNUAL FIXED CARRYING CHARGES

Project Type		Economic Life - Years	Economic Parameters			
			Cost of Money %	Amortization %	Insurance %	Total Annual Fixed Cost %
Thermal	- Gas Turbine (Oil Fired)	20	3.00	3.72	0.25	6.97
	- Diesel, Gas Turbine (Gas Fired) and Large Steam Turbine	30	3.00	2.10	0.25	5.35
	- Small Steam Turbine	35	3.00	1.65	0.25	4.90
Hydropower		50	3.00	0.89	0.10	3.99

TABLE 8.13: RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS - MEDIUM LOAD FORECAST

Susitna Development Plan Inc.	Online Dates					Installed Capacity (MW) by Category in 2010							
	Stages					Thermal			Hydro		Total System Installed Capacity In	Total System Present Worth Cost	Remarks Pertaining to the Susitna Basin
Plan No.	1	2	3	4	OGP5 Run Id. No.	Coal	Gas	Oil	Other	Susitna	2010-MW	$ Million[1]	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	
	1993	1996	--	--	L7W7	500	651	0	144	800	2095	6960	Stage 3, Devil Canyon Dam not constructed
	1998	2001	2005	--	LAD7	400	276	30	144	1200	2050	6070	Delayed implementation schedule
E1.4	1993	2000	--	--	LCK5	200	726	50	144	800	1920	5890	Total development limited to 800 MW
Modified E2.1	1994	2000	--	--	LB25	400	651	60	144	800	2055	6620	High Devil Canyon limited to 400 MW
E2.3[1]	1993	1996	2000	--	L601	300	651	20	144	1200	2315	6370	
	1993	1996	--	--	LE07	500	651	30	144	800	2125	6720	Stage 3, Vee Dam, not constructed
Modified E2.3	1993	1996	2000		LEB3	300	726	220	144	1300	2690	6210	Vee dam replaced by Chakachamna dam
3.1	1993	1996	2000	--	L607	200	651	30	144	1180	2205	6530	
Special 3.1	1993	1996	2000	--	L615	200	651	30	144	1180	2205	6230	Capital cost of tunnel reduced by 50 percent
E4.1	1995	1996	1998	--	LTZ5	200	576	30	144	1200	2150	6050	Stage 4 not constructed

NOTES:

(1) Adjusted to incorporate cost of re-regulation dam

TABLE 8.14: RESULTS OF ECONOMIC ANALYSES OF SUSITNA PLANS - LOW AND HIGH LOAD FORECAST

Plan No.	Susitna Development Plan Inc. Online Dates Stages 1	2	3	4	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010 Thermal Coal	Gas	Oil	Hydro Other	Susitna	Total System Installed Capacity In 2010-MW	Total System Present Worth Cost $ Million	Remarks Pertaining to the Susitna Basin Development Plan
VERY LOW FORECAST[1]													
E1.4	1997	2005	--	--	L7B7	0	651	50	144	800	1645	3650	
LOW LOAD FORECAST													
E1.3	1993	1996	2000	--	--	--	--	--	--	--	--	--	Low energy demand does not warrant plan capacities
E1.4	1993	2002	--	--	LC07	0	351	40	144	800	1335	4350	
	1993	--	--	--	LBK7	200	501	80	144	400	1325	4940	Stage 2, Devil Canyon Dam, not constructed
E2.1	1993	2002	--	--	LG09	100	426	30	144	800	1500	4560	High Devil Canyon limited to 400 MW
	1993	--	--	--	LBU1	400	501	0	144	400	1445	4850	Stage 2, Vee Dam, not constructed
E2.3	1993	1996	2000	--	--	--	--	--	--	--	--	--	Low energy demand does not warrant plan capacities
Special 3.1	1993	1996	2000	--	L613	0	576	20	144	780	1520	4730	Capital cost of tunnel reduced by 50 percent
3.2	1993	2002	--	--	L609	0	576	20	144	780	1520	5000	Stage 2, 400 MW addition to Watana, not constructed
HIGH LOAD FORECAST													
E1.3	1993	1996	2000	--	LA73	1000	951	0	144	1200	3295	10680	
Modified E1.3	1993	1996	2000	2005	LBV7	800	651	60	144	1700	3355	10050	Chakachamna hydroelectric generating station (480 MW) brought on line as a fourth stage
E2.3	1993	1996	2000	--	LBV3	1300	951	90	144	1200	3685	11720	
Modified E2.3	1993	1996	2000	2003	LBY1	1000	876	10	144	1700	3730	11040	Chakachamna hydroelectric generating station (480 MW) brought on line as a fourth stage

NOTE:

(1) Incorporating load management and conservation

TABLE 8.15: RESULTS OF ECONOMIC SENSITIVITY ANALYSES FOR GENERATION SCENARIO INCORPORATING SUSITNA BASIN DEVELOPMENT PLAN E1.3 - MEDIUM FORECAST

Description Parameter Varied	Parameter Values	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010: Thermal			Hydro		Total System Installed Capacity In 2010 MW	Total System Present Worth Cost $ Million	Remarks
			Coal	Gas	Oil	Other	Susitna			
Interest Rate	5%	LF85	300	426	0	144	1200	2070	4230	
	9%	LF87	300	426	0	144	1200	2070	2690	
Fuel Cost ($ million Btu, natural gas/coal/oil)	1.60/0.92/3.20	L533	100	576	20	144	1200	2040	5260	20% fuel cost reduction
Fuel Cost Escalation (%, natural gas/coal/oil)	0/0/0	L557	0	651	30	144	1200	2025	4360	Zero escalation
	3.98/0/3.58	L563	300	426	0	144	1200	2070	5590	Zero coal cost escalation
Economic Life of Thermal Plants (year, natural gas/coal/oil)	45/45/30	L585	45	367	233	144	1200	1989	6100	Economic lives increased by 50%
Thermal Plant Capital Cost ($/kW, natural gas/coal/oil)	350/2135/778	LED7	300	426	0	144	1200	2070	5740	Coal capital cost reduced by 22%
Watana/Devil Canyon Capital Cost[2] ($ million, Watana/Devil Canyon)	1990/1110	L5G1	300	426	0	144	1200	2070	6210	Capital cost for Devil Canyon Dam increased by 23%
	2976/1350	LD75	300	426	0	144	1200	2070	6810	Capital cost for both dams increased by 50%
Probabilistic Load Forecast		L8T5	200	1476	140	144	1200	3160	6290	

NOTES:

(1) Alaskan cost adjustment factor reduced from 1.8 to 1.4
(2) Excluding AFDC

TABLE 8.16: ECONOMIC BACKUP DATA FOR EVALUATION OF PLANS

Parameter	Total Present Worth Cost for 1981 - 2040 Period $ Million (% Total)			
	Generation Plan With High Devil Canyon - Vee	Generation Plan With Watana - Devil Canyon Dam	Generation Plan With Watana - Tunnel	All Thermal Generation Plans
Capital Investment	2800 (44)	2740 (47)	3170 (49)	2520 (31)
Fuel	3220 (50)	2780 (47)	3020 (46)	5240 (64)
Operation and Maintenance	350 (6)	330 (6)	340 (5)	370 (5)
TOTAL:	6370 (100)	5850 (100)	6530 (100)	8130 (100)

TABLE 8.17: ECONOMIC EVALUATION OF DEVIL CANYON DAM AND TUNNEL SCHEMES AND WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

		Present worth of Net Benefit ($ million) of total generation system costs for the: Devil Canyon Dam over the Tunnel Scheme	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	650	210	The net benefit of the Watana/Devil Canyon plan remains positive for the range of load forecasts considered. No change in ranking.
	High	N.A.	1040	
- Capital Cost Estimate		Higher uncertainty associated with tunnel scheme.	Higher uncertainty associated with H.D.C./Vee plan.	Higher cost uncertainties associated with higher cost schemes/plans. Cost uncertainty therefore does not affect economic ranking.
- Period of Economic Analysis	Period shortened to (1980 - 2010)	230	160	Shorter period of evaluation decreases economic differences. Ranking remains unchanged.
- Discount Rate	5% 8% (interpolated) 9%	As both the capital and fuel costs associated with the tunnel scheme and H.D.C./Vee Plan are higher than for Watana/Devil Canyon plan any changes to these parameters cannot reduce the Devil Canyon or Watana/Devil Canyon net benefit to below zero.		Ranking remains unchanged.
- Fuel Cost	80% basic fuel cost			
- Fuel Cost Escalation	0% fuel escalation 0% coal escalation			
- Economic Thermal Plant Life	50% extension 0% extension			

TABLE 8.18: ENVIRONMENTAL EVALUATION OF DEVIL CANYON DAM AND TUNNEL SCHEME

Environmental Attribute	Concerns	Appraisal (Differences in impact of two schemes)	Identification of difference	Appraisal Judgement	Scheme judged to have the least potential impact: Tunnel	Scheme judged to have the least potential impact: DC
Ecological:						
- Downstream Fisheries and Wildlife	Effects resulting from changes in water quantity and quality.	No significant difference between schemes regarding effects downstream of Devil Canyon.	---	Not a factor in evaluation of scheme.		
		Difference in reach between Devil Canyon dam and tunnel re-regulation dam.	With the tunnel scheme controlled flows between regulation dam and downstream powerhouse offers potential for anadromous fisheries enhancement in this 11 mile reach of the river.	If fisheries enhancement opportunity can be realized the tunnel scheme offers a positive mitigation measure not available with the Devil Canyon dam scheme. This opportunity is considered moderate and favors the tunnel scheme. 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 8.19: SOCIAL EVALUATION OF SUSITNA BASIN DEVELOPMENT SCHEMES/PLANS

Social Aspect	Parameter	Tunnel Scheme	Devil Canyon Dam Scheme	High Devil Canyon/ Vee Plan	Watana/Devil Canyon Plan	Remarks
Potential non-renewable resource displacement	Million tons Beluga coal over 50 years	80	110	170	210	Devil Canyon dam scheme potential higher than tunnel scheme. Watana/ Devil Canyon plan higher than High Devil Canyon/ Vee plan.
Impact on state economy	--	All projects would have similar impacts on the state and local economy.				Essentially no difference between plans/schemes.
Impact on local economy	--					
Seismic exposure	Risk of major structural failure	All projects designed to similar levels of safety.				
	Potential impact of failure on human life.	Any dam failures would effect the same downstream population.				

Overall Evaluation	1. Devil Canyon dam superior to tunnel. 2. Watana/Devil Canyon superior to High Devil Canyon/Vee plan.

TABLE 8.20: ENERGY CONTRIBUTION EVALUATION OF THE DEVIL CANYON DAM AND TUNNEL SCHEMES

Parameter	Dam	Tunnel	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	2850	2240	Devil Canyon dam annually develops 610 GWH and 540 GWH more average and firm energy respectively than the Tunnel scheme.
Firm Annual Energy GWH	2590	2050	
% Basin Potential Developed[1]	43	32	Devil Canyon schemes develops more of the basin potential.
Energy Potential Not Developed GWH	60	380	As currently envisaged, the Devil Canyon dam does not develop 15 ft gross head between the Watana site and the Devil Canyon reservoir. The tunnel scheme incorporates additional friction losses in tunnels. Also the compensation flow released from re-regulation dam is not used in conjunction with head between re-regulation dam and Devil Canyon.

Notes:

(1) Based on annual average energy. Full potential based on USBR four dam scheme.

TABLE 8.21: OVERALL EVALUATION OF TUNNEL SCHEME AND DEVIL CANYON DAM SCHEME

ATTRIBUTE	SUPERIOR PLAN
Economic	Devil Canyon Dam
Energy Contribution	Devil Canyon Dam
Environmental	Tunnel
Social	Devil Canyon Dam (Marginal)
Overall Evaluation	Devil Canyon dam scheme is superior Tradeoffs made: Economic advantage of dam scheme is judged to outweigh the reduced environmental impact associated with the tunnel scheme.

TABLE 8.22: ENVIRONMENTAL EVALUATION OF WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE DEVELOPMENT PLANS

Environmental Attribute	Plan Comparison	Appraisal Judgement	Plan judged to have the least potential impact HDC/V	W/DC
Ecological: 1) Fisheries	No significant difference in effects on downstream anadromous fisheries. HDC/V would inundate approximately 95 miles of the Susitna River and 28 miles of tributary streams, including the Tyone River. W/DC would inundate approximately 84 miles of the Susitna River and 24 miles of tributary streams, including Watana Creek.	Due to the avoidance of the Tyone River, lesser inundation of resident fisheries habitat and no significant difference in the effects on anadromous fisheries, the W/DC plan is judged to have less impact.		X
2) Wildlife a) Moose	HDC/V would inundate 123 miles of critical winter river bottom habitat. W/DC would inundate 108 miles of this river bottom habitat. HDC/V would inundate a large area upstream of Vee utilized by three sub-populations of moose that range in the northeast section of the basin. W/DC would inundate the Watana Creek area utilized by moose. The condition of this sub-population of moose and the quality of the habitat they are using appears to be decreasing.	Due to the lower potential for direct impact on moose populations within the Susitna, the W/DC plan is judged superior.		X
b) Caribou	The increased length of river flooded, especially upstream from the Vee dam site, would result in the HDC/V plan creating a greater potential division of the Nelchina herd's range. In addition, an increase in range would be directly inundated by the Vee reservoir.	Due to the potential for a greater impact on the Nelchina caribou herd, the HDC/V scheme is considered inferior.		X
c) Furbearers	The area flooded by the Vee reservoir is considered important to some key furbearers, particularly red fox. This area is judged to be more important than the Watana Creek area that would be inundated by the W/DC plan.	Due to the lesser potential for impact on furbearers the W/DC is judged to be superior.		X
d) Birds and Bears	Forest habitat, important for birds and black bears, exist along the valley slopes. The loss of this habitat would be greater with the W/DC plan.	The HDC/V plan is judged superior.	X	
Cultural:	There is a high potential for discovery of archeological sites in the easterly region of the Upper Susitna Basin. The HDC/V plan has a greater potential of affecting these sites. For other reaches of the river the difference between plans is considered minimal.	The W/DC plan is judged to have a lower potential effect on archeological sites.		X

TABLE 8.22 (Continued)

Environmental Attribute	Plan Comparison	Appraisal Judgement	Plan judged to have the least potential impact: HDC/V	Plan judged to have the least potential impact: 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 8.23: ENERGY CONTRIBUTION EVALUATION OF THE WATANA/DEVIL CANYON AND HIGH DEVIL CANYON/VEE PLANS

Parameter	Watana/ Devil Canyon	High Devil Canyon/Vee	Remarks
Total Energy Production Capability			
Annual Average Energy GWH	6070	4910	Watana/Devil Canyon plan annually develops 1160 GWH and 1650 GWH more average and firm energy respectively 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 gross head between the Watana site and the Devil Canyon reservoir. The High Devil Canyon/Vee Plan does not develop 175 ft gross head between Vee site and High Devil reservoir.

Notes:

(1) Based on annual average energy. Full potential based on USBR four dam schemes.
(2) Includes losses due to unutilized head.

TABLE 8.24: OVERALL EVALUATION OF THE HIGH DEVIL CANYON/VEE AND WATANA/DEVIL CANYON DAM PLANS

ATTRIBUTE	SUPERIOR PLAN
Economic	Watana/Devil Canyon
Energy Contribution	Watana/Devil Canyon
Environmental	Watana/Devil Canyon
Social	Watana/Devil Canyon (Marginal)
Overall Evaluation	Plan with Watana/Devil Canyon is superior Tradeoffs made: None

TABLE 8.25: RESULTS OF ECONOMIC ANALYSES FOR GENERATION SCENARIO INCORPORATING THERMAL DEVELOPMENT PLAN - MEDIUM FORECAST

Description Parameter Varied	Parameter Value	OGP5 Run Id. No.	Installed Capacity (MW) by Category in 2010 Thermal: Coal	Gas	Oil	Hydro	Total System Installed Capacity In 2010 Total MW	Total System Present Worth Cost $ Million	Remarks
Interest Rate	5%	LEA9	900	800	50	144	1895	5170	
	9%	LEB1	900	801	50	144	1895	2610	
Fuel Cost ($ million Btu, natural gas/coal/oil)	1.60/0.92/3.20	L1K7	800	876	70	144	1890	7070	20% fuel cost reduction
Fuel Cost Escalation (%, natural gas/coal/oil)	0/0/0	L547	0	1701	10	144	1855	4560	Zero escalation
	3.98/0/3.58	L561	1100	726	10	144	1980	6920	Zero coal cost escalation
Economic Life of Thermal Plants (year, natural gas/coal/oil)	45/45/30	L583	1145	667	51	144	2007	7850	Economic life increased 50%
Thermal Plant Capital Cost ($/kW, natural gas/coal/oil)	350/2135/778	LAL9	1100	726	10	144	1980	7590	Coal capital cost reduced by 22%

TABLE 8.26: ECONOMIC SENSITIVITY OF COMPARISON OF GENERATION PLAN WITH WATANA/DEVIL CANYON AND THE ALL THERMAL PLAN

Present worth of Net Benefit ($ million) of total generation system costs for the Watana/Devil Canyon plan over the all thermal plan.

Parameters	Sensitivity Analyses	Present worth ($ million)	Remarks
LOAD GROWTH	Very low	1280	The net benefit of the Watana/Devil Canyon Plan remains positive for the range of load forecasts considered.
	Low	1570	
	Medium	2280	
	High	2840	
CAPITAL COST ESTIMATE	Low Thermal Cost[2]	1850	System costs relatively insensitive. Capital cost estimating uncertainty does not effect economic ranking.
	High Hydroelectric Cost[3]	1320	
PERIOD OF ECONOMIC ANALYSIS	1980 - 2040	2280	Shorter period of evaluation decreases economic differences. Ranking remains unchanged.
	1980 - 2010	960	
DISCOUNT RATE	3%	2280	Below discount rate of 8% the Watana/Devil Canyon plan is economically superior.
	5%	940	
	8% (interpolated)	0	
	9%	-80	
FUEL COST	Low[4]	1810	
FUEL COST ESCALATION[5]	0% escalation for all fuels	200	Watana/Devil Canyon plan remains economically superior for wide range of fuel prices and escalation rates.
	0% escalation for coal only	1330	
ECONOMIC THERMAL PLANT LIFE	50% extension to all thermal plant life	1800	Economic benefit for Watana/Devil Canyon plan relatively insensitive to extended thermal plan economic life.

Notes:

(1) All parameters, except load growth, tested using medium load forecast.
(2) Thermal capital cost decreased by 22%.
(3) Estimated Susitna cost increased by 50%.
(4) All fuel costs reduced by 20%. Base case costs $/million Btu: Coal 1.15, Gas 2.00, Oil 4.00

TABLE 8.27: SOCIAL COMPARISON OF SYSTEM GENERATION PLAN WITH WATANA/DEVIL CANYON AND THE ALL THERMAL PLAN

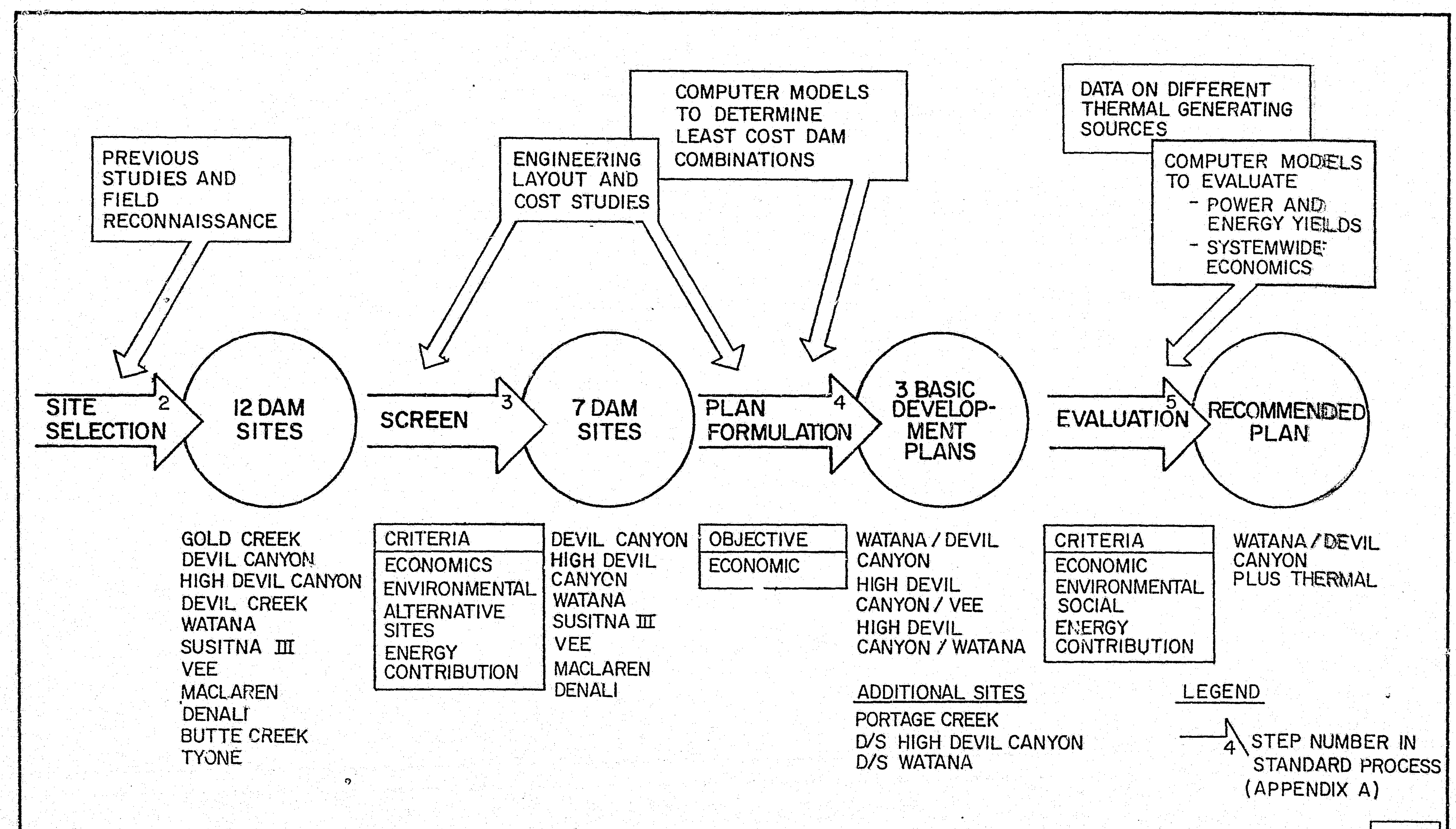
Social Aspect	Parameter	All Thermal Generation Plan	Generation Plan with Watana/Devil Canyon	Remarks
Potential non-renewable resource displacement	Million tons of Beluga coal, over 50 years	--	210	With Watana/Devil Canyon plan is superior.
Impact on state economy	Direct & Indirect employment and income.	Gradually, continuously growing impact.	Potentially more disruptive impact on economics.	Available information insufficient to draw definite conclusions.
Impact on local economy	Business investment.			
Seismic exposure	Risk of major structural failure	All projects designed to similar levels of safety.		Both scenarios judged to be equal.
	Potential impact of failure on human life.	Failure would effect only operating personnel. Forecast of failure would be impossible.	Failure would effect large number of people located downstream, however, some degree of forecasting dam failure would be impossible.	
Overall Comparison	No significant difference in terms of overall assessment of plans.			

TABLE 8.28: GENERIC COMPARISON OF ENVIRONMENTAL IMPACTS OF A SUSITNA BASIN HYDRO DEVELOPMENT VERSUS COAL FIRED THERMAL GENERATION IN THE BELUGA COAL FIELDS

Environmental Attributes	Concerns Susitna Basin Development	Thermal Generation
Ecological:	Potential impact on fisheries due to alteration of downsteam flow distribution and water quality. Inundation of Moose and furbearer habitat and potential impact on Caribou migration. No major air quality problems, only minor microclimatic changes would occur.	Potential for impact on fisheries resulting from water quality impairment of local streams and local habitat destruction due to surface disturbances both at mine and generating facilities. Impact on air quality due to emission of particulates SO_2, NO_x, trace metals and water vapors from generating facilities.
Cultural:	Inundation of archeological sites.	Potential destruction of archeological sites.
Aesthetic/ Land Use:	Inundation of large area and surface disturbance in construction area. Creates additional access to wilderness areas, reduces river recreation but increases lake recreational activities.	Surface disturbance of large areas associated with coal mining and thermal generation facilities. Creates additional access and may restrict land use activities.

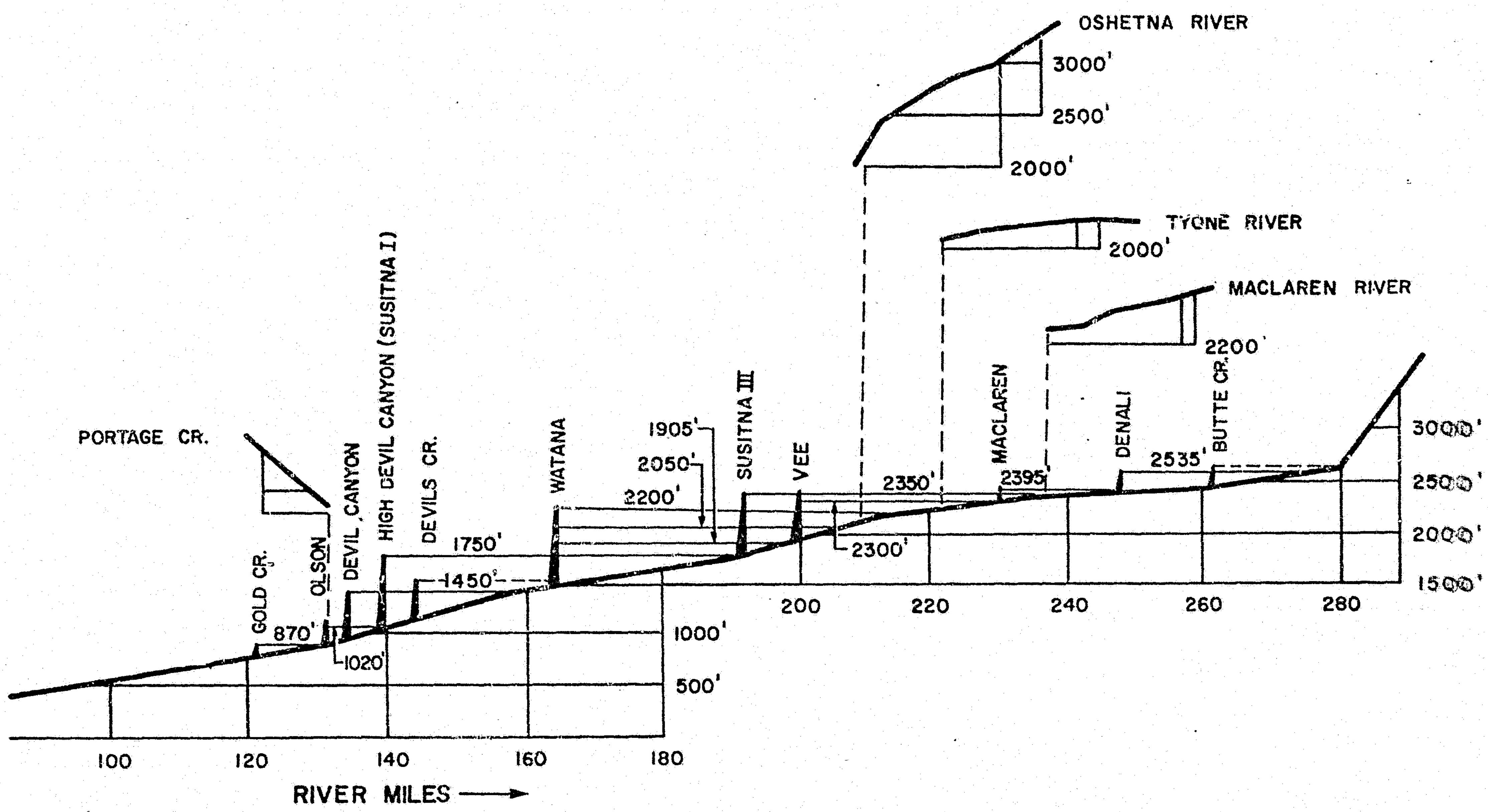
TABLE 8.29: OVERALL EVALUATION OF ALL THERMAL GENERATION PLANS WITH THE GENERATION PLAN INCORPORATING WATANA/DEVIL CANYON DAMS

ATTRIBUTE	SUPERIOR PLAN
Economic	With Watana/Devil Canyon
Environmental	Unable to distinguish difference in this study due to site specific nature of impacts
Social	No significant overall difference
Overall	Plan with Watana/Devil Canyon is judged to be superior
Evaluation	Tradeoffs made: Not fully explored



SUSITNA BASIN PLAN FORMULATION AND SELECTION PROCESS

FIGURE 8.1



PROFILE THROUGH ALTERNATIVE SITES

FIGURE 8.2

	GOLD CREEK	OLSON	DEVIL CANYON	HIGH DEVIL CANYON	DEVIL CREEK	WATANA	SUSITNA III	VEE	MACLAREN	DENALI	BUTTE CREEK	TYONE
GOLD CREEK	░											
OLSON		░	890 (30)									
DEVIL CANYON			░	1030 (160)	1070 (200)							
HIGH DEVIL CANYON				░	░	1465 (445)						
DEVIL CREEK					░	1465 (405)						
WATANA						░	1810 (355)	1925 (470)				
SUSITNA III							░	1925 (125)	2320 (520)			
VEE								░	2320 (405)			
MACLAREN									░			
DENALI										░	░	░
BUTTE CREEK											░	
TYONE												░

LEGEND

COMPATIBLE ALTERNATIVES (blank box)

MUTUALLY EXCLUSIVE ALTERNATIVES ░

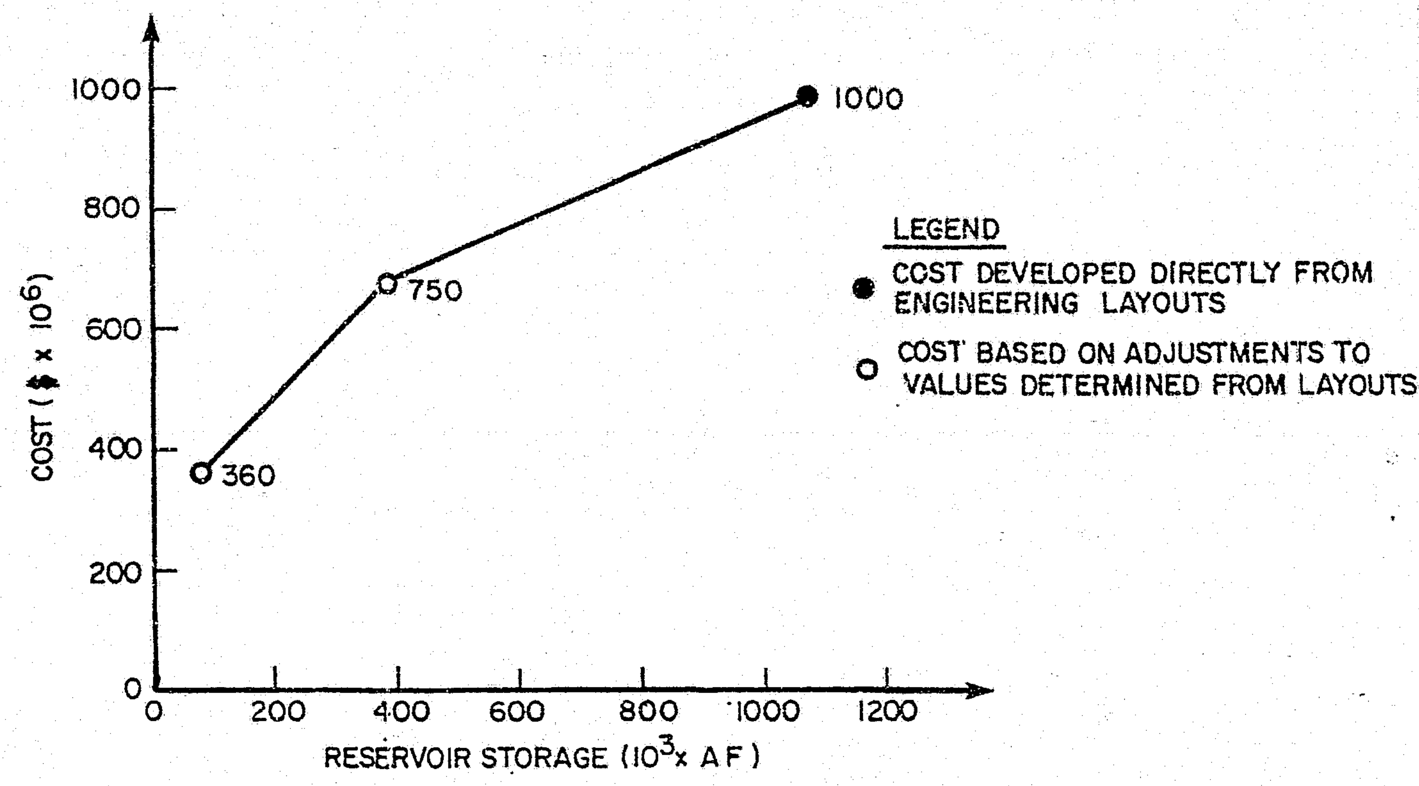
1465 (405) ░ — DAM IN COLUMN IS MUTUALLY EXCLUSIVE IF FULL SUPPLY LEVEL OF DAM IN ROW EXCEEDS THIS VALUE - FT.

VALUE IN BRACKET REFERS TO APPROXIMATE DAM HEIGHT.

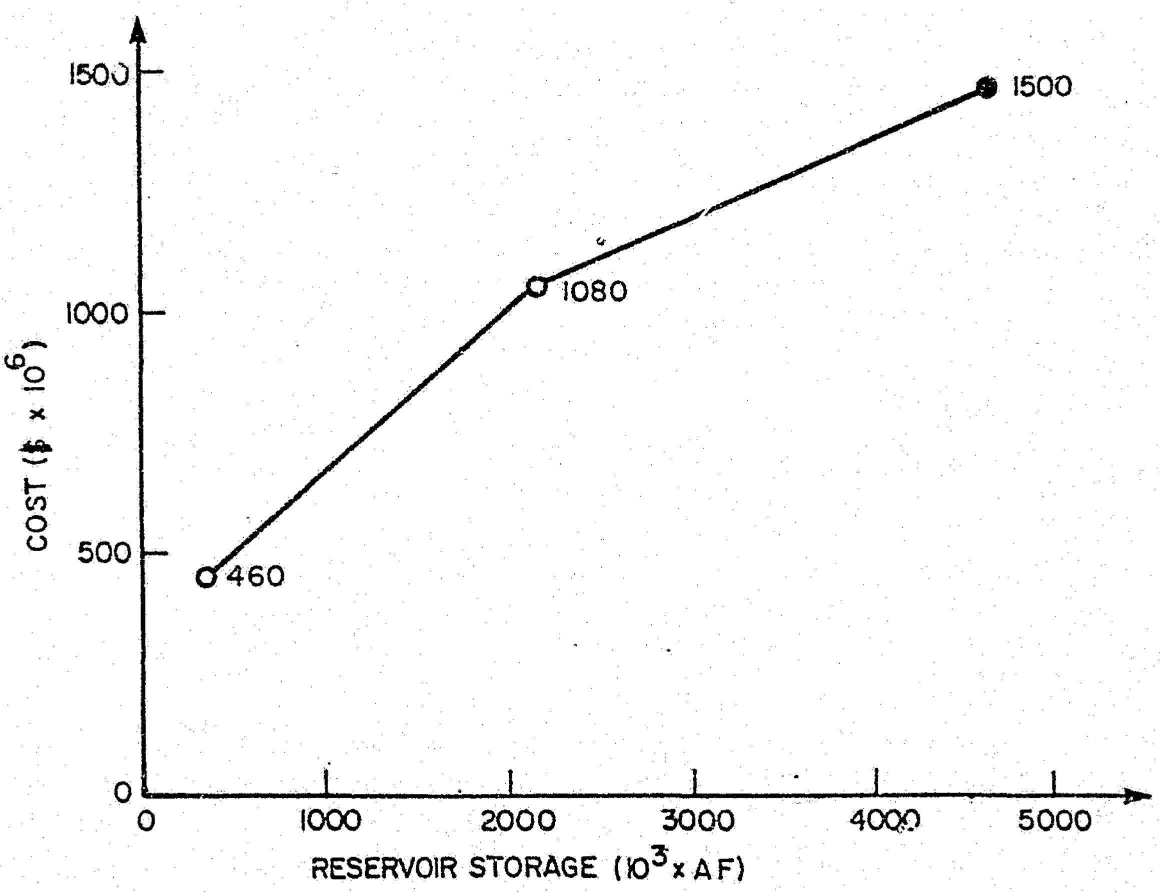
MUTUALLY EXCLUSIVE DEVELOPMENT ALTERNATIVES

FIGURE 8.3

ACRES



DEVIL CANYON

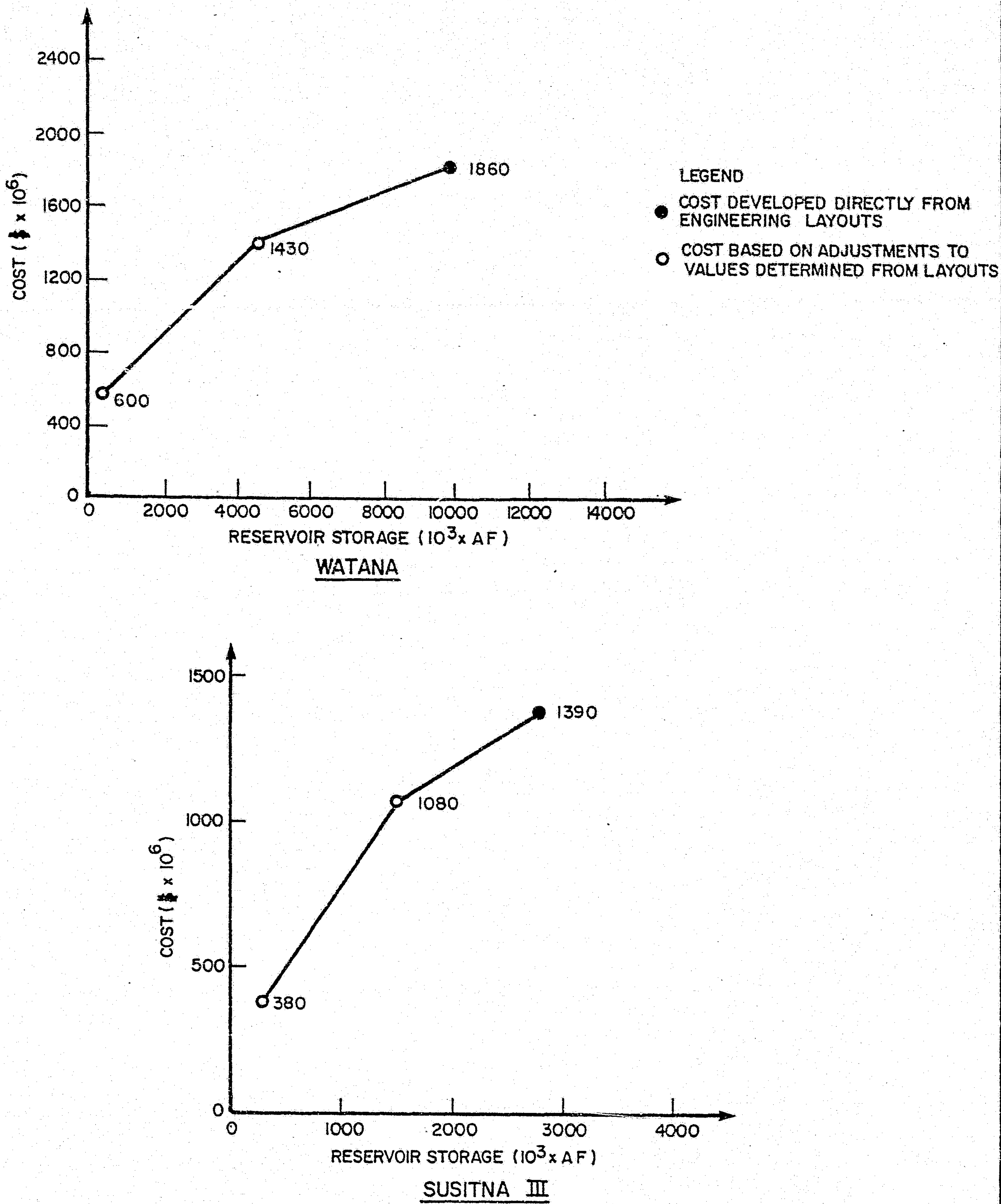


HIGH DEVIL CANYON

DAMSITE COST VS RESERVOIR STORAGE CURVES

ACRES

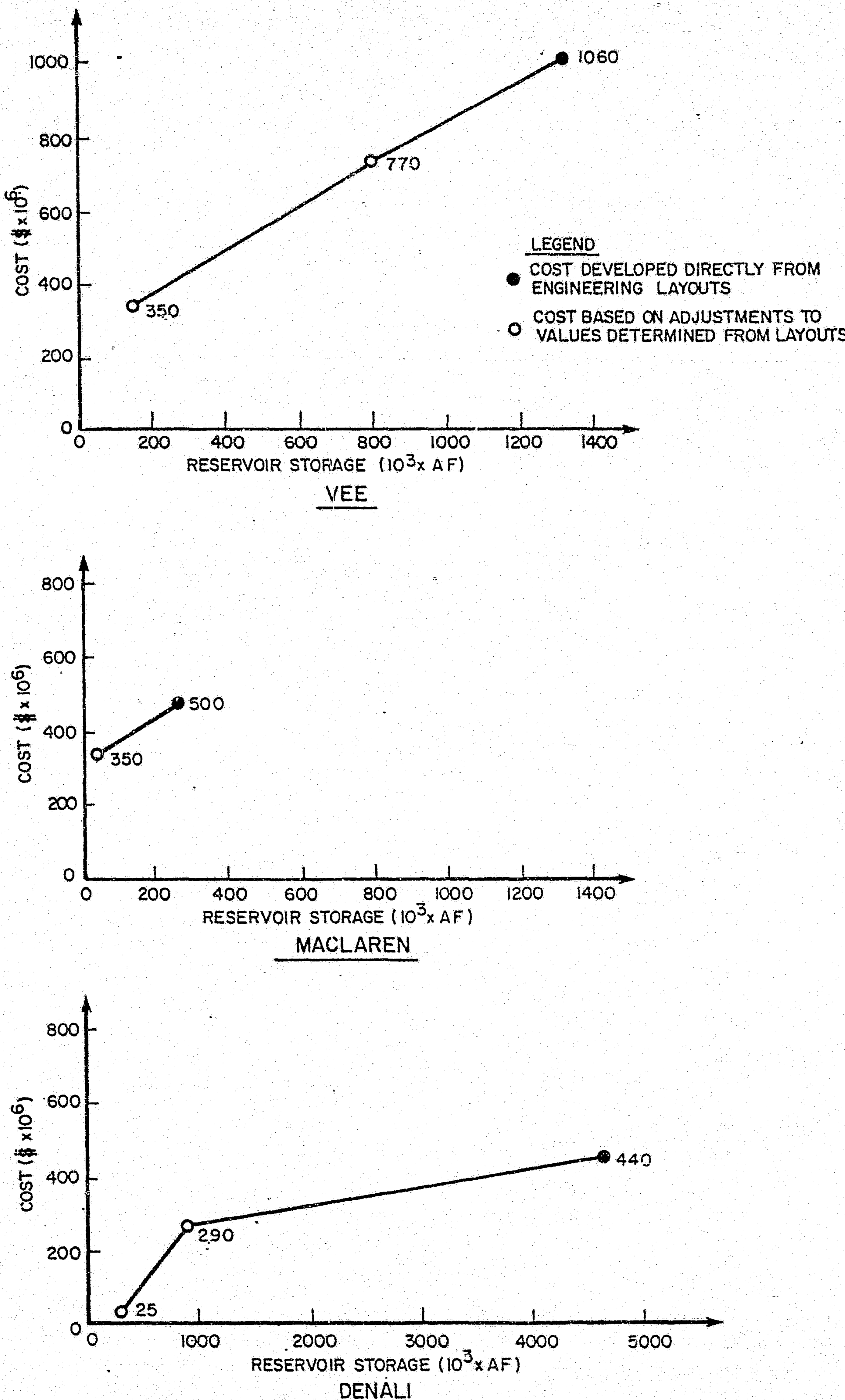
FIGURE 8.4



DAMSITE COST VS RESERVOIR STORAGE CURVES

ACRES

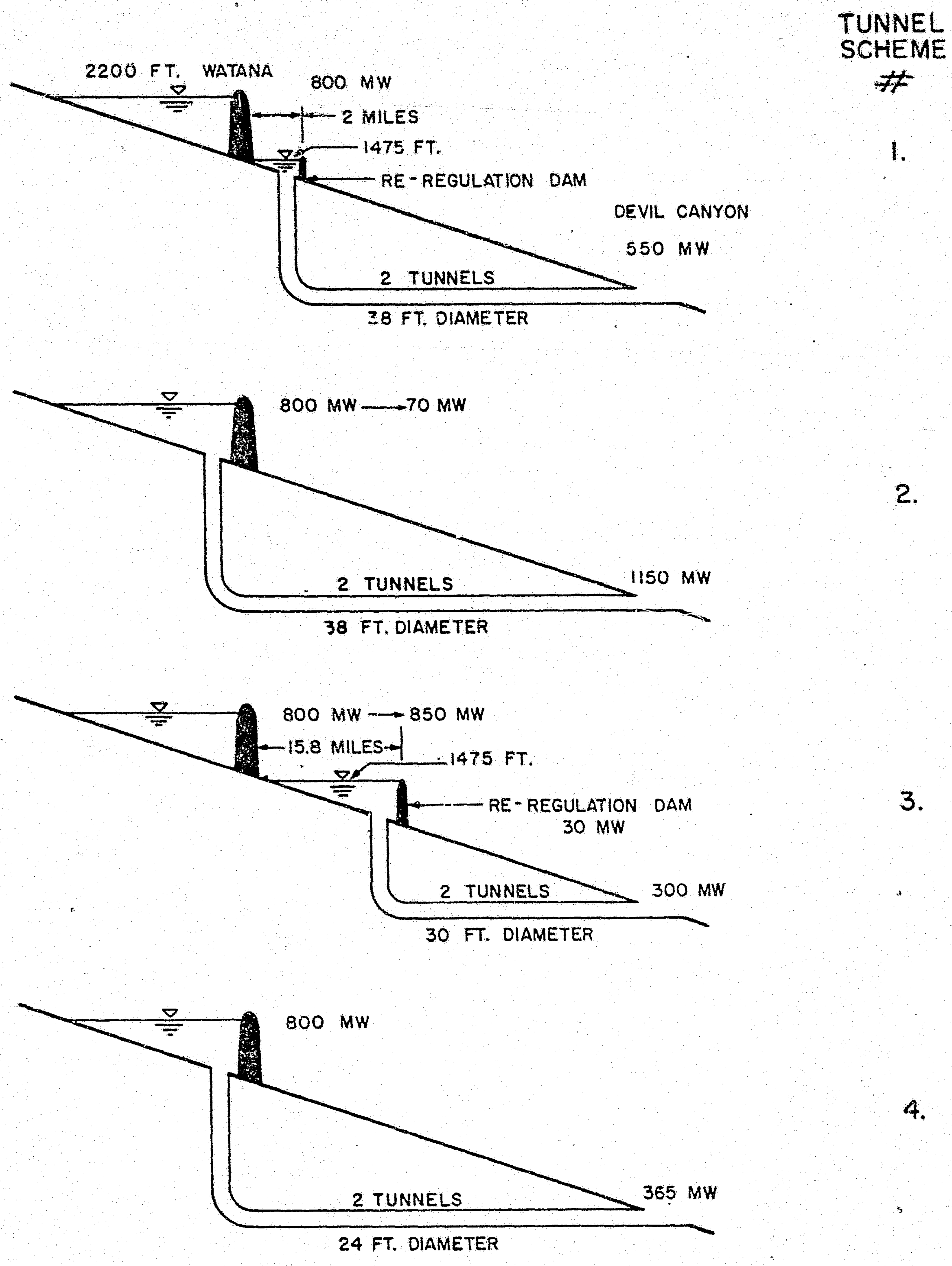
FIGURE 8.5



DAMSITE COST VS RESERVOIR STORAGE CURVES

FIGURE 8.6

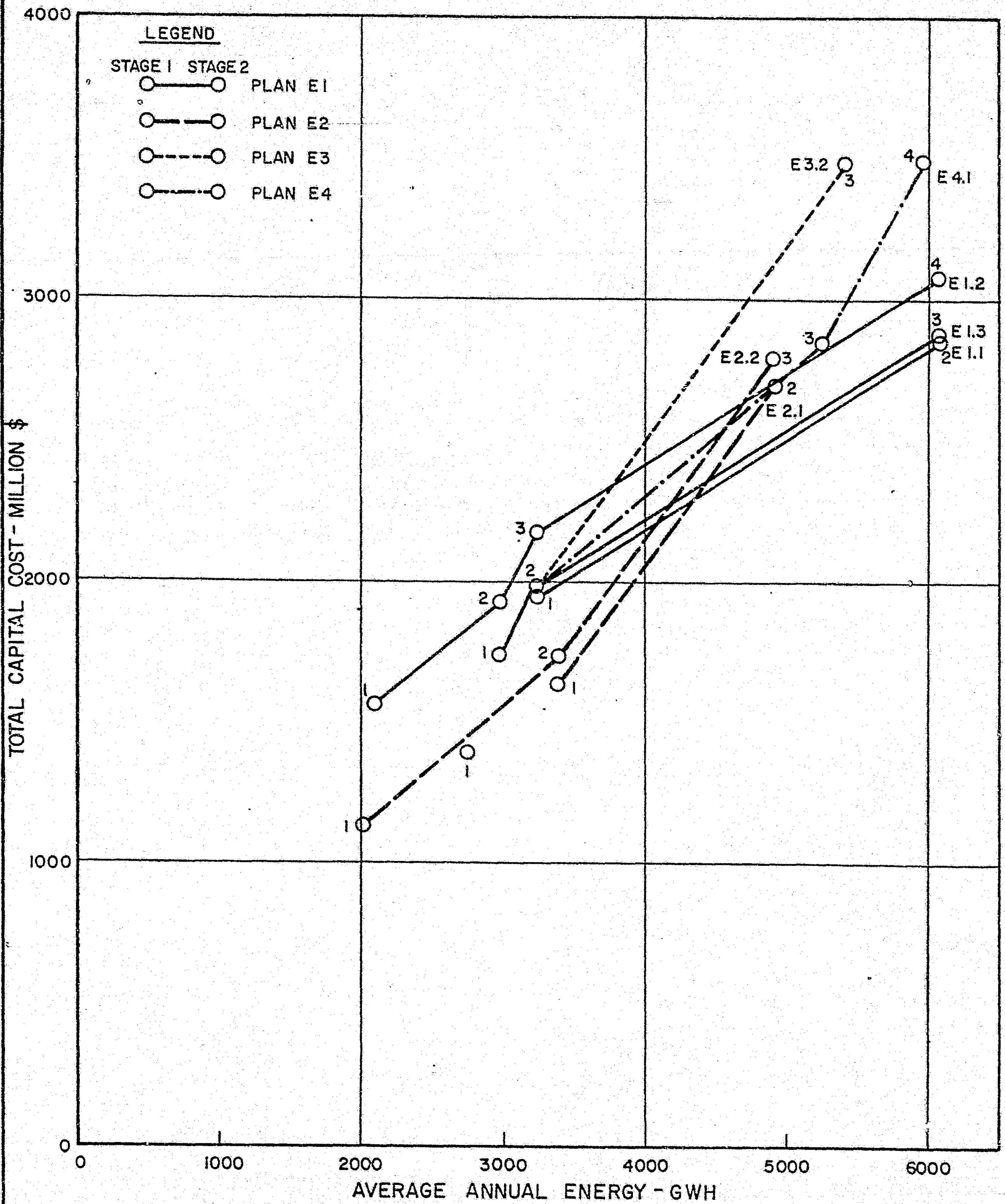
ACRES



SCHEMATIC REPRESENTATION
OF CONCEPTUAL TUNNEL SCHEMES

FIGURE 8.7

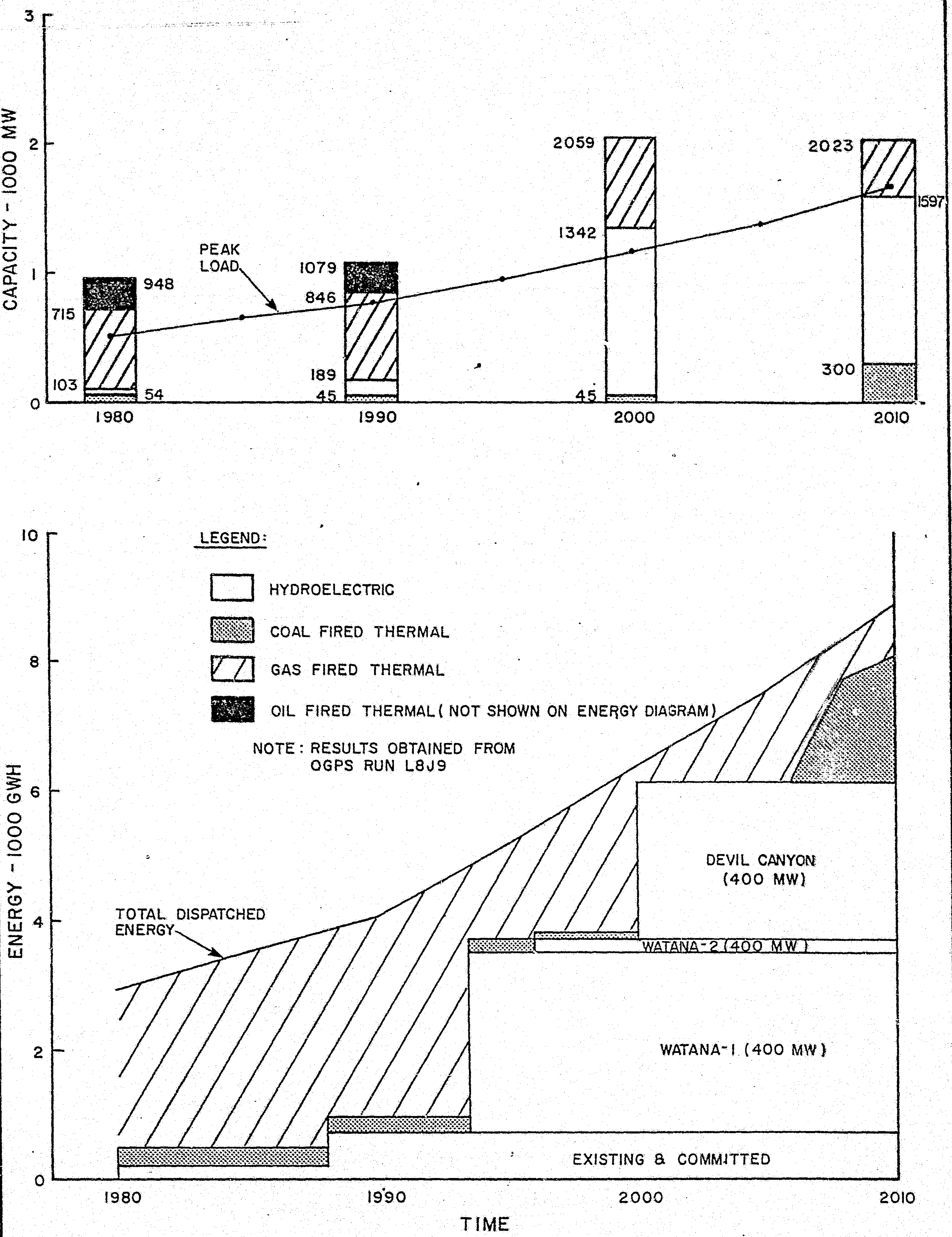
ACRES



CAPITAL COST VERSUS ENERGY PLOTS
FOR ENVIRONMENTAL SUSITNA BASIN PLANS

ACRES

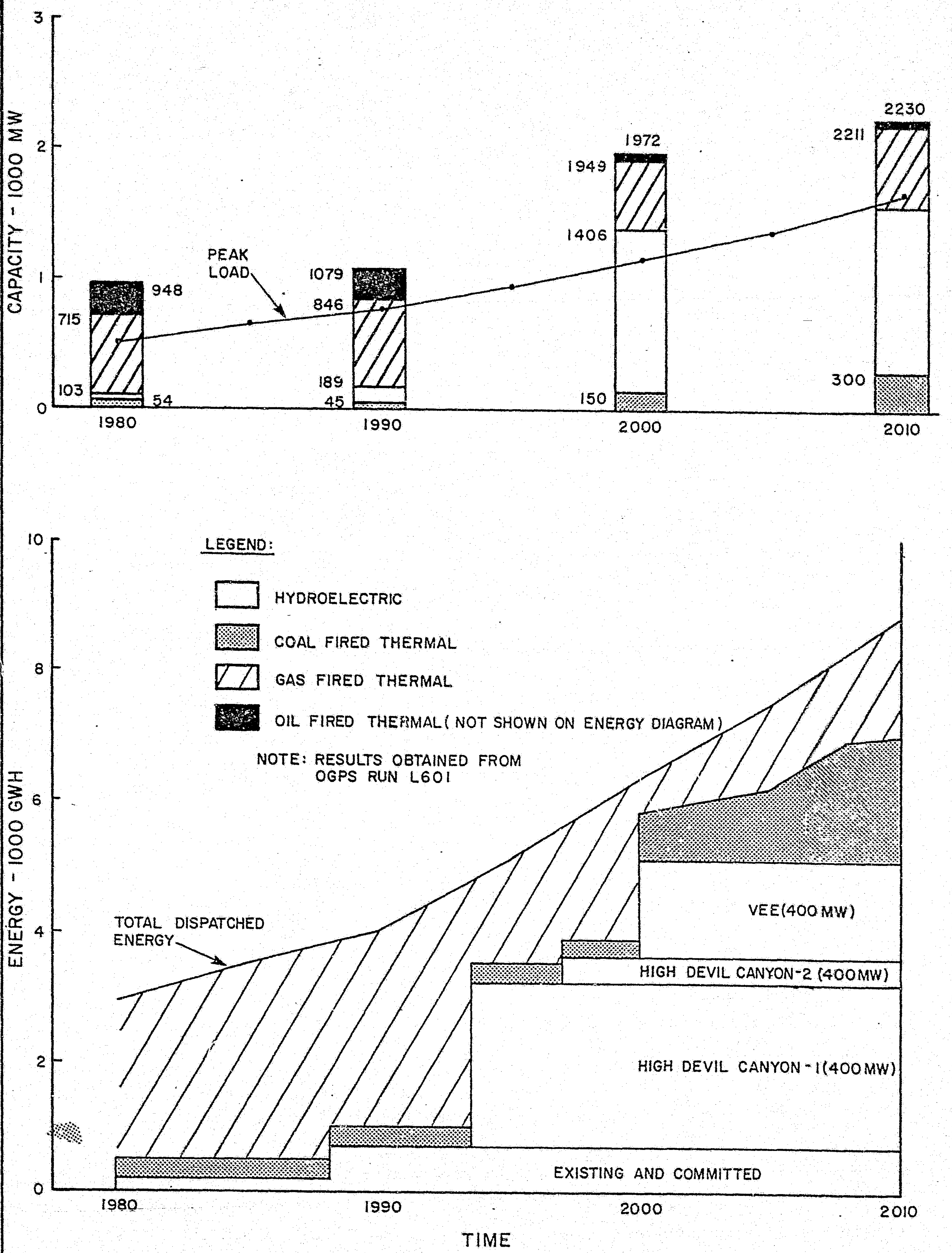
FIGURE 8.8



GENERATION SCENARIO WITH SUSITNA PLAN E1.3 -MEDIUM LOAD FORECAST-

ACRES

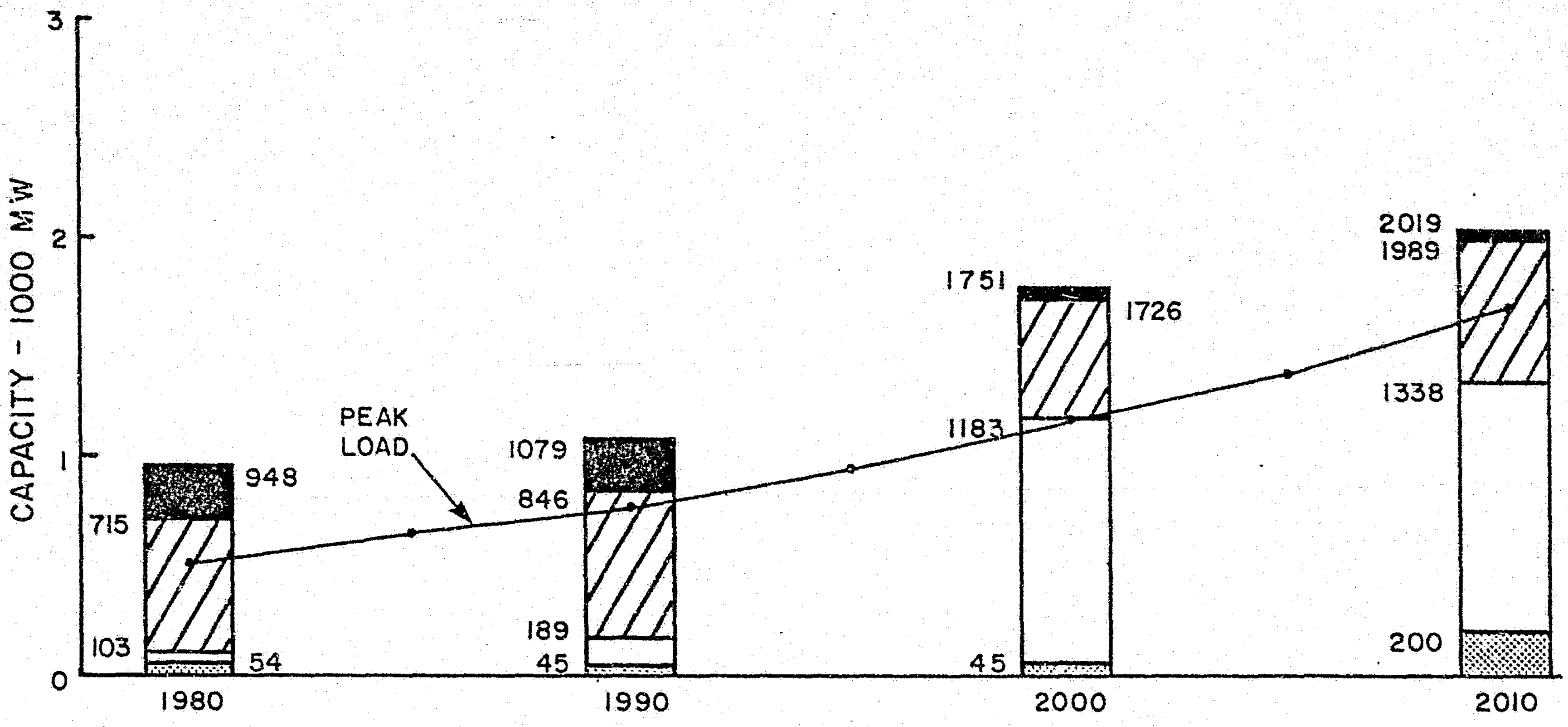
FIGURE 8.9

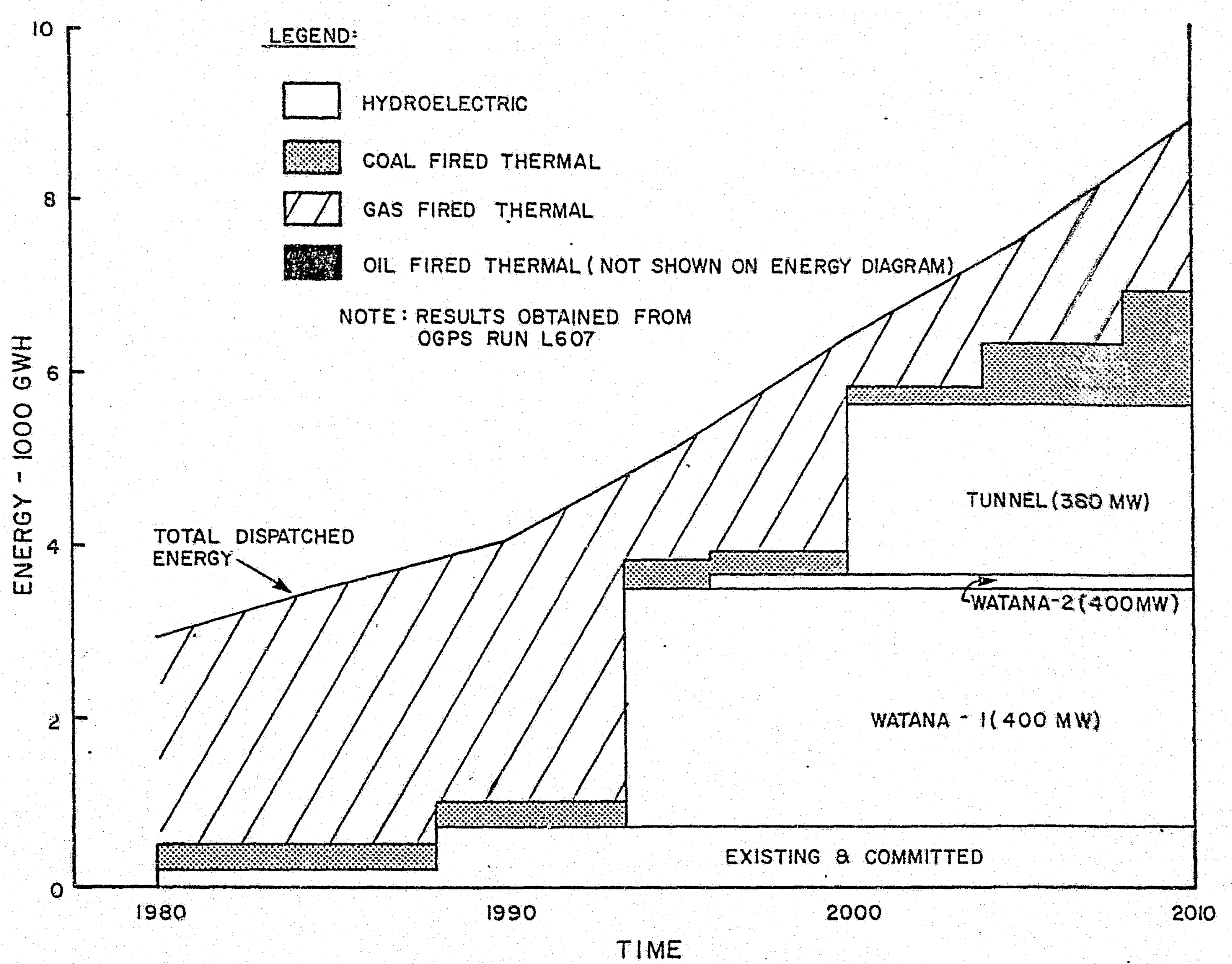


GENERATION SCENARIO WITH SUSITNA PLAN E 2.3
- MEDIUM LOAD FORECAST -

FIGURE 8.10

ACRES

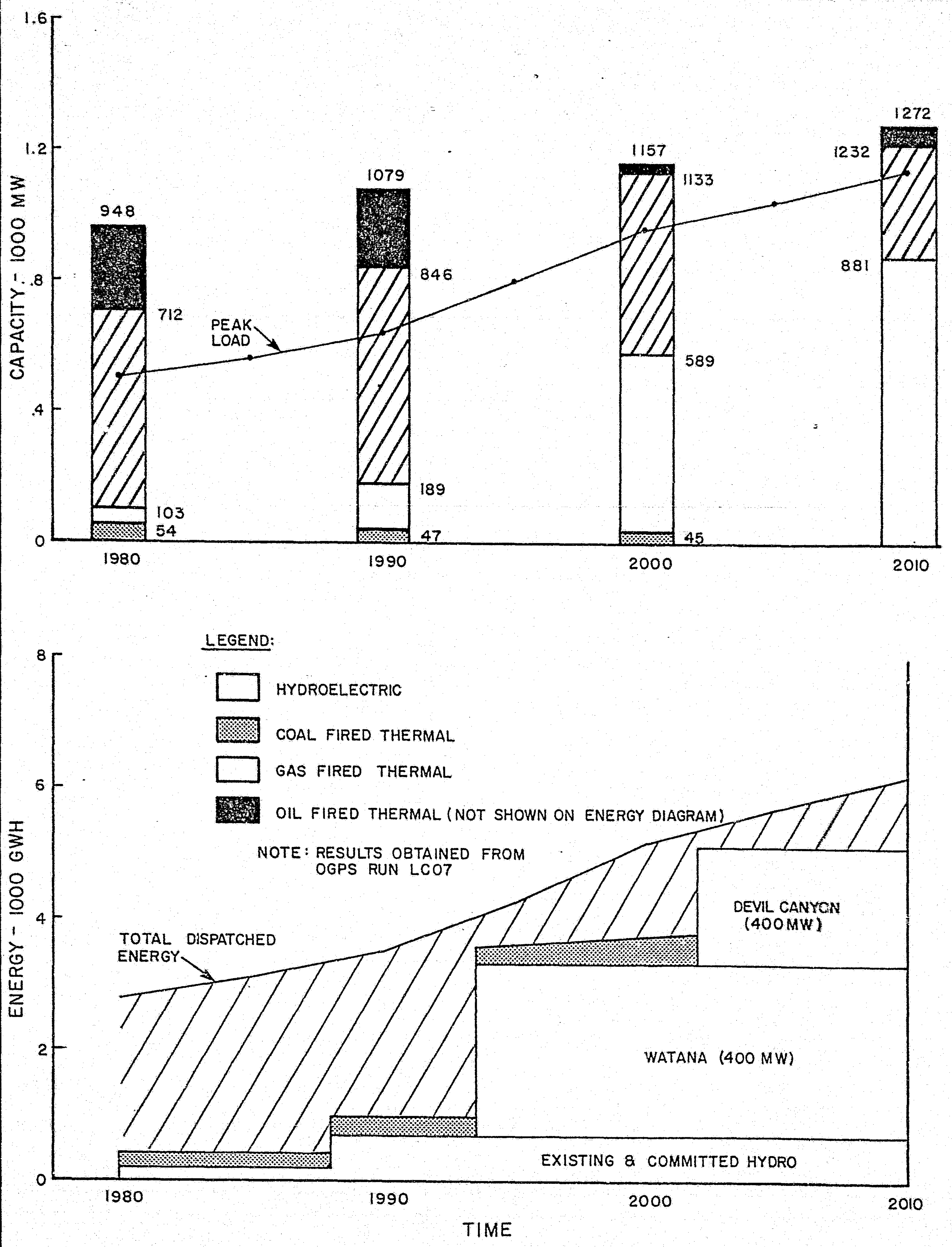




GENERATION SCENARIO WITH SUSITNA PLAN E3.1
- MEDIUM LOAD FORECAST -

FIGURE 8.11

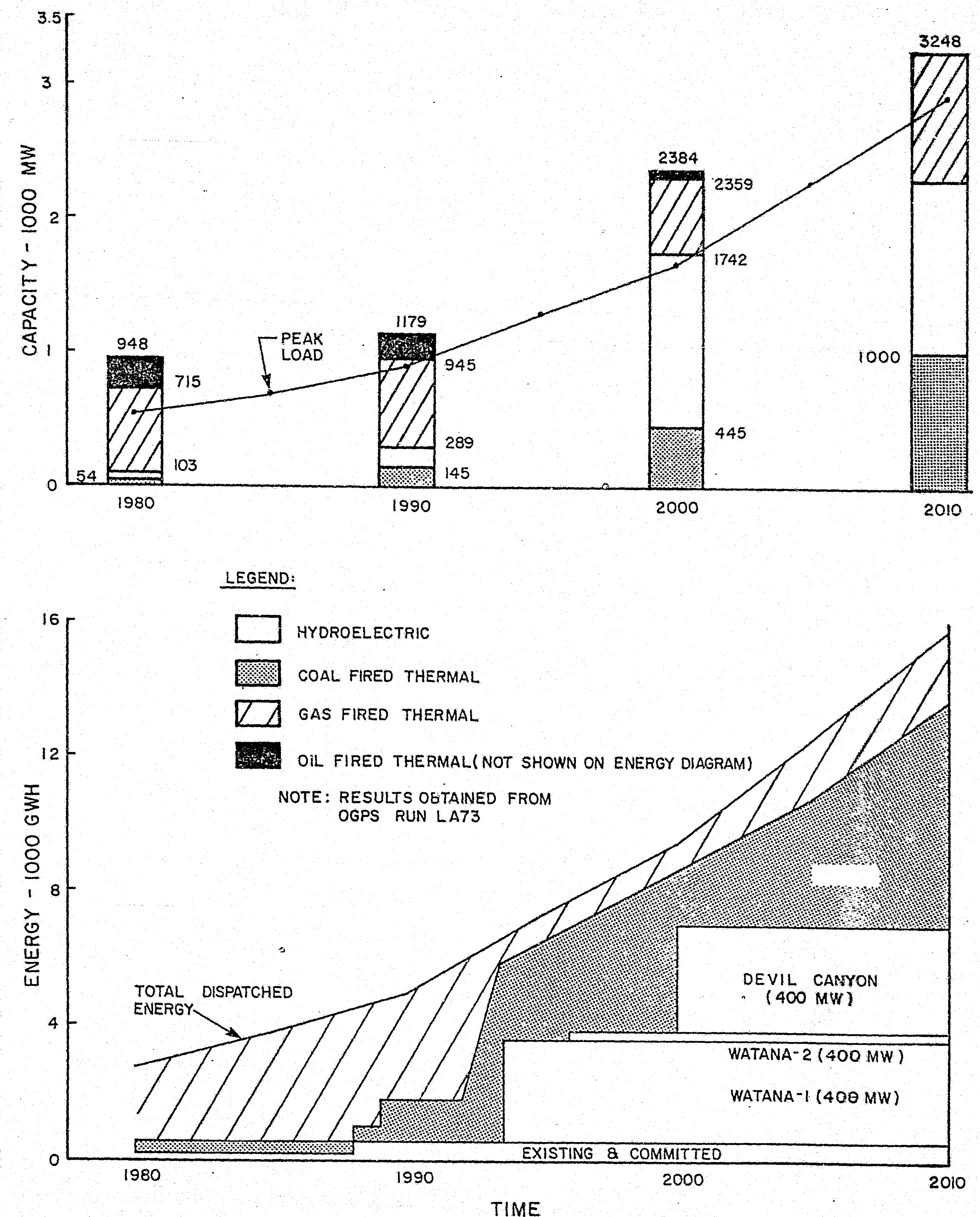
ACRES



GENERATION SCENARIO WITH SUSITNA PLAN E1.5
- LOW LOAD FORECAST -

FIGURE 8.12

ACRES



GENERATION SCENARIO WITH SUSITNA PLAN E1.3
HIGH LOAD FORECAST

FIGURE 8.13

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