BRADLEY LAKE

HYDROELECTRIC POWER PROJECT

FEASIBILITY STUDY

VOLUME 1
REPORT

OCTOBER 1983

Stone & Webster Engineering Corporation

ALASKA POWER AUTHORITY

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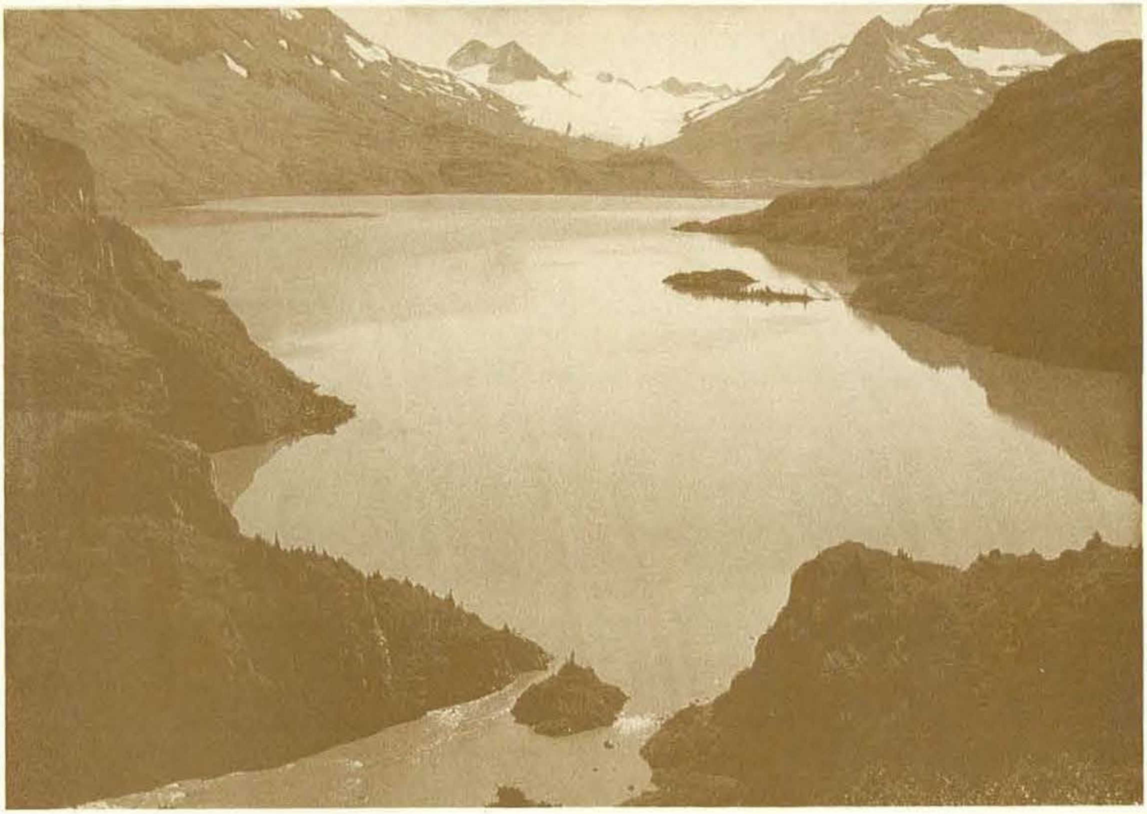

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CERTIFICATIONS

BRADLEY LAKE HYDROELECTRIC POWER PROJECT

FEASIBILITY STUDY

The technical material and data contained in this report and its Appendices were prepared under the supervision of the following individuals and organizations:

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Appendix B - Phase I Feasibility Study, Final Report	Victor J. Gretzinger Project Manager R&M Consultants, Inc.
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This study was prepared under the supervision and direction of the undersigned whose seal as professional engineer is affixed below.

Robert J. Conlon
Principal-In-Charge
Stone & Webster Engineering Corp.

BRADLEY LAKE HYDROELECTRIC POWER PROJECT
FEASIBILITY STUDY

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EXECUTIVE SUMMARY

1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

The role that Bradley Lake Hydroelectric Project will play in meeting the electrical needs of the State of Alaska has been under study for some time. Study of the Bradley Lake Project was initially authorized by the Federal Government in 1962 and since then, many studies and evaluations have been performed by the U.S. Army Corps of Engineers (COE) to determine the technical and economic feasibility of developing the power potential of Bradley Lake. The State of Alaska became directly involved in 1981 when the Alaska Legislature appropriated funds to initiate construction of the project. In 1982 the Legislature authorized the Alaska Power Authority to assume the development of the project, and in October 1982, the Power Authority's Board of Directors authorized pursuing design and construction of the project by the Power Authority.

Shortly after assuming the responsibility for the Bradley Lake Project, the Power Authority issued a Request for Proposal in November 1982, soliciting professional services for the engineering and design work of the Bradley Lake Hydroelectric Project. Stone & Webster Engineering Corporation (SWEC) was selected as the Architect/Engineer and this selection was approved by the Board of Directors on March 14, 1983. The Power Authority contract with SWEC, dated April 20, 1983 required that, prior to the initiation of engineering and design, a feasibility study be performed to re-evaluate the technical and economic feasibility of the project. These efforts were designated as Phase I - Feasibility Study, and had the following objectives:

- o Ascertain the technical feasibility of the project in sufficient detail to eliminate all major uncertainties.

- o Select the most attractive size plant and scheme of development for the Bradley Lake Hydroelectric Project.

- Determine the role that a Bradley Lake Hydroelectric Project will have as a power development in the overall energy plans for the State of Alaska and evaluate the economic merits of the project as compared to alternative generation in the State.

1.2 BRADLEY LAKE PROJECT FEASIBILITY STUDY

Beginning in April 1983 SWEC organized the scope of work of the Feasibility Study under the following work tasks:

- Data Collection
- Review of Data
- Technical Review Board
- Conceptual Design of Common Items
- Conceptual Design of 60 MW, 90 MW and 135 MW Plants
- Evaluation of Construction Facilities
- Quantity Development and Construction Cost
- Power Study and Economic Analysis Approach
- Geotechnical Investigations
- Instream Flow Studies
- Transmission Lines
- Selection of Preferred Plan
- Feasibility Report

All of the above work tasks were pursued to completion. The data collection and review process resulted in a thorough understanding of previous work and identified areas requiring further investigation. Previously identified areas of concern were evaluated and feasible solutions pursued. Conceptual engineering and design efforts permitted the assessment of previous concepts and the implementation of new innovative ideas. Geotechnical work resolved foundation uncertainties and hydrologic and instream flow studies substantiated the energy capabilities of the development. Cost and economic evaluations confirmed the economic merits of the Bradley Lake Hydroelectric Project.

1.3 RECOMMENDED PLAN

The recommended plan developed for the Bradley Lake Project would use water stored at the lake and the effective pressure head between the lake and Kachemak Bay to generate electricity. A dam, at the outlet of the lake, will impound water and raise the lake level thereby increasing the effective generating head. Additional water is provided with the diversion of natural flows from the Middle Fork drainage basin to Bradley Lake. Stored water is conveyed to the generating facilities through a concrete lined tunnel and a buried penstock power conduit. The power generating facilities are housed within an above ground enclosed powerhouse located at the eastern shoreline of Kachemak Bay. Two separate and parallel transmission lines, each about 20 miles long, connect the project to a transmission line to be constructed by others. Table 1.3-1 gives a summary of the salient Technical Data for the project development.

1.4 PRINCIPAL FEATURES OF RECOMMENDED PLAN

Access Facilities

The prime access to the site during construction of the project and later during project operation will be by water using an access channel and barge basin. Additional access is provided by an airstrip located in the vicinity of the powerhouse. Helicopter pads are also located at key areas within the Project boundaries. Access roads are provided to serve the project during construction and permanent operation. Three road networks have been established: one network serves the airstrip, powerhouse, dock, staging area and lower camp; a second network will connect the lower camp to the upper camp and continue to the dam area; and a third network will allow access to a construction borrow area.

Dam and Spillway

A concrete faced rockfill dam with an ungated concrete gravity spillway is to be constructed at the outlet of Bradley Lake. These structures will impound the natural inflows and allow raising the present lake level by about 100 feet to elevation 1,180. The dam crest is set at elevation 1,190 and the total top length is about 605 feet. The maximum dam height above its foundation is about 125 feet. Upstream and downstream cofferdams are provided for construction of the main dam.

The reservoir impounded by the dam will contain an active storage of about 284,000 acre-feet at normal operating pool elevation 1,180 with a surface area of about 3,820 acres.

An ungated concrete gravity overflow spillway is located over the bedrock saddle formation at the right abutment area of the lake outlet. The spillway has an ogee set at elevation 1,180 with a crest length of 165 feet. The length of the spillway including abutments is approximately 230 feet. The spillway is designed to pass the Standard Project Flood, as well as the Probable Maximum Flood.

Construction Diversion

Diversion of the natural outflow from Bradley Lake during construction of the main dam and other structures at the lake outlet will be accomplished by a horseshoe shaped tunnel excavated through the right rock abutment, approximately 100 feet east of the lake outlet. The 470 foot long tunnel will discharge into the large natural pool downstream of the main dam. A concrete intake portal will be constructed with provisions for steel bulkhead gates.

Permanent Outlet Facilities

Permanent outlet facilities will be incorporated into the construction diversion tunnel. The outlet facilities will serve as low level outlets providing for emergency drawdown of the reservoir and diversion of flows to the Bradley River for fish habitat. Flows will be controlled by hydraulically operated slide gates.

Intake Channel

Stored water is conveyed to the power tunnel intake structure through a 50 foot wide by 360 foot long intake channel. The channel is located at the left bank area and allows the reservoir to be drawn to elevation 1060.

Power Conduit

The power conduit includes all water passage structures that are used to bring water from Bradley Lake to the Kachemak Bay Powerhouse. From an intake structure provided at Bradley Lake, a 18,820 feet long, 11 foot diameter underground power tunnel connects Bradley Lake to the powerhouse. Located about 800 feet downstream of the intake structure is a circular shaped gate shaft which contains two hydraulically operated gates for emergency closure of the power conduit. The concrete and steel lined tunnel connects to a buried steel penstock at the tunnel portal near the powerhouse. The steel penstock then bifurcates into 8 feet diameter steel branches leading to the hydraulic turbine generating units. Each branch is equipped with a spherical valve located immediately upstream of the units.

Powerhouse and Tailrace

The powerhouse is located near sea level on the eastern shore of Kachemak Bay. The powerhouse will contain two Pelton hydraulic turbine generating units having a combined rating of 107 MW. Each unit is capable of generating 45 MW at minimum head with a nominal operating speed of 300 rpm. The powerhouse substructure is constructed of reinforced concrete which is enclosed with an insulated steel superstructure. The tailrace is an excavated trapezoidal unlined channel approximately 100 feet long extending from the powerhouse into the tidal flats.

Substation and Transmission

The substation is located adjacent to the northeastern end of the powerhouse and is rated 115,000 volts, 3-phase, 60 Hz. It contains the main power transformers, circuit breakers, disconnecting switches, and line takeoff towers.

Power from the Bradley Lake substation is carried via two parallel 115 kV transmission lines. These lines are constructed using wood pole, H-frame structures and aluminum conductors, steel reinforced. Each line is designed to transmit the full output of the plant, in the event one line is lost. The Bradley Lake lines are connected to another 115 kV transmission line which transmits power between Soldotna and Fritz Creek. The connection to this line, at a location called Bradley Junction, is about 20 miles from the power plant.

Middle Fork Diversion

The Middle Fork Diversion is located approximately one mile northeast of Bradley Lake in an adjacent basin, and provides seasonal diversion of water into Bradley Lake. The diversion scheme consists of a 20 feet high embankment dam and 1,900 feet of 6 feet diameter steel conduit. Other features include a spillway and bypass conduit which will be used initially for construction diversion and later to divert the natural winter flows downstream into the Middle Fork.

1.5 ALTERNATIVES

In arriving at the selection of the Recommended Plan of development, it was necessary to review the previous studies and to appraise various design alternatives in order to develop the most economical and sound plan of development. The major alternatives considered in the study are as follows:

Dam and Spillway

The following dam and spillway configurations were reviewed and considered:

- Concrete gravity dam incorporating a concrete spillway section
- Concrete gravity dam with a separate ungated spillway dam
- Rockfill dam with a side channel spillway
- Rockfill dam with a separate ungated spillway dam
- Double curvature arch dam
- Roller compacted concrete gravity dam
- Concrete faced rockfill dam with a separate spillway

The recommended plan includes the concrete faced rockfill dam with a separate ungated spillway dam.

Construction Diversion

Various diversion schemes were analyzed. These included tunnel arrangements through the right and left abutments at the lake outlet and also buried conduit through the main river channel. A tunnel alignment through the right abutment with diversion flow discharging into a natural stilling pool was judged the best and included in the Recommended Plan.

Power Conduit

The previous COE concept of the intake located at the right bank of Bradley Lake was reviewed for applicability. As an alternative, intake located on the left bank was analyzed and found feasible. From this location three alternative power tunnel alignments to the powerhouse were investigated. All three alignments utilized deep settings with concrete lined tunnels and buried steel penstocks. The COE concept had included a higher set tunnel with an exposed surface penstock along the hillside above the powerhouse. The lower setting for the tunnel and buried penstock was determined to be the most desirable alternative.

Powerhouse

The COE had previously investigated above and underground powerhouses and concluded that the above ground arrangement would be the most economical. SWEC concurred and investigated the above ground powerhouse only. The COE powerhouse arrangement included three generating units whereas SWEC adopted the more conventional and economical two unit arrangement as an alternative.

Middle Fork Diversion

The COE had previously investigated a steel bin wall dam, concrete gravity dam, and a timber buttress dam for diverting the Middle Fork flows. To maximize use of natural materials in the area, SWEC analyzed two variations of rockfill dams: a concrete faced rockfill and a steel sheet pile cut-off rockfill. The latter was judged the most attractive scheme and was included in the Recommended Plan.

1.6 TECHNICAL CONSIDERATIONS

The project's regional geologic setting and the hydrologic influences of its environment largely dominated the spectrum of technical considerations addressed in the study. These two areas substantially controlled the engineering and economic feasibility of the more salient features of the project.

Geology

The Bradley Lake Project is located in an area of the Kenai Mountains which is composed primarily of mildly metamorphosed argillite and graywacke rock. These rocks have been uplifted and deformed from past seismotectonic activity and shaped by continuous erosional processes.

The two major geologic features within the project site are informally known as the Bradley River and Bull Moose Faults. Although no direct evidence of recent activity along these or regional faults is known, all are considered capable of independent earthquake generation. Statistical analysis of the magnitude of historical ground motion from earthquakes indicates that earthquake accelerations ranging from 0.3g to 0.75g should be used in the final design of the major surface structures. Evidence gathered to date has not revealed any geologic features with potential for ground displacement at the main dam or powerhouse. Although the potential for ground shifting associated with large earthquakes exists along the power tunnel alignment at the two major faults, it would be possible to repair any resulting damage.

Hydrology

The intensity and seasonal distribution of storms producing precipitation within the Bradley Lake drainage basin reflect the maritime climate of the region. The runoff response from rainfall precipitation, which is influenced largely by the geologic conditions, exhibits a rapid rise in streamflow, with little flow going into groundwater storage. Recorded streamflow data at the Bradley Lake outlet consequently reflects the maritime influences and geologic conditions of the basin. Analysis of these data indicate that highest streamflows occur during May through October. Snow and glacial melt water contribute a substantial portion during the spring and summer months and rainfall contributes to streamflow during the fall months. Flood peaks during this period have exceeded 5,000 cfs, however, streamflows during the drier winter period, seldom exceed 75 cfs.

To account for possible future changes in streamflows and its effect on power production of the project, the historical streamflow record required several adjustments for glacial influences. Initial adjustments were made to the first half of the records to reflect Nuka Glacier runoff being redirected into the Bradley Lake drainage basin. Other adjustments were then made to the entire record to reflect both historical and potential climatic effects of the glaciers on streamflow. Although these adjustments resulted in noticeable yearly fluctuations in streamflow in comparison with the initial adjustments, the overall effect of the more conservative glacial adjustment on annual energy production was found to be a reduction in generated energy of less than 2 percent.

The Probable Maximum and Standard Project Floods as developed by the COE were used in this study without modifications. The floods have peak inflows of 31,300 cfs and 14,400 cfs, respectively.

1.7 ENGINEERING AND ECONOMIC EVALUATIONS

Various engineering studies and economic analyses were conducted in selecting the most attractive scheme of project development. In pursuing this goal, previous work and findings were reviewed and new ideas and concepts developed in the preliminary stages of the feasibility study. A screening process was established which identified the more promising alternatives and project features for further evaluation. These evaluations included engineering and operating considerations as well as cost comparisons and economic appraisals.

A list of alternatives and project features used in comparative evaluations together with the sequence in which they were studied follows.

- o Use of Tunnel Boring Machine for power tunnel excavation
- o Economical power tunnel diameter
- o Francis or Pelton turbine/generator equipment
- o Middle Fork Diversion facilities
- o Rockfill vs. concrete gravity main dam
- o Plant capacity
- o Bradley Lake reservoir operating levels

These features as well as the alternatives, which affect the economic benefits of the project, were evaluated using computer simulations and a matrix developed of energy potential versus alternatives. Economic benefits were then computed and compared with estimated costs together with engineering and environmental considerations to arrive at the preferred plan for development of the project.

1.8 ENVIRONMENTAL ANALYSES

The Bradley Lake Hydroelectric Project is in an area of high peaks, glacier, wildlife and sub-alpine terrain. The area is inhabited by a diversity of wildlife species. Although the site itself is free of human habitation, the project can be constructed with minimal impact and will provide benefits serving the population of the Kenai Peninsula and the developing area of south central Alaska.

The Corps of Engineers' (COE) environmental studies identified the effects of developing the Bradley Lake Project on biological and socio/cultural resources, and addressed these in its Final Environmental Impact Statement (FEIS) issued in August 1982. Areas of environmental concern, identified in the FEIS, are slow releases for downstream fish habitat; resolution of access to the project; rehabilitation of the Martin River borrow area; plans for developing waterfowl nesting; and assessment of moose migrations.

Since the SWEC Recommended Plan is essentially similar to the COE's preferred plan for Bradley Lake, there should not be other unresolved issues or impacts. In fact, the SWEC Plan reduces the environmental impacts with the following eliminations:

- The 2800 foot long above ground penstock extending from the powerhouse to the tunnel portal.
- The two mile access road from the powerhouse to the tunnel portal.
- Surge shaft and associated access road.
- Exposed steel penstock and bridge as required for the power tunnel crossing over the Bradley River.

Further, and as part of this feasibility study, instream flow studies have been conducted to assess downstream fish habitat; means of access to the project were re-assessed; plans are being considered for developing waterfowl nesting and for the rehabilitation of the Martin River borrow area; and a program for studying moose migrations is being planned for early implementation. Data from the instream flow studies show that fish habitat at the lower Bradley River can be maintained by regulating river flows or even improved. The re-assessment of providing project access, by means other than the preferred plan, showed that alternatives would either present greater environmental impacts, cost more, or both. Mitigation of waterfowl nesting and for the Martin River borrow will be developed as part of the license application effort to the Federal Energy Regulatory Commission (FERC). The assessment of moose migratory habits has been authorized and will be implemented as part of other project development efforts.

Some further assessment and environmental evaluation work may be required in relation to the proposed transmission line and upper camp area.

1.9 PROJECT SHCEDULE

The Project Schedule extends over a five year period with the initial construction activities dependent on the award of a FERC License. Receipt of the FERC License is anticipated in May 1985, with commercial operation of the units scheduled for October 1988 and completion of the project by the end of 1988. Should award of the FERC License be delayed, seasonal scheduling problems will ensue, and the project schedule including the commercial operation dates, will be delayed.

The engineering and design is scheduled to commence in February 1984, coincidental with the submittal of the FERC License Application to the Regulatory Commission. The construction schedule for the Bradley Lake project is predicated on three major construction contracts (1) General Civil Contract; (2) Powerhouse Contract and (3) Transmission Line Contract. Several major equipment supply contracts such as hydraulic turbines, generators, governors, powerhouse crane, gates, valves, pumps and electrical accessory equipment will be awarded separately to support engineering-design needs and delivery dates to meet the required construction erection schedule.

1.10 PROJECT COST ESTIMATES

The Overnight Cost Estimate for the preferred 90 MW plan is $283,019,000. This cost includes: direct material, labor, and construction equipment; engineering and design cost; cost for the management of construction; Owner's cost including previous expenditures realized for project studies and development; land and land rights cost; all risk insurance; and a contingency of 25 percent. The Overnight Cost Estimate refelcts cost as of July 1983.

1.11 POWER STUDIES AND ECONOMIC EVALUATION

The objectives of the power study and economic evaluation of the Bradley Lake Project were to identify the economic advantages or disadvantages of the Project for the Railbelt and to select the preferred plant capacity. Several variations in Railbelt generation expansion plans were evaluated. Separate analyses were performed for generation expansion plans using thermal power plants (gas-fired combined cycle, gas-fired combustion turbine, and coal-fired steam turbine), the Susitna Hydroelectric Project combined with thermal plants, and the Bradley Lake Project (with and without Susitna) for the three proposed project capacities of 60MW, 90MW, and 135MW. Also, sensitivity studies were performed to determine the effect of variations in the Railbelt load growth rate on the economic performance of the Bradley Lake Project.

The primary tool used in this evaluation was a computer program developed for the Electric Power Research Institute. This program, Electric Generation Expansion Analysis System, provided the capability to automatically develop electric generation expansion plans based on the characteristics and costs of alternative generation sources, existing unit characteristics and retirement dates, and electric load data. The total present worth cost for each generation expansion plan was determined, with the lowest cost plan being the optimum.

This computer program was also used to perform a two-area analysis where reserve sharing and economy interchange were modeled between the Kenai Peninsula and the remainder of the Railbelt. This analysis was used to apportion costs between the two regions and to evaluate the effect of transmission limitations between Anchorage and the Kenai Peninsula on the present worth costs of the generation expansion plans. An assessment of the differences in transmission costs associated with generation expansion plans including and not including the Bradley Lake Project was essential to the power study.

The primary data source for the study was the Harza-Ebasco Susitna FERC application of July 1983. Information derived from this document included items such as fuel prices and escalation rates, new generation alternatives, Susitna characteristics, and existing generation units in the Railbelt. The Reference Case Railbelt electric load forecast used in the Bradley Lake study was also derived from this source. The Reference Case forecast, titled "Sherman H. Clark Associates NSD Case," has an average annual compound load growth rate of about 2.8 percent for the period 1983 through 2007.

The power study and plant capacity selection were based on Bradley Lake capital costs and average anual energy values developed during the feasibility stage evaluations. These plant parameters included the following:

Bradley Lake Capacity, MW	Capital Cost,* Millions 1983$	Average Annual Energy, GWH
60	275.70	330.5
90	287.95	345.4
135	303.50	356.6

* Includes IDC.

The power study evaluations indicate that the Bradley Lake Project is economically beneficial for the Railbelt at any of the three proposed plant capacities, both with and without the presence of Susitna. The optimum capacity for Bradley Lake is dependent on and sensitive to the projected load growth rate for the Railbelt. The differences in present worth cost between the three proposed capacities for alternative load growth projections are relatively small.

For the Reference Case load projection, the 90MW Bradley Lake Project shows the largest net benefit for the Railbelt without the presence of Susitna, while the 60MW and 90MW Bradley Lake Projects exhibit approximately equal benefits when Susitna is present. The Reference Case present worth costs for the cases without Susitna are as follows:

	Present Worth, Millons 1983$			
	Total Railbelt		Kenai Peninsula	
Bradley Lake Capacity, MW	Total Cost	Savings Due to Bradley Lake	Total Cost	Savings Due to Bradley Lake
0 (Base Case)*	5,832	---	904	---
60	5,517	315	605	299
90	5,464	368	599	305
135 *	5,535	297	695	209

*Includes 230 kV Anchorage/Soldotna transmission line.

For the total Railbelt, the Bradley Lake savings range from 5.1 to 6.3 percent of the base case present worth cost. The savings for the Kenai Peninsula alone (taking into account reserve sharing and economy interchange with the rest of the Railbelt) varied from 23.1 to 33.7 percent of the base case. The Reference Case present worth costs for the cases including Susitna are as follows:

	Present Worth, Millons 1983$			
	Total Railbelt		Kenai Peninsula	
Bradley Lake Capacity, MW	Total Cost	Savings Due to Bradley Lake	Total Cost	Savings Due to Bradley Lake
0 (Base Case)*	5,724	---	674	---
60	5,548	176	531	143
90	5,549	175	523	151
135 *	5,658	66	624	50

*Includes 230 kV Anchorage/Soldotna transmission line.

With Susitna, the Bradley Lake savings range from 1.2 to 3.1 percent for the total Railbelt and from 7.4 to 22.4 percent for the Kenai Peninsula alone.

Two sensitivity cases were evaluated to determine the economic impact on Bradley Lake if the Railbelt electric load growth is less than the Reference Case. The two cases included an assumed load growth of zero percent per year (with the Reference Case fossil fuel price projections) and a load growth and fossil fuel price projection titled "DOR 50% Case."

For the no-growth sensitivity study, the 1983 Railbelt electric load was assumed to remain constant for the study period. The present worth costs, for the total Railbelt without Susitna, are as follows:

Bradley Lake Capacity, MW	Present Worth, Millions 1983$ Total Cost	Savings Due to Bradley Lake
0 (Base Case)	3,194	---
60	2,966	228
90 *	2,990	204
135 *	3,010	184

*Includes 230 kV Anchorage/Soldotna transmission line.

The 60MW Bradley Lake Project is the preferred capacity under a no-growth scenario.

The second sensitivity study using the July 1983 "DOR 50% Case" was performed for only two generation expansion plans. These plans without Susitna included a base case (new thermal plants) and a case with the 90MW Bradley Lake Project plus thermal plants. The results are as follows:

Case	Present Worth Cost Millions 1983$
Base *	3,461
90MW Bradley Lake	3,305

* Includes 230kV Anchorage/Soldotna transmission line.

Under the "DOR 50% Case," the installation of the 90MW Bradley Lake Project results in a present worth savings of about $156 million for the total Railbelt.

Lastly, an evaluation was performed for the selected 90 MW Bradley Lake Project to determine the economic effect of changes in the feasibility stage values for plant capital cost and average annual energy. After selection of the 90 MW plant as the preferred capacity, detailed reviews of the plant capital cost and average annual energy were performed by SWEC. As a result of these reviews, the 90 MW plant capital cost was increased from $287.95 million to $300 million (1983 dollars including IDC), and the average annual energy was increased from 345.4 GWH to 369.2 GWH. The 90 MW Bradley Lake Project was reevaluated with these revised parameters under the Reference Case load and fossil fuel price projections. The resulting present worth costs (without Susitna) are as follows:

	Present Worth, Millions 1983$	
	Total Cost	Savings Due to Bradley Lake
Base Case	5,832	-
90 MW Bradley Lake Project	5,455	377

As before, significant life-cycle savings result by using the selected 90 MW Project in place of thermal generation alternatives for the Railbelt. The selected 90 MW Project present worth cost is slightly lower than the value associated with the feasibility stage plant, indicating that the increase in capital cost is more than offset by benefits from the additional average annual energy generated.

1.12 FINDINGS AND RECOMMENDATIONS

Findings

The major aspects of developing the Bradley Lake site have been reviewed and analyzed during this Feasibility Study. Conceptual design drawings have been developed, alternative designs evaluated, construction costs estimated, and the cost benefits of the three sizes of plants measured against alternative types of generation. The results are reflected in the Recommended Plan. The main findings are:

- The 60 MW, 90 MW, and 135 MW Pelton plants produce about the same average annual energy, however, based on given load growth criteria, the 90 MW plant is the most economical choice for developing the project.

- The level Bradley Lake should be raised some 100 feet for added benefits. Of the three maximum operating levels of the lake studied, elevation 1170, 1180 and 1190, elevation 1180 was judged as the most attractive.

- The most economical method to raise the level of Bradley Lake, is to construct a concrete faced rockfill dam at the mouth of the lake and a separate concrete ogee spillway at the right abutment.

- The power tunnel between Bradley Lake and the powerhouse can be bored with a tunnel boring machine and/or conventional techniques which are both technically feasible.

- Geotechnical considerations and findings show that acceptable foundation and rock conditions exist at the locations of proposed project structures.

- The Pelton type turbine is preferred, mainly because of lower project costs and the ability to follow greater fluctuations of peak power loadings.

- An above ground powerhouse containing two generating units is preferred.

- The Middle Fork Diversion, used to divert seasonal flows into Bradley Lake, is economically viable.

- Diversion for construction is technically feasible by a tunnel through the right abutment. Also, this tunnel can be converted into a permanent outlet facility for downstream releases after construction.

- Land and land rights should pose no problems for construction of the Bradley Lake Hydroelectric Project, as the majority of the project lands were withdrawn in 1966 by Public Land order 3953 for the purposes of development of the project. The withdrawal included about 40,000 acres of Federal lands, whereas the project reservoir and structures require approximately 4,500 acres with the remaining used for protection of the watershed.

- The power plant output should be transmitted over a two circuit 115 kV transmission line system with each line capable of handling the full plant load. The selected 90 MW plant will not require another transmission line between Soldotna and Anchorage as the existing 115 kV line is capable of providing reserve sharing and economy interchange between Anchorage and the Kenai Peninsula.

- The project can be developed in a manner that is responsive to environment and impacts and known environmental concerns can be resolved .

- The project cost estimates and the economic evaluation shows that:

  - The Recommended Plan of the 90 MW can be developed at an estimated overnight cost of $283,019,000, July 1983 price base.

  - Economic evaluations of the 90 MW installation shows that the Bradley Lake is economically beneficial for the Railbelt, both with and without the presence of the proposed Susitna Hydroelectric Project.

Recommendations

Based on the above findings it is recommended that:

- The project be developed using two Pelton hydraulic turbines to generate a minimum of 90 MW, a concrete faced rockfill dam, a machine bored concrete lined tunnel, the Middle Fork diversion and a two circuit parallel transmission line.

- To avoid lengthly delays and subsequent potential cost increases, the Power Authority should proceed with the Bradley Lake Project by initiating the preparation of a FERC License Application.

- Unresolved environmental concerns and issues should be addressed during the early stages of FERC License Application preparation.

TECHNICAL DATA

BRADLEY LAKE HYDROELECTRIC PROJECT

(Based on Recommended Plan of Development)

PROJECT FEATURES:

Reservoir

Elevation of existing lake surface, feet	1,080
Elevation of normal full pool water surface, feet	1,180
Elevation at minimum operating pool, feet	1,080
Elevation at emergency drawdown, feet	1,060
Elevation at Spillway Design Flood, feet	1,190.6
Area of reservoir at full pool, acres	3,820
Area of reservoir at minimum pool, acres	1,568
Initial active storage capacity, acre-feet	284,150
Additional storge for emergency generation, acre-feet	31,200

Bradley Lake Dam

Type	Concrete Faced Rock Fill
Length, feet	605
Height of maximum section, feet	125
Top of dam elevation, feet	1,190

Bradley Lake Spillway

Spillway type	Ungated Ogee
Spillway crest elevation, feet	1,180
Gross spillway length, feet	230
Spillway crest length, feet	165

Power Tunnel

Length, (concrete & steel lined), feet	18,820
Nominal Diameter (lined), feet	11
Intake invert elevation, feet	1,030

TABLE 1.3-1

TECHNICAL DATA

BRADLEY LAKE HYDROELECTRIC PROJECT

(Based on Recommended Plan of Development)

Steel liner & Penstock

Liner	
Type	Embedded
Outside Diameter, feet	11
Length, feet	2,400
Material	ASTM A710
Min. Yield Strength, psi	85,000
Penstock	
Length, feet	135
Outside diameter at portal feet	11
Material	ASTM A710
Min. Yield Strength, psi	85,000
Diameter of Bifurcation, feet	8.0

Powerhouse

Plant, KVA (Nameplate rating)	112,600
Number of Units	2
Type of Turbine	Pelton
Turbine Rating at 1130 feet rated net head, Hp	73,900
Rating of Generating Unit, KVA (nameplate)	56,300
Maximum Operating Pool Elevation, feet	1,180
Minimum Operating Pool Elevation, feet	1,080
Maximum Tailwater Elevation, feet	11.4
Minimum Tailwater Elevation, feet	- 6.0
Centerline Turbine Runner Elevation, feet	15.0
Bottom of Turbine Chamber, feet	- 6.0
Unit Spacing, feet	43.0

Project Generation

Flow regime is Bradley River, Middle Fork diversion, and releases for fish habitat.

Yearly firm energy	334.1 GWH
Average annual energy	369.2 GWH

TABLE 1.3-1

TECHNICAL DATA

BRADLEY LAKE HYDROELECTRIC PROJECT

(Based on Recommended Plan of Development)

Switchyard and Transformers

Type	Conventional
Generator Bus	
Type	Copper conductor Non-segregated Phase
Rating	15000 volts; 3000 amps Continuous; 80,000 amps Momentary
Enclosure	
In powerhouse	Ventilated
Outside powerhouse	Enclosed; weatherproof
Main transformers	
Number	2
Rating	OA/FA/FA 33.8/45/56.3 MVA Three phase, 60 Hz
Circuit Breaker	
Number	3
Type	Oil
Rating	1200 amps

Transmission Line

Line number	2 parallel
Type	H-Frame Wood Pole
Voltage, kilovolts	115
Conductor size, KCM, ACSR; "Dove"	556.5
Overall length overhead section, miles	20

Tailwater Data For Powerhouse

TIDES	BEAR COVE MLLW DATUM	BEAR COVE MSL DATUM	BRADLEY PROJECT DATUM
HT	25.00	15.39	11.37
MHHW	18.17	8.56	4.78
MHW	17.60	7.99	+ 3.87
MSL	9.61	0.00	- 4.02
MLW	1.61	- 8.00	- 12.02
MLLW	0.00	- 9.61	- 13.63
LT	- 6.00	- 15.61	- 19.63

Unless otherwise noted, all elevations given are based on project datum.

TABLE 1.3-1

2
INTRODUCTION

2. INTRODUCTION

2.1 PROJECT LOCATION AND SETTING

The proposed Bradley Lake Hydroelectric Power Project would be located on the Kenai Peninsula, about 105 miles south of Anchorage, Alaska. Bradley Lake, with a natural elevation of about 1080 feet, is located in the Kenai Mountain range. Geographically, Bradley Lake is about 27 miles northeast of Homer, Alaska. Access to the project site is limited at present to boat at high tide, or helicopter.

The Kenai Mountains, above an elevation of 3,000 feet, have been eroded by glaciers and form rather rough terrain characterized by cirques, horns, and deep U-shaped valleys. Above this elevation, the mountains are covered principally by glaciers, except for scattered peaks which protrude above the ice. Valley glaciers are present in the upper reaches of most valleys and in some cases are a major source of water for rivers, lakes and streams on the lower Kenai Mountain slopes.

The Bradley Lake area, with steep sloped reliefs reaching 4,300 feet, is dominated by the lake and gorge of the Bradley River. The lake is about 3 miles long and varies from 0.2 mile to about 1.2 miles in width. The maximum depth of the lake is about 268 feet. Except for the southeast portion of the lake, where Kachemak Creek and the Nuka Glacier flow into the lake, the land rises abruptly from the lake shore, with some portions nearly vertical.

Bradley Lake inflow is derived principally from rainfall and snow melt with some contribution from glacier melt of the Kachemak and Nuka glaciers. Outflow from the lake flows northwestward into the Bradley River. The river flows in a gorge which is between 725 feet and 1,200 feet deep and up to 750 feet wide. The river channel passes through several very narrow reaches, which include rapids and waterfalls, before reaching the floodplain and tidal flats of Kachemak Bay.

The project site area is considered to be located in a major earthquake region, with recorded earthquake magnitudes of 6.0 - 6.9 on the Richter Scale. Several historical earthquakes have occurred within a radius of 500 miles of Bradley Lake.

The area of the Kenai Peninsula is strongly influenced by the maritime climate that prevails along coastal regions adjacent to the Gulf of Alaska. Cool summers and moderate winter temperatures prevail, with occasional winter intrusions of cold Arctic air masses. Fog, rain, and clouds occur frequently in the area and gusty, turbulent winds are common in the upper basin and near Kachemak Bay. Precipitation is light during late winter and early spring, and increases to maximum amounts from August through December, varying with geographic location and elevation. Precipitation in the lower elevations is predominately rain with upper elevations receiving snow. The project area is moderately forested with white spruce, birch, aspen, and willow along the areas adjacent to Kachemak Bay. Areas above an elevation of about 1,000 feet have very little growth and are essentially barren. The entire Kenai Peninsula area has been classified as being generally free from permafrost.

The waters of Kachemak Bay are subject to tidal fluctuations of up to about 23 feet. Although some ice forms, the bay is essentially open. Bradley Lake surface waters begin to freeze by early winter and ice cover stays on the lake till late April or early May. Ice thickness varies as a mixture of slush and solid ice, with an estimated solid ice thickness of about 28 inches.

The Bradley Lake area encompasses several fish and wildlife habitat areas. The area has a high diversity of species and the Fox River Flats, comprising the estuarine areas of the Fox, Sheep, and Bradley Rivers, at the head of Kachemak Bay, has been designated as "critical habitat area".

2.2 BACKGROUND AND PAST STUDIES

Many studies and evaluations have been performed over the years to determine the technical and economic feasibility of developing the Bradley Lake drainage system into a hydroelectric power project. Most of this work was conducted by the Corps of Engineers (COE) and various architect/engineering firms subcontracting to the COE. The bibliography contained in this report provides a listing of the studies previously performed on the Bradley Lake development.

Study of the Bradley Lake Project was initially authorized by the Federal Government in 1962. Engineering, design, economic and other studies were undertaken by the COE. The results of the COE findings and recommendations are presented in a series of Design Memoranda, culminating with the issuance of the General Design Memorandum No. 2 in February, 1982. This later memorandum was issued in two volumes, Volume 1, "Main Report" and Volume 2, "Appendices". The COE studies and findings concluded that the Bradley Lake Project is technically feasible, and economically attractive. The COE recommended the development of a project with 135 MW of capacity, utilizing three Francis type hydraulic turbine units to generate up to an average annual energy of about 356 GWH. This installation was preferred over two other alternatives studied, namely a 60 MW and a 90 MW plant. Substantial work was accomplished by the COE and its subcontracting firms in collecting base line data relating to both environmental and technical aspects of the recommended project. The environmental efforts resulted in the preparation and issuance of a Final Environmental Impact Statement, dated August, 1982. The COE had reached the milestone for initiating definitive engineering-design; however, due to lack of funding, work on the project could not continue to completion.

The involvement of the State of Alaska with the project commenced in 1981 at which time the Alaska legislature appropriated funds to initiate construction of the project. Later, in 1982, the state legislature appropriated additional funds, and authorized the Alaska Power Authority to assume the development of the project. The Power Authority's Board of Directors, in October 1982, authorized the design and construction of the project by the Power Authority. Federal legislation deauthorizing the project was passed in December, 1982.

Additional studies were performed by the Power Authority on costs, project economic and other factors to further assess project feasibility. Key studies included cost estimates by the firm of Ebasco Services, Inc., and project-economic assessments by the firm of R.W. Beck and Associates, Inc..

2.3 THE BRADLEY LAKE FEASIBILITY STUDY

Shortly after assuming the responsibility for the Bradley Lake Project, the Power Authority issued a Request for Proposal (RFP) - APA-83-R-027, on November, 1982, soliciting professional services for the engineering and design work of the Bradley Lake development essentially as recommended by the COE. Stone & Webster Engineering Corporation (SWEC) was selected and this selection was approved by the Power Authority Board of Directors in March 1983. The SWEC contract with the Power Authority required that, prior to the initiation of definitive engineering-design work, preliminary conceptual engineering-design studies be performed to re-evaluate the technical and economic feasibility of the project. These efforts were designated as Phase I - Feasibility Study and had the following objectives:

- o Ascertain the technical feasibility of the project in sufficient detail to eliminate major uncertainties.
- o Re-evaluate the previously studied installations with respect to capacity, energy and costs, and select the most attractive plant and scheme of development.
- o Determine the role that a Bradley Lake power development will have in the overall energy plans of the Power Authority and evaluate its economic merits in comparison to alternative generation mixes.

The study was to consider the impact of the project on: (1) the entire Railbelt electrification plan, (2) its affect on the Anchorage-Kenai Peninsula area, and (3) its implication on the Kenai Peninsula alone. The study was to consider "with or without Susitna" project scenario and various mixes of fossil fueled generating plants and transmission line arrangements.

The scope of services of the study included resource assessment, field surveys, and hydrologic, glacier trending, geotechnical, environmental, engineering-design, cost, and economic evaluation studies necessary to assess project feasibility. A specific objective of the study is to select a preferred installation that best responds to the energy needs of the area or areas to be served.

This report documents and summarizes the Phase I Feasibility Study efforts.

2.4 STUDY METHODOLOGY AND APPROACH

The Bradley Lake Feasibility Study included the following Scope of Work:

- Data Collection - Compiled data developed by others which are applicable to the study and distribute these data.

- Review of Data - Reviewed the information compiled, noted applicable areas and communicated and exchanged this information with project personnel.

- Technical Review Board - The project Technical Review Board contributed to conceptual development and assessed applicability of project concepts.

- Conceptual Design of Common Items - Conceptualized engineering of items that are common to the 60, 90 and 135 MW installations, including preparation of preliminary drawings.

- Conceptual design of 60, 90 and 135 MW Plants - Engineering-design efforts for the conceptual development of powerplants using two turbine-generator units for each size of plant. Each installation were developed for Francis type turbine units and Pelton type turbine units and conceptual arrangement drawings were prepared for costing efforts.

- Evaluation of Construction Facilities - Performed technical evaluations and determined costs of key facilities required to support construction activities as well as those facilities needed for permanent plant operation of the project.

- Quantity Development and Construction Cost - Performed quantity take-off of the various installations and alternatives. Developed cost estimates for comparative assessments and for use in economic evaluation studies.

- Power Study and Economic Analysis Approach - Considered modelling of base and alternative generation-transmission line power development scenarios to explore the role and economic feasibility of Bradley Lake on the Railbelt area, the Anchorage-Kenai Peninsula and on the Kenai Peninsula alone.

- Geotechnical Investigations - Collected geotechnical data and performed field explorations to support project evaluation.

- Instream Flow Studies - Collected technical and scientific data relating to affected fish habitat areas of the Bradley River.

- Transmission Lines - Developed conceptual engineering/design and cost estimates for transmission line systems associated with project development.

- Selection of Preferred Plan - Evaluation of data and study results to select a recommended installation.

- Feasibility Report - Prepared this report to present findings, conclusions, and recommendations.

All of the above activities were pursued to completion. The data collection and review process resulted in a thorough understanding of previous work. The review process identified areas requiring further investigation. Previously identified areas of concern were evaluated and feasible solutions pursued. Conceptual engineering and design efforts permitted the assessment of previous concepts and the implementation of new innovative ideas for project development. Geotechnical work resolved areas of major uncertainties; specifically in the development of the power tunnel and dam. Hydrologic and instream flow studies substantiated the energy capabilities of the development. Cost and economic evaluations confirmed the feasibility of the Bradley Lake Hydroelectric project.

The goal of the above described feasibility study was to arrive at a selection of the most attractive plant size and scheme of development. This was achieved, and Stone and Webster recommended a 90 MW plant, with two Pelton type hydraulic turbines, be the selected scheme of development for the Bradley Lake Hydroelectric Project. The Overnight estimated cost of this selected scheme is $283,019,000. The scheme of development includes a concrete faced rockfill dam, a machine bored tunnel, the Middle Fork diversion and a scheme for augmenting flows for aquatic habitat. The recommended scheme does not require a Soldotna/Anchorage transmission line as the existing 115 kV line is capable of providing reserve sharing and economy interchange between Anchorage and the Kenai Peninsula for the 90 MW Bradley Lake installation.

2.5 STUDY PARTICIPANTS

Assisting SWEC in studying the feasibility of the Bradley Lake Project were the following Alaskan firms who contributed to the study work in the areas indicated:

- Woodward-Clyde Consultants - Performance of instream flow studies and evaluation of aquatic habitat flow requirements.

- Shannon & Wilson, Inc. - Geotechnical data collection and analyses.

- R&M Consultants, Inc. - Performance of engineering-design studies and cost development relating to the various construction and civil facilities of the project.

- Dryden & LaRue Consulting Engineers - Engineering and design studies and cost development of electrical transmission lines.

2.6 REPORT ORGANIZATION

This report is arranged under the following main headings:

1. Executive Summary
2. Introduction
3. Recommended Plan
4. Alternatives Investigated
5. Technical Considerations
6. Engineering and Economic Evaluations
7. Detailed Project Description
8. Environmental Analysis
9. Land and Land Rights
10. Design and Construction Schedule
11. Cost Estimates
12. Power Studies and Economic Evaluation
13. Findings and Conclusions
14. Bibliography

In Section 1, the Executive Summary provides a synopsis of the engineering and economic evaluation studies that led to the selection of the optimum scheme of developing hydroelectric power at Bradley lake. Section 2 describes the background, location, setting, previous studies and the Stone & Webster Feasibility Study Program on the Bradley Lake Hydroelectric Project. Section 3 details the Recommended Plan and Sections 4 through 12 describe the technical, environmental and economic findings as well as the cost estimates and proposed construction schedule for building the project. Section 13 presents the conclusions and recommendations.

Reports prepared by SWEC and its subcontractors are included in the appendices. Pertinent data collected for the feasibility study are listed in the bibliography, Section 14, at the end of the main report.

3. RECOMMENDED PLAN

3.1 GENERAL

The recommended plan for development of the Bradley Lake Project uses water stored at the lake and the effective pressure head between the lake and Kachemak Bay to generate electric energy. A concrete faced rockfill dam is proposed at the outlet of the lake to impound water and increase the available generating head. Additional water is provided with the diversion of natural flows from the Middle Fork drainage basin to Bradley Lake. Stored water is conveyed to the generating facilities through a concrete and steel lined tunnel and a buried penstock power conduit. The power generating facilities are housed within an above ground enclosed powerhouse located at the eastern shoreline of Kachemak Bay. Two separate and parallel transmission lines, each about 20 miles long, connect the project to the transmission line to be constructed by Homer Electric Association. Plates 1, 2 and 3 show the location, overall features, and general plan of the project, respectively.

3.2 PRINCIPAL FEATURES OF RECOMMENDED PLAN

3.2.1 Access Facilities

The prime access to the site during construction of the project and later during project operation will be by water using an access channel and barge basin located northwest of Sheep Point. Additional access will be provided by an airstrip north of the powerhouse and helicopter pads located at key areas within the Project as shown on Plate 4.

The access channel and barge basin areas, shown on Plate 5, are formed by dredging to a bottom elevation -14. The access channel, basin and dock is capable of accommodating sea-going barges and tugs. Barge movements based upon a 10 feet draft could be accomplished on 99 percent of all high tides, or on 49 percent of all hourly tidal stages. The barge basin will allow the barges to rest on the bottom during the low tide cycle. The dock 200 feet by 50 feet. A reciprocating off-loading ramp is provided for roll-on-roll-off unloading operations. A small section of the basin will allow sheltered anchorage for a limited number of small boats.

Access roads are provided to serve the project during construction and permanent operation. Three road networks, as shown on Plate 4, have been established. One network consists of a 2.5 mile, 28 feet wide, two lane road and serves the airport, powerhouse, dock, staging area and lower camp. The second network consists of a 5.7 mile, 28 feet wide, two lane road that will connect the lower camp to the upper camp and continue on to serve the dam area. The third network is a 1.4 mile long construction type temporary access road that will allow access to the Martin River delta borrow area. Fill-borrow sections of this temporary access are 18 feet wide, one lane travelway while graded portions have a 28 foot wide, two lane, travelway. A contemplated one lane road to the surge shaft area will not be required under the recommended plan.

In general the roads are cut and fill. Surfacing gravel material will come from the Martin River borrow area. Culverts and bridges are provided as required. A portion of the road between Sheep Point and the Powerhouse is located in the tidal mud flats and will be used as a retention dike for the disposal of dredged material from the access channel and barge basin. Special rip-rap armor is provided along this section of access road for wave protection and slope stability.

3.2.2 Dam and Spillway

A concrete faced rockfill dam with an ungated concrete gravity ogee shaped spillway is to be constructed at the outlet of Bradley Lake. These structures will impound the natural inflows and allow raising the present lake level by about 100 feet to elevation 1,180. The rockfill dam structure occupies the main river channel near the lake and has a crest set at elevation 1,190 and a total top length of about 605 feet. The maximum dam height above its foundation is about 125 feet. A plan and details of the proposed dam are shown on Plates 7 and 8, respectively.

The rockfill material needed to construct the dam are quarried from a rock knoll that is located near the left abutment, upstream of the proposed dam. This excavation also facilitates the development of the intake channel. Material excavated for the preparation of dam foundations and for the spillway will be partially used in cofferdam development with the excess material placed in suitable areas along the left bank or in the main dam.

An upstream cofferdam is being provided to block off lake flows during the construction of the main dam. The cofferdam is a rockfill embankment structure with filter and impervious material dumped at its upstream face to seal off water. The structure, which has a crest height at elevation 1,100 is located immediately at the lake outlet. Material for its construction will come from the quarry area and from material removed for the preparation of the main dam foundation area.

A similar type cofferdam structure is provided downstream to block off water from entering the construction area during lake diversion. This structure is designed to be incorporated into the embankment of the main dam.

The reservoir created behind the dam will impound an active storage of about 284,150 acre-feet above a normal minimum operating pool at elevation 1,080. At the full normal operating pool of elevation 1,180, the reservoir has a surface area of about 3,820 acres. The reservoir can be drawn down to elevation 1,060 for maintenance of structures and for additional emergency generation. The additional active storage gained is about 31,200 acre-feet.

Minimum and selective reservoir clearing is being considered, as necessary for operation of the plant.

The ungated concrete gravity overflow spillway is located over the saddle formation at the right abutment area of the lake outlet, Plates 7 and 9. The spillway has an ogee set at elevation 1,180 with a crest length of 165 feet. The overall length of the spillway including its adjacent concrete abutments is approximately 230 feet. The spillway is designed to pass the routed Probable Maximum Flood under a discharge head of about 10 feet and the routed standard Project Flood under a discharge head of about 5 feet.

3.2.3 Construction Diversion

Diversion of the natural outflow from Bradley Lake during the construction of the main dam and other structures at the lake outlet will be accomplished by a horseshoe shaped tunnel excavated through the right rock abutment approximately 100 feet east of the lake outlet, Plate 7. The 22 foot diameter unlined tunnel will be 470 feet long and discharge into the large natural pool downstream of the main dam. The intake portal will be constructed of reinforced concrete with provisions for a steel bulkhead. The tunnel invert will slope downstream on a hydraulically steep slope from elevation 1,078 at the inlet portal to elevation 1,074 at the tunnel outlet, Plate 10.

Construction of the tunnel will be by conventional drill and blast techniques, with the initial heading advancing from the downstream end. Steel sets installed at the portals will be embedded in concrete as protection against the relatively high flow velocity when discharging the design flood.

After the main dam and power tunnel intake are completed the steel bulkhead gates will be installed in the intake portal and construction of the permanent outlet facilities within the tunnel will be completed including partial concrete lining of the downstream tunnel section.

3.2.4 Permanent Outlet Facilities

Permanent outlet facilities will be incorporated into the construction diversion tunnel. The outlet facilities will serve as low level outlets, and provide for emergency drawdown of the reservoir and for diversion of fish habitat flows to the Bradley River.

The facility will consist of a concrete plug, 30 feet long, constructed about 260 feet downstream of the portal, with two 3.5 feet high by 5.5 feet wide conduits formed within the plug. Each conduit will be controlled by two hydraulically operated slide gates. The two downstream gates will control the outflow during normal operations and the two upstream gates will serve as guard gates during emergencies. A hydraulic power unit and suitable air-oil accumulator will be provided to operate the gates, Plate 10.

3.2.5 Intake Channel

Stored water is conveyed to the power tunnel intake structure through an intake channel. The channel is about 50 feet wide and 360 feet long and is located at the left bank area. The channel is excavated down to elevation 1,030 and allows the reservoir to be drawn down to elevation 1,060 for maintenance of structures and for an additional 20 feet of active storage for emergency generation. Rock traps are being provided along the channel invert and in front of the intake structure to collect fallen and ice carried rocks, Plates 7 and 11.

3.2.6 Intake Structure

An intake structure is located at the downstream end of the intake channel. The intake is excavated in rock as an extension of the upper end of the power tunnel. The excavation is suitably shaped and concrete lined for proper hydraulic performance. Removable steel trash racks installed at the inlet, preclude floating debris from entering the power conduit, Plate 12.

3.2.7 Gate Shaft

A vertical gate shaft is being furnished along the power tunnel alignment. The gate shaft is a concrete lined 22 feet circular shaft about 173 feet high, Plate 12. Two hydraulically operated slide gates are being provided to serve as emergency shut-off gates for flow shutdown and for unwatering the tunnel for maintenance. One gate is considered active during such an emergency while the second serves as a backup. The passive gate is used for servicing the active gate. The gate shaft will be dry and provisions are made within the structure for in-place maintenance of the gates. Access to the gate shaft is from the road serving the dam.

3.2.8 Power Conduit

The concrete lined power tunnel conduit is approximately 18,860 feet long, and connects the intake structure to the turbine generating units. The nominal tunnel flow diameter is 11 feet. Starting from the intake, the power tunnel consists of a 950 feet long horizontal tunnel that connects to a 810 feet long shaft, inclined at 55° from the horizontal. A 38 feet long bend is provided at each end of the shaft. The power tunnel continues for about 14,450 feet to the beginning of a concrete and steel lined tunnel section that is about 2400 feet long and extends to the tunnel portal near the powerhouse. An exposed, girder reinforced, steel "roll-out" penstock section is provided near the portal. From this point on, the power conduit consists of a 135 feet long steel penstock section that bifurcates into two flow lines, one for each of the two turbine generating units. The penstock section is encased in concrete and buried below grade for most of its length. A surge shaft will not be required for the power tunnel conduit. Material excavated from the tunnel will be used either for airfield fill or for upgrading access road surfaces. The arrangement of the power conduit is shown in Plate 12.

3.2.9 Powerhouse and Tailrace

The powerhouse is located just above sea level on the northeast shore of Kachemak Bay. The powerhouse will contain two Pelton turbine generating units having a combined rating of 107 MW. Each unit is capable of generating 45 MW at minimum head with a nominal operating speed of 300 rpm. The powerhouse, penstock, bifurcation, and power tunnel portal are situated on an excavated rock bench at elevation 40. The powerhouse is constructed of reinforced concrete with an insulated steel superstructure. The tailrace is an excavated trapezoidal, unlined channel approximately 100 feet long extending from the powerhouse into the tidal flats. The discharge from the turbines will flow across the tidal flats to connect with Kachemak Bay. Excavated material will be used in the construction of a laydown area and a switchyard adjacent to the powerhouse excavation along the shoreline of the tidal flats. Plates 13 and 14 show plans and details of the powerhouse arrangements.

3.2.10 Substation and Transmission

The substation is located adjacent to the northeastern end of the powerhouse. It is rated 115,000 volts, 3-phase, 60 HZ, and contains the main power transformers, line and tie circuit breakers, disconnecting switches, coupling capacitor voltage transformers, and line take-off towers. Conventional, oil-filled, outdoor equipment is utilized for power circuit breakers, and power transformers. The disconnecting switches are manually-operated, vertical-break units. Each generator is connected to a three-phase power transformer, power circuit breaker and then to a 115 kV transmission line. Between the two outgoing lines there is a normally closed power circuit breaker. This allows power in the Soldotna-Fritz Creek transmission line to flow through the Bradley Lake substation. The substation is designed to transmit the full output of the Bradley Lake Plant, during maintenance of or failure of one of the line breakers. Plate 15 shows the general plan of the substation.

Transmission of the power from the Bradley Lake plant is via two, parallel 115 kV transmission lines. These lines are constructed utilizing wood pole, H-frame structures and aluminum conductors, steel reinforced (ASCR). Each line is designed to transmit the full output of the plant, in the event one line is lost. The Bradley Lake lines are connected to a 115 kV transmission line which transmits power between Soldotna and Fritz Creek. The connection to this line, at a location called Bradley Junction, is about 20 miles from the power plant. A typical wood pole transmission line structure and the Bradley Lake Junction arrangement are shown on Plate 15.

3.2.11 Construction Camps

Two construction camps are planned to accommodate personnel during project construction. The lower camp area is located on the right bank of Battle Creek, approximately one mile southeast of Sheep Point. The upper camp is located near the upper dam access road about one mile west of the Bradley Lake outlet. The area is designed to accommodate 240 beds and the upper camp 210 beds. Each camp will have housing, dining, recreation, offices, utilities, sewer, and other support facilities. The lower camp area will also be used as the site for the permanent housing facilities to be constructed for the plant operation and maintenance personnel. The camps will be operated by the contractor during the project construction and will be sized to also provide facilities for visiting personnel, and the Power Authority's Construction Manager and Engineering support staff. The general location for these construction camps is shown on Plates 3 and 4.

3.2.12 Buildings, Grounds and Utilities

Permanent buildings and grounds will be limited to those required to support operation and maintenance of the Project. These facilities are located at the lower construction camp site area and consist of four residences provided for supervisory and operations and maintenance personnel and their families. In addition, a bunkhouse will be provided for maintenance personnel in the event of major maintenance. The permanent facilities will be totally selfcontained with water and sewage facilities, electric service from the powerhouse station service system, and a standby electric generator. The permanent facilities will also include a warehouse, a fully equipped machine shop, and a storage yard each sized to support anticipated project material, spare part storage, and maintenance requirements.

The powerhouse and powerhouse substation will also be self-contained with fire, water and sewage facilities, station service power service, a standby electric generator, and station batteries for emergency power to critical equipment and controls.

Microwave and other means of communications will be provided from Homer to the powerhouse and other key project facilities.

3.2.13 Middle Fork Diversion

The Middle Fork Diversion is located approximately one mile northeast of Bradley Lake in an adjacent basin, and diverts up to 450 cfs of water into Bradley Lake during May through October. The diversion consists of a small rockfill embankment dam and 1,900 feet of 6 feet diameter steel flow line. The rockfill dam is approximately 20 feet high and has a steel sheet pile central cut-off wall. The dam will be constructed of material excavated from the 30 feet wide, 12 feet deep, and 210 feet long chute spillway located in the right abutment.

A 6 feet diameter steel pipe will be used initially for construction diversion and later as a low level outlet to pass the natural winter flows downstream into Middle Fork. An entrance sluice gate and manual operator is provided for closure of the low level outlet. Also, a 6 feet diameter, steel pipe is provided to serve as the main diversion conduit into Bradley Lake. A closure sluice gate and manual operator is located at the pipe entrance. The pipe is buried for its total length to allow animal passage over the pipe and to preclude damage from snow creep and avalanche. The entrance sluice gate for the main diversion conduit will be fully opened during May through October and closed from November through April.

The plan and profile of the Middle Fork diversion and details of the recommended rockfill dam structure and its appurtenances are shown on Plates 16 and 17, respectively.

4

ALTERNATIVES INVESTIGATED

4. ALTERNATIVES INVESTIGATED

4.1 GENERAL

A large number of alternatives were investigated during the study. In addition, reviews were made of concepts developed under studies by the COE and others. The alternatives studied in the selection of the preferred plan are briefly discussed in this section and in greater detail in the report section describing the specific features of the plan.

4.2 DAMS

The following types of dams were considered:

- Concrete gravity dam with a flip bucket spillway positioned at its central monolith section.

- Concrete gravity dam with an ungated concrete gravity spillway in the right abutment saddle.

- Concrete double curvature arch dam in the immediate vicinity of the lake outlet.

- Roller compacted concrete gravity dam.

- Concrete faced rockfill dam.

Preliminary engineering evaluations and, when appropriate, engineering analyses were conducted on the above dam types to select the best two alternatives for more in depth engineering and cost analyses. The two dam types considered in depth were the concrete gravity dam and the recommended concrete faced rockfill dam.

4.3 SPILLWAYS

Due to the topographical and geologic features at the site, the only practical locations for a spillway to handle the Design Floods would be either the left or right abutments or a design incorporating the spillway into the main dam at the lake outlet. The dam type and location also affect the selection of the spillway location, type, and design details.

Side channel spillways were extensively studied by the COE in conjunction with rockfill dams. The COE also investigated a spillway within the main central section of a concrete gravity dam. The present study investigated and recommends an ungated ogee type spillway located in the right abutment saddle.

Two types of spillways were investigated by the COE, an uncontrolled free discharge ogee shaped crest and a gated spillway. The gated spillway was abandoned due to the higher capital and maintenance cost as well as operational constraints. SWEC agrees with this conclusion and only investigated the uncontrolled ogee spillway.

4.4 CONSTRUCTION DIVERSIONS

The diversion concepts reviewed in this study considered major engineering and cost factors affecting overall project development. These factors included the impacts of alignment and arrangement on the power tunnel, intake structure, cofferdams, spillway, construction ease, and the accessibility during and after construction. In addition, hydrologic, hydraulic, and environmental factors were considered for the various schemes studied.

Previous studies conducted by the COE and others were the basis for the initial review. Several other diversion schemes were analyzed and reviewed. These included tunnel arrangements through the right and left abutments at the lake outlet, and a buried conduit through the main river channel. Variations in each of these schemes were also reviewed. An alignment through the right abutment with the diversion flow discharging into the large stilling pool was judged the best in terms of the above considerations and is the recommended concept.

4.5 INTAKES

Previously identified intake structures studied by the COE were reviewed and, in addition two new intakes were investigated. These were:

- A bellmouth intake in combination with a channel excavated within the cofferdammed area.

- A bellmouth intake in combination with a channel developed as part of the quarrying operations required for the rockfill dam.

The latter of the two is the preferred concept.

4.6 GATE STRUCTURES

Gate structures considered by previous studies were reviewed. The preferred gate structure, consisting of a concrete lined circular shaft and housing two hydraulically operated slide gates also was studied.

4.7 POWER CONDUIT AND SURGE SHAFT

Three alternative power tunnel alignments, connecting the left bank of the river channel to the powerhouse were investigated. The three power tunnel alignments considered utilize a deeply set concrete lined tunnel and eliminate the exposed penstock. Because of topographic relief, the surge shaft location was fixed to that identified under previous studies.

4.8 POWERHOUSE AND TAILRACE

The COE had previously investigated both above and below ground powerhouses, and pressure and non-pressure tailraces for the below ground powerhouse and concluded that an above ground arrangement would be most economical. SWEC concurred with this COE finding and investigated only above ground powerhouse arrangements. Conceptual powerhouse arrangements were developed for Francis and Pelton types turbines for 60 MW, 90 MW, and 135 MW capacities. Two unit powerhouse arrangements were considered in the powerhouse arrangements to take advantage of the resulting cost economy. In all cases the powerhouse was located so that the tailrace arrangements considered were founded on rock.

Variations considered for the Francis powerhouse included machines with and without synchronous by-pass valves and a power tunnel with and without a surge shaft.

4.9 TRANSMISSION FACILITIES

A transmission line corridor other than that proposed by COE was studied and is the recommended corridor discussed within this report. In addition, two separate transmission lines that would connect the Kenai Peninsula to Anchorage were evaluated.

4.10 CONSTRUCTION CAMPS

The COE had previously looked at several camp sizes with alternatives of road and water access from Homer and concluded that a construction camp alternative would be most economical. SWEC concurs and considered the use of a single camp to be located near the mouth of Battle Creek and a two camp scenario which has a lower camp near the mouth of Battle Creek and an upper camp on the plateau west of Bradley Lake. Each camp considered would provide services to support construction activities. Permanent project buildings were investigated only in the lower camp site area.

4.11 MIDDLE FORK DIVERSION

The COE had previously investigated a steel bin wall dam, concrete gravity dam, and a timber buttress dam with buried or above ground steel diversion pipes. SWEC concurs with the COE's recommended buried steel diversion pipe. To make the maximum use of material natural to the diversion site, two additional dam types were considered: concrete faced rockfill dam and a rockfill dam with a steel sheet pile cut-off. The concrete faced rockfill alternative was selected for development along with a spillway excavated in right abutment. The steel sheet pile cut-off rockfill alternative was developed with a side channel spillway located in the right abutment.

5

TECHNICAL CONSIDERATIONS

5. TECHNICAL CONSIDERATIONS

5.1 GENERAL

Two main areas of technical considerations are identified as having a major impact on project feasibility. These are project geology and hydrometeorology. The geologic conditions found at the project area substantially control the engineering and economic feasibility of structures such as the dam, tunnels and powerhouse. Hydrometeorologic conditions relate primarily to the energy producing capability of the project and also affect the engineering design and economics of the main project structures. A good understanding of conditions and limitations regarding these two technical aspects is important in the development of engineering concepts and project economic evaluations.

A third but less critical technical consideration was identified during the course of the study. This consideration relates to the horizontal and vertical survey control which establish the physical interrelationships of the project structures. This consideration was found to have a minimal impact on project feasibility but it did point out the need for developing an accurate horizontal and vertical survey control network for the project.

These technical considerations are discussed in greater detail below.

5.2 PROJECT GEOLOGY

This section outlines the current scope of investigations, geologic conditions at the site, the seismotectonic setting of the site and seismic design guidelines. The major portion of work in defining geologic conditions was performed by Shannon & Wilson (S&W), Fairbanks, Alaska, subcontractors to SWEC. Details of site geologic conditions are included in their report, Appendix A of this report.

5.2.1 Scope of Investigations

Previous investigations of the site by the COE, their various subcontractors, and the U. S. Geological Survey (USGS), acting at the request of the COE, were available for study and use in the current investigations. These previous studies were of sufficient detail to allow the current program to focus on specific areas rather than the site area as a whole. The scope of current investigations is as follows:

- o Review of existing data accumulated by the COE, their subcontractors, and the USGS. These reports are listed in the "Bibliography" section at the end of this section of this report. This work was performed jointly by SWEC and S&W personnel.

- o Reconnaissance geologic mapping, including aerial photograph interpretation, and field checks of previous work were conducted by S&W, assisted by SWEC personnel. Work was concentrated at the dam site, powerhouse site and, particularly, along the tunnel alignment. Where necessary for overall understanding of conditions in the area, selected off-site locations were visited.

- o Four borings and one test pit were made by S&W. Three borings recovered rock core; at the left abutment area of the dam and along the tunnel alignment at its projected intersection with the Bradley River and Bull Moose Faults. The fourth boring was made in soil in the general location of the barge basin; both disturbed and undisturbed samples were taken for laboratory testing. Results of these activities are outlined in following sections describing the geology of individual project facilities.

- o Laboratory tests of soil samples from the boring in the barge basin area were made by S&W and are outlined in Section 7.1.8.

- o Laboratory tests of selected portions of rock core were made under the direction of Dr. A. J. Hendron of the Technical Review Board, Atlas Copco Jarva, Inc. and The Robbins Company. The results are presented in tabular form in Section 7.4.5.

- o Petrographic examination of selected portions of rock was done by SWEC. Results are included in Section 7.4.5.8.

- A final report, Bradley Lake Hydroelectric Power Project, Geotechnical Studies; August, 1983, was prepared by S&W and is included as Appendix A.

- SWEC Geotechnical personnel provided input to the feasibility level design efforts detailed in this report.

5.2.2 Geologic Conditions

This section is divided into a brief synopsis of the regional geologic setting and a more extensive outline of the general site geologic conditions.

5.2.2.1 Regional Geologic Setting

The portion of the Kenai Mountains in which the Bradley Lake Project area is located is composed of mildly metamorphosed rocks of upper Mesozoic Age, informally named the McHugh Complex. These rocks are thought to have been deposited in deep water on the continental margin. The rocks have been uplifted, deformed, and shaped by erosional processes. Accentuated by glacial and colluvial influences, the local topography is dominated by conspicuous lineaments that are surficial expressions of a complex network of faults or major joint sets that are the result of the activity of the seismic region in which the area lies.

The Kachemak and Nuka Glaciers, along with several smaller alpine glaciers, feed meltwater into the Bradley Lake drainage. The proposed reservoir will reach to within approximately 1.5 miles of the Nuka Glacier and 2.5 miles of the Kachemak Glacier. Although they do not have extensive rubble at their termini, their meltwaters contain a significant amount of glacial rock flour, which is responsible for the cloudy condition of the water in Bradley Lake.

An expression of the primary tectonic influence on the project area is found in the Gulf of Alaska, where, about 185 miles southeast of Bradley Lake, the axis of the Aleutian Arch-Trench occurs sub-parallel to the prevalent NE-SW strike of the prominent tectonic features found around Bradley Lake and the surrounding region.

Immense compressional forces generated by the plate tectonics activity in the Kenai Region have resulted in deformation of the upper crust materials of the Kenai Peninsula in the form of folding, jointing and faulting. Of the several major regional fault systems that express this deformation, two faults are found in the vicinity of the Bradley Lake Hydroelectric Power Project. The Eagle River Fault crosses through the southeastern portion of Bradley Lake, and the Border Ranges Fault forms the northern front of the Kenai Mountains and flanks the northwest portion of the project area passing beneath the length of Kachemak Bay. Two other locally major faults cross the proposed tunnel alignment, the Bradley River Fault and the Bull Moose Fault. Like the Eagle River and Border Ranges Faults, the Bradley River and Bull Moose Faults strike in the general NE-SW direction that is characteristic of the regional tectonic grain, and they have been suggested to be extensions of the Border Ranges Fault. Together with several other randomly oriented faults, these lineaments create much of the topographic features found in the Bradley Lake project area.

5.2.2.2 Site Geologic Conditions - General

The project area is underlain by weakly metamorphosed sedimentary strata of the McHugh Complex. This bedrock is locally mantled by unconsolidated glacial, alluvial, and colluvial deposits and, below tree line, is generally obscured by vegetation and soil cover. The McHugh Complex in the project area is comprised primarily of weakly metamorphosed graywacke, argillite, and cherty argillite. Locally these rocks are intruded by dacitic dikes.

The graywacke, argillite, and cherty argillite of the McHugh Complex have a complex distribution as a result of their intense deformation and structural juxtaposition. Recognizable bedding planes and marker beds are generally absent or masked by tectonic foliation. Many contacts appear to be tectonic rather than depositional, and individual lithologic units commonly are discontinuous over short distances. Many of the thicker lithologic units either pinch out or are truncated within a few hundred feet along their trend, whereas the thinner units often can be traced no more than a few feet to few tens of feet. Consequently, projection of lithologic units and rockmass characteristics from surface exposures laterally into areas where the rock is obscured and vertically into the subsurface is necessarily speculative.

5.2.2.3 Lithologic Units

For the purpose of this evaluation, the bedrock has been subdivided into five lithologic units based on their distinctive rockmass properties. These units are graywacke, massive argillite, foliated argillite, foliated cherty argillite, and dacite intrusives. The sedimentary classifications represent further subdivisions of the graywacke and argillite units utilized in earlier studies. The general characteristics of these bedrock units are discussed below.

The graywacke is highly indurated, dark gray to dark greenish gray, very fine to medium grained, weakly metamorphosed sandstone. Fine, irregular quartz and calcite veins are locally common in the graywacke. The unit is massive with little or no evidence of bedding except for lenses or detached remnants of beds of foliated argillite and cherty argillite that locally occur within the unit. The graywacke is relatively resistant to weathering and generally underlies the more prominent hills in the project area. Where exposed, the rock is fresh to slightly weathered and strong. Moderately to widely spaced, partly opened to very tight joints are typical on vertical exposures of the graywacke.

The massive argillite is a strongly indurated, dark gray to dark greenish gray, weakly metamorphosed siltstone to very fine grained sandstone. It is a fine-grained equivalent of the graywacke and has similar rockmass properties. Exposures of this unit are fresh to slightly weathered, massive and typically have moderately to widely spaced joints.

A weakly metamorphosed tuff was identified in a thin section from a sample taken from a location just northwest of hill 2070. Tuff was also identified in a thin section of a sample of graywacke taken from a location midway between hill 2070 and the surge tank. The COE classified a thin section sample from their boring DH-11 as a "volcanic graywacke".

It is difficult to make any firm statement regarding the distribution of the tuff because it can only be positively identified in thin section. It appears to be present within both the graywacke and the massive argillite. Twenty-two thin sections of various rock types, many selected because of their anomalous megascopic appearance, were examined with only two samples identified as tuff, and only two field occurrences were noted. It is likely that it is a minor component of the overall rock mass. Thin section analysis (see Figure 7.4-7) indicates that it was deposited in water and could simply be considered a sub-type of the graywacke, that is, a "volcanic graywacke" as classified by the COE.

The foliated argillite and foliated cherty argillite are differentiated solely on the abundance of chert within the rock. For this evaluation we have considered the argillite to be "cherty" if interlayered and lenticular chert exceeds about 10 percent of the outcrop. The argillite is a dark gray to black, weakly metamorphosed siltstone and very fine sandstone. Chert occurs throughout the rock (in various percentages) typically as discontinuous layers and elongated nodules. Foliation is predominantly a shear foliation that has developed along the regional structural trend. Jointing is not frequently expressed in outcrops of the foliated argillite but where present the joints are typically widely to very widely spaced and very tight. Outcrops of the foliated argillite are fresh to slightly weathered.

Two dacite dikes were observed in the map area. One is known from a single small outcrop of the exit portal, whereas the other is exposed to the east near the middle of the tunnel alignment. The eastern dike trends northeasterly to easterly across the regional structural trend, cutting across both graywacke and argillite units. It is about 30 to 50 feet wide and can be traced to the northeast of the tunnel alignment where it dips nearly vertically. The dacite is a light greenish gray, porphyritic rock, is typically slightly weathered in outcrop, and appears to be slightly more resistant to erosion than the units it intruded. It is a massive rock with widely spaced, very tight joints. Its strength and other rockmass properties appear to be similar to the massive argillite and graywacke.

Overburden ranges from a few tenths of a foot to 15 or more feet thick and consists of sands and silts covered with a thick mat of organic, mossy material. In some cases the organic material is the only covering.

The unconsolidated sediments in the Bradley Lake area consist of glacial outwash and till, river and tidal flat deposits, and talus rubble. These sediments are dominated by clasts of graywacke and argillite which vary depending on the composition of the source area. The tills and talus deposits are composed of gravel to boulder size clasts of subangular to angular graywacke and flaky gravel to cobble size argillite. These clasts are in a matrix of gravel, sand, and silt. Graywacke dominates the coarse fraction of these deposits, while the argillite appears to dominate the fine gravel and sand-size fraction.

5.2.2.4 Structure

The most prominent structural elements in the project area are the pervasive, closely-spaced shear foliation in the argillites, and the complex structural distribution of bedrock units. The area is complexly deformed by the pervasive shearing, by two major fault zones, and by numerous smaller faults in a variety or orientations. The significance of folding in the project area is not apparent because; a) well-defined marker horizons and bedding are lacking, b) vegetative cover obscures much of the rock, and c) the bedrock units are complexly distributed.

The Bradley River and Bull Moose faults are the most significant faults in the project area. These faults zones are high-angle structures that trend N5°E to N20°E and extend for at least a few miles outside the project area. Several smaller high-angle faults and a few low-angle faults have also been identified in this and previous studies. The high-angle faults tend to fall into two general sets: those subparallel to the Bradley River and Bull Moose fault zones and those at about 90° to these larger structures. Only a few minor low-angle faults have been noted.

Jointing is present in all the rocks in the area although it is generally best developed in the graywacke. Joint orientations are highly variable. Joint surfaces are generally relatively smooth, and range from very tight to open cracks about 2 inches wide. Joint spacing is highly variable, ranging from a few inches in local areas to several tens of feet in other areas. Generally at least three joint sets at high angles to one another can be found, resulting in a blocky rockmass.

A number of well developed linear topographic depressions cross the project area. A few of the most pronounced and continuous of these lineaments are recognized as faults, but the origins of many of the others are not readily apparent. Most of the lineaments are probably the surface expression of either faults or series of closely spaced joints. Rock exposures along the lineaments are commonly absent, and colluvial or glacial deposits obscure the evidence needed to determine the nature of these features.

5.2.3 Seismotectonic Setting

The primary cause of seismic activity in southern Alaska, including the site area, is the stress imposed on the region by the relative motion of the Pacific and the North American lithospheric plates at their common boundary. The Pacific plate is moving northward relative to the North American plate at a rate of about 6cm/yr. causing the underthrusting of the Pacific plate. This underthrusting results primarily in compressional deformation which causes folds, high-angle reverse faults, and thrust faults to develop in the overlying crust.

The boundary between the plates where the underthrusting occurs is a northwestward-dipping megathrust fault or subduction zone. The Aleutian Trench marks the surface expression of this subduction zone and is located on the ocean floor approximately 185 miles south of Bradley Lake. The orientation of the subduction zone is inferred along a broad inclined band of seismicity, referred to as the Benioff Zone, that dips northwest from the Aleutian Trench, and is approximately 30 miles beneath the Bradley Lake Site. Historically (1899 to date), eight earthquakes ranging between 7.4 and 8.5 Richter magnitude have occurred within 500 mi of the site.

12eat earthquakes (surface wave magnitude M_s 8 or greater) and large earthquakes (greater than M_s 7) have occurred historically throughout the region and can be expected to occur in the future.

Bradley Lake is situated on the overriding crustal block above the subduction zone and between the Castle Mountain fault to the north and the Patton Bay-Hanning faults to the southeast on Montague Island; all of these faults have documented Holocene or historic surface ruptures. Because of the active tectonic environment, activity is probable on other faults, such as those found near or on the project site, which are also located in the overriding crustal block and between the known active faults mentioned above.

Two faults of regional extent occur at or near the site. The Border Ranges Fault trends southwest beneath Kachemak Bay and the Eagle River Fault crosses the southeastern portion of Bradley Lake at about the same trend. While no direct evidence or recent activity along these faults is known in the site area, recently-defined data indicates recent activity on the Eagle River Fault near Eklutna (125 mi NE of the site.) Given the tectonic setting, it is reasonable to consider these faults potentially active.

In addition to the nearby regional faults, the site is crossed by two large local faults, informally called the Bradley River Fault and the Bull Moose Fault, and a number of probable smaller faults. The dominant trend is northeasterly, paralleling the regional trend. The larger local faults, particularly the Bradley River, are probably capable of independent earthquake generation while any of the local faults could probably move in sympathetic response to earthquakes generated by the regional faults.

It is therefore concluded that the site will probably experience at least one moderate to large earthquake during the life of the proposed project. The possibility of ground rupture exists but is much less subject to prediction.

5.2.4 Seismic Design

Based on previous studies and evaluations, supplemented by data and considerations of this study, it is recommended that design maximum earthquakes include a magnitude M_s 8.5 at 30km directly below the site and a magnitude M_s 7.5 on either the Border Ranges or Eagle River Fault at their closest approach to the site (less than 3km or 1.8 mi). Possible ground displacement is addressed in the final portion of this section.

Seismic exposure analysis, for a 100 year duration, for the site yields the results tabulated below:

Exceedance Probability	Maximum Horizontal Acceleration
50%	0.37g
30%	0.43g
10%	0.58g

The controlling feature for this evaluation is the Aleutian Megathrust; in its absence, acceleration levels would be reduced about 0.10 to 0.16g.

The values given above are considered to be as accurate as available data allows. It must be recognized that historical data, except for very large events, is sparse beyond about 100 years ago and instrumental data is available for less than the past 75 years. Recommendations for probable design acceleration values, given below, are based on general economic considerations for the project and on the consideration that seismic failure of even a major project facility would not result in a life-threatening situation for any existing or projected population. All major project facilities will be founded on or excavated in rock and design acceleration values given below are for horizontal acceleration in rock.

- Dam - 0.75g. Loss of the dam for the operational project would mean temporary loss of the project and a major reconstruction expenditure. However, by the very nature of the dam type selected, although it might be damaged and leak, the dam would still remain in place and retain the reservoir impoundment. The acceleration of 0.75g corresponds to an M_s 7.5 shallow crystal event with a recurrence probability of less than 10% in 100 years. This envelopes the more probable megathrust event of M_s 8.5 (approx. 0.55g) with a 100-year recurrence probabilility of 10%. This is a relatively short significant duration event (25 sec) and, as such, has less effect on massive structures such as a dam. Current studies at the dam site have not revealed any structures with potential for ground displacement.

- <u>Intake Structure/Gate Shaft - 0.75g</u>. These structures are considered to be critical installations with respect to seismic shock resistance. Seismically-induced damage to the intake channel (rockfall) or the dam (leakage) would not prevent water from entering the power shaft/tunnel system should the closure gate become inoperative. The diversion/low-level outlet facilities are at an elevation above that of the power tunnel intake and could not be used to lower the water level below that of the intake. Reconstruction under such conditions could be costly. A design level of 0.75g represents a conservative value, since it is based on the postulated shallow crustal fault event. However, since the gate shaft and intake structure integrity are significant during and after a major seismic event and represent a moderate expenditure, in comparison to overall cost, it is recommended that the maximum acceleration value be considered in final design for these structures.

- <u>Power Tunnel, including Steel Liner/Shafts</u> - No acceleration value assigned. Fully embedded installations tend to react in concert with the surrounding rock mass, unless actual rupture and displacement of the rock mass occurs. It has been assumed that the Bradley River and Bull Moose Faults are capable of independent earthquake generation, implying surface and subsurface rupture potential, and are also capable of rupture in response to events on adjacent, larger faults. Thus, the largest potential displacements, up to 300 cm (10 feet) have been postulated on these faults; the probability is very small for this case. Smaller faults are not considered capable of independent earthquake generation and any displacement on them would occur as a response to forces produced by events on larger faults. The range of potential displacement for minor faults is assessed as from 20 cm (0.6 feet) to 100 cm (3 feet). Should displacement occur, it is anticipated not to exceed about 120 cm (4 feet). The probability of this event is in the range of about $2X10^{-4}$ for a 100 year interval. The most probable event (in 100 years) has been estimated at $4X10^{-3}$ with a displacement of only 20 cm (0.6 feet).

It is considered to be impossible to design to withstand or accommodate rock mass rupture. In the absence of safety-related considerations, it is recommended that no consideration other than those consistent with normal tunnel design be applied. There are undoubtedly a number of minor faults which also intersect the tunnel facilities; no special design features are necessary for reasons stated above. Should rupture occur, provisions for access for repair equipment has been included in the form of a roll-out section in the steel penstock, adjacent to the powerhouse. A tunnel bypassing the offset section could then be driven.

- Powerhouse - not to exceed 0.35g. There is a 50% chance that the site will experience horizontal bedrock acceleration up to about 0.35-0.4g during a 100 year interval. This represents a commonly-accepted level for an operating-basis earthquake. An earthquake design for 0.35g, using normally acceptable stresses and operating requirements commonly results in the ability of the structure(s), equipment and systems to safely sustain higher earthquake accelerations at increased but acceptable stress levels and operating extremes. If a higher recurrence factor is considered acceptable during final design, an acceleration value less than 0.35g could be utilized. The depth of bedrock was the primary geotechnical concern at the powerhouse site. A hand-dug test pit confirmed the presence of bedrock at shallow depths. Also, faults, and even joint swarms, which have strong topographic expression throughout the site area, were not found to occur at the powerhouse site. If faulting is present, it is minor. Given the above conditions, it is recommended that the powerhouse, and ancillary facilities required for continued operation, be designed for this level of shock.

- Other Project Facilities - not to exceed 0.35g. These include such facilities as accommodations for operation personnel, barge access channel and basin, shop, warehouse, oil and water storage tanks, structures housing sluice and intake gate controls, and bridges. For final design purposes, it may be desirable to evaluate the possible costs of repairs as opposed to initial construction costs for various levels of seismic design. Many structures of conventional design and proper construction can withstand accelerations in the 0.2-0.35 range while sustaining only moderate, repairable damage. If a higher recurrence factor is considered acceptable during final design, a design value of less than 0.35g could be utilized. Given a probable recurrence interval of several tens of years, it may not prove economic to design non-critical facilities to totally withstand the effects of major seismic events. It is also considered that minor project facilities cannot practicably be designed to accommodate ground rupture. It should be noted that failures in soils such as those found in and immediately adjacent to Kachemak Bay are practically unavoidable at the peak accelerations considered for this site. Such failures could result in slope failures in the access channel and barge basin side slopes, and differential settlement of the air strip. These are possibilities which must be considered in evaluation of the project.

5.3 HYDROMETEOROLOGY

5.3.1 General

The COE conducted extensive studies of the hydrologic and climatologic characteristics of the Bradley Lake drainage basin. The results of their studies are contained in their "Design memorandum No. 1, Hydrology," dated June 1981, and "General Design Memorandum No. 2, Volumes 1 and 2," dated February 1982. In general, all data as reported therein, except as described below, provided the basis for developing the criteria used in the present study.

The following sections summarize the important hydrologic parameters gathered by the COE and SWEC's subcontractor R&M Consultants, Inc. (R&M), and utilized in this study. Where appropriate, summaries are provided to describe changes to the COE's baseline data or to indicate where additional future data development and studies are required.

5.3.2 Basin Description

The Bradley Lake Project is located within the Kenai Mountains approximately 27 miles northeast of Homer, Alaska. The project utilizes water stored in Bradley Lake which is situated about 1,080 feet above Kachemak Bay in an ice-free subalpine valley.

The basin above the lake consists of rugged and precipitous rocky slopes interspersed with various forms of low vegetation and other growth. Higher elevations are characterized by barren slopes with most of the land features carved from the various glaciers within the basin. The Nuka and Kachemak glaciers are the two largest glaciers providing runoff into Bradley Lake. The drainage area above the lake outlet is 56.1 square miles of which approximately 36 percent is covered with glaciers.

The Middle Fork diversion facility which will divert streamflow into a tributary of Bradley Lake is located about a mile north of Bradley Lake. The physiographic features of the basin are similar to the Bradley Lake basin. The drainage area above the point of diversion is 10.1 square miles with about 29 percent of the basin covered by glaciers and permanent snowfields.

5.3.3 Climatology

5.3.3.1 General

The Bradley Lake basin is influenced by a maritime climate with associated cool summer and moderate winter temperatures. Average annual temperature has been estimated as 35°F. Fog, rain, and clouds are characteristic of the basin with high winds frequently occurring.

Until 1980, no climatological records were available for the Bradley Lake basin. Climatological data used in previous studies were developed through correlation and regression analyses of nearby basins on the Kenai Peninsula. The following summarizes the results of these studies.

5.3.3.2 Precipitation

Precipitation within the basin is greatest during the August through December period with the smallest amounts occurring from January through July. Most storms occur in the fall and early winter months and move in a northeasterly direction from Kachemak Bay with the greatest amounts of precipitation occurring in the higher elevations of the basin (1.5 inches per hour).

5.3.3.3 Snow

Snowfall is greatest in the upper elevations of the basin which contributes materially to the volume of the larger glaciers producing runoff during the summer months. First snows usually occur in October and extend through early May with the heaviest accumulation occurring during December and January.

5.3.3.4 Ice

Lake ice thickness of 17-28 inches was estimated by the COE and should have minimal impact on project operation. Future studies should address the effects of ice formations near the power conduit intake channel and its impacts on wildlife migratory patterns in the upper reaches of the reservoir. Ice and snow accumulations on project structures and the transmission lines will also have to be addressed, however, these effects are not insurmountable from a design standpoint. Ice accumulations within Kachemak Bay and the areas subject to tidal influences are also expected to be minimal with no affects on project operations or access.

5.3.3.5 Wind

Wind data at the site has been gathered since August 1979. The COE's analysis of the limited data indicates that highest winds occur from October through April with several speeds exceeding 70 MPH during this period. The 100 year return period speed has been estimated as 115 MPH in the area with the predominate direction of the winds toward the northwest.

Wind speed, direction, duration, frequency, and seasonal distribution are the major factors which will have to be reviewed in future studies as all these factors could be significant in the design of the various project structures. The wind criteria developed in the final design studies will determine the spectrum of various wave characteristics to be expected in Bradley Lake at the damsite by which final freeboard requirements for the main dam will be set. More directly, wind characteristics will determine the criteria to be used in final design of the transmission lines, powerhouse superstructure, and other structures. The present study did not analyze these wind characteristics in detail due to the limited amount of data available. Should final engineering and design studies proceed in the near future, the wind data developed at that time will be thoroughly reviewed.

5.3.4 Hydrology

5.3.4.1 Runoff

The runoff response from precipitation in the Bradley Lake watershed is influenced greatly by the geologic conditions of the basin. Due to the limited amount of soil cover overlying bedrock, almost all of the runoff reaches the streams and tributaries of the basin with very little flow going into groundwater storage. Mean annual runoff exceeds 90 percent during the May through October period which is characteristic of the basin's maritime influence. Runoff contributions from snowmelt usually occur in May and June, with intense rainfall contribution to the maximum runoff during August through October.

Glacier contributions to runoff are dependent on seasonal and long term temperature and precipitation variation. Their affects are discussed further on and a detailed discussion can be found in R&M's report included as Appendix B of this report.

5.3.4.2 Streamflow

Streamflow records at the Bradley Lake outlet are available from October 1957 to the present, however, records for the Middle Fork flows and Upper Bradley River were not started until October 1979.

As stated above, higher streamflows occur in the May through October period as a result of snowmelt and intense rainstorms during the summer and fall periods. Maximum mean daily discharges during this period have exceeded 5,000 cfs.

Typical low flows during the November through April period range from 20 cfs to about 250 cfs with higher flows seldom exceeding about 750 cfs in November. Flows in the drier December through April periods seldom exceed 20 to 75 cfs.

5.3.4.3 Streamflow Adjustments -- Power Studies

Adjustments to the historical streamflow records (October 1957 through September 1982) were required to reflect potential future inflows to Bradley Lake for use in predicting expected power and energy generation from the project. A detailed description of the methodology used to establish the adjusted streamflows is included in Appendix B. Only a summary of results is presented herein.

Initial streamflow adjustments of the historical records were made to reflect switching of the Nuka glacier runoff from the Nuka River to the Bradley River after 1970. The results of this analysis indicate that the COE's estimate of flow adjustment during this period was too conservative by a factor of about 50 percent. Instead of the 46 cfs annual runoff added to the 1957 through 1970 period, this most recent analysis indicates that an additional 43 cfs of streamflow over the COE's estimate would have been available. The additional 43 cfs was therefore added to the COE's tabulated flows over the 1957-1970 period and distributed on a monthly basis in accordance with the pattern estimated by the COE. The revised monthly flows are shown in Table 5.3-1 and an annual flow-duration curve is presented in Figure 5.3-1.

5.3.4.4 Middle Fork Streamflows

Middle Fork monthly streamflows were developed on the basis of the above adjusted Bradley River Streamflows (Table 5.3-1) for the period of the Bradley Lake record. Because an additional two years of monthly flow data at the Middle Fork Diversion were available since the COE's analysis, the Middle Fork flows presented herein represent a refinement over that used by the COE. A description of the methodology used to establish the Middle Fork flows is included in Appendix B. Table 5.3-2 shows the adjusted monthly flows used in this study and Figure 5.3-2 shows the mean annual flow duration curve.

5.3.4.5 Lower Bradley River Streamflows

Monthly flows were also developed for the Lower Bradley River for the unregulated portion of the drainage below the Middle Fork Diversion and Bradley Lake outlet. These flows are shown on Table 5.3-3. The purpose of these estimates was to determine the contribution that these flows would have in meeting the target flows established by the instream flow assessments for aquatic habitat enhancement. Although these flows are not used directly in determining the potential power output of the project they do contribute in minimizing the amount of water which may have to be diverted out of Bradley Lake to satisfy minimum instream flows for aquatic habitat. An annual flow duration curve for the above conditions is shown in Figure 5.3-3.

5.3.4.6 Bradley River Glacial Adjustments

To account for possible future changes in the flow regime of the Upper Bradley River due to glacial influences, studies were conducted to determine their affects on runoff production. Aerial photos of the glaciers within the basin were used in estimating an equivalent water thickness loss of 14 $\pm$ 18 feet averaged over the glaciers between the period 1952 and 1979. Although the glaciers have retreated in this time period, the upper mass of the glaciers has actually increased, which is consistent with other glaciers in the area.

The total loss of water equivalent in the glaciers was then distributed over the previously adjusted historical Bradley Lake streamflow record using a runoff precipitation model which was calibrated for other glaciers of Alaska. Monthly distribution of the annual loss was distributed to the months of June through September using a thawing degree-day index. The revised streamflow record which represents a condition where the glaciers are neither gaining nor loosing water from storage in any given year is shown in Table 5.3-4. An annual flow duration curve for the above mass balance adjustments is shown in Figure 5.3-4.

The above flow scenario represents a condition on the conservative side in terms of available streamflow for power production. Should climatic conditions similar to the historical records occur in the future then flows in Table 5.3-4 would be representative. However, a small change in climatic conditions in the future could cause the glaciers to return to a state similar to that at the beginning of the period of record. In order to reflect this possibility, Table 5.3-5 has been prepared to indicate the streamflow record wherein year-to-year variation in glacial mass caused by differences in climatic conditions occurs. This represents a condition wherein only the trend of long term glacier wasting is removed. The annual flow duration curve for this record is shown in Figure 5.3-5.

A detailed description and methodology of the above glacial adjustments to streamflow can be found in Appendix B.

5.3.4.7 Floods

Flood peaks usually occur between June and September with most floods in early summer caused by snowmelt and those in August and September from rainfall. Characteristics of the geologic conditions of the basin, most flood hydrographs are characterized by typically skewed distribution of discharge with a fairly steep rising limb and asymmetric recession limb.

The COE analyzed the flood characteristics of the basin and developed a flood frequency curve based on the historical records. Their analysis included adjustments of the annual flood peaks during the 1958 through 1970 period to account for the Nuka Glacier runoff switching from the Nuka River to the Bradley River. It has been shown above that their estimate of this adjustment was too low which would tend to underestimate the discharge for a given return period flood. In addition, it appears that their analyses used the recorded discharges at the lake outlet which would be lower than the actual inflow into the Lake due to the regulation effects of surcharge storage. However, it has just recently been found (August 1983) that the Nuka Glacier runoff has switched back again to the Nuka River with a diversion of flow between the Nuka and Bradley Rivers similar to that which occurred in the 1958 through 1970 period. It therefore appears that the COE's estimate of the flood frequency is acceptable for the runoff conditions now being experienced in the basin. Should this condition continue into the construction period of the Project, it would obviously reduce the expected flood peaks which the diversion tunnel would have to pass. A small diversion dike or an improvement to the outlet channel flowing to Bradley Lake will have to subsequently be developed near the terminus of Nuka Glacier to insure the glacier runoff is directed into Bradley Lake, as all power and energy values reported herein are based on this condition.

5.3.4.8 Probable Maximum and Standard Project Flood

The COE conducted a fairly extensive study of the hydrologic characteristics of the Bradley Lake drainage basin in determining the Probable Maximum Flood. The methodology and approach used by the COE was reviewed by SWEC and appears thorough. The Probable Maximum Flood (PMF) inflow was determined for Bradley Lake both with and without Middle Fork Diversion, however, it was shown that the Middle Fork Diversion's contribution to the peak PMF inflow was only about equal to its maximum diversion capacity of about 450 cfs.

The PMF study conducted by the COE is discussed in their "Design Memorandum No. 1" entitled "Hydrology" dated June 1981 and in "Design Memorandum No. 2", "General Design Memorandum" dated February 1982. However, the results reported in these references are not the same. The COE stated that the peak flow of the Standard Project Flood (SPF) reported in their design memorandum was about equal to the estimated 100 year flood. Because the Probable Maximum Precipitation (PMP) used in deriving the SPF was a fixed ratio (50%) of the PMP used in deriving the PMF, the streamflow routing parameters were revised to increase the peak flood discharge of the PMF and the SPF. The revised PMF and SPF hydrographs were therefore included in the COE later issued General Design Memorandum No. 2. Plate 18 shows the COE's updated hydrographs which were used in the present study to size the spillway.

5.3.4.9 Sedimentation and Evaporation

The COE's analysis of sedimentation in both Bradley Lake and Middle Fork indicated suspended sediment concentrations were so low so as not to present any long term sedimentation problems.

Evaporation from the lake surface during project operation was also found to be minimal. Since the historical streamflow records used in developing the power generation estimates already reflect the effects of evaporation, no adjustments to recorded streamflows are required.

5.4 SURVEY CONTROL

The project datum used in this report is based on Alaska State Plane Coordinate System Zone 4, which is referenced to the North American datum of 1927 (NAD 27/Clark Spheroid of 1866). The project vertical datum is based on an assumed datum for this project which was initiated by using the scaled elevation of control point referred to as JEFF at 26.24 feet. Later observations by National Oceanic and Atmospheric Administration (NOAA) placed the local project datum origin for Mean Sea Level (MSL) 4.02 feet lower. The Mean Lower Low Water datum (MLLW) origin is 9.61 feet lower than MSL origin or 13.63 feet lower than the project datum origin.

The differences between project elevations referenced and used by this study and MSL or MLLW can be equated as follows:

MSL elevation	=	Project Elevation + 4.02 feet.
MLLW elevation	=	Project Elevation + 13.63 feet.

Recent field surveys performed by R&M in conjunction with field study efforts showed further horizontal and vertical discrepancies between previously published coordinate values of monumented stations as discussed in Appendix B. Horizontal shifts varying from 0.502 feet to 1.687 feet feet were noted. Similarly vertical position shifts of + 1.170 feet to + 4.719 feet were determined. The study recognized these discrepancies. However, since the relative value of elevations would be within $\pm$ 2.5 feet, it was decided to only consider the 4.02 feet correction for reference in the study. Future efforts must include a new, stronger control network for project use in definitive engineering and design work.

In addition to the above discrepancies, it was also observed during the course of field work that certain areas of the topographic maps utilized in the COE study were not accurate. Although the discrepancies would not impact the results of this study, it is recommended that more accurate maps of selected areas be prepared for future engineering-design.

BRADLEY RIVER FLOWS AT LAKE OUTLET
ADJUSTED FOR NUKA GLACIER SWITCH
DRAINAGE AREA = 56.1 SQUARE MILES
MONTHLY, ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1958	775	577	111	79	42	32	74	389	1,378	1,410	1,692	446	587
1959	275	102	60	33	25	22	33	308	1,055	1,052	1,041	419	371
1960	187	94	60	39	35	24	33	593	900	1,166	1,094	572	403
1961	249	144	179	199	107	42	30	436	948	1,361	1,166	1,258	512
1962	347	116	71	55	31	22	39	177	852	1,101	881	500	351
1963	269	317	127	113	87	67	45	237	781	1,512	1,481	1,228	525
1964	562	94	108	75	63	40	33	87	841	1,227	1,597	1,151	494
1965	477	140	85	64	50	55	75	131	655	1,153	1,227	1,756	490
1966	595	165	70	39	32	31	41	150	966	1,146	2,162	1,819	604
1967	525	64	43	35	31	29	36	253	910	1,241	1,562	1,802	506
1968	231	224	136	99	91	105	62	307	739	1,140	1,287	513	415
1969	277	73	41	35	35	34	43	310	1,673	1,543	1,065	723	489
1970	1,900	211	239	118	116	109	103	331	895	1,324	1,410	740	631
1971	197	382	76	45	36	31	31	115	641	1,394	1,262	507	396
1972	376	108	55	32	20	17	17	141	517	1,172	1,378	1,019	406
1973	413	123	56	34	26	24	28	128	600	918	870	908	346
1974	575	173	50	32	23	19	23	227	551	860	1,000	1,501	421
1975	346	224	112	55	43	34	30	355	1,035	1,068	864	850	420
1976	424	118	52	39	32	26	41	206	813	1,107	1,153	1,293	443
1977	420	414	312	326	306	178	119	354	995	1,653	2,049	646	652
1978	407	70	37	34	40	42	56	291	755	1,081	1,182	959	415
1979	572	161	104	43	30	27	31	290	712	1,004	1,883	1,357	521
1980*	1,173	411	85	67	81	74	58	326	936	1,332	1,304	897	564
1981*	779	150	110	233	160	170	310	788	908	1,490	1,643	885	640
1982*	298	251	98	52	73	45	37	138	677	1,107	904	1,780	456

* Recorded

TABLE 5.3-1

MIDDLE FORK FLOWS AT DIVERSION DAM

(Based on ratios developed for Bradley River Flows
adjusted for Nuka Glacier Switching*)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1958	59	64	6	6	5	4	4	14	126	214	188	47
1959	34	10	8	4	4	2	4	14	93	113	127	43
1960	23	9	8	4	4	2	4	21	90	152	137	60
1961	31	9	9	15	9	5	4	15	85	204	157	107
1962	35	12	8	6	5	2	4	10	85	121	110	53
1963	34	35	6	8	7	5	4	11	78	227	163	147
1964	42	9	12	6	8	5	4	5	84	160	176	138
1965	48	8	10	7	6	4	4	7	66	150	166	149
1966	45	10	8	4	5	4	4	8	87	149	238	155
1967	53	6	5	4	5	3	4	11	91	161	172	153
1968	29	25	7	7	7	7	4	14	74	148	174	54
1969	35	7	5	4	4	4	4	14	151	231	133	76
1970	143	13	12	9	9	8	4	12	90	172	190	78
1971	25	42	9	5	5	4	4	6	64	209	170	53
1972	38	11	7	4	3	2	4	8	52	152	186	122
1973	41	7	7	4	4	2	4	7	60	101	109	109
1974	43	10	6	4	3	2	4	10	55	95	125	128
1975	43	25	6	6	5	4	4	12	93	117	108	102
1976	42	12	7	4	5	2	4	9	81	122	144	110
1977	42	46	16	24	24	12	4	12	90	248	225	68
1978	41	7	5	4	5	5	4	13	76	119	160	115
1979	43	10	12	5	5	3	4	13	71	110	207	115
1980**	98	35	9	5	5	4	4	14	85	208	180	115
1981**	51	8	5	17	9	7	4	24	92	211	183	88
1982**	38	33	13	7	9	5	4	8	67	144	113	136
Average	46	19	8	7	6	4	4	12	83	162	162	101

* Nuka Glacier Basin switching assumed to occur after 1970.
** Recorded monthly averages.

TABLE 5.3-2

ESTIMATED AVERAGE MONTHLY FLOW
LOWER BRADLEY RIVER

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1958	125	190	40	36	23	28	65	113	182	103	63	53
1959	51	50	24	32	23	19	29	110	177	99	52	50
1960	52	51	29	36	25	20	28	115	186	104	58	63
1961	52	42	41	75	37	22	44	112	181	104	59	99
1962	55	53	27	34	24	22	39	115	185	99	55	38
1963	49	55	25	44	61	90	30	104	167	102	47	54
1964	61	20	24	38	29	16	13	149	240	115	61	50
1965	60	71	27	23	15	29	40	115	186	120	54	88
1966	59	23	13	27	26	18	24	125	202	113	74	94
1967	75	57	34	35	21	13	16	107	172	102	56	69
1968	48	123	48	45	32	18	38	105	169	94	41	33
1969	42	27	15	24	17	13	16	87	141	91	38	30
1970	270	58	46	49	45	52	43	94	152	98	46	47
1971	47	76	22	29	21	16	16	112	180	104	67	48
1972	50	33	29	39	27	18	17	71	114	87	34	58
1973	64	32	18	13	11	10	16	66	148	92	35	43
1974	41	30	22	17	13	12	21	97	135	53	22	52
1975	66	59	29	16	13	11	11	80	213	139	40	66
1976	80	30	20	15	13	11	22	87	184	106	35	117
1977	105	100	74	107	80	41	33	114	202	144	97	36
1978	107	32	14	14	15	12	15	99	180	82	34	41
1979	133	56	52	28	18	13	27	96	151	82	69	39
1980	156	175	52	23	36	24	29	127	215	131	104	76
1981	134	45	28	112	61	52	42	205	160	120	61	45
1982	58	69	36	19	29	20	18	59	139	77	29	99
Average	82	62	32	37	29	24	28	107	174	102	53	60

* Unregulated area below Bradley Lake damsite and Middle Fork Diversion.

TABLE 5.3-3

BRADLEY RIVER FLOWS AT LAKE OUTLET
ADJUSTED FOR NUKA SWITCH AND GLACIER BALANCE CHANGES
DRAINAGE AREA = 56.1 SQUARE MILES
MONTHLY AND ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1958	775	577	111	79	42	32	74	389	1,430	1,470	1,750	475	604
1959	275	102	60	33	25	22	33	308	1,070	1,080	1,070	436	379
1960	187	94	60	39	35	24	33	593	990	1,320	1,230	651	441
1961	249	144	179	199	107	42	30	436	1,160	1,650	1,440	1,440	591
1962	347	116	71	55	31	22	39	177	937	1,220	1,000	541	382
1963	269	317	127	113	87	67	45	237	560	1,120	1,090	944	417
1964	562	94	108	75	63	40	33	87	769	1,140	1,510	1,090	468
1965	477	140	85	64	50	55	75	131	625	1,100	1,180	1,710	475
1966	595	165	70	39	32	31	41	150	596	660	1,690	1,480	465
1967	525	64	43	35	31	29	36	253	820	1,110	1,430	1,730	510
1968	231	224	136	99	91	105	62	307	585	929	1,060	416	358
1969	277	73	41	35	35	34	43	310	1,080	820	466	308	295
1970	1,900	211	239	118	116	109	103	331	771	1,170	1,250	660	588
1971	197	382	76	45	36	31	31	115	862	1,750	1,670	710	495
1972	376	108	55	32	20	17	17	141	484	1,120	1,320	987	391
1973	413	123	56	34	26	24	28	128	760	1,150	1,090	1,030	407
1974	575	173	50	32	23	19	23	227	309	530	652	1,250	324
1975	346	224	112	55	43	34	30	355	1,280	1,450	1,250	1,090	523
1976	424	118	52	39	32	26	41	206	777	1,050	1,100	1,260	428
1977	420	414	312	326	306	178	119	354	1,350	2,100	2,550	927	784
1978	407	70	37	34	40	42	56	291	670	966	1,050	889	382
1979	572	161	104	43	30	27	31	290	739	1,050	1,930	1,390	533
1980	1,170	411	85	67	81	74	58	326	936	1,332	1,304	897	564
1981	779	150	110	233	160	170	310	788	908	1,490	1,643	885	640
1982	298	251	98	52	73	45	37	138	677	1,107	904	1,780	456

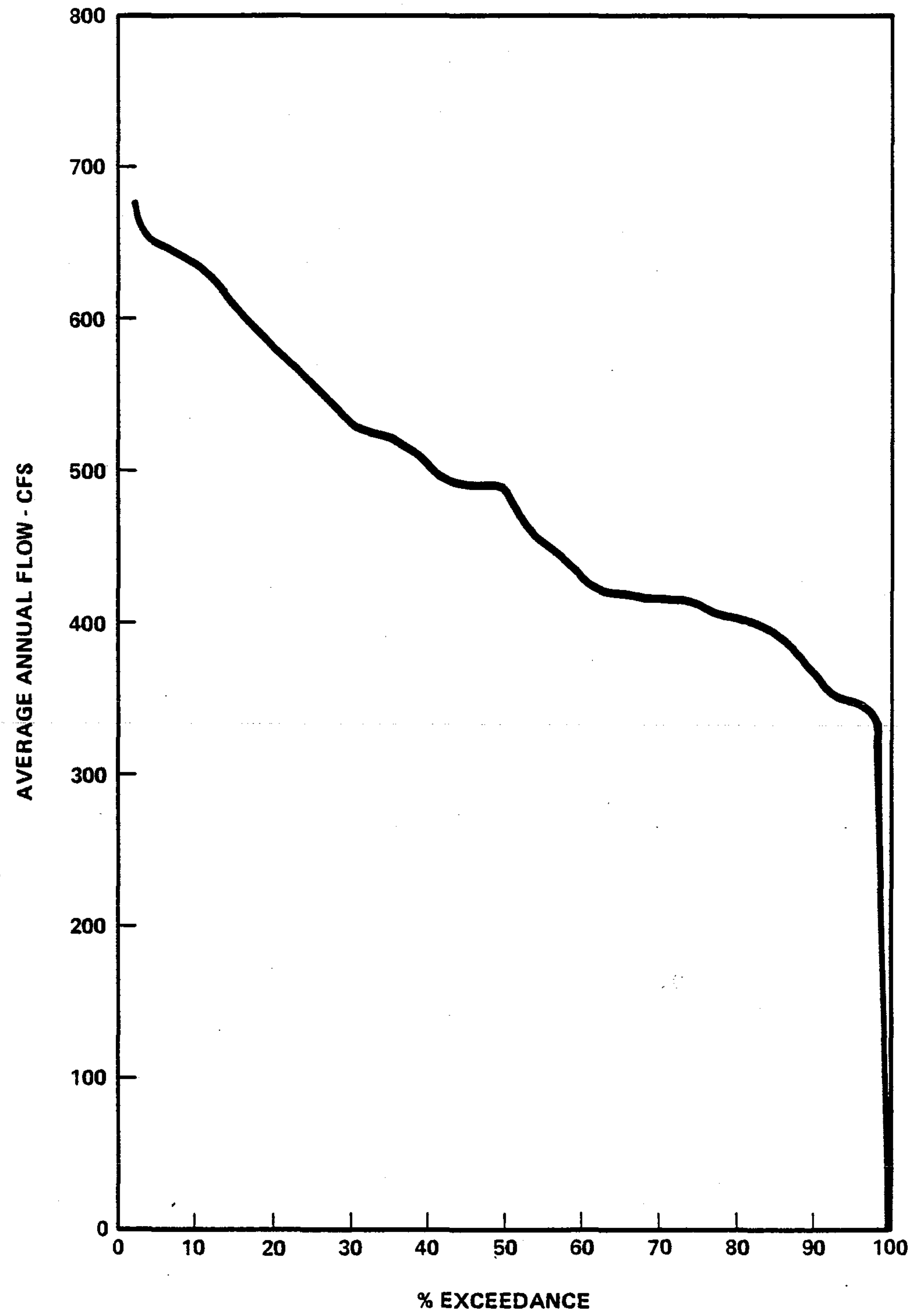
TABLE 5.3-4

BRADLEY RIVER FLOWS AT LAKE OUTLET
ADJUSTED FOR NUKA SWITCH AND FOR TREND OF GLACIER WASTING
DRAINAGE AREA = 56.1 SQUARE MILES
MONTHLY AND ANNUAL MEAN DISCHARGE, IN CUBIC FEET PER SECOND

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
1958	77	577	111	79	42	32	74	389	1,340	1,360	1,640	422	573
1959	275	102	60	33	25	22	33	308	1,030	1,020	1,010	402	363
1960	187	94	60	39	35	24	33	593	879	1,130	1,060	553	394
1961	249	144	179	199	107	42	30	436	915	1,320	1,130	1,230	500
1962	347	116	71	55	31	22	39	177	833	1,070	853	491	344
1963	269	317	127	113	87	67	45	237	765	1,480	1,450	1,210	517
1964	562	94	108	75	63	40	33	87	813	1,190	1,560	1,130	484
1965	477	140	85	64	50	55	75	131	635	1,120	1,193	1,720	480
1966	595	165	70	39	32	31	41	150	942	1,110	2,130	1,800	595
1967	525	64	43	35	31	29	36	253	885	1,200	1,520	1,780	536
1968	231	224	136	99	91	105	62	307	720	1,110	1,260	501	408
1969	277	73	41	35	35	34	43	310	1,650	1,520	1,040	708	482
1970	1,900	211	239	118	116	109	103	331	858	1,280	1,360	716	618
1971	197	382	76	45	36	31	31	115	619	1,360	1,220	487	386
1972	376	108	55	32	20	17	17	141	500	1,140	1,350	1,000	398
1973	413	123	56	34	26	24	28	128	576	884	838	890	337
1974	575	173	50	32	23	19	23	227	534	837	975	1,480	414
1975	346	224	112	55	43	34	30	355	1,010	1,020	821	821	408
1976	424	118	52	39	32	26	41	206	792	1,070	1,120	1,270	434
1977	420	414	312	326	306	178	119	354	947	1,590	1,980	608	634
1978	407	70	37	34	40	42	56	291	888	1,460	1,610	868	407
1979	572	161	104	43	30	27	31	290	651	1,060	862	1,750	509
1980*	1,173	411	85	67	81	74	58	326	936	1,332	1,304	897	564
1981*	779	150	110	233	160	170	310	788	908	1,490	1,643	885	640
1982*	298	251	98	52	73	45	37	138	677	1,107	904	1,780	456

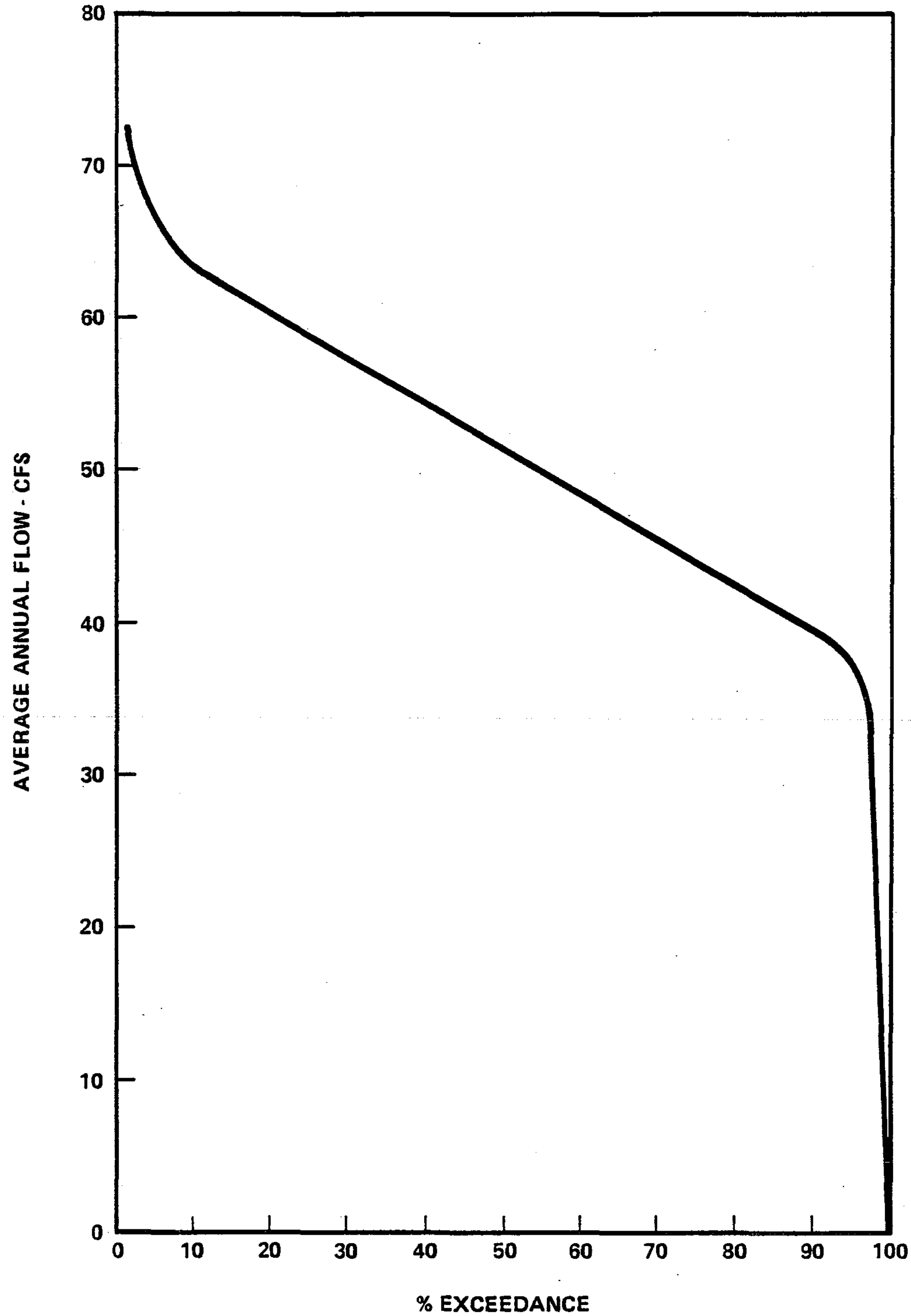
*Recorded

TABLE 5.3-5



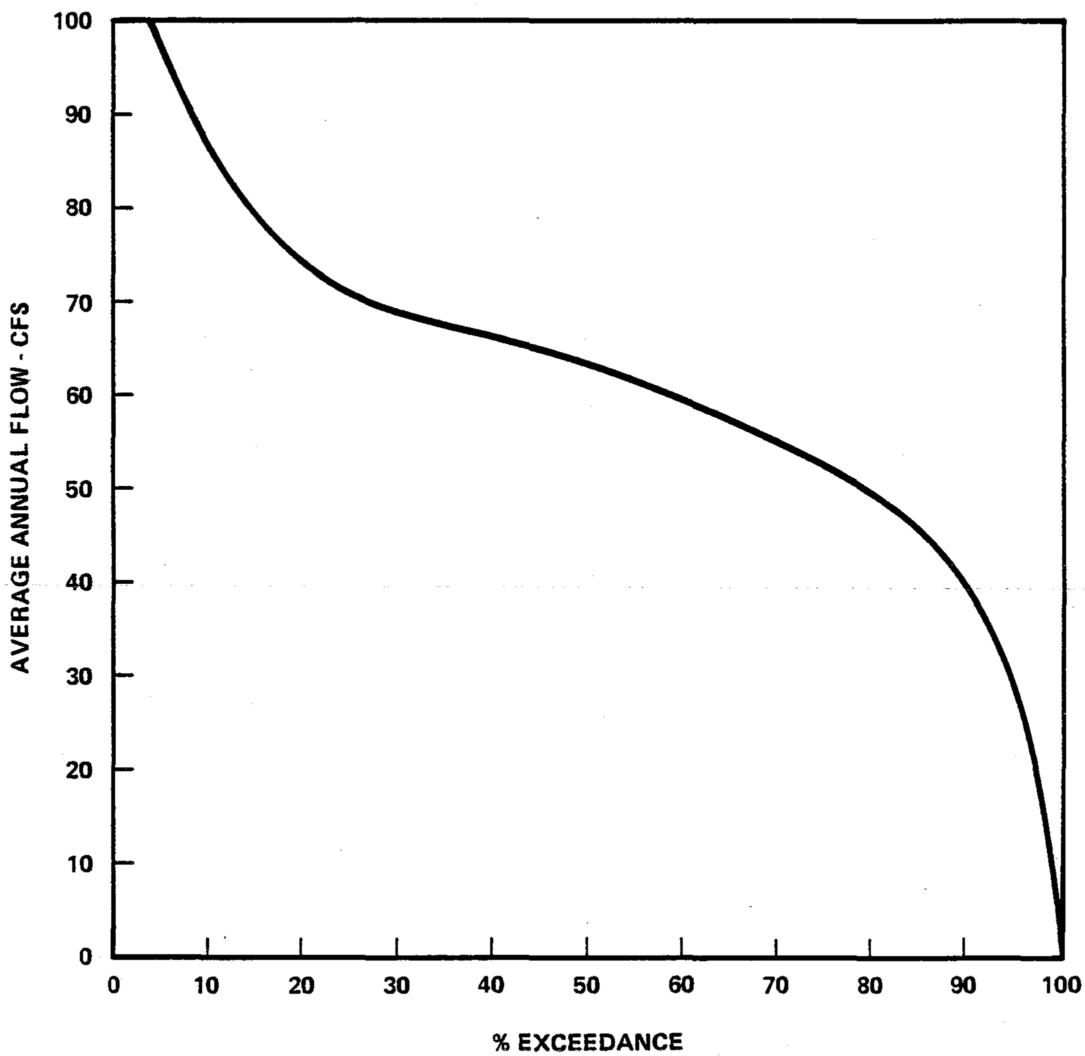
ANNUAL FLOW DURATION
BRADLEY LAKE OUTLET
ADJUSTED FOR NUKA GLACIER SWITCH ONLY

FIGURE 5.3-1



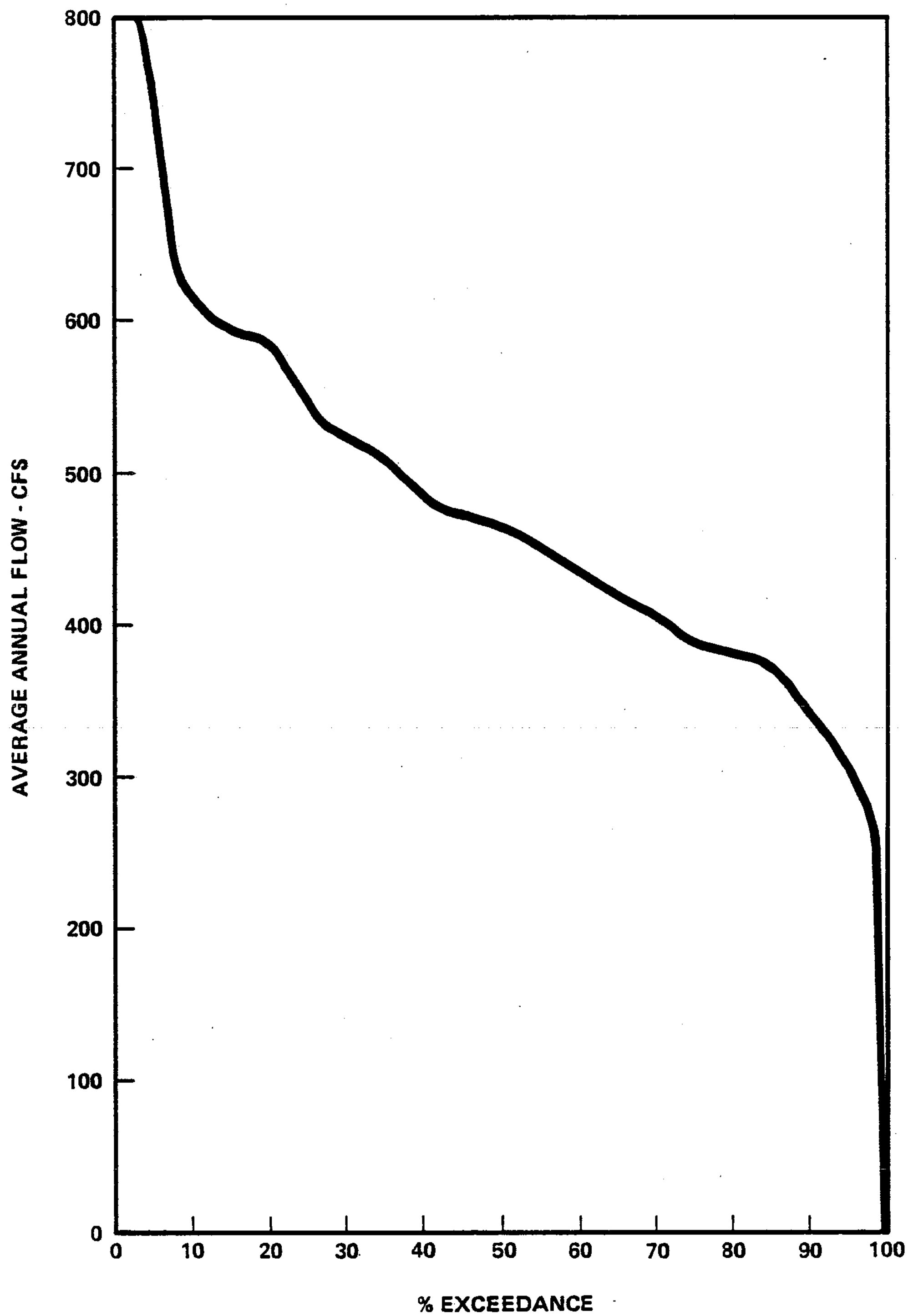
ANNUAL FLOW DURATION
MIDDLE FORK
AT MIDDLE FORK DIVERSION DAM

FIGURE 5.3-2



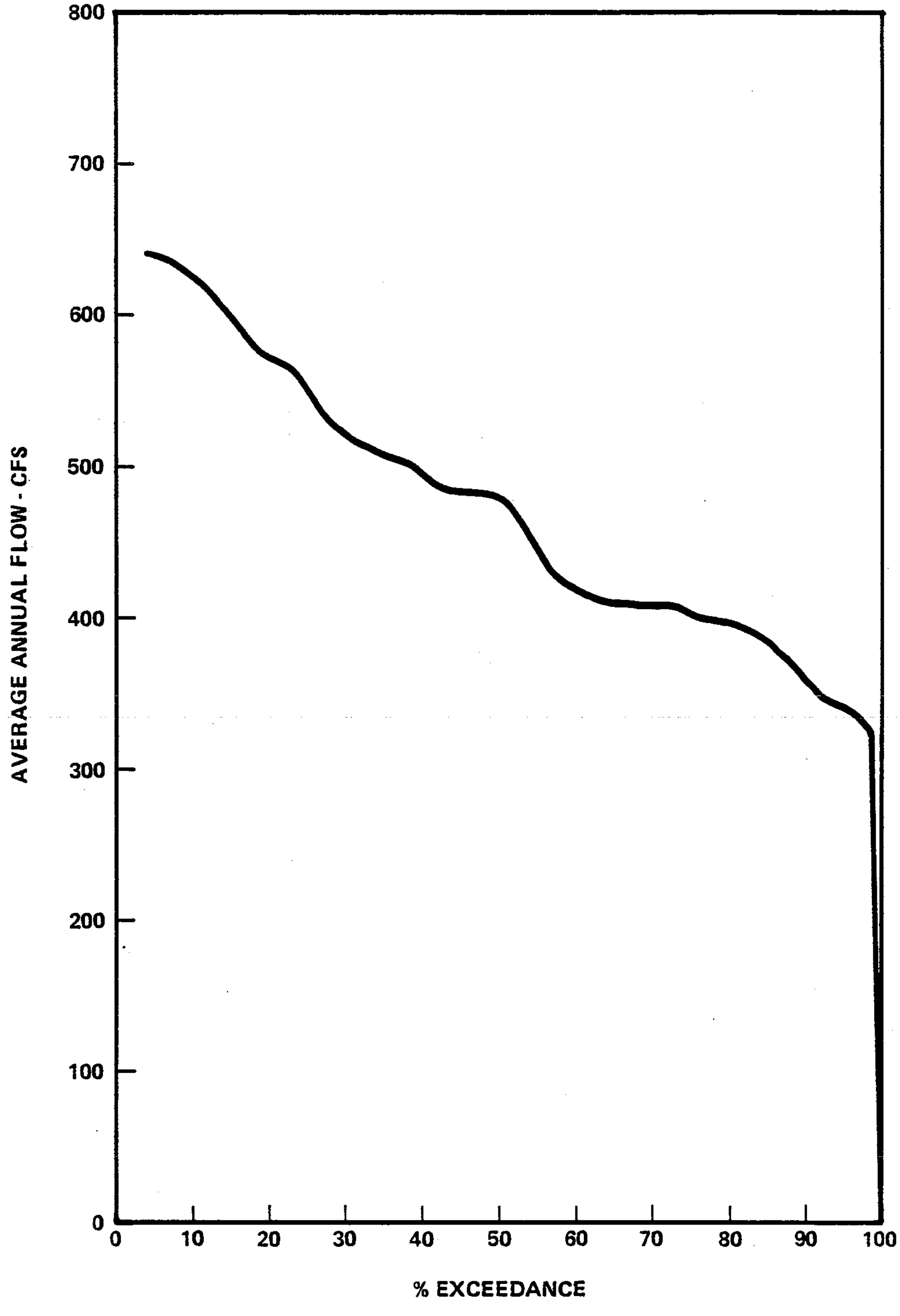
ANNUAL FLOW DURATION
LOWER BRADLEY RIVER

FIGURE 5.3-3



ANNUAL FLOW DURATION
BRADLEY RIVER
WITH GLACIER MASS BALANCE ADJUSTMENTS

FIGURE 5.3-4



ANNUAL FLOW DURATION
BRADLEY RIVER

WITH GLACIER WASTING TREND REMOVED

FIGURE 5.3-5

6

ENGINEERING AND ECONOMIC EVALUATIONS

MANUFACTURERS TURBINE DATA

30 MW UNITS - VERTICAL SHAFT MACHINES

DATA	FRANCIS TURBINES: ALLIS CHALMERS	DOMINION ENGINEERING WORKS, LTD.	SULZER BROS., INC.	KVAERNER BRUG A/S	TOSHIBA	NISSHO IWAI (FUJI)	PELTON TURBINES: ALLIS CHALMERS	SULZER BROS., INC.	KVAERNER BRUG A/S	NISSHO IWAI (FUJI)
PRICES: millions (1)										
Two Turbines	incl.	$5.05	$1.67	$1.73	$2.70	$5.25	incl.	$1.90	$2.70	$6.06
Installation	incl.	1.10	0.32	1.25	0.76	Price	incl.	0.32	1.35	Price includes
Two Inlet Valves	incl.	1.50	0.75	0.89	0.80	includes	incl.	0.75	0.89	Gen. and is
Installation	incl.	0.20	0.075	-	0.25	Gen. and is	incl.	0.75	incl.	FOB Japan.
Two Bypass Valves	0.24	0.75	-	0.20	incl.	FOB Japan.	-	-	-	No installa-
Installation	incl.	0.10	-	-	incl.	No installa-	-	-	-	tion or
Two Governors	incl.	incl.	0.70	0.63	incl.	tion or	incl.	0.70	0.63	freight.
Installation	incl.	incl.	0.05	-	incl.	freight.	incl.	0.05	incl.	
TOTAL INSTALLED	$4.64	$8.70	$3.565	$4.70	$4.51	-	$8.64	$4.47	$5.57	-
RATINGS:										
Rated Power, MW	30.00	34.25	30.00	30.00	34.00	30*	30.00	30.00	30.00	30*
Rated Flow, CFS	342.00	-	419.00	353.00	399.00	348.00	-	427.00	352.00	354.00
Rated Head, FT	1112.00	1112.00	1112.00	1112.00	1112.00	1112.00	-	1100.00	1100.00	1100.00
Sync. Speed, RPM	900.00	900.00	900.00	720.00	600.00	720.00	360.00	360.00	400.00	400.00
Specific Speed (Engl.)	28.10	30.00	30.00	22.80	20.00	22.40	-	-	-	5.10
Runaway Speed, RPM	-	1360.00	1520.00	1135.00	1067.00	1280.00	-	660.00	705.00	730.00
No. of Jets (Pelton)	-	-	-	-	-	-	6.00	6.00	6.00	6.00
Submergence of Runner at c.l., ft	-12.40	-19.00	-46.00	-22.00	-10.50	-15.00	-	+12.50	+7.50	+8.00
DIMENSIONS: (Ft.)										
Runner Throat Diameter	-	3.50	3.10	3.12	-	3.50	6.75	6.55	6.09	5.97
Runner O.D.	4.17	5.20	4.20	5.31	6.30	5.80	-	8.33	7.87	8.20
Runner Height	-	1.90	1.50	1.80	1.74	2.30	-	-	-	-
Spiral Case Inlet Dia.	3.54	3.66	3.30	2.95	3.71	2.90	-	4.27	4.25	4.27
Overall Width of Spiral Case	11.85	13.90	11.55	12.55	15.83	14.40	-	32.27	31.25	27.80
Draft Tube Depth from c.l.	10.20	11.35	9.60	21.40	10.83	10.34	-	17.85	19.00	14.50
Total Draft Tube Depth from min. TWL	22.60	30.35	55.60	43.40	21.33	25.34	-	5.35	11.50	6.50
Draft Tube Outlet Width	8.32	8.90	6.70	7.90	13.45	8.40	-	13.41	12.50	12.00
Head Cover O.D.	-	-	5.40	-	8.53	6.36	-	-	-	-
Distributor Height	-	-	0.62	0.55	-	0.61	-	-	-	-
WEIGHTS: (lbs)										
Runner	-	5,900	14,000	9,330	5,800	5,820	-	14,100	14,800	11,550
Spiral Case	-	21,000	42,000	13,120	22,000	39,000	-	64,000	33,000	34,000
Total Turbine Weight	-	95,000	120,000	-	120,000	-	-	190,000	-	247,700
Hydraulic Thrust	-	94,000	74,500	40,000	-	90,200	-	-	-	-

COMMENTS

(1) FOB jobsite unless otherwise noted

*Will not produce rated power at min. head.

*Will not produce rated power at min. head.

TABLE 6.2-1

MANUFACTURERS TURBINE DATA

45 MW UNITS - VERTICAL SHAFT MACHINES

DATA	ALLIS CHALMERS	DOMINION ENGINEERING WORKS, LTD.	SULZER BROS., INC.	KVAERNER BRUG A/S	TOSHIBA	NISSHO IWAI (FUJI)	ALLIS CHALMERS	SULZER BROS.,INC.	KVAERNER BRUG A/S	NISSHO IWAI (FUJI)
	FRANCIS TURBINES						PELTON TURBINES			
PRICES: millions (1)										
Two Turbines	$5.070	$6.30	$1.90	$2.175	$3.90	$6.66	incl.	$2.60	$3.383	$7.65
Installation	incl.	1.20	0.34	1.347	1.10	Price	incl.	0.34	1.444	Price includes
Two Inlet Valves	incl.	1.90	1.03	1.128	1.20	includes	incl.	1.03	1.128	Gen. and is
Installation	incl.	0.25	0.10	-	0.34	Gen. and is	incl.	0.10	incl.	FOB Japan.
Two Bypass Valves	0.258	0.95	-	0.234	incl.	FOB Japan.	-	-	-	No installa-
Installation	incl.	0.12	-	-	incl.	No installa-	-	-	-	tion or
Two Governors	incl.	incl.	0.80	0.715	incl.	tion or	incl.	0.80	0.715	freight.
Installation	incl.	incl.	0.05	-	incl.	freight.	incl.	0.05	incl.	
TOTAL INSTALLED	$5.328	$10.72	$4.22	$5.600	$6.54	-	$11.61	$4.92	$6.670	-
RATINGS:										
Rated Power, MW	46.80	52.50	45.00	45.00	51.00	45*	45.00	45.00	45.00	45*
Rated Flow, CFS	533.00	-	622.00	530.00	597.00	521.00	-	639.00	530.00	530.00
Rated Head, FT	1112.00	1112.00	1112.00	1112.00	1112.00	1112.00	-	1100.00	1100.00	1100.00
Sync. Speed, RPM	720.00	720.00	720.00	600.00	514.00	600.00	300.00	300.00	360.00	327.00
Specific Speed (Engl.)	28.00	30.00	30.00	23.30	21.00	22.90	-	--	--	5.10
Runaway Speed, RPM	-	1100.00	1220.00	950.00	917.00	1060.00	-	550.00	640.00	600.00
No. of Jets (Pelton)	-	-	-	-	-	-	6.00	6.00	6.00	6.00
Submergence of Runner at c.l., ft	-12.40	-19.00	-46.00	-22.00	-13.10	-15.00	-	+14.30	+9.20	+8.20
DIMENSIONS: (Ft.)										
Runner Throat Diameter	-	4.33	3.90	3.83	-	4.25	8.10	7.84	6.77	7.28
Runner O.D.	5.22	6.40	5.24	6.36	7.40	7.00	-	10.00	9.00	9.84
Runner Height	-	2.30	2.20	2.25	2.10	2.70	-	-	-	-
Spiral Case Inlet Dia.	4.43	4.53	4.30	3.60	4.46	3.50	-	5.58	5.10	5.20
Overall Width of Spiral Case	14.82	17.20	14.65	16.97	18.86	17.55	-	-	37.75	33.91
Draft Tube Depth from c.l.	12.80	14.05	12.00	23.03	13.06	12.94	-	20.83	23.30	16.00
Total Draft Tube Depth from min. TWL	25.20	33.00	58.00	45.03	26.16	28.00	-	6.56	14.10	7.80
Draft Tube Outlet Width	10.40	11.00	8.40	9.30	16.40	10.30	-	16.40	14.75	14.70
Head Cover O.D.	-	-	6.70	-	10.10	9.02	-	-	-	-
Distributor Height	-	-	0.78	0.69	-	0.75	-	-	-	-
WEIGHTS: (lbs)										
Runner	-	10,000	20,000	11,180	9,550	10,700	-	26,000	18,500	21,700
Spiral Case	-	28,000	60,000	21,870	33,000	59,500	-	-	41,200	54,500
Total Turbine Weight	-	155,000	160,000	-	180,000	175,000	-	360,000	-	362,200
Hydraulic Thrust	-	150,000	117,000	60,000	-	134,200	-	-	-	-

COMMENTS

(1) FOB jobsite unless otherwise noted

*Will not produce rated power at min. head. (Francis)

*Will not produce rated power at min. head. (Pelton)

TABLE 6.2-1

MANUFACTURERS TURBINE DATA

67.5 MW UNITS - VERTICAL SHAFT MACHINES

DATA	FRANCIS TURBINES: ALLIS CHALMERS	FRANCIS TURBINES: DOMINION ENGINEERING WORKS, LTD.	FRANCIS TURBINES: SULZER BROS., INC.	FRANCIS TURBINES: KVAERNER BRUG A/S	FRANCIS TURBINES: TOSHIBA	FRANCIS TURBINES: NISSHO IWAI (FUJI)	PELTON TURBINES: ALLIS CHALMERS	PELTON TURBINES: SULZER BROS.,INC.	PELTON TURBINES: KVAERNER BRUG A/S	PELTON TURBINES: NISSHO IWAI (FUJI)
PRICES: millions (1)										
Two Turbines	incl.	$8.20	$2.20	$2.89	$5.50	$8.47	incl.	$3.20	$4.21	$10.50
Installation	incl.	1.40	0.39	1.44	1.40	Price	incl.	0.39	1.54	Price includes
Two Inlet Valves	incl.	2.50	1.34	1.40	1.63	includes	incl.	1.34	1.40	Gen. and is
Installation	incl.	0.32	0.11	incl.	0.46	Gen. and is	incl.	0.11	incl.	FOB Japan.
Two Bypass Valves	0.30	1.25	-	0.28	incl.	FOB Japan.	-	-	-	No installa-
Installation	incl.	0.15	-	incl.	incl.	No installa-	-	-	-	tion or
Two Governors	incl.	incl.	0.90	0.78	incl.	tion or	incl.	0.90	0.78	freight.
Installation	incl.	incl.	0.05	incl.	incl.	freight.	incl.	0.05	incl.	
TOTAL INSTALLED	$6.35	$13.82	$4.99	$6.79	$8.99	-	$16.47	$5.99	$7.93	-
RATINGS:										
Rated Power, MW	67.50	77.00	67.50	67.50	76.50	67.5*	67.50	67.50	67.50	67.5*
Rated Flow, CFS	770.00	-	941.00	795.00	890.00	784.00	-	962.00	795.00	797.00
Rated Head, FT	1112.00	1112.00	1112.00	1112.00	1112.00	1112.00	-	1100.00	1100.00	1100.00
Sync. Speed, RPM	600.00	600.00	600.00	514.30	450.00	514.00	240.00	257.10	277.00	257.00
Specific Speed (Engl.)	28.10	30.00	30.00	24.50	22.50	24.00	-	5.00	5.37	4.90
Runaway Speed, RPM	-	910.00	1010.00	820.00	809.00	910.00	-	470.00	490.00	470.00
No. of Jets (Pelton)	-	-	-	-	-	-	6.00	6.00	6.00	6.00
Submergence of Runner at c.l., ft	-12.40	-19.00	-46.00	-22.00	-17.10	-19.00	-	+17.30	+11.10	+10.00
DIMENSIONS: (Ft.)										
Runner Throat Diameter	-	5.25	4.70	4.69	-	5.10	10.10	9.14	8.80	9.35
Runner O.D.	6.26	7.80	6.30	7.45	8.50	8.20	-	11.70	11.52	12.80
Runner Height	-	2.80	2.80	2.91	2.54	3.00	-	-	-	-
Spiral Case Inlet Dia.	5.32	5.49	5.00	4.40	5.40	4.24	-	6.56	6.25	6.40
Overall Width of Spiral Case	17.80	20.75	17.70	17.96	22.05	21.10	-	45.71	46.45	43.85
Draft Tube Depth from c.l.	15.35	17.00	14.50	26.00	15.52	15.85	-	25.30	28.50	19.00
Total Draft Tube Depth from min. TWL	27.75	36.00	60.50	48.00	32.60	34.85	-	-	-	9.00
Draft Tube Outlet Width	12.50	13.36	10.20	10.90	19.36	13.00	-	20.12	18.70	18.00
Head Cover O.D.	-	-	8.00	-	11.65	10.84	-	-	-	-
Distributor Height	-	-	0.94	0.89	-	0.90	-	-	-	-
WEIGHTS: (lbs)										
Runner	-	16,100	30,000	13,120	15,000	18,900	-	40,800	34,500	45,150
Spiral Case	-	40,000	75,000	34,020	49,000	85,500	-	180,000	66,200	82,600
Total Turbine Weight	-	235,000	200,000	-	250,000	258,000	-	500,000	-	596,000
Hydraulic Thrust	-	220,000	169,000	80,000	-	194,000	-	-	-	-

COMMENTS

(1) FOB jobsite unless otherwise noted

*Will not produce rated power at min. head. (Francis Turbines)

*Will not produce rated power at min. head. (Pelton Turbines)

TABLE 6.2-1

MANUFACTURERS GENERATOR DATA

DATA	---ALTERNATIVE 1. 33334 KVA 720 RPM VERTICAL FRANCIS---					---ALTERNATIVE 2. 50000 KVA 600 RPM VERTICAL FRANCIS---				
	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE
Price - 2 units (millions of $)	$3.60	$3.10	$2.26	$5.00	$3.50	$5.30	$4.10	$3.22	$5.80	$4.60
Installation	1.33	0.77	0.79	N/A	-	1.96	1.00	1.13	N/A	-
Total Price	4.93	3.87	3.05	5.00	4.20	7.26	5.10	4.35	5.80	5.63
FOB Point	Jobsite	Japan	Jobsite	Jobsite	Jobsite	Jobsite	Japan	Jobsite	Jobsite	Jobsite
Efficiency at Percent Load 100%	97.7	97.6	97.6	97.2	97.5	97.7	97.8	97.6	97.5	97.65
75%				96.8						97.1
50%				95.7						96.2
25%				92.2						93.4
Overall Height/in	252	240	184	295	243	290	256	198	315	265
Overall Diameter (in)	180	232	260	145	204	240	256	285	180	240
Total Weight/lbs	210,000	310,900	320,000	265,000	276,000	380,000	443,100	400,000	370,000	400,000
Size of Largest Piece/in.	144x144x132	91x173x90 (stator sect)	No data	150x150x100 (stator)	-	204x120x100	106x197x102 (stator sect)	No data	175x87x105 (stator)	-
Weight Largest Piece/lbs (1)	80,000 (stator sect)	52,900 (stator sect)	160,000 (rotor/shaft)	90,000	95,725	66,000 (stator sect)	75,000 (stator sect)	200,000 (rotor/shaft)	60,000	70,000 (not incl. S.A.)
Location of thrust bearing, above or below rotor	Above	Above	Above	Above	Above	Above	Above	Above	Above	Above

Notes:
(1) In most cases, the weight of the largest piece is a shipping weight.
For maximum crane lift, use 40% of total weight for vertical units. (Rotor weight)
For maximum crane lift, use weight of largest piece for horizontal units.

TABLE 6.2-2

MANUFACTURERS GENERATOR DATA

DATA	-----ALTERNATIVE 3. 75000 KVA 514.3 RPM VERTICAL FRANCIS-------------					--ALTERNATIVE 4. 33334 KVA 720 RPM HORIZONTAL FRANCIS--				
	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE
Price - 2 units (millions of $)	$6.00	$5.50	$4.26	$6.90	$5.66	$3.40	$2.90	$2.20	$4.50	$3.25
Installation	2.22	1.40	1.49	N/A	-	1.23	0.70	0.77	N/A	-
Total Price	8.22	6.90	5.75	6.90	6.95	4.63	3.60	2.97	4.50	3.93
FOB Point	Jobsite	Japan	Jobsite	Jobsite	Jobsite	Jobsite	Japan	Jobsite	Jobsite	Jobsite
Efficiency at Percent Load 100%	98.0	97.9	97.6	97.6	97.77	97.7	97.7	97.6	97.3	97.6
75%				97.2						96.9
50%				96.4						95.9
25%				93.7						92.5
Overall Height/in	280	244	222	335	270					
Overall Length/in						252	232	226	295	251
Overall Diameter (in)	260	287	306	205	245	180	154	146	155	158
Total Weight/lbs	454,000	613,000	640,000	595,000	575,000	210,000	154,000	No data	245,000	203,000
Size of Largest Piece/in. (stator)	204x105x130	106x197x102 (stator sect)	No data	205x103x120 (stator)	-	144x144x132	53x181x154 (stator sect)	No data	195x100x155	-
Weight Largest Piece/lbs (1)	88,000 (stator sect)	75,000 (stator sect)	320,000 (rotor/shaft)	100,000 (stator)	90,000	80,000 (stator sect)	46,300 (stator sect)	160,000 (rotor/shaft)	65,000 (stator)	88,000
Location of thrust bearing, above or below rotor	Above	Above	Above	Above	Above	-	-	-	-	-

Notes:
(1) In most cases, the weight of the largest piece is a shipping weight.
For maximum crane lift, use 40% of total weight for vertical units. (Rotor weight)
For maximum crane lift, use weight of largest piece for horizontal units.

TABLE 6.2-2

MANUFACTURERS GENERATOR DATA

DATA	--------ALTERNATIVE 5. 50000 KVA 600 RPM HORIZONTAL FRANCIS----------					--ALTERNATIVE 6. 75000 KVA 514.3 RPM HORIZONTAL FRANCIS--				
	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE
Price - 2 units (millions of $)	$5.00	$3.80	$3.00	$5.20	$4.25	$5.70	$5.20	$4.00	$6.20	$5.28
Installation	1.85	0.95	1.05	N/A	-	2.11	1.30	1.40	N/A	-
Total Price	6.85	4.75	4.05	5.20	5.21	7.81	6.50	5.40	6.20	6.50
FOB Point	Jobsite	Japan	Jobsite	Jobsite	Jobsite	Jobsite	Japan	Jobsite	Jobsite	Jobsite
Efficiency at Percent Load 100%	97.7	97.9	97.6	97.6	97.7	98.0	98.0	97.6	97.7	97.82
75%				97.3						97.4
50%				96.4						96.6
25%				93.7						94.0
Overall Height/in										
Overall Length/in	290	268	232	310	275	280	311	250	325	293
Overall Diameter (in)	240	173	166	180	190	300	197	186	215	
Total Weight/lbs	380,000	181,000	No data	345,000	302,000	454,000	205,000	No data	550,000	302,000
Size of Largest Piece/in.	204x120x100	63x201x173 (stator sect)	No data	230x105x180 (stator)	-	210x105x130	71x228x197 (stator sect)	No data	230x125x215 (stator)	-
Weight Largest Piece/lbs (1)	66,000 (stator sect)	53,900 (stator sect)	200,000 (rotor/shaft)	100,000 (stator)	74,000 (stator)	88,000 (stator sect)	57,300 (stator sect)	320,000 (rotor/shaft)	165,000 (stator)	100,000 (stator)
Location of thrust bearing, above or below rotor	-	-	-	-	-	-	-	-	-	-

Notes:
(1) In most cases, the weight of the largest piece is a shipping weight.
For maximum crane lift, use 40% of total weight for vertical units. (Rotor weight)
For maximum crane lift, use weight of largest piece for horizontal units.

TABLE 6.2-2

MANUFACTURERS GENERATOR DATA

DATA	ALTERNATIVE 7. 33334 KVA 327.3 RPM VERTICAL PELTON					ALTERNATIVE 8. 50000 KVA 240 RPM VERTICAL PELTON				
	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE
Price - 2 units (millions of $)	$4.20	$3.50	$2.75	$5.50	$4.00	$5.50	$5.00	$3.45	$6.70	$5.18
Installation	1.55	0.85	0.96	N/A	-	2.04	1.20	1.20	N/A	-
Total Price	5.75	4.35	3.71	5.50	4.83	7.54	6.20	4.65	6.70	6.27
FOB Point	Jobsite	Japan	Jobsite	Jobsite	Jobsite	Jobsite	Japan	Jobsite	Jobsite	Jobsite
Efficiency at Percent Load 100%	97.5	97.5	97.5	97.3	97.5	97.6	97.7	97.4	97.6	97.6
75%				96.8						97.3
50%				95.8						96.4
25%				92.7						93.7
Overall Height/in	210	213	212	270	226	220	228	224	285	240
Overall Diameter (in)	280	283	300	215	270	330	339	360	295	331
Total Weight/lbs	300,000	381,400	400,000	430,000	378,000	420,000	566,600	560,000	700,000	561,000
Size of Largest Piece/in.	250x125x75	71x161x83 (stator sect)	No data	No data	-	300x150x70	79x201x94 (stator sect)	No data	No data	-
Weight Largest Piece/lbs (1)	50,000 (stator sect)	33,100 (stator sect)	200,000 (rotor/shaft)	No data	42,000	80,000 (stator sect)	48,500 (stator sect)	280,000 (rotor/shaft)	No data	-
Location of thrust bearing, above or below rotor	Above	Below	Above	Above	Above	Above	Below	Above	Above	Above

Notes:
(1) In most cases, the weight of the largest piece is a shipping weight.
For maximum crane lift, use 40% of total weight for vertical units. (Rotor weight)
For maximum crane lift, use weight of largest piece for horizontal units.

TABLE 6.2-2

MANUFACTURERS GENERATOR DATA

DATA	--------ALTERNATIVE 9. 75000 KVA 276.9 RPM VERTICAL PELTON-----------					---ALTERNATIVE 10. 33334 KVA 327.3 RPM HORIZONTAL PELTON--				
	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE
Price - 2 units (millions of $)	$6.40	$6.40	$4.70	$7.70	$6.36	$4.00	$3.20	$2.60	$4.90	$3.68
Installation	2.37	1.60	1.65	N/A	-	1.48	0.80	0.91	N/A	-
Total Price	8.77	8.00	6.35	7.70	7.71	5.48	4.00	3.51	4.90	4.47
FOB Point	Jobsite	Japan	Jobsite	Jobsite	Jobsite	Jobsite	Japan	Jobsite	Jobsite	Jobsite
Efficiency at Percent Load 100%	97.9	97.9	97.6	97.8	97.8	97.5	97.6	97.6	97.4	97.5
75%				97.5						97.0
50%				96.7						96.0
25%				94.2						93.0
Overall Height/in	250	272	236	295	263					
Overall Length/in						210	295	250	315	268
Overall Diameter (in)	300	339	360	255	313	280	197	210	235	231
Total Weight/lbs	570,000	758,400	600,000	900,000	707,000	300,000	187,000	400,000	375,000	317,000
Size of Largest Piece/in.	290x145x100	95x197x95 (stator sect)	No data	No data	-	250x125x75	45x228x197 (stator sect)	No data	280x80x235 (stator)	-
Weight Largest Piece/lbs (1)	90,000 (stator sect)	54,000 (stator sect)	300,000 (rotor/shaft)	No data	-	50,000 (stator sect)	55,100 (stator sect)	200,000 (rotor/shaft)	120,000 (stator)	100,000
Location of thrust bearing, above or below rotor	Above	Below	Above	Above	Above	-	-	-	-	-

Notes:
(1) In most cases, the weight of the largest piece is a shipping weight.
For maximum crane lift, use 40% of total weight for vertical units. (Rotor weight)
For maximum crane lift, use weight of largest piece for horizontal units.

TABLE 6.2-2

MANUFACTURER'S GENERATOR DATA

-------ALTERNATIVE 11. 50000 KVA 276.9 RPM HORIZONTAL PELTON---------

DATA	GE Co.	TOSHIBA	SIEMENS-ALLIS	HITACHI	AVERAGE
Price - 2 units (millions of $)	$5.10	$4.70	$3.40	$5.90	$4.78
Installation	1.90	1.20	1.19	N/A	-
Total Price	7.00	5.90	4.59	5.90	5.85
FOB Point	Jobsite	Japan	Jobsite	Jobsite	Jobsite
Efficiency at Percent Load 100%	97.65	97.8	97.6	97.6	97.7
75%				97.3	
50%				96.6	
25%				94.1	
Overall Height/in					
Overall Length/in	240	354	250	335	295
Overall Diameter (in)	310	220	272	265	267
Total Weight/lbs	390,000	212,000	540,000	575,000	430,000
Size of Largest Piece/in.	270x135x80	59x252x220	No data	310x100x265	-
Weight Largest Piece/lbs (1)	75,000 (stator sect)	61,700 (stator sect)	270,000 (rotor/shaft)	155,000 (stator)	-
Location of thrust bearing, above or below rotor	-	-	-	-	-

Notes:
(1) In most cases, the weight of the largest piece is a shipping weight.
For maximum crane lift, use 40% of total weight for vertical units. (Rotor weight)
For maximum crane lift, use weight of largest piece for horizontal units.

TABLE 6.2-2

PRELIMINARY ANNUAL ENERGY — GWH

GENERATING FLOW REGIME		OPERATING HEADWATER POOL ELEVATION		2 UNITS EQUAL SIZE — NOMINAL PLANT RATING AND UNIT TYPE						3 UNITS EQUAL SIZE — NOMINAL PLANT RATING AND UNIT TYPE		
				FRANCIS			PELTON			FRANCIS		
				60 MW			60 MW					
Mid.Fork	Fish Div.	Max. HW	Min. HW	FIRM	SEC	AVG.AN.	FIRM	SEC	AVG.AN	FIRM	SEC	AVG.AN
With	Without	1170	1081	304.6	19.3	323.9	329.9	19.2	349.1			
Without	With	1170	1081	280.9	25.2	306.0	296.7	21.2	317.8			
With	With	1170	1081	280.9	35.9	316.7	304.1	26.5	330.6			
				80 MW						90 MW		
With	Without	1170	1081	-	-	-				-	-	-
Without	With	1170	1081	-	-	-				-	-	-
With	With	1170	1081	312.3	31.3	343.7				285.6	45.5	331.1
				90 MW			90 MW			120 MW		
With	Without	1170	1081	333.9	28.2	362.1	332.0	29.7	361.6	-	-	-
Without	With	1170	1081	291.8	30.7	322.5	298.2	31.8	329.9	-	-	-
With	With	1170	1081	304.5	35.5	340.0	308.2	37.3	345.5	313.4	44.3	357.4
				135 MW			135 MW			135 MW		
With	Without	1170	1081	282.5	39.0	321.5	333.2	37.2	370.4	334.6	36.4	371.0
Without	With	1170	1081	239.2	41.9	281.1	299.3	39.1	338.3	292.5	38.6	331.1
With	With	1170	1081	255.0	48.1	303.1	309.2	47.5	356.6	306.9	46.2	353.1

BASIS OF RESULTS:

1. Bradley River flows from Corps of Engineers' Design Memo Number 2, Tables 7 - 1.

2. Middle Fork flows, unregulated basin flows and fish diversion flows (30 cfs min./150 cfs max.) based on preliminary estimates.

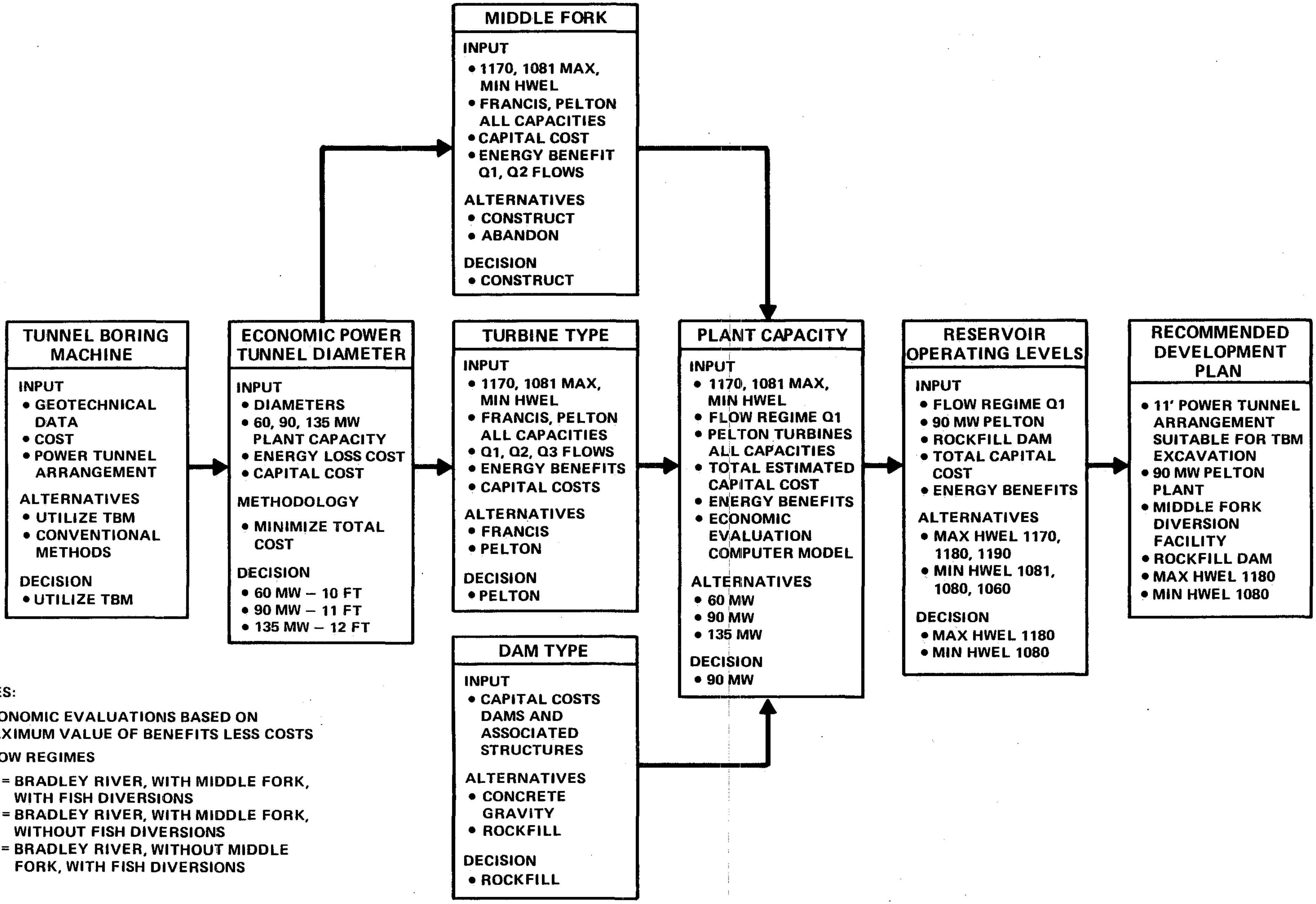
TABLE 6.2-3

RESERVOIR ELEVATIONS SENSITIVITY ANALYSES
90 MW PELTON — TWO 45 MW UNITS

PRELIMINARY GENERATING FLOWS
WITH MIDDLE FORK
WITH PRELIMINARY FISH DIVERSIONS
(30 CFS MIN/150 CFS MAX)

		AVERAGE ANNUAL ENERGY -- GWHRS		
MAX HW	MIN HW	FIRM	SECONDARY	AVG. ANNUAL
1170	1081	308.2	37.3	345.5
1170	1060	313.5	33.1	346.6
1180	1081	318.4	32.6	350.9
1180	1060	323.6	27.8	351.4
1190	1081	328.3	27.3	355.5
1190	1060	333.8	18.6	352.4

TABLE 6.2-4



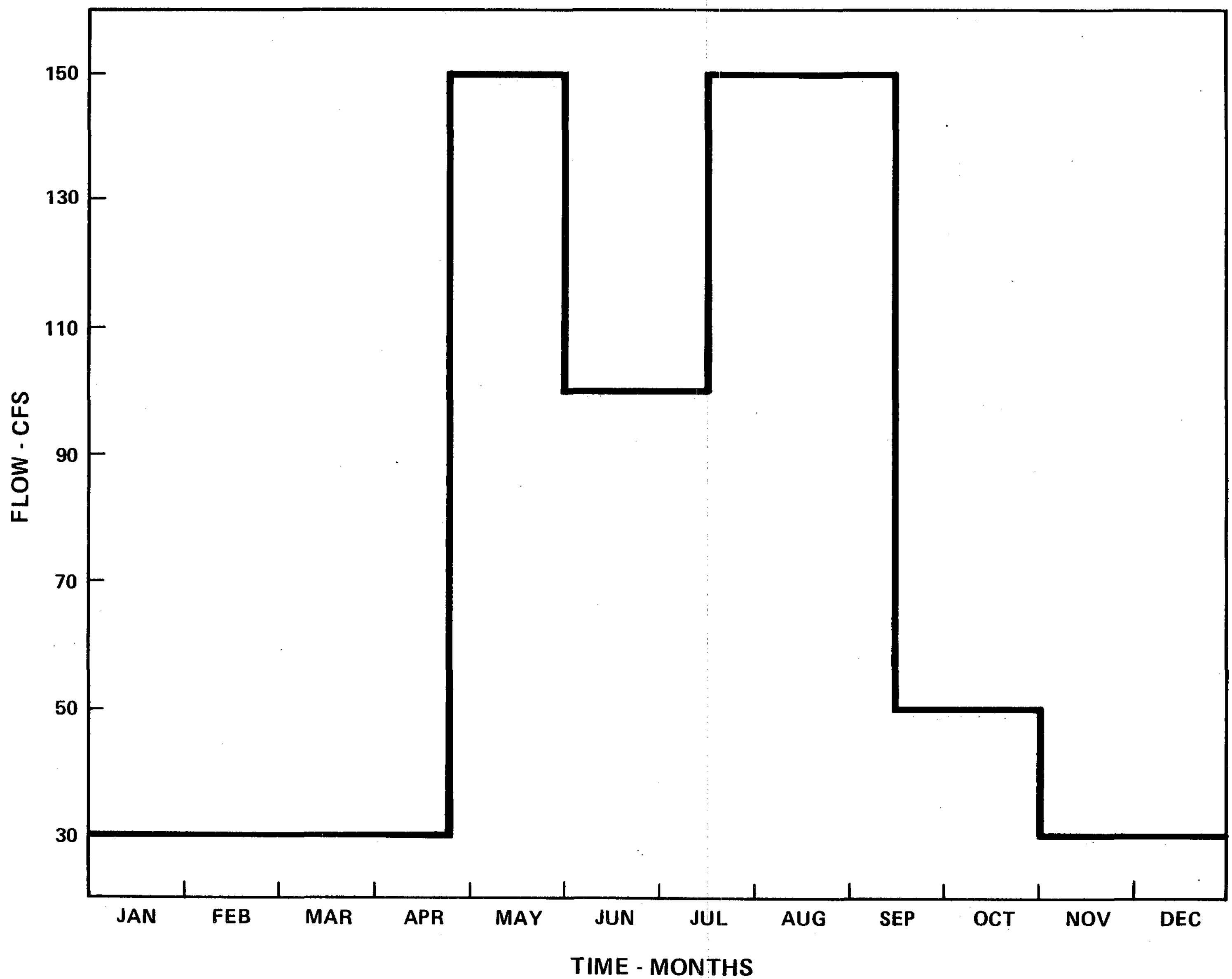
NOTES:

1. ECONOMIC EVALUATIONS BASED ON MAXIMUM VALUE OF BENEFITS LESS COSTS
2. FLOW REGIMES

   Q1 = BRADLEY RIVER, WITH MIDDLE FORK, WITH FISH DIVERSIONS
   Q2 = BRADLEY RIVER, WITH MIDDLE FORK, WITHOUT FISH DIVERSIONS
   Q3 = BRADLEY RIVER, WITHOUT MIDDLE FORK, WITH FISH DIVERSIONS

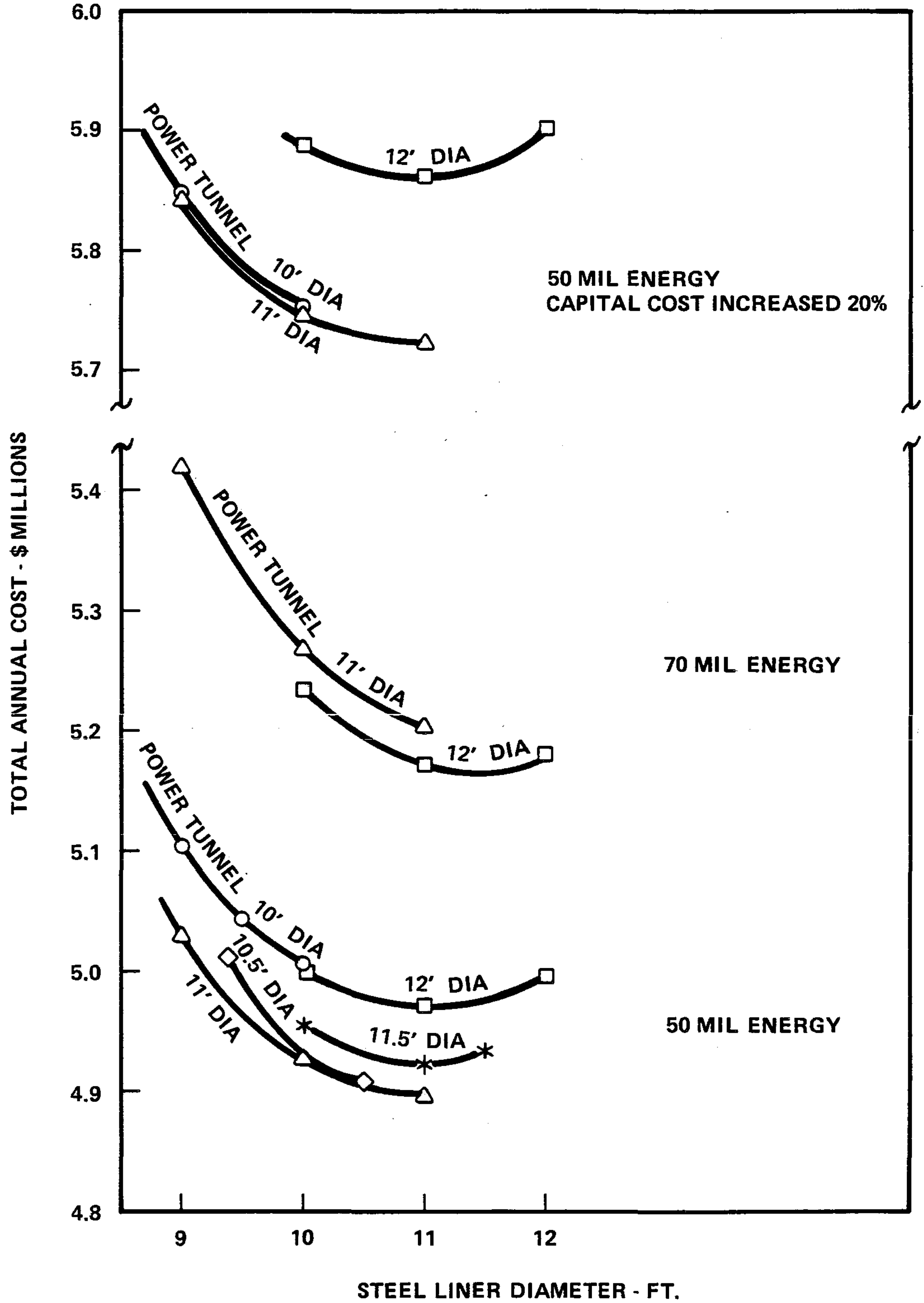
ASSESSMENT OF PRINCIPAL FEATURES – BRADLEY LAKE PROJECT

FIGURE 6.1-1



PRELIMINARY INSTREAM FLOWS

FIGURE 6.1-2

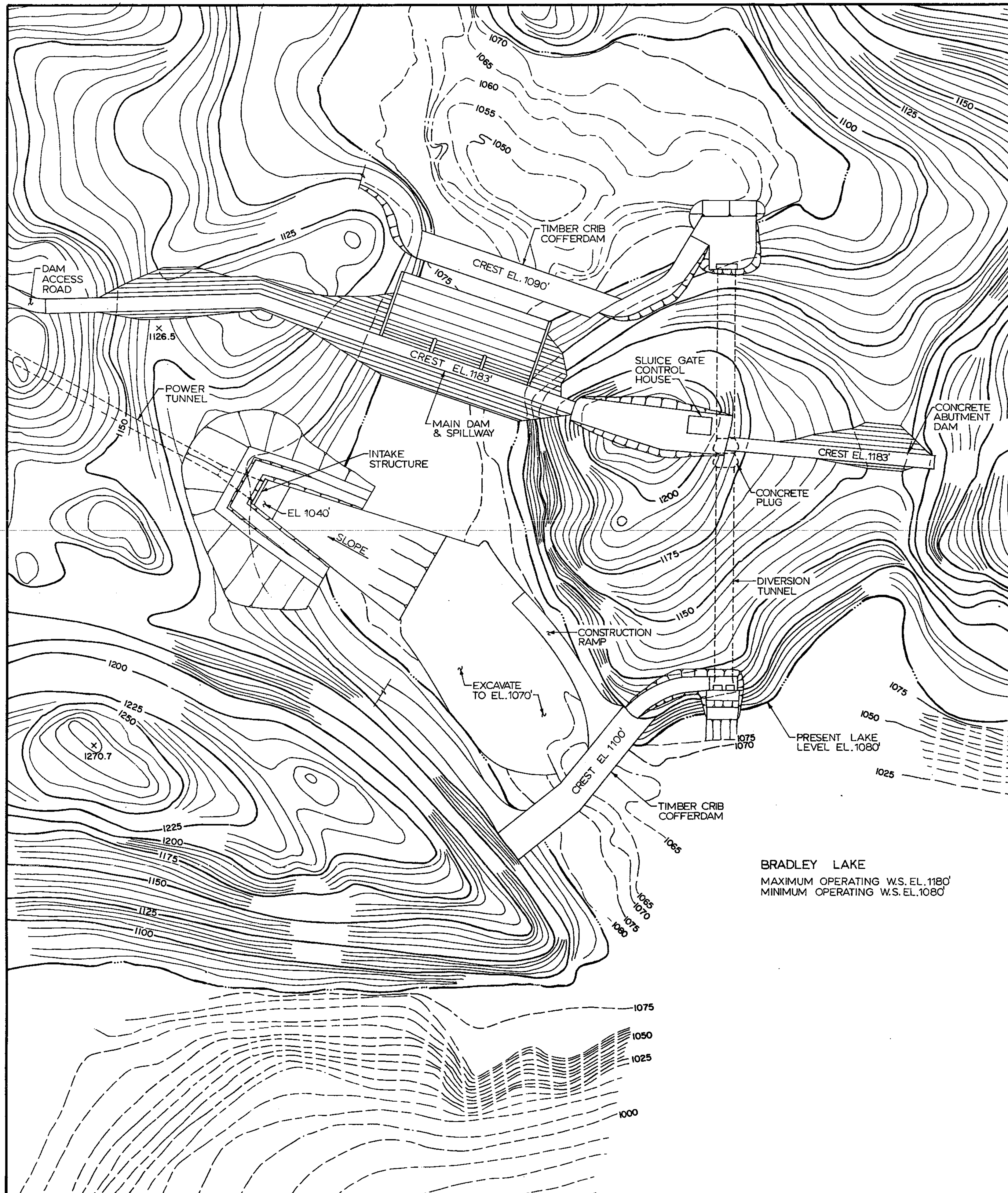


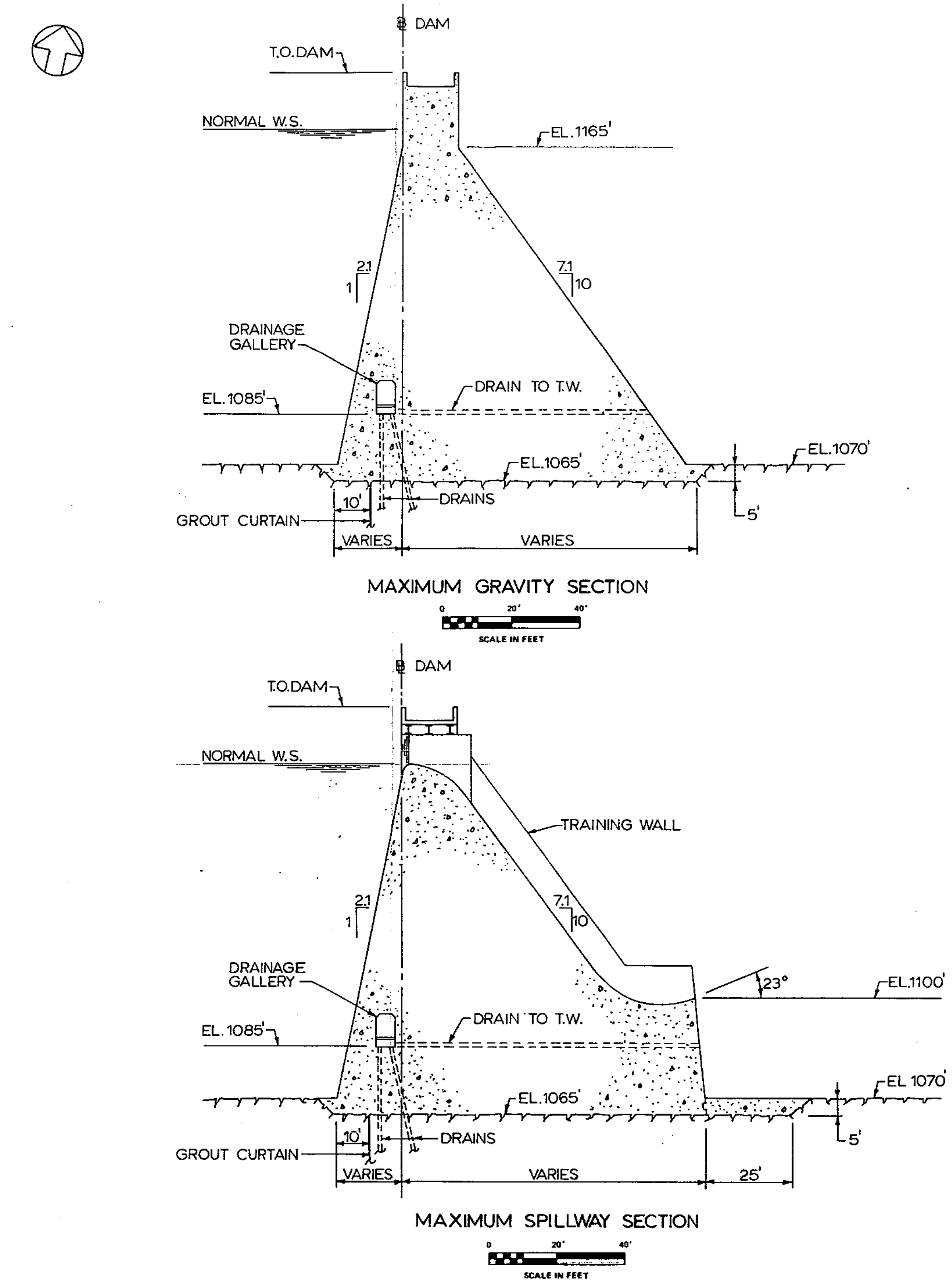
NOTE:

COST OF CAPITAL BASED ON
3.5% INTEREST FOR 50 YEARS

ECONOMIC DIAMETER ANALYSIS
POWER CONDUIT - 90 MW PLANT

FIGURE 6.2-1



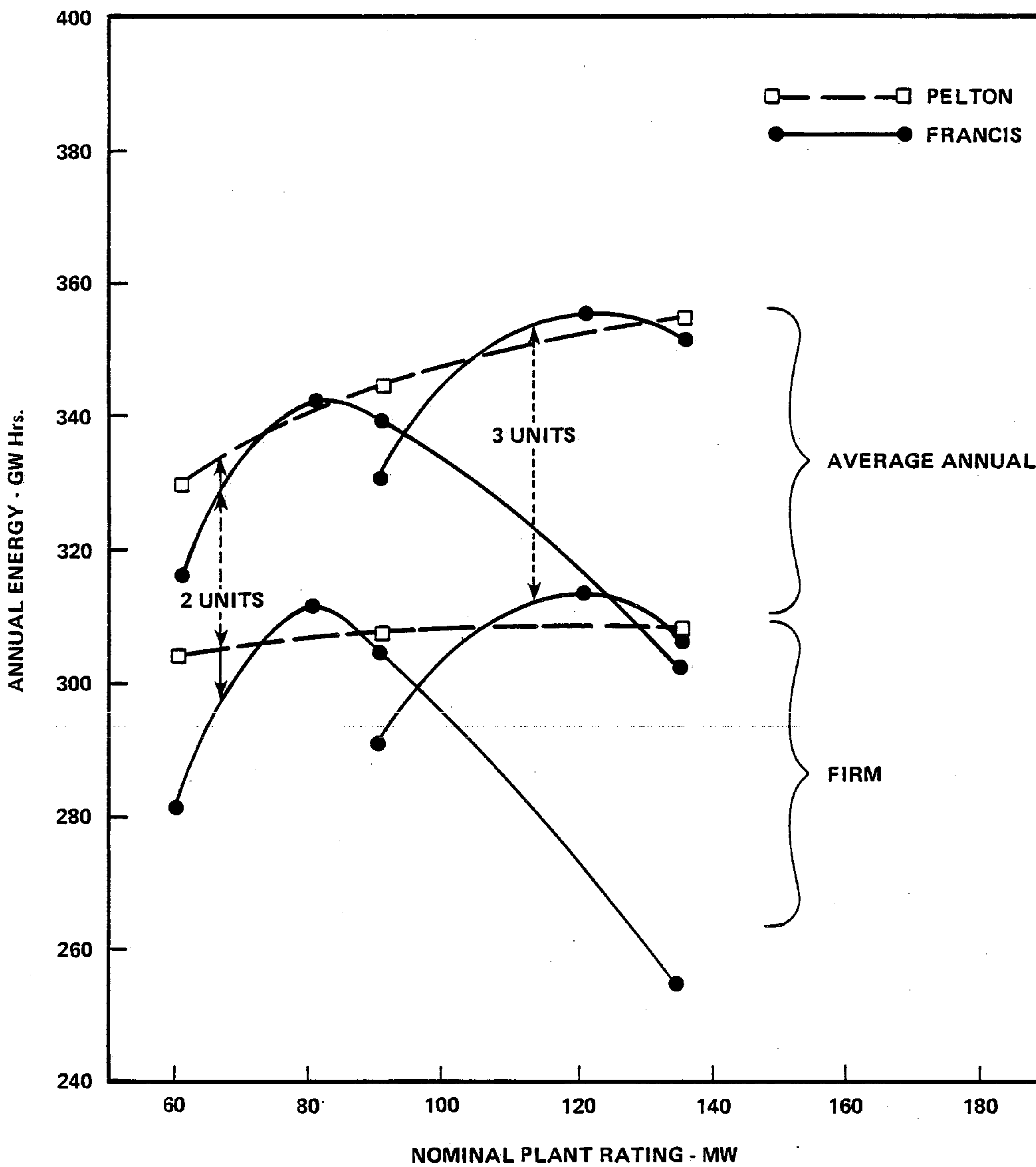


NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

GRAPHIC SCALE 1"=50'-0"

ALTERNATIVE CONCRETE GRAVITY DAM CONCEPT

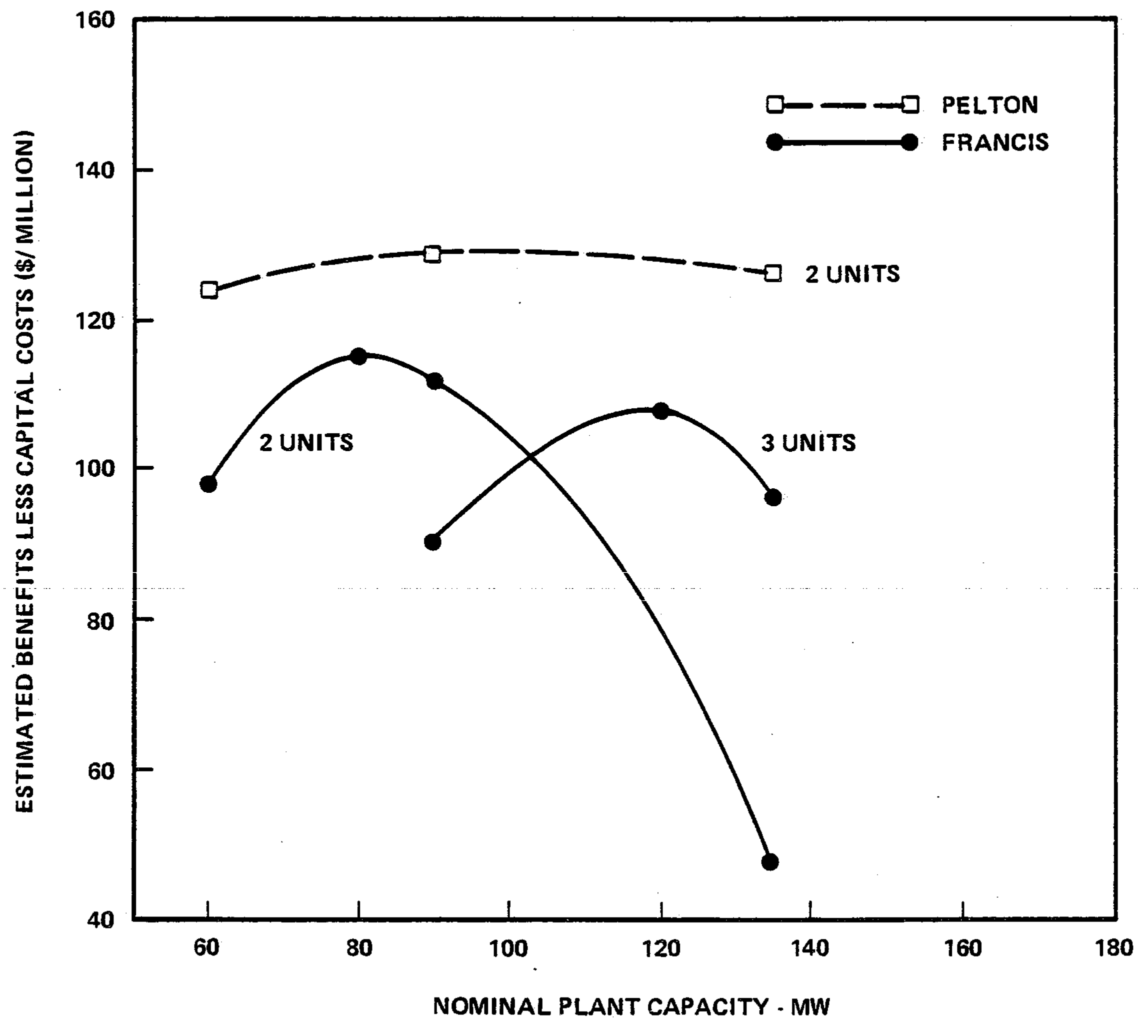
FIGURE 6.2-2



NOTE:
CURVES BASED ON EQUAL SIZE UNITS
MAXIMUM HW EL 1170.
MINIMUM HW EL 1081.
BRADLEY RIVER FLOWS FROM CORPS
OF ENGINEERS DESIGN MEMORANDUM
NO. 2 TABLE 7-1
WITH MIDDLE FORK FLOWS
WITH FISH DIVERSION FLOWS

ENERGY EVALUATIONS
FRANCIS AND PELTON TURBINES

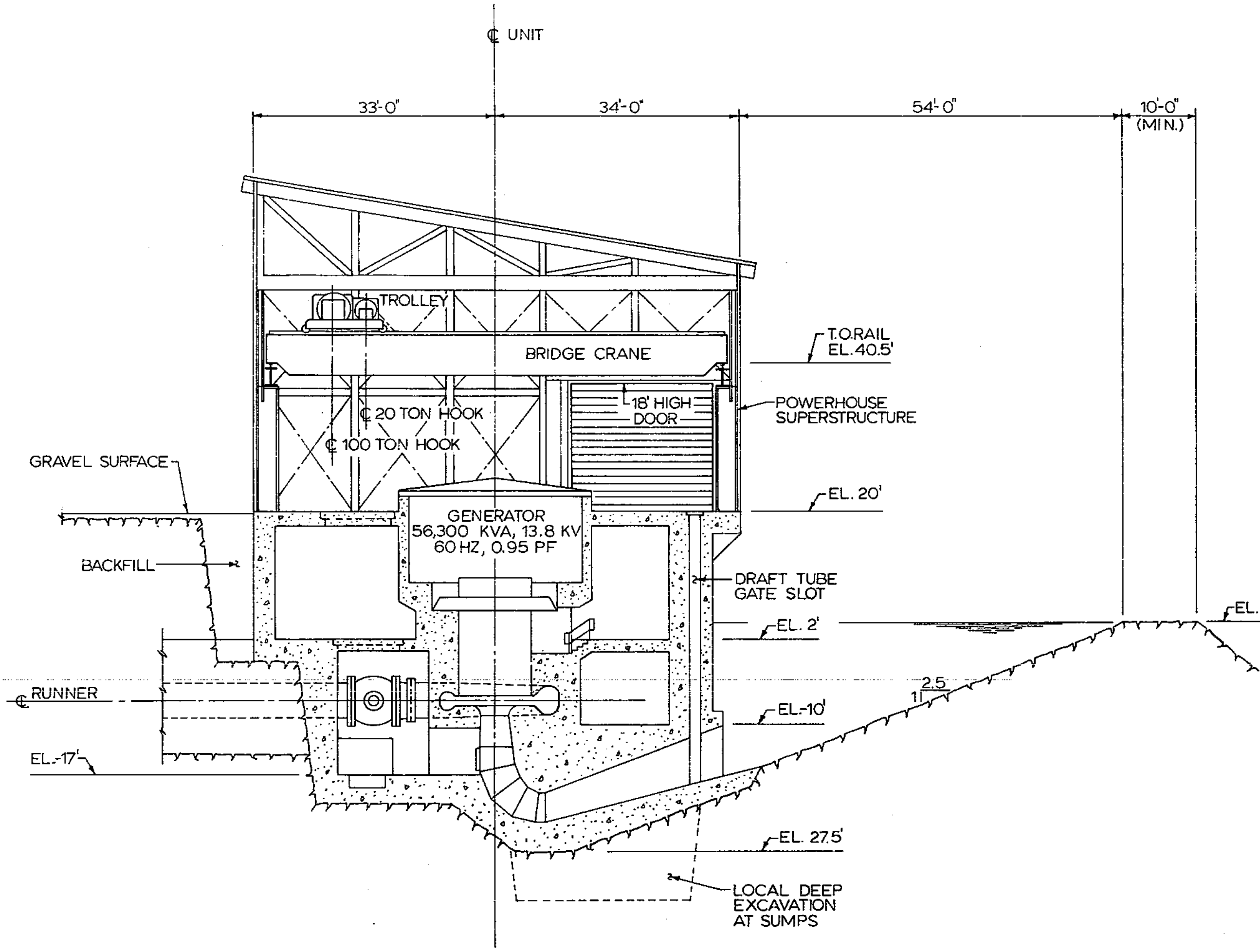
FIGURE 6.2-3



NOTE:
NET BENEFITS DO NOT INCLUDE COST OF 230 kV
ANCHORAGE INTERTIE TRANSMISSION LINE REQUIRED
FOR PLANT CAPACITIES ABOVE 90 MW.

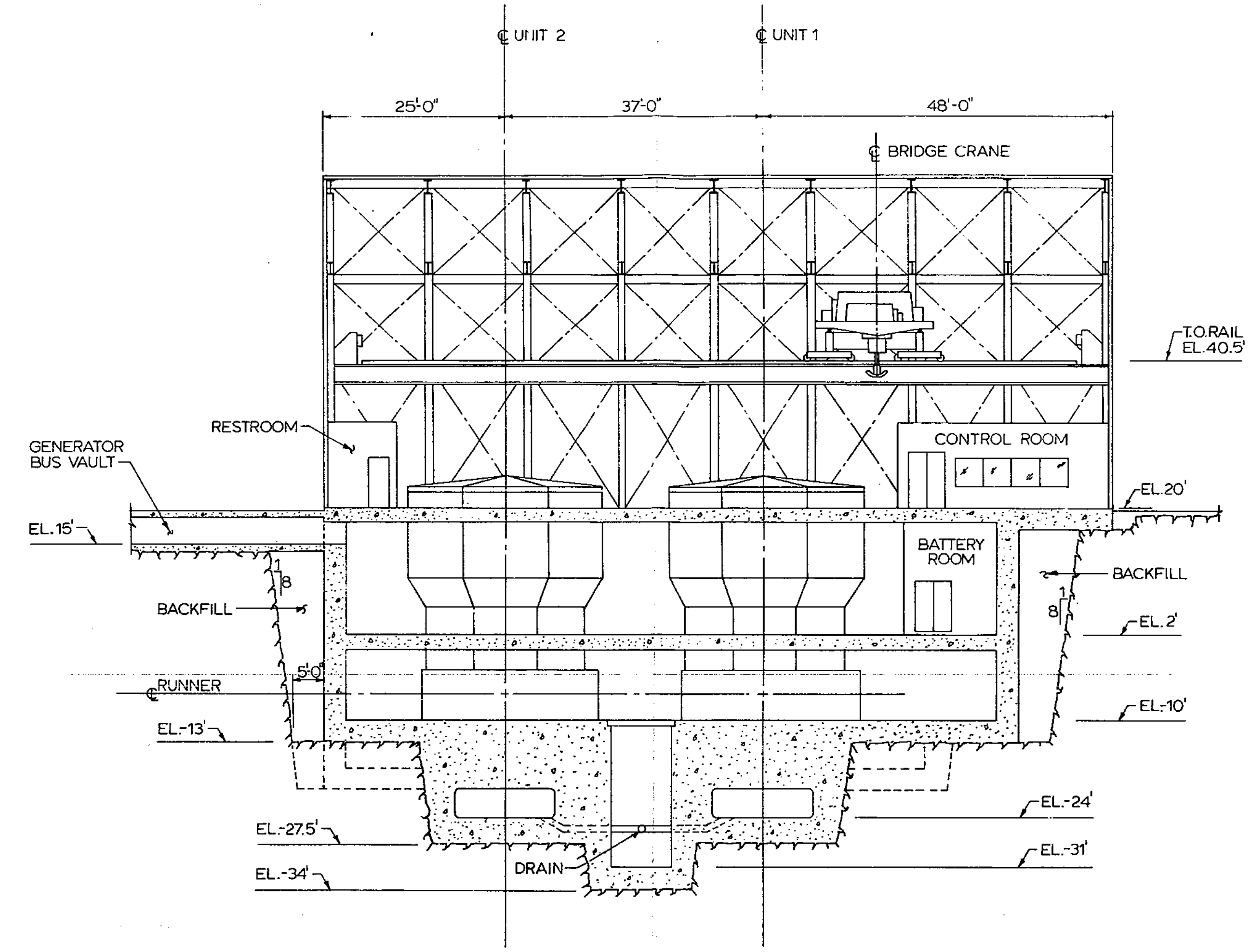
COMPARATIVE EVALUATIONS
FRANCIS AND PELTON TURBINES

FIGURE 6.2-4



TYPICAL CROSS SECTION

SCALE IN FEET



LONGITUDINAL SECTION

SCALE IN FEET

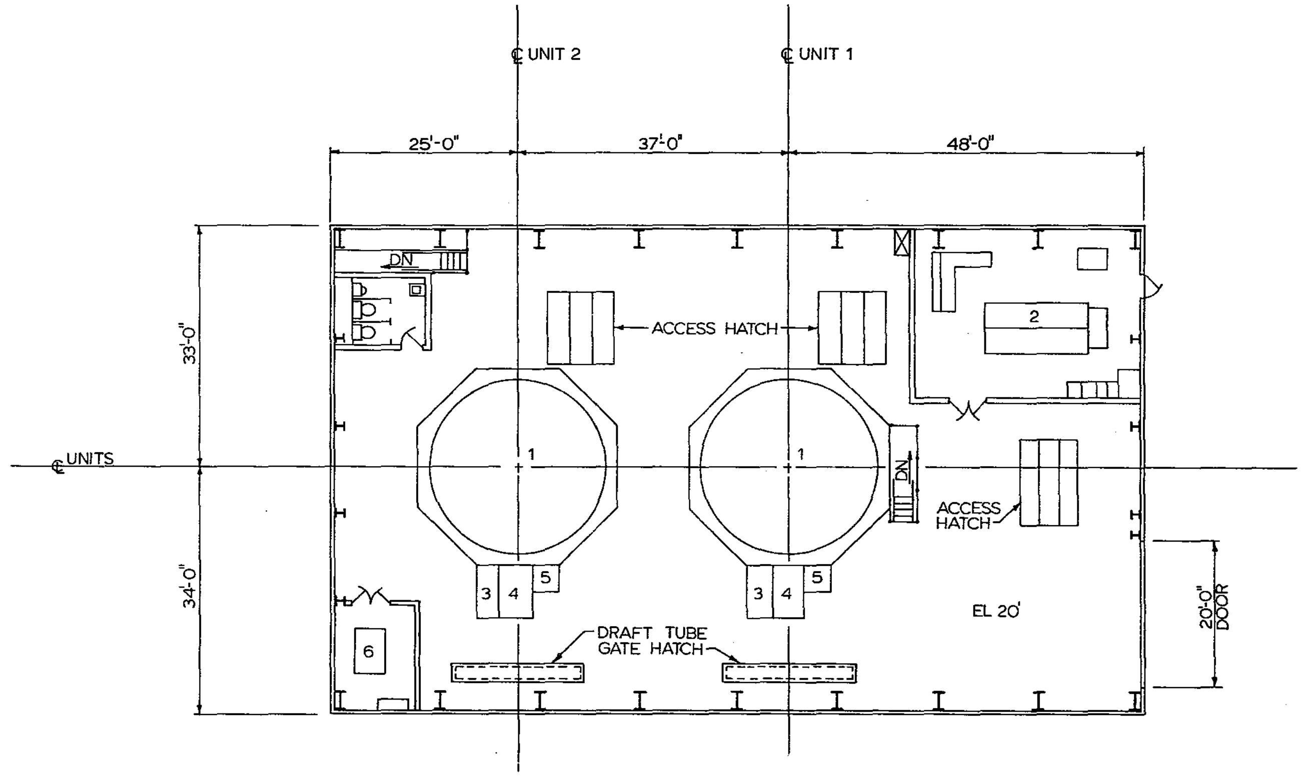
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

ALTERNATIVE

90 MW FRANCIS UNIT

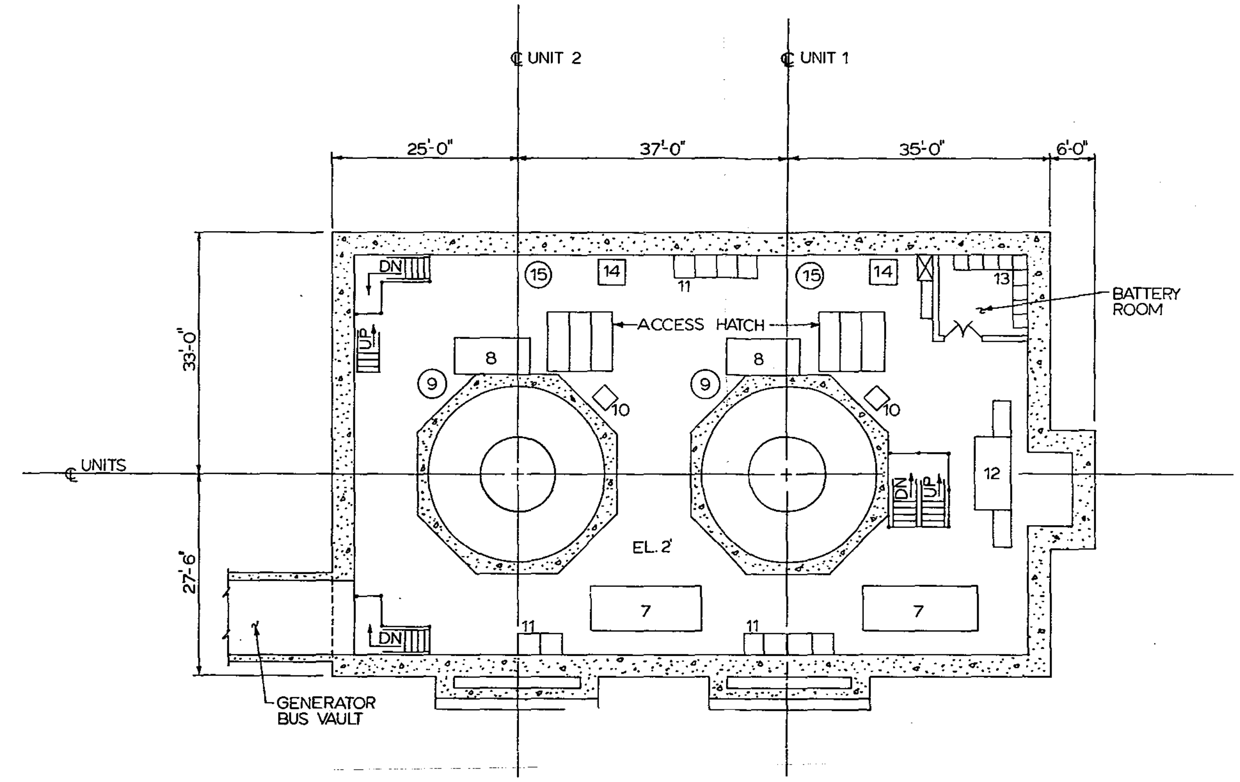
POWERHOUSE SHT. 1

FIGURE 6.2-5



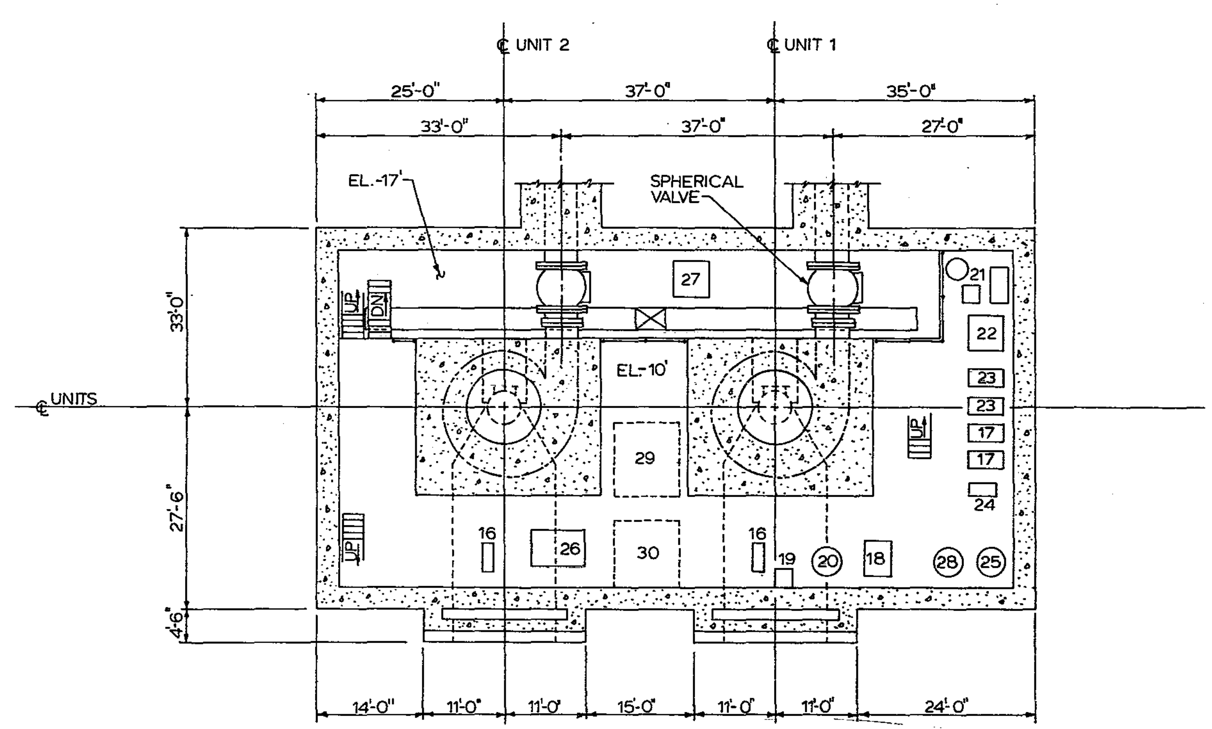
PLAN - FLOOR EL. 20'

SCALE IN FEET



PLAN - FLOOR EL. 2'

SCALE IN FEET



PLAN-FLOOR EL-10'

SCALE IN FEET

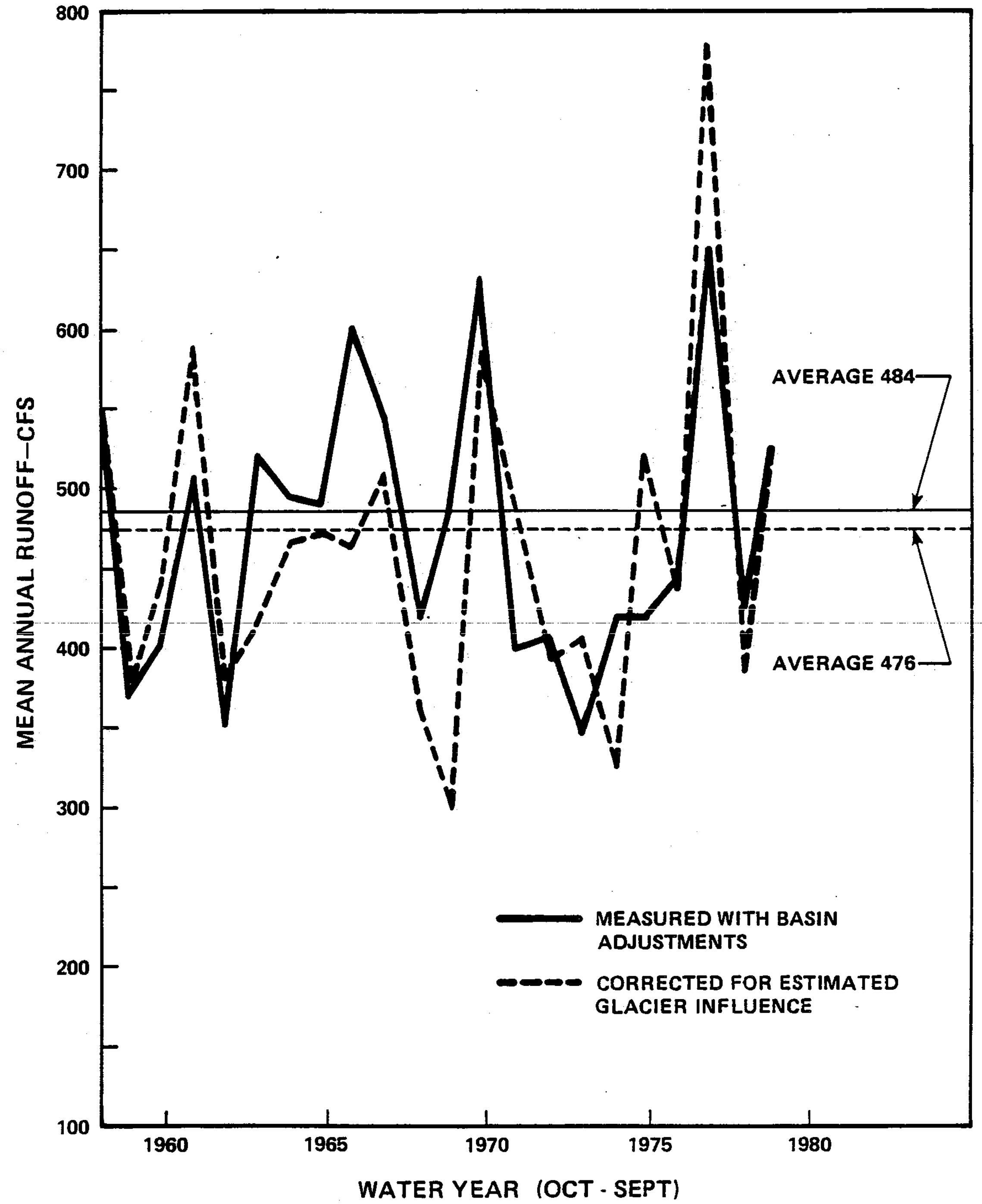
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

EQUIPMENT DATA

1 GENERATOR
2 CONTROL PANELS
3 GENERATOR BREAKER
4 GENERATOR POTENTIAL TRANSFORMER
5 NEUTRAL TRANSFORMER
6 DIESEL GENERATOR
7 STATIC EXCITATION
8 GOVERNOR ACTUATORS
9 GOVERNOR OIL ACCUMULATORS
10 GREASING UNITS
11 MOTOR CONTROL CENTERS
12 480V LOAD CENTER & 480 V SWITCHGEAR
13 BATTERY
14 SPHERICAL VALVE CONTROL
15 SPHERICAL VALVE ACCUMULATORS
16 UNIT SERVICE WATER PUMPS
17 FIRE PUMPS
18 AIR COMPRESSORS
19 AIR DRYER
20 AIR TANK
21 WATER PURIFICATION EQUIPMENT
22 WATER TREATMENT
23 DOMESTIC PUMPS
24 JOCKEY PUMP
25 HOT WATER HEATER
26 OIL SEPARATOR
27 SEWAGE TREATMENT MODULE
28 AIR RECEIVER
29 UNIT/STATION SUMP
30 DIRTY WATER SUMP

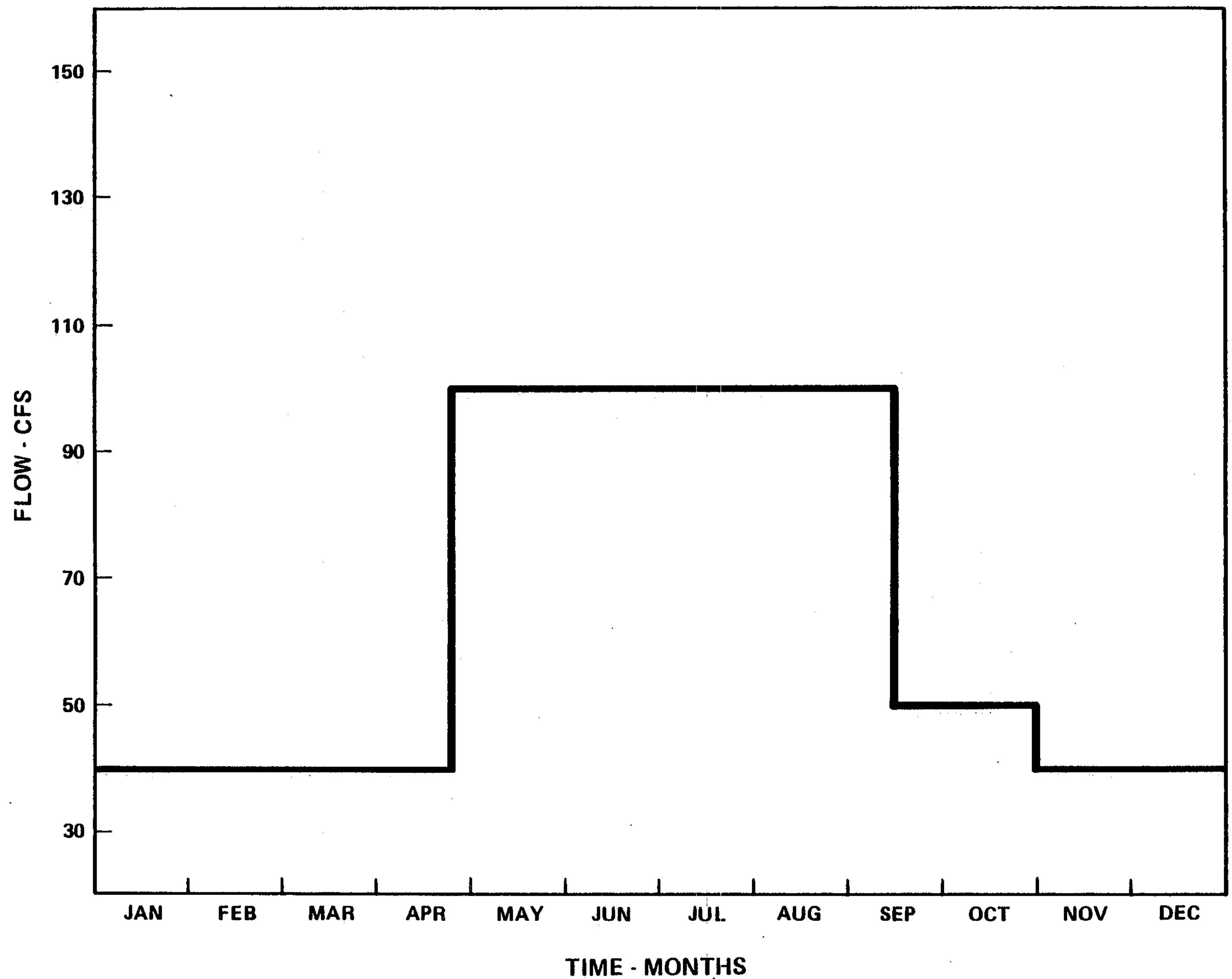
ALTERNATIVE
90 MW FRANCIS UNIT
POWERHOUSE SHT. 2

FIGURE 6.2-6



STREAMFLOWS - BRADLEY RIVER AT BRADLEY LAKE

FIGURE 6.3-1



RECOMMENDED INSTREAM FLOWS

FIGURE 6.3-2

7

DETAILED PROJECT DESCRIPTION

7. DETAILED PROJECT DESCRIPTION

7.1 ACCESS FACILITIES

7.1.1 General

The permanent access facilities for the recommended plan, shown on Plates 4, 5, and 6, include the access channel and barge basin, airstrip, and project roads including:

- o Airstrip to powerhouse
- o Powerhouse to lower camp (via barge basin and staging area)
- o Lower camp to upper camp areas
- o Upper camp to dam (via intake gate shaft, spillway, and construction diversion tunnel)

A temporary road will be constructed between the lower camp and the Martin River material borrow site. This temporary road will be used during project construction but will be later removed and the surrounding terrain rehabilitated. Parking, lay down and storage areas will be used for helicopter access. Access to the Middle Fork Diversion dam will be by helicopter only. Under the recommended plan it was determined that satisfactory operation of the turbine units would be achieved without the need for a surge shaft. Therefore, the access road needed for the development of the surge shaft has been eliminated.

The feasibility level engineering and design studies and the costs developed for the permanent access facilities were prepared by R&M and are given in greater detail in Appendix B of this report.

7.1.2 Barge Basin and Dock

Movements of heavy, bulky equipment, construction material and parts to the Bradley Lake Project site can be accomplished economically and with a minimum of social and environmental impacts by waterborne transportation.

Barge transport allows material and equipment to be prefabricated, largely preassembled or modularized at the manufacturer's or fabricator's shop which accelerates field installation. To accommodate the use of sea going barges to support the project construction a small harboring facility or barge basin is required at the project site. Homer, strategically located at the mouth of Kachemak Bay is approximately 27 miles from the project site and would serve to refuel, and provide shelter and services to sea going barges and tugs enroute to and from the project site. Kachemak Bay is characterized from Homer by "deep water" for 15 1/2 miles, shallow conditions for 3 miles, and tidal mud flats for the final 1 1/2 miles to the project site. To accommodate barge traffic, improvements in the 1 1/2 miles approaching the project are required. These improvements include dredging to a depth sufficient to allow sea-going barge and tug traffic; channel markings; barge docking and off loading facilities; and a materials lay down area. In addition, the inclusion of small boat facilities within the barge basin are desirable for construction, and maintenance and operations personnel use.

In Kachemak Bay, prevailing winds are from the north during winter and southwest during summer. Summertime windspeeds from the southwest were found to be 35 to 65 percent higher at Sheep Point than at Homer due to funneling effects of the terrain surrounding Kachemak Bay. Wintertime windspeeds were considered equivalent at Sheep Point and Homer since the wind direction does not promote a funneling effect. Table 7.1-1, Design Wind Speeds at Sheep Point, presents 1 and 12-hour duration winds for exceedance intervals of 2, 5, and 50 years. The summer southwest winds are relatively strong and have a duration which can affect off loading operations. SWEC concurs with the COE that a barge basin sheltered from southwesterly winds is required. Waves associated with the predominant winds were estimated and are presented in Table 7.1-2. Design wave heights are shown at frequency intervals of 2, 5, and 50 years for Sheep Point and Chugachik Island. Tidal exceedance curves were generated by the COE based on 1982 predictions of the Seldovia Station. These curves were studied together with the wave estimates. Wave estimates by the COE may be conservative with regard to the actual frequency of occurrence due to differences between assumed and actual tidal elevations caused by continuous tidal fluctuation. Additional study is required to confirm this observation. Observations of Landsat photography and conversations with tug captains familiar with Kachemak Bay conditions led the COE to the conclusion that floating and shore-fast ice should not impact winter shipping movements to the project site. Bottom-fast ice may be produced in the shallow channel which would connect the bay and the barge basin. The bottom-fast ice may be produced by increased formation of frazil ice and adherence in the channel resulting from greater fresh water flows into the Bay from power generation, or the growth of surface ice lenses between high tide periods during extreme cold weather.

The operational considerations for the barge basin-dock facilities involve two aspects; barge and tug sizes, and material and equipment quantities and movements across the dock. A design barge of size 250 ft. long by 76 ft. beam by 10 ft. draft, and design tug of size 90 ft. length by 30 ft. beam by 10 ft. draft, were selected based on standard Alaska practice. The handling of material and equipment during barge unloading and loading operations involves roll-off, pass-pass, and crane lift operations. Roll-off operations involve movement of wheeled or tracked vehicles from the barge via a reciprocating off-loading ramp to an earthen ramp rising to the staging area. Pass-Pass operations include barge off-loading via two fork lift trucks, one working on the barge deck passing the load to the other on the dock. The dock fork lift truck would transport the load to the staging area. Crane-lift operations would supplement and support roll-off or pass-pass unloading operations.

Channel excavation on the tidal mud flats is probably not feasible in-the-dry due to the soft silty clay, sandy silt and clayey silt deposits which predominate. Excavation by either barge mounted clam-shell or hydraulic suction dredging during tidal periods when sufficient water is available to float the dredge is anticipated.

Sedimentation in the access channel and barge basin was studied, but insufficient data exists to make an accurate quantitative determination of the sedimentation rate. A quantitative refinement of the rate of sedimentation in the access channel and barge basin is required which should include water sampling and tests at the various tide stages, developing a sedimentation model for predicting sedimentation rates and maintenance requirements, a study of the potential for channel side slope erosion, and the effect of the tidal currents as a source of bed load sediments.

The COE published "Bradley Lake Hydroelectric Project Final Environmental Impact Statement", August 1982, which identified that marine mammal, and waterfowl are the most affected life forms by the construction of the access channel and barge basin. The FEIS indicates that any dredge disposal areas on the tidal flats are to be redeveloped into waterfowl habitat at an appropriate time during construction and that such a measure would enhance the nesting habitat of the tidal flats which is currently non-productive due to periodic tidal submergence. During the first year of construction, to accommodate migrating shorebirds, all dredging, dock, and road construction on the tidal flats would cease from May 1 through 15, in accordance with U.S. Fish and Wildlife service recommendations. The recommended dredge spoil disposal area is located between the powerhouse access road northeast of Sheep Point and the shoreline. The disposal area results in the loss of approximately 40 acres of sedgegrass vegetation. The spoil will be contoured and seeded to enhance waterfowl nesting habitat as discussed in the FEIS. The details of the disposal area have not been developed. Agency consultation and further study of the dredge spoil disposal area will be conducted during the preparation of the FERC License Application.

The access channel from Kachemak Bay to the barge basin has a 200 ft. bottom width. This selection is based on a 1/2 knot tidal current. A turning basin width of 350 ft. was chosen to accommodate the length of the longest barge (up to 343 ft.) using the project facility. To accommodate 10 ft. draft barge movements on 99 percent of all high tides,, or 49 percent of all hourly tidal stages, dredging would be to bottom elevation -14. Due to the depth and extent of the "shallows" at the head of the Bay near the Project site, deepening beyond elevation -14 would require impractically large dredging quantities to improve the functional value of the barge facility.

In order to provide crane hook coverages to most of the design barge deck surface area, dock dimensions of 200 ft. length by 50 ft. width are provided. The dock is of timber pile supported deck construction, Plate 6. This type of dock has several advantages including:

- o Short construction time
- o Constructed of readily available material
- o Allows phased construction
- o Environmental impacts are limited

A reciprocating barge off-loading ramp is provided to allow roll-off barge unloading through the full tide cycle. The ramp is 68 ft long and 20 ft wide and is a single span bridge resting on one end upon the barge deck and pivoting on the shore end on a pile supported concrete abutment. Above the pile supported abutment is a concrete log surface ramp having a maximum 15 percent grade up to the staging area at elevation 18. The small boat launch ramp is built of granular material placed in the barge basin and surfaced with concrete logs. The ramp has a maximum 15 percent grade up to the staging area at elevation 18.

The staging or laydown area, and dock access roads are constructed of well compacted graded granular borrow material placed upon the tidal mud flat north of Sheep Point. These soil pads are to be built north of the slough oriented east to west at Sheep Point. A 100 ft long, single lane bridge crosses over the slough to connect the barge basin facilities and the lower camp to powerhouse access road.

7.1.3 Access Roads

The access roads required to support construction of the major project structures and later operations and maintenance are as follows:

- o Airport to Powerhouse
- o Powerhouse to Lower Camp (via barge basin and staging area)
- o Lower Camp to Upper Camp
- o Upper Camp to dam (via intake gate shaft, spillway and construction diversion tunnel)

The general layout plan which shows the interrelationships of the access roads and project structures is shown on Plate 4. Typical road cross-sections are included in Appendix B. The recommended road types should allow required access and permit economical construction of the project structures. A two-lane road in a high traffic area and single lane road in a low traffic area is warranted. The road to the surge shaft will not be required under the preferred plan.

Critical data considered in the conceptual design of the recommended road system were as follows:

	Two Lane	Single Lane
o Design Speed, mph	20	20
o Lane Width, ft	12	12
o Shoulders, ft	2	2
o Horizontal Curves (Minimum Radius), ft.	100	100
o Sight Distances, ft.	150	300

- o Vertical Curves
  To be calculated in accordance with State of Alaska DOTPF Highway Preconstruction Manual Procedure 11-10-5. Value dependent on design speed and grade difference. Note: "K" value for a single lane two direction road is four times that for a two-lane road.

- o Grades
  Desirable 10%
  Maximum 14%

- o Super elevation
  Not to exceed 6%

- o Cross Slope
  0.02 foot per foot

- Clearing and Stripping

  5 ft from edge of cut slope or 10 ft from toe of fill

- Surfacing

  2 in. minus gravel

- Culverts

  24 in minimum CMP

Construction of the access roads is important in order to allow the movement of equipment, men and material throughout the project site. To permit the earliest commercial operation dates for the project, it is necessary to construct the roads in one season. To accomplish this schedule the roads must be constructed concurrently, and in the case of the road between the lower camp and the dam, from several staging locations enroute with helicopter support to accelerate progress.

The development of an airstrip is proposed under the recommended plan. The location of the airstrip as recommended by the COE, north of the powerhouse is a good general location. Further study indicates that approximately 1000 ft of road savings are possible on the airstrip access road length by locating the landing strip 500 ft closer to the powerhouse location with a runway alignment of 23/5, and locating the parking apron in a natural bay on the southern one third of the landing strip. The access road to the airstrip from the powerhouse has an overall road width of 18 ft allowing single lane traffic. An 18 feet road width provides suitable and economical access to the airstrip. The alignment follows the coastline utilizing slight cuts and associated benching. This alignment minimizes the opportunity for settlement, which could be significant in the tidal clay areas in the adjacent mud flats; and takes full advantage of the higher natural ground relief to reduce the embankment material.

The access road from the powerhouse to the lower camp will be subject to high traffic volume during construction and is a two-lane road. Overall, the alignment suggested by the COE is satisfactory. The changes in the alignment that have occurred have to do with setting the powerhouse and tunnel portal, and relocation of a section of road northeast of Sheep Point to incorporate the barge basin dredge spoil disposal area. The road design elevations provide 0.5 ft of freeboard for the fifty year design wave. Armor is provided to prevent roadside slope deterioration on the Kachemak Bay side. At this time there is insufficient soils information available for determination of expected settlement in those portions of the access road which are located on the tidal clay deposits in the mud flats. Settlements as large as 2 ft in those areas underlaid with deep fat clay can be expected and further settlement analysis prior to final design are required. Conservative borrow quantities have been assumed, but it should be noted that 2 ft of settlement represents an increase of nearly 25 percent in borrow quantities. The magnitude of the expected settlement is related to the soil properties, layer or bedding thickness, real or apparent preconsolidation and the loads imposed. Further consolidation testing and field determination of the layer thicknesses of the fined grained soils will be necessary prior to the road embankment design. The use of Martin River borrow material for the road bed embankment has been assumed for cost estimating purposes. Ground surveyed topographic mapping with cross-sections constructed at 100 ft intervals were used to establish reliable embankment quantity take off data for cost estimating purposes.

The access road from the lower to the upper camp will be subject to high traffic volume during construction of the construction diversion, main dam, spillway, and power conduit intake works. A two-lane road is recommended. The road is a combination of cut and fill type of construction. The lower section road bed along the tidal flats will be constructed with borrow material from the Martin River. The steeper relief sections will be almost entirely of cut construction to establish road benches and switchbacks in rock and then surfaced with selected Martin River borrow gravel. This access road is heavily forested between the lower camp and approximately elevation 1500. The route is characterized by steep side slopes and shallow soils over bedrock. Large quantities of rock excavation are required, but much of this excavated material can be used in the fill portions of the road, and excess cut material can be placed in areas designated as disposal areas or at switchbacks and turnouts. Based upon preliminary examination no avalanche hazards have been identified, but more investigation is required. It is anticipated that this road would be constructed in stages to allow early access to the dam site. The initial stage would be a single lane pioneer road which would be subsequently improved to the final two lane road. To expedite road construction several work areas would be established along the road route to allow accelerated cutting and grubbing and later rock excavation.

The access road from the upper camp to the dam will be subject to high traffic volume during construction of the main dam, spillway and power conduit intake works. A two-lane road is recommended. This road is of cut and fill construction, and surfaced with selected Martin River borrow gravel. The route traverses intermittent areas of exposed bedrock, colluvium, talus, till, and some areas of peat bogs at the lakes and undrained depressions. Bedrock cuts will be required, and the excavated material used in fill embankment sections with excess material hauled to local designated disposal areas.

A temporary haul road is required to transport granular fill, select gravels and concrete aggregate from the Martin River borrow area. The COE proposed alignment is reasonable and the location of the bridge crossing Battle Creek was not changed. After crossing Battle Creek the route stays clear of the outwash fan by following higher terrain to the east. The route continues crossing a rather large tidal flat drainage slough where use of a drainage culvert is possible. No rip rap protection or gravel top course are included. The top of the road has been located at elevation 12. The terrain on alluvial fans from Battle Creek and Martin River is approximately elevation 12, and leveling and grading along the road route will suffice for a temporary roadway surface. A single lane road is recommended in the fill/borrow road section where the natural relief is below elevation 12, all other sections of the road would have two lanes for travelway. Maintenance would be provided on a need basis.

7.1.4 Airstrip

An airstrip is included as part of the project works to allow fixed wing access to the project. The landing strip is located north and adjacent to the powerhouse site with a runway alignment of 23/5 as shown on Plate 4. The layout is consistent with the COE except that a parking apron is located in a natural bog on the southern one third of the landing strip. The airstrip will be designed to meet Federal Aviation Administration criteria for Utility Stage 1. The airstrip geometry is 2,200 ft long with the centerline grade at elevation 16. The runway will be gravel surfaced and will accommodate helicopters and approximately 75 percent of all gross weight fixed wing aircraft under 12,500 pounds. The selected type of airstrip appears adequate for the foundation materials, but like the roads in the tidal flats further geotechnical investigations are required to determine in situ consolidation.

7.1.5 Emergency Access

Permanent Emergency Access throughout the project will be by helicopter because landing is possible along roads; parking, lay down and staging areas; and adjacent to each project structure. All-terrain vehicles including a snow cat are provided with the operations equipment to permit all weather emergency access, but these would be used as the means of last resort in view of helicopter speed and accessibility.

7.1.6 Permanent Maintenance

The permanent operations and maintenance personnel are provided with construction heavy equipment as part of the plant operations equipment and will be able to perform normal and routine maintenance to the roads and airstrip. In the event of a major landslide, sedimentation of the access channel and barge basin, or other major unlikely event, the services of a contractor will be required.

7.1.7 Alternatives

Alternatives for permanent site access facilities developed by the COE were reviewed and other alternates were studied. Detailed discussions of the alternatives are presented in the report prepared by R&M, included as Appendix B of this report.

7.1.8 General Geology

This section includes a discussion of conditions at the Barge Basin, along Access Road alignments, and at the airstrip.

7.1.8.1 Barge Basin

The boring performed in the area of the proposed barge basin, SW 83-3, was advanced using rotary wash techniques with a Simco 2400 drill rig. Samples were obtained at the base of the advanced casing with either a 3" O.D. thin-wall sampler (Shelby Tube), or a 2" O.D. split-spoon sampler driven by a 140-pound hammer falling 30 inches onto the drill rods (Standard Penetration Test). Torvane shear tests and pocket penetrometer tests were performed on each Shelby Tube in the field. In addition to the sampling of Boring SW 83-3, vane shear tests were performed at two depths in the finegrained material.

An additional shallow boring, numbered SW 83-3A, was drilled adjacent to Boring SW 83-3 specifically to obtain Shelby Tube samples from zones interval of Boring SW 83-3. All of the samples obtained from the barge basin location were sealed and returned to S&W's Fairbanks office for laboratory testing.

The potential stability of the soils in the vicinity of the proposed barge basin was evaluated by a laboratory testing program on samples from the single boring location in that area. These soils consist of soft to stiff silty clay and clayey silt overlying silty and clayey sands.

The sensitivity of the fine grained soils was calculated from the results of natural and remolded field vane shear tests, laboratory Torvane tests, and unconsolidated-undrained triaxial compression tests.

Details of the laboratory tests are available in Appendix A. In general, sensitivity ratios between 3.0 and 8.6 were measured. In one case, a value of 1.2 was obtained. This may be anomalous since the water content of the remolded sample was 3% below the natural content. Triaxial test (unconsolidated/undrained) maximum unit stresses (20% strain) were as follows:

Undisturbed	Remolded
5 psi	3.5 psi
13.5 psi	5 psi
18 psi	7 psi

Plastic limits ranged between 17% and 23%, while liquid limits ranged between 24% and 32%.

It appears that soil conditions are adequate to accommodate the proposed Barge Basin under normal conditions. It should be noted that it would probably be impossible to prevent slumping of this material if subjected to the forces of a large or major seismic event.

The test results from soils in the vicinity of the proposed Barge Basin, while suitable for evaluation of feasibility, should not be used for design purposes. In addition to possible variation of soil types between locations in the tidal flat deposits, not all representative soil types may have been sampled or tested at this given location.

7.1.8.2 Airstrip

Soil conditions at the airstrip are anticipated to be similar to those at the Barge Basin, described above. Since the site is somewhat closer to the mouth of the Bradley River, slightly coarser-grained materials may be encountered. No subsurface exploration has been done at this location.

7.1.8.3 Access Roads

In general, road alignments on side slopes will involve near-total or total excavation in slightly weathered to fresh rock with only a few feet of soil cover. In valley bottoms and similar low points, glacial and/or alluvial soils up to several tens of feet thick may be encountered; in places these may be covered by swamp-like peat deposits. While the glacial and alluvial soils should provide adequate subgrade conditions, it may be necessary to completely remove peat and associated organic deposits and replace them with a suitable fill. Roads constructed on or adjacent to the tidal flats of Kachemak Bay will encounter conditions similar to those described for the Barge Basin, above.

7.2 DAM AND SPILLWAY

7.2.1 General

A concrete faced rockfill dam has been selected by the project team as the most technically and economically suitable structure for increasing the storage capacity of the Bradley lake reservoir.

Geologic investigations were conducted along the axis of the proposed dam and its abutments. The findings of these investigations indicate that the site conditions are favorable for construction of the rockfill dam. The proposed dam has an upstream concrete face and the conceptual design has been conservatively developed to resist all expected loads.

An ungated concrete gravity ogee spillway will be located within the saddle of the right abutment and founded on bedrock. It has been designed to pass the Probable Maximum Flood without overtopping the main dam.

7.2.2 Dam and Spillway

A plan of the main dam, spillway, and associated structures is shown on Plate 7. The layout and conceptual details of the dam and spillway are shown on Plates 8 and 9, respectively.

The axis of the recommended dam is approximately 520 feet downstream of the lake outlet. This location and the axis orientation were selected to best utilize existing topographical features and to minimize rockfill quantities for the embankment structure. The selected location also makes effective use of previously obtained geologic data and allows for the development of the embankment within the restricted area of the river. The axis orientation offers good alignment for the upstream toe slab, and results in toe slab construction without excessive three dimensional discontinuities. In addition, the alignment balances the upstream and downstream road access requirements for construction of the dam.

The dam has a crest 18 feet wide, 610 feet long, at elevation 1190 and a height above the lowest average foundation level of 125 feet.

The rockfill embankment section conceptual design is conservatively developed with selected zoned material to withstand hydrostatic, ice, earthquake, and other external loads. The dam is developed using three zones of material compacted to form upstream and downstream embankment slopes of 1.6H:1V. Zone 1, forming the upstream face of the rockfill, consists of selected 6 inch minus material. This zone is placed in 15 feet wide horizontal layers of one foot lifts and is compacted with heavy steel drum vibratory rollers. Zone 2 forms a highly pervious drainage band at the base of the central section of the dam. This zone is composed of selected 6 inch to 24 inch material placed in 3 foot lifts and compacted with vibratory rollers. Zone 3 is quarry material placed in 18 inch lifts and compacted with vibratory rollers. Material placement within this zone will be such as to direct the better quarry material to the upstream half of the zone. Larger or oversized material will be pushed to the downstream face. A total of 362,000 cubic yards of rockfill is required in the dam.

Use of the proper material gradation in these selected zones, coupled with controlled placing techniques, proper spreading and compacting, and controlled use of water to improve workability results in an embankment that is stiff and able to withstand the forces on the dam with minimum deformation. The gradation of the material within the selected zones distributes contact forces with smaller size material occupying the voids between larger rock pieces locking both into position. At the same time adequate space is provided within the rockfill to assure high permeability for the drainage of surplus water.

The upstream face of the dam consists of a parapet wall, concrete face slabs, and toe slabs. The concrete parapet wall, extending 4 feet above the dam crest, is provided with a curved upstream surface to act as a wave deflector.

The impervious upstream face is formed by a series of reinforced concrete slabs. Central face slabs have been conceptually designed as 50 foot wide monoliths. Abutment face slabs are narrower and articulated to provide freedom of movement and to accept greater deflections. The slabs are conceptually designed to have a nominal thickness of 12 inches at the top, near the parapet, varying uniformly to a maximum thickness of 18 inches at the lowest elevation of the dam. Concrete toe slabs are constructed to connect with the face slabs and to form the watertight closure between the upstream heel of the embankment and its rock foundation. A grout curtain is placed under the toe slab for a seepage cutoff in the bedrock.

Approximately 8,900 cubic yards of concrete are needed in the construction of the upstream face slab of the rockfill embankment dam. This is about 11 percent of the amount that would be required for a concrete gravity dam. The smaller quantity of concrete reduces the quantity of aggregate material that would have to be taken from selected borrow areas at the Martin River Delta.

The rockfill embankment is developed in an essentially continuous operation. Materials for its construction are readily available from quarry sources adjacent to the structure. Concrete mixes particularly suitable for cold and harsh environments will be used in the construction of these members, offering excellent resistance to freeze-thaw action, ice buildup, and strains resulting from seasonal temperature variations.

An ungated concrete gravity ogee spillway is located on the saddle feature approximately 150 feet to the right of the main dam and along the same general alignment. The overall length of the spillway including abutments is approximately 220 feet of which 165 feet is provided for the overflow crest. The height from foundation level to the crest varies from 50 feet at the central portion to about 15 feet at the left.

The spillway is founded on bedrock with its concrete gravity abutments keyed into the adjacent rock. It is estimated that approximately 17 feet of overburden and weathered rock will be removed in the central portion with the excavation tapering to either side. A 30 feet deep grout curtain will be developed along the spillway below foundation level and extend westward from the right abutment to the main dam. For added safety, a drainage system is provided downstream of the grout curtain. The system consists of vertical drain holes drilled into foundation rock, a collector pipe, and a lateral pipe discharging seepage into the spillway chute. Also, provisions are made to access the drain holes for cleaning or re-drilling.

The spillway is similar to the COE's design with rounded abutments and an upstream sloping face. The crest is shaped and contoured to produce a gradually accelerating flow on the basis of a 10 feet design head.

The spillway chute directs the discharge onto the exposed rock and into the large natural pool downstream. Erosion of the soil cover will occur, however, once the soil mantle is removed little erosion should occur in the exposed bedrock. A concrete training wall is located on the left side to direct the discharge away from the diversion tunnel outlet. The spillway chute is divided into two sections, a downward sloping section on the left, 55 feet wide, and a 110 foot wide section on the right. This avoids unnecessary rock excavation and helps in dissipating the energy of the flow. Although flow velocities could be high as the flow is directed across the toe of the main dam into the streambed, heavy rip rap armor is placed in this area to avoid serious erosion. In addition, the cost estimate contains funds for model testing this aspect and includes an allowance to cover the cost of providing additional energy dissipating devices.

7.2.3 Hydraulics

Hydraulic aspects of the recommended spillway are basically the same as those in the COE's report. The 165 foot long ogee shaped free flow crest will be capable of passing the routed Probable Maximum Flood and Standard Project Flood with 10.6 and 5.6 feet heads respectively, assuming the powerplant and permanent outlet facilities are inoperable.

Although the crest elevation has been raised 10 feet above the COE's, the effect of the increased surcharge storage of the lake at the higher elevation on the outflow discharge was found to be negligible. The flood routings are shown on Plate 18.

PMF Flood routings were also made assuming one half of the total powerplant hydraulic capacity would be available in one case, and in addition, the full capacity of the permanent outlet facilities above elevation 1185 lake level in another case. The results indicate a decrease in the routed peak outflow about equivalent to the total assumed additional hydraulic capacity available, with corresponding decreases in maximum lake levels. These results are not utilized, however, as they are considered as additional freeboard safety factor for the dam.

Future studies should investigate the hydraulic aspects and structural stability effects of shaping the crest on the basis of a design head less than 10 feet. This would increase the discharge efficiency of the spillway, but at the expense of increased loads due to pressure reduction on the downstream side at heads exceeding the design head. The effect on structural stability however, is expected to be minimal.

7.2.4 Selection of Dam Height

Wave analyses were made to determine the freeboard requirements of the dam under the simultaneous occurrence of waves induced by 70 mph winds, normal maximum water level, and the passing of the Standard Project Flood (SPF). A significant wave height of 4 feet was computed for a sustained wind speed of 70 mph over a fetch distance of 1.6 miles. The run-up induced by this wave on the upstream face of the dam combined with set up in the reservoir was estimated to be 7.5 feet. This produces a required freeboard allowance, when combined with the SPF surcharge level, of 14 feet above the spillway crest level. The crest of the dam was set 10 feet higher than the spillway crest with a 4 feet high wave deflector wall on the upstream face to provide the estimated freeboard. Maximum water level attained during passage of the Probable Maximum Flood was checked to ensure it was within the selected freeboard.

The above criteria are less severe than that used by the COE which is believed to be too conservative. The combined probability of the simultaneous occurrence of the high winds aligned in the direction of the dam along the critical fetch, occurrence of a flood equivalent to twice the flood of record, and the maximum reservoir elevation is considered to be small. The reservoir regulation studies show that maximum reservoir elevation will occur predominantly in August and September, prior to the expected maximum winds. Available wind data, although limited at the site, indicates higher wind speeds in the October through April period during which time the reservoir is expected to be ice covered.

Obviously, the subject of freeboard requirements is subject to the uncertainties of many combined events. The data currently being gathered at the site should be thoroughly reviewed in determining the final freeboard requirements. Analysis of the data should remove some of the uncertainty and result in a more economical structure.

The recommended maximum operating pool level, which has been set equal to the spillway crest elevation of 1180, when added to the estimated freeboard requirements of 14 feet, results in a freeboard elevation of 1194 feet. Since a 4 feet high wave deflector wall will be provided on the upstream face of the dam, the dam crest elevation was set at elevation 1190.

7.2.5 Geology and Foundation

Previous investigations indicate that the location of the proposed dam and intake is in an area underlain by graywacke and argillite. The U.S. Corps of Engineers have previously conducted investigations in the general area of the dam. Field checks confirm conditions delineated by the previous studies. Efforts for this study have been concentrated in the proposed intake area which differs from that considered by the COE.

The current axis alignment is upstream of the COE alignment and varies from it by about 25 to 100 feet.

Since the current alignment is close to that investigated by COE, conditions at this alignment are nearly identical. Conditions and recommendations described below are derived primarily from previous studies supplemented by field observations during this investigation.

Damsite exploration by the COE included eight holes spaced along the dam axis. Drilling exploration indicated an alternating sequence of argillite and graywacke along the entire dam axis. Preliminary studies indicate generally good overall rock quality. Two 45° angle holes were drilled, one on the river's left bank and one in the right saddle, with lengths of 249.9 and 201.7 feet respectively. Vertical holes at the left abutment, left saddle, left knob, and right dam abutment and saddle penetrated 248.3, 133.0, 246.9 and 75.1 feet of rock respectively. One short vertical hole (60 feet) was drilled in the middle of the river.

The right or east abutment at the damsite is a continuous outcrop of massive graywacke, exhibiting poorly developed bedding, in association with thin lenses of cherty argillite. Bedding generally dips at high angles to the west with a strike of about N 10° E-W. Well developed joints are present; spacing varies from less than 1 feet up to 10 feet. The two major joint patterns strike N 60°-70° E and N 45°-55 W. The first has a predominant dip orientation of 65°-75° SE. Dip angles of these joint systems form an "X" and appear evenly divided between 60°-70° NE and 60°-70° SW with a few steep dips of 80°-84° NE and SW. Accessory joints are of minor importance. Overburden appears shallow, with observed depths of 5 feet or less.

A number of minor shear zones or joint swarms were observed in the general area. The largest of these is located on the north flank of the left abutment knob, approximately 150 feet SW of the downstream end of the small rock island. This fault strikes N 4° E and dips vertically. The shear zone ranges from 1 to 15 inches wide and contains a small amount of clayey, silt gouge. A crevice 15 inches to 3 feet wide is eroded 5 to 6 feet back from the face of the rock. A possible continuance of the shear zone exists on the river side of the left abutment knob. This zone is a linear feature about 3 feet wide at the top, tapering to a soil-filled depression 2 feet wide. This feature also approximately follows a minor joint trend and has a strike of N 23° E and dips between 48°-59° SE. This fault is a minor structural feature and is not considered to influence the proposed location or design of the dam.

Investigations in the right abutment saddle (spillway location) indicate 17± feet of talus and overburden overlying moderately jointed, fractured graywacke. Weathering effects persist to the bottom of COE hole DH-33, (75.1 feet). Polished, grooved, and straited bedrock surfaces are present and are typical of areas recently vacated by ice. The right abutment appears to be satisfactory for the planned dam and spillway.

Overburden on the left abutment appears generally shallower than on the right abutment and varies from 0.5 to 2.5 feet on the average. COE drill hole DH-35, drilled in 1981, indicates a depth of 9.4 feet of overburden. Unconsolidated materials appear in the saddles of both abutments. These materials include talus, sand, gravel, and topsoil.

The left abutment is composed of a more argillaceous graywacke that contains thin beds of argillite and argillite-graywacke conglomerate. Aligned, pillow-shaped pieces of graywacke, in a boudinage structure, have been observed in exposed outcrops 600 feet to the south. COE drilling logs from DH-5 and DH-16 show alternating argillite and graywacke units and graywacke with various percentages of argillaceous material. Observed jointing is similar to that of the right abutment, with major joints cutting through bedding planes, striking N 55°-80° W and dipping 80° SW to vertical. Minor localized joints strike N 74° E with dips of from 78°-83° SE. The left abutment rock conditions are also considered to be satisfactory.

The dam will be founded on bedrock composed chiefly of alternating sequences of argillite and graywacke. The in situ rock visible at the surface in the damsite area is all moderately hard to hard and is considered quite adequate to support a rockfill dam. Surficial weathering is generally confined to the upper few feet of rock; however, staining on joints and fractures in the rock are potential leakage channels from the reservoir and provision must be made for seepage control. A grout curtain is required beneath the toe slab of the dam to control underseepage.

7.2.6 Access

Access to the dam is provided by the road that connects the upper reservoir area to the lower campsite, staging, and powerhouse areas. This road is aligned to also provide access for the gate shaft, described elsewhere in the report, and to other structures at the upper reservoir area.

Access to the spillway will be across the crest of the rockfill dam and through a rock cut at the right aubtment. Access across the spillway ogee has been eliminated. Elimnation of this access way and its required support structures results in improved discharge characteristics, lower maintenance, reduces the likelihood of structural and flow blockage problems from icing conditions, and reduces the overall cost for developing the spillway.

7.2.7 Alternatives

The study considered the feasibility of developing a retaining dam using concrete gravity, rockfill, roller compacted concrete, and a double curvature arch dam. Preliminary study findings and conclusions were presented to the Power Authority and preferred alternatives were selected for further refinement and cost development.

The roller compacted concrete dam structure was eliminated because of unknowns in the development of a suitable structure that would provide watertight construction and adequate resistance across the rolled jointing planes to resist the seismic loads associated with the area as well as anticipated construction difficulties due to climatic conditions. The double curvature concrete arch dam was eliminated because of ecnomics. The arrangement of the concrete gravity dam is shown by Figure 6.2-2.

The two types of dams considered for detail evaluation were a concrete gravity dam and a concrete faced rockfill dam. Each type was investigated for a storage pool at elevations 1170, 1180, and 1190 project datum. Design criteria affecting dam stability, dam configurations, and engineering details for each dam type and size were developed and used in conceptual designs. Engineering sketches showing layouts of likely arrangement and physical dimensions of each dam type were prepared and used for quantity estimates. Cost estimates were made for each dam type and size using conceptual arrangement corresponding to each of the three different storage pool levels studied.

Spillway layouts applicable to either a concrete gravity dam or a concrete faced rockfill dam, as evaluated under previous studies, were reexamined. Alternative arrangements for the development of a suitable spillway structure were also formulated and conceptualized. Technical and economic evaluations were made between these alternatives and the previously suggested spillway layouts. Study findings were discussed with the Power Authority and the preferred spillway concepts were selected for further refinement and cost development. Spillway layouts reexamined consisted of: 1) a side channel type spillway at the left abutment; 2) a side channel type spillway at the right abutment; and, 3) a spillway that would be constructed as an integral part of the dam. The first two types of spillways would be developed in conjunction with the construction of a rockfill embankment dam, while all three types would be suitable with a concrete gravity dam. Alternative spillway concepts developed under this study considered the construction of a concrete gravity chute type spillway at the right abutment saddle or the possible development of a fuse plug as a spillway. These spillway concepts would be applicable for both the concrete gravity and rockfill dam.

Comparative direct cost estimates of the concrete gravity dam and the concrete faced rockfill dams, with an overflow spillway at the right abutment, showed a $4 million to $6 million differential in favor of the rockfill. The cost of the concrete faced rockfill dam with an ungated concrete ogee spillway at the right abutment was found to be the lowest of all the alternatives that were studied. The concrete faced rockfill dam was therefore selected in the preferred scheme based upon this cost advantage, timing for construction and material needs.

7.3 CONSTRUCTION DIVERSION

7.3.1 General

Bradley Lake flows need to be diverted or handled in a manner that allows for the construction of the main dam and other associated structures within the river channel near the lake outlet. Diversion concepts perviously identified and their relationship to the development of other water conveyance and control structures were reviewed. Alternative concepts representing independent modes of flow diversion were identified and studied. The ability for providing a suitable permanent low level outlet and controlled flow releases was also studied. Environmental and construction attributes were evaluated and conceptual designs prepared for costing and economic comparisons.

7.3.2 Diversion Tunnel

The recommended method for diverting Bradley Lake flows, during the construction of the main dam and other related structures, is by a short tunnel constructed through the right abutment. This concept allows for passage of flows, as they occur naturally within the drainage system, and does not require the lowering of Bradley Lake. Also, the diversion allows for the development of a low level outlet for controlled flow discharges during the life of the project, as may be required for maintenance or for downstream aquatic habitat.

The diversion tunnel is an 18 foot nominal horseshoe shaped tunnel about 470 feet long and is shown by Plate 10. The tunnel is constructed during the late fall/early winter period and is advanced from the downstream portal towards Bradley Lake using drill and blast techniques. This construction time period is selected so that the diversion works can be made operational by the spring of the following construction year.

The horizontal alignment of the tunnel has been selected such that both portals can be made accessible to construction, and to respond to restraining conditions imposed by other nearby structures developed in the adjacent areas of the river channel. The vertical alignment is established to provide the desired flow characteristics while minimizing cofferdamming needs at the portals. Only the downstream and upstream portal areas will be lined prior to diverting flows. This is done to provide structural support and protection from erosion by flow velocities. The upstream lining is constructed as an extension of a concrete intake portal that is designed to accept steel stop logs for closure of the diversion tunnel.

About 8,300 cubic yards of material will be excavated from the diversion tunnel and its portals. Excavation for the upstream portal will be spoiled in the lake adjacent to the portal area. Material excavated from the downstream portal will be used to improve the construction working area at this portal. Tunnel excavation will be spoiled in designated waste areas near the vicinity of the dam.

Subsequent to the need for construction diversion, the tunnel will be closed off and completed with the construction of a concrete plug and by concrete lining the invert and tunnel sides up to the spring line, downstream of the concrete plug. The low level outlet with its flow regulating gates is constructed as part of the concrete plug as described herein. A grout curtain plane is developed around the concrete plug to cut off seepage flows. The plane is oriented to connect with or complement similar grout cut off systems developed as part of the spillway and dam structures. The tunnel between the concrete plug and the concreted upstream portal section is left unlined. The steel stop logs are removed when the concreting is completed and the diversion tunnel becomes a low level outlet. A heavy grillage or other protective device is provided at the outlet of the tunnel to prevent large animals from using the tunnel as a habitat area.

7.3.3 Permanent Outlet Facilities

The permanent outlet facilities and fish bypass system is constructed as part of the diversion tunnel concrete plug. The low level outlet consists of two 3.5 feet wide by 5.5 feet high sluicing conduits built at the tunnel invert and extending the full length of the concrete plug. Each sluicing conduit is provided with two hydraulically operated slide gates. Within each sluiceway one gate is considered active and is operated to regulate flow. The second gate is used in an emergency and if maintenance is required to the active gate.

7.3.4 Hydraulics

The diversion scheme developed in this study is based on the need to safely pass the routed peak discharge of a flood which could reasonably be expected to occur during the time period which the diversion facilities would be in operation.

The COE study utilized the 1979 flood of record as the inflow design flood for its diversion scheme. This flood had an average daily peak discharge of 5210 cfs and an instantaneous peak discharge of 6200 cfs. An inspection of the COE flood frequency curve indicates a flood of this magnitude would have a probability of being equaled or exceeded of about 10% in any given year on the average.

The Construction sequence developed in the present study will require the diversion tunnel to be operational for a period of up to two years. The 1979 flood would therefore have a probability of occurring in this two year period of about 20 percent. Stated otherwise, there is a 80 to 90 percent chance that a flood with a peak discharge of 6200 cfs would not be exceeded during the required diversion period. Based on this, past experience and judgement, and the relatively short period of recorded flows used in evaluating the probabilities, the 1979 flood was chosen as the design flood for construction diversion.

The 1979 flood flows were recorded at the lake outlet under natural stream conditions. Because of this it was necessary to adjust the recorded discharge hydrograph to reflect the regulation effect of the lake in determining the actual inflow. This adjustment was made by reverse routing the recorded outflow hydrograph and smoothing the resulting estimated inflow hydrograph shape until it resulted in the recorded hydrograph when rerouted through the lake. The estimated inflow and recorded discharge at the lake outlet are shown in Figure 7.3-1. An maximum inflow of 6800 cfs was estimated to cause the 6200 cfs to result at the lake outlet with a lake level at elevation 1088.5.

The inflow hydrograph thus obtained was then routed by the lake through the diversion tunnel to determine the peak discharge and surcharge level of the lake. The results of the routing are shown on Figure 7.3-2. It can be seen that the peak inflow is attenuated considerably from 6800 cfs to 4000 cfs but the lake level surcharges to elevation 1096.5 reflecting the smaller discharge capability of the diversion tunnel over the natural lake outlet.

Based on this surcharge level, the top of the upstream cofferdam and the bottom of the lowest excavated bench for the dam quarry were set at elevation 1100 providing 3.5 feet of freeboard.

From a hydraulic standpoint, a large range of tunnel sizes could be constructed which would pass the design flood. The only practical differences between the different sizes would be the level the lake would rise to provide the hydraulic head required to pass the peak discharge. Smaller size tunnels would result in excessively high lake surcharge levels which would require very high cofferdams at the lake outlet. The selected tunnel size will satisfy the hydrologic criteria and result in a reasonable size cofferdam.

The diversion tunnel was sized to pass the routed peak discharge of 4000 cfs under open channel flow conditions.

To minimize tailwater encroachment and provide additional construction work area at the outlet portal a small pilot channel will be excavated in the downstream river bed which will lower the water level in the large natural stilling pool about 3 feet. The stream channel rating curve is shown in Plate 21 and is based on the COE rating curve adjusted for at the lower flows to reflect the lower water levels in the channel.

Permanent outlet facilities will be incorporated as part of the diversion tunnel after construction. The two sluice conduits within the concrete plug of the diversion tunnel were sized on the basis of providing a minimum flow to satisfy instream flow requirements and provide sufficient flow capacity for reservoir drawdown. The facilities are capable of passing about 150 cfs at the minimum operating lake elevation of 1080 and a maximum flow of 2750 cfs at the maximum elevation 1180. Flow through the conduits will change from open channel to orifice flow at a discharge of about 300 cfs with a small hydraulic jump occurring upstream of the plug at the lower discharges. The rating curve for the permanent outlet facilities is shown in Plate 21 and represents the flow capacity with both sluice gates fully open.

7.3.5 Geology

The construction diversion tunnel will be excavated in the right abutment, passing beneath the left edge of the spillway structure. The tunnel and portals will be located wholly in massive graywacke with occasional thin lenses of cherty argillite. This is a sound rock presenting favorable tunneling conditions. Major joint orientations are also generally favorable, intersecting the alignment at about 35°-45° and 75°-85°; dip angles range from 60° to vertical. Joint spacing ranges from one to ten feet; in relation to the tunnel diameter (19 ft horseshoe) this will yield somewhat blocky ground conditions. A few minor, high-angle shears or faults are anticipated but are not expected to exceed about 1.5 feet in width and are not expected to require any unusual support techniques. In summary, geologic conditions for the diversion facility are considered to be favorable.

7.3.6 Structures and Appurtenances

A sluice gate control and equipment house is provided at ground level near the vertical projection of the diversion tunnel's concrete plug. This structure contains the hydraulic power pack unit and the air-oil accumulators needed to actuate the sluice gate hydraulic cylinders. Both manual and automatic gate control is provided. Manual control is available from a control panel within the house as well as from a portable hydraulic pump at the hydraulic cylinder area. Automatic control is available from a control panel in the gate house or from the main powerplant. Telemetering equipment are provided to receive control signals and transmit gate position data to the powerplant. Electrical power is provided by long life batteries and a propane generator. The air-oil accumulators are sized to allow for one close-open-close cycle of the active gate and one close-open-close cycle of the emergency gate, before recharging is required.

The proposed generator is used to recharge the batteries and to operate the hydraulic power pack pump motor. Also, this unit will be used to provide electric power for lighting the tunnel area, as may be required for inspection and during maintenance. Electrical, control, communication, and hydraulic line systems are brought from the sluice gate control house to the gate area and the tunnel through a suitably sized hole drilled to connect the two structures.

7.3.7 Access

Access to the construction diversion tunnel and low level outlet sluice gates is provided across the crest of the downstream cofferdam. Access within the downstream tunnel section is by a steel walkway suspended from the tunnel crown and braced against the spring line. Access to the sluice gate control house is from the crest of the main dam. The upstream stop log structure is accessible from the lake by use of a barge facility. The tunnel section, upstream of the concrete plug can be accessed either through the sluiceways, with the steel stop logs in place, or through the sluiceways and reservoir area, when the power pool is drawn down to its minimum emergency level at elevation 1,060.

7.3.8 Alternatives

The COE investigated two alternative diversion schemes to their recommended plan of bypassing the natural inflow through the power tunnel and returning it to the stream through a branch tunnel downstream. One alternative consisted of diverting water through a portion of the existing lake outlet channel while constructing the dam in the dry streambed behind cellular cofferdams. This was abandoned due to excessively high cofferdam requirements. SWEC agrees that this scheme is impractical. The other scheme studied by the COE involved a pressure tunnel through the right abutment and this was also discarded due to excessive cofferdam heights. SWEC agrees that a pressure tunnel would not be feasible at this site. The COE recommended diversion scheme was also discarded in this study since it is an integral part of the power conduit arrangement which has been abandoned for other reasons.

Several other diversion schemes reviewed in this study included tunnel arrangements through the right and left abutments at the lake outlet, and a buried conduit through the main river channel. Arrangements through the left abutment with variations in details were abandoned due to interference with other structures, impacts on the construction schedule, and excessive costs. The buried conduit scheme through the main river channel was also discarded due to excessive costs, technical difficulties in constructing a suitable intake structure, and excessive cofferdam heights.

An alignment through the right abutment was judged the best in terms of satisfying both temporary diversion capabilities and permanent low level outlet requirements. Initial concepts included analyzing 16 and 18 foot diameter horseshoe shaped fully lined tunnels. The 16 foot diameter tunnel was abandoned because it was judged too small to ensure proper hydraulic performance while passing the design flood and resulted in larger cofferdam sizes which would encroach on the available construction working areas for the permanent structures. The 18 foot diameter fully lined tunnel was found acceptable in meeting the various criteria and was initially adopted. However, further studies indicated that use of an initially unlined tunnel for diversion during construction would enhance construction scheduling needs and would be more economical. Partial concrete lining of the tunnel would be done subsequent to diversion. This concept was subsequently adopted for the recommended plan.

7.4 POWER CONDUIT SYSTEM

7.4.1 General

The power conduit is defined as the water passage structures that are used to bring water from the Bradley Lake to the turbine-generator units. These structures include the intake channel, the power intake, the gate shaft, the power tunnel and steel liner, and the penstock.

Previously identified concepts were reviewed and new concepts developed for study. The new concepts considered relocating the power conduit intake to the left abutment area, straightening the power tunnel alignment, and placing the majority of the tunnel at a level which provides over 1000 feet of rock cover for resisting the internal pressures.

The merits of lowering the tunnel to eliminate the long exposed penstock along the mountain slope were evaluated. The feasibility of using a tunnel boring machine was investigated and economic analyses were performed to determine hydraulic losses and economic diameters of the water flow conduit sections.

Hydraulic transient analyses were performed to determine pressure characteristics and surge shaft requirements under full load rejection and acceptance conditions. Consideration was given to a pressurized underground surge chamber. These studies and economic comparisons of alternative turbine types concluded that a surge shaft is not required to suppress hydraulic transients under the preferred plan.

The water conveyance structures forming the power conduit are described in detail in the write-up which follows.

7.4.2 Power Conduit System

7.4.2.1 Intake Channel

The intake channel developed for the preferred plan is excavated as part of the rockfill dam quarrying operations. The channel is approximately 360 feet long and 50 feet wide at its base. The channel connects the power tunnel intake structure and Bradley Lake and is shown on Plates 7 and 11. During construction of the channel and other power conduit structures, water would be blocked from entering the work area by a rock plug; a large unexcavated rock section at the lake end of the channel. An invert at elevation 1,030 is selected and allows drawing the reservoir down to elevation 1,060, as may be required for maintenance of the dam or for additional generation under emergency conditions. This minimum drawdown elevation is selected to provide adequate submergence of the intake structure and for keeping the water flow velocity in the channel to less than 1 fps during full power generation. The low velocity reduces hydraulic losses; minimizes the attraction of waterlogged debris; and, allows for the build up of an ice layer which is desirable to preclude the development of frazil and anchor ice within the channel. Rock traps are being provided along the length of the channel and in front of the intake structure to retain loose rocks that may fall from the excavated slopes or may be transported by ice. About 74,000 cubic yards of material will be excavated to form the intake channel. Of this, over 52,000 cubic yards will be used as part of the dam rockfill. Of the remaining 22,000 cubic yards, about 12,500 cubic yards of excavation is from the rock plug cofferdam. Most of this material will be excavated in a manner that will place the material in the lake area adjacent to the channel to form a protective rock-mantle along the lake shoreline. The remaining excavation will be spoiled in waste areas designated in the vicinity of the dam.

7.4.2.2 Intake Structure

The intake is a concrete lined structure shaped to form a gradual contracting transition, varying from a rectangular shape at the intake channel to a full circular section where it connects with the upper section of the power tunnel, Plate 12. The intake is formed by a 490 cubic yard excavation along the side of the intake channel. The total transitional length of the intake is about 42 feet. Removable trash racks are provided at the inlet to prevent floating debris from entering the power tunnel. The total gross area of the trash racks is about 460 square feet, resulting in an average velocity through the trash racks of less than 3 pfs, at full power flow.

The trash racks are supported in guides at the sides of the intake structure and by a vertical concrete pier located at the upstream center of the structure. The trash rack guide system is designed to accept steel stop logs should the need arise. Access to the trash rack is by barge from the lake, at high reservoir levels, or directly by crane from the adjacent quarry benches, when the reservoir is drawn below elevation 1,100. The entire intake is submerged below the minimum emergency drawdown pool of elevation 1,060 to prevent air entrainment during generation. However, it is recommended that hydraulic model tests be performed of the intake channel and the intake structure to determine acceptable flow conditions.

7.4.2.3 Gate Shaft

Emergency closure of the power conduit is provided by two hydraulically operated slide gates located in a gate shaft. The gate shaft, shown on Plate 11, is a vertical, concrete lined, circular shaft with an internal diameter of 22 feet.

The shaft is located over the tunnel alignment, about 800 feet downstream of the intake portal. The top of the shaft is at elevation 1203 feet and the shaft extends into the ground for about 173 feet, to the invert of the power tunnel. The shaft will be developed by raised boring and slashing. About 2,500 cubic yards of material excavated to form the shaft will be spoiled in the waste areas designated in the vicinity of the dam.

The concrete lined shaft will form a dry well for the two hydraulically operated slide gates and other equipment. The gates, each 9 feet wide by 11 feet high are installed in tandem. The downstream gate is considered the active gate and will be used in the event of an emergency to close off flow in the power tunnel. The upstream gate is considered passive and is primarily used when there is a need to service the downstream gate. Both gates will be used when maintenance of the power tunnel conduit is required. An access way is provided downstream of the active gate to allow entrance to the power tunnel. Suitable venting is also provided on the downstream side of each gate to vent the water passages to above ground level. Access to the hydraulic cylinders and gate area is provided by spiral stairs or other suitable means.

A platformed area is provided at elevation 1170 for major maintenance to the gates. This platform is made from structural steel shapes with grating and checkered plate covering. Access to the gates and to the maintenance platform is through openings at the top of the gate shaft structure. An equipment platform, of similar construction, is provided at elevation 1190. This platform will support the equipment needed to control, monitor, and operate the gates such as: a control panel for manual and remote gate operation; long life battery and propane generator; the hydraulic power pack and air-oil accumulators; and, other telemetering and communications equipment. Separate air-oil accumulators are provided for each gate. These are sized to allow one closeopen-close cycle before recharging is required by the hydraulic power pack. The propane generator is sized to provide the power needed by the power pack for lighting within the gate shaft during maintenance and for recharging the battery. Access to the gate shaft from the outside is provided by a concrete stairwell, leading to the equipment platform, and by a steel stairway that connects the two platformed levels.

7.4.2.4 Power Tunnel

The power tunnel is an 11 foot nominal diameter, concrete lined, circular conduit as shown on Plate 12. Starting at the intake, the tunnel extends horizontally downstream for about 950 feet to a 38 feet long bend that connects to a 810 feet long concrete lined shaft inclined at 55° with the horizontal. A similar bend connects the inclined shaft to the main power tunnel. The main power tunnel is 16,850 feet long and includes a 2,400 feet concrete and steel lined section. The invert of the tunnel at the downstream portal is set at elevation 42 feet. The vertical alignment of the main tunnel was limited to a grade of 1 foot in 600 feet for safety of personnel during mucking operations and to enhance the productivity of its excavation. A minimum of one foot thick concrete lining is used throughout the entire tunnel length, including the steel lined section, the inclined shaft, and the upper horizontal section. Reinforcing is provided within the concrete lined sections along the lengths crossing known faults and at the lower and upper bends. The steel lined section of the tunnel is not reinforced.

The power tunnel is developed by drill and blast techniques, raised boring techniques, and by the use of a tunnel boring machine (TBM), as appropriate. The main power tunnel is advanced from the downstream portal located near the powerhouse area. The first 100 to 300 feet is excavated by the drill and blast method. This is done to enhance the construction schedule and to develop a good heading for the TBM. The heading is supported by steel sets and rock bolts. The remaining tunnel length, up to and just beyond the lower elbow; is excavated with the TBM. Fault crossings may be excavated by the TBM or conventional drill and blast methods, depending on the rock conditions encountered. It is anticipated that rock bolting and/or use of steel sets will be required at the fault areas. Some rock bolting may be required in the remaining length of the tunnel for safety reasons. The area at the lower elbow is to be enlarged to accommodate equipment during mucking operations for the inclined shaft.

The inclined shaft is developed by the raised bore method. Under the present concept, a pilot hole is to be drilled from ground surface, at an inclination of 55° with the horizontal, to intercept the upper end of the main tunnel near the lower bend. This pilot hole is enlarged to a suitable diameter and serves as an opening for the torque shaft of the raise boring machine. The shaft is then excavated by a series of reaming operations using increasingly larger size raise bore bit assemblies, until the desired excavated diameter of about 13 feet is reached. The full 13 feet excavated diameter is carried up to and just beyond the projected intersection of the inclined shaft and the upper horizontal tunnel. This intersection area is then excavated and shaped to form the upper bend of the power conduit.

About 89,300 cubic yards of material is excavated from the main power tunnel, the bends and the inclined shaft. This material will be spoiled as fill in the construction of the airstrip, or as road topping on the powerhouse access road or both.

The upper horizontal tunnel section of the power tunnel is developed using drill and blast methods and connects the intake structures and the inclined shaft. Material excavated from this section will be spoiled in the designated waste areas, near the dam or may be used in the dam.

7.4.2.5 Steel Liner and Penstock

The 11 feet outside diameter steel liner will be approximately 2,400 feet in length. Preliminary data and discussions with steel and penstock fabricators indicate that the steel lining can be constructed from high strength steel plates such as ASTM 517 or ASTM A710. An investigation of these materials showed that the A710 steel, with yield strengths of better than 85,000 psi and other desirable characteristics, can be considered for use. The steel liner has been conceptually designed to satisfy the following conditions:

- The steel liner will be terminated within the tunnel at a point where the rock cover around the liner is about one half of the transient pressure head.

- The steel liner will be checked against possible buckling failure from an external hydrostatic pressure equal to the height of rock cover above the liner. Required shell thickness shall be based on the Amstutz theory of failure, assuming 0.03% initial gap and a minimum safety factor of 1.2.

- The maximum hoop stress will be limited to 50 percent of yield strength, assuming no support is provided by the concrete and rock.

Using the above criteria, shell thickness varying from 3/4 inch to 1 inch were calculated for the steel liner, resulting in a total material weight of 1,380 tons. In the final design, detailed analyses will consider the assistance of the surrounding rock mass for resisting the internal pressure.

The interior of the steel liner is painted with an acceptable paint system.

The steel penstock section begins at the downstream end of the steel liner and terminates at the upstream end of the spherical valve of each turbine unit. The penstock consists of a roll-out section, a reverse bend section, a straight pipe section, a reducing wye, two reducing bends and two cylindrical shells connecting to spherical valves. The overall length of the penstock is about 135 feet. The roll-out section is about 11 feet long. It is stiffened by two end girders which also serve as the sliding supports of the section. The roll-out section is coupled to the steel liner and downstream penstock by specially designed high pressure couplings. The roll-out section is provided to allow for access into the tunnel section, should major maintenance be required. A man-door is provided on the side of the roll-out section for routine inspections of the tunnel.

The wye section is of the internal splitter design. This eliminates the heavy external reinforcements and results in reduced hydraulic losses. The wye configuration results in two outlet branches each 8 feet in diameter. These outlets are connected to the corresponding units spherical valves by an 8 feet diameter straight penstock section, a reducing bend with an outlet diameter of 5 feet, and a 5 feet diameter straight section that is about 25 feet long. The wye and other downstream penstock members are conservatively sized to withstand the maximum internal transient pressure with an allowable hoop stress equal to less than 40 percent of yield.

Both the interior and exterior surfaces of the penstock, including the roll-out section are painted with an acceptable paint system. Also, the penstock sections, downstream of the roll-out section, are encased in reinforced concrete. Part of this concrete encasement is provided by a large thrust block at the upper bend of the penstock designed to resist hydrostatic and dynamic loads. In addition to concrete encasement, the penstock sections downstream of the thrust block are placed in a rock trench cut below the yard grade of elevation 40. This type of construction affords protection of the penstock from the elements and other factors, improves the aesthetics of the project, and more importantly eliminates the possibility of vibrations along the penstock length.

7.4.3 Hydraulics

The power conduit system consists of the intake channel, intake structure, gate shaft, and pressure tunnel. The intake channel will be excavated in rock and has been sized to maintain average flow velocities of less than 1 fps under full power operation at the minimum drawdown level elevation 1060. This low velocity will result in negligible hydraulic losses in the channel. When the lake level is drawn below elevation 1100 all flow will be constricted to the 50 foot wide intake channel. Although velocities will be quite low there is the potential for eddy formation within the channel due to the oblique flow condition from the lake into the channel. To ensure satisfactory hydraulic performance under those conditions, a physical hydraulic model of the flow phenomenon will be conducted. The cost of this study is included in the estimate.

The intake structure is of a conventional type with an bellmouth shaped roof and uniform transitioned side walls. It has been sized to maintain average velocities of about 3 fps at full power output. This low velocity will result in relatively minimal hydraulic losses within the intake and across the trash racks. Vortex formation at the intake should not occur under normal power operations. The intake invert has been set 30 feet below the minimum drawdown elevation of 1060 which is based on past experience in a large number of projects. However, as an added safety factor, the physical model discussed above will include the intake structure to study vortex formation under adverse conditions.

The gate shaft structure will house the rectangular slide gates with a smooth transition from the circular pressure tunnel. Losses in this section will also be minor. Other minor losses will occur in the various bends of the power tunnel and penstock.

Of the total hydraulic losses in the system, the largest will occur due to friction. It has been estimated that the combined friction and minor losses will vary between less than one foot under minimum power operation to about 55 feet under maximum power generation. The hydraulic losses are calculated as : $H_L = 3.22 \times 10^{-5}(Q^2)$, where H_L is the loss in feet and Q is the flow in cubic feet per second.

7.4.4 Transient Analysis

Transient studies were performed for each project capacity studied, 60, 90, and 135 MW; and each type of turbine, Francis or Pelton. The objective of these studies was to determine the maximum and minimum pressures in the power conduit during full plant load rejection and load acceptance, and identify surge facility requirements. The transient analysis was performed using the SWEC Hydraulic Transient Analysis Program HY-001. The power conduit arrangement varied with each type of turbine and capacity which required that each type of turbine and capacity be analyzed as an individual case.

For the purposes of the transient analysis the Francis turbine runner was set at elevation -6. The power conduit was 10, 11, and 12 feet in diameter for capacities of 60, 90, and 135 MW, respectively. The following is a description of the modeled power conduit:

Segment	Description	Length
	Powerhouse -- 2 units	
A-B	Steel penstock	200 feet
B-C	Steel and concrete lined tunnel	2,600 feet
C-D	Concrete lined tunnel	1,700 feet
	Surge tank	
D-E	Concrete lined tunnel	12,950 feet
E-F	Concrete lined inclined shaft	850 feet
F-G	Concrete lined tunnel	650 feet
	Intake (invert elevation 1,040)	

During initial computer runs, varying surge tank diameters and orifices diameters in the riser shaft to the surge tank were tried. Transient pressures were reduced upstream of the surge tank, but remained high downstream in the steel lined tunnel section and penstock. Synchronous bypass valves were added to the computer model upstream of the turbine scroll case and the transient analysis was repeated; the transient pressures were significantly reduced downstream of the surge tank. Figure 7.4-1 shown the maximum transient pressure gradient and Table 7.4-1 shows the respective maximum and minimum pressures at various powerhouse capacities, synchronous bypass valve sizes, and wicket gate opening and closure times. There was no water column separation indicated during either full load acceptance or rejection for the cases depicted in the Table 7.4-1. The full load acceptance was modeled at minimum headwater elevation and the full load rejection at maximum headwater elevation.

The Pelton turbine runner was set at elevation 14, 15, and 16 feet, and the power conduit was 10, 11, and 12 feet in diameter, for capacities of 60, 90, and 135 MW, respectively. The following is a description of the modeled power conduit:

Segment	Description	Length
	Powerhouse -- 2 units	
A-B	Steel penstock	200 feet
B-C	Steel and concrete lined tunnel	2,600 feet
C-D	Concrete lined tunnel	14,650 feet
D-E	Concrete lined inclined shaft	850 feet
E-F	Concrete lined tunnel	650 feet
	Intake (invert elevation 1,040)	

The power conduit was modeled without a surge tank with needle valve opening times of 35 and 60 seconds and closing times of 60 seconds. The computer's results indicated acceptable transient pressures exist in the power conduit under these cases. The needle valves are commonly equipped with a hydraulic cylinder operated deflector which deflects the jet from the Pelton runner during the load rejection. Once the jet is deflected the needle valve can be closed at a gradual rate such as 60 seconds. Figure 7.4-2 shows the maximum transient pressure gradient and Table 7.4-2 shows the respective maximum and minimum pressures at various powerhouse capacities, and needle valve opening and closure times. There was no water column separation experienced during either full load acceptance or rejection for the cases depicted in the Table. The full load acceptance was modeled at minimum headwater elevation and the full load rejection at maximum headwater elevation. The transient results indicate that a surge tank is not required.

7.4.5 Geology

This section includes outlines of geologic conditions at the Intake Structure and for the various segments of the Power Conduit System; these subdivisions are based on geologic terrain rather than design elements. Also included are the results of laboratory tests on selected rock cores and an outline of the results of petrographic examination of the various rock types present. Details of geologic conditions are available in Appendix A.

7.4.5.1 Intake Area

Surface reconnaissance reveals that the rock is comprised of complexly mixed graywacke and foliated argillite with less than 10 percent chert nodules and layers. The contacts between the graywacke and argillite roughly parallel the foliation in the argillite, which typically trends N-S to N20°E and dips steeply. Several small faults and joint sets are present. These features have been described in some detail by Woodward-Clyde (1979) and Dowl Engineers (1983) as part of their investigations for the left abutment of the dam. No faults are known to intersect the currently proposed location for the intake portal.

An east-northeast-trending topographic lineament, which passes near the proposed location of the intake portal, was suspected to be the surface expression of an east-northeast-trending rockmass discontinuity. This lineament is the gully between Hill 1270.7 and Hill 1525.6. About 1,000 feet to the west of Bradley River the lineament merges with an east-trending fault mapped by Woodward-Clyde (1979). Directly east across Bradley River, it trends into the vicinity of two small covered areas which are probably the surface expression of joints or small faults. The lineament also parallels an east-trending fault located about 250 feet to the north on the east side of the river, and a series of lineaments, of unknown origin, to the southwest.

Boring SW83-2, oriented S6°W and angled at 45°, was made to define subsurface conditions causing the prominent lineament. The boring was oriented to cross the lineament described above and encountered 28.4 feet of colluvium and 126.9 feet of bedrock (20.1 feet and 89.7 feet vertical depth). Bedrock is primarily graywacke with varying amounts of associated argillite; the overall rock mass fabric appears to be cataclastic in origin. Close to very close jointing was encountered in portions of the boring; no indications of significant faulting were found.

Since the feature sampled by Boring SW83-2 is the most prominent lineament in the Intake area, it is considered that the Intake facilities should not encounter any significant faults or shear zones. Several minor shears have been previously mapped in the Intake area (Woodward-Clyde, 1979). These are well exposed and are not known to exceed one to two feet in width. Several of these may be expected to cross the Intake channel but are not considered significant to construction or operation of the facility. Geologic conditions are considered to be satisfactory for construction of the proposed Intake facilities.

7.4.5.2 Bradley Lake to Bradley River Fault Zone

This easternmost section of the tunnel alignment is underlain by interbedded graywacke and argillite. Because of their complex mixing, these rock types have been mapped as a single unit comprised of approximately 50 to 65 percent massive graywacke and 35 to 50 percent argillite. The argillite is commonly foliated and occurs as interbeds and pockets that range from less than a foot to as much as 100 feet thick.

Jointing is more apparent along this section of the tunnel alignment than further to the northwest. Several lineaments also cross this section of the tunnel alignment at various orientations. It is suspected that some of these features may be faults, but there is generally insufficient rock exposure to determine whether they represent faults or major joints. One pair of parallel lineaments, located about 1,700 feet northwest of the intake structure is particularly suggestive of a fault zone. Their origin is uncertain; if they are the surface expression of a fault, the zone may contain highly fractured and crushed rock up to about 200 feet wide along the proposed tunnel alignment.

7.4.5.3 Bradley River Fault Zone

At a distance of approximately 3,900 feet from the intake, the tunnel alignment crosses the Bradley River Fault zone. The main trace, can be followed for several miles along a trend of about N15°E. The fault is mantled by colluvial and glacial deposits, but is believed to be nearly vertical because of its linear topographic expression. Exposures elsewhere along the Bradley River Fault have suggested that the main fault trace can have a gouge zone of finely pulverized material that is up to 50 feet wide, with sheared argillite extending another 50 to 75 feet on either side (Dowl Engineers, 1983).

The Bradley River Fault zone was explored by boring SW83-2, which was drilled perpendicular to the fault trace at an orientation of N75°W and at an angle of 45°. Drilled to a depth of 262.3 feet, the boring penetrated two shear zones at 47.4 - 62.0 feet and 138.0 - 175.6 feet, possibly representing branches of the fault.

From the surface to a drilled depth of about 30 feet, loose gravelly sands with cobbles and boulders were encountered above bedrock. Striations observed on a cobble suggested that these materials are, at least in part, glacial.

Beginning at the top of bedrock, shear-foliated cherty argillite was encountered, and encompassing the two shear zones, continued to a drilled depth of about 197 feet. This rock is closely jointed to locally very closely jointed.

Below a depth of 197 feet, alternating zones of graywacke and chert were encountered, with local zones of cherty argillite and foliated argillite. Joint spacings in these materials increase to moderately widely spaced joints when argillite materials are not significantly present.

It is possible that additional shear zones exist to the east of the upper one encountered in boring SW83-2. The material observed in similar zones is predominantly brecciated argillite rock containing clasts of chert. Locally the rock has been reduced to fault gouge consisting of breccia fragments in a clayey silt matrix.

The cherty argillite adjacent to the shear zones is generally very closely jointed and the argillite faces adjoining shear planes are extremely slickensided, often containing crushed rock fragments as breccia and gouge.

The amount and sense of displacement along the Bradley River Fault zone is not well established. Slickensides rake from 0 to 30° along the fault suggesting a vertical component of up to 400 feet associated with the 1,000 feet of apparent horizontal displacement. Horizontal offset of a dacite tends to confirm this.

7.4.5.4 Bradley River Fault Zone to Bull Moose Fault Zone

Northwest of the Bradley River Fault zone, the tunnel alignment crosses the highest elevations and best exposed bedrock along its route. This area is underlain predominantly by foliated argillite, with lesser amounts of massive argillite, graywacke, and a single dacite dike. Much of the foliated argillite contains nodules and thin discontinuous layers of chert comprising about 10 to 20 percent of the volume of the rock. A few massive lenses of very closely fractured chert up to 10 feet wide were also found interspersed with the foliated argillite in this area. The foliation in the argillite and cherty argillite strikes from N-S to N20°E and typically dips greater than about 75 degrees. The dacite dike, although not exposed on the alignment itself, appears to cross the proposed tunnel alignment along a N80°E trend with a nearly vertical dip. For tunneling purposes this rock will probably behave similarly to the massive argillite or graywacke.

Bedrock outcrops along this segment of the tunnel alignment tend to be widely to very widely jointed. Hundreds of short, linear, soil-filled depressions can be seen in this area, many of which are presumably the surface expression of bedrock joints and/or minor faults. Unfortunately, however, without better rock exposure it is not possible to distinguish which of these features are faults or joints.

Larger lineaments, also common in this area, present the same problem for attempts to define their structural significance. A series of lineaments, occupying an area about 1,000 feet wide, located east of and subparallel to the Bull Moose fault zone are possibly the surface expression of smaller faults associated with the main fault trace, but exposures are insufficient to conclusively determine their origin. In spite of relatively good rock exposure in this area, it was not possible to determine conclusively whether these represent minor faults or prominent joint sets. In either case, exposures limit the width of these apparent discontinuities, at the surface, to less than about 10 to 15 feet where they cross the tunnel alignment.

7.4.5.5 Bull Moose Fault Zone

The main trace of the Bull Moose fault zone is located approximately 9,800 feet northwest of the tunnel intake. It is expressed as a narrow, topographic notch with a 200-foot-high, steep west wall. This area is densely vegetated and rock is exposed only in small isolated outcrops. No exposures of the crush zone in the fault were found, but relatively undeformed rock on either side of the main fault trace indicates that this zone must locally be less than about 50 feet thick.

The tunnel alignment crossing of the Bull Moose Fault was explored with boring SW 83-4. Drilled at an orientation of N80°W and an inclination of 45°, this boring was carried to a depth of 206.2 feet.

Bedrock was encountered after only 4.2 feet of penetration, and the shear zone of the Bull Moose Fault was encountered at a drilled depth of about 146 feet. Random alternating zones of graywacke, argillite, and chert, as well as mixtures of these lithologies were logged within the depth explored.

The shear zone of the Bull Moose Fault was encountered from a depth of about 146 feet to 154 feet in the boring (horizontal width of 6 feet). The brecciated argillite and graywacke in this zone is locally sheared to silty sand and zones of clayey gouge. The rocks adjacent to the shear zone, argillite above and chert below, are highly fractured from considerable shear deformation.

The vertically projected location of the shear zone encountered in boring SW83-4 is consistent with the mapped location of the fault trace for a near-vertical fault plane.

7.4.5.6 Bull Moose Fault Zone to Powerhouse Site

The bedrock exposure is much more limited along this segment of the tunnel alignment than it is to the southeast. This is particularly true to the northwest of the possible surge tank location where forest and soil cover mantle all but a few small isolated rock outcrops. The available exposures indicate that this section of the tunnel alignment is underlain predominantly by foliated and massive argillite. Cherty argillite and graywacke crop out in relatively small amounts, although boring data indicate that these rock types are more common than their surface exposure suggests. The predominance of argillite is also indicated by natural outcrops visible 1000 - 1500 feet southwest of the tunnel alignment in a gully which roughly parallels the alignment.

The recognizable structural trends in this area conform to those elsewhere along the tunnel alignment. Foliation in the argillites is consistently oriented at N-S to N20°E. Jointing is widely to very widely spaced in most exposures, with a dominant strike of N75-85° North.

7.4.5.7 Laboratory Rock Testing

Selected portions of N-size rock cores recovered from COE borings were tested to define general rock strength properties and, more particularly, to ascertain the feasibility of driving the tunnel using a tunnel boring machine (TBM). Various tests were conducted by Dr. A. J. Hendron, member of the Project's Technical Review Board, and by TBM manufacturers Atlas Copco Jarva, Inc. and The Robbins Company. In addition to this current data, the results of previous tests by the COE are included. The results of the tests, grouped by rock type, are shown on Tables 7.4-3 through 7.4-8.

Several tests on rock from APA's Terror Lake Hydroelectric Project (Kodiak Island, AK) are included for comparison with Bradley Lake rock types. A tunnel is currently being successfully driven at Terror Lake using a TBM. It should be noted that the fabrics of rock types (with the possible exception of the dacitic dike rock) from Bradley Lake differ from that of the quartz diorite of Terror Lake. The various testing agencies conducted different types of tests and direct comparisons of results are difficult. In the case of the tests conducted by the TBM manufacturers, some test methods and all interpretation methods are proprietary.

In summary, it is seen that among the major rock types the graywacke tends to yield the highest unconfined compressive strengths (up to 34,975 psi) and generally the greatest hardness (various methods). In decreasing order, following graywacke, are graywacke/argillite mixtures, massive argillite, foliated cherty argillite, and foliated argillite, which yields unconfined compressive strength in the range of 8000 - 6500 psi and Total Hardness as low as 68. Chert, in large, discreet masses is very uncommon and is the only rock type judged as "abrasive" for TBM tunneling purposes. Unconfined compressive strengths for chert were fairly low, 6800 - 11,120 psi (one at 22,730 psi), reflecting both macro- and microscopic in situ fracturing; Total Hardness ran as high as 204.4. In comparison, Terror Lake quartz diorite (including even sericitized specimens) tested from 22,800 to 26,050 psi with Total Hardness from 106 to 133 (one at 74.8). Typical values for the majority of Bradley Lake specimens are very similar to values obtained from Terror Lake samples.

Advance rates for a TBM have been estimated as outlined below:

Rock Type	Rate (ft/hr)	Estimated Tunnel Length (ft)
Graywacke, Graywacke/Argillite	6-8	4300
Massive Argillite	8-10	5000
Foliated Argillite	10-12	3500
Foliated, Cherty Argillite	8-10	3790
Chert	3.0-5.75	50

It should be noted that tunnel lengths may not correspond exactly to those given in a similar table on page 43 of Appendix A. The lengths above have been slightly revised based on petrographic data unavailable at the time of issue of Appendix A.

Tunnelling conditions for fault zones, fracture zones, and at portals, where drill and blast techniques and temporary steel sets would be used, are shown in Table 7.4-8.

It is concluded that the use of a TBM for tunnel excavation is technically feasible at the Bradley Lake site. However, to support the definitive engineering and design, the characteristics of the fault formations should be determined at tunnel depth.

7.4.5.8 Petrographic Examinations

Thin sections were taken of selected surface specimens and portions of rock core samples. The primary purpose of these examinations was to provide a check on the megascopic field classifications assigned to various rock types during surface mapping. In a few cases, the examinations provided clarification for rock types of uncertain origin and classification. General characteristics of the major rock types were established by rigorous petrographic analysis and the remainder of the samples identified by sight under the petrographic microscope. A list of samples, their locations and their classifications are included in Table 7.4-9. Analysis sheets for the major rock types - graywacke, massive argillite, foliated argillite, cherty foliated argillite, and tuff (or volcanic graywacke) are included as Figures 7.4-3 through 7.4-7. Also included and shown by Figures 7.4-8 and 7.4-9, are analyses of quartz diorite and hydrothermally-altered quartz diorite from the Terror Lake project. As outlined in the section above, these samples were tested to provide a comparison of strength properties with rocks from the Bradley Lake area.

With the exception of one rock type, the tuff or volcanic graywacke, thin section examination confirmed megascopic field classification of rock types. The tuff had been identified in the field as an anomalous rock type but, because of its fine-grained nature, could not be positively classified by megascopic examination. Microscopic examination positively identified its volcanic origin but also established its grain-size distribution and probable mode of deposition as essentially the same as that of the graywacke, thus the alternate term, volcanic graywacke.

Certain conditions, applicable to the general geologic setting of the site area, were noted in the thin sections. These include:

- o Pervasive alteration of feldspar, particularly plagioclase, to sericite.
- o Pervasive but low-level chloritization.
- o Development of cataclastic textures in virtually all clastic rock types. The degree of development roughly corresponds to grain size, with the finer-grained rocks showing more pronounced development.

Petrographic examination has confirmed the validity of rock type classifications made by megascopic examination during the current field mapping program. In addition, the postulated cataclastic origin of major rock mass and structural features is reflected at the microscopic level; taken together, it would appear that the areas has been subjected to repeated deformation.

7.4.6 Access

Access to the power conduit is available from the area adjacent to the powerhouse. Access within the power conduit is through the roll-out section, the mandoor at the roll-out section or the man access way at the gate shaft. The roll-out section affords access to large equipment should major repairs be needed within the power conduit. Mandoor access is principally for general inspection.

7.4.7 Alternatives

Several alternative power conduit alignments were identified under previous studies by the Corps of Engineers and dismissed for valid technical and economic considerations. The power conduit alignment selected by the COE was reviewed under this study and a comparative evaluation was made to the alignment recommended by this report. The comparison showed substantial savings and other construction environmental improvements resulting from the following:

- o Use of the tunnel boring machine.
- o Elimination of the exposed side hill penstock.
- o Elimination of the hillside access road to the high tunnel portal.
- o Elimination of the access and haul road to the bridge crossing at the upper Bradley River.
- o Elimination of the bridge crossing.
- o Elimination of the access adit to the power tunnel.
- o A reduction of the power conduit length.

Because of the above, the decision was in favor of the preferred alignment presented by this report.

7.5 POWER PLANT

7.5.1 General

The powerhouse is located near sea level on the southeastern shore of Kachemak Bay at approximately N2,112,430,E327,100. The relief at the powerhouse site rises steeply from the tidal flats near elevation 10 to elevation 1400.

The powerhouse and power tunnel portal are situated upon an excavated rock bench at elevation 40. This excavation has an oblonged triangular arrangement as shown on Plate 13. Local excavations below elevation 40 are required to contain the powerhouse substructure, the steel penstock, and the bifurcation and thrust block. The excavated material would be utilized to form a construction laydown area and switchyard in the tidal flats adjacent to the powerhouse excavation.

The powerhouse is approximately 138 feet long, 66 feet wide and 112 feet high. The powerhouse substructure is constructed of reinforced concrete detailed to be integrally keyed into the surrounding bedrock. The Pelton turbine, inlet penstock, and manifold are entirely housed within the reinforced concrete portion of the structure. An insulated structural steel superstructure is above elevation 40 housing the generators and bridge crane. The bridge crane runway is comprised of steel columns and girders which also serve as the main structural members for the powerhouse superstructure. The powerhouse plans and elevations are shown on Plates 13 and 14.

The powerhouse has two main operating floors, the turbine floor at elevation 23 and generator floor at elevation 40. Local spherical valve pits are provided below the turbine floor at elevation 5 to house the spherical valves and hydraulic cylinders. Access to the turbine chamber can be obtained from the spherical valve pit via a steel mandoor.

A 16 feet wide tailrace deck is provided downstream of the powerhouse superstructure to provide access to the turbine chamber through a deck hatch should major maintenance be required.

A tailrace channel will be excavated downstream of the powerhouse through the tidal flats to allow a free discharge of generating flows to the Kachemak Bay.

7.5.2 Basic Data

Plant, KVA (nameplate rating)	112,600
Number of Units	2
Type of Turbine	Pelton
Turbine Rating at 1130 feet rated net head, Hp	73,900
Rating of Generating Unit, KVA (nameplate)	56,300
Maximum Operating Pool Elevation, feet	1,180
Minimum Operating Pool Elevation, feet	1,080
Maximum Tailwater Elevation, feet	11.4
Minimum Tailwater Elevation, feet	-6.0
Centerline Turbine Runner Elevation, feet	15.0
Bottom of Turbine Chamber, feet	-6.0
Unit Spacing, feet	43.0

7.5.3 Tidal Considerations

The powerhouse setting and tailrace configuration are based upon the following range of tides developed by the COE:

	Elevation Based on Project Datum
Highest Tide (estimated)	11.37
Mean Higher High Water	4.78
Mean High Water	3.97
Mean Sea Level	-4.02
Mean Low Water	-12.02
Mean Lower Low Water	-13.63
Lowest Tide (estimated)	-19.63

Of particular concern at the powerhouse is salt water intrusion and the resulting corrosion problems for steel and other metals. To avoid direct salt water contact with the Pelton turbine runner, the runner is set at elevation 15, 3.6 feet above the estimated high tide level. Tailwater depression will be used to maintain free runner discharge. The tailrace deck has been set at elevation 23 with a 3.5 feet high concrete parapet wall. This will provide 15 feet of wave run-up at high tide. This setting also prevents the manifold and penstock from coming in direct contact with the salt water intruding during high tide periods. Cathodic protection is provided to protect steel and other metal components from accelerated corrosion that are near or in the salt water interface.

7.5.4 Turbines and Generators

The turbines selected for the preferred plan are 6 jet Pelton vertical shaft type units direct coupled to the generators rated for a net head of 1130 feet at 300 rpm. The generating unit nominal rating is 45 MW at full 6 jet gate and at the minimum gross generating head of 1065 feet. The best point efficiency rating of the turbines was set at a rated head 10 feet above the weighted average net generating head. The 10 feet upward adjustment was made to better represent anticipated turbine operating conditions for years other than the critical period operation. The rated net head was also used in determining maximum full gate horsepower of the turbine. The Pelton unit is accessible and removable through the turbine chamber and tailrace hatch without requiring the dismantling of the generator. Needle valves are equipped with jet deflectors and hydraulic operators.

Each of the two generators is rated 56300 KVA, 13800 volts, threephase, 60 HZ, 0.95 power factor, 300 rpm. The generators are of the vertical shaft, suspended type with a guide and thrust bearing located above the generator rotor, and a guide bearing below the rotor. Generator insulation is class B or better. Winding temperature rise is 75°C over a maximum ambient air temperature of 40°C. The stator winding is wye-connected, and the winding neutral is grounded through a transformer-resistor arrangement to limit line-to-ground fault current. The generator is completely enclosed and equipped with a CO_2 fire protection system. The generator excitation is provided by a static exciter, which consists of a three-phase transformer, rectifier and voltage regulator. Power for excitation is taken from the generator terminals.

7.5.5 Powerhouse Arrangement

The powerhouse location was selected to assure that the powerhouse substructure would be located on rock and to take advantage of the natural coastal relief in order to minimize the overall excavation required to accommodate the powerhouse, penstock and tunnel portal. Field topographic surveys were conducted at the proposed powerhouse site to accurately depict the relief.

Of particular importance was the interrelationship of the powerhouse, penstock, and power tunnel and portal in determining the overall excavation size. In order to fully support the construction efforts, continued access is required to the power tunnel and portal throughout the construction schedule. Normal minimum distances around the powerhouse were increased from 40 feet to 100 feet to improve access to the tunnel portal during powerhouse and penstock construction. In addition, a lay down and storage area at elevation 20 is provided adjacent to the powerhouse excavation to support the powerhouse, penstock, and power tunnel construction activities. This lay down area will increase the staging area available to the construction contractors by 1.2 acres and will later be used to site the powerhouse substation.

The initial construction activities to establish the power tunnel portal and initiate tunneling operations with the TBM are very critical to the project schedule. Therefore, the construction of the powerhouse has been delayed until the intense tunneling effort is essentially over. The powerhouse and penstock excavation will be established at the same time that the initial powerhouse elevation 40 bench open cut excavation is established. These excavations will be back-filled with granular material to increase the staging area available to the tunneling contractor. The powerhouse contractor will remove the granular material during the construction of the powerhouse and penstock.

In sizing the powerhouse structure, the 90 MW Pelton generating equipment was evaluated to determine the key factors which affect the internal powerhouse layout. These are:

- Manifold and Turbine Chamber
- Spherical Valve Dimensions and Orientation
- Generator Overall Dimensions
- Size and Location of the Auxiliary Electrical and Mechanical Equipment
- Control Room Size

The manifold and turbine chamber dimensions are representative of dimensions obtained from turbine manufacturer inquiries. Each unit is self contained and may be operated when the other unit is dewatered for inspection or maintenance. The manifold is downstream of the spherical valve and is equipped with needle jet valves and nozzle deflectors to control flow to the Pelton runner. The manifold is of high strength welded steel construction and is embedded in a minimum of two feet of reinforced concrete. The upper turbine chamber is steel lined and hydraulically shaped to provide a free water discharge from the Pelton runner buckets. The turbine chamber will be pressurized by air to depress the water surface level during periods of high tailwater resulting from tides. An air recovery system was considered but was not pursued due to the relatively short tailwater channel between the turbine chamber and the draft tube gates. This aspect should be investigated further during the final design phase and generating equipment selection.

Accessibility to the turbine chamber for periodic inspection and maintenance on the Pelton runner, needle jet valves, and subcomponents is provided. Turbine inspection can be performed through the spherical valve pit into the turbine chamber via a 3 feet wide and 5 feet high water-tight mandoor. This means of access also serves as a second means of egress from the turbine chamber during periods of major maintenance and allows for air circulation during welding operations in the turbine chamber. The normal access for major maintenance will be through an access hatch provided at each unit and located in the elevation 23 tailrace deck. This access hatch has a 10 feet wide and 16 feet long clear opening, which is sized to accommodate the removal of the turbine runner. The turbine chamber floor is at elevation -6 requiring staging to provide vertical access to the turbine equipment located at elevation 15. The tailrace access hatch is oriented to allow a 9 feet by 15 feet by 17 feet staging to be lowered in a single piece. The staging would be equipped with rollers and a jacking table for runner installation and dismantling in the event of major maintenance.

The spherical valves, hydraulic operator, power units, and accumulator, are representative of dimensions obtained from manufacturers. Each valve has a self-contained hydraulic operator which has an accumulator tank sized to permit a close-open-close cycle, without recharging, in the event of total power loss (station service, emergency diesel generator and battery). The power unit and accumulator tank are located on the elevation 23 floor with the spherical valve and hydraulic ram in the valve pit. The valve pit has been sized to permit access on each side of the spherical valve body for complete visual inspection and maintenance. Access is provided into the pit by a ladder on the operator side of the valve and 6 feet of headroom is provided under the penstock downstream of the valve body to permit access to the other side of the valve. A sectional covered hatch is provided over the valve pit in the floors at elevation 23 and 40 to permit bridge crane access to the valve pit.

The largest generator manufacturers' dimensions were used to layout the powerhouse. This is a conservative approach and allows a powerhouse arrangement to be developed at the conceptual stage which can accomodate a variety of generator manufacturers dimensions. During the final design phase, definitive manufacturers dimensions will be available and may allow the overall dimensions to be reduced. To ease installation of the generator, a powerhouse layout was developed which permits the stator and rotor to be delivered to the project site fully assembled. The powerhouse door adjacent to the assembly bay is 30 feet wide and 20 feet high. The powerhouse bridge crane has been sized to accommodate both the stator and rotor lift.

The size and location of the auxiliary electrical and mechanical equipment is based upon actual project experience. Space is allowed around the equipment to permit installation and maintenance access, and allow space for egress. The floor plans at elevation 23 and 40 are shown on Plates 13 and 14.

The size and location of the control room is based upon actual project experience. Space is allowed around the control panels and consoles to permit installation and maintenance, and allow two doors, one exterior and one interior, for egress. Space has been allowed for office desks, files, and cabinets within the control room. Restroom facilities are provided adjacent to the control room.

7.5.6 Electrical Equipment

The one-line diagram for the plant, of key electrical equipment and their arrangement, is shown on Plate 22. There are two main power transformers, located in the substation, one for each generator. The transformers are each rated OA/FA/FA-33.8/45/56.3 MVA, three-phase, 60 HZ. The high voltage winding is rated 115,000 volts, grounded wye, and the low voltage winding is rated 13,800 volts delta. The transformers are oil-immersed, with a self-cooled rating, and two stages of forced air cooling. The generator circuit breakers, potential transformers and generator surge protection are contained in 15 kV metal-clad switchgear cubicles. The generator breakers are rated 3000 A continuous, 1000 MVA interrupting capacity, and include (6) 3000/5 amp current transformers. Each generator is provided with (4) 11400-120 volt single phase potential transformers for metering, relaying, and synchronizing. The potential transformers are fused on the high and low voltage sides and are drawout type. Protection for each generator consists of three 15 kV lightning arresters and three surge capacitors mounted in a switchgear cubicle. Each of these protective devices are connected between the generator terminals and the powerhouse ground system. Each of the switchgear groups associated with a generator is located adjacent to the generator on the operating floor level. The generators are connected to the switchgear, and then to the transformers via copper conductor, three-phase, non-segregated phase bus. The bus is rated 15000 volts, 3000 amps continuous, and 80,000 amps momentary. The portion of the bus in the powerhouse is ventilated, and the outdoor portion is fully enclosed and weatherproof.

Station service power is provided by a double-ended load center. There are two dry-type transformers, rated 450 KVA, 13.8 kV-480V, threephase, 60 HZ. Each transformer is connected to the generator terminals through a 15 kV, current limiting, fused disconnecting switch and via 15 kV shielded cables. One transformer is connected to Generator No. 1 and the other transformer is connected to Generator No. 2. Due to the use of generator breakers, both station service transformers are normally energized, even during generator shutdown. The station service switchgear is 600V class drawout type arranged in two main buses. Each bus is provided with an 800 amp, electrically operated main circuit breaker, with an 800 amp normally open tie breaker between the buses. The tie breaker closes upon loss of voltage on either bus. Each transformer and main breaker is capable of carrying full station service load, in the event one transformer fails. Each main 480V bus has a sufficient number of manually operated switchgear type feeder breakers and potential transformers.

Starter, contactors, and feeder breakers are contained in several motor control centers located strategically throughout the power plant. The motor control centers are rated 480V, three-phase, 60 HZ. Combination starters are provided for motors, each starter consisting of a molded case circuit breaker, a 3-pole contractor, and 3 overload relays. Molded case feeder breakers, single and three-phase, are provided for protection of feeders for lighting panels, electric heaters, and other equipment.

The Bradley Lake is to be designed as an unattended plant, normally operated from a remote location. However, complete control facilities are also provided for local operation at the plant. Remote control and indication is via a microwave communication system. A supervisory, control and data acquisition system (SCADA) is provided to furnish plant control and receive plant operational data at the remote location. The SCADA system is a computer-based system consisting of a master control unit located at a dispatch center, and a remote terminal unit at the power station. In addition, a second remote terminal unit is located at the reservoir gate house to start the propane generator and remotely operate the gate and receive gate position and reservoir level data. Local control consists of vertical, duplex panels, with control and indication on one side, and protective relaying equipment on the other.

Direct current power for control, relaying and emergency power and lighting is provided by a 125 volt, 60-cell, 200 amp-hr storage battery and battery charger. A separate 48-volt and uninterruptible power supply (UPS) is provided by the SCADA, microwave, and other critical electrical equipment power requirements. The batteries are located in a separate and well ventilated room, which includes an emergency eyewash station. The UPS and battery charger is located outside the battery room.

The plant telephone system consists of an initial quantity of 12 telephones located throughout the plant, with provision for an additional 4 telephones. Included are connection to three outside lines, with provision for the addition of three lines, and plant paging. The telephone system is designed to operate from 120 V.A.C. 60 HZ, power and will be completely automatic. The off-site communication consists of a microwave system. This system will provide channels for remote control of the Bradley Lake plant from a dispatch center to be determined later, and also for telephone communications. The microwave system is designed to transmit data voice, and control information between the Bradley Lake power plant and Homer which is the nearest point in the communication system of the Bradley Lake plant that is controlled from a point in Anchorage. Communication between Homer and Anchorage will be via existing systems. Microwave is also used to provide control communication and data collection between the powerhouse and the reservoir dam. Where line-of-sight between two points in the system is not available, a passive "billboard" reflector is provided.

A diesel driven generator is provided in the power plant to supply a station service power under emergency conditions. The generator is rated 250 KW, 480V, three-phase, 60 HZ. It is installed in a separate diesel generator room in the powerhouse. Provisions include air in- take, diesel engine exhaust, a day fuel tank, and a large fuel storage tank. Control features are provided to start the diesel engine and automatically connect it to the station service system, in the event normal station service power is lost. Other features include a 12 volt battery, cooling equipment, brushless excitation, voltage regulator, and an automatic transfer switch rated 480V, three-phase, 60 HZ, 400 amp. A small propane-fueled engine generator is provided at the gate house and the diversion tunnel control house at the reservoir dam. Each generator is rated 5KW, 240V, single phase, 60 HZ. It is equipped with automatic control, a 12 volt battery, equipment for remote starting and stopping, and a battery charger. The set is operated remotely from the powerhouse.

Corrosion protection of steel structures and copper grounding gride in the powerhouse and substation is provided by cathodic protection equipment. The equipment consists of electronic rectifiers to produce a DC voltage of the required magnitude and polarity, and several sacrificial anodes strategically located.

Electrical power is provided to several outlying areas such as the permanent village, the domestic water pump house, and the barge docking facilities. This power is provided to these areas via a wood pole line along the access road. Power is furnished at generator voltage of 13.8 kV, 30, 60 HZ. A pad-mounted transformer rated 300 KVA, 13.8 kV-480V, 30 60 HZ. A pad-mounted transformer rated 300 KVA, 13.8 kV-480V, 30, 60 HZ is installed at the village to provide power to the residences, the storage warehouse and domestic water pump house. In addition, a 300 KW diesel generator set is installed at the village to provide power during emergencies. At 75 KVA, three-phase, 60 HZ, 13.8 KV-480V pad-mounted transformer is located at the barge docking facilities, and energized by the 13.8 KV pole line.

7.5.7 Mechanical Equipment

The turbine will have an actuator-type governor located in a cabinet mounted on floor elevation 23. The governor actuator air-oil accumulator tanks are located adjacent to the governor cabinets. The governor will be an oil-pressure, pilot operated distributor valve, actuator type with solid-state electrically controlled speed responsive elements.

The spherical valves are 5 feet in diameter and hydraulic operated. The valves and operating mechanism are located in the valve pit at elevation 5. The hydraulic power unit and accumulator tanks are located on floor elevation 23. The accumulator tanks are located adjacent to the hydraulic power units and have a reservoir capacity for one close-open-close cycle without recharging.

A 115 psig air depression system is provided which will depress the tailwater water level to elevation 6 when there are higher tide water levels. Pressurized air is injected into the turbine chamber via embedded wall jets. An air receiver, air dryer and filter, two 40 hp air compressors, and four air accumulator tanks are provided on floor elevation 23. There is also a by-pass air manifold provided, which interconnects with the station air system and the air depression system, yet allows each to be isolated for inspection and maintenance.

A 115 psig station air system is provided to supply air tools used for operations and maintenance. Air ports are provided at strategic locations throughout the station. This system includes one 30 hp air compressor and a single air accumulator tank.

A 50,000 gallon concrete water tank is provided to serve as the powerhouse source of domestic water for potable, fire and cooling water. The tank is located on a bench adjacent to the tunnel portal. Booster pumps are provided at floor elevation 23 to boost water pressure throughout the power station.

The water treatment and potable water system includes a treatment module, purification equipment, holding tank, water softener, demineralizer, hot water tanks, storage tank, and necessary distribution. This equipment is located on floor elevation 23.

Two fire systems , water and CO_2 system are provided. The water system includes two 200 gpm booster pumps located at floor elevation 23 to boost station water pressures throughout the fire piping distribution system. This system utilizes the 50,000 gallon domestic water tanks as the primary source of water, and penstock and tailrace are used as the back-up or secondary source. The CO_2 system is confined to the generator in the event of an electrical fire. The system includes two banks of eight to ten high pressure CO_2 tanks will control unit and injectors located in the generator cover.

The station unwater system consist of two 500 gpm single stage vertical lift pumps and piping discharging to tailwater. The pumps are connected by a common manifold with isolation gate and check valves provided to dewater each turbine chamber, and allow one pump to be dismantled f·: maintenance. The unwatering sump is connected to the dirty water sump by a common line which would allow the dirty water pumps to back-up the station unwatering pumps in the event of pump failure or vise versa. All station dirty water is routed to the station dirty water sump. Two 100 gpm pumps are provided which route dirty water to the oil separator and returns water to the station unwater sump.

A 48 feet span, 150/25 ton powerhouse bridge crane is provided. The bridge crane is of conventional arrangement. The crane is used for unit assembly, erection and maintenance.

Two 12 feet by 17.5 feet draft tube gates are provided for turbine chamber dewatering. These gates are of conventional design and would weigh approximately 4 tons each.

A conventional heating and ventilation system is proposed which would be designed to accommodate the minimum recorded temperature of -20°F. A special ventilator will be provided for the auxiliary diesel generator room.

A sewage treatment module will be provided in the powerhouse which will be designed for continued plant service and will discharge treated material into the tailrace. The module would provide primary, secondary and tertiary treatment.

7.5.8 Geology

The proposed powerhouse location is situated on a topographic bench above the Kachemak Bay tidal marsh. This bench is underlain by rock at shallow depth as indicated by exposures along the shoreline bluffs. However, with the exception of the bluff exposures and outcrops along a stream 500 feet to the south, the bedrock is almost completely covered by a veneer of soil. Based on these exposures and previous borings drilled to the south along the stream channel, the powerhouse site appears to be underlain by fractured argillite and lesser amounts of fractured graywacke. A dacite dike also occurs in the area and was seen only at a single exposure observed near alternate Francis unit portal location.

A hand-dug test pit was located in the area of the portal for the alternate Francis powerhouse. Shallow bedrock was confirmed at this site below about 1 to 2 feet of overburden material. The dacite bedrock encountered in the test pit is similar to other outcrops of dacite dike rocks observed in the Bradley Lake project area. Although the lateral extent of this material at the powerhouse site is not known, its width should not be expected to be great.

Although the rock is typically fractured, it is considered satisfactory as a foundation material for the powerhouse. Higher cut slopes, such as above the power tunnel portal, may require some slope protection to control nuisance-level ravelling.

7.5.9 Access

Permanent access to the powerhouse will be provided by road from the permanent camp, barge basin, and airport. In the event of emergency a helicopter can be landed adjacent to the powerhouse near the powerhouse substation in the lay down area.

7.5.10 Powerhouse Alternatives

The Corp of Engineers previously studied a shallow underground powerhouse with an underground penstock and pressure tailrace with surge chamber and an above ground powerhouse with an open rip-rap tailrace. The underground powerhouse was more expensive and was not preferred.

Only an above ground powerhouse was considered based upon the previous Corp of Engineers findings. A total of six two-unit powerhouse arrangements were developed; three capacities, 60 MW, 90 MW, and 135 MW for Pelton or France turbine generating equipment. Sketches were prepared for each arrangement in order to accurately depict quantities and form the basis for the preparation of cost estimates and economic analysis. All the powerhouse arrangements were technically feasible but the 90 MW Pelton arrangement was economically preferred.

7.6 SUBSTATION AND TRANSMISSION

7.6.1 General

Transmission of the power from the Bradley Lake plant is over two parallel, wood pole, 115 kV lines, about 20 miles long. These lines will tap into a new transmission line to be built by Homer Electric Association between Fritz Creek and Soldotna. The powerhouse substation is located adjacent to the powerhouse, as close as possible to minimize the bus connection between the generators and the step-up transformers. Because of the wide range in power plant outputs studied, it was deemed prudent to perform a transmission line analysis to determine a suitable line voltage. The voltage selected is 115 kV.

7.6.2 Transmission Line Analysis

The Bradley Lake plant represents a substantial addition to the generating capability of the Kenai Peninsula. The existing transmission system in this area has already reached its maximum capacity without the addition of Bradley Lake. Therefore, it became imperative to perform a transmission line analysis to determine transmission requirements when Bradley Lake becomes operational. SWEC performed this study and details of findings are given in Appendix C of this report. A similar study was made previously by the Alaska Power Administration and is included in the COE General Design Memorandum No. 2 for Bradley Lake. The purpose of the present study is to determine the suitable operating voltage for the transmission lines from Bradley Lake and to determine if the existing transmission line system will be capable of economically transmitting the additional power generated by Bradley Lake.

As a result of the analysis the following conclusions have been reached:

- Two parallel 115 KV, 3-phase, full capacity lines are required to reliably transmit the power from the Bradley Lake plant to the peninsula transmission system.

- For Bradley Lake plant outputs up to and including 90 MW, a second transmission line between Anchorage and Soldotna is not required.

- For Bradley Lake plant output of 135 MW, a second transmission line, preferably rated 230 KV, is required between Anchorage and Soldotna. For maximum reliability, this transmission line should be installed over a different route than the existing Anchorage to Soldotna line. A suggested route would be similar to the existing gas pipeline route, with a submarine cable crossing Turnagain Arm, at the east end of Chickaloon Bay. The requirement for a second transmission line between the above two points is based on a substantial portion of the power from Bradley Lake being exported to Anchorage on a normal basis.

- By the year 1995, a new switchyard will be required at Kasilof to tie the two Diamond Ridge-to-Soldotna lines together. This will "stiffen" up the system and increase its transmission capability.

The Anchorage/Kenai Peninsula transmission systems were modeled on a computer. The computer program used for this purpose is the Electric Power Research Institute (EPRI) Transient Midterm Stability Program. Updated transmission line data was introduced into the computer representing about 25 buses on the Kenai Peninsula. The Anchorage area was represented as a single bus. Included were all generating facilities in Anchorage and the Kenai Peninsula areas. Peak load flows for the years 1983 to 2003 were determined using data developed for the Alaska Power Authority, by Harza-Ebasco in July 1983. Several load flow cases were simulated on the computer to determine their effect on the lines, such as losses and voltage levels. Most of the load flows were for the 135 MW plant, during the year 1988. Some 135 MW plant load flows were simulated for the years 1995 and 2003. The effects on the system, stability, losses and bus voltages were determined by simulating several different transmission line outages.

The peak load forecasts for the years 1983 to 2003 were obtained from the Harza-Ebasco Susitna FERC License Application dated July 1983. The load forecasts were based on the "Sherman H. Clark Association NSD Case", which listed the Anchorage Area peak load forecasts for each year. Based on historical data, it was determined that the Kenai Peninsula loads were approximately 15% of the Anchorage area loads. This value was used for the load flow studies. For individual bus loads within the Kenai Peninsula transmission system, Exhibit A1 of the "Feasibility Study of the Soldotna-Fritz Creek Transmission Line", June 1983 by Gilbert/Commonwealth was used. Individual bus loads were assumed to increase uniformly at the same rate as the overall Kenai forecasted loads.

The results and conclusions of the load flow studies are based on the following assumptions:

(1) The present transmission system will be expanded to include a new 115 kV line from Fritz Creek to Soldotna prior to commercial operation of the Bradley Lake Plant.

(2) Existing generating capacity at Bernice Lake is 70 MW and is 15 MW at Cooper Lake. No other generation, other than Bradley Lake will be installed through the year 2003.

(3) Acceptable line losses are 10% and acceptable bus voltages are 90% of rated.

(4) Bernice Lake will not normally generate power after Bradley Lake is built, but will provide reserve power for emergencies.

A power flow diagram was developed for each load flow case. These are shown in the detailed report of the Transmission Line Analysis found in Appendix C.

7.6.3 Powerhouse Substation

The substation, shown by Plate 15, is designed in a unitized arrangement. Each generator is connected to a separate step-up transformer, which in turn is connected to a line circuit breaker, then to a transmission line. In addition, the substation contains voltage transformers to measure line voltages, vertical break disconnecting switches and the transmission line steel termination towers. The power transformers are furnished with water spray fire protection and oil spill collection systems. A tie circuit breaker is connected between the two 115 kV circuits. This breaker is normally closed to allow power in the Soldotna-Fritz Creek transmission line to flow through the Bradley Lake substation. The substation is designed to transmit the full output of the plant with the loss or removal of one of the two line circuit breakers. Conventional outdoor equipment is utilized in the substation. The power transformers are oil-immersed, tripled rated, OA/FA/FA-33.8/45/56.3 MVA, three-phase, 60 HZ, HV 115 kV grounded wye, LV 13.8 kV delta. Winding rise is 65°C above an average ambient of 30°C. The circuit breakers are oil immersed, 121 kV class, 3-pole 1200 amp. continuous, 40,000 amp. interrupting. The disconnecting switches are 115 kV, 3 pole, 1200 amp continuous, manually operated, with grounding switches. There are six single phase coupling capacitor voltage transformers rated 115 kV to 115 volts, with dual secondaries. Because of the close proximity of the substation to a body of salt water, all outdoor equipment bushings and substation insulators are extra creep design. A copper ground grid is embedded in the substation which is connected to the substation steel work, the steel fencing, and to the powerhouse grounding system. The surface of the substation consists of crushed rock.

7.6.4 Transmission Lines

The transmission facilities for the Bradley Lake project consist of two parallel 115 kV three-phase lines. The proposed routing of the lines is shown on Plate 2. The lines originate at the powerhouse substation and terminate at a location called Bradley Junction, where the two lines tap into a new line to be built by Homer Electric Association (HEA) between Fritz Creek and Soldotna. This new (HEA) line will be in place before the Bradley Lake plant becomes operational. The feasibility study relating to the transmission line systems associated with the Bradley Lake development was prepared by the firm of Dryden and LaRue and is contained in this report as Appendix D.

The selection of the line routing was based, in general, on the COE original routing, with some minor changes. These changes are the result of some geological investigations and determinations of private land ownership. The selected routing avoids the southern boundary of the Kenai National Moose Range, and minimizes private property crossings. In addition, the selected route minimizes the visual impacts of the line and its right-of-way clearing. The selected routing also avoids soft muskeg, swamp and mud areas where line maintenance would be difficult.

The design of the lines is based on National Electric Safety Code, grade "B" construction, and the Design Manual for High Voltage Transmission Lines, REA Bulletin 62-1, revised August 1980. The structures consist of single circuit H-frame wood poles, as shown in Plate 15. The poles are 80 feet long, with embedment from 10 to 14 feet, depending on the soil conditions. The average span between structures is 1000 feet. The selected conductor is 556.5 KCM, ACSR, code name "Dove".

The two lines from the plant connect into the Homer Electric Association Fritz Creek line to Soldotna, at Bradley Junction. At this location, there are three independent, manually operated disconnecting switches. The switches will normally be set so that all power in the Fritz Creek/Soldotna line will flow through the Bradley Lake powerhouse substation. In an emergency, the switches at Bradley Junction can be operated to isolate the Bradley Lake plant lines and close the gap in the Fritz Creek/Soldotna line to allow power in that line to bypass the Bradley lake plant substation. The COE envisioned electrically operated load break switches, remotely operated, at Bradley Junction. Because of its remote location, this design would be difficult to accomplish. A source of power would be needed to operate the switches, communication and control equipment.

The need for remote control of the equipment at Bradley Junction can be investigated further at a later date.

Due to the inaccessibility of a large portion of the transmission lines to normally utilized maintenance vehicles, maintenance costs for the lines will be relatively higher than that for other, more accessible lines. Much of the equipment required for line maintenance will be used only for emergency repairs, and will be used rarely for normal operations. Roads are not practical and environmentally not desirable or even allowed. The line will be patrolled and even repaired by helicopter. All terrain vehicles (ATV's) will be used to maintain parts of the line, using the right-of-way for access. The structures are designed to be installed and maintained by helicopter. Storage space is provided at the Bradley lake plant for various items of line maintenance equipment and supplies.

The recommended transmission line right-of-way and clearing limits have been determined on the basis of the following:

- Construction of two, 115 kV, 3-phase transmission lines simultaneously and side-by-side.

- Minimum width necessary to maintain proper clearance between lines and to the edge of the clearing due to high winds and falling line structures.

- Minimum width necessary to allow clear cutting removal of all major foliage directly under the line and within limits that might threaten line interference in the future.

- Minimum width necessary to allow selective cutting of the tallest timber adjacent to the line to eliminate danger trees from falling across the power lines or structures.

- Minimum width necessary to provide favorable blending of the right-of-way with natural surrounding environment.

This determination indicates a clear cutting width of 225 feet along the right of way. To prevent 100 foot high trees from interfering with the line, a selective cutting width of 325 feet will be required. Only the tallest danger trees will be selectively cut in this additional area beyond the clear cut right-of-way.

7.6.5 Kenai Peninsula - Anchorage Transmission Line

Two transmission line routes are investigated that would connect the Kenai Peninsula to Anchorage. These investigations were for the purpose of developing costs for use in the economic evaluation studies. One route follows the existing 115 kV line and the second route examined a line that follows the existing gas line to Chickaloon Bay and crosses Turnagain Arm with submarine cable. The study efforts and findings for this transmission line are given in Appendix D of this report.

7.6.6 Alternatives

An alternative 115 kV substation consisting of gas insulated equipment, utilizing sulphur hexafluoride (SF6) gas under pressure as the insulating medium was also investigated. See Figure 7.6-1. The entire equipment for this substation is installed in a weather proof enclosures at the factory and shipped to the jobsite as a modular unit. The complete module is approximately 15 feet wide by 30 feet long by 12 feet high, and the weight including all equipment, is about 25 to 30 tons. Outdoor installation of the gas insulated equipment was investigated. However, because of the adverse effect on the gas insulating medium by low temperatures expected at the project location, it was decided to utilize an enclosed substation. The gas insulated substation (GIS) arrangement is more costly initially over a substation utilizing conventional equipment. However, the GIS substation requires only a fraction of the space needed by the conventional equipment and can be installed with a minimum of time and on-site labor. In addition, the modular GIS substation can be completely checked and tested in the factory, thus minimizing field testing and delay during initial plant operation. The enclosed substation protects the HV equipment from the elements and reduces the cost of maintenance. The substation equipment includes a line breaker for each line, and a tie breaker connected between each line. Each breaker is equipped with disconnecting switches to isolate the breakers during maintenance and repair. Included are current and potential transformers to measure line currents and bus voltages. The tie breaker is normally closed to allow power in the Soldotna-Fritz Creek transmission line to flow through the Bradley Lake substation. The substation is designed to transmit the full output of the plant with either the loss of or removal of one of the two line circuit breakers. A copper ground grid is embedded in the substation surrounding the power transformers and the substation module. This grid is connected to the substation steel work, all equipment enclosures, and to the powerhouse grounding system. Connection of the 115 kV GIS equipment to the power transformers is through a GIS bus passing through the substation module wall, and the use of SF6-oil transformer bushings. The 115 kV power is brought out of the substation module via SF6-to-air insulating bushings which are connected to the overhead transmission lines. The modular substation includes all controls for the breakers and motor-operated switches, wired and tested for proper operation in the factory. These control cabinets are installed inside the module.

Alternative types of transmission lines from the Bradley Lake project to the Homer Electric Association line were not investigated during this study. However, buried and submarine cable alternatives were considered by the COE. These alternatives were dismissed by the COE as being too costly or impractical.

7.7 CONSTRUCTION FACILITIES

7.7.1 General

The recommended project requires the development of facilities for access to and within the project area during construction. Also, facilities for housing of personnel and for storage of construction and operational equipment are provided. Whenever possible, facilities required during construction will be so located and designed that they may be used as permanent facilities to serve the long term needs of the project. Facilities not needed for long term project use will be removed and the affected grounds reasonably restored to allow for the reestablishment of natural conditions. Permanent access facilities have been identified and are discussed in Section 7.1 of this report.

Essentially all construction facilities will be developed under the first construction contract and will include: development of staging areas and camp sites; domestic water supply and sewage disposal and/or treatment plant; housing for permanent plant operations personnel and construction manager and engineering support staffs; field laboratory testing, warehousing, and garaging structures. Also to be provided under the first construction contract are the essential services to these facilities including heating, water, sanitary disposal systems, and electricity. The key facilities and services to be provided are described in greater detail in the following paragraphs.

7.7.2 Staging Areas

Two staging areas are planned for the project. A small staging area approximately 150 feet by 350 feet is being provided as part of the development of the barge basin access way. The area is located at the terminus of the barge basin and will serve as a temporary laydown area for off loading personnel, equipment, and supplies needed for project development. This area will become the permanent staging area of the project after completion of construction.

The second and main staging area for construction needs is to be located at the south side of Sheep Point. This area is presently sized as 600 feet by 1,000 feet. However, further study of construction and scheduling needs for equipment and material should result in a reduction to the staging area requirements. This area will serve as laydown and storage area for each of the contractors on the project and for the construction manager's needs in storing of equipment and supplies. Temporary warehousing and garaging facilities as well as diesel electric power facilities and fuel needs will be located here. In addition, the laboratory testing facilities could be located in this area.

7.7.3 Camp Areas

Two camps of modular construction are proposed for the project. The two-camp concept locates the work force closer to the area of construction activity. Approximately half of the work force will be working on the dam, upper tunnel work, upper access roads, the Middle Fork diversion, and upper reservoir area. The other half would be working on construction efforts closer to the lower camp, such a lower access road construction, the power tunnel, the powerhouse, and the transmission line. The main advantages of splitting the camps are safety of personnel, shorter travel time, increased job accessibility, and better production and efficiency for the construction efforts, particularly during inclement weather. The disadvantages are additional costs, duplication of utilities, and the early establishment of the upper camp site before access roads are built. The evaluation and studies for the camp sites are discussed in greater detail in Appendix B. Reconnaissance and map interpretation have identified an acceptable location for the lower camp site and a suitable location for the upper camp site.

The lower camp area reviewed was that previously identified by the COE in Design Memorandum No. 3. The camp area is located within the floodplain of Battle Creek, approximately 1,000 feet southeast of the main staging area and near the proposed access road serving the upper dam site. Unvegetated overflow channels are found throughout the east end of the camp area; however, soil borings show excellent foundation material. The positive aspects of the site, the foundation conditions, flatness, size, and proximity to the work area offset the fact that site is within the floodplain. This negative aspect is further offset with the location and properly design road section that acts to protect the site from floods. This site is planned for development to accommodate about 240 beds. Suitable housing and recreational facilities will be provided for the crafts. In addition, office and housing facilities are being provided for the needs of contractor's management staff and for staff personnel of the Construction Manager and Engineering Support Services. Messing facilities are being provided to accommodate all personnel using the camp site, including Owner's personnel housed elsewhere. All of the lower camp site facilities can be mobilized by landing craft or barge, then skidded in with a cat or driven in by truck.

Several locations were investigated near the dam for a suitable upper camp site. The only suitable site located is about 1.2 miles due west of the dam near the proposed access road. The site has 4.6 acres of land under 20 percent slope, an apparent water supply, and an area for a sewage lagoon that drains away from the water supply. However, shallow soil conditions present some problems in site development and it is likely that sanitary effluents will need to be trucked to the lower site facilities for disposal. Also, because of difficult early accessibility to the site area, all mobilization must be by helicopter for site development and early use, until the access road is completed. The upper camp site is planned for up to 210 bed capacity. The camp will serve also construction and management staff activities associated with work in the dam area, within the reservoir, and most likely for work on the Middle Fork diversion. Offices, recreational, and messing facilities are provided.

As previously stated, office and messing facilities for Owner's personnel are provided at each camp area, as appropriate. However, it is planned to use the permanent plant housing accommodations as sleeping quarters for Owner's personnel. In addition, a project liaison office will be established in Homer to serve the needs of the Owner and its Construction Manager. Permanent plant warehousing, garaging, and other facilities will be installed under the first construction contract for early use by the Owner and its Construction Manager.

7.7.4 Borrow and Waste Area Access

Access roads to borrow areas will be either by fill embankment sections or grade cut-fill sections. One major access road has been identified for the project. This is a 1.4 mile road for borrow from the Martin River Delta area. The road alignment previously identified by the COE was reviewed and was determined to be reasonable and used under this study. The road will begin near the lower camp and extend in a westernly alignment to borrow areas at the Martin River Delta. This is considered a temporary access road and will be removed and the surrounding terrain rehabilitated. Its development would consist of essentially leveling and grading the terrain of alluvial fans at about a grade contour of elevation 12 feet. Because of its temporary nature no rip rap protection or gravel top course are provided in its construction. A bridge crossing is required at Battle Creek. That portion of the access road requiring fill/borrow has been assumed as a one lane road. The graded portions of the road are developed as a two lane travelway.

Other borrow access roads identified are those relating to the rock quarrying operations for the rockfill dam. These roads are essentially in rock cut and become part of the quarry operations. The roads are within the reservoir area and will be essentially inundated by the increased reservoir height.

Waste areas will be located as close as possible to the work so as to minimize their impact and the need for access roads.

7.7.5 Construction at Dam Site

The preferred plan places the dam and other adjacent project structures within the compact river channel area near the outlet of Bradley Lake. This consolidates construction activities within a small area. The major construction efforts at the dam site are: the dam and its spillway; the diversion tunnel; the power tunnel intake channel and intake structure; and the gate structure and adjacent tunnel and inclined shaft.

Construction facilities at the dam site will consist of office trailers, a small concrete batching plant, and the short roads needed to access the various construction activities. Construction activities and access roads relating to the placement of dam fill material, the concrete facing, the intake channel and intake structure, and the power tunnel work will all be located within the reservoir and eventually these structures will be under water when the reservoir is raised. The construction access road, placed downstream of the dam and used to develop the diversion tunnel, will be refurbished and used as a permanent access to this structure. The gate shaft is located near the main access road for the dam and requires only little additional work for its development. Similarly, bridging of Bradley River, needed for the construction of the diversion tunnel, would be removed prior to constructing the dam.

7.7.6 Construction at Powerhouse

Under the preferred plan the excavations required for the power tunnel portal and the powerhouse are combined into one single excavation. Excavated material is placed in the tidal flats adjacent to the shore to create laydown and work areas for construction, including an area for onsite office trailers and the diesel generating equipment needed for powering the tunnel boring machine and for lighting this area. After construction these laydown areas would serve the permanent plant. One area will be used for development of the plant substation and the other will form an access area for plant maintenance needs.

7.7.7 Water Supply

The first construction contractor will be required to develop the water system for the project needs. The water supply for domestic water will be designed to provide the domestic flow demand of the construction camp or the fire flow demand, whichever is greater. For the lower camp, the water supply will be from surface runoff or underground sources. Water treatment facilities will be provided to assure good quality and safe potable water. It is anticipated that ground water treatment will consist only of chlorination; however, surface water may require more extensive treatment,including sedimentation and filtering. It is more likely that wells will be developed for the water supply. The water system for construction needs will be designed so that it can also serve the long term needs of the permanent plant. Water for construction will be similarly collected and treated only to the extent required for good concrete development. Domestic water sources will be developed in full compliance with applicable regulations.

Domestic water needs for the upper camp will be from the lake adjacent to the camp or other nearby lakes. The water supply will be sized to provide either the domestic needs of the camp or fire fighting needs, whichever is greater. It is anticipated that the water treatment will be by filtration and chlorination. It is doubtful that a ground water source can be developed for the upper camp area. Water for construction will be from Bradley Lake. Some treatment by filtering may be required to remove suspended material.

7.7.8 Sewage Disposal

The first construction contractor will be required to develop the sewage collection system and connect it to the appropriate facilities. Waste water will be placed in an aerated sewage lagoon. Effluent will be discharged into Battle Creek or some other point acceptable to the controlling agency.

Because it is likely that suitable sewage treatment facilities cannot be developed at the upper camp site, it is planned to provide a series of holding tanks to retain waste material. The waste material will be trucked to the lower camp sewage facilities for treatment and disposal. Additional field investigations are needed to better define sewage handling for the upper camp.

7.7.9 Electric Power

Electric power for construction and domestic needs will be under the responsibility of the first construction contractor. This contractor will be the first on site, will require the greatest amount of electrical energy and will be responsible for the establishment and operation of all camp facilities. It is anticipated that about 5 to 6 MW of capacity will be needed at the lower construction area. Of this, 2 to 3 MW will be required by the tunnel boring machine, about 1 MW for the lower camp and miscellaneous housing, warehouse and garaging facilities, and about 1 MW for lighting of the main storage and construction areas. Additional diesel generated power will need to be provided at the upper camp and construction area. It is anticipated that about 2 MW of capacity will be needed to serve these facilities. Adequate fuel supply and reserves will be provided to allow for 2 weeks of operation without refueling. Fuel storage will be developed in full compliance of State and Federal requirements.

7.7.10 Other Facilities

Facilities for storage of explosives will be provided at appropriate and safe locations in full compliance with State and Federal requirements.

7.8 BUILDINGS, GROUNDS AND UTILITIES

7.8.1 General

The remote Bradley Lake Project site will have air or waterborne access only. The plant will be computer controlled and remotely dispatched via a microwave link. A resident staff will be required to perform daily operation functions and routine maintenance.

The project site is relatively close to Homer, but because of limited access, onsite facilities and operations equipment must be provided to perform all necessary maintenance and repair.

The permanent buildings, grounds and utilities required are located near the lower construction camp adjacent to Battle Creek. Family residences are provided for each of the permanent onsite personnel. In addition, a twelve man bunkhouse with kitchen facilities is provided in the event more personnel are required onsite during periods of major maintenance.

7.8.2 Staffing

The permanent resident staff will consist of a plant supervisor and three maintenance-operators. Additional maintenance personnel would be assigned to the site during periods of major maintenance on a temporary basis. Dispatching will be performed remotely by the operating utility. Since the area utilities presently have 24 hour dispatch coverage, no additional dispatch personnel are required.

7.8.3 Maintenance Facilities

The following maintenance facilities are provided:

- 10,000 square feet warehouse and machine shop
- Outside fenced-in storage area
- Outside fenced-in parking area for operations equipment
- Fuel storage - underground tanks for gas and diesel fuel

One of the construction warehouses will be left in place as part of the permanent building facilities. This warehouse will be remodeled to include 4000 square feet of bin and rack storage, 2000 square feet for the machine shop, and the remaining floor area will be open for laydown work and vehicle maintenance. Additional tool and small part storage is provided on the generator floor of the powerhouse.

Designated outside fenced-in parking and storage areas are provided. A 6000 square feet fenced-in gravel surfaced area is provided adjacent to the warehouse, to park the operations equipment. Outlets for resistance heaters would be provided at each parking space. A 6000 square feet fenced-in gravel surfaced storage area is provided also adjacent to the warehouse. Bulk outdoor storage racks are provided for material storage. Fuel storage will utilize underground tanks of 10,000 gallon capacity, one each for gasoline and diesel fuel.

7.8.4 Operations Equipment

A comprehensive list of operating equipment was made available to the Alaska Power Authority. Included are heavy road and building maintenance equipment, machine shop equipment and maintenance equipment for each project structure. The capital cost of this equipment is included in the project cost estimate and a sinking fund is included in the annual operations and maintenance budget estimate for future equipment replacement.

7.8.5 Residential and Office Facilities

The residential facilities are as follows:

3 - three bedroom houses (permanent personnel quarters)
1 - four bedroom house (supervisors quarters)
1 - twelve bed bunkhouse with kitchen facilities (temporary personnel quarters)

The permanent houses will be architecturally blended into the timber adjacent to the lower construction camp site and above the flood plain.

Each residence will be separated from each other and the warehouse, bunkhouse and other permanent camp facilities, to permit some seclusion and privacy. The office facilities are part of the control room in the powerhouse. A small office and conference room will be included in the bunkhouse. Due to the site's isolation, facilities will be incorporated into the permanent residences for long term subsistence. Fireplaces and wood stoves would also be provided for back-up heating. A stand-by diesel generator is provided in the event of power loss. Telephone communication will be provided via microwave link.

7.8.6 Water

Surface or well water resources can be developed to provide domestic water for the construction camps and permanent camp. To be conservative, water treatment facilities are based on a surface water source. Well water would simply require chlorination. The domestic water would be furnished as part of the contract which develops the construction camps. Each residence, bunkhouse and warehouse has a 200 gallon capacity domestic water storage tank. A separate domestic water system is provided at the powerhouse including extensive treatment facilities. The powerhouse domestic water is also used for generator equipment cooling. Drinking water at the dam, intake gate shaft, and other locations will be transported with personnel.

7.8.7 Wastewater Treatment and Disposal

Aerated lagoons are provided for the lower construction camp, but may be too far removed from the permanent camp facilities to be retained. A conventional septic tank and drain field is therefore provided for each permanent residence, bunkhouse, and warehouse. Effluent will be transported from the upper construction camp to the lower construction camp facilities for treatment. The powerhouse has a self-contained sewage treatment module. The treatment and disposal method will comply with applicable Federal and State standards, and the applicable permits will be obtained. Portable toilets will be used at other site locations.

7.8.8 Fire Protection

Each structure will be furnished with a minimum of two means of egress. Emergency lighting and smoke alarms will be provided in each structure. Fire water will be provided by the domestic water system supplemented by surface water at the permanent camp. The powerhouse has two fire protection systems, one water and the other carbon dioxide. Hand fire extinguishers are provided in each building.

7.8.9 Project Physical Security

Vandalism and theft after construction are not anticipated due to the remoteness of the project site. However, steel doors with dead bolt security locks will be provided for the exterior doors of all project structures. Chain link fencing with two top barb wires will surround the powerhouse substation and designated project storage areas. Access into these fenced areas will be through locked gates.

7.8.10 Solid Waste Facilities

Solid waste disposal will be in accordance with applicable Federal and State requirements. Several methods of disposal are under consideration, including incineration, local sanitary land fill operated by project personnel, and containerization and transportation of solid waste to a suitable disposal site. The local sanitary land fill operated by project personnel may be the most economical but additional study is required. All necessary permits will be obtained.

7.8.11 Other Facilities

Site Power will be provided by the station service facilities at the powerhouse. Standby diesel generators are provided at the permanent building area and powerhouse for emergency and start-up power. Small propane generators and batteries are provided at the intake gate shaft and diversion gate house for power.

7.9 MIDDLE FORK DIVERSION

7.9.1 General

The Middle Fork Diversion is located approximately one mile north of Bradley Lake in an adjacent drainage at elevation 2,200 on the Middle Fork stream. The Middle Fork Diversion facilities consist of a small dam, spillway, and two diversion lines. One line is provided for initial construction efforts to bypass natural streamflows, and subsequently to serve as a permanent outlet for downstream releases. The other main diversion line conveys water to Marmot Creek, a tributary to Bradley Lake. The interbasin diversion facility which will be operational from May through October, provides additional water to the Bradley Lake reservoir and increases the energy benefits for the project approximately 1,000 KWHR for every acre-foot diverted.

7.9.2 Recommended Plan

The recommended plan for developing the Middle Fork Diversion is a small 20 foot high rockfill dam with a sheet pile cut-off wall and an excavated channel spillway in the right abutment. The main diversion line and low level outlet intake works are integral with the dam. The low level outlet serves as a temporary diversion during construction of the dam, spillway, and main diversion flow line intake. Both the main diversion line and low level outlet are 6 foot diameter steel pipes with face mounted manually operated intake sluice gates.

The main diversion line is approximately 1,900 feet long and is buried along its entire length with a slope of 0.6 percent. The terrain along the proposed alignment is typically exposed bedrock, and "drill and shoot" excavation techniques are required. The pipeline bedding and cover material is shot rock from the excavation.

The low level outlet is located in an excavated rock trench on the left bank. The low level outlet pipe invert is located approximately 3 feet below the natural stream channel bottom elevation to permit streamflow diversion during the dam and spillway construction and allow the reservoir to be lowered for intake sluice gate inspection. It also serves as a permanent outlet for downstream releases during the November through April period.

The intake for the main diversion line and the low level outlet is a reinforced concrete structure with a platform for the manual operators at elevation 2,212. The intake works encases the 6 foot diameter pipes and provides anchorage for the intake sluice gates and operators.

The spillway is a 30 feet wide channel located in the right abutment. The material excavated for the spillway will be used for the dam rockfill. A 30 feet wide, 4 feet high concrete wier with crest at elevation 2,204 is located in the spillway channel at the dam axis. The spillway channel is excavated in bedrock and is not lined. The Middle Fork Diversion concept is shown on Plates 16 and 17.

7.9.3 Geology

The bedrock in the area between the Middle Fork Diversion and Marmot Creek is predominantly graywacke with argillite interbeds. Much of the proposed route is covered with talus and muskeg swamps, which prevented a detailed assessment of geologic conditions. Overburden depths vary from less than 1 foot to over 15 feet as determined by seismic refraction surveys by others. Gravel and/or sand footings may be required for diversion pipe supports. For such support systems, the bedrock structure should not present any stability problems. This information is derived from COE data; the scope of this current study did not include further investigation of this area.

7.9.4 Technical Details

The hydraulic rating curves for the spillway and main diversion line are shown on Figure 7.9-1. The main diversion line can pass 450 cfs into Marmot Creek without spillway discharges occurring at the diversion dam. The spillway can pass about 1,600 cfs at pool elevation 2,210 which exceeds the 100 year design flood discharge with no flow in the main diversion line and 2 feet of freeboard on the dam crest. The main diversion line can pass an additional 670 cfs if operational with the pool at elevation 2,210. Should streamflows exceed 1,600 cfs (or 2,300 cfs if the line is operational), the water level will continue to rise until the dam is overtopped at pool elevation 2,212 which corresponds to a spillway flow of 2,600 cfs. The combined capacity of the spillway and main diversion pipe at pool elevation 2,212 is approximately 3,400 cfs. This represents about 85 percent of the PMF peak flow as determined by the COE. Should the diversion dam be overtopped little damage is anticipated to either the dam, flow lines, or the downstream river section, and it is not justified to design the structures for larger and more improbable design flows. The main diversion line and low level outlet will be vented downstream of the intake sluice gates.

Field observations indicate that the Middle Fork and Marmot Creek streambeds are cut into rock. The spillway channel is excavated in rock and directs discharges into the natural streambed downstream of the dam toe. The low level outlet discharges water onto a concrete apron and into the natural streambed also downstream of the dam toe.

The COE expected some limited erosion of the tundra and soil cover below the outlet of the main diversion line. This appears reasonable based on field observations in this locale and the Marmot Creek streambed.

The COE field observations indicated that snow remained in the diversion area well into August but that snow slide areas were not evident. SWEC concurs with the COE that a buried pipeline is the most reliable means to convey diverted waters to the Bradley Reservoir during the May to October period. Snow is likely to drift and pack itself against an exposed pipeline resulting in large external loads from snow creep. Technically the buried pipeline offers the best solution.

Operating the main diversion line from May to October will limit ice formation in the diversion pipeline or low level outlet. The reinforced concrete intake structure, rockfill dam, and reinforced concrete spillway weir offer suitable ice resistance.

7.9.5 Dam, Gates, and Conduit

The rockfill dam will be approximately 140 feet long and 20 feet high with a central sheet pile cut off wall embedded in a rock key along the dam axis. A 15 feet deep grout curtain seals the foundation rock below the concrete key. The 6 feet diameter diversion pipes are encased in reinforced concrete at the rock key and the sheet pile is embedded in the encasement. At each end of the dam the sheet pile is embedded in concrete keyed into the abutment rock.

The concrete spillway weir, 4 feet high and 30 feet long, is also keyed into the foundation rock, and the 15 feet deep grout curtain along the dam axis is continued under the weir and into the right abutment. The spillway weir crest is 8 feet below the top of the dam.

The main diversion line consists of a common intake structure with the low level outlet, a 6 feet entrance sluice gate with manual operator, a 1,900 feet long, 6 feet diameter, 3/8 inch thick steel pipe buried throughout its length to preclude snow creep damage, and a screened outlet. The low level outlet consists of a intake structure common with the main diversion line, a 6 feet entrance sluice gate with a manual operator, a 6 feet diameter 3/8 inch thick steel pipe embedded in the dam, a screened outlet to prevent entry, and a concrete apron downstream of the outlet.

7.9.6 Access

Access to the Middle Fork Diversion during construction will be by helicopter. Sky cranes will be used to transport personnel, material, and construction equipment. Two helicopter trips will be required to the Middle Fork Dam each year for operations and maintenance, one trip in May and one in October. The trip in May will be required to open the Main Diversion flow line sluice gate and close the low level outlet sluice gate. The October trip will be required to close the diversion gate and open the low level outlet gate.

The COE studies concluded that an access road to the Middle Fork Diversion is not recommended. SWEC concurs with this recommendation, however, remote telemetry to control the sluice gates or monitor Middle Fork flows as recommended by the COE, will impose an additional operations and maintenance expense which is considered unwarranted.

7.9.7 Alternatives

The COE considered several types of diversion dams and conveyance alternatives. The COE concluded that an uncovered trapezoidal channel would be blocked by snow and ice for parts of the planned operation period between May and October and that it would not be feasible to keep the channel free to pass the required discharge. Also, the COE studied an above ground pipeline and concluded it would be uneconomical to design the pipe to resist the large forces exerted by the snow cover. The COE concluded that a buried pipeline is the best method for conveyance of diversion flows from the dam to the Bradley Lake drainage basin. SWEC reviewed the various conveyance alternatives and concurs with these conclusions.

The COE developed timber dam, concrete dam, and a metal binwall dam alternatives at Middle Fork. SWEC developed two additional alternatives: A concrete faced rockfill and a central sheet-pile cutoff rock fill dam. The rockfill dams utilize rock available at the dam site. Material excavated from the spillway is utilized for the dam rock fill. Due to the remoteness of the Middle Fork Dam durability and ability of the dam to resist the elements is of prime importance. A substantial dam, as proposed by SWEC, offers better durability to weather and other severe factors, such as snow and ice that will be present at the site, and is preferred. The central sheet-pile cutoff rockfill dam offers better internal drainage within the dam, eliminates concrete work, and is technically preferred.

DESIGN WINDSPEEDS (MPH) AT SHEEP POINT
KACHEMAK BAY, ALASKA

Orientation	Duration (hours)	Exceedance Interval (years) 2	5	50
210° - 260°	1	57	62	68
(summer)	12	47	52	63
300° - 30°	1	32	36	47
(winter)	12	21	26	36

(1) After Corps of Engineers, NPS, Design Report Access Channel and Moorage Basin Facilities.

TABLE 7.1-1

DESIGN WAVE CHARACTERISTICS (1
SHEEP POINT AND CHUGACHIK ISLAND SITES
KACHEMAK BAY, ALASKA

		Frequency (years)					
	Wave	2		5		50	
Location	Origination	Hs (ft)	T (sec)	Hs (ft)	T (sec)	Hs (ft)	T(sec)
Sheep	250°AZ	4.4	4.3	4.7	4.5	5.1	4.7
Point	270°AZ	3.5	3.8	3.8	3.9	4.1	4.1
	315°AZ	2.0	2.8	2.4	3.1	2.9	3.4
Chugachik	240°AZ	6.1	5.3	6.7	5.6	7.4	5.8
Island	260°AZ	5.9	5.3	6.5	5.5	7.2	5.7
	360°AZ	2.2	3.0	2.5	3.2	3.1	3.5

(1) After Corps of Engineers, NPS, Design Report Access Channel and Moorage Basin Facilities.

(2) H_s (ft) = wave height
T (sec) = wave period

TABLE 7.1-2

HYDRAULIC TRANSIENT ANALYSIS
FRANCIS TYPE TURBINES

POWER HOUSE CAPACITY (MW)	TYPE OF EVENT	SYNCHRONOUS BYPASS BYPASS VALVE SIZE (FT)	WICKET GATE CLOSURE TIME (SEC)	WICKET GATE OPENING TIME (SEC)	SURGE TANK DESCRIPTION	WATER SURFACE ELEVATION @ SURGE TANK (FT)	HGL PT "A" POWERHOUSE (FT)	HGL PT "C" END OF STEEL LINER (FT)	HGL PT "D" SURGE TANK BELOW ORIFICE	HGL PT "E" BOTTOM OF 50° SHAFT (FT)	HGL PT "F" TOP OF 50° SHAFT (FT)	HGL PT "G" HEADWATER LEVEL (FT)
60	Load Acceptance	Valve Closed	---	10	15 ft. Tank I.D. 5 ft. Orifice	964 (min)	621	827	964	995	1,105	1,081
							--------------- No Water Column Separation --------------					
	Load Acceptance	Valve Closed	---	20	15 ft. Tank I.D. 5 ft. Orifice	963 (min)	810	938	967	1,035	1,047	1,081
							--------------- No Water Column Separation --------------					
	Load Rejection	2.5 Diameter 65 Sec. Closure	5	---	15 ft. Tank I.D. 5 ft. Orifice	1,149 (max)	1,478	1,425	1,247	1,251	1,222	1,170
							----------------- No Water Column Separation ------------					
	Load Rejection	3.0 Diameter 65 Sec. Closure	5	---	15 ft. Tank I.D. 5 ft. Orifice	--- (max)	1,284	1,282	---	---	---	---
							----------------- No Water Column Separation ------------					
90	Load Acceptance	Valve Closed	---	10	15 ft. Tank I.D. 5 ft. Orifice	932 (min)	544	777	933	976	999	1,081
							----------------- No Water Column Separation ------------					
	Load Acceptance	Valve Closed	---	20	15 ft. Tank I.D. 5 ft. Orifice	930 (min)	754	907	935	1,023	1,038	1,081
							----------------- No Water Column Separation ------------					
	Load Rejection	3.0 Diameter 65 Sec. Closure	5	---	15 ft. Tank I.D. 5 ft. Orifice	1,149 (max)	1,517	1,449	1,256	1,267	1,231	1,170
							----------------- No Water Column Separation ------------					
	Load Rejection	3.5 Diameter 65 Sec. Closure	5	---	15 ft. Tank I.D. 5 ft. Orifice	--- (max)	1,318	1,308	---	---	---	---
							----------------- No Water Column Separation ------------					
135	Load Acceptance	Valve Closed	---	10	20 ft. Tank I.D. 6 ft. Orifice	924 (min)	442	711	924	955	978	1,081
							----------------- No Water Column Separation ------------					
	Load Acceptance	Valve Closed	---	20	20 ft. Tank I.D. 6 ft. Orifice	922 (min)	675	863	926	1,010	1,026	1,081
							----------------- No Water Column Separation ------------					
	Load Rejection	4.0 Diameter 65 Sec.	5	---	20 ft. Tank I.D. 6 ft. Orifice	1,101 (max)	1,422	1,383	1,215	1,270	1,232	1,170
							----------------- No Water Column Separation ------------					
	Load Rejection	4.5 Diameter 65 Sec.	5	---	20 ft. Tank I.D. 6 ft. Orifice	--- (max)	1,223	1,218	---	---	---	---
							----------------- No Water Column Separation ------------					

HGL = Hydraulic Grade Line

TABLE 7.4-1

HYDRAULIC TRANSIENT ANALYSIS
PELTON TYPE TURBINES

POWER HOUSE CAPACITY (MW)	TYPE OF EVENT	NEEDLE VALVE OPENING TIME (SEC)	NEEDLE VALVE CLOSING TIME (SEC)	HGL PT "A" POWERHOUSE (FT)	HGL PT "C" END OF STEEL LINER (FT)	HGL PT "D" BOTTOM OF 50° SHAFT (FT)	HGL PT "E" TOP OF 50 ° SHAFT (FT)	HGL PT "F" HEADWATER LEVEL
60	Load Acceptance	35	--	629 (min)	668	1,021	1,051	1,081
					-------- No Water Column Separation --------			
	Load Acceptance	60	--	768 (min)	803	1,046	1,063	1,081
					-------- No Water Column Separation --------			
	Load Rejection	--	60	1,407 (max)	1,379	1,196	1,183	1,170
					-------- No Water Column Separation --------			
90	Load Acceptance	35	--	543 (min)	586	1,005	1,042	1,081
					-------- No Water Column Separation --------			
	Load Acceptance	60	--	699 (min)	740	1,036	1,058	1,081
					-------- No Water Column Separation --------			
	Load Rejection	--	60	1,479 (max)	1,443	1,204	1,187	1,170
					-------- No Water Column Separation --------			
135	Load Acceptance	35	--	437 (min)	482	981	1,030	1,081
					-------- No Water Column Separation --------			
	Load Acceptance	60	--	606 (min)	653	1,021	1,051	1,081
					-------- No Water Column Separation --------			
	Load Rejection	--	60	1,599 (max)	1,547	1,216	1,193	1,170
					-------- No Water Column Separation --------			

HGL - Hydraulic Grade Line

TABLE 7.4-2

ROCK CORE PROPERTIES
GREYWACKES, GREYWACKE/ARGILLITE (CATACLASTIC), AND TUFF

Rock Type (Or Notes)	Sample No.	Testing[1] Agency	Unit Weight (lb/cu ft)	Unconfined Compressive Strength (psi)	Total Hardness	Modulus of Elasticity ($Ex10^6$psi)	Poissons Ratio (u)	Splitting Tensile Strength (psi)	Point Load (psi)	Shore Hardness	Chercher[3] Abrasivity	Abrasion Hardness
Gywke/Arg	S-4	S	171	12,763	110.39	-	-		-	73.4	-	5.1
Greywacke	S-5	S	171	10,168	108.86	-	-	-	-	72.1	-	5.4
Greywacke	S-6a	S	172	32,825	149.84	-	-	-	-	73.0	-	5.85
Greywacke	S-6b	S	174	34,975	153.51	-	-	-	-	73.1	-	6.3
Gywke/Arg	J-2	J	-	No Test	-	-	-		10.0	-	3.0	-
Greywacke*	J-3	J	-	10,295	-		-	-	6.1	-	2.0	-
Greywacke*	J-5	J	-	No Test	-	-	-	-	9.1	-	2.4	-
Greywacke*	J-6	J	-	8990	-	-	-	-	8.0	-	3.2	-
Gywke/Arg	4-1 (2)	C	172.8	14,900	-	10.07	0.285	1600	-	-	-	-
Gywke/Arg	5-2 (2)	C	170.9	10,500	-	7.22	0.375	860	-	-	-	-
Gywke/Arg	5-3 (2)	C	170.9	10,000	-	9.58	0.245	No Test	-	-	-	-
Greywacke	6-2 (2)	C	172.8	31,200	-	11.24	0.267	1770	-	-	-	-
Greywacke	6-3 (2)	C	173.4	35,600	-	13.80	0.355	2070	-	-	-	-
Greywacke	7-1	C	171.6	26,600	-	9.77	0.267	No Test	-	-	-	-
Greywacke	7-2 (2)	C	171.6	30,000	-	10.10	0.267	2400	-	-	-	-
Gywke/Arg	8-10	C	172.8	33,200	-	11.14	0.228	2320	-	-	-	-
Greywacke	8-11	C	172.2	30,900	-	10.79	0.249	1950	-	-	-	-
Gywke/Arg	9-9	C	170.9	26,800	-	10.35	0.248	2820	-	-	-	-
Greywacke*	11-46	C	173.5	20,400	-	9.45	0.235	1650	-	-	-	-
Greywacke*	12-2	C	170.9	11,500	-	9.50	0.265	No Test	-	-	-	-
Gywke/Arg	13-31	C	172.2	17,200	-	10.10	0.257	1900	-	-	-	-
Greywacke	14-7	C	170.9	29,400	-	10.43	0.224	2180	-	-	-	-
Greywacke	16-2 (2)	C	172.2	34,100	-	10.37	0.224	2260	-	-	-	-
0.224	2260	-	-	-	-							
0.224	2260	-	-	-	-							
Gywke/Arg	R-4	R	No Test	No Test	-	-	-	-	7.9	-	-	-
Greywacke	R-6	R	No Test	No Test	-	-	--	-	No Test	-	-	-
Greywacke	R-3	R	168.7	12,943	-	-	-	-	No Test	-	-	-
Greywacke	R-1	R	169.0	24,413	-	-	-	-	8.4	-	-	-

* Probable Tuff or Tuff/Greywacke

(1) S - A. J. Hendron for SWEC
C - U. S. Army Corps of Engineers
J - Atlas Copco Jarva, Inc.
R - The Robbins Co.

(2) From Dam Area

(3) 0 = Least, 6 = Most Abrasive

Estimated:
Tunnel Length Involved - 4300 ft
Penetration Rate - 6-8 ft/hr
Delay Time - N/A
Temporary Support - Selectively located, 3/4 in. diameter, 6 ft long, mechanically - anchored rock bolts. Two bolts per 4 lin. ft; 215 bolts total

TABLE 7.4-3

ROCK CORE PROPERTIES
MASSIVE ARGILLITE

Rock Type (Or Notes)	Sample No.	Testing[1] Agency	Unit Weight (lb/cu ft)	Unconfined Compressive Strength (psi)	Total Hardness	Modulus of Elasticity ($Ex10^6$ psi)	Poissons Ratio (u)	Splitting Tensile Strength (psi)	Point Load (psi)	Shore Hardness	Chercher[3] Abrasivity	Abrasion Hardness
	S-1	S	171	8,266	56.73	-	-	-	-	38.6	-	2.16
	H-1A	S	170.5	18,958	86.82	-	-	-	-	76.4	-	3.11
	H-1B	S	169.5	19,718	85.28	-	-	-	-	71.4	-	2.95
	H-2	S	169.4	12,733	57.40	-	-	-		74.8	-	2.06
Moderately Siliceous	H-3	S	169.7	25,820	81.23	-	-	-	-	71.7	-	3.50
V. Weak Foliation	J-1	J	-	6,670	-	-	-	-	7.3	-	2.2	-
	J-8	J	-	8,700	-	-	-	-	10.0	-	2.4	-
Slightly Cherty	J-11	J	-	Not Tested	-	-	-	-	4.8	-	2.2	-
V. Weak Folliation	R-9	R	165.5	15,784	-	-	-	-	No Test	-	-	-
	R-10	R	Not Tested	19,993		-	-	-	No Test	-	-	-
Slightly Cherty	R-7	R	Not Tested	Not Tested	-	-	-	-	5.0	-	-	-

(1) S - A. J. Hendron for SWEC
C - U. S. Army Corps of Engineers
J - Atlas Copco Jarva, Inc.
R - The Robbins Co.

(2) From Dam Area

(3) 0 = Least, 6 = Most Abrasive

Estimated:
Tunnel Length Involved - 5000 ft
Penetration Rate - 8-10 ft/hr
Delay Time - N/A
Temporary Support - Selectively located, 3/4 in. diameter, 6 ft long, mechanically - anchored rock bolts. Two bolts per 4 lin. ft; 250 bolts total

TABLE 7.4-4

ROCK CORE PROPERTIES
FOLIATED ARGILLITE

Rock Type (Or Notes)	Sample No.	Testing[1] Agency	Unit Weight (lb/cu ft)	Unconfined Compressive Strength (psi)	Total Hardness	Modulus of Elasticity ($Ex10^6$psi)	Poissons Ratio (u)	Splitting Tensile Strength (psi)	Point Load (psi)	Shore Hardness	Chercher[3] Abrasivity	Abrasion Hardness
A few Calcite Veins	Ch-11A	S	168	6,661	92.53	-	-	-	-	86.3	-	2.16
	CH-11B	S	168	5,038	68.65	-	-	-	-	69.2	-	2.71

FOLIATED, CHERITY ARGILLITE, INCLUDING DACITE

Rock Type (Or Notes)	Sample No.	Testing[1] Agency	Unit Weight (lb/cu ft)	Unconfined Compressive Strength (psi)	Total Hardness	Modulus of Elasticity ($Ex10^6$psi)	Poissons Ratio (u)	Splitting Tensile Strength (psi)	Point Load (psi)	Shore Hardness	Chercher[3] Abrasivity	Abrasion Hardness
	S2	S	169	2,943	54.67	-	-	-	-	69.2	-	2.57
	9-10	C	169.7	12,500	-	7.20	0.119	910	-	-	-	-
	10-13	C	166	9540	-	4.67	0.265	1,180	-	-	-	-
Highly Cherty	J-4	J	-	No Test	-	-	-	-	6.8	-	4.8	-
40% Argillite	J-9	J	-	3915	-	-	-	-	4.0	-	3.8	-
70% Argillite	J-10	J	-	No Test	-	-	-	-	4.8	-	2.2	-
Highly Cherty	R-11	R	No Test	No Test	-	-	-	-	5.9	-	-	-
40% Argillite	R-5	R	162.7	6,945	-	-	-	-	3.2	-	-	-
70% Argillite	R-8	R	No Test	No Test	-	-	-	-	No Test	-	-	-
Chert Nodules (No dacite Tested)	S-3	S	165	4,204	67.28	-	-	-	-	69.6	-	4.8

(1) S - A. J. Hendron for SWEC
C - U. S. Army Corps of Engineers
J - Atlas Copco Jarva, Inc.
R - The Robbins Co.

(2) From Dam Area

(3) 0 = Least, 6 = Most Abrasive

Estimated:
Tunnel Length Involved - Foliated Argillite, 3500 ft; Foliated, Cherty Argillite, 3790 ft
Penetration Rate - Foliated Argillite, 10-12 ft/hr; Foliated, Cherty Argillite 8-10 ft/hr
Delay Time - N/A
Temporary Support - (Both Units) Selectively located, 3/4 in. diameter, 6 ft long, mechanically - anchored rock bolts. Two bolts per 4 ft; 365 bolts total

TABLE 7.4-5

ROCK CORE PROPERTIES
CHERT

Rock Type (Or Notes)	Sample No.	Testing[1] Agency	Unit Weight (lb/cu ft)	Unconfined Compressive Strength (psi)	Total Hardness	Modulus of Elasticity (Ex10^{6}psi)	Poissons Ratio (u)	Splitting Tensile Strength (psi)	Point Load (psi)	Shore Hardness	Chercher[3] Abrasivity	Abrasion Hardness
	CH-11D	S	167	11,121	199.34	-	-	-	-	98.3	-	11.3
	CH-11E	S	168	7,570	181.04	-	-	-	-	92.0	-	9.6
	CH-11F	S	169	9,215	204.41	-	-	-	-	91.4	-	14.5
	CH-11G	S	No Test	No Test	171.76	-	-	-	-	91.2	-	8.8
	CH-11H	S	167	6,897	185.39	-	-	-	-	94.4	-	11.8
	CH-11I	S	168	8,416	204.33	-	-	-	-	99.2	-	15.5
	J-7	J	-	No Test	-	-	-	-	8.2	-	4.4	-
	R-2	R	169.5	22,729	-	-	-	-	8.4	-	-	-

(1) S - A. J. Hendron for SWEC
C - U. S. Army Corps of Engineers
J - Atlas Copco Jarva, Inc.
R - The Robbins Co.

(2) From Dam Area

(3) 0 = Least, 6 = Most Abrasive

Estimated:
Tunnel Length Involved - 50 ft.
Penetration Rate - 3.0-5.75 ft/hr
Delay Time - N/A
Temporary Support - Selectively located, 3/4 in. diameter, 6 ft long, mechanically - anchored rock bolts. Two bolts per 4 ft; 6 bolts total

TABLE 7.4-6

ROCK CORE PROPERTIES
FRESH & ALTERED QUARTZ DIORITE
TERROR LAKE TUNNEL

Rock Type	Sample No.	Testing[1] Agency	Unit Weight (lb/cu ft)	Unconfined Compressive Strength (psi)	Total Hardness	Average[5] Penetration Rate(ft/hr)	Distance Penetrated (ft)	Splitting Tensile Strength (psi)	Point Load (psi)	Shore Hardness	Chercher[3] Abrasivity	Abrasion Hardness
Altered Quartz	A Station 242+71	S	No Test	No Test	106.59	No Data	-	-	-	43.3	-	6.06
Diorite Test	B Station 242+71	S	162.22	22,809.1[4]	No Test	No Data	-	-	-	No Test	-	No
Fresh Quartz Diorite	A Station 241+59	S	165.98	22,598.3[4]	106.4	7.1	35	-	-	85.26	-	6.51
	B Station 241+59	S	164.98	22,008.8[4]	119.31	7.1	35	-	-	88.69	-	6.64
	C Station 241+59	S	166.11	23,178.4[4]	121	7.1	35	-	-	83.04	-	7.25
Altered Quartz Diorite	SR-1 Station 224+64	S	No Test	No Test	74.82	14.2	57	-	-	84.8	-	6.17
Fresh Quartz Diorite	Hr-1 Station 239+30	S	165.2	26,055	123.05	8.4	42	-	-	94.6	-	7.94
	HR-2S Station 239+30	S	165.1	22,682	133.27	8.4	42	-	-	91.7	-	7.52

(1) S - A. J. Hendron for SWEC
C - U. S. Army Corps of Engineers
J - Atlas Copco Jarva, Inc.
R - The Robbins Co.

(2) From Dam Area

(3) 0 = Least, G = Most Abrasive

(4) Not Corrected for L/D 2

(5) Average Shift Penetration Rate, Includes Machine Down Time

TABLE 7.4-7

TUNNELING CONDITIONS
FAULT & FRACTURE ZONES, PORTAL

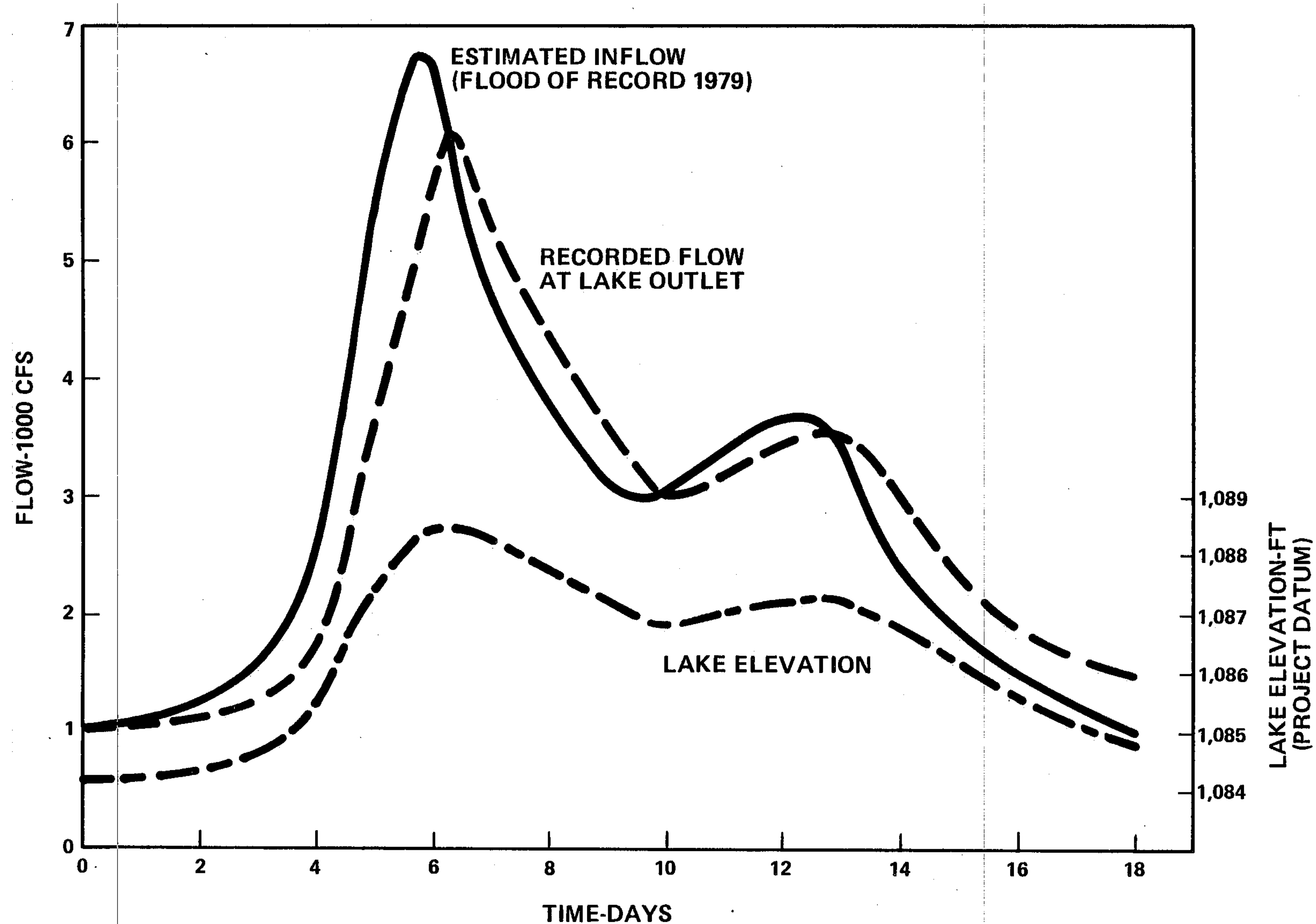
Rock Type and/or Conditions	Length (ft)	Penetration Rate (ft/hr)	Hardness	Delay Time (days)	Temporary Support	Remarks
Fault Zones						
Bull Moose	100	N/A	N/A	5	2/3 Sets, WF 4x13	Probably primarily fractured, cherty, foliated argillite. Re-steel - #8 @ 12 in. each way.
Bradley River	250	N/A	N/A	12	2/3 Sets, WF 4x13	
Fracture Zones						
Lineaments	200	N/A	N/A	10	2/3 Sets, WF 4x13	
Random	200	N/A	N/A	10	2/3 Sets, WF 4x13	
Gouge/Breccia						
Bull Moose	15	N/A	N/A	2	Full circle sets, WF 5x19	Breccia w/Gouge Matrix
Bradley River	30	N/A	N/A	5	Full circle sets, WF 5x19	Gouge
Random	15	N/A	N/A	2	Full circle sets, WF 5x19	Gouge
Portal, D/S	50	Drill & Blast	130	N/A	Full sets, WF 4x13	

TABLE 7.4-8

LIST OF THIN SECTIONS

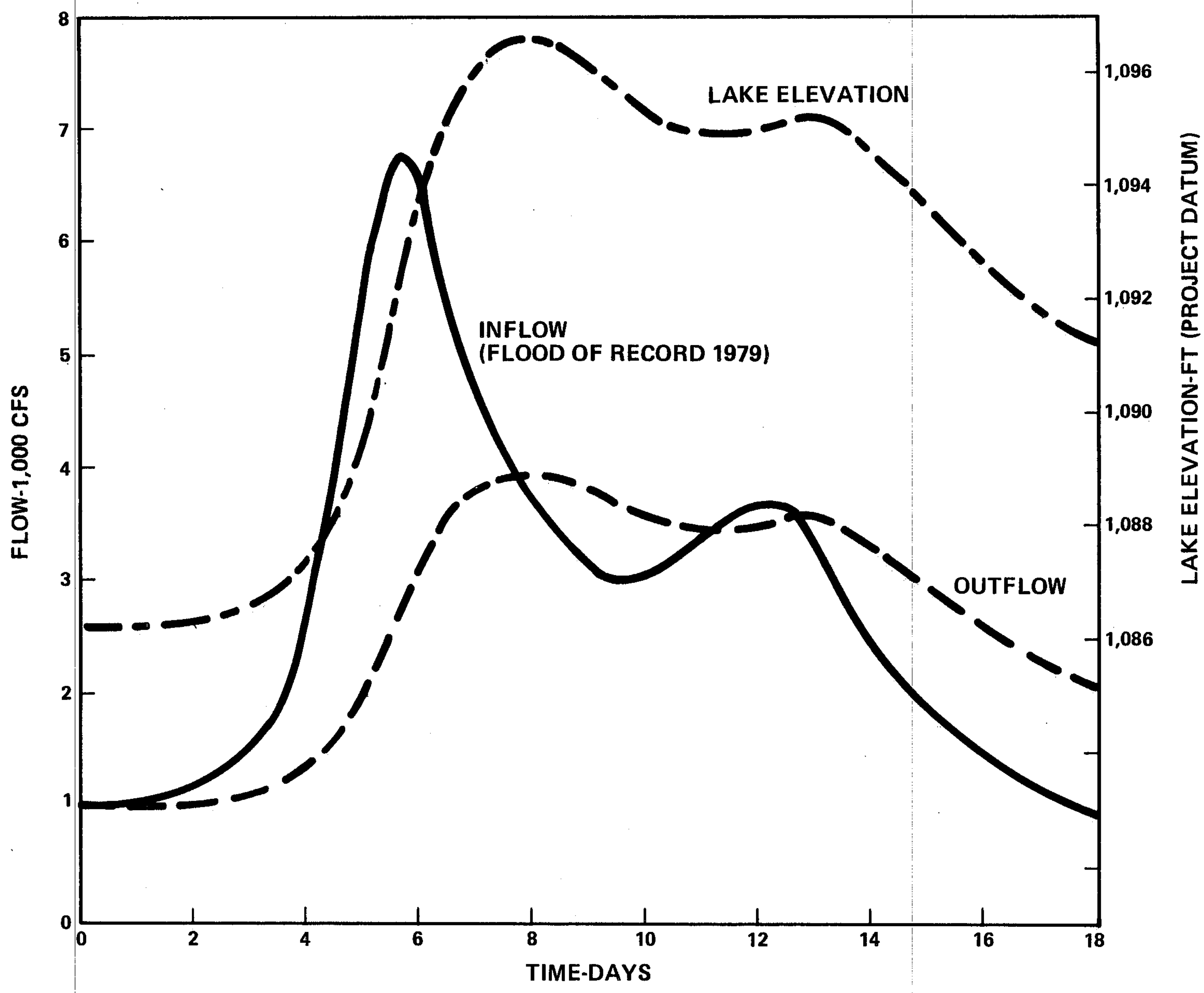
Section No.	Coordinates	Depth (ft)	Classification
S-1	N2,103,760 E343,580	11.9	Massive Argillite
S-1	N2,103,760 E343,580	18.4	Foliated Cherty Argillite
S-3	N2,111,580 E328,110	82.3	Foliated Cherty Argillite
S-4	N2,103,760 E343,580	38.0	Mixed Graywacke/Argillite
S-5	N2,103,760 E343,580	54.0	Graywacke
S-6A	N2,103,780 E342,760	17.3	Graywacke
S-6B	N2,103,780 E342,760	19.0	Graywacke
M-1	N2,106,720 E366,200	Surface	Foliated Cherty Argillite
M-2	N2,106,930 E366,200	Surface	Tuff
M-3	N2,108,770 E331,450	Surface	Graywacke
M-4	N2,109,420 E330,730	Surface	Chert
M-5	N2,111,800 E327,910	Surface	Dacite
M-6	N2,112,670 E328,110	Surface	Graywacke
CH-11	N2,109,720 E330,400	18.2	Chert
CH-11A	N2,109,720 E330,400	168.7-177.9	Foliated Argillite
CH-11I	N2,109,720 E330,400	168.7-177.9	Foliated Argillite
H-1	N2,111,580 E328,110	255.5	Massive Argillite
H-2	N2,112,090 E327,430	61.0	Massive Argillite
H-3	N2,111,580 E328,110	243.0	Massive Argillite
D-16I	N2,108,900 E331,350	Surface	Graywacke
D-36B	N2,101,461 E343,083	Surface	Dacite
D-37	N2,106,870 E335,650	Surface	Tuff
SR-1	Sta. 242+71 Terror Lake	Tunnel	Quartz Diorite
HR-7	Sta. 239+30 Terror Lake	Tunnel	Altered Quartz Diorite

TABLE 7.4-9



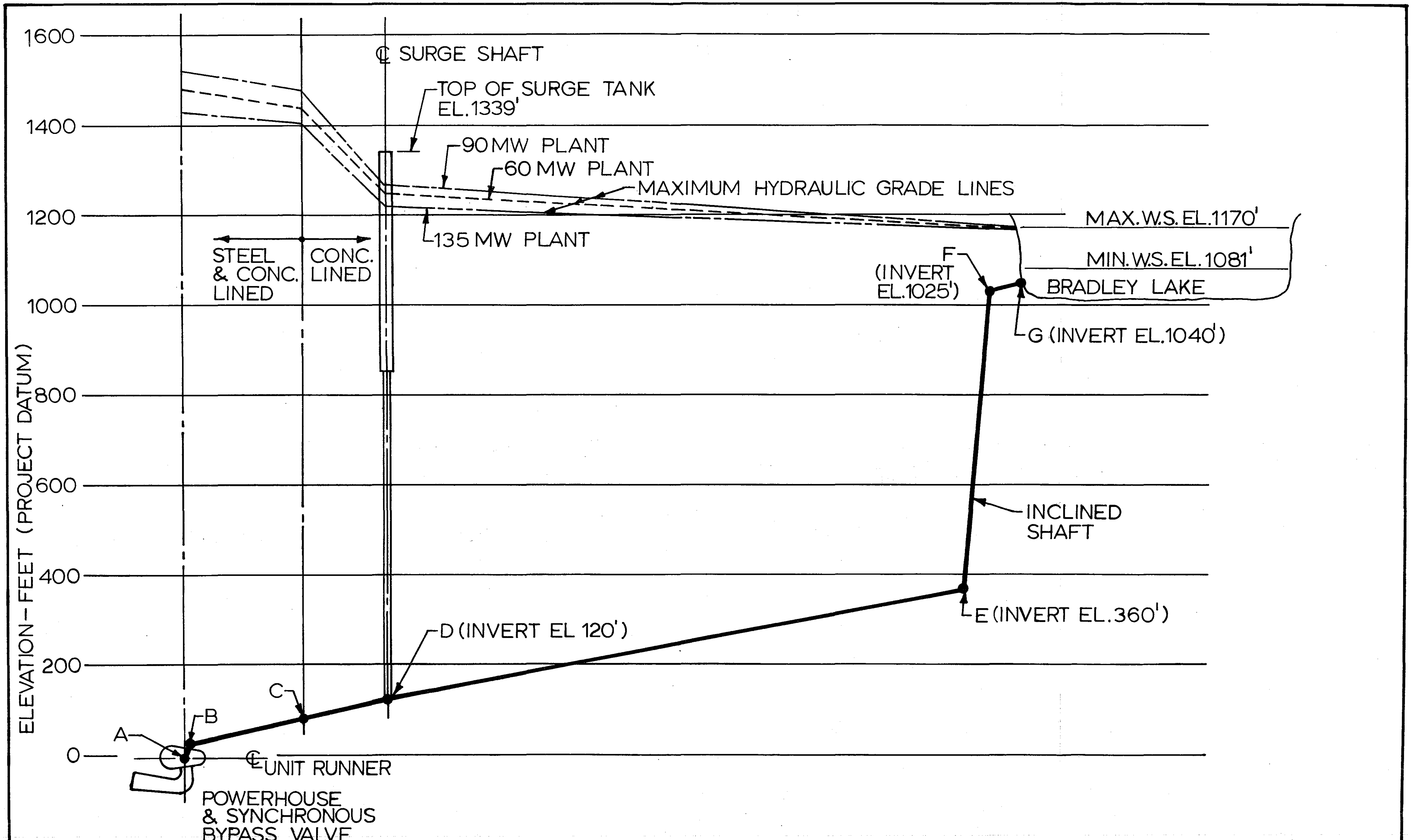
1979 INFLOW–OUTFLOW HYDROGRAPHS

FIGURE 7.3–1



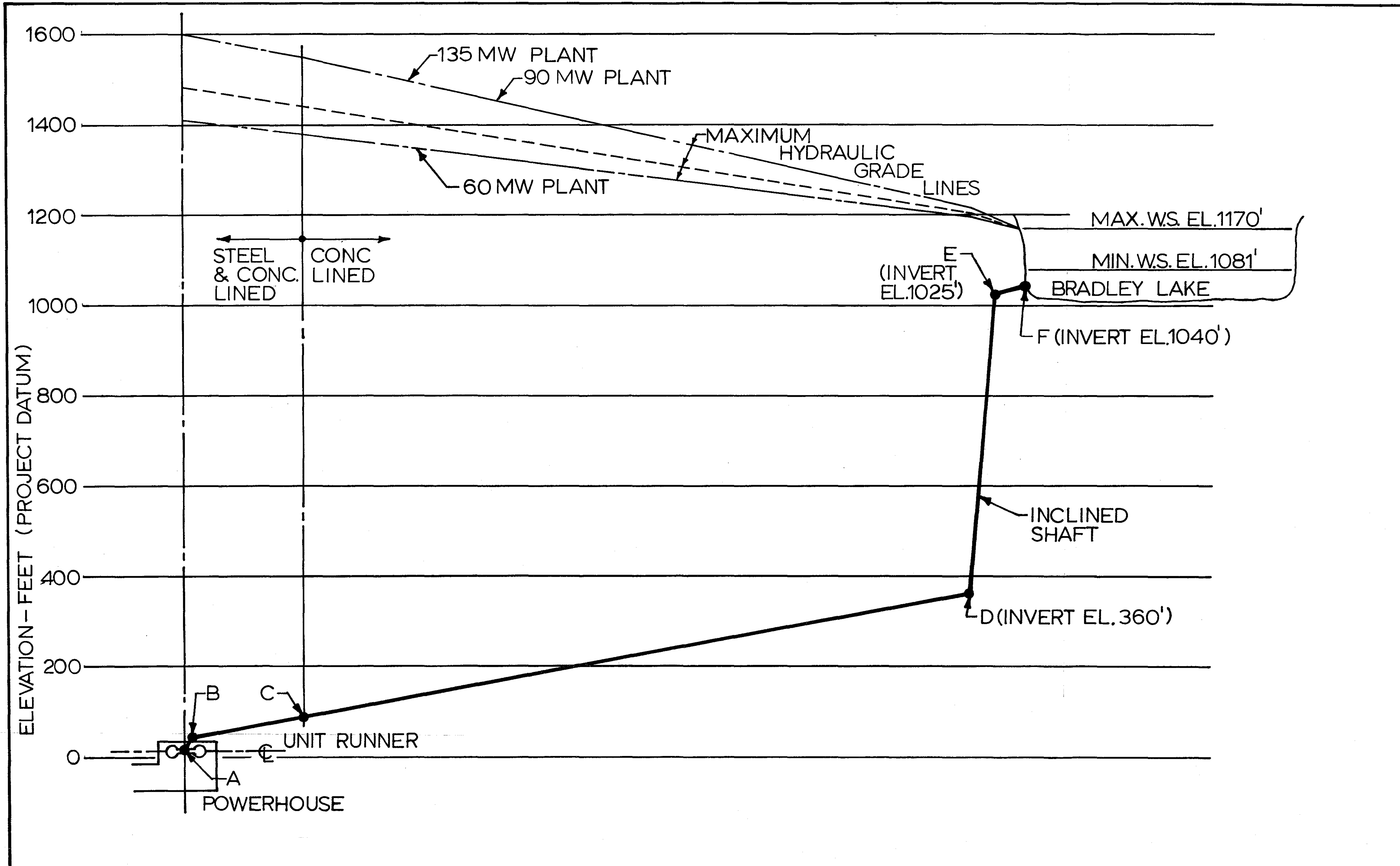
DIVERSION TUNNEL FLOOD ROUTING

FIGURE 7.3–2



HYDRAULIC TRANSIENTS
FRANCIS UNITS

FIGURE 7.4-1



HYDRAULIC TRANSIENTS
PELTON UNITS

FIGURE 7.4-2

Project: BRADLEY LAKE HYDROELECTRIC PROJECT

Location: KENAI PENINSULA, AK (APPROX. N59°46', W150°15')

Coordinates: N2,108,900 E331,350

Specimen No.: D-16I

Description of Sampling Point: OUTCROP

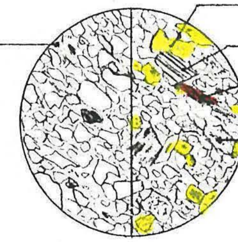
Thin Section No. D-16I Date: 9/12/83

GEOLOGIC DESCRIPTION

Rock Name: GREYWACKE

Petrographic Classification: SERICITIZED, QUARTZOFELDSPATHIC, VERY FINE GRAINED, PROTOMYLONITIC, GREYWACKE

Geologic Formation: "McHUGH COMPLEX"



Sketch ☒ Photomicrograph ☐

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: VERY SLIGHT TO SLIGHT

Structure: MASSIVE

Discontinuities: WIDE TO VERY WIDE JOINT SPACING

QUALITATIVE DESCRIPTION

Texture: CLASTIC, GRAINS & MATRIX MODIFIED BY SERICITE ALTERATION ACTING AS CEMENT; SLIGHT DEVELOPMENT OF AN ORIENTED FABRIC OF CATACLASTIC ORIGIN

Fracturing: NONE

Alteration: SERICITIZATION OF FELDSPARS IS COMMON, VERY MINOR CHLORITIZATION

Matrix: PRIMARILY CLAY-SIZE MATERIAL OF TOO SMALL A SIZE TO ALLOW OPTICAL IDENTIFICATION.

MINERAL COMPOSITION (VISUAL ESTIMATE)

Major	%	Minor	%	Acces.	%
QUARTZ	20	CHLORITE	2	MUSCOVITE	<1
PLAGIOCLASE	30	CLAY-SIZE	5		
SERICITE	30	K-FELDSPAR	13		

RESULTS OF ROCK PROPERTY TESTS

NONE MADE

SIGNIFICANCE TO ROCK ENGINEERING

CATACLASTIC FABRIC IS INSUFFICIENTLY DEVELOPED TO SIGNIFICANTLY INFLUENCE BEHAVIOR UNDER LOAD. SERICITIZATION HAS SOMEWHAT WEAKENED THE ROCK IN COMPARISON TO AN UNALTERED PARENT ROCK.

Grain Size/Distribution mm	%
0.2 - 0.0625	70
0.0625 - 0.0039	25
<0.0039	5

GENERAL REMARKS: NONE

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-3

Project: BRADLEY LAKE HYDROELECTRIC PROJECT

Location: KENAI PENINSULA, AK (APPROX. N59°46'W 150°50')

Coordinates: N2103770, E342760

Specimen No.: S-1-1

Description of Sampling Point: DH 35 (USACE), APPROX. DEPTH - 11.2 ft. (DAM AREA, LEFT SIDE)

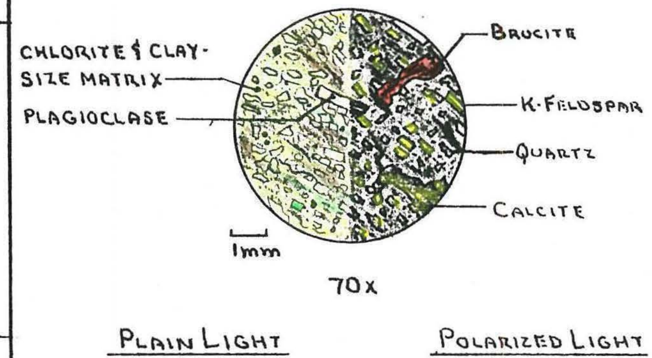
Thin Section No. S-1-1 Date: 9/1/83

GEOLOGIC DESCRIPTION

Rock Name: MASSIVE ARGILLITE

Petrographic Classification: CHLORITIZED, SILTY, QUARTZ ARGILLITE

Geologic Formation: "McHUGH COMPLEX"



Sketch ☒ Photomicrograph ☐

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: FRESH TO VERY SLIGHT

Structure: MASSIVE

Discontinuities: OCCASIONAL, IRREGULAR, CALCITE-FILLED FRACTURES UP TO 1.0mm WIDE; JOINTING - WIDELY TO VERY WIDELY SPACED.

RESULTS OF ROCK PROPERTY TESTS

UNIT WEIGHT - 171 lb/ft^3

q_u - 8266 psi

H_R - 38.6

H_A - 2.16

SHORE HARDNESS - 53.2

H_T - 56.7

LONGITUDINAL WAVE VELOCITY @ 2000 psi AXIAL LOAD - 17,743 ft/sec

GENERAL REMARKS:

QUALITATIVE DESCRIPTION

Texture: CLASTIC - GRAIN/MATRIX/CEMENT. VERY SLIGHT CATACLASTIC ORIENTATION OF SILT-SIZE PARTICLES

Fracturing: IRREGULAR ("WAVEY"), CALCITE-BRUCITE FILLED; UP TO 1mm WIDE. HEALED.

Alteration: MODERATE ALTERATION OF MICAS AND CLAY MINERALS TO CHLORITE.

Matrix: VERY FINE SILT AND CLAY-SIZE PARTICLES WITH CHLORITE. MINOR AMOUNTS OF CARBONACEOUS MATERIAL AND/OR GRAPHITE ARE PROBABLY INCLUDED.

MINERAL COMPOSITION (VISUAL ESTIMATE)

Major	%	Minor	%	Acces.	%
QUARTZ	50	K-FELDSPAR	10	BRUCITE (?)	5
CHLORITE	15	PLAGIOCLASE	2	CALCITE	3
CLAY-SIZE*	15			MAGNETITE (?)	<1

SIGNIFICANCE TO ROCK ENGINEERING

SLIGHT ANISOTROPIC BEHAVIOR UNDER LOAD IS PROBABLE. SHOULD YIELD GENERALLY EQUI-DIMENSIONAL PARTICLES WHEN BLASTED OR CRUSHED

Grain Size/Distribution

mm	%
>0.1	5
0.1-0.05	5
0.05-0.005	75
<0.005	15

* SEE "MATRIX" SECTION

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-4

Project: Bradley Lake Hydroelectric Project

Location: Kenai Peninsula, AK (Approx. N59°46', W150°50')

Coordinates: N2,109,720 E330,400 (Approx.)

Specimen No.: CH-11A

Description of Sampling Point: Core from Boring DH-11, 168.7-177.9 ft. depth interval

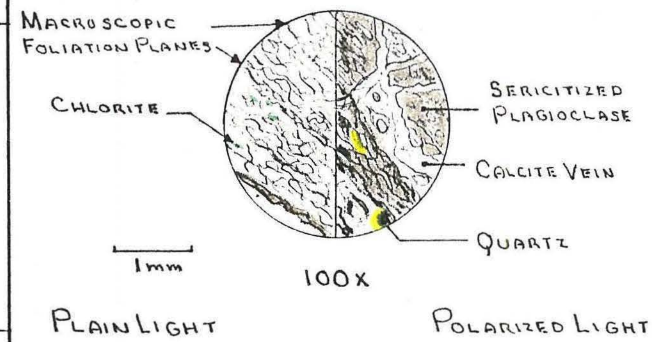
Thin Section No. CH-11A Date: 9/14/83

GEOLOGIC DESCRIPTION

Rock Name: Foliated Argillite

Petrographic Classification: Sericitized, Silty Argillite Protomylonite

Geologic Formation: "McHugh Complex"



Sketch ☒ Photomicrograph ☐

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: Fresh

Structure: Distinctly foliated @ a dip of 80° ±

Discontinuities: Randomly-oriented, calcite-filled fractures up to 1mm thick.

QUALITATIVE DESCRIPTION

Texture: Clastic-protomylonitic cataclastic fabric strongly developed.

Fracturing: Numerous microscopic fractures < 0.01mm wide oriented generally in the direction of the cataclastic fabric and spaced 0.1-0.5 mm. Occasional swarms of "braided" fractures spaced 0.001± mm primary cohesion usually maintained.

Alteration: Considerable sericitization of feldspars; slight to very slight chloritization; possibly some kaolinitization

Matrix: Primarily clay-size particles too small to be identified. Some graphite and/or other carbonaceous material is probably present

MINERAL COMPOSITION (Visual Estimate)

Major	%	Minor	%	Acces.	%
Plagioclase	35	Chlorite	2	Pyrite	<1
Sericite	20	Quartz	15		
Clay-Size*	20	Calcite	3		
		K-Feldspar?	5		

RESULTS OF ROCK PROPERTY TESTS

Unit Weight - 168 lb/ft³

q_u - 6661 psi

H_R - 55.1

H_A - 2.82

Shore Hardness - 86.3

H_T - 92.53

Longitudinal Wave Velocity @ 2000psi Axial Load - 18,913 ft/s

SIGNIFICANCE TO ROCK ENGINEERING

Should exhibit strongly anisotropic deformation behavior under load. Strength parallel to foliation should be significantly less than that normal to the "grain". Resistance to weathering may be noticeably less than other rock types at the site.

Grain Size/Distribution mm	%
0.1-0.0625	10
0.0625-0.004	70
<0.004	20

*See "Matrix" section

GENERAL REMARKS: Rock is noticeably susceptible to weathering where seen at the surface.

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-5

Project: BRADLEY LAKE HYDROELECTRIC PROJECT

Location: KENAI PENINSULA, AK (APPROX. N59°46' W150°50')

Coordinates: N 2,111,700 E 328,520 (APPROX.)

Specimen No.: S-3

Description of Sampling Point: BORING DH-13 @ APPROX. 82.3+ ft. DEPTH

Thin Section No. S-3 Date: 9/15/83

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: FRESH

Structure: WELL-DEVELOPED FLUXION STRUCTURE DIPPING @ 60°±; PORPHYROCLASTS OF CHERT UP TO 10mm x 5cm IN AN ARGILLITE MATRIX

Discontinuities: JOINTING VERY CLOSE ALONG FLUXION/FOLIATION BANDING; WIDE TO VERY WIDE @ OTHER ORIENTATIONS; OCCASIONAL CALCITE FILLINGS

RESULTS OF ROCK PROPERTY TESTS

UNIT WEIGHT - 165 lb/ft³

q_u - 4,204 psi

H_R - 30.7

H_A - 4.8

SHORE HARDNESS - 69.6

H_T - 67.28

LONGITUDINAL WAVE VELOCITY @ 2000 psi AXIAL LOAD - 16,759 ft/sec

GENERAL REMARKS: FEATURES INDICATIVE OF SEVERAL EPISODES OF DEFORMATION.

GEOLOGIC DESCRIPTION

Rock Name: CHERTY, FOLIATED ARGILLITE

Petrographic Classification: GRAPHITIC, CHERTY, PROTOMYLONITIC ARGILLITE

Geologic Formation: "McHUGH COMPLEX"

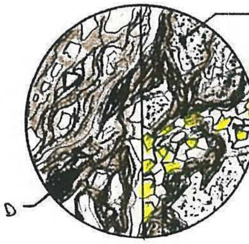
QUALITATIVE DESCRIPTION

Texture: CLASTIC-PROTOMYLONITIC; INTERNAL TEXTURE OF CHERT PORPHYROCLASTS IS ALLOTRIOBLASTIC-GRANULAR AT THE MICRO- TO CRYPTO-CRYSTALLINE SIZE LEVEL. RECRYSTALLIZED HYPIDIOMORPHIC-GRANULAR QUARTZ IS PRESENT.

Fracturing: MICRO-FRACTURES ARE COMMON, USUALLY ALONG THE FABRIC OF THE ARGILLITE MATRIX; LESS COMMON ARE RANDOMLY-ORIENTED FRACTURES WITHIN CHERT PORPHYROCLASTS. MOST FRACTURES SHOW SOME DEGREE OF HEALING.

Alteration: NONE VISIBLE. IT IS PROBABLE THAT SOME CONSTITUENTS OF THE MATRIX MATERIALS HAVE BEEN ALTERED BUT THIS IS MASKED BY THE HIGH PERCENTAGE OF GRAPHITE IN THE MATRIX (SEE BELOW). MINOR SERICITE AFTER FELDSPAR (?).

Matrix: CLAY SIZE PARTICLES TOO SMALL FOR VISUAL IDENTIFICATION. IT IS ESTIMATED THAT AT LEAST 60% OF THIS MATERIAL IS GRAPHITE/CARBONACEOUS MATERIAL.



PLAIN LIGHT POLARIZED LIGHT

Sketch ☒ Photomicrograph ☐

MINERAL COMPOSITION (VISUAL ESTIMATE)

Major	%	Minor	%	Acces.	%
CHERT	55	QUARTZ	7	CALCITE	1
CLAY-SIZE*	35			SERICITE	2

SIGNIFICANCE TO ROCK ENGINEERING

	Grain Size/Distribution	mm	%
PROBABLE STRONG ANISOTROPIC BEHAVIOR UNDER LOAD. CHERT IS IN SUFFICIENTLY SMALL PORPHYROCLASTS AS TO HAVE LITTLE OR NO EFFECT ON EXCAVATION TECHNIQUE. ULTIMATE STRENGTH SHOULD BE DETERMINED BY MATRIX MATERIAL PROPERTIES.	CHERT PORPHYROCLASTS	500x15-50x5	30
		5 - 2	15
		2 - 1	7
		<1	3
	SILT-CLAY MATRIX	<0.0625	35
	OTHER	<0.2	10

*SEE "MATRIX" SECTION

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-6

Project: BRADLEY LAKE HYDROELECTRIC PROJECT

Location: KENAI PENINSULA, AK (APPROX. N59°46', W150°50')

Coordinates: N106870, E335650 (APPROX.)

Specimen No.: D-37

Description of Sampling Point: OUTCROP, TUNDRA CONDITIONS

Thin Section No. D-37 Date: 8/31/83

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: SLIGHT TO NONE

Structure: MASSIVE

Discontinuities: WIDELY SPACED JOINTING

RESULTS OF ROCK PROPERTY TESTS

NONE MADE

GENERAL REMARKS:

GEOLOGIC DESCRIPTION

Rock Name: TUFF

Petrographic Classification: CHLORITIZED RHYOLITIC CRYSTAL TUFF

Geologic Formation: "McHUGH COMPLEX"

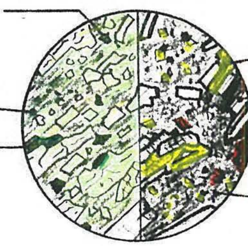
QUALITATIVE DESCRIPTION

Texture: PYROCLASTIC; PROBABLY DEPOSITED IN WATER

Fracturing: COMMONLY ABOUT 0.04mm WIDE, SPACED 1-2mm CHLORITE FILLED; COMMONLY SUB-PARALLEL

Alteration: SLIGHT KAOLINITIZATION OF FELDSPAR; EXTENSIVE CHLORITIZATION OF MICAS & CLAY-SIZE PARTICLES

Matrix: GENERALLY TOO FINE-GRAINED TO BE VISIBLE; WHERE VISIBLE - CHLORITE, FELDSPAR, AND QUARTZ



Sketch ☒ Photomicrograph ☐

MINERAL COMPOSITION - BY VISUAL ESTIMATE

Major	%	Minor	%	Acces.	%
FELDSPAR (SANADINE?)	40	HORNBLENDE	2	MAGNETITE?	4
		BIOTITE	4	CALCITE	<1
QUARTZ	20	CHLORITE	30		

SIGNIFICANCE TO ROCK ENGINEERING

ALTHOUGH THE ROCK IS MASSIVE, THE NUMEROUS CHLORITE-BONDED MICROFRACTURES PROBABLY SERVE TO LOWER THE OVERALL STRENGTH PROPERTIES. THE PRESENCE OF A PREFERRED ORIENTATION AMONG THE FRACTURES WILL PROBABLY BE REFLECTED IN ANISOTROPIC BEHAVIOR UNDER LOAD.

Grain Size/Distribution	%
0.5x2mm to 0.5x0.5mm	25
0.5mm to 0.1mm	15
<0.1mm	25
CLAY	35

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-7

Project: TERROR LAKE HYDROELECTRIC PROJECT

Location: KODIAK ISLAND, AK

Coordinates: STA. 239+30

Specimen No.: HR-1

Description of Sampling Point: TUNNEL

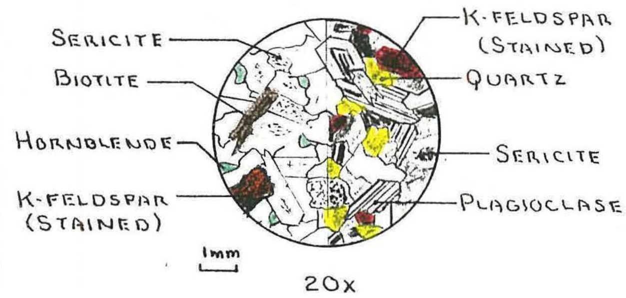
Thin Section No. HR-1 Date: 9/6/83

GEOLOGIC DESCRIPTION

Rock Name: QUARTZ DIORITE

Petrographic Classification: FINE-GRAINED, SLIGHTLY SECERITIZED, QUARTZ DIORITE

Geologic Formation: NOT KNOWN (A JURASSIC INTRUSIVE)



PLAIN LIGHT POLARIZED LIGHT

Sketch ☒ Photomicrograph ☐

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: FRESH

Structure: MASSIVE

Discontinuities: (EXAMINER HAS NOT SEEN ROCK IN OUTCROP)

QUALITATIVE DESCRIPTION

Texture: HYPIDIOMORPHIC - GRANULAR; MUCH OF THE PLAGIOCLASE EXHIBITS GROWTH ZONING.

Fracturing: NONE VISIBLE IN THIN SECTION (QUARTZ EXHIBITS WAVEY EXTINCTION INDICATIVE OF PAST OR PRESENT STRAIN)

Alteration: SLIGHT TO MODERATE SERICITIZATION OF PLAGIOCLASE

Matrix: NONE

MINERAL COMPOSITION (VISUAL ESTIMATE)

Major	%	Minor	%	Acces.	%
PLAGIOCLASE (SODIC)	45	K-FELDSPAR	5	HORNBLENDE	<1
				BIOTITE	10
QUARTZ	25			SERICITE	15

RESULTS OF ROCK PROPERTY TESTS

UNIT WEIGHT - 166, 165, 166.1 lb/ft³

q_u - 22,598.3; 22,008.8; 23,178.4 psi

H_R - 41.7, 46.3, 45.3

H_A - 6.51, 6.64, 7.25

SHORE HARDNESS - 85.26, 88.69, 83.04

H_T - 106.4, 119.31, 121.97

LONGITUDINAL WAVE VELOCITY @ 2000 psi AXIAL LOAD - 14,882; 14,798; 15,145 ft/sec

SIGNIFICANCE TO ROCK ENGINEERING

SIGNIFICANCE TO ROCK ENGINEERING	Grain Size/Distribution mm	%
SOUND ROCK. MAY BE UNDER STRESS AND/OR CONTAIN LOCKED-IN RELICT STRESS. MAY BE CONSIDERED SUBJECT TO SPALLING IF STRESSED TO A SUFFICIENTLY HIGH LEVEL.	2.0-1.0	25
	1.0-0.5	60
	<0.5	15

GENERAL REMARKS: STAINED FOR K-FELDSPAR; CALLED "HARD ROCK".

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-8

Project: TERROR LAKE HYDROELECTRIC PROJECT
Location: KODIAK ISLAND, AK
Coordinates: STA. 242+71
Specimen No.: SR-1
Description of Sampling Point: TUNNEL

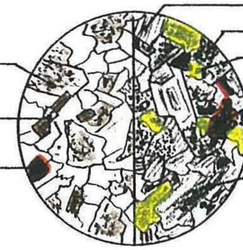
Thin Section No. SR-1 Date: 9/7/83

GEOLOGIC DESCRIPTION

Rock Name: QUARTZ DIORITE

Petrographic Classification: FINE GRAINED, SERICITIZED QUARTZ DIORITE

Geologic Formation: NOT KNOWN (A JURASSIC INTRUSIVE)



Sketch ☒ Photomicrograph ☐

MACROSCOPIC DESCRIPTION OF SAMPLE

Degree of Weathering: SLIGHT TO MODERATE; OCCASIONAL IRON OXIDE STAINING DISSEMINATED THROUGHOUT; POSSIBLE KAOLINITIZATION OF FELDSPAR (?)

Structure: MASSIVE

Discontinuities: JOINTING (VERY CLOSE) IN CORE SAMPLE. EXAMINER HAS NOT SEEN ROCK IN OUTCROP.

RESULTS OF ROCK PROPERTY TESTS

UNIT WEIGHT - 162.2 lb/ft^3

q_u - 22,809.1 psi

H_R - 43.3

H_A - 6.06

SHORE HARDNESS - 72.04

H_T - 106.59

LONGITUDINAL WAVE VELOCITY @ 2000 psi AXIAL LOAD - 14,000 ft/sec

GENERAL REMARKS: CALLED "SOFT ROCK". STAINED FOR K-FELDSPAR

QUALITATIVE DESCRIPTION

Texture: HYPIDIOMORPHIC-GRANULAR; PLAGIOCLASE COMMONLY EXHIBITS GROWTH ZONING

Fracturing: NONE VISIBLE IN THIN SECTION. (QUARTZ EXHIBITS WAVEY EXTINCTION INDICATIVE OF PAST OR PRESENT STRAIN.)

Alteration: MODERATELY EXTENSIVE SERICITIZATION OF PLAGIOCLASE ACCOMPANIED BY VERY MINOR KAOLINITIZATION.

Matrix: NONE

MINERAL COMPOSITION (VISUAL ESTIMATE)

Major	%	Minor	%	Acces.	%
PLAGIOCLASE (SODIC)	35	K-FELDSPAR	5	BIOTITE	10
				SERICITE	25
QUARTZ	25			LIMONITE	<1
				KAOLIN (?)	<1

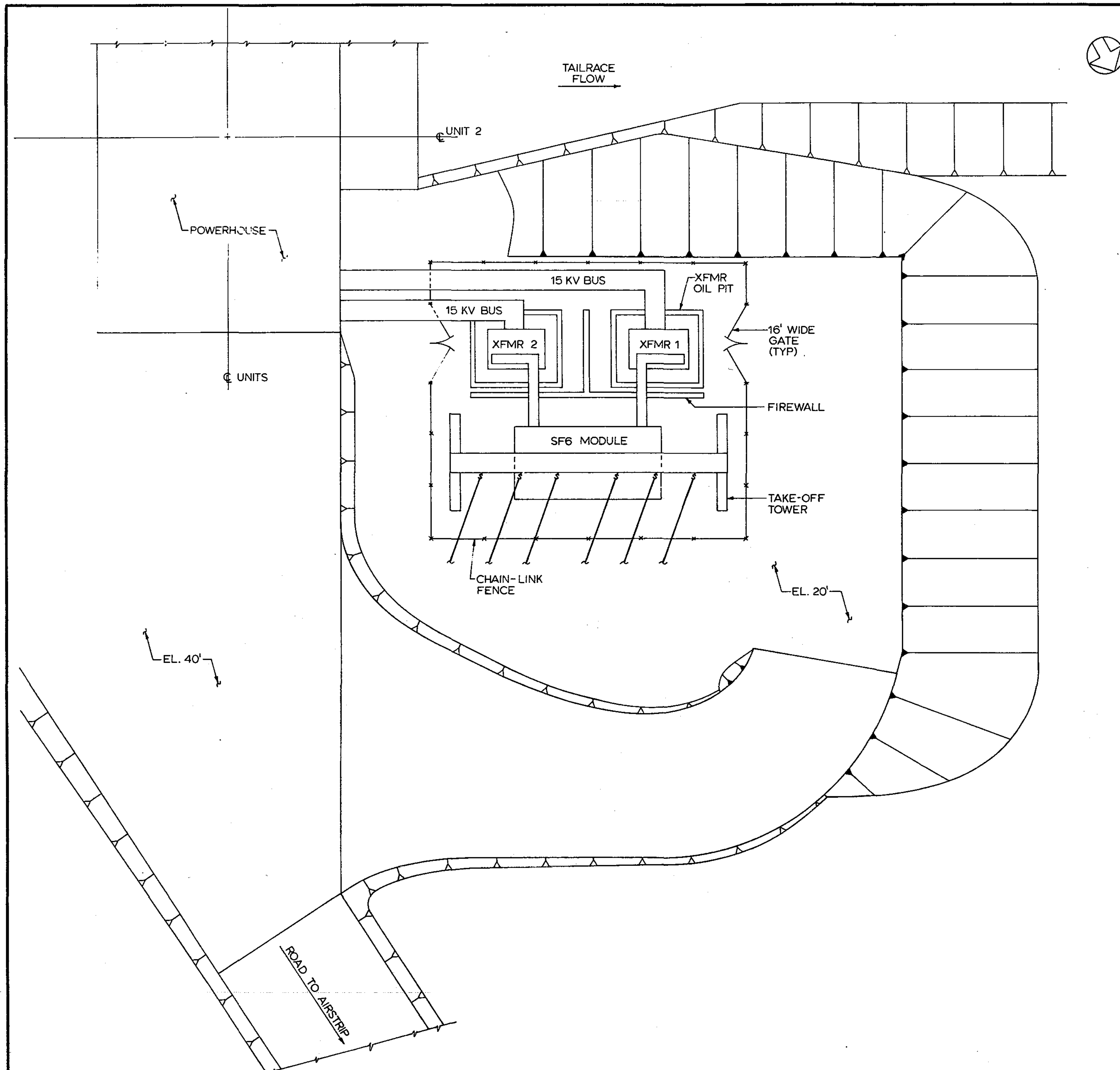
SIGNIFICANCE TO ROCK ENGINEERING

SERICITIZATION HAS WEAKED THIS SPECIMAN IN COMPARISON TO FRESH, UNALTERED PARENT MATERIAL (SAMPLE HR-1). SOME STRESS RELIEF HAS PROBABLY OCCURRED AS A RESULT OF WEATHERING AND ALTERATION.

Grain Size/Distribution mm	%
2.0-1.0	25
1.0-0.5	55
<0.5	20

REPORT OF PETROGRAPHIC EXAMINATION

FIGURE 7.4-9



PLOT PLAN - SF6 POWERHOUSE SUBSTATION

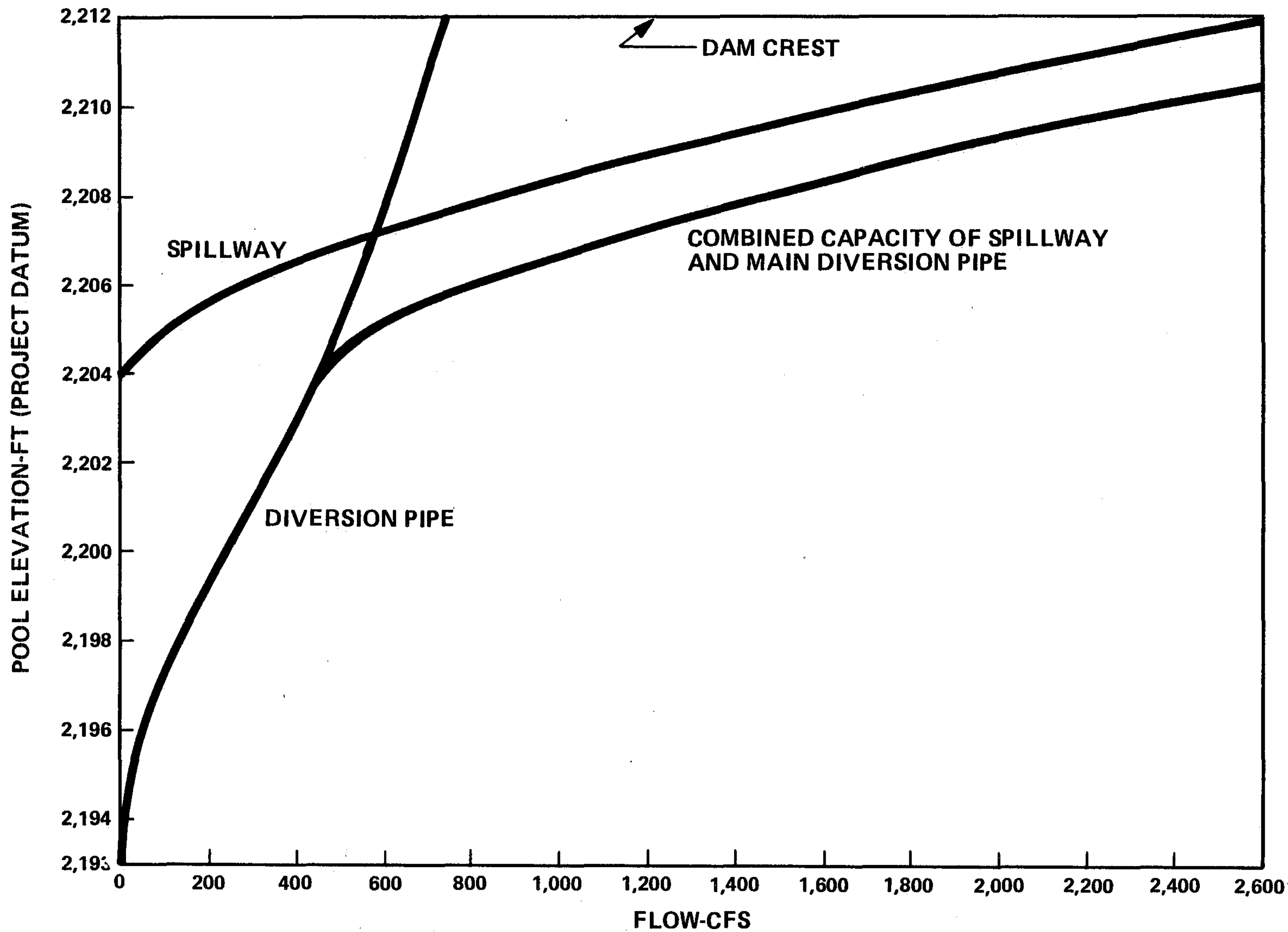
SCALE IN FEET 0 20' 40'

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

ALTERNATIVE

SF6 SUBSTATION

FIGURE 7.6-1



HYDRAULIC RATING CURVES
MIDDLE FORK DIVERSION

FIGURE 7.9-1

8

ENVIRONMENTAL ANALYSIS

8. ENVIRONMENTAL ANALYSIS

8.1 GENERAL

In considering the development of a major project, regardless of type, in a remote environment, it is impossible to present a plan that will not have some degree of impact. The impact severity depends on project type, magnitude, and location. It is therefore necessary to study and evaluate the long term benefits, as well as the impacts the project will have on the environment, the region, and its people.

The Bradley Lake hydroelectric project will provide benefits and serve the developing area of southcentral Alaska and more specifically the Kenai Peninsula. The project location, on the eastern slopes of Kachemak Bay, places the project in an area of remarkable peaks, glaciers, wildlife, and subalpine terrain which have a high aesthetic quality. The project area has a high wilderness quality with a high diversity of wildlife species, and is reasonably free from physical encroachment.

In studying the project, the COE conducted environmental studies and has identified the affects of project development on biological and socio/cultural resources. Involvement of concerned agencies and the people of the region allowed for communication, consultation, and exchanges of information on issues affecting the people, the environment and the project itself. These studies and communication programs have been the means and basis by which the COE prepared and issued a Final Environmental Impact Statement (FEIS) on August, 1982, responsive to the development of the COE's preferred Bradley Lake Hydroelectric project.

A review of the FEIS showed the following major areas of controversy and unresolved issues:

- o The volume and scheduling of mitigative flow releases from project storage necessary to protect aquatic habitat in the lower Bradley River.

- The resolution of access to the project area.

- The development of plans for mining gravels and for the rehabilitation of the Martin River borrow site.

- The development of a plan to establish waterfowl nesting and feeding habitat in the area of the dredge spoil site.

- Assessment of moose utilization of the area above Bradley Lake.

The preferred Bradley Lake development, as proposed by this report, is essentially similar to the preferred concept presented and addressed by the COE. However, under the present plan, concepts have been introduced that will result in lower impacts to the environment and studies have been initiated that will provide the information, as needed, for the resolution of the above issues.

8.2 MITIGATIVE STUDIES AND EVALUATIONS

8.2.1 Instream Flow Studies

Under the present scope, the Alaska Power Authority authorized the performance of an instream flow study with the purpose of assessing the Bradley River aquatic system to determine a flow regime which will support salmon spawning and rearing habitat. This study was performed in consideration of mitigative measures of project impact to the Bradley River fishery habitats. In addition, the economic feasibility of the Bradley Lake project could be realistically evaluated, reflecting proposed flow releases. This study was performed by the firm of Woodward-Clyde Consultants (WCC). Details of the study and the findings are presented in Appendix E of this report.

The method used for the instream flow study was the incremental methodology developed by the U.S. Fish and Wildlife Service (USFWS) Instream Flow Group. In designing an appropriate study approach, it was necessary to address several issues before estimates of acceptable flow regimes could be prepared. Key among these issues was the need to know whether: (1) any mainstream spawning occurred in the river; (2) salt water intrusion under reduced flows would progress further upstream and potentially effect spawning and rearing habitat; and (3) stream channel characteristics would allow favorable fish spawning habitat under reduced flow. The study program and methodology was presented to an interagency group attended by state and federal resource agencies, the Alaska Power Authority, SWEC and WCC. The study addressed fishery resources of the Bradley River, slough and tributary habitat, mainstream habitat, and both the spawning and rearing attributes of the river system.

In determining the instream flow required to maintain salmon production in the lower Bradley River, the information gathered from incremental analysis of habitat was combined with: seasonal distribution and habitat utilization data for targeted species; streamflow estimates for natural and post-project conditions; and potential changes in salinity and water temperature regimes to determine a proposed flow regime, shown on Table 8.2-1. The salmon species considered in the study were pink, chum and coho. Habitat requirements vary with season of the year, fish species, and life history stage. The Bradley River presently provides limited habitat for these species, and many of these habitats will be lost under post-project operation. However, there is a high potential for utilization of replacement habitat that would become available if appropriate streamflows are provided, with indications of improving production in spawning areas of the Bradley River.

The flow regimes selected and shown on Table 8.2-1 provides effective spawning and rearing habitat which are in excess of natural conditions. The instream study showed that post-project operation should not result in material temperature variations. Similarly, the selection of appropriate seasonal flow releases considered the needs of juvenile fish and salmon embryos for incubation, passage for outmigration and passage to and from feeding areas.

8.2.2 Access to Project Site

Several means of access to the project site, other than those proposed by the preferred plans of both the COE and this report, have been studied and reviewed. In its FEIS, the COE identified an alternative access that requires extension of the East End road. This road runs northeast out of Homer through the hills above Kachemak Bay. To develop this road for project access would require extending the East End road northeastward past Caribou Lake, across Fox River Valley, and along the foothills of the Kenai Mountains to join the project road. Although parts of this road could be made to parallel or be contained within the right-of-way of the presently proposed transmission line, the road alignment would cross the fresh water wetlands and impact moose habitat, eagle nesting areas, river otter habitat and approach important staging and nesting areas of migrating waterfowl and shorebirds. About 20 miles of new construction would be needed, along with adequate clearing for road construction and right-of-way. In addition, to the impacts within the Fox and Sheep River wetlands, further consideration of the East End road would require additional technical and environmental studies to fully assess impacts along its entire length and to formulate appropriate mitigation recommendations. It is concluded that both environmental and economic concerns resulting from the development of this alternate access way preclude its further consideration.

8.2.3 Martin River Borrow Site

The Martin River area is considered the most economically and environmentally acceptable area for borrow of gravel and other similar materials needed for project construction. The preferred plan described by this report reduces the quantities of material that would be borrowed from the Martin River gravelled delta area in comparison to previously suggested plans. Borrow material from this site have been identified for the following project construction needs:

PROJECT ROADS	Borrow Quantity (cubic yards)
Airstrip to Powerhouse	
Embankment	1,500
Gravel Surfacing	1,000
Powerhouse to Lower Camp	
Embankment	215,000
Gravel Surfacing	12,900
Rip rap (from excavation of lower-to-upper camp road)	0
Lower-to-Upper Camp	
Embankment	0
Gravel Surfacing	8,500
Upper Camp to Dam	
Embankment	0
Gravel Surfacing	6,900
Martin River Access	
Embankment	25,000
Gravel Surfacing	0
BARGE BASIN-DOCK CONSTRUCTION	
Embankment	55,000
Slope Protection (from excavation of lower-to-upper camp road)	0
LOWER CAMP SITE AREA	
Embankment	150,000
AIRSTRIP	
Embankment (less material from tunnel excavation)	156,000
POWERHOUSE & SUBSTATION CONCRETE	
Gravel and Sand	6,000
POWER CONDUIT & WATERWAYS CONCRETE	
Gravel and Sand	41,000
DAM AREA & SPILLWAY CONCRETE	
Gravel and Sand	25,000
TOTAL ESTIMATED NEEDS FOR BORROW	703,800

The above total quantity represents a reduction of about 333,000 cubic yards of material, when compared to the quantities for similar construction items of the preferred plan previously studied by the COE.

The areas that would need to be excavated to provide the total quantity of embankment material, gravel, and sand material would greatly depend on the depth of excavation that can be developed within acceptable environmental limits. For example, a 10 foot deep excavation would require about 55 acres assuming a 20 percent allowance for waste and bulking. The concepts for developing the borrow area will be prepared during the FERC License Application effort of the project and will consider both environmental aspects as well as availability and location of material sources.

An acceptable development plan for this site, which is currently being evaluated, will review the possibility of excavating for borrow with a work area of irregular forms and shapes, and with depths of excavation varying from 6 to 15 feet. Small causeways, from where excavating and trucking equipment can operate, would be incorporated in the plan. Contouring during development and after construction would also be considered to ensure the area would minimize fish and wildlife habitat impacts. The plan would be submitted to resource agencies for input and comment prior to its incorporation in construction documents for the project.

8.2.4 Waterfowl Nesting

Under the present concepts of project development, it is planned to spoil material excavated from the barge basin and its access channel in an area that will be enclosed by the powerhouse to camp access road embankment and the shoreland. The area identified for spoil is about 40 acres and is located east of Sheep Point. About 464,000 cubic yards of material would have to be dredged and spoiled. Disposal of these materials would be accomplished by pumping the dredged material into large compartmentalized areas. Present data on the slurry material indicates that about 18 hours of retention will be needed within these diked areas to allow for settlement of clayey silt soils. Although definitive plans for the disposal-dike area have not been determined, it is proposed that upon completion of disposal, the ground surface of the spoil area be graded to raise portions of the fill surface to above mean higher high water elevation, to provide surface drainage and ponds. The plans for developing waterfowl habitat would be prepared during the FERC License Application effort in consultation with agency personnel, before incorporating into construction contracts.

8.2.5 Moose Migration

Previous environmental evaluations have identified that moose use the upper flatlands of Bradley Lake as a migratory corridor to reach wintering habitat near Nuka Bay on the east coast of the Kenai Peninsula. In order to obtain a better understanding of moose migratory and dispersal patterns, the Power Authority has authorized a fall-winter 1983 study to observe moose movements across the upper reaches of Bradley Lake. This study would record the moose pattern and characteristics of moose migration from the Kachemak Bay area, across the upper end of Bradley Lake and over to the Nuka River Valley crossing area. The results from this study will be used as input for formulating mitigative measures regarding moose.

8.3 IMPACT ADJUSTMENTS

8.3.1 Elimination of Alternative Structures

The preferred plan presented in this report incorporates several modifications that either eliminate or minimize environmental impacts resulting from project development.

Environmental impacts to the project have been reduced with the elimination of:

- The 2,800 feet long exposed penstock from the powerhouse to the tunnel portal.

- A 2-mile access road from the powerhouse to the power tunnel portal.

- The access road that would have been required for the development of the surge shaft and the surge shaft construction itself.

- The exposed steel penstock and bridge, and its associated access road, needed for the power tunnel Bradley River crossing, about one half a mile downstream of the dam.

The above modifications have eliminated wildlife, terrestrial and visual impacts that would have resulted had these structures been included in the preferred plan. It is estimated that about 26 acres of timber resources, consisting of mature conifer and mixed conifer-deciduous forest will be saved by the elimination of the penstock and access road clearing. Similarly, the visual aesthetics of the mountain slope will remain intact.

The elimination of the exposed steel penstock and bridge and its associated construction work will reduce the impact to the mountain goat wintering area and movement corridor.

8.3.2 Additional Project Features

One of the requirements of the present feasibility study was to review previous transmission line routes and to identify alternative routes that may be considered technically acceptable and which have a reduced environmental impact and may be more acceptable to the people of the region. In selecting alternative routes, a review was made of the FEIS to ascertain the concerns and impacts associated with transmission alignments previously proposed by the COE. The impacts identified were:

- Encroachment on privately owned lands
- Encroachment on nesting and staging areas for migratory birds

Two field trips, a brief review of land ownership and preliminary soil probes along considered routes resulted in the corridor alignment presented by this report. The proposed corridor has not been presented to any agencies, or the public. Although portions of the corridor are in the same alignment as the transmission routes studied by the COE, it will be necessary to better assess the environmental effects of this new alignment. The first section of the proposed corridor, from the powerhouse to the Fox River and Sheep Creek deltas, is approximately 6 miles long and transverses the heavily forested area along the slopes of the Kenai Mountains. The second section, across the Fox River delta at the head of Kachemak Bay, is approximately 3 miles long and is over open terrain. Toward the northwest, the third section traverses a flat plain for about 10 miles from the delta to the tie with the Homer Electric Association transmission line. Although a 1600 feet wide corridor is offered for flexibility of line alignment, the two circuit parallel lines will actually require a right-of-way width of 225 feet plus an additional 50 feet on either side for selective cutting of trees to prevent high tree fall from interfering with the line. Only the tallest danger trees will be selectively cut in this additional width beyond the clear cut right-of-way. An assessment of these impacts will be made during the FERC license preparation period.

An additional feature presented by this report, not previously identified, is the construction of a 210 bed campsite near the upper dam area of the project. Development of this campsite will require the preparation of about 3 acres of land that is found adjacent to an oblong lake, approximately 1.1 miles west of the proposed dam, near the recommended access road alignment. If developed, the camp will draw water from the lake for domestic use and fire protection. Specific utility requirements for this site have not been defined and additional baseline data are needed to ascertain and resolve such requirements, as well as, environmental impacts to the lake and the transportation corridor between the upper camp and the lower area facilities.

PROPOSED HABITAT MAINTENANCE FLOWS FOR PROJECT PLANNING PURPOSES

Month	Activity (life stage)	Recommended[1] Streamflow
October	Rearing	50
November	Incubation	40
December	Incubation	40
January	Incubation	40
February	Incubation	40
March	Incubation	40
April	Incubation/Outmigration	40/100
May	Outmigration	100
June	Rearing	100
July	Spawning	100
August	Spawning	100
September	Spawning/Rearing	100/50

(1) Instantaneous minimum flows to be provided at the USGS gage station at RM 5.1 on the lower Bradley River

TABLE 8.2-1

9

LAND AND LAND RIGHTS

9. LAND AND LAND RIGHTS

The majority of project lands were withdrawn for the purposes of the development of a hydroelectric project by Public Land Order 3953, dated March 15, 1966, and amended by Public Land Order 4056, dated July 18, 1966. The withdrawal included approximately 38,066 acres of Federally owned land. The project reservoir and structures will require approximately 4,300 acres. The remaining 33,766 acres will be used for watershed protection.

The Bradley Lake transmission line corridor extends from the powerhouse to the new transmission line to be built by Homer Electric Association between Fritz Creek and Soldotna. The corridor is approximately 20 miles long in three contiguous sections. The first section extends northeastward from the powerhouse to the Fox River and Sheep Creek delta and is approximately 6 miles long. The second section, 3 miles long, crosses the delta at the head of Kachemak Bay in a northwesterly direction. The third section traverses about 10 miles extending toward the west from the delta to the Bradley Junction and the tie with the Fritz Creek-Soldotna line. A preliminary corridor width of 2,000 feet has been identified within which the final alignment will be established. The right-of-way for the two parallel, wood pole, 115 kV lines will consist of a 225 to 325 feet wide corridor and will encompasses approximately 750 acres of land.

The borrow sources for construction materials are located in lands withdrawn for the project under Land Orders 3953 and 4056.

The project facilities are located within Federal, State, and private lands. The transmission line corridor crosses mostly Federal and State lands: the Fox River Flats Critical Habitat Area on the east side but does not enter the Kenai National Moose Range Expansion, withdrawn by Public Land Order 5653, dated November 16, 1978. It does cross six identified parcels of private land, however title and ownership for these private land were not investigated in this study.

An estimate of land acquisition cost is included in the Project Cost Estimate for private lands along the transmission line. Further investigation is required within the transmission line corridor to establish the required 325 feet wide right-of-way limits. This will be accomplished during preparation of the FERC License Application for the project.

10

PROJECT SCHEDULE AND CONSTRUCTION CONTRACTS

10. PROJECT SCHEDULE AND CONSTRUCTION CONTRACTS

10.1 GENERAL

The proposed project schedule is shown on Plate 23. The schedule has been developed to delineate the major construction and procurement contracts described below.

The project schedule extends over a five year period with the initiation of construction activities dependent upon the award of a FERC license for the project. Receipt of a FERC license is anticipated in May 1985 with commercial operation of the units scheduled during the Fall of 1988 and final project completion before the end of 1988. The critical path involves those activities related to FERC license Application processing; design, fabrication, and delivery of the tunnel boring machine; power tunnel excavation; inclined shaft excavation; concrete tunnel lining and steel liner embedment, penstock installation, and start up of the turbine generators.

Should award of the FERC license be delayed, seasonal scheduling problems will ensue, and the entire project schedule and commercial operation dates will be delayed.

10.2 ENGINEERING AND DESIGN

Engineering and design activities will commence upon submittal of the FERC license application in February 1984. The initial thrusts of these activities will be directed toward scoping and implementing various field surveys, and conducting detailed engineering studies and analyses. The results of these studies will then be utilized in developing design criteria for final design of the various civil features and developing performance standards and specifications for purchasing the major mechanical and electrical equipment.

Procurement of the turbine/generator equipment will be required at an early stage to provide data and information to support continuing work efforts on the powerhouse auxiliary equipment, and allow commencement of engineering and design of the powerhouse civil works and powerhouse crane.

Concurrently, engineering and design of the other major civil structures and facilities will occur during 1984 and extend into 1985. Other activities scheduled within this period will include FERC licensing support activities and preparation and submittal of the various Federal and State licenses and permits required prior to construction.

Environmental monitoring and agency consultation will continue as required throughout the entire schedule.

10.3 CONSTRUCTION SCHEDULE

With the exception of transmission line construction, the primary criteria utilized in developing the overall schedule was to schedule the various construction activities during the milder seasons.

Upon award of the General Civil Contract, the Contractor will mobilize, and design and fabrication of the Tunnel Boring Machine (TBM) will commence. This will be followed by construction of the lower access, staging and camp facilities, powerhouse excavation, and power tunnel portal excavation, all of which must be completed to accept delivery of and commence power tunnel excavation with the TBM.

Access from the barge basin and staging facilities to the reservoir area will be established in two phases. The initial phase will consist of developing a pioneer road along the final alignment utilizing work crews to develop initial headings at strategic points along the route. The initial headings will be extended until the route is completely opened, allowing access to begin construction of the diversion tunnel. The second phase, concurrent with diversion tunnel construction, will consist of roadway widening and other improvements and will be completed prior to the harsher winter months.

Construction of the cofferdams at the lake outlet will commence in March 1986, followed by construction of the main dam and excavation of the intake tunnel. Should work on the main dam be delayed during 1986, due to the early onset of inclement weather, it can be completed during 1987 since the dam is not on the critical path.

Excavation of the power tunnel using the TBM will continue through 1986 followed by excavation and lining of the inclined and intake gate shafts. Once excavation of the inclined shaft has been completed, installation of the concrete and steel lining for the power tunnel will commence from the inclined shaft and continue toward the tunnel portal.

The powerhouse construction contract award has been scheduled for October 1986 with construction extending over an 18 month period. Powerhouse excavation will be performed to accommodate simultaneous work activities on the powerhouse and power tunnel during this period.

Construction of the transmission facilities and switchyard are not critical to project completion since construction electrical power will be furnished by contractor supplied diesel generators. As such, these activities have been tentatively scheduled for the 1986-87 winter period.

10.4 CONTRACTS

It is unlikely that sufficient information will be available to permit the construction facilities, main dam, power conduit and powerhouse to be included within a single contract. Therefore, three major construction contracts are proposed, as well as one major equipment order and various miscellaneous supply orders. The facilities, material, and equipment encompassing each of the contracts and procurement orders are described below.

10.4.1 General Civil Contract

The General Civil Contract will include the construction of the barge basin, access roads, construction camps, warehouse, and staging area, powerhouse excavation, powerhouse laydown and staging area, airstrip, borrow pits, tunnel portal, power conduit, steel liner, construction diversion facilities, cofferdams, main dam, spillway, Middle For Diversion, and the permanent camp and warehouse facilities.

10.4.2 Powerhouse Contract

The Powerhouse Contract will include the construction of the powerhouse, installation of the generation equipment and auxiliary electrical and mechanical equipment and the penstock between the tunnel portal and powerhouse, powerhouse substation, and tailrace.

10.4.3 Transmission Line Contract

The Transmission Line contract will include the construction of two parallel 115 kV three phase lines to connect the Bradley Lake powerhouse substation with the new line to be built between Fritz Creek and Soldotna. The new Fritz Creek-Soldotna line will be in place and provision for the construction of a tap is included at Bradley Junction.

10.5 SUPPLY ORDERS

The major equipment order will include the design, manufacture, fabrication, and delivery of the generation equipment including two Pelton turbines, generators, governors, spherical valves, air depression system, and accessory mechanical and electrical equipment.

Miscellaneous supply orders will include:

- Electrical and Controls

    1. Generator Breakers
    2. Main Power Transformers
    3. Control and Relay Boards
    4. Supervisory Control and Data Acquisition Equipment

5. Station Batteries and Battery Chargers
6. 480V Load Centers
7. Motor Control Centers
8. Isolated Phase Bus and Enclosures, PT's and Surge Equipment
9. Plant Telephone and Paging System
10. Event Recorder
11. Diesel and Propane Driven Generators
12. Reservoir Water Level Recorders

- Mechanical and Building Service

1. Powerhouse Bridge Crane
2. Station and Unit Unwatering Pumps
3. Service Water Pumps
4. Transformer Oil Treatment System
5. Lube Oil Treatment System
6. Oil Separators
7. Dirty Water PUmps
8. Air compressors System and Driers
9. Service Water Strainers and Filters
10. Special Hazards Fire Protection Systems
11. CO_2 Detection System
12. Fire Pumps, Motors, and Accessories
13. HVAC Equipment

- Hydro-Civil and Power

1. Intake Gates, Guides and Operators
2. Intake Trash Racks and Bulkheads
3. Draft Tube Gate and Lifting Beam
4. Miscellaneous Large Gates and Valves
5. Construction Diversion Stop Logs

- Switchyard

1. Carrier Equipment

2. High Voltage Breakers
3. Disconnect Switches

- o Construction Support

1. Penstocks, Tunnel Liners, and Miscellaneous Large Pipe
2. Structural Steel and Crane Rails

11. PROJECT COST ESTIMATES

11.1 PROJECT COST ESTIMATE SUMMARY

In response to the requirements of the Alaska Power Authority and the needs of the feasibility study, a cost estimate has been prepared for the preferred 90 MW Bradley Lake project. The cost estimate is:

- Bid Price Cost $308,400,000
- Overnight Cost $283,019,000

A summary of the main stem accounts by FERC classification and other costs included are shown by Table 11.1-1. The summary is followed by the expenditure forecast of the overnight estimate, and the detailed estimate consisting of eleven pages.

The Cost Estimate includes the following:

- Direct material, labor, and construction equipment.
- Engineering and design.
- Construction management.
- Construction distributables.
- Contingency.
- All-risk insurance.
- Land and land rights.
- Based on the Project Construction Schedule in Section 10 of this Report.
- Bid price estimate assumes July 1983 construction start date, the Overnight Estimate assumes a present day of July 1983.
- Owner's cost; including general and administrative, legal, engineering, financing cost, etc.
- Escalation during the construction period only.

This estimate excludes the following:

- Escalation other than that during the construction period.
- Interest during construction.

The Overnight Estimate is the Bid Price Estimate modified by the amount of \$25,381,000, which reflects a credit for the escalation during the construction period. It is our understanding that the Alaska Power Authority will use the Bid Price Estimate, and adjust this accordingly, to develop the Nominal Cost Estimate for project financing studies and plans.

The estimates are based on conceptual level studies and drawings and a preliminary construction schedule. Representative data and budget costs received from major equipment manufacturers on items such as turbines, generators, bridge cranes and transformers were used in the cost estimates. Estimates of major quantities are developed from the conceptual level drawings and smaller items are prorated from costs for similar past projects. Material unit prices are from several sources such as existing purchase orders, contracts on current work, publications, budget prices from suppliers and other bona fide data. Labor manhour rates were developed from State of Alaska Department of Labor publications with appropriate adjustments as required. Contractor's equipment costs are included where applicable.

The economics of the Bradley Lake Hydroelectric Project is dominated by the cost of the power tunnel. Field and office investigations by SWEC engineers and the Consultants on the Technical Review Board conclude that a substantial portion of the power tunnel can be excavated using a tunnel boring machine (TBM) including crossing through the fault zones. The project cost estimate is therefore based on the contractor using a tunnel boring machine to excavate approximately 16,850 feet of the tunnel. The rates of progress for the TBM excavating the tunnel as used in the cost estimate were developed from on-site field examinations of the various rock types along the tunnel alignment, laboratory testing of rock samples of the rock to be excavated; and correlation with the progress rates being experienced on the Power Authority's Terror Lake Project. In addition, allowances are included in the estimate for full concrete lining of the entire length of tunnel. The cost estimate for the tunnel was reviewed by an expert in tunnel construction and construction costing.

The cost of engineering and design is based on SWEC's Bradley Lake Proposal and includes the cost of this Feasibility study.

The costs for the Construction Manager were made available to SWEC by the Power Authority as were Owner's cost. Owner's cost includes previous expenditures for studies on Bradley lake subsequent to its assumption by the Power Authority.

A contingency of 25 percent is applied to arrive at the Bid Price Estimate. Escalation is included at the rate of 6.3 percent annually for the three year construction period only, assuming a start of construction date of July, 1983.

11.2 COST ESTIMATES FOR ECONOMIC ANALYSIS

In determining a selected installation for development of the Bradley Lake Project, it was necessary to cost and evaluate 60 MW, 90 MW and 135 MW installations using both Francis and Pelton type hydraulic turbine units in the powerhouse, as well as a range of different dam heights for the upper reservoir. Cost estimates prepared for each of these installations were then used in the economic evaluation computer model which assessed the merits of Bradley Lake in a mix of alternative generating and transmission line scenarios. A summary of the Present Day Estimates (Overnight) selected for the scoping economic evaluation studies are given in Table 11.2-1. It should be noted that these estimates reflect costs for interest during construction less escalation (interest at discount rate). The inclusion of this cost item complies with the Alaska Power Authority Economic Evaluation Guidelines FY83. Having selected a preferred plan, a similar cost estimate was prepared and used in the final economic evaluation study reflecting the attributes of the preferred plan in the generation planning scenarios.

Plant Operating and Maintenance (O&M) costs were developed for the economic evaluation studies, as were O&M costs for the transmission line connecting the project to the proposed Homer Electric Association line. Further, construction costs were prepared for a 230 kV transmission line that would connect the Kenai Peninsula to the Anchorage area, as were O&M costs for this line. These cost data are shown on Tables 11.2-2 through 11.2-5.

FEASIBILITY STUDY COST ESTIMATE
90 MW PREFERRED PLAN

FERC ACCOUNT	DESCRIPTION	($ in 000's)
	Production Plant	
330	Land & Land Rights	2,783
331	Power Plant Structures	9,443
332	Reservoirs, Dams & Waterways	87,715
333	Turbines & Generators	16,829
334	Accessory Electrical Equipment	4,501
335	Misc Power Plant Equipment	4,411
336	Roads, Barge Facility & Airstrip	13,474
	TOTAL PRODUCTION PLANT	139,156
	Transmission Plant	
350	Land & Land Rights	11
352	Switchyard Structures	1,940
353	Switchyard Equipment	1,279
357	Transmission Line	7,599
	TOTAL TRANSMISSION PLANT	10,829
	Construction Distributables	
	Construction Camp	24,263
	Mobilization/Demobilization	10,476
	Other Construction Items	13,133
	Construction Management	14,243
	TOTAL CONSTRUCTION DISTRIBUTABLES	62,155
	TOTAL CONSTRUCTION COST	212,100
	Engineering & Design	28,500
	TOTAL CONSTRUCTION & ENGINEERING	240,600
	Owner's Cost	6,100
	TOTAL CONSTRUCTION & INDIRECTS	246,700
	Contingency	61,700
	BID PRICE ESTIMATE	308,400
	Escalation	(25,381)
	OVERNIGHT ESTIMATE*	283,019

*Present day as of July, 1983.

TABLE 11.1-1

EXPENDITURE FORECAST OF OVERNIGHT ESTIMATE
(PRESENT DAY 7/83)
BRADLEY LAKE PROJECT
ALASKA POWER AUTHORITY

Calendar Year	Dollars in Thousands
1983	2,200
1984	8,200
1985	65,990
1986	78,160
1987	83,080
1988	45,389
Total Overnight Estimate	283,019

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

CLIENT-ALASKA POWER AUTHORITY   STONE & WEBSTER ENGINEERING CORPORATION   DATE OF ESTIMATE 10/24/83   JO# 14500
BID PRICE DATE - JULY 1983   PG 1 OF11
PROJECT-BRADLEY LAKE HYDROELECTRIC PROJECT   ORDER OF MAGNITUDE ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
330	1000	1000	0	0	0	LAND & LAND RIGHTS	1	LS	0.00	0
330	3000	0	0	0	0	ENVIRONMENTAL MITIGATION	1	LS	2,226,000.00	2,226,000
330	5000	0	0	0	0	EXHIBIT R -RECREATION	1	LS	556,500.00	556,500
330						TOTAL LAND & LAND RIGHTS				2,782,500
331						POWER PLANT STRUCTURES & IMPROVEMENTS				
	1000	7100				POWER HOUSE				
	1100	7100	2	A	A	EXCAVATION-UPPER BENCH	1000	CY	14.54	14,537
	1110	7100	2	A	A	EXCAVATION-FIRST STAGE	53000	CY	14.54	770,466
	1120	7100	5	A	A	BACKFILL-SELECT TEMP.	1380	CY	6.57	9,070
	1130	7100	1	A	E	REMOVAL OF TEMP. FILL	1380	CY	5.41	7,470
	1200	7100	2	A	A	EXCAVATION-SECOND STAGE	13800	CY	24.23	334,353
	1201	7100	5	A	A	BACKFILL-COMMON	1180	CY	6.78	8,000
	1202	7100	7	A	A	ROCK BOLTS	120	EA	364.14	43,697
	1320	7100	10	A	E	SURFACE CLEANING	6900	SF	1.02	7,017
	1511	7100	11	A	E	CONCRETE	4600	CY	213.29	981,123
	1522	7100	15	A	E	FORMS-STRAIGHT	39200	SF	38.59	1,512,708
	1523	7100	16	A	E	FORMS-CURVED	4650	SF	54.24	252,216
	1524	7100	19	A	E	REINFORCING	278	TN	3,175.30	882,733
	1520	7100	14	A	E	SURFACE FINISH	16000	SF	1.02	16,272
	1530	7100	22	A	E	EMBEDMENTS	22000	LB	5.93	130,515
	1610	7100	20	A	E	STRUCTURAL STEEL	270	TN	3,710.92	1,001,948
	1630	7100	99	A	E	ARCHITECTURAL ALLOWANCE	1	LS	722,635.00	722,635
	1650	7100	31	A	E	FIRE PROTECTION-WATER	1	LS	75,841.50	75,842
	1660	7100	31	A	E	PLUMBING & DRAINAGE	1	LS	665,215.00	665,215
	1670	7100	31	A	E	HEATING & VENTILATION	1	LS	78,870.50	78,871
	1680	7100	41	A	E	LIGHTING	1	LS	175,449.00	175,449
						TOTAL POWER HOUSE				7,690,138

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
331										
	1700	7100				STATION YARD				
	1710	7100	98	A	A	CLEARING @ POWER HOUSE	2	AC	6,090.00	12,180
	1711	7100	99	A	E	GRADE,DRAIN & LANDSCAPING	5	AC	5,075.00	25,375
	1722	7100	99	A	E	FENCING & GATES	1	LS	16,747.50	16,748
	1730	7100	41	A	E	LIGHTING	1	LS	50,496.25	50,496
	1740	7100	31	A	E	WATER SUPPLY	1	LS	39,458.12	39,458
						TOTAL STATION YARD				144,257
	2000					MISC BLDG & STRUCTURES				
	2400	8220	26	A	A	WAREHOUSE & SHOP	1	LS	618,600.00	618,600
	2500	8220	26	A	A	MISC	1	LS	38,662.50	38,663
						TOTAL MISC BLDG & STR				657,263
	3000	8220				OPERATORS VILLAGE				
	3100	8220				STRUCTURES				
	3110	8220	26	A	A	PERMANENT CAMP	1	LS	541,275.00	541,275
	3120	8220	26	A	A	SINGLE FAMILY RES.	1	LS	409,822.50	409,823
	3200	8220				SERVICES				
	3210	8220	31	A	A	WATER		LS		
	3220	8220	31	A	A	SEWER		LS	COST INCLUDED WITH	
	3230	8220	41	A	A	LIGHTING		LS		
	3300	8220	99	A	A	GROUNDS		LS	TRMPORARY CAMP	
						TOTAL OPERATORS VILLAGE				951,098
331						TOTAL POWER PLANT STRUCTURES & IMPROVEMENTS				9,442,755

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
332						RESERVOIRS, DAMS & WATERWAYS				
	3000	3000				RESERVOIR				
	3110	3000	98	A	A	CLEARING	2480	AC	461.27	1,143,956
	3200	4100				ROCKFILL DAM-1180 POOL ELEVATION				
	3210	4100				COFFERDAM & PUMPING				
	3211	4100	6	A	A	U/S COFFERDAM	1	LS	293,056.40	293,056
	3212	4100	97	A	A	PUMPING & MAINT.	24	MO	24,277.50	582,660
	3213	4100	1	A	A	REMOVAL	1	LS	135,954.00	135,954
	3220	4100	6	A	A	D/S COFFERDAM W/ MAIN DAM	1	LS	0.00	0
	3300	4100				EXCAVATION				
	3311	4100	1	A	A	UNCLASSIFIED	63500	CY	14.57	924,973
	3312	4100	2	A	A	SOLID ROCK-TOE SLAB	3200	CY	50.71	162,282
	3313	4100	10	A	A	FOUNDATION PREPARATION	1900	SY	5.50	10,456
	3314	4100	8	A	A	DRILL & GROUT	1	LS	86,239.08	86,239
	3400	4100				CONCRETE-FACE & TOE SLAB				
	3411	4100	19	A	A	REBAR	563	TN	2,114.84	1,190,655
	3412	4100	15	A	A	FORMS	131100	SF	28.59	3,748,608
	3413	4100	11	A	A	CONCRETE	8940	CY	203.66	1,820,732
	3414	4100	99	A	A	DEFLECTOR	64300	LB	2.29	147,432
	3500	4100				EMBANKMENT				
	3511	4100		A	A	QUARRY & PLACE				
	3512	4100	6	A	A	ROCKFILL	278700	CY	10.47	2,916,958
	3513	4100	6	A	A	SELECT FILL	83000	CY	12.56	1,042,443
	3514	4100	6	A	A	RIP-RAP-HEAVY	2400	CY	104.66	251,191
						TOTAL ROCKFILL DAM EXCL RESERVOIR				13,313,638

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
332										
	2900	4200				SPILLWAY				
	2911	4200	1	A	A	EXCAVATION-COMMON	8500	CY	10.17	86,445
	2912	4200	2	A	A	EXCAVATION-ROCK	7300	CY	16.44	120,023
	2913	4200	5	A	A	BACKFILL	300	CY	10.17	3,051
	2915	4200	7	A	A	ROCK BOLTS	1800	LF	14.80	26,645
	2930	4200	12	A	A	CONCRETE	10075	CY	190.97	1,924,023
	2931	4200	15	A	A	FORMS-STRAIGHT	23000	SF	25.43	584,775
	2932	4200	16	A	A	FORMS-CURVED	4700	SF	61.59	289,450
	2933	4200	19	A	A	REBAR	167	TN	2,327.80	388,743
	2950	4200	9	A	A	DRAINS	1	LS	13,899.00	13,899
	2960	4200	8	A	A	GROUTING	80	CF	28.25	2,260
	2961	4200	10	A	A	FOUNDATION CLEANING	3500	SY	5.76	20,171
	2962	4200	18	A	A	WATERSTOPS	1	LS	2,825.00	2,825
	2970	4200	14	A	A	ENERGY DISSIPATOR	1	LS	56,500.00	56,500
						TOTAL SPILLWAY				3,518,809
	5000	4700				WATERWAYS				
						DIVERSION TUNNEL				
	5100	4700	2	A	A	EXCAVATION-PORTAL	1550	CY	30.24	46,868
	5120	4700	4	A	A	EXCAVATION-TUNNEL	6170	CY	386.63	2,385,476
	5125	4700	2	A	A	EXCAVATION-D/S CHANNEL	600	CY	30.24	18,142
	5130	4700	7	A	A	ROCK SUPPORTS	1	LS	482,095.60	482,096
	5151	4700	13	A	A	CONCRETE	941	CY	307.80	289,643
	5152	4700	19	A	A	REBAR	16	TN	3,386.84	54,189
	5153	4700	17	A	A	FORMS-TUNNEL	15100	SF	14.92	225,348
	5154	4700	15	A	A	FORMS-STRAIGHT	2330	SF	27.43	63,923
	5160	4700	24	A	A	STEEL STOP LOGS	76000	LB	3.62	274,759
	5161	4700	12	A	A	CONCRETE	420	CY	244.17	102,552
	5162	4700	19	A	A	REBAR	21	TN	3,856.58	80,988
	5163	4700	15	A	A	FORMS	1895	SF	23.59	44,712
	5170	4700	8	A	A	GROUT RING (PLUG)	1	LS	148,229.90	148,230
	5180	4700	32	A	A	GATES & VALVES	1	LS	310,419.20	310,419
	5181	4700	22	A	A	MISC STEEL	1	LS	256,569.04	256,569
						TOTAL DIVERSION & CONTROL STRUCTURE				4,783,915

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
332										
5200	4500					MIDDLE FORK DIVERSION				
5210	4500	99		A	A	SKY CRANE $8000/HR	1	LS	994,400.00	994,400
5211	4500	2		A	A	EXCAVATION	100	CY	35.60	3,560
5213	4500	10		A	A	SURFACE CLEANING	9000	SF	1.36	12,204
5215	4500	6		A	A	ROCKFILL-DAM	4500	CY	35.60	160,178
5216	4500	28		A	A	SHEET PILE	42	TN	1,586.52	66,634
5217	4500	11		A	A	CONCRETE	190	CY	324.87	61,726
5218	4500	19		A	A	REBAR	20	TN	3,599.05	71,981
5219	4500	15		A	A	FORMS	3100	SF	42.94	133,114
5220	4500	8		A	A	GROUT CURTAIN	1	LS	9,605.00	9,605
5225	4500	99		A	A	WOODEN ACCESS BRIDGE	1	LS	30,510.00	30,510
5231	4500	2		A	A	EXCAVATION-PIPE TRENCH	6600	CY	35.60	234,927
5232	4500	5		A	A	BACKFILL	8250	CY	15.26	125,854
5235	4500	33		A	A	STEEL PIPE 6'DIA 3/8"WALL	2020	LF	562.18	1,135,594
5236	4500	24		A	A	SLUICE GATES	2	EA	44,917.50	89,835
5237	4500	99		A	A	MISC STEEL	1000	LB	3.11	3,108
						TOTAL MIDDLE FORK DIVERSION				3133228
5300	4410					POWER TUNNEL				
5310	4410					HORIZONTAL @ INTAKE				
5311	4410	4		A	A	EXCAVATION-ROCK-CONV	5400	CY	328.80	1,775,520
5312	4410	7		A	A	ROCK BOLTS	25	EA	450.46	11,261
5313	4410	7		A	A	STEEL SETS	7000	LB	2.85	19,947
5317	4410	13		A	A	CONCRETE	2285	CY	320.01	731,230
5318	4410	17		A	A	FORMS-TUNNEL	33000	SF	7.55	249,060
5319	4410	19		A	A	REBAR	31	TN	4,656.82	144,361

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
332										
	5330	4410				INCLINED SECTION				
	5331	4410	4	A	A	EXCAVATION-RAISE BORE	4000	CY	890.40	3,561,600
	5332	4410	7	A	A	ROCK BOLTS	50	EA	457.44	22,872
	5336	4410	13	A	A	CONCRETE	1550	CY	315.27	488,669
	5337	4410	17	A	A	FORMS-TUNNEL	28650	SF	8.04	230,345
	5337	4410	16	A	A	FORMS-ELBOWS	2800	SF	63.85	178,766
	5338	4410	19	A	A	REBAR	22	TN	4,587.80	100,932
	5340	4410				HORIZONTAL FROM INCLINE TO OUTLET PORTAL				
	5341	4410	3	A	A	EXCAVATION-TBM	85300	CY	280.63	23,937,910
	5342	4410	7	A	A	ROCK BOLTS	450	EA	431.58	194,210
	5343	4410	7	A	A	STEEL SETS	127000	LB	2.76	351,003
	5346	4410	13	A	A	CONCRETE	24030	CY	350.98	8,434,097
	5347	4410	17	A	A	FORMS	504600	SF	6.32	3,189,057
	5348	4410	19	A	A	REBAR	255	TN	4,656.82	1,187,489
	5350	4410	27	A	A	STEEL LINING	1380	TN	7,203.16	9,940,361
						TOTAL POWER TUNNEL				54,748,689
	6100	4430				INTAKE @ RESERVOIR				
	6110	4430				CHANNEL EXCAVATION				
	6111	4430	2	A	A	EXCAVATE & SPOIL	22300	CY	15.70	350,098
	6112	4430	6	A	A	EXCAVATE (INCL W/DAM)	52100	CY	0.00	0
	6113	4430	2	A	A	EXCAVATE PORTAL	490	CY	50.71	24,849
	6114	4430	7	A	A	ROCK BOLTS-1" 10'	120	EA	347.71	41,725
	6115	4430	7	A	A	ROCK BOLTS-1" 15'	75	EA	519.54	38,965
	6116	4430	7	A	A	STEEL SETS	3700	LB	2.40	8,883
	6120	4430	11	A	A	CONCRETE	130	CY	284.46	36,979
	6121	4430	19	A	A	REBAR	16	TN	4,083.32	65,333
	6122	4430	15	A	A	FORMS-STRAIGHT	1170	SF	30.40	35,563
	6123	4430	16	A	A	FORMS-CURVED	1190	SF	43.01	51,185
						TOTAL INTAKE STRUCTURE				653,580

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
332										
	6300	4430				GATE SHAFT				
	6310	4430	1	A	A	EXCAVATE-OVERBURDEN	1350	CY	10.17	13,730
	6311	4430	2	A	A	EXCAVATE-ROCK ABOVE GRD	2500	CY	15.93	39,833
	6312	4430	4	A	A	EXCAVATE-SHAFT	2350	CY	904.00	2,124,400
	6313	4430	7	A	A	ROCK BOLTS 3/4" 8'	75	EA	63.28	4,746
	6314	4430	7	A	A	ROCK BOLTS 3/4" 6'	750	EA	49.72	37,290
	6331	4430	13	A	A	CONCRETE	800	CY	242.05	193,637
	6332	4430	19	A	A	REBAR	41	TN	3,570.80	146,403
	6333	4430	15	A	A	FORMS-STRAIGHT	2220	SF	44.58	98,964
	6334	4430	16	A	A	FORMS-CURVED	11650	SF	63.28	737,212
	6341	4430	22	A	A	MISC STEEL	1	LS	331,655.00	331,655
						TOTAL GATE SHAFT				3,727,869
	6600	4430				INTAKE APPURTENANCES				
	6610	4430	24	A	A	GATES INCL GUIDES & HOIST	1	LS	433,680.70	433,681
	6611	4430	24	A	A	TRASH RACKS	1	LS	234,704.88	234,705
						TOTAL INTAKE APPURTENANCES				668,386
						TOTAL INTAKE STRUCTURE, GATE SHAFT & APPURTENANCES				5,049,835

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
332										
	8000	4420				PENSTOCK				
	8010	4420	2	A	A	EXCAVATION-ROCK	1380	CY	22.24	30,692
	8011	4420	5	A	E	BACKFILL	880	CY	10.65	9,369
	8015	4420	7	A	A	STEEL SETS	0	LB		
	8016	4420	7	A	A	ROCK BOLTS	0	EA		
	8200	4420	27	A	E	STEEL PENSTOCK	80	TN	8,695.05	695,604
	8205	4420	27	A	E	ROLL OUT SECTION	10	TN	9,168.25	91,683
	8210	4420	27	A	E	WYE	30	TN	9,641.45	289,244
	8220	4420	33	A	E	VALVES INCL W/ T/G	0	EA		
	8300	4420	11	A	E	CONCRETE-STRUCTURAL	720	CY	246.66	177,592
	8310	4420	11	A	E	CONCRETE-LEAN	470	CY	179.99	84,597
	8320	4420	14	A	E	CONCRETE FINISH W/ CONC	0	SF		
	8330	4420	15	A	E	FORMS-STRAIGHT	4600	SF	31.35	144,208
	8350	4420	19	A	E	REBAR	115	TN	3,324.23	382,286
						TOTAL PENSTOCK				1,905,274
	9000	7500				TAILRACE				
	9120	7500	2	A	A	EXCAVATION-ROCK	3590	CY	19.68	70,664
	9300	7500	24	A	E	DRAFT TUBE GATES	1	LS	46,538.75	46,539
						TOTAL TAILRACE				117,203
332						TOTAL RESERVOIRS, DAMS & WATERWAYS				87,714,546

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
333						WATER WHEELS, TURBINES & GENERATORS				
	1000	7200	51	A	E	TURBINES-PELTON TYPE 300 RPM INCL SPHERICAL VALVES, GOVERNORS & MODEL TESTS	2	EA	4,317,950.00	8,635,900
	2000	7200	51	A	E	GENERATOR-45MW-56.31MVA EXCITATION, REGULATION, GROUNDING XFMR, COOLING & SHOP TESTS	2	EA	4,096,729.00	8,193,458
333						TOTAL TURBINES & GENERATORS				16,829,358
334						ACCESSORY ELECTRICAL EQUIPMENT				
	1000	7300				CONDUCTORS, CONDUITS & CABLE TRAY				
	1220	7300	41	A	E	GENERATOR LEADS	260	LF	1,747.88	454,449
	1230	7300	41	A	E	POWER CABLE	1	LS	666,029.00	666,029
	1240	7300	41	A	E	CONTROL CABLE	1	LS	683,774.00	683,774
	1250	7300	41	A	E	GROUNDING INCL CATH. PROT	1	LS	282,737.00	282,737
	1320	7300	41	A	E	CONDUIT	1	LS	306,988.50	306,989
	1340	7300	41	A	E	CABLE TRAY	1	LS	357,561.75	357,562
	2000	7300				SWITCHGEAR & CONTROL EQUIPMENT				
	2310	7300	41	A	E	GENERATOR BREAKERS,METAL CLAD SWITCHGEAR,POTENTIAL XFMR,GEN. SURGE PROTECT., ETC.	1	LS	408,726.50	408,727
	2500	7300	41	A	E	MAIN CONTROL & RELAY PNLS	1	LS	431,292.23	431,292
	2610	7300	41	A	E	AUX GENERATORS-250KW DIESEL & 5KW PROPANE	1	LS	103,175.35	103,175
	2620	7300	41	A	E	STATION BATTERY-125V	1	LS	28,451.15	28,451
	2630	7300	41	A	E	COMMUNICATION BATTERY	1	LS	21,944.65	21,945
	2700	7300	41	A	E	SUPRV. CONTROL & DATA AQ.	1	LS	87,394.13	87,394
	3000	7300				CUBICLES & APPURTENANCES				
	3200	7300	41	A	E	STATION SERVICE LOAD CTR	1	LS	174,788.25	174,788
	3300	7300	41	A	E	MOTOR CONTROL CENTERS	6	EA	82,277.65	493666
334						TOTAL ACCESSORY ELECTRICAL EQUIPMENT				4,500,978

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
335						MISCELLANEOUS POWER PLANT EQUIPMENT				
	1000	7400				AUXILIARY EQUIPMENT				
	1100	7400	35	A	E	UNWATERING & LOW LVL DRN	1	LS	71,867.25	71,867
	1300	7400	35	A	E	MISC SYSTEMS	1	LS	106,174.25	106,174
	1400	7400	35	A	E	COMPRESSED AIR SYSTEM	1	LS	150,832.50	150,833
	1500	7400	35	A	E	FIRE PROTECTION(INCL CO2)	1	LS	202,647.90	202,648
	1600	7400	35	A	E	POWER HOUSE CRANE 150TN	1	EA	874,828.50	874,829
	2000	7400	35	0	0	PERMANENT OPERATING EQUIP	1	LS	1,301,300.00	1,301,300
	3000	7400	35	A	E	COMMUNICATION SYS-LOCAL	1	LS	62,107.50	62,108
	3100	7400	35	A	E	MICROWAVE,SUPRV&TELEMETRY	1	LS	458,708.25	458,708
	9000	0	99	0	0	SPARE PARTS	1	LS	1,183,000.00	1,183,000
335						TOTAL MISC POWER PLANT EQUIPMENT				4,411,466
336						ROADS, BARGE FACILITY & AIR STRIP				
	1000	8100				ROADS-PERMANENT				
	1001	8100	96	A	A	AIR STRIP TO PH	1	LS	175,087.50	175,088
	1002	8100	96	A	A	PH TO DAM	1	LS	7,026,337.50	7,026,338
	1004	8100	96	A	A	CAMP TO MARTIN RIVER	1	LS	471,975.00	471,975
	3000	8200	96	A	A	DREDGED CHANNEL	1	LS	3,560,043.00	3,560,043
	3100	8200	96	A	A	BARGE FACILITY	1	LS	1,144,410.00	1,144,410
	4000	8102	96	A	A	AIR STRIP	1	LS	1,096,000.00	1,096,000
336						TOTAL ROADS, BARGE FACILITY & AIR STRIP				13,473,853
						TOTAL PRODUCTION PLANT				139,155,455
						TRANSMISSION PLANT				
350	1000	7800	0	0	0	LAND & LAND RIGHTS-XMSSN	1	LS	11,130.00	11,130

TABLE 11.1-1

ORDER OF MAGNITUDE ESTIMATE
90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

CLIENT-ALASKA POWER AUTHORITY — STONE & WEBSTER ENGINEERING CORPORATION — DATE OF ESTIMATE 10/24 83 — JO# 14500

BID PRICE DATE - JULY 1 83 — PG 110F11

PROJECT-BRADLEY LAKE HYDROELECTRIC PROJECT — ORDER OF MAGNITUDE ESTIMATE

90 MW PLANT
FEASIBILITY STUDY COST ESTIMATE

MAIN STEM	SUB ACCT	CORP ACCT	CC ST	M	L	DESCRIPTION	QUAN	UN	UNIT COST	TOTAL COST
352						SUBSTATION & SWITCHING STATION STRUCTURES				
	1230	7600	99	A	E	FENCING	1	LS	27,120.00	27,120
	2110	7600	5	A	E	SUBSTATION FILL	16500	CY	8.50	140,210
	2115	7600	2	A	E	RIP-RAP	700	CY	106.22	74,354
	2116	7600	5	A	E	CRUSHED ROCK	185	CY	22.06	4,081
	2410	7600	99	A	E	MISC. WORK	1	LS	101,022.00	101,022
	3110	7600	11	A	E	CONCRETE	515	CY	269.53	138,807
	3112	7600	19	A	E	REBAR	52	TN	3,175.30	165,116
	3113	7600	15	A	E	FORMS-STRAIGHT	10700	SF	29.95	320,412
	3114	7600	22	A	E	EMBEDS	1800	LB	5.93	10,679
	3115	7600	99	A	E	MISC. WORK	1	LS	28,984.50	28,985
	4130	7600	99	A	E	DUCTLINES & MANHOLES	200	LF	124.30	24,860
	4210	7600	20	A	E	STRUCTURAL STEEL-MISC	1	LS	73,450.00	73,450
	5220	7600	41	A	E	POWER SUPPLY-CAMP & SERV.	1	LS	830,781.65	830,782
352						TOTAL SUBSTATION & SWITCHING STATION STRUCTURES				1,939,876
353						SUBSTATION & SWITCHING STATION EQUIPMENT				
	1210	7600	44	A	E	INSULATORS & BUSHINGS	1	LS	13,503.50	13,504
	1220	7600	44	A	E	ALUMINUM TUBULAR BUSWORK	1300	LF	62.49	81,236
	1250	7600	44	A	E	GROUNDING SYSTEM		LS	INCLUDED IN ACCT # 334	
	2110	7600	44	A	E	POWER XFMR- 115KV-13.8KV	2	EA	319,196.75	638,394
	2200	7600	44	A	E	POWER CIRCUIT BREAKERS	1	LS	323,914.50	323,915
	2220	7600	44	A	E	DISCONNECT SWITCHES	1	LS	101,671.75	101,672
	3210	7600	21	A	E	STRUCTURAL STEEL TOWERS	1	LS	120,062.50	120,063
						TOTAL SUBSTATION & SWITCHING STATION EQUIPMENT				1,278,781
357	1000	7800	49	B	T	TRANSMISSION LINE	1	LS	7,599,182.20	7,599,182
						TOTAL TRANSMISSION PLANT				10,828,969

TABLE 11.1-1

COST ESTIMATES OF STUDY ALTERNATIVES

JO# 14500
8/19/83
PD 7/83

FERC ACCT	DESCRIPTION	1190 POOL 135MW PELTON	1190 POOL 135MW FRANCIS	90MW PELTON	90MW FRANCIS	60MW PELTON	60MW FRANCIS
		(000)	(000)	(000)	(000)	(000)	(000)
	PRODUCTION PLANT						
330	LAND & LAND RIGHTS	0	0	0	0	0	0
331	POWER PLANT STRUCTURES	7,128	8,097	5,934	6,125	5,424	5,303
332	RESERVOIRS, DAMS & WATERWAYS	81,812	93,287	75,530	84,025	70,422	78,762
333	TURBINES & GENERATORS	16,656	14,814	13,921	11,920	11,337	8,932
334	ACCESSORY ELECTRICAL EQUIPMENT	3,837	3,837	3,055	3,055	2,817	2,817
335	MISC POWER PLANT EQUIPMENT	2,691	2,721	2,661	2,551	2,551	2,441
336	ROADS, BARGE FAC. & AIRSTRIP	14,166	14,834	14,166	14,834	14,166	14,834
	TOTAL PRODUCTION PLANT	126,290	137,590	115,267	122,510	106,717	113,089
	TRANSMISSION PLANT						
350	LAND & LAND RIGHTS	10	10	10	10	10	10
352	SWITCHYARD STRUCTURES	1,717	1,717	1,717	1,717	1,717	1,717
353	SWITCHYARD EQUIPMENT	2,472	2,472	2,311	2,311	2,190	2,190
357	TRANSMISSION LINE	6,725	6,725	6,725	6,725	6,725	6,725
	TOTAL TRANSMISSION PLANT	10,924	10,924	10,763	10,763	10,642	10,642
	CONSTRUCTION DISTRIBUTABLES						
	CONSTRUCTION & PERMANENT CAMP	29,000	30,100	28,500	29,300	28,000	28,900
	MOBILIZATION/DEMOBILIZATION	10,000	10,000	10,000	10,000	10,000	10,000
	OTHER CONSTRUCTION ITEMS	11,800	11,800	11,800	11,800	11,800	11,800
	CONSTRUCTION MANAGEMENT	13,200	13,200	13,200	13,200	13,200	13,200
	TOTAL CONSTR. DISTRIBUTABLES	64,000	65,100	63,500	64,300	63,000	63,900
	TOTAL CONSTRUCTION COST	201,214	213,614	189,530	197,573	180,359	187,631
	ALLOWANCE FOR INDETERMINATES	50,286	53,386	47,370	49,377	45,091	46,919
	TOTAL CONSTR. COST & AFI	251,500	267,000	236,900	246,950	225,450	234,550
	ENGINEERING & DESIGN	28,500	28,500	28,500	28,500	28,500	28,500
	TOTAL CONSTRUCTION & ENGR	280,000	295,500	265,400	275,450	253,950	263,050
	OWNER'S COST	6,300	6,400	6,250	6,300	6,150	6,200
	TOTAL PRESENT DAY ESTIMATE	286,300	301,900	271,650	281,750	260,100	269,250
	ESCALATION	-----	-----	NOT INCLUDED		-----	-----
	IDC (-) ESCALATION	17,200	18,100	16,300	16,900	15,600	16,150
	TOTAL PRESENT DAY ESTIMATE INCLUDING (IDC-ESCALATION)	303,500	320,000	287,950	298,650	275,700	285,400

TABLE 11.2-1

HYDROELECTRIC PLANT O&M COSTS
BRADLEY LAKE HYDROELECTRIC PROJECT

ITEM		ANNUAL ESTIMATED COST - 1983 DOLLARS
A.	Plant Operators at $68,000 to provide daily coverage and daily maintenance.	$204,000
B.	Plant production supervisor; assigned 100% of the time at $78,400/year.	78,400
C.	APA operations staff time at 100 hours/year.	21,500
D.	Consulting services contracts for operation and maintenance.	40,000
E.	Department of Energy fees.	18,800
F.	Operating Utility administrative overhead costs.	18,800
G.	APA Administrative overhead costs.	25,000
H.	Minor operation contracts.	40,000
I.	Annual replacement costs.	114,700
J.	Miscellaneous services and supplies.	16,900
K.	Travel (2 trips per week to Homer)	52,000
L.	Property and machinery insurance	100,000
M.	Casualty, Workman's Compensation, auto, marine and airplane insurance.	50,000
	Subtotal	$780,100
	20% Emergency Contingency	156,000
	TOTAL	$936,100
	USE	$940,000

TABLE 11.2-2

TRANSMISSION LINE O&M COSTS
BRADLEY LAKE POWERHOUSE TO PROPOSED
HOMER ELECTRIC LINE

ITEM		ANNUAL ESTIMATED COST - 1983 DOLLARS
A.	Substation periodic inspection and testing.	$ 34,200
B.	Transmission line inspection and maintenance including SCADA communication line rental charge.	133,300
C.	Maintenance of SCADA System.	8,100
D.	Annual relay and meter inspection, testing, and calibration.	19,000
E.	Right-of-way clearing, inspection and maintenance.	10,200
F.	Transmission line loss insurance.	10,000
G.	Operating Utility administrative overhead costs.	13,000
H.	APA operations staff time at 200 hours.	9,100
I.	APA administrative overhead costs.	8,700
J.	APA accounting costs.	2,200
K.	Annual replacement costs.	7,700
L.	Miscellaneous supplies and services.	4,400
	Subtotal	$259,900
	20% Emergency Contingency	52,000
	TOTAL	$311,900
	USE	$312,000

NOTE: Totals rounded up to the nearest $10,000; line items rounded up to the nearest $100.

TABLE 11.2-3

230 KV ANCHORAGE/SOLDOTNA TRANSMISSION LINE

LAND & LAND RIGHTS		
Allowance		$ 1,280,000
OVERHEAD PORTION		
Labor & Material		$16,000,000
Clearing @ 15%		2,400,000
Engineering & Construction Management @ 12%		1,900,000
Owners Costs @ 8%		1,300,000
		$21,600,000
Contingency @ 15%		3,240,000
	Subtotal	$24,840,000
SUBMARINE CABLE		
Labor & Material		$28,500,000
Engineering & Construction Management @ 15%		4,275,000
Owners Costs @ 8%		2,280,000
		35,055,000
Contingency @ 25%		8,764,000
	Subtotal	$44,000,000
SUBSTATIONS & SWITCHYARDS		
Allowance		$ 5,000,000
TOTAL COST		$75,120,000

TABLE 11.2-4

TRANSMISSION LINE O&M COSTS
ANCHORAGE/SOLDOTNA
230 KV TRANSMISSION LINE

	ITEM	ANNUAL ESTIMATED COST - 1983 DOLLARS
A.	Substation periodic inspection and testing.	$ 34,200
B.	Transmission line inspection and maintenance including SCADA communication line rental charge.	179,300
C.	Maintenance of SCADA System.	8,100
D.	Annual relay and meter inspection, testing, and calibration.	19,000
E.	Right-of-way clearing, inspection and maintenance.	10,200
F.	Transmission line loss insurance.	10,000
G.	Operating Utility administrative overhead costs.	13,000
H.	APA operations staff time at 200 hours.	9,100
I.	APA administrative overhead costs.	8,700
J.	APA accounting costs.	2,200
K.	Annual replacement costs.	7,700
L.	Miscellaneous supplies and services.	4,400
M.	Sinking fund for submarine crossing conductor replacement and inspection.	479,300
	Subtotal	$785,200
	20% Emergency Contingency	157,000
	TOTAL	$942,200
	USE	$943,000

NOTE: Totals rounded up to the nearest $10,000; line items rounded up to the nearest $100.

TABLE 11.2-5

12

POWER STUDIES AND ECONOMIC EVALUATIONS

12. POWER STUDIES AND ECONOMIC EVALUATION

12.1 INTRODUCTION

The objectives of the power study and economic evaluation of the Bradley Lake Project are to identify the economic advantages or disadvantages of the Project for the Railbelt and to select the plant capacity. The analyses were performed using data from several sources, including the FY83 Power Authority economic guidelines, previous Bradley Lake studies performed by other organizations, and the Harza-Ebasco Susitna FERC application dated July 1983.

The primary tool used in this evaluation was a computer program developed by SWEC and the Massachusetts Institute of Technology for the Electric Power Research Institute. This program, Electric Generation Expansion Analysis System (EGEAS), provides the capability to automatically develop electric generation expansion plans based on the characteristics and costs of alternative generation sources, existing unit characteristics and retirement dates, and load data. A mathematical optimization method (dynamic programming) is used to consider all feasible plans for installing new generation capacity to meet the load requirements. The total present worth cost for each plan is determined, with the lowest cost plan being the economically preferred plan. A detailed description of EGEAS is provided in Reference 1.

Several variations in the Railbelt generation expansion plans were evaluated during the Bradley Lake power study. Using EGEAS, separate analyses were performed for generation expansion plans using thermal power plants (gas-fired combined cycle, gas-fired combustion turbine, and coal-fired steam turbine), Susitna combined with thermal plants, and the Bradley Lake Project (with and without Susitna) for the three proposed project capacities of 60 MW, 90 MW, and 135 MW. Also, sensitivity studies were performed to determine the effect of variations in the Railbelt load growth rate on the economic performance of the Bradley Lake Project.

In addition, EGEAS has a unique capability to perform a two-area analysis which models reserve sharing and economy interchange between two connected utility systems. This capability was used in the Bradley Lake study to evaluate the effect of transmission limitations on the present worth costs of the optimized expansion plans associated with the Kenai Peninsula. The current transmission tie between the Kenai Peninsula and Anchorage is a 115 kV transmission line. The addition of a 230 kV line with its substations and switching stations, between Anchorage and Soldotna, would cost about $75 million (Table 11.2-4). Therefore, an assessment of the differences in transmission costs associated with generation expansion plans including and not including the Bradley Lake Project is essential to the power study. This was accomplished using the EGEAS two-area analysis capability.

The primary data source for the study was the recent Harza-Ebasco Susitna FERC application dated July 1983 (Reference 2). Information derived from this document included items such as fuel prices and escalation rates, new generation alternatives, Susitna characteristics, and existing generation units in the Railbelt. The Railbelt electric load forecast used in the Bradley Lake study was also derived from this source. The load forecast, titled "Sherman H. Clark Associates NSD Case," has an average annual compounded load growth rate of about 2.8 percent for the period 1983 through 2007.

12.2 METHODOLOGY

The Bradley Lake and Susitna projects have been the subject of previous reports and projections for the power requirements of the Railbelt area of Alaska. Since the Bradley Lake Project is small compared to the total Railbelt load, the relative economics of Bradley Lake can become lost in the much larger present worth costs of the entire Railbelt. The objective of this power study was to clearly and precisely define the economic advantages or disadvantages of the Bradley Lake Project.

A two-phased approach was used, with one phase based on life cycle cost comparisons of Bradley Lake with other alternative generation sources and one based on optimum expansion plans developed for the Railbelt using EGEAS.

Although the Bradley Lake Project will impact the entire Railbelt Area, its greatest impact will be in the Kenai Peninsula. Most of the investment and annual expenses incurred outside the Kenai Peninsula will be common to generation plans with and without Bradley Lake. However, the small proportion that is not common is significant in the determination of Bradley Lake size and overall economics. In order to capture the essential variations in total cost to the Railbelt due to alternative Bradley Lake options, a two-area analysis was made in which the total present worth of annual expenses and investment were segregated into a Kenai area and a Railbelt-without-Kenai area. For the purposes of determining the benefits of the Bradley Lake Project, incremental differences in the costs associated with the Railbeltwithout-Kenai were combined with the total Kenai costs. This approach prevents the cost of alternatives with respect to Bradley Lake being lost in a one-area Railbelt analysis. It should be emphasized that the objective was to reduce total Railbelt costs to a minimum and not to limit the study to the Kenai Peninsula.

The two-area analysis was also required to assess transmission requirements between the Kenai Peninsula and the Anchorage systems. The transmission requirements were a significant factor in the evaluation of the Bradley Lake Project. The computer program EGEAS was selected specifically for its unique ability to perform a two-area analysis and optimize the whole Railbelt area while maintaining the identity of the Kenai Peninsula, and to include the effects of transmission limitations on the overall optimization. These concepts will be expanded in the following sections.

12.2.1 Electric Generation Expansion Analysis System

Electric Generation Expansion Analysis System (EGEAS) is a computer program that was developed jointly by SWEC and the Massachusetts Institute of Technology for the Electric Power Research Institute and represents state-of-the-art methodology. Representatives of 15 electric utilities were intimately involved in the development and testing of the program. It incorporates a number of optimization methods and generation dispatch algorithms within one modular set of programs using one common data base. A short description is given here of those particular features that were used for this project.

In EGEAS, each plan is evaluated in terms of present worth of all expenses incurred over the study period including fuel cost, operation and maintenance cost, and investment. Investment in a particular unit can be considered to be a one-time expense at the time of unit installation, or an annual cost of interest and depreciation may be used to represent the cost of capital for each year of the economic life of the unit.

Expansion plans may be developed for 20 years during which system load will grow as specified. An end-effects period can also be used to extend the economic analysis for any number of years. During the end-effects period, the load is assumed to stop growing in the 20th year. New generation installed during the first 20 years will be retired at the end of its economic life and replaced in-kind during the extension period. Fuel costs can be escalated in the end-effects period at a rate different than that used in the expansion period. The program develops the preferred plan based on minimum present worth of costs over both the expansion period and the end-effects period.

Generation expansion plans are developed automatically and optimized by EGEAS based on characteristics and costs of alternative generation sources, existing unit characteristics and retirement dates, and load data. A mathematical optimization method (dynamic programming) is used to consider all feasible plans for installing generating capacity to meet the new generation requirement. Several thousand plans may be analyzed and the one-hundred least cost plans are retained for printout. The plans are printed in order of least cost. The ability to retain and list suboptimum plans allows the user to consider other plans that may be better for the short term (20 years) as compared to the long term (50 years), particularly if the long term advantages of the "optimum" plan are relatively small compared to the short term advantages of another plan.

Two areas, "A" and "B," can be modeled by EGEAS. In this formulation, area "A" is optimized for a fixed expansion plan in "B." Stated another way, a small system connected to a large system by limited transmission capacity may be optimized without involving the whole pool in the optimization process, but including the reserve sharing and economy interchange provided by the large system up to the limit of the transmission system.

As a practical matter, EGEAS provides a very economical and yet accurate method for performing the Bradley Lake studies. Even though probabilistic production cost simulation using conventional methods (Booth-Baleriaux convolution) is relatively efficient compared to hour-by-hour simulation, a new method (the Method of Moments) devised for EGEAS is an order-of-magnitude faster than Booth-Baleriaux and produces identical results. Furthermore, because of its water storage characteristics, the Bradley Lake Project lends itself to an annual load duration curve analysis rather than monthly or a more frequent sub-yearly analysis. The slight loss in accuracy in representing unit maintenance by using an annual load duration curve is more than offset by the ability of the program to perform many studies at relatively low cost with a true system optimization in the process. Maintenance is modeled by derating units by an amount equal to the expected time on maintenance.

Two separate economic analyses were performed for the power study as follows:

A. Life Cycle Cost

Bradley Lake was compared unit-to-unit with each feasible power supply alternative in terms of levelized energy costs for a range of capacity factors.

B. Railbelt Generation Expansion Optimization

Railbelt power supply scenarios were developed and optimized by EGEAS from the feasible energy supply alternatives (Bradley Lake, Susitna, combined cycle, combustion turbines, and coal-fired steam plants) and economic evaluations were performed on a net present worth cost basis.

12.2.2 Life Cycle Cost

In general, there is a need for several different types of capacity to supply the system load. Base load, intermediate, and peaking capacity is one broad generalization. For fossil fueled plants, base load capacity is characterized by high investment and low energy cost and is expected to run at high capacity factors. Intermediate load capacity has lower investment and higher production cost than base load and may be expected to follow morning and evening loads on the system. Peaking capacity usually has lower investment and higher fuel costs than the other two types and tends to be used only during system peak load periods and, as a result, is characterized by low capacity factors. Most systems need all three types and each will be selected as an economic choice over a particular range of capacity factors.

A life cycle bus-bar cost analysis is one in which the cost of energy in mills/kWh, levelized over the life of the unit, is computed for various assumed capacity factors. The two major components of this analysis are investment and operating expense. Typical life cycle cost curves are shown in Figure 12.2-1.

Each pair of life cycle cost curves cross at a particular capacity factor which may be designated as the break-even capacity factor. The lower investment/higher fuel cost alternatives will be the economic choice at capacity factors lower than break-even and the other unit will be more economical at all other capacity factors. For instance, it can be seen from Figure 12.2-1 that peaking capacity is more economical than other sources for capacity factors less than about 10 percent, intermediate capacity has an economic range of 10 percent to 40 percent, and base load units are economical at capacity factors higher than 40 percent.

The life cycle analysis was useful for several purposes. First, it was used to determine which fossil-fueled alternative would be the most economical source within the Bradley Lake capacity factor range and the difference in bus-bar cost between this alternative and Bradley Lake. Also, the life cycle analysis was used to screen fossil-fueled alternatives to be included in the EGEAS optimization (an alternative that is not economical at any capacity factor in the life cycle analysis will not be selected for installation by EGEAS).

12.2.3 Generation Expansion Optimization with EGEAS

A meaningful study of the Bradley Lake Project must take into account the relative isolation of the Kenai Peninsula from the remainder of the Railbelt Area, from the standpoint of both supplying the Kenai load and distributing Bradley Lake generation.

Currently, the transmission tie between Kenai and Anchorage is limited to approximately 40 MW and consists of one 115 kV transmission line. Single contingency planning requires that the system continue to operate with the loss of this circuit. This is currently accomplished by installing enough generation in the peninsula to supply the load, with the tie used only as back-up. When Bradley Lake comes on line in 1988, and depending on the capacity installed, this transmission capacity may have to be increased to allow full utilization of the Bradley Lake generation to the Railbelt. In the alternatives that do not include Bradley Lake, the tie capacity may also have to be increased to allow the load in the Peninsula to be supplied from other Railbelt sources or to allow economy interchange. Therefore, the installation of new transmission circuits coincident with the installation of the Bradley Lake Project may represent early installation of circuits that will be needed at a later date in any case. An accurate assessment of the differences in transmission costs associated with plans including and not including Bradley Lake was essential to this analysis.

Separate analyses were performed using the optimization program, EGEAS, as follows:

- I. Without Bradley Lake
    - a. without Susitna
    - b. with Susitna
- II. Bradley Lake at 60MW
    - a. without Susitna
    - b. with Susitna
- III. Bradley Lake at 90MW
    - a. without Susitna
    - b. with Susitna

IV. Bradley Lake at 135MW

a. without Susitna

b. with Susitna

The following sequence was used for each of these analyses:

Stage 1, (Figure 12.2-2)

A single-area optimization of the total Railbelt was made. In this analysis, the "existing" capacity included the thermal generation in service in 1983 plus Bradley Lake installed in 1988 and the two stages of Susitna installed in 1993 and 2002 in those cases that include the respective hydroelectric projects. The existing thermal units and new thermal units were retired at the appropriate year in the study. The Railbelt generating reserve was maintained at a minimum of 30 percent of the peak load requirement.

Stage 2, (Figure 12.2-2)

The new generation installed in the Stage 1 optimization was assigned to either area "A" or area "B" as appropriate and the present worth of annual costs segregated into these two subdivisions (the total will equal the Stage 1 optimum cost). At this stage, unlimited tie capacity between the Kenai Peninsula (Area "A") and the Railbelt-without-Kenai (Area "B") was assumed and EGEAS was rerun. The one important additional piece of information that was developed at Stage 2 that was not available from the single area analysis of Stage 1 was the flow of energy over the ties between "A" and "B." From this information, it was possible to estimate the transmission ties required to provide "unlimited" tie capacity (the ties are unlimited in the sense that they do not impede economy interchange or reserve sharing).

A new total present worth cost was developed at Stage 2 that included the cost of the new transmission lines (if any) between the two areas.

Stage 3 (Figure 12.2-2)

If appreciable tie capacity is required in Stage 2, it may be possible to develop a more optimum plan by reducing the amount of transmission capacity between areas "A" and "B". The offsetting penalty for reducing transmission capacity and cost will come in two forms: more capacity in Kenai and higher fuel cost due to limitation in economy interchange. As demonstrated in Figure 12.2-2, some capacity installed in area "A" may have to be transferred to the Kenai Peninsula if the transmission capacity is reduced. This will usually require substituting capacity available for installation on the peninsula for a different type of capacity available only in area "B" (i.e., coal-fired capacity) or in some cases the same type of capacity may be transferred but at a higher fuel cost or smaller unit size.

Economy interchange takes place mainly during off-peak periods when lower cost energy in one area is substituted for high cost energy in another area. A reduction in tie capacity will limit the amount of economy energy transfer and thus cause higher fuel cost. An EGEAS two-area analysis at Stage 3 correctly models these two effects of limited ties on the overall cost to both areas.

12.2.4 Bradley Lake and Susitna Energy Dispatch

EGEAS uses a probabilistic generation dispatch method based on an annual load duration curve. Hydroelectric plants such as Bradley Lake and Susitna are modeled as "limited energy sources" and are used by the model to provide as much peak shaving as possible within the operational constraints imposed by each project. The effective storage available for daily load cycling at Bradley Lake is large enough to allow maximum peak shaving within the energy constraint.

Since all three proposed Bradley Lake unit sizes produce essentially the same total energy, the evaluation of unit size pivots on two factors:

1. transmission requirements for each size to allow economy interchange and reserve sharing between the Kenai Peninsula and the rest of the Railbelt, and

2. advantages of higher capacity replacement value and the displacement of higher cost fuel by the larger generation as compared to the incremental investment of the larger units.

Figure 12.2-3 demonstrates the manner in which the three different sized Bradley Lake units were modeled by EGEAS. The larger units operate at a lower capacity factor than the smaller alternatives and are loaded "higher" on the load duration curve. The hydroelectric units are "loaded" by EGEAS by finding the proper location on the load duration curve that will use all the energy available while running at maximum output as much as possible.

12.3 ECONOMIC PARAMETERS AND DATA

Numerous types of data are required in order to model a Railbelt power supply plan with EGEAS and perform the economic analysis. These data include items such as the Railbelt load growth projection, fuel prices and escalation rates, costs and operating characteristics of existing and future generation units, transmission requirements, and economic parameters.

Several sources of data were used in the Bradley Lake evaluations. As a part of the Susitna Hydroelectric Project evaluation, Harza-Ebasco compiled a significant part of the data required. In addition, the Chugach Electric Association has operating and cost data available for the existing generation units in their system. These data sources were supplemented, as needed, by the data contained in reports from previous Railbelt power supply studies.

The parameters used in the economic evaluations are summarized in Table 12.3-1. The majority of these parameters are consistent with the FY83 Power Authority economic guidelines (Reference 3). However, certain parameters, such as fuel escalation rates and the period of time over which fuel escalation occurs, were consistent with the values assumed by Harza-Ebasco in their projection of the Railbelt load growth.

12.3.1 Reference Case Railbelt Load Projection

Detailed electric load growth projection studies have been recently completed in support of the Susitna FERC application. The results of these studies are reported in Exhibit "B" of the Susitna FERC application dated July 1983 (Reference 2). In accordance with agreements reached with the Power Authority, the Bradley Lake power study was based on a load growth projection resulting from these studies titled "Sherman H. Clark Associates No-Supply-Disruption Case." This projection, referred to as the "Reference Case" by Harza-Ebasco, was in the middle range of the forecasts evaluated and was used as the base case in the Susitna power study. A brief overview of the analysis performed by Harza-Ebasco will be provided here.

One of the primary factors in the Susitna analysis which affected the load projection was the assumed world oil price. Several oil price projections were considered by Harza-Ebasco, including the Sherman H. Clark projections. The oil price affected the need for Railbelt electric power in four ways:

1. petroleum revenues available to the State of Alaska are a direct function of the market price of petroleum;

2. the price of electricity to the consumer is impacted since most Railbelt power is generated from fossil fuels;

3. the ability to economically substitute different fuels for power generation is dependent on the price of oil;

4. the level of oil exploration and development in Alaska will vary with the world oil price.

Harza-Ebasco used four interrelated computer models to project the future Railbelt load growth for each oil price projection. The four models included the following:

1. PETREV -- Operated by the Alaska Department of Revenue. This model uses a probability distribution of possible values that affect Alaska petroleum revenues to predict a range of royalties and production taxes.

2. MAP -- Developed by the Institute of Social and Economic Research (ISER), University of Alaska. The MAP (Man-in-the-Arctic Program) is an economic model that simulates the behavior of the Alaska economy and population growth for each of twenty regions of the state.

3. RED -- Developed by ISER and modified by Battelle Pacific Northwest Laboratories. The RED (Railbelt Electricity Demand) model is a simulation model which forecasts annual electricity consumption for each end-use sector in the Anchorage-Cook Inlet and Fairbanks-Tanana Valley load centers.

4. OGP -- Developed by General Electric Company. OGP (Optimized Generation Planning) is a model used to produce generation expansion plans based on system reliability, operating, and investment costs.

With these models, Railbelt load growth projections for several oil price scenarios were produced for the Susitna FERC application. A complete description of the procedure is provided in Exhibit "B" of the Susitna FERC application dated July 1983 (Reference 2).

A summary of the input and output data for the Reference Case is presented in Table 12.3-2. During the 28 years included in this scenario, the net Railbelt electric energy demand is projected to increase 109 percent from 2,803 GWH to 5,858 GWH, while the peak demand increases 110 percent from 579 MW to 1,217 MW. This load projection is shown in Table 12.3-3 for each year in the period 1983-2010. The Kenai Peninsula load is included in the Anchorage-Cook Inlet category. Table 12.3-4 shows the annual change in the Railbelt load.

In order to perform a two-area analysis with EGEAS and identify the impact of Bradley Lake on the Kenai Peninsula, a separate load projection for the Kenai Peninsula was required. For this purpose, the Anchorage-Cook Inlet load from the Reference Case in Table 12.3-3 was separated into Anchorage area and Kenai Peninsula components. The historical load in each region was the basis used to separate the projection. The historical Anchorage-Cook Inlet utility peak demand and energy requirements are shown in Tables 12.3-5 and 12.3-6, respectively. In both cases, the portion of the total Anchorage-Cook Inlet load occurring in the Kenai Peninsula varied from 14 to 16 percent during recent years. Based on this information, it was assumed that the Kenai Peninsula would represent 15 percent of the Anchorage-Cook Inlet load during the 1983 through 2007 time frame of the Bradley Lake power study. The resulting load projections for the Anchorage area and

Kenai Peninsula are shown in Table 12.3-7. This projection represents a conservative estimate of the load portion occurring in the Kenai Peninsula since other recent projections (such as Reference 4) indicate that the Kenai Peninsula may grow at a somewhat faster rate than the rest of the Railbelt. Assuming a slightly higher load growth for the Kenai Peninsula would have little effect on the study, but would tend to favor the Bradley Lake Project.

12.3.2 Reference Case Fuel Price Projections

As part of the Susitna FERC application, Harza-Ebasco also performed studies to determine the future availability and price of fossil fuels in the Railbelt. Projections for natural gas, coal, and distillate oil were made so that Railbelt generation expansion plans involving alternatives to Susitna (thermal plants) could be developed and evaluated on a life cycle cost basis. The fuel price projections developed for the Reference Case were used in the Bradley Lake power study to evaluate hydroelectric alternatives. A complete description of the fuels pricing studies is included in Exhibit "D" Appendix D-1, of the July 1983 Susitna FERC application (Reference 2).

The fuel prices used in the Bradley Lake studies are shown in Table 12.3-8. The following major assumptions relate to these price projections:

1. The escalation in the price of natural gas will vary in the same manner as that of oil.

2. Although proven Cook Inlet natural gas reserves will be exhausted around the year 2000, it was assumed that sufficient additional reserves will be discovered to meet all future demand during the study period. No supply restrictions were imposed in any portion of the Bradley Lake power study.

3. The Beluga coal field, presently undeveloped, will be opened for development and coal will be exported to Japan.

12.3.3 Existing Railbelt Generation System

The Railbelt electric power market contains two primary load centers (Anchorage-Cook Inlet and Fairbanks-Tanana Valley) and is served by several utilities and other suppliers. The 1982 Railbelt generating capacity is shown in Table 12.3-9. For the Bradley Lake power study, the market was considered to be interconnected with the addition of the transmission tie between Anchorage and Fairbanks (currently under construction by the Alaska Power Authority). The existing 115 kV transmission tie between Anchorage and the Kenai Peninsula was subject to the capacity limitations discussed previously.

For the generation expansion plans developed by EGEAS, the cost of new transmission lines was included as required. The natural gas-fired combustion turbines and combined cycle plants had no additional transmission cost since their siting flexibility allowed them to be located near the load centers. The coal plants, however, required transmission from the plant site to the nearest load center, and this cost was included accordingly. The Bradley Lake plants included the cost of transmission from the plant to the existing transmission line in all cases plus the cost of a new 230 kV line between Anchorage and Soldotna when required.

The existing Railbelt generating plants were included in the generation expansion plans developed by EGEAS. These existing plants were dispatched by EGEAS along with new generation plants to arrive at an optimum generation expansion plan for the total Bradley Lake power study period.

All plants, both existing and new, were retired in accordance with the equipment lifetimes shown in Table 12.3-1. A complete listing of the existing generating plants in the Railbelt is shown in Table 12.3-10.

In addition to Bradley Lake benefits for capacity and energy, an allowance was also made for the ability of the Project to provide spinning reserve. As a conservative estimate of the capability, spinning reserve benefit was applied for the Kenai Peninsula load only. This was accomplished with EGEAS by forcing the CEA Bernice #3 and #4 gas-fired combustion turbine units (see Table 12.3-10) to operate continuously at no less than 20 percent capacity in those scenarios without Bradley Lake. The heat rate of these units at this reduced capacity was approximately 28,000 BTU/kWh, with the heat rates decreasing as the output approached full load to the values shown in Table 12.3-10. In the EGEAS simulations, these two units were dispatched in an optimum manner except that they never dropped below 20 percent of their full output. Thus, the scenarios without Bradley Lake had the portion of the capacity of these plants in excess of their current operating level available as spinning reserve. In the cases where the Bradley Lake Project was included, the two Bernice units were dispatched by EGEAS without a requirement to continuously operate at any level, and Bradley Lake provided spinning reserve for the Kenai Peninsula.

12.3.4 Future Railbelt Electric Generation Alternatives

The development of Railbelt generation expansion plans with EGEAS required performance and cost specifications for the feasible Railbelt electric generation alternatives. A screening of alternatives was not performed for the Bradley Lake power study since the performance and cost of possible choices were evaluated in previous Railbelt studies. The technical and economic feasibility of numerous options was evaluated by Battelle Pacific Northwest Laboratories in 1982 (Reference 5). Battelle evaluated a wide variety of electric generation options, taking into account the unique characteristics of the Railbelt. The candidate resources included coal, natural gas, petroleum, peat, municipal refuse, wood waste, geothermal, hydroelectric, tidal power, wind, solar, and uranium. The most readily adaptable thermal alternatives for the Railbelt included coal, natural gas, and oil resources. Thus, the thermal generation alternatives in the Bradley Lake power study included coal-fired steam, gas-fired combustion turbines, and gas-fired combined cycle plants. These thermal options are described in detail in Exhibit "D" of the Susitna FERC application of July 1983 (Reference 2). A summary of the thermal generation plant parameters used in EGEAS is shown in Table 12.3-11.

The hydroelectric plant parameters and costs used in the Bradley Lake power study are summarized in Tables 12.3-12 through 12.3-14. Table 12.3-12 shows the Bradley Lake Project parameters developed by SWEC and the Susitna Project parameters obtained from the Susitna FERC application of July 1983. The capital and fixed operating and maintenance costs for the Bradley Lake options and Susitna are shown in Tables 12.3-13 and 12.3-14, respectively.

12.3.5 Sensitivity Studies

The Railbelt load and price projections are dependent on numerous factors which involve various degrees of uncertainty (such as future world oil prices). Sensitivity studies were performed with EGEAS to determine the effect of load and fuel price variations on the economic performance of the Bradley Lake Project. In addition to the Reference Case (Sherman H. Clark NSD) Railbelt load growth and fuel price projections, two other cases were examined in the Bradley Lake power study. These are:

1. A Railbelt no-growth case where the 1983 load (2,803 GWH at a peak of 579 MW, net) was assumed to remain constant for the duration of the power study. The fossil fuel price projections were the same as in the Reference Case.

2. A Railbelt load growth and fossil fuel price projection titled "DOR 50% Case." This projection, developed in July 1983, was supplied to SWEC by the Power Authority. The case was studied with EGEAS for the base case (new thermal plants only) and the 90 MW Bradley Lake option.

The load growth and fossil fuel projections for the DOR 50% case are shown in Tables 12.3-15 and 12.3-16. For the period 1983 to 2010, the Railbelt load shown in Table 12.3-15 grows at an average compound rate of about 2.3

percent per year. The fossil fuel price projections in Table 12.3-16 indicate that coal prices remain constant, the turbine oil price decreases by about 25 percent between 1983 and 2000 and then remains constant, and the natural gas price decreases by about 11 percent between 1983 and 2000 and then also remains constant. For comparison, the levelized fuel costs for natural gas and coal are shown in Table 12.3-17 for the Reference Case and DOR 50% Case projections.

12.4 RESULTS

The evaluations indicate that the Bradley Lake Project is economically beneficial for the Railbelt at any of the three proposed plant capacities, both with and without the presence of Susitna. Significant life-cycle savings result by using Bradley Lake in place of thermal generation alternatives (gas-fired combined cycle, gas-fired combustion turbines, and coal-fired steam plants). The capacity for Bradley Lake is dependent on and sensitive to the projected load growth rate for the Railbelt. The differences in present worth cost between the three proposed capacities for alternative load growth projections are relatively small. Of the three capacities evaluated, the 90 MW Bradley Lake Project is the economically preferable choice at the reference load growth rate of an average 2.8 percent per year as adopted in this study. It is also economically beneficial under the DOR 50% Case. For an assumed load growth rate of zero percent per year, the 60 MW plant is the preferred choice. However, since the 90 MW Bradley Lake Project is the least sensitive to load growth variations, it appears to be the most favorable plant capacity. The Bradley Lake Project options are very close in terms of annual average energy, with only a 3 to 5 percent difference between successively larger installations.

EGEAS was used to develop optimized Railbelt generation expansion plans for the various scenarios discussed in the previous sections. For each generation expansion plan, EGEAS created an extensive printout of results which was unrealistically long to attempt to reproduce in this report. Thus, the power study results are summarized in the following sections with certain pages extracted from the EGEAS output data primarily for the base case (new thermal plants only) and the recommended Bradley Lake capacity of 90 MW.

12.4.1 Reference Case

This section presents the results of the Bradley Lake power study for the Reference Case load and fuel price projections (Sherman H. Clark NSD). Tables 12.4-1 through 12.4-14 summarize the results of the study. Present worth costs, in 1983 dollars, are shown for all cases in terms of total Railbelt cost and the portion of the cost attributable to the Kenai Peninsula alone. The present worth savings due to the Bradley Lake Project (base case cost minus Bradley Lake cost) are also shown along with the fraction of the base case cost which these savings represent.

Table 12.4-1 shows the present worth costs for the plans consisting of alternatives to Bradley Lake. The thermal plant base case with the lowest present worth cost includes the Anchorage-Soldotna 230 kV transmission line and has a value of $5,832 million. This base case is compared to the "Bradley Lake without Susitna" plans. The "Bradley Lake with Susitna" plans are compared to a base case including Susitna and thermal plants which has a total present worth cost of $5,724 million.

The "Bradley Lake without Susitna" cases are shown in Tables 12.4-2 and 12.4-3 for the total Railbelt and the Kenai Peninsula, respectively. For all three Bradley Lake capacities, significant savings are realized when compared to the base case. For the total Railbelt plans, the savings range from 5.1 to 6.3 percent of the base case. However, when the present worth costs are separated for the Kenai Peninsula using the EGEAS two-area evaluation, the Bradley Lake savings range from 23.1 to 33.7 percent of the Kenai Peninsula base case cost. the 90 MW Bradley Lake Project shows the largest present worth savings for the total Railbelt and the Kenai Peninsula and is the optimum choice. The incremental cost for increasing the plant capacity to 135 MW (including the additional plant capital cost plus the Anchorage-Soldotna 230 kV transmission line) is not justified since the total savings are less than for the 90 MW plant.

Additional information for the "Bradley Lake without Susitna" cases is presented in Tables 12.4-4 to 12.4-11. The new generation capacity projected by EGEAS for installation in the Railbelt is shown in Tables 12.4-4 to 12.4-7 for the base case, 60 MW Bradley Lake, 90 MW Bradley Lake, and 135 MW Bradley Lake, respectively. These Tables show that the optimum expansion plans, with and without the presence of Bradley Lake, include the addition of natural gas-fired combined cycle units in the years prior to 2000, with coal-fired steam plants added in the successive years through 2007. Natural gas-fired combustion turbines were also added in the year 2000 timeframe.

Tables 12.4-8 and 12.4-9 illustrate the energy generation and cost by fuel class for the "Bradley Lake without Susitna" case. The energy generated and total fuel cost for each year in the 1988 through 2007 period are shown for natural gas, coal, oil (existing plants only -- no new oil-fired plants were added), and existing hydroelectric.

Tables 12.4-10 and 12.4-11 show the Reference Case expansion plan summary for base case and 90 MW Bradley Lake cases. These summary pages, copied from the EGEAS output, show the annual Railbelt load, capacity installed and retired, reserve percent, capital cost of the new units, production cost (fuel cost plus variable O&M), fixed O&M cost for the new units, total and cumulative annual cost, and total and cumulative present worth cost.

Lastly, life cycle levelized cost curves were produced for the Reference Case as discussed in earlier sections and are presented in Figure 12.4-1. These curves illustrate the relative levelized energy costs of the Railbelt generation alternatives taking into account capital costs, variable O&M costs, fixed O&M costs, and fuel costs. Other benefits which accrue to the Bradley Lake Project, such as spinning reserve, are not reflected on these curves as in the EGEAS evaluations. On the basis of levelized bus-bar energy cost, Figure 12.4-1 shows that the three Bradley Lake capacities are the least cost alternatives compared to the thermal plants at the same capacity factor. The levelized energy cost for the 90 MW Bradley Lake Plant is about 34 percent lower than for the natural gas-fired combined cycle plant.

Tables 12.4-12 and 12.4-13 present the results for the "Bradley Lake with Susitna" plans. As expected, the present worth savings for the three Bradley Lake capacities are less due to the presence of the large Susitna plants. However, savings still result for all three plants and range from 1.2 to 3.1 percent for the total Railbelt base case and from 7.4 to 22.4 percent for the Kenai Peninsula base case. In these plans, the present worth savings are essentially equal for the 60 and 90 MW Bradley Lake capacities. The 135 MW plant results in less savings, indicating that the economically preferable Bradley Lake plant capacity for the cases including Susitna should be either 60 MW or 90 MW.

The "Bradley Lake with Susitna" plans did not require the addition of any new thermal generation plants after the Bradley Lake on-line date of 1988. In the succeeding years, the existing generation plants with Bradley Lake Project and Susitna (Watana in 1993 and Devil Canyon in 2002) were sufficient to meet the Railbelt Reference Case load with adequate reserves. The expansion plan summary from EGEAS for the 90 MW "Bradley Lake Project with Susitna" case is shown in Table 12.4-14.

12.4.2 Sensitivity Studies

It is recognized that uncertainty exists in the projections for future Railbelt electric loads, primarily because of the volatile nature of world oil prices. If the Railbelt load growth were to exceed the Reference Case projection, then Bradley Lake would continue to be an economically beneficial option for the Railbelt. However, in order to determine the impact on Bradley Lake if the Railbelt growth is less than the Reference Case, two other scenarios were examined with EGEAS.

A load growth rate of zero percent per year was assumed to determine the economic performance of Bradley Lake under a Railbelt no-growth scenario. The 1983 Railbelt load was assumed constant for the duration of the power study. The fossil fuel prices were the same as in the Reference Case. The results of the sensitivity study are shown in Table 12.4-15. The present worth costs indicate that Bradley Lake remains competitive with a thermal plant base case for all three Bradley Lake capacities. For the zero load growth rate, the 60 MW Bradley Lake Project provides the largest net benefit since the 230 kV Anchorage-Soldotna transmission line was required for the 90 and 135 MW cases to allow economy interchange and reserve sharing between the Kenai Peninsula and Anchorage. The cost for this line was greater than any additional savings due to either the 90 or 135 MW capacities.

Tables 12.4-16 and 12.4-17 show the generation installation schedule developed by EGEAS for the base case and 90 MW Bradley Project under zero percent load growth. The generation by fuel class for the 1988 through 2007 study period is shown for these two cases in Tables 12.4-18 and 12.4-19. Lastly, the summaries of annual and present worth costs are shown in Tables 12.4-20 and 12.4-21 for the expansion plan with new thermal plants only and the plan including the 90 MW Bradley Lake Project.

The second sensitivity study, performed at the request of the Alaska Power Authority, used the July 1983 "DOR 50% Case" load growth and fuel price projections which were described previously. Only two expansion plans were generated with EGEAS for this study: A base case (new thermal plants only) and a case with the 90MW Bradley Lake Project plus thermal plants. The results are as follows:

Present Worth Cost --- Millions 1983 Dollars

Thermal Plants*	3461
90 MW Bradley Lake + Thermal Plants	3305

*Includes 230kV Anchorage-Soldotna transmission line.

The installation of the 90 MW Bradley Lake Project results in a present worth savings of about $156 million. This savings is comprised of approximately $56 million for spinning reserve and energy cost savings plus $100 million for not installing the 230 kV Anchorage-Soldotna transmission line. For the DOR 50% case, this line is not required if the 90 MW Bradley Lake Project is installed on the Kenai Peninsula. A comparison of life cycle levelized bus-bar costs for Bradley Lake and thermal generation alternates is shown in Figure 12.4-2 for the "DOR 50% Case." The 90 MW Bradley Lake Project has a slight energy cost advantage when compared to the 200 MW natural gas-fired combined cycle plant at the same capacity factor.

Tables 12.4-22 to 12.4-27 contain further information from the EGEAS evaluations for the "DOR 50% Case." The plant installation schedules for the base case and 90 MW Bradley Lake case are shown in Tables 12.4-22 and 12.4-23. The corresponding annual values for energy generation and cost by fuel class for 1988 through 2007 are summarized in Tables 12.4-24 and 12.4-25. As for the Reference Case, the major Railbelt fuel source is natural gas, with combined cycle plants being the primary generation method with a smaller installed capacity of gas turbines. However, since the "DOR 50% Case" projects the price of coal as a constant value and the price of natural gas decreasing in real terms, the optimum expansion plans developed by EGEAS do not include the addition of any coal plants during the period of the power study. The summaries of annual costs for the two "DOR 50% Case" expansion plans are included in Tables 12.4-26 and 12.4-27.

12.4.3 Evaluation of Selected 90 MW Bradley Lake Project

The power study results described in the previous sections were based on the Bradley Lake Project designs developed during the SWEC feasibility studies. After the selection by SWEC of the 90 MW Bradley Lake Project as the recommended option, additional refinements of the 90 MW plant were undertaken. As a result, small changes were made in the capital cost and annual average energy output from the 90 MW plant. The cost used for the economic analysis of the selected 90MW plant is the \$283,019,000 overnight cost plus an additional \$16,981,000 for interest during construction at the discount rate, for a total of \$300,000,000. The original feasibility stage values and refined values for the selected plant are shown in Table 12.4-28. These changes to the 90 MW Bradley Lake Project resulted from the following:

1. A detailed review of the feasibility stage cost estimate,

2. Detailed evaluations of reservoir inflow conditions, and

3. Reevaluation of minimum diversion flows for aquatic habitat.

EGEAS was run for the selected 90 MW Bradley Lake Project plus thermal plants (at the Reference Case load and fossil fuel price projections) to test the effect of the changes in capital cost and energy on the generation expansion plan. The present worth costs are shown in Table 12.4-29 along with the values from the base case for comparison. The present worth cost for the feasibility stage 90 MW Bradley Lake Plant was $5,464 million, or only $9 million higher than the selected plant present worth value. The lower present worth cost for the selected plant indicates that the increase in capital cost is more than offset by benefits from the additional average annual energy generated. Table 12.4-30 is a summary of the annual costs and present worth cost from EGEAS for the selected 90 MW Bradley Lake Project. As before, significant life-cycle savings result by using the refined 90 MW Bradley Lake Project in place of thermal generation alternatives for the Railbelt. The generation expansion plan developed by EGEAS for the selected plant is identical to the feasibility stage plan in Table 12.4-6. Figure 12.4-3 shows the levelized bus-bar cost for the selected 90 MW plant and the thermal alternatives.

Although the 60 MW and 135 MW Bradley Lake Projects were not reevaluated after the feasibility stage, similar results would be obtained for these plant capacities. The cost and annual average energy values would change in the same proportion as for the selected 90 MW Plant. The three Bradley Lake plant capacities would have the same relative economic performance as discussed in the previous sections. Thus, the conclusions reached in the power study remain unchanged, and the 90 MW Bradley Lake Project is the recommended capacity.

POWER STUDIES AND ECONOMIC EVALUATION

REFERENCES

1. Electric Power Research Institute, "Electric Generation Expansion Analysis System," Report No. EPRI EL-2561, Six Volumes.

2. Alaska Power Authority, Susitna Hydroelectric Project FERC Application, prepared by Harza-Ebasco Susitna Joint Venture, July 1983.

3. Alaska Power Authority, "FY83 Guidelines for Power Studies and Economic Analyses," July 1982.

4. Burns & McDonnell, "Report on the Power Requirements Study for Chugach Electric Association, Inc.," Report No. 82-182-4-001, 1983.

5. Battelle Pacific Northwest Laboratories, "Railbelt Electric Power Alternatives Study: Evaluation of Railbelt Electric Energy Plans," for the Office of the Governor, State of Alaska, Division of Policy Development and Planning and the Governor's Policy Review Committee, February 1982.

ECONOMIC EVALUATION PARAMETERS

PARAMETER		VALUE
Inflation Rate		0%
Real Discount Rate		3.5%
Equipment Economic Lifetimes (years)		
Gas Turbines		20
Combined Cycle Turbines		30
Steam Turbines		30
Hydroelectric Projects		50
Transmission Systems		
	Wood Poles	30
	Steel Towers	40
	Submarine Cables	30
Base Year		1983
Planning Period (20 years)		1988-2007
Economic Analysis Period (50 years)		1988-2037

TABLE 12.3-1

SHERMAN H. CLARK NSD CASE FORECAST
SUMMARY OF INPUT AND OUTPUT DATA

ITEM DESCRIPTION	1983	1985	1990	1995	2000	2005	2010
World Oil Price (1983$/bbl)	28.95	26.30	27.90	32.34	37.50	43.47	50.39
Energy Price Used by RED (1980$)							
Heating Fuel Oil - Anchorage ($/MMBTU)	7.75	6.45	6.84	7.93	9.19	10.65	12.35
Natural Gas - Anchorage ($/MMBTU)	1.73	1.95	2.88	4.05	4.29	4.96	5.38
State Petroleum Revenues[1] (Nom.x10^6$)							
Production Taxes	1,474	1,561	2,032	1,868	1,910	2,150	2,421
Royalty Fees	1,457	1,555	2,480	2,651	3,078	3,799	4,689
State Gen. Fund Expenditures (Nom. x10^6$)	3,288	3,700	5,577	7,729	9,714	13,035	17,975
State Population	457,836	490,146	554,634	608,810	644,111	686,663	744,418
State Employment	243,067	258,396	293,689	313,954	325,186	345,701	376,169
Railbelt Population	319,767	341,613	389,026	423,460	451,561	486,851	533,218
Railbelt Employment	159,147	169,197	190,883	204,668	214,542	231,584	255,974
Railbelt Total Number of Households	111,549	120,140	138,640	152,463	163,913	177,849	195,652
Railbelt Electricity Consumption (GWh)							
Anchorage	2,322	2,561	3,045	3,371	3,662	4,107	4,735
Fairbanks	481	535	691	800	880	986	1,123
Total	2,803	3,096	3,736	4,171	4,542	5,093	5,858
Railbelt Peak Demand (MW)	579	639	777	868	945	1,059	1,217

[1]Petroleum revenues also include corporate income taxes, oil and gas property taxes, lease bonuses, and federal shared royalties.

Source: Reference 2, Exhibit B, Table B.103.

TABLE 12.3-2

PROJECTED PEAK AND ENERGY DEMAND (NET)
SHERMAN H. CLARK NSD CASE

	Anchorage-Cook Inlet Area		Fairbanks-Tanana Valley Area		Total Railbelt	
Year	Energy GWh	Peak MW	Energy GWh	Peak MW	Energy GWh	Peak MW
1983	2,322	469	481	110	2,803	579
1984	2,442	493	508	116	2,950	609
1985	2,561	517	535	122	3,096	639
1986	2,658	538	566	129	3,224	667
1987	2,755	558	597	136	3,352	695
1988	2,852	579	629	144	3,481	722
1989	2,949	599	660	151	3,609	750
1990	3,045	619	691	158	3,737	777
1991	3,111	633	713	163	3,824	796
1992	3,176	646	735	168	3,911	814
1993	3,240	659	757	173	3,997	832
1994	3,306	672	778	178	4,084	850
1995	3,371	686	800	183	4,171	868
1996	3,429	697	816	186	4,245	884
1997	3,487	709	832	190	4,319	899
1998	3,545	721	848	194	4,394	914
1999	3,604	732	864	197	4,468	930
2000	3,662	744	880	201	4,542	945
2001	3,751	762	902	206	4,652	968
2002	3,840	780	923	211	4,762	991
2003	3,929	798	944	215	4,872	1,013
2004	4,018	816	965	220	4,983	1,036
2005	4,107	834	986	225	5,093	1,059
2006	4,232	859	1,013	231	5,246	1,091
2007	4,358	885	1,041	238	5,399	1,122
2008	4,484	910	1,068	244	5,552	1,154
2009	4,609	936	1,096	250	5,705	1,186
2010	4,735	961	1,123	256	5,858	1,217

Source: Reference 2, Exhibit B, Table B.117.

TABLE 12.3-3

RAILBELT PEAK DEMAND AND ENERGY PROJECTION (NET) SHERMAN H. CLARK NSD CASE

Year	Peak Demand MW	Peak Demand Change, %*	Energy GWH
1983	579	5.18	2,803
1984	609	4.93	2,950
1985	639	4.38	3,096
1986	667	4.20	3,224
1987	695	3.88	3,352
1988	722	3.88	3,481
1989	750	3.60	3,609
1990	777	2.45	3,737
1991	796	2.26	3,824
1992	814	2.21	3,911
1993	832	2.16	3,997
1994	850	2.12	4,084
1995	868	1.84	4,171
1996	884	1.70	4,245
1997	899	1.67	4,319
1998	914	1.75	4,394
1999	930	1.61	4,468
2000	945	2.43	4,542
2001	968	2.38	4,652
2002	991	2.22	4,762
2003	1,013	2.27	4,872
2004	1,036	2.22	4,983
2005	1,059	3.02	5,093
2006	1,091	2.84	5,246
2007	1,122	2.85	5,399
2008	1,154	2.77	5,552
2009	1,186	2.61	5,705
2010	1,217	----	5,858

Average annual compound growth rate: 2.8%
Average load factor: 55%

*Percent change from current to following year.

TABLE 12.3-4

HISTORICAL ANCHORAGE AND COOK INLET PEAK DEMAND

Year	Peak Demand, MW				Load Fraction Occurring in Kenai Peninsula[5]
	Chugach[1]	HEA+KCL[2]	Seward[3]	AMLP[4]	
1974	185.6	24.7	5.8	76.8	0.12
1976	217.6	34.8	4.1	91.2	0.13
1978	290.1	50.6	7.0	94.5	0.15
1980	337.4	58.5	5.0	121.0	0.14
1982	372.3	66.9	5.3	118.5	0.15

1. Includes Chugach Electric Association, Homer Electric Association (HEA) and Kenai City Light (KCL), Matanuska and Seward.
   Source: Reference 4.
2. Reference 4.
3. Reference 4.
4. Data obtained from Anchorage Municipal Light and Power (AMLP), July 29, 1983.
5. $\frac{\text{HEA + KCL + Seward}}{\text{Chugach + AMLP}}$

TABLE 12.3-5

HISTORICAL ANCHORAGE AND COOK INLET ENERGY REQUIREMENTS

Year	Energy Requirement, GWH: Chugach[1]	HEA+KCL[2]	Seward[3]	AMLP[4]	Load Fraction Occurring in Kenai Peninsula[5]
1974	708.4	124.8	16.0	391.7	0.13
1976	1,091.0	174.9	19.2	444.9	0.13
1978	1,351.0	240.0	23.2	443.1	0.15
1980	1,491.8	284.6	26.0	486.6	0.16
1982	1,765.2	346.5	29.5	579.5	0.16

1. Includes Chugach Electric Association, Homer Electric Association (HEA) and Kenai City Light (KCL), Matanuska and Seward. Source: Reference 4.
2. Reference 4.
3. Reference 4.
4. Reference 2, Exhibit B, Table B.86 except 1974 value which was obtained from Anchorage Municipal Light and Power (AMLP) data.
5. $\frac{\text{HEA + KCL + Seward}}{\text{Chugach + AMLP}}$

TABLE 12.3-6

LOAD PROJECTION (NET)
SHERMAN H. CLARK NSD CASE
SEPARATION OF ANCHORAGE — COOK INLET LOAD
INTO ANCHORAGE AND KENAI PENINSULA

Year	Anchorage		Kenai Peninsula	
	Energy-GWH	Demand-MW	Energy-GWH	Demand-MW
1983	1,974	399	348	70
1984	2,076	419	366	74
1985	2,177	439	384	78
1986	2,259	457	399	81
1987	2,342	474	413	84
1988	2,424	492	428	87
1989	2,507	509	442	90
1990	2,588	526	457	93
1991	2,644	538	467	95
1992	2,700	549	476	97
1993	2,754	560	486	99
1994	2,810	571	496	101
1995	2,865	583	506	103
1996	2,915	592	514	105
1997	2,964	603	523	106
1998	3,013	613	532	108
1999	3,063	622	541	110
2000	3,113	632	549	112
2001	3,188	648	563	114
2002	3,264	663	576	117
2003	3,340	678	589	120
2004	3,415	694	603	122
2005	3,491	709	616	125
2006	3,597	730	635	129
2007	3,704	752	654	133
2008	3,811	774	673	137
2009	3,918	796	691	140
2010	4,025	817	710	144

TABLE 12.3-7

FUEL PRICE PROJECTIONS
SHERMAN H. CLARK NSD SCENARIO
1983 $/MMBTU

Year	Natural Gas*	Diesel Oil	Turbine Oil	Beluga Coal	Nenana Coal
1983	2.77	6.87	6.23	1.86	1.72
1984	2.57	6.55	5.94	1.89	1.74
1985	2.46	6.25	5.66	1.92	1.77
1986	2.81	6.25	5.66	1.95	1.83
1987	2.81	6.25	5.66	1.98	1.83
1988	2.89	6.25	5.66	2.01	1.92
1989	2.96	6.43	5.83	2.05	1.97
1990	3.04	6.63	6.01	2.08	2.02
1991	3.13	6.83	6.19	2.11	2.07
1992	3.21	7.03	6.38	2.15	2.11
1993	3.30	7.24	6.57	2.18	2.17
1994	3.39	7.46	6.76	2.21	2.22
1995	3.48	7.68	6.97	2.25	2.27
1996	3.57	7.91	7.18	2.29	2.32
1997	3.67	8.15	7.39	2.32	2.38
1998	3.77	8.39	7.61	2.36	2.43
1999	3.88	8.64	7.84	2.40	2.48
2000	3.99	8.91	8.08	2.44	2.55
2001	4.10	9.18	8.32	2.48	2.60
2002	4.21	9.45	8.57	2.51	2.66
2003	4.33	9.74	8.83	2.55	2.73
2004	4.45	10.03	9.09	2.60	2.79
2005	4.57	10.32	9.36	2.64	2.85
2006	4.70	10.63	9.64	2.68	2.93
2007	4.83	10.95	9.93	2.72	2.99
2008	4.97	11.28	10.23	2.77	3.06
2009	5.11	11.62	10.54	2.81	3.14
2010	5.25	11.97	10.85	2.86	3.21
2011	5.38	12.26	11.31	2.90	3.28
2012	5.50	12.57	11.40	2.95	3.35
2013	5.63	12.88	11.69	2.99	3.43
2014	5.77	13.21	11.98	3.04	3.51
2015	5.90	13.54	12.28	3.09	3.58
2016	6.04	13.88	12.59	3.14	3.66
2017	6.19	14.22	12.90	3.19	3.75
2018	6.34	14.58	13.23	3.24	3.83
2019	6.49	14.94	13.56	3.29	3.91
2020	6.64	15.32	13.89	3.35	4.00

TABLE 12.3-8

FUEL PRICE PROJECTIONS
SHERMAN H. CLARK NSD SCENARIO
1983 $/MMBTU

Year	Natural Gas*	Diesel Oil	Turbine Oil	Beluga Coal	Nenana Coal
2021	6.74	15.55	14.10	3.40	4.09
2022	6.83	15.78	14.31	3.45	4.18
2023	6.93	16.02	14.53	3.51	4.28
2024	7.03	16.26	14.75	3.57	4.37
2025	7.13	16.50	14.97	3.62	4.47
2026	7.23	16.75	15.19	3.68	4.57
2027	7.34	17.00	15.42	3.74	4.67
2028	7.44	17.25	15.65	3.80	4.77
2029	7.55	17.51	15.89	3.86	4.88
2030	7.66	17.78	16.13	3.92	4.99
2031	7.73	17.95	16.29	3.98	5.10
2032	7.81	18.13	16.45	4.05	5.21
2033	7.88	18.31	16.61	4.11	5.33
2034	7.96	18.50	16.78	4.18	5.45
2035	8.03	18.68	16.95	4.25	5.57
2036	8.11	18.87	17.12	4.31	5.70
2037	8.19	19.06	17.29	4.38	5.82

* Includes 30¢/MMBTU for pipeline transportation cost.

Source: Reference 2, Exhibit D, Appendix D-1, Table D-1.9 (natural gas), Table D-2.14 (Beluga coal and Nenana coal), and Table D-3.2 (diesel oil and turbine oil).

TABLE 12.3-8

TOTAL GENERATING CAPACITY WITHIN THE RAILBELT SYSTEM -- 1982

Abbreviations	Railbelt Utility	Installed Capacity[1]
AMLP	Anchorage Municipal Light and Power Department	311.6
CEA	Chugach Electric Association	463.5
GVEA	Golden Valley Electric Association	221.6
FMUS	Fairbanks Municipal Utilities System	68.5
MEA	Matanuska Electric Association	0.9
HEA	Homer Electric Association	2.6
SES	Seward Electric System	5.5
APAd	Alaska Power Administration	30.0
U of A	University of Alaska	18.6
Total		1,122.8[2]

(1) Installed capacity as of 1982 at 0°F.
(2) Excludes National Defense installed capacity of 101.3 MW.

Source: Reference 2, Exhibit D, Table D.13.

TABLE 12.3-9

EXISTING GENERATING PLANTS IN THE RAILBELT

Plant/Unit	Prime Mover	Fuel Type	Date	Nameplate Capacity (MW)	Generating Capacity @ 0°F (MW)	Heat Rate (BTU/kWh)
ALASKA POWER ADMINISTRATION						
Eklutna[a]	H	--	1955	30.00	--	--
ANCHORAGE MUNICIPAL LIGHT AND POWER						
Station #1[b]						
Unit #1	SCCT	NG/O	1962	14.00	16.3	14,000
Unit #2	SCCT	NG/O	1964	14.00	16.3	14,000
Unit #3	SCCT	NG/O	1968	18.00	18.0	14,000
Unit #4	SCCT	NG/O	1972	28.50	32.0	12,500
Diesel 1[c]	D	O	1962	1.10	1.1	10,500
Diesel 2[c]	D	O	1962	1.10	1.1	10,500
Station #2[d]						
Unit #5	SCCT	O	1974	32.30	40.0	12,500
Unit #6	CCST	--	1979	33.00	33.0	--
Unit #7	SCCT	O	1980	73.60	90.0	11,000
Unit #8	SCCT	NG/O	1982	73.60	90.0	12,500
CHUGACH ELECTRIC ASSOCIATION						
Beluga						
Unit #1	SCCT	NG	1968	15.25	16.1	15,000
Unit #2	SCCT	NG	1968	15.25	16.1	15,000
Unit #3	RCCT	NG	1973	53.30	53.0	10,000
Unit #4[e]	SCCT	NG	1976	10.00	10.7	15,000
Unit #5	RCCT	NG	1975	58.50	58.0	10,000
Unit #6	CCCT	NG	1976	72.90	68.0	15,000
Unit #7	CCCT	NG	1977	72.90	68.0	15,000
Unit #8[f]	CCST	NG	1982	55.00	42.0	--

EXISTING GENERATING PLANTS IN THE RAILBELT

Plant/Unit	Prime Mover	Fuel Type	Date	Nameplate Capacity (MW)	Generating Capacity @ 0°F (MW)	Heat Rate (BTU/kWh)
CHUGACH ELECTRIC ASSOCIATION (continued)						
Cooper Lake[g]						
Units #1, 2	H	--	1961	15.0	16.0	--
International						
Unit #1	SCCT	NG	1964	14.0	14.0	15,000
Unit #2	SCCT	NG	1965	14.0	14.0	15,000
Unit #3	SCCT	NG	1970	18.5	18.0	15,000
Bernice Lake						
Unit #1	SCCT	NG	1963	7.5	8.6	23,400
Unit #2	SCCT	NG	1972	16.5	18.9	23,400
Unit #3	SCCT	NG	1978	23.0	26.4	23,400
Unit #4	SCCT	NG	1982	23.0	26.4	12,000
Knik Arm[h]						
Unit #1	ST	NG	1952	0.5	0.5	--
Unit #2	ST	NG	1952	3.0	3.0	--
Unit #3	ST	NG	1957	3.0	3.0	--
Unit #4	ST	NG	1957	3.0	3.0	--
Unit #5	ST	NG	1957	5.0	5.0	--
HOMER ELECTRIC ASSOCIATION						
Kenai						
Unit #1	D	O	1979	0.9	0.9	15,000
Point Graham						
Unit #1	D	O	1971	0.2	0.2	15,000
Seldovia						
Unit #1	D	O	1952	0.3	0.3	15,000
Unit #2	D	O	1964	0.6	0.6	15,000
Unit #3	D	O	1970	0.6	0.6	15,000

EXISTING GENERATING PLANTS IN THE RAILBELT

Plant/Unit	Prime Mover	Fuel Type	Date	Nameplate Capacity (MW)	Generating Capacity @ 0°F (MW)	Heat Rate (BTU/kWh)
			MATANUSKA ELECTRIC ASSOCIATION			
Talkeetna						
Unit #1	D	O	1967	0.9	0.9	15,000
			SEWARD ELECTRIC SYSTEM			
SES[(j)]						
Unit #1	D	O	1965	1.5	1.5	15,000
Unit #2	D	O	1965	1.5	1.5	15,000
Unit #3	D	O	1965	2.5	2.5	15,000
			MILITARY INSTALLATIONS -- ANCHORAGE AREA			
Elmendorf AFB						
Total Diesel	D	O	1952	2.1	--	10,500
Total ST	ST	NG	1952	31.5	--	12,000
Fort Richardson						
Total Diesel[(c)]	D	O	1952	7.2	--	10,500
Total ST[(i)]	ST	NG	1952	18.0	--	20,000
			GOLDEN VALLEY ELECTRIC ASSOCIATION			
Healy						
Coal	ST	Coal	1967	64.7	65.0	13,200
Diesel[(c)]	D	O	1967	64.7	65.0	10,500
North Pole						
Unit #1	SCCT	O	1976	64.7	65.0	14,000
Unit #2	SCCT	O	1977	64.7	65.0	14,000
Zendher						
GT1	SCCT	O	1971	18.4	18.4	15,000
GT2	SCCT	O	1972	17.4	17.4	15,000
GT3	SCCT	O	1975	2.8	3.5	15,000
GT4	SCCT	O	1975	2.8	3.5	15,000
Combined Diesel	D	O	1960-70	21.0	21.0	10,500

TABLE 12.3-10

EXISTING GENERATING PLANTS IN THE RAILBELT

Plant/Unit	Prime Mover	Fuel Type	Date	Nameplate Capacity (MW)	Generating Capacity @ 0°F (MW)	Heat Rate (BTU/kWh)
UNIVERSITY OF ALASKA -- FAIRBANKS						
S1	ST	Coal	--	1.50	1.50	12,000
S2	ST	Coal	1980	1.50	1.50	12,000
S3	ST	Coal	--	10.00	10.00	12,000
D1	D	O	--	2.80	2.80	10,500
D2	D	O	--	2.80	2.80	20,500
FAIRBANKS MUNICIPAL UTILITIES SYSTEM						
Chena						
Unit #1	ST	Coal	1954	5.00	5.00	18,000
Unit #2	ST	Coal	1952	2.50	2.50	22,000
Unit #3	ST	Coal	1952	1.50	1.50	22,000
Unit #4	SCCT	O	1963	5.30	7.00	15,000
Unit #5	ST	Coal	1970	21.00	21.00	13,320
Unit #6	SCCT	O	1976	23.10	28.80	15,000
Diesel #1	D	O	1967	2.80	2.80	12,150
Diesel #2	D	O	1968	2.80	2.80	12,150
Diesel #3	D	O	1968	2.80	2.80	12,150
MILITARY INSTALLATIONS -- FAIRBANKS						
Eielson AFB						
S1, S2	ST	O	1953	2.50	--	--
S3, S4	ST	O	1953	6.25	--	--
Fort Greeley						
D1, D2, D3[i]	D	O	--	3.00	--	10,500
D4, D5[i]	D	O	--	2.50	--	10,500
Fort Wainwright[j]						
S1, S2, S3, S4	ST	Coal	1953	20.00	--	20,000
S5[i]	ST	Coal	1953	2.00	--	--

TABLE 12.3-10

EXISTING GENERATING PLANTS IN THE RAILBELT

Legend:

H	-	Hydro.
D	-	Diesel.
SCCT	-	Simple cycle combustion turbine.
RCCT	-	Regenerative cycle combustion turbine.
ST	-	Steam turbine.
CCCT	-	Combined cycle combustion turbine.
NG	-	Natural gas.
O	-	Distillate fuel oil.

Notes:

(a) Average annual energy production for Eklutna is approximately 148 GWh.

(b) All AMLP SCCT's are equipped to burn natural gas or oil. In normal operation they are supplied with natural gas. All units have reserve oil storage for operation in the event gas is not available.

(c) These are black-start units only. They are not included in total capacity.

(d) Units #5, 6, and 7 are designed to operate as a combined cycle plant. When operated in this mode, they have a generating capacity at 0°F of approximately 139 MW with a heat rate of 8,500 BTU/kWh.

(e) Jet engine, not included in total capacity.

(f) Beluga Units #6, 7, and 8 operate as a combined cycle plant. When operated in this mode, they have a generating capacity of about 178 MW with a heat rate of 8,500 BTU/kWh.

(g) Average annual energy production for Cooper Lake is approximately 42 GWh.

(h) Knik Arm units are old and have higher heat rates; they are not included in total.

(i) Standby units.

(j) Cogeneration used for steam heating.

Source: Reference 2, Exhibit B, Table B.73.

TABLE 12.3-10

THERMAL GENERATION PLANT PARAMETERS
1983 DOLLARS***

Years	Capital Cost* $/KW	Fixed O&M $/KW-YR	Variable O&M $/MWH	Forced Outages %	Heat Rate BTU/KWH	Construction Period Years	Lifetime Years
Combined Cycle 200 MW	1,185	7.76	1.81	8.0	8,000	2	30
Gas Turbine 70 MW	683	2.89	5.18	8.0	12,200	1	20
Coal** 200 MW	2,632	18.01	0.64	5.7	10,000	6	30

* Includes IDC at the rate of 3.5 percent per year.

** Includes transmission cost.

*** 1982 dollars were escalated to 1983 dollars by 7 percent.

Source: Reference 2, Exhibit D, Table D.18.

TABLE 12.3-11

NEW HYDROELECTRIC GENERATION ALTERNATIVES
PLANT PARAMETERS

Hydroelectric Plant	Capacity MW	Average Annual Energy, GWH	Projected Installation Year
Bradley Lake	60	330.5	1988
Bradley Lake	90	345.4	1988
Bradley Lake	135	356.6	1988
Watana*	1,020	3,499.0	1993
Devil Canyon*	600	3,435.0	2002

*Source: Reference 2, Exhibit B, page B-3-11.

TABLE 12.3-12

BRADLEY LAKE HYDROELECTRIC PROJECT
PLANT COSTS

Bradley Lake Capacity, MW	Millions 1983 Dollars Capital Cost*	Annual Fixed O&M**
60	275.70	1.252
90	287.95	1.252
135***	303.50	1.252

* Includes IDC.

** Includes cost of annual capital renewals (i.e., sinking fund for periodic major equipment replacement).

*** Excludes cost of 230 kV Anchorage/Soldotna transmission line.

NOTE: For description of Capital Costs and Annual Fixed O&M Cost, see Section 11 of this report.

TABLE 12.3-13

SUSITNA HYDROELECTRIC PROJECT
PLANT COSTS

	Millions 1982 Dollars*		
	Capital Cost**	Annual Fixed O&M	Annual Capital Renewals
Watana	4081	10.4	10.79
Devil Canyon	1734	4.8	4.66

* 1982 dollars were escalated to 1983 dollars by 7% for the economic analysis.

** Includes AFUDC.

Source: Reference 2, Exhibit D, Table D.1, Table D.5 and Table D.12.

TABLE 12.3-14

RAILBELT PEAK DEMAND AND ENERGY PROJECTION (NET) DOR 50% SCENARIO (JULY 1983)

Year	Peak Demand MW	Peak Demand Change, %*	Energy GWH
1983	580	5.34	2,808
1984	611	4.91	2,956
1985	641	3.12	3,104
1986	661	3.18	3,198
1987	682	2.93	3,292
1988	702	2.99	3,385
1989	723	2.77	3,479
1990	743	1.35	3,573
1991	753	1.33	3,620
1992	763	1.18	3,667
1993	772	1.30	3,714
1994	782	1.28	3,761
1995	792	1.64	3,808
1996	805	1.61	3,871
1997	818	1.59	3,935
1998	831	1.56	3,998
1999	844	1.54	4,062
2000	857	2.10	4,125
2001	875	2.06	4,211
2002	893	1.90	4,297
2003	910	1.98	4,384
2004	928	1.94	4,470
2005	946	2.64	4,556
2006	971	2.57	4,676
2007	996	2.41	4,796
2008	1,020	2.45	4,916
2009	1,045	2.39	5,036
2010	1,070	----	5,156

Average annual compound growth rate: 2.3%
Average load factor: 55%

*Percent change from current to following year.

Source: Alaska Power Authority

TABLE 12.3-15

FUEL PRICE PROJECTIONS
DOR 50% SCENARIO (JULY 1983)
1983 $/MMBTU

Year	Natural Gas*	Turbine Oil	Coal
1983	2.77	6.23	1.80
1984	2.60	5.80	1.80
1985	2.43	5.37	1.80
1986	2.47	5.30	1.80
1987	2.51	5.23	1.80
1988	2.54	5.16	1.80
1989	2.58	5.09	1.80
1990	2.62	5.02	1.80
1991	2.60	4.98	1.80
1992	2.58	4.95	1.80
1993	2.57	4.91	1.80
1994	2.55	4.88	1.80
1995	2.53	4.84	1.80
1996	2.52	4.81	1.80
1997	2.50	4.77	1.80
1998	2.49	4.74	1.80
1999	2.47	4.70	1.80
2000**	2.46	4.67	1.80

* Includes 30¢/MMBTU for pipeline transportation cost.
** All fuel prices remain constant after the year 2000.

Source: Alaska Power Authority

TABLE 12.3-16

LEVELIZED FUEL COSTS (1988-2037)
$/MMBTU

	Natural Gas	Coal
Sherman Clark NSD Case	4.77	2.73
DOR 50% Case (July 1983)	2.50	1.80

TABLE 12.3-17

ALTERNATIVES TO BRADLEY LAKE
PRESENT WORTH COST OF OPTIMUM EXPANSION PLANS

ALTERNATIVE	PRESENT WORTH COST MILLIONS OF 1983 DOLLARS
° Thermal without hydroelectric (combined cycle, gas turbines, coal)	
- with Anchorage/Soldotna 230 KV Tie	5,832
- without Anchorage/Soldotna 230 KV Tie	5,860
° Susitna and Thermal	
- with Anchorage/Soldotna 230 KV Tie	5,724

TABLE 12.4-1

BRADLEY LAKE WITHOUT SUSITNA
PRESENT WORTH COSTS AND SAVINGS
FOR DIFFERENT BRADLEY LAKE CAPACITIES
TOTAL RAILBELT EXPANSION PLANS

BRADLEY LAKE CAPACITY, MW	ANCHORAGE/SOLDOTNA 230 KV TIE	PRESENT WORTH, MILLIONS 1983 $ TOTAL COST	SAVINGS DUE TO BRADLEY LAKE	SAVINGS COMPARED TO RAILBELT BASE CASE, %
60	NO	5,517	315	5.4
90	NO	5,464	368	6.3
135	YES	5,535	297	5.1

Railbelt Base Case Present Worth Cost = $5,832 (Millions 1983 $)

TABLE 12.4-2

BRADLEY LAKE WITHOUT SUSITNA
PRESENT WORTH COSTS AND SAVINGS
FOR DIFFERENT BRADLEY LAKE CAPACITIES
KENAI PENINSULA EXPANSION PLANS

BRADLEY LAKE CAPACITY, MW	ANCHORAGE/SOLDOTNA 230 KV TIE	PRESENT WORTH, MILLIONS 1983 $ TOTAL COST	PRESENT WORTH, MILLIONS 1983 $ SAVINGS DUE TO BRADLEY LAKE	SAVINGS COMPARED TO KENAI PENIN. BASE CASE, %
60	NO	605	299	33.1
90	NO	599	305	33.7
135	YES	695	209	23.1

Kenai Peninsula Base Case Present Worth Cost = $904 (Millions 1983 $)

TABLE 12.4-3

NEW GENERATION CAPACITY ADDED
BASE CASE (THERMAL PLANTS ONLY)
SHERMAN H. CLARK NSD CASE

	Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	200	---	---	---	---
1989	---	---	---	---	---	---
1990	---	---	---	---	---	---
1991	---	---	---	---	---	---
1992	---	---	---	---	---	---
1993	---	---	---	---	---	---
1994	1.0	200	---	---	---	---
1995	---	---	---	---	---	---
1996	---	---	---	---	---	---
1997	1.0	200	---	---	---	---
1998	---	---	---	---	---	---
1999	---	---	---	---	---	---
2000	1.0	200	---	---	---	---
2001	---	---	---	---	---	---
2002	---	---	---	---	---	---
2003	---	---	---	---	1.0	70
2004	---	---	1.0	200	---	---
2005	---	---	1.0	200	---	---
2006	---	---	1.0	200	---	---
2007	---	---	---	---	---	---
Total	4.0	800	3.0	600	1.0	70

TABLE 12.4-4

NEW GENERATION CAPACITY ADDED
60 MW BRADLEY LAKE PROJECT
SHERMAN H. CLARK NSD CASE

	Hydroelectric		Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	60	1.0	200	---	---	---	---
1989	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	1.0	200	---	---	---	---
1997	---	---	1.0	200	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	1.0	70
2001	---	---	---	---	---	---	---	---
2002	---	---	---	---	---	---	1.0	70
2003	---	---	---	---	---	---	1.0	70
2004	---	---	---	---	1.0	200	---	---
2005	---	---	---	---	1.0	200	---	---
2006	---	---	---	---	1.0	200	---	---
2007	---	---	---	---	---	---	---	---
Total	1.0	60	3.0	600	3.0	600	3.0	210

TABLE 12.4-5

NEW GENERATION CAPACITY ADDED
90 MW BRADLEY LAKE PROJECT
SHERMAN H. CLARK NSD CASE

	Hydroelectric		Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	90	---	---	---	---	---	---
1989	---	---	1.0	200	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	1.0	200	---	---	---	---
1997	---	---	1.0	200	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---
2001	---	---	---	---	---	---	1.0	70
2002	---	---	---	---	---	---	1.0	70
2003	---	---	---	---	1.0	200	---	---
2004	---	---	---	---	---	---	---	---
2005	---	---	---	---	1.0	200	---	---
2006	---	---	---	---	1.0	200	---	---
2007	---	---	---	---	---	---	---	---
Total	1.0	90	3.0	600	3.0	600	2.0	140

TABLE 12.4-6

NEW GENERATION CAPACITY ADDED
135 MW BRADLEY LAKE PROJECT
SHERMAN H. CLARK NSD CASE

	Hydroelectric		Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	135	---	---	---	---	---	---
1989	---	---	1.0	200	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	1.0	200	---	---	---	---
1997	---	---	---	---	---	---	---	---
1998	---	---	---	---	---	---	1.0	70
1999	---	---	---	---	---	---	---	---
2000	---	---	1.0	200	---	---	---	---
2001	---	---	---	---	---	---	---	---
2002	---	---	---	---	---	---	---	---
2003	---	---	---	---	---	---	1.0	70
2004	---	---	---	---	1.0	200	---	---
2005	---	---	---	---	1.0	200	---	---
2006	---	---	---	---	1.0	200	---	---
2007	---	---	---	---	---	---	---	---
Total	1.0	135	3.0	600	3.0	600	2.0	140

TABLE 12.4-7

GENERATION BY FUEL CLASS
BASE CASE (NEW THERMAL PLANTS ONLY)
SHERMAN H. CLARK NSD CASE

	Natural Gas		Coal		Oil		Existing Hydroelectric		Total Railbelt	
Year	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy* GWH	Fuel Cost $\$10^6$
1988	2,903	78	633	16	28	1	190	0	3,753	96
1989	3,032	84	638	16	39	2	190	0	3,899	103
1990	3,153	91	642	17	54	3	190	0	4,039	111
1991	3,237	97	645	17	66	4	190	0	4,137	118
1992	3,303	102	647	18	90	5	190	0	4,230	125
1993	3,375	107	649	18	108	7	190	0	4,322	132
1994	3,652	109	543	16	33	2	190	0	4,418	127
1995	3,726	115	550	16	46	3	190	0	4,511	134
1996	3,794	120	556	17	50	3	190	0	4,590	140
1997	4,288	135	172	5	19	1	190	0	4,669	141
1998	4,342	140	177	5	34	2	190	0	4,743	148
1999	4,416	147	179	6	39	3	190	0	4,824	155
2000	4,616	154	89	3	14	1	190	0	4,909	158
2001	4,731	163	89	3	17	1	190	0	5,027	167
2002	4,836	171	89	3	27	2	190	0	5,142	176
2003	4,947	180	89	3	29	2	190	0	5,255	185
2004	3,890	146	1,292	34	0	0	190	0	5,372	180
2005	3,005	117	2,447	65	0	0	42	0	5,493	182
2006	1,992	82	3,623	98	0	0	42	0	5,657	180
2007	2,131	90	3,643	100	0	0	42	0	5,816	189

*Gross Generation

TABLE 12.4-8

GENERATION BY FUEL CLASS
90 MW BRADLEY LAKE PROJECT
SHERMAN H. CLARK NSD CASE

Year	Natural Gas Energy GWH	Natural Gas Fuel Cost $10^6	Coal Energy GWH	Coal Fuel Cost $10^6	Oil Energy GWH	Oil Fuel Cost $10^6	Hydroelectric* Energy GWH	Hydroelectric* Fuel Cost $10^6	Total Railbelt Energy** GWH	Total Railbelt Fuel Cost $10^6
1988	2,498	73	675	17	44	2	535	0	3,753	92
1989	2,710	70	642	17	11	1	535	0	3,899	87
1990	2,842	76	646	17	16	1	535	0	4,040	94
1991	2,934	82	648	18	21	1	535	0	4,138	100
1992	3,015	87	650	18	30	2	535	0	4,232	106
1993	3,099	92	652	18	38	2	535	0	4,325	113
1994	3,170	97	650	19	61	4	535	0	4,418	120
1995	3,251	102	652	19	73	5	535	0	4,511	126
1996	3,479	104	562	17	18	1	535	0	4,594	122
1997	3,948	119	178	5	10	1	535	0	4,672	125
1998	4,017	124	180	6	16	1	535	0	4,748	130
1999	4,100	130	180	6	16	1	535	0	4,831	137
2000	4,258	139	89	3	24	2	535	0	4,906	144
2001	4,390	148	89	3	14	1	535	0	5,029	152
2002	4,511	157	89	3	13	1	535	0	5,148	160
2003	3,429	121	1,292	34	8	1	535	0	5,264	155
2004	3,547	129	1,292	34	0	0	535	0	5,375	163
2005	2,657	99	2,451	65	0	0	387	0	5,496	164
2006	1,635	63	3,638	98	0	0	387	0	5,660	161
2007	1,773	71	3,656	100	0	0	387	0	5,817	171

* 90 MW Bradley Lake Project plus existing hydroelectric plants.
** Gross generation.

TABLE 12.4-9

EXPANSION PLAN SUMMARY
BASE CASE (THERMAL PLANTS)
REFERENCE CASE LOAD

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW....... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	780.	3757.			1079.	38.29		
1988	779.	3754.	200.	6.	1279.	64.07	200.	237.
1989	810.	3899.	0.	0.	1279.	57.95	0.	0.
1990	839.	4040.	0.	1.	1278.	52.39	0.	0.
1991	859.	4139.	0.	19.	1259.	46.58	0.	0.
1992	879.	4232.	0.	31.	1228.	39.76	0.	0.
1993	898.	4326.	0.	8.	1221.	35.91	0.	0.
1994	918.	4419.	200.	28.	1393.	51.78	200.	237.
1995	937.	4513.	0.	20.	1373.	46.54	0.	0.
1996	954.	4596.	0.	88.	1285.	34.69	0.	0.
1997	970.	4674.	200.	129.	1356.	39.71	200.	237.
1998	987.	4752.	0.	49.	1307.	32.50	0.	0.
1999	1004.	4835.	0.	1.	1306.	30.13	0.	0.
2000	1020.	4913.	200.	45.	1461.	43.26	200.	237.
2001	1045.	5032.	0.	0.	1461.	39.86	0.	0.
2002	1070.	5152.	0.	45.	1416.	32.40	0.	0.
2003	1093.	5266.	70.	53.	1433.	31.05	70.	48.
2004	1118.	5386.	200.	139.	1494.	33.61	200.	526.
2005	1143.	5505.	200.	89.	1606.	40.46	200.	526.
2006	1178.	5672.	200.	188.	1618.	37.36	200.	526.
2007	1211.	5833.	0.	0.	1618.	33.57	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	........................COST SUMMARY........................ ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	104.	2.	13.	118.	118.	100.	100.
1989	112.	2.	13.	126.	245.	103.	202.
1990	120.	2.	13.	135.	379.	106.	308.
1991	128.	2.	13.	142.	521.	108.	416.
1992	135.	2.	13.	149.	671.	110.	526.
1993	143.	2.	13.	157.	828.	112.	637.
1994	136.	3.	26.	165.	993.	113.	750.
1995	143.	3.	26.	172.	1165.	114.	864.
1996	150.	3.	26.	178.	1343.	114.	978.
1997	150.	5.	39.	193.	1536.	119.	1097.
1998	157.	5.	39.	200.	1737.	119.	1217.
1999	164.	5.	39.	208.	1944.	120.	1337.
2000	167.	6.	52.	225.	2169.	125.	1462.
2001	176.	6.	52.	234.	2403.	126.	1588.
2002	185.	6.	52.	243.	2646.	126.	1714.
2003	195.	6.	55.	257.	2903.	129.	1843.
2004	189.	10.	84.	282.	3185.	137.	1980.
2005	189.	14.	112.	315.	3500.	148.	2128.
2006	186.	17.	141.	344.	3844.	156.	2284.
2007	196.	17.	141.	354.	4198.	155.	2439.
EXT.						3293.	5732.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-10

EXPANSION PLAN SUMMARY
90 MW BRADLEY LAKE PROJECT
REFERENCE CASE LOAD

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	CAPACITY, MW INSTALLED	CAPACITY, MW RETIRED	CAPACITY, MW TOTAL	RESERVE PERCENT	NEW UNITS CAPACITY, MW	NEW UNITS CAPITAL COSTS, M$
BENCH	780.	3757.			1079.	38.29		
1988	779.	3754.	90.	6.	1169.	49.96	90.	288.
1989	810.	3899.	200.	0.	1369.	69.06	200.	237.
1990	839.	4040.	0.	1.	1368.	63.12	0.	0.
1991	859.	4139.	0.	19.	1349.	57.05	0.	0.
1992	879.	4232.	0.	31.	1318.	50.01	0.	0.
1993	898.	4326.	0.	8.	1311.	45.93	0.	0.
1994	918.	4419.	0.	28.	1283.	39.79	0.	0.
1995	937.	4513.	0.	20.	1263.	34.80	0.	0.
1996	954.	4596.	200.	88.	1375.	44.12	200.	237.
1997	970.	4674.	200.	129.	1446.	48.99	200.	237.
1998	987.	4752.	0.	49.	1397.	41.62	0.	0.
1999	1004.	4835.	0.	1.	1396.	39.10	0.	0.
2000	1020.	4913.	0.	45.	1351.	32.47	0.	0.
2001	1045.	5032.	70.	0.	1421.	36.03	70.	48.
2002	1070.	5152.	70.	45.	1446.	35.21	70.	48.
2003	1093.	5266.	200.	53.	1593.	45.69	200.	526.
2004	1118.	5386.	0.	139.	1454.	30.03	0.	0.
2005	1143.	5505.	200.	89.	1566.	36.96	200.	526.
2006	1178.	5672.	200.	188.	1578.	33.97	200.	526.
2007	1211.	5833.	0.	0.	1578.	30.27	0.	0.

YEAR	ALL UNITS PROD. COST	NEW UNITS ONLY FIXED O & M	NEW UNITS ONLY FIXED CHARGES	COST SUMMARY ANNUAL	COST SUMMARY CUM. ANNUAL	COST SUMMARY PRESENT WORTH	COST SUMMARY CUM. PRES. WORTH
1988	102.	1.	14.	117.	117.	99.	99.
1989	94.	3.	27.	124.	242.	101.	200.
1990	102.	3.	27.	132.	374.	104.	304.
1991	108.	3.	27.	138.	512.	105.	409.
1992	115.	3.	27.	145.	657.	106.	515.
1993	122.	3.	27.	152.	809.	108.	623.
1994	129.	3.	27.	159.	968.	109.	732.
1995	136.	3.	27.	166.	1134.	110.	842.
1996	130.	4.	40.	174.	1309.	111.	953.
1997	133.	6.	53.	192.	1500.	118.	1072.
1998	139.	6.	53.	198.	1698.	118.	1189.
1999	145.	6.	53.	204.	1902.	118.	1307.
2000	153.	6.	53.	212.	2114.	118.	1425.
2001	161.	6.	56.	224.	2337.	120.	1546.
2002	170.	6.	60.	236.	2574.	123.	1669.
2003	163.	10.	88.	261.	2835.	131.	1800.
2004	172.	10.	88.	270.	3105.	131.	1931.
2005	172.	14.	117.	302.	3407.	142.	2073.
2006	167.	17.	146.	330.	3738.	150.	2223.
2007	178.	17.	146.	340.	4078.	149.	2372.
EXT.						3089.	5461.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-11

BRADLEY LAKE WITH SUSITNA
PRESENT WORTH COSTS AND SAVINGS
FOR DIFFERENT BRADLEY LAKE CAPACITIES
TOTAL RAILBELT EXPANSION PLANS

BRADLEY LAKE CAPACITY, MW	ANCHORAGE/SOLDOTNA 230 KV TIE	PRESENT WORTH, MILLIONS 1983 $ TOTAL COST	PRESENT WORTH, MILLIONS 1983 $ SAVINGS DUE TO BRADLEY LAKE	SAVINGS COMPARED TO RAILBELT BASE CASE, %
60	NO	5,548	176	3.1
90	NO	5,549	175	3.1
135	YES	5,658	66	1.2

Railbelt Base Case Present Worth Cost = $5,724 (Millions 1983 $)

TABLE 12.4-12

BRADLEY LAKE WITH SUSITNA
PRESENT WORTH COSTS AND SAVINGS
FOR DIFFERENT BRADLEY LAKE CAPACITIES
KENAI PENINSULA EXPANSION PLANS

BRADLEY LAKE CAPACITY, MW	ANCHORAGE/SOLDOTNA 230 KV TIE	PRESENT WORTH, MILLIONS 1983 $ TOTAL COST	SAVINGS DUE TO BRADLEY LAKE	SAVINGS COMPARED TO KENAI PENIN. BASE CASE, %
60	NO	531	143	21.2
90	NO	523	151	22.4
135	YES	624	50	7.4

Kenai Peninsula Base Case Present Worth Cost = $674 (Millions 1983 $)

TABLE 12.4-13

EXPANSION PLAN SUMMARY
90 MW BRADLEY LAKE PROJECT WITH SUSITNA
REFERENCE CASE LOAD

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW....... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	780.	3757.			1079.	38.29		
1988	779.	3754.	90.	6.	1169.	49.96	90.	288.
1989	810.	3899.	0.	0.	1169.	44.36	0.	0.
1990	839.	4040.	0.	1.	1168.	39.27	0.	0.
1991	859.	4139.	0.	19.	1149.	33.78	0.	0.
1992	879.	4232.	0.	31.	1118.	27.25	0.	0.
1993	898.	4326.	1020.	8.	2131.	137.23	1020.	4367.
1994	918.	4419.	0.	28.	2103.	129.16	0.	0.
1995	937.	4513.	0.	20.	2083.	122.32	0.	0.
1996	954.	4596.	0.	88.	1995.	109.10	0.	0.
1997	970.	4674.	0.	129.	1866.	92.27	0.	0.
1998	987.	4752.	0.	49.	1817.	84.19	0.	0.
1999	1004.	4835.	0.	1.	1816.	80.94	0.	0.
2000	1020.	4913.	0.	45.	1771.	73.65	0.	0.
2001	1045.	5032.	0.	0.	1771.	69.53	0.	0.
2002	1070.	5152.	600.	45.	2326.	117.47	600.	1855.
2003	1093.	5266.	0.	53.	2273.	107.87	0.	0.
2004	1118.	5386.	0.	139.	2134.	90.84	0.	0.
2005	1143.	5505.	0.	89.	2046.	78.95	0.	0.
2006	1178.	5672.	0.	188.	1858.	57.74	0.	0.
2007	1211.	5833.	0.	0.	1858.	53.39	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	........................COST SUMMARY........................ ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	102.	1.	14.	117.	117.	99.	99.
1989	111.	1.	14.	126.	244.	103.	202.
1990	120.	1.	14.	136.	379.	107.	308.
1991	128.	1.	14.	144.	523.	109.	417.
1992	136.	1.	14.	152.	675.	112.	529.
1993	8.	24.	233.	265.	940.	188.	717.
1994	11.	24.	233.	268.	1208.	184.	900.
1995	14.	24.	233.	271.	1479.	179.	1080.
1996	17.	24.	233.	274.	1753.	175.	1255.
1997	21.	24.	233.	277.	2031.	171.	1426.
1998	24.	24.	233.	280.	2311.	167.	1594.
1999	27.	24.	233.	284.	2595.	164.	1757.
2000	31.	24.	233.	288.	2883.	160.	1918.
2001	36.	24.	233.	293.	3175.	158.	2075.
2002	0.	34.	325.	360.	3535.	187.	2262.
2003	0.	34.	325.	360.	3895.	181.	2443.
2004	0.	34.	325.	360.	4254.	175.	2618.
2005	0.	34.	325.	360.	4614.	169.	2786.
2006	0.	34.	325.	360.	4973.	163.	2949.
2007	0.	34.	325.	360.	5333.	157.	3107.
EXT.						2439.	5545.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-14

RAILBELT GENERATION EXPANSION PLANS
SENSITIVITY ANALYSIS TO RAILBELT NO-GROWTH CASE

	MILLIONS OF 1983 DOLLARS	
	PRESENT WORTH COST	PRESENT WORTH SAVINGS
0% Load Growth per year		
Without Susitna		
Thermal Plants only	3,194	-
60 MW Bradley Lake	2,966	228
90 MW Bradley Lake*	2,990	204
135 MW Bradley Lake*	3,010	184

* Includes Anchorage/Soldotna 230 KV Transmission Line

TABLE 12.4-15

NEW GENERATION CAPACITY ADDED
BASE CASE (THERMAL PLANTS ONLY)
0% LOAD GROWTH SENSITIVITY CASE*

	Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	---	---	---	---	---	---
1989	---	---	---	---	---	---
1990	---	---	---	---	---	---
1991	---	---	---	---	---	---
1992	---	---	---	---	---	---
1993	---	---	---	---	---	---
1994	---	---	---	---	---	---
1995	---	---	---	---	---	---
1996	---	---	---	---	---	---
1997	1.0	200	---	---	---	---
1998	---	---	---	---	---	---
1999	---	---	---	---	---	---
2000	---	---	---	---	---	---
2001	---	---	---	---	---	---
2002	---	---	---	---	---	---
2003	1.0	200	---	---	---	---
2004	---	---	---	---	---	---
2005	---	---	---	---	2.0	140
2006	---	---	1.0	200	---	---
2007	---	---	---	---	---	---
Total	2.0	400	1.0	200	2.0	140

*Assumed 0% load growth was used in combination with fuel prices from the Sherman Clark NSD Case.

TABLE 12.4-16

NEW GENERATION CAPACITY ADDED
90 MW BRADLEY LAKE PROJECT
0% LOAD GROWTH SENSITIVITY CASE*

	Hydroelectric		Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	90	---	---	---	---	---	---
1989	---	---	---	---	---	---	---	---
1990	---	---	---	---	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	---	---	---	---	---	---	---	---
1998	---	---	1.0	200	---	---	---	---
1999	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---
2001	---	---	---	---	---	---	---	---
2002	---	---	---	---	---	---	---	---
2003	---	---	---	---	---	---	---	---
2004	---	---	---	---	---	---	2.0	140
2005	---	---	---	---	---	---	1.0	70
2006	---	---	---	---	1.0	200	---	---
2007	---	---	---	---	---	---	---	---
Total	1.0	90	1.0	200	1.0	200	3.0	210

*Assumed 0% load growth was used in combination with fuel prices from the Sherman Clark NSD Case.

TABLE 12.4-17

GENERATION BY FUEL CASE
BASE CASE (NEW THERMAL PLANTS ONLY)
0% LOAD GROWTH SENSITIVITY CASE*

	Natural Gas		Coal		Oil		Hydroelectric*		Total Railbelt	
Year	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy** GWH	Fuel Cost $\$10^6$
1988	2,124	63	675	17	21	1	190	0	3,010	81
1989	2,124	64	675	17	21	1	190	0	3,010	83
1990	2,124	66	675	18	21	1	190	0	3,010	85
1991	2,124	68	675	18	21	1	190	0	3,010	88
1992	2,119	70	675	19	26	1	190	0	3,010	90
1993	2,119	72	675	19	26	2	190	0	3,010	92
1994	2,106	73	675	20	39	2	190	0	3,010	95
1995	2,097	74	675	20	47	3	190	0	3,010	97
1996	2,097	76	675	20	46	3	190	0	3,009	100
1997	2,584	87	219	7	16	1	190	0	3,008	94
1998	2,570	88	219	7	28	2	190	0	3,006	97
1999	2,570	91	219	7	28	2	190	0	3,006	100
2000	2,682	98	89	3	42	3	190	0	3,003	103
2001	2,682	100	89	3	42	3	190	0	3,003	106
2002	2,661	102	89	3	57	4	190	0	2,997	109
2003	2,711	101	89	3	16	1	190	0	3,007	106
2004	2,714	105	89	3	0	0	190	0	2,993	108
2005	2,869	114	89	3	0	0	42	0	3,000	117
2006	1,687	72	1,265	35	0	0	42	0	2,994	107
2007	1,687	74	1,265	35	0	0	42	0	2,994	110

*Assumed 0% load growth was used in combination with fuel prices from the Sherman Clark NSD Case.
**Gross generation.

TABLE 12.4-18

GENERATION BY FUEL CLASS
90 MW BRADLEY LAKE PROJECT
0% LOAD GROWTH SENSITIVITY CASE*

Year	Natural Gas Energy GWH	Natural Gas Fuel Cost $\$10^6$	Coal Energy GWH	Coal Fuel Cost $\$10^6$	Oil Energy GWH	Oil Fuel Cost $\$10^6$	Hydroelectric** Energy GWH	Hydroelectric** Fuel Cost $\$10^6$	Total Railbelt Energy*** GWH	Total Railbelt Fuel Cost $\$10^6$
1988	1,796	48	675	17	4	0	535	0	3,010	65
1989	1,796	49	675	17	4	0	535	0	3,010	67
1990	1,796	51	675	18	4	0	535	0	3,010	69
1991	1,796	52	675	18	4	0	535	0	3,010	71
1992	1,795	54	675	19	5	0	535	0	3,010	72
1993	1,795	55	675	19	5	0	535	0	3,010	75
1994	1,792	56	675	20	7	0	535	0	3,010	77
1995	1,790	58	675	20	9	1	535	0	3,010	78
1996	1,790	59	675	20	9	1	535	0	3,010	80
1997	2,218	79	233	7	22	1	535	0	3,010	87
1998	2,246	71	221	7	7	0	535	0	3,010	78
1999	2,246	73	221	7	7	1	535	0	3,010	81
2000	2,376	79	89	3	9	1	535	0	3,009	83
2001	2,376	82	89	3	9	1	535	0	3,009	85
2002	2,371	84	89	3	13	1	535	0	3,008	87
2003	2,357	86	89	3	24	2	535	0	3,006	91
2004	2,382	89	89	3	0	0	535	0	3,006	92
2005	2,528	100	89	3	0	0	387	0	3,004	103
2006	1,343	57	1,269	35	0	0	387	0	3,000	91
2007	1,185	50	1,433	40	0	0	387	0	3,005	90

*Assumed 0% load growth was used in combination with fuel prices from the Sherman Clark NSD Case.
**90 MW Bradley Lake Project plus existing hydroelectric plants.
***Gross generation.

TABLE 12.4-19

EXPANSION PLAN SUMMARY
BASE CASE (THERMAL PLANTS)
NO GROWTH CASE

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW....... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	625.	3010.			1079.	72.59		
1988	625.	3010.	0.	6.	1079.	72.59	0.	0.
1989	625.	3010.	0.	0.	1079.	72.59	0.	0.
1990	625.	3010.	0.	1.	1078.	72.50	0.	0.
1991	625.	3010.	0.	19.	1059.	69.52	0.	0.
1992	625.	3010.	0.	31.	1028.	64.50	0.	0.
1993	625.	3010.	0.	8.	1021.	63.30	0.	0.
1994	625.	3010.	0.	28.	993.	58.82	0.	0.
1995	625.	3010.	0.	20.	973.	55.68	0.	0.
1996	625.	3010.	0.	88.	885.	41.63	0.	0.
1997	625.	3010.	200.	129.	956.	52.93	200.	237.
1998	625.	3010.	0.	49.	907.	45.17	0.	0.
1999	625.	3010.	0.	1.	906.	45.02	0.	0.
2000	625.	3010.	0.	45.	861.	37.81	0.	0.
2001	625.	3010.	0.	0.	861.	37.81	0.	0.
2002	625.	3010.	0.	45.	816.	30.61	0.	0.
2003	625.	3010.	200.	53.	963.	54.08	200.	237.
2004	625.	3010.	0.	139.	824.	31.86	0.	0.
2005	625.	3010.	140.	89.	876.	40.10	140.	96.
2006	625.	3010.	200.	188.	888.	42.02	200.	526.
2007	625.	3010.	0.	0.	888.	42.02	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	........................COST SUMMARY........................ ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	89.	0.	0.	89.	89.	75.	75.
1989	91.	0.	0.	91.	179.	74.	148.
1990	93.	0.	0.	93.	272.	73.	221.
1991	95.	0.	0.	95.	367.	72.	294.
1992	98.	0.	0.	98.	465.	72.	365.
1993	100.	0.	0.	100.	565.	71.	436.
1994	103.	0.	0.	103.	668.	70.	506.
1995	105.	0.	0.	105.	773.	70.	576.
1996	108.	0.	0.	108.	880.	69.	645.
1997	101.	2.	13.	115.	995.	71.	716.
1998	103.	2.	13.	118.	1113.	70.	786.
1999	106.	2.	13.	121.	1234.	70.	856.
2000	110.	2.	13.	125.	1359.	69.	925.
2001	113.	2.	13.	128.	1486.	69.	994.
2002	116.	2.	13.	131.	1617.	68.	1062.
2003	111.	3.	26.	140.	1757.	70.	1132.
2004	114.	3.	26.	143.	1900.	69.	1202.
2005	124.	4.	32.	160.	2060.	75.	1277.
2006	113.	7.	61.	181.	2240.	82.	1359.
2007	115.	7.	61.	183.	2424.	80.	1439.
EXT.						1755.	3194.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-20

EXPANSION PLAN SUMMARY
90 MW BRADLEY LAKE PROJECT
NO GROWTH CASE

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW....... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	625.	3010.			1079.	72.59		
1988	625.	3010.	90.	6.	1169.	86.99	90.	288.
1989	625.	3010.	0.	0.	1169.	86.99	0.	0.
1990	625.	3010.	0.	1.	1168.	86.90	0.	0.
1991	625.	3010.	0:	19.	1149.	83.92	0.	0.
1992	625.	3010.	0.	31.	1118.	78.90	0.	0.
1993	625.	3010.	0.	8.	1111.	77.70	0.	0.
1994	625.	3010.	0.	28.	1083.	73.22	0.	0.
1995	625.	3010.	0.	20.	1063.	70.08	0.	0.
1996	625.	3010.	0.	88.	975.	56.03	0.	0.
1997	625.	3010.	0.	129.	846.	35.33	0.	0.
1998	625.	3010.	200.	49.	997.	59.57	200.	237.
1999	625.	3010.	0.	1.	996.	59.42	0.	0.
2000	625.	3010.	0.	45.	951.	52.21	0.	0.
2001	625.	3010.	0.	0.	951.	52.21	0.	0.
2002	625.	3010.	0.	45.	906.	45.01	0.	0.
2003	625.	3010.	0.	53.	853.	36.48	0.	0.
2004	625.	3010.	140.	139.	854.	36.66	140.	96.
2005	625.	3010.	70.	89.	836.	33.70	70.	48.
2006	625.	3010.	200.	188.	848.	35.62	200.	526.
2007	625.	3010.	0.	0.	848.	35.62	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	........................COST SUMMARY........................ ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	71.	1.	14.	87.	87.	73.	73.
1989	73.	1.	14.	89.	176.	72.	145.
1990	75.	1.	14.	90.	266.	71.	216.
1991	77.	1.	14.	92.	358.	70.	287.
1992	78.	1.	14.	94.	453.	69.	356.
1993	80.	1.	14.	96.	549.	68.	424.
1994	82.	1.	14.	98.	647.	67.	491.
1995	84.	1.	14.	100.	747.	66.	557.
1996	86.	1.	14.	102.	849.	65.	623.
1997	95.	1.	14.	111.	960.	68.	691.
1998	83.	3.	27.	113.	1073.	68.	759.
1999	85.	3.	27.	115.	1189.	67.	825.
2000	88.	3.	27.	118.	1307.	66.	891.
2001	90.	3.	27.	120.	1427.	65.	956.
2002	92.	3.	27.	123.	1549.	64.	1019.
2003	96.	3.	27.	126.	1675.	63.	1083.
2004	98.	3.	34.	135.	1810.	65.	1148.
2005	109.	3.	37.	150.	1960.	70.	1218.
2006	96.	7.	66.	169.	2129.	77.	1295.
2007	94.	7.	66.	167.	2296.	73.	1368.
EXT.						1516.	2884.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-21

NEW GENERATION CAPACITY ADDED
BASE CASE (THERMAL PLANTS ONLY)
DOR 50% CASE (JULY 1983)

	Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	200	---	---	---	---
1989	---	---	---	---	---	---
1990	---	---	---	---	---	---
1991	---	---	---	---	---	---
1992	---	---	---	---	---	---
1993	---	---	---	---	---	---
1994	---	---	---	---	---	---
1995	---	---	---	---	---	---
1996	1.0	200	---	---	---	---
1997	1.0	200	---	---	---	---
1998	---	---	---	---	---	---
1999	---	---	---	---	---	---
2000	---	---	---	---	---	---
2001	---	---	---	---	---	---
2002	---	---	---	---	1.0	70
2003	---	---	---	---	1.0	70
2004	1.0	200	---	---	---	---
2005	---	---	---	---	2.0	140
2006	1.0	200	---	---	---	---
2007	---	---	---	---	---	---
Total	5.0	1,000	-0-	-0-	4.0	280

TABLE 12.4-22

NEW GENERATION CAPACITY ADDED
90 MW BRADLEY LAKE PROJECT
DOR 50% CASE (JULY 1983)

	Hydroelectric		Combined Cycle 200 MW		Coal 200 MW		Gas Turbine 70 MW	
Year	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW	# Units	Capacity MW
1988	1.0	90	---	---	---	---	---	---
1989	---	---	---	---	---	---	---	---
1990	---	---	1.0	200	---	---	---	---
1991	---	---	---	---	---	---	---	---
1992	---	---	---	---	---	---	---	---
1993	---	---	---	---	---	---	---	---
1994	---	---	---	---	---	---	---	---
1995	---	---	---	---	---	---	---	---
1996	---	---	---	---	---	---	---	---
1997	---	---	1.0	200	---	---	---	---
1998	---	---	---	---	---	---	---	---
1999	---	---	---	---	---	---	1.0	70
2000	---	---	---	---	---	---	1.0	70
2001	---	---	---	---	---	---	---	---
2002	---	---	---	---	---	---	1.0	70
2003	---	---	---	---	---	---	1.0	70
2004	---	---	1.0	200	---	---	---	---
2005	---	---	---	---	---	---	1.0	70
2006	---	---	1.0	200	---	---	1.0	70
2007	---	---	---	---	---	---	---	---
Total	1.0	90	4.0	800	-0-	-0-	6.0	420

TABLE 12.4-23

GENERATION BY FUEL CLASS
BASE CASE (NEW THERMAL PLANTS ONLY)
DOR 50% CASE (JULY 1983)

Year	Natural Gas Energy GWH	Natural Gas Fuel Cost $10^6	Coal Energy GWH	Coal Fuel Cost $10^6	Oil Energy GWH	Oil Fuel Cost $10^6	Existing Hydroelectric Energy GWH	Existing Hydroelectric Fuel Cost $10^6	Total Railbelt Energy* GWH	Total Railbelt Fuel Cost $10^6
1988	3,012	71	492	12	26	1	190	0	3,719	84
1989	3,099	75	507	12	34	2	190	0	3,830	88
1990	3,185	78	518	12	43	2	190	0	3,936	93
1991	3,177	77	523	12	98	4	190	0	3,989	94
1992	3,261	80	528	12	62	3	190	0	4,041	95
1993	3,235	78	532	12	131	6	190	0	4,089	96
1994	3,255	78	535	13	161	7	190	0	4,141	97
1995	3,308	78	534	13	161	7	190	0	4,193	98
1996	3,701	81	329	8	43	2	190	0	4,263	91
1997	4,045	86	77	2	19	1	190	0	4,331	89
1998	4,102	87	80	2	26	1	190	0	4,398	90
1999	4,170	88	81	2	25	1	190	0	4,467	90
2000	4,256	89	51	1	34	1	190	0	4,531	92
2001	4,347	91	54	1	36	1	190	0	4,626	94
2002	4,447	93	55	1	30	1	190	0	4,722	96
2003	4,534	96	56	1	31	1	190	0	4,811	98
2004	4,685	97	32	1	0	0	190	0	4,906	97
2005	4,924	102	38	1	0	0	42	0	5,004	103
2006	5,071	105	19	1	0	0	42	0	5,132	106
2007	5,197	198	21	1	0	0	42	0	5,261	108

* Gross generation.

TABLE 12.4-24

GENERATION BY FUEL CLASS
90 MW BRADLEY LAKE PROJECT
DOR 50% CASE (JULY 1983)

	Natural Gas		Coal		Oil		Hydroelectric*		Total Railbelt	
Year	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy GWH	Fuel Cost $\$10^6$	Energy** GWH	Fuel Cost $\$10^6$
1988	2,498	64	645	15	40	2	535	0	3,719	81
1989	2,592	68	648	15	54	2	535	0	3,830	86
1990	2,862	66	526	12	12	1	535	0	3,936	78
1991	2,889	66	531	12	34	2	535	0	3,989	80
1992	2,952	67	536	13	19	1	535	0	4,042	81
1993	2,965	67	540	13	50	2	535	0	4,090	82
1994	3,004	67	539	13	64	3	535	0	4,143	83
1995	3,044	68	544	13	72	3	535	0	4,195	84
1996	3,097	69	549	13	79	3	535	0	4,262	85
1997	3,634	76	131	3	30	1	535	0	4,331	80
1998	3,670	76	150	3	41	2	535	0	4,396	82
1999	3,747	78	161	4	25	1	535	0	4,468	82
2000	3,911	81	76	2	15	1	535	0	4,537	84
2001	4,002	84	76	2	18	1	535	0	4,632	86
2002	4,100	86	77	2	15	1	535	0	4,728	88
2003	4,188	89	78	2	16	1	535	0	4,817	92
2004	4,317	88	60	1	0	0	535	0	4,912	89
2005	4,556	94	61	1	0	0	387	0	5,005	95
2006	4,723	97	28	1	0	0	387	0	5,139	97
2007	4,850	100	32	1	0	0	387	0	5,269	101

*90 MW Bradley Lake Project plus existing hydroelectric plants.
**Gross generation.

TABLE 12.4-25

EXPANSION PLAN SUMMARY
BASE CASE (THERMAL PLANTS)
DOR 50% CASE

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW...... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	772.	3718.			1079.	39.73		
1988	772.	3719.	200.	6.	1279.	65.60	200.	237.
1989	795.	3830.	0.	0.	1279.	60.79	0.	0.
1990	817.	3936.	0.	1.	1278.	56.38	0.	0.
1991	828.	3989.	0.	19.	1259.	52.06	0.	0.
1992	839.	4042.	0.	31.	1228.	46.32	0.	0.
1993	849.	4090.	0.	8.	1221.	43.73	0.	0.
1994	860.	4143.	0.	28.	1193.	38.63	0.	0.
1995	871.	4196.	0.	20.	1173.	34.63	0.	0.
1996	886.	4265.	200.	88.	1285.	45.13	200.	237.
1997	900.	4334.	200.	129.	1356.	50.67	200.	237.
1998	914.	4403.	0.	49.	1307.	43.01	0.	0.
1999	928.	4471.	0.	1.	1306.	40.72	0.	0.
2000	943.	4540.	0.	45.	1261.	33.80	0.	0.
2001	962.	4636.	0.	0.	1261.	31.05	0.	0.
2002	982.	4731.	70.	45.	1286.	30.95	70.	48.
2003	1001.	4821.	70.	53.	1303.	30.17	70.	48.
2004	1021.	4916.	200.	139.	1364.	33.63	200.	237.
2005	1041.	5012.	140.	89.	1416.	36.04	140.	96.
2006	1068.	5144.	200.	188.	1428.	33.66	200.	237.
2007	1096.	5276.	0.	0.	1428.	30.31	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	.......................COST SUMMARY....................... ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	92.	2.	13.	106.	106.	90.	90.
1989	97.	2.	13.	111.	218.	91.	180.
1990	102.	2.	13.	116.	334.	91.	271.
1991	103.	2.	13.	117.	451.	89.	360.
1992	104.	2.	13.	119.	570.	87.	448.
1993	106.	2.	13.	120.	690.	85.	533.
1994	107.	2.	13.	122.	811.	83.	616.
1995	108.	2.	13.	122.	934.	81.	697.
1996	99.	3.	26.	128.	1062.	82.	779.
1997	97.	5.	39.	140.	1202.	87.	865.
1998	98.	5.	39.	142.	1344.	85.	950.
1999	99.	5.	39.	142.	1486.	82.	1032.
2000	101.	5.	39.	144.	1630.	80.	1112.
2001	103.	5.	39.	146.	1776.	79.	1191.
2002	105.	5.	42.	152.	1929.	79.	1270.
2003	108.	5.	45.	159.	2087.	80.	1350.
2004	107.	7.	58.	172.	2259.	83.	1433.
2005	113.	7.	65.	185.	2444.	87.	1520.
2006	116.	9.	78.	203.	2647.	92.	1612.
2007	119.	9.	78.	206.	2853.	90.	1702.
EXT.						1658.	3361.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-26

EXPANSION PLAN SUMMARY
90 MW BRADLEY LAKE PROJECT
DOR 50% CASE

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW....... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	772.	3718.			1079.	39.73		
1988	772.	3719.	90.	6.	1169.	51.35	90.	288.
1989	795.	3830.	0.	0.	1169.	46.96	0.	0.
1990	817.	3936.	200.	1.	1368.	67.40	200.	237.
1991	828.	3989.	0.	19.	1349.	62.92	0.	0.
1992	839.	4042.	0.	31.	1318.	57.04	0.	0.
1993	849.	4090.	0.	8.	1311.	54.33	0.	0.
1994	860.	4143.	0.	28.	1283.	49.09	0.	0.
1995	871.	4196.	0.	20.	1263.	44.96	0.	0.
1996	886.	4265.	0.	88.	1175.	32.71	0.	0.
1997	900.	4334.	200.	129.	1246.	38.45	200.	237.
1998	914.	4403.	0.	49.	1197.	30.98	0.	0.
1999	928.	4471.	70.	1.	1266.	36.41	70.	48.
2000	943.	4540.	70.	45.	1291.	36.98	70.	48.
2001	962.	4636.	0.	0.	1291.	34.16	0.	0.
2002	982.	4731.	70.	45.	1316.	34.00	70.	48.
2003	1001.	4821.	70.	53.	1333.	33.17	70.	48.
2004	1021.	4916.	200.	139.	1394.	36.57	200.	237.
2005	1041.	5012.	70.	89.	1376.	32.19	70.	48.
2006	1068.	5144.	270.	188.	1458.	36.47	270.	285.
2007	1096.	5276.	0.	0.	1458.	33.05	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	........................COST SUMMARY........................ ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	90.	1.	14.	106.	106.	89.	89.
1989	96.	1.	14.	111.	217.	91.	180.
1990	86.	3.	27.	116.	333.	91.	271.
1991	87.	3.	27.	117.	450.	89.	360.
1992	88.	3.	27.	118.	569.	87.	447.
1993	90.	3.	27.	120.	688.	85.	531.
1994	91.	3.	27.	121.	809.	83.	614.
1995	92.	3.	27.	122.	932.	81.	695.
1996	94.	3.	27.	124.	1056.	79.	775.
1997	88.	4.	40.	132.	1188.	82.	856.
1998	90.	4.	40.	134.	1322.	80.	937.
1999	91.	5.	44.	139.	1461.	80.	1017.
2000	92.	5.	47.	144.	1605.	80.	1097.
2001	95.	5.	47.	147.	1752.	79.	1176.
2002	98.	5.	50.	153.	1906.	80.	1256.
2003	102.	5.	54.	160.	2066.	81.	1336.
2004	98.	7.	67.	171.	2237.	83.	1419.
2005	105.	7.	70.	182.	2419.	85.	1505.
2006	107.	9.	86.	202.	2621.	92.	1596.
2007	111.	9.	86.	206.	2827.	90.	1686.
EXT.						1614.	3301.

NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-27

CAPITAL COSTS AND AVERAGE ANNUAL ENERGY
90 MW BRADLEY LAKE PROJECT
FEASIBILITY STAGE AND SELECTED VALUES

	Capital Cost* Millions 1983 $	Average Annual Energy, GWH
Feasibility Stage Values	287.95	345.4
Values for Selected Plant	300.00	369.2

* Includes IDC

NOTE: For description of Capital Costs and Annual Fixed O&M Costs, see Section 11 of this Report.

TABLE 12.4-28

SELECTED 90 MW BRADLEY LAKE PROJECT WITHOUT SUSITNA PRESENT WORTH COSTS AND SAVINGS

	Present Worth, Millions 1983 $	
	Total Cost	Savings Due to Bradley Lake
Base Case	5,832	---
90 MW Bradley Lake Project	5,455	377

TABLE 12.4-29

EXPANSION PLAN SUMMARY
SELECTED 90 MW BRADLEY LAKE PROJECT
REFERENCE CASE LOAD

ELECTRIC POWER RESEARCH INSTITUTE BRADLEY LAKE

EGEAS REPORT VER 00 LEV 00 EXPANSION PLAN SUMMARY

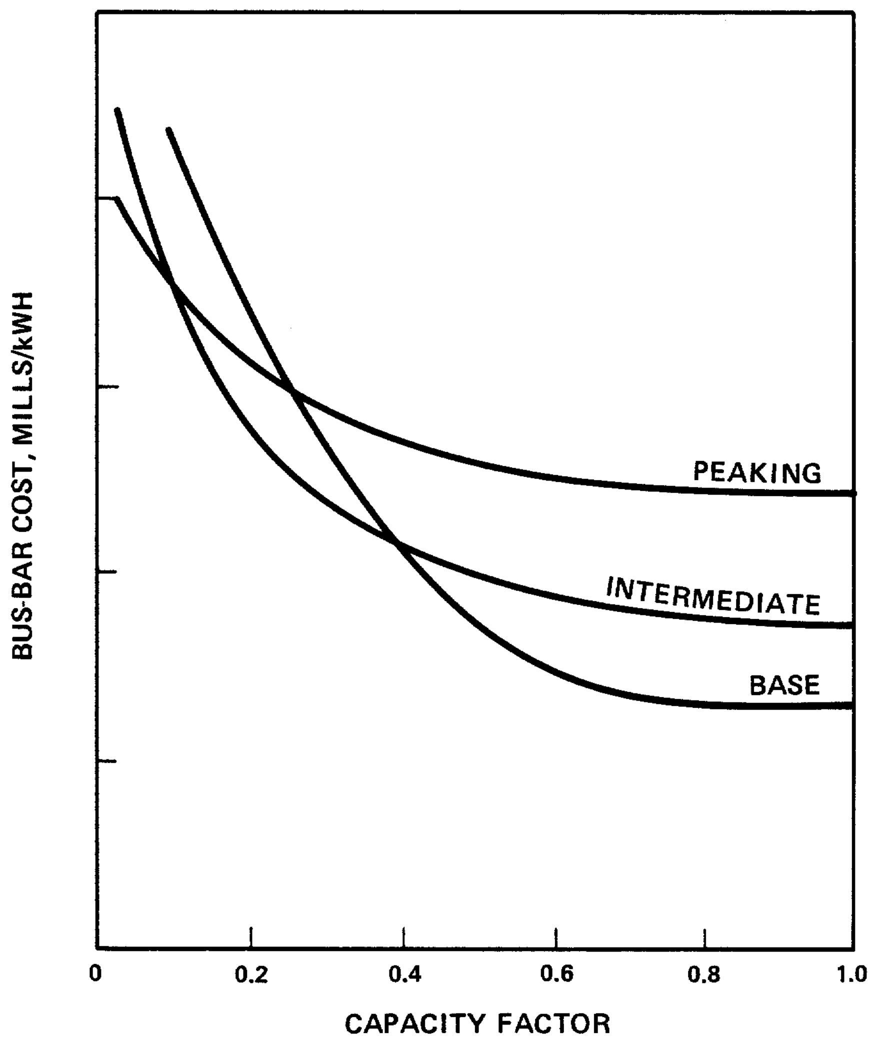
PLAN 1

YEAR	PEAK LOAD, MW	ENERGY GWH	......CAPACITY, MW....... INSTALLED	RETIRED	TOTAL	RESERVE PERCENT	..........NEW UNITS.......... CAPACITY,MW	CAPITAL COSTS,M$
BENCH	780.	3757.			1079.	38.29		
1988	779.	3754.	90.	6.	1169.	49.96	90.	300.
1989	810.	3899.	200.	0.	1369.	69.06	200.	237.
1990	839.	4040.	0.	1.	1368.	63.12	0.	0.
1991	859.	4139.	0.	19.	1349.	57.05	0.	0.
1992	879.	4232.	0.	31.	1318.	50.01	0.	0.
1993	898.	4326.	0.	8.	1311.	45.93	0.	0.
1994	918.	4419.	0.	28.	1283.	39.79	0.	0.
1995	937.	4513.	0.	20.	1263.	34.80	0.	0.
1996	954.	4596.	200.	88.	1375.	44.12	200.	237.
1997	970.	4674.	200.	129.	1446.	48.99	200.	237.
1998	987.	4752.	0.	49.	1397.	41.62	0.	0.
1999	1004.	4835.	0.	1.	1396.	39.10	0.	0.
2000	1020.	4913.	0.	45.	1351.	32.47	0.	0.
2001	1045.	5032.	70.	0.	1421.	36.03	70.	48.
2002	1070.	5152.	70.	45.	1446.	35.21	70.	48.
2003	1093.	5266.	200.	53.	1593.	45.69	200.	526.
2004	1118.	5386.	0.	139.	1454.	30.03	0.	0.
2005	1143.	5505.	200.	89.	1566.	36.96	200.	526.
2006	1178.	5672.	200.	188.	1578.	33.97	200.	526.
2007	1211.	5833.	0.	0.	1578.	30.27	0.	0.

YEAR	..ALL UNITS.. PROD. COST	.......NEW UNITS ONLY....... FIXED O & M	FIXED CHARGES	........................COST SUMMARY........................ ANNUAL	CUM. ANNUAL	PRESENT WORTH	CUM. PRES. WORTH
1988	101.	1.	15.	117.	117.	99.	99.
1989	93.	3.	28.	124.	241.	101.	199.
1990	101.	3.	28.	132.	373.	103.	303.
1991	108.	3.	28.	138.	511.	105.	408.
1992	114.	3.	28.	145.	655.	106.	514.
1993	121.	3.	28.	152.	807.	107.	621.
1994	128.	3.	28.	159.	966.	109.	730.
1995	135.	3.	28.	166.	1132.	110.	840.
1996	129.	4.	41.	174.	1306.	111.	951.
1997	132.	6.	54.	191.	1497.	118.	1069.
1998	138.	6.	54.	198.	1695.	118.	1187.
1999	145.	6.	54.	204.	1899.	118.	1305.
2000	152.	6.	54.	211.	2110.	118.	1423.
2001	160.	6.	57.	224.	2334.	120.	1543.
2002	169.	6.	60.	236.	2570.	123.	1666.
2003	162.	10.	89.	261.	2831.	131.	1797.
2004	171.	10.	89.	270.	3101.	131.	1928.
2005	171.	14.	118.	302.	3403.	142.	2070.
2006	166.	17.	146.	330.	3733.	149.	2219.
2007	177.	17.	146.	340.	4072.	149.	2368.
EXT.						3082.	5451.

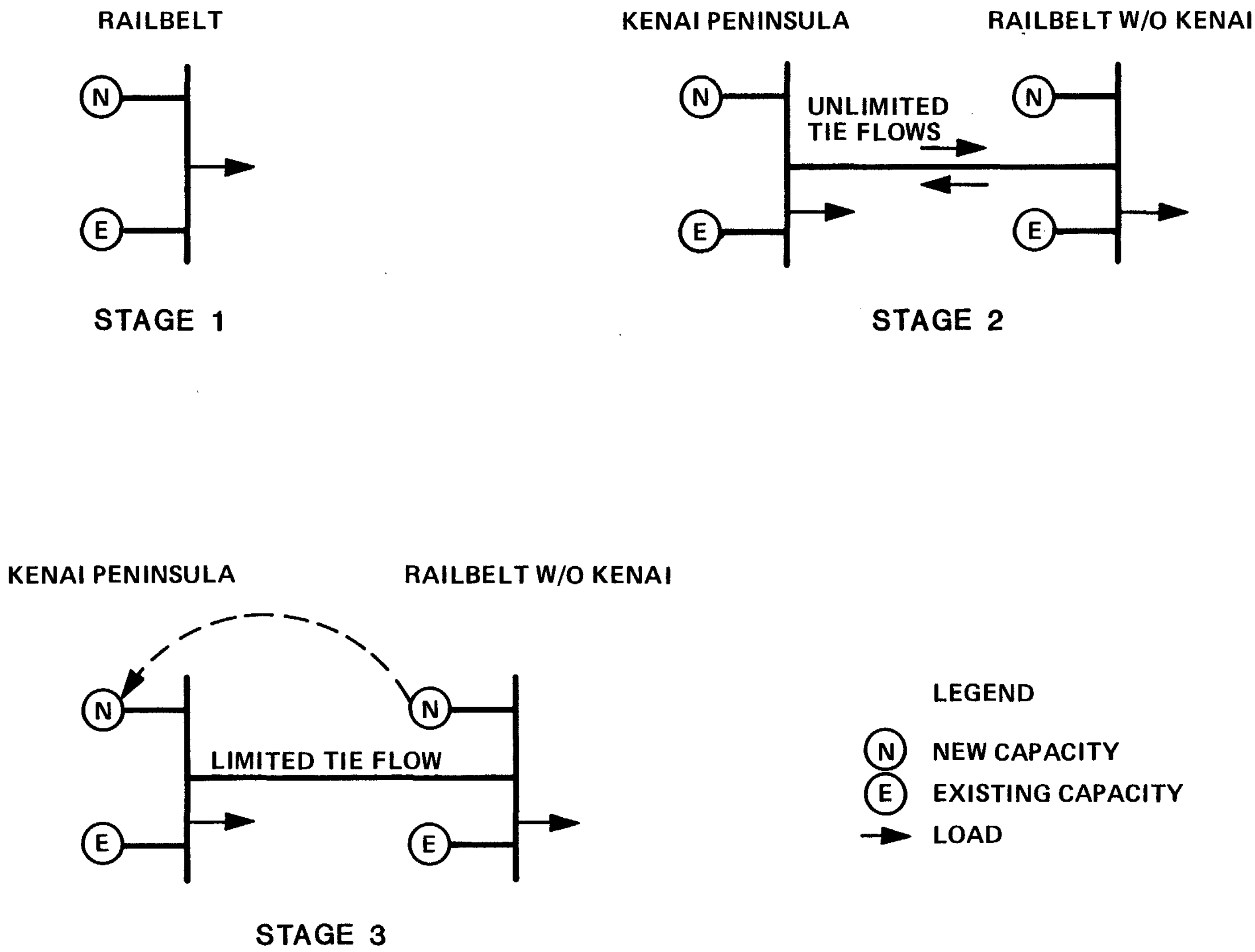
NOTES - ANNUAL COSTS ARE IN MILLIONS OF CURRENT DOLLARS.
- PRESENT WORTH COSTS ARE IN MILLIONS OF DOLLARS DISCOUNTED TO THE BEGINNING OF 1983.

TABLE 12.4-30



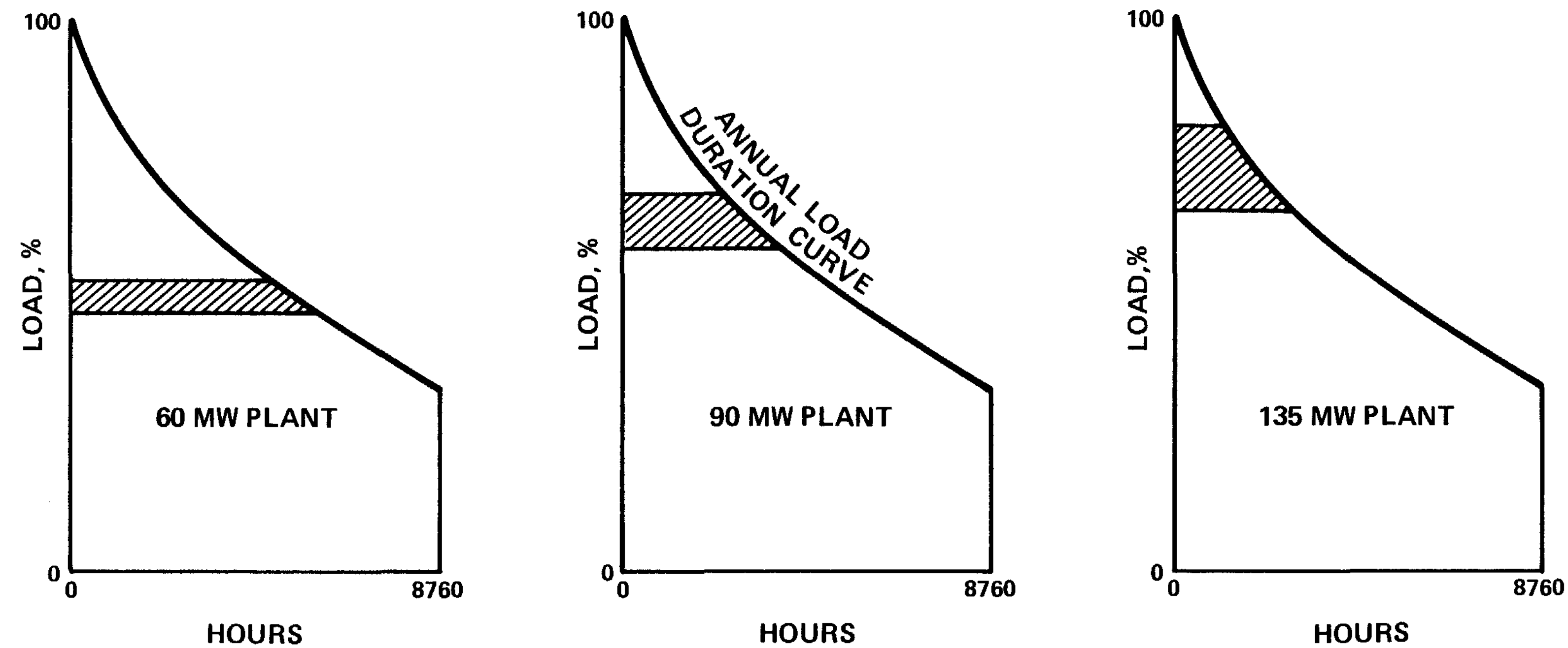
TYPICAL BUS-BAR COSTS

FIGURE 12.2-1



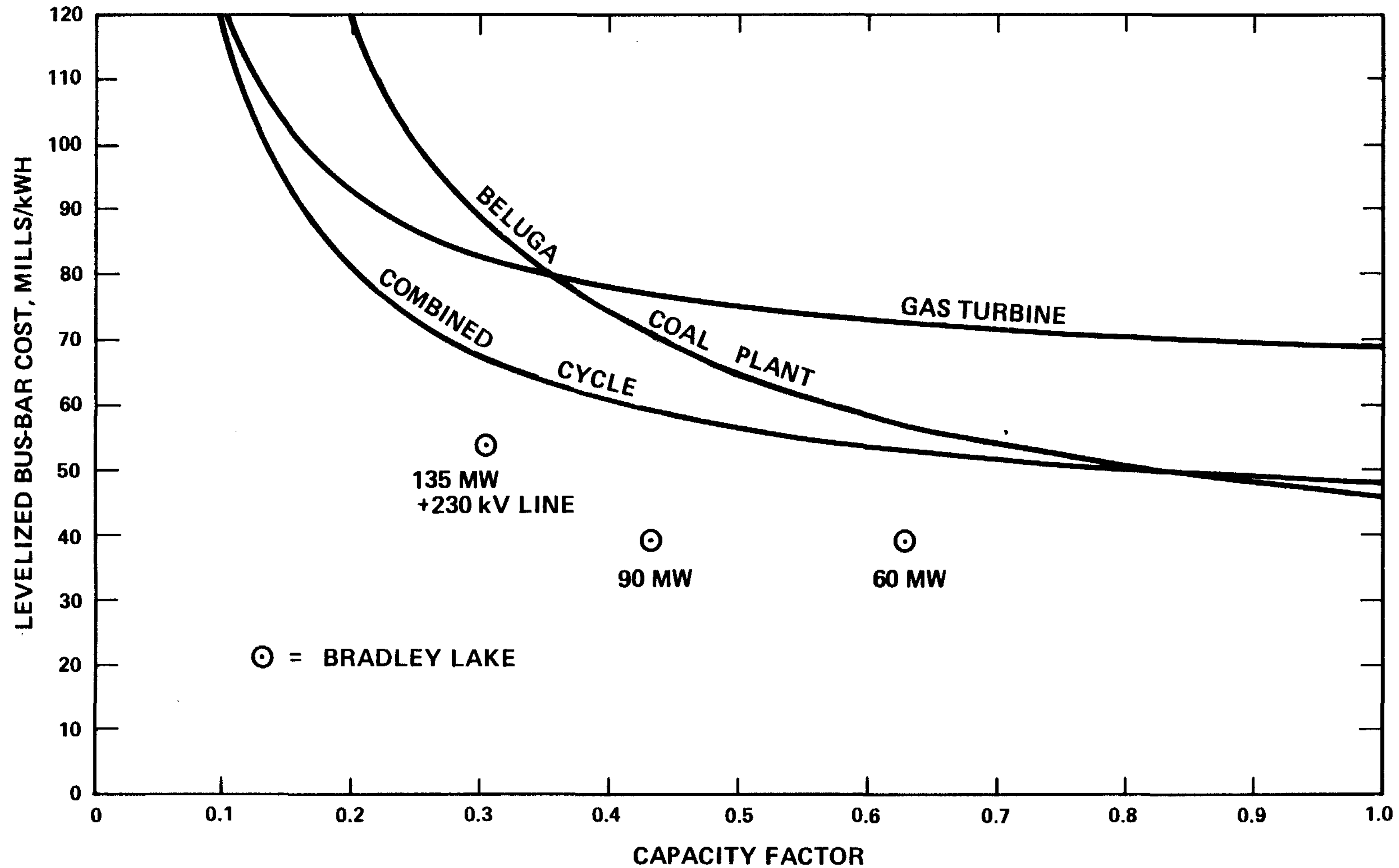
STAGES IN EGEAS GENERATION EXPANSION ANALYSIS

FIGURE 12.2-2



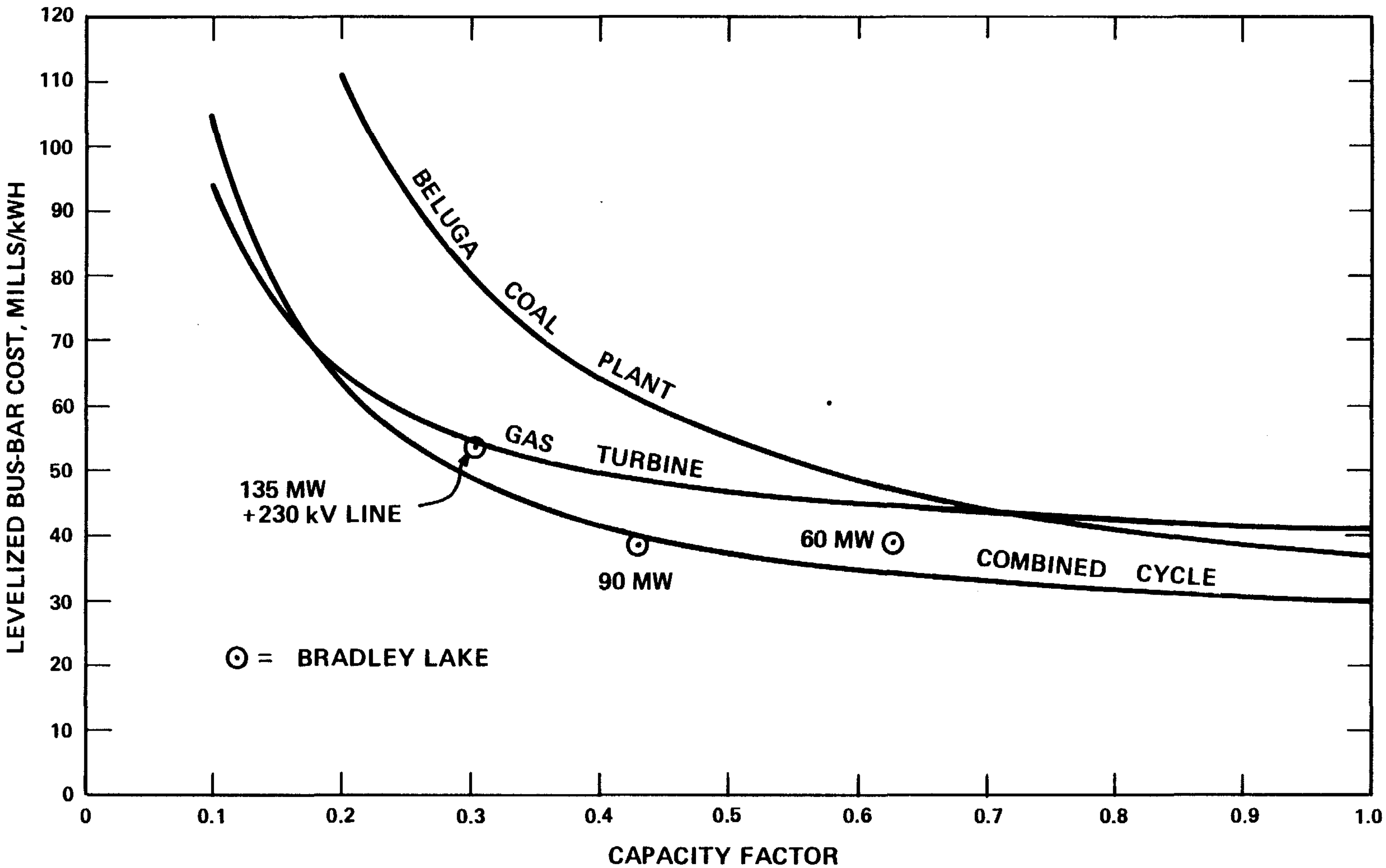
BRADLEY LAKE DISPATCH BY EGEAS

FIGURE 12.2-3



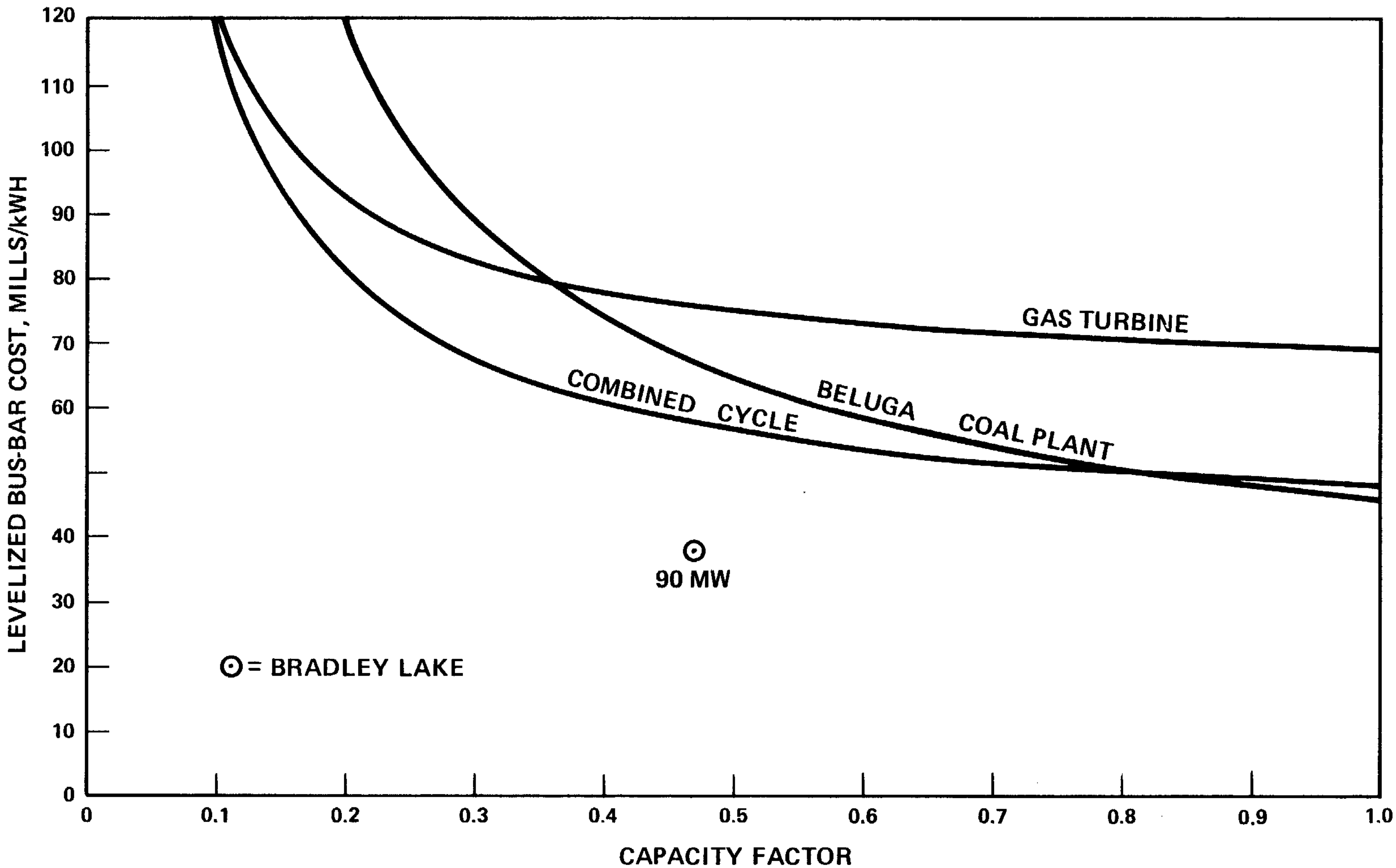
SHERMAN CLARK NSD CASE

FIGURE 12.4-1



DOR 50% CASE (JULY 1983)

FIGURE 12.4-2



SHERMAN CLARK NSD CASE
SELECTED 90 MW PLANT

FIGURE 12.4-3

13

FINDINGS AND RECOMMENDATIONS

13. FINDINGS AND RECOMMENDATIONS

13.1 FINDINGS

13.1.1 Introduction

The findings address major portions of the study efforts and the overall objective of the study for selecting a technically, environmentally, and economically preferred plan for development of the Bradley Lake Hydroelectric Power Project.

These findings are based on available data and information gathered during the study, on preliminary engineering and technical investigations, and on environmental and economic evaluations.

13.1.2 Technical Findings

Foundation conditions in the area of the main dam, powerhouse, access roads, and barge channel are considered satisfactory for the development of these structures. Further, it was determined that the use of a tunnel boring machine for excavating the main portion of the power tunnel is feasible on the basis of the available data and represents the least cost alternative. Conventional drill and blast, as well as raised boring techniques can be applied to other appropriate sections of the power conduit such as the portals, the inclined shaft and short tunnel lengths. Exploratory work and available data also indicate that the power tunnel can be excavated through the Bradley River and Bull Moose fault zones using these methods. Further, combined use of these techniques will result in a lower total project cost without extending the construction schedule developed in previous studies.

The findings show that Pelton units, rather than Francis units, are preferred for the Bradley Lake Project. The Pelton units offer lower total project costs, better response to peak load following operations, less complicated control equipment, easier maintenance, and avoidance of immersion of the turbine equipment and penstock in tidewater.

With respect to the main dam, the findings show that a concrete faced rockfill dam is preferred because of lower cost, greater use of natural material, and ease of construction. A dam built to accommodate a maximum operating pool for generation of elevation 1180 was selected for the preferred plan. This pool level provides essentially optimum storage for generation, avoids suspect areas of possible reservoir rim leakage near the Battle Creek headwaters, and allows maximum effective use of available riverbed area and channel topography for the development of the dam.

Inclusion of the Middle Fork Diversion concept to seasonally divert water to Bradley Lake was found technically and economically feasible. The estimated additional energy generated by use of Middle Fork flows is 16 GWH per year. Including these seasonal diversion flows, the 90 MW preferred plant could provide about 378 GWH of average annual energy if water is not released for maintaining aquatic habitat and about 369 GWH when some of the storage is used to supplement natural flows, as needed for aquatic habitat. Average annual firm energy generation during the critical 44 month historical period was computed to be 348 GWH and 334 GWH, respectively. These energy values represent the total plant output available at the generator leads.

Two 115 kV parallel transmission lines, each capable of handling the full plant output, are provided for greater reliability when transmitting power to the Kenai Peninsula transmission line grid. Study findings also show that the selected 90 MW plant will not require another transmission line between Soldotna and Anchorage as the existing 115 kV line is capable of providing reserve sharing and economy interchange between Anchorage and the Kenai Peninsula.

Two separate camps will better support the construction activities of the project. A lower camp near tidewater will serve the powerhouse, main tunnel, and transmission line construction; and an upper camp will support construction of the main dam, diversion tunnel, Middle Fork and other structures such as the intake channel, upper tunnel and gate shaft. Development of the proposed upper camp will require additional baseline data to further assess its technical feasibility as well as its impact to the local environment.

Development of an access channel and barge basin at Sheep Point is technically feasible and cost effective with less environmental impacts than other alternatives considered. Similarly, access road routes identified during the study are the best alignments possible for development, both from a technical and construction scheduling standpoint.

13.1.3 Costs and Economics

For all plant capacities evaluated, developments with Pelton type turbines result in the lowest estimated capital cost. Although the Pelton turbine and generator equipment costs more than the related Francis equipment, powerhouse civil costs are less. In addition, surge facilities are not required for the Pelton turbine installations.

Similarly, cost comparisons for the different dam types favored the recommended concrete faced rockfill dam over a concrete gravity dam.

The utilization of a tunnel boring machine for the excavation of the major portion of the main power tunnel results in substantial savings over convential methods.

The Overnight Cost Estimate for the preferred 90 MW plant is $283,019,000. This cost includes direct material, labor, and construction equipment; engineering and design cost; cost for the management of construction; owner's cost including previous expenditures realized for project studies and development; land rights cost; all risk insurance; and a contingency of 25 percent. The Overnight Cost Estimate reflects cost as of July 1983.

Economic evaluations show that the 60, 90 and 135 MW installations studied for the Bradley Lake Project are economically beneficial for the Railbelt, both with and without the Susitna Hydroelectric Development. Significant life-cycle savings result by using Bradley Lake in place of thermal generation alternatives. The optimum Bradley Lake project capacity is dependent on and sensitive to the projected load growth rate for the Railbelt area and the Kenai Peninsula. The economic evaluation studies showed that the 90 MW selected plan is the prefered choice at the reference load growth rate of an average 2.8 percent per year as adopted in this study. Also, the findings show that this selected installation is less sensitive to load growth variations.

The study findings show that the Bradley Lake options are very close in terms of annual energy developed from the project, with only 3 to 5 percent differences between the three capacities evaluated. The findings also show that the 90 MW installation would better respond to the load growth demands for capacity and energy for the Kenai Peninsula area and would result in greater relative cost savings (due to less transmission costs) when serving this area rather than the entire Railbelt region.

In conclusion, the feasibility study findings indicate that the Bradley Lake Hydroelectric Power project is a technically feasible development, economically attractive and can be adopted to its environmental setting.

13.2 RECOMMENDATIONS

Based on the above outlined findings and conclusions, it is recommended that the energy potential of Bradley Lake be developed utilizing a 90 MW, two unit Pelton turbine powerhouse, a concrete faced rockfill dam, a machined bored concrete lined power tunnel, the Middle Fork diversion, and two 115 kV parallel transmission lines. Efforts should now proceed with the preparation of a Federal Energy Regulatory Commission (FERC) License Application and continue with the definitive engineering-design phase of the work.

In conjunction with the License Application it is recommended that unresolved environmental concerns and issues be addressed, and mitigation and enhancement plans be conceptually developed in the following areas:

- Bradley River fishery habitat
- Rehabilitation of the Martin River borrow areas

- Waterfowl nesting in select spoil areas
- Moose dispersion and migration corridors
- Environmental impacts along the preferred transmission line corridor and upper camp area

To support the engineering-design phase of the work, it is recommended that field investigative programs be identified at an early stage to develop additional geologic, survey, and other engineering data.

14
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14. BIBLIOGRAPHY

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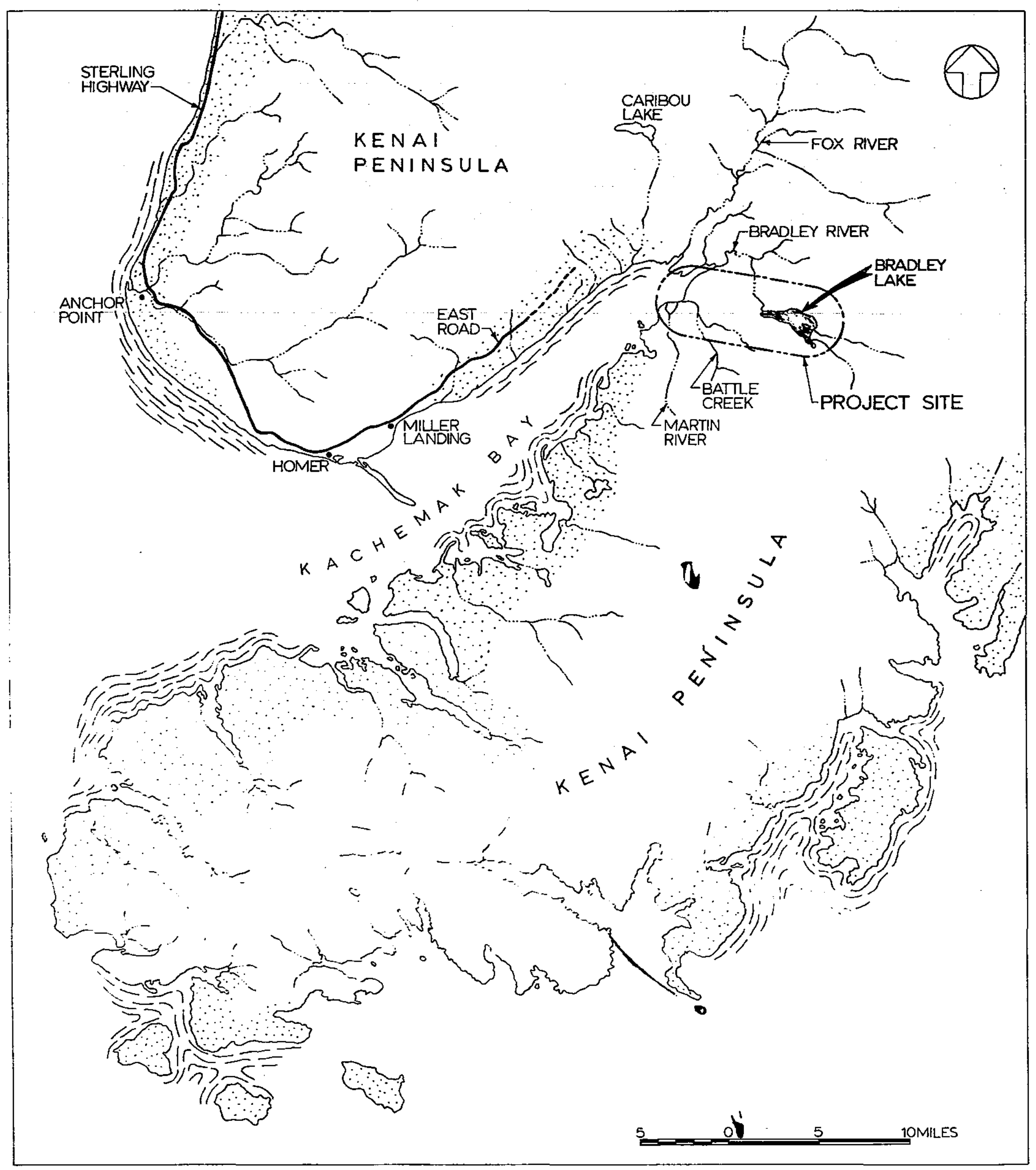
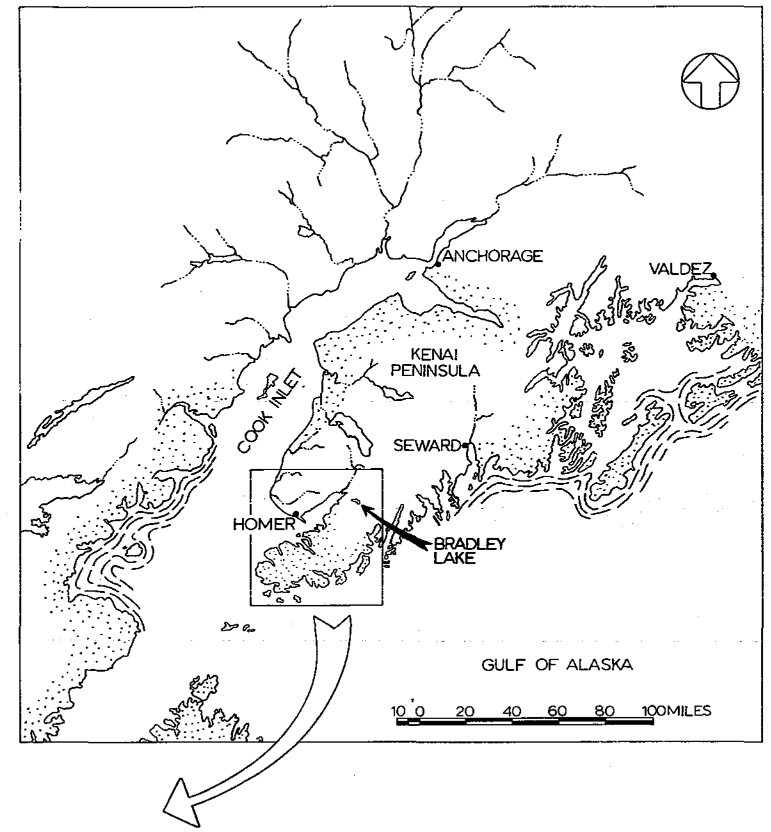
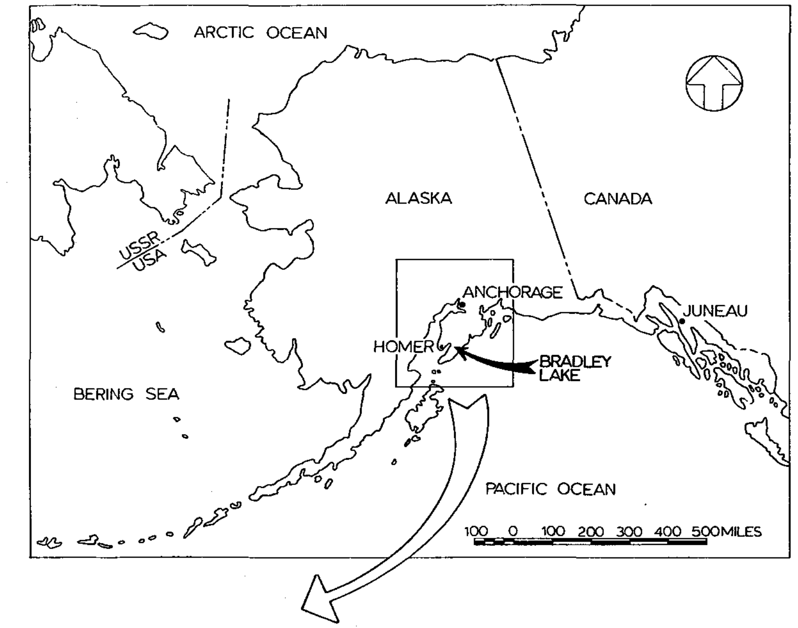
PLATES





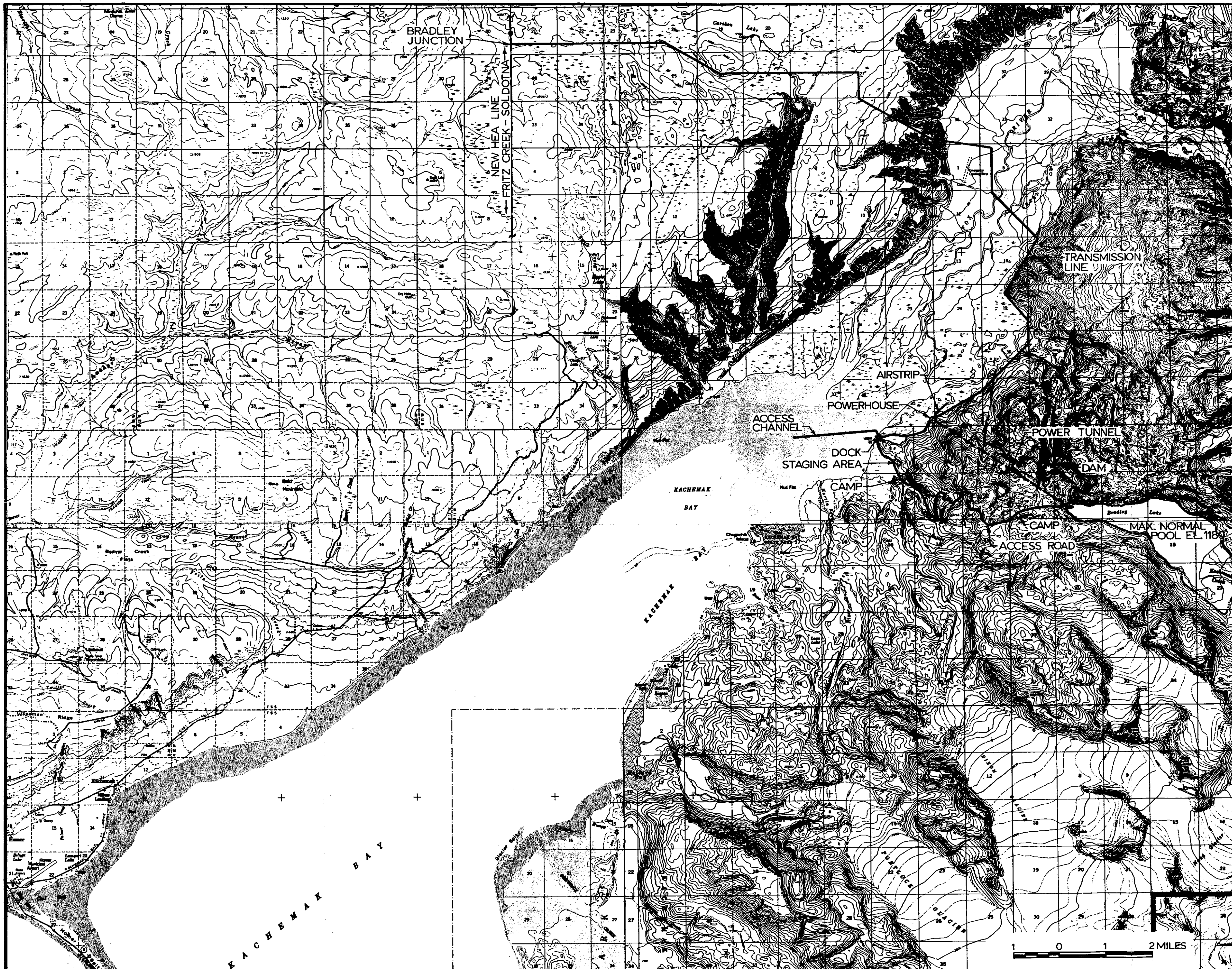


BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

LOCATION MAP

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 1

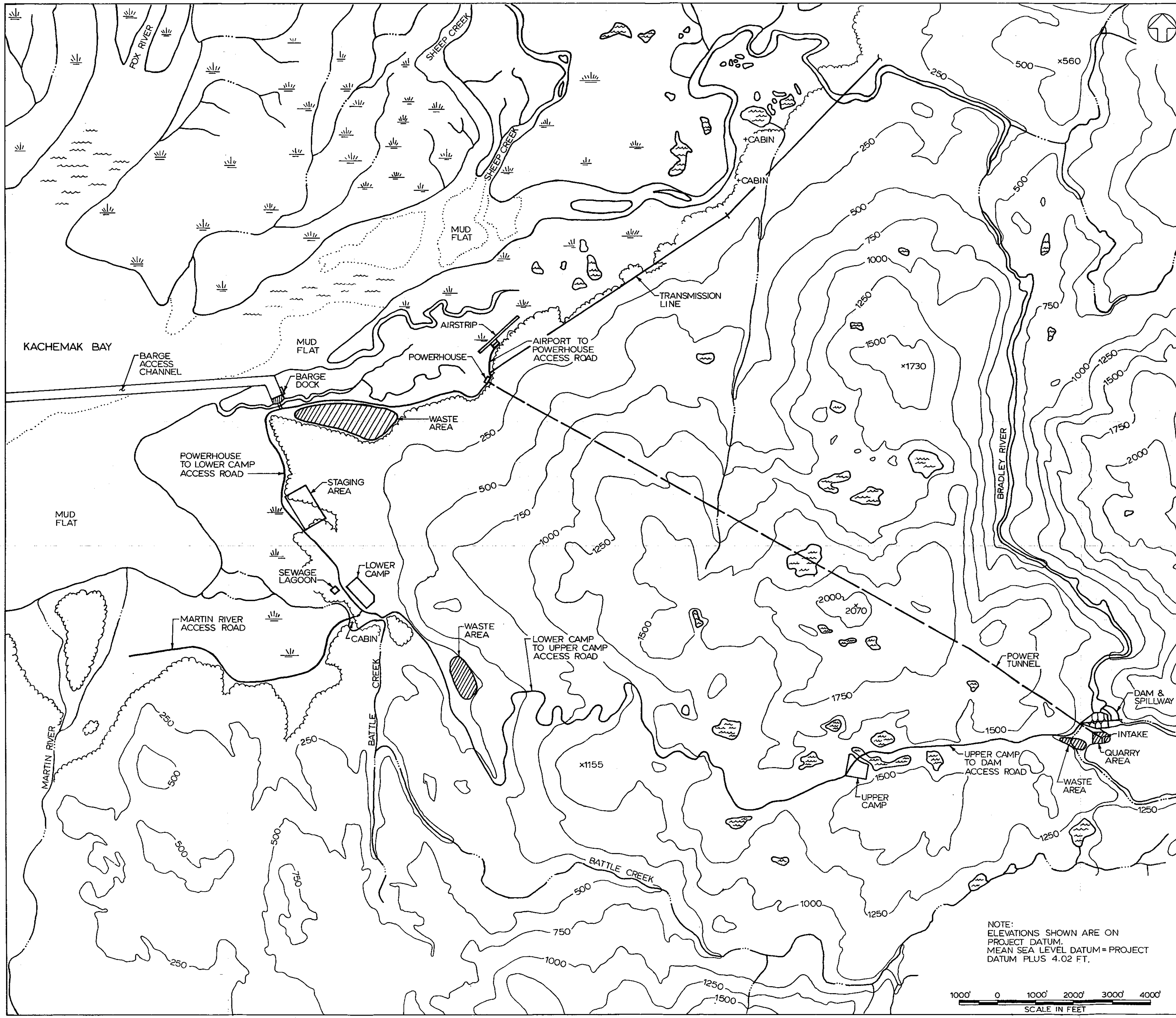


BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

OVERALL PROJECT FEATURES

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 2

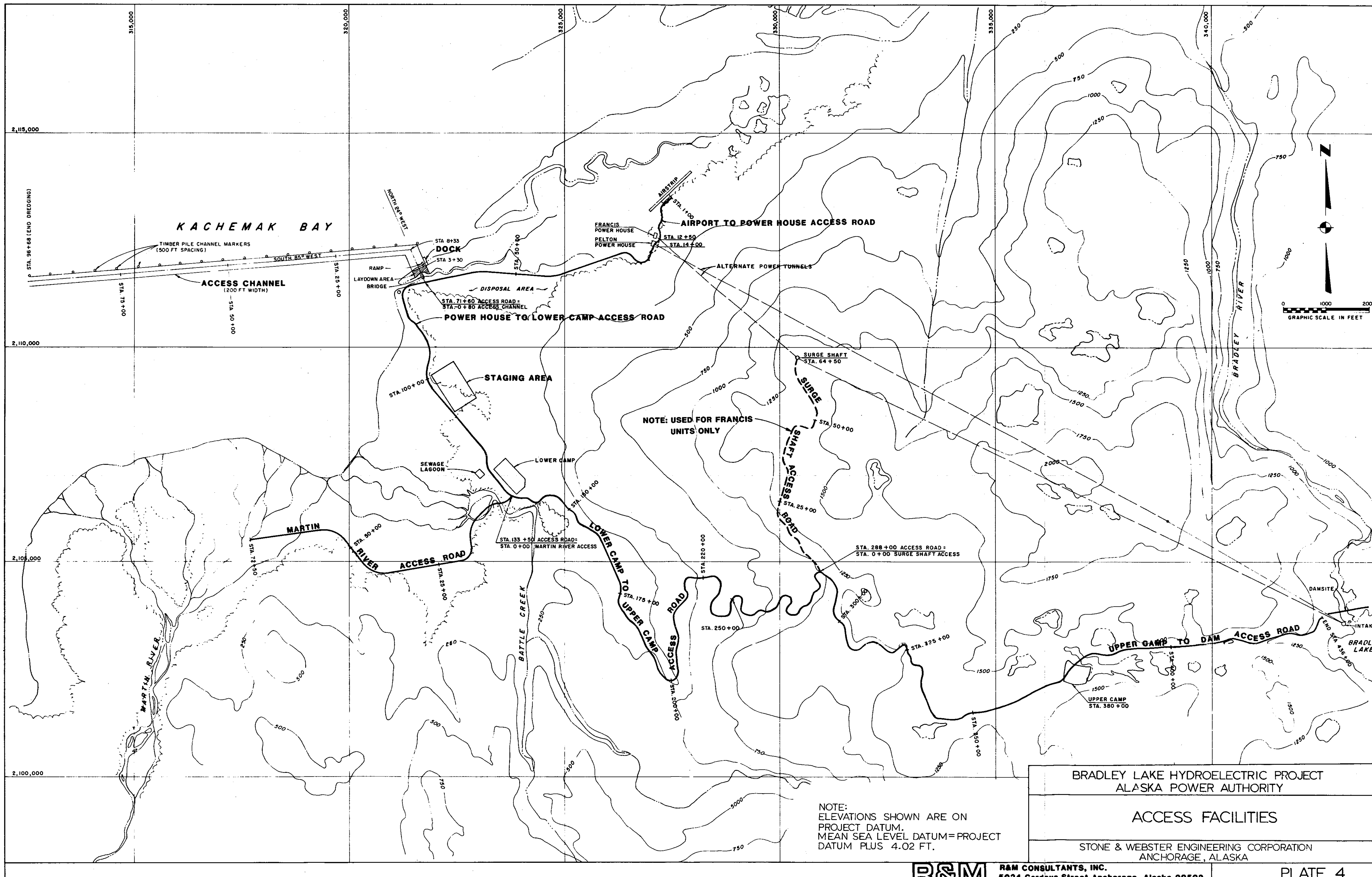


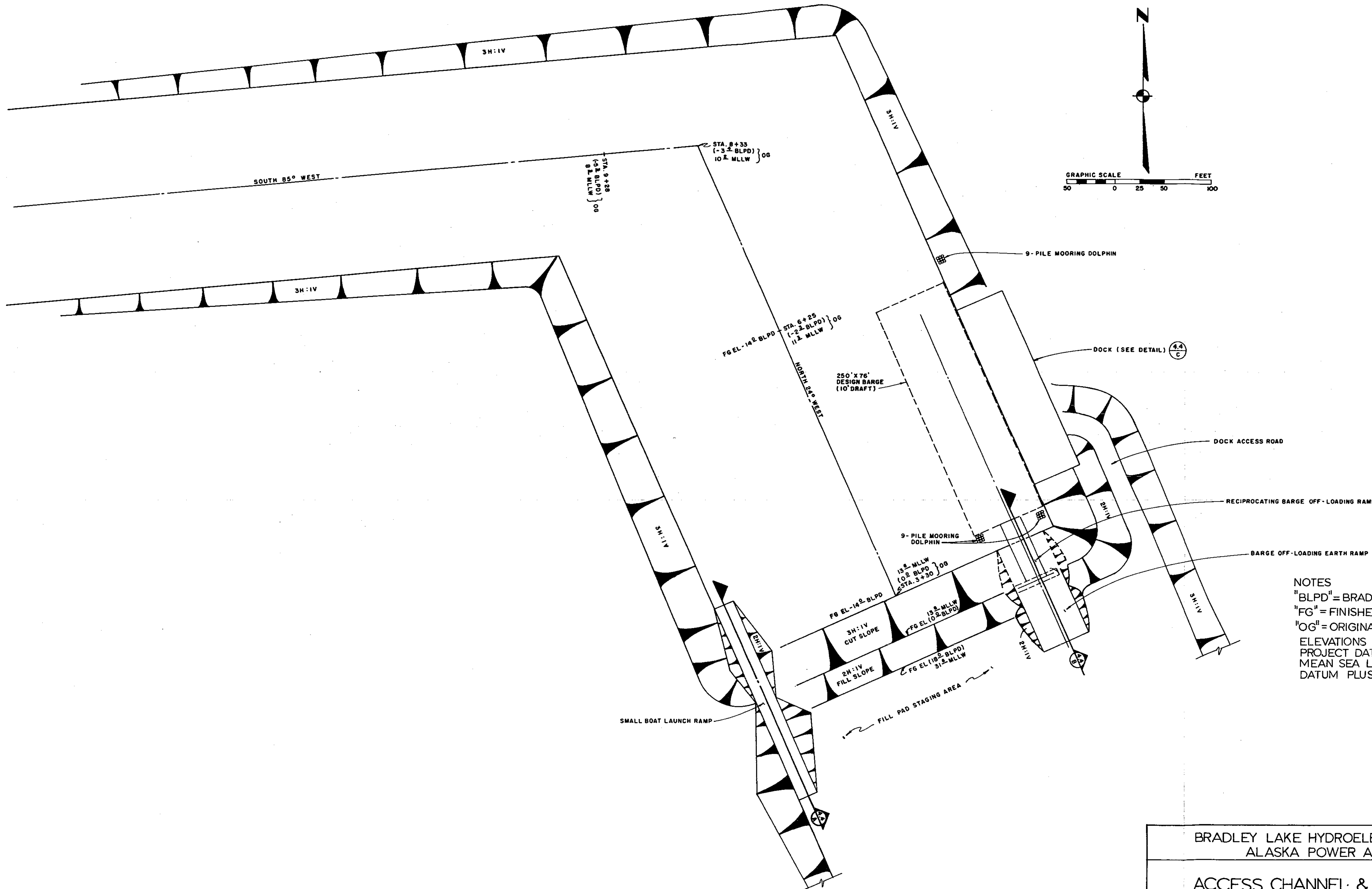
BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

GENERAL PLAN

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 3


KACHEMAK BAY
TIMBER PILE CHANNEL MARKERS (500 FT SPACING)
SOUTH 85° WEST
NORTH 84° WEST
ACCESS CHANNEL (200 FT WIDTH)
STA. 96+68 (END DREDGING)
STA. 75+00
STA. 50+00
STA. 25+00
STA 8+33
DOCK
STA 3+30
RAMP
LAYDOWN AREA
BRIDGE
DISPOSAL AREA
STA. 71+60 ACCESS ROAD = STA. 0+80 ACCESS CHANNEL
POWER HOUSE TO LOWER CAMP ACCESS ROAD
STA. 50+00
AIRSTRIP
STA. 1+00
AIRPORT TO POWER HOUSE ACCESS ROAD
FRANCIS POWER HOUSE
STA. 12+50
PELTON POWER HOUSE
STA. 14+00
ALTERNATE POWER TUNNELS
STAGING AREA
STA. 100+00
SEWAGE LAGOON
LOWER CAMP
NOTE: USED FOR FRANCIS UNITS ONLY
SURGE SHAFT
STA. 64+50
SURGE SHAFT ACCESS ROAD
STA. 50+00
STA. 25+00
STA. 288+00 ACCESS ROAD = STA. 0+00 SURGE SHAFT ACCESS
MARTIN RIVER ACCESS ROAD
STA. 72+50
STA. 50+00
STA. 25+00
STA. 133+50 ACCESS ROAD = STA. 0+00 MARTIN RIVER ACCESS
STA. 150+00
LOWER CAMP TO UPPER CAMP ACCESS ROAD
STA. 175+00
STA. 200+00
STA. 220+00
STA. 250+00
STA. 300+00
STA. 325+00
STA. 350+00
UPPER CAMP
STA. 380+00
UPPER CAMP TO DAM ACCESS ROAD
STA. 400+00
END STA. 435+60
DAMSITE
INTAKE
BRADLEY LAKE
BRADLEY RIVER
MARTIN RIVER
BATTLE CREEK
GRAPHIC SCALE IN FEET
0
1000
2000
315,000
320,000
325,000
330,000
335,000
340,000
2,115,000
2,110,000
2,105,000
2,100,000
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.
BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY
ACCESS FACILITIES
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA
R&M
R&M CONSULTANTS, INC.
5024 Cordova Street Anchorage, Alaska 99502
PLATE 4



NOTES
"BLPD" = BRADLEY LAKE PROJECT DATUM
"FG" = FINISHED GRADE
"OG" = ORIGINAL GROUND
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

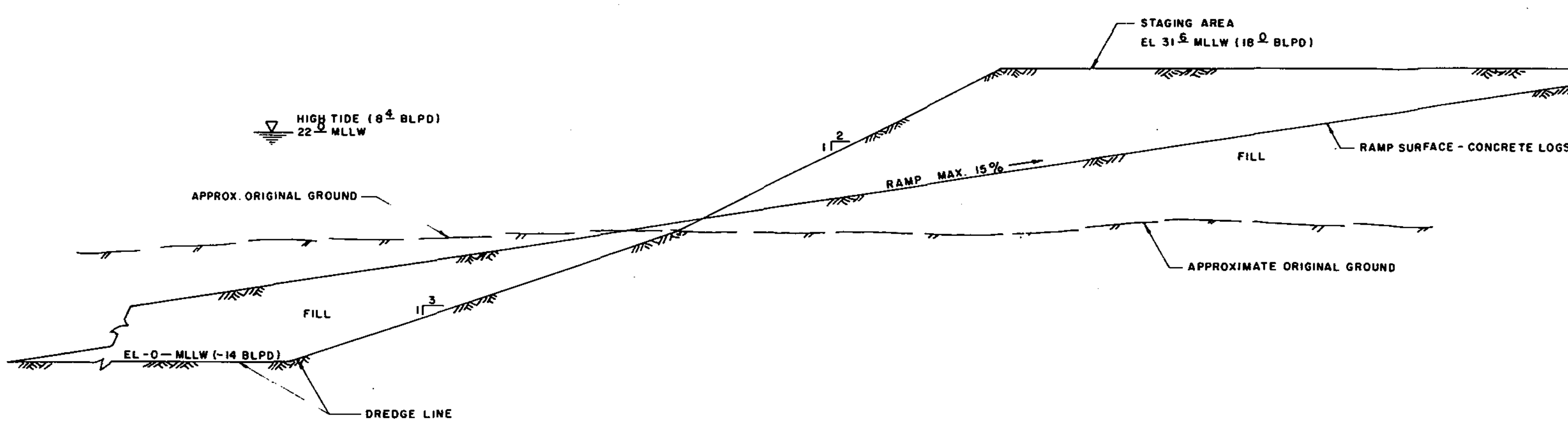
BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

ACCESS CHANNEL & BARGE BASIN

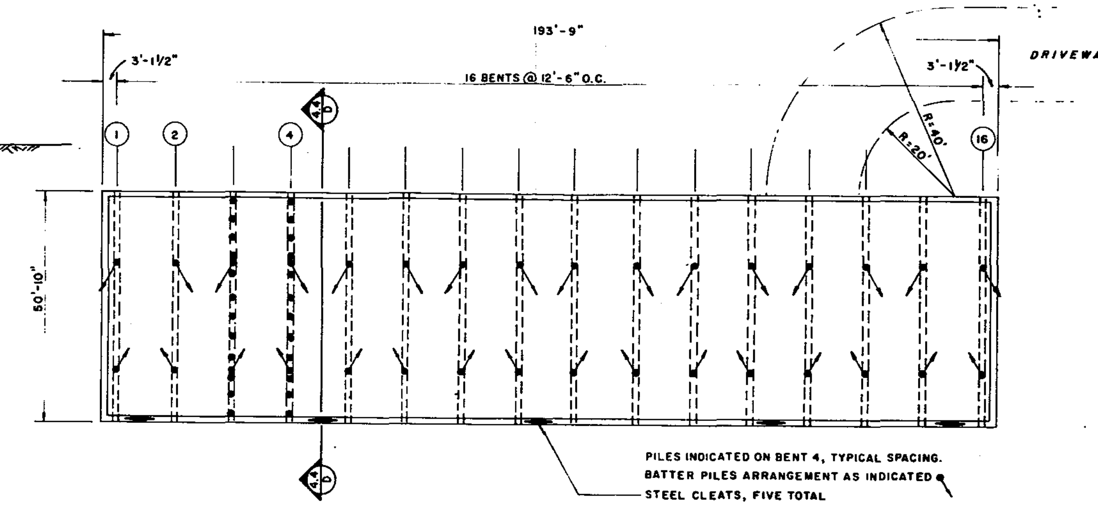
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

R&M CONSULTANTS, INC.
5024 Cordova Street Anchorage, Alaska 99502

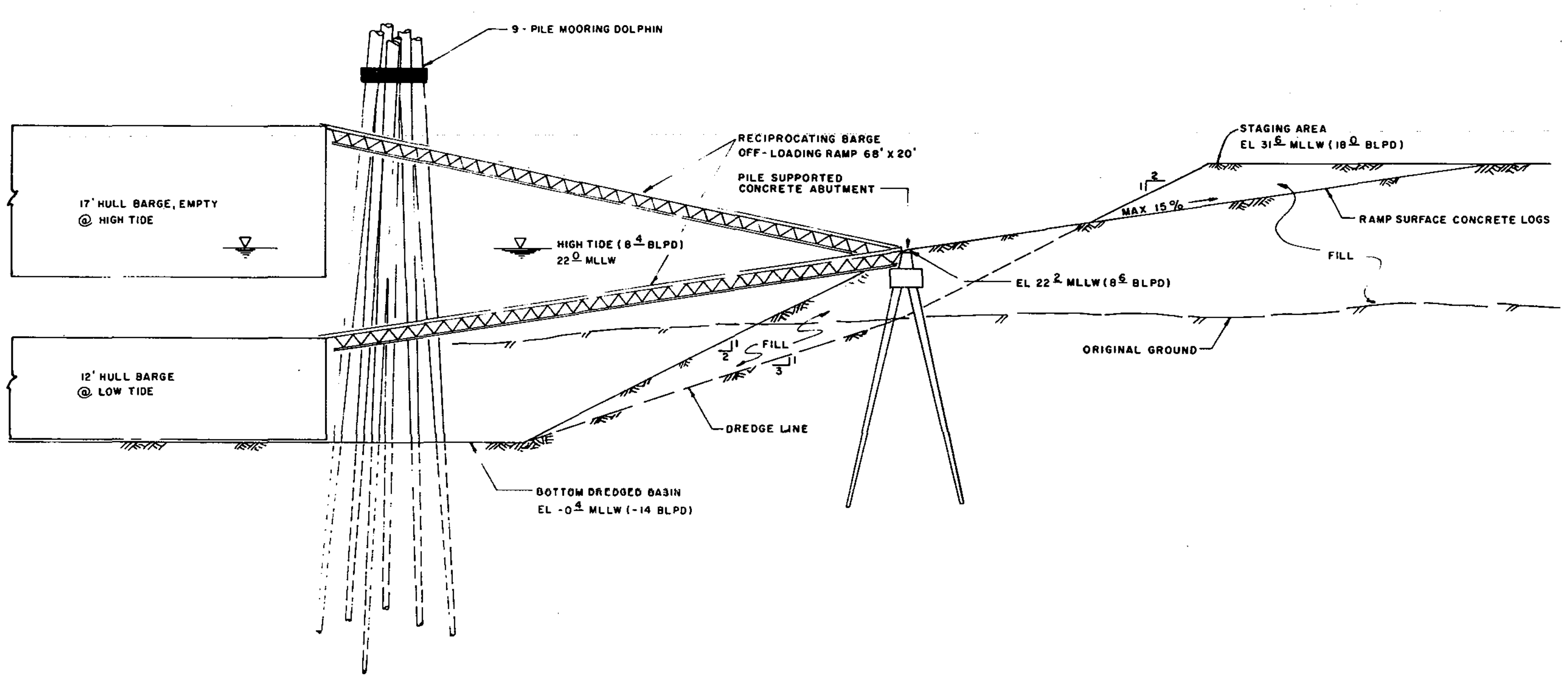
PLATE 5



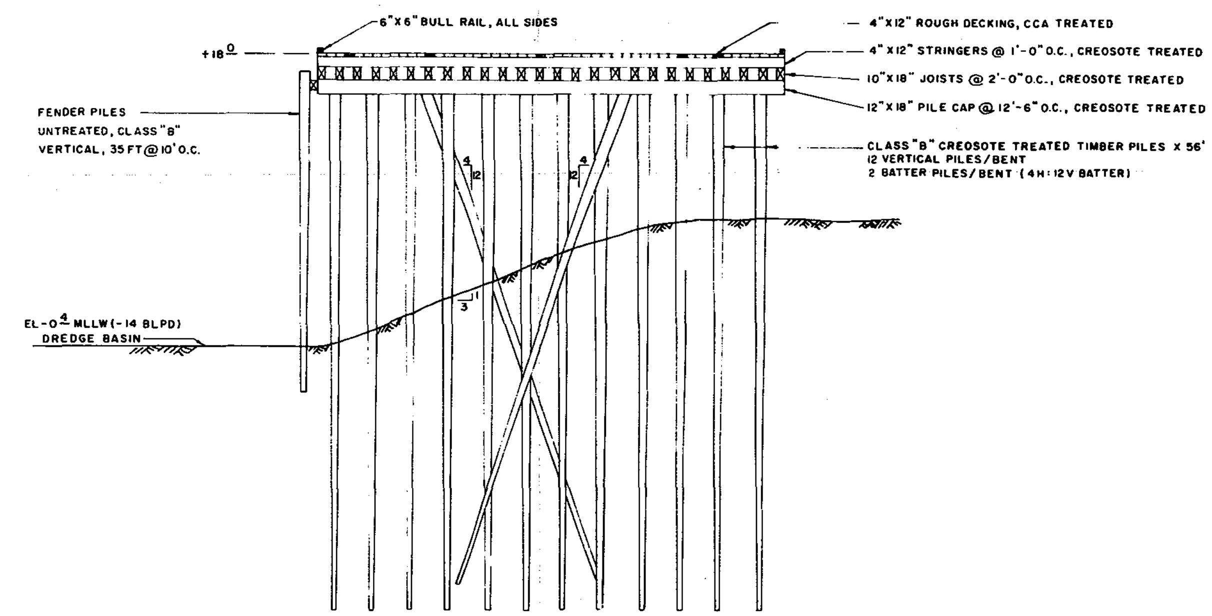
4.4 A **SMALL BOATS RAMP SECTION**
GRAPHIC SCALE 5 0 10 FT.



4.4 C **DOCK PLAN**
GRAPHIC SCALE 10 0 20 FT.



4.4 B **OFF-LOADING RAMP SECTION**
GRAPHIC SCALE 5 0 10 FT.



4.4 D **TYPICAL SECTION - PILE BENT**
GRAPHIC SCALE 5 0 10 FT.

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

DOCK STRUCTURE DETAILS

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

R&M CONSULTANTS, INC.
5024 Cordova Street Anchorage, Alaska 99502

PLATE 6

BRADLEY LAKE

MAXIMUM OPERATING W.S. EL. 1180'
MINIMUM OPERATING W.S. EL. 1080'

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

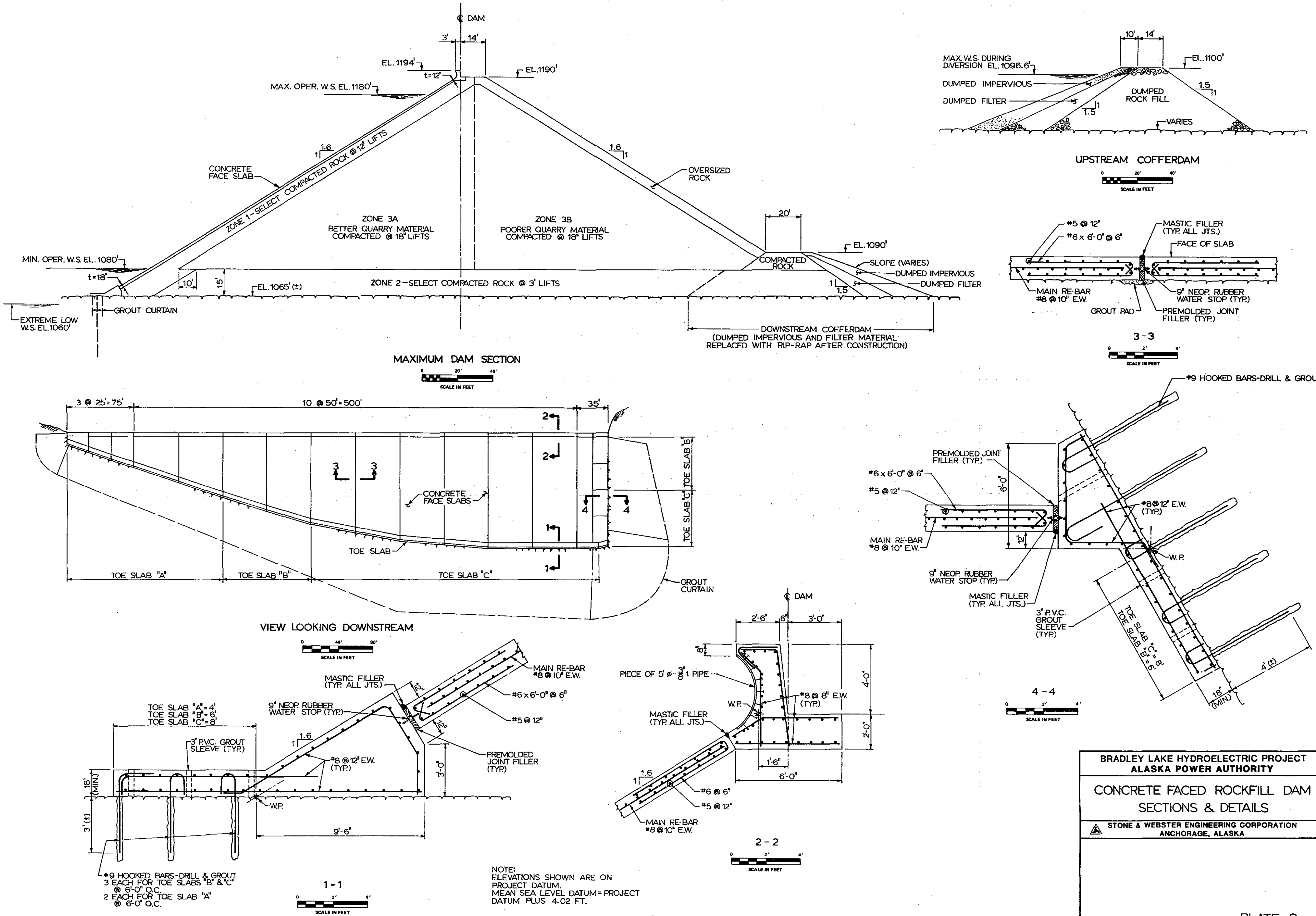
GRAPHIC SCALE 1" = 50'-0"

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

GENERAL ARRANGEMENT
DAM, SPILLWAY & FLOW STRUCTURES

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 7



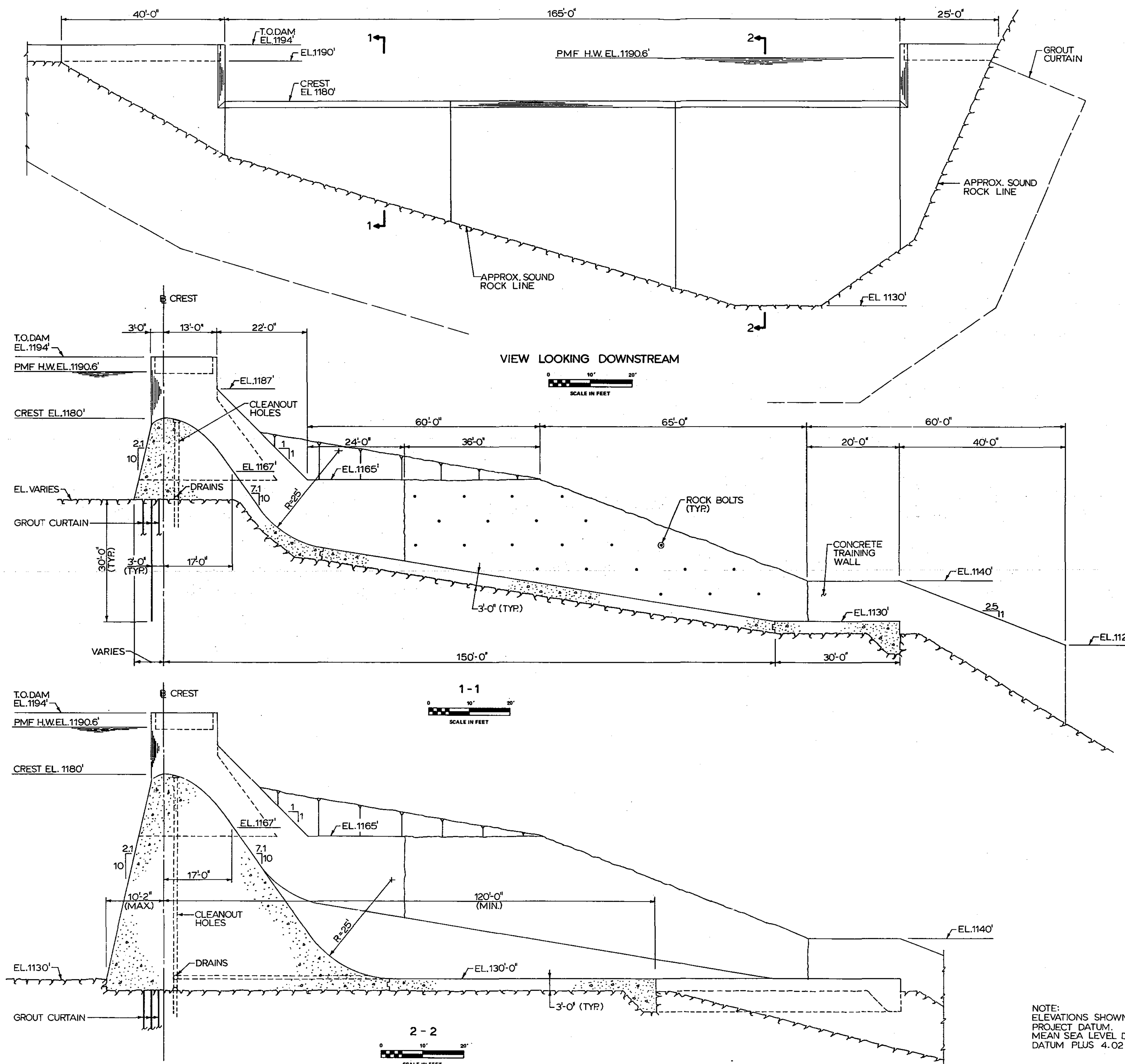
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

CONCRETE FACED ROCKFILL DAM
SECTIONS & DETAILS

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 8



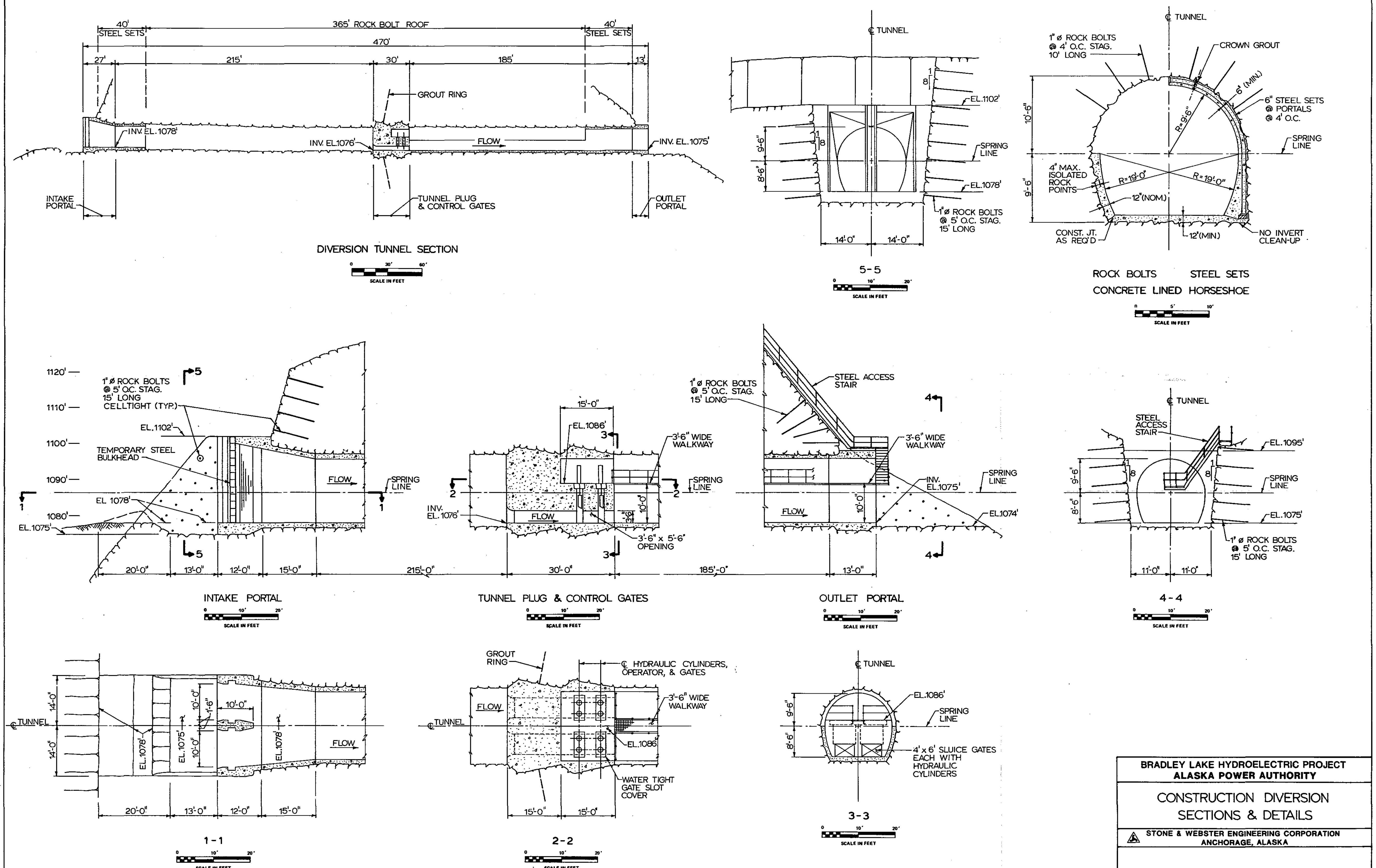
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

SPILLWAY
ELEVATION & SECTIONS

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 9

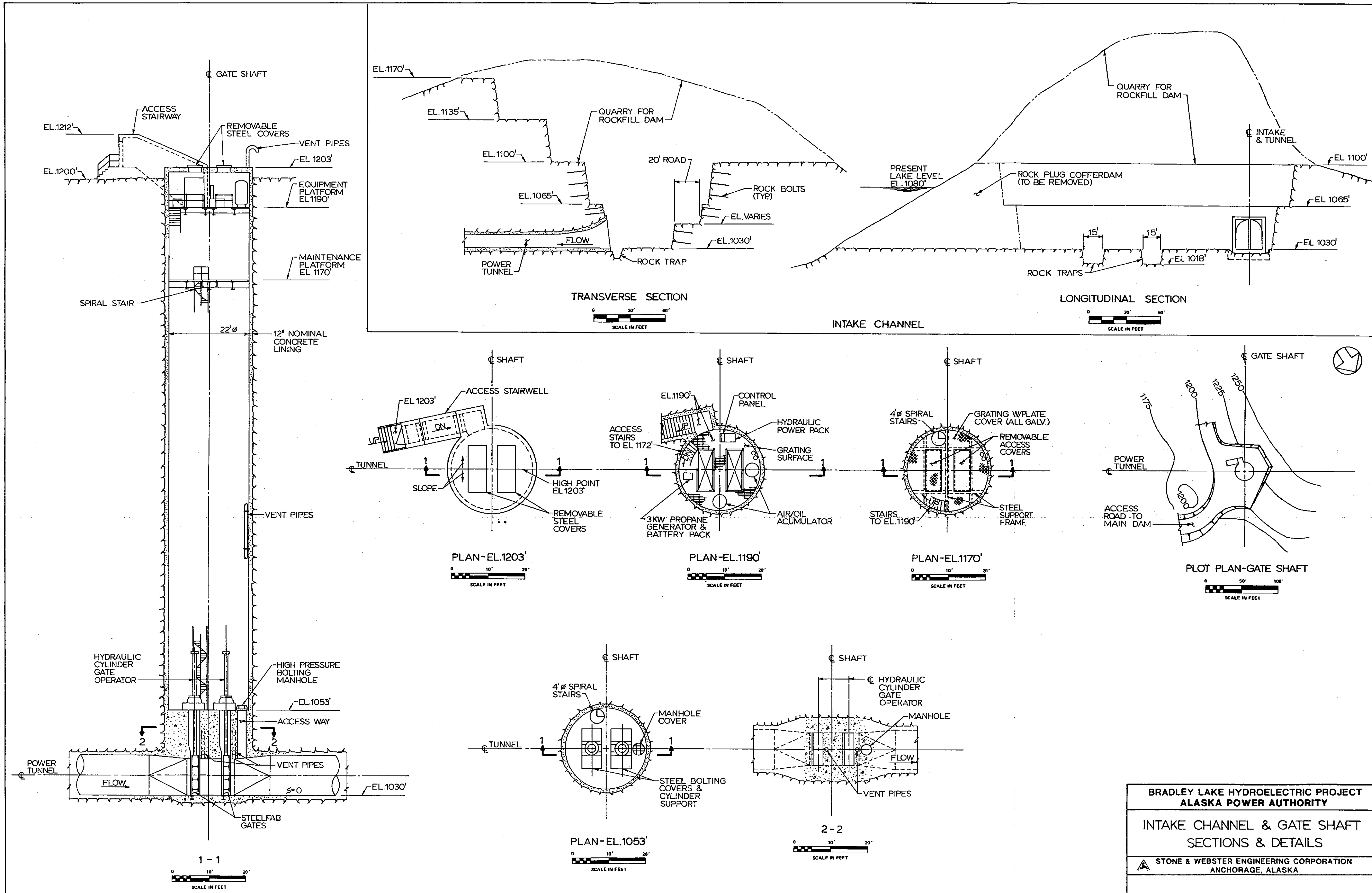


NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

CONSTRUCTION DIVERSION
SECTIONS & DETAILS

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA



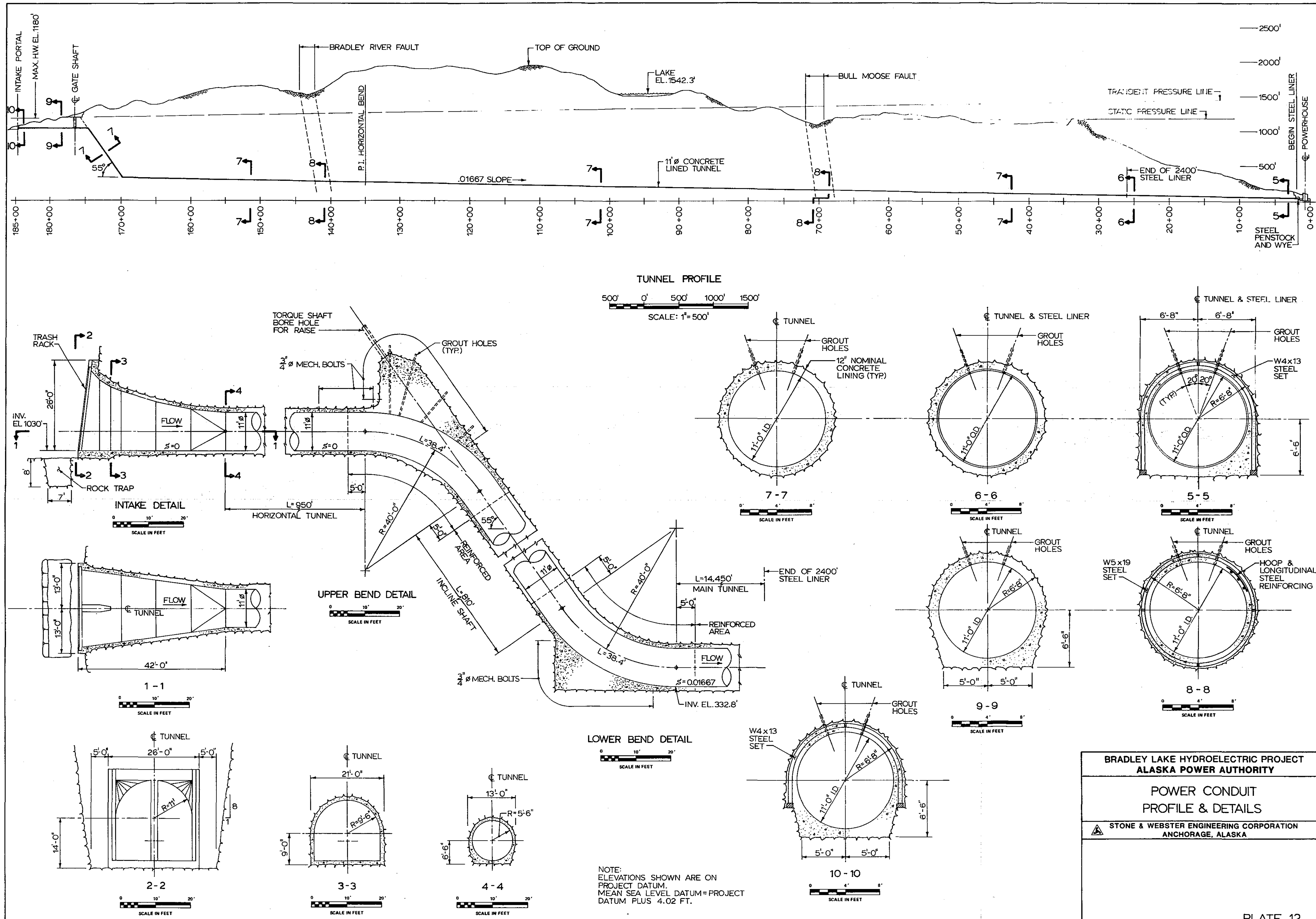
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM=PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

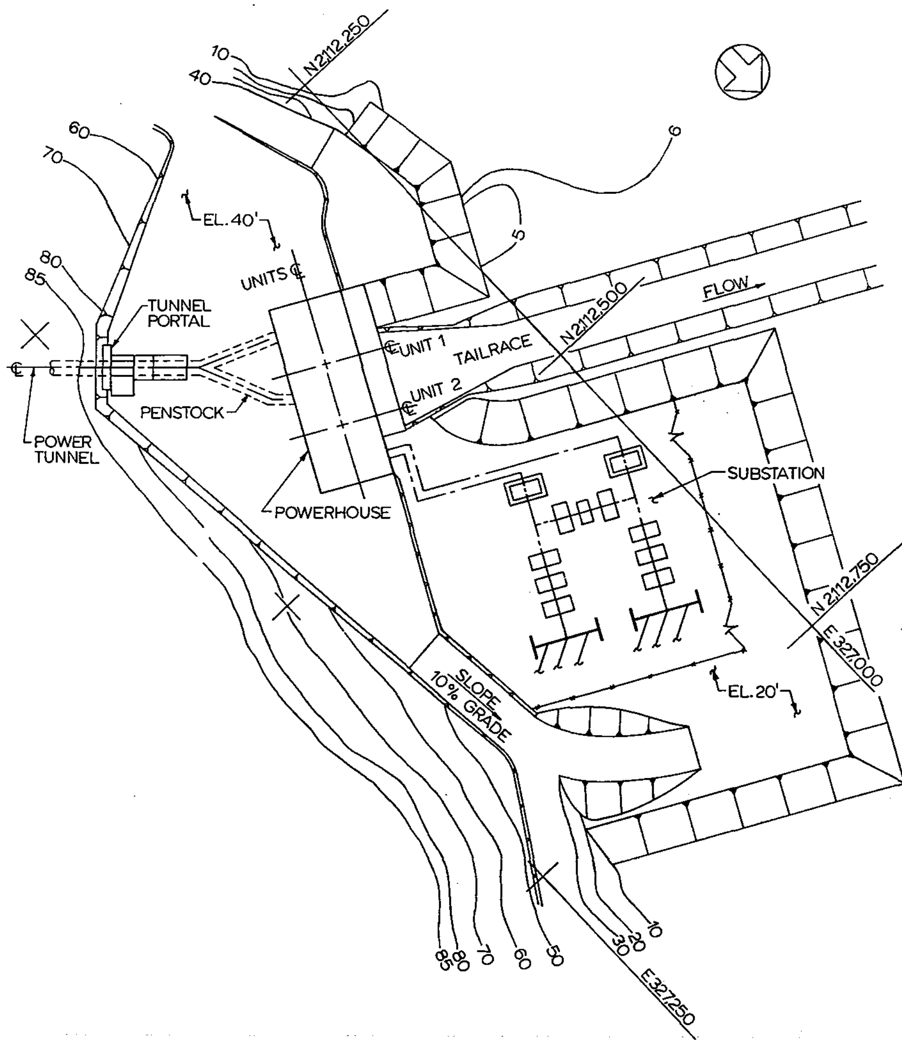
INTAKE CHANNEL & GATE SHAFT
SECTIONS & DETAILS

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 11

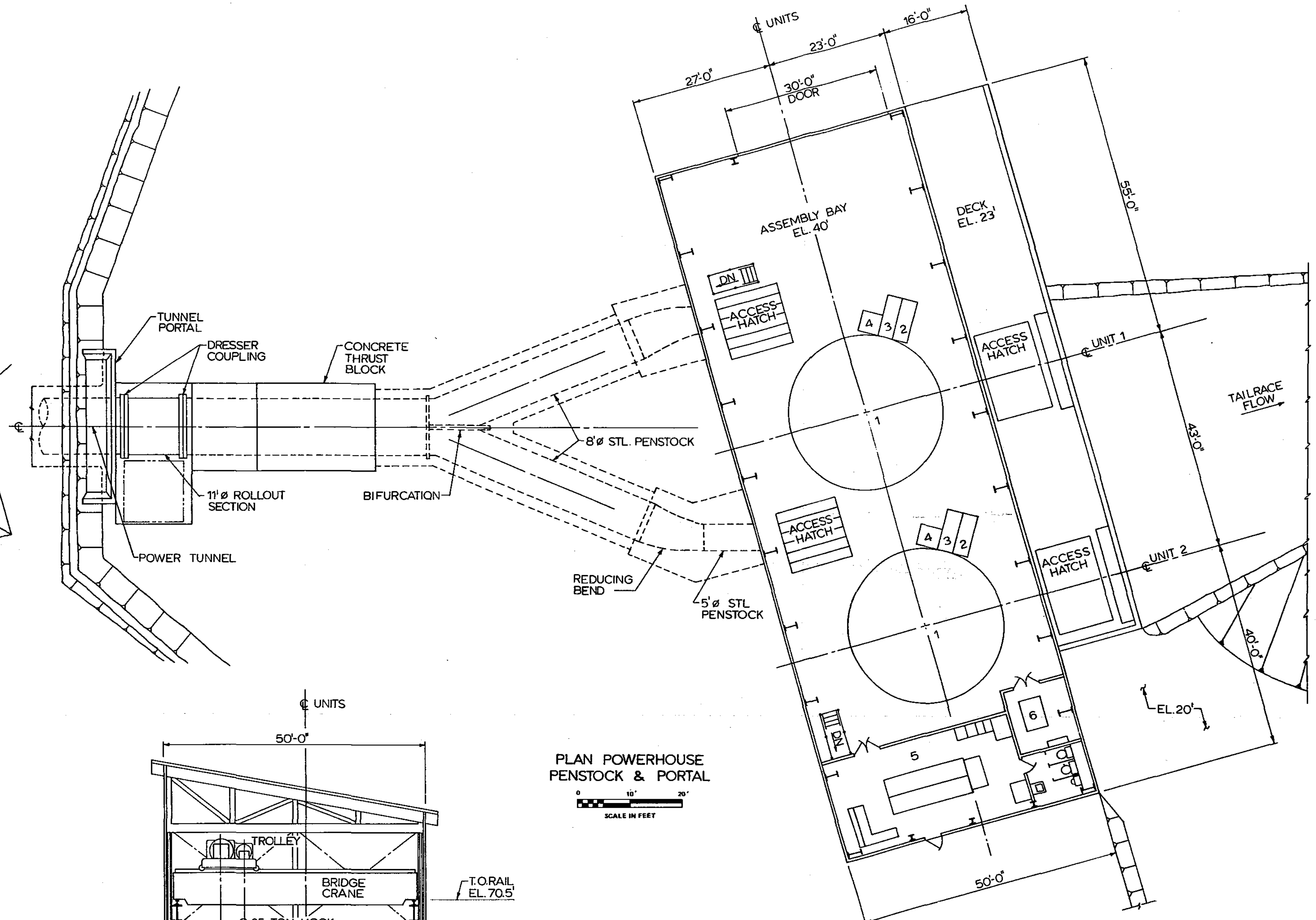


TUNNEL PROFILE
SCALE: 1"=500'
INTAKE PORTAL
MAX. HW. EL. 1180'
GATE SHAFT
BRADLEY RIVER FAULT
TOP OF GROUND
LAKE EL. 1542.3'
BULL MOOSE FAULT
TRANSIENT PRESSURE LINE
STATIC PRESSURE LINE
P.I. HORIZONTAL BEND
11'ø CONCRETE LINED TUNNEL
.01667 SLOPE
END OF 2400' STEEL LINER
BEGIN STEEL LINER
POWERHOUSE
STEEL PENSTOCK AND WYE
INTAKE DETAIL
TRASH RACK
INV. EL 1030'
ROCK TRAP
FLOW
UPPER BEND DETAIL
TORQUE SHAFT BORE HOLE FOR RAISE
GROUT HOLES (TYP.)
3/4"ø MECH. BOLTS
L=950' HORIZONTAL TUNNEL
R=40'-0"
L=38.4'
REINFORCED AREA
L=810' INCLINE SHAFT
LOWER BEND DETAIL
L=14,450' MAIN TUNNEL
END OF 2400' STEEL LINER
INV. EL. 332.8'
S=0.01667
1-1
2-2
3-3
4-4
5-5
6-6
7-7
8-8
9-9
10-10
12" NOMINAL CONCRETE LINING (TYP.)
W4x13 STEEL SET
W5x19 STEEL SET
HOOP & LONGITUDINAL STEEL REINFORCING
SCALE IN FEET
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM=PROJECT DATUM PLUS 4.02 FT.
BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY
POWER CONDUIT PROFILE & DETAILS
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA
PLATE 12



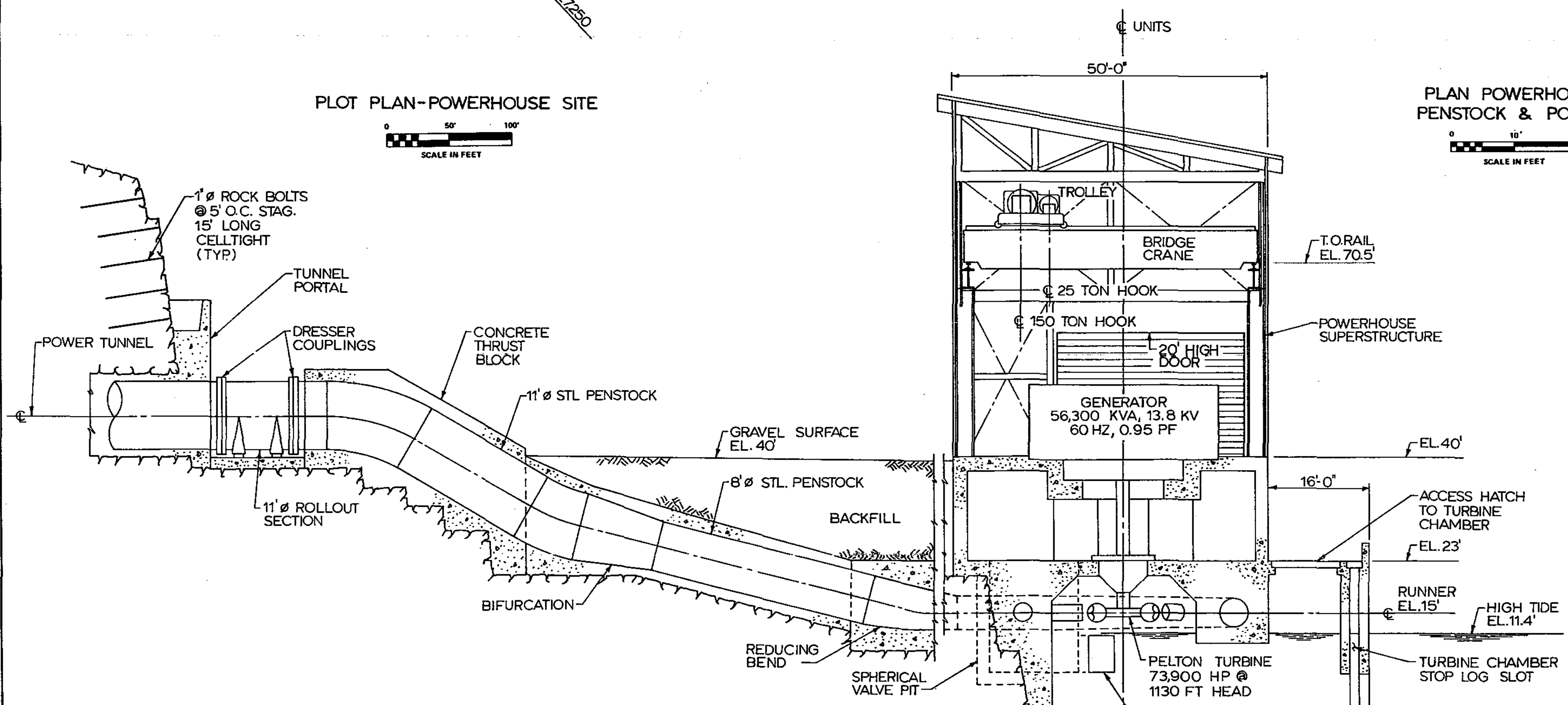
PLOT PLAN-POWERHOUSE SITE

SCALE IN FEET



PLAN POWERHOUSE PENSTOCK & PORTAL

SCALE IN FEET



ELEVATION-POWERHOUSE, PENSTOCK & PORTAL

SCALE IN FEET

EQUIPMENT DATA

1 GENERATOR
2 GENERATOR BREAKER
3 GENERATOR POTENTIAL TRANSFORMER
4 NEUTRAL TRANSFORMER
5 CONTROL ROOM
6 DIESEL GENERATOR

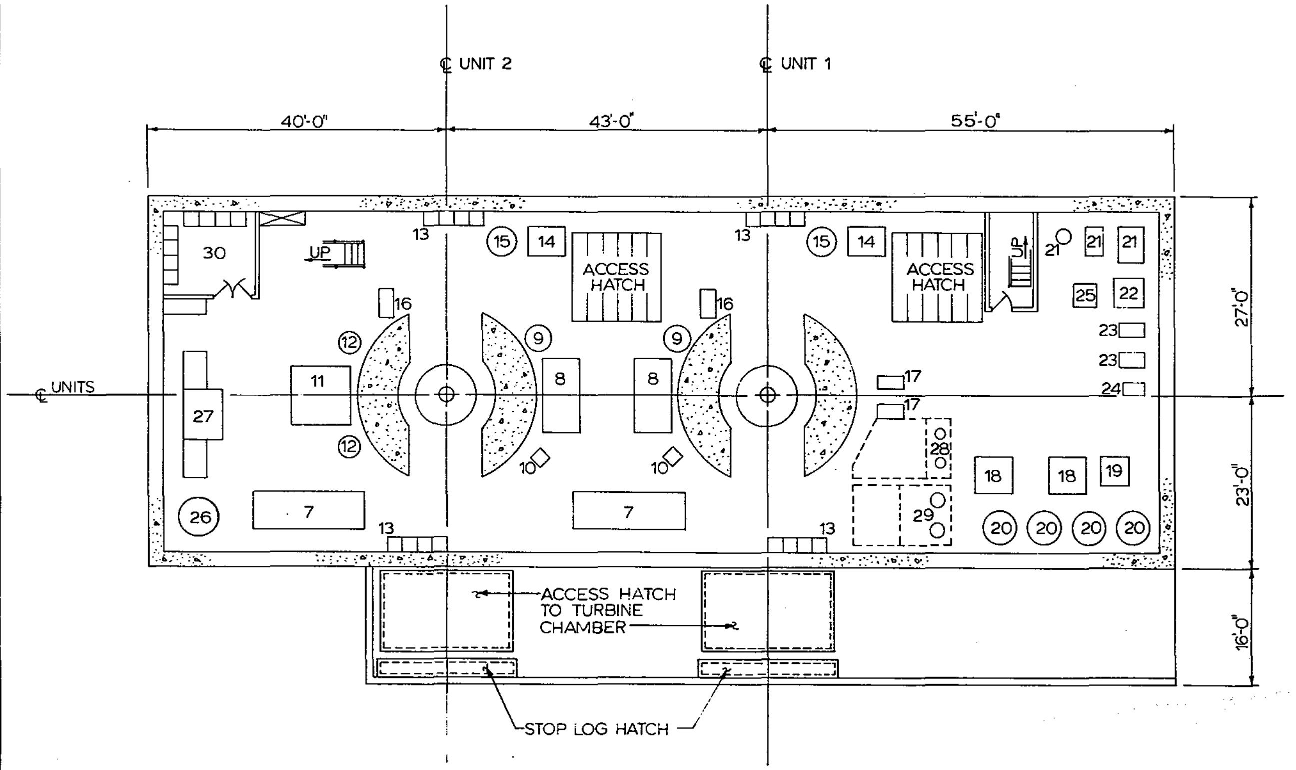
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM=PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

90 MW PELTON POWERHOUSE
PLANS & SECTIONS-SHT. 1

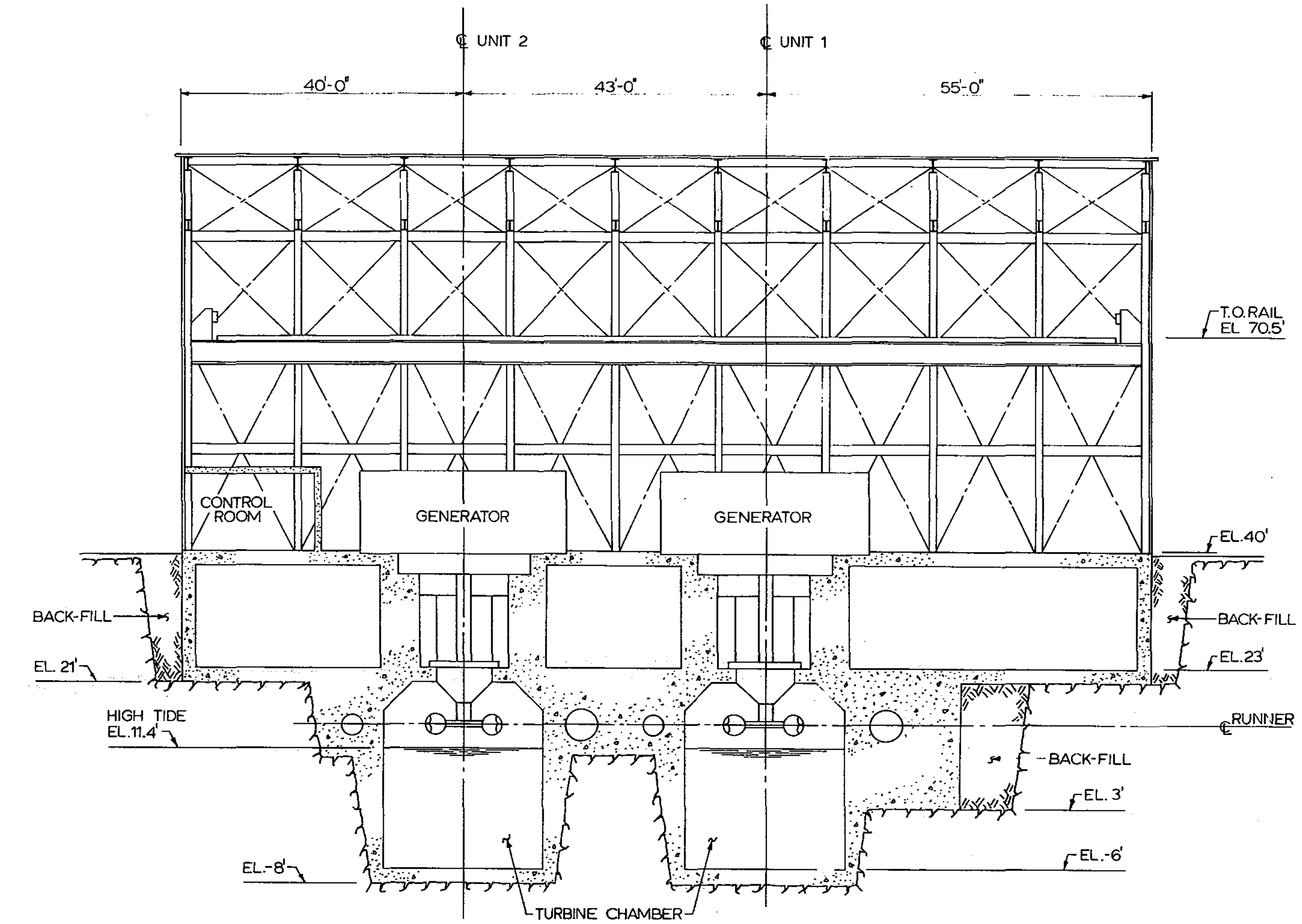
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 13



PLAN-FLOOR EL.23'

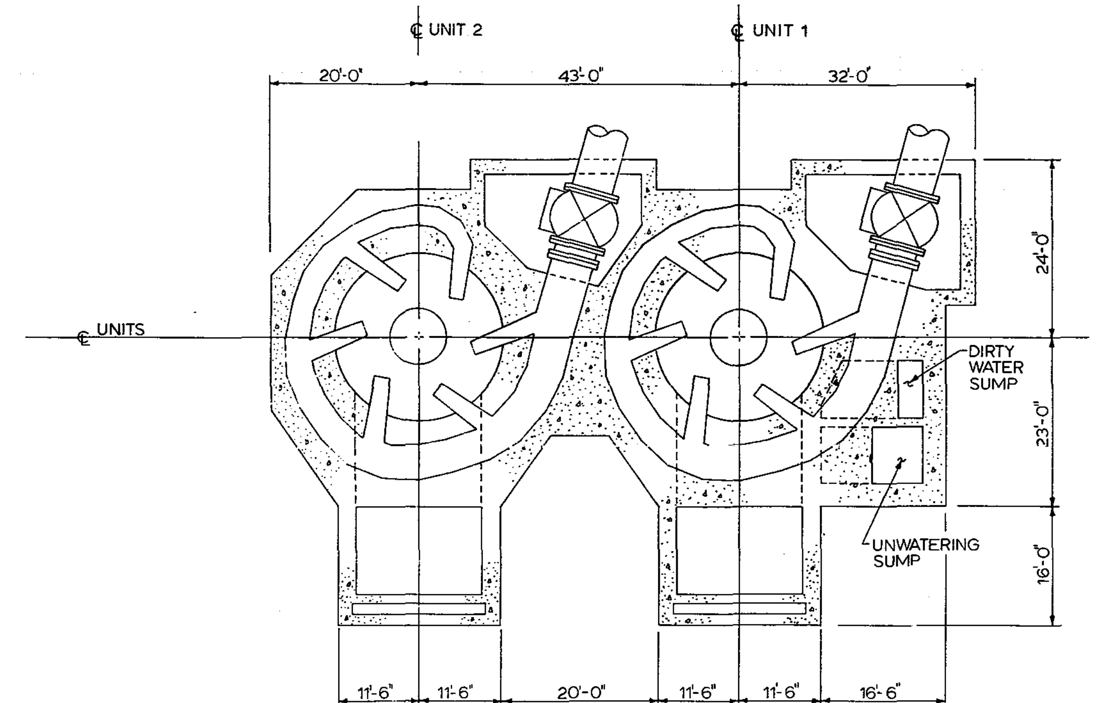
SCALE IN FEET



LONGITUDINAL SECTION

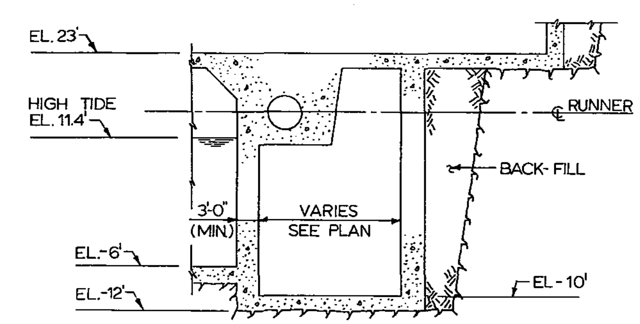
SCALE IN FEET

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.



PLAN-RUNNER EL.15'

SCALE IN FEET



TYPICAL SUMP SECTION

SCALE IN FEET

EQUIPMENT DATA

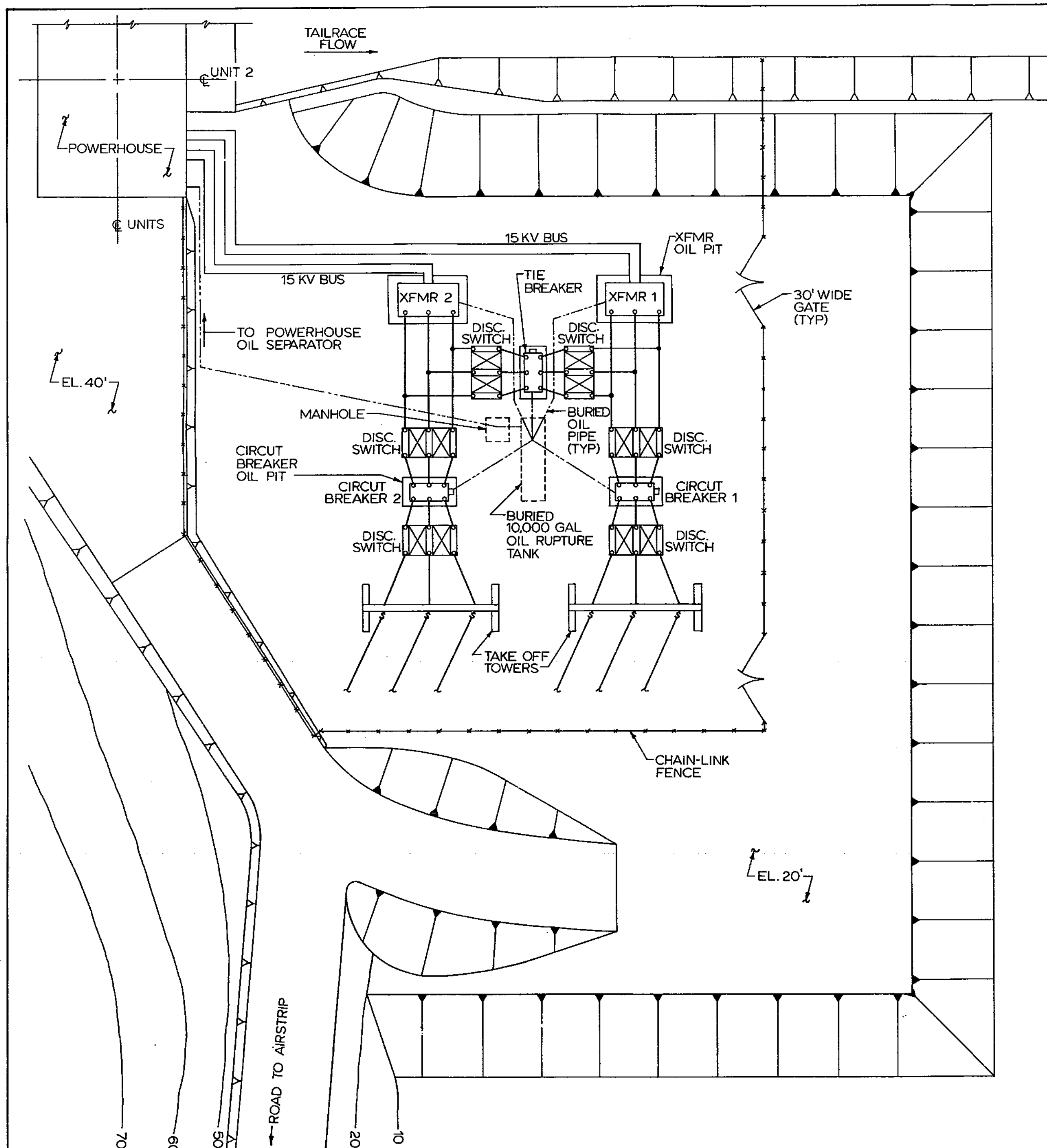
7 STATIC EXCITATION
8 GOVERNOR ACCUMULATORS
9 GOVERNOR OIL
10 GREASING UNITS
11 OIL SEPARATOR
12 OIL TANKS
13 MOTOR CONTROL CENTERS
14 SPHERICAL VALVE CONTROL
15 SPHERICAL VALVE ACCUMULATORS
16 UNIT SERVICE WATER PUMPS
17 FIRE PUMPS
18 AIR COMPRESSORS
19 AIR DRYER
20 AIR TANKS
21 WATER PURIFICATION EQUIPMENT
22 WATER TREATMENT
23 DOMESTIC PUMPS
24 JOCKEY PUMP
25 STATOR SUPPORT COLUMN
26 HOT WATER HEATER
27 480V LOAD CENTER & 480V SWITCHGEAR
28 2-100 GPM DIRTY WATER PUMPS
29 2-500 GPM UNWATERING PUMPS
30 BATTERY ROOM

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

90 MW PELTON POWERHOUSE
PLANS & SECTIONS-SHT. 2

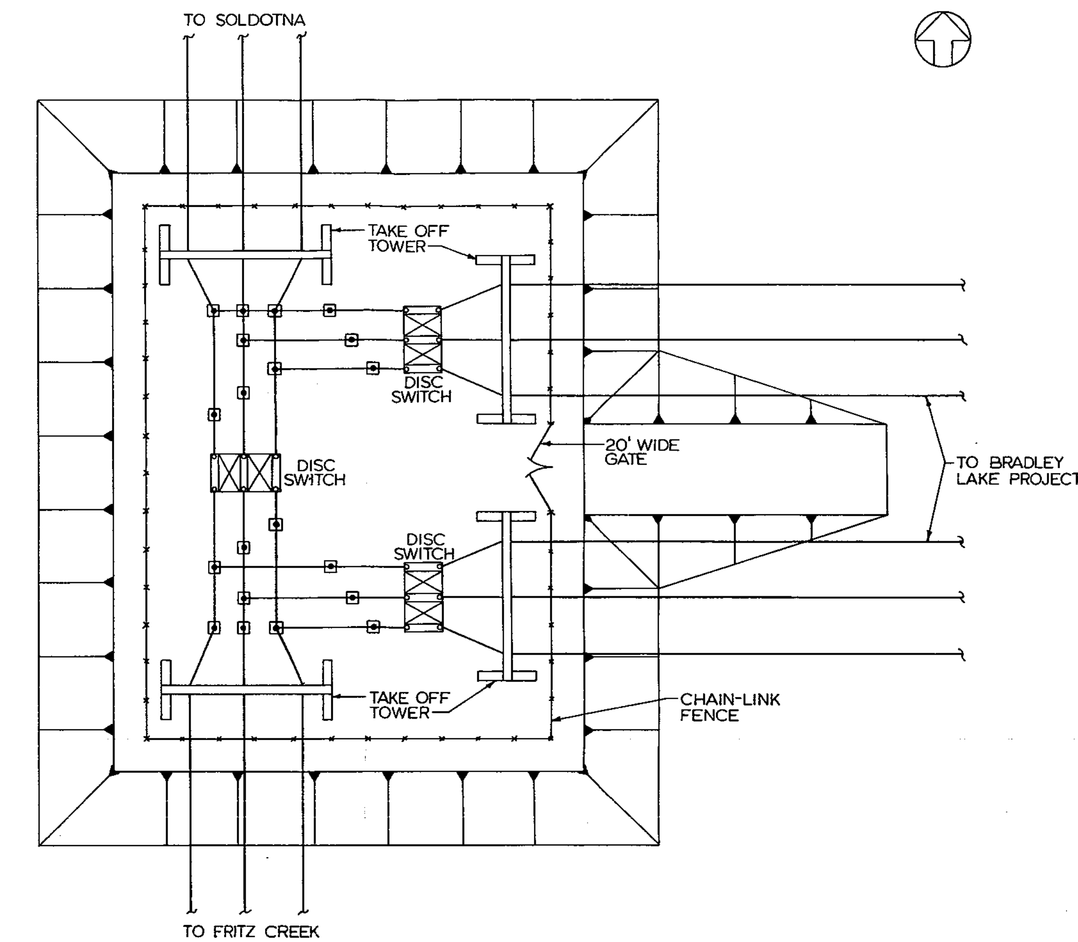
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 14



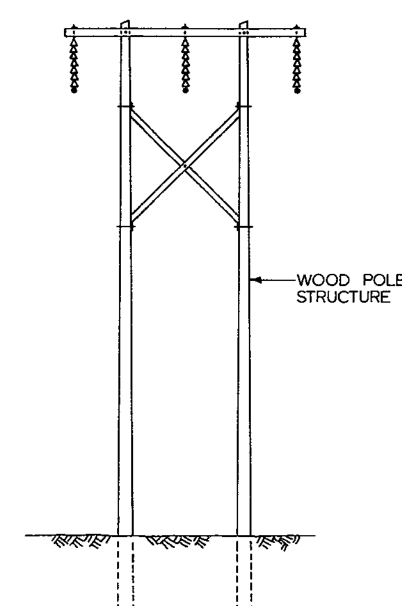
PLOT PLAN-POWERHOUSE SUBSTATION

0 20' 40'
SCALE IN FEET



PLOT PLAN - BRADLEY JUCTION

0 20' 40'
SCALE IN FEET



TYPICAL TRANSMISSION LINE STRUCTURE

0 10' 20'
SCALE IN FEET

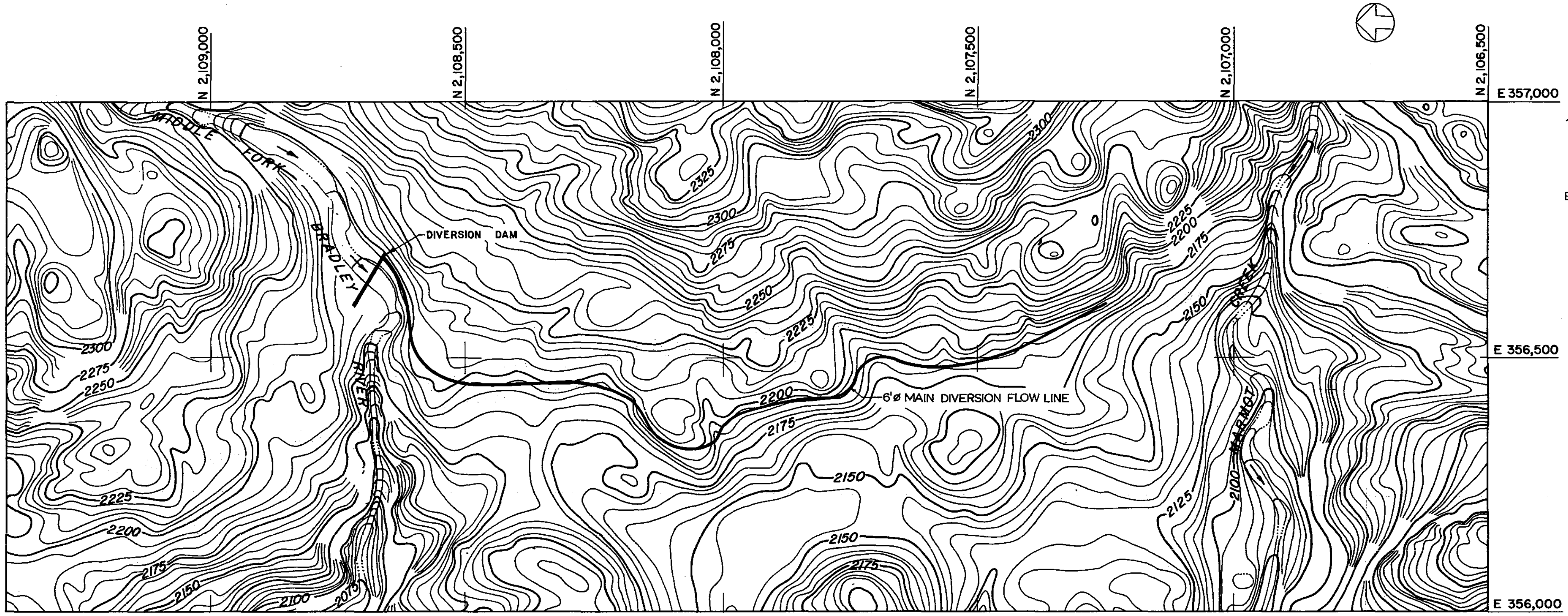
NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

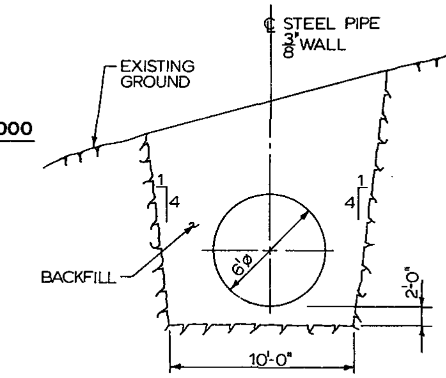
BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

POWERHOUSE SUBSTATION AND BRADLEY JUNCTION

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 15





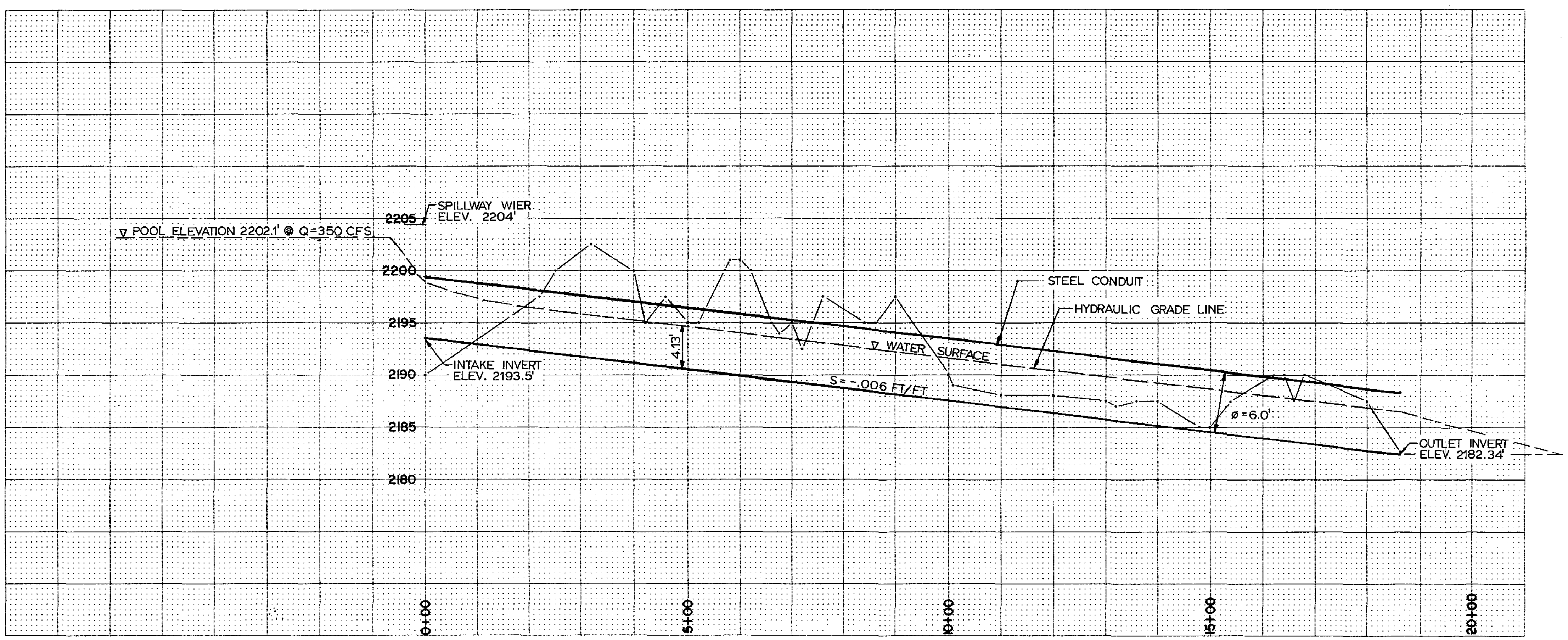
TYPICAL SECTION

SCALE IN FEET

CONDITIONS IN CONDUIT

DISCHARGE = 350 CFS
CORRESPONDING DEPTH = 4.13 FT
VELOCITY = 16.9 FT/SEC.
STATE – SUPERCRITICAL

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.



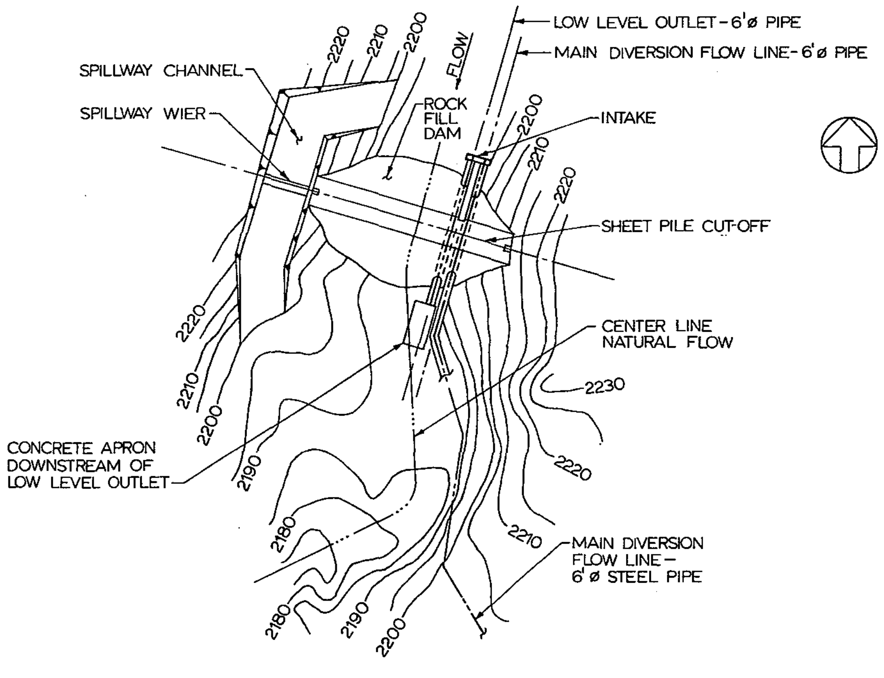
VERTICAL SCALE: 1"= 5'
HORIZONTAL SCALE: 1"= 100'

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

MIDDLE FORK DIVERSION
PLAN & PROFILE

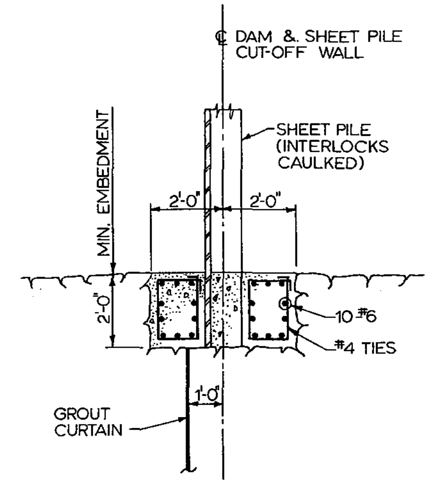
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 16



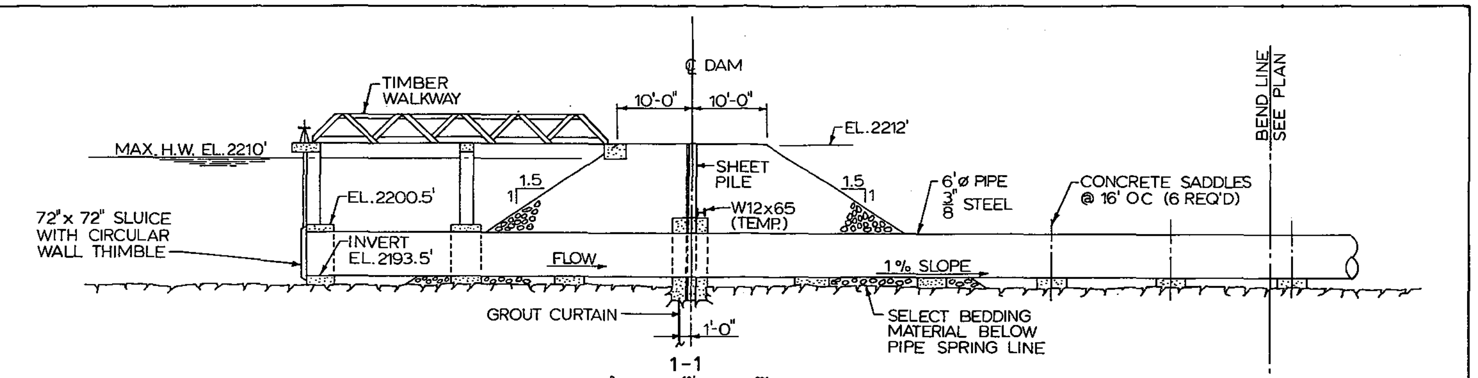
PLAN-MIDDLE FORK DIVERSION

SCALE IN FEET



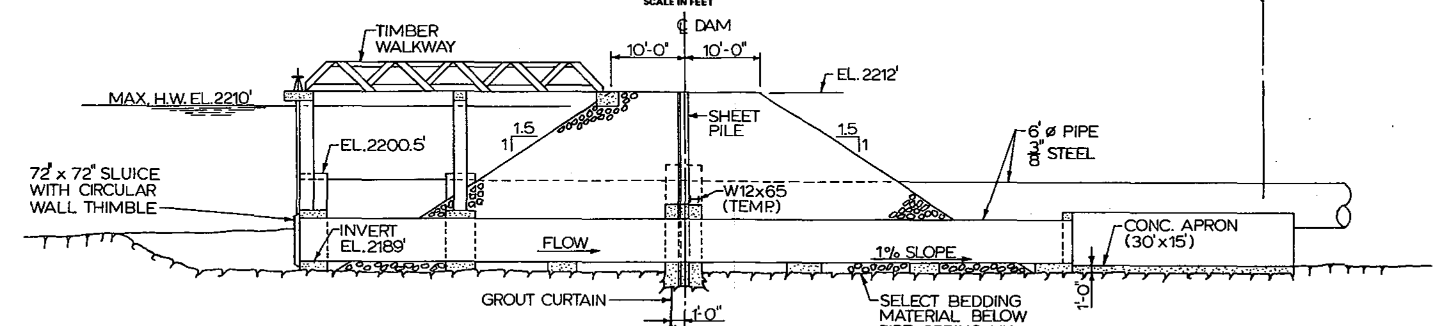
DETAIL A

SCALE IN FEET



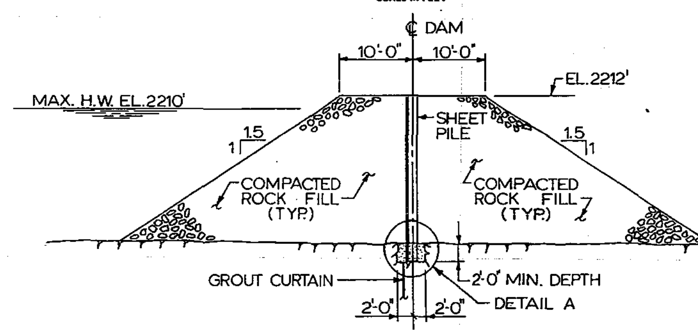
1-1

SCALE IN FEET



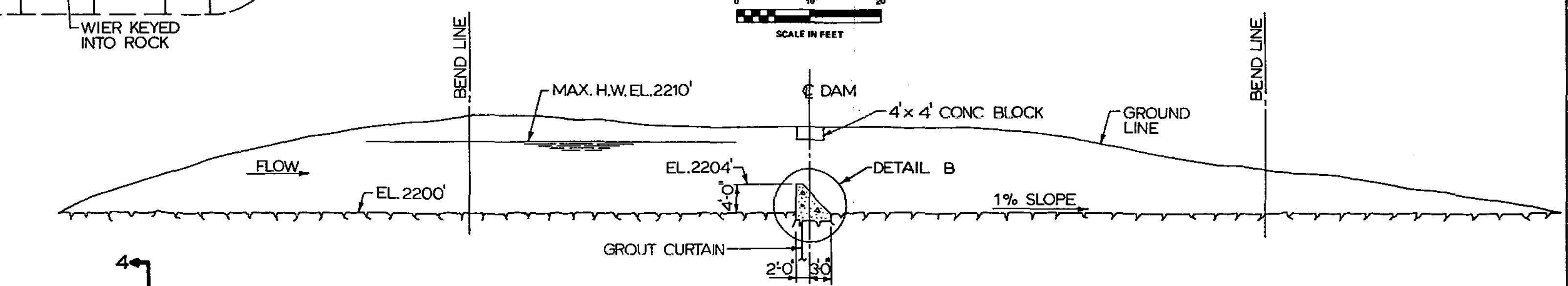
2-2

SCALE IN FEET



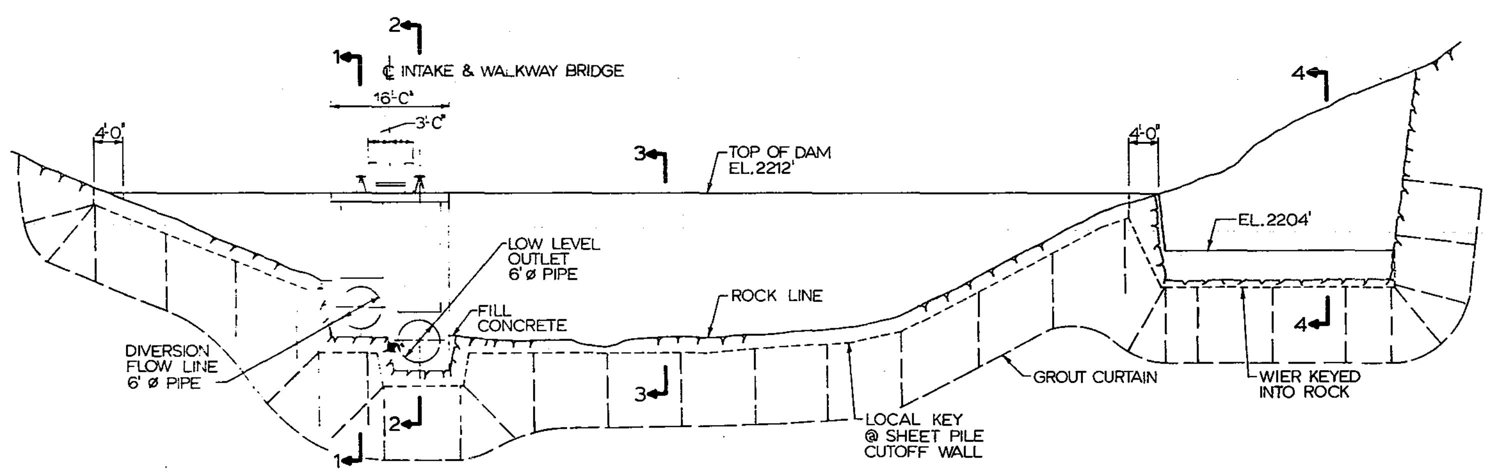
3-3

SCALE IN FEET



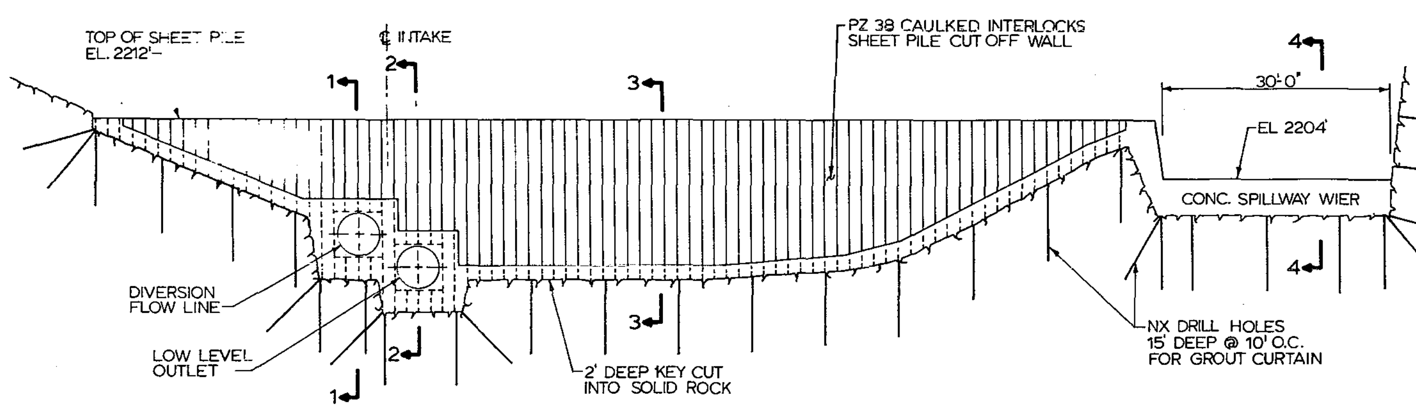
4-4

SCALE IN FEET



VIEW LOOKING DOWNSTREAM

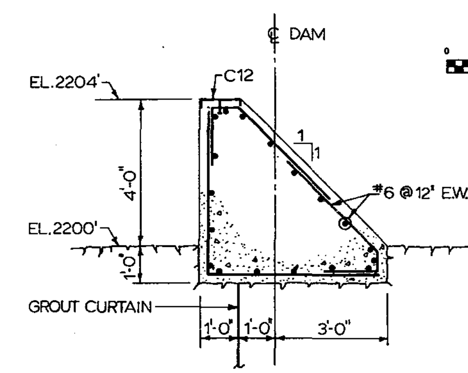
SCALE IN FEET



VIEW LOOKING DOWNSTREAM
AT SHEET PILE CUT-OFF WALL

SCALE IN FEET

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.



DETAIL B

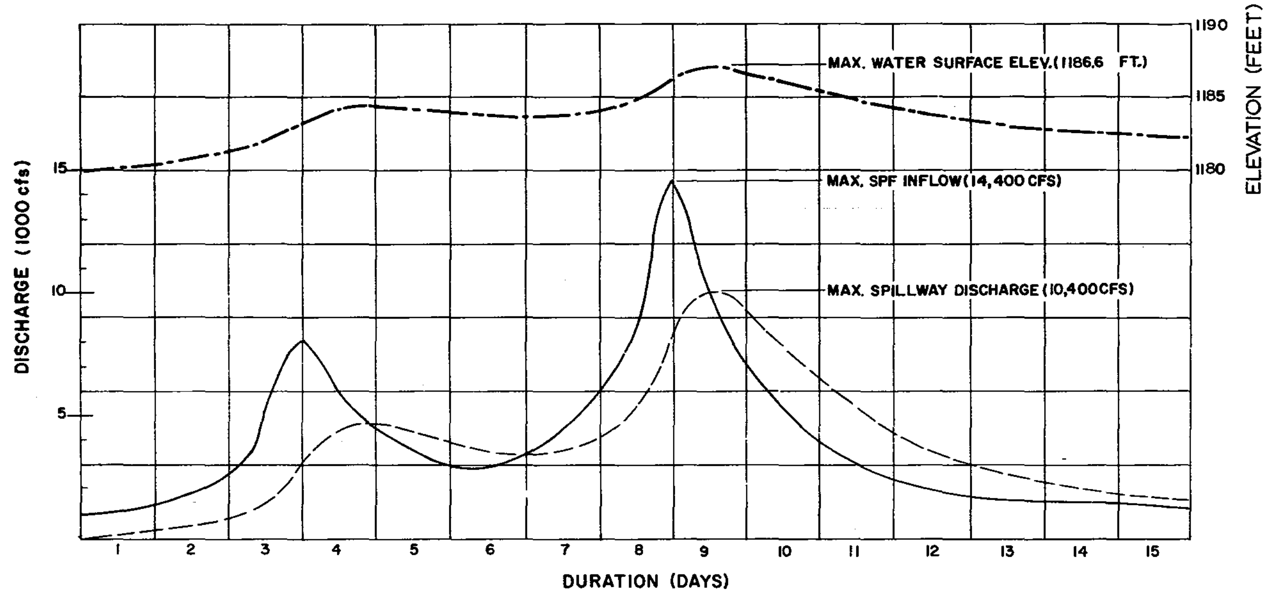
SCALE IN FEET

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

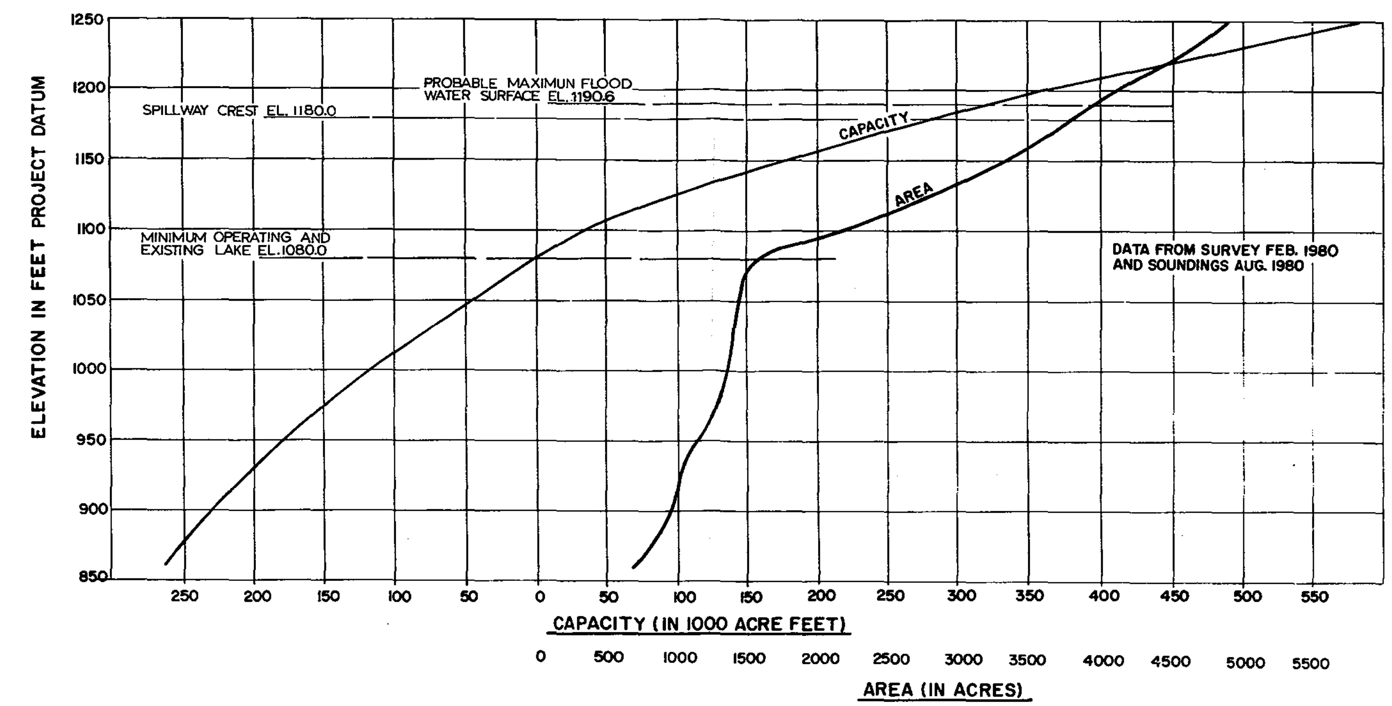
MIDDLE FORK DIVERSION
ELEVATIONS & DETAILS

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

PLATE 17



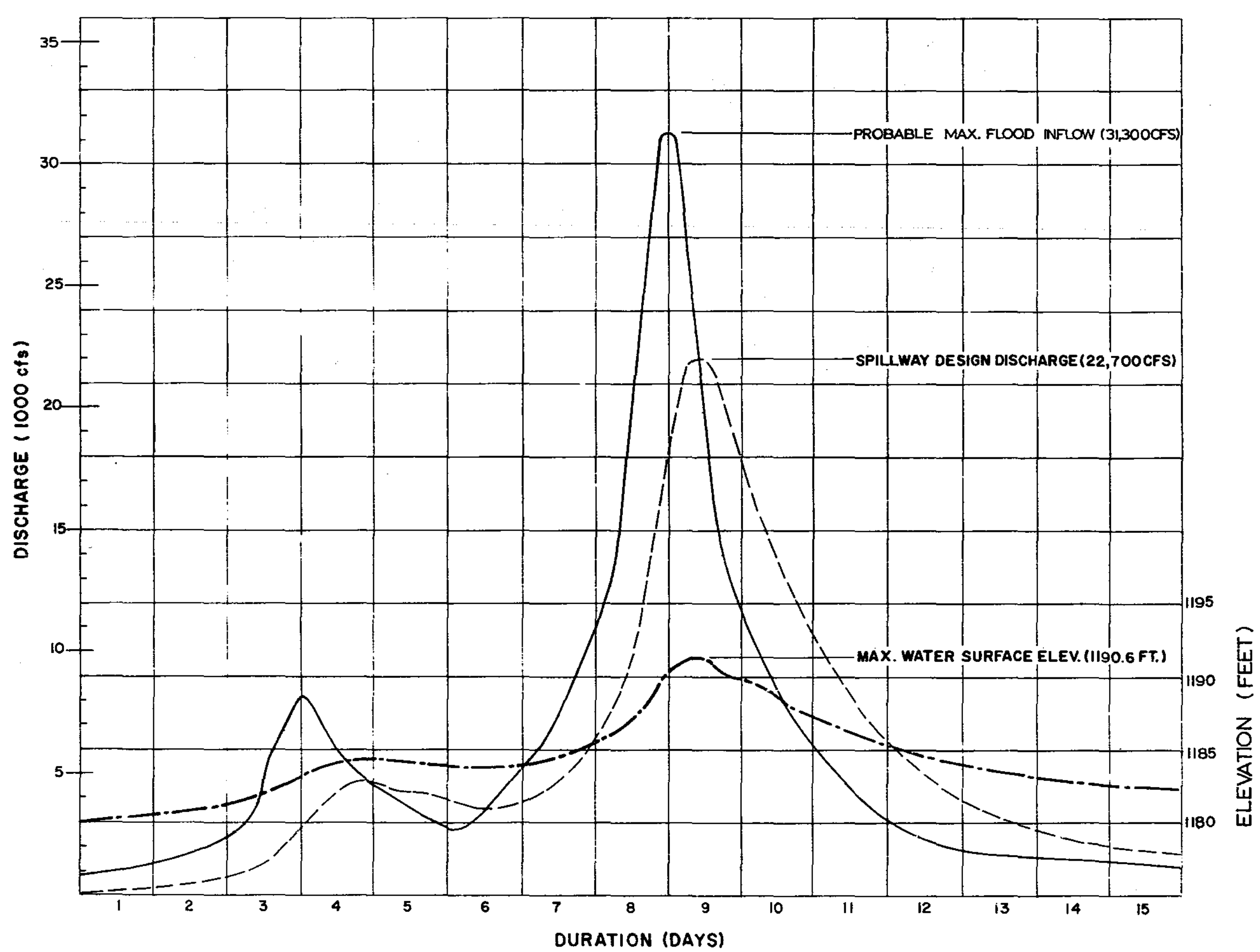
STANDARD PROJECT FLOOD



AREA & CAPACITY CURVES

ALTITUDE (FEET)	AREA (ACRES	CAPACITY (ACRE-FEET) BELOW LAKE SURFACE	CAPACITY (ACRE-FEET) ABOVE LAKE SURFACE	ALTITUDE (FEET)	AREA (ACRES)	CAPACITY (ACRE-FEET) BELOW LAKE SURFACE	CAPACITY (ACRE-FEET) ABOVE LAKE SURFACE
860	668	263,318	--	1,060	1,462	31,223	--
880	829	248,337	--	1,080 1/	1,568	--	0
900	946	230,570	--	1,100	2,177	--	36,339
920	991	211,188	--	1,125	2,808	--	98,672
940	1,087	190,396	--	1,150	3,353	—	175,707
960	1,217	167,338	--	1,175	3,749	--	264,502
980	1,290	142,249	--	1,200	4,106	—	362,699
1,000	1,349	115,840	--	1,225	4,544	—	470,834
1,020	1,393	88,403	--	1,250	4,897	--	588,868
1,040	1,430	60,158	--				

1/ MINIMUM OPERATING AND EXISTING LAKE SURFACE



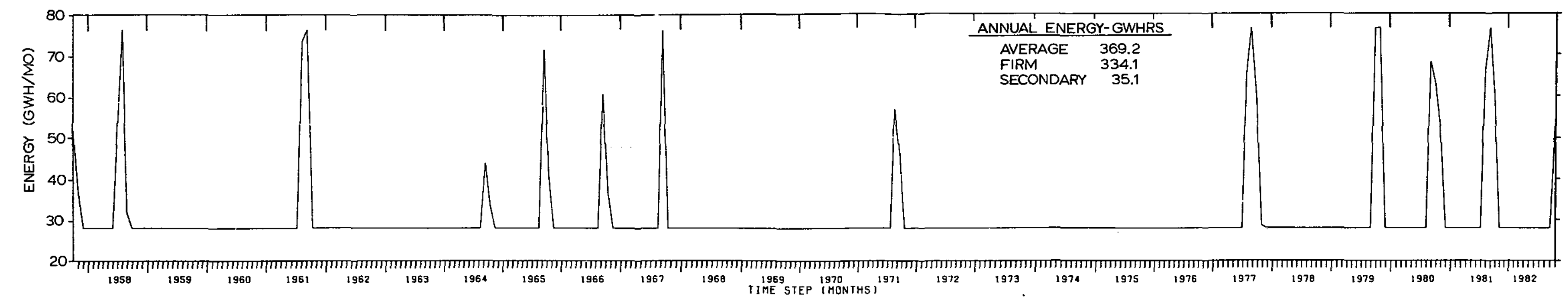
PROBABLE MAXIMUM AND SPILLWAY DESIGN FLOODS

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

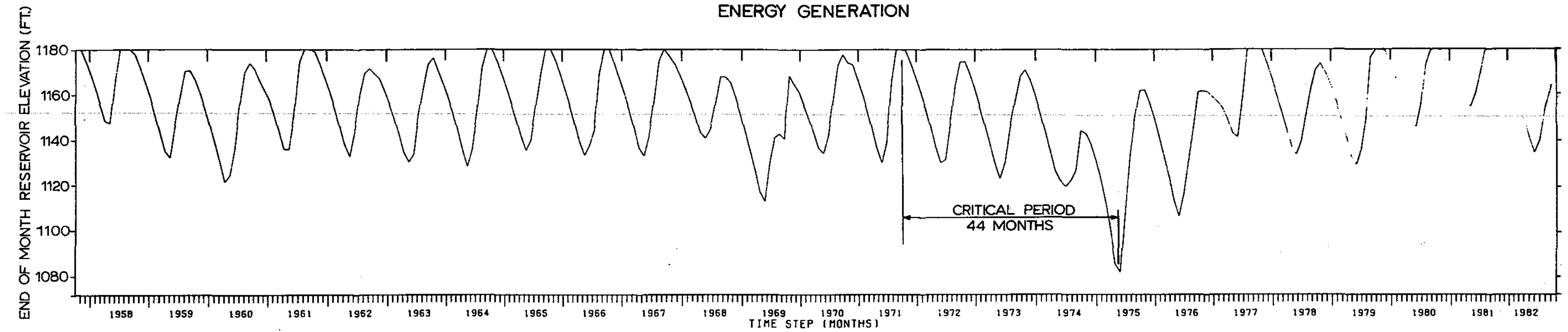
BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

PROJECT DESIGN FLOODS AND RESERVOIR AREA-CAPACITY CURVES

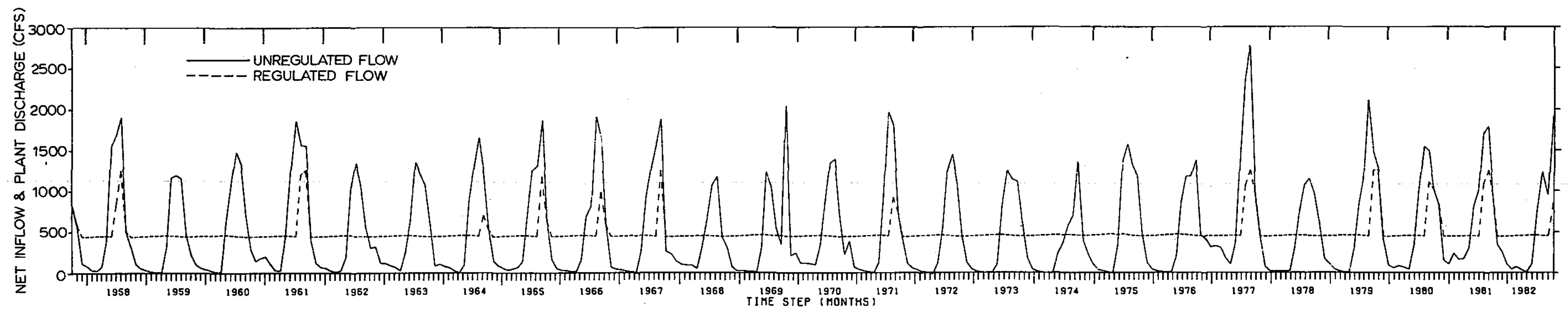
STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA



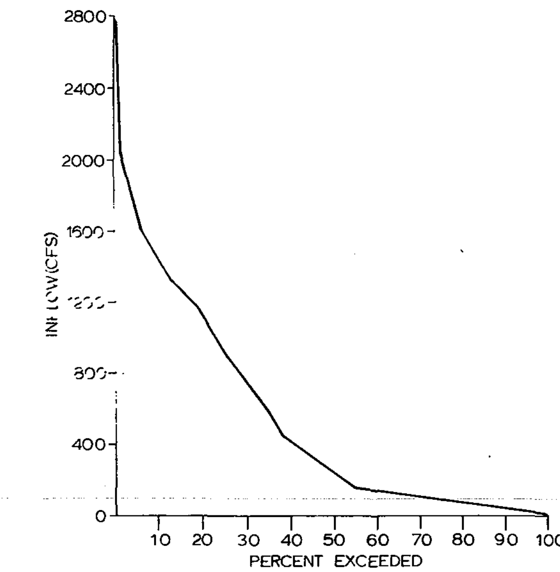
ENERGY GENERATION



RESERVOIR FLUCTUATION

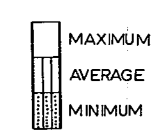


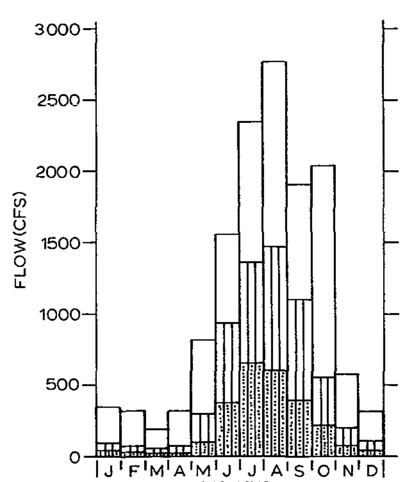
FLOW



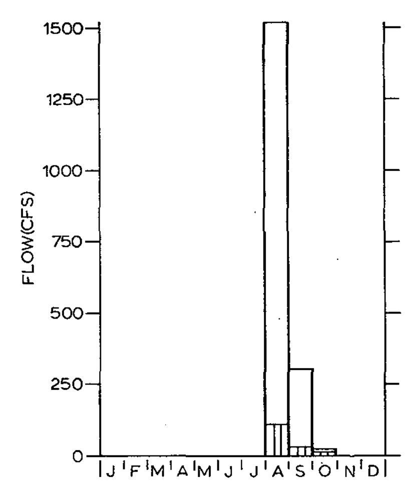
MONTHLY
RESERVOIR INFLOW DURATION CURVE

NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

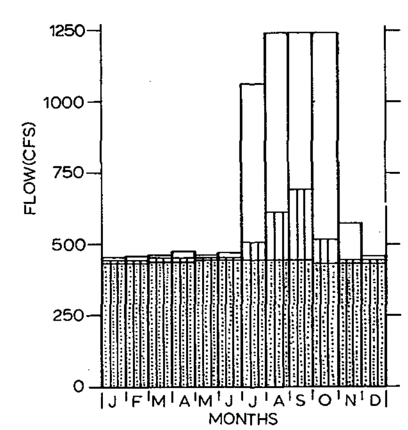




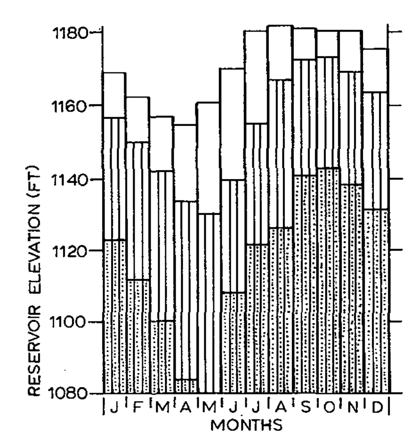
DISTRIBUTION
RESERVOIR INFLOW



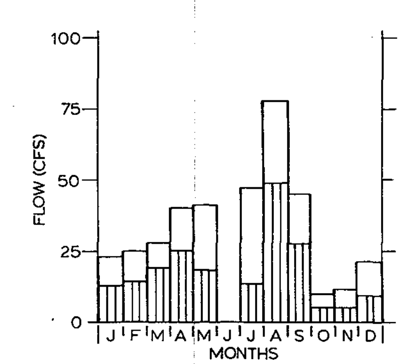
DISTRIBUTION
SPILLWAY DISCHARGE



DISTRIBUTION
POWERPLANT DISCHARGE



DISTRIBUTION
RESERVOIR ELEVATION



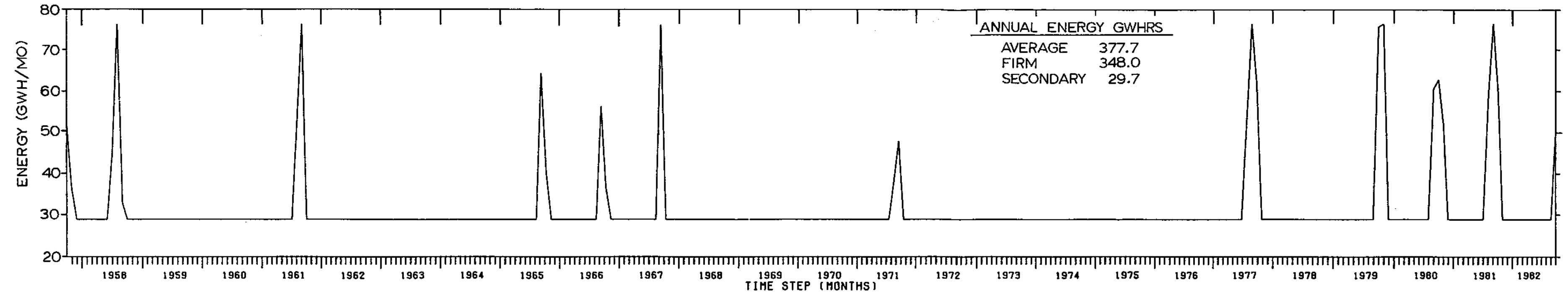
DISTRIBUTION
FISH DIVERSION DISCHARGE

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

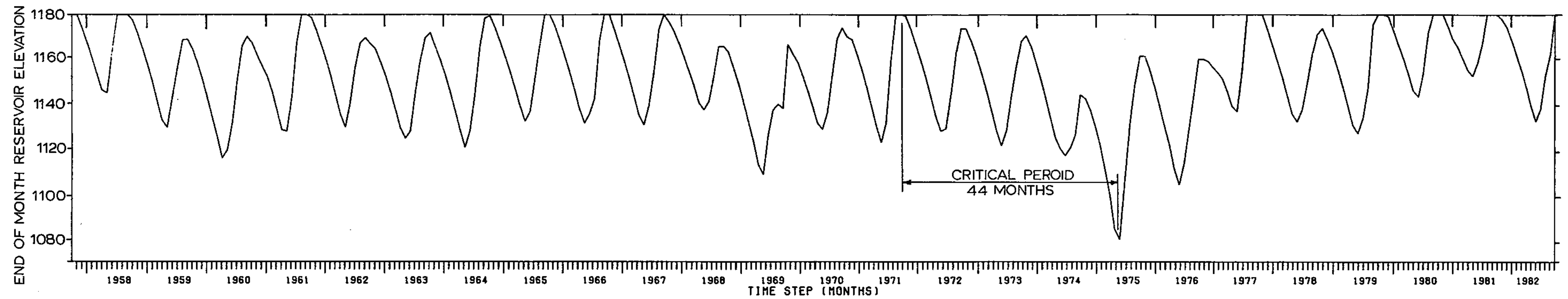
RESERVOIR REGULATION-90 MW PLANT WITH FISH DIVERSION DISCHARGE

STONE & WEBSTER ENGINEERING CORPORATION
ANCHORAGE, ALASKA

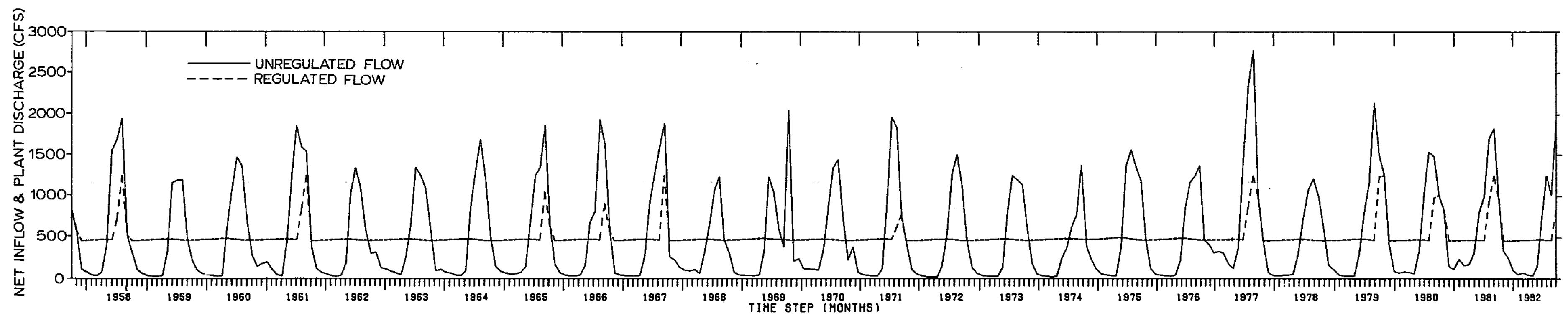
PLATE 19



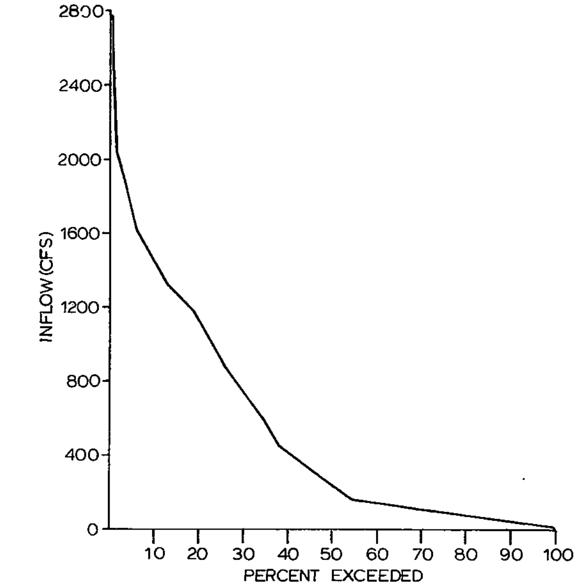
ENERGY GENERATION



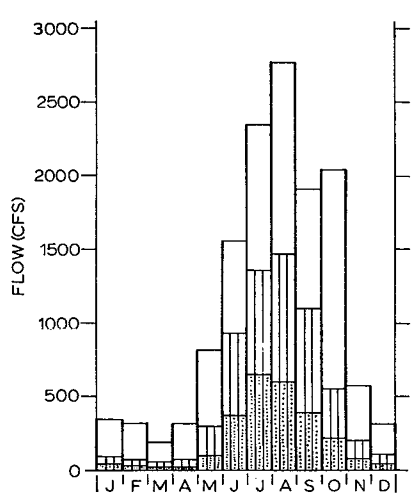
RESERVOIR FLUCTUATION



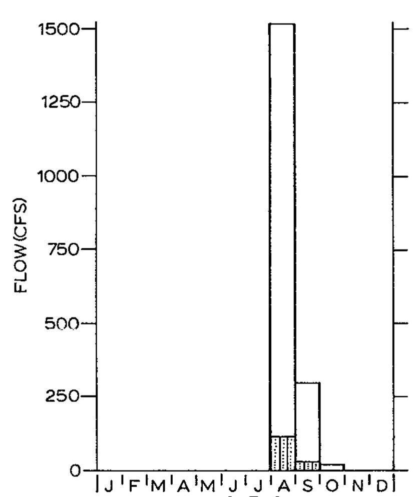
FLOW



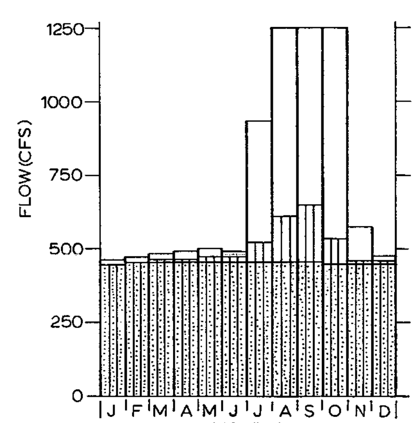
MONTHLY
RESERVOIR INFLOW DURATION CURVE



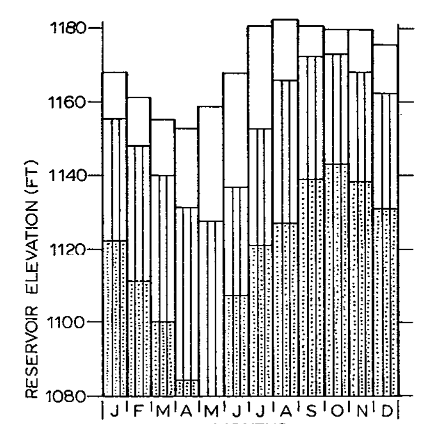
DISTRIBUTION
RESERVOIR INFLOW



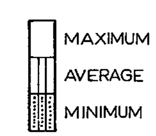
DISTRIBUTION
SPILLWAY DISCHARGE



DISTRIBUTION
POWERPLANT DISCHARGE



DISTRIBUTION
RESERVOIR ELEVATION



NOTE:
ELEVATIONS SHOWN ARE ON PROJECT DATUM.
MEAN SEA LEVEL DATUM = PROJECT DATUM PLUS 4.02 FT.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

RESERVOIR REGULATION-90MW PLANT
WITHOUT FISH DIVERSION DISCHARGE

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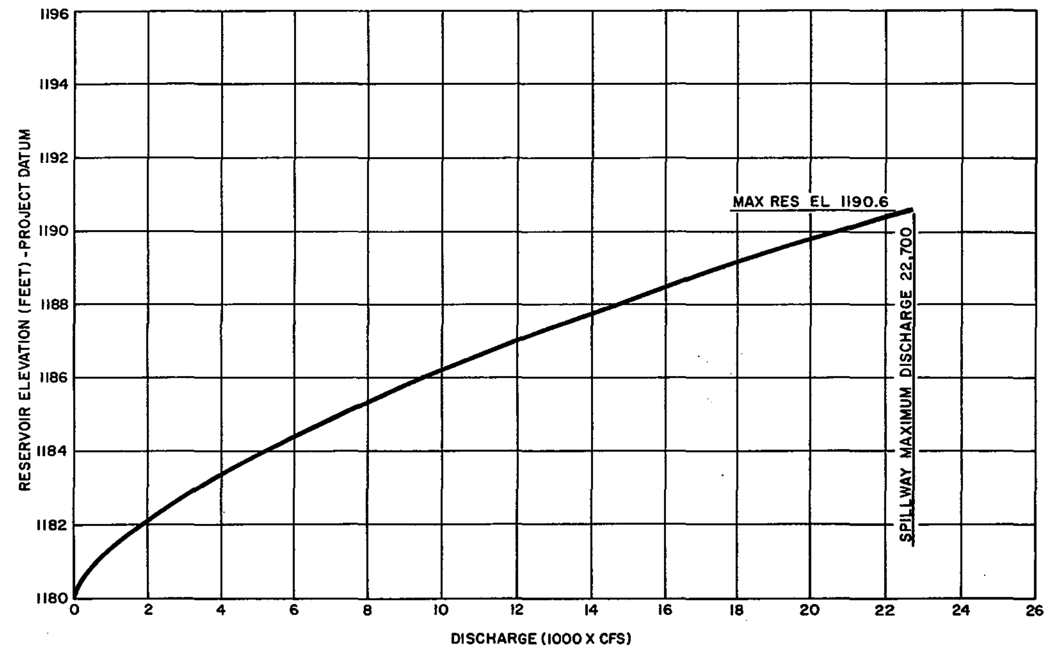
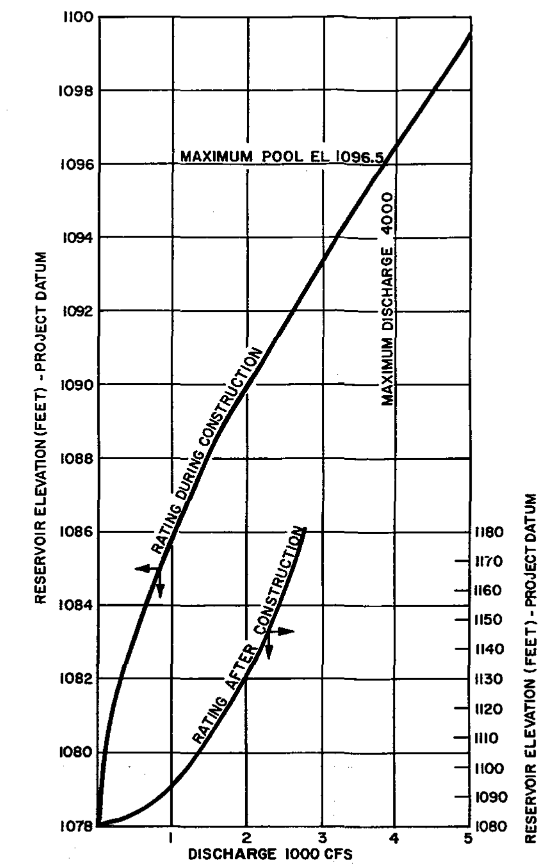
ANCHORAGE, ALASKA

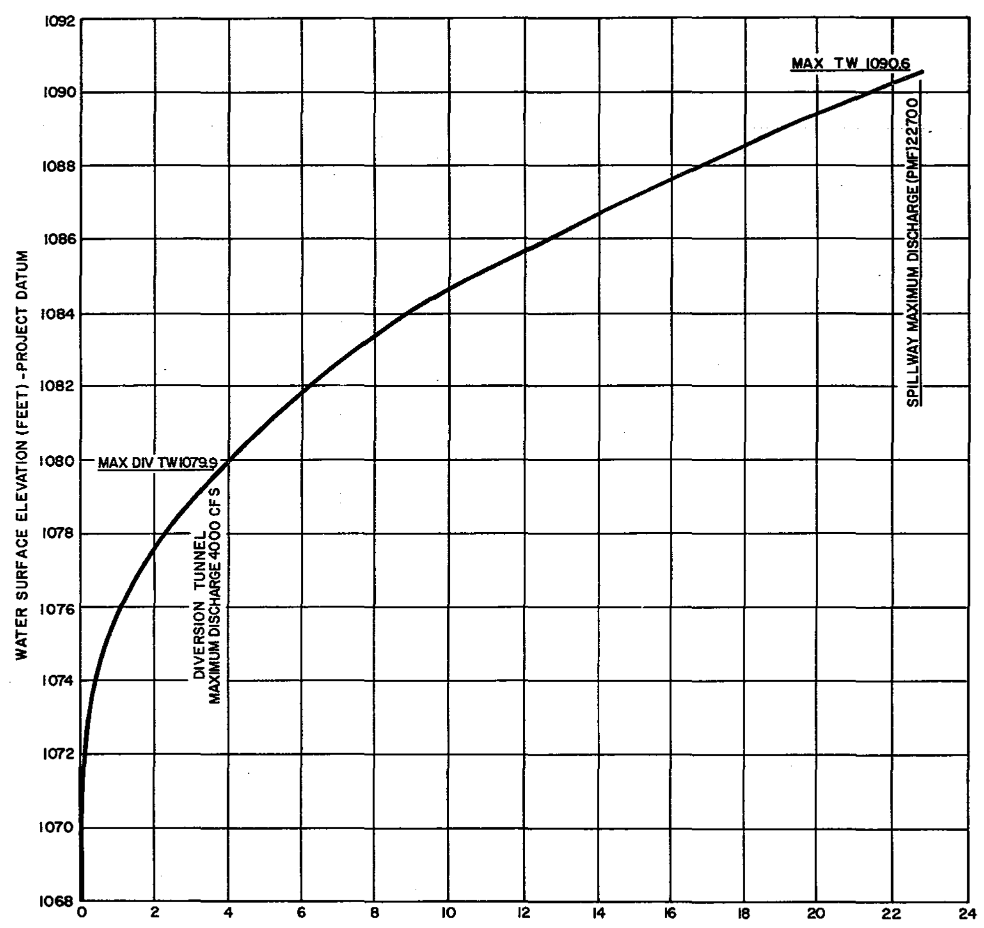
PLATE 20



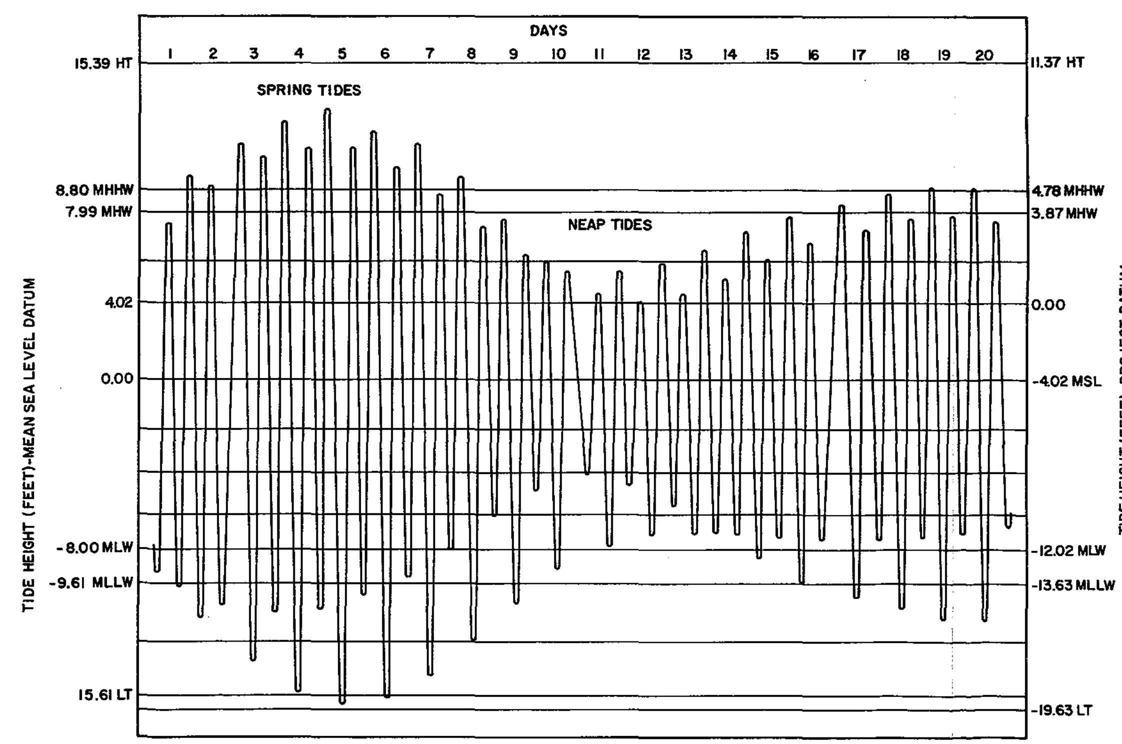
SPILLWAY RATING CURVE



DIVERSION TUNNEL RATING CURVES



UPPER BRADLEY RIVER TAILWATER RATING CURVE
(POST PROJECT CONDITIONS)



MAY TIDAL RATING CURVES
(SEE NOTE 1)

NOTES

1. TIDE HEIGHTS BELOW EL 6.0 PROJECT DATUM WILL NOT AFFECT POWERPLANT OPERATION. IN THOSE INSTANCES WHERE TIDE HEIGHT EXCEEDS EL 6.0 A TAILWATER DEPRESSION SYSTEM WILL MAINTAIN WATER LEVELS WITHIN THE DRAFT TUBE BELOW EL 6.0.

BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

RATING CURVES

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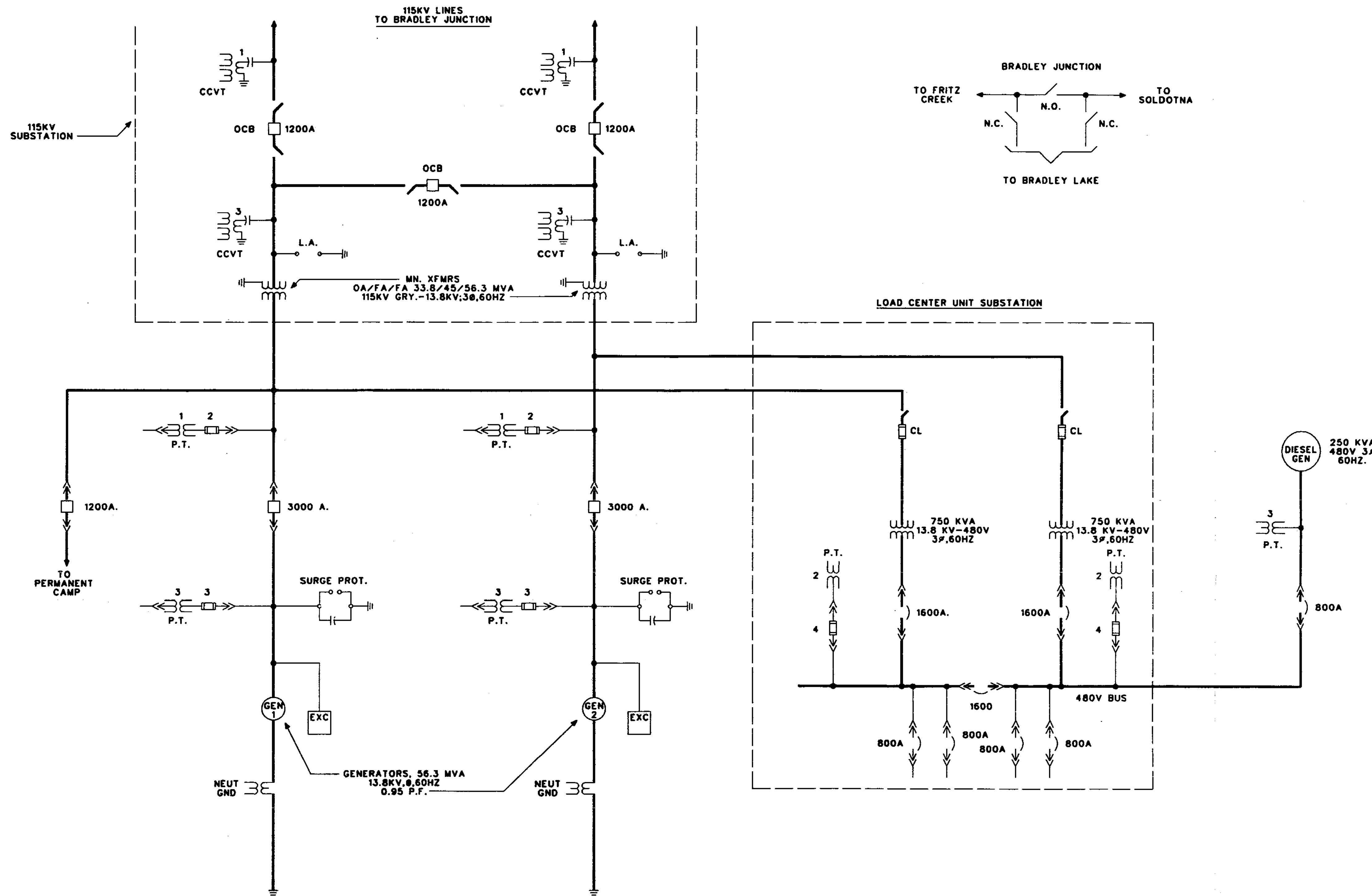
PLATE 21



BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

MAIN ONE LINE DIAGRAM

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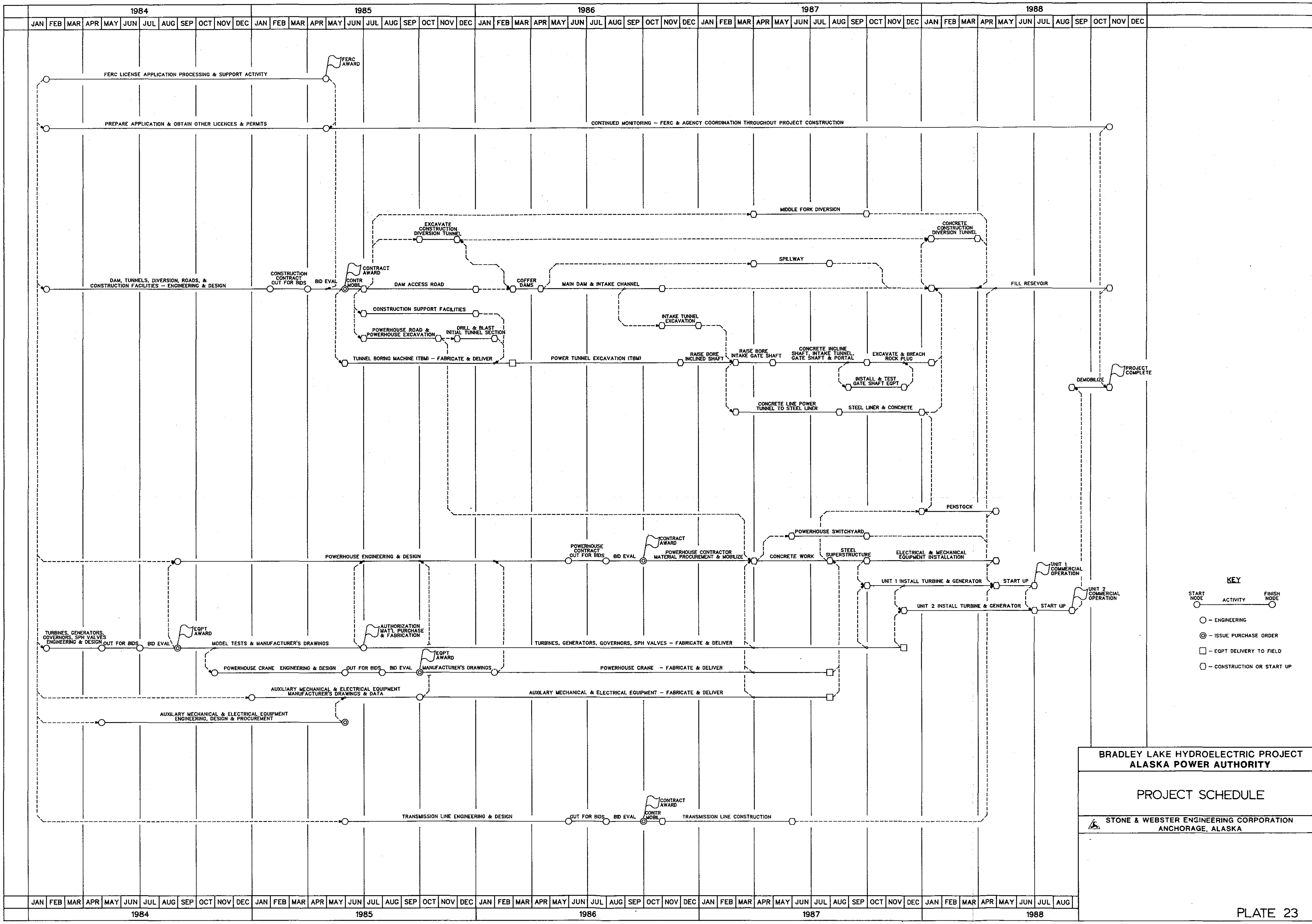
PLATE 22



BRADLEY LAKE HYDROELECTRIC PROJECT
ALASKA POWER AUTHORITY

PROJECT SCHEDULE

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ANCHORAGE, ALASKA

PLATE 23